all right hello everybody welcome
happy january
welcome to cons
one two seven
i am going to not keep you for too long today
it'll be a pretty quick lecture
i'm just going to introduce the tas really quickly
they'll give each a quick introduction about themselves
i'll introduce myself quickly
go a little bit over the course structure
talk about some learning objectives for the course
some tips and tricks for succeeding in this course
that's old i'm not gonna start that lecture
so don't worry
we're we're not gonna do an actual lecture per se today
i'll i'll lecture but just about course format
course content
and then tomorrow
tuesday we'll start our first actual lecture
so first off is evan
he's your head ta
alright hello everyone
uh my name is evan
uh i'm the head tier for this course
i've been tearing this course for maybe two years now
three or four semesters
uh so i've got a lot of experience with it
i did my undergrad uh nova scotia at delhas university
currently i'm doing my phd
in the integrated remote sensing studio
which is lab in forestry
i'm a big fan of pretty
well everything discussed in this course
so like remote sensing data science conservation
uh and then there's me and my dog
so yeah that's pretty much all you need for me
if you have questions about syllabus stuff like that
i'm the person you should go to
or just generic course questions
generally speaking
if you have any questions that you want to ask
about this course in general send them to evan
yeah you can

you can email me
you're welcome to
but nine times out of ten
i'm gonna forward that email to evan
and then i'll just respond directly to you so
so you're welcome to email me
you might not hear back from me
but go ahead and contact us yeah cool
who's next leanna
leanna is not here today and is not here
she'll be here next week
next is tristan
he is also not here
he'll be here tomorrow to introduce himself
and after that we have stable
hello everyone
i will be doing assignment six and seven with you
i'm from the great state of vermont
and i did my undergrad at university of vermont
in environmental sciences
and i'm a phd candidate in the irss with bud
and where chris used to be here
and in my research i use drone data
multispectral imagery and structural point cloud data
to study climate adaptation in spruce and douglas fir
so observing the earth from space but very close
very close to the earth
and i'm also really into orchids and succulents
hi everyone i'm julia
and i'm going to be the ta for assignment seven
i did my undergrad actually with evan
at dalhousie in environmental science and biology
and now i'm doing my masters in oceans and fisheries
and specifically i'm studying zooplankton
which are pray for a lot of fish and mammals
along the coast and in the deeper ocean
so if you're interested in marine science
always happy to chat about that
um yeah and i also love to be outside
so i love climbing
skiing and backpacking
there's a photo of me climbing and yeah cool
there's one more thing i forgot to say yeah good

so two more things for me
i'm going to be showing up like now every week
so mondays at five p m
and i'll just be giving you like
an overview of what to do in the upcoming weeks
so like for example
the blog posts
they're just little things that you fill out
the worth ten percent of your grade overall
there's one coming up that's due
two weeks from thursday
and i'll come into class and i'll announce that
other than that
one other thing i want you to do is
if you have an a and d form
send those directly to me
i'll make a spreadsheet
and i'll make sure you get all your extra time for your
assignments
midterm final
awesome one
just kind of general note about how tas work
in this course
you have evan who's kind of your head ta
he's kind of general course ta
general questions general
he'll help you administer and
get through the midterm final exam
he's in charge of all the blog posts
and he kind of helps organize some of the other tas
and all the other tas
are assigned to a specific assignment
so leanna who's not here today
is doing assignments one and four
tristan who's not here
is doing assignments two and three
samuel who is here
does assignments five and six
and julia who's here
is doing assignments seven
so you won't actually see
or have any contact with samuel and julia
till much later in the semester

you'll start with leanna next week
and then tristan after that
but you'll have evan
all the way through for everything course related
sweet cool thanks guys
okay
so myself what about me
my name is chris
hello welcome again
you i am not a professor nor do i have a phd
so you do not need to call me professor
or doctor golden or anything like that
you can if you would like to
you don't have to
um you can just call me chris
that's fine
you'll probably quickly ask yourself the question
who am i and why am i teaching you this course
it's a fair question to ask
i also ask myself the same question sometimes
um no i'm just kidding
i'm a lecturer at ubc
so i just teach classes
i did my undergrad here in forestry
and then i did a masters in forestry
studying grizzly bears and how they are affected by
forestry in western north america
i did that using camera traps
this is a cool grizzly bear photo for my research
using a camera trap
and then some fun fieldwork photos
that i took of myself
but in general
my research was
again using camera traps and earth observation data
earth observation
remote sensing
which is the fundamental things
that we're going to be learning about in this course
to in my case
study grizzly bears
and how they are affected by forestry
we'll give a

or i'll give
one of the lectures that i give in this class
is a wildlife lecture
which is my favorite lecture
because that's the lecture that kind of
is most related to my research
but in general
we'll be talking about earth observation as a whole
which and we'll kind of focus on satellites
and that kind of data
but you are also welcome to come talk to me anytime
about bears and wildlife research
i'm really interested in that field as well
my emails up there
it's also on the homepage of canvas
i do have a room in forestry i'm not
i don't actually hold any office hours for this course
so you you probably aren't gonna stop by
generally speaking
if you're trying to get in contact with me
i will for the most part never really take up the full
hour and twenty minutes that we have each class
so if you want to chat with me
you don't need to schedule an office hours or whatever
the best thing to do is just come to class
wait till after class
there'll be plenty of time after class
before the next class is in
or even if there is a class after this i'm not sure
but you can just come and chat with me
in lecture at the end of class
all the material for this course is in canvas
so i will always upload pdfs of the lecture notes
and i'll post those
sometime before the start of lecture
the ones that i'm using right now
should already be posted on canvas
if they're not for some reason
let me know
but you should see them up there
as well as any additional videos
or youtube links that are in the lectures themselves
canvas also has access to all of the assignments

all of the blog posts
all of the exams
which is just the midterm and the final exam
and as well as zoom links for office hours for the tas
so the tas for each of their assignments will hold
office hours throughout the week
and those will be through zoom
and you can access those zoom links through
the canvas page
in terms of how the course works
you'll have seven assignments in total in this course
which will each be introduced by the respective ta
as i pointed out earlier in class
i'll get a ta to come kind of when you're supposed
to start working on that assignment
and give a little intro about what the assignment is
about what you're supposed to be doing
and then you'll have about one to two weeks
to complete each assignment
just kind of depending on the schedule
on the course syllabus online
there's a schedule of when each assignment is due
and kind of how long you'll have to do each assignment
but you'll submit those on canvas
then there's also six blog posts
the blog posts are marks for participation
they're really just meant for easy marks
you do need to complete them
according to the instructions
and evan will click through them to make sure
that you have actually follow the instructions
and that you have actually completed the blog
i've had in the past
i've had people just kind of put an exclamation point
and hit submit so that they have a submission
it won't work
evan will go through and make sure that there
has been a submission by you for that blog post
but it generally speaking
doesn't need to be extravagant
just make sure you follow the instructions
okay for exams
they are also both administered through canvas

midterm and final exam are a hundred percent online
the midterm is tuesday
february fourteenth
administered during class time
so from five to six thirty pm
so you'll have a time limit of ninety minutes
to complete the midterm
but it's just through canvas
so you don't need to come to class
you don't need to write it here
we're not going to be invigilating the exam in any way
you don't need to join the zoom call
or anything like that
you just write the exam from wherever
you have a ninety minute time limit
that's a lot of work
the final exam is
going to be during the scheduled exam period
it'll work pretty much the exact same
as the midterm exam
ubc will schedule us a certain time and day
you'll write the final exam during that time and date
and it will be also completely online
also completely on canvas
i'll release more info on the midterm and final exam
closer to the date
including practice questions format
things like that
any questions about exams
ok sweet so grading breakdown in this course
blog posts are worth ten percent
assignments are worth thirty percent
of which there are seven
midterm exam is worth twenty percent
final exam is worth forty percent
boom boom boom
i want to give you a quick rundown of the canvas page
so you guys know exactly what you're looking at
and then i'll go on give a little intro lecture
it's just about five slides or so
and then i'll let you go for the dice
just give me one second here to pull this up
okay can i grab your guy's attention real quick

so this is the canvas page
this is the home page
you got my contact info
all the contact info for the tas
you got the syllabus modules
assignments and discussions
those are kind of the key tabs on the course page
so if you go to modules here
this is the main part that you'll navigate
you got your syllabus here
read through the syllabus please
when you get the chance
it has our course schedule
has our lectures all here
and then it has also
the due dates of all your blog posts and assignments
so check that out
and then here's where i'll post all of the lectures
so the lecture for today is posted right here
then blog post will be under here
all the assignments will be under here
the midterm and final exam will be under here
so blog post one is posted
it's not due till january twenty six
but you're welcome to get started on that if you like
the discussion pages here are mostly for the blog post
you post the blog post as a discussion
we'll also have discussion boards here for
the assignments
and then also we'll be using the announcements tab
so i'd recommend turning on your notifications
for announcements so that you get an email notification
or something like that
because we'll often release announcements
just reminding you about midterm stuff
about final stuff
about assignment stuff
whatever it might be
all your assignments are also on this assignments page
as well grades
and then zoom here is where the zoom links will be
for the ta office hours
okay that's pretty much it

okay so
i wanted to start
off today by asking you guys the question
what do you think of
when you hear the term earth observation
so do you think of maybe satellites
maybe flying in a plane
looking down at some mountains the ocean
whatever you might be flying over
or maybe you're thinking of flying in an air balloon
and you're looking down from the air balloon
at something below you
or maybe you're skydiving
someone told me recently they thought this was me
you guys think that looks like me
i didn't really think so but i don't know anyways
mostly in this course
we're talking about satellites
and also the international space station a little bit
but generally speaking
when we're talking about earth observation
in this course
we're going to be talking about it from the perspective
of satellites
and these satellites that we'll be talking about
might be used to monitor
things like weather on the earth
things like oceans
things like forestry and logging
or maybe urban environments
so we're going to kind of go over all
different kinds of satellites
and overview how they're used to monitor
different land surfaces of the earth
okay so i got a quick video here
that just kind of introduces
it's just a cool video
from the international space station
that introduces a couple of the
cool things that we'll be talking about in this course
seven eight seven
becoming an astronaut
was like you were walking in the clouds

when you first found out that you've been selected
my first space flight was on the space shuttle endeavor
sds one thirteen
six group and bows off to the line
government down the head for their new home space
looking at earth from space is amazingly beautiful
it's a perspective
when you can see things on a scale of half a car
apart from everything else an astronaut does on orbit
photography is actually part of our job
i'm getting set up to do atmosphere air flow
in the chest
we take pictures of earth and the surroundings of earth
the upper atmosphere
and we have stuff
but then focus
and now you got to look through this thing
these pictures in themselves
represent a scientific data set
recorded over now for fourteen years
astronaut imagery of earth is an example of learning
what we need to take pictures of
and how to take the pictures
space is a place
where your normal intuition does not apply
things don't work the way they do down here
on earth you are moving in eight kilometers a second
that's fast
and so you have to be able to smooth the camera
at the same rate
or no motion while you're taking pictures
to actually put the sharpest image here
my favorite subject is the earth at night
a war is just amazingly beautiful
and it's this blowing up a part of the atmosphere
that crawls around like amoeba is in the sky
and then sings at night
the way human beings sprinkle their light bulbs around
it's a fascinating statement on how we
as human beings define our urban areas
in terms of the star trail pictures
the stars are moving
because the pitch axis is stationed

the city is moved by
because of your orbital motion and earth rotation
there's all kinds of other delightful physics and
natural phenomenon that you can see in these pictures
and we can tickle our imagination and enrich our minds
from this gaining knowledge
when you explore frontier
the people who explore bring back images
and bring back stories
about what these frontiers are like
i feel the obligation to share this experience
so that everybody else can at least participate
through the eyes of the people who do
go into the frontiers
i'm don pettit
i'm a photographer and an astronaut
ok cool so specifically in this course
when we're talking about learning objectives as a whole
for the entire course
we're going to be talking about
earth observation technologies
how they're used to understand how the earth
is changing and how the climate is changing
we're going to talk a little bit more
so in labs or not lab sorry
assignments
you'll be looking at geopositioning technologies
and we'll talk about in lecture
gps and location services
we'll also talk a little bit of very very light
very very brief physics
just about how light interacts with
earth surface materials
allowing us to sense color
and surface attributes
we'll also talk about emerging technologies
like remote sensing
web based technologies
google earth
and then we'll talk about some location based services
gps like i said
remote sensing
virtual globes

web based mapping
whole bunch of different things that we will talk about
but the biggest focus of this course is really on
satellites and earth observation
data obtained from satellites
and what we're able to do with that data
so that's broken into four modules for this course
four yeah four modules
i believe the first is where am i
and so when you look at the lecture content
on the canvas page
it'll be broken into four modules
the first will just be titled where am i
and we're going to talk in that and that module
about understanding where you are located on the earth
how the earth is portrayed in maps
and how it's imaged from satellites
how you work out how far you've traveled
if you're on the surface of the earth
how you measure distance from space
how you figure out where your location is
if you're in a car
if you're on a ship
and you're using something like gps
and understanding where something like your phone knows
or how your phone knows where it is and where you are
and then we'll talk a little bit about the history of
satellite positioning
and also where is space located
then we'll talk about what can i see
and that'll be based on understanding
how light travels through space
and how our eyes are actually able to observe color
we'll talk about wavelengths
that are used for earth observation
the smallest objects that we can see from space
um other energy that we can use
to sense the earth's environment
what canada looks like from space
and then ultimately
how the biosphere
oceans and cryosphere
are monitored

and measured from space
using satellite based earth observation data
we'll then talk about how the environment is changing
we'll talk about the different types of change
that we can observe from the earth
which are cyclical
abrupt and gradual change
then we'll talk about land cover and land use
how we can observe that from space
how the oceans look
and how they're changing
some urban environments
and some urban applications
in terms of using satellites to look at cities
and how cities are changing over time
we'll talk a little bit about wildlife again
which is my favorite lecture
and then we'll end on talking about the future
of earth observation data
we'll talk about a little bit about drones
a little bit about drone imagery
and how it can be used in earth observation
how we can use earth observation data
to monitor the human footprint
and that will be the course
so that's it
in like a minute
so i have about three or four slides here
that i'm just gonna go through
to kind of give you a little bit of introduction
to the course
to what we'll be talking about
how we'll be talking about it
hopefully give you a little bit of sense on
how i lecture
i got a couple of tips for success
after those slides
and then you guys can get out of here
so i always start this course with this photo
so this photo is often called the most influential
environmental photograph ever taken
so it's a photo of earth
as you can tell

it was taken on december twenty fourth
nineteen sixty eight
from the apollo eight mission
it was from a moon orbit
so they were orbiting the moon
and as they were coming around the orbit of the moon
they you know
popped over one side of the moon
they were able to see the earth
and they took this photo of the earth
and this was kind of one of the first
long distance photos of earth from space
and one of the first photos
that forced a lot of the public and a lot of scientists
to kind of really look back
and realize that we are just a bunch of humans
floating on this speck or this rock through space
and because of that
we don't have another
and it's important to conserve it
it's important to monitor it
and understand how it's changed through the past
how it's currently changing
and how it might change in the future
this other photo was taken in nineteen ninety
by nasa's voyager one spacecraft
which was just a spacecraft
designed for deep space observation
and this photo shows what our planet looks like
from about four billion miles away
this pale blue streak that you see here
that actually doesn't exist
is just an artifact of the photo
but this photo inspired the pale blue dot
which just again was referring to earth
and just gave us this sense
this idea that again
we're kind of just all on this tiny speck
in the universe
now in reality
in most of this course
we're going to look at a lot of satellite imagery
so this is an example of a satellite image from night

we'll talk especially in the human footprint lecture
about using earth observation data at night
to monitor urban areas
and to monitor other phenomena
that are occurring on the surface of the earth
so what i want you to do right now
before we finish off with a couple of tips and tricks
is i want you to take a look at this photo
this is british columbia
this is alberta
and we have some bright lights here and here and here
and kind of up here
and i want you to try and think about
what each of these kind of clusters
of bright lights at night
that this satellite is able to observe represent
so what's going on here
you might be able to tell that from down here
you can clearly see vancouver
so obviously
there's going to be some other cities around
but what else are you actually able to observe
in this image
so turn to someone sitting next to you
or a couple people
introduce yourself
your name what you study
and what year you're in
try to answer this
i'll give you a couple minutes
we'll come back and answer it
and then we'll finish off
oh my god
hey yeah
thank you
okay guys let's try to come back and
answer this real quick
can i
seoul or two to help me
can anyone name some urban environments
other than vancouver yeah
calgary and edmonton
yeah you got calgary and edmonton

yeah totally
what about non urban environments yeah
what do you think you could see that isn't a city
yeah definitely some resource extraction going on
for sure definitely some oil and stuff like that
what else any other ideas yeah
yeah yeah you can see that
what else what else from
from the light specifically
there's one thing that wasn't mentioned
specifically
in parts of bc
interior bc there's a couple of bright spots
that aren't necessarily cities yet
of lights smaller lights yeah
yeah
totally yeah
could be that
one of the other things
that maybe we can see with nighttime lights
that it can be really good at detecting
is wildfires too
we can often see wildfires at night from
from this photo
but also that was great
so we're gonna be
looking at lots of different kinds of satellite images
i'm gonna be asking you guys to identify
lots of different phenomena in those images
it'll be fun
i hope okay
so terms of tips and tricks for success in this course
it's pretty simple
i am not the type of instructor to trick you
or to try and ask you
exam or midterm content
that i do not directly discuss in lecture
so it's pretty simple
come to class
ask me questions
if you don't understand something
do the assignments
ask the tas for help

do the blog post
those are participation marks
for the midterm and final
will post practice questions
those will be really reflective
of the kinds of questions
you'll see on the midterm and the final
at the end of each lecture
i also give a bunch of
about one slide's worth of practice questions
and then i let you guys discuss them
and then i come back and discuss them with you
so that's also another set
of practice questions that you'll get
but it's that simple that's it
any questions
that's pretty much all i have
i will the one thing i'll note is
i voice record all my lectures
that's what i'm doing right here
there's no attendance for coming to class
so you don't get a direct hit on your grade or whatever
if you don't come to lectures
i try to make it worth it for you to come to lectures
by being interactive
by making lectures fun
by giving you lots of tips and tricks and hints
about what's gonna be on the midterm and the final
and the tas will also be coming to lectures
and you'll get a chance to ask them
questions about the assignments
if you aren't able to attend their office hours
and things like that
but other than that that's pretty much it
yeah no problem
just one other thing quick announcement type thing
tuesday tomorrow we're not in this lecture hall
hopefully you guys all caught that online
it's a different lecture hall i'll see you there
okay guys let's get started
uh it's another quick lecture today
so you'll be out here pretty pretty fast i'd say um
i'm gonna try to not use a mic

so i'm just gonna try to project
if you can't hear me at the back
just put up your hand or thumbs up
nice sweet um yeah
so today we're talking about
observing your position on the earth
i was tristan was going to come to class today
and introduce himself
and then he just messaged me about thirty minutes ago
saying he's going to come monday instead so
skip that
so in this lecture today
we're going to talk about two main things
one how to define your position
on the surface of the earth and two
what is the shape of the earth
and how do we generally define the shape of the earth
so i wanted to start with this map
it's an old map
it's from fourteen eighty two
and i want you to take a moment
i'll give you about five minutes or so
maybe a little bit less
well not about five minutes
and i want you to try and see what you can recognize
on this map
in terms of
way points on the map that maybe you can recognize
and then i want you to think about
given that this is a really
really old map from fortune eighty two
why might this map be historically significant
why might i be forcing you to look at this thing
so take five minutes
chat with someone sitting next to you
uh if you don't know them
again introduce yourself
but brainstorm that a little bit
we'll come back
we'll discuss it quickly
and then we'll go on
so start with that
europe

it's okay
i don't think
yeah i did
okay
the middle east is back
open your toilet
okay guys let's come back
let's try to work through this a little bit
generally speaking
i like to often give you guys a chance
to talk to your neighbors about stuff
and then i try to come back
and try to lead a couple minutes of discussion
i'll kind of ask you guys to help me with some things
something like this for example
where i get you to brainstorm
if no one's really helping me out
i'll typically just say please don't make me beg
so you know that's just a preface
i'm hoping that i don't to say that
it's not like to shame you guys or anything like that
it's just i try to say that to provide a bit of
comic relief and stuff like that so
yeah okay cool
so what do you guys think
what can you guys see on this map
can anyone tell me what they can see yeah
the arid codes are nowhere to be seen
probably because this is pre
christopher columbus's journey
and the southern hemisphere is mostly mount
there at all
yeah for sure
that's something like
in terms of way points that you can see
with continents and countries totally
anyone else yeah
the parts of the map that are maybe the most accurate
beer towards europe
north africa
and maybe the closer part of the middle east there
yeah you could maybe assume that the map maker
or the group of people that collaborated

were more central with that vision
sure for sure
that that totally makes sense
what about in terms of not you know
not a geographic sense
in terms of where things are and what you can recognize
in terms of countries and continents
and things like that
what else in terms of
maybe more along the lines of map elements
can you notice yeah
yeah exactly that is
that was super impressive yeah
yeah exactly yeah exactly
so the anyone else
yeah
yeah
yeah totally
for sure yeah
so the reason those are all really good observations
the reason that i show this map at the start of class
is because this is the first map
it's made by this guy named ptolemy and he or
yeah he had the
he created this map
and it's the first map to have a coordinate system
so you can see along the bottom here all these numbers
and along the side here all these numbers
and then these kind of grid lines
these gradicules
that represented latitude and longitude
someone said
and this was the first map that had a coordinate system
that used latitude longitude
which is historically really important
because nowadays we still use latitude and longitude
it's still the fundamental way in which we locate
where we are on the surface of the earth
or where other people are
or where we are with our phone
or wherever it might be
so like i said
john fortune

eighty two by
told me it's not important in terms of its detail
although i'm glad you guys were able to point out
lots of cool things about it
but it was the first map to use a coordinate system
it was the first map with latitude and longitude
and for the rest of
well for the first half of this lecture anyways
we're going to go into some detail about
what latitude is
what longitude is
and how we use that
to map where we are on the surface of the earth
so the first is latitude
latitude is an angle
that describes the north south position
so you can imagine if you have you know
a point kind of right in the center of the earth
you can imagine
literally if you went to the center
center core of the earth
and then drew a line out to the equator
it'd be a zero degree line of latitude
because you'd be going straight out
and then slowly
as you go either north or south
the degrees are going to be a bit more
all the way to
if you go to the north pole
straight from here
you can see that's going to be a ninety degree angle
right there
so that is what latitude measures
that's what it is
a parallel is any circle
connecting all locations with a given latitude
so a parallel is three dimensional
it would travel
all the way around the surface of the earth
these are examples of parallels here
the arctic circle is an example of a parallel
tropic of cancer
and tropic of capricorn are examples of parallels

the equator is also an example of a parallel
the equator is the largest parallel
because it's right at the middle part of the earth
and its intersection is with the earth's surface
with a plane perpendicular to the access of rotation
which just means that
we have the north pole and south pole here
and that shows the access
that the earth actually rotates on
and then the equator
cuts right through that access of rotation
the poles are where the earth's access of rotation
meet its surface
so again if i were to kind of imaginary
put my finger on the north pole and the south pole
i could have my fingers there
and the earth would just rotate
in between my two fingers
the arctic circle is the southernmost latitude
in the northern hemisphere
where the sun can remain continuously
above or below the horizon
for twenty four hours
the antarctic circle is the same thing
but in the southern hemisphere
the northernmost point
that the sun can remain continuously above the horizon
for twenty four hours
and i'll explain how that works in a moment
similarly the tropic of cancer
and tropic of capricorn are
in the case of tropic of cancer
the northernmost circle of latitude
so you can see here in the northern hemisphere
where the sun can be directly overhead
and the tropic of capricorn
is the southernmost circle of latitude
where the sun can be directly overhead
in a exam setting
in a midterm setting
for example
hint hint wink wink
nudge nudge

if i were to ask you what the tropic of cancer
or tropic of capricorn is
you could use these definitions
but remember that fundamentally
the tropic of cancer and tropic of capricorn
are also just a specific type of parallel
or a specific parallel
and their specific latitude and longitude
for the tropic of cancer is
twenty three point five degrees north
and for the tropic of capricorn
twenty three point five degrees south
now the way that works
in terms of measuring where that is
it's not just that
we've arbitrarily assigned these latitude values to say
the tropic of cancer and tropic of capricorn
and to the arctic circle and antarctic circle
those latitudes are based off of these definitions
of what each of these parallels are
and the way that works is because the earth is tilted
so because the earth is tilted
when the northern hemisphere is tilted towards the sun
so you can imagine the
i meant to bring my
my blow up globe today
and i forgot
but i'm gonna make a fake
you know sun here
let's say this telephone
you know is my sun
i got my earth here
the earth is tilted this way
this is the northern hemisphere
when it's tilted that way
it's summer
and then it's going to rotate here
all the way around to the other side of the sun
it's still going to be uh tilted
still gonna be tilted in the same direction
so now the bottom of it is gonna be closer to the sun
that would be summer in the southern hemisphere
this would be summer in the northern hemisphere

and the way that works
for the tropic of cancer
the tropic of capricorn
and the antarctic and arctic circle
is because of
where this tropic of capricorn is
and the tilt of the earth
the sun will remain
or can potentially remain
directly above the tropic of capricorn
at some point during the day
at all days of the year
so anytime any latitude
north of the tropic of cancer
at some point of the day
the sun will not be directly overhead
and by directly overhead
i just mean
if you were standing in a given spot
on the surface of the earth
and you looked straight up
perfectly perpendicular
away from the surface of the earth
then you would see the sun
directly in your plain sight
and that only happens
if you are either below the tropic of cancer
yeah below the tropic of cancer
or above the tropic of capricorn
the arctic and antarctic circles
are the only places
where either
below the antarctic circle
or above the arctic circle
where the sun
can potentially remain
above or below the horizon
for all twenty four hours of the day
and again that's just because of the actual tilt
of the earth
does that make sense
any questions about that
dna

cool okay
now elements of longitude are how we describe east west
the meridian is a half a circle
essentially
that goes north to south
and terminates at the north pole
and terminates at the north pole and the south pole
so it connects all points of equal longitude
the prime meridian is typically the origin
of our measurements for longitude
historically and oftentimes nowadays still
the prime meridian is in greenwich england
and that's kind of just this arbitrary prime meridian
you can kind of see it
i think they pointed out here
yeah it goes through
that's the uk up there
and there's this observatory in greenwich england
and this line right here
is literally the prime meridian that they have there
so if you wanted to go stand on the prime meridian
now you know where to go
i'm probably not going to visit there myself
but if you wanted to you could
so longitude essentially measures again with an angle
based on where the prime meridian is
so we'll say this is zero
it measures east
and it measures sorry west
in that case
measures west and east
how far away we are from that prime meridian
and a given meridian is just
again if you took a great circle
which is just as a circle
that goes all the way around the earth
through the north pole
through the south pole
and cut it in half
that would be a meridian
prime meridian is where we start
zero for longitude
this is just another animation

that kind of breaks this down and shows what i mean
in terms of measuring it from the center of the earth
so we have our north pole and our south pole here
our lines of latitude are called parallels
again there you can see if we draw a straight line out
that's at zero degrees then we have a greater angle
greater angle
greater angle all the way up to ninety degrees
that's our north pole and our south pole
and then similarly it's going to show us longitude
and then same thing here
from the center of the earth
you got your prime meridian
and then to the left you got west
to the right you got east
you can also imagine
when i was kind of talking about the tropics
and the arctic and antarctic circles
you can see here
this is a good depiction of the tilt of the surface
or the tilt of the earth
so you can see that north pole and the south pole
isn't just perfectly at the top here and at the bottom
so if i had
you know the sun right in the middle here imaginary
then it'd be the
summertime for the northern part of the hemisphere
because it'd be closer to the sun there
that makes sense
any questions on latitude longitude
you'll get a bit more familiar with it
in the first assignment as well
all sound good sweet
ok so the next thing that we're going to talk about
are models of the earth
all models that we have of the earth are just that
their models
which just means that they are not perfectly
ever reflecting reality
something has to be simplified
in order to create a model
and generally speaking
the more you simplify it

the less representative of reality it's going to be
so we're going to talk about a couple examples here
on the left we have the earth
so this you can imagine is reality
and then as we go to the right here
we have more simple and simple
and simple models of the shape of the earth
and then on the farthest left here
we have reality
and thus the most complex
most realistic model of the earth
and then it kind of gets least complex
and least reflective of reality
as we move to the right here
so the first example there is the geoid
the geoid is a physical approximation
of the figure of the earth
it's the shape of the surface of the earth
based on calmed oceans
and the absence of other influences
such as winds and tides
all that means is just that it
simplifies the surface of oceans
based off of tides and currents that we know exist
it says okay
if we pretend those things don't exist
what would the shape of the ocean look like
and that's all computed
using these complex physical models
based off of gravity readings
on the surface of the earth
so there's this satellite called the grace satellite
that we're going to talk about later in the semester
that essentially orbits earth
and measures what the gravitational pull is
directly below it
it then relates that to how much mass there is
directly below it
and based off that
is able to really accurately approximate
what the shape of the earth looks like
so generally speaking
it's just used to measure surface elevations

with a really high degree of accuracy
when we're out in reality
as remote sensing scientists
earth observation scientists
we're often not using something as complex as a geode
to measure or
or uh map parts of the surface of the earth
it's just so complex
the algorithms
and the data required to build this model
it's just not realistic to be able to plug that in
and use it for our maps and our modeling
because it'll just take too long
and it's just too complex
so what we generally do
most of the time
is use something called ellipsoid
ellipsoid is a mathematical approximation
of the shape of the earth
so it's like a sphere
but it's flattened
so the poles
is flattened at the poles
and bulges out the equator
and that's based off of the revolution of the earth
so it's suitable for direct mathematical computations
and all that means is that it's just a lot simpler
than something like a geode
we can apply it in a mathematical way
much much simpler
it's based off of these two values that represent
the radius of a sphere
and in this case
they're called the semi major axes and semi minor axes
the semi major axis
for an ellipsoid
is always going to be larger than the semi minor axis
so this a value right here
is always going to be larger than this b value here
and that's essentially what separates it from
the simplest model that we have of the earth
which is the sphere
so in this case of the sphere

the semi major and semi minor axis
which is just the radius
going out in this direction
and going out perpetual indicular
to that direction are equal
so the semi major and semi minor axis
are always equal
which just means that earth's radius
is always constant with the sphere
this is generally speaking
the least accurate approximation
of the shape of the earth
so sometimes we use it
if we want a really really
really simple measurement
to base our mapping off of
but generally speaking
when we're looking at the surface of the earth
when we're mapping
and trying to position where we are
on the surface of the earth
we generally use the ellipsoid
the geoid's typically
too complicated
the sphere is too simple
it doesn't quite perfectly
or at least
doesn't quite represent reality
as much as the ellipsoid does
so we generally use the ellipsoid
in general though
just main takeaway
the earth is not quite a perfect sphere in reality
it is bulging at the equator
so the ellipsoid makes it slightly more accurate
and this whole kind of universe of research and
mathematical computation
that looks at these measurements
and tries to approximate
what the earth actually looks like
it's called geodesy
and based off of geodesy
we have all of these different models that in some way

define or represent the earth's surface
varying in their complexity
varying in their accuracy
varying in how well they represent reality
generally the geode is the most accurate
represents reality the most
the sphere is the least accurate
represents reality the least
but the sphere is also the simplest
and that kind of is what makes the ellipsoid
the happy medium
it's pretty simple to compute mathematically
but it's also not crazy
crazy complicated the way the geode is
okay believe it or not that is it for today
couple practice questions
i'm starting you guys off easy but my
my class last semester
this lecture in the past lecture were one lecture
and then i forgot that we had imagined day
so i kinda had to cancel my first class and
and mix those together and i
i didn't you know
decide to give you guys an extra lecture
because of that
so you have two really
really short lectures between yesterday and today
um so these are a couple practice questions again
these practice questions i give at the end of lecture
as well as what i highlight during lecture
about what might be
i got your attention for a second
or at least i think you'll find it important exam stuff
i just thought maybe you'd all quiet down if i said
exam stuff so when i highlight things and say hint
hint wink wink
nudge nudge
you might see this on a midterm or final exam
take that to heart
you probably will
those things that i say might be on the exam
as i'm lecturing throughout
you'll probably see them on

i can almost
maybe even guarantee it
these questions at the end of each lecture
are super representative
of what you might see on the midterm or final exam
some of them are taken right from here
some of them are very
very similar
maybe worded slightly differently
or asking about something slightly different
but that's why i give these
so usually at this point at the end of the class
i give you again
a couple minutes to try and brainstorm these answers
with your notes or with my slides
with someone sitting next to you
so take a couple minutes
brainstorm these
you also don't have to stay if you don't want
me to go over the answers with you guys
if you wanna head out right now
you're welcome to
if you wanna stay about three
four five minutes
practice these questions
with someone sitting next to you
come back and talk with me
and the whole class will go over the answers
and that'll be it for today
yeah yeah
hey
what's up
wink wink nudge nudge
yeah was it about the tropic of cancer
yeah yeah it was
specifically
you know when i said
when i was talking about
i was just highlighting that if i were to ask you
in a midterm or final exam setting what the
tropic of cancer and tropic of capricorn are
there's like three key things that i want you to hit
just beyond the definition

one of them is just the definition
which is right in the slides
the other is what the actual
latitude and latitude values
are of the tropic cancer and tropic of capricorn
and the other is just that they are a parallel
there is just two different parallels
just quick question
yeah the exams are not visually
they're open but
yeah yeah yeah hey
i have a question about simon
is it gonna be like reflection paper
or just answering questions
there's no like
i mean maybe at most you'll have a short answer
but generally speaking most of the assignments
you submit the questions as true or false
multiple choice fill in the blank
okay that's just the form of the assignment yeah
so it won't be like researching no okay
and also you just mention it will be like online exam
so it would be like open
yep okay yeah
so i have a hand up over here
yeah yeah hey
you said the meridian was like a semi circle right yeah
yeah it's like a half circle
the parallels are full circle yeah
so like on the back of the meridian
is that like one eighty east or so
so the back of a meridian is
so the meridians connect on either side
to form something called a great circle
but in terms of measuring longitude with meridians
you have zero degrees which is your prime meridian
and then it goes up in degrees west or east
depending on which way you go
all the way back to essentially a hundred and eighty
either east or west
that's the same point
and that's it yeah
so it does it to the

the prime radio yeah
it doesn't go one two three
one two three
like to the left or right yeah
goes both ways and then connects on the other end
and that's a hundred and eighty east or west yeah
with latitude it's a full circle
yes so there's no one eighty degree ladder to right
maximum ninety exactly
yeah exactly
that's cool
yeah thank you
yeah thank you no problem
okay if you're heading out that's no problem
just scurry for me
i'm just gonna go over these questions quickly
if you're heading out it's all good
go ahead but just head out
if you're gonna head out
and i'm gonna go over the answer to these
do
okay sweet so defining latitude and longitude
so can someone tell me what is the tropic of cancer
please don't make me back yeah
it's the angle that describes the northwest position
north south yeah
angle that describes the north south position exactly
what is the latitude value of the tropic of cancer
yeah twenty three point five degrees north
yeah twenty three point five degrees north
and fundamentally what is the tropic of cancer
yeah the northernmost point
where the sun can be directly above you yeah
what did you say the tropic of cancer was
the first time
sorry yeah you define latitude right
yeah yeah sorry sorry
so that's not the topic of cancer
oh first question is defining latitude
did you think i was just asking to define latitude
my bad my bad so
if i ask the question
sorry reset

what is the tropic of cancer
the answer was down here yeah
the northernmost point
where the sun can be directly above you
the northernmost point where the sun
at some point of the year
can still be directly above you
or at all times of the year
so the northernmost point
where the sun can be directly above you
the value is twenty three point five degrees north
and what is beyond just defining where it is
what is the tropic of cancer yeah
it's a parallel exactly
tropic of capricorn is also a parallel
twenty three point five degrees south
and then how do we define where that is
yeah
exactly southernmost latitude where the sun can also
be directly above you
okay approximations of the shape of the earth
we talked about three
which one is the most accurate
which one most accurately represents earth the geoid
and the least accurate the sphere
what one's in the middle
ellipsoid exactly cool yeah
is it one like someday in the year at some time
it'll be directly about
at every day of the year
at every day of the year
at some point during that day
can be any point during that day
but at every day of the year
at some point during a day
the sun will be directly overhead
in both the tropic of cancer
and the tropic of capricorn
and anywhere within those two latitudes
any other questions any clarifications
i'll be down here if you want to come ask a question
or you need to talk to me at all
otherwise that's it

i promise the lectures won't always be this short
but generally speaking
i always leave a lot of time at the end
for you to ask questions and such
that's it have a good week
hey yeah i think the heater will be the most accurate
and least accurate
what's the answer oh sorry
no it's okay
what are the answers
so the most accurate is the geoid
oh it's also the most complex
and then the least accurate is the sphere
okay thank you
yep no problem
hey my name is kevin
nice what kind of assignment are we expecting like um
paper lighting or uh
the assignments are essentially instructions
that you often have to use
with some sort of online tool
some sort of website
and then you just answer questions
based off the task that we've given you
so your actual submission is just answering a bunch of
typically multiple choices
still in the blank
maybe a couple short answer questions
maybe uploading a file or something
but it's no paper writing or anything like that i think
yeah no problem
hey so in this lies
like when we were discussing about the arctic circle
so it said this is the southernmost latitude
in the northern hemisphere
uh it is the southernmost latitude
in the northern hemisphere
so why is it like the southernmost latitude
if it's in the northern hemisphere
yeah because
so essentially
the way to think about it is
in the arctic there's

in the summer in the arctic
it's possible for the sun to be above the horizon
so that means that there's daylight
for twenty four hours of the day
so at a certain latitude below the arctic circle
that then there is no longer a single day in the year
in which the sun can be directly
the sun can be over the horizon
or just available for twenty four hours of the day
yeah yeah oh
so that's why it's like this
oh i see so that's why it's the southernmost latitude
in the northern hemisphere
because below that
south of that latitude
it would be no longer
the daylight for twenty four hours exactly
just at some point of the year
the way it gets more extreme
the further
like north you get
but just anywhere below
the line of the circle of the arctic
then it is not possible
to have twenty four hours of daylight
or twenty four hours of night time
yeah yeah no problem hey
this is a picture of venice pre pandemic
during pandemic
it shows like
the boat traffic and the quality of the waters
with boats and without boats
is that okay for
yeah a vlog yes
that's great
yeah thank you
from yeah fuse
yeah like for the artists
because his southern most likely
yeah yeah so that would imply like the southernmost
and the northern hemisphere with the tropic of cancer
wouldn't it
so what that means is

the arctic circle
where the arctic circle is
is defined by what latitude in the northern hemisphere
at which below that latitude
it's no longer possible for you to experience
either twenty four hours of daylight
or twenty four hours of nighttime
okay okay that makes sense
does that make more sense
yeah yeah okay
um i just wanna clarify on the degree
is my mind like kind of blanked out so i know
is it twenty three point five yep
twenty three point five for
twenty three point five for both
for both yeah
but it's just like north and south yep
okay and then also for the tropics it's
the sun is directly above
only at some point of the year
not all here
uh so the sun in the tropic
at the tropic within
between the tropic of cancer
and the tropic of capricorn
the sun is directly above
uh you is directly above
at least at some point during the day
every day of the year
oh okay does that make sense yeah
so it's kinda like
like summer
like depending on the season
no it's so so it's like so that
that's the thing it's
it's not dependent on season
so between uh
the tropic of cancer and the tropic of capricorn
at all points of the year
so three hundred and sixty five days a year
it's possible every single day
and it's not just possible
it happens every single day

at some point during the day
the sun is directly overhead
okay does that make sense yeah
so at some point of the day
the sun's directly
when the sun is directly overhead
changes based on the season
that's true
but the point of
where the tropic of capricorn
and where the tropic of cancer is defined
is based off of
if you go either north or south
of either of those latitudes
then no matter what
at some point during the year
the sun will not be directly overhead on a given day
does that make sense
that's a more confusing way
to think about it
i think it's easier to just think about it as
between the tropic of cancer
and the tropic of capricorn
if you are standing anywhere between those latitudes
every single day of the year
the sun will be directly overhead you
at some point during the day
every single day
okay that point during the day will change
depending on the season
but at some point during the day
every single day
between the tropic of cancer and capricorn
the sun will pass directly overhead you
that makes sense
does that make sense yes
okay and that's just all that
the only reason we talk about that
is just cause that's used to define
where the tropic of cancer and capricorn are
so the twenty three point five degrees north and south
is just based off of that measurement
of where it's no longer possible

to have the sun overhead you
at some point during the day
every single day
does that make sense
yeah okay cool
hey uh what does it mean by parallel
parallel yep
so a parallel is uh
any circle around the entire earth
connecting all points of equal latitude
come again i don't think i quite understood
so do you know what latitude is
right yes okay
so our latitude measures how far north or south we are
on the surface of the earth
a parallel is a line
connecting all of the equal points of latitude
so the equator is a parallel
because it connects all the points
that are exactly zero degrees
okay what about longitudes
can we count them as parallel
no the longitude is based off of meridians
okay so meridians are essentially
if you took a parallel right
if you took the equator
which is a parallel
and you turned it ninety degrees
okay right so now it's passing through the north pole
and the south pole
yes that's called a great circle
if you cut that in half
that's called a meridian
so a meridian is a straight line essentially
that you draw from north pole to the south pole
that connects it
and that will be all equal points of longitude
along that line
the prime meridian
is just where we define zero degrees longitude
and then anywhere east or west of that is gonna have
is gonna be you know ten degrees east
ten degrees west

twenty degrees east
twenty degrees west
does that make sense
yes it does
okay alright thank you
yeah no problem
hey hi um i was just wondering like for longitudes
are they parallel to each other
or are like the parallel only so
so parallels are just the names
of the circles that connect points of equal latitude
okay so the longitudes aren't parallel to each other
so like each gradient well so so
it's a circle as well
right but a meridian
which is what we use to measure longitude
is a half circle
right so if you have a meridian
that goes around both sides of the earth
that's called a great circle
if you cut it in half that's called a meridian
the meridians are what we actually
use to measure longitude
and they are
you know if you were to put them kind of
depending on how you projected them
if you were to put them on a map that preserved shape
they would be technically parallel
but that's what i'm saying
the term parallels
when we're referring to parallels of latitude
doesn't apply to longitude
well it just doesn't mean we don't use that word
because the lines are literally parallel
they are but
but they're not if that makes sense because
because if you if you take a
because it depends on how you project the map
and we'll get into this in the next lecture
a little bit more
but you can think of parallels
i wouldn't think them as
they don't think of them as

they're just lines that are parallel to each other
think of parallels as lines of latitude
that connect all equal points of latitude
around the surface of the earth
so the equator is a parallel
the tropics
tropic cancer
tropic capricorn are parallel
the arctic and antarctic circle are parallels
any circle that connects all equal points of latitude
is a parallel
a line that connects equal points of longitude
is called a meridian
okay that's the easiest way to
to think about it
and also one more question about like how there's like
twenty four hour days and twenty four hours nights
like south on the north yeah
so once we cross that twenty three point five latitude
yeah ish circle yeah
so why is that
is it because like the earth is tilting so the
so the twenty four hours of daytime or night time
only occurs
either north or south of the arctic or antarctic circle
so that that doesn't have to do with
tropical cancer or capricorn
okay so what is the tropical cancer
capricorn actually do so
so they where they are is defined by
up is defined by
if you go as long as you're within those two tropics
so if you are south of the tropic of cancer
north of the tropic of capricorn or just you
you're at any point in between the two parallels
that represent the tropics
trop of cancer tropic of capricorn
then every single day of the year
at some point during the day
the sun will pass directly overhead you
but if you're north
if you're outside of those two
if you're outside of the tropics

so if you're either north of the northernmost tropic
or south of the southernmost tropic
then at some point during the year
the sun will not pass directly overhead you
okay does that make sense
i know it's a bit confusing too
because the earth tilts
or is it because
yeah it's because of the earth's tilt
okay so when you are
for example when it's
i again wish i had my globe
but you know
i'll go back here
if this is our sun right
this is my earth right
and this is the north pole right at the top here
and it's tilted like this right
then you can imagine at some point coming up
eventually you are going to have a direct line
between the sun and that point on the earth
right like that
if you keep rotating at different parts of the year
then the sun's not going to be passing
directly overhead
yeah i'm trying to visualize this in my head
thank you yeah
yeah yeah exactly exactly yeah
just a very quick question
so is google earth a form of garage
a form of what sorry
so the model
you talking class like
yeah describe the earth
we have the most accurate one with the geoid
yeah yeah and these accurate one we should
it like the sphere is the least accurate
yeah so is the google earth
can we like understand it
it's actually a firm like um
or time of joy
the google earth
oh google earth you're saying

yeah google earth you
google earth is like a type of geode
okay yeah yeah
that's my question
yeah yeah yeah no problem
how does that apply to the southern illustration
i mean the twenty four hours on forehead
well because of the tilt of the earth
yeah it is tilted towards north
and i must be alright
when it's summer in the northern hemisphere yes
when it's summer in the southern hemisphere
and the earth is
you know if it's tilted like this
and it's summer right here in the northern hemisphere
then when the earth travels around the sun
and now it's on the other side here
it's still tilted the same way
but now the southern hemisphere is closer to the sun
so then it's summer in the southern hemisphere
yeah i'll bring my globe next week
and i'll try and do a much better
like approximation of what that looks like but
yeah thank you
yeah no problem
do you have a question
okay cool
no not really
and i mean i mean
the
the geoid is just meant kind of as a term for something
for a model of the earth
that can't be kind of simply calculated
using some sort of
approximation of an ellipsoid or spear
i'm trying to
so the geoid and the spheroid and the sphere
are really just meant to
yeah like they're used in reality
especially the ellipsoid and the sphere are used like
that's the most common way we use
we apply projections to maps
or the most common way we think about the earth

when we for example have google maps on our phone
that usually uses some sort of
it's based off of some sort of ellipsoid
when you have a really accurate
representation of all of the
kind of little bumps and elevation points and every
all the topography and stuff of the earth
and how much mass there is and all of that
that's kind of what we mean by geoid
and it's not really used in reality
when it comes to things like earth observation
because it's just way too complicated
yeah and i mean
that was kind of just
that was just kind of to like
help simplify for him
because like
if i said that that a joy wasn't google earth
then i think he might have lost his mind but
but the point of that is just
the most complex models of the earth that we have
are geoids the simplest versions
the simplest models of the earth we have are spirits
and the most frequently
used models of the earth we have are typical ellipsoids
and that's just because
they're a little bit more accurate than a sphere
but a billion times
less complicated than something like a geoid
yeah so it's more of
the geoid in particular is
you're right
it's more of an abstraction
the ellipsoid and the sphere are real
it is like we will take an ellipsoid
that has a defined semi major and semi minor axis
in order to approximate the shape of the earth
and then where we are on the shape of the earth
the geoid is
it's never really used
to be honest
yeah yeah no problem
hey i was just wondering if this is like how the

the degrees are
yeah represented just like this
yeah exactly
okay and also i was like up there like
and then there was another student i was
i'm asking about like parallel lines
and i didn't really get all of it
like what really defines the parallel so
so a parallel
a parallel is any circle around the earth
that connects points of equal
all the points of equal latitude
so just like
can i imagine like a ring
yeah totally like that
yeah just like that
but it has to connect points of all equal latitude
so that's why the equator is a parallel
because anything along the equator is zero degrees
that's why the tropic of cancer
and tropic of capricorn are parallels
because anything along those lines is either
twenty three point five degrees north or south
that's why the arctic
circled antarctic circle are parallels
okay i'll get that
okay well thank you very much
no problem hey
i have questions
you know yeah
look at old satellite pictures through google earth
so i thought the gaza strip would be cool
be it in headlight
um you're probably not
that they're off through google earth
um i'm not sure of how to change
i feel like google earth just has base maps
and i don't know if you can really pick a year
of what that base map is from
um generally speaking
for trying to find satellite imagery
your best bed
just kind of should just like

google places
like it's hard to find them on just like
google earth or google maps
um uh later in the semester
we get you to use this website called earth explorer
where you can download
actual satellite imagery of the exact same place
at any point in the past thirty years or so
but that's kind of really only
available on that website
you can't really do it
generally speaking
from something like google earth or google maps
so i would just do
you're just looking for the blog post right
yeah i'm saying yeah
so i would just try and
like honestly
your best best
just use like
google images
the images have to be perfect then
right because
well you can
comparisons
but yeah the exact
the exact comparisons are like
are like literally based off
like googling an exact comparison
so if you google a place
and then say comparison
satellite imagery
or something like that
then that's probably where they're getting those
i must see something good here
i think i might change locations
because these are too zoomed in
it might also be in like if you search
you mind if i
if you also just search like in
rather than images just here
sometimes it's easier because they'll pop up in like
articles and stuff like that

yeah i think in articles i saw some
gaza strip comparison
satellite imagery
yeah i mean the gaza strip is pretty small area right
so that's gonna be
that's gonna be zoomed in pretty well
what what if you like
if you search maybe more on the scale of like
a state or like
like just something like larger than it might
because like you're
you're saying your problem is that the images are like
too zoomed in for
yeah like that's like a block
yeah i don't think i would get
yeah so where is
so so i would do instead just something like comparison
satellite imagery is real
yes okay and then maybe something them to like
way more will pop up and then you can just say
you can just
when you talk about it you can say i google these
but i'm looking at the gaza strip specifically
kind of thing goodbye
no one did that i thought
cool cool thanks
yeah no problem hey
the question about this thing
oh sorry this is still
all right hi everyone
can i grab your attention take a seat
happy monday hopefully you had a good weekend
i'm going to start with evan so that he can update you
on what you're supposed to be working on this week
if you have questions about blog post
or course logistics
anything kind of related to that
this is a good time to ask him
so i'm gonna give it to him and then
and then i'll get going for the day
all right hello everyone
start a semester
there's not too much going on yet

but things you should be working on and keeping in mind
is next thursday at eleven fifty nine pm
the first assignment is due
and the first blog post is due
one thing i want to highlight about the blog post is
if you haven't looked at it yet
it says you either submit your own
submit a response just to the prompt
or you can respond to someone else's response
you don't need to do both
just pick one or the other
be getting a bunch of emails about this
so just do your own response or respond to someone else
other than that
leanne has got office hours over the next two weeks
there's four hours in total
she's also available via email
they're up here
so on this tuesday and next tuesday
there'll be three to four pm pst
and then this thursday and the thursday afterwards
ten am to eleven pm pst
now is a great time to ask me about
any course logistics or anything like that
if not i'm going to dip
any questions for evan
okay you can always email him or anything like that too
email whenever
thanks man i guess yep i'll see you soon yep
okay so today we are talking about projections
for most of the lecture
and then we'll talk a little bit about scale
evan gave his updates already
i wanted to start with some review
clarifications from last tuesday
there are some things
i think i could have explained a bit better and
yeah i got my
i got my props today
so i can give some demos and kind of
more clearly explain what was going on with the
specifically
i'll just talk about the elements of latitude

so go over again
tropic of cancer trop
tropic of capricorn
arctic circle
antarctic circle
why those parallels are the latitude values
that they are
i'll talk about briefly the models of the earth
we have again the geoid the ellipsoid the sphere
and then most of the day today
we'll talk about projections so
again these are things i'm going to review
first thing i wanted to go over
was the elements of latitude
so this seemed a bit confusing for a couple of you
i got a couple of questions
i just want to go over it again
parallels are all of these lines
that connect all the points of the earth
with an equal latitude value
so the equator is a parallel
connects all the points on the earth
that are at zero degrees latitude
tropic of cancer is a parallel
tropic of capricorn is a parallel
and the arctic and antarctic circle are both parallels
the arctic circle
which is sixty six point five degrees north
is denoted by that latitude value
because anywhere below the arctic circle
in the northern hemisphere
is not capable of having continuous
twenty four hours of daylight or night time
at some point during the year
and the same but in the southern semis
sorry the same but in the southern hemisphere
for the antarctic circle
i'm going to explain that with my globe again
so if that's still confusing don't worry
the tropic of cancer and the tropic of capricorn
are essentially between those two latitudes
between those two
guys excuse me thank you

between those two parallels
between those two values of latitude
it is never possible
for the sun to be directly overhead
and i'll explain a little bit more what that means
i think this graphic does a pretty good job
depicting how that looks
i was hoping to get
maybe i'll do it like right here
can i get a volunteer to come down and be my son
yeah can you come up here
do you like that one nice
okay can you stand right here
kind of on this yeah
gross spot right there
perfect you can face any direction
okay so summer solstice
i'll kind of go in line with what
what the graph looks like up here
so summer solstice
i'm over here right
the northern hemisphere is pointed towards the sun
when it's summer in the northern hemisphere
twenty four hours
in a twenty four hour cycle
the earth is rotating on its axis like this
and then in a whole year
it's coming all the way around the sun like this right
the whole time it's doing that it's tilted on its axis
so it's not rotating like this relative to the sun
is rotating like this relative to the sun is tilted
and it's always tilted like that
no matter if it's here or here
but that's what creates summer and winter
so when it's the summer solstice
and we have the longest days of the year
in the northern hemisphere
the earth is tilted
the northern part of the earth is tilted
towards the sun
and on the day of the summer solstice
the sun at high noon
is directly overhead the tropic of cancer

does that make sense
because again
if i'm tilted here
my tropic of cancer is kind of somewhere around here
the sun is kind of directly perpendicular
with that latitude
with that point on the earth
this tilt never changes
so if i come over here
halfway between
the summer solstice and the winter solstice
then the sun is directly over above
over above the
directly over or above the equator
so the sun is directly over the equator
twice a year
when i come over here to the winter solstice
the sun is directly over the tropic of capricorn
and then the sun comes
the earth comes back over here
and then again
it's directly overhead the equator
so it's never possible
for the sun to be directly overhead
if you're not within the tropic of cancer
and tropic of capricorn
now similarly
if i am here
right summer solstice
summer in the northern hemisphere
and i am right at the arctic circle
if i'm right on the arctic circle
for one day
at the summer solstice
i'm going to get twenty four hours of daylight
i'm going to get one day of full sun
similarly winter solstice
in the northern hemisphere
over here i'm going to get
on the day of the winter solstice
if i'm right on the antarctic circle
i'm going to get twenty four hours of daylight
so anywhere between

so above the antarctic circle
and below the arctic circle
is never capable of getting twenty four hours
of either daylight
or sunlight
sorry daylight or nighttime daylight
is sunlight
the same thing
does that make sense
any questions about that yeah
yeah thanks
you can sit down thank you
exactly yeah
once well so
so so so both
technically the sun passes directly overhead
if it's possible for it to be directly overhead
once a day at high noon
right because no matter where you are on the earth
the sun's always going to rise and set
so it's never going to be directly overhead
for the whole day
and then it's
other than the equator everywhere else it would be
it would go let's see up down
maybe twice a day or twice a year sorry
if it was going to be directly overhead
so it's directly overhead
the tropic of cancer once a year directly overhead
the tropic of capricorn once a year directly overhead
everywhere between there
just the equator twice i think just like that
or between the equator i think it'll be twice
yeah you're right i think it'll be twice
exactly yeah yeah yeah so twice
does that make sense yeah
exactly yeah
exactly yeah
but no matter where
no matter if it's possible to have the sun
directly overhead once or twice a year per day
it's only ever going to be once
just at high noon

when the sun's at its highest point in the sky
and high noon is just
it means noon
but noon we denote in society as noon
twelve o'clock
high noon just means the point
when the sun is at its highest in the sky yeah
yeah sorry per me
can you guys quiet down
thank you yeah
twice a year for everywhere except the tropics
once a year for the tropics
and then during that one day
yeah at one point during that day high noon
yeah exactly
yeah exactly
yeah that makes sense that is
this is all extra
i don't expect you to know each of that kind of detail
i wanted to explain this
so you guys could wrap your head around it
all i really expect you to understand
is why the tropic of cancer
tropic of capricorn
as well as the arctic and antarctic circle
have the values of latitude that they have
which is these reasons here
but i wanted to try and give you a better graphic
to wrap your head around
any other questions about that yeah
correct yeah correct
and same with the tropic of capricorn
if you're south of that
yeah any other questions about that about the tropics
yeah
yeah the antarctic or the arctic above both
yeah sure yeah
there's gonna be one day where there's either no sun
or it's always sunday
no only if you're right
on the arctic circle or antarctic circle
will there only be one day
if you're well above the arctic circle

there'll probably be a couple days
maybe a couple weeks maybe a couple months
where you'll have continuous twenty four hour daylight
or continuous twenty four hour nighttime yeah yeah
that makes sense
any other questions
sweet okay so the other thing i wanted to go over was
quickly the shapes of the earth
there was maybe a little bit of confusion around that
so again we have our reality over here
what earth actually looks like we have our geoid
which is our most accurate
most complex approximation of the shape of the earth
we have the ellipsoid here and we have the sphere
in reality for the most part
when we talk about something like
i mainly wanted to go over this because last week
someone asked me if google earth uses a geode
didn't think that through properly
i said yes it doesn't
whoever asked me that
i changed my answer
google earth
generally speaking
uses an ellipsoid
and the reason that google earth
and most mapping services in general
use an ellipsoid as the model of the earth
is because something like a geoid is way too complex
the whole point of a geode
is that it's not a mathematical shape
you can't approximate it
by just calculating a few simple radii or radius
like you can with the ellipsoid
the ellipsoid is just defined by this semi major
and semi minor axis
which is just
the radius out to here
and the radius up to here is what defines an ellipsoid
a sphere is just defined by its radius
which is constant in every direction from the center
a geode it doesn't have a constant shape
you see how it's kind of undulating

and it's kind of this weird
kind of funky shape
that's the whole point of a gioid
it's meant to represent more closely
what the surface of the earth actually looks like
and in reality
the surface of the earth does undulate like this
it's not a perfect ellipsoid or sphere
the way we often model it
but to say that it's a geode for mapping purposes
whether it's google earth
google maps whatever
is generally way too complicated for that software
or just would require a lot of computations
and just makes it more complex than it needs to be
so generally speaking
we use an ellipsoid
to approximate the shape of the earth
for google earth or other mapping services
really the geoid is only used if you need a very very
very very precise
specific location measurement
or height measurement
or elevation measurement
so i know sometimes
when they are trying to measure
how far below the surface an earthquake occurred
so maybe measure that relative to a geode
because they need a very
very precise measurement
but generally speaking
for most mapping services
you're gonna see them using an ellipsoid
because for an ellipsoid
all you have to say is
okay my semi major axis is this wide
my semi minor axis is this long
that's it we have an approximation
of what the shape of the earth looks like
any questions about that does that make sense
going to assume yes
sweet okay so today
we are mostly going to be talking about projections

we're going to be talking about
how the earth is projected onto maps
what units we use to observe the earth
and then we're going to
talk about the scales of the universe
going from very
very minute scales to very
very coarse scales
and talk about how we observe those different scales
and how we represent them on maps
so to start i need volunteers and groups of two
so i need three pairs of two to come down and
blow up one of these for starters
and then i'll tell you what you're gonna do
but can i get some volunteers yeah you two
you wanna come up you two pick someone back
yeah you two
sorry guys
all right can you guys blow up a globe
first things first
so just just
just one globe for two of you
can you guys blow up a globe
okay you can do it
you just gotta
you just gotta pinch the little like
you gotta pinch it as you blow aaron you got it
it just takes some effort
you feel it working
if you can't do it i've practiced this a couple times
so i can also try and do it
yeah you got it
it takes a bit of time
you'll get there okay
then you guys
you can each pick somewhere up on the wall here
so one of you on the left here
one of you kind of in the middle here
and then one of you on the far right here
i just want to apologize
oh that's okay don't worry about it yeah
where did
you got it you got it you're getting there

okay one team one team right here
it hurts so much you know it is working
can i get you guys in the center right over here
you guys are over here in the center
and you guys yeah you guys can go right here
all right you're almost there yeah almost got it
okay i'm gonna explain the rules
as you guys are finishing blowing up here
you're almost there nice
if it makes you feel any better
someone last term literally couldn't blow it up
and i had to blow it up for them
so you guys are already doing way better than they were
okay so this is what these guys are gonna do
they're each going to have a globe
in a moment that's blown up
i gave them each one set of scissors
scissors one roll of tape tape
and what they are going to try to do is in a minute
i'm going to put a timer on
they are going to try to take this globe that they have
and make it flat
so you have the tape
so that you can tape it up to the wall here
i want you to try to do your best
so that you can see the entire globe
on this flat surface
so not just one side of it
but all of it
you can do whatever you want to it
but i want you to try and minimize
how much damage you do to it
so you can do whatever you want
but the more you change about it
the worse you're doing
if that makes sense yeah
like just like mathematically wouldn't that be
we'll talk about it
okay you look almost good there that's good enough
you can close it up
okay you guys can move over a little bit
i'm like right there
so you got the tape you got the scissors

you can do whatever you want to it
the more you change it
the worse off or the lower ranking i'm gonna give you
but you can do whatever you want
but you want to try and get it
try and get the whole globe nice and flat up on here
okay okay you guys ready
you ready you got the scissors you got the tape
you got one minute so sixty seconds
okay ready set go
you gotta go fast only one minute
don't cut yourself please
i got i tried to get safety scissors
so hopefully you guys don't hurt yourself
you already had twenty seconds
to give you context
you gotta go
you gotta go fast fast fast
i unfortunately
only have an hour and a half to teach you guys so
you're already at thirty seconds
i don't even see anyone having flat on the wall yet
okay i'll give you guys an extra minute
because this is not going as smoothly
as i hoped it would
so you're approaching a minute now
you got twice as much time
you got another minute
do whatever you want to do to it
to get it up there flat
no you don't have to
you don't have to do whatever you want
okay we're almost at a minute and a half here
i'll give you guys thirty more seconds
thirty more seconds starting now
this is it make your final make your finishing touches
get it looking nice
all right ten more seconds
all right i'll give you guys an extra ten
this is it though
this is it this is it though
five more seconds
all right and that is it

all right stop there
see what we got
okay all right not bad
it's gonna be worse
okay you guys can sit down unless you want me
i don't want to like
have to shame you guys while you're up here but yeah
give a round of applause
okay so we're ranking these
if we're ranking these
based off of how flat they were able to get it
how much of the earth they were able to get flat
and the amount
and we penalize them a little bit for
for those that changed it more
that changed the globe more than others
but really what we want here is flat
so whoever got it flat us
whoever you guys think the best job
let's start on this guy on this side
we're gonna vote you get one vote
boo who thinks this one is the best job
okay what about this one
okay what about this one really okay nice good job
and i want that
that was actually pretty good to be honest
okay the point is the reason i got them to do this was
how did you guys
how'd you guys find out
was that hard
it was hard
okay so the reason it's hard
you almost gave it away there
is that it's physically impossible
to take the earth and make it flat on a map
without doing some sort of distortion
one of the things that i did
when i got some students to do it last year
i think they've done this before
they kind of cheated
but they took the globe and kind of
along the lines of what you guys were doing here
they made like several slices all the way to the center

and kind of spread out each of those slices
that got it pretty flat
but that's obviously
heavily changing what that globe looks like
this whole procedure of taking a three d globe
and putting it onto a flattened two d surface
is something that has
been a field of research for a very very
very long time
and it's generally called projections
so a map projection
is a set of mathematical formulas and equations
that enables the curved surface of the earth
so a three d globe like this to be shown on a flat map
only a globe that kind of looks like this
only a three dimensional curved surface globe
can accurately represent
all of earth's metric properties
things like area
distance shape and direction
can only all be perfectly represented
on something three dimensional like this
on a flat surface
only some of these properties
can be accurately presented
now that means that sometimes
you can accurately represent area
or you can accurately represent shape
or you can accurately represent distance
but it is impossible to act to room look
it is impossible
to accurately represent all of those things
every single two d map that you look at
every single map that's on a flattened surface
unless it has some sort of
three dimensional aspect to it
has some sort of distortion
so essentially
no matter what kind of map you're looking at
if it's a two d map
in some way
shape or form
is lying to you

it's not telling you in reality how that looks
but map projections are super
super useful to us
for navigation purposes
for understanding our landscapes
for mapping the world
we still use them all the time
but no matter what
there's gonna be some error associated with them
okay i have a little video here
that kind of helped describe some of that phenomenon
the boat has flowed into a flat map
flying flat
i had to cut it several places
i've had to stretch it
so that the country is going to look all wonky
and even still it's almost impossible to get it
and that right there is the eternal
the surface of the spirit
cannot be represented as a plane
without some form of distortion
that is mathematically approved by this guy
a long time ago
since around the fifteen hundred
mathematicians have said
about creating algorithms
that would translate the globe into something flat
and to do this
they use a process called projection
popular rectangular mats use a cylindrical projection
imagine putting a theoretical cylinder over the globe
and projecting each of the points of the sphere
onto the cylinder surface
unroll the cylinder into a flat rectangular mat
but you can also project the globe onto other objects
and the map used by mapmakers to project the globe
will affect the way the map looks
when it's all flattened out
and here's the big problem
every one of these projections comes with trade offs
in shape distance
direction and land area
certain map projections can either be misleading

or very helpful
depending on what you're using them for
here's an example
this map is called an retainer projection
if you're american
you've probably studied this map in school
it's also the projection at google mountains
the mercator projection
is popular for a couple of reasons
first it generally preserves the shape of countries
brazil on the globe
has the same shape as brazil on the mercator projection
but the original purpose of the mercator
projection was navigation
it preserves direction
is a big deal
to try to navigate the ocean with only a compass
it was designed to
that a line drawn between two points on the map
would provide the exact angle to follow on a compass
the travel between those two points
if we go back to the globe
you can see that this line is not the shortest route
but at least it provides a simple
reliable way to navigate across the ocean
gerardus mark peter
who created the projection of sixteen century
was able to preserve direction
by varying the distance between the latitude lines
and also making them straight
creating a grid of right angles
that created some of their problems
where the mercator fails is the representation of size
look at the size of africa as compared to greenland
on the mercator map
they look about the same size
but if you look at a globe for greenland's true size
you'll see that it's way smaller than africa
by a factor of fourteen in fact
if we put a bunch of dots onto the globe
that are all the same size
and then project that onto the mercator map
we will end up with this

the circles retain their round shape
but are enlarged so they get closer to the holes
one modern critique of this
is that the distortion perpetuates imperialist attitude
of european domination over the southern hemisphere
the mercator conjunction has fostered
european and careless attitudes for centuries
and hid an ethnic bias against the third world
really so if you want to see a map
that more accurately displays land area
you can use the gaul peters projection
this is called an equal area map
look at greenland and africa
now the size comparison is active
much better than the mercator
but it's obvious now
that the country shapes are totally distorted
here those dots again
so that we can see how the projection preserves area
while totally distorting shape
something happened in the late sixties
that would change the whole purpose of math
being the way that we think about projections
satellites orbiting our planets
started sending location and navigation data
to little receiver units all around the world
today orbiting satellites
of the navy navigation satellite system
provide round up ultra precise position fixes
from space to units everywhere
in any kind of way
this global positioning system
wiped out the need for paper maps
as a means navigating
well to see in the sky
map projection choices
became less about educational imperatives
and more about aesthetic design and presentation
the mercator projection
that once vital tool of pre gps navigation
was shunned by photographers
who now saw it as misleading
but even still

most web mapping tools like google maps
used a mercator
this is because the mercator's ability to preserve
shake and ankles
makes close up views of cities more accurate
a ninety degree left turn on the map
is a ninety degree left turn on the street
that is driving down
the distortion is minimal when you're close up
but on a world map scale
cartographers rarely use the mercator
most modern photographers have settled on
a variety of non rectangular projections
that split the difference
between distorting either size or shape
in nineteen ninety eight
the national geographic society
adopted the wiggle triple projection
because of its pleasant balance
between size and shape accuracy
but the fact remains that there's no right projection
cartographers and mathematicians
created a huge library of available projections
each with a new perspective on the planet
and each useful for different tasks
the best way to see the earth is to look at a globe
but as long as we use flat maps
will have to deal with the trade offs of projections
and just remember
there's no right answer
okay so there are two ways
that we can classify or categorize projections
one of them is based off of the shape or surface
that we use to project the earth onto
so in this case we talk about cylindrical projections
conic projections
and planar projections
the cylindrical projection
is similar to a mercator projection
that's what that guy showed in the video
where you take a cylinder
cover it around the globe
and use that to project the earth's surface onto it

roll it out
you get this nice rectangular looking map
you can also do a conic projection
where you project onto a cone
you can also do a planar projection
where you just project onto a plane
sometimes these are categorized
with the second type of categoration
that you can use for projections
i've showed them separately here
because in the past
i've shown them together for simplicity
but i think that just ended up confusing students
and you'll see why
maybe why that is in a moment
so the first way that we classify
different types of projections
is just based off of the shape
that is used to project the world onto
and for exam purposes
for midterm purposes
all i expect you to know
is that you either project onto a cylindrical surface
a conic surface
or a planar surface
or just a plane
the other way we categorize projections
is based off of what map elements are preserved
and what map elements are distorted
so the first category we talk about
is the conformal projection
the conformal projections preserve angles
similar to again what was talked about in that video
with the mercator projection
these make them really convenient for navigation
so for something like see navigation
or for google maps
like it was showing
a ninety degree right turn on the map
is a ninety degree right turn in real life
but they also heavily distort area
the equivalent or equal area projections
are projections where the size of say

continents are preserved
you can see that here in reality
africa is about fourteen times bigger than greenland
and that looks true in this projection
whereas not so much in this one
but the shapes in this projection are wrong
so greenland obviously isn't actually shaped like that
it's actually shaped like that
but that's much bigger than it is in reality
the other two categories are equidistant projections
this is where in some way shape or form
distance is preserved in the projection
and this example on the right here
it's from the center point of the map
to anywhere else on the map
distance is preserved
if you tried to say
measure distance from this point on the map
to this point
any two points that didn't include the center point
it wouldn't be correct
but from the center point to any point outward
distance is preserved on that map
shape and size are not preserved on this map
the last category is compromise style projections
compromise essentially
balances the distortions of shape
area distance
those are the three main map elements
that we'll discuss
they kind of produce these visually appealing maps
that are more true across categories
but don't have one specific map element
that is a hundred percent preserved
so you can't measure any metric properties on a map
that compromises
so you can't measure area distance or shape
but it does produce a nice kind of balanced map
sometimes for example
the mercator projection is a conformal
cylindric projection
so oftentimes
when a projection is described

it'll be described
using the shape that it's being projected onto
as well as what map properties are being distorted
and being preserved
i used to teach this as
just a category called cylindrical
conformal projections
but that's kind of confusing
because in reality
if you go out there and look
across a wide variety of projections
not all conformal projections are cylindrical
not all cylindrical projections or are conformal
most of the time they are
but not always
so i stopped teaching it like that
so for the purposes of this course
for midterm purposes
all i want you to understand is that
you can project onto one of these three surfaces
and then just understand what is being distorted
and what is being preserved
when we talk about a conformal projection
an equivalent or equal area projection
an equidistant projection
or compromised projections
any questions about that
see ok i'm going to play another video
about projections
you don't often see a world map like this
but it's one of the best ways to highlight the oceans
there's no perfect way to put a rock planet
on a flat map
something is going to be distorted
cartographers have peeled the road
in many different ways
and each has its own advantage
the famous mercator projection
from the sixteenth century was great for sea navigation
but greenland looks bigger than africa
even though africa is fourteen times larger
a german mathematician named karl malaide
created an electrical projection

you can't use it
for navigation
but it accurately compares
land areas pull the oceans apart
and land areas lie even flatter on the page
and are even more accurate in shape
for our map of the ocean floor
we used an interrupted volidae centered on the pacific
and divided the land rather than the seas
the three main oceans are shown in their entirety
with the least distortion possible
so the whole point of that is
there are a wide variety of projections
that can look a ton of different ways
if you're say
mapping oceans
you'll use a projection
that hopefully doesn't distort ocean areas that much
if you're mapping say
north america
you'll probably try to pick a projection
that doesn't distort north america as much etc etc
so one of the recurring kind of concepts
that's talked about in a couple of those videos
is eurocentric mapping
associated with the mercator projection
and so this has kind of been shown
again in a couple of those videos
and i've pointed it out in a couple of these
images of the mercator projection
you can expect
a midterm question on this
wow a lot of heads just came up so
there's a couple of key concepts to understanding this
one is what eurocentric attitudes mean as a whole
and that just means that
it perpetuates this thought that
europe is more dominant relative to other countries
now you can see here that africa looks kind of
not too much larger than a lot of these other countries
close to it
in reality all of those countries in size
could fit inside of africa

so that is one way that the mercator projection
has perpetuated this eurocentric attitude
is that it distorts areas more heavily
that are closer to the poles
so countries continents
that are high in the northern hemisphere
that are very far north
look larger and larger and larger and larger
the farther north you get
that's why the arctic
baffin island in canada
northern canada
arctic greenland
all looked really
really really big in that projection
as you can see here
is because they are heavily distorted
the further away you get from the equator
so on this projection
in the mercator projection
you can see again
greenland and africa look almost the exact same size
in reality if you used an equal area projection
you'll see that greenland is much
much much smaller than africa
so the mercator projection
has been argued to perpetuate eurocentricism
in institutions such as educational institutions
schools etc
partly because it heavily distorts areas like europe
that are in the northern hemisphere
to appear much much larger
the other reason
or the other feature of that map
that is often argued to perpetuate eurocentricism
is where the prime meridian is
so the prime meridian
the center of the map
if we look back to the mercator projection here
is europe europe is typically what we think of
as the prime meridian
it passes through
there's the prime meridian actually

right there
passes right through greenwich england
and that centers the map there
that's an arbitrary center
we don't have to center our map there right
so there's other maps that have been created that say
center the map over the americas over asia
there's other maps where we kind of flip it upside down
so that we get this completely different view
of what the world looks like
the point is that the big take home from all of this
is that map projections
have the potential to influence
our perception on the world
and our perception of our surroundings
so it's important to critically think about
what map projection we're using
under certain circumstances and why
in terms of the midterm question
the key topics i want you to bring up
if i ask you about how the mercator projection
has perpetuated eurocentricism is a
that it heavily distorts
the size of countries and continents
as you get closer to the poles
making areas in the northern hemisphere
often more first world countries in europe canada etc
to appear much
much much larger than they are in reality
which potentially perpetuates this sense
that they're more dominant than other countries
maybe in the southern hemisphere
the second point i want you to get at
is where the prime meridian is
the prime meridian in the mercator projection
is centered on england
or on europe
which again
makes europe the very
very center of the map
and that again
potentially perpetuates the sense of eurocentricism
any questions about that

these are some additional readings
and stuff about projections
they're optional
don't have to read them
but any questions about projections
about how the mercator projection
influences your perception
has perpetuated eurocentricism etc etc
you can definitely
definitely definitely expect a midterm question on that
and you can trust me when i say or just
just trust me if i say it's gonna be on the midterm
i'm not gonna trick you
it's gonna be on the midterm
so believe me
any any questions
clarifications
anything like that
looks good okay
now this is a kind of brainstorming question
that i want you guys to
discuss with someone sitting close to you
in terms of measuring distances right
today we have the metric system
the imperial system
we use meters kilometers
inches feet
whatever it might be
but we didn't always have these standards
so way way way back
before you might pull out a meter stick
or your measuring stick or your measuring tape
or whatever it might be
what do you think we used people
i mean what do you think people used to measure things
how would we measure something without a measuring tape
without a measuring stick
without a standard like that
that we use worldwide in order to measure things
yeah
yeah hand span or wingspan
really good example
using kind of parts of our body

yeah isn't like the imperial system of
like what a foot is literally just like
roughly the size of the human foot
yeah yeah for sure yeah
legs and nuts
yeah how do those work i'm not even sure
okay yeah yeah
yeah yeah okay
all of these kind of have a similar kind of concept
which is that it's related to some sort of standard
that some people commonly do
right in some way
another one that i've seen is
the furlong
this guy here
which is roughly the distance
a team of oxen could plow through a field
kind of random
but the point is we used to always use thumb breath
hand breath hand span
these kind of body measurements fathom
just a wingspan qubit from your elbow to your fingertip
to try and measure things
because we all have those things
the problem obviously is if some guy that six
eight is standing next to me he's gonna have a much
actually i'm gonna have a much larger wingspan than him
no he's obviously gonna have a much larger fathom qubit
hand breath
thumb breath
whatever than i am
so that wasn't a standard way
to be able to measure things eventually
people wanted to be able to standardize measurements
so here came the meter
quick side note
the slides that are posted on canvas right now for this
lecture don't have these two slides on it
generally speaking
i'm not going to examine you guys on this
these two slides anyway
so it shouldn't really matter
but you'll notice

the file name of the slides i posted for today
ends in tmp
anytime i post slides that end in tmp
it just stands for temporary
it's just because i didn't want to include
a couple slides
for you guys before i gave the lecture
because i wanted you to kind of genuinely
brainstorm things and think of things on your own
it stands for tmp temporary
because i'll upload these full slides
as soon as the lecture is over
so just a quick side note
okay so eventually came normalization
aka the meter
after the french revolution
there was this new normalized decimal metric system
which was proposed
and the meter
originally defined in seventeen ninety three
was defined as one ten millionth of the distance
from the equator to the north pole
that's how we kind of standardized what a meter was
from eighteen eighty nine to the sixties
that standard was based on a platinum and iridium bar
stored in the international bureau
of weights and measures in paris
the point is
it was just this physical bar
that's how we kind of had our standard
for what a meter was
it was still very close to this
this length
which was one ten millionth of the distance
from the equator to the north pole
but to have our
you know standardized
safe measurement of what a meter was
we had this bar that we stored
and was like
you know this is what a meter is
since nineteen eighty three
it's been defined using the speed of light

the speed of light in a vacuum is constant
it never ever
ever changes
so we've said
that a meter is the length of the path traveled
by light in a vacuum
during a time
second interval
or during a time interval of about
one three hundred millionths of a second
and that essentially
is still based off of
we didn't just pick this
you know three hundred millionths of a second
completely randomly
that kind of approximates
what one ten millionth of the distance
from the equator
to the north pole is
but nowadays
we often use these standards
based on some physics
that we have that exist
that we know now in the world
that give us a really
really precise
accurate measurement
and standardization of
in this case
what the length of a meter is
so in general the metric system
which uses the meter as its fundamental
kind of base measurement
is an internationally agreed upon system of measurement
most places in the world use it
other than the states and some other spots
what i want you to be able to do
in terms of midterm questions
you'll probably see a probably
i mean you will see at least
well not at least one question
you'll see one question that'll ask you to
convert measurements

so i'll ask you maybe how many microns are in a meter
how many meters are in a kilometer
something along those lines
it's an open book
open internet test
so if you don't get that question right
i'll be upset
it happens it does i get it
sometimes you click the wrong thing
or whatever it might be
but you don't have to overcomplicate this
you don't have to memorize how to make conversions
you can google it
we live in an age of information
you can find that pretty easily
but i will ask you about it on the midterm anyways
just to make sure that you know how to use google
so let me grab your attention again
we're getting through here
we're almost done
don't worry
well getting close
so until twenty
eighteen the kilo
the kilogram was the last physical standard that we had
in order to define what a measurement was
so a kilo was defined based on this rock
that was also held
in the international bureau of weights and measures
and it was this hundred and forty three old
golf ball sized metal cylinder
and it was our definition of a kilo
it was the last measure that was physically defined
a kilo is now defined using plank's constant
again another kind of big fancy looking number
plank's constant is just a constant value
that helps describe the relationship between
the amount of energy associated with a quantum of light
or a discrete package of light
and its frequency
you don't have to understand that
this isn't a physics class
we will talk a little bit about radiation

and about some fundamentals
of the electromagnetic spectrum in a coming lecture
but for this purpose
the only reason i bring this up
is to just note that the kilo was the last
unit of measurement defined by a physical object
most things now are defined using the speed of light
using some sort of relationship that explains
the energy associated with something
related to something else
related to something else
yada yada yada
in this case
it's called planx constant
initially in the states
thomas jefferson
jefferson rejected the metric system
because he thought it was too french remember
the meter was originally a french kind of development
in eighteen sixty six
the use of metric weights and measures became legal
but not standard in the us
and since then many people have tried to standardize it
for many different arguments
have essentially
tried to get the states to convert to the metric system
probably won't ever happen
i mean you know
i don't really know how i feel about that
in today's day and age
it's really not that hard
to convert between metric and imperial
for the most part
we all have google
we can all convert things pretty easily
but historically in the past
in earlier decades this was actually a problem
this did actually cause issues
one example of that is the mars climate orbiter
which was supposed to be the first weather satellite
observing other planets
so not observing earth
but observing other planets in our solar system

and in nineteen ninety nine
it burned up when entering into the mars atmosphere
because engineers failed to convert the units
from imperial to metric
lot of money wasted there
i got a quick video about that
mars high orbiter
launched on december eleventh
nineteen ninety
on a mission to orbit mars
this first interplanetary weather satellite
was designed to gather data on mars climate
and also serve as a relay station
for the mars polar lander
a mission that launches completes later
but you can't just launch a spacecraft to mars
and trust it's going to get where it's going
you have to monitor its progress
many spacecraft have reaction wheels
to keep them oriented properly
and navigation teams behind interplanetary spacecraft
that constantly monitor
the annual momentum
and adjust trajectory
to make sure it gets exactly where it needs to go
in the case of the mars planet orbiter
monitoring its trajectory and angle of momentum
involved a few steps
first data from the spacecraft
is transferred to the ground by telemetry
there was processed by software program
and stored in an angular momentum desaturation file
that process data was what scientists used
to adjust the trajectory
the adjustments that were made by
thoroughly the spacecraft's process
every time the crust was required
the resulting change of velocity
was measured twice
once by a software program on the spacecraft
and ones by software program off grant
and here's where the problem comes in
it turned up the two systems

the processing software on the spacecraft
and the software on the ground
were using two different units and measurements
the software on the spacecraft measured impulse
or the changes five thrusters in newton seconds
a commonly accepted measured unit of measurement
while the processing software on the ground
used the imperial count seconds
and it was unfortunately
the ground computer data
that scientists used
to update the spacecraft trajectory
and because one pound of force
equal to four point forty five mutants
every adjustment was off
by a factor of four point forty five
the first spacecraft
traveling tens of millions of miles to the destination
a number of seemingly small errors
really add up
during the mars time
over his nine month cruise to mars
seventy errors were introduced into the strict
that met it
when it reached the red planet
it was one hundred and five miles
closer to the martian surface than expected
this turned out to be an unsurvivably low altitude
for its martian counter
when the spacecraft fired its main engine
to the orbit
in search of burn
that was designed to put it into an elliptical orbit
nothing happened
nasa lost contact quite abruptly with spacecraft
so what we know the group cause of just what went wrong
we'll never know exactly what happened
to the mars time order
the loss of the mars time order
very sadly happened in space
fun aside that story
i'm not gonna test you on the mars orbiter
just an example of why units of measurement

why conversions may actually matter sometimes
okay last topic to go over scale
it's a pretty quick topic
i wanted to briefly introduce that
introduce scale
by just discussing the scale of the universe
and the different tools that we have available to us
to measure things that are very very
very small and very
very very large
the electron microscope
is for the finest scale measurements
it kind of looks like this
it's a very expensive instrument
and can help us see down to individual atoms
so this is a gold atom here
it works by accelerating electrons
and using that to illuminate a target
beyond that
don't ask me how it works because i don't really know
the point is
it is able to view things all the way down to atoms
something that we can't see with our naked eye
the optical microscope kind of looks like this
maybe you've used it in other science classes at ubc
maybe you've used it in high school
or before university or something like that
but it just uses a bunch of lenses
to create a ten to hundred times zoom
and that can allow us sometimes to see individual cells
so these are chlorophyll cells under a microscope
but the point is we're going from extremely extremely
extremely small
to a little bit bigger
but still requires us to have
a special instrument to view it
then we have a camera right
a camera is kind of the standard
instrument that we use to be able to observe
things that we can see with our naked eye
whether that's the leaf
a tree a forest
an entire landscape

these are things that we can just
see with our naked eye
and the scale of these is obviously
completely different
to the scale when we're looking at individual cells
or individual atoms
and then lastly
we use a telescope often to view planets
galaxies stars
things that are really
really really big
but way way
way far away
i'm not gonna play the whole thing
this doesn't need to
i don't really need music for it
but just to give you a sense of that
i'm gonna play
maybe the first minute or two of this video
that was created by ibm back in
think the nineties or so
and it zooms out of a picnic in chicago i believe
each what is it
each ten seconds
or each second by a power of ten
and you'll see as it zooms out
you eventually see the whole planet
and then it'll start going to the solar system
and eventually galaxies
and eventually further and further and further
it's a ten minute video
i'll post it on canvas
if you want to watch the whole thing
we don't have time to watch the whole thing right now
but i'll play the first minute
just to give you a sense of you know
just the scale of the universe
kind of how small we are relative to
things that exist in our solar system and our galaxy
and beyond that
and they've been lost to sight
one hundred meters wide
the distance of ambient around in ten seconds

cars crawled by the highway
probabilts lie for months
and cut off the leach of their soldiers people
this square is kilometer one
one thousand meters
the distance racing car can travel in ten seconds
we see the great city
ten to the fourth meters
ten kilometers
this is a supersonic airplane can travel in ten seconds
we see first around the land of lake michigan
then whole great lake
ten to the fifth meters
the distance is already satellite covers in ten seconds
long parades of clouds
the day's weather the west
ten of the six of one of six zeros a million meters
soon the earth was shown as a solid sphere
we are able to see the whole earth now
just over a minute along the journey
the earth diminishes into the distance
but those background stars are so much farther away
that they do not yet appear to move
our line extends at a true speed of light
in one second half process a tilted orbit of the moon
now we mark a small part of the path
in which the earth moves about the sun
now the orbital paths of the neighbor planets venus
and mars and mercury
entering our field of view
is the glowing center of our solar system the sun
followed by the mass in other planets
swinging wide into big orbits
an hour that belongs to pluto
a fringe and a million comets too faint to seek
against the solar system
ten to the fourteenth
as the solar system shrinks to
one bright point of the distance
our sun is flaming
now only one with the surface
looking back from here
we know four southern constellations

still much as they appear
from the far side of the earth
this squares ten of sixteen meters
one light year not yet out to the next star
our last ten second step
towards ten light years further
the next will be a hundred
our perspective changes so much each step now
that even the background stars will appear to converge
last we pass the right star
monsters and some stars in the room
normal but white
unfamiliar stars and clouds of gas ceramics
as in traverse milky way gas
giant stacks carry us into the outskirts of the galaxy
and as we pull away
we begin to see the great flat spiral facing us
the time and path we chose to leave shrunk
has brought us out of the galaxy
on the course nearly perpendicular to its disc
the two little satellite galaxies
of our own are the clouds of the jungle
ten of twenty second time
a million light years
okay i'm gonna stop there
it's a pretty cool video
it goes for ten minutes
so it still goes quite a bit further
really interesting
if you want to watch the whole thing
i'll post it on canvas
right under the slides for today
there's also this really cool website
where you can essentially do the same thing
but you just control the scale
and you can zoom in and out
to get a sense of at what scale you can observe
different phenomena that exists in our universe
it's pretty interesting
the point is
the universe is very very large
and relatively speaking
we are very very small

now in terms of this course
and why that's
valuable for understanding earth observation
for understanding how satellites work
is really fundamentally about mapping
and how we display scales on maps
a map scale is just defined as the ratio
of the distance between two points on the map
corresponding to the real distance
of those two points on the ground
so how far apart is this distance on the map
relative to what that represents in real life
that's what a scale is
and on a map
it can be be defined using a graphic scale
or a bar scale
that looks something like this
can be defined using a fractional scale or ratio scale
where you just say
one centimeter is equal to fifty thousand centimeters
or a verbal scale
where you verbally say
one centimeter on the map
represents five hundred meters on the ground etc
the part of this that i want you to remember
for midterm purposes
for testing purposes
is the last couple points on this slide
which is that a small scale map
covers a large area with coarse detail
a large scale map covers a small area with great detail
so it's a little bit counterintuitive
the larger scale map you have
the more zoomed in it's going to be
so small scale maps are further zoomed out
have less detail
larger scale maps or finer scale maps
are more zoomed in and have more detail
you'll notice as you get larger and larger scale maps
the area or distance that is represented relatively
between the map and real life
is going to decrease
right so you start up here at about ninety five million

you get down here to about three hundred thousand
or one million
three hundred thousand
the smaller that number gets
the larger and larger and larger scale
your map is becoming
so generally speaking
a worldwide map
you might say
is one forty million
so one centimeter on this map
represents forty million centimeters in real life
a continental map
maybe one to twenty million
national map
maybe one to ten million
a provincial
regional or state map
maybe one to one million
metropolitan area
one to fifty thousand
a city maybe one to thirty thousand
a neighborhood
maybe one to fifteen thousand
and a cadastral map
which is just a map that's made for tax purposes
so it needs to be really zoomed in
so you can see each individual property
maybe has a scale of one to five thousand
or one to five hundred
i don't expect you to be able to
match you know
large scale and small scale
with a specific numerical value
or specific numerical scale
what i do want you to be able to understand is
if you're looking at a scale
or looking at a map
understanding relatively
which one is larger scale
which one is smaller scale
the only exception to that
which you'll see in the practice question

that i have here is
maybe i'll ask one that's really obvious which is
if you have a map with a scale of one to five hundred
that's the largest scale that we've talked about
you can assume that that's a large scale map
if i do something that's really really
really small scale
you know something like one to forty million
you can assume that's a small scale
but generally speaking
what i want you to understand is this
these two definitions
what a small scale map is
what a large scale map is
and then be able to describe relatively
if you're getting to larger scale maps
or smaller scale maps
by either looking at a given scale
or just looking at
two different maps
or multiple
different maps
and comparing them
okay that is it for today
i'm going to give you five or so minutes
to practice these questions
that are up here with a neighbor or by yourself
so go over them
these are questions that are very reflective
of what you'll see on the midterm or final exam
practice them
you don't have to stay if you don't want to
if you want to head out right now go ahead
if you want to stay and go over these answers
then we'll do that in about five minutes
thank you
that was amazing
hey i'm trying to minor in this icon
so i could not register
you could just fool
so i contact the department but they are not responding
did you email me
no just email me yep

then are you
then are you gonna let me in
yep yep yep
no problem hey
yep how's it going um
so if it's one to five hundred
yeah is this large or small
large large yeah
so if it's a large scale
so is this large
so this is what i was saying
i don't expect you to know
like on an absolute sense which of
if you're comparing all of these
which is large and small
but i do expect you to know which is larger
and which is smaller relative to the others right so
so this is the smallest scale map that we looked at
the one that's furthest zoomed in the cadastral map
is the largest scale map that we looked at
and then i expect you to understand relatively
how would you describe the other so
so this one scale
so it covers like big areas
exactly yeah
so it's not
it doesn't have details correctly
correct yeah
um and then one more thing
oh actually i don't
oh yeah yeah
what exactly is the prime meridian
is essentially what describes the center of the map
or what describes zero degrees longitude equator
the equator
if you're talking about latitude
but if you're talking about longitude
then the prime meridian is perpendicular to the equator
because it represents longitude not latitude
so the latitude is this latitude
is what latitude
the prime meridian has nothing to do with latitude
prime meridian has to do with longitude

longitude would be this
yeah up and down exactly
so when this is one zero
sorry you're saying is the prime meridian up and down
like i'm just asking
like what exactly this is and where it's located
so so in in general on most maps
it's located
the prime meridian is the very center of the map
it's the gratitude
it's the gratitude or meridian
that goes right through the middle of the map
in most cases
it goes through greenwich england
so in this map if you zoom in
you'll see it past that line right there
passes right through british england
right there
that's typically the prime meridian
and then you know that these ones are smaller than the
these ones for the contour
what was it contour
like i remember the name of the map
uh the conformal projection
the most common one that we use
that's like two d
yeah the conformal projection yeah yeah
so this one's bigger and then this smaller
so yeah areas
areas towards the poles in this kind of projection
are more distorted than areas close to the equator
and appear much larger than they are in reality
i got it thank you
yeah no problem hey
i'm gonna go over them right now
yeah yeah it's a large scale yeah yeah yeah
hey some questions regarding okay
can we go over it after i go over these questions okay
all right guys if you're heading out please head out
i'm gonna go over the answer to these
if you want to ask me a question just take a seat
and just hold off till right after i go over these
we'll have some time

i'm not going anywhere
but just want to go over the answers to these
guys if you're heading out please do so swiftly
briskly quickly
however you want to describe it
if you're staying that's great
you guys stay in or stay in or leaving
you can do whatever you want it doesn't matter to me
just if you're heading out just head out
ok cool so what type of distortion
i'm going to crowd source these
so just put up your hand if you want to answer
what type of distortion is minimized
in a conformal projection
yeah
yeah exactly the angles
angles are minimized in a conformal projection
angles and shape
in terms of describing distortions on maps
will often use interchangeably
so you could say angles are preserved
or angles are preserved or shape is preserved
either of those i would accept
how can someone describe to me how map projections
have potentially perpetuated eurocentricism yeah
it diminishes the importance of countries in the group
exactly okay that's
okay that's okay
the one other thing maybe you can help me with this is
what projection specifically are we talking about here
yeah so that one was like the mercator projection yeah
and then the other thing that was mentioned was like
how the prime meridian goes through greenwich england
which makes europe look like the center of the world
exactly exactly
perfect okay
how many microns are in one meter
nice good job you google it
good work killer
i don't actually know if that's right
i'm assuming you googled it and it's right
if i have a map scale of one to five hundred
would you consider that a small or large scale map

yeah large scale exactly
and how was a meter defined originally
kind of historically
and how is it currently defined
yeah it was originally defined as like
one ten millionth
of the distance from the north pole to the equator
but now it's defined as
like the speed
the distance that light travels
in one three hundred millionth of a second
exactly yeah
i'll just repeat that just so that this guy picks it up
it was originally defined by one ten millionth
of the distance from the north pole to the equator
it is now defined as the distance
light travels in a vacuum in one
approximately three hundred millionth of a second
it's actually
you know two hundred ninety nine
whatever all those numbers were but
approximately one three hundred millionth of a second
hey great that's it for today guys
i'll see you tuesday in the other lecture hall
wait were you guys coming to ask a question
you're good okay yeah no problem
hey how's it going it's good how about you good
okay hi everyone let's get started
a quick announcement from
or just i guess announcement sort of from yesterday
someone emailed me saying that they left their e
their laptop i believe in the sirs lecture hall
anyone come across a laptop by chance
it was you you found it okay never mind we're all good
okay sweet don't really have any other
announcements for today
any questions about assignments blog posts
course format
before i get started
okay yeah you got a question
no from home or wherever
but there won't be a
we hopefully won't be

well i tell ubc to not assign us a room because
there's no in person component to the final exam
last semester they did
and it confused a couple students
if they assign us a room don't go to it or
yeah just don't go to it
there's no final in person component
the final exams online
you can write it from wherever you want
home somewhere on campus doesn't matter
but it's online
fully online yeah
sorry guys can you quiet down i can't hear the question
what was that
midterms also online yeah hundred percent online yeah
is it open book yep yep both open book open internet
can use whatever you want
any other questions
yeah
the midterm is
thirty multiple choice and six short answer questions
the final exam is forty multiple choice
and six short answer questions yeah
i'll release a bunch more information about the midterm
and final when we get closer as well yeah
do you have a question back there
no okay yeah
you'll have practice questions
for the midterm and final exam posted
kind of two weeks or so before the exams
yeah and then you can also use the questions
that are at the end of each set of lectures
that i put up yeah
it's about sixty percent post midterm
and forty percent pre midterm
yeah so it's cumulative
technically it includes pre midterm stuff
but it's a little bit heavily weighted
more weighted on the post midterm stuff
yeah
is it what sorry
time limited yeah midterm is two
no midterm is an hour and a half

final is two hours i'm pretty sure
yeah so they're both pretty short
anything else
ok sweet today we are talking about
the history of positioning
just a note about
i mean just kind of the first
couple of lectures that we go through in this course
they are a little bit
there's kind of
a couple of fundamental baseline concepts
that i like to get you guys kind of up to speed with
at the start of the course
that are a little bit
at least i think are a little bit less interesting
and a little bit less fun
so this lecture is about the history of positioning
there's a little bit of
you know important earth observation information
sprinkled in here and here and there
but we kind of have to go through a couple weeks
first about background info
context setting the scene
before we start kind of diving into more technical
information and content
about earth observation
about satellites
about satellite data and their applications etc etc
so bear with me
i don't love lecturing these kind of earlier lectures
just because they are a little bit more dull
but we'll get to the fun stuff
so today we're going to talk about
the history of positioning
we're going to talk about why positioning is important
today and why it was important historically
we'll talk about the concepts of positioning
and how they've developed through time
how they've ultimately resulted in the technology
that we use today
and then we'll talk about some of the principles behind
space technology we currently use today
and historically

again how we've gotten to where we are today
in terms of positioning
a position fundamentally can be described in two ways
a relative position or an absolute position
a relative position
just means that you're describing where you are
you're describing your position
relative to other landmarks or features
so you describe your position
relative to other things that exist in the world
an absolute position is just defined or described
using coordinates of a point in space
so when we were talking about
latitude and longitude yesterday
we're talking about absolute position
we're using coordinates to define a point in space
it's a form of absolute positioning
to obtain an absolute position
it generally requires quite sophisticated equipment
and precise measurements
in the case of you know
google maps
or any kind of positioning service or app
that you might have on your phone
on your computer
we generally use gps
and global navigation satellite systems
which use complex computations
to determine your location on the surface of the earth
we're going to kind of talk about
how we've gotten there
how we were able to define our position
before we had satellites to describe where we are
so if i gave you this kind of example
if i wanted you to describe where jericho beach park is
you could describe it as
it's at forty nine degrees latitude
and minus a hundred and twenty three degrees longitude
that would be your absolute position
that's a set of coordinates in space
you could also describe it
we're not in the forest science center at the moment
but if you were on ubc

you could say to get to jericho beach park
or where jericho beach park is located
is about a couple kilometers down university boulevard
and then you can hang a left on blanca
and then go down fourth avenue for a couple kilometers
and then you should see it on your left
i'm describing in this case where jericho beach park is
using relative positioning
i'm just using landmarks that exist in kitsellano
in this case to describe where this park is
now astronomy navigation
surveying geodesy
were based on similar instruments and methods
historically
the most important practical application of positioning
was for sea navigation
and this was often based on this concept
called triangulation
triangulation is based off this trigonomic rule
trigonometric rule
that if one side and two angles of a triangle are known
the remaining sides can be computed
and you can do that by measuring angles
which is called triangulation
or distances
which is called trilateration
for this lecture today
i don't want you to worry
or really think at all about trilateration
we're gonna be discussing that the next lecture
the one after
i believe that's the method that
global navigation satellite systems like gps use today
to locate where you are on the surface of the earth
i want to talk today about triangulation
because that's kind of
historically where we started
in terms of determining our position
so in this example that i have up here
if i am located here
and i want to figure out
how far away this star is for me
and then i am just located in between two points

a and b where i know the exact distance
to each one of those points
then if i just measure this angle here
and this angle here i can
using trigonometry
which i don't expect you to to know
you know i'm not going to ask you to plug into
trigonometric equations
to solve for
you know a solution like this
what i want you to mostly
remember is just
if you know two points
where exactly two points are in space
then you can determine relatively
however far this third point might be
using trigonometry and using triangulation
so the kind of example i wanted
i thought i maybe give
to just illuminate this a little bit more
can i get two people to come stand down here
you too sure yeah yeah
okay so you stand right here
right there and then you stand right over here
okay perfect
stay right there so
if i know exactly how far these two are from each other
if i know exactly
what's your name
wayne and muhammad
if i know exactly how far apart wayne and muhammad are
then if i am anywhere else
if i am right here
say for example
and they just measure an angle of where i am
relative to where the other is
and then you get an angle for both of those spots
they can compute where i am
so if muhammad's here and he says okay
if i'm standing over there
i wanna know what the angle is from here
to where he is there
and then vice versa over here

if he says i wanna know where the angle is to there
from where he is here
and i'm standing over there
then we can essentially compute
what the distance is between them
or really any point between them
to where i am over here
if i stand wherever
zoom zoom zoom
zoom zoom zoom
if i stand right back here
oh that's my phone falling apart
if i stand way back here
he's got my angle there
you have this other angle here
relative to that line that's drawn between them
then they can determine
or i can determine
how far away i am from anywhere along that line
thanks guys
you can sit down
that's how it works
fundamentally
that's all i really expect you to know how it works
and in terms of midterm final exam questions
all i'm really gonna ask you about triangulation is a
what it is used to map
and i'm gonna talk about what that is in a moment
it's called a geodetic network
and then just that
it uses angles
triangulation uses angles
trilateration uses distances
you have a question
i was just gonna wonder if we needed to know the math
no definitely don't even know the math no
okay historically
to measure angles
we just had essentially these fancy protractors
it was called a theodolite
and it would just measure angles
both vertically and horizontally at a very
very precise level of measurement

so that's what we used historically to measure angles
and then determine using triangulation
a relative position in space
now just remember
triangulation is still a relative form of positioning
what they were used for eventually
was to create these geodetic surveys
so the first geodetic survey was undertaken in france
at the end of the seventeenth and early
eighteenth century
by the end of the nineteenth century
there were major geodetic networks
covering the us
canada india
great britain
large parts of europe
and essentially
it was the creation of all of these geodetic points
and they are really the historical basis
for mapping the earth's surface
all they did was provide a number of fixed stations
or fixed points
whose relative and absolute positions
were accurately established and again
all that means is that if i have two points in space
and i know in an absolute sense
where those two points are positioned in space
then using triangulation
based on measuring the angle between those two points
and any other point that i choose
i can determine a position
i can figure out where i am or where someone else is
and so essentially it was just these little markers
that kind of look like this
they're about the size of a plate or something
there was a lot of jail time associated
if you tampered with them
because they were really really important
really valuable for positioning
for society operating essentially
but all it was was these little plates
located all across the surface of the earth
and they just represented a known location

a location with absolute coordinates
that you could then use
to triangulate any other position
because you know two positions for sure
and this is kind of what it would look like
so you've got all your positions
all your dots of known position all over
and then any other position close by
you can determine using triangulation
okay now that was for land
but often for sea navigation
you wouldn't have
these points of no locations in the sea
so navigators had to figure out different ways
to be able to determine their position
as they were traveling on ships
through the sea etc
so they used
there were a couple methods
that i'm going to talk about
and in a chronological order
they were pilotage
dead reckoning
celestial navigation
and the marine chronometer
the first two were forms of relative positioning
so pilotage and dead reckoning
were both forms of relative positioning
they essentially used landmarks
to determine where you were in space
and then celestial navigation
and the marine chronometer in combination
was the first real form of absolute positioning
where you were able to determine
what your coordinates were in space
essentially
what your latitude and longitude were
now i'm going to talk about those individually here
for a moment
the first method of navigation used was pilotage
this was before the fifteenth century or so
and you always had to be within site of land
it was based on visual triangulation

to known landmarks
so essentially
how it work
is if i was
you know again
if i was in my ship
i'm sailing
going across
and i see this chair here
you know in reality
maybe it's some sort of mountain
some sort of big rock or something
and i see another one over there
and i know the exact point of where that chair
that mountain is in real life
and i know the exact point
of where this other landmark is
then by determining the angle to each of those
i can determine where my position is
relatively to those two known landmarks
yep alternatively like if you know where you are
and you know where one landmark is
you could triangulate the position of another landmark
yep totally yep
but in this case
the context that i'm talking about
in this case
is more about trying to figure out where you are
relative to
more so than where other things are
because in the case of
c navigation back in the day
you don't really have a lot of ways to tell
you know there's nothing
there's nothing telling you on your phone or whatever
exactly where you are in space
so for this specific form of positioning this pilotage
there wasn't really a need for accurate positioning
it was just to kind of let sailors know
whether they were on a safe heading in a safe area
and it was generally helped by maps or nautical charge
so you would have your map open
and you would in the distance say okay

i see that landmark over there
i can see it on my map
and then i see another one over here
we know based on this map
exactly where those two landmarks are
let's measure our angle to each of those
and then we can determine our position from there
the next was dead reckoning
dead reckoning was the first method of navigation
in the open sea
which just means that you didn't need to be next to
you know a land form
you didn't have to be close to the shore
you didn't have to have land in sight
it was used from about
the fifteenth to seventeenth century
and how it worked was
you would calculate your position
by using a previously determined position
and advancing that position
based upon estimated speed over time
all that means is
if i know exactly where i'm starting
if i start right here
and i say okay
i'm going to head in this direction
i'm going to be going at a certain speed
i'm going to time how long i'm going in that direction
for that amount of speed
then i stop
i know the heading that i had at the start
that i've tried to ensure
is the same the whole way through
i know the speed i was traveling
i know how long i was traveling that speed
based on that
i can calculate my new position
relative to the original position that i had
so that's how dead reckoning works
back in the day believe
they would determine speed based off of
it's called dead reckoning
because they would determine their speed

by throwing a log or something overboard the ship
and then see how fast that log would disappear
as they were sailing away from it
that's how they would kind of estimate their speed
that's why it's called dead reckoning
because the log was dead
or not moving
and it was pretty accurate at short distances
you can imagine if i'm standing here
and i walk this way
and i time how long i go in this direction for
you know five seconds or whatever
i'm probably going to get a pretty good estimate
of where i am
relative to where i started
if i do that same thing
but i'm walking for days and days and days and months
and months and months
maybe even years
you can imagine
i'm probably not going to get a very good estimate
of where my new position is
relative to where i started
so it was accurate at short distances
but over long distances
you would get cumulative errors
which just means that the longer you traveled
the less accurate your estimate would be
yeah is that because your speed varies
yeah it's partly because your speed varies
it's partly because
it's hard to always stay on the exact same heading
it's hard to
essentially
it's this concept of
the more data you have
the longer you're traveling
the more variation there is
potentially
the more different speeds you could be at
the more different heading
you could slightly have
the potentially

less accurate
your sense of
how long you've been traveling in that direction
might be that kind of thing
okay eventually
people realized dead reckoning
had these errors associated with them over long voyages
so navigators tried to figure out other ways
for these really
really long trips
in order to get a sense of where they were
and their positioning
part of that solution lied in the sky
another part of that solution relied on time
and i'm going to talk about what those two were
for celestial navigation
in order to calculate latitude you can use the stars
now the stars in the night sky change for most of us
on a daily or seasonal scale
and this kind of goes back
to what we were talking about yesterday
with how the earth is rotating
and how it's revolving around the sun
if i am say you know
somewhere here in the united states or something
and my earth is spinning like this
and there are stars
existing in the universe in every single direction
then you can imagine
as it's spinning
i'm gonna be pointing in a different direction
the whole time
so for some time
if you know
if i'm again
if i'm located wherever i was in the states here
and my earth is
and i'm located right here
and i'm rotating
i'm gonna be looking at all the stars
that are in this direction
but as i keep rotating
i'm gonna be looking at all the stars

that are in this direction
you obviously don't see stars when it's daytime
so wherever you are pointed on the earth
when it's night time
that's the direction of the stars
that you're going to be looking at
which also means
if i'm rotating this way right
if my son is
if i say my
my son is this
this chair right here right
and i'm rotating like this on a daily basis
but on an annual basis
i'm also revolving all the way around the sun
and i'm over here
then that means now
my daytime is gonna be when i'm pointed this way
which means my night time
is gonna be when i'm pointed this way
so the stars that i see at night
are all gonna be the stars in this direction
when i revolve back around the sun over here
my daytime now is going to be when i'm pointed this way
all the stars that i see at night
are going to be the stars that are in this direction
so that kind of creates a bit of a problem
for navigating
for using the stars
because the stars that you see
are always going to change on a daily basis
and are generally going to change on a seasonal basis
now there is
a bit of an exception to that
and the way we generally use celestial navigation
which just means
using the stars to figure out where you are
is by using the north star
so to measure latitude
only latitude
not longitude
we can use the north star
the north star is a really special example

well it's actually not that special of a star
but what is special about it is that it is located
almost directly above the north pole of the earth
so if a star is located
directly above the north pole of the earth
that means as it's rotating
that north star is pretty much not going to move
it's always gonna be in that same location
directly above the earth
as i'm revolving around the earth
around the sun
it's also not going to move in the sky
just because of how far away it is
and the distance that we travel
revolving the sun
doesn't really make any difference in how far away
or in the location of that north star
relative to us on the planet
does that make sense
ok sweet so essentially how that works then
is if you determine in the northern hemisphere
what your angle is relative to the north star
you can determine what your latitude is
if you are directly on the north pole
to get or to see the north star
you're going to look straight up
so you're going to be at a degree of ninety degrees
ninety degrees we know is the north pole
if you're at the equator
and you're looking towards the north star
the north star is going to be right on the horizon
you're going to be looking straight out
instead of straight up
which means you're going to be at zero degrees
zero degrees latitude
does that make sense
sweet okay so the angle of the north star never changes
if you're in the southern hemisphere
you're not as lucky
there's no south star
so there's no star that is
kind of perfectly over the north pole
where there's no star that is perfectly over

the south pole
the way that the north star
is pretty much perfectly over the north pole
there are some
stars that are very close by to the south pole
that are typically used
and will still give you a pretty good sense
or a pretty good estimate of your latitude
but the north star
for navigating the northern hemisphere
is pretty accurate
it's pretty solid for determining your latitude
if you're in the northern hemisphere
okay longitude is a lot harder
and resulted in a lot of shipwrecks
for a long long time
no one could really figure out how to use the stars
to measure longitude
and it turns out that you can't
you can't use the stars
you can't use celestial navigation to measure longitude
but what you can use is time
so the key to calculating longitude is time
whoops the distance from a line of longitude
to the prime meridian
can actually be measured in hours and minutes
and that is because of the rotation of the earth
so the earth revolves once on its axis
every twenty four hours
we know that there's three hundred and sixty
degrees of the earth
because it's a full spear
one hundred and eighty degrees longitude east
one hundred and eighty longitude west
there's three hundred and sixty degrees total
it revolves fully on its axis every twenty four hours
that means every hour it revolves about fifteen degrees
and every four minutes it revolves about one degrees
so if you compare time between a known location
and where you are standing
you can equate the difference in that time
to your longitude value
or to where you are

say relative to the prime meridian
or something like that
and that was done using this marine chronometer
which was developed by this guy named john harrison
it was essentially just a really really
really really
really accurate clock
that's all it was
just a fancy clock
it requires that an observer knows exact green
greenwich meantime at the moment of observation
which kind of denotes your zero degrees longitude
and then every four seconds of time error
the position measurement will be off
by approximately one nautical mile
which is just to say
the clock had to be really really really
really really precise
just had to have a really good sense of time
and how it works is kind of shown in this graphic here
so if i start at zero degrees longitude
at my prime meridian
that goes through greenwich england
and it is twelve noon in greenwich england
i'm gonna have two clocks on the marine chronometer
one that's gonna keep the time in greenwich england
and one that's gonna be changed
to reflect the time of wherever i move to
the time that's changed
the time that i'm going to change myself
is going to be based upon where the sun is in the sky
so anywhere around the world
when the sun is at its highest point in the sky
that's generally noon so
if i say start here
i got my two clocks
i travel say thirty degrees west
i then look at my
how did this one work in this case
i then look at my ships chronometer
which is just the time
that it is in the place where i am
so i look up in the sky

i say okay the sun's going over
it's reached its highest point in the sky
it's exactly noon right now
i change one of my clocks
to show that it's noon right now
i can then look at my other clock
which is showing what the time is in greenwich england
in this case it shows ten am
and because it's a two hour difference
i can say two hours times fifteen degrees
it's thirty degrees i know
i've traveled thirty degrees from the prime meridian
does that make sense
you want me to go over that again yeah yeah
okay i'll go over it again okay
so essentially it's based on the marine chronometer
the key about this is that you have two clocks
one clock is always constant
it never changes
in this case that's
that's this one here
that's representing
they call it local time
which is a bit confusing
but this local time clock
is referring to the time in greenwich england
you're never changing that clock
that clock is always remaining the same
this other clock
the ship's chronometer
you are changing based off of
when the sun is reaching its highest point in the sky
so when the sun reaches its highest point in the sky
you change the clock onboard the ship to say okay
it's now noon
you never ever ever touch this other clock
so when you change this clock to say okay
i saw the sun just reach its highest point
i know it's noon
i'll change my clock to say that it's noon
you look at your other clock
that's telling you exactly what time it is in greenwich
england and you see that there's a two hour difference

we know that
the earth revolves fifteen degrees every hour
so if there's a two hour difference
you just say
two hours times fifteen degrees
that's a thirty degree difference in longitude
yeah
no you'd use the theodolite that i was showing before
so you'd have a really really accurate measurement
that would tell you the angle of the sun yeah yeah
yeah and the one which is not changing yeah
exactly so it's changing but we're not exactly
yeah yeah yeah yeah
sorry i can't hear you let me come up that way
sorry what was that
two clocks
yeah yeah so one is showing
one clock here is showing wherever you started
and then one clock is showing wherever you've gotten to
so this clock here
in this case
ten am local time
is referring to what time it is in greenwich
and then this clock here
is referring to what time it is locally
on board this ship
does that make sense
which one is referring to the onboard ship
which one is referring to what onboard onboard
this one here
this one's referring to the time onboard the ship
this one's referring to the time back in greenwich
england so this clock here and this clock here
the same clock
this clock here and this clock here are the same clock
this clock we're changing manually
based on where the sun is located in the sky
this clock is changing but not by us
it's just ticking through time
that makes sense yeah
so guys can you quiet down
i can't can't hear the questions
can you repeat the part like you say

like two hours times fifteen degrees
like what is that
yeah that's because we know that the earth revolves
on its axis of rotation by fifteen degrees every hour
so we know that there's
if there's a change in two hours
then that's fifteen degrees per hour
that it's changed two times fifteen
thirty degrees
yeah that's how we measure the longitude is we say
we say what's
essentially we say what's the difference in time
and then if it's in hours we just say
multiply the amount of hours time difference by thirty
that's the change in longitude that we have
and then that gives us what our longitude value is yeah
yeah that thirty degrees yeah exactly yeah yeah yeah
because that goes back to
to what i was showing here
if we are you know around here in longitude
anywhere you are in longitude at a certain
in a given day for example
is pretty much all going to see the same stars
if you're at the same latitude
does that make sense
because the stars that you see depend on or that the
okay let me pardon me
right exactly
the angle of the stars won't be different
depending on what longitude you're at
yeah okay yeah
that you'd have to determine on your own
you'd have to know
whether you're traveling east or west
but you would be able to do that with a compass
yeah
you might have to do number of hours different times
thirty degrees
that'll be all you have to do yeah
sorry times fifteen degrees my bad
times fifteen degrees
number of hours difference times fifteen degrees yeah
so if you're traveling diagonally

yeah
yeah exactly
if you're if you're traveling diagonally
all you're measuring is the difference in
the essentially angle of the sun
from where you started to where you ended
so if you're traveling diagonally
the difference in the angle of the sun
is only really going to matter because of the longitude
does that make sense
so essentially
if you were traveling diagonally
trying to figure out where your location was
you would use the stars
the north star for example to determine your latitude
and then you would use your marine chronometer
the difference in local time
to determine your longitude
does that make sense
okay see yeah
sorry i can't hear you
i mean it could be in minutes could be in hours
doesn't really matter
yeah exactly yeah
so it's one degree of longitude for every four minutes
yeah it's listed where my clicker go
so sit right there
one degree of longitude in four minutes
or fifteen degrees in an hour
yeah
so that's just another
way to denote latitude and longitude
i mean they're not using google maps
is not using celestial navigation
and a marine chronometer to determine your location
they're using a global navigation satellite system
like gps but they are giving you latitude and longitude
it's just degrees
minute seconds
it's just another unit of measurement that you can use
instead of decimal degrees
which is kind of the example that's given here
so that's in decimal degrees

but degrees
minutes seconds
which you'll often see
on whatever other platform you're using
to look at position
is it's measuring the same thing
it's just a different way to denote
the angular unit of degrees
that makes sense
just historically that's how they traditionally
showed latitude and longitude
it has nothing to do with like the marine chronometer
and using time difference to measure longitude
degrees minutes seconds
is just another way to show latitude and longitude
it's how it works is in degrees minutes seconds
you have three numbers
the first one is degrees the second ones is minutes
there's sixty minutes in a degree and then it's seconds
there's sixty seconds in a minute
it's literally just another way
to show latitude and longitude
but it's shown the exact same thing
yeah
yeah
yeah
what's straight up
it's exactly perpendicular to where you are
to have the highest point in the sky
exactly right at the horizon
so because if my
if i am located right on the equator
and i have the north star
that's located directly north of the north pole
or directly up from the north pole
then if i'm on the equator
i can only see
and it's straight up there
the angle that i'm at only allows me to see
the north star right on the horizon
if i'm on the north pole
i'm looking just like straight up in the sky
because i'm here

and my north star is straight up that way
whereas if i'm on the equator
the north star is that way
and because of the shape of the earth
because it's an ellipsoid
because it bulges at the center here if i am
or just because it's a sphere
if i'm below the equator looking north
you're not going to see the north star
because it's going to be below the horizon
ok see i am going to go on then
so essentially what you can expect
in terms of talking about the marine chronometer
and using a marine chronometer to measure longitude
i'll just give you questions
if it were in a midterm or final exam setting
about the difference between two local times
so i'll just say something like
if i'm measuring a change in local time of four hours
what is that difference in longitude
say four hours times fifteen degrees
that would be your answer
okay now all we've really done today
is instead of using stars
and natural objects that exist in our sky
to locate where we are
since about nineteen fifty seven
we've changed celestial navigation
to be with satellites
and satellites are just these artificial
objects that are in the sky
they represent a landmark that exists in the sky
and we can use satellites to just locate where we are
on the surface of the earth
you need at least four satellites to accurately
determine where you are on the surface of the earth
and we are going to talk exactly about
how that is done next week
so for today
you can practice
try and answer these questions
try and practice them with uh
someone sitting next to you or

or just by yourself
what is the difference between relative
and absolute position
what is the difference of longitude
represented by twelve hours difference in local time
using a marine chronometer
which methods of historical positioning use absolute
and which use relative positioning
and why is latitude easy to determine
with celestial navigation
at least in the northern hemisphere
i'll give you five or so minutes to practice those
we'll come back and answer those all together
if you don't want to be here for that
feel free to head out
otherwise we will go over those in a sec
hey can you explain what the second question
is actually asking like
are you asking what
difference in line two by each hour
difference in local time and
time on the boat
well how much
how much difference does one hour represent
well i'm just
fifteen okay so
how much difference would twelve hours represent then
fifteen times twelve yeah
hey
looking at the north star would determine our latitude
so is that not
did i understand
no no no you're right
so so if you're in the northern hemisphere
and you look up to the north star
the angle that you look to the north star at
is equivalent to your latitude
so if you're the equator
the north star is just over the horizon
which means you're looking straight out at zero degrees
so that means you're at zero degrees latitude
if you're looking if you're
not if so if you are right

if you hold this
and i say that this is my north star right
so it's directly north
over the equator or over the north pole
rights directly over the north pole like this
if i'm positioned on the equator right here
and i'm looking at it this way
it's right over the horizon
that's the line
okay yeah okay
that makes sense
so but then if you're here for example
and then it's zero
or if you're here and you're looking straight up
perfectly up right into the center of the sky
then you'd be at ninety degrees
so you're at ninety degrees
ninety degrees north
okay yeah okay
that makes sense thank you
yeah no problem
hey slides so
i was confused about the chronometer in the local time
so is one held constant while the other is
exactly yeah
and then the kilometers constant
so does it does
there will not change this one
this one showing uh
so this one's a little bit
this one's a little bit confusing
so this one's showing that
this one saying
your local time is established by the angle of the sun
so this one's saying that if you were here
then you would determine that it is ten a m
local time by looking at the angle of the sun
and your marine chronometer is saying noon
so that's a two hour difference
make sense okay thank you
yeah no problem hi hey
actually a little bit confused about second question
did the line here

represented by twelve hours differently local time
did we use this equation
right yep so you just wait to do basically the answer
so how if a fifteen degrees difference is one hour
then how much degrees difference would twelve hours be
okay got it
yeah i also have a slight question about our assignment
so for i think
what a question about mount logan
i'm not gonna know the answer to it
you gotta talk to uta
oh oh oh okay
for sure you
you can ask me if you want
but i'm probably not gonna know
so the location is really not exact so maybe
so for for for example the
we talking about a specific question
yeah the question about i think we're fifteen
okay yeah you definitely asked today
okay i'm not gonna know
thank you so much
yeah sorry about that
it's okay hey um
so there are two types of locations
relative and then
absolutely just like relatively on the other objects
and then like where exactly you are yeah
so all these methods that you went over in class
aren't they like all relative then
cause you are trying to know your location
based on what other landmarks there are
yeah and then they were like
you know yeah
so the only the
the difference in that is just like
based off the definition of relative
and absolute positioning
absolute positioning allows you to determine
an absolute position in space
which just means that you're able to determine
coordinates
you're able to determine a latitude and longitude

and what about relative and relative
you're maybe not able to determine
a latitude and longitude value
you're not maybe able to determine
exactly where your point is in space
but you can describe where you are
relative to something with maybe a known location
okay then for example um
this kind of like
not precise method would be relative yeah
and then this kind of like
precise method would be um
absolute yeah yeah
and then like
i can see where you're getting that
because you could
you could argue that for
like you know
for pilotage
if you were looking at like
a chart here or something
and you were using like two
uh you know
two known locations on this chart
exactly where you are
and then using triangulation
to figure out where you are relative to that
and then based on that
deriving what your absolute position is
i can see like
how you could think like
that's a bit confusing
but in general
we classify this as relative
as relative positioning
and then one more thing
um can you go over this
yeah yeah so
the geodetic points are just these points that are
this is a nice like diagram looking here
geodetic points are
each one of these points on this like
map example that it shows here

and it's just a point that has either a known absolute
or relative position
so the points that we know the coordinate
like exact coordinate of exactly
and then you can
if you can locate two points
that you know the exact coordinate of
then you're able to locate any other point in
you know close proximity to those using triangulation
so you'd be like okay
this point here and then another point here
and you would know your location wherever
like exactly relative to those two triangle and exactly
exactly thank you
yeah no problem yeah
sorry one second
one second time
yeah what's up
i just wanted to you know
yeah sure yeah
how does this like
yeah uh so so you want me to display it again
yeah just this
so the so all
all this is
all this is
all this is fundamentally
is just based on a difference in time right
notice the clocks here
both the same
the clocks here as you've traveled away from the start
are two hour difference
all you got to do is two hours
time is fifteen degrees
that's a thirty degree difference in longitude
okay but here we are taking the underwood district
this unlike for both the places
and so here
yeah so here you're saying
okay i'm going to set two of my clocks
both clocks
to exactly noon
when the sun is at its highest

then when i get here
i'm gonna use the angle of the sun
to determine the time of one of my clocks
and i'm gonna leave my other clock untouched
it's gonna keep continuing to track time
but i'm not gonna adjust its time manually and then
based off the difference between those two clocks
you can determine
how far and longitude you've traveled from the start
he has no effect of the speed of the ship
correct yeah
no effect or speed of the speed no
yeah okay so
if we even already considered the effect of the speed
it's just rotation
speed of the angle of speed
exactly yeah
all that this is based off of the idea
or the fact
that the earth spins about its axis like this
it does a full rotation every twenty four hours
which means that every hour
it's rotating fifteen degrees
so shift speed is unrelated to this
yeah yeah no problem
hey assignment
so the assignment
yeah okay pdf
and where do we answer it
do we there's a
there's like a canvas quiz on the submission page
so you'll put all your answers in through that
okay so yeah
we don't like
what if say if we started it and then
yeah what if
is there a tap time limit
nope there's no time limit
what if we we quote having to close down that page
should save all your answers
i would maybe also save your answers
in a word document or something as well
just in case

so i saw as we don't hit the submission button so
yep if you don't hit the submission button
it should just save your answers
and it won't submit till you submit
yeah yeah no problem
hey guys i'm just gonna go over these questions
can i chat with you after
i just review the answers to these
it will be okay
i was trying to like register for this
it's like yeah
did you email me yeah i email you
did you mail me yesterday yeah
okay i haven't gone to those yet but i will
okay okay yeah yeah no problem we're good
okay cool thank you
yeah no problem
i can go over the answer to these
can we talk after yeah okay
okay let's just go over the answers to these
can someone tell me please what is the difference
between relative and absolute positioning
so maybe start with relative
what is relative positioning
how do you describe relative positioning
yeah exactly
uses landmarks and features to describe your location
relative to those landmarks or features
what is absolute positioning
how do you describe your absolute position
yeah using coordinates of a point in space
okay what is the difference of longitude represented by
twelve hours difference in local time
using a marine chronometer
yeah hundred and eighty degrees exactly twelve hours
hundred and eighty degrees
twelve hours times fifteen degrees per hour
hundred and eighty degree difference
which methods of historical positioning
use absolute positioning
and which use relative
so which two do we talk about
that use absolute positioning

yeah
yeah and then one other as well
for absolute positioning per me
that's okay
yeah exactly
the celestial navigation and the marine chronometer
in combination
essentially celestial navigation gives us our latitude
marine chronometer gives us our longitude
so why is latitude easy
relatively to determine with celestial navigation
at least for the northern hemisphere
yeah you can use the north star as slight parameters
yeah and why can you use the north star
exactly and
what is your angle to the north star represent
it's in the question
yeah exactly
yeah yeah exactly
okay sweet that's it for today guys
i will see you monday
liana has office hours for assignment one
she'll also be here next week on monday and tuesday
to answer questions you might have in class as well
so if you can't make her office hours
she'll be here in class
the assignments due thursday next week
thanks have a good day
the wise words of snoop dogg
recording them i'll leave it i won't say that
we can figure it out after just let me know
you can give her a habitat
maybe something to do with the files
like already been named the same
or something like that yeah
cool i can i'm blind yeah we're starting yeah
so we're good to do these tips tomorrow
or you want me to do them like right after
like switch them
never mind never mind i think i'll give mine
okay okay
oh there
i think i just severed one of them

what do you i clicked
don't mind evan's vulgar language
all right we're getting started
all right everyone take a seat please
evans just kind of give you some reminders
about what you're working on this week
and then i'm gonna hand it to liana
she's gonna give you some tips and tricks
for the assignment that you're working on this week
that's due on thursday
if you have any questions for her
this is a good time to pose them
and then she'll head out
and then i'll give my lecture
and she'll be back tomorrow as well
if you have further questions for her
so start with evan
then we'll go to leanna
and then we'll go to meet
sweet so pretty straightforward this week
there's assignment and blog post one
do on thursday at eleven fifty nine pm
i've had a few questions about blog post one
where to get the actual imagery
like the before and after
you're using google
matt earth pro in the assignment one right
yeah that's a great spot to look
because it'll have historical imagery
and you can flick it on and off
other than that
things like google earth engine
google maps used to have the functionality
i don't know what happened to it
yeah so blog post one
find some images that are changed
and then blog post do
is do next thursday from
same idea thursday
eleven fifty nine pm and that
and then office hours
leon has got two more this week
so tomorrow three to four p m

and then thursday ten a m
to eleven a m
that's it for me
if you have any questions about like syllabus content
let me know
if not i'll hand it off to liana
any questions fred
these will also be uploaded on canvas
okay okay cool all right
can you wait for me i'm going on the same bus
okay hey guys i'm leanna
nice to meet you
i know i wasn't here when we did introductions
i was home but
i think i've met a couple of you in office hours
i'm doing this assignment
and i'm also doing assignment four
so you'll see me this week and then after your midterm
so just a couple tips for assignment one
i know there are some
questions which are kind of confusing
and that's because we kind of
redid some of these assignments over the break
and i was trying to make them less confusing
and i think especially for one
i did the opposite and i made it more confusing
so for oh also
these are not the right slides
i updated them
they didn't take
so this will be updated
so i'm going to go through these tips and
just clarify a couple things i know
there's been a lot of chat on the discussion board
so just overall
when you're using google earth
use either the google chrome tab
or download the google earth software
someone was using a
ipad app i'm sorry if i'm calling you out right now
is i'm not using a name
but i don't know how that works
and there was like a confusing

like one of the numbers wasn't showing up
so i would really really recommend
using either the google chrome tab on a computer
or also the google earth software on a computer
if you don't have access to a computer
wherever you live
you're free to use the library
if you really
really have no access to a computer at all
come to one of the office hours
or message me and we can figure something out
yeah so please
just use either the chrome tab or the software
it's easier to use a mouse with like a scroll bar
so like i can't lift that up but you know
like an actual mouse and not the mouse pad
but laptops um
make sure to turn on everything under the map style tab
that will really help you during this assignment
and if you are really really new to google earth
there's the video which is posted on us
the assignment one tab
and that kind of goes over
just a bare bones introduction to
how to use the google earth tab
so some question clarification
and again i have to go over this a bit
so question five is referring to the main feature
so when you turn on that three d thing
like you can see boats or grass or something
but what we're really asking for is
which of the features listed on canvas is now like
popping out at you
and i changed this one a little bit
so it should be a little more clear
for question seven who owns the land
there's a bunch of signs and labels nearby
and it might take a little digging
but it's definitely on the google earth
it's in the area
so you might have to click around a little bit
but it should be there
question nine can be any type of equipment

and it's going to count multiple answers
for question ten if you
if you saw this and thought wait
why is it asking for two names when on canvas
it only asked for one
this is the thing that it
this was from last year
so that this question
had a lot of confusion with it last year
we're only asking for one name
this needs to be changed in the assignment tips
so there's only one name for sea wash rock
that we're asking for
it's the squamish name
it can be found on wikipedia
scroll down until you see name
and it should be like right there
don't if you just look at like the first part
and it says like nine pin rock or something
don't put that
that is wrong
that also was confusing last year
that is not the right one
we're looking for the squamish name
ok
these are also the wrong office hours
because these are from last year
so when you check office hours
look at evan slides that are posted today again
i know that i updated these slides
but i think i posted the wrong one
so thanks to those of you who
mentioned this in the discussion board
i'll fix this tonight
you can find the right zoom hours in
the zoom tab on canvas
and it'll have the link and the right time
so if you're confused about when the office hours are
it's under the zoom tab
i'm going to open this up for questions in a second
but i'm going to go over question fifteen
um because people are a bit confused
about where we're looking

so in question fourteen we have like
a specific mountain in british columbia
and then question fifteen asks you
to put a negative sign in front of the north um
coordinate point
and then we flip hemisphere
so we go from the north hemisphere
to the south hemisphere
and then question fifteen is asking you
what land masses you see
you have to zoom out
i recognize that the first wording was confusing
because it just drops you
in the middle of the pacific ocean
so you zoom out
i'm zooming in
you zoom out until it's like right here
you zoom out until you get to see where it says
camera kilometers
it goes to like oh boy
this is about it
uh oh two thousand kilometers and
yeah just scroll around until you kind of see like
what's down here a little bit
what's over here
and then any answers
where am i this is hi
yeah i was wondering the same issue
like this question right
when i zoomed out it was kind of like go up
zoom out from a weird angle
so then when you zoom back in it's not the same place
okay just kind of stick towards
there should be four answers
and this was updated in canvas
there's four answers that are listed
stick to like what's in the general vicinity of
there's one where the camera goes to
there's one that might be close
but it's much farther than the other four
this question was somehow even more confusing last year
and i tried to change it to be less confusing
and that failed

and this is that question
i guess what i did is i just zoomed all the way out
and like with that
going through the center of the earth
so i zoomed all the way out to see a full field without
the other day
yeah i think so
and then like if it's showing you more than four
pick like the four that are closest to
that point that google takes you to
there was a question over here
i think no okay
any other questions for assignment one so far hello
there was a question about the arctic circle sign
and then it asked the coordinates
is that the coordinate of the arctic circle
or the arctic circle sign
it's the arctic circle sign
so when we go to the arctic circle sign
arctook
it's this one here the arctic circle sign
and like don't touch anything
so for all of these things that have like
look down in the camera
so see there's like this says camera
this has those coordinates
do not touch anything
oh wait sorry
don't touch anything
for the mountain
when it asks for the height
i think that's question ten
but for this one you do want to
what are you doing close this
you want to hit that middle part of
yeah you want the compass to be facing north
so remember if you click the center of it
it'll just take you back the camera angle
to north and then you look down here for
what the coordinates are
but just like
there's a little bit of fudge points on that one
because it changes a little bit

but you're looking for this
don't put it in
the coordinate format where it says like
blah blah blah north blah blah blah west
and that'll only be two numbers
like we're oh sorry
decimal point numbers
where it's like sixty point something
we want it to be sixty six degree signed thirty
apostrophe thirty two
double apostrophe what is that quotation mark
does that kind of make sense
yeah so try to just like
hover above
the compass
yeah for the
for number twenty with the antarctic one it's
you're not scrolling somewhere on google earth
that's kind of like
applying what you've learned through the assignments
to figure out what that would be
and it's similar to what you do in question
fifteen to get from
the northern hemisphere to the southern hemisphere
any other questions hello
for the mountain one
like the elevation changes
depending on where your cursor is on the mountain
and because like the camera rotates
the elevation is constantly changing
so i just like
put my cursor on like the very tip of the mountain
the peak where like i tried my best
if i'm like one or two minutes off
that's not gonna be a big deal
no yeah there's like a standard deviation
so like plus or minus
however many meters
which is factored into canvas
so if you're in within ten meters or something
it'll be fine
was there another question hi
screenshot of an image

how like is there one
certain image that you guys are looking for
or is it like around that area
yeah it's around that area
it's like in the assignment
it's kind of outlined like the path you should be on
and so you should be able to see like
from the path across the lake to the
the buildings
but it's really not like
that's not that exact image
it's very flexible
um canvas marks the assignment
but i go through the assignment
to mark the open ended questions
and if there's one where like
say you're doing the equator and you write the equator
but canvas says that's wrong because you have the twice
i go in and i mark it and say no
that's fine
so it's a lot more flexible than
what canvas might look like
hello
and there's two lights does this
is that the one where it says to use the wikipedia yeah
so use the number that's listed in the wikipedia thing
on google earth
the paragraph
the paragraph
hello
yeah sorry this is question fifteen
what i was doing down here so when you're
nope sorry that's not it that's not it
what question seven
what's question seven
no yeah but i don't know what it is
sorry
i'm going to move down here
super quick and then oh do you have it okay
right so for question fifteen
zoom out to the number that it says on your canvas quiz
and pick like the four countries or landmasses
that are closest to that point

hi
approximate
approximate
like put exact
but there are fudge points
so if you get like a couple meters off
it should be fine
reminder i have office hours tomorrow at three
so if you have any more questions email me
use your discussion board
a lot of these have been covered
on the discussion board already
so make sure you're checking that before
coming to office hours
cool thanks guys
thanks santa
see you guys later
thank you leanna
you'll be back tomorrow right
leanna will come back tomorrow
if you do have any last minute questions
and then she also has office hours thursday morning
and the assignments do thursday night
so if you have any last last minute questions
you can ask her then
okay
so today with me we are talking about space and orbits
so we're going to talk about defining space
talk about what space is
we're going to talk about what makes an orbit
and how an orbit works
we'll then talk about different types of orbits
and their applications
essentially
what kind of satellites we have in different orbits
and then we'll talk a little bit about space junk
some of the issues around space junk
some of the solutions we have for space junk
did i mention
have i told you guys already
that i went over my student surveys from last term
have i had that conversation with you guys already
so one of the most common complaint that i had

or critique or whatever
was that i sometimes talk too fast
which i know i do
so i'm trying to work on that
if i'm ever talking too fast
or you want me to go over something again
or you're just noticing that i'm going a bit fast
and you'd like the pace to slow down
just put your hand up and just let me know
sometimes i just get in the zone and talk a bit fast
if that makes sense
cool okay sweet
so first thing we're going to talk about is
how do you define space
and how far away is space
we know that
or at least it seems to us
when we're standing on the surface of the earth
we look up to space
when it's night time
we just kind of see this black abyss
but there isn't
you know this straight line that exists through the sky
that defines the difference between our atmosphere
the earth's atmosphere and space
so we're going to talk a little bit
about how that's defined
generally speaking
most satellites are
at least four hundred to five hundred kilometers
above the surface of the earth
and generally speaking
from the surface of the earth
as we increase altitude up
we get lower and lower air pressure
which just means that
there's lower and lower air density
there's less air molecules closely together
as we just travel
further and further away from the surface of the earth
we can see that here
this just shows us
on the right

a depiction and illustration
of what those air particles
or air molecules
would look like
you can see close to the surface of the earth here
there's lots of them
including oxygen
which we used to breathe
and then as we get further and further away
from the surface of the earth
there's slowly less and less and less air molecules
now for international laws and treaties and governance
we kind of have to have a political definition
for where space starts
and that's because
generally speaking
countries have what they define as their own airspace
which they kind of have governance and control over
but beyond a certain altitude
it's considered space
and it's governed by
kind of very loose international agreements and laws
so what we have is something called the carbon line
that's this line here
it's just an imaginary line
you don't actually see an orange line in space
but essentially what it is
is this arbitrary boundary of
between the atmosphere and space
that's recognized by the fai
which is just the
federation aeronautique internationale
it's just this international
organization that keeps records related to aeronautics
which just means related to space
and for governance
because they all use this carbon line
essentially
a country's airspace
typically in international politics
is considered up to about a hundred kilometers
or where the carbon line is
from the surface of the earth

the problem with that definition
is that we know air molecules
and thus the earth's atmosphere
extend way way
way way beyond the carbon line
so we have you know
particles all the way up here
and like i said
there's no distinct boundary or line drawn
between the atmosphere and space
so in reality
the atmosphere actually extends way way
way up from the surface
beyond the carbon line
about four hundred and eighty kilometers
above the surface of the earth
or at four hundred and eighty kilometers altitude
and in that general range
of four hundred to five hundred kilometers ish
that's when
essentially
space kind of scientifically begins
that's when air pressure approaches a vacuum
a vacuum just means an area that's devoid of any matter
air molecules are a type of matter
and as we get further
and further away from the surface of the earth
there's less and less and less air molecules
eventually approaching what's called a vacuum
or what we consider space
it's called space
because there's a lot of space there
there's no matter there
there's nothing actually existing in that space
so there is really no distinct boundary
that we can say it holds
the difference between the atmosphere and space
but we roughly
say that the transition
between the atmosphere and space
occurs at about four hundred to five hundred kilometers
one of the reasons this carbon line is really useful
for international and

you know country governance and that kind of thing
is because airplanes don't really ever travel
above a hundred kilometers altitude
and pretty much all satellites that exist
are well above the carbon line
so things that we just naturally think about
to be in space
and things that we naturally think about
to not be in space
like planes
are generally on either side of this line
but in reality
space doesn't really start
until you're about
four hundred to five hundred kilometers
above the surface of the earth
and it's just this general transition
now orbits are what holds satellites
it's what holds these artificial objects
that humans have created
that we've launched into space
that are now just traveling around the earth
and the orbits came from a couple of concepts
that you can think of
try to wrap your head around it
so first of all
an orbit is just a curved path
around a celestial object
and that path is created from gravitational attraction
between the two objects
if you imagine
in this case
throwing a javelin
you throw a javelin really really far
kind of in a straight or slightly up angle
the javelin is going to travel really really far
it's going to go straight
and then eventually it's going to fall
back towards earth right
and that's because you've thrown it
you've put power
momentum into it
so it's going to travel that direction

but eventually
gravity is going to pull it back down to the surface
of the earth
the same with if you shot a gun
but that bullet's gonna travel way
way further
it has way more power or thrust associated with it
than if you threw a javelin
so that bullet's gonna travel
travel travel
travel travel
really really far
but then eventually
gravity is just gonna pull it towards the earth
an orbit is really no different
an orbit ultimately
is the effect
of something continuously falling towards the earth
now there was this famous
newton cannonball experiment
where newton kind of deduced that orbits were possible
and his theoretical experiment
he didn't actually do this
but he theorized that with significant thrusts
enough power forward
and enough altitude or lift
so you're high enough above the surface of the earth
a cannonball
in his case
could maintain a circular orbit around the earth
which just meant that if you had enough power or thrust
behind a cannonball
and it was high enough up in the air
or in the atmosphere
or in the case of satellite orbits in space
if it was high enough above the surface of earth
and had enough power behind it
it could continuously fall towards the earth
in such a way
that it would just keep going
over and over
and over just keep falling towards the earth
and that is what creates an orbit

so an orbit ultimately
which i've noted here
is just the effect
of something continuously falling towards the earth
so satellites orbiting the earth
have just been given enough thrust
enough momentum
in a certain direction
and are high enough above the surface of the earth
that they can just continuously fall towards the earth
and just keep circling it
any questions about that about how an orbit works
yeah
does fall though correct
it always comes back
not if you get it at just the right spot
there are and i'll talk about that in a moment
briefly there are
you know when satellites are actually in orbit
they will sometimes deviate from their orbital path
which needs to be corrected sometimes
but generally speaking
theoretically if you put the right sized object
at the right direction
with the right amount of thrust and the
right amount of altitude
you could theoretically get it just right
to where it's always going to be orbiting
and it's always
kind of infinitely falling towards earth yeah yeah
have they tried to send a cannonball into orbit
not no not literally
i mean they've
they've reproduced it
in the sense that satellites orbit earth
right so that's essentially the same thing that newton
was theorizing
but now we just have these kind of spacecraft
in the case of satellites that orbit earth
that are doing just this
they're continuously falling towards earth
we should reproduce it
yeah we should set a cannonball in space

i could be down for that yeah
are they just like deviated a little bit in some time
that's a thousand years beautiful
sorry say it again
what's all satellites in the streets
that they always find out yeah
or are some of them like
most of them like
somewhere deviated or something a hundred years ago
yeah most of them have a slight deviation
but are always
generally in the case of satellites
they're always corrected
so they there's
there's never deviation
in the sense that they're gonna deviate
and actually fall towards earth
which kind of ruins a question
that i was hoping to ask you guys
um but uh but in general um
in reality there's other forces
that could act upon them
that could potentially
force them to deviate their orbit
but the theoretical sense of it is still that
if you are high enough above the surface of the earth
with enough power
moving forward at just the right direction
you could theoretically infinitely orbit the planet
yeah yeah if most satellites are like
in the same like
number of kilometers above the earth
then wouldn't they like
crash into each other
or is the earth just
like so big
that satellites are so small in comparison to scale
that like it doesn't really happen
we're gonna get there in lecture
we'll talk about that
but generally speaking
satellites can orbit anywhere
from about four hundred kilometers above the earth

to thirty five thousand kilometers above the earth
so there's a wide range
four hundred to five hundred
is just kind of the minimum
yeah yeah i guess
like i said both
well but never
okay so there's four kind of orbits
that we talk about in this course
low earth orbits
close elliptical orbits
far elliptical orbits
and geostationary orbits
this is the classic
you'll get asked about these on the midterm
many not many
but students every year
google this answer
and google will tell you a different
way to categorize orbits
so if you googled the answer to this question on
the midterm
you're probably gonna get it wrong
you need to make sure that you're using
the classifications that we use in class
so the first is the low earth orbit
and each of these orbits we just defined
essentially based off of
how far above the surface of the earth they are
so just what their altitude is
so the first is the low earth orbit
the low earth orbit travels at a speed of about
in the case of the international space station
about twenty six thousand
twenty seven thousand kilometers per hour
so that's really
really fast
they are about four hundred
the international space station
is about four hundred kilometers
above the surface of the earth
and in general
its applications are earth observation

which just means that there are sensors cameras
and actually
video cameras
which we'll talk about later in the course
that are on board the international space station
that are used to collect imagery and videos
of the service of the earth
it's also used for human space flights
so we know that the international space station
is home to astronauts
for certain periods of time
what's nice about the low earth orbit
for something like the international space station
is it is the lowest orbit
which just means that
satellites that are in
low earth orbit
are the closest to the surface of the earth
of satellites that we have
so for something like the international space station
that's really nice
if we're trying to send astronauts
up to the space station
if they were way
way way further up
if i had an international space station
that was eight hundred kilometers
above the surface of the earth
instead of four hundred
that would just be twice as far
for me to travel to get to it
which is just a lot of fuel
and a lot of money
the international space station
is essentially
the lowest orbiting
or one of the lowest orbiting satellites
that we have
the international space station
is also pretty much the only satellite
that we talk about
that's relevant to this course in low earth orbit
and so it's used for

like i said
earth observation
human spaceflight
as well as microgravity experiments
so there's a lot of experiments
that go on on board the international space station
to test what things like cell growth
and chemical reactions and stuff like that
would look like
in a setting where there's little to no gravity
now although the international space station
and in general
satellites that are in low earth orbit
they're close to the earth
because that's valuable
for something like human spaceflight
but that also makes satellites in low earth orbit
the least stable
so the low earth orbit
is actually the least stable type of orbit
it's very susceptible to atmospheric drag
more than any other kind of orbit
which means that it is subsequently
subject to orbital decay
now that just means that
the international space station
is kind of right at that transition boundary
of the atmosphere and space
and that definition is just based off of
where air molecules get so sparse
that it's transitioning from the atmosphere
into a vacuum
but there are still air molecules and particles
that are there
which means that the international space station
is still occasionally
hitting some air molecules
and some air particles
that are suspended
in that part of the atmosphere
or in that part of the transition
between the atmosphere to space
and that's what creates

this thing called atmosphere drag
essentially
the international space station
is traveling so so so fast
that even though these air molecules are very
very sparse
and very very small
friction associated with them can be quite impactful
and essentially
the friction between air molecules
that are suspended in that part of the upper atmosphere
where space is kind of starting to begin
force the international space station
to kind of lose momentum
lose power because of that friction
and that results in orbital decay
which just means that the international space station
kind of gets pulled down to earth a little bit
again i've kind of already given
this question away a little bit
but if the international space station
is in this really unstable orbit
right an orbit that is very
is well known
for pulling things back down towards earth
and we know that in general
an orbit is just defined as
continuously falling towards the surface of the earth
then i wanted to ask you guys the question
will the international space station
eventually be forced to earth
i feel like i've kind of answered that question already
maybe so extra question
if you know the international space station
as i've kind of alluded to
is never actually going to fall down to earth
why would that be
what would allow it to stay in orbit
despite it being in this really unstable orbit
that could potentially
drag it down to earth a little bit
hold your question
i'm going to get you guys to discuss

so brainstorm a little bit
with someone sitting next to you
take a couple minutes
i'll give you three
four or five minutes
something like that
brainstorm it for a moment
and then we'll come back and we'll talk about it
they used
okay can i grab your guys attention again
so what do you guys think
anyone have any ideas
so first of all
can someone just tell me
is the international space station eventually
going to hit the surface of the earth
you think so
right okay and so how do you think
so we know it's not going to fall to earth
essentially
so how would it stay in orbit
yeah you have like
pricing with engines that are on the satellite
or the international space station
like to know
to maintain velocity
yeah so essentially
if you look at
this is just a graph of
the altitude of the international space station
through time
and all of these little quick increases here
are essentially orbital corrections
so that's a little thruster going off
on the international space station
because the astronauts on board
or houston has said
we've deviated a little bit
off the orbital path that we want to be on
let's just correct ourselves a little bit
thrust a little bit away from the surface of the earth
and that'll correct us
okay but and you can kind of see right

you can see the orbital decay
because of the atmospheric drag going on
that's kind of this slow decrease
each of these like slow
kind of sections where it's pulling
the international space station
back towards the surface of the earth
what about these big drops here
so there's one kind of big quick drop here
and here and here
what do you think those
that's not atmospheric drag
it doesn't work that quickly
so what do you think that could be yeah
is that the space station actually doing the reverse
and moving downwards to avoid something
not to avoid something
that's a really good guess
but that is what it's doing
it's moving closer to the surface of the earth
why would it want to do that yeah
the ship that brings in the new round of
yeah exactly yeah
so there's astronauts that are flying occasionally
from earth up to the space station
and it is way cheaper and quicker for them
if the international space station just says
okay let's just
like we're in orbit
we're not actually using much fuel
thrusting us forward
we've already gained the momentum that we need
we're just going around
if we move ourselves a little bit closer
to the surface of the earth
then the spacecraft that's bringing up the astronauts
doesn't have to travel as far
doesn't have to use as much fuel
so yeah that's exactly what's going on there
so
from about
four hundred or so
five hundred kilometers above the surface of the earth

from the international space station
this is kind of what earth looks like
so this international space station like i said
in this case is traveling at about twenty six thousand
twenty seven thousand kilometers per hour
so it's going really really really fast
and can someone tell me
just kind of a pop quiz from one of our past lectures
based off this little map that you can see
up here in the northern hemisphere
is it summer or winter right now
in the northern hemisphere is its summer or winter
i guess that kind of gives it away
because it has the actual date right there
so didn't think that went fully through
but the idea is what i was trying to get you to look at
and what i'll just point out myself is
you can see here
this depiction here is showing you
whether the international space station
is traveling through darkness
or traveling through sunlight
or traveling when the earth is pointed towards the sun
and what you can see here is that antarctica
kind of close to the south pole
is in sunlight
has direct sunlight
for what it appears like most of the day
maybe almost twenty four hours
whereas it looks like there's portions up here at very
very northern latitudes
where the sun might not be reaching at all
at any point during the day
so you know
based on that
that the southern part of the hemisphere
must be tilted right now towards the sun
if that makes sense
okay so next we have
that was the low earth orbit
the only like i said
the only satellite that we talk about
that's in low earth orbit

is really the international space station
the next type of orbit that we talk about
is the close elliptical orbit
so the close elliptical orbit
starts at an altitude just above the low earth orbit
at about six hundred kilometers
all the way up to about two thousand kilometers
and depending on the satellite
it'll be traveling at a slightly different speed
generally speaking
because this is a much more wider range
the further you are away from the surface of the earth
if you're a satellite
and you're orbiting the earth
the further away you are
the slower that you're generally going
so the fastest satellites
are typically the ones closest to earth
the slower ones
are typically the ones further from earth
this one is an exception
this one's you know
i put up here
twenty seven thousand kilometers per hour
that's about the speed that
the landsat satellite travels at
which we'll talk about a lot throughout this course
so that's kind of an exception to the rule
but generally speaking
whether it's the close elliptical orbit
or a different kind of orbit
the further you are from the surface of the earth
the slower you're going to be moving
so the close elliptical orbit is about
six hundred to two thousand kilometers altitude
and its applications
the main applications of satellites in that orbit
are really just earth observation satellites
satellites like landsat modest
which we'll talk about in depth throughout this course
but for midterm purposes
you can just say
if i ask you

what are the applications of a close elliptical orbit
you can just say earth observation
okay next yeah
what i just said
if i were to ask you on the midterm exam
what are the applications
of satellites in close elliptical orbit
you would just say earth observation
okay next we have the far elliptical orbit
so the far elliptical orbit travels
mostly at about fourteen thousand kilometers per hour
you can see that's substantially slower
than satellites in the close elliptical orbit
it's at an altitude of about twenty thousand kilometers
above the surface of the earth
so much much higher
than satellites in the close elliptical orbit
and really the only satellites that we talk about
that are in this orbit
are satellites that are a part of
global navigation satellite systems or gps
that's what we'll be talking about tomorrow
but that's essentially the satellites
that are able to determine your position
these are the satellites that
when you pop out google maps
and you see where your location is on google maps
it's these satellites telling you exactly where you are
lastly we have geostationary orbits
geostationary orbits travel at the slowest speed
at about ten thousand kilometers per hour
and their altitude is generally around
thirty five thousand kilometers per
or sorry thirty five thousand kilometers
above the surface of the earth
they have a couple of different applications
the main application we'll talk about
of geostationary orbits in this course
is weather satellites
what's really unique about the geostationary orbit
is satellites in geostationary orbit
are fixed above one position
or one side of the earth

which means that they are essentially always looking at
one single portion of the earth
they always have the exact same target
they're always looking at the exact same
view of the surface of the earth
you can see that here
the satellites here are just orbiting such that
as the earth rotates
they're just orbiting right with it
just so that they're always looking
at the exact same point of the surface of the earth
that makes him really useful for something like
understanding weather or monitoring weather
because we often want to know what weather patterns are
at a very very fine temporal scale
which just means
we want to know what weather is doing all the time
we want to know
what it's going to be like this afternoon
what it's going to be like right now etc
so these geostationary orbits are really
really good for that
because they're always looking at the same
spot on the earth
so for example
we have the go satellite
that's an example of a weather satellite
it is a geostationary satellite
it has positions all around the surface of the earth
but for north america
there's a couple of satellites that kind of
just look right at north america
right at canada
in the states
and can give us year round
around the clock
information on what weather is doing
at that point yeah
do you want to know
just what's on the slides yeah
in terms of knowing what
for the midterm
for the final exam

what you need to know about each of these orbits
just roughly how we classify them
which is their altitude
what kind of altitude they're at
and then just each of their applications
so for geostationary we talk about weather satellites
for far elliptical
just gnss satellites
for close elliptical earth observation satellites
and for low earth orbits
saying either earth observation
human space flight microgravity experiments
those would just be the applications yeah
and is the reason you can't see the poles
because you wouldn't be able to orbit with the earth
yeah you can't
you couldn't have a geostationary orbit
that is looking at the poles
you are able to see poles with certain satellites
mostly with close elliptical satellites that are
that earth observation satellites are in
and you can see here in this little kind of graphic
this little video
these satellites are actually going over the poles
so those are the ones you would use
to be imaging the poles
but the geostationary satellites
are typically quite limited to mid latitude areas
close to yeah close to
they can often still view pretty far up
either north or south of the equator
because they're so far away
they have such a wide angle of view
but generally they're pretty much
situated right above the equator yeah
ok any questions about orbits
about each of the orbits
we just talked about their applications
how we classify them anything like that
sweet okay so we know that we have all these satellites
they're in all these different kinds of orbits
this is kind of going back to a question
that i had earlier

now this is kind of a scale depiction of
if you just blew up the size
of each of those satellites relative to earth
and you are trying to visualize and look at
all of the satellites that we are tracking
that are currently orbiting the earth in some way
shape or form
this is kind of what it would look like
so you can see here there is a ton of stuff
a ton of artificial objects
satellites in this case
that are orbiting the earth
you can zoom in
you can see there's lots and lots and lots and lots
now obviously
you could think of
this would be a bit of a problem
and that's where this idea of space junk comes in
so we've had
these growth of satellite programs over the years
kind of from the sixties
when the space age started
we've had all these different countries and companies
launching satellites into orbit
and we've never really had a particularly
well regulated way to control
who's launching what into where
because space is space
we don't really have you know
agreements or laws to govern what can be done in space
and so through time
and you can see that here
going from the sixties
all the way up to two thousand nine
we've slowly accumulated more and more
and more and more tracked artificial objects
that are orbiting the earth that we've launched
and what's really interesting and pretty crazy now
is that more than ninety five percent
of these tracked objects
which just means that
objects that we've launched into space
that we are still tracking

so we know where they are
a lot of them are just debris
which just means that they're not actually useful to us
they're not taking images of the surface of the earth
they're not actually
doing anything for earth observation
remote sensing
they're literally just junk
and that has its risks associated with it
so it's difficult to launch new satellites
because you put all this money into a satellite
and now there's the potential
that if you launch this satellite
it could get hit by old ones
and by other junk
you might be wasting all this time and money
to send this satellite into space
just for it to be hit by some piece of junk
and maybe malfunction
it's also now more dangerous
and difficult for space exploration by people
there's this higher risk
of potentially getting hit by some sort of space debris
if you're in a spacecraft
or if you're on the international space station
so scientists have predicted that close encounters
between satellites and debris
are going to rise by about fifty percent in ten years
and about by about two hundred fifty percent
by twenty fifty nine
and that's kind of the foundation
of this thing called the kessler effect
and the kessler effect is just about exponential growth
it's the idea that
as we increase space junk that's orbiting earth
then there's going to be more collisions
because there's going to be more collisions
more smaller pieces of space junk
are going to break off
and now be going all kinds of directions
and now those have potential
to collide with something else
and now those have the potential

to collide with something else
and it's this exponential growth
of problems
of collisions
that are going to be associated with space junk
now the most current research hasn't suggested
that we have currently
right now reached the point of that happening
where we've reached the point of
the start of exponential growth
this kessler effect of space debris
but there are studies to suggest
that we're potentially coming upon that
within the next twenty to thirty years
and that this next decade
has a lot of influence
over what the next couple of decades
are going to look like
in terms of space junk
and safety for astronauts
and that kind of thing
so this is just an example of an image
from an astronaut on the international space station
they kind of had a chipped windshield here
that was from something i believe
about the size of a softball that hit their window
that hit their window
pretty scary
i mean if i were an astronaut
on the international space station
and something came hit my window and this
i saw this little chip
i mean i wouldn't go to space in the first place
because i'm not brave enough frankly
but you know
if i was up there
and i saw this little chip
created by something that was flying through space
and hitting the side of my window
i'd be pretty scared
so there's this sense of increased danger
for astronauts associated with space junk
this is an example from the hubble telescope

which is a really famous telescope
that's actually orbiting the earth
it's orbiting the earth
so that it can take images from space
of things deeper into space
so not of earth
but because it's orbiting in space
and surrounded by
essentially darkness
it's much easier for it to take images of things
further away
that are much more sensitive to the light
because it's just surrounded by darkness
as opposed to being kind of polluted by
the light that we have here on earth
that's kind of aside
it doesn't really matter
the point is
it's this really expensive
well known telescope
that's gotten us lots of really
really valuable imagery
for exploring space
and all of these are little individual dents
that have occurred
from space junk hitting it
so there's tens and tens
dozens and dozens and dozens
this is just a little section of the hubble telescope
in reality it's huge
so you can imagine
there's probably hundreds of little dents and impacts
that have been created
between space junk
and just this one telescope
the sentinel one satellite is a pretty new satellite
it's only been orbiting the earth for about ten years
and you can see here
it's already accrued some damage
from running into some space debris
okay so i kind of wanted to
that was a little bit
a little bit doomy and gloomy

we got all this junk that's in space
what can we actually do about it
there's three kind of key things
that we can actually do about it
two of them will talk in detail
one is more of a
kind of a side
so what can we do
we can create debris reduction programs
we can actively go out and launch satellites
or launch some sort of spacecraft
to go out and try to remove space junk
we can also try to develop
technologies
for new coming satellites
so that when they get launched into space
they can kind of remove themselves
from being space junk
and generally
all of these things
kind of a prerequisite maybe
to being able to fund
and have support for those first two things
is being able to implement
stronger international agreements
like i said
the governance of space is very
very very fuzzy
so with stronger international agreements
and support from governments
there be this sense hopefully
that we'd have more funding
more support
to go out and try and reduce the space junk problem
but the two that i'm going to talk about in general
and the two that i would
want you to use as an answer
if i were going to ask you
on a midterm
or final exam
hint hint wink wink
nudge nudge
are either debris reduction programs

or developing new technologies
to avoid oncoming space debris
now debris reduction programs
are typically involving
sending satellites into space
that might use a harpoon
or a neck capture
to actually
get rid of those kinds of space junk
or a new satellite
that can be launched
and then maybe
once its lifespan has been reached
then it kind of deploys a big boom
that creates a bunch of atmospheric drag
and pulls it back to the atmosphere
where it burns up
and kind of
removes itself from space junk
so i'm going to play a video
that's about three or four minutes long
that kind of has some graphics depicting
how these debris reduction programs might look
or you know
how these new satellites might look
that would have a way
to remove themselves
from space junk
and then i'll talk again
in detail about kind of
what's going on
and how it's working yeah
i would just like to list what we can do
i'm going to talk about it
and you'll see what i want you to know
oh whoops
in a world reliant on mobile phones
communications such as internet
and electronic monitoring systems
satellite technology
is crucial to our modern way of life
perhaps unsurprisingly
with their more demand for services

more and more satellites have been popping up large
around the earth
whether this is like your problem
is now some junk in space
this space dome comes in all shapes and sizes
in the tiniest black of paint
right through the dead satellites that no longer work
even sections of all rockets
are part of the earth's space junk problem
scientists have estimated that there's already
incredible seven thousand tons of junk in space
and it's increasing
the majority of useful satellites today
launched into low earth orbit
which is ending up to around
two thousand kilometers above the earth
here there is the greatest risk of collision
seem to be on gravity
well in reality
a huge pilot like that is unlikely
however satellite collisions have occurred in space
such as the original thirty three collision
in two thousand and nine
scientists allowed for
in the best ways to minimize and remove space junk
in order to combat a problem
there are two methods
ensure future satellites
are able to get rid of themselves
so they don't contribute to the population of junk
and actively launch missions
to rendezvous with a capture space junk
the removed debris mission
will be the world's first mission to demonstrate
capturing technologies that could deorbit space junk
the first experiment is net capture
a small cube that will be ejected
which acts as an artificial junk
this will require an inflatable structure
the inflatable structure
helps the cubes out to deal a bit quicker
getting the net
and the platform directly aligned with the jump

so the capture system doesn't miss is a big challenge
in a full mission
the net would have a tether line
to pull the junk back down to earth
the second experiment is harpoon capture
here a oil target
is used to demonstrate the use of a harpoon
to capture space junk
the third experiment is a vision based navigation
and will also use an ejected cube set
but simply in order for satellites to rendezvous space
camera and lidar technologies need improvement
lidar is a measurement technology that uses a laser
to illuminate the cubesat and read back information
such as position and orientation
the final experiment is the drag sail
in order for satellites to dispose of themselves
future missions may have such drag sails attached
by deployment
drag sail using an inflatable boom
drag supply to the satellite as it passes
through the outer elements of the earth's atmosphere
this added drug will turn the satellite to earth faster
where it will burn up in the atmosphere
here we show the burner for the main platform
the extreme temperatures during the entry
cause the platform to completely burn up
if we fail to clean up our space environment
more collisions are going to keep occurring
potentially making whole segments of space unusable
or damaging critical services
that we use on a daily basis
the cleaning off the space jugs is crucial
to ensure the same ability of space
for future generations to enjoy
okay quick one quick clarification
just so you don't get confused
in that video
they classify low earth orbits
as anything up to two thousand kilometers altitude
in this class
we do low earth orbits
at about four hundred kilometers altitude

and then close elliptical
from six hundred kilometers
up to about two thousand kilometers altitude
okay but just a quick kind of review
or extra explanation
about how these methods or systems would work
so the first is debris reduction programs
which means that you launch a satellite out
or some sort of spacecraft
that wouldn't have a person in it
it would just go by itself
you actively launch this satellite
and it would be able to harpoon
send out a harpoon
and grab some junk
and pierce it
and then pull it back into itself
so if i was a
you know if i was this satellite
that was sent out to get all the space junk
i'd be going through space
i would go boo
boo boo boo
i would send out all these harpoons
and i'd punch a bunch of stuff
and then i reel it back towards me
and then once i have a bunch of space junk on me
once i've kind of reached my max capacity
then i would just increase the thruster on me
to send myself back towards the atmosphere
and then because of all of the air molecules
in the atmosphere
when i travel back towards earth and hit the atmosphere
i'm traveling at such a
such a fast speed
that the friction
between all the air molecules and myself
will cause me to just burn up
so i just burn up upon re entering the atmosphere
all of these methods
in one way or another
involve pushing
the space junk back towards the atmosphere

so that it's burned up as it hits the atmosphere
just a quick note
the other method is
which pulls it down
i'd say the second one first contained a small here
oh yeah sorry
so the other method is
as opposed to going out
if i find that satellite
harpooning a bunch of things
and then pulling it into me
and then sending myself
back down towards the atmosphere
i might also send out a harpoon that hits the satellite
but that has
or the space junk
but that has a little thruster on it
so it just kind of individually sends
that piece of space junk back down to the atmosphere
where it burns up when it hits the atmosphere yeah
yeah great question
so up until recent years
the general consensus was no
that it's so
the size of the atmosphere
relative to the amount of space junk that we have
or the amount of satellites that we have
that would be re entering the atmosphere and burning up
that probably wouldn't pose a problem
but there's been new research
that's come out in the past couple of years
that has suggested that it could be a problem
one of those being associated with the fact that
most of these satellites or pieces of space junk
have high amounts of aluminum in them
and that if they come down
if we have tons and tons and tons of satellite debris
that's coming towards the atmosphere
and burning up when it hits the atmosphere
that there might actually be this increased level of
non natural or human caused aluminum
in our upper atmosphere
and that could potentially

cause problems with our ozone and things like that
the like i said
the consensus was for many
many many years
that it wasn't a problem
but because of the
proposed ideas from spacex and other companies
to have these massive
massive mega constellations of satellites
where they're sending up thousands
and thousands and thousands of satellites all the time
just a ton of them
and replacing them really quickly
just constantly sending out more and more satellites
the idea is that
or the thought is that
because now
we're going to potentially have so many satellites
that are going to be sent into orbit
that there's going to be so many
much more that are going to be coming
and hitting the atmosphere and burning up
that it could potentially have an impact
and to be honest the impact
based off the research that's out there right now
isn't particularly clear
there hasn't really been enough research or experiments
to know exactly what the byproducts
of those chemical reactions could be in the atmosphere
so it's kind of unknown
but there's a lot of research that suggests
or questions
should we kind of allow this
be okay with this
given we don't really know what could happen if we have
potentially all this extra stuff in our atmosphere
do you have a question
was there a question here
okay but so the two kind of examples here
are both harpoon based examples
one where you harpoon out to a bunch of space junk
pull it in and then
go down to the atmosphere with all that space junk

or you send a harpoon out that leaves the kind of
main spacecraft that's out there to remove the junk
and it hits some space junk
has a little thruster on it
and then it just individually
thrusts that space junk down to the atmosphere
the other example is a net and capture system
where the satellite goes out to remove the space junk
it identifies some bigger pieces of space junk
it sends this massive net
essentially
to encapsulate the space junk
and then has this tether
which is essentially just this long rope
that kind of looks like
the fin of a tadpole or something
that just kind of is leading off the back of the net
and essentially
some crazy physics go on that i do not understand
that occur in the upper atmosphere
where that tether on the back of the net
is able to create enough orbital decay
to pull that satellite back towards the atmosphere
and again it burns up when it hits the atmosphere
the one other example
which is not about sending out a satellite
to actively remove junk
but to design new satellites that are launched
to be able to remove themselves from space
is that they're just able to go out and
once they've reached their lifespan
deploy this big boom
and that boom creates enough atmosphere drag
creates enough friction
with the air molecules that are out there
that it can kind of
drag that satellite back towards earth
hit the atmosphere
burns up when it hits the atmosphere
any questions about any of those methods
you can definitely expect a midterm question on it
yeah exactly
so i would specify the question

probably along the lines of
give me one example of how we can
actively remove space junk
give me one example of how we can design new satellites
to reduce space junk
so that they don't become space junk
does that make sense
any other questions
sweet okay so i often got this question
the past couple times i was teaching this course
why do we not spend send all our garbage to space
there is for example
this literally massive container of garbage
that was dropped
or dumped from the international space station
it's got two point nine tons
of used nickel and hydrogen batteries
and it's currently orbiting the earth
at about four point eight miles per second eventually
it's gonna get pulled into earth's atmosphere
where it's going to
you know quote unquote
safely burn up in the atmosphere
with no byproducts or other effects
supposedly anyways
the point is is that it's going to come down
it's going to hit the atmosphere it's going to burn up
so why wouldn't we just do that
we know we have a bit of a garbage problem on earth
on the planet
why wouldn't we just send all of our garbage into space
and then allow it to fall back into the atmosphere
as it re enters the atmosphere it would burn up
it would get rid of a bunch of garbage for us
so the problem with that is that the world makes about
two point six trillion pounds of garbage per year
that would take about a hundred and sixty eight million
rocket launches
to get all that garbage into space
just for one year
which would cost about thirty three quadrillion
us dollars for one year
which that number literally looks like this

i've never seen a number that big before
until i look this up
to be honest
but this is about fifteen hundred times
the annual gdp of the states
so beyond it just being a problem
because of all the fuel you would burn
and all the greenhouse gases
that you admit is also just ridiculously
ridiculously expensive
so unfortunately
we can't send all of our garbage to space
okay that is pretty much all i have for today
i'm going to give you guys about five minutes
to try and brainstorm the answers to these questions
where does space begin
what is the altitude of each orbit type
what are the common applications of each orbit type
why is space junk a problem and how can we fix it
if you want to stay and go over the answers
you are welcome
if you don't you want to head out please do so swiftly
and i will see you tomorrow
okay
nice you guys are my favorites
stick around talk with me more
nice okay cool
we can go over these
i'll get you out of here quick
so where does space begin it's kind of a trick question
we talked about some different definitions
so maybe we can kind of mention all of those
but if i were to just ask you where does space begin
what would you say
pardon me what about the carmen line yeah
so that's the political boundary
that we kind of have established for where space begins
what's kind of our
more scientific sense of where space begins yeah
four hundred and eighty to five hundred kilometers
yeah somewhere in the range of
four hundred to five hundred kilometers
and why is it about there

you can answer if someone else can answer if you want
because that's when
the air particles kind of fade out yeah
it's like a vacuum at that point
exactly that's where
about four hundred to five hundred kilometers altitude
that's where air molecules get so sparse
that it essentially is approaching a vacuum
there's so little air molecules
there's so little matter
that we're starting to get into
what's considered a vacuum
which is space
okay what is the altitude of each orbit
what is the altitude of low earth orbit yeah
four hundred kilometers
four hundred kilometers
what about close elliptical orbit yeah
six hundred to two thousand kilometers
and what about far elliptical orbit
sure yeah do it again
beautiful we're on a roll
you can kind of rough those
you don't need to give me the exacts
each individual satellite in that orbit
will kind of vary a bit
i just picked one specific satellite and threw it up
but in that general range of twenty
twenty one thousand kilometers or so
and then what about geostationary orbits
yeah thirty five thousand kilometers altitude
so what are the common applications of each orbit
so what kind of satellites
and what maybe are they used for
are in the low earth orbit yeah
exactly so earth observation
human space flight and microgravity experiments
are the common applications of low earth orbit
what about close elliptical orbit
oh yeah keep it going
earth observation yeah far elliptical orbit
sure why not yeah
gnss global navigation satellite systems

or positioning satellite systems
those are the satellites that tell us
where we're located on the surface of the earth
we'll talk about those in detail tomorrow
and then lastly geostationary satellites
common application of those
weather satellites
exactly okay
last question we can answer in two parts
why is space junk a problem
what's the issue with space junk
why are we concerned about it yeah
yeah
exactly slight bit more expansion on the first point
why is it difficult to launch new satellites yeah
it's expensive
yeah it's expensive and what's the kind of
can you elaborate like a little bit more
okay same same yeah
yeah exactly
so they're expensive
they're valuable
they're hard to launch
if we're launching them
there's this increased risk now of collision with
space junk that's out there
okay so how can we fix it
what are the ways that we can fix space junk yeah
send out a thing that goes out and harpoons
all the space junk
and then breaks it into the atmosphere to burn off
or use like a net to grab it all
and then put it into atmosphere to burn
yeah so there's
yeah yeah new satellites that were launching put like
like a sale on it so they can eventually slow down
yeah exactly
so we got yeah
yeah exactly
the stronger international agreements
is kind of more around what we can do to support
or get more support for those methods that are actually
physically going out and removing space junk

so if i were to ask you on a midterm or final setting
what are the
solutions to actively go out and remove space junk
then it would be either the harpoon
or the net and catapult
if i were to ask you
what are the ways that we can
that we can design future satellites
to not create so much space junk
that would be designing new satellites that have a boom
an inflatable boom
that inflates
when the satellite has reached its maximum lifespan
so that it drags back into earth
i'll just add the harpoon and the net and catapult
the net is kind of pretty simple to understand
just that it's a net
that's shot out from this satellite
it covers the space junk
and then there's this tether
essentially
the net itself creates the drag
that pulls that space junk back down to the atmosphere
the harpoon
there's kind of two specific harpoon methods
one of them being
you kind of harpoon out and pull all the space junk
back into that original spacecraft or satellite
and then it sends itself back towards the atmosphere
or you send out a harpoon
that completely detaches from where it's sent from
and it just has a little thruster
that's on it
that when it hits the space junk
it then just thrusts
that individual piece of space junk
back towards the optimus here
does that make sense
makes sense yeah
sorry say that again
the inflatable thing
so yeah so for new satellites
if i were to ask you

how you could design new satellites
to limit or reduce space junk
new satellites would be designed
so that they have this inflatable boom
so it's this sail essentially
that inflates
when the satellite has reached its lifespan
and then that creates drag
creates friction with air particles
that just pulls it back down to the atmosphere
where it burns up
yeah that makes sense
see any other questions at all
see all right thanks guys see you tomorrow
how's the week going it's going good
pretty good
not too shabby
that was good
yeah yeah everything's going smooth
it's in here actually
i've been used to this lecture hall
it felt really big on the first day
now it feels pretty normal
okay i'm gonna start here
never use your mic oh right
hi guys i'm gonna get started here
i just wanted to introduce you to tristan
he's one of your tas for your next assignment
and the assignment after that
he's gonna say hello
then he'll be out here
yeah yeah oh yeah
just a quick hello
my name is tristan
i'm your ta for assignment two and three
um i am a phd student in the integrated
remote sensing studio in the department of forestry
yeah so assignment two
is going to be going up this week before thursday
along with my office hours so yeah
all right
so
oleanna wanted me to go over something

which was just that
the assignment submissions
so the way you answer all your questions
for the assignment is through a canvas quiz
and she said that
there have been some confusion about that
so that just means that you know
the submission page for the assignment for simon one
in this case
is just a canvas quiz
there's no timer on it
it'll just close when the assignment is due
which is at midnight on thursday
but the quiz is how you actually submit your
answers to the question so you can open the quiz
you can work on answering the questions
as you work on them
the quiz will save your answers
you should just be able to close it and then reopen it
and it should save all your answers
and saying that don't trust canvas if you
are just hoping that canvas will save your answers
if you're trying to save your work
and then keep working on it another time
i would just back up your answers somewhere
just have a word document or something where you can
just put the answers to your questions as well
just in case
if you reopen canvas it doesn't save your work but
but it should yeah
yeah
yeah so the
our policy i believe is
twenty percent late deduction per day
so it's open for five days after it's due
because five days after it's due
that be minus a hundred percent
so you get zero anyways
so we accept them
but they just get docked late marks yeah
any questions about that
about how you submit answers to your questions
for the assignments

ok sweet so today we are talking about
satellite navigation systems
and global satellite navigation systems
we're going to be talking about how they work
what information you need from space
from global navigation satellites
in order to figure out
where your location is on the earth
we'll talk about how they actually go away and do this
and then we'll talk about some different kinds of gnss
the difference between differential and kinematic gnss
and i'll just end on some applications of gnss so
i always start this lecture by just asking you
if you have used gps today
if you google maps something
or you looked at your location on google maps
then sure enough
you've used gps already some point
today we know
we have these car gpss
that are sometimes built into our cars
we have these really fancy ones
that scientists will take out into the field
to get really accurate measurements of where they are
or of points that maybe they're surveying
and we also know that
maybe if you're on a plane
planes are using gps or gnss to navigate where they are
through three dimensional space
and as we talked about in our
history of positioning lecture
it's not new for humans to be
looking at things in the sky
in order to figure out where we are located
on the surface of the earth
the only new thing since the early sixties
late fifties
is that instead of looking to
natural objects that are way distant in the sky
like stars like the north star
for example
instead we just look to these artificial objects
these satellites

that we've launched into the sky
and are in orbit around the earth
navigation satellites
or navigation satellite systems
are like orbiting landmarks
if the landmark
or the position of that landmark is known in this case
a satellite
if we know exactly where the position
of that satellite is
then you can determine what your position is
using at least four satellites
and i'll talk about in detail
how that's actually done
just want to make sure i'm recording here
i'm paranoid now
i somehow accidentally turned it off
in one of my other classes
so history of yeah question
um so that'll
that'll become clear throughout this lecture
i'm gonna talk about that in detail
so maybe just hold off on that for now
that's okay
okay so history of gps
the global positioning system
gps is just an american
global navigation satellite system
so gps is called
stands for global positioning system
it's the american
the united states developed version of gnss
so gnss global navigation satellite system
refers to all the satellite systems that exist
gps is a specific gnss
that was developed by the american
so gps was developed by the us military and about
started getting developed around the nineteen seventies
became operational with twenty four satellites in orbit
in nineteen ninety five
and then many people started using it
from nineteen ninety six onwards
and became a civilian asset

which just means that pedestrians
people started using it on a relatively common basis
from two thousand on
there's three segments to how
a global navigation satellite system works
and i just will quickly go over
what i stated on the last slide
because you can definitely expect a
midterm question about it
i will want you to know
what the difference is between gps and gnss
gps again just the american version of a gnss
there's many global navigation
satellite systems out there
i'll mention what the other ones are in a moment
gps is happens to be the one that's most familiar to us
because it was developed in america
so any gnss system essentially works the same way
there's three segments to it the space segment
the control segment and the user segment
satellites are communicating with control stations
so with the control segment with a two way signal
which just means that
satellites are sending information down to
the control segment
and those control segments are sending information
and commands back to the satellite
so there's a two way signal going on there
the user segment
which is just you
that's you holding your phone or your gps device
whatever it might be
your receiver
it's just receiving information from the satellites
so you are never
with your phone or whatever gps device you're using
you're never sending information to the satellite
the satellite is simply sending information to you
now like i mentioned
gps is the american gnss system
there's always a minimum of twenty four satellites
across six different orbits
and from any point on earth

at least four satellites are typically visible
for the receiver
so like i mentioned
gps is the american gnss
there's also the russian gnss glonas
the chinese badu
the american gps and the european galileo system
so these are all different
global navigation satellite systems
so when you hear oftentimes
gps and satellite systems being used interchangeably
they're not exactly the same thing
each of these
the glonass gps
baydu and galileo are a different gnss system
this graphic is a little bit outdated
i just put it up there to kind of give you a sense
that there are different ones that exist
there's much more than twenty four gps satellites
in orbit now
there's probably about thirty two
thirty four
that are operating as we speak
generally speaking
most gps devices
most receivers
whether that's your phone
or some other fancy gps device you have
is able to use not just gps satellites
but also satellites from glonass
from galileo from baydu
so that gives you a wide variety of satellites
that you could potentially get a signal from
in order to determine your position
gps and all the other gnss systems
are always launching new satellites into space
they all have fitted lifespan
so as ones get old and stopped working
we launch new ones into space
which again
starts contributing to that space junk issue
we talked about yesterday
these gps three and gps three f satellites

these are the newest ones
as they become newer
they just have longer lifespans
they get more accurate etc etc
so that's an example of the space segment
the space segment are the actual satellites
that are in space
we know that they are all in far elliptical orbit
the user segment that's you
so that's just your receiver
that's your phone
that's your trimble receiver
whatever it is that you are using
to determine your position
that's what the user segment is
so that's the space segment
the user segment
then we have the control segment
and the control segment
is this entire system as a whole
so you can see here we got a master control station
and a backup master control station
that's essentially where people are sitting in offices
collecting all the data
that ground stations are receiving from satellites
running a bunch of analysis
figuring out how the satellites are performing
whether any of them need to be adjusted in their orbit
etc you then have the ground antennas
which are collecting that information
these monitor stations
are collecting the information from the satellites
and then these ground antennas
are sending information back to the satellites
so you know
an example might be
this monitor station
receives information about a satellite's orbit
it comes then to the master control station
the control station says
okay we've received this information about the orbit
and looks like maybe this satellite
has deviated from its orbit a little bit

where it's supposed to be
let's send a command via these ground antennas
back to the satellite and say
thrust yourself a little bit to the left
just to get you back onto the orbit
that you're supposed to be
that's what the control assignment does
so it's just for controlling
monitoring the satellites
that kind of thing
okay any questions about those
about those three segments
kind of what they do
what their importance is
so control segment user segment space segment
so how do we actually determine
the location of an object
or of an entity or of ourselves using these satellites
it uses a method
a kind of mathematical principle called trilateration
now we talked about the other week i guess
wasn't yesterday i don't think no
the other week we talked about triangulation
which uses angles fundamentally to figure out position
trilateration uses distances
and this is an example of how that will work
if we want to say okay
i'm a city i don't know which city i am
or i don't know
yeah i don't know which city i am
i'm looking at this map right
but i know that as a city i am
a hundred and seventy five kilometers from amsterdam
three hundred and twenty kilometers from london
and a hundred and eighty five kilometers
from luxembourg
so i know that i am
a given distance from these three cities
which city am i
how can i figure out where i'm located
so if we say okay
when we know we're
a hundred and seventy five kilometers from amsterdam

it's the first set here
if we draw this
little circle that's
has a radius of a hundred
and seventy five kilometers around amsterdam
then we know okay
we have to be located somewhere along this dotted line
we're somewhere along this circle
because we know that we are
a hundred and seventy five kilometers from amsterdam
then we say okay
we also know we're a hundred and eighty five kilometers
from luxembourg city
so that means that we also
have to be somewhere along this line
now if we know that we're
a hundred and eighty five kilometers from luxembourg
and we are a hundred and seventy five kilometers
from amsterdam
that means that we have to either be right here
where these two lines intersect
or right here
where these two lines intersect
so we're probably either brussels
or dozaldore from
probably absolutely butchering that pronunciation
but we know that we're one of those two cities
if we add one more city
and we say okay
we also know
that were three hundred and twenty kilometers
from london
then we can narrow it down and say okay
we're definitely brussels here
because that's where each of those lines overlap
that's the only point
that we can see on this map
that is a hundred seventy five kilometers
from amsterdam
three hundred and twenty kilometers from london
and a hundred and eighty five kilometers
from luxembourg
so we know it has to be here

and that's essentially how satellites work
they know exactly where they are in the sky
based off of what orbit they're in
and their orbital parameters
and then your receiver says
okay if i can figure out the distance
to three of these satellites
then i can determine exactly where i am
and this is exactly how it works
so you use this
trilateration
rather than triangulation
in this case
the global navigation satellite systems
use the speed of light
to calculate distances
so they're not just
you know there's not just a measuring tape
that's determining how far you are
from each satellite
pardon me the satellites are sending signals
down to your receiver
and then your receiver is determining
based off of knowing
that those signals were sent
at the speed of light
using radio waves
it then determines okay
how long did it take for me to receive that signal
based off that
how far away did that signal come from
how far away is that satellite
and by combining those distance
distance measurements
for at least three satellites
but generally speaking
if i ask you in an exam
how many you need
you would always say four
and that's because three satellites
are able to determine the
position of something
but four are needed

to get an accurate and verified position
so you always have a fourth satellite
to essentially say yep
it looks like the measurement
that we've gotten
from the three satellites
is accurate
and that's just because you need three
to essentially determine where your position is
using trilateration
using this method i've gone over here
and then you add in a fourth just to say
yep that's definitely correct
generally speaking
that's just the minimum
the more satellites
that are communicating with the receiver
so the more satellites the receiver
can be in contact with
the better accuracy
your calculated position is going to be
so more satellites are always really better
now in reality
that process is in a few steps
so radio waves send from the satellite
down to your receiver
down to your phone
down to whatever it might be
and then your receiver downloads the almanac
downloads the ephemeris
downloads the gps date and time
which just means
the date and time associated with that satellite
and then it measures the change in time
to at least four satellites
to determine how far each satellite is away
and based off that
calculates a position
for exactly where you are on the earth
now i'm going to go into detail about how exactly
it uses time and the speed of light
to calculate distance to each of the four satellites
but if i were to ask you

what are the steps for a receiver to ultimately go away
and determine position
it would be first
download the almanac
then download the ephemeris
then download date and time
that's all sent together via these radio waves
and then based off those measurements
i'd measure my change in time
to at least four satellites
determine the range
how far they are
and then based off that
be able to calculate a position
so those are the steps
now the ephemeris and the almanac
each contain different kinds of information
and there's a reason that they're downloaded
the ephemeris
generally speaking
contains detailed information on date time
satellite accuracy and health
orbital parameters
clock correction coefficients
essentially a bunch of very
very fine scale information
the ephemeris often tells the receiver
exactly where that satellite ought to be in orbit
so the ephemeris gives really detailed information
about where that satellite is
and about the orbit that it's in
the almanac just essentially
contains less accurate information than
compared to the ephemeris
it's valid for about ninety days
and the main purpose of the almanac is just to speed up
the time it takes a receiver to find other satellites
so once a receiver comes in contact with one satellite
it'll download the almanac from that satellite
and then that makes it easier for it to find other
nearby satellites that are orbiting
when it downloads the ephemeris
it's then able to determine

where that satellite essentially is
above the surface of the earth
where it's at in its orbit
what orbit it's actually in
because of that
a receiver can always work without the almanac
because the almanac's purpose
is just to help it find other satellites
but it always needs the ephemeris data
because the ephemeris is what actually tells you
or tells the receiver
where those satellites are in orbit
and what the health of them are
whether they're operating properly or not
okay so that's the ephemeris and the almanac
any questions about
but ephemeris and almanac
they're a bit of an abstract topic
they're a little bit hard to wrap your head around
i don't expect you to know in detail
each specific kind of information
that's associated with them
but just generally speaking
what they are and what they do
the almanac just being
course information about the satellite
allowing that receiver to connect
to other satellites that are nearby quicker
the ephemeris contains the really
really detailed information
about the orbit that that satellite it's in
and its health and etc
that makes sense
yeah yeah
where is it being downloaded
onto the receiver
so if you're looking at your location on your phone
it'd be onto your phone in that case yeah
so the almanac
has course info
and it's used to work with other satellites
the almanac has course information
about the satellite's health

and just general information about it
the purpose of the almanac is that it helps
the receiver find other satellites that are nearby
in orbit that are nearby in the sky
the receiver has to find at least four satellites
in order to be able to calculate position
so once it finds one satellite
downloads the almanac from that satellite
then it's easier for that receiver
to find other satellites that are nearby
yeah yeah are you noticed when i'm on my phone that
when i'm connected to wi fi
where it's data
yeah i was wondering if this has to do anything yes
so that has to do with something called assisted gps
which we'll actually talk about
towards the end of the lecture yeah
ok sweet
so the almanac
the ephemeris are downloaded
but how do we actually measure change in time
how do we actually calculate how far a receiver is from
say four satellites
that are somewhere above it in the sky
that's by comparing these transmitted prn codes
prn codes stands for a pseudo random number code
and essentially
your receiver receives this prn code
is transmitted via radio waves
and that prn code comes with a date and time
that it was transmitted from the satellite
then the receiver marks a date and time
when it receives that prn code
based off the difference in time
from when the satellite transmits the code
to when the receiver receives the code
we can then calculate how far away that satellite is
all of these codes are traveling at the speed of light
because they are being transmitted via radio waves
so we know that they're
all traveling at a standard speed
so therefore
if we determine

okay you know
it was transmitted
and then received
the difference between
the time that that code was transmitted
and then that code was received
we can just multiply that by the speed of light
that tells us how far away
that satellite is from the receiver
okay i'll maybe go over that one more time
so we send out this pseudo random number
from the satellite
it's sent out with a date and time
the difference between when that pseudo random number
is sent from the satellite
to when it's received by the receiver
is then multiplied by the speed of light
that gives us the distance
how far away the satellite is from the receiver
you do that with four different satellites
that means now the receiver knows the exact distance
to four different satellites in the sky
based off that
using trilateration
it can determine exactly where it is
on the surface of the earth
does that make sense
yeah so we use
try not intervention
of the satellites
of the satellites
so because the satellites have very precise
orbital parameters
we essentially
have the satellites as these known landmarks
that have their position known
and so we're kind of using the receiver
and the information about where those satellites
are in the sky to determine where we are
does that make sense
is there any questions about this
i know it's a bit can be a bit confusing
ok so that's fundamentally two different kind of

concepts but they're very linked
right so here is the steps of what the
receiver is actually downloading and then calculating
and then how it actually measures this change in time
based off of downloading
the gps date and time is kind of done
with this method here
with the prn codes
which are transmitted and then have a
specific date and time that they're transmitted
the receiver marks that specific date and time
where it receives it
that change in time is then calculated
that's multiplied by the speed of light
that tells us
how far away the satellite is from the receiver
yeah in front of the prn code
just said it gets received
and then you can tell the time difference right
that's what the prn code is for yeah
yeah well yes
the prn code is what tells you the time difference yeah
so because of that
because essentially
we're facing these measurements on distance
off of clocks
essentially off of the change in time
we have to have super super
super accurate clocks
the signal travels about a meter
in three billionths of a second
which is just the speed of light
so satellite clocks are off by about just
one millionth of a second
our position would be off by potentially
three thousand meters
because of that
satellites use something called an atomic clock
which is essentially
by most standards
the most accurate clock
or measurement of time that we have available to us
atomic clocks

work by monitoring the vibrations of an atom
essentially
that's why they're called atomic clocks
i don't expect you to know how that works
but kind of a fun fact i think
ok kind of just to summarize
a couple of those concepts that i just talked about
and how gps or gnss determines our location
i just got a video that we're going to watch
it's about five minutes long
the video then also goes into a little bit
about some of the concepts i'm gonna talk about next
things like differential gps
so i don't expect you to necessarily know
what's going on
when it starts talking about differential gps
and some of the other concepts
in the second half of the video
but it serves as a good introduction
because i'm going to go over them in detail
so it's good watch
so we'll watch here
and the european union
got its own satellite language system
it joins the american gps and the russian government
to be carrying
the third system available around the globe
and while it did cost more time
and when it affected
it also decreases europe's reliance on other systems
navigation systems
have long become a part of our everyday lives
they power the world
for dissects
orchestration of the agent
and the name
will be going to take you anywhere in the world
or just find you to the nearest status
by looking at the history of these systems
it's key at the motivation you have
the ones that shake your next cappuccino
but instead
what always pushes technology forward wrong

especially if it's cold
when the soviet union launched
footing one hundred space in nineteen fifty seven
they became the first nation
to put a man made satellite into orbit
that of course annoyed the americans
but more importantly
it marked the beginning of settlements
a radio of space
that constantly orders to go
intended for communication or spying
or on navigation
this is especially important if you have things
that really should know where they are
gps first became operational in nineteen seventy eight
and the love of the russian donors
was one of the two major satellite navigation systems
for multiple decades
china has since set up its base game as well
and plans to expand its regional value
into a global system
by twenty twenty
and europe's own failure to spend on night
with a reach completion in twenty nineteen
probably i'll focus on gps
because it's the most popular
but i'll be systems with more or less the same gps
not just one settler
but actually a number of two thousand two satellites
orbiting the earth
twenty thousand kilometers above ground
that right there are always a few above you
these two pairs of lights
are basically atomic blocks
to the radio
and solar panels
constantly sending signals back to her
each broadcast on
hence the current location
the precise time the signal sent
and even though these broadcasts occurred
with the shield light
it still affects

between fifty and a hundred forty seconds
to them to each year
if you can actually listen to all of the seconds
but because some satellites are further away
from you than others
their seconds are very different times
so when satellite a and b sit on the signal
say that it's exactly through a clock
but the signal from satellite vegas to reverse
then you have to be closer to satellite a and b
you could actually see
like you know
your local size signage
and calculate how much close a satellite a is
because the satellites also
set on their current position
you don't want to know where you are
in relating to the satellites
but where you are exactly
and the birds are alive
and you can get toward them
in two dimensional space or to map
and with a fork
you can also calculate elevation
and with a system like that
you can pinpoint your exact position on earth
with an accuracy of up to one million
but it wasn't always this accuracy
when gps was first developed
it was supposed to provide public accuracy
of one hundred meters
but somehow
accidentally turned off
the entire caprica
for resistance
invalid to everyone
the military drop
is to be right to occur
so they implemented selected availability
which added a random offset
to the public signal
but still retained accuracy
of an encrypted signal

which only the military could use
so now public institutions
had to work
with a signal
that was significantly
less accurate
so that led to the development of differential gps
which improves accuracy
by using reference points
take the landmark someplace
you know the exact problem
stick a duplicates receiver on top
and you can always compare its actual location
with the location
to receive a calculator
and apply that difference to other receivers nearby
but the artificial
offset is not the only thing that affects accuracy
gps satellites broadcast the location
but slightly
the engines in orbit will
not be avoided
and while the atomic clocks are really precise
over a lifespan of multiple decades
the clocks were ever so slightly wrong
location and accuracy
and clockwork
are the same around the block
and can be easily compensated
but for the signal to get from the satellite
to the ground
they have to go through
the atmospheric storage
distortions are much harder to deal with
because they are highly local
depending to grab your arm
the signal has to travel further
and the atmosphere itself changes
all the time
so generating a single
offset isn't enough
which is why there are a number of these stages
all around the globe

the issue is
how to get these corrections to
the rescuing one
were explicitly broadcast
the locally
the us postcard
the just that
and by the late ninety nines
at most ports
and american waterways covered
but that still lands a large part of the continental us
without keyproof accuracy
which brings us back to satellites
to improve navigation
and aviation
the faa and others
work on the system
to broadcast these differential
information
via satellites
to make them available
all around the us by now
they are built for
the grandchild of jf systems
available in different parts of the world
to restaurants like
all of these systems
ended up making jks
more accurate
than it could ever be on its own
more accurately than jks
would be without
artificial distortion
which may select
availability useless
so wasn't exactly
the order from earthling
it was finally
turned off from the daily cloud
that is why
the european union
launched trailing
to have a system of its own

where no one else can flip a switch
so the next time
you never get into starbucks
remember all the lonely satellites above you
always predict
the world of dying
and no one will ever promise
okay so historically we've kind of
as most things happen with technology
have gotten receivers that have gotten more and more
and more and more accurate through time
and have become smaller and smaller and smaller
and have become again through time
less expensive and less expensive
the first gps receiver from nineteen seventy seven
looked like this
so there's this massive unit
where you were just kinda had to sit here
and wait for all the calculations to happen
today we have
you know microchips that are in our phones
that are essentially gps receivers
maybe as small as the fingertip
we also have gps receivers that are much
much much more accurate than something like this
where we have these big antennas like that
they're much more expensive
they're often just used in industry
environmental applications
whatever that might be
generally speaking
as you get from the spectrum of left to right here
you're getting more accurate gps measurements
but each receiver is costing more and more
so obviously you have your phone here
it's the least accurate
cost the least
you have the garmin and the tremble gps
and then you have here a trimble gps
that just has this attached antenna to it
so the trimble gpss are the most expensive
they get up to around three thousand canadian dollars
and then these antennas

that you can buy to go with them are usually
another three to five thousand canadian dollars
so your phone
generally speaking
has an accuracy of about three to fifteen meters
ninety five percent of the time
and we say ninety five percent of the time
just because you need a clear view of the sky
in order to get the typical accuracy
associated with the gps on your phone
accuracy in general
is influenced by the number and position of satellites
that your receiver is able to connect with in the sky
atmospheric effects
instructions like trees and buildings
just how good how high quality your receiver is
as well as whether or not you're using any kind of
post processing corrections
i'll talk about each of those in a bit more detail
in a second here
the maximum accuracy you can generally get with a gps
is from those very expensive
trembled receivers like this
that have these antennas attached to them
and then also use a form of differential gps and again
i'll explain what differential gps is in a moment
but the point of this slide is just to tell you
that the maximum accuracy
generally speaking
that we can get from gps measurements
horizontally
is about ten millimeters
which is just kind of your xy coordinate
and then vertically is about twelve millimeters
which is essentially just telling you your elevation
or your z coordinate
so generally speaking
highest accuracy
we can get about ten to twenty millimeters
using gps technologies
that we have available to us today
but that's really good you know
that's zero point one to zero point two centimeters

that's super
super good accuracy
considering we're just using these
you know flying objects through the sky
in order to determine our position
now there's lots of sources of error with gps
there's lots of reasons
why you might not get a very accurate gps measurement
one of them is that radio waves
can't pass through some objects
things like buildings
trees mountains
radio waves can bounce
off of some of these objects sometimes
and then still kind of reach your receiver
and this results in something called multi path errors
where the actual time it's taking
to get to the receiver
doesn't reflect how far away that satellite actually is
that's called a multi path error
it's generated by obstructions
landmarks buildings
big mountains trees
those kinds of things
generally speaking
if you're using your gps
you want to get the best measurement possible
you want to try and remain in the open
try and avoid buildings tall trees
you wanna try and take several measurements
through time
over and over and over again
and average them
that's gonna give you your most accurate measurement
and then you wanna also be patient
sometimes when you pop open your phone it doesn't
can't figure out exactly where you are right away
that's typically just because the receiver is
looking for some satellites that can send in a signal
and as it's looking for those satellites
it's slowly connecting to them
and getting a better and better accuracy
in terms of determining your position

one of the ways that we measure how accurate
your satellite based position is
is with something called dilution of position or dopp
it's a measure of the geometry
of the visible gps constellations
so you can definitely expect a midterm question
or final question about dilution of precision
and essentially what it is
is a measure of the geometry of the visible satellites
so this is a good dilution of precision
this is an example of a good one
because all of the satellites
are spread out over the horizon
they're not all bunched together
this should be an example
of a poor dilution of precision
because all of the satellites are very very
very close together
we get more accurate gps measurements
when our satellites
that we're using to determine our position
are spread out more throughout the horizon
or throughout the sky
so again that might look like this
you got here a good dilution of precision
your satellites are
in one sense
spread out horizontally
they're not too close together horizontally
they're also kind of spread out vertically
you got some that are further away from the surface
of the earth than the others
that will give you a really nice dilution of precision
this is an example of again
a bad dilution of precision
all these satellites are kind of bunched together
both horizontally and vertically
there's not a lot of diversity
in terms of where they're located
above your position on the earth
if you were to be standing right here
so that's an example of a bad dilution of precision
generally speaking

you can break down the dilution of precision
into a couple different measurements
you have your position dilution of precision
which is just
you're you adding
your vertical and horizontal dilution of precision
and the vertical and horizontal dilution of precision
is kind of what i just mentioned
which is that a horizontal dilution of precision
measures horizontally
how far the satellites are spread out
and your vertical dilution of precision measures
vertically how far your satellites are spread out
so you can see here
these two satellites vertically
are kind of at the same point
these two satellites
vertically are kind of at the same point
whereas this one
there's one lower
bit higher bit higher bit higher
so that's a nice vertical dilution of precision
then you got your time dilution of precision
your time dilution of precision is just an estimate of
clock errors associated with the satellites
or maybe with the ephemeris
and then add all of that together
and you get an overall dilution of precision
which gives you
a measurement of the accuracy of your positioning
generally speaking
how dilution of precision values work
and you'll look at these
and one of the assignments coming up
a lower dilution of precision
so a lower value is a good dilution of precision
so when you look at dilution of precision
the higher the value is
the more it's diluting your precision i e
the less accurate your value is
so a very good dilution of precision
is a smaller number
now in general

to get a good dilution of precision
when you're going out and making measurements
you want to have high quality mission planning
which just means that before you go out and measure
your gps locations
you want to ensure that you're going out at a time
and a point
where there's going to be lots of satellites
scattered all throughout the sky
that are going to give you a nice accuracy
and so that's where mission planning comes in
you can use websites like this
to look at where satellites are
estimated to be over
your point or where you're going out
approximately to measure gps points
and then you can look at a graph like this and say okay
throughout the day at a given point
when is the dilution of precision going to be the best
when is it going to be the worst
and you'll do this
like i said
and one of the assignments coming up
in general if we look at
all the different kinds of errors that we can get
we could have gps receiver errors
which just means that
maybe we have a lower quality receiver
our phone for example
is a much lower quality receiver
than a trimble
a really expensive gps receiver
we might look at clock errors
associated with either the satellite or our phone
we might look at ephemeris errors
tropospheric delays
ionospheric delays
these are both just different parts of the atmosphere
that result in
potential refraction
of the radio signals
that are being transmitted from the satellites
to your phone

and might actually slow down the signals
or force them to go in a different direction
that can cause some errors as well
and then multi path errors
which we already talked about
if the radio waves are coming down
and bouncing off of buildings and things like that
the biggest issue generally
or the largest source of error
is coming from the ionosphere
and the ionosphere is this part of the atmosphere
that ionosizes
which just means
that all of the molecules there become ions
which means that
there's all of these floating electrons
that are in this part of the atmosphere
it's often influenced based off
how much solar radiation is coming from the sun
which just means that it can change on a daily basis
during kind of high noon or the middle of the day
when there's lots of sunlight coming from the sun
the ionosphere effect is very
very strong
because there's tons of these free electrons
floating around in that part of the atmosphere
whereas at night
it's not so much of an issue
because there isn't this solar radiation
coming down
and interacting with the ionosphere
to create all these electrons
that influence the radio waves
being transmitted from the satellites
coming down to your receiver
it's a lot of words i know
it's not really that important
in terms of midterm
final exam purposes
all i expect you to know
are the different kinds of errors
that you can get with a gps position
and which one has the largest impact

which you can see right from this graph
is the ionosphere
okay any questions about where we're at so far
about gps errors
anything like that
ok sweet
now the next couple of things i'm going to talk about
are the different ways that we have come up with
in order to improve standard gps measurements
or standard gps positioning services
one of them is called differential correction
or differential gnss
or differential gps
and it's used to increase the accuracy of gps location
by taking a base station with a known location
and using that to compute corrections
for wherever you're measuring location
that's maybe somewhere nearby
so this kind of
as an example here
if i am the receiver here
i'm looking to find my position
and i have connected to a bunch of satellites
in order to find my position
but i have a reference station
which just means that i have a
some sort of nearby building
or in this case
they have a little rover here
some sort of other receiver
that's gone ahead and established its position
then i can say okay
based off of knowing exactly where this is
i can actually correct
the measurements that i'm getting
and get an even more accurate sense of my location
on the other hand
i'll go over that again
i went over it quick
but that's just because
i'm going to go over it again here in a second
we also have rtk
or real time kinematic gps

rtk is just a type of differential gps
it's kind of a newer version
it works a bit more accurately
and it works a bit more faster
it's called real time kinematic
because it provides corrections in near real time
but it works the exact same way
you have your rover or your receiver here
you are trying to determine your position
you have this other
rover that has a known position as well
you use that to then transmit corrections
to wherever you are trying to get a position for
so if you compare them
differential gps
it still uses satellites
just like any gnss
it uses a base station with a known location
oftentimes in the case of differential gps
this is one of the key differences
it uses a permanent location
so something like what was mentioned in the video
we just watched
it said that
you know there's different differential gps systems
that are set up kind of across the world
that's often true
sometimes it's like a building or something somewhere
that has a very well known
and established accurate position
and it's able to transmit corrections
to wherever your measuring position
based off its well known position
relatively speaking
differential gps provides less correctional information
than real time kinematic gps
and it's transmitted a little bit slower
it can be transmitted in near real time sometimes
but often it requires post processing
which just means that you go out there
you measure your point
in the field
or wherever you're working

and then you go home to your office
later you pop that point into your computer
you download the corrections for that date and time
from the differential gps system
and you're able to calculate a nice
even more accurate position
using differential gps
on the other hand
we have this
rtk gps also uses satellites
just like any other gps or gnss
it has again
a base station with a known location
just like differential gps
generally speaking
though the key difference here is that rtk
uses a mobile station
which just means that if you're going out in the field
typically you take this extra
rover with you
set it up close to where you're going out
to measure a bunch of points
or a bunch of positions
and you let it establish a nice
accurate position
for exactly where it is
and then you go and walk around
so you're actually still pretty close
to where that rover is
and it will transmit
real time corrections
to exactly where you're measuring
it also just generally
transmits more correctional information
than differential gps
it just has a newer algorithm
and again it generally transmits it a bit faster
typically always
in real time
which just means right away
instantaneously
so differential gps generally looks like this
where we have our rover

we're going out to determine positions
using this tool right here
using this instrument
we're going out getting information from satellites
determining our position
but then there's this base station
often a building with differential gps
something permanent that has a known location
and it's transmitting correctional information to us
so that we get an even more accurate sense of position
or more accurate measurement
real time or rtk
on the other hand
you typically have
you're going out with your rover
this is where you're measuring gps
where you're moving around
getting a sense of measurements from positioning
and you have brought out with you
some sort of base station that you set up
you leave it in one place
you let it measure an accurate position
for exactly where it is
and then you leave it
you walk around with your receiver
and then in real time
that rover that you've set up
is transmitting correctional information to you
as you are collecting or measuring points using gps
using whatever gnss satellites
are available to you yeah
no using the same
same exact satellite
same number of satellites yeah
yeah nothing's different about the use of satellites
between the two
oh you're asking the number of satellites
so generally speaking
just because rtk is a more accurate
it generally is a little bit more accurate
so it might use an extra satellite
just to have an extra verified position
but i don't think it honestly matters too much

i wouldn't ask you about it anyways
yeah so basically we have like google maps
generally speaking today
most civilian
gps systems do use some form of differential gps
yeah but none of them really use rtk gps
because that would involve going out to exactly
wherever you're doing your measurements
and setting up your own rover
setting up your own kind of base station
does that make sense yeah okay
any other questions about the two
just about how they work in general
no
ok sweet
so assisted gps
there was a question about this kind of earlier
about using cellular
networks and wi fi and things like that
to get better gps measurements
that's kind of what this is about
so assisted gps or agps
is when a receiver uses
cellular networks to essentially
establish a more accurate or quicker position
so agps typically just improves startup performance
by using cellular network towers
that pass information about the location
of relevant satellites to the receiver
so in general
agps or assisted gps
is just the use of a bunch of
a network of cellular towers
that are able to just quickly send information
to your phone or whatever gps receiver
about satellites that might be nearby in orbit
that you can connect to
so often times
you might notice
i think someone asked about it
but if you have your cellular data on
for example
or you have

you have uh just your
your network
your cellular network on
doesn't have to be data
but you'll get a better
a quicker measurement of your gps location
then say if you are trying to determine
your location on your phone in airplane mode
you can actually determine the location on your phone
in airplane mode
because gps
your positioning isn't using cellular networks
it's using global navigation satellite systems
which are completely
completely different
but if you turn your network on
then it can use those network towers
to transmit extra information about where
satellites are so that you can connect to those quicker
and get a quicker measurement or quicker location
does that answer the question that was earlier
yeah kind of
so that's what assisted gps is
it uses cellular networks
dead reckoning is another form of
kind of correctional gps
and it just uses
it calculates your position
by using a previously determined position
and an estimating based off of if you're moving
what speed you're moving at
what direction you're moving at
where exactly you might be
so you'll notice sometimes
if you are using gps in your car
and you're about to go through a tunnel
as soon as you're inside the tunnel
it kind of has a much tougher time
figuring out exactly where you are
because it's maybe not connected
to those satellites anymore
but it'll still move along
it'll still kind of

roughly tell you where you are inside the tunnel
and that's because it's using dead reckoning
so it's just kind of calculating okay
based off of where you were when you entered the tunnel
or right before you entered the tunnel
the speed you were traveling at
and the direction you were traveling at
it'll continue to estimate where you are
when you're inside that tunnel
does that make sense
see the last kind of correctional information
that we talk about is indoor positioning systems
and we don't talk about them very much
because they are still relatively new
but indoor positioning systems use things
like wi fi or bluetooth
typically to send signals out to your phone
in order to detect where they are
kind of an enclosed indoor space
again not super
super commonly used
but something that's on the forefront
in terms of being able to better
measure and determine your position indoors
because generally speaking
it's really hard to determine your position indoors
because it's hard to get information from satellites
it's hard for those satellites
to transmit their signals to your receiver
if you're standing inside
so that's where these
indoor positioning systems come in
typically based off of wi fi or things like bluetooth
and often how they work
again like i said is just
your phone is kind of like a
an rfid if you will
it's it's it's being able
it can be detected by sensors that are set up
often bluetooth sensors
that are set up around a building
and are just transmitting signals outwards
throughout the whole building

it can detect where your phone is
and then kind of use
determine your location in the building based off that
does that make sense
any questions about that
it's a bit complicated
i don't honestly know that much about it yeah
pardon me
it wouldn't
you mean the
so in this case
the indoor positioning systems
the signals that i'm talking about
are coming from someone going in and setting up
these little devices inside the building
that are transmitting their own signals
exactly it's completely
separate from satellites sending their information
so you'd go in
you'd have someone come in
they would set up these devices all over the building
and then they would program those devices
to know exactly where they are
so if those devices know exactly where they are
and then they transmit out these bluetooth signals
they can detect where your phone is
and then based off knowing where they are
trying to determine where you are in the building
so completely separate
from global navigation satellite systems yeah
any other questions
ok i got some
oh last slide here
generally speaking
there's a wide
wide wide variety of applications
for gps and satellite navigation systems
we obviously use them in transportation and navigation
whether it's on your bike
in your car in a plane
we use them for lots of mapping
and surveying applications
we use them in agriculture aviation

like i mentioned
environmental applications
oftentimes with public safety and disaster relief
as well as in recreation and wildlife research
so it's a really
really fundamental component
to a lot of different kinds of industry
a lot of different kinds of research
and now hopefully
you know kind of how it works
so the last thing i have is a couple of questions
for you to practice
either with a neighbor
by yourself
so i'm going to
like i always do
give you about five minutes
to practice these questions with someone
if you want to head out now
you're welcome to do so
liana is going to be here in about five minutes
so if you have questions about assignment one
you're welcome to stay and ask her
she'll be here in literally a couple minutes
but if you don't want to do that
and you don't want to go over the answers to these
then you are welcome to head out
and i'll see you guys next week
hey we sort of lose dna
like interchangeably with gps right
well i use the terms interchangeably
because in practice they're often used interchangeably
but what i tried to do at the start of lecture
was lay out how they are different
so they are technically different things
but we typically just in north america
refer to gnss as gps
because it's just the most well known gnss system
have a preference for like in the midterm or the final
no you can generally use them interchangeably
unless i am asking you specifically
what the difference is between them yeah
hey hi i'm so confused about ips

like you mentioned how bluetooth is
and wi fi is basically
someone goes into the room and sets up a system
but with bluetooth how can you set up a system
oh for example
if i got my phone and i have bluetooth connect
but i can airdrop something from my mac to my iphone
uh huh i'm very confused there
so how it work is there would be a bunch of
sensors devices
that are set up all throughout a building
and that transmit a bluetooth signal out from them
to then try and locate something like your phone
um but if i'm not in the building
i can still use bluetooth though
sure but if you're not in the building
then you don't have sensors
that are specifically designed to transmit out signals
in order to find your location
right like if you're not in a building
you're not using indoor positioning systems
if you're not in a building you're using gps or gnss
but i can still use bluetooth if i'm outside of them
right but it's not being used for positioning services
right like you can
you can use bluetooth out
you can use bluetooth anywhere for different purposes
right but when you are sending
airdropping something from your laptop to your phone
your laptop isn't sending out bluetooth signals
in order to determine where your phone is
it's just sending out signals
in order to transfer something
from your phone to your laptop or vice versa
yeah so they're basically like
built to the signal station everywhere around us
so we can actually just use like
bluetooth to fly our location
i mean not in reality no
like i don't think
i don't think that this building
for example
has a bunch of bluetooth

you know sensors that are set up all around
that's kind of
when i was talking about indoor positioning systems
that's something that you know
can be installed in a building and has been used before
but it's not something standard
it's not something that you would commonly see
right yeah yeah no problem
hey something real quick
yeah so gss is like a big branch
and the gps is one of the
exactly it's specifically the american gss system
and gss means global navigation satellite
systems satellite
and can you quickly
like if you have time
yep no worries
quickly go over um
the difference between the rt
yeah the rtk and the differential gps
yeah yeah so the
so the key difference is they both have the
these second diagrams are a bit better
i think they both have a base station
that has a known location associated with it
the main differences are a differential gps
the base station is typically permanent
it's a building or something like that
is this permanent
where is rtk
typically the base station is mobile
so you can move it to
wherever you're going out to take your measurements
and then the differential gps
or i should say maybe the rtk gps
sends more correctional information
so it's just a newer algorithm
and it transmits faster than differential gps
how come how come this has more accuracy than
if this is mobile
cause i feel like this is permanent
so it should be like more accurate
right that's

that's a good
i can understand why you would think that
the main difference is the correctional
information you'd be sending from a base station in rtk
is gonna be much more localized
because you're taking it to wherever
you're doing your measurements
so you're never getting that far away from it
whereas differential gps
you might have a base station that
say in vancouver
but you might be doing measurements up in
you know northern bc
make sense and the other
the other reason it's a bit more accurate
is just cause it has a newer algorithm
a newer it just
it just is better
essentially
and then you have differential gns
so maybe i was thinking
this is gps
yeah so i use differential gps
i use the terms gnss
gps kind of
more or less interchangeably throughout lecture
because that's how the terms are often used in practice
but i do and that's fine
for you to use the terms interchangeably the only
setting in a midterm or final
where you shouldn't use them interchangeably
as if i'm specifically asking you which i probably will
what the difference between gnss and gps is okay right
other than that you could like interchange totally
yeah yeah thank you
yeah no problem
we actually got one more
yeah the gnxs
yeah ameris
and yeah yeah
so for ameris can we understand americ like
like kind of schedule
for a kind of calendar for the satellite

the almanac or the ephemeris
the almanac
yeah almanac
the almanac
a schedule kind of
i mean the ephemeris has the
more detailed information about orbital parameters
so it really has the more important information
about exactly where a specific satellite is
the almanac
all you need to
the best way to understand an almanac
is just providing course
general information
about the health of a given satellite
and then allows the receiver
to connect to other satellites quicker
that's really the fundamental use of it
so basically these two are using in tandem
and a humorous
is basically the only thing that we need
and almanac speeds up the operator
the time in which no
it basically speeds up the operation of the ephemeris
exactly oh yeah
doesn't doesn't literally speed up the operation
of the ephemeris
but it speeds up the ability
to connect to other satellites
in order to download their ephemeris
if that makes sense
is the information like
share between satellite
generally speaking
yes and no it
the information sharing between satellites
is when satellites transmit information
down to the ground stations
and then the ground stations analyze
all the information
that they're getting
from different satellites
and then maybe transmit info

or commands back to the satellites
but the satellites aren't typically
going from satellite to satellites
sure thank you so much
yeah and a problem
does that make sense yeah
so basically
it's indirect
it speeds up the operation of the fimmers
but it's because
the almanac allows you to find other satellites nearby
and this in turn
increases the efficiency
at which the fimmers operates
yes but you're talking about the ephemeris as if it's
i don't know
as if it's a tool
the ephemeris is just a set of information
very similar to the almanac
and that is just a set of information
the ephemeris isn't actually doing
it's not performing the calculations in order to find
the location of way more
so can we understand that
amaris is actually more detailed than elm
yeah the fmris is more detailed than the almanac
and the ephemeris provides
specifically
what the ephemeris provides that's important
is orbital parameters
so it tells you exactly what orbit that satellite is in
which in turn
tells you exactly where that satellite is in the sky
and then when you use the pseudo random number code
to determine how far that satellite is from you
you can then
based off that
determine an absolute position
because you know exactly where that satellite is
in the sky because you've downloaded its ephemeris
okay does that make more sense
yeah yeah it makes great sense
and the ephemeris is like

the information can be gained through the gnss
so like the gns says
gets both of these pieces of information
well so your receiver does
your receiver
cause the gnss is
is an overarching term for the control segment
the user segment
and the space segment
right so the gnss is the whole system as a whole
your user segment is your receiver
your space segment is the satellites
and your control segment is
those control stations on the ground
that are monitoring their performance
essentially
does that make sense
we can talk again in a sec if you like
i'm going to go over these questions
yeah no problem
okay guys we're going to go
i'm going to go over these questions here
so
what side of the woodward building are we on here
any of you guys know like cardinal direction
east northwest
north side around the north side
leanna your ta is lost right now somewhere
somewhere in this building
she can't find us
she just said where the hell is this room
so i'm gonna say north side of the building
and hope that she finds it
i said yeah
that's why i told her that
she knows it's room too
uh but i'm guessing she's never been
this is a funny thing about
i don't know
grad students i guess
i went to i did my undergrad here
so i have a slightly better sense of where things are
she's doing grad school here

and she's in the forestry building
she's literally probably never
been in any other building ever
so this is probably kind of overwhelming for her
hopefully she finds it
ok so how does a receiver find your position
we can break that into two questions
what is the method or principle used
what's the mathematical
she said everything is labeled with gs
what does that mean
are those like
on the same level as these big lecture halls
they're in the basement
oh oh
gs are this
gs are this floor so they're just like the small rooms
okay
oh you made it nice
okay let's go over these real quick
so what is first of all to find your position
for a receiver to find your position
first of all
what is the method or principle used
what's the mathematical principle that we talked about
that satellites and your receiver
use in order to find your position
trilateration exactly
and then what are the steps required
in order to find your location
what do you download and then what's calculated
yeah yeah yeah
yeah the date and time yeah
and then what and then what do we do
oh we calculate things
yeah we calculate the change in time
yeah and then we determine
the range based on that change in time
and then we calculate our location
nice good job
what is the accuracy of gnss positioning
that's kind of a trick question
i wouldn't actually ask you that

loose or not specific of a question in an exam setting
because you can really break it into two kind of
things that we've covered
what is generally speaking
the accuracy of dps on your phone
yeah about three to fifteen meters
and what's about the maximum accuracy that we can get
with a gps device
yeah
yeah
exactly about ten to twenty millimeters perfect
what does dop stand for yeah
and what does it measure
that's okay
exactly it's a measure of the geometry
of the satellites
that you're using to determine your position
a good dilution of precision is when
all of the satellites are spread out across the sky
a poor dilution of precision is when they're all really
really close together ok what
can someone try to explain to me what rtk gps is
please
don't make me
don't make me beg
come on yeah
yeah
yeah
exactly yeah exactly
so it's a type of differential gps
uses a mobile base station
to correct your positional information in real time
produces or uses a newer
better algorithm than differential gps
and it transmits correctional information faster
and uses like we said that mobile rover
okay awesome
do you have slides or anything you want to go over
you just okay
do you want to go over them or
you're just doing q and a
yeah i'm gonna go over some tips and then
okay sounds good

sorry i forgot my flash drive again that's okay
what the hell is this building oh my god
yeah sorry you got lost
i was asking people
like how to describe to you where it is
if you imagine
your grandmother is trying to find this classroom
okay
one two seven
modules sorry it's in assignments i didn't
i think lecture six is labeled lecture five also
so i didn't know if that was today's
so it's here
yeah in these ones
one more yeah that one this one
okay there you go
there's your mic
all right hi guys
sorry i'm late
if you're heading out
please do so swiftly
just so you're not distracting anyone that's staying
please thank you cool
thanks for trying to help me get here
i appreciate that
i have terrible sense of direction for geographer
so uh some clarifications to assignment one
and these are based off of questions
that i've been getting in the zoom office hours
um so we're gonna go over that
and then i'll open it up for just like
general q and a
and then if you wanna ask like
more specific questions after
you can just come down and ask me some questions
so what am i doing here
i'm just scrolling
okay first of all
please make sure that you're using either
like a desktop computer or a laptop for like
either the chrome browser or the google earth software
if you're using an ipad
it doesn't show that camera view

like number
which is needed for one of the questions
so like that's something that people
have been running into some problems with
if you don't have access to
a desktop computer or a laptop
the library has some
we really recommend going to the library
if not if you really can't get there
come see me
come to office hours and like
we'll figure something out
i can let you drive
i can share my screen and let you like
you know work that on my computer
but you know
we can't just be like
here's the answer anyway
um remember that it's really
really good practice to try to complete the assignment
if you're not already trying to complete the assignment
in canvas like alongside with the quiz
it's really good practice to have the quiz open
cause sometimes there will be multiple choice answers
or like a format to the answer that you wouldn't know
if you're just doing the assignment
um so just like
if you're confused about something
make sure you can check the
that you're checking the canvas quiz at the same time
you can enter the quiz and leave the quiz at any point
and it'll save everything
but if you submit it
that's your submission
so like you can start the quiz
leave the quiz
and your answers will be saved
you can come back to the quiz
but if you submit the quiz
that's it um
so like for this assignment
just let us know
if that's something you accidentally did and like

we'll talk about it
but just remember that
and then just like a general
to pay attention to the directions in the assignment
so some of the questions we've been getting
for question five
which is when the camera is tilted like this
which of the following
now appears in much greater detail
and the thing we're looking for is
that much greater detail
because you can
kind of see some of these answers if you're
i mean closer up
we're assuming that you're answering this question
right after going through the steps to get here
so like you should have this view
that's up on the screen right now
sort of like this
if you have to zoom out a little bit
to see all of those things
and you're not just
like you know
it's really zoomed in
vancouver there should be one object that is
much more obvious than the others in this three d view
so make sure that you're in three d view and kind of
have something similar to what's on the screen
like that's what you're looking at
any questions about that
cool
for question eight which is
please take a screenshot from this path facing south
and upload it onto canvas
so on the assignment pdf
it has that blue line with the arrow pointing to it
and that's like the path that you should
drop your little person icon onto
and then like
you can use your compass to face south
and so you should be facing this down here
which in the assignment pdf
it describes as the buildings of the west end

if you end up like
over here or over here for your screenshot
it's fine it's okay
there's no like
one exact screenshot that we're looking for
and if you are
like five degrees off
then we're gonna take points off
this is a very
very flexible question
we're just looking for a screenshot
in the vicinity of lost lagoon in stanley park cool
cool question ten
what is the squamish name for sea wash rock
and remember this is the one where in the original tips
it said two names
we changed that from last year
so there's only one name
and that's in the tips pdf
which is on canvas under assignments
and also under your lecture five module
so there were a couple questions about
typing that into canvas
if you can't spell
there's a little symbol kind of letter
if you can't spell that on your own
just copy paste it from wikipedia
and that should be kosher
and then for question fourteen so this is
this is a really important one to pay attention to
so it says according to the camera view
in the lower right hand corner
how tall is this mountain
and the thing to pay attention to is camera view
and that is what is outlined in red in this part of the
in the lower right hand side near your little like
compass thing
your person guy that's
it's that camera view that you're looking at
for question fourteen
there's like another number over here
and that is not what we're looking for
for question fourteen

some people are writing this number
but we're looking for this
and it says camera view in the assignment pdf
i'm sorry i keep saying camera view
i just really want to clarify that
because that's been tripping people up
and also please note that this is not the number
we're looking for for question fourteen
this is just an example cool
this one is also really
really confusing
and this is my fault
and i tried to make this easier
and again it didn't work as well
now we're on the opposite side of the world
opposite side of the world
which of the land masses can you see from this view
select all of the ply on canvas
it's been changed so that it's edited where it says
zoom out to two thousand kilometers
some people are still only
so like when you type in the coordinates
it takes you to this random dot
in the middle of the pacific ocean
some people
even when they zoom out to two thousand kilometers
are still getting a random dot
in the middle of the pacific ocean
and like there's nothing
you can't see anything
that's fine
you're not doing anything wrong
just kind of like pan around a little bit
it's okay if you're not exactly two thousand kilometers
like the cameras
not exactly two thousand kilometers away
it's okay if you need to move your cursor
just what we're looking for is which of the four
or there's six answers listed on canvas
which of those four are closest to this dot
which is the coordinate that we tell you to put in
yeah that's right cool
i think i got lost somewhere

does that make sense
are there any questions about question fifteen
amazing
what is for question nineteen
what is the latitude of the arctic circle sign
in degree or arctic circle in degrees
orient the compass to north
and use the coordinates found on google earth so the
oh sorry it's been
it's six o'clock and i know you guys are tired too
twenty three says
to type in the arctic circle sign into google earth
this is where you're getting the location
of the arctic circle
you need to type in the arctic circle sign
to get the coordinates for the arctic circle
and when you do that
try to keep your mouse in the middle of the compass
so you're not getting a slightly different answer
than what your peers are getting
if it's like
point three degrees off
or it's not really
really like small number
like say it's night
someone's getting sixty six forty eighteen
and you're getting sixty six forty nineteen
that's okay
there's like a little
you know plus or minus thing in canvas
that is fine
as that's a really
really infinitesimal
like amount of distance in reality
um and you should be writing the coordinates
like this example
again this is just an example
and not the real answer that we're looking for
it'll say like sixty six degree sign
twenty seven apostrophe
thirty four
double apostrophe
which is actually feet

and wait no
minutes and degrees
minutes seconds
thank you professor
um yeah and this is on canvas
so when you like
open canvas
it has like
blank degree
blank minute
blank second
hello
sorry there's like north and
don't put north
we just want the numbers for this
and if you're doing question twenty and you decide
hey if i want to go to the opposite side of the world
to antarctica
maybe i'll put a negative sign in front of it
if you want to put a negative sign in front of
a coordinate point
just put it in front of the degree sign
just sixty six
so if that's how you decide
you want to say now we're in the southern hemisphere
it's just in front of sixty six
does that make sense hello
if you want to get from the same form of cancer
and like i get a complimentary little drop of cancer
you would just change the sign on the first right
it's very similar to what you do
in quest to get to this
coordinate point in question fifteen
where we go from mount logan
down to this coordinate point
it's very similar to that concept cool hi
yes the dominion building there sorry
so i clicked on it
and there's a height that school provides
and i click on wikipedia and then an article there's a
in the details there's a height
so there's three different types
there are two heights listed in wikipedia

either of those two is fine
because wikipedia is super weird for having two heights
you can't have that
but no one decided to tell wikipedia that
so there's two answers
which one is that
i forget what number that is
but there's two answers to the dominion building one
and either one you put in will be fine
but yeah don't use like
the number in google earth itself
use the wikipedia one cool yeah
but i don't remember exactly which ones
but some of them don't exactly special
we only want the number
yeah it's easier if you don't put
like a minute or meters or degree sign
and usually we'll have like
well sometimes with meters we don't have it
but like for the degrees we'll have that but it's
better to err on the side of just putting the numbers
yep i think
yeah i have one more
so that's it for what i'm covering for
questions but please just remember again
you can exit the canvas quiz and come back
but once you've submitted
you've submitted
please remember to check the discussion board before
sending an email
or coming to office hours about something
just because someone else might have had the question
that you're asking
and it might just be right there
and i do just want to point out
for this assignment and for future assignments
it's not really the point of office hours
to come and check every single answer with us
we can't tell you if you're right exactly
we can only guide you towards the right answer
if you're confused
so if you come to office hours and asking
is this right

is this right
it's not quite what we're looking for
because we want you to understand how to do this
on your own
so thank you so much
please go eat dinner or something
thanks guys
you just come out yeah
oh
fuck sorry all right everyone take a seat
i'm just gonna give it to evan
he's just gonna give you some reminders for the week
i'm gonna give it to tristan quickly
to introduce your next assignment
and then we will get going for the day
sweet all right
hi everyone
pretty straightforward stuff for me again this week
this thursday you have blog post
do blog post two
and assignment two
do thursday at eleven fifty nine pm
and then next week there's blog post three
that's february ninth
the midterms coming up
the week after that
i'll have information on the midterm
and a whole slide deck
with all the format and everything
next week we can go over it then
if you're concerned you can email me in advance
i'll give you all that information via text
other than that
tristan's got office hours
they're listed up here
these are also online in the zoom section
but other than that
i'm going to hand it off to tristan
and he's going to talk a little bit about
assignment two
i'm just saying he'll contact you via text
he won't do that
i will not text you

yeah email me
no you don't need it
hey everyone just a few
brief introductory notes about assignment two
so on the canvas page there's a little
introductory video
and it walks you through all the different websites
that you are going to be using for this assignment
so it's pretty simple
the websites are mainly
they're used to compare different map projections
as a way to explore the different compromises
that you have to make by using different projections
and there's another website that lets you compare
distance measurements
so rum lines versus great circle distance
but all that is explained in this introductory video
yeah so my office hours are posted
they're here in the zoom tab in canvas
the first one is tomorrow at ten a m
yeah so for questions
you can use the assignment to discussion board
i'm gonna be checking that every day
or you can send me an email
i'll get back to you within twenty four hours
but it's probably sooner
i'm gonna try to check that at least a few times a day
okay good luck with you simon
anyone got any questions for tristan
the start of the assignment
no yeah
no nothing examinable from a science
just like your kind
it'll be released with the marks for assignment one
which usually take around two weeks
give or take a little bit
so somewhere around there
yeah i'm almost done assignment
but i just had a like
there's somewhere
it's like is there any distortion shape or size of this
and like when you look at the map
it's like only very very subtle

so i don't know how like
specific you want us to get with
like if there's a slight deviation
that is like not preserving the shape hmm um
a good way is to look at the arcgas website
which gives you the official
like it gives you
the technical properties of each map projection
and it gives you
it tells you which parameters are distorted or not
but if you want to email me the question
i can give you a more specific answer to your question
as well yeah
yeah for sure
okay thanks yep
any other questions
no cap awesome thanks man
all right
so we have
this lecture
i actually forget
let me take a look real quick
we have this lecture
one more lecture
two more lectures after today
and then that will be the last lecture
that's included on the midterm
so this is the third
last lecture that's included on the midterm
and then we'll do
one lecture that won't be included on the midterm
and then we'll do a review lecture
and then you'll have your midterm
and then we will get into post midterm content
but today we are talking about
the history of the earth from space
and canada's role
first three
of observing there
i was gonna say the history of the earth from space
that sounds nearly uh
so we're talking about the history of earth observation
so it's a little bit again

more history
similar to what we've talked to
talked about over the past kind of
couple of weeks
couple of lectures
but today kind of focusing a little bit more on
specifically
earth observation
different earth observing systems
and a little bit of canada's role specifically
in earth observation
and some of the
earth observation systems that canada has
that are analyzing data
collecting data
etc etc etc
so today we're going to talk about
history of earth observation
we're going to talk about four
major earth observing systems in space
the four that we talk about
i'll mention this again when we get there
but we'll talk about them in a lot more detail
after the midterm
so this kind of introduction to
the major earth observing systems
landsap modus
icesat and worldview
it's kind of just to introduce you guys
familiarize you guys
with those earth observation systems
and then we'll talk about them
and their applications a lot more post midterm
i'll make it clear as i talk
what it is that you need to know for the midterm
and then we'll talk kind of lastly about
canada's contributions to earth observation from space
and some of the key roles that canada has played
in those systems
starting off
we're talking about earth observation from space
we're talking about essentially
the first cameras that were launched into space

to take photos of the earth
now initially
these were just cameras fixed to unmanned rockets
so these rockets that would just launch into space
kind of orbit the earth a little bit
take a couple photos
the first one
the first photo taken from space
was from an american owned v two rocket
and these images here show
new mexico and the gulf of california
it didn't get very high up you know
these rockets were still pretty new technologies
back in the late forties
the american v two rocket
was actually originally a german owned rocket
it turned out that after world war ii
the germans were much more advanced and
where they had gotten with their rocket technologies
than the soviet union
than america
so naturally they
after the world war two
america got their hands on some of these rockets
and started
experimenting around with their applications
started launching them into space etc
so this was the first rocket that was launched
that took images from space
so that's important
midterm question maybe
possibly who knows
probably will be
when was the first image taken from space
or what decade at least
was taken in the forties
specifically in nineteen forty six
this was specifically the very first image
taken of earth from space
again by that v two rocket
and you can see here
you can see maybe kind of
depict a little bit of the curvature of the earth

but again not much there in terms of detail
but very monumental in terms of
the history of earth observation from space
now following the successful launch of
rockets with a camera attached to them
systems specifically designed for cameras
were developed by the military
so the corona
the argon and the lanyard
programs were three of the first programs
that were designed
specifically to create these satellites
that their main application
was to go and take images of the earth from space
the corona one is probably the one that is most famous
and that we'll talk about the most
so this is an image from corona
of the pentagon
back in the sixties
and you know
back then there was no remote transmittance of data
or anything like that
these rockets would get launched into the sky
they'd kind of look like this
they'd get into probably approximately
a low earth orbit
and they take photos
they take several photos on a roll of film
once that film was full
it would be deployed from the rocket
it would get sent kind of back down to earth
separately from
what was now the satellite that was orbiting the earth
and there would be a parachute that would deploy
and it would just be kind of falling towards the earth
and then you know
in this case corona
all of these were american systems
so the americans would have jets or whatever
that would go fly around
grab these falling parcels
that had parachutes
they were just floating down to earth

they pick them up from the air
bring them back
and analyze them
now sometimes those parcels of film
would reach all the way to the ground
but there wasn't necessarily a good way to
you know find them
or to know where they fell on the ground
so sometimes
the american government would just put out a really
large reward
and say you know
we know it fell
fell somewhere in south america
or somewhere outside of our jurisdiction
will give someone a bunch of money
if they return it to us
yeah yeah yeah
the point is
the film had to be deployed from the satellite
come down to the earth
or to the atmosphere
and be floating in the air
and they had to go out
and manually retrieve the film themselves
in order to get those images
so that's how the first true satellite programs worked
now we've come a long way from
these first images of the earth that we got from space
this is a high resolution image from a
satellite called quickbird
which is one of the highest resolution satellite
systems that we have available to us today
for earth observation
you can obviously see in comparison to this
we get a ton
ton more detail
much higher spatial resolution
much clearer image etc etc
so what is an earth observing system
they are these essentially continuous data streams
that provide observations of the earth
they're for monitoring a wide variety of things

but mainly the major systems of the earth
including the atmosphere
the biosphere
the cryosphere
the lithosphere
whatever it is on the surface of the earth
these systems help us monitor it by collecting data
mostly about the reflectance properties
of those surfaces
we'll talk a bit more about what that means
in coming lectures
but essentially
these earth observing systems
just collect data about the earth from space
and part of their immense value
is just having a really nice
repeat stable
and consistent measurement
for different features of the earth
we can't track things like climate change
and the effects of climate change
if we don't have data
that kind of explains to us
what has happened in the past
what is currently happening
and then allows to predict
what might happen in the future
so my question to you is
we know that from what i just kind of mentioned
back to these
you know these first satellite programs
corona argon lanyard
these were all for military purposes
so they were never really for any
civilian or research purposes
what do you think the first
environmental application of images from space were
want you to brainstorm with someone
sitting close to you
brainstorm for a couple minutes
come back and then i want to hear you guys
ideas of what you think the first
specifically environmental application

of images from space might have been go ahead
all right any ideas
anyone want to tell me what they thought of yep
the hole in the ozone layer yeah good idea
deforestation maybe another good idea
anyone else yeah hurricanes
hurricanes yeah good idea
anyone else yeah sorry
sorry one more time
i don't know what you're saying
okay yeah yeah yeah
weather monitoring is that what you said okay
yeah yeah yeah
weather monitoring
anyone else have any ideas yeah
so i say it again
facilities
public terrain
yeah things like that
terrain facilities things like that yeah
forest fires maybe forest fires yeah
melting ice caps
melting ice caps yeah
all really good ideas
anyone else any ideas
yeah looking at crops
yeah good idea
all really good ideas
all things that today
there's been some application of earth observation data
for the first one
the first kind of
environmental application of images from space
was indeed weather
which i know somebody said
so the first earth observing systems in space
specifically for environmental applications
was weather satellites
so there was always this practical need
to monitor weather patterns
predict our weather
understand storms
so that you know

we could plan for crops
things like that
the first televised picture from space
was this image here
which is aboard the tyross weather satellite
from nineteen sixty
and again you can compare that to
something that we have today
a nice really detailed image from
in this case
the ghost series of satellites or the
geostationary operational environmental satellite
these are satellites that are in geostationary orbit
and so they provide this twenty four seven coverage
for a hemispherical side of the earth
which just means that
they provide twenty four seven coverage for the target
or the portion of the earth that they're looking at
i'm getting confused
between all my courses
we've talked about orbits
right yeah okay
so you guys remember what a geostationary orbit is
so it's orbiting at the kind of same point
it's always looking at the same point
on the surface of the earth
you can imagine
for something like weather
that's super
super useful
because that allows us to continuously track
weather through time
so that we can get really
really good estimates of weather forecasting
really good tracking of historical weather
something that's immensely valuable to us as a society
stitch kind of all these images
these high resolution images together
and we can get these really
really amazing hd videos
in this case of something like a hurricane
images that you know
back in the forties fifties

sixties we kind of
never really imagined we could get this far with
so we're not going to really talk that much about
the go series of satellites
which is the kind of series of satellites
i just mentioned
the weather satellites in general
throughout this course
we talk about four major earth observation programs
or four major satellite systems
one is modus
and i say in brackets
on board tara and aqua
because tara and aqua are kind of a brother
sister satellite
there are two different satellites
one's named tara
one's name aqua
that's the actual name of the satellite
both of them have a modest sensor on board
which is the exact same sensor
or camera if you will
but modus onboard the terra and aquas satellites
that's one satellite program
we're going to talk about a lot throughout this course
landsat is another one
that we're going to talk about
a lot throughout this course
and then worldview and icesat we'll talk about a bit
not in as quite much detail
as landsat and modus
but we will talk about them quite a bit
so modus is kind of our coarser resolution satellite
it takes images of the largest areas
landstats kind of a moderate resolution satellite
it takes pictures of regional areas
and then worldview
is kind of the highest resolution satellite system
that we'll talk about in this course
and it takes satellite images
with spatial resolutions
or pixel sizes
all the way down to thirty centimeters

which is really really
really small
extremely detailed images and data
and then lastly
we'll talk about icesat
which uses lidar
all i really expect you to know
for midterm purposes
about icesat
is what it images
and just that it uses lidar
we'll talk about what lidar is
in a lot more detail
later in the course
but i'm going to go kind of a brief overview
of each of those
now and again
kind of highlight
what i want you to know for the midterm
because we are going to talk about
each of these satellite systems
in much much more detail
following the midterm
how's my pace doing am i going too fast for anyone
thumbs up blank faces
sweet okay cool
so the first that we talk about is modus
which stands for moderate resolution
imaging spectrometer
it's on board the terra and aqua satellites
that's a really important distinction
that a lot of students get confused
so there's two satellites
terra and aqua
they're pretty much the exact same
they both have a modus sensor on board them
so if you say modus
you're really referring to both terra and aqua
which is fine
we'll mostly refer to that satellite system as modus
modus has two hundred and fifty to five hundred
meter pixels for land research
and a thousand meter pixels for ocean

and atmospheric research
and it has a one to two day return period
which just means that every one to two days
modus is able to take an image of the entire earth
and subsequently
of the same point on the surface of the earth
so every one to two days
modus is able to image
take an entire image of all of the earth
which also means that every one to two days
it will return back to the same spot
on the surface of the earth
to re image that same target or same area yeah
yeah so we'll talk about what a pixel is in further
or in coming lectures
so don't worry about it too much right now
not for the midterm at least
essentially all it is is every image that exists
including satellite images
are made up of pixels
which are just kind of little squares
that have some sort of color associated with them right
so if we zoomed into this image
i have up on the screen here
if we zoomed in and zoomed in and zoomed in
eventually you'd see pixels right
so with a satellite
when it is taking an image
of an area on the surface of the earth
it has a given pixel size
which means that it has a given
you know square area
where it's going to measure the amount of reflectance
of a certain type of electromagnetic radiation
for a certain area
in this case
for about two hundred and fifty to five hundred meters
or a thousand meters
we'll get into what that means in a lot more detail
in coming lectures
essentially what it is is
the smaller pixel size you get with a satellite image
the more detail you're able to make out in that image

so two hundred and fifty to five hundred meters
or a thousand meter
pixel size is pretty coarse
we don't get a ton of information
from the modest satellite in terms of detail
but what is really amazing about the modest data
is this one to two day return period
the ability to get an entire image
for all of the surface of the earth
every one to two days
so for midterm purposes
all i expect you to know for the modus system
is that it's on board the terra in aqua satellites
it collects daily imagery
and it represents a coarse scale of spatial information
so you're not going to get very zoomed in
high resolution high detail images of areas with modus
but what you do get is a very fine scale
temporal level of information
which just means that every one to two days
every single day you're able to get information or data
about a given point on the surface of the earth
which is really really really valuable in its own sense
any questions about modus yeah
is what depending on the orbit
yeah yeah so the return period
is partially dependent on the orbit
partially dependent on something called the swath width
again we will talk about that in a lot of detail
in coming lectures
so i'm not going to go into detail about it right now
but we'll go over it in about three or four lectures
ok so when you look at google earth
when you're looking at an image of the entire globe
generally speaking
these are put together by modest imagery
again because modus just
gives us that coarse level of spatial detail
allows us to get really nice images
of the entire surface of the earth
ok the next system that we talk about is lansat
lansat has a thirty meter pixel
so smaller than the two hundred and fifty meter

to one thousand meter pixel that we get with modus
that means that it allows us to get a little bit
relatively speaking
a little bit higher level of detail in those images
it has a sixteen day return period
as opposed to a one to two day return period
that modus has
and it's a series of about eight satellites
comprised of four different sensors and again
we'll talk a bit about what those different sensors are
and how they work in coming lectures
but what i want you to know for the midterm is
essentially that landsat is the longest collection
of satellite imagery that we have through time
so landsat one
the first landsat satellite
was launched in nineteen seventy two
and operated until nineteen seventy eight
and so that means that for landsat
we have imagery
we have data
dating all the way back to nineteen seventy two
so that's forty plus years of data that we have
all from the same satellite
now the most recent satellite was lance at nine
launched in twenty twenty one you'll see
what did i say here
i said it's a series of eight satellites
but you'll say
well what the heck chris
looks like there's nine
the reason is
the reason i say eight here
is because landsat six here
actually never made it to orbit
so it actually was never able to collect any data
it was launched
upon its launch it kind of failed
never made it to orbit
never collected any satellite imagery
so we actually have eight operate or eight
satellites from landsat that were able to give us data
starting from lands at one

then lands at two
three four five
and then lands at seven
eight and nine
so if i were to ask you what the most recent
landsat satellite is
you say landsat nine
the two most recent satellites are landsat eight
and landsat nine
and the first landsat satellite
landsat one
was launched in nineteen seventy two
so the data set for landsat goes back all the way
to nineteen seventy two
might see a midterm question on it
who knows okay
in terms of just kind of a summary
what i want you to remember about landsat
it's the oldest program
so it dates back to nineteen seventy two
the thematic mapper
which is kind of the modern era sensor
on the landsat satellites
that we use in most applications today
dates back to eighty two and eighty four
i don't expect you to remember that part
just know that the landsat satellite system or dataset
dates all the way back to nineteen seventy two
just that it's a moderate scale of spatial information
and that allows for a fine to moderate level
of temporal information
so thirty meter pixels
sixteen day return time
don't expect you to memorize those specific numbers
just that lancethat
is a moderate scale of spatial information
and gives us a fine to moderate level
of temporal information
okay any questions
about landsat
we always say in this course there's one thing
if you learn nothing from this course
you decide to just leave with one single thing

just remember what landsat is
this course is just kind of a landsat course
more or less
but we'll talk about lan sat a lot more in detail
we'll talk about its applications a lot more
but you know if you leave this course with one thing
remember what lan sat is
any questions yeah
what is the website
fine to moderate temporal info
so that just refers to how often
we get an image of the entire surface of the earth
with that satellite system
so sixteen days in this case
means that every sixteen days
we get an image of the entire surface of the earth
so fine to moderate temporal information
just means that
in terms of how frequent we can get information
or how frequent we can get data of a certain area
it's kind of fine to moderate
it's not quite coarse
it's not quite fine
an example of a data set that provides us a fine
temporal resolution
or a fine level of temporal information
would be the modest satellite
that gives us that one to two day return period
yeah well like
considering that it's revolving around the earth
when it gets like a full image of the earth
it's not all taken at the same time
correct yeah
it's like taken over the course of a day or
yeah yeah so it's taken it's taken
in this case
it's taken sixteen days
oh right right
okay yeah yeah okay
but for modest it only takes one to two days
all right so when you're on google earth then
because on google earth you can zoom all the way in
yeah very specific areas yeah

no once you're
once you with something like google earth
where you have satellite imagery
kind of at different scales
depending on how far you're zooming in
this is all of them
yeah essentially
so as you zoom in
they will kind of overlay finer and finer
spatial resolution satellite imagery
wow it's just like stitched all together
yeah yeah yeah yeah
so basically
so it's smaller than
so the more
what you tell information when you see it cracked
yeah yeah yeah
so if thirty five is a moderate
what's an example of
a fine spatial resolution
that would be something
again we will define those terms how we talk
we'll define the exact pixel size
of what classifies a low
moderate versus high resolution sensor
in the resolutions lecture
which is about three lectures from now
i think generally speaking
high resolution sensors are
anything that's lower than a meter
so in that case
that transitions nicely into this
which is the worldview constellation of satellites
this is by the worldview satellites
are owned by this company called digital globe
it's one of the largest and most well known
private satellite companies
which has launched
six high spatial resolution satellites
and these would kind of classify as your
high spatial resolution satellites
in some cases
they have pixels

with a size all the way down to thirty centimeters
so literally
you can see things
that are all the way down to about that big
just pretty crazy
note though
that with these high spatial resolution satellites
generally speaking they're all private
which just means that you all have to
you have to pay an exorbitant amount of money
for a license
in order to use any of the high spatial resolution data
you might get from worldview
or from other high resolution satellites
for landsat and modus
they are both us owned
and they are both generally speaking open source
which just means that any of the modus and landsat data
anybody can access completely for free
high resolution satellites like worldview
cost a lot of money
so finest scale spatial information
you can get from worldview
and it's private
these kind of summary slides
after i talk a little bit in detail
about each of these systems
these quick summary slides
are really all i want you to remember
about those satellites for the midterm purpose
so you know
that is this one
modus daily imagery
core scale of spatial information landsat
wait this one landsat oldest program
moderate scale spatial information
and then this one worldview
finest scale of spatial information private
anyone recognize this image
was that yeah yeah exactly
that's the suez canal when he got stuck
yeah fun stuff
yeah that's from world b

yeah yeah wait
so somebody like
paid to get the license to give that image to the world
yeah yeah someone
someone probably paid for this image
i mean in certain cases
you know worldview is a private company
so they kind of have access to their own data
they might have said oh this is like a really
you know crazy photo
it'll get us a bunch of public attention
yada yada yada
so they might have just posted it themselves
and just said
look at this haha
our data is awesome
kind of thing
regulations for them like
if the government needed their suspect or something
they'd be forced to
that's a great question
generally speaking
you know because we'll talk about
that's kind of a topic we'll cover later in the course
there aren't a ton of
with things like landsat and with modis
where they're kind of
moderate to coarser spatial resolution
there's international agreements whereby it's legal for
images to be taken all around the earth
and their open source
so anyone can access them
with these high resolution satellites
it becomes a bit more tricky
like you're saying
so there's lots of sensitive areas
where information isn't let out to the public
so company like worldview has to have
agreements with different governments etc
in order to kind of tackle that issue
generally speaking
if the say us government or whoever
wanted satellite imagery from worldview

they would just pay for it
and like i don't know which country worldview is from
but the states
so if the states was at war with a country
that was using worldview
because they stopped worldview from like
sensing that information
maybe i mean
i think it would be difficult probably
i would guess
but you know
it's one of those issues that's tough
because we're talking about
you know sensitive areas
that are in different political jurisdictions
but space itself and satellite imagery itself
is still relatively unregulated
despite kind of the really high
detail information and images you can get from it
so i'm honestly not sure off the top of my head
yeah auto office is relevant
wouldn't it just be a lot easier
if the us government just nationalized worldview and
like nasa bought it or something
yes that would be easier
i'm not sure exactly
because the big obstacle to that is
they don't want to pay millions and millions
and millions and millions and millions and millions of
dollars to buy this company
right that's the
that's still the issue there
because you know
that's still taxpayer money
and this is still a
you know private enterprise
so you know
technically yes
there is kind of this
you know thought to
that it's better off
the high the the
the thing to note about

i guess in general
the high spatial
resolution data
these images that give you really
really high amounts of detail
they're still really new
and so they don't necessarily
give you the highest quality level data
they give you you know
really high spatial information
but one of the nicest things about landsat and modus
is just how high quality those data sets are
and how high quality the imagery is
i've worked with some high spatial resolution
imagery before
and it's riddled with errors and noise
and all kinds of stuff
that lancead modes has just kind of perfected
and doesn't really have as much of an issue with
so it's not quite a perfect product yet
i guess is what i'm saying
yeah that's a part of it too
any other questions
sweet okay the last program that we'll talk about
is the icesap program
which just stands for ice
cloud and land elevation satellite
they really just decided to omit the l
from their acronym
guess icesat sounds better
it was originally designed for imaging ice
so they wanted to call it icesat
fair enough
it has a seventy meter footprint
so that's related to something called lidar
which again we haven't talked about yet
so i don't expect you to know what that means
but it essentially is this space borne
laser ranging system
which just means that
it travels over the surface of the earth
and it pulses down lasers and individual beams
and then those laser beams reflect off the surface

of the earth
and icesat is able to determine how far away
that target is from where the satellite is
and by doing that
can build up kind of three d topographical models
of what the surface of the earth looks like
we'll talk about lidar and how icesat works
and how lidar works in general
and much much
much more detail later in the course
so don't worry about it too much for now
all i want you to remember is that icesat uses lidar
that's it we'll talk about what latter is later
and for now
just know that icesat is mostly used to image
or to monitor ice clouds and measure elevation
okay
like i said
we've talked about
i kind of threw around a lot of terminology there
that might be new to you
that maybe we haven't talked about yet
for example
modus having different pixel sizes
just what pixels are in general
talked about icesat
the footprint that it has
talked about lidar again
just hold off on worrying about those topics too much
we're gonna talk about them in a lot more detail
in about three lectures
and then also just in a lot more detail
throughout the course
so hopefully i've made it pretty clear
what you need to know
about those systems for the midterm
it's not too much
just trying to introduce you to them
how much they cost
just know that modus and landstat is free
just know that worldview is expensive
it's not free
and then just kind of generally

the level of spatial and temporal information
you can get from each that's it
okay now we are going to transition to
canada's role in earth observing systems
so canada as a country is very large
it's very vast
has a lot of resources
contains about seven percent of the earth's renewable
fresh water
and so there is this underlying need to monitor
resources and to monitor them efficiently
repeatedly and constantly
to make sure that we are conserving them
managing them properly
managing them sustainably and responsibly
and things of that nature
so we will talk about four
kind of five different contributions
two earth observation from space
that canada has contributed
one being astronauts
so we'll talk about chris field and roberta bondar
and then we'll talk about radar sat
which is a radar satellite
that is owned and operated by canada
we'll talk about the canada arm
and we'll talk about earth cast
so chris hadfield
took over the international space station
in twenty twelve
he became the first canadian
to command the international space station
ever came back to canada or back from space
in twenty thirteen
and he took
as we learned
if you guys remember back to our introduction lecture
with that video from don pettit
one of an astronaut's jobs is to take photography
and take images from the international space station
of space of earth etc
so he took a ton of images
over forty five thousand while he was in space

he was the first canadian to walk in space
he actually in two thousand one
helped install the canada arm two
to the international space station
we'll talk about what the canada arm two was
in a second
there was also dr
roberta bondar
she was canada's first female astronaut
she was also the first neuroscientist
to be launched into space
her main research focus was the health sciences
so a lot of the research she did was studying
the effects of microgravity on the human body
which is essentially just the study of
when you're in space
when you're in the international space station
there obviously isn't much gravity going on
they call it microgravity
because technically there's a tiny little bit
because gravity is what's holding
the international space station in its orbit
close to earth
so they call it microgravity
but she was just studying the effects of microgravity
on the human body
then we have the canada arm one and canada arm two
which we can often see on our bills
canada arm one was a
canada arm was this robotic arm
that was put on space shuttles
so they started being put on space shuttles
in eighty one
and then canada arm two
was a second iteration of the first canada arm
and it was mounted permanently
directly on the international space station
so there were several canada arm ones
each of them
were kind of just attached to different space shuttles
there's only one canada arm two
and it was permanently mounted
on the international space station

so in nineteen sixty nine
canada had this agreement with nasa
to contribute to the space shuttle mission
and it just agreed to deliver and create
and kind of produce
these robotic arms
called the canada arm
the first one was delivered in nineteen eighty one
there were five canada arms
in this case i'm referring to just canada arm ones
so there were five canada armed ones
that were delivered
each costed around a hundred million dollars canadian
and the last canada armed one
left the space station in two thousand eleven
so literally how it worked was
these robotic arms
were just mounted onto a space shuttle
that space shuttle would be launched
from the surface of the earth
out to the international space station
it would dock on the international space station
and then they could use the robotic arm
the canada arm one
that was attached to the space shuttle
to kind of do maintenance or other things
on board or outside the international space station
but that just meant that every time the canada arm one
came to the international space station
it would have to leave
eventually that space shuttle that it was mounted to
would eventually leave
travel back to the surface of the earth
and thus so would the canada arm that was mounted to it
so eventually they said all right
well we want a canada arm that's permanently mounted
on the international space station
and that was canada arm two
so canada arm two was a second generation arm
mounted on the space station permanently
in two thousand one
so there were several canada armed ones
these were all fixed to different space shuttles

the last canada arm one
left the space station in twenty eleven
but there was only one canada arm two
and it's been permanently mounted
on the international space station since
two thousand one
makes sense
any questions
nae nae see okay
the next kind of contribution we're going to talk about
is radar sat
so radar sat is a
there's been a variety of radar sats launched
but it is this radar based satellite system
that is designed to measure and monitor ice winds
oil pollution
ships identifying
track disasters and monitor ecosystems
so radar sat one and two
were the first radar sats that were launched
the first operational civilian radar
satellite was launched in november nineteen ninety five
that was radar sat one
and then radar sat two was launched in december
of two thousand seven
it used a sea band radar
don't expect you to know what that is
we'll talk about it later in the course
but essentially
sea band just represents the specific wavelength sizes
of radio or microwaves that the radar sat was using
in order to image the earth
again don't worry about that
we'll talk about it in a lot more detail
it had kind of a moderate defined spatial resolution
of about eight to a hundred meters
and what's super valuable
what was probably the most valuable thing
about radar sat
was that it was able to see through clouds
so no matter what the weather conditions were
no matter if it was day or night
whatever it was

radar sat was always able to collect data
and collect images of the surface of the earth
so this is what a image of canada looks like
derived from radar sat
radar sat one
in this case
you can see kind of
the lot of the ice sheets and things like that
that are up near the arctic appear a lot brighter
as well as kind of a lot of the mountains
areas that have a lot of snow in that kind of thing
but that's what a radar sat image looks like
one of the really valuable things about radar sat
and actually what it was the first satellite to do
was create the best
map that we have had available to us of the antarctic
so this is what the antarctic looks like
and this was derived from radar set one
and it was the first instrument
that was able to go out and collect a kind of full
pretty detailed map of what antarctica looked like
and so that's kind of what it looks like there
okay this is a video just kind of about radar sat
some of its applications
in december two thousand seven
canada's earth observation satellite radar step two
was launched into space
capable of scanning the earth at all times
day or night
through any weather conditions
the satellite typically acquires
more than thirty thousand
these images are used by resource centers
private industries
and government departments and agencies
across the country and around the world
the information they provide
is used for vast relief applications
from helping monitor fishing activities on our coast
to increasing our agriculture's profitability
and sustainability
radar statue technology
can be used to monitor lands like this

along strategic transportation and energy corridors
giving our country
the needs to better protect critical infrastructures
because it delivers data in real time
its energies are also used to help our neighborhood
species on the ground following natural disasters
making radar statue an essential tool where bikes
communities and environments are at stake
radar sets you collect critical information
on remote or inaccessible areas
helping ships navigate safely through canadian waters
enabling northern communities to collect safer routes
for fishing and hunting expeditions
satellites renew solutions to earth challenges
okay so that was kind of about radar sat two
there's a third radar sat
that is going to be launched soon
or was already launched actually sorry
and it was called the radar stack constellation
so it is instead of one single satellite
it is three identical smaller satellites
that all together have
each one has a slightly finer resolution
finer spatial resolution than those
radar sat one and radar sat two satellites
but it's three identical satellites
they're all kind of staggered in orbit
so they allow us to take
more images at a greater frequency
and they were launched by spacex from california
in february of twenty nineteen
this is a video of just them getting launched
they love anything space they love the dramatic music
so i'm going to have to get used to that
so those are the satellites right there
you'll see each of them get detached
so there's the first one going right there
and then the second one
and the third one
so that's the radar stack constellation
it's three identical satellites
all kind of staggered around earth
the last application that we're going to talk about

is earthcast
so earthcast has launched a video camera
that operates on the international space station
it's the first high res hd video from space
and the camera allows
tracking of objects on the earth's surface
so things like cars boats
things that are moving
it's actually a vancouver based
canadian earth observation company
but it's now called earth daily
so the video that i have about it says earthcast
but it's called earth daily now
after they went bankrupt
that's what insolvency is just a fancy word for
they went bankrupt and someone bailed them out
but they're not called earth daily
but really really cool
kind of videos that they were able to collect
you know of the service of the earth
so you can see all the cars and stuff moving
there's some boats
what's the uh
anyone remember what's
what's the uh
what's the space movie name
the space movie with matthew mcconaughey
interstellar
every single video
has an interstellar kind of soundtrack
that's about like
space or about satellites or whatever it is
but it is it is really cool the
the data it's able to collect
so one of the things that it noted there
i don't know if you guys caught that
but it's only able to look over a certain area
and kind of monitor it
collect video data for about a minute
and that's because the space station is moving right so
this kind of shows how that works
so the space station
is kind of traveling over the surface of the earth

it's got its video camera
the earth cast
it's kind of pointed
down towards the surface of the earth
and it gets angled
so it'll kind of point at a target
boom down here
and then just consistently look at that target
for a little bit
and that's what it would actually look like
the angle that it was looking at
would kind of change as it flies over
so it would look kind of just like that
but you also probably noticed that in that last video
you saw things like cars and boats and whatnot
that were moving
but the image below kind of looked stable
didn't really look like the international space station
or the earthcast video camera
was kind of changing its angle at all
so how that works
essentially what earthcast does is it takes a bunch of
kind of referenced satellite imagery that's static
and then kind of superimposes it
below the video data that it's collecting
so that you know
things that are moving
like cars like boats
are really just superimposed
over a different satellite image that's static
that's still
so that you can get kind of a more realistic looking
image of or video of a certain area over about
i think it said over about sixty seconds or so
any questions about that
about those
so you'll definitely see a midterm question
that'll ask you something along the lines of
you know name one of the
canadian contributions to earth observation from space
that we talked about in class
so there's really five that we talked about
uh we talked about roberta

talked about chris
we talked about
not me astronaut chris
uh we talked about
uh earth cast
we talked about radar sat
and we talked about the canada arms
so one of those
you'll want to discuss
to answer that question
now like i always do
bit of a shorter lecture today
i got some practice questions
so go over these by yourself
with something sitting next to you
if you'd like to stay and go over them
you're welcome to
i'll give you about five minutes to go over them
and if you would not like to
then you can head out
and i'll see you tomorrow in woodward
we'll see you tomorrow
hey
i was just wondering that
all the land stats before lands that mine
are they all part of space junk now like
or do they like
return back after
like no space junk
space junk yeah like just
are they still like orbiting
yeah for the most part yeah
okay did you know that we could
see satellites from our naked eye
like i yeah
i witnessed some satellites
you know when you go to marine drive and there's like
no light at all
it disappears
yeah i could see like
really really tiny satellites just moving in
and then you know like
you can open your phone and like

there's an app where you can like
monitor lowest points
yeah different kinds of satellites
i thought it was pretty cool
yeah yeah totally
yeah you're definitely able to view
them from just your naked eye
if you're just standing at the right point
and they're passing over
totally yeah yeah
thank you cool
yeah no worries
hey hey how's it going
so um i was just like
i just wanna get the chart
yeah yeah sure
and then yeah
and yeah and then
this is the ice sat
you know you know
you don't even need to put ice sat on that
on that list
honestly i think ice sat is free
but we don't really talk about it
it's it's it's kind of a
its own category
because it's not a form of spectral
or optical or passive remote sensing
it's really kind of a different
kind of data than these three
so just in terms of knowing what's free and what's not
just know that modus and lance
that's free on worldview is not good
that's it yeah
no problem hey
what does what mean
sorry footprint
like footprint yeah
so we didn't really
we don't we didn't talk about it
and i don't expect you to know what it means
but essentially
what it is is um

ice at is a lidar instrument
which just means that it sends laser pulses
to the ground
yeah the size of the laser pulse
like the area that the laser pulse covers
on the surface of the ground
is about seventy meters
so that's kind of what that is
thank you yeah
no problem hey
i was wondering um
for the worldview satellite
this is just
interest yeah
um would a place like
a concentration camp or
like the weakers in china
or something like that
i know there was a lot of controversy about
getting photos of that
yeah would world
would worldview have gone to the government of china
and like we're not gonna release photos of that
or we're gonna um
probably i mean
so the thing that's kind of unique
about the worldview satellites
is they are able to point to
kind of target what they're gonna take an image of
so they kind of
as they're yeah
as they're passing over areas
on the surface of the earth
they kind of choose
what they're looking at
like whereas
landsat and modus it is
landsat and modus is everything
exactly but for those finer resolution satellites
they are typically kind of pointing at
um you know
what area on the earth that they're looking at
so they probably

you know there's international agreements
international laws
that would probably limit them from
collecting data on certain
things in certain areas
but um yeah
does that answer your question
that's correct
thanks so much yeah
hey longest operating observation satellite machine
would that one be like
blind sat or that
oh i thought i was referencing like
the longest
time to take the photo
no no that's how
that's just how long it's been operating
not the not the
short part me
not the revisit time
thank you yeah no problem
yeah it was static
how like you're the cast
it was static
and it relies on a different reference point
to its greatest static image yeah so
does it actually launch multiple satellites into space
no so it's using satellite imagery
from a different satellite
or or imagery that's just collected
from a different camera or different sensor
that's on the international space station
so how do they have authorization to actually
use other satellites
because landsat modest data is free and open source
so they can use whatever they want
in terms of those two data sets
if they want a higher resolution imagery
like worldview
for example
then they would just pay for it
so they're all attached to the internet
fashion space station

no no only earth casts
worldview lancetab modus
they're all completely separate satellites
yeah they just take satellite imagery
and then based off the location
that they take that satellite imagery
earth cast can say
okay we're taking video over the exact same area
so we'll superimpose it on the image
that'll say
landsat is taken
because we know it's the same area
oh so as long as it doesn't really pivot to a
extreme degree or something like that
it can capture something
yeah it has like a
they have kind of advanced algorithms
that correct for the different angles
that they use to look at the surface of the earth
as they're passing over
for the case of earth cast um
for landsat and and modest
they're pretty much always looking straight down
so you never really get like
a situation where they're looking at
yeah exactly
you never get a situation where they're
kind of looking obliquely or anything like that
yeah thank you
yeah no problem
okay guys let's go over this
and i'll get you guys out of here
so
what is the significance of the v two rocket
can anyone think way back to about
fifty minutes ago yeah
guys pardon me quite a bit thank you yeah
uh don't think it was sixty three
but it is the first
first image
exactly yeah
but first image of the earth from space
yeah exactly you got it

nineteen forty six
what was the first environmental application of earth
observing satellites
weather monitoring yeah
how often does modus image the earth
every one to two days
what is the longest operating earth observation
satellite mission
yeah landsat
yeah and then lastly
what's earth cast and why is it significant
that operates on the international space station
which orbits the
welcome back to the visuals of the art
yeah that's exactly right
it's a vancouver based company
they launched a high res hd video camera
that's mounted on the international space station
so they're able to take hi res hd videos from space
cool that's it from you guys
see you tomorrow
have a good week
have a good day
good evening
all that stuff
all right hi everybody
we can get started here
i just had a question for you guys first
has anyone started
or submitted their assignment to
anyone by chance
no okay so shouldn't be a problem then
okay i'm not gonna
there was a typo in
the canvas quiz submission for the assignment
which we just fixed
so if you haven't opened it yet
then it doesn't matter
so i was just checking if anyone had opened it
uh it doesn't seem like it so
that's okay
um so today
we are talking about the electromagnetic spectrum

we're going to be talking about
what the electromagnetic spectrum is
the different wavelengths
in the electromagnetic spectrum
the ones that we use to observe the earth
the ones that we don't use to observe the earth as much
and we're going to want to be able to describe
essentially
the different types of radiations
that are emitted from the sun
that we use to ultimately go away and observe
the surface of the earth
wow there's a ton of movement going on
settle settle down guys
easy peasy lemon squeezy
you guys okay
all right okay cool sweet so
i gotta get you guys quiet down for me
i apologize
i gotta do that but it's really hard for me to focus
guys in the back right there
i can hear you all the way down here
still talking buddy please hey
thank you
all right awesome
so
we are going
to be talking about radiation pretty much all day today
or for the whole lecture
the fundamental unit of radiation
is something called the photon
photons are released from objects
when matter is either excited thermally
so when things warm up
or when they're engaged in some sort of nuclear process
whether that's fusion or fission
photons are emitted from the sun
so that's radiation
photons are just the fundamental unit of radiation
photons are emitted from the sun
and then they travel towards the earth
where they'll hit the atmosphere
or hit the surface of the earth

and be absorbed or reflected or transmitted by matter
the speed of photons in a vacuum
is three point o times ten
to the eight meters per second
so all that means is that
a photon is essentially a type of light
or the fundamental unit of light
light is radiation
all of that radiation
all of those photons
no matter what kind of light it is
no matter what kind of radiation it is
all travels at the exact same speed
of three point o times ten
to the eight meters per second
so photons all travel at the exact same speed
no matter what
any kind of radiation
any kind of electromagnetic radiation
travels at the exact same speed no matter what
and that speed is
three point o times ten to the eight meters per second
it's often denoted as c
it's the speed of light
it's really fast
now depending on the type of wave
or type of wave length
or length of wave length
type of radiation that you're talking about
that you're referring to
there might be a different level of energy
associated with it
so that just means that again
the speed of light
the speed of that radiation at which it's traveling at
will always be the same
it's always three point o times ten
to the eight meters per second
but they have different energies
related to their wavelengths
so there might be more energy or less energy involved
or associated with that radiation
depending on the wavelength

depending on the size of the wavelength
at which those photons are traveling at
so photons even though they're this fundamental
unit of radiation
they're particles and they're waves
and that's kind of the basis of
the dual nature of light and of radiation
is that they can be measured with
as particles
they can be also measured as waves
generally speaking
we're going to be considering them and measuring them
in this course as waves
because it's the wave properties of radiation
that are important to us
when we're trying to use them to observe the earth
so pretty much all of the radiation
all of the light
that we use to observe the earth
comes from the sun
so the sun is about
a hundred and nine times bigger than the earth
makes up in mass
nearly a hundred percent
over ninety nine
percent of the total mass of the solar system
it's really hot
about fifty
eight hundred kelvin
and the energy created from the sun
or on the sun
is from this nuclear fusion of hydrogen into helium
all that matters about the sun
for our purposes
for earth observation
for remote sensing
for this course
is that the sun emits
essentially every part
or every type of electromagnetic radiation
so this ems here
just stands for electromagnetic spectrum
now generally speaking

we relate frequency and wavelength
by this equation
here c equals lambda times v
c here is that speed of light
so that's that three point o times ten
to the eight meters per second
lambda here
is our wavelength size
and v here is our frequency
all that's important to remember about this equation
is that there is a proportional relationship
between wavelength size
and frequency
because this value here
c will never change
no matter what
it's always three point o times ten
to the eight meters per second
if you have a lambda value
that's increasing
then your v value here
your frequency
has to decrease
and the same vice versa
so that means that wavelengths that are larger
have a lower frequency
while wavelengths that are smaller
have a higher frequency
now we measure wavelength
in order to understand just what a wavelength is
we measure wavelength
by just measuring the distance from one peak
the peak of one wave
to the peak of an adjacent wave peak
sorry that didn't say that
well you measure your wavelength from
the peak here to the adjacent peak here
of a given wave
so you can see here
you've got a relatively longer wavelength here
and a relatively shorter wavelength here
and this is how radiation travels
this is how light travels

this is how all kinds
of electromagnetic radiation travel
they all travel as waves
you can measure them as waves
and thus you can measure their wavelength
so you can measure the length or the distance
from a peak of the wave to the adjacent peak
you can also do the same with the trough of the wave
so from the bottom of wave here
to the adjacent trough here
to do the same thing
now frequency
the definition of frequency is just the number of waves
or the number of wave peaks
that pass by a certain point in a given amount of time
generally in a second
so if you go back to this equation
c equals lambda times v
c here never changes right
that speed is always the same
so you can see here
if these two waves here
this one that's got the longer wavelength
this one that's got the shorter wavelength
they're both traveling at the exact same speed
and you measure
say at this point right here
and this point right here
how many individual peaks of waves
travel by that one point
you can see here
for the one with shorter wavelengths
there's gonna be more waves traveling by this point
than there's gonna be
for this wavelength
this longer wavelength here right
does that make sense to you guys
do you see what that is
they're both traveling at the same speed
there's going to be more of these peaks
that pass by a given point
than for this one here
because it's traveling the same speed

but there's less peaks
that's what frequency is
so inevitably
if we have a smaller wavelength here
we're going to have a higher frequency
more of these individual wave peaks
are going to pass by a given point
because it's traveling at the exact same speed
as this wave here
with a slightly longer wavelength
now these different sized wavelengths
and the different frequencies
associated with those wavelengths
are essentially how we define and describe
what's called the electromagnetic spectrum
the electromagnetic spectrum is essentially a spectrum
that describes
all of the different kinds of wavelengths
and thus all the different kinds of radiation
that we know that exist
all of those different kinds of wavelengths
all of those different kinds of radiation
are emitted from the sun
and that's ultimately what we use to measure
and observe the earth
they come from the sun
they pass through the atmosphere
they bounce off or reflected
by the surface of the earth
and that's what we use in earth observation to measure
now essentially
what we're doing for the rest of class today
we'll first introduce the electromagnetic spectrum
a little bit more
and then we'll talk about
each of the kind of broad categories
of different types of radiation
which are categorized by wavelength size
and we'll talk about what they're used for
some properties of them
if they're important or not
for earth observation etc etc
so it's a pretty

today's lecture is pretty physicsy
i'll try to make it really clear
what you need to know for the midterm
i'm not going to expect you guys to do any calculations
or anything like that using this equation
but i do want you to be able to describe
the relationship between wavelength and frequency
which is just that
longer wavelength
longer wavelength here
lower frequency
smaller wavelength here
higher frequency
i want you to be able to describe that relationship
but beyond that
i'm not going to ask you to use this
to calculate anything
i will want you to understand the different types of
radiation across the electromagnetic spectrum
they're approximate wavelength sizes
and some rough
you know some kind of
easy background info about their properties
which we'll go over in detail
so first i'm going to play a video
just introducing
the electromagnetic spectrum as a whole
i'll go over it then
and i'll highlight
some important points from that video
and then we'll talk about each of the different
types of radiation across the spectrum
one by one by one
so we'll start with a video here
lot of videos today
so you don't have to listen to me too much
something surrounds you a barbecue
some of which you can't see touch or even feel
every day everywhere you go
it is odorless and tasteless
yet you use it and depend on it every hour of every day
without it the world you know could not exist
what is it electromagnetic radiation

these waves spread across the spectrum
from very short gamma rays to x rays
ultraviolet rays
visible light waves
even longer infrared waves
microwaves to radio waves
which can measure longer than a mountain range
this spectrum is the foundation of the information age
and of our pottery world
your radio remote control
text message television
microwave oven
even a doctor's x ray
all depend on waves within the electromagnetic spectrum
electromagnetic waves
or em waves
are similar to ocean waves
in that both are energy waves
they transmit energy
em waves are produced by the vibration of charged
particles and have electrical and magnetic properties
but unlike ocean waves that require water
em waves travel through the vacuum of space
at the constant speed of light
em waves have crests and troughs
like ocean waves
the distance between crests is the wavelength
while some em wavelengths are very long
and are measured in meters
many are tiny
and are measured in billions of a meter nanometers
the number of these crests
that pass a given point within one second
is described as the frequency of the wave
one wave or cycle per second is called a hertz
long em waves
such as radio waves
have the lowest frequency and carry less energy
adding energy increases the frequency of the wave
and makes the wavelength shorter
gamma rays are the shortest
highest energy waves in the spectrum
so as you sit watching tv

not only are there visible light waves from the tv
striking your eyes
but also radio waves transmitting from a nearby station
and microwaves
carrying cell phone calls and text messages
and waves from your neighbor's wi fi
and gps units in the cars driving by
there is a chaos of waves from all across the spectrum
passing through your room right now
with all these waves around you
how can you possibly watch your tv show
similar to tuning a radio to a specific radio station
our eyes are tuned to a specific region
of the em spectrum
and can detect energy
with wavelengths from four hundred
to seven hundred nanometers
the visible light region of the spectrum
objects appear to have color
because em waves interact with their molecules
some wavelengths in the visible spectrum are reflected
and other wavelengths are absorbed
this leaf looks green because
em waves interact with the chlorophyll molecules
waves between four hundred ninety two
and five hundred seventy seven nanometers in length
are reflected
and our eye interprets this as the leaf being green
our eyes see the leaf as green
but cannot tell us anything about
how the leaf reflects ultraviolet
microwave or infrared waves
to learn more about the world around us
scientists and engineers have devised ways
to enable us to see
beyond that slipper of the em spectrum
called visible light
data from multiple wavelengths help scientists study
all kinds of amazing phenomena on earth
from seasonal change to specific habitats
everything around us emits
reflects and absorbs em radiation differently
based on its composition

a graph showing these interactions
across a region of the em spectrum
is called a spectral signature
characteristic patterns
like fingerprints
within the spectra
allow astronomers to identify an object's chemical composition
and to determine such physical properties
as temperature and density
nasa's spitzer space telescope
observed the presence of water and organic molecules
in a galaxy three point two billion light years away
viewing our sun in multiple
wavelengths with the soho satellite
allows scientists to study and understand sunspots
that are associated with solar flares and eruptions
harmful to satellites
astronauts and communications
here on earth
we are constantly learning more about our world
and universe
by taking advantage of the unique information contained
in the different waves across the em spectrum
ok so
quick summary
wavelengths range in size from radio waves
which are the longest down at this end of the spectrum
and they can be several meters long to kilometers long
and then we have visible light
kind of in the middle part of the spectrum
which we typically measure in microns or millions
millionths of a meter
and then we have all the way down here gamma rays
which we typically measure with angstroms
a unit that's about ten
to the power of negative ten meters
and these wavelengths down here
the gamma rays
they have the smallest or shortest wavelengths
radio wave over here have the largest wavelengths
and thus inherently
gamma rays also have the greatest frequency

radio waves have the lowest frequency
side note not side note i guess
but important note
that frequency is also directly proportional to energy
so these gamma rays here
they have the most energy associated with them
because they have the highest frequency
these radio waves down here
they have the lowest energy associated with them
because they have the longest wavelengths
you can see that here
frequency is given in hertz
lowest here
lowest frequency
slowly increases
slowly increases
slowly increases
and then our wavelength size here
smallest here increases
now i generally speaking
we want you guys to remember for midterm purposes
what or where these different classes of wavelengths
or radiation occur on the spectrum
so if i say you know
what's the longest wavelength
i want you to know that it's radio waves if i say
which wavelengths have the greatest amount of energy
or the highest frequency
i'd want you to be able to identify gamma rays
if i said where does the
where do uv rays
ultraviolet radiation
where does it lie on the electromagnetic spectrum
i'd want you to be able to identify that
it's between visible and x ray
those are the kind of questions you can expect
about where things are on the electromagnetic spectrum
any questions about this
ok sweet so
now we are going to talk in a bit more detail
about each of these different kinds of wavelengths
or each of these different kinds of radiation
so we're going to start with radio waves

each of these videos that i play are from nasa
we're going to watch about a three minute video or so
and then i'll kind of overview
highlight what i'll actually want you to know
or remember for midterm purposes
is it too loud or too quiet
by the way thumbs up good okay
who yelled on
marconi's first radio transmissions
in eighteen ninety four
have spread into space for over one hundred years
at the speed of light
they passed serious in nineteen o three
vega in nineteen nineteen
and regulus in nineteen seventy one
that signal has already passed over one thousand stars
anyone orbiting one of those stars
with a really good receiver
could detect marconi signal
and know that we are here
radio waves are the longest
and contain the least energy
of any electromagnetic wave
while visible light
is measured in minute fractions of an inch
radio waves vary from about nineteen centimeters
about the length of a water bottle
two waves the length of cars
ships mountains
all the way up to monstrous waves
longer than the diameter of our planet
heinrich hertz discovered radio waves
in eighteen eighty eight
the first commercial radio station went on the air
in pittsburgh
pennsylvania
on november second
nineteen twenty
then in nineteen thirty two
a major discovery by carl jansky at bell labs
revealed the stars and other objects in space
radiated radio waves
radio astronomy was born

however scientists need giant antennas to detect weak
long wavelength radio waves from space
the enormous parasibo radio dish antenna
measures three hundred five meters in diameter
over three football fields
scientists can link the signals
from an array of separate radio antennas
to focus on tiny slices of distant space
such arrays act as a single immense collector
this giant new mexico array
uses twenty seven aramali dish antennas
shaped into a giant wide
with each arm capable of stretching for thirteen miles
scientists have even spread these linked
antennas across the globe
one of the largest stretches from hawaii
to the virgin island
and acts like such a powerful telephoto lens
that a baseball sitting on the moon
would fill its entire field of view
many of the greatest astronomical discoveries
have been made using radio waves pulsars
the existence of giant clouds of superheated plasma
which are among the largest objects in the universe
and even quasars
such as this one
over ten billion light years away
were all discovered using radio waves
radio waves
also provide more local information
astronomical objects that have a magnetic field
usually produce radio waves
such as our sun
thus nasa's stereo satellite
is able to monitor bursts of radio waves
from the sun's corona
wave sensors on the wind
spacecraft report the radio waves
emitted by a planet ionosphere
such as the birds from jupiter
whose wavelength measures about fifteen meters
radio waves fill the space around us
to bring entertainment

communications
and key scientific information
we have here these radio waves
when you tune your radio to your favorite station
the radio receives these electromagnetic radio waves
and then vibrates a speaker
to create the sound waves we hear
we may not be able to tap our toes
to the cosmic radio transmissions
but we certainly discovered much
about our universe's grand cosmic dance
by listening to that
okay radio wave summary
most importantly
kind of their most important or notable property
is that radio waves
have the longest wavelengths in the spectrum
the size of their wavelengths
can range from the size of a football field
all the way to larger than our planet
what the video was talking about there is
you can tune a radio
to a specific amplitude or frequency
so like a radio in your car
if you tune it to an am radio station
then the frequency of the radio waves
you are kind of intercepting
or measuring as they come in
that are being transmitted from a radio station
the different am stations are for different amplitudes
of those waves that are being transmitted
and then measured by your car's radio
if it's an fm radio station
then the amplitude is staying the same
and you are measuring different frequencies of
radio waves that are coming in and being measured
and then converted to sound by your speaker
so radio radios receive these electromagnetic
radio waves
and then we'll just convert them
to mechanical vibrations in the speaker to create sound
but am fm am changes the amplitude
fm changes the frequency

now these massive
telescopes that they were talking about
that are used to measure radio waves
that are coming from all parts of the universe
they are these telescopes
these radio telescopes
and they have to be massive
because astronomical objects will produce radio waves
but the size of these radio waves
can be absolutely huge
so the size of this dish
essentially
to measure these incoming radio waves
needs to be as big as the waves
as the size of the wavelengths
we got these massive
massive telescopes that are built up
eventually people
scientists realized that we were limited
we couldn't just build a
dish that kind of extended forever
and that's where these arrays started being built up
so now you'll see that these arrays are kind of
set up in y shapes
in flat areas across the world
and they work just as one kind of giant telescope
so each one of these kind of telescopes
is connected to one another
because they're at a set distance apart
from one another
scientists can just interpret
what the wave would look like
in between the readings or measurements
that each individual telescope is getting
and by doing that
if you have a array that kind of stretches
all across our planet
then we can measure radio waves
that are the size of our planet
so that's kind of how these array
radio telescopes work
any questions
in terms of radio waves

all i want you to really remember is
that they are the longest wavelengths
that we use them for radios
am changes the amplitude
fm changes the frequency
and then we often use them
with these radio telescopes yeah
amplitude is the
sorry if i didn't mention that
amplitude is the distance from kind of the
the middle of the wave
halfway between the crest and the trough
out to where the crest or trough is
so so amplitude is from this imaginary dotted line here
out to the peak
that distance right there
so a higher amplitude would be a larger distance
from this dotted line out to the peak
so a higher amplitude wave would kind of look like
and is that ever associated with
greater or lower frequency
or is it totally separate
frequencies set the same
if it's for different amplitudes
okay so now we are going to talk about microwaves
micro wings can pop your popcorn
they can catch your spirit
they carry thousands of phone channels
to speak your calls
but can microwaves help us learn about our world
and our universe
let's find out
with weight lengths ranking from thirty centimeters
down to one millimeter
microwaves fall between radio waves and infrared
microwaves are used in doppler radar
which is widely used for short term
localized weather forecasting
and what you see on tv
weather news
satellites have revolutionized weather forecasting
by providing a global view of weather patterns
and surface temperatures

this unique perspective has greatly increased
the accuracy of a tropical storm and climate forecast
different wavelengths of microwaves
grouped into bands
provide different information to scientists
medium length
sea band microwaves penetrate through clouds
dust smoke snow
and rain to reveal the earth's surface
satellite microwave measurements reveal the full arctic
sea ice cover every day
even where clouds exist
these measurements show great variability
from year to year
but also an overall decrease in arctic
sea ice since the late nineteen seventies
illustrated here with maps
and a time series of arctic sea ice in september
at the end of the summer melt
the japanese earth resources
satellite uses longer wavelength l band microwaves
for forest mapping
by measuring surface soil moisture
such as this image of the amazon basin
to identify areas of recent deforestation
l man microwaves are also
used by global positioning systems
such as the one in your car
scientists routinely combine microwaves
with information from other parts of the em spectrum
to study the composition of cosmic dust
or of a supernova
such as this supernova image
that combines x ray
radio and microwave data
this recently known supernova
in the milky way
exploded just over one hundred forty years ago
at the time of the american civil war
one important phenomenon is unique to microwaves
in nineteen sixty five
using long l band microwaves
arno penceus and robert wilson

made an incredible
accidental discovery
they detected what they thought was noise
from their instrument
but was actually a constant background signal
coming from everywhere in space
this radiation is called cosmic microwave background
and if our eyes could see microwaves
the entire sky would glow
with a nearly uniform brightness
in every direction
the existence of this background radiation
has served as important evidence
supporting the big bang theory
for how our universe began
microwaves have become both staples
and wonders of modern life
they are also the backbone of communications
and of earth sensing systems
and they are an excellent guide
to the ancient history
and origins of our universe
ok so microwaves are the portion of the spectrum
just smaller than radio waves
communication satellites often use microwaves
they denoted in that video the different bands they use
c x ku bands
and in remote sensing or earth observation
we often use these xcl and p bands
if you think back to our lecture yesterday
when we were talking about radar sat
it uses the c band
so each one of these just describes
the specific portion of the microwave spectrum
that is being used for that satellite
or for that instrument
you don't need to worry too much about what
these represent right now
and what bands are
we'll talk about them in a lot more detail next week
and later in the course
but the advantage of using microwaves for communication
for satellites

whatever it might be
is that microwaves can penetrate through haze
light rain clouds and smoke
so that means that if there's crappy weather
or something like that
and you're using microwaves
for your communication satellites
you're not going to have any communication disrupted
by crappy weather
by large amounts of fog or storm
or whatever it might be
any questions about microwaves
when you use a remote control
to change channels under your tv
your remote is using light waves
but this light is beyond the visible spectrum of light
you can see
back in eighteen hundred
william herschel conducted an experiment
measuring the temperature changes
between the colors of the spectrum
plus one measurement beyond visible red
when that thermometer registered a temperature
warmer than all the other colors
herschel had discovered
another region of the electromagnetic spectrum
infrared light
this region consists of short wavelengths
around seven hundred sixty nanometers
two longer wavelengths
about one million nanometers
or about a thousand micrometers in lane
we can sense some of this infrared energy as heat
some objects are so hot they also emit visible light
such as a fire
other objects
such as humans
are not as hot
and only amid infrared waves
we cannot see these infrared waves with our eyes alone
however instruments that can sense infrared energy
such as night vision goggles or infrared cameras
allow us to see these infrared waves from warm objects

like humans and animals
infrared energy can also reveal objects in the universe
that cannot be seen with optical telescopes
infrared waves
have longer wavelengths than visible light
and can pass through dense regions of gas and dust
with lower scattering and absorption
when you look up at the constellation of orion
you see only the visible light
but nasa's fixer telescope was able to detect
nearly twenty three hundred planet forming discs
in the orion nebula
by sensing the infrared glow of their warm dust
each disc has the potential to form planets
and its own solar system
incoming ultraviolet
visible and a limited portion of infrared energy
together sometimes called short wave radiation
from the sun
drives our earth system
some of this radiation is reflected off of clouds
and some is absorbed in the atmosphere
larger aerosol particles
in the atmosphere interact with
and absorb some of the radiation
causing the atmosphere to warm
the heat generated by this absorption
is emitted as long wave infrared radiation
some of which radiates out to space
the solar radiation that does pass
through earth's atmosphere is either reflected off snow
ice or other surfaces
or is absorbed by the earth's surface
this absorption of radiation warms the earth's surface
and this heat is admitted as long wave radiation
into the atmosphere
which allows only a small amount
to radiate out to space
greenhouse gases in the atmosphere
such as water vapor and carbon dioxide
absorb most of this emitted long wave
infrared radiation
and this absorbs includes the lower atmosphere

in turn the warm atmosphere emits long wave radiation
some of which radiates towards the earth's surface
keeping our planet warm and generally comfortable
the energy entering
energy reflected
energy absorbed
and energy emitted by the earth system
constitutes the components of the earth
radiation budget
a budget that's out of balance
can cause the temperature of the atmosphere to increase
and eventually
affect our climate
for scientists to understand climate
they must also determine what drives the changes
within the earth's radiation budget
the series instrument aboard nasa's aqua
and terra satellites
can measure the reflected short wave
and emitted long wave radiation
into space accurately
enough for scientists to determine the earth's total
radiation budget
other nasa instruments monitor the changes
in other aspects of the earth's climate system
such as clouds
aerosol particles
or surface reflectivity
and scientists are examining their many interactions
with the energy budget
a portion of solar radiation
from the sun that is just beyond the visible spectrum
is referred to as near infrared
scientists can study how this radiation reflects
off the earth's surface
to understand changes
in land cover
such as growth of cities
or changes in vegetation power
eyes perceive a leaf as green
because wavelengths in the green region
of the visible light spectrum
are reflected

while other visible wavelengths are absorbed
yet the chlorophyll
and the cell structure
of the leaf
are also reflecting near infrared light
like we cannot see
this reflected
near infrared radiation
can be sensed by satellites
allowing scientists to study vegetation from space
using these data
scientists can identify
some types of trees
can examine
the health of forests
and can even monitor the health of vegetation
such as forests infested with pine beetles
or crops affected by drought
studying the ambition
and reflection
of infrared waves
helps us to understand
the earth system
and its energy budget
near infrared data
can also help scientists study land covers
such as changes in snow
ice forests
urbanization
and agriculture
scientists are beginning to unlock the mysteries
of cooler objects across the universe
such as planets
cool stars nebulae
and much more
using infrared waves
okay there was kind of a lot more information
in that video
in particular
than you're going to need to know
for this course at least
so i'll try to summarize it kind of clearly
so the infrared region of the spectrum is next to

as the name suggests
the visible red part of the spectrum
so the infrared region is just a little bit longer
has slightly longer wavelengths
than the visible part of the spectrum
it can be generally split up into near
mid and far infrared energy or radiation
the mid infrared can also be called shortwave infrared
sometimes this general
these two here
both near and mid infrared
are generally classified as reflective infrared
so that's the infrared radiation
in the latter part of that video
where he was talking about
radiation that comes down from the sun
interacts with leaves
with vegetation
with forests
and then is highly reflected back out to the atmosphere
and in our case
back out to our satellite
or whatever instrument we're using to observe the earth
on the other hand
we have this far infrared
also called thermal or long wave infrared
and these wavelengths are generally best for studying
the long wave thermal energy radiating from our planet
objects any object will emit heat
so the thermal or far long wave infrared radiation
that is emitted as an object warms
is what we sense as heat
so if you have your thermal infrared goggles
or whatever that military use
the reason that people appear so bright
as opposed to some forests or some plants
is because we're much
much warmer than those other objects like plants
because of that
we are emitting more thermal
long wave or far infrared energy
and that's what these kind of thermal goggles measure
they measure how much radiation

of that far infrared energy is leaving a person's body
now some objects
are so hot that they also emit visible light
such as a fire
so as objects heat up
they'll emit all different kinds of radiation
all across the spectrum
sometimes that includes visible light
which is why a fire appears red
as it gets hotter you know
the hottest part of the fire will often appear blue
that's because that's the hottest part of the fire
so as things change in temperature
they release different kinds of energy
different kinds of radiation across the spectrum
humans us we don't emit any visible radiation
the only real radiation that we emit
because of the temperature that we are at
which you know
is about whatever our body temperature is
thirty degrees celsius or something like that
we only emit far infrared energy
which is what you can measure
with these night vision goggles
now the portion of radiation that's
just beyond the visible red part of the spectrum
so far or thermal infrared energy
is kind of well beyond the visible part of the spectrum
it goes visible red
then near infrared
then far infrared
the near infrared part of the spectrum
the part that is
the wavelengths that are really close to visible red
in terms of the size of those wavelengths
these are the radiation or wavelength types
that come down
and interact
with different kinds of surfaces on the earth
in particular
they're really
really useful for environmental applications
for conservation

for forestry
because forests
vegetation and particularly
healthy vegetation highly reflects near infrared energy
so incident near infrared energy
is highly reflective by healthy vegetation
which means that if i am a satellite
and i am observing the reflectance
of different kinds of surfaces across the spectrum
if i look at just the near infrared energy
that's being reflected off the surface of the earth
areas where there's very healthy forests
are going to have very
very high near infrared reflectance
which is very
very useful for monitoring things like forest health
vegetation health
vegetation cover
whatever it might be
so just note that there's a big difference there
between what we consider to be thermal infrared
and this reflective infrared
this reflective near or mid infrared
we often use to measure vegetation health
whereas that thermal infrared is really what we use
to measure things like temperature
make sense sort of
any questions
okay next we are going to talk about visible light
so this is the part of the spectrum
that you can actually see with your eyes
this is the part of the spectrum
that allows you to make up different colors
and perceive things that are blue green red
whatever it might be in our world
that you see through color
all electromagnetic radiation is light
visible light is the only part of the spectrum
you can see
for all your life
your eyes are relied on this one narrow band
of em radiation
to gather information about your world

though our suns
visible light appears white
it is really the combined light of the individual
rainbow colors
with wavelength ranging from five hundred
three hundred eighty nanometers
to red at seven hundred nanometers
before isaac duke
spain experimented
sixteen sixty five
people thought that a prism
somehow colored the sun's white light
as it bent to the spread of sunbeam
newton disproved this idea by using two prisms
to show that white light is made up of the bands
of colored light
newton used a second prism
to show that the bands of colored light combine
to make white light again
visible light contains important scientific clues
that reveal hidden properties
of objects throughout the universe
my new gaps in energy at specific visible wavelengths
can identify the physical condition and composition
of stellar and interstellar matter
human eyes aren't nearly
sensitive enough to detect these faint peaks
but scientific instruments can
scientists can learn the composition of an hemisphere
by considering how atmospheric particles
scatter visible lines
earth's atmosphere
for example
generally looks blue
because it contains particles of nitrogen and oxygen
which are just the right size to scatter energy
with the wavelength of blue light
when the sun is low in the sky however
light travels through more of the atmosphere
and more blue light is scattered
out of the beam of sunlight before it reaches your eyes
only the longer
red and yellow wavelengths are able to pass through

often creating breathtaking sunsets
when scientists look at the sky
they don't just see blue
they see clues about the chemical composition
of our atmosphere
however visible light reveals
more than just composition
as objects grow hotter
they radiate energy with a shorter wavelength
changing color
before our eyes
watch a flame shift in yellow to blue
as it is adjusted to burn hotter
in the same way
the color of stellar objects
tells scientists much about their temperature
our sun produces more yellow light than any other color
because of its surface temperature
if the sun's surface were cooler
say three thousand degrees celsius
it would look reddish
like the stars antares and beetlejuice
if the sun were hotter
say twelve thousand degrees celsius
it would look blue
let the star arrive to
like all parts of the electromagnetic spectrum
visible lighthead
can also help scientists study changes on earth
such as assessing damage from a volcanic eruption
this nasa e o
one image combines both visible and infrared data
to distinguish between snow and volcanic ash
and to see vegetation more clearly
since nineteen seventy two
images from nasa's landsat satellite
have combined visible and infrared data
to allow scientists to study changes in cities
neighborhoods
forests and farms over time
visible light images taken by nasa's mars lanterns
have shown us what it would look like to stand
on another planet

they have expanded our minds
our imagination
and our understanding
nasa instruments can do more than passively
sense radiation
they can also actively send out electromagnetic waves
to map topography
the mars orbiting laser altimeter
sends a laser pulse to the surface of the planet
and sensors measure the amount of time it takes
for this laser signal to return
the elapsed time allows the calculation
of the distance from the satellite to the surface
as the spacecraft flies above hills
valleys craters
and other surface features
the return time varies
and provides a topographic map of the planet's surface
back in earth orbit
nasa's icesat mission uses the same technique
to collect data
about the elevation of the polar ice sheet
to help monitor changes
in the amount of water stored as ice
on our planet
laser altimeters can also make unique measurements
of the heights of clouds
the top of the vegetation
canopy of forests
and can see the distribution of aerosols
from sources such as dust storms and forest fires
finally visible light helps us to explore
the far reaches of the universe
that humans could not hope to reach physically
using visible light
the hubble space telescope has created countless images
that spark our imagination
inflame our curiosity
and increase our understanding of the universe
ok so on a day to day basis
you can imagine visible parts of the spectrum
are probably the most useful to you
they are the part of the spectrum

that your eyes are actually capable of sensing
so all of these different types of waves
they're always existing
at least on our planet
if they're able to pass through our atmosphere
they're always kind of all over the place
it just so happens that our eyes
the only ones that we can sense
are in this narrow part of the spectrum
from about three hundred and eighty nanometers
in wavelength size
all the way to about seven hundred nanometers
in wavelength size
so on the smallest wavelengths
here we have indigo and blue
and then we have red
in the longest wavelengths
of the visible part of the spectrum
now they did
in that video there
they actually showed
if you guys remember
from yesterday
i briefly mentioned that icesat uses a lidar instrument
so they actually showed there a nice
visualization of what lidar is and kind of how it works
just kind of travels over an area
sends laser pulses down to a target
and then measures how long it takes
for that pulse of laser light to return to the sensor
by measuring how long it takes the light to travel
and hit a target and go back to the sensor
it can get a measurement for how far away the target is
and thus the elevation
of that target on the surface of the earth
now they use that
or they show that with an example of visible light
and icesat does use visible light in their lidar sensor
and their laser light
generally speaking
lidar uses near infrared energy
not visible light
so just kind of a side note

we'll talk about that in a lot more detail
after the midterm
when we talk about active remote sensing
and we talk about lidar and ice at in a lot more detail
for now what's important to understand is that
when we have a satellite a camera
whatever kind of sensor it might be
that's measuring electromagnetic radiation
being reflected off of a target
if it's measuring the visible part of the spectrum
then it's measuring the parts that we can
or the colors that we can see
or the wavelength sizes that we can see with our eyes
as soon as you go beyond
three hundred and eighty nanometers
or seven hundred nanometers on either end
you have gone into parts of the spectrum
that we can no longer sense with our eyes
so our eyes are just able to sense
wavelength sizes in this range
and beyond that
our eyes can't see them
but we do have sensors on board satellites
on cameras that we mount on drones or airplanes
that can sense and measure
the reflectance of those different sized wavelengths
and that is really kind of the basis
of earth observation and of remote sensing
is that we have all these different kinds of radiation
all these different wavelength sizes
and we can pick our sensor
to measure certain wavelength sizes
and the reflectance of those wavelengths
and then from that
be able to deduce
information about the characteristics of that surface
again we'll get into that
in a lot more detail in coming lectures
for now just kind of understand
what the sizes of the visible spectrum are
so that it kind of starts from
four hundred or three hundred and eighty nanometers
you'll see on one of my other size

it says it starts at four hundred nanometers
not three hundred and eighty
either one i would accept in a midterm or exam setting
it's different
depending on what source you're looking at
if you want a rough fence estimation
four hundred to seven hundred nanometers is fine
about five hundred or so six hundred nanometers
and that range is where green and yellow are
ok any questions about visible light
so your camera on your say
iphone or whatever
your android
it's a remote sensing instrument
it's just only able to measure reflectance
of wavelengths in the visible part of the spectrum
all we do with earth observation is just expand that
to create sensors that are able to measure wavelengths
outside of just the visible part of the spectrum
but we also measure
the visible part of the spectrum as well yeah
so you know how like
when you look at like
the sun or you don't wear sunglasses
they say like
the uv light damages your eyes yeah
how come visible like
doesn't damage your eyes or like
yeah like another example is like x rays
yeah x ray too much
the radiation
like harm your body yeah
how come certain types of radiation are
yeah so generally speaking
that's usually because of the frequency
associated with a given wavelength type
as soon as you go on this end of the spectrum
as soon as you move this way
and you get into uv light
and then x rays and then gamma rays
all of those have a very high frequency
thus a very large amount of energy associated with them
so when they come into contact with your body

they can have kind of potentially negative effects
from the chemical reactions
associated with the energy
from those wavelengths interacting with your body
that's essentially
exactly because they don't have
nearly as much energy associated with them yeah
ok sweet next is ultraviolet
we'll watch the video for ultraviolet
and then that'll probably be
the last video that we watch
we'll also go over x rays and gamma rays
but i won't play them
or i won't play the videos
that are from nasa about them
because they're not very applicable to
earth observation
the videos are posted on canvas
so if you're curious to watch the video about
about gamma rays or about x rays
you're welcome to
but i'll play the video on uv
ultraviolet
i'll talk about it
and then i'll just go over briefly x rays
briefly gamma rays
and then kind of summarize
all of the different wavelengths
that we've talked about
and highlight what i want you to know for the midterm
of galaxy m
thirty three can be seen in visible light
but the true extent of these spiral arms are revealed
in ultraviolet light
just as a dog can hear a whistle
just outside the range of human hearing
bugs can see light just outside the range
our eyes can see a bug zapper
amidst this ultraviolet light
to attract insects
johan ritter conducted an experiment in eighteen o one
to find out what if any
electromagnetic waves are beyond violent

ritter knew that photographic paper would turn black
more rapidly in blue light than in red light
so we tried exposing the paper beyond the violet
end of the visible spectrum
sure enough
the paper turned black
proving the existence of light beyond violet
ultraviolet rays
these ultraviolet rays
or uv radiation
vary in wavelength from four hundred nanometers
to ten nanometers
and can be subdivided into three regions uv a
uv b and uvc
visible light from the sun passes
through the atmosphere and reaches the earth's surface
uva long wave ultraviolet
is the closest to visible light
most uva also reaches the surface
but shorter wavelengths called uvb
are the harmful rays that cause sunburn
fortunately
about ninety five percent of these harmful uvb rays
are absorbed by ozone in the earth's atmosphere
uvc rays are the shortest and most harmful
and are almost completely absorbed by our atmosphere
the ozone monitoring instrument
aboard nasa's aura satellite
detects ultraviolet radiation to help scientists study
and monitor the chemistry of our atmosphere
including uv absorbing ozone
while atmospheric protection from harmful uv radiation
is good for humans
it complicates the study of naturally produced uv rays
in the universe by scientists
here on the earth's surface
young hot stars shine most of their light beyond
the visible light spectrum
at ultraviolet wavelengths
scientists need telescopes
in orbit above the earth's uv absorbing atmosphere
to find and study these uv
bright regions of star formations in distant galaxies

new young stars
in the spiral arms of galaxy m eighty one
can be seen in this galaxy evolution explorer
galaxy image from nasa
chemical substances
both atoms and molecules
interact with uv light
making this region particularly
interesting to scientists
an ultraviolet instrument aboard cassini
have detected hydrogen
oxygen water ice
and methane in the saturn system
uv data have also revealed details of saturn's aurora
scientists also use uv waves shining from distant stars
to view permanently shadowed regions of lunar craters
the lyman alpha mapping project
or land instrument
aboard nasa's lunar reconnaissance orbiter
can use this faint star shine
to look for possible water ice on the moon
ultraviolet grades may be harmful to humans
but they are essential
to studying the health of our planet's protected
atmosphere and give us valuable clues to the formation
and composition of distant celestial objects
ok so ultraviolet light
is slightly shorter wavelengths than visible light
most uv well
all uv waves are visible to humans
there's some insects bumblebees
other species that are able to see uv light
the sun is a source of all uv light as well as
you know radiation across the entire spectrum
all of the radiation
that we know that exists is emitted by the sun
the uvc rays
which they mentioned in that video
those are the most harmful ones
they're almost completely absorbed by our atmosphere
so our atmosphere blocks those rays from coming down
and hitting us or the surface of the earth
uv b rays are the ones that cause sunburn

so some of those are transmitted through the atmosphere
and then only a small amount of these uv
a waves hit the earth
and those are sometimes used in earth observation
but generally speaking
not really used very commonly
so we're not really going to talk about the use of uv
for earth observation at all throughout this course
but they are generally used for monitoring the o zone
and the absorption characteristics of the o zone
okay next couple kinds of waves
again this is a video on x rays
i'm not going to play it
because we don't really use x rays in earth observation
x rays have a much higher energy
and much shorter wavelength than ultraviolet light
as a result
we often refer to x rays in energy
rather than their wavelength size
just because they're so small
now how x rays are able to image things like our teeth
like our bones
is because different objects absorb
different levels of x ray radiation
so if we image
our arms or whatever
our bones absorb x rays much more than our skins
that's how we're able to
penetrate through our skin and see our bones
and we have sensors that are able to detect
the level of absorption of those x rays
now like i said
we don't really use x rays to observe
changes on the earth
or for earth observation in general
or remote sensing
so i'm not going to
we're not really going to talk about them at all
throughout this course
but just note they exist
the last is gamma rays
gamma rays have the smallest wavelengths
and thus the most energy associated with them

they're produced by the hottest
and most energetic objects in the universe
like neutron stars
pulsars and regions around black holes
on earth gamma rays are generated by nuclear explosions
lightning radioactive decay
those are really the only phenomena that we know
that generate these gamma rays
and unlike optical light or visible light and x rays
gamma rays can't be captured or reflected by mirrors
so that means that in order to detect gamma rays
we have to have these very special kinds of sensors
wavelengths of gamma rays are so small
that they can literally just pass through the atoms
that make up a detector or make up a mirror
so gamma ray detectors
are usually these densely packed crystal blocks
as a gamma ray passes through those crystal blocks
they collide with electrons
and then sensors are able to measure those collisions
based off of how those electrons are reacting
after they get hit by gamma rays
the point is
gamma rays are really hard to measure and to monitor
we don't really use them very much in earth observation
okay summary
kind of up here
gamma rays and x rays
are normally measured in angstroms
that's a unit that is about
ten to the power of ten meters
and most of these kinds of radiation
are completely blocked by the earth's atmosphere
we then have ultraviolet radiation
in the range of about one to four hundred nanometers
in wavelength size
these are also pretty much completely blocked
by earth's atmosphere
except for a small portion
close to the visible spectrum
near about three to four hundred nanometers
we then have the visible part of the spectrum
which we classify as about four hundred

to seven hundred nanometers
starting at about violet or blue
all the way up to red
this is the peak solar wavelength
which just means that the sun emits visible wavelengths
more than any other kind of wavelength
that we know that exists
and earth's atmosphere is mostly completely transparent
which just means that visible light
that's being emitted from the sun
comes down to the atmosphere of the earth
and pretty much gets transmitted
right through the atmosphere
which comes down
hits the surface of the earth
and allows us
when we're outside
to be able to see things in color
we then have the reflective infrared
so this is both near and mid infrared
at about seven hundred to three thousand nanometers
there's high absorption of near infrared
by water vapor in the atmosphere
but this is commonly used
by earth observation satellites
to monitor vegetation cover and health
so reflective
near infrared
very very commonly used in earth observation
very very useful for us
we're going to be talking about it a lot
and its applications throughout this course
we then have thermal
far infrared
that's how we
feel or sense heat
that's from about
three thousand to ten thousand microns
or micrometers
it's terrestrially derived
which just means that thermal or far infrared energy
is heat that's being emitted from objects
it's not something that we measure

that's being reflected off objects
it generally speaking
also has a lot of absorption in the atmosphere
and then the last two
we have the microwave and the radio
part of the spectrum
microwaves are about
zero point one to thirty centimeters in size
they're the wavelengths used in radar
so in radar sat
we use microwaves
despite radar standing for radio detection and ranging
we actually use microwaves in radar
the atmosphere is mostly transparent to microwaves
and then we have radio waves
radio waves are anything bigger than thirty centimeters
but can be hundreds and hundreds
and hundreds of meters long
and the atmosphere is also
pretty much completely transparent
to radio waves
any questions about these yeah
so essentially
the reason that
the atmosphere blocks certain wavelengths
and transmits certain wavelengths
is because of the chemical makeup of our atmosphere
so certain molecules that exist in the atmosphere
when they interact
with these incoming kinds of radiation
just have a specific kind of chemical reaction
where they get absorbed and then re emitted as heat
whereas others are just able to pass right through
that's really all it is
just the different
generally speaking
we talk about molecules or particles
that are highly absorbent in the atmosphere
of radiation
being things like water vapor
carbon dioxide
ozone there's a bunch of different
but depending

there's all these kind of different compositions
and makeups of the atmosphere
and each one of them may interact with
different parts of the spectrum differently
that's kind of the long answer
does that answer your question though
any other questions
yeah yeah
sorry can you say it louder for me i can't hear you
near infrared
absorbed by objects so
objects can absorb any part of the spectrum
technically
it just so happens that
most radiation that comes down and hits a surface
if it's absorbed
then the chemical reaction that goes on
results in thermal
far infrared
than being emitted as heat
so generally speaking we don't really have any far
thermal infrared radiation
that's emitted from the sun
and passes through the atmosphere
and hits the surface of the earth
all the thermal infrared energy that we talk about
is being omitted from different objects
i'm not sure if that answers your question or not
yes no
is absorbent with what
with human beings
yeah yeah so it would be so we you know we as
as an object as a
you know a bunch of matter essentially that are
that's composed together
we have our own spectral signature
so we absorb and reflect different kinds of radiation
depending on the chemical makeup of our skin
or whatever it might be
so sometimes you know
in the case of near infrared that you're talking about
yeah we would likely be absorbing that radiation
and then re emitting it as thermal infrared or as heat

does that kind of make sense
okay that kind of brings me to surface interactions
electromagnetic radiation interacts with the features
on the earth's surface in three ways
it can be absorbed
where it kind of comes and hits that surface
some chemical reactions go on
and essentially
that energy is lost and partially re emitted
as heat or as long wave thermal radiation
it can be reflected where it comes down
bounces off the surface
and is reflected away in opposite direction
that it came down and hit that surface
or it can be transmitted
it can pass right through that surface
and if you think about it
if you think about it logically
different kinds of surfaces that
you know that exist in the world
they have different levels of absorption
of reflection
of transmittance
you think of
something like very clear water
when you're able to kind of see through it
there's a lot of transmittance there going on
there's a lot of light
that's penetrating through the surfaces of that water
reflection is often very high
with things like ice and snow
when you're walking out on a mountain
and there's a ton of snow
you got to be really careful
that you don't get burnt
by all the energy that's coming down
being reflected off that snow
and going back and hitting you
and then there can also be lots of absorption
things like black concrete
have really high absorption properties
where energy comes down
and is absorbed by that concrete

and that's why when you touch that concrete
it's really really hot
because it's absorbing a ton of energy
and re emitting it as heat
now when visible light strikes a leaf
certain light is reflected
creating the image of the leaf we see
and this is true for any object
it just so happens with leaves
the visible parts of the spectrum
come down from the sun
get transmitted through the atmosphere
hit a leaf and the leaf absorbs the red energy a lot
and the blue energy a lot
and reflects the green energy
more than the red or blue energy
so then when we are looking at that leaf
because there's more green light
being reflected off that leaf
than red or blue light
our eyes perceive it as green
so that's essentially how that works
that's why leaves look the color they do
now some of that energy that that leaf absorbs
is going to be re emitted as heat
and the leaf's reflectance
and absorption characteristics
are ultimately
what gives it the color we perceive it as
so upon striking some sort of surface
whatever it might be
incoming radiation is partitioned
into one of these three responses
it has to be one of these three
it's either transmitted
so when radiation penetrates into certain surfaces
like water other materials
that are very transparent and thin
it'll just kind of pass right through
it can be absorbed
some radiation is absorbed
through electron and molecular reactions
within that medium

a portion of that energy is then re emitted as heat
as far infrared
so think of concrete
something like that
and then reflectance
some radiation reflects
so it bounces off the target
scatters away
in potentially one angle
potentially various different angles
depending on the surface roughness of that target
and the angle of incidence of the rays
we'll talk about transmittance absorption
reflectance
in a bit more detail next lecture
so don't worry too much
about their definitions right now
but what i do want you to know for now
is that all the energy
that comes down and hits a surface
has to either be transmitted
absorbed or reflected
so these three parameters can be dimensionless numbers
represented generally between zero and one
often as just a percentage
so if i say
you know i have some light coming down
some energy
sixty percent of that light is being transmitted
thirty percent of that light is being reflected
how much absorption would be going on
anyone guess
ten percent has to equal a hundred percent
so the total has to equal a hundred percent
energy has to either be transmitted
reflected or absorbed
okay some practice questions for you guys
i'll leave you for a couple minutes
i'll go over these
if you want to head out now
you are welcome to
and i will see you next week
if you want to stay and go over the answers to these

i'll go over them in three minutes or so
hey yeah what's up
is it like it's open for example
like in a time period and you do in that time period
but you can do it anywhere or
yes that's correct
so it'll be open during class time
uh so it'll be open from five to six thirty pm on
i forget exactly what day of the week it's on
it'll be open from five to six thirty pm
uh you'll write it during that time
but from anywhere
we're not gonna be here
so you can write it still completely online
it's not like it's open and you do it anytime that day
it's correct
it's like open just during schedule
class time five six thirty
yeah no problem
hey i'm confused with like these two concepts
yeah briefly explained
yeah yeah so
so the main difference here is
is that there is emitted radiation
and reflected radiation
emitted radiation
is that thermal infrared energy
it's what we sense is heat
so that's like what's emitted from the
like laptop
yeah yeah anything
yeah that that's
that's the heat that we sense
thermal that's thermal
that's thermal
and then these two are for near and mid infrared
these are both reflective infrared types of energy
which means it's energy that comes from the sun
bounces off a target and is measured
the reflectance of it
how much is bouncing off of a given surface
is what we measure
so this is near

this is mid
no sorry no
so infrared includes all of the mid
near and far infrared energy
the near and mid infrared energy
are the energies that are reflected
the far infrared energy is the energy that's emitted
which is the thermal
yeah exactly
and then what does this mean exactly
infrared yeah
it essentially just means that it is close to red
in the part of the
in the visible part of the spectrum
all right yeah no problem
can you walk me through
transmission yeah
can i for all of you
yeah we'll talk right after
i'm just gonna go over these answers
because it's almost the end of class
and i'll talk to all of you
okay
let's go over the answers to these guys
because i know it's almost technically the end of class
so i want to get you guys out of here
if you wanted to stay for the answers
what happens to photons which we know
photons are just the fundamental unit of radiation
so when i say photons talking about light
what happens to photons that are not reflected yeah or
pardon me guys pardon me
guys pardon me thank you
yeah absorb what did you say absorbed or
yeah so if they're not reflected
they're either absorbed or
absorbed or transmitted exactly
so how do you calculate the frequency of a wave
what's that
equation look like that we were looking at yeah
people's fancy upside down y yeah lambda lambda yeah
times v how often a point passes
or how often

a point yeah exactly
yeah exactly
and you could calculate
you calculate frequency by just saying
the speed of light divided by the wavelength
that also be the kind of mathematical calculation
okay what is the longest wavelength type
that we talked about yeah
radio waves
exactly what is
what did i mention
that near infrared light is frequently used to measure
or monitor from earth observing satellites yeah
exactly vegetation
health and vegetation cover is the key one
that i want you to remember for that question
and then what are the shortest and longest wavelength
sizes of visible light in nanometers
and what colors do they represent
so what's the shortest wavelength of visible light yeah
exactly and what color does that represent
yeah like a violet or blue
violet for three eighty
blue for about four hundred
what's the longest wavelength
size of visible light yeah
and that what color is that red exactly
awesome great job guys thank you see you next week
you gotta click it yes
alright guys we'll get started here
so i'm gonna give it to evan
he's gonna give you his usual reminders
of what to be working on this week
and then talk about midterm format
if you have any questions about the midterm blog post
anything course logistics related
it's a good time to ask evan
all right hello everyone
what you should be working on this week
both do on thursday
assignment two and blog post three
and then next week on tuesday
february fourteenth

we have our midterm
i'll talk a little bit more about that later
but i'm just going to go over office hours
and a few other things first
so tristan douglas
he's going to be holding office hours
this wednesday and thursday
times are up there
this will be posted
so no need to take a picture or anything
and then one thing about assignment grading
so when we give you your assignments
and we get them back
sometimes we give you these fill in the blank answers
and they'll show up
like you see here
you can see that red dot
where it says you answered twenty one
the correct answer is nineteen
and that's showing you that you've
put it in incorrectly
but before you email us saying
i think the answer is actually nineteen
just make sure that you check
that you haven't had it manually adjusted
to two point five
out of two point five points
so basically
what's happened here is
when the assignment was designed
we put the correct answer in improperly
and we can't go back and change it
so we have to manually adjust it
so all i want to get across here is
before you email us
saying that you put the right answer
and it's showing up wrong
is just to double check that your points are correct
that's all i want to get across here
we get a bunch of emails about this every year
we don't have a workaround yet
but just make sure you've got
the right mark before you email us

and yeah under the midterm
so midterms are coming
hope you guys are all
having a good time in your courses
i like this little graphic of how i feel about midterms
i'm personally number five
where i just want to eat them
uh great so midterm date and time on tuesday
february fourteenth
that's next tuesday
there's no class
the midterms online open book
you're welcome to come to the class
to write your midterm
no teaching staff is going to be here
so feel free to come and work here if you want
it's a semi decent idea
if you don't have a reliable internet
because ubc has decent internet
it's going to be an hour and a half long
it's during class time
make sure you start on time
because you will get cut off at the end
it's going to be administered through canvas
so you just log into canvas
open the quiz
i'm going to be on my email the entire time
so if you have any technical issues
email me immediately
don't wait don't mess around with it
if it's just internet reboot it whatever
but if something's gone wrong
email immediately
i can extend your midterm
i can do a bunch of stuff to work through it
the format there's me
thirty multiple choice questions
four film the blank questions
and six short answer questions
we only want like
a brief paragraph for the short answer questions
don't write like a huge novel for us
we're just looking for that

you get what's going on
pretty much
the exam is open book online
the questions are going to appear one by one
and you must answer a question
to go on to the next question
one unique thing about this midterm
because it's online
an open book
you can't go back and change your answers to a question
so make sure you are very
sure on your answer before you move on
and in addition to that
the questions appear in a random order
this is to reduce group work
we want you all to work individually
it must be done individually
don't work together
don't share answers
don't discuss answers
if you are an access university student
that'll be manually added to your profile
so you don't need to email me asking for it
if you've given me the sheet
i will update it as a reminder
if you haven't given me your a and d forms
to send them to me before the midterm
uh plagiarism
don't be a copycat
this is an open book midterm
that being said
is no book midterm
we encourage you to utilize the slides
and other materials
but what we don't want you to do
is to copy sentences directly
looking for something like spelling
totally chill
don't worry about it
but just make sure for the short answer questions
you answer in your own words
so don't go and just
copy paste directly from the slides

or just google the question
and copy paste the first thing that comes up
we can find that
chris is going to host a review session next monday
the day before the midterm
if you post questions in the midterm discussion board
that's the best way to make sure that he goes over it
um yeah final notes is worth
twenty percent of your overall grade
all the practice questions are posted on canvas
we don't directly provide answers
but if you post a discussion board saying hey
i'm not really sure what's going on with this question
i'll get back to you and tell you what's up
we're not gonna give you a whole list of the answers
but we will like
try and guide you along the right way
midterm content covers everything
from lecture one up until
spectral signatures are you doing resolutions today
okay so today is the last thing before the midterm
resolutions content
that's tomorrow
not on the midterm
anything that's on the assignments
not on the midterm
you just want to focus on the lectures
if you have questions
post in the discussion board
that's where chris is going to know what to
talk about in the review session
i'm going to be monitoring it and answering questions
make sure you have reliable internet
don't do this via your hotspot on your phone
in the middle of the woods bad idea
you won't be able to email me
saying you're having technical difficulties
we're not reliable for your internet connection
that being said
if you do have technical difficulties
send me an email
i'll do what i can to get you extra time
or another attempt if something's gone wrong

one other thing with that is
make sure you start your exam on time
don't start it at six p m
and assume you'll get the hour and a half
you need to start by five to get the whole time
another thing with that
there's a ten minute buffer on either side of the exam
so you can start at four fifty
and you can write until six ten six forty
so the absolute last
time of day you can start at
to get the full hour and a half would be five ten pm
good luck do the practice questions
look over your notes
make sure you pay attention to what chris highlights
he really highlights the important stuff all the time
and you're going to do great
if you have any questions about the midterm
now's a great time hi
yep
assignment one yeah we're aiming for friday yeah
you can't go back and check them yeah so
make sure you're confident your answer before moving on
it just appeared
it just appeared
one at a time
yeah and then you have to submit that question
to go on to the next question
so you can't go back and look at it
once you go on to the next question
you're on to the next question
all good sweet
any other questions for evan
yeah
no assignments or anything yeah
and feel free to email me
or post in the discussion board if you have questions
and don't want to ask in front of the class
that's totally chill
thank you okay
one yeah you can head out
one thing i want to highlight that evan noted was that
next monday

so week today
i'll do a review session
i'm not gonna
really prepare any new content for the review session
if there's lecture content from before the midterm
that you want me to go over
then post that in the discussion board say hey
can we go over this in the midterm review session
and i'll go over it so i'll
i'll update kind of a powerpoint presentation
up to about an hour or so before lecture next monday
so as long as you post before then
then i'll have some content to go over
but if you don't
if no one posts anything and
you know no one asks any questions
then it'll be
it'll be quick
i won't have anything kind of prepared
but you guys are also welcome
just come and ask questions
i'll have all the slides
for all the different lectures and everything available
ok tristan's going to come at the end of
class today to talk about assignment two
give you some tips and tricks
you can ask him any questions
if you have any questions about assignment two
today we are talking about spectral signatures
i think that in this course
this is the kind of part of the course
that starts to get a bit more fun
a bit more interesting
a little bit more sciencey as well
um so bear with me
so today we are going to talk about something called
spectral signatures
and there's really two key things
that i'm hoping that you'll take away from class today
one is just understanding what a spectral signature is
and how it might look
for different surfaces of the earth
and then the second is understanding

the spectral response of
specifically vegetation
so we'll talk about leaves
and the spectral response of leaves
and the properties of leaves
that influence the spectral response
across different parts of the electromagnetic spectrum
okay so reviewing from where we ended off last week
kind of one of the final slides we looked at
was about surface interactions
so we know that there's all these different kinds
of radiation
all across the electromagnetic spectrum
they're all emitted from the sun
they travel at the speed of light through space
eventually they come
in contact with the earth's atmosphere
if they make it through the earth's atmosphere
they come down to the earth's surface
where they interact with surfaces on the earth
in one of three ways
they're either absorbed
reflected or transmitted
so they're either transmitted
where they kind of pass through a material
they're reflected
where they bounce off a material
or they're absorbed by that material
so common materials
that have relatively high transmission
on the surface of the earth might be things like water
when you're underwater
and you look up
you can kind of see little bits of light rays
that are penetrating below the surface of the water
that's because that light is being transmitted
through the water reflected
common surfaces that have high levels of reflection
might be something like ice
ice and snow
when sun comes down
or when you know
light rays from sun come down and hit snow or ice

they bounce off that snow or ice
in the opposite direction
or they might be absorbed
black concrete is really really hot
because all the incident light
that's coming down and hitting that concrete
is absorbed
not much light is reflected
and really none is transmitted
now for visible light striking a leaf in particular
if you imagine a leaf on a particular tree in a forest
when light strikes that leaf
some of the light is absorbed
some of it is reflected
the light that is reflected
is what allows you to perceive that object
in this case that leaf
as a particular color
so leaves are green
because visible light is radiated from the sun
travels through space
through the earth's atmosphere
down to the surface of the earth
hits a leaf
and when that visible light hits the leaf
green light is reflected
more than the other visible wavelengths of light
that hit the leaf
so all parts of the visible spectrum
will come down through space from the sun
and hit the leaf
but red parts of the spectrum
blue parts of the spectrum
are absorbed more than green
visible green light
is reflected relatively more than red and blue light
which allows us and our eyes
to perceive that leaf as green
and that's true for anything
when you're outside
when you're outside walking around
and you see something that is brown
say a tree trunk or something else

or brick on the side of a house
that's because that brick
that tree trunk
is reflecting more red light than say
blue and green light
give me a kind of a brownish
reddish haze
so your eyes perceive colors because of the light
that is reflected off of those surfaces
off of those surfaces
or off of those targets
now a spectral signature is just the pattern
of spectral response
of a material
across a certain part of the electromagnetic spectrum
it's typically visualized with a graph
and it just shows the percentage of radiation
of different wavelengths
reflected from a given object
so this is an example
of a couple different spectral signatures
here you'll have the wavelength size along the x axis
you'll have the reflectance in percentage
along the y axis
here you can see here for green vegetation
that's this green line here
we have a little bit of a peak there
in the visible green part of the spectrum
and then it increases
and there's lots of near infrared reflectance
and then it's variable
in the mid infrared part of the spectrum
you can see for soil
soil has strong absorbents
so low reflectance
in the blue and the green part of the spectrum
but when we get to the visible red part
right around seven hundred microns or micrometers
it's got a relatively higher level of reflectance
than say in the green or blue part of the spectrum
when we look at water spectral signature
it's going to have the most reflectance
in the blue part of the spectrum

and then lower
and well lower
but kind of close
in the green part of the spectrum
and then much lower
in the visible red part of the spectrum
and all of that allows you to perceive
certain surfaces in certain colors
now by plotting spectral signatures
of different materials together
the portions of the spectrum
where their signatures differ
can be readily identified
so all that means is that
if i plot several spectral signatures
which i've done here
and then i say okay
let's look at the near infrared part of the spectrum
and see how difference the reflectance is
for wavelength of that size
you can see that the green vegetation
has a much higher reflectance
in the near infrared
soil kind of has a moderate amount
and water has a very
very low amount
the value in that for remote sensing scientists
for earth observation
is that by knowing what level of reflectance there is
for certain materials at different wavelength sizes
we can easily differentiate which materials or surfaces
we're looking at on the surface of the ground with say
a satellite or some other sensor for earth observation
so that's really the value of that
okay this is a video that kind of just introduces
in a bit more detail
what spectral signatures are
and how they might look for different common
surface materials on the earth
hi everyone
in this video
we're going to be covering spectral signatures
in remote settings

we use the spectral information
of materials or features
to be able to distinguish between them and analyze them
each material or feature reflects energy differently
due to the chemical and structural compositions
energy emitted by the sun
is reflected by objects on earth
which we have been able to measure in remote sensing
we call this reflectance of energy
spectral information
a simple way of analyzing spectrum information
is through a spectral signatures graph
which is what you see here
a spectral signature
shows how much an object or material
reflects energy
across the spectrum of weight loss
as we learned
a photon can be either reflected
absorbed or transmitted
and what we receive with our eyes
and our camera systems
is the reflected light
in this graph
we see percent reflectance of photons on the y axis
and the wavelength on the x axis
for the purposes of this tutorial
we're going to distinguish between
three components of the electromagnetic spectrum
visible which we're able to see with our eyes
and near infrared and shortwave infrared
which are wavelengths we cannot see
the visible part of the spectrum
is the easiest for us to interpret
because it is the only part
of the electromagnetic spectrum
we were able to see with our naked eyes
we see the wavelengths in the visible spectrum
as colors while all other wavelengths
outside of the visible spectrum
are invisible to us
for example
the color blue

is actually about four hundred nanometers
green about five hundred fifty nanometers
and red about seven hundred nanometers
so now that we understand that colors
are actually wavelengths within the visible spectrum
that we can see
let's take a look at some of the
some common features
that we would recognize in our both sense of imagery
let's start with ocean water
which looks blue to us
but remember that blue is a wavelength
the water looks blue because the wavelength
which is around four millimeters
is being reflected
the most invisible spectrum
water can look somewhat green
but rarely red
that's why these wavelengths are not reflected
as much as blue
what about water and aneur infrared
remember that just because we see water is blue
doesn't mean that it isn't reflecting
absorbing or transmitting other wavelengths
water is particularly simple
in the near infrared and short wave infrared
as almost always wavelengths are absorbed
that's why we see zero reflectance
for most of the near infrared
and shortwave infrared wavelength
okay let's do another feature class now
how about soil
in the visible spectrum
soil is often brown
which means that it is reflecting the red wavelengths
which are around seven hundred centimeters
the most blue and green wavelengths
are still being reflected
but not as much as red or brown
in the near infrared part of the spectrum
we see that the reflectance of soil continues to rise
and then starts to let aloft
in the short wavelength thread

you can see that soil reflects much more energy
in the shortwavement of thread wavelengths
than it does in the visible
or near infrared parts of the electromagnetic spectrum
let's try clouds next
clouds are very white
which means that they reflect
all wavelengths in the visible spectrum a lot
remember that when you combine all colors together
that we can see
you get white
in near thread
in a short wave of thread
we see that clouds then start to drop
off in reflectance
this happens because clouds are mostly made of water
and as we saw earlier
with the dark blue signature on our graphs
water absorbs wavelengths in the near infrared
and shortwave infrared
which is why we see the special signature of cloud
continue to suddenly drop
okay let's take a look at one more feature class
how about vegetation
like a forest
a healthy forest looks green to our eyes
which means that it is reflecting more
green wavelengths than blue or red
this is why we see a dramatic bump
in the reflectance of vegetation
in the green wavelengths
around five hundred fifty animators
what about vegetation in the near infrared
probably the most dramatic
change in reflectance we've seen so far
forest has shown to be very highly reflected
in the near infrared section
this is largely due to the structural
and chemical compositions of the leaves
which highly reflect near infrared
weight loss
in the short wave of thread
force is shown to be variable

depending on the wavelength
we see that force reflects the clients
and falls with an overall downward trend
okay so let's wrap up now
this is the final product of our spectral
signatures graph
which shows us how water
soil cloud and forest
reflect photons at different wavelengths
in a visible near thread and shortwavement thread
sections of the electromagnetic spectrum
the chemical and structural compositions
of each feature cause reflectances cross wavelengths
be different from one another
telling us how much energy a particular
feature class reflects for each wavelength
a real world application of this information
would be to determine which wavelengths
would be best for differentiating amongst
features in a remote sensing image
for example
for water we see relatively high reflectance
in the blue wavelength
around four hundred nanometers
and very low reflectance
from around nine hundred nanometers onwards
using this information
could help us differentiate water
from other features in an image
soil reflects the red
around seven hundred millimeters
quite a bit
and it's also highly reflected
in the short wave of red range
around twenty five hundred millimeters
using these two wavelengths
to help us differentiate soil
from other features in an image
cloud is unique in that it reflects
highly through the whole physical spectrum
and has low reflectance
at around twenty five hundred nan meters
these wavelengths could be

used to help us differentiate clouds in advantage
and finally
vegetation reflects green
around five hundred fifty nine meters a lot
and has a big spike in reflectance in the near threat
around one thousand fifty nine meters
these wavelengths can be used to differentiate forest
or vegetation in the image
we can quickly see that
understanding the spectral signatures and features
can help us to distinguish them
within remote sensing information
and lead to high quality analyses
okay so
the key here is that when we use more
two or more wavelengths
or more than two wavelengths
when we use multiple wavelength sizes
and plot the reflectance of different materials
for those particular wavelength sizes
then we have this improved ability
to be able to distinguish
different materials on the surface of the earth
and that is really the basis
for pretty much all of earth observation
remote sensing
all that means is
if we have this spectral signature graph here
and we say okay
what is the spectral response
or the reflectance of each of these different materials
for a wavelength size of about five hundred microns or
sorry five hundred nanometers or point five microns
then we can say okay
well green vegetation is a little bit lower
water is a bit higher
soil is a bit higher etc
and then we can say ok
well what about the reflectance of those materials
in this near infrared band
this part of the spectrum here
and then what about those
reflectance of those materials

also in the mid infrared or shortwave infrared
this part of the spectrum here
if we combine the information from each of these bands
each of these particular wavelength sizes
which are just kind of arbitrary
i've just picked at random
but if we combine multiple of them
we can very very
very accurately
and efficiently distinguish different materials
that are on the surface of the earth
and potentially
monitor how they're changing through time
so if we look at this example
we have a spectral signatures graph
of four different materials
grasslands pinewoods
red sand and silty water
and i wanted to kind of ask you guys some questions
about how you can pick apart this graph
how you can derive some information from this
to use in an earth observation setting
which region of the spectrum
shows the greatest reflectance
for each one of these different surface cover types
so maybe just
you can just
someone just yelled out to me
so for grasslands
what region of the spectrum
what approximate wavelength size
has the highest level of reflectance
yeah kind of right around there exactly
what about pinewoods
also kind of around there
so we got grasslands yellow right there
pinewoods and green
kind of a similar area of peak reflectance
what about red sand
point six or so
yeah right around here
and then what about salty water
where's its highest reflectance

yeah point five or so
point six right around there
about point seven five
we could say for grasslands about point eight two
for pinewoods about point five nine
for red sand
maybe about point five four for salty water
okay now at zero
point six microns
so right here
do you guys think that you could distinguish
these four classes
these four different materials
on the surface of the earth
yes or no could you
well let discuss with someone sitting next to you
brainstorm for a bit
i'll give you a couple minutes
and we'll come back and talk about it
but which of these materials could you distinguish
and why which of them could you not
brainstorm for a couple minutes
then we'll discuss
yes
yeah
one two three four
ok what do you guys think
which ones could i distinguish maybe
which ones could i maybe not distinguish
anyone have any ideas
feel like bravely
yeah we thought that grasslands and pinewoods
would be really hard to distinguish
grasslands and pinewoods yeah
the green yellow signatures here
would be really hard to distinguish
how come they're just so close and
yeah totally
yeah so they
for sure yeah
their reflectance is so close at zero point six microns
it'd be really hard to tell them apart
what could you maybe easily distinguish though

yeah yeah
yeah red sand from probably all the rest
it has a really high reflectance
very different from all of the other ones
and what about silty water down here this blue one
it's like decent
you could probably distinguish it at least very well
from maybe red sand
you might have a little bit of difficulty
distinguishing it from
say grasslands or pinewoods
but in general it's still pretty different
so you could maybe distinguish it
so if we saw
grasslands had about an eighteen percent reflectance
and pinewoods
had about a twenty one percent reflectance
of wavelengths with a size of zero point six microns
yeah for sure those would be hard to distinguish
but red sand has a much higher reflectance
salty water has a much lower reflectance
those maybe we could much more easily distinguish
ok and then just lastly
which material is brightest
at about zero point six microns
we would say red sand
that's right around here
and at one point two microns
right around there
we would say grasslands has the highest reflectance
or are the brightest materials
okay so that's kind of just a brief example
of how you could look at spectral signatures for
various different materials on the surface of the earth
and analyze them and consider how they're different
how they have different levels of brightness
or reflectance for different wavelengths
now for the rest of the lecture
we're going to focus specifically on vegetation
and essentially specifically on leaves
and how the spectral signature of
healthy versus unhealthy vegetation looks
and why it looks that way

what influence is it
so we know that as we go from summer into fall
into winter
back into spring
and then summer again
we can get a wide variety of colors
when we look at leaves
so leaves in the middle of summer might be nice
and bright green
leaves in towards the fall
we'll start getting a bit red
a bit orange
maybe eventually kind of brownish
eventually they'll fall off
but there's all these different potential colors
that you can see leaves
and we're going to talk about essentially
why they appear
the colors that they do
from kind of more of a scientific perspective
so this is the spectral signature for vegetation
for healthy vegetation in particular
you can see here
that it's characterized by a little bit of a peak
in the visible green part of the spectrum
with much lower blue and visible red reflectance
and then as we get into the near infrared
part of the spectrum here
it's got much higher reflectance
up around fifty percent
and then as we get into the mid infrared
or shortwave infrared part of the spectrum
through here
you can see that it kind of fluctuates
but generally
has an overall decreasing trend of reflectance
so just a reminder
review from our electromagnetic spectrum lecture
this is the visible part of the spectrum here
from about zero point four to zero point seven microns
in wavelength size
we have the near infrared here
from about zero point seven

to one point five microns in wavelength size
and then we have our mid infrared
which will sometimes be interchangeably used
with the term shortwave infrared
from about one point five to two point five microns
now for each part of the electromagnetic spectrum
there's a different function
or different factor of the leaf
that influences the spectral response
that we see there
in the visible part of the spectrum
it's a cell type in leaves
called the paloside perenkoma
in the near infrared part of the spectrum
it's a different type of cell in leaves
called the spongy mesophyll cells
and then in the mid infrared part of the spectrum
what dominates the shape of the spectral signature
is the leaf content
or sorry the water content in a leaf
now one other thing that you'll notice on this graph
and that i have listed on the right here
is something called water absorption bands
water absorption bands
are where water vapor in the atmosphere
or just water in general
has highly absorptive properties
or essentially just absorbs wavelengths very very
very strongly
which will result in very low reflectance
and that's at about these different wavelength sizes
at about zero point nine seven microns
one point one nine microns
one point four
five microns
one point nine four and two point seven
and that's what each of these dips are here
so when you see this dip here
that large dip there
this dip here
this dip here and this dip here
these are the atmospheric absorption bands
these two are also atmospheric absorption bands

this diagram just only points to the three of them here
but these kind of gray dips
are representing this y axis here
which is atmospheric transmission
and what you can see here
is that atmospheric transmission
is a hundred percent at the top here
zero percent or close to zero percent
at the bottom here
and so each of these dips
of this kind of gray that's coming down from the top
represent wavelength sizes that have very
very very little transmission through the atmosphere
when they hit the atmosphere
water vapor in the atmosphere
strongly absorbs wavelength of those sides
so very little of them actually make it down
to the surface of the ground
now we're going to talk in a bit more detail
about each of the different factors
that influence the spectral response
in these three different parts
of the electromagnetic spectrum
so if we look at the cross section of a leaf
it'll look a little bit something like this
so by a cross section
i mean if you kind of turned a leaf on its side
so you know
this was the top of my leaf
this was the bottom of my leaf
and you were looking right at the side of the leaf
and you zoomed in and you zoomed in and you zoomed in
got kind of a microscope style of zoom in on the leaf
you would see something that essentially
would look like this now
this top layer here is something called the epidermis
we're not going to worry about that too much
but these right here
these kind of perpendicular or parallel cells
that are all lined up next to each other nicely
these are called the paloside
perenkomous cells
so these cells here that are lined up

you can imagine
you know there's been many depictions of them
one common one is if you're barbecuing
and you are barbecuing some hot dogs
some sausages
some wieners
if you will
getting some nice juicy wieners going on your barbecue
you might line them up like this
all next to each other
right on the grill
boom boom boom
boom boom boom right
and so that's what you can imagine
the palicide parentoma look like
a bunch of sausages or hot dogs
lined up nicely on your grill
the spongy parentoma misofill cells are just called
often the spongy misofill cells
are these circular cells
these ones here
and these ones you can see have a lot of
actually empty space between them
if you notice there's kind of a lot of these gaps here
like right there
right there
right there
right there
and that's just air
there's a lot of air in between
each of the individual spongy mesophyll cells
again if we look at
yeah this is like one slide back
so what does atmosphere transmission mean again
so that's how well
that particular wavelength size of light
is being transmitted through the atmosphere
through the atmosphere
yeah so for these wavelength sizes here
this one this one this one
as well as kind of these two here
there's very very little transmission
of those wavelength sizes through the atmosphere

because they're getting absorbed by water vapor
very very strongly
all of it is correct
correct yeah yeah
ok so this is just another
example of diagrams of the cross section of a leaf
this is kind of a graphical depiction of it
and this is what it would actually look like
if you're looking at it with a microscope
but again you can see here
the paloside pyrenchomas cells all lined up like this
and this is what they would actually look like
in reality these are all the palicide pyrenchoma cells
all lined up
and then you have your spongy mesophyll cells
just below that
and again this diagram nicely points out
that there's a lot of space
sometimes in between the spongy mesophyll cells
there's a lot of air
whereas these palicide parenthemic cells
are all lined up very close to one another
boom boom boom boom boom
now there's chlorophyll pigments
chlorophyll pigments
that reside in the paloside pyrenkoma cells
chlorophyll in plant cells
is what drives photosynthesis
so chlorophyll is a pigment in cells
that drives photosynthesis
which is essentially how the leaves create energy
and ultimately
how they create matter to be able to grow
so chlorophyll pigments in the paloside perenkama
have a very significant impact
on the absorption and reflectance of visible light
paloside perenkoma cells
are what control the spectral response of leaves
and the visible part of the spectrum
on the other hand
spongy mesophyll cells have a significant impact
on the absorption and reflectance
of near infrared light

or near infrared energy
so spongy mesophyll cells
are what dominate and highly influence
the spectral response of leaves
in the near infrared part of
the electromagnetic spectrum
so the paloside perenkima here
that hosts the majority of the chlorophyll
that's what dominates the spectral response
and the visible part of the spectrum
the spongy mesophyll
these guys here
that have a lot of airspace between them
kind of look like little peas or little pods
these are what dominate the spectral response of leaves
in the near infrared part of the spectrum
so for
for the paloside perinchemous cells
again these ones that are all nicely lined up
these have chlorophyll that reside in those cells
the chlorophyll drives photosynthesis in that cell
which drives the health and the energy creation
in that cell
chlorophyll has very high absorption properties
of visible blue and visible red light
high absorption properties
of visible blue and visible red light
that means that chlorophyll
de facto has to have low reflectance of low
of blue visible light and red visible light
so chlorophyll strongly absorbs
blue visible and red visible light
and thus has very
very low reflectance
of blue visible light and red visible light
that's why you see this pointed out here
these chlorophyll absorption bands
so chlorophyll in the paloside perinchemous cells
strongly absorbs light in this area of the spectrum
and in this area of the spectrum
and that's why you see this little hump of green
is because it doesn't absorb green light
as much as it absorbs blue and red light

now in reality
there's lots of other pigments
that also reside in the paloside pyrenkema cells
and potentially can influence color
in the visible part of the spectrum
or the spectral response
in the visible part of the spectrum
four leaves
there's things like
there's obviously chlorophyll
that's what we've talked about
but there's also carotenoids flavonoids
carotenoids
anthocyanins
xanthophylls
all of these different pigments
that could potentially influence the spectral response
of the leaf
in the visible part of the spectrum
now chlorophyll
the part that
the pigment that drives photosynthesis in the leaf
has as i mentioned
very high absorption
in both the blue and red part of the spectrum
very very high absorption
in the blue and red part of the spectrum
now technically
there's two specific types of chlorophyll
chlorophyll a and chlorophyll b
i don't expect you to be able to
differentiate between the two of them
but it's very important to know
that chlorophyll's influence
on the spectral response of a leaf
is that it has very high absorption
of visible blue light
and very high absorption of visible red light
which is what you can see here
so on this graph here
you're seeing absorption on the y axis
wavelength size on the x axis
you can see here

very high absorption
in the visible blue part of the spectrum
and here quite high absorption
in the visible red part of the spectrum
now because of that
subsequently
you're going to see very low reflectance
in the blue part of the spectrum
and very low reflectance in the visible
red part of the spectrum
due to chlorophyll
but i also mentioned that there's these other pigments
that are potentially present
in the paloside pyrenkema cells of leaves
we have carotenes
xanthophils
file synons
all of these other kind of wavelengths
and these wavelengths might have absorption
that's high in say
the green part of the spectrum
and the blue part of the spectrum
and that's what you see here
you can see here
there's much more absorption going on
in the kind of green part of the spectrum right here
very little
absorption going on in the green part of the spectrum
here much higher levels of absorption going on
in the green part of the spectrum
by these other pigments
that are always present in leaves
so each of these pigments
all of these ones
they're always present in the leaf
they're always there
chlorophyll absorbs blue and red light strongly
most of these other pigments
absorb blue and green light strongly
so why is it then that we see a healthy leaf as green
well the reason is
when vegetation is healthy
chlorophyll pigments

are just the dominant pigment in a leaf
there's lots of photosynthesis going on
it's a very healthy leaf
so there's lots and lots and lots of chlorophyll
this essentially
masks the effect of these other pigments
that are also always present in the leaf
so essentially
this strong influence of large amounts of chlorophyll
results in very
very high visible blue absorption
and very very high visible red absorption
that essentially precedes this absorption
going on in the green part of the spectrum
now what that means is
when vegetation starts to snes
when fall comes around
vegetation starts to get yellowish or reddish
that's not because there's new you know
there's new pigments that are appearing in the leaf
that's only because chlorophyll pigments are dying out
in the paloside perenkimous cells
when the chlorophyll pigments die out
there's no longer that very strong absorption
in the visible blue and visible
red part of the spectrum
but the absorption properties of those other pigments
the keratinines
phylcyanins
xanthophylls
are still present
which means that there's still
relatively strong absorption
in the blue and green part of the spectrum
resulting in a higher overall reflectance
in the red part of the spectrum
which is why we then see leaves as red
orange yellow
things like that
so healthy leaves are going to look like this
it's going to have
because of the chlorophyll
very low reflectance

in the visible blue
and visible red part of the spectrum
again because chlorophyll absorbs
visible blue and visible red light very strongly
it's going to have relatively low
or very low
reflectance
of the visible blue and visible red light
and then overall
it's going to have a slightly higher
reflectance in the visible green
when leaves become unhealthy
when they lose their chlorophyll
you don't see a massive dip
in the amount of green reflectance
because all that's really changing
is now you don't have chlorophyll
strongly absorbing visible blue and visible red light
so chlorophyll
essentially
because it absorbs
visible blue and red light so strongly
it makes the leaf appear green
when the leaf becomes unhealthy
it loses that chlorophyll
that visible blue and red absorption
that the chlorophyll was doing is no longer there
thus we're going to have higher reflectance
in the visible blue
and particularly high reflectance in the visible red
meaning that now our leaf is going to appear
kind of reddish
or kind of yellowish
or kind of orange juice
this is a super
well it's a pretty important concept
and it's one that i'll definitely test you guys on
on the midterm
on the final exam
potentially
leaves appear green not because they have an overall
very high reflectance of green light
they appear green

because blue light and red light is absorbed
much more strongly by chlorophyll than by green light
so it doesn't necessarily have to do with
green reflectance being much higher
in an absolute sense
green reflectance is higher than blue and red
for a healthy leaf relatively
but that's only because the abundance of chlorophyll
and healthy leaves
strongly absorbs visible blue and visible red light
makes sense any questions
sweet okay definitely expect a midterm
or final exam question on that maybe both
okay so that's the visible part of the spectrum
that's what influences the response that we see
in the visible part of the spectrum
so a healthy leaf is characterized by strong visible
blue and red absorption
and a relatively higher amount of green reflectance
and then an unhealthy leaf
is characterized by much lower visible
blue and red absorption
and thus much higher visible
blue and red reflectance
kind of a relatively similar level of green reflectance
but because we now have these other pigments
that are dominating
we'll see that the leaf will appear yellow or orange
because this wavelength size here
and the yellow or orange part of the visible spectrum
will be a much
much higher level of reflectance
than if there were an abundance of chlorophyll
lot of words
a lot of things being said
are you guys with me
decent amount of knots i'll take it okay cool
okay next part of
the spectrum that we're going to look at
the near infrared part of the spectrum
i mentioned that spongy mesophyll cells
are what controls the spectral signature
or the spectral response in that part of the spectrum

in the near infrared part of the spectrum
when you look at the spectral signature of a green leaf
of a healthy green leaf
the near infrared reflectance dramatically increases
between seven hundred
to about twelve hundred nanometers
which you can kind of see here right
once we get to the
once we get to the edge
of the visible part of the spectrum
we get to red here
we get into the near infrared
boom our reflectance gets much
much much higher
in the near infrared
healthy vegetation is generally characterized
by a high level of reflectance
and a relatively high transmittance as well
to potentially underlying leaves
below that leaf in the canopy
there's very little absorption going on
but there's a moderate amount of reflectance
and a moderate amount of transmission
now the key of why you see
such a large amount of reflectance here
despite when light hits the leaf
it doesn't have a ton of reflectance right away
maybe just for you to sixty percent
but it will have an overall high reflectance
when you look at a whole forest
or a whole tree
and that's because there's high diffuse reflectance
of the near infrared energy
from plant leaves
due to internal scattering
at the cell wall interface
or cell wall air interface
and i'll talk about what that means now
so essentially
the spongy mesophyll cells right
these are the ones below the paloside perenkoma
light comes down from the sun
gets through the atmosphere

comes down and hits the leaf
when it hits the leaf
the visible light
interacts with the chlorophyll and other pigments
in the paloside pyrenkoma cells
the near infrared light
gets transmitted through the paloside perenkama cells
so it doesn't really interact
with the paloside perenkoma very much
but does interact
with these spongy mesophyll cells here
so the near infrared light
goes through the paloside perenkoma
but then starts to interact
with the spongy mesophyll cells
the way that near infrared light
interacts with spongy mesophyll cells
is quite unique
it essentially will hit a spongy mesophyll cell
and potentially refract
or reflect off that cell
out to another cell
and then kind of reflect off that cell
potentially over to another cell
so essentially
when near infrared light comes down
gets to the spongy mesophyll cells
it's bouncing all around
it's bouncing all around within the leaf structure
so it looks something like this
and there's an audio to this that i do not require
so if we have near infrared photons
which we know is just light
is radiation coming down from the sun
we got these spongy mesophyll cells in green here
once those photons hit the cells
they're going to bounce all around within those cells
that's because there's so much air space
between those cells
there's this ability for this near infrared light
to bounce around between the cells
eventually those photons
that light is gonna bounce out of the cell

now it might bounce out of the cell
and thus out of the leaf
back to our sensor
back to our satellite
back to whatever it is that we're using
to measure reflectance on that target
or at that point of the surface of the earth
but that light may also just bounce out
down to another leaf below it
or across over to another leaf on the side of it
and then when that light hits that other leaf
that's next to it
it'll start bouncing around
between the spongy mesophyll cells
in that leaf again
when it does that
it might then be kind of bounced out back
towards the sensor
that we're using
to measure reflectance
or maybe it'll bounce down to another leaf
and hit that leaf
and bounce around again
the point is
is that there is a ton of essentially
near infrared light
coming down
hitting a leaf
bouncing around in the spongy mesophyll cells
and then bouncing out in kind of a diffuse direction
which just means in all potential directions
and then maybe we'll hit another leaf
this repeated coming down
of near infrared light
interacting with spongy mesophyll cells
bouncing around
and then bouncing out to hit another leaf
and then bouncing around
and then bouncing out to hit another leaf
and then bouncing around
and then bouncing out to hit another leaf
and again and again and again
that process is what results in this very high level

of near infrared reflectance
this repeated reflectance
and transmission
of near infrared light
through a leaf to another leaf
then repeated reflectance
and transmission
through that leaf to another leaf
and so on and so on and so on
so the leaf already off the bat may reflect say
forty to sixty percent
of the near infrared energy that comes down
but the remaining forty five to fifty percent
of that near infrared energy may penetrate
may transmit through that leaf
or may be scattered to a different direction
from that leaf
and then be reflected again by a potential other leaf
to the side of it
above it below it
whatever direction it might be
so this part of the spectrum
why we see such a high level
of near infrared reflectance here
is really due to the structure
which it says here
the structure of the spongy mesophyll cells
because the spongy mesophyll cells
are this kind of pod shape
and they have lots of
intercellular air space between them
there's this ability for near infrared light
to bounce around all between the spongy mesophyll cells
and then bounce out to another leaf
and then bounce all around
the spongy mesophyll cells in that leaf
and again and again and again
which results in ultimately this very high level
of overall near infrared light reflectance
does that make sense
nod still sweet
this part of the
this lecture is usually the lecture that i get students

saying that they have the toughest time with
so if you're not following around
and you want this kind of reviewed
in the midterm review session
final review session
whatever it is
feel free to ask me
but just a warning
you'll definitely see midterm in final exam
questions about this stuff
and i know it's a little bit
tougher to wrap your head around
so feel free to ask me questions as we go through okay
everyone's good for now though
sweet ok last part of the spectrum
we're going to talk about the mid infrared
or short wave infrared part of the spectrum
that's kind of this part of the spectrum here
now as i kind of mentioned
when we first looked at this graph
water vapor in the atmosphere
creates five major absorption bands
across the near infrared
two mid infrared part of the spectrum
and that's each of these dips that you see here
in terms of transmission
so when these dips come all the way down here
on this part of the graph
that's showing a zero percent transmission
for that wavelength of light
that's called an absorption band
that is where water vapor in the atmosphere
is highly absorbent
of wavelengths of that size
you can see there's five of them
one two three four five
and they're denoted by these wavelength sizes here
now likewise
water content in leaves create water absorption bands
so when you look at a detailed
spectral signature of a leaf
you'll see a slight dip in reflectance
at those same bands

so there's a slight dip there
a slight dip there
a slight dip there
a slight dip there
and a dip here
and that's because water that's present in the leaf
is highly absorbed
it absorbent
absorptant absorb
what's the word absorption
absorptance
absorptance
i have no idea
that's okay
there's a lot of absorption going on
that's the point
so right around this wavelength size
this wavelength size
and then these three wavelength sizes here
water that's present in the leaf
is highly absorbing those wavelength sizes
the same way that those
that water vapor in the atmosphere
is highly absorbing incident energy coming from the sun
of those wavelength sizes
so that's why you see these kind of little dips here
here and here
this is just a less detailed version of this
which is why you see these two little dips here
but you don't see them here
but they do exist
now that just explains why you see this general kind of
pattern of a dip
a dip a dip
a dip a dip
in this spectral signature
the more important thing to remember
is that there is a strong relationship
between the reflectance in the mid infrared region
and the overall amount of water present in the leaf
water and leaves
absorbs incident energy between the absorption bands
in the mid infrared or shortwave part of the spectrum

at increasing strength at longer wavelengths
all that means is when you look at this spectrum
you'll see here that from right about there
where the mid
or shortwave infrared part of the spectrum starts
as we travel to the right
and get longer and longer wavelength sizes
you'll see overall
there's this trend of lower reflectance
longer wavelengths we see lower reflectance overall
there's this overall downward trend
that's all we're describing here
and that's just because at longer wavelengths
in the short wave infrared
or mid infrared part of the spectrum
water is more strongly able to absorb
the longer the wavelength
and the mid infrared
or shortwave infrared part of the spectrum
the more strong
water in the leaf is able to absorb that energy
this is what i just said
water is good absorbent in france
the gray and the water kind of leaves the lower
the mid infrared reflectance
yeah exactly
so if we look at a spectral signature of leaves
of say wet leaves versus dry leaves
we'll see that if we look at the spectral signature
of a dryer leaf
say only about thirty percent moisture content
there's this overall higher level of reflectance
all throughout the mid infrared
or shortwave infrared part of the spectrum
if we have a wetter leaf
say ninety percent moisture content
then you'll see that overall
there's a much lower level of reflectance
in the short wave infrared
or mid infrared part of the spectrum
so that just means that this whole line
either shifts up or down
all throughout that part of the spectrum

ok just to review
there's three kind of key concepts we went over
talking about the spectral signature of vegetation
in the mid infrared
or shortwave infrared part of the spectrum one
is why we see these dips
why we see each of these little dips here
these ones are especially prominent in the shortwave
mid infrared part of the spectrum
why do we see those dips
it's because those are absorption bands
those are called water absorption bands
that's where water is strongly absorbent
of those particular wavelength sizes
then we also talked about why we see
this overall decreasing trend
throughout the mid infrared
or shortwave infrared part of the spectrum
that's because as we get longer wavelengths
as we get larger and larger wavelengths
water absorbs mid infrared or shortwave infrared light
more strongly and more strongly and more strongly
okay so we've explained why we see these dips
we've now explained also
why we see this overall downward
decreasing trend in that part of the spectrum
and then lastly
the overall amount of water content in the leaf
will dictate overall
how high or low
this whole part of the spectral signature is
in our spectral signature's graph
a drier leaf
for the whole part of the spectral signature
will be a much
much higher reflectance throughout
while a wetter leaf
for the whole part of the spectral signature
and the mid infrared
or shortwave infrared part of the spectrum
will have a lower reflectance
because that increased level of water
is absorbing that energy more

are you still with me
couple of nods
i'll still take it
okay cool so
quick review then
kind of summary
the dominant factors controlling leaf reflectance
in the visible part of the spectrum
are the various leaf pigments
in the paloside perenkoma
when leaves are healthy
chlorophyll dominates
and chlorophyll has very high absorption properties
in the visible blue
and visible red part of the spectrum
when leaves become unhealthier
that chlorophyll goes away
that strong absorption
in the blue and red part of the spectrum is lost
and thus those other pigments start to become dominant
we see higher levels of reflectance
in the yellow red parts of the spectrum
we see leaves that appear more yellow or red
in the near infrared part of the spectrum
the scattering
the repeated reflectance and transmission
of near infrared energy
that's bouncing all around the spongy mesophyll
is why we see a very high level of overall
near infrared reflectance
in that part of the spectrum
for vegetation
for short wave infrared or mid infrared light
we know that that's controlled by water
we see those dips in the spectrum
in the spectral signature
because we know that there's water absorption bands
we see that there's an overall
increased amount of absorption
as we get longer and longer wavelengths
so water absorbs more strongly in the mid infrared
as we get longer and longer wavelengths of light
and then we also see

for the entire portion of the shortwave infrared
or mid infrared part of the spectrum
there is going to be a higher overall reflectance
for that whole portion of the spectrum
if we have a drier leaf
and there's going to be a lower level of reflectance
for that whole portion of the spectrum
if we have a wetter leaf
make sense
ok sweet
video here just kind of summarizing that
just to drill it home one more time
let's just remind ourselves
how the spectra signature should be drawn
on the x axis we have y
which could be an animators
from four hundred to twenty five hundred
and on the y axis in the reflectance
in percent of those between zero and one hundred
and now let's think about the three main components
of a leaf and how that affects the vegetation response
and the leaf is made up of the palisade borencoma
and the palisade borencoma houses the pigments
the dominant pigment being chlorophyll
we know this pigment response drives our response
in the visible part of the spectrum
from four hundred to seven hundred nanometers
in the near infrared part of the structure of the leaf
in the spongy mesa film is driving the effect
and then in the middle shot i think for red
as the water in the leaf
that causes the patterns that we see
now let's draw a healthy way
we know a healthy need is for chlorophyll
in the green part of the spectrum
there is an option because of chlorophyll
so we see a characteristic green peak
associated with why we see vegetation of green
in the near infrared
part of the spectrum
we see a massive change
we see large amounts of photons
bouncing around inside the leaf structure

that ultimately go away and bounce back to the sensor
and as a result we see very
very high levels of reflectance
up to eighty percent
in the near infrared part of the spectrum
associated with the spud
in the mid infrared part of the spectrum
water becomes a major impact
leaves are very hot
the air loss of water
as a result the photons are being absorbed
a wetter leaf will have more phase on absorption
if there's more absorption
there must be less reflectance
so we see that high peak
in the infrared part of the spectrum drop down
as the water absorption starts to have an effect
we see a dip around fifteen hundred
that's associated with the water vapor
in the atmosphere
and then reduction in reflectance
down to about twenty percent
in the mid infrared
jaw and infrared part of the spectrum
now let's contrast this health relief spectrum
with an unhealthy leaf
and this prefaces by saying that an unhealthy leaf
is going to have less chlorophyll
breaking down the structure and will be dry
with that in mind
let's think about the visible part of the spectrum
an unhealthy knee has less chlorophyll
if it has less chlorophyll
it must have less absorption
if it has less absorption
it must have more reflectance
so therefore we would expect the line in the red
and the blue part of the spectrum
to be above that of the healthy nine
the green may stay the same
so we still may be having a green leaf
that's starting to lose some of its chlorophyll
so expect the green reflectors to be similar

but the blue and the red to be higher
in the near to red part of the spectrum
there's much less bouncing around
because the structure of a leaf is breaking down
the photons are not able to bounce around as much
and they start to get absorbed by the leaf itself
this absorption increases
causing a reduction in the reflectance
so we expect to see the line
increase in the near infrared
but nowhere near as steeply
as it does for a healthy leaf
and ultimately
it'll be less inherent inference
than for the healthy education
in the water
the dry range of water in the shot
by the infrared part of the spectrum
the leaf is becoming dry
that means there's less water
if there's less water
there's less absorption
if there's less absorption
there's more reflectors
so we would actually
expect higher levels of reflectance
in drier levels
in disseminated correction
so connecting those components together
we see that the vegetation spectrum of diet leaf is
in fact above the healthy leaf in the visible
below the healthy leaf in the amphorae
and back above the leaf
the healthy leaf in the mir
and infrared
the short wave infrared
as we move to that longer part of the spectrum
okay now any questions about that
before we kind of move on to our final topic
no okay cool
so the last thing i want to talk about
is essentially just an example
of applying the knowledge we have

of the spectral signatures
of healthy versus unhealthy vegetation
to create something called a vegetation index
or vegetation indices
so essentially
we know that
you know in this red edge part of the spectrum
where we go from visible red to near infrared
there's this very large discrepancy
in the level of reflectance
for a healthy leaf
we get this characteristic
very high near infrared reflectance
and very low visible red reflectance
and we could take advantage of that
to be able to assess things like vegetation health
and vegetation cover
so the first vegetation index that was created
was called the simple ratio
it just used the near infrared
divided by the visible red
to get a ratio
to get a value that essentially just described
the health of the vegetation
so if it was healthy vegetation
there be a higher near infrared value
so an overall higher simple ratio
if there was less near infrared reflectance
an unhealthier leaf
you get a lower simple ratio value
indicating lower plant health
conversely in the red part here
if you had a healthy leaf
you'd have very low red reflectance
so you get an overall
very high simple ratio value
reflecting a healthy leaf
and on the other hand
if you had an unhealthy leaf
you'd get very
or relatively much higher red reflectance
giving you a lower overall simple ratio value
reflecting a unhealthier leaf or portion of vegetation

so it just takes advantage of this inverse relationship
between chlorophyll
absorption of red radiant energy
visible red
and increased reflectance of near infrared energy
when plants are healthy
so just takes advantage of this right
takes advantage of healthy
healthy leaf
healthy plant
high near infrared reflectance
low visible red reflectance
unhealthy leaf
unhealthy plant
much lower near infrared reflectance
much higher visible red reflectance
now the problem with the simple ratio was
it was just kind of an arbitrary value
there was no range to it
there wasn't anything to kind of say
well you know
this value is reflective
or associated with this amount of plant health
so we came up with something called
the normalized difference vegetation index or ndvi
and all ndvi does is
takes the concepts behind the simple ratio
and just allows
for standardized values
which just means that ndvi
only ranges from a value of positive one
to a value of negative one
generally speaking
where any positive value from zero to one
represents some sort of vegetation cover
and values that are closer to one
represent much healthier vegetation
values closer to zero
represent much less healthy vegetation
and again it takes advantage of this same concept
where we just have a higher
level of near infrared reflectance
for our healthy vegetation

so this near infrared value is going to be high
and a lower value
of visible red reflectance
when we have healthy vegetation
so this visible red value is gonna be low
that's gonna give us an overall high value
of our denominator
which is gonna give us an overall high ndvi value
and then vice versa
if we have unhealthy vegetation
so ndvi is a variety of applications
i've used vegetation indices
in my research
to quantify
the greenness
or presence
of green vegetation
around areas
where we're sampling
for grizzly bear
and grizzly bear occurrence
which i think is a pretty fun application of it
but there's also a wide variety
in agriculture
in just being able to monitor
levels of growing seasons
how long growing seasons occur
how the green up vegetation occurs seasonally
large variety of applications
but if i ask you on an exam
and you say
to quantify
bear habitat
is a nice application of ndvi
i'll be really stoked
just saying
you don't have to
but again it just takes advantage of the phenomenon
that we know exists where
if we have a high level of near infrared reflectance
and a low level of visible red reflectance
for healthy vegetation
we're going to get a larger denominator

which gives us a positive
very high positive value
closer to one representing healthier vegetation
and then if we have lower near infrared reflectance
higher visible red reflectance
then we're going to get a value for ndvi
that's closer to the value zero
representing much unhealthier vegetation
again still taking advantage of this phenomenon
right here boom boom
ultimately we can also go away and build up entire
kind of grids or rasters or data sets
that look at the entire surface of the earth
and can help us understand things
like where different eco regions are
where different biomes occur
all different kinds of things
based on understanding what the ndvi
or in this case the evi
which is just an updated version of ndvi
is telling us about vegetation health
about vegetation cover
about greenness
about how plants are cycling through the year
when they're senescing
when they're greening back up
and starting to grow again
lots of different applications
and a really valuable data set
i'm sure you are all tired of hearing me talk
which is totally understandable
i want to give you a couple minutes
to quickly brainstorm these practice questions
give you about two minutes or so
and then we'll go over the answers to them
and then i'm going to give it to tristan
he's going to go over a couple tips and tricks
for assignment two
and then you can ask him
come down and ask him any questions if you have any
about assignment two
so if you want to head out now
and knock over these questions

please do so
if you want to stick around and go over these then
i'll do that in about a minute or two
if you are heading out
please do so swiftly
we don't have a lot of time
so i'm going to have to go over these quite soon
thanks guys
hey yeah photograph right
so like divided to three thirds right
yeah i understand this
i understand the uh
what was the middle one called
the near infrared
the near infrared yeah yeah
over that one right
what affects it is the structure
yeah where it bounces around
yeah yeah cause the higher one
yeah yeah yeah
but when it breaks down like how does it differ
so essentially when it breaks down
the spongy mesophyll cells just aren't as healthy
they're not spaced out as nicely
and so the chemical
essentially reactions that go on with the incident
near infrared light and with the spongy mesophyll cells
are no longer such that it's bouncing around
and reflecting everywhere
the spongy mesophyll cells are now absorbing
more of that near infrared light
also hypothetically
feels like it works
right correct
correct correct
but if you're more space together
it wouldn't work if like
the spongy music
those were like really tight
yes sir if they're more tight yeah
then there wouldn't be nearly as much
kind of bouncing around between the cells as there is
yes yes yeah no problem

yeah hey yeah
so the spongy mesophyll cells
controls how much you reflect the light
in the near infrared
the light is in the
just in the near infrared portion of the spectrum okay
portion only
um and i have a question on
okay so the healthy one in the nir
it reflects a lot cause like
like half of the
one or half of the lights
did you say weight length
half of the weight length are absorbed
and then you have to like
reflect it to
not not not
half are absorbed
half are reflected
half are transmitted
a very very low proportion is absorbed
when it's healthy vegetation
half are reflected
half are transmitted
and then yeah
bounces off
keep bouncing off and
yeah reflex right yeah
so theoretically even
like i got a i
we're gonna run out of time
so i gotta go over these questions really quick
but i'll plenty of time to talk to you
like right after i go over these
is that okay
sorry about that
i gotta go over these and then we can talk after
i don't have any
no no if you need to ask questions
that time is right after lecture
yeah yeah but you can also
you can also email me
i'm happy to type that response

if you really need to set up a meeting with me
you can also do that too
yeah yeah okay guys
we don't have a lot of time left
so let's quickly go over the answers to these questions
so the first one
which surface interaction
is used by earth observing satellites
to take images of the surface of the earth
so there's three interactions
that can occur between light and surfaces on the earth
there's transmission
absorption reflectance
which one of those is the surface interaction
that we use to take images of the earth
reflectance
yeah exactly
and then what are remote sensing scientists
able to accomplish
by comparing spectral signatures of different materials
what's so valuable about doing that
they can distinguish and analyze
david j exactly
they can easily differentiate different materials
on the surface of the earth and then analyze them
what does ndvi stand for
anyone tell me
anyone
normalize different vegetation index
and what parts of the electromagnetic spectrum
does it take advantage of
what two parts of the spectrum yeah
visible red light and near infrared light
yeah exactly
and then one final time let's go over together
what are the dominant factors
controlling the respectful response of leaves
in the visible part of the spectrum
yeah chlorophyll
chlorophyll in which cells
the palisy perenkoma
yeah chlorophyll in the palisy perenkoma
and then in

the near infrared part of the spectrum it's what
spongy mesophyll
yeah exactly
so it's the leaf structure exactly
the structure of the spongy mesophyll
having lots of air between them
so that the near infrared can bounce around and then
what about the mid infrared part of the spectrum
water water content in the leaf
exactly okay
that is it for me
i'm gonna hand it to tristan here
he's gonna go over some tips quickly
and then you're welcome to come chat with him
if you have any questions about further about that
there's only
technically about three minutes left in class
so be swift and then they can always come down
this guy right there yeah
you can hold this
oh right right yeah
hey everyone
yeah so i'm just gonna go over a few tips and tricks
just as a reminder
i have two hour long office sessions remaining
one on wednesday at eleven a m
and one on thursday at five
so there hasn't been
a whole lot of questions about this assignment
and very few people have shut up to office hours
so this could either mean
that people haven't got around to starting it
or nobody's having any issues
so that's both perfectly good reasons but i
so instead of addressing common problems
i thought i would just
just further explain some of the questions
and make sure everyone knows
how to interpret some of the websites you have to use
so the first is regarding question six and seven
where you use
the tisic indicatrices to compare map projections
so basically

the way this works is that you have a series of
red spheres
and in an idealized map
where there's no distortion taking place
you would see that all of the circles
would be the exact same size and shape
so that's the ideal
and that would correspond to a map that depicts
all of the surface features of earth
as they are on the actual earth
but as you know
all map projections
have to make some sort of compromise
so basically
if you look at the mercator
we know that it is a conformal map projection
that prioritizes preserving angles
so this means that shapes
i shouldn't just give the answer but yeah
so you can see that one of the features is distorted
so the size of features is distorted
and you can see
moving from the equator out towards the poles
that the shape of these spheres remains circular
but they're inflating in size
and so you can use the same line of thinking
to investigate the other map projections
and just see whether or not
it's preserving the shape and size
so in some of them
it'll preserve the shape in certain areas
but then if in other areas it distorts it
yeah and for question seven
it's basically asking
in these two map projections where you know that
shape is being distorted
it's just asking you
to look at certain parts on the map
and to visually inspect whether or not
in these areas
if there is a region where the shape is being preserved
and you can basically figure this out by looking at
the ticit indicators

and then you can also look at
some other supplemental information
that can help bolster your argument for it
i mean wikipedia
is it's an okay resource for this level of information
but there's also
and i'm going to post this in the discussion board
there's the ezri arc gis
page that gives you definitions
of all the map projections
and some of them it'll just tell you where the shape is
preserved in the different projections
so i'll be posting that to the discussion board tonight
i haven't had any questions about this
but for question thirteen
yeah so one of this
if you plug in the coordinates properly
you'll end up with to maps like this
and it's just asking you which is the most direct route
comparing these two types of distances
so by direct we just mean the shortest distance
so it's not taking into account any
means of travel or anything
so it's just comparing distances
so for question fourteen this has to do with utm zones
so i'll just quickly explain how to read a utm zone
so unlike for example the mercator
which is measured the coordinates
the utm zone the unit of measurements are always meters
and so in each of them
the centerline
the meridian
always corresponds to five hundred kilometers
so it's basically asking you
at the widest part in the utm zone
which is at the equator
what is the maximum meters on this side
and on that side
so it's a pretty
simple calculation you have to make knowing
my pointer's gone
knowing what the width is at the equator
and knowing what the value is at the center point

and for question sixteen it's
you're comparing a geographic north pole
so basically true north
so that is a fixed point
so it's based on the rotational axis of the earth
so that's always in one fixed point
and basically the idea is just to think about
how that differs from magnetic north
so magnetic north is based on the earth's magnetic
properties and it is not based on like
a reference coordinate system
it's based on other physical properties of the earth
and so this is an interesting figure
that shows how much the magnetic north has drifted
since nineteen hundred
so yeah i think the question is pretty straightforward
if you look at a few figures like this
yeah and that's it
alright hi everyone we can get started
can any of you tell is this
is this lecture hall much bigger than the other one
or do we just have way less people today
what do you guys think
fewer people
and that's probably just because
this isn't on the midterm
probably yeah
yeah fair fair
cool okay um
so today we are talking about resolutions
resolutions in earth observation
it's one of two lectures the end of class today
if you are still
if you have any last minute questions
he still has some office hours later in the week
but if you want to talk to
tristan about the assignment that's due this week
he'll be here towards the end of class
you're welcome to chat with him
today we're talking about
like i said
resolutions
we kind of rushed the end of

or i kind of rushed the end of
lecture yesterday a little bit
so i just wanted to review
the last concept that we covered
which was about vegetation indices
so we talked about two vegetation indices
that you can derive from earth observation
satellite data
one of them was called the simple ratio
or often the near infrared to red simple ratio
the reason that we talked about that one
and its significance is that it was the first spectral
or remote sensing derived vegetation
indexed from satellite imagery
and other similar kinds of datasets
it's very simple
it's just near infrared divided by red
if you have a higher simple ratio value
then that represents healthier vegetation
that's all you need to know about the simple ratio
ndvi normalize difference vegetation index
the reason that we talk about ndvi
is that ndvi is the standard today
for spectral remote sensing derived vegetation indices
so today you were to try and find
some sort of vegetation index from satellite imagery
for the most part
it's going to be ndvi or some other derivative of ndvi
you won't ever really see the simple ratio
used these days anymore
ndvi can range on a scale from negative one to one
which was kind of its big improvement
over the simple ratio
the simple ratio
just kind of had an arbitrary range of values
but the ndvi value is standardized
from values of negative one to one
values closer to one being healthy vegetation
and in general
you're never going to see
an area that's covered by vegetation
whether it's healthy or unhealthy
with an ndvi value lower than zero

so if it's lower than zero
it's probably not vegetation cover
it's probably not a forest or grass
or some other form vegetation
if it's zero to one
then it's probably some sort of vegetation
if it's closer to one
then it's healthier
if it's closer to zero
then it's unhealthier
now both metrics take advantage
of the exact same process
or the exact same phenomena
which we talked about in detail
when we talked about spectral signatures
they take advantage of the fact that
healthier vegetation
will have higher near infrared reflectance
and lower visible red reflectance
while unhealthier vegetation
will have lower near infrared reflectance
and higher visible red reflectance
so these are the equations for the two indices
they both take advantage of that same phenomena
they just essentially scale the values differently
because ndvi
just standardizes them from negative one to one
whereas the simple ratio
you might get a wide range of arbitrary values
but again just to drill at home
they both take advantage of the exact same process
which is just that
if you're looking at the spectral signature
of healthy vegetation here in green
you're going to have much lower visible red reflectance
much higher near infrared reflectance
that's going to give you a higher ndvi value
if you have unhealthier vegetation
you're going to have much lower
sorry much higher visible red reflectance
much lower near infrared reflectance
you're going to result with a much lower ndvi
or simple ratio value

any questions about that
but ndvi that will be on the midterm
all good okay sweet
just make sure this is recording it is
okay so today
we are going to talk about the different resolutions
that are important to consider in earth observation
we'll try and understand why they're important
when imaging the earth
and then we're going to talk about three
different types of resolution
spatial resolution
spectral resolution
and temporal resolution
we're going to define each of them
discuss their importance
and then hopefully
you know you can
hopefully you'll get kind of a
holistic view of how all of these different resolutions
can result in different kinds of data
different kinds of satellite imagery
and thus different applications for that imagery
but you can definitely expect that
a lot of the topics that we talk about today
especially resolutions
there will be a lot of questions about that
on the final exam
it's a really
really important topic
when it comes to earth observation
okay to start
i just have this intro video that kind of talks about
some of the stuff we talked about yesterday
and then also introduces some of the concepts
we're going to talk about today
sensing spectral
related to the electromagnetic spectrum
which includes light that is both visible
and invisible to human eyes
and a real sensing
which involves measuring the properties of objects
without directly touching them

the typical camera that you use measures your records
visible light objects like trees and rock and flats
this light might come from the sun
but it also might come from other sources
like light bulbs
while we often use cameras to take selfies
in silly pictures of our furry friends
scientists use high powered cameras
called imaging spectrometers
to measure changes
in things that impact our environment
like water quality or vegetation cover and health
imaging spectrometers
mounted on airplanes and satellites
help us create maps like this
vegetation cover map for the entire united states
but how exactly
do scientists measure changes to our environment
using reflected light energy
to answer this question
let's have a look at the electromagnetic spectrum
which is composed of thousands of wavelengths of energy
physical light
what we see with our eyes is containing the blue
green and red portions of the spectrum
the rest of the spectrum is not visible to human eyes
but can be detected and recorded by sophisticated
camera like sensors called imaging spectrometers
now there are thousands of wavelengths
to record in the electromagnetic spectrum
to deal with all these wavelengths
imaging spectrometers divide the spectrum
into groups of wavelengths called bands
for example
a band in the near infrared region of the spectrum
could include energy
from eight hundred to eight hundred fifty nanometers
this band is useful to map healthy vegetation
the width and number of bands
is what we call the spectral resolution of an image
higher spectral resolution needs more bands
that are spectrally more narrow
lower spectral resolution needs fewer bands

each of which covers more of the spectrum now
imagery spectrometers measure reflected light energy
you see different objects reflect
absorb and transmit light differently
depending on their chemical and structural
characteristics
for example plant
these are green
because they reflect more green light
than blue or red light
on the other hand
fight of the dog
reflects more light in the red portion of the spectrum
because of the chemical
and structural makeup of his fur
if phyton's chemical and structural makeup
was the same as in plants
then he would look green
now when you point your camera
towards your favorite canine doing something silly
the camera records the amount of light reflected
from the dog in its surroundings
in the visible or red
green and blue bands of the electromagnetic spectrum
the camera creates what's called an rgb image
which is composed of millions of pixels
each pixel in the image contains a value
representing the amount of red
green and blue light reflected
we can break the image out into its red
green and blue bands too
here's the red band on its own
brighter pixels mean that more light is reflected
by objects in the image
and recorded by the camera
in the red part of the electromagnetic spectrum
the darker parts
are areas where less light was recorded
when we combine the red
green and blue lights together
we get an image that looks similar
to what we see through the camera lens
we can plot the amount of red

green and blue light
imported in each pixel
to create what's called a spectral signature
in this signature
the amount of energy reflected
in a particular wavelength
is shown in the y axis
and the full range of wavelengths
that were measured by the camera
in this case blue
green and red
is on the x axis
the spectral signature for phyto
is quite different from the spectral signature
for a plant
this makes it appear visually different to our eyes too
differences in spectral signatures can help scientists
identify different types of surfaces in objects
within images
most cameras record light in invisible or red
green and blue bands
however plants
dogs and other objects on the earth
also reflect light that we can't see with our eyes
for example
plants reflect up to sixty percent more light
in the near infrared portion
of the electromagnetic spectrum
than they do in the green portion of the spectrum
this is why differences in reflected light
in the near infrared portion of the spectrum
are important for mapping vegetation on the ground
to measure these differences
in the non visible portion of the spectrum
we use imaging spectrometers
which record light in both the visible
and non visible parts of the spectrum
imaging spectrometers produce what are called multi
and hyperspectral remote sensing data
multi meaning many bands
more than three
and hyper meaning up to hundreds of bands
puts it at very high spectral resolution

we use these multi and hypersectual
remote sensing datasets to measure light energy
reflected from objects on the earth's surface
and to estimate many physical and chemical properties
of objects that we wouldn't see with our own eyes
we then use these measurements to classify
what's on the ground
for example
pixels that have a spectral signature
with a lot of near infrared light energy
are often vegetation
to review different objects reflect
absorb and transmit both visible light
and light energy that we can't see
differently
imaging spectrometers
record the amount of light that these objects reflect
the amount of light energy reflected by an object
throughout the electromagnetic spectrum
is called its spectral signature
which is driven by the physical structure
and chemical makeup of the object
we can use that signature to identify different objects
in both the photograph
and across the earth's surface
and that my friends
is how we use reflective light energy
to both map what's on the ground
and measure changes in our environments
okay so they kind of mentioned
they really went over in detail
spectral resolution a little bit
but they also reviewed
the concept of spectral signatures
which was the focus of what we talked about yesterday
so we're going to talk about today
three different kinds of resolution
spatial resolution
spectral resolution
temporal resolution
spatial resolution and temporal resolution
are a little bit easier to wrap your head around
spectral is usually the one

that students struggle with the most
so if you have questions
feel free to stop me
if i'm going too fast
just tell me to slow down
okay so first off
we have spatial resolution
spatial resolution
is the smallest possible feature or object
that can be detected with a satellite image
with digital satellite imagery
which is pretty much the standard
that's the kind of imagery we have today
it's the minimum area
that can be resolved by the sensor
generally denoted by the pixel size
so any image that we take
say this is a satellite image here
and we zoom in on it
and zoom in
and zoom in
and zoom in
eventually you'd see a pattern
that would look something like this
you'd see this grid of pixels
that would have each
a different shade associated with them
a different brightness associated with them
the brightness
or the shade
that that pixel has
is denoted by something called a brightness value
or a digital number
so in this case
we have here just what's called a panchromatic image
it's just a black and white image
where we're showing overall
the amount of light
that's reflected
all across say
the visible to near infrared part of the spectrum
for this image here
and we're saying okay

let's zoom into just one section of the image
right in the middle here
let's zoom in
zoom in zoom in
zoom in eventually
we'll see something that looks like this
this kind of grid of pixels here
each one of these pixels has a value
a numerical value associated with it
that numerical value describes how much light
was reflected
off that area
that's described by the pixel
on the surface of the earth
okay so if we look at
this kind of grid of squares on the right here
we see a value of zero
that's going to be shown
very very dark
as a black pixel
there's very very
very little to no reflectance of light
of radiation
in that specific pixel
and so it gets a value of zero
and it's displayed in our image
as a completely black pixel
on the other hand
if we look at this value here
a very high value here
two hundred and fifty five
that's a very
very bright pixel
that's an area on the ground
where there is a high level of light
or radiation
reflected off of that part of the ground
back to and measured by the sensor
and we can see here
that is denoted by a very
very bright pixel
or a very very bright square
and white there

the size that each of these pixels
each one of these individual pixels
which is each measuring
the reflectance for a particular area on the ground
the size of one of these pixels
meaning the area that they represent on the ground
is what's called the spatial resolution
so if i have a pixel that say
thirty meters by thirty meters
or in other words
i have a sensor onboard a satellite or a plane
or whatever it might be
and it's able to resolve areas on the ground
at thirty by thirty meters
which means it's measuring the reflectance
for discrete parcels of surfaces of the earth
at a thirty by thirty meter scale
then that's what my spatial resolution is
it's thirty by thirty meters
generally speaking
resolutions on satellites are always fixed
because satellites are orbiting the earth
at a constant altitude
whereas if they were on board an airplane or something
it could be variable
variable depending on the altitude
that that airplane was flying at
so it might depend
that's not too important for us
we'll mostly focus on satellite imagery
so if we took this image here
say this was a very fine resolution satellite image
then in this case
it's an image of alberta
and it's a forest in alberta
it's a lodgepole pine forest in alberta
and we zoomed in on it
right in this spot here
and we said ok
let's zoom let's zoom
let's zoom let's zoom
now we can start to see some of that pixelated effect
in this image right

we can see those little squares
we know that in this case
we're looking at a lodgepole pine forest in alberta
we know lodgepole pine trees
are about three meters or so wide
and we can see here
we can kind of start to make out those individual trees
here and here and here and here
and i can see there's maybe about
five to a dozen individual pixels
covering one of those trees
if i know that those trees are about three meters wide
then i can guess that those pixels are maybe
twenty to fifty centimeters wide
which means that my spatial resolution
is about twenty to fifty centimeters
if i zoom in even more and more and more again
you can see that pixelated structure very very well
the area that these individual pixels represent
on the ground in real life
is what we describe as our spatial resolution
does that make sense any questions about that
the importance of spatial resolution
is that it directly relates
to how much information or detail
we can see in an image
if we go from a very fine resolution image here
to very coarse here
where we have
pixels that are fifteen meters by fifteen meters
to pixels that are thirty by thirty meters
sixty by sixty meters
hundred and twenty by a hundred twenty meters
two hundred forty by two hundred forty meters
all the way to four hundred eighty by four hundred
eighty meters
then that means
as we get to this coarser
and coarser and coarser spatial resolution
we have pixels
that are representing larger and larger areas
on the surface of the ground
that means that when we look at that image

it's gonna give us way less detail
with a larger pixel size
or a coarser spatial resolution
than if we look at an image
that has a much finer spatial resolution
with a much smaller pixel size
so coarser resolution has less detail and information
and finer resolution has more detail
more information
as you can see this
you can see this fine resolution image here
is really detailed
we can make out a lot of the urban environment here
we can make out a lot of the different kind of
mountains and vegetation on the side here
but when we get that coarser spatial resolution here
it's much harder to make out those kind of details
all we can really see
is kind of the boundary of the lake
and maybe some rough boundaries of generally
just dark areas versus brighter areas
does that make sense
any questions about spatial resolution
just how we define it
so we just define it with the size of the pixel
that we have in our image
and that just means that each pixel
is measuring how much brightness there is
how much reflectance there is
off the surface of the earth for a particular area
the size of that area
the size that this pixel represents in real life
is our spatial resolution
so in this case
if one of these pixels
was twenty centimeters by twenty centimeters wide
that would be a twenty centimeter resolution
of spatial resolution
makes sense
yeah yeah so
it's dependent on how far the sensor is from the ground
generally yes
we don't really go into that in depth very much

because that's really only something
you have to consider with aerial or drone imagery
where you're controlling the altitude
that you're flying at
with satellite imagery
it's always at a constant altitude
so its resolution is always fixed
it never changes
but with aerial and drone imagery
yes it depends on the height that we're flying at
correct yeah correct exactly yeah
ok so to summarize
our spatial resolution
is typically defined by the pixel size
and that is generally just a function of the platform
and the sensor specifications
in geometry
as well as maybe if we're doing aerial imagery
how high we're flying
but there's two other important considerations
that we have to look at
when we consider spatial resolution
because there's really two ways
to think about spatial resolution
one of them is just the pixel size
the smallest area that we measure reflectance for
on the surface of the earth
the other is the smallest object or feature
that we can actually measure or look at
on the surface of the earth
with that image
we might have a constant pixel size
but we may be able to detect smaller or larger images
or smaller or larger features
or targets of interest
on the surface of the earth
depending on things like the spatial arrangement
of those targets
and the data quality
that we have on a given day
from a given sensor
from a given satellite
so the first one to consider

is this example here
so let's say we take an image
we have a satellite image of an area
where there's some tennis courts
right tennis court
we have black concrete
with these white lines over that concrete
the spatial resolution of this image is
sixty centimeters
so the pixels in this image
are a size of sixty centimeters
by sixty centimeters
that means that in this image
we've measured reflectance
for a sixty centimeter by sixty centimeter area
all across this image
now if we know that these tennis court lines
are less than twenty centimeters
so much smaller than our pixel size
why would we still be able to see those lines
in this image
so say we know that
these white lines on the tennis court
are about fifteen to twenty centimeters in width
but our spatial resolution for this image
our pixel size
is only sixty centimeters
somehow we're still able to see those lines
why do you guys think that might be
i'll let you brainstorm
talk about with someone
with your neighbor for a couple minutes
and then we'll come back and discuss it
brainstorm brainstorm
have at her
give her
you guys are quiet today
what do you guys think
what do you guys think
well if you look at the image
the lines aren't actually white
so with the sixty centimeter
each pixel it has some of the line in it

but it also has some of the dark in it
so the white ends up being tainted
and the kinds of end up being lined
so the pixel
pixel ends up being like a gray color
yeah like a solid white
yeah exactly yeah
does that make sense
yeah it's kind of like averaging that whole area that
yeah because there's white and black
just appears as like a really light gray kind of thing
cool that makes sense
of each pixel like
that number that they get is an average of our g and b
like the digital number
the brightness value
so you'd have
generally speaking
you'd have a different digital number
or a different brightness value
for each band or channel
of the electromagnetic spectrum that you're measuring
so you have a reflectance of blue light
reflectance of red light
reflectance of green light
reflectance of near infrared light
but you get to define
what that band or channel looks like
so in that black and white image
we were just getting one single reflectance value
for all the visible light
so we said just
if there's a really large range of
wavelength sizes that we can detect
what's the overall reflectance for all of those
so in that case
it wasn't an average
it was kind of just like a total
for all the visible part of the spectrum
ok anyone have any ideas
i know you do because we just talked about it
anyone not in the front row
that i didn't just chat with want to have a swing yeah

yeah essentially
because the lines are so reflective of visible light
and the surface that they're on is not
so if we have black concrete
with a white line going through it
the white line is twenty centimeters wide
our pixel size is sixty centimeters wide
that means we kind of have this line here
but our pixel is kind of all around it
our pixel is gonna measure the reflectance
how many photons essentially
are bouncing off that target
that sixty six
that sixty centimeter by sixty centimeter area
but it's just gonna
it's just gonna measure kinda
the average or total amount of photons
that are bouncing off that target
if we have a white line
that's sending a ton of photons back to the sensor
a ton of light back to the sensor
but then we have adjacent black concrete
that's sending very
very little to no photons back to the sensor
we're only getting one measurement for that whole area
which means that overall
we're still going to get
quite a high level of reflectance
because we have that even little sliver of a white line
reflecting all the visible light very very
very strongly
and because we're just kind of getting
an average or total measurement
of that whole
sixty centimeter by sixty centimeter pixel
it's still going to appear relatively bright
in our image here
so then would you say that the pixels in this image are
twenty centimeters
is our spatial resolution or our pixel size
twenty centimeters in this image
what do you guys think
no yeah someone shut it out

no our spatial resolution hasn't changed
our pixel size hasn't changed
we're still dealing with a sixty centimeter pixel
but the smallest object that we can resolve
or that we can detect on this image
is actually smaller than our pixel size in this case
just because of the spatial arrangement of the targets
in this case
a very bright white line
over top of a very dark black concrete surface
and the different spectral responses of those surfaces
one being very
very high in all visible light reflectance
one being very very
very low to no visible light reflectance yeah
so why isn't this image
just sixty centimeter chunks of generalized reflectance
for that sixty centimeter chunk like
if it's aggregating the amount of photons coming back
why isn't these tennis sports just average white chunks
in six to seven meters
instead of this resolution that you can see
like why are we able to kind of see
these two adjacent lines next to each other
and they're not just kind of merge together yeah
or just like the photos we were looking at previously
yeah right so that's because
we're still looking at a pixel by pixel basis
right so if we have a sixty by sixty centimeter pixel
with the twenty centimeter white line going through it
and that's for that pixel
we get generally
a pretty high level of reflectance overall
then we have an adjacent pixel to that
that's also sixty centimeters by sixty centimeters
but there's no white line going through it
we're measuring the reflectance for just that pixel
it's going to be really really low
because it's just a black concrete area
that we're looking at
we're sort of still zoomed out enough on this photo
that we're not seeing as pixels
yeah yeah i mean

you can kind of
you can kind of see them a little bit
the pixelated effect but yeah
if you zoomed in on this image close enough
you would start to see the individual pixels
yeah there's at least a sixty centimeter gap
between the two white lines
yeah so you're gonna have one gray pick like box
one black box
and then the next one is going to be white
exactly yeah
does that make sense
yeah yeah yeah yeah
ok so that's one thing you have to consider
when you're essentially looking at
what's often termed the effective spatial resolution
which refers to the smallest object or feature
that you can actually look at on an image
versus the spatial resolution
purely related to the pixel size of the image
the other thing that we often consider
is the data quality
so poor atmospheric and light conditions
when you're taking a satellite image over an area
can often reduce the effective spatial resolution
or the smallest object
that you're able to look at on a given image
these two images are of the exact same area
using the exact same sensor
but you can see here
you can make out a lot more detail in this image
because it was taken with better
light and atmospheric conditions
the atmosphere
the components of our atmosphere
are changing all the time
and as a satellite goes very
very quickly
over kind of the top
upper layer of our atmosphere
the conditions that it will pass over
will always be varying
sometimes there's really good atmospheric conditions

for satellite imagery to be taken
sometimes there's very bad atmospheric conditions
for satellite imagery to be taken
and that can have a very large effect
on what you're actually able to see in an image
so in this case
our pixel size is the exact same
but the poor conditions
increase the size
of the smallest detectable object or feature
that you can actually look at in this image
make sense any questions
a couple of nods here and there all right
so generally speaking
we can classify spatial resolution
into four broad categories
the first being low spatial resolution
so low spatial resolution we generally classify
where pixel size is greater than about a hundred meters
the low resolution satellite
that we talk about in this course a lot
is the terra and aqua satellites
which have the modest sensor on board them
they have a spatial resolution
of about two hundred and fifty meters
to a thousand meters or one kilometer
these kinds of data sets
these low spatial resolution data sets
are really good for looking at very
very broad areas
for looking at things like land cover type
or sea surface temperature
or vegetation phonology
for an entire continent or for the whole globe
because each pixel
takes up such a large area on the surface of the ground
it's very easy to make up maps or images
covering the entire surface of the earth
or covering an entire continent
an area that might be very very large
generally speaking
this kind of imagery
in the case of modus

for example is free
it's typically government owned and operated
so anyone can go onto a website called earth explorer
and download modus imagery
as well as other kinds
of low spatial resolution imagery for free
really anytime you want
but the key here
in terms of the applications
of low spatial resolution imagery
is that you don't require smaller pixels
in order to differentiate
the different surface covers that you're looking at
or the different objects or features
that you're interested in
when you're using low spatial resolution imagery
then we talk about moderate spatial resolution imagery
as about smaller than a hundred meters in a pixel size
the platform that we often talk about
and we'll talk about throughout this course
that's a really good example
of moderate spatial resolution imagery is landsat
landsat has a bunch of different landsat satellites
ranging from one to nine
landsat one to landsat nine
as well as a bunch of different sensors
we'll talk about the thematic mapper
and the operational land imager
it has a spatial resolution landsat
that is of about thirty meters
so thirty meters by thirty meters in pixel size
we're looking at here
lancethat image of vancouver
so you can see we can make out the difference between
at a much finer scale
we can see the river here
going through the frasier right there
we can see more agricultural
rural areas down here
we can make out forests and mountains up here
we can make out differences in kind of
the sediment plume
that's coming out from the frasier river here

we can make out urban areas here
and even just small
forested areas within those urban areas
details that you wouldn't be able to see
when you were looking at vancouver
from this scale here
from an image that had a much larger pixel size
so the applications of moderate spatial resolution
allow for mapping things like forest cover
insect infestation
crop forecasting
or land cover at maybe a much finer resolution
one of the biggest things that
moderate spatial resolution data is really good for
that is much harder with course
or low spatial resolution data
is mapping disturbances
mapping things like how much logging is occurring
how much burnt forest there's been from a forest fire
how much area has been
or how much forest has gotten plowed down
by an avalanche
or by a landslide
or something like that
landsat and moderate spatial resolution data
is often necessary to measure and track those things
over something like modest
which is a low spatial resolution data set
lansat is also operated by the government
by the us government
and it is free
and open source
so anyone can go online again
and download lansat data whenever you want
ok then we have high spatial resolution imagery
which we generally classify as
imagery with smaller than about a five meter pixel size
this image here is from the iconus satellite
which is no longer operating
but this example is a satellite image
with a spatial resolution of about four meters
and you can see now
we're able to make out individual buildings

individual roads
making this high spatial resolution data
really valuable for urban mapping
for road mapping
the largest difference between
high spatial resolution data
and moderate spatial resolution data
is that high spatial resolution imagery is never free
it's always privately owned and operated
which just means it gets quite expensive
you have to pay licenses or pay
kind of buy a square kilometer
in order to download and access
some of this high spatial resolution imagery
so you generally have to have
some funding from somewhere in order to get
your hands on some of this high spatial resolution data
okay for the most part
we talk about high spatial resolution data
being satellite derived
very high spatial resolution data
is generally collected from airplanes and drones
so the sensor can just be a digital camera
or some kind of fancier spectral radiometer
or other sensor that we might mount on a drone or plane
in order to fly over and take some imagery
of a certain area of interest
the spatial resolution can be quite variable
depending on the sensor you're using
depending on the altitude that you're flying
that drone or airplane over a given area
it can be all the way down to less than centimeters now
so we can get imagery that's ten millimeters
by ten millimeters
on some very high resolution sensors
that are often flown on drones at very
very low altitudes
the biggest application for those
in kind of a conservation
environmental application sense
is for monitoring individual trees
so when we fly drones and aerial imagery
at relatively low altitudes

we can see individual trees in those images
and because we have many
many pixels
representing the reflectance for an individual tree
we can very
very accurately monitor the health and progress
and growth of individual trees within say
a forest stand
so we can measure their health
if they're being infested by insects
we can monitor how big trees are
if they're growing
what their shape is like
a bunch of different things
and that's kind of the
new age form of earth observation
remote sensing
is this push towards drones in their application
which we'll talk about
in a lot more detail towards the end of the course
drones in aerial imagery
you can also imagine for the most part are not free
you have to pay for a pilot or someone to go and fly
your airplane or fly your drone
so it's often
it often requires funding as well
generally not free
to be able to go get aerial or drone imagery
which means that for a very high spatial
resolution imagery
you're going to have to pay some money for it
ok any questions about
different kinds of spatial resolution imagery
spatial resolution as a whole no yes no
the next kind of resolution that we'll discuss
is spectral resolution
spectral resolution is usually the type of resolution
that students struggle with the most
so if you have any questions
if i'm going too fast
let me know
we can define spectral resolution as
the number and dimension of specific

wavelength intervals in the electromagnetic spectrum
to which a remote sensing instrument is sensitive to
that's kind of the long sentence form
and kind of point form
how we can describe
spectral resolution is with three components
the number of spectral channels or bands being used
their location in the electromagnetic spectrum
and the band
width or range of each of those channels or bands
so if i were to ask you
say on a final exam
what are the three components of spectral resolution
you would say
the number of spectral channels used
their location in the electromagnetic spectrum
and the bandwidth or range
of each of those channels or bands
if i were to ask you on the final exam
hint hint win
twink nudge nudge so
if we were to look at a spectral signature
of vegetation
right of healthy vegetation
we see that characteristic green hump
in the visible part of the spectrum
that high level of near infrared reflectance
and then kind of a steady drop off
as we get into the short wave
infrared part of the spectrum
we said okay
for this particular sensor
we want six different bands
or ranges across the electromagnetic spectrum
that we want to measure reflectance for
we could say okay
well we're going to put band one here
in kind of the blue part of the spectrum
we're going to put band two here
in the green part of the spectrum
band three in the red
band four in the near infrared
and then band five and seven here

over in the short wave infrared part of the spectrum
now this is the actual
a depiction of an actual spectral resolution
from the lanstat seven satellite
and you'll notice that it goes from band five
to band seven
that's just because landsat has a sixth band
called band six
but it's in the thermal infrared part of the spectrum
not sure why they don't just call that one band
eight or band seven instead
but they call it band six
it's in the thermal infrared part of the spectrum
so it's not shown on this graph here
because the wavelength size of a thermal infrared band
would be theoretically way off here in a much
much higher wavelength size
or longer wavelength size
but essentially
landstat seven
from the visible to shortwave infrared part
of the spectrum
senses reflectance in each of these bands
so from wavelength sizes of about
four hundred and thirty to five hundred nanometers
it's able to measure reflectance
of just those wavelengths
just those photons
with that size wavelength
then it's also simultaneously
able to take a measurement
of wavelengths with a size of say
five hundred to five hundred and sixty nanometers
and measure the reflectance
of just those wavelength sizes
separately from the wavelengths in the band one here
then it does the same thing for band three
and band four
and band five
and band seven
so for each pixel
landstat seven
as an example

will get a measure of reflectance
how many photons are bouncing off a target
going back to the sensor
for each of these bands
so say okay
how many photons am i getting for band one
for wavelengths that have a size in this range
for band two
for wavelengths that have a size in this range
for band three
wavelengths that have a size in this range
and etcetera
etcetera etcetera
does that make sense have i lost anyone
guys are so quiet it's scary
okay i'm gonna assume
hopefully ok
so if we looked at this in kind of a table form
as opposed to a graph form
we have here our band numbers
and where they are located in the spectrum
so we see here
okay there's seven bands
for lancet at seven
they're located in the blue green
red near infrared
shortwave infrared
thermal and again
in the shortwave infrared part of the spectrum
and then each of them
band one goes from four hundred and fifty
to five hundred and twenty nanometers
band two goes from five hundred and twenty
to six hundred nanometers
band three goes from
six hundred and thirty to six hundred
six hundred and ninety nanometers
so on and so on and so on
i'm not gonna keep going through every single one
because i will get tongue tied
but the point is landsat
the thematic mapper sensor on landsat
if you were to describe its spectral resolution

you could also say
well it's got seven channels or seven bands
they're located in the visible
near infrared
mid infrared
and thermal infrared part of the spectrum
and they have bandwidths ranging from sixty
to two hundred and seventy nanometers or
and additionally
the thermal one is about
twenty two hundred nanometers wide
so you could describe the band widths
or the range of wavelength sizes
that each band or channel is sensitive to
by just saying
what the start and end point is of each band
or by just saying approximately
where they are located in the spectrum
and then what the actual width is
in nanometers of each one
makes sense yeah
so is spectral resolution defined as
like when something has a higher spectral resolution
does it just mean that it takes like it can see light
detects light from more of a spectrum
correct okay so
it has nothing to do with the actual size of each hand
it does a little bit
those things are inherently connected
so if you increase your spectral resolution
you're going to have more bands
but each of those bands is going to be thinner
does that make sense
so if you have what's called a panchromatic image
which just has one band
it would be one large broadband
it would measure photons
with a size of four hundred and thirty nanometers
all the way to seven hundred nanometers
it'd be one broadband
that be the lowest spectral resolution
you then go to a multi spectral sensor
say a moderate spectral resolution

maybe you're looking at something like lance at seven
where you have about seven spectral bands
now though they're not as wide
right the the panchromatic one
the one that had the lowest spectral resolution
had this one broad band
covering this whole part of the spectrum
for lance at seven it covers
each band covers a smaller part of the spectrum
a smaller region
but there's more of them
and they each get thinner and thinner
and thinner and thinner yeah
yes but the technical definition
and what i would expect from you on an exam
if i asked you to define spectral resolution
or describe spectral resolution
i'd expect the number of bands
but not just the number of bands
also where they're located in the spectrum
say visible near infrared
shortwave infrared
and the width
and wavelength size of each of those bands
or just where they start and end
specifically in nanometers or micrometers
on the electromagnetic spectrum
does that make sense
because technically speaking
and the reason for that is
technically speaking
you could just add more bands
but if we're just adding more bands
and they all have the exact same band width
then that's not really describing what our spectral
resolution is per se
you need to be able to describe
where the bands are located
how wide each of them are
and how many of them there are
makes sense yeah cool
ok
any final questions on spectral resolution yeah

yeah
so we haven't talked about
what the spectral resolution of modus is yet
we'll talk about that in our resolutions
part two lecture
which will be the first lecture after the midterm
but modus has
relative to lancethat
what you would probably describe as a higher
spectral resolution
it has more bands
so it's sensitive to a larger number of bands
across the electromagnetic spectrum
so then sorry
how is the spatial resolution
connected to the spectral resolution
we haven't really talked about that at all oh sorry
that's okay
no we were just talking about spectral resolution
just in the context of spectral resolution it is
all of these resolutions are inherently connected
but again we'll talk about that in our next lecture
or the next resolutions lecture at least
okay last resolution we're going to talk about today
is temporal resolution
this one i think
is probably the easiest to wrap your head around
so temporal resolution
is just the amount of time it takes
to revisit the same place on earth
we know satellites are orbiting the earth
they're always orbiting the earth
and they're taking images of the earth as they orbit it
the amount of time it takes for a satellite
while it's orbiting
to return to the same point on the earth
to take another image of that point on the earth
is what we describe as our temporal resolution
often just termed revisit time
now it's really important for a variety of reasons
the most being at the courses scale
that it controls
the level or the scale of time

or change analysis
that we can look at
we know that our environment is changing
but our environment changes
sometimes on the scale of a couple minutes
a couple hours
a couple days
a couple years
couple decades
the temporal resolution of a satellite
essentially defines
what temporal scale we can look at
when we want to monitor change
say for example
vegetation phonology
whether uh you know
whether vegetation is green
or whether starting to finesse and get yellow
and then die off in the winter
and then spring comes back and it gets green again
that's a seasonal cycle right
we probably need a temporal resolution
or an image
at least once per season
once in the summer
once in the fall
once in the spring
once in the winter
think that's the season i missed
in order to be able to quantify
that seasonal change in vegetation
on the other hand
sea surface temperature
for example
changes on a daily scale
certain days
temperature is warm
other days temperature is cool
we need daily imagery or daily data
to be able to monitor that change
another example is deforestation
forests getting cut down
it takes sometimes weeks or months or years

for an entire forest to be cut down
if it's being deforested or if it's being logged
whatever that case might be
if you want to just measure for a certain area
using satellite imagery how much forest has been lost
really all you need is an image
before the forest cut down
and an image after all that forest got cut down
say that's five years apart
say it took someone or an organization
a group company whatever
say it took them five years
to cut down all the forest in a particular area
then the temporal resolution you would need
to measure how much forest they cut down
would only be about five years
you would need an image from before and from after
so this is about really the difference
when you're trying to monitor changes
that happen on a daily scale
or maybe happen on a seasonal scale
or maybe happen on a yearly scale
or maybe happen on a multi annual scale
taking decades or longer
so maybe we need an image of a certain area
that same area
once every day
maybe we only need an image of that area
once every month
maybe only once every year
but that's what our temporal resolution is describing
or defining
now our temporal resolution
generally depends on two key things
one being the orbit that the satellite is in
we know that earth observation satellites in general
are in one of two orbits
either a close elliptical orbit
or a geostationary orbit
generally speaking
most of these satellites
most earth observation satellites that we look at
landsat motors etc

they're in a close elliptical orbit
we know that a geostationary orbit
is always looking at the same point
on the center of the earth
not in the center of the earth
but the same point on the earth
if a satellite is in geostationary orbit
it's always looking at the same point on the earth
what do you think its temporal resolution would be
yeah
if it was taking an image every twenty four hours
yeah you could say that but yeah
essentially it be constant
it's always looking at the same point on the earth
it can take as many images
of that same point on the earth as it is capable to do
essentially it can take images every minute
every thirty seconds every hour
if it's in a geostationary orbit
because it's always looking at the same point
on the surface of the earth
if it's in close elliptical orbit
which most earth observation satellites are in
that we'll discuss
then its temporal resolution
is more related to its swath width
so close elliptical orbits
or satellites in close elliptical orbits
generally speaking
have polar or near polar orbit
which means that they orbit from north to south
over the globe
so their swath
their path over the earth kind of looks like this
they kind of come down over the pole
orbit down to the south pole
and then return back on the other side
and keep orbiting like that
the swath width is the geographic width or area
that the satellite sensor is able to take images of
as it crosses over that point
or that area on the surface of the earth
and we know that from one of our last lectures actually

i don't know if i talked about that with you guys
that might be a different class
but in general
when we have a coarser spatial resolution say modus
because the pixels are larger
they generally create a larger swath width
which means that as the satellite is traveling
over the surface of the earth
the width of the area or path
that it's able to cover and take images of
is going to be wider
for something like modus
with a lower spatial resolution
because it has a larger pixel size
the same amount of pixels
the same amount of modus pixels
versus the same amount of landsap pixels
if you stack them up side by side
say five modus pixels right next to five landsap pixels
the five modus pixels are going to cover a wider area
because they're a larger pixel
the landstat pixels all stacked next to each other
are going to cover a smaller relative area and width
because they are a smaller pixel
if we have a larger swath width
say a swath width like this
as opposed to a thinner swath width like this
or like this
we're able to cover all of the surface of the earth
quicker with a larger swath with
imagine that we take this kind of red swath here
and we stack it up side by side by side by side by side
over and over and over again
until it covers the entire surface of the earth
if we do that with a larger swath width
we're going to be able to cover
all of the earth with less orbits
and thus less time
if we're trying to cover
all of the surface of the earth
with this thin little swath like this
we're going to have to orbit the earth way
way more times

which is going to take much
much longer
resulting in a lower temporal resolution
so if we have a larger swath width
we have a higher or finer temporal resolution
if we have a smaller swath width
we have a lower or coarser temporal resolution
does that make sense
ok
now we again talk about these two orbits
that are used in earth observation
either close elliptical orbits or geostationary orbits
just to remind you of some of their characteristics
the close elliptical orbit
we define as having an altitude of somewhere between
seven hundred to two thousand kilometers
above the surface of the earth
and the geostationary orbit we define as
the orbit speed
being matched to the rotation of the earth
so that its location is static
above a geographic spot on the earth
and it has an altitude of above about
thirty six thousand kilometers
now we can further break down
what we call a close elliptical orbit
into a polar or near polar orbit
and then into also a sun synchronous orbit
so a polar orbit is a type of close elliptical orbit
whereby the satellite passes over the poles
or near the poles
imagine that point
there is the satellite
you can see that as it's rotating
or as it's orbiting around earth
it passes over the north pole
and then it passes over the south pole
then it passes over the north pole
and then it passes over the south pole
an orbit a close elliptical orbit
that is oriented such that it passes over
either directly over the north pole or close to it
or directly over the south pole or close to it

is termed a polar or near polar orbit
so it looks like this
now the key here in how satellites work
is that they continue to orbit on this same plane
essentially
but because earth is rotating as its orbiting
then if it comes around in orbit
see where it passes over right there
now when it passes over that spot again
the equator is passing over a different area
than where it was passing over before
so if we look at that in this diagram below here
if the satellites orbiting a near polar orbit
going over close to the pole
and then back close to the south pole
if it goes over the equator at first here
and then orbits around
and the earth continues to rotate underneath it
then when it passes over the equator again
it's going to be at a different longitude
that it's passing over the equator
it's going to be at a different point
on the surface of the earth
and then as the earth continuously rotates and rotates
and our orbit
our orbiting satellite continues to orbit and orbit
eventually the satellite is able to get an image
or take imagery of the entire surface of the earth
and then once it's done that
it's able to return
to the same spot on the surface of the earth
to start retaking imagery there again
now in the case of say landsap for example
landsat always passes over the equator
at a local time of about nine forty two am
so that means that lancet at it's in its polar orbit
or near polar orbit
it comes from the north pole
and then it travels southward over the south pole
passes over the south pole
and then travels northward back towards the north pole
and then each time it passes over the equator
it passes over the equator at the same local time

always at nine forty two am
which is possible
because the earth is rotating underneath landsat
underneath the satellite as its orbiting
and so it's pushing it into a new time zone
which also simultaneously
allows it to take images of a different area
because landsat
because its orbit is also planned out
such that it passes over the equator
at the same local time
each time it passes over it
it's also termed what's called a sun synchronous orbit
i'll talk a little bit more about what that means
in the second
i'm just going to show you guys this video here
so you get a depiction
of what that lancet at orbit looks like
and thus what a polar or near polar orbit looks like
as a lands and satellite flies
over the surface of the earth
the instruments aboard the satellite
are able to view a swath
of hundred eighty five kilometers wide
and collect images along that swath
as the satellite proceeds through its orbit
the spacecraft travels
at approximately four point seven miles per second
the satellite travels from north to south
while it's over the sunlit portion of the earth
and travels south and north
over the dark side of the earth
one orbit takes about ninety minutes
so that's about
approximately fifteen orbits in the twenty four hour
the orbits maintain such that after sixteen days
the entire surface of the earth has come within view
of the landsat instruments
well sunlit
and then on day seventeen
the first ground we have is repeated
so we get to view the entire surface
once every sixteen days

so leggy said
at the very end there
landsat is able to view the entire surface of the earth
every sixteen days
that means on the seventeenth day
it starts reimaging the spot
where it first started that sixteen day cycle
that means that the temporal resolution
of landsat is sixteen days
so this is just kind of
a graphical illustration of what that looks like
its orbit is going north to south like this
orbit orbit orbit
earth is rotating underneath it
because of that
it's first orbit
the swath is going to be here
it's second orbit
the swath is going to be here
it's third orbit
the swath is going to be here
it's fourth is going to be here
fifth is going to be back over on the right side here
and then six seven
eight nine ten
eleven twelve
thirteen fourteen
that's done in about one day
so it'll do about fourteen or fifteen orbits
in about one day
in about twenty four hours
and then it'll start again
just adjacent to this first orbit here
and it'll do another fifteen orbits in a day
and then it'll start again
just adjacent to that orbit
or that path here
and then it'll do another fifteen orbits
it'll do that for sixteen days
until it's finally built up an image
or collected imagery
for the entire surface of the earth
at which point

it'll then return to the starting point of its orbit
and go over the same portion of the earth
that it's already taken an image of
so we've kind of thrown around
a couple of different terms
when we talk about these orbits
when we talk about close elliptical orbits
in particular
so what is the difference
between a close elliptical orbit
a polar orbit
and a sun synchronous orbit
so a close elliptical orbit is defined by its altitude
we've described a close elliptical orbit
as being about seven hundred to two thousand kilometers
in altitude
so above the surface of the earth
a polar orbit
is defined by the orientation of the orbit
a polar orbit
is a specific type of close elliptical orbit
that passes over the poles or close to them
that means that its orbital plane
is near perpendicular to the equator
when it passes over the equator
it's pretty much perpendicular in its path of travel
relative to the equator
a sun synchronous orbit is a specific kind of polar
or near polar orbit
where it passes over the equator at the same time
each day lansat passes over the equator
between about ten to ten thirty am
that's different from the other illustration i showed
just because
it's referring to a different lansat satellite
but the point is
any satellite that's in sun synchronous orbit
will pass over the equator
or just generally areas of the same latitude
at the same local time
every single time it passes over them
which also just means
that it passes over any same point on the earth

at the same local time
that's essentially inherently
where the value in a sun synchronous orbit lies
and why we use sun synchronous orbits
so why then
why do you think a sun synchronous orbit
would be useful
if i was taking imagery of a certain area
a certain point on the surface of the earth
why might it matter
what time i pass over that point on the earth
consider these two images
this is a bit of a hint
this sounds like an assortment is helpful
because it means that you'll always be able to see
different points of the earth at day or night
based on like probably two cycles of landslide
so in its second
return time
yeah after its revisit time yeah
mm hmm
yeah
i hear what you're saying
that's not quite what i'm hoping to get out of it yeah
that's that's the key
that's the key
so the problem is
if you take an image of the same area
at different times of the day
then you are gonna get different values of reflectance
for that same area
just based on the time
that you're taking that imagery at
that introduces a certain level of discrepancy
or error or deviation
that you can't really account for
but if you take an image of the same point
at the same local time
every single time you take that image
then that means you can essentially say
well if there's different values of reflectance
that i'm measuring
then it has to be due to some sort of environmental

change going on on the surface of the ground there
it's not due to the time that i'm taking the image at
because i'm taking the image at the exact same time
you could imagine
if you look at this example here
and you take an image of
say this urban area at noon
versus an area of
versus that same image of that same area
but at midnight
the reflectance values you're going to get
the levels of radiance you're going to get
for each pixel
are going to be very very very
very different
but that doesn't mean that anything is changing
in these two areas
you've just taken
the image at a different time of the day
so a sun synchronous orbit
the reason that landsat
and many earth observation satellites
are in a sun synchronous orbit
is because it's able to control some of the deviation
or some of the differences in reflectance values
that you may be able to otherwise attribute
to taking an image
just at a different time of the day
if you take an image at the same point
always at the same time of day
then if you see changes in reflectance
there's got to be some sort of change going on
on the surface of the earth
at that point of interest yeah
does night time
just taking photos of places like safe forest
areas of canon
at night time
give us less overall information
or the sensors
i guess because it's not visible
right well so
so you can take

you can take nighttime imagery
and we'll talk about
some applications of nighttime imagery
but it's the same thing where
if you are taking images of a certain area at night
you want to try to take images
at the same time of night
every time you're taking an image of that same point
because if say
you're measuring the difference
in the amount of night lights
the amount of street lights
that are present on the ground
in order to quantify urbanization
then you want to make sure you're taking that image
at the same point of the night
every night
because otherwise
you're going to get different levels of emittance
just based on taking the image
at a different time at night
correct but the idea is with say
landsat or some of these other satellites
is that the temporal resolution is defined by
how long it takes that same satellite
to return to the same point on the surface of the earth
when it does return to that same point on the surface
of the earth
it'll be at the same local time
that it last passed over that point
on the surface of the earth
it's a little bit harder to integrate
different satellite data sets
because they're inherently different spectral bands
different spatial resolutions
lots of different things about them
but when you're looking at just the same satellite
that's where
the sun synchronous orbit is really valuable
because you have then the same data set
the same sensor
always taking an image
over the same point on the surface of the earth

given the same amount of angular
radiation coming from the sun
it's always at the same angle
it's always taken at the same time of day
ok now just lastly to highlight
which i already mentioned
are geostationary orbit
generally speaking most or most
earth observation satellites that we talk about
that are in a geostationary orbit
are weather satellites
an example of that is the ghost satellite
sometimes there's also telephone and
television relay satellites in geostationary orbit
because in that way
they have constant communication with ground stations
satellites that are in geostationary orbit
often have quite limited spatial coverage
they do have very high temporal resolution
because they can always take an image
of the exact same point
but they generally have quite limited spatial coverage
each satellite can only cover about
twenty five to thirty percent of the earth's surface
and the coverage generally
only extends to mid latitude areas
say at about fifty five degrees latitude north or south
so you don't get great global coverage
with geostationary satellites
but you do get very very high temporal resolution
so this is what a geostationary satellite
would look like
you've got a couple of the go satellites here
some weather satellites
some other weather satellites here as well
you'll see in a moment
they're kind of spotlight
the area that they're looking on
on the surface of the earth will be kind of illuminated
given that they're always only looking at one point
on the surface of the earth
they're actually still able to see
quite a large view of it

just because they're at such a high altitude
they're so far away from the surface of the earth
but this is the idea here
this goes satellite
it's always looking at this portion of the earth
so it's always taking imagery there
allows for a very high temporal resolution in that spot
ok couple practice questions here
i'll give you guys a couple minutes to look at them
brainstorm them with a neighbor
i have tristan here
in case you want to come down and ask him any questions
about the assignment that you're working on this week
so i'll give you
a couple minutes
brainstorm needs
we'll go over the answers
if you want to head out now you're welcome to
if you want to go over these answers in a moment
you're also welcome to stay
thanks guys
hey
so they're not exclusive right so
it could be a close elliptical
polar yeah so
close elliptical is kind of like the broadest category
so a sun synchronous orbit is a type of polar orbit
a polar orbit is a type of close elliptical orbit
okay yeah hey
i just have very quick questions about the
special resolution and also the bend
so um can we actually use the like
depend numbers to actually kind of explain why here
in these questions that the white line is
like reflective
not really not really no
so in this specific question the answer is just like
okay because the ground actually is not reflective
so the white line is like more um
kind of significant here
yeah so if you
if you like thought of it as like
this is a pixel right

this is one pixel
yeah it's sixty centimeters by sixty centimeters right
there's a white line going through this pixel
right like this
this this is a white line right
but this is black
this is all black
this is all black
this is all black
if we measure
an overall amount of reflectance of photons
for this whole
sixty centimeter by sixty centimeter square
because there's this white line going through it
and it's reflecting so many white photons
we're going to get an overall reflectance
that's relatively high for this entire pixel
so in the image here
that's sixty by sixty centimeters
the whole thing is going to be white
so this is what it looks like in reality
this is what it looks like on there in our image
and that's just because the spatial arrangement
is this one very bright line
on top of very dark black materials
so if we measure the reflectance for this overall
entire pixel
it's still going to be quite high just because this
just because this white line
even though it's smaller than the pixel size
is reflecting so many photons
okay right yes got it
yeah no problem
like this one
hey so for the spatial resolution
yeah um so if the
if this image is sixty centimeters
is it saying that each square is
sixty centimeters square yep or yep
okay you got it
and then okay
so the tennis court line would be like
yeah or like

or like like
the way i like to think of it is like
is like something like this like
like this is a sixty centimeter
by sixty centimeter pixel
and the white line kind of looks something like
like that yeah
can you go over this
can you go over this for me what sport please
yeah let me just go over the answers to these
and then we'll go over them
i'm just gonna go over the answers then we can talk
yeah so that one if you look at the distortion section
can you guys just hold on one sec
like over the answer is these
then you can chat to him
okay let's just go over the answer these real quick
what are the three resolutions that we discuss today
that are important in earth observation yet
yeah spectral resolution
spatial resolution
temporal resolution exactly
what are the three aspects that we use
to describe the spectral resolution of satellite
yeah the number of channels or bands moves
the band locations
and the bands with the range of those channels
exactly the number of bands or channels
their location in the electromagnetic spectrum
and each of their band widths
or ranges in wavelength size
okay this one maybe you guys can just kind of
shout out as we go through
so if we're talking about a sun synchronous orbit
is a sun synchronous orbit a close elliptical orbit
yay nay yeah it is
a sun synchronous orbit
is a type of close elliptical orbit
is a sun synchronous orbit a polar orbit
yes yeah exactly
yeah yes it's a polar orbit for sure
so a sun synchronous orbit
is a specific type of polar orbit

a polar orbit is a specific type
of close elliptical orbit
ultimately how is a sun synchronous orbit defined
how would you describe a sun synchronous orbit
you wanna go again yeah
and because it passes the rate at the same time of bj
it helps control the deviation of reflection values
because it measures different
you got it that's enough
that's good
yeah you're good
yeah really good job yeah
so a sun synchronous orbit is just a polar orbit
a close elliptical orbit
whereby you
pass by any point on the surface of the earth
at the same local time each time you pass over it
or you could say you pass over the equator
at the same local time each time you pass over it
and then you already mentioned also why it's useful
it's useful because it helps control potential changes
or deviations in reflectance that might occur
if you're taking imagery
and measuring reflectance at different times of the day
if you're always measuring reflectance
for a given point at the earth
on the earth at the same time of day
then that means that if there's different levels
of reflectance that you're measuring
it's not due to just the time that you're looking at
that portion of the earth
must be due to something else
ok and then lastly
we already talked about this one
we kind of answered it directly
what is the temporal resolution
of a satellite in geostationary orbit
it's very very high
it can be very very fine
we can essentially take repeated images all the time
of a certain point on the earth
if we're in a geostationary orbit
okay next week on monday

we're doing a review session
please post in the discussion board
if there's anything in particular
you want me to go over and
otherwise have a good week guys
and i will see you next week
oh
my god
alright hi everyone welcome back
hope you had a good break
yeah how was your break good bad
decent thumbs up
couple thumbs up
cool okay so today announcements
keep an eye out for class getting cancelled tomorrow
it might i don't know
um i know that the uh
the office that we have in the department where i work
they have already said
that they're not coming into the office tomorrow
sometimes they just do that
and class will still go on no matter what
so i'll be here as long as it's not canceled
but just keep an eye on that
what else we're trying to
we're going to try to give the midterms back to you
tomorrow so either before class or just after class
we will post midterm grades
they were pretty well done overall
how did you guys find it
decent thumbs up
sweet ok cool
sweet so for now what you should be working on
assignment three is due this thursday
tristan is going to come to the end of class tomorrow
assuming we have class
and you can ask him any questions if you'd like
there was a change to his office hours
hopefully you guys saw that
so think evans sent out an announcement
office hours are now thursday morning
i think he had a late thursday afternoon set
and now the thursday morning instead

because he has some medical appointment i believe
so that got changed
there's also two sets of office hours on wednesday
i'll actually pull those up in a second here
and then blog post four is due march ninth
so that is next week
and then assignment four due march sixteenth
so that's two weeks from this week
like i said
office hours
two office hours on wednesday
for assignment three
one set on thursday
their thursday morning
now instead of thursday afternoon or evening
on zoom as usual
that's pretty much it
any questions about assignments midterm
anything like that
okay great so
quick review reminder
where we are at in the course
i really like where we're at in the course
from now on
i think it's a lot more fun to learn and talk about
the second half of the course content post midterm
but just to remind you
the last thing that we talked about
prior to the midterm
was spatial resolutions
spectral resolutions
and temporal resolutions
so i just want to quickly jog your memory
about what each of those are
and kind of what we discussed about each of them
and then we'll go on to
kind of part two of this resolutions lecture
so quick reminder
spatial resolution
is the smallest possible feature or object
that can be detected on an image
it's typically defined by the pixel size
so the pixel size is just the smallest resolvable area

on that image
we have a pixel size of ten meters
then that means that the area
on the surface of the ground that we're measuring
reflectance for individually
is a ten meter by ten meter area
and this just impacts our level of detail
or information that we're able to get in an image
coarser spatial resolution data gives us less detail
less information
we talked about some other considerations as well
such as the spatial arrangement of targets
we use the example of the white tennis court lines
on top of the black pavement
as an example
where you might be able to resolve or detect features
that are smaller than the pixel size of the image
we also talked about data quality
how the atmosphere can heavily influence
our ability to take high quality satellite imagery
if we have poor atmospheric conditions
we might get a poorer
effective spatial resolution
so we might actually not be able to pick out
smaller features
with poorer atmospheric conditions
relative to better atmospheric conditions
when that imagery is being taken by the satellite
we then talked about low
moderate high
and very high spatial resolution imagery
we loosely defined each of them
low being greater than
what did we say
a hundred meters
i think moderate around
being less than a hundred meters
high resolution imagery
being less than about five meters
very high spatial resolution
being less than about a meter
and then we talked about
some of the applications of each of those

and kind of
you'll notice
from here on out
throughout the course
a lot of the things that we talk about
a lot of the practice questions i'm going to give you
are going to be trying to link
different topics together
so there's topics from a lot of the different lectures
that we'll discuss
that'll have a lot of overlap
and have a lot of influence on other topics
and so we're going to try to
with the practice questions
in particular
towards the end of lecture
link a lot of those topics together
one example of that is going to be
talking about
some of the specific applications
or examples
where you might need
low spatial resolution imagery
versus moderate or high spatial resolution imagery yeah
pardon me
they're on lecture ten
so there's a part two
so if you go to the lecture ten
so the same page that we had
like the last resolutions set of lecture slides on
there's a part one and then my recording from that
and then a part two right under that
and this is that part two
so it should be there
if it's not then let me know again
but i think it's there
ok so the second thing that we
or the next resolution that we talked about
is the spectral resolution
so the spectral resolution is the number and dimension
of wavelengths in the electromagnetic spectrum
that the sensor measures
so it can be

classified or categorized using three different things
that is the number of spectral bands
their location
on the electromagnetic spectrum
and the band width of each of those bands
so again if we look at this example here
we can see that there's one
two three four five
six bands here
their location on the spectrum are in the visible blue
green and red
and then in the near infrared
and shortwave infrared part of the spectrum
and we could list off the band width
of each of these bands as well
if we wanted to
we could say band one is from
four hundred fifty to five hundred nanometers
band two is from about five hundred nanometers
to five hundred and seventy nanometers
band three is about
six hundred and thirty to seven hundred nanometers
and so on and so forth
we then also lastly talked about temporal resolution
which we just defined as the amount of time it takes
to revisit the same place on earth
it impacts the level of temporal analysis possible
so do we want to look at changes
occurring on a landscape
at a daily scale
or at a seasonal scale
or at an annual scale
maybe we want to know
the daily sea surface temperature of an area
then we need very high temporal resolution data
maybe on the other hand
we're just interested in tracking deforestation
which occurs at a much slower rate
so maybe in that case
we only need annual imagery
which would be a low temporal resolution data set
we talked about how the temporal
resolution mostly depends on two things

what orbit you're in
and what the swath width of the sensor in that orbit is
so the orbit
in particular
we talked about how the geostationary orbit
gives us a very high temporal resolution
because it's always looking at the same place
on the surface of the earth
we then talked about how
we have the close elliptical orbit
the near polar orbit
and the sun synchronous orbit
so those are the orbits that look more like this
that are going north to south
from pole to pole
and when we have a larger swath width
so the sensor is imaging a wider area
as it's traveling over the surface of the earth
a larger swath width
so that would look like this
this is an example of a larger swath width
we're covering a wider portion of the earth
as we take images of it
as the satellites traveling
say north to south
a wider swath width
gives us a finer temporal resolution
because it doesn't take us as long
to image the entire surface of the earth
if we have this larger swath width
a smaller swath width
gives us a coarser temporal resolution generally
also associated with a higher spatial resolution
is a coarser temporal resolution
because with higher spatial resolution data
we have a smaller pixel size
which generally results in a smaller swath width
and thus a coarser temporal resolution
now we know kind of some of the characteristics
now of each of these sensors
we can describe them using the different resolutions
most satellites do not have a lot of onboard recorders
in order to

kind of record and store the data that they're taking
as they're orbiting the earth
they need to downlink their data to
essentially ground stations that collect the data
so this is an example of landsat stations
all across the world
and their range
so each of these symbols is a station
and then the kind of elliptical circle around them
describes the range of those stations
when a satellite is within the range of those stations
so it's within this kind of area
for this one
for example
then that means the satellite is able to send down
information and data to that ground station
now they can also use other satellites
that are in different orbits
and transmit data to a different satellite
which then transmits data down to a ground station
but you'll see here
this is an example of a satellite orbiting
and as it's orbiting around
when it comes into range with a ground station
boom boom boom
it's able to send that data down to that ground station
then it keeps orbiting around
it gets outside the range of that ground station
it can no longer send data to that ground station
but then eventually
it'll come into contact with another ground station
it'll get into range with another ground station
and it'll send down its data again
now what's interesting
is that some satellites in geostationary orbit
for example
they're in constant contact
with certain ground stations
so some satellites that are orbiting around
will just send data out
to these geostationary satellites
like this one is doing
sending data out there

and then it will transmit
from those geostationary satellites
down towards a ground station
so there's lots of different ways
for us to retrieve the data
from these satellites that are in close elliptical
polar or sun synchronous orbit
one of them is just transmitting
straight to the ground station
other times
there's these complex networks
where data is getting transmitted to other satellites
and then to other satellites maybe
and then eventually down to the ground
now in canada
the government operates three ground receiving stations
one in quebec
one in saskatchewan
and one in the northwest territories
because of the large range in total
between each of these ground stations
you can see these yellow circles are the range
we're able to essentially get close to
near real time data collection
for most of canada and parts of the states
which just means that if a satellite is traveling
over top of canada
and it's imaging
say an area right around here
then it could immediately send that data
down to this ground station
or maybe down to this ground station
and so for purposes
for applications that require
near real time data collection
canada is in a really good position
because we're able to transmit that data
almost immediately after it's collected by a satellite
now i mentioned a couple lectures ago
that there are a few key satellite missions
that we're going to focus on throughout this course
and what i'm going to do for the rest of this lecture
is we're going to talk about the

terra and aqua satellite
which has the modest sensor on board
and then the landsat satellite
which has the thematic mapper
and operational land imager on board
and then the worldview satellites
and we're going to break down the spatial
temporal and spectral resolution
of each of these satellites
so that if you were to look up the resolutions
the characteristics of these satellites yourself
you would hopefully be able to
piece together the pause a little bit
and understand what kind of data set
each of these satellite missions is collecting
so first is the terra and aquas satellites
so the terra and aquas satellites
are two sister satellites
they're essentially the same satellite
but there's two of them
and they're just in a staggered orbit around the earth
both of them have a modest sensor on board
so both of them have a sensor
that collects literally the same identical data
but because they're staggered
at different times in their orbit
we're able to get a really nice temporal resolution
combined from modus
between the two satellites
of about one to two days
so we can image the entire earth
with this data set in one to two days
now the modest sensor
is the one that we're going to focus on
that is on board the terra and aqua satellites
there's several other sensors
that are also on board the terra and aqua satellites
the advanced
spaceborn thermal emission radiometer after
and then there's a bunch of other ones here
we're not going to get too much into them
other than acknowledging that they exist
we're going to focus on modus

for the purposes of environmental
conservation
forestry applications
modus is the main sensor that's used
onboard the terra and aqua satellites
ok so this is what those satellites look like
they're quite large
they are used for a large variety of applications
of biological and geophysical applications
including measuring and imaging temperature
of both the land and sea
understanding ocean color
global vegetation patterns
clouds and aerosols
and snow cover
it has a swath width of two thousand
three hundred and thirty kilometers
so that just means that when the motor sensor
is on board the terra and aqua satellite
and it's traveling over the earth
and it's taking images
it's taking imagery of an area
that's over two thousand kilometers wide
so it's pretty large
it's imaging quite a large area at once
the modest sensor has twenty spectral bands
in the visible
and near infrared portion of the spectrum
and then sixteen spectral bands in the mid infrared
and thermal infrared portion of the spectrum
so here's a quick video
kind of introducing modus and some of its applications
of all the instruments in nasa's birth observing system
modus has proven to be one of the most versatile
producing both groundbreaking science
and compelling music
the modern resolution antigen spectral radiometer
on both the aqua and terracellites
has changed the way we look at our atmosphere
oceans and wind
modus prestige wavelength range covered more physical
properties of the environment that it can monitor
it measured down a small turn fifty meters

size of a couple football fields and size
and many more spectral games
to study more aspect of the ocean
biology of the land fires
and it was a very technological advance of capabilities
and for a long time in the us community
it was referred to as the quintessential instrument
the less the more things
more people
more disciplines than any other single history
the study of clouds is not surprisingly
incredibly important
for understanding weather and climate
and until notice being one
it was commonly accepted that at any given time
the earth was about fifty percent covered by clouds
but data from the instrument showed the cloud cover
was actually closer to seventy percent
photos can also measure the temperature
and height of clouds
and differentiate between clouds
composed of liquid water and those made of ice
modest also monitors the world's oceans
measured sea surface temperature ocean coloring
clarity and the basis of the marine food chain
phytoplankton
most a very good job of getting this
biological seizure of chlorophyll pain
falls by the ocean currents
you can see the seasonal variation of things
where the biological productivity of the ocean
this is important because it's biological
since this takes carbon dioxide out
this is oxygen
part of the synthesis is always the same for carbon
we may have put in the atmosphere
motus also looks at the land monitoring fires
ladies change
and various measures of the earth's planet
it's been used for a long time to monitor
the growth of education
the seasonal cycle
and how to change year to year

whether it's due to droughts
or spread of the sahara
but it's a very good index to monitor
the first agility of motors as it measures land
sea and air
contributes to the wealth of information
being revealed by the aqua mission
okay so in that video
they were just referring to the aqua satellite
but everything they talked about in reference to motors
could also be applied to the terra satellite
because they're essentially the same satellite
they both have a motor sensor on board
so to kind of summarize some of the properties of modus
it has a spatial resolution of about
two hundred and fifty to five hundred meter pixels
for land research
so for spectral bands that are focused on
imaging and understanding land properties
those pixel sizes
the spatial resolution of those bands is
two hundred and fifty to five hundred meters
and then they have one thousand meters
or one kilometer pixels
for ocean and atmospheric research
and again this one to two day return period
now this is the most important
and probably valuable part of modus
is this last part right here
we can get imagery of say
sea surface temperature of ndvi
whatever it might be
for the entire surface of the earth
every single day
so those fine scale processes
that maybe we want to monitor
whether it's vegetation phonology or snow melt
to understand fine scale changes that are going on
maybe due to climate change
or other anthropogenic impacts
are really only capable to be done with modus
so for example
if i were to give you on an exam

a question that was asking you
what kind of satellite would be suitable
for an application that requires daily measurements
you know right off the bat
it's probably gonna have to be modus
modus is the only sensor
that we talk about in this course
that collects imagery at a daily temporal resolution
so if you want that very fine scale information
it has to be collected with modus
now modus has a very large spectral resolution
so it has a bunch of bands ranging from the visible
all through the eventually near infrared
thermal infrared
and shortwave infrared part of the spectrum
and they all have a wide variety of applications
a lot of these visible ones
near infrared
are for the purposes of land cover mapping
and land use changes
and then they also have a bunch that are for
monitoring the oceans
monitoring the atmosphere
monitoring clouds
monitoring what else we got here
temperature
whole variety of things
we're not going to go into detail too much
about each of these specific bands
but the capability of modus to look at
upwards of thirty six different spectral bands
is really really valuable
that's thirty six different measurements
for each individual pixel that it's measuring
thirty six measurements of reflectance
for each individual band width
that we're looking at here
now hopefully part of the goal
i'm hoping to get you guys out of this course
is that if you were to look up
what the spectral resolution is of modus
or what the bands are that modus use
you would see this table

and so hopefully you could look at this and say okay
i know kind of what is going on here
i know that these bands
this band width over here
is just denoting the wavelength size of that band
and then this spatial resolution here
is just telling me
what the pixel size would be for that band
and this spectral domain here is just telling me
where that band is located
in the electromagnetic spectrum
now with something like modus again
we can get something like this
where we're looking at the entire globe
in this case for ndvi
for a vegetation metric
such as telling us how green
or how healthy vegetation is across the whole world
and again something that is
really only capable with modest data
when we're looking at the scale of the entire globe
it's really hard to do that with something
that has a moderate or high spatial resolution
the low temporal or the low spatial resolution of modus
makes imaging the whole globe a little bit easier
because we don't have quite as much data
we don't have as small of a pixel size
to look at this whole area
to look at this whole globe
so it's a little bit of a smaller dataset relative to
if you were to try to do something like this with
say landsat
which makes processing time and analysis a lot easier
so to highlight that again
if i were to ask you in an exam setting
for an application that
say required
you to measure or take images
with earth observation satellites of the entire globe
some sort of global metric
again that's a hint
that is probably gonna have to be done with modus
there aren't many worldwide applications

at the scale of the entire globe
that are applicable with
say landsat
and especially not with high spatial resolution data
like worldview
so if it requires daily imagery
high temporal resolution
or it requires imagery of the entire globe
then it's probably going to need modest data
one thing one particular application
that's very valuable from modus
especially in today's day
and age is its ability to detect fires so modus
because it's able to image the entire globe every day
we're able to get an image of one spot on the earth
revisited every single day
it does a really good job at detecting fires
it can detect fires on a day by day basis
so this is modest
detecting fires at different places around the globe
california and these two
and australia up here
and this is just put together
a detection of all of the fires going on
all across the world
month by month
year by year
so again a really really
really valuable dataset
our ability to measure where fires are
all across the world every single day
is really really invaluable
not just for our ability to predict and model
and monitor fires
and their effect on the environment as a whole
and in the long term
but also just in our safety
in our ability to plan for communities
and plan for natural disasters
okay so that's modest
so key hints about modest for an exam setting
if i am referring to things at a global scale
or at a very

very high temporal scale
say at a daily scale
that is probably modest
that you need to be thinking about
the next earth observation mission
we talk about is landsat
landsat has a thirty meter pixel
so a moderate spatial resolution
has a sixteen day return period
so it revisits everywhere on the earth
every sixteen days
similarly it's able to take an image
of the entire surface of the earth
every sixteen days
it's a series of eight satellites
comprised of four different sensors
there have been nine landstats launched
but one of them didn't make it to orbit
which is why we say there's only eight
and it has a
one hundred and eighty five kilometer swath width
now again linking that back to our temporal resolution
think about what the swath width of modus was
it was about two thousand kilometers
so way way way
way bigger than this
again that's why we're able to get that very
fine temporal resolution with modest data
with landsat data
it has a much smaller swath width
so we're really only able to get this
moderate to low temporal resolution of sixteen days
okay quick intro video from landsat
the music i will warn you about
like a lot of space videos
is super over the top
think it's very james bondy but anyways it's cool video
such aggressive music
so unnecessary
okay so key thing about landsat
the way that we talk about modus
and how i mentioned
if we're talking about

things that require daily imagery
or things that require us to image the entire globe
a key indicator that in an exam setting
you should be thinking about landsat
is that landsat is the longest continuous record
of the surface of the earth that we have
so landsat one was launched in nineteen seventy two
and this was
you know very
very revolutionary
and the key part about landstat is its data continuity
so not only was it launched
all the way back in nineteen seventy two
but there's no gaps in the data
so this is the lifespan
of each of the landsat satellites
and you can see they're always overlapping
so there was never a time
where there is no landsat data available
dating from now
all the way back to nineteen seventy two
now you'll see here lancet at six
that was the one that got launched
and there was essentially a math error
and it did not make it into orbit
so we don't have any data from lancet at six
luckily landsat five lasted a really long time
so we survived without landsat six
and then landsat nine
was the newest landsat that was just launched
and then in one of our lectures
towards the end of the course
we'll talk about
the next landsat satellite that's going to be launched
but key thing to note here is that
if we're talking about an earth observation application
that requires us to take imagery or look at imagery
beyond the eighties and eighties and seventies
into the past
for looking at any change
that occurred from nineteen seventy or nineteen eighty
we have to be looking at landstat data
modest data doesn't go back that far

it only goes back as far as nineteen ninety nine
i believe or two thousand
around there
and worldview
the high spatial resolution data sets we'll talk about
were in the late two thousands and early twenty tens
so anything that requires us to look at data
from the eighties and the seventies
requires us to use landsat imagery
now a brief summary of kind of the history of landstat
it was originally called the earth resources
observation satellites program
and then it was changed to landsat in seventy five
and over its history it's kind of passed from public
from government owned
to private industry
back to public
and ultimately will stay in public ownership
operated by nasa and the geological survey
which is essentially just us government
and that's in law now
so there was the land remote sensing policy act
that was passed back in ninety two
and this authorized the procurement of landsat seven
and future landsats
which just meant that the us government
was to own and operate all the land stats going forward
and they were going to ensure data accessibility
for everyone at the lowest cost
which is what it is now
it's open source and it's free
so anyone can access landsat data at any time
onboard the different lansats are different satellites
so lansat four and five had the thematic mapper
which is really the first sensor
that was kind of more modern
that gave us a high
much higher level of data quality
than what was on lansat one two three
and so that's where we'll start
in terms of the sensors we'll talk about
so you have lanstat four to five
with the thematic mapper

lanstat six never made it to orbit
so we don't have it here
lanstat seven had the enhanced thematic mapper plus
not just enhanced
enhanced thematic mapper plus
no you guys are tough okay
so and then we had landstat eight
and nine had the operational land imager
and thermal infrared sensor
or tears now
one thing that's kind of interesting to note on these
if you want to try to link back to
some other concepts of this course
and you know
a good kind of exam question is
why do you think for
on the enhance thematic mapper plus sensor
this band here
band six here
why do you think it has a higher or
you know larger pixel size
lower spatial resolution
than the rest of the bands here
similarly band six on the thematic mapper
as well as band ten and eleven
on the oli and tiers sensor
each of those have a slightly higher
well lower spatial resolution
higher or larger pixel size than the rest of the bands
anyone want to guess why that might be
maybe i'll give you a couple minutes to brainstorm
i'll give you one or two minutes
brainstorm with a neighbor sitting next to you
think it through
relates really nicely to a concept that we talked about
when we discussed the electromagnetic spectrum
but take a moment brainstorm a little bit
and then let's see if we can try and get an answer
i got
oh
alright
are you guys okay
this is the quietest i've ever heard you

kind of concerned
you guys just like not back in the
not back in school mode yet
still in reading break mode kind of thing
that's fair
okay um you guys are really hard to make laugh
you're killing me
so what do you guys think
any ideas why
those bands might have a slightly larger pixel size
or slightly lower spatial resolution
anyone have any guess anyone discuss anything
yeah
good guess no
that's not the case for these
they are valuable
you could argue they're less important
than some of the other ones
but that's not why they have a lower spatial resolution
anyone else yeah
is the part of the electromagnetic
electromagnetic spectrum that they're looking for like
just like require less resolution for some reason
yeah so that's totally on the right track
so notice here
for each of these bands that have a
lower spatial resolution
all of the wavelength sizes are much
much larger
see here we have in micrometers ten and eleven
up here we have ten to twelve
up here we have ten to twelve
the rest of the wavelengths are all you know
micrometers of one point five
zero point five
zero point six
zero point four
so what is the relationship
if we can remind ourselves
what's the relationship between wavelength size
and frequency of a wave
of a photon
when we have a larger wavelength size

we have a lower frequency
when we have a lower frequency
there's a smaller amount of energy
associated with those photons or with those waves
so that means that when we're imaging
or trying to sense portions of the spectrum
that are out in the thermal
infrared part of the spectrum
where wavelength sizes are a lot larger
those wavelengths
those photons
also have much less energy associated with them
that makes them a lot harder to sense and to measure
so to make up for that
to account for the fact
that they have less energy associated with them
and they're much harder to measure
we just image them over a larger area
so we collect a larger amount of them
by looking at a bigger area
and then we can still get a nice
clean measurement of that part of the spectrum
does that make sense
sweet okay
so this is an example of again
looking at a change through time with landsat data
you would know if i just gave you these images and said
okay we're looking at deforestation through time here
from the seventies to the nineties
if i asked you what kind of satellite
or which satellite system in particular
was responsible for measuring this data
or could you measure this change with
you would want to say lan set data we know
lan set data is the only data that we have available
that's all the way back to the seventies
with a continuous record all the way through time
all the way up till now
now one other kind of example here is from lancethat
change detection in las vegas nevada
we have on the left here
an image from nineteen eighty four
on the right here an image from two thousand seven

and you can see the abrupt change
in the amount of urban areas around las vegas
now again if i were to show you these two images
or ask you to compare or look for a data set
that was able to compare
or measure the change in urban sprawl
in a particular city
from the nineteen eighties onwards
you would say okay
well i have to do that with landsat
because there's no other satellite imagery
that looks back that far
you'll notice also
with these landsat applications that we're discussing
they also generally
aren't looking at quite of a large area
as we did with modus
when we were talking about modus
we talked about a lot of global metrics
a lot of measurements that we can get at a global scale
whereas these lands at examples
we're really just looking at
you know in the case of las vegas here
one particular city
it's more of a regional application
and that's because
partly because that moderate spatial resolution imagery
that thirty meter pixel size
is perfect for looking at a spatial scale like this
a regional scale
if we wanted to use landsat to look at say
the entire globe we could
but the amount of data to do that would be huge
our processing times would be much
much larger
something like modus is much more suitable for that
i don't need the music here
so this is just a composite of images through times
that you're going to be using
for one of the assignments coming up
believe it's mount saint helens
before and then after it erupted
and you can see kind of the change through time

due to all the debris that came out of the volcano
you can also see through time
kind of the increase of forestry cup blocks
or clear cuts kind of around the area
like you can see down here
they're really picking up
and then you can also see some areas
that were harvested
where trees were cut down back in you know
the seventies eighties
recovering and vegetation starting to regrow
so really cool example there
and one that you'll be looking at in detail
in one of the assignments coming up
now just a quick note that
landsat data officially became free and open source
here in two thousand eight
and since then there was initially this exponential
increase in the demand of landstat data
and ever since then it's been steadily increasing
in a linear fashion
so the need and use of landsat imagery
is always increasing
mostly for monitoring land use and land cover change
that's probably the most common application
of landsat data
its spatial resolution of thirty meters
makes it really ideal for that
as well as fire science and management
some education purposes here
and a whole
wide variety of other purposes all around here
that i'd encourage you to take a look at
if you're interested
ok the last
satellite mission that we're going to talk about today
is the worldview satellite mission
so worldview is launched and operated
by a company called digital globe
it's one of the largest and most successful
private satellite companies
so worldview is a
or digital globe

which launches and operates the worldview constellation
of satellites
is a private company
it's not government owned
it's not government operated
it's a private company
which means the data is not open source
it's not free
it does cost money and a license
in order to get this data
now they have three
well four now
worldview satellites
and those are the satellites that we'll talk about
digital globe also has a variety of other
high spatial resolution satellites
they were kind of the mother or father of
high spatial resolution satellite missions
and nowadays they have sensors
in the case of worldview one
two three and four
where you can get imagery as low as thirty centimeters
so a thirty centimeter pixel size
so you know
about the size of a ruler
so almost not quite
you can't quite make out people
but we might be getting there eventually
which is kind of scary
but we'll talk about that actually later in the class
a little bit about the ethics and policy behind that
so worldview one to four launched in two thousand one
then worldview two in two thousand nine fourteen
was worldview three
twenty sixteen was worldview four
and worldview one was really the first generation
or the first satellite in this next generation
of high resolution satellite imagery
and worldview is capable of imaging up to
seven hundred and fifty thousand kilometers square
per day of this very high
or high spatial resolution satellite imagery
now this is some imagery you can see over here

one very common example of using worldview imagery
is for urban mapping
you can make out individual buildings
individual roads
which makes it really nice for that high resolution
urban mapping applications
you can see worldview four here has eight bands
so it's got two blue bands there
a green yellow
red red edge
and two near infrared bands
and then again
if you were to look up the spectral resolution
or just google
what are the bands that worldview three has
you'd come across a table like this
and again i'm hoping that after this course
you guys would be able to look at a table like this
and make out a little bit
of information about it
so you'd say okay
i know that i have a bunch of different bands here
that i'm measuring the reflectance for
this is where they're located in the port
in the electromagnetic spectrum
and then this is their bandwidth size
this is the smallest and largest wavelength range
for that particular band that i'm measuring
now you'll notice here there's a
up here a nadir and off nadir measurement
so there's different spatial resolutions
and different temporal resolutions
associated with each of the different
worldview satellites
because they have
one thing that's very different about them
compared to the landsat and motors data sets
and that is that worldview has a tiltable sensor
so landsat and modus are always looking straight down
whereas worldview
can actually tilt its sensor side to side
that's part of the reason that it makes a really good
private satellite data set

because someone can essentially pay worldview to say
hey keep your sensor always tilted
at this specific target
so i can get an increased temporal resolution
of the area that i'm interested in
and i can also get images from different angles of that
target that i'm interested in
so little bit different
in terms of worldview's capabilities
and how you describe
its spatial and temporal resolution in general
for exam purposes
you can just assume
worldview satellites have a spatial resolution of about
thirty to fifty centimeters
and this roughly describes their spectral resolution
and i wouldn't really
ask you too much about their temporal resolution
because it is a bit tricky
and it depends
now we've looked at all of these tables
that show and describe the different bands
for each of these different satellites
i'm not going to ask you to list off
or name off the bands by heart
for the final exam
what i at most
would want to get you to do is ask you a question
like describe to me you know
i'd give you an example of a specific application
and i'd ask you
what satellite mission would be best to use
for this specific application and why
and the why part you would describe with
well because it has this level of spatial resolution
and it has this level of temporal resolution
and it has roughly this level of spectral resolution
it has bands in the visible and near infrared
portion of the spectrum
so it would be really good for measuring vegetation
health or measuring forests and things like that
so that's kind of the nature of the kind of question
you can expect in terms of this content

now just some examples here of worldview imagery
some famous places around the world you can see
again really really beautiful imagery
you can even see shadows of individual buildings
really really cool
here are some images of areas in bc
so that's the science center there
that's bc place there
again really
really high detail
pretty amazing imagery
but very very expensive
and this is the last thing i want to mention
worldview two and worldview three
imagery is at a price of about
twenty four dollars per square kilometer in us dollars
and the minimum order is generally
about a hundred kilometers squared
so you have to pay for at least
three thousand dollars worth of imagery at once
so it makes it really hard to use this imagery
unless you have some sort of private funding
from some source or
or something like that
so some sort of company is generally paying for this
sometimes there are large licenses
that institutions and organizations can use
i know that there's a different company
that ubc has a license for
for their high spatial resolution satellite imagery
and i think you can just obtain that
through the ubc library
but just an example here
to kind of just nail down that it is very expensive
and it's hard to access
much harder to access than say
landsat or modest data
which you can access at any time
totally free
okay shorter lecture today
that's all i really have
got a couple of practice questions here
if you want to practice them

stay for a couple minutes and then go over them with me
you are welcome to
if you don't
then you are welcome to head out now
and i'll see you guys tomorrow in the other building
tristan will be here
and evan will be here
and we will talk about the midterm tomorrow as well
thanks guys
uh uh
all right hi everyone
so sorry i'm late
i'm in the right spot right
this is constant to seven
yeah okay cool
i went to our other lecture hall
and then i got in there
i was like where is everyone
did they all think class was canceled
and i was like oh no i'm in the wrong lecture hall
and then i sprinted over here so
one second sorry
that's actually pretty impressive
that's what i thought
i thought it was decent not gonna lie i have no cardio
about halfway through i started cramping up
i was like oh my god i'm not gonna make it
oh gosh okay we're here
it's all good
okay
midterm scores are going to be posted
after lecture today
so evan's going to come here
towards the end of class and just give a
quick rundown of average time to complete the exam
average score
high scores
things like that
then we'll post them right after class
if you have
questions or disputes about the grading on them
email evan and we'll put a time limit of two weeks
from when we release the exam marks

which will be today
and essentially that timeline is just
if you do not reach out to us within two weeks
of us releasing the grades
then we're just not gonna consider
changing any marks whatsoever
so if you have any issues with the grading
anything you want to dispute email evan
do within two weeks after that
if you email us
asking about marks being changed on the midterm
we're just gonna say no
it's past the a lot of time that we had to do that okay
today and i kind of mentioned this yesterday
a little bit
but in general
the rest of the course content that we'll talk about
from here onwards
kind of all the post midterm content
i think personally it's a lot more fun
it's a lot more interesting
so if you are still coming to lecture
i hope it'll make your time worth it
there's some really fun concepts
some really interesting concepts
today we are going to talk about active remote sensing
so far up till today
we've been really talking about passive
remote sensing systems
and so today
we're going to introduce active remote sensing
and just what it is
how it differs from passive remote sensing
we'll then talk a little bit about lidar
radar and sonar
i'm going to just define what those are today
and then we'll talk about radar today in detail
and then next week on monday
we'll talk about lidar in detail
then briefly we'll just talk about some applications of
how each of those systems work
how lidar works
how radar works

how sonar works
some applications of each of them
again today just focusing on radar
okay so i'm going to start with a video
that kind of outlines and reviews some of the concepts
we've talked about so far
and then also introduces some of the concepts
surrounding active remote sensing
if we measure the earth from the ground
we can get a good
local picture of what is going on around us
but if we only measure larger portions of the earth
then we'll need to use remote sensing
remote center measures the earth and its features
with acne and physical contact
we can gather data from entire continents
over longer time periods
so we can look at how the earth is changing
nasa uses specialized aircraft
and sophisticated satellites to gather data
using both passive and active remote sensing methods
passive remote sensing measures the natural energy
for radiation of the earth
active remote sensing gathers data
by actively sending out signals
that interact with the target of interest
using both active and passive remote sensing techniques
nasa can look at soil moisture maps to monitor drown
estimate snow pack
in areas where snow is crucial for fresh water
measure the change in ice sheets and sea level
tracking storms that could impact human lives
and observing how precipitation changes
affect where we get our fresh water
the global precipitation measurement mission
helps fill in the gaps
where ground measurement isn't enough
places with rugged terrain
can block the signals from ground radars
the oceans are too vast to cover with enough ships
and measurement stations on the surface
and places without a network of instruments needed
to measure fresh water

for people and agriculture
we can then unify the measurements
to create a consistent and accurate picture
no matter where we are
because satellites get more complete coverage
than ground based instruments
we can use remote sensing
to better see how the whole earth is changing over time
with a long data record
we can make better predictions about the water cycle
the climate
and the impact on humans
by observing our earth from above
we get a much better understanding of what is happening
on the surface
in the atmosphere
underground
over the globe
and in our own backyard
okay so the first thing
the main point of showing that video
was really the first thing that they illustrated
which was very brief
but we're going to go over in detail
and that is the difference between passive
and active remote sensing
so up until this point
what we've been talking about is passive remote sensing
passive remote sensing measures energy
that is naturally emitted
typically from the sun
so that's again what we've been talking about so far
we've talked about how radiation
is emitted from the sun
travels through space
ultimately through the earth's atmosphere
bounces off different surfaces of the earth
reflects back to our satellites
or other remote sensing systems
where that reflectance is measured
by doing that
we're able to monitor things through time
how forests are changing

how oceans are changing
and we're able to even just go away
and detect and classify
different surfaces that we see on the earth
one more time
just to drive it home
passive remote sensing
energy comes from the sun
bounces off targets or surfaces of the earth
travels to the sensor where it's measured
active remote sensing does not use energy
that is emitted from the sun
active remote sensing
instruments provide their own energy
and just send radiation from the system itself
so from the remote sensing instrument
it sends radiation or energy towards the target
that radiation or energy
bounces off of that target
and then its reflectance is measured by the sensor
so fundamentally different than passive remote sensing
passive remote sensing
we only measure energy that is naturally emitted
typically from the sun
that comes down and bounces
off the surface of the earth to the sensor
active remote sensing
the instrument itself sends radiation
sends energy from it towards the target
towards the surface of the earth
that energy bounces off the surface of the earth
goes back towards the sensor
the remote sensing system
where it's measured
so this is how that looks in comparison
side by side
passive remote sensing
energy from the sun travels down
bounces off different surfaces
travels to our sensor where it's measured
active remote sensing
the instrument emits its own energy
so no energy in this case is coming from the sun

the active remote sensing instrument
emits its own energy
which travels through the atmosphere
bounces off a target of interest
some surface on the earth
and then travels back towards the sensor
where it's detected and measured
ok so for a kind of more of an exam style question
how might you answer the difference between
passive and active remote sensing
you can really use this slide here
there's a couple key points
so passive as i've mentioned
passive remote sensing
uses energy that is naturally emitted from the sun
this energy is reflected off the surface of the earth
and that reflection
of this energy is measured by the sensor
active remote sensing
instruments produce their own energy or radiation
that energy travels towards a target
where it's reflected
and then that sensor detects
and measures that reflected radiation
so why might we want to use active remote sensing then
what might be its benefits
what might be some of its downfalls
some of the issues with it
well with active remote sensing
we often have
particularly with radar
a weather independent instrument
so radar can actually see through clouds rain
different kinds of weather
passive remote sensing instruments can't
if we are using say
landsat or modus
which are forms of passive remote sensing instruments
and say landsat is
traveling over the surface of the earth
it's orbiting earth
and it's taking an image of the earth
where there happens to be a bunch of cloud cover

then that image is just going to be a bunch of cloud
we're not actually going to be able to see
any of the landforms in that image
with radar in particular
the microwave energy that is emitted from radar
actually penetrates and travels right through clouds
unobstructed
so we can image surfaces of the earth
under any weather conditions
only for radar
doesn't apply to lidar or sonar
what does apply to all of the different kinds
of active remote sensing
is that it is sunlight independent
meaning that we just get to choose
what form of energy or radiation
is emitted from the active remote sensing instrument
with passive remote sensing instruments
we're just measuring the entire
whatever bands we choose to measure
that are emitted from the sun
with active remote sensing
if sunlight independent
we don't need the sun
in order to remotely sense
with active remote sensing systems
so we can survey at any time of day
night or day
again passive remote sensing instruments
if we want to measure the reflectance of visible green
blue red light
we have to be doing that during the day
if there's no sun there
to be emitting radiation
visible radiation
in the example that i'm referring to
then there's not going to be any visible radiation
being reflected off that surface
to be measured
that's not the case with active remote sensing
even in the middle of the night
a radar satellite
can still measure surfaces of the earth

it can still emit energy
that goes down to the earth
bounces off the target
and travels back to the sensor
and as i mentioned before as well
you can also just control
what energy is emitted
with radar we generally use microwave energy
with lidar we might use visible light energy
or we might use near infrared energy
but we get to define
what kind of energy we're going to be emitting
from the active remote sensing system
and lastly one of its key
arguably the most valuable part
of active remote sensing systems
is that we can often get three d information
from active remote sensing systems
we can penetrate vegetation soil
ice and snow
so we can actually get a sense of the structure
of forests and canopies
we can get a sense of
you know layers of soil
below just the surface
we can actually
measure different properties of ice and snow
below the top layer of ice or snow
say on a frozen lake
or on a glacier
we can actually see below the surface
so in that way
we get a kind of three d
or three dimensional
type of information
something that's really
really hard
and most of the time impossible
to get with passive
remote sensing systems
we'll talk a bit
well we'll talk a lot
in detail about how that's actually done

how we go away and get three d information
from active remote sensing systems
that'll be for later in the lecture
and for next week
so we can get information on surface layers
and structure
three dimensional information
with active remote sensing systems
now then why wouldn't we just want to use
active remote sensing systems all the time
is maybe a question you could be asking yourself
well key problem
or a key downside to active remote sensing systems
is a very limited amount of spectral information
there's also quite a higher
and more complicated level of analysis
that's undertaken with active remote sensing systems
and they're a lot more expensive
so in short
passive remote sensing systems are simpler
easier to analyze
and give us kind of a wider breadth
of spectral information
active remote sensing systems
give us much more limited spectral information
and are a lot more complicated and costly
but still sometimes can provide very
very valuable information despite those costs
so question i have for you guys to try and brainstorm
that i kind of briefly mentioned
is why would active remote sensing systems
have limited amounts of spectral information
so spectral information
you know if you think back to our resolutions lecture
and what spectral resolution is
our spectral information is just you know
the breadth of different bands or different portions
of the electromagnetic spectrum that we're measuring
so why might active remote sensing systems have limited
spectral information as opposed to a passive system
i want to give you two or three minutes to brainstorm
with a neighbor ideally
or just by yourself

take a couple minutes
think about it
and then i'll try and crowd source an answer from you
guys and then we'll carry on
so go ahead
try this
okay what do you guys think any ideas
anything at all
yeah we had two possible ideas
the first one was that simply
satellite can't emit
all of the different types of radiation
yeah the way that the sun can for sure
and then the other one was a little more specific
and kind of based on this diagram here
but we're getting a ton of radiation from the sun
yeah so your satellite
wherever it is
is going to be able to pick up on some of it
yeah but the satellite can't emit nearly that much
so it has to be very specific in which band it emits
so it knows what to get back
totally yeah
that's exactly right
no that's exactly right
so two things that he mentioned there
one was that the sun emits all forms of radiation
every type of wavelength
every size of wavelength
on the electromagnetic spectrum
the sun emits all of it
it'd be really unpractical
and probably close to impossible for a sensor
a man made product
to emit all types of radiation known to us
that's probably just not very practical
not very possible
the other part
and the part that's kind of more technical
and more important to
how an active remote sensing instrument works
is that with active remote sensing
the user has to very specifically

specify which type of radiation it's going to emit
because it has to be then very sensitive
to that exact same form of radiation
to make sure it's not measuring some other radiation
that's just existing
coming from the sun or somewhere else
so for example
radar instruments
they'll emit a very specific wavelength size
in the microwave portion of the spectrum
so that when that radiation is emitted
hits the surface of the earth
travels back to the sensor
it knows pretty confidently
that it's measuring only the energy
or only the type of radiation
that it emitted from the sensor
and not some other radiation
that was just emitted from the sun
nice work yeah
does that make sense
any questions about that
good exam question here hint hint
so three types of active remote sensing that we discuss
are radar lidar and sonar
radar uses high frequency radio or microwaves
higher frequency radio and microwaves
just meaning smaller wavelengths
relative to the spectrum
of different wavelength sizes
in the radio and microwave part of the spectrum
lidar uses laser light
it actually sends a laser pulse or laser beam often
in the visible or near infrared part of the spectrum
generally the near infrared part
we'll talk in detail about lidar next week on monday
and then sonar uses sound waves
so sonar is sound propagation
and it's more often used in boats
for things like understanding and measuring
the topography of the ocean floor
not very commonly used in terrestrial remote sensing
so we'll mostly focus on radar and lidar

and i'll briefly mention sonar a bit more next week
so for today we're going to focus on radar
so radar works with different wavelengths
in the microwave part of the spectrum
so just to remind you guys
that's kind of this part of the spectrum here
that range of wavelength sizes
and a radar instrument transmits a microwave
or radio signal towards the scene
technically
microwaves are actually more of a subsection
of the radio wave part of the spectrum
don't expect you guys to know or remember that for
exam purposes
but the reason i say it is
you're probably looking at this and going okay radar
radio detection ranging
then why aren't we using radio waves
why are we using microwaves
microwaves are technically a subsection of radio waves
so they're still a type of radio wave
and sometimes we do use radio sized waves
and not necessarily microwaves
again that's just kind of the nature of dealing with
a spectrum of wavelength sizes
there's not always a clear
distinct cutoff
the point is
don't let that get you too confused
radar radio detection ranging
generally speaking
for exam purposes
you're going to want to say
uses the microwave portion of the spectrum
so it emits microwave signals
microwave radiation
towards a target
towards a scene
and then the portion of transmitted energy
backscattered from the scene is measured by the sensor
so it emits microwave energy
it travels towards the surface of the earth
eventually it hits the surface of the earth

bounces off the surface of the earth
travels back towards the sensor
and the sensor does a couple of things
when that microwave energy travels back towards it
it observes the strength of that energy
which is called detection
so how intense that microwave energy is
after being omitted
bouncing off the target
and traveling back to the sensor
that's called detection
it also can measure the orientation and time delay
or ranging of the return signals
so put that all together
that means that a radar instrument can measure
how far away a target is
because it can use ranging
that's the time delay portion here here
and all ranging is
all of that refers to
is when a radio wave
or microwave is emitted from radar instrument
the radar instrument times how long it takes
that microwave energy to travel towards the earth
bounce off a target and travel back towards the sensor
by measuring how long it takes to travel to the target
and back to the sensor
it can measure how far away that target is
so that's the three dimensional part
so radar can measure how far away something is
and in what orientation it is
so in what direction
but more kind of
applicable to what we'll talk about in this course
is the strength or detection capability of radar
which is just its ability to say okay
i've sent a microwave signal down to a target
it's hit that target
come back to the signal
i just want to measure how strong that signal is
by measuring how strong that signal is
we can relate it to different properties
that are known to exist

in different surfaces on the earth
and in that way
we can try and detect and classify different targets
different features
different materials on the earth
the same way we can
with some passive remote sensing systems
i'll get into that in a bit more detail
again why use radar
what's its value
it uses active microwave energy to penetrate clouds
and conserve
as an all weather remote sensing system
this makes it particularly good for things like
emergency response
because if you're using modus or landsat
and you need to know where a fire is
or something like that
and you're orbiting the earth and the area
you're concerned about is covered by clouds
then you're going to have a really hard time detecting
any change or any phenomenon that's going on there
with radar because we can penetrate through clouds
and we can use it in all kinds of weather
we're always able to see the ground no matter what
can also be similarly
we can obtain radar imagery at any time of the day
even at night
does anyone recognize this image
we i popped it up in kind of color a couple weeks ago
does anyone know what that is yeah
yeah exactly
it's the suez canal again
so what's interesting about this
is that the radar satellite was
that this image is from
which i believe was radar sat
but i'm not a hundred percent sure
but this radar satellite was the first one to be able
the first satellite to be able to get an image of this
because the passive remote sensing satellites
that were orbiting
weren't able to get an image till daytime

because it was night
so they couldn't see anything
so just an example of when you need a quick response
or you need imagery taking at night time
or taken in poor weather conditions
radar has a substantial advantage
in those circumstances
okay now i mentioned two slides ago
kind of the big thing that we'll talk about
at least in lecture today
about what radar can do
is its detection
its ability to measure
how intense the microwave energy is
that it's emitted
bounced off a target
and traveled back to the sensor
and then measuring how intense that energy is
that's essentially how radar is able to go away
and classify different materials
on the surface of the earth
by measuring how intense that microwave energy is
after it's been omitted
bounced off a target
and traveled back to the sensor
and there's three factors that govern
how intense that backscatter is
or how intense that reflected energy is
one is surface roughness
two is dielectric properties
and three is moisture content
surface roughness
is kind of the easiest one to wrap your head around
because we've talked about
diffuse and specular reflectors i think
have we talked about that
i'm not sure
either way doesn't matter too much
a diffuse reflector
if we have talked about it and we're reviewing if not
a diffuse reflector like this
is when energy that is emitted from some source
comes and hits that surface

and then bounces off in all directions
so you can see here energy
in this case
we're thinking about microwave energy
comes down from the sensor
hits the target
bounces off in all different kinds of directions
a specular reflector is where the angle of incidence
is the same as the angle of reflection
so this angle here
that would be the angle of incidence
this would be the angle of reflection
and you can see it's the same angle
specular reflectors are things like very flat
very reflective surfaces
mirrors is the perfect example
but also in nature
things like glaciers
things like ice caps and ice sheets
very kind of smooth
white snowy
icy features
are often specular reflectors
and then oftentimes if we have other kind of features
like buildings
that kind of create more of a corner
we call those corner reflectors
and you can imagine
depending on where this
in this case
it's a plane
could be a satellite
let's think of it in the situation of a plane
in this case
if we have a radar instrument
mounted on board this plane
and it is sending microwave energy
to each of these different kinds of reflectors
you can imagine we're going to get a different level
of microwave energy measured
that's bounced off of those targets
if our airplane is right here
and thus our radar instrument is right here

and we send down energy towards this target here
say it's a bunch of ice
all that microwave energy
is pretty much all going to travel this way
away from our instrument
if we have a corner reflector here
it's all going to travel boom boom
right back to the instrument
if we have a diffuse reflector here
some of that microwave energy
is going to travel back to the instrument
some is going to travel away
generally the best kinds of surfaces for using radar
are things like diffuse reflectors
where you get an equal amount of
reflection in all directions
but in reality
when we're using radar to measure things like ice and
ice and glaciers and ice sheets and ice caps
we're often dealing with more of a specular reflector
which can be a big problem
because the angle at which
the energy is coming towards the target
is going to heavily influence how much energy is back
scattered or reflected back towards our sensor
so i'll give an example a little bit later
about how exactly
or just a more specific example
of an application
of how understanding different surface roughnesses
can allow us to use radar to detect different features
but for now
just know that with these different kinds of reflectors
they can heavily influence the amount of backscatter
or reflected microwave energy
back to our radar instrument
these two other properties are very important as well
but we're not going to talk about them in depth
because they're very complicated
and they're very physics heavy
and i'm not a physicist
and they mostly are over my head
but in short

dielectric properties are just the ability
for a material to hold and transmit electricity
or electric properties
and then moisture content is just how much moisture
or liquid water is in a given surface
generally things that have a higher dielectric constant
are going to reflect or backscatter
more microwave energy
and generally
things that have a higher moisture content
are going to increase the level of backscatter
or reflected microwave energy from a radar instrument
you don't need to know that
i'm not going to test you on that
just know that these are the three things
that influence radar backscatter
and just know
kind of in a bit more detail
how surface roughness works
in terms of how it influences
the backscatter you'd get from a radar instrument
okay now in radar
we also have to specify what band we're going to use
we have to specify the range of wavelength sizes
of the energy that we're going to emit from the sensor
the same way how in passive remote sensing instruments
like landsat like modus
we specify a wavelength range in the form of a band
for reflectance that we're going to measure
this is the same concept really
it's just with radar
we're choosing
not only the band that we're going to measure
from energy
emitting from the sun
and bouncing off the surface of the earth
the band that we're choosing
is the wavelength range of energy
that we're going to emit from the radar sensor
or from the radar instrument
and that we're then going to measure the backscatter
or reflectance of
so there's four that we talk about in this class

the xcl and p band
so they're all denoted with letters
this is their frequency and their wavelength size here
not going to ask you to remember these values
off by heart or anything
note though
one thing kind of relating back to earlier topics
from this course so far
is we have our smaller wavelength size here
greater frequency
larger waves length size here
lower frequency
each of these have a different purpose
have different applications in their use
which i've kind of listed on the right here
but what i mostly want you to remember
about these different bands is a
that they exist
that the xclmp band exist
and just relatively
what their wavelength size is
so know that x is the smallest
p is the biggest
c is a bit bigger than x
l is a bit smaller than p
some of their applications are here
i'm not going to test you on their applications
but i do want you to know
that along with wavelength size
comes the ability
for these different bands
to penetrate the ground
or penetrate surfaces
the larger the band is
the larger the wavelength size
of the band that you use in radar
the more ground penetration you're going to get
when you're imaging
a portion of the surface of the earth
so the longer the band
the further underground
you're actually able to see and sense
with a radar instrument

now in general
when you're trying to pick
which band you might want to use
the rule is you want to choose the wavelength size
or the band that approximates your object of interest
if you want to look at a smaller target
say something like rain droplets
rain droplets are quite small
therefore you probably want to use the x band
the x band is the smallest band that we've talked about
if you want to look at a medium sized target
maybe you want to understand leaf structure in a forest
or in a tree
then you're probably going to want to use
something like sea band
kind of a medium sized wavelength or band
and then if you want to be able to measure
and get information about tree branches and tree trunks
then you probably want to use a larger band
maybe the l or the p band
and again the band size
or the wavelength range
wavelength size
range of the different bands
relates to the size
of the targets that you're interested in measuring
so raindroplets
quite small
if we go back here
raindroplets are often kind of in this size
similarly larger things like branches and tree trunks
are often about this size
so the size of the wavelengths
that you want to use for your band
should be similar to the size of
the targets that you're interested in measuring
now we've kind of already briefly talked about
radar sat one and radar sat two
which are canadian owned and operated radar satellites
radar sat one was the first civilian radar satellite
which was launched in november of nineteen ninety five
and radar sat two was launched a bit more recently
in december of two thousand seven

they both use the sea band
and have a spatial resolution
of about eight to a hundred meters
spatial resolution with radar is quite variable
i'm not going to get into too much detail as to why
because it's quite complicated
but just know that for radar
for radar sat
we have a spatial resolution of about
eight to a hundred meters
and with both of these satellites
we have the ability to see through clouds
and it's very good at detecting sea ice and snow
radar sac covers polar regions daily
and then tempered zones and tropical zones
every three to five days
respectively
the third radar sat is the radar sat constellation
so radar sat one and radar sat two
have already been launched
and then recently
the radar sat constellation was launched
the radar sat constellation is a bit different
because it is three identical satellites
so radar sat one was one single satellite
radar sat two was one single satellite
the radar sat constellation
which is the third radar sat mission
is a set of three identical satellites
they have a higher spatial resolution
of about three to eight meters for pixel size
and we're going to watch a quick video
believe now yep
about building and launching
the radar set constellation
and then quickly
another video on some of its applications
our country is vast with very different challenges
from coast to coast to coast
with the help of satellite technology
the canadian space agency provides solutions
to some of those challenges
the radar set constellation mission

uses a trio of satellites
to take daily scans of our country and its waters
equipment radar and ship identification systems
they collect invaluable information about our country
satellites assist to determinate ice conditions
helping captains navigate through arctic waters
and bring supplies to remote villages
and helping northern communities travel safely over ice
during hunting and fishing expeditions
satellites monitor soil stability
and changes in the permafrost
and gather important data
that contributes to understanding climate change
so we can better protect our environment
and our wildlife
to maximize crop yields
ferris use satellite data
to measure moisture levels in soil
reducing how much water
pesticide and fertilizer they use
in order to protect and improve the environment
for years to come
and when disaster strike and people are in danger
satellite images help rescue teams respond faster
saving lives
and reducing the impact on people and infrastructure
the radar side constellation
satellites work together to bring solutions
to important challenges that affect all canadians
the canadian space agency
finding solutions for a better canada
okay so that is
the radar set constellation
so one kind of question
again for you guys to think about
i'll kind of just help you answer it
but why do you think radar is particularly
suitable for a country like canada
so not every country in the world
that is really into earth observation systems
has invested as heavily in radar as canada has
canada has been kind of at the forefront
of this kind of technology

with the first launch of radar sat one
and then the follow up of radar sat two
and then this radar sat constellation
that's going to go up
so why do you think radar might be particularly
suitable for a country like canada
and think about canada's geographic location
and some of its properties as a whole
anyone want to brainstorm any ideas yeah
because canada is such a big country
we have so many different types of like biomes
like planes
we have farmland
forests even deserts
yeah because it's so large
there's lots of applications
such as like looking at it for crops
looking at it for like
ice melting in canadian doors for sure
what do you think
is there anything though
in what you just mentioned there
that couldn't be done with a passive
remote sensing instrument versus something like radar
radar would be able to go through clouds
yeah great point
vancouver for example is a very cloudy city
yeah totally
so we got kind of a large coastal area
that has a ton of clouds all the time
so radar would be really good for
imaging those areas that are super cloudy
that's a great point
building off of that
in terms of its geographic location
canada yeah yeah
exactly yeah
that's one of the big points
so canada has a really northern latitude
and a large part of canada up here is in the arctic
a lot of those areas are dark
for vast and very long amounts of time
so radar sat

is super valuable for collecting data up in those areas
because landsat and modus isn't able to collect data
in a lot of those areas for most of the winter
radar sat allows us to continue to collect data
even when it's really
really dark up there
throughout a large part of the winter
and then there's one other thing
that comes along with that
which is that
again because we're such a high latitude
northern latitude country
we also have a ton of ice
all up here is a lot of tundra
a lot of permafrost
a lot of ice
something that radar happens to be particularly good
at collecting data for
the big the kind of main
answer that i wanted to get out of this
which was what was answered in the back there
which is that canada
being a northern latitude country
has large portions of its land in darkness
for large portions of the year
so radarsad is super valuable
because we get a continuous data stream
even through the winter
in those kind of arctic portions
when it's dark for most of the day
okay couple of last
kind of three things i'm going to talk about
are some examples of radar applications
just to give you a bit more of a specific sense
of what radar can do
so we're going to talk about ice mapping
oil spill detection
and ground penetrating radar for archaeology
so the image you see on the left here
was actually the first seamless mosaic
which just means the first kind of entire image
that didn't have any breaks or anything in it
one whole continuous image of antarctica

and it was compiled by radar sat
between about september and october
nineteen ninety seven
this was actually one of the largest motivations
to initially launch radar sat one
we did not have a continuous
full mosaic image of antarctica
until radar sat one
was launched
so soon after it was launched
one of its main purposes
was to build up this map of all of antarctica
now we've moved on from just
mapping what antarctica looks like
to trying to understand ice patterns and ice flows
and typology around antarctica
to be able to predict and understand
influences of climate change
as well as other
you know other anthropogenic influences
so this image on the right here this map
this was the first complete map
of the speed and direction of ice flow of antarctica
and it was derived from radar sat two
with the addition and in collaboration
of two other japanese and european satellites
but radar sat two was really fundamental
to building up this map and again
gave us the first complete map of all of antarctica
to understand ice speed and ice direction flow
which was super
super super valuable
and continues to be valuable
so that we can understand the ice dynamics
that are occurring in such a place that is really
really hard to get to you know
radar sat saves us from having to go down there
and try and take these measurements by hand
granted people still do that
because they have to validate the data
they have to ensure that what radar sat is telling them
is actually true
but not nearly as

not as nearly
small of a scale
you know generally
we'll talk about later in the lecture
how data validation works
with remote sensing
in this case
from this radar satu map
there'd be a couple scientists that would go
to a couple specific spots all across antarctica
and take some field measurements
to ensure that what we're measuring with radar sat
is actually pretty accurate
okay so big application of radar sat one
and radar sat two in particular
both mapping antarctica and understanding ice flow
speed and direction in antarctica
quick video i think about that here
for decades
scientists have been probing the greening dye sheet
from the ground
air in space
now a new study uses those observations
to see within the issue
lame bear a tale
more than a hundred thousand years in a mannequin
when we look inside an issue we can see distinct layers
formed by thousands of years of snowfall
at a snowing noise
these layers get progressively compacted into ice
which then flows under its own weight
to get a precise
history of a particular spot on an ice sheet
scientists drill into it and recover ice cores
which provide a record of the ice age
and what the past climate was like
seasonal variations
along with ash and volcanic eruptions
show up in the course
allowing us to date the ice
and correlate samples from different sites
to extend this age information across the ocean
the best tool that we have

is ice penetrating radar mountain
on aircraft flying low over the surface
radar transmits electromagnetic pulses into the ice
and records the reflected signals
allowing us to track the depth
of a layer detected in the ice
since two thousand nine
nasa's operation ice bridge
has flown over greenland more than one hundred times
with a wide variety of instruments
including radar
and produced fast quantities of data
adding to the work from many other missions
this is allowed researchers
to generate a three dimensional map
depicting the age of the ice
throughout the green lineage
this three d eight map
shows that three distinct periods of climate
are evident within the ice sheet
the policy shown here in green
the last ice age
shown in blue
and the ianian
shown here in red
the top layers from the holocene period
formed during the last
eleven point seven thousand years
and a fairly flat in uniform
though the thickness varies
depending on how much snowfall occurred below this
deeper within the ice sheet
we see layers that form during the last pace age
layers from this period are darker and more complex
having been further squeezed and sometimes folded
as they flowed over the rugged bedrock below
deeper still are layers of ice
left over from the warm period before the last ice age
more than one hundred fifteen thousand years ago
amy and ice can reveal
how the ice sheet responded to a period of warmth
similar to the one we are experiencing today
several ice cores were recovered

amy and ice
but it is difficult to interpret
this new map of the age of the aishi
shows that there is more indian ice than expected
in northern greenland
where it made it easier for scientists to collect
and analyze
this new analysis reveals a three d map
of the age of the greenland ice sheet
from the oldest aemian ice
to the layers deposited during the last ice age
to the ice that formed during the policy
the response of the ice sheet to pass climate change
led to its current age structure
further study
some of us better understand
how the greenland ice sheet will respond
to today's changing climate
okay key differences there in that video
from what i was talking about
first thing was
i was talking about ice mapping in antarctica
so that was obviously in greenland
second thing was
those two images i was showing you of antarctic maps
were collected with radar sat
so a space born satellite
whereas the application they were talking about there
was a ground penetrating airborne radar instrument
so a radar instrument just mounted onboard a plane
that they just flew systematically over the ice sheet
and were able to use
to penetrate through the top of the ice surface
and get a sense of the different layers
below the surface
okay another really useful
really common application of radar
is oil spill detection
so this is an example of an oil spill detection
from a radar satellite in wales
on the right here
so you can see
the oil spill there

and the way that it works is oil floats on top of water
when oil floats on top of
in this case
oceanic water or just oceans
it suppresses oceanic capillary waves
those are just kind of the little microwaves
that occur on the surface of the water
so when oil is on top of the water
those capillary waves kind of disappear
it's much flatter
so it is a much less rough surface
ocean water without the oil on top of it
is a rougher surface
oil on top of that suppresses these capillary waves
makes it a smoother surface
that difference in surface roughness
which we talked about earlier
which is one of the things that governs
the backscatter we get from radar
this change in surface roughness
created by an oil spill is very
very easily and accurately detected at night
at day under any weather circumstances with radar
so that makes radar again very
very valuable
for detecting something crucially important
like oil spills
because we can do it at day or night
in any weather circumstances
and the properties that oil change
when it spills and is on top of oceans
that change in surface roughness is very
very easily detectable and classified by radar data
make sense
okay see last application
also pretty fun one
is geophysical archaeological study
in this case
several viking age and medieval sites in denmark
so this is how terrestrial
ground penetrating radar works
so this here is a bunch of archaeologists
remote sensing scientists

that are driving atvs or tractors on top of the surface
or the area that they are researching
and looking at
what they are towing in the case of these two
or pushing in the case of
this top image
is a radar instrument
so you can see here
they're either pulling it
they're pushing it
and as they're moving along
that radar instruments
either being pulled behind them
or pushed in front of them
and as they're traveling
that radar instrument is sending microwave energy
through the ground
which is eventually hitting different layers
below the surface of the ground
and back scattering
or reflecting back to that radar instrument
so this is the area
that they were looking at on the right here
and then this is the radar image
actually overlaid on their study area here
so they would have systematically
just in these little atvs or tractors
gone back and forth
and back and forth
and back and forth
and back and forth
and back and forth
until ultimately
they were able to build up an image of that entire area
and what they were able to do with that data
was actually go and map medieval viking buildings
so you can see here
all these buildings here in gray
denoted by h
are different buildings that they were able to detect
and how they were able to detect them
was looking at a radar
image like this

so this is a zoomed in radar image
of one of the buildings that they were able to detect
and you can see here
you see these little dots here
there's like dot
dot dot dot
dot dot dot
and then next to it parallel
there's these dots
dot dot dot dot
dot dot dot
so those are pegs
from a medieval viking building
and you can see that building here
so that's the h
one building
that's this guy right here
and you can see the shape of it
that they've mapped out
is just denoted by
these pegs that they were able to find
that were used to hold up the building
so pretty cool
interesting application of ground penetrating radar
ok couple of review questions for you guys to go over
i'll leave you for a couple minutes to brainstorm them
try to answer them yourself
i'll come back answer them with you
and then i'm going to hand it to evan
he's going to quickly talk about the midterm
and then i'll hand it to tristan
to talk about the assignment that's due this week
and then that'll be it
so if you want to head out now you're welcome to
and in about three minutes or so two and a half minutes
i'll go over the answers to these
and then we'll get evan and then we'll get tristan
whoa
you know the secret pathway amazing
you gotta show me that
no no no see that i'm
i'm glad you guys made it yeah thank you
okay guys let's crowd source these answers

so how does an active remote sensing instrument
differ from a passive one
can someone explain
please yeah
while passive remote sensing just receives
the wavelengths which come from the sun
yeah passive remote sensing is like
giving them out
and then making the waves reflect off of the earth
and then sensing them again once they come back
exactly so passive remote sensing
involves energy being emitted from the sun
bouncing off the surface of the earth
and then being measured by the sensor
active remote sensing involves energy being emitted
from the instrument itself
traveling towards the surface of the earth
reflecting off the surface of the earth
and then being measured again by the sensor
what are two advantages of using radar
there's two key ones we talked about yeah
yeah
yeah
exactly yeah so
the two key things that were mentioned up there were a
that it is a weather independent instrument
it can see through clouds and storms
and then also it can be used at any time of the day
so we can get radar imagery at night as well as daytime
okay what are the common radar bands used in practice
that we discussed in class
and which of them are the largest
so there were four
so want to just list them off for me yeah
xl and p and what was the largest
p is the largest exactly
and then what types of waves
this was at the start of lecture
what types of waves do radar lidar and sonar each use
so what types of waves do radar use
we talked about that one the most
yeah microwaves
and then what kind of waves does lidar use

anyone remember top right yeah
laser light beams exactly
exactly that
so laser light beams of either visible
generally near infrared light
but just saying
laser light beams is sufficient for that
and then sonar
what kind of waves does sonar use
yeah sound waves exactly
and then lastly
what do you think
was the most interesting application of radar
from what we discussed in class just now
we just discussed three
someone can just shout out one to me
yeah
mapping the viking village is perfect
ground penetrating radar used to map medieval buildings
awesome okay i'm going to hand it to evan now
just going to switch slides here
just this one yep
everyone so i've got my normal stuff today
things you should be working on
assignment three
that's due march second which is thursday
tristan's going to talk a bit about it
blog post four do next thursday
and then assignment four do the thursday after that
tristan has office hours
two of them tomorrow one of them on thursday
there has been a change
i sent an announcement out about that
and that's just the one
on thursday and that
we're going to talk a little bit about the midterm
so great job everyone
the average was eighty nine percent
high score a hundred percent
quite not quite a few
a few people got a hundred percent
and the average time was
about an hour and twenty two minutes

so some people around time but a lot didn't
we're going to be posting the grades for everyone
after class
if you have any questions comments concerns
send me an email
there is a two week period
where we'll be accepting grade change comments
so don't come to us at the end of the semester
right after the final saying
i need this two percent on the midterm
do it now check it over like asap
basically we won't be releasing an answer key
that being said
if you're curious about what the actual answer is
we will tell you
we're just not giving you a
a document of the answers
before you email me
make sure that if you have something like this
see this question thirty two
how you've answered geodetic points
and the correct answer is geodetic point
it looks like you're incorrect
but if you check in the top right corner right there
you got four to four points
so before you email me about these
fill in the blank questions
please check this over
every year i get a bunch of these ones
and i just respond
you did you got the question
right but there's a bunch of time out of my hands
right that's it for me
so if you have questions about midterm
but the grades aren't out yet so you shouldn't
if not i'll hand it off to tristan
he'll go over assignment four
three three three
any questions about the midterm
before the grades come out
oh oh
okay so there's not a whole lot to go over
at this point

because i haven't had too many questions so
yeah so feel free to drop into my office hours
tomorrow and thursday
and i just want to make one clarification
i'll do that first
so for question fourteen and fifteen
it says to uh
it says to deal with this date
august twenty
first of two thousand seventeen
but um the timeline you're looking at
actually goes beyond that
so you're gonna look at this entire chart
so it goes a bit into the twenty second as well
so just make sure you look at all of that
to answer that question
and for question fourteen and fifteen you will be
you do choose all of those options
between the two questions
also
for the dop questions
remember the dilution of precision is
it decreases your precision
so if you want to take a field measurement
on a good time of day
it will have a low dilution of precision
yeah i think that's about it
now i'll take any questions if anybody has them
and you can come down here and ask me them
any questions
you want tristan to go over the slides with yeah
but
you want us to give the time range
like one of the times
did it ask for the lowest dilution of precision
yeah are you thinking of the one
when there's two different times yeah
yeah you can pick either of those
for the correct answer yeah
anything else
i've really looked into it
but just from seeing that chart
is a higher numerical value

for the dilution of precision mean that it's good
dilution of precision as in
like the satellites are more spread out or
no you want a lower dilution of precision
yeah yeah correct yeah yeah
higher value means the precision is more diluted
essentially yeah
okay feel free to come down if you have any questions
for me or tristan or anything
otherwise see you next week
that's when i get home
oh see thank you yeah thanks
sorry for
oh okay yeah yeah
so the two parts were that
so really the most important part to remember right
active remote sensing
so i think you know that very constant
like a satellite system too many satellites wait
would be visible
most likely
but by doing that if the
whether or not they're tightly clustered together
looking at probably wouldn't make any difference
so in the case of safe radar staff
we're only looking at exceeding
with passive remote sensing systems
say modis lancead we can look at ten twenty
thirty bands because we can simultaneously
oh so yeah so for this one
because you know that the gps is american
the reason you're seeing it above that area is one
you have to look at what latitude zone
yeah so
does that make sense yeah yeah
yeah i mean
after the most sexy
so with radar you'll specify
but you're only ever eating
so the fact that it's large is
one reason you're seeing it
and then another reason is because it is
because the place you're looking is in this one

latitude zone so it's
so you just need to find out
which of these latitude zones basically
that's then like north american
it's really hard to sign the tip
you just google that
if you look at the basic like mids low height
is ultimately that would be done by
so this one is kind of a trick with a
no just this last one all the different
yeah basically
but yeah you want to look between these three
okay hope that makes sense
yeah part of that is just like practicality
it would be really
really hard to admit all possible forms of radiation
from a sensor at the same time
and then the other part of that is just
let me check the
with active remote sensing
you pick what band we're gonna use
and then there are two tabs
so you can pick either of those
which is how long it takes
that energy to travel towards the target
bounce off that target
and travel back towards the sensor
which tells us how far away that target is
and then the case radar will also measure how strong
because the pass gate is still valid
because that is the most recent
but again will information that it's received
well you can still receive something in the past eight
to do that it's just the most recent
more than that is really difficult
so it can still be relevant in our past eight
but it can't be healthy in something different future
that means forming a star
once we're getting a measure of backscatter
from the energy that we've been in that
we're generally getting the information that we want
so that's kind of a very long tangential
answer to your question

but there are kind of several different reasons
why you would only ever use one man
but that kind of
the fact that we only do ever use one man
that question of why we have a spectra
yeah that makes sense
because it's about the gravitational pull from the sun
and what is the other one
the sun look solar
radiation like
those would be pretty weak effects on a satellite
so they would not likely affect like
the actual position of the satellite
it would affect like the fine
the fine measurements and so yeah
so that was good there
yeah you're welcome yeah hi
okay yeah i mean these
for both of these
it's like a combination of electric slides
videos and i guess sounds will require but yeah
so you're confident
the three you underlying and so
and so you can go to satellite receivers
sources of air
usually you won't be also getting air
ground patient because you'll just store that
and then reflective surface
i think this isn't
but um yeah
basically if
if your signal is bouncing off the surface
increasing the time
the time that it takes to proceed to hit the
so it would
this one
yeah so look atmospheric modeling differential
yeah so this was more of an application
these are all you can also kind of classify
these are the types of error modeling here
so the only one that i would look at is this runway
you're welcome
sending energy through the ground

and then it's penetrating to a specific depth
and then bouncing off of whatever's down there
coming back to its sensor
so by doing this again and again and again
systematically across the study area
you're able to build up an entire image
of that whole area
of what the penetrating radar is seeing
and then in this case
what they were able to do with that
oh sorry so when you go to the quiz
i think you'll see that for this choice for a
you'll only have
the two options
precise or down
precise travel i think on the ground
anyway but i think you should the lunar cycle
i would not look at those suctions
yeah you're welcome hey
all across that study area
so in this case
this building that is here is this age one building
so that one made
because that one we didn't cover in class
was kind of a red herring
oh so i had to give a
heavy penalty to a yeah
um you could but
but did you learn anything about lead satellites
just like there's not really
it's a constellation
okay because that's what i mean
like i didn't care about anything but yeah
yeah it wasn't that one yeah
yeah yeah no
and then if you think about like
because all those
stylistic precision measurements are related
and they are
based on the relative positions of the stylist yeah
oh no also don't especially
there were like an okay number of satellites
but a lot of them close together

and having a
bad time to do it it would
would you consider
also a factor in that because i would
but there were lots of round but they weren't like
so you're using the sky chart stands
i would not use the sky chart
yeah you're
i would use
was that so
he claimed we use this chart or the exam
whether or not that's true i don't know
but he claimed that he was still in his award
i would use both so
on a good time you want a high number of
translate and copied it and or yeah
so you just go over
each time you see a correspondent into
in the number of satellites
then you can see like how many are there
but yeah i think probably
just might be more clear this way instead of like
obviously for the story
the answers you had
were those the ones you just translate
yeah yeah so i would
i would double check
yeah and if you can email me the candy answers
and i can tell you
yeah yeah because those aren't yeah so yeah okay yeah
well is the like when you look at it
is it in the great gate or the pass gate
for being very reasonable i was
i know i know yeah yeah
and i could because i can go
as i put it in the chat
yeah yeah because this isn't like a concept question
was like still clean
the healthy one is it
does it say it's the current or past questions yeah
the content into or the actual thing
and i created notes based on that
of super sense right

yeah that looks good
that all looks great
yeah yeah i was emailing you about the important topics
things from yesterday
oh yeah and i just put yeah
i just read your like reply to like
yeah it's totally clear
now the only thing i'm wondering is like
if you ask about the
yeah you too
is a pretty good threshold that would be
yeah because it's really
it's really a combination of the high numbers that like
but two ended up being the good
because isn't that kind of an overall yeah
so like i expect the rest is kind of more an overall
yeah exactly
so like you would say
in that case you would just say bands in the
nearly correct
okay okay okay great
i just wanted to make sure i had the drum roll
the other ones like spatial resolution
yeah say like high spatial or high to oh
yeah just like a ring yeah
so could you say like yeah that looks good
for example like any like under a hundred something
that's different
yeah okay exactly
that's great
thank you so much
yeah so with the healthy side like the measurements
i guess i feel it would be for the current
but even if it's in the past it doesn't mean
it just means it has the latest update
so that can still mean it helps us like
but i mean this guy kind of influenced
like it was pretty
it was pretty flagrant
all right hi everyone welcome happy monday
i wanted to
i'll go over this
this is kind of a quick side note to start off

i'll go over this again when we get closer to the date
and look exactly at how the
uh i look exactly at how the weeks are gonna shape up
and how the syllabus looks
but i just realized
for a couple of classes that i teach
that the last kind of weekend
where classes are still happening
which is the weekend of the eighth and ninth
it is a holiday
the friday and the monday before and after that
so it's a holiday on april tenth for easter
and the university is gonna be closed
and then we technically have a
lecture scheduled for the following day on the eleventh
um so you know
everywhere to shape out
normally we'd have a lecture
on the third and the fourth of april
which is the monday tuesday
and then one following on the eleventh
the eleventh
realistically
would be our review session
but maybe i'll
you guys can think about it
maybe i'll kind of pull you guys
in a week or two to see what you want to do
um just in the sense that
yeah i don't know that
i feel like it's gonna be a bit awkward
to come back and try to lecture after a long weekend
on this one day
before the end of class and before exam start
so we could just take that day off
we don't have to have a lecture that day
we don't have to do the review session that day
i could move it to the fourth
essentially the week before
and then the fourth would be our last day of class
so maybe think about how you want to do that
it would involve me maybe condensing a couple lectures
maybe moving a little bit quicker

than i was planning to
but it honestly wouldn't result in that much
of a change
and would just kind of
at least for one to seven
it would relieve you from you know
having to attend lecture anytime after april fourth
and then we have the final exam
which i'll talk about in a moment later
so maybe think about that
i'll i'll maybe get you guys to give me a vote
next week or the week after that or something
and see how you guys would like to do it
but i don't
i don't mind either way
so it's kind of up to you
um okay so today
quick notes about what you should be working on
blog post four is due march ninth
assignment four is due march sixteenth
march sixteenth is next thursday
so liana has some office hours for that to say
assignment three
evan man come on
let's just say assignment four
boom right assignment three you already submitted
i'm not losing my mind right yeah okay
but so leanna will have some office hours
this week and next week for that
if this wants to load
i shouldn't have clicked save
there should be now an introduction video
posted on canvas on the assignment for submission page
that leanna made to go with that assignment
so i usually tell the tas
either they can come into lecture at the end of class
and give a bit of an introduction
to help provide you guys some context
about what you're doing for the assignment
or they can just make a video and post that on canvas
so she opted to make a video
there's a video on canvas on the lab
on the assignment for submission page

for assignment four
so go check that out when you get the chance
and then next week
monday tuesday
i'll get liana to come into class
and give you some tips and tricks
you can ask her questions
if you can't make it to office hours and so on
these are her office hours this week and next week
and so the last set are the day the assignment is due
from two to three pm
and she's also got some next week from ten to eleven
and some this week as well
okay final exam date has been given to us
it is dreadfully at seven pm
they always
i don't know what it is with this course they
i guess i'm just
i'm pretty low
i'm probably the lowest in seniority
in terms of instructors across all of ubc
so they probably are just like whatever
chris is just a lecturer who cares
give him a crappy time
so i'm sorry for that
um so april twenty seventh
at seven pm
that i think is the second last day of exams
so it really
i mean obviously
you know seven pm
not ideal for you guys
and i'm sorry
it's kind of at the very end of exam season
also sucks for us
because we have a super tight timeline
to submit final grades for
so we essentially have to have this marked by the
end of the following day
so it blows for us too but yeah
sorry about that
but that's what we'll work with
it'll also be fully online

and also open books
so if you're planning on leaving
vancouver for whatever reason
you don't need to be here
you can write it online
you just need to make sure you have good internet
we'll give some more details and
obviously post practice questions and things like that
closer to the exam
okay any questions about course logistics
assignments blog posts exams etc yeah
there's no video yet okay
okay i told her
i just talked to her
and she said that she had accidentally
uploaded it to the wrong uh
course section to like an older years course section
so she said she was uploading it right now
so maybe refreshing thirty minutes or so
and it should be there
i'll maybe send her
i'll send her a quick message as well and just say hey
it's still not up yet
she just messaged me at five o seven saying
should be up
do you see it now
if you refresh
nothing yet
okay i'll look into that after
it should be posted very soon after lecture today
i'll get that sorted out with her
okay okay going back then to lecture content
what we're talking about today
we are continuing on with active remote sensing
so just to quickly remind us what we're talking about
i know it's been a little while
since we've seen each other
we're talking about active
versus passive remote sensing
passive remote sensing
up until now
has dominantly been what we've been talking about
passive remote sensing involves energy

radiation being emitted from the sun
traveling through space
getting towards the earth
traveling through the earth's atmosphere
bouncing off of some surfaces of the earth
traveling then back to
through the atmosphere
some sort of remote sensing sensor
some sort of remote sensing system
where we measure how much reflectance
for different bands or for different wavelengths
is being reflected off that surface
that's passive remote sensing
active remote sensing
we emit energy from the instrument itself
so our active remote sensing systems
send out energy from the instrument
just like this boom
it travels towards a target or towards the surface
bounces off that target
bounces off the surface of the earth
travels back to the instrument
and that's what we then detect and measure
now we talked about briefly
i just introduced
three different kinds of active remote sensing
radar lidar and sonar
radar was the one that we focused on the most
but we generally just noted that radar uses microwaves
lidar uses lasers
and that's what we'll focus on mostly today
sonar uses sound waves
so sound propagation and all
i got a slide or two about sonar
we don't talk about it that much
because it's not very applicable to earth observation
remote sensing
but i'll briefly discuss it and some applications of it
and then last week on tuesday
we mostly focused on radar
we talked about how radar works
so we talked about how
radar instruments emit microwave energy

so even though it's called radio detection and raging
they emit microwave energy
that energy travels towards a target
and then it bounces off that target
and depending on different properties of that target
such as the surface roughness of that target
the moisture content
and the dielectric properties of that surface
we might get a different level of backscatter
or reflectance of that microwave energy
after it's been omitted
bounced off that target
and traveled back to the sensor
we talked about how radar is advantageous
because it's an all weather system
microwave energy can penetrate through clouds
through storms wow
didn't see that one coming
microwave energy can penetrate through clouds
through storms
through all kinds of weather
you can also use it at night or during the day
so it's an all time of the day
all weather remote sensing system
the bands that we talked about used in radar
the xcl and the p bands
we talked about briefly just how the
band size that you pick
should be related or associated to
the size of the targets that you're looking at
so you want to use smaller
radar bands for looking at smaller targets
you want to use larger
radar bands for looking at larger targets
so if you're looking at big tree trunks
you want to use larger radar bands
if you're looking at tiny little leaves
or little rain droplets
you want to use smaller radar bands
we also talked briefly about how radar
can be used to penetrate the ground
and that the amount of ground penetration
that you can get with radar

also depends on the bands you use
the larger the band
the more ground penetration
you're going to get with radar
we briefly talked about the different radar satellites
particularly
that canada is involved in
talked about radar sat one
radar sat two
then briefly mentioned the radarsat constellation
which is three identical radar satellites
and then we talked about three applications
of radar data
we talked about monitoring detecting oil spills
we talked about antarctica mapping
and we talked about
the use of ground penetrating radar in archaeology
specifically for mapping of ancient viking villages
so now today
we're going to talk about lidar
now lidar is what's used to create
something called a point cloud
this is an example of what a point cloud looks like
and a point cloud is a set of
or a collection of
three dimensional points
where each point represents
a three dimensional coordinate in space
so each one of these individual dots that you see here
on this point cloud has an x
y and z coordinate associated with it
so it has a x and y coordinate
as well as an elevation
a z coordinate
associated with it
and when you get a large collection
of these point clouds
you can see
you can start to make out some features
and some attributes
of different kinds of surfaces
of different kinds of targets
in this case

and what i'll mostly be talking about today
is the use of lidar in forestry
so in this case
we've used a lidar instrument
to derive a point cloud
of a forest
so you can see here
kind of the individual trees
that are making up this forest
you can see the top of their canopy here
you can kind of get a sense of
the shape of these trees here
and then you can also get a sense of
where the ground is located
below those trees
so we're going to talk about in depth
how you go away
and create this point cloud
using lidar data
so lidar is an acronym for light detection
and ranging
and how lidar works is
it sends a pulse of laser light
towards a target
a laser is just a narrow beam of light
all with the exact same wavelength
so this that i have in my hand here
this is a laser
this this isn't sending pulses of laser light
this is just one
constant stream of laser light
that's being
sent towards whatever target i'm pointing at
but it's a laser
because it's this discrete
narrow beam of light
and all of this light has the exact same wavelength
size in this case
on my laser pointer is red
so with lidar
you can pick
which wavelength size you want to use
to send your laser pulse

you can use visible
red if you want
just like i'm using
on this laser pointer
you can use visible green
you can use near infrared
you can use shortwave infrared
you get to pick
what you want your laser pulses to be
but ultimately
whatever wavelength you choose
you're still going to be pulsing laser energy
which if i were to
if this were
say a lidar instrument
and i were pulsing it
at a target of interest
say my target was the screen
it would look like this
that would be pulses of laser light
it's sending and then it stops
then it's sending and then it stops
now why do you think
or what do you think
might be the most common types of electromagnetic waves
or radiation
used in lidar for environmental applications
specifically for say
measuring and looking at vegetation forestry
what kind of laser light
if i have a lidar instrument on board this plane here
and i'm sending lidar pulses
down towards this forest here
and i want to get a nice clean response
of that laser light back towards the sensor
given what we've talked about
and say our spectral signatures lecture
what do you think might be a good
wavelength size to use or a
good portion of the electromagnetic spectrum to use
so say visible red
visible green
visible blue

near infrared
shortwave infrared
what do you think
near infrared
shortwave infrared
near infrared for vegetation
for forestry purposes is generally the most common
because we know from our spectral signatures lecture
that healthy vegetation in particular
reflects near infrared light very very very
very strongly
so when we send individual laser pulses down towards
say a forest
we're going to get a strong response
a nice clean bounce of that near infrared laser light
off of each individual leaf
which ultimately is going to give us some very
very high resolution
three dimensional information
okay i have a quick video here
that just kind of demonstrates it
actually uses
a space born lidar instrument as an example
to look at the terrain of mars
i believe it's not earth
but it's a good depiction
and a good illustration of exactly how lidar works
if you want to find out how tall mountains are
on other planets
how would you do it
if you're on earth it's easy
you can take a picture
fly over the mountain
or you can actually go there and measure how high it is
on other planets
it's much more difficult
you might be able to estimate how using shadows
or you can take three d pictures from a satellite
but what if you wanted to know
what the mountain look like
is a three d model
to find out
nasa scientists can use a precise measuring tool

called lidar
mounted on a satellite already high above the planet
lidar instruments are able to accurately measure
the distance
between the instrument and the landscape below
using laser pulses
to make these measurements
the lockout instrument first sends a laser pulse
down to the planet's surface
the pulse hits the ground
and reflects back to the instrument
where an onboard counter
measures the time to poke the pulse to make it straight
that gives a precise measurement
of the distance between the instrument and the ground
with respect to the planet's gravitational center
as the satellite passes under the landscape
the instrument sends out a series of regular pulses
by recording and combining these measurements
scientists can use the instrument
to gradually build up a map
of the height of the terrain
after many more measurements
the end result is a high resolution three d model
that scientists can hear
is that they are actually on a planet
flying over the terrain
they can then study the shape of more detail
looking for clues to the relative ages of craters
the shape of valleys and landscape features
and much more
the latter is far more versatile than simply measuring
the shapes of mountains and craters
earth scientists
for example
use lidar to measure the height and density
of the earth's forests
others use lidar to study small changes
in the heights of the earth's major ice caps over time
still other scientists use lidar to study
the composition and structure of earth's atmosphere
as well as the atmosphere of other planets
and they can do all that

without ever having to climb a mountain
okay so just to break that down in a bit more detail
i'll go over kind of the nice illustration they gave
to show exactly how lidar works
but lidar sends pulses of laser light towards a target
most times oftentimes
lidar is mounted on an airplane
sometimes a drone
that's becoming more common nowadays
it's not as frequently used as a space born device
it still is sometimes
icesat which we'll talk about
is a spaceborne lidar instrument
most commonly though
it's onboard an airplane
so we'll talk about it in that context
imagine there's a lidar instrument
on board this airplane
the airplane is flying over a surface
and it's continuously sending down pulses
of laser light towards the surface
generally pulses of near infrared laser light
now that's kind of the first technology involved
in the makeup of a lidar instrument
is laser ranging
so by sending pulses
of laser light towards the surface of the earth
and then measuring how long it takes those pulses
to bounce off a target and come back to the instrument
we can determine how far away
that target is from the instrument
so say that again
if we have a lidar instrument onboard a plane
my plane is flying over a certain area
the plane is sending down pulses of laser light
and those pulses of laser light are traveling
at the speed of light
which we know is a constant speed
then we can time how long it takes
for each pulse of laser light
to be emitted from the lidar instrument
travel towards the surface of the earth
bounce off of a target

travel back towards the instrument
and by using
by timing how long it takes to do that
and then combining
our knowledge of what the speed of light is
what the speed that those waves
that laser light is traveling at
we can then determine how far away that target is
so that's the concept of laser ranging
to the ability to measure time
of how long it takes a laser pulse
to be emitted from a sensor
travel towards a target
bounce off that target
and travel back towards the sensor
the other technology that lidar takes advantage
of is gps or gnss
we've talked about gps and gnss in detail
but essentially
what gps allows us to do now
is to determine our geographic location
and height of the sensor
with a really
really high accuracy
so that means that when we are again in our plane
flying over a portion of the surface of the earth
sending our laser pulses down
we know the exact location
we know our x
our y and our z coordinate
so we know our exact location and height
that each individual laser pulse is emitted from
we know exactly where each individual pulse
is sent from
because we have a really accurate gps measurement
if we know exactly where each pulse is sent from
and then exactly how long it takes for that pulse
to travel towards the surface of the earth
bounce off of a target
and travel back towards the sensor
that not only do we know
how far away that target is from the sensor
we know also exactly where that target is

in three dimensional space
the last technology that is involved in lidar
is the use of something called inertial
measurement unit or an imu
and it just helps determine the precise orientation
of the sensor
so when you're on board an airplane
an airplane can have pitch
yaw and roll
so it can it can roll like this
it can pitch like this
or it can yaw like this
which essentially just means that
the airplane can kind of distort
the exact angle that it's flying at
or that it's positioned at
depending on winds
depending on a whole bunch of things in nature
that we can't really control
but what we can do is we can measure
with an inertial measurement unit
exactly what the pitch
roll and yaw is of the airplane
so if we know the exact orientation of the plane
we know the exact position of the plane
and then we measure
we time how long it takes that laser pulse
to travel from the sensor
to the target
back to the sensor
then we can get an ultra
ultra precise measurement
and three dimensional space
of how far away that target is
on the surface of the ground
that the laser pulse is bouncing off of
okay just in a bit more detail here
lidar systems emit pulses of laser light
again we just time how long it takes that pulse
to travel to the target
bounce off that target and return to the sensor
we use the speed of light
it calculates how far that target is from the sensor

and then we combine our gps and imu measurements
to calculate where that target is
in three dimensional space
so that means that if we go back
if you think about
back to that first image we looked at
of the point cloud
each one of those three dimensional points
in the point cloud
is something that a laser pulse
bounced off of
so we get all of those really
really precise individual three dimensional points
because we have this laser pulse
that's sending towards the surface of the earth
bouncing off a bunch of targets
and we get a really
really precise measurement
of exactly where that target is
in three dimensional space
using the combination of lidar
which is laser ranging
gps and imu technologies
ok so just to look at that video that
that we showed or that i showed
we're not going to look at the whole thing again
but again we have this instrument or lidar instrument
it's flying over the surface of the earth
this is a satellite
could be a plane
flying over the surface of the earth
sending pulses down boom time
how long it takes to get to the ground and back
so each of these pulses is timing
it's timing
it's timing
it's timing
so it knows how far away
that's what this is
how far away those targets are from the sensor
you flip that around
and we get a nice measurement of the terrain
of exactly where the ground is

now we can do the exact same thing as that
but we can do it with a forest
and we can get individual points
not just across entire hills like this
but for each individual leaf
or each individual branch of a tree
which gives us that really
really high resolution three dimensional information
now lidar system generally
emits thousands to millions of pulses per second
the speed of light is very
very very fast
as we've talked about
about three point o times ten
to the eight meters per second
so a lidar system is capable
of emitting thousands to millions of pulses per second
so every second it's going
sending tons and tons and tons of laser pulses
towards the surface of the earth
each one of those pulses
each individual laser pulse
that's being sent from the sensor towards the target
may have one to five return measurements
so that means
that if we send one pulse towards the target
it might hit a leaf
and then send back a signal to our instrument but
the original laser pulse may keep traveling downwards
past that leaf
and then hit a leaf below that
and then send another signal back to the sensor
and then the pulse will keep traveling below that
maybe hit another branch
send another signal back to the sensor
and then keep traveling below that
eventually hit the ground
once it hits the ground
it'll send its final response
its final measurement back to the sensor
so in that way
with a single individual laser pulse
we can get multiple three dimensional measurements

that lends itself in part
to why we're able to get such high resolution
three dimensional information from lidar
if you're sending thousands to millions of pulses
of lasers per second
and each one of those pulses
is resulting in one to five
three dimensional measurements in space
you can imagine the extreme
wealth of information you're getting from that
the point cloud you would get would be very
very very very dense
you might get a point cloud every couple of centimeters
in three dimensional space
which gives you a really good sense of things
like structure of trees
things like terrain
three dimensional information
now this is just a depiction of ultimately
how that would work
so if this is our plane here
we're sending one individual laser pulse from our plane
down towards the earth
when it first
hits the top of the canopy of this tree here
it'll send its first return back to the sensor
so our laser light travels down
boom it hits the tree
some of that laser light gets sent back to the sensor
so it records that as what's called the first return
that's the first measurement that it gets
from that laser pulse
some of that laser light continues to travel
deeper into the canopy
and then it hits another dense layer of leaves
and it sends a second return back to the sensor
it keeps traveling down
maybe hits another smaller tree below
it sends another return back to the sensor
and then it keeps traveling even lower
eventually hits the ground
sends a really strong return back to the sensor
and the buildup of those returns

essentially looks like this
it looks like this graph here
so as the sensor
once it sends one individual laser pulse
it's continuously recording
how much of that laser light
is being reflected back to the sensor
so you can see here
the returned energy on the x axis here
is just how much energy is being reflected
back to the sensor
after it's been omitted from the plane here
and you can see here
the first return right here
that's kind of where there's a peak
in the energy that's reflected
second return
there's another peak here
third return
there's another peak here
fourth return
there's another peak here
so each one of these returns
is essentially just a peak in the amount of laser light
being reflected back towards the sensor
and in this case
we see four returns
sometimes it might just be only one return
if there's no trees
for example
it's just bare ground
that the laser pulse is sending down to
then there's probably just going to be
one return back to the sensor
because there aren't a bunch of different targets
for it to bounce off of
but if we have
say you know
a forest that has a very
very loose or very
very sparse canopy
that has lots of space in it
then the laser light will continuously penetrate

all the way through the canopy
and intermittently send back returns or signals
to the sensor as it does so
okay any questions about that yeah
sorry i can't i didn't catch that
a large boulder yeah
so if it's so
that's a key thing the
the differently from radar
radar actually penetrates through surfaces
lidar doesn't actually penetrate through surfaces
so the difference with lidar is that
say a pulse you know
say a pulse about this big is sent down to the ground
then a target smaller than that
will partially send back some energy to the sensor
but the rest of the light will keep going down
so if there's a boulder say a rock
and it's say this big
but the size of the laser pulse i send down is this big
and it hits that boulder right in the center
then it's just going to send back one pulse
so it's not actually going to know where the ground
is below that boulder
you know i'm just saying
how big this would ever be
to see a difference in the sensing
so that we know there is something there
like can it be like
mind you like
would we know that a small rock is there
or will we not know
yeah totally
that's a great question
so it it it depends
depends on a lot of things
it depends on how many pulses you're emitting
whether you're emitting a couple hundred pulses
per second or a couple million pulses per second
it depends on how wide that pulse is
it can be say
a couple centimeters wide
or it can be ten twenty

fifty meters wide um
generally speaking with lidar
we can detect changes in terrain
in topography that are very very
very minute centimeters in size
it isn't i'd say you know
a matter of how big does
say a boulder need to be to detect it
it's more of a question of
how small can it be for us to still detect it
and that's usually around maybe
you know we can't see like pebbles
but with high resolution lidar data
we can definitely see
you know cobbles and things like that pretty well
you're not going to get a sense of
you know how high the top of that cobble is
below the ground necessarily
but if it's just a cobble standing alone
you'd get ground measurements next to it
so you'd see this kind of like hump in the ground
so you can maybe determine it like that
yeah that can i answer your question yeah
so for the returning energy
is basically people returning life back to the incident
correct yeah
that's exactly right
okay so this is another animation to help us kind of
wrap our heads around how lidar works
so let's say this blue dot here
is a pulse of laser light
traveling from an airplane down towards a target
down it's gonna travel through this tree
through this tree here
hit the ground
and as it does so
on the right here
we're going to see the return strength
and the elevation of that return
strength on the y axis here
so let's watch this play
so the laser light comes down
you'll see boom

it hits something
there's a jump
there's a jump
and then ultimately
once it hits the ground
there'd be another kind of quite large jump
but that's essentially how it works
so this laser light
travels towards the surface of the earth
it hits some targets up here
some energy is reflected back to the sensor
some energy continues to travel through the canopy
then it hits this canopy layer here
it sends some light back to the sensor
some light continues down through the canopy
it then hits this part of the canopy here
send some light back to the sensor
some light continues down towards the ground
ultimately once it hits the ground
all of the light is gonna travel back to the sensor
at least all of the remaining light
that made it that far
and that brings me
that question
was really good
because it brings me to a key point
which i just mentioned
but i'll reiterate
lidar does not penetrate through targets
radar can penetrate through targets
it can go straight through the surface
straight through soil
lidar cannot
so the way that lidar ultimately enables us to get this
structural three d information of say
the canopy of this tree here
is because some light from an individual lidar pulse
will be sent back to the sensor
once it hits a target
but if that target is small or sparse
say it's just a small leaf
and it doesn't make up
or isn't as big as the entire footprint

or the width of the laser pulse that's being emitted
then some laser light will continue to travel downwards
towards the ground
even after some energy
or some laser light has bounced back towards the target
that's ultimately how we're able to get
more than one return per laser pulse
but it's a key distinction there
lidar does allow us to get structural
three d information
but it doesn't actually penetrate through things
it just might hit a target
and then some of that light be reflected
and then some of the light that missed that target
will keep traveling downwards towards the ground
whereas radar
can actually just see right through things
can go right through ice
right through soil
okay there's two types
any last questions about just kind of technically
how latter works yeah
so can you not use any wavelength you want
on the electromagnet spectrum for that you can
so why couldn't you just use
the wavelength that radar does to penetrate
or is that just that radar exactly
exactly you got it
yeah exactly
so you can use
generally speaking
for purposes
for lidar purposes
you'll see very rarely
maybe visible blue or red light
sometimes more commonly than that
you might see visible green light
by far the most common is near infrared light
because most of the time
we're looking at forests and vegetated areas
which reflect near infrared light really strongly
in theory you could use a shortwave infrared
but beyond that portion of the spectrum

as soon as we get into ultraviolet light
that doesn't really provide us any information
because that light doesn't have very important or very
tangible spectral signatures that we can measure
and same thing on the other side of the spectrum
thermal infrared
are emitted radiation
so measuring its reflectance isn't really going to work
so generally
we'd use either the visible
somewhere in the visible
or near infrared part of the spectrum
and then like you said
if you were to say
use microwave
then you would be using a radar instrument
and the thing is with sending that
and the big reason that
you're able to kind of get this very fine
three d information with lidar
does have to do a little bit with the size
of the wavelengths you're using
radar uses larger wavelengths
than what's available
in the visible
and near infrared portion of the spectrum
so if you're trying to get
say something like
three d structural information
of a forest canopy
which you can get
you can get really nice
three dimensional information with lidar
of the entire structure of a forest
all its branches
all its leaves everything
you're not gonna be able to get that with radar
because radar's wavelengths are so big
they're not gonna interact with all those
features nearly as much
so does that kind of help thank you
okay so couple applications of lidar
that we'll talk about

there's two key ones that i'll discuss in class
that is the use of lidar to derive terrain data
in the form of digital elevation models
and the use of lidar to derive structural information
on vegetation
in the form of point clouds
point clouds being that image that we looked at
when we first started talking about lidar
ok so first we'll talk about digital elevation models
so digital elevation models
tell us what the elevation is of a particular area
lidar gives us really
really highly accurate
high spatial resolution digital elevation models
so in this case
this is an example of a digital elevation model
this is just a three d depiction
of what a digital elevation model would look like
in reality it would actually just look like
something like this
so this is an example where they had
they used lidar
so each one of these boxes
is describing a lidar footprint
so essentially an area where they were sending down
pulses of laser light
and then the gray here
this kind of grayscale area here
is the digital elevation model that they derived from
that you can see here
ranges on a scale from two thousand
two hundred and fifty meters
to one thousand and fifty meters
and essentially
each pixel in this digital elevation model
each pixel which represents a specific area
depending on the spatial resolution of that pixel
say it's a ten meter pixel
it's representing a ten by ten meter area in real life
on the surface of the ground
but as opposed to
the data that we've been talking about
that you can derive from passive

remote sensing instruments
where each pixel
represents the reflectance of radiation
for a particular band or wavelength
in this example here
we've taken the lidar information
and we've derived a digital elevation model
where each pixel
represents the elevation of the area in that pixel
so twenty meters
thirty meters
forty meters represents an elevation
you can get really really
really accurate terrain information from lidar
because there's so many laser pulses being sent down
at such a high frequency
you can get a very
very high spatial resolution
when resolving digital elevation models
so that's all this is as well
this is just a three d depiction
of what you see in gray here
this is just kind of a classic raster
where each pixel describes
based off this grayscale
whether it's very high elevation and light gray here
or very low elevation in black or dark gray
this is just a three d depiction
of that exact same thing
now lidar is also a really excellent tool
for measuring forest structure
it can be used to gather a tremendous amount of detail
relating to forest structure
and the vertical organization of plant biomass
so if we look at this example here
this is a point cloud
on the right
here we got on the left here
a pole or sapling
point cloud
a pole or sapling
in forestry terms
is just a very young forest

very young forests are generally very very dense
while old growth forests
are generally very structurally complex
there's a lot of gaps in old growth forests
a lot of complexity in the branches
a lot of different levels to old growth forests
while young forests mostly have all of their trees
all the exact same age
all clumped together really tightly
and you can see that here
this is a young forest
a polar sapling forest on the left
then an old growth forest on the right
here there's a couple things
that you can really clearly make out from
this point cloud
and again this is just a cross section
of these point clouds
where each point here
each little bubble
represents a dimension in three d space
represents three d coordinates
but you can tell here
from looking at the cross section of that
that a the left
the pole or sapling forest
is not very structurally complex
you can tell most of the biomass
most of the canopy in this forest
is right at the top
all at the exact same height
you can see the density and returns from lidar is very
very highly dense right in that area
that's because most of the biomass
most of the leaves
and branches of this forest are all very
very very tight
right at this exact elevation
contrast that to on the right here
with that old growth forest
you see a very structurally complex forest
you see that there's lots of light
lots of laser pulses

that are not only able to make it
all the way from the top
through to the middle of the canopy of this forest
but also all the way down to the ground
you'll notice
in the pole sapling stand on the left here
we don't really have many points
that are denoting or describing
where the actual ground is
and that makes it really tough to actually
derive a digital elevation model
when we're looking at these very young forests
if we can't get ladder pulses
that get all the way to the ground
then it's very hard for us to determine
what the elevation of the ground is
when we have these old growth forests
that are very structurally complex
have lots of gaps in between their different branches
and their different leaves
it allows for lots of space for those lidar pulses
to get all the way down and
interact with all the different layers in the forest
ultimately till it gets to the ground
where it then sends all the remaining laser light
back to the sensor
so you see a very dense canopy on the left here
and you see lots of canopy gaps on the right here
and you can see with this box and whisker plot
which is right here and right here this line
this line there to the top and bottom right here
that line that just describes the variation
in the elevation of the point clouds here
and you can see it's very very small
all of the point cloud
all of the points in the point cloud
pretty much all at this kind of range of elevation
whereas you can see the variation
for the old growth forest is really really large
we get lots of points coming at very high elevations
as well as moderate and low elevations
whereas with this very dense
this very dense pole or sapling forest on the left here

all our points are just ranging kind of in that
twenty to thirty meter height above the ground
okay this is just another example of some information
that you could derive from lidar
so this is again just a cross section of a forest stand
but a little bit more zoomed out
so you can see some other features in this area
again we can guess
or we can see here that there's a lot of density
at kind of this general information or sorry
at this general elevation
so we can guess from that
that this probably isn't a very old forest
but it's probably not as young as this forest
because we are able to get some points
that reach all the way to the ground
so we get laser light
coming down from our plane up here
boom coming down
interacting with the top of this canopy
sending lots of returns back to the sensor
but then lots of that laser light
is also able to get all the way down below the canopy
you can see kind of
in this region
there aren't many points
that's probably because there's not many branches
or not many leaves
at this general elevation
most of the biomass
in this forest is kind of all right around here
but then some of that laser light
is able to get all the way down to the ground
so we can get a sense of where the ground is
below these trees
you can also make out the shape
of these individual tree crowns
so you can see here if we look at this pattern here
you can see a little hop and a hop and a hop
and a hop and a hop
and those are all individual trees
so we can actually make out individual trees
in the cross section of this point cloud

and then one other thing we can make out
you can see this kind of gap right here
and that looks like a road right there
so there's obviously no trees there
all the laser light would go boom
right down all the way to the ground
and send a bunch of returns back from there
and so we can tell that there is a road right there
this is just another example of
what that point cloud would look like
again of a older forest on the right here
of a much younger forest on the left here
and we could get a sense of really nicely
how this forest looks
what the elevation of the ground is in this area
and get some
we can derive lots of different kinds of information
from these point clouds
we're going to look at one example here
of using lidar to understand the impacts of storms
in different rainforests around the world
pulses of laser light three hundred thousand per second
each one represented by a single leaf
flying above a protected area of a brazilian rainforest
nasa scientists measure changes in the canopy
to understand how climate change
affects the amount of carbon
stored in the amazon's mighty trees
they flew the same transept of the forest
three times over three years
first comparing two fairly normal weather years
twenty thirteen and twenty fourteen
and then surveying again
twenty sixteen
after six years on the new drug
with treaties more than sixteen stories tall
airborne measurements capture changes
in forest structures
not possible from the ground or from space
land areas seem following way
here represent limbs and home trees
crashing to the ground
as a result of storms and environmental stress

as they fall they take color trees with them
in collaboration with brazilian science
the team also conducted ground service
to measure the wood material on the forest floor
we found that eighty percent of the carbon losses
came from the depth of larger trees
surprisingly
large trees were not hurt
comparatively more by the dried up
than were smaller trees
as had been previously suspected
the team also surveyed areas of forest
impacted by logging
or even more dramatic changes can be seen
researchers will continue to analyze
how the changing climate and human activity
affect rainforests
and how much carbon these forests will pick up
and release to the atmosphere
okay so a couple examples there of specifically
kind of in a forestry context
how the structural information of forests from lidar
can be used to understand storms
understand forest harvest practices
things like that
that's really just the start
and this isn't an exhaustive list here
but some other examples of what lidar can be used for
are habitat mapping
understanding the structure of habitat for birds
another wildlife species
for resource management
community planning
environmental disasters
for predicting them and for responding to them
for biomass mapping
which we'll talk about in our next lecture a bit more
for forest growth models and for storm impacts
as we watched in those videos there
this is one specific example of a wildlife application
where there was a study area in alberta
and they flew lidar over this whole area here
the areas that they've shown here

and they were able to
derive information like forest height
forest canopy cover
and forest complexity
so how complex the structures of those forests were
they were able to then model
and relate that to bird species richness
and derive a map
almost for the entire province
of a predicted level of bird species richness
this is a really
really valuable data set for managers
for practitioners
for decision makers
because they can then go away
and look at a map like this and say okay
we should prioritize these areas for protection
for critical
for critical habitat
for conservation
because we can see that there is a higher level
of bird species richness in this particular area
and in particular with lidar
its ability to predict and understand
forest complexity and forest structure
is really valuable for understanding bird
species distribution
birds especially birds that live in forests
which are a lot of birds
birds that don't particularly reside in urban areas
exhibit really strong responses
to different types of forests
to different types of
heights in forests
canopy covers
complexity of forests
and so our ability to get that three d
structural information from lidar
something that we really can't derive from passive
remote sensing
imagery such as landsat
such as motives
such as worldview

enables us to get that three d information
which is really valuable for predicting something like
bird species richness
okay last kind of
active remote sensing that we'll talk about is sonar
sonar stands for sound navigation and ranging
and essentially
how sonar works is it transmits a signal
that signal propagates towards an object
so it transmits a sound signal
and then that signal is reflected off the target
or object and is recorded by a receiver
same kind of ranging system
where we time how long it takes
for that sound wave to travel towards the target
bounce off that target
and travel back towards the sensor
and some sonar signals we can hear
because again
it's just sound
it's just sound being propagated through an area
and others are at such high frequencies
that we can't hear them
and they're completely silent to us
but very similar to some of the other
active remote sensing systems we've talked about
just with sound this time
sound waves are propagated towards an object
they then hit that object
bounce back towards the receiver
we time how long it takes those sound waves to do so
now i'm not going to talk about sonar in detail
with its applications
because it's not as applicable to earth observation
and definitely not as applicable
to earth observation from space
but some common uses are
submarines use sonar to detect other vessels
to detect obstacles that may be in front of them
fishing boats might use sonar to locate schools of fish
oceanographers might use sonar
to map the contours of the ocean floor
to essentially get a sense of the terrain

and the topology of the ocean floor below the boat
some animals might use bio sonar or echolocation
to see bats and dolphins actually send out sound waves
and echo locate
which just means
they time how long it takes that sound wave
to travel to an object
bounce off that object
and travel back to them
literally in order to see
but these are just some examples of some different
applications of sonar that you might see all around
okay that is it for today
got some practice questions here
i'll leave you guys for a couple minutes to
practice answering them
i just checked that
liana's introduction video is up now
just double checked it on the assignment four page
so be sure to take a look at that before you start
assignment four
i'll give you three four
five minutes or so to chat about these questions
then we'll talk about them
if you don't want to stay for that
and you want to head out now
you're welcome to do so
and otherwise i'll see you tomorrow
i miss the definition
what the wait
for gps transition and how it interacts with lidar
how it interacts with lidar yeah
so it is one of the technologies that is
fundamentally a part of how lidar works
and its role is that it measures the exact location
in three dimensional space
of where the laser pulse is emitted from
also i slightly measure
definition on the official definition of
point cloud
i only yeah
feature the forest yes
yeah so this is

this is a point cloud right here
so so all it is
is a set of points in three dimensional space
okay yeah that's all it is
yeah yeah so
i kind of sketched this based off what was up there
but so you know
the return strength is different for both of these
does that mean that this one is denser than that
yes okay yes
and that's why
that's why you kind of see the strongest level
yeah the strongest return being this kind of
really dense section of vegetation right there
sorry yeah okay yeah
but either way
when we take that data to create a point cloud
we essentially just set a threshold of return strength
and then look at that peak in energy
being reflected back to the sensor as just a point
if that makes sense
so we would just like look at this for example
and say okay
above this threshold that we set
is a point in three d space
so we just say that's a point
that's a point
and that's a point
this is just how we ultimately
get to deriving the points
from the return strength measurement
so anything above a certain is going to be a point
exactly yeah exactly
you need to come home
this is
okay guys let's go over these
the remaining stronghold of you guys
appreciate you guys
so is lidar an all weather form of active
remote sensing technology
what do you guys think
can it be used in all kinds of weather
no no it cannot why

yeah exactly
clouds other kinds of poor weather
will interact with the wavelengths you're using
essentially
the key is you're not using microwave energy
you're not using energy that could penetrate clouds
or other poor weather conditions
so it's not an all weather remote sensing technology
what are the three technologies
that lidar relies on yeah
exactly yeah
laser ranging
gps measurements
and imu measurements
okay what are the two types of information
lidar can be used to derive
what are the two that we discussed in class
just now
yeah
terrain data and structural information of vegetation
and what might be some applications of each of those
maybe just give me one example
anyone of an application of
either of those kinds of information
that you can derive from lidar
we watched the videos
and then we talked about some other ones briefly
yep
yeah exactly
forest density is a really good example
understanding how denser forests are
understanding the impacts of logging
what the shapes of the forest are
prior to and post logging
for sure and then what is one application
that we briefly mention in relation to sonar
one thing that sonar can do yep
yep submarines will use it to detect other vessels
other obstacles in the water
totally right awesome
thanks guys
i will see you tomorrow
haha

alright hi everyone welcome happy tuesday
i
wanted to see if i could change these quick
i don't know where to change it okay
so today we are talking about imaging the biosphere
and just the biosphere a little bit in general
so we're going to talk about what the biosphere is
we'll start by defining it
we'll talk about briefly
why it's important to monitor it
some metrics we use to monitor the biosphere
and then we'll kind of dive into remote sensing
technologies used to monitor the biosphere
with some specific examples and applications
you'll notice that for the rest of the class whoa
that's fun
oh wait oh that was just me
that's the start of the video sorry
so you'll notice that for the rest of the course
pretty much
all of the lectures are going to follow a very very
very similar format
so today we're talking about the biosphere
and then we're going to talk about the cryosphere
and then we're going to talk about oceans
and then we're going to talk about wildlife
and then we're going to talk about monitoring change
all of these lectures are going to kind of have a very
very similar flow
a very very similar outline
where we'll essentially define what it is
we're talking about the general topic
in this case it's the biosphere
in coming weeks it'll be the cryosphere
it'll be wildlife
other things like that
we'll talk about why they're important
to monitor all these kind of
different environmental applications and examples
we'll talk about then
for each of them
the different remote sensing technologies
we have available to monitor them

and then how those remote sensing technologies
actually do monitor them
and then we'll talk about the different things
that are being monitored by those earth observation
remote sensing technologies
so all of the lectures from here on out
for the most part
kind of follow this very
very similar structure
and you'll notice a reoccurring theme
at the end of the lecture
where we talk about the advantages
of using remote sensing earth observation technology
to monitor whatever it is we're talking about
so in this case in this
this lecture is the biosphere
but in all the future lectures
you'll kind of notice very similar reasons
for why it's useful or advantageous
to use remote sensing technologies
and i say that just to note that
in an exam setting
you can expect a question to kind of
be surrounded around
why it might be advantageous to use remote sensing
earth observation technology
for a specific purpose
and just make sure that
you are kind of answering that question
specific to the application that is being given
so for example
today we're talking about the biosphere
we're going to talk about why remote sensing technology
is useful for the biosphere
but again the reason that it's useful
the reason it's advantageous is very
very similar
to all of the other applications
we're gonna talk about in the coming classes
so just make sure
when you're answering that question on the exam
you're kinda given some specifics
towards the biosphere

the cryosphere oceans
whatever it is we're asking you to talk about
okay i'm going to start today with a video
it's about five minutes long
kind of introducing the biosphere and earth
observation
from the biosphere
it's a nasa video here
you probably think of this
but as soon as we made it
beyond the limits of our atmosphere
one of the first things we did
was turn our cameras around
and look at this
the first us satellite was launched
in nineteen fifty eight
that's eleven years before neil armstrong
became the first person to walk on the moon
explore one built at the jet propulsion laboratory
initiated a long living sea satellite
said to take our understanding of earth to new heights
in nineteen ninety seven
nasa launched a satellite
that began a twenty year continuous global record
of the very thing that
as far as we know
makes earth special life
while most satellite missions capture data
on the physical characteristics
of our planet's climate and weather
others allow us to measure life itself the result
the most complete view of global biology today
greatest of this data sets kind of hard to explain
it allowed me to understand
ocean is such an organic way
that's the voice of oceanographer doctor evo
of a syndic
evoma and the rest of the nassautic ocean ecology lab
help oversee the twenty year data set
if you take a closer look at this animation
you'll see what looks like a repetitious
end flow on the land and smoothness of the ocean
we're actually watching the planet breathe

about half of the total photosynthesis on the planet
occurs on land
and half of the oceans
that's dr conton tucker
who pioneered satellite monitoring
and vegetation on land
the spring and summer months
kick off the growing season for plants on land
illustrated in dark rain
and tiny microscopic plant like organisms in the ocean
called phytoplankton
seen in the light blue
they take carbon dioxide out of the atmosphere
and use it for energy
causing the total amount of carbon in the air
to drastically drop
the opposite is true during colder months
during winter
in the northern hemisphere
which is home to most of earth's landlands
carbon in the atmosphere increases as plants go dormant
and then there are extreme zones in the ocean
purple patches are nearly devoid of any phytoplankton
they're basically deserts at sea
while the redstones
tell us that there's either a high concentration
of phytoplankton hugging the coastline
or our satellite sensors
are picking up on another input
changing the color in water
we have marvelous biological diversity
of plants and animals
both on the land and also in the oceans
but hold on
if we have an amazing biological diversity
of plants and animals
why do scientists spend all their time observing plants
you know how they say you are what you eat
in the same way
if one understand the ocean
the life of the ocean
we have to start from face
might have been things changing

the whole ecosystem will change
the changes that imbona is talking about
are much easier to see
when we can study a continuous global record
and that means
not only being able to look into the past
but also into the future
it's a long term data set
allows not only to see exactly what's happening
but to be able so much better way to predict
what's gonna happen
a global perspective
gives scientists the power to forecast events
like harmful algal blooms
disease outbreaks
and even fanning
maybe one of the most useful applications of the data
is its ability to show us where we've been
in twenty years
the planet has changed in noticeable ways
and this data set gives us a visualization to prove it
arctic greening comes with retreating arctic sea ice
are probably
one of the most well known examples of this
if you look at the higher northern latitudes
you see in the white
where there's snow
and that then moves further north of the seeds
it's then followed by very
very green colors
because plants are really photosynthesizing
in those dark green pyramids
scientists think that there are likely
trillions of planets
yet earth is still the only planet we know of with life
and with that in mind
our habitable home world
seems ever more fragile and beautiful
when considering the vastness of a movable space
i have several friends and acquaintances
who are astronauts
they all say the same thing when they're in orbit
on the space shuttle

or in the international space station
and look down at the earth
they see one planet one planet
we're all in this together
and we need to work together to make sure that life
as we know it continues on this wonderful planet
ok so the data set that they were talking about
is this c whiffs or c
wide field of view satellite
so all the imagery
of kind of greenness on terrestrial areas
and the amount of photosynthesis due to phytoplankton
occurring kind of in the oceans here
those were from this
this seawhifts or seaweefs
uh satellite
it was launched in ninety seven
it died in in twenty ten
it's not a satellite that we talk about in depth
throughout this class
but it did give a really
really cool daily temporal resolution
at about a one kilometer spatial scale
of not just the amount of chlorophyll in the oceans
which was kind of a measure of the photosynthesis
the amount of phytoplankton in the oceans
but also ndvi in terrestrial areas
and it was kind of the first
full system that gave us a really
really nice look
and nice breath of the base
of all of the biosphere
the base of all of the ocean ecosystems
and all of the terrestrial and freshwater ecosystems
and that's ultimately what the biosphere is
the biosphere is just a collection
of all the ecosystems on earth
so that includes both terrestrial land ecosystems
and marine ocean
and freshwater and others ecosystems
so all the ecosystems on the planet earth
are what's considered to be a part of the biosphere
now photosynthesis is the process

by which plants convert solar energy
carbon dioxide and water
into sugar and oxygen
so we have an equation for that here
we have light energy
carbon dioxide and water
add all that together
and your output is sugar and oxygen
and photosynthesis
this process
this equation right here
is the fundamental basis for energy flows
in all the ecosystems of the biosphere
so that means that this little equation here
this little phenomena
photosynthesis
forms the basis
forms the platform
that all other ecosystems function off
whether that's marine ecosystems
or terrestrial ecosystems
now the biosphere
through photosynthesis
absorbs carbon dioxide very
very strongly from the atmosphere
and it's crucial to monitor the biosphere
so we can understand carbon cycles
now the base kind of understanding
or in its simplest form
carbon cycles look something like this
so carbon cycles include photosynthesis
so plants photosynthesizing with sunlight
with carbon dioxide
and then ultimately creating organic matter
which they store in the form of biomass
whether that's a forest itself or grass
and then ultimately that grass
that forest is eaten by
in this case
we have sheeps
but other forms of wildlife
other organisms
which eventually die and create waste products

but that also just feeds into the ground
where lots of more organic matter is kept
then ultimately
plants also respire
animals also respire
we respire we breathe
we exhale carbon dioxide
and then as well
we have factories that create emissions
things like that
all different sources of emissions around the world
emit some sort of carbon dioxide or some other
or some other emission
in this case
i'm talking about carbon dioxide
because we're talking about the carbon cycle
but cars factories
whatever it might be
they are emitting carbon in the form of carbon dioxide
back into the atmosphere
that carbon dioxide
that's gone back into the atmosphere
it eventually gets cycled back through ecosystems
through photosynthesis
through other organisms
back into the ground ultimately
and then again through respiration
and through the burning of fossil fuels
and other things
we cycle it back out in the atmosphere
this is a repeated process
it's going on all the time
and we know that this process
and the balance of carbon
in the form of dead organisms
waste products
and fossil fuels
as well as in the form of forests
and organic matter that's living
as well as carbon dioxide
that's ultimately in the atmosphere
as a really
really large influence on our planet

we know that
as carbon has been increasing its concentration
in the atmosphere due to anthropogenic effects
so just due to human caused effects
we've seen an associated increase in the temperature
of the planet
so to understand climate change
ultimately to understand these carbon cycles
we need to be able to monitor the biosphere
because the biosphere
through this key equation
through photosynthesis
is ultimately what's going to take
that carbon from the atmosphere
and put it back into the earth
in some sort of solid matter form
some sort of form
that just takes it out of the atmosphere
that's ultimately
why it's important for us to monitor the biosphere
so that we can understand carbon cycles
so we can understand
why there are certain levels of concentrations
of carbon in our atmosphere
to help better understand climate change
better help us plan for the future
for our own communities
as well as for our resources
and for wildlife that exists
ok so a couple of metrics that we'll talk about
that can be used to monitor the biosphere
one is productivity
which is essentially directly measuring
the levels of photosynthesis that are occurring
we'll talk about gross primary productivity
and net primary productivity
and then just what affects productivity
we'll talk about
what a carbon source and a carbon sink is
we'll talk about briefly how define what biomass is
and then after that we will talk about
the different remote sensing technologies
we can use to monitor and measure each of these metrics

and then ultimately
why those are useful
okay so primary production can be broken into two terms
gross primary production and net primary production
gross primary production is defined as
the amount of energy created by plants
so ultimately
that's just how much photosynthesis is occurring
photosynthesis creates energy
how much energy is created by plants
is what we term gross primary production
net primary production
is the amount of energy stored in the plant
typically as biomass
after accounting for plant respiration
so cells within the plant have to respirate
they have to breathe
essentially
and they use the oxygen
that's created by photosynthesis to do that
then ultimately
that emits a little bit of carbon dioxide itself
so if we look here at just this illustration of that
we have solar energy helping create photosynthesis
this photosynthesis
the amount of photosynthesis occurring
the amount of energy created
we call gross primary production
then some of that energy is used for cellular work
which is the respiration
and then some of that energy is stored as biomass
so as physical matter
as leaves as stems
as physical matter in the plants
so our net primary productivity
is just the amount of gross primary productivity
minus the amount of respiration occurring
so that tells us
how much net primary productivity there is
can also be very well related to biomass
it's essentially the amount of solid matter created
and stored as energy
from the gross primary productivity

that's occurring
now productivity can be affected
by a variety of factors
we'll talk about a couple of key climatic factors
that affect primary productivity
and we'll talk about light
air temperature
precipitation
and carbon dioxide concentration
and all of these factors vary quite a lot
all throughout the world
so as we're talking about them
think to yourself
rationalize why certain levels of productivity
would be different around the world
why do temperate rainforests in british columbia
have a pretty high level of productivity
while deserts and other areas that are very arid
maybe have a much lower level of productivity
okay the first one that we'll talk about
and the one that we'll talk about in most depth
is temperature
so we can see that as temperature increases
the amount of gross photosynthesis
continuously increases
at about twenty or so
eighteen or so degrees
the amount of gross photosynthesis occurring
kind of tapers off a little bit
so it doesn't kind of increase linearly the entire way
once it reaches a certain temperature
it starts to taper off a bit
but it's still slowly increasing
now the key here is that high temperatures
will induce stress in plants
stress causes plants to respire more
so as we see an increase in temperature
we see this exponential increase in plant respiration
because of that
we see this characteristic
hump shape of net photosynthesis
and this net photosynthesis again
is just gross photosynthesis

minus the respiration
so you can see here
where gross photosynthesis is at its peak
or at its highest
or close to its highest
and respiration is kind of at its lowest
or furthest away from gross photosynthesis
so where this line
this green line
is the furthest away from this red line here
that's where you see a peak in net photosynthesis
that's where you see the most
photosynthesis
the most net photosynthesis occurring
that's where there is the greatest level
of gross photosynthesis
in a ratio to the lowest level of respiration occurring
and this kind of makes sense
when you think about ecosystems around the world
you think about temper
rainforests
you think about tropical rainforests
whatever it might be
they're often hovering around this temperature
they're often hovering right around that temperature
kind of all the time
very very frequently
and in those areas
we get the most amount of net photosynthesis
consequently
in those areas
we also see very high levels of biomass
there's lots of net photosynthesis occurring
it's peaking kind of around this temperature
we'll also see a lot of biomass
because there's a ton of energy
to be stored as physical plant matter
because gross photosynthesis is really high
and respiration is really low
right around that temperature
so if i ask you
on an exam setting
to be able to describe

how gross photosynthesis
net photosynthesis
and respiration
change with respect to temperature
and you could say well
gross photosynthesis
it increases up to a certain temperature
and then tapers off
respiration
slowly increases at first
but then exponentially increases
at about twenty degrees
and net photosynthesis
slowly increases
peaks at about
eighteen or so degrees celsius
and then slowly continues to decrease
decrease after that
okay so that's temperature
there's a bunch of other factors
that also will influence productivity
so that will also influence
how much photosynthesis
is occurring in an area
in an ecosystem
in a certain part of the biosphere
one of them is light
so the more sunlight there is
the sunnier a region is
the more photosynthesis there's going to be
up until saturation
that just means that
once we hit a certain level of light
then any amount of
increased light past that
won't further increase
the amount of photosynthesis occurring
that's all that's meant by
until saturation
carbon dioxide increases
the amount of photosynthesis
because it is kind of one of the key inputs
for that photosynthesis equation

again up until a level of saturation
you can see that on the graph
on the right here
we have rate of photosynthesis
on our y axis
we have carbon dioxide
on our x axis
you can see
we are at about
four hundred
that's a bit outdated
we are at about
thinking about
four hundred and fifty
four hundred and sixty
parts per million
in our atmosphere
today on average
you can see
right around there
that's pretty much the saturation level
for most plants
any amount of carbon dioxide
past that is not going to further increase
the level of photosynthesis occurring
and this is true
this depicts a
form of saturation
right so at this point
it's saturated
the level of
carbon dioxide
that can increase photosynthesis
is saturated
if we increase
any more carbon dioxide
it's not going to
proportionally increase
the rate of photosynthesis
so you'd see a similar kind of
curve like this
if you were to look at
the relationship

between light
and photosynthesis
as well as water
and photosynthesis
so with water
it also increases
photosynthesis
as there's more water
again up until a point of saturation
and again we already talked about temperature
it increases
photosynthesis
but levels off
at a higher temperature
and net photosynthesis
will start to decrease
at higher temperatures
because plants will get stressed
and require
much more respiration
and again if you think about
all these things
and you tie them all together
and then you think about
different ecosystems
different parts
of the biosphere
around the earth
it kind of makes sense
again tropical areas
get a lot of light
they get a lot of water
and they have that
perfect temperature
kind of hovering
in this range right here
on the other hand
desert areas
they might have a lot of light
a lot of sunlight
but they don't have enough water
or the perfect temperature
to kind of have

that peak level
of net photosynthesis
so depending on these different characteristics
we'll see different levels
of productivity
different levels of photosynthesis
all across our different ecosystems
all across different parts
of the biosphere
ok so that is one way
that we can
kind of get
a measure for
different parts
of the biosphere
is by measuring
productivity
by essentially
measuring the amount of photosynthesis occurring
another way
that we can monitor
the biosphere
is by understanding
carbon sinks
and carbon sources
so carbon sink
is something
that absorbs
more carbon
from the atmosphere
than it releases
a carbon source
is something
that releases
more carbon
to the atmosphere
than it absorbs
and by measuring carbon
sinks and sources
we can monitor
carbon transfer
and carbon storage
in the biosphere

so for example
how much carbon
is in the atmosphere
versus how much carbon
is stored in forests
if we monitor
things like
deforestation
things like
when forests are burning
things like
agriculture
things that
change areas
from forest to
maybe residential
or urban areas
we can monitor
what our carbon sinks
and what our carbon
sources are
how many sinks are there
how many sources
are there and
in that way
we can monitor carbon
exchange and
in that way
subsequently
we can monitor
the biosphere
as a whole so
looking at a couple examples here
i'll give you guys maybe
a couple minutes
discuss with a neighbor
sitting close to you
it shouldn't take too long
but which of these
examples up here
would you define
as a carbon sink
which would you define

as a carbon source
so we have here
a forest that's
recently been cut down
we have some
medium to old
forest up here
we have some forest
that's been infected
by an insect
in this picture here
we have a forest
that's on fire here
and we have
a forest here
that's been
recently cut down
but it's starting to regrow
take a couple minutes
brainstorm with someone
sitting next to you
or someone sitting
close to you
and then we'll come back
and try to answer them
i'll give you about two
three minutes
thank you thank you
all right what do you guys think let's
start with this one up on the top left here
would you consider this
a carbon sink or a carbon source
put your hand up
show though yeah
maybe a source because of decomposition
yeah carbon source
that would make sense
there's been trees cut down
that decomposition
is releasing carbon into the atmosphere
probably be a carbon source
what about this one up in the top right here
sink yeah carbon sink

yeah for sure
it's absorbing carbon
we got lots of healthy trees in there
they are acting as a carbon sink
because they are photosynthesizing
they are taking carbon from the atmosphere
putting it into a solid organic matter form
okay what about this one here
where we got the insect infestation going on
source yeah
carbon source
yeah probably
that was a tougher one
we have some
we do have some healthy trees in here
but we got lots of dead and dying trees as well
there'd be a balance going on there
there'd be some individual trees
maybe acting as a bit of a sink
some individual trees maybe acting as a bit of a source
so it'd be kind of a balance of the two probably
in this example there are more
dead and dying trees than there are healthy ones
so we could say overall it's probably close to a source
what about this one in the bottom right here
the wildfire
carbon sink or carbon source
source yeah exactly
yeah it's burning off the trees
it's burning
it's taking solid organic matter
releasing it as carbon into the atmosphere
definitely a carbon source
and then what about this one right here
we got some area that was cut down
and then there's a little bit of
regrowing bushes and stuff
carbon sink or carbon source
yeah it could be a sink
as the vegetation develops
yeah right now
probably isn't enough of it to counteract all of the
for sure yeah

it's probably a little bit more of a source than a sink
because we don't have a ton of vegetation
growing here yet
as this kind of forest starts to grow back in
as there's a lot more vegetation that comes through
it probably result in being more of a sink
the point of this
this exercise
is to get you thinking about dynamic sinks and sources
so forests are a really good example
of a dynamic carbon sink or source
where forests can act both as
carbon sink and a carbon source
depending on what's going on there
if we have a nice
healthy standing forest
it's probably acting as a carbon sink
if we have a forest that's been recently harvested
it's probably acting as a carbon source
but if we get some regrowth going on in that area
if it's regrowing
if it's being replanted
there's vegetation and trees growing back in that area
that was cut down
then maybe once again
it would eventually be a carbon sink
so in an exam setting
i'd be really specific
i'd tell you if it was a forest
for example
what was going on with that forest
whether there was a fire going on
whether there was an insect infestation going on
and i'd want you to be able to tell me
whether it's a source or sink
or kind of something in between
where there's a little bit of both going on
ok so that's carbon sources and sinks
that's one way that we can monitor the biosphere
so we've talked about two now
we've talked about productivity
we've talked about monitoring carbon sources and sinks
one other way that we can measure

and monitor the biosphere is by just measuring biomass
so biomass is the dry weight
of living organic matter in an area
it can include above or below ground or both
so you can say okay
i want to measure above ground biomass in this area
that would essentially be every piece of biomass
every piece of living organic matter
that is above the surface of the ground
so in this case
you know above ground biomass of this tree
would be everything from here up
below ground biomass of this tree
would be all its roots
and then both above ground and below ground
biomass of this tree would be both the roots
and the tree trunk
and the leaves
and everything that is involved in this tree altogether
the dry weight of all of that matter
would be what we call the biomass
or what we define as biomass
and it's a really good reflection
of the productivity of an ecosystem
because increased biomass
high biomass areas
generally are associated with areas that have very high
net primary productivity
areas that are kind of that perfect combination
of all the different factors
that produce high levels of productivity
and allow large levels of biomass
to be stored as solid organic matter
in the biosphere
in the trees
in the vegetation
whatever it might be
okay so three ways that we can measure the biosphere
with productivity
with carbon sinks
and sources
with biomass
now monitoring the biosphere

historically
before we kind of had remote sensing
earth observation
data available to us
was mostly done with field based estimates
so we would go out into the field
we would measure
how wide our trees
what's the canopy cover of a tree
or what's the height of that tree to
this guy's doing so
he's using something called a vertex
where you can look at the base of the tree
and then look to the top of the tree
and get a sense for how tall it is
so you'd measure how wide trees are
how tall trees are
how much root
biomass is there below ground for that tree
maybe if there's not a big tree there
you'd just put a little
kind of plot like this down
and cut away all the grasses
all the vegetation that's above the ground
dry it out weigh it
that would give you a sense of the biomass
for that particular plot
for that particular little area
you can imagine though
that this is super
super time consuming
this does not give us an estimate
or a measurement
of our biosphere
or an ability to monitor our biosphere
at a large or
at a large kind of area or small scale
it doesn't allow us to zoom way out and say
for an entire forest
for an entire country
this is what the biosphere is kind of doing
this is what's going on
these are point based estimates that take a very

very long time to go out and measure
require a lot of costs
a lot of energy
because you have to go
out and physically do these measurements yourself
so eventually
one technology that was developed
this isn't a remote sensing technology
but one technology that was then developed
was the eddie flux towers
so these eddie flux towers are just towers
they look something like this
and they have some sensors on board
that measure carbon flux at a single point
so they monitor gas concentrations at very
very high frequencies
well above the height of vegetation
and by analyzing and processing that information
and that data
you're able to get from eddie flux towers
estimates on the exchange of carbon dioxide
from the atmosphere to vegetation
now again these are point based estimates
so this example of an eddy flux tower right here
you would get a sense of the carbon exchange going on
kind of right at this point
or right in this particular area
again we can't be setting up any flux towers
every couple of hundred meters all across the world
so it's a very small area that this is covering
gives us just a point based estimate
again you have to take the money and the time
to go out and set these towers up
so still not a great way to be able to monitor regional
national or even global biospheric metrics
so we'll talk about a couple of remote sensing
earth observation technologies
that are really useful for monitoring the biosphere
and give some examples of what they can measure
this isn't an exhaustive list
but these are the kind of things
these are the topics
in terms of monitoring the biosphere

that i would examine you on for the final exam
so first we'll talk about modus
we've talked about modus a bit already in this class
we'll talk about modus
and how it can measure productivity
how we can take information from modists
to build models
using the known factors that affect productivity
to be able to estimate gross primary productivity
and net primary productivity
and environmental respiration
all across ecosystems
we'll talk about lidar
lidar we talked about yesterday
how you can get three d
or three dimensional data sets from lidar
so we'll talk about how you can use lidar to estimate
above ground biomass
and then lastly
we'll talk about landsat
which we'll talk about in the context
of monitoring carbon sinks and carbon sources
to be able to be able to detect disturbances
and understand how forests are changing
when they're losing carbon
when they're taking on carbon
and creating more of a sink
okay so first is modus
this is a map derived from modus's global annual
net primary productivity product
and this is over the period of
two thousand to twenty fifteen
and you can see here again
what we've been talking about
you can see these high areas of net
primary productivity
tropical areas
areas down here
high areas here
areas that have that nice perfect level of temperature
a good amount of light
a good amount of water
those factors that contribute to high levels

of net primary productivity
modus is really
really good
because it has that
large pixel size
that low spatial resolution
and that high temporal resolution
of daily imagery
it's really good for getting global estimates
of things like productivity
so if i'm asking you what you might want to use
to measure global productivity
in across the biosphere
you'd want to say modus
now modus ultimately goes away
and takes spectral information
so if you remember back to our resolutions lecture
modus has thirty six bands on board it
so there's a ton of spectral information
associated with modus data
and we know that productivity is affected by light
by temperature
by carbon dioxide
and by one other thing
that i forget off the top of my head
but it's affected by those four things
that we talked about earlier today
and what we can do is
we can take all that spectral information
that we can get with modus
use that to get an estimate of
how much light is in an area
what's the temperature of an area
using the thermal infrared band
we can use other bands
to get a sense of moisture content
to get a sense of how much water there is in areas
so we can get a sense of
how much water there would be
for net primary productivity
we can also get a sense of
how much carbon is in the atmosphere
all these kinds of things

we can input that into a model
get an estimate from modus for all across the world
at a two hundred and fifty to one thousand kilometer
spatial resolution
of what net primary productivity might look like
this is just another example of that
just breaking it down into the
couple of metrics that we talked about
gross primary productivity
net ecosystem productivity
or net primary productivity
and then environmental respiration here
so again this value here
this map here
is just taking the values here
subtracting the values here
and then getting the difference of those values
for this net ecosystem or net primary productivity
map on the right here
okay so that's modus
being able to monitor very small scale or large areas
of net primary productivity
or gross primary productivity
or just productivity as a whole
another example that we can use
and that i kind of already introduced is lidar
and lidar's ability to collect
three dimensional information
so we know with lidar
from talking about it yesterday
we can get really efficient
three dimensional data collection
and that allows us
in the case of lidar
to get very high accuracy
above ground biomass estimates
so this map that you're looking at here
is a study area from california
where they were able to detect with lidar
individual trees
so each one of the dots in this map
is an individual tree
that they were able to detect with lidar

data and then
from the structural information
of each of those individual trees
that they got from the lidar data
they were able to estimate how much biomass
which they've termed here
above ground biomass
there is for each tree
so each tree
which is denoted by each of these little circles
that is very green
are very big trees
trees that have large amounts
of above ground biomass associated with them
small trees
which are donated by red here or orange
have very low amounts of above ground biomass
associated with them
so this ability
with something like lidar at a very
very very very
very small scale
or a very very large scale
very small area
for each individual tree
the ability to estimate the biomass associated
with each of those trees
is invaluable
it's something that we didn't think
that we'd be able to collect and monitor
nearly as efficiently
as we're able to do today
with something like lidar
if you can think back to what i mentioned before
which is that
historically
to monitor the biosphere
we had to go out
and measure each one of these trees individually
we had to go out and measure with a measuring tape
how wide it is
how tall it is
and from that

derive a biomass estimate
we can now just fly a plane with a lidar instrument
over a pretty large area like this
and get a biomass estimate for each individual tree
so with dataset
that is really
really come a long way
and really valuable to us today
okay last example we will talk about is landsat
so landsat has a couple of significant advantages to it
over something like modus or lidar
they all are useful for their own things
in the case of lansat
we have a really large time dimension
which just means that
lidar is one of our oldest satellite programs
that we have data available for
all the way back to the seventies and eighties
so we can monitor change in the biosphere
all the way back to seventies and eighties
with the lansat data set
has a moderate spatial resolution
that thirty meter spatial resolution
which actually makes it really ideal
for monitoring changes in forests
a two hundred and fifty meter spatial resolution
that you get with modus
isn't nearly as useful
as a thirty meter spatial resolution
for monitoring and detecting things like forest harvest
for monitoring and detecting things like wildfires etc
landsat is really
really good at that
it still has a pretty moderate temporal resolution
so we can at minimum
get really nice composites
for every single year of an area
at a thirty meter spatial resolution
and that's what you see up on the right here
this is a composite of canada
using a best available pixel method
which just means
each individual pixel in this composite

is being pulled from a set of potential images
all throughout that given year
and the pixel it's pulling
is just representing the best dataset
or the best pixel available for that area
so the one that has the least amount of noise
the least amount of clouds in it etc
and here we're getting a nice clean composite
a nice clean image
of all of canada
at a thirty meter spatial resolution
for each year
and this example
i think it's all the way back to nineteen eighty four
from landsat
that allows us then to compare
year by year
these images
and look at something like ndvi
look at the spectral information
in each of these pixels
year by year by year
and detect and quantify
how much forest harvest might be going on
how many wildfires there might be
where landslides are
how much areas getting converted into agriculture etc
so this is just an example
of an output from that kind of analysis
where we looked from nineteen eighty four
all the way to twenty eleven
in this case
and for each thirty meter pixel
we classified
whether or not a change had occurred
so anywhere that there's gray on this map
no change had occurred
but then all of these colors here
represent a year
so all the colors on the map here
represent a year
and the year that it's representing
is when the greatest amount of change occurred

for that specific pixel
which is when
essentially
there was a large disturbance in that area
and it could have been a wildfire
it could have been forest harvest
it could have been a change of forest to agriculture
some sort of change occurred
in these pixels
if they're colored
for that specific year
if we zoom in
we can look at a couple specific examples
of some different changes
and some different disturbances
that we know to exist
across these provinces
so this is looking at new brunswick here first
and you can see here
these are the kind of raw
composite images
and you can see the landscape changing
in this case
due to agriculture
so you can see lots of farms
and other things like that popping up
and you can see here
on the right this
is just a data set from here
showing us when the largest change in this area
in this case in new brunswick occurred
so what year was the largest change occurring
for each individual one of these pixels
so this is an example looking at agriculture
in manitoba
they get a lot of wildfires
so this is an example looking at wildfires
you can see the fire scars kind of popping up here
as we look through time
and then you can see associated with that
this map on the right here
that shows you essentially when that fire occurred
what year that fire occurred

again at a thirty meter spatial resolution
we can get a data set like this for every single year
in this case
all the way back to nineteen eighty four
so this is fires in manitoba
one other example
this is forest harvesting
so forestry
so the creation of clear cuts or cut blocks in alberta
so you can see kind of the checkerboard shape looking
cut blocks or clear cuts occurring on the landscape
and then again on the right here
we can just see in what year that forest was cut down
and what year that clear cut was created
again at a thirty meter spatial resolution
we can check that for every single year
all the way back to nineteen eighty four
super super
super valuable data set for us to understand
carbon sinks
carbon sources
the dynamics of our forest
and something that we can collect freely
this is landsat data
we're able to download this data for free
anyone can download it
it's a really really valuable data set
that's really accessible to everyone
ok finally i'll just mention
we've talked about modus
we've talked about lancethat
we've talked about lidar
there's always the possibility to combine and fuse
the information
you can get from these different data sets as well
so in this case
using that same data set
this is a map in the top left here
just using landstat
showing us where there was wildfires
where there was forest harvest
where there was some sort of
non stand replacing disturbance occurring

that's just this blue right up here
and then for that area
this whole study area
so pretty much all of the forests in canada
we combined the landsat data with lidar data
so with three d structural information
and created estimates across all of canada
for all the forests
at that same thirty meter spatial resolution
for above ground biomass
so this is an example of
above ground biomass in nineteen eighty four
and then above ground biomass in that same area
or in those same areas in twenty sixteen
and then just the variation
or change in above ground biomass during that time
shown up in the top right here
so again a super
super invaluable data set
thirty meter spatial resolution
we can do this for every single year
dating back to nineteen eighty four
okay just to sum up here
we talked about a couple of
we talked about historically
how we monitored the biosphere
we then talked about the remote sensing
earth observation methods we used today
to monitor the biosphere
the historical methods we talked about were field
we're field methods
going out and collecting field data
as well as carbon flux towers
and just to kind of summarize
the differences and key points
about each of these different types of ways
we can monitor the biosphere
with field data and carbon flux towers
we get point based data collection
so we get really limited spatial coverage
we're not able to look at an entire region
an entire country
an entire province

we only get data for that specific area
where we've either set up a tower
or where we are going out and physically measuring
the vegetation and biosphere that's there
there's a lot of operational costs associated with that
in the case of any flux towers
they're not cheap to install
so you have to go out and contract someone
to build that
to put it in
to then be able to monitor it
in the case of field work
you have to pay individuals
to go out and do that field work
and it's super inefficient
again because you're out there
physically monitoring and measuring
each individual piece of vegetation or tree
that you see
and there's limited collection for those two data sets
eddie flux towers and field data
there's limited collection of standardized data
this is a really
really common problem with field data
with historical data
with essentially
a lot of non earth observation
remote sensing data sets
is that they're often not standardized
if i go out into the field
and i want to measure
measure vegetation
i want to measure the biosphere and a particular area
and i'm going to conduct some field work to do so
i'm not go out there and say okay well
it makes sense that i measure how wide these trees are
how tall these trees are
and you know
how many trees there are okay sweet
someone else might then go to the same area
and say okay
we want to go out
do some field

work to monitor and measure the biosphere in this area
but we're gonna actually measure
how many roots there are below the ground
for each tree
and we're gonna measure the leaf area index
how wide of a surface area
or large of a surface area there is
for all the collective leaves in this forest
that's gonna be how we monitor or measure
how much biomass there is in this area
the point is that both of those in a way
are measuring or monitoring the biosphere
but both in completely different ways
so that's not an example of a standardized data set
you can't compare those data sets through time
because they're very
very different
you can't compare those data sets in space
because they're very
very different
that's not the case for earth observation
remote sensing data
with earth observation
remote sensing data
we always get a standardized type of data collection
landsat data
is landsat data
it's always collected the exact same way
modest data is modest data
it's always collected the exact same way
it adds a lot more objectivity
to the data
and to the analysis
it's not subject to
one person's perception
of what they should measure
or how they should measure something
it's just very
very objective data
so it allows us to have a very nice
standardized data set
through a large amount of time
and across a vast spatial scale

now not only that
it also allows us
with earth observation remote sensing data
in the case of monitoring the biosphere
allows us to have very efficient data collection
we get for example
in the case of modus
two hundred and fifty meter spatial resolution imagery
every single day of the entire earth
and we being
you know me for example
if i want to use that data
i don't actually have to go out and do anything
to collect that data
all i got to do is log into the website
that i download that data from
pick the areas i want to download it for
boom download
it's on my computer
so really really efficient data collection
and really really efficient movement of data collection
all the way to me
the user ultimately being able to analyze that data
with earth observation remote sensing data
we also get large spatial coverage
and high spatial resolution
so we get these images
say for example
in the case of landsat
at that thirty meter spatial scale
for all of canada
for all of our forests
all of the biosphere
and we get it at a pretty decent spatial resolution
of thirty meters
now note that you know
our ability to get large spatial coverage
and high spatial resolution data
depends fully on the data set
we might not get very large spatial coverage
when we're flying say
a drone based lidar system
or even an aeroplane based lidar system

for that matter
we're going to have to just fly it
over the specific area of interest
we'll get decent spatial coverage
considering how high resolution that data is
but the level of spatial coverage
and the level of spatial resolution we know
directly relates to the instrument
or the data set that you're actually using
so you know
with modus sure
you get that really good global coverage
but you only get it at maybe a two hundred and fifty
to one thousand meter spatial resolution
again in the case of landsat and modus
if i the user
want to download it
it's completely free
i don't have to pay someone
to go out and collect that data
i don't have to go out and physically collect it
it's just free
it's online
it's that standardized dataset
which we've already talked about
and it has a really nice
large temporal dimension
in the case of landsat
going back all the ways to the eighties and seventies
in the case of modus
to the late nineties and early two thousands
and then with kind of lidar data
it varies depending on when an area was flown
but generally
we do get large collections of data
now i put this slide up here to kind of end off
because we've really only kind of scratched the surface
of the different types of spectral information
that we can ultimately use to monitor the biosphere
so this illustration up here kind of alludes to
a lot of the different things that we can measure
and monitor in the biosphere
and all of the different spectral bands

that we can use to do that
so you can see here everything from the visible
to the near infrared
to the shortwave infrared
to the thermal infrared
to the microwave part of the spectrum
and a couple of the biosphere metrics
that we can derive from these different data sets
ok that is essentially it for me
lecturing today as usual
going to give you guys a couple minutes to practice
these questions
evans here too
he's gonna give you some reminders
of what you should be working on
and then if you have any questions for evan
of course logistics
but blog posts
you can come down and chat to him
so i'll give you a couple minutes to
to go over these questions
try and develop an answer for them
we'll crowdsource them
evan will give his little spiel
and then i'll go over the answers
and then you guys can get out of here
if you want to head out right now and not go over these
you are welcome to
please do so swiftly as usual
if you're doing that
i'll see you next week
and if not then you guys are welcome to stay
oh she goes
your slides where are they no clue i got them
yeah sure so especially
for the interaction growth
growth for the synth is actually decreased
was not for the synthesis
right but it decreased more slowly
in a lot of ways
um well so so net photosynthesis is just the product
or the difference
between gross photosynthesis and respiration

so really you should think of this curve
kind of being an outcome of this curve
in this curve
so how would
growth photosynthesis fit into this interaction
so growth photosynthesis increases
up to about twenty degrees or so
and then it slowly tapers off
it does continue to
to increase for the most part
but kind of slowly decreases
the level at which it increases
so this is kind of more of a logarithmic curve
and this is more of like an exponential curve
on the bottom and then
and then the net photosynthesis here
is just the difference between this and this
so you can see when these
exactly kind of how you've drawn here
as these are where these two lines are the widest apart
that's where your nut photosynthesis is the highest
i see thank you so much
yeah the front
green eh green yeah
you caught that when you caught your cargo things
do it first bud america really was cheap
when were you there florida
mom took me outlet shopping
i hope you know this is being recorded
sir i hope you know this conversation
is being recorded hell yeah
well i'm not going through and editing the audio so
of course not
did i put o seven on this was o six yesterday
i changed it because it's o seven today
this was wrong though
it'll survive
you never find errors in your slides
i mean like a little bit here and there
but i'm making like thirty to forty slides a lecture
so you're making one to two
oh man
taco night yeah

taco night i'm ripping costco so hot dogs
good stuff
you're in downtown friends driving
if they bailed on me and then they bailed on me which
nothing i can do about that
so what what they'll do like if they're just not going
oh there's no go
maybe what to do
get this they're walking shadow first to
they sound like
three clutch friends pretty clutch friends
okay okay
all right watch
as i have to pavely wait for answers from everyone
i can go sit and answer if you want to
that honestly speed things up quite a bit
okay let's try to answer these guys everyone
so what is the biosphere
can someone define for me what is the biosphere
all ecosystems on earth
terrestrial and marine
all ecosystems on the earth
great so can someone describe to me the pattern
of gross photosynthesis and net photosynthesis
as temperature increases
how does that kind of graph look
yeah
yeah exactly
so they're both going to increase
they're both going to decrease
at about twenty degrees celsius
net photosynthesis is gonna really drop off steeply
and continue to decrease
and then gross photosynthesis is kinda gonna taper off
it'll still stay pretty high
but it's not gonna drop right off
but it will kinda level off
and be kinda steady as temperature increases
exactly um okay
we already went over these examples
we can go over them again quickly
which of these are carbon sinks and sources
maybe just shout out to me a sink or a source

so growing forest
is it a sink or a source
sink wildfire
sink or source
source insect outbreak in a forest
sink or source
source depending on how intense the outbreak is
and then how has the biosphere been monitored
historically
two examples that we talked about
oh
yep field based estimates and then eddie flux tower
yep field based estimates and eddie flux towers
and then lastly
describe the use of landsat to monitor the biosphere
so what can it track and how is that related to carbon
so what did we
the last example we talked about
in terms of how landsats used to monitor the biosphere
what were we actually tracking
what was i showing
the ability of landsat to be able to track
yeah
carbon losses and gains
that's ultimately what it was being related to
that's really good answer
the more correct answer is
we were looking at disturbances
so we were looking at disturbances in forests
in the biosphere
and then using those to quantify how much carbon
sinks there were
how many carbon sources there were
all across ecosystems in canada
and the example we were looking at
we were looking at all of the forests in canada
and monitoring how many disturbances there are
how large they are
when they occur
so looking at forest harvesting
looking at wildfires
when these disturbances occur
where those disturbances occur

and then ultimately
we can relate that to things like carbon dynamics
things like how much carbon source are these forests
how much of a carbon sink are these forests
okay and then lastly
kind of a broad question
why is that advantageous
what is advantageous about landsat
specifically for monitoring biosphere
in the case of specifically looking at disturbances
detecting and monitoring and looking at disturbances
looking at wildfires looking at
forest harvesting
looking at land conversion to agriculture
why is landstaff
really good for doing that kind of thing
yeah exactly
so we have a thirty meter spatial resolution
that's probably the most important factor in this case
we have a nice moderate spatial resolution
we can't detect or it's really hard
at least to map the extent of wildfires
of clear cuts
of cut blocks with something like motors
lancet at that thirty meter spatial resolution
is really good for that
it also has that really large temporal dimension
dates back all the way to the seventies and eighties
all the way up to the present time
so we can track lots of changes
that have occurred through time
those are the big ones generally
you could apply some of the other examples of why
earth observation remote sensing data
is useful for monitoring the biosphere as a whole
to help answer that question
so things like
am i plugged in
oh not there anymore
things like the fact that with lansat
we got really efficient data collection
with lansat we get a set of standardized data
we also get large spatial coverage

we're able to cover the entire surface of the earth
with lansat every sixteen days
so you could apply those
to help you answer that question
but the most important factor there
was exactly what you said
which is that it is a thirty meter spatial resolution
makes it super useful for monitoring disturbances
of forests in particular okay
yep
yep
so a disturbance
in the context that we've talked about
there is essentially when there's a
certain level or certain magnitude of change
that's associated with an ecosystem
in the case that we were talking about
we were looking at a forest
so a disturbance can be either stand replacing
or non stand replacing
we mostly talked about stand replacing disturbances
where in the case of say
forestry or a wildfire
all of the forest is burned down
or all of the forest is cut away
none of the trees are left there
so you've gone from in a specific area forest
to essentially no forest
in a very brief time
for a discrete event
that discrete event being the forest being cut down
or the wildfire occurring
so that's ultimately what a disturbance is
it's a discrete event that produces
a particular magnitude of change on a forest
in the context that we talked about it today
it can be applied in many different scenarios
with slightly different definitions
but for this course
and for how we'll be talking about it
in the case of earth observation data
and the case of landsat data in particular
that's how you can think about it

does that make sense okay
yeah alright
thanks guys
see you next week
oh sorry like give
give bud your ear for a quick second
he's got a real short thing
yeah so what you should be working on
blog post four
it's about finding a sensor
do march ninth
that's this thursday
assignment four with liana
do next thursday
she's got office hours
as follows today at ten to eleven am
that one's gone
thursday two to three pm for the next two weeks
and then next tuesday from ten to eleven am
if you have questions about the blog post
or the midterm come ask me
remember to check over your midterms
and send me your questions comments
concerns before next week
that's it for me
awesome thanks guys
see you next week
all right hi everyone welcome
happy monday
we are getting towards the end of the semester
so that's exciting
congratulations
today we're going to talk about the cryosphere
so we're essentially going to talk about ice and snow
for the whole lecture
today i have leanna coming at the end of class
to talk about the assignment that's due this week
so if you have any questions for her
you're welcome to ask her when she's here
and i think she'll also just provide some
tips and tricks and some suggestions to work on
the assignment that you have that's due this week
so simon four

that's the one that lean is gonna come and talk about
to do thursday
and then for the next two assignments
i believe assignment five and assignment six
you only have one week for each of those
so assignment five is due march twenty third
assignment six is do the following week after that
and then you only have one assignment after that
that's assignment seven
all of most of liana's office hours
except the tuesday ones those haven't happened
so pretend there's no cross there
so leon has got some office hours tomorrow
and on thursday
the day the assignment is due as well
so if you are non class
so you need to talk to her more outside of class
or you just want an extended period of time
to be able to talk to her about the assignment
you can attend those office hours
so that should be good
and so today
we are going to talk about the cryosphere
we're going to talk about what the cryosphere is
why it's important to monitor the cryosphere
how we've historically monitored the cryosphere
a couple of remote sensing technologies
used to monitor the cryosphere
we'll talk about landsat and modus
radar and icesat
kind of the key technologies
that we really focus on throughout this course
and then we'll touch on some specific examples
and applications
of being able to use those different data sets
for monitoring different features of the cryosphere
so first off
what's the cryosphere
so the cryosphere are portions of the earth's surface
characterized by frozen water
so that includes anywhere
where there is an area covered with snow
with ice or with permafrost

permafrost is just ground that is permanently frozen
so some solid ground
that's just completely frozen throughout the year
so it's not necessarily ice
because ice is water that is solid frozen
and ice can be broken down into ice sheets
ice shelves
glaciers and sea ice
ice sheets are these massive glaciers
that are on top of land parcels
so you can see
ice sheets are mostly what covers antarctica here
and mostly what covers greenland up here
and then we have ice shelves
which are above water
so they're above sea
above oceans
but they're attached to ice sheets
so you can see a couple of ice shelves here
that are attached to these antarctica ice sheets
in brown there
and then we have glaciers
which are essentially
just smaller versions of ice sheets
glaciers are anything that's less than
fifty thousand kilometers squared in size
whereas ice sheets are anything larger
than fifty thousand kilometers squared in size
and then sea ice is just any free floating ice
that is above sea
or above oceans
floating on the top of them
so the difference just between sea ice
and ice shelves
are that ice shelves are connected to an ice sheet
so they're connected to some larger parcel of ice
whereas sea ice is just free floating in the water
so we have all these different kind of features
of the cryosphere
and all of them
we can monitor
in different ways
using earth observation data

but why monitor the cryosphere
why is it important for us
to monitor snow
to monitor ice
to monitor glaciers
to monitor ice sheets
ice shelves
whatever it might be
there's a wide variety of reasons
that it is very important and useful
to monitor the cryosphere
one is that it is a really good tell for us
of climate variability and change
which is really important
for community impacts
as well as biodiversity impacts
so we know that there's a lot of ice
for example
that's melting
at northern
and very southern latitudes
this has a lot of impacts
for rural northern communities
areas that maybe were once covered
by permafrost
once covered by lots of ice
are no longer
are covered by more water
areas are melting a lot more
so that has a lot of impacts
on communities
abilities to obtain resources
whether that sustenance
hunting food
whatever it might be
a lot of community impacts there
so impacts on people on humans
there's also biodiversity impacts
so there's impacts on species
that we know
that live in these northern latitudes
famous ones that you might be familiar with
like polar bears

kind of an example
of the charismatic megafauna
so just animals that are
in the case of polar bears
really cute
and well known to the public
for the most part
but also lots of other animals
that live in these northern communities
or these northern areas
that rely on ice
that rely on snow
that rely on
that seasonal variation
of snow and ice cover
to perform and live in
whatever habitat niche
they might live in
it also is a really useful way
for us to monitor weather
and predict climate
so it's really important to monitor
patterns of the cryosphere
patterns of ice and snow
so that we can predict things like storms
so that we can go away
and plan for communities and things like that
and also that we can understand
transportation corridors
it's really easy to access communities
that are really far north
when there's a lot of areas that are frozen
as opposed to areas that have water in them
it's really easy to take a snowmobile or a big truck
and drive it across a big lake or portion of the sea
further north
than it is to bring a boat throughout that area
so there's a lot of transportation impacts
that have to do
with the availability and cover of ice and snow
especially in those northern areas
and probably the most important wonder
or the one that's most impactful to us in general

you know kind of down at more of a mid latitude
where we live here
is that a lot of the cryosphere
most of the cryosphere
houses a very
very significant
very large portion of fresh water storage
so ninety nine percent of all fresh water storage
is stored in just ice sheets
so just those very
very large pieces of ice
essentially and snow
house the vast majority of fresh water storage
which is really important for us
because we need fresh water in order to survive
there's often
there's also a lot of
then subsequent and indirect impacts
on ecosystems
and on hydrologies
so there's a lot of flooding impacts
there's a lot of impacts
on the moisture content of forests
that these glaciers and ice sheets
are maybe melting into
there's lots of impacts on ecosystems
including plant species and wildlife species
due to areas maybe being covered by snow
maybe not being covered by snow
maybe being covered by ice
maybe not being covered by ice
so a lot of different
reasons why it's important to monitor the cryosphere
this is just a couple of examples here
not an exhaustive list
but remote sensing makes it really easy
to monitor the cryosphere nowadays
we get really good global coverage
lots of different kinds of data sets and information
that we can get with earth observation
remote sensing data
in order to go away and monitor things that ultimately
may impact communities of people

may impact biodiversity very strongly
may impact our transportation corridors
and our water resource management
now historically
we generally monitor the craft sphere
using systematic annual measurements
and we have these from about the
nineteen forties or nineteen fifties
and they can provide a very powerful time series
of changes in the craft sphere
so we often monitor the cryosphere historically
by looking at things like glacial mass balance
glacial extent
and sea ice thickness
but historically
this could have been from
a couple of different data sources
a couple of different methods
one being going out in the field
and people just on their feet
on their hands and knees
taking physical measurements
with literal measuring tapes
across you know
large glaciers
whatever it might be
obviously something that is not very efficient
requires a lot of time and requires a lot of effort
but you could do that
if you wanted to measure things like glacial extent
if you wanted to measure
see ice thickness
maybe you'd just be drilling
essentially a big hole
all the way into the ice
if you're out there in the field
so this is just an example of some historical data sets
a bunch of different data sources here
including aerial photography
and then here
one of the kind of
more historical examples of a data set
we have of glaciers all over the world

and the number of glaciers
the extent of those glaciers
where they're located
so this still provides a really
really valuable data source
because we only have earth observation
remote sensing data
for most data types
dating back to
at least in the case of satellites
the seventies
you know that's kind of the oldest
that we have satellite data available for
because the landsat mission was launched first
in the seventies
so prior to the seventies
forties fifties and sixties
we don't really have much
at least much satellite based remote sensing
earth observation information
so these data sets
these historical data sets
are still really
really valuable
because we have to compare something
we have to have some sort of baseline
to be able to compare our satellite data to
now i'm going to talk about three different ways
that historically
we went away and monitored the cryosphere
before satellite based remote sensing
earth observation really became more prominent
one was aerial photography
so something we've talked about a little bit
but being able to go away in a plane
and just take either oblique or vertical images
of areas of interest
this was a little bit trickier back in the day
because when we're going away
and taking these aerial images
you might get a bunch of images like this
but they're all potentially going to be
from slightly different angles

we didn't have really accurate gps measurements
to be able to track
where we're taking these images from
and what angle we're looking at
so we'd go away and maybe get a bunch of images
from one particular mission
or one particular outing
and then we could print them out all on film
and then we could put them up on a wall
and kind of make a mosaic
by overlaying them all together
but not a particularly efficient
or particularly standardized way
of us to be able to go away
and monitor ice sheets and glaciers
and things of that sort
so one other version
or kind of derivative of that
that we do have
is repeat terrestrial photography
so especially
back when we didn't have gps available to us
when we didn't have something
to be able to monitor and track
where exactly we are in the world
in three dimensional space
when we're taking imagery
aerial imagery
in this case
then maybe we could use something like
repeat terrestrial photography instead
with repeat terrestrial photography
you would essentially just go pick a landmark
so somewhere just on the surface of the ground
that you could walk out to
in the field
you'd pick a certain direction
get a certain bearing
at that specific location
so whether it's north
south east west
whatever it might be
and then you could continually go back

to that exact same landmark
to that exact same position
put your camera in the exact same position
find that exact same bearing
that exact same direction
and then just repeat photography
just take photos of the exact same target
over and over and over again
every couple months
every couple years
if you wanted
and this is one of the most valuable
historical data sets
particularly for monitoring the crash here
that we have available to us
it's very high resolution data
for the most part
because we're so close to the target
you know you can see here
in this example
on the right
this is looking at the glacial extent
of this glacier
in alaska right here
you can see we're pretty close to it
so we can get
a pretty detailed
level of information
about the extent of ice
on this glacier
in this example
but again still not super standardized
we still have different scientists
going out in the field
maybe collecting their photography
in slightly different ways
maybe we didn't have gps to be able to track exactly
in space where this photography was being taken from
so if someone was picking a landmark
from where they could choose to take the photos from
then if we find that landmark
how do we know we're placing the camera in the exact
exact same position

it was difficult
still not super standardized
but did give us a wide breath of information
with a pretty large temporal dimension
which just means we have data going back quite far
of this kind of terrestrial photography of glaciers
in particular
the other way that we have monitored the cryosphere
and that we still continue to use
to monitor the cryosphere
is field work
so two examples of field work
from monitoring snow and ice
and glaciers and things of that sort
one here is a
a pit a snow pit in this example
or an ice pit
where you essentially take a cross section
of somewhere in the glacier
in the snow in the ice
and you just dig or drill down really
really far till you essentially hit either the ground
in this case
i think they've hit the ground there
so just as far as you can go
essentially
before there's no ice
and you just hit the ground
and then you can look at that and say okay
i can measure how deep this is from the surface
i can kind of monitor
and look at all the different layers in this ice
and collect a wide breath of information
about the glacier
in this case
or about the snow cover
or about the ice
if you just go away and dig a pit like this
one other very common way
that we measure and monitor glaciers
especially historically
is with something called ablation stakes
so that's what this example is on the right here

and it's just taking a
piece of wood
or an iron rod or something that is
can just be used as a stake
where you just stake it into the ground
it's essentially just a pole that you put into the snow
and by doing that
because glaciers move
because they oblate
they kind of move down
whatever parcel of landscape that they're on top of
you can monitor where you put your ablation stakes
and then go away for a certain amount of time
and then come back
and check where your ablation stakes have moved to
so by being able to measure and monitor
how far your ablation stakes may have moved
you can measure things like glacier mass balance
things like glacier ice flow
things like glacier retreat
and so that's done with these stakes
called ablation stakes here
both of these methods
you know relatively speaking
have been pretty standardized
there's relatively
clear guidelines for how to do this appropriately
but it still has a certain level of subjectivity to it
because individuals can go out and do all of these
kinds of measurements slightly differently
so then enter
remote sensing
earth observation data
where we can go away and get measurements like this
of all of the ice
the sea ice
in this example
of the arctic
at a global scale
every single day
for all days of the year
so this is an example
using modest data

modest data we know
has global temporal resolutions
with a two hundred and fifty to one thousand meter
spatial resolution
and it allows us to go away
and build up really nice visualizations like this
and be able to track
through time
at a really nice scale
how sea ice is changing
how things like snow cover
and glacial extent
might be changing
all across the world
so specifically
the data sets that i'm going to talk about today
for monitoring different portions of the cryosphere
are landstat
modus radar and lidar
now just to kind of overview them briefly
before we talk about them
and this is kind of a good chance for me to remind you
about the different
advantages and disadvantages to each of these data sets
we've talked about each of these
kind of a fair bit throughout the course
and we're going to continue to talk about
each of these data sets
lansat modis
radar and lidar
but now more with regard to specific applications
so in this case
for the lecture today
with specific applications
toward monitoring the cryosphere
so towards monitoring snow and ice
but the fundamental characteristics
of each of these data sets
remains the same
and so because of that
a lot of their advantages remain the same
even though we're looking at something
slightly different

even though we're looking at the cryosphere
as opposed to looking at the biosphere
like we did last week
a lot of the advantages of each of these data sets
remains consistent
so in an exam setting
particularly on a short answered question
i'm asking you to describe appropriate data sets
that could be used for a specific application
then really
the advantages and disadvantages
and your reasoning for using a specific application
is going to be relatively the same
you just have to apply it to whatever
specific example i'm talking about
whether that's specific to sea
ice and snow
or specific to monitoring
primary productivity of the biosphere etc
so for landstaff
for example
we know landsat
gives us that fine to moderate spatial resolution
of thirty meters
we know it has data
dating back to the seventies and eighties
and we know it gives us a spectral amount
or a spectral type of information
because it's a passive remote sensing instrument
now we're going to talk about specifically
the kinds of applications
for monitoring snow and ice
that that ultimately makes landsack good for
but whether i'm asking you on the exam
about the cryosphere
about the biosphere
about oceans and fresh water
if you are thinking about
describing why landsat might be a good thing to use
to monitor that specific application
you should always be kind of thinking back
to something like this
where you're thinking

okay landsat
i know has that
find a moderate spatial resolution
so it gives me
a good amount of spatial detail
it dates back to the seventies
or eighties
so if i want to monitor something back to
then i need to use that
et cetera et cetera
so i'll give some examples of that
and i'll try to go through
and give some examples of that
as we talk about some different
applications of each of these
data sets today
so modus on the other hand
just to remind you guys
gives us that fine temporal resolution
that daily revisit time
it's applicable for imaging much larger areas
things like global coverage
or in the case of the cryosphere
looking at sea ice
across all of the arctic
for example
it's also a passive system
so it provides us that spectral information
gives us a range of measurements
across different bands
of the electromagnetic spectrum
then we have radar
we know we have radar sat
the canadian owned and operated satellite mission
we also have
different forms of airborne and terrestrial radar
which i'll talk about briefly today
and we know that that's an all weather system
it can see through clouds
it uses microwaves
and it has the potential to be surface penetrating
then lastly we have lidar
either icesat

which is a satellite or a spaceborne lidar system
or airborne lidar
where we just have a lidar
instrument mounted on a plane
and we know that can be used to measure elevation
and give us really high resolution
three d information on topography
ok so just then
thinking in general
about each of those applications
or about each of those data sets
what characteristics of the craft sphere
could we measure or monitor with earth observation data
and then maybe which earth observation data sets
might be the most applicable
for measuring that characteristic
this is a really nice example i think
to kind of try and get your minds working
for questions you might see on the final exam
we know that the main data sets
we've talked about throughout this course
are things like lancetap modus
lidar and radar
so in the case of the crysphere
what can we measure
and then which of these data sets
would be most appropriate for measuring those things
so for the cryosphere
for ice and snow
maybe we can just measure cover
maybe we can just measure
how much snow cover is on the ground
is there a zero percent snow cover so no snow
is there twenty five or fifty percent
seventy five percent or a hundred percent snow cover
we can measure things like extent
what's the level of surface area
that snow or ice might cover
we can measure things like depth
how deep is snow
how deep is the ice in a particular area
we can measure things like type
is the snow or ice in a particular area

is it glacial fern
is it fresh snow
we can measure things like ice and snow age
particularly with something like ice penetrating radar
when we're able to see below the surface
we can get a sense of what the different ages are
of the different layers of snow we can see in glaciers
and in different portions of ice
we can also get a sense for movement
with things like lidar
things like radar
that give us that three dimensional information
we can get a sense of how glaciers are moving
how their topography is changing
so hopefully
you know if i were to just kind of give you this list
of different characteristics of the cryosphere
that are known to be measured by
different forms of earth observation data
you could maybe hypothesize a little bit
which of these might make sense
for each of these applications
maybe we'll come back to that
i don't expect you to be able to do that
before i talk about it all
so i'll talk about it a little bit
we'll talk about some specific applications
of each of these data sets
and then that's ultimately
what i want you guys to be thinking about
in terms of trying to apply
kind of what i'm going to lecture about
for the rest of the class today
in terms of a final exam setting
is based off of what i'm talking about
based off the examples i'm giving
then which of these datasets would make the most sense
for monitoring each of these different forms
of the cryosphere
or each of these different metrics for snow and ice
that we can look at
okay so the first kind of category of
data sets that i'll talk about are spectral data sets

now spectral data sets
i will refer to as lancet and modus
for this course
spectral data sets are
essentially
they don't have the same definition
as a passive remote sensing data set
technically
passive just means that we are measuring
energy that's come from the sun
and reflected off the surface of the earth
while spectral information just refers to
the diversity of spectral information we can get
meaning that we can measure
the reflectance of different bands
all across the electromagnetic spectrum
but you can kind of
for now at least
think of spectral remote sensing data sets
kind of in coherence with
passive remote sensing data sets
just because we've talked about
what passive data sets are
and what the definition of those are
in an exam setting
it'd be good to
understand the difference between those terms
and i'll make sure i clear that up in our
review session
but in terms of spectral datasets
we're able to get spectral information
which means that
if we look at the electromagnetic spectrum
we can use our knowledge of spectral signatures
in order to gain some sort of information about
in this case
snow and ice cover
so in this example up here on the right
in this graph
why might it be that
we can see fresh snow here at the top
so this is the spectral signature for fresh snow
versus dirty

glacier ice
kind of down here
and we can see that the reflectance of glacier ice
particularly in the visible portion of the spectrum
here is very
very very low
compared to
say the spectral reflectance of fresh snow
way up here
now ice snow
they're not the exact same thing
but they're pretty close to one another
so why would we see this massive
you know difference
between the spectral response
of glacier ice
versus something like fern or fresh snow
these different kinds of snow and ice
that we can see
when we're looking at the cryosphere
when we're looking at a particular glacier
there's two main reasons why
particularly with dirty
well with glacier ice
the term dirty kind of gives it away
but with glacier ice
there's always lots of impurities and debris cover
so you'll often see lots of dust
lots of dirt
lots of debris
essentially rocks
cobbles things of that nature
on the glacier snow so
that ultimately results in it having less reflectance
because it doesn't have that kind of clear
white appearance that really really
really fresh snow has
it also has its higher degree of surface roughness
now that matters because kind of fresh
smooth snow
are more like pure specular reflectors
where all the light coming down
kind of gets reflected straight back up

so there's a very strong signal
that might get sent back
to the landstadder modest sensor
if you have a high degree of surface roughness
which you often do on glacial ice
then a lot of the energy coming down
and hitting the glacial ice
is kind of being bounced around
in all kind of different directions
so you don't get as much overall signal
back towards the sensor
of that light
so that's kind of
there's some other reasons as well
that are a little bit more physicsy
and a little bit more aggressive in nature
in terms of their science
but the two that i want you to be aware of
for exam purposes
of why do glaciers have lower reflectance that
say fresh snow
is because glaciers have a higher level of impurities
and debris cover
and they have a higher degree of surface roughness
you can kind of see that in this example here
so kind of at the back
towards the top of this glacier
you can see some fresher snow
and then the older glacier snow
you can see down here
has kind of this gray appearance to it
there's lots of dirt
lots of debris cover on it
and that's something that we're able to pick out
with these spectral remote sensing data sets
because we can measure different bands
in the visible portion of the electromagnetic spectrum
so we can kind of identify and differentiate
this is older glacial snow versus
this is much newer
whiter snow
and that has a lot of implications
for melting patterns on glaciers like this

areas that are much darker like this
areas that have much less albedo
that have a lot of impurities
and are very dirty
are going to melt much
much much quicker
than areas like this
that are reflecting all of that energy
the wider areas
the newer snow
if they're reflecting more energy
they're absorbing less energy
which means that they don't have to melt
nearly as quickly
because these kind of dirty portions of ice and snow
down here on that portion of the glacier
are absorbing much more energy
because they're not nearly reflecting as much radiation
they're going to melt much much
much quicker
okay so i just have an example here a quick video
there's no kind of voiceover to go with it
there's some music that
it's kind of soothing
if you guys want to sit back and relax
it's not that exciting
but this is just to give you a sense
of all of the different kinds of textures and colors
that you can see from a satellite
of something as simple as a glacier
and just different kinds of ice
come on
everyone's just looking for a little bit of something
just to get him through the christmas
and into the new year
and i'm just another weary christopher columbus
i'm sailing this devotion with my head held high
and all these currents i need me astray
take me away that i'm seeking
and all these kinds of being real strange
number five
in my headphones
don't turn my blood out like you

the happiness
now i'm slipping into
the sky
and i watch your face when i lie you say
where you are from
my god i would like to know and i don't know
where you are from my god i would like to know
he is now enjoying it again
hotsy longs general dance straight up protected
i'm proud of every mother i am
where you are from with my god i would like to know
and i don't know
where you are from with my god i'd like to know
is i'm gonna break your phone with my heart
i'd like to know and i'm gonna
that's not me by the way
just you know
that's not my video
but what's nice about that video
is you can kind of get a sense of
even for something that is as simple as a glacier
which you might think would
generally speaking
always have the same spectral signature
and thus always appear pretty similar to a satellite
or to earth observation data
could be very
very very very
very different
depending on its characteristics
and we can analyze that
and sense how those things are changing
with something like earth observation data
so this is an example of just up here
a landsat image
just the true color composite of the landsat image
and then what seems to be what they've applied
as a snow detection or ice detection algorithm
where they've mapped out all the areas in this area
or in this study area
that are covered by ice or that are covered by snow
now with landsap
it allows us to really

at a fine spatial scale
make out a lot of those differences
that were shown in that video just now
a lot of those kind of changes
those different characteristics of ice and snow
on ice shelves
on glaciers
whatever it might be
wouldn't be able to be discriminated
without something that has a fodder
fine to moderate spatial resolution
like landsat
now inherently
that also means that landsat isn't great
or isn't super useful
for monitoring things like global sea ice cover
but for monitoring in a more regional area
for maybe a particular range of mountains
or maybe say
the size of provincial parks
that we have in british columbia
we can really accurately
at a nice fine spatial resolution
monitor and detect ice throughout the year
and get a sense of how the ice and snow
in the glaciers and the mountains is changing
and how their dynamics look
across time
in different portions of the season
so landstaff
really applicable
in terms of the craft sphere
for making out those very fine scale changes
in whatever it might be
if it's color
or those different patterns that you see us saw
whether it's braided or humped
a lot of those very fine scale changes
that you're able to detect with spectral information
landsat is really really good for
but inherently
it's only good for kind of a smaller area
something like a regional scale

something the size of maybe a couple of mountains
or provincial park
this is another example
just specifically
of using landsat eight
to monitor glaciers
music
oh
again not made by me
made by the same researcher that we looked at
that made that first video
but gives you just a bit of a sense of the scale
at which something like landsat is being used for
to monitor glaciers and ice and parts of the cryosphere
this other example
here i am showing a series of modus images
and in this particular series of images
we're looking at a rapid breakup
of an ice shelf in antarctica
between july twenty eighth and thirty first
two thousand eight
now what you can see here is kind of right around here
there's this big ice shelf
and you can see it's starting to break off here
and then fully breaking off in this last image here
and what you might notice
right away by looking at this series of images
or at least
what i'd hope that you can kind of notice by
by looking at these
is their dates
so notice this is july twenty eighth
july twenty ninth
july thirty first
so again modest data
revisit time
every one to two days
so we can monitor a change that's happening
on a daily temporal scale
we can monitor something like
the rapid breakup of this ice shelf
in this case
something that would be not possible with landsat data

landsat data has a revisit time
a temporal resolution of sixteen days
so we wouldn't be able to monitor something like this
that's happening on a daily scale in the cryosphere
with landsat
so modest data allows us to monitor these kind of rapid
fine temporal scale changes
while landsat doesn't allow us to do that
or something like
modus is also particularly well suited
for very large spatial coverages
so because it has a low spatial resolution
of two hundred and fifty to a thousand meters
it's particularly good for looking at very large areas
so in this case
this graph on the right here
is showing the arctic sea ice extent
over the last
yeah about fifteen years or so
so the gray shaded area here
is plus or minus two standard deviations
from the average pattern
of sea ice extent in the arctic
so this gray line here
is the average amount of sea ice in the arctic
from nineteen eighty one to two thousand ten
on this kind of rate of change
in this portion of the year
from february to june
and then it just shows for more recent years
twenty eleven
twenty twelve
twenty thirteen
twenty fourteen
and twenty fifteen
what the pattern of sea ice extent was
from february to june
and you can see here
the most recent one being twenty fifteen
so obviously
the lowest run right here
that kind of bright blue here
and you can notice that pattern where each year

we're kind of getting this lower level
of sea ice extent throughout the entire year
now again this is derived from looking at
all of the arctic
all of the sea ice in the arctic
you could technically try to do that with landsat
realistically
with landsat
you would only be able to measure something like
overall ice cover across the whole year
you're not gonna get that fine temporal resolution data
the way you do with modus
so modus allows us to look at patterns
say on this monthly scale
something that would be very difficult with landsat
and modus allows us to look at very large areas
because it's got that lower spatial resolution
so i didn't necessarily give two specifics
didn't go into too much depth
about exactly what landstack can do
in terms of monitoring the cryosphere
and exactly what
modus can do in terms of monitoring the cryosphere
gave you a couple of examples
and a couple keywords
key topics that i would hope
that you could touch on in an exam setting
for landsat
we know it's got that lower spatial resolution
so it can make out some of those finer details
in terms of differences of spectral signatures
that you might see between
say fern versus dirty glacier
ice versus clean
new white snow on glaciers
so you can get some of those fine scale patterns
with modus we know
it's got that lower spatial resolution
so it's good for looking at more global metrics
and it's got that high temporal resolution
so it's good for looking at things
that are happening on a very short time scale
any questions about that

the extent as all the cover is an extent
like covering how much snow is next to it
extent snow
sorry like snow extent versus snow cover
yeah so snow extent is essentially related to the size
of the area that snow is covering
cover is related to the percentage
of snow covering a particular pixel generally
so with snow extent
you would be describing it with an area
with snow cover
you'd be describing it with a percentage
so zero percent cover
twenty five percent cover
thirty percent cover
extent would be
is it covering
is there snow covering this area or is it not
and then the total extent would just be
the total amount of area that the snow is covering
does that make sense
yeah no problem
any other questions
ok sweet
so this is again an example of a data set
a visualization you could get with modest data
where we're able to look at
in this case
the extent of snow across north america
every month for a variety of years
you can see the cyclical pattern of snow kind of
coming down
covering these lower latitudes
and then receding back up during the summer again
a data set that would be really hard to put together
and to collect with landsat
but something that modus is super capable of
because of that high temporal resolution
that lower spatial resolution
okay the next data set i'm going to talk about
in terms of its applications for the cryosphere
is radar sat
now radar if you remember

we briefly talked about
radar being able to detect things as well as
radar being capable of making ranging measurements
radar being able to detect things relating to
essentially
the backscatter
the type of signal that's coming back
after microwaves are sent down to a target
bounce off that target and come back to the sensor
and then the ranging part
being radar being able to measure
how far away that target is from the sensor
so i've classified that up here
i've talked about that in terms of backscatter
versus ranging
so backscatter refers to detection
it refers to the ability to discriminate different
signals that you're getting from different targets
just based off of their properties
whereas ranging refers to kind of the three d
information that you can get from radar
to be able to monitor things like
topological characteristics
so with radar
i've broken it into
essentially radar sat
which is our spaceborne radar
and then airborne or terrestrial radar
which i'll talk about in a moment after this
so in terms of radar sat
our space borne radar
we can estimate things like snow mass
so areas that have different levels of snow mass
because of their properties
because of their dielectric or chemical properties
they'll actually give different signals
of microwaves bouncing off of them
back to the radar sensor
depending on how much mass there is associated
with the snow in that area
so using the backscatter
using the detection capabilities of radar sat
we can get estimations of snow mass

we can also get estimations of snow cover
or ice cover
areas that are covered by ice
will have different backscatter
different types of detection
from radar signals
than areas not covered by snow
so using the backscatter
using the detection capability of radar
we can measure things like ice cover
where we just say okay
that backscatter looks different from that backscatter
therefore that must be ice
and that must be not ice
we can also get really interesting
very cool measurements on things like permafrost
so with permafrost
we can get more of a
or we can apply
more of the ranging capabilities of radar
and we can see okay
how are areas covered by permafrost changing
in the sense that
areas that are generally frozen all year round
are pretty stable
in areas where there's lots of permafrost
so in canada
for example areas like
where there's very high northern latitudes
like nunavut
lots of these northern communities
that generally have permafrost all year round
as they lose permafrost or as
which happens as the temperature slowly warms
their soil stability
gets much much lower
which creates loss of these sinkholes
things that are very dangerous
and potentially hazards for communities
so one thing that radar sat is really good at
and it's been applied to
and it's shown in this map here on the right
is its ability to detect and monitor soil stability

so what it's using is its ranging capabilities
its ability to kind of measure topography
and how that topography is changing
so that we can understand soil stability
areas where there's lots of changes in the topography
lots of dips that are being created
as that permafrost becomes less stable
can be detected and quantified
by something like radar sat
so you can see here
this is just a comparison
on the top map here
and the bottom up here
between summer of twenty fifteen
and summer of twenty sixteen
and you can see lots more areas in this bottom map
that are blue
and kind of pinkish and purplish
those are areas that have much lower soil stability
than in this upper map here
where you can see areas in general
have a higher level of soil stability
we can also with radar sat lastly
measure and monitor things like ice flow mapping
we can use the combination of backscatter
of the detection capabilities of radar
in combination with its ranging capabilities
to monitor ice
and understand how ice is flowing across a glacier
and actually get a sense of how it's moving
so we can measure things like ice flow rate
what's the actual speed in meters per second
of how fast
ice is flowing and moving down through a glacier
some pretty cool applications of using spaceborne radar
in this case radar sap
now we can also
use radar that is mounted on board airplanes
we can also use radar that is terrestrial
so like i said
airborne radar
pretty simple
you just apply

or mount a radar instrument right onto a plain wing
terrestrial radar
a bit more complicated
generally works something like this
where you have a sled
that has the radar instrument in it
where it's pointing straight down
sending radar microwaves into the snow or into the ice
and then you got some poor guy here
who's towing this thing along the ice
he's got a gps antenna attached to him
so he can monitor exactly where he is
in two or three dimensional space
as he's pulling this radar instrument along the ground
but both of these work in kind of the same sense
where whether it's airborne or terrestrial radar
they're just flying or walking
transex back and forth and back and forth
and back and forth and back and forth
across a study area
to build up an image
or a data set
that is covering a kind of large
maybe rectangular or square area of interest
by doing that
they can go away and create images like this
so this is an image that's derived from an
airborne radar data set
where they were trying to go away and map
how deep the rock bed was below the ice
and so you can see here
this layer right here
that is the bedrock layer right there
they were actually able to measure
at what depth below the ice that bedrock was located at
you can also get a sense here
of all the different kind of layers in the ice
that you can see
and so with the ice penetrating radar
different surfaces below the top surface
so different kind of layers of ice
will give different types of signals
back to the radar instrument

and thus allow the radar instrument to discriminate
what and where these different layers are located
below the surface of the ice
really valuable data set
and something that is
you know kind of
groundbreaking
and its ability to efficiently
in a standardized way
go away and collect data from below the surface
without ever having to go away and dig a big hole
or anything like that
this is another example
from a terrestrial based radar system
where their goal was to go away and try and identify
how deep below the ice or snow was the water layer
and so again you can see that here
they were able to differentiate it
so this layer right here
is where the water layer was located below the ice
and then again
here you can make out all the different fern layers
all the different layers below the surface of the ice
that were accumulated over years and years and years
okay any questions about radar radar applications
cryosphere applications of radar yeah
yeah so it is very
very complicated
radar is notorious for being very complicated
and very hard to understand
often involves very high level calculus and physics
to be able to understand different backscatter signals
essentially
in kind of its simplest form
it's just the microwave signals that are sent down
that bounce off of whatever target
whatever feature is below the surface of the earth
it will come back towards the sensor
in a specific pattern
so in kind of a specific waveform
depending on how deep it went
depending on what surface
or what kind of material it was bouncing off of

and essentially they go away and apply again
stuff that's way over my head
very high level calculus
to be able to understand the signs and the waveforms
of the microwaves
that are reflecting off these materials
and coming back towards the sensor
the wavelength of the microwave yes doesn't change
but the level of the type of backscatter you're getting
for example
the polarization that you might be getting
the different characteristics of the waves
that are way beyond just the actual wavelength
are gonna be potentially very
very different
depending on
what the material is that they're bouncing off of
that's kind of the
the basics of it i honestly
i know it's based off calculus
beyond that
i honestly don't know
yeah no problem
do you have a question
yeah i think that you want to answer my question
yeah okay yeah
it's very complicated
it's not easy
this you know
to give you maybe a bit more background
these two images
this kind of image here and this image here
would take a ton of pre processing
processing calculus algorithms
ton of computer power
way beyond what i am capable of wrapping my mind around
to go away and actually output
so yeah it's a cool technology
radar in general
but it's also very notorious
in the remote sensing community
for being very difficult to work with
and very hard to wrap your head around

hence i don't understand it very well
but some people do
so we can get cool images like this
okay last data set
i'll talk about briefly just lidar
so with airborne lidar which we talked about
we talked about active remote sensing
we can get vary
we know we can get high resolution
three d information from lidar
things like digital elevation models
things like structural information on forests
with icesat
we talked about icesat very
very briefly
but icesat is a space born lidar system
and kind of
as suggested by its name
one of its key purposes was to go away and measure
and monitor the cryosphere and portions of ice
it was also developed for measuring
clouds and elevation
which is where its acronym comes from
it's actually ice cloud and elevation satellite
but one of its key things was to measure ice
i sat one was kind of the first mission from i sat
it was operating from two thousand three
to two thousand nine
i sat two was launched in twenty eighteen
and one thing
one kind of key characteristic about icesat
that i always like to know to point out
because it's kind of fun
is that icesat uses visible green laser pulses
with a wavelength size of about
five hundred and thirty two nanometers
if you remember from our active remote sensing lecture
i mentioned that generally speaking with lidar
particularly with applications in forestry
and for monitoring terrestrial areas
we typically use lidar that has a
wavelength in the portion of the near infrared spectrum
we use that generally because things like forests

vegetation reflect near infrared light very
very strongly
now icesat doesn't use near infrared
light in its laser pulses
it uses visible green light
and using this spectral signature here of ice
as a bit of a hint
why do you think we might use green light
visible green light
as opposed to something like near infrared light on ice
at on a lidar space borne sensor
that's kind of meant to monitor specifically ice
and the key here is really in this spectral signature
you can see that the peak of reflectance for ice
is kind of in the green portion of the spectrum
kind of right up here
unlike something like vegetation
where we know vegetation's peak reflectance
is often in the near infrared portion of the spectrum
kind of around here
so for icesat
it makes sense to use a green visible laser light
because that is going to give us the highest signal
it's going to have the most reflectance
of those laser pulses
if we're monitoring something like ice
okay our quick video on ice stat and how it works
and then we will go over some practice questions
and then i'll give it to liana
from fell out there
there are very good cameras all around
looks like you can see the ocean
you can see the sea eyes you can see the porous
but it's much much more optimistic
it's how high seams are on a little bit of scale
almost impossible
i set two as the third dimension
yellow is repeating measurements from i set to
will allow us to measure changes in the ice sheets
or in the ocean or in land
i set two is designed
to measure the changes that are going on in the crabs
all the change is at the edges

those are the steeply sloping parts of the glacier
that interact with the ocean
and that's where all the action is
that's where all the mass is being lost
in order to estimate the mass changes
we need to know the height of things
the emission asset to carries a single instrument
is called atlas
the advanced topographic laser alternative system
atlas sends out small pulses of laser light
ten thousand times a second
and by measuring precisely
how long it takes that light to go from the spacecraft
down to the earth
and back into the spacecraft
allows us to figure out
what the height of the surface is beneath that tube
we need to measure the time of flight
of a single photon
or a single laser pulse
with a precision of a billionth of a second
nasa engineers had to come up with entirely new ways
of measuring time
very precisely
a billionth of a second
translate to an elevation change precision
of just a few centimeters
climate change is amplified in the port
our regions
isatu is designed to measure those areas
and will help us to
understand what's going on with our planet
okay so there's just a bit of a oh it's really lagging
i don't think it's supposed to look like that
okay so this is just an illustration
a little bit of how icesat works
so these green kind of paths would be the swath
or the area that the icesat satellite was looking at
as it passes over a polar region
and then in the top left window here
this would be its measurement
so this kind of dark blue here would be the ocean
and then the kind of little white peaks

you see that it's measuring
would be the topography of the ice on top of the ocean
so ice that works
it doesn't kind of
directly measure things like ice depth and ice mass
what it does is it measures the elevation
or topography of ice
so of say arctic sea ice
for example
and then it measures the nearby sea level elevation
and then says okay
if the ice is this high
and the sea level is this high
then the ice depth is about the difference between that
and then using that
as well as some other modeling and algorithms
they can also go away determine
how much ice there is below the surface of the water
and how much mass there is in the ice
and those kind of metrics
but it doesn't kind of directly
measure depth
in the sense that
as we hopefully remember
from the active remote sensing lecture
lidar doesn't penetrate through materials
so lidar doesn't penetrate through ice
the way radar is capable of
but we can still
with combining it with other data sets
measure things like ice depth
by understanding okay
what's the sea level
of nearby areas
and then using some modeling techniques
to figure out
then what the difference is
and what the depth of that ice might be
so this is just an example of a data set
derived from ice
at just showing sea ice thickness
and meters across a portion of the arctic
okay so lastly

kind of just to summarize
talking about using earth observation data
for monitoring the cryosphere
couple of key reasons it's useful
versus the historical ways we used to monitor
the cryosphere
with aerial photography
with repeat terrestrial photography
with field measurements
one is we have standardized data
we have a standardized way of collecting data
always land set data
it's always modest data
it's always ice set data
that's always from the same data source
allows us to have a standardized
level of data collection
we also have efficient data collection
we're getting pretty good
global coverage a lot of the time
from a lot of these satellite missions
and we're not having to go out and collect it ourselves
we don't have to actually put too many resources
into going out and doing that
we get good coverage in space
so we get satellite data
that is covering
large portions of the surface of the earth
and we can get different types of information
because of the different resolutions and specifications
of those different data sets
with landsat
we can get that moderate to fine spatial resolution
information
to be able to make out some of those fine details
in different portions of the spectrum
we can get that fine temporal level information
with something like modus
to be able to monitor changes in the cryosphere
that are happening on a daily scale
we can get that
you know pretty impressive
level of spectral information

from same modest or lansat
where we can look at the visible portion
of the spectrum
but also the near infrared
and shortwave
infrared and thermal infrared portions of the spectrum
to be able to
pull apart different types of metrics
and different kinds of information
related to the cryosphere
now if you were here for our last lecture
you may notice a pattern here
where kind of at the end of
well at the start of each of the lectures
i say this is how we used to monitor this kind of thing
this is why it's not very efficient
this is how we monitor it now
with earth observation data
this is why it's efficient
this is why
it allows us to give standardized data collection
it has good coverage in space
it allows us different kinds of information
with all these different resolutions
that's pretty much gonna hold
so i say that because for final exam purposes
a lot of the
or at least you can expect
short answer questions related to
okay well why is earth observation data good or useful
for this particular application
again your reasoning is always going to be
fundamentally very similar
it's always going to relate back to
standardized data collection
efficient collection
good coverage
the different kinds of information we can get
you just need to be able to apply it to the specific
example or application that i'm referring to
whether that's productivity in the biosphere
monitoring ice in the cryosphere
we'll talk about wildlife and oceans in freshwater

tomorrow and then next week
so just to give you a sense
just to give you kind of a reminder
i'm gonna be drilling home this exact same thing
pretty much every lecture from here on out
but with specific applications
to each of the topics that we're talking about
whether it's ice
whether it's wildlife
whether it's oceans
whether it's the biosphere
okay i have a couple of practice questions here
so you're welcome to try these out yourself
and then i'll go over the answers with you
in a couple minutes
maybe about three
four minutes
and then i will give it to liana
are you talking or are you
just q amp a kind of thing
okay leanna will give
pull up one thing quickly
about the assignment that's due this week
and then she'll be here
if you want to ask any questions
about the assignment that's due thursday
if you want to head out now
you're welcome to do so
and i will see you tomorrow
if you want to stay and go over the questions
you are also welcome to do that
and if you want to stay and talk to leanna
also welcome to do that
but otherwise i will see you tomorrow
and yeah happy monday
thanks for coming
now i'm just gonna pull up
the last website that they have to use
cause there's like a bit of a
just to give it
exactly okay
do you want to pull it up now
oh actually never mind

i should leave that up
we can pull it up on here
that's pretty good
can i like do some yep yep i notice
okay guys let's try and answer these questions together
so three examples that we talked about
how was the cryosphere monitored historically
yeah systematic annual measurements by aero photography
repeated restaurant photography
and you got it yeah
aerial photography terrestrial repeat photography
as well as field work in the form of
we talked about digging ice pits
as well as using ablation
what i call them ablation stakes
that's what they're called ablation stakes
okay is snow always white why or why not
anyone answer that for me yeah sure
totally
exactly yeah
it's got different
so snow's not always white
it's got different reflectance patterns
depending on if it's fern
depending on if it's old dirty glacier snow
depending on if it's fresh snow
and then how ultimately are we able to
with spectral earth observation data sets
take advantage of that phenomenon
what can we ultimately
what are we going away and measuring with
say landstat
that allows us to take advantage of the changes
or the different kinds of spectral signatures or colors
that we can see with snow
depending on the color of the snow or ice
it melts at different rates
exactly yeah
that's great example
yeah depending on the color of the snow
depending on the patterns of the
snow that you can detect with something like landsat
it's gonna melt to different rates

which is gonna have
different impacts for downstream ecosystems
different impacts for fresh water
different impacts for water management for people
all kinds of things
so can you name please
one cryosphere specific example of radar set
we talked about a couple
just one yeah
because they use microwaves
can like penetrate through ice
you can get that picture of like
the bedrock and all the layers by
so that was maybe that
i'm glad you said that
because that's a
there's a good chance for me to clarify that
generally speaking
radar sat which is a
the space born radar system
isn't ground penetrating generally
for it to be a ground penetrating radar system
it's either an airborne system or a terrestrial system
that's flown much closer to the surface of the earth
so for radar sats specifically
do you remember one
if not maybe someone else
yeah yeah exactly
yeah yeah monitoring
measuring something like snowmass
the backscatter
the detection from radar will be different
depending on the different levels of mass of snow
in the target area that it's reflecting off of
how is ice penetrating radar typically collected
you were on to that one
you want to go for it
it's like either with like a plane
the radar is attached to a plane that's going over
or terrestrial and someone's literally dragging it away
yeah exactly
that's a key point
generally speaking with radar sat

we don't see penetration properties specifically of ice
if we're getting ice penetrating radar measurements
we're generally using airborne radar
where it's just mounted on a plane or terrestrial radar
where it's just being dragged along the ground
ok and then lastly what is isat
essentially
what kind of remote sensing
instrument is on board i sat
yeah it's a lidar instrument built for ice
clouds and elevation
yeah you got it
ice cloud and elevation satellite
but it's a spaceborne lidar system
essentially
and what type of laser light does it use and why
yeah visible green
because unlike it wouldn't use near infrared
like something that's supposed to do vegetation
because vegetation gives off
reflects near infrared light
exactly the visible green portion of the
electromagnetic spectrum
is where the highest reflectance is
for ice in particular
exactly yeah
so the spectral signature of ice is such that
it reflects visible green light
more than any other portion
of the electromagnetic spectrum
as opposed to something like vegetation
something like forests
where we often
with lidar use near infrared light as our laser pulse
with icesat
we use visible green light because our target ice
for the most part
reflects visible green light
more than other wavelengths in the spectrum
perfect awesome
okay i will hand it to you
here's your mic thank you
hi guys how we doing good

go for it cool
so this is the last question on assignment
for i'm just going to go over this super quick
because this is the question
that there seems to be the most confusion around
i haven't really gotten many questions
on the other questions
questions twice but
so that's good
so i'm going to use this as an example
so we have our transect drawn over this area
down here in red
so this is not
the pattern that you'll be looking at when you're doing
this is the color composite
for questions nineteen and twenty
so this is not
the spectral reflectance pattern you'll be seeing
so this is just an example
but for the purpose of these questions
when you draw the transect across the color composite
and you're looking at those spectral reflectance curves
so we have like
the red channel
the blue channel
and the green channel
and you're looking at
okay band five is in the red channel
so that's near infrared
so how you would go about answering the question
is to look at what each of the lines are doing
so we can see that the red channel band
or the red channel line
or the near infrared band
is being very highly reflected
and i would consider these down here
the blue channel and the green channel
to be absorbed
for the purpose of these questions
so i've kind of like
put
sorry i've kind of like
in the introduction video

i think i might say that like if it's
but it's being absorbed if it's at thirty two or below
but if we're asking a question
and you don't really have an option like okay
all three of them are being reflected like this
just try to look at what
brightness behavior of the
channel lines is doing in relation to the other bands
so for again for this question
red would be reflected
but blue and green would be absorbed
does that kind of makes sense
this is definitely the trickiest part of
the whole assignment
does anyone have any questions about that
or any other part of the assignment
why just come down if you have yeah
otherwise thanks guys
awesome thanks
all right hi everyone welcome
today we are talking about oceans and freshwater
so far we have gone over
kind of post midterm
we've talked about resolutions
we've talked about active remote sensing
we've talked about then specific applications
looking at the biosphere first
and then looking at the cryosphere
and today we're going to look at freshwater and oceans
next week monday
the first lecture will be on wildlife
wildlife that lecture that i give for this course
is probably my favorite lecture for the course
because it's the most specific to
the research that i've done
and my experiences with remote sensing
so i'm excited about that one
today we're gonna talk about oceans and freshwater
i wanted to first just clarify something
while i was struggling through my monday yesterday
talking to you guys about radar
we had a couple questions about just how
radar measurements are made

how we actually measure and detect different things
different surfaces on the earth
and i wanted to just briefly remind you to kind of
link back to our active remote sensing lecture
when we talked about how dielectric properties
and water content and surface roughness
can affect the backscatter of radar
and the main things that
the main kind of feature
characteristic of the backscattered radar waves
or microwave waves
that are being measured there
is the intensity of the scatter
so does that kind of help answer your question
a little bit yeah
so it has to do with the intensity of the backscatter
so we know radar sends out microwaves
it bounces off the targets
how much of those microwaves get returned to the sensor
as a portion
or a function of the amount that was sent out
is kind of what's being measured there
to allow us to create detections
and classify different things that we're looking at
on the surface of the earth
that's kind of in its simplest form
i grabbed some resources about radar
because it's a pretty complicated topic
that we don't cover really in depth
at least especially in a technical sense
in this course
so i gathered a resource
a good reading on that
and i'll post that online
if anyone's interested or curious about it
okay for today though
we're talking about oceans
evan's going to come to the end of the class
so if you have questions about
any final questions
about the midterm grading
last day to
email either he or i about that is today

so he'll be here at the end of the class
if you want to talk to him then
liana will also be here at the end of the class today
as well to talk about the assignment that's due today
not today sorry
sorry not scary
assignment that's due thursday
my bad okay
so today we'll talk about
oceans and freshwater
what is it why monitor it
we'll talk about
historically
how it's monitored
remote sensing
earth observation
ways technologies methods
that we use to monitor oceans in freshwater today
and we'll relate that
to some specific applications and examples
again very similar outline format
of this lecture
as the past two lectures
very similar to the outline format
we're going to have
for the next
two or so lectures
after today as well
so oceans are the body of salt water
that cover about seventy percent of the earth's surface
and contains
ninety seven percent of earth's water as a whole
so that's spread between the atlantic
pacific indian
and arctic ocean
then there's also the southern
which is this kind of newest ocean
it's not recognized worldwide
but it's often recognized in these
either it's recognized in the states or
the states is the one place that doesn't recognize it
can't remember off the top of my head
but there's this new ocean in the world

called the southern ocean
that is often recognized by a lot of political areas
fresh water is just any water
that's naturally occurring liquid or frozen water
containing low concentrations of dissolved salts
so that includes glaciers
lakes reservoirs
ponds rivers
streams wetlands
and groundwater
it's only three percent of the earth's water
so only three percent of the earth's water is
fresh water
and that's less than one percent
of earth's total surface area
so on the scale of the whole globe
the amount of fresh water we actually have isn't huge
this is the map i was talking about that now
denotes this southern ocean here
so in terms of ocean
we have the arctic ocean
the atlantic ocean
the pacific ocean
the indian ocean
the pacific ocean
and the southern ocean here
i'm pretty sure it's the states
is the only place
that doesn't recognize the southern ocean
and i think that kind of goes in line with their
you know empirical units of measurement
and then also not being willing to do metric
not being willing to recognize the southern ocean
anyways doesn't matter too much
the point is
for the most part worldwide
we recognize there being the pacific atlantic
southern ocean
indian ocean
pacific and arctic ocean
so about ninety seven percent of
earth's water as a whole
all of the global water that we have

is held in oceans
is in that kind of high salt concentration state
and then about three percent or so
or two point five percent
is held as fresh water
the majority of that is held in glaciers and ice caps
and then a smaller portion of that
is held in groundwater
and then in surface
and other freshwater things like lakes
that's just one point two percent
or one small percentage
of all the available freshwater that we have
so of all the water on the earth
about three percent of it is fresh water
of all the fresh water
surface water only makes up about one percent of that
and then most of that surface water
is actually ground
ice and permafrost
with about twenty percent or so in lakes
and then we have rivers
and some other sources
and atmospheric water as well up there
so that's kind of how water is spread
all across the different sources and resources
that we have on the earth
so why monitor oceans
why monitor fresh water
why is it important to monitor
global water resources as a whole
very similar reasons
to the cryosphere
which makes sense
the cryosphere and water are inherently very linked
the cryosphere is just areas that have frozen water
so it's a very useful indicator
of climate variability and change
monitoring things like sea surface temperature
and how those metrics have changed through time
potentially has a lot of impact
on things like rise and sea level
which again

can impact people
as well as biodiversity
impacting species
habitats and the niches that they live in
it often has a very strong
oceans in particular
have a very strong hold
on weather and climate
so understanding our ocean currents
is a really big deal
when it comes to understanding
how our climate works
how our weather systems work
and oceans in particular
are really important for regulation
so often continental areas
will have a lot of fluctuation
in their temperatures
and in their weather patterns
and oceans often
regulate a lot of that
so a lot of the ocean currents we have
regulate a lot of the land surface
temperatures
that we live in
and keep things nice and moderate
and nice and consistent
and comfortable for us
and then as well
similar to the cryosphere
obviously water is important
because of fresh water storage
because we need to know
where our drinking water is coming from
as well as understanding how
water is affecting
other ecosystems
and hydrological processes
things like flooding
things like how water is moving through the soil
and forests
that kind of idea
so lots of different reasons

that we might want to monitor
oceans and fresh water
and historically
monitoring oceans and fresh water
was done in boats
makes a lot of sense
so people were usually in boats
placing nets or streams
into the water
and then just going
and collecting data
on composition of water
and surfaces
either below the water
or layers of the different
kind of columns
of the water
you can also go away
and historically
we saw a lot of nautical charts
so we saw a lot of people going away
and just kind of by paper
manually by hand
understanding tides and currents
building up these big charts
but nowadays we don't really
i mean we still go out and use
you know people in boats to go and conduct fieldwork
to validate a lot of the earth observation
remote sensing data that we collect
but the problem
obviously with this is that it's not super efficient
we have to go and send people out in a boat
we don't get great coverage take some very long time
for a boat to cover a large area
a satellite can
obviously cover a much larger area much quicker
and we get now with our remote sensing data collection
much more standardized data sets that we can compare
year after year after year after year
okay so different characteristics and features
that we can measure and monitor in the oceans
in freshwater

include things like sea surface temperature
sea levels freshwater storage
habitat characteristics
such as coral reefs and salmon habitat
and freshwater streams
so this list i've given up here
is most definitely not a cumulative or exhaustive list
there's lots of other characteristics and features
of oceans and fresh water
that we could go away and measure
i'm going to focus on a couple of key ones
that i've listed up here
that are important on a global scale
things like sea surface temperature and sea levels
but then i'll also kind of focus on some more specific
large scale or fine scale examples
looking at habitat characteristics
like the coral reefs
and like salmon habitat and freshwater streams
and as we go through and look at each of these examples
we'll also be relating them
and talking about
which earth observation data set is used
to monitor and measure each of those things
and we'll mostly focus on again
similar data sets that we've talked about before
landsap modus
radar lidar
and as well
a couple of new ones that we haven't mentioned before
that we'll kind of get to familiarize ourselves
with a little bit today okay
so we're going to talk about sea surface temperature
measurements first
so before satellites
measurements were usually done from boys
those were the main tool
and they just provide a point measurement
so boys naturally
only represent one single point in the ocean
they don't represent a large area
they just represent exactly
whatever point that that boy is floating in

but you can potentially get very
very fine temporal scale measurements with a boy
you can get measurements of temperature every hour
minute second
every millisecond
if you like
and they're all weather systems
so as opposed to having to deal with passive
remote sensing systems like modus
like landsat
boys are obviously an all weather system
they're functioning
no matter if there's a thunderstorm or rain
or a windstorm
whatever it might be
they're pretty
not completely indestructible
but decently indestructible
and so they're collecting lots and lots of data
through time
unfortunately
we just get that single point measurement
with each boy
and we're not going to have
millions and millions
and millions and millions and millions of boys
all lined up
one next to each other
to be able to get coverage
over the entire surface of the ocean
so enter earth observation
satellite data
we can get fundamental information
on climate systems as a whole
such as identifying el ni o
and ladenenia patterns
with earth observation systems
these are typically measured
with passive systems like modus
like glandsat
for sea surface temperature
generally we're looking at sea surface temperature
for a pretty large coverage

it's not super common
that we'd look at sea surface temperature
for small regional areas
if that was the case
maybe you could use something like landsat
but generally speaking
we usually measure sea surface temperature
with motors
it's generally the preferable instrument
to measure sea surface temperature
because it's good for a coarse spatial scale
because it has those small pixel sizes
and it's better
temporal resolution
we can get those daily
to buy daily measurements
of sea surface temperature
with something like modest
so onboard modest
we have bands
thirty one and thirty two
which i don't expect you to remember off by heart
but just to kind of remind you
bands thirty one and thirty two
use the thermal infrared portion of the spectrum
and so modus
uses these two bands
to get pretty precise
measurements
of sea surface temperature
all around the world
at a pretty
incredible daily time scale
now unfortunately with modus
it's not an all weather system
and oftentimes
over oceans
there's storms
there's clouds
there's lots of things
that could potentially
not allow the
emittance values

in this case
of thermal infrared energy
to reach the sensors
but we can go away and we can get really
really incredible data sets like this
so this is just an example
looking at sea surface temperature
all around the world every month of the year
so pretty incredible data set
now
we kind of know
based off of
talking about the electromagnetic radiation
as well as talking a little bit about motors
and talking about
how we can measure sea surface temperature
with the thermal infrared bands that motors has
we know that the ocean emits thermal infrared radiation
and that can be measured by space
from sensors like motors
and is proportional to sea surface temperature
just meaning that the more thermal infrared radiation
that is emitted from the sea
the warmer the sea is
now infrared radiation
thermal infrared radiation in particular
comes from about the top ten microns
of the surface of the ocean
so the very very very
very top of the ocean surface
the top ten microns
which is just another word for micrometers
a very very
very small depth of the top of the ocean
is what is responsible
for where the thermal infrared radiation comes from
that say an instrument like modest measures
but the ocean also emits radiation
in the microwave part of the spectrum
and that radiation is also proportional
to sea surface temperature
microwave radiation comes from the top millimeter or so
of the surface of the c

so you can see that in that
this illustration on the right here
so this is microwave instrument versus infrared
and the measurements that you're taking with
still a passive instrument
so not radar here
still a passive instrument
measuring the microwave radiation
from the surface of the c
in this case
allows us to also measure sea surface temperature
but it allows us to get a measurement
that relates to a one millimeter depth
of the surface of the sea
as opposed to just a couple of microns
the top ten microns
so different measurements that you can get
by measuring passively
microwave radiation
versus thermal infrared radiation
the reason i bring that up
is because there is a satellite out there
called the tropical rainfall measuring mission or trim
and it has a microwave imager
so it's a passive system
it's a passive sensor
and it measures the emission of microwave radiation
from surfaces
so it's not radar
it's not an active sensor
it doesn't send out pulses of microwave energy
it just measures the emittance of microwave energy
and it allows for really highly accurate
sea surface temperature estimates
and what's nice about it
is that it works in all weather conditions
so even though this is a passive sensor
this is kind of the one exception
where a passive sensor
can still work in really cloudy conditions
we know that microwaves
can penetrate right through clouds
so the emittance coming from the top of the sea

that say the trim instrument is going to measure
of microwave radiation
can go right through clouds all the way to the sensor
it's representative of about the top
one millimeter of the surface
and the reason that i bring this up
kind of bigger picture
is because this trim satellite was kind of very
very progressive
and was a pretty big deal
in terms of getting really accurate
sea surface temperature measurements
in all forms of weather conditions
so still a passive sensor
but allowing us to get more frequent measurements
because we didn't have to worry about clouds
and things like that
unfortunately
it's because it was targeted for tropical areas
its orbit was only restricted to plus or minus
thirty degrees above the equator
which is why in this image
where you have derived
sea surface temperature measurements
from the trim satellite
you don't see it going all the way
to the north or south pole
so its latitude coverage was pretty limited
but you did get really
really accurate measurements
of microwave emission emittance based
sea surface temperature measurements
in all weather conditions
so it was a pretty cool instrument
i just have a quick video
talking about that satellite mission here
the term is the tropical rainfall measuring mission
it was launched in november of nineteen ninety seven
richly designed as a five year mission
but we've gone now for thirteen years
fifteen years and thousands of storms later
train has contributed to the advancement
of scientific milestones

trim has advanced research in the areas of agriculture
disease tracking
precipitation physics and natural hazards
we get roughly three hourly rainfall estimates
across much of the globe
at fairly high resolution
and these rainfall estimates
are used to monitor major rainfall events
and to look for events
that might lead to significant flooding
even landslides
and there are a number of groups
that have been using it
as sort of an early morning system
trips unforeseen
from has provided more robust information
on weather and climate patterns
that can only be seen after years of observations
this decade and a half of data lets scientists see
variations in rainfall from year to year
how a linear affects brain patterns worldwide
and the anatomy and life cycle
of major storms like hurricanes
it's also proven to be an extremely useful satellite
for understanding hurricanes
part because its orbit stays within the tropic
so you get much more frequent observations
and it's just provided a wealth of rainfall information
over its growth from a short time period
that in many ways
surpasses all the information we had prior to that
from giant storms to individual droplets
trim also provides scientists with data
on the precise physics of falling raindrops
trim has a unique set of instruments
including the first and only
precipitation radar in space
also has a microwave imagery which is
an instrument that can give you the equivalent of
like an x ray of a storm
whereas the radar is giving you more of a cat scan
of the storm
it provides extremely valuable information

on the structure of rainfall
structure of storms
which tells us something about
how the storm is responding to its environment
whether or not it might intensify or weaken
in the upcoming average
building on trim's success
will be the global precipitation measurement
or gpm mission
its two instruments are more advanced
and more sensitive versions of trim's microwave imager
and precipitation radar
gps orbit will also extend coverage beyond the tropics
and provide measurements
of light to heavy rain and snow
expanding trans legacy into the future
okay so just to clarify
in case you kind of got confused
at the start of that video
the trim satellite also has a
radar instrument onboard it
so it has a radar instrument
which is the active remote sensing
that's sending out microwaves
and measuring the backscatter of those microwaves
back to the sensor
and in the case of trim
they use bands
that interact really well with rainfall droplets
so that's how they're able to
get a lot of those rainfall measurements
and then it also has that microwave imager
which is that passive instrument
that's able to measure emittance
coming from the surface
traveling through clouds
out to the sensor
now often times
we maybe don't want a sea surface temperature
maybe we want a measurement of below the surface
and those are
primarily taken from mooring and drifter boys
we don't have a ton of

really any earth observation systems
that are designed to measure below surface temperature
so mooring boys are good for measuring time series
through the depths of the water column
mooring boys are essentially just boys
that are always anchored in the exact same spot
so it might look like this
or might look like this
where there's a subsurface float
or a surface float
but either way
these instruments can measure
at different points of depth below the surface
what the temperature is
and then most deeper ocean temperature data
are measured with drifter boys
drifter boys are just boys
that aren't anchored to anything
they drift around with the currents
and for really really
really really
really deep portions of the ocean
drifter boys make a lot more sense
because you don't have to have
a crazy long
chain like this
that's maybe swinging in all kinds of directions
and measuring different points
usually just have a drifter boy
that you set in a certain area
and have kind of a calculated estimate
of exactly where it's going to travel
and then you get really deep ocean
temperature measurements
from something like that
now we also often sometimes want to measure
sea or fresh water surface temperature
things like lake temperature
and we use very
very similar methods
for monitoring lake surface temperature
modus is still really frequently used
especially for something like

monitoring the great lakes
freshwater systems that are very very large
for smaller targets
again thinking back to the difference
of the characteristics
between some of the data sets that we're talking about
landsat is probably going to make a lot more sense
it's got that thirty meter spatial resolution
for much smaller lakes
it's going to make a lot more sense
and be much easier to use the landsat thermal bands
to go away and try and measure
things like lake surface temperature
ok just a brief kind of empirical example or comparison
of really efficient data collection of a satellite
versus kind of historical methods like boys
if you in the mid atlantic
have a passing satellite measuring
a sea surface temperature
then it might contain around
six hundred thousand pixels of data
and cover an area of about
two hundred and fifty thousand
or a quarter square miles
quarter million square miles
now in that same area
there's probably only about a dozen boys
and given the vast size and variability of the ocean
the applications of those boys become very
very limited
it's hard to use twelve point measurements
of sea surface temperature
over a quarter million square miles
to try and derive any kind of meaningful information
about sea surface temperature trends
on the other hand
a satellite that's passing over in seconds
maybe minutes
can collect data over that same large coverage
and a fraction of the time
very very little time
we still need boys
and things that are collecting point data today

to go away and validate our satellite measurements
but this is just an example
of the extreme level of data collection efficiency
that you can get with earth observation data
okay so that's sea surface measurements
we're going to talk next about sea level
so in general
i'll start off by just mentioning that we know that
sea level is rising primarily because of two factors
thermal expansion of water from increased temperatures
so as water warms up
which is just kind of going along with the
same trend that we see on the surface of land
we know that our air temperature is warming
because of climate change
global warming
at the same time
our oceans are also warming
for some of the same reasons
as our oceans warm
they expand a bit
as they expand
they kind of cover more area
so we see this rise in sea level
we also because of increased temperatures
see melting of land based ice
glaciers polar ice caps
things like that
areas where water was previously stored as solid ice
is now being stored as liquid water
so because of that
we're seeing also an increased sea level
and historically
the first satellites that we used to measure sea level
were to topex poseidon mission
and then the jason series of satellites
the jason series of satellites
were essentially just a continuation
of the topex poseidon mission satellites
so you can kind of think of these all together as one
large kind of mission of satellites
the topex poseidon was the first satellite
then there was the jason one

the jason two
and the jason three
all of these satellites were a joint mission
between the french space agency and nasa
and the topex poseidon mission
this first satellite here was the first time
scientists were able to map ocean topography
with a high level of accuracy
all across the world
all four of these satellites
the topex poseidon
the jason one
jason two and jason three
were all radar satellites
so they all used radar in order to measure topography
and thus derive measurements for sea level
all across the world
so that on the right there is just a visualization
of sea level change measurements
derived from topex poseidon
and adjacent series satellites
from when they were launched in nineteen ninety two
all the way to pretty much now in twenty twenty two
so nice data continuation
through each of these missions
and a really
really groundbreaking satellite mission
when it was first launched in nineteen ninety two
because it was able to measure sea level
to a high degree of accuracy
yeah how did you say it measured sea level again
so with the
essentially
with the ranging capabilities of
um of radar
so it was able to say okay
my satellite is here
how far away is the ocean from where i am
and then based off that
get a measure of overall for the whole world
what the sea level measurement is like
i can see why
because when i first started to

learn about this kind of stuff
it was a bit confusing
how can you actually get a measurement for
where sea level is above land
if you don't know where land is
essentially
and so the kind of
simple answer to that
there isn't one really
but the simple ish answer to that
is combination of a couple of different data sets
so these radar satellites
toe packs and the jason series satellites
they were kind of able to measure
a if something was water or land
and then b kind of the topography of that water
they related that then to
essentially
what's called a geode
which we talked about kind of way
at the start of the semester
and is this very advanced
complex mathematical approximation of the earth
essentially
the way that we actually estimated our geode
which is what we used then
as a reference for measurements like this
for measurements of sea level
was actually this satellite here
which is called the gray satellite
that stands for the gravity recovery
and climate experiment
so this was a satellite mission
that measures gravitational pull
across the surface of the earth
by measuring gravitational pull
we can measure the mass balance of the earth
and then derive a geode
which we would then go away
and take these radar measurements
ranging how far away water is from the satellite
relate that to
okay this is the shape of the earth that i have

and then based off that
try and estimate sea level yeah
exactly yeah exactly
similarly there's lots of different ways
and there's definitely lots of different data
combinations
that you can go away and derive that kind of thing from
but generally speaking
ocean depth was first very accurately measured
with the gray satellite here
by measuring mass balance
so it could estimate okay
where is there the most mass of land
where is there less massive land
assuming where there's more mass of land
those are things like mountains
where there's less mass of man
those are things like really deep ocean trenches
so
the gray satellite
was capable of measuring sea level itself
but then we went away and combined that with
these other radar satellites that we just talked about
to get even more accurate measurements
the sea level measurements we got from grace
weren't super accurate
but still were very
very useful
for the time that the gray satellite was launched
we could also get estimates of fresh water storage
land mass storage
and as i mentioned
it was the main tool used to calculate the geoid
which was a really
really valuable application for a long period of time
so this is a video that kind of goes over grace
and some of its applications
specific to
i think water
around the world
water is constantly moving
from two thousand two to two thousand sixteen
a pair of nasa satellites witness massive ships

in the freshwater stored on land
related to water management
climate change
and natural cycles
the gravity recovery and climate experiment
or race mission
use precise measurements
of the motions of two spacecraft in earth's orbit
to track the movement of water through the oceans
land and atmosphere
nasa scientists combined grace data
with satellite based
observations of precipitation and crop irrigation
climate model predictions
and other information in order to identify the causes
of regional trends in freshwater storage
in this visualization
blues indicate areas
with more stored freshwater than the average
and oranges and reds denote areas with less
the science team classified the major trends
observed by grace as driven by natural variability
human activity
or climate change
for instance
the steady decrease in freshwater storage in greenland
is caused by the melting of glaciers
which drain water into the oceans
in the western united states
a long drought reduced mountain snowpack
and river flows
causing heavy reliance on aquifers for crop irrigation
and severe depletion of freshwater resources
precipitation measurements together with grease data
show how natural variations in the weather
and unsustainable rates of water use
conspire to deflate groundwater in california
in southern africa
the okavango delta region experienced
a huge increase in stored freshwater
during the period of the grace mission
the science
team analyzed precipitation data for the area

and found that it was caused by a pronounced increase
in rainfall
between two thousand four and two thousand twelve
the region saw about fifteen percent more annual
rainfall than during the previous twenty five years
the rain ended a regional drought
and replenished water storage in the area
in northern saudi arabia
grace detected a dramatic
decrease in freshwater stored in aquifers
images taken by nasa's landsap program
show a rapid increasing irrigated cropland
supported by water pumped from those aquifers
most of that water is non renewable on human timescales
but in two thousand fourteen
the saudi government
ended a domestic wheat farming program
and grace data suggests that aquifer levels
may be stabilizing
in northwest china
grace revealed a rapid decrease in freshwater storage
without an obvious cause
scientists knew that mountain glaciers were melting
but the meltwater did not leave the region
so they looked for another explanation
as it turns out
much of the region's surface
water is redirected to agricultural areas
and the desert to the south
where in fat rates
leaving the region with a net loss of water
the original grace satellites
stock operating in two thousand seventeen
but nasa and the german research center for geosciences
are partnering to launch a new satellite pair
grace follow on in late spring
two thousand eighteen
to continue providing data about freshwater trends
around the world
so pretty different satellite
there than what we've been talking about
i'll briefly
i'm not gonna get too deep into it

just kind of a brief summary of how it works
but essentially it's two satellites
that are really close to each other in space
they're orbiting the earth
kind of right next to each other
and then the distance between them changes
depending on the gravitational pull between the earth
well between the satellites and the earth
and so they have a radar ranging system
that measures the distance between each of them
between the two satellites
and depending on if they're closer or further apart
they can relate that to the gravitational pull
that's underneath them
caused by how much mass there is on the earth
right below them
then they can relate that to things like mass storage
and then go away and derive that kind of information
that they were shown in that video
okay two examples that we're going to end on
that i think are kind of fun
kind of cool
one being observing coral reefs with landstat
and then the other being looking at salmon habitat
and freshwater systems with lidar
so coral reefs
just as an introduction
if you're not super familiar with them
they cover less than zero point zero
one percent
of the total surface of the earth
but are home to five percent of the global biota
so global biota just means
all of the world's plant and animal species
they're home to twenty five percent
of all marine species
so even though they're kind of a small pocket
of habitat in the oceans
they're home to a large breadth of biodiversity
and increased sea surface temperatures
among other causes
like pollutants and things like that
have led to increased coral bleaching

and bleaching just makes reefs really receptable
susceptible to stress and disease
and increases their possibility of death
so coral bleaching doesn't actually kill coral reefs
but it makes them really
really stressed
makes them very susceptible to dying
and lots of other diseases
coral reefs can bleach and potentially recover
some coral reefs can bleach
and then are just really susceptible
and potentially could die
so it's really important to monitor
in the case of reefs here
when they are at risk of bleaching
now landsat has emerged as a really key tool
for mapping and monitoring coral reefs
so there's a variety of reasons
why landsat is a really good use
or really good data set to apply
for mapping coral reefs
landsat eight in particular
and the key reasons are that a
we have that fine
moderate spatial resolution with landstat
that thirty meter pixel size
which is ideal for something like coral reefs
because coral reefs aren't particularly big
they're not particularly large targets
so we need something that has a pretty fine to moderate
spatial resolution
in order to go away and map and monitor them
we also have a nice long record through time
with the landsat series of satellites
so we can monitor
how coral reefs have changed through times
how trends of bleaching have changed through time
it's a free data set
anyone can download it
but most importantly
in particular
with landsat eight
one of the newer satellites in the landsat mission

and landsat nine
they have these newer spectral bands
that are really
really useful for monitoring coral reefs
and monitoring other features in the ocean
but they've been applied really
really nicely
for monitoring coral reefs
the key is the key band that they have is
lancet at eight and lancet at nine
have an extra band
in the visible blue part of the spectrum
so usually in lancethat
there is a red
green and blue band
in lancet at eight and lancet at nine
there's an additional blue band
so there's a red
green blue band
and then another blue band
that's kind of closer
to the ultraviolet portion of the spectrum
so it's a slightly smaller wavelength size
than the original blue band
and it turns out that that band is really
really useful
for oceanic purposes
and for monitoring things like coral reefs
these two satellites
in particular
lance at eight and lance at nine
have an extra level of sensitivity
related to something called radiometric resolution
which we don't actually talk about in this course
but for exam purposes
just knowing that lance had nine
are really useful
for monitoring coral reefs
because they have an extra level of sensitivity
is sufficient
they also have a better signal to noise ratio
which just means
essentially

that the quality of the data is really
really high
so for all those purposes
you can go away
and with something like lancet eight
get a really nice
clear image
of coral reefs
and be able to check
and monitor
if they are bleaching
and when they are bleaching
so this is just an example of a bunch of
not landsat derived data
in this case
much lower spatial resolution data
on a global scale
using ghost satellites
which are weather satellites
as well as a couple other satellites
designed by noah
to go away and monitor
on a global scale
at a very very tight
fine temporal scale
where we need to be worrying about
coral reefs bleaching
so just an example here
kind of going away a little bit
from the lancet at eight
lancet at nine example
but being able to use earth observation data
at a global scale
at a really fine temporal resolution
to monitor potentially
when coral reefs are at risk of bleaching
okay last example that i am going to talk about today
is mapping salmon habitat with lidar
this is something that's particularly new
and a kind of portion of research
that i'm decently familiar with
because too close colleagues of mine are really
we're really into this research

and are still very involved in this research
so first off
just salmon in general are a keystone species
if you aren't familiar with salmon ecology they are
typically a sign of greater ecosystem diversity
so generally when you have a healthy salmon population
you have a lot of
really high quality ecosystem diversity
they're really important in energy cycles
so they are part of what cycles
nitrogen and other important nutrients
from marine systems into forests
and terrestrial systems
they're also really important species for economies
because we eat a lot of them
and for sustenance for some communities as well
there are particularly vulnerable species
for several reasons
lots of stressors and threats out there
just to name a couple
climate change
lots of habitat degradation
because of industry and other things being built up
and historically
kind of untouched streams and freshwater systems
as well as pollutions
so just oil spills
things like that
that are spilling into these salmon habitats
now what's really cool about lidar
again that we've already talked about
is that we can get that three d information from lidar
so we can get information about forest structure
we can also get information about surface topography
and using that
we can map habitat units of salmon
which is really important
for understanding salmon behavior and abundance
so lidar allows for efficient data collection
and mapping
of things like riffles
pools cascades and glides
which we generally denote as

different habitat units of salmon
so a riffle is kind of something that
looks a little bit like this
where you'll see lots of bumps in the stream
of the water
a pool is kind of a very calm
very deep section of a stream
a cascade is where you'll see kind of
a waterfall type feature
and then a glide is similar to a riffle
but typically little bit deeper
where the water is flowing a little bit faster
but what we can do now is using something like lidar
we can in an automated fashion
go away and map out all of the different habitat units
in a given stream
now generally
historically
and i mean it's still done to this day
again to validate this data
and because some people don't have access to lidar data
but generally speaking
historically
if we wanted to map habitat units
of salmon in freshwater streams
we would have to go out there
and i've done it myself
i've gone out there
put on waiters
walk around the stream
and literally with you know
a piece of paper and a pen
kind of map out by hand
where each of these habitat units might be
i kind of draw like a depiction of the stream by hand
and be like okay
here there's a riffle
here there's a pool
here there's a cascade
so obviously not very efficient
takes a lot of time
very strenuous
not super safe

because you got to be walking through a stream
but what we can do with lidar data
is essentially collect that same kind of information
so lidar data
can use that terrain and structural information
to map salmon habitat units
with a really
really high accuracy
up to ninety six percent
so that accuracy would be related to that field data
that validation data
so if i went out and i mapped by hand
where all of these same in habitat units were
and then i did the same thing
but with lidar data
the lidar data would match it
at about a ninety six percent rate
so this is an example here
of the different kinds of data
we know we can derive from lidar
so normalized elevation here
that's essentially our digital elevation model
that's telling us what the terrain is like
of the stream
where kind of the steep parts are
where the less steep parts are
we got a measurement here of roughness
so based off the variation of the terrain
we can identify areas that are really
really rough
versus areas that are really smooth
we can also get things like canopy height
under store
understory cover
and in stream wood
these are all things derived more
from the structural information
that we get from lidar
so canopy height is essentially
how tall are the leaves
or how high above the ground
are the leaves on the trees
understory cover is

how much cover is there in the understory
the understory is just in the forest
the area below the canopy
so if you're looking at a forest
the canopy is kind of like the top layer
of all the branches and leaves
and their understory is kind of the bottom layer
of all the smaller plants
that's below the canopy
below the really big trees
and with lidar
we can get a sense of okay
how much understory cover is there
how much vegetation is there on the ground
and what's the height of a canopy
how high up are the leaves in the trees
we can also even derive things
like in stream wood
we can actually detect and measure
individual logs and pieces of wood
that are in the streams
and if we combine all of that information
the topography information
with the structural information
of the forest in that area
we can go away and predict
with some modeling techniques
where there's pools
where there's riffles
where there's glides
and where there's cascades
and that's what this map on the right is showing here
so it's just showing
for a couple of
different streams
this one's called elk creek
this one's called gray creek
this one's called headwater creek
the als which just stands for
airborne laser scanner
this means lidar derived habitat units
so the prediction from the lidar
of what kind of habitat unit we can see

and then comparing that to the field measurements
so people that went out there
and measured out manually
where each of those habitat units were
and you can see it's pretty similar
it's not too far off
the lidar from the field measurements here
so it's about a ninety six percent accuracy
in this example
this is something that's really new
so i think the citation there is
twenty twenty two
so something that's kind of newly been done
it's a really cool
new application of lidar
and an example of the really
really high resolution
three dimensional
information you can get from something like lidar
and applying it to
a really interesting example
of looking at salmon habitat units
and identifying where they are in a stream
okay so in summary
we talked about first
sea surface temperature
talked about how we can use motors
and the thermal infrared bands that are on board
motors to go away
and passively measure sea surface temperature
we then talked about the microwave sensor
that's on board the trim satellite
so it uses microwave bands to go away
and still passively measure the sea surface temperature
but it relates to the one millimeter depth
of sea surface temperature
as opposed to the top ten microns
like thermal infrared does
we then talked about a couple of new satellites
that we haven't mentioned before
that can be used to measure sea level
so we talked about topex and the poseidon
as well as the jason series of satellites

all radar satellites
and then the gray satellite
which measures gravitational pull
to be able to create something like a geoid
and then be able to derive information on sea level
and then lastly
we talked about habitat characteristics
we talked about using landsat to monitor coral reefs
and then lastly talked about using salmon
or using lidar
to monitor and measure salmon habitat units
now again you've seen this live before
nothing new
why is it useful for us to use earth observation
remote sensing data
to monitor all these different features
all these different metrics
that are throughout the oceans and fresh water
it's nothing different
from what we've already talked about
with the biosphere and with the cryosphere
we get standardized data
with something like modus
we are getting the exact same data set
there's no subjectivity to it
when we were thinking about the
salmon habitat units
for example
and you're imagining me out there
kind of manually measuring out
and drawing where all the habitat units are
that can be super
super subjective
different people might do that in very different ways
if we just fly lidar over the area
and we say okay
we're going to fly the exact same lidar instrument
with the exact same altitude
exact same plane
exact same ladder instrument
the data collection is standardized
it's going to be the exact same
so we can repeat those data collections

and get a nice standardized piece of data
rather than getting different people
to go out there in the field
and try and subjectively measure
and denote habitat units for salmon
we have efficient data collection
we know we can get really
really quick data collection all across the world
so really really good coverage as well
and then depending on the data sets we're talking about
we can get fine to moderate spatial resolution data
with something like landsat
super useful for maybe monitoring
sea surface temperature of much smaller lakes
or maybe monitoring coral reefs
we can get potentially very fine temporal
resolution data
which maybe would be really good for monitoring
something like daily sea surface temperature
and we know that we can get different kinds of spectral
information
really good example of that that we talked about today
is the measurement of
modus using the thermal infrared bands
versus the trim satellite using the microwave bands
so the different kinds of spectral information
that we can get from each of these different satellites
allows us to derive different kinds of information
so all really valuable data sets
really valuable examples
hopefully you're seeing a pattern by now
as i mentioned yesterday
same topics so applied in an exam
these are the things that i would want you to bring up
again just making sure that you're relating them
to the specific example that i'm giving
whether it might be relating to fresh water and oceans
or the cryosphere or the biosphere
or what we'll talk about in the future
like wildlife or the human footprint
okay got some example questions to go over
so i'll give
like i always do

a couple minutes for you to go over those
evan and leanna will be here in a couple minutes
so we will go over the answers to these
and maybe three four
five minutes
and then i will give it to evan to give his reminders
as usual and then
i will let liana give any tips that she wants to give
and you're welcome to ask her about the assignment
that's due this week
if you would like
if you want to come down and chat
before i go over these and ask questions or anything
you're welcome to
if you want to head out
you're also welcome to do that and
yeah that's pretty much it yeah
yeah yeah
i think i definitely seen some imagery
and some articles where they have
and they can um
i'm not sure of which satellites those are
off the top of my head
happy to to look into it for you and get back to you
but definitely something that i'm sure
cause the the
i've definitely seen some images in the news and stuff
of those those big patches of garbage in the oceans
i think they're pretty massive
i don't know off the top of my head to be honest
i haven't looked into it very very much before
but i'm happy to i'll check it out for you
i'll let you know yeah
okay guys we can go over these answers
and evan and leanna will be here in one second so
how was sea surface temperature measured historically
well how do we measure c surface temperature before
satellites still use it now but
boys boys yep exactly
and is that still used today
kind of just gave the answer
yes no
yes why is it still used today

what do we still need boys for
buoys boys depending on where you're from
yeah
exactly yeah
to validate our satellite measurements
to make sure that we have a level of accuracy
with our satellite measurements
we can check how true our satellite measurements are
so for validating satellite data
it's kind of the key term you'd want to use there
great awesome
so what is one advantage of using satellite data
to monitor sea surface temperature
when compared to historical methods
we just talked about
so boys what's one method or one advantage one reason
using satellite data to monitor sea surface temperature
specifically is advantageous when compared to
say using boys yeah
they can cover a lot more area
absolutely yep
covers a ton more area
one other kind of really
key point that we mention is the difference between
not just the coverage as a whole
the amount of area it covers
but the type of measurement it is
with boys we have point measurements
so you're only measuring one single point
with satellites we're measuring areas
so much larger regions of measurement
pretty similar to what you mentioned
but a little bit of a distinction there
both would be totally acceptable answers
what was the purpose of the topex
poseidon and jason series of satellites
why were they launched what did they do primarily yep
measure sea level rise
exactly you measure sea level as a whole
pretty much
yet what is a newer or useful satellite
that's really good for coral reef mapping
yeah yeah land set

which land set specifically
land set eight nine in particular
yeah exactly
and then lastly really straightforward
talked about it for like ten fifteen minutes
what is an example of freshwater habitat mapping
using lidar
yeah
mapping not the salmon themselves
yeah
kind of sort of
you want to be careful with that
i've had you know be be
be careful with your terminology around that
so the the lidar that we talked about is measuring
and kind of mapping out habitat units of the salmon
so it's kind of quantifying the habitat that the salmon
is in it's not necessarily saying
this is where the salmon are
and this is where they aren't
it's kind of helping to predict where they might be
but that's done by mapping out their habitat
and quantifying their habitat
does that make sense
not actually counting any salmon
no that's that's a
that's an important distinction
that i think a lot of people get mixed up
yeah yeah yeah
i can talk about it
and if i could count salmon with lidar
phd done that would be amazing
you can't do that anyway sorry
but yeah so you're quantifying the habitat essentially
i had someone recently also kind of do make a similar
or just not make that distinction as well
when i was talking to them
or when i was teaching about how you can use
satellites to monitor and quantify bear habitats
where they said oh
we can use landsat to see where bears are
and that's not in a way
it gets there

because you can use landsat to quantify habitat
to then be able to predict where they might be
but to know where they actually are
you need some sort of
actual movement data
so in the case of salmon
to know kind of where the salmon actually are
maybe you put tags on them or something like that
so you could actually see where they literally are
yeah that makes sense
yeah ok sweet
ok i will give it to evan
quick couple of announcements
do you have any signs ok
there's also bathy metric glider
and you can see alligators
which one bathy metric water
no sorry which slides
that's today right
bathy metric glider
yeah nicholas refuses to buy the bath metric water
so i can't do that
all right pretty short stuff for me today again
as always this week assignment four is due on thursday
diana is going to talk about that in a bit
next week assignment five will be due on thursday
sam grubanger is going to come in
next week and talk about that
no sorry next slide
the last office hours left for assignment four
which is with vienna
is on thursday
the it's due at two to three pm
other than that
last thing i want to remind you about
is to check over your midterm
and email me if you have any questions
comments or concerns
if you have it on your laptop
you can also come talk to me now
if you do email me please
include the question numbers you're concerned about
and some way for me to identify you in canvas

so your name that's in canvas
or your student number also
today is the last day that you should be doing this
after this time
it gets a bit more iffy on
whether or not we're going to do the grade changes
because we told you there's a two week we won't
we're not doing the grade changes after today
send me your emails
come say hello to me
that's it for me
leanne is gonna talk about the assignment
do you have any tips you want to announce to everyone
i have no tips
you guys are doing very well
but if you have questions
i will be here
okay awesome
thanks guys
have a good week
how do i stop this
i'm just sitting here
all right hi guys welcome
getting close to the end of the semester now
so welcome to the final grind
hopefully things aren't too stressful for you guys
if they are
then you're getting close to the end
so little bit of a light at the end of the tunnel
for this week
you should be working on assignment five
so that's due thursday
then it's a quick turnaround for assignment six
which is due next week on thursday as well sam
who is your ta for assignment five and assignment six
will be coming at the end of class today
to talk a little bit about assignment five
and just be available
if you have any questions about assignment five
and then he will also post assignment six
it's not published yet
so you can't see it on canvas yet
but he will do that tonight at some point

so he's just making a little bit of an intro video
to go along with assignment six
so he'll post that with the submission
with the assignment tonight at some point
so you can get started on it early if you'd like
and then you just have assignment seven after that
the next blog post
i believe is blog post five
is that correct
does anyone know
yeah so the next blog post is blog post five
which will be due in a couple of weeks
we're going to talk about that blog post in class
and i'll give you kind of
some more details and context for it in class
and then you can go away and do it after that
so it will be published
aka you'll be able to view it
as soon as we talk about it in class
which will be coming up in a couple weeks
i'll show you the schedule for the next couple weeks
and let you know when that will be
so assignment five this week
assignment six next week
assignment five
office hours are this week
so the four to five set of office hours
will have just happened for sam
and then he's got two wednesday sets of office hours
a thursday set of office hours
all for assignment five
so that is office hours and assignments for this week
today we are talking about monitoring wildlife
with earth observation
remote sensing
which is super fun for me
because that is kind of what i am a
at least the closest to an expert in
but quickly
before we get into that
just a schedule for the rest of the semester
today we're going to talk about wildlife
tomorrow we're going to talk about the human footprint

next week monday
tuesday we'll talk about environmental change
and then the future
which will focus mostly on drones
and then april third
which will be the week after that
we'll talk about canada from space
we'll talk about eco zones
and that's the lecture that i'll kind of introduce
the blog post
blog post five
that you'll be working on from that lecture
so it won't be posted until that day
so april third
at five p m
on the monday
we'll come in
i'll give a lecture about canada from space
and simultaneously
blog post five will be published
it's a quick turnaround
so it'll be due that thursday
so you only have about four or five days to do it
but it won't be posted till we
talk about it in lecture that day
and then the following day
tuesday april fourth
is our final exam review
that is our last day of class
so the week after that
the monday is a holiday
technically
the tuesday
is still class time
we're not gonna have class on the tuesday so take it
i should probably say you know
take it to study for the final exam
or do whatever you would like with it
take a break
get outside um
so that's our
that's our schedule for the end of the semester
any questions about that

ok sweet ok
so today we are going to talk about wildlife
and how we can monitor wildlife
with different earth observation technologies
so we're going to talk about what wildlife is
why it's important to monitor it
how we've monitored it
monitored it historically
again all very similar
format to our last couple of lectures
we'll talk about some remote sensing technologies
used to monitor wildlife
specifically how we can track animal movement
how we can quantify animal habitat
and then how we can combine animal movement data
and animal habitat data derived from satellites
to answer questions related to conservation
and wildlife management
so talk about what kinds of questions we can ask
what kinds of questions we can answer
and then we will focus on a grizzly bear example
because i study grizzly bears a lot
and grizzly bears are just fun and cool i think
so brief introduction
the term wildlife
just refers to any un domesticated animal species
so any animal that lives independently of people
so you know dogs cats
household pets
not considered under the umbrella of wildlife
but any un domesticated animal
typically includes mammals
birds fishes
amphibians reptiles
we have a really interesting
fun assemblage of wildlife here in canada
and here in british columbia
so we have beavers
bears caribou
eagles lynx
orcas a really
really interesting variety of wildlife to monitor
to conserve

to manage for
and make sure that they have enough sustainable habitat
so there's lots of reasons to go away
and monitor wildlife
one of them is ethical
there's an intrinsic value
and need for a lot of people to preserve wildlife
species for future generations
to be able to view and enjoy
so there's this intrinsic value in life
in other wildlife species
there's political reasons
that we have to conserve and monitor wildlife
oftentimes species that have
low population demographics
or are threatened or endangered are listed on
you know politically
in certain countries and certain jurisdictions
we in the province of bc
have a list of endangered and threatened species
in the country of canada
we have a list of endangered and threatened species
and there's also worldwide list as well
a lot of those lists come with political
thresholds and steps that have to be taken
by people working in those industries
in order to conserve habitat and conserve those species
so that's kind of the political aspect of it
sometimes we have to
because according to the law
if certain species are under certain lists
then we have to do a certain amount of work
to conserve their habitat
culturally some local communities have identities
that are intertwined in different wildlife species
or may hunt wildlife species for sustenance
and then lastly
there's oftentimes an ecological reason
to monitor wildlife
because different species can serve very key purposes
in ecosystem functions
beavers for example
is a really obvious one like that

they will build these big dams
and rivers and lakes
kind of alter the whole function of an ecosystem
and without that
versus with that
the ecosystem can function very very
very differently
so we'll talk about these kind of
as an example later
when we talk about grizzly bears as a specific example
but lots of different reasons to monitor wildlife
now the actual practice of monitoring wildlife
you know not just conserving them
but just going
out and collecting data to learn about them
allows us to track population trends
and identify threatened and endangered species
so by us going out and monitoring species
saying okay
how many are there
are they healthy populations
are they not
we can monitor their trends through time
and identify if there's threatened
or endangered species
the kind of semi recent addition of earth observation
remote sensing data
allows us to
again similar pattern
from what we've talked about in other lectures
allows us to efficiently collect data
on animal movement
and efficiently quantify animal habitat
and we do that to ultimately try to make inferences
on why species may be threatened
if we see that
a particular species is all of a sudden declining
then we can collect very efficiently
animal movement data
so we know where they are
and then try to relate that to remote sensing
derived animal habitat data
to understand why they're there

and by doing that
we can ultimately try to figure out
why their populations are maybe declining
so ultimately
in the kind of biggest picture
at the end of that process
we can go away
and make some sort of management decisions
change something about our policies
about our laws
about the way that we operate
in order to hopefully better conserve that species
and provide a better habitat for them
so that they can continue to thrive
okay so there's two key aspects to this
that we're going to talk about today
the first being tracking animal movement
the second being quantifying animal habitat
tracking animal movement
we're going to talk about the use of gps collars
gps tags so
gps collars are just collars that are put on a species
on an animal
tags are a very
very similar thing
but they are often used on birds
and we'll also talk about camera traps lastly
which are technically a remote sensing device
but don't really have a space element to them
then we'll talk about quantifying animal habitat
so we'll first talk about how do we track animals
how do we know where they are
and then we'll talk about quantifying animal habitat
so trying to figure out if animals are in forests
or are in wetlands
or are in urban areas
trying to figure out where they are
by describing their habitat
and we'll talk about the data
that we often used to do this
focusing mostly on landset as a specific example
so historically
before we add gps callers

before we had landstat data
how would we track animal movement
scientists would have generally go into the field
place themselves in some safe position
or use an aircraft maybe
and just quantify animal movement and behavior
for hours days or weeks
so this would look literally like me going out into say
this field here
full of bison or buffalo
whatever i'm studying
in this case
going out standing at a distance
that's maybe not too close to them
but close enough so that i can see them
and try and see what they're doing
and then just having a notepad
piece of paper and just writing down
okay that one over there is
yeah it is sleeping
yeah that one over there
it is eating grass yeah
okay that one over there
it's doing something else
looks like maybe it's taking a poop
i don't know
it's hanging out
but that's how it would look like
by hand just drawing down
what each of these individual animals were maybe doing
now obviously
that's not very efficient
highly susceptible to human error
the way that i classify
or maybe document
how a particular animal is behaving
could be very
very different from how someone else
maybe classifies how that animal is behaving
i could sit there and say okay
it looks like that animal is maybe being quite
aggressive right now
and then someone else might

sit there and look at the same animal and say yeah
that animal is just relaxing
they don't really care about anything
so highly highly susceptible to human error
lots of different people can quantify
animal movement manually very very
very differently
however these field expeditions were still important
they are still important today
because they provided the first data sets
on animal movement and animal behavior
we only have you know
similar to most remote sensing satellite derived data
we only have animal movement data from say
callers and camera traps
and tags maybe back to the nineties and eighties
when those technologies started to be developed
and implemented a lot in practice
and these field surveys also allowed
a quantification of behavior
something that's really hard to do today
with callers and with camera traps
so you could say by looking at a species
okay is it sleeping
is it moving
is it being vigilant
how scared does it look of potentially being eaten
or attacked by another predator
is it feeding
we have a really tough time nowadays
getting that kind of information from
say a caller
a gps caller tells us exactly where an animal is
maybe every thirty minutes
but it doesn't tell us whether that animal is sleeping
or moving or how vigilant it's being
or whether it's eating
we can sometimes try to infer that kind of information
based off of its movement patterns
but again it's not very reliable
so these kind of historical field surveys
still hold a lot of value
and sometimes are still used to this day

for particular applications
now in terms of using kind of more modern
remote sensing
earth observation technology
to track animals
there's two key approaches
a landgrangian approach
and a eulerian approach
so a landgrangian approach
uses an animal born tracking device
a eulerian approach
uses a predetermined frame of reference
so lingragen approach would include a gps collar
so something like this or gps tag
where the animal is essentially
wearing the tracking device
so there's the collar onboard our animal here
the eulerian approach
the predetermined frame of reference
might include visual surveys
so just like those historical surveys
that i just talked about
a predetermined frame of reference
just means you pick a particular viewpoint
you're always looking at that viewpoint
so all you can really say is
if there is an animal in front of you or not
so a visual survey is a really good example of that
you stand at a particular point
you look out at the landscape
and you're just looking at that one particular area
all you can see
is the animals that are within your viewpoint
you can't see any others
so that's a predetermined frame of reference
camera traps
also use a predetermined frame of reference
so these are often remotely triggered cameras
that are just mounted on trees
or something else
that's maybe out in the forest or on the landscape
and they can get really cool photos like this
generally at night and during the day

but again a camera is just mounted on a tree
looking at a particular frame of reference
and just telling you whether or not there's an animal
in front of that particular camera
whereas a collar
a landgrangian approach
is mounted on the animal
so it tells you exactly where that animal is
no matter where it is
so a languangian approach
will give you a data set that looks like this
if this circle here
is an animal
then you can track at a very fine scale
exactly where that animal is
all through space
in this example
in this eulerian approach
maybe using a camera trap
if these squares are cameras mounted on trees
and they're all looking downwards
all looking in this direction here
then essentially this camera will say okay yeah
there's an animal right here
i see an animal right in front of me
this camera will say there's no animal
this camera will say there's no animal
so the eulerian approach here
has a predetermined frame of reference
it's always looking at the exact same position
or exact same area
langrangine approach
can track the animal no matter where it is
there's pros and cons to each of these approaches
which we'll talk about in a moment
so with gps collars
we put gps collars
generally on a wide variety of species
i've mostly focused here on canadian and
british columbia
species that are important
and that are of value in terms of wildlife management
wolves moose

bears caribou deer
there's a wide wide
wide variety of species that we will put gps collars on
so a gps collar might look something like this
this is called a televit gps collar
this one in particular is used on grizzly bears
and they have an accuracy of about five to ten meters
depending on the terrain
so their accuracy
similar to any gps device
whether it's your phone or some fancy schmancy
gps device is gonna depend on potential obstructions
potential errors
that we've talked about a little bit in this course
so if you're in a deep
deep valley
or if a bear
in this case
is in a deep
deep valley
surrounded by a really
really dense forest
it's gonna have a much lower accuracy
if it's say
at a really high elevation
in an alpine meadow
on the side of a mountain
where it's really clear
it's gonna have probably quite a good accuracy
so the accuracy of the color
kind of depends
generally on the terrain
as well as some other errors
that could potentially influence it
today we can usually customize
how often we get locations from a caller
so for example
we might get a location
from a collar
mounted on a bear
once each day
once each hour
maybe once every thirty minutes

the finest you can see
generally is
most often at a thirty minute scale
if you really
really wanted to
you could get locations every five or ten minutes
now there's a bit of a trade off
between how often you get locations
and how long a caller might last
if you get locations say
every five minutes
every twenty minutes
every thirty minutes
the caller might only last a couple years
because the battery will die
if you're getting locations
maybe only once every hour
or a couple times a day
then the caller might last years and years and years
maybe even a decade or two
so it'll last a lot longer
because the battery will last a lot longer
ultimately the collars are removed
so they typically have a rot off feature
so that is on this one kind of
this portion of the collar here
and all that means is after a certain amount of time
after a couple years
that portion of the collar will literally rot
and just fall right off the animal oftentimes
there's sometimes an electronic mechanism instead
where after a specified amount of time
or after the battery on the collar dies
it just pops off
falls on the ground
tags are very
very similar to callers
they operate in the same way like any gnss gps system
but they're generally just a lighter weight version
so they can be attached via rings around bodies
or necks or sometimes the leg
so there's one that's attached to a leg
and then generally they work like this

where there's kind of a small string
that goes around the neck of the bird
and then it will often just sit on the back of the bird
like that but same as the caller
it uses gps
gns s technology
to just figure out exactly where the bird is
you can get transmissions or locations
every couple minutes if you really want
but generally once every hour
once every two hours
maybe once or twice a day
okay so couple advantages and disadvantages of callers
callers and tags generally give you really
really fine scale level movement data
so you can get potentially
a location of an individual animal every thirty minutes
it's remote data collection
which means that if you are a scientist
and you have callers out on a bunch of species
then you'll just be sitting at your computer
and every couple of days or every day
just remotely
the data will transmit from the satellites
down to your computer
you don't actually
ever have to go out and retrieve the data
disadvantages include that
gps collars only provide individual level movement
which just means that if i put a collar on an animal
i'm tracking that single animal
not tracking a population of animals
unless i happen to collar an entire population
which is generally not feasible
so typically you might call her in a single project
say with bears
maybe if you're lucky three four
five six bears
so you're taking a sample of the actual population
over a given area
in bc maybe there's a couple hundred bears
and you get to call her maybe three
four or five

so you have to hope that the ones that you call her
are representative
of the behavior of the whole population
which they may or may not be
yeah just out of curiosity
how do you like
put a collar on there
so generally it's
they are tranquilized from helicopters
so someone flies around in a helicopter
they tranquilize the bear
they go down
find the bear
they'll do a bunch of measurements
like the size of their teeth
the size of their neck
the size of their paws
things like that
then they'll put a collar on the bear
and then after about forty five
sixty ninety minutes
depending on how strong the anesthetic was
the bear will wake up walk away
because of that
because of that whole process
they're also really expensive callers in general
you have to pay someone to fly a helicopter
you have to pay someone to
who's legally allowed to tranquilize a bear
you have to pay someone who's legally allowed
to handle bears
there's lots and lots of laws and regulations
about that in canada
so it's not a very easy process
very expensive
the collar itself is expensive
the process of doing the collaring is expensive
but also they're frequently considered
even more expensive because of how often they fail
an individual gps collar is maybe
anywhere from two to three to six thousand dollars
and if it fails
if it just happens to stop working

then all of a sudden
all the money and resources you've put
into getting a pilot
into tranquilizing a bear
into putting a collar on it etc etc
all that money's gone to waste
if your collar just fails
which happens more than you would think it would
and then lastly
another disadvantage is that it is an invasive process
you do have to get right up close
and personal with a bear
generally the bear is asleep
but regardless
it is still an invasive process
so this is an example of a data set you might see
from a gps color project
this example is looking at wolf packs in the midwest
believe it's in minnesota
and again you can see here that really
really fine scale
level of movement data
you're getting locations here multiple times a day
and this is an example where they were really
clearly able to map out different wolf packs
so wolves are very territorial
and you can see here
this pack of wolves stayed in their territory
this pack of wolves stayed in their territory
so this project
which was called the voyager's wolf project
from minnesota
they were able to really
really accurately map out the different
territorial ranges of each of these wolf packs
but that's just an example of how
a gps collar data set might look like
you get essentially
a point in space that has a timed stamp on it
just related to whenever that
location was collected or measured
okay quick video here
showing an example of the use of callers

but outside of canada
outside of bc in africa
we can witness one of nature's grandest events
the migration of the wildebeest
we arise at the loite of lanes
near musk myan national park
these are the movements of twelve wildebeest
representing the thirty thousand wildebeest
in the lloyd herd
will these move the cross prefer
yeah it's an eight year old feeling
when the boys are heard
and curiously they often leave south early in november
at the start of the season
to travel through the setting yeti and tanzania
she has joined up with one million
though the dry season is just underway
this behavior teaches us about the value
of maintaining continuity of our school dress
to preserve the complex
and the one expatments of the rain
france and the northeast
okay the second kind of animal movement data collection
we're going to talk about
is from a tool called a camera trap
so a camera trap will often look just like this
there is a infrared sensor here
a digital camera
a flash array here
and then it's often just in this weatherproof case
and how it works essentially
is a camera trap will detect
something that is moving and warm
in front of the camera frame
so something
in this case
you know they're showing a wolf in this image here
if something that is warm
which would be detected by the infrared sensor here
and is moving in front of the frame
then it'll snap a picture of it
so if this wolf is outside of the frame of this camera
it's not going to take a picture

if it starts moving into the frame
it will take a picture
if it sits in the frame and it's completely motionless
it won't take any pictures
then if it moves again
it'll take another picture
so this is kind of the infrared sensor image
but generally you just get a normal rgb
kind of plain digital image looking something like this
of whatever point of reference the camera trap has
whatever area it's looking at
so it's remotely triggered by moving warm objects
in this case this camera trap here is mounted on a tree
and it's just looking at boom
this general area here
so anything that's warm and moving within that zone
will trigger the camera and it'll take a picture
so couple of advantages
and disadvantages of a camera trap versus a gps caller
one nice thing about it is it's non invasive
so you don't have to get up and close and personal
to a bear or any other wildlife species
you can just go out in the field
set up the camera on a tree
or some other kind of post type thing
and it just sits there and just takes pictures
it's cost effective
it's not super expensive
a camera trap is maybe three to four
to five to six hundred dollars per camera
maybe even cheaper than that
sometimes you can get as low as a hundred and eight
two hundred dollars
while a caller might be upwards of six thousand dollars
per caller plus all the resources needed to get a pilot
to get someone to tranquilize an animal etc
so much more cost effective
you do get a population level data sample
which means that rather than with collars
where you put a collar on one individual animal
then you're tracking that one individual animal
with camera traps
you're effectively

measuring or sampling the entire population
no matter which individual animal it is
if the animal moves in front of the camera
it'll take a picture of that animal
so in that sense
you get more of a population level data estimate
it's multi species
so no matter what the species is that's in front of it
it'll take a picture
that includes birds as well
so it'll take pictures of birds squirrels
hairs wolves deer
bears people
it's really nice way to also get an estimate
of the human use of an area
because they'll also always take images of people
and sometimes from camera traps
you can derive some behavior information
sometimes from a photo or a sequence of photos
you can say okay
that animal is feeding
or that animal is vigilant
because it looks like it's moving really
really fast
or that animal
maybe you can see it sleeping
or something like that
either way you can't get that kind of level of behavior
information ever
really with gps collars
unless you're trying to infer
based off how frequently something is moving around
whether it's resting or feeding or whatever it's doing
but it's possible to get
sometimes behavior information with camera traps
now disadvantages are you get a much coarser level
of movement data
say you put one collar on a bear for a summer
and you are collecting a location of that bear
at a pretty coarse level
maybe just one location of a bear a day
you're still guaranteed for say
three months

ninety locations of that individual bear
if you put on the other hand
say fifty or sixty cameras
out over an area that's five hundred kilometers squared
you maybe if you're lucky
will get two hundred or three hundred detections
of all of the bears in the entire area
so one caller potentially gives you
hundreds and hundreds and hundreds and hundreds
maybe thousands
of locations of an individual bear
whereas a camera trap might only give you
a couple locations
maybe a few hundred
if you're lucky
of all the bears that are living there
so much coarser level of information
also require manual data retrieval
you have to go out into the field
to the camera traps to get the memory cards
and bring them back to your computer
it's not like with satellites
where the information is just sent remotely
to a satellite then downloaded to your computer
camera traps also have the potential
to be affected by weather
so sometimes in the winters
especially in a place like canada
camera traps that are mounted on trees
are just fully covered by snow
so you can't get any data
in the winter
or sometimes in tropical areas
where flooding is really frequent
then the camera traps are just fully covered by water
the generally still be preserved
once the flooding goes down
it'll still take photos
not always but most of the time
they're pretty weatherproof like that
but you're not gonna be collecting data
when the whole area is covered with water
can't take any images of any species

that are walking by when it's flooded like that
other kind of plus fun thing about camera trap data
you do get lots of really fun images
so this is from an area in southwest pc
about twice as far north from vancouver as whistler is
so if you just drive straight north to whistler
then you drive another four hours or so
six hours four hours
this north from whistler
to an area called the south chilcoton mountains
that's where these images are from
so these are from the south chilcoton mountains
provincial park
we got some really really amazing imagery here
of this very curious grizzly bear
a couple of grizzly bears that were fighting
and then this one is this hair
sprinting away from this weasel
or other kind of weasel like species
so you can see these are taken right after one another
thirty one seconds
thirty nine seconds
this guy probably didn't make it
not gonna lie
but yeah some cool imagery
fun stuff to look at yeah
yeah
yeah totally
yeah so usually
it's associated with some sort of sampling design
typically it's a systematic design
where if you have an area of interest
then you'll systematically place one camera
at a specified distance from one another
so that they're kind of equally spread out
sometimes you might just randomly place them
sometimes you might
apply a stratified random sample where you say okay
i know there's these three kinds of habitats
that exist in this area of interest
so i'll put ten camera traps randomly
across each of the three habitat types that exist
so really depends

there's lots of different ways that you can do it
but it's definitely true that
you might put up a camera somewhere
and you might not get images of anything
which is you know
one of the downsides of using a camera trap
if you put a caller on something
you're gonna get location data no matter what
if you don't
if you put up only say
ten cameras
you might not get much
generally you typically in a camera trap project
wanna put up at least fifty or sixty cameras
but the more is always the better
most projects aim for seventy eighty
maybe even over a hundred cameras in say an area
and you ranging from anywhere from three hundred
four hundred kilometers squared
to a thousand plus kilometers squared
yeah that help answer yeah
do you have a question
for cold blooded animals
like do you have an example
like snakes yeah
something that wouldn't be warm
that wouldn't kind of be triggered by the
so generally
i mean in the case of canada and bc
we don't have a lot of species like that
at least not ones that were particularly
interested in studying
so we don't have that issue too much
i'm honestly not exactly sure
off the top of my head
my gut would say that just the motion trigger
itself would be enough
to to trigger the camera to take a photo
so even if it's not super warm
just the motion of it in front of the camera
would probably allow it to still snap a photo
we get a lot of
false triggers sometimes with camera traps

because we'll set it up in an area that's really windy
and even just the plants that are swaying
across the image will trigger it to take tons of photos
so it probably wouldn't be an issue
as my guess
yeah but yeah
good question
haven't thought about that before
any other questions yeah
take videos
yeah some of them can take
well yeah so the short answer is yes
some of them can take videos
generally there has to be quite a specific
niche reason to do that
because it's hard to know when exactly
to record a video for
you could in theory always be recording a video
but the sd card
the memory card is going to fill up really really
really quickly if you're constantly recording video
so typically
you know if you wanted to get say
a nice video of a species interacting
or doing something in front of the camera
you'd have to know that the species was gonna be there
so maybe you'd be kind of hidden
you know and camouflage
like waiting for a species to come
and then once you saw it
then like triggering the video to start
the kind of more common thing that you see
that's not really a video
is you'll see image sequences just stitched together
to kind of create a video
so if an animal is spending a lot of time
moving right in front of the camera
you might get a photo every second or every two seconds
so if you stitch that all together
it kind of looks close to a video
but not quite
and then the last thing that you'll often get sometimes
is the ability to get time lapse videos

so a lot of these cameras
even though they're motion triggered
they'll take a photo every single day
at the exact same time
say at noon
and then you can stitch all those together
and get a time lapse of that whole area
does that answer your question
any other questions
cool okay so up till now we talked about just
how we collect animal movement data
specifically with callers
specifically with camera traps
now how do we actually quantify an animal's habitat
we need to relate where they are
where the callers
or where the camera traps
tell us that animals are
to information about the environment
and about their habitat
to ultimately try to answer questions like
okay we know an animal is here
but based off that
what kind of habitat do they actually prefer
where are they most commonly located
and what do they avoid
what do they not really like to spend time around
and that ultimately allows us for management
to make decisions
like for example
well we know that
this particular species really likes this area
and that particular area
has a lot of hiking going on in the summer
but that has the potential
to displace those wildlife
to displace those animals
so let's maybe close that area down
for hiking for people in the summer
because we know it's an area
that this particular species
that we're concerned about really likes
so we can try and derive information

to allow us to make these management decisions
by asking these questions
like what kinds of habitat do animals prefer
and what kinds do they avoid
now ultimately
today we do that mostly with satellites
but we always talk about
in this course
what we did before satellites
so historically
we quantified habitat manually
you went out into the field
you went out to a site
that you knew an animal might spend a lot of time in
and you'd look around
and try and quantify the habitat
just manually
so you might
look at your gps collar data
for example
and say okay
it looks like
this animal is spending a ton of time
around this particular area
let's go survey that area
let's walk around
let's do some hiking
let's maybe fly and helicopter or plane over it
and try and take some notes down about it
is there lots of coniferous trees
is there lots of deciduous trees
is there lots of open space
are there lots of water sources
try and quantify some data related to
why that species may or may not like it there
with camera traps
very very similar
but a lot easier to pick an area
that you might want to go survey
you have all of your cameras
maybe set up all across a study area
you're getting a ton of photos
of one particular species

at a couple of cameras
or at one particular camera
so you can go right out
to exactly where that camera is located
and kind of just survey
look around
get a sense for what the terrain's like
what's the slope
what's the aspect
how many plants are there
what's the vegetation cover
like what kind of plants are there
are there a lot of food sources
are there roots and berries and plants
that a particular animal might really like to eat there
but you do that all manually
just by going out there
and just jotting down on a notebook what you see
sometimes you might do it
like i mentioned
from a plane or from a helicopter
and you'd literally have just someone
sitting in the plane or helicopter
with a piece of paper
where they're just manually mapping out
all the different types of habitats
that they can see on the ground
again subjective
not very efficient
so let's we're going to use then
to kind of wrap our heads around
these kind of questions we want to answer
and our ability to combine animal movement data
and satellite derived habitat data
we're going to look at an example
because i think it's fun
hopefully you do too
we'll see about grizzly bears
so let's say that you have gps collar data
so in this case
this is showing a bunch of gps collar data
from southeast bc
and kind of northwest ish usa

so all of these points here
all of these individual dots you can see on this map
represent a discrete location from an individual bear
so the different colors here
represent different individual grizzly bears
and each dot represents a location
where that gps collar found that bear to be
so let's say you have eighteen thousand
gps telemetry locations on thirteen grizzly bears
what do you actually do with this data
now you have all these points
you know where these bears are located in space
but how do you know what habitats they like
what they don't like
how can you make
some management decisions based off this data
that's where this
satellite habitat characterization comes in
so we still require fieldwork
generally to validate satellite data
so we'll still go out to much fewer sites
but still a couple of sites
to ensure that
what we're looking at from our satellite data is true
that it's actually accurate
but overall
we can with satellite data
efficiently
get very informative information about habitat
over pretty large areas
this i'm showing an example of
is from habitat characterization of rhinos
so not a canada bc example
but you can see here for the study area
we have information about land cover
so maybe that was derived from some passive
remote sensing system
like landsat or like modus
we have aspect here
we can derive that from a digital elevation model
which maybe was collected with a lidar instrument
or with a radar instrument
we have information about slope here

again derived from a digital elevation model
potentially from lidar or radar
we have information about precipitation here
maybe that was derived from
you know the thermal microwave imager
on the trim satellite that we talked about
when we talked about oceans in freshwater
we have forest cover here
how much forest is covering a particular area
maybe that was derived from land
saturn modus
so we have all of these different kinds
of satellite data
that we've talked about throughout this course
that now we can derive real information about
in the form of habitat characteristics
to try to understand
okay we know where an animal is located
is it located in areas that have high forest cover
or low forest cover
is it located close to human settlements
or far away from human settlements is it
are they found to be very close to roads
or do they like to avoid roads
do they never really come anywhere close to roads
we can get all of that from satellite data
so we've talked about in this course
where we've looked at this map a couple times
this is a landsat derived
thirty meter spatial resolution land cover map
all across canada
so we can take information from gps collars about bears
about wolves
about some species of interest
look across this land cover map
that's at a thirty meter spatial resolution
covering pretty much all of canada
and say okay
well do these species seem to prefer shrubbed areas
or wetland areas
or coniferous areas
or broadleaf areas
do they like to be located close to water

how do they feel about snow and rock
so all of this kind of information
we can get from combining that animal movement data
and that satellite derived
in this case
land cover or habitat data
we've also briefly talked about the ability of landsat
to quantify disturbances
so to tell us where forest fires are occurring
where forest harvest is occurring
where areas are being converted to agricultural land
again similarly
we can then
look at our animal movement data and say okay
are these species
ever located close to areas that are burned
or do they always stay in areas that have really dense
healthy forests
are they ever located close to agricultural areas
these are the kinds of questions we can try to answer
by combining these different data sets
so we're going to look at specifically
as i kind of mentioned already
a grizzly bear example
so grizzly bears
are often a focal point of wildlife conservation
particularly in western north america
for a variety of reasons
ethical reasons
their intrinsic value
political reasons
for a period of time
they were listed as a threatened or endangered species
in both alberta
british columbia and canada
they are still
kind of listed as an endangered species
in the states
there also have a lot of cultural value
to a lot of local communities
and oftentimes
they are considered an ecological keystone species
or an umbrella species

because they can
really influence how an ecosystem functions
and they're such a wide ranging species
they'll be found in so many different areas
that often time
if you are conserving or preserving
grizzly bear habitat
you're simultaneously just conserving and preserving
habitat for a bunch of different wildlife species
because grizzly bears
are found in such a wide variety of areas
so let's say we have gps collar data
from some grizzly bears
we want to take some land sat derived
habitat information about land cover
about disturbances
to try to answer some questions
so we know when and where fires have occurred
we know when and where logging has occurred
and we know when and where grizzly bears are located
so let's look at this example here
this is an example from carne et al
two thousand nineteen
so it's a publication that's pretty recent
a couple years ago
and they were interested in looking at
how grizzly bears in west central alberta
in this case
so this is just a map of alberta here
this is the study area that they looked at right here
outlined in red
they were interested in how bears might be responding
to logging and other disturbances
that were going on in west central alberta
we have here our top map showing location density
this is derived from our grizzly bear gps collar data
so the kind of yellower areas
represent high density areas
where lots and lots and lots of bears were found to be
according to the gps collar data
then we have these kind of bluer areas around here
these areas represent low density
so there were never really many grizzly bears

found to be in this area
in these kind of blue areas here
so we know where lots and lots of grizzly bears were
and we know that they were frequently located
in kind of these
you know yellowish areas here and here
and then we also know
at a thirty meter spatial resolution
where and when logging occurred
so that's the green
you can see there was quite a lot of logging
in this area here
we know where forest fires occurred
so that was the red here
and then we also have non stand replacing disturbances
which is just a general disturbance term
for when a forest isn't fully cut down
there's never a new forest stand regrowing
that's called a non standard placing disturbance
no need to worry about that too much
what they were most interested in is
how was this logging
and maybe these fires as well
affecting where grizzly bears were being located
how they were behaving
and what they found in
a lot of this research in west central alberta
was that bears were often
very commonly found in
or very near to
forestry cut blocks
when i say cut blocks
it's a forestry term
i'm referring to clear cuts
so clear cuts are generally the most common form
of harvesting forest or logging
in most of western north america
so when i say cut blocks
i just mean clear cuts
but bears were often found in cup blocks
more than other habitat that was available to them
so more than forested areas
that was only at certain times of the year

but at those certain times of the year
particularly in summer and fall
often times as well
bears were in this case
one point six times more likely
to be found in cup blocks
than any other habitat
and this at the time
so this study here is from two thousand four
but is looking at
using very similar data
and very similar methods
to what this map is showing here
and they both researchers had very
very similar outcomes
of their research
both of them essentially found
that grizzly bears
were really frequently located
in these forestry cut blocks
and at first
they were kind of perplexed by that
didn't really make a lot of sense
why would bears like clear cuts
why would they be located in clear cuts
the key reason
the key driver that they found
that bears were located in clear cuts or in cut blocks
was because of food availability
so grizzly bears are a species that are very
very strongly driven by food
so where there's available food
is generally where you'll find bears
bears especially in west central alberta
really really like berries
and what they found was there's a lot of food
a lot of berries
located in cup blocks
that are regrowing
so particularly clear cuts
or cup blocks
that were harvested
within the past seven to thirty years

so in the kind of stage of regrowth
where they've had enough time
to start regrowing vegetation
in the cup block
but there hasn't been so much time
that trees have fully grown
and kind of enclosed the canopy
so there's kind of cup blocks that look like this
they're very bushy
and because of that
they have lots of these kind of berries
that bears really
really like to eat
contrast that to maybe say a second growth forest
so forest that are maybe forty fifty
sixty seventy years old
and you get something that looks more like this
the canopy is kind of enclosed over top
you don't get a lot of vegetation growing on the ground
so generally you get less food availability for bears
so what about other disturbances then
why was it particularly cup blocks
why would you know
cup blocks be the habitat of choice for bears
sure they would like to get food
but there's got to be other habitat types
that are available for them
and for a long time
that was generally areas burned
so areas that were subject to wildfires
forest fires would burn areas
parcels of forest
and then those areas would kind of regrow
lots of berries
and vegetation would regrow in those burned forests
and give lots of food availability to bears
historically
in the past half decade or so
humans have gotten really
really good at suppressing fires
so at fighting wildfires
so the result has meant that there's kind of
this overall lack of natural forest openings

for grizzly bears
grizzly bears in general really
really like open areas
they like sub alpine meadows
they like cuplocks
they like burn forests
they like areas
where there's lots of openings in the forest
so where there's not really
really dense forest
because that's where they find berries
that's where they find a lot of the food
a lot of the vegetation that they like to eat
historically
especially in western north america
and bc in alberta
we have spent a lot of time and money and effort
fighting fires
because we need to protect human communities
and things like that
because of that
there is proportionally
less natural forest openings available
for grizzly bears
to try and go find food
than there may have been prior
to kind of excessive management of forest
like we see today
with lots of fires being fought
and with lots of forest harvesting going on
so what these authors
ultimately were able to conclude
was that it appeared though
as though bears were adapting
to utilize cup blocks
as kind of a surrogate
or a replacement
for natural forest openings
like burn forests
less of those habitats are available now
and more of these cup blocks are becoming available
because there's a lot of forest harvesting going on
there's a lot of logging

there's a lot of active forest management
so because that's what's available
and because there's a lot of food located there
bears are hypothesized to be using those habitats
much more than adjacent habitats
so again if we go back to this
we can kind of see that
we have our study area again
here in red
we got our location
density of bears
kind of very high right here
we see a ton of harvest there
lots of forest harvest
again kind of
right in here
which is right kind of
in this area here
lots of forest harvest in there as well
we got a little bit of wildfires going on here and here
and we do see some bears out in that way
but generally speaking
a lot of the areas that they were finding bears in
was where there was a lot of forest harvest going on
and again we are able to derive all of that information
using the combination of that gps collar data
with this derived
land cover and disturbance information
from the thirty meter spatial resolution
landsat data
now that's really important
and really nice for a species like grizzly bears
when we're trying to manage them
and we're trying to conserve their habitat
because from that information
we can make really valuable management decisions
we can say for example
in the forestry industry
let's try to harvest forest
where there is a lack of natural forest openings
we've identified an area where maybe
there hasn't been a wildfire in a really long time
all there is

is a bunch of really dense second growth forest
maybe it would be useful
for us to harvest some forest in that area
to produce a forest opening
anthropogenic
in this case
not natural
but nevertheless the forest opening
where bears can maybe go find some more food
maybe also we need to protect disturbed areas better
maybe we can identify cut blocks or clear cuts
that bears might really
really like
and say okay
we're not gonna really allow much access
for humans in those areas
because we want to leave them aside
as kind of a bear habitat
now the one thing i'll say before i summarize this is
don't take this too out of context
in the sense that
please don't go tell anyone that chris told you today
that cutting down trees is good for bears
that's not exactly what i mean
the context of all this is that today
nowadays a lot of forest
especially in western north america
is managed for timber production
and there's a lot of wildfire fighting that goes on
so given that context
that's where these findings kind of come from
in reality if you had a completely natural forest
that had no kind of
you know at least
no real human interaction
in the sense of the kind of more western
and modern type of management that we do today
then this wouldn't really necessarily be the case
you know that there's a good chance that
cup blocks would not be a preferable area for bears
but because we have this
historical fire suppression that we've seen
and this lack of natural forest openings

then we've come up with this hypothesis
and this phenomenon where we see bears potentially
using cut blocks and clear cuts
as a circuit for naturally open areas in a forest
does that kind of make sense
okay don't tell anyone chris told you
that cutting down trees is good for bears
it's not true
it's not what i mean
okay so just in summary
we talked about tracking animal movement
in a couple different ways
with gps collars
with gps tags
and with camera traps
talked about how we can quantify animal habitat
with satellite data
looking at land cover information
so we looked at that big map of all of canada
that has at a thirty meter spatial resolution
information about where there's coniferous forests
and where there is deciduous forest
and where there's wetlands
and where there's herbs and shrubs and things like that
and then we can also get that disturbance information
we can get that again
landsat derived disturbance information
telling us where there's logging that's occurred
where there's been forest fires etc
and we can combine all that data to go away
and try and answer questions
to help us inform our management decisions
so a couple of review questions for you guys here
a couple of practice questions
i'll leave you to try to answer them yourself
and then i will go over them with you
in a couple of minutes
and then i'm gonna give it to sam
i think he's got maybe one slide to show
to give you a couple tips
for the assignment that you're working on this week
if you have questions for him after that
you're welcome to come down and chat with him

so if you're going to head out now
please do so
and do so swiftly
and then we will go over these in a couple minutes
then i'll give it to sam
thanks guys
hey how's it going
this you can just like hold it as a mic
i just like do a voice recording
boxers got hosted
okay guys let's do a quick
let's do a quick crowd source here
and then i will hand it over to sam
so from what we talked about today
what are some advantages of using camera traps
to collect animal movement data
we talked about a couple
let's do maybe two yeah
exactly cost effective provides population level data
what about some advantages of using a caller
a gps caller to collect animal movement data
yep
fine scale movement data
totally fine scale movement data
and remote data collection
you don't actually have to go out into the field
to collect the data
and you get really
really fine scale level movement data
maybe up to every thirty minutes
if you really like
okay so bit of a longer question here
a longer answer to this next question
describe how you might use gps caller data
and landsat derived data or information
to determine what habitat an animal prefers or avoids
for that case
feel free to use the grizzly bear example
to help explain
you don't have to
i feel like it's probably the easiest
cause we just kinda went over it in detail
but maybe in a couple sentences

can someone kind of explain to me
just kind of theoretically how that works
how you can combine gps
collar data and landset data to try and understand
what kind of habitat an animal prefers
yeah well like
gps data will tell you where the animal is
and the landset data will tell you
what kind of environment that area is
you could say
for example
the grizzly bear prefers this area
because this area has environmental factors
that help the grizzly bear thrive
because it you know
recently burned down and has berries or something
totally yeah
like specifically
what we talked about with the landsat
specifically what kind
what are some examples
of the habitat information that we got from landsat
you mentioned one of them already just now
right just like
i forgot what the term for is
like a disturbance
is that what you're thinking of
yeah yeah so
disturbances
get things like disturbances
so just to reiterate his answer there
with the caller data
we can determine where animals are located
then with the landsta data
we can quantify the habitat
we can say okay
this is where coniferous forces
this is where deciduous forces
this is where wetland is
then we can also quantify disturbances
how the land is changing
we can say okay
this is where logging is occurring

this is where wildfires are occurring etc
we overlay those two informations
and we have
okay we know where our animals are
we know where the habitats are located
are animals close to these kinds of forests
are they close to wetlands
are they close to herbed areas
are they close to these disturbances
are they close to
harvested areas
logged areas
are they close to wildfires
okay great great answer
okay lastly
specifically
with the examples i gave about grizzly bears
what insights have we gained
about grizzly bear habitat preference
using caller data
and landstat data in west central alberta
well it was kind of the final outcome
of the research that i was talking about just there
what were they able to kind of determine yeah
yeah exactly
specifically
they prefer open areas such as cup locks
specifically it was
they determined
they found out that there's potentially this phenomenon
where grizzly bears are substituting cut blocks
kind of an anthropogenic or human created open forest
four natural open forests
like burned areas
or areas that may have disturbed in other ways
such as avalanches and things like that
so they were able to determine that cut blocks
or clear cuts were being used kind of as a surrogate or
replacement for some of these natural forest openings
great awesome
okay i'm going to give it to sam here
he had a couple of slides he just wants to go over
and then you're welcome to come ask him if you have

any questions after that
so i got the one image
the second image
and then both of them side by side here okay cool
before we talk about that
we have some updates about assignment five on canvas
there was a mistake
question seventeen
refers back to questions fifteen and sixteen
on the version that went up
it said questions sixteen and seventeen
so that should be fifteen and sixteen
i've changed it now
but i think that those of you who started
the quiz already are not gonna see the change
but just know that if your version says
sixteen and seventeen
the sixteen should be fifteen
the seventeen should be sixteen
i've made no changes except swapping those numbers
if you're confused
you can message me
and you know
if you get it wrong before you're confused
we can work it out
so don't stress over
that is my mistake
if you're wondering exactly what that difference is
what the kind of mistake is that sam fixed
he just sent an announcement about it on canvas
so it's right on canvas
an announcement
see very clearly
just lined out
this number actually means this number
and then one more thing
i did have a few questions about question eighteen
it's just where it falls in the assignment
it's unclear if it's referring to the pixel
numbers from the previous few questions
or the image is referring to this image
the image that you're given in the document
so that's what question eighteen is about um

yeah again if you're confused
you can reach out but
it's not to trick you
it's just how the document is laid out
and then yeah
i've gotten a few questions about like oh it says
it says that my image should be purple and green
now that's great
says that my image should be purple and green
but it looks more red and blue to me
or something like that
right and these are real images
that have changed in real time
so it's not always going to look like it looked when
we wrote the lab
because a new landslide image has come out
this lab that question was written in the fall maybe
so just as an example
here are two images of exactly the same place
mount saint helens
which you'll be talking about
one is from october
one is from a few weeks ago
and with that composite that it asks you to use
that exploits the shortwave
infrared and the thermal bands
you're going to see some big changes in color because
there's snow in the winter
there wasn't in october
and then there's a lot of changes
that have to do with water
that have to do with temperature
that have to do with
with snowpack and with snow melt
and those longer waves of landsat
are sensitive to those changes
really sensitive
if it doesn't look quite as it does in the image
in the text don't sweat because it's a new image
it's dynamic
and then the other thing is these images are stretched
so just keep that in mind as you zoom in and out
there's going to be some changes

and that's just the way that
that's just a way
that the website is displaying those images
it's not that the numbers have changed
it's just has a built in
stretch that optimizes the image to make it very clear
what the differences are based on what's in that image
so you know
don't worry too much about the details of that
just big picture
look at differences
interpret the image
this lab is all about interpreting the image
and interpreting differences among images
yeah and again
reach out if you're confused
but none of this is a trick question to trip you up
because oh it was purple and you said green
you know there are no questions like that
okay awesome
thanks guys
feel free to come down if you got any questions for sam
about the assignment
all right hi everyone
welcome to class
today we have
just a couple another weeks of lectures to get through
so we got human footprint today
and then we got next week environmental change and
one other lecture i'm forgetting for some reason
but we got two lectures next week
still going over class content
then the following week
we have a canada from space lecture
which will be a very short lecture related to
one of your last blog posts
so blog post five won't be available until that lecture
which will be our second last day of class
so monday two weeks from now essentially
and in class we're going to go over a couple things
that you'll then use to go and do blog post five
so we'll go over that when we get to it
and then in terms of class today

we'll do the human footprint lecture
end of class
sam had an appointment
so he's not going to be here at the end of class
but if you have questions about assignment five
evan will be here
and i'll be here
so we'll leave some time at the end of class
if you need to ask us any questions about that
and then also at the end of class today
after i go over this lecture
evan's going to be here
and talk about the final exam as well
so he'll talk about final exam format
practice questions that will post timing etc
so if you have any questions about that
you are welcome to ask
any that will sound good
good to go see
ok so today we are talking about
observing the human footprint from space
again similar format to what we've done our past
four or five or so lectures
talking about what the human footprint is
why it's important to monitor it
how we've monitored it historically
what are some of the remote sensing technologies
that we use today to monitor it
and then use some specific applications and examples
to kind of further explain and dive deeper
into monitoring the human footprint
particularly towards the end of the class
when we're talking about
specific applications and examples
associated with a particular
earth observation remote sensing data set
we are going to focus on night lights
so data of the earth
earth observation satellite imagery
that is collected at night
and is related to how much
essentially
light pollution there is

across the surface of the earth
it's kind of a fun
cool topic to add on
so we'll get to that in a moment
first off what is
the human footprint
i'm sure it's a term that probably you have heard
tossed around a little bit
and maybe some readings
maybe just chatting with people
conversations you might have had
there's lots of different ways that we can describe
what is termed as the human footprint
so sometimes it's considered just the geographic extent
of land that's under human use
so how large of an area of the surface of the earth
has some influence by humans
sometimes it's just considered a measure
of how much we are using the earth's natural resources
sometimes and generally more
so it's just some sort of metric
that allows us to calculate human pressure
on the earth
and on the earth's resources
but that's kind of three very different definitions
so let's keep that in mind
we'll get back to that in a moment
but not a particularly
clear definition of exactly what the human footprint is
and that's part of the reason that
earth observation data is really valuable
for monitoring and measuring
something like the human footprint
again we'll loop back to that in a second
so there's lots of different ways that we can try
and quantify
or measure the human footprint
so can be sometimes assessed by just the size
of a population
how many people do we have on the earth
can be assessed by the amount of human settlements
how many cities and towns and villages do we have
all across the earth

maybe we can assess it using the degree
of resource extraction
how much forest have we cut down
all across the earth
how much oil or gas
have we mined or extracted
we can also maybe look at other metrics
like the number of products people consume
or the number of cars being driven
and how much they're being driven
how often they're being driven
so there's lots and lots and lots
and lots and lots of different ways
that we can try to measure
how much pressure
we as humans
are putting on the earth
there's lots of different ways to do it
and it's important to monitor
it's important to measure
because it essentially allows us to assess
our impact on the world
both environmentally
economically socially
when we think of the human footprint
usually we think of our environmental impact
and ultimately
that allows us to make decisions on resource management
on land use planning
on urban planning
how can we plan our cities
our settlements our towns
to ensure that we don't have as much
of a human footprint
as maybe we could if we planned it in a different way
or a different manner
so this allows us to create conservation focuses
it allows us to monitor how we're performing
and essentially monitor what our impact on the earth is
now one of the common ways that we might describe
the human footprint
one of the ways that i mentioned earlier
is by trying to quantify how much urban areas there are

all across the surface of the earth
so i wanted to start by looking at this
and i'm going to try and get you guys
to help me out here
if we want to look at some of these images
and consider from a satellite's perspective
how we could classify these images as either urban
or not urban
and then furthermore
as either contributing to the human footprint
or not contributing to the human footprint
so let's start kind of in the bottom left here
this one's pretty easy
would you call this one in the bottom left here
would you call that area an urban area
nods i'm going to lost some nods yeah probably
what about this one just to the right here
would you consider that an urban area
some nod semi yeah maybe maybe not
kind of suburban
a little bit harder to tell on that one
what about say this area as a whole here
would you consider that an urban area
no i see some head shaking some heads nodding
we do have some really high density
you know housing going on here
so depending on what we consider to be an urban area
you know maybe a bare minimum
this could be an urban area maybe
this one not so much
because there aren't as many buildings there
okay fair enough
what about this one in the top right here
consider that an urban area
yeah some nods maybe so
so and in the bottom right here
urban area no
probably not okay fair
so now what if we considered each of those images
from the perspective of a human footprint
so for example we start in the bottom left here
we said yep
that's definitely an urban area

is that area contributing to the human footprint yes
obviously it's a super super urbanized area
it's definitely contributing lots
to our human footprint
what about this kind of suburban area here
yes contributing to our human footprint
but a little bit
less clear whether that's urban or not urban
what about this one up here
would you say it's contributing to the human footprint
maybe a couple of nods sort of
what about this
just this particular area
we said that maybe this area isn't urban
would that still be an area that you consider
as contributing to the human footprint
yeah i have some nods
you could argue it is for sure
it's still a vegetated area but it's farmed
it's under a use by humans
and then what about
let's end on this one right here
we said that that one's definitely not an urban area
would you say that this area is contributing
to a human footprint
couple of nods
yeah you could again
argue it is
maybe not so much in kind of this forested
kind of preserved area in the back here
but the farmlands sure
and the areas where there's houses
and other buildings related to the farm
sure probably
the point is
from looking at all of this
it's hard to necessarily classify
an area as urban or not urban
and subsequently
it's also really hard to classify an area
as contributing to the human footprint
or not contributing to the human footprint
and just because you classify something as urban

or as not urban
does not necessarily mean that it is
or is not contributing to the human footprint
so all this makes trying to measure and monitor
the human footprint a little bit more complicated
so the definition of the human footprint
is really hard to quantify and to define
what is an urban area
is it just an area with lots of buildings
is it a residential area
is it you know
at what point transitioning from say
an urban to a rural area do we draw that line
it's hard to say
when you're just looking at images like this
this and this
sure this is definitely urban
but this one maybe is urban
probably still
this one definitely
maybe urban over here
probably not over here
but there's still lots of humans
in this area as a whole
so maybe you could consider it urban still
the point is
it's just really hard to classify and identify
the really nice part about earth observation
remote sensing it
is that it allows us to standardize those measurements
allows us to look at an area on a pixel by pixel basis
and according to some metric that we define
typically related to the spectral properties
of the reflectance of the surface of that area
we can define areas discreetly
as urban or not urban
as contributing to the human footprint
or not contributing to the human footprint
that doesn't necessarily
that mean that
however we are defining an urban area
or defining an
area that contributes to the human footprint

is appropriate
we still have to deal with this issue
of not really having a clear definition
of what an urban area is
or what the human footprint is
but it allows us at least to define a methodology
that we might use to identify urban areas
to try and quantify the human footprint
and then repeat that process
over different areas across the surface of the earth
so you're using the same
standardized metric and measurement
to try and derive a measurement of urban areas
of the human footprint
now there's lots of other reasons
why the human footprint is particularly
difficult to quantify and measure
if i ask you on an exam
i'll probably focus on
it not having a very clear definition
so if you see me ask you something on the exam
along the lines of
why is the standardized nature of earth observation
remote sensing
particularly useful for quantifying the human footprint
well there are these other reasons like
the human footprint is different at multiple scales
it's constantly changing
it's hard to find detailed data with global coverage
but the most important one
the most valuable reason there is for earth observation
monitoring and measuring the human footprint
is this last one here that is
the human footprint has a really uncertain definition
there's no clear and universally accepted definition
and so earth observation remote sensing data at least
allows us to measure it in some standardized way
that we can repeat
all across different parts of the world
now similar to all of our kind of most recent lectures
before we had earth observation data
before we had satellite data
or at least space based earth observation data

we often quantified say
urbanization
which was a common metric
to relate to the human footprint
with aerial imagery
and aerial imagery of urban areas
and expanding urban areas
so aerial imagery provides the longest available record
of landscape change
that we have available to us
typically going back about a hundred years or so
and it's really useful for comparing
to more recent satellite imagery
because it gives you a little bit
of the history of an area
prior to say
the seventies and eighties
when we know the landsat mission
and other earth observations
satellite missions started being launched
so aerial photos were the first form of remote sensing
remote sensing just being any kind of measurement
where you have a sensor
that is measuring the properties of something
that are not in the immediate vicinity of that sensor
so a camera
in that case
a satellite
is measuring things
that are kind of maybe kilometers or meters away
so that's just what remote sensing is as a whole
aerial photography was the first form of remote sensing
so during world war i
aerial photography was used for reconnaissance missions
and then after the war
canada had a large surplus
of planes and camera equipment
given to them by britain for military purposes
so they started using aerial photography
for more civilian applications
we started flying planes across the country
across different landscapes
to look for forest fire detection

to look and monitor fisheries
to try and map urban areas
and start trying to quantify things like urbanization
so typically historical aerial imagery is panchromatic
which just means it's black and white
it generally just has one broad spectral band
so if we think back to our spectral resolutions lecture
aerial imagery generally it's panchromatic
just has one broad band
usually spanning the entire width
of the visible part of the electromagnetic spectrum
it's generally quite a high spatial resolution
because the plane was probably not flying at
an altitude as high as satellites are orbiting at
so the plane's flying a lot lower than satellites
because of that
we generally get a higher spatial resolution
say around one meter
we can get vertical or oblique imagery from this
historical aerial imagery
i'll show some examples of the two of those in a moment
vertical just means looking straight down
oblique means kind of looking at an angle to the side
now downsides
individual photos from aerial imagery
had quite limited spatial coverage
which meant they needed to be mosaic
so generally you'd get a bunch of images
overlapping a particular area
you'd have them on prints pieces of paper essentially
and you'd have to toss them up on the wall
and kind of pin them all together like this
to make a mosaic of a whole region
and the spatial and temporal coverage
of aerial imagery projects
generally depended on the needs of the project
so if you were looking at forest fires
or maybe deforestation or forestry
you might have a spatial and temporal coverage
specific to those project needs
so specific to monitoring deforestation
in the thirties or in the forties for a particular area
so this is just an example of some historical

vertical imagery
some imagery that's just looking straight down
taken from a plane
compared to some newer
high resolution satellite imagery
on the right here
so these are two aerial images
and again this is just an example
of being able to look back through time
compare to newer satellite imagery
and make out differences in the landscape
in this case an urban area
you can see kind of the big thing that was changed here
there used to be a big kind of train station here
and that was changed into kind of
more of a mall and fitness center here
you can see also the difference
in the density of cars
the amount of cars being driven on the road
you can see lots more little specks of cars here
than you can see in the older image here
from the twenties
but just an example of some vertical imagery
looking at the change of an urban area through time
this is another example
looking at kind of less large scale
so zooming out a little bit
looking at kind of the urban
rural transformation of a particular area
so less of a transition from maybe an industrial
kind of place
to more of a residential kind of modern place
and something here where we have
the edge of residential areas and then farmland
slowly being converted
in this case over almost a hundred years
to more suburban residential areas
now those two examples kind of focus more on
residential areas
urban areas per se
we can also look at historical imagery
from aerial imagery
and look at landscape changes

so natural environment changes
in this case
we can see here there was a reservoir that was created
after a dam was placed and flooded this whole area
so this is what that landscape looks like
prior to that dam being put in
prior to the creation of that reservoir
which you can now see here
this one's from alberta
okay and then the last one that i'll show
an example of an oblique image
so being able to kind of look to the side a bit
which is really nice sometimes
because you can get different features
and different characteristics of the imagery
than you might get if you're looking straight down
in particular for urban areas
you get a really good sense of the skyline
so a sense of how many buildings there were
and how tall those buildings were
so you can see here
in comparison
we got our stanley park on the left
here in vancouver downtown
lots of skyscrapers
lots of big buildings
and then in comparison
much older from the nineteen twenties
much less buildings
no bridge built yet over here
a lot of change that you can observe here
and again this is just an example
of taking some historical aerial imagery
being able to
in this case
compare it to some more modern aerial imagery
now we kind of know
from talking about it a little bit in class
that you can take these true and false color composites
that you guys have worked with
a couple times in the assignments
and you can look at images
of the same place through time

to track changes in those areas
one of the things that we can look at now
is urbanization
but again we know
from talking about the landsap mission
that that only allows us to go back
as far as the seventies and eighties
so prior to that
if we wanted to try and
monitor something like urbanization
to consider how the human footprint might be changing
we have to incorporate some sort of
historical aerial imagery
but seventies up until the present
we can mostly use satellite imagery
and we can look at images through time
to try and quantify and depict the human footprint
by in this case
looking at things like urbanization
however with traditional
kind of classic satellite
imagery we'll generally get of an urban area
something that looks like this
and you can see here in this urban area
this is definitely an urban area
this is in warsaw
there's lots of different features
lots of different characteristics
of the surface of the earth
for this particular urban area
you can see we have
you know water features
we got a river there
we got some parks
so we got some green areas here
even the buildings themselves
we have here a stadium that's really
really bright white
we have another kind of neighborhood over here
where we see colors
more along the lines of kind of grays
we then have an area up here
a historical portion of the town

where there's lots of red buildings
and actually even kind of bright green buildings
that you can barely see there and there
what this is an example of
is the large amount of diversity of color
and thus of spectral properties
that you might see across an urban area
that makes it really
really hard to classify an area as urban
when you're looking at imagery of a place
during the day
using this kind of traditional
classic looking imagery
it's hard to tell a computer algorithm
or even to just make out with your eyes
well okay this is urban
but it's red and green
and this is urban
but it's kind of grayish
and this is urban
but it's really bright white
it's hard to be able to try and quantify
say the human footprint
by looking at something like urbanization
with an image like this
because we have so many different characteristics
so many different colors and spectral properties
all across this particular area
so that is where this data set
called a night lights data set comes in
and that's kind of what we're talking about
for most of the rest of the class today
so i got a quick
kind of intro video about night lights data sets
before i kind of launch off on it
in daylight our big blue marble is all land
oceans and clouds
but the night is electric
seen from space our planet comes alive with water
on the other side
and she can be be someone
aboard the satellite
a new design instrument called beers

is able to collect what time to say
is a remarkably detailed view of the earth at night
in some places
city lights
resemble the solitary stars in the night star
from other places dense clusters of galas
the satellite can even distinguish widely lit boats
that line egypt's now river
and the massive flame from gas waves
produces a byproduct of oil and gas absorption
in the release
as the satellite passes
over the darkness of the himalayas
it shows how human settlement
is bound by natural borders
even political borders are starkly visible
in this view of north and south korea
and in a line of fishing boats
that dot the yellow city
but not all white is electric
glowing just as bright
flaming wildfires burned across australia
this new view of the earth at night
offers a unique perspective
for exploring many places in which we live
and seeing the impact
of human populations around the world
no matter how faint or how bright their bodies shine
okay so we're going to talk about a couple of
nightlights datasets
the first one
or the first satellite mission
being the operational line scan system or ols
on board the defense meteorological satellite program
so it's often just called the dmsp ols sensor
and this sensor was originally designed
to detect clouds at night
and aid mostly in meteorological interpretation
by chance scientists also noticed
that it detected city lights really well
and gas flares and fires
and essentially
all of these emissions of brightness

of light at night
so they actually
weren't planning on launching this satellite
in order to monitor and detect lights emitted by humans
or fires or whatever it might be
but they found that once they launched it
it was really
really good at monitoring and detecting those things
and they quickly realized that this was a really
really good metric
for looking at something like the human footprint
it's hard to look at you know
buildings and their spectral signatures
because they could be so different
and classify them all as urban areas
or consider them as having a potential level of
human footprint
what's really nice about night lights data sets
is lights or lights
lights will always have some sort of emission
associated with them
and generally
even if they're different colors
they're going to be picked up by these sensors
that's partly because these sensors
are just measuring
the emission
of wavelengths
all across the visible portion of the spectrum
so by measuring
all across the visible portion of the spectrum
any kind of light
that is being emitted
across any portion of the surface of the earth
is going to be picked up by these sensors
so this one
the first one
the dmsp ols sensor
operated from ninety two till twenty thirteen
and produced the first data sets of night lights
that we got from space
it measured radiation
from five hundred to nine hundred nanometers

so spanning that whole range
of the visible portion of the spectrum
as well as a little bit into the near infrared
portion of the spectrum
now the dmspos sensor
even though they kind of stumbled upon it
as a really good tool
for monitoring and measuring
something like the human footprint
it had its limitations
so because it was not designed for
measuring and monitoring night lights
it was designed for measuring and monitoring clouds
and for meteorological purposes
had quite a coarse spatial resolution
so only about two point seven kilometers
and it had a pretty low level of sensitivity
which meant that you generally got saturated brightness
pixels close to cities
and didn't get very good detection
of areas that had very
very faint lights
so you can kind of see that in this example here
so this is kind of a new
updated sensor
used for monitoring night lights
called the veer sensor
which we'll talk about in a moment
but if you compare that to the older dmsp ols sensor
you'll see very
very bright areas
kind of like cities
which you can see here and here
get fully saturated in this imagery here
which just means the maximum amount of brightness
is measured
all across those pixels
you also don't get nearly as much detail
in this newer sensor image
in kind of areas that don't have very bright lights
so this kind of area out here
you don't really get a lot of detail
you can kind of see some faint patterns

but you don't really get a sense of exactly
where these faint sources of light are coming from
it also had a limited spectral resolution
so again it only looked at that one band
ranging from five hundred to nine hundred nanometers
and then it also had no in flight calibration
all that means is that often satellites
because of different atmospheric
compositions
at different times of the day
over different portions of the surface of the earth
they can calibrate themselves
during flight
while they're orbiting
to maximize or optimize
the data that is being collected
and the dmsp ols was an older sensor
it didn't have that capability
so then came the visible
infrared imaging radiometer suite
also just called veers
which is a sensor on board a nasa noaa
swomi national polar orbiting satellite
it's often just called the swomi mpp
veers mission
veers is the sensor
swomi mpp is the satellite
and it has provided global daily measurements
of night lights
since twenty eleven
so this satellite was launched specifically
for the purpose
of measuring and monitoring night lights
and one of the big reasons for that
was so that we could
in a standardized and efficient way
be able to track urbanization
and try and quantify the human footprint
so it included a higher spatial resolution
so a smaller pixel size
of about three hundred and seventy five
to seven hundred and fifty meters
it has a daily temporal resolution

so it gets more complete global coverage
than the dmsp ols sensor did
it has improved sensitivity
so you don't get nearly as much saturation
in the really bright areas
and you still get good detection
of kind of faintly bright areas
out in more of the rural areas here
it has more spectral resolution
so it measures more bands
and it has that in flight calibration ability
so overall it's a better sensor
and allows us to get these really nice detailed images
of the nights of light
all across the earth on a global scale every single day
so this is a video specifically about the vier's sensor
okay so we generally don't look at the
night lights data sets and just say okay
bright areas are associated
with regions that have high human footprints
we generally try and associate the night lights
to some sort of metric
that is related to the human footprint
potentially
so we'll often correlate
bright night lights with things like population
with energy consumption
economic activities such as gdp
urban extent
gas flaring volume
co emissions
all of these kind of things that
generally are associated with an increased
pressure from humans on the environment
have been found to be strongly correlated
with night lights
so it gives us that ability to maybe kind of summarize
all of these different sorts of metrics
by just looking at something like night lights
now we can do that in space
so we can look across an area and say ok
these areas are dark
these areas are brighter

and that gives us a sense of where there is
a higher human footprint
where there's a smaller human footprint
we can also look at that through time
so we can see how
for a particular area
how night lights are changing
and relate that to how urbanization is changing
how energy consumption is changing
we can also relate it to kind of more nuanced things
like culture and population
so i have a quick video
kind of with a cool example about that
when seen from the ground
holiday lights give us cheer
and help us celebrate the season
but from space
over time they can tell us something about both culture
and energy usage
three years ago
a new satellite called swomi ndp
began to give us brilliant new use of the earth
by day and by night
but as sunny as it is to see earth all a glow
this is still just one composite image
averaging observations over a period of months
getting a big picture from space is always healthy
but we can learn even more
seeing that picture change over time
a nasa led team of researchers
has been pouring over the data from swomi and pp
and compensating for factors
like the reflection of the moon
and the effect of terrain
clouds and aerosols
to produce a scientifically valuable product
measuring earth's lights on a daily basis
the first thing they noticed in the data
was the effect of holidays
when we started looking at the data at night
over the united states
we were expecting to see a lot of stability
in the night at night

and we were really surprised to see this vibrant
increasing activity
during the holidays
and particularly in around paris
in the suburbs
you have a lot of single family homes
with a lot of dark space to put in lights
comparing the six weeks
between thanksgiving and new years
to the rest of the year
the team noticed large areas
where nightlights were twenty
thirty even fifty percent brighter
for the holidays
has shown here
in shades of green
and so what we're seeing is this shift in location
but in activity
where people are
staying in their homes
and they're celebrating
or they're traveling to
the rural areas
and they're celebrating
and they're turning on the lights
and whereas in the urban centers
people are turning off the lights
because they're going off for the holidays
researchers actually first saw changes
in holiday lighting patterns
during ramadan
in the middle east
well in contrast to the western holidays of christmas
and new years
during round night
you don't see a shift in activity
in location
what you're seeing is
the communities are staying where they are
and they're shifting
other activities
to the night
another thing that the measurements are telling us

is that there is capturing cultural differences
even within a single community
like the muslim community
during the month of ramana
we're seeing
patterns and behavior
that far significantly
from country to country
smaller inquisitive nights and nights in turkey
large inquisit nighttime nights in saudi arabia
i'm no increase in night time nights in israel
because it's not a predominantly muslim country
so it's a lot of diversity
seeing within the day
because the night light data has such good resolution
researchers from yale university
have even been looking at neighborhoods within cities
and correlated that data
with known political and socioeconomic factors
but from a nasa perspective what isn't important
to concentrate on earth's lights from space
a lot of our capability focuses on
using satellites to get a global picture
of where we are with respect to the environment
and with respect to the daily processes that drive
steering system
a big component of that is human activity
and it's how they drive into different processes
that impact your carburetor missions
and like the heating patterns across cities
and so by looking at the lights
we can see changes in human behavior
throughout the seasons
throughout the movies
and we can use that information to then understand
what are the norms
that are driving the decision behind energy
if you look at climate change research right now
we know that more than seven percent of missions
are happening in cities
and so nasa is putting a lot of emphasis
on understanding cities and understanding the dynamics
of how cities are interacting with the climate

and our systems all
wash your hands
ok so just to kind of summarize a bit of a comparison
between the use of say
aerial imagery and of satellite data for monitoring the
the urbanization patterns
for monitoring and trying to measure and quantify
the human footprint
with aerial imagery
we generally get quite a high spatial resolution
we get a pretty small pixel size
so we get lots of detail across an area
makes it a little bit easier to try and quantify
and pick out really small changes in
areas that may affect the human footprint differently
so maybe much easier to say
i don't know
pick out a park
a really small park
from an urban area
and say well
maybe this doesn't necessarily contribute
to something like the human footprint
aerial imagery makes that a bit easier
because you have a high spatial resolution
you get more detail in the imagery
with aerial imagery though
you also have to use manual interpretation
you have to mosaic all of your images
essentially pin them up where they overlap
to try and put together an image
or composite of the whole area you're looking at
and you have to manually classify it
you have to manually look at it with human eyes
and draw essentially
boundaries around areas that
maybe are contributing to the human footprint
maybe not contributing to the human footprint
areas that are very urban
areas that are less urban etc
it's not a very efficient way to collect data
to try and monitor and measure the human footprint
you have to go out

and you have to fly planes
that cost a lot of money
you potentially
don't get a very good temporal resolution
oftentimes with aerial imagery
you might have an area that has been flown over
maybe once a year
if you're lucky
so you're definitely not going to get that potential
for a daily temporal resolution
like you might with say
the veers sensor
but you do get that historical data
so you do get data
often dating back to the twenties
thirties forties
a time period that we can't really quantify with say
lancetab modus
or the veers or dmsp
ols sensors
now in terms of the satellites
same kinds of
concepts and topics we've been talking about
for our other applications
when we've been talking about the biosphere
the crysphere
oceans and water
particularly for
the human footprint was really
really key and nice
about satellite data
is it standardized
we can use a consistent definition
of the human footprint
because it's not subjective
we can say okay
our human footprint is going to be associated with
this level of night light submission
and we can use that same threshold
all throughout the world
all across the surface of the earth
so it allows us
in a certain way

to try and standardize the definition
of what the human footprint is
or of what urbanization might be
it allows us that efficient data collection
and process analysis
we can often automate it
to classify where areas are urban and where they're not
we get really good coverage
we generally get
from the veer sensor
global coverage
images of the whole earth
every single day
and we have the potential
for different spatial resolutions
different temporal
resolutions
and different spectral resolutions
different bands that we might be looking at
ok bit of a shorter lecture today
ripped through that
got a couple of practice questions here
so why is the night lights data
advantageous
when trying to map urban areas
compared to daytime satellites
what are some examples
of metrics that
night lights data from space can be related to
why is the standardized nature of satellite data
particularly helpful
for measuring the human footprint
can definitely expect
a question like that on the final exam
and lastly just describe a situation
where satellite data alone
may not be applicable
for measuring
change in the human footprint
and you may have to incorporate the use of
aerial imagery
so i'll give you about
five or so minutes to try

and draft up some answers to those
then we will
kind of crowd source the answers to those quickly
and then we'll get into talking about
the final exam
lastly and then
i will leave
sometimes you guys want to ask me or evan about
assignment five sound good
okay sweet if you don't want to stick around
for going over these questions
or for talking about the final exam
you don't have to
you are welcome to head out if you want to please
you're welcome to stay
encourage to stay
yeah i'll give you guys a couple minutes
then we'll go over these in a second
hey i should have a question
yeah sure i don't have a thing about it but
okay guys let's try and work through these guys
so first one
why is night lights data advantageous
compared to daytime satellite imagery
when trying to map urban areas
yeah nighttime data has a lower diversity
of spectral properties
which makes it easier to classify
great great answer
yeah nighttime data
has a lower diversity of spectral properties
which makes it much easier to classify
than standard daytime imagery
daytime imagery of urban areas
potentially
you could have a wide variety of different colors
different spectral properties
making it a lot harder to identify and classify
awesome what are some examples of metrics
that night lights data from space can be related to
so we know loosely we can say okay
well it's kind of related to the human footprint
but what were some specific examples of metrics

that can be used to describe the human footprint
that night lights data sets can be related to
yeah urbanization like social economic culture
yeah socioeconomic factors
gdp emissions co emissions gas flares
those kinds of things
yeah totally
why is the standardized nature of satellite data
particularly helpful for measuring the human footprint
hopefully i drilled that
yeah
exactly yeah
the human footprint is a really hard thing to define
there's no universally accepted definition
for the human footprint
so the standardized nature of earth observation data
makes it really
really nice for monitoring and measuring
and detecting the human footprint
because we can use a standardized
repeatable metric
to try and quantify and measure the human footprint
totally okay
last thing describe a situation
where satellite data alone may not be applicable
for measuring change in the human footprint
and you may have to incorporate the use of
aerial imagery
so what kind of analysis might you be looking at
in relation to the human footprint
that may require
you to incorporate some aerial imagery yeah
yeah historical analysis absolutely
if you're looking anywhere before
about the nineteen seventies
for changes or properties
measurements of urbanization of the human footprint
you're gonna have to incorporate some aerial imagery
we don't really have any satellite imagery
dating back prior to the seventies and eighties
okay awesome
just gonna switch out my slides here
and just pop in my final exam slides

and perfect timing look who it is
okay
this guy should be yeah
that had a great timing
that was perfect timing yeah
okay please give evan your attention
while he talks about the final exam
i may obnoxiously chime in here and there
but if you have any questions
this is a really good time to ask us about the final
so cons twenty seven final
this is you guys
you're pondering earth observation
in case you need the meme explained
oh it didn't click
it's not clicking
it's not clicking
we're stuck on the meme
we're stuck on the meme
i'll just hit a button
oh sorry
the laser pointer doesn't rely on that
yeah i realize that
yeah i didn't
yeah so coms
one two seven
final brief information
final date and time
it's thursday april twenty seventh
so like over a month away
you guys have plenty of time
it's two hours
long seven and nine pm
same setup as the midterm
there's a buffer
so you have ten minutes beforehand and after
in case you're running late or something like that
no worries same thing
it's administered through canvas
i'm gonna be on my email the whole time
send me emails if anything comes up that you think is
wonky and i'll deal with it
we'll get it sorted

ten minute buffer
but two hours no matter when you start
yeah if you start
i get to that later
but if you start at eight p m
you're only getting an hour and ten minutes
uh there's forty multiple choice questions
they're worth one and a half points each
some are gonna have pictures that you have to interpret
there is one matching question
is worth four points each
and there's six short answer questions uh and you
you wanna write around the same as the midterm
on the short answer
one brief paragraph
we give you like
a guideline on how much for each question section
and that's worth six points each
so thirty six points total
again the exam is open book
same setup as the midterm
the questions are going to appear one by one
in a random order within groups
so all your multiple choice
then the matching question
then all the short answer
and you will not be able to return to questions after
completing them
same as the midterm
finals got to be done individually
don't work together
don't share answers
don't discuss answers
and if you're an a amp d student
we will add the time beforehand
so you don't need to worry with that
just if you haven't sent me your form
send it to me before the final please
pre post midterm split
we get this one a lot
it's about forty percent pre midterm
sixty percent post midterm
the short answers are a little more integrated

where one is like hardcore pre midterm
two is hardcore post midterm
and then three are like synthesis questions
where we want you to think about
everything that's happened and put it all together
the final final notes
i love this one
it's worth forty percent of your overall grade
we've posted the practice questions on canvas
we don't same as the midterm
we're not directly giving you guys
a sheet with all the answers
but if you're unsure of anything
put in the discussion board and we'll respond there
and the final includes all lecture content
but not assignment material
so anything on the assignments
don't worry about
you don't need to study it
just what chris talks about
there's a final discussion board posting it
ask us questions
they don't have to be from the practice questions
they can just be clarifying stuff
discuss with your peers if you'd like
i'm going to be monitoring and answering
and chris is going to do a review session
where he's going to go over the stuff that's asked
to be reviewed in this discussion board
so if you're like
i want more info on spectral signatures
same as the midterm
he'll know what to prep to bring for you
you need reliable internet
please make sure you have reliable internet
don't do this hotspotting off your phone
we're not reliable
we're not accountable for that
that being said
if you've got an emergency
your internet goes down for ten minutes or something
immediately email me
if you have a problem

immediately email me
don't wait till the end
just email me asap
and again we can't answer content related questions
so we can't clarify anything
if you say what does this mean
i'm going to respond
i can't answer that
if it comes up with a lot of students
will void the question
and then i'll give you probably two minutes extra time
to account for you waiting for me to respond
if you open your exam at eight pm
you're still going to get cut off at nine pm
nine ten pm
so make sure you start by at least seven ten pm
plagiarism results in zero marks
don't copy basic sentences from slides of the internet
answering your own words
don't work with your neighbors and classmates
and then don't just change a few words
and call it a day
that's still plagiarism
good luck do the practice questions
go over your notes
pay attention to what chris highlights
he really highlights the important stuff
and you're gonna do great
you got anything else
yeah i got two things
grab my little microphone here
i got two things that i will just highlight
from what evan said
one is we always get students giving
asking us questions
or concerns
about this slide
just about plagiarism
because there are
questions where you don't necessarily have to answer
with whole sentences
where maybe it's just an equation
or something like that

this doesn't apply to those instances
so if we're asking you
what is the equation of this
and you take it from my slides or whatever
that's fine
this is really referring to
more so the short answer questions
especially the synthesis ones
but just the short answer questions as a whole
when we are asking you to explain something
which means we want a couple sentences of you
synthesizing some information
explaining some information
discussing some information
that's when we want you guys
to be answering in your own words
you can use whatever resources you want
any online resources
anything from the slides
but it has to be in your own words
which includes copying pasting something
and then just changing one or two words
around here there
you have to make sure it's answered in your own words
it's generally pretty easy for us to tell
if it's not answered in your own words
and if we catch you doing that
then we have to give you zero for the whole exam
unfortunately
which is a lot of your grade so
yeah that's my note about that
any questions about that
ok the other thing that i wanted to
highlight was the discussion board
so if you have questions
clarifications about practice questions
the ones that evan just posted on canvas or about
the ones that i go over at the end of each lecture
you can post about them there
and we'll walk you through and try and
confirm your answer for that
but we just don't give a key
for all of the practice questions

that's the first thing
which i haven't already mentioned
the second thing is our
uh final exam review session will be tuesday
april fourth
i believe is the day
yeah tuesday
april fourth
which i know is really early
you know that's way before our actual final exam
so i know it's tough to figure out
you know what you want me to go over before then
but if there's anything that you any topics
specific lectures that we've talked about throughout
the semester that were particularly tricky for you
we often get often
the most common one is spectral signatures
but if there's any other
particular lectures that were tricky for you
any other particular topics that were tricky
please post about it in the discussion board
and just say hey
can we go over this again in the review session
and i'll create extra content so that we can go over it
really really at home
really make sure that you're prepped for the final exam
and then i'll also just review a couple things
that i think are really key
that you're likely to incorporate on the final exam
and try and just clarify anything that looks like
you guys might be struggling with
through the discussion board
the discussion board is kind of our measuring stick
for what we want to go over in the final exam
so please be active on it
because it'll reflect
in what we actually talk about in the review session
make sense any questions about that
okay anything else no
did you do the what's due or
no we haven't done that
is there any questions about the final exam in general
as a whole yeah

so although there
might be like
a designated room on the ssc
we can take it from anywhere
anywhere you want
yes that's a good point
thank you for asking that question
the whoever posts the schedule for the exams
never looks at the form that they get me to fill out
every single semester where i say the class is online
because every single semester
they still always schedule us a building
don't go to that building
there's no in person invigilation of this final exam
it's a fully online exam
it's fully through canvas
there is no in person writing
there's no in person assessment
there's no in person exam
it's all fully online
i know on your schedules
there might be a building that has popped up
on the schedule that says our exam is in that building
it's not we won't be there
um i emailed them about it
asked them if they could change it
they said they're working on it
i don't know if they have or not
sounds like they probably haven't
i checked it today
it says ask prof
okay says ask prof now
so ask me we don't
no in person
don't go there
we always get people emailing us the day of the exam
saying hey i am at the exam location
i don't see it
there's no in person
it's an online exam
um okay drill that home
i know that's probably not you guys doing that anyways
cause you guys are actually in lecture

so uh yeah um
it's pretty much it then
right yeah okay
sam's not here
but if you want to come down and
ask us any questions about simon five
you're welcome to
i'll put up the slides that evan always has right now
about what's due this week
um but yeah
other than that
you're welcome to head out
and i'll see you guys next week
yeah it's been updated
alright hi everyone welcome
hope you are all enjoying the sunshine
we're getting
just a couple of reminders
so assignment six is due thursday
you got blog post five
which is due thursday of next week
not this week
and we'll talk about it on monday
so week today
i'll give you instructions or help provide some context
for the blog post in class on monday
uh just a schedule for the rest of the semester
we're going over environmental change today
and probably tomorrow as well
and then we'll probably start uh
the future tomorrow
so talk about the future of earth observation
and then on monday following
we might finish off the future
and then talk about canada from space
which is the kind of lecture
to go along with the blog post
and then the tuesday after that
we'll have a final exam review session
so week tomorrow we'll have a final exam review session
and that will be the last day of class for us
so sam has office hours this week
he should have just

or is just finishing off
i guess his office hours that are happening right now
and then he'll have some tomorrow
wednesday and thursday as well
so we'll go over uh
i think i mentioned it already but try to
i know it's kind of hard
cause our exam is way at the end of the exam period
but there's a discussion board up about
final exam questions
if there's anything that you'd like me to go over
during the final exam review session
please post it there
if there's anything you post
i'll bring some stuff prepared to talk about
otherwise it'll just kind of be q and a
and if you have questions
you can ask and
yeah that's all i'll do
okay so today we are talking about how
environmental change is monitored from space
we're going to talk about cyclical
abrupt and gradual changes or patterns
this lecture does a good job i think
of bringing together a lot of
the different topics and concepts
we've been talking about all semester
so it's really good
not literally a review
but it's a really good review session in a way
because it'll help us practice
kind of bridging some topics that we've talked about
in previous lectures
so i'll first just introduce
the types of change that we'll talk about
which will be cyclical
abrupt and gradual change
and then the data considerations for monitoring
each of those kinds of change
and then for each kind of change that we'll discuss
cyclical abrupt
and gradual
we'll go over a quick definition

we'll talk about using earth observation data
to measure these different kinds
of environmental change
and we'll use some specific examples
to kind of help finish
wrap our heads around each of them
so just to provide some background context
we know that the earth is constantly changing
we know that there's natural changes that occur
we know that there's human cause changes that occur
and we know that
all of these different kinds of changes
can occur at very very very different time scales
so we can have things like wildfires
forest fires
you have a question
they should be yeah
do you not see them
it only ends
you got it yeah okay
so we know that these changes
these environmental changes
whether they're natural
whether they're human caused
they can occur at really different scales
through time and space
so things like forest fires
wildfires might burn over a couple days
a couple weeks
you know climate change is a phenomenon
that's occurring over decades
potentially centuries
we know that in space
wildfires forest fires might burn over
you know zero point one to ten kilometers squared
pretty small discrete area
whereas climate change is something that's potentially
affecting the whole globe
the whole earth
we know that it's important to monitor
all of these different kinds of change
whether they are occurring at
really small spatial scales

really large spatial scales
really broad or fine temporal scales
whether they are natural or human caused
because we want to be able to monitor and assess
our impact on the environment
we want to be able to make sure that we are
complying with different laws
whether that's related to things like
you know resource extraction
mining forest harvesting
making sure that we're complying with the laws
that are set out in different political jurisdictions
we want to protect human health
and we also
want to be able to predict and understand our future
so that we can start to plan now
for how things might change with climate change
so based on what we have talked about so far in class
isn't a trick question
we've kind of
at the end of every single lecture had very
very similar themes concepts
ideas around what makes space based satellite data
really advantageous for monitoring different phenomena
whether that was oceans and freshwater
or the cryosphere or the biosphere or wildlife
what were some of those advantages
why do you think as a whole
satellite data might be advantageous
for monitoring something like environmental change yeah
you can see the whole earth totally
you got really good spatial coverage
yeah standardized and consistent
standardized and consistent
exactly yeah
same kind of things we've been talking about
two really good points
it's efficient
we can get different kinds of information
at different spatial and temporal scales
we can get different kinds of information
from all across the electromagnetic spectrum
so lots of different reasons why it's really

really advantageous
and a really nice data set
for us to be able to monitor change
now whenever we're monitoring environmental change
which is often just broadly
one of the very common applications of space based
earth observation data
we have to consider
what kind of data we need to do that
so we've talked
about specifications and characteristics of say modus
landsat lidar
all these different kinds of data
that we know we can collect
so now we're going to try and talk about it from
the other perspective
which is now
rather than looking at a specific data set
and understanding its characteristics
let's consider a specific change
a specific kind of environmental phenomena
and the characteristics
or the data requirements needed
to monitor and assess that change
so there's four that we'll talk about
the level of spatial detail
the region of the electromagnetic spectrum
the frequency of revisit
and the temporal dimension
the level of spatial detail
is just the smallest ground object
that can be resolved in an image
and we know generally
more detail
generally implies
less area covered by a single image
and a bigger file size
just as an example
you might require a moderate resolution image
to detect an amount of forest lost or forest gain
over a particular area
but we know that it requires a very
very fine level of resolution

if we want to detect say
changes at a single tree level
so really that just relates to spatial resolution right
we talked about spatial resolution
back to when we had our resolutions lecture
we know that spatial resolution
can be a kind of a coarse
moderate or very
very fine scale
we have a course scales
things like ice sheets
very large things
we know generally
for course scale applications
modest is a really
really good data set to use
we know at the moderate scale
mapping things like land cover
monitoring changes in forests
lost in forest gain
is a really common application
landsats a very common
moderate spatial resolution sensor
for fine scale
for monitoring things
that may be an individual tree level
we know we need very
very fine spatial resolution data
maybe drone data
or high spatial resolution
satellite imagery
that's at a spatial scale of maybe less than one meter
or pixel size
less than one meter
so our level of spatial detail
ultimately relates back to our spatial resolution
we also want to consider
what region of the electromagnetic spectrum
the change is occurring in
the specific regions of the electromagnetic spectrum
where the change occurs
could have a large impact on the dataset that we choose
so for trying to identify

trying to map broad classes
like dead or live vegetation
we can maybe use a few wide spectral bands
if we want more specific classes
like trying to understand different rocks
then maybe we need a very
very fine spectral resolution
maybe we need lots of bands
lots of narrow bands
so that really just relates to our spectral resolution
if we want to measure something like vegetation health
and how vegetation health is changing through time
we know that maybe all we need is the red
and near infrared band
we can measure and monitor something like ndvi
if we want to
measure and monitor how land cover is changing
so that we can try and detect not just forest
but also soil
maybe different kinds of forest
deciduous forest
broad leaf forest
mixed forests
then we're going to need many
many more bands of spectral information
okay the next one to consider
is our frequency of revisit
how often do you need to see an area
to characterize the change
if we want to monitor and map logging or deforestation
something like that
probably the sixteen day revisit time of landsat
is going to be sufficient
because that is
you know a discrete event
logging takes place of a particular area
maybe over a couple days to a couple weeks
so we don't really need a picture of somewhere
every single day
to be able to quantify how much an area has been logged
with something like a forest fire progression
that's happening very
very very very

very quickly
we need to be able to have daily imagery of that area
if we want to be able to detect and monitor that change
in an appropriate way
so this is just an example of a fire perimeter map
so daily imagery would have been necessary here
in order to kind of map out
how this fire is changing on that scale
now temporal dimension
is something that we have alluded to
a couple times throughout the course
but we haven't explicitly defined
so temporal dimension is
how long do you need to collect data
to be able to characterize the change
and that potentially varies with the scope of the study
so for example
if you want to try monitor changes in climate change
or changes due to climate change
those changes are often really really
really slow
so they require long term information
maybe you're going to have to collect
decades and decades and decades of data
in order to monitor or measure that change
but in contrast
a wildfire might occur over a couple of days
and all the information you're really interested in
is either before the wildfire
during the wildfire
right after the wildfire
that wildfire only occurs for maybe a week
then maybe you only need to be collecting data
for a week or two
so a week or two worth of data
is obviously very
very very different
from decades and decades and decades of data
so the change
how long that change is occurring for
something that's very important to consider
now we have aerial imagery generally
dating back about the last hundred years or so

while satellite data
we have only for the last fifty years or so
so when you're considering your temporal dimension
you're considering
based on that
what kind of earth observation data you might need
if it's beyond
in the past fifty years
then you're probably gonna have to incorporate
some sort of aerial imagery
just satellite data alone probably won't be sufficient
so we're now going to spend the rest of the lecture
talking about different kinds of change
and specific examples of those change
and for each of them
we'll run through a couple examples together
as we go through them
but as we go through them
consider yourself as well
if we don't explicitly go through it together
try and consider the data requirements necessary
to detect the different kind of changes
that we're going to be looking at
when we talk about these different kinds of changes
think about what level of spatial detail
would be required to detect it
do we need a lot of spatial detail
or not much really
think about what region of the electromagnetic spectrum
the change is occurring in
if we're talking about vegetation in forests
then maybe the red
and near infrared portion of the spectrum is sufficient
if we're talking about something like land
surface temperature
or sea surface temperature
then maybe thermal bands
parts of the thermal spectrum
are more important
think about the frequency of revisit
think about
do we need an image
of a particular area

every single day
consecutively
in order to map and monitor that area
or do we just need one
maybe once every week
maybe once every month
and then lastly
think about the temporal dimension that's required
think about whether
you only need data for a couple of weeks
or a couple of months
or whether you needed data for years
or decades or centuries
to be able to detect
and monitor the change that we're talking about
okay we're going to start by talking about
cyclical change
cyclical change is
pretty simple
pretty easy to wrap our heads around
we're pretty familiar with it
things that are just repeating through time
so temperature
goes up and down every day
day length changes
throughout the seasons
snow cover and winters
especially up here in canada
in winters we had lots of snow
and summers
all that snow
kind of melts away
the greening and browning
of vegetation every year
animal migration
animal hibernation
canadians going to florida each winter
some of our hobbies
like skiing in the winter
hiking and biking in the summer
all these are seasonal changes
they're all
cyclical changes

that we can see repeat
through time
so a cyclical pattern
is just a pattern
that repeats over time
we are going to focus on
vegetation phonology
and vegetation phonology cycles
and being able to monitor
and track changes
in vegetation phonology
using two different kinds of data sets
that will kind of
compare and contrast a bit
we'll talk about using camera traps
and then also
using modest data
so we are pretty familiar
with the fact that
as temperature warms
in the summer snow melts
vegetation greens up
vegetation greening up just means
vegetation starts growing
deciduous leaves come out
and that vegetation just starts
getting very
very healthy
and then as temperatures cool
into the fall
and as we get into the winter
the snow generally returns
the vegetation
starts to brown
starts to die off
doesn't look nearly as healthy
right so we know this
seasonal change of
vegetation occurs
one way that we can monitor that change
at a very fine spatial scale
is with camera traps
so we can set up a network of cameras

or just one
if you're only interested in maybe one particular spot
and if we take a picture of our area of interest
every single day
then we can get a single point measurement of red
green and blue spectral information every day
for that particular point
that we have the camera pointed at
so time lapse data from cameras
is generally single point data
data collected just
at the one spot that the camera is pointed at
it's very very fine spatial scale
because you can get very
very small pixels out of it
has a very high temporal resolution
we can get imagery every single day
sometimes it even has a higher temporal resolution
if we want than what we can get with motors
motors only takes an image of an area every day at most
with um time lapse camera data
we can also be able to take images
when there's poor weather
so when it's cloudy
modest won't be able to see an area
if it's cloudy
our time lapse camera can still see an area
and we get visible red
green and blue data
so we get spectral bands in the red
green and blue
part of the visible spectrum
and we can use that kind of data
to understand phonology patterns
we can use it to try and validate
satellite data that we acquire
and we can also use it to analyze very
very fine scale phonology in space and time
so this is just an example of what a time lapse
photography data set might look like
you'll see kind of the cyclical
seasonal pattern occur through it
you'll see we'll start with the green vegetation

it'll start to get brown
and kind of die off a little bit
you'll start to see snow and stuff like that
start to come in
so this is one image taken every single day
for all days of the year
this is just another example here
starts with the snow melt
and you'll see the snow will melt away
we'll start to green up here
we'll start to see greener vegetation
healthier vegetation
and this itself is a really nice data set
we can get a really nice fine scale measurement
of the vegetation phonology
for these two particular areas
that these cameras are pointed at
so how do we actually take that then
and get some kind of meaningful measure from it
we're starting with just maybe hundreds of photos
three hundred and sixty five photos
of the exact same point
we can take what we know about spectral signatures
to try and derive some more information from this
so if we have a camera trap image here
a time lapse image
we're taking a photo of this particular area
every single day
if we start here
we can see that
there's not a lot of healthy vegetation here
there's a little bit of greenness kind of going on here
but lots of kind of brown
reddish action going on in behind here
so our spectral signature of that reason
is going to look something like this
here we got our blue band
our green band and our red band
so the camera functions
like any other remote sensing instrument
they have a defined spatial resolution
so they have a particular pixel size
and it just uses three bands

rather than the kind of
dozens of bands that we're used to with maybe
lancettader modus
it uses a red
of green and a blue
so all digital cameras
camera that is on your phone
kind of work in the exact same way
they take a measurement of red
green and blue visible light
and then by adding red
green and blue together in equal amounts
you're ultimately able to create a white color
so white represents things that kind of have
maximum brightness
black represents things that have
no brightness whatsoever
so you got red
green and blue here
got our blue band or green band
or red band here
so if we start here
we start kind of in the
you know right after winter has ended
we have lots of brown
reddish colors going on here
got our blue
green and red band here
we can see on our spectral signature
we got a very low amount of blue visible reflectance
a little bit of green
and then quite a high amount of red visible reflectance
now as we get into spring
into summer
we'll see that plants will start emerging
we'll get much more of a green image
we'll see that visible red reflectance
kind of drop down
we'll see that visible green reflectance
start to increase
as we get deeper and deeper into summer
once we get fully mature plants
we'll see that fully take effect

our red will kind of dip
at its minimum point
our green will kind of max
and hit its highest point of reflectance
and then we get into fall
we'll see that same pattern reoccur
we'll see more kind of browns and reds coming out
we'll see this red reflectance start to increase
this green reflectance start to decrease
and ultimately
we'll get back to winter
or we'll again see
this high level of red reflectance
and this lower level of green reflectance
now because a camera again
works like any other remote sensing instrument
we can just derive a metric
from these three bands
to try to measure the health
of vegetation
in this area
so we can derive something called the two g rbi metric
where you take two times the visible green reflectance
minus the visible blue
plus visible red reflectance
and then by getting that
you can get a high two g rbi value
when vegetation is very healthy
when we have lots of green reflectance
very low blue and red reflectance
and then we can get a low two g rbi
when vegetation is less healthier
when it's senescing
when it's brown or red
where we get much higher
red reflectance
and much lower visible green reflectance
if we plot that through time
so if we plot the two g rbi metric
that we've derived
from our time lapse camera
trap imagery
for every day of the year

all through the year
we'll end up with a curve
that'll look something like this
and from this
we can identify
key phenological events
of that vegetation
we can see here
the green up occurring
so we can see that steep increase
in vegetation
starting to get green
starting to kind of bud
and show its leaves
and then ultimately
we can see it
reach maturity
kind of here
where it levels off
so our two g rbi value
kind of levels off here
and then we'll see it decrease again
as we get into fall
as we get into senescence
and we can take
really nice measurements from this
we can say okay
at what time of the year
is green up occurring
at what time of the year
is senescence occurring
at what time of the year
is maturity occurring
we can also measure things like
the growing season
so we can say okay
how far away is this
this date from this date
and get a sense
for how long
of the year
or for how many weeks
or how many months

vegetation is actually growing
really important implications
of that data set
in particular
for farmers
that need to understand
at what points of the year
they're going to be able to grow their crops
so you get lots of different kinds of metrics
from looking at a curve like this
but obviously
with time lapse
camera imagery
gives us a detailed look
at vegetation
for a few select areas
it doesn't give us a view of the whole planet
or necessarily
even a whole country
maybe we'll go away and set up
one camera trap image
if we're just interested
in you know
our backyard
or something like that
maybe we'll go and set up thirty
forty camera trap images
but we're not gonna be setting cameras up
all across the world
we're not gonna
be setting up millions and millions of cameras
so what if we wanna look at
vegetation cycles
over much larger reasons
or the whole planet
well generally for that
we'll typically use
modest data
so modest data
gives us those daily
satellite images
at a two hundred and fifty meter
two thousand meter

spatial resolution
and modest really
allows us to observe
how vegetation changes
throughout the year
across the entire planet
so we can look at modest data
the same way that we looked at
that camera
time lapse imagery
so in this case
this whole area
might fall in one
two maybe three
modest pixels
but we can essentially
derive a similar metric
so from time lapse data
we're looking at the blue
green and red
visible bands
we can get that
two g rbi value
and then for modest data
we can use red
and near infrared
and this is a good example
of why the ndvi
metric is so valuable
you can see here
the difference
in red versus near infrared
reflectance is really
really large
whereas here
the difference
between visible red
and visible green
reflectance
is not very much
so even though we can go away
and get this
two g rbi value

all we're measuring
is the difference of
these kind of reflectance values here
compared to here
which isn't changing very much
but in comparison to that
the near infrared portion of the spectrum
really really
really low reflectance
when the vegetation is unhealthy
really really
really high reflectance
when the vegetation
is healthy so
we can plot that
with modest
we can get a
very similar
looking graph
so again here
if we say okay
we want to look at
the reflectance
of this area
but now from a
perspective
of a modest pixel
we can say okay
we'll start here
we start kind of in
the browner
reddish kind of region
we got relatively moderate
near infrared
reflectance
pretty moderate
red reflectance
we start to green up
we get much
more mature
healthy vegetation
we see that
characteristic

very very high
near infrared reflectance
very very low visible
red reflectance
we get into fall
we start seeing that
finessing again
leaves start to die
leaves start to turn
red and orange
those kinds of colors
we start to see
much lower near infrared reflectance again
much higher visible
red reflectance
and we can calculate ndvi from that
same way we can calculate two g rbi
from our time lapse imagery
so we can see here for our healthy vegetation
we have that low visible red reflectance
that high near infrared reflectance
and overall we get a high ndvi value
we can see here for much unhealthier vegetation
maybe in the winter or fall
we get that lower near infrared reflectance
that higher visible red reflectance
we're going to lower overall ndvi value
but similarly
just like with the two g rbi value
we can plot ndvi through the year
for every single day
for each modus pixel
and we can still go away
and try and identify key phenological events
like senescence
like maturity
like greenup
and then we can go away
and try and calculate things like growing season
so this is a modest arrived map
showing growing season all across north america
you can see we obviously have much smaller
much shorter growing seasons

as we get further north
as well as in kind of mountainous areas
we have much longer growing seasons
kind of more in areas that are closer to the coast
as well as areas that are a little bit further south
and that growing season again is just a measure of
how long we're in this kind of state here
between senescence and greenup
so with years of modest observations
we can see how these vegetation cycles
might start changing with something like climate change
so we can plot something like this say ndvi
and we can see throughout the whole globe
that cyclical change every single year
going up and down and up and down and up and down
winter summer
winter summer
winter summer
we can start to assess how those cyclical changes
might be changing themselves
we can say okay
if this is our growing season up here
where this kind of part of the curve peaks
is it shortening
is it getting longer
is it reaching a maximum higher level of ndvi
a maximum lower level of ndvi
so we can go away and try and understand
how these cyclical changes
might be changing through time
okay so just to review
cover two approaches there
camera time lapse imagery
where we can get detailed information
on vegetation cycles for a few areas of interest
and then we have modest data
where we can get broad scale information
for potentially the whole planet
in both techniques
we are identifying changes
in the spectral signatures of plants
and then using different spectral bands
in the case of camera time lapse imagery

we're using the green
blue and red visible bands
in the case of modus
we're using red and near infrared
to get the ndvi metric
but in both cases
we're plotting that through time
for every single day
to try and pull out metrics
like when green up's occurring
when maturity is reached
when synescence is occurring
and then try and derive from that information
things like growing season
okay so really good example exam question here
what are the data requirements
if i want to measure phenological changes
in my backyard
due to this year's drought
and then in comparison
what are the data requirements
if i want to measure global phenological changes
due to climate change
so i don't want an answer here
about just what data set would make the most sense
i want kind of justification
through an explanation
of the data requirements
for measuring or monitoring each of these things
so if i want to measure phenological changes
in my backyard
due to this year's drought
what's the level of spatial detail i require
what's the frequency of revisit i require
what is the region of the electromagnetic spectrum
i require and what is the temporal dimension i require
so i'll give you guys a couple minutes
to maybe try and brainstorm by yourself
or ideally with a neighbor sitting close to you
what the data requirements might be for each of these
and then we'll come back
and try and answer them together
so i'll give you maybe two

three minutes
try and brainstorm the answers to these
and then we'll talk about them
i see stuff in the backyard
maybe even two
maybe some of the throwing systems on us
or there's just a gentleman screaming in your garden
yeah for sure
which kind of is a
spatial utility
or oh no this is
okay guys let's try and talk about these ones
so what are the data requirements if i want to measure
phenological changes in my backyard
due to this year's drought
so let's start with level of spatial detail
what level of spatial detail do i need to measure
philological changes in my backyard
yeah you need very fine spatial detail
considering your
precisely yet
you need a very fine amount of spatial detail
because we're just measuring my backyard
it's a really small area
yeah exactly
what is then the portion
what region of the electromagnetic spectrum
would i require to measure those changes
yeah i said near infrared and red yeah
totally yeah
near infrared and red would be the most ideal for sure
we could also get away with visible green and red
we talked about how the camera data can use the two g
rbi metric so we could get away with that
but you're right in the sense that the most ideal
the best option would be red and near infrared
and then what about the frequency of revisit
how often do we need to measure my backyard
yeah daily scale
yeah daily would be ideal
and then what about our temporal dimension
how long do we need to collect data for
yeah it depends

if you did for the year then maybe
you could see the long term effects of the drought
but if you were
i don't know if you didn't have the resources for that
then maybe you are
a week before the drought
during the drought and after yep
totally yeah
so a bare minimum
just before the drought
during the drought and just after the drought
so depending on how long the drought is lasting
maybe a couple months
maybe a year or two at maximum
but somewhere in that range of half a year
maybe two years maximum
something like that
yeah totally
so that would be ideal for
measuring phenological changes in my backyard
due to this year's drought
what if i want to measure
what are the data requirements for measuring global
phenological changes due to climate change
so what is the level of spatial detail that i require
that i would need
david you would need a very broad
spatial detail to be able to measure things with
measure incredibly large swathes of area at once
yep need a very broad amount of spatial detail
we're measuring the whole globe in this case
what portions of the electromagnetic spectrum
would i want to be looking at ideally
i guess it heavily depends
on what you're trying to measure
so if you're trying to measure like ice melt
you might use lidar
well so in this case
in this case we're doing
we're saying vegetation phonology
yeah vegetation phenology
so sorry that's not there
but by phenological changes i mean vegetation phonology

that's okay
totally you would be able to calculate the ndvi
exactly exactly
so you'd want near infrared or red
to be able to monitor and measure something like ndvi
some sort of metric for vegetation health absolutely
and then what is the
revisit time that we were to require
for these phenological changes on a global scale
yeah
monthly monthly might be a bit too coarse
when we were talking just previously
about measuring phonology
ideally you want daily data
so daily is probably our best option
you could maybe get away with monthly
because you could see kind of the lows and the highs
but if we were trying to measure vegetation phonology
traditionally
we would be trying to identify say
the exact date of greenup
or the exact date of maturity
or exactly how long our growing season was
we'd want to know it at least within a couple days
so we'd probably want at least a daily scale
or close to
maybe we could get away with a weekly
monthly would probably be a bit too coarse
and then lastly
what is the temporal dimension i would need
how long would i need to be collecting data
for decades
decades decades
maybe even centuries
but if i want to measure changes due to climate change
i'm going to need a large temporal dimension
of data required
so just to summarize that
same all those answers that we just looked at
high level of spatial detail for monitoring my backyard
visible or near infrared
ideal daily measurements required
only one to two years of data required

so from that
i can say okay well
what data set makes sense for me to use
based off of these data requirements
well i can't necessarily
i mean maybe i could find a camera
that also measured near infrared
but if i just got a standard camera trap
that kind of comes closest to checking all these boxes
minus the near infrared band
but we could use the visible
and try and get the two g rbi metric
from using our camera trap
on the other hand
we wanted to measure global phenological changes
due to climate change
we know it's just a
low level of spatial detail required
visible in near infrared
we can get from a satellite
daily measurements required
probably decades of data required at minimum
modest gives us a really good option
the only thing that we're kind of restricted by
with modest is really the temporal dimension
with modest
we have that coarse level of spatial detail
we have those visible and near infrared bands
we have those daily measurements
but with modest
we only have data back to about
nineteen ninety nine
or very very early
two thousands
if we're trying to
measure or monitor something related to climate change
two decades of data is maybe right on the brink
of what would allow us to do that
ideally we probably want to go back into the
kind of industrial
kind of period
of maybe forties
fifty sixties

to really be able to get a good sense
of the effect of climate change
but given all that
given what our data requirements are
kind of our best option
our closest to meeting all of those
would probably be modus
so this is also a good example here of
the data requirements
that would be most ideal
for a particular situation
for a particular application
and contrasting that
and comparing that
with what you do actually have available
when we have
you know when i say okay
i'm gonna use a camera trap
to collect time lapse imagery
to understand vegetation
phonology in my backyard
sure it doesn't collect near infrared data
but it checks all of these other boxes really well
so it's probably okay for me to settle with that
i've met the minimum data requirements
necessary for me
to detect that change
because i can measure at least the visible red
green and blue portions of the spectrum
similarly with modus here
checks all these boxes
except maybe
the decades of data required
we do at this point
have over two decades
of data acquired from modus
so we kind of just barely check that box
it's just enough
and we can probably settle with that
we can probably use that data to try and perform
this analysis
so good job guys
really good example

of an exam question
really good
kind of example of how i would like you guys to
think through a question like this
so providing
the data requirements
for what would be ideal
for measuring or monitoring particular change
and then ultimately
suggesting a data set
that would at least come close to meeting those
maybe you can't check every single box perfectly
but you could kind of
compare and contrast that a little bit in your answer
make sense any questions
you'll probably see an exam question like this
i've said it a couple times now so don't be surprised
okay next we are going to talk about abrupt change
so abrupt change is a change that creates a rapid shift
of the environment
from one state or condition to another
so forest fire
or wildfire is a really easy example of that
we can go from something that looks like this
really green
healthy vegetation
to immediately after a couple hours a day
something that looks like more like this
where we kind of have bare soil and lots of dead trees
we'll focus on three dominant types of change
that are very commonly measured and monitored
with earth observation
we'll talk about forest fires
forest harvesting
and then monitoring and measuring
land cover and land use change
so first off
why do we care about monitoring and measuring
each of these different kinds of change
why do we care about forest fires
forest harvesting
and land cover and land use
they all in different ways

can have large impacts
on the global carbon cycle
is essentially the short answer to that question
forest fires will have carbon transferred to atmosphere
in the short term
in the long term
that forest typically regrows
carbons often transferred back to the forest
similarly with forest harvest
carbon is transferred
sometimes to the air
sometimes to forest products
houses paper
things like that
but ultimately usually
at least in british columbia
it's mandated
it's illegal
to not be planting
in that harvested forest
after it gets cut down
so generally
in bc and in canada
forests regrow
forests are replanted
and that carbon is transferred back to the forest
land cover and land use change
can be a bit trickier
how the carbon changes
can depend a little bit
on what's logged
and what happens to those logs
but the big difference
with land cover and land use change
is typically
the forest does not regrow
so carbon is generally
not transferred back to the atmosphere
if we take an area that was forest
and then we convert it to a residential area
or to an urban area
then there's not going to be that transfer of carbon
back to the forest

and that could have a large impact
on lots of different things
particularly for wildlife habitat
fires are often a natural part of ecosystems
recently burned areas can be really important habitat
particularly for large mammalian species
like grizzly bears like moose
forest harvesting
on the other hand
can potentially alter ecosystems in unnatural ways
can potentially remove important habitat
we know of kind of a special
unique case with grizzly bears in west central alberta
where they were found to actually be located
in cup blocks or clear cuts pretty often
but that was more so as a surrogate
or as a replacement for burned areas
for areas that had been subject to forest fire
because we've historically
kind of suppressed those very often
so lots of kind of unique
modern novel phenomena
that can go on here
with these different kinds of environmental changes
and how they can affect different ecosystems
again big difference between each of these
being that land cover and land use
typically result in some kind of conversion
so some kind of change from forest to agriculture
to some development
that doesn't ultimately
kind of cycle back into that forest regrowing
now detecting abrupt change
with earth observation imagery
is typically done in a couple steps
so first we have to detect where
and when the change occurred
then we have to identify what type of change it was
or what type of disturbance it was
disturbance
you can think of just as a discrete event or change
we often think of
a disturbance as being an abrupt change

although you can also argue that a insect infestation
is a type of disturbance
but that's more of a gradual change
so you'll see me use this word kind of disturbance
a little bit loosely
more or less
it means an abrupt change
or some kind of change
so if we look at these two images
we can ask the question here
okay we got a before wildfire image
an after wildfire image of the same area
how would we actually detect or monitor
try and identify
that a change occurred here
by looking at this satellite imagery
well again we would just
use what our knowledge is on spectral signatures
so if we look at an area before a fire occurs
before a wildfire occurs
we can see that characteristic
large amount of near infrared reflectance
that very very low red reflectance
immediately after the fire has burned that area
we'll see a much
lower level of near infrared reflectance
and a slightly higher level of visible red reflectance
and that's just due to that live vegetation
that healthy vegetation
being burned and removed from that particular area
now it's not very efficient to look at the entire
spectral signature
so similarly to how we did with vegetation phonology
we can derive a metric
that kind of summarizes vegetation health for us
so we'll look at ndvi as an example
so before a fire again
we have that high near infrared reflectance
low visible red reflectance
will have a high end dvi value
after the fire
will have a much lower near infrared reflectance
much higher visible red reflectance

will have a pretty low end dvi value
so that means that if we look at a time series of ndvi
over time for that particular area
we're gonna get something that looks like this
we're gonna see
before the fire
healthy vegetation
we're gonna see
right after the fire
an immediate drop in healthy vegetation
so a much lower ndvi value
and then over time
we'll probably see that vegetation regrow again
which is characteristic of a forest fire
so if we were to just look at this graph right
if i were to not give you this image
or this image
or this image
to tell you what's going on here
you would be able to deduce
just from looking at this time series of ndvi
that a disturbance occurred
somewhere in the range of
nineteen ninety four
and you'd be able to say
after that disturbance occurred
the vegetation
or forest regrew
because you'd see that slow increase in ndvi
after the disturbance occurred
okay now how are we then able to differentiate
forest fire versus harvesting
forest fire and harvesting
are both going to have a curve
that looks like this
they're both going to have high end dvi values
a quick drop off
and then a slow increase after
either that vegetation starts to recover after the burn
or after someone goes in and replants
the forest that was cut down
so to try and differentiate fires and harvests
will typically look at the different shapes and sizes

of the disturbances
that we'll see across the landscape
fires have very irregular patterns and perimeters
and generally
burn very large areas
so something that looks more like this
where the kind of purple area
is the burned region
harvest forest harvest
particularly in bc and alberta
and in western north america
here have quite regular shapes
and are subject to
a relatively smaller area
than forest fires typically are
so you can see here
kind of in the pink
these are areas that have been recently harvested
and you can see
you kind of get almost a checkered board pattern here
that's kind of this
pretty distinct pattern
pretty different looking
than what you can see here
so by looking at those different shapes
we can identify
whether it is a fire
or whether it is forest harvest
so then how can you differentiate between say
forest harvest and land conversion or land use change
well forest is going to regrow after harvest
you have to go in and plant
where you cut down trees and those trees
and that vegetation will eventually regrow
after a land use conversion the forest won't regrow
so you'll see that quick immediate drop off of ndvi
but you'll see that low ndvi value persist through time
you won't see that increase
as vegetation recovers through time
so then you're able to deduce
from something that looks like this
this must have been some sort of land use conversion
so summary of that process

step one you detect the change
where and when did the disturbance occur
you can identify a quick
large change in ndvi or some other spectral data
we're just using ndvi as an example here
and then you got to figure out
what type of disturbance was it
was it fire
or was it forest harvest
so for this you can use the information on the shape
and size of the disturbance to try and make it out
and then if you want to compare okay
i've determined that it is probably not a forest fire
based on its shape
determine maybe it's forest harvest
but it could still be a land use conversion
if a particularly small area
had a disturbance occur
had an abrupt change occur
you might not know whether it's forest harvest
or some sort of land use conversion
or maybe some development is going on
unless you look back at your ndvi time series
and see whether there's a recovery
in the vegetation after the disturbance occurred
if there's a recovery after the disturbance occurred
then it must have been a forest harvest or a fire
if there was not
then there must have been some sort of land conversion
going on there
now there's this kind of very impactful paper
that came out in twenty thirteen by hanson it all
and they used landsat data
to map abrupt changes across the entire planet
from two thousand to two thousand and ten
so this was a particularly large undertaken
because generally
we know from kind of discussing in class a little bit
if you're looking at things on a global scale
you probably want to use modest data
a two hundred and fifty meter pixel size
it's a little bit easier to use
when you're processing data for the whole planet

than say a thirty meter pixel size
but hansen it all went away and said
well that may be true
but for monitoring abrupt changes
for trying to map and detect forest fires
as well as forest harvesting
and other kinds of land use and land cover conversion
like the creation of agricultural areas for example
that two hundred and fifty meter pixel size isn't ideal
it's better to have a more moderate spatial resolution
like the thirty meters from landsat
so again i kind of answered
i guess the question that's up there
i meant to pose that to you guys
but essentially
landsat is a bit more ideal for mapping abrupt changes
because the size that abrupt changes occur at
are generally a bit more fine than say a
vegetation phonology change covering the whole world
forest harvest
forest fire
conversion of areas to agricultural regions
are a little bit more difficult to monitor
with a two hundred and fifty meter pixel
that's much more ideal to look at them
with a thirty meter pixel
so they were able to come up with this map
if i can pop it up
see here if i can get this mouse working
that i just wanted to show you guys
that we can explore a bit
just to give you guys a sense of quickly
the breadth of this information
so this is a map here showing
i'm gonna pop up their loss extent gain
so here we got forest loss across the whole planet
from two thousand to two thousand twelve
or two thousand and nineteen in red
so we got forest loss in red
forest gain in blue
both loss and gain in purple
and then we got forest extent
so just what areas across the world

have forest and green here
so we zoom in on say british columbia here
where we kind of are
so you guys can
you guys kind of see the spatial patterns going on here
what do you think this kind of big red region is here
fire yeah big wildfire that occurred
what about what about these kind of
these kind of blue things here
cup blocks yeah
those are clear cuts
so in this case these blue areas
these underwent forest gain
so these would have been areas where
forest was harvested prior to two thousand
and then planting occurred
and the vegetation kind of regrew here afterwards
so these in this case represent areas of forest gain
you can see if we go kind of back out to a coastal area
area that you guys looked at
in your assignment recently
so we got nuka island here
so we can see both some force lost
some force gain
couple of areas that underwent both force lost
and force gain
hopefully you guys figured out in your assignment
what kind of change is this
what kind of disturbance is going on here
or you're about to get mad at me
because you gave the wrong answer
what do you guys think this was
cut blocks yeah
it's clear cuts
it's forest harvesting
so sorry if you got that wrong
but that's what's going on here
so we can make out kind of from the shape of these
these aren't those big kind of widespread
random patterns that we'll see with you know
forest fires like we'll see up here with these big guys
those are more
those kind of discrete cup block looking things

the point is
this is a really really invaluable data set
we can look across the whole planet here
at all the forest lost
and all the forest gain that's occurred
from all different kinds of disturbances
so really really valuable data set
in this case
at a thirty meter spatial scale
okay back to here
so they were able to deduce kind of
summary statistics from that from that
hence in it all paper
they are able to find that
from two thousand to two thousand and twelve
two point three million kilometers squared
a forest were lost
zero point eight million kilometers squared
a forest were gained
they also assessed some spatial trends of deforestation
they found that deforestation in brazil
decreased through time
but increased in other tropical countries
in this case
they have indonesia here
showing that
deforestation increased in indonesia through time
so just an example here of a really
really valuable data set a very
very quantifiable level of forest loss and forest gain
that can help us really understand
what our impact is on the forest
in this case
from deforestation
from forest harvesting
as well as what natural causes
may have an impact on the forest
things like wildfires
and other natural disturbances that we can assess
okay gonna dive in now to a couple of
the different uses or applications
of the ability to detect and monitor
some of these abrupt changes

including wildfire
forest harvest
land cover and land use
so i'll keep going for about another ten minutes or so
sam is not coming today
but he is coming tomorrow
so i'll leave like
ten minutes or so
the end of class
in case you guys have any questions
about the assignment for me
okay so with wild fire detection
we can generally use satellite imagery to detect fires
so for monitoring hot spots
we can use it to monitor fire progression
so to see how large a particular fire is
getting through time
we can calculate burned area
so trying to get a measurement
for the extent of forest fires
we can try and also monitor vegetation recovery
after a fire
so really good example here
kind of good practice
if you're trying to study for the exam
walking through what the data requirements might be
for each of these different kinds of change
because even though they're all wildfire related
there's going to be different levels
of data requirements
associated with each of these
for detecting fires
for example
if you want to know just where a fire is
and whether one is occurring immediately
you need to be looking pretty much all across the world
all the time
so you need a daily revisit
you don't need a particularly large temporal dimension
if you just want to know where it is in real time
but you do need a really frequent revisit
on the other hand for say
calculating a burned area

all you need is an image before the fire occurred
and an image after the fire occurred
so you don't need a very
you don't need a high frequency of revisit
you can just have an image before and an image after
so just an example
to kind of get you guys thinking
hopefully help you
if you're trying to figure out what to study
of some practice questions
hotspot detections in particular are cool example
these are areas on the ground
that are distinctly hotter than their surroundings
and so we use thermal sensors
on board different satellites
to be able to measure the surface temperature
and thermal properties of targets
which allows for early detection
and coordination of forest fire fighting efforts
so we might use this case here
if you guys want to check it out
it's kind of a cool interactive map
that's a combination of the veers data set
so the nighttime data set that we talked about
as well as landsat and modus
and the thermal bands onboard those satellites
to be able to go and monitor hotspots
so these are essentially all areas where wildfires are
essentially
have a potentially a high probability of occurring
these are areas
where they've noted from the satellite data
okay this particular spot on the ground
is much hotter than its surroundings at the moment
so maybe there's a fire going on there
and we can do this
we can collect this data
map this out in near real time
so we can find out about it almost immediately
so really valuable for planning for communities
and for wildfire fighting
so this is kind of just an animation
of what that would look like

this is just from two thousand two
you can see kind of the seasonal pattern of greenup
and of snow
as well as where these hot spots are located
in this case
through continental united states
now we can also look at that for the entire globe
so this is a similar animation
showing wildfires occurring all across the world
and again when it comes to kind of linking back
to trying to classify these different kinds of change
because that's definitely a question
i'll ask you on the final exam
is trying to identify and classify
whether something's a cyclical
or an abrupt or gradual change
you really got to think about kind of
the details of the context of the change
i'll make it really clear to you in the example or
or in the question on the exam
but just as an example
when we think about fires
fires inherently
one single fire
that's an abrupt change
but we can also think about fires as a cyclical change
we have fires that occur seasonally
we have fires that will occur in a greater frequency
in the summer
and in a much lower frequency in the winter
we could also
if we kind of plotted the frequency of fires
through time
all the way from
you know say
the fifties
all the way up to the current time
but maybe we would potentially see an increase
in the frequency of fire through that time
and that would be more of a gradual change
maybe related to climate change
or some other kind of change
so the point is fires

is a really good example
of something that could be an abrupt
a cyclical or a gradual change
so kind of making sure you read the question carefully
looking at the details that
we provide you in the question
to try and identify what change it might be
is really important
ok with satellite imagery from space
we can also detect forest harvests
so see where areas have been chopped down
essentially we can calculate harvested areas
calculate how much area
has been subject to forest harvest
and again we can monitor forest recovery
we can get a sense for how the vegetation is regrowing
after the forest has been cut down
again different data requirements
potentially for each of these
so try and think those through on your own time
one particularly useful endeavor for
monitoring forest harvest with satellite data
is that government and industry
will often make targets on forest harvest
so they'll set a limit oftentimes
for how much forest can be harvested by industry
and then generally industry have to create reports
about the amount of harvesting they actually do
satellite data is a really nice
independent
standardized
and objective data set
that allows us to go and look at a region
look at an area
and very distinctly quantify
the amount of forest harvest that's occurred
so that government or other agencies
can go and look at the numbers
the metrics that industry has provided
and say okay
did you guys actually
cut down as much forest as you say you did or not
so it acts as a sense

a kind of validation data in that way as well
where we can compare it to
how much forest is being harvested on the ground
according to those companies
ok i'll end talking about this last example
the idea of land cover versus land use
and i'll use forest harvest as an example
so on the final exam
i'll definitely ask you a question about
what the difference is between land cover and land use
and i'll use the deforestation versus forest harvest
as an example to kind of walk us through
so with deforestation
the forest is cut down to start
with forest harvest to start
the forest is also cut down
so starts in the exact same way
with deforestation farms
plantations and communities may be developed
so there's some kind of land use change going on there
with forest harvest
the trees are planted and regrown
so the land cover change in the case of deforestation
goes from forest to maybe soil or crops or buildings
whereas with forest harvest
it goes from forest to bare ground initially
when the trees are cut down
but then eventually back to forest
the land use change in the case of deforestation
might go from forestry
or just nature reserve or something like that
to farm plantation
maybe community
the land use change in the case of forest harvest
goes from forestry
to forestry
there's no change going on there
so in the case of forest harvest
land use never changes
land cover does change
but it just goes from forest to bare ground
then back to forest
in the case of deforestation

we see that there's a land cover change
a permanent land cover change
not one where it goes from something to something
back to something
we see a permanent land cover change here
and we see a land use change
where maybe we're going from forestry
or natural environment or something like that
to a farm or plantation or community
so a land cover is the physical and biological
cover over the surface of land
so that might be water
vegetation bare soil
something like that
it's the physical material on the ground
land use is related to human activities
like agriculture forestry
urban construction
it's about what humans are actually
using that parcel of land for
whereas land cover is about what physical material
is actually located on the ground there
so often a change in land cover could be temporary
so logging forest harvest
the land use does not change
it's still forestry
it's still managed forest
but the land cover may undergo a temporary change
it might go from forest to bare soil
then regrowth of that vegetation
so bare soil to shrubs
ultimately back to forest
while a change in land use could be much more permanent
could be long term
so in the case of a residential development
maybe the land use is changing
from natural ecosystem to residential area
you're going from
in land cover
forest to concrete
that's it that's the permanent change
there's no regrowth after that
land use versus land cover change

is an important distinction
they have very
very different consequences
if land cover changes
then potentially that land cover could change back
if land use changes
it's generally a much more permanent long term change
there's often much larger impacts
of a land use change than a land cover change
so this is an example of a land use change here
some satellite imagery from bolivia from landsat
going from forest
to plantations or agricultural environments
so you can see here
land use change
land cover is also changing
maybe going from forest to croplands
land use may be going from natural environment
to agriculture agroforest
on the other hand
this could be an example here
of no land use change occurring
but a land cover change occurring
in this case
a wildfire and yellowstone that occurred
so the area maybe went from forest
to bare ground after the fire
but then after some time
the vegetation regrew
went from bare ground land cover back to forest
the land use never changed
make sense any questions
ok sweet we will end there for today
we'll pick back up we'll finish this off tomorrow
and then we'll start talking about the future
and then we only have two lectures
after that next week and that'll be it
see you guys tomorrow
alright hi everyone
happy tuesday
i'm going to finish off talking about change
and then i will probably start
talking about the future lecture

might not finish it
we might finish it next monday
then talk about the last blog post
or second last blog post
then we'll have our review session after that
uh as i've kind of mentioned a couple times
if there's anything that you want me to go over
in the review session
which is a week today
please post it on the final exam discussion board
and i'll make sure that i have slides
and other content to try and go over it and clarify
anything that you're interested in me talking about
you got assignment six due this thursday
so sam will be here at the end of class
if you need to ask any questions to him
and then like i already mentioned
blog post five
will talk about next monday in class
back to where we were here
so we've talked about
cyclical and abrupt change so far
we started by talking about data requirements
for detecting and monitoring change
talked about the level of spatial detail required
the region of the electromagnetic spectrum
the frequency of revisit required
the temporal dimension required
we will continue to
kind of apply that style of questioning
and those concepts
throughout this latter part of the lecture
so we talked about cyclical
specifically
talked about looking at vegetation phonology patterns
using camera time lapse data versus modest data
the different kinds of vegetation phonology patterns
we can get a sense of from those data sets
we then talked about abrupt change in a lot of detail
we talked about forest harvest
we talked about wildfires
we talked about land cover and land use conversion
kind of defined the difference

between land cover and land use
land cover just being the physical material
on the surface of the ground
land use being how humans actually
use that particular area or parcel of land
and kind of the differences you might see with say
forest harvest versus deforestation
in terms of how land cover might change
and how land use might change
then we just ended
the last thing we talked about
was just some more specific applications
of the uses
of being able to detect and monitor fires
forest harvesting
and land use and land cover conversion
so the last kind of change we're going to talk about
is going to be gradual change
so gradual change is a slow shift
from one state or condition to another
or a trend over some extended period of time
so we can look at something like
rising sea surface temperatures
as an example of a gradual change
something that's happening over decades and decades
maybe centuries of time
we can also see
if we look at this graph here
of global sea surface temperature
we can see that annual kind of cycle of up and down
and up and down
and up and down
so this is another reminder of
in an exam setting
being weary of the context and details i give you
or we give you around
trying to identify
whether certain kinds of changes are gradual
or abrupt or cyclical
sea surface temperature itself could be cyclical
or could be gradual depending
if you're talking about just the seasonal cycle
of sea surface temperature

the daily cycle of sea surface temperature
those might both be cyclical types of change
but if we're talking about
the slow increase in sea surface temperature
measured through time
over decades to centuries
due to something like climate change
we'd be talking about more of a gradual change
now a lot of the focus in this course
and in this lecture is kind of more on forests
because a lot of the research in particular
that comes out in the earth observation
remote sensing realm of work is often forest focused
so what kind of gradual trends can we see in forests
in particular
we can see for example
slow mortality of trees due to insects or disease
we can see gradual regrowth of vegetation in forests
after a disturbance event like a fire
like a forest harvest event
we can also see potentially reforestation
so we can see
maybe areas that are transitioning from agriculture
or developed land back to forests
maybe after particular areas were abandoned
or something like that and slowly
vegetation starts to encroach back in that region
these are all gradual changes
they all happen very slowly
and they're just very gradual in a particular direction
and we'll talk about these three examples
the one that is kind of most relevant
at least in western north america
british columbia
alberta type sense
is the western mountain pine beetle
so the mountain pine beetle
is a native insect to western north america
lives in the barks of trees
and even though it's only
about five millimeters in size
they've caused
a really large amount of damage to forests

nbc and in alberta
and in kind of the
western portion of north american forests
now they have been
native to north america for a very long time but as
minimum or as the lowest temperatures in winter
have slowly started to increase
meaning it's not getting quite as cold in winters
for as long of periods of time as it used to
these beetles
don't die off as easily in the winter anymore
so oftentimes
the really cold
extended temperatures that we would get in bc
and in alberta
would kill off these
mountain pine beetles in the winter
but because that's happening less
they've been able to expand their range
and have caused quite a lot of damage
throughout western north american forest
so in the most recent outbreak
from the nineties to the two thousands
it's affected about eighteen point one million hectares
of forests and they've killed a total of about
seven hundred and ten million cubic meters of timber
if you look at their map
kind of across bc and alberta
you can see they're kind of everywhere
so they've caused a ton of damage
throughout the nineties
and two thousands
the way that they actually kill trees
is essentially
adult beetles
will lay eggs under the bark of pine trees
and the beetles prevent the movement of nutrients
through the tree
effectively kind of choking the tree
and then adults will also release a fungus
that damages the tree
so there's kind of two ways that the beetles actually
negatively impact these trees

one just the beetles prevent the movement of nutrients
and then the adults also release a fungus
that will damage the tree
if you look across a forest
that's being infected
by a mountain pine beetle infestation
you'll often see trees that are in one of three
a green attack
a red attack
or a gray attack
the green attack
is where the adult beetles have tunneled under the bark
and the tree begins to die
but the needles still remain green
so the beetles don't immediately kill the tree
it's a slow process
and so we have this first stage of the green attack
where the leaves still appear
relatively green on the tree
then we have the red attack
where after the tree's been dead for a couple of months
the needles begin to turn red
then we have the gray attack
where the dead needles eventually fall off the tree
and just a bare
dead tree is left
if we look at an image like this
so this is where
a mountain pine beetle infestation has occurred
you can kind of see the green
red and gray stages of attack right
you can see some green trees
you can see some red trees
you can see some gray trees here
so you can see all of these stages of attack
now for a moment
just remember that from a satellite's perspective
when we're talking about space based earth observation
this might all fall under one pixel right
we're generally not getting individual
tree measurements
from satellite based earth observation measurements
so an insect

outbreak appears particularly gradual from space
because the needles do not fall immediately
when the tree dies
and not all trees die at the exact same time
so if we're taking a landsap pixel
for example
we'll see maybe a pixel full of healthy trees
maybe a pixel that has a mix of healthy and dead trees
and maybe a pixel that has all dead trees
each of these might have
a slightly different spectral response
but they're going to slowly
kind of gradually move from this state to this state
it's not like we have healthy trees
and then boom
we wake up a week later
and all of a sudden all the trees are dead
and all their leaves
have fallen
the way that insect infestations generally work
is you start with the healthy trees
the infestation starts to occur
a couple of trees get hit
then a couple of more
so it gradually transitions
into this kind of more dead forest
like we have on the right here
if we plot like we've been doing
to be able to detect and monitor these changes
through time
if we plot ndvi or no
we're not plotting ndvi in this one
we are looking at the spectral signature
so if we look at the spectral signature
to be able to derive our ndvi values
we can say okay
well if we look at a pixel that has a healthy forest
we get again
that characteristic low visible red reflectance
high near infrared reflectance
with a high ndvi
slowly as the infestation occurs
and gets worse and worse

will gradually
on a pixel by pixel basis
see a slightly lower near infrared reflectance
slightly higher visible red reflectance
more of a moderate ndvi value
and then eventually
when we get to lots of dead trees
we'll see a much lower near infrared reflectance
a much higher visible red reflectance
ultimately a pretty low ndvi value
so again we can plot that through time
so this is our ndvi time series
going eighty five to two thousand ten
in this case
we have our ndvi value on the left here
now hopefully you can remember
think back to yesterday
i know it was a while ago
but hopefully you can remember
what this graph looked like with say
an abrupt change
when there was forest harvest or a fire
we saw high end dvi
and then a quick drop
then we saw recovery
with the insect infestation
here we're seeing high ndvi
a slow gradual drop of ndvi
and then recovery after the infestation has finished
so we get healthy trees here slowly
a mix of healthy and dying trees
gradually to a larger proportion of dead trees
till we hit this low value of ndvi right here
and then we'll get that vegetation regrowth eventually
so again we can see here if we compare over time
we'll get a slow gradual change
from a spectral signature like this
high near infrared low red
moderate near infrared moderate red
low near infrared
high red versus an abrupt change
will quickly maybe in just a couple of days
couple of weeks

go from a spectral signature that looks like this
very low red
very high near infrared reflectance
to all of a sudden boom
very low near infrared reflectance
very high visible red reflectance
so side by side this is what that might look at
so in an exam
i might also give you a graph that just looks like this
and say okay
hypothesize to me
what kind of change you're likely seeing here
do you think it is a gradual change
an abrupt change
if you think it's a gradual change
what might it be
is it an insect infestation
probably if it's occurring over maybe five
ten fifteen years
it's something like an impact insect infestation
if it's occurring
occurring over decades and decades and decades and
you know maybe up to centuries
like sea level rise does
then maybe it's not an insect infestation
with fire and harvest
we know that if it's a quick drop off of ndvi
it's probably an abrupt change
maybe something like forest fire or forest harvest
if we see that vegetation recovery
after the disturbance
that it is indeed probably a forest harvest
or a forest fire
as opposed to a land use conversion
where maybe we'd see that steep drop
and then it would just stay low
because the area has been converted
to a residential area
a development
something like that
now again while fires burn most trees
mountain pine beetles will only attack certain trees
so the amount of damage will depend

on what species are in the forest
we might if we're looking at a gradual change
save from insect infestation
save from mountain pine beetles
we might see a pretty distinct drop off
if it's a pretty intense infestation
but maybe the beetles only are attacking
say half of the trees or something like that
so the decrease in ndvi
might not be as drastic as it is up here
mountain pine beetles are known to only
in fact lodgepole pine stands
lodgepole pine is a particular species of tree
that is pretty common in parts of british columbia
and alberta
but if it's a mixed stand of trees
where maybe there's lodgepole pine trees
but also a bunch of other trees
then the infestation might not be as intense
so you might not see as large of a drop off
so here we go from an ndvi of point seven
maybe down to point one
whereas here we go from point seven
maybe only down to point four or so
if there's not as many trees being infected
so this is just an example of what that might look like
from a satellite
what a mountain pine beetle outbreak might look like
from a satellite
this is just south of prince george
so more kind of northern bc
and you'll see we're going here from two thousand seven
two thousand four
sorry from two thousand three
two thousand four to two thousand seven
we're having a kind of slow gradual transition
going from you know very very green healthy forest
to slightly more red
bit more of a mix here
and then ultimately to a kind of large widespread area
that's been infected
by a mountain pine beetle infestation
just question for you guys to just get you going

what do you think these are
these little pinkish things right here
on this satellite image
yeah cup blocks
absolutely yeah
hopefully you guys are nice and familiar
with how those look by now
from a satellite
okay now with mountain pine beetles
and several different kinds of insect infestations
you can get one particularly unique phenomenon
that you can quantify from space
so here in this example
we're starting with our healthy vegetation
healthy forest
here you can see a couple of cup blocks there
some newer ones
also a couple of cup blocks here
that look like they've started to regrow a little bit
there's been some vegetation regrowth in them
and then into two thousand four
here we're starting to see some more damage
starting to see some less green areas
some less healthy forests
and then boom
here in two thousand six
we got pretty wide spread damage
from mountain pine beetle infestation
now following that
sometimes in order to save
the monetary or economic value
of the timber
that's being infected by mountain pine beetles
sometimes industry will actually go in
and perform something called salvage logging
where they go and cut down all the trees
that are either partially
semi or fully
infested by the beetles
to try and get some lumber
some timber out of the stand
that essentially is going to have no value
once it's fully infected by beetles

and then kind of all decomposes and starts regrowing
so sometimes you'll see
the infestation will gradually occur
from the mountain pine beetles
and then in that same exact area
you might see some forest harvest occurring
some cut blocks being created
so that might look like
if we plotted it as ndvi
through time
something more like this
we might see that high level of ndvi
representing a healthy forest
and then slowly
that bit of decrease
but gradually through time
and then boom
right around here
we said okay
this forest is kind of toast
let's try to get some value out of it still
let's go and harvest what's left there
so this kind of quicker drop off here
would represent some salvage logging
so healthy forest
insect infestation
salvage logging
vegetation recovery
all things that i'm hoping you'll be able to describe
and identify
on a final exam
and this is just what that would look like
what each of these events would look like from space
in terms of their satellite imagery
nice green healthy forest
insect damage here salvage logging here
eventually some vegetation recovery
any questions about that
okay see
forests that are impacted by mountain pine beetle
are also more likely to burn
which is sometimes the reason
that we'll also just go in and salvage log

instead of just letting it burn
so mountain pine beetle followed by fire
is potentially another example of a gradual change
followed by an abrupt change
so in the example we looked at here
we said healthy forest
gradual change from insect damage
abrupt change from salvage logging
gradual change again
as vegetation recovery occurred here
but without looking at the imagery
and identifying the patterns
of the abrupt change spatially
to say okay
was it clear cut
or the creation of cut blocks from forest harvesting
or was it a fire
we wouldn't necessarily be able to know that
but this is just an example where
if i didn't give you
kind of the context of this satellite imagery here
and what the disturbance looked like here
then you would look at
say just this graph and be able to say okay
healthy forest
gradual disturbance
gradual change
abrupt change
and then gradual change afterwards again
this might have been an insect infestation
this may be salvaged logging
maybe it was just a forest fire
and then here
probably vegetation recovery
so it could be a fire
could be forest harvest
depending on what the shapes
of those disturbances look like
ok there's a couple other types of
gradual change in forest that we can observe
from satellite imagery
we can observe mortality from disease
and just overall change in forest health

it's not just insect infestation
we can also observe
as climate change occurs
areas may be becoming more unsuitable
or potentially more suitable for forests
so as climate changes
and species of trees
of vegetation
that are kind of on the brink of their range
kind of on the edge of the
environmental characteristics that they like to live in
as the climate changes
they might either contract their range a little bit
or expand their range a little bit
but that'd be a slow process
that'd be a gradual change through time
so these are some of the other kinds of gradual changes
that we can often identify
with satellite imagery from space
we often care about monitoring these gradual changes
because even though they're not abrupt
they still can have very large impacts
on carbon storage and habitat over time
if you think back to how large of an area was impacted
by the mountain pine beetle infestation
in bc and alberta
gradual change through time
but really really large consequences for carbon storage
for timber for the forestry industry
for wildlife habitats
lots of different implications
now we talked about land conversion so far
really as an abrupt change
we talked about the conversion of forests to say
development
the conversion of forest to say
agriculture being a pretty abrupt change
but not all land conversions are abrupt
especially if you're going the other way around
from say a development or agriculture
maybe back to a nature reserve
or natural ecosystem or forest
if we go from an agricultural area to a forest

or if we go from say
a developed area to a forest
that's also probably going to look like
a gradual change
a really nice example of that is detroit so detroit
had this large decline in manufacturing jobs
between kind of seventy eight
and two thousand and eight
and as a result the population of the city
substantially kind of dropped off
and with that decrease in population
a lot of neighborhoods just became abandoned
so while a lot
of american cities were growing in population
detroit during this time had a lot of abandoned areas
increasing in their neighborhoods
and so what you saw from say
looking at an ndvi value around detroit
is the development of these detroit neighborhoods
would have been an abrupt change
so it would look like this boom
quick drop off of ndvi
and then it would have stayed low
because it's converted into concrete or some urban area
but the abandonment of those neighborhoods
and then vegetation slowly recapturing and regrowing
in those previously concrete areas
resulted in this slow gradual change
back to an increased level of ndvi
so this is just a map showing the changes in ndvi
from nineteen seventy five
to two thousand five in detroit
from landsat images
and we can see increases in ndvi across the city
so this being nineteen seventy five ndvi values
this being two thousand five ndvi values
and again this isn't because you know
there was more green space or more parks being created
this is because there were so many buildings
that were abandoned and unkept
that there was this large encroachment of vegetation
back into those previously concrete areas
yeah why is it like the major roads and like downtown

why have they also increased ngbi
is it like because there's less cars or something
so wouldn't be due to cars
probably similar thing
it would be due to the areas
directly adjacent to the roads
so essentially
on the roads
just being abandoned
so there just be abandoned buildings there
as opposed to maybe where there was previously
corner stores
grocery stores
more bustling things where people had to maintain
the buildings and stuff like that
all of a sudden
those buildings weren't being maintained
so then we saw this kind of vegetation
encroaching in the area
and that was just kind of widespread
all over the city yeah
so the changes that we were able to map using landstat
are not always disturbance or habitat loss
there's also forest gain
there's also things like vegetation recovery
after forest harvest
after forest fire
and those are equally as important to monitor
and detect as the disturbances themselves
where we're losing forest
because it allows us to get an entire holistic view
or paint a whole picture about carbon storage
and about the health of our forests and ecosystems
okay so just in review
one more time
we talked about four data requirements
for monitoring change
detecting change
the level of spatial detail
the revisit time required
the region of the electromagnetic spectrum
the temporal dimension required
and then we talked about three types of change

cyclical particularly with vegetation phonology
abrupt change
particularly wildfires
forest harvest
land cover or land use change
and then also we talked about gradual changes
particularly insect infestation
forest recovery
and also potentially land cover or land use change
okay so i want to give you guys a moment
to practice
so i want to try to get you guys to match these graphs
that are showing different kinds of change
to the potential change that might be occurring there
so i want to give you a moment to try to practice this
so you want to kind of match a b
c d and e here
with one two three
four and five
and then also tell me whether it is a cyclical
abrupt or gradual change
so i'll give you a couple minutes
maybe two three minutes
to go over that
either by herself hopefully
maybe with a neighbor sitting close to you
so you guys can chat about it
good practice here for the final exam
and then i got some more practice questions
right after that here
that we'll go over after that
so let's go over these first
we'll go over the practice questions
and then we'll move on to the next lecture after that
so i'll give you a couple minutes here
okay guys we can go over these
and then we can move on so
let's start with the
start with graph a there
what what kind of disturbance
cyclical abrupt or gradual is graph a
yeah
gradual exactly

and what kind of
specifically
what kind of disturbance do you think it is
one two three four or five
five reforestation yep definitely nice
what about graph b
what is going on in graph b yeah
abrupt and you think it's fire why do you think that
exactly because you see that abrupt change
then you see that gradual increase in ndvi
after suggesting vegetation recovery
probably a fire
nice what is c
what do you think's going on in c
yeah
yeah gradual change
and what specific kind of gradual change
one two three four or five
which one sorry
insect damage
yeah probably an insect damage and then
followed by some vegetation recovery and then d
what is d
three clearing a forest and building a parking lot
yep nice work
that'd be an abrupt change
and then lastly e
last one left
one vegetation phonology cyclical change
nice make sure on
well you'll probably see
potentially maybe
who knows on the final exam
you might see these graphs
or you might come across these questions
where you have to identify
the multiple changes going on within them
so for b for example
there is an abrupt change
but that is followed by a gradual change
technically
so you have the abrupt change of
in this case

probably a force fire
and then the gradual change of vegetation recovery
following that
so make sure that in an exam question
you're specifying kind of all the changes going on
in that particular question
nice straightforward
ok i will continue with the future lecture
but i do want to give you guys
a couple minutes to try and practice
answer these questions
so i'll give you
how long do you guys want three four minutes
something like that
ok give you about three four minutes
go over these ideally again with a partner
if not maybe just by yourself
practice them really good
final exam practice questions
and then we'll go over them together
and then we will move on to the future
i'll probably lecture on the future for about
might probably won't get through it all
but then we'll wrap it up
and then i'll finish it off next week
and then talk about the last blog post
so take a moment to try and answer these guys
then we'll go over them
ok let's do these
and then we can move on
so what are the four data requirements to consider
when using satellite data to detect change
easy one hopefully
yeah
yeah exactly
level of spatial detail
frequency of revisit reasonably
electromagnetic spectrum and temporal dimension
can someone describe the data requirements necessary
to detect sea surface temperature rise
due to climate change
so what is the level of spatial detail
frequency of revisit

region of the ems and temporal dimension
necessary to detect sea surface temperature rise
due to climate change
we can go one by one if we want
so what is the level of spatial detail required
yeah david very course spatial detail totally
yep very course very broad spatial detail
what is the frequency of revisit required
how often do we need a measurement of
sea surface temperature
yeah probably monthly something like that will go
we don't necessarily need it every single day
but we need enough to be able to kind of
get a sense for the variation throughout the year
so probably monthly
weekly or daily would also suffice
that one's pretty flexible
what about the region of the electromagnetic spectrum
what kind of band might we want
what region of the electromagnetic spectrum
would we want to measure
yep
yeah what portion of the infrared specifically
we got the near infrared and we got the
starts with a t
no not sure
yeah thermal infrared
yeah exactly
thermal infrared
is what will be used to measure temperature
we also talked about using passive microwave sensors
to measure sea surface temperature as well
so that would also work
but more common one would be thermal infrared
and then what about temporal dimension
how long do we need to collect data for
many many years
many many years
probably several decades
maybe a century plus
something like that
awesome okay
what is the difference between land cover and land use

and maybe use a specific example
to help explain the difference
yeah sorry land cover describes the physical
and biological cover
land use is related to human
for an example
a forest that is cut down
would have a change in land cover
but if it is a managed forest it
remains exactly
whereas if the forest is cut into a parking lot
there is a change in land cover as well
as exactly yeah
so land cover
just to repeat
in case anyone didn't hear
that land cover is the
physical material on the surface of the earth
land uses how humans use that particular area
that particular parcel of land
and then a specific example
maybe using forest harvest versus deforestation
with forest harvest
trees are cut down
the land cover will change from forest to bare soil
but maybe eventually back to forest
the land use does not change
if it's a managed forest
if it's there for forestry
it's still there for forestry
on the other hand
with deforestation
if we cut down trees to create a parking lot
the land cover will change
potentially permanently
so go from forest to concrete and then stay as concrete
and the land use may also change
so the land use maybe went from natural ecosystem
or forestry to residential or urban or shopping
or something like that
awesome yes
great answer
classify the following changes as cyclical

abrupt or gradual
a single wildfire
cyclical abrupt or gradual
so i wanted to shout it out
was that abrupt
yeah abrupt
what about the seasonal change
and frequency of wildfire occurrence
yeah
yeah good good answer
yeah cyclical and gradual
not really enough context there
to necessarily make it out
we have cyclical changes of fires occurring
because in winter they occur less
in summer they occur more
if we look at that though
across maybe decades
we might see an increase
or decrease in the change of frequency
throughout a whole year
so seasonally cyclical change
but maybe annually more of a gradual change
potentially
okay what about an insect outbreak in a forest
followed by salvage logging
and then vegetation regrowth
yeah it would be a gradual decrease in nubi
and that depending on when they logged it
it would might be a very abrupt decrease in mdvi
when it's regrowing is going to be a gradual increase
exactly yeah
so the insect outbreak gradual change
salvage logging abrupt change
regrowth gradual change
okay what about sea surface temperature
cyclical abrupt or gradual change
yeah gradual gradual
if we're considering how it's changed over decades
maybe centuries due to climate change for sure
could it be argued something else as well
dependent on the temporal range totally
if you're measuring it at just one place one time

then it could be abrupt
for example absolutely
if you're measuring it like
the seasonal change over a few years
it could be cyclical
but if you're measuring like
at the same time every year over multiple years
that could be considered exactly
so really really good point there
really good thing to consider for final exam question
that one totally depends on the scale
of time that you're looking at
so are you considering
how sea surface temperature is changing on a
just daily basis
than maybe it's more cyclical
are you considering how it's changing seasonally
and again maybe more cyclical
are you considering how it's changing
over decades or centuries
due to climate change
may be more gradual
are you considering how it's changing
because there's an oil spill that has a fire occurring
right on that portion of the sea
that wasn't happening five minutes ago
then maybe it's a big
abrupt change
so totally depends on the circumstances in context
in the final exams setting
i'll give you those circumstances in context
so these are a bit harder than realistically
you would see on the final exam
but i just want to get you guys thinking about those
okay awesome
any questions
cool okay
we will get started on this next lecture here
then i will
okay sweet
so
we are gonna talk about some new
some future satellite missions

we'll talk about satellite constellations
the concept of the democratization of space
and open skies
and then also briefly
kinda end on observing other planets using satellites
and then we'll touch on drones a little bit as well
so landsat again
if there's one thing that
hopefully you remember from this course
it's landsat
what landsat is
what we're actually able to measure and monitor
with landsat
we know the first landsat
launched in nineteen seventy two was landsat one
we know that landsat four never reached
or sorry landsat six never reached orbit
and then we know that landsat nine
is the most recently launched landsat
so lance at nine was just launched in september of
twenty twenty one
it has the oli two and tiers two sensors on board it
which are essentially just copies of the oli
and tiers sensor from lancet eight
just with a slightly improved radiometric resolution
not something that we talked about in this class
so don't worry about what radiometric resolution means
essentially just an improved sensitivity
on the lansat nine versus lansat eight sensors
quick video here about lansat nine
we will provide critical data on
our earth is changing
circling the globe every nine minutes
fourteen orbits a day
continuing decades of observations
the impact of the landslide record
is the sheer amount of information we've collected
all across the world since nineteen seventy two
and it is high quality science television data
enabling us to accurately track changes over time
now fifty years of las vegas
expanding may be fairly simple to notice
but we can also observe short term changes

like the growth of farm crops
through a season in south central kansas
with more than one landsat satellite in orbit
plus the european sentinel two satellites
we will get data several times each week
improving our ability to track crop health and more
the temperature measurements from landsat nine
will be used to calculate how much water
was used by each farm field
the central platinumatical resources district
like many throughout the western united states
relies on lands that data to manage irrigation
and increase water efficiency
landsat nine will also improve
monitoring of coastal waters
the increased precision
and data sent back from landsat nine
will allow finer distinctions
in the levels of light reflected from water
making it easier to identify
any pollutants that are present
around the globe
growing population and expanding development
result in higher amounts of runoff
damaging sensitive near shore ecosystems
landsat's long history lets us look into the past
to see the effects of land use changes
the consequences of climate change
can also be seen in lansat's long data record
scientists have used lansat to track shrinking glaciers
for decades
and lansat nine will continue that effort
the glaciers in the himalayas are a key water source
for billions of people in south asia
due to global warming
the increased meltwater collects
in large lakes at high altitudes
and poses a flooding risk to downstream villages
lands that data is essential
to monitor the growth of these lakes
because of their location
glaciers are not easy to study in person
but landsats view from space

allows us to study glaciers all around the globe
lands at nines improvements will make it easier
to see features on the glacier surface with that
we can better track how fast the glacier is moving
knowing the velocity of the ice now
and how it has changed over the past decades
helps us forecast likely contributions
to rising sea levels in the changing climate
lance at nine joins lance at eight
to continue the unbroken spirit of lance at david
for five decades
we've relied on lancet's high caliber science
quality observations
to understand and protect our own planet
and while lance at nine begins sending back data
we are already planning for the next evolution
in the lance act program
okay so the literal next
lansat mission that's to be launched
is called lansat next
so it is planned to be launched in
twenty thirty
and it's actually going to be a constellation
of three satellites
so up till now
all the landsat satellites are just one satellite
operating by itself
landsat one is one satellite
landsat two is one satellite
so on and so forth
landsat next
which will be after landsat nine
is going to be three identical satellites
and so that's going to essentially artificially improve
the temporal resolution of the land satellite
it'll be three satellites
staggered in the exact same orbit
so it'll take less orbits
and thus less time
for the next landsat satellite
from the landsat next constellation of satellites
to go view the exact same point on the earth
so it's going to have this increased

level of temporal resolution
because it's a constellation
we'll talk about constellations in a bit more detail
in a moment here
but a constellation of satellites
is essentially a group of identical satellites
all operating together
with all of these kind of future landsat missions
that we're seeing planned
and future satellite missions as a whole
we're seeing
this continued increase of spatial resolution
continued increase of spectral resolution
many more bands
you can see in comparison here
landsat eight and landsat nine bands
versus landsat next band
landsat next is going to have twenty six bands
so a much much higher spectral resolution
than lancet at eight
and lancet at nine
is two predecessors
and then also we're seeing just increase sensitivity
which really just means increased
radiometric resolution
the plan for landsat next to have three satellites
to increase its temporal resolution
is a part of a more common thing we're seeing now
with newer satellite missions being launched
where they are being launched in constellations
where multiple identical satellites are being launched
put into orbit
just staggered behind one another
so that we can get quicker images of the same area
on the surface of the earth
from the same sensor
just mounted on board two different spacecraft
or two different satellites
okay quick video about landsat next here
oh
and they absolutely love the hype music
so one thing to note there
i don't know if you guys picked that up

but on a couple of the bands
that lancetad next will have
they're gonna have an increased spatial resolution
so generally speaking
when we've talked about landsat
we've talked about
landsat having a thirty meter spatial resolution
and for exam purposes
if i ask you what the spatial resolution of landsat is
should say thirty meters
landsat next isn't launched into space yet but
little bit of a hint
maybe kind of
sort of for the final exam
something for you guys to kind of consider
maybe think about
landsat has
you know this
record of data collected since the seventies
eighties with a thirty meter spatial resolution
all of the newer landsat
satellites that have been launched
including lands at seven
lands at eight
lands at nine
also all have this thirty meter spatial resolution
do you think that there might be any issues
with having a spatial resolution on newer
to be launched satellites from landsat that are finer
that have a smaller pixel size
there is a trade off
potentially
between increasing the quality of the data
and having data continuity
one of the most valuable parts about landsat
is that it has thirty meter spatial resolution imagery
all the way back to the seventies and eighties
and it's always been that
thirty meter spatial resolution
so no matter what satellite you download
landsat data from
it's always the exact same resolution
that makes integration of data

between the different landsat satellites really
really easy
because the pixels are the exact same size
covering the exact same area
now if we have ten meter spatial resolution
that sounds really
really awesome
and probably will be really awesome
i'm super excited about the ability to have
ten meter spatial resolution
covering the entire earth every six days
in the case of landsat next
but that also poses issues for data continuity
it's going to make it a lot harder to integrate
ten meter spatial resolution data
from that new landsat next satellite
with historical archives of landsat data from landsat
one two three
four five seven
eight and nine
might see something like that on the exam
maybe maybe maybe not see
but just something to think about
that's kind of more of a
i don't even actually have any slides up about it
it's a bit more of kind of an open ended
food for thought kind of question
that there won't necessarily be a right answer to
if it is on the exam
who knows might not be
we'll see um
but uh yeah
so bit of an open and a question just
just food for thought
something for you guys to think about
just in general um okay
they also mentioned on board or in that video there
the european space agency sentinel series of satellites
and it's relatively a newer series of satellites
the european space agency undertook the sentinel series
as a whole in order to replace a lot of their older
european space agency satellites
so there's six satellites

in the sentinel series mission
we don't talk about it as much in this course
because we kind of focus on
north american centric satellites
like lancead and modus
but sentinel has
they're all just named sentinel one
two three four
five and six
so sentinel one is a weather satellite
it's a radar satellite
sentinel two is kind of the closest satellite
to the landsat series of satellites
it's a multi spectral sensor
sentinel three is for ocean land monitoring
sentinel four is for atmospheric monitoring
it actually has not been launched yet
sentinel five is again for atmospheric monitoring
it has been launched
and sentinel six is for global surface height
for climate studies
it again has been launched
it's also a radar satellite
so lance our sentinel five here
in this case is the only one
sorry sentinel four is the only one
that has not been launched yet
now we've already talked about icesat
which we know is a space based lidar sensor
the global ecosystem dynamics investigation
lidar or short term jedi
is on the international space station
it is also a lidar sensor
to one of the few other
space based lidar sensors that we have
and its main goal is for
getting biomass estimations across forests
because we know that lidar data
enables us to get that structural
three d information about forests
about vegetation
about biomass
so it's kind of a newer

sensor that's on board the international space station
i mentioned a little bit earlier
about what constellations of satellites are
so constellations are groups of identical satellites
working together
and the main reason to have
a constellation of satellites
is that it improves the temporal resolution
of those particular satellites
so earth observation satellites
and constellations are generally just offset
in the exact same orbit
so that when one satellite comes over
it passes over
the next one's going to come back
and the next one's going to come back
and they'll kind of continue
rotating in a staggered sense
in orbit around the earth
and for the future
we're probably going to see a lot more
continuous development
of global navigation satellite systems
and of earth observation constellations
so we talked about again
this was pre midterm
but we talked a while ago
about global navigation satellite systems like gps
like they do
those are inherently constellations of satellites
there are groups of identical satellites
all working together
so gps is one constellation of satellites
for example
the landsat next satellite mission
will be a constellation of three satellites so any
constellation is just a group of identical satellites
that are all working together
one particularly interesting development
with constellations of satellites
is the advent of very
very small earth observing satellites
launched in very large constellations

potentially hundreds and hundreds of small
identical satellites launched together
these are called cubesats
and we're going to talk a bit
more about those in a moment later in the lecture
i first want to touch on
what the concept of open skies is
so open skies
well i'll first just provide a little bit
of historical context
so historically
there's always been very high cost
of operating large earth observing satellites
and that always made it really difficult
for a single nation or company
to collect all the relevant data
we've shown
or i've shown a couple times throughout this course
the creation
kind of the engineering
that's gone into the creation of landsat satellites
modus satellites
sometimes they're as big as an entire tractor trailer
they can be absolutely massive right
they're really
really expensive
takes a lot of money to launch those very
very technologically advanced
very very large satellites into space
now because of that
we have generally had open skies
which just means that
because not everyone in the world
had the capability to launch satellites into space
we had say pretty well off nations like america
like the united states
like the european space agency as a whole
launching satellites
so for example
nasa from the states
from america launched the landsat series of satellites
but the landsat series of satellites
are completely public

open source and free
so anybody can download landsat data
so the fact that it was really hard for nations
to go away and launch their own satellites
generally created this sense of open skies
where any imagery
with these kind of moderate to coarse
spatial resolutions
could be taken legally
across all areas of the earth
and then because that imagery was open source
freely available for anybody to access
it allowed anybody
any country
myself people in new zealand
australia south america asia
wherever you are
anybody can go and download landstadt imagery
for any portion of the surface of the earth
now because we have started to see
higher and higher spatial resolutions from satellites
this has led to a little bit of
couple of issues
a little bit of controversy right
so we know that
say with worldview satellites
now we can get spatial resolutions
all the way down to thirty centimeters
and some areas may be kind of sensitive for
satellite imagery
in other words
some nations
some people
some groups
whoever might be
might not want high spatial resolution imagery
of particular areas available to the public
that was never really too much of an issue with say
modus landstat data
because we only had a moderate
to core spatial resolution
now these satellites that are vary
or pretty high spatial resolutions

are generally commercial
which means that the imagery is not free
it's not open source
it's not publicly available
and so on websites where satellite imagery
and aerial images can be freely viewed
many areas are typically blurred out
so oftentimes
google will have large licenses
pay a lot of money
to some of these commercial satellite companies
that have high spatial resolution data
so that they can get really aesthetic
and pretty looking base maps
but oftentimes
they'll just blur out areas
that are kind of sensitive for the public to know
right so this
this imagery here
this probably isn't a thirty meter landsat image
this is a much higher spatial resolution image
in this case
this is the nato headquarters in the netherlands
they didn't want this to be publicly available
so they have it all blurred out now
it no longer takes necessarily
an entire nation to build a satellite
lots of private enterprises
can enter into earth observation now for much
much lower costs
and that's due to technological advancements
and for example
we have these miniature satellites
these cubesats
so planet labs is a pretty well known company
that has gone away
and launched these many
many satellites
hundreds and hundreds of them
to kind of start what's called
the democratization of space
where by nowadays
it doesn't take a really rich nation

to launch a satellite into space
you can if you really wanted to
if you were you know
pretty smart engineer
you could probably go to home
hardware and find
the materials needed to create a little cubesat
that was maybe
ten centimeters by ten centimeters by ten centimeters
put a camera on it
launched into space
and all of a sudden
you have an earth observing satellite
so just to kinda clarify
the concept of democratization of space
is that concept of
anybody really being able now
to enter into earth observation
it's a lot more accessible
you know that's not necessarily true
not literally everybody
but it's much more accessible
than it historically used to be
while open skies
is more related to the concept of
legally allowing
missions like landsat to take imagery
all across the world
and then having that imagery be open source
being able to be downloaded by anybody
for any purpose
okay i'm gonna save talking about cubesats
until next week
so on monday
we'll finish off talking about cubesats
finish off talking about this
future lecture
we'll talk about the last blog post that is due
i will wrap up now
do you have anything you want to announce
just kind of q and a
gt gt ok sweet
if you want to come down and

chat to sam about the assignment that's due thursday
you're welcome to
otherwise i will see you next week
don't forget to post on the discussion board
if you want me to go
and review anything in class
a week today
so on tuesday
when we have our final exam
review session
awesome thanks guys
see you next week
all right hi everyone
we are nearly done for the semester
so second last class today
we are last class tomorrow for our final review session
i'll talk today first
i'll finish off the lecture about
kind of the future of earth observation
and then i will dive into briefly the
uh canada from space lecture
which is pretty brief
it's mostly just me
introducing what you're gonna do for blog post five
so that will have just been posted
but i'll go over the instructions in my slides as well
and then i got a couple kind of final reminders um
to go over at the end
julia is not gonna be here today for assignment seven
but she will be here tomorrow
if you need any help outside office hours
on assignment seven
so i'm gonna continue where i finished off last week
so just to jog your memory bit
the last kind of thing we talked about
were the two concepts of the democratization of space
and of open skies
so open skies was kind of this idea that we have
landsat and other satellite missions
that can legally go all around the world
and collect
moderate to coarse spatial resolution imagery
and anyone can download it

and it's free
and it's open source
they can use it for whatever they want
and that was mostly due to
historically
it being hard to access
or create your own earth observation program
or mission satellites have historically
always been really expensive
not easy to launch
it's not easy to get something into space
but that ultimately has led us to where we are now
and kind of the creation
of this democratization of space
and the democratization of space
is the trend that we're seeing now
where the technologies
and the materials used to create satellites
is getting really
really inexpensive
so anyone can now really create a satellite
enter into the earth observation field
and this has led to this democratization of space
i can't give a moment
i know it was restless
second last day of class i hear you
we're almost done
we can do it
okay so the next thing that this kind of leads into
this idea of the democratization of space
of materials becoming really inexpensive
of anyone really being able to
get access into the earth observation field
is the creation of something called cubesats
so cubesats are pretty new
they've been developed over the past
five to ten years or so
they are miniature satellites that are usually about
ten centimeters by ten centimeters
by ten centimeters
so they're you know
literally the shape of about a cube
of something like this size

they generally weigh less than about a kilogram
and there's been hundreds of cubesats already launched
from governments
by nasa by private companies
because anyone can go away and build these
you can go and just get a standard optical
little camera from best buy or something like that
you can mount it onto
a little cubesat that has some solar panels
and you can figure out a way to just
attach it to some other
you know large space program
where they're launching a bunch of other cubesats
then it's not that hard
to actually get it up into space and into orbit
so these cubesats are very
very inexpensive
they generally use off the shelf technologies
which again
just means it's very accessible to find the materials
to build these cubesats
they can be built very
very quickly
and they have a really simple design
which ultimately means
that you can efficiently build up a very
very large constellation of satellites
now just to remind you guys
a constellation of satellites
is a series of multiple satellites
that are all identical
all working together
typically they're all in the same orbit
and they're just kinda staggered a little bit
in that same orbit
and that allows that satellite
constellation to have a very high temporal resolution
because there's
you know instead of one satellite orbiting
there's maybe ten or twenty
or thirty or forty or fifty
all in the same orbit
so it takes less time for us to see an image

because a different satellite will just come by
and look over that same area of interest very
very quickly
now cubesats often are also flown at pretty
low altitudes
which means that potentially
they can also have very high
or at least moderate spatial resolution
with again potentially global daily coverage
the kind of advent of cubesats
the kind of technical specifications
of why they're kind of
considered this new frontier of earth observation
is because we can potentially
with cubesats
get daily imagery
so an image of the entire globe
every single day
sometimes at a spatial resolution less than a meter
so fifty centimeters
twenty centimeters
thirty centimeters
now again none of these uh
none of these cubesat companies
have publicly available data
you have to
you know agree to all of their licenses
and you have to pay
quite a lot of money to get their data
but potentially
this could be quite revolutionary
when we think about modest data
we're thinking about yes
that daily global imagery
but that's not a spatial resolution
of two hundred and fifty to a thousand meters
so with cubesats here
we're talking about the potential
for ten to fifty centimeter spatial resolution data
fine enough to potentially make out individuals
people on the surface of the ground
at a global
daily scale

so a pretty kind of
incredible breadth of potential data that we could see
now can anyone kind of
off the top of their head
think about
or give me an idea
what you know
an issue might be with cubesats
like the idea of daily
very very fine spatial resolution data
covering the entire globe
sounds amazing
but why do you think maybe a cubesat constellation
could be an issue yeah
absolutely yeah
probably contribute to space junk
rather than launching one satellite
you might be launching hundreds of satellites
that means they're probably not going to
be built to the same rigor or have the same
lifetime as those large satellites that take years
and years and years and years to develop and launch
so potentially contributing to more space junk
yeah probably
like privacy issues
with private individuals owning their own satellite
yeah privacy issues
issues with potentially these cubesats
taking high resolution imagery of sensitive areas yeah
it can't be used kind of to look back
you mean in time yeah
is that what you mean yeah
so you don't have that kind of data standardization
back through decades and decades
like you do with landsat data
we have the same landsat data
all the way back to the seventies
so potentially with these newer cubesats
we don't get that temporal dimension yeah
there might be what sorry
a lack of regulation
yeah absolutely
that could definitely be a problem

one other thing
well i'll maybe mention it after
we're gonna watch
as we do a lot in this course
we're gonna watch another hype video
it's gonna be awesome
um this one is a ted talk from a cubesat company
that's kind of one of the you know
one of the companies that's kind of starting to
break the boundaries of entry into earth observation
is trying to industrialize cubesats
so let's watch this video
and then right after they hype us up
i'm going to kind of
bring us back to earth a little bit
let's get started
the earth needs no introduction
it needs no introduction
in part because they pull us seventeen astronauts
when they were hurling around the moon
in nineteen seventy two
so this iconic image
it galvanized the whole generation of human beings
to realise the world's spaceship earth
fragile and finite energy is
and we need to take care of it
but while this picture is beautiful it's static
and the earth is constantly changing
it's changing on days time to go with human activity
and the sunlight image we have of it today is old
typically years old
and that's important
because you can't fix what you can't see
what we ideally want
is images of the whole plant everyday
so we're standing in our way
what's the problem
this is the problem
satellites are big expensive and they're slow
this one weighs three tons
it's six meters tall four meters wide
it took up the entire fairing of a rocket
just to launch it

one satellite on rocket
it cost eight hundred and fifty five million dollars
satellites like these have done an amazing job
at helping us to understand our planet
but if we want to understand it much more regularly
we need lots of satellites
and this model isn't scale at all
so me and my friends we started client labs
to make satellites ultra compact and small
and highly capable
i'm going to show you what our satellite looks like
this is our satellite
this is not the scale model
this is the real size
it's ten by ten by thirty centimeters
it weighs four kilograms
and we've stuffed the latest and greatest electronics
and sensor systems into this little package
so that even though this is really small
this can take pictures
ten times the resolution of the big satellite here
even though it weighs one thousandth of the mass
and we pull this up like dove i'm thinking
we call this satellite dove
and we call it dove because uh
satellites are typically named after birds
but normally birds are prey like eagle hawks
swoop kill orchestral eye these sort of things
but us have a humanitarian mission
so we wanted to call doves
and we haven't just built them then we've launched them
and not just one but many
it all started in our garage yes
we built our first satellite prototype in our garage
now this is pretty normal for a silicon valley company
that we are
but we believe it's the first time for a space company
and that's not the only trick
we learned from silicon valley
we rapidly prototype our satellite
we use early release often on our software
and we take a different risk approach
we take mountain outside and test them

we even put satellites in space
just to test the satellites
and we've learn to manufacture our satellites at scale
we've used modern production techniques
so we can build large numbers of them
i think for the first time
we call it agile aerospace
and that's what enables us to put so much capability
into this little box
now what has bonded our team over the years
is the idea of democratizing access
to satellite information
in fact the founders of our company
chris robbie and i
we met over fifteen years ago at the united nations
when they were hosting a conference
about exactly that question
how do you sell out to help humanity
how do you sell out
to help people in developing countries
or with climate change
and this is what has bonded us
our entire team is passionate
about using satellites to help humanity
you could say we're space east
but not only do we care about what's up there
we care about what's down here too
i'm gonna show you a video from just four weeks ago
of two of our satellites
being launched from the international space station
this is not an animation
this is a video taken by the astronaut
looking out of the window
gives you a bit of a sense of scale of two satellites
it's like some of the smallest satellites ever
being launched with the biggest satellite ever
and right at the end
the solar array glits in the sun
is really cool
wait for it
boom it's like money shop um
so we did just lost two of them like this
we lost twenty eight of them

it's the largest constellation
of earth imaging satellites in human history
and it's going to provide a completely radical
new data set about our changing planet
but that's just the beginning
you see we're gonna launch more than a hundred
of these satellites like these
over the course of the next year
it's gonna be the largest constellation of
satellites in human history
and this is what it's gonna do
acting in a single orbit plane
that stays fixed with the effect of the sun
the earth flow takes underneath
they're all cameras pointing down
and they slowly scan across
as the earth rotates underneath
the earth rotates every twenty four hours
so we scan every point on the planet
every twenty four hours
it's the line scanner for the planet
we don't take a picture of anywhere on the planet
every day we take a picture of every single place
on the planet every day
even though we launched these just a couple weeks ago
we've already got some
initial imagery from the satellite
and i'm going to show it publicly
for the first time right now
this is the very first picture taken by a satellite
it happened to be over uc davis campus in california
when we turn the camera off
was even cooler
as when we compared to the previous
latest image of that area
which was taken many months ago
and the image on the left is from our satellite
and we see buildings have been built
the general point is that we will be able to track
urban road as it happens around the whole world
in all cities everyday
water as well thank you
we'll be able to see the extent of all water bodies

around the whole world every day
and have water security
from water security to food security
we'll see crops as they grow in all the fields
on every farmer's field around the plant every day
and help them to improve crop yield
this is a beautiful image
that was taken just a few hours ago
when the satellite was flying over argentina
the general point is there are probably
hundreds of thousands of applications this day
do i mention a few
but there's others
deforestation
the ice caps melting
we can track all these things
every tree on the planet everyday
if you took the difficulty
today's image and yesterday's image
you can see much of the world news
you can see floods and fires and earthquakes
and we have decided therefore
that the best thing that we can do with our data
is to ensure universal access to it
we want to ensure everyone can see it thank you
we want to empower ngos and companies
and scientists and journalists
to be able to answer the questions
that they have about the planet
we want to enable the developer community to
run their apps on our data
ensure we want to democratize
access to information about our planet
which brings me back to this
you see this will be an entirely new global data set
and we believe that together
we can help to take care of our spaceship earth
and what i would like to leave you with
is the following question
if you had access to imagery of the whole planet
every single day
what would you do that data
what problems would you solve

what exploration would you do
well i invite you to come and explore with us
thank you very much
all right massive hype video
so that ted talk i think was from two thousand eight
so their technology has come
or maybe it's more recent not
are you like
twenty twelve or so
so it's not brand brand new
the idea of cubesats isn't brand brand new
but it's starting to be used more and more in research
um couple notes just to my
my personal notes i guess
but you know
he mentions he asked
he leaves you with the question
at the end of that ted talk
what would you do
if you had imagery of the whole planet every single day
as if we haven't had that for years
before he gave that talk
but we've had modus for a while
modus gives us imagery
the whole earth every single day
in a really really high quality dataset
so we have had imagery of the whole earth
every single day for a little bit already
at least since the nineties
early two thousands
he also mentions that they want to
you know give data
that they want to make it universally available
to everyone
he or that company called planet labs
they do make a lot of partnerships
collaborations with ngos
with government with academic researchers
whatever it might be
but generally speaking
that data is not available to the public
you do have to go and pay for it
it's really expensive

so when he says
we're going to make it available for everyone
kind of sort of
they make it available for ngos for organizations
that kind of help also bolster their image a little bit
so not to say that he's lying
he's not lying but you do
if you just sitting here
wanted to go access this imagery
you couldn't
per say be really
really hard
which is vastly different from landsat modest imagery
which you guys have gone and downloaded yourself
so and then the last note about kind of
cubesats and the advent of cubesats
and the one thing that
you guys all made really good points about
what some of the issues with cubesats might be
the one thing that's kind of extra
that i'll add to that
is when you have
hundreds of different satellites taking imagery versus
say just one
the variation in data collected is typically massive
all that means is
the imagery that's collected by these cubesats
because there's so many of them
and the technology
you know they try to standardize it best they can
so that every single image that they take
represents a similar type of data set
but inherently
no matter what
if you're taking data
from hundreds of different sensors versus one sensor
then you're going to have a whole variety
of different errors
standardization issues
i say that just to say that i've
briefly a little bit
worked with some cubesat based data
and it's often riddled with noise and errors

it's just not nearly as clean
of a dataset that we might get from
say to land
saturn modest
or some of these kind of
larger satellite programs that have been
have taken you know
decades and decades to
to be developed
so those are kind of my
my couple notes about that
any questions about cubesats
anything like that okay sweet yeah
i mean there will be many country many people
absolutely
not at the moment
yeah yeah yeah
i mean you know
there's still our barriers to launch them
we say or i say you know
when we think about the democratization of space
we're thinking about accessibility
for anyone to launch them
in reality you do still need to
you know have the materials
know how to put them together
be able to have the right connections
to be able to get that satellite onto
a space shuttle mission
where you can get launched to the space station
and then ejected from there
so there still are some barriers but yes
there are lots of private companies now entering
earth observation
and at the moment
there aren't really any regulations around space
and how much we can put up there
and there's no real regulations for companies
dealing with their space junk or removing it
there aren't any
commitments they have to make around that at the moment
it's starting to really
really come to the forefront now

i'd say of policy makers
just in the past year or two
because there's just been this crazy uptick in cubesats
especially starting to be launched
there's been a lot of conversations and
you know articles and stuff coming out
about regulations related to space junk
related to having all these
you know artificial materials in space
so it's starting to come to the forefront
a lot more now
but it's a huge issue for sure
and we're kind of just
we kind of just are at the tip of the iceberg right now
yeah any other questions
okay sweet so i just wanted to mention that you know
we've talked about throughout this whole course
earth observation from space
there are also lots of other
satellite observation missions that don't observe space
so there's currently
or have been satellite missions to observe mars
saturn venus
mercury jupiter
we also have other satellites that are observing moons
and asteroids
and these satellites are mainly observing
atmospheric composition
and geological composition
terrain sometimes as well
there's a lidar instrument
that's orbited mars for quite a period of time
to get a sense of the topography of mars
a really interesting example is pluto
and pluto is just kind of fun
because it's one of the furthest planets in our
not planet anymore dwarf planet
but was one of the furthest planets in our solar system
and pluto was observed using
the new horizons spacecraft
in twenty fifteen
which you see an image from on the right here
and that was kind of a really big deal

because it was the first
kind of higher resolution image
that we had ever seen of pluto
that was pretty recent
that was only twenty fifteen
up until then
the best image we had of pluto and its moon was this
which kind of didn't really look like much
so i just got a brief video
about the new horizons satellite here
pluto was the last of the nine traditional bands
to be explored
this was due to the distance from us but also
can you believe this
it wasn't considered
a very interesting celestial object
thankfully the new horizons team pushed hard
for this mission to be approved
and in two thousand six
new horizons launched
as part of nasa's new frontiers program
for media budget space missions
the goal of this mission was to get the blue zone
as soon as possible
and as such
new horizons was the fastest launch ever
it'd be a light spacecraft
on the most powerful rocket of all time
be at aspire
it whized past the moon in only nine hours
the apollo mission
from ten times long
on its way to pluto
and used jupiter as a gravity assist
which shaped three years of the arrival time
it also used jukedeck as a trial run for its systems
taking some remarkable videos and images
of the planet and its moons
after this successful trial
new horizons went into hibernation mode
to prevent wear and tear against instruments
leading up to its approach
in twenty fifteen

the team turned the systems back online
and every day
the spacecraft sent back images of the pluto system
this was an incredibly exciting time for enthusiasts
following story
we began to get hints
on what pluto would possibly look like
and saw how different pluto was
from his biggest room cara
everyday the resolution got higher and higher
and more details could be made out
yes there were other scientific goals for the mission
but the most interesting thing to me
was what it looked like
and soon there can be seen
what not to be
a heart shape on the dwarf planet
on the fourteenth of july
the new horizons probe made its closest approach
at only twelve thousand
five hundred kilometers from the surface of pluto
however mission controllers
didn't get a look straight away
firstly the probe was too busy
taking a lot of photos during a flyby
to send back anything immediately
once they detrans their immense
they have to deal with a slower speed of botting
one kilobit per second
further to that
there was a four point five hour latency
between the spacecraft and earth
but what it did see and sent back
was spectacular
mountain ranges
ice planes glaciers
and an atmosphere
so that was
the first kind of high resolution image we got of pluto
was in twenty fifteen
like that video said it was
the new horizons spacecraft was launched
believe in o six is what it said

so took almost ten years
for it to get all the way out to pluto
to take a high resolution image pluto
okay we're going to kind of end off this course
talking about drones
so drones are not obviously
earth observation from space
but they are still a really important kind of
future path of remote sensing
there's already a ton of work and research
and even industrialization of drones into forestry
resource conservation management
so i just want to talk a little bit briefly
about drones
some of their advantages
what's led to the kind of increase of drone use
so generally speaking
when we use drones for research purposes
for conservation
for environmental purposes
we program the drones to fly on a predetermined path
at a predetermined altitude
and then they just take photos
however frequently we want them to take photos
so maybe we plan it so that the
you know drone is gonna fly through this lecture hall
back and forth and back and forth
all the way
and it's gonna take a photo every two seconds or so
so you end up with a bunch of overlapping photos
kind of show how we take that data
and get some measurements and metrics from it
generally speaking
drones can be used to determine plant health and cover
determine mineral locations
create three d models of areas
potentially map wildlife migrations
they're often
frequently used in emergency responses
attracting storms
and a whole lot more
there's three key technologies
that i'll talk about

that have allowed the advancements of drones
so if you if i ask you on the exam
what are the three key technologies
allowing the advancements of drones
that would be this right here
the first is the price
so the electronics that are used on drones
have gotten much
much cheaper over the past ten to fifteen years or so
the gps has gotten much
much better
we get accuracies from gps measurements at a much
much higher precision than we ever used to
so that means that when the drone is kind of
flying back and forth over a particular area
it knows where it's taking a picture from
in a very very
very accurate measurement
because we have such accurate gpss these days
and then lastly
commonly a limiting factor
with drones is the battery
the battery is generally the heaviest part of the drone
and typically might only last thirty to forty minutes
we get some drones that can maybe last
an hour or so max
there were times where the batteries in drones
might only last ten
fifteen twenty minutes
so we've come a long way from then
batteries have continued to get lighter
continue to become longer lasting
so that we can fly larger and larger areas with drones
so this is kind of how the path of a drone might work
so generally you have a predetermined path
so this is the path that this drone flew
back and forth over this study area
and then each blue dot here is a photo it took
just looking straight down
so each blue dot was a photo
and this would have been a pre programmed flight path
so we would have already gone into our computer system
and programmed out and mapped

the exact path we wanted the drone to fly
then we would have gone out into the field
popped open our drone case
started up the drone
clicked fly
the drone would go up
fly the path it was supposed to fly
and then take photos
however often we tell it to take
every five ten
thirty seconds
maybe something like that
and then using that
it can kind of stitch together
all of the individual images
that it took
to create kind of one whole composite
of the whole area that it's looking at
now generally
with drones
we get very
very high resolution imagery
oftentimes sub centimeter
so potentially
millimeters in pixel size
so we can make out individual
leaves and shrubs
and plants and grasses
from imagery that's that high of a resolution
we can often get a custom spectral resolution
with drones
we can just mount kind of a standard
normal camera on it
that just collects rgb visible information
but sometimes
we can mount a near infrared camera on it as well
we can mount a thermal
near infrared camera on it
to be able to try and detect
exactly where
wildlife might be
where people are located
we can maybe have

lidar on it as well
to be able to
try and piece together
some three d
structural information
that we can get from lidar
so we can kind of put
whatever sensor we want on a drone
we can put just a normal camera
we could put an infrared camera
we could put a lidar sensor on it
whatever we want
and then we can fly a drone
however frequently we want
we can fly it every day
if we want every week
every month
every year most times
at least you know
for research purposes
for industry purposes
you're not going to see drones being flown
every single day
it's possible
but it's not very common
because you have to go away
and charge the batteries
and get out to the field
wherever you're flying the drones
but there are studies that might fly drones every week
every month
build up imagery of that area
and be able to track changes at again
maybe a sub centimeter
spatial resolution
occurring every week
every month
something like that
now that sounds amazing
as i often kind of
pitch with a lot of the technologies in this course
there's a lot of really cool things about them
a lot of advantages of them

there are still disadvantages to drones
they're still heavily limited by their flight time
so generally
batteries might only last thirty to forty five minutes
if you're trying to fly an entire forest stand
and you're only
getting thirty to forty five minutes of flight time
it can be a real pain
because you know
it might take you hours and hours and hours and hours
to collect imagery for a forest stand
or for a particular
area of interest that you're studying
you have to change the battery
every thirty to forty five minutes
it can be quite tough
it can be quite a limiting factor
so it reduces really
the ability of drones to get large coverage
you can't usually use drones to study an area
that's maybe bigger than
i don't know
maybe ten twenty thirty
forty meters squared
even that it's kind of getting large
once you're getting into like hundred meters squared
two hundred meters squared
that's gonna be probably
too large to be collecting drone imagery for
so the flight time reduces
our ability to get large coverage with drones
the battery lives will continue to improve
as technology continues to improve
but still a big limiting factor
another key limiting factor is licensing
in flight zone
so you often need a license to fly certain drones
most drones
if they're under
believe it's two hundred and fifty grams
you don't need a license to fly
so a lot of drone companies will make their drones
two hundred and forty nine grams

so that they're kind of the maximum size
without needing a license to fly them
but anything bigger than that
which are often used in industry and research
especially if you're putting a big heavy sensor on it
can only be flown in certain areas by certain pilots
so you have to have licenses to fly the drones
you often also have to have a license
to be in the area where you're flying the drone
so for example
you generally can't fly drones in urban areas
you know i'll go to the park
and often see drones being flown around by whoever
technically speaking
pretty sure that's illegal
obviously i'm not going to go up to them and say hey
that's illegal
but generally speaking
in kind of more urban areas
you can't legally fly drones
people will do it
but particularly anywhere near airports
anything like that
anywhere where there's any other aircraft
you can't fly drones
i'll give you
just one brief example of why that might be an issue
there's researchers
in the forestry faculty at ubc that use drones
to monitor um
kinda coastal mudflats of the frasier estuary
and that's an area that's very
very close to the richmond airport
so they have a ton of issues oftentime
getting licenses to be able to fly their drones
they can also
only fly them at certain times of the year
certain times of the day
where they'll have a very specific window
if they decide that there's good weather conditions
they want to fly their drone this week
a lot of the time
they just can't

because they can't get the licensing sorted out in time
so it's still a big
disadvantage and kind of limitation of drones
now this is what kind of a data set from drone imagery
might look like
so each of these blue dots
for this particular forest stand
represent a photo that was taken
so each individual
here is a photo that was taken by the drone
and the drone would have flown back and forth
and back and forth
and back and forth
and back and forth
all the way across the study area
taking pictures again and again and again
and again and again and again
that's gonna wind up
with potentially thousands of overlapping photos
so you can see the same features
in a lot of these photos
you can see the road
you know you can see kind of
this area is moving over up there
but this is a set now
derived from this
of all of these overlapping photos
with those overlapping photos
we can plug them into computer algorithms
and because the photos overlap in such a way
where you get multiple angles
of the exact same features
computer algorithms can go away
and generate three d models
in a process called photogrammetry
so because say
we get an image of this tree over here
at the edge of the image
from an angle
where it's kind of leaning out a little bit
you can see kind of the center of this image here
we're looking straight down at these trees
but kind of toward the edge of the image here

we're kind of looking at the sides of these trees a bit
so if we get
overlapping photos again and again and again
we get images from a bunch of different angles
of the same trees
so using that
we can plug them into algorithms
use photogrammetry
and ultimately
go away and build up three d models of the four stand
so this is the real imagery
this is what this four stand looks like in reality
and then this is the photogrammetry based
drone derived model
of that same four stand
again really
really high resolution three d model here
just from overlapping photos
not from using lidar or any kind of fancy instrument
just a typical standard camera
so pretty cool
kind of progress
and advent of drone imagery
now generally drones
like i mentioned earlier
used for a wide variety of things
right now very commonly used these days
to create three d models of forests
potentially again using imagery or lidar
and this is really
really valuable for predicting timber volume
forest structure
and fire regimes at a really fine scale
and oftentimes
flying these drones is a lot less expensive than say
flying aerial based lidar
so the comparison there is flying a drone
whether it's for
whether it's with a lidar sensor on board
or just a normal camera that's taking rgb photos
where you're gonna apply photogrammetry
to build up a three d model either way
if you're using a drone with a sensor on board

a drone is a lot cheaper than an airplane
airplanes are a lot more expensive
a lot more inaccessible
so there's been kind of a large push
towards drones recently
because for a lot of companies
for a lot of researchers
they're a much more cost effective option
than trying to get someone to fly a plane
so you can collect lidar or something like that
okay any questions about that
yeah
that's not what sorry
um so both so aerial image
so the aerial imagery reference is airplanes generally
but you know the word
aerial technically means any image taken from air
so we have historically
lots of aerial imagery from planes
potentially just with a normal camera or with lidar
and then the kind of future here that i'm talking about
is using drones
still has aerial imagery technically
but as a replacement for aeroplane based imagery
because it's a lot more cost effective
does that answer your question okay sweet
any other questions yeah
absolutely yeah
you can put a lidar sensor on a drone for sure
if you'd like
ok sweet got some review questions here
i will maybe
do you guys want some time to practice these or
do you want me to just answer them with you right now
and we can move on to the kind of last lecture
nobody cares either way
okay well let's take a break then
let's do like two three minutes
i'll give you a moment to answer these questions
we'll come back we'll answer them
and then we'll go on to the last lecture and finish off
okay let's do these guys
so what technologies

three of them are allowing the advancements of drones
yeah
yeah
wait i don't know um
lighter and longer lasting
yeah exactly
so cheaper electronics
highly accurate positioning measurements
from better gps and gis
and then longer lasting and cheaper batteries
awesome what are cubesats
yep yeah just a really small satellite
usually ten by ten by ten centimeters absolutely
what is a satellite constellation
yeah exactly
identical satellites that are working together
all collecting the same imagery
typically all in the same orbit
just staggered in the exact same orbit okay
lastly what has led to the democratization of space
this is the last end of lecture question
you guys ever have to do with me this is it
you're still gonna make me wait for it
yes
yes sir you said high cost of satellites
you said high cost of satellites
right so that's kind of more related to the open
skies concept
so the open skies concept is kind of related to
satellites being really expensive to create and launch
so we just had kind of one or two satellites
legally collecting data across the whole world
and being able to share their data with everyone
democratization of space come from
it has
yes
yeah yeah so
so just to kind of summarize
key difference
good exam question
difference between open skies
and democratization of space
open skies is really related to

you know historically
satellites being really expensive
so them not being very accessible
the materials and the ability to launch a satellite
not being very accessible
so we have programs like landsat
like modest
that were legally allowed to collect data
all around the world
and they shared their data freely for anyone
for any purpose
democratization of space is
what has led to the democratization of space
is kind of the opposite
in the sense that
what's led to the democratization of space
is materials becoming much
much much cheaper
so anyone can really go and find the materials now
to build a satellite
and so this accessibility
to be able to build and launch a satellite
has led to this democratization of spaceware
it doesn't require an entire nation
it doesn't take you know
a large nation like america or china or russia
to launch a satellite
anyone can really go and do it now
if they really want to
okay awesome
i'm going to
i will stop
one here okay
so we're just going to briefly introduce
canada's eco zones
which is often how we actually classify
the different regions of canada
that we can look at from a satellite's perspective
and then i'm going to kind of
introduce you to the instructions for blog post five
in the past
i hope it's useful
in the past

we've done this blog post a little bit differently
but often i found that
because some of you are art students
are kind of from all faculties across campus
you might have not yet been introduced to
how to look up scientific literature
and how to look up peer reviewed journals
so i'm going to talk about that a little bit
because that's what you'll be doing for blog post five
and hopefully it'll be something that is
useful for you guys in the future
introduction to canada as a whole
so second largest country in the world after russia
has sixty percent of the world's lakes
ten percent of the world's forest
almost ten million kilometers squared
in landmass
canada is a large large
large country
has a ton of resources
and its large size leads to a
vast diversity of landscapes and climates
often the way that we classify
these different landscapes and climates
is with something called eco zones
so eco zones are this method that we use
to describe ecosystems all across canada
we generally
have fifteen terrestrial eco zones in canada
the largest one being the boreal shield
this big green one across the center here
that has about twenty percent of canada's
canada's land mass
and about ten percent of its fresh water
and what you know
you can notice
from looking at this map of the eco zones
kind of all distinguished with different colors here
and then looking at a composite
from remotely sensed imagery from landsat
in this case
of all of these eco zones
you can see

just visually
some of the spectral differences
that reflect the different characteristics
of the ecological areas we're looking at
we can see the boreal plains here
lots of green and some brownish up here
we got lots of ice up here
lots of tundra
potentially permafrost
we got much greener areas
kind of down here in the atlantic maritime
and the boreal shield
lots of mountains in the montagne cordillara here
and the pacific maritime
lots of green forest out on the island here
so you can see a lot of these spectral differences
that reflects a lot of the different
ecological characteristics
and makeups of these different eco zones
so oftentimes
when we are trying to take
you know place like canada
say classify it into some of these different eco zones
that we've mapped out here
we might look across the whole area
and we might try and use the spectral information
derived from say
landsat or some other satellite
classify land cover
classify forest cover
derive a bunch of metrics and measurements
about the landscape
and then categorize them based on that into
in this case
the maritime region versus montagne
cordilla etc etc
so this is how we ultimately
in a bigger picture
go and try and map out different ecological regions
across canada
so for blog post five
what i want you to do
is look up some research

about how earth observation
remote sensing
is being used
in one of canada's terrestrial ecozones
there's some marine ecozones as well
please omit those
just look at the terrestrial ecozones
we want you to specifically
find a peer reviewed journal article
about remote sensing
about earth observation
and just briefly describe it
just with three sentences
four sentences max
to answer these couple of questions
what is the unique feature
of the eco zone that the authors are monitoring
what's the specific process
or phenomena
that earth observation is being used to measure
and what is the specific satellite or sensor
or data set
being used in that particular study
now first off
we want you to find peer reviewed literature
so what is peer reviewed literature
in scientific literature
which just means
science that gets published
in scientific journals
they always undergo a rigorous peer review process
which means that before an article is published
it has to be reviewed
by other well established scientists in that field
and that's essentially a way to perform quality control
on the science
generally in science
when you create science
when you perform science
you write up a report
you write up an article about it
about your methods
about what you found

and then if you want it kind of
recognized as
peer reviewed science
if you want it published
then you have to submit it to a journal
at that journal
it goes through
this peer review process
where they send it to
scientists relevant
in the field that you're studying
and they get back and say yep
this is good science or no
this is poor science
these things need to be changed
so it's essentially how the scientific community
performs quality control
before articles are published
now finding a peer reviewed article
is not too difficult
what i want you to try and be able to do here
is combine some research
on different eco zones
with your knowledge from class
to be able to find articles that are relevant
so you can use an academic
search engine
like google scholar to do that
there's other ones out there
you can use
the ubc library
search engine
if you want
but i just wanted to walk through an example
of what that might look like
so on this map of canada
with all of our different eco zones
we kind of live in the bottom
southwest corner here
way down here
and the eco
zone that we live in
is the pacific maritime

so we can go to
the website
that i've given you
that this kind of map is from
and it looks like this
so the link is in the blog post
and in these slides here
and you can read about
that particular eco zone
you can read about
its landforms
the climate
the wildlife
the plants in that particular eco zone
and then from that
you can try and relate
what we've talked about in class
to what you
found out about this eco zone
to try and find
a peer reviewed article
or research
that has occurred in that area
so for example
if i look up the pacific
maritime eco zone
i'm reading about it
on this website
that we've posted
and notice that
one of the common human activities there
is forestry
i know from class
forest harvesting
is often monitored
and detected
with landsat
so i can use
some keywords
based off knowing that
to be able to
try and look up an article
now the reason

i'm going through this
is because oftentimes
students really struggle to find
a relevant article
one big tip i give don't use
the ecozone name itself as a keyword
you know oftentimes
students want to just say pacific maritime satellites
if you look up the ecozone
it's a lot tougher to find hits
to find relevant papers
it's much easier to look up a geographic area or region
within that ecozone
so for example
i looked up the pacific maritime
i found that forest harvesting is really common
in the pacific maritime
i know from class
landsat is frequently used with
measuring and monitoring forest harvest
and i know that the pacific maritime includes
vancouver island
and i know vancouver island has a lot
of potentially forest harvest going on
so i can go to google scholar here
can look up landsat forest harvest
vancouver island
landsat forest harvest
vancouver island
you're going to get a couple of different hits right
you're going to get a couple
that you're going to have to search through
to try and find something that makes sense to you
i like this one here
characterizing stand level
forest canopy cover
and height using land set time series
samples of airborne lidar
and the random forest algorithm
lot of jargon
lot of technical information there
but i review the abstract
that say okay

they're just trying to map forest attributes
essentially
so then i pick this article
looks like something that's useful
so this is that same article that i just looked up
just by looking up landsat forest harvest
vancouver island
again vancouver island
a lot better than specifying the eco zone
pacific maritime
you're not gonna get nearly as many hits
much better
just specify a geographic area
and then i look at this paper
and the study area of this paper
is located within the pacific maritime eco zone
i can confirm that
i look at the study area map
it's in vancouver island
and what they're looking at is
they're monitoring forest inventories
in areas with active forest management
and they're combining landsat and lidar data
to derive better metrics
a forest canopy and height
across mature and young forestants
that's the answer to my
my blog post five
right there
they're looking at monitoring forest inventories
so the phenomena that's particularly
unique or common to this eco zone
is that there's lots of forest harvesting
what they're actually monitoring is changing
characteristics of the forest
changing forest canopy cover
changing forest height
across different kinds of forest stands
across mature and young forest stands
and the specific data set that they're using is
they're combining landsat and lidar data
make sure you include a screenshot
of the first title page

so it should look kinda something like this
and again needs to be peer reviewed
needs to be from a scientific journal
so just a website
or a government document isn't gonna work
needs to be peer reviewed
scientific journal
published in a scientific journal
okay note you can't use the paper that i've given today
as an example
so you need to look up your own paper
you can't use the pacific maritime landsat
forest harvest as a topic to look up
need to use your own topic
look up your own eco zone
no plagiarism
so must be written in your own words
other map try to have fun with it
try to find something interesting to research
try to use what you've learned in this course
as well as understanding kinda
some of the broad
characteristics across different eco zones
to try and be able to find something
that's interesting to you
hopefully you have fun with it
this used to be an exam question
and we kinda
moved away to that
and have made it a bit of a blog post
so it's a little bit less high stakes
because i kind of recognize that
some of you might not have much experience
in looking up literature
but i still think
you know for taking a science course
it's a really important skill to have
so i'd encourage you to
try and play around with keywords
play around with
trying to find
a piece of research that's appealing to you
that's interesting to you

and that you can kind of try and decipher
and summarize a little bit
okay a couple of due dates
just finishing off here
blog post five
so the blog post i've just talked about today is
do this thursday
so quick turnaround for that
simon seven is due next thursday
april thirteenth
last blog post
blog post six is posted now
it's due next thursday as well
april thirteenth
it's a pretty easy one
we're just getting you to kind of
tell us about what you learned in the course
whether or not you enjoyed it or not
office hours
for assignment seven by julia
we got some tomorrow
thursday and then next week
tuesday and wednesday as well
julia is going to come to class tomorrow
the end of our review session
if you have any questions for her
you're welcome to come and ask her then
last note final exam review session is tomorrow
this is the last class
there's no class next week
tomorrow is the last class
don't come next week
i won't be here
no one will be here
tomorrow is the last class
please post what you want me to go over
in the final exam discussion board
so if you post on there i'll have slides
i'll have topics to go over
if you don't post anything
i'm not gonna know what to go over
i'm not gonna have any slides ready
it'll essentially just be a q and a

so please please post on that
other than that i will see you guys tomorrow
for last thoughts
okay hi everyone
welcome to our midterm review session
i am going to start by giving the mike to evan
he's going to just go over the midterm format again
i know we already talked about it
but he's just going to drill it home one more time
if you have any questions
feel free to ask him
he'll also just give you his usual weekly update
and then i'll do what
i'll lecture about what there were some questions about
on the discussion board
so i have some slides prepped for that
and then i'll just kind of leave the rest of the time
for just an open q amp a
so i'll give it to em first
alright hello everyone
as chris said
i've got the midterm tomorrow
that's really the major thing that you guys have
coming up for the next few weeks
other than that
after the midterm
next week's reading week
so there's nothing due next week at all
that being said
we've posted assignment three
blog post four
and then assignment four will also be posted by friday
so if you do want to get ahead in the class
you'll have plenty of time to do assignments
if you are interested in doing that over reading week
as for office hours
we're going to announce them after the midterm
so don't stress out about it
that's pretty well it
after the midterm
it's coming tomorrow
i've already done this meme
i'm not doing it again

but it's on the slide
so it's tomorrow
it's during class time
there's no class
you can come here and do your midterm if you want
the wi fi should be decent
you'll have an hour and a half to write it
make sure you start on time
that being said
there isn't a ten minute buffer surrounding it
so you can start at four fifty pm
and you can write until
what is an hour and a half
six forty pm
it's going to be administered through canvas
i'll show you where it is in the modules
after the slideshow
and i'll be monitoring my email the whole time
in case you have technical difficulties
your internet goes out
let me know
anything like that
let me know
i'll deal with it
format there's thirty multiple choice questions
worth one point each
four fill in the blank questions worth four points each
they vary in how many blanks there are
and then there's six short answer questions
each of them is about one brief paragraph
don't write us a novel
they're with four points each
the exam's open book
the questions are going to appear one at a time
you have to answer questions you go to the next one
you can't go back and change your answers
so once you've answered a question
you can't look at it again
and also the questions are going to appear
in a random order
multiple choice question and the short answer question
no within groups
so all the multiple choice

all the fill in the blank all the short answer
great question
yeah so make sure you're
confident in your answer before you move on
because you can't go back
uh please work individually
don't work together
don't share answers
don't discuss answers
if you're an accessing diversity student
uh i've gotten all the forms i believe
and that's already been updated
so you'll already have your extra time
uh if you haven't sent me your form
please do so before the midterm
so that i can update your uh
your profile
um please don't plagiarize
it's an open book midterm
utilize the slides and other materials
that's totally chill
just don't copy entire slides
or entire sentences from the internet
or the slides for the short answer questions
write your answers in your own words
that's like copycat
don't be a copycat
uh review session
chris is hosting review session right now
uh you posted question to the discussion board
he's got slides related to them
uh it's worth twenty percent of your final grade
practice questions are available on canvas
uh i'll be monitoring that discussion board
to answer last minute questions
pretty much until the midterms open
so at four fifty pm i'll stop looking at it
you'll still be able to look at that during the midterm
so if you ask questions there
you can see what we said
and it covers everything up to it
including spectral signatures
resolutions

content is not on the midterm
i know chris started that last week
and then assignment material
not on the midterms
you don't need to worry about anything from there
unless chris is also covered in class
you need reliable internet
please make sure you have reliable internet
that being said contact me if anything goes wrong
and ensure you start your exam by five ten pm
in order to get the full hour and a half
you guys are gonna do great
do the practice questions go over your class notes
pay attention to what chris highlighted
that's the important stuff
you're gonna do great
and now i'll show you where on canvas it is
so you're in canvas your home your modules
scroll all the way to the bottom
there's midterm exam in the exam section
that's where you want to find it
you can also probably find it in assignments
c
yep midterm exam right there
if anyone has any questions now's a great time
if not chris will go into the review session wait
is lecture eight spectral signatures
no that's lecture nine
so lecture nine spectral signatures
that's the last one that's included
resolutions
the lecture after that is not included
we removed references to numbers in this slideshow
yeah so anything after resolutions don't worry about
anything before resolutions
but not including resolutions that's on the midterm
make sense any other questions go format
sweet sweet
all right cool
good luck everyone
you're gonna do great
i'll see you tomorrow sometime yeah
oh i just closed the wrong one

okay i'll just highlight
one thing that evan went over again
he had a slide about plagiarism
so just a note on that
there are a couple of short answer questions
where you might be able to answer in a brief phrase
you might not need an entire sentence
that's fine
and in that case
you don't need to worry about
answering in your own words per se
because you know
if it's just two or three words
and it's just a two or three word answer
then that's fine
you can use the exact wording that
we've talked about in our lecture slides
whatever it might be
there are a couple questions that require you
to synthesize things
which just means you have to write
a couple of sentences
couple of complete sentences
in order to link some things together
and for those questions
you need to answer in your own words
specifically
just don't copy and paste things from the slides
from the internet
whatever might be
does that make sense
any questions about that
okay see so i'm going to go over map distortions
how to use a marine chronometer
my animations are messed up
i'm going to go in the order
i don't know why
this is just awful that that's appearing like that but
so i'm going to go over map distortions
and then the marine chronometer
how it works
we'll talk about global navigation
satellite system errors

there were some questions on that
we'll talk about the first images acquired from space
and then we'll talk about
i had a question
specifically about the spongy mesophyll
and how it controls spectral reflectance
in the near infrared part of the spectrum
i'll just talk about as a whole
leaf properties and how they influence
the spectral response of vegetation
so hopefully that answers that question
but if you have any questions as we're going through
i'm hoping this will be
you know relatively interactive
if you have extra questions
if you're not understanding things
please let me know
i'm happy to dive deeper to explain further okay
so first thing that i'll talk about is map distortions
to essentially summarize
the different projections we talked about
and how they are distorted
you can more or less just look at this slide
so there's four types of projections that we discussed
conformal projections
equivalent equal area projections
equidistant projections
and compromised projections
generally speaking
we talked about distortions of shape
direction distance and area
shape and direction are more or less analogous
or the same
you can consider
if something has a shape that is distorted
then its direction is distorted
and if something has a direction that is not distorted
then its shape is also not distorted
you can more or less consider those two the same
for the purpose of this midterm and for this course
so when we talk about conformal projections
those are projections where shape or direction
is preserved

a direction on a conformal projection is true
if you look at a conformal projection
and try and get directions with it
and it shows you to take a turn
ninety degrees to the right
then in real life
it would want you to take that turn
ninety degrees to the right
so direction is preserved
because of that
shape is also preserved
so this is a conformal projection up here
one that we often talk about is the mercator projection
the mercator projection preserves shape
so it makes these very
relatively aesthetically pleasing maps
but it distorts area and distance quite heavily
in particular
we talked about how it distorts area
and how because the mercator projection is often used
or has often been used historically
in institutions and education
that it has perpetuated eurocentricism
and we've talked about that in the context of
increased distortion in the mercator projection
as we travel from the equator to the poles
in either direction
specifically
with regards to area
things appear bigger and bigger and bigger
the further we get to the north and south pole
in the mercator projection
than they are in reality
because of that
it perpetuates this sense of european dominance
or of northern hemispherical dominance
on the rest of the world
or greater importance
greater in dominance
greater dominance
whatever you want to consider
you'll definitely see a question about eurocentricism
related to the mercator projection on the midterm

and there are two real key things that we talked about
one was what i just mentioned
the increased distortion of areas
as you get closer to the north and south pole
the other that we talked about is how
in the mercator projection
the prime meridian or central meridian
is often right here the very center of the map
often passing through england
which just makes europe kind of always the center part
or centerpiece of the map
so two key things that we talked about there
i'll leave it there
any questions about that
then we talked about the equivalent
equal area projection
this projection preserves area
it distorts distance and shape or direction
then we talked about the equidistant projection
the equidistant projection preserves distance
generally just from a single point on the map
so in this example that we looked at in class
the distance that is preserved
is the distance from this center point
to any other point on the map
if you try to measure distance from say
over here to over here
that would be incorrect
it wouldn't be proportionally correct
correct but if you tried to measure distance
from the center point
anywhere out to any other point on the map
it would be proportionally correct
equidistant projections do
however distort shape
direction and area
the last kind of projection we talked about
are the compromise projections
compromise projections often look something like this
they can create pretty aesthetically pleasing maps
however none of the map elements
shape direction
distance or area

are preserved in a compromise map
every map element we discussed is distorted
which generally makes it not very commonly used
when you're talking about using compromise maps in
in mapping because it's not very practical
since all of its elements are distorted
but just for the purpose of creating something
that looks aesthetically pleasing
we often might use a compromise map
any questions about that
about map projections
nope okay okay
next thing i wanted to talk about
was the marine chronometer
we talked about the marine chronometer quite a bit
first off wanted to remind you of its significance
why we talked about it
we talked about it because when we talked about
historically
the first methods used
in order to define someone's absolute position
you know mostly in the context of c navigation
we had for finding latitude
celestial navigation
so using say
the north star
for example
and for longitude
we talked about the use of the marine chronometer
so its significance is that it was the first instrument
used to measure longitude accurately at sea
and how it essentially works is the marine chronometer
is really just a very
very accurate clock
one of the you know
for its time
when it was created
the most accurate clock that there was available
for sea navigation
the marine chronometer
would essentially keep track of mean greenwich time
or potentially you know
a different time wherever you were leaving from

but generally
it was mean greenwich time
and so this chronometer
this clock essentially
would just always keep the time
of what it was in greenwich england
it would always just measure
what time it is in greenwich england
no matter where you were
across the globe
navigators could then use
the angle of the sun in the sky
to determine their local time
so they could look up in the sky
and wait for the sun
to reach its highest point in the sky
and say okay
i now know that it is noon
that it is noon because
the sun has reached its highest point in the sky
i know it's noon
exactly where i am
if i then look at my marine chronometer
and i say okay
i know it's noon where i am
but my marine chronometer
with its very accurate clock
says that back in greenwich
it's say you know
two o'clock
then i know okay
there's a two hour time difference there
and every hour difference
is equal to a fifteen degrees difference in longitude
so if i have a two hour difference
that's a thirty degree difference in longitude
that makes sense
any questions about that clarifications yeah
yeah their own clock
they would kind of estimate what time it is
where they are themselves
and say okay
we know that based off the angle of the sun

it's this time where we are
and then our chronometer has the time of
what it is back in greenwich
and then we would just compare the times
between those two clocks
and then work out our difference in longitude from
that make sense
well so yes
i mean there often wasn't you know
literally a second clock
they were just determining what time it was
based off the angle of the sun
and then they say okay we know what time it is here
our chronometer is essentially just a clock
measuring what time it is in greenwich england
cool any questions about that
yeah
this instantaneous moment
i know that i'm here
like i'm absent of position
but i'm not adhering like
oh i traveled like two hours
so i traveled there correct
it's not traveling how far
or how long you've been traveling for
it's just telling you what the time is in greenwich
england then you determine what time it is where you
are based off the angle of the sun
the difference between those two times
is your longitude
any other questions
okay so that's the chronometer
we then talked about global navigation
satellite systems and location findings
we talked about how you can determine
your position using gnss
in a couple of steps
you download the almanac
from a satellite onto your receiver
you download the ephemeris
and synchronize the receiver clock
you measure the change in time
delta t to at least four satellites

for a verified and accurate position
then you determine the range
using that difference in time to those four satellites
and then based off that
you're able to calculate a position of x y and z
now quickly
i know there's always confusion
about what the difference is
between the ephemeris and the almanac
i'll just briefly mention here
the ephemeris is always required to calculate position
you have to have the ephemeris
in order to locate where you are using your receiver
the almanac's not required
you don't need the almanac to determine your position
but it is very useful
because it generally allows the receiver
to find other nearby satellites
for positioning much quicker
the ephemeris gives you detailed information
about the satellite accuracy and health
clock correction coefficients
the orbital parameters of those satellites
so where they're supposed to be in their orbit
and it's valid for only two hours
the almanac is generally much less accurate information
about the satellites and their health
it really is just used to speed up connection
to other satellites
and it's valid for ninety days
so quite a while
you always need the ephemerus
it's only valid for two hours
you don't always need the almanac
but it is useful
and it's valid for ninety days
any questions about the difference between these two
i also had a question about how accurate our phones are
for positioning services
so generally speaking
depending on obstructions or potential causes of errors
our phones are about three to five meters
in accuracy or error for our positioning

the accuracy of our phone
and its ability to determine our location
is influenced by the number and position of satellites
that it's able to get in contact with
by atmospheric effects
by obstructions such as trees and buildings
by the receiver quality
so if you have a newer phone
you might just get a better
more accurate position
and by the potential or ability to have corrections
or post processing
now in general
we talk about or classify
several different kinds of gns errors
as the following here
receiver errors
so just errors associated with maybe having an older
or poor receiver
clock errors
so clock errors
either coming from the satellite or on your receiver
but issues with timing with the clocks
ephemera's errors
so some ephemera's data
that's just outdated or incorrect
tropospheric delays
ionospheric delays
both delays related to atmospheric effects
we discussed how the ionospheric delays
are much more prominent
much more of a larger issue
often the largest source of error
in gnss positioning comes from ionospheric delays
we also talked about multipath errors
where you might have trees or buildings obstructing
the ability for those
waves to come down and reach your receiver
multipath errors specifically
being when that radio wave is bouncing off of
obstructions buildings
then ultimately
bouncing all the way down to your receiver

ok so those are the different types of errors
and how do we actually reduce those errors
there's a number of things that we can do
and we can generally classify them into
before taking our positioning measurements
while taking our positioning measurements
and after taking our positioning measurements
before taking our measurements
we can perform good mission planning
we can go on to some of the websites
that i think you guys have already played around with
or are going to be playing around with
and determine
okay for this specific area or location
where i'm going to go out
and take some position measurements
when is there going to be a lot of satellites overhead
when am i going to get a good level of accuracy
while taking my measurements
i want to make sure i'm remaining in the open
i don't want obstructions
i don't want to be under a very dense forest canopy
or under a bunch of buildings
that's going to make it very hard
i wanna avoid these buildings in tall trees
i wanna take several measurements
so i wanna just stand there
and take lots and lots and lots of measurements
and then average them
if they're all kind of a little bit different
by zero point zero zero zero one meters or whatever
and i average them
then i'll get the most accurate possible measurement
and then i also want to be patient sometimes
because satellites are constantly orbiting
satellites that are maybe not in view of your receiver
will come into view of your receiver
once they've traveled over to a different portion
on the surface of the earth
after taking your positioning measurements
you can engage in post processing
so we talked about differential gps
where you have a base station nearby

that already has a well established position
and you can use that well established position
to correct for potential errors
in the position measurement that you've done yourself
makes sense
any questions
okay see yeah
yeah multipath error
so multipath error specifically is when we have
radio waves that are bouncing off of buildings trees
other obstructions
ultimately bouncing
bouncing bouncing
but then reaching down to our receiver
so they're not traveling
straight from the satellite to our receiver
they're bouncing around
hitting a bunch of obstructions along the way
ok
now we also talked about how we measure errors
or measure accuracy of our positioning measurements
we talked about dilution of precision
we have a good dilution of precision
when our satellites are spread
equally across in the sky
horizontally side to side
and vertically up and down
so you can see here
there's lots of kind of low satellites
lower satellite
medium satellite
medium satellite
nice high satellite
so that's a good vertical dilution of precision
and then we have also
ones that are far out to the right
far out to the left
then kind of middle to the left
middle to the right
that gives us a good dilution of precision
because those satellites are nicely
spread out in the sky
a bad dilution of precision

might come in a situation like this where
all of those satellites are kind of bunched together
these satellites are horizontally side to side
very close to each other
and vertically
up and down
pretty close to each other
that's going to result in a bad dilution of precision
which is going to give us poor accuracy
in our position measurements
there's a couple of different
parts to dilution of precision
we generally classified position
dilution of precision
is the most commonly used measurement
it's a combination of vertical dilution of precision
and horizontal dilution of precision
then we also have time dilution of precision
which is just a measure of the accuracy of our clocks
ok any questions about satellite positioning
accuracy errors dilution of precision
okay yeah yeah
yep exactly
yeah exactly
because you got something that kind of looks like this
as opposed to this yeah
we don't get too much into the details of exactly why
i'm mathematically
but that is right
one more thing
so the difference between different gps and the rdk
was that rdk is like a real time processing
so is there any benefit of
that's the main one cheaper
that's pretty much it
the other made
the other difference that is possible
is sometimes with differential gps
you have a permanent base station
so like a building
something that is always there
whereas with rtk it's generally a rover
that you bring around to your site

where you're doing the measurements
and so just because of that
that's maybe a little bit of extra work
no no it's not
yeah assisted gps mainly just uses cell towers
to connect your receiver to satellites quicker
so it doesn't necessarily improve the accuracy
it just allows you to connect quicker yeah yeah
okay
so one of the things we talked about
when we started talking about
the history of earth observation from space
were the first images acquired from space
so the first images acquired from space
were taken from rockets
the american v two rocket in nineteen forty six
was the very first one
and generally
there were a lot of disadvantages
of using rockets
to take imagery of the earth
but the big issue that we discussed in class
was that rockets would have film on board
which the imagery would be stored on
so it would be just literally a film camera
on the rocket
that would take the image
and then this film
would have to be physically retrieved
so it would essentially get ejected from the rocket
have a little parachute
that it would kinda float down to earth
and then someone
you know in this case the americans
would have to go out and find it
and physically retrieve it
so nowadays
imagery is just sent remotely to ground stations
but back in the day
you had to go out and search
and retrieve these capsules of film
that was a lot of work
so that was a major disadvantage

that we talked about
in terms of rockets collecting satellite imagery
or not collecting satellite imagery
but collecting imagery of the earth from space
questions about that at all
ok think this is the last topic i had to go over today
it's always the one that
students i find struggle with the most
so i will go over in detail
feel free to stop me if you have questions
a spectral signature
is the pattern of spectral response of a material
it's typically visualized with a graph like this
where we have wavelength size along the x axis
and then reflectance as a percentage along the y axis
and it just shows the percentage of radiation
of different wavelengths
reflected from a certain object
and it's important because it essentially
creates and forms the foundation
of multi spectral earth observation
remote sensing
and one of the key things that we do
in earth observation
is take our knowledge of spectral signatures
and differentiate different materials and surfaces
that are on the surface of the earth
based off of what the reflectance is
that we measure from satellites of those surfaces
now we talked in detail specifically
about the spectral response of vegetation and of leaves
and i'll go over briefly here
kind of a summary of those properties
and how they influence the spectral response
of vegetation
so we break our spectral signatures graph of vegetation
into three sections
the visible
the near infrared
and the middle infrared
part of the electromagnetic spectrum
we know that the visible part of the spectrum
is influenced by palicide pyrenkema cells in the leaf

paloside pyrecoma cells
are where the pigments in the leaf are stored
including chlorophyll pigments
chlorophyll pigments have very strong
red and blue visible light absorption properties
which is why we get these kind of
chlorophyll absorption bands
where there's very low reflectance
in the blue and red part of the spectrum
because of that
there's relatively more green light reflected
than blue and red in the visible part of the spectrum
which is why leaves appear green to our eyes
okay then we have
the near infrared part of the spectrum
the near infrared part of the spectrum
is influenced by the spongy mesophyll cells
near infrared light penetrates
through the paloside pyrenkoma cells
down to the spongy mesophyll cells
where because there is so much intercellular air space
in between the different spongy mesophyll cells
near infrared light
repeatedly bounces around all the different cells
within the structure of the leaf
ultimately that near infrared light
bounces out of the leaf
maybe back towards where the light came from
but maybe in a completely different direction as well
because it can then hit another leaf
and interact with that leaf again
by bouncing around its spongy mesophyll cells
and then bouncing out again
there's this repeated effect of near infrared light
reflecting and transmitting off of a leaf
potentially to another leaf
and then to another leaf
and then to another leaf
and then to another leaf
and because of that
repeated reflectance and transmission
and reflectance and transmission
we get this very high overall level

of near infrared reflectance
when we look at leaves or at vegetation
the last part of the spectrum we talked about
was the mid infrared
or shortwave infrared part of the spectrum
there were a couple of different things
that we talked about in detail
about this part of the spectrum
the most important to remember is simply that
when we have a leaf that has an increased water content
so a wetter leaf
there is going to be lower
mid infrared reflectance overall
when there is a drier leaf
there is going to be a higher amount
of mid infrared reflectance overall
that's really the key there
now we also talked about the absorption bands
and we talked about how
at longer wavelengths
water absorbs more strongly than at shorter wavelengths
in the mid infrared
we talked about those as well
but what's most important for you to remember
is just that when leaves are wetter
they will reflect less mid infrared light overall
when leaves are drier
they will reflect more mid infrared light overall
okay so i have these two summary slides
to kind of just summarize all of that
in the visible part of the spectrum
the various leaf pigments in the paloside perenkoma
such as the chlorophyll and keratins and other pigments
dominate the spectral response of leaves
in the visible part of the spectrum
in the near infrared part of the spectrum
the scattering
or the repeated reflectance and transmission
of near infrared energy in the spongy mesophyll
is what dominates the reflectance pattern we see
in the near infrared portion of the spectrum
in the mid infrared portion of the spectrum
the reflectance pattern we see

is dominated by the amount of water in the plant
to dive a little bit deeper
in the visible part of the spectrum
chlorophyll pigments dominate and absorb
very strongly visible blue and red light
when the leaf is healthy
other pigments such as carotene xanthophylls
are generally always present in the leaf
but when the leaf becomes unhealthy
and those chlorophyll pigments are no longer dominant
there's no longer that strong absorption
in the blue and red part of the spectrum
so there's a higher level of reflectance
in the red and yellowish parts of the spectrum
which is why in fall for deciduous trees
we get their leaves appearing yellowish and reddish
and eventually brownish when they die off
in the near infrared portion of the spectrum
there's high near infrared reflectance
when leaves are healthy
because there's this nice healthy leaf structure
of spongy mesophyll cells
that are nicely spaced around
with lots of intercellular air space between them
when leaves are unhealthy
they have lower near infrared reflectance
because that structure of those cells
starts to break down
and you no longer get that repeated effect
of reflectance and transmission and bouncing around
of the spongy mesophyll cells
or of the near infrared light
in the spongy mesophyll cells
or in between them
i should say
so lastly mid infrared portion of the spectrum
higher water content
just want to make sure i'm recording here
bam thank goodness
higher water content results in lower
mid infrared reflectance overall
well lower water content
results in higher mid infrared reflectance overall

so that is ultimately why
we get a spectral signature pattern
that looks like this
we get that strong blue and red absorption
from the chlorophyll when the leaf is healthy
thus relatively speaking
more visible green light
then we get that very characteristic peak
in the near infrared part of the spectrum
because of the spongy mesophyll cells
the ability of the light to bounce around
between the spongy mesophyll cells
and then the repeated reflectance and transmission
between leaves
in the forest
or in the canopy
or in the trees
and then in the mid infrared part of the spectrum
we get an overall much higher level
of mid infrared reflectance when the leaf is drier
and an overall much lower level
of mid infrared reflectance when the leaf is wetter
any questions about that
okay last thing i want to go over is just a reminder
because we just had the resolutions lecture
what you need to know for the midterm
about each of the satellite programs we discussed
it's not too much
so for modus
you just want to remember
that modus gives us fine temporal resolution data
and coarse spatial resolution data
so it has very large relatively large pixel sizes
and can revisit
any point on the earth every one to two days
lancet you need to know it's the oldest program
dating all the way back to nineteen seventy two
it gives us a moderate spatial resolution
at about thirty meters
and a moderate to fine temporal resolution
with a sixteen day revisit time
worldview we briefly talked about
you just need to know that it is the finest spatial

resolution satellite data that we have available to us
and that is private
which just means it's expensive
it costs money
lastly we briefly mentioned icesat
all you need to know is that it uses lidar
don't need to know what lidar is
just know it uses lidar
we'll talk about what lidar is after the midterm
and just know that it's used to image ice
clouds and elevation
that's what ice stands for in icesat
ice cloud and elevation
ok any questions
anyone wants me to go over with the whole class
otherwise i'm happy yeah yeah
so that would generally
that would be either the landsat or modus program
potentially worldview
but really just any spectral or optical sensor
any satellite sensor that's using
parts of the near infrared or visible red spectrum
you can use to get those indices
so it doesn't really matter too much
specific two way satellite
but of the ones we've talked about
lidar is really the only one
you couldn't do that with
so therefore isat
you wouldn't be able to get that information from
ok yeah yeah
what's ndvi used for
so ndvi the normalized differenced vegetation index
is used to measure the health of vegetation
the greenness of vegetation
as well as just vegetation cover across the landscape
those are the key things it's used for
it can be applied
in a variety of different ways on top of that
but that's ultimately what it's used to measure
but it can be used for crop forecasting
for understanding the health of forest
for understanding habitat of wildlife

so it can be applied in many ways
but that's what it's ultimately measuring
okay if you want to head out you're welcome to
i'm happy to stick around
if any of you want to come up and ask me any questions
otherwise good luck on the midterm tomorrow
have a good reading break
and i will see you after the break
alright hi everyone
welcome to your last cons one to seven class
ah there we go
lovely okay
hopefully this will be useful for you guys
i've kind of gone off
i got a decent amount of posts on the discussion board
which is great
so i've kind of gone off that for what to go over today
i'm going to start by going over again the exam format
just to remind you guys
in case you have any questions about that
and then we'll dive into the review
we'll go over a couple topics
that were posted on the discussion board
i do have julia here today
if you have questions about simon seven
otherwise you know she has lots of office hours
this week and next week still
but if you do want to talk to her while she's here
that's fine too
so i'll get her to come in right as we finish class
okay uh so just reminder due dates
so blog post five do this thursday
and then assignment seven
blog post six do next thursday
april thirteenth
julia has office hours later this week
and then twice next week as well
okay final exam
here we go one more time
just to remind you guys
it's thursday april twenty seventh at seven pm
don't know why they gave us such a crappy time
they give me a crappy time every single semester

they just they don't like me very much i guess
um so it's two hours long
it's from seven pm to nine pm
there's a ten minute buffer from when you open
and close the exam
so that means that the exam will open at six fifty pm
and it'll close hard at nine ten pm
but no matter when you start it
you'll have two hours to complete it
so if you start it at
six fifty pm
it'll close at eight fifty pm
but no matter what
it'll close at nine ten pm
so if you start it at eight pm
it'll still close at nine ten pm
it's through canvas
it's online it says
i think i just checked on ssc or whatever it says
for location
it says c prof
and then in brackets was src or something like that
they really just like to confuse you guys
and they really annoy me
because i said please remove the location
it's an online exam
i told you guys
it's an online exam
remove the location
and their solution to that was just to change it to c
prof but was in src
which is probably even more confusing
so sorry about that
it's online
it's fully online
it's on canvas
there's no in person component anywhere
so don't show up in person
if you have any technical difficulties
while you are writing the exam
you can email evan
if you do have technical difficulties
while writing the exam

email evan right away
don't wait until the exam closes
to email him and say hey
there was an issue
i didn't get all the time i was supposed to
if there's an issue
as soon as it occurs email him
because we can tack on extra time
while you're writing the exam
but it's much more difficult to reopen it
after it's been auto submitted
once the time is expired
so if you have an issue
just email evan right away ok
there's forty multiple choice questions worth one point
five marks each
so sixty points total
some will have graphs
or pictures that you have to interpret
not many maybe about
i think five or six
there's one matching question worth four points
so it's kind of like there's eight little parts to it
so each worth half a mark essentially
so one marking question worth four points total
there's six short answer questions
each requiring one very brief paragraph
maybe four lines five lines maximum
each worth six points as well
so for a total of thirty six points there
just make sure i'm recording here
okay the exams open book
questions will appear one by one
just like the midterm
they'll appear in a random order within groups
so multiple choice first
matching second
short answer last
you won't be able to return to any questions
after completing them
question will pop up
you'll put in the answer
we'll go on to the next one

it'll go on to the next question
you can't go back
to any previous questions
final has to be done individually
you can't work together
you can't answer answers
you can't discuss answers
extra time for a amp d students
is added to their canvas profiles automatically
so you should see that reflected in the closing time
of your final if you're an a amp d student
and then you'll also have an extended deadline
to accommodate the extra time as well
so if you're an a and d student
your time should already be applied
you shouldn't have to email us or anything
if by chance you start the exam
and you're an a amp d student
and the timer doesn't look right
it doesn't look like you
have as much time as you're supposed to
again just email evan right away
we'll get it sorted right off the bat
ok in terms of pre and post midterm content
there's about a forty sixty split
for the multiple choice and matching
so about forty percent of it is pre midterm
about sixty percent of it is post midterm
for the short answer questions
one of them is pre midterm
two of them are post midterm
and three of them are kind of whole course
they incorporate
topics and concepts from multiple lectures
both pre and post midterm
and kind of force you to link together
different things that we've talked about
okay the finals
worth forty percent of your overall grade
there's practice questions posted on canvas
we don't provide
any answers for those practice questions
but if you're unsure about any

you can post in the final exam discussion board
and evan or myself will answer
tell you whether you're on the right track
what needs to be improved
the final includes all lecture content
assignment material that's not covered in lecture
will not be on the final
so i say that just to say i often get the question
are assignments covered on the final exam
in kind of a strict sense no
but in a more general sense
if it's a topic that we've covered in lecture
that occurred on the assignment
then sure it might be in the final exam
but that's because we've talked about it in lecture
that makes sense okay
please post in the final discussion board
for questions about the final
if you have any questions concerns about content
about format
feel free to discuss with each other
answer each other's questions
myself and evan will also monitor that
that's the best place to go to ask questions
if you're studying
and you can't figure out an answer to something or
yeah anything like that
just post on the final exam discussion board
okay you need reliable internet
please make sure you have reliable internet
during the final exam period
we can't be reliable for your internet connection
again if you have an emergency during the exam period
contact evan right away
we won't answer any questions related to content
we'll help you with a technical difficulty right away
but if it's a question related to
the actual content of the exam
then we'll just respond and say hey
we can't answer this again
if your exam opens at eight
it'll still close at nine ten pm
it'll close at nine ten no matter when you start it

and if you start it earlier than seven ten pm
you'll still only have two hours to complete it
ok no plagiarism
plagiarism will give you a zero on the final
you can't copy and paste sentences from the slides
or the internet and you must answer in your own words
don't copy work of your neighbors or classmates
copy and pasting and changing a few words
still plagiarism
so please just make sure you answer in your own words
i always get questions or concerns about this slide
and i'll try to clarify with a couple more details
the concern about plagiarism on the exam
is really just with the short answer questions
obviously we can't really
in a strict sense
monitor plagiarism on the multiple choice questions
we try to reduce it by the format of the exam
by only having one question pop up per time
and by it being random questions popping up
we try to limit your ability to kind of plagiarize
and work together with the final
with the short answer questions
it's a little bit more difficult to monitor that
and i am aware that for some of the questions
maybe you only need to answer
a short phrase or something or a list
and kind of inherently
that's going to be copy and pasted from the slides
that is fine
if it's you know a list
if it's kind of direct fact
relating to something that we've discussed in class
that's fine
this really relates to
the questions that are a bit more application based
that are really requiring you to link topics together
that are requiring you to maybe
give your own opinions and thoughts
those are where we really want you to answer
in your own words
and so please be aware of that
and that's where we want you to focus with that

does that make sense
you can still use notes
internet whatever
to answer the questions
you can read and comprehend whatever you want
but you still have to type out
your answer in your own words
if you you know
take something over
you change a couple ands and ors or whatever
change the order of the sentence
that still constitutes its plagiarism
so just try and avoid that
does that make sense
any questions about that
sweet
if you do the practice questions
you go over class notes
you take note of what i've highlighted during lecture
as well as the end of the lecture
with the practice questions and the final exam
practice questions we've posted
you're going to do great
that covers the vast majority of anything
that you're possibly gonna see on the final exam
i don't try to trick you with the final exam questions
it's all stuff that we've covered
it's all stuff that i've highlighted is important
so you're gonna do great
don't worry about it
all good sound good ok
so i'm going to go over for the review
a couple topics that
were posted on the discussion board
going to talk about map projections
orbits briefly
spectral signatures and ndvi
just briefly
talk about active versus passive remote sensing
and then some data types
applications
and advantages of earth observation
so i'll use the cryosphere as an example

but it could kind of be applied to
any of those topics we talked about
whether it's biosphere
oceans and fresh water or wildlife
but i'll kind of focus on the cryosphere
as a specific example
i can't it's hard for me to go over
every single one of those in detail
for all of those
because that's essentially me
kind of just giving each of those lectures
start to finish again
but i'll kind of go over
synthesizing
you know data types
applications
and advantages of earth observation data
for just as an example
the crysphere
and then i'll end kind of linking that
potentially giving you some ideas
for the other topics we talked about
like the biosphere
like oceans of freshwater etc
and then lastly
i mention three of the short answer questions
kind of require you to link topics
together to bridge concepts between different lectures
to bring together
information from pre midterm and post midterm
and i'll kind of try to talk about in a bit more deal
i can't give away what the questions will be
but i'll try and kind of explain what i mean by that
in a bit more detail
and then look at um
an example question of that
that was posted on the discussion board
that was just taken from the end of one of my slides
as an example question
but it kind of is close to an example of
of this idea of having a question
that forces you to link together multiple lectures
and topics from both pre and post midterm

okay so let's talk about projections first
first off let me just say
projections are confusing and weird and funky
so if you have had
you know trouble wrapping your head around projections
and how they work and what they are
that's totally understandable
that's totally fair
even very advanced
earth observation data users are still
perplexed and confused by projection so
don't be concerned if it's a confusing concept for you
there's really
two kind of key categories of information
you need to know about projections
and that's essentially just how we classify
the different kinds of projections that are out there
one of the ways that we can classify
the different kinds of projections
is based off this type of surface
that the map or that the globe is projected onto
so you can project the globe
onto a cylindrical surface
onto a conic surface or cone
or onto a planar surface
so cylindrical projections
are where the earth is projected onto a cylinder
which creates whole world maps
that are rectangular
and distortion is really heavy towards the pole
so that's like the mercator projection
for example
conic projections
is where the earth is projected onto a cone
it's good for representing parts of the earth
but not necessarily all of the earth
and planar projections
is where the earth is projected onto a plane
and there's a particularly large amount of distortion
in planar projections
towards the edge of the projections
all you really need to know about the different classes
the different types of projections

in this case
is that one of the ways we classify them
is based off the type of surface
the globe is projected onto
whether that's cylindrical
konic or planar
the other way we talk about projections
is based off what is being distorted
and what is being preserved in that projection
there's four categories that we generally talk about
first is conformal projections
conformal projections are any projection
where angles between positions are preserved
makes it really convenient for c navigation
that's why these projections were developed
so that if you got a heading on the map
it was a true heading in real life
but it has a high amount of distortion
of countries and continents
areas or size
an example of that again is the mercator
now you'll notice that
i mentioned the mercator in the last slide as well
that's because the mercator happens to be a cylindrical
conformal projection
it is a cylinder that is used to project the globe onto
in the case of the mercator projection
and in the case of the mercator projection
it's conformal angles are preserved
the reason that we talk about
the two different ways we can classify projections
aka the type of surfaces you can project onto like this
or the type of distortions that you can have like this
such as conformal
is because a cylindrical projection
is not always necessarily a conformal projection
and a conformal projection is not always necessarily
a cylindrical projection
the mercator projection is a unique example
where it is a cylindrical conformal projection
but these can be mutually exclusive
so the type of projection it is based off its
preservation and distortion of different map elements

such as angles
such as size
such as distance
is a different way that we can classify projections
from just the type of surface
the globe is projected onto
like is the case with this
so conformal projections
angles are preserved
area and distance is distorted
particularly increasing towards the poles
in an equivalent equal area projection
the area of countries and continents is preserved
the size of them is preserved
but the angles are distorted
and thus the shapes of the continents
and countries are distorted
example of that is the mallweed
or the gal peters projection
then we have equidistant projections
all distances from a single point are correct
in this case and most commonly equidistant projections
that common point is the very center of the map
so in this example
any distance measurement
from the very center of this map to anywhere else
is proportionally correct
but if you say
try to distance measurement from here to here
it would not be correct
so any distance measurement from the center of this map
to anywhere else is correct
otherwise it's not correct
an example of an equidistant projection
is the azimithal equidistant projection
lastly we have the compromised projections
that has a balance of the different distortions
of both shape and area and distance
produces quite visually appealing maps
but none of the metric properties of this map
are proportionally correct
area distance and shape cannot be measured accurately
with a compromised map

it just gives us something that is aesthetic so again
two ways that we can classify our map projections
the different types of surfaces
that we project the globe onto
these three here cylindrical conic planar
or based off what element of the map
what metric property is preserved
conformal angles are preserved
equivalent equal area area or size is preserved
equidistance distance is preserved
typically just from one point
and then compromise
nothing is preserved
everything is distorted
make sense
so we talked about four different key types of orbits
before the midterm
talked about low earth orbits
close elliptical orbits
far elliptical orbits
and geostationary orbits
low earth orbit
so the closest to earth
we talked about the international space station
as well as potentially
some other earth observation satellites
being in low earth orbit
we talked about the close elliptical orbit
which mostly has earth observation satellites in it
we talked about the far elliptical orbit
which mostly has gnss
or global navigation satellite systems in it
and then we talked about geostationary orbits
mostly used for weather satellites
now i wanted to clarify
because i know it's always a little bit confusing
the difference
because we then talked about polar orbits
and sun synchronous orbits
as soon as we're talking about polar orbits
or sun synchronous orbits
we are specifically talking about
distinct kinds of close elliptical orbits

so as soon as you see polar orbit
or sun synchronous orbit
you don't need to be thinking about low earth orbit
far elliptical orbit
geostationary orbit
don't think about those anymore
polar orbit or sun synchronous orbit
are specific types of close elliptical orbits
so the close elliptical orbit
is defined by its altitude
at an altitude of about
seven hundred to two thousand kilometers
the polar orbit is a close elliptical orbit
that has a particular orientation
the polar orbit
is oriented
such that the satellites pass over
or very close to
the north and south pole
so a polar orbit is just a close elliptical orbit
with a specific orientation
such that the satellites pass over
close to or right above the north and south pole
the sun synchronous orbit
is a specific type of polar orbit
so the sun synchronous orbit
is a specific type of polar orbit
which is a specific type of close elliptical orbit
so the sun synchronous orbit
is defined as an orbit
that passes over the equator
at the same time each day
landsat for example
passes over the equator
at ten to ten thirty am local time
every single day
as such it also passes over
any exact same point
on the earth
at the same local time
each time it passes over it
and we do that so that we can kind of control
for potential variation

in the angle of the sun
when we're collecting
earth observation
remote sensing imagery
so the purpose of the sun synchronous orbit
is so that if we're taking an image
of a point on the earth
the same exact point
at the same local time
every time we take it
that eliminates some of the potential variation
associated with taking an image
at the same point
across different times of the day
so a sun synchronous orbit
is a specific type of polar orbit
and a polar orbit
is a specific type of close elliptical orbit
so by nature
is a sun synchronous orbit
a close elliptical orbit
it's where you all go yes chris yes
no okay i get it
last class it's all good
okay yes is the answer
sunstringness orbit is a type of close elliptical orbit
okay let's go on now
a briefly kind of summarize
some of what we talked about
in the electromagnetic spectrum lecture
so kind of the first thing we talked about
were radiation fundamentals
we talked about how the photon is kind of the unit
or discrete package
the smallest kind of package of light
that we can describe
or radiation
and we can often describe
the characteristics of photons of light
of radiation of energy
using this equation
c equals lambda times v
where c is a constant

c never changes to the speed of light
c is always the exact same
three point o times ten to the eight meters per second
it's always constant
lambda and frequency
v will potentially change
depending on the type of radiation you have
lambda is wavelength size
v is frequency
lambda and frequency
wavelength size and frequency
are inversely proportional
as wavelength size decreases
frequency increases
as frequency increases
energy associated with those photons
with that radiation increases
so larger wavelengths
lower frequency
less energy associated with those wavelengths
with that radiation
with that light
we then talked about different portions of the spectrum
talked about radio waves microwaves
ultraviolet waves
infrared waves
visible portions of the spectrum
we discuss kind of their approximate wavelength sizes
the range of each of those wavelength sizes
for different portions of the spectrum
and then their level of use in earth observation
remote sensing
do we use x rays very often in earth observation
remote sensing
no we do not
do we use near infrared very often
in earth observation mode sensing
yes we do so
that kind of stuff
and the last thing we talked about
was surface interactions
so just that when light
when energy and radiation

hits a surface on the earth
it is either reflected
transmitted
or absorbed
it has to go into one of those three domains
of interactions
any radiation that hits a surface of the earth
is either reflected
transmitted
or absorbed
in some proportion
maybe it's a hundred percent absorbed
and zero percent transmitted and reflected
maybe it's fifty percent reflected
and then twenty five percent transmitted
twenty five percent absorbed
but a hundred percent of the incident radiation
of the incoming radiation
is either reflected
transmitted
or absorbed
ok i'm going to talk about spectral signatures and ndvi
in a lot of
in kind of more detail
than i will with a lot of the other topics
partly because i know it's a difficult
topic for students to wrap their heads around
partly because there were some posts about it
on the discussion board
and maybe just maybe
there's another reason
why i'm going over this in detail
maybe
okay
take a hint
so a spectral signature
is the pattern of spectral response of a material
it's typically visualized with a graph
showing the percentage of radiation
of different wavelengths
reflected from an object
so here we have various spectral signatures
plotted for different materials

we got the spectral signature of water
the spectral signature of green vegetation
and the spectral signature of soil
a spectral signature inherently
can describe
the spectral response
of a material
across really any range
or any kind of portion of the electromagnetic spectrum
oftenly or often times
we only show the visible
near infrared
and mid infrared
because that's what we commonly use as bands
for detecting and measuring
in earth observation remote sensing
but by definition
a spectral signature
can cover any portion of the electromagnetic spectrum
we often just show visible
near infrared and mid infrared
now by plotting spectral signatures
of different materials together
like we've done here with water
vegetation and soil
the portions of the spectrum
where their signatures differ
can be easily identified
we can look at this spectral signature of soil
green vegetation and water
and say okay
right on the edge here
a visible red light and near infrared light
we can see that vegetation
has a high level of reflectance
soil has a medium level of reflectance
and water has very
very little reflectance
using that knowledge
we can measure
the radiation reflectance
of different surfaces of the earth
with remote sensing instruments

with earth observation satellites
and we can use that information
of their spectral signatures
to say well
according to these measurements
this area is probably soil
or this area is probably green vegetation
or this area is probably water
and we can say that because we measure
near infrared reflectance over an area
and we know that near infrared reflectance is very high
for green vegetation
so if we measure a high amount of
visible green reflectance
then we sorry
of near infrared reflectance
then we can say okay
that area is probably vegetation
if we measure
near infrared reflectance in a particular area
and we see that the reflectance is very very
very very low
then we can say okay
that's probably water
this process forms the basis of earth observation
remote sensing
because it's how scientists are able to differentiate
different surfaces of the earth
using multi spectral satellite data
by measuring the reflectance of different bands
across the surface of the earth
we can differentiate different materials
on the surface of the earth
by relating those measurements
to the known spectral signatures
we have about those different materials
now ndvi is a vegetation metric or index
derived from spectral remote sensing data
and in terms of vegetation
it tells us how healthy or unhealthy vegetation is
it measures how healthy or unhealthy vegetation is
and it takes advantage of
two different spectral signatures

takes advantage of the spectral signature
of healthy vegetation
and the spectral signature of unhealthy vegetation
the spectral signature of healthy vegetation
looks something like
low red visible reflectance
high near infrared reflectance
the spectral signature of unhealthy vegetation
looks like this
much lower near infrared reflectance
relative to healthy vegetation here
and proportionally
a little bit more visible red reflectance
than what you see here
so this kind of boom goes up to here
and this boom drops down to here
boom from there to there
if we're looking at unhealthy vegetation
this is the equation for ndvi
near infrared reflectance minus visible red reflectance
divided by near infrared reflectance
plus visible red reflectance
and it's a commonly used spectral
or passive remote sensing satellite system or sorry
it's commonly used with spectral
or passive remote sensing satellite systems
that we talked about in class
like landsat like modus
these instruments have bands
measure reflectance in portions of the spectrum
such as near infrared and visible red
which allows us to use those satellites
to derive the ndvi metric
which essentially again
tells us how healthy or unhealthy vegetation is
so if we look at a spectral signature here
of healthy vegetation
and then we look at the bands of say
lancet at seven
we know that lancet at seven has a band in the visible
red and in the near infrared
we again know that with ndvi
we use reflectance in the near infrared

and the visible red
in order to derive that metric
in order to measure vegetation health
okay so just to compare again
the spectral signature of healthy vegetation
on the left here
the spectral signature of unhealthy vegetation here
on the right
again red when it's healthy vegetation
very low reflectance
but very high near infrared reflectance
when vegetation is healthy
when vegetation is unhealthy
much higher visible red reflectance
much lower near infrared reflectance
this is the spectral signature
that ndvi takes advantage of
because we see low red reflectance
and high near infrared reflectance
for healthy vegetation
we get a high ndvi value
because we see higher red reflectance
and lower near infrared reflectance
for unhealthy vegetation
we see a lower ndvi value
so ndvi takes advantage of the difference in visible
red and near infrared reflectance
for healthy versus unhealthy vegetation
any questions about that
i'm drilling it for a reason again
hanging in there
next thing i want to talk about
is active versus passive remote sensing
so want to clarify a couple terms
in case you are using them on the final exam
i've kind of tossed around terms that maybe
you guys haven't differentiated in your minds
so passive remote sensing
spectral remote sensing
or spectral information
and optical information
so passive by definition
a passive remote sensing instrument involves radiation

naturally being emitted from the sun
bouncing off of the surface of the earth
and being measured by the instrument
spectral information relates to our ability with say
a passive remote sensing system
to measure different bands across the spectrum
to measure reflectance
of different bands across the spectrum
so a higher amount of spectral information means
essentially
that you have more bands
a larger portion
of the spectrum being measured
and then lastly optical
optical essentially means visible
so if you're using the term optical
then it essentially refers to
anything measuring visible light
optics it's how things are actually viewed
so optical data essentially means
data in the visible portion of the spectrum
spectral data means information across
the electromagnetic spectrum
and passive data
passive remote sensing means any data collected
based off of radiation
naturally being emitted from the sun
hitting the surface of the earth
and then being measured by the sensor
oftentimes those things kinda overlap
because passive sensors
often give you a large breath of spectral information
including optical data
but they are technically different
so i just want to clarify those
in case you're using those terms on the exam
okay just to drill home
difference between passive and active remote sensing
passive remote sensing is
when energy is naturally emitted from the sun
energy is reflected off the surface of the earth
and then that reflection is measured by the sensor
active remote sensing produces their own energy

from the sensor
from the instrument
that energy
that radiation travels towards a target
bounces off that target
and then the sensor detects and measures
that reflected radiation
ok some advantages and disadvantages
of active remote sensing advantages
active remote sensing are often weather independent
not all though
radar is weather independent
lidar is generally not so
lidar is typically
not able to see through clouds radar is
it is however
in both the case of radar and lidar
sunlight independent
you don't need to have radiation
being emitted from the sun and bouncing off the earth
in order to collect active remote sensing data
so you can survey at any time of the day
and you can control what energy you're omitting
you can use near infrared
or visible red or visible green whatever
microwave radiation if you want
whatever wavelengths you desire
it potentially can penetrate vegetation soil
ice and snow
and give you information on surface layers
and structure
note there again
key difference there between radar and lidar
radar can penetrate through surfaces
lidar cannot
lidar can give you three d structural information
but lidar cannot actually
penetrate through materials radar can
to disadvantages
it gives you limited spectral information
because you're essentially only emitting
and measuring one single wavelength
it's a much more complicated analysis

than traditional passive remote sensing systems
and they are often more expensive
okay important note
some advantages or disadvantages
mostly advantages only apply to specific sensors
or specific types of active remote sensing
so for example
active remote sensing systems that
are weather independent
that can see through clouds
is only true for radar
it's not true for lidar
in an exam setting
if i ask you
what are some of the advantages and disadvantages
of active versus passive remote sensing
if you do not specify this
if you do not clarify this
then you won't get full marks
so if i ask you
what are the advantages of active remote sensing
and you say whether independent
but you don't specify that that's only true for radar
then you won't get full marks
ok
had a request to quickly
summarize some of the topics from the biosphere lecture
so the biosphere
we started off by talking about what the fundamental
driver of the biosphere is
which is essentially photosynthesis
we talked about measuring photosynthesis with
gross primary productivity and net primary productivity
and then we talked about some of the factors
that could affect gpp and mpp in detail
we talked most about temperature
and how temperature can affect gpp and mpp
and how gpp and mpp change as temperature increases
we then talked about how we measure gpp and mpp
with earth observation data
we mostly focused on modus
then we talked about carbon sinks and sources
we talked about what carbon sinks are

what carbon sources are
so sinks being things that take
carbon out of the atmosphere more than they release it
sources being things that
produce or give carbon to the atmosphere
more than they sequester it
then we talked about dynamic sinks and sources
forests for example
if a forest is burning
then it's kind of more of a source
but if it's a forest that's growing
that's healthy
it's more of a sink
and then we talked about how we can measure
these changes in carbon sinks and sources
using earth observation data
we talked about measuring biomass with lidar
using the structural three d
information you can get from lidar
we talked about using landsat
to detect and map disturbances like wildfires
like logging and forest harvest
to be able to quantify
some of these carbon sinks and sources
and be able to get a sense of our carbon budget
and carbon cycles all across the world
okay in class
we often talked about kind of four main data types
data sets sensors satellites
we talked about lansat
motors radar
and lidar in really the most detail
we talked about some other ones too
that you'll see kind of
maybe a little bit on the exam
but you'll see more
or a heavier weighting of questions towards lancetap
modus radar
and lidar so
i'm going to use the cryosphere as kind of an example
so in the case of the cryosphere
what kinds of data
can we get from each of these sensors

lancetap modus
radar and lidar
and what are some of their applications
then i'll end talking about
what are some of the advantages
of using earth observation to monitor the cryosphere
okay so landsat and modus
inherently give us spectral data
they give us multi spectral data
they give us measurements of reflectance
across various bands in the electromagnetic spectrum
so when you think of that
when you think
you know spectral data
when you think about llandstat and modus
think spectral signatures
think about differentiating different materials
based off knowledge of spectral signatures
so for example
with lancetta and modus
we can differentiate different craft spheric materials
the types of applications of landsat and motives
are mostly specific
to their spatial and temporal resolutions
so landsat has that moderate
thirty meter spatial resolution
it's best for differentiating
different cryspheric materials
in kind of regional or moderate sized areas
because of that finer spatial detail
so it can be used for things like
ice and snow type mapping
in specific glaciers
or in specific mountain ranges
it's not super practical
to map snow coverage
across the whole world
using something like landsat
makes more sense to probably use modus for that
if you're looking at more of a regional scale
specific mountain range
a specific group of glaciers
all kind of together

and you want a higher level of detail
of the different types of ice and snow
in those particular areas
landsats probably the satellite you want to use
modest on the other hand
has that fine temporal resolution
of one to two days
so it's best for either tracking things
at a global scale
because as that coarser spatial resolution
or for tracking things
that might change on a daily basis
so we for example
look that ice sheets breaking off in antarctica
something that really
in terms of a spectral dataset
in terms of passive remote sensing
something only modus could track
because it was changing on a daily time scale
if something's changing daily
we can't really
track it with landsat
because we only get a landsat image every sixteen days
radar can give us information on backscatter
and ranging
backscatter is the strength
of the radiation that bounces off the target
which can be used for things like estimating snow mass
estimating ice cover
and that's because the different levels of snow mass
or ice cover
will result in a different backscatter
will result in a different level of intensity
of microwave energy being reflected back to the sensor
ranging is how far the target is from the sensor
and that can be used for things like
quantifying soil stability
for mapping ice flow
so the ranging kind of gives us that three d
level of information
so we can see how shapes of surfaces might be changing
because we can get things like topography
we can get three dimensional information

using ranging measurements
so from radar
we can get backscatter or ranging measurements
sometimes both
and we'll combine them
backscatter has to do with the strength
of the signal returned
ranging has to do with how far away the target is
and each of those might have different applications
again one of the unique things about radar
is its ability to penetrate below the surface
pardon me are you on the phone at the back there
are you on the phone you gotta get out out please
okay i gotta be honest
the only reason i did that is because
when i was in first year i did the same thing
and the prof kicked me out so
you know i learned my lesson she'll probably learn hers
okay so one of the super unique things about radar
is that it is able to penetrate below the surface
so in the case of the cryosphere
for example
it can be used for understanding snow and ice layers
below the surface
which can be potentially used
to gauge and measure things like snow
ice and age
different types of snow and ice layers
that exist below the surface
and maybe where water tables lie below the surface
or where the bedrock is below the surface
so with radar
we can penetrate below the surface of the ice
and get measurements of the different surface layers
below the very very top
we can see how deep is the water underneath this ice
or how deep is the bedrock underneath this ice
things like that
again only radar is capable to actually
penetrate the surface
spectral or passive remote sensing data sets cannot
lidar cannot
however lidar does give us high resolution

three dimensional information
again it does not penetrate the surface
but we can get high resolution
three dimensional information
and we talked kind of in general
about two types of data that we can get with lidar
the terrain or topography information
generally in the form of digital elevation models
or dems as well as the vegetation
structural information
we can get to kind of build up the models
of what the structure of trees might look like
now in the case of the craft sphere
really only the terrain information
is helpful for measuring and monitoring ice
there's not much structural information
that we can derive
but we can get really high resolution
three d sea ice topography
and terrain measurements
which can be really helpful
for understanding things like melt patterns
we can get a sense
for sea ice elevation above sea level
so often times
icesat for example
as its orbiting
will take really high resolution
three d measurements
of the surface of the ice
and then relate that to what the sea level is
to then get a measurement of how deep the ice is
again lidar
not penetrating the surface
even if it's measuring how deep the ice or snow is
it's measuring
in this case
in the case of lidar if it's measuring ice depth
it's just measuring where the top of the ice is
and then is relating that to some other
sea level measurement
only radar can actually penetrate through the surface
make sense

so depending on the data set advantages
in kind of the context of the cryosphere
you get a standardized data collection
so we talked about how
historically
cryospheric information was derived from field data
from digging snow pits
from using ablation stakes
kind of a subjective process
lots of human error involved
um people might take different measurements
different ways
so it's not a standardized way to collect data
we also talked about historical
either aerial or terrestrial imagery or photography
again potentially
people could collect that data in different ways
so earth observation
particularly in the case of landsat and modus
these satellites or even icesat
are very very standardized
they always collect the exact type of data all the time
so you always have just a standard
data set to work with
also allows for really efficient data collection
going out historically
and measuring or taking photos of ice on foot
not very efficient
you gotta get a plane
you gotta hike out there
takes a lot of time
takes a lot of resources
not an efficient way to collect data
with satellites or with airborne radar or lidar
very very efficient data collection
coverage is very very high
we can collect data over a large area very
very quickly
and that kind of just brings us to that next point
which is just coverage as a whole
it's hard with field data
or with historical terrestrial or aerial photography
to get good coverage

to get imagery or data covering a large area
with remote sensing with earth observation data
we can get a large amount of coverage very easily
potentially globally every single day
if we're talking about same mode as for example
and lastly you can get different kinds of information
that might have different advantages
associated with them
depending on the resolutions
of the instrument or data
you're using
for example
with landsat
we have that moderate spatial resolution
that gives us a
moderate to fine level of detail about the cryosphere
about ice about snow
with modus maybe we don't have that same
fine to moderate level of spatial information
but we can get global daily estimates
again something that's very advantageous
something that you can't do with terrestrial
photo photography
or aerial photography
or field data
that requires digging pits or using ablation stakes
so that's a couple examples of kind of
advantages of earth observation
specifically for the cryosphere
there's also ones
that would be specific to the biosphere
specific to oceans and freshwater
they wouldn't really be any different
in the sense that it's still all about
standardized data
efficient data collection
good coverage
potentially different advantages
associated with the different resolutions of your data
but they maybe just be kind of fine tuned
specific to that topic
so for the cryosphere that i just talked about
i was relating all of that to kind of

historically
how we've collected data right
ablation stakes
snow pits terrestrial photography
aerial photography
so with say
oceans and freshwater
you would then kind of relate
your answer to a question like this
to that topic
so for example
with oceans
you know historically
measuring sea surface temperature
we use boys right
boys or people that were in boats
that were taking measurements out there
boys don't give us good coverage
they're only a single point measurement
so they might have a really good temporal resolution
they might collect sea surface measurements
every couple of minutes
every couple of hours
but you only get a single point measured
with earth observation data
you get much
much much larger coverage
again potentially globally
every single day
depending on the data set
so you can kind of fine tune
an answer to a question like this
such as what's the advantage of
using earth observation data
to monitor the crysphere
to monitor the biosphere
to monitor oceans in freshwater
you can fine tune your answer
using these exact same points that i discussed
but based on
or relating to
historically
how we monitored and measured

that phenomenon
so i focused
in my example answer on the cryosphere
but there would also be
a way to relate that to the biosphere
to oceans in freshwater
does that make sense
i don't know if the person's here
but someone kind of posted or asked what the advantages
of using earth observation data were for each of these
like for the biosphere
for the crysphere
for oceans of fresh water
and i feel like i kind of answered them all
there at the same time
because it's really all the same things
you just need to relate your answer back to
kind of the context of either the cryosphere
the biosphere
or oceans in freshwater
makes sense
ok so i can't clarify what i necessarily mean by
by linking topics without giving away the exam question
too much what i will say is that you know
again it's about
getting you guys to bring together information from
pre midterm and post midterm
so just as an example
i had this question pop up on the discussion board
and i thought this was a good example
of linking topics together
what attributes and resolutions would be appropriate
for if we are designing a satellite
for monitoring regional forest cover change
ok well there's a couple things that we talked about
throughout the course related to this right
we talked about
data requirements for monitoring change
so there's that kind of perspective
to try to answer this question
we talked about resolutions of satellites
and different data sets
so there's that kind of perspective

to answer this question
and then we talked about spectral signatures
and the kind of different spectral responses
you might have for different materials
so that can also be integrated into this question
so for what attributes and resolutions
would be appropriate
if we are designing a satellite
for monitoring regional forest cover change
okay so there's a couple keys here
first off would be regional
the coverage is a regional area
that we're looking at here
regional we're all looking at a global scale
just regional
it's not as big
and then we're looking at forest cover change
so probably kind of like a land cover change
then you're saying okay
regional forest cover change
in your head
you should already
probably be going to landsat
landsat is good for regional areas
for monitoring things like land cover
and land use change
but why well
we know for monitoring forest cover change
for example
monitoring wildfires
monitoring forest harvest
we know and can consider
some of the data requirements for that
right so we have the level of spatial detail required
the level of
the frequency of revisit required
the temporal dimension required
and the spectral region required
so we know for example
for monitoring force cover change
okay the level of spatial detail we require
pretty moderate
nothing crazy

the level of
revisit time we require
the temporal resolution
probably also pretty moderate
maybe once a month
twice a month would suffice
we just want to see the forest cover
kind of before and after some sort of change
maybe wildfire's forest harvest
the spectral domain
the region of the electromagnetic spectrum
well again linking back to earlier in the course
we know that
vegetation that's healthy
has very high near infrared reflectance
we know unhealthy vegetation
has very low near infrared reflectance
so we probably want to be looking
in the range of the near infrared
maybe visible
red portion of the spectrum
and then for temporal dimension
how long do we need data for
well how long are we monitoring forest cover for
if we're just monitoring forest cover
for a couple years
we just need data for a couple years
for monitoring forest cover change
due to climate change
then maybe we need data for decades
and decades and decades
okay so that's kind of the
you know the data requirement side
then there's the actual resolution side
where i say
okay well if i had to pick a satellite to use here
which you know
is kind of a different question
than what we see here
this is just
you know asking you to describe
the attributes and resolutions
of a dataset

or of a satellite
that would be ideal for monitoring this
so that's kind of different
that's what i just did
i just kind of describe
the characteristics you would need
okay but what if i actually asked you to pick
a satellite
what if i said
monitor forest cover
regional forest cover change
pick a satellite
why that satellite
well in this case
i probably say landsat
probably say landsat
because it has a thirty meter spatial resolution
it has a sixteen day revisit time
it has it to portal dimension
all the way back to the seventies
or eighties
if we want to look at change
all the way back then
and it has banned
in the visible
red and near infrared portion of the spectrum
so it would make it really ideal
for this kind of monitoring
so again question like this
it requires
those links right
to a couple of different topics
it requires you to think about
potentially
the data requirements
for monitoring this change
potentially
the resolutions
for a particular satellite
and then potentially
the spectral signature
of the phenomena
or of the material

that we're talking about here
ok i think that's a good example to get you guys going
you can definitely kind of
expect questions in the realm of this
it's not exactly like this
but note you know
the difference in terms of me asking you
okay pick a satellite
and justify to me why that satellite is
ideal for monitoring or detecting this phenomenon
versus what resolutions or attributes would be ideal
for monitoring this particular phenomenon
the way that this question is worded
it says for designing a satellite right
so doesn't have to be something that actually exists
so maybe in my absolutely perfect scenario
for forest cover change
maybe i don't want the thirty meter spatial resolution
that lancet has
in my perfect
perfect situation
if i were to answer this question directly
maybe i'd say
well i don't know
maybe a ten
fifteen meter spatial resolution would be ideal
maybe a weekly temporal resolution would be ideal
you know the
the spectral regions in the visible
red and near infrared would probably still be ideal
and a temporal dimension
maybe spanning a couple decades
three four decades
would be pretty ideal
so i just described the characteristics of a satellite
that doesn't actually exist
but i did just directly answer this question
in terms of what resolutions and attributes
would be most appropriate for monitoring this change
again i might ask you something like that
i might ask you
just pick a satellite
tell me its resolutions

why would it be ideal for monitoring this change yeah
like for example
we say like thirty days of spiritual evolution
or we need to be like just water
so for this question here
you know this question is kind of asking you
what attributes and resolutions would be appropriate
if you were designing a satellite
so it's not asking you to call on
the characteristics of a satellite that actually exists
so therefore for this it can be a bit broad
so you could just say
oh a moderate spatial resolution would be ideal
you could give a range if you want
you could say a moderate spatial resolution
maybe around twenty meters
fifty meters
somewhere less than a hundred meters would be ideal
but all i would require you for this kind of answer
right here is moderate
course fine
kind of thing
if it's pick a specific satellite or data set
tell me its resolutions
tell me why those resolutions are ideal
then i expect specifics
like you know
thirty meter spatial resolution for lancet
sixteen day revisit time
spectral bands in the visible
red and near infrared data
all the way back to the seventies
that kind of thing yeah
yes yes yeah
so that's just fundamentally
two different kinds of questions
me asking you to design a satellite
or to describe the attributes of the perfect situation
the perfect satellite is different than me saying
pick a satellite
what are its resolutions
why would it be ideal
for monitoring this particular thing

does that kind of make sense
ok in general with the short answers
be specific
fully explain your answers
may ask you for examples to help explain your answers
point form is fine
as long as you're still providing enough information
to fully answer the question
you should still be using the correct terminology
if you're using point form
you should still be linking topics appropriately
and explaining your answers in full
even if you're using point form
so just make sure that if you are using point form
it doesn't kind of take away from
the quality of your answer
so the important just kind of final tips and tricks
reminders things that are good to go over
the important topics
questions the kind of final slide i have
at the end of each lecture is a good thing to go over
the practice questions we provided on canvas
are both those two sets of questions
end of each of my slides
practice questions on campus
both very very representative of final exam questions
they may not be the exact same
but the type of questions and the content covered is
quite representative
post on the final exam discussion board if you have
questions leading up to the exam
and you'll do great if you go over these things
if you use those resources
go over those practice questions
you are going to do great
ok after the final exam
our final exams on one of the last exam days
so i have a really
really tight turnaround to get final grades submitted
so april twenty seventh is a thursday
so we will mark the
finals probably the following friday
and hopefully have them done by the end of friday

but if for some reason we don't
the absolute latest that will post
the final exam grades will be monday morning
so may first
just crazy that's like a month away
but the absolute latest that we will post
final exam grades is may first at nine am
if you have any concerns
i'm sorry it's such a short window
i'm i'm kinda buckled by the
the deadline that ubc gives me
if you have any concerns about your final exam
you have to email evan by five pm on that monday
on may first
i'm gonna do our absolute best to get the final
to get the final exam grades posted before then
but worst case scenario
they'll be posted by nine am may first
and you have to email evans that day
by five pm may first
if you have any concerns
you want any grades changed
you want us to look over anything
it's a hard deadline
i literally have to submit grades the next day
so if you haven't emailed us
then we'll just go ahead and submit the grades
i'll take questions in one sec
if we have any general questions
that anyone else wants me to answer
i always end the semester by just thanking you guys
it's been a ton of fun to teach you guys
don't do this job because i have to
i do this job because i really like it
and i really enjoy it
and whether it's your first semester
your last semester at ubc
i hope you've learned something in this class
hope you have a good journey ahead of you
the positive interactions i have with you guys really
really make my day
they mean the world to me
i hope you learned something in the class

be kind be safe
and that's kind of it
okay is there anything
anyone wants me to go over for the whole class
if not you can kind of just come down
i'll be here for another
fifteen minutes
julia's literally outside the door here
so if you have questions about assignment seven
you can come down and chat with her