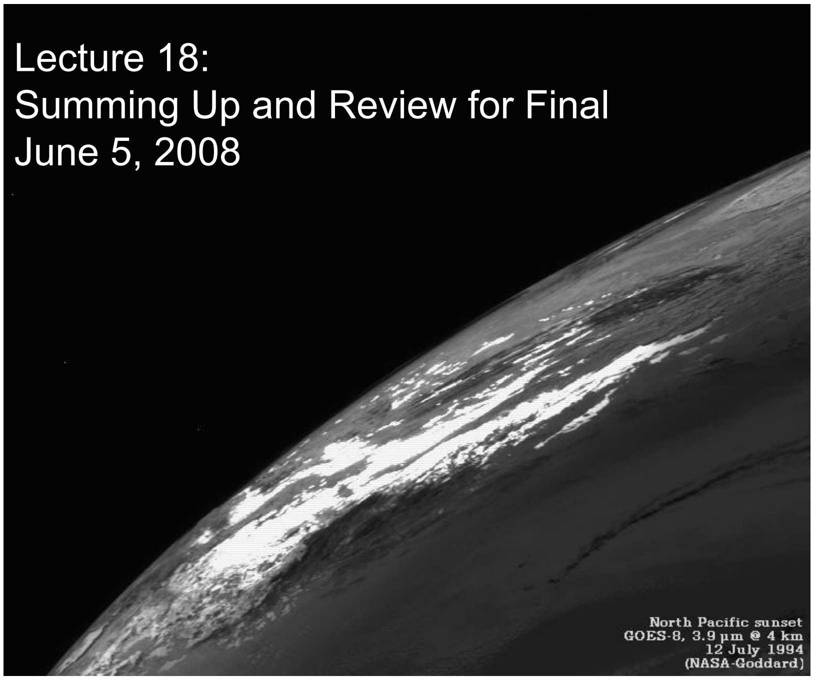
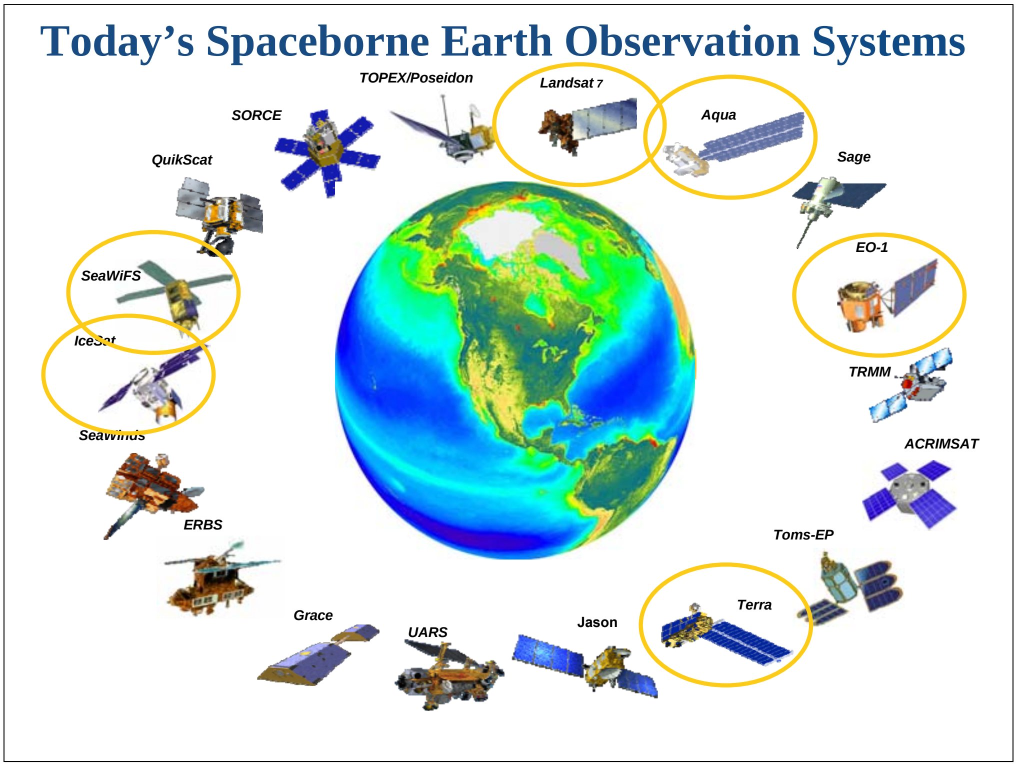
Lecture 18:
Summing Up and Review for Final
June 5, 2008





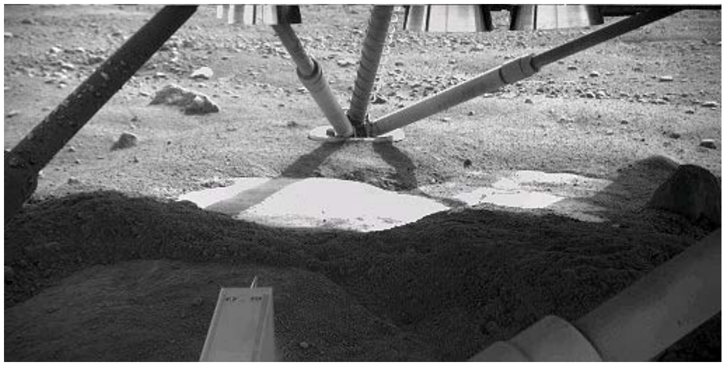
Circled instruments monitor the terrestrial environment;

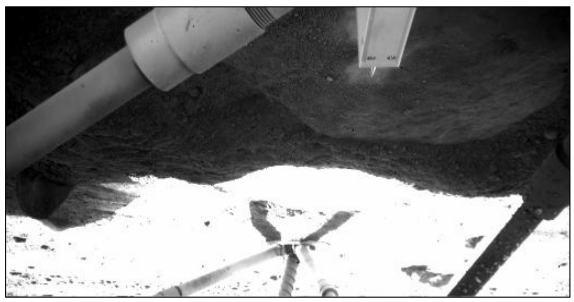
How to do land cover classifications?

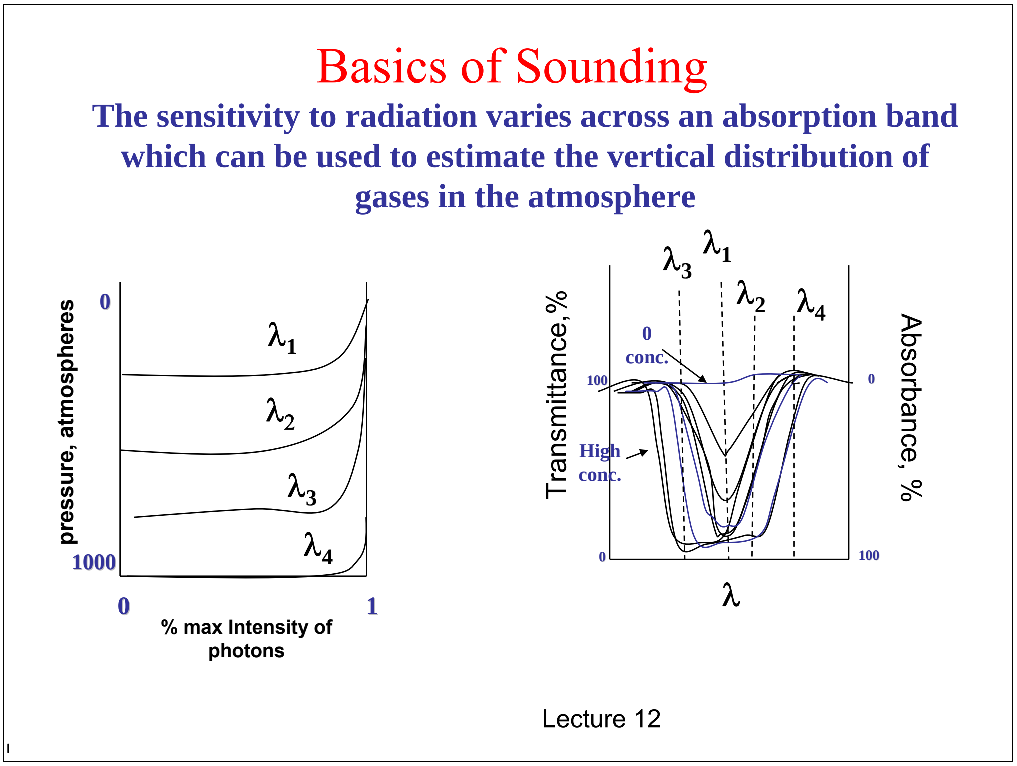
Classes: grassland, savanna, chaparral, live oak woodland, and riparian vegetation

Develop a spatial land cover map. What spatial, spectral and temporal coverage do you need to map the following classes: grassland, savanna, chaparral, live oak woodland, and riparian vegetation?

Mars Phoenix showing area where surface dust was blown off to expose below what is (currently) thought to be ice.

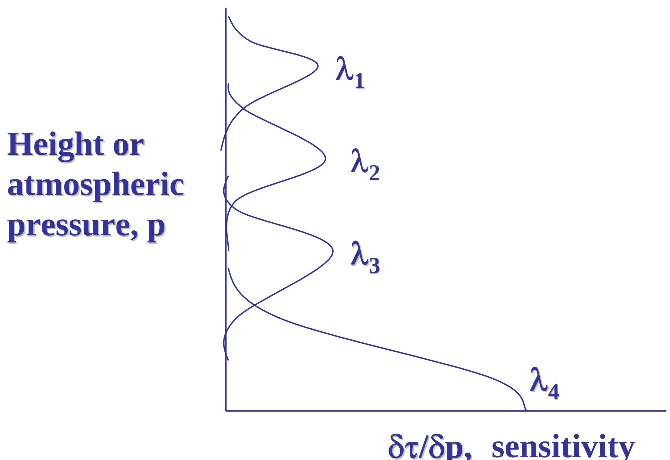






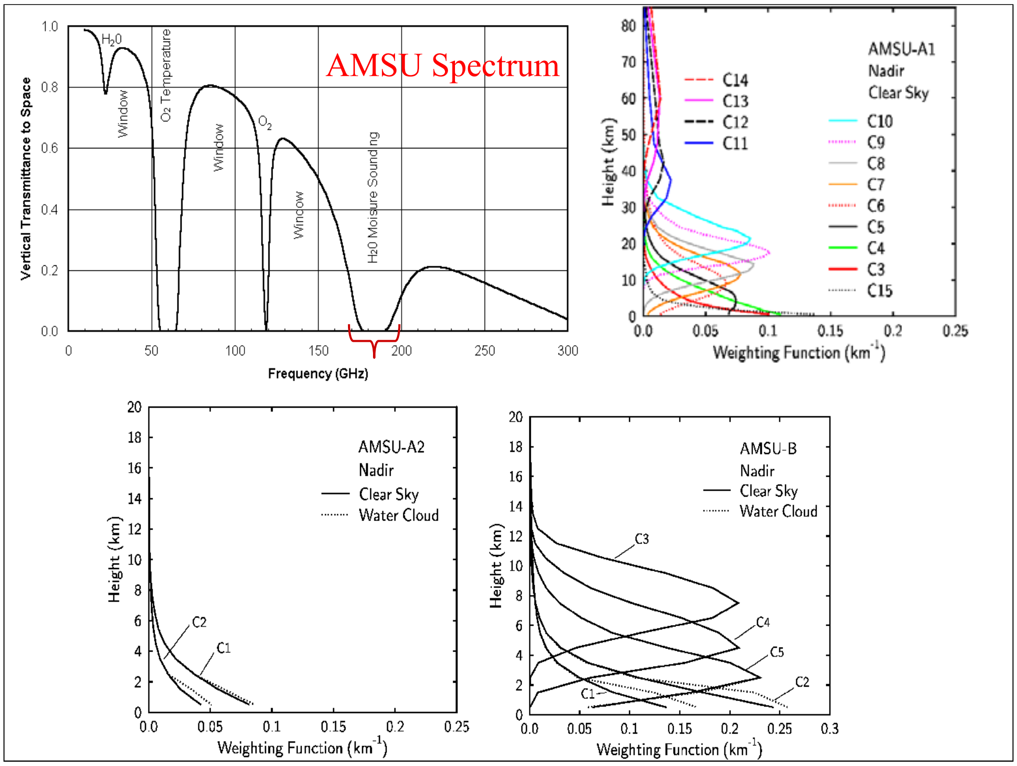
Absorption increases with concentration of water vapor and the volume of the gas layer which determines the transmittance of energy through the atmospheric profile. The atmosphere is not homogenous through its profile and differences in the concentration of water vapor occurs, thus the transmittance will change faster in some regions of the profile as compared to others. This is quantified by the derivative of transmittance with respect to atmospheric pressure (height) for different wavelengths. Thus for each wavelength, the radiation received at the sensor is predominantly comes from a different altitude. Moreover, if the temperature at each level is known and the pressure is known, than it is possible to estimate the concentration of the water vapor (or other gases). If the bands are placed with respect to other gasses, such as C02, than their concentrations can be estimated.

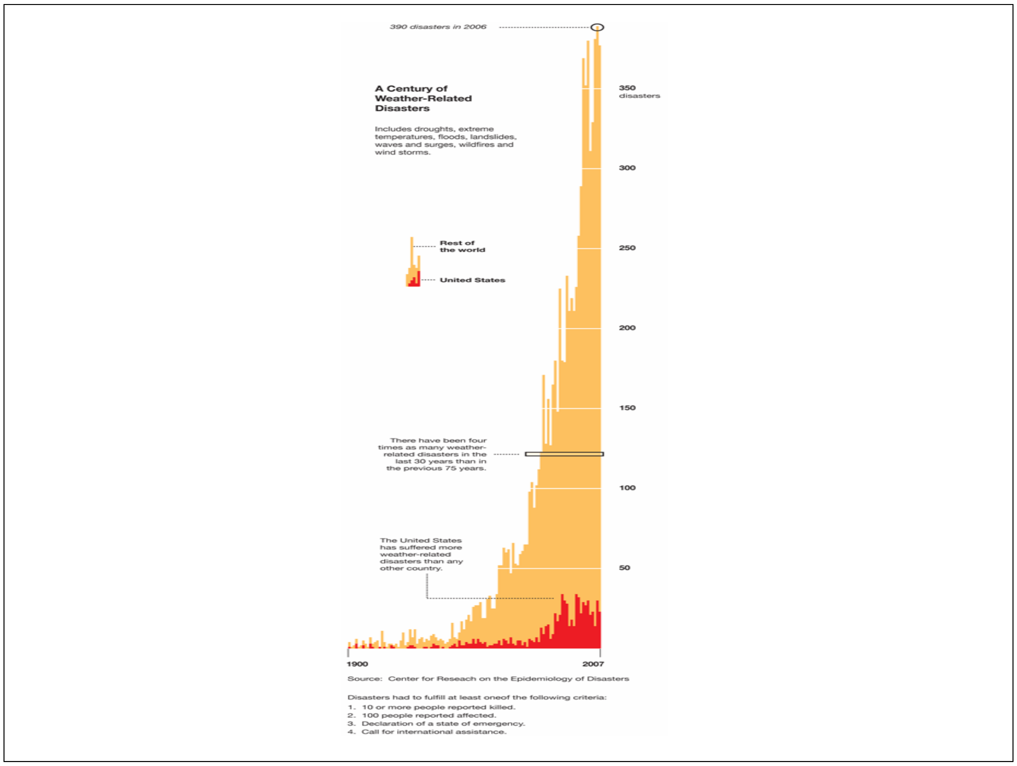
The Basics of Sounding



$\delta\tau$ / $\delta\rho$ = the change in transmission with the change in pressure

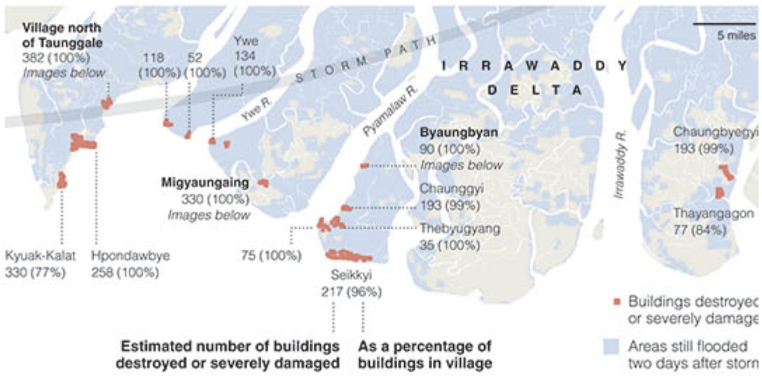
Absorption increases with concentration and the thickness (depth) of the gas layer. These variables determine the transmittance of photons through the atmospheric profile. If the wavelength is located in an atmospheric window and there is very little absorption, than the photon will penetrate further down towards the surface. For example, if the wavelength is located at a strong water absorption feature, then there will be enough water vapor even at high altitude, that the transmittance will be low and the photon will not penetrate very far. Nearer to the edge of the absorption the photon will penetrate further, thus for each wavelength, the radiation received at the sensor comes from a different altitude in the atmosphere. If the temperature and the pressure at each level are known, it is possible to estimate the concentration of the water vapor (or other gas).


AMSU Spectrum
Vertical Transmittance to Space
Frequency (GHz)
H_2O
Window
O_2 Temperature
Window
O_2
Window
H2O Moisture Sounding
AMSU-A1
Nadir
Clear Sky
C14
C13
C12
C11
C10
C9
C8
C7
C6
C5
C4
C3
C15
Height (km)
Weighting Function (km^{-1})
AMSU-A2
Nadir
Clear Sky
Water Cloud
C2
C1
Height (km)
Weighting Function (km^{-1})
AMSU-B
Nadir
Clear Sky
Water Cloud
C3
C4
C5
C2
C1
Height (km)
Weighting Function (km^{-1})

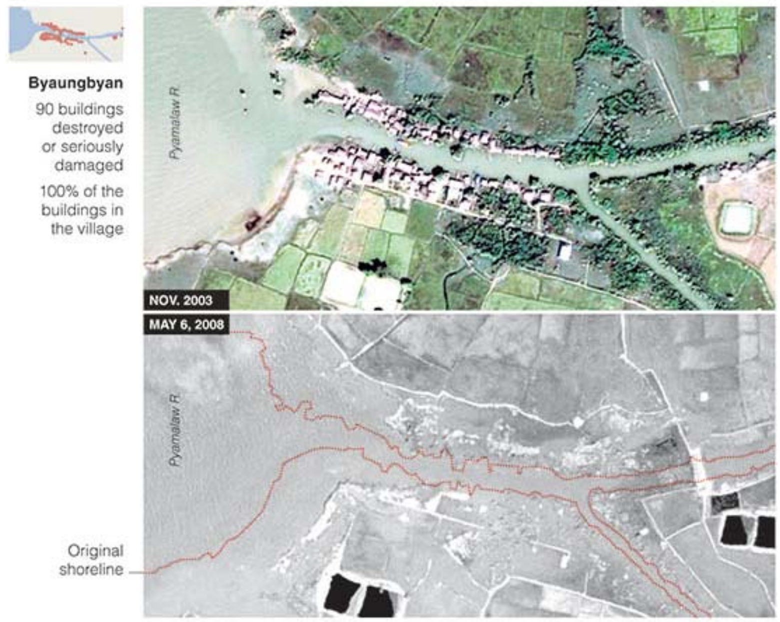

390 disasters in 2006
A Century of Weather-Related Disasters
Includes droughts, extreme temperatures, floods, landslides, waves and surges, wildfires and wind storms.
350 disasters
300
250
200
150
100
50
Rest of the world
United States
There have been four times as many weather-related disasters in the last 30 years than in the previous 75 years.
The United States has suffered more weather-related disasters than any other country.
1900
2007
Source: Center for Reseach on the Epidemiology of Disasters
Disasters had to fulfill at least oneof the following criteria:
1. 10 or more people reported killed.
2. 100 people reported affected.
3. Declaration of a state of emergency.
4. Call for international assistance.

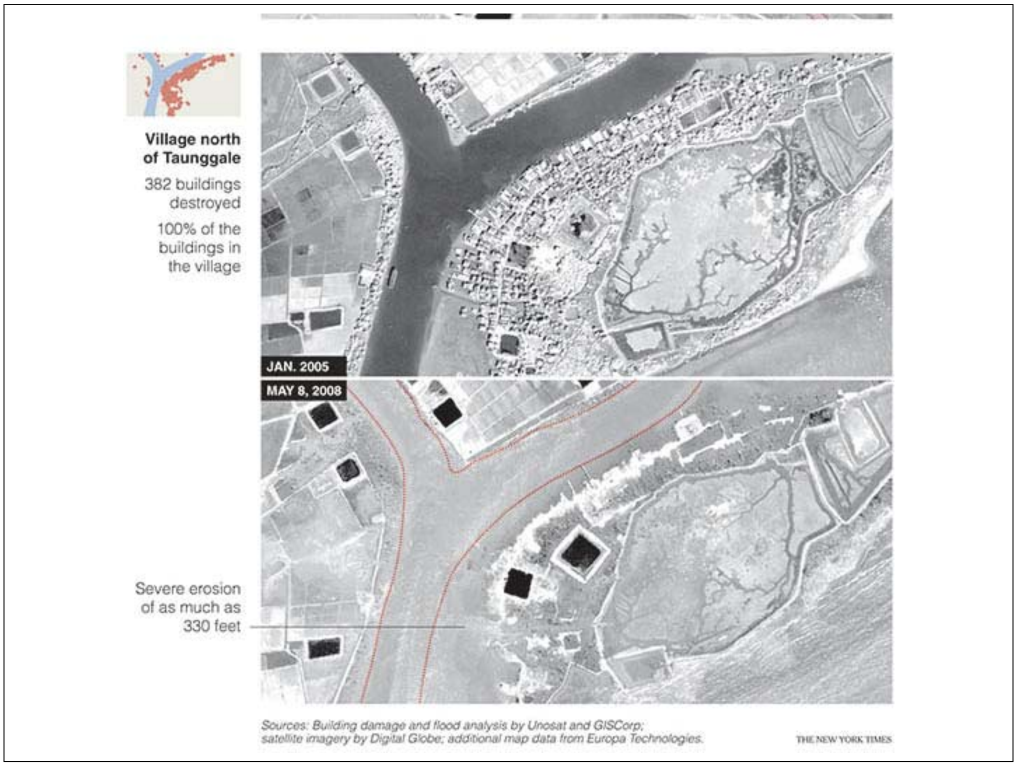
In Myanmar, Villages Washed Away by Cyclone

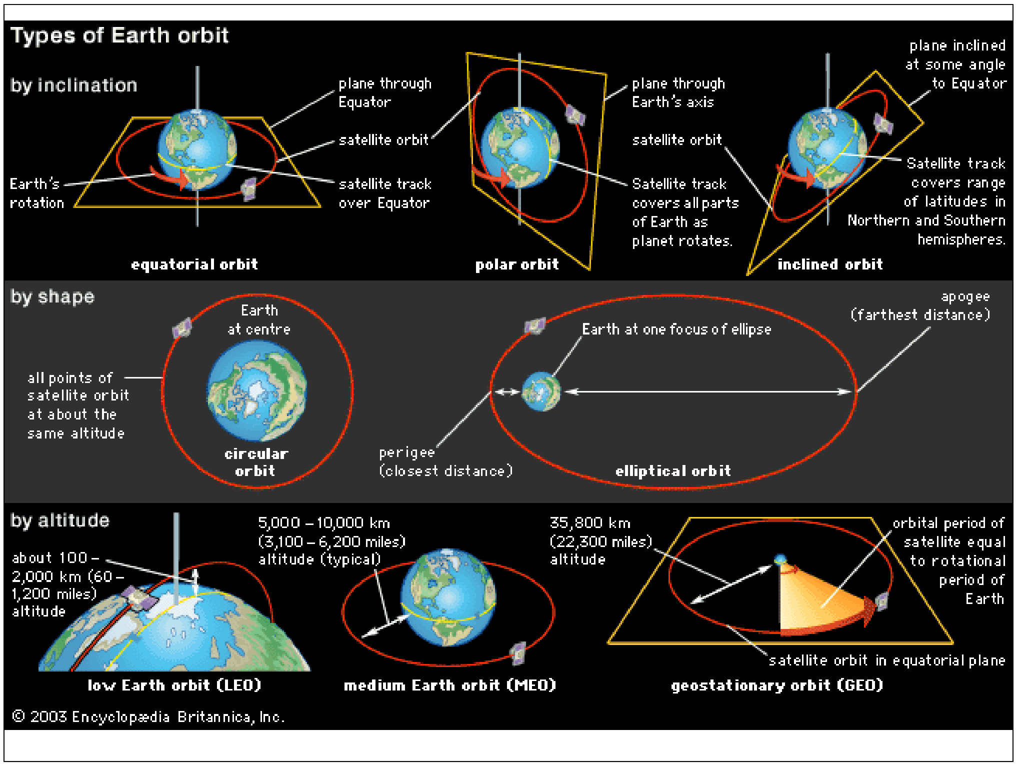
When Cyclone Nargis hit Myanmar on May 3, it wiped out whole communities and killed more than 134,000 people. Unosat, the United Nations satellite service, has been analyzing satellite images of villages in the Irrawaddy Delta, the hardest hit region. In 12 of 14 villages studied so far, the agency found that almost all buildings were destroyed or severely damaged. The images show some places where nearly everything appears to have been washed away. Many delta residents who survived have taken refuge in towns like Labutta, Bogale and Phyarpon. International aid officials hope to help them return by increasing aid deliveries, which have been insufficient because of restrictions by Myanmar's military dictatorship. *ARCHIE TSE*



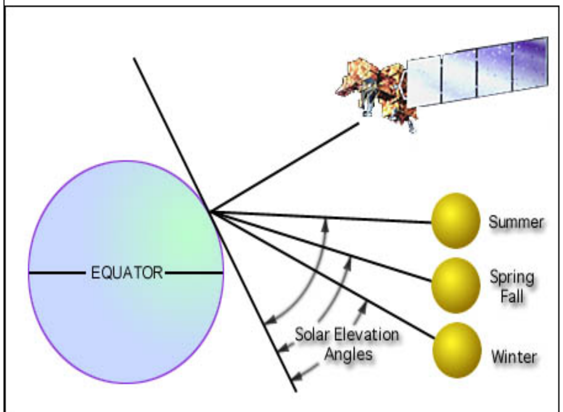
Migyaungaing
330 buildings destroyed or seriously damaged
100% of the buildings in the village
FEB. 2004
MAY 6, 2008
Bomi R.
Original shoreline
Severe erosion along the riverbank probably destroyed most buildings

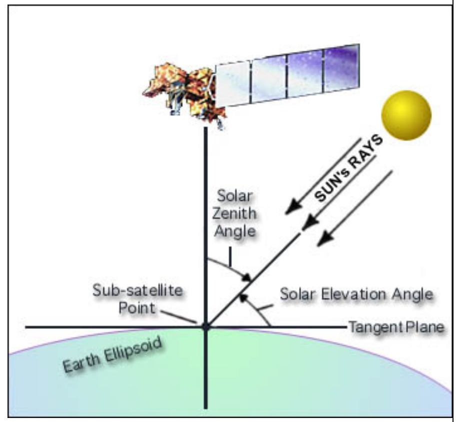

Byaungbyan
90 buildings destroyed or seriously damaged
100% of the buildings in the village
Pyamalaw R.
NOV. 2003
MAY 6, 2008
Pyamalaw R.
Original shoreline

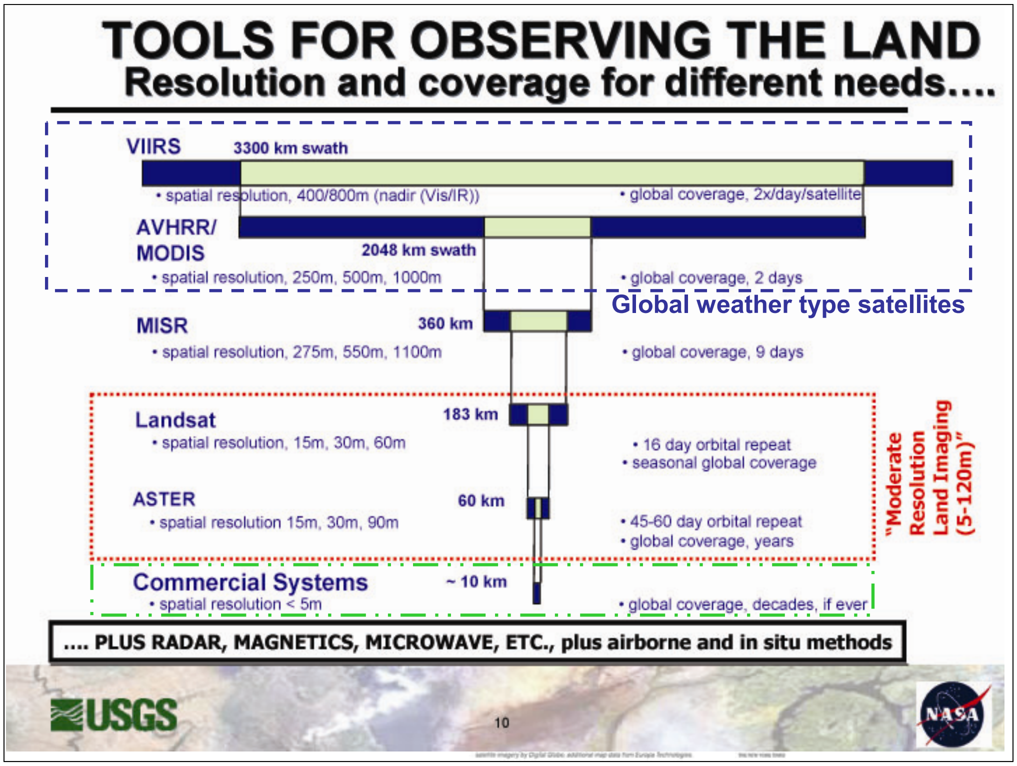

Village north of Taunggale
382 buildings destroyed
100% of the buildings in the village
JAN. 2005
MAY 8, 2008
Severe erosion of as much as 330 feet
Sources: Building damage and flood analysis by Unosat and GISCorp; satellite imagery by Digital Globe; additional map data from Europa Technologies.
THE NEW YORK TIMES


Types of Earth orbit
by inclination
plane through Equator
satellite orbit
Earth's rotation
satellite track over Equator
equatorial orbit
plane through Earth's axis
satellite orbit
Satellite track covers all parts of Earth as planet rotates.
polar orbit
plane inclined at some angle to Equator
Satellite track covers range of latitudes in Northern and Southern hemispheres.
inclined orbit
by shape
Earth at centre
all points of satellite orbit at about the same altitude
circular orbit
Earth at one focus of ellipse
apogee (farthest distance)
perigee (closest distance)
elliptical orbit
by altitude
about 100 – 2,000 km (60 – 1,200 miles) altitude
low Earth orbit (LEO)
5,000 – 10,000 km (3,100 – 6,200 miles) altitude (typical)
medium Earth orbit (MEO)
35,800 km (22,300 miles) altitude
orbital period of satellite equal to rotational period of Earth
satellite orbit in equatorial plane
geostationary orbit (GEO)
© 2003 Encyclopædia Britannica, Inc.

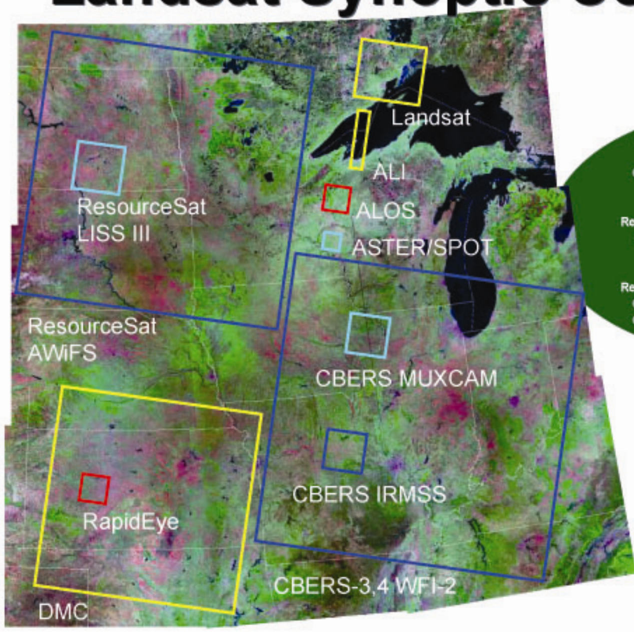
Sunsynchronous satellites reduce the sun angle variation that happen on a diurnal basis. But do not eliminate different sun angles due to change with seasons






TOOLS FOR OBSERVING THE LAND
Resolution and coverage for different needs….
VIIRS
3300 km swath
• spatial resolution, 400/800m (nadir (Vis/IR))
• global coverage, 2x/day/satellite
AVHRR/ MODIS
2048 km swath
• spatial resolution, 250m, 500m, 1000m
• global coverage, 2 days
Global weather type satellites
MISR
360 km
• spatial resolution, 275m, 550m, 1100m
• global coverage, 9 days
Landsat
183 km
• spatial resolution, 15m, 30m, 60m
• 16 day orbital repeat
• seasonal global coverage
ASTER
60 km
• spatial resolution 15m, 30m, 90m
• 45-60 day orbital repeat
• global coverage, years
"Moderate Resolution Land Imaging (5-120m)"
Commercial Systems
~ 10 km
• spatial resolution < 5m
• global coverage, decades, if ever
…. PLUS RADAR, MAGNETICS, MICROWAVE, ETC., plus airborne and in situ methods
USGS
10
NASA

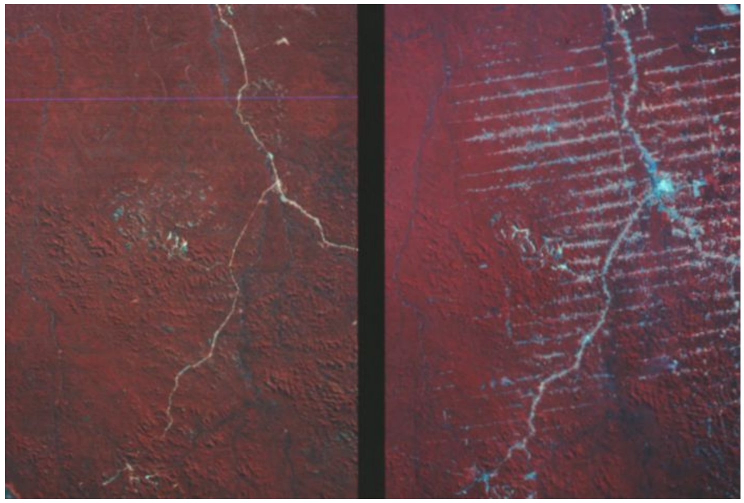
Landsat Synoptic Coverage



Satellite	Sensor	Ground Sample Distance (m)
RapidEye	REIS	6.5
ALOS	AVNIR	10
CBERS-3,4	MUXCAM	20
SPOT 5	HRG	10/20
Terra	ASTER	15/30/90
ResourceSat-1	LISS III+	23.5
Landsat 7	ETM+	15/30/60
EO-1	ALI	30
DMC	MSDMC	32
ResourceSat-1	AWiFS*	56
CBERS-3,4	WFI-2	73
CBERS-3,4	IRMSS	40/80

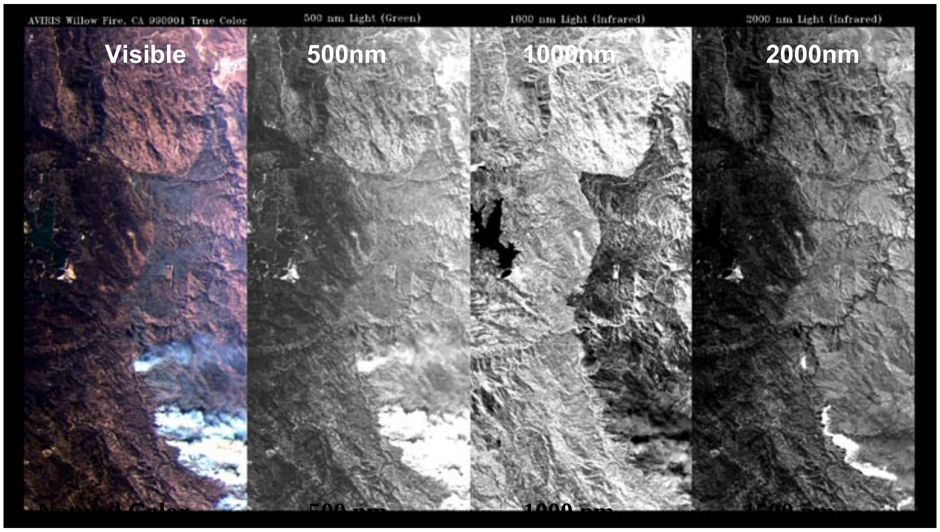
Note: For purposes of scene size comparison only. Locations do not represent actual orbital paths or operational acquisitions.

Brazil Change Detection



Landsat TM 6/9/1975 8/19/1986

Mapping Wildfires



- Applications: BGC cycles, disturbance regime, biomass, black carbon, burn temperature

(Ustin et al., 1999)

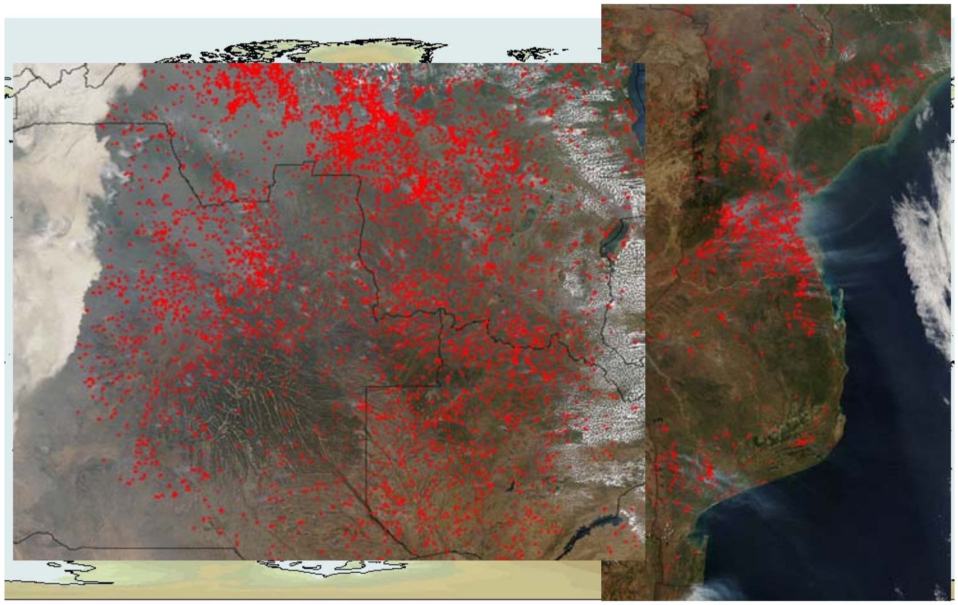
Fuel Emissions: Aerosols & particulates

Aboveground Biomass; black carbon

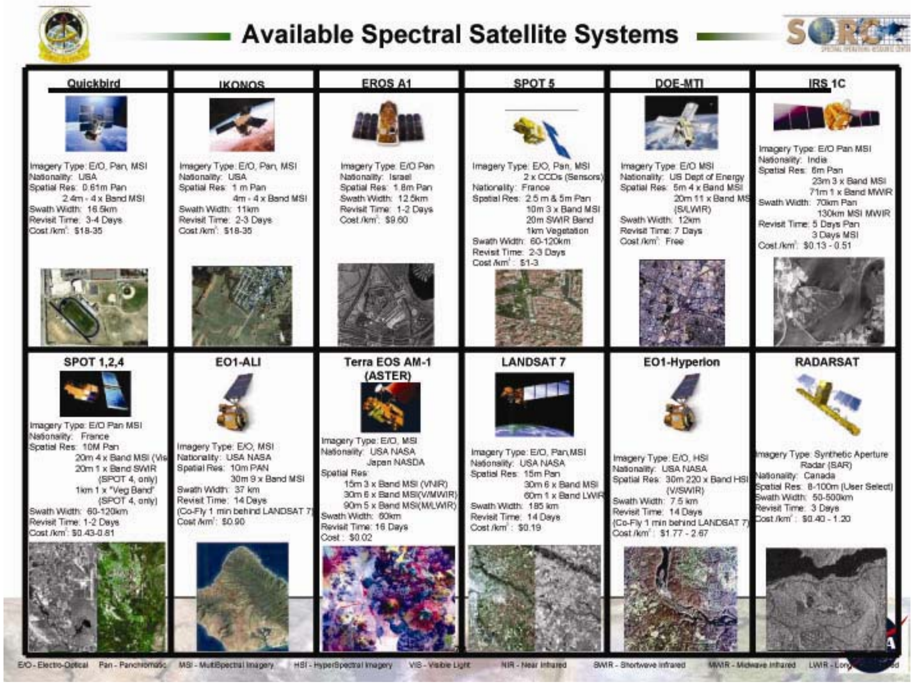
BGC storage and cycles


Santa Cruz Fire
May 15, 2008
Copyright CNES 2008, distributed by VITO

Fires Burning The Last Week April

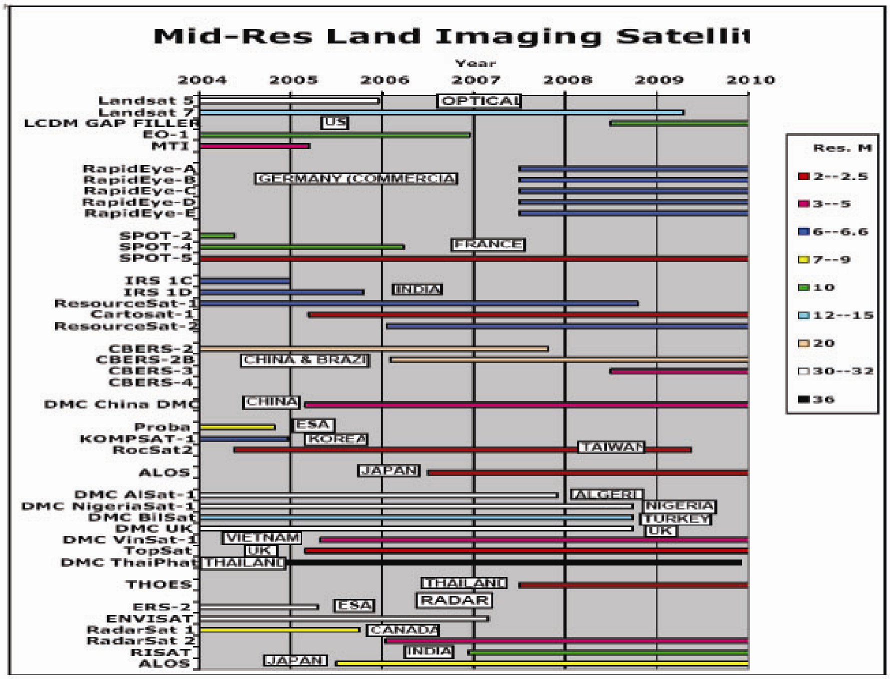


MODIS Operational Wildfire Detection System



Satellites Measuring at Appropriate Scales for Land Cover Classifications

Landsat-Type Systems Considered



Remote Sensing Is Possible Because Different Materials Have Different Reflectance Patterns

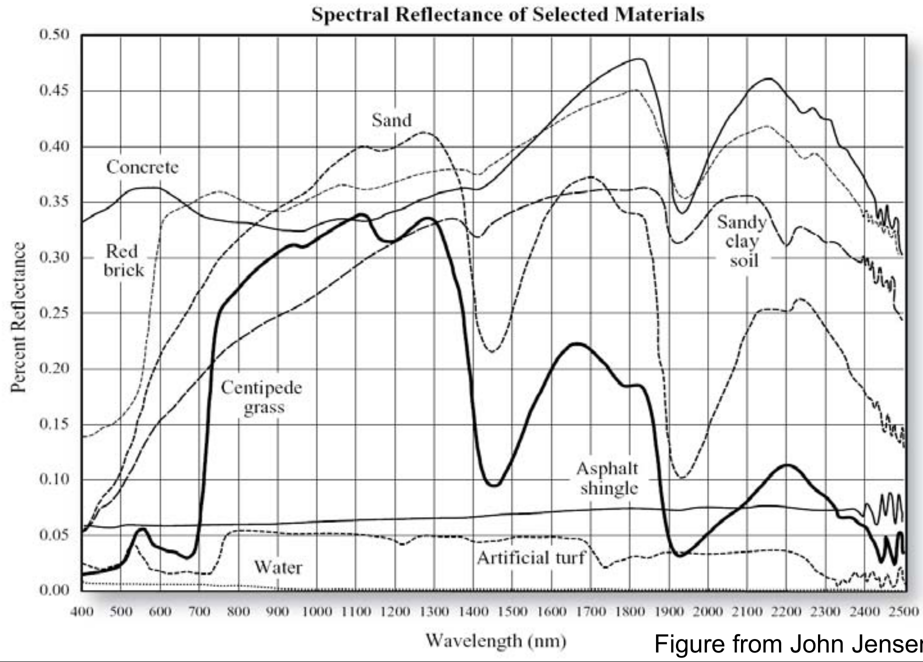
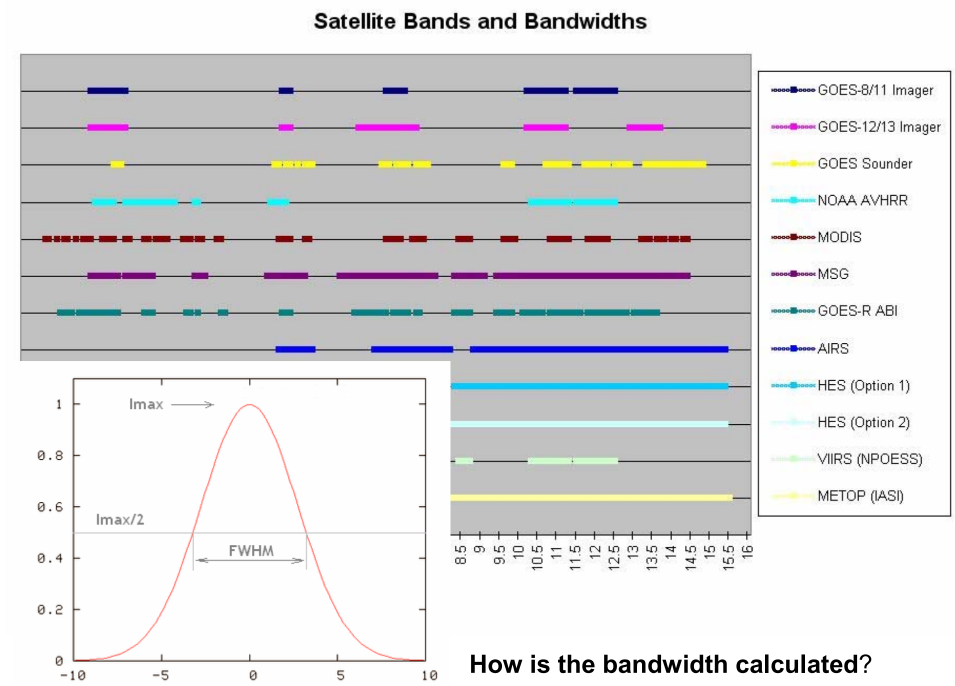
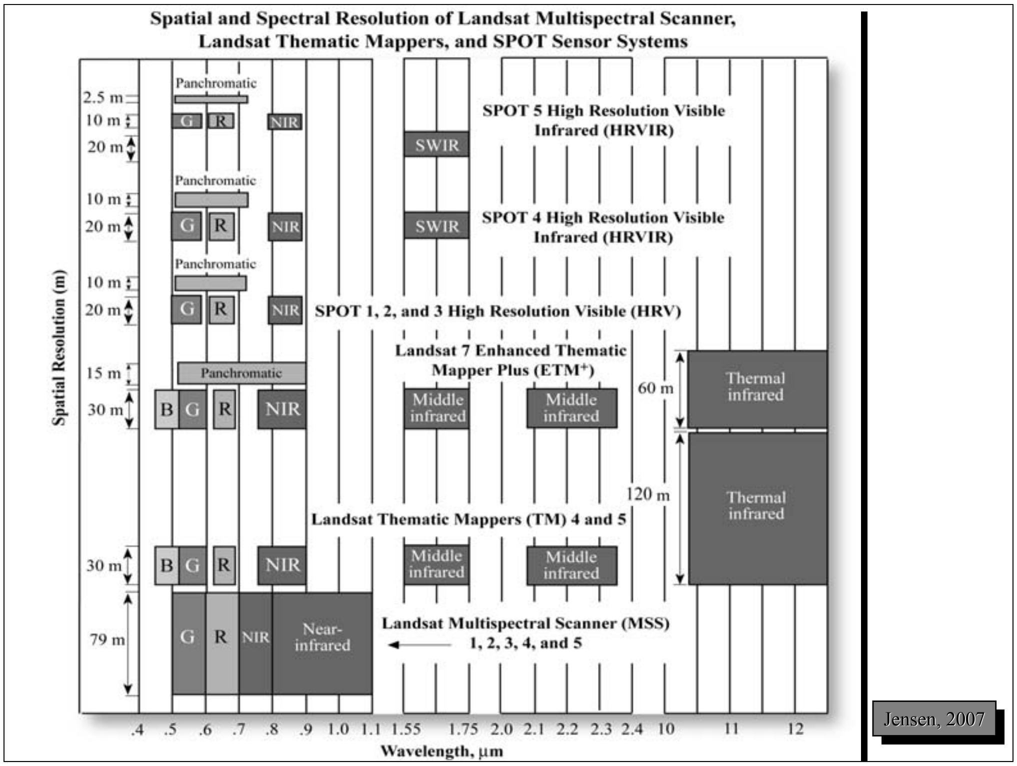


Figure from John Jensen

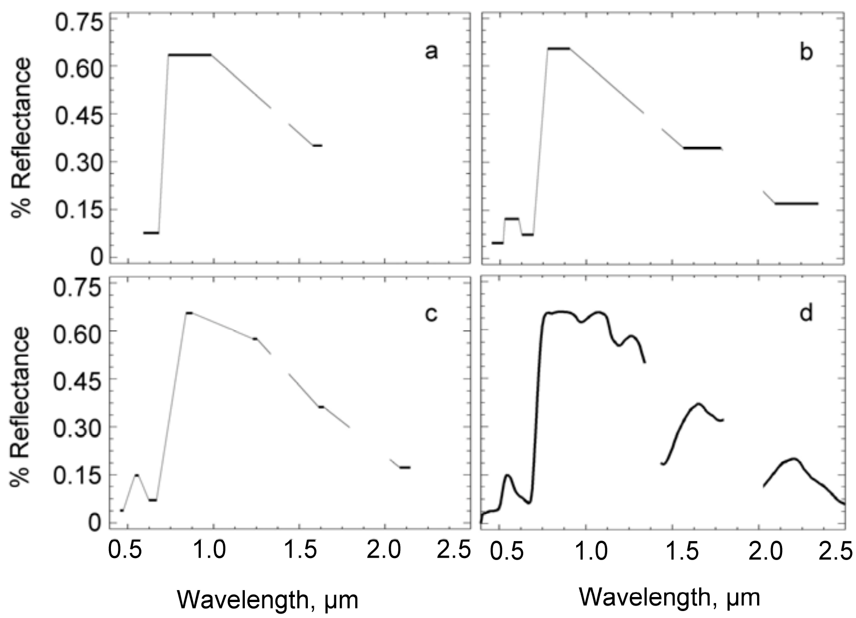


How is the bandwidth calculated?

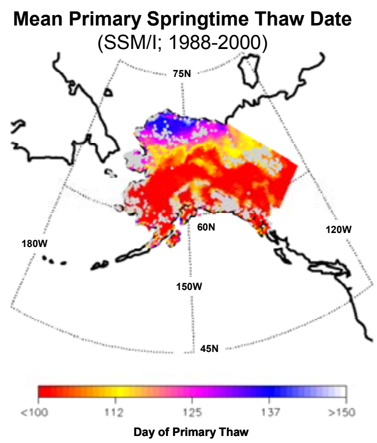


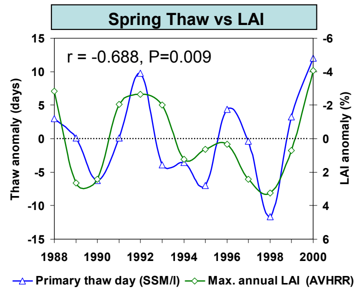
Spatial and Spectral Resolution of Landsat Multispectral Scanner, Landsat Thematic Mappers, and SPOT Sensor Systems
Panchromatic
2.5 m
10 m
20 m
G
R
NIR
SWIR
SPOT 5 High Resolution Visible Infrared (HRVIR)
SPOT 4 High Resolution Visible Infrared (HRVIR)
SPOT 1, 2, and 3 High Resolution Visible (HRV)
Landsat 7 Enhanced Thematic Mapper Plus (ETM+)
15 m
30 m
B
Middle infrared
60 m
Thermal infrared
120 m
Landsat Thematic Mappers (TM) 4 and 5
79 m
Near-infrared
Landsat Multispectral Scanner (MSS) 1, 2, 3, 4, and 5
Spatial Resolution (m)
.4 .5 .6 .7 .8 .9 1.0 1.1 1.55 1.75 2.0 2.1 2.2 2.3 2.4 10 11 12
Wavelength, μm
Jensen, 2007

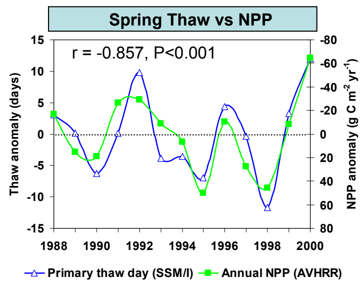
Band Width and Placement Determines What can be Detected



Timing Spring Thaw Influences Northern Productivity

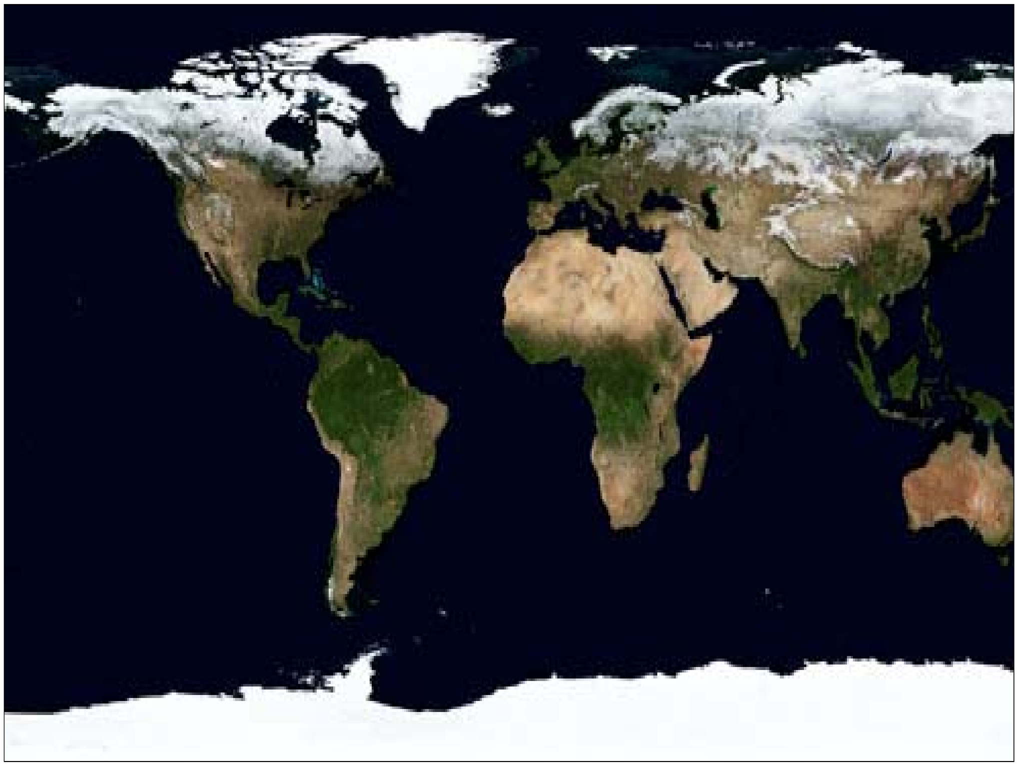




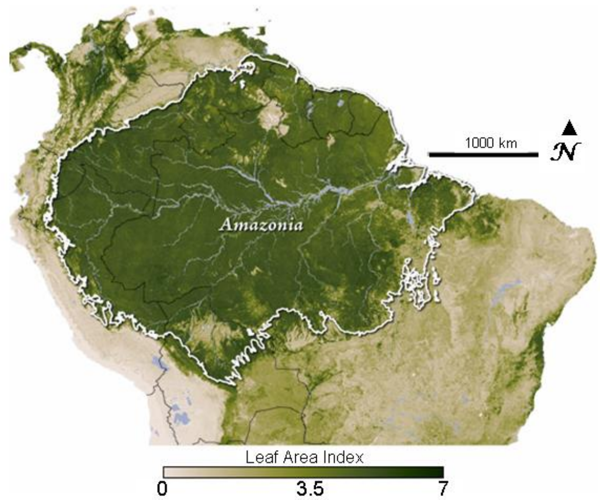


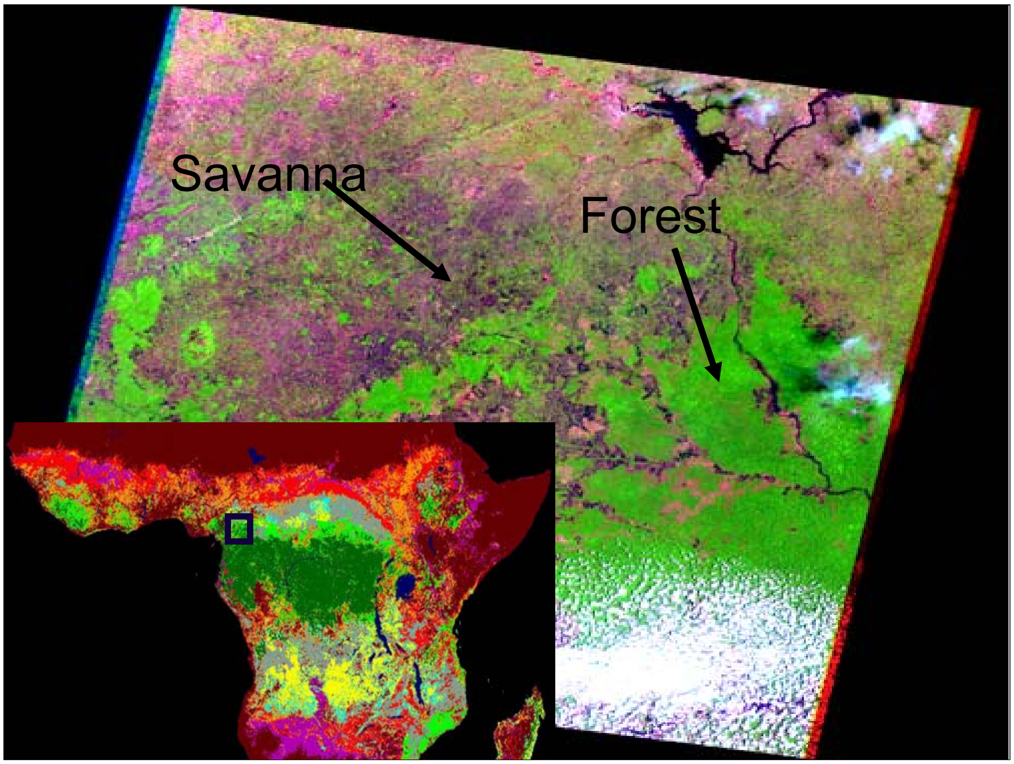
- Annual variability in AK springtime thaw from SSM/I record is ~ ±7 days (SD), with corresponding impacts to annual NPP of ±1% per day.
- Satellite (SSM/I) record shows earlier springtime thawing of -4.6 days per decade, sufficient to explain Northern greening and magnitude of satellite (AVHRR) productivity growth trends.

Source: Kimball, McDonald, and Zhao, 2006. ***Earth Interactions.*** 10, 21 .



NASA MODIS website; Changing Planetary Greenness and Leaf Area Index (LAI). Values range from 0 to about 10 or slightly more. Highest LAI forests are in the Pacific Northwest.


1000 km
N
Amazonia
Leaf Area Index
0
3.5
7



Although the Sahel has received considerable attention from remote sensing due to its sensitivity to drought, little attention has focused on gradients between rainforest and Savanna, which have a role in divergence and speciation.

This transition zone (ecotone) is very large, can be 1000 km wide, covers over 8 million square kilometers of the continent and contains forest fragments of varying size and isolation

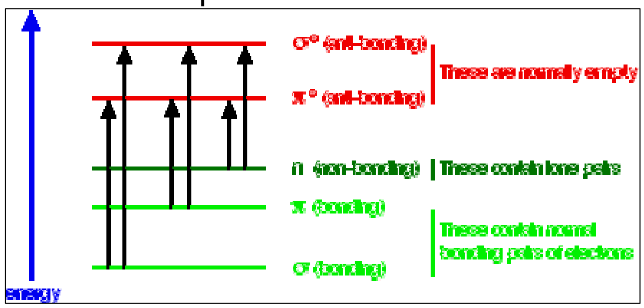
Ecotones are a mosaic of habitats and are characterized by variable environments,

Annual rainfall is typically 2 to 3 times more variable than in the forest.

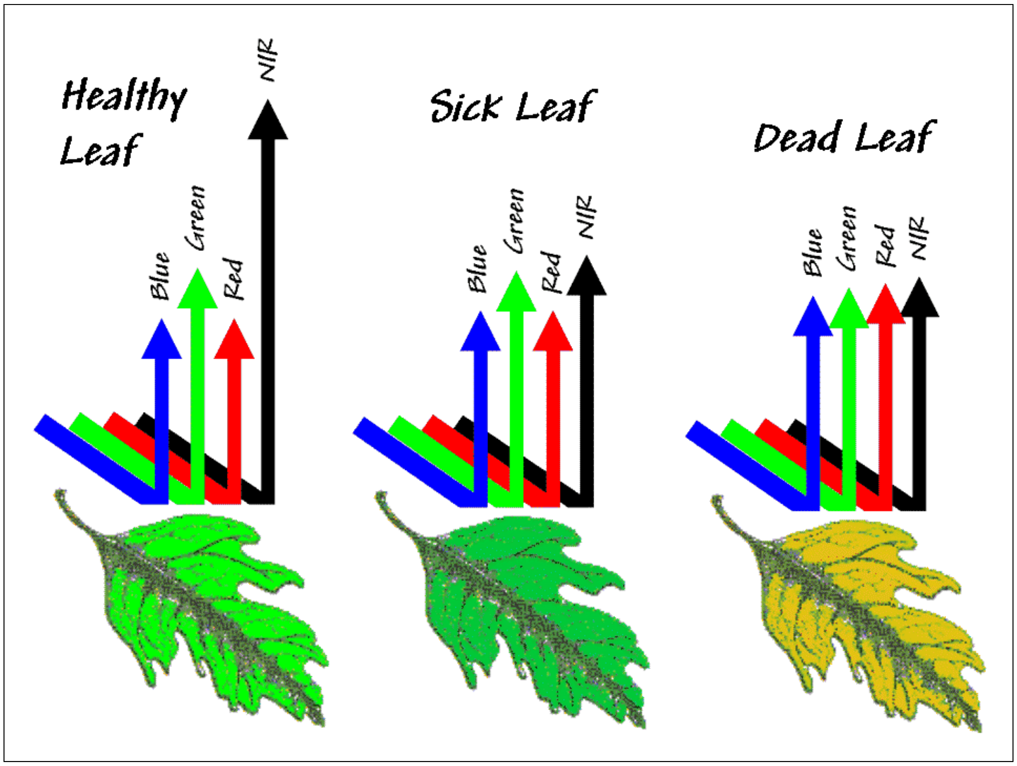
Vegetation, species assembles are different and as we will see creates changing selection pressures as one moves from the forest to savanna across the ecotone

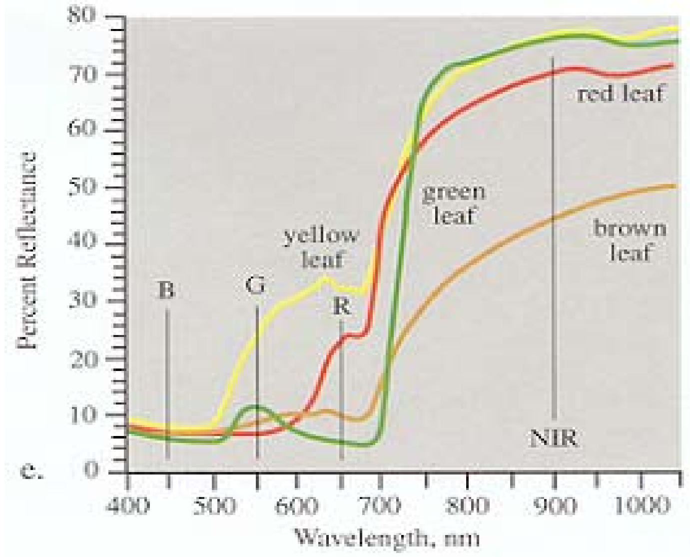
Remote sensing is based on detecting what wavelengths of energy are absorbed or reflected by different materials.

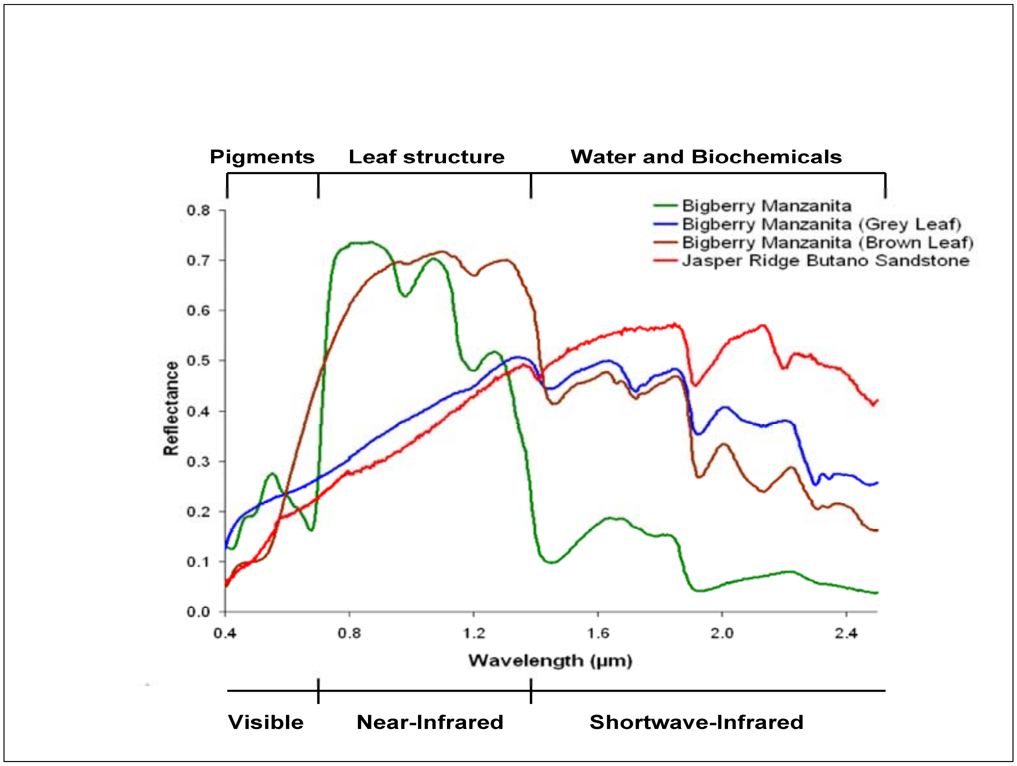
What causes an absorption feature?

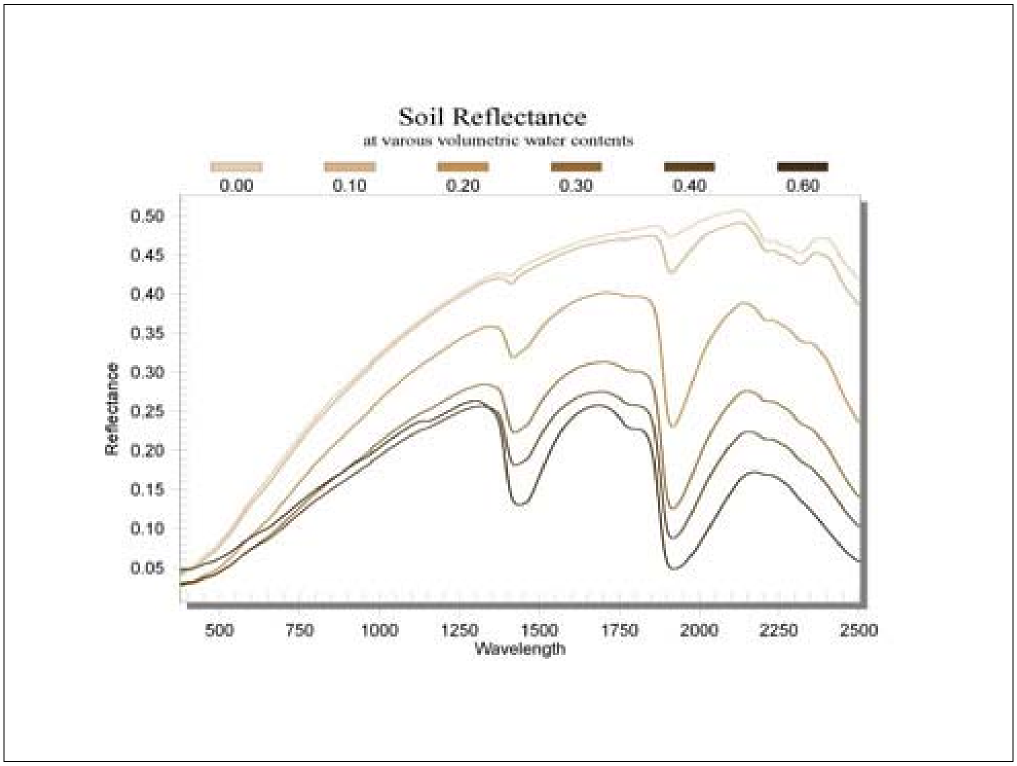


Energy is absorbed that temporarily excites an electron to a higher energy state. The wavelength of the photon absorbed matches the energy difference between the “resting” state and one of the allowable higher energy levels


Healthy Leaf
Sick Leaf
Dead Leaf
Blue
Green
Red
NIR
Blue
Green
Red
NIR
Blue
Green
Red
NIR

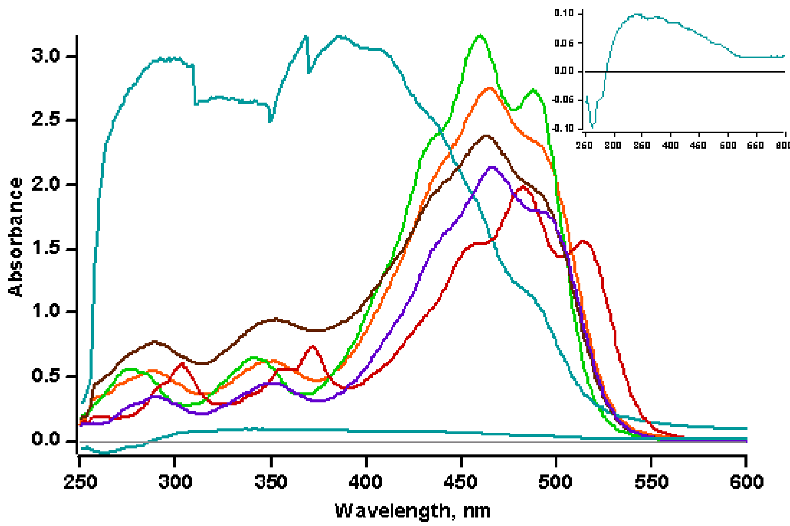

80
70
60
50
40
30
20
10
0
Percent Reflectance
e.
400
500
600
700
800
900
1000
Wavelength, nm
B
G
R
NIR
yellow
leaf
green
leaf
red leaf
brown
leaf


Pigments
Leaf structure
Water and Biochemicals
Bigberry Manzanita
Bigberry Manzanita (Grey Leaf)
Bigberry Manzanita (Brown Leaf)
Jasper Ridge Butano Sandstone
Reflectance
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.4
0.8
1.2
1.6
2.0
2.4
Wavelength (µm)
Visible
Near-Infrared
Shortwave-Infrared

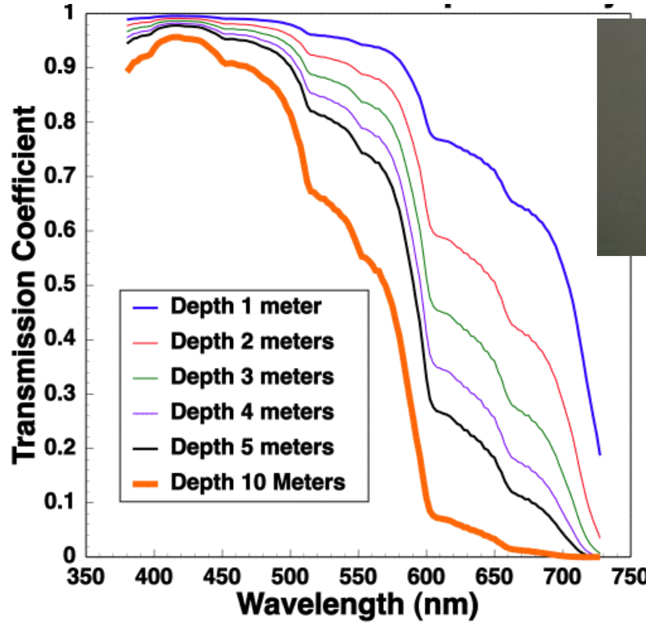


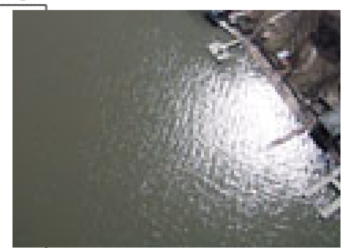
Soil Reflectance
at varous volumetric water contents
0.00
0.10
0.20
0.30
0.40
0.60
Reflectance
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength

Sediment, phytoplankton, and clear water



Penetration of wavelengths of light at different water depths

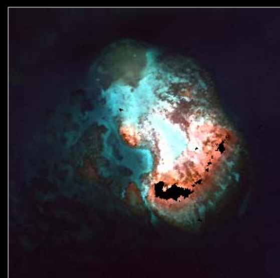




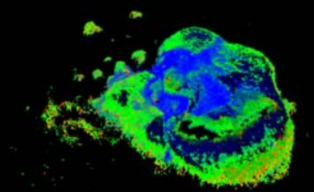
Specular Reflection

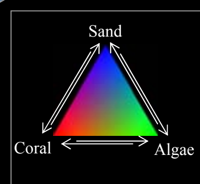
J. Goodman (UPRM)

2005 AVIRIS: From Imagery to Information



AVIRIS Data



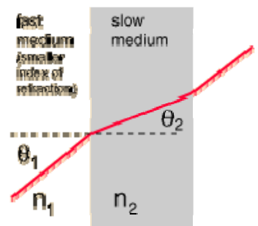


Benthic Composition

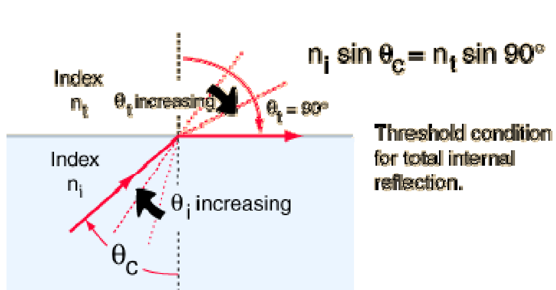
Refraction Between Water – Air Interfaces

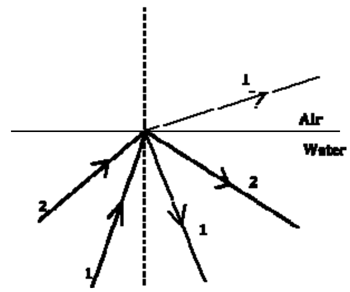
Snell's Law

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

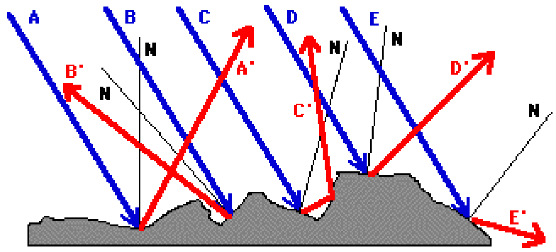


The index of refraction for water is 4/3, indicating that light travels only 3/4 as fast in water as it does in vacuum.



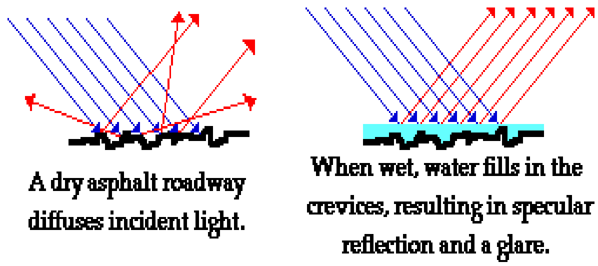


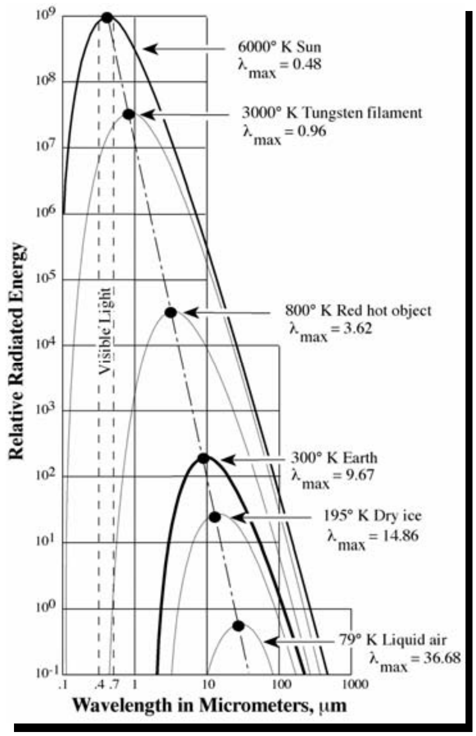
One reason reflectance from water is dark is the index of refraction. If light reaches the surface from a low angle, it is refracted back into the water and away from the air.



Scattering from a rough surface (wavelength dependent)

Example, Glare from Wet Roads:





The distribution of energy emitted from a blackbody is dependent on the temperature

Stefan-Boltzmann Law:
$M_{b\lambda} = \sigma * T^4$

Total radiated energy (j or watts/m^2) by a black-body = $(\sigma) * T^4$

$\sigma = 5.6697 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$ µm K

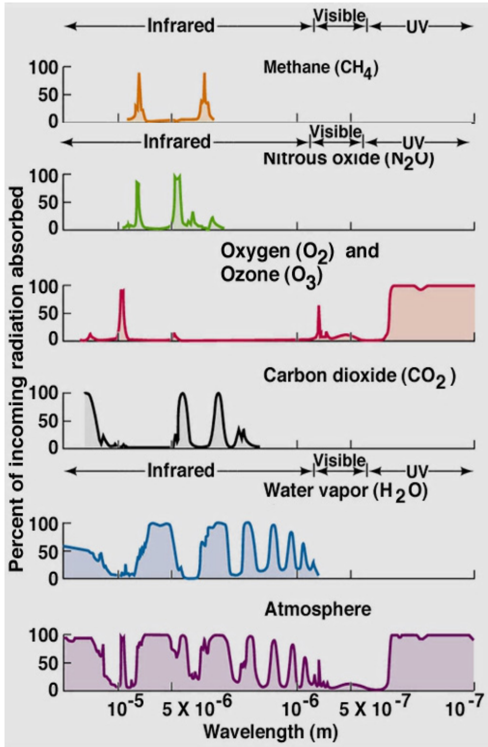
Wein's Displacement Law

$$\lambda_{max} = \frac{k}{T} \approx \frac{2898\ \mu m\ K}{T}$$

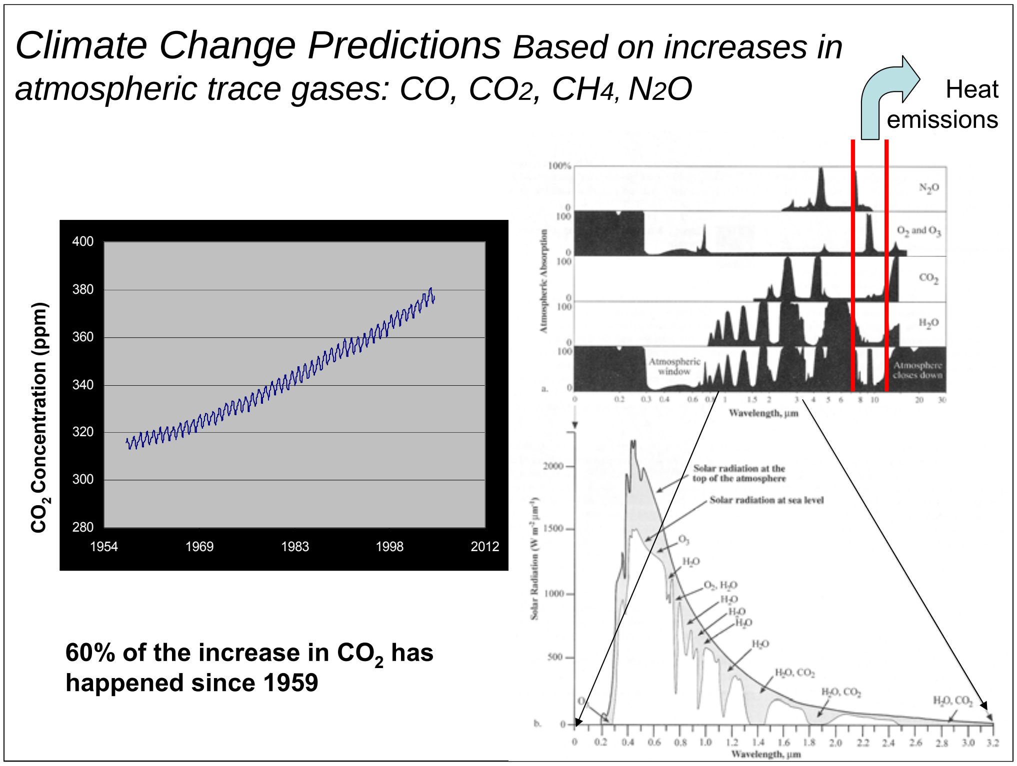
Stefan-Boltzmann (blackbody) Law is derived from Planck's Law (which is also derived from the relationship between energy, wavelength and frequency of electromagnetic waves). For non-blackbodies an emissivity term (ε) is needed to correct for materials that do not emit energy proportional to their temperature at all wavelengths. The wavelength of maximum energy emittance is calculated from Wein's Displacement Law.

Gases that absorb energy in different wavelength regions

Greenhouse gases absorb energy in the Earth's Atmospheric Window

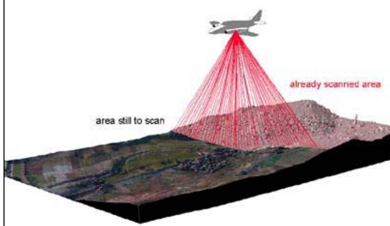


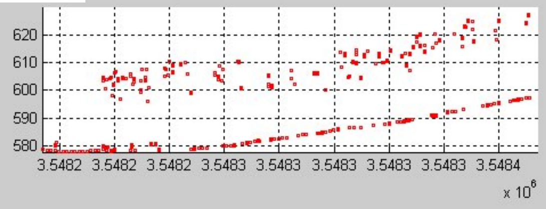
NOTE: This figure shows wavelength in the reverse order of how we are used to seeing it presented. So long wavelengths are on left.



through "Trends Online," from the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory. This is referred to as the "single best source" of information on fossil fuels use, CO2 and temperature trends.

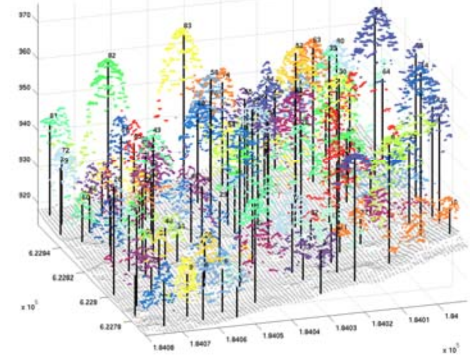
Lidar: An important new tool for developing a 3-D structure map of the surface





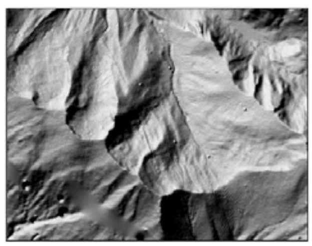
Bare earth topography, tree height, canopy volume, fuel ladders, canopy gap structure, species distribution, forest composition, understory presence, etc.

Fuel Type Mapping

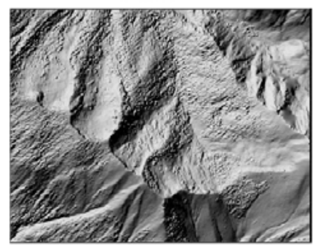


Morsdorf, et al. RSE 2004

LIDAR



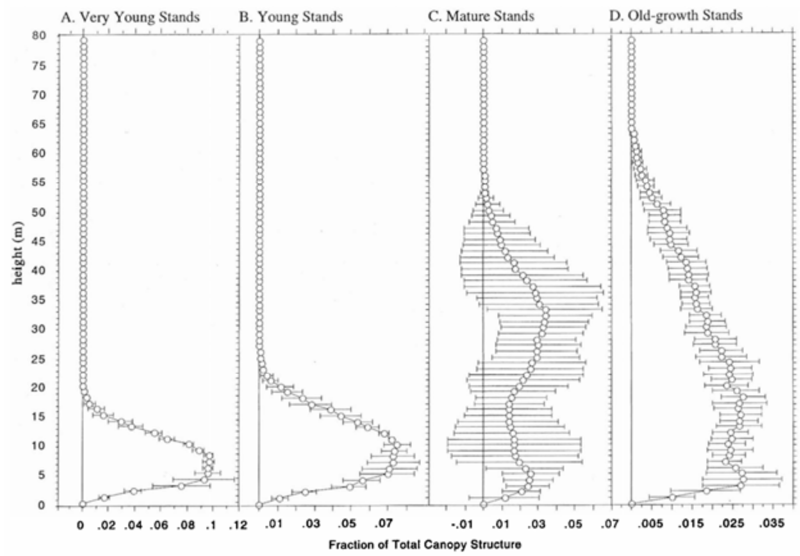
IFSAR



Dubayah, et al. 2003

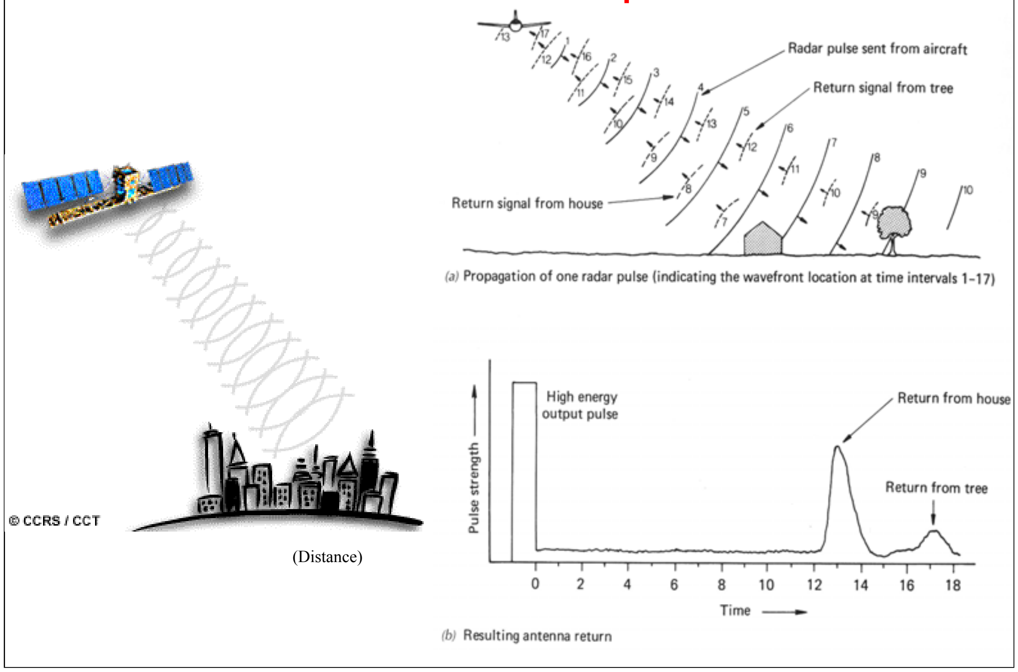
Drake JB, Knox RG, Dubayah, RO, Clark, DB, Condit, R, Blair, JB, Hofton, M. 2003. Above-ground biomass estimation in closed canopy Neotropical forests using LIDAR remote sensing factors affecting the generality of relationships. Global Ecology and Biogeography 12(2) 147-159.

Full Waveform Lidar Extracts canopy profiles



Lefsky et al., 1999

RADAR Principles



Slant range (SR) is distance between transmitter and object

SR = ct/2

c = speed of light

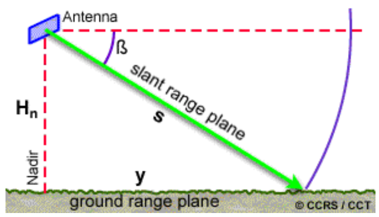
t = time between transmission and echo reception

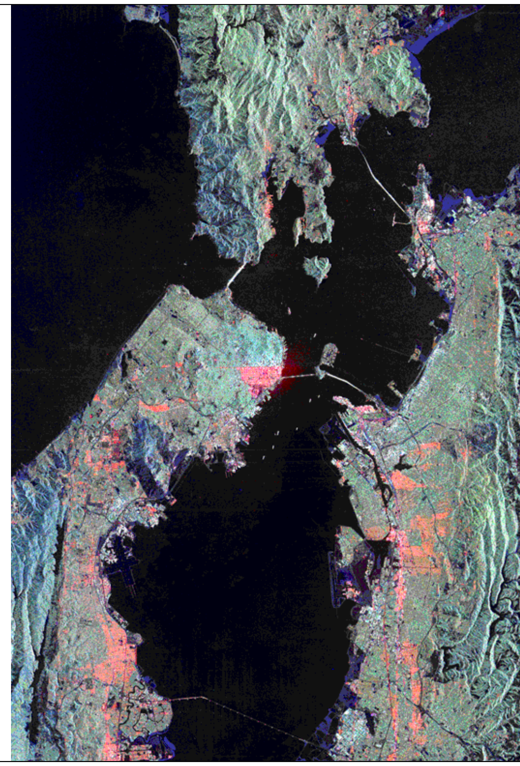
What causes radar backscatter?

Structure: corners, orientation, roughness, scattering

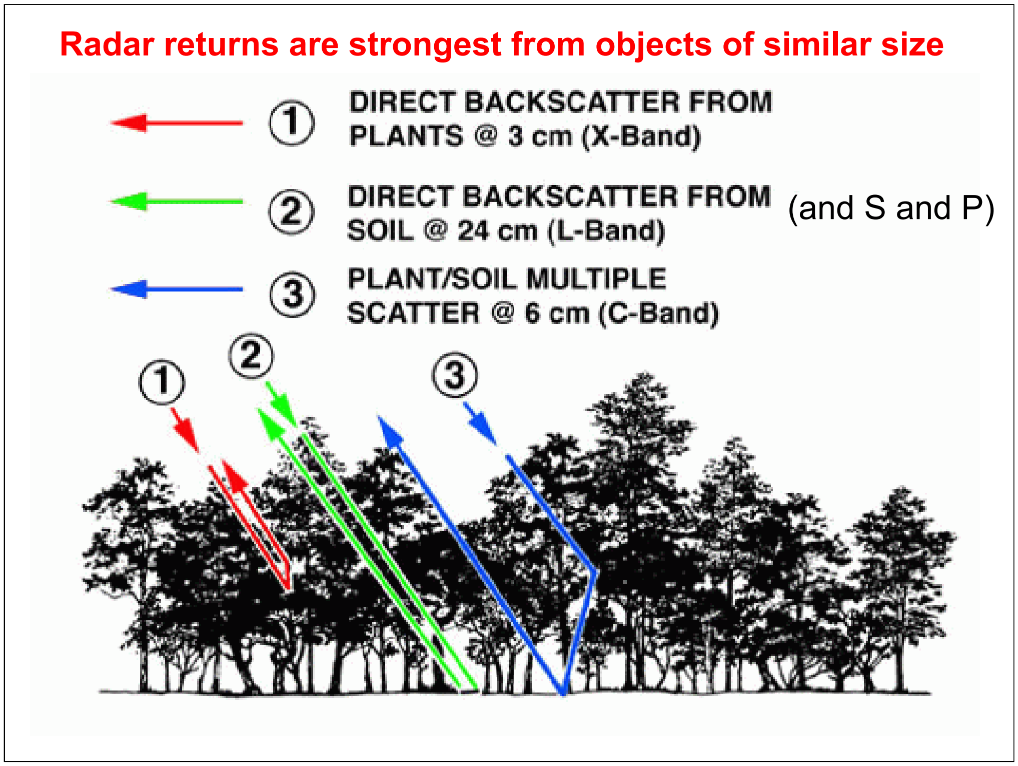
Materials: water, dielectric constant

Vary by wavelength, polarization





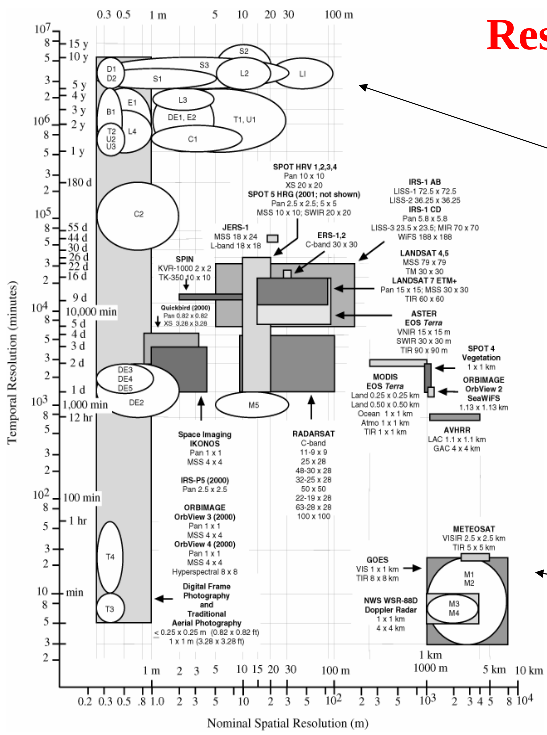
SIR C data pf San Francisco region. What would you say? 3 bands, some areas mostly from one band or another (pure colors) but much of the area is intermediate (contribution from all 3 bands). What would red be responding to? Blue?



Radar signals can be generated at several different wavelengths, which is useful because the energy has an ability to travel through vegetation or soil to different amounts that are controlled by the dielectric constant of the material. As this diagram shows, short wavelength radar (2 cm) will be reflected from the tops of trees. Long wavelength radar (24 cm) data will normally go right down to the ground and be reflected off of the surface. Intermediate wavelength radars (say, 6 cm) will sometimes experience multiple scattering events within the canopy.

If we had a set of different wavelength radar images over a forest, it should be possible to use this changing penetration capability to study the structure of the trees and the total amount of material ("biomass") in the forest.

Resolution Requirements



Clear polygons represent the spatial and temporal characteristics of selected *urban attributes*

Gray boxes depict the spatial and temporal characteristics of the *remote sensing systems* that may be used to extract the required urban information

Consider resolution requirements for different types of conditions.

DMSP Night Lights Image of the U.S. in 2003

Produced by Chris Elvidge, NOAA

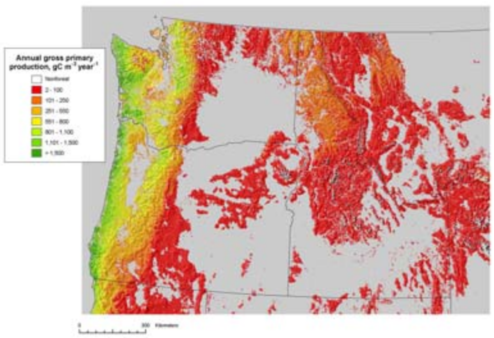
Brightness of nightlights has been used to map population density.

The next generation weather satellite system, NPOESS, will have an instrument, VIIRS, that will be able to continue making these measurements.

Focus Now is on Developing models that use RS inputs:

GPP Predictions Tested in the Pacific Northwest

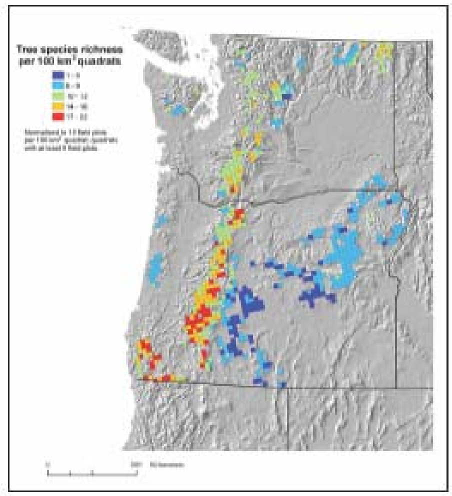
(Swenson & Waring 2006 Global Ecology & Biogeography)

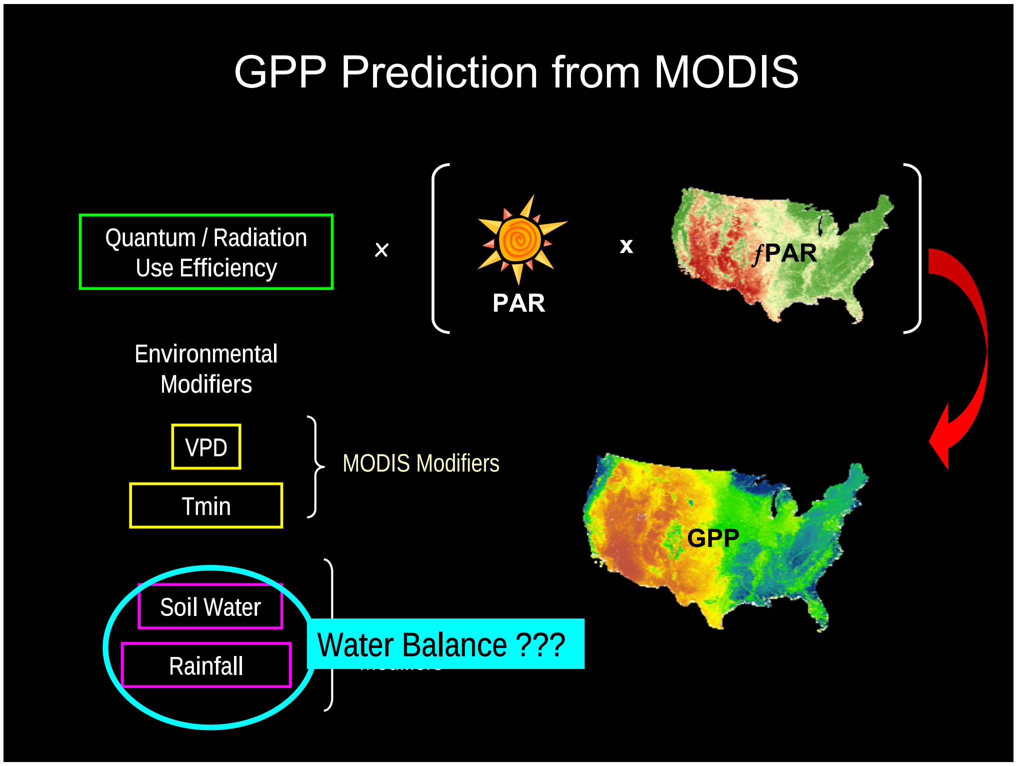


Recorded Tree richness

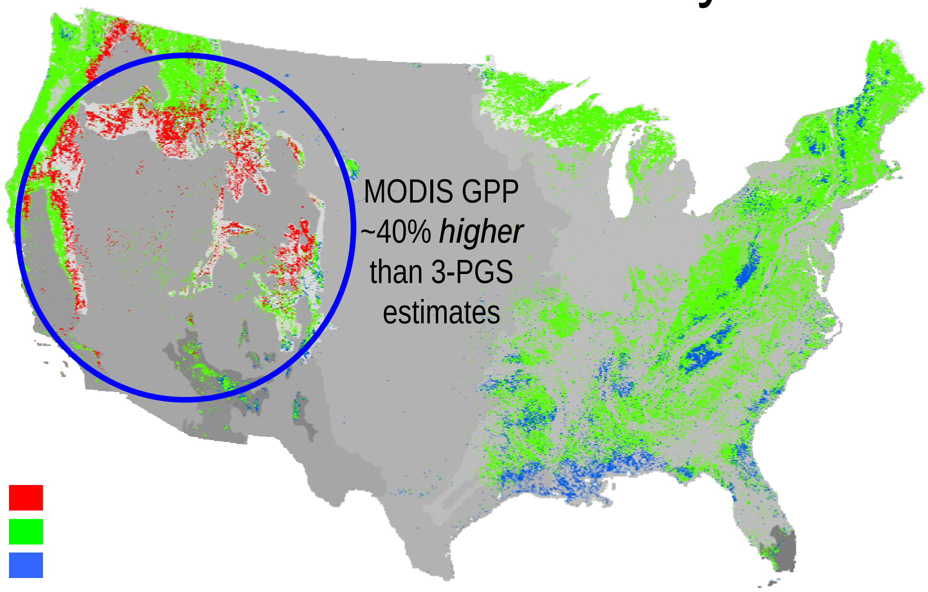
n = 10 300 CVS plots

Model GPP with 3-PG

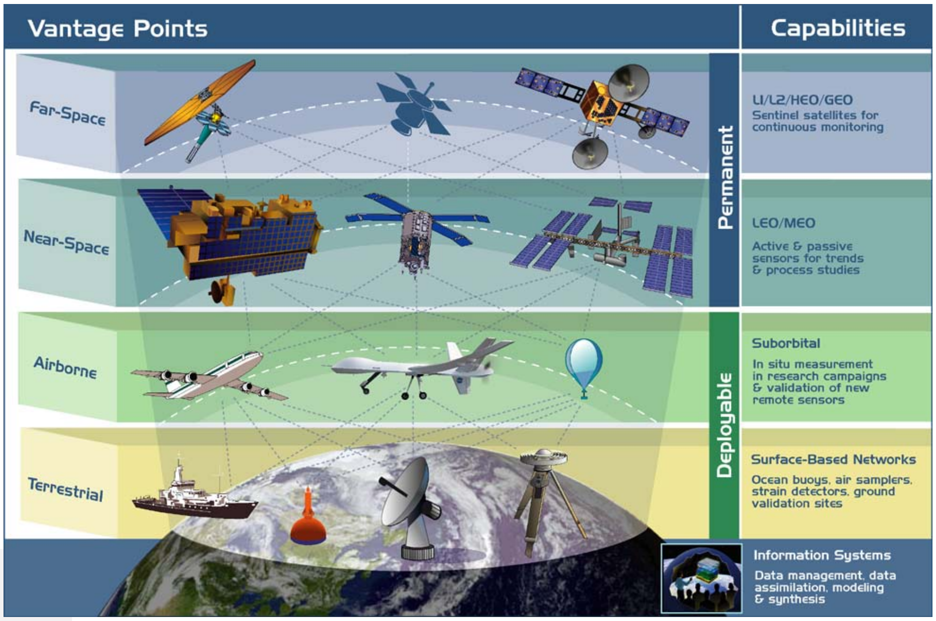



GPP Prediction from MODIS
Quantum / Radiation Use Efficiency
x
PAR
x
fPAR
Environmental Modifiers
VPD
Tmin
MODIS Modifiers
GPP
Soil Water
Rainfall
Water Balance ???

Soil Water Sensitivity

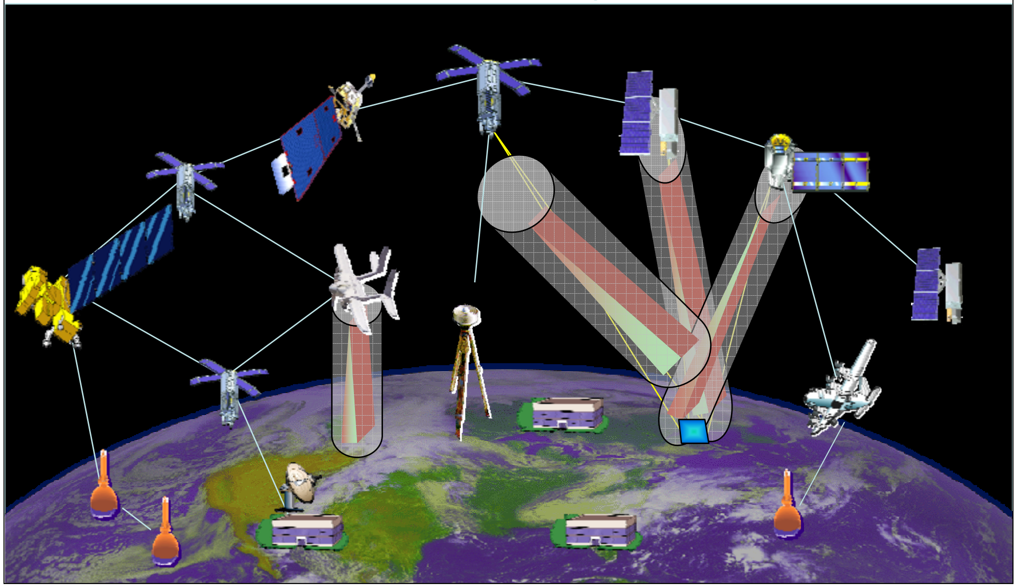


NASA's Concept for Integrated Future Global Earth Observing Systems



Sensor webs

A sensor web is a coherent set of distributed "nodes", interconnected by a communications fabric, that collectively behave as a single, dynamically adaptive, observing system.



.Lecture 19; Review

1. Be prepared to synthesize information: If you were given an image, think about how it is interpreted, or what data type it is, etc.
2. For different applications, try to be able to identify what types of information are needed, what instruments would produce the data in the best spatial, ,spectral and temporal scales.
3. Examples from Landsat, SPOT, and high resolution satellites like Quickbird and Ikonos
4. Remember basic physical facts of measurements: processes controlling reflectance: scattering, absorption, transmission
5. What are differences between plants/vegetation, soils, geology and water that require specialized measurements or considerations?
6. Processes controlling thermal emissions
7. How lidar and radar systems work
8. What is needed for weather and climate information?
9. Go back and review the “what you should know sheets” at the end of each lecture.
10. Check the text if you are uncertain.