THE UNIVERSITY OF ARIZONA

BE/BAT 485/585

Remote Sensing Data and Methods

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vip.arizona.edu

vegetation index & phenology lab.

...Understanding a piece of the Earth system

Today we Will

- Clarify a few more things about the class
- Establish a Foundation & Context
- Introduce basic concepts
- HW#2 if we have time!

Course Outlook

- **Programming, Data Science, and Python**
  - Any prior experience is a big plus, you can still do fine with a minimum to no exposure
  - Lots of programming, and you must be patient and super organized
  - I highly encourage you to work together if possible
  - Armando & Truman will help (and of course me)
    - A drop-in ZOOM office hour weekly right after the Friday lab.
- **Grad students Project**
  - Start thinking now and work should start by Spring break (~20 hrs of work)
  - Something of interest. We can talk if you need too
  - Must be about RS, Images, Time Series, etc.
- **During this Pandemic**
  - Take it easy, stay positive, and reach out (!!??)
  - Do not worry about the grades
  - Find 'buddies' and work together
  - Open offer to all, we can go for a coffee if anyone needs to chat (I will buy!)

Some Context

- Science while mostly **exploratory**, **explanatory**, and about **creativity** needs a context
  - Arguably we do things for curiosity and fun
  - **CONTEXT** [MW Dictionary]:
    - *In its earliest uses (documented in the 15th century), context meant "the weaving together of words in language." This sense, now obsolete, developed logically from the word's source in Latin, contexere "to weave or join together*.
    - *Context now most commonly refers to the environment or setting in which something (whether words or events) exists. When we say that something is contextualized, we mean that it is placed in an appropriate setting, one in which it may be properly considered. And without which it may mean little to most.*
- You could think of it as the "Why?"

So why do we Care?

- The following 2 statistics should convince you:
  - 3.39 B or ~76% increase in global population
    - From 4.45 B in 1980 to ~7.921 B as of today (2022)
    - Check these two links
      - https://www.worldometers.info/world-population/
      - https://visual.ly/community/interactive-graphic/geography/world-population-density-2010-3d-rotating-globe
  - ~21.77% increase in atm. CO_2 (https://gml.noaa.gov/ccgg/trends/)
    - In 2022: From 340 *ppmv* (1980) to 414.01 *ppmv* (as of Jan. 5th, 2022)
    - Was 411.66 *ppmv* in Jan. 2021

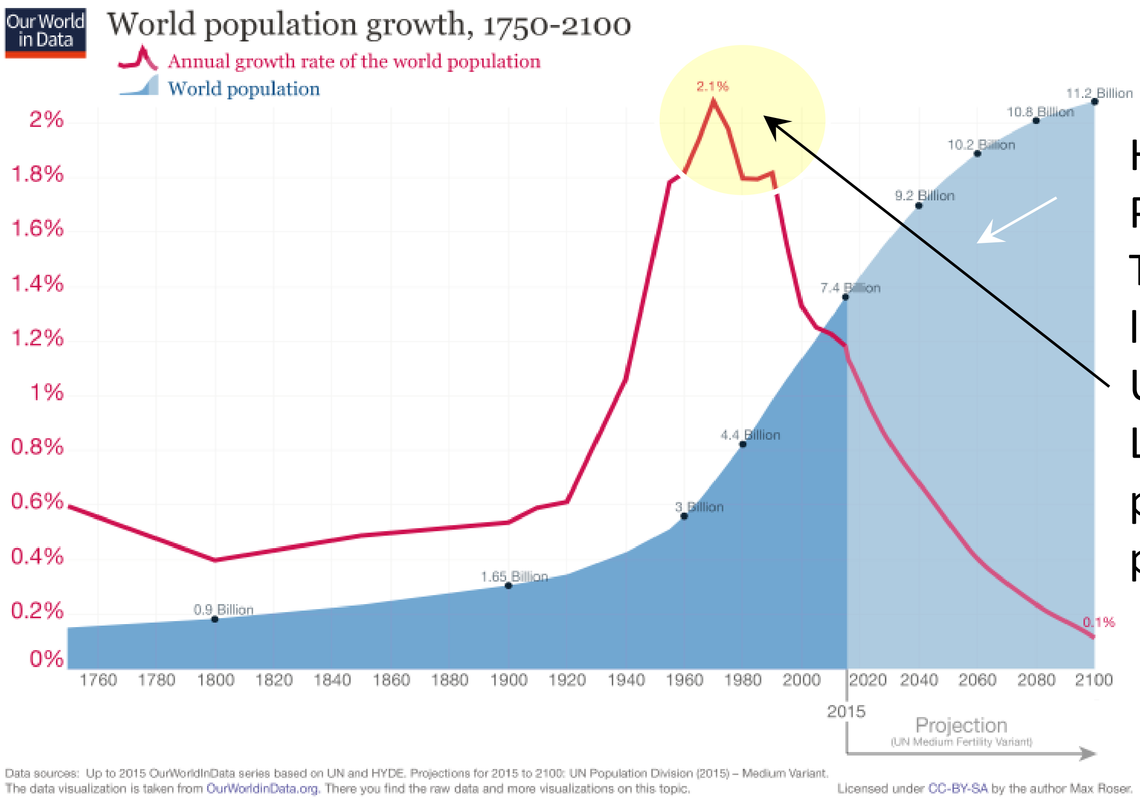
So why Do We Care?

- **This is not abating**
  - **Humans are having serious impacts on Earth (Resources, Diversity/Richness, Distribution, etc.)**
  - **And this requires monitoring**
- **We should care**
  - **And caring starts by observing, monitoring, predicting, and devising solutions, then making tough decisions**
  - **This is not even about global warming, this is about simple math (resources consumption and management and the associated changes)**
  - “*Fearmongering “prophets of doom” who will cripple global economies and strip away individual liberties in what he described as a misguided mission to save the planet*”. **That was President Trump’s opening remarks at the World Economic Forum’s annual meeting in Davos, Switzerland (Jan. 2020). Many unfortunately hold the very same convictions.**

WORLD Population

By the time, this lecture is over the world population would have increased by **~ 9000 people**

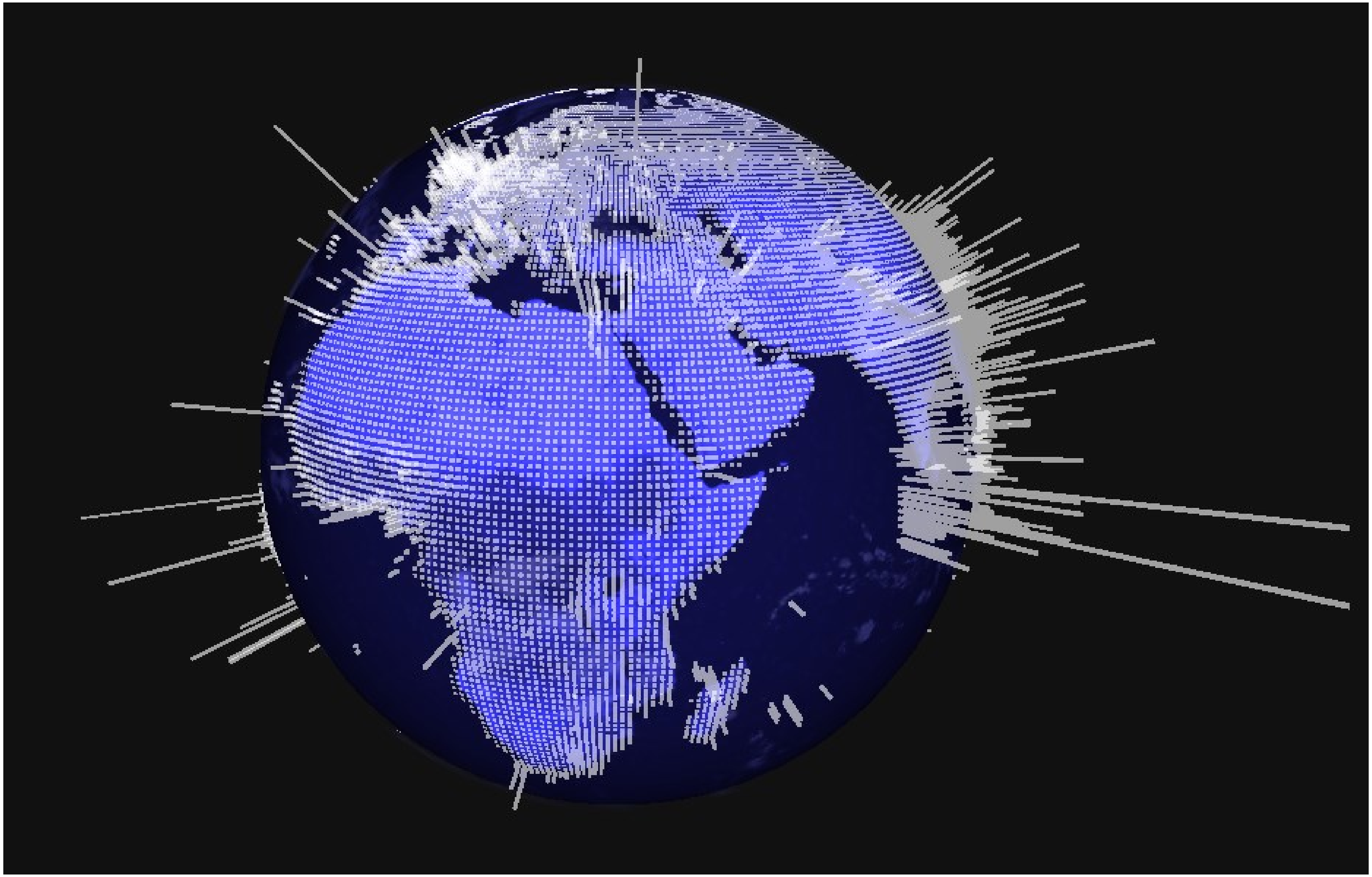
https://www.worldometers.info/world-population/



Health care
Post Colonialism
Then Education and quality of life.
Unbelievable rate of 2.1%
Likely to be followed by a population decline at some point.

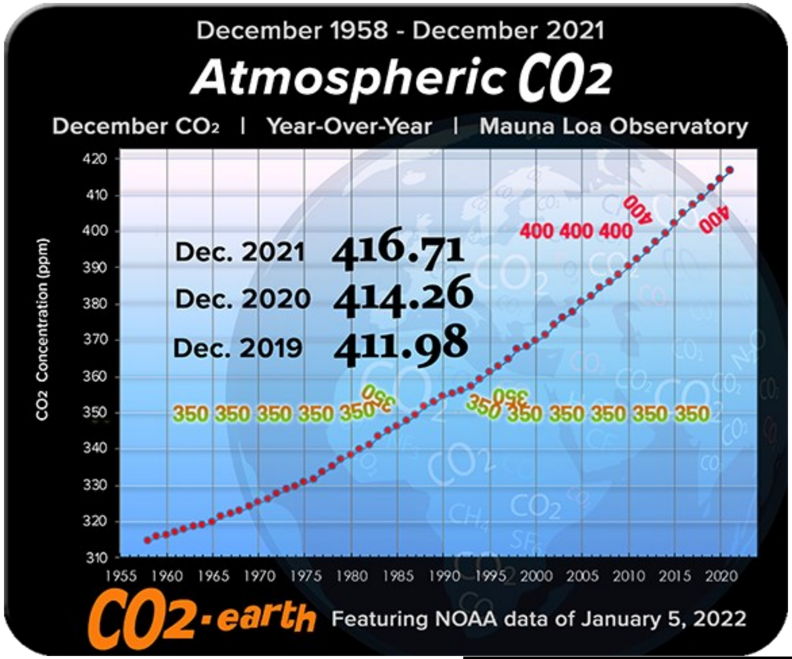
WORLD Population Distribution

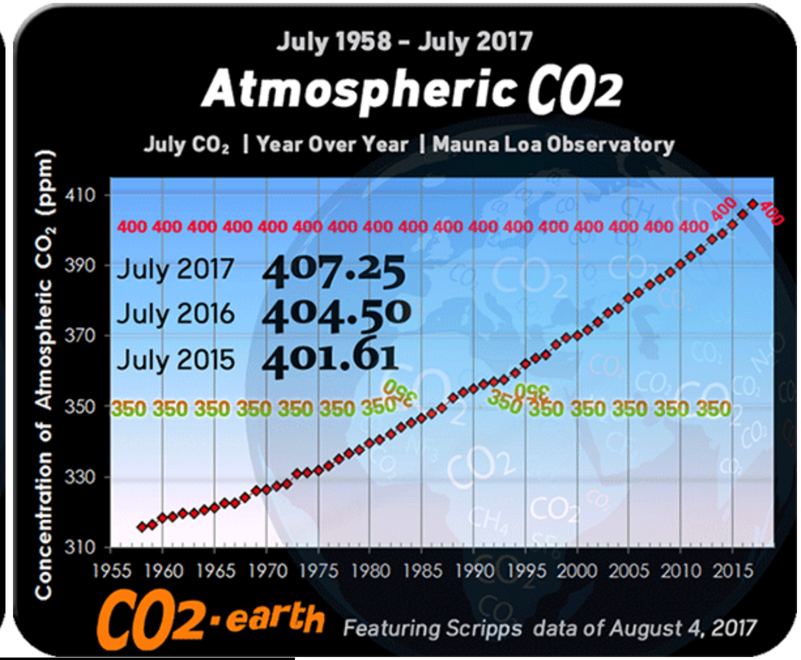
http://www.smartjava.org/examples/population/



The Keeling Curve (Human Impact)

https://www.co2.earth/

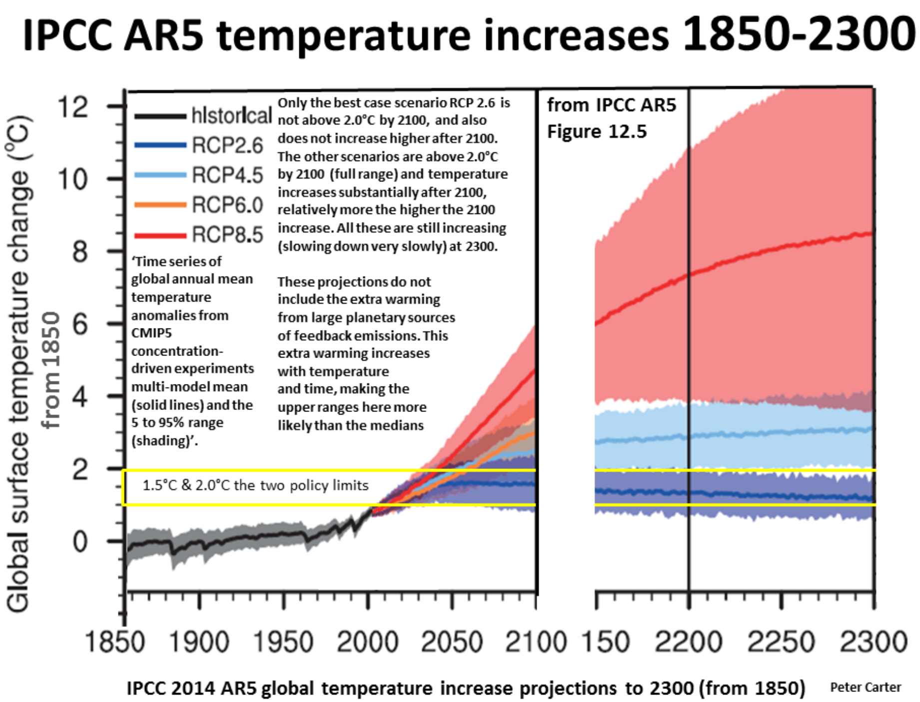


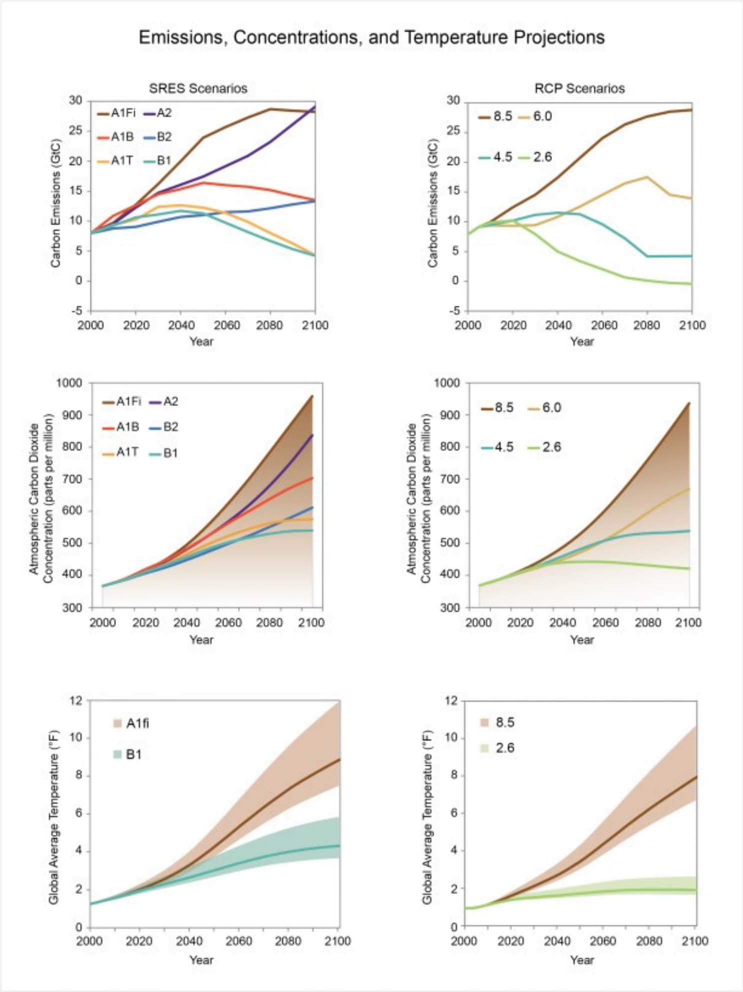


Climate Change Projection

- **Weather (short term) vs. Climate (long term normal)**
- **With Climate we mean**
  - **Temperature, Precipitation, and other indicators/parameters (Glacier's thickness, Sea Ice, Sea surface level, etc…)**
- **Observation vs. Simulation/Projection**
- Two families of scenarios are commonly used for future climate projections
  - The 2000 Special Report on Emission Scenarios (SRES)
    - The SRES scenarios are named by family (A1, A2, B1, and B2), where each family is designed around a set of consistent assumptions: for example, a world that is more integrated or more divided (Population growth, Economic growth, Resources use, Fossil fuel burning, Policy change, etc.)
  - And the 2010 Representative Concentration Pathways (RCP)
    - The RCP scenarios are simply numbered according to the change in radiative forcing (from +2.6 to +8.5 watts per square meter) that results by 2100.
    - SRES A1fI is similar to RCP 8.5;
    - SRES A1B to RCP 6.0 and SRES B1 to RCP 4.5. The RCP 2.6 scenario is much lower than any SRES scenario because it includes the option of using policies to achieve net negative carbon dioxide emissions before the end of the century, while SRES scenarios do not. (Data from CMIP3 and CMIP5).

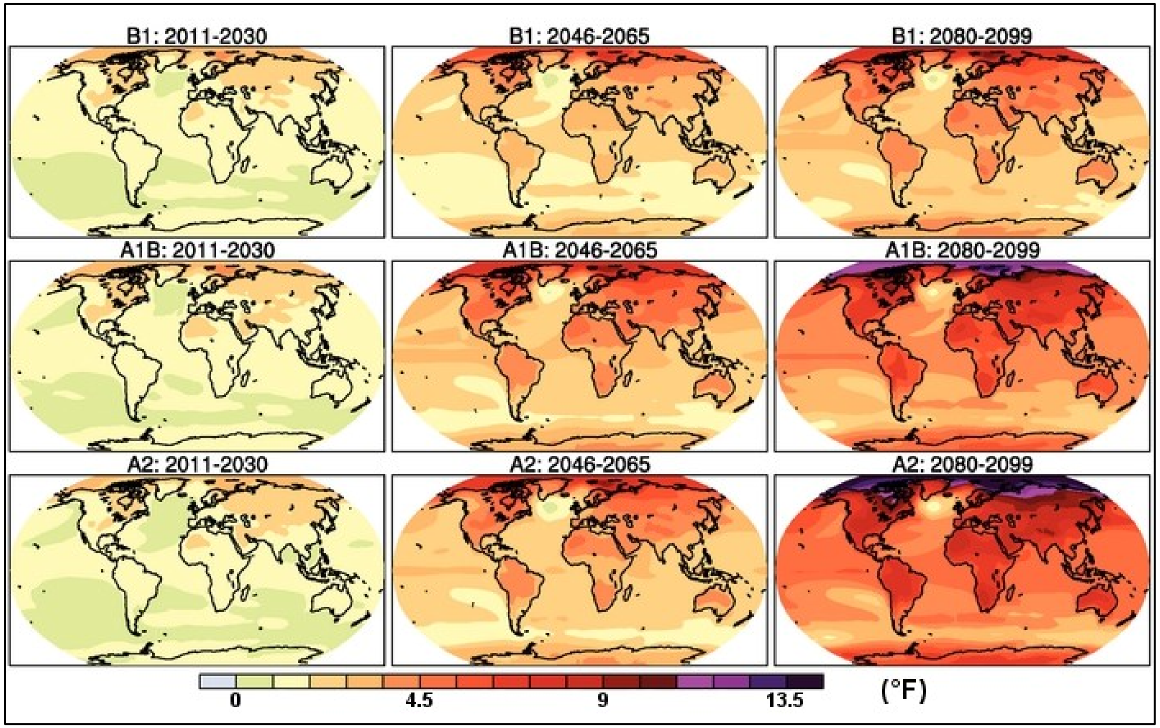
Climate Change Projection



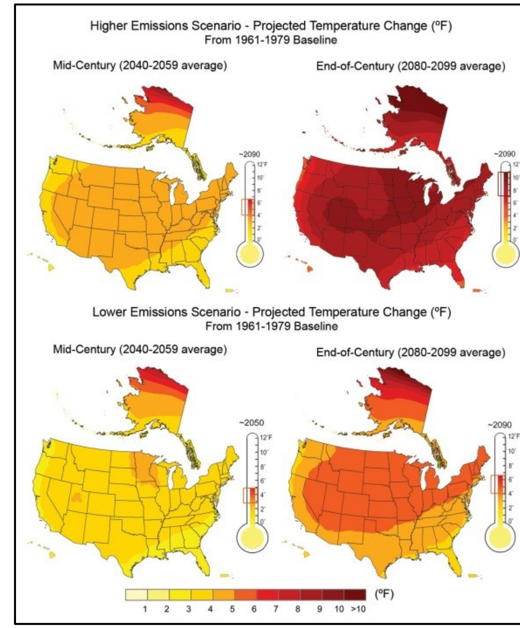


CC Projection-Temperature

Early Mid End

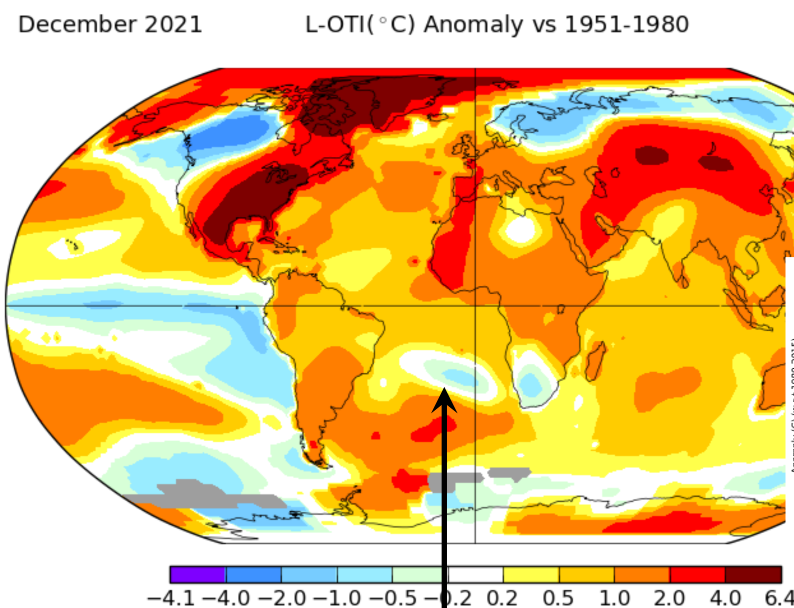


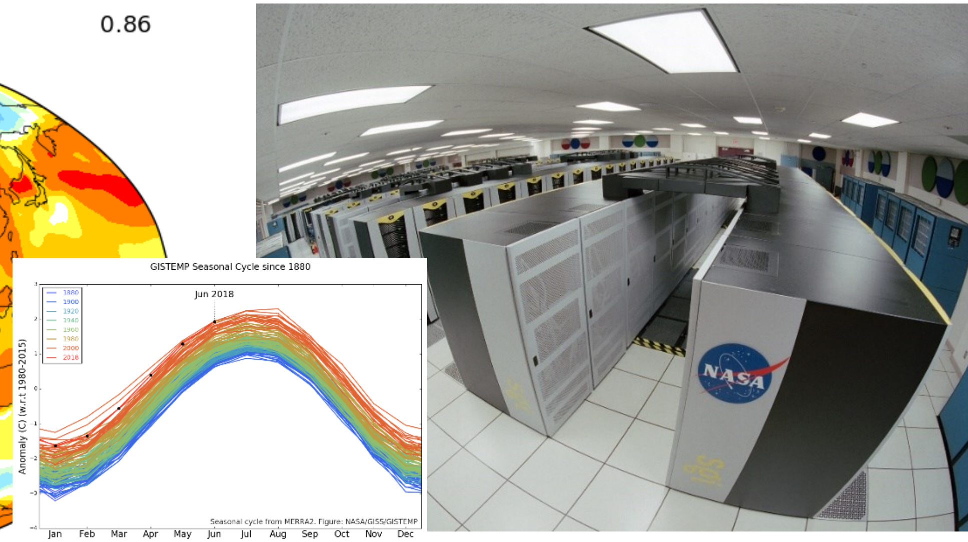
Projected changes in global average temperatures under three emissions scenarios (rows) for three different time periods (columns). Changes in temperatures are relative to 1961-1990 averages. The scenarios come from the IPCC Special Report on Emissions Scenarios: B1 is a low emissions scenario, A1B is a medium-high emissions scenario, and A2 is a high emissions scenario ([NRC 2010](#)).



Projected temperature change for mid-century (left) and end-of-century (right) in the United States under higher (top) and lower (bottom) emissions scenarios. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible ([USGCRP 2009](#))

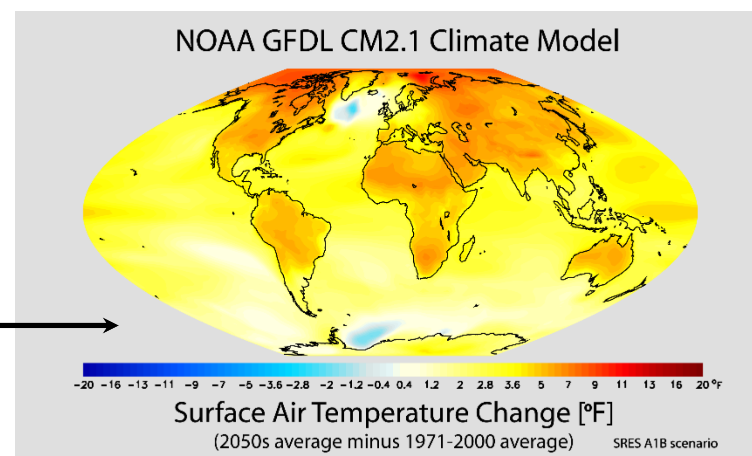
Observed vs Modeled Change in Temperature - Higher Certainty





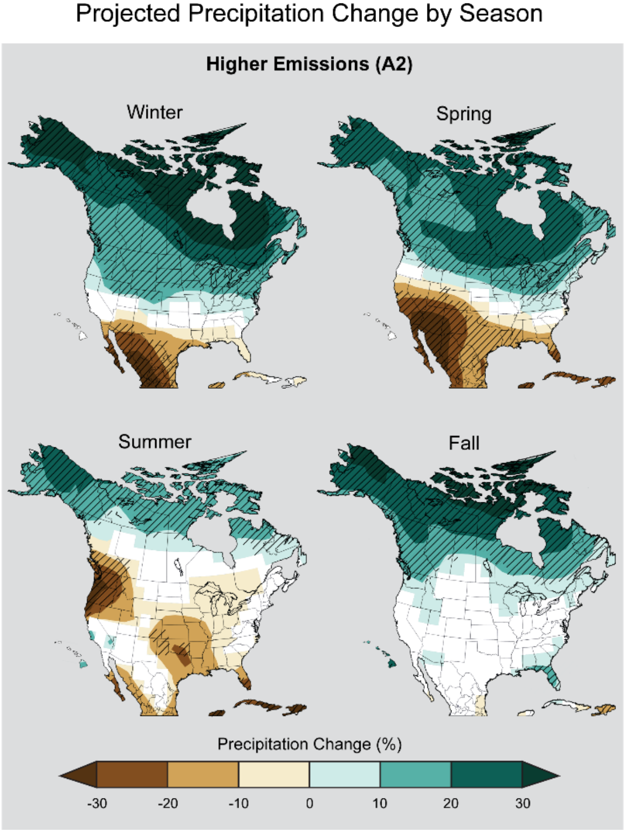
A global map of the Dec 2021 L-OTI (land-ocean temperature index) anomaly, relative to the 1951-1980 Average.
https://data.giss.nasa.gov/gistemp/maps/

Geophysical Fluid Dynamics Laboratory

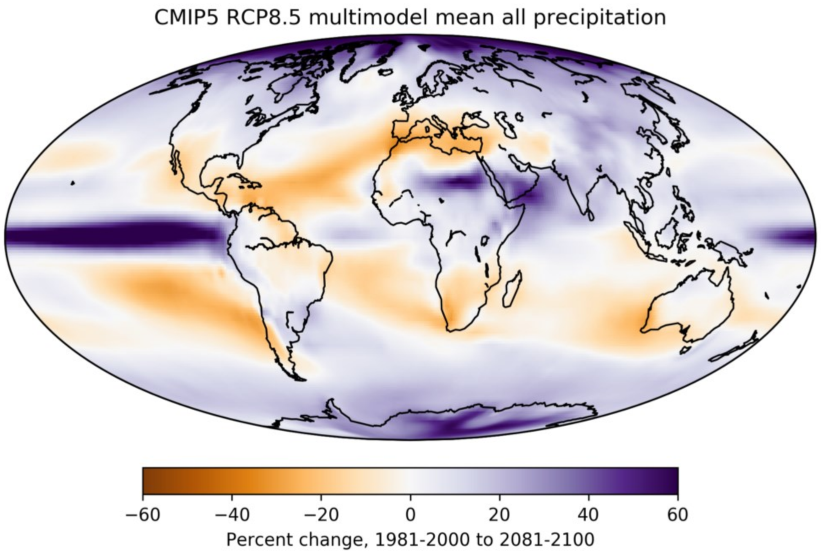


There is an overall correspondence and certainty at least in terms of direction of change

CC Change Projection – Precipitation – Less Certain



Projected change in seasonal precipitation for 2071-2099 (compared to 1970-1999) under an emissions scenario that assumes continued increases in emissions (A2). Hatched areas indicate that the projected changes are significant and consistent among models. White areas indicate that the changes are not projected to be larger than could be expected from natural variability. In general, the northern part of the U.S. is projected to see more winter and spring precipitation, while the southwestern U.S. is projected to experience less precipitation in the spring. (Figure source: NOAA NCDC / CICS-NC).

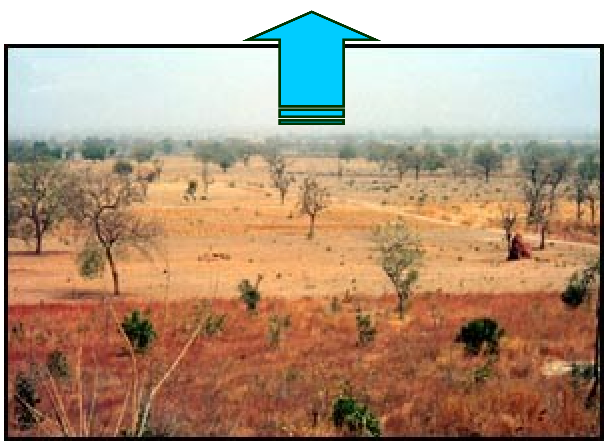


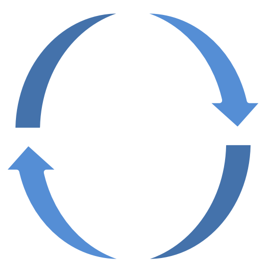
CMIP5 RCP8.5 multimodel average percent change in total precipitation (rain and snow) between 1981-2000 and 2081-2100. Uses one run for each model, 38 models total. Data from KNMI Climate Explorer; map by Carbon Brief.

Plants and Atmosphere

- The pulse of our planet is an essential and critical component of environmental science influencing biodiversity, species interactions, their ecological functioning, and their effects on fluxes of water, energy, and biogeochemical elements at various scales.
- The changes in land surface characteristics depict an integrated response to environmental change and provide valuable information for global change research, invasive species management, drought monitoring, wildfire risk assessment, and agricultural production

Water+CO_2+Radiation





Implications on
Water, Energy,
Carbon balances

Water +CO_2+Radiation

What is the Goal of Science?

- **The goal of science is:**
  - To discover **universal truths** that are the same yesterday, today, and tomorrow and ‘**almost**’ everywhere.
    - Can you name few?
    - Why ‘**almost**’? and not simply everywhere?
- **The hope is:**
  - The knowledge we obtain or understand can be used to improve the ‘quality & way of life’ and our ‘environment’ [from the perspective of this course]
  - Can you think of examples?

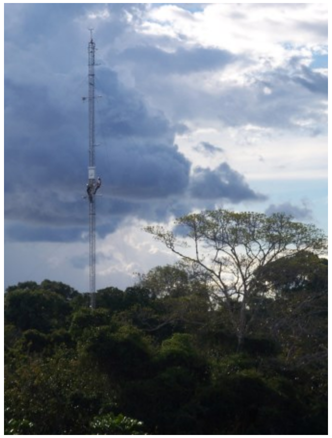
How do we do it?

- **To identify these universal truths scientists:**
  - Observe
  - Make measurements
  - Infer rules
  - Create models
  - Then <u>predict</u> and this is “the epitome and ultimate goal of science”
    - *The most gratifying and flattering achievement is when you find out you were right, or better yet someone else proves you were right.*
      - A famous example is Einstein theory prediction that “gravity bends light”
- **About**
  - The physical world (e.g., the atmosphere, water, soil, rock, forces, etc.)
  - Its living inhabitants (e.g., *Human*, flora, and fauna), and
  - The processes at work, ex. Erosion, Deforestation, Urban sprawl
  - Weather & Climate
  - Can you think of others?

In situ Observations/Measurements

- Recall the ultimate goal is to be able to **model** and **predict**
  - Think of an example?
- In that regard:
  - Scientists and based on observations and measurements formulate ***hypotheses*** and then
  - Attempt to accept or reject them in a **systematic** and **unbiased** fashion
    - **Systematic**: logical, unfailing, repetitive, and orderly
    - **Unbiased**: balanced, impartial, applies everywhere with no exceptions
  - The data necessary to accept or reject a hypothesis may be collected directly in the field, often referred to as *in situ* or *in-place (field)* data collection.
  - But this can be a time-consuming, expensive, and inaccurate process
    - Why inaccurate?

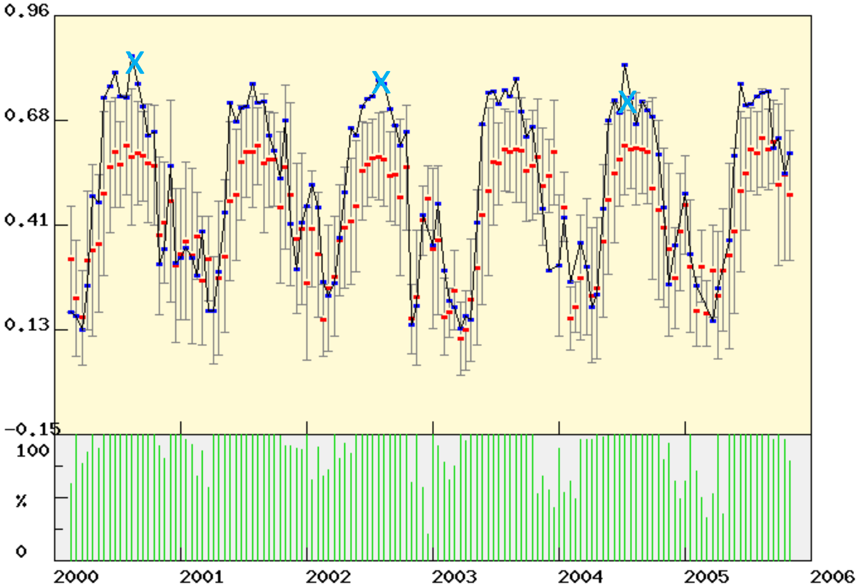
How to Measure and Monitor?



Few meters to
few hectares
Time series

Very Time consuming

A few
hectares/transects
One time



In Situ Data Collection

a. Spectroradiometer measurement.

b. Global positio

In situ Observations/Measurements Challenges

- Collecting data in the field can be subject to **biased procedures** referred to as ‘***<u>method-produced error</u>***’.
- Such error can be introduced by:
  - Sampling design does not capture the spatial variability of the phenomena under investigation
    - **Example**: Some phenomena or geographic areas are oversampled while others are under-sampled
  - Improper operation of *in situ* measurement instruments
  - Uncalibrated *in situ* measurement instruments. This is very critical to Remote Sensing and Imaging

Ground Reference Information vs. Ground Truth

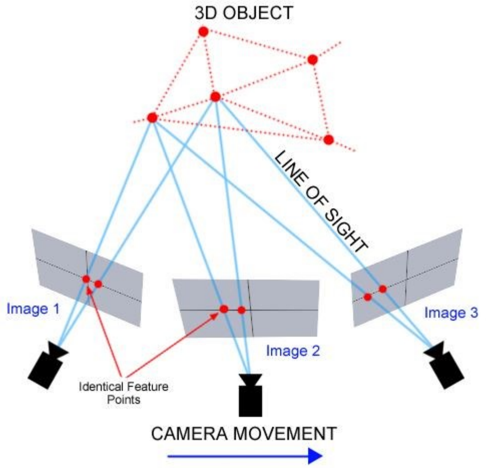
- Could ‘***in situ* data**’ be ‘***ground truth data***’? Yes or No
  - Why?
- Generally, it should be referred to as ‘***in situ ground reference data***’, to acknowledge the potential for <u>**error**</u>
- But generally, and for all practical purposes “***in situ***” data is the closest to truth (true data that is free of most issues) and could be used to validate and characterize other data
  - Recall this is in the context of data collected by cameras/sensors?

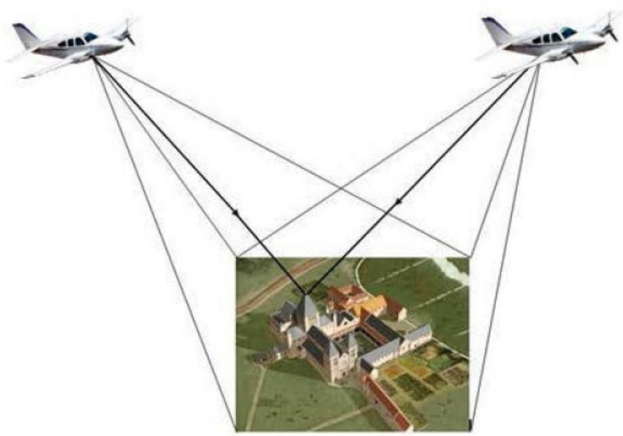
So, What is Remote Sensing?

- There are many definitions, and they are probably all correct, however the "American Society for Photogrammetry and Remote Sensing [**ASPRS**] adopted the following formal definition to describe *photogrammetry* and *remote sensing* as (Colwell, 1997):
  - *Photogrammetry* and Remote Sensing is "the art, science, and technology of obtaining **reliable** information about **physical objects and the environment**, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from **noncontact** sensor systems".

Photogrammetry

- It is a 3-dimensional coordinate measuring technique that uses photographs as the fundamental medium (basis) for ***metrology*** (or measurement).
- The fundamental principle used by Photogrammetry is **triangulation** or more specifically called **Aerial Triangulation**.
- By taking photographs from at least two different locations, so-called "**lines of sight**" can be developed from each camera to points on the object.
- These lines of sight (sometimes called rays owing to their optical nature) are mathematically intersected to produce the 3-dimensional coordinates of the points of interest (used in Structure from Motion to reconstruct 3D space).
- The expression photogrammetry was first used by the Prussian architect Albrecht Meydenbauer in 1867 who fashioned some of the earliest topographic maps and elevation drawings. Photogrammetry services in topographic mapping is well established but in recent years the technique has been widely applied in the fields of architecture, industry, engineering, forensic, underwater, medicine, geology and many others for the production of precise 3D data.





Branches of photogrammetry

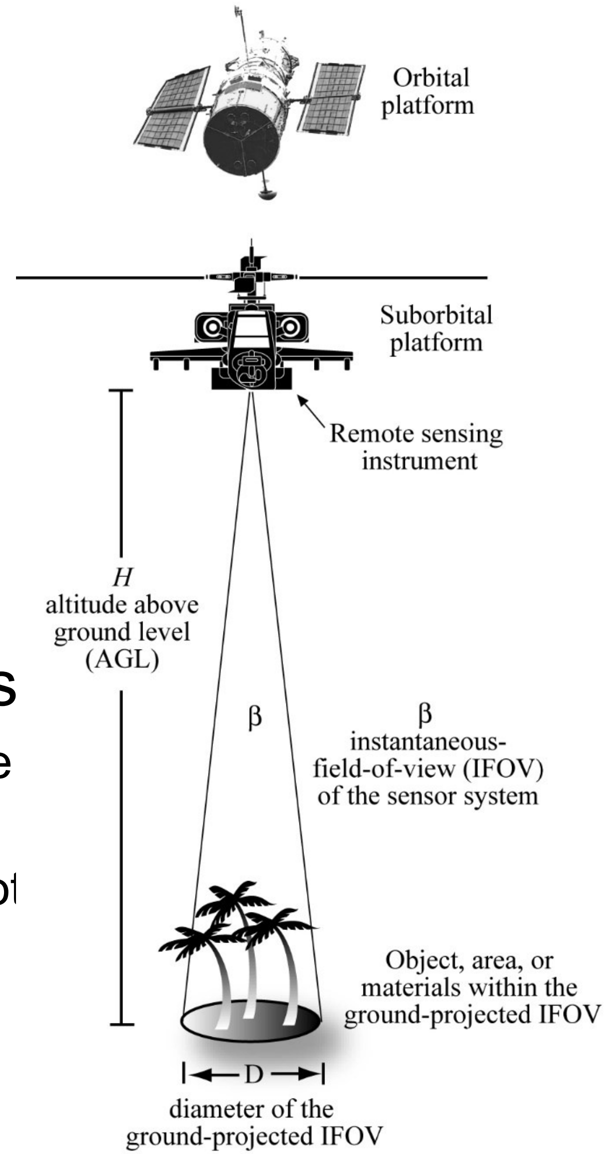
- There are 2 main and broad-based branches in photogrammetry:
  - **Metric Photogrammetry**: Deals with the precise measurements and computations on photographs regarding the size, shape, and position of photographic features and/or obtaining other information such as relative locations (coordinates) of features, areas, volumes, These photographs are taken using a metric camera and is mostly used in the engineering fields e.g. surveying
  - **Interpretive Photogrammetry**: Deals with recognition and identification of the photographic features on a photograph such as a shape, size, shadow, pattern, etc. to add value and intelligence to information seen on the photograph (annotation).

Remote Sensing

- It is a closely aligned technology to photogrammetry in that:
  - It also collects information from imagery.
  - The term is derived from the fact that information about objects and features is collected without coming into contact with them.
- Remote sensing differs from photogrammetry in many ways:
  - The type of information collected, which tends to be based on differences in color (spectra)
    - Ex: Land use and land cover are some of the primary output of remote sensing processing
  - Remote sensing was originally conceptualized to exploit a large number of color bands in satellite imagery to create 2D data primarily for spatial analysis (ex: using GIS).
  - These days, remote sensing tools/software are used with all types of imagery to assist in 2D data collection and derivation, such as biophysical or physical info (ex: slope).
  - Software tools today tend to hold a much wider range of image technologies such as image mosaicking, 3D visualization, GIS, radar, Lidar

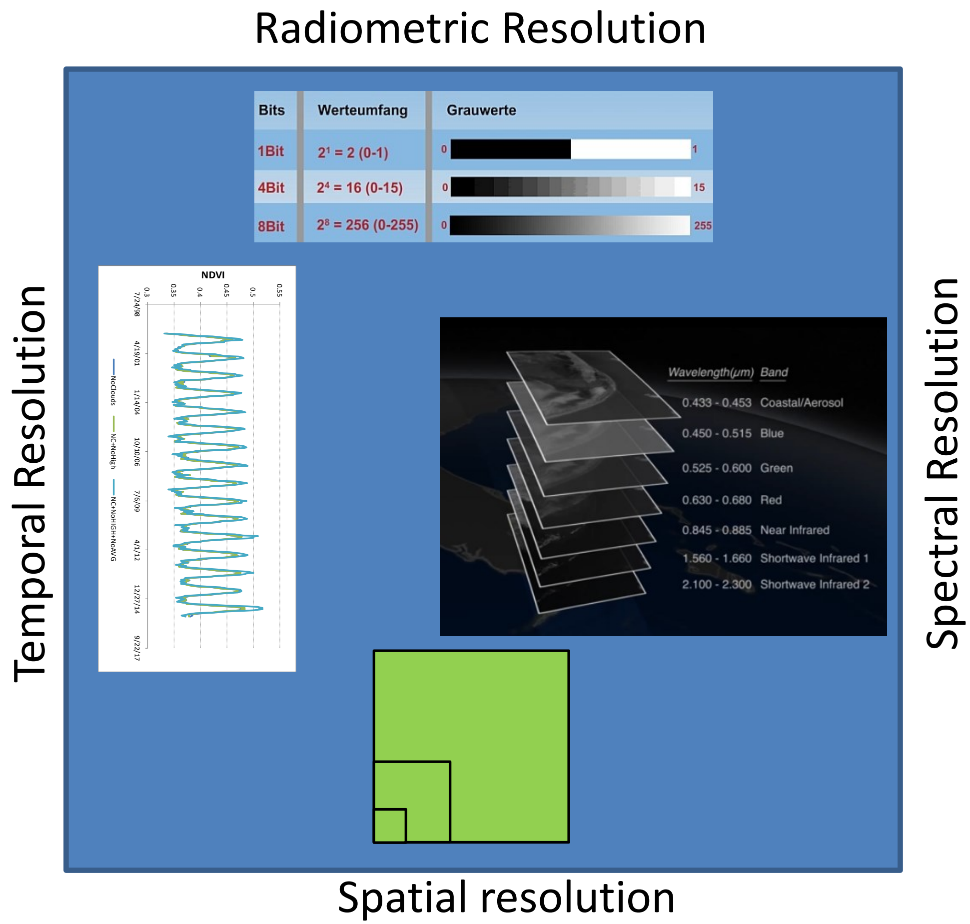
Remote Sensing Instruments

- A remote sensing instrument collects information about an object or phenomenon within the instantaneous-field-of-view (**IFOV**) of the sensor system without being in direct physical contact with it.
- The sensor is located on a suborbital or satellite platform.
- There are different satellite formations
  - ***Geosynchronous*** (with respect to a reference sun rotation)
  - ***Geostationary*** (looks at almost the same spot always)
  - Hybrid



Key Characteristics of Remote Sensing

- There are some extremely critical characteristics of a remote sensing systems. Need to always remember and keep them in perspective:
  - Spatial resolution
  - Spectral resolution
  - Radiometric resolution
  - Temporal resolution
- The **radiometric resolution** and the spatial resolution are key characteristics
- Let's review them one at a time

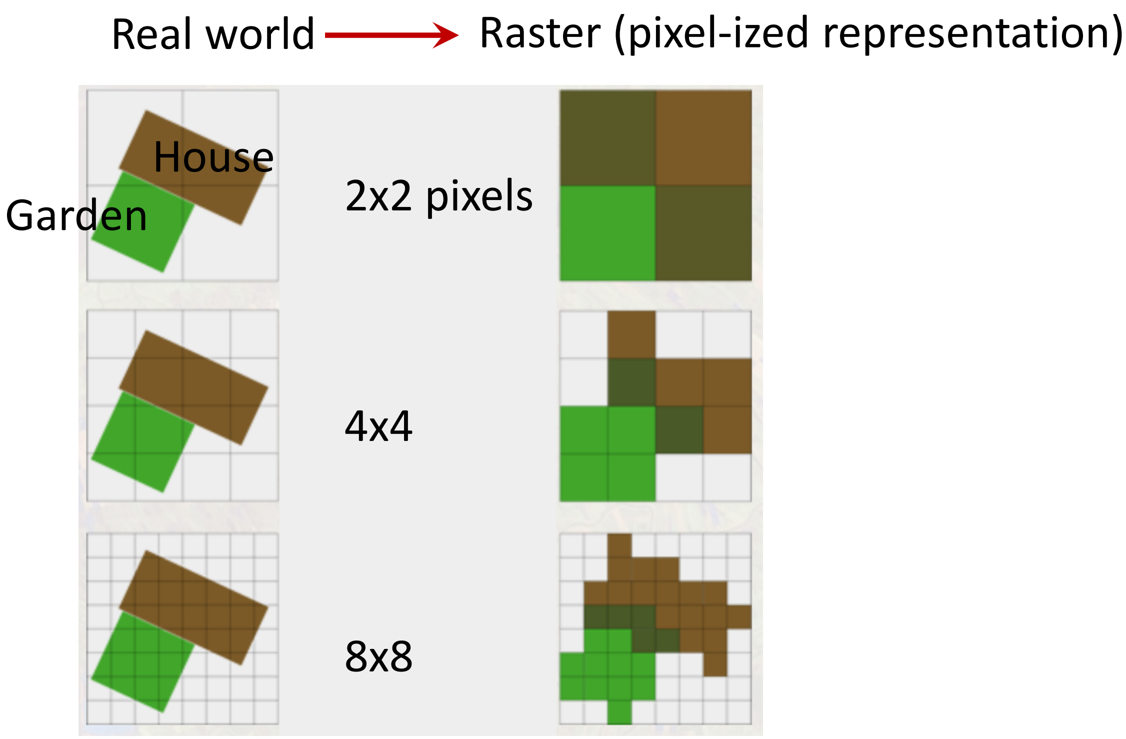


Spatial Resolution

- The **spatial resolution** signals the size of the section of the surface of the Earth which can be depicted in one pixel (one Digital Number – DN - value). Stated in cm/meters/km
- It describes the ability of a sensor to identify the smallest size detail of a pattern on an image. In other words, the distance between distinguishable patterns or objects in an image that can be separated from each other is often expressed in meters.
  - There is a limit and a tradeoff here
  - Finer resolution means smaller coverage area and longer revisit time (monthly and even yearly)
  - Coarser resolution means larger coverage area and more frequent revisit (daily and even multiple times a day)
    - **Can you guess why?**
  - Everything within the pixel is aggregated (averaged).

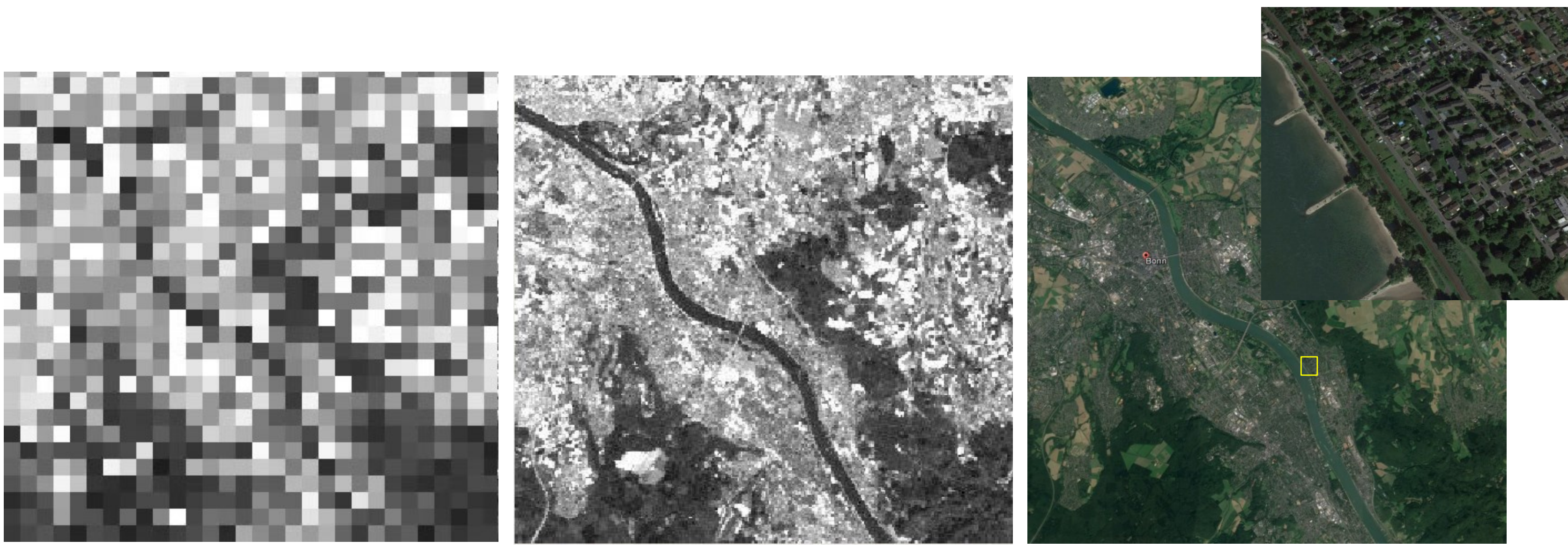
Spatial Resolution

- A **spectral remote sensing sensor** detects the reflected/emitted radiation of the Earth's surface and stores it as **digital numbers** (**DN**) in a **Raster (**matrix**)**.
- Each area detected constitutes a cell in a raster. And these raster cells are called **pixels**.
- The size of an area represented in a pixel depends on the capability/design of the sensor to detect details.



Low and High Spatial Resolution

- The ability of a remote sensing sensor to detect **details** is referred to as **spatial resolution**.
- The spatial resolution is defined in meters.
- The more pixels the more details can be observed, the higher the spatial resolution
- In the images below you can distinguish the higher spatial resolution of 30 m and a lower spatial resolution of 300 m.
- As resolution degrades (low) **much more different objects must be aggregated** in one pixel



Three images of the same location (Bonn, Germany) with Spatial resolution of 30 m and 300 m and 30m (© USGS/NASA Landsat Program).

Mixed Pixels – Spectral Mixing

- Objects that are close together must be represented by one pixel (one value).
- Such pixels are called **mixed pixels**.
- Depending on the sensor design and other factors the color (spectral) components of the pure objects are aggregated and result in mixed color/pixel (spectra), which is quite challenging to analyze.
- The lower the spatial resolution, the more mixing and the harder the analysis

Mixed Pixels – Spectral Mixing

- Objects that are close together must be included in one pixel.
- Such pixels are called **mixed pixels**.
- Depending on the sensor design and other factors the color (spectral) components of the pure objects are aggregated and result in mixed color/pixel (spectra), which is quite challenging to analyze.
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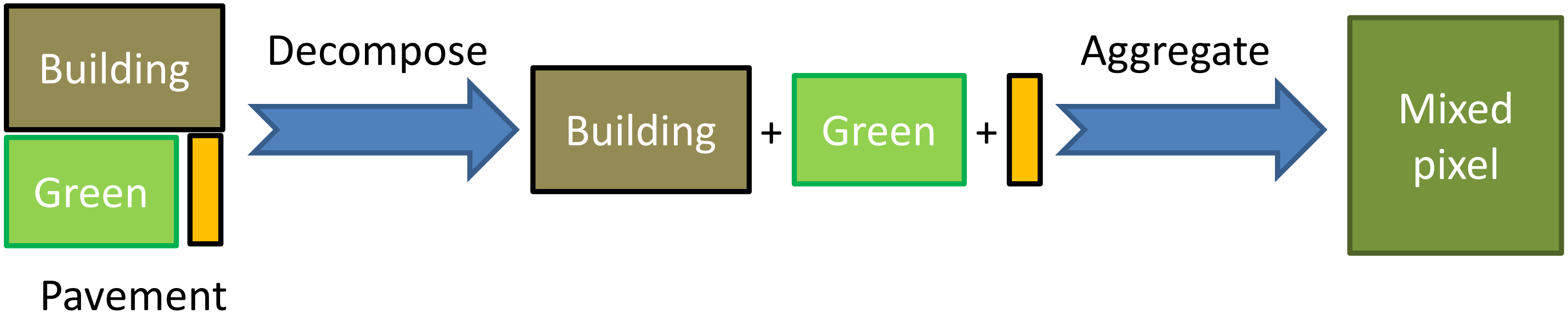
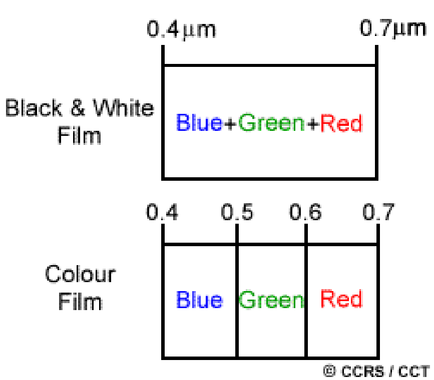


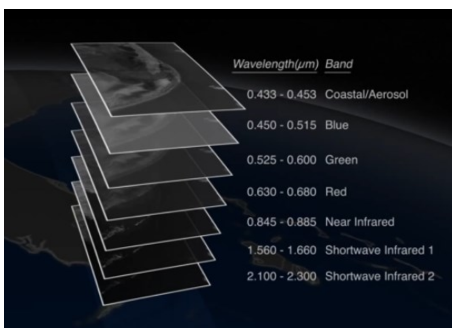
Why do Only Some Sensors Have a High Spatial Resolution?

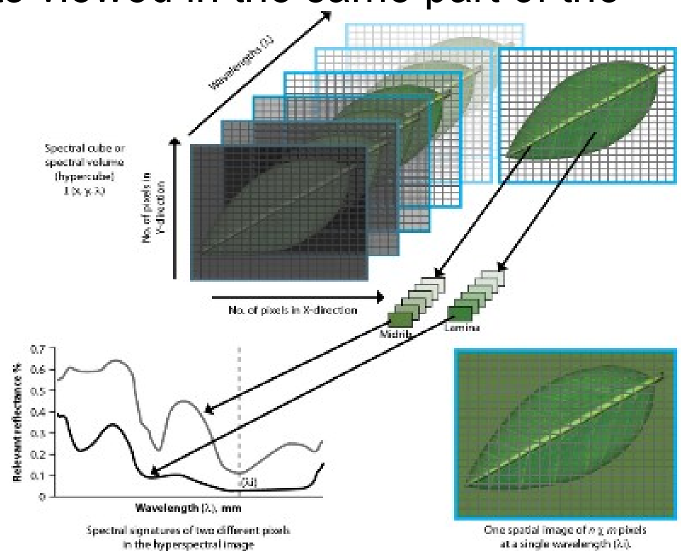
- It depends on the objectives and purposes of the remote sensing systems. The same sensor attached to an airplane will have a very high resolution (ex: 1 m, even few mm with drones these days), whereas the satellite-based sensor will have a lower resolution (ex: 30 m).
- At the same time, the satellite-based sensor detects a wider area in one single image and circles the Earth completely in only few days. This is impossible for aircrafts!
- So, the spatial resolution characteristics of spectral sensors are determined by the ratio of **extend** and **resolution**.
- If a maximized extend is required in order to capture greater areas, we have to lower our resolution
- Other considerations are the resulting data size, required supporting systems, distribution, redundancy, etc…
- Each remote sensing sensor produces ***raster image*** data. And each raster consists of raster cells, which are also referred to as pixels.
- The larger the pixel, the more objects on the surface of the earth are captured and the lower the spatial resolution.

Spectral Resolution

- The sensitivity of a sensor to respond to a specific frequency/band range (for satellite and airborne sensors).
  - The frequency ranges include visible light, and non-visible light and electromagnetic radiation.
  - Objects on the ground can be identified by the different wavelengths reflected (interpreted as different colors) but the sensor used must be able to detect these wavelengths in order to see these features.
  - Visible, Infrared, Thermal, Monochromatic, Multispectral, and hyperspectral
- The smallest ‘slice’ of a band or portion of the EM spectrum in which the reflectance of a feature may be assigned a digital number
- Finest distinction that can be made between objects viewed in the same part of the EM spectrum.

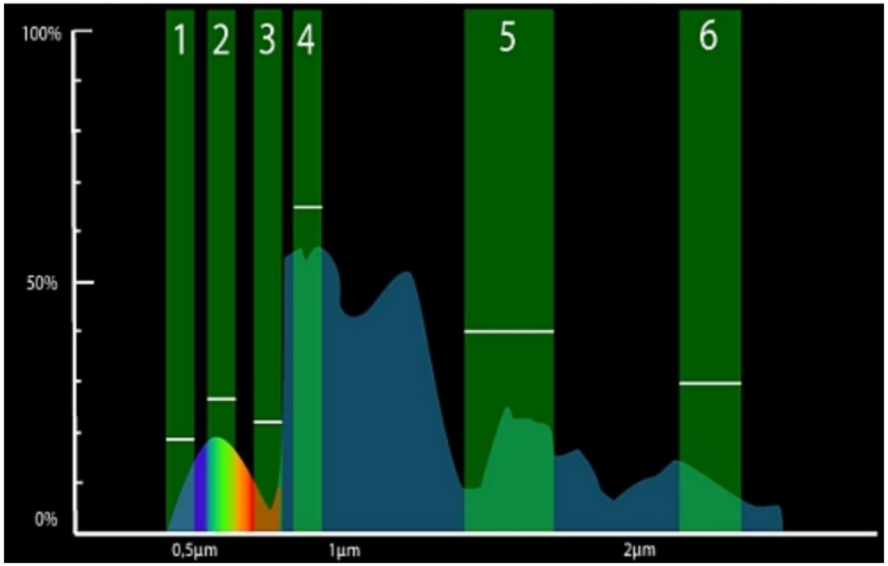






Spectral Resolution

- A Spectral sensor perceives objects as levels of grey.
- Each spectral band (wavelength) is detected separately and stored as light intensity.
- Blue light is stored in the blue band, green light in the green band and red light in the red band, etc.
- The higher the number of bands of a remote sensing sensor, the higher its spectral resolution.
- Ex: Landsat or OLI has multiple spectral bands (7+ bands)
  - Usually composed of the visible light, infrared light, and thermal radiation.

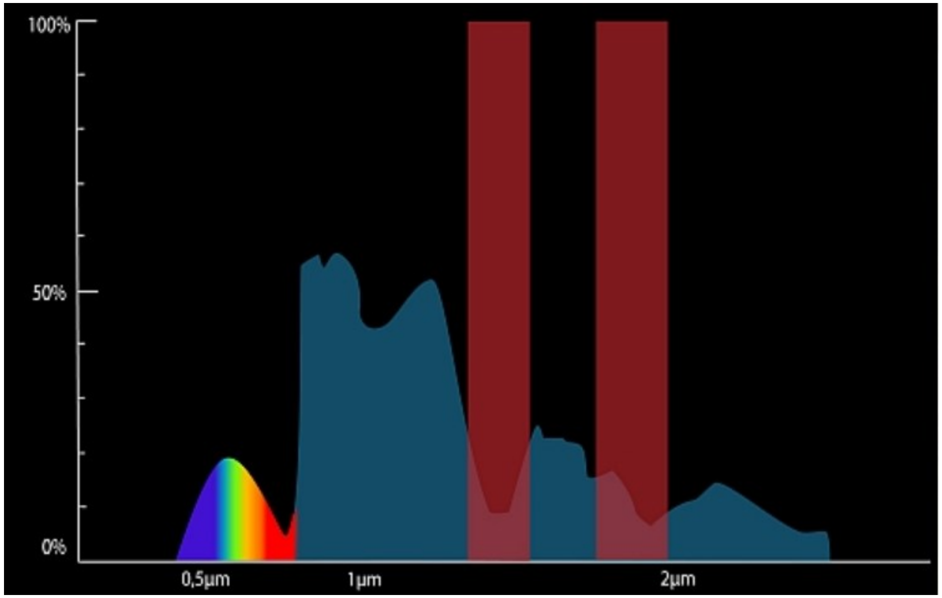


Spectral Resolution

- When using several separate bands for observing the Earth these techniques are called **multispectral remote sensing**.
- There are sensors with 200-400+ bands as well. Called **hyperspectral**.
- Two fundamental conditions have to be considered in order to determine which spectral bands are appropriate for a particular application/sensor:
  - The **atmospheric window** and,
  - The **spectral signature** of the object in question.

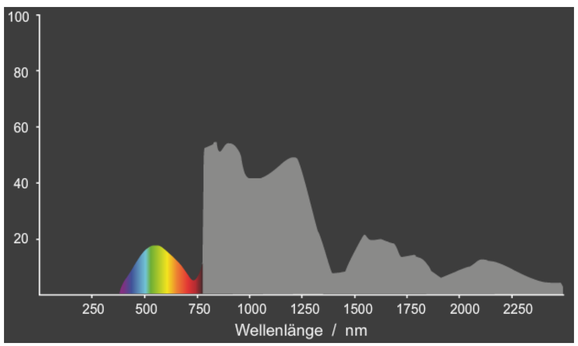
Atmospheric Windows

- Spectral sensors can only store the detect parts of the electromagnetic radiation scattered back from the Earth surface that can pass the atmosphere.
- The Earth's atmosphere contains gases (Water, Ozone, Nitrogen, CO2, etc.) and small particles like smoke, ice crystals, water drops, dust, etc.… These so-called **aerosols absorb** and **scatter** all or some parts of the electromagnetic spectrum.
- So regions of the spectrum that are absorbed by the atmosphere are called **absorption bands**.
- Wavelengths getting through the atmosphere to the sensor are called **atmospheric window**.
- The figure below depicts how intense the solar radiation is per wavelength range.
- The intensity of the reflected **radiation energy** decreases the closer we get to the long-wave range of the electromagnetic spectrum.



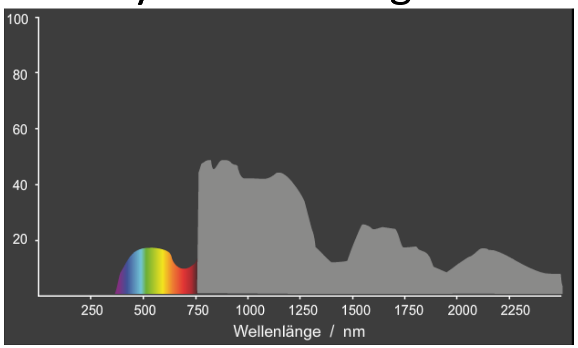
Spectral Signature

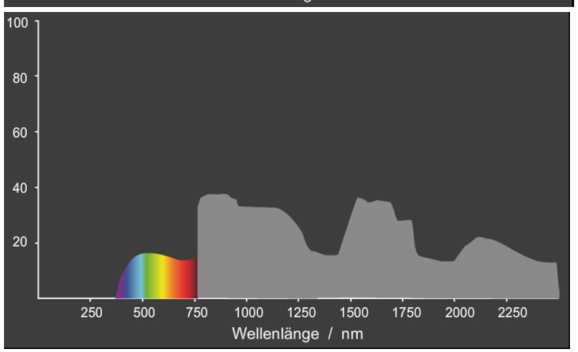
- Besides atmospheric windows, the selection of spectral bands must consider the reflection characteristics (spectral signature) of objects on the Earth's surface.
- Different object on the surface of the Earth reflect differently in the various parts of the electromagnetic spectrum.



Healthy Active Vegetation

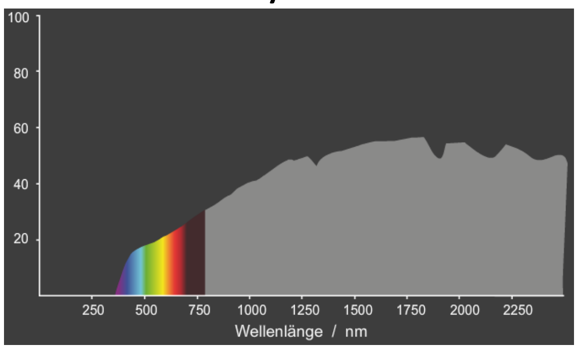
Mildly Stressed Vegetation

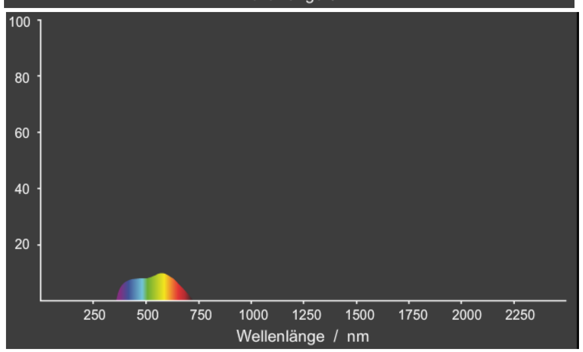




Heavily Stressed Vegetation

Dry soil



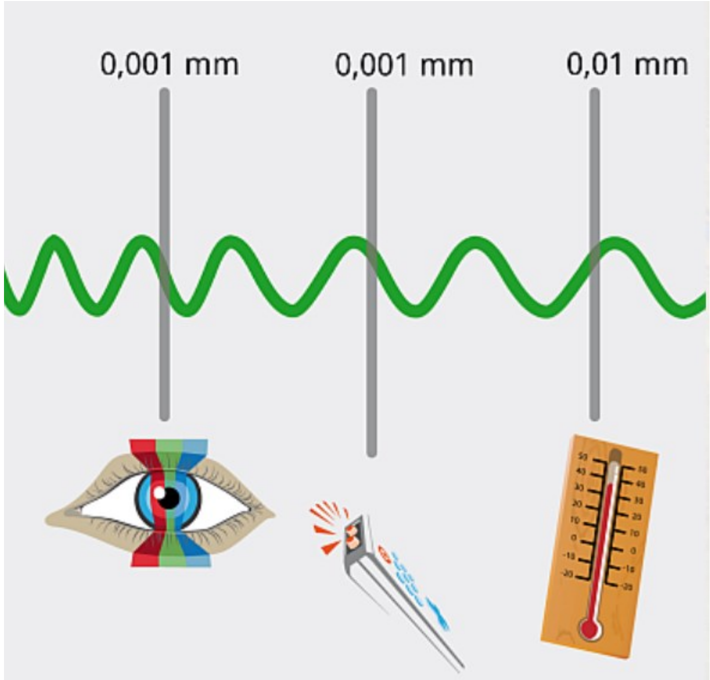


Water

- Dry soil reflects highly in the infrared region, whereas water reflects in the visible range of light only (blue or color of mud). All objects on the surface of the Earth have a specific **spectral signature or fingerprint** that results from its ability to absorption and reflect light.

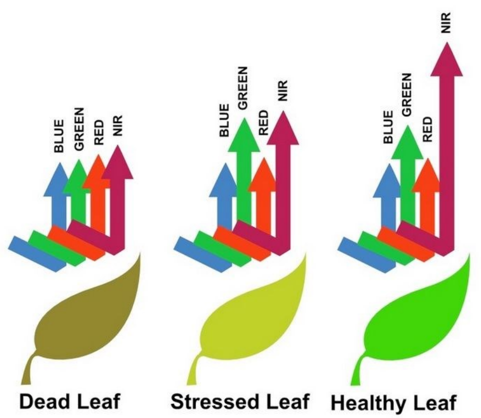
Invisible Infrared

- The visual light(VIS) as well as the **infrared range** are the most important for land multispectral remote sensing.
- The infrared range follows the visible range (0.3-0.7μm) in the electromagnetic spectrum and its wavelengths are between 0.7 und 1000+ micrometer.
- Infrared radiation is **invisible to the human eye** and is divided into near (NIR), short-wave (SIR) mid-wave (MIR), long-wave (LIR) and thermal (TIR) infrared.

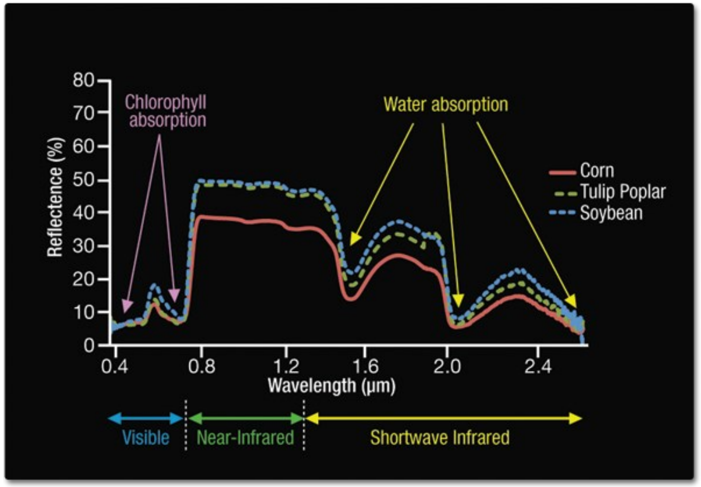


Plant Spectra

- The reflection characteristics of **vegetation** are interesting.
- Active green plants reflect green light greatly, red and blue light partially.
- This is caused by **chlorophyll** which uses the blue and red range of light for **photosynthesis** but reflects the green light.
- The reflection curve has a steep slope in the infrared range and is steady on a high level until it drops down in the range of mid-infrared because of absorption due to the high moisture content in green vegetation.
- This is the so-called **red edge**?
- This jump in signature is due to the plant cell walls which reflect infrared light within the cells several times. Due to the high reflection values in the infrared range we see that plants (much chlorophyll and stable cell walls) are prominent in the infrared band of satellite images.
- If humans were able to see infrared light, leaves would not be green but infrared to us.

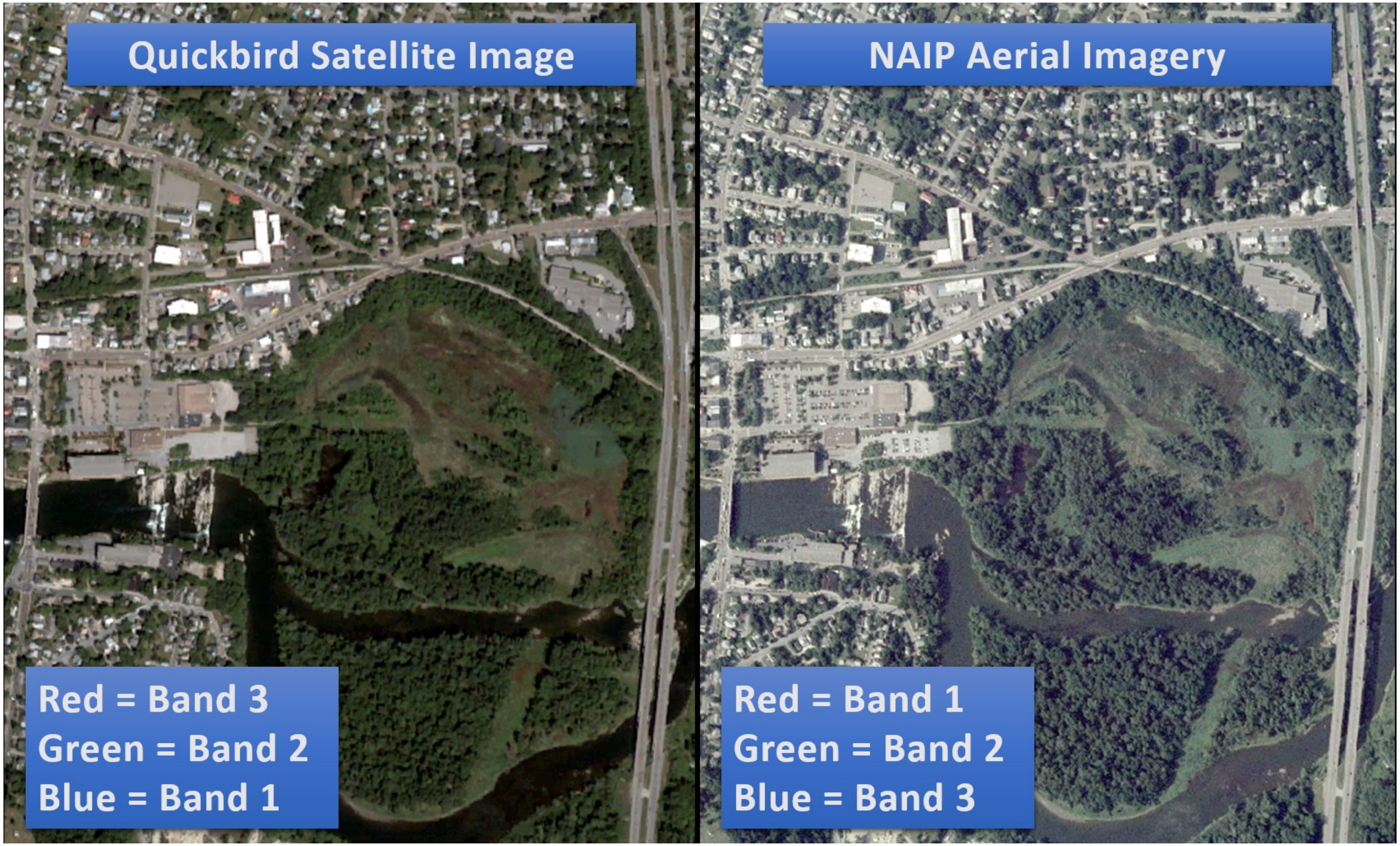


The basic principle of NDVI relies on the fact that, due the their spongy layers found on their backsides, leaves reflect a lot of light in the near infrared, in stark contrast with most non-plant object. When the plant becomes dehydrated or stressed, the spongy layer collapses and the leaves reflect less NIR light, but the same amount in the visible range. Thus, mathematically combining these two signals can help differentiate plant from non-plant and healthy plant from sickly plant.



Spectral Resolution

- Same area by different sensors with different spectral resolutions



Radiometric Resolution

- **O**ften called contrast.
  - It describes the ability of the sensor to measure the signal strength (reflectance) or brightness of an object. The more sensitive a sensor is to the reflectance of an object as compared to its surroundings, the smaller an object that can be detected and identified.
  - The ability of the system to discriminate very slight differences in the energy being measured (reflected or emitted)
  - The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in the reflected or emitted energy
- The radiometric resolution of image data in remote sensing stands for the ability of the sensor to distinguish different grey-scale values. It is measured in bit. The more bit an image has, the more grey-scale values can be stored, and, thus, more differences in the reflection on the land surfaces can be spotted.
- The radiometric resolution stands for the ability of a digital sensor to distinguish between **grey-scale values** while acquiring an image.
  - Humans see the nature in color. However, a satellite perceives different wavelengths in different intensities only.
  - A sensor can distinguish between bright and dark with a great deal of precision.
  - A spectral image is not less than a **raster** consisting of different grey-scale values (at the respective band).
- The next slide contains two spectral images of Bonn: The first has a radiometric resolution of 2 and the second has a radiometric resolution of 8 bit. It becomes clear that surfaces can be distinguished much better in the 8-bit image than in the 2-bit image.

Radiometric Resolution

The surfaces can be distinguished much better with a higher radiometric (bit) resolution

2 Bit

8 Bit

Temporal Resolution

- **T**his depends on many factors
  - How long it takes for a satellite to return to (approximately) the same location in space
  - The swath of the sensor (related to its ‘footprint’), and
  - Whether or not the sensor can be directed off-nadir.
  - This is formally known as the ‘revisit period’
    - Ex: MODIS aboard Terra and Aqua revisit is 16 days (same for VIIRS aboard S-NPP)
- Image acquired by remote sensing sensors do not only differ with regard to the spatial, radiometric, and spectral resolutions: The so-called **temporal resolution** is also very important.
- The temporal resolution provides information on the time between the acquisitions of two images of the same area. The higher the temporal resolution, the shorter the distance of time between the acquisitions of images.
- Many satellites have a temporal resolution of about 14-16 days. But there are also satellites with a very high temporal resolution capable of acquiring images of the same area every 15 minutes. That is because satellite sensors with a high temporal resolution such as weather satellites are **geostationary** satellite sensors.

What is a BIT then?

- In **<u>remote sensing</u>**, a bit stands for the number of grey-scale values a spectral sensor can tell apart (separate).
- The greater the bit number, the greater the number of grey-scale values a spectral sensor can distinguish, and therefore, the higher the radiometric resolution of a spectral sensor.
- One bit stands for a sensor that knows only **<u>black</u>** and **<u>white</u>**.
- 2 bit equals 4 grey-scale values and
- 4 bit equals 16 values.
  - The equation is as follows:
    - 2^{bit} = Number of grey-scale values
  - 16 bit? How many values?
    - <u>65536</u>

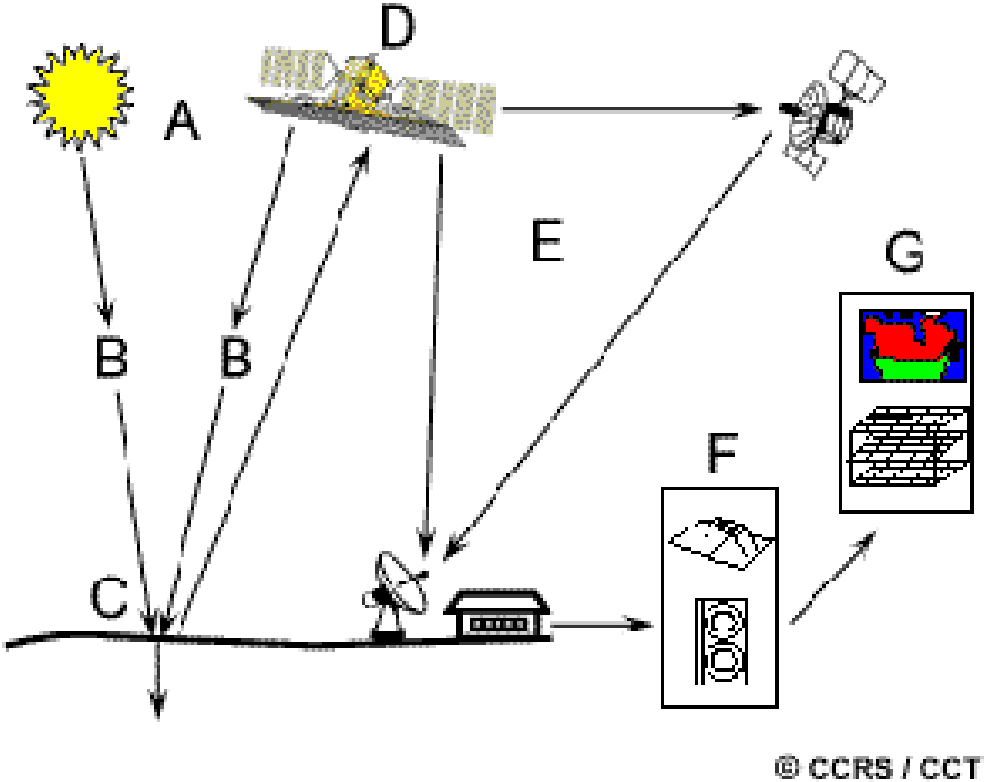
Bits	Werteumfang	Grauwerte
1Bit	$2^1 = 2$ (0-1)	0 … 1
4Bit	$2^4 = 16$ (0-15)	0 … 15
8Bit	$2^8 = 256$ (0-255)	0 … 255

Remote Sensing System

- *"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."*
- **The process** involves an interaction between incident radiation and the targets of interest.
- Remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.

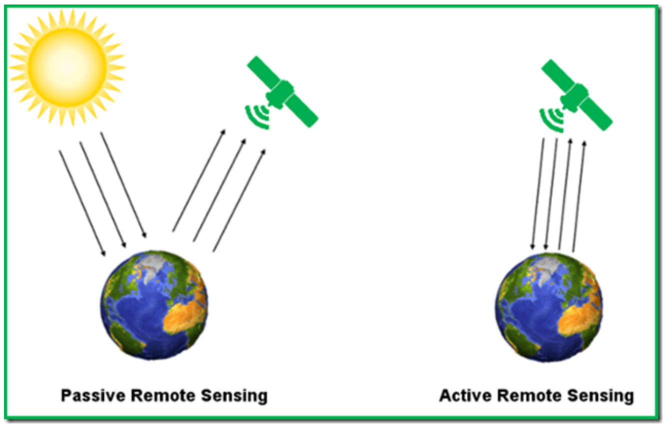
Remote Sensing System

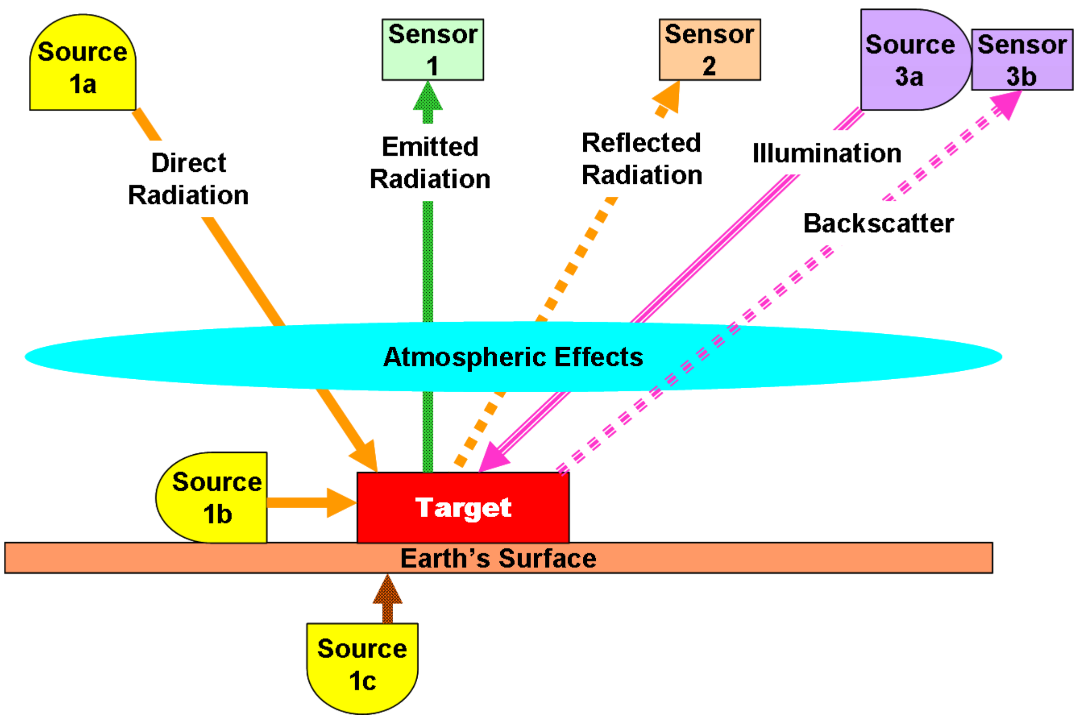
1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B
3. Interaction with the Target (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception, and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)



Energy Source or Illumination (A)

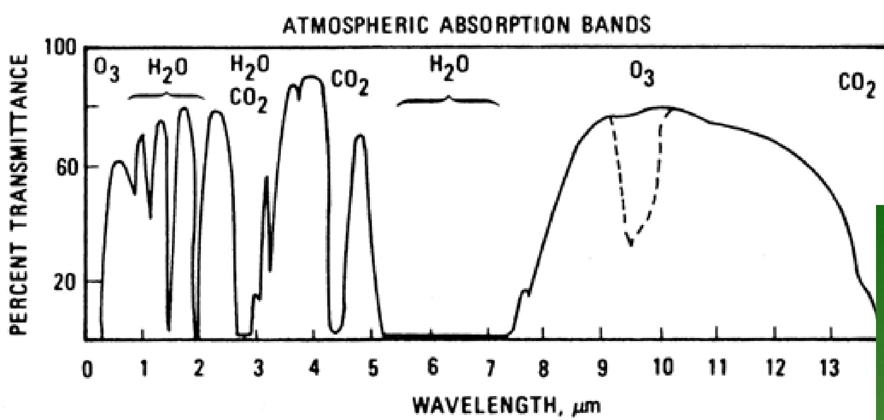
- The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
- There are two types: Active & Passive

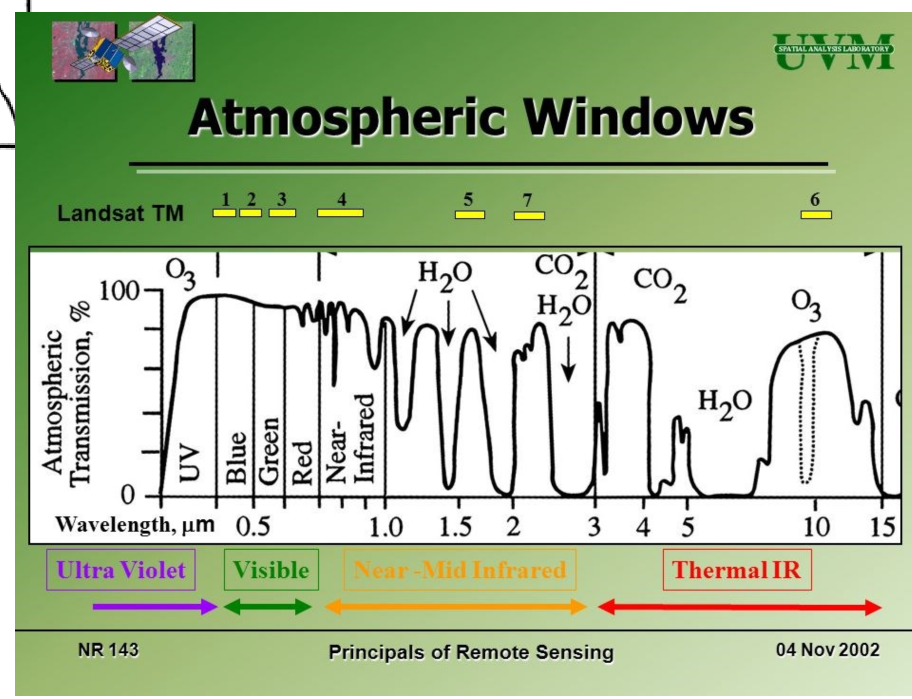




Radiation and the Atmosphere (B)

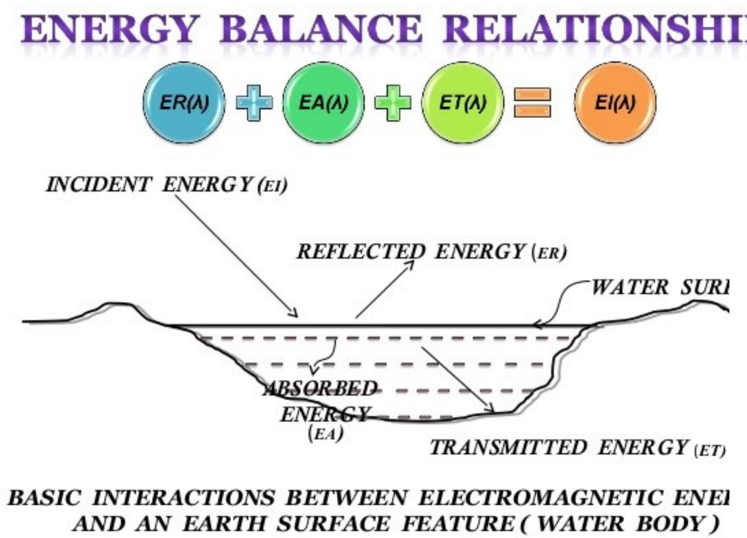
- **As** the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through.
- This interaction may take place a second time as the energy travels from the target to the sensor.

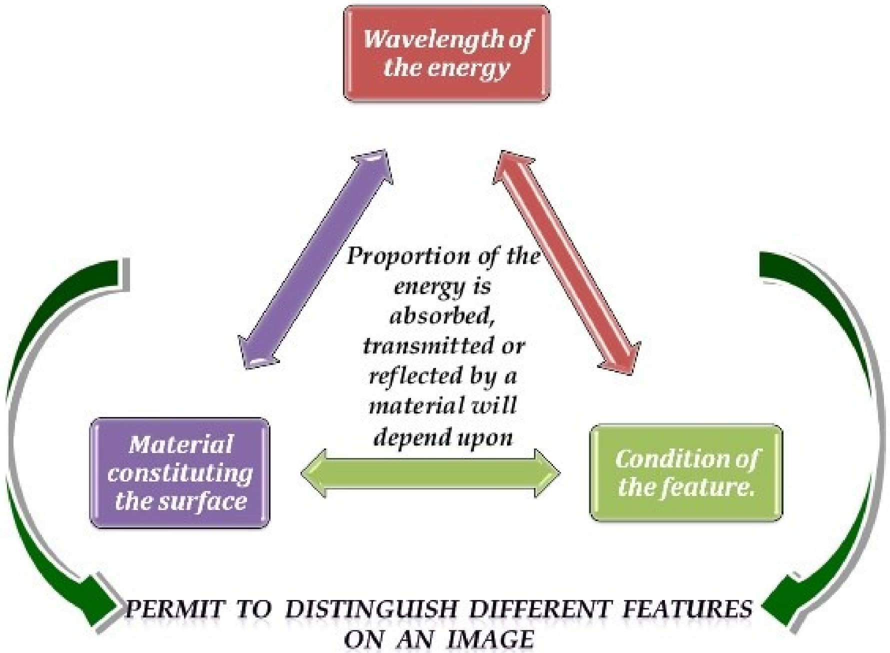




Interaction with the Target (C)

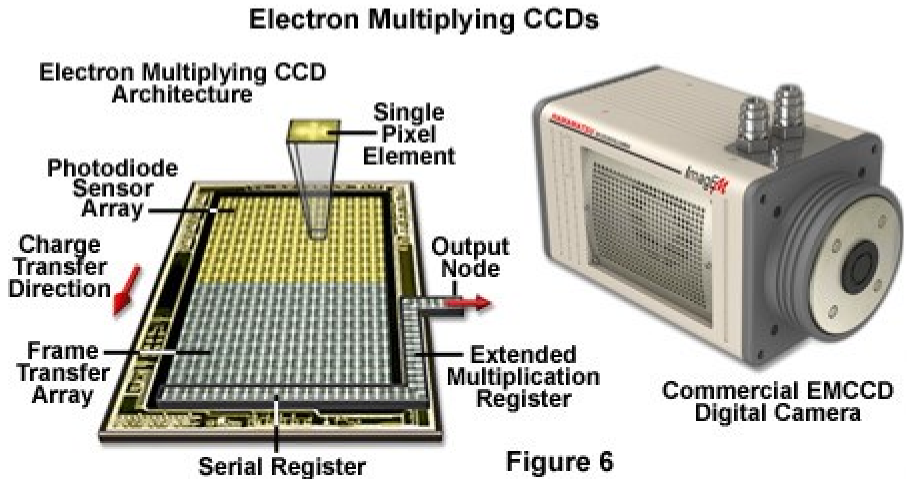
- **O**nce the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

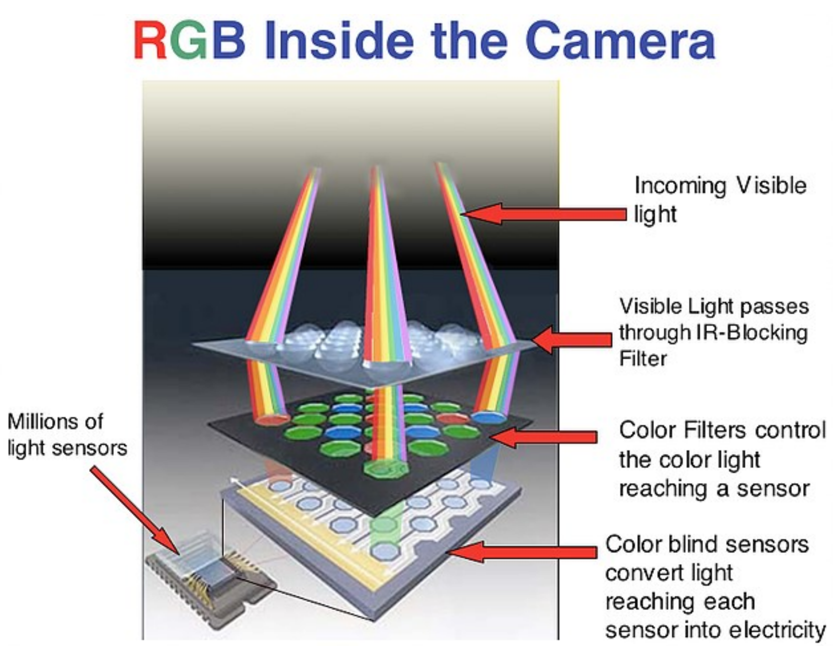




Recording of Energy by the Sensor (D)

- After the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation in a digital format (Digital Number = DN).
- Uses an Analog to Digital encoder



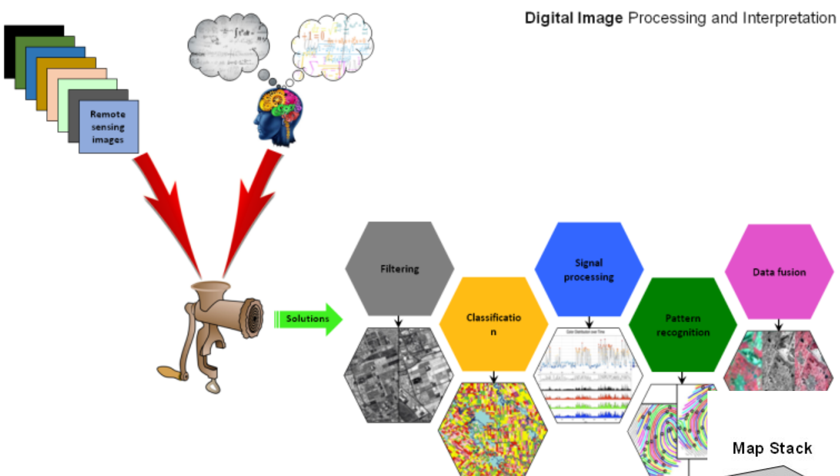


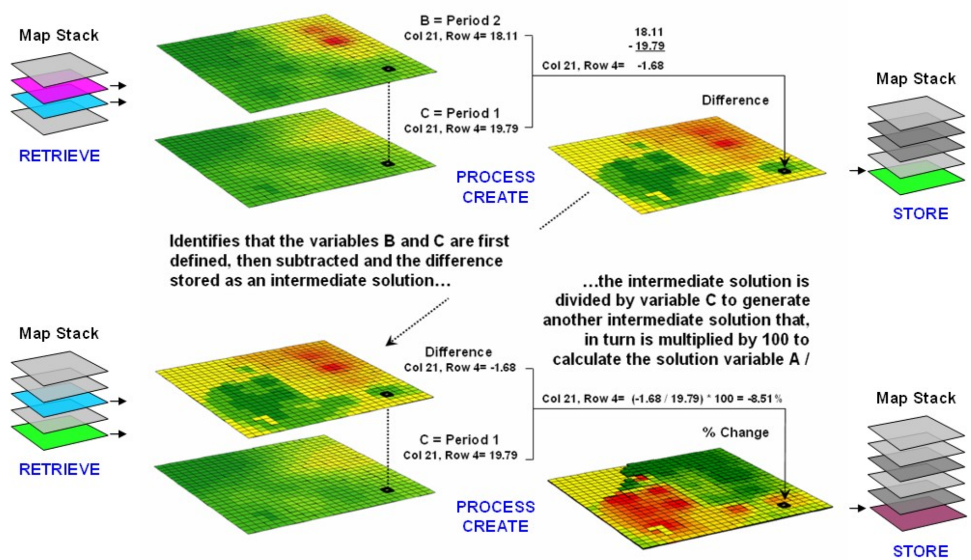
Transmission, Reception, and Processing (E)

- **T**he energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

Interpretation and Analysis (F)

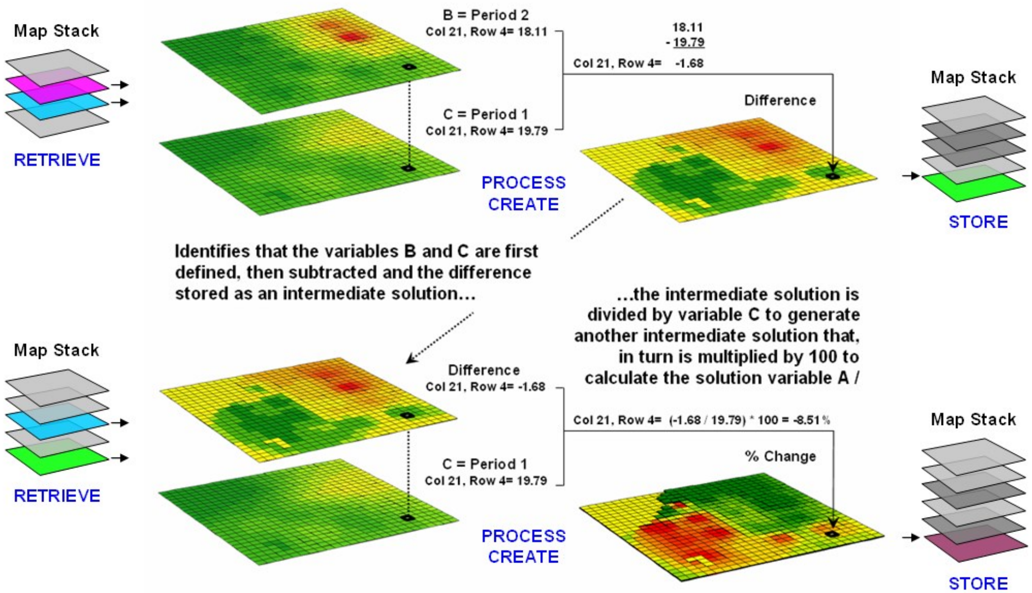
- The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.





Application (G)

- **T**he final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.
- These seven elements comprise the remote sensing process from beginning to end.



Homework #2

- Can you perform a search on the Operational Land Imager (OLI) and find its 4 basic characteristics?
  - Spatial
  - Radiometric
  - Spectral
  - Temporal
  - Can you find and acquire a recent image from this sensor (ex: Tucson)

backup