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

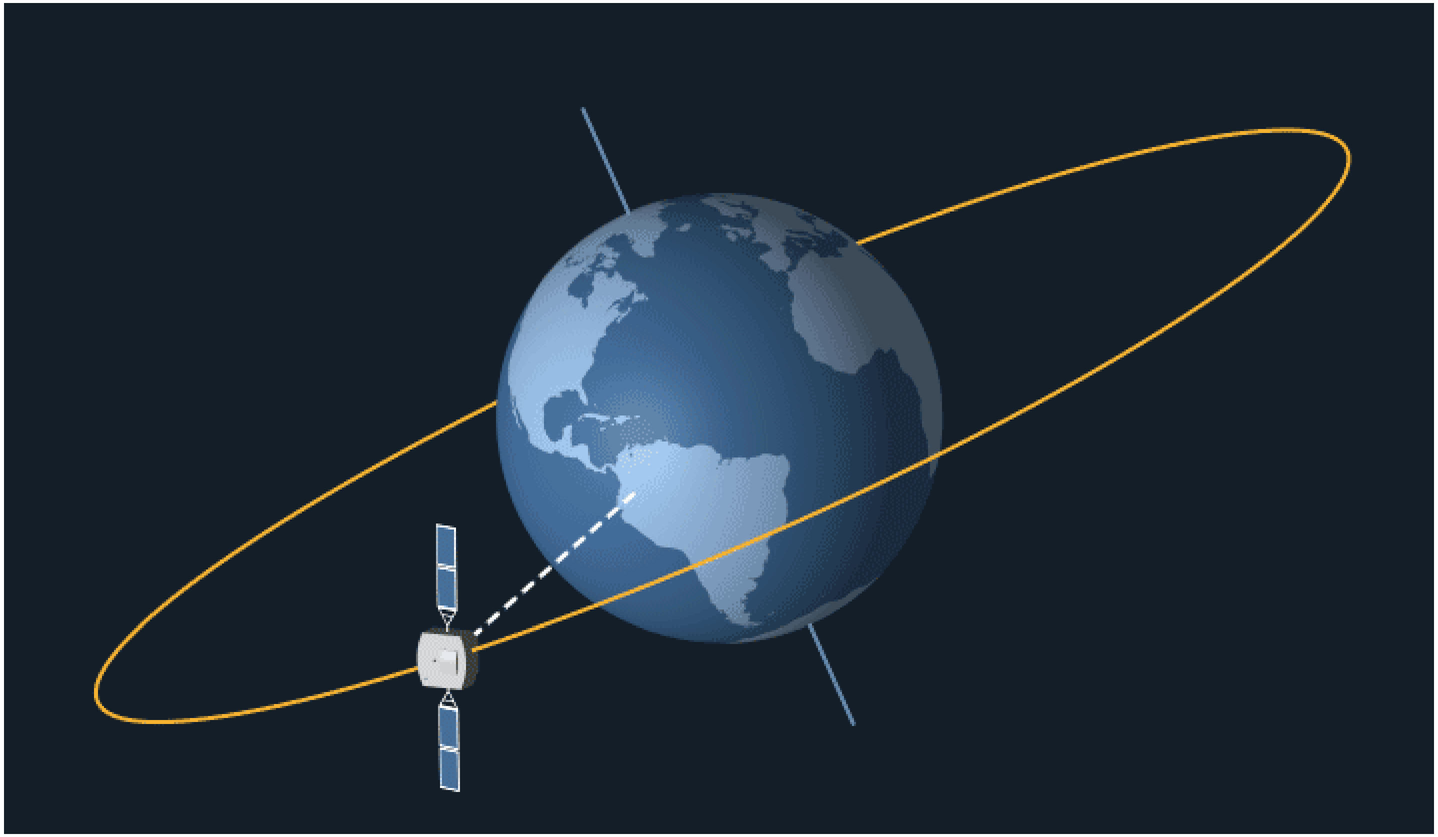
Today we Will

- Understand the 4 fundamental characteristics of a remote sensing system
- Discuss the remote sensing system components
- HW#2 (still trying to catch up)

Last time we …

- Talked about satellite platforms
  - Geostationary/Geosynchronous
  - Polar Orbiting/Sun Synchronous

Geostationary Satellite

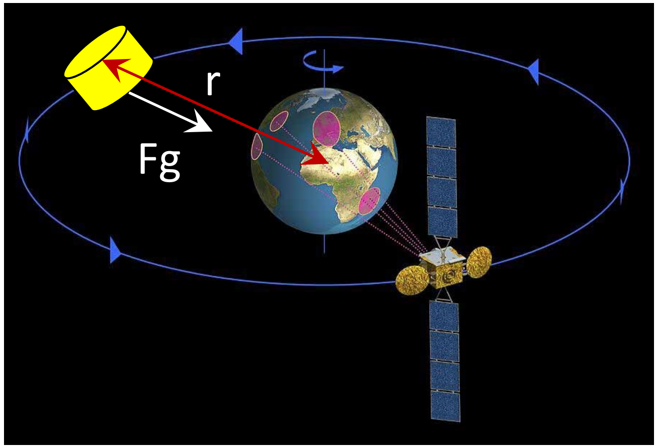


How Did we Derive This?

- And because we are far away from the Earth surface, we need to use Newton's universal Law of Gravity and recognize that the satellite is also under a centrifugal force (pull) = m.a

$$\mathbf{F_g} = \frac{G.M.m}{r^2} = m.a$$

  - G : Universal constant
  - M = Mass of Earth
  - m = Mass of satellite
  - R = Distance between Earth (center) and Satellite
  - a = Centripetal Acceleration (= v^2/r)
  - The **centripetal** ('center-seeking') **acceleration** is the motion inwards towards the center of a circle. The **acceleration** is equal to the square of the velocity, divided by the radius of the circular path. **Centripetal Acceleration** = V^2/r



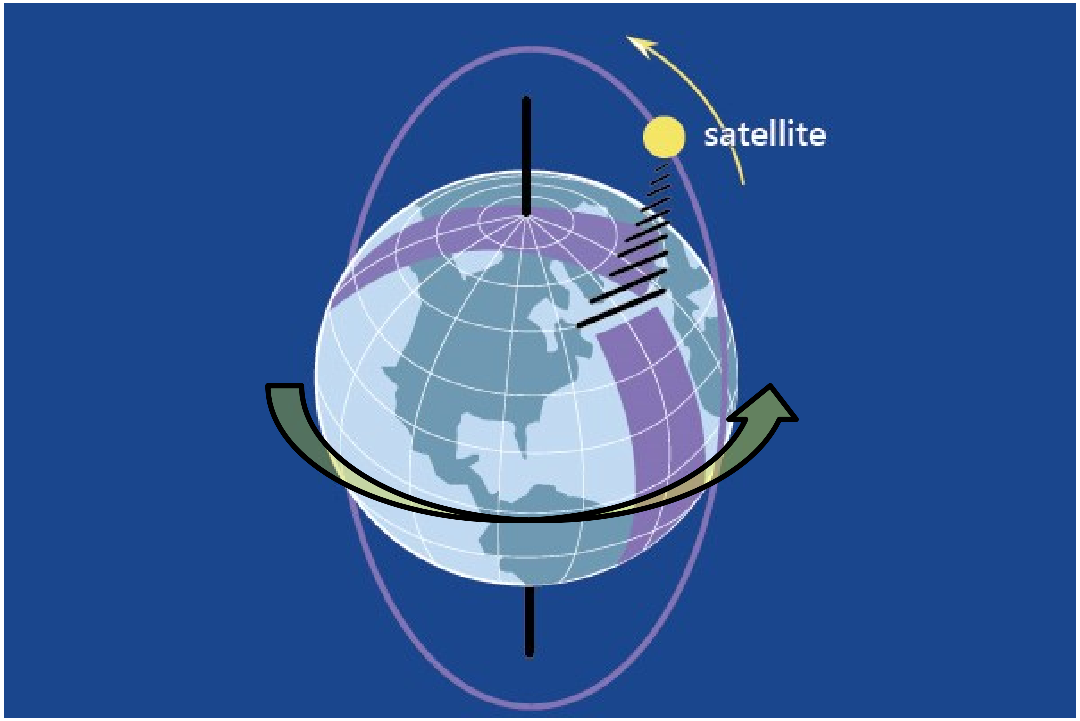
- So: $\mathbf{F_g} = \frac{G.M.m}{r^2} = m.\frac{v^2}{r}$
  - We need to find r? and the only unknown is v (speed) in the Eq?
  - And v = Distance/Time
  - Distance is the orbit circumference = $2\pi r$
  - T = Period (or in the case of the geosynchronous satellites it is a day = ~24 hrs)
  - $V = 2\pi r/T$ and $V^2 = 4\pi^2 r^2/T^2$
- And if we **substitute**, **rearrange** and **simplify**, we get

$$\frac{G.M.m}{r^2} = m\frac{4\pi^2 r^2}{r.T^2} \quad \text{or} \quad \frac{G.M}{4\pi^2}T^2 = r^3$$

- and $T = \sqrt{\frac{4\pi^2 r^3}{G\ M}}$ or $r = 3\sqrt{\frac{T^2 G\ M}{4\pi^2}}$

Polar Orbiting Platforms

- A **polar orbit** platform is one in which the **satellite** passes above or nearly above both poles (N and S) of the body being **orbited** on each revolution (ex: a planet such as the Earth, the Moon, or even Sun provided from a far away distance).
  - It therefore has an inclination of (or very close to) 90 degrees to the poles
  - A satellite in a polar orbit will pass over the equator at a different longitude on each of its orbits.
    - Why? Because the Earth rotates around its axis (below it)



[Polar Orbiting Animation]

(Near)Polar Orbiting Platforms

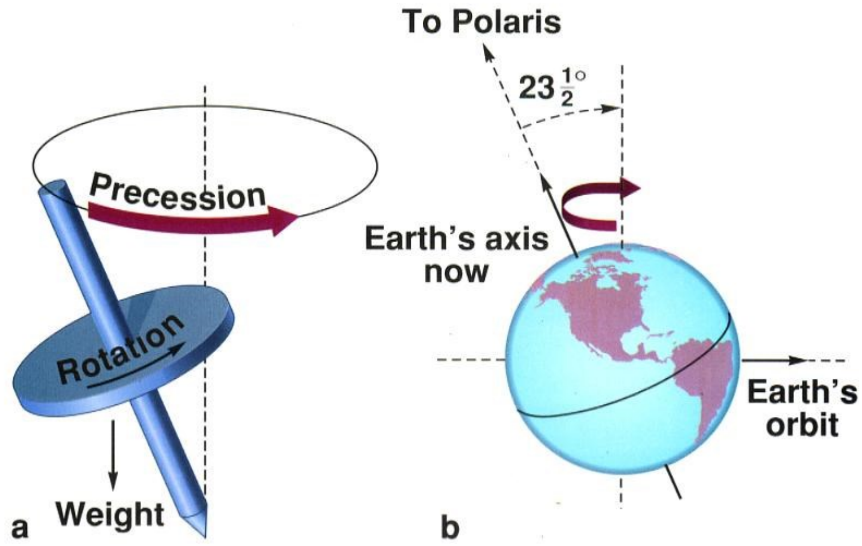
- Polar orbits are often used for earth-mapping, earth observation, capturing the earth surface below as time passes from one vantage point, reconnaissance satellites, as well as for some weather/atmosphere satellites (not common).
- The Iridium satellite **constellation** also uses a polar orbit to provide telecommunications services.
- The disadvantage to this orbit is that no one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit (as the Earth rotates).
- **Sun orbits**
  - Source of energy/illumination
  - Near-polar orbiting satellites commonly choose a **Sun-synchronous orbit**, meaning that each successive orbital pass occurs at the same **local time of day**. The sun remains relatively at the same position.
  - This can be **particularly important** for applications such as remote sensing atmospheric temperature, where the most important thing to see may well be *changes* over time which are not aliased onto changes in local time.

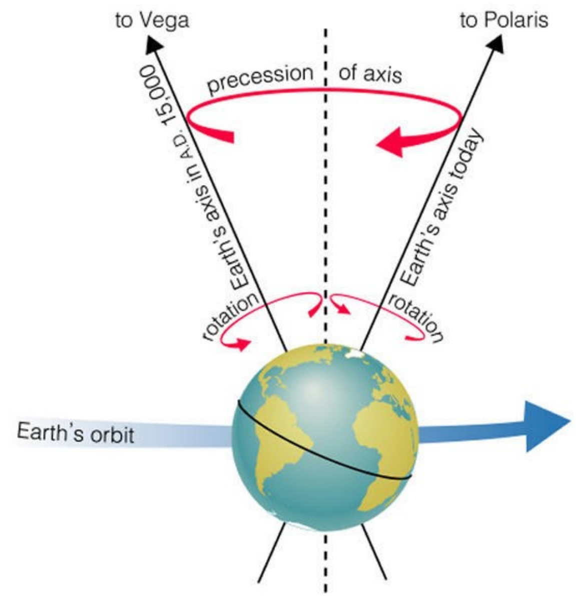
Polar Orbiting Platforms

- To keep the same local time on a given pass, the time period of the orbit must be kept as short as possible, this is achieved by keeping the orbit lower to the Earth.
  - **Why?** Higher orbit (larger circle) takes longer to complete
- However, very low orbits of a few hundred kilometers **rapidly decay** due to drag from the atmosphere.
  - Continuous attitude correction (hence their limited life – related to fuel and maneuvers)
  - The NOAA AVHRR series suffered major decay throughout its life (from 10:30 am it became ~3pm)
- Commonly used altitudes are between **700 km and 800 km**, producing an orbital period of about **100 minutes** (full circle)
  - Can you compute the speed of satellite at 700 and 800km?
  - Pick any satellite, find its orbital period, and compute the speed.
- The half-orbit on the Sun side then takes only 50 minutes, during which local time of day does not vary greatly and that is somewhat the trick
  - Scientists and Engineers come up with these clever ideas all the time so keep the tradition
  - One of the “simplest and clever ideas” we implemented ourselves here on behalf of NASA is staggering two data streams from two identical satellites (Terra and Aqua MODIS)
    - Staggering here ,means double the data (1 point every 16 days but produced 8 days apart and meaning 2 data points each 16 days)

Polar Orbiting Platforms

- To retain the Sun-synchronous orbit as the Earth revolves around the Sun during the year, the orbit of the satellite must **precess** at the same rate, which is not possible if the satellite were to pass directly over the pole.
- Because of the Earth's equatorial bulge, an orbit inclined at a slight angle is subject to a torque which causes precession; an angle of about **8 degrees** from the pole produces the desired precession in a **100-minute** orbit.
  - **Precession** is a change in the orientation of the rotational axis of a rotating body.



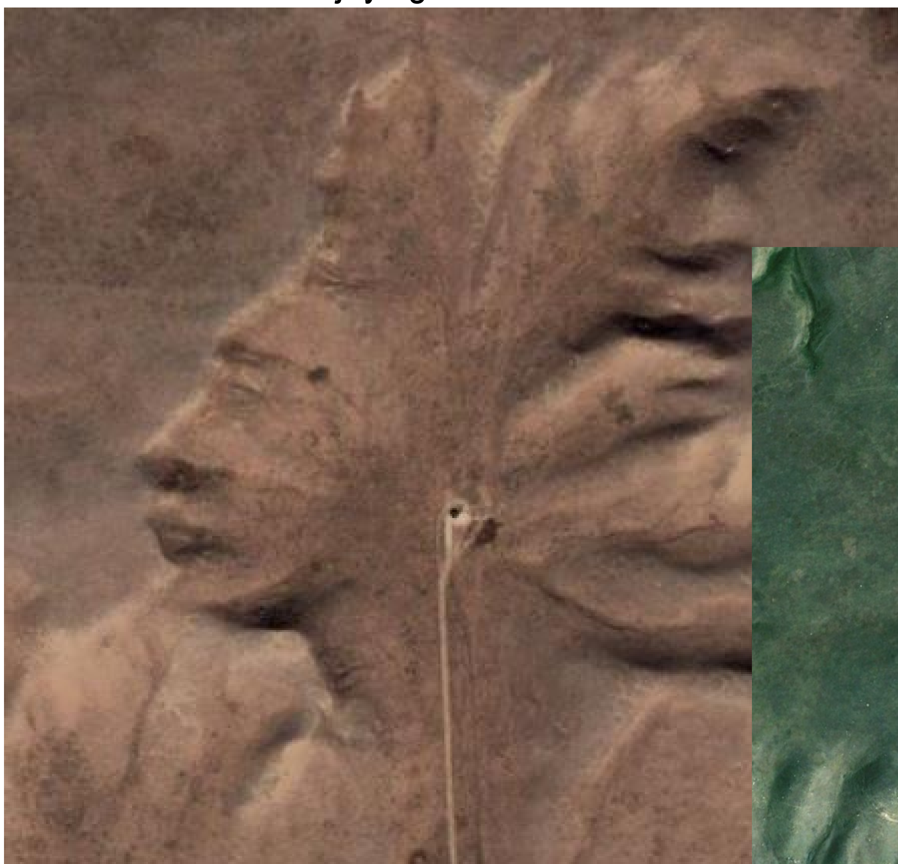


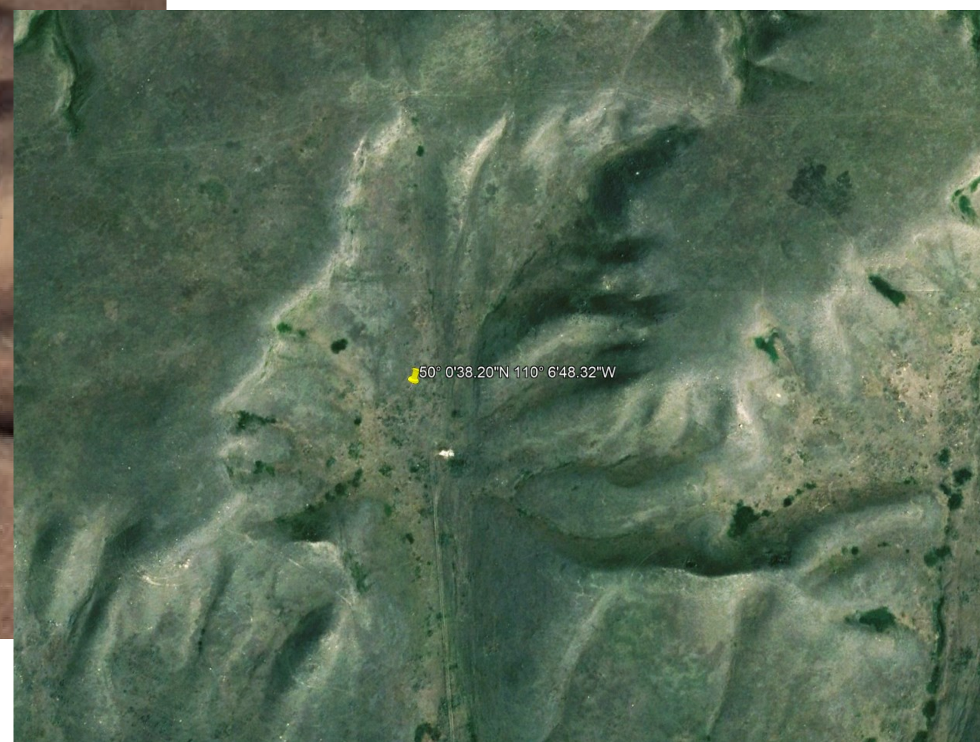
Daily Coverage

- Polar orbiting (sun-synchronous) are designed to standardize observations globally.
  - How?

So is Remote Sensing an Art?

- What do you think this is?
  - Indian man enjoying some music on an iPod?





Information about an Object or Area

- Sensors can be used to obtain specific information about an object
  - e.g., the Size of a city block or the distance between two objects in an image
- Or the geographic extent of a phenomenon
  - e.g., the boundary/size of an object (like a lake)
- The EMR reflected, emitted, or back-scattered from an object or geographic area is used as a ***surrogate*** (proxy) for the actual property under investigation
  - In other words, we do not measure directly the property
- The electromagnetic energy measurements must be calibrated/standardized and turned into information using visual and/or digital image processing techniques.

Advantages of Remote Sensing

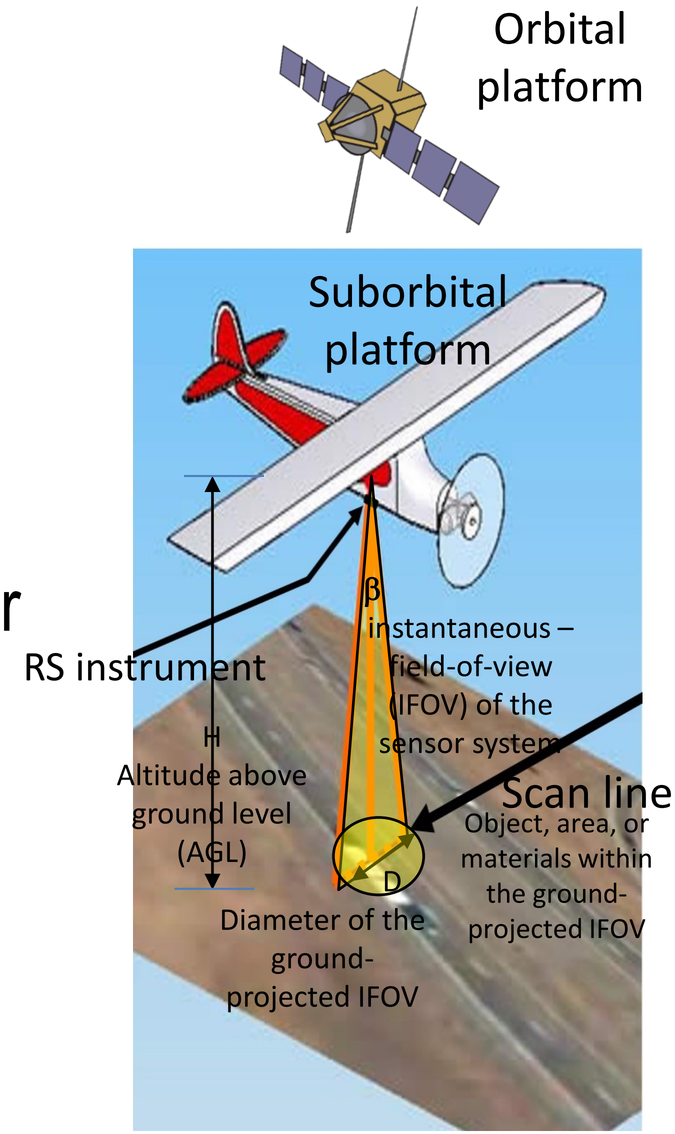
- Remote sensing is ***unobtrusive*** if the sensor *passively* records the EMR reflected or emitted by the object of interest.
- Passive remote sensing does not disturb the object or area of interest.
- Remote sensing devices may be programmed to collect data systematically, such as within a N×N m window/frame of vertical aerial photography.
- This systematic data collection can remove the sampling bias introduced in some *in situ* investigations.
- Under controlled conditions, remote sensing can provide fundamental biophysical information, including *x,y* location, *z* elevation or depth, biomass, temperature, moisture content, or quasi-biophysical (model driven by RS) information
- Remote sensing–derived information is now critical to the successful modeling of numerous natural (e.g., water-supply estimation; eutrophication studies; nonpoint source pollution) and cultural (e.g., land-use conversion at the urban fringe; water-demand estimation; population estimation) processes.

Limitations of Remote Sensing

- The greatest limitation & issues are that it is quite often ***oversold***.
- *Remote sensing is not a* ***panacea*** that provides all the information needed to conduct physical, biological, or social science research.
- It provides some spatial, spectral, and temporal *information* of value in a manner that we believe and strive to make it efficient and economical.
- *Human beings* select the appropriate remote sensing system to collect the data, specify the various resolutions of the remote sensor data, calibrate the sensor, select the platform that will carry the sensor, determine when the data will be collected, and specify how the data are processed.
- Human **method-produced error** may be introduced as the remote sensing instrument and mission parameters are specified.
- Powerful *active* remote sensor systems that emit their own electromagnetic radiation (e.g., LIDAR, RADAR, SONAR) can be intrusive and affect the phenomenon being investigated. Additional research is required to determine how intrusive these active sensors can be.
- Remote sensing instruments may become ***uncalibrated***, resulting in **uncalibrated** remote sensor data.
    - A famous example is the drift over time of platforms (AVHRR sensor for example)
- Remote sensor data may be *expensive to collect and analyze*.

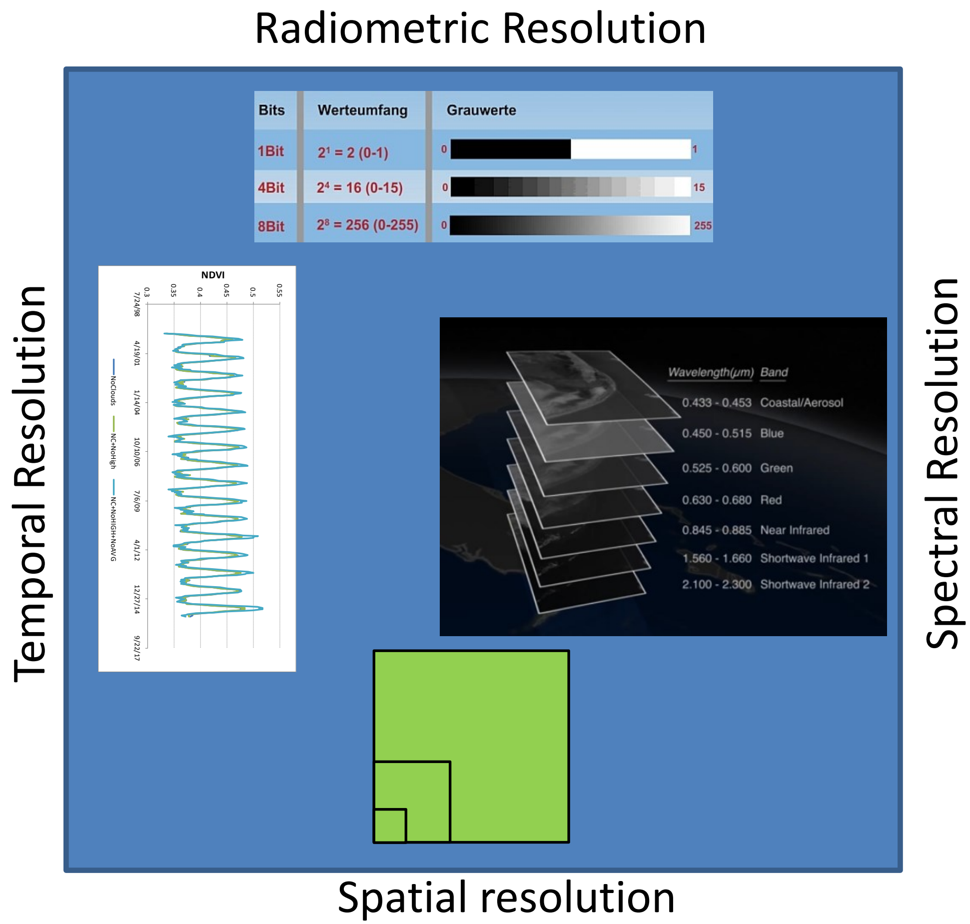
Remote Sensing Instruments

- 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
  - **Geo**synchronous (with respect to a reference)
  - Geostationary (looks at almost the same spot always)
  - Polar Orbiting (N-S)
  - Sun synchronous polar orbiting



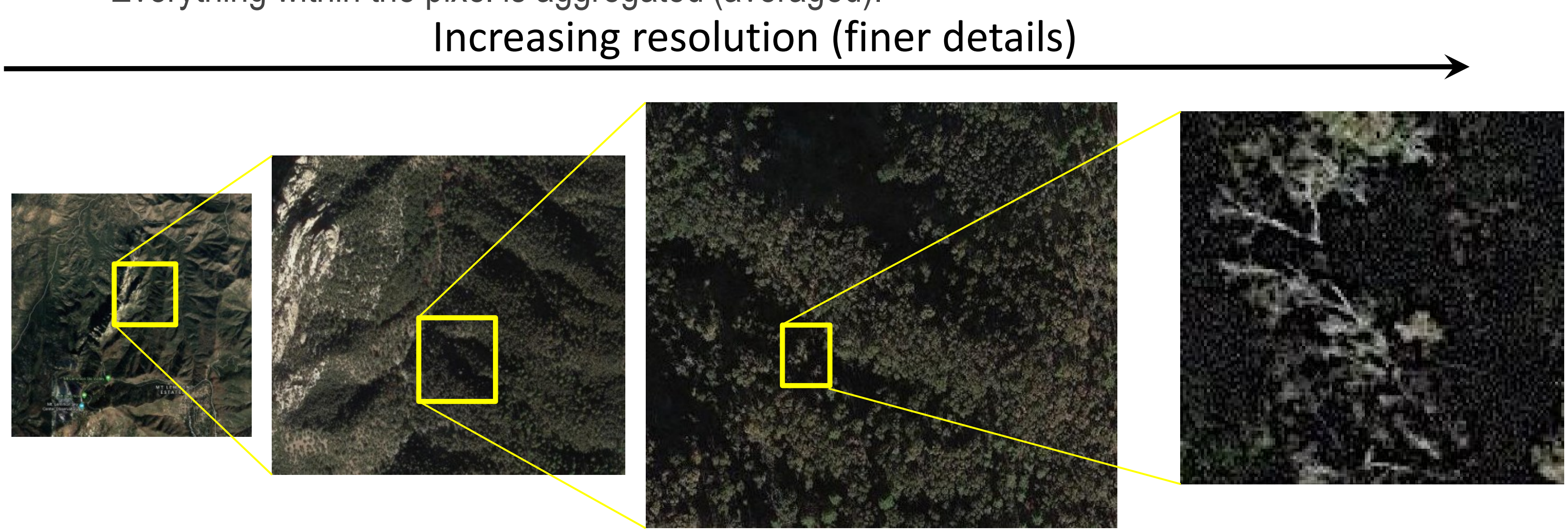
Key Concepts of Remote Sensing

- There are some critical characteristics of a remote sensing system.
- 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



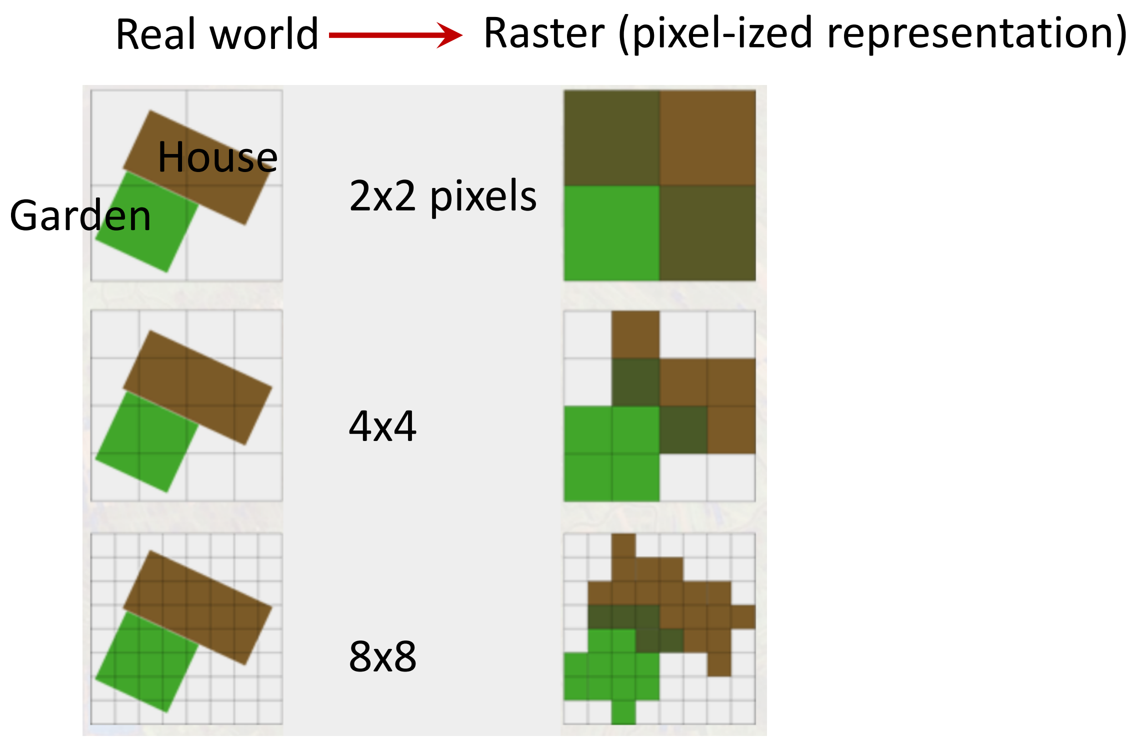
Spatial Resolution

- 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 mm/cm/meters/km/degrees
  - **Can you convert between degrees and m/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 and 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).

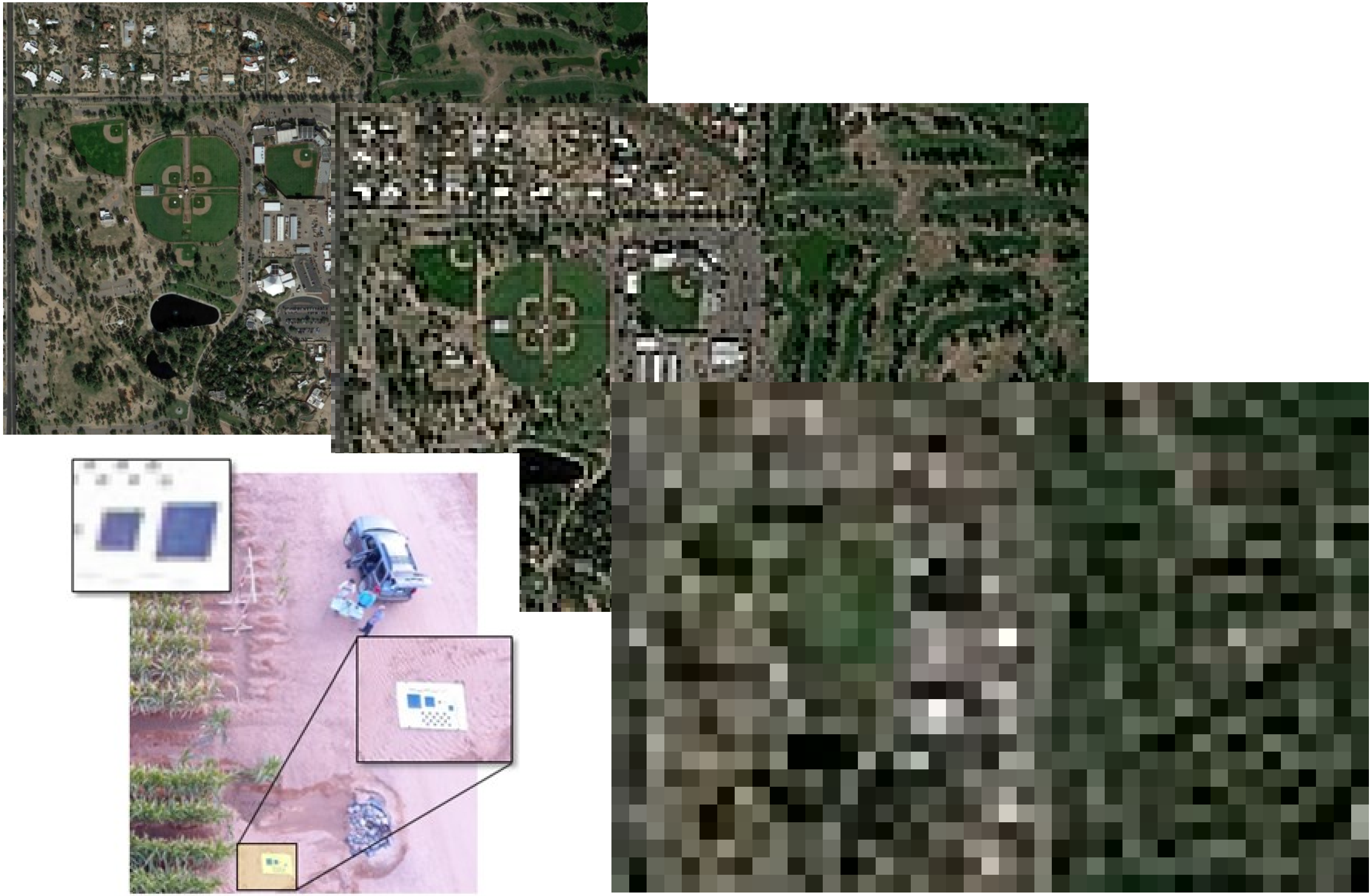


Spatial Resolution

- 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.

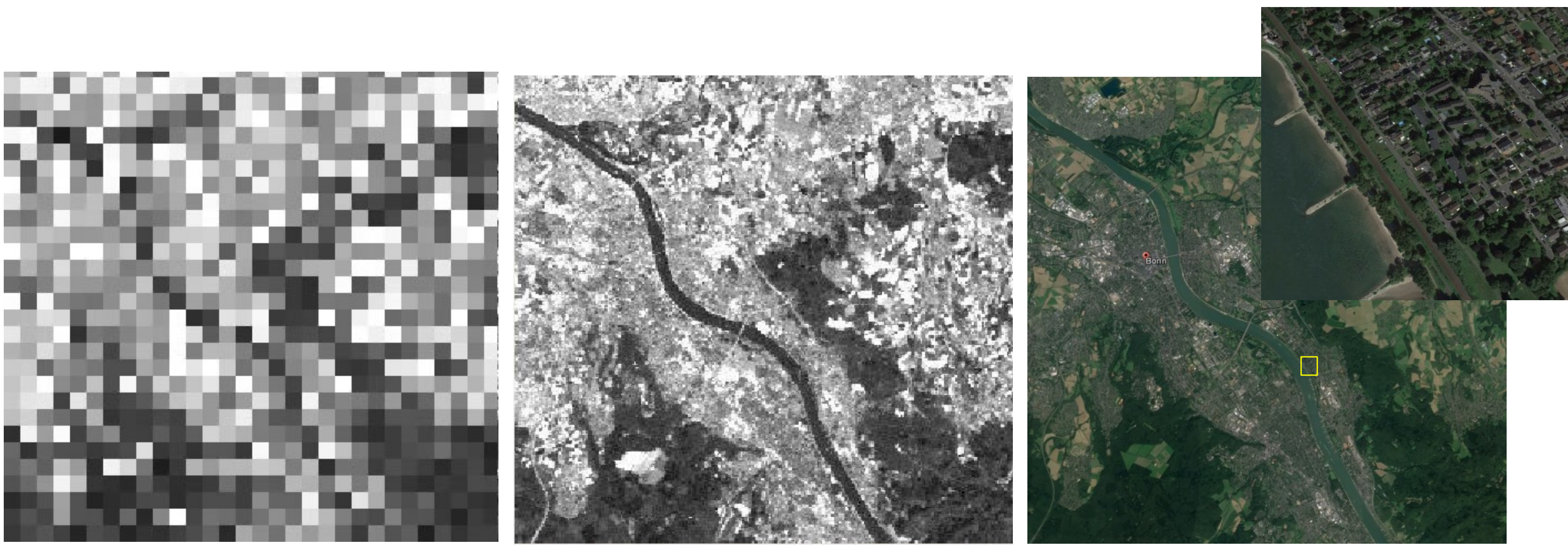


Spatial Resolution



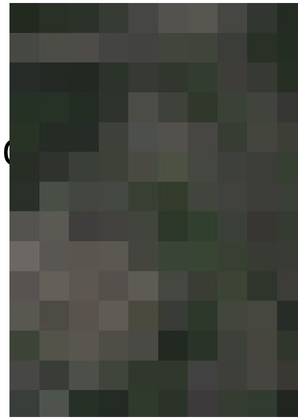
Low and High Spatial Resolution

- 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).

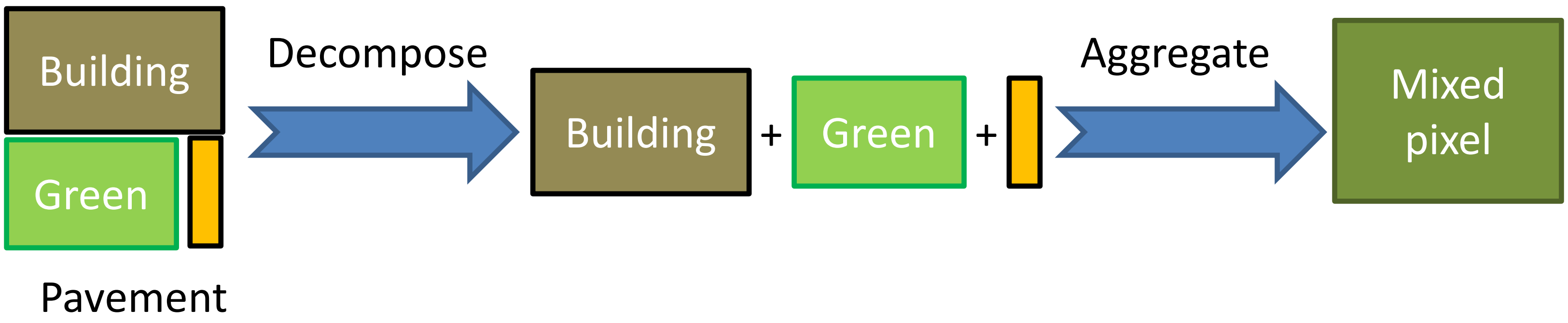
Mixed Pixels – Spectral Mixing



- 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 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

- 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.

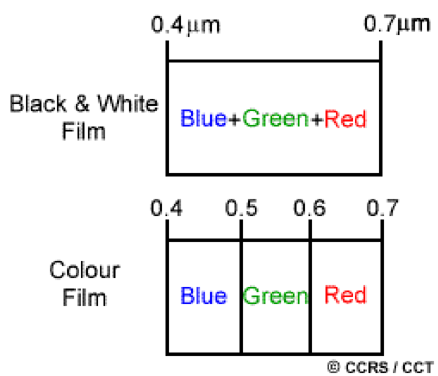


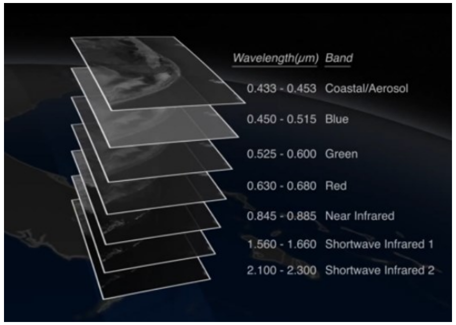
Why do Only Some Sensors Have a High Spatial Resolution?

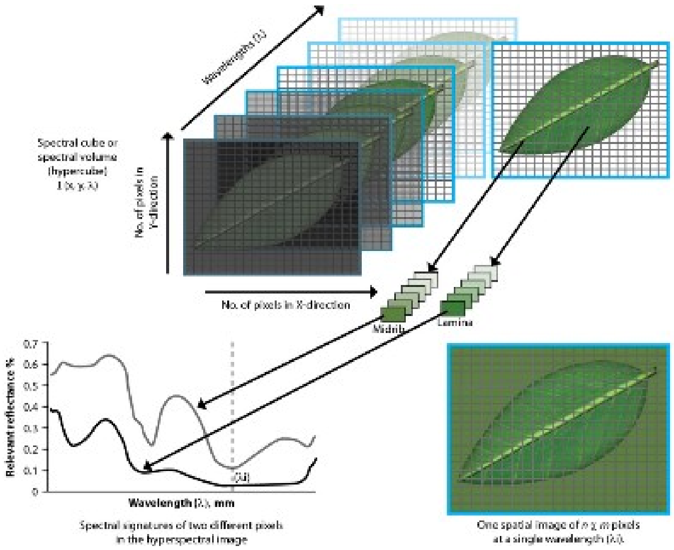
- It depends on the objectives and purposes of the remote sensing systems. The same sensor attached to an airplane will have a very high resolution (ex: 1 m, even few mm with drones these days), whereas the satellite-based sensor will have a lower resolution (ex: 30 m).
- At the same time, the satellite-based 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.

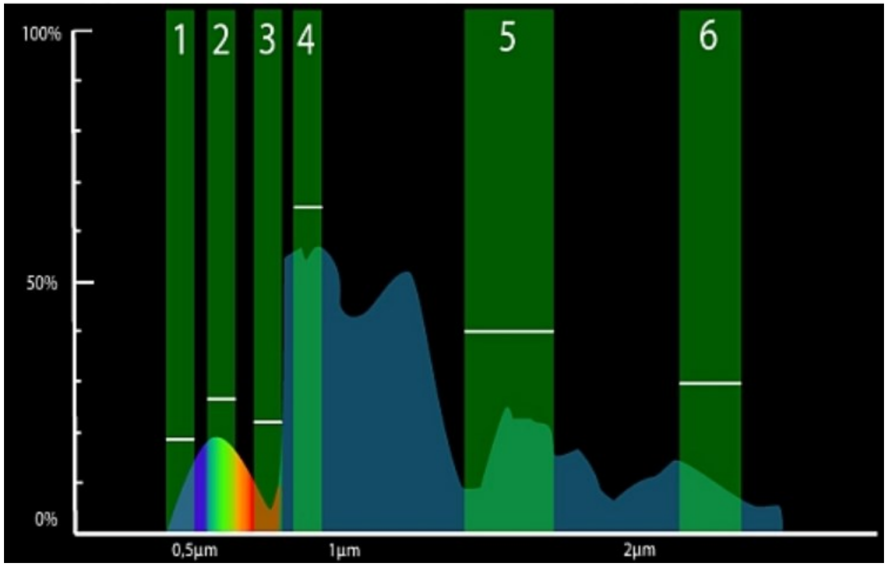




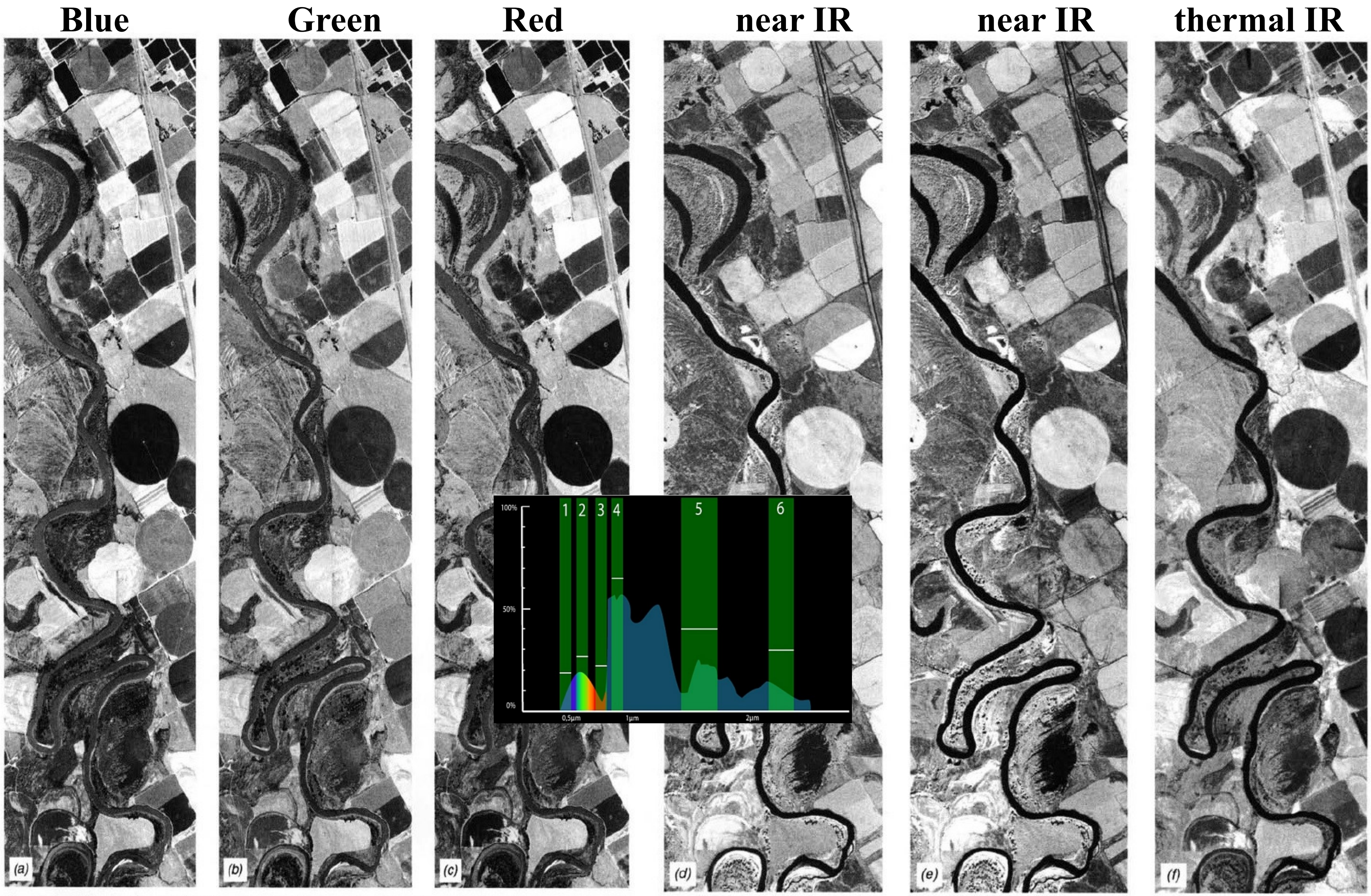


Spectral Resolution

- 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). MODIS has 36 bands (7 for land)
  - Usually composed of the visible light, infrared light, and thermal radiation.



Spectral Resolution



TM Spectral bands

Landsat 1-5 Multispectral Scanner (MSS)

Landsat 1-3	Landsat 4-5	Wavelength (micrometers)	Resolution (meters)
Band 4	Band 1	0.5-0.6	60
Band 5	Band 2	0.6-0.7	60
Band 6	Band 3	0.7-0.8	60
Band 7	Band 4	0.8-1.1	60

Landsat 4-5 Thematic Mapper (TM)

Landsat 4-5	Wavelenth (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.76-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	120 (30)
Band 7	2.08-2.35	30

Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Landsat 7	Wavelength (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.77-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	60 (30)
Band 7	2.09-2.35	30
Band 8	.52-.90	15

Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

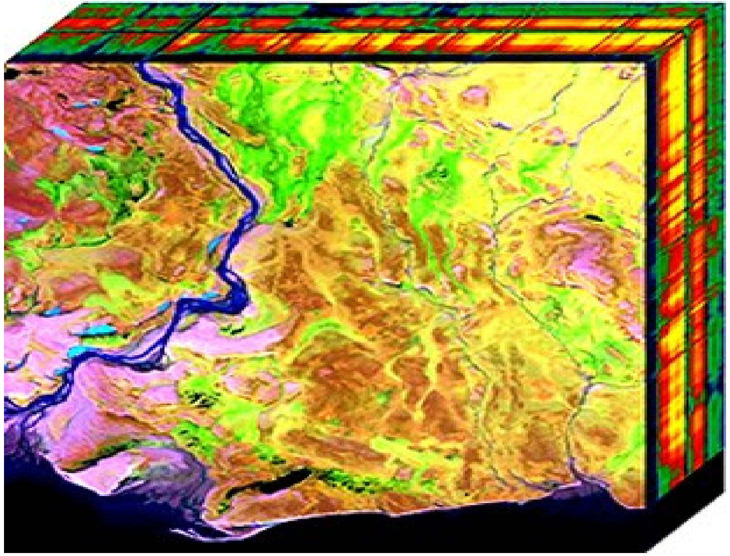
Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 - Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100

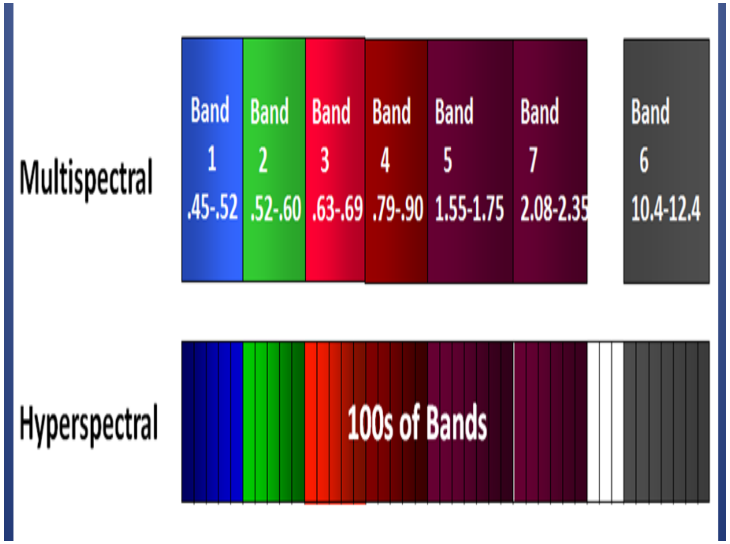
Spectral Resolution

- 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 must 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.

MS vs. Hyperspectral

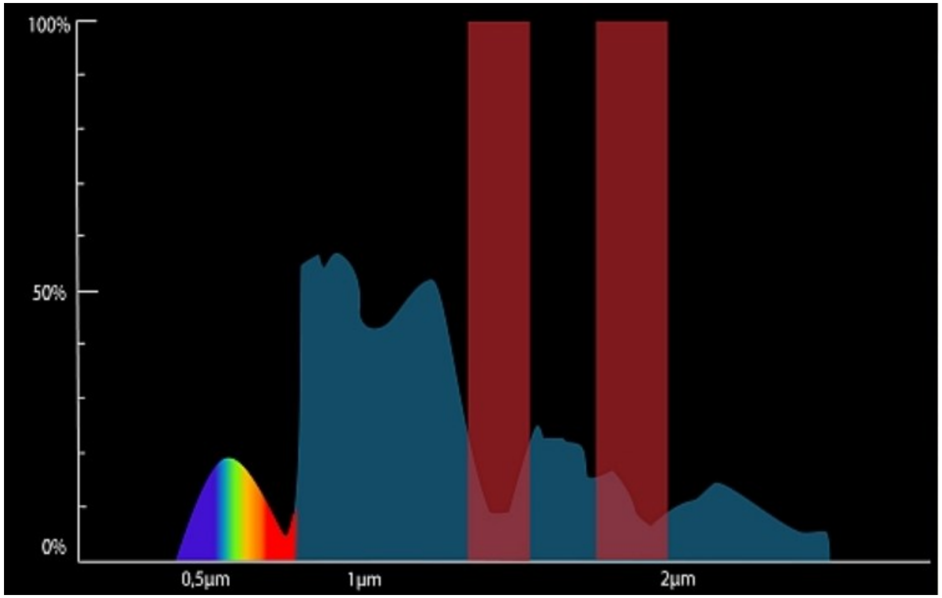
- Difference between multispectral & hyperspectral sensing is:
  - Number of Bands
  - Narrowness of the Bands
- Multispectral data:
  5-10 bands of large bandwidths (70-400 nm).
- Hyperspectral data:
  100-400+ bands of narrow bandwidths (5-10 nm).





Atmospheric Windows

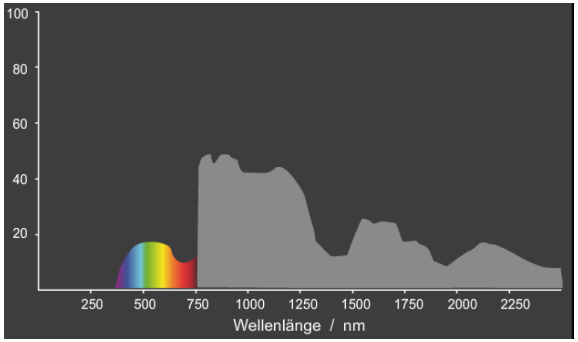
- Spectral sensors can only store the detect parts of the electromagnetic radiation scattered back from the Earth surface that can pass the atmosphere (window).
- The Earth's atmosphere contains gases (Water, Ozone, Nitrogen, CO2, etc.) and small particles like smoke, ice crystals, water drops, dust, 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.



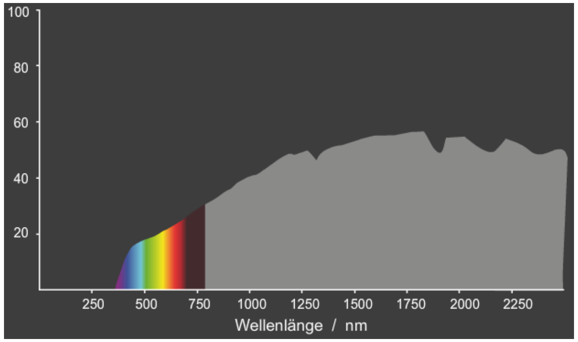
Spectral Signature

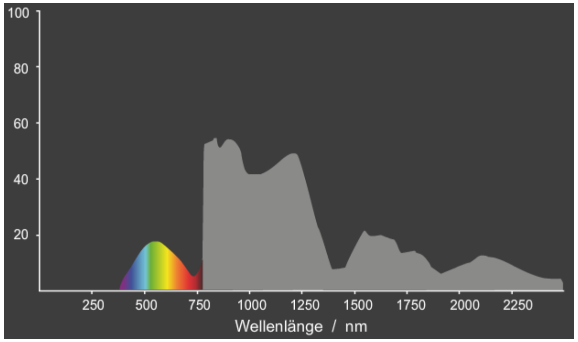
- Besides atmospheric windows, the selection of spectral bands must consider the reflection characteristics (spectral signature) of objects on the Earth's surface.
- Different object on the surface of the Earth reflects differently in the various parts of the electromagnetic spectrum.

Mildly Stressed Vegetation

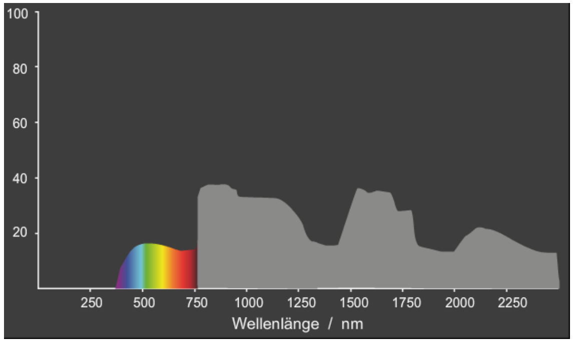


Dry soil

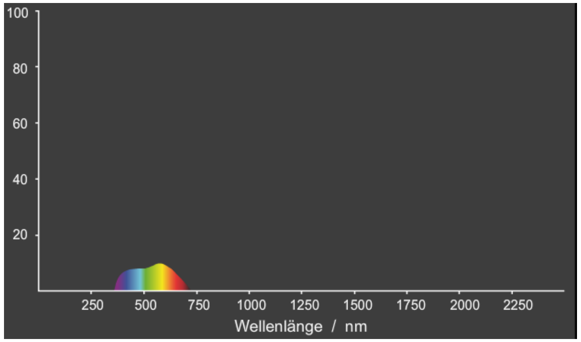




Healthy Active Vegetation



Heavily Stressed Vegetation

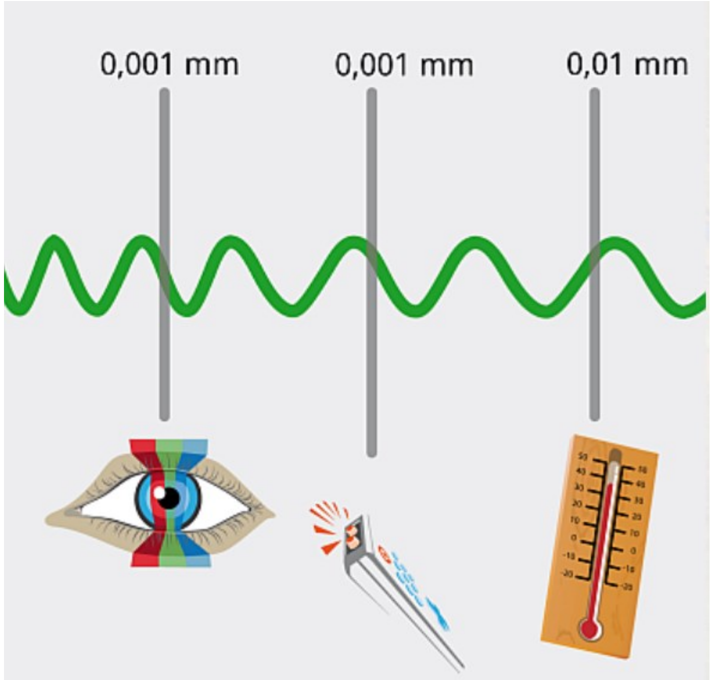


Water

- 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 their ability to absorption and reflect light.

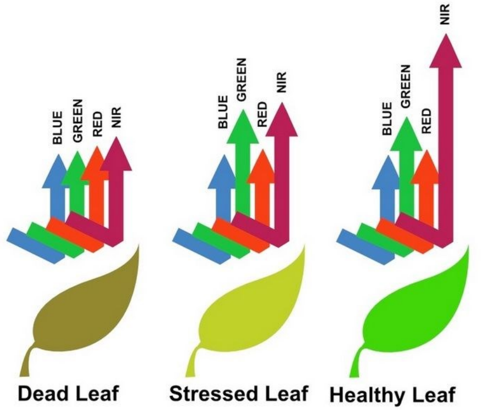
Invisible Infrared

- 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 (**<u>0.3-0.7μm</u>**) 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 (SWIR/SIR) mid-wave (MIR), long-wave (LIR) and thermal (TIR) infrared.

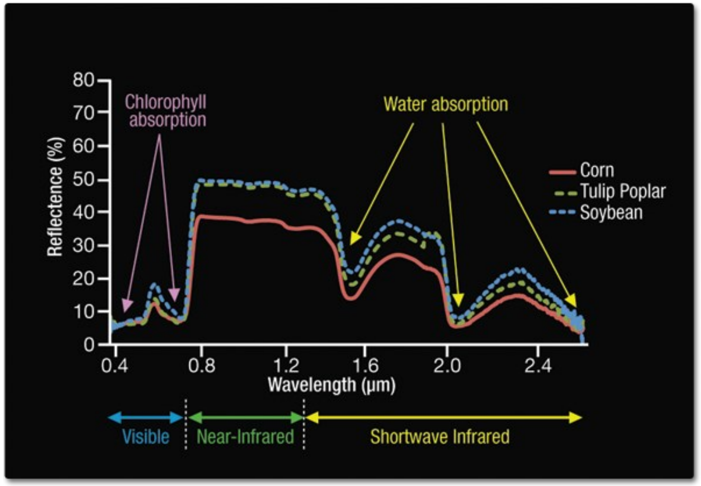


Plant Spectra

- The reflection characteristics of **vegetation** are interesting.
- Active green plants reflect green light greatly, red and blue light hardly to partially (Why?).
  - 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 (**the large increase form red to NIR**)**?
- 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.

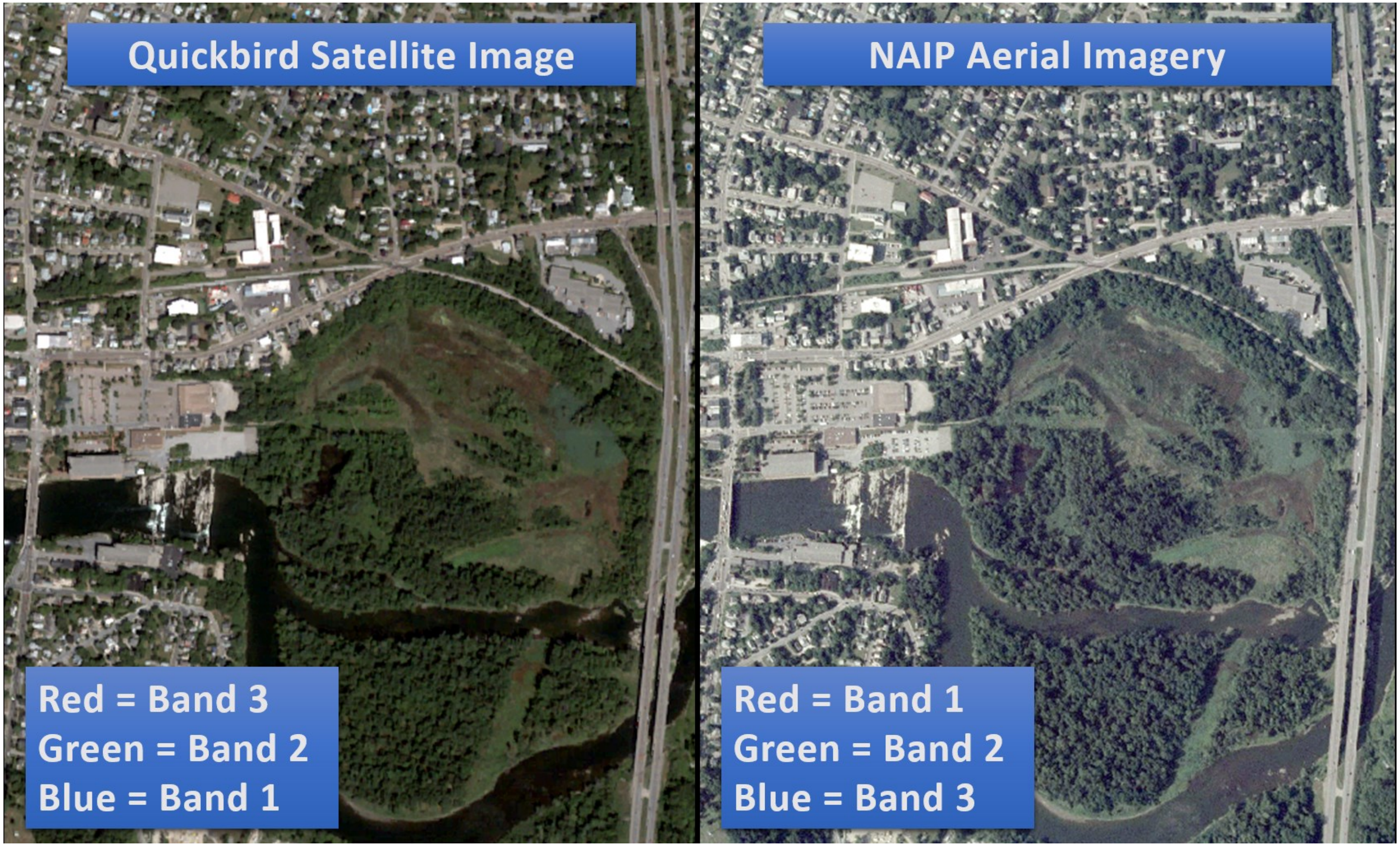


The basic principle of NDVI relies on the fact that, due the their spongy layers found on their backsides, leaves reflect a lot of light in the near infrared, in stark contrast with most non-plant object. When the plant becomes dehydrated or stressed, the spongy layer collapses and the leaves reflect 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



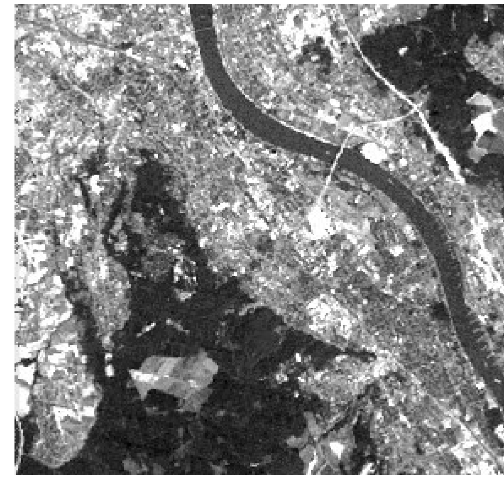
Radiometric Resolution

- **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



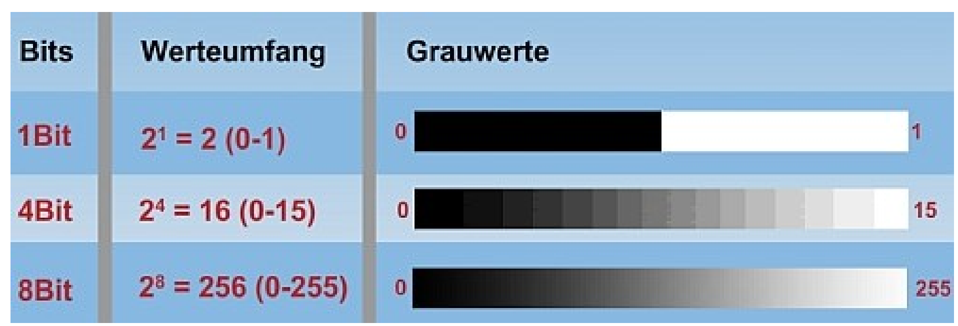
8 Bit

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 (tasking).
  - 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?

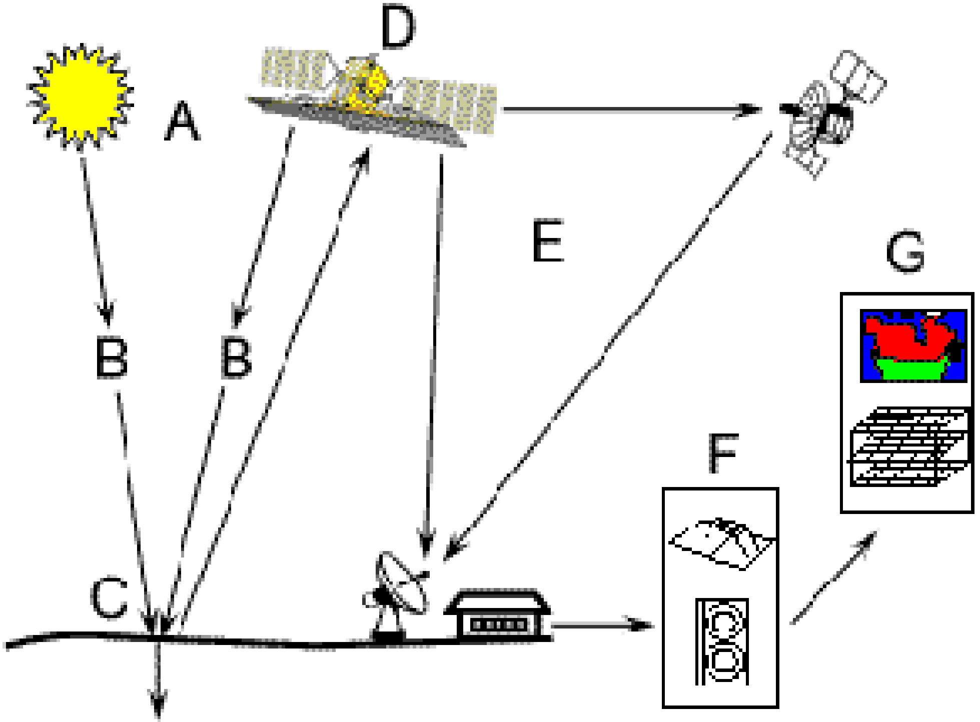
- In **<u>remote sensing</u>**, a bit stands for the number of **<u>grey-scale</u>** values a spectral sensor can tell apart (separate).
- The greater the bit number, the greater the number of grey-scale values a spectral sensor can distinguish, and therefore, the higher the radiometric resolution of a spectral sensor.
- **<u>1 bit</u>** stands for a sensor that knows only **<u>black</u>** and **<u>white</u>**.
- 2 bits equals 4 grey-scale values and (2^2)
- 4 bits equals 16 values.
  - The equation to derive the number of values is:
    - $2^{[bit]}$ = Number of grey-scale values
  - 16 bit? How many values?
    - **<u>$2^{16} = 65536$</u>**
  - What is the Max value then?



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

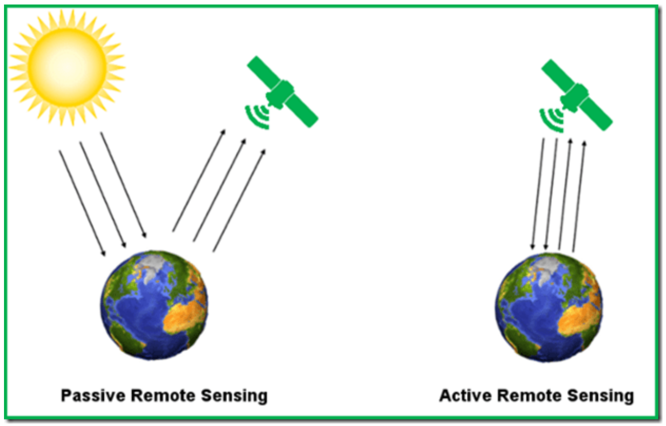
Remote Sensing System

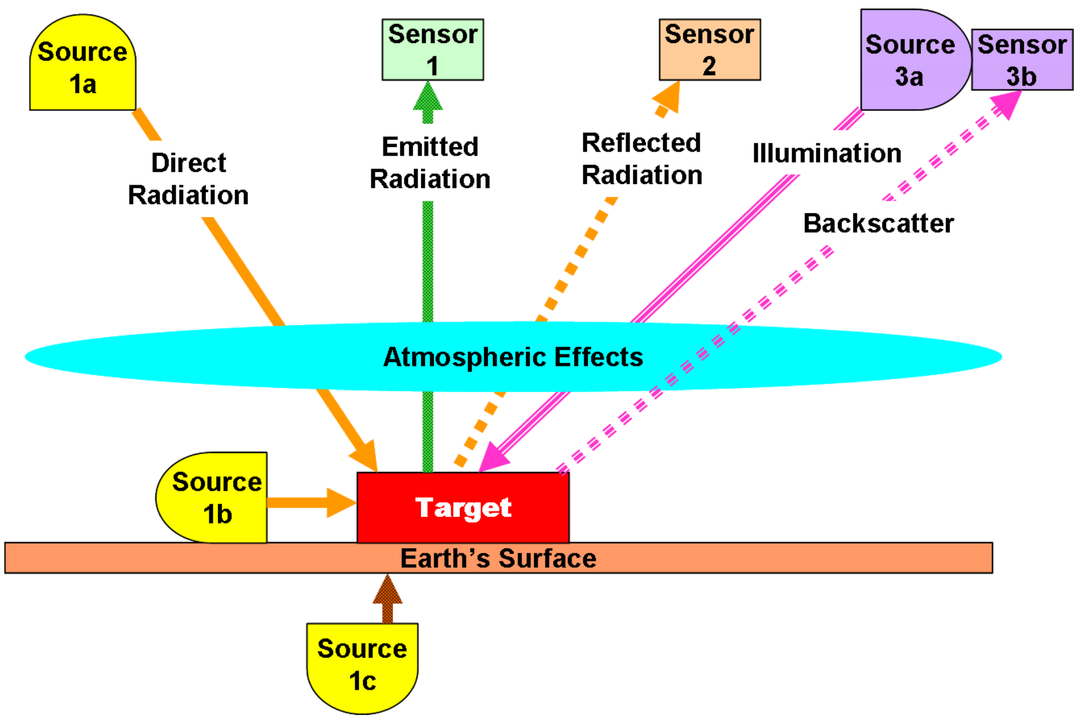
1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B
3. Interaction with the Target (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception, and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)



Energy Source or Illumination (A)

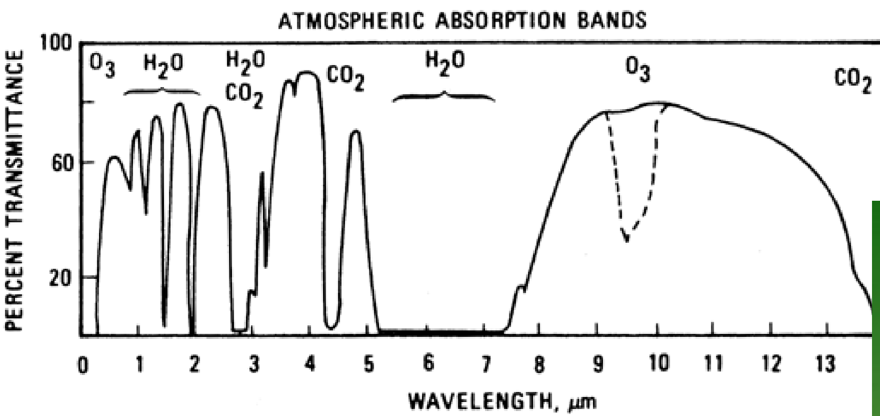
- The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
- There are two types: Active & Passive

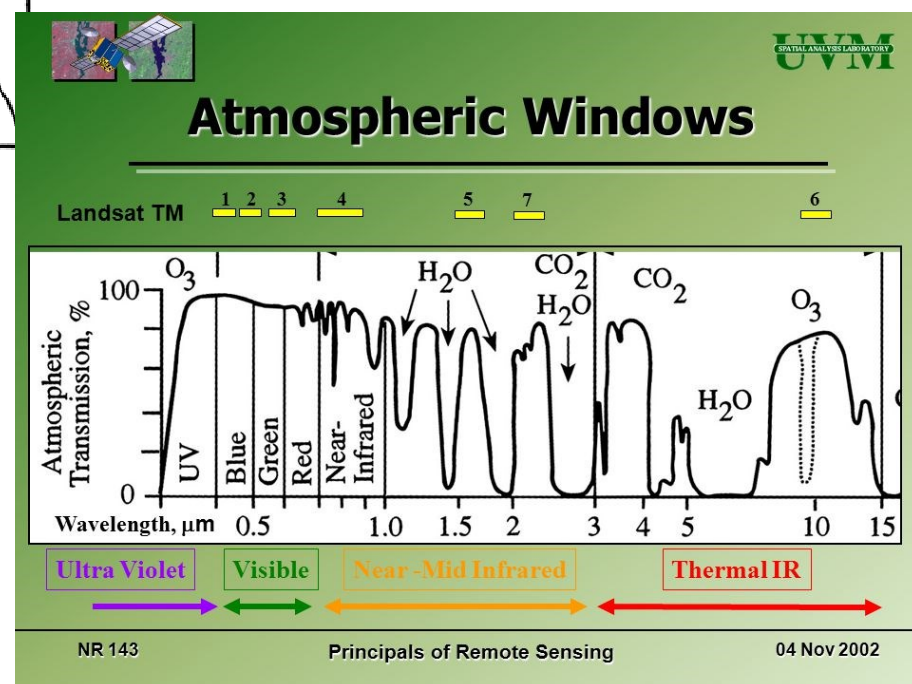




Radiation and the Atmosphere (B)

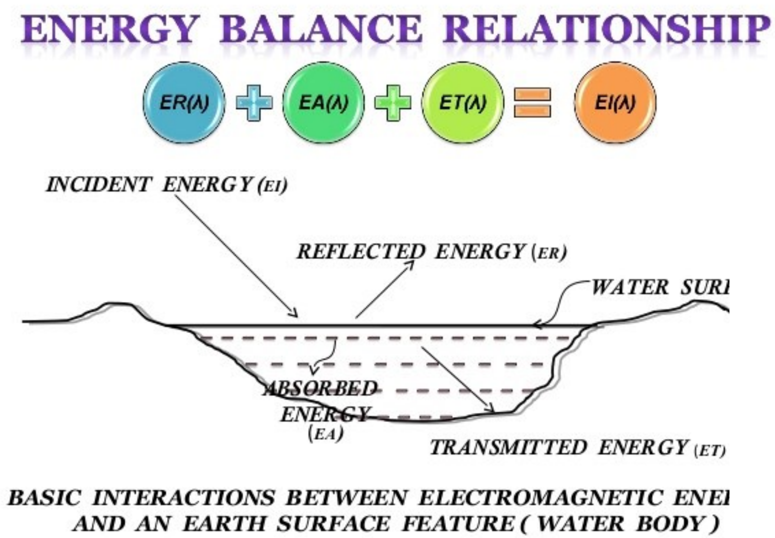
- **As** the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through.
- This interaction may take place a second time as the energy travels from the target to the sensor.

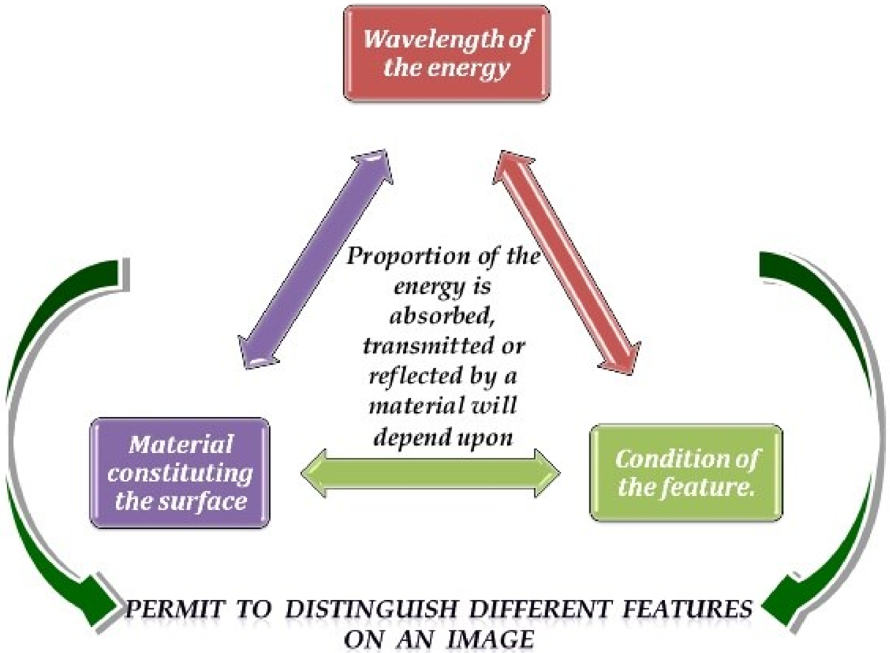




Interaction with the Target (C)

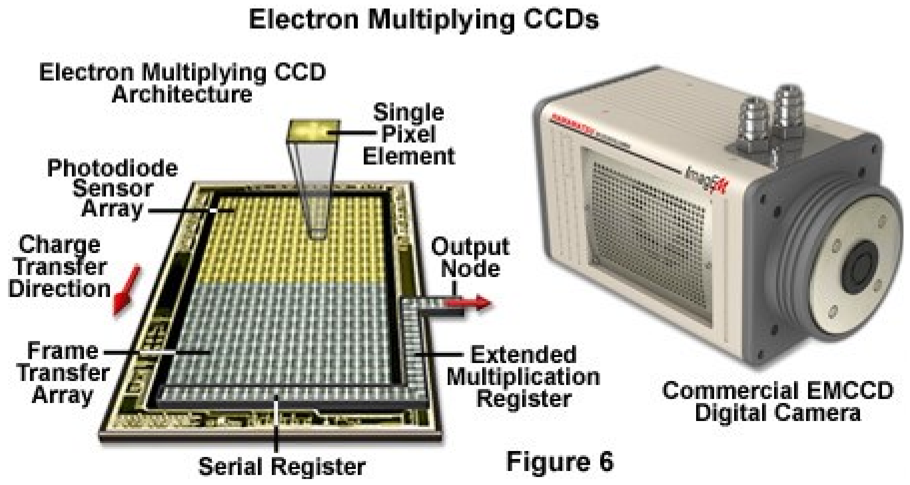
- **O**nce the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

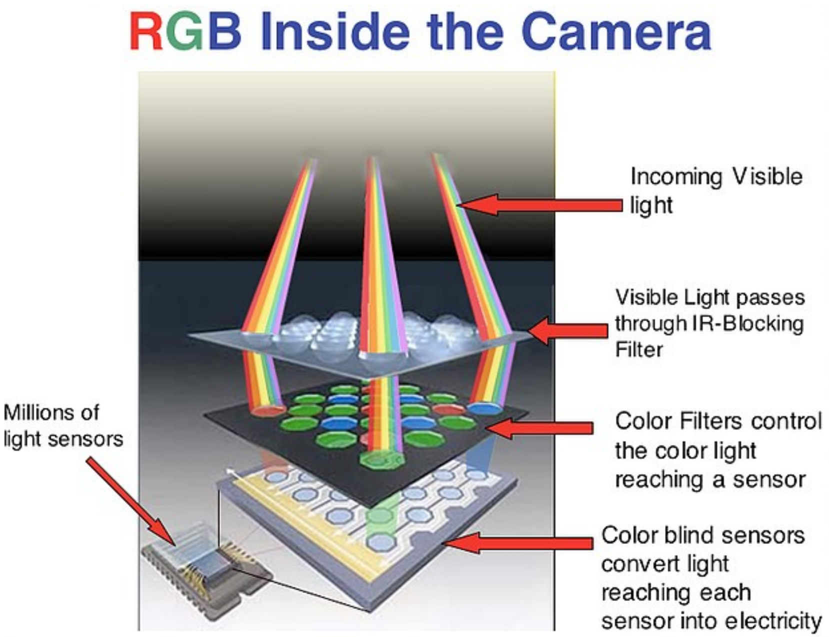




Recording of Energy by the Sensor (D)

- 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



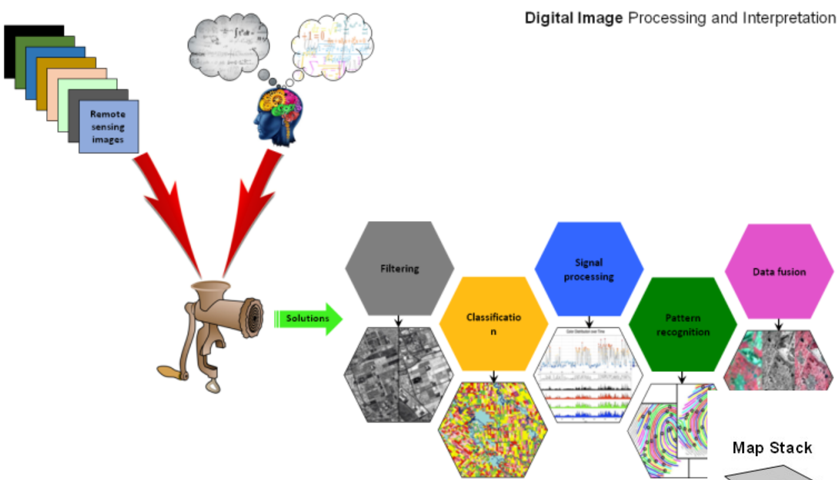


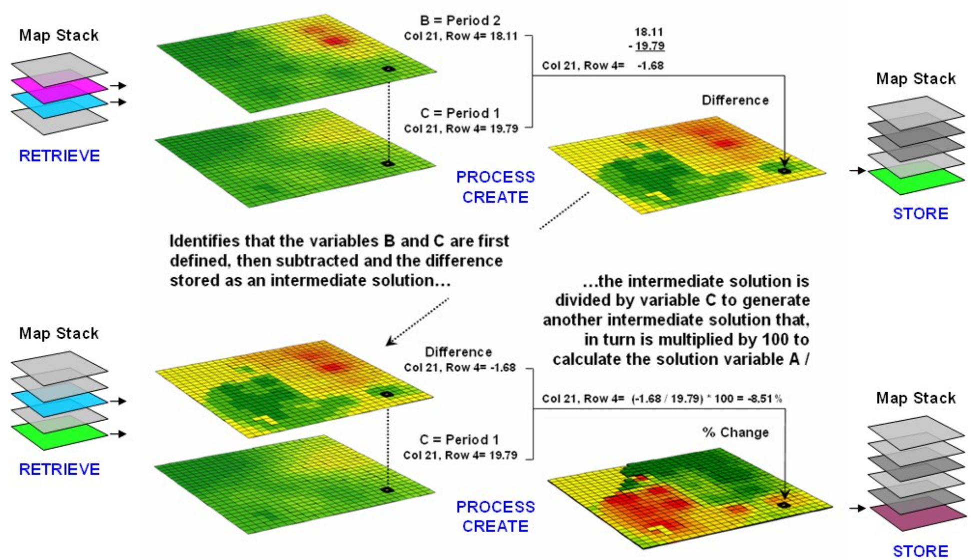
Transmission, Reception, and Processing (E)

- **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)

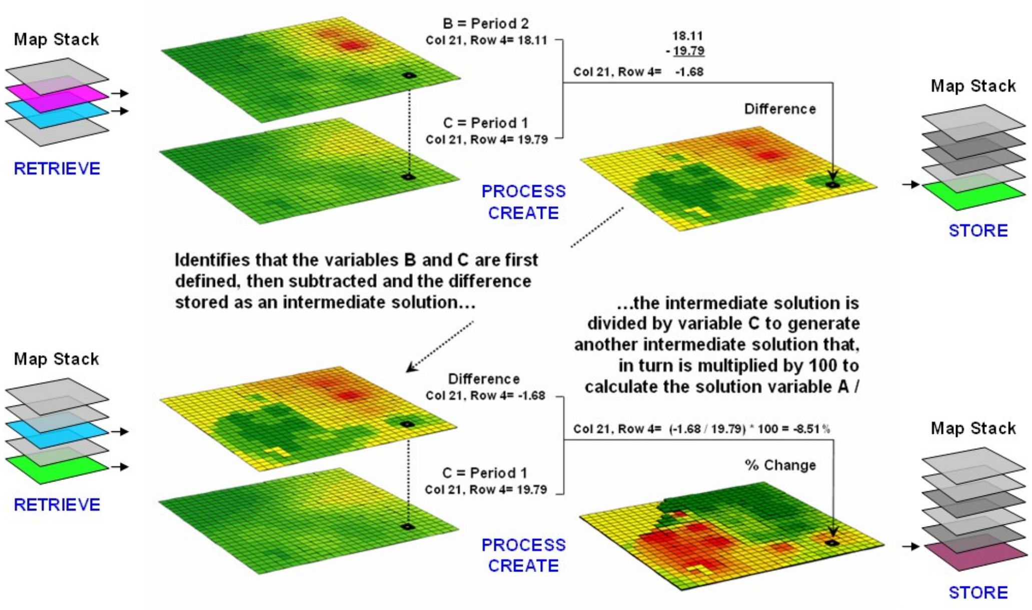
- The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.





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 an internet search on the Operational Land Imager (OLI) and the MODerate resolution Imaging Spectroradiometer (MODIS) and find their 4 basic characteristics?
  - Spatial, Radiometric, Spectral, and Temporal
  - Can you find the most ‘recent’ AZ/Tucson image form this sensor ?

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