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Standard course – Remote Sensing
Lesson SR1 – Principles and concepts of Remote Sensing

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Index

What is remote sensing?

Fundamentals

Remote Sensing

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth

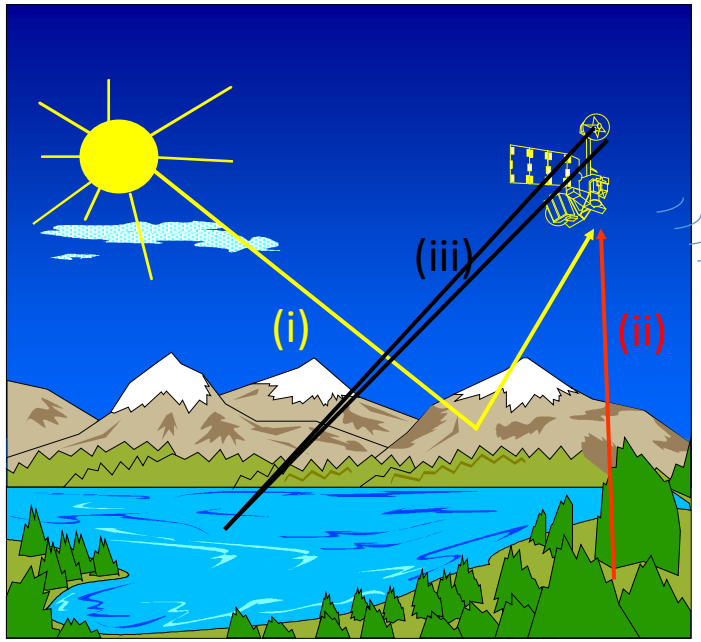
Remote sensing is a way of collecting and analysing data to get information about an object without the instrument used to collect the data being in direct contact with the object.

Remote Sensing

- Remote acquisition does not require direct or total contact of the sensor with the object of study and, when it is not or does not return to our hands in a short time, it also involves the transmission of data.
- It uses as a source of information the electromagnetic energy emitted or reflected by objects (although also other signals such as mechanical waves - sound - or variations in gravity).
- In a broad sense it includes techniques such as aerial photography, photogrammetry and cartography based on data provided by artificial satellites, sonar, etc.
- In other languages: *Teledetekcja, Teledetección, Télédétection, etc*

Fundamentals of Remote Sensing

- Principles:
  - (i) Electromagnetic radiation emitted by the sun towards the Earth is reflected (visible, nm) on the surface and captured by sensors (aircraft, satellite, towers…)
  - (ii) Natural radiation is also emitted (IRT, µm)
  - (iii) Electromagnetic radiation emitted by an active sensor towards the Earth is reflected on the surface and recaptured by the same sensor.



- Data acquired by the sensor is transmitted to a Ground Reception Station
- Data is processed later on
- Final products on Surface information are generated and distributed

Transmission
Recording

Reception station

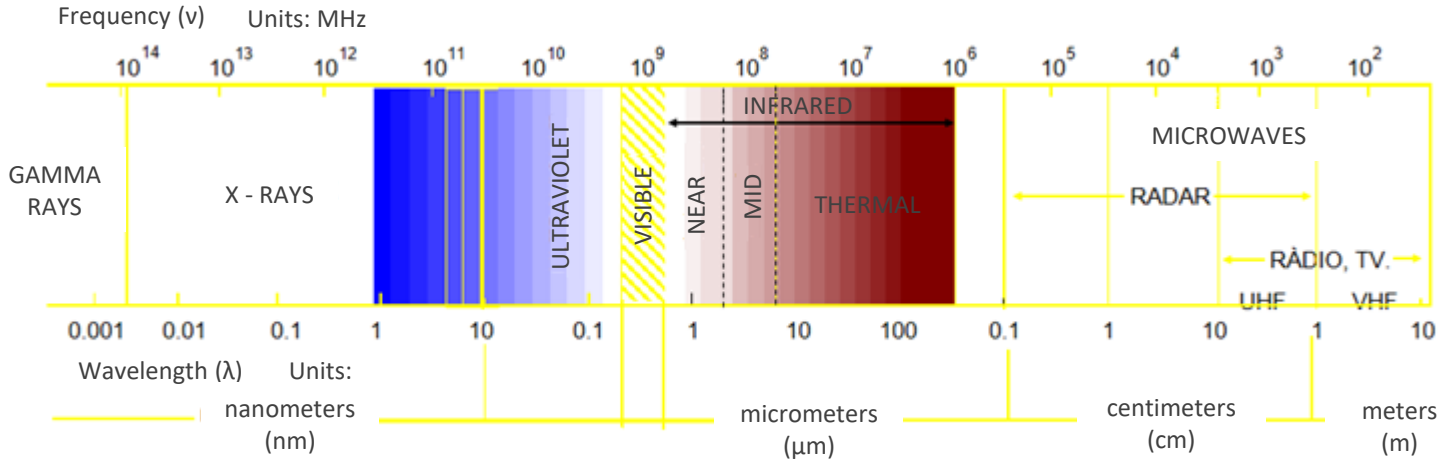
Data processing

Production of information on the surface

Fundamentals of Remote Sensing

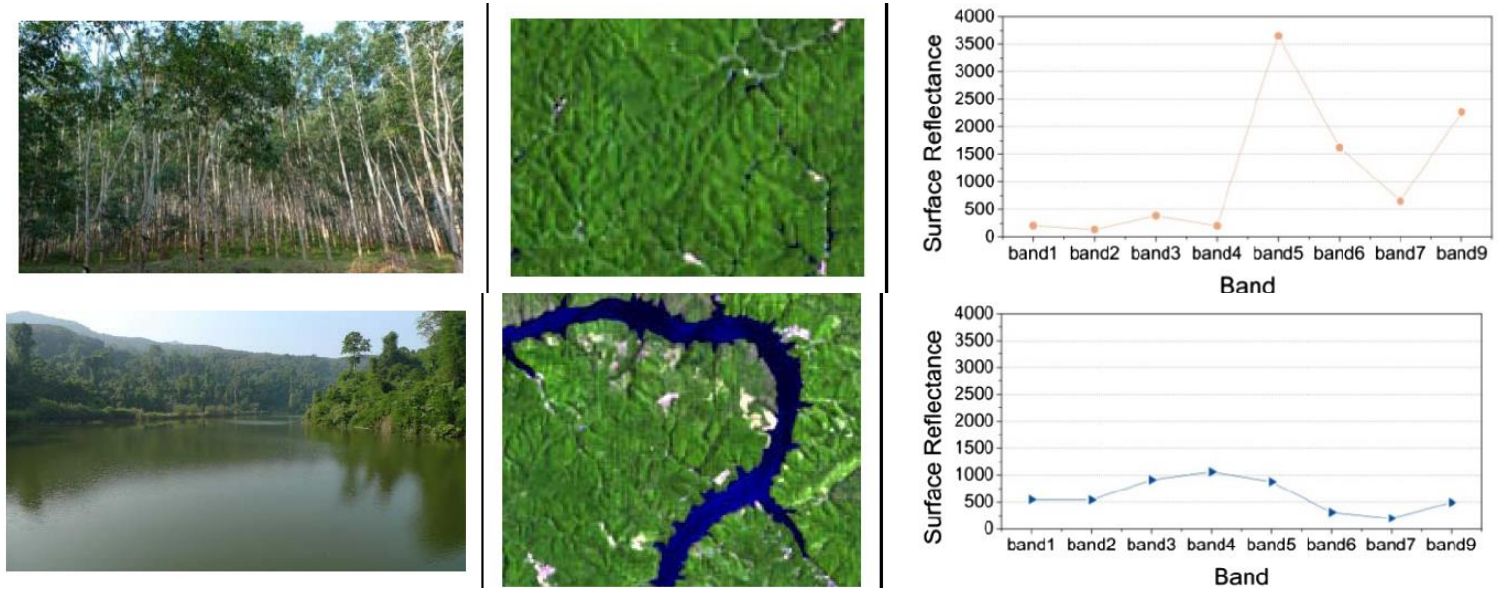
- Main spectral regions:
  - Visible (blue to red: wavelength, λ, 400 to 700 nm, VIS)
  - Infrared:
    - near (λ: 700 to 1300 nm, IRp, NIR)
    - shortwave (λ: 1300 to 2500 nm, IRoc, SWIR)
    - medium wave (λ: 2500 to 8000 nm, IRom, MWIR)
  - Thermal (λ: 8000 nm to 1 nm, IRt, TIR)
  - Microwave (λ: ~ cm)

E. Chuvieco, modified



The key idea

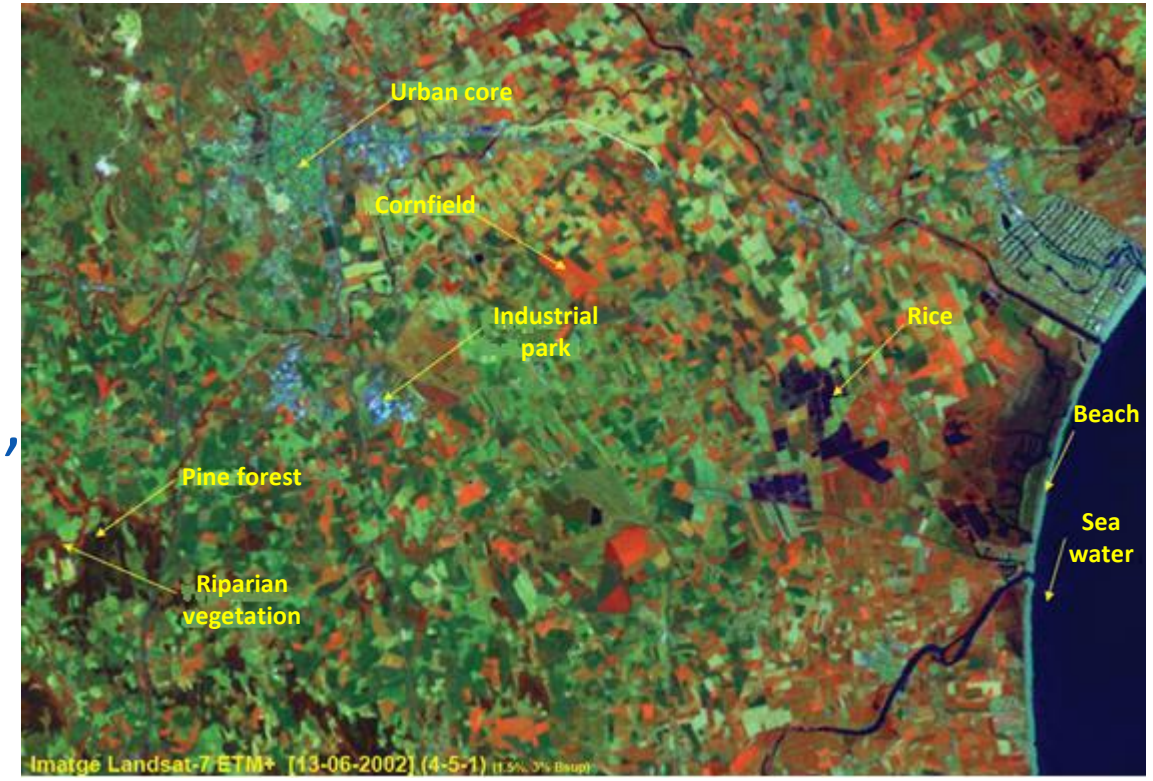
- Each type of object (a tree, a crop, a road, water, etc.) emits or reflects radiation in a characteristic way, called SPECTRAL SIGNATURE.
- This property allows them to be identified (visually or algorithmically) and is the basis of Remote Sensing



Spectral signatures

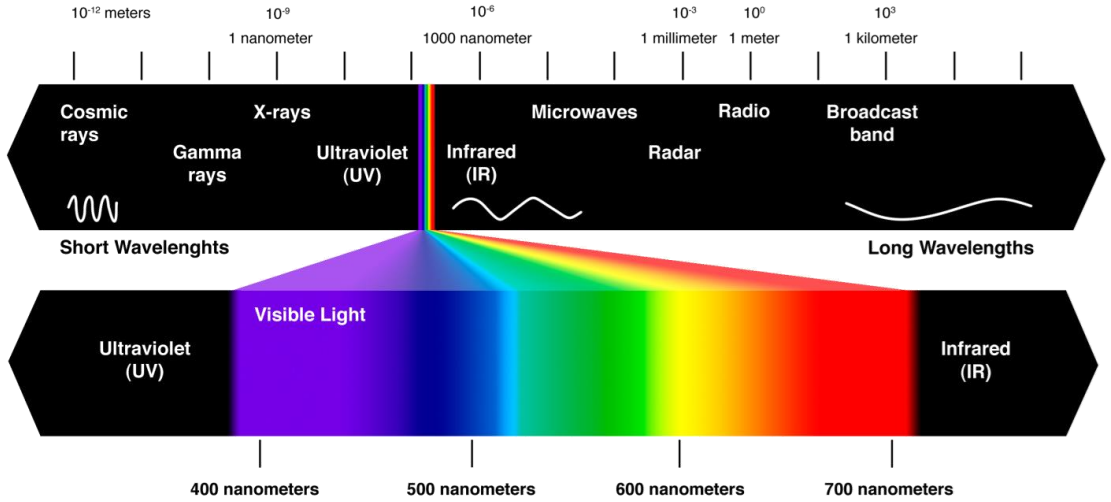
Spectral signatures

- Definition: Spectral reflectance / emitted radiance characteristics of a common earth surface material for a given wavelength.
- Sensors measure radiances (~energy)
- Reflectance is the proportion of reflected radiance vs radiance that arrived to the observed surface.
- There are many well know consistent spectral behaviour, such as vegetation, that presents a high reflectance at Near Infrared (NIR) wavelenghts

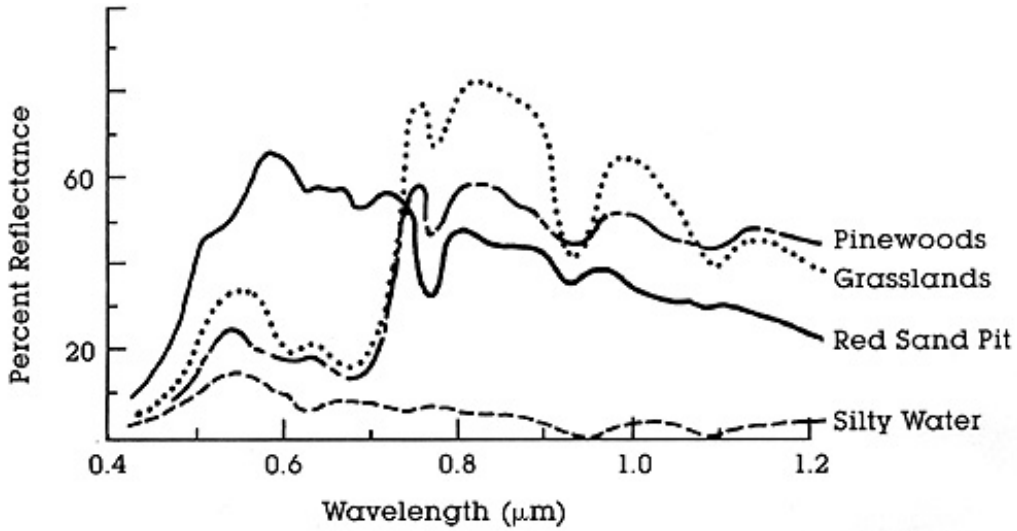


Spectral signatures

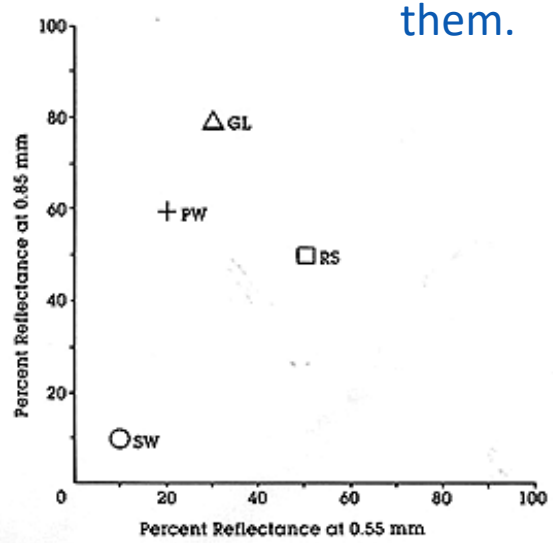
Visible and non visible light



Spectral signature of different land covers...

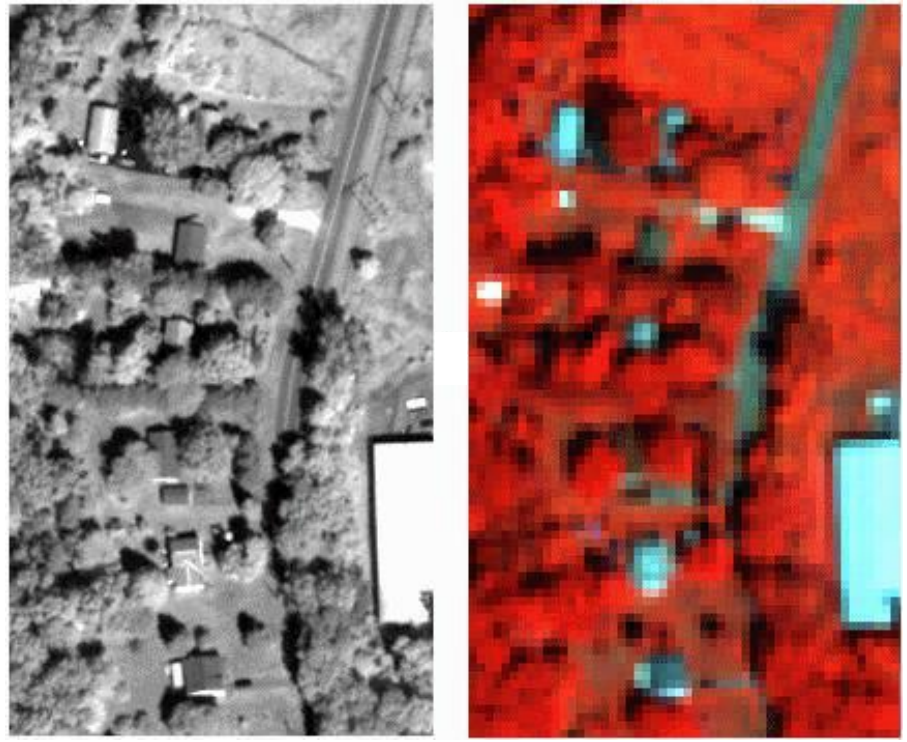


...let us classify them.



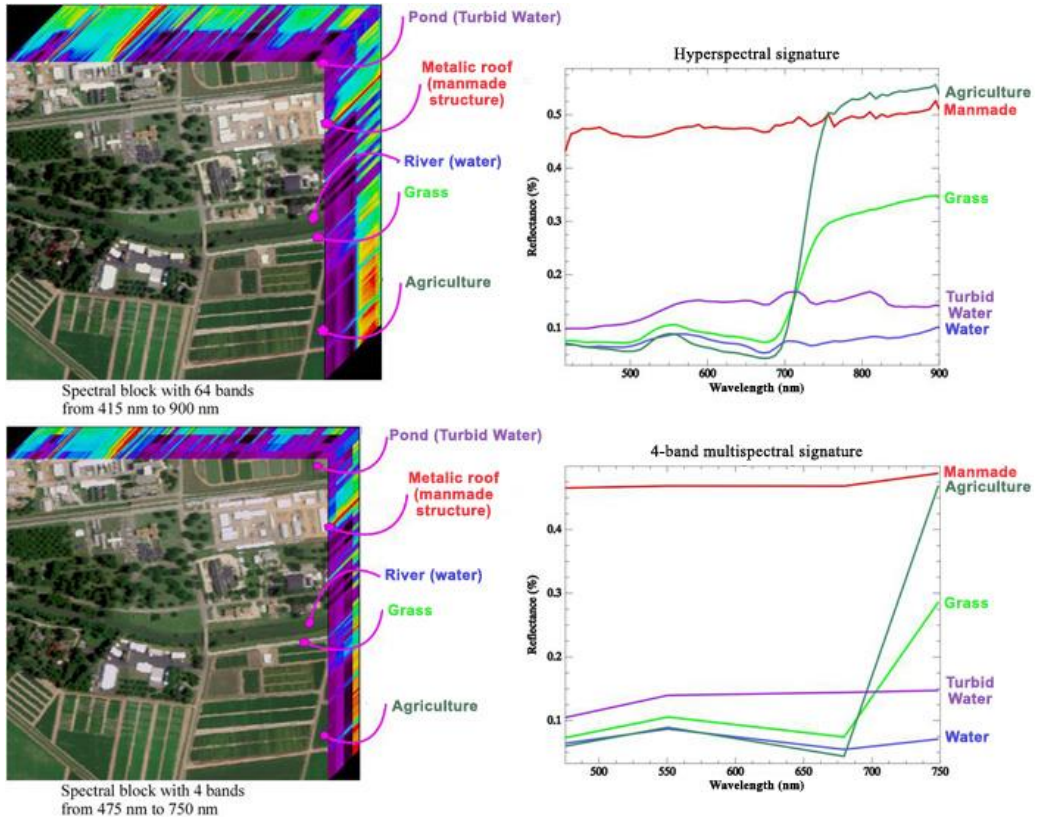
Spectral signatures

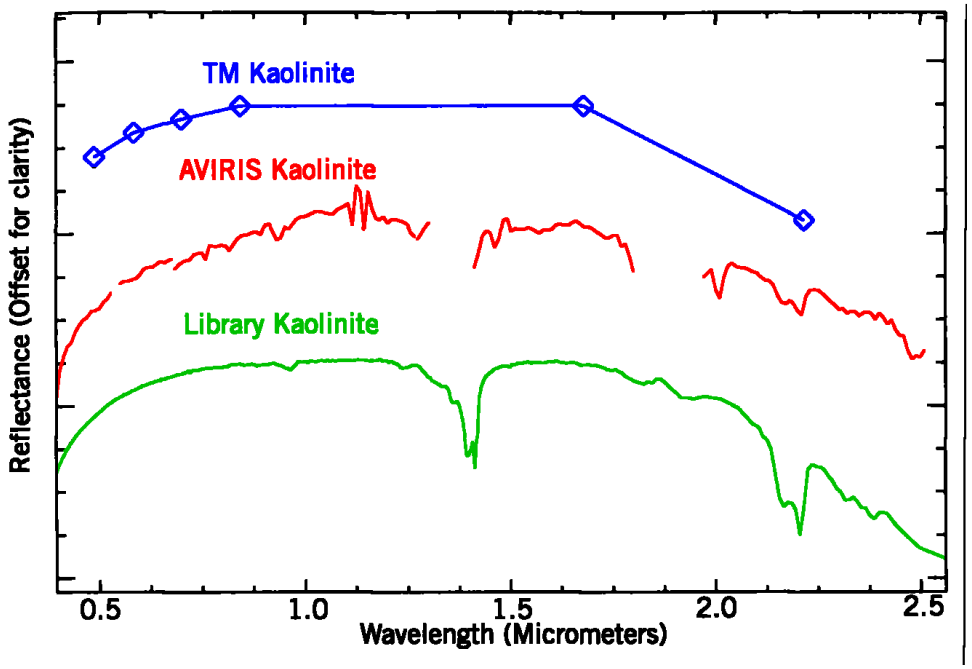
- What else influence on a spectral signature?
  - **Type of sensor** used on the acquisition (optical, infrared, thermal, radar...)
  - Sensor's **spatial resolution**: from 60 cm to 40km



Spectral signatures

- **Spectral Resolution**: Number of sensor's bands (multispectral / hiperspectral)

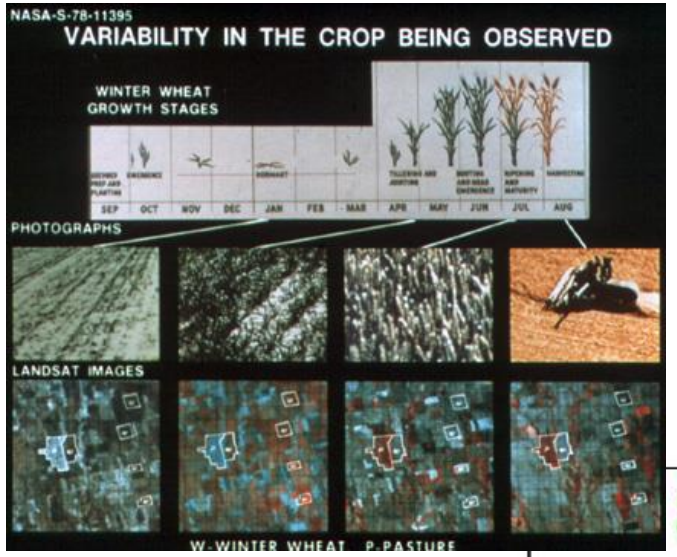


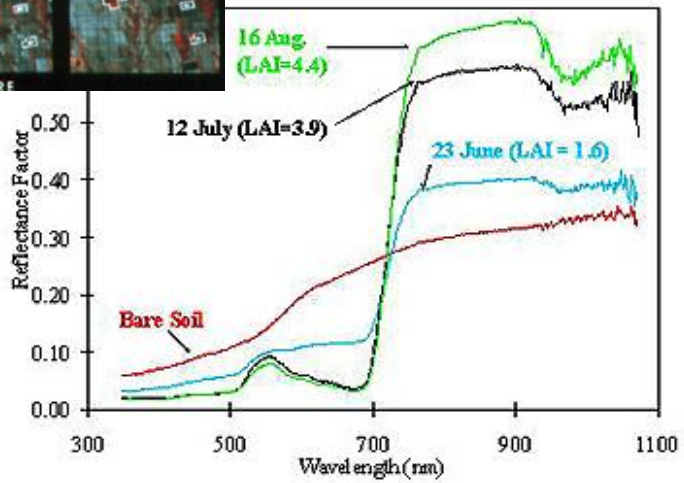


Spectral signatures

- **Temporal Resolution**: Interval elapsed between sensor "revisits" over the same area

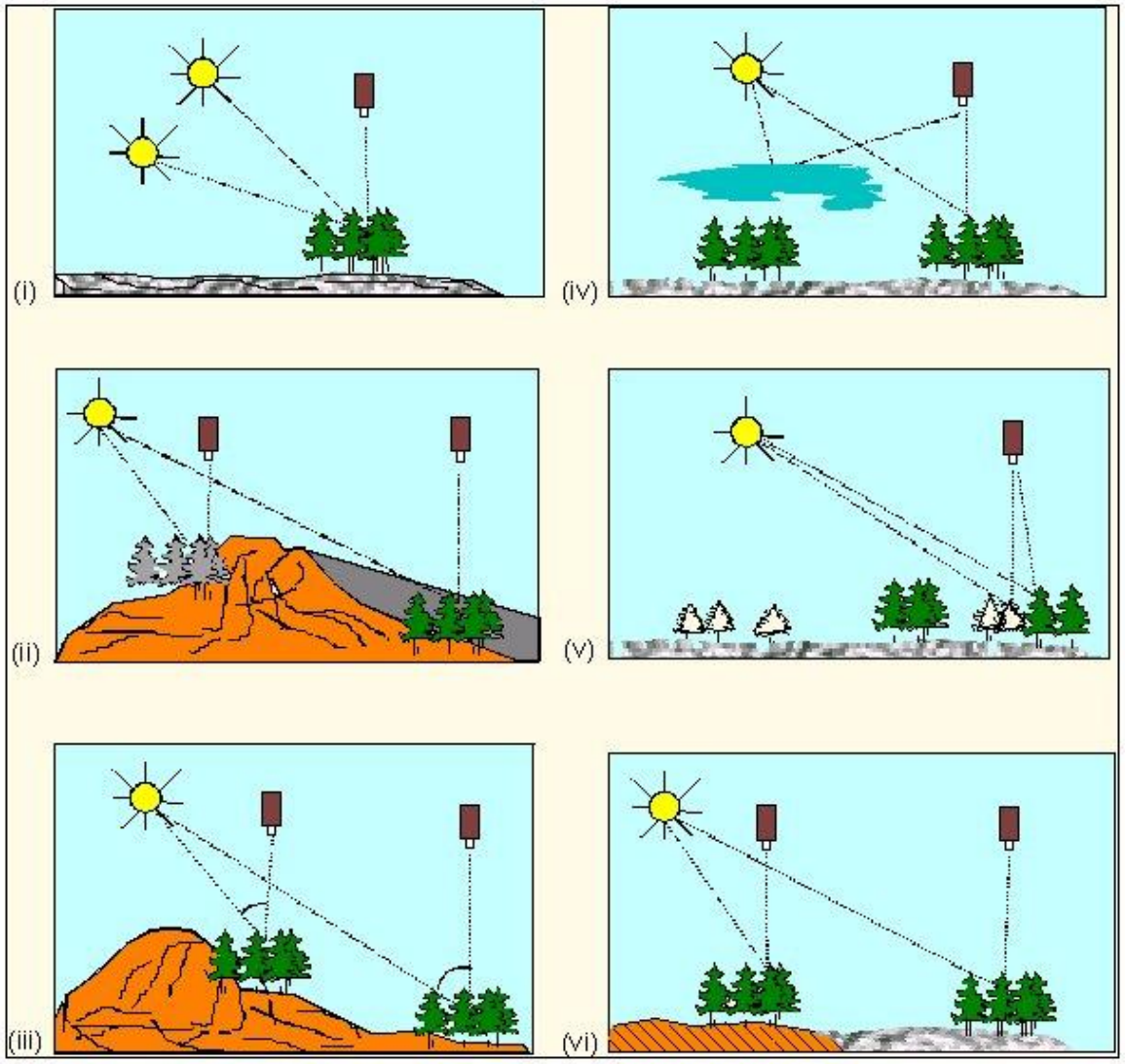
system	revisit interval (days)	daylight equatorial crossing time
Landsat 1, 2, 3	18	9:30–10:00 A.M.
Landsat 4, 5	16	9:45 A.M.
AVHRR	1 7 hours (two systems)	7:30 A.M. 2:30 P.M.
SPOT	26 (nadir only); 1, or 4–5 (pointing)	10:30 A.M.
IRS-1A, B	22	10:30 A.M.
MODIS	2	10:30 A.M. or 1:30 P.M.
GOES	30 minutes	NA





Spectral signatures

- Other factors such as:
    1) solar height
    2) aspect
    3) slope
    4) atmospheric conditions
    5) Phenology
    6) soil effects.



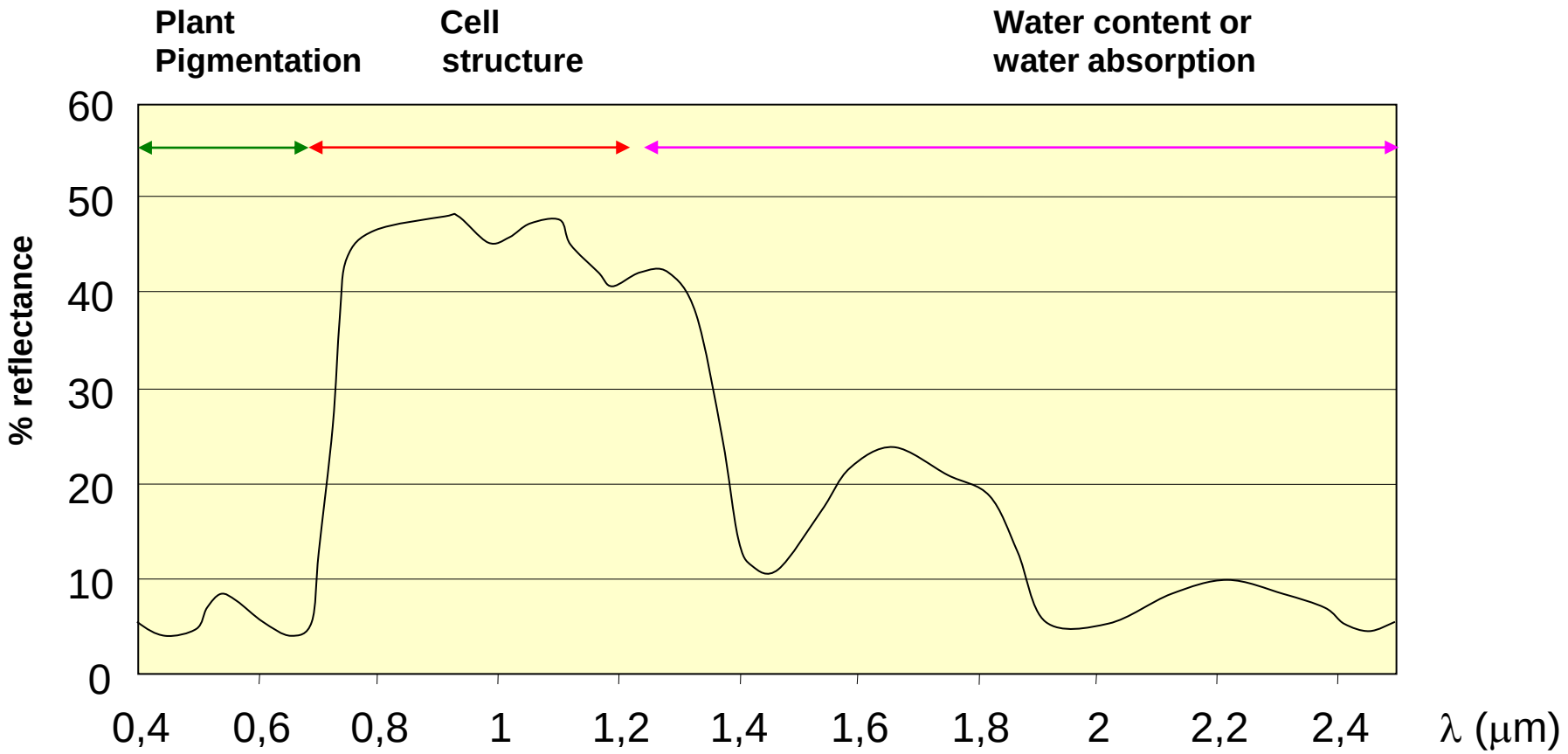
Spectral signatures

- Main types of spectral signatures:

1. Vegetation
2. Soils and geology
3. Water bodies and snow

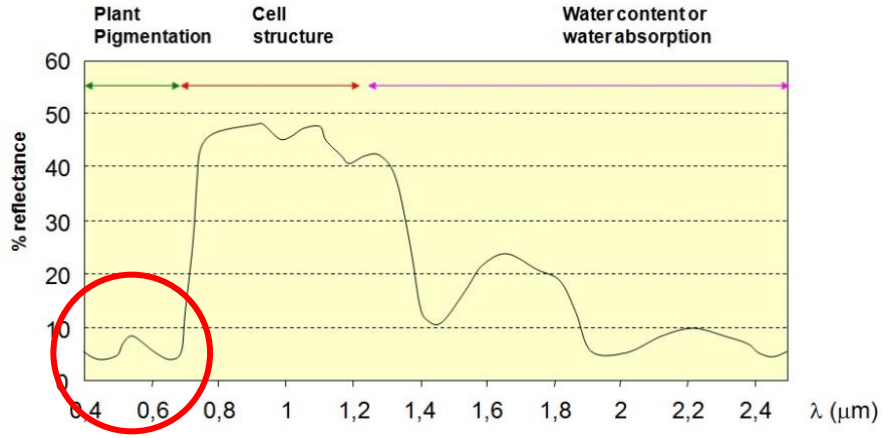
Spectral signatures: vegetation

Standard spectral signature of Vegetation



Spectral signatures: vegetation

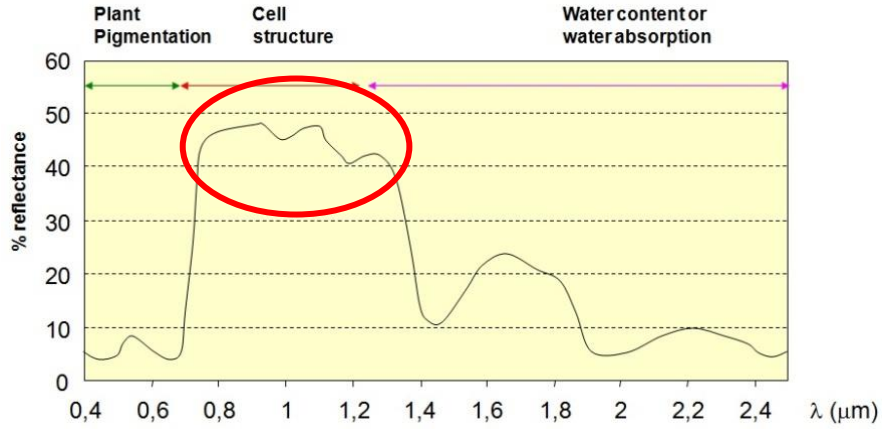
Visible and Infrared (no thermal)



- Chlorophyll absorption at 445 nm and 645 nm. (Photosystems I i II)
- Other pigments: xanthophylls, carotenes, anthocyanins...
- High reflectance in the Near Infrared (700-1300nm) due to plant cell structure: Sponge mesophyll with large spaces between cells: large structural variation, better discrimination potential
- Water absorption of plant leaves in the Middle Infrared: two absorption peaks: 1500-1800nm and 2000-2400 nm
- The cuticle partially polarizes the radiation reflected

Spectral signatures: vegetation

Visible and Infrared (no thermal)



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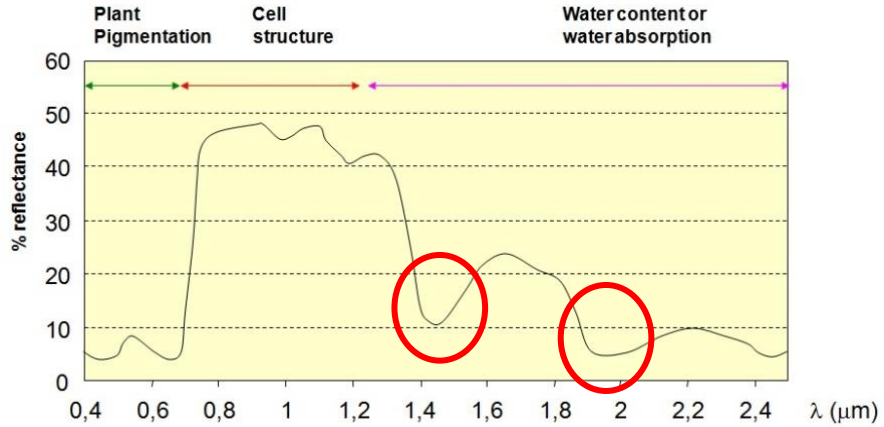
Spectral signatures: vegetation

Visible and Infrared (no thermal)



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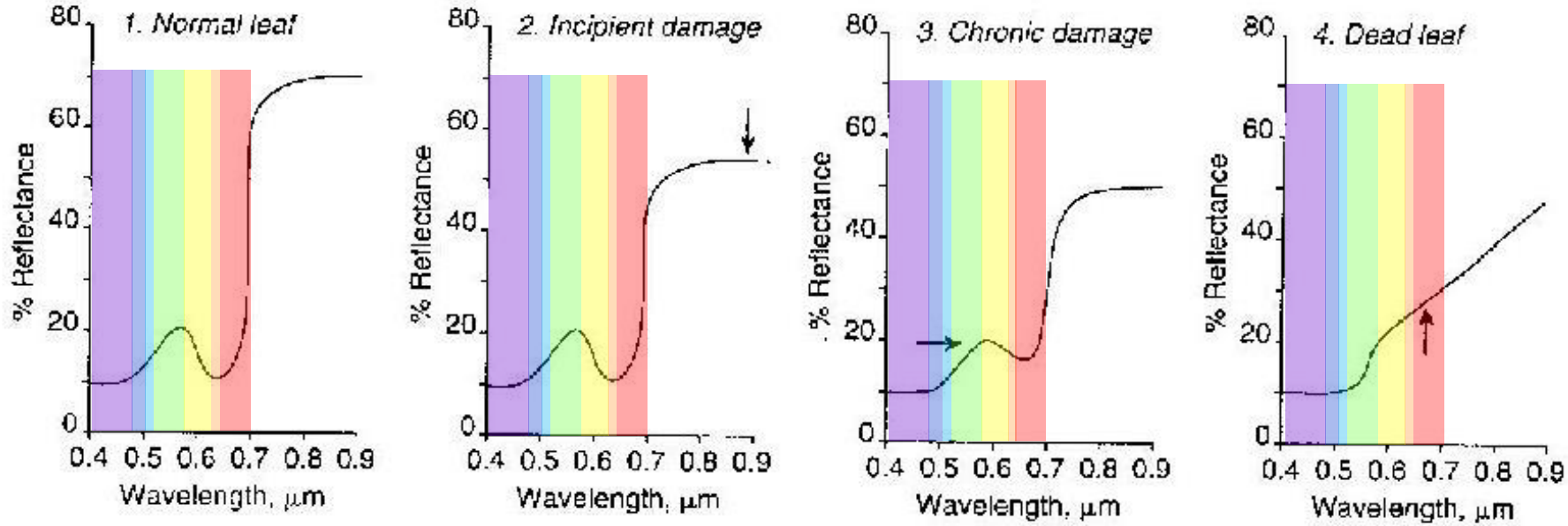
Spectral signatures: vegetation

- Senescence: the NIR region levels decline first, with an increase in the red region reflectance caused by a loss of photosynthetic chlorophyll (red+green: yellow)



Spectral signatures: vegetation

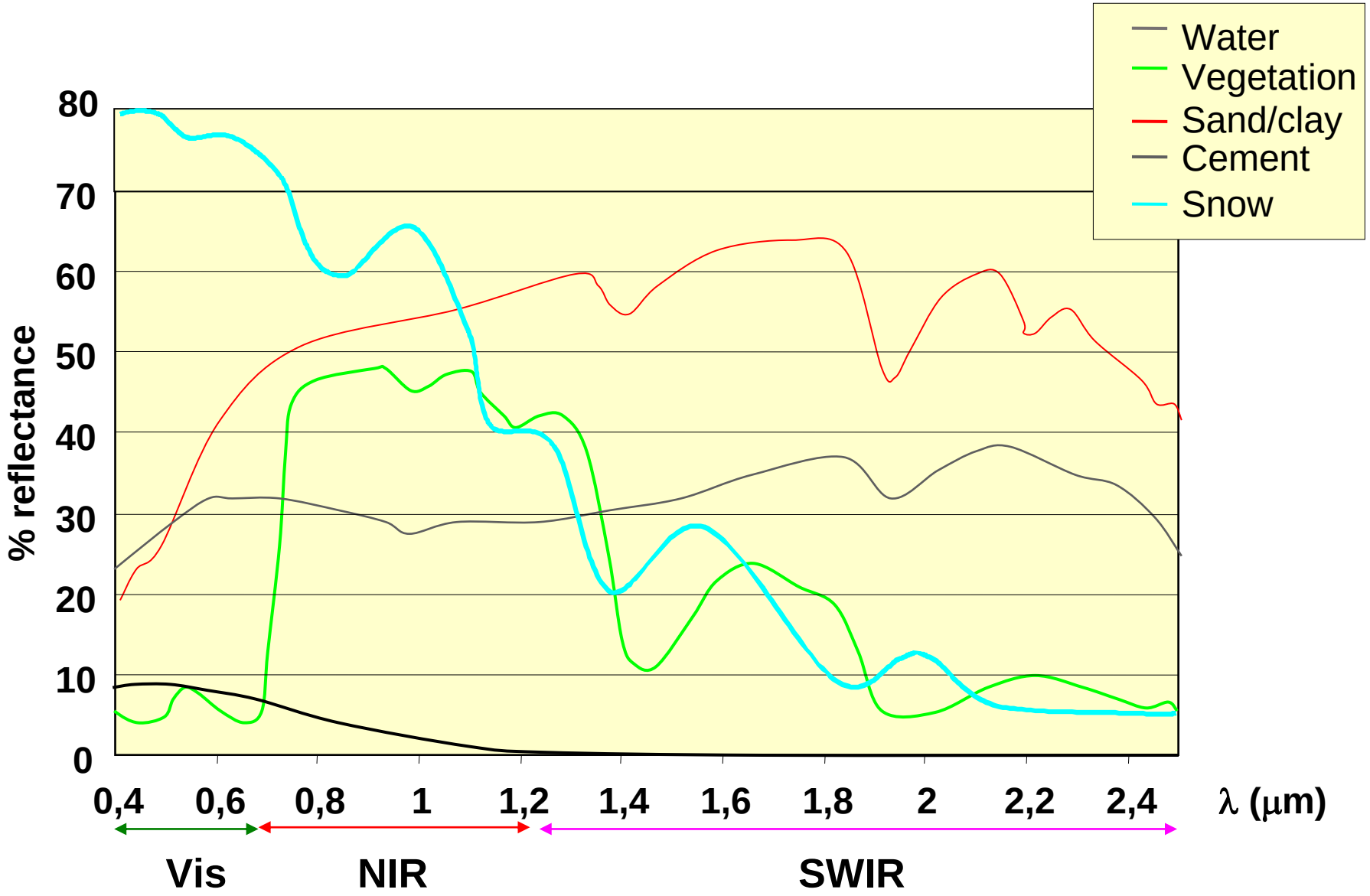
Thermal infrared

- Daytime temperature over vegetation cover is essentially a function of the top layer of the cover
- Very low reflectance(< 6%, normally < 1 %); healthy green leaves have lower reflectance
- Large thermal inertia (humidity): daytime colder than environment, night-time hotter than environment
- Influenced by: wind, radiation useful for photosynthesis, atmospheric humidity, surrounding air temperature and soil water availability
- Emissivity: 0.98-0.99

Microwave

- Cover geometry and cover water content (density, leave aspect, sunlight visible portion) drastically change the response

Spectral signatures: other covers



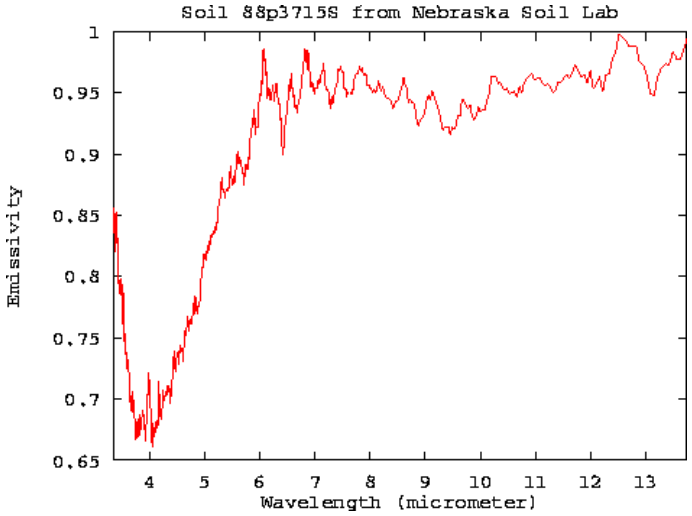
Spectral signatures: soil and geology

Visible and Infrared (no thermal)

- Reflectance increases approx. monotonically with wavelength
- Dips centred at about 1400nm, 1900nm and 2700nm owing to moisture content
- Clay soils also have hydroxyl absorption bands at 1400 nm and 2200nm.

Thermal infrared

- Water content is the most important soil factor at thermal infrared
- More humidity, large thermal inertia (daytime hotter, night- time colder)
- Emissivity: 0.8-0.9



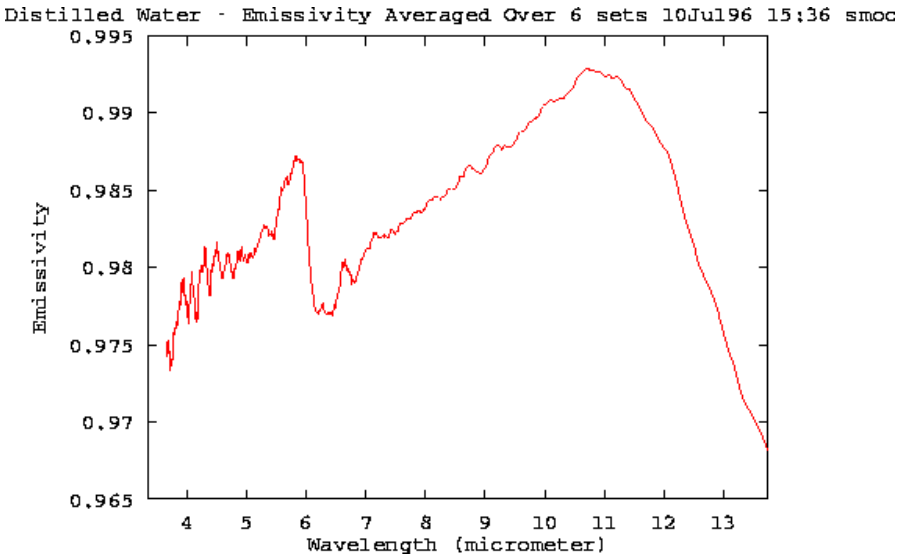
Spectral signatures: water bodies and snow

Visible and Infrared (no thermal)

- **Water**: General reduction in reflectance with increasing wavelength. About 10 % or less in the blue-green range, smaller % in the red and certainly no energy in the IR range
- Response affected by: presence and concentration of dissolved and suspended organic and inorganic material and the depth of the water body
- High specularity

Thermal infrared

- Greatest thermal inertia
- Emissivity: 0.99



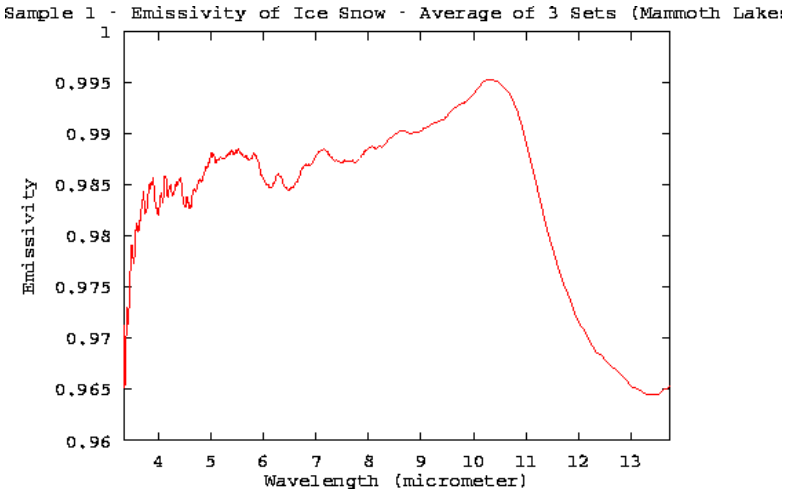
Spectral signatures: water bodies and snow

Visible and Infrared (no thermal)

- **Snow**: High and quite constant reflectance at short wavelength and NIR due to grain size, depth and cover density and impurities

Thermal infrared

- Affected by crystal size and water content
- Emissivity: Fresh snow – 0.99
  Old snow- 0.82



Platforms overview

Platforms overview

- Depending on the **position**:
  - Terrestrial: ex. field manuals, cranes, naval platforms, etc.)
  - Aerial (e.g. aircraft pressurized or not), balloons, unmanned aerial vehicles [UAVs or drones], etc.)
- The Kármán line, about 100 km above the Earth's surface, is often considered the boundary between the atmosphere and outer space from an aeronautical point of view.
  - Spatial (eg satellites, space launchers, space stations, etc.)
- Below 180 km approximately, the atmosphere is too dense to orbit without ignition due to friction.
- Above 600-800 km, there is little atmosphere and it can stay in orbit indefinitely

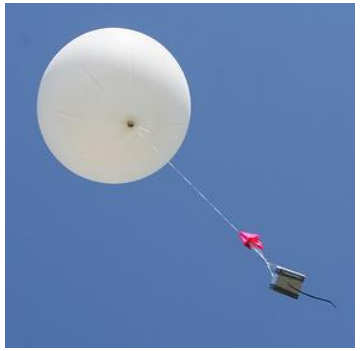
Platforms overview

Terrestrial Platforms

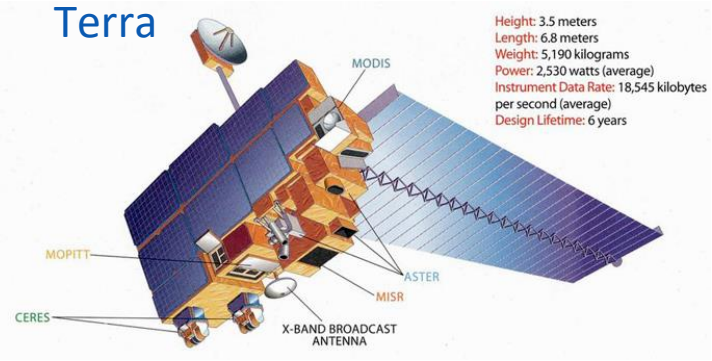




Aerial Platforms



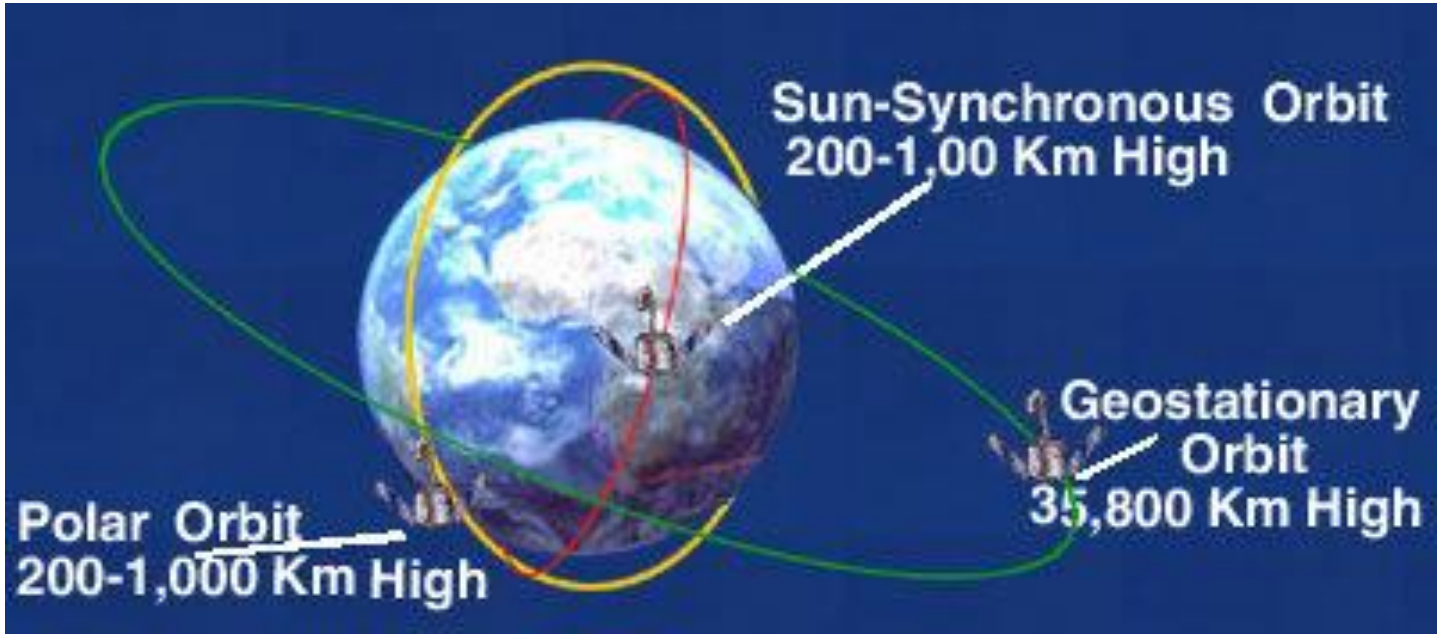

Spatial Platforms



International space station

Platforms overview

- Depending on the **type of orbit** (in satellites):
  - Geostationaries (ex. Meteosat, GOES-E&W, GMS)
  - Heliosynchronous (ex. Landsat, SPOT, IRS)
  - Others

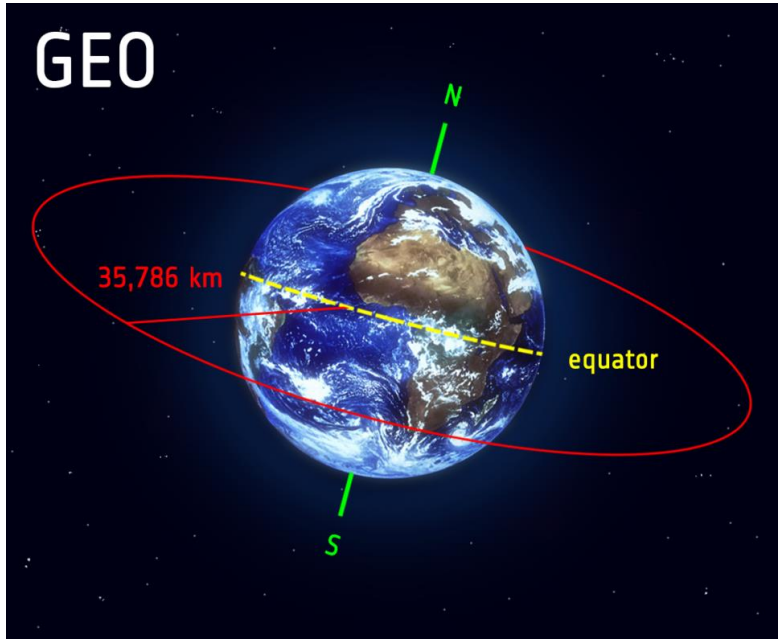


ESA

Platforms overview

Geostationary orbit:

Circular and equatorial geosynchronous orbit, at a distance of about 35786 km above the Earth's surface, in which a satellite maintains its position constant on the Earth's surface as it takes to orbit the planet exactly the time of rotation of this.

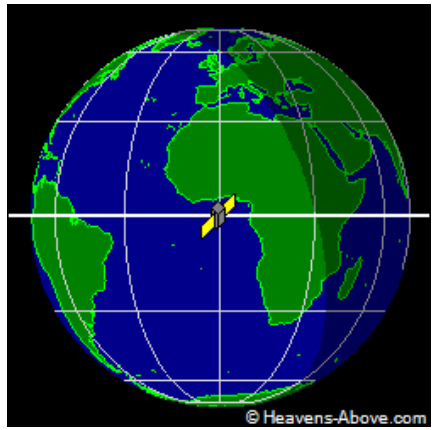


ESA

Platforms overview

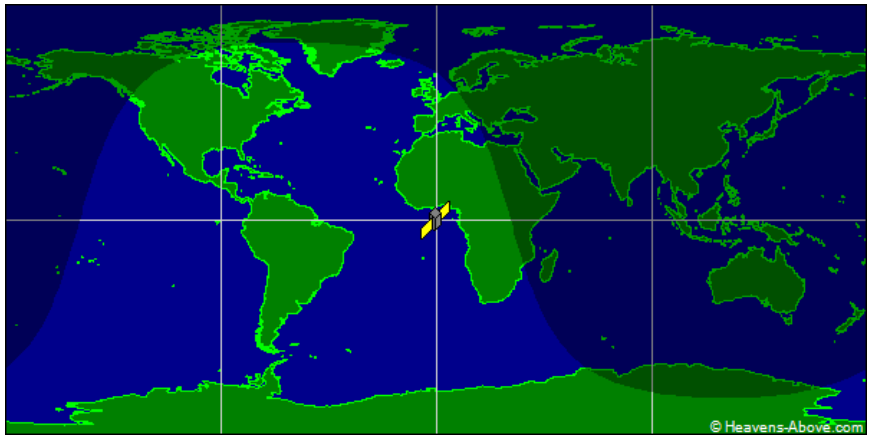
Geostationary orbit:

The enormous distance to the planet means that the spatial resolution is necessarily modest, but allows widgets in this orbit both to observe and make communications over very large regions, so these orbits are used by telecommunications satellites (which are visible constantly and for which the receiving antennas on the ground can be fixed) and by many remote sensing satellites intended for meteorological observation, such as Meteosat.



View from above satellite

Chris Peat



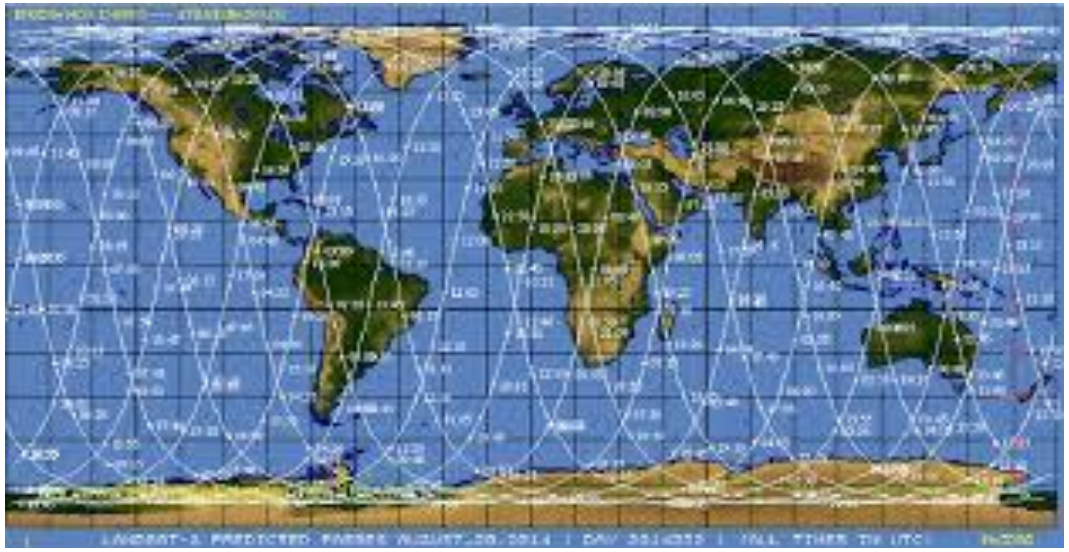
Ground track

Platforms overview

Heliosynchronous orbit:

Generally polar orbit around the Earth at a certain altitude (usually between 600 and 1000 km above the surface, although they can be more extreme) which means that the satellite passes through each latitude at approximately the same local solar time in each pass, which facilitates the interpretation of the images because the illumination of the Sun is similar, especially in the interannual revisits at the same time of the year.

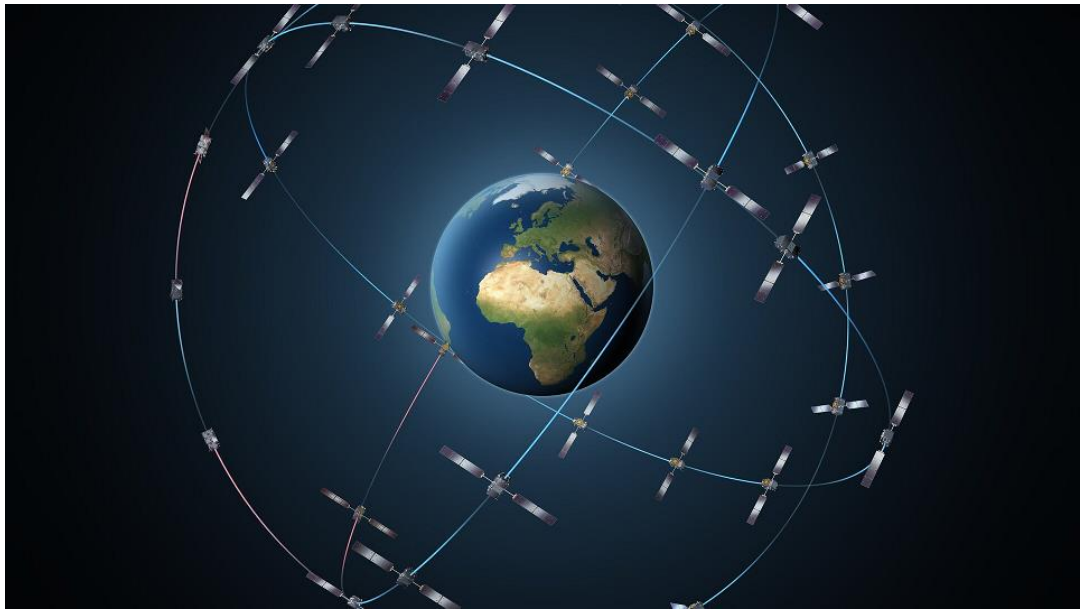
Landsat orbits



Herbei Mihai

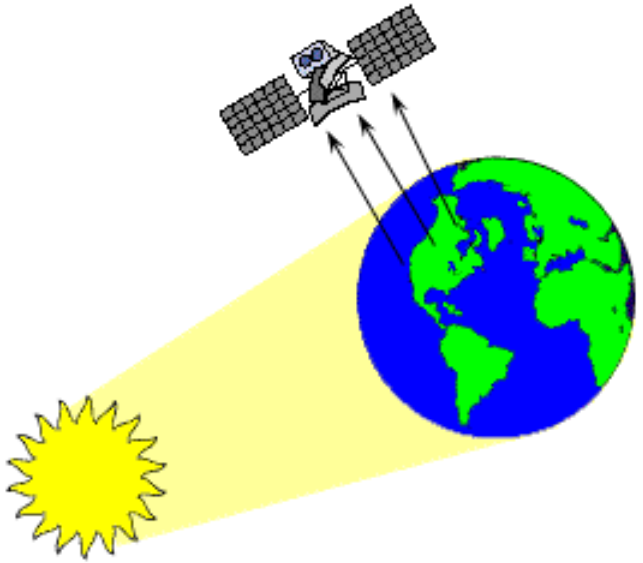
Platforms overview: Constellation

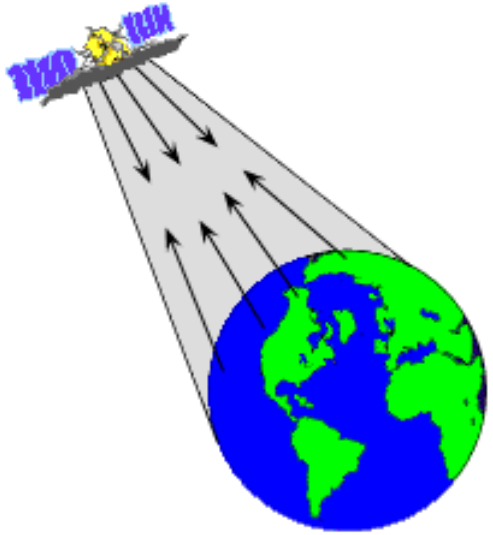
- Set of contemporary, or almost, satellites acting for common purposes, whether remote sensing (e.g., DMC1), positioning, and navigation (e.g., GLONASS), etc.
- Sometimes formed by microsatellites, nanosatellites, etc.



Galileo constellation ESA

Platforms overview: active and passive





Passive remote sensing: solar radiation reflected by the covers and captured by the sensor

Active remote sensing: radiation emitted by the sensor, reflected by the covers and captured by the sensor

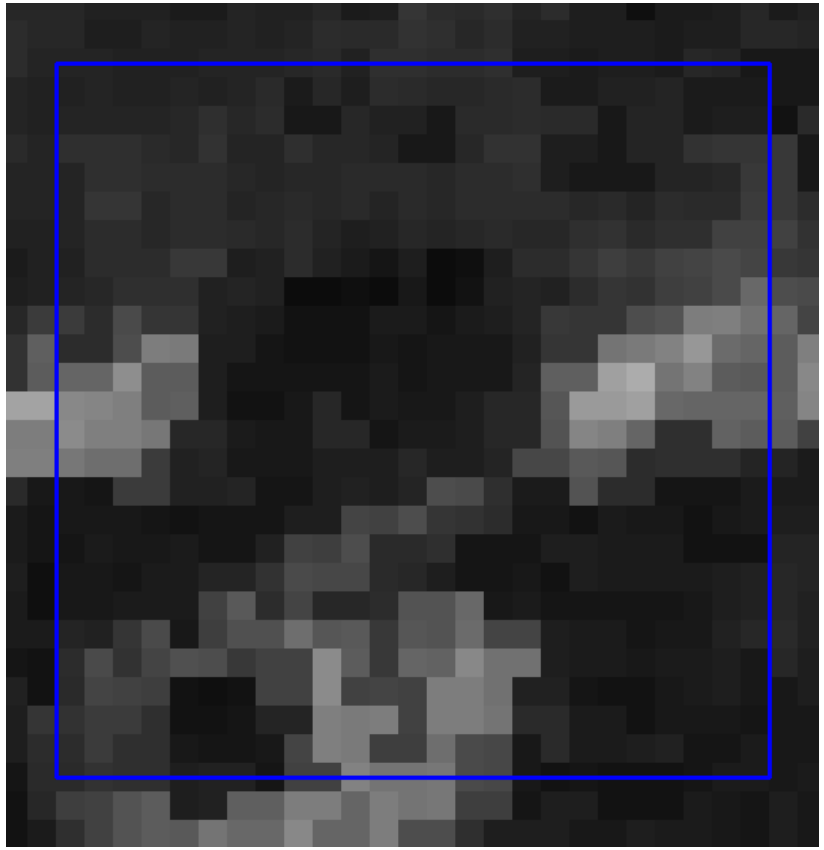
R. Sanderson

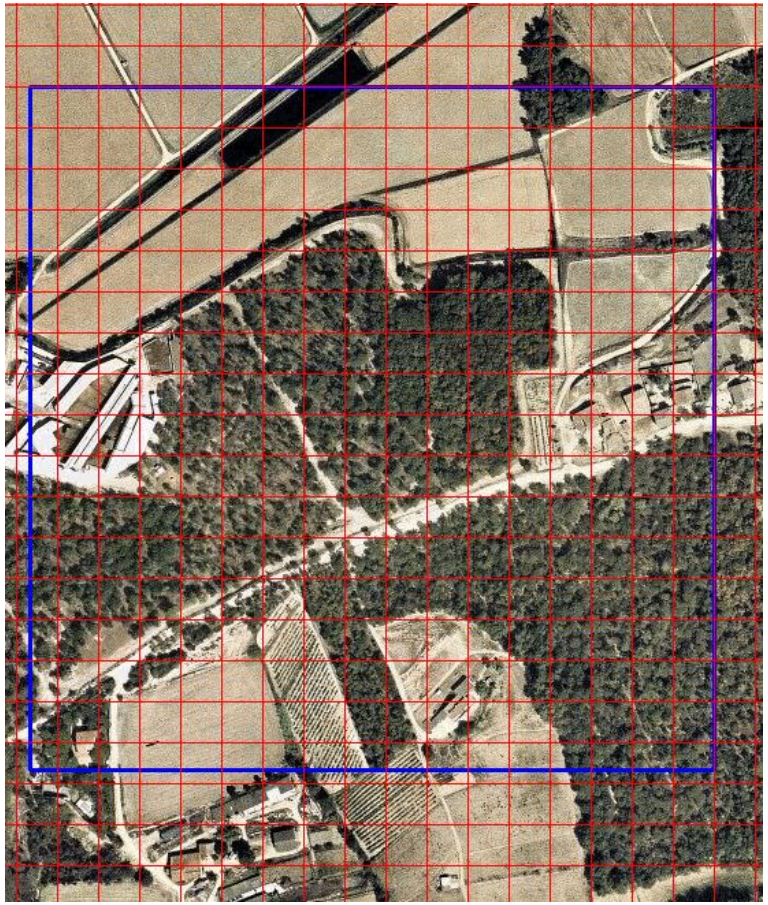
Pixel and resolutions

Pixel and resolutions

- **Pixel**: (picture & element) The smallest element that can be solved, once captured and stored.
- **Resolutions:**
  - **Spatial**: Size of the smallest object that can be distinguished in an image, but often defined as the size of the pixel. It is actually linked to the instantaneous field of view (IFOV) height and speed of the platform (in optical sensors). Not to be confused with the pixel side.
  - **Spectral**: Spectral regions in which the sensor is able to capture (e.g., VIS and IRp), total number of bands, and the spectral range of each.
  - **Temporal**: Time interval between two covers of the same area (at nadir and at Ecuador).

Spatial resolution

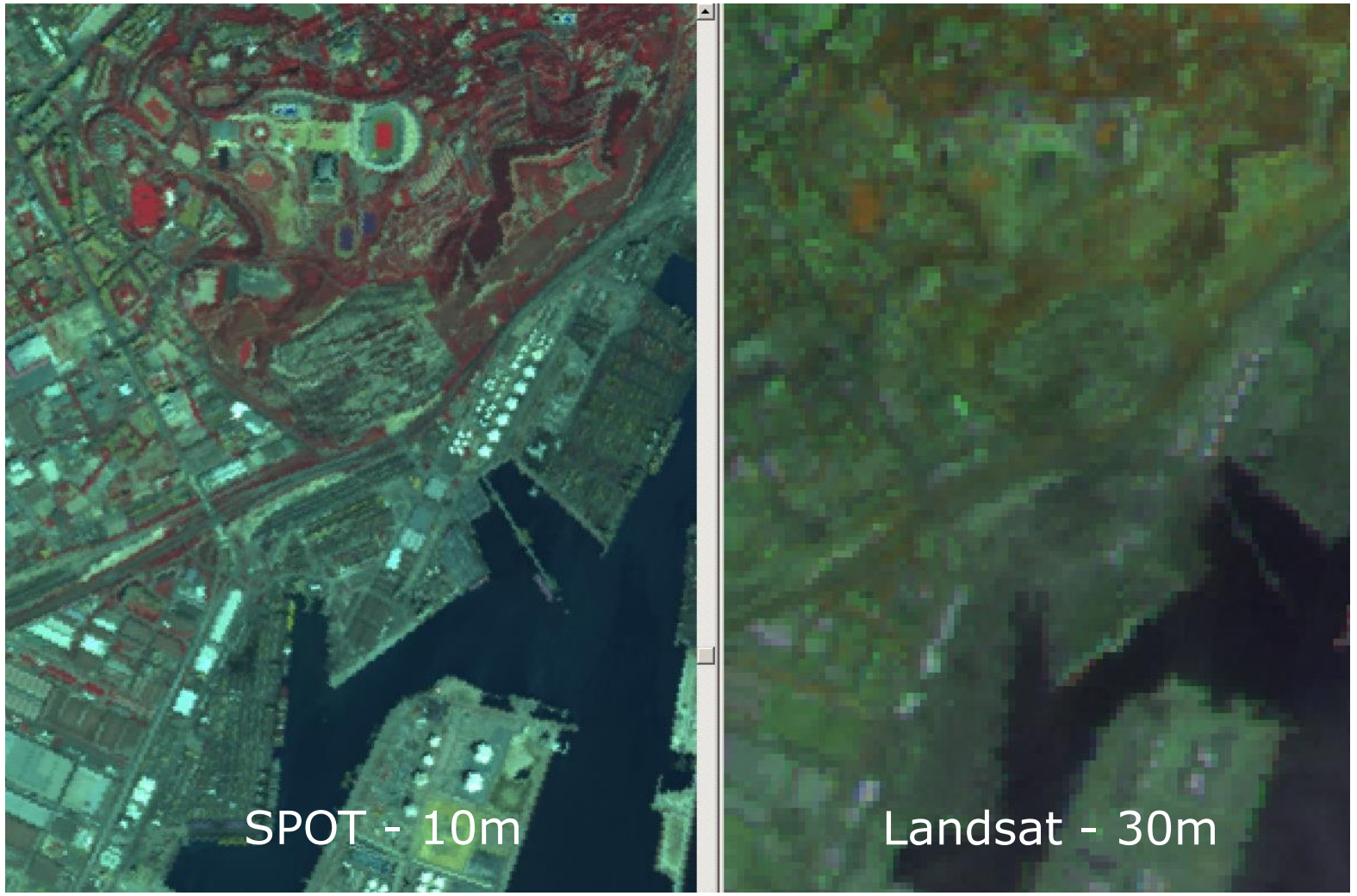




MODIS

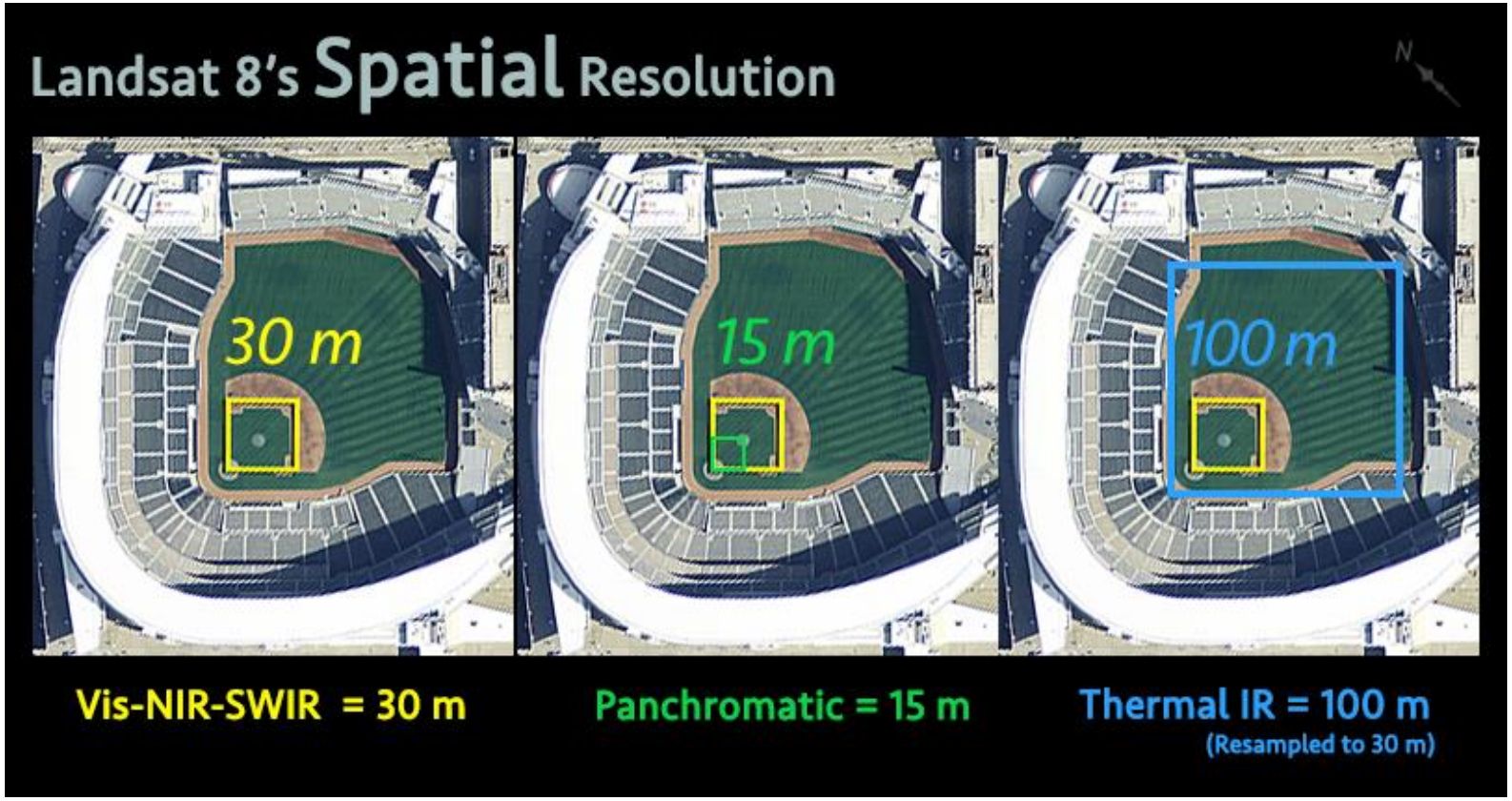
LANDSAT

Spatial resolution



Spatial resolution

Spatial resolution is often associated with the platform (Landsat), but it should be noted that different sensors on the same platform may present captures at different resolutions.



Spectral resolution

- **Resolutions**
  - **Radiometric**:

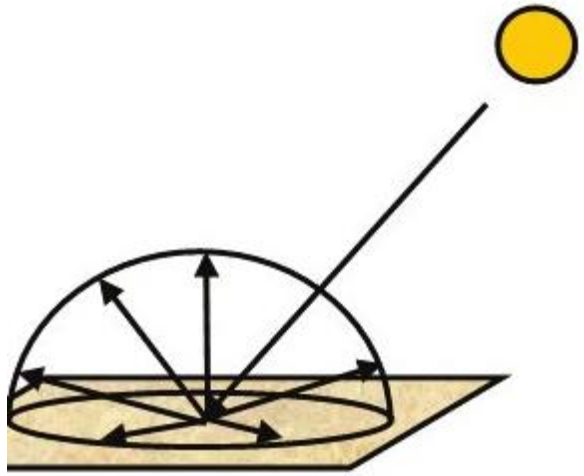
    Ability to discriminate different levels of energy received. Number of values, different and discrete, that each pixel can take (ex. 64, 256). In fact also linked to the minimum and maximum radiance, etc.

2-bit image vs. 8 bit

Pixel and resolutions

- **Resolutions**

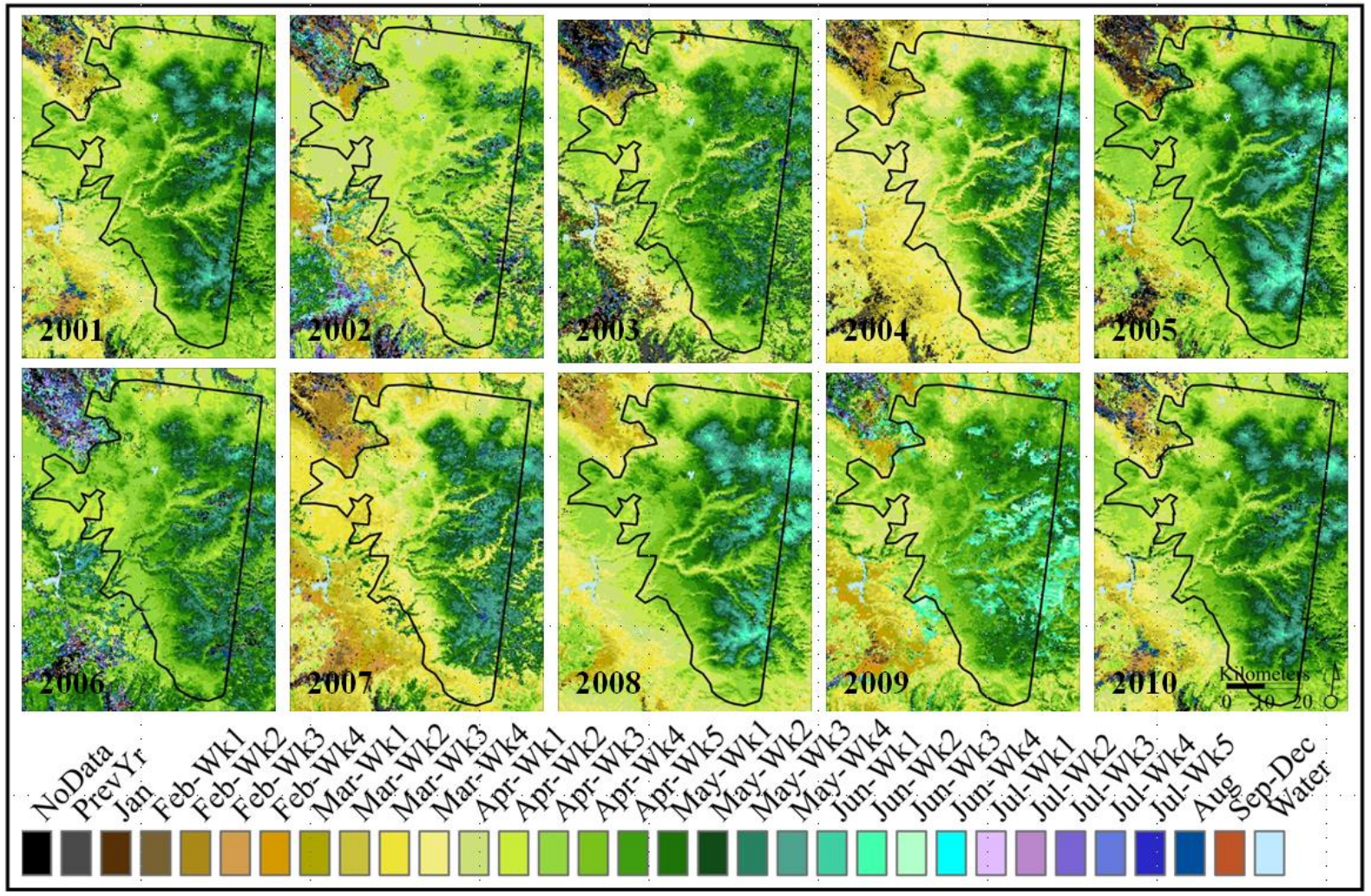
  - **Angular**: number and direction of the angles at which, approximately simultaneously, a sensor is able to observe a scene.
  - There are very few sensors that have simultaneous multiangular observation capability (eg the MISR of the Terra, with 9 angles, the CHRIS of the PROBA, with 5 angles) is a particularly interesting property for the identification and monitoring of those covers that present a little Lambertian response



Temporal resolution

- **Temporal**: Time interval between two covers of the same area (at nadir and at Ecuador).
- Notes:
  - The temporal resolution does not apply to geostationary platforms since in these the nadiral position is permanent.
  - Not to be confused with revisit time, which can be much longer.
- Temporal resolution (nuanced by revisit time) is basic for tracking and monitoring applications, as well as for alerts and emergency systems.

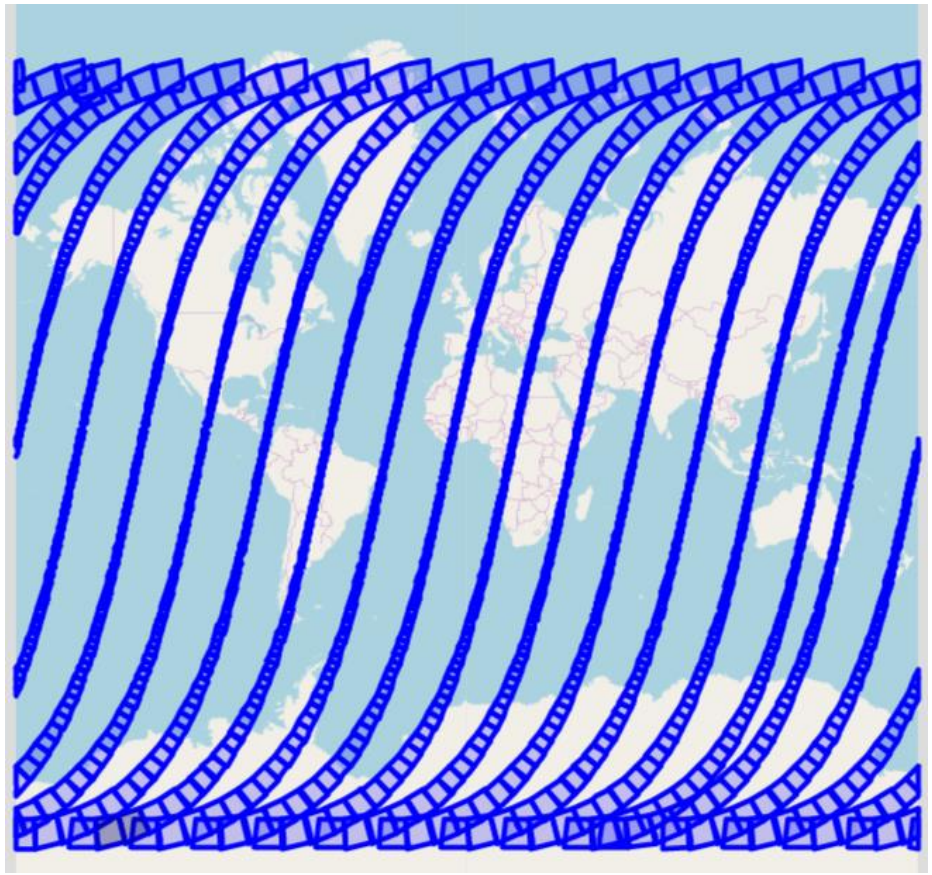
Temporal resolution



Revisit time

- **Revisit time**: Minimum time required for a satellite sensor to re-observe the same area of the Earth.
- Revisit time is related to:
  - the characteristics of the orbit (temporal resolution)
  - The characteristics of the sensor (pointing capacity)
- In sensors capable of pointing, the revisit time can be significantly lower than the temporal resolution, while in sensors that always have the same attitude and sub recurrent orbits, it coincides with the temporal resolution.
- Note that there is also a constellation temporal resolution and revisit time.

Revisit time

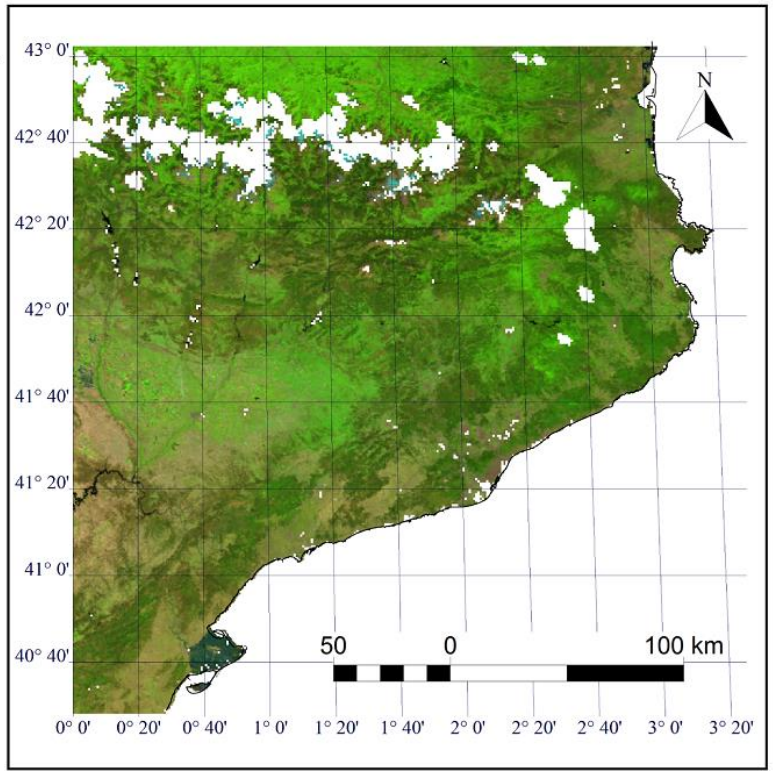


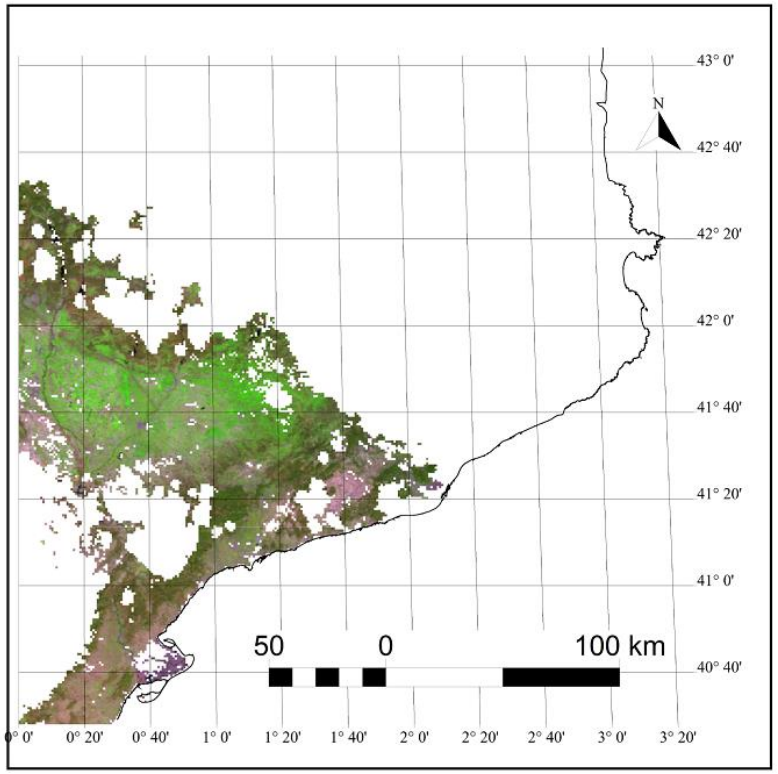
https://landsat.usgs.gov/landsat_acq

Revisit time and temporal resolution decrease very noticeably at latitudes close to the poles in sensors in polar orbits.

Revisit time

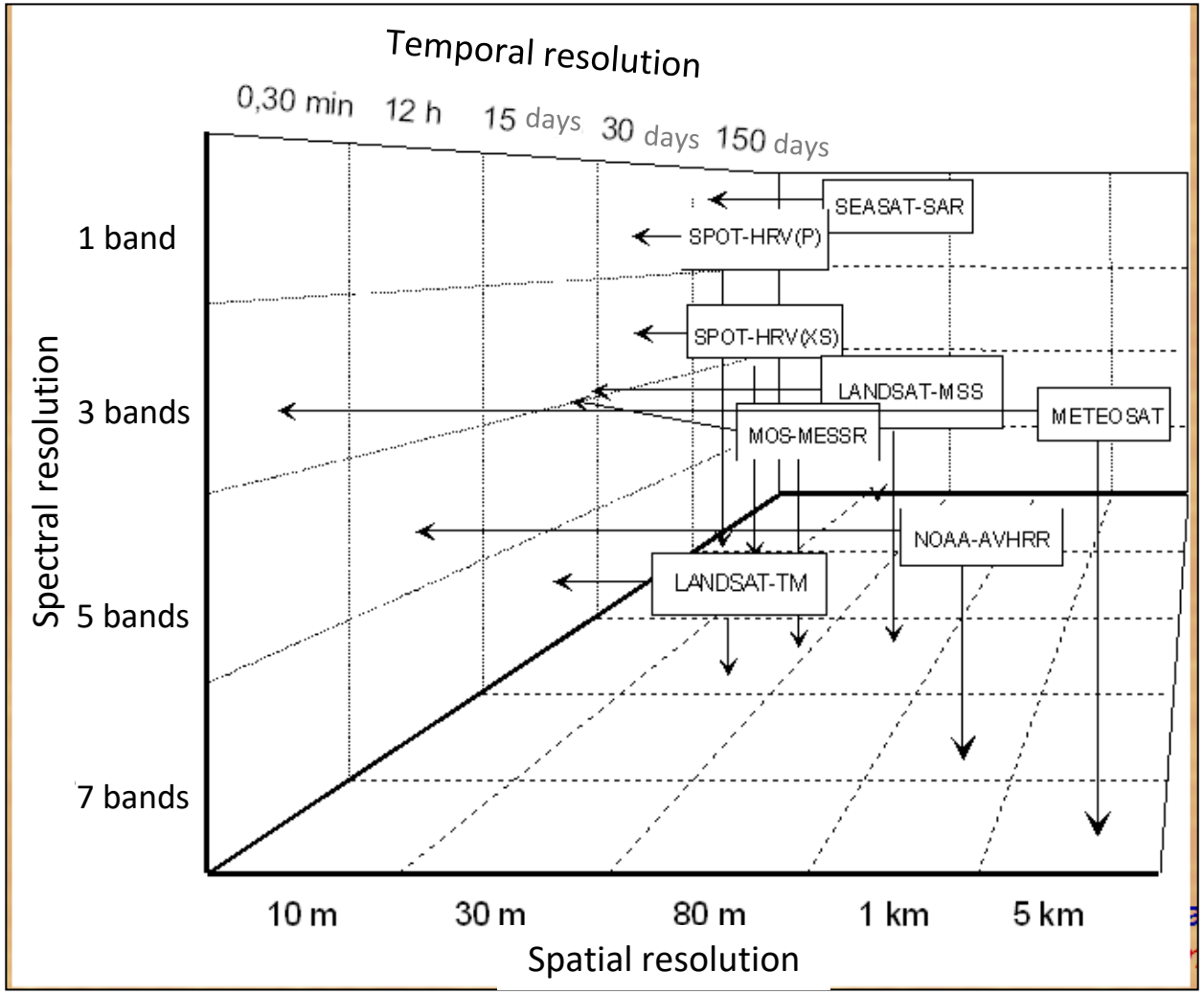
In practice, the **useful revisit** time can be greatly altered by cloudiness





Compositions RGB 6-2-1 MOD09GA 01-08-2009 and 29-05-2009

Resolutions



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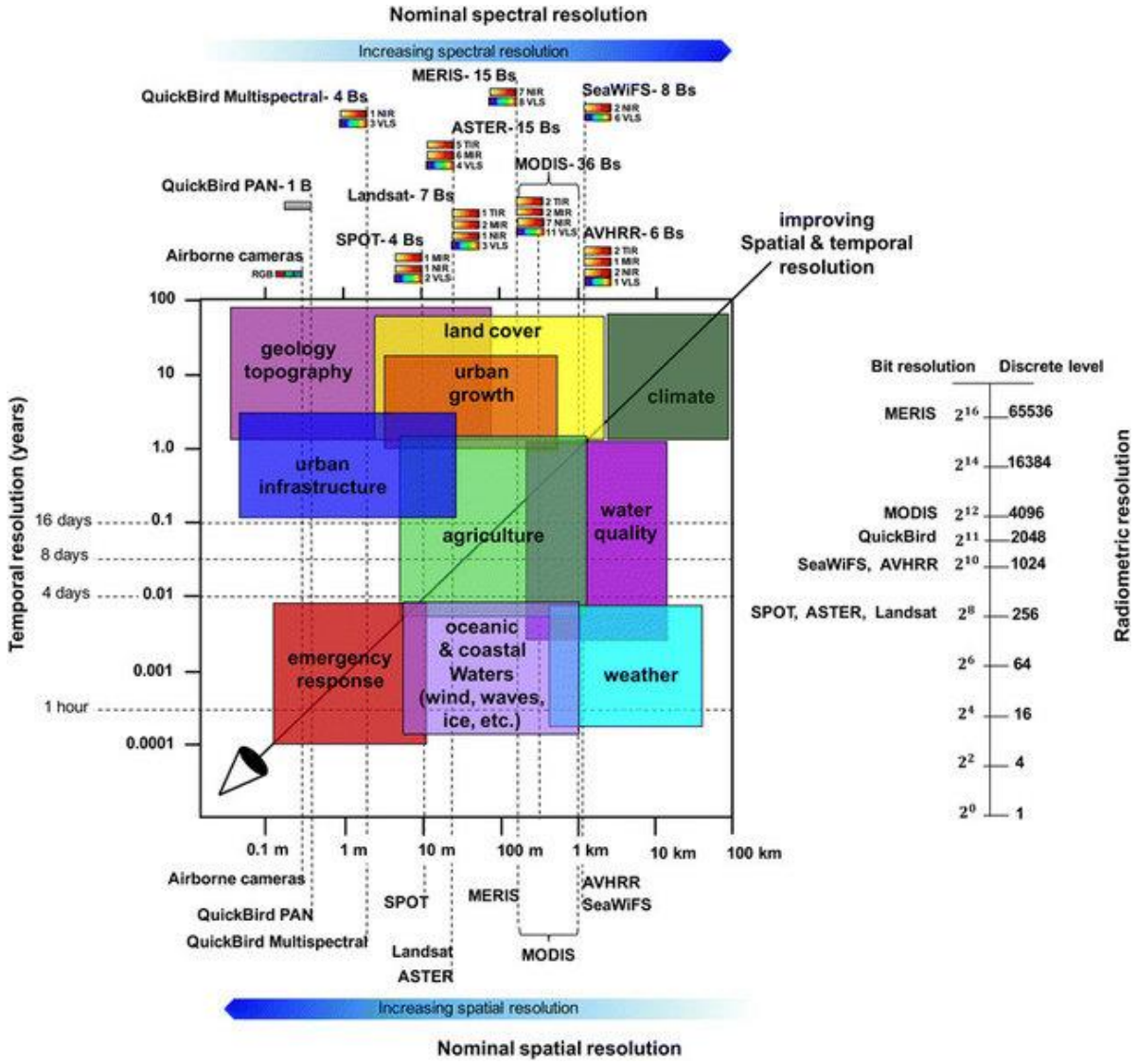
Resolutions and applications



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