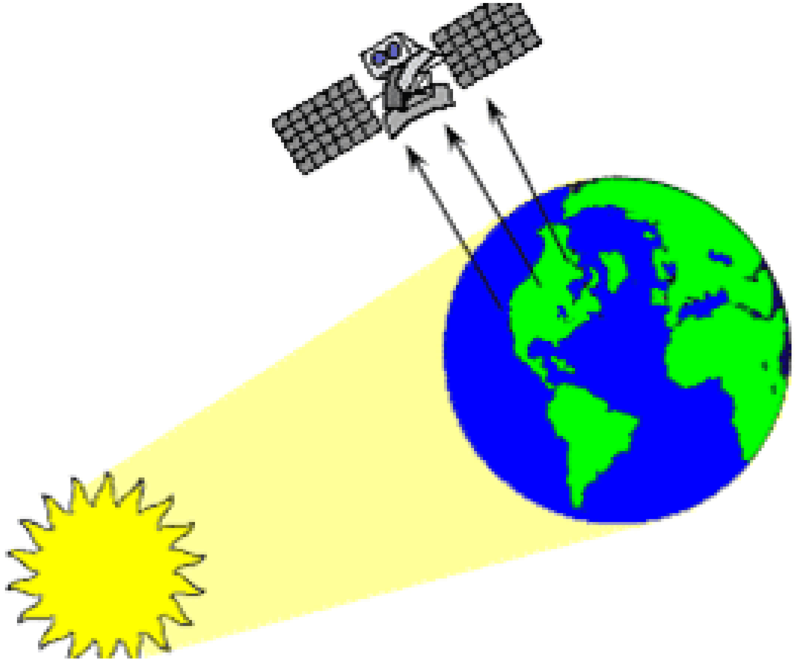
UiO : University of Oslo

Remote Sensing (including GPS)



GEO-DEEP9300

Petra Hatalova, CEED, University of Oslo, 2021

DEEP
Norwegian Research School for Dynamics and Evolution of Earth and Planets

CEED
The Centre for Earth Evolution and Dynamics

What is Remote Sensing?

Process of ***acquisition of information*** *about an object or phenomenon* ***without making physical contact*** *with the studied object.*

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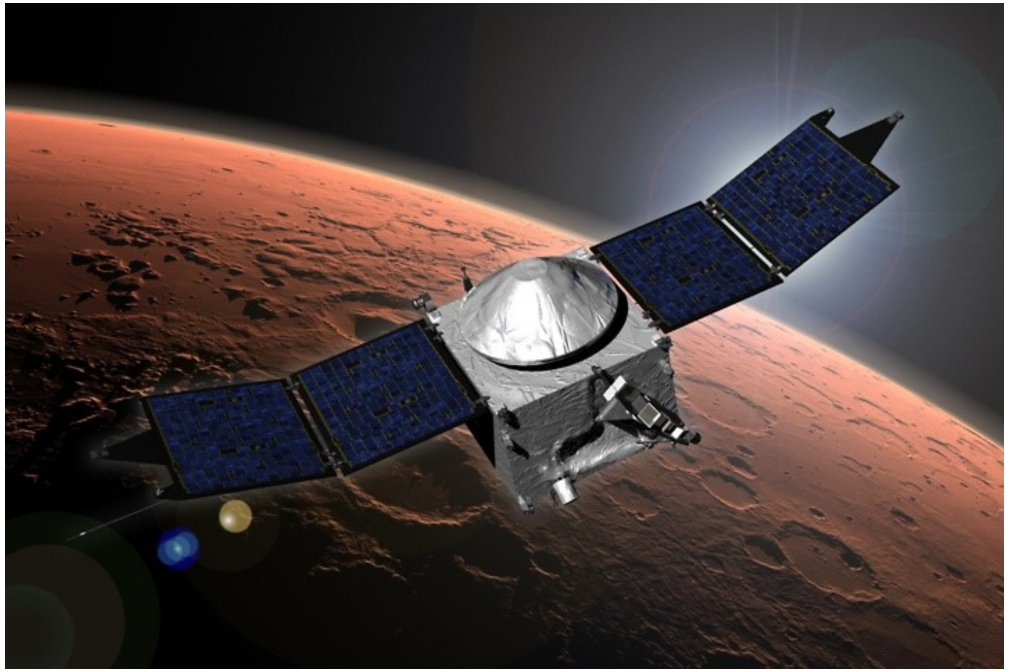
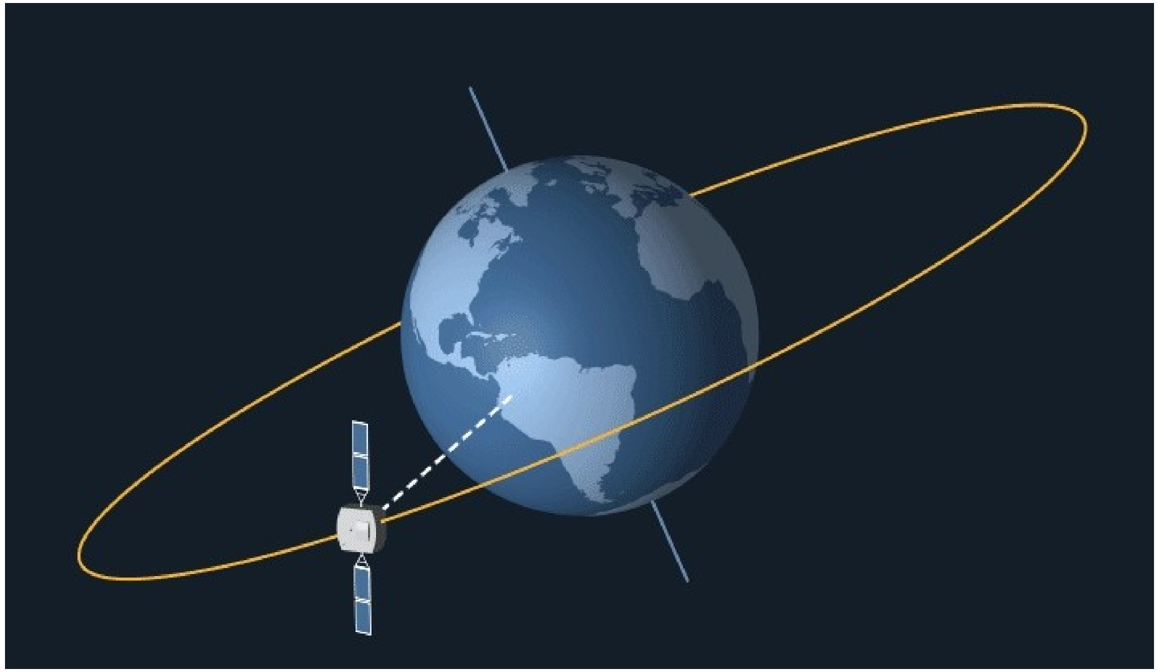


Source: eijournal.com



Source: earthdata.nasa.gov

What is Remote Sensing?

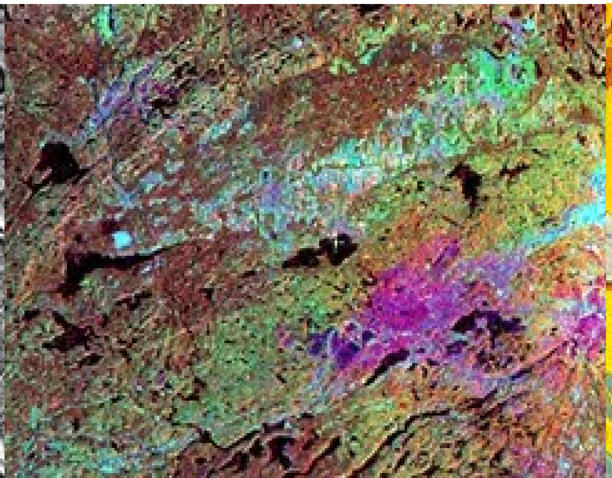
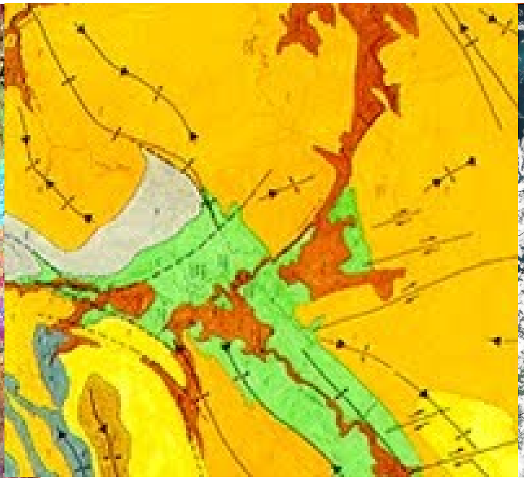
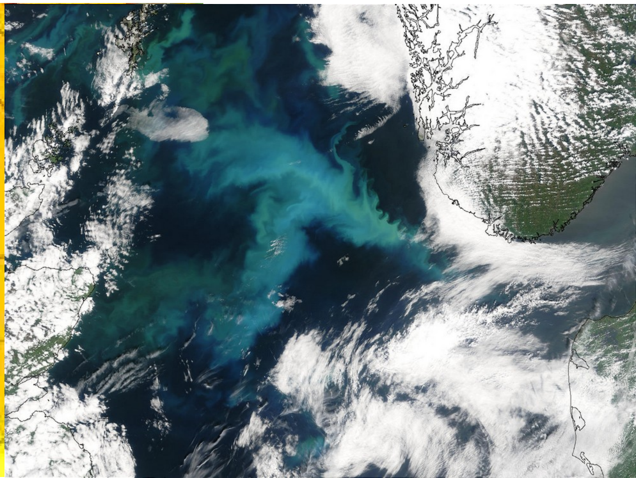
*Process of **acquisition of information** about an object or phenomenon **without making physical contact** with the studied object.*

*The term "remote sensing" was first coined in the 1950s by **Evelyn L. Pruitt**, a research geographer with the US Navy.*

Remote Sensing

- Instrument-based techniques for acquisition and measurement of **spatially organized data**
- Utilizing **electromagnetic radiation**, force fields, or acoustic energy sensed by cameras, radiometers and scanners, lasers, radio freq. receivers, radar systems, sonar, thermal devices...
- Used in geography, land surveying and most **Earth science disciplines** (hydrology, ecology, meteorology, oceanography, glaciology, geology)
- It also has military, intelligence, commercial and economic applications

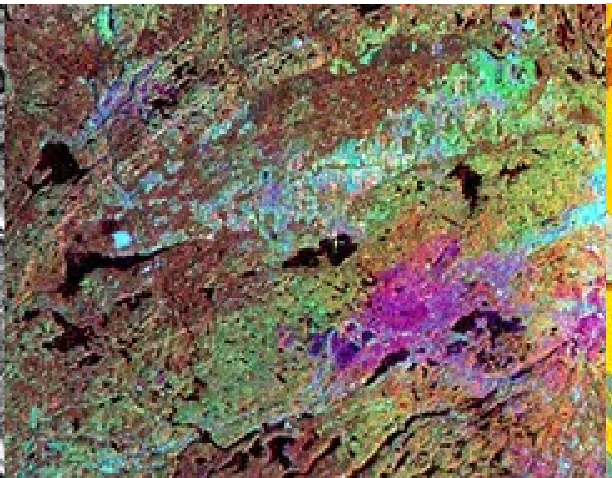
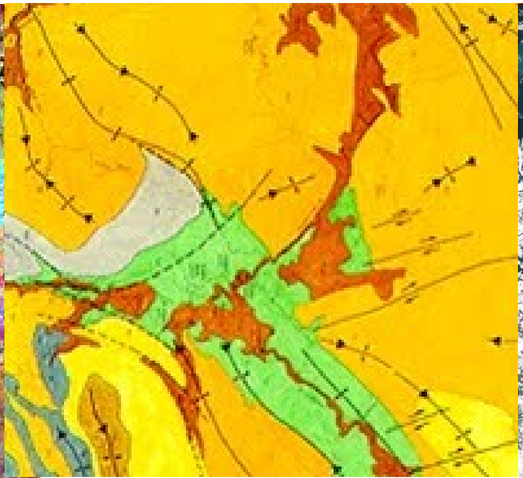
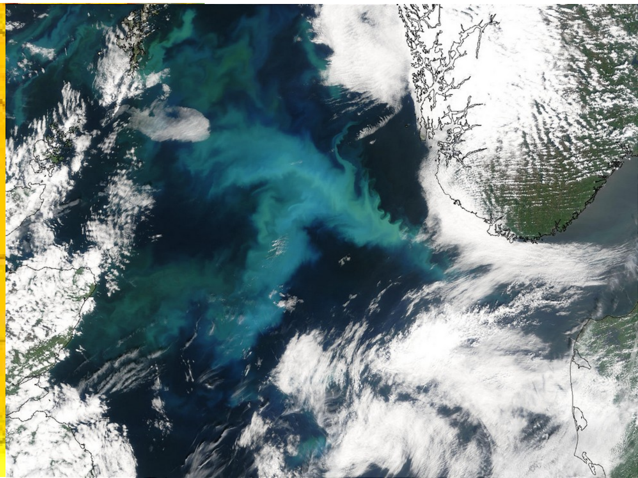
Source: Canada Centre for Remote Sensing

Typical applications

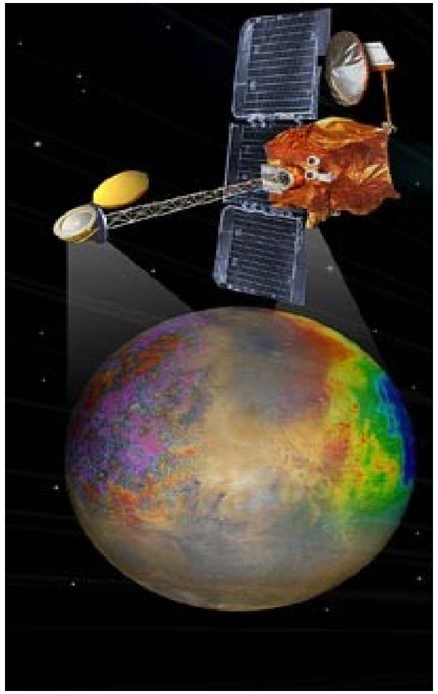
- **Conventional radar** - associated with aerial traffic control, early warning, and large-scale meteorological data
- **Laser and radar altimeters on satellites** - by measuring the height and wavelength of ocean waves, they measure wind speeds and direction, and surface **ocean currents**
- **Cameras on satellites and airplanes** - take images of large areas on the Earth's surface
- **Sonar systems on ships** - create images of the **ocean floor**
- **Geophysical remote sensing** - measuring particles, fields, and radiation associated with both the solid Earth, its surface, and the external environment, magnetic and gravitational properties, movements of the lithosphere

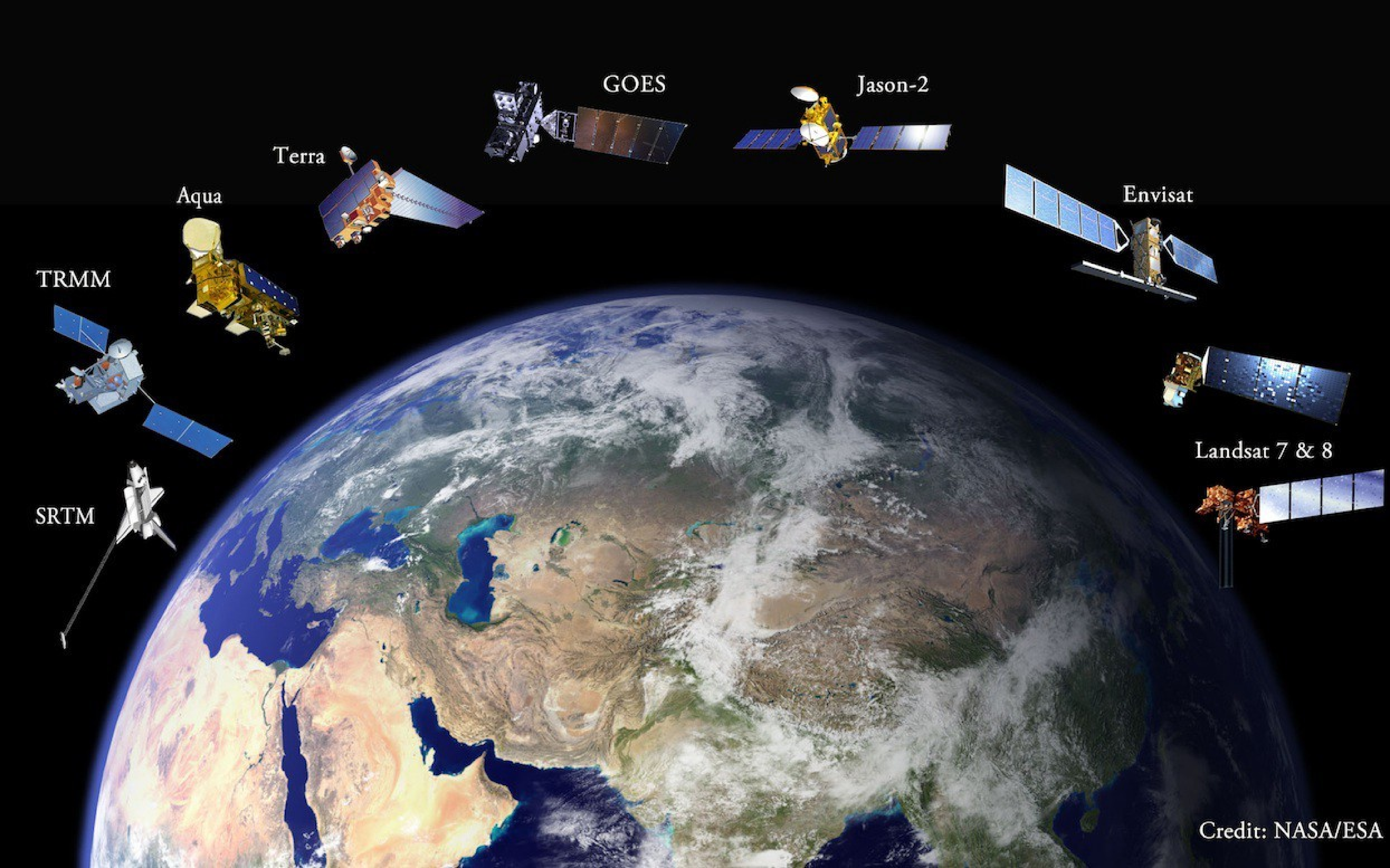
Source: Canada Centre for Remote Sensing

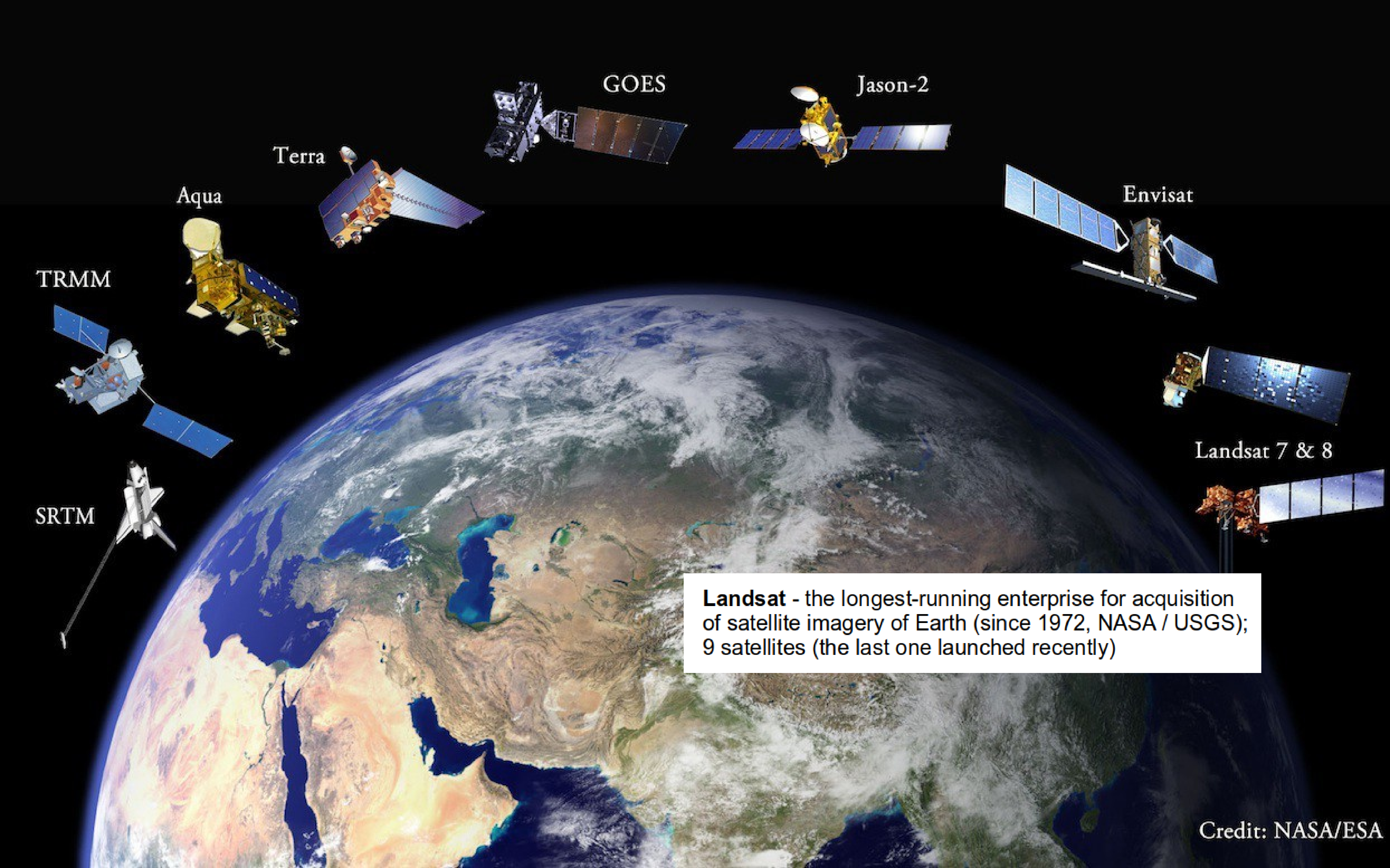





Remote Sensing – platforms

- Ground-based, airplane-base, satellite-based platforms
- The term "remote sensing" generally refers to the use of **satellite** or **airplane-based sensors** to detect and classify objects on Earth using **electromagnetic radiation** (reflected sunlight)



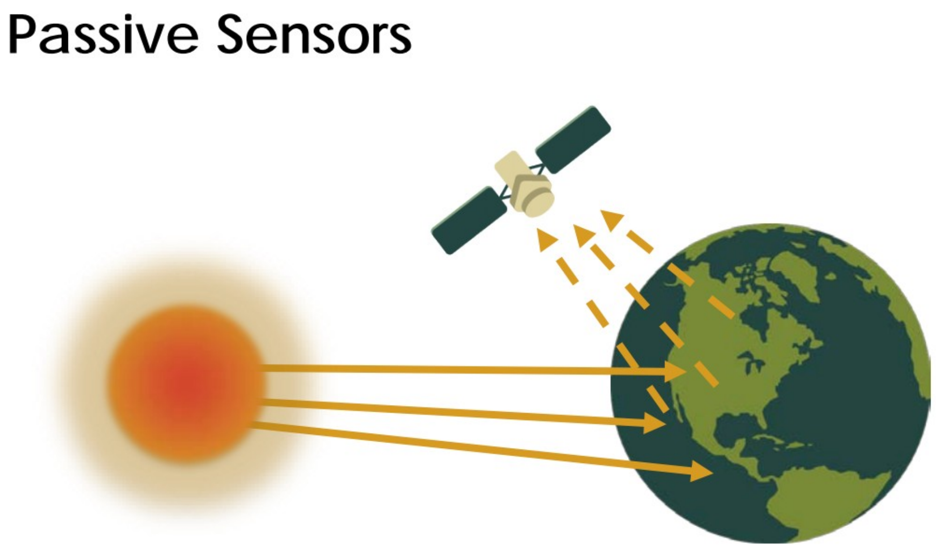

GOES
Jason-2
Terra
Aqua
Envisat
TRMM
SRTM
Landsat 7 & 8
Credit: NASA/ESA

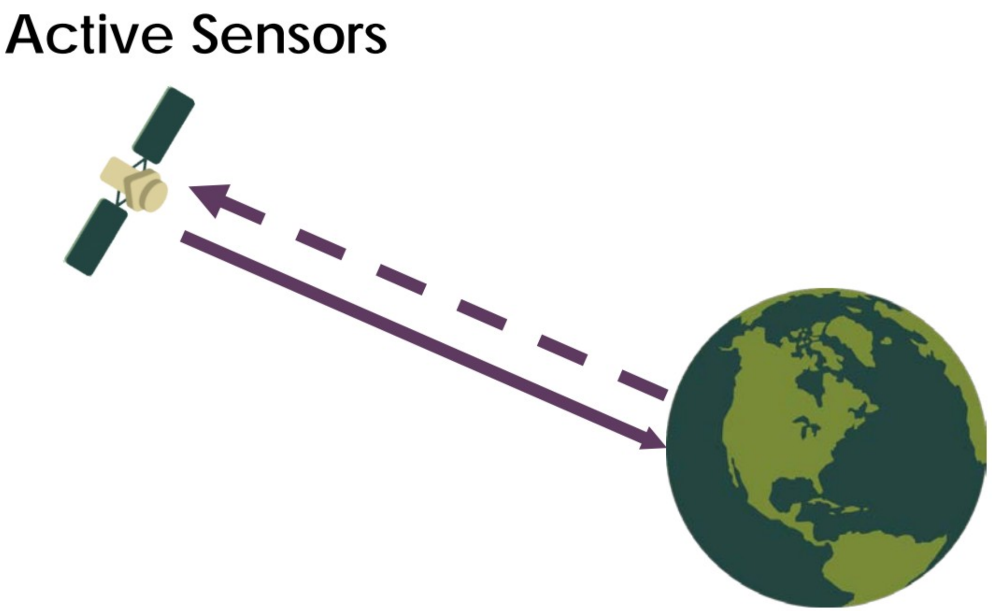


Landsat - the longest-running enterprise for acquisition of satellite imagery of Earth (since 1972, NASA / USGS); 9 satellites (the last one launched recently)

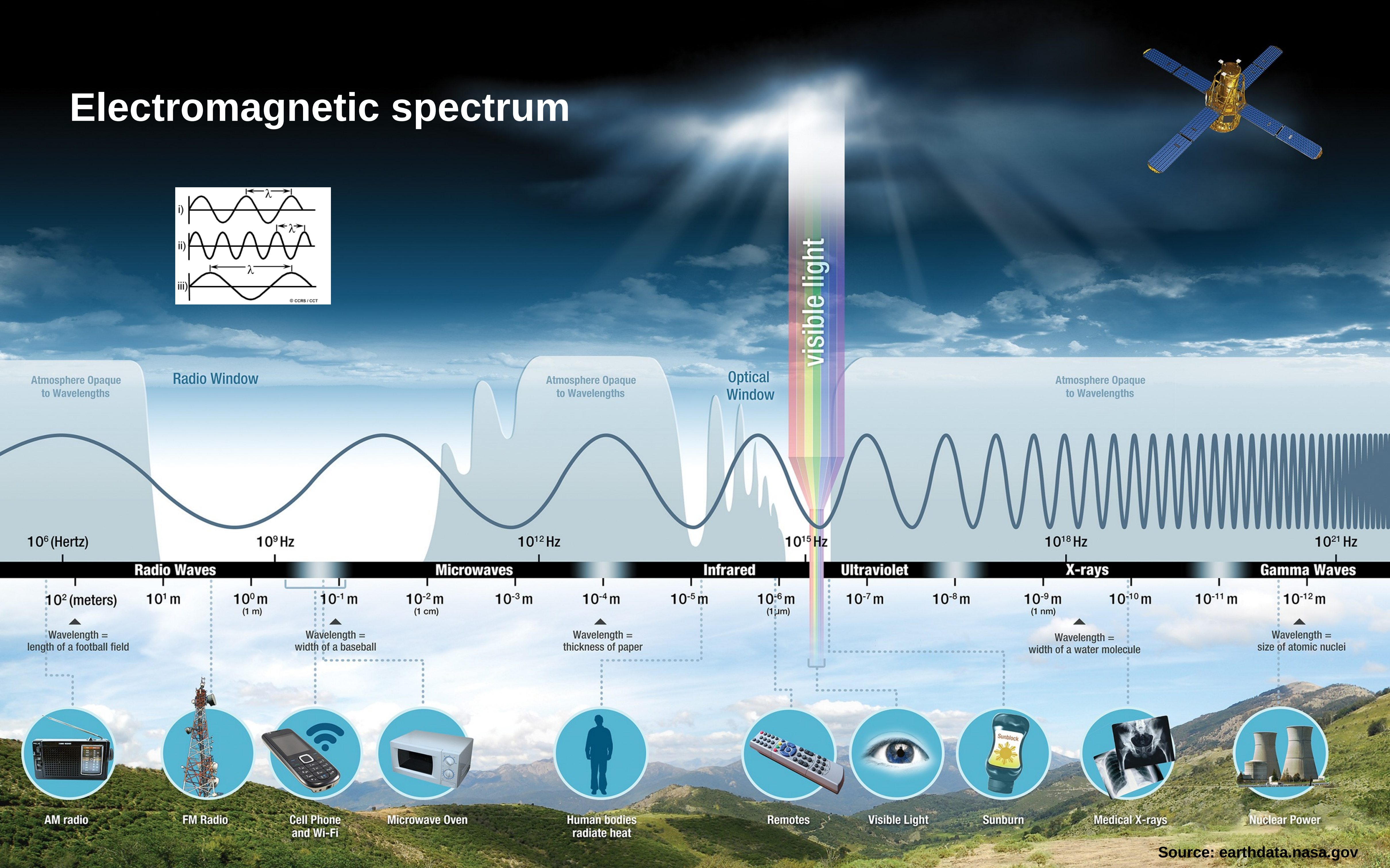
Passive vs. Active Sensing

- **Passive RS** – detect natural radiation emitted/reflected from an object within its field of view (e.g. reflected sunlight), **only receives radiation** from a target
- **Active RS** – create their own electromagnetic energy, **emit radiation towards the object**, then detect and measure the reflected/back-scattered radiation from the target, e.g**. radar**, uses radio waves to determine the distance or velocity of objects



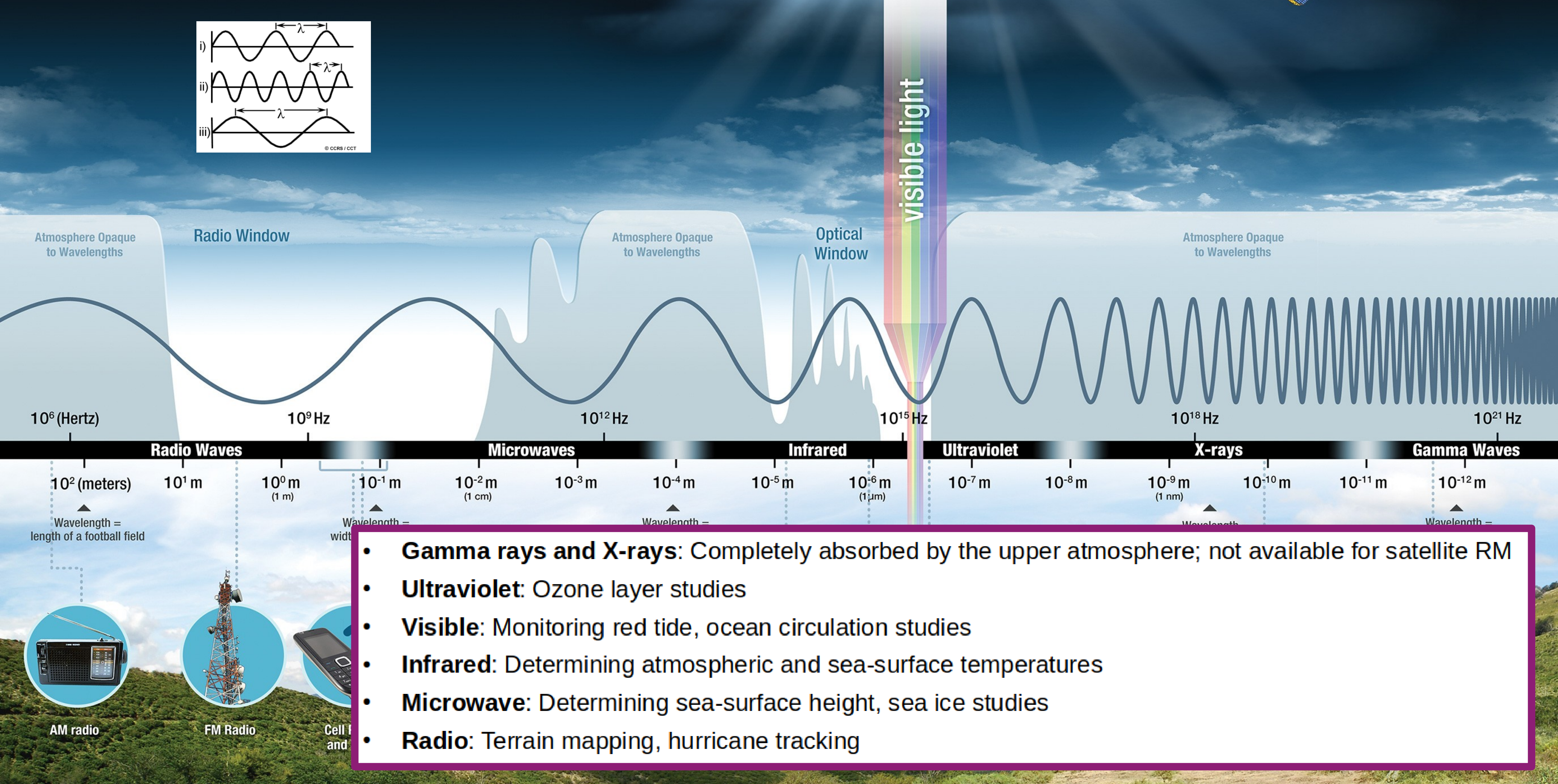


Source: NASA Applied Remote Sensing Training Program



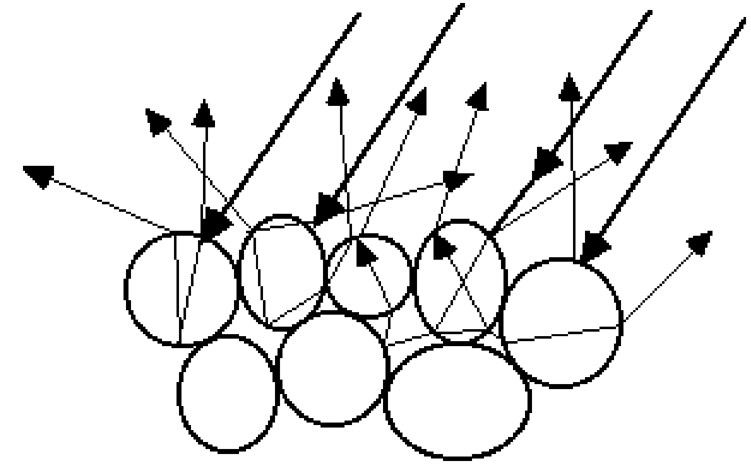
Electromagnetic spectrum
i)
ii)
iii)
λ
© CCRS / CCT
visible light
Atmosphere Opaque to Wavelengths
Radio Window
Atmosphere Opaque to Wavelengths
Optical Window
Atmosphere Opaque to Wavelengths
10^6 (Hertz)
10^9 Hz
10^12 Hz
10^15 Hz
10^18 Hz
10^21 Hz
Radio Waves
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Waves
10^2 (meters)
10^1 m
10^0 m (1 m)
10^-1 m
10^-2 m (1 cm)
10^-3 m
10^-4 m
10^-5 m
10^-6 m (1 µm)
10^-7 m
10^-8 m
10^-9 m (1 nm)
10^-10 m
10^-11 m
10^-12 m
Wavelength = length of a football field
Wavelength = width of a baseball
Wavelength = thickness of paper
Wavelength = width of a water molecule
Wavelength = size of atomic nuclei
AM radio
FM Radio
Cell Phone and Wi-Fi
Microwave Oven
Human bodies radiate heat
Remotes
Visible Light
Sunburn
Medical X-rays
Nuclear Power
Sunblock
Source: earthdata.nasa.gov

Electromagnetic spectrum

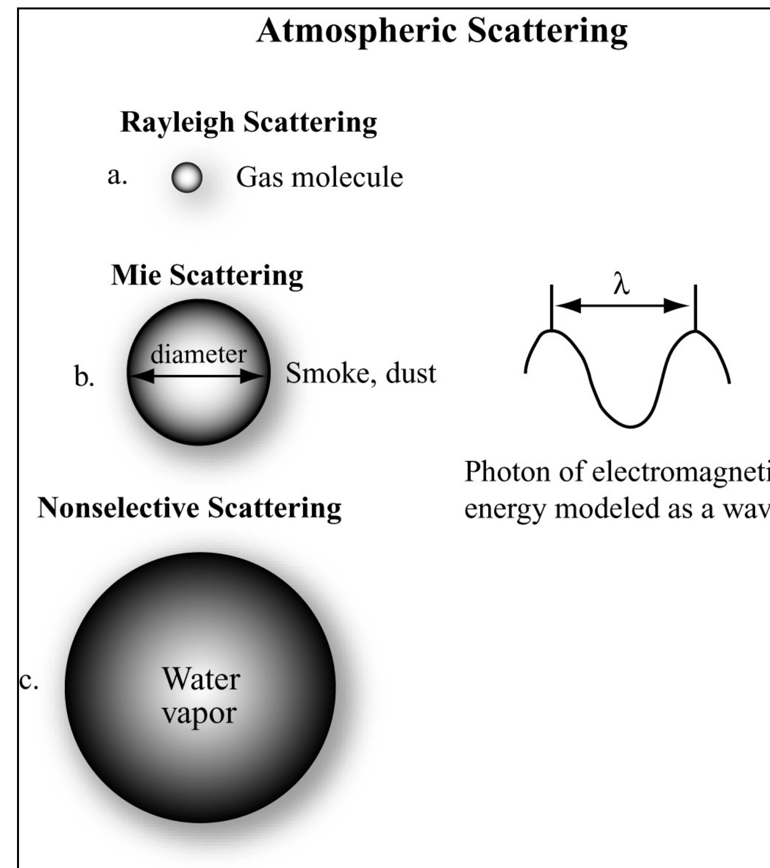


- **Gamma rays and X-rays**: Completely absorbed by the upper atmosphere; not available for satellite RM
- **Ultraviolet**: Ozone layer studies
- **Visible**: Monitoring red tide, ocean circulation studies
- **Infrared**: Determining atmospheric and sea-surface temperatures
- **Microwave**: Determining sea-surface height, sea ice studies
- **Radio**: Terrain mapping, hurricane tracking

Interaction with the atmosphere

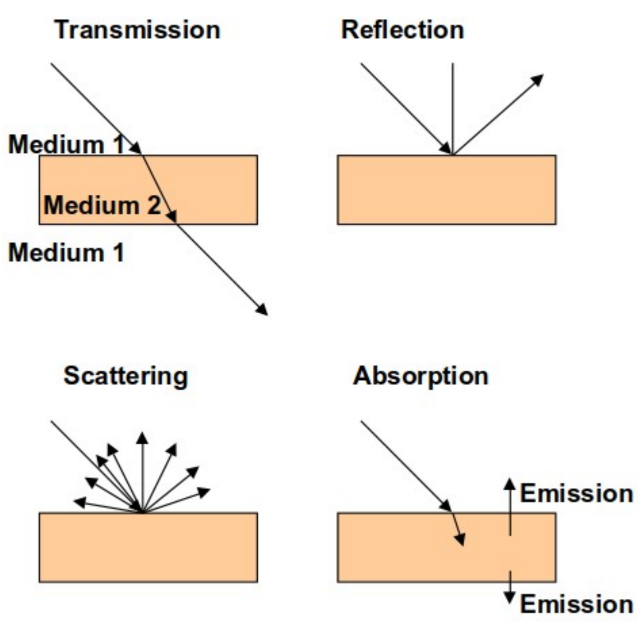


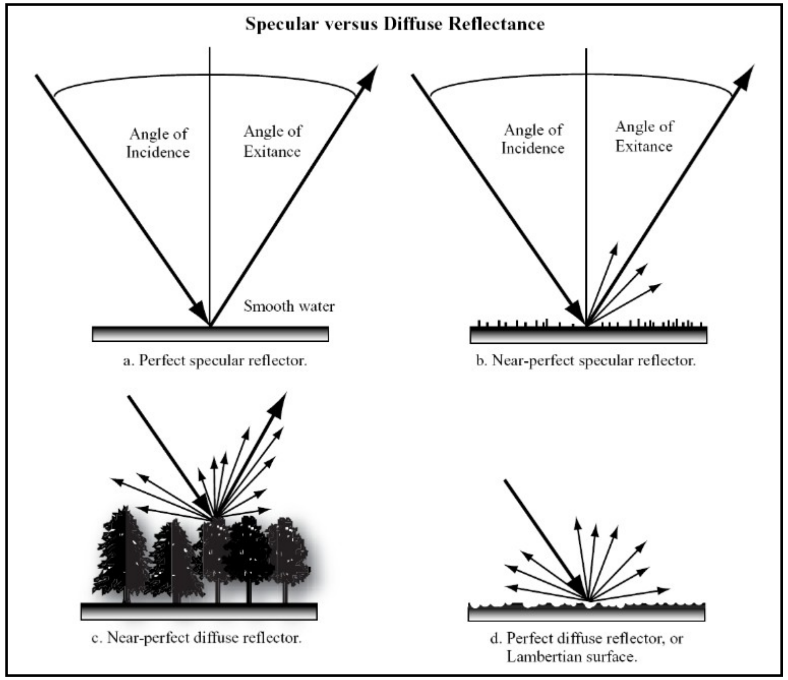
- Particles and gases in the atmosphere affect the incoming radiation → **scattering** and **absorption**
- **Scattering** - particles or large gas molecules interact with and cause the EM radiation to be redirected from its original path (depending on λ, the abundance of particles, and the distance the radiation travels)
- **Absorption** - causes molecules in the atmosphere to absorb energy at various wavelengths (mostly ozone, CO_2, and water vapor)



Interaction with the Earth's surface

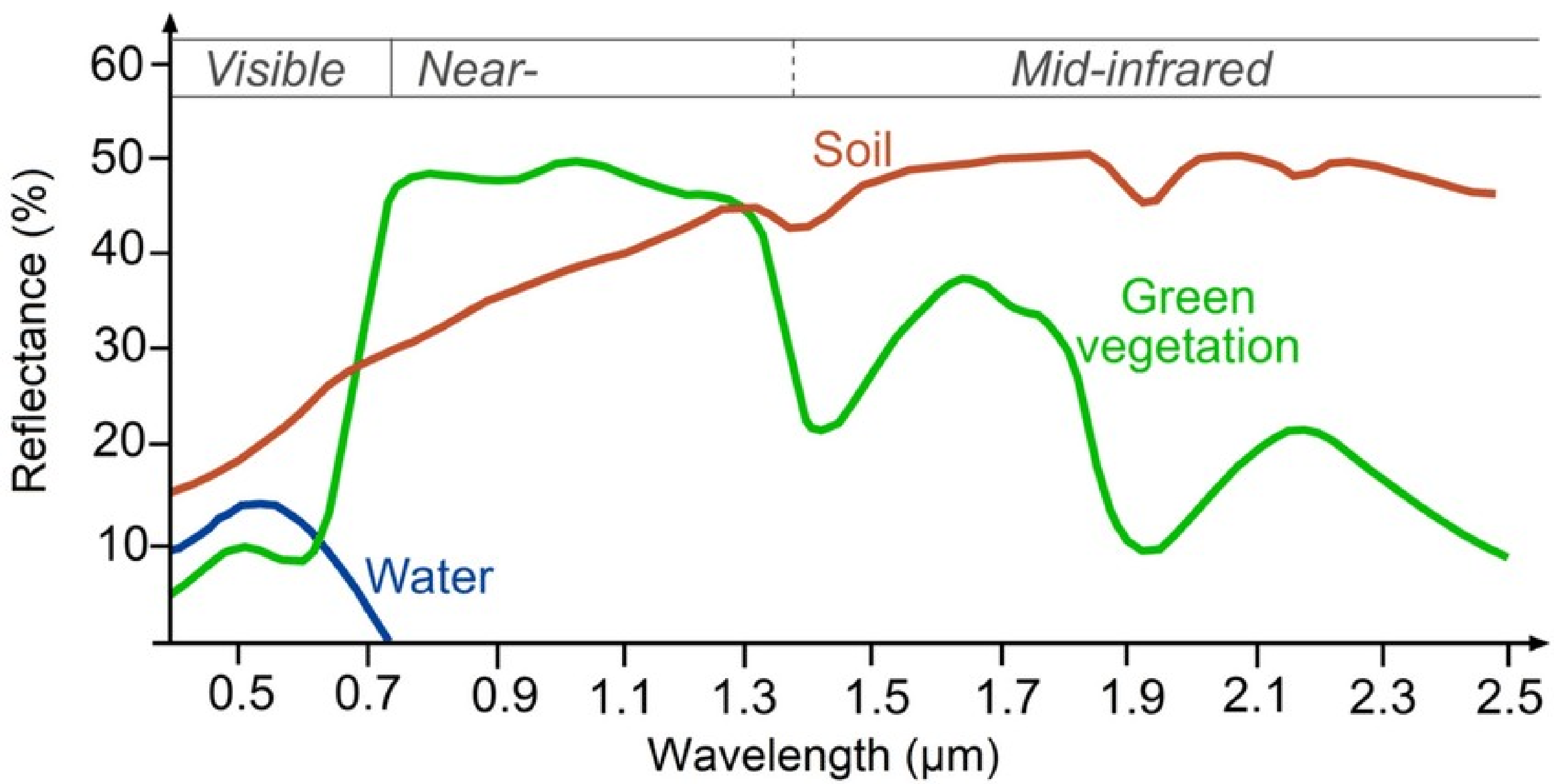
- Radiation interacts with the surface → **absorption**, **transmission, reflection** and **scattering**
- 2 types of reflection represent the 2 extreme ends of the way in which energy is reflected from a target → **specular reflection** (mirror-like) and **diffuse reflection** (rough surface)
- When λ is much smaller than the surface variations → **diffuse reflection** will dominate





Spectral signatures

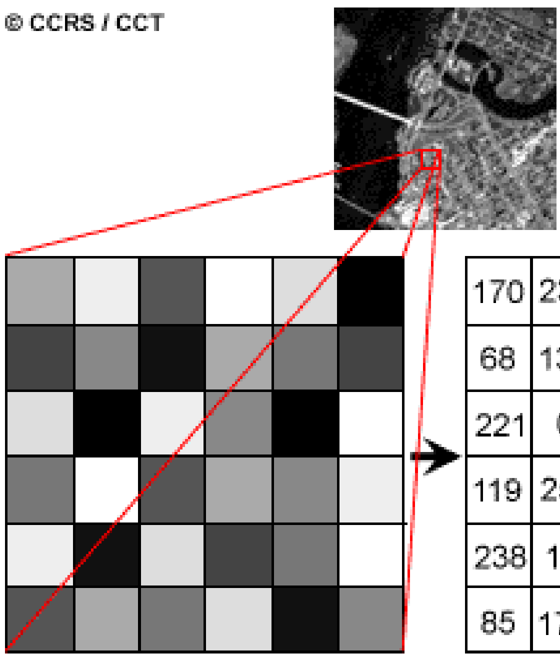
- By measuring the energy that is reflected (or emitted) by targets over a variety of different λ, we can build up a **spectral response (signature)** for that object/phenomenon
- By comparing the response patterns of different features we can distinguish between them



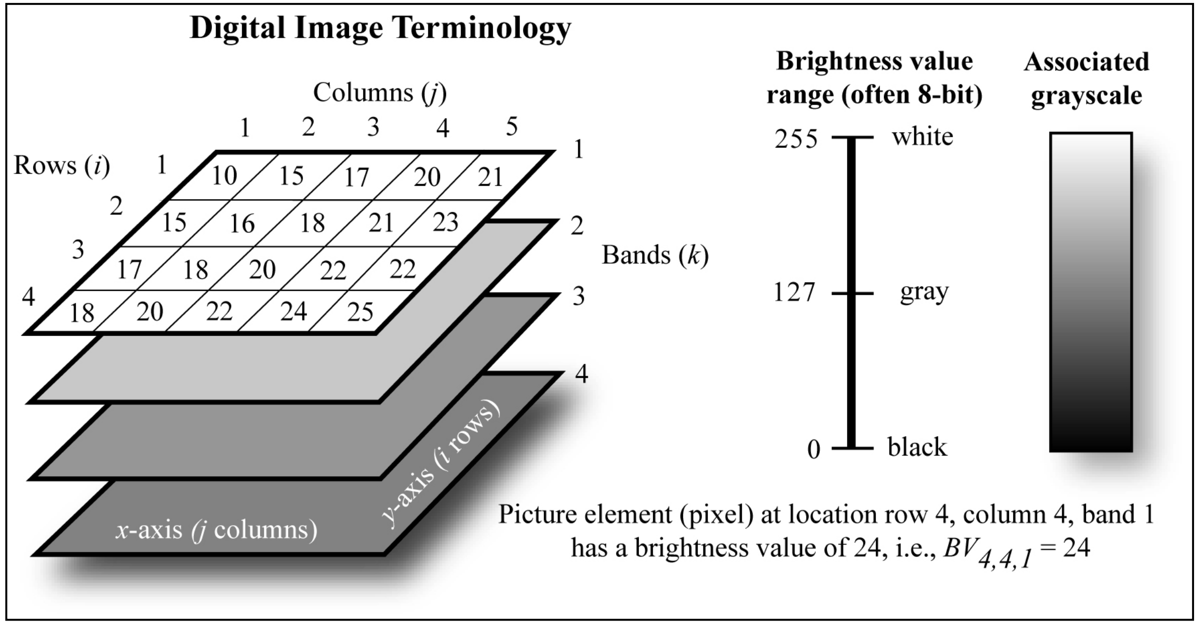
Source: http://www.seos-project.eu/

Characteristics of RS images

- Most RS images are **digital images** composed of a matrix of picture elements or **pixels**
- **Pixels** - small equal-sized and shaped areas, the brightness of each area is represented by a **digital number**
- The information from a narrow wavelength range is gathered and stored in a channel, or a **band**

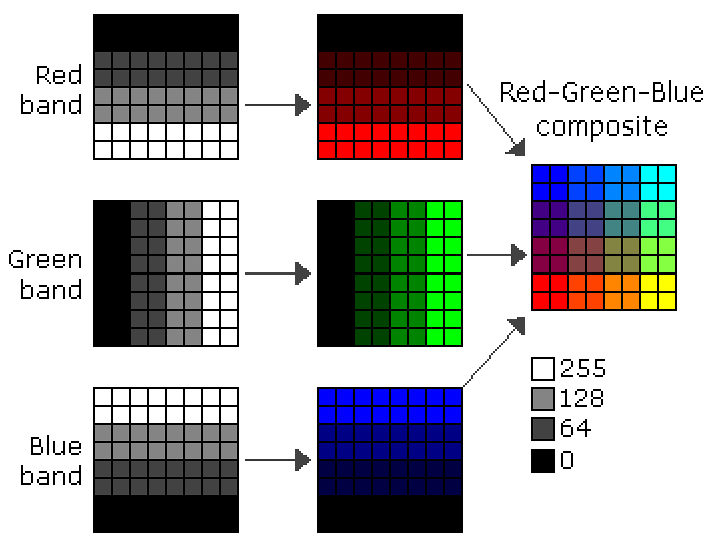


170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136



Characteristics of RS images

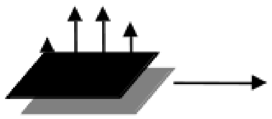
- Spectral satellite sensors perceive the Earth as **grey**, each wavelength range is detected separately via bands (only the differences in light intensity). Blue light is stored in the blue band, green light in the green band and red light in the red band.
- We can combine and display **bands** digitally using the three **primary colors**
- Single band → **black and white** image, multiple bands (different primary colors) → **color image**



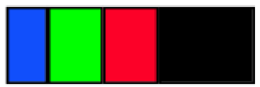
Source: ArcGIS

Source: Canada Centre for Remote Sensing

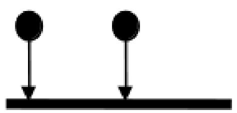
Quality of RS data – remote sensor resolution



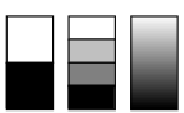
- **Spatial** - the size of the instantaneous field-of-view (IFOV), 10 x 10m



- **Spectral** - the number and size of spectral regions the sensor records data in, e.g. blue, green, red, near-infrared, thermal infrared, microwave (radar)...



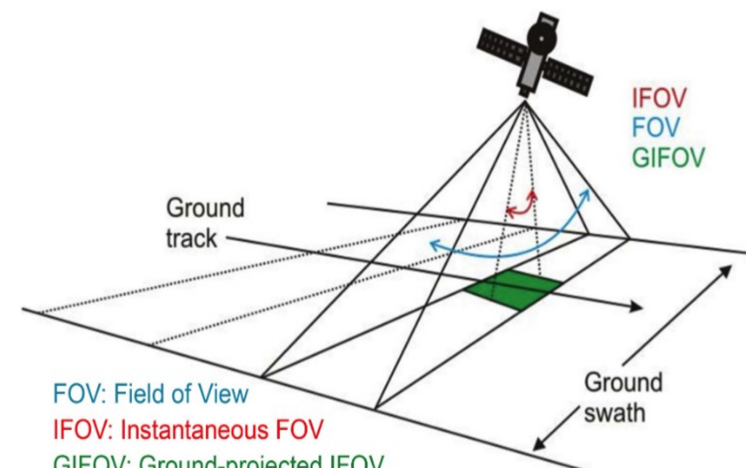
- **Temporal** - how often the sensor acquires data, e.g. every 30 days



- **Radiometric** - the sensitivity of detectors to small differences in electromagnetic energy

Too high resolution  ***data could be noisy (SNR)!***

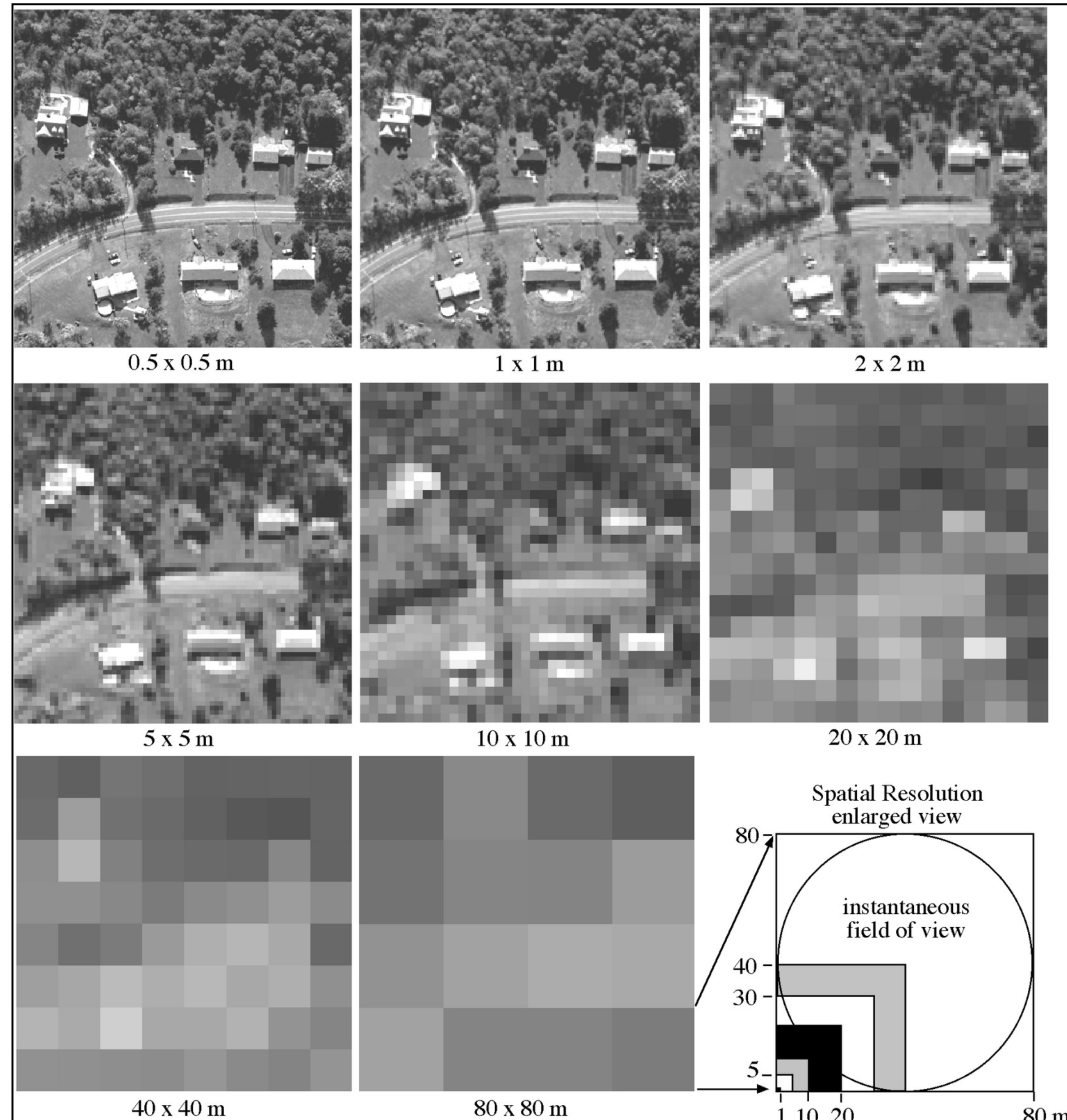
As a satellite revolves around the Earth, the sensor "sees" a certain portion of the surface ***(FOV)****, the area imaged on the surface=* ***swath***



Source: geo.uzh.ch

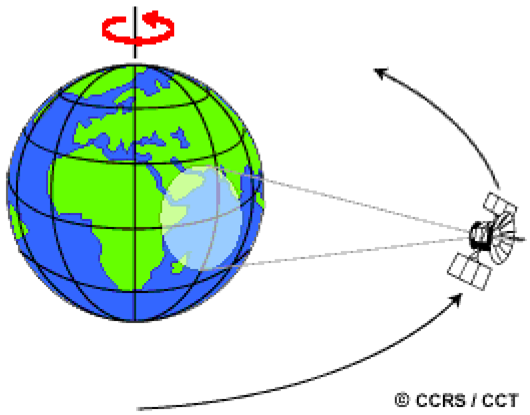
Spatial resolution

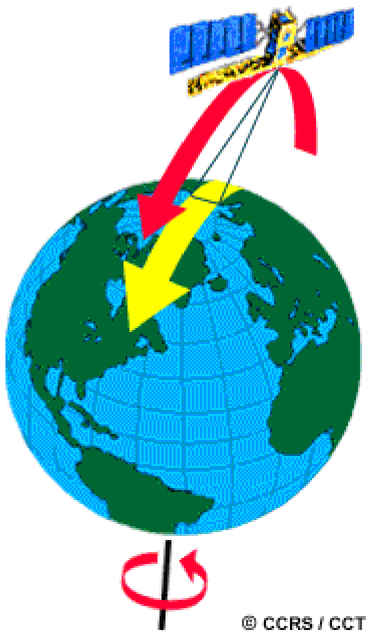
The size of a pixel that is recorded in a **raster image**, typically pixels may correspond to square areas ranging in side length from 1 to 1000 m

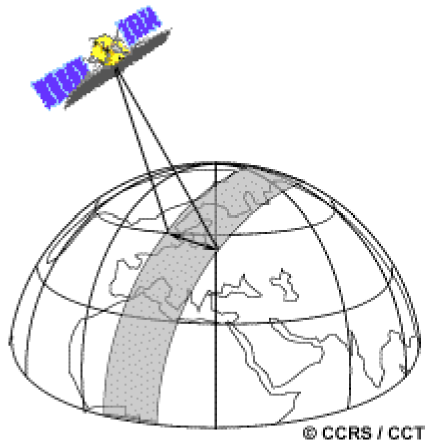


Temporal resolution

- Depends on the length of time it takes for a satellite to complete one entire orbit cycle
  - **Geostationary orbits** - satellites at very high altitudes (~36 000 km), which view the same portion of the Earth's surface at all times; they revolve at speeds which match the rotation of the Earth, and collect information continuously over specific areas, e.g. weather and communications satellites
  - **Near-polar orbits** - satellites follow north-south orbits, which, in conjunction with the Earth's rotation (west-east), allows them to cover most of the Earth's surface over a period of time
  - **Sun-synchronous orbits** - satellites cover each area of the world at a constant local time of day (local sun time)

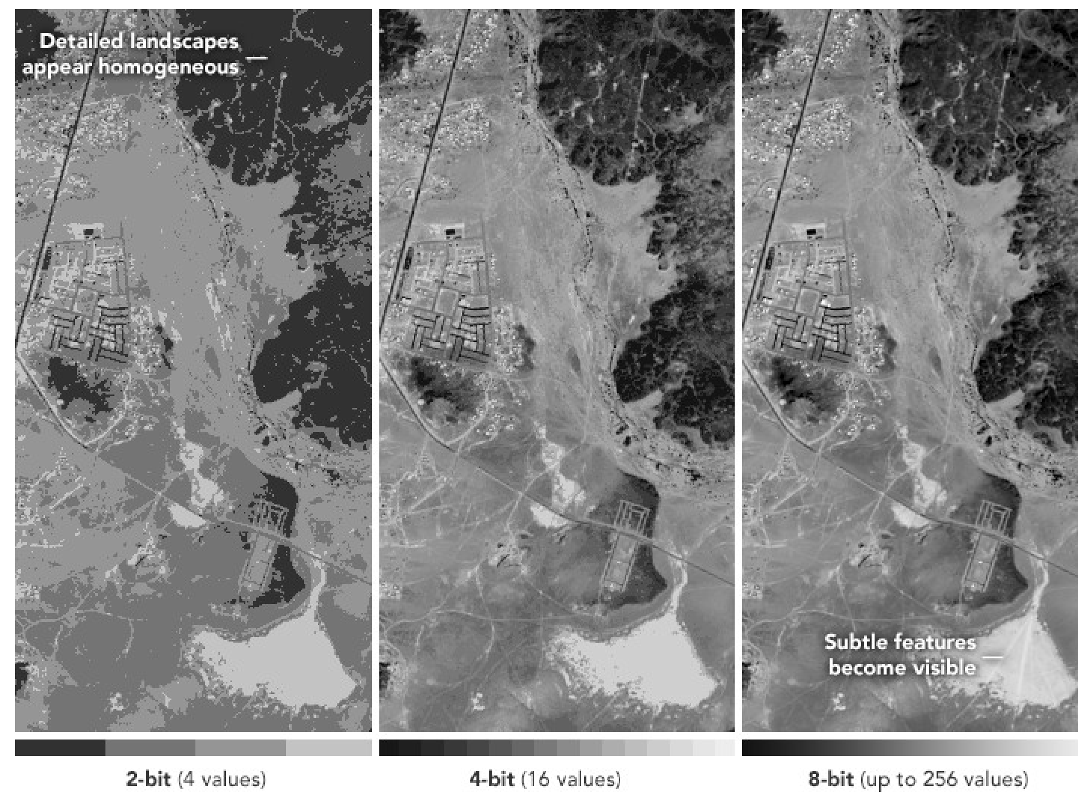






Radiometric resolution

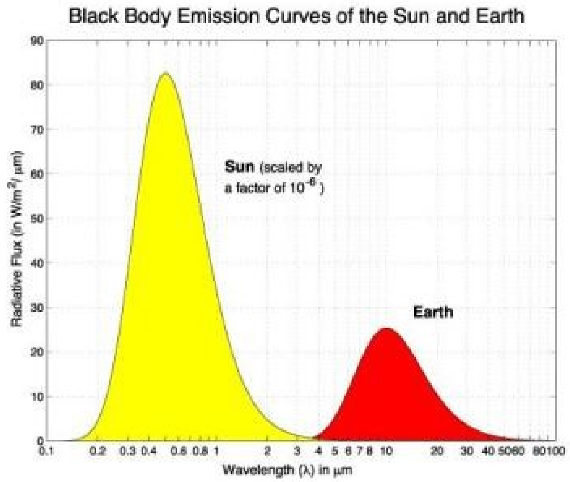
- The amount of information in each pixel, i.e. the number of bits representing the recorded energy
- Each bit records an exponent of power 2, e.g. the 8-bit sensor has **256 potential digital values** (0-255) to store information
- The higher the radiometric resolution, the more values are available to store information, providing **better discrimination** between even the slightest differences in energy



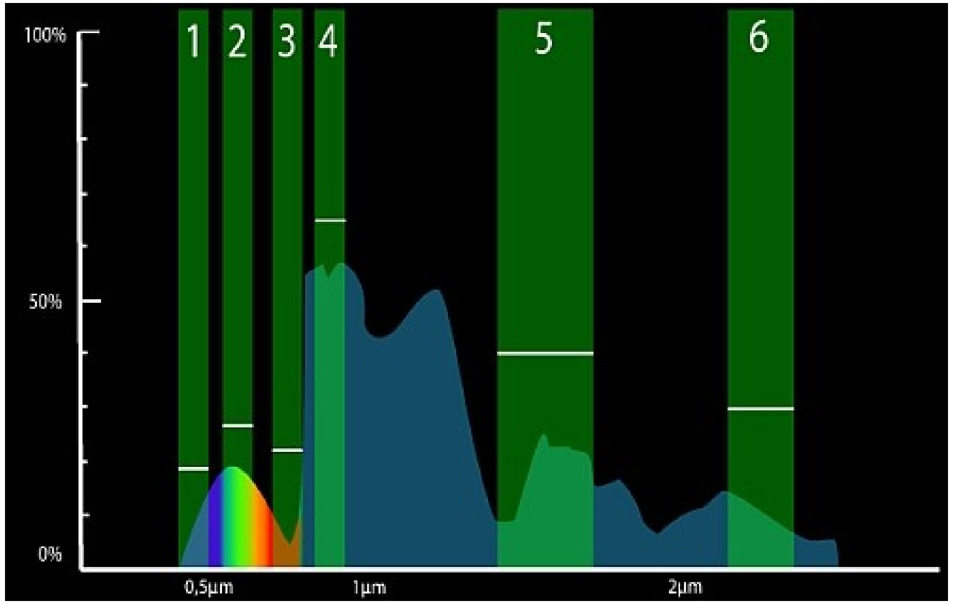
Source: NASA Earth Observatory images by Joshua Stevens

Spectral resolution

- The higher the number of bands, the higher the spectral resolution
- Conventional sensors (e.g. on satellite **Landsat**) have a spectral resolution of at least 7 bands → 3 for the visible light, 3 for IR and 1 thermal radiation of the Earth's surface
- **Multispectral** sensors - between 3-10 bands
- **Hyperspectral** sensors - hundreds to thousands of bands



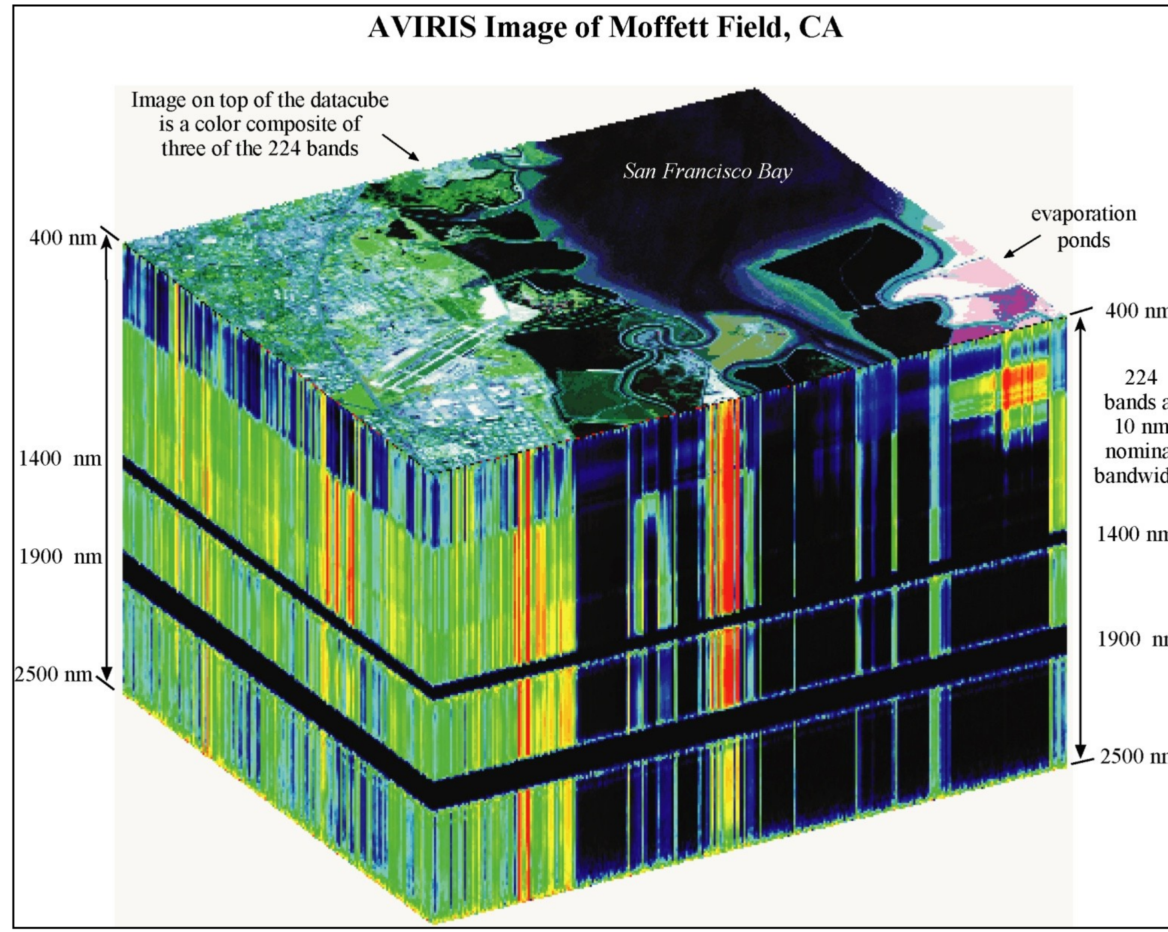
Landsat 4-5	Wavelenth (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.76-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	120 (30)
Band 7	2.08-2.35	30



Source: fis.uni-bonn.de

Hyperspectral imaging

- Produces an image where each pixel has **full spectral information** with imaging narrow spectral bands over a contiguous spectral range
- Hyperspectral data sets are generally composed of about **100 to 200 spectral bands** of relatively narrow bandwidths (5-10 nm)
- Used in various applications including mineralogy, biology, defence, and environmental measurements

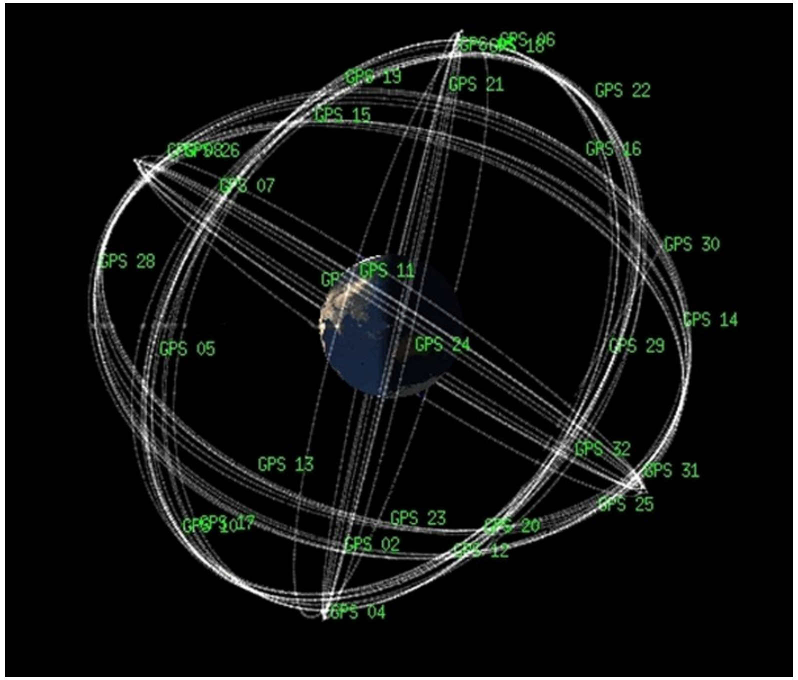


Data Processing and Interpretation

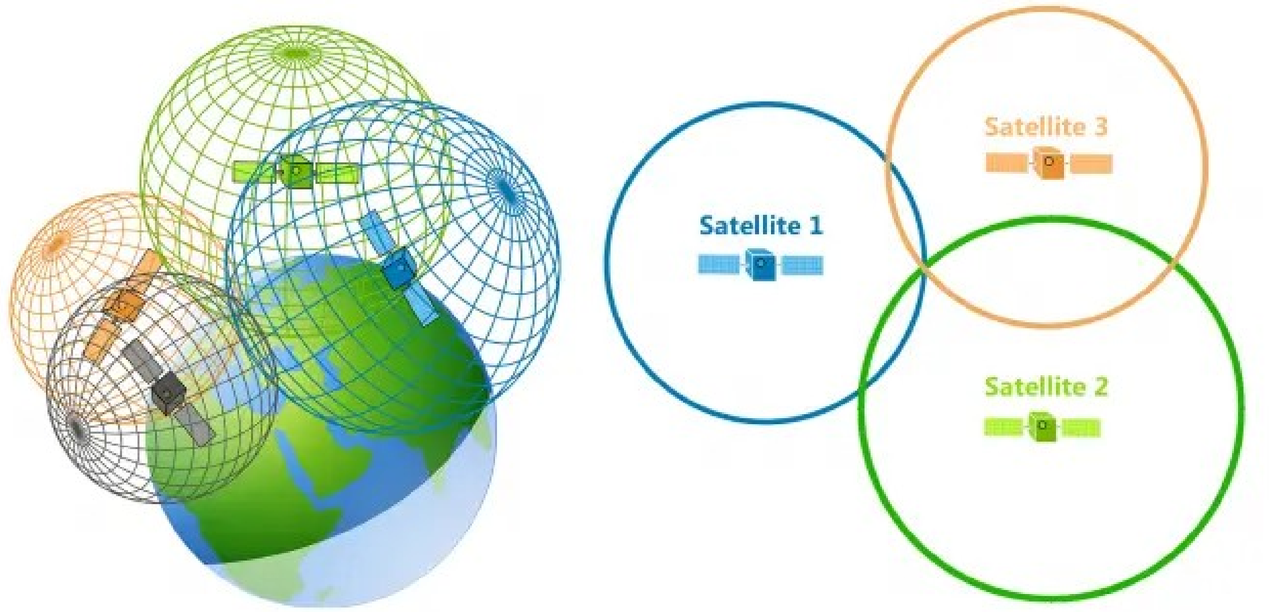
- **Pre-processing operations** - to correct for sensor- and platform-specific radiometric and geometric distortions of data
  - **Geometric distortions** - due to representing the 3D surface of the Earth as a 2D image
  - **Radiometric correction** - reduces the effects of the various reflectivity of an environment
  - **Topographic correction** - the illumination of pixels can vary considerably as a result of terrain
  - **Atmospheric correction** - removes the scattering and absorption effects from the atmosphere
- **Processing** - happens in series of levels, numerous data tools are available to subset, transform, visualize, and export the data to various formats
- **Image interpretation** – identification of patterns, shapes and textures; colors to distinguish features

Global Positioning System - GPS

- Radio-navigation system of **24+ satellites** along with a network of ground tracking stations
- The satellites carry atomic clocks, operated by the **US Space Force**
- Follow a near-circular orbit, altitude = 20,200 km, an average speed = 3.88 km/s
- By measuring the time required for signals to travel from the satellites to the receivers, the positions of the receivers can be precisely determined, **min. 4 satellites are necessary**



Source: Astronoo

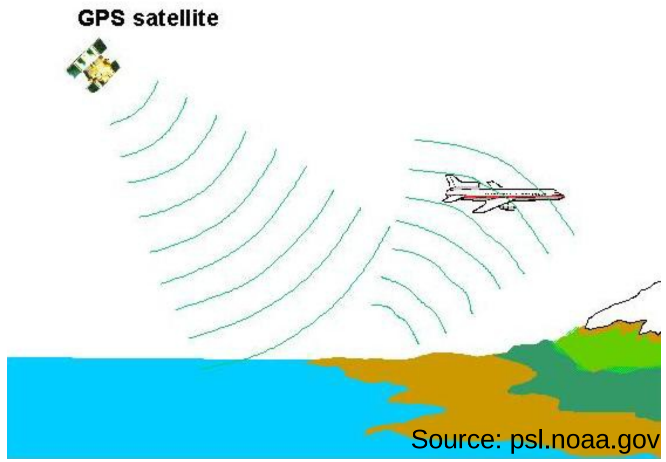


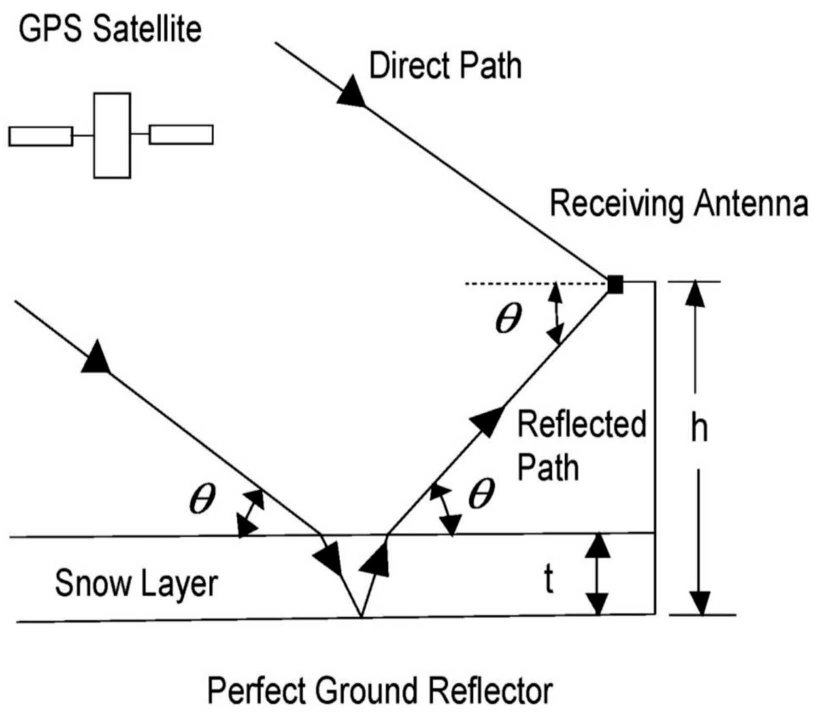
Trilateration

Source: GISGeography

Remote Sensing using GPS

- The GPS signal can arrive to the receiver from nearby reflecting surfaces - **multipath**
- Multipath signals interfere with the signals received from the satellites and **reduce positioning accuracy**
- GPS multipath signals reflected off the ocean or land can be used as a source of valuable information about **sea state, soil moisture, snowpack...**
- Surface reflections of a radio wavelength of ~ 20 cm emitted by GPS transmitters are very **sensitive to these environmental parameters**
- The weak reflected GPS signals can be detected by airborne instruments and used to map ocean surface topography, measure ocean waves, sea ice...





Source: Jacobson 2010

Remote Sensing is essential in many areas

- Collecting **Earth's pictures** from space
- Modern mapping technologies (e.g. **Google maps**)
- Mapping large **forest fires**, tracking **dust storms**, monitoring erupting **volcanoes**
- Tracking clouds for **weather forecast**
- Predicting potential **landslides** (Norway)
- **Monitoring climate changes...**