

1st INIOAS Training Course on Ocean Remote Sensing, 2023



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<https://www.inio.ac.ir/ORSA>

Fundamentals of Remote Sensing

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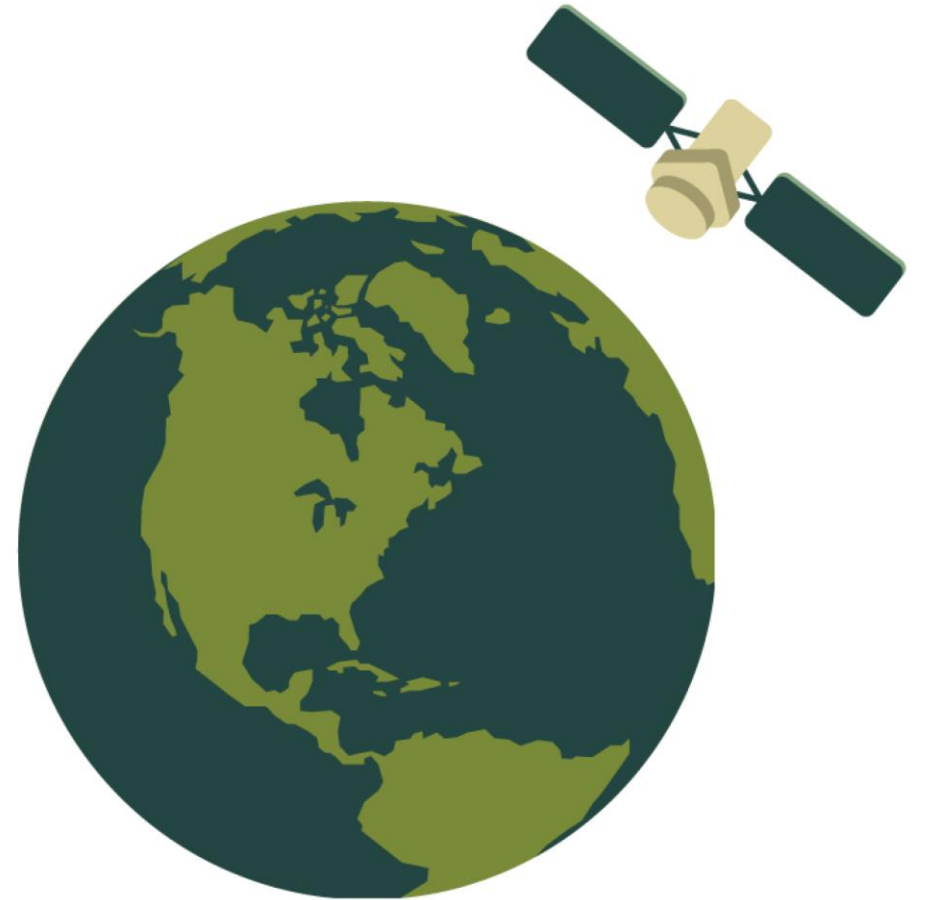
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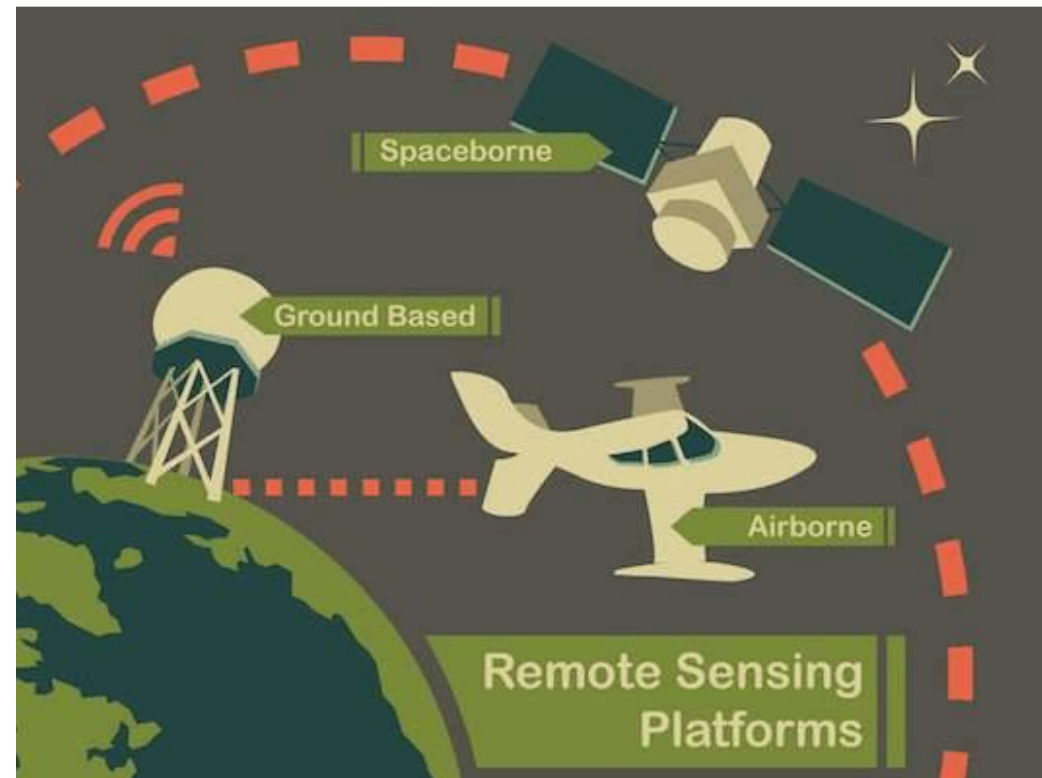
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Outlines

- Fundamentals of Remote Sensing
- Satellites and Sensors
 - Types
 - Resolution
- Satellite Data Processing Levels
- Advantages and Disadvantages of Remote Sensing
- Remote Sensing Terminology



What is Remote Sensing?



Remote sensing is obtaining information about an object from a distance.

Photography is a very common form of remote sensing.

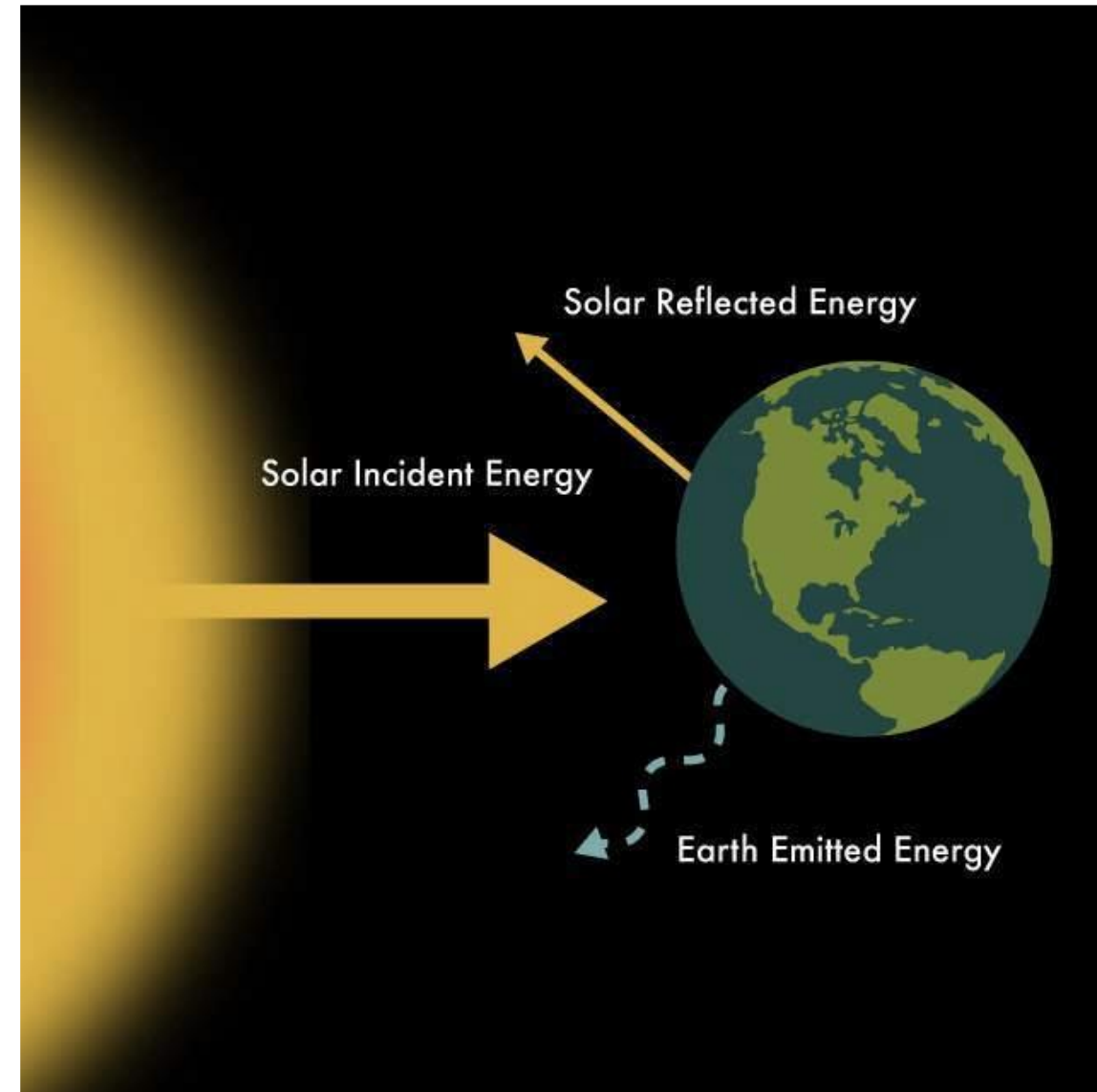
There are different ways to collect data, and different sensors are used depending on the application.

Some methods collect ground-based data, others airborne or spaceborne.

- What information do you need?
- How much detail?
- How frequently do you need the data?

What is Remote Sensing?

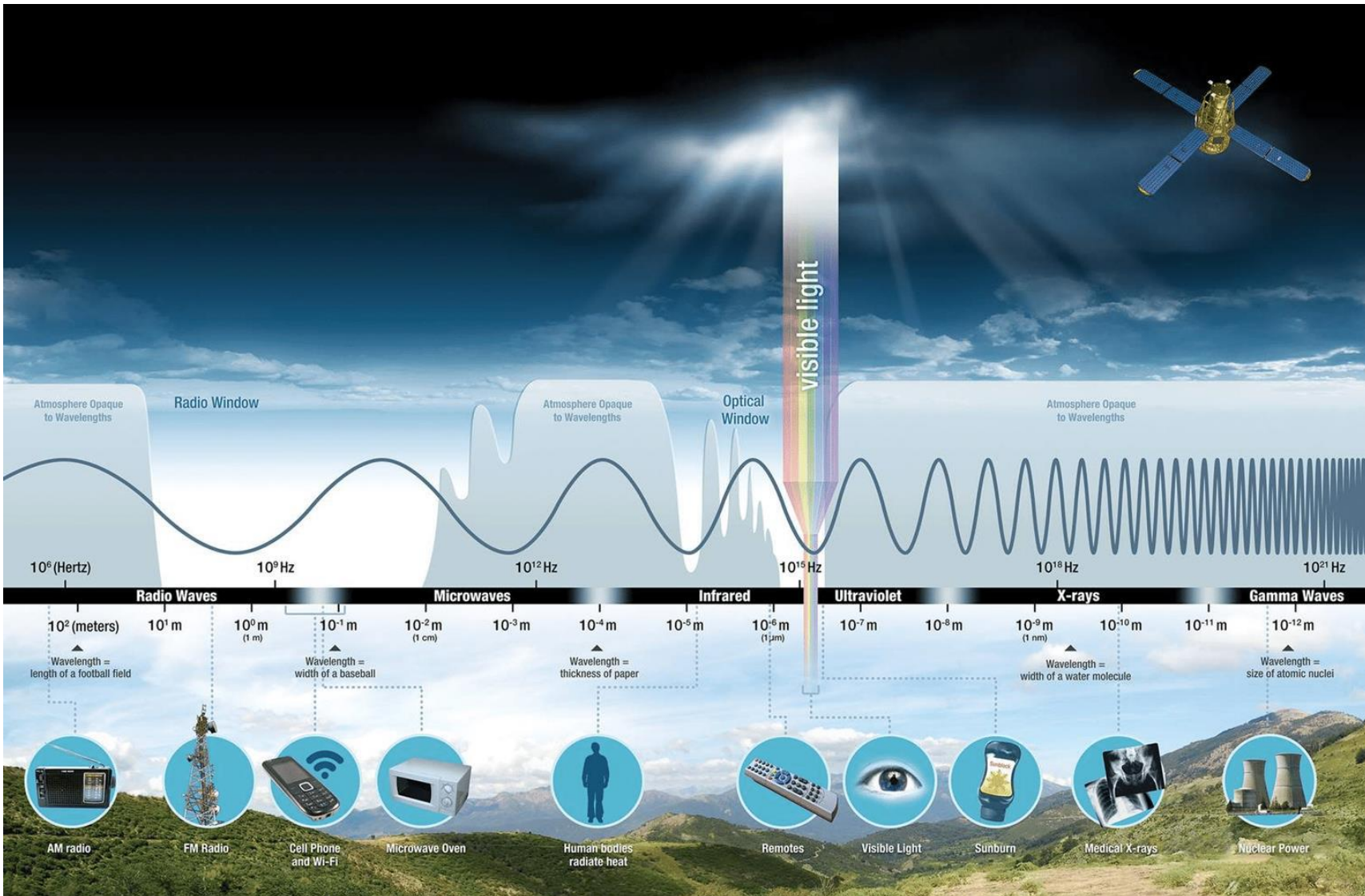
- The energy Earth receives from the sun is called **electromagnetic radiation**.
- Radiation is reflected, absorbed, and emitted by the Earth's atmosphere or surface
- Satellites carry instruments or sensors that measure electromagnetic radiation reflected or emitted from both terrestrial and atmospheric sources
- With calibrated instruments, scientists can measure the height, temperature, moisture content (and more) for nearly every feature of the Earth's atmosphere, hydrosphere, lithosphere, and biosphere



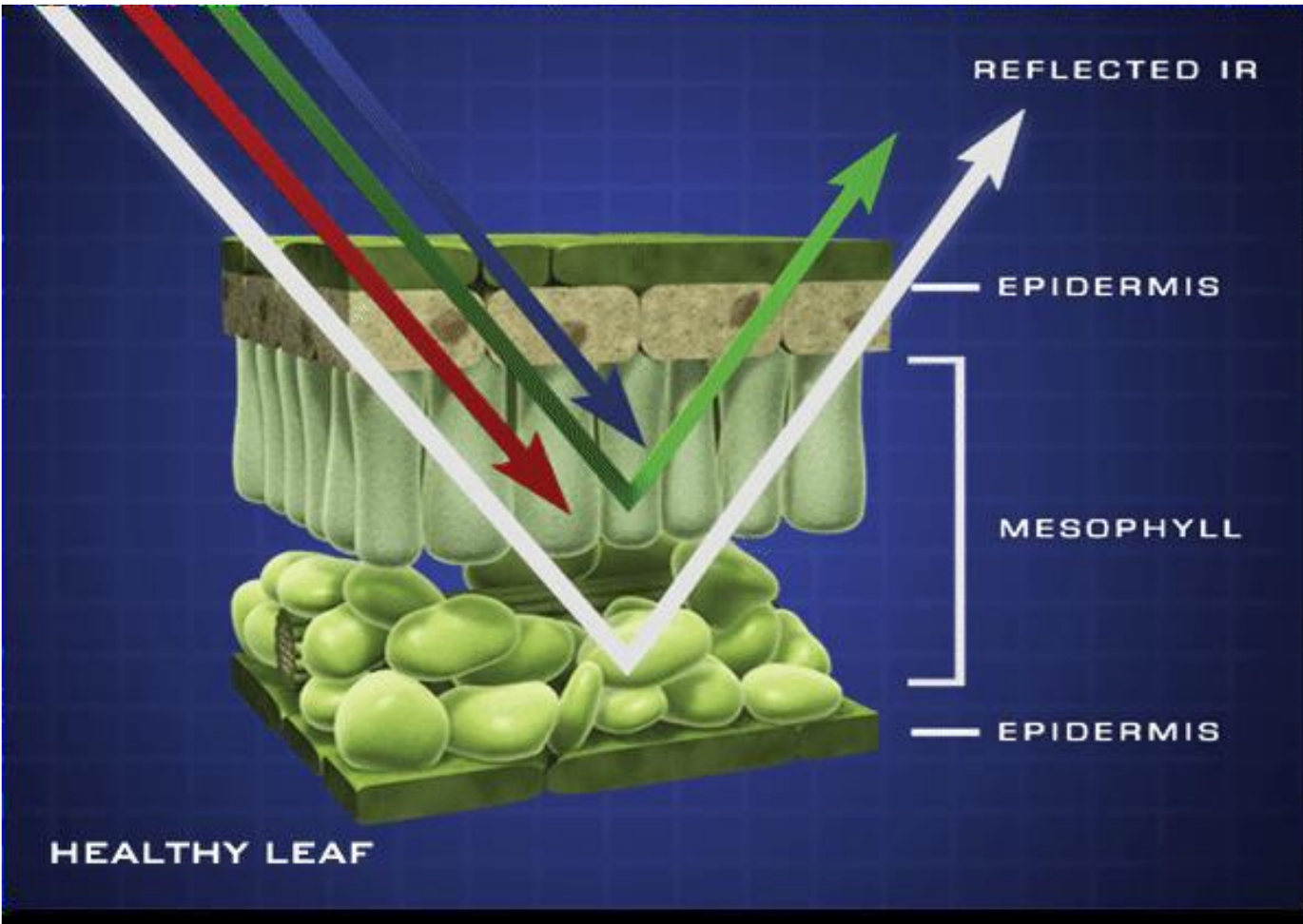
What is Remote Sensing?

The electromagnetic spectrum is simply the full range of **wave frequencies** that characterizes solar radiation.

Although we are talking about light, most of the electromagnetic spectrum cannot be detected by the human eye. Even satellite detectors only capture a small portion of the entire electromagnetic spectrum.



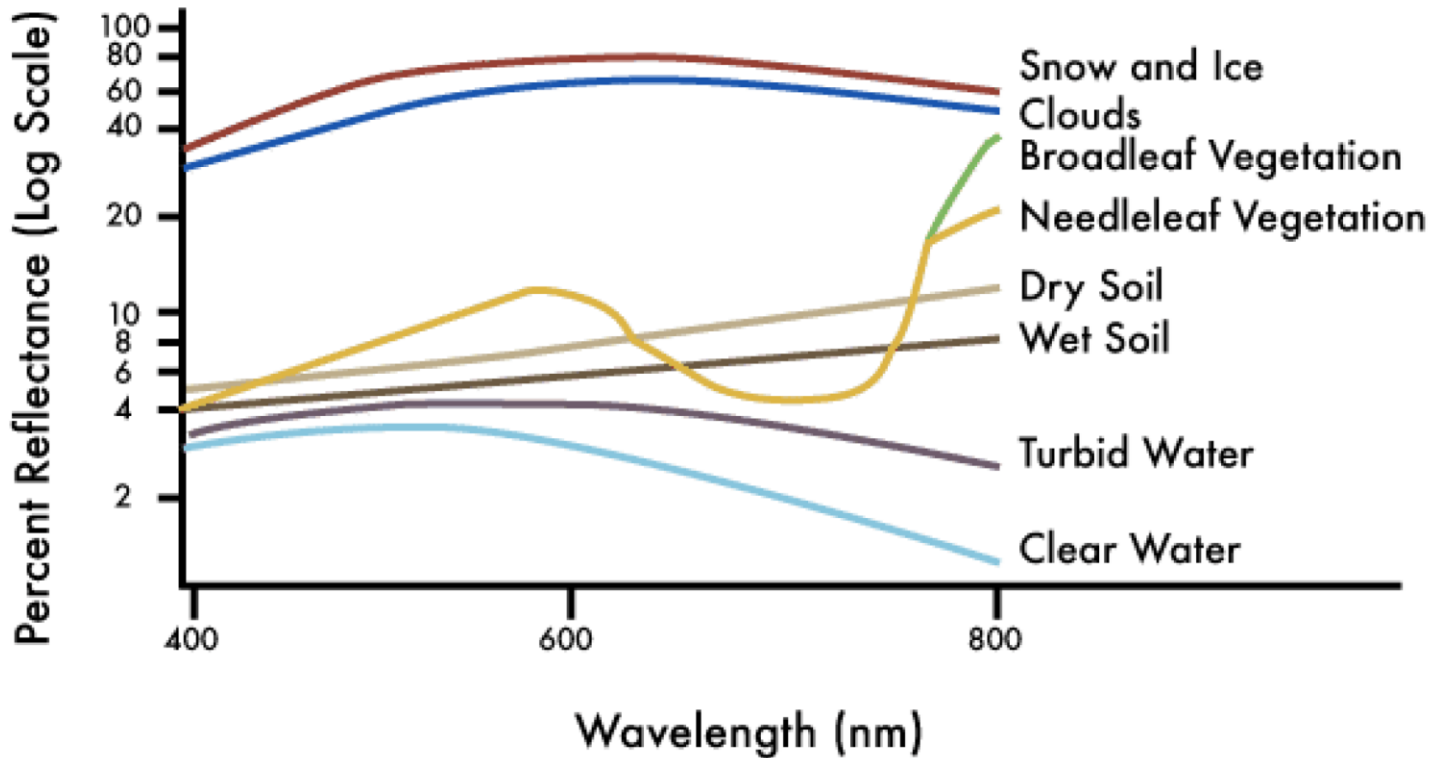
What is Remote Sensing?



Vegetation

- Certain pigments in plant leaves strongly absorb wavelengths of visible (red) light.
- The leaves themselves strongly reflect wavelengths of near-infrared light, which is invisible to human eyes.
- As a plant canopy changes from early spring growth to late-season maturity and senescence, these reflectance properties also change.
- Since we can't see infrared radiation, we see healthy vegetation as green.

What is Remote Sensing?



- Different materials reflect and absorb different wavelengths of electromagnetic radiation.
- You can look at the reflected wavelengths detected by a sensor and determine the type of material it reflected from. This is known as a **spectral signature**.
- In the graph on the left, compare the relationship between percent reflectance and the reflective wavelengths of different components of the Earth's surface.

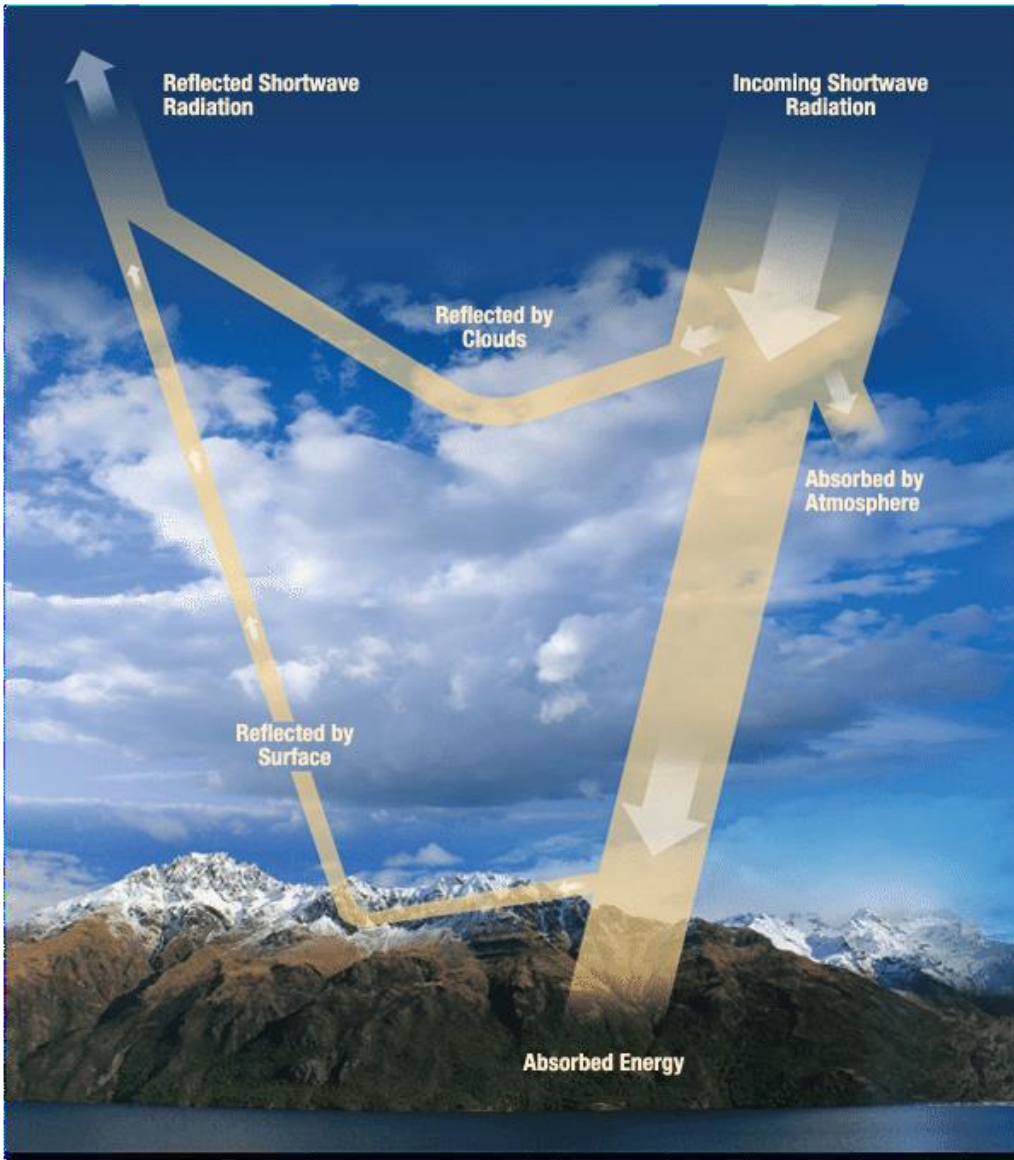
What is Remote Sensing?



Water

- Longer visible wavelengths (green and red) and near-infrared radiation are absorbed more by water than shorter visible wavelengths (blue) –so water usually looks blue or blue-green.
- Satellites provide the capability to map optically active components of upper water column in inland and near-shore waters.

What is Remote Sensing?



Atmosphere

- From the sun to the Earth and back to the sensor, electromagnetic energy passes through the atmosphere twice.
- Much of the incident energy is absorbed and scattered by gases and aerosols in the atmosphere before reaching the Earth's surface.
- Atmospheric correction removes the scattering and absorption effects from the atmosphere to obtain the surface reflectance characterizing surface properties.

Satellites and Sensors

Satellites carry sensors or instruments. The names of sensors are usually acronyms that can include the name of the satellite.

Landsat 9

Operational Land Imager 2
(OLI-2)

Spacecraft Bus

Thermal Infrared Sensor 2
(TIRS-2)



Satellite Characteristics

Orbits: Polar/Non-Polar Orbit vs. Geostationary

Energy Source: Passive vs. Active

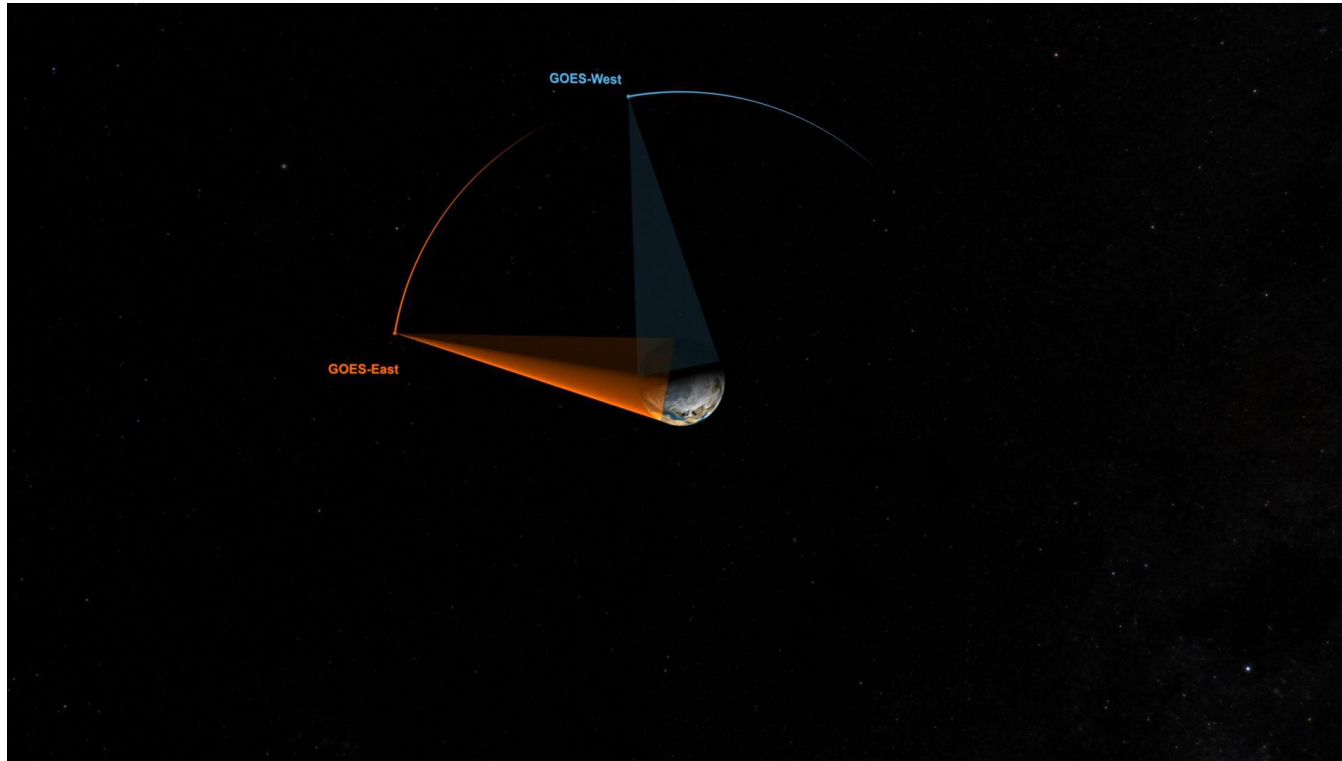
Solar and Terrestrial Spectra: Visible, UV, IR, Microwave...

Measurement Technique: Scanning; Non-Scanning; Imager; Sounders

Resolution Type and Quality: Spatial, Temporal, Spectral, Radiometric

Application: Weather, Ocean Color, Land Mapping, Air Quality, Radiation Budget, etc.

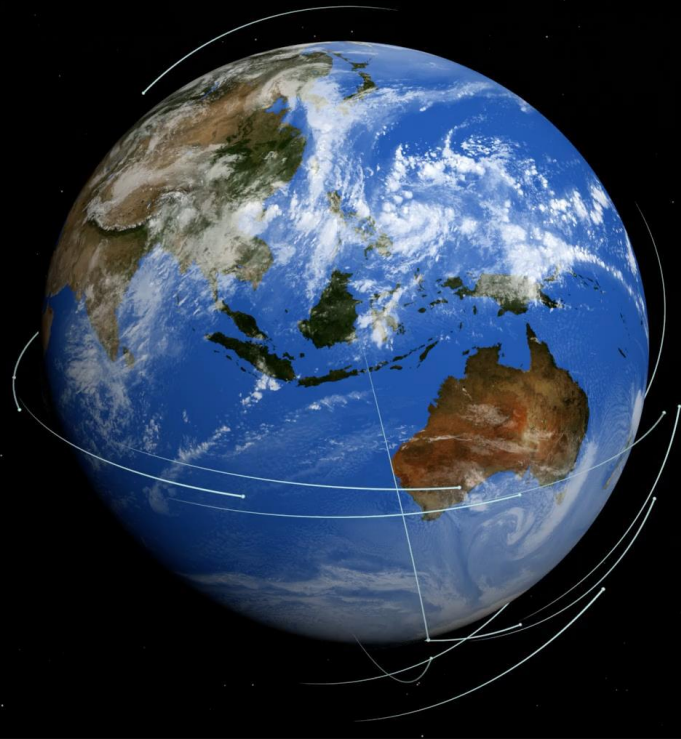
Satellite Characteristics



Geostationary Orbit

- Geostationary satellites typically orbit ~36,000 km over the equator with the same rotation period as Earth.
- Multiple observations/day
- Limited spatial coverage—observations are always of the same area
- Examples: Weather or communications satellites

Satellite Characteristics



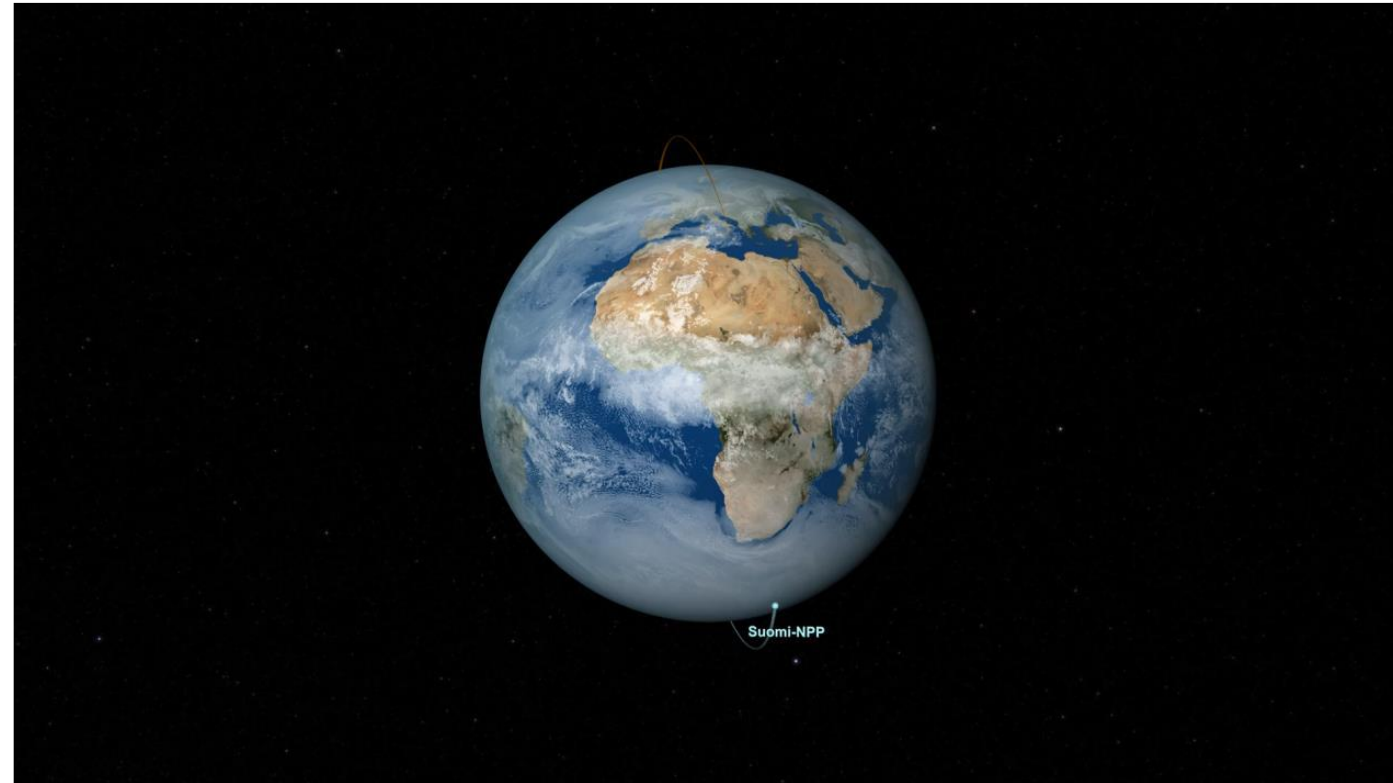
Low Earth Orbit (LEO)

- Orbit moving relative to Earth –can be polar or nonpolar
- Less frequent measurements
- Global (or near-global) spatial coverage
- Examples:
 - **Polar:** Landsat or Terra
 - **Nonpolar:** ISS or GPM

Satellite Characteristics

Polar Orbit & Sun-Synchronous Orbit (SSO)

- Global coverage
- Varied measurement frequency (once per day to once per month)
- Larger swath size means higher temporal resolution
- Satellites in SSO traveling over the polar regions are synchronous with the sun—this means that the satellite always visits the same spot at the same local time (e.g., passing the city of Paris every day at noon).



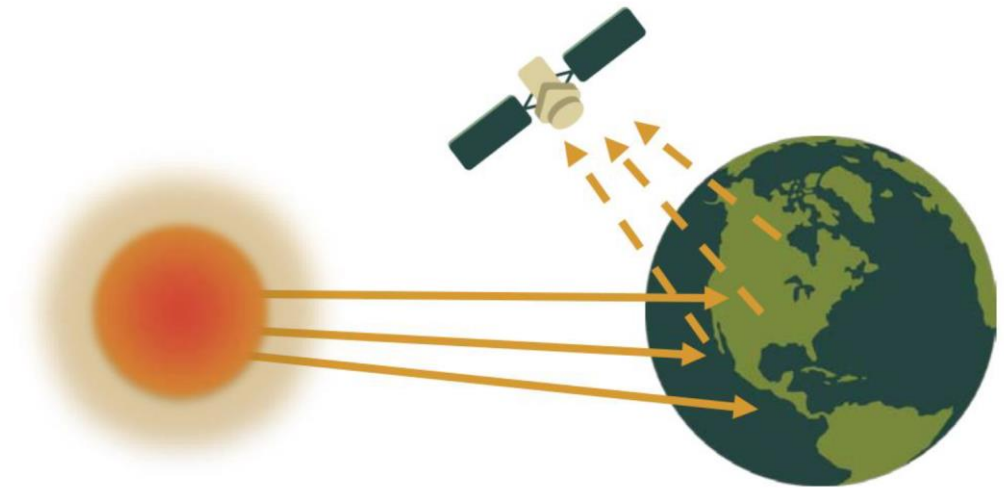
Satellite Characteristics

Satellite Sensors: Passive

- Passive remote sensors measure radiant energy **reflected** or **emitted** by the Earth-atmosphere system or changes in gravity from the Earth.
- Radiant energy is converted to bio-geophysical quantities such as temperature, precipitation, and soil moisture.
- Examples: Landsat OLI/TIRS, Terra MODIS, GPM GMI, GRACE, etc.

<https://earthdata.nasa.gov/learn/remote-sensors/passive-sensors>

Passive Sensors

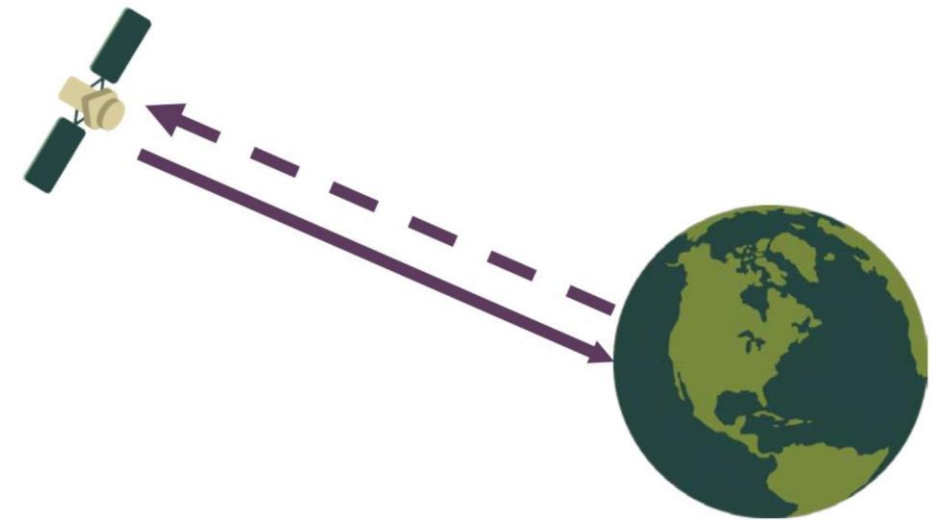


Satellite Characteristics

Satellite Sensors: Active

- Active sensors provide their own energy source for illumination
- Most active sensors operate in the microwave portion of the electromagnetic spectrum, which makes them able to penetrate the atmosphere under most conditions and can be used day or night.
- Have a variety of applications related to meteorology and observation of the Earth's surface and atmosphere.
- Examples: Laser Altimeter, LiDAR, RADAR, Scatterometer, Sounder
- Missions: Sentinel-1 (C-SAR), ICESat-2 (ATLAS), GPM (DPR)

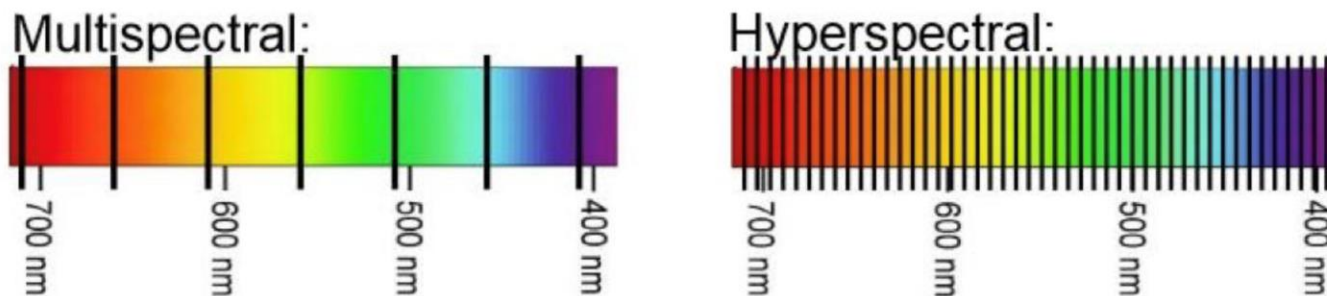
Active Sensors



<https://earthdata.nasa.gov/learn/remote-sensors/active-sensors>

Spectral Resolution

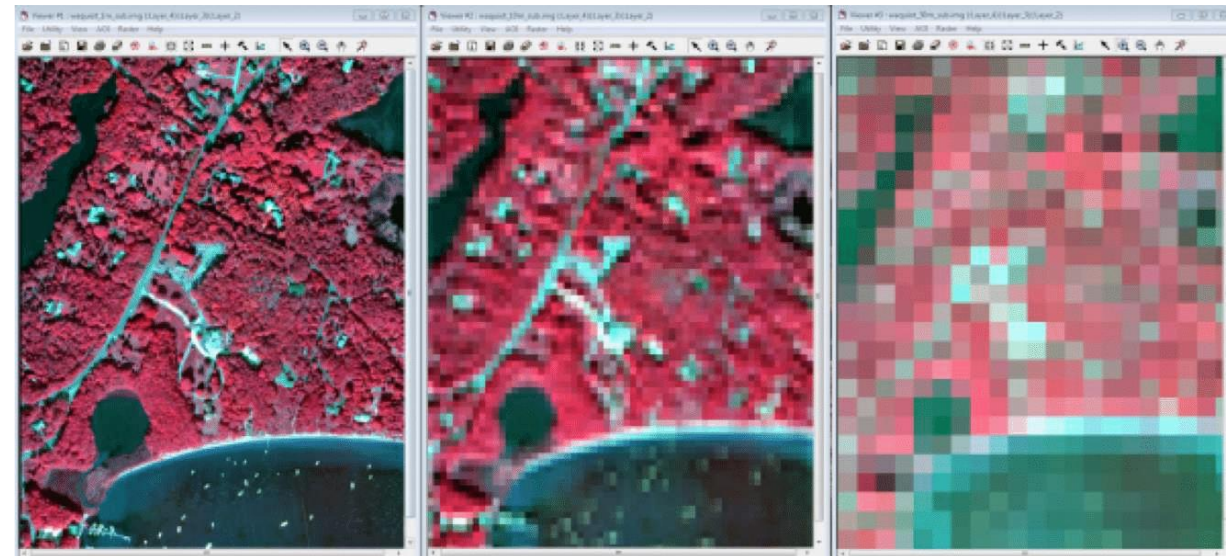
- Resolution depends upon satellite orbit configuration and sensor design. Different sensors have different resolutions.
- Signifies the number and width of spectral bands of the sensor. The higher the spectral resolution, the narrower the wavelength range for a given channel or band.
- More and finer spectral channels enable remote sensing of different parts of the Earth's surface.
- Typically, multispectral imagery refers to 3 to 10 bands, while hyperspectral imagery consists of hundreds or thousands of (narrower) bands (i.e., higher spectral resolution). Panchromatic is a single broad band that collects a wide range of wavelengths.



Spatial Resolution

- Resolution depends upon satellite orbit configuration and sensor design. Different sensors have different resolutions.
- Signifies the ground surface area that forms one pixel in the image. Sub-pixel objects can sometimes be resolved.
- It is usually presented as a single value representing the length of one side of a square.
- The higher the spatial resolution, the less area is covered by a single pixel.
- The image in the bottom right shows the same image at different spatial resolutions: (from left to right) 1 m, 10 m, and 30 m.

Sensor	Spatial Resolution
DigitalGlobe (and others)	<1 m - 4 m
Landsat	30 m
MODIS	250 m - 1 km
GPM IMERG	~10 km

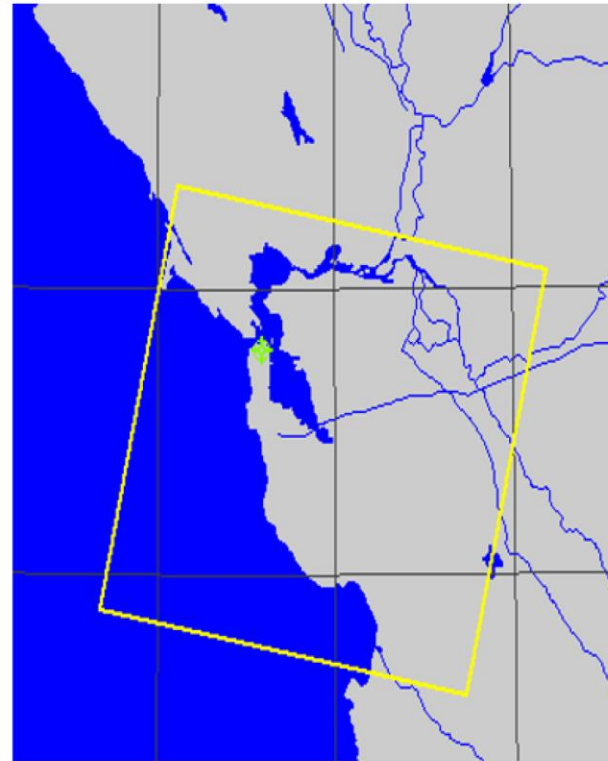


Spatial Resolution vs. Spatial Extent

Generally, the higher the spatial resolution, the less area is covered by a single image.



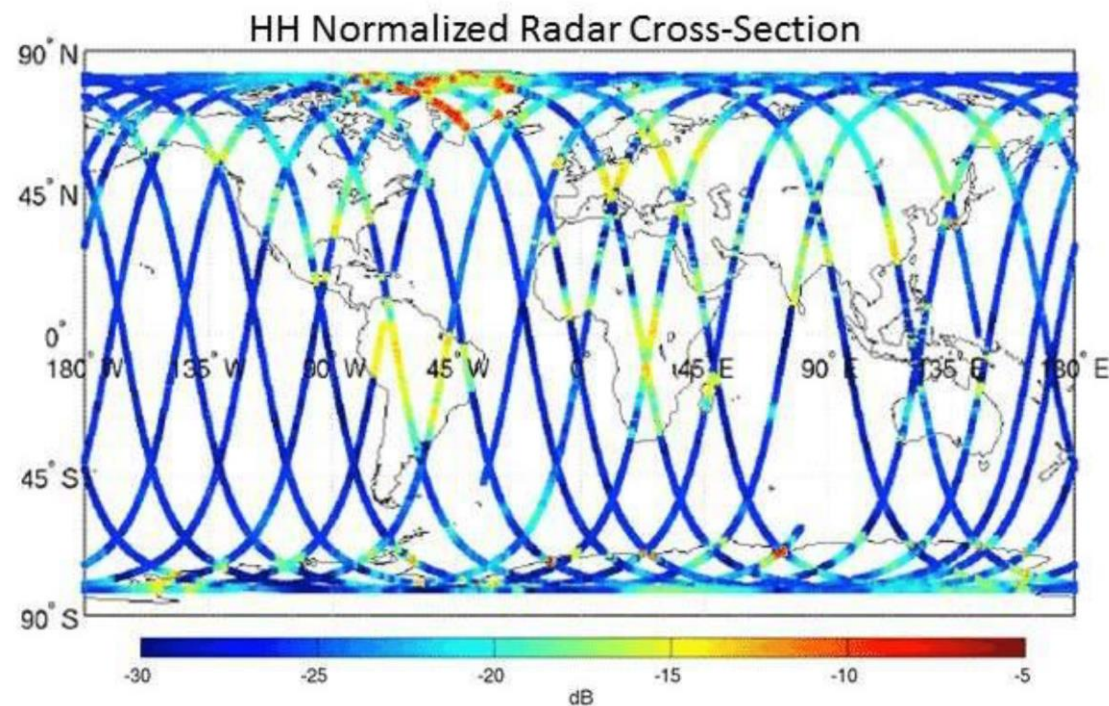
MODIS (250 m - 1 km)



Landsat OLI (30 m)

Temporal Resolution

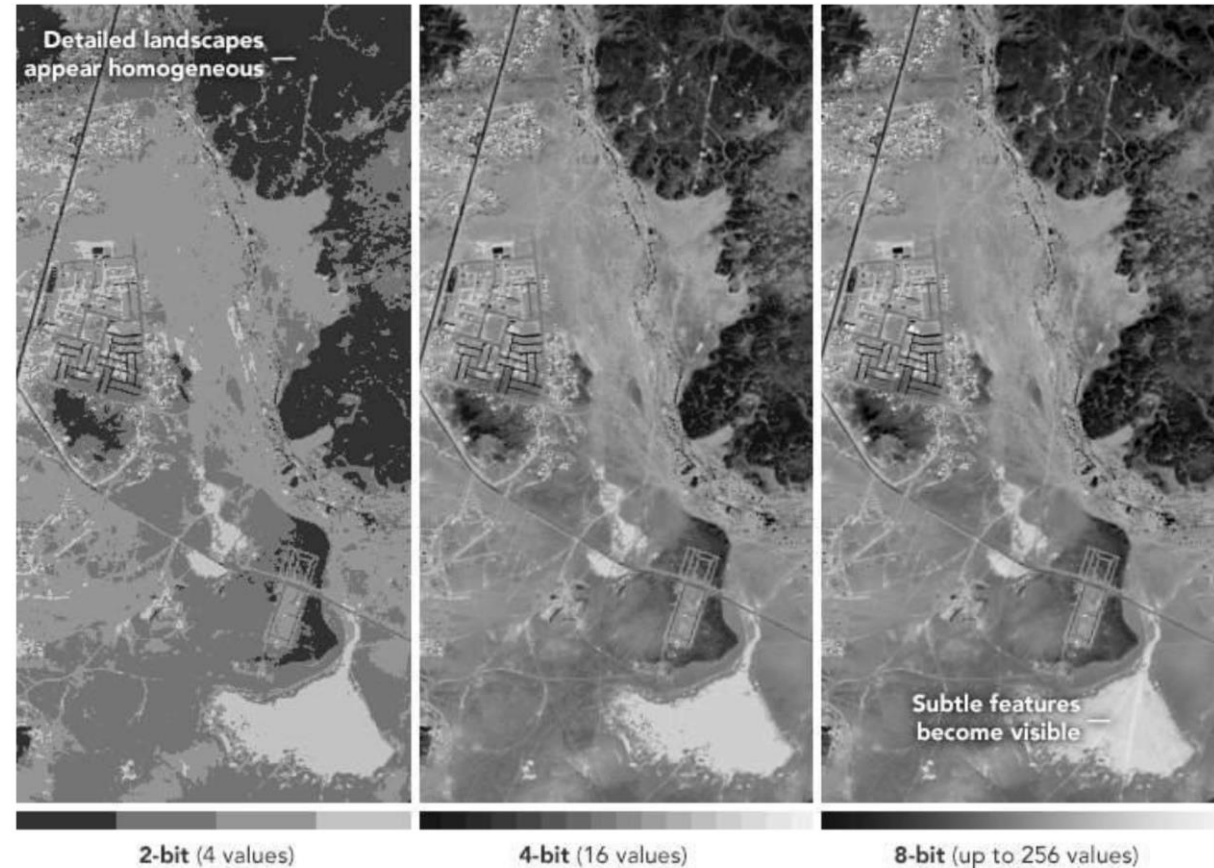
- The time it takes for a satellite to complete one orbit cycle—also called “revisit time”
- Depends on satellite/sensor capabilities, swath overlap, and latitude
- Some satellites have greater temporal resolution because:
 - They can maneuver their sensors
 - They have increasing overlap at higher latitudes



Sensor	Revisit time
Landsat	16-days
MODIS	2-days
Commercial (OrbView)	1-2 days

Radiometric Resolution

- Describes a sensor's ability to discriminate differences in energy (or radiance).
- The better radiometric resolution, the more sensitive the sensor is to small differences in energy. The larger this number, the higher the radiometric resolution, and the sharper the imagery.
 - 12-bit sensor, 4,096 levels: Landsat OLI
 - 10-bit sensor, 1,024 levels: AVHRR
 - 8-bit sensor, 256 levels: Landsat TM
 - 6-bit sensor, 64 levels: Landsat MSS



The images show what the same scene looks like at different levels. From left to right: 2-bit, 4-bit, and 8-bit.
Image Credit: [NASA's Earth Observatory](#)

Satellite Data Processing Levels

- Satellite data is available at different stages (or levels) of processing, going from raw data collected from the satellite to polished products that visualize information.
- NASA takes the data from satellites and processes it to make it more usable for a broad array of applications. There is a set of terminology that NASA uses to refer to the levels of processing it conducts:
 - **Level 0 & 1** is the raw instrument data that may be time-referenced. It is the most difficult to use.
 - **Level 2** is Level 1 data that has been converted into a geophysical quantity through a computer algorithm (known as retrieval). This data is geo-referenced and calibrated.
 - **Level 3** is Level 2 data that has been mapped on a uniform space-time grid and quality controlled.
 - **Level 4** is Level 3 data that has been combined with models or other instrument data.
 - Level 3 & 4 data is the easiest to use.

Advantages and Disadvantages of Remote Sensing

Advantages of Remote Sensing

- Provides information where there are no ground-based measurements.
- Provides globally consistent observations.
- Provides continuous monitoring of our planet.
- Earth systems models integrate surface-based and remote sensing observations and provide uniformly gridded, frequent information of water resources data parameters.
- Data are freely available and there are web-based tools for data analysis.

Advantages and Disadvantages of Remote Sensing

Disadvantages of Remote Sensing

- It is very difficult to obtain high spectral, spatial, temporal, and radiometric resolution all at the same time.
- Large amounts of data in a variety of formats can lead to more time and processing.
- Applying satellite data may require additional processing, visualization, and other tools.
- While the data are generally validated with selected surface measurements, regional and local assessment is recommended.

Remote Sensing Terminology

Amplitude: The “height” of a wave or its maximum displacement from equilibrium.

Electromagnetic Radiation: The energy the Earth receives from the Sun.

Frequency: The number of cycles of a wave passing a fixed point per unit of time.

Geodesy: The science of accurately measuring and understanding three fundamental properties of the Earth: its geometric shape, its orientation in space, and its gravity field.

Geodetic: Relating to geodesy.

Geoid: The hypothetical shape of the Earth, coinciding with mean sea level and its imagined extension under (or over) land areas.

Georeference: To link spatial data to its correct location.

Geostationary: Remaining fixed over a specific location on Earth’s surface.

Gridded: Spatial data displayed over a uniform grid, often tied to specific locations.

Nadir: The point on the Earth’s surface directly below the observing satellite.

Polar: A type of orbit that crosses the poles.

Polarization: The orientation of an electromagnetic wave.

Radiometric Resolution: Describes a sensor's ability to discriminate differences in energy (or radiance).

Spatial Extent: The overall surface area covered by a given dataset.

Spatial Resolution: The ground surface area that forms one pixel in the image.

Spectral Resolution: The number and width of spectral bands of the sensor. The higher the spectral resolution, the narrower the wavelength range for a given channel or band.

Sun-Synchronous: The satellite always visits the same spot at the same local time.

Temporal Resolution: The time it takes for a satellite to complete one orbit cycle—also called “revisit time.”

Thank You