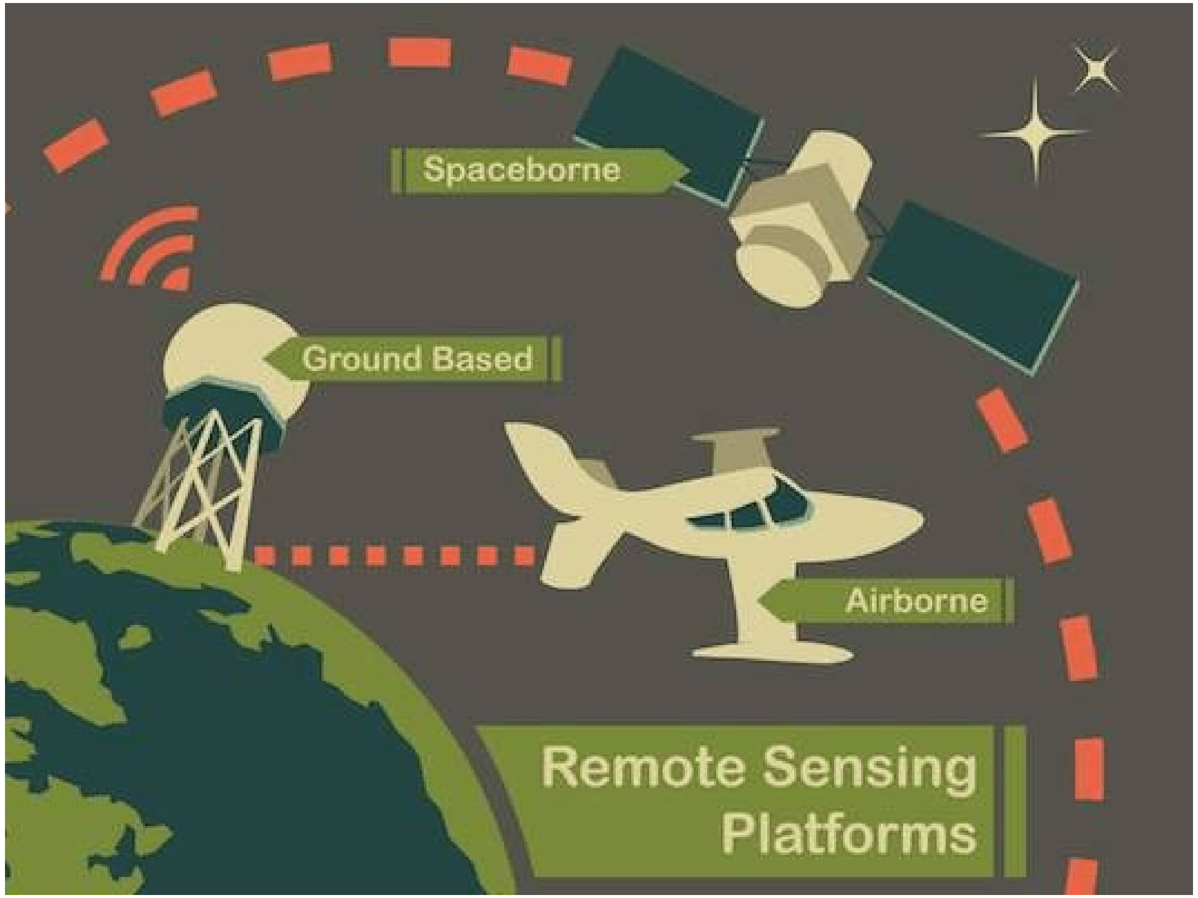
What is remote sensing?



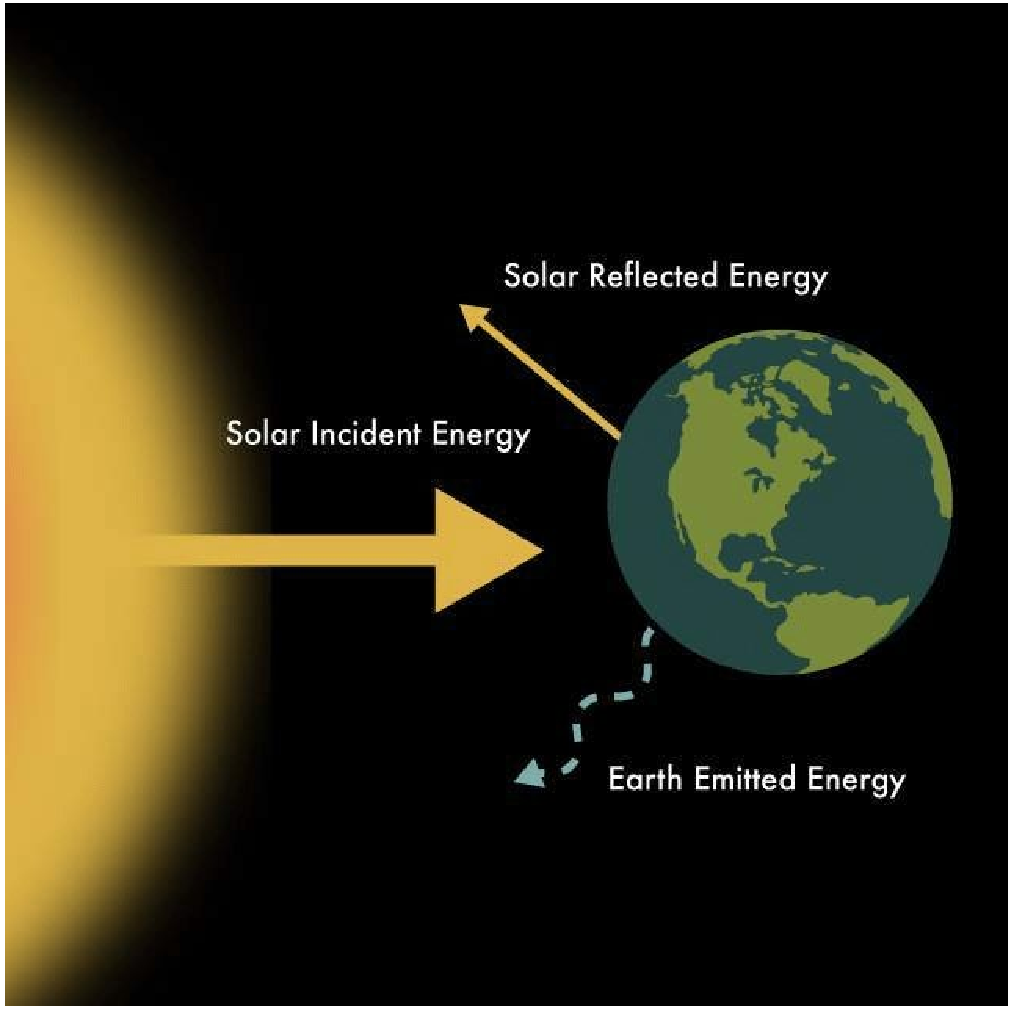
Remote sensing is obtaining information about an object from a distance.

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.

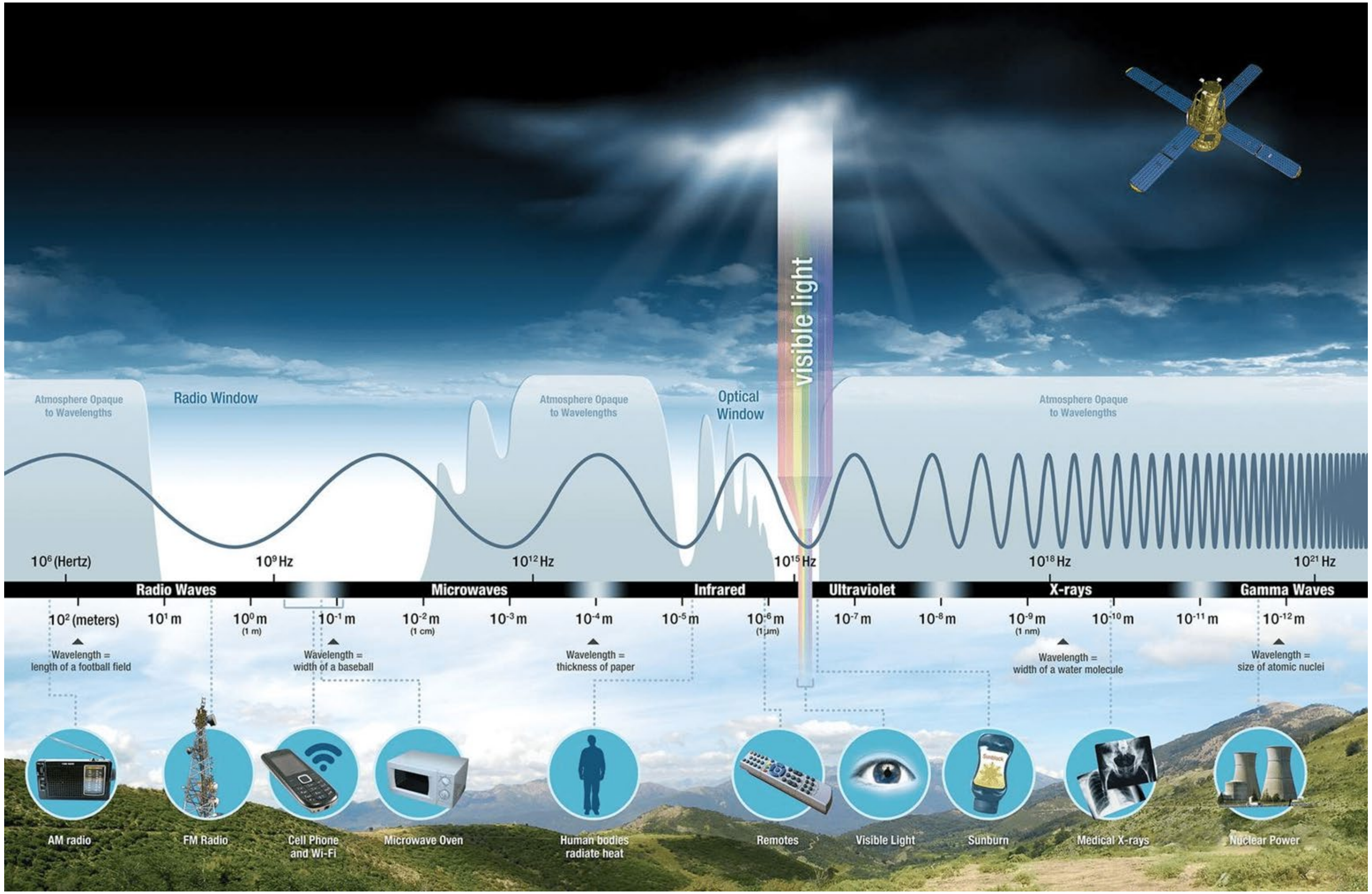
- What information do you need?
- How much detail?
- How frequently do you need the data?

What is remote sensing?



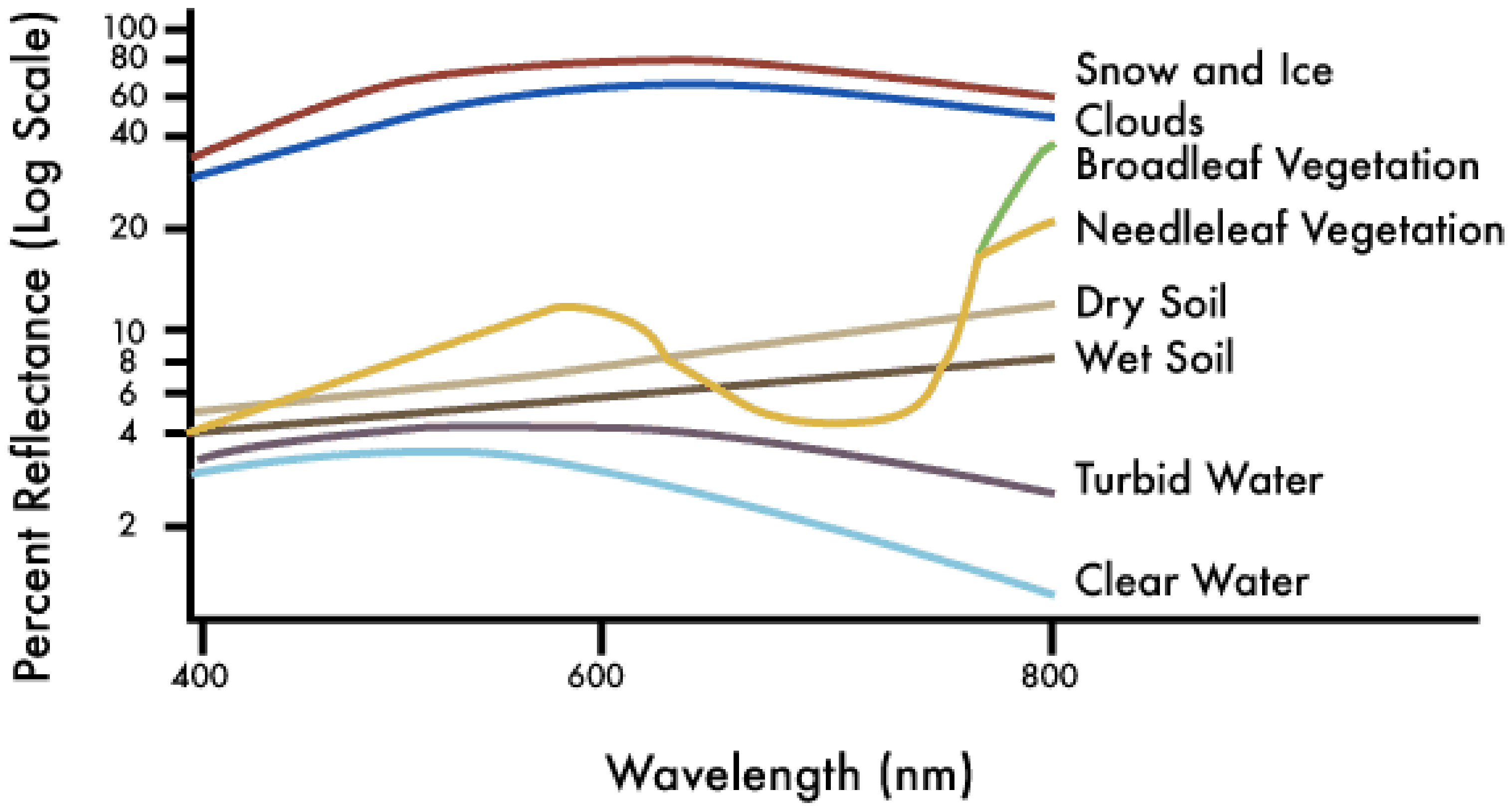
- The energy Earth receives from the sun is called **electromagnetic radiation**.
- Radiation is reflected, absorbed, and emitted by the Earth's atmosphere or surface, as shown by the figure on the left.
- Satellites carry instruments or sensors that measure electromagnetic radiation reflected or emitted from both terrestrial and atmospheric sources.

What is remote sensing?



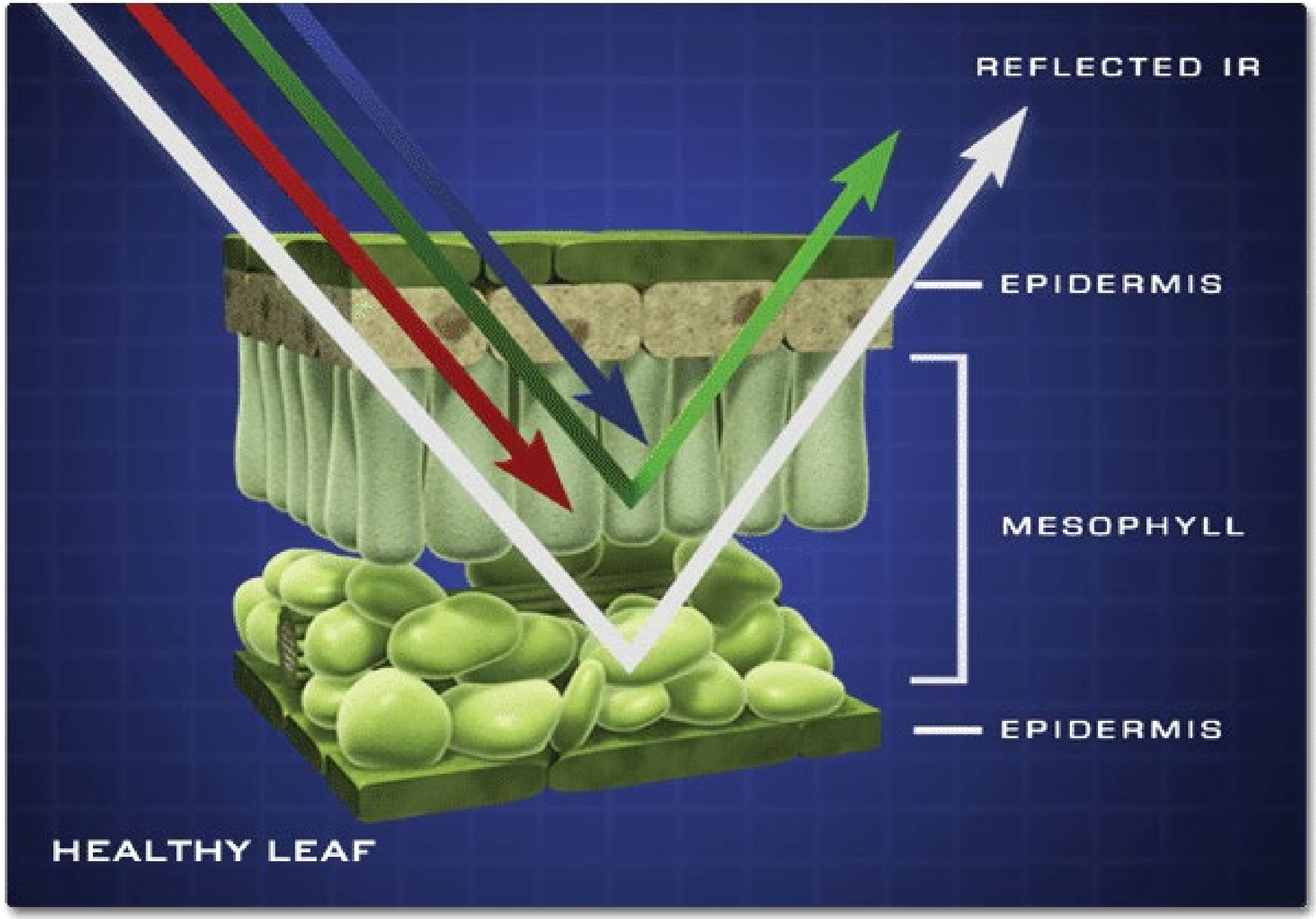
- The electromagnetic spectrum is simply the full range of **wave frequencies** that characterizes solar radiation.
- Although we are talking about light, most of the electromagnetic spectrum cannot be detected by the human eye. Even satellite detectors only capture a small portion of the entire electromagnetic spectrum.

What is remote sensing?



- 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?



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.
- Since we can't see infrared radiation, we see healthy vegetation as green.
- As a plant canopy changes from early spring growth to late-season maturity and senescence, these reflectance properties also change.

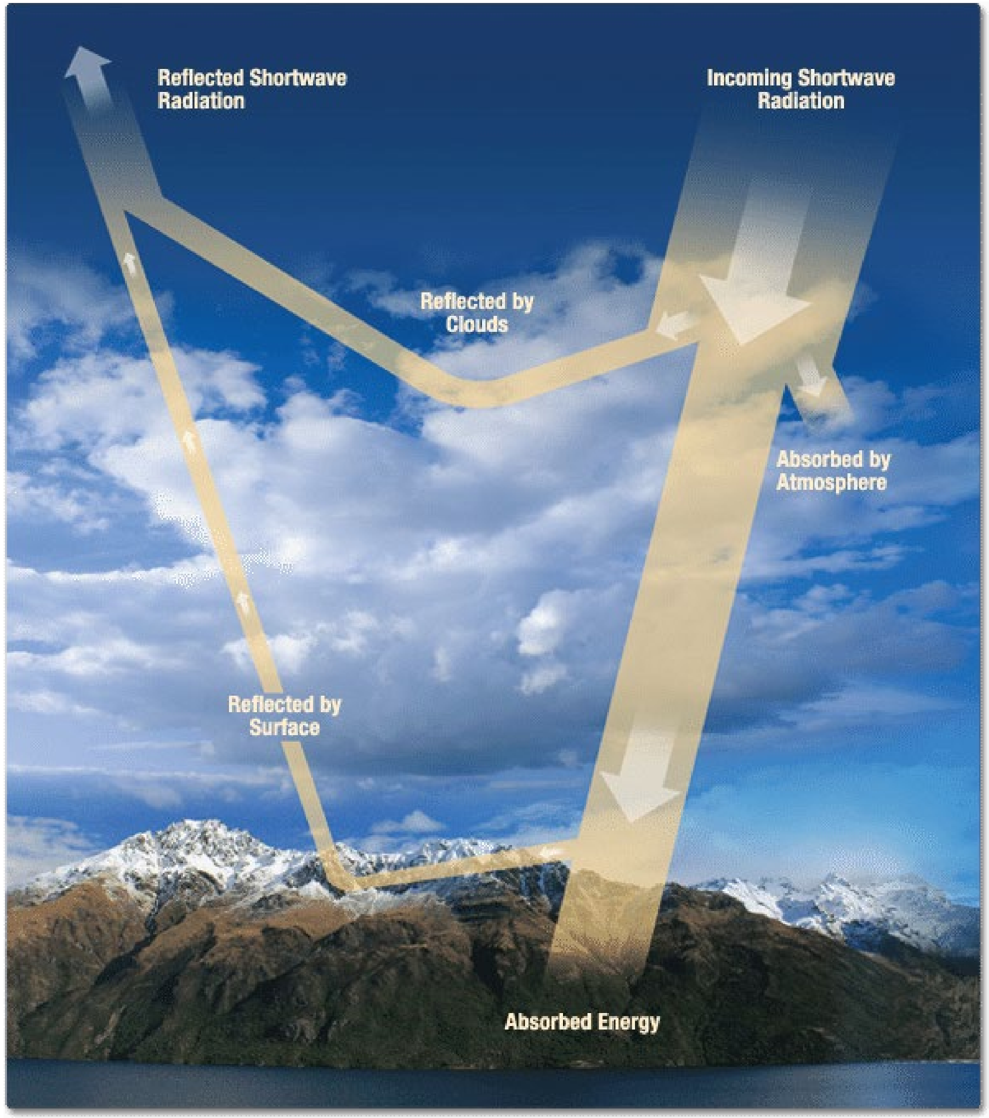
What is remote sensing?

Image Credit: NASA Earth Observatory, using Landsat data courtesy of USGS.

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.

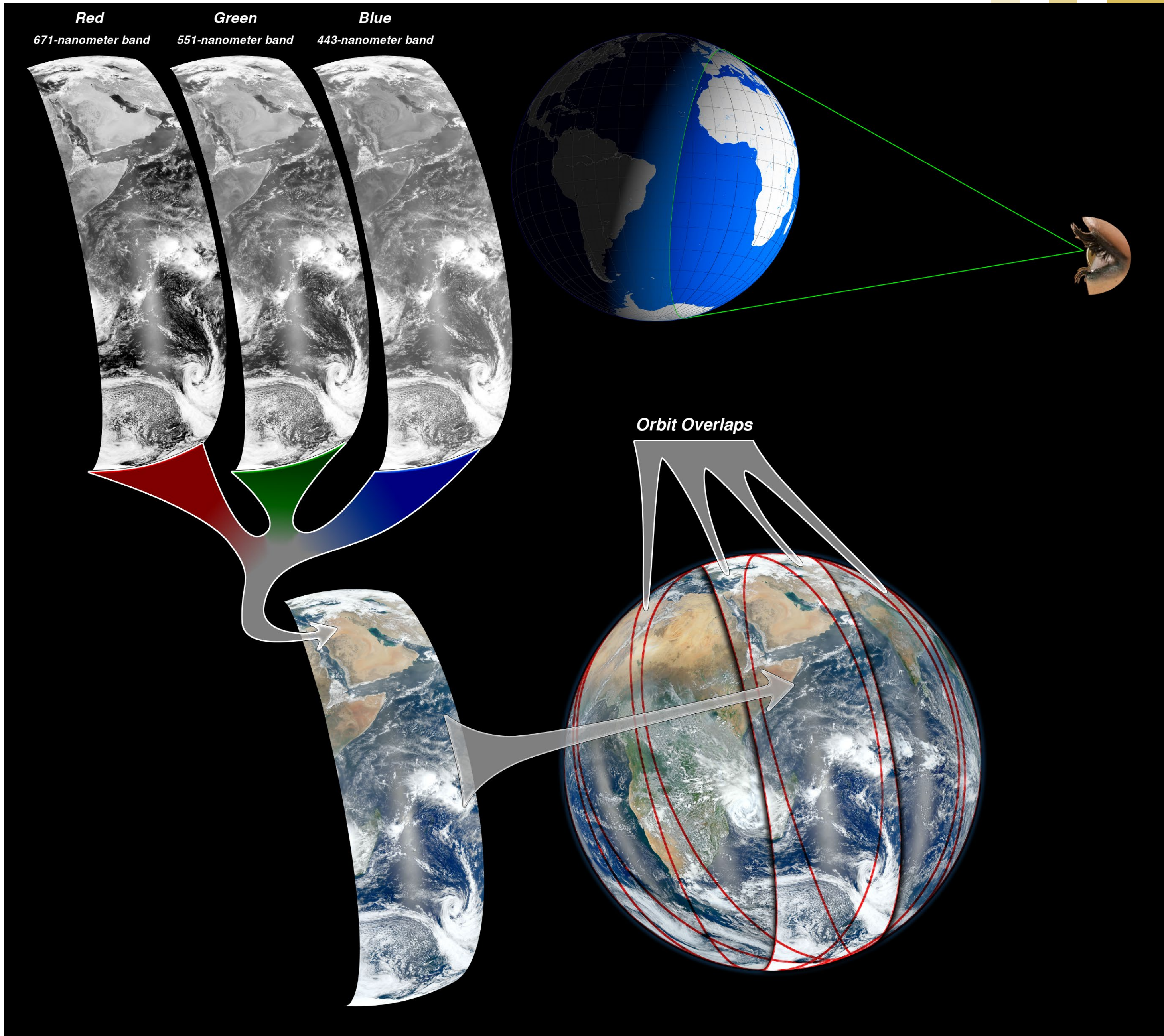
True Color Image (or RGB)

A Moderate Resolution Imaging Spectroradiometer (MODIS) "true color image" will use visible wavelength bands 1, 4, 3

R = 0.66 µm

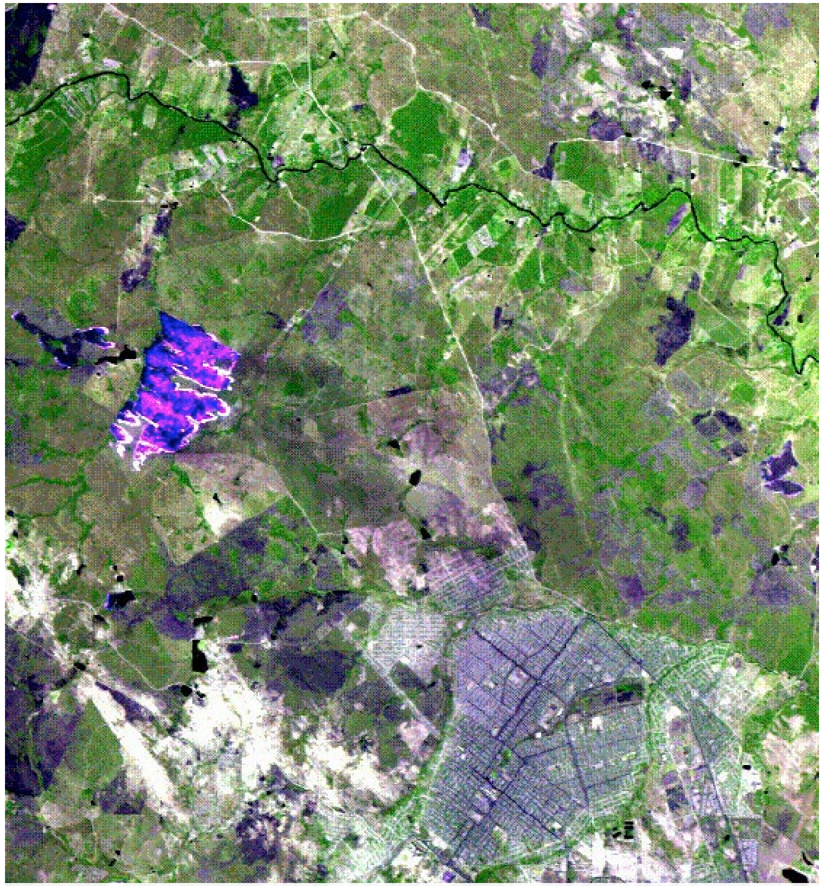
G = 0.55 µm

B = 0.47 µm



True vs. False Color Images

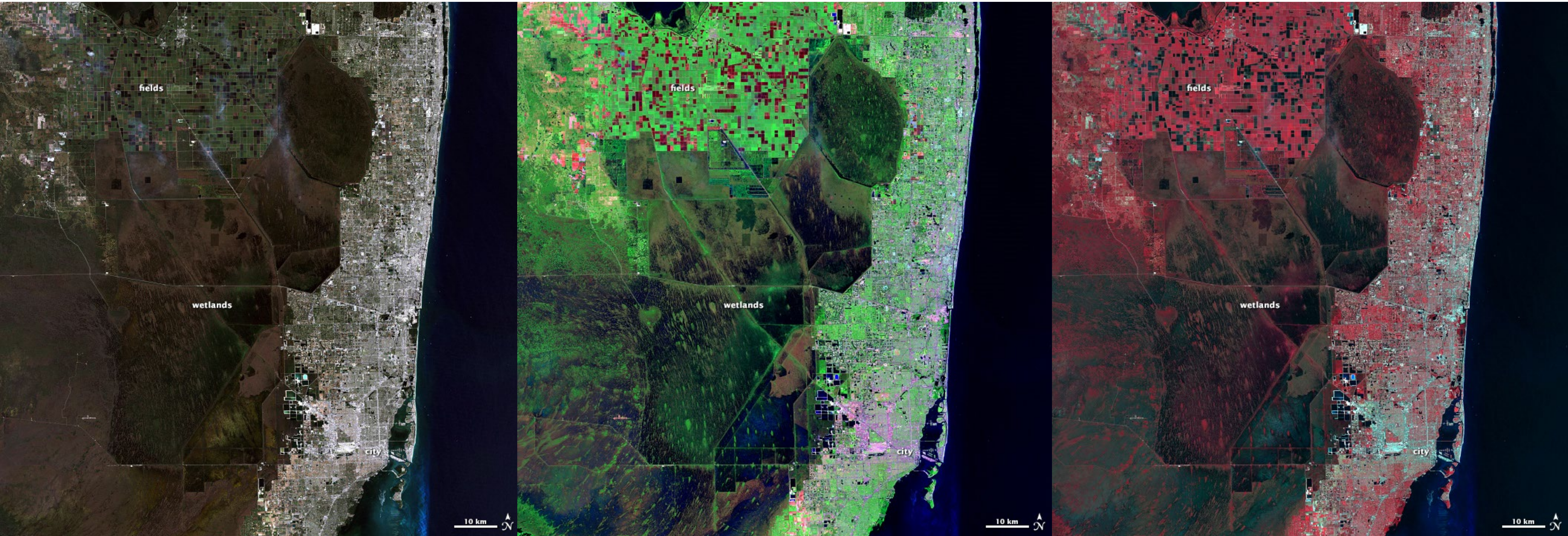
R = 0.66 µm (Red)
G = 0.55 µm (Green)
B = 0.47 µm (Blue)



R = 1.6 µm (Shortwave Infrared)
G = 1.2 µm (Near-Infrared)
B = 2.1 µm (Shortwave Infrared)

False-Color Satellite Image

- A natural or "true-color" image combines actual measurements of red, green, and blue light.
- A false-color image uses at least one non-visible wavelength, though that band is still represented in red, green, or blue.



Satellites and Sensors

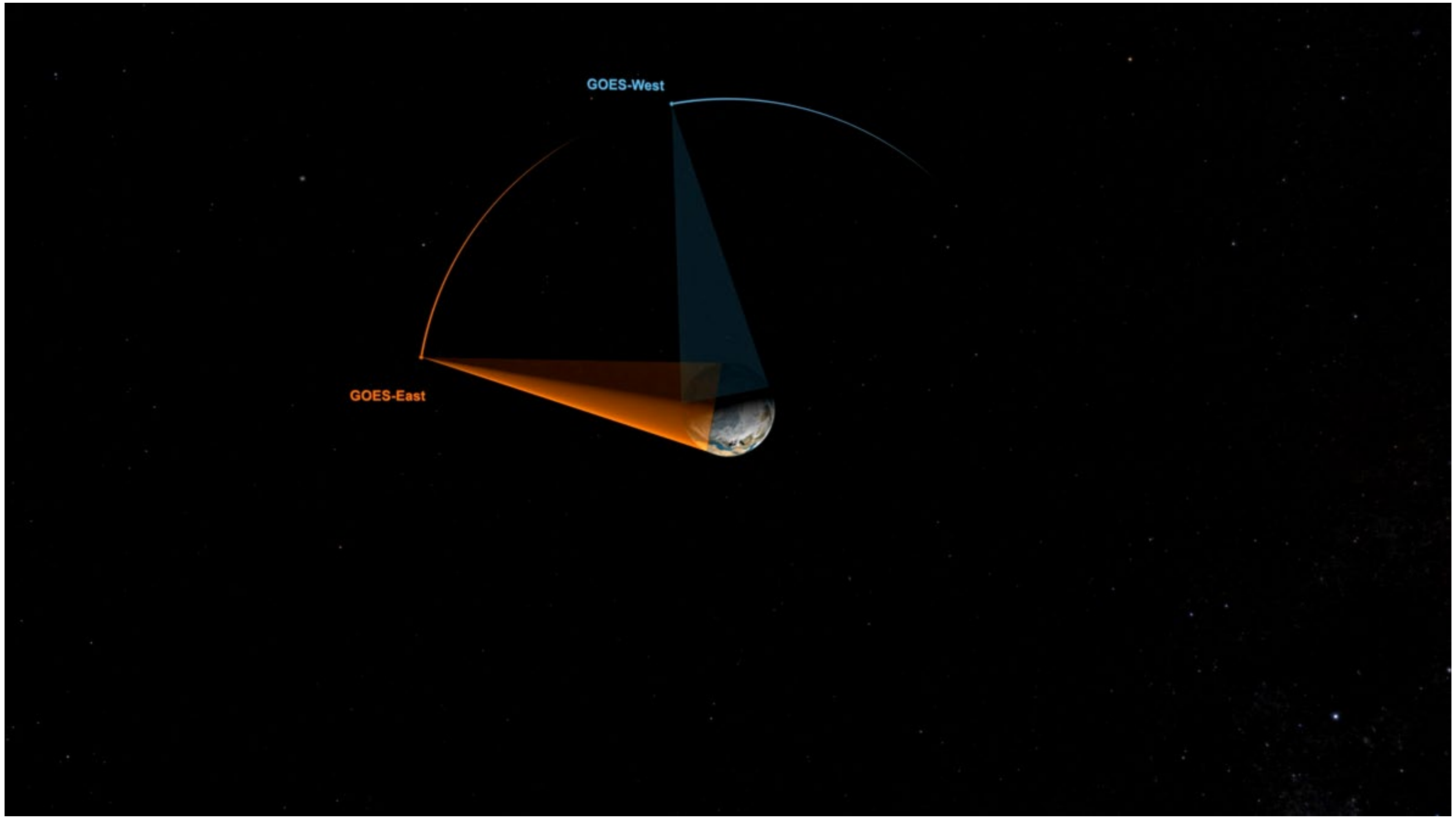
Satellites carry sensors or instruments. The names of sensors are usually acronyms that can include the name of the satellite.

Image Credit: NASA

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

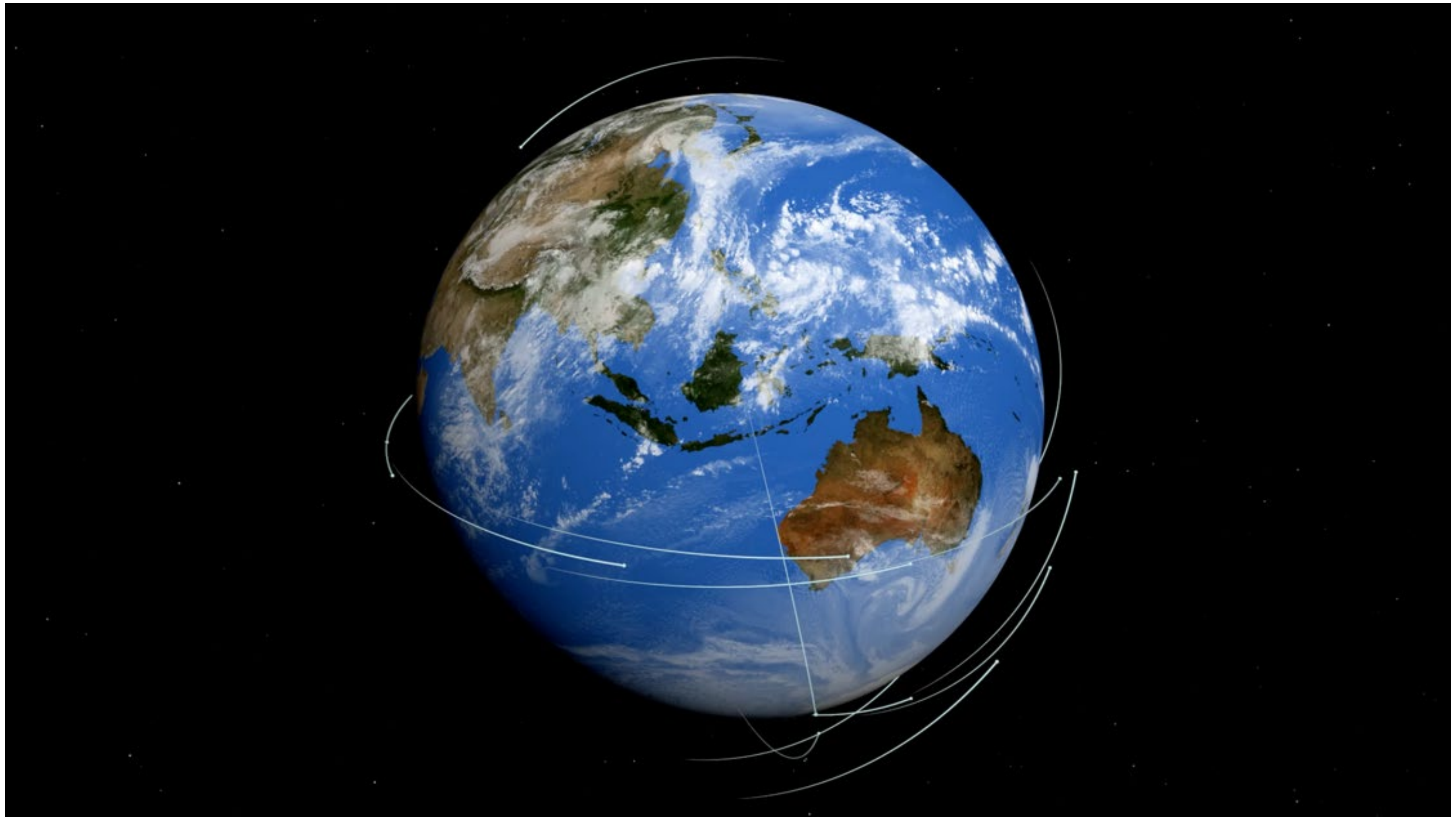


Video Credit: NASA

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



Video Credit: NASA

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).

Video Credit: NASA

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

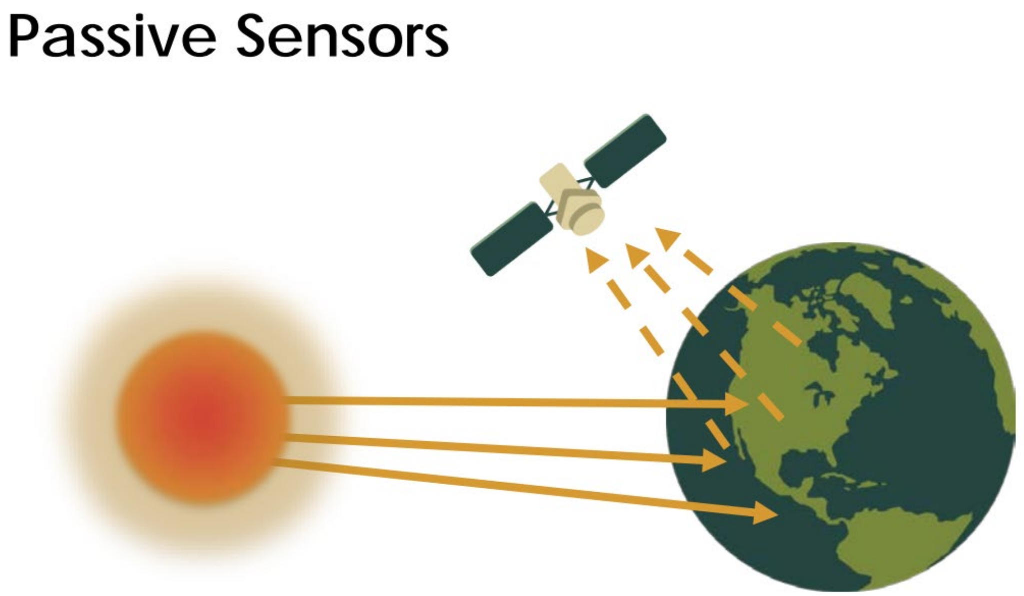


Image Credit: ARSET

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

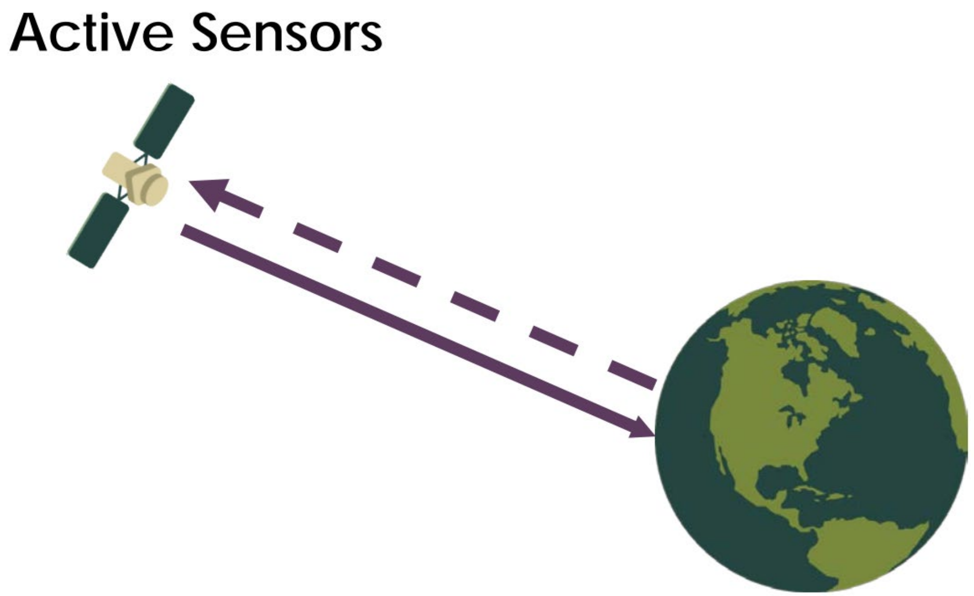
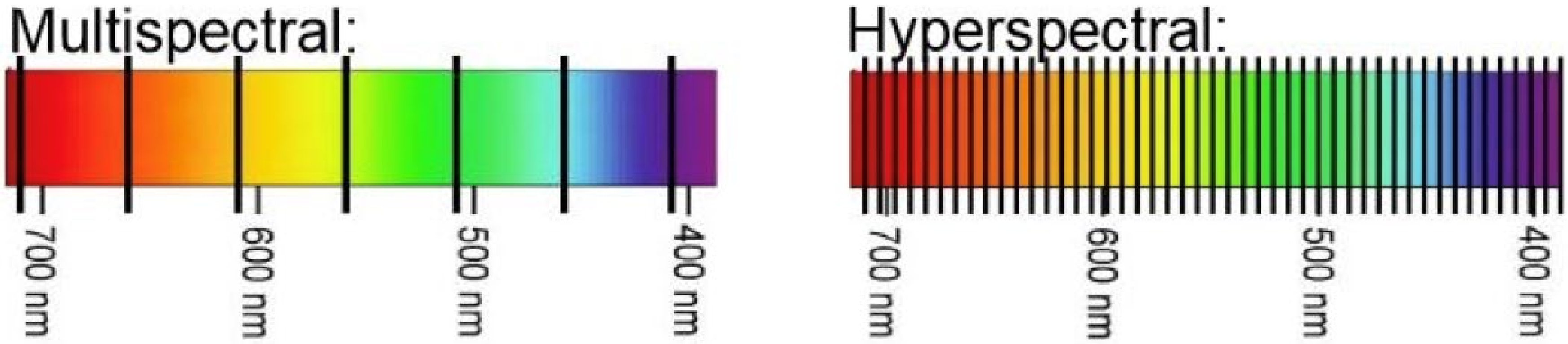


Image Credit: ARSET

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

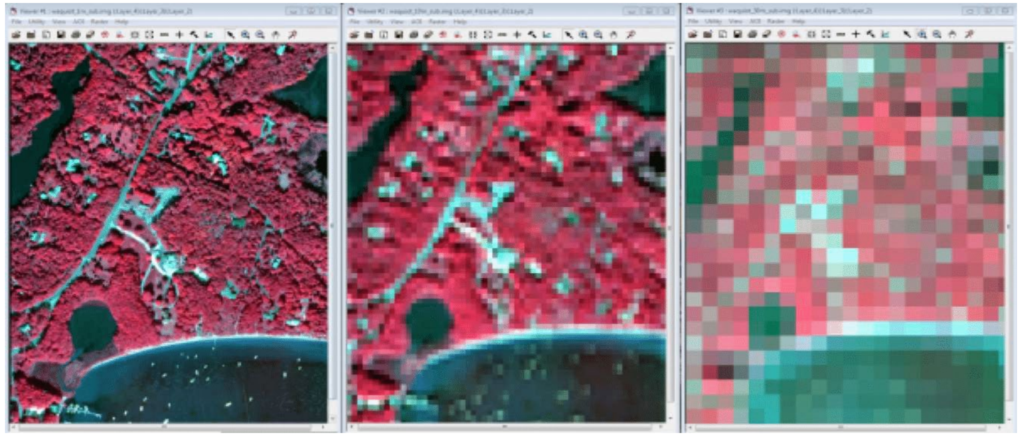
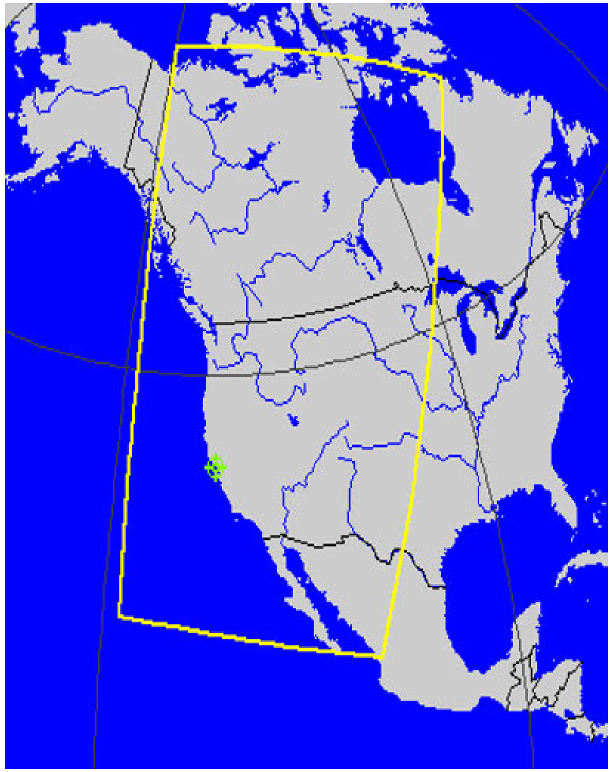


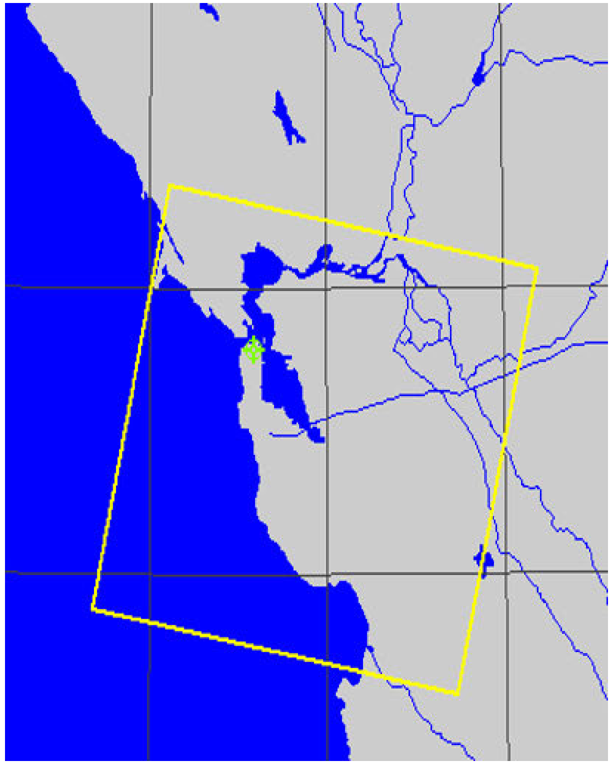
Image Credit: csc.noaa.gov

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)

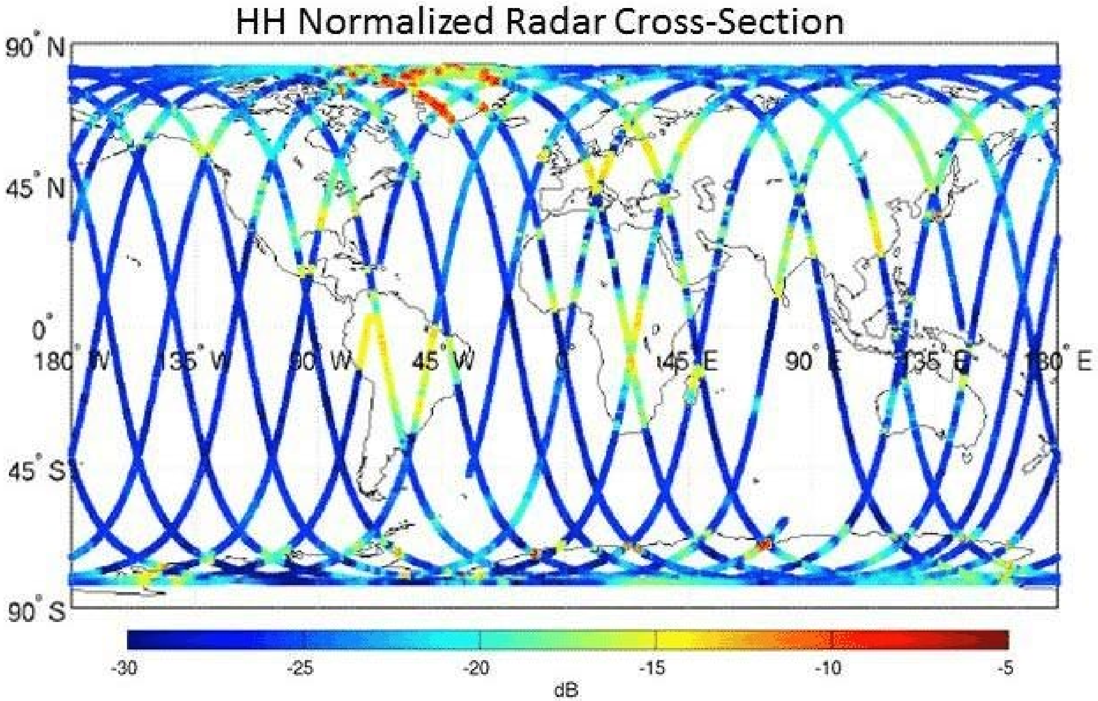


Landsat OLI (30 m)

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



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 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.

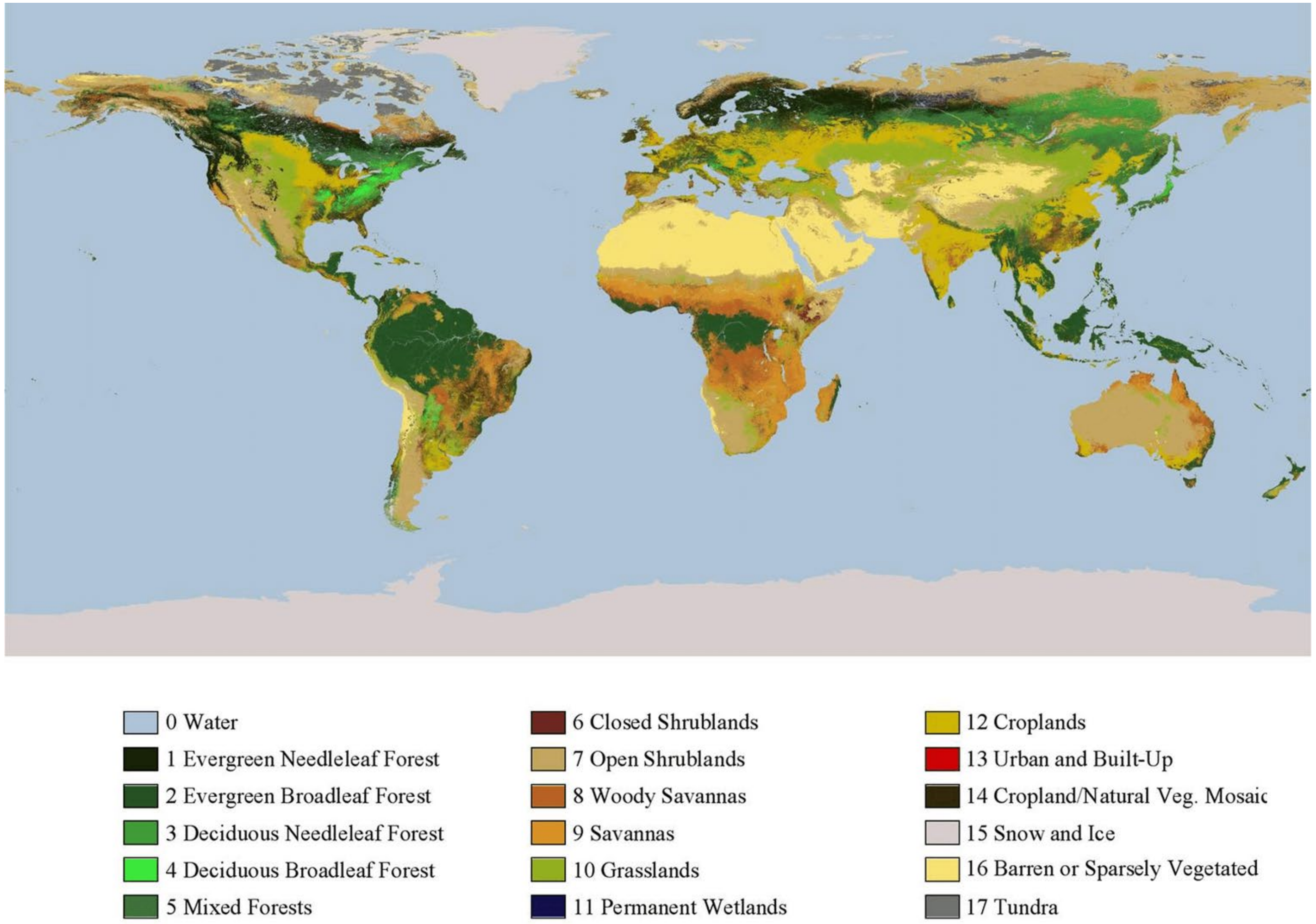


Image Credit: NASA GSFC

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.

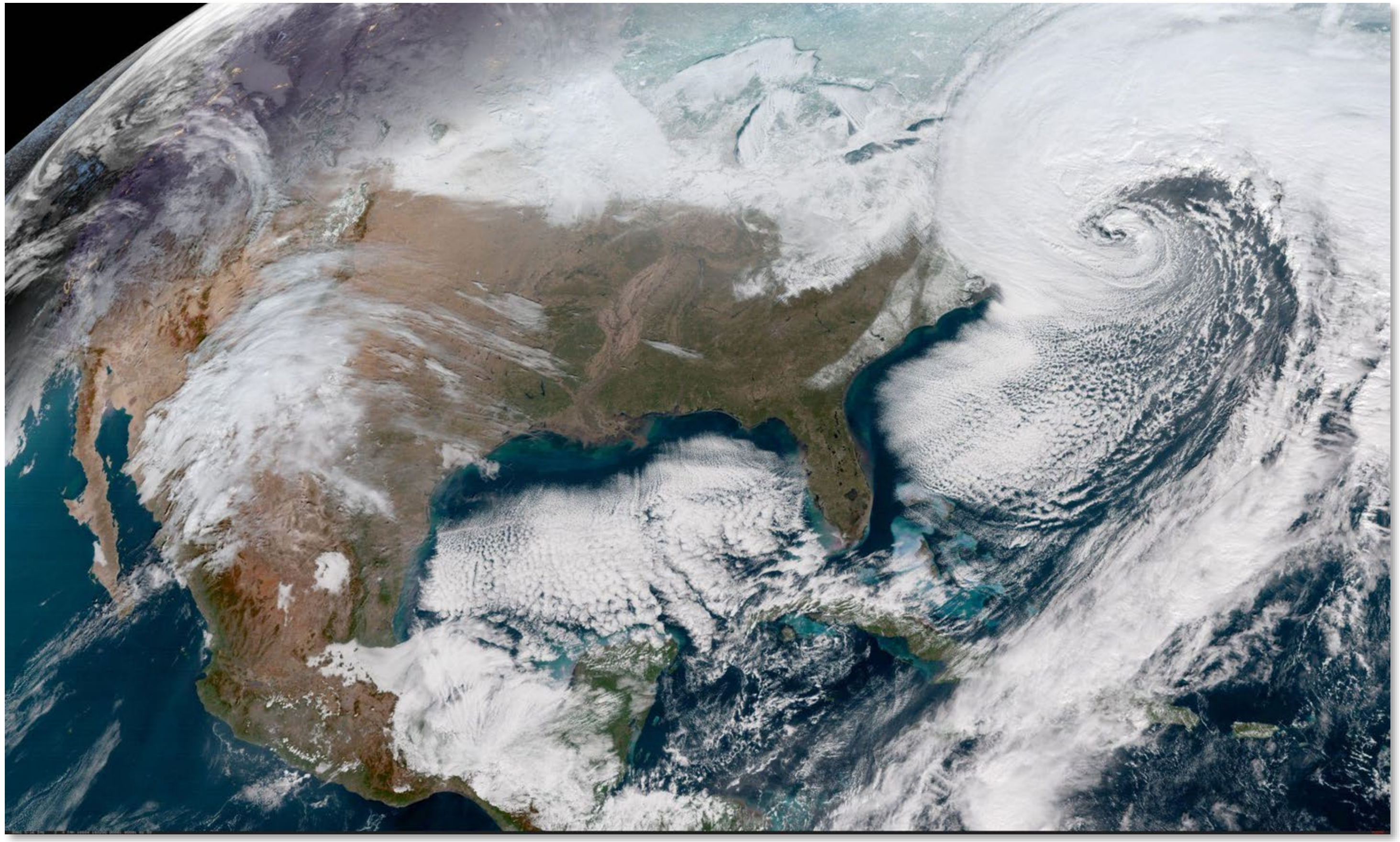
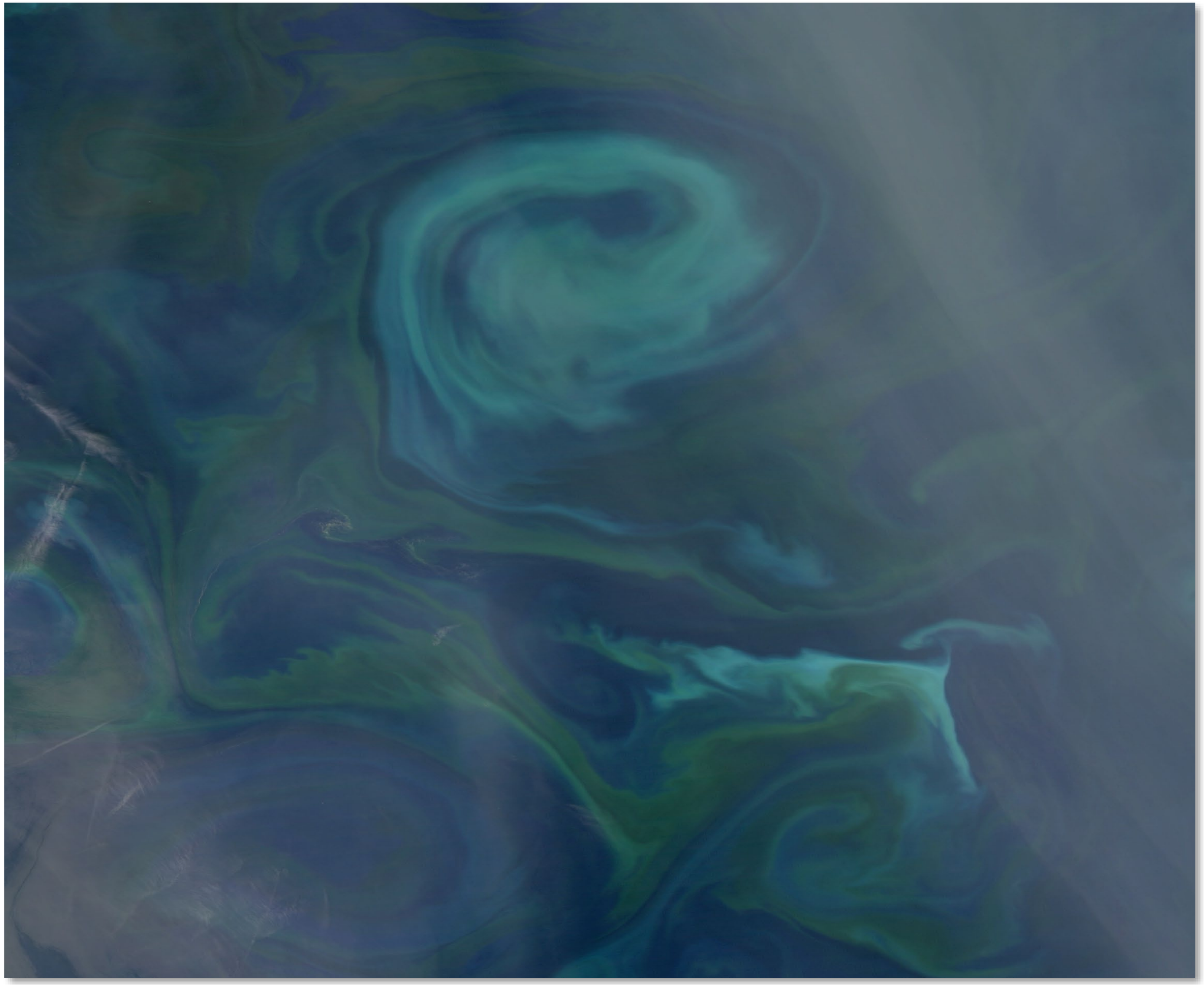


Image Credit: NOAA

Remote Sensing Game

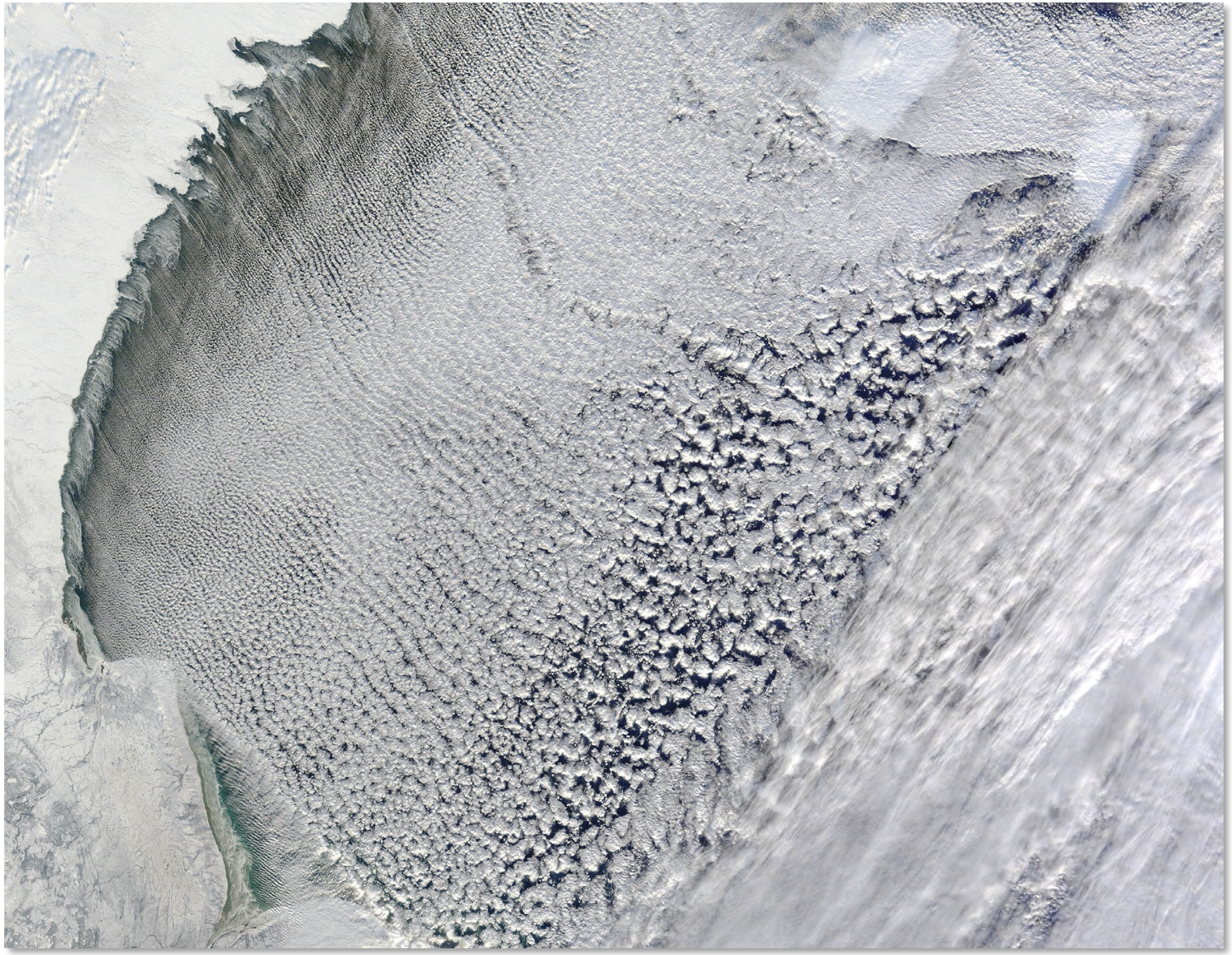
What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



What color(s) do you think are reflected?

- RED
- BLUE
- GREEN