National Aeronautics and Space Administration

Building Capacity to Use Earth Observations in Addressing Environmental Challenges in Bhutan

Day 1 – Fundamentals of Remote Sensing

Public

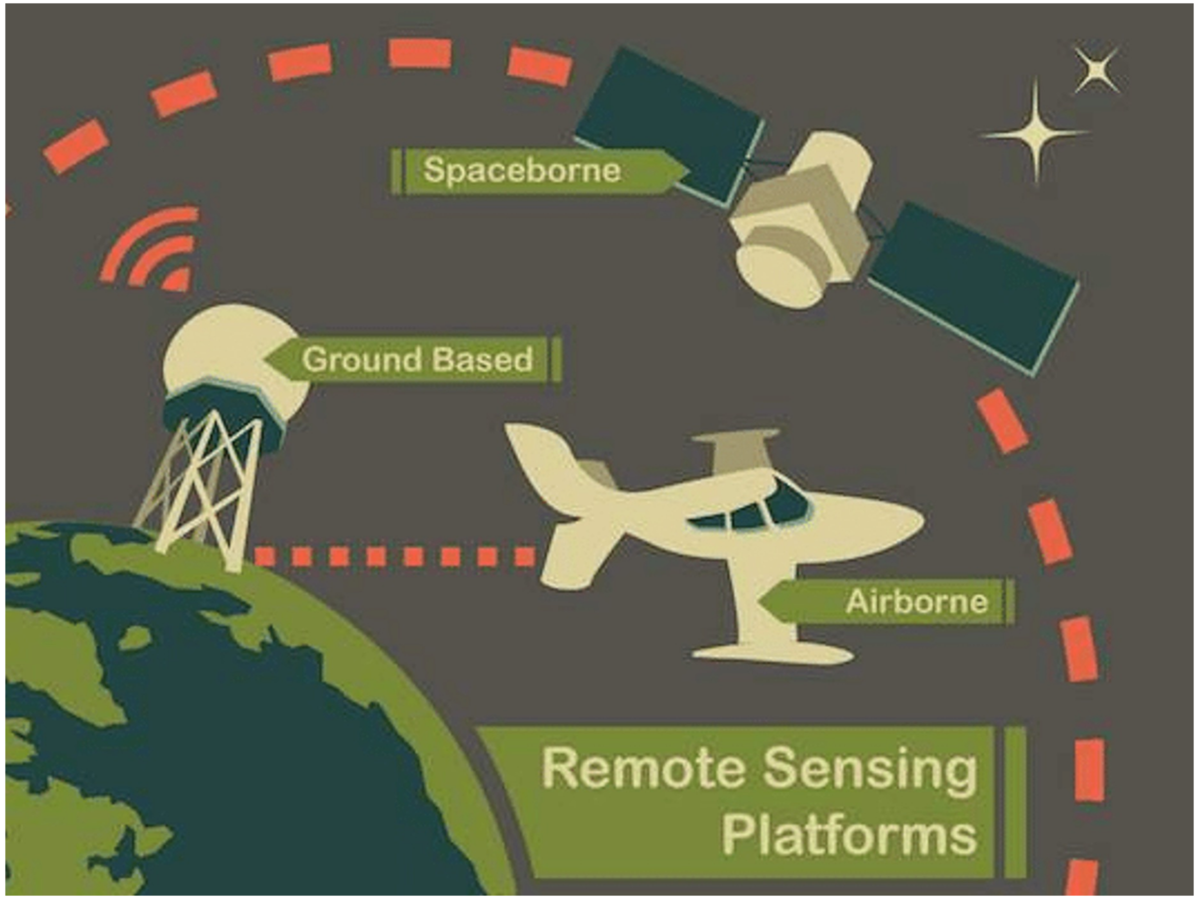
Objectives

By the end of this session, participants will become familiar with:

- Satellite Orbits
- Orbit Types
- Resolutions
- Sensors
- Processing Levels

In addition to a conceptual understanding of remote sensing, attendees will also be able to articulate its **advantages** and **disadvantages** to environmental monitoring and management.

What is remote sensing?



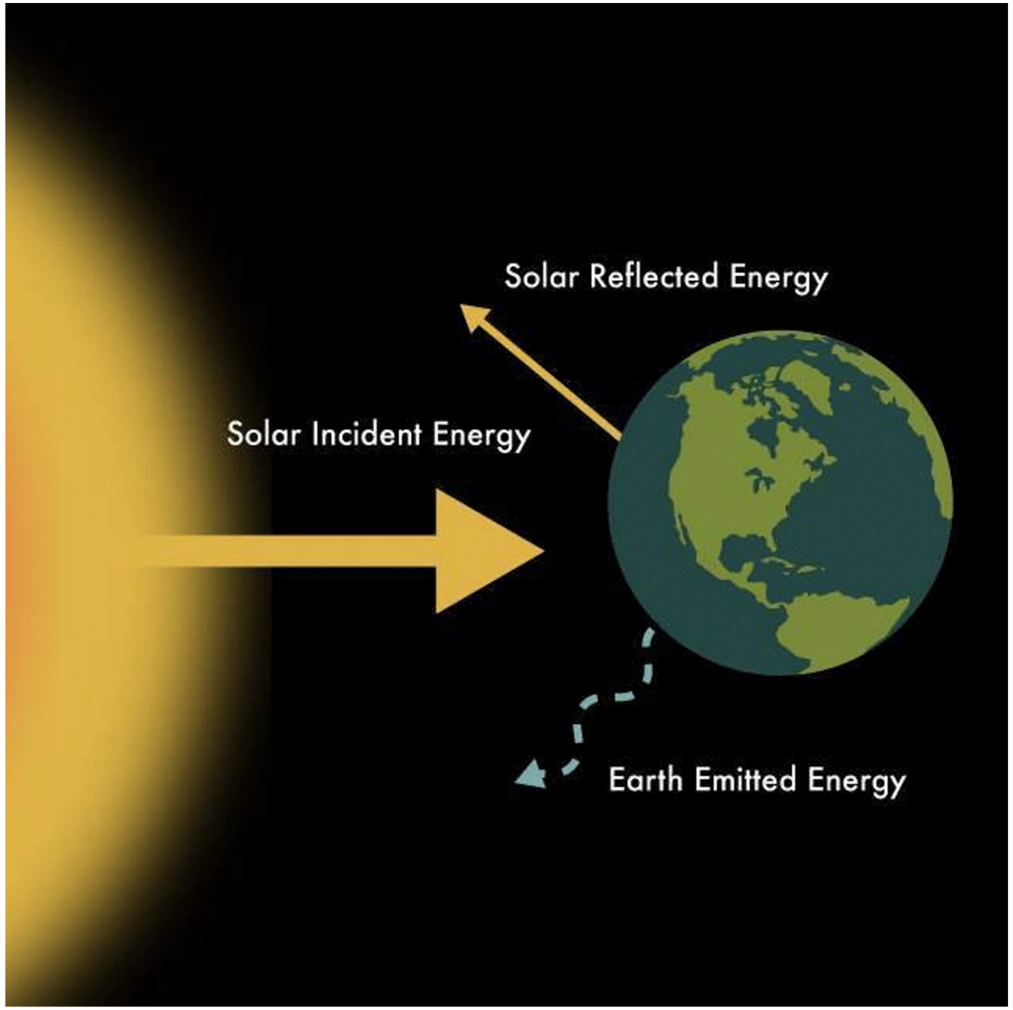
Remote sensing is obtaining information about an object from a distance.

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.

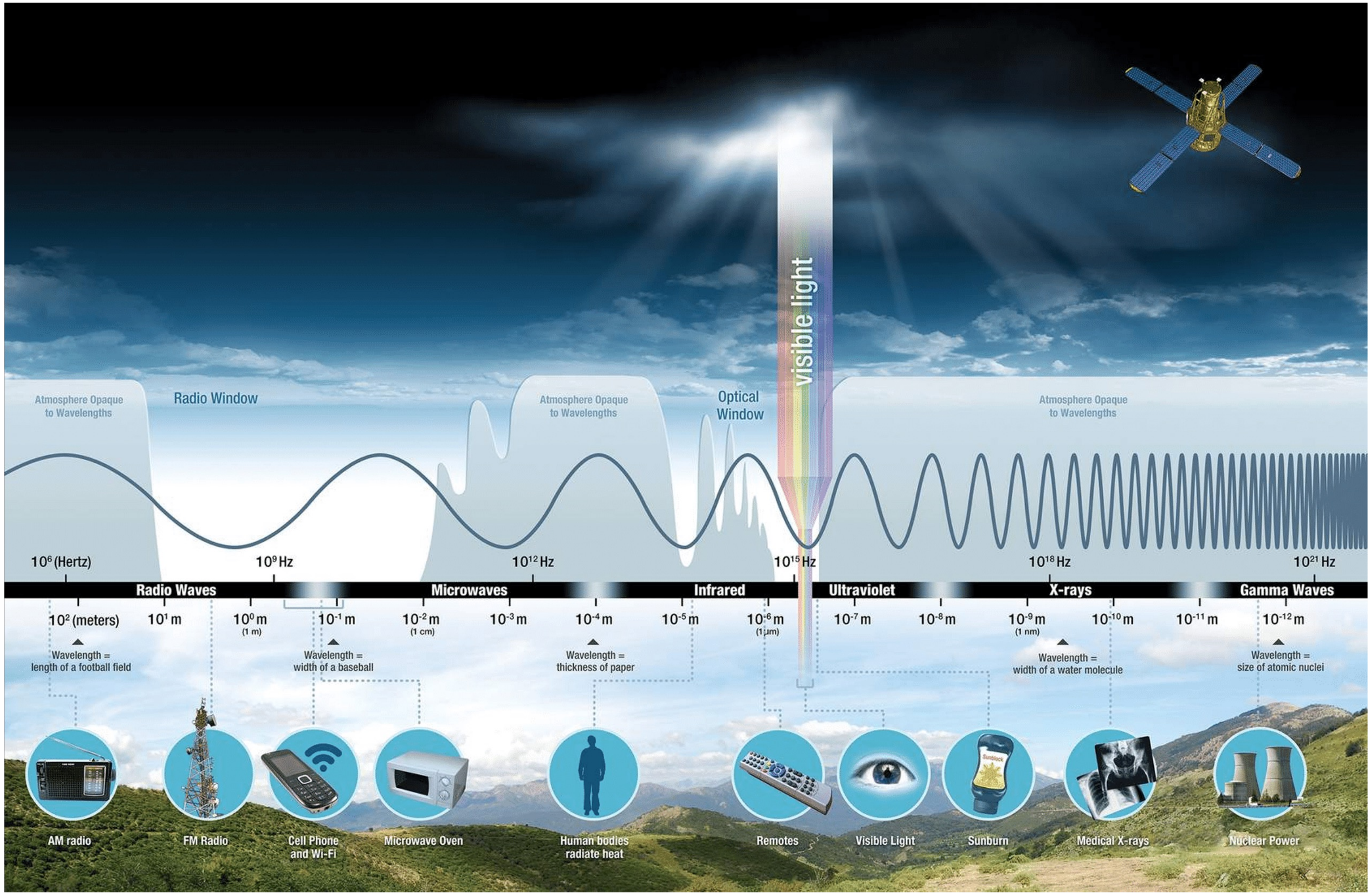
- What information do you need?
- How much detail?
- How frequently do you need the data?

Electromagnetic Radiation



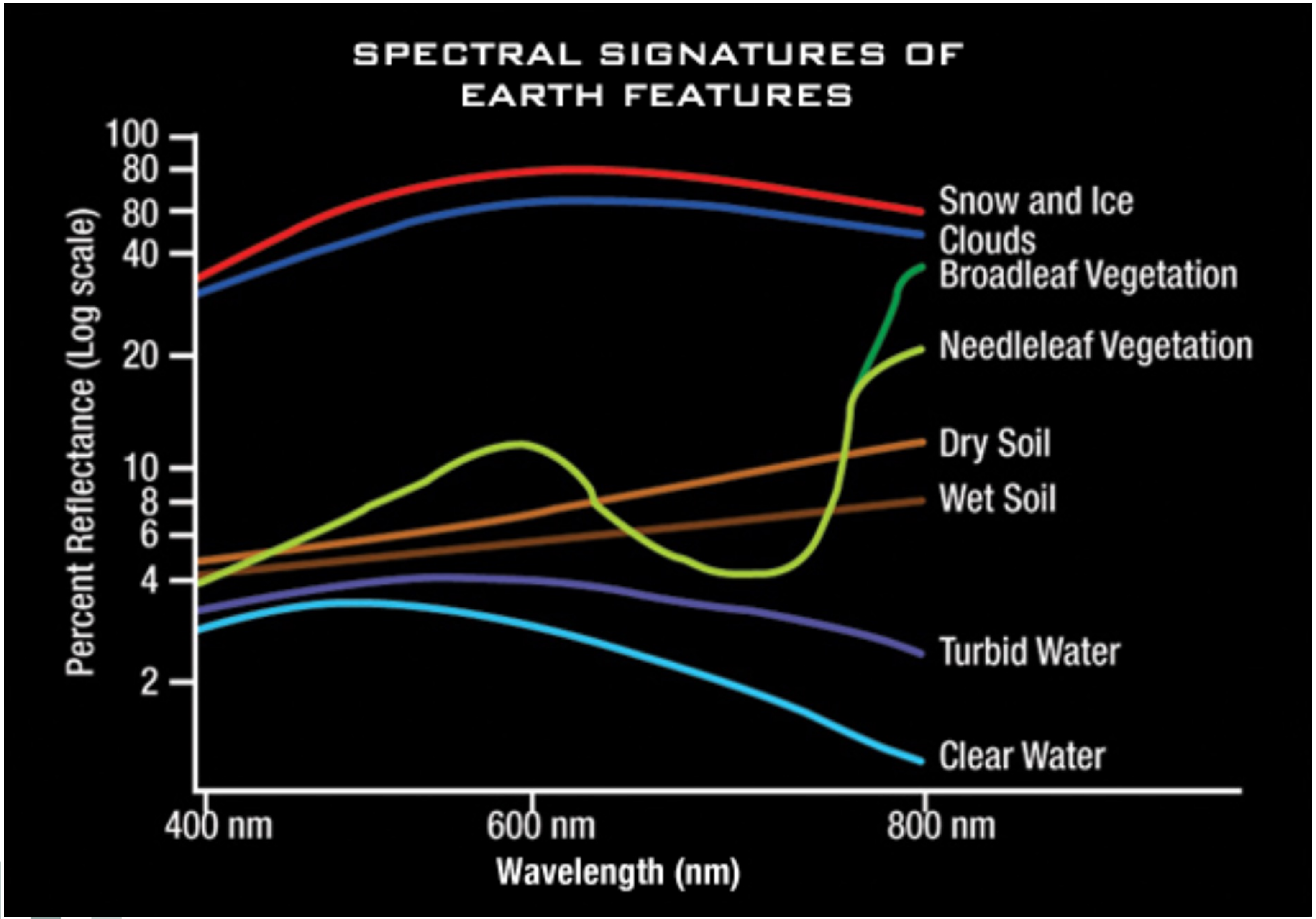
- The energy Earth receives from the Sun is called **electromagnetic radiation**.
- Radiation is reflected, absorbed, and emitted by the Earth's atmosphere or surface, as shown by the figure on the left.
- Satellites carry instruments or sensors that measure electromagnetic radiation reflected or emitted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

Electromagnetic Spectrum



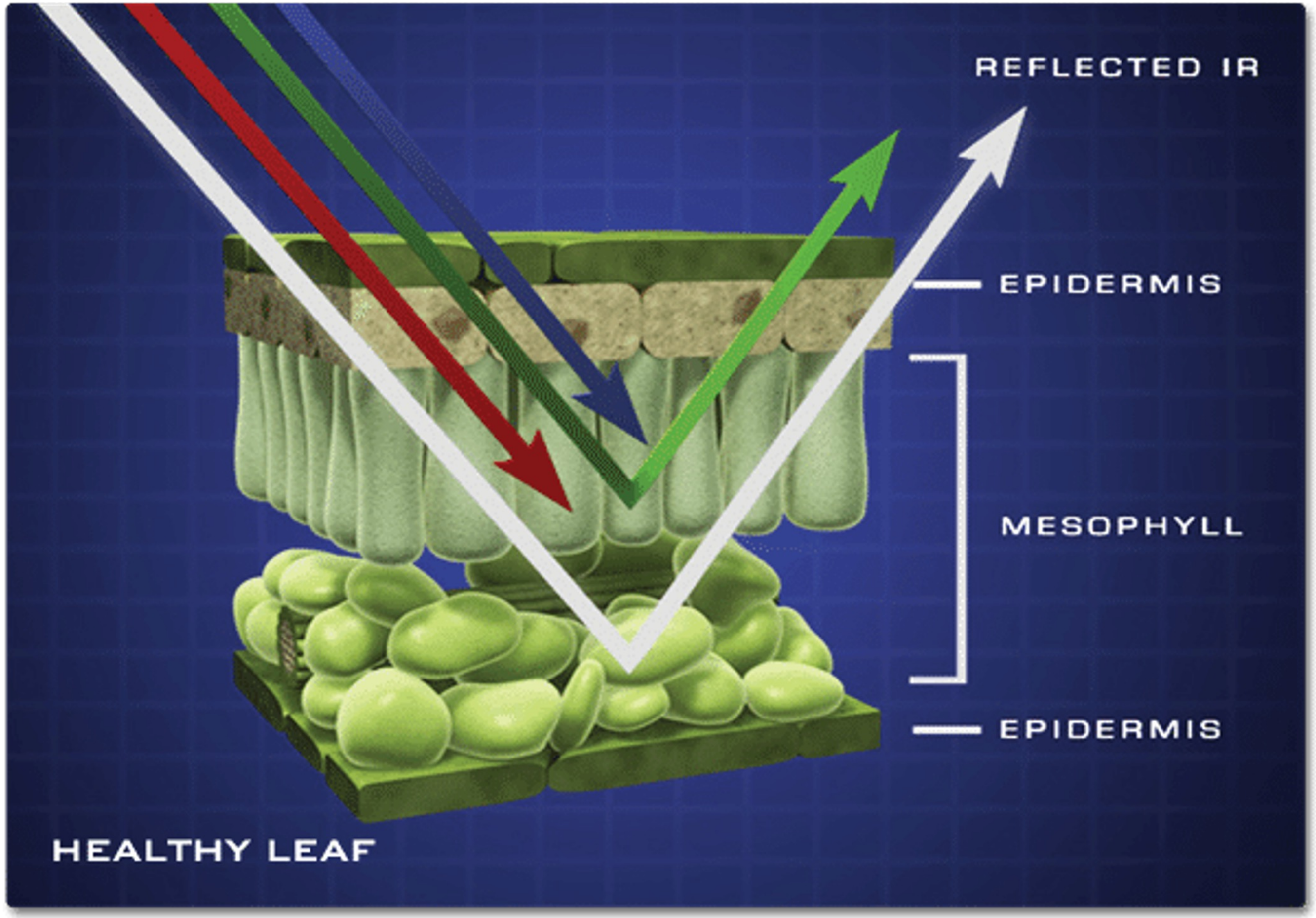
- The electromagnetic spectrum is simply the full range of **wave frequencies** that characterizes solar radiation.
- Although we are talking about light, most of the electromagnetic spectrum cannot be detected by the human eye. Even satellite detectors only capture a small portion of the entire electromagnetic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

Spectral Signatures



- 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.

Spectral Signature – Vegetation



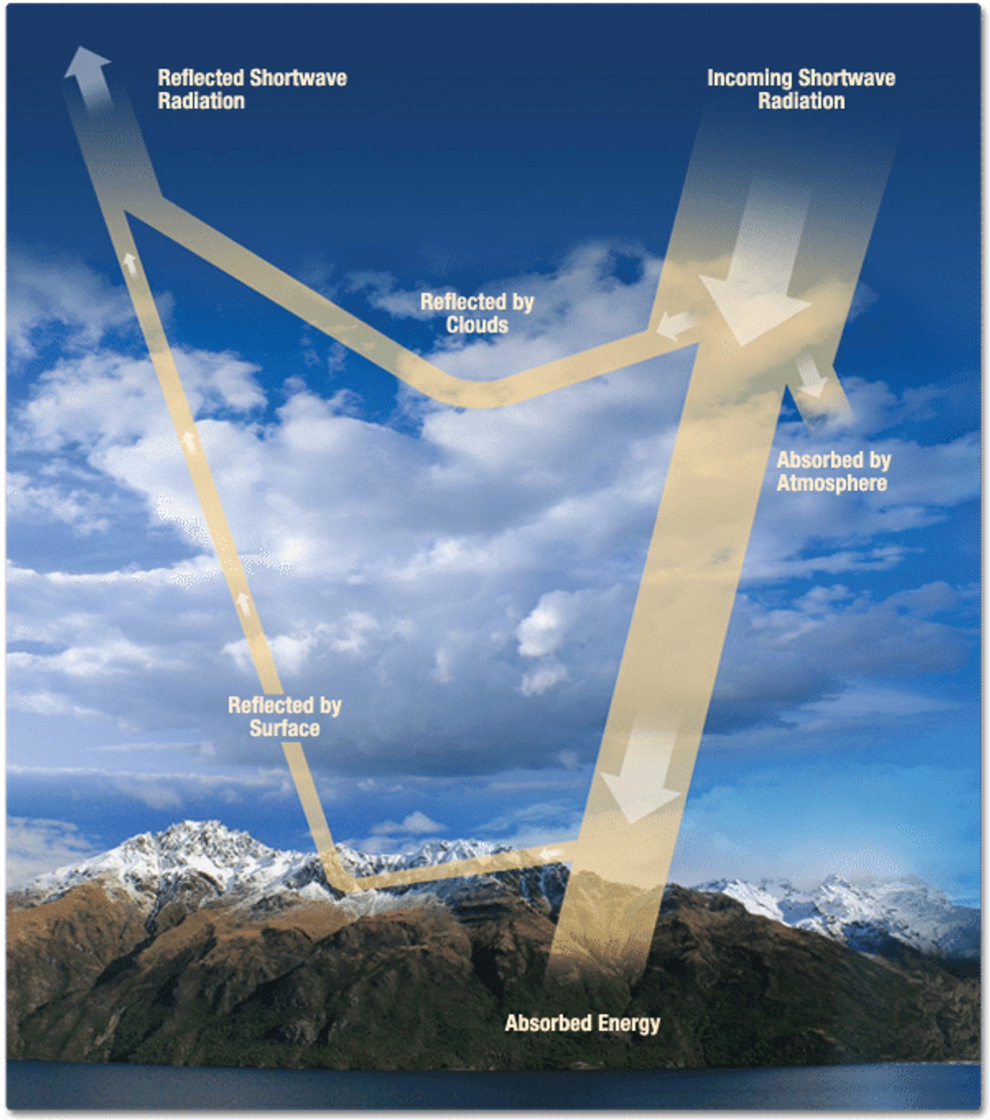
- Certain pigments in plant leaves strongly absorb wavelengths of visible (red) light.
- The leaves themselves strongly reflect wavelengths of near-infrared light, which is invisible to human eyes.
- Since we can't see infrared radiation, we see healthy vegetation as green.
- As a plant canopy changes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

Spectral Signature – Water

Image Credit: [NASA Earth Observatory](), using Landsat data courtesy of USGS.

- 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.

Spectral Signature – 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.

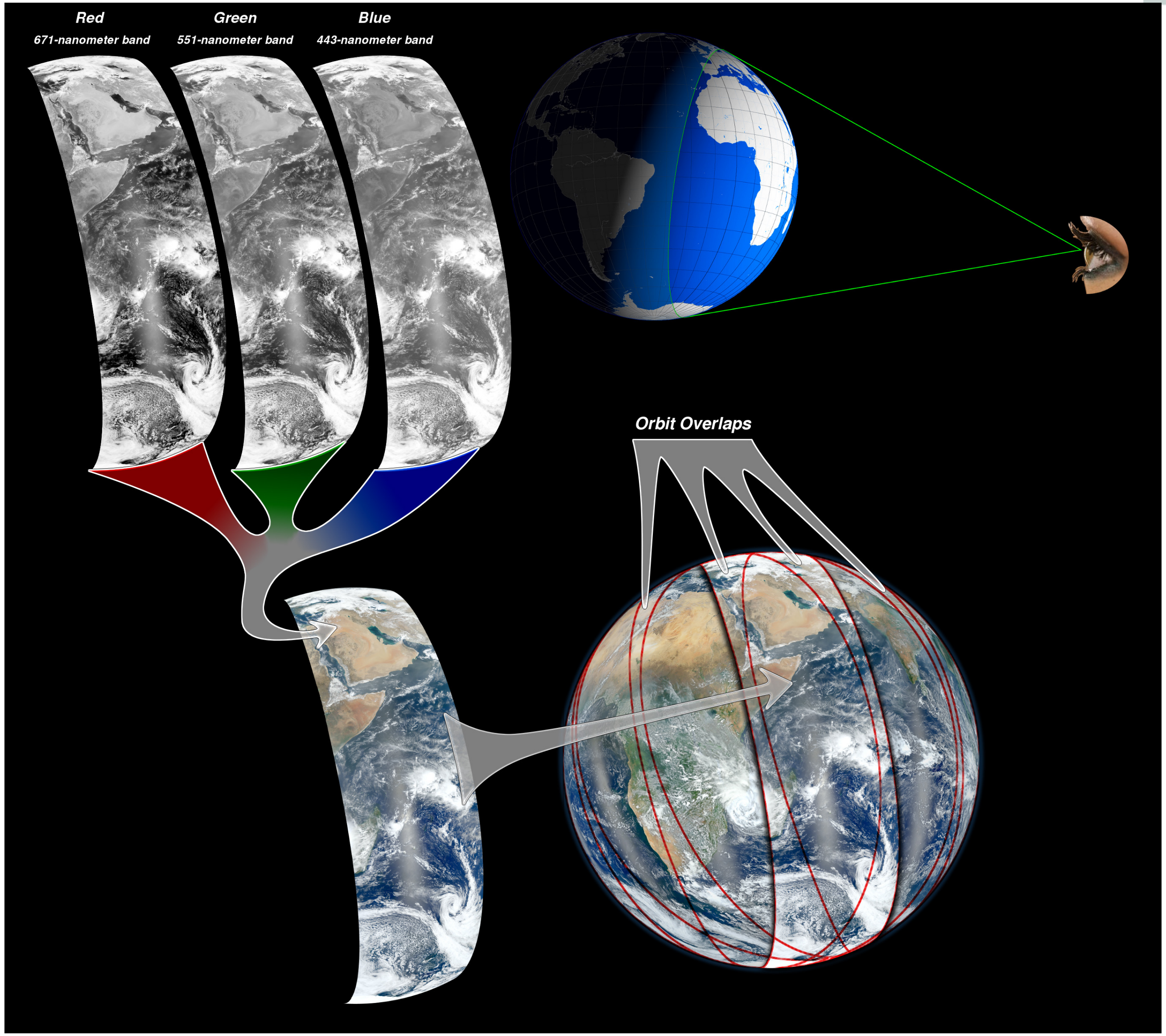
True Color Image (or RGB)

- A Moderate Resolution Imaging Spectroradiometer (MODIS) “true color image” will use visible wavelength bands.

R = 0.66 μm

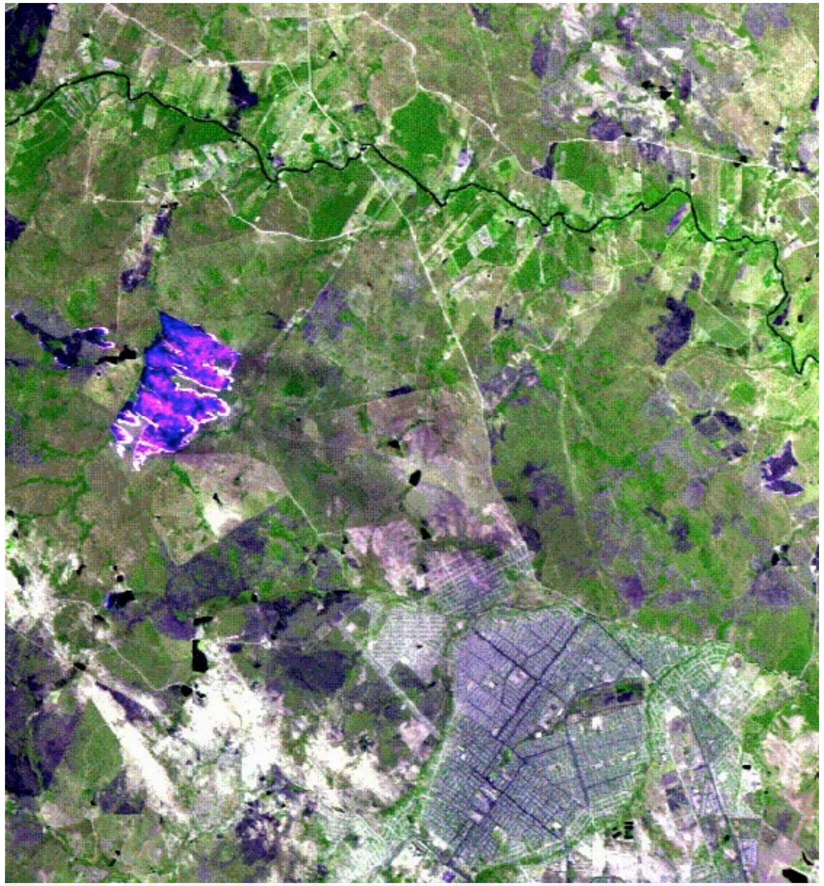
G = 0.55 μm

B = 0.47 μm



True- vs. False-Color Images

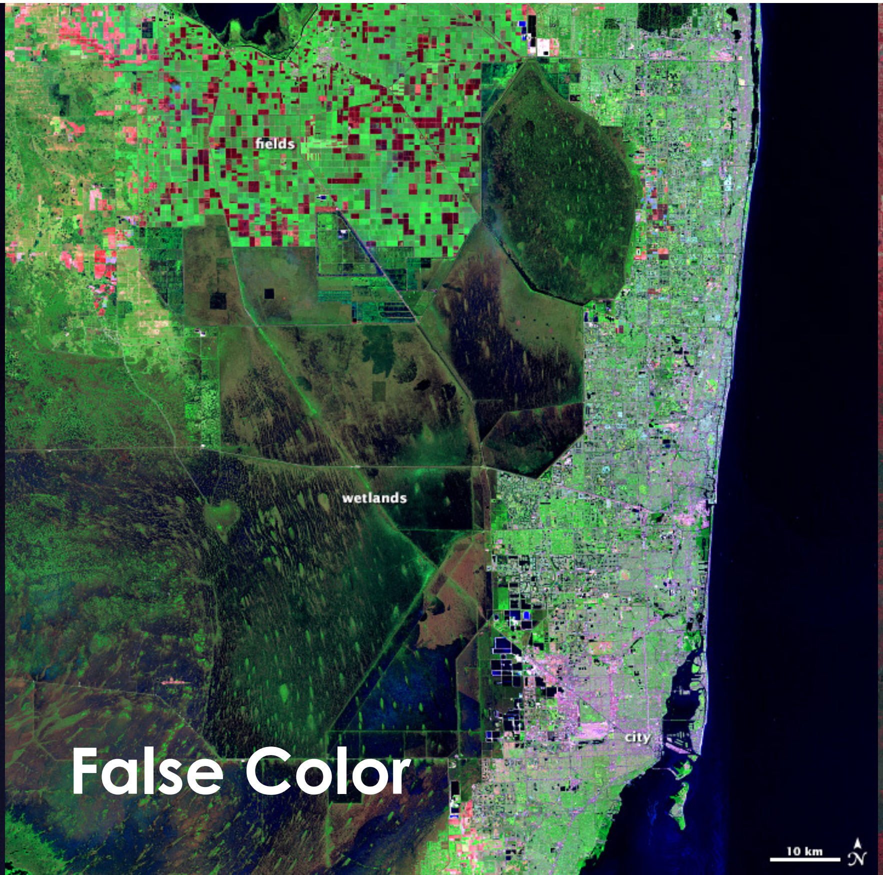
R = 0.66 µm (Red)
G = 0.55 µm (Green)
B = 0.47 µm (Blue)



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

False-Color Satellite Images

- 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.

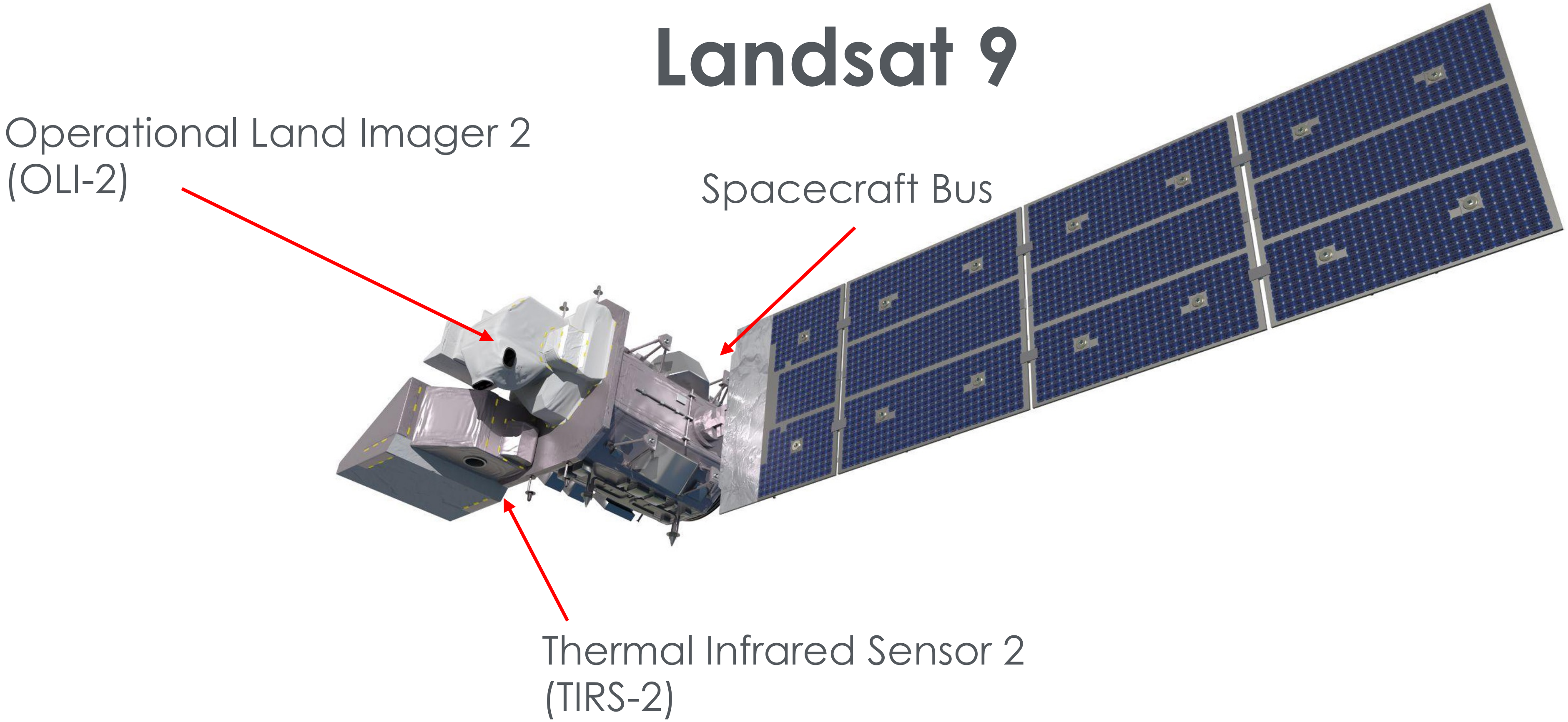
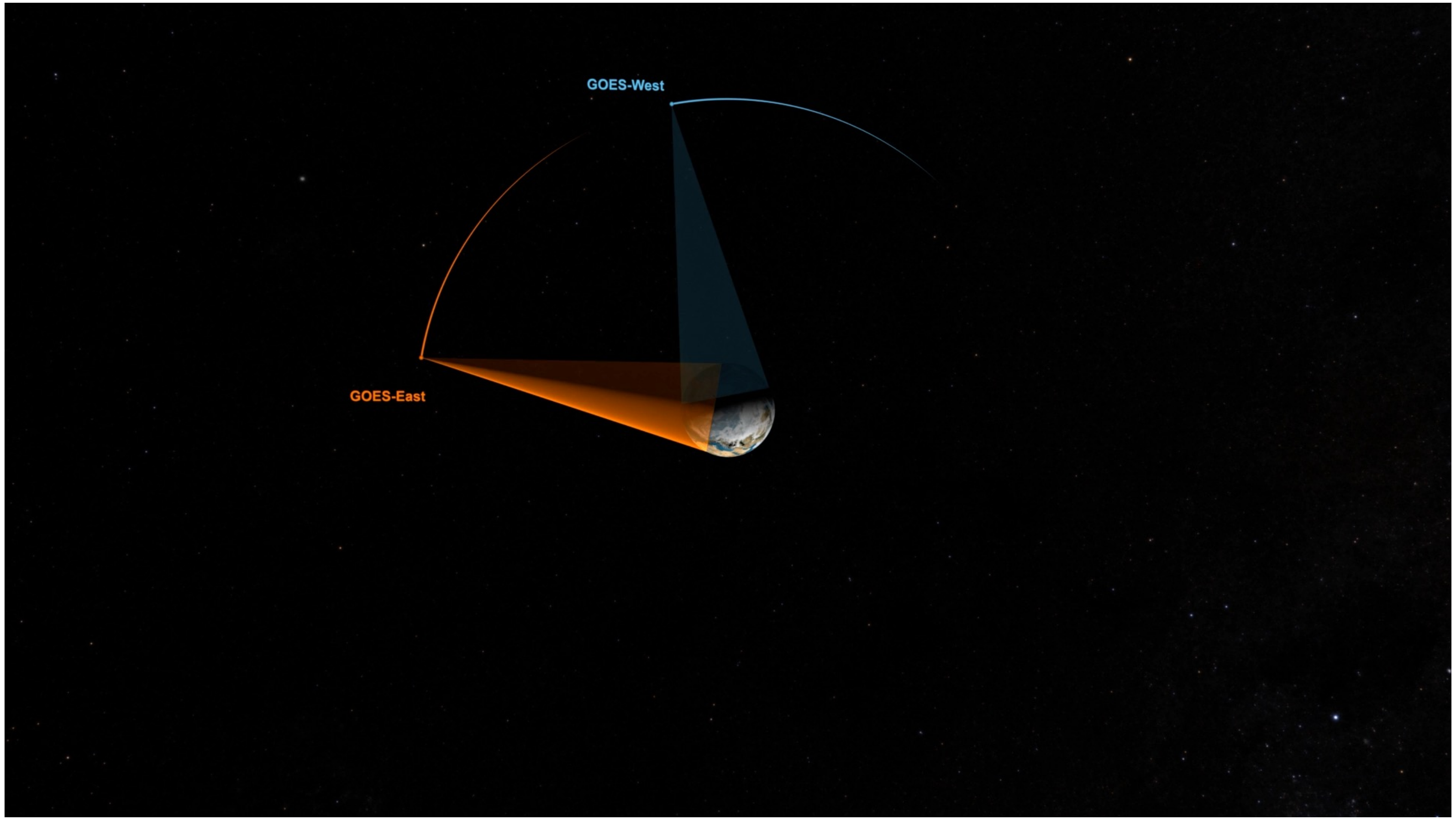


Image Credit: [NASA]

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; Imagers; Sounders
- **Resolution Type and Quality:** Spatial, Temporal, Spectral, Radiometric
- **Application:** Weather, Ocean Color, Land Mapping, Air Quality, Radiation Budget, etc.

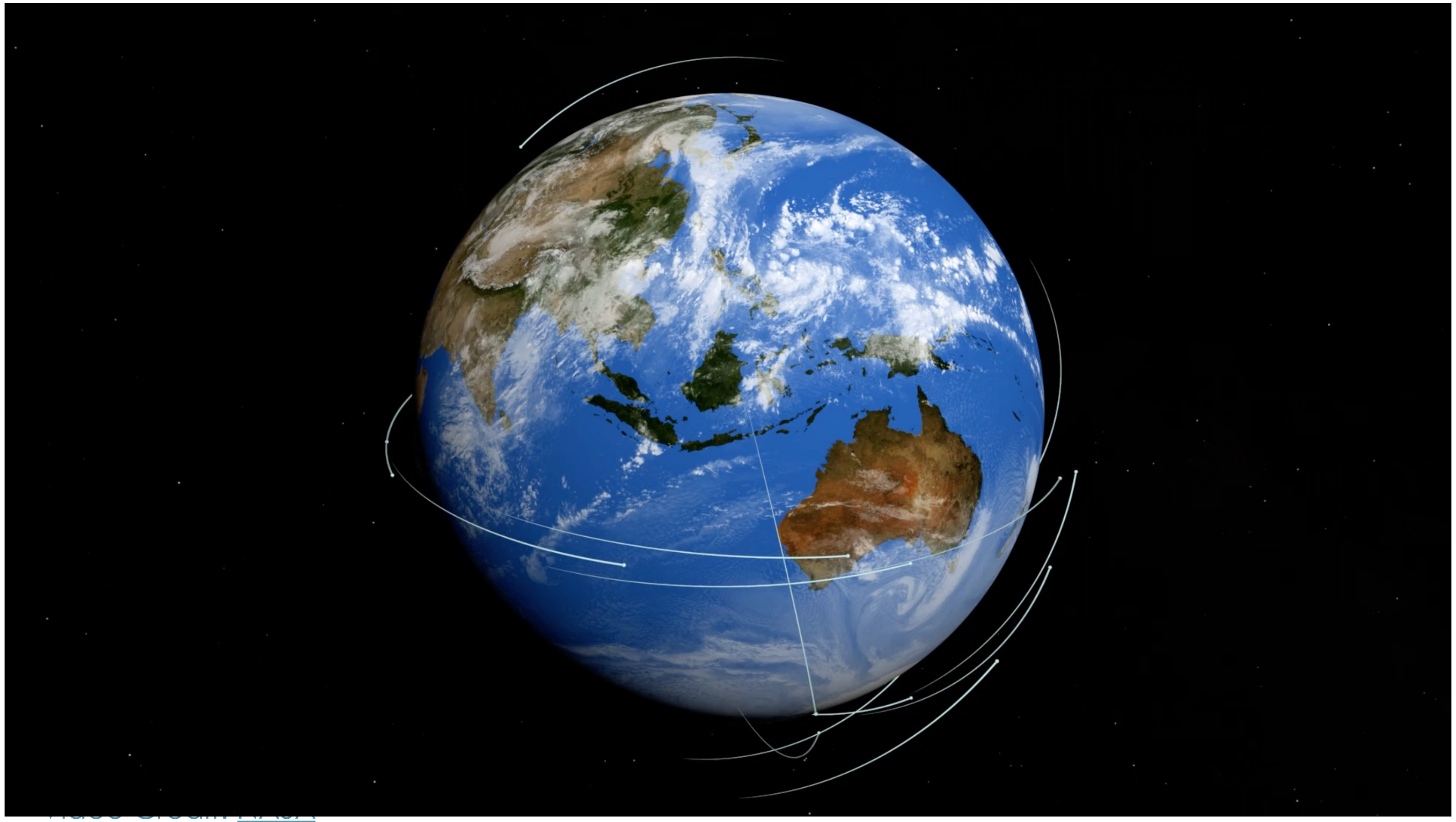
Geostationary Orbit (GEO)



Video Credit: NASA

- 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

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

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 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

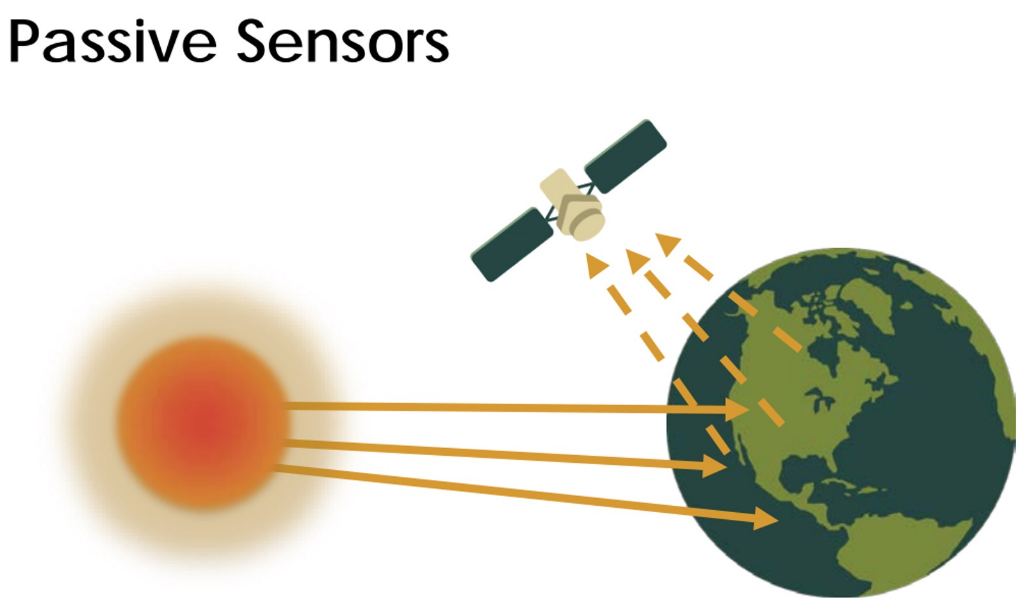


Image Credit: ARSET

Satellite 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

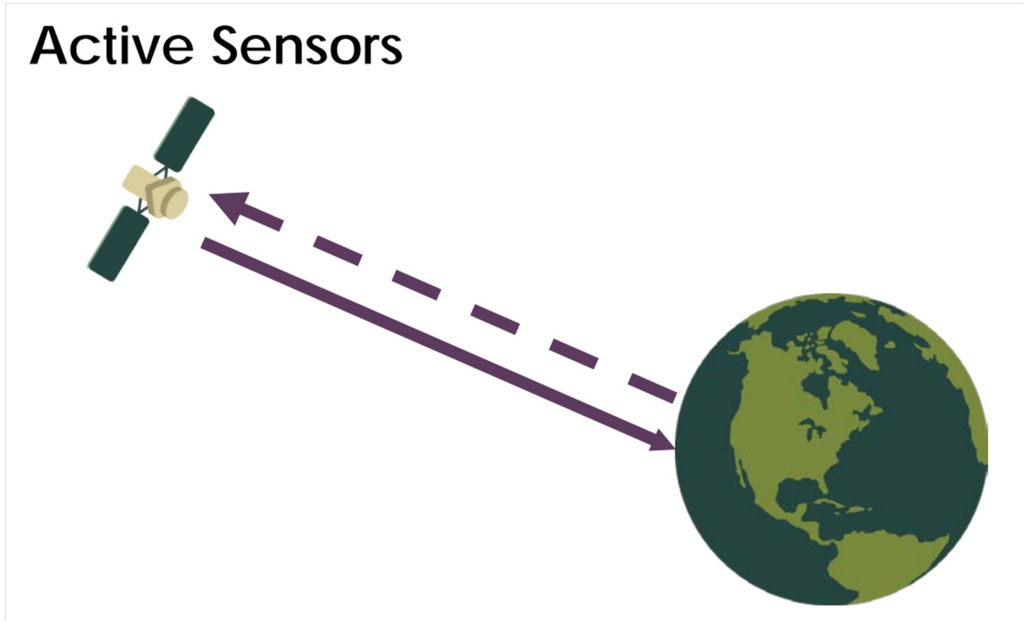
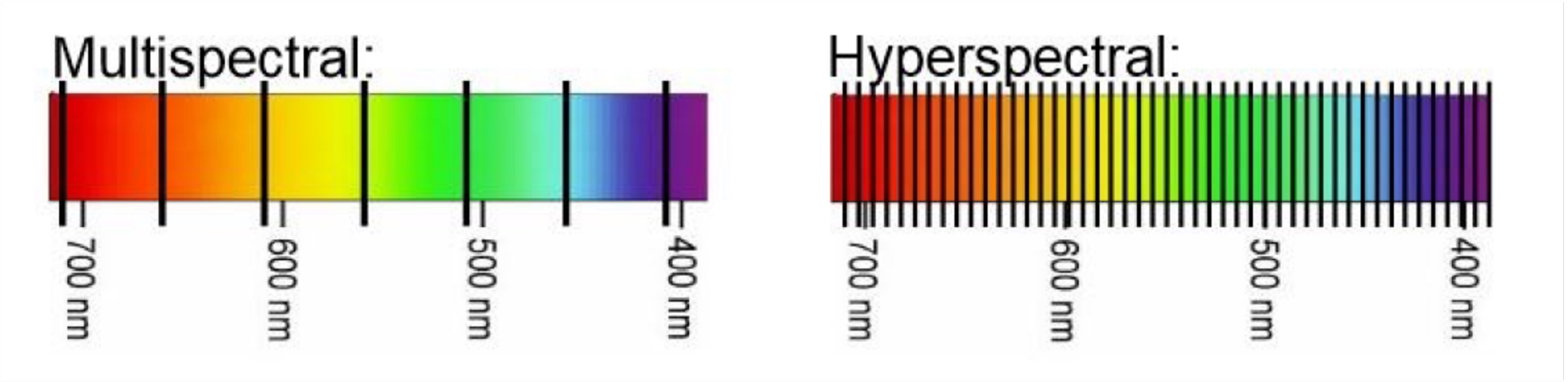


Image Credit: ARSET

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.



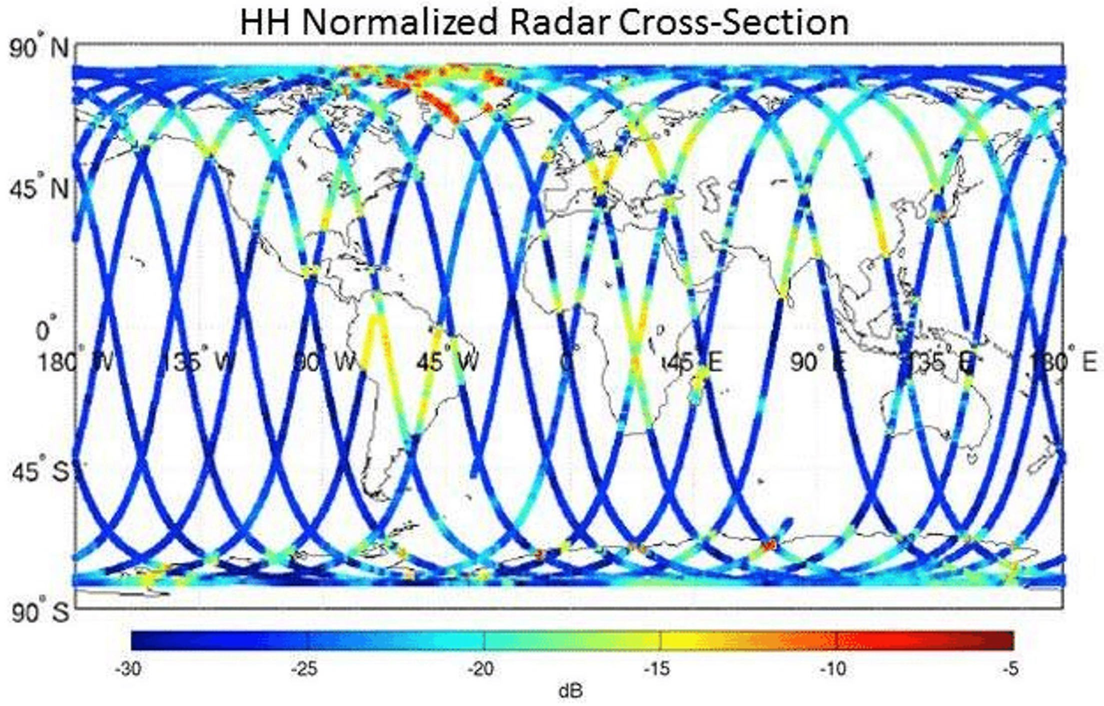
Spatial Resolution

- Different sensors have different resolutions.
- Signifies the ground surface area that forms one pixel in the image.
- The higher the spatial resolution, the less area is covered by a single pixel.
- The image on the right shows the same image at different spatial resolutions: (from left to right) 1 m, 10 m, and 30 m.

Image Credit: csc.noaa.gov

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.

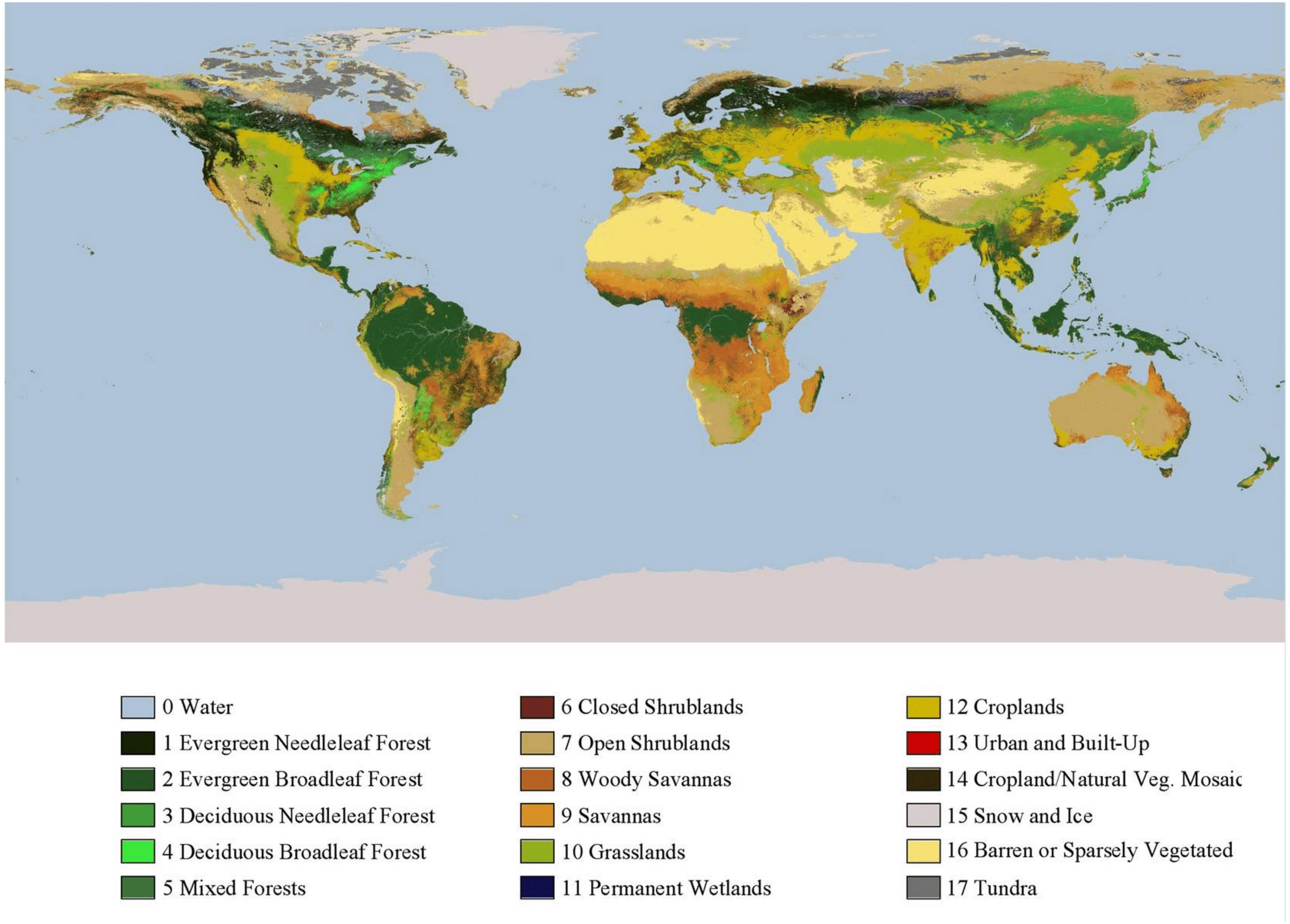


Image Credit: NASA GSFC

Disadvantages of Remote Sensing

- It is very difficult to obtain high spectral, spatial, temporal, and radiometric resolution all at the same time.
- Limited by atmospheric conditions, such as cloud cover or haze.
- 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.

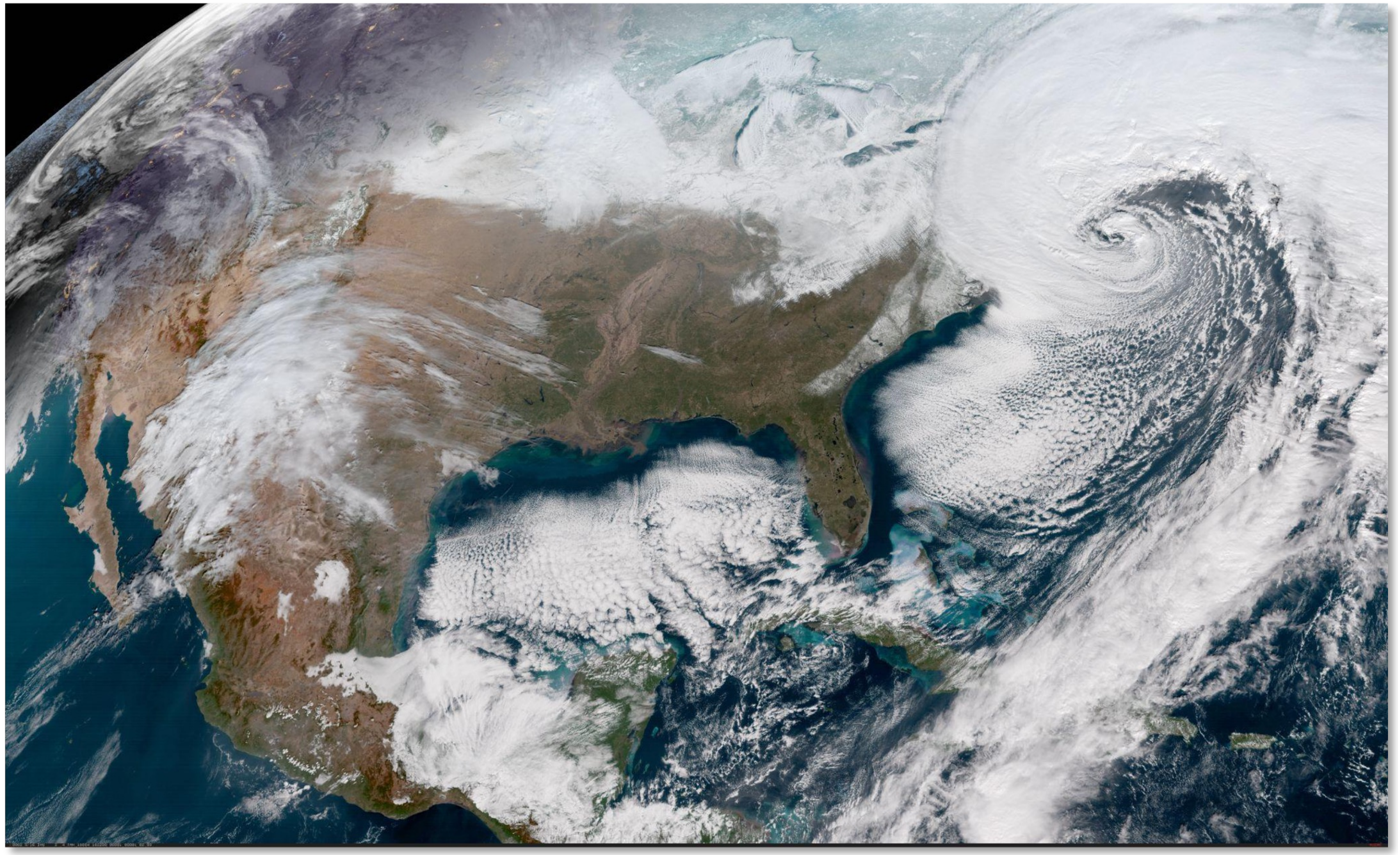
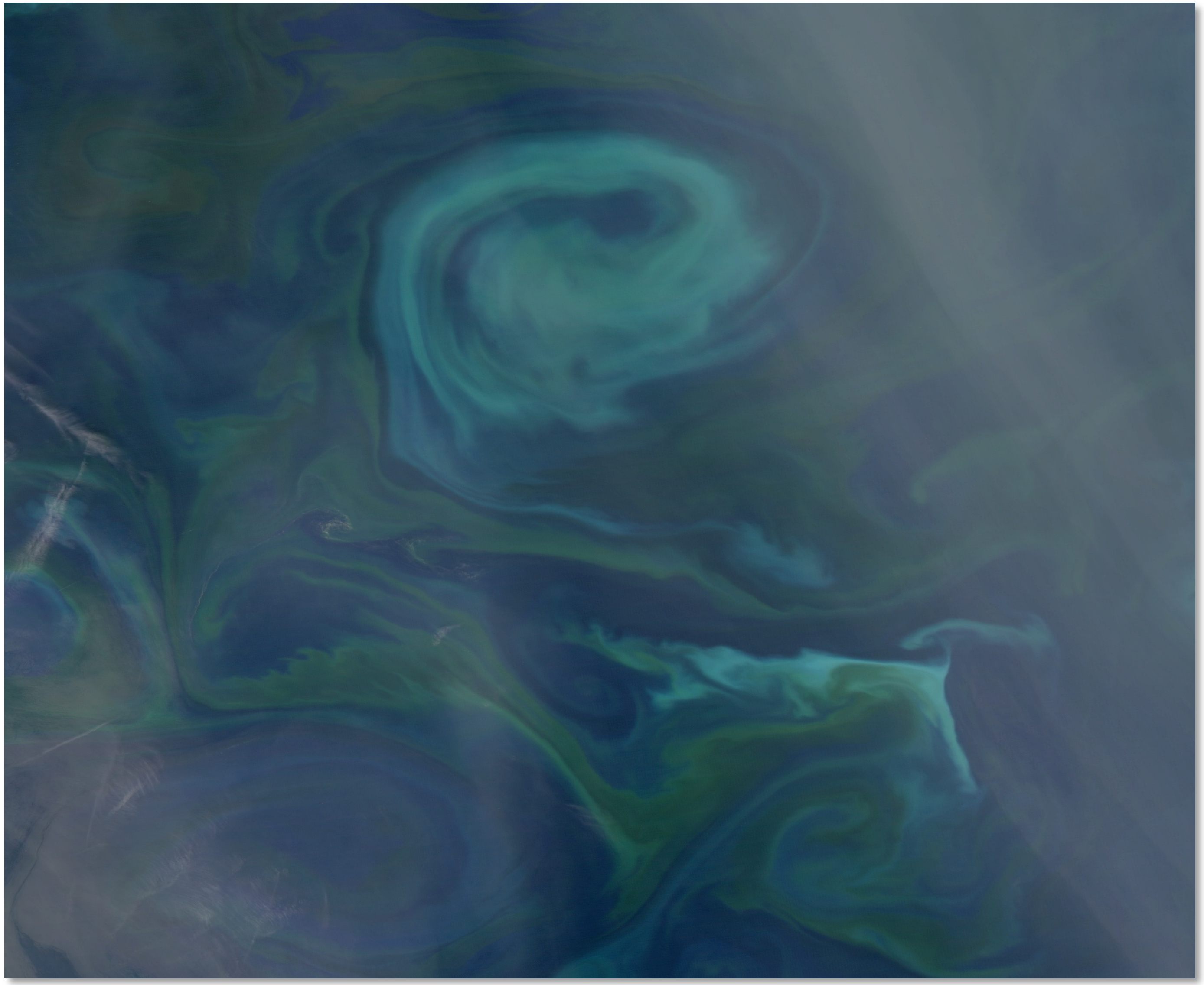


Image Credit: NOAA

Remote Sensing Game

What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



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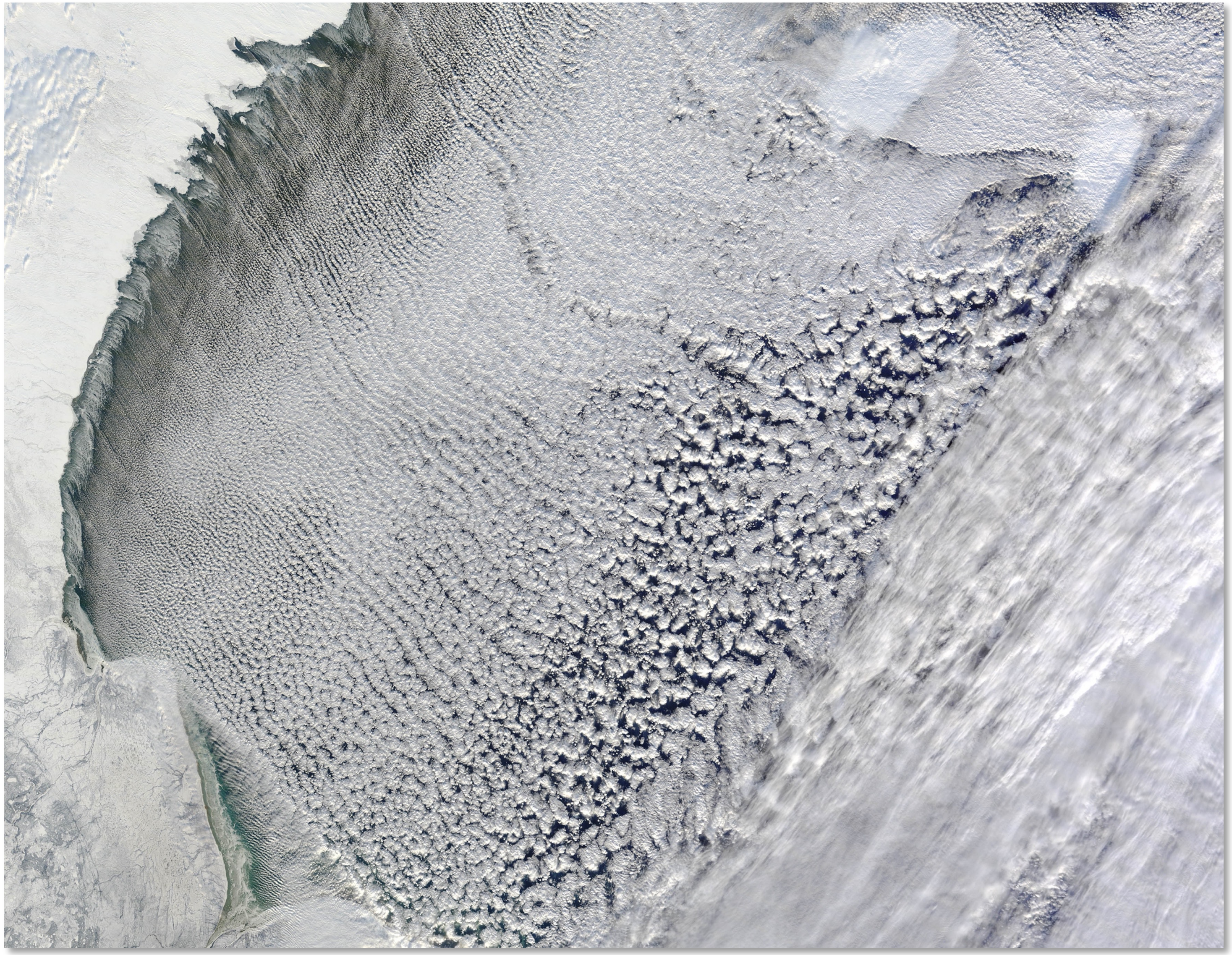

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