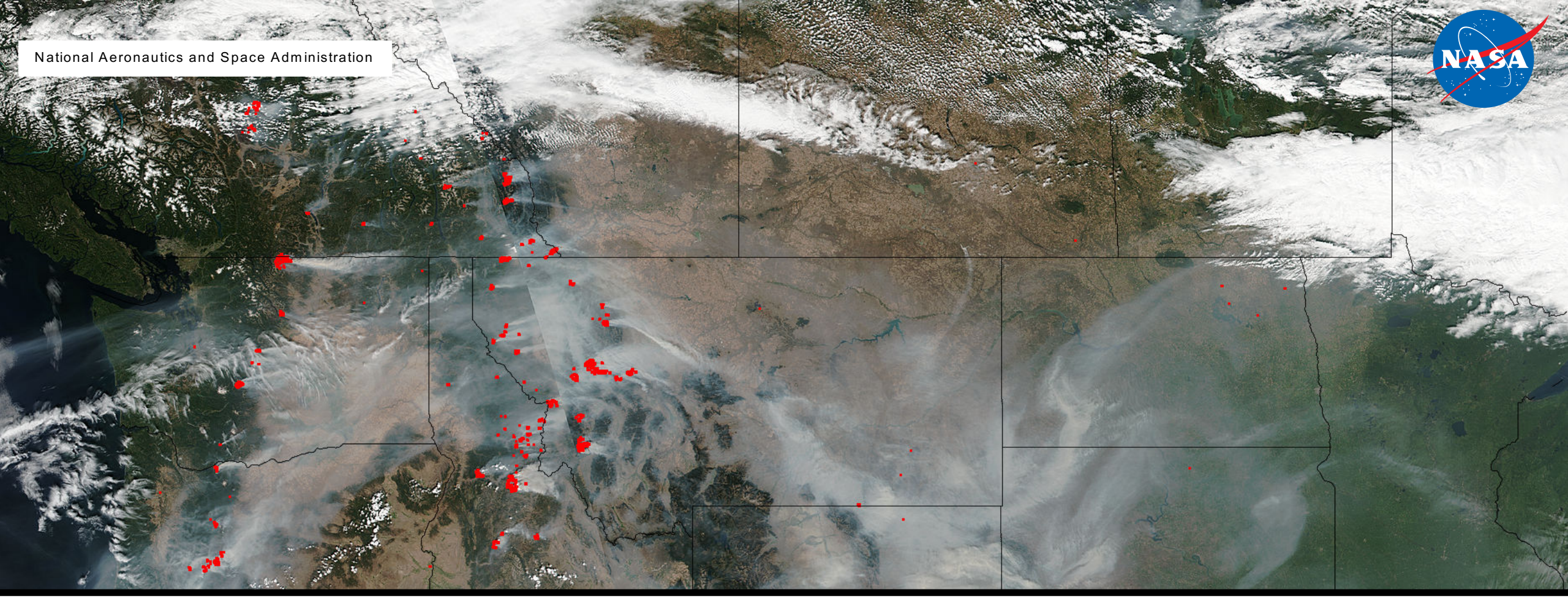


Fundamentals of Satellite Remote Sensing

Pawan Gupta, and Melanie Follette-Cook

Satellite Remote Sensing of Dust, Fires, Smoke, and Air Quality, July 10-12, 2018

Objectives

By the end of this presentation, you will be able to:

- outline what the electromagnetic spectrum is
- outline how satellites detect radiation
- name the different types of satellite resolutions

What is remote sensing?

Collecting information about an object without being in direct physical contact with it

What is remote sensing?

Collecting information about an object without being in direct physical contact with it

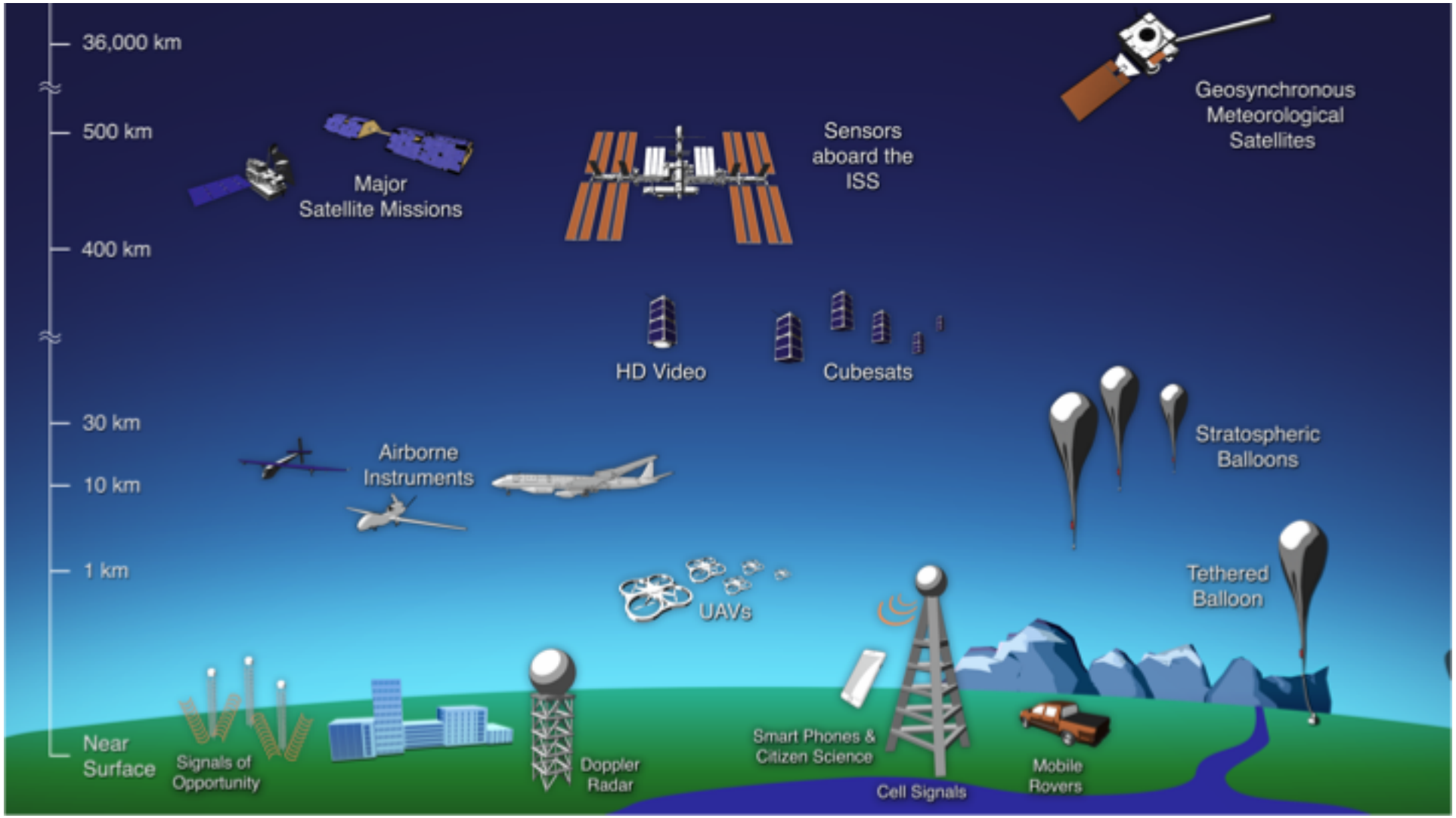
Remote Sensing: Platforms




http://www.nrcan.gc.ca/node/9295

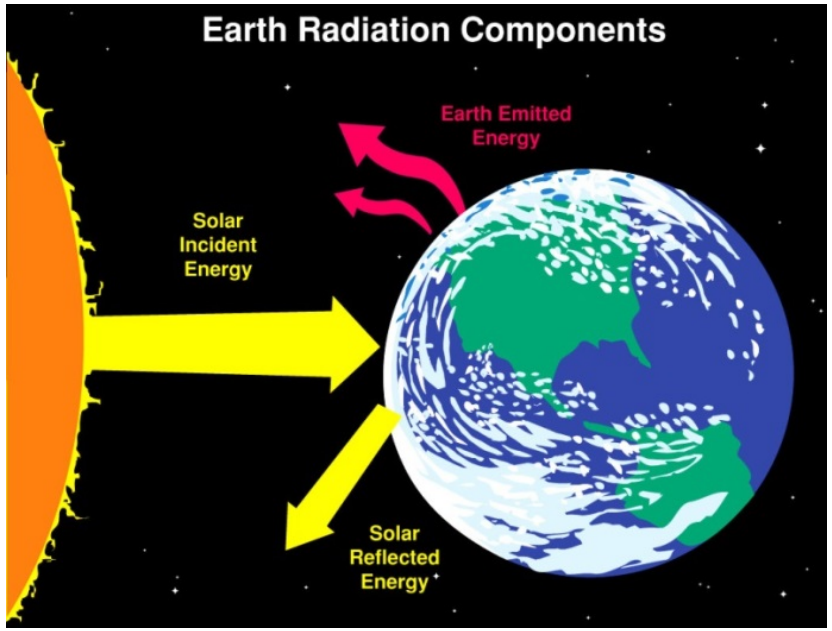
- The platform depends on the end application
- What information do you want?
- How much detail do you need?
- What type of detail?
- How frequently do you need this data?

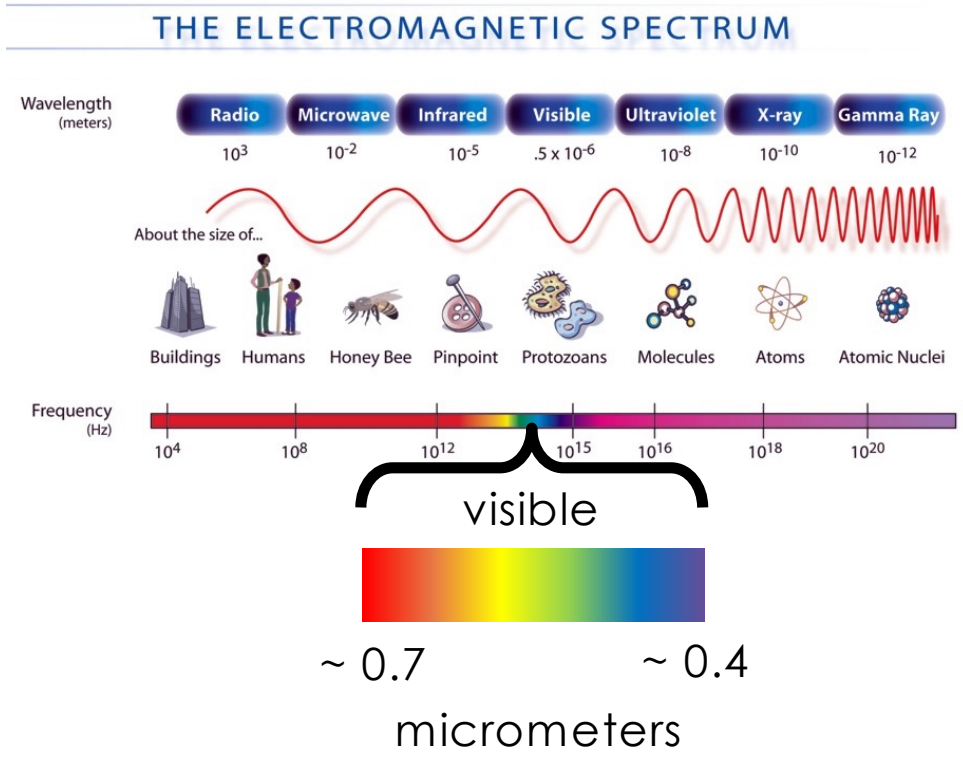
Remote Sensing of Our Planet



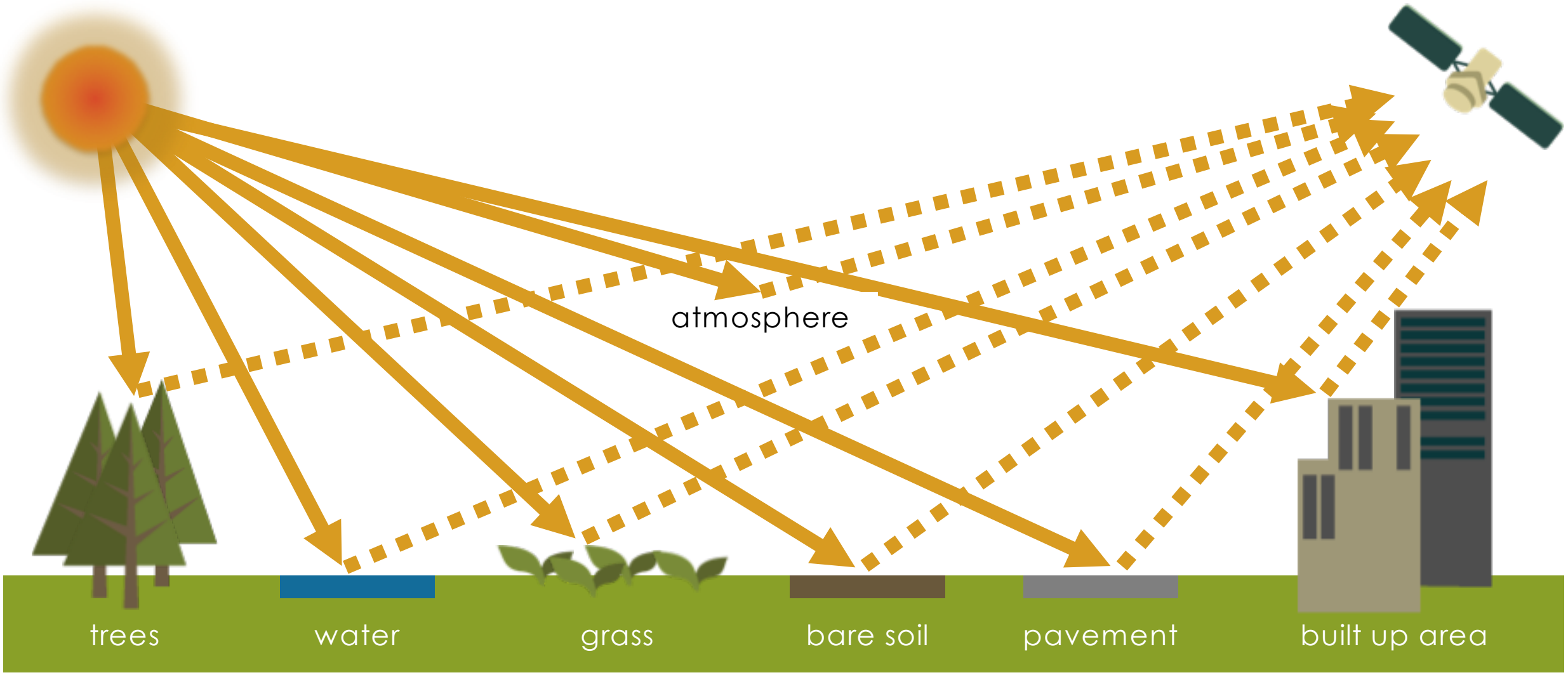
Electromagnetic Radiation

- Earth-Ocean-Land-Atmosphere System
  - Reflects solar radiation back into space
  - Emits infrared and microwave radiation into space



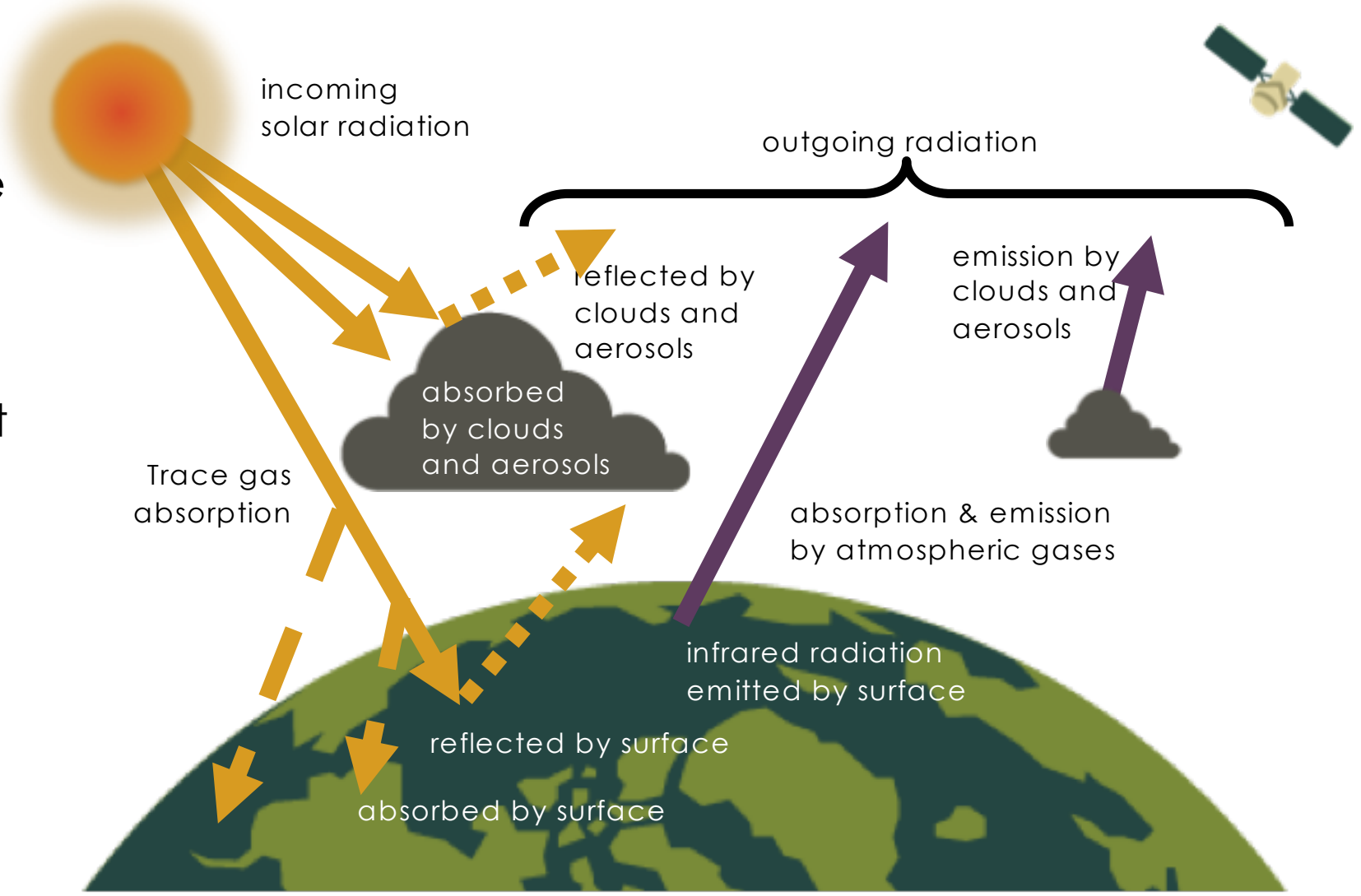


What do satellites measure ?

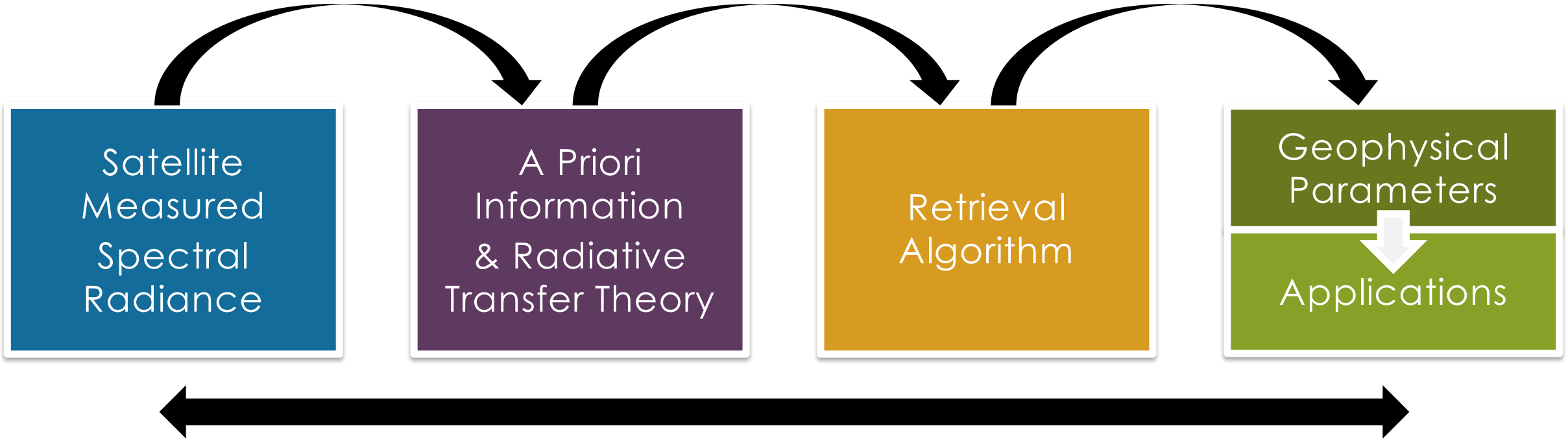


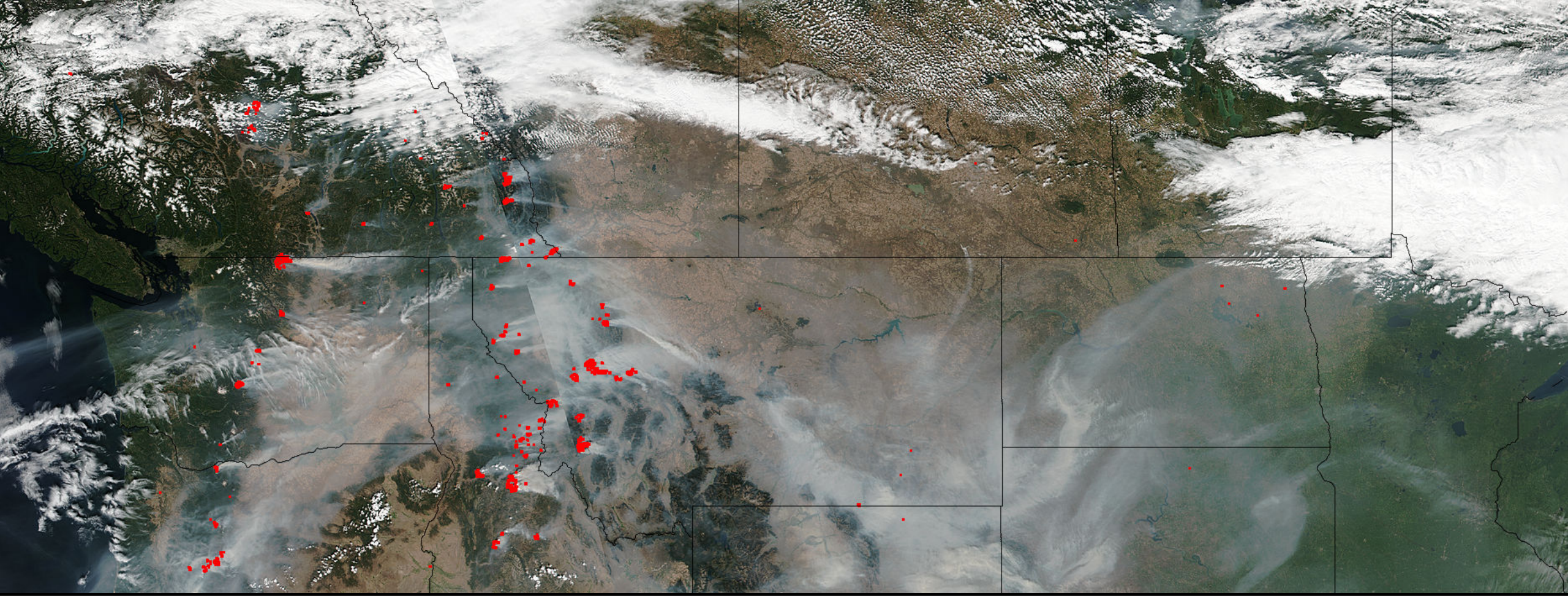
Measuring Properties of the Earth-Atmosphere System from Space

- The intensity of reflected and emitted radiation to space is influenced by the surface and atmospheric conditions
- Satellite measurements contain information about the surface and atmospheric conditions



The Remote Sensing Process





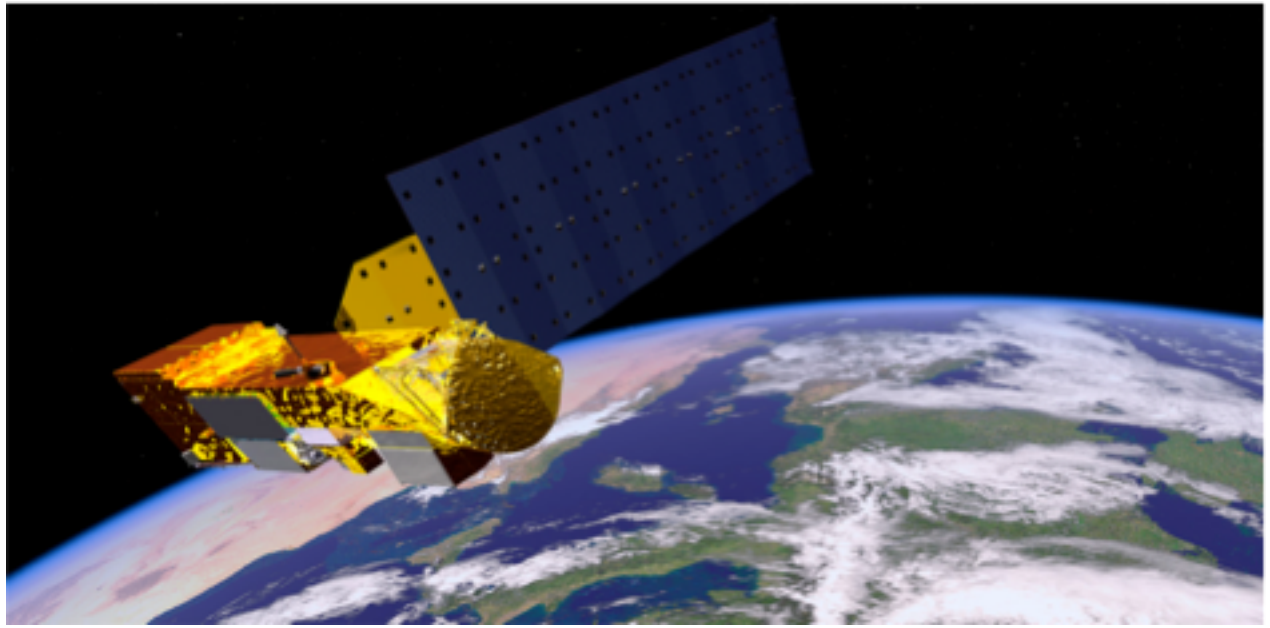
Satellites, Sensors, and Orbits

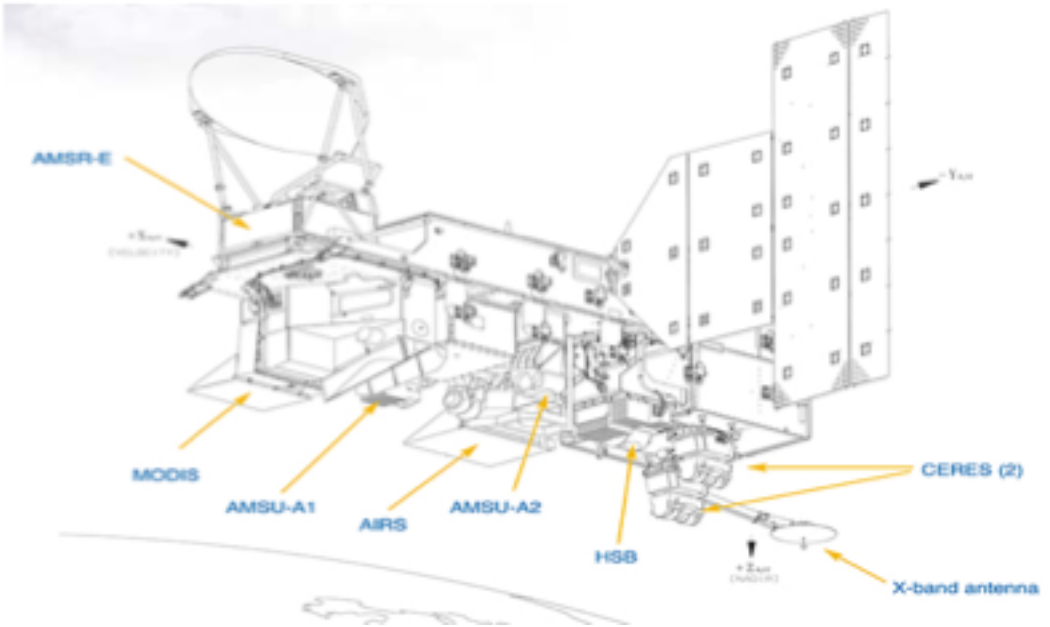
Satellites vs. Sensors

Earth-observing satellite remote sensing instruments are named according to:

1. the satellite (platform)
2. the instrument (sensor)

Aqua Satellite

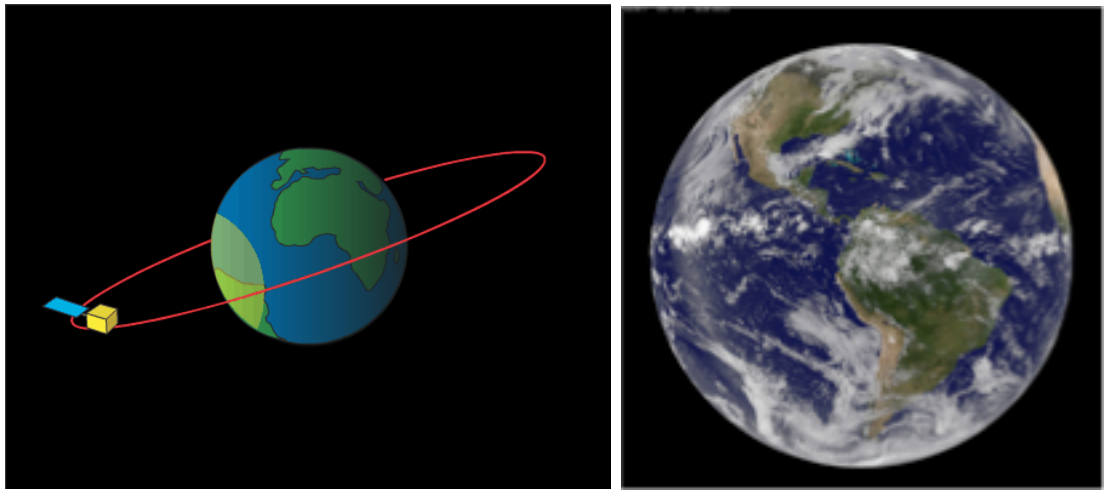




Characterizing Satellites and Sensors

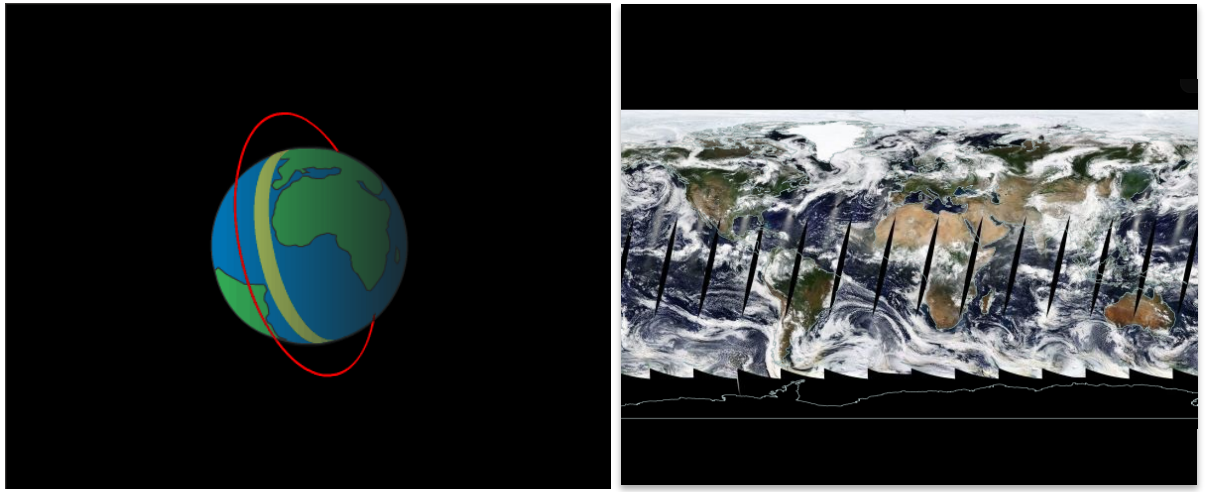
- **Orbits**
  - Polar vs. Geostationary
- **Energy Sources**
  - Passive vs. Active
- **Solar and Terrestrial Spectra**
  - Visible, UV, IR, Microwave…
- **Measurement Techniques**
  - Scanning, Non-Scanning, Imager, Sounders...
- **Resolution (Spatial, Temporal, Spectral, Radiometric)**
  - Low vs. High
- **Applications**
  - Weather, Land Mapping, Atmospheric Physics, Atmospheric Chemistry, Air Quality, Radiation Budget...

Common Orbit Types



Geostationary Orbit

- Has the same rotational period as Earth
- Appears 'fixed' above Earth
- Orbits ~36,000 km above the equator



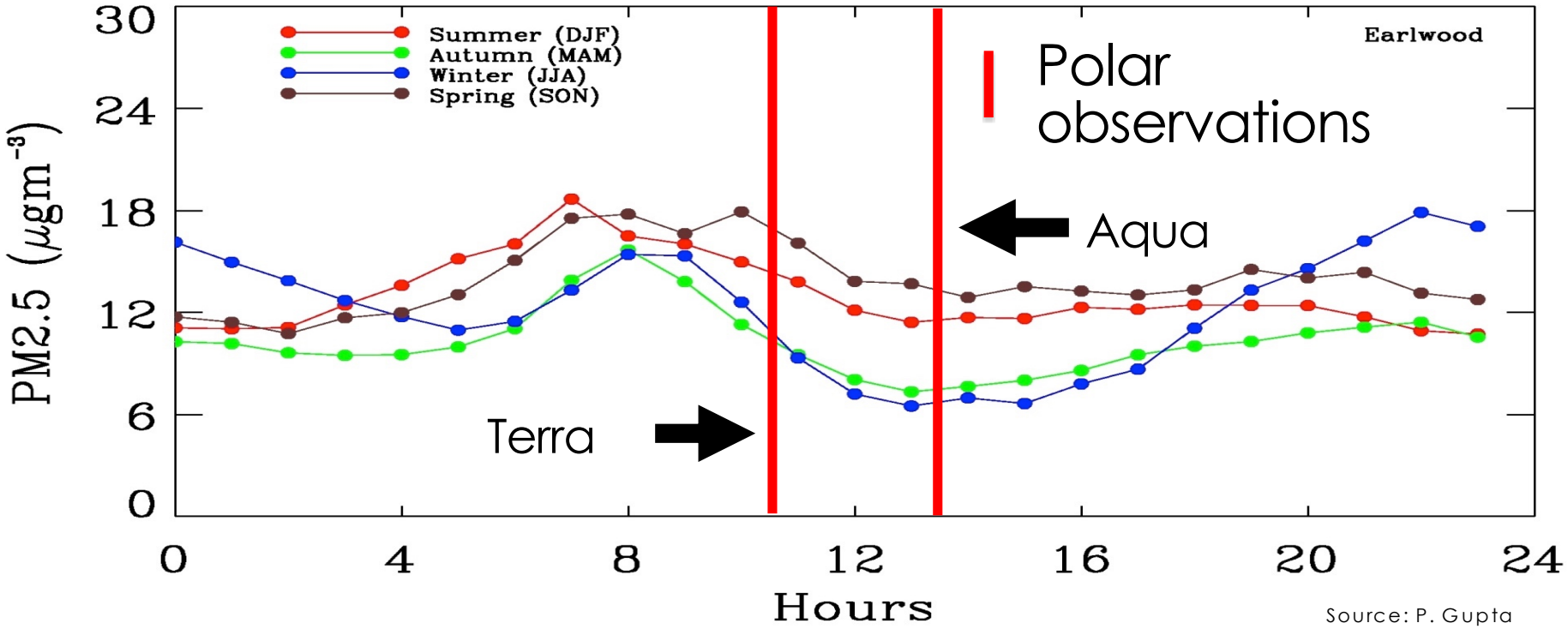
Polar Orbit

- Fixed, circular orbit above Earth
- Sun synchronous orbit ~600-1,000 km above Earth with orbital passes are at about the same **local solar time** each day

Aqua Satellite Orbiting the Earth

Observation Frequency

Polar Orbiting Satellites: 1-3 observations per day, per sensor

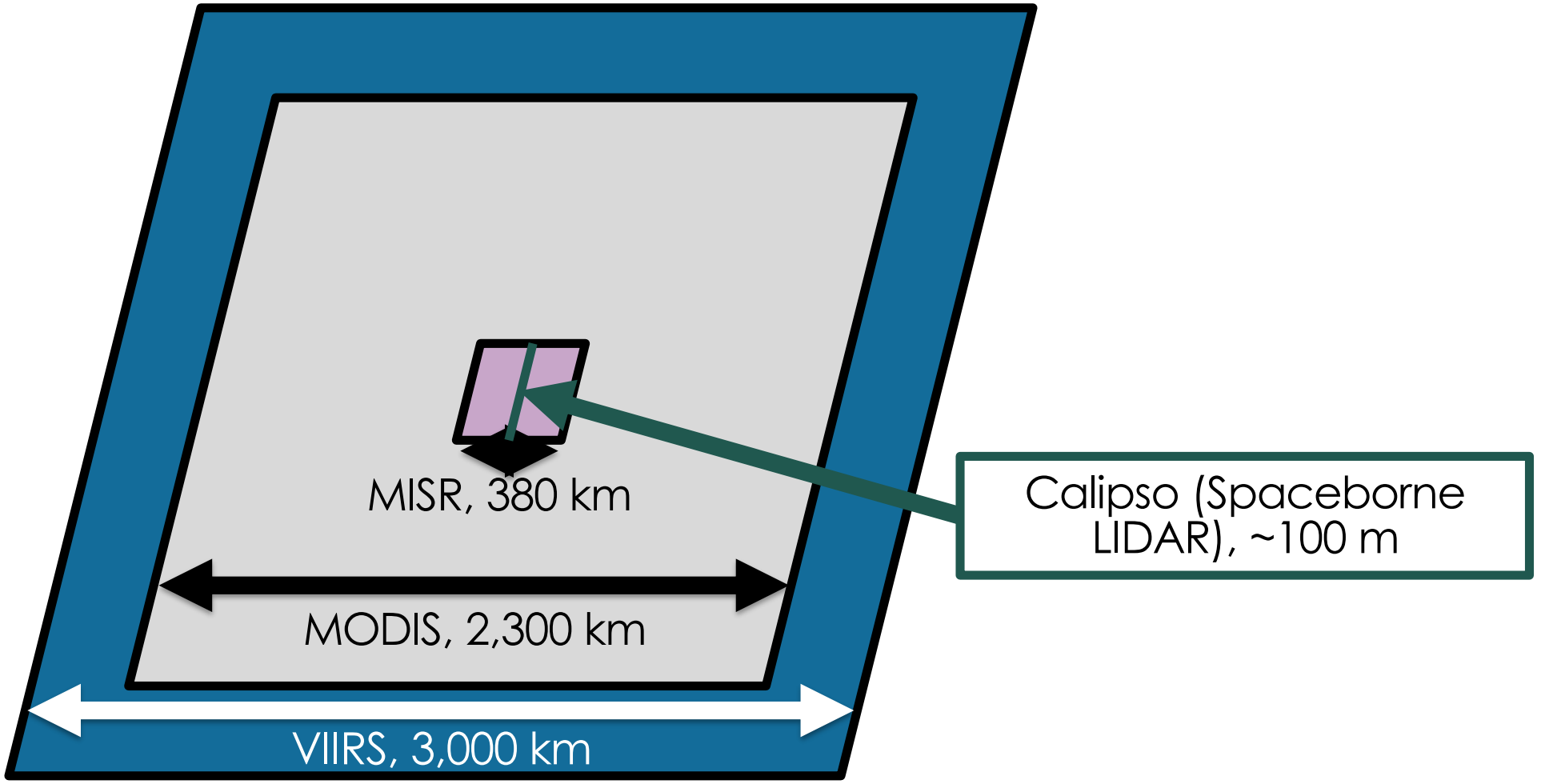


Source: P. Gupta

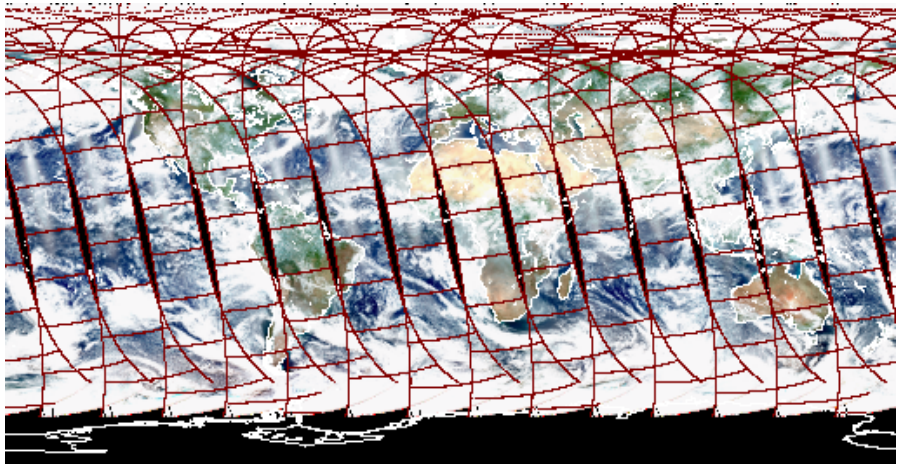
Geostationary Satellites: Every 30 sec. to 15 min.

Future Geo satellites: TEMPO, GEMS, Sentinel-4

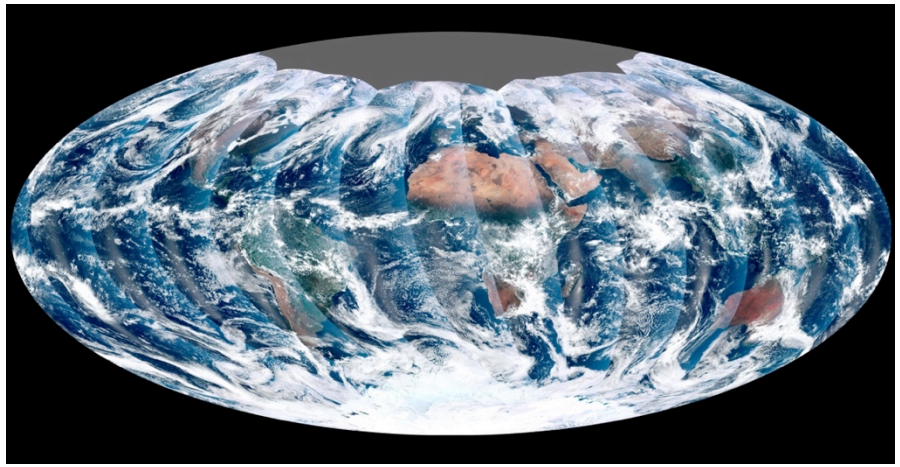
Satellite Coverage – Swath Width



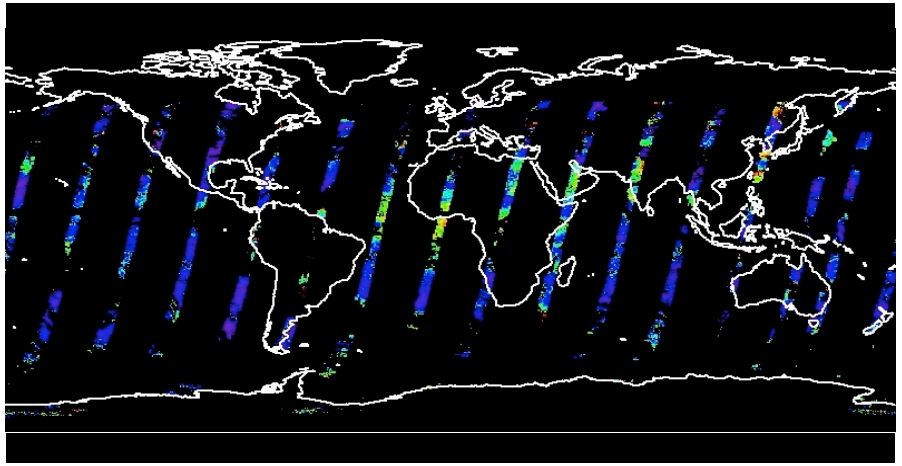
Satellite Coverage



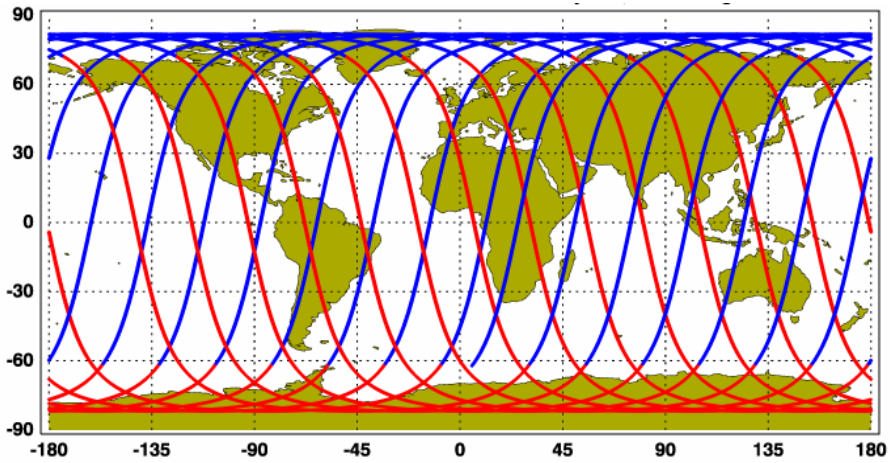
MODIS



VIIRS



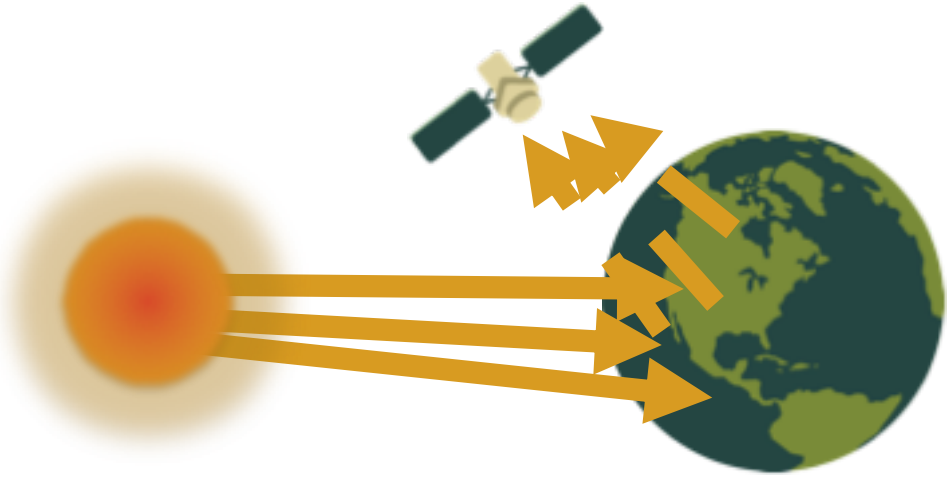
MISR



CALIPSO

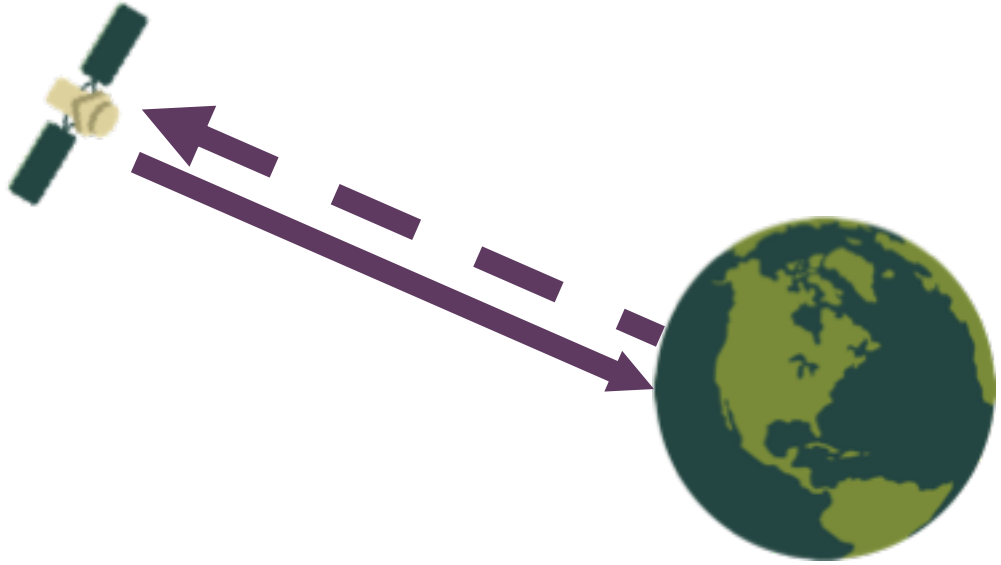
Active & Passive Sensors

Passive Sensors



- Detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun)
- Examples: (**MODIS**, **MISR**, **OMI**, **VIIRS**)

Active Sensors

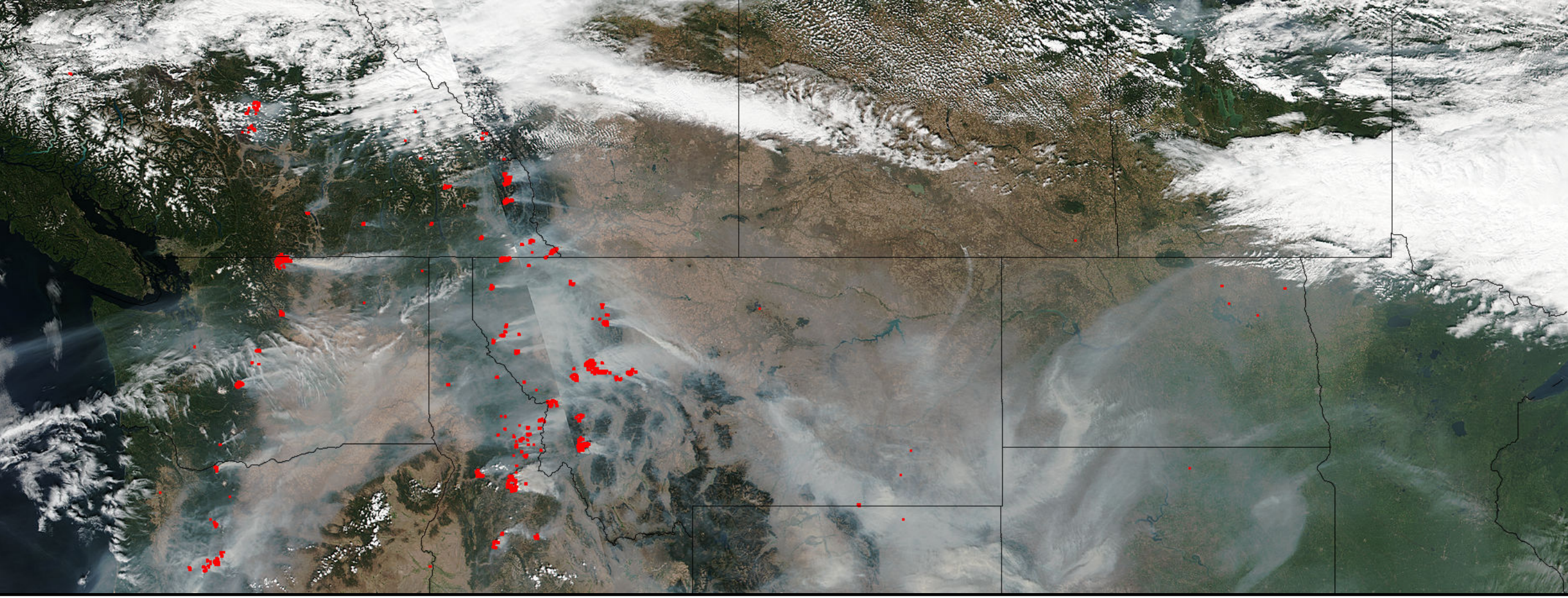


- Instruments emit their own signal and the sensor measures what is reflected back (e.g. sonar and radar)
- Example: **CALIPSO**

Active & Passive Sensors

Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.



Resolution

Remote Sensing – Types of Resolution

- **Spatial Resolution**
  - Smallest spatial measurement
- **Temporal Resolution**
  - Frequency of measurement
- **Spectral Resolution**
  - Number of independent channels
- **Radiometric Resolution**
  - Sensitivity of the detectors

Each resolution depends on the satellite orbit configuration and sensor design.
Resolutions are different for different sensors.

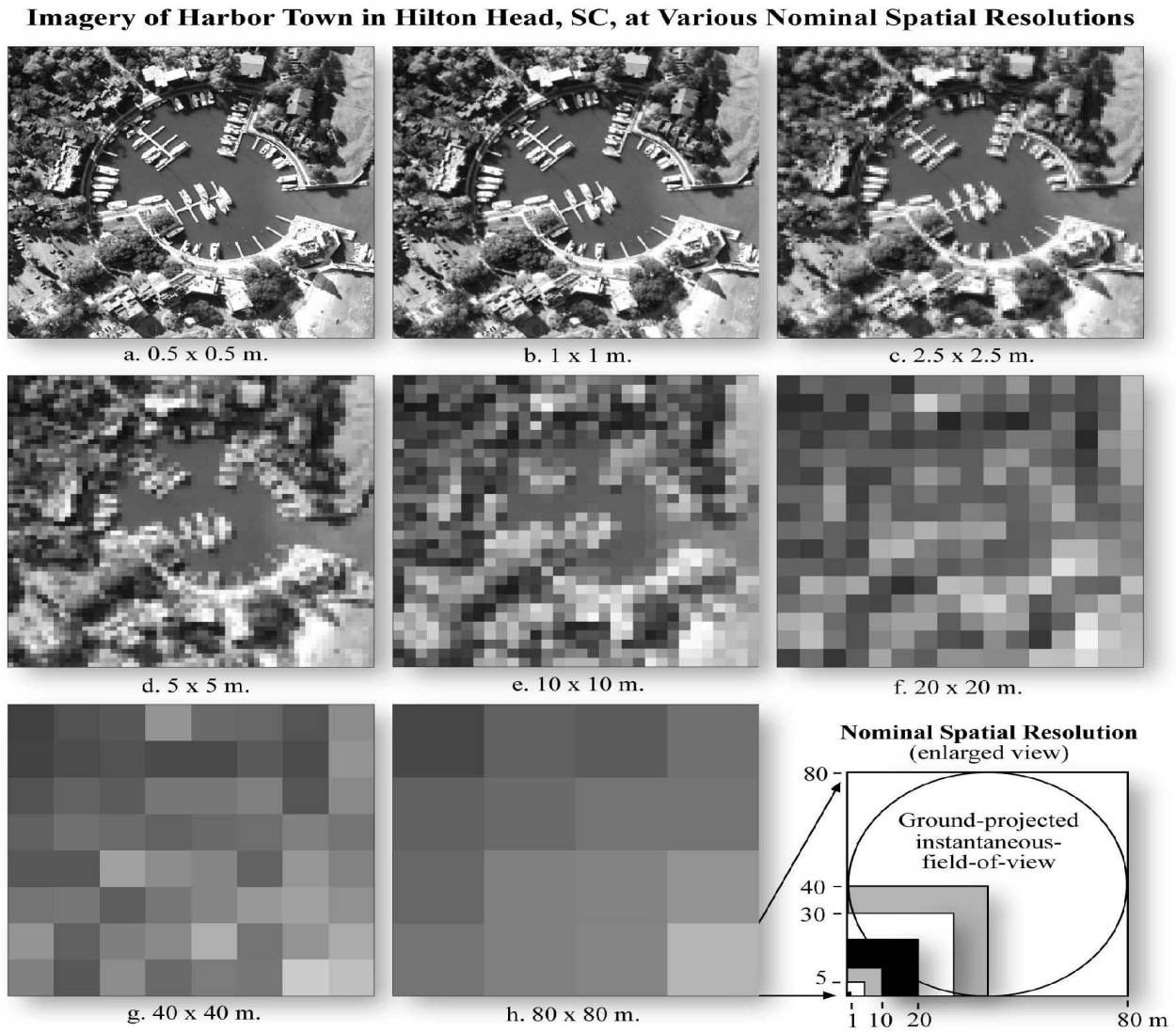
Pixel – the Smallest Unit of an Image

- A digital image is composed of a two-dimensional array of individual picture elements – called pixels – arranged in columns in rows
- Each pixel represents an area on the Earth's surface
- A pixel has an intensity value and a location address in the 2D image
- Spatial resolution is defined by the size of a pixel

*Text Source: Center for Remote Imaging, Sensing & Processing

Why is spatial resolution important?

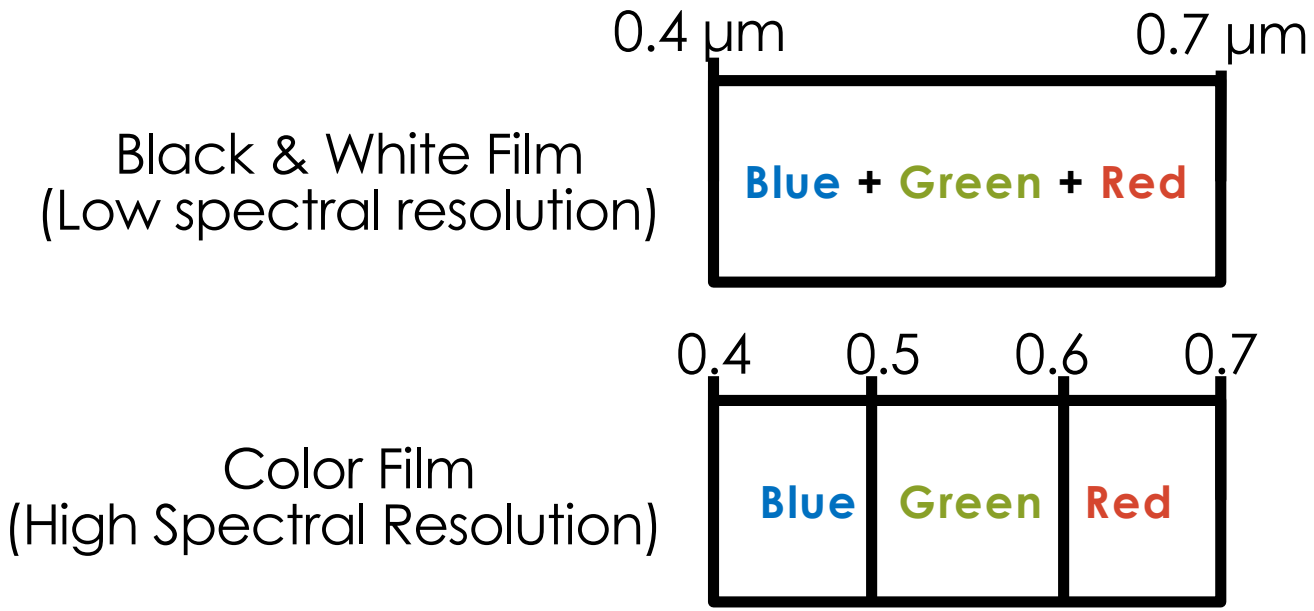
- MODIS
  - 250 m – 1 km
- MISR
  - 275 m – 1.1 km
- OMI
  - 13x24 km
- VIIRS
  - 375 m



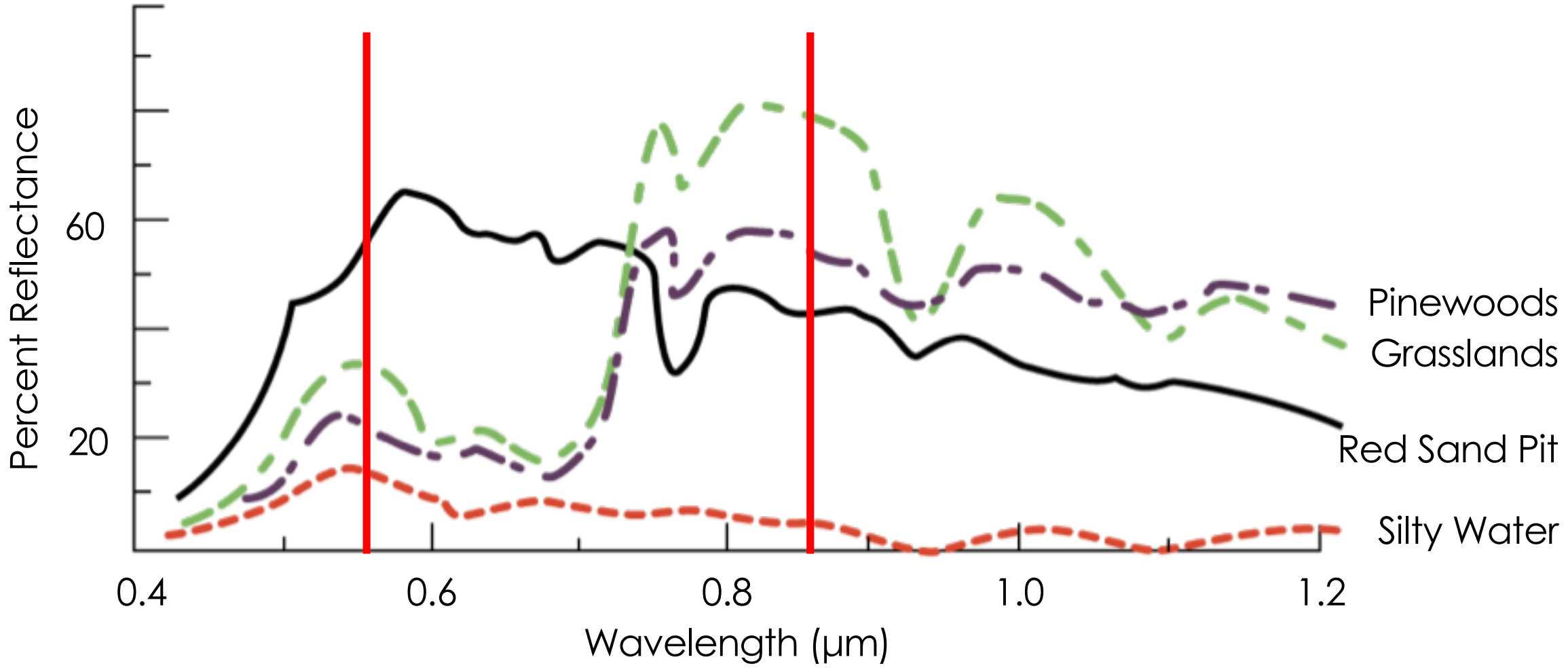
Source: Introductory Digital Image Processing, 3rd edition, Jensen, 2004

Spectral Resolution

- Spectral resolution describes a sensor's ability to define fine wavelength intervals
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band
- **Multispectral Sensors**
  - MODIS
  - moderate spectral resolution
- **Hyperspectral Sensors**
  - OMI, AIRS
  - High spectral resolution



Why is spectral resolution important?



Adapted from image from: Indian Institute of Science

Radiometric Resolution

- Imagery data are represented by positive digital numbers that vary from 0 to (one less than) a selected power of 2
- The maximum number of brightness levels available depends on the number of bits (represents radiometric resolution) used in representing the energy recorded
- The larger this number, the higher the radiometric resolution

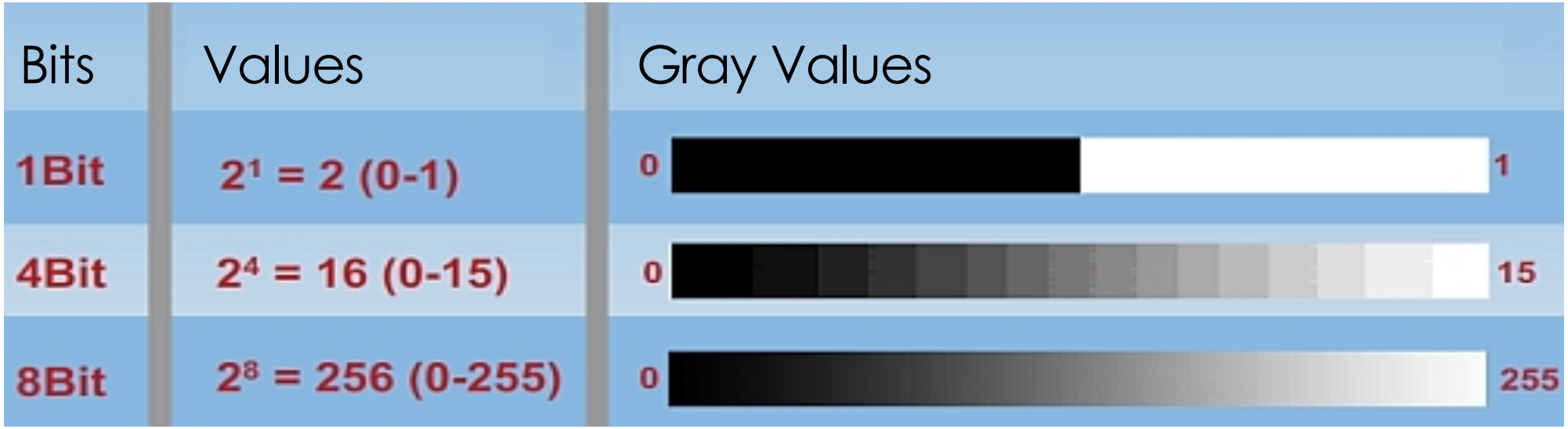


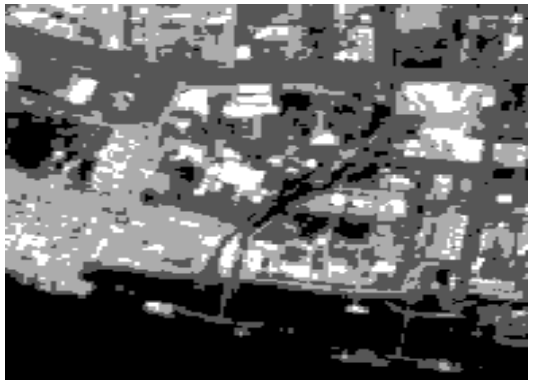
Image Source: [redacted] ; *Text Source: [redacted]

Radiometric Resolution

- Detects the difference in brightness levels
- The more sensitive the sensor - the higher the radiometric resolution
- If radiometric precision is high, an image will be sharp
- Expressed in bits
- NASA Satellite Sensor Examples:
  - 12 bit sensor (MODIS, MISR, Landsat-9 TM/MSS): 2^{12} or 4,096 levels
  - 10 bit sensor (AVHRR): 2^{10} or 1,024 levels
  - 8 bit sensor (Landsat-7 TM): 2^{8} or 256 levels (0-255)
  - 6 bit sensor (Landsat-7 MSS): 2^{6} or 64 levels (0-63)

Radiometric Resolution

2 - levels



4 - levels

8 - levels

16 - levels

In classifying a scene, different classes are more precisely identified if radiometric resolution is high

MODIS has 4,096 levels

Temporal Resolution

- How frequently a satellite can provide observation of the same area on the earth
  - It mostly depends on the swath width of the satellite – the larger the swath – the higher the temporal resolution

Global coverage in….

- MODIS
  - 1-2 days
- OMI
  - 1 day
- MISR
  - 6-8 days
- VIIRS
  - 1 day
- Geostationary
  - 30 sec – 1 hr

Remote Sensing Tradeoff

It is **very difficult** to obtain extremely high spectral, spatial, temporal, **AND** radiometric resolutions, all at the same time

References and Further Reading

- Natural Resources Canada: http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309
- Center for Remote Imaging, Sensing, and Processing: http://www.crisp.nus.edu.sg/~research/tutorial/image.htm
- NASA Earth Observatory: http://earthobservatory.nasa.gov/Features/RemoteSensing/remote_06.php
- EOS-Goddard: http://fas.org/irp/imint/docs/rst/Front/tofc.html
- Spectral Resolution: http://web.pdx.edu/~jduh/courses/Archive/geog481w07/Students/Cody_SpectralResolution.pdf