

# Fundamentals of Satellite Remote Sensing

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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

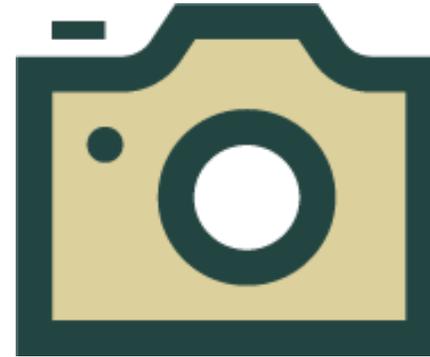


# What is remote sensing?

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

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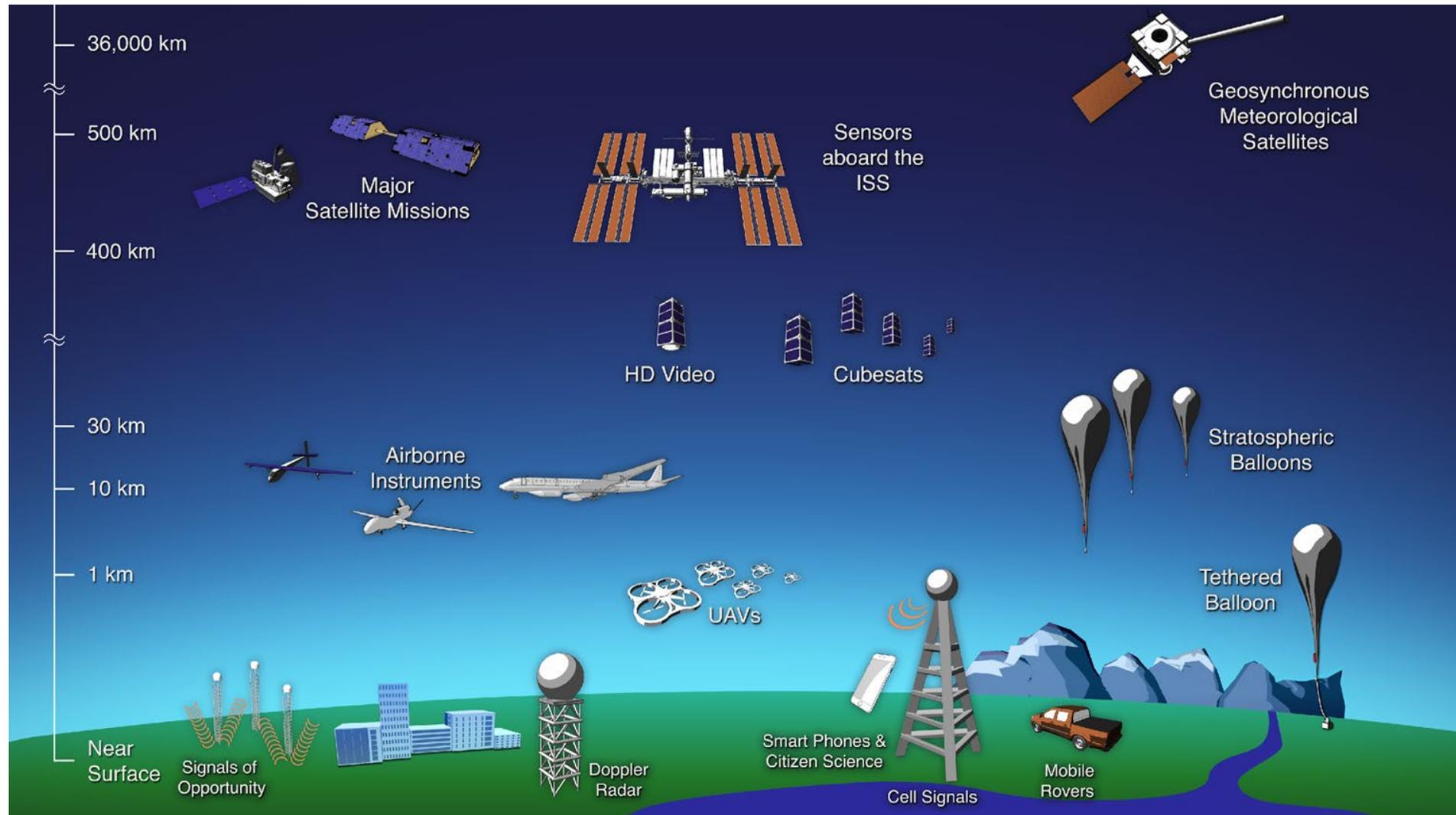
# Remote Sensing: Platforms



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

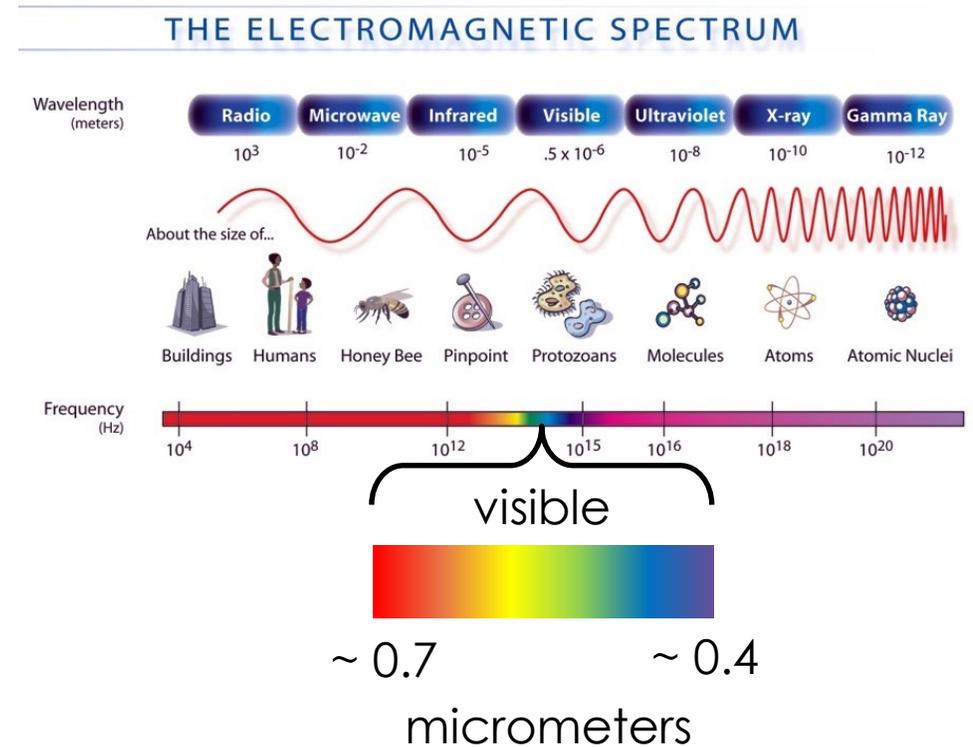
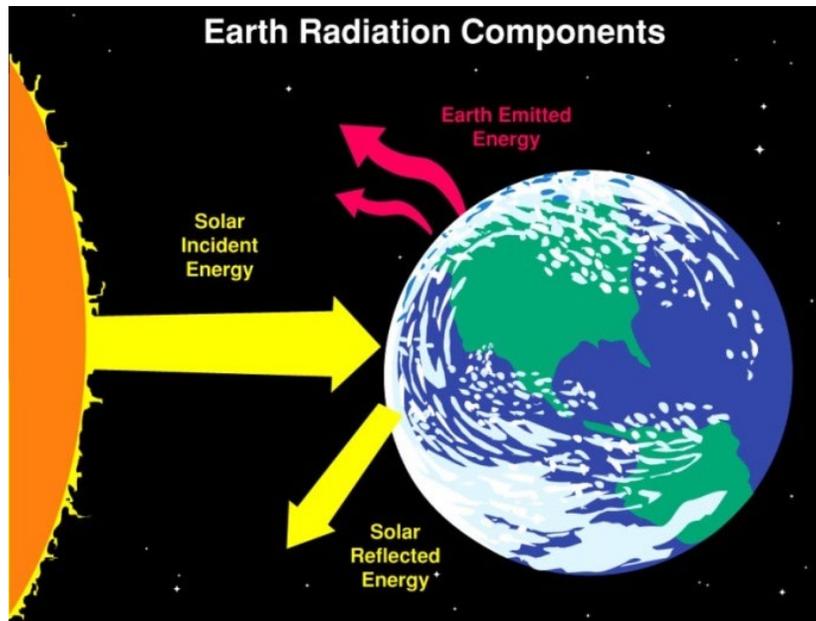
- The platform depends on the end application
- What information do you want?
- How much detail do you need?
- What type of detail?
- How frequently do you need this data?

# Remote Sensing of Our Planet

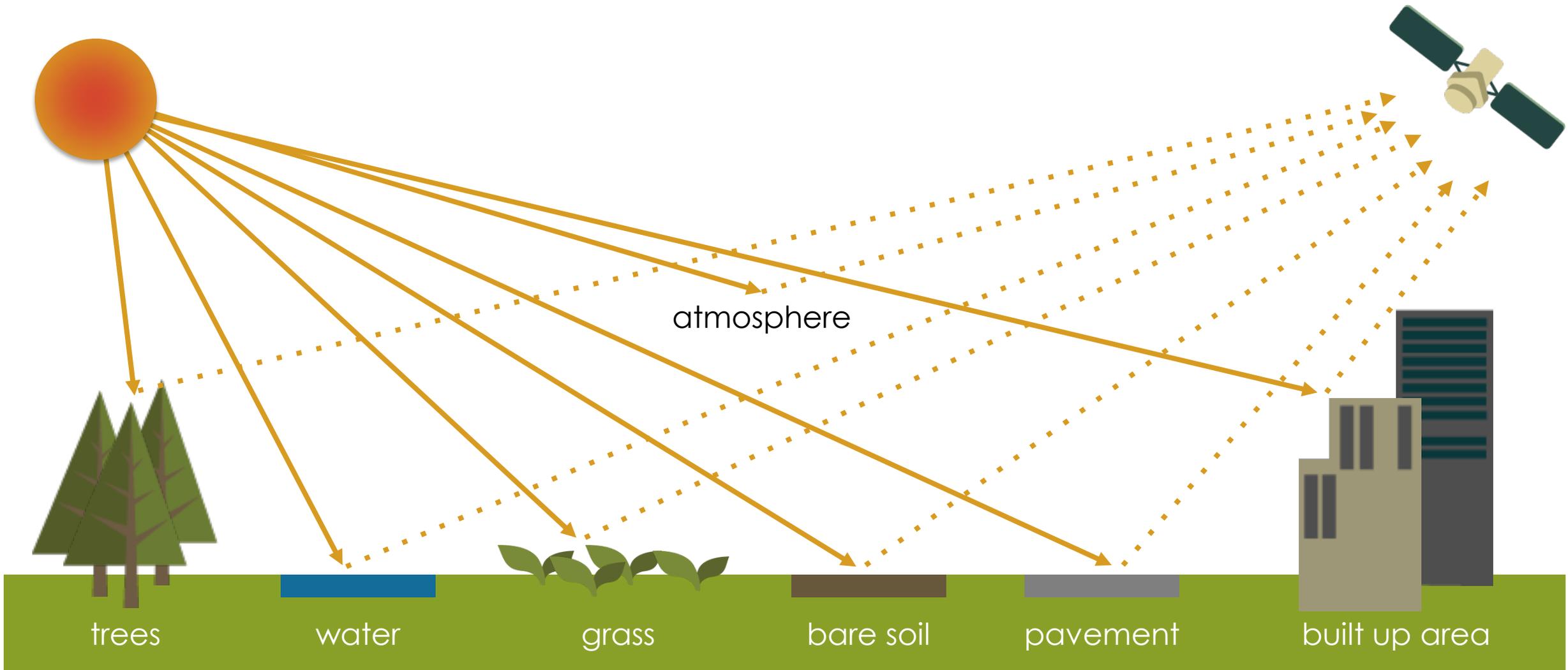


# Electromagnetic Radiation

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

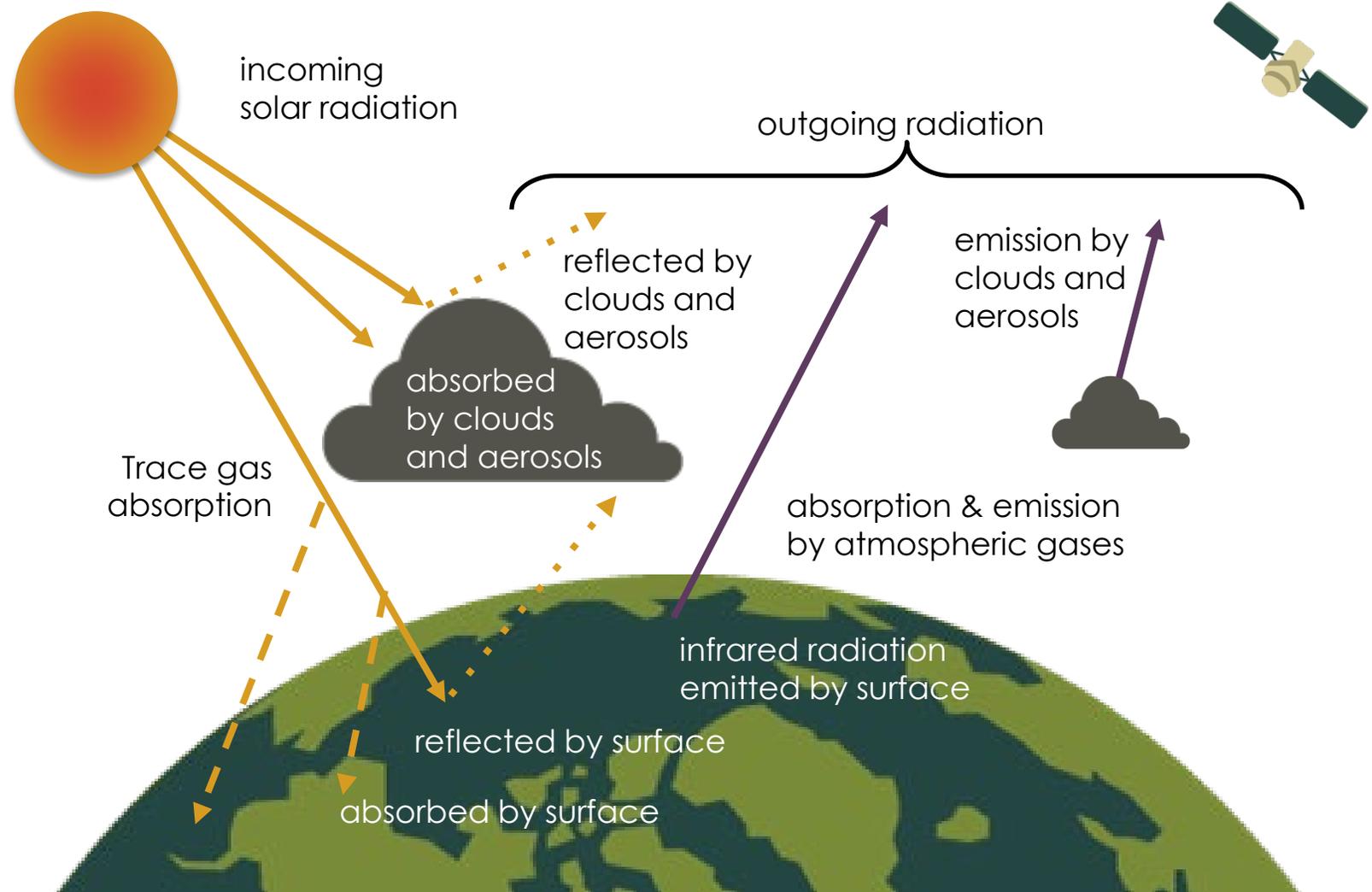


# What do satellites measure ?

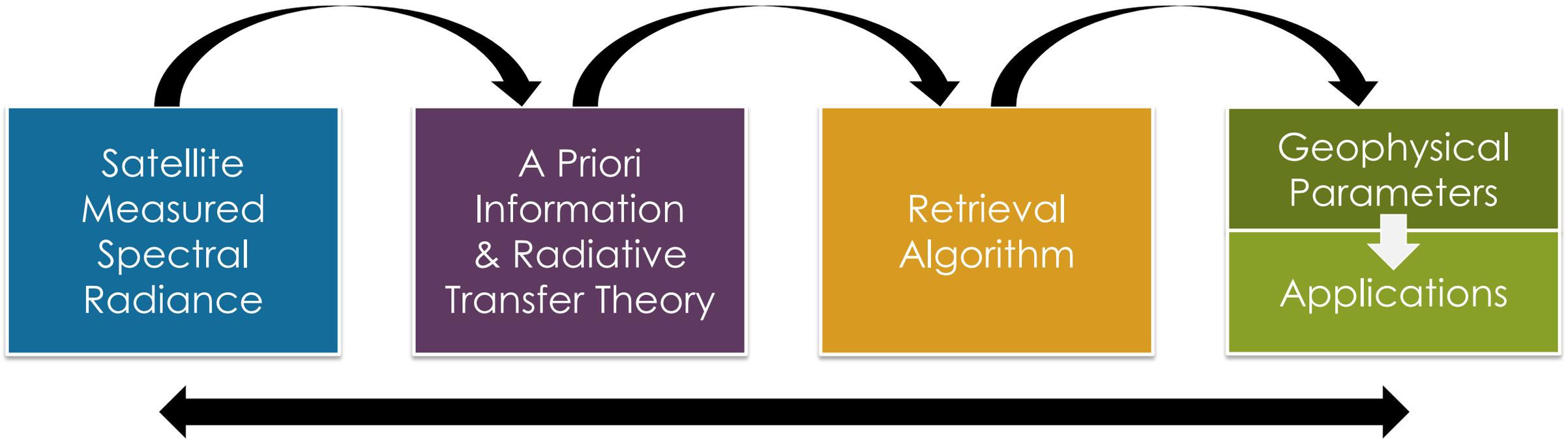


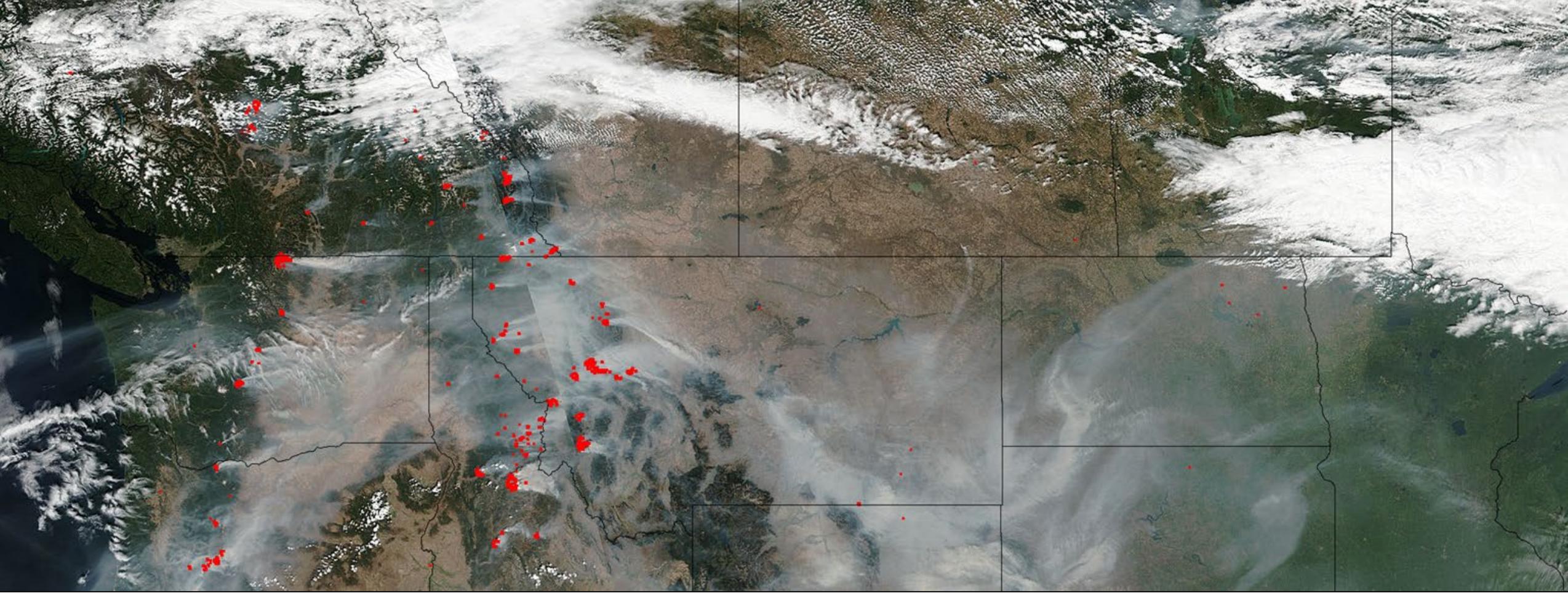
# Measuring Properties of the Earth-Atmosphere System from Space

- 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





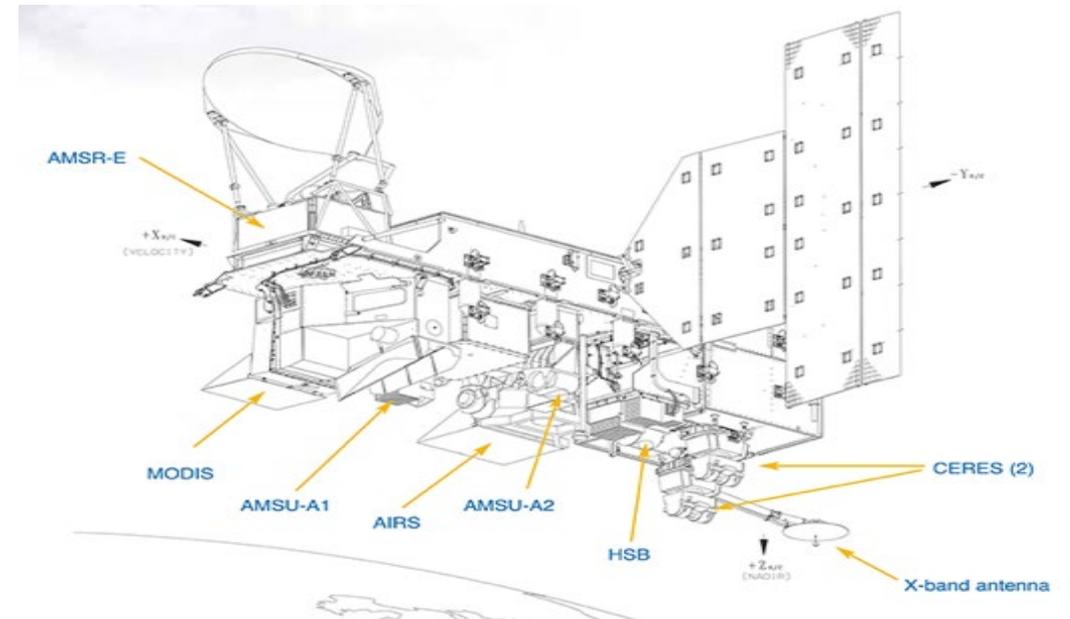
## Satellites, Sensors, and Orbits

# Satellites vs. Sensors

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

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

## Aqua Satellite

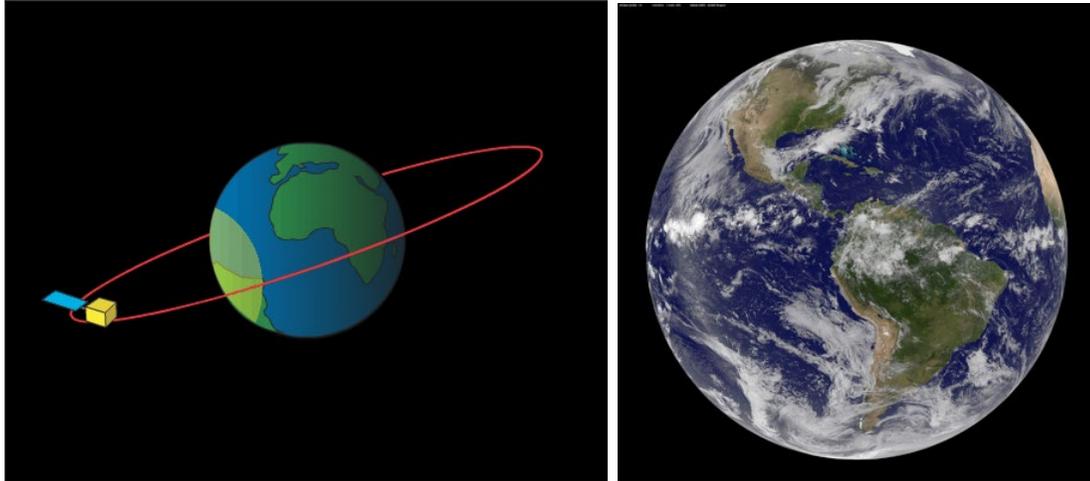


# Characterizing Satellites and Sensors

- **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...

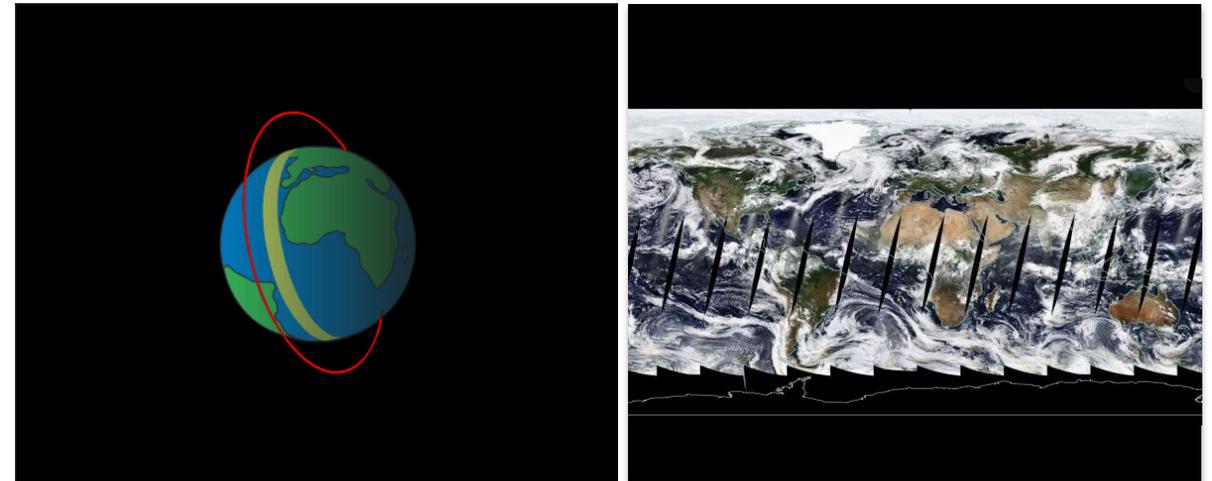


# Common Orbit Types



## Geostationary Orbit

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

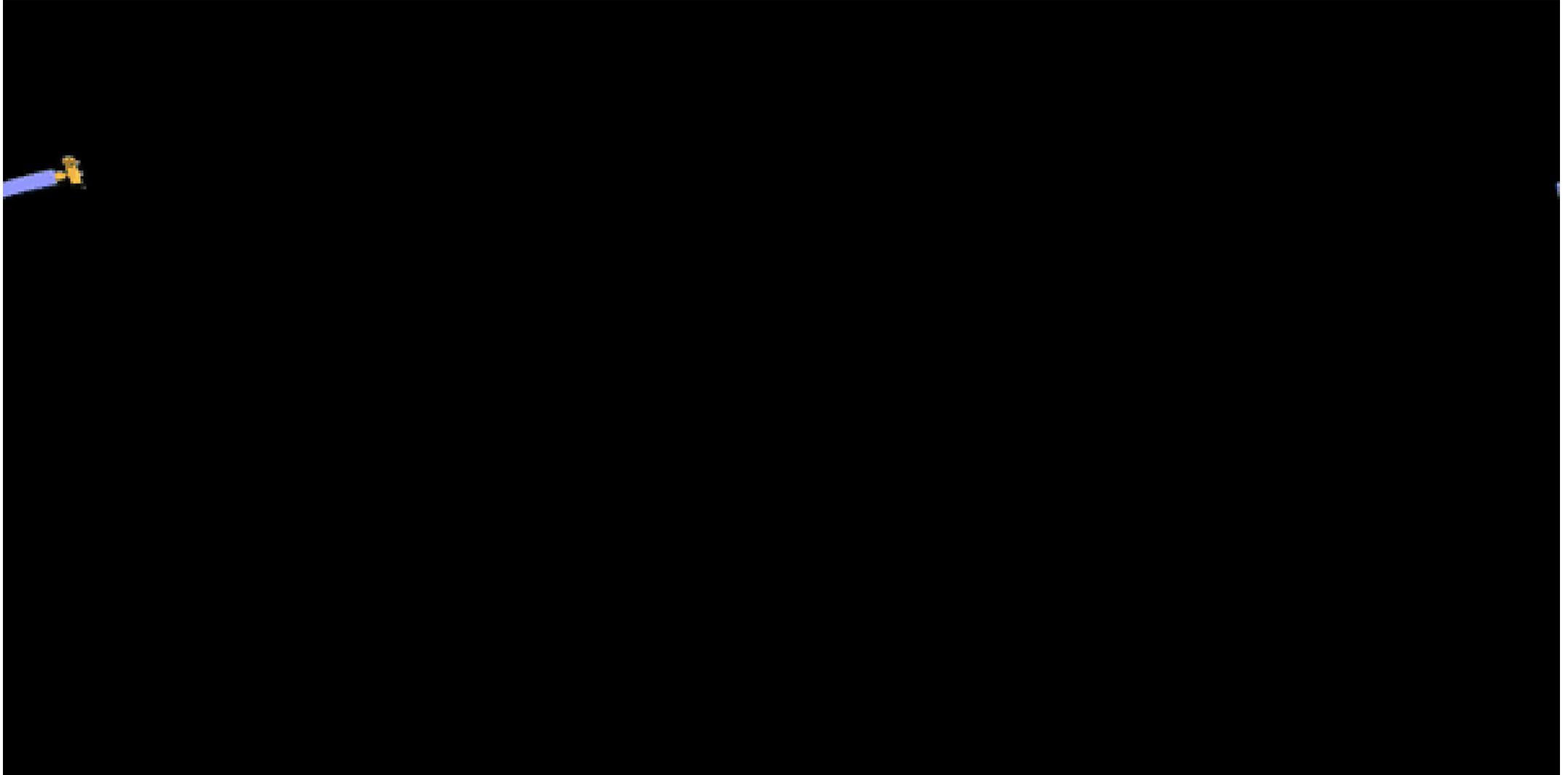


## Polar Orbit

- 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

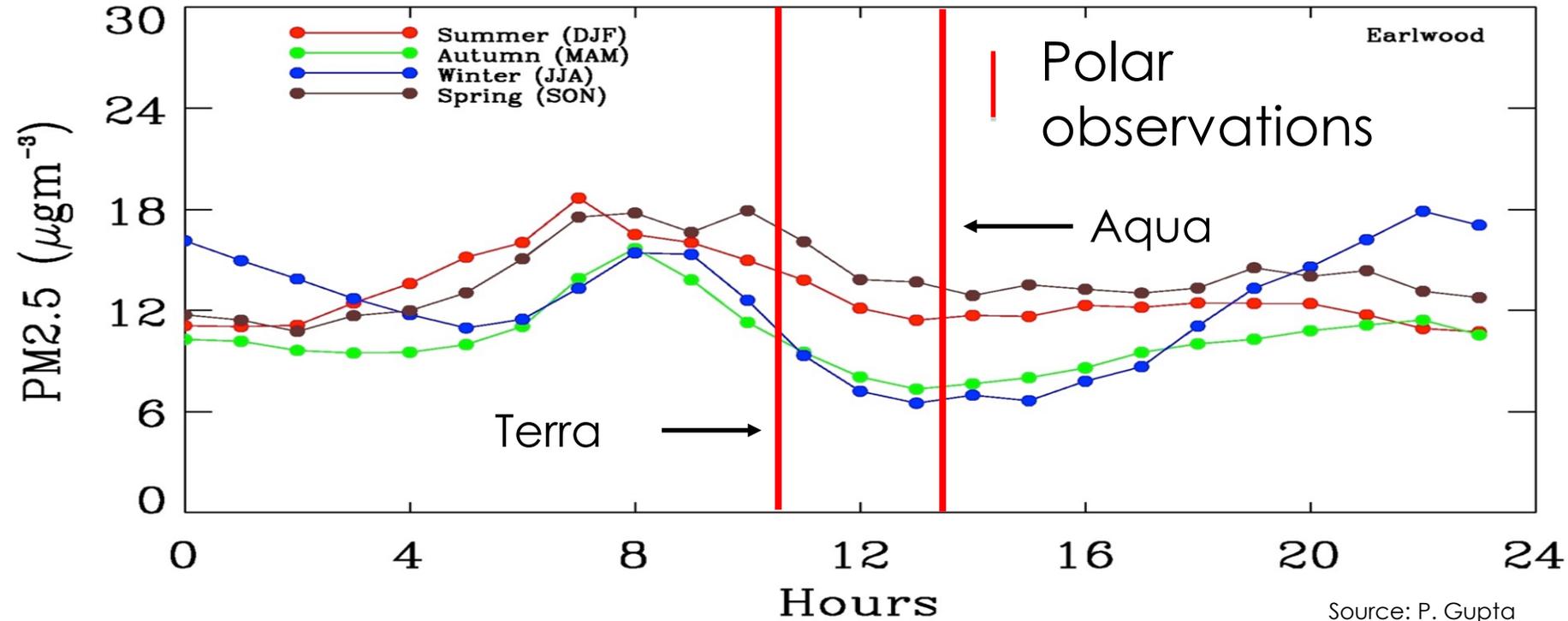


# Aqua Satellite Orbiting the Earth



# Observation Frequency

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

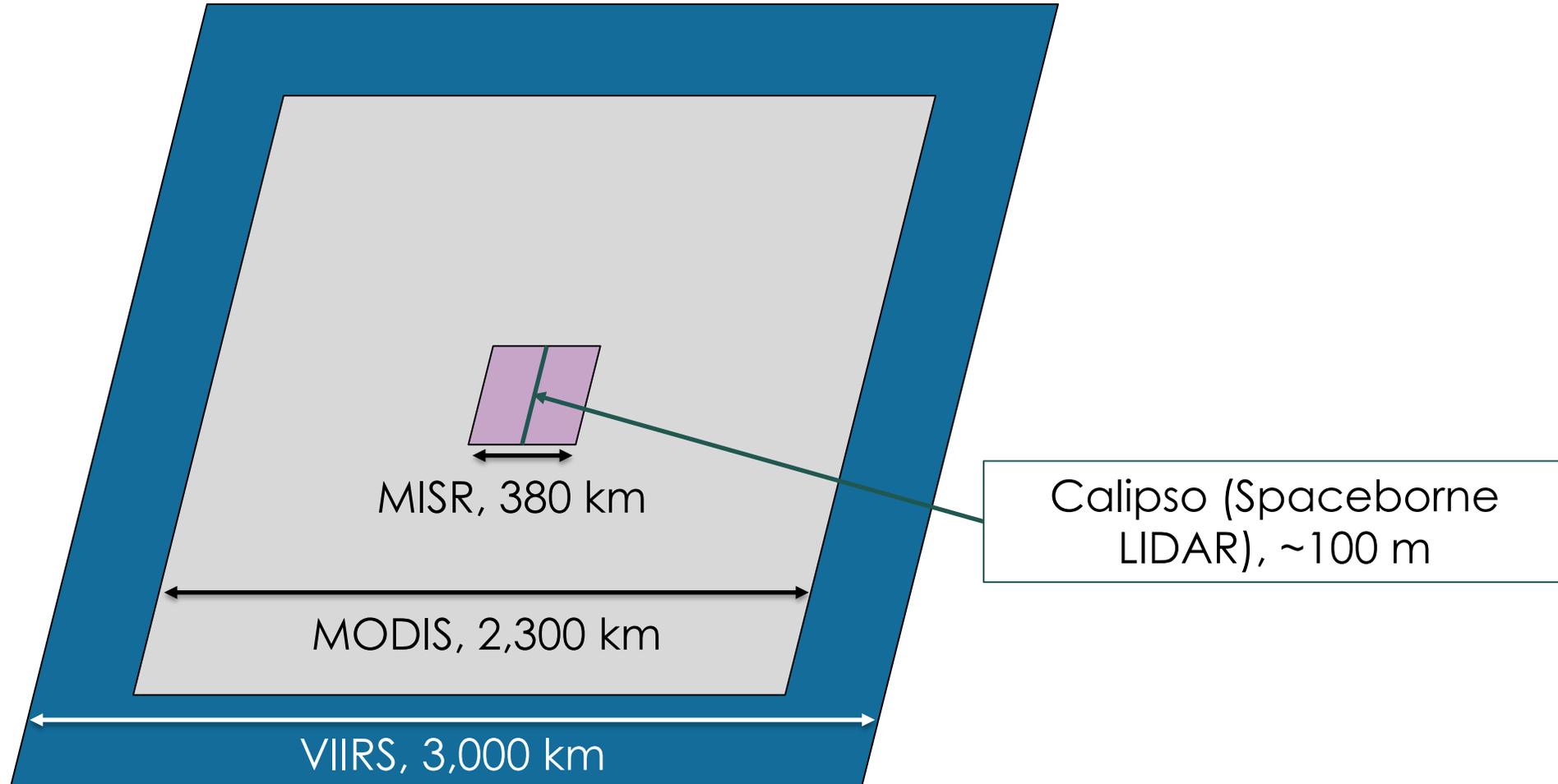


Geostationary Satellites: Every 30 sec. to 15 min.

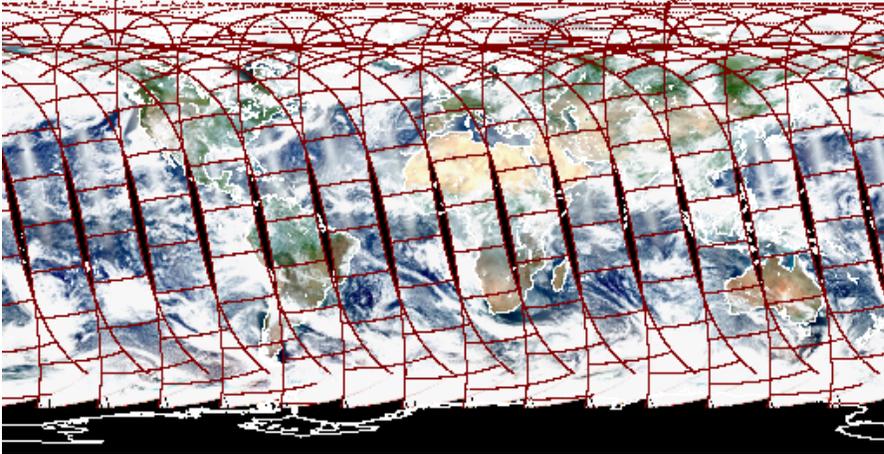
Future Geo satellites: TEMPO, GEMS, Sentinel-4



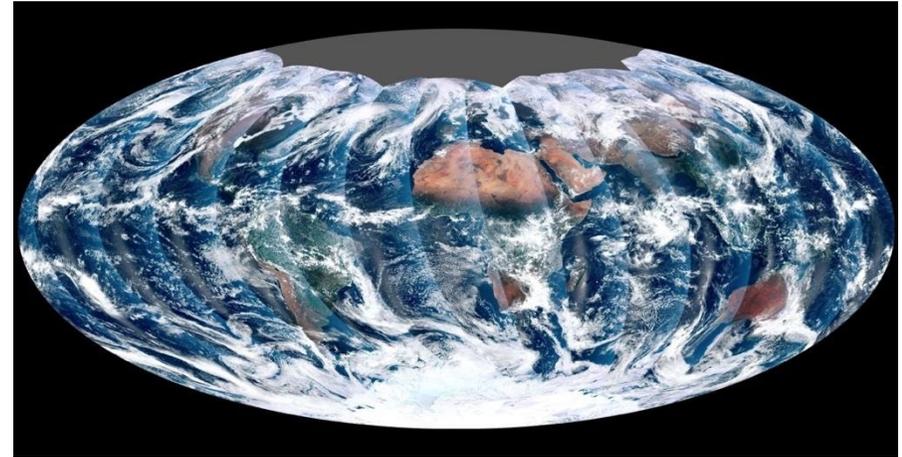
# Satellite Coverage – Swath Width



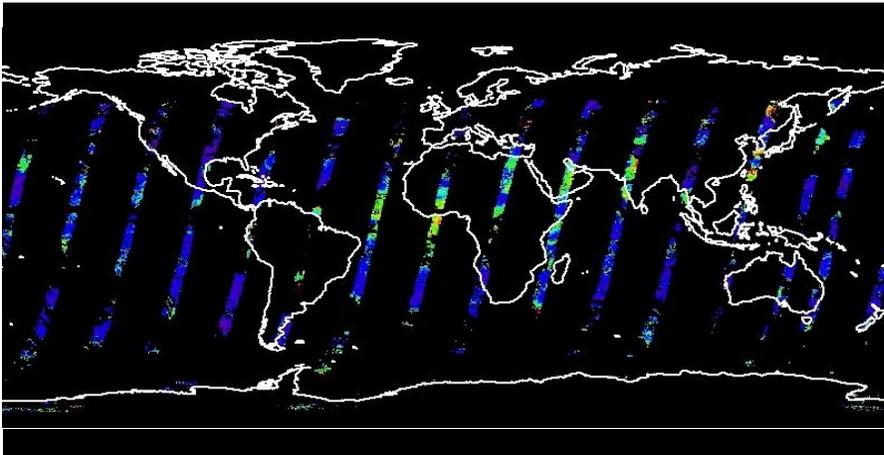
# Satellite Coverage



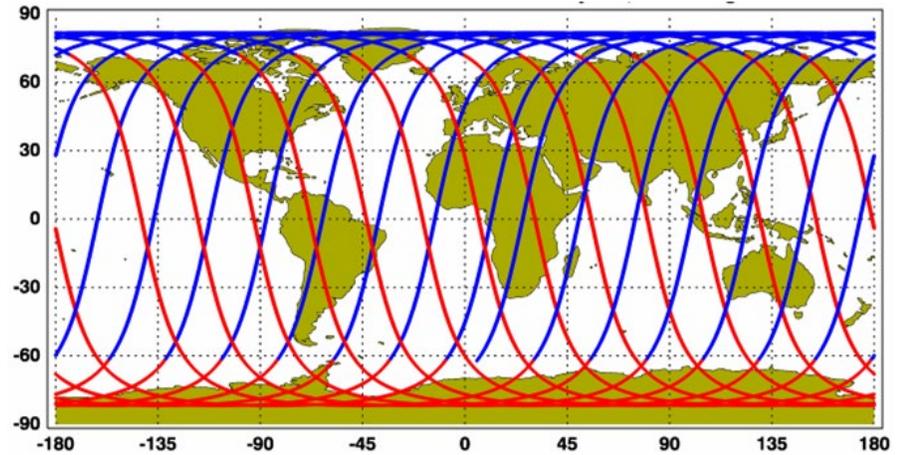
MODIS



VIIRS



MISR



CALIPSO



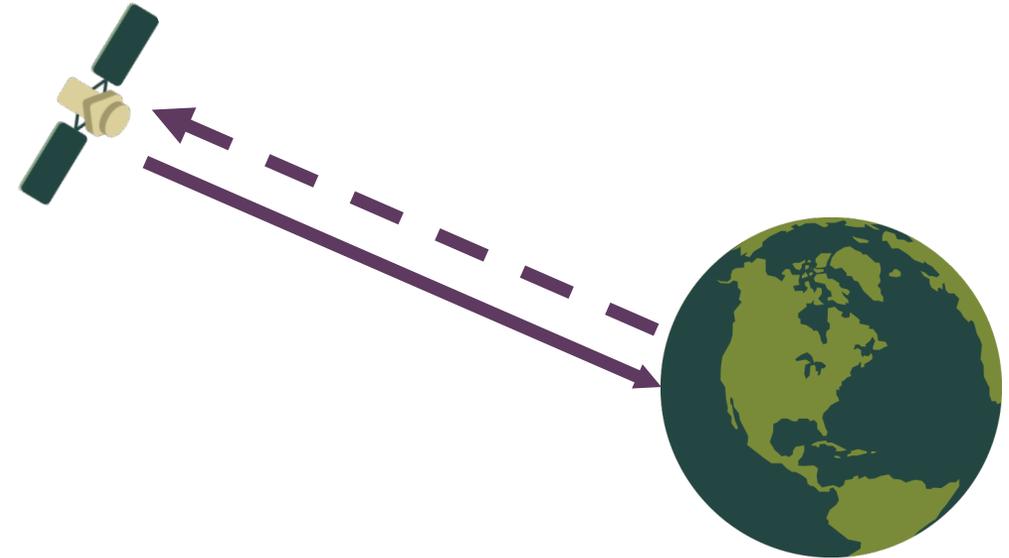
# Active & Passive Sensors

## 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**)

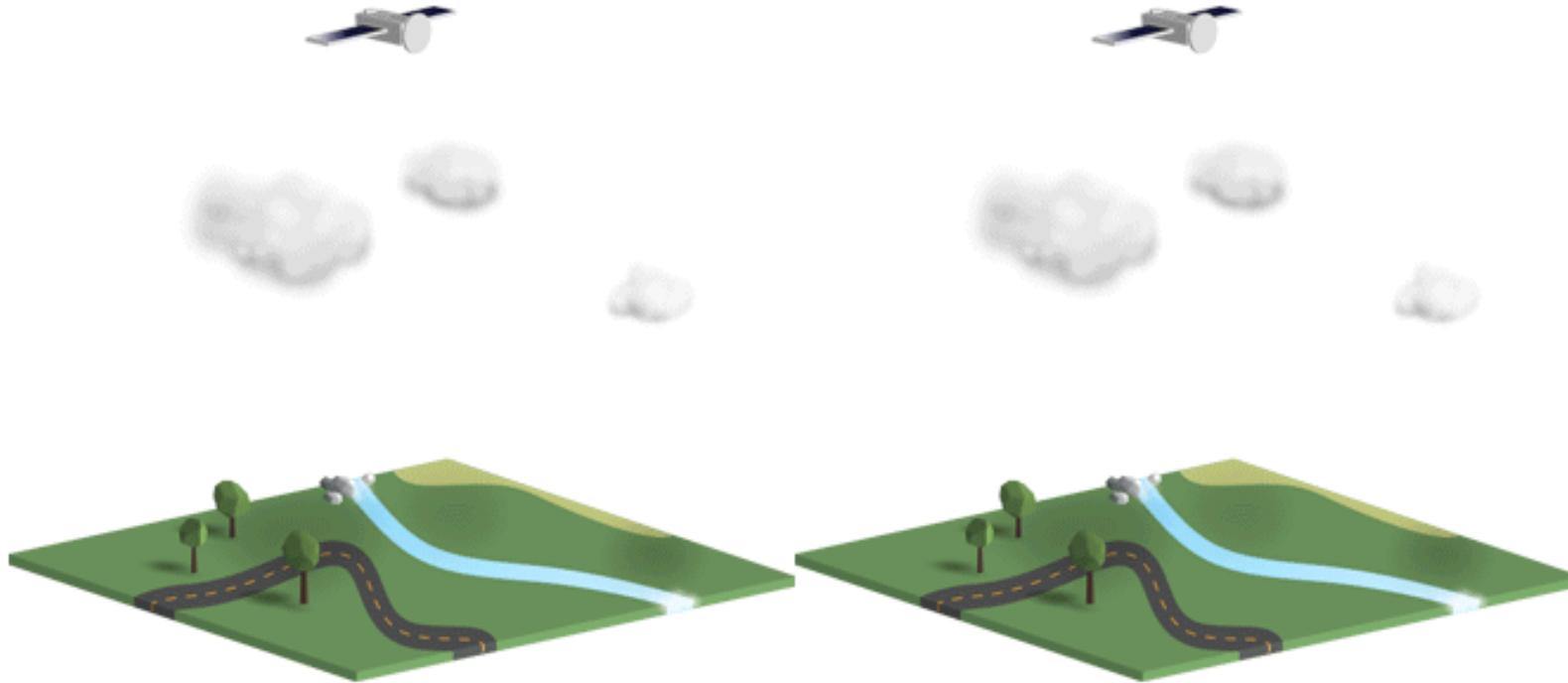
## Active Sensors



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



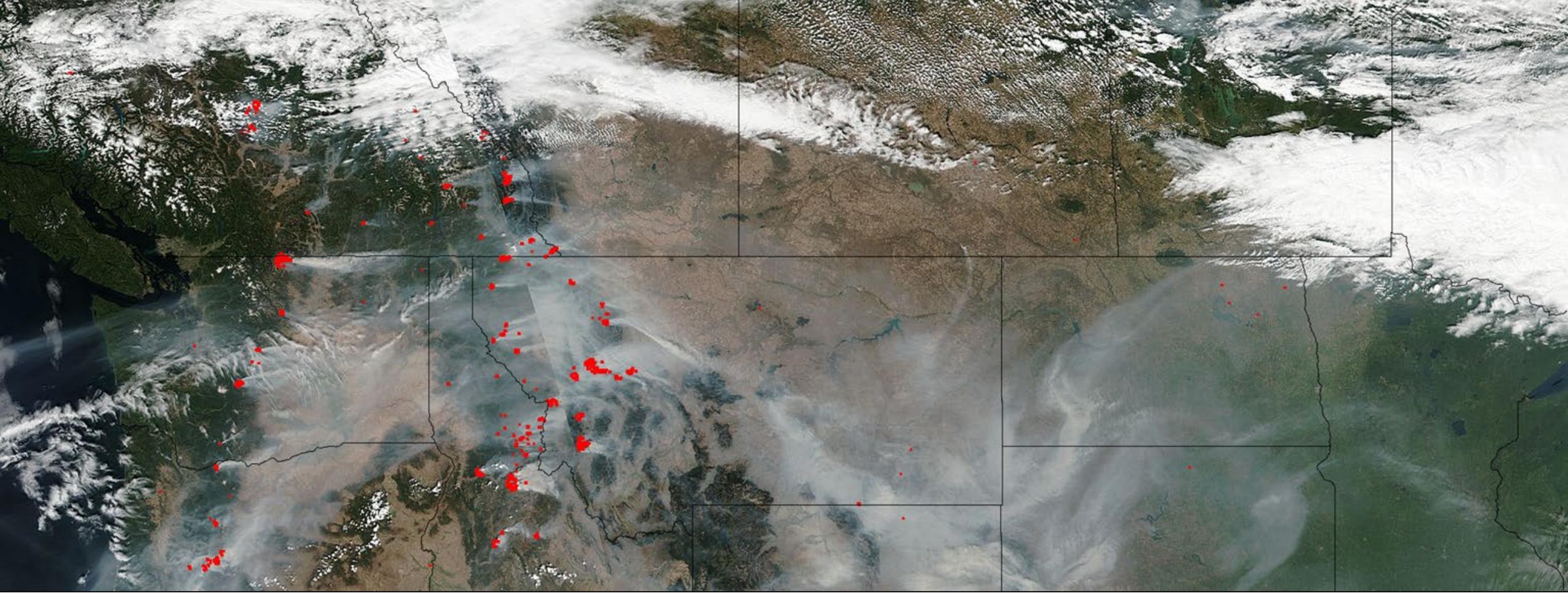
# Active & Passive Sensors



**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

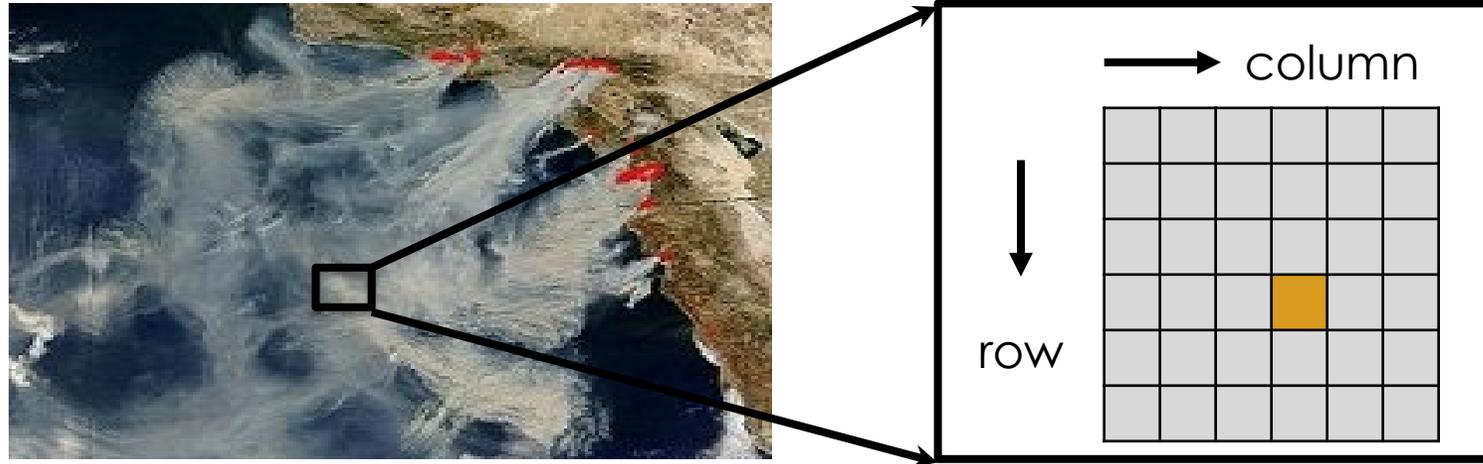
# Remote Sensing – Types of Resolution

- **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

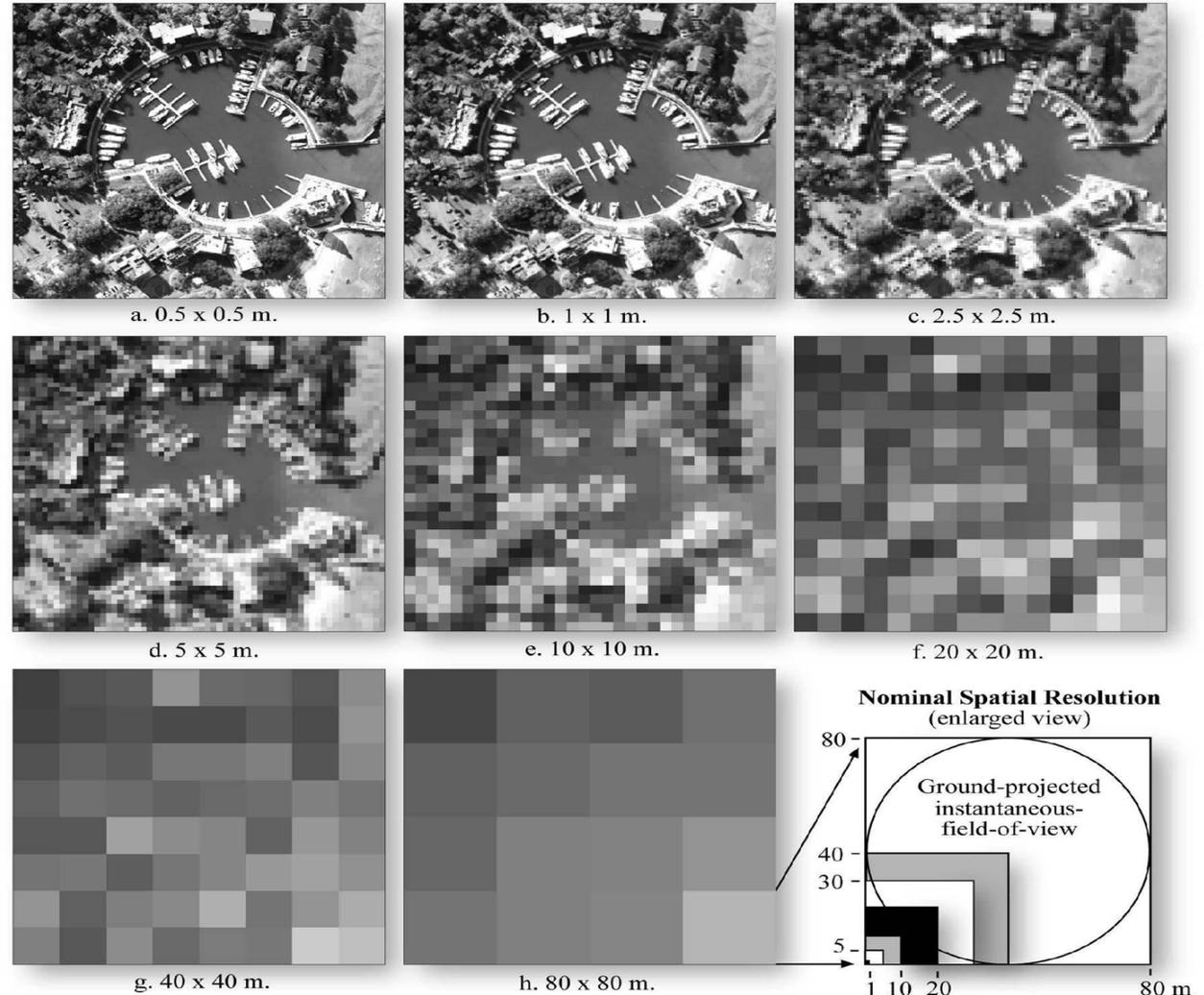
\*Text Source: Center for Remote Imaging, Sensing & Processing



# Why is spatial resolution important?

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

Imagery of Harbor Town in Hilton Head, SC, at Various Nominal Spatial Resolutions



Source: Introductory Digital Image Processing, 3<sup>rd</sup> 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**

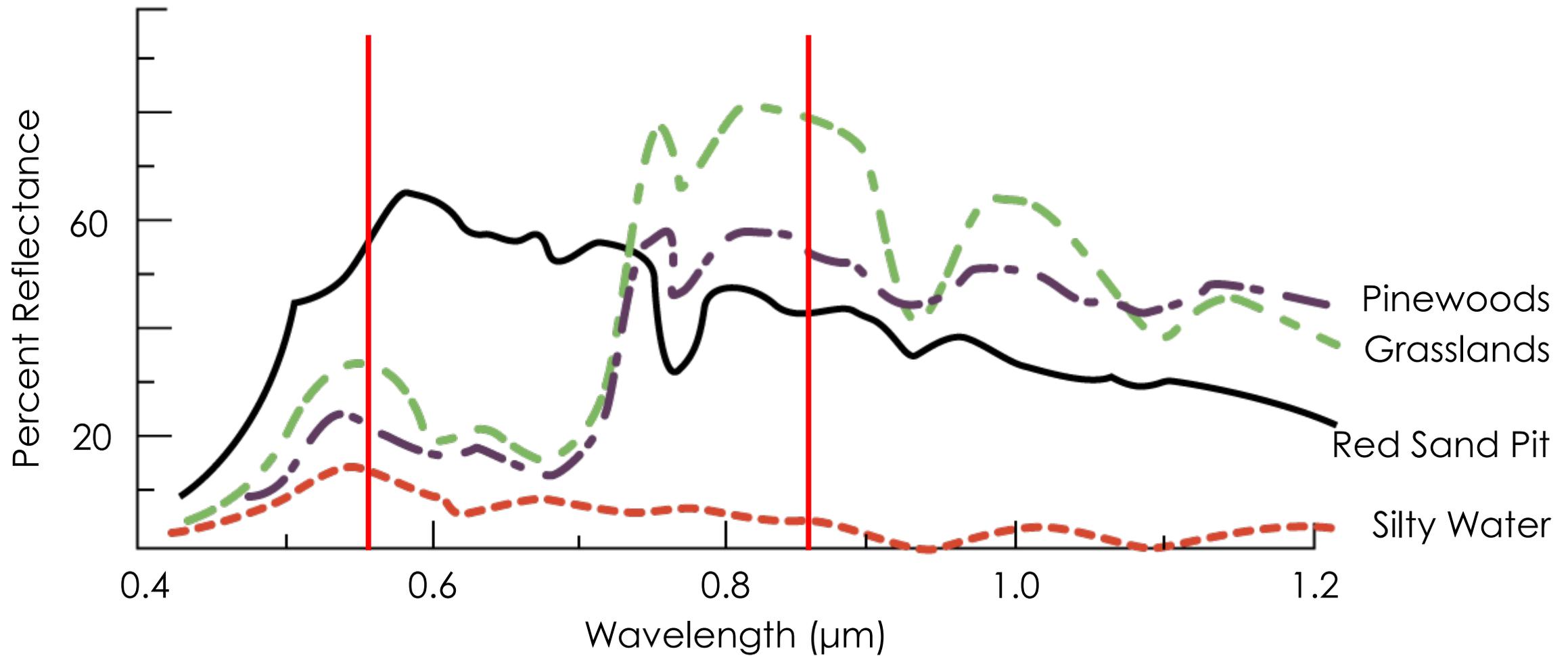
- MODIS
- moderate spectral resolution

- **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

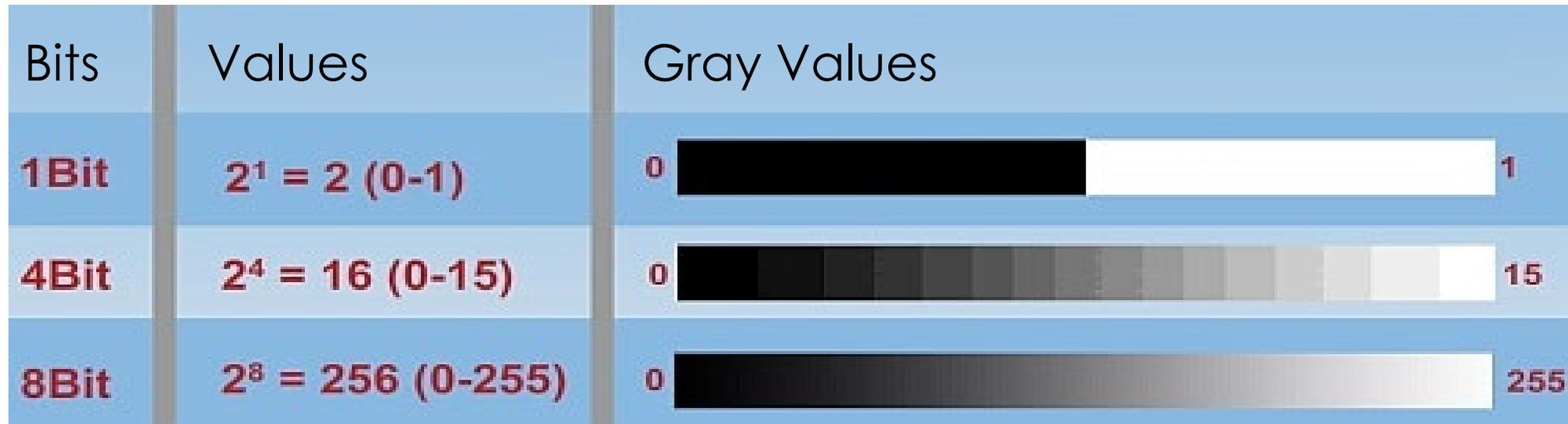


Image Source: [FLS](#) ; \*Text Source: [Natural Resources Canada](#)



# 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)

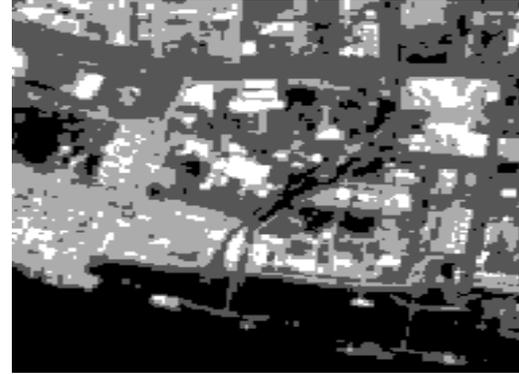


# Radiometric Resolution

2 - levels



4 - levels



8 - levels



16 - levels



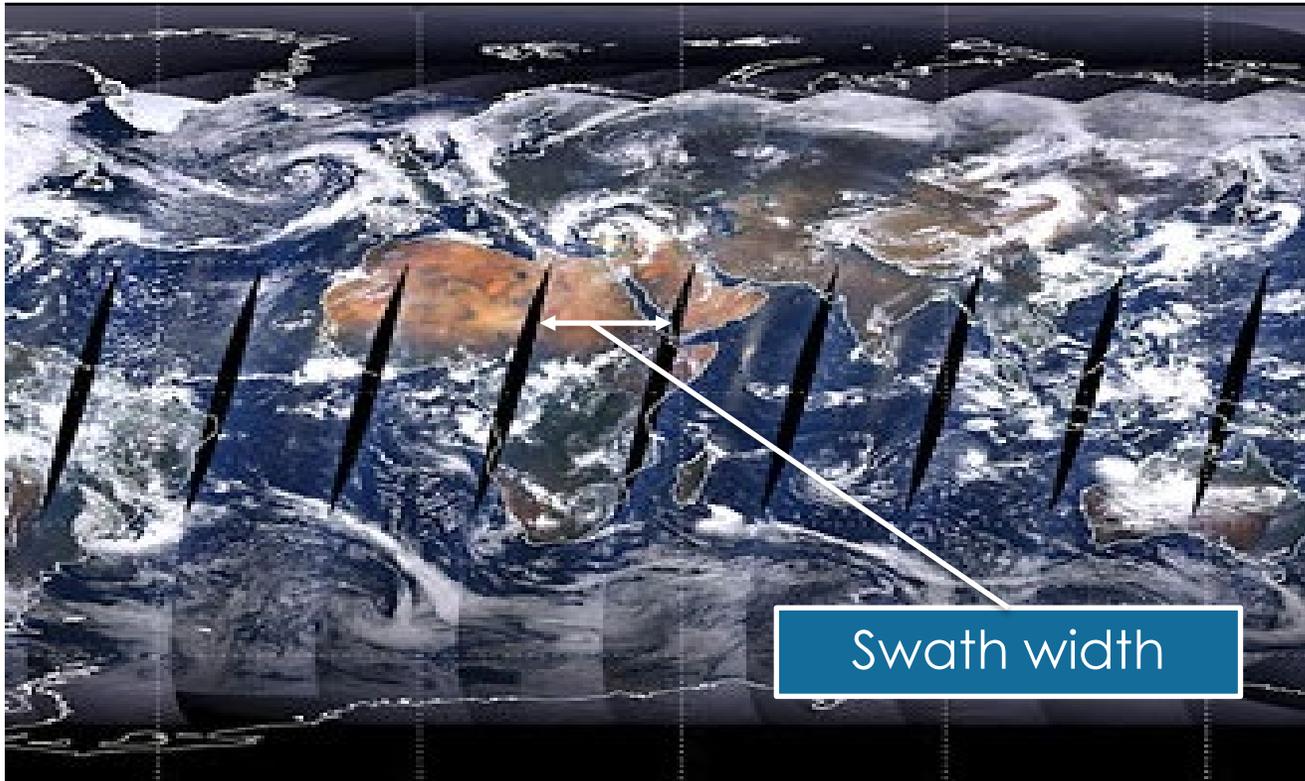
In classifying a scene, different classes are more precisely identified if radiometric resolution is high

**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](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\\_Spectral\\_Resolution.pdf](http://web.pdx.edu/~jduh/courses/Archive/geog481w07/Students/Cody_Spectral_Resolution.pdf)

