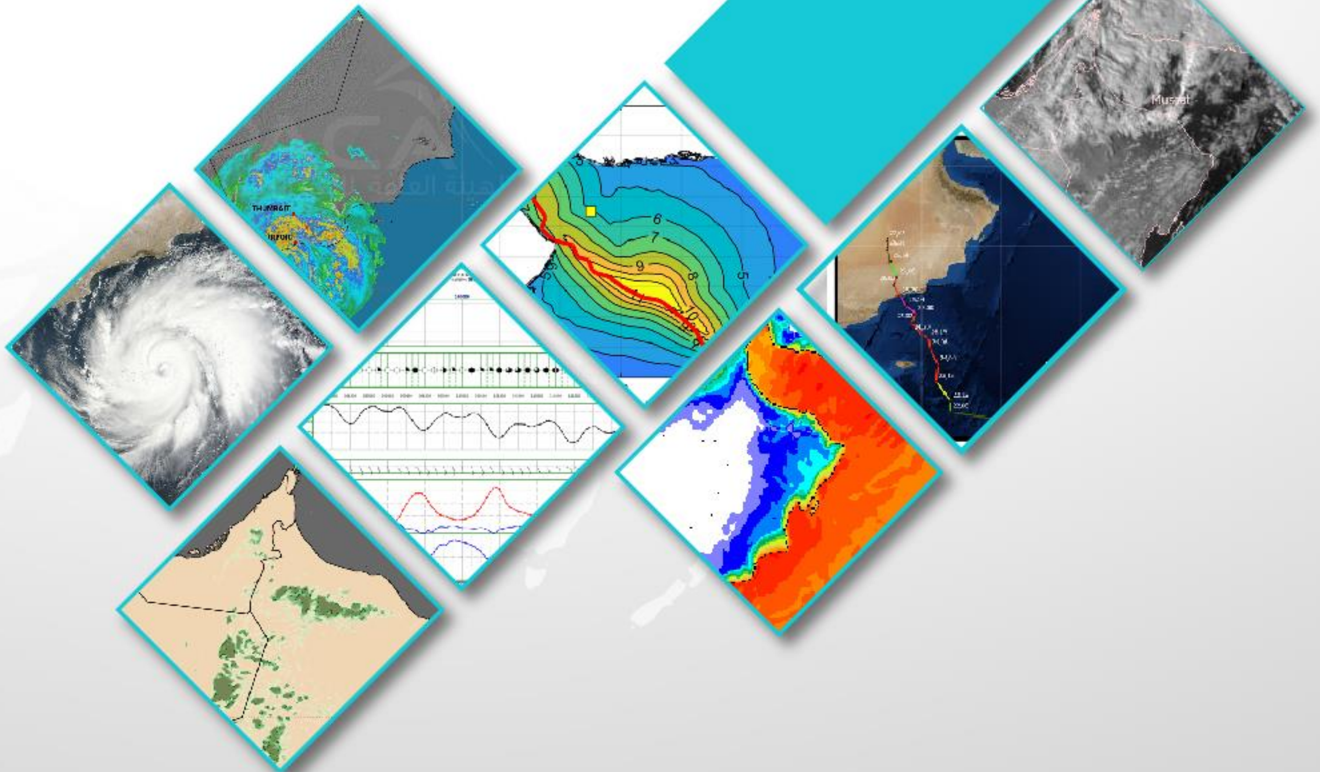
Principles of Remote Sensing



Content creator: R&D Team

Lecturer: Zamzam AL-Rawahi

Content

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

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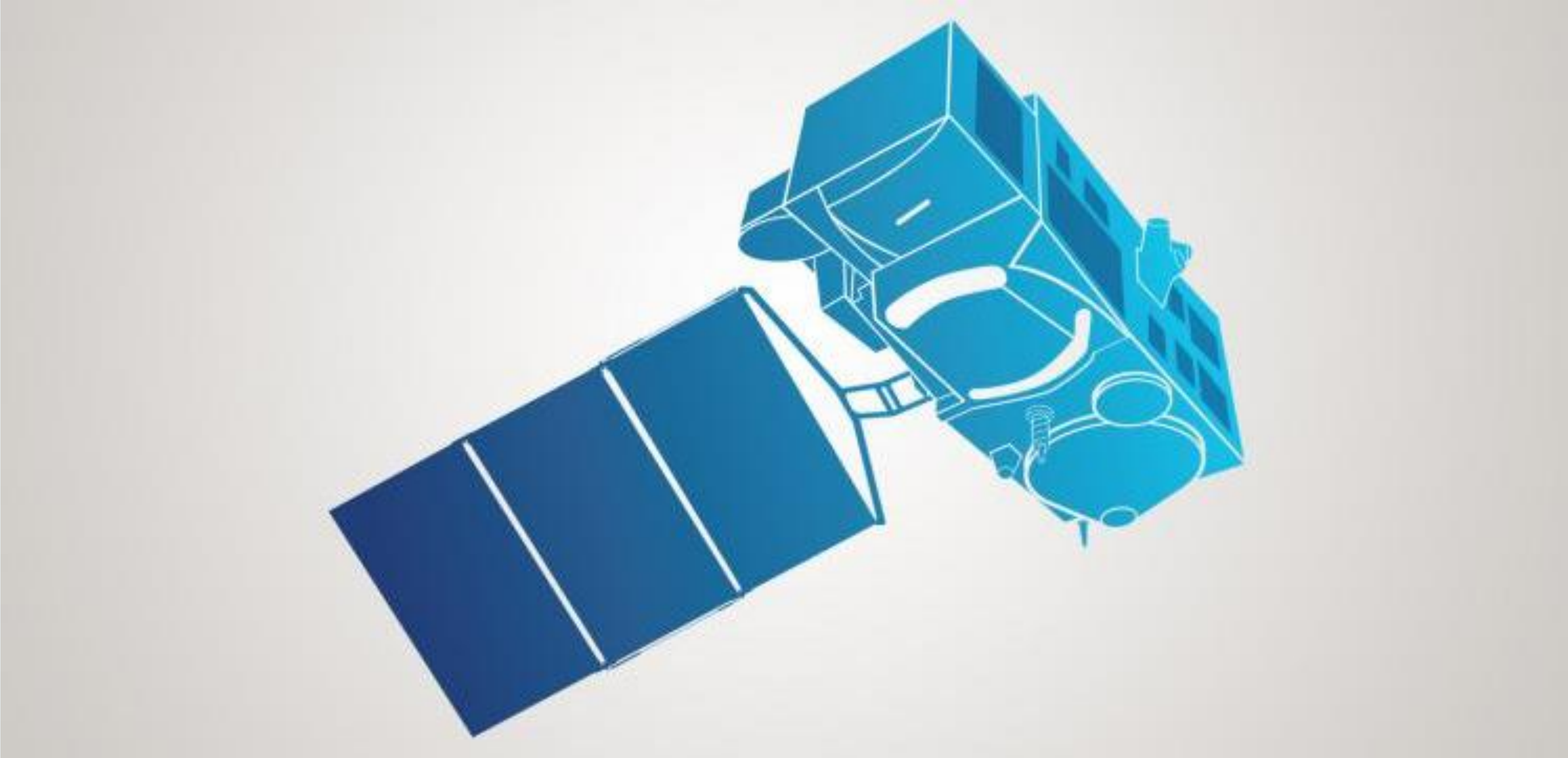

Fundamentals of Remote Sensing

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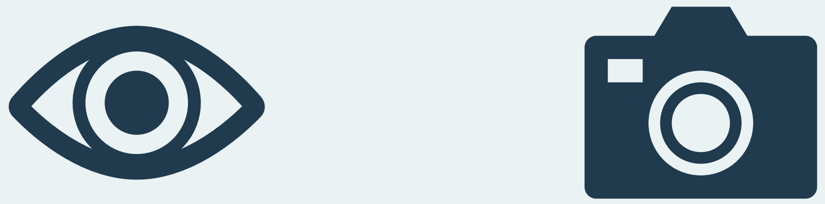
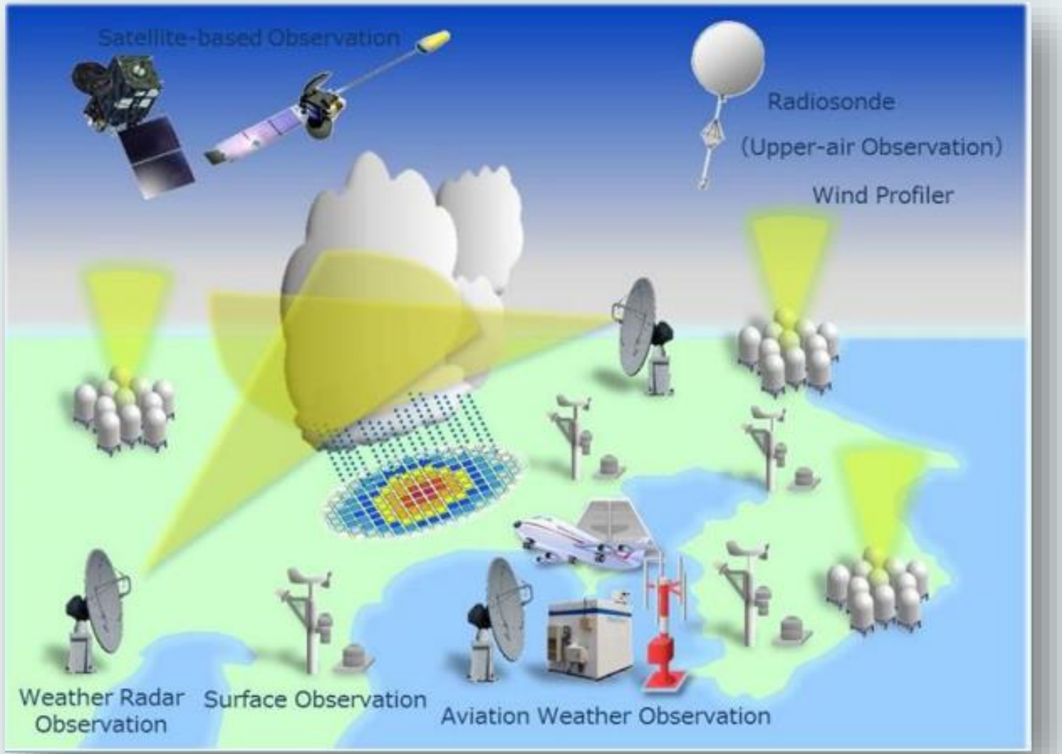
What is remote sensing?

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



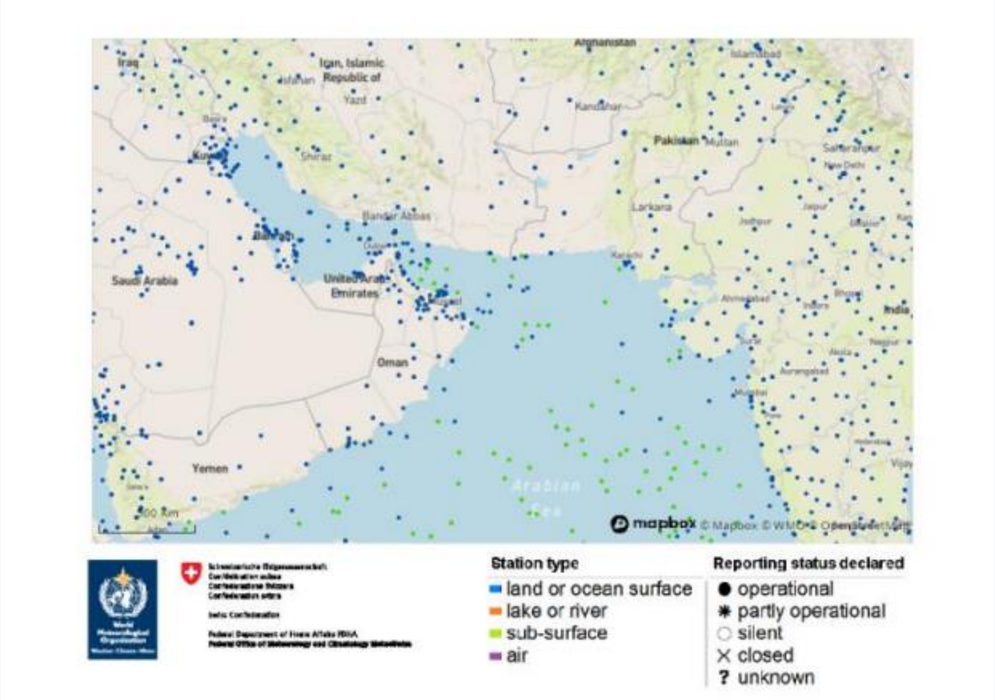
What is remote sensing?

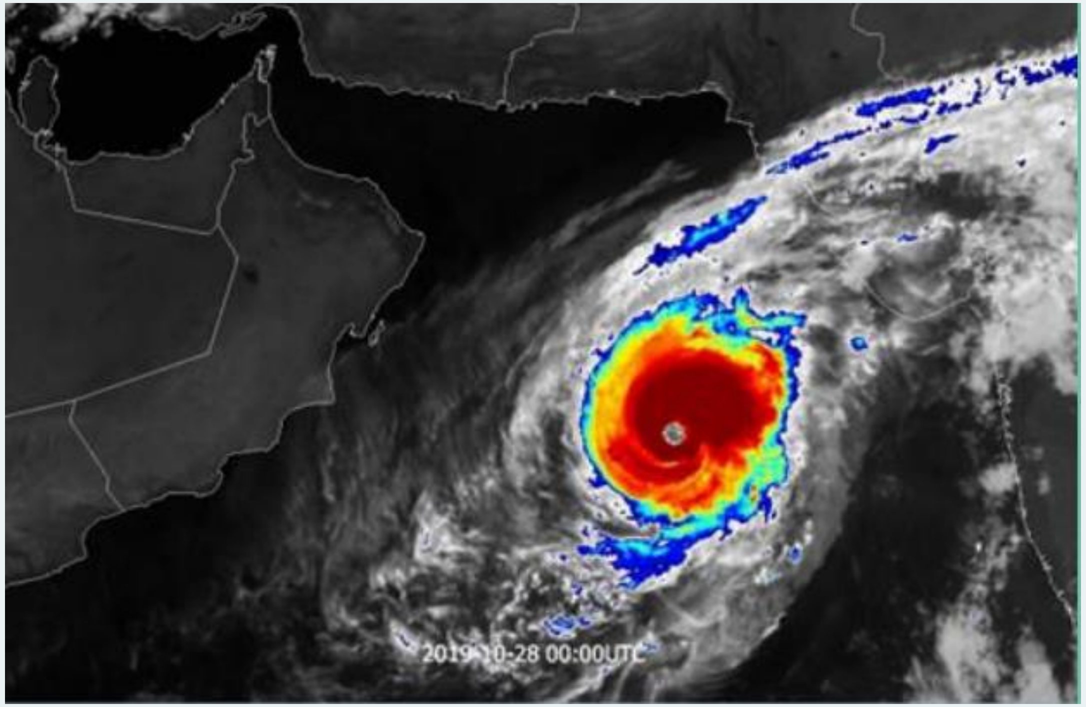


- There are different ways to collect data, and different sensors are used depending on the application.
- Some methods collect ground-based data, others airborne or spaceborne.

1. What information do you need?
2. How much detail?
3. How frequently do you need the data?

Importance of Satellite Remote Sensing





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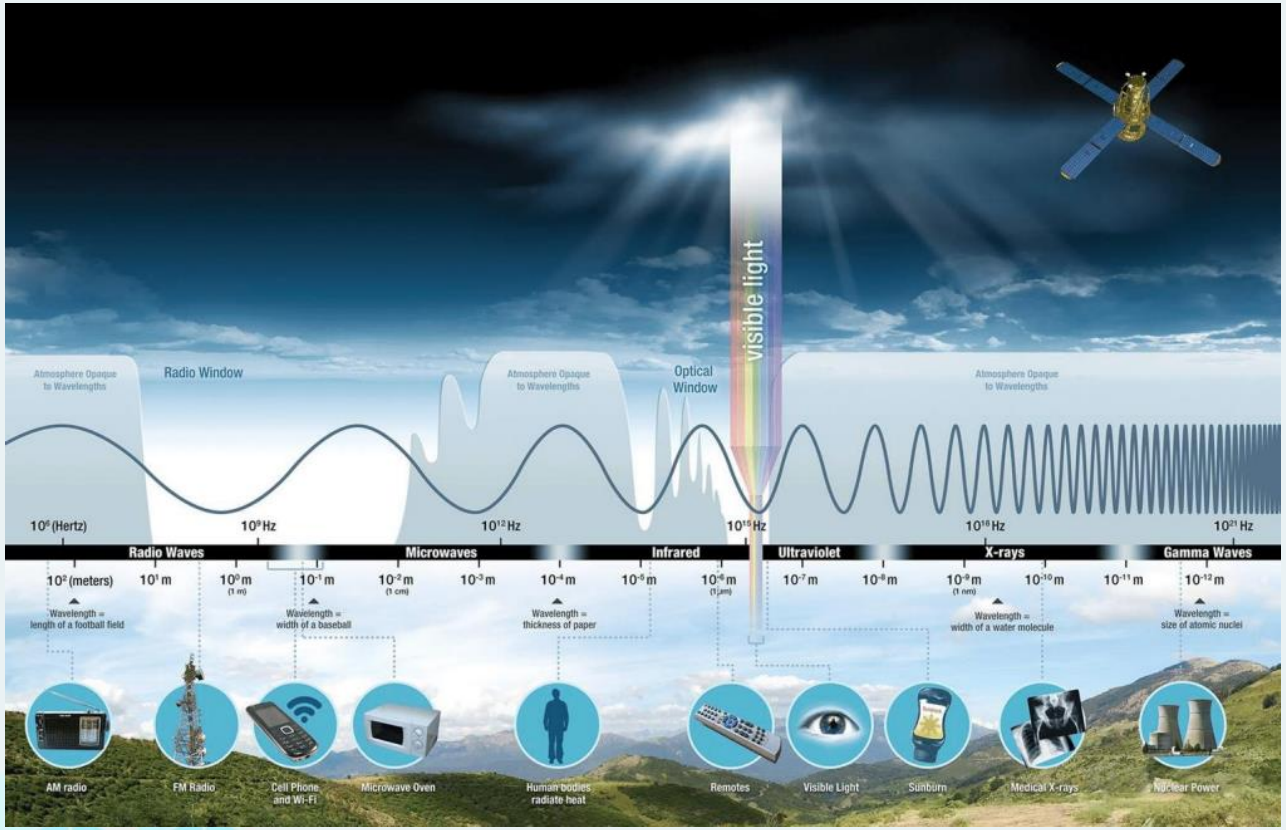
What is remote sensing?



- 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

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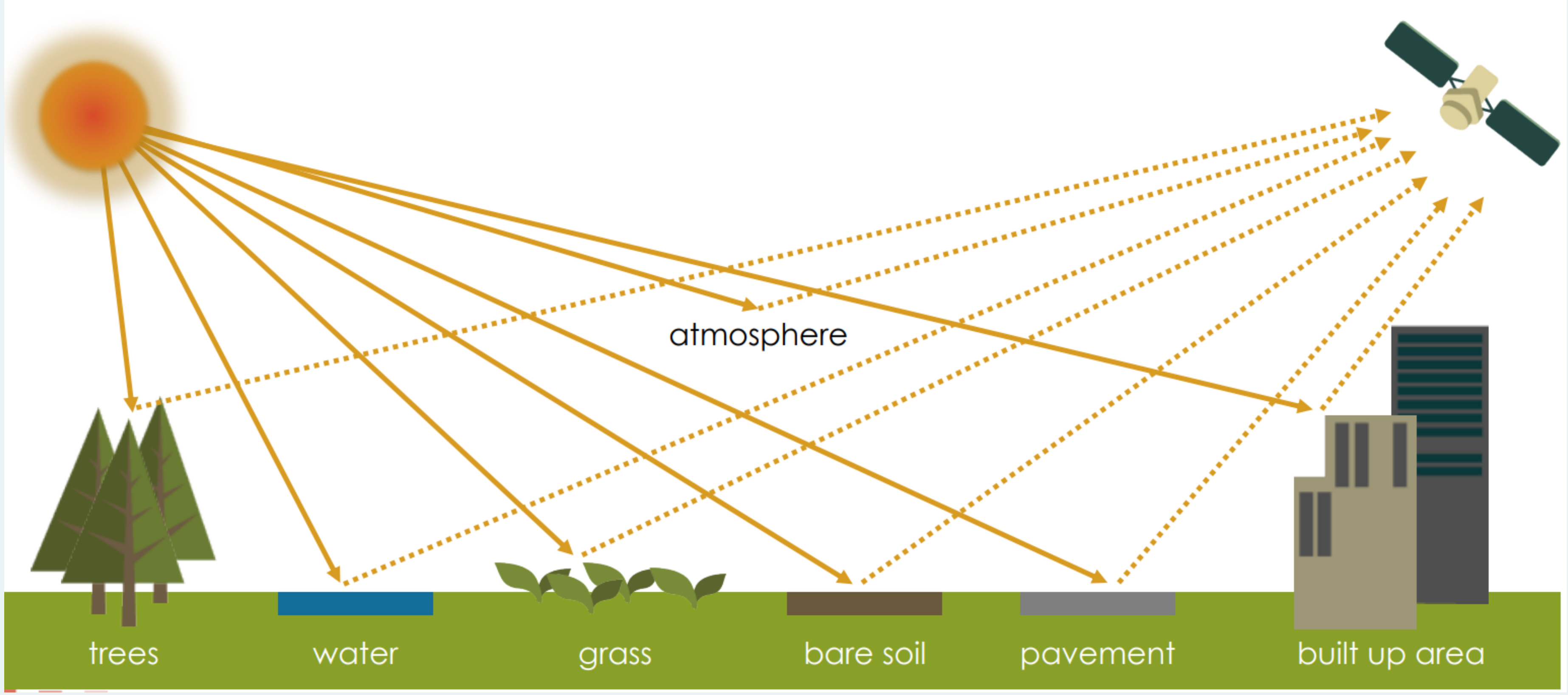
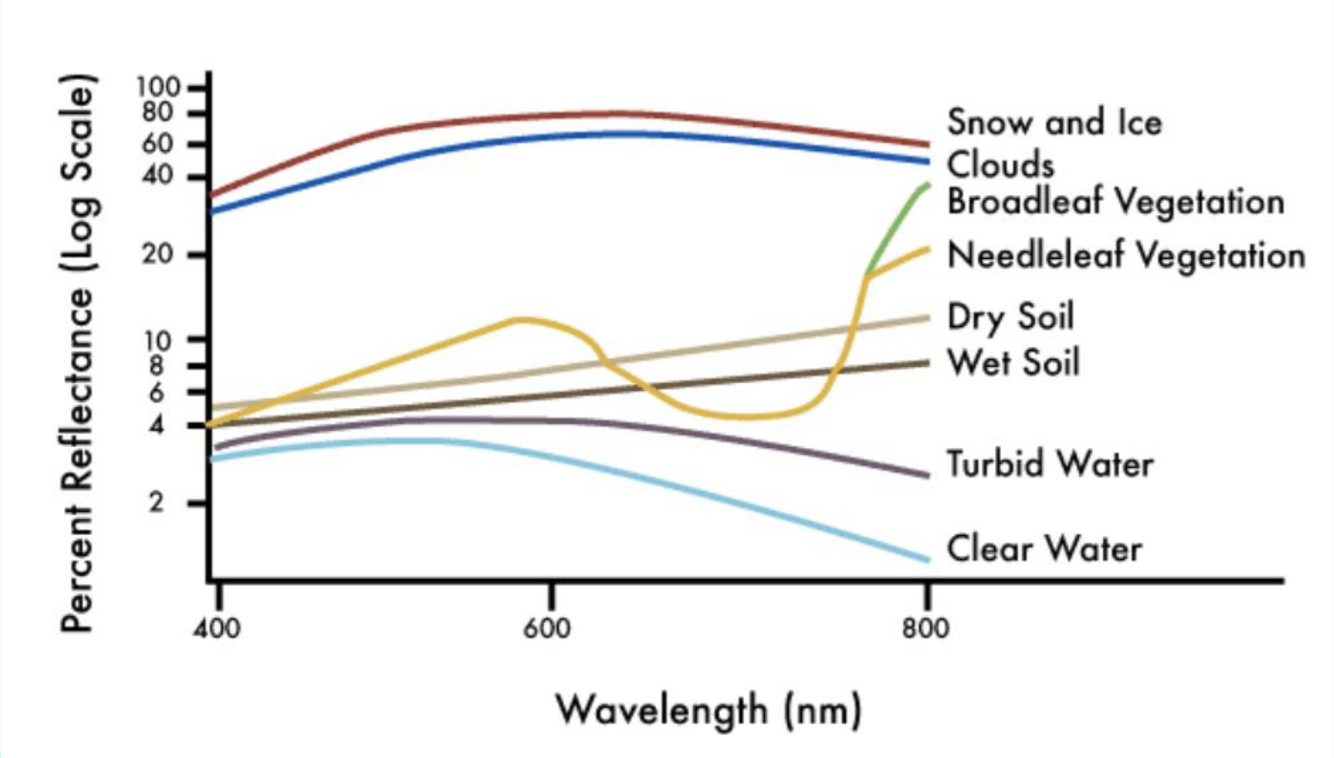
What do satellites measure ?



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.

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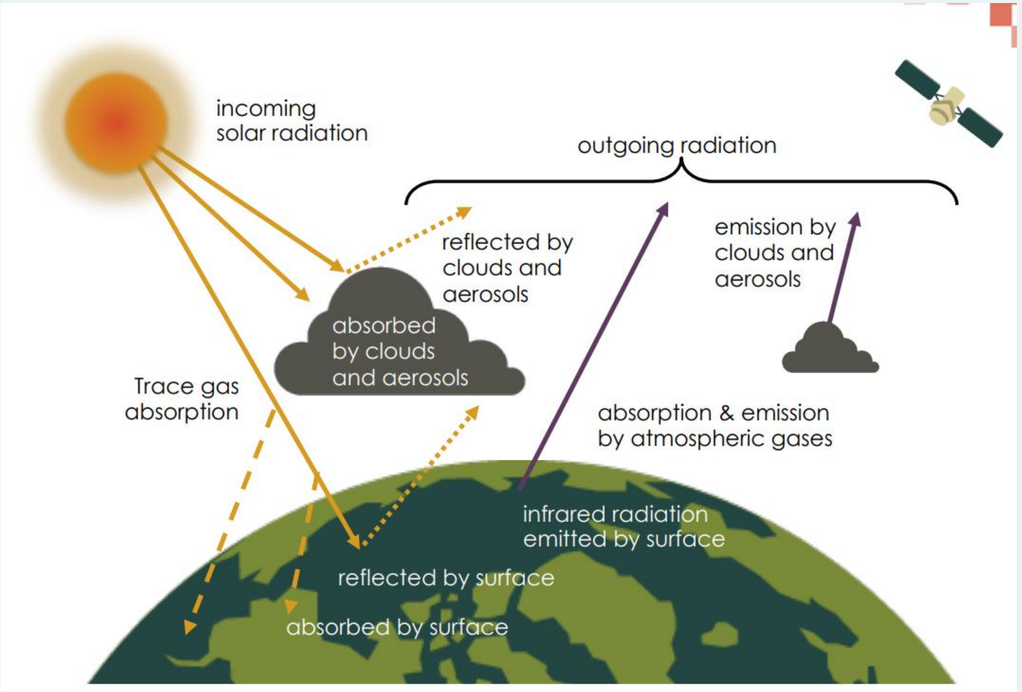
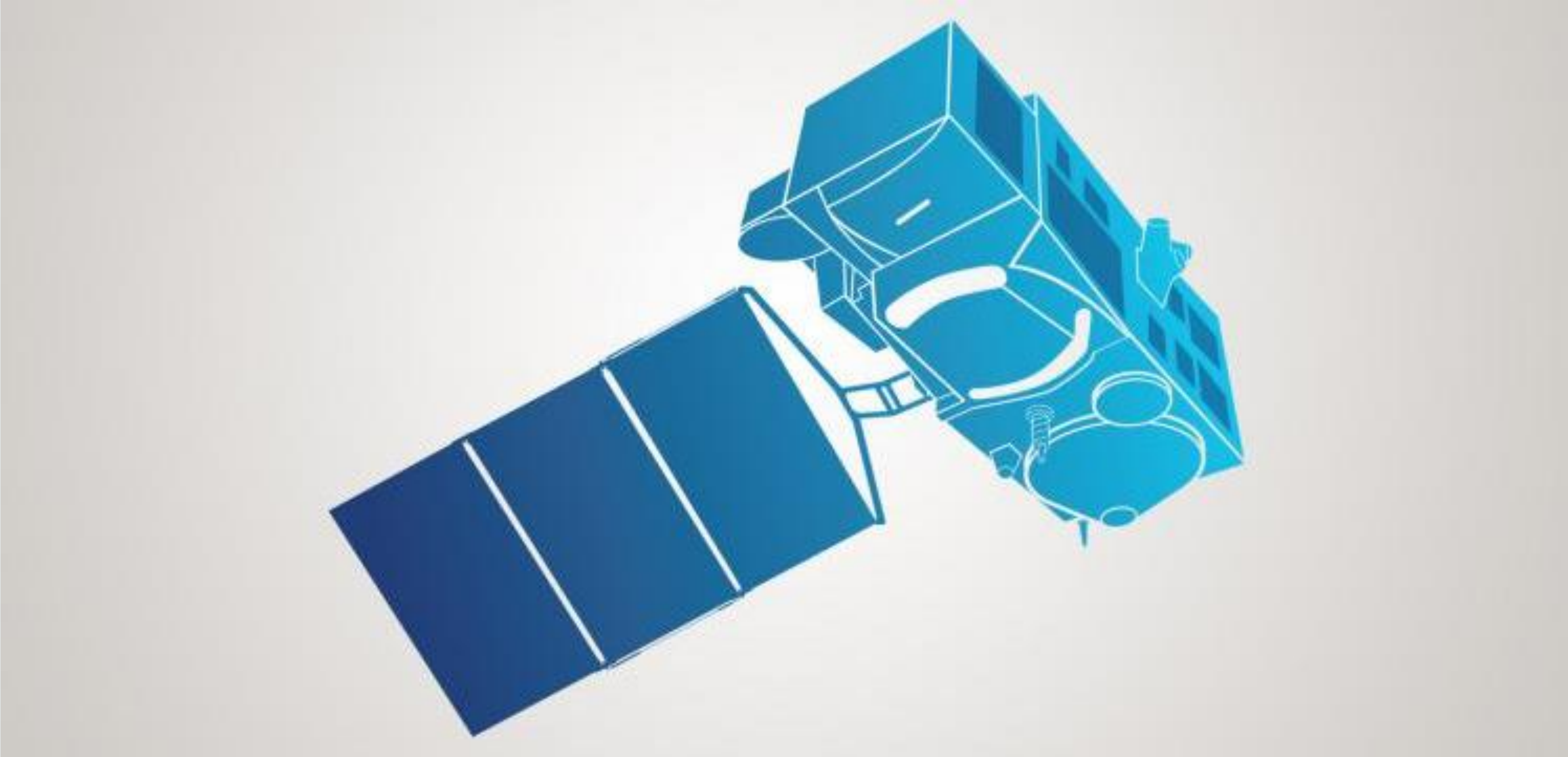
Measuring Properties of the Earth-Atmosphere System from Space

- 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





Satellites, Sensors, and Orbits

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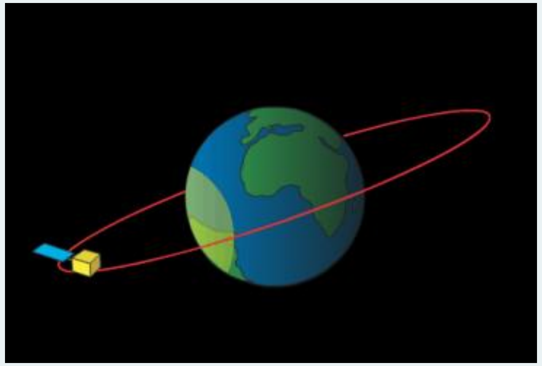
Characterizing Satellites and Sensors

- **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...

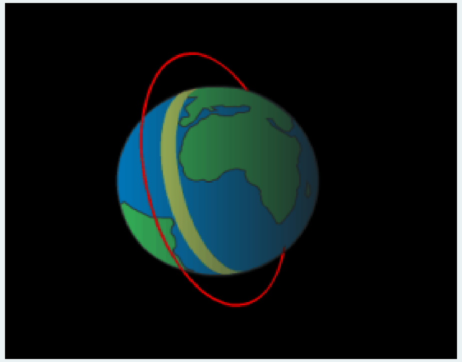
Common Orbit Types

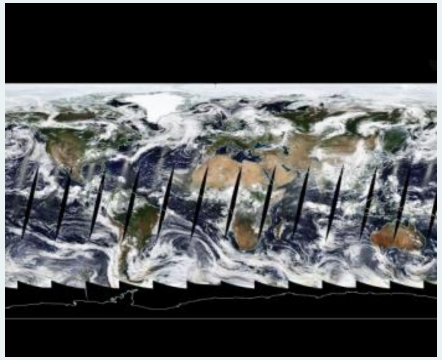
Geostationary Orbit



- Has the same rotational period as Earth
- Appears 'fixed' above Earth
- Orbits ~36,000 km above the equator
- Limited Spatial Multiple observations/day • Limited spatial coverageGeostationary Satellites: Every 30 sec. to 15 min.

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

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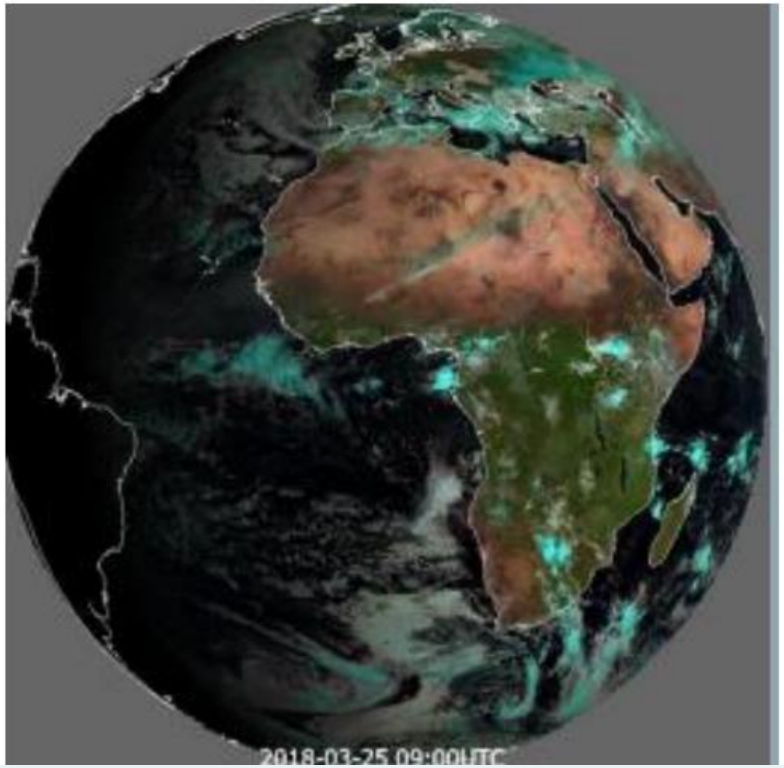
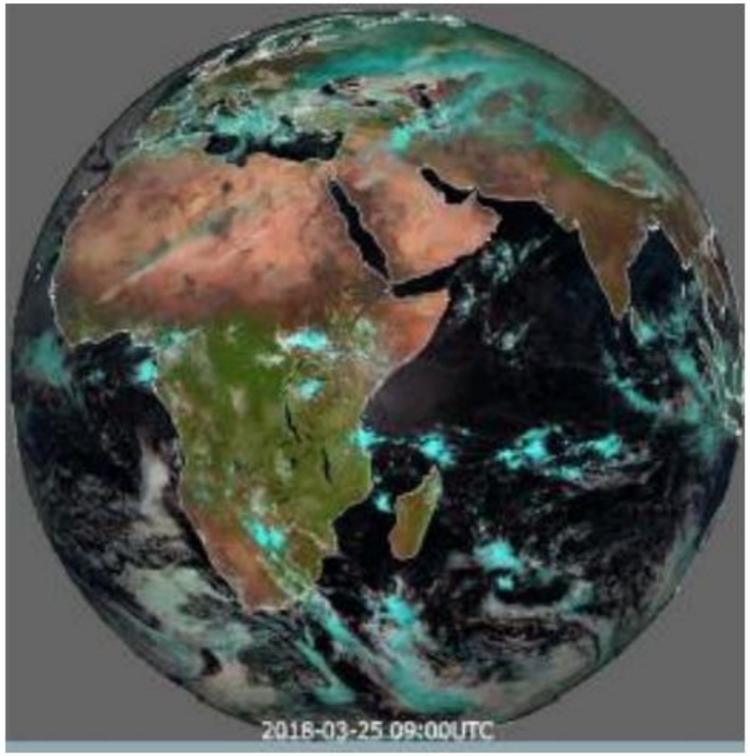
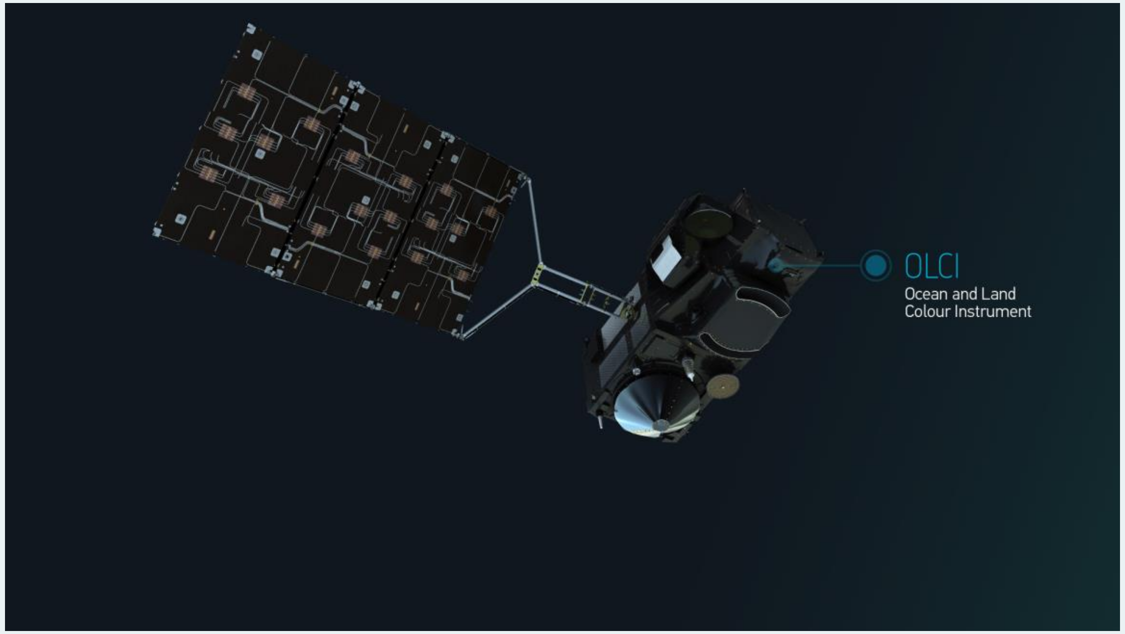
Geostationary Satellites



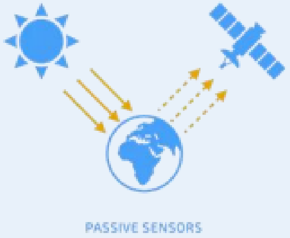


Satellites and Sensors

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



Satellite Characteristics/Satellite Sensors

Passive Sensors	measure Radiation from external source	radiometers sounders	
Active Sensors	Measure its return radiation	Altimeter Radar scatterometer	

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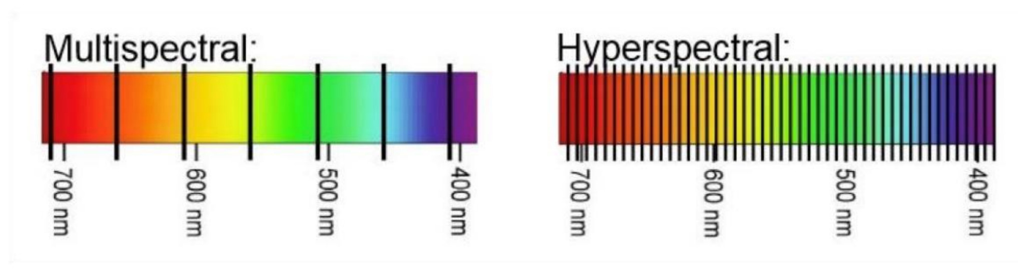
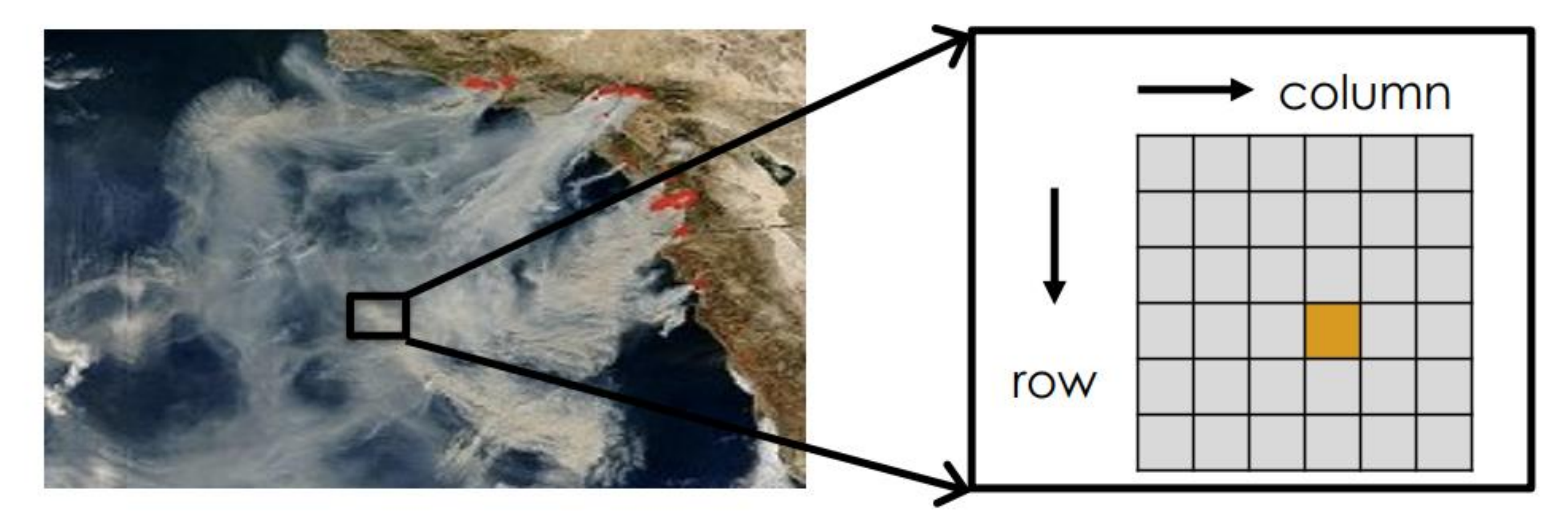
Satellite Characteristics/Spectral Resolution

- 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



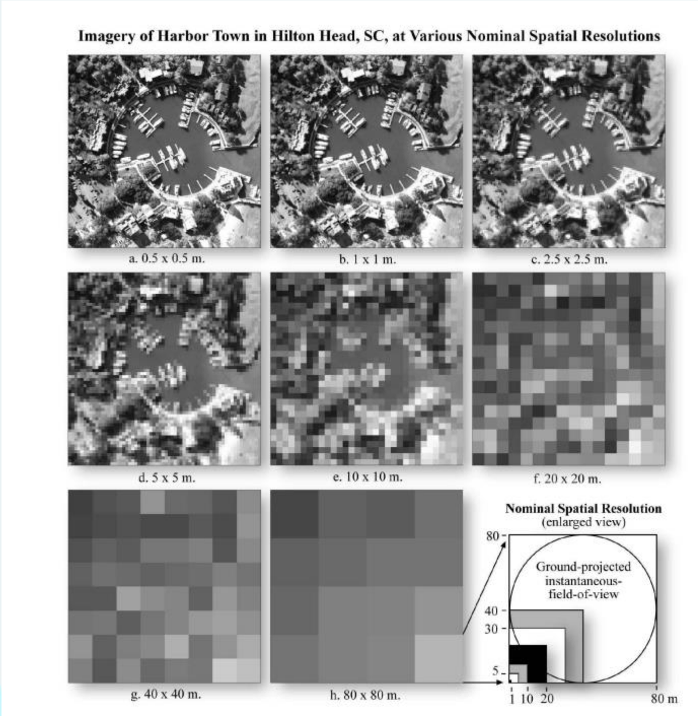
Satellite Characteristics/Spatial Resolution



- **Pixel – the Smallest Unit of an Image**
- **Spatial resolution is defined by the size of a pixel**

Satellite Characteristics/Spatial Resolution

Why is spatial resolution important?



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

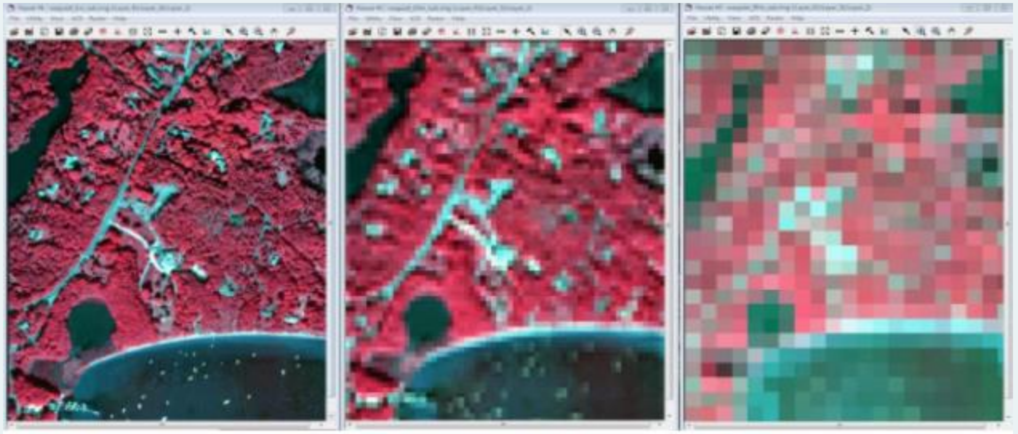
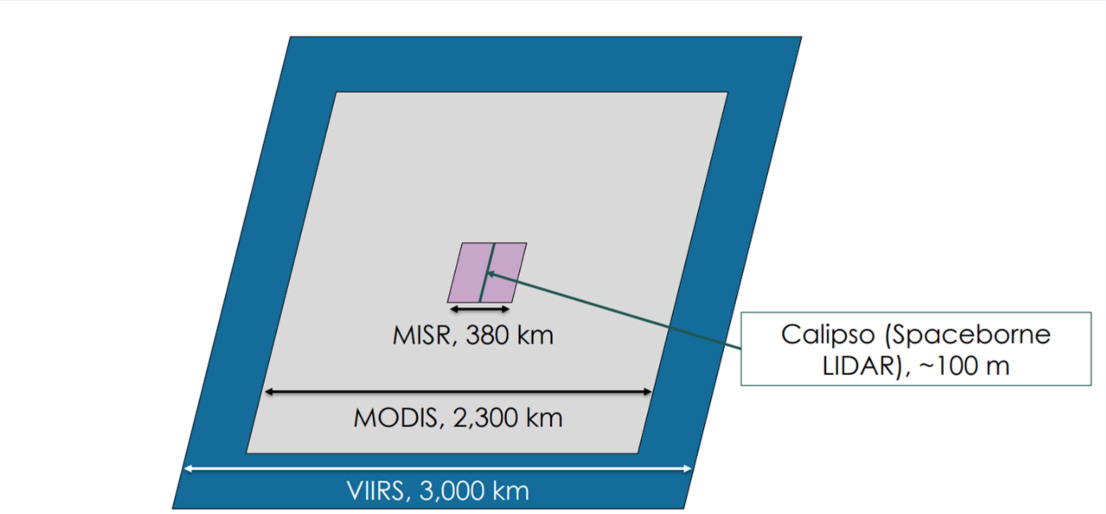


Image Credit: csc.noaa.gov

Satellite Characteristics/Spatial Resolution

Spatial Resolution vs. Spatial Extent

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



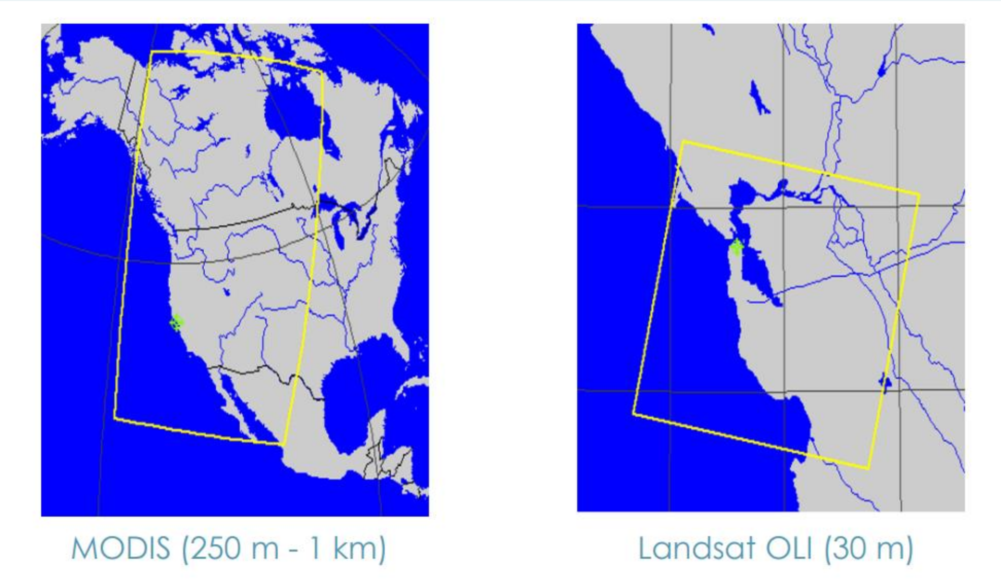


Image Credit: csc.noaa.gov

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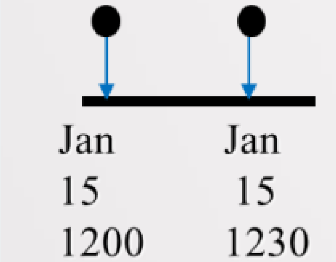
Satellite Characteristics/Temporal Resolution

- The time it takes for a satellite to complete one orbit cycle—also called "revisit time"
- It mostly depends on swath width of the satellite – the larger the swath – the higher the temporal resolution



Satellite	Sensors	Resolution
Landsat	• Enhanced Thermatic Mapper (ETM+) • Operational Land Manager (OLI)	185km Swath; 15m, 30m,60m 16 day revisit
Terra & Aqua	Moderate Resolution Imaging Spectrometer (MODIS)	2330Km Swath; 250m, 500m, 1km 1-2 day revisit
Suomi NPP	Visible Infrared Imaging Radiometer (VIIRS)	3040km Swath; 10m,20m 60m 1-2 day revisit
Sentinel 2	Multispectral Imager	290 km Swath ; 10m, 20m, 60m 5 day revisit
Sentinel 3	Ocean and Land Color instrument (OLCI)	1270 km Swath; 300m 27 day revisit
Sentinel 1	SAR	400 km Swath; 12 day revisit

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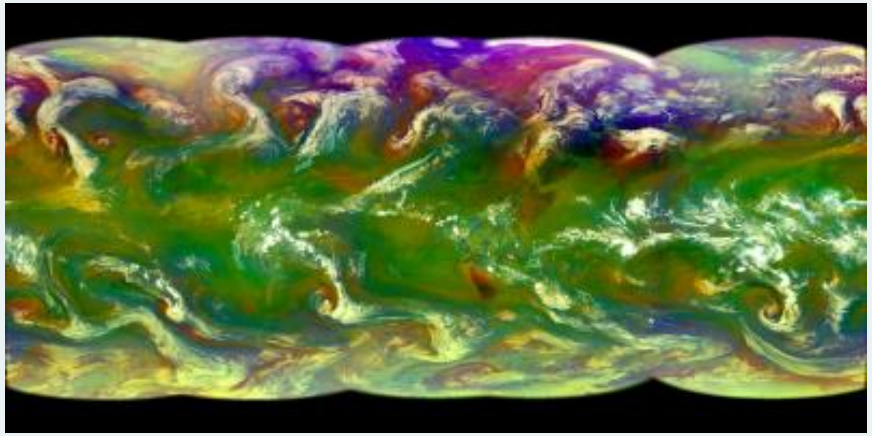
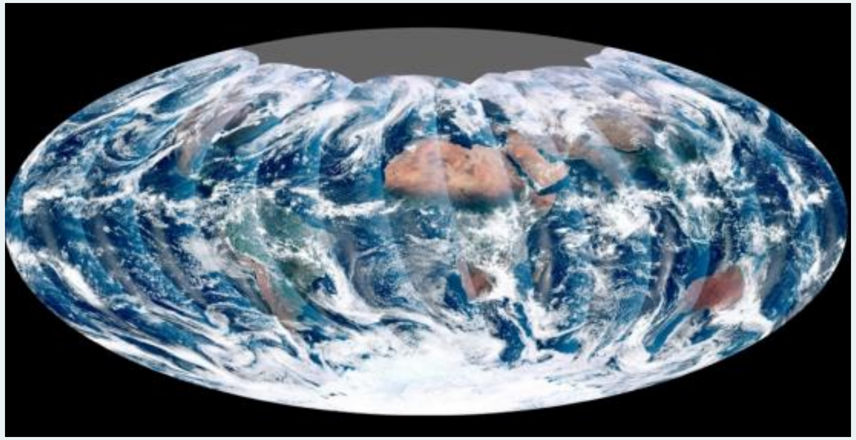
Temporal Resolution

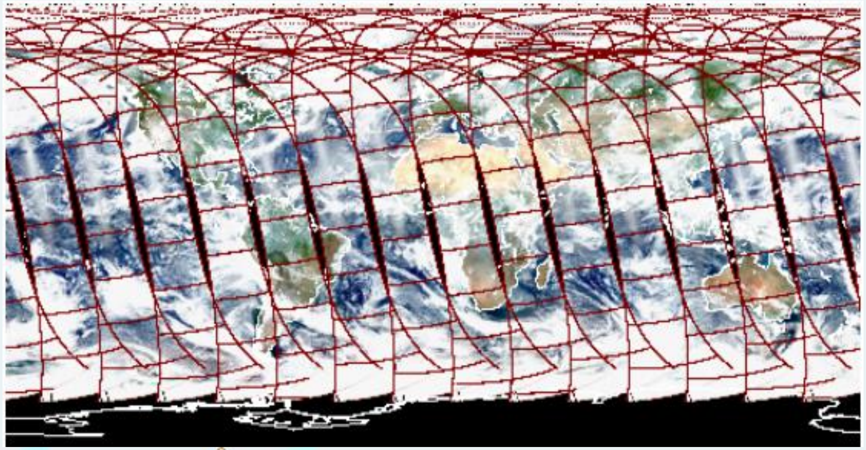
Geostationary

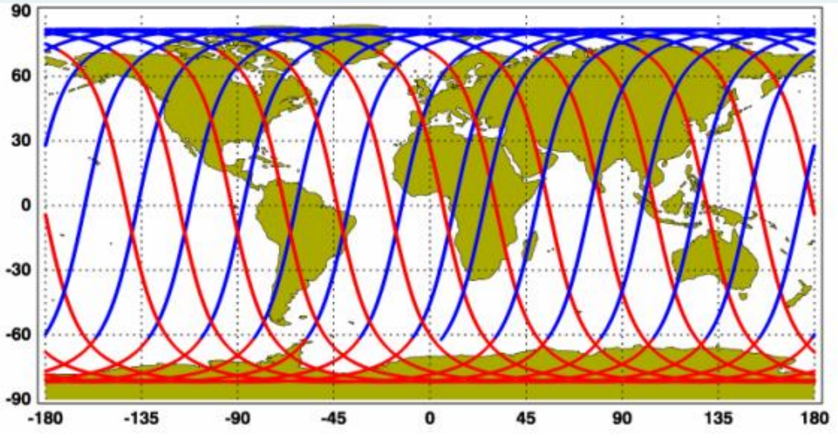




VIIRS

MODIS





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Satellite Characteristics/Radiometric Resolution

- The sensitivity of detectors to small differences in electromagnetic energy.
- The better the 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.

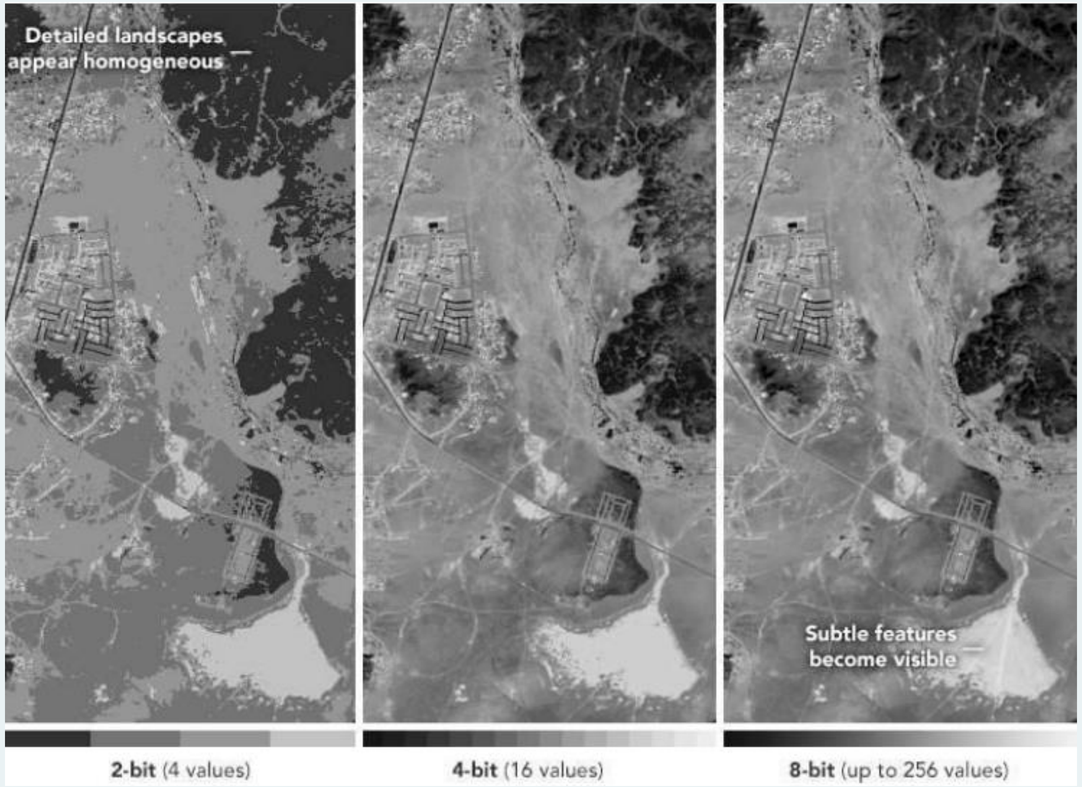


Image Credit: NASA's Earth Observatory

Remote Sensing – Types of Resolution

- **Spatial Resolution**

  Smallest spatial measurement

- **Temporal Resolution**

  Frequency of measurement

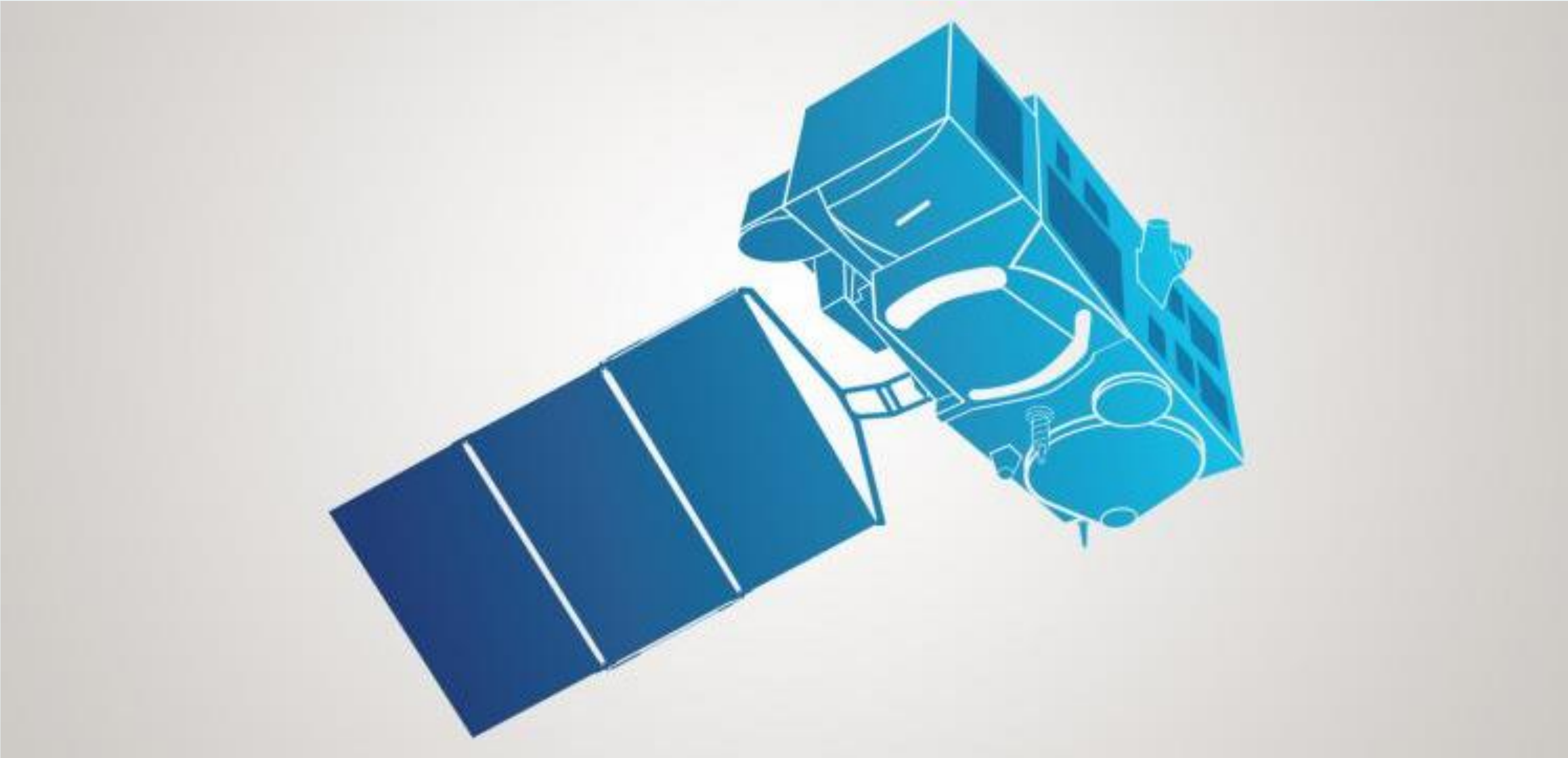
- **Spectral Resolution**

  Number of independent channels

- **Radiometric Resolution**

  Sensitivity of the detectors

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



Satellites Data Processing

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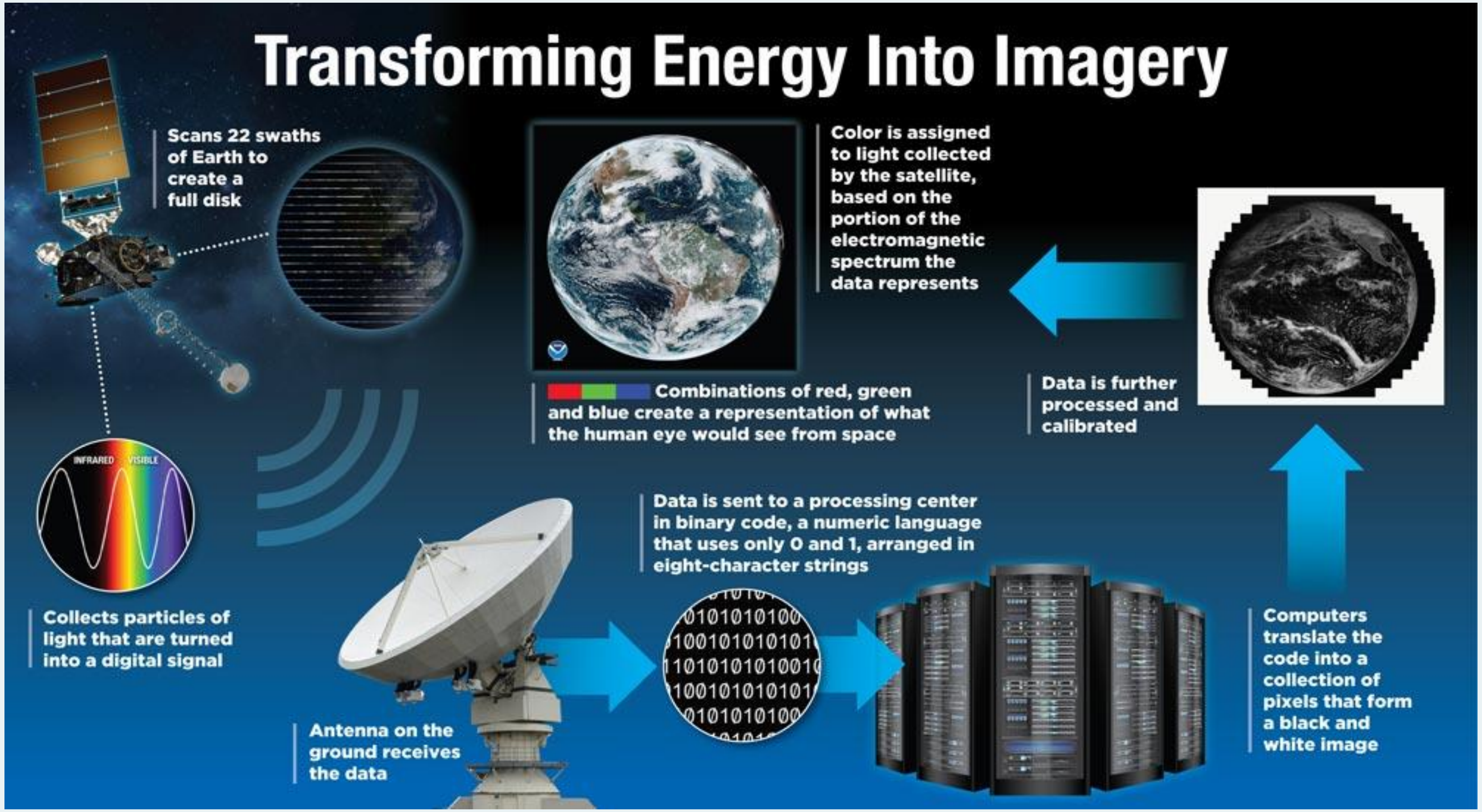
Satellites Data Processing



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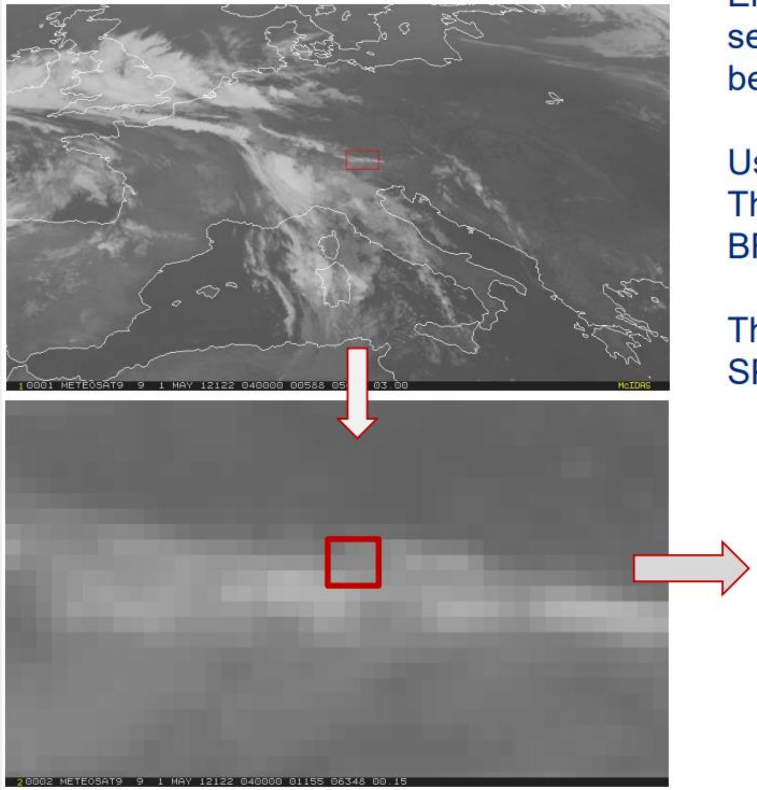
What is really measured?



Energy emitted by clouds or the land surface is received at the sensor as some measure of the electric signal, which is digitized to be transmitted to ground station – COUNTS

Using calibration the counts are converted to RADIANCE.
Then, via Planck's law the radiance can be converted to BRIGHTNESS TEMPERATURE.

This is done in discreet squares – pixels, size depending on the SPATIAL RESOLUTION of the instrument.

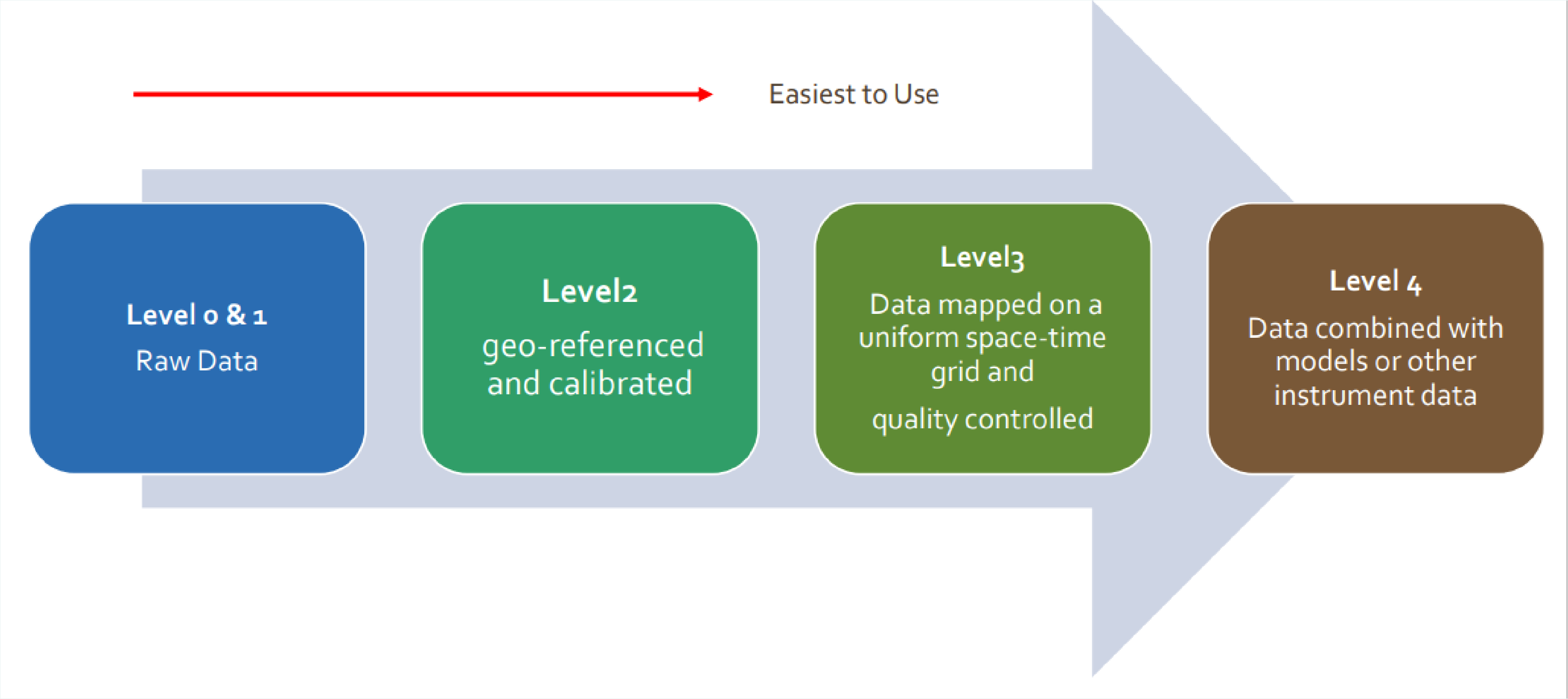
387 270.76	352 264.90	339 262.62
340 262.79	333 261.54	333 261.44
276 250.53	297 254.77	305 256.32

Count 339 - 262.62 K
Count 340 - 262.79 K

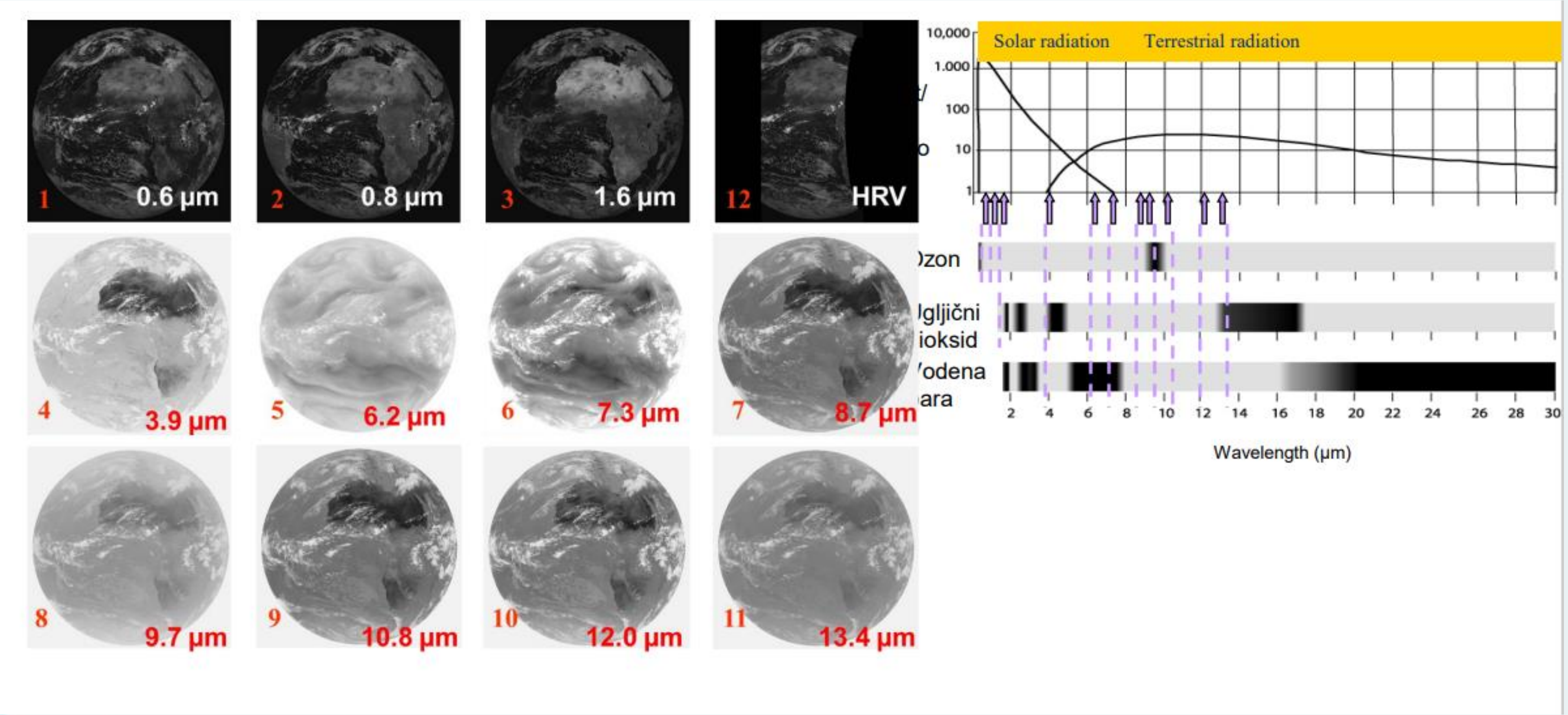
Temperatures "in between" cannot be measured – RADIOMETRIC RESOLUTION

Counts
Brightness Temperatures

The Remote Sensing Process

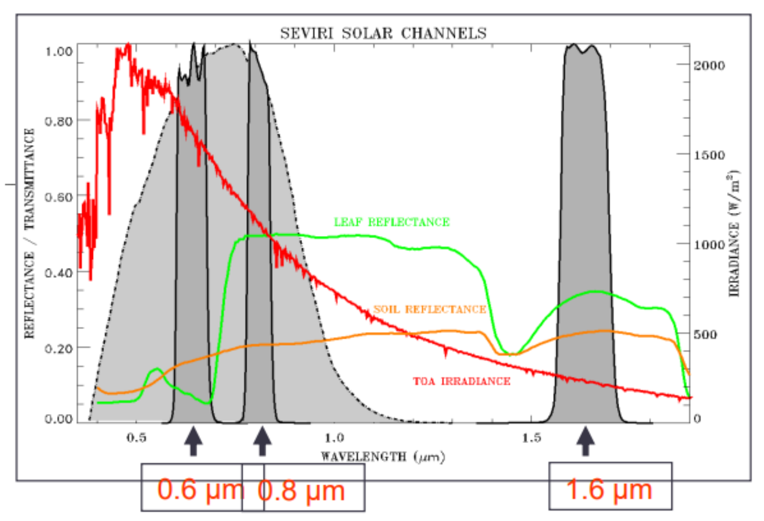


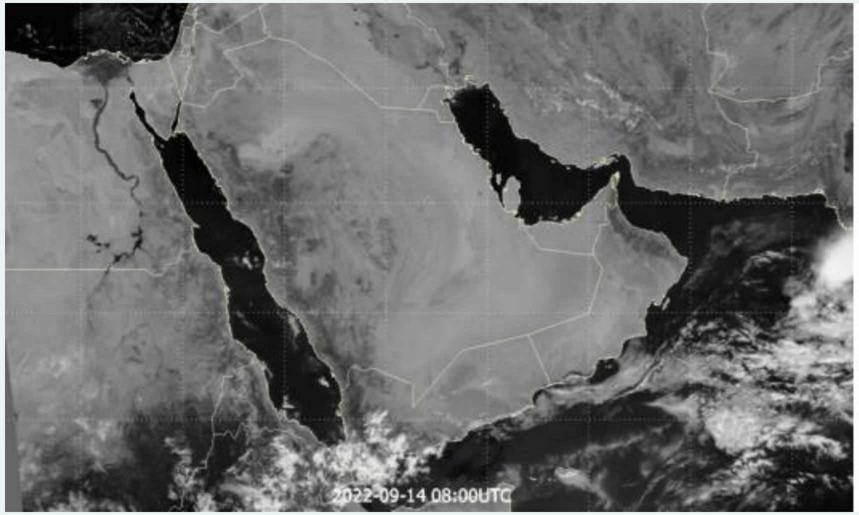
Single Channels

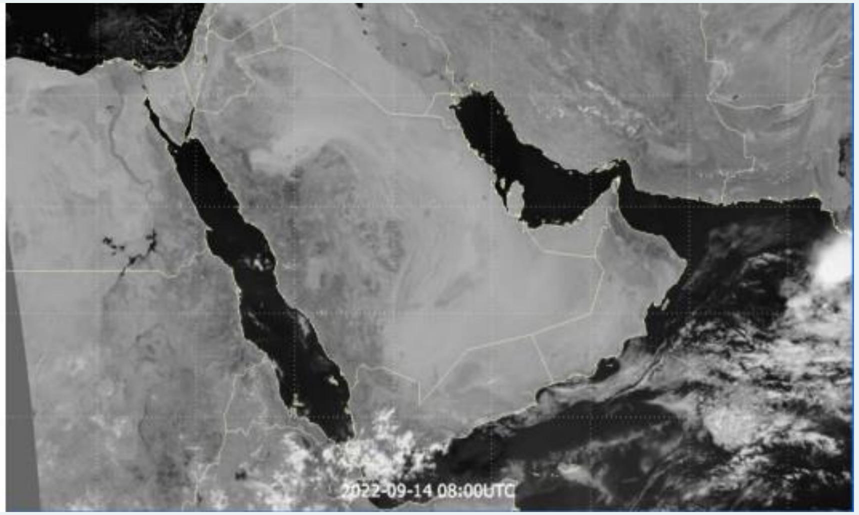


Single Channels

- Reflected solar radiation
- Available during daytime only.
- Cloud monitoring
- In 0.8 µm vegetation reflects much more used for land an vegetation products







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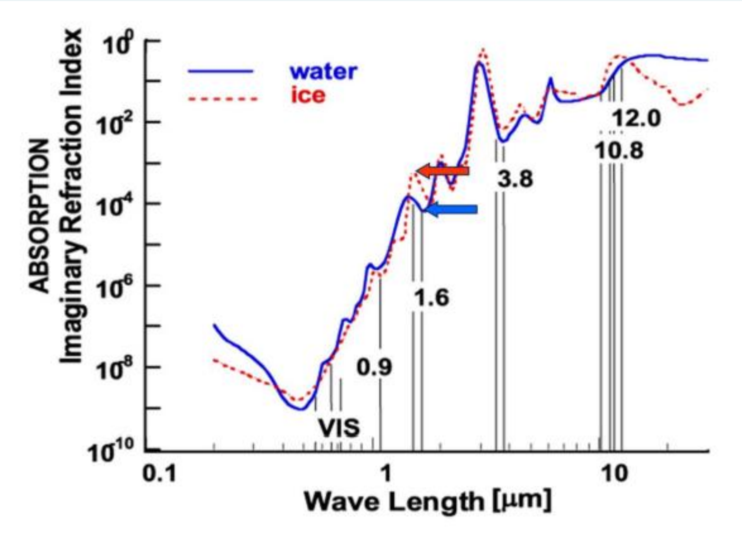
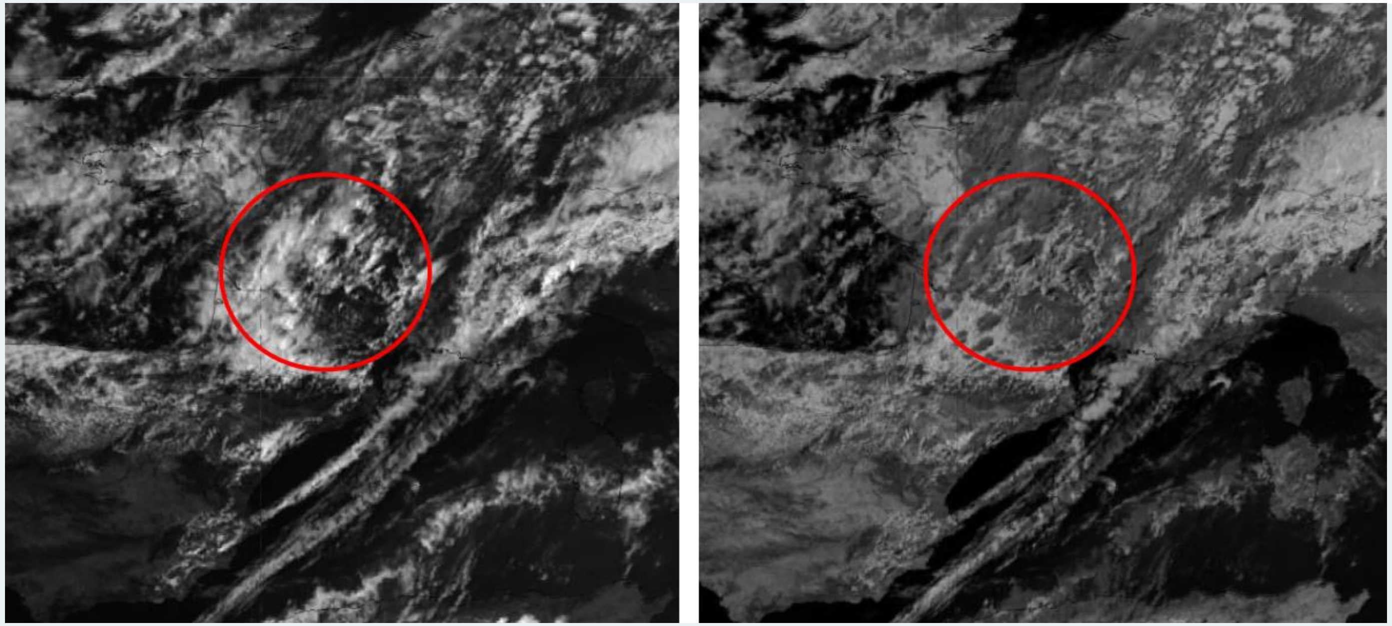
Single Channels

- Different reflectivity of ice and water!
- Ice absorbs more in 1.6 – ice clouds are dark!
- Differing snow from water clouds





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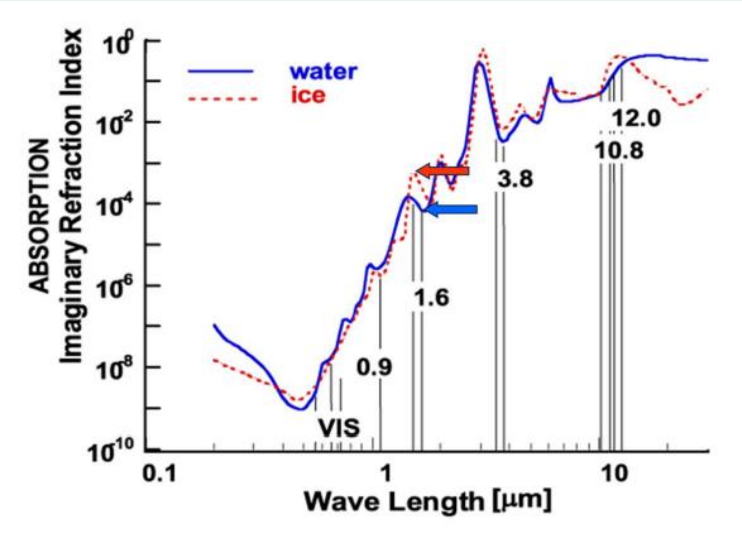
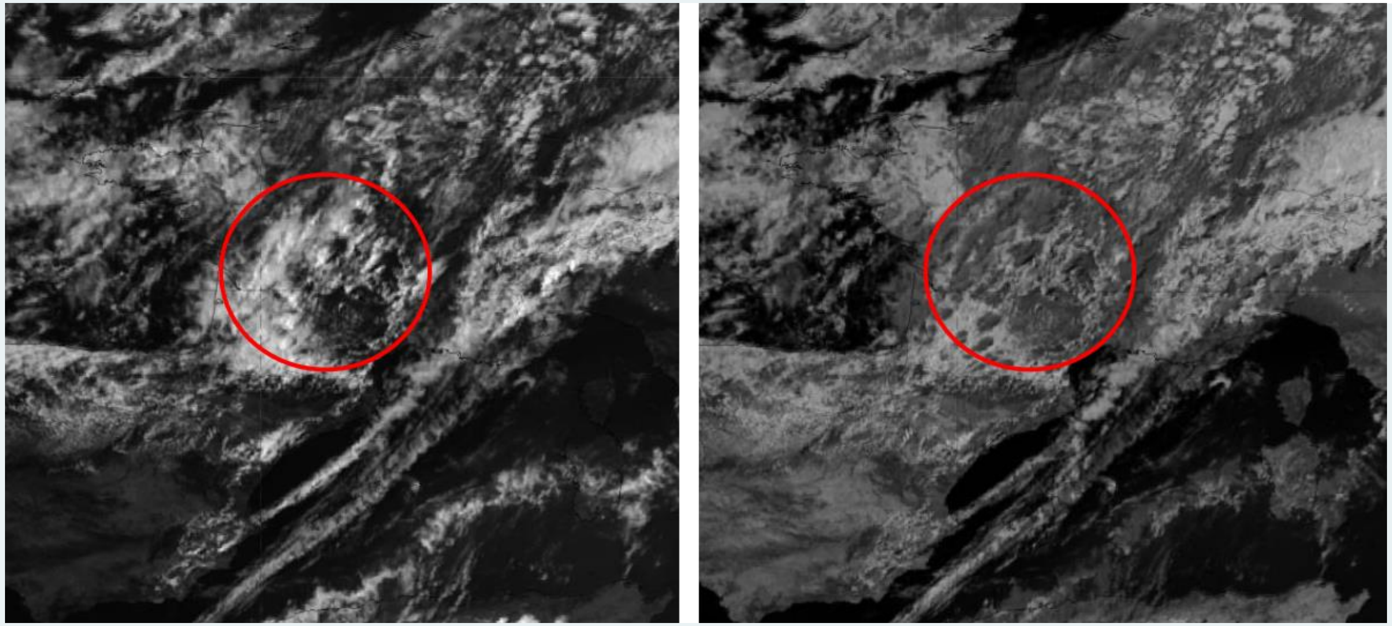
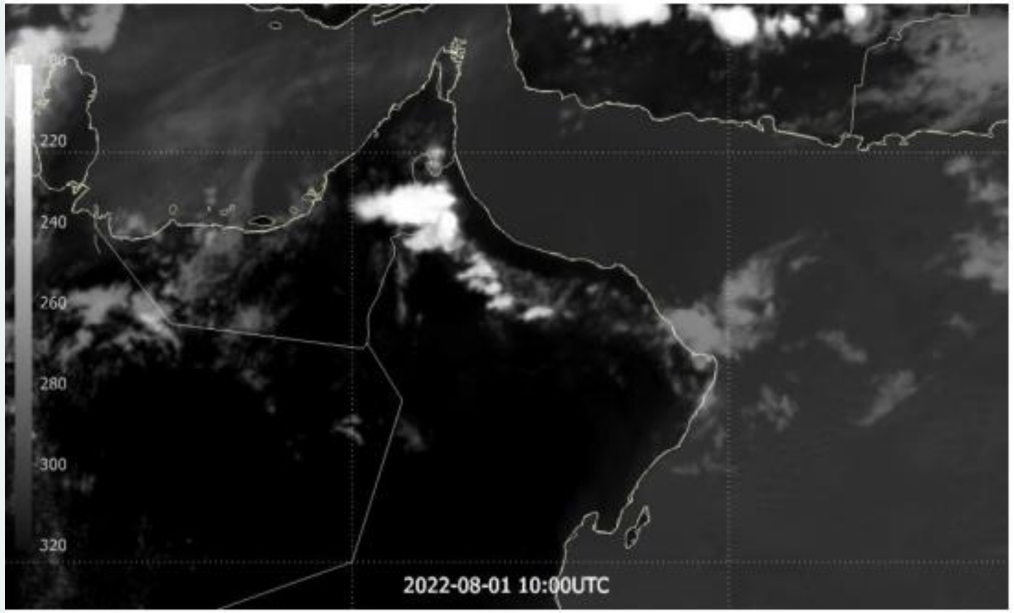
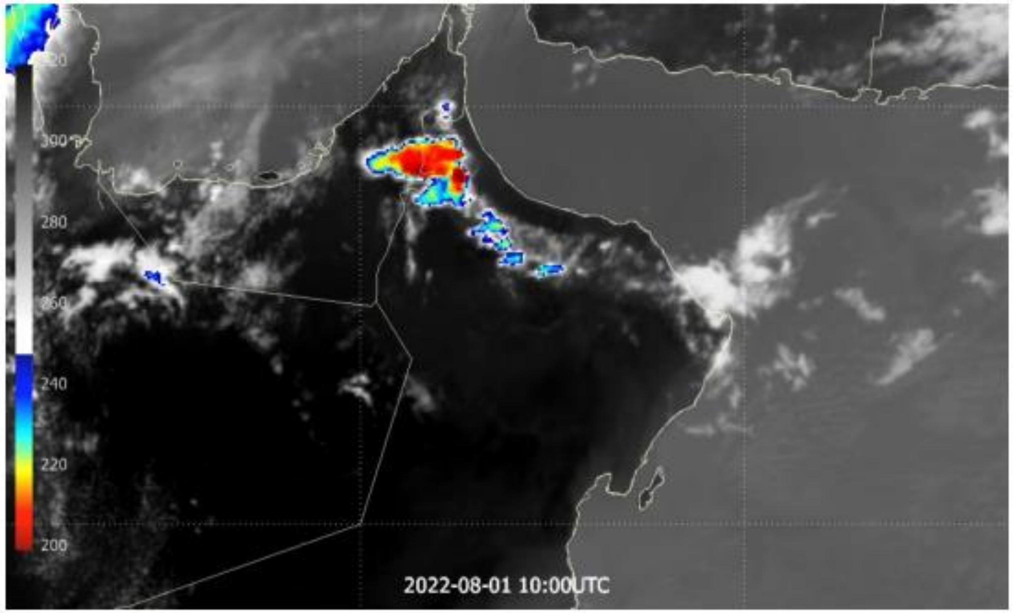




Single Channel (Enhanced IR10.8)





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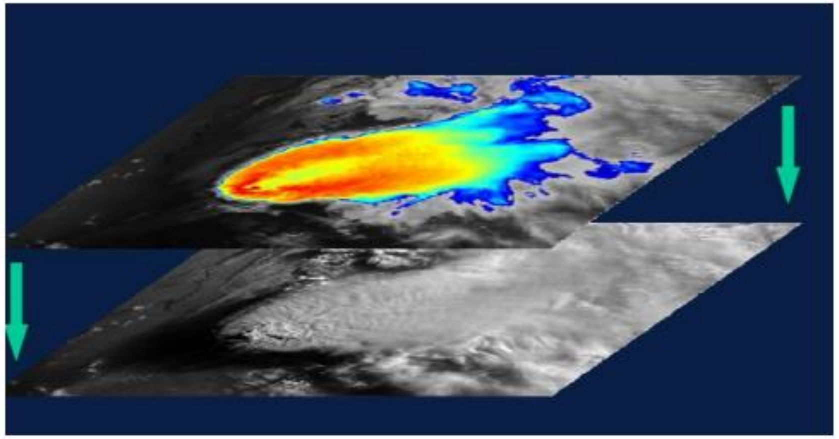
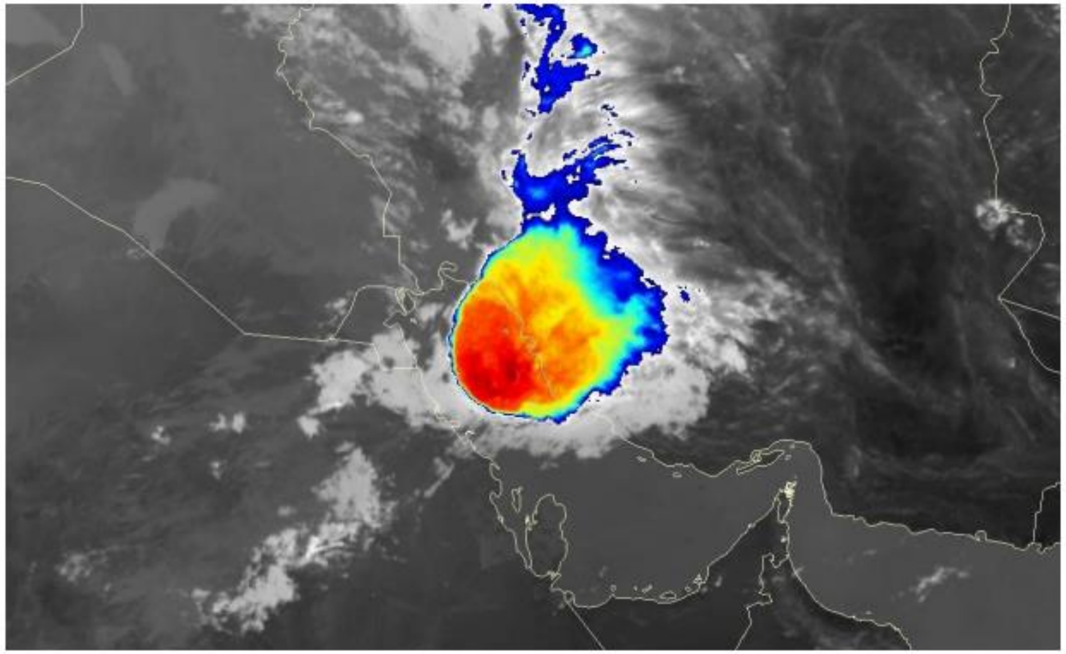
Sandwich Products

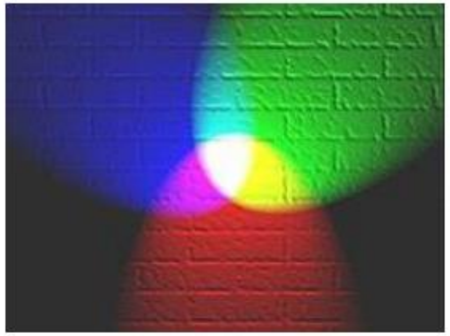




But we have many more channels!

RGB Composite

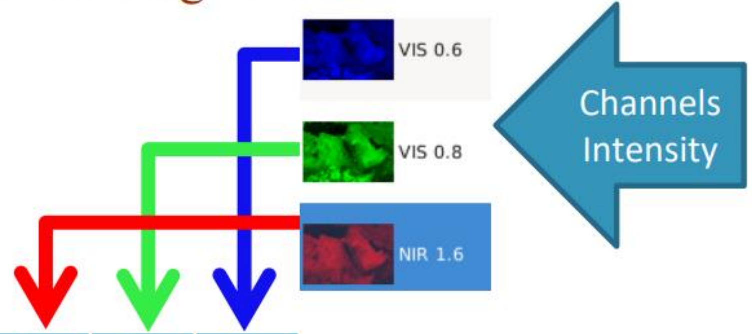
- **Every spectral channel** (or combination) is assigned to **one of the RGB** components
- All colours follow this colour **RGB mixing**:



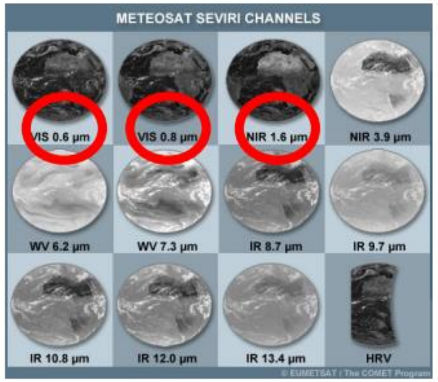
- Allows analysis of 3 (or more) spectral regions **at once**!

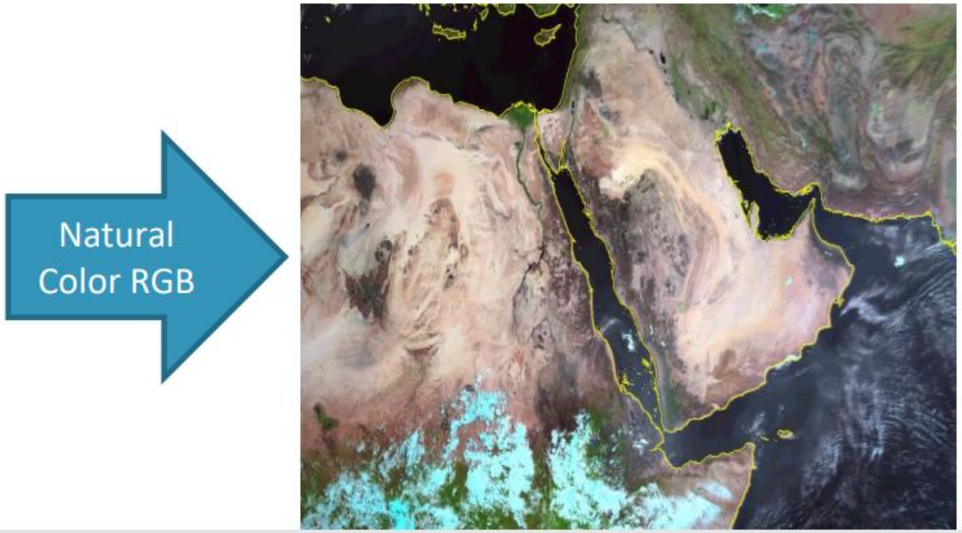
RGB Composite

How an RGB image is made ?

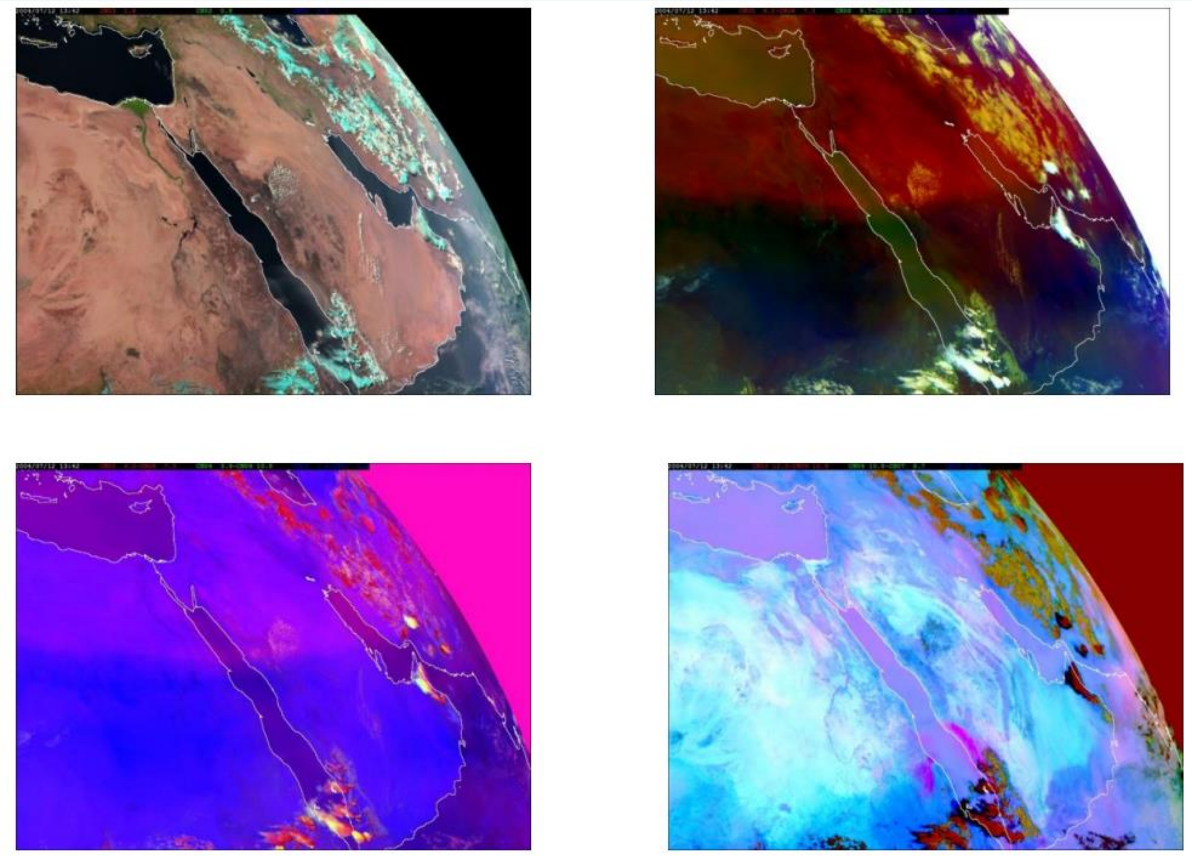


	R	G	B
	255	255	255
	255	255	0
	255	0	255
	0	255	255
	0	0	0
	143	143	143
	255	0	0
	0	255	0
	0	0	255





RGB Composite



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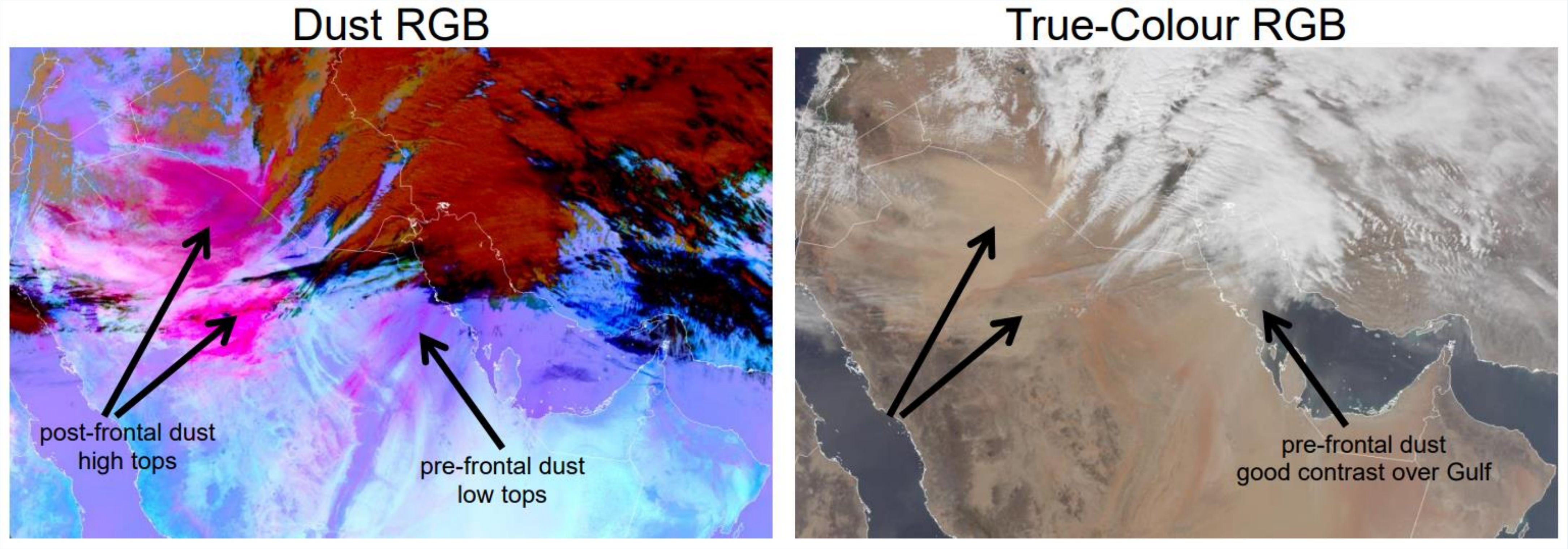
RGB Composite



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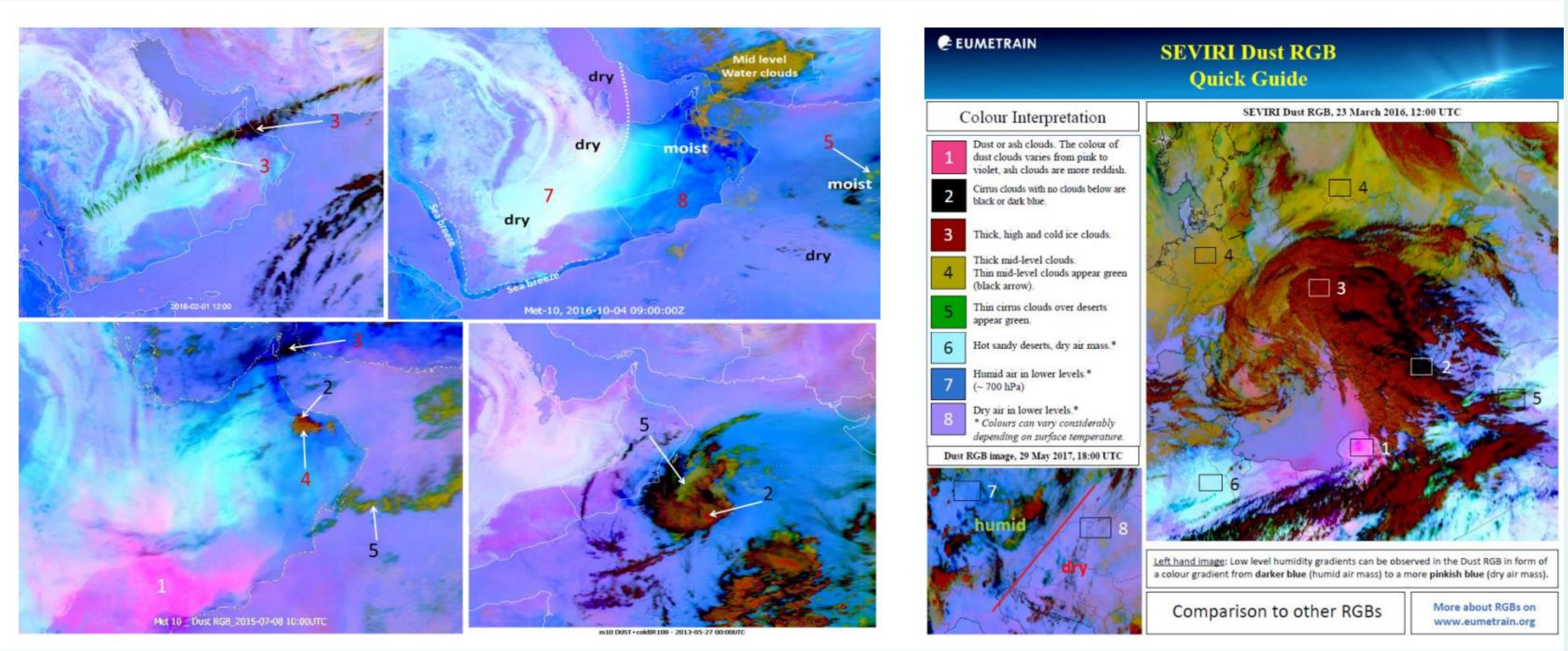
RGB Composite



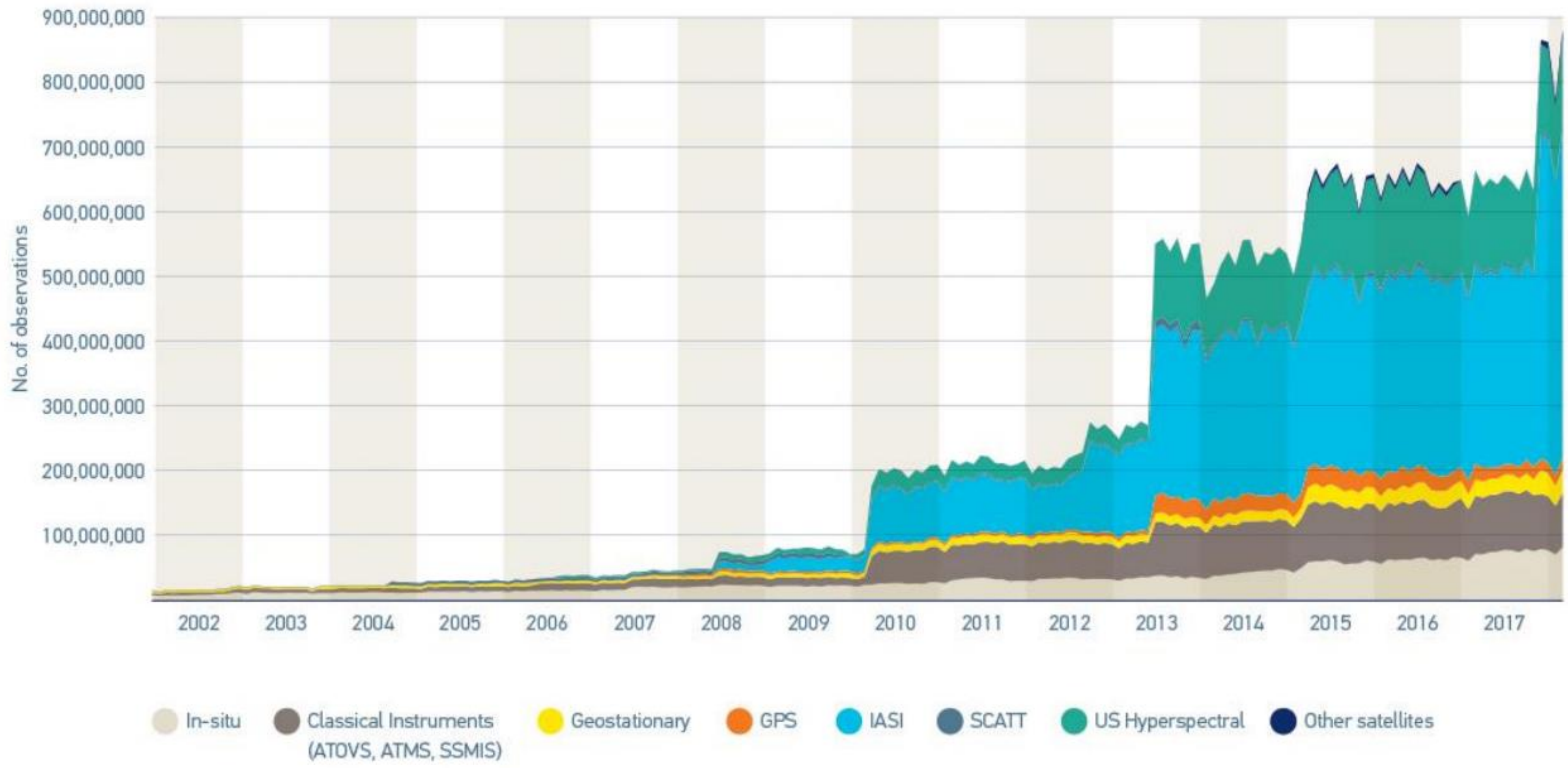
Ground Measurements

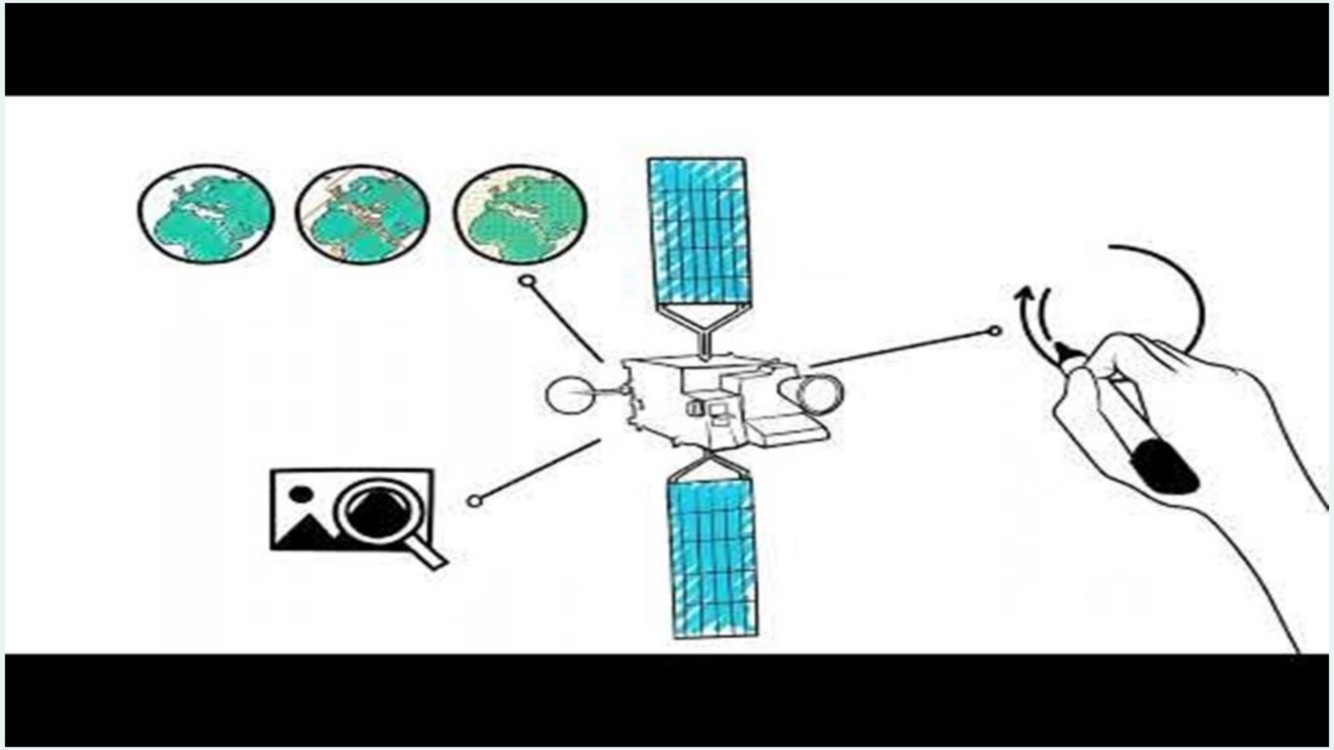
Remote Sensing

Models

Centre of Excellence-MUSCAT
for Satellite Applications

CAA
هيئة الطيران المدني


900,000,000
800,000,000
700,000,000
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
No. of observations
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
In-situ
Classical Instruments (ATOVS, ATMS, SSMIS)
Geostationary
GPS
IASI
SCATT
US Hyperspectral
Other satellites



Thank you

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