Remote Sensing Basics: Satellites and Sensors

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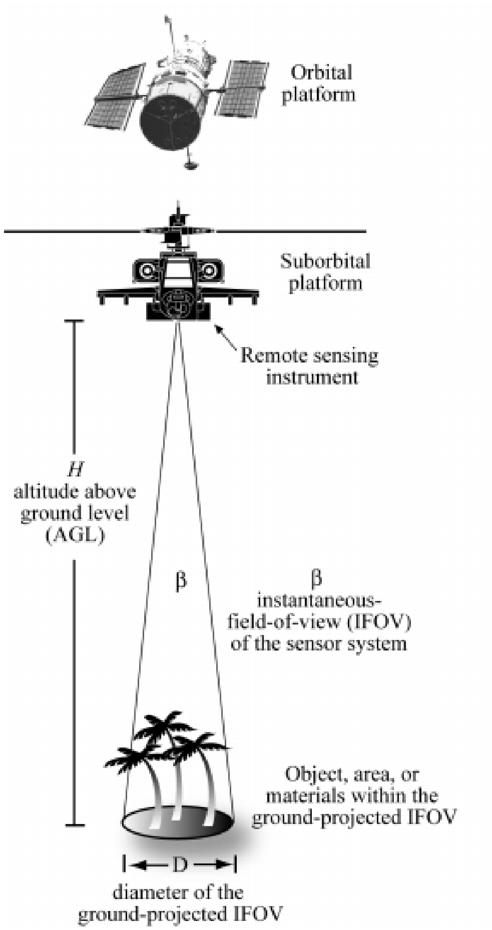
In this lecture:

- Active and passive remote sensing
- Satellite orbits and swaths
- Satellite sensor characteristics
    - Spatial coverage, revisit time
    - Spectral Coverage, spectral resolution
- Calibration, navigation, gridding
- Data processing stages

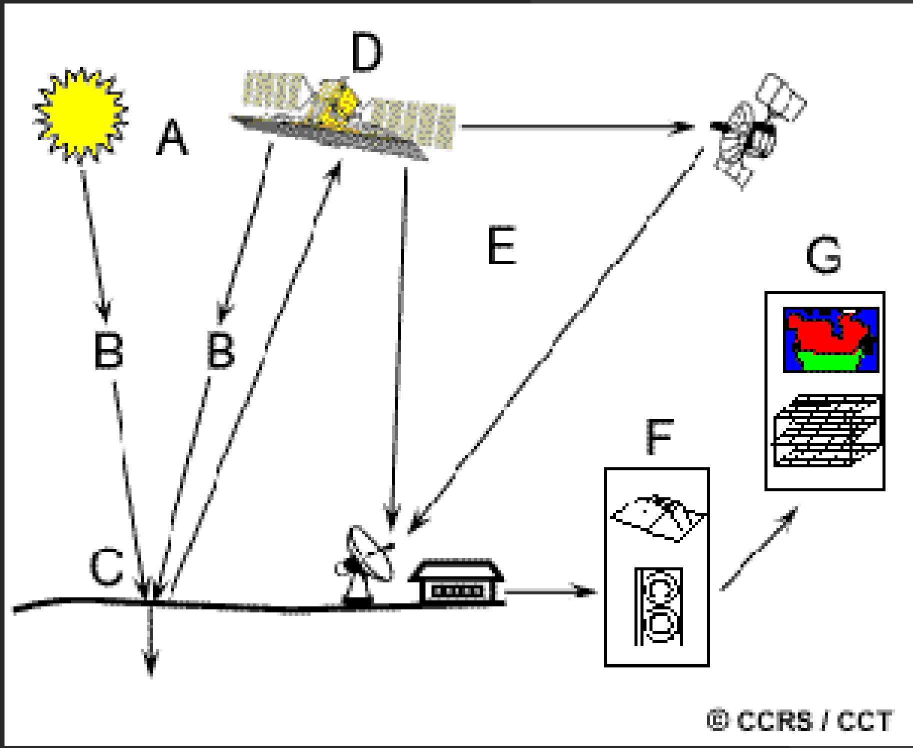
Remote Sensing



A remote sensing instrument collects information about an object or phenomenon within the instantaneous-field-of-view (IFOV) of the sensor system without being in direct physical contact with it. The sensor is located on a suborbital or satellite platform.

Elements of Remote Sensing

- Energy Source or Illumination (A)
- Radiation and the Atmosphere (B)
- Interaction with the Target (C)
- Recording of Energy by the Sensor (D)
- Transmission, Reception, and Processing (E)
- Interpretation and Analysis (F)
- Application (G)

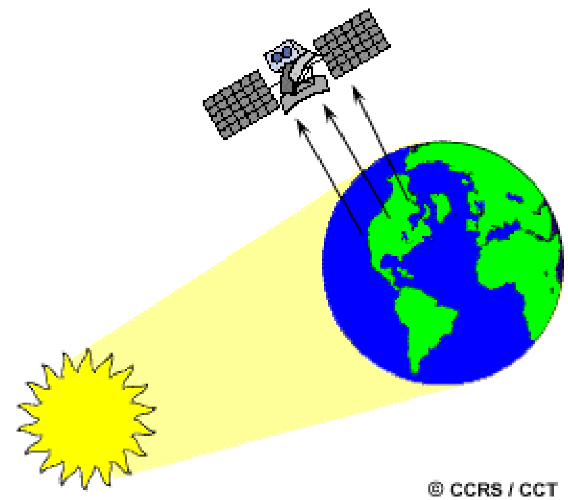


Observation Techniques

Two Basic Remote Sensing Techniques: Active and Passive

Passive sensors: Remote sensing systems which measure energy that is naturally available

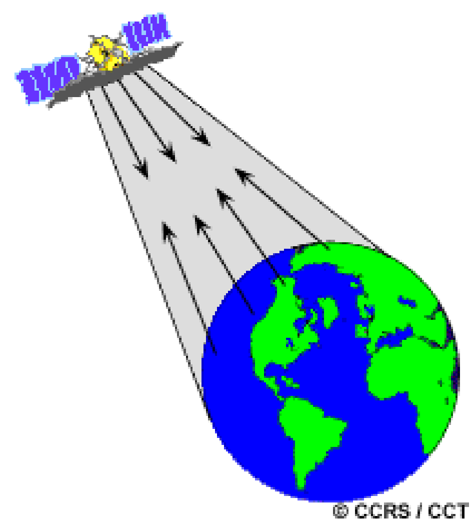
- Sun's energy which is reflected or
- Emitted thermal infrared



Active sensors, provide their own energy source for illumination

-Emit radiation

-Reflected radiation is detected and measured



Active Remote Sensing Techniques:

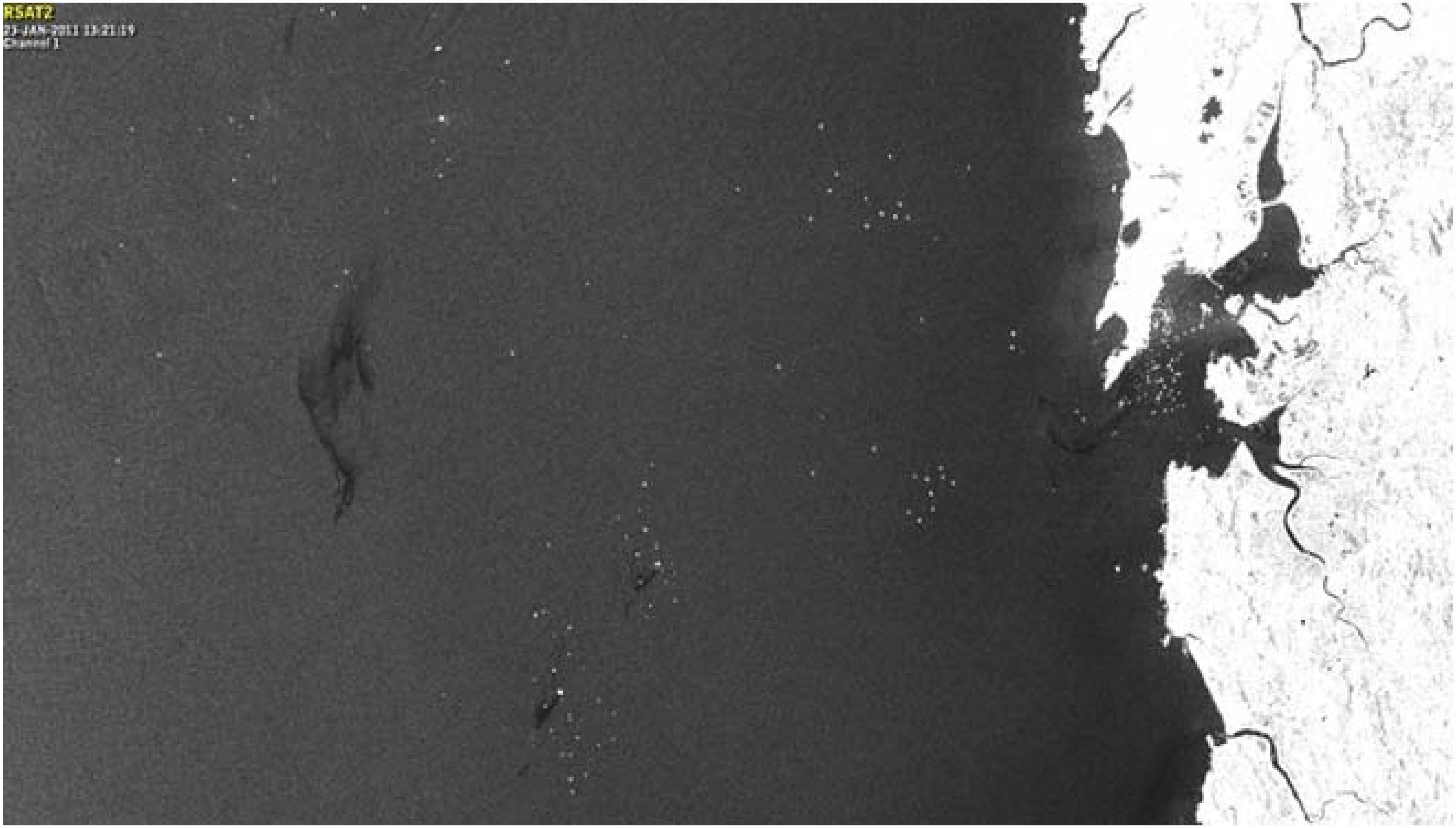
- Operations are independent of weather, time, or season.
- Can use frequencies unavailable from natural sources
- Can provide high spatial resolution

- **but**

- Require large amount of energy to operate
- Selective spatial coverage of the Earth's surface
- Observations performed at one frequency

At this time active sensors are not installed onboard weather satellites and are not used in operational meteorology and weather prediction. Radar data are available from number of environmental satellites.

Ships and Oil Spills in Radar Image

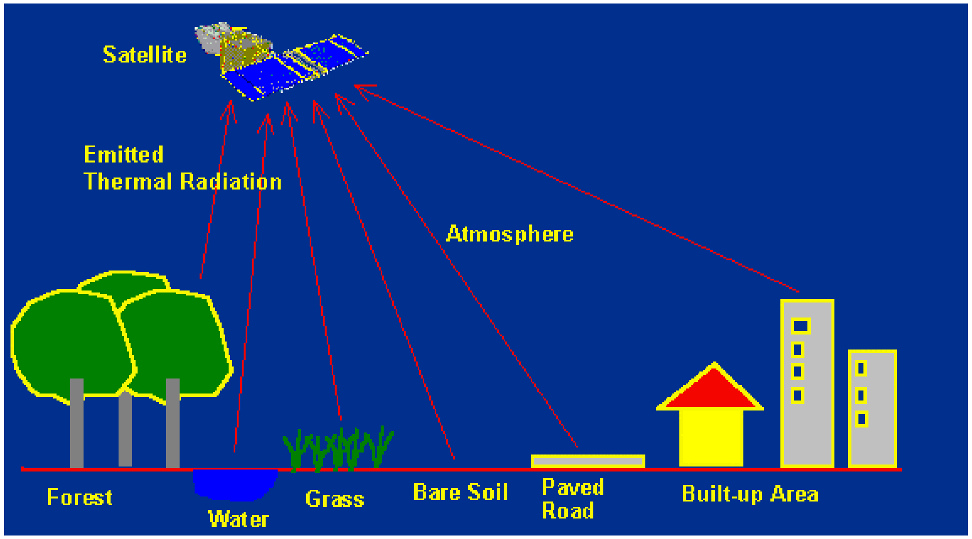


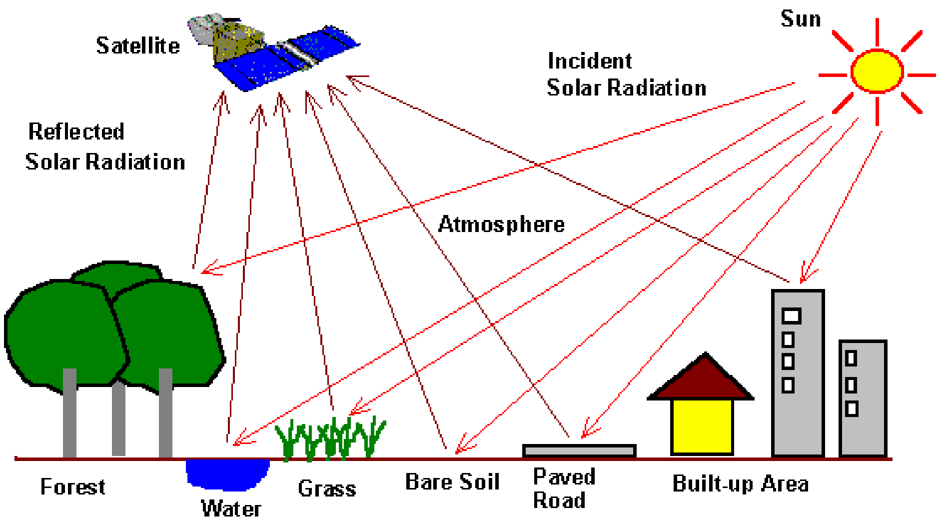
Still active remote sensing has attractive potentials and therefore interest to this technology is very high.

Passive Remote Sensing

Infer information on the atmosphere and Earth surface properties and state from observations of

- Reflected solar radiation
- Thermal and microwave radiation emitted by the Earth, clouds or atmosphere





Passive Remote Sensing Techniques:

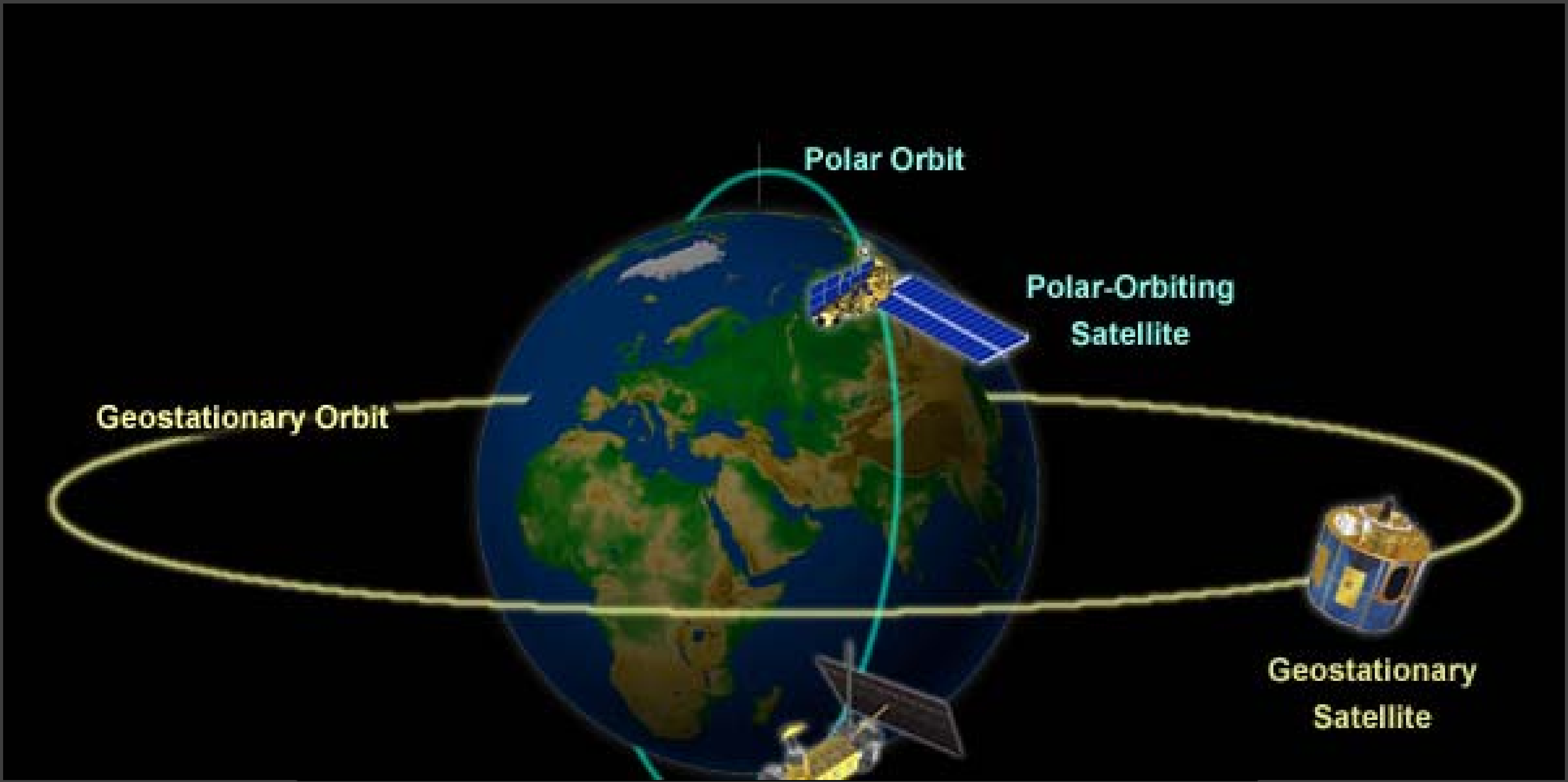
- Cheaper, easier to implement than active measurements
- Observations can be performed in multiple spectral bands

But

- May have limitations due to dependency on the weather, availability of the daylight or sufficient emission from the surface

At this time only passive observations are performed from board weather satellites. They are used to retrieve information on the state of the land surface, oceans and atmosphere.

Satellite Orbits



Satellite Orbits

Polar-orbiting (sun-synchronous) satellites

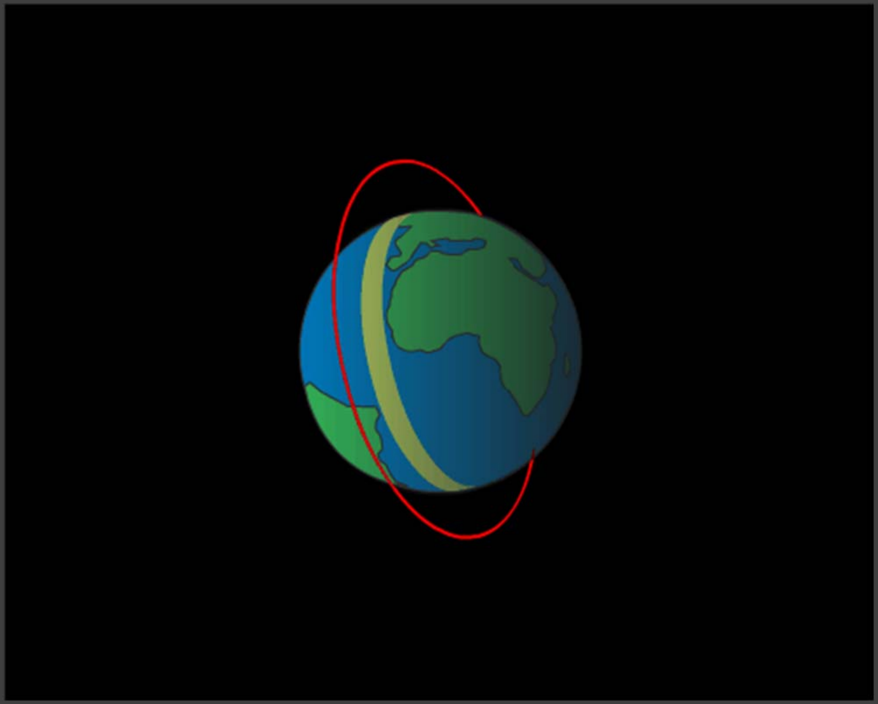
- Circle the Earth passing close to both poles on each revolution
- Altitude: 700-800 km

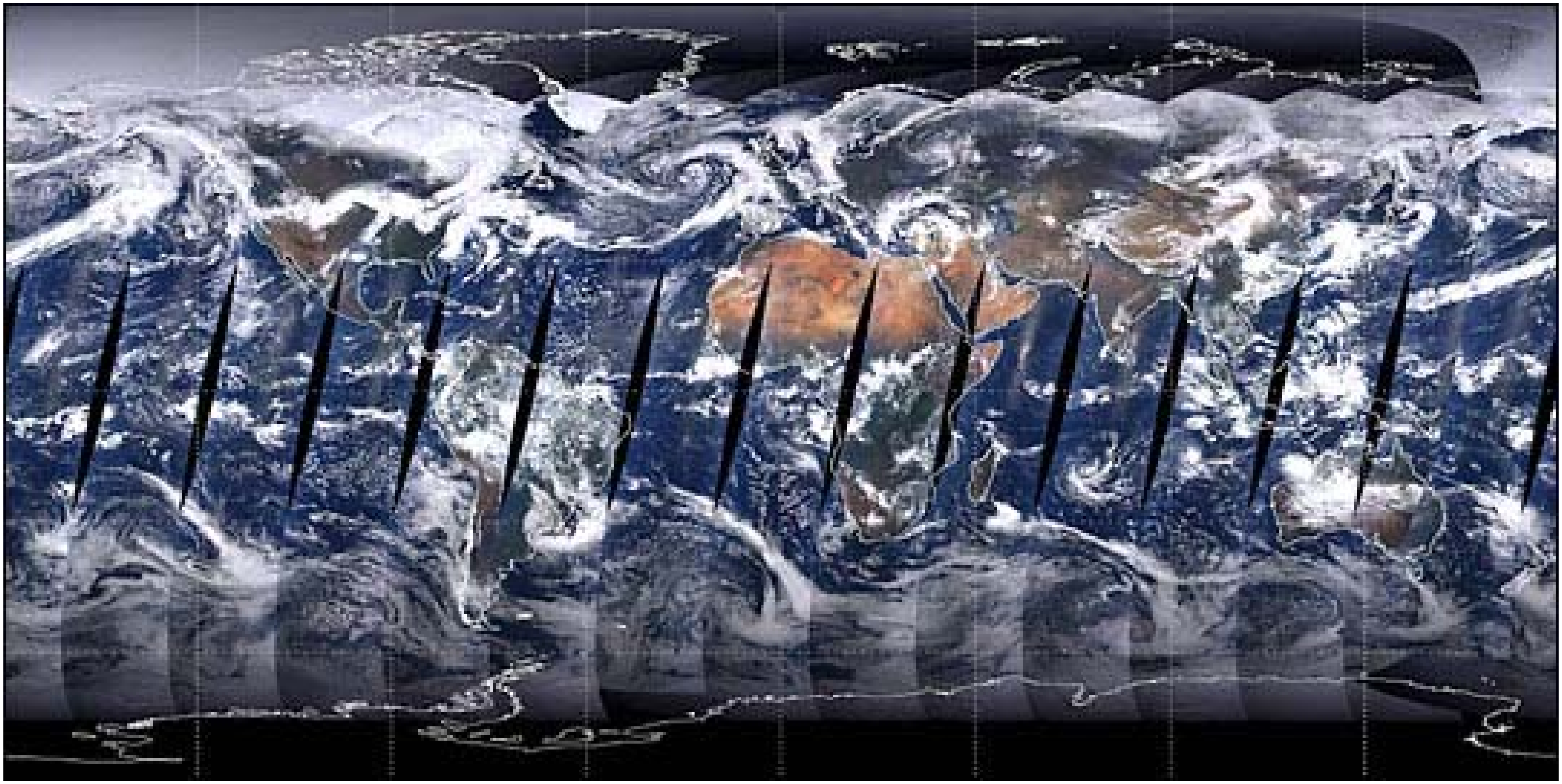
Geostationary satellites

- Remain stationed over one location
- Altitude: 36000 km

Polar-orbiting satellites:

- Provide global coverage
- Enable data collection at the same local (solar) time
- Helps consistent long-term monitoring of surface properties
- Provides at least two observations per day over most of the globe
- Polar regions are observed more frequently (up to 12-14 times daily)
- Low satellite altitude helps to attain better spatial resolution

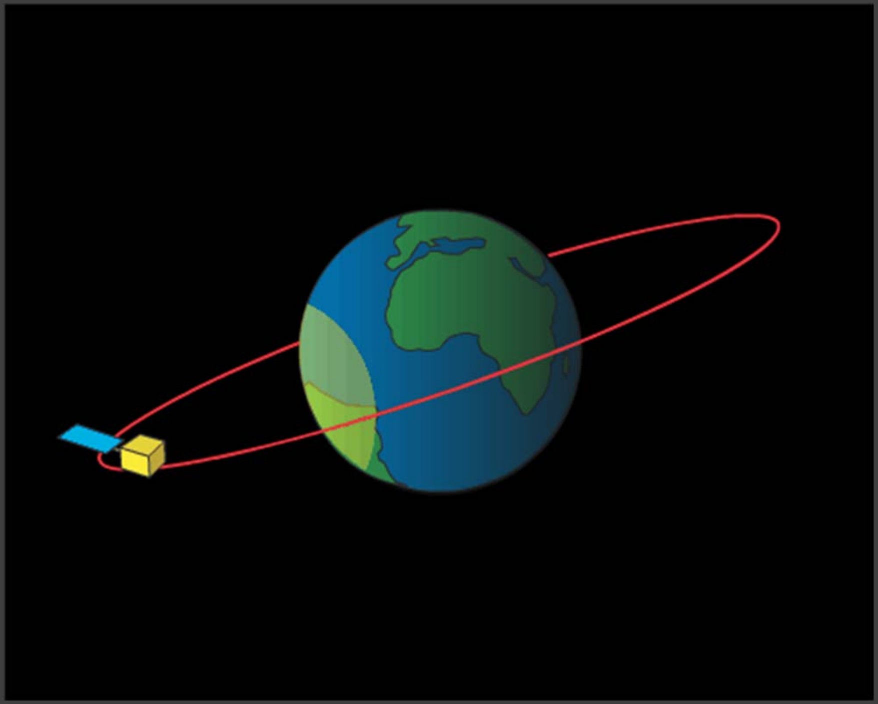




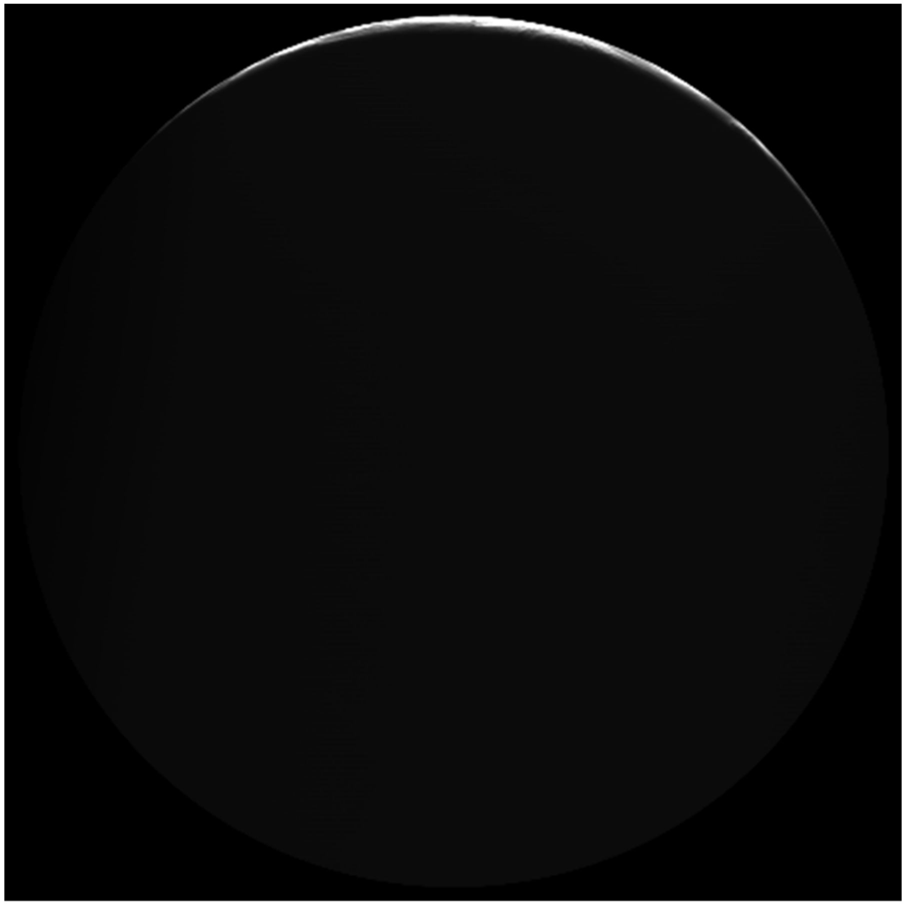
Sample daily day-time coverage of polar-orbiting satellite imaging sensor: MODIS Terra true-color image.

Geostationary satellites:

- Frequent images of the same area (up to 1 min)
- Important for monitoring fast-developing weather processes
- Support tracking of cloud motion
- Coverage limited to specific portion of the globe

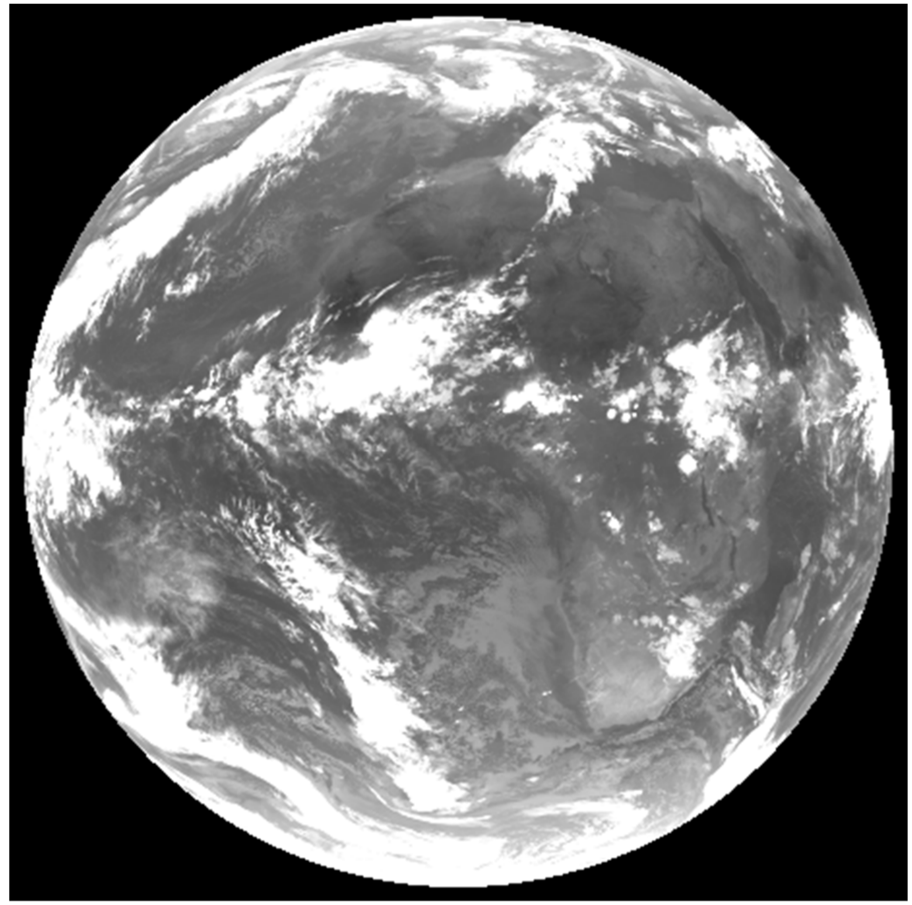


MSG SEVIRI, April 10, 2010



Near IR band (0.8 μm)

Less reflective objects look darker

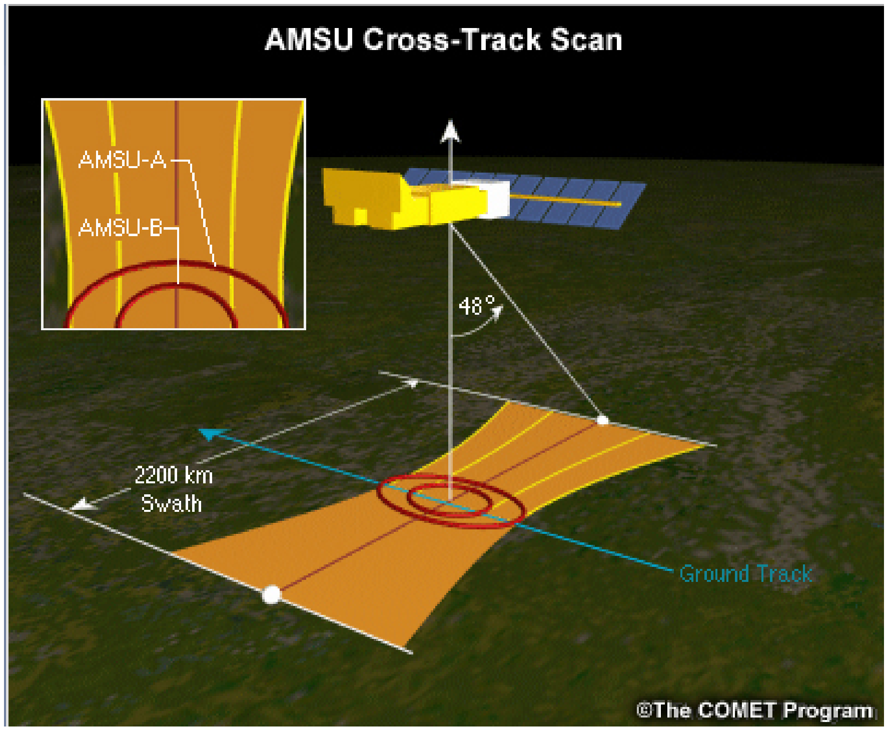


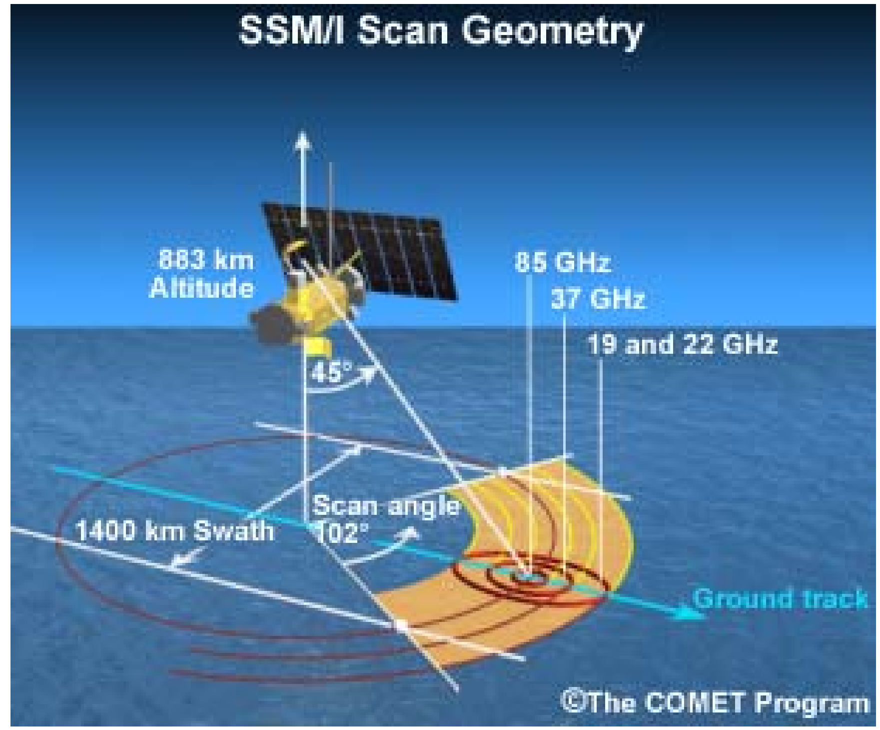
Infrared band (11 μm)

Warmer objects look darker

Satellite Sensor Characterization

Scanning Pattern: Conical, cross-track



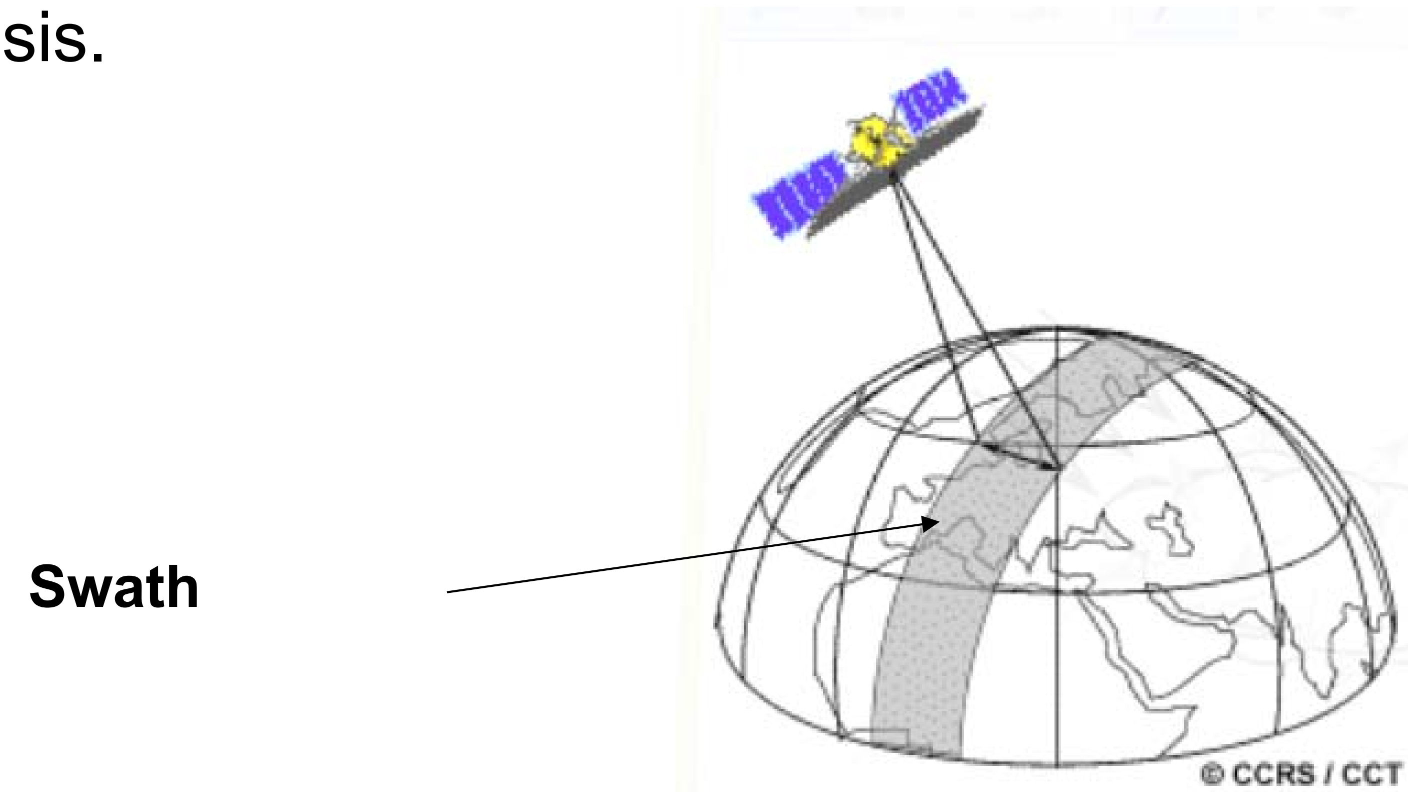


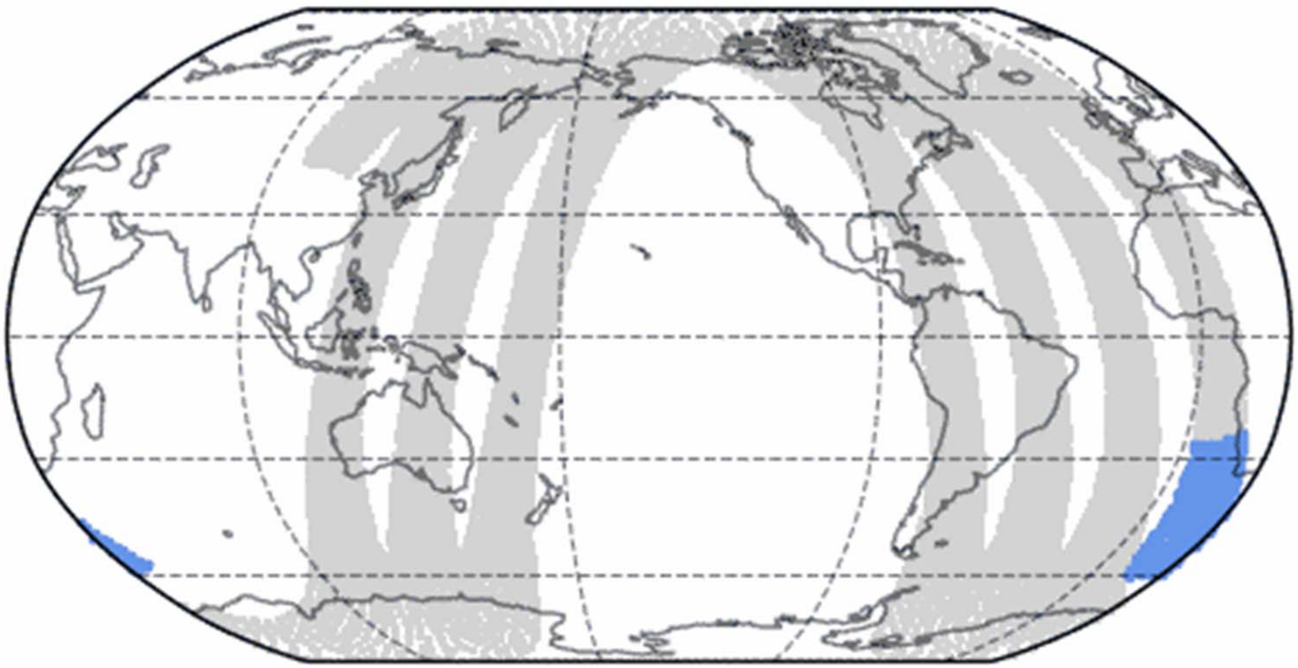
Cross-track : Scanning is performed at the right angle with respect to the satellite orbital track

Conical: Scanning is performed at a constant view zenith angle: used mostly in microwave radiometers

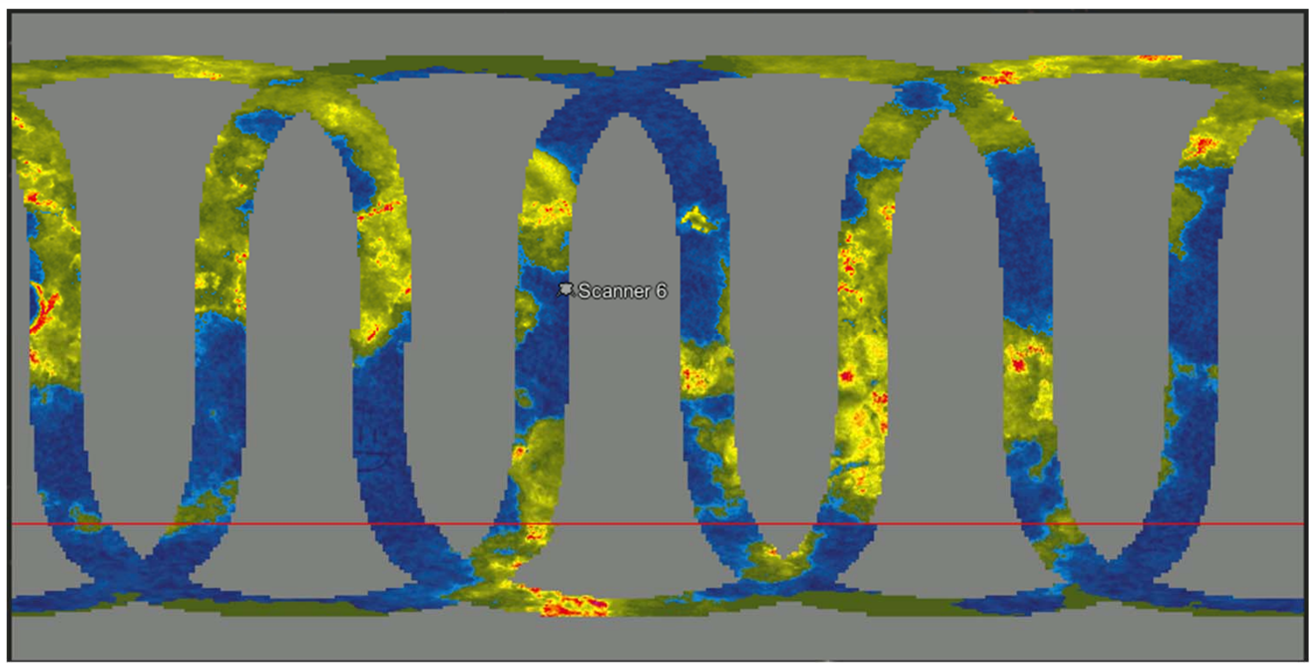
Swath

- **Swath**: Area imaged on the surface while satellite revolves around the Earth
- Swath width may vary between tens to thousands km.
- Weather satellite sensors typically have a swath width of 2300-3000 km which provides a complete (or almost complete) coverage of the globe on a daily basis.





2020-05-15 21:00:00 ±10min



Spatial Coverage, Pixels

Spatial coverage: Area of the globe covered by satellite sensor
Polar satellites: global (typically)
Geo satellites: Regional, full disk at satellite location

Spatial resolution is typically understood as the size of the sensor
Instantaneous Field of View (IFOV) or footprint

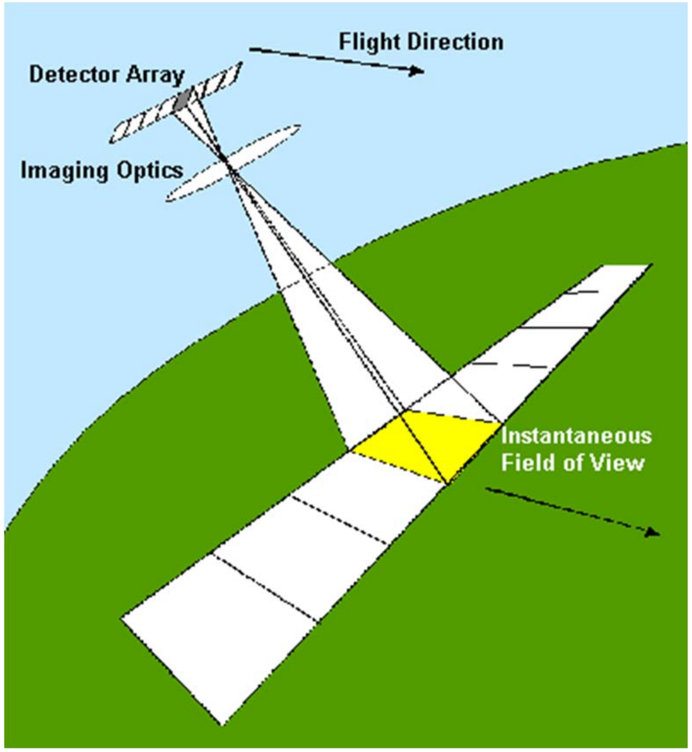
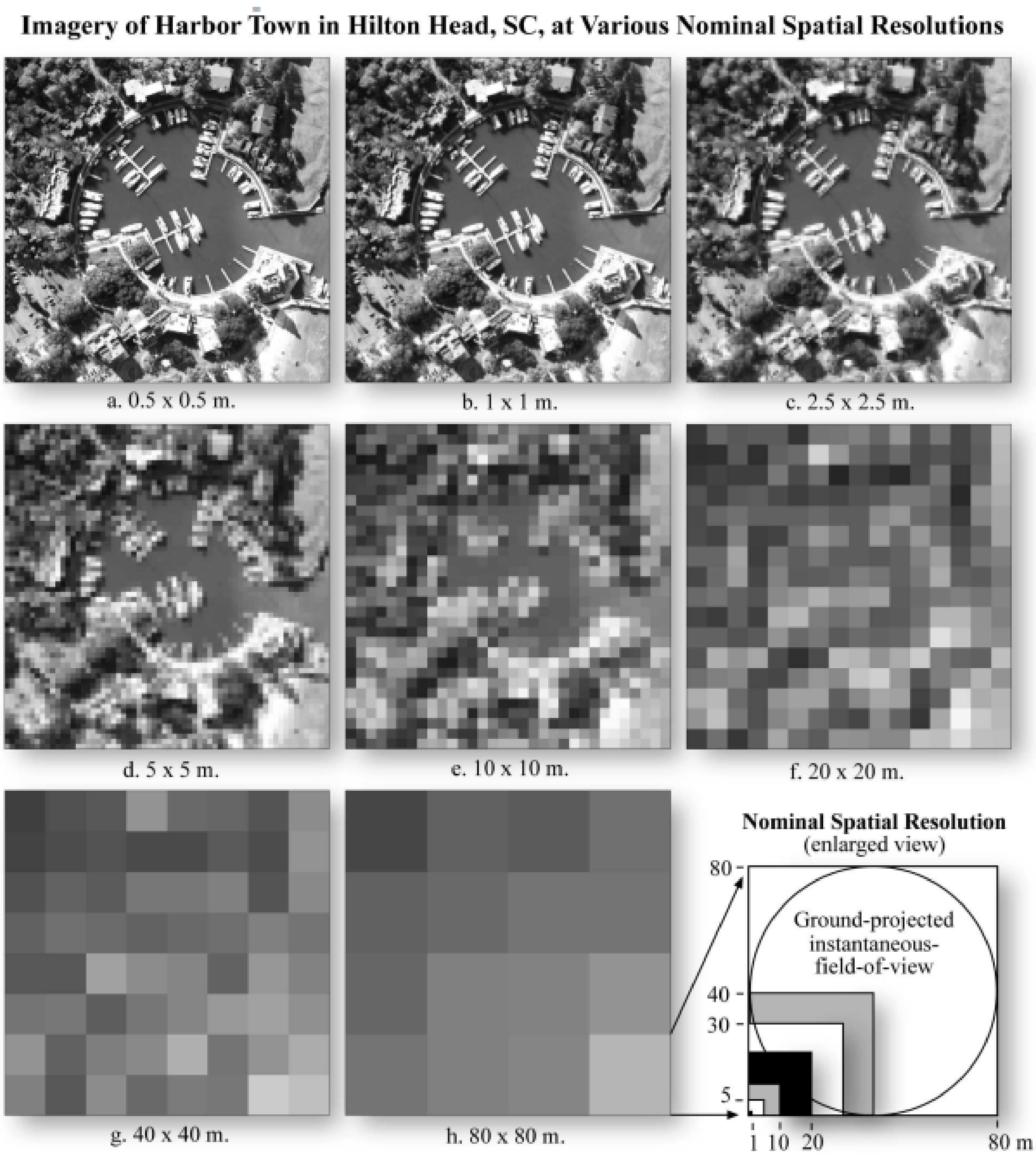


Image produced by satellite sensor while scanning the Earth consists of picture elements or **pixels**

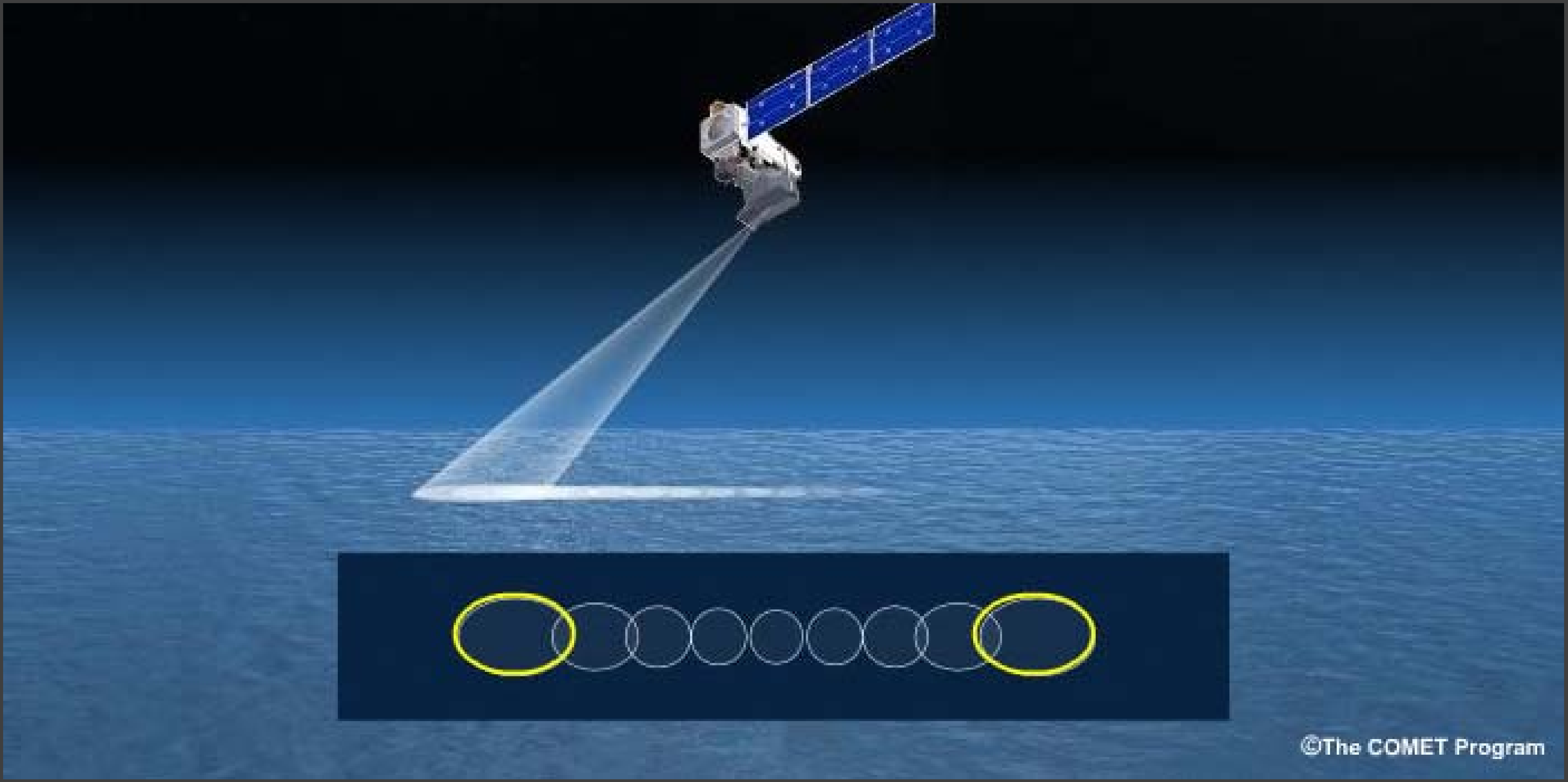
Spatial Resolution



Better spatial resolution allows for discriminating smaller objects in the image

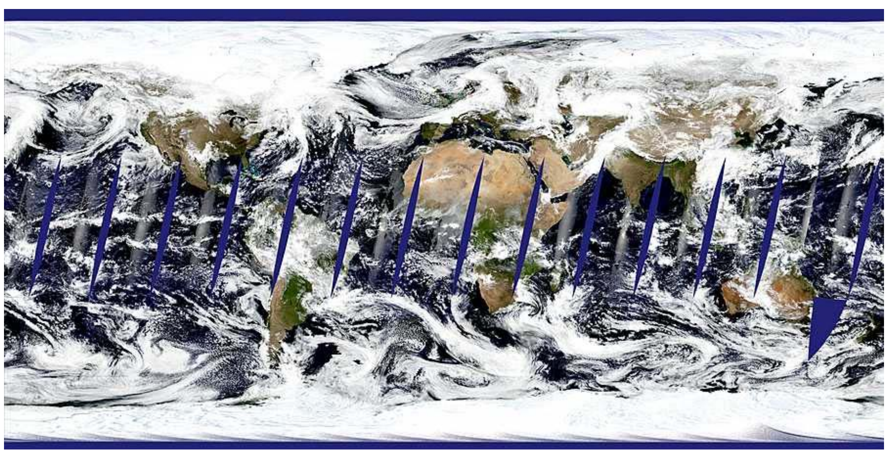
Spatial Resolution: View Angle Effect

- For cross-track scanning radiometers the effective spatial resolution changes within the same image due to changing view zenith angle.
- At the scan angle of 50-60 deg, the size of the sensor field of view increases 4-5 times from nadir to the edge of scan.



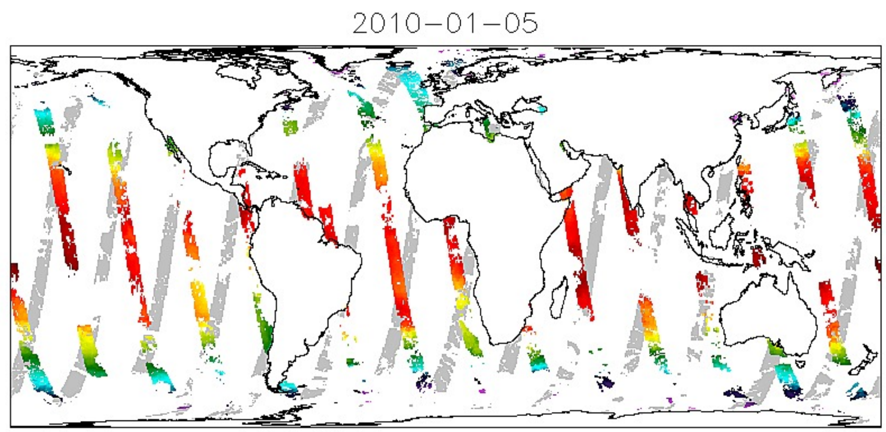
Complete vs Partial Coverage

- Imaging sensors onboard polar orbiting weather satellites typically provide complete or almost complete coverage of the globe on a daily basis.
- Many environmental satellites (e.g., Landsat, ATSR) provide higher spatial resolution, but do not provide daily continuous area coverage due to a narrow swath.



Complete daily coverage by MODIS sensor

(weather satellite)

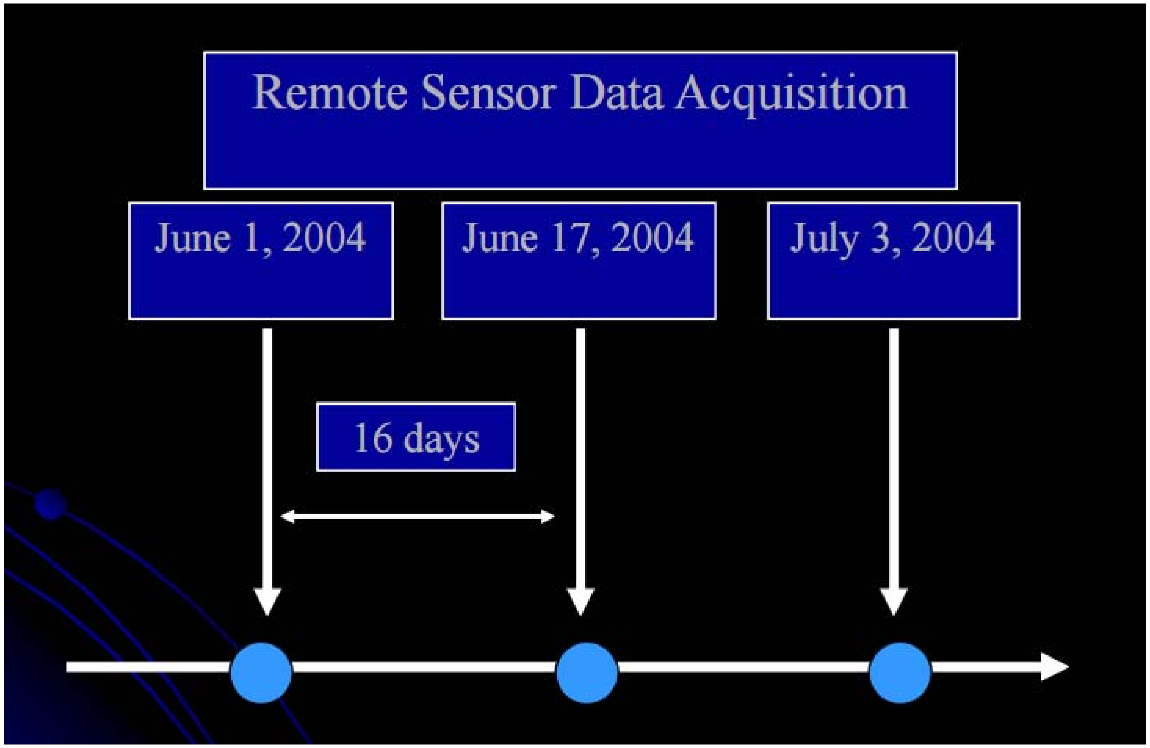


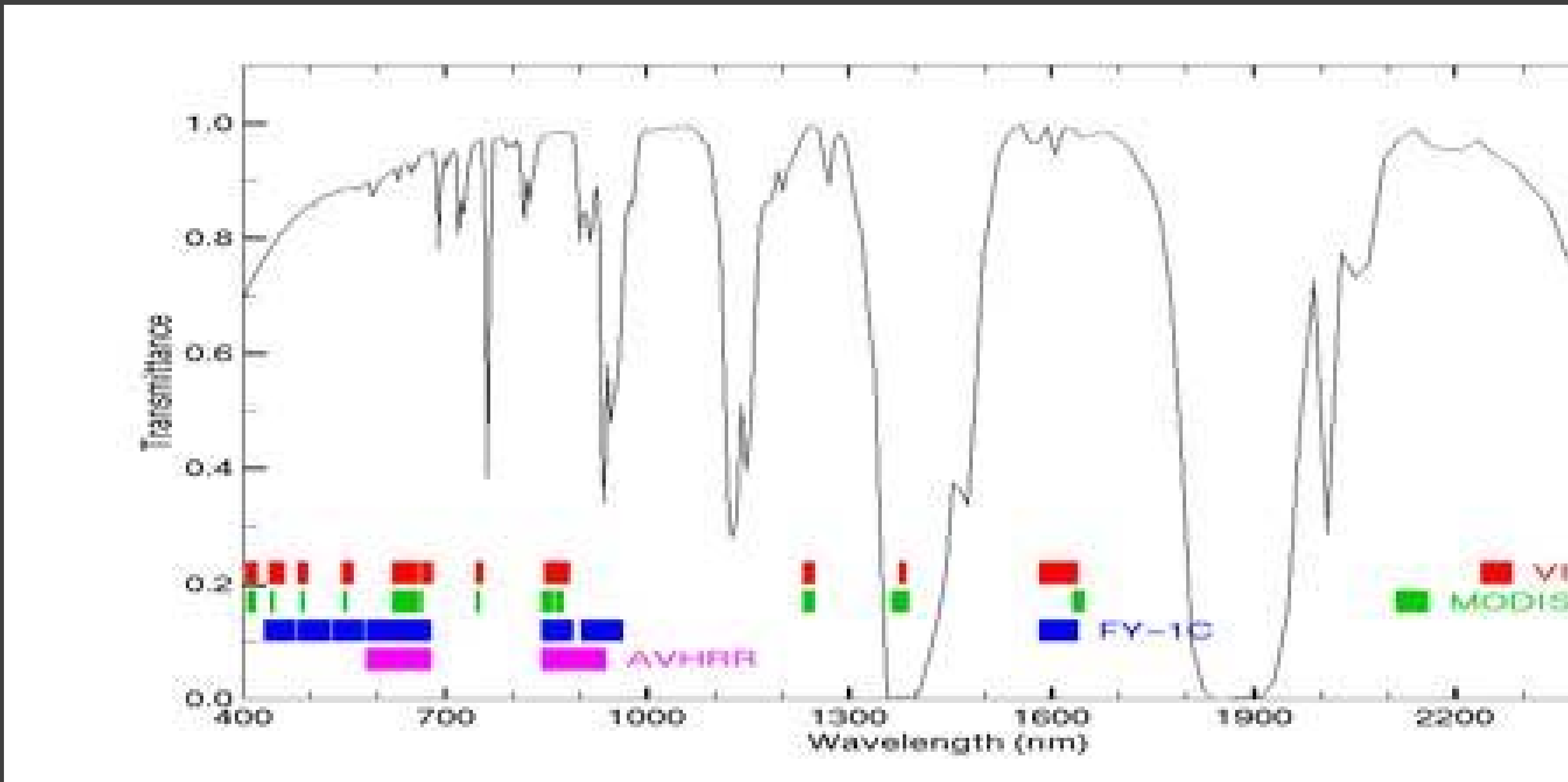
Partial daily coverage by ATSR sensor

(environmental satellite)

Temporal Resolution

- Characterizes the time between two consecutive observations of the same area.
- **Temporal resolution** is also referred to as a **revisit time** or **repeat cycle**.
- **Geostationary satellites**: temporal resolution is determined by the time interval between consecutive images
- **Polar orbiting weather satellites**: 12 hours or 24 hours if only daytime or nighttime observations are meant.





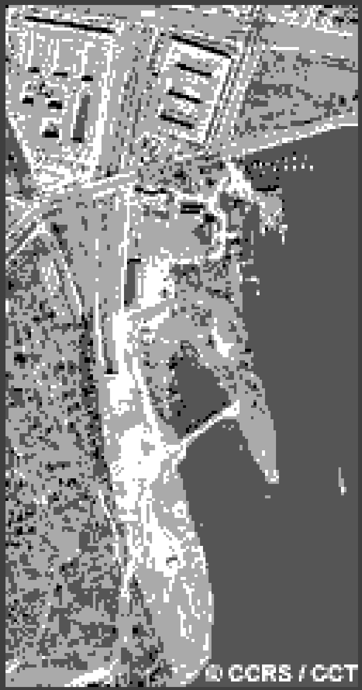
Location and width of spectral bands of several imaging radiometers onboard weather satellites

Spectral Coverage and Spectral Resolution

- **Spectral resolution:** Width of the spectral interval where radiance data are sampled.
- **Spectral coverage** or spectral range: the number of sensor spectral bands and the range of wavelengths covered by these bands.
- Wide spectral coverage and high spectral resolution is needed to enable better discrimination between various surface types.

Radiometric Resolution or Depth

- Describes the ability of the imaging system to discriminate very slight differences in energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.



2 bit resolution
(4 shades of gray)

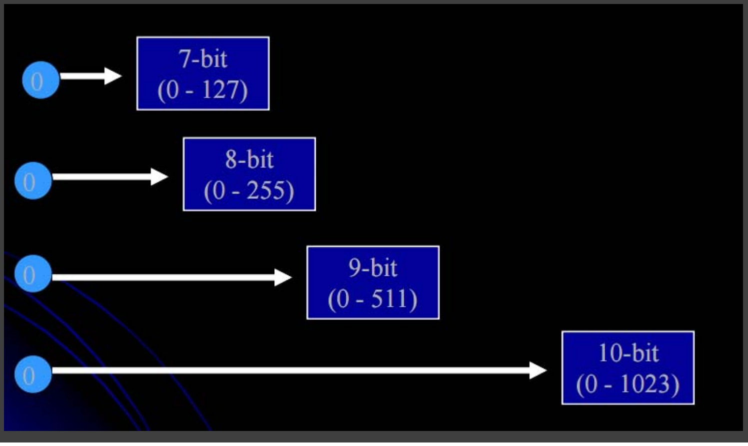
8 bit resolution
(256 shades of gray)

Radiometric Depth and Image Quality

2 bit: 4 shades of gray

8 bit: 256 shades of gray

10 bit: 1024 shades of gray



Sample Satellite Sensor Characteristics

AVHRR onboard NOAA satellites

AVHRR: Advanced Very High-Resolution Radiometer

- Onboard NOAA polar orbiting satellites since early 1980s

-Since 2004 AVHRR sensor is also installed on METOP satellites

- AVHRR swath width is about 2900 km, global coverage 2 times a day

- Radiometric resolution is 10 bits

AVHRR Spectral Bands

Band	Wavelength Range (μm)	Spatial Resolution (km)	Application
1	0.58 - 0.68 (visible, red)	1.1	cloud, snow, and ice monitoring
2	0.725 - 1.1 (near IR)	1.1	water, vegetation, agriculture
3a	1.58-1.64 (short IR)	1.1	snow, ice
3b	3.55 -3.93 (mid IR)	1.1	sea surface temperature, volcanoes, fires
4	10.3 - 11.3 (thermal IR)	1.1	surface temperature, clouds
5	11.5 - 12.5 (thermal IR)	1.1	surface temperature, clouds

Moderate Resolution Spectro-radiometer (MODIS)

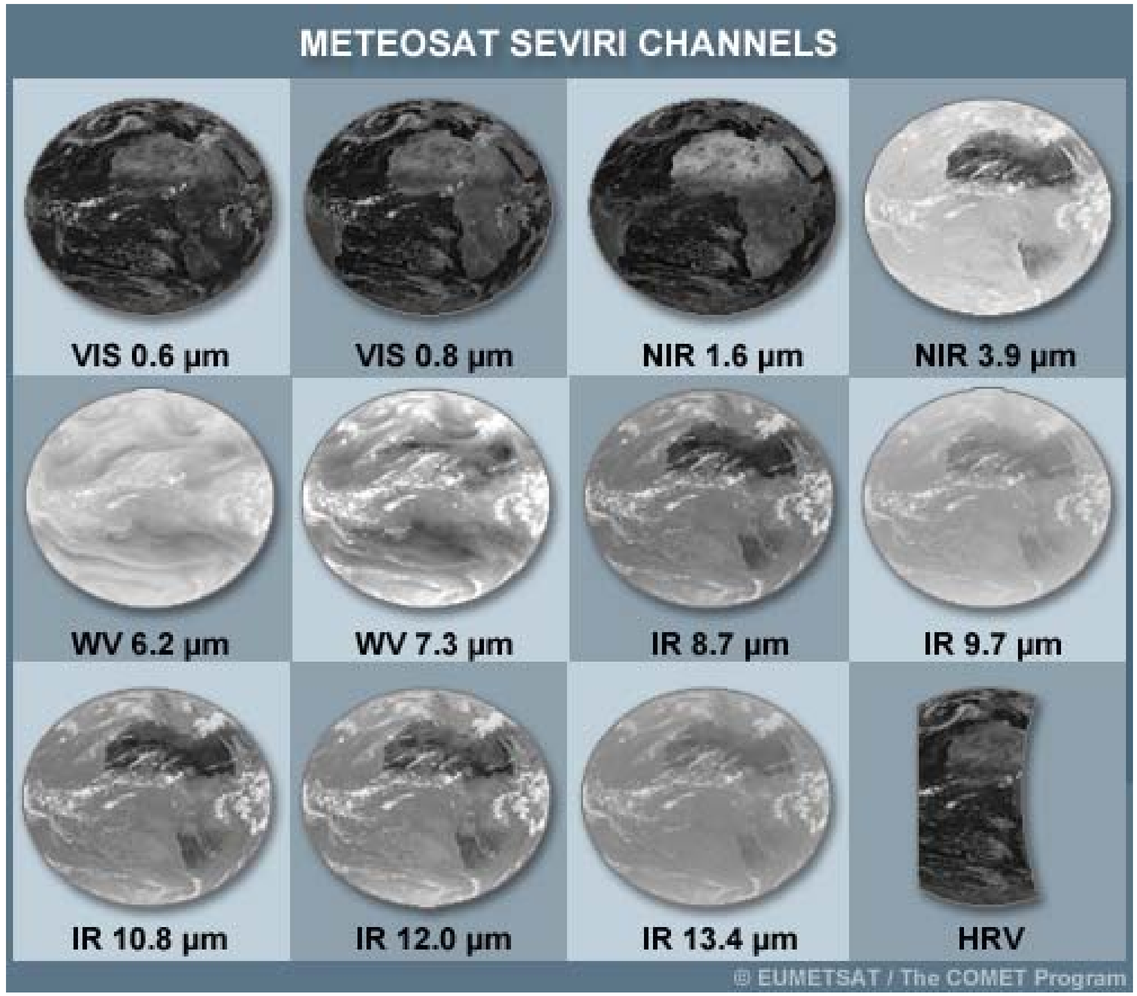
- Onboard NASA polar orbiting satellites Terra (since 1999) and Aqua (since 2002)
- Swath width is about 2300 km, near-complete global coverage
- 250 m to 1 km spatial resolution, channel dependent
- 36 bands, visible to infrared spectral range
- Radiometric resolution is 12 bits

MODIS observations have been made continuously for the last 15 years

SEVIRI onboard Meteosat satellites

SEVIRI: Spinning Enhanced Visible and Infrared Imager onboard geostationary Meteosat satellites, since 2002.

- 12 bands, visible, SWIR, MWIR, Water vapor, TIR
- Full disk imaging every 15 min
- Spatial resolution 1 to 4 km



Observations in the visible, MIR, TIR and water vapor (6.7 µm) bands are available from all current geostationary satellites

SSMI onboard DMSP satellites

SSMI: Special Sensor **Microwave** Imager onboard polar-orbiting US Defense Meteorological Satellite Platform (DMSP) since 1987

- 7 bands, in 19 – 85 GHz range
- Spatial resolution ~15 to 50 km depending on the band
- Swath width: 1707 km
- Conical scanning

Band	Frequency (GHz)	Polarization	Pixel size (km)
1	19.35	Horizontal	69 x 43
2	19.35	Vertical	69 x 43
3	22.35	Vertical	50 x 40
4	37.0	Horizontal	37 x 28
5	37.0	Vertical	37 x 28
6	85.5	Horizontal	15 x 13
7	85.5	Vertical	15 x 13

Since 2004:**SSMIS**: Special Sensor Microwave Imager Sounder

- Added 17 bands for vertical temperature profile retrievals

Processing Levels of Satellite Data

Level 0: Satellite telemetry information, unprocessed instrument data with any and all communications artifacts

Level 1: Instrument data at full spatial resolution geo-referenced and converted to physical units. Not mapped.

Level 2: Derived geophysical variables at the same resolution and location as Level 1 source data. Not mapped

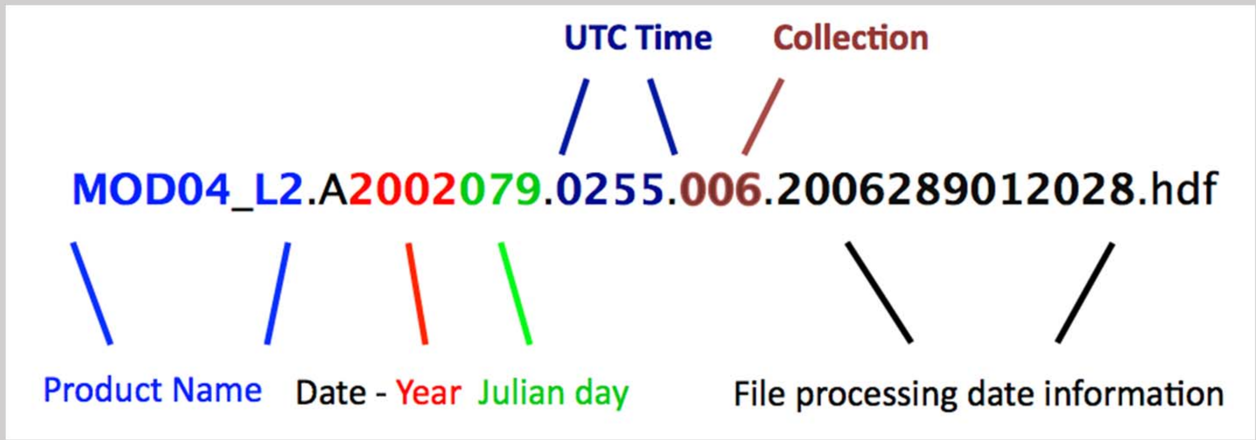
Level 3: Geophysical variables mapped on uniform space-time grid scales.

Level 4: Results from analyses of lower-level data (e.g., parameters derived from multiple measurements).

File Naming Convention

Some information (but not all) on what the satellite data file contains can be found from the file name. Typically file name includes:

- Name or identification code of the product
- Level of processing
- Date and time of the data collection and processing



MOD: MODIS Terra data file
04: Product type (Aerosol)
L2: Level 2 product, swath projection
hdf: File is in HDF format

Units

- Most often data from weather satellites is provided:
- In reflective bands as Reflectance (0.0 to 1.0 or 0% to 100%)
- In thermal and microwave bands as brightness temperature (deg K)

SUMMARY

Sensors onboard current weather satellites implement solely passive remote sensing technique. Active sensors are not yet used operationally but their high potentials are known and will be utilized in the future. .

Observations from weather satellites are available in the visible, infrared and microwave. All sensors provide observations in multiple spectral bands (multispectral capability)

Observations are made both from polar orbiting and geostationary platforms. Polar orbiting satellites provide full global coverage twice a day, whereas geostationary satellites provide frequent in time coverage over a limited geographical area

There are multiple parameters characterizing satellite sensors. These parameters should be considered when deciding on what sensor to use in particular application.

READING

- **Fundamentals of Remote Sensing. Canada Center for Remote Sensing**
http://www.ldeo.columbia.edu/res/fac/rsvlab/fundamentals_e.pdf
- Chapter 2

- **Curtis Seaman's Presentation on VIIRS imagery (RDR, SDR, EDR)**
- http://rammb.cira.colostate.edu/projects/npp/Beginner_Guide_to_VIIRS_Imagery_Data.pdf