# Instruments onboard Polar and Geostationary Satellites

*Satellite Course 2014 – 6 May 2014*

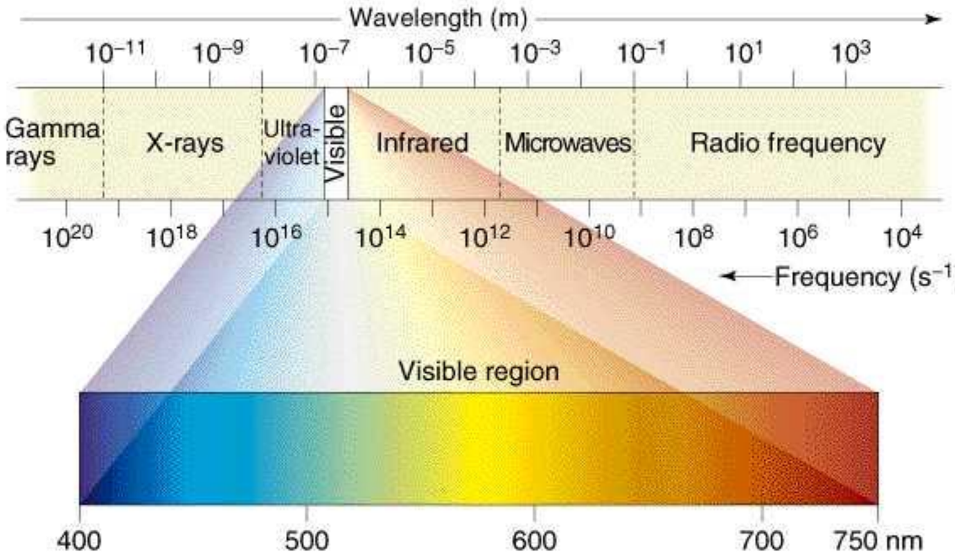
ZAMG
Zentralanstalt für
Meteorologie und
Geodynamik

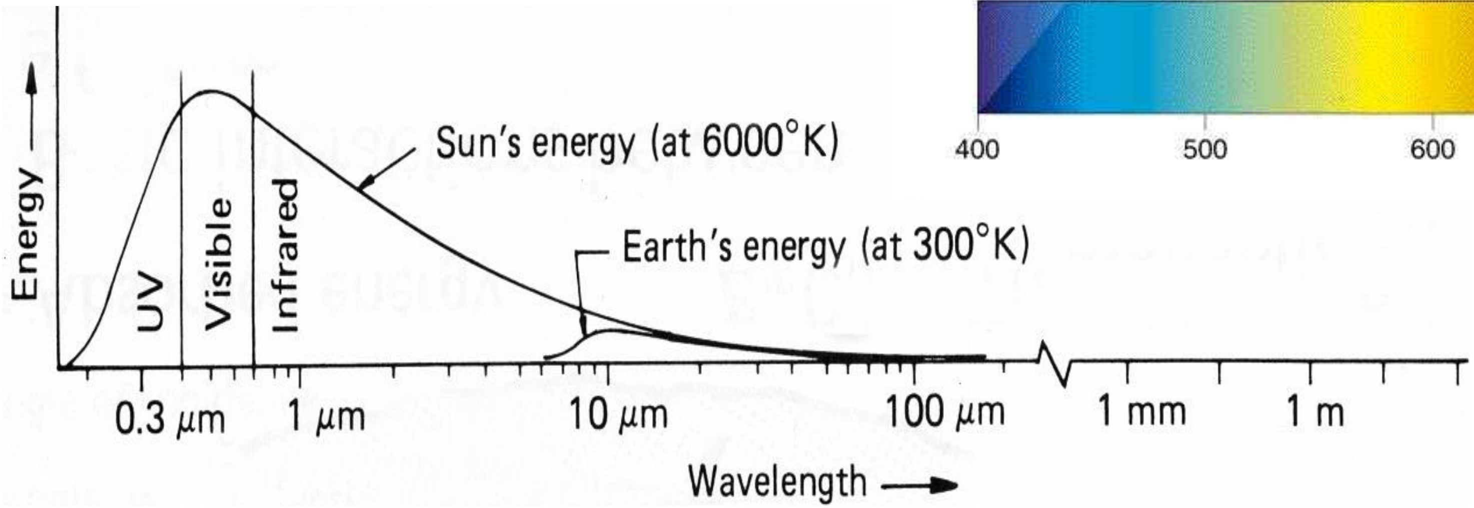
# Outline



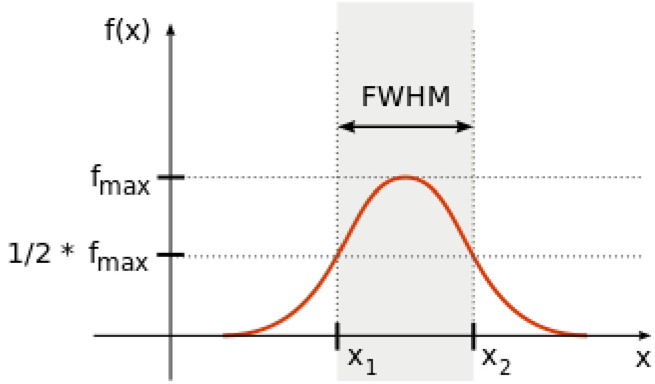
- Technical Development of Satellite Remote Sensing Instruments
- Ultraviolet earth-observing satellite remote sensing instruments
- Visible earth-observing satellite remote sensing instruments
- Infrared earth-observing satellite remote sensing instruments
- Micro wave earth-observing satellite remote sensing instruments
- Radio wave earth-observing satellite remote sensing instruments
- Active vs. passive instruments
- Scanning geometry and spatial coverage

**What do we measure?**
Earth-observing satellite remote sensing instruments make observations across the entire electromagnetic spectrum



*Wavelength resolution* or *bandwidth* is typically given as the Full-Width at Half-Maximum (FWHM).




Example: MSG Channel 9 (10.8 $\mu m$)

- The FWHM range of this channel extends from $x_1$ = 9.8 to $x_2$ =11.8 $\mu m$.
- 10.8 $\mu m$ is also called the central wave length of channel 9.

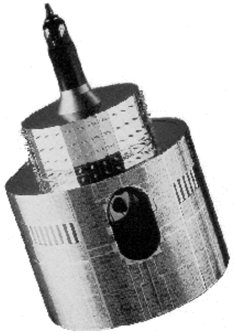
# Technical Development of Satellite Remote Sensing Instruments

Older earth-observing satellite remote sensing instruments typically made observations at only a few discrete wavelength bands.



## Meteosat 1-7: MVIRI

| Central wavelength | Spectral interval |
|---|---|
| 0.70 µm | 0.50 - 0.90 µm |
| 6.40 µm | 5.70 - 7.10 µm |
| 11.5 µm | 10.5 - 12.5 µm |



## Nimbus 7: THIR – Temperature-Humidity Infrared Radiometer

- Two-channel IR radiometer, 6.5-7.0 µm and 10.5-12.5 µm

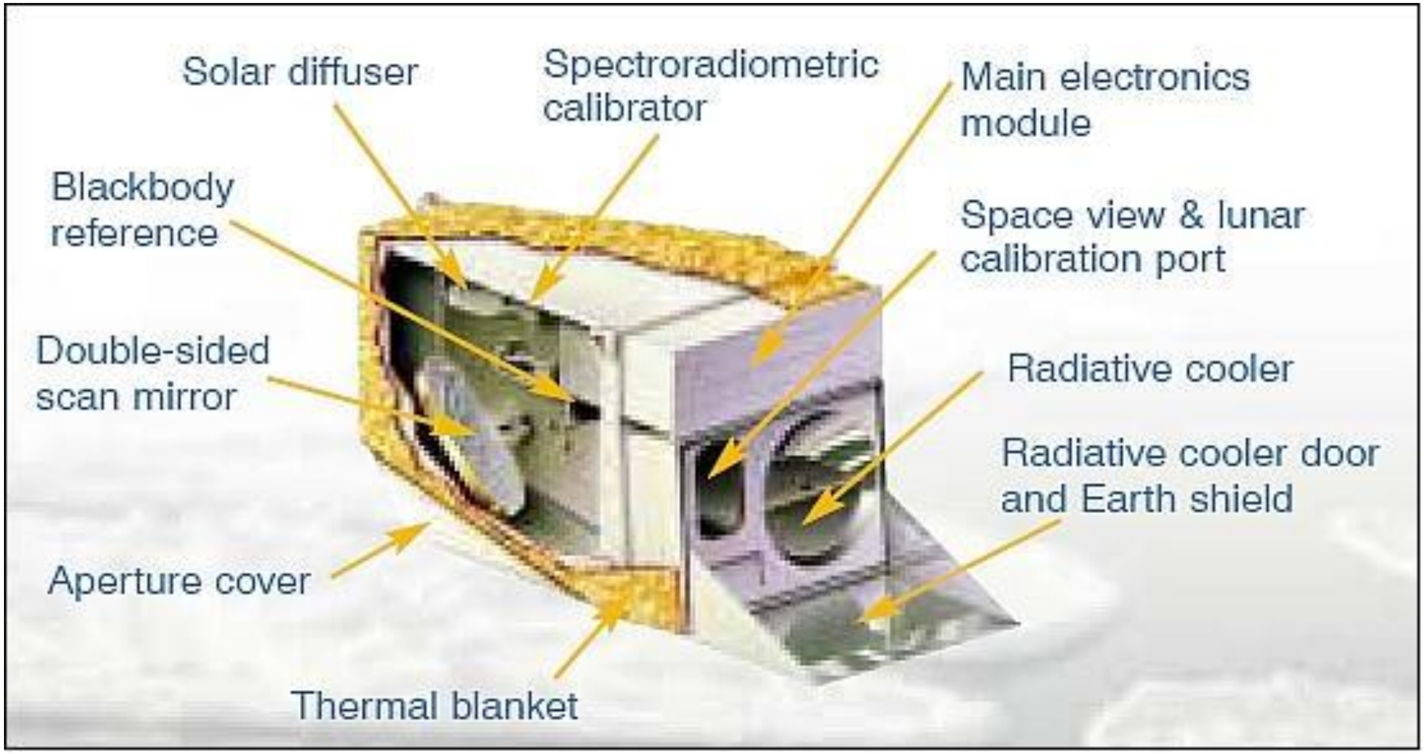
# Technical Development of Satellite Remote Sensing Instruments



Newer earth-observing satellite remote sensing instruments typically make observations at many discrete wavelengths or wavelength bands.

Terra: MODIS (MODerate resolution Imaging Spectro-Radiometer)

36 spectral bands: 0.4 to 14.4 μm    Resolution: 250m to 1 km at nadir



# Technical Development of Satellite Remote Sensing Instruments



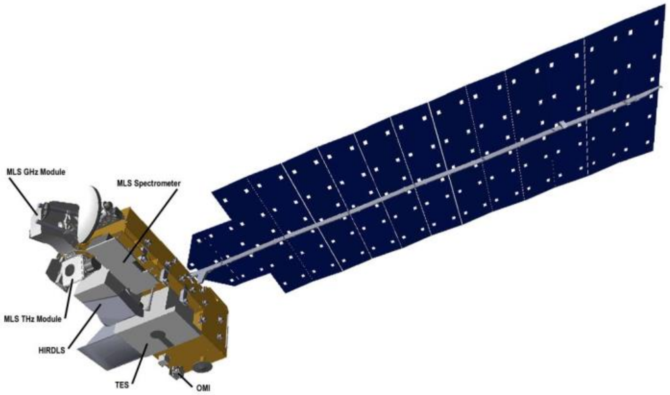
Most recent earth-observing satellite remote sensing instruments make continuous multi-spectral observations across a wide range using CCD array or cameras.

Aura: OMI (Ozone Monitoring Instrument)

Visible: 350 – 500 nm

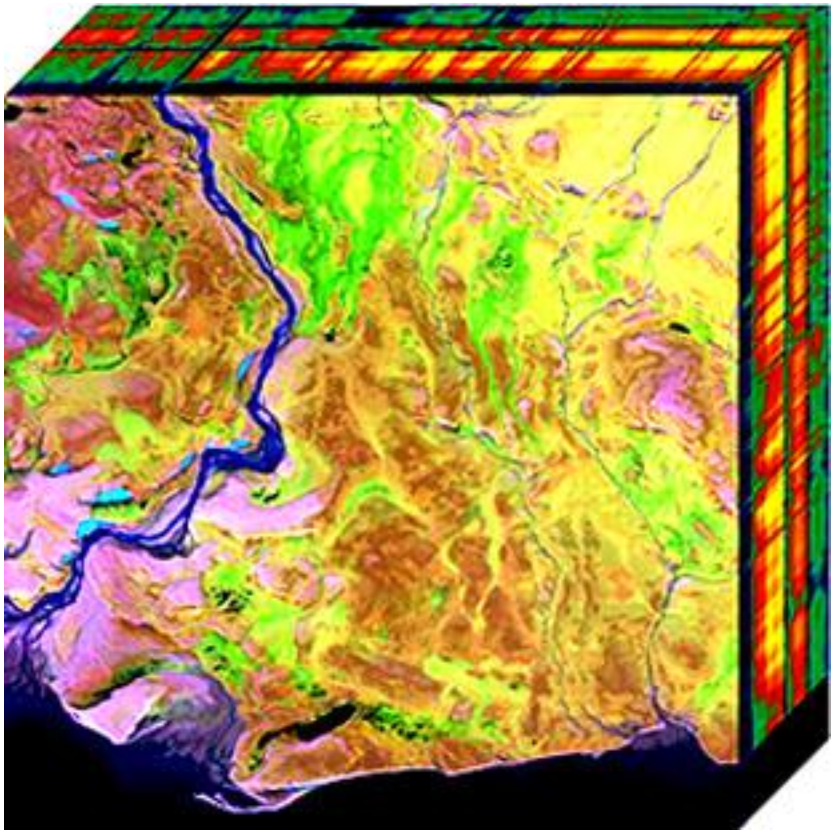
UV: 270 – 380 nm

With a spectral resolution of 0.45 – 1.0 nm FWHM




The OMI instrument employs hyperspectral imaging in a push-broom mode to observe solar backscatter radiation in the visible and ultraviolet.

Hyper spectral imaging spectrographs provide 3-D images or maps (lat x lon x wavelength) using 2-dimensional CCD cameras at thousands of wavelengths.



# Ultraviolet earth-observing satellite remote sensing instruments



Nimbus 7: TOMS (Total Ozone Mapping Spectrometer)

- 6 spectral bands (312 nm – 380 nm)

Earth Probe: TOMS

Aura: OMI

- Continuous scan: 270 – 380 nm

Applications: Ozone and aerosol concentration

# Visible earth-observing satellite remote sensing instruments



Terra/Aqua: MODIS (MODerate resolution Imaging Spectro-Radiometer)

- 16 channels in the visible range

TRMM: VIRS (Visible and Infrared Scanner)

- 0.63 μm, 1.6 μm

MSG: SEVIRI (Spinning Enhanced Visible and InfraRed Imager)

- 0.6 μm, 0.8 μm, 1.6 μm

MetOp A/B: AVHRR (Advanced Very High Resolution Radiometer)

- 0.63 μm, 0.865 μm, 1.610 μm

<u>Applications</u>: Day-light applications in nowcasting, ocean colour, biogeochemistry, Phytoplankton

# Infrared earth-observing satellite remote sensing instruments



Aura: TES (Tropospheric Emission Spectrometer)

- Contiuous 3.2 µm to 15.4 µm

CALIPSO: IIR (Imaging Infrared Radiometer)

- 8.7 µm, 10.5 µm,12.0 µm

Terra/Aqua: MODIS

- 16 spectral channels in the IR band

MSG: SEVIRI

- 6.2 µm, 7.3 µm, 8.7 µm, 9.7 µm, 10.8 µm, 12.0 µm, 13.4 µm

MetOp A/B: AVHRR

- 3.7 µm, 10.8 µm, 12.0 µm

Applications: Wide range of nowcasting applications, trace gas detection, clouds and earth observation

# Microwave earth-observing satellite remote sensing instruments



Aura: MLS (Microwave Limb Sounder)

TRMM: TMI (TRMM Microwave Imager)

- 5 frequencies: 10.7, 19.4, 21.3, 37 and 85.5 GHz

MetOp: MHS (Microwave Humidity Sounder)

- 89.0 GHz and 157 GHz

Applications: humidity profiles, low altitude clouds and precipitation, surface temperature, trace gases

# Radio wave earth-observing satellite remote sensing instruments



CloudSAT: CPR (Cloud Profiling Radar)

- 94 GHz nadir looking radar

TRMM: PR (Precipitation Radar)

QuickScat (Quick Scatterometer)

- 13.4 GHz

MetOp: ASCAT

- C-band radar (5.255 GHz)

Applications: Soil moisture, sea surface winds, cloud profiles, precipitation – rain rates

# Active vs. passive instruments



Earth-observing satellite remote sensing instruments are either *active* or *passive*, depending on the original source of the observed radiation.

*Active* remote sensing instruments send out a signal of radiation at a particular wavelength.

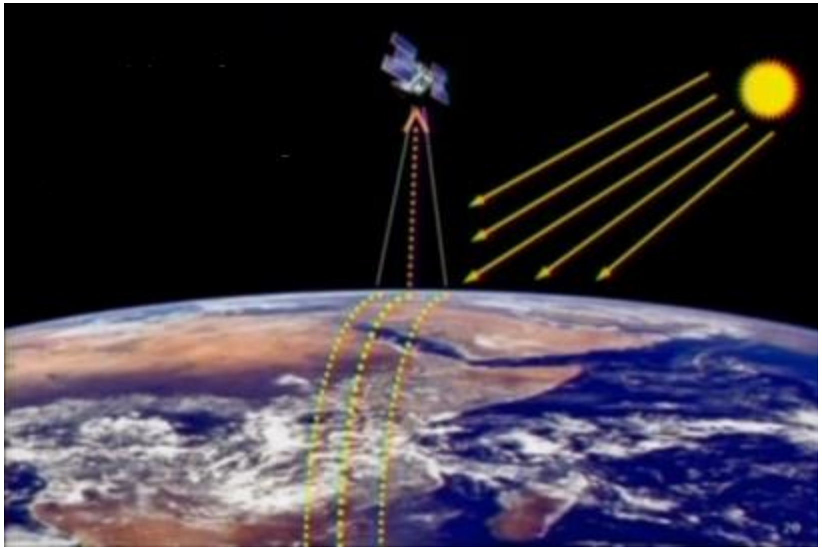
*Active* instruments rely upon the amount of radiation reflected back to the satellite instrument by the earth's surface or atmosphere.

# Active vs. passive instruments



*Passive* remote sensing instruments either use the sun as source of radiation or use the radiation emitted by the earth's surface or atmosphere.

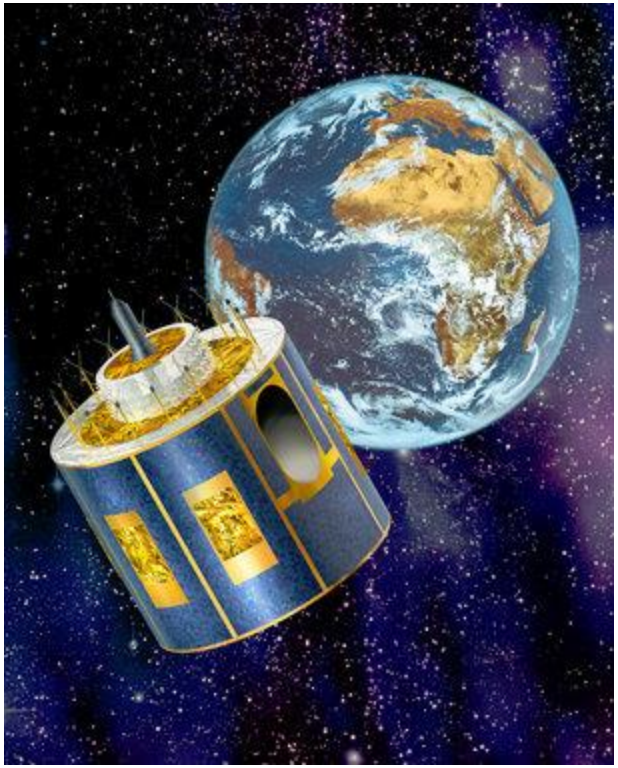
Most satellite instruments rely on passive observations.



# Scanning Geometry and spatial coverage



Geostationary satellites have a field of view which covers almost ½ of the earth's surface. The scanned area can be reduced to obtain a high image frequency (RSS).



MSG: since 2002 -
SEVIRI

- Repeat cycle: 15 min
- Rapid scan: 5 min

MTG: 2018 –
FCI

- Repeat cycle: 10 min
- Rapid scan: 2.5 min

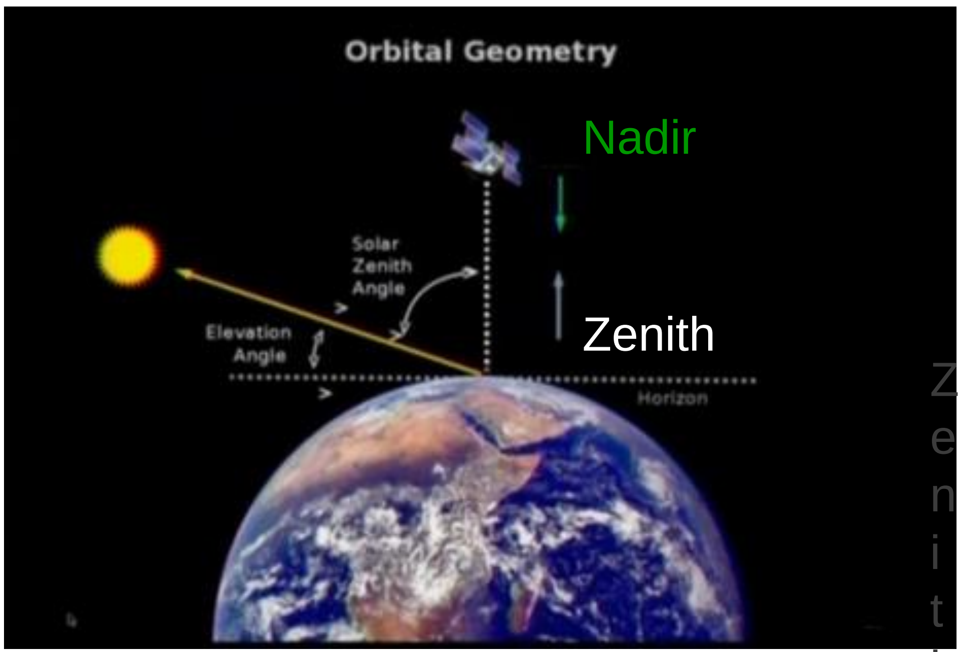
# Scanning Geometry and spatial coverage

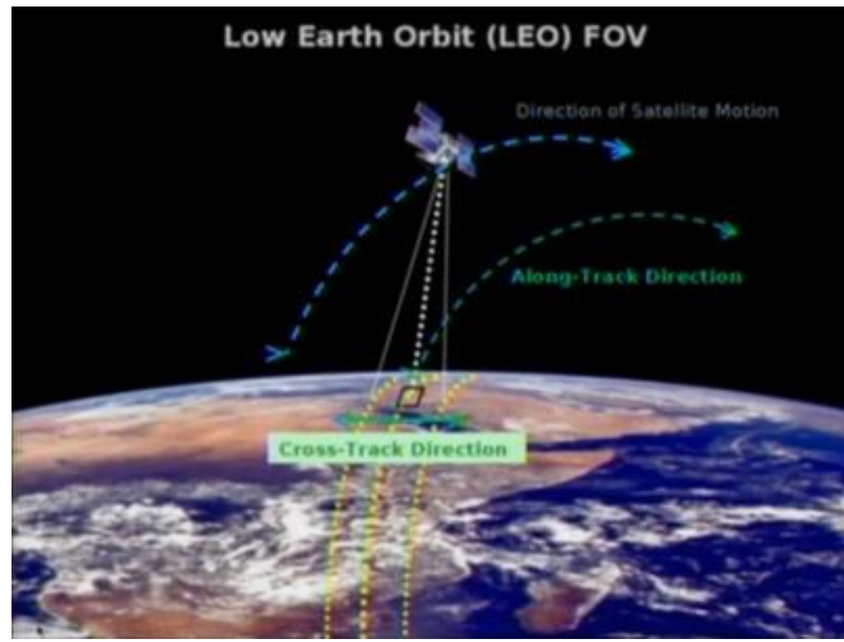


Orbital geometry: Nadir, Zenith, elevation angle

The nadir FOV is defined as directly beneath the satellite track when the satellite is overhead. The nadir FOV represents the spatial resolution.

The orbit is defined as having a cross-track and an along-track direction.




Zenith

# Scanning Geometry and spatial coverage



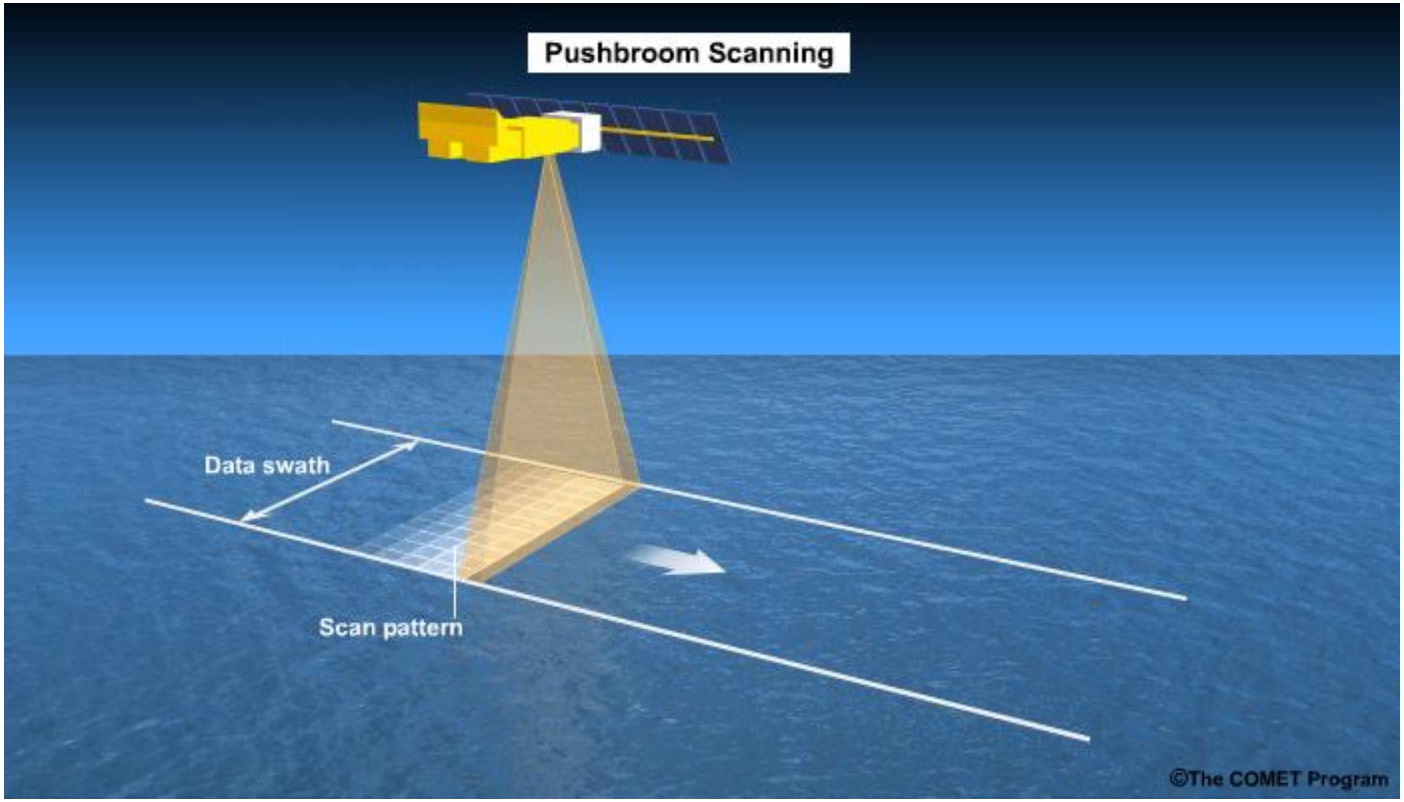
Satellites in Low Earth Orbit (LEO) have a limited FOV compared to geostationary satellites, because they are closer to the earth's surface. They use a variety of techniques to expand their coverage:

- Push-broom sensors
- Cross-track scanning sensors
- Conical scanning sensors

# Scanning Geometry and spatial coverage



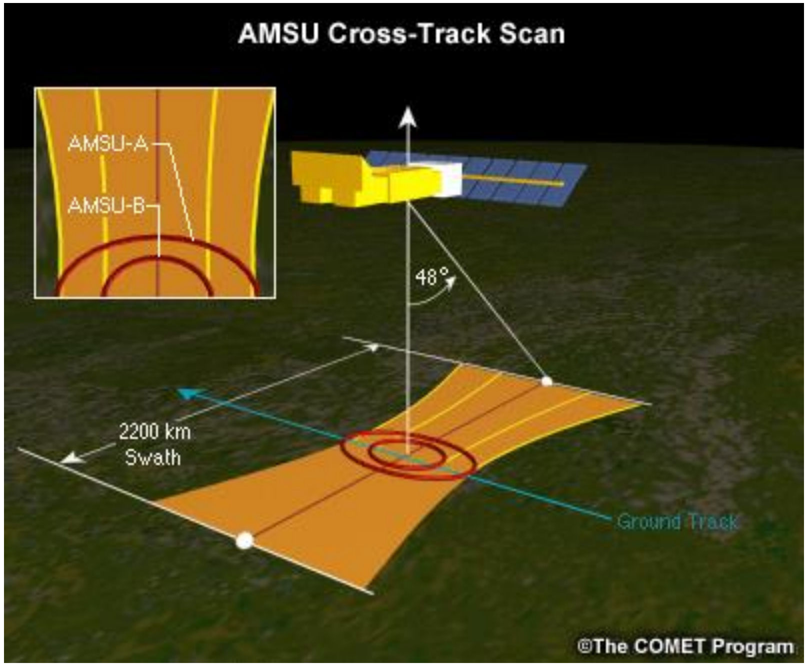
Push-Broom sensors provide a line array of several sensors (e.g. CCD optical array) all of which show a small strip of the earth's surface parallel to the satellite motion path (e.g. Jason-1 and MetOp ASCAT).

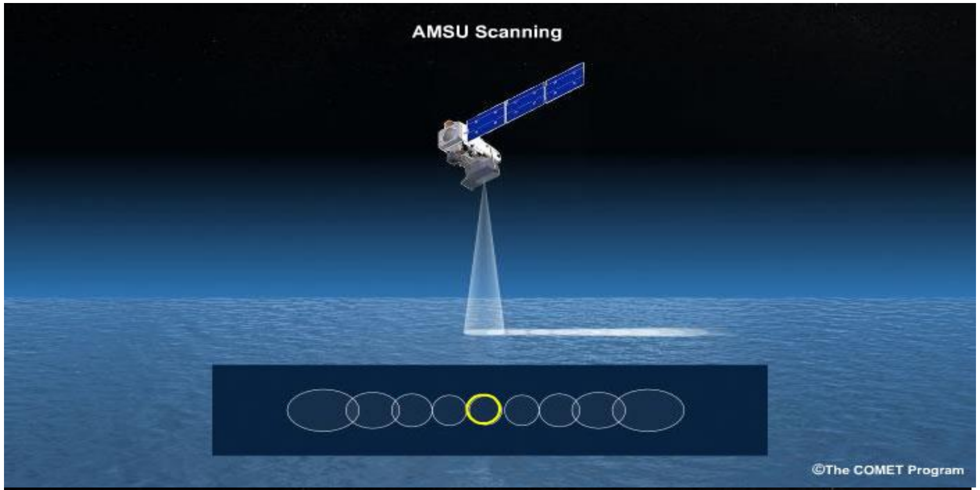


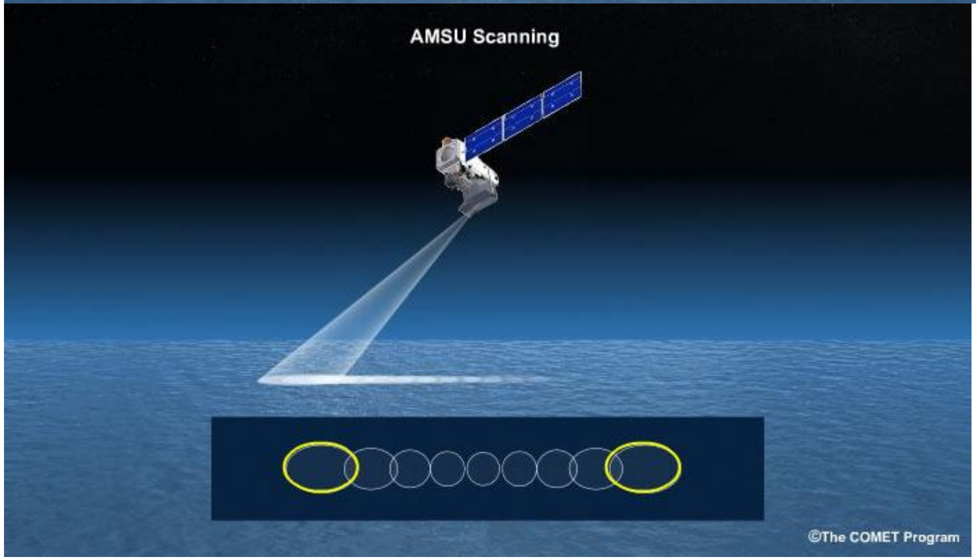
# Scanning Geometry and spatial coverage



In cross-track scanning sensors a scan mirror swings back and forth along the suborbital track. Cross-track scanning results in individual observations of varying size.



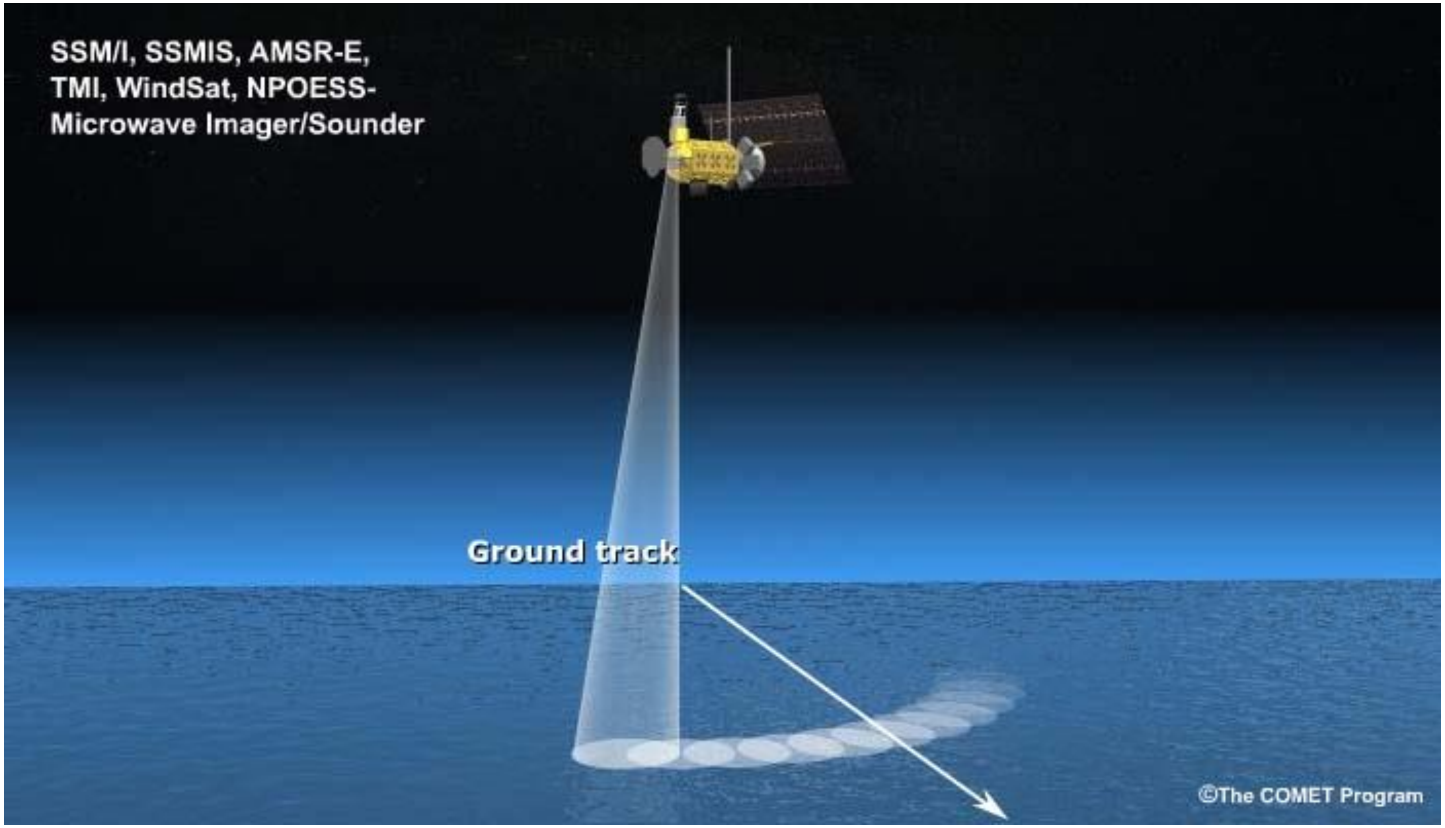



# Scanning Geometry and spatial coverage



Conical scanners sweep out consecutive arcs perpendicular to the satellite's orbital track.

The beam angle or look angle determines the width of the data swath, and because this angle is fixed, ground resolution remains constant across the scan.

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# Scanning Geometry and spatial coverage



- If the orbit is too low and/or the FOV too small a complete global coverage cannot be obtained in 24 hours. This results in an incomplete global coverage.
- Polar regions are scanned on every overpass.
- Depending on the scan geometry, a global coverage can be obtained in 2 or 3 days.