Introduction to Remote Sensing, Earth Observation and the Characteristics of Satellite Data

Cyprus/ESA ECS Agreement Earth Observation Downstream Applications for Public Sector Workshop
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This Presentation

- ESA – some very brief facts
- What is remote sensing?
- What is Earth Observation with satellites?

The European Space Agency

The European Space Agency

Make Space for Europe

5500 employees

Promoting cooperation among European States in space research, technology and applications, for exclusively peaceful purposes – since 1975

HQ in Paris, 7 sites across Europe and a spaceport in French Guiana

22 Member States
3 Associated Member States
1 Cooperating Member State

€ **2022 Budget**
7.15 billion = 12 per European citizen

Member States

22 ESA Member States:

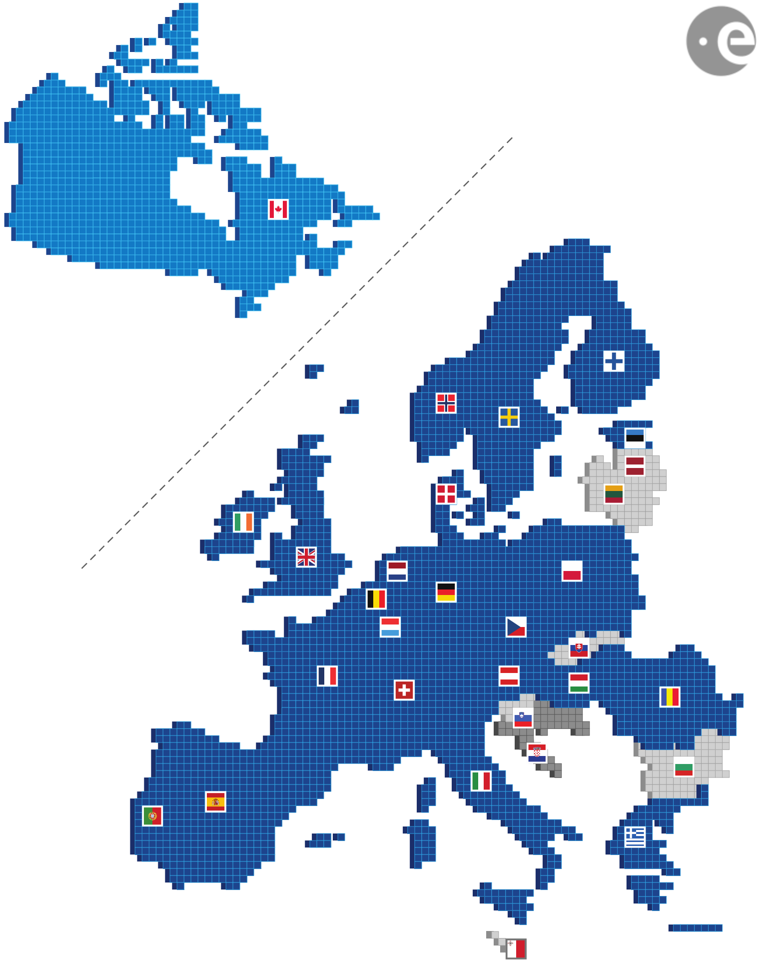
- 20 states of the EU (**AT**, **BE**, **CZ**, **DE**, **DK**, **EE**, **ES**, **FI**, **FR**, **IT**, **GR**, **HU**, **IE**, **LU**, **NL**, **PT**, **PL**, **RO**, **SE**, **UK**)
- Non-EU: **Norway** and **Switzerland**

- 3 Associate Members: **SI**, **LT**, **LV**

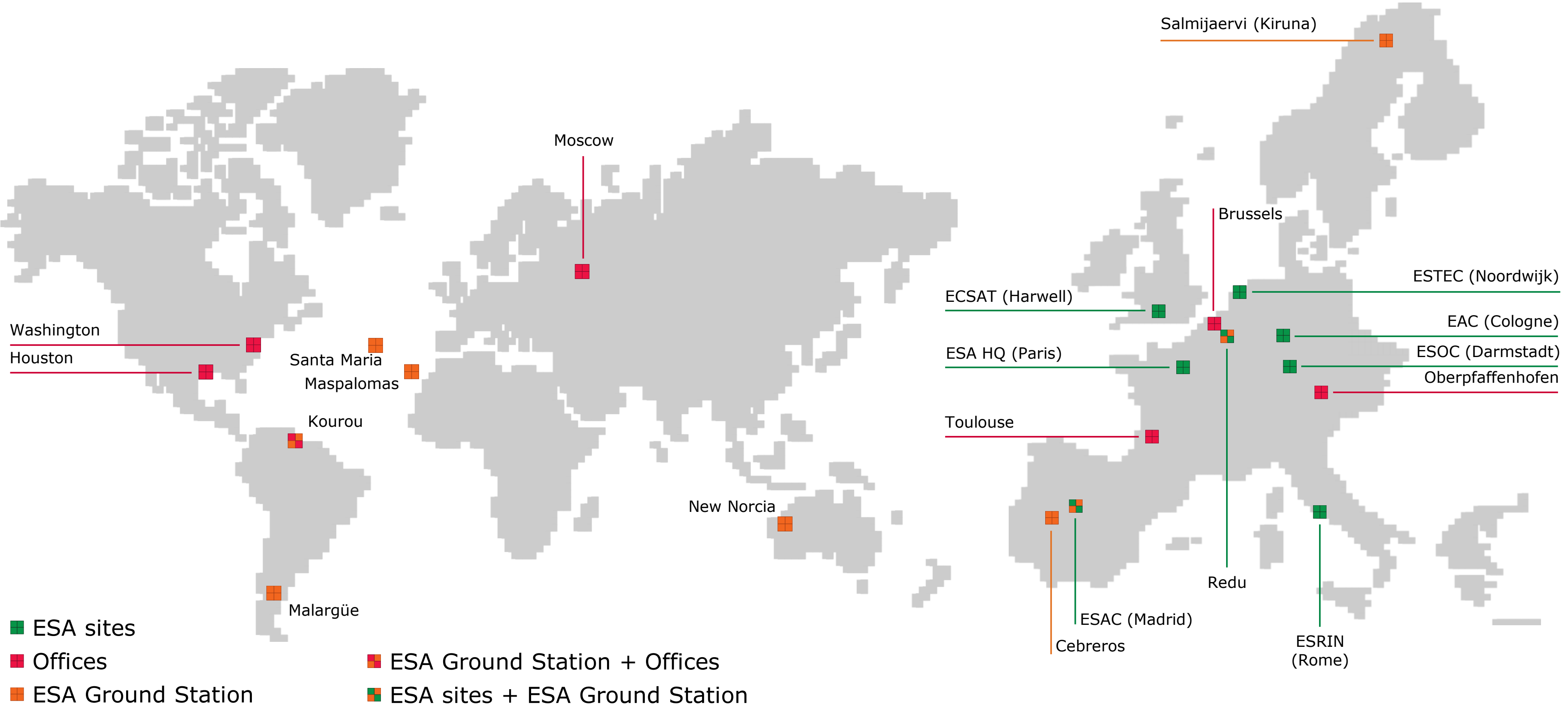
Cooperation Agreements with ESA:

- **BG**, **CY**, **HR**, **MT** and **SK**

Canada takes part in some programmes under a long-standing Cooperation Agreement



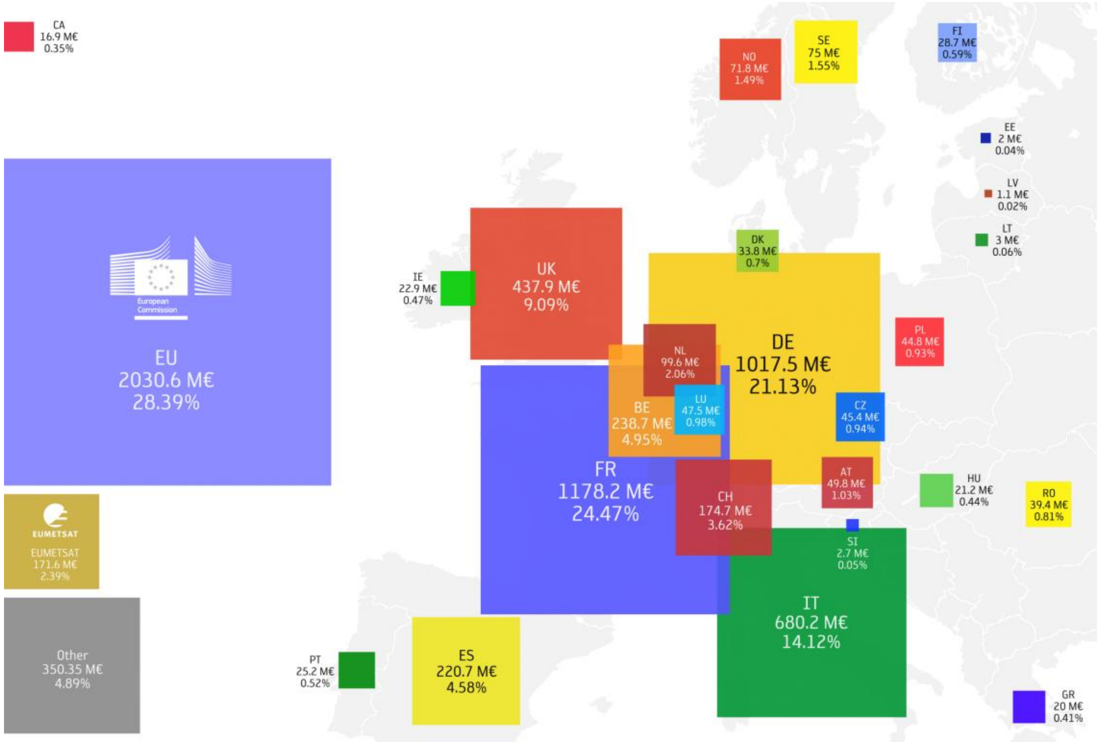
ESA's Locations



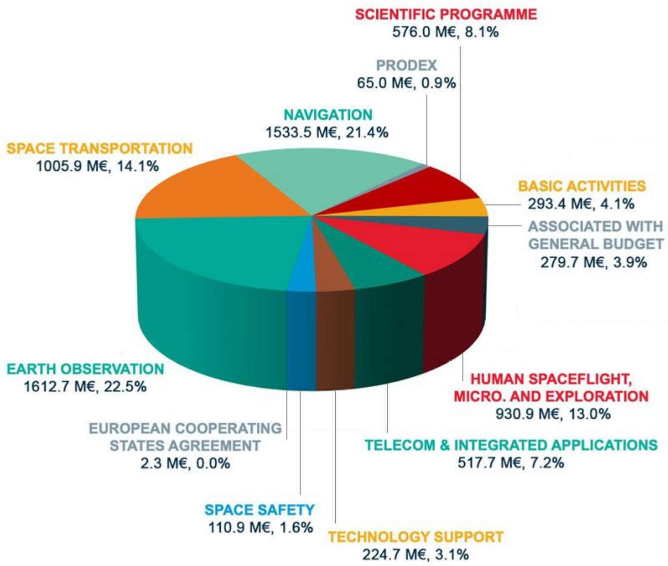
→ THE EUROPEAN SPACE AGENCY

ESA Budget for 2022: 7.15 B€

Funding sources by Member States and other incomes



Budget by domain *

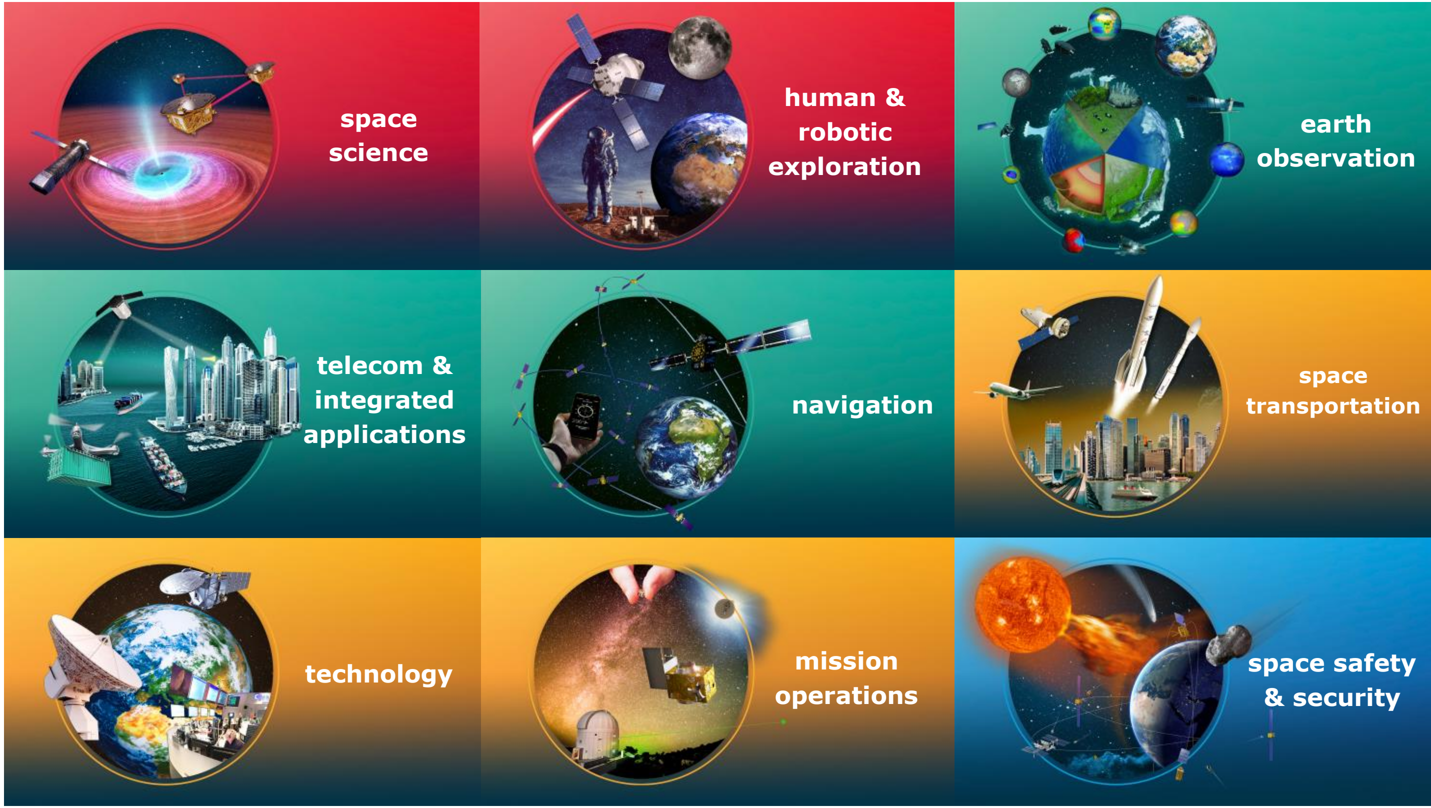


* *Includes activities implemented for other institutional partnerrs*

ESA Activities

Exploration and use of space for exclusively peaceful purposes.

ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.



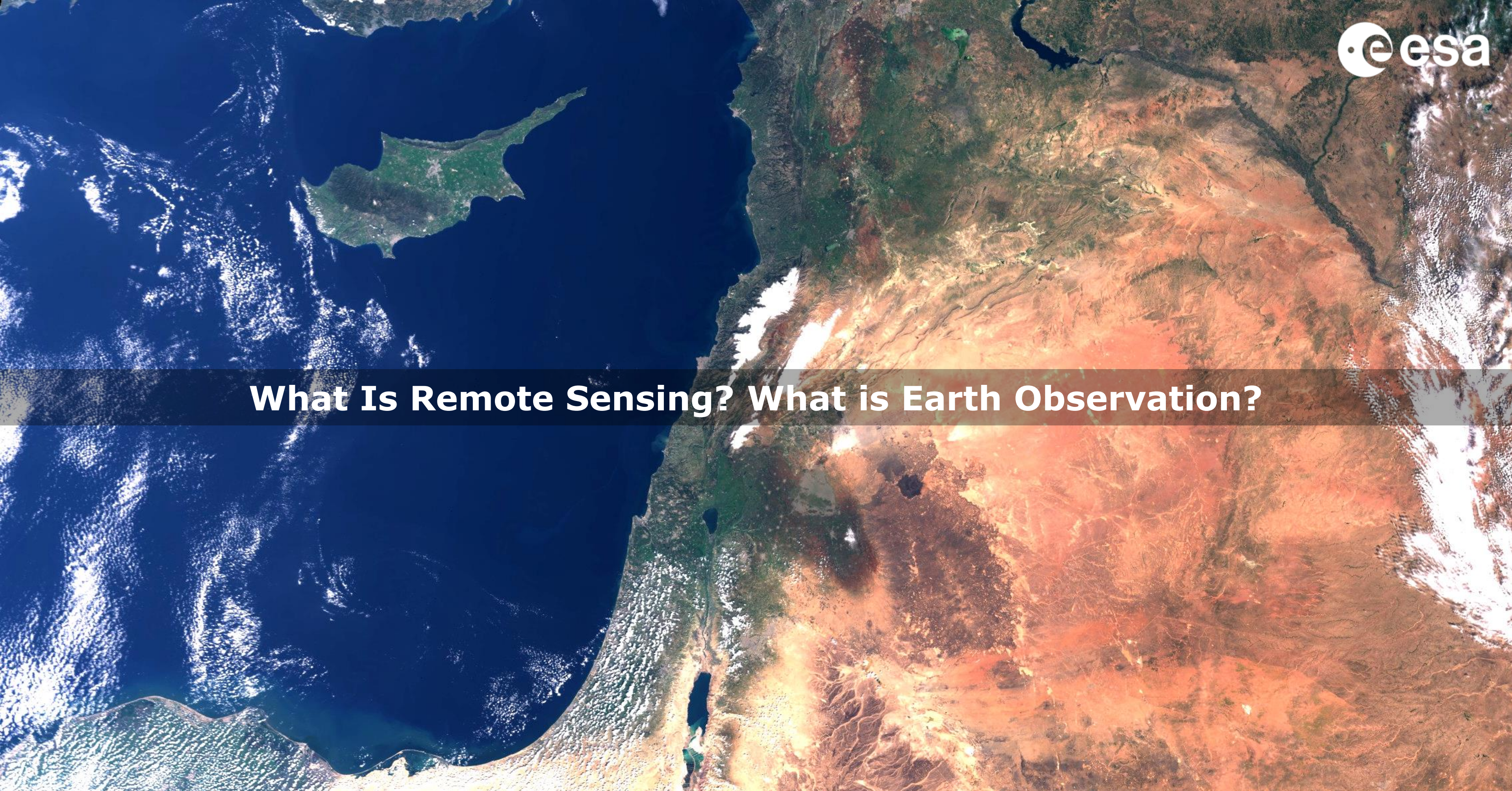
ESA's Industrial Policy

About 85% of ESA's budget is spent on contracts with European industry.

ESA's industrial policy:

- Ensures that Member States get a fair return on their investment
- Improves competitiveness of European industry
- Maintains and develops space technology
- Exploits the advantages of free competitive bidding, except where incompatible with policy objectives

What Is Remote Sensing? What is Earth Observation?

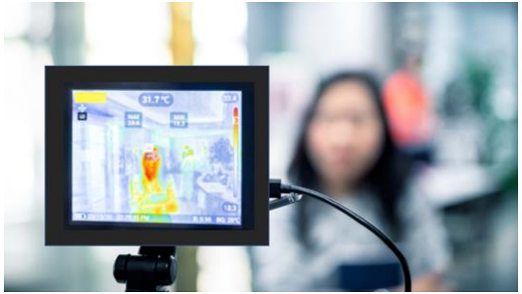


Remote Sensing

Remote Sensing: Science and art of obtaining information about an object, area or phenomenon through an analysis of data acquired by a device that is not in direct contact with the area, object or phenomenon under investigation.

Lillesand, Thomas M. and Ralph W. Kiefer, *Remote Sensing and Image Interpretation*, John Wiley and Sons, Inc, 1979, p. 1

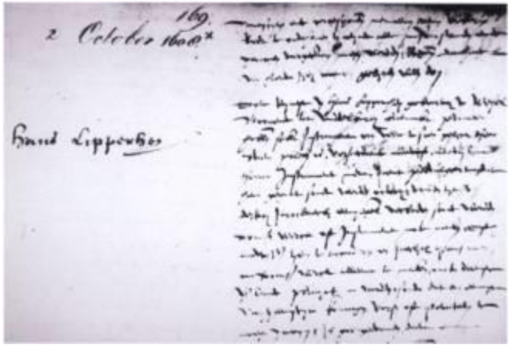
Temperature screening (such as at the airport) during pandemics



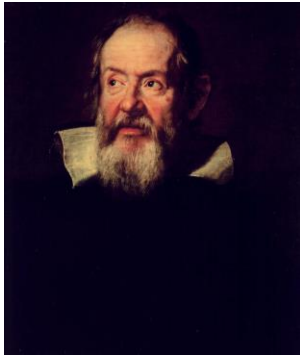
Not Remote Sensing: In-situ or on-site observation

History of Remote Sensing

- 5th century BC: Greek accounts of the optical properties of water-filled spheres
- 2nd century AD: Ptolemy in his Optics, writes about the properties of light including reflection, refraction, and colour
- 1451: Nicholas of Cusa uses concave lenses to correct near-sightedness
- 1608: Hans Lippershey (Netherlands) files patent for instrument "for seeing things far away as if they were nearby"
- 1609: Galileo Galilei builds his Galilean telescope



Lippershey telescope patent application



Galileo Galilei

History of Remote Sensing

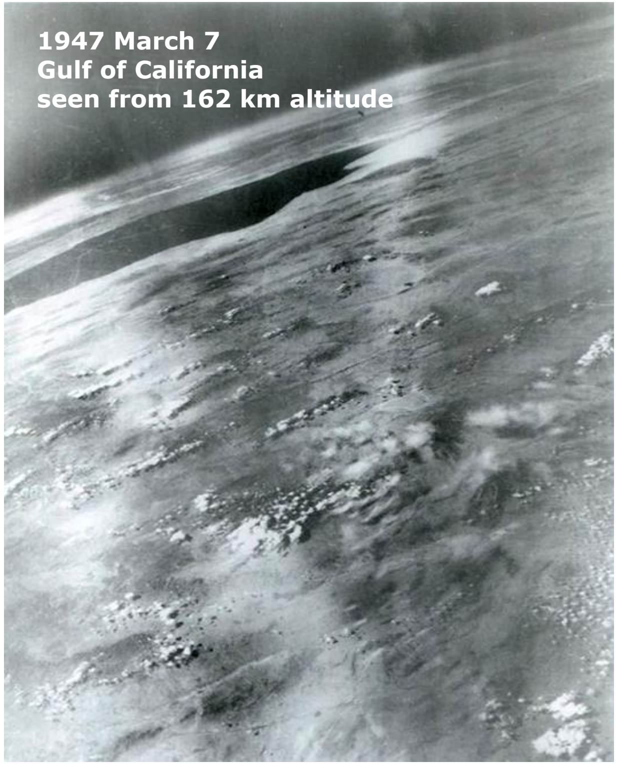
- 1858: Gaspard-Félix Tournachon (pseudonym *Nadar*) captures the first aerial photographs from a hot air balloon over Paris
- 1860: James Wallace Black takes photographs from a hot air balloon above Boston (oldest surviving aerial photos)
- 1887: Arthur Batut takes aerial shots of the south of France using just a kite, a camera, and a fuse
- 1906: George R. Lawrence photographs damage of the San Francisco earthquake, from 2000 feet up
- 1908: Julius Neubronner invents a miniature camera that could be worn by a pigeon

G.-F. Tournachon

1860: Boston from the air

History of Remote Sensing

- Late 1940’s: First photos of the Earth from space
  - Team of Clyde Holliday, Applied Physics Laboratory, Johns Hopkins University
  - “one day the entire land area of the globe might be mapped in this way…”



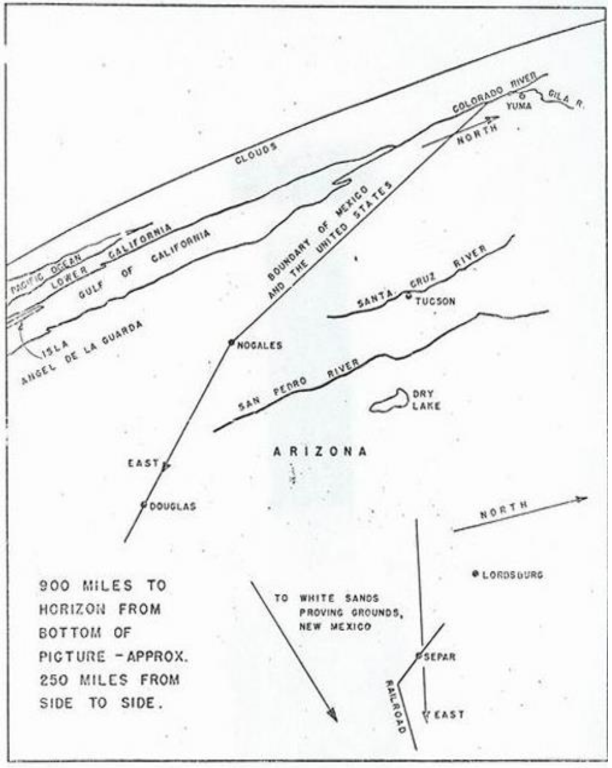
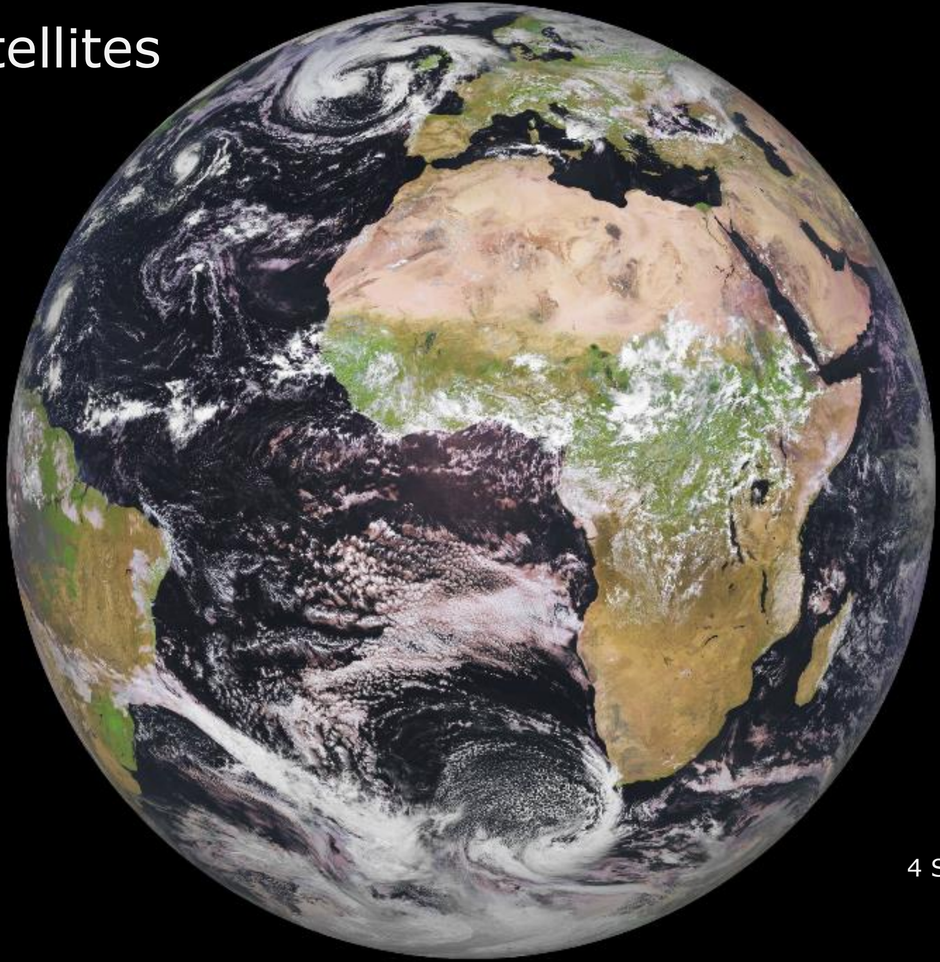


Figure 11. A photograph taken 227 seconds after takeoff at an altitude of 162 kilometers (101 miles). The rocket was then within a quarter of a kilometer of the peak of its trajectory. The camera was pointed southwest.

Earth Observation with Satellites

One single location where we can learn the most about our planet as a whole cannot be found anywhere on Earth, but only high up above it!

Remote Sensing of our planet = Earth Observation



4 September 2022

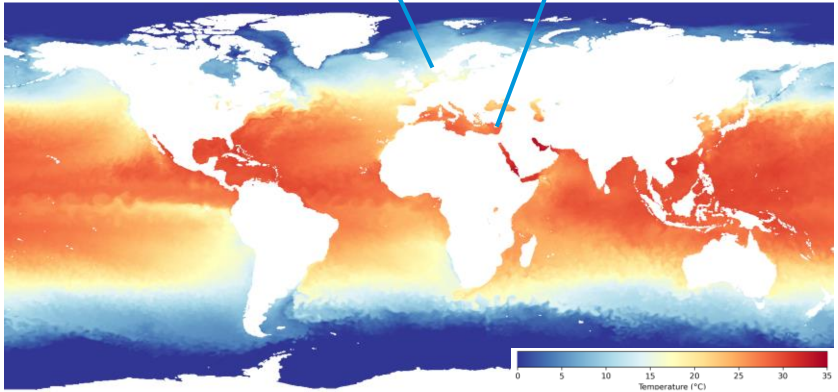
Meteosat-11


Earth Observation with Satellites
Nicosia, 15 September 2022
Sentinel-2 True Colour
→ THE EUROPEAN SPACE AGENCY

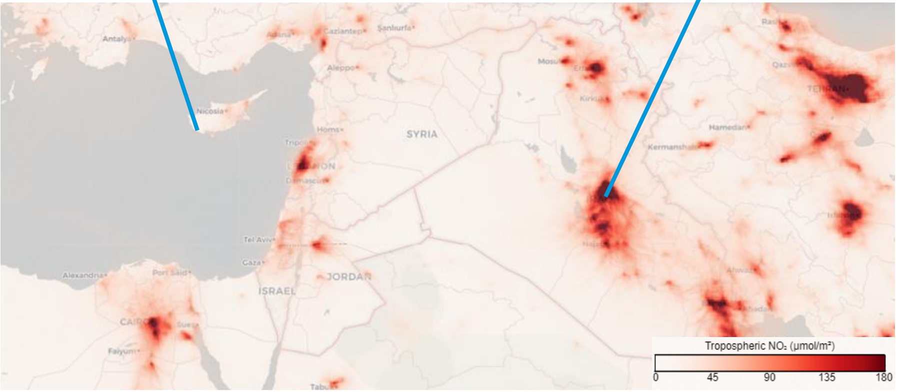
Why Earth Observation with Satellites?

However... are satellites just taking **"photos"** of the Earth?



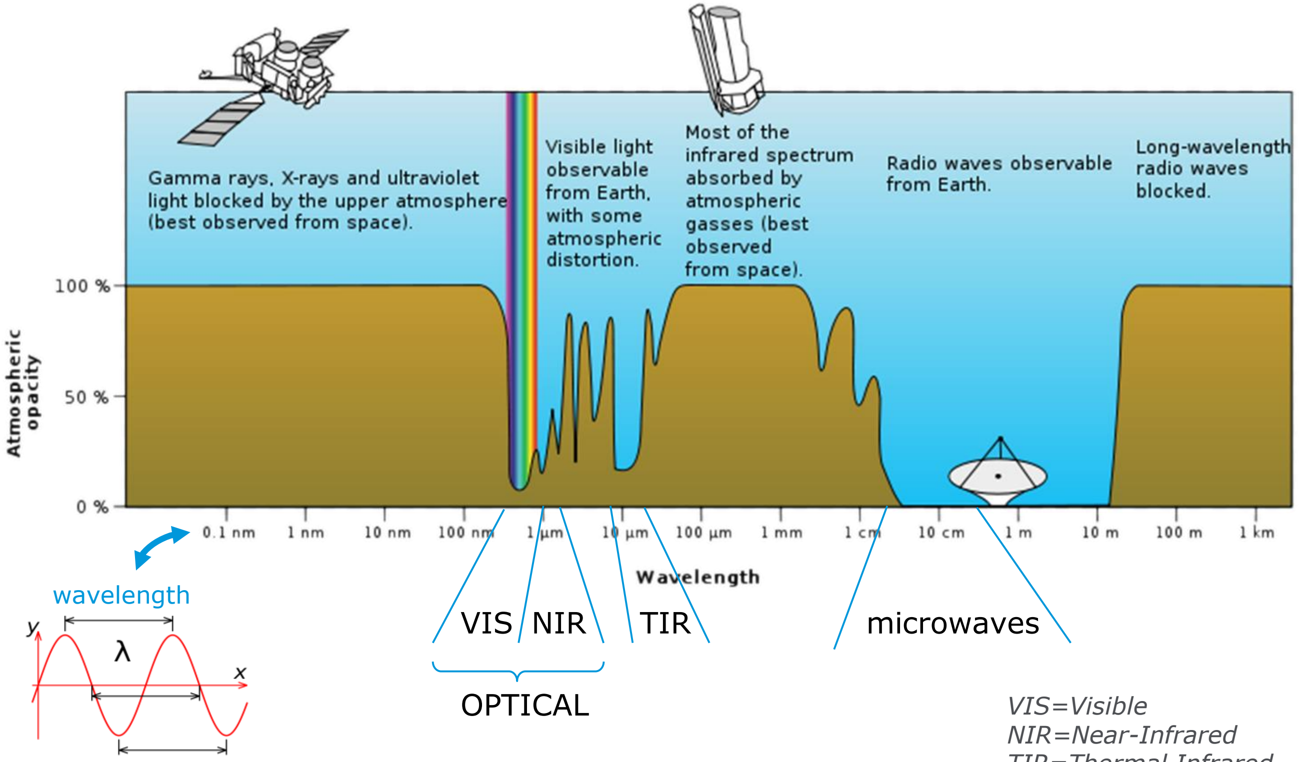
Sea Surface Temperature
2022 September 16



Tropospheric Nitrogen Dioxide
2022 September 3–16

The Electromagnetic Spectrum

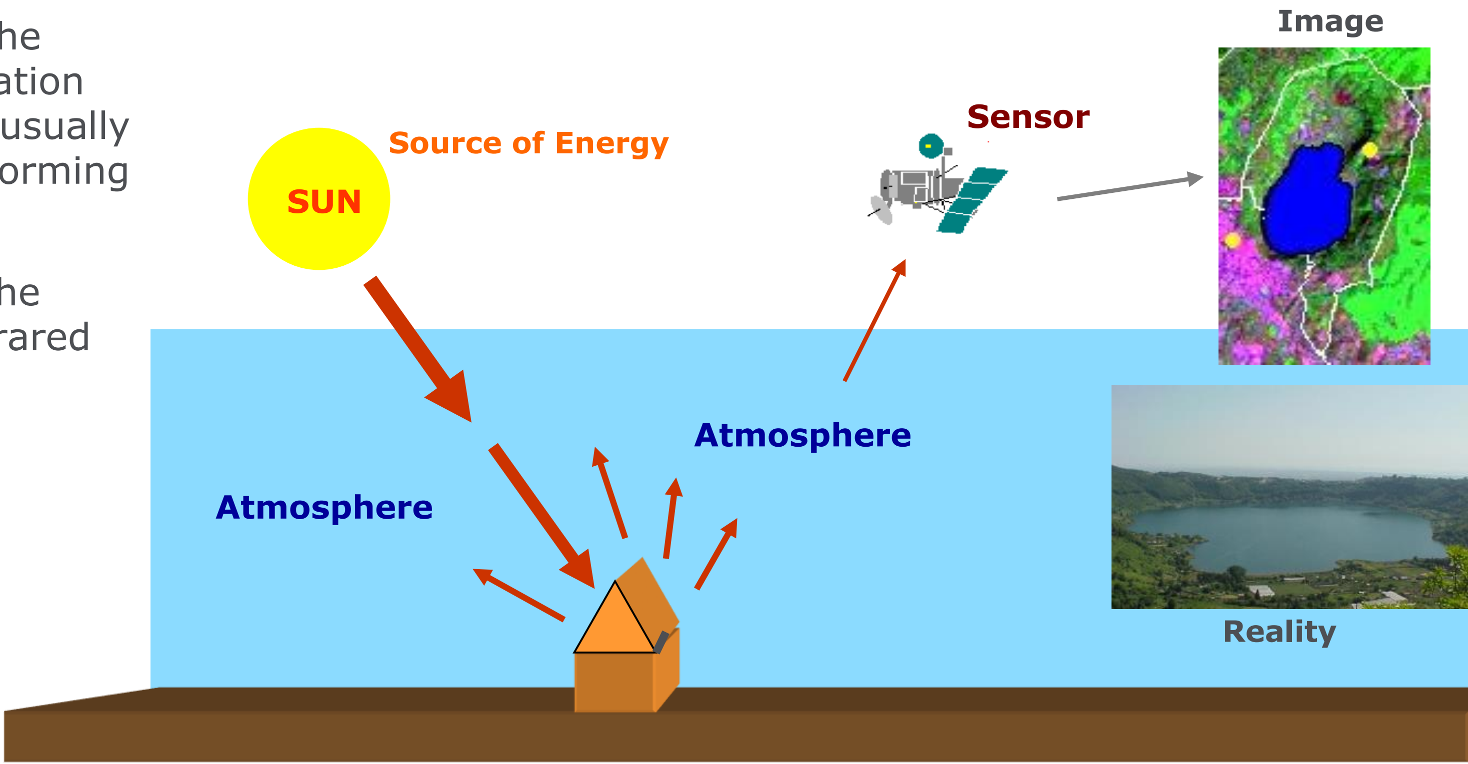
- Our eyes, like any other sensor, measure some radiation
- Our eyes are sensitive only to visible light
- But other sensors can be sensitive also to other “types” of radiation, more or less attenuated by atmosphere during transmission
- Radiation is characterised by a wavelength



VIS=Visible
NIR=Near-Infrared
TIR=Thermal Infrared

Passive Sensors

- Sensors capturing the reflection of illumination by another source (usually the Sun) and transforming it into an image
- Usually sensors in the visible and near-infrared ranges



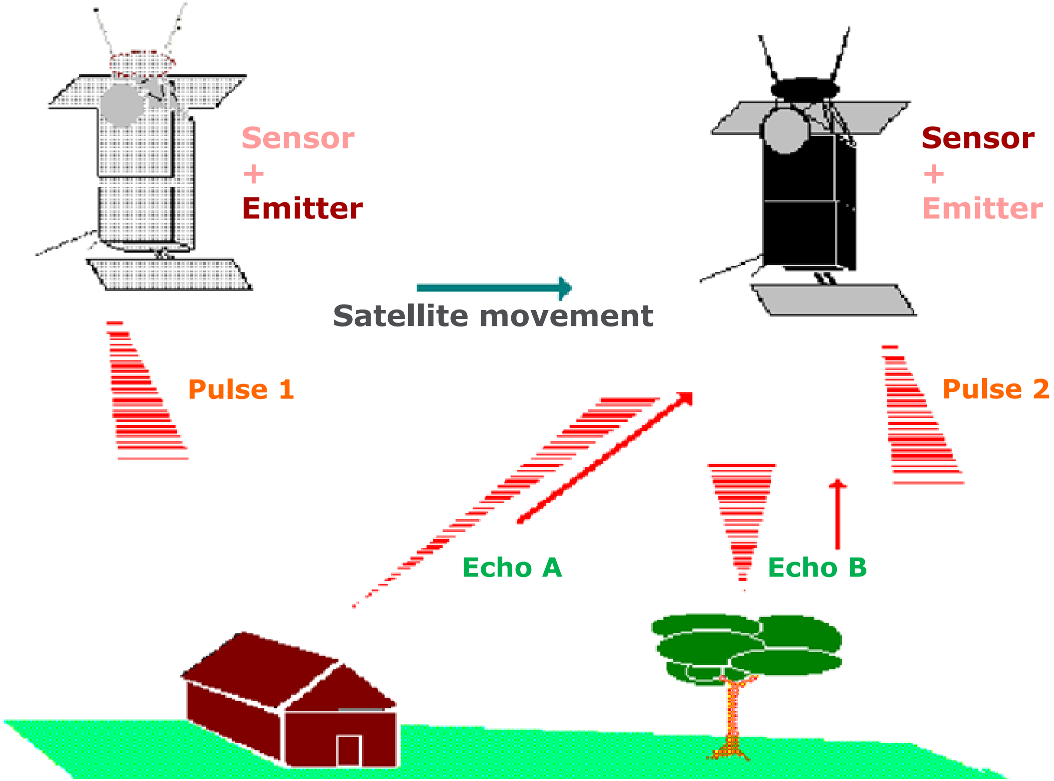
Passive Sensors

Sensors can also capture the directly emitted light, as in visible light emitted by artificial illumination in the cities

Cyprus seen from the International Space Station

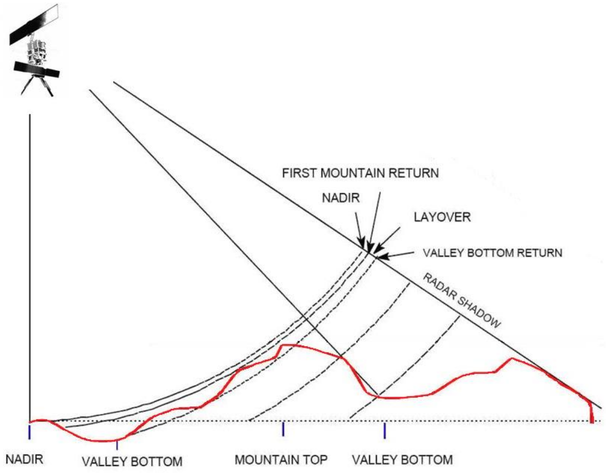
Active Sensors

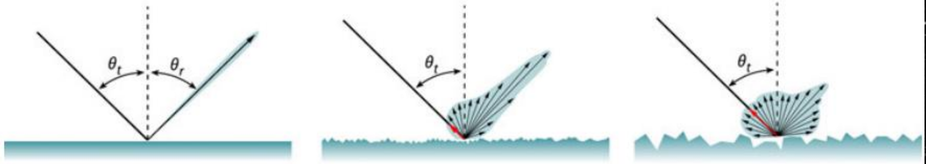
- Sensors use their own signal sources (their own “illumination”) to retrieve information of the Earth surface
- Usually using microwaves
  - Advantage: works through clouds

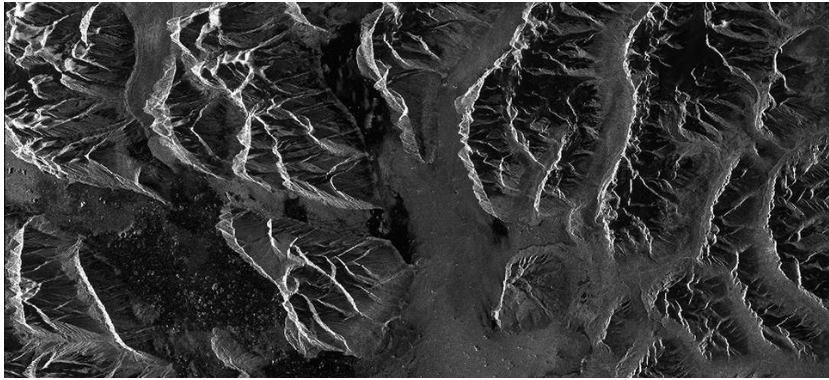


Active Sensors

- Synthetic Aperture Radar (SAR) uses microwaves
- Resulting images are not always easy to interpret
- They represent a combination of where and when the signal bounces back from the ground and with what intensity
- Complications arise when imaging three-dimensional targets such as tall buildings or mountains





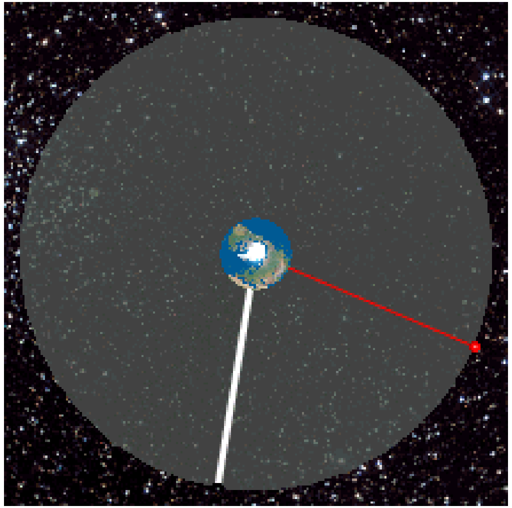


Satellite Orbits

Geostationary orbits

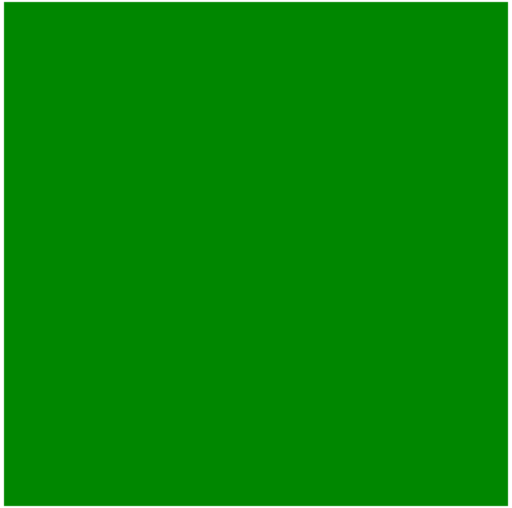
- Orbiting at 36000 km above the Earth
- Synchronized with Earth’s rotation around its axis
- Remain “stationary” above one area of the Earth
- Applications: meteorology, telecommunications

Two satellites on geostationary orbit



Near-polar orbits

- Pass (nearly) above the poles
- Low Earth Orbits (LEO): about 700 to 1700 km height
- Typical for EO: sun-synchronous orbits (600 to 800 km height) achieve constant angle of sun illumination
- Numerous applications over land, atmosphere, oceans and ice



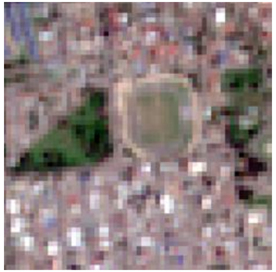
Swaths and Passes

- Most of the satellite EO platforms today are in near-polar orbits: the satellite travels northwards on one side of the Earth (ascending pass) and then toward the southern pole on the second half of its orbit (descending pass).
  - Sun-synchronous orbits: the ascending pass is most likely on the shadowed side of the Earth while the descending pass is on the sunlit side.
- The area imaged on the surface is the swath. Wider swath = more coverage.
- The satellite rotation along its orbit and the rotation of the Earth allow new areas to be covered with each consecutive pass
- Full coverage achieved when one full cycle of orbits is completed

Animation of the coverage (full cycle of 5 days) achieved by the two units of Sentinel-2 in orbit

Spatial and Temporal Resolution

- Spatial resolution of a sensor refers to the size of the smallest possible feature that can be detected
- Images are composed of a matrix of picture elements, or pixels
- The temporal resolution is based on the revisit time = the time it takes between two consecutive viewings of the same area
  - Temporal resolution of imaging the exact same area at the same viewing angle a second time is equal to the orbit cycle time
  - In practice the temporal resolution can be
    - higher e.g. because sensors can sometimes be steered to look sideways = more frequent coverage
    - lower, due to clouds coverage (in case of optical sensors)
  - Wider swaths = more frequent coverage (but at varying viewing angles)
  - Higher latitudes = more overlaps between consecutive passes = more frequent coverage

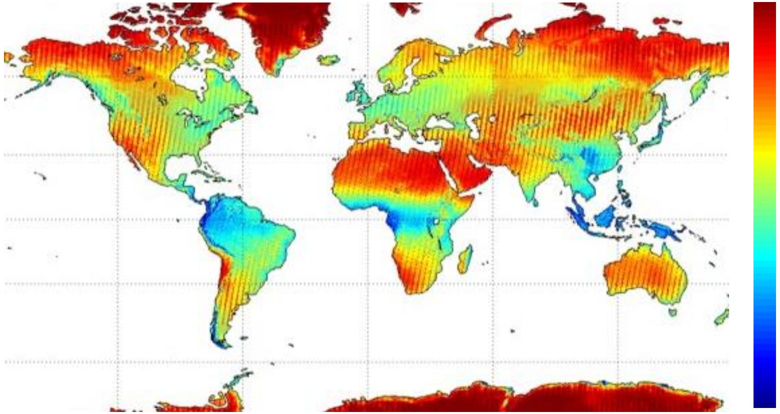


Sentinel-2
- 10 m resolution
- available every 5 days
- free and open

Coarse or low resolution

WorldView-2
- 0.5 m resolution
- normally available a few times per year
- commercial

Fine or high resolution



More frequent coverage

Higher temporal resolution

Shorter revisit time

Longer revisit time

Lower temporal resolution

Less frequent coverage

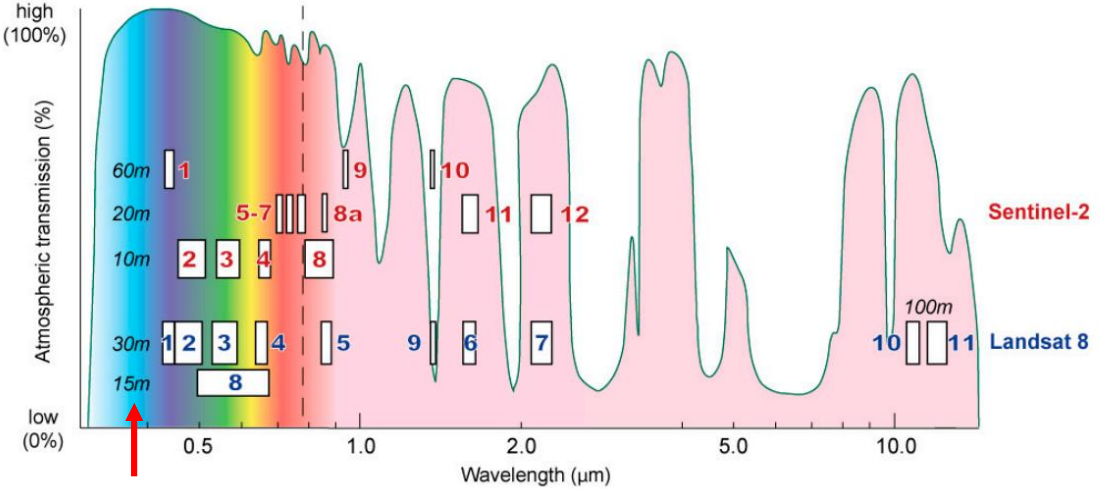
Typical coverage frequency when the average cloud cover is considered

Spectral and Radiometric Resolution

- Spectral resolution is based on which areas (bands) of the electromagnetic spectrum a sensor is capturing
- Typically separate images are produced in each of many bands (multispectral imaging) or in a very high number of narrow bands (hyperspectral imaging)
- Physical limits to how much information can be collected in each band during a certain observation time = impact on spatial resolution

- The radiometric resolution of a sensor is related to its ability to discriminate very slight differences in incoming energy
- The higher the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy

Comparison of Landsat and Sentinel-2 bands



Varying spatial resolution!

Source: https://www.mdpi.com/2072-4292/8/7/598

Why Earth Observation from Satellites?

- EO can deliver key environmental information that supports decision-making
- EO data brings benefits through being globally consistent (both spatially and temporally), comparable, timely and impartial
- EO allows for cost-effective collection of large amounts of data in a very short time span
- EO provides non-intrusive access to remote regions
- Through archived data, EO provides access to the past history of our environment, allowing for straightforward and powerful detection of long- and short-term changes