1. Radar Earth Observation and evolution – current and next generation missions, ESA EO Data Access and resources, applications

Purpose of The European Space Agency (ESA)

"To provide for and promote, for **exclusively peaceful purposes**, cooperation among European states in **space research** and **technology** and their **space applications.**"

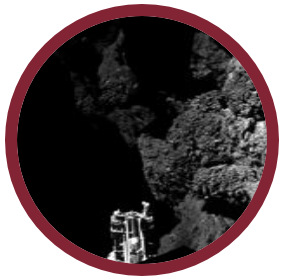
Article 2 of the ESA Convention

Source: https://www.isprs.org/proceedings/2018/2018-Dehradun-IPAC-Session/A6_ESA-Copernicus-HOSFORD.pdf

Activities

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

- Space science is a Mandatory programme, all Member States contribute to it according to GNP. All other programmes are Optional, funded by Participating States.


space science


human spaceflight


exploration


earth observation


launchers


navigation

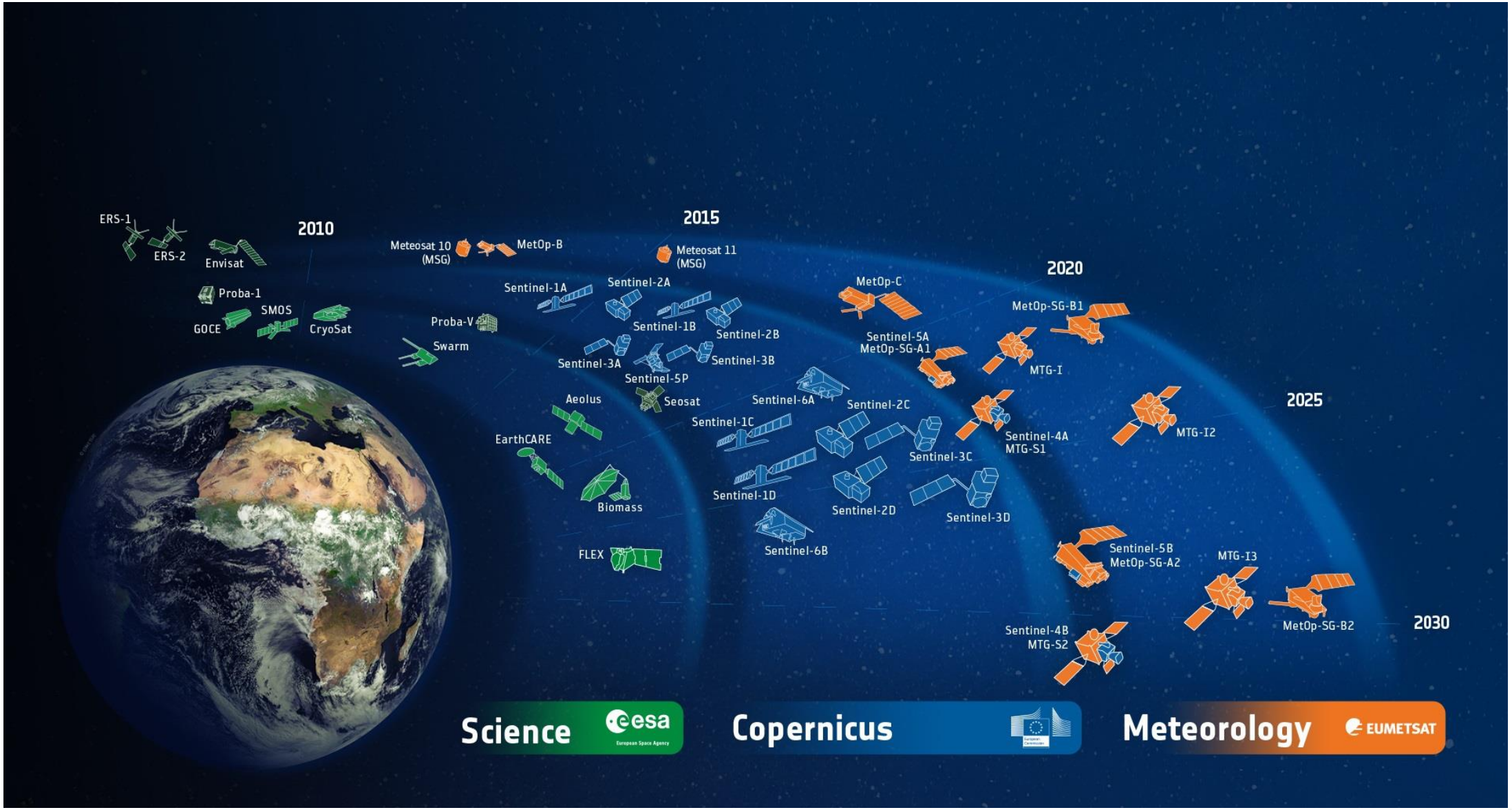

operations


technology


telecommunications

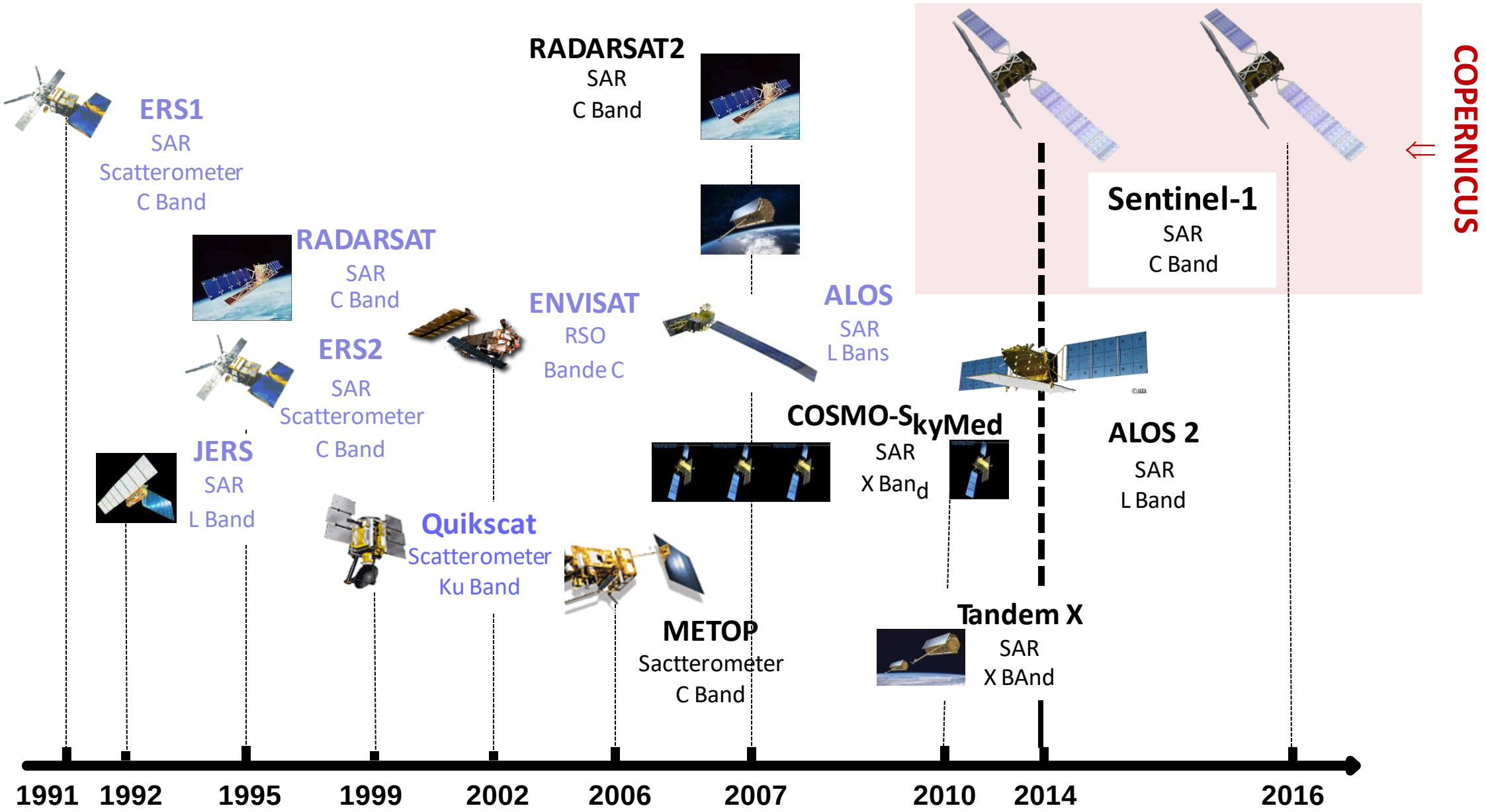
Source: https://esamultimedia.esa.int/docs/corporate/ESA_Corporate_Presentation_Fr.pdf

ESA-Developed Earth Observation Missions



Source: https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/Earth_Day_taking_the_pulse_of_our_planet

Examples of Spaceborne Radar sensors



Examples of Spaceborne Radar sensors

Satellite	Owner	Band	Resolution	Look Angle	Swath	Lifetime
ERS-1	ESA	C	25 m	23°	100 km	1991-2000
ERS-2	ESA	C	25 m	23°	100 km	1995-2012
Radarsat-1	Canada	C	10 m - 100 m	20°- 59°	50 - 500 km	1995-2013
ENVISAT	ESA	C	25 m - 1 km	15°- 40°	100 - 400 km	2002-2012
ALOS	Japan	L	10 m -100 m	35°- 41°	70 - 360 km	2006-2011
Cosmo	Italy	X	ca. 1 m - 16 m	…	…	2007-
TerraSAR-X	Germany	X	1 m - 16 m	15°- 60°	10 - 100 km	2007/2010-
& TanDEM-X						
Radarsat-2	Canada	C	3 m - 100 m	15°- 59°	10 - 500 km	2007-
ALOS-2	Japan	L	3 m – 100 m	8°-70°	25 – 350 km	2014-
Sentinel-1	ESA	C	5 m – 50 m	20°-46°	20 - 400 km	2014-

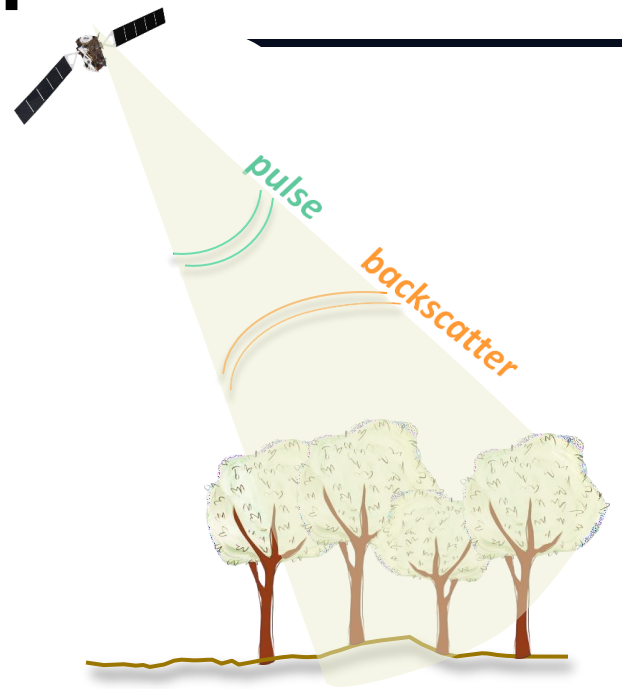
Sentinel-1 – Radar vision

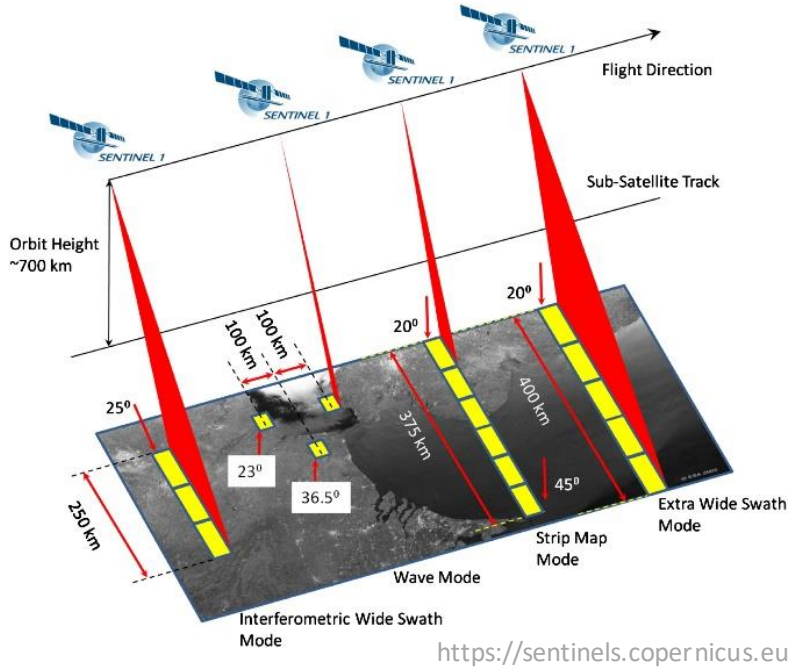
Mission objectives:

- Marime and land monitoring
- Emergency management

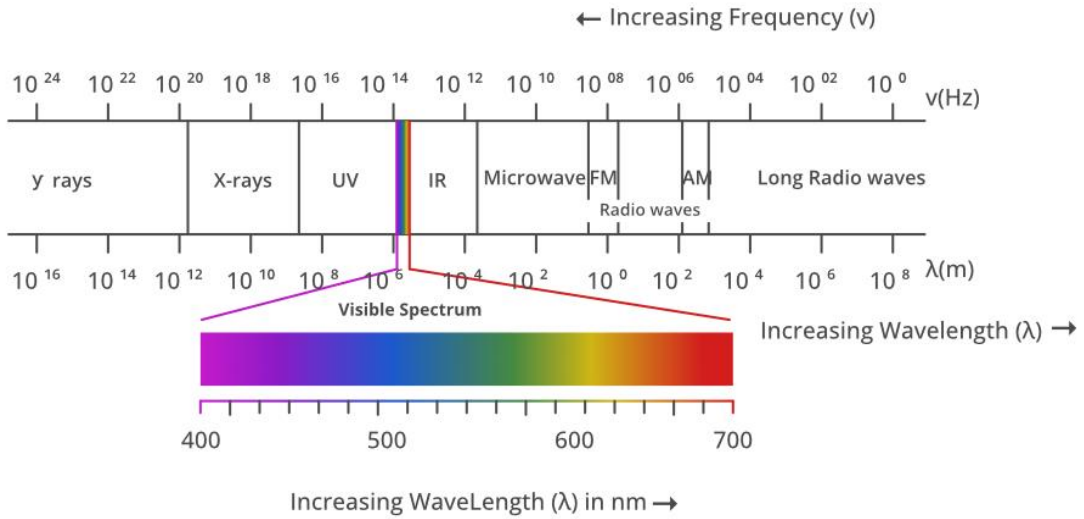
Mission profile:

- C-Band SAR mission at 5.4 GHz
- Multi-polarisation
- Sun synchronous orbit at 693 km mean alt.
- 6 days repeat cycle at Equator with 2 satellites
- 4 operation modes





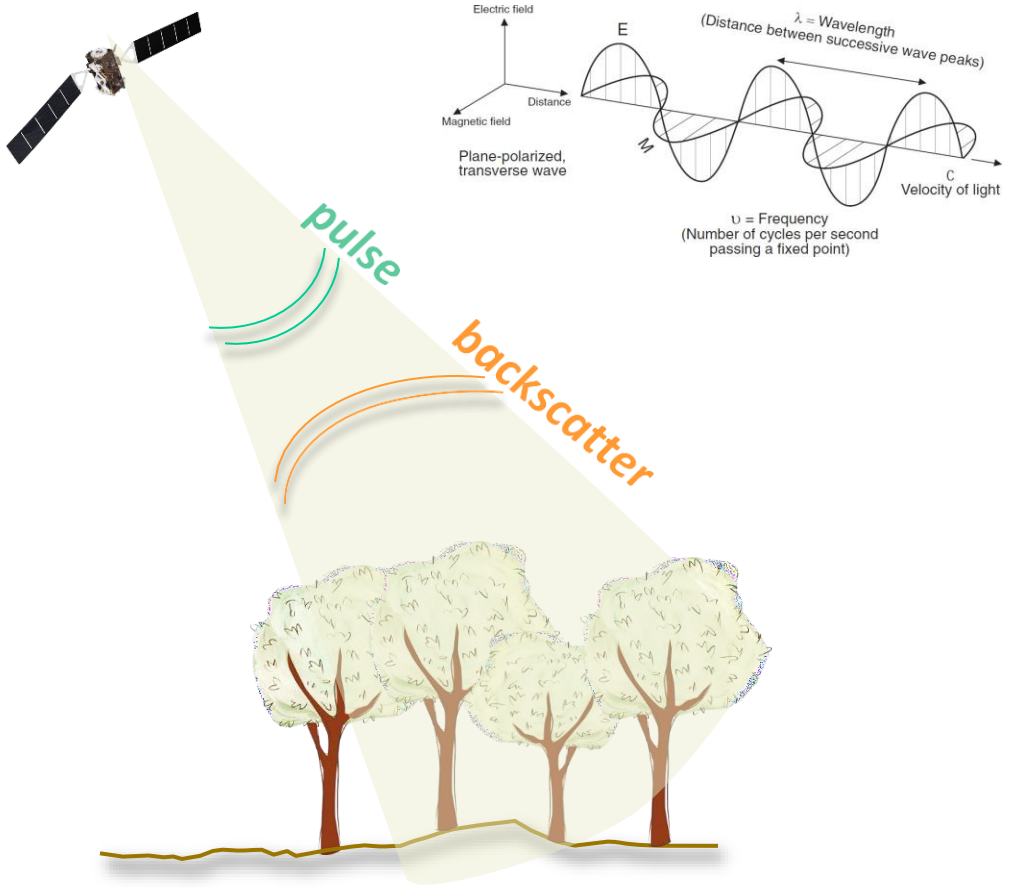
https://sentinels.copernicus.eu

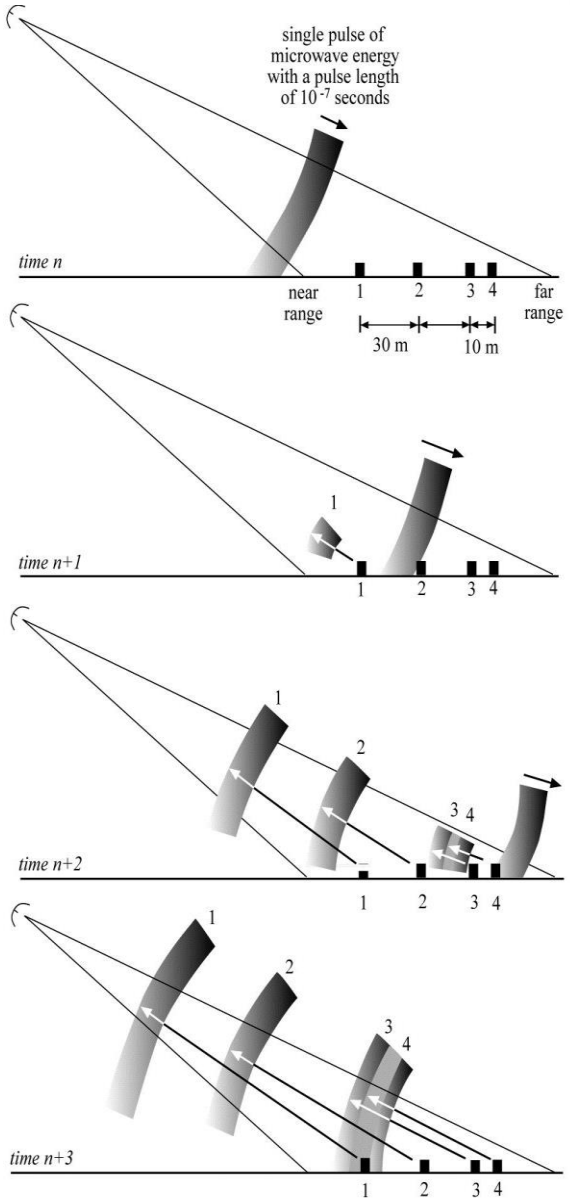


Active Radar Remote Sensing

Basic characteristics of radar systems/SAR sensors

Active ⇒ **independent of sun illumination** (generate EM-waves)





Radar principle

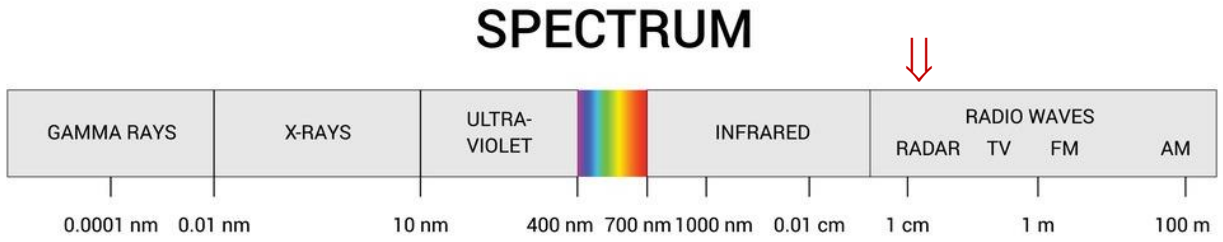
EMG transmitted in bursts of energy - pulses (approx. every 0.000 000 1 s)

The energy of a single pulse is reflected from objects on the surface in order of distance from source/transmitter on board

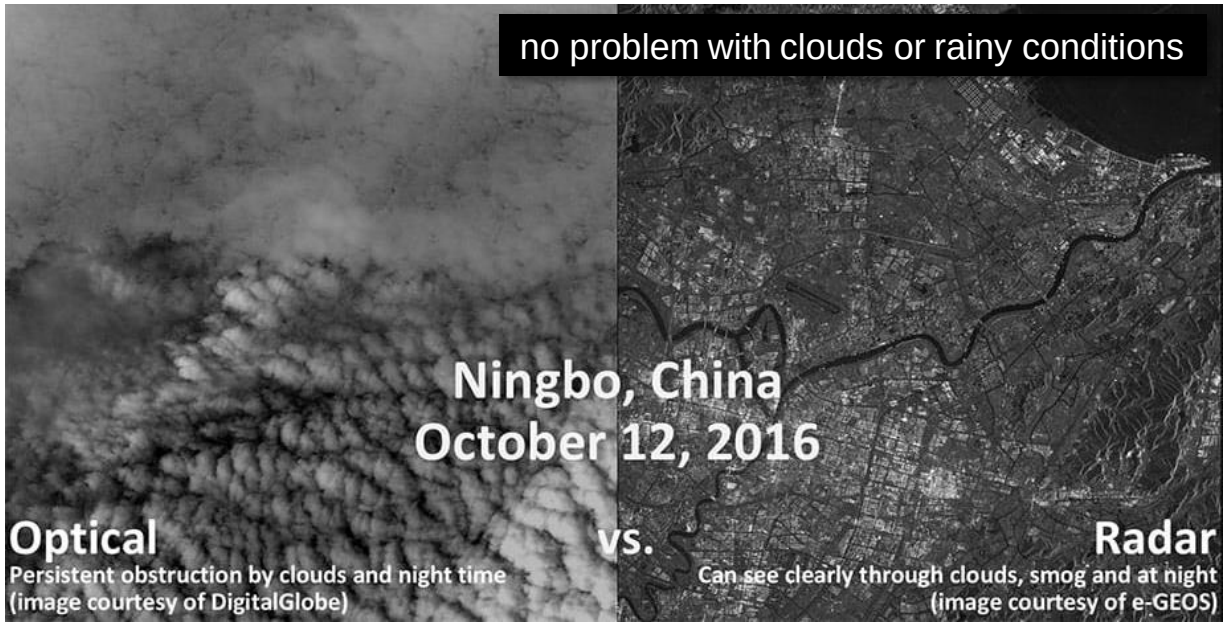
The intensity of the reflected energy and the time it takes for a given pulse to return are recorded

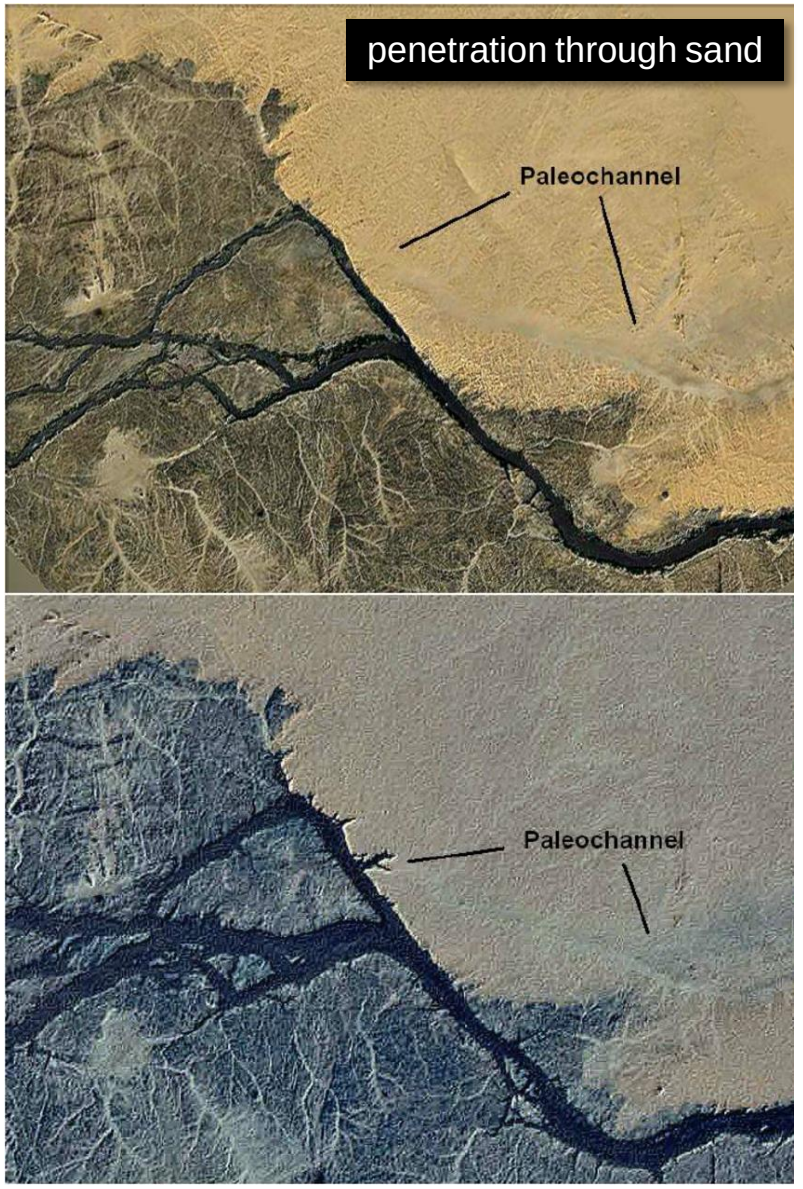
Active Radar Remote Sensing

Basic characteristics of radar systems/SAR sensors



Microwave ⇒ penetrates into/through objects

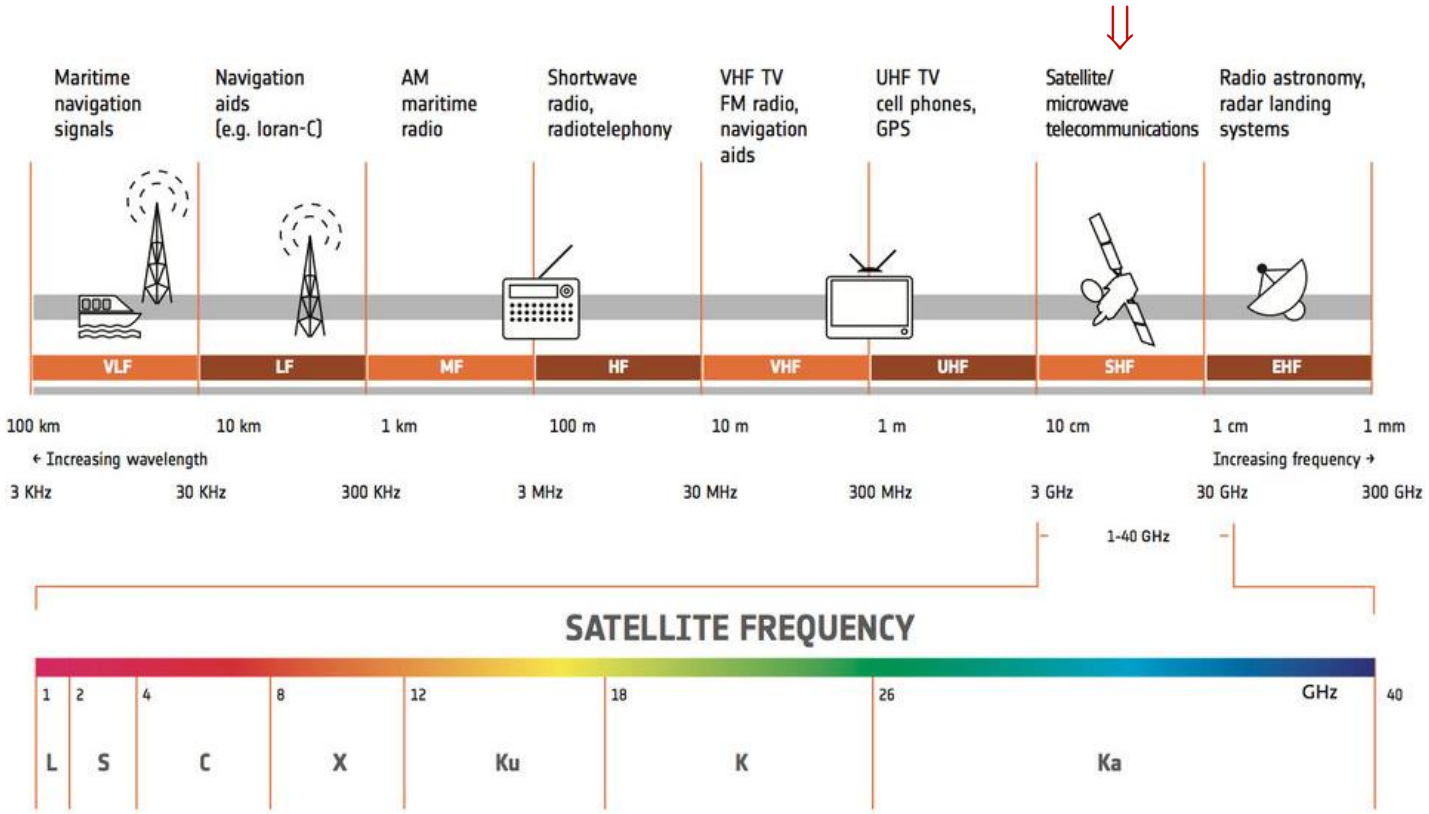


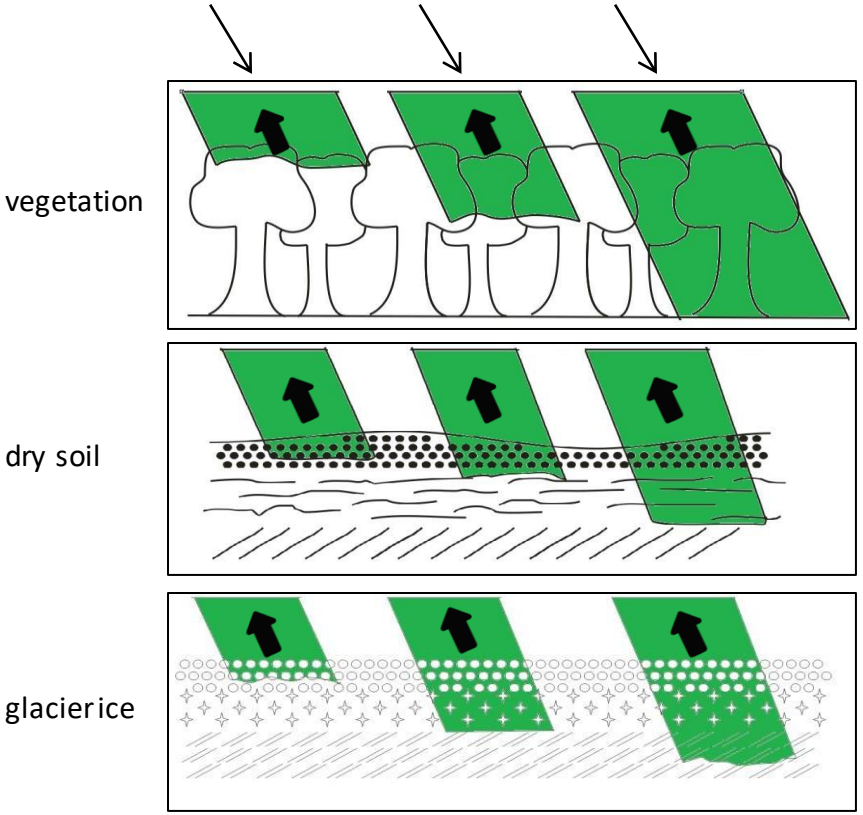


Active Radar Remote Sensing

RADAR band designations, wavelenghts and frequencies

- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects

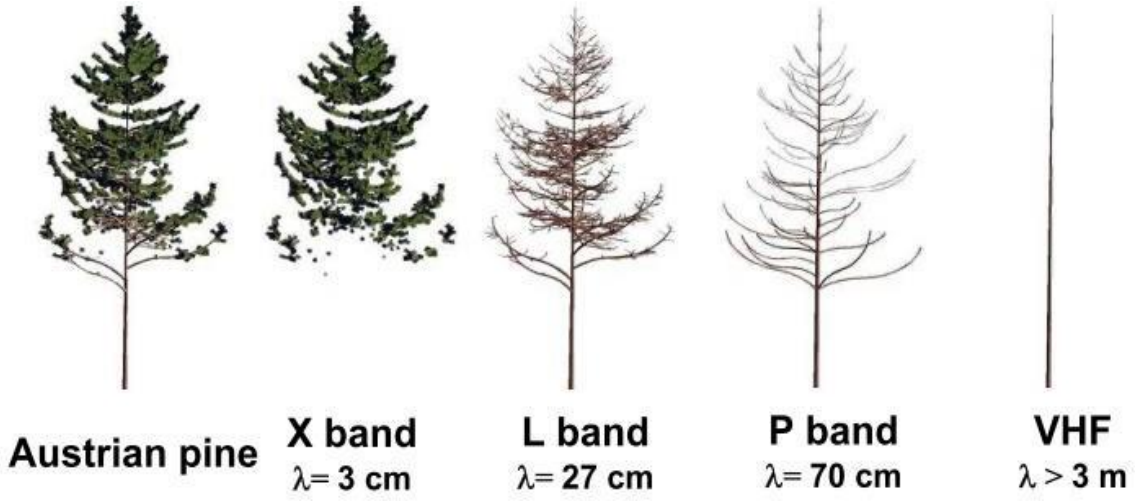


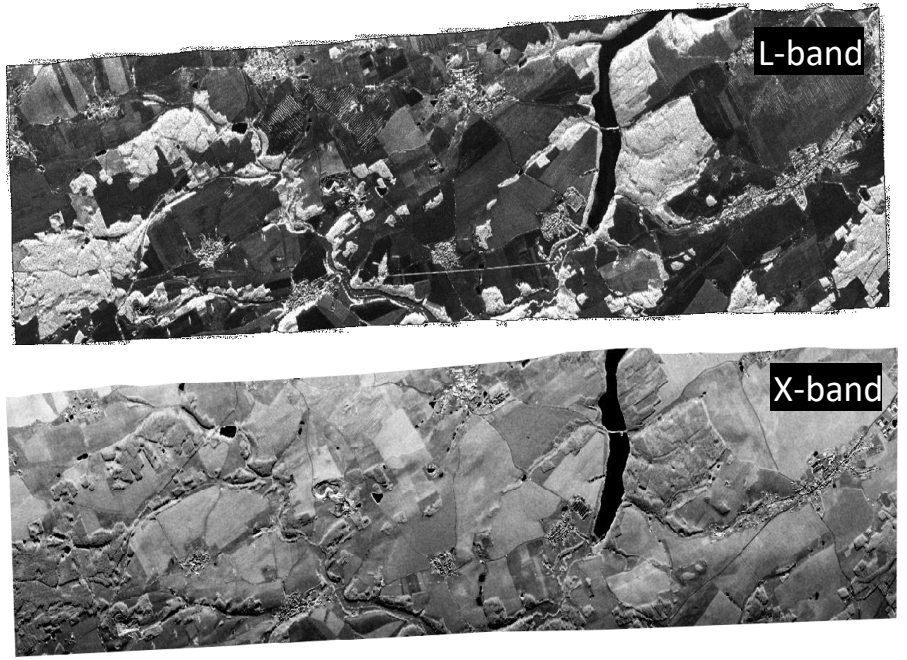


Active Radar Remote Sensing

RADAR band designations, wavelenghts and frequencies

- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects





Active Radar Remote Sensing

- Radar altimetry
- Radar imaging
  - SLAR – side look-angle radar
  - INSAR – interferommetric synthetic aperture radar
    - D-insar
    - PS-insar

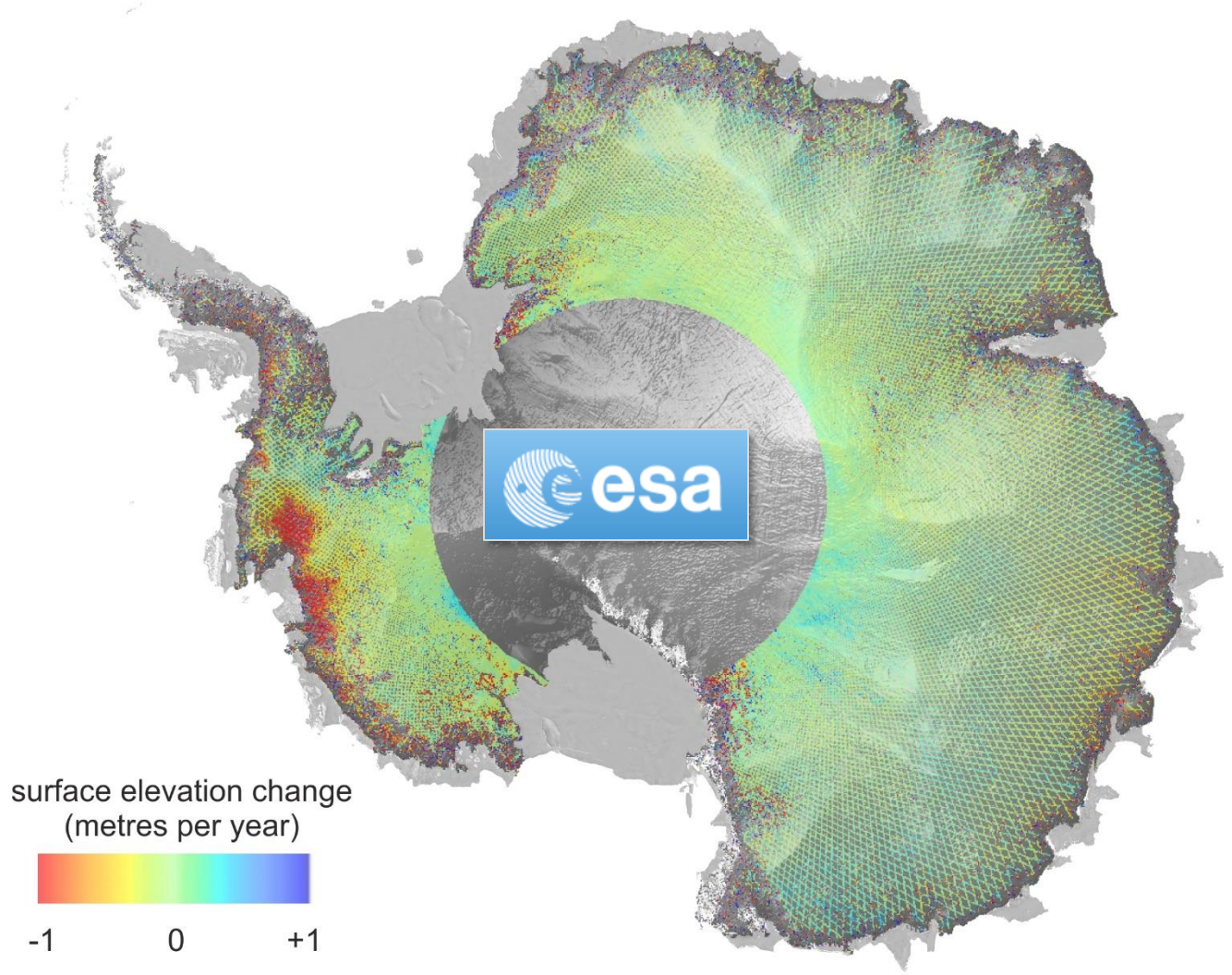
Radar Altimetry = measuring altitude / vertical height

Article ESA

video

video 2

Radar Altimetry = measuring altitude / vertical height



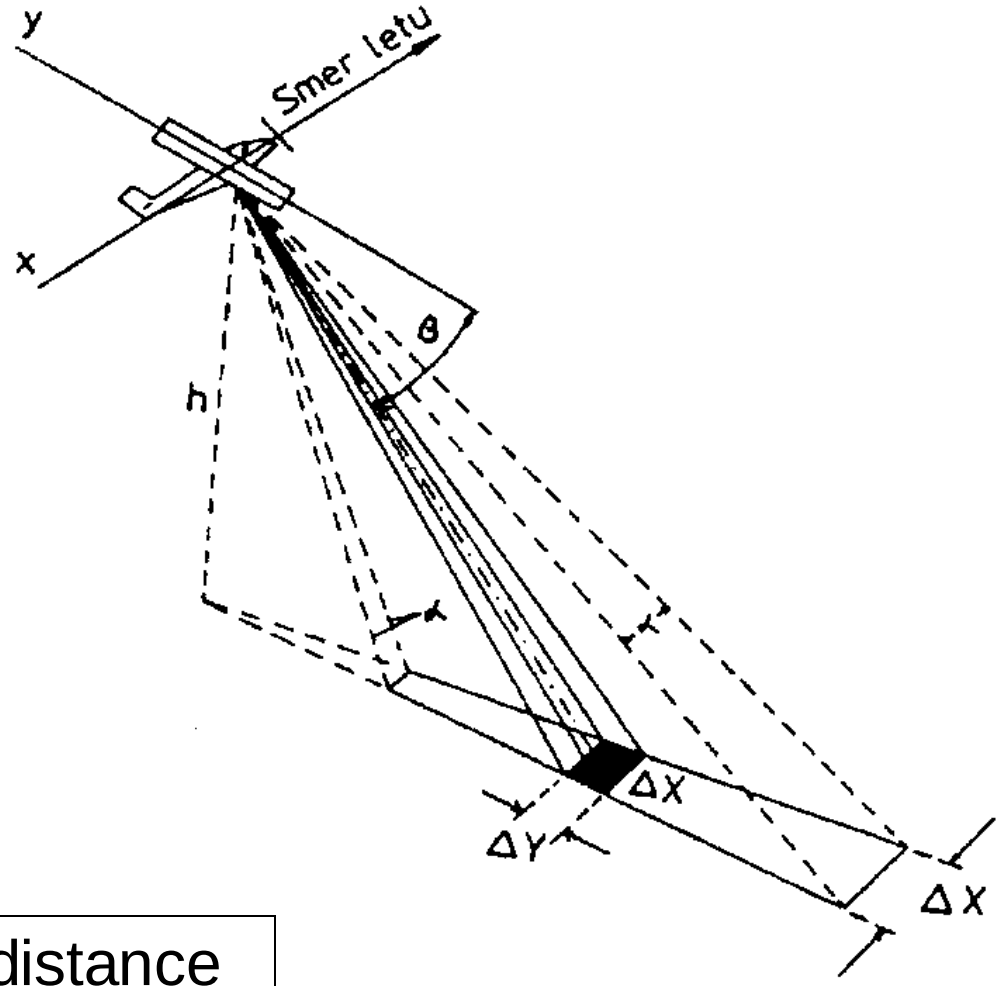
[Copernicus Sentinel-3 provides new measurements of Antarctic Ice Sheet
08 March 2019]

Side looking radar (SLAR)

$$\Delta x = \frac{h.\lambda}{L.\sin\beta}$$

$$\Delta y = \frac{c.\Delta t}{2.\cos\beta}$$

h – flight altitude, L – length of antenna, β - angle between the horizontal plane and the emitted beam



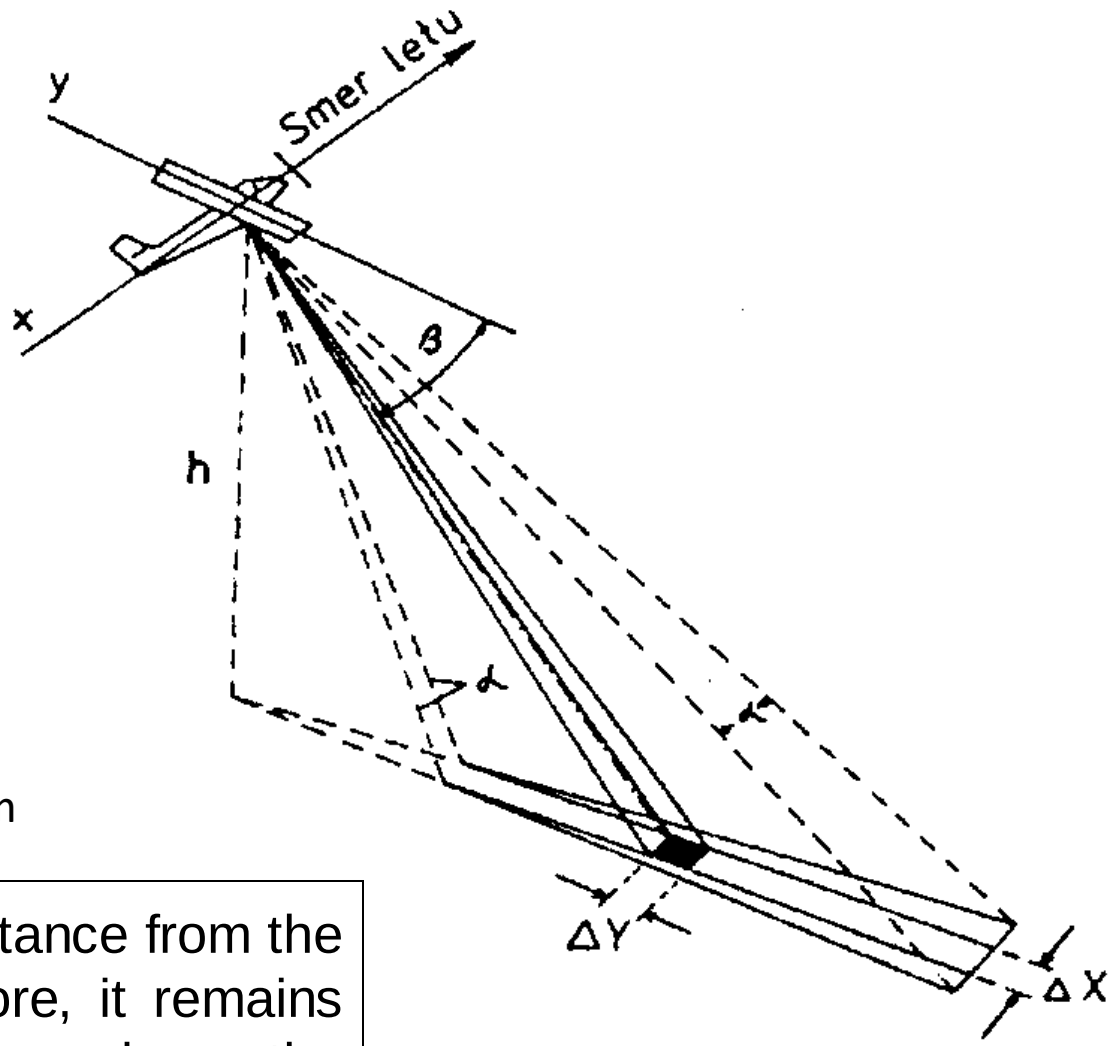
Spatial resolution deteriorates as the distance between the object and the antenna increases.

Synthetic aperture radar (SAR)

$$\Delta x = \frac{L}{2}$$

$$\Delta y = \frac{c.\Delta t}{2.\cos\beta}$$

h – flight altitude, L – length of antenna, β - angle between the horizontal plane and the emitted beam



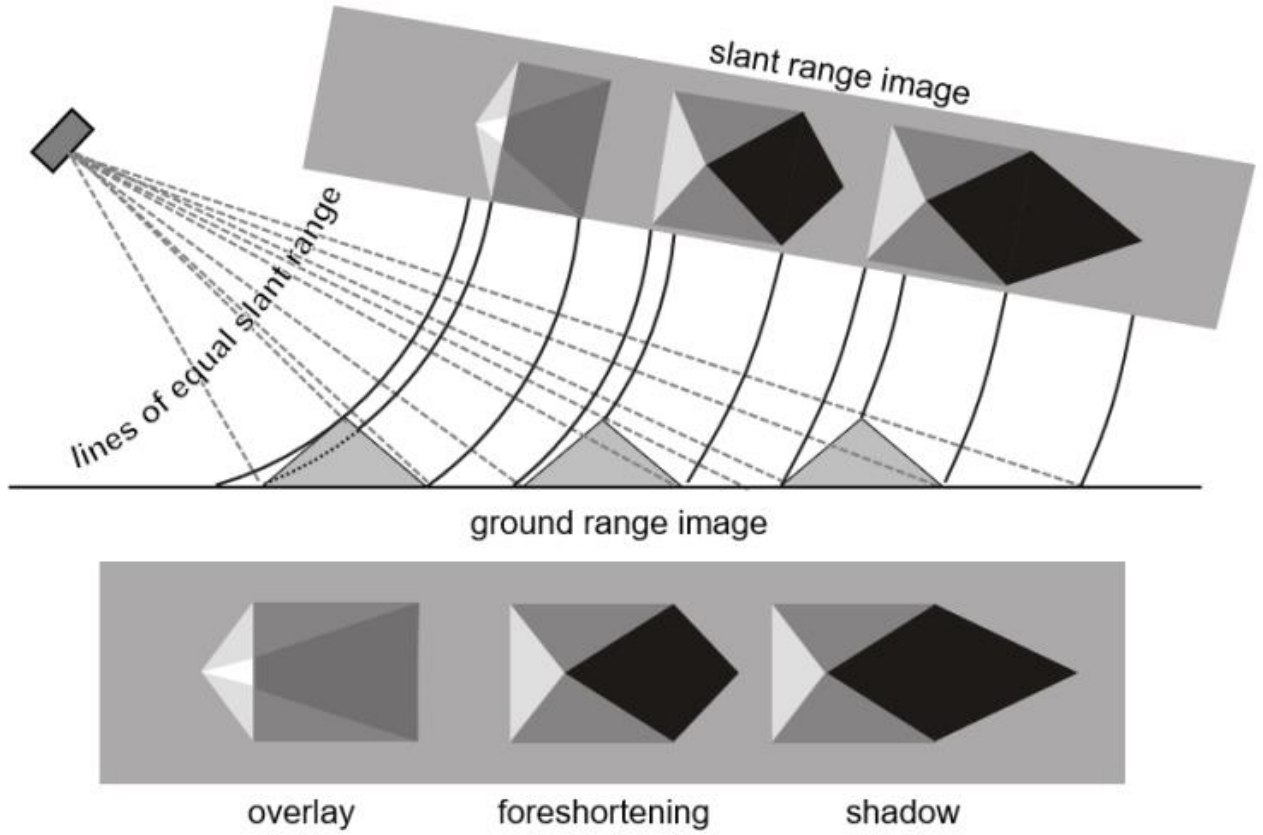
Spatial resolution is independent of the distance from the antenna in the direction of flight. Therefore, it remains constant in the flight direction, while it depends on the viewing angle perpendicular to the flight direction.

Geometric Effects in SAR images

Effects of side-looking geometry

→ Side looking geometry of SAR systems cause some typical geometric effects

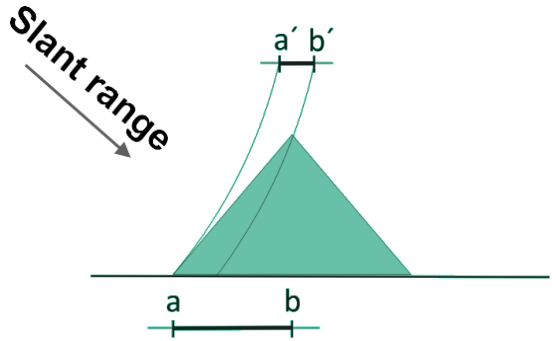
- The effects are:
  - ❖ Foreshortening
  - ❖ Layover
  - ❖ Radar shadow
- Controlled by:
  - ❖ Incidence angle
  - ❖ Topography



Geometric distortions in radar images (Braun 2019)

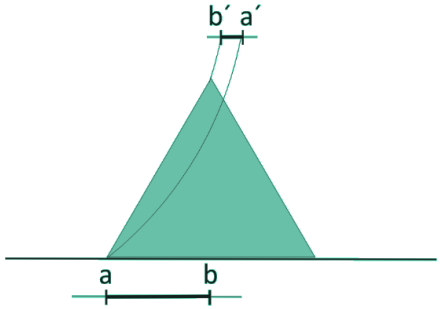
Geometric Effects in SAR images

Foreshortening



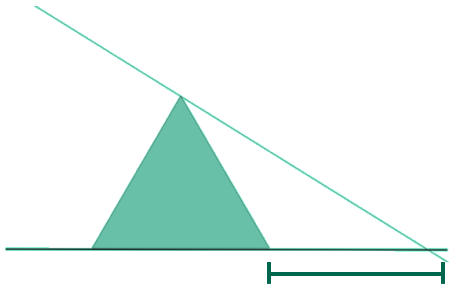
- Slopes oriented to the SAR appear compressed (Distance between a and b is shortened)
- Appears as very bright area
- More pronounced in near range (small incidence angle) than in far range (high incidence angles)

Layover

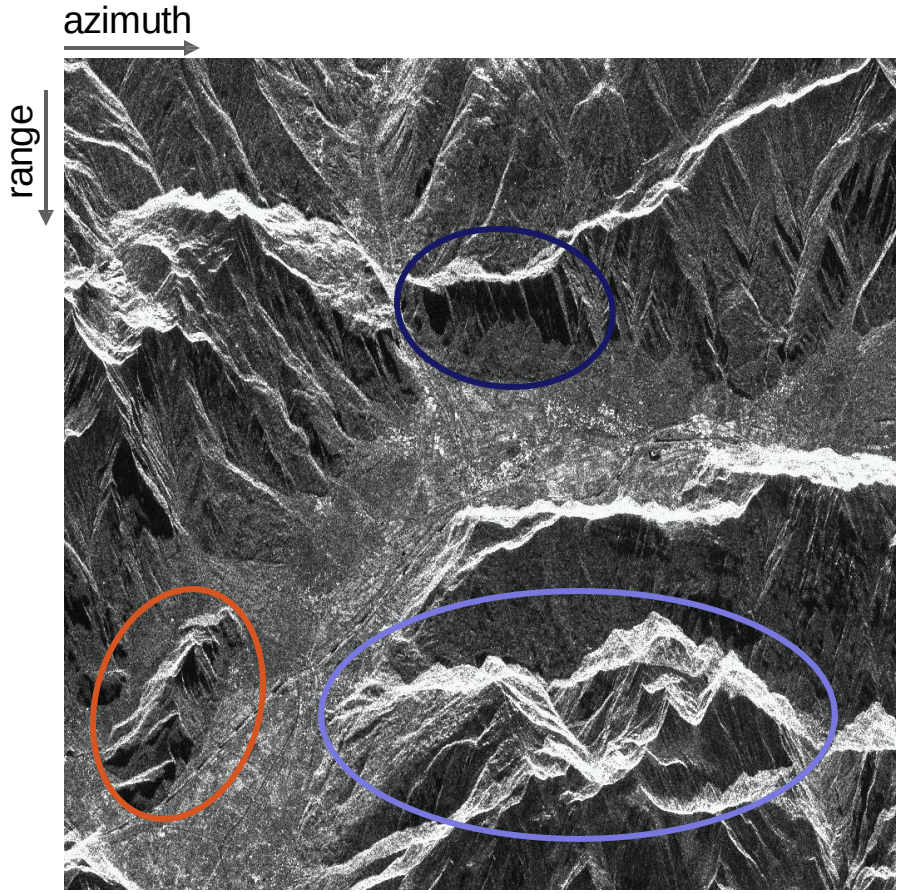


- Steep slopes oriented to the SAR lead to ghost images
- When radar beam reaches the top of a high feature (b) before it reaches the base (a)

Radar shadow



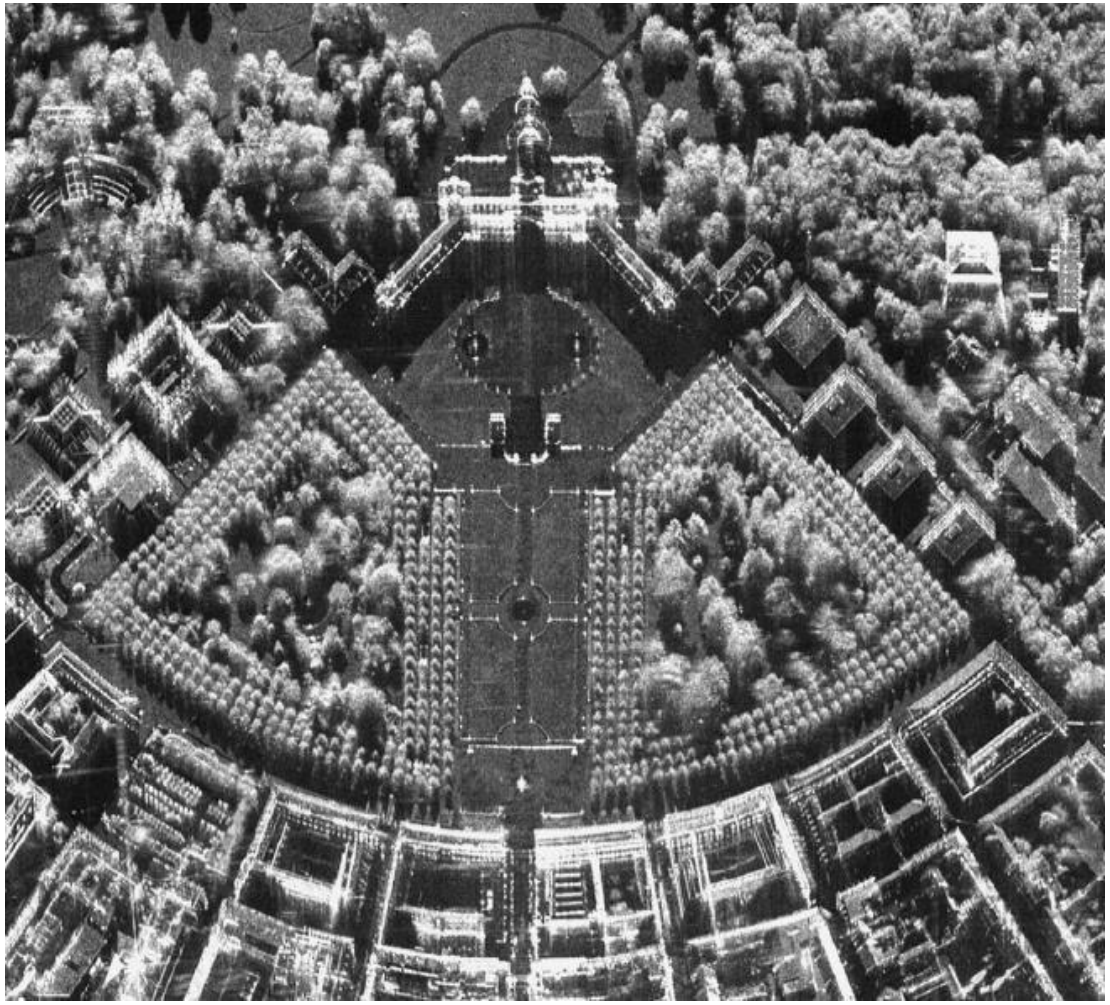
- Steep slopes oriented away from the SAR return no signal
- No signals can be transmitted to this area (as it is blocked by the slope), thus no signals can be scattered back from these areas
- Appears as black area in the image



Geometric Effects in SAR images

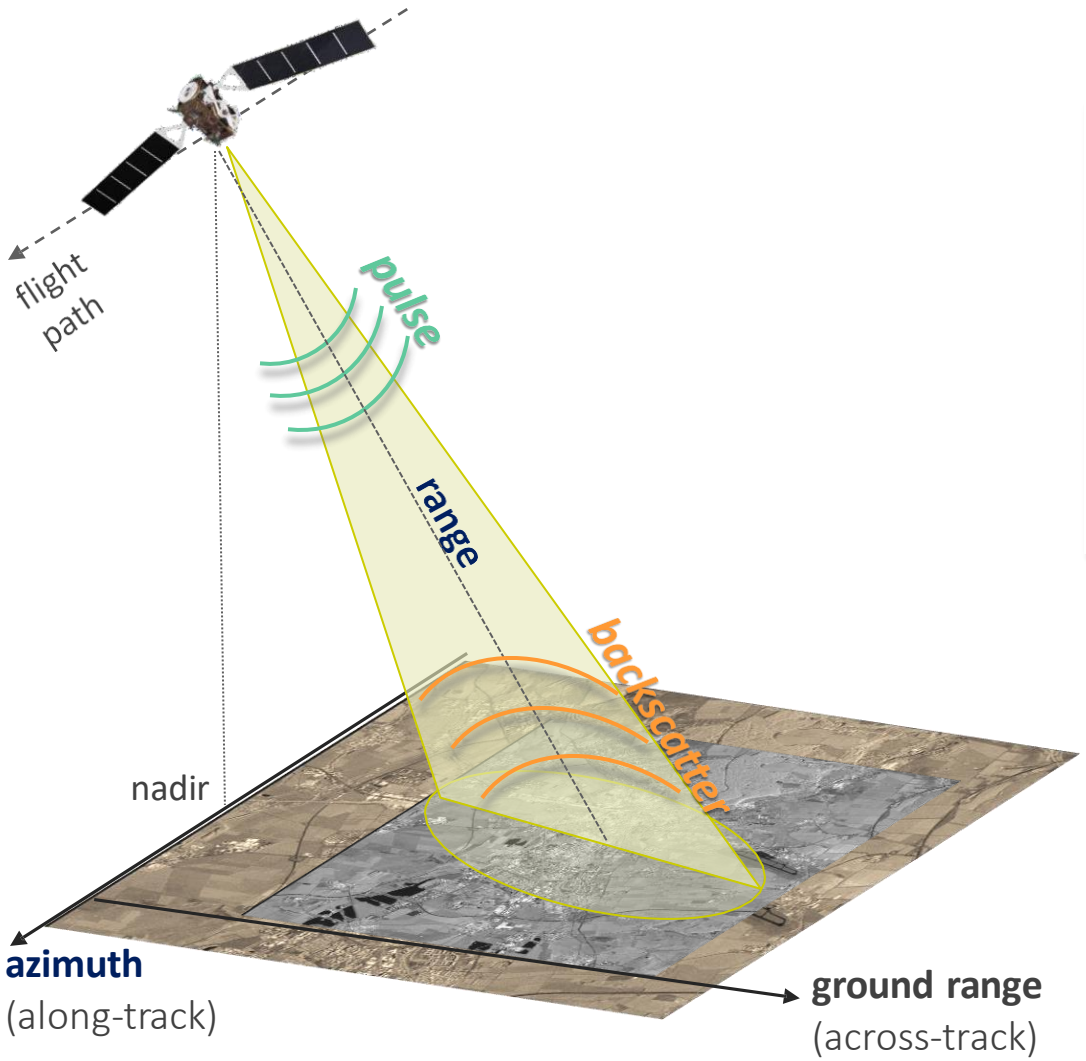
Effects of side-looking geometry

Google maps

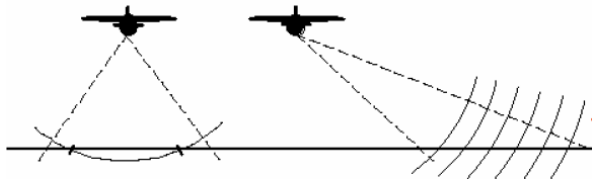


Andreas R. Brenner and Ludw ig Roessing, Radar Imaging of Urban Areas by Means of Very High-Resolution SAR and Interferometric SAR, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 46, NO. 10, OCTOBER 2008 (X-band)

Radar side looking imaging geometry



Is side looking really necessary?



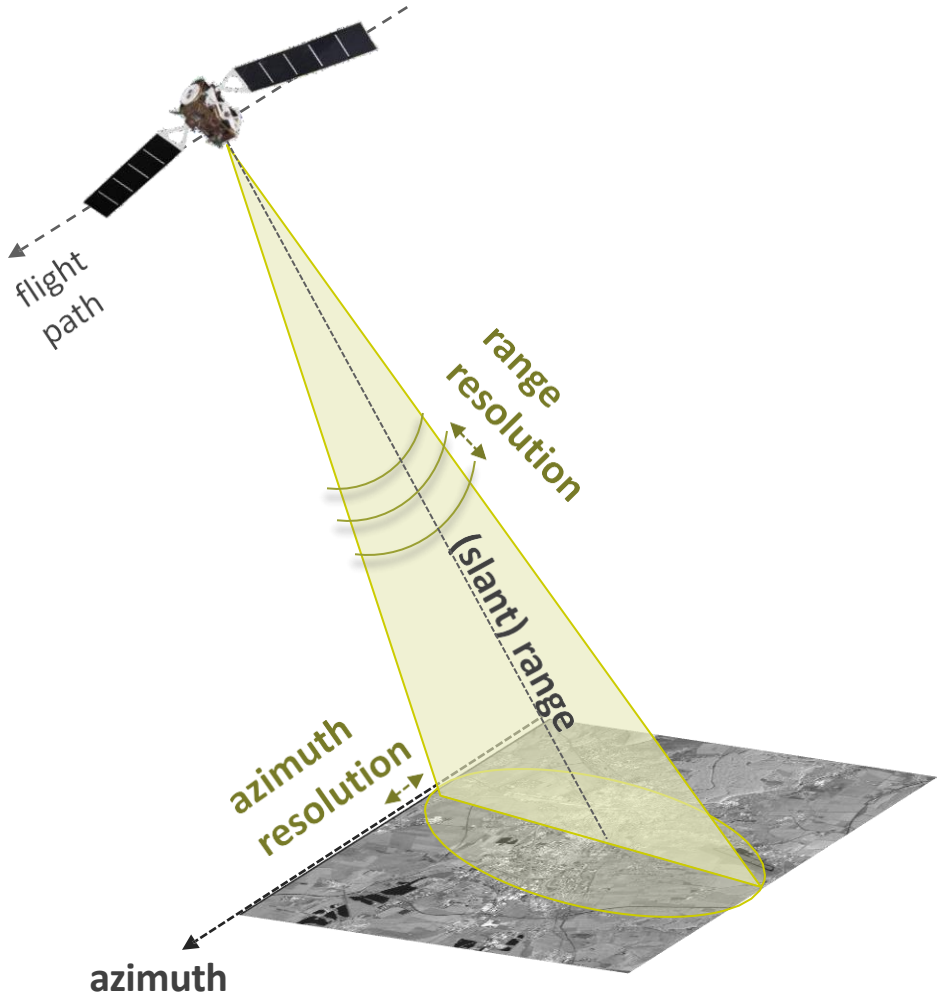
Nadir looking,
e.g. aerial photography

Side looking,
e.g. SLAR, SAR

range: scanning in the look direction at the speed of light

azimuth: scanning in flight direction at the speed of the sensor

Radar side looking imaging geometry



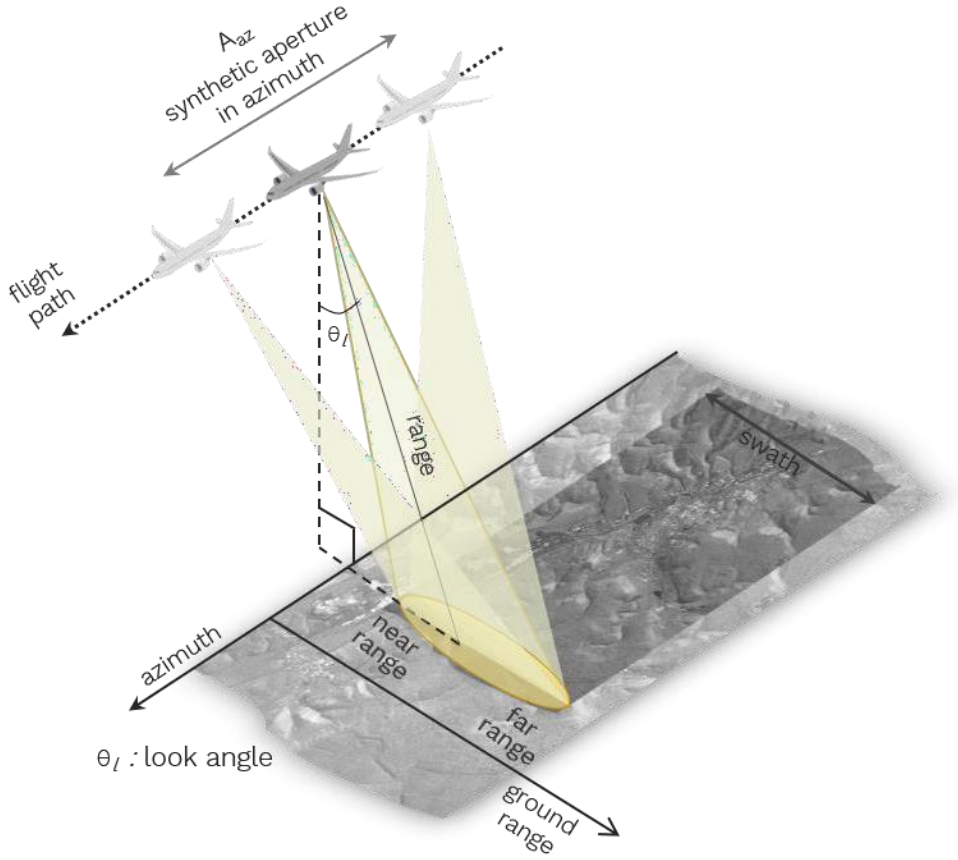
slant-range resolution depends on the **bandwidth of the system**

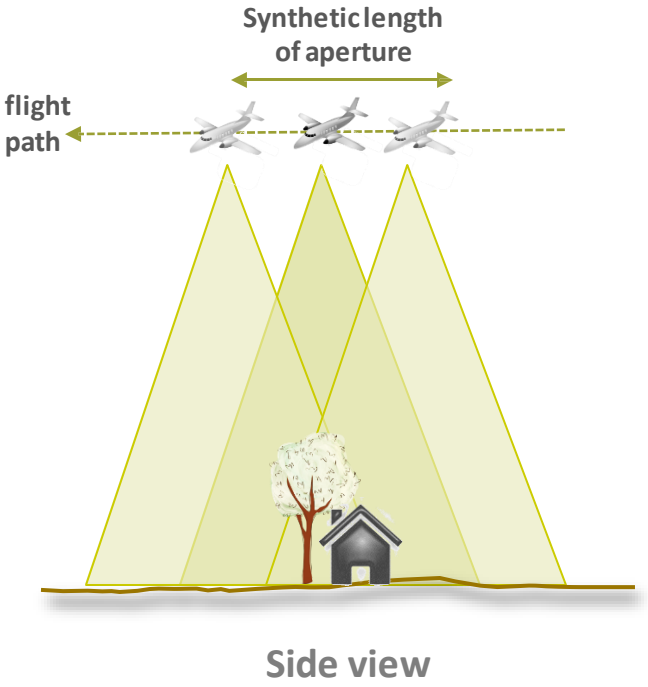
azimuth resolution is a function of the **antenna length** and **sensor height** over the Earth's surface

Synthetic Aperture Radar (SAR)

The principle of extending the antenna

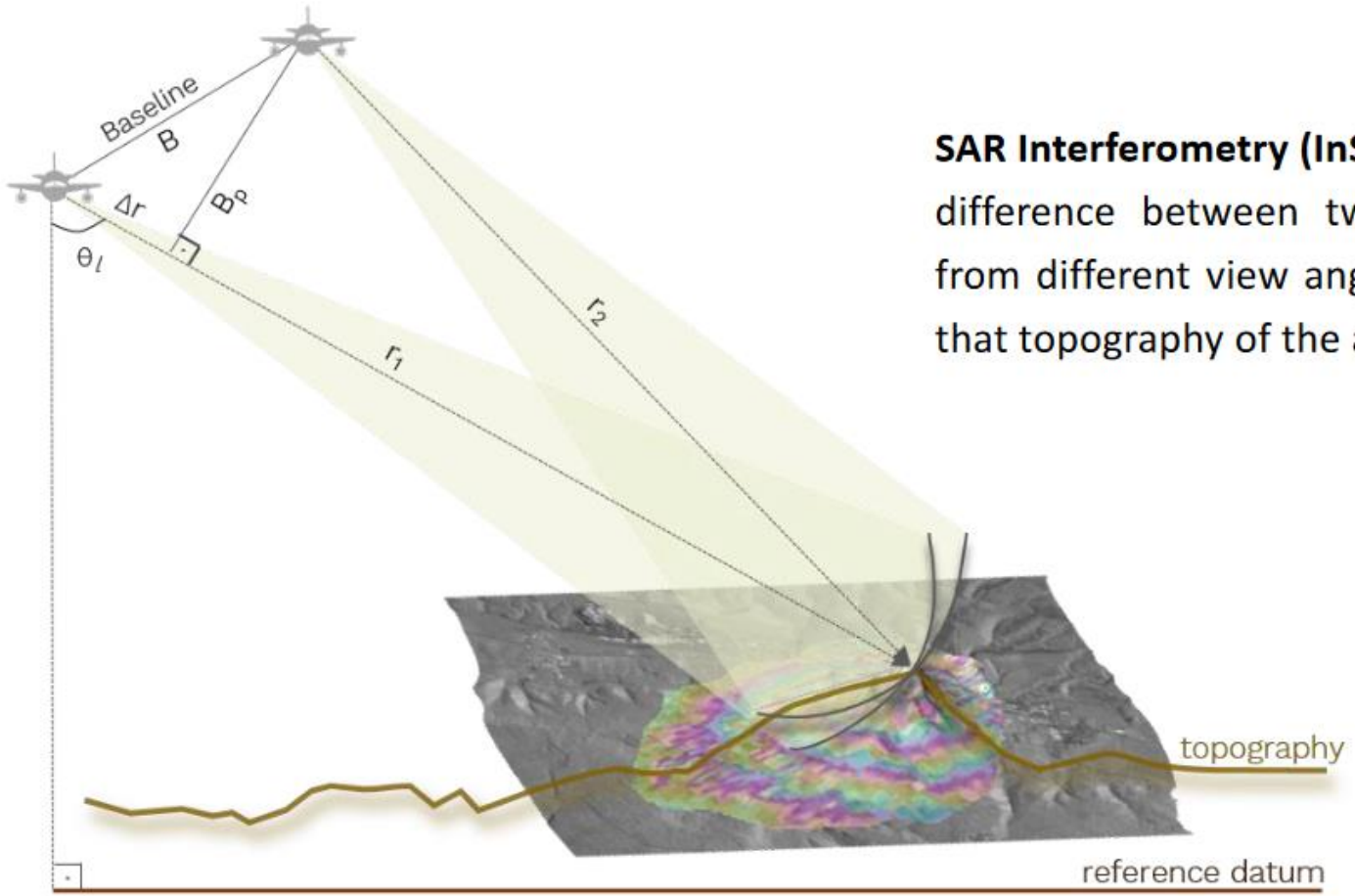
The key factor that is utilized in SAR is to synthesize a much longer antenna in azimuth direction by making use of the motion of the SAR sensor in order to achieve finer resolution.





Synthetic Aperture Radar (SAR)

Determining elevation



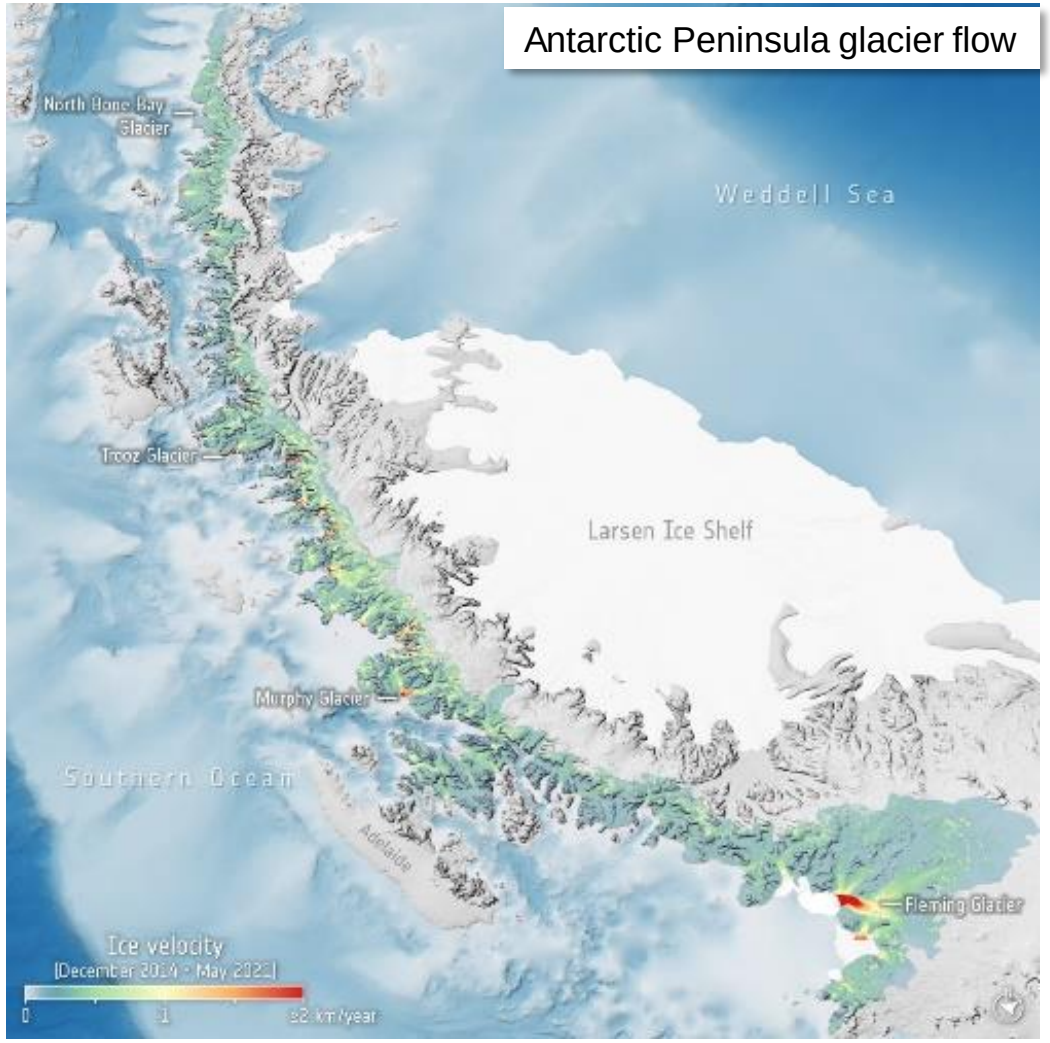
SAR Interferometry (InSAR) makes use of the phase difference between two complex valued images from different view angle, i.e. forming baseline, so that topography of the area can be imaged.

B : baseline
B_p : perpendicular baseline
θ_l : look angle

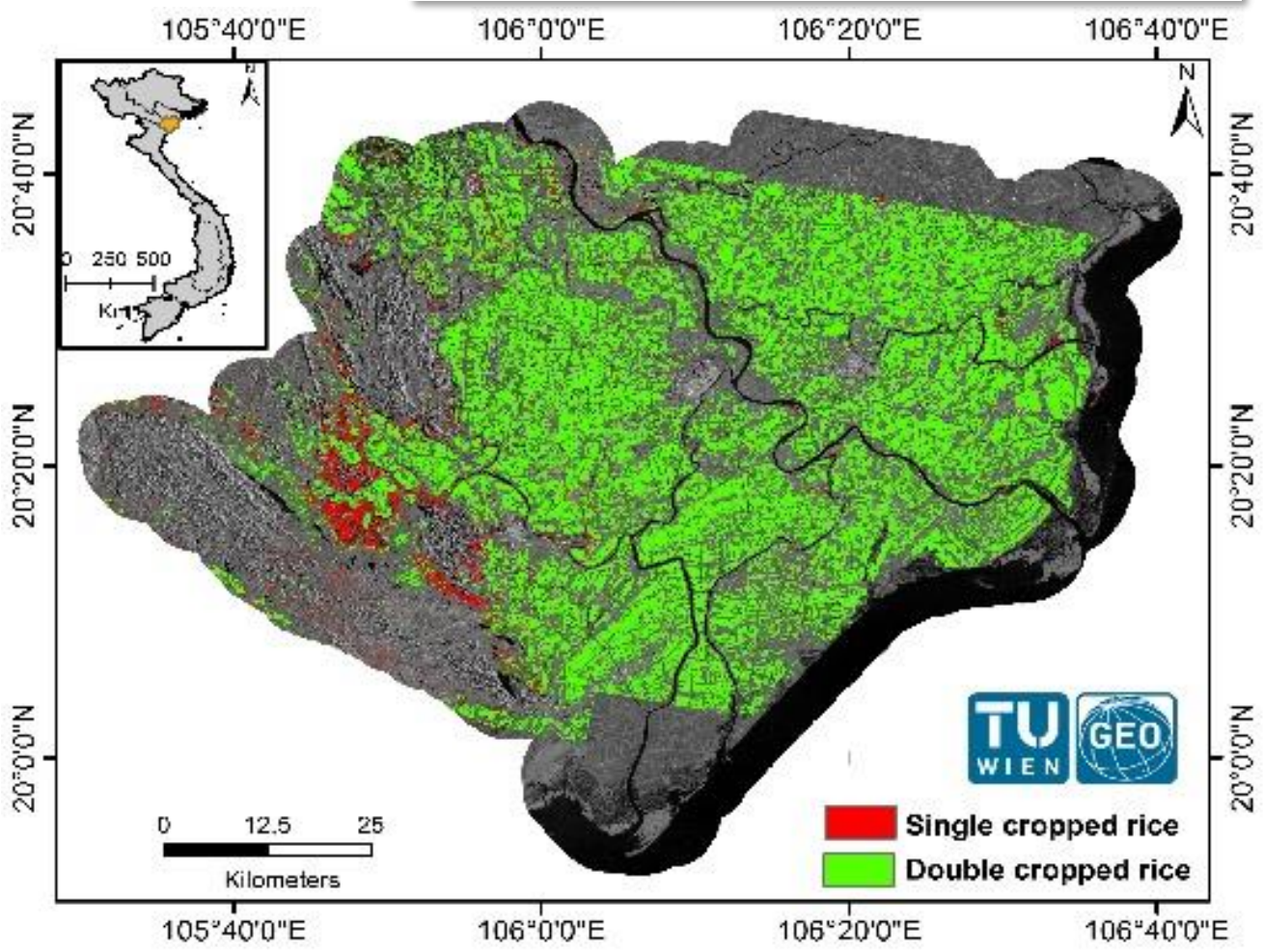
r_1 & r_2: range distance for the respective acquisitions
Δr : range difference

Sentinel-1 – Applications

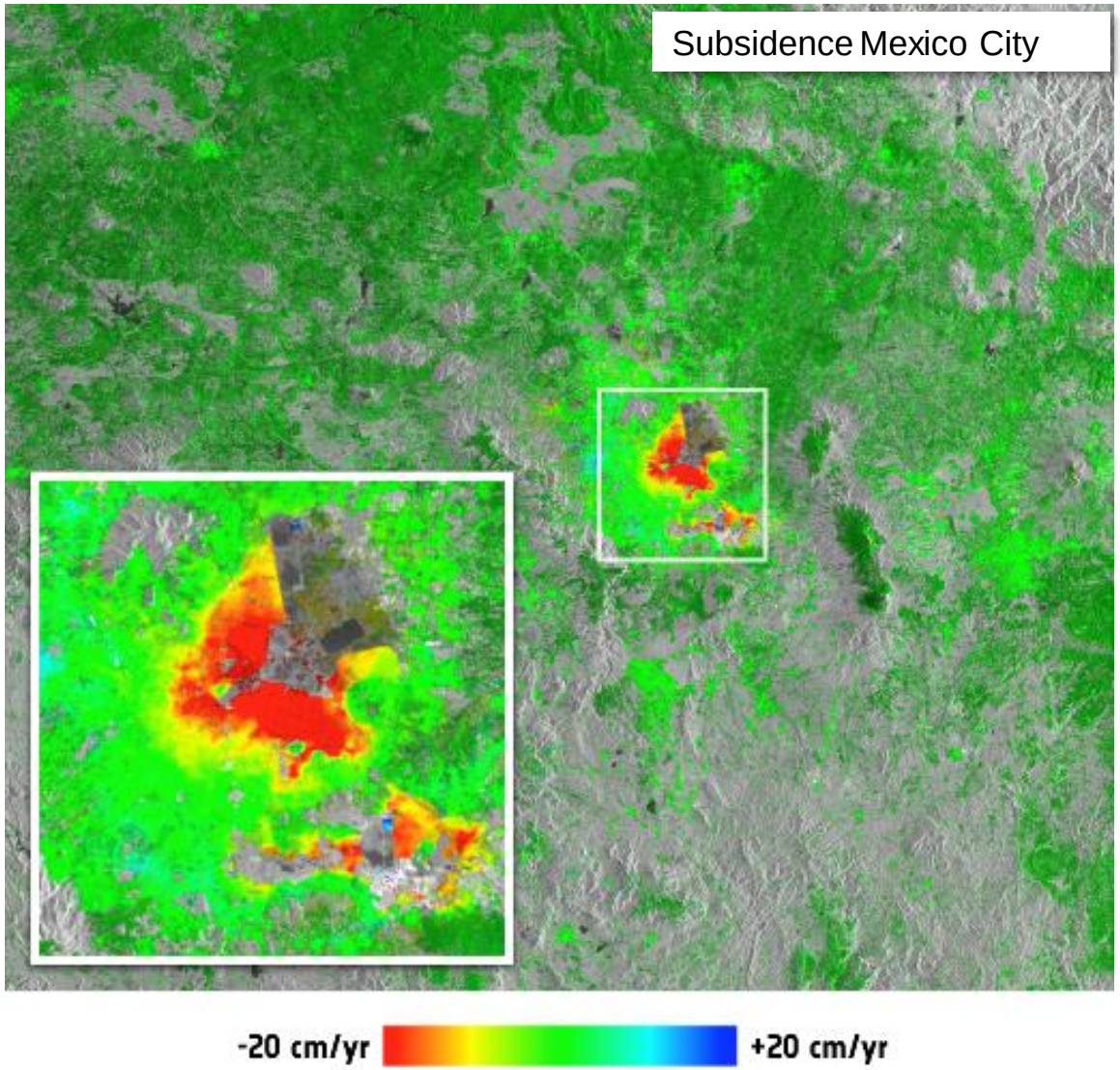
Antarctic Peninsula glacier flow

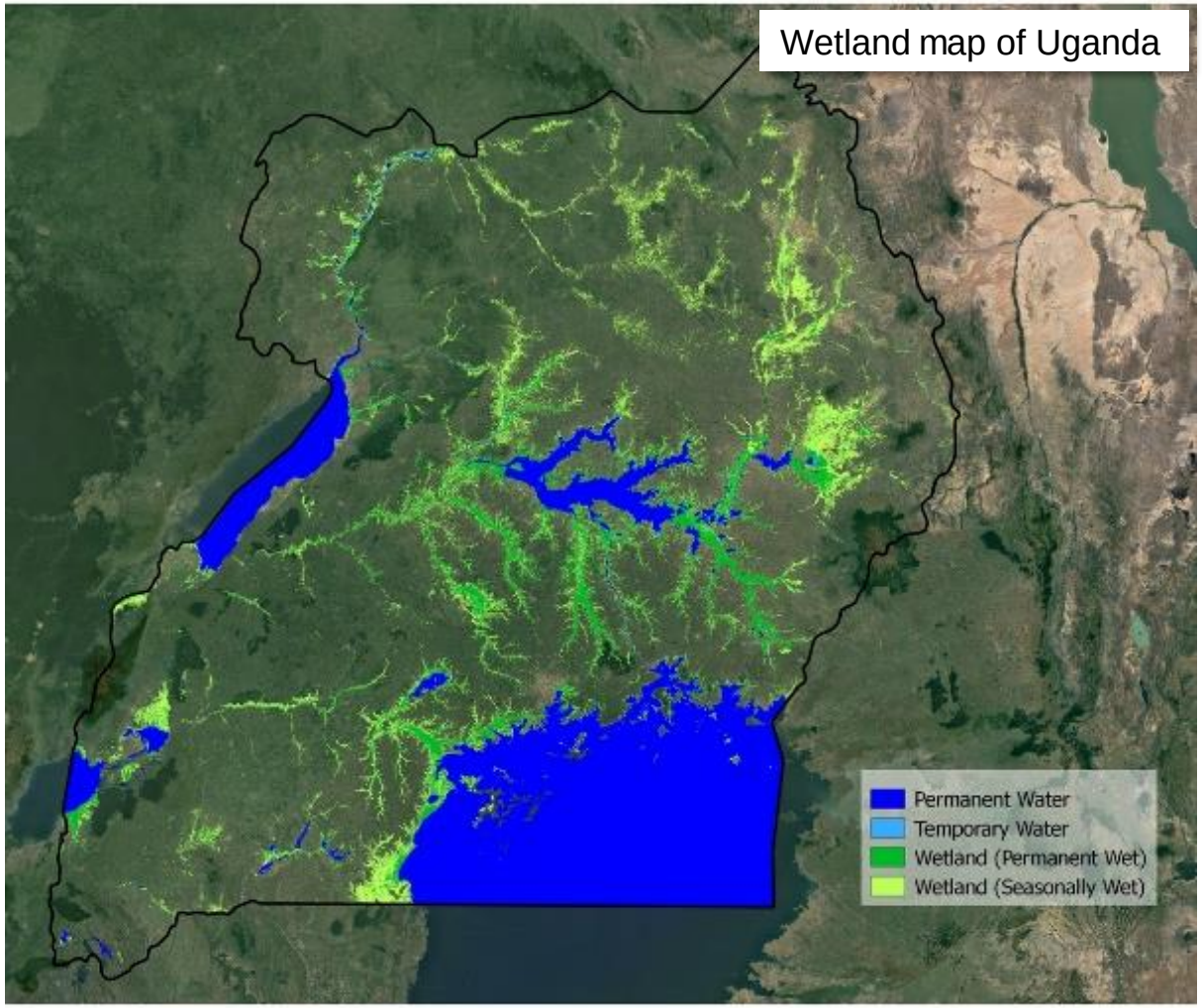


Rice-cropping systems in Vietnam's Red River Delta

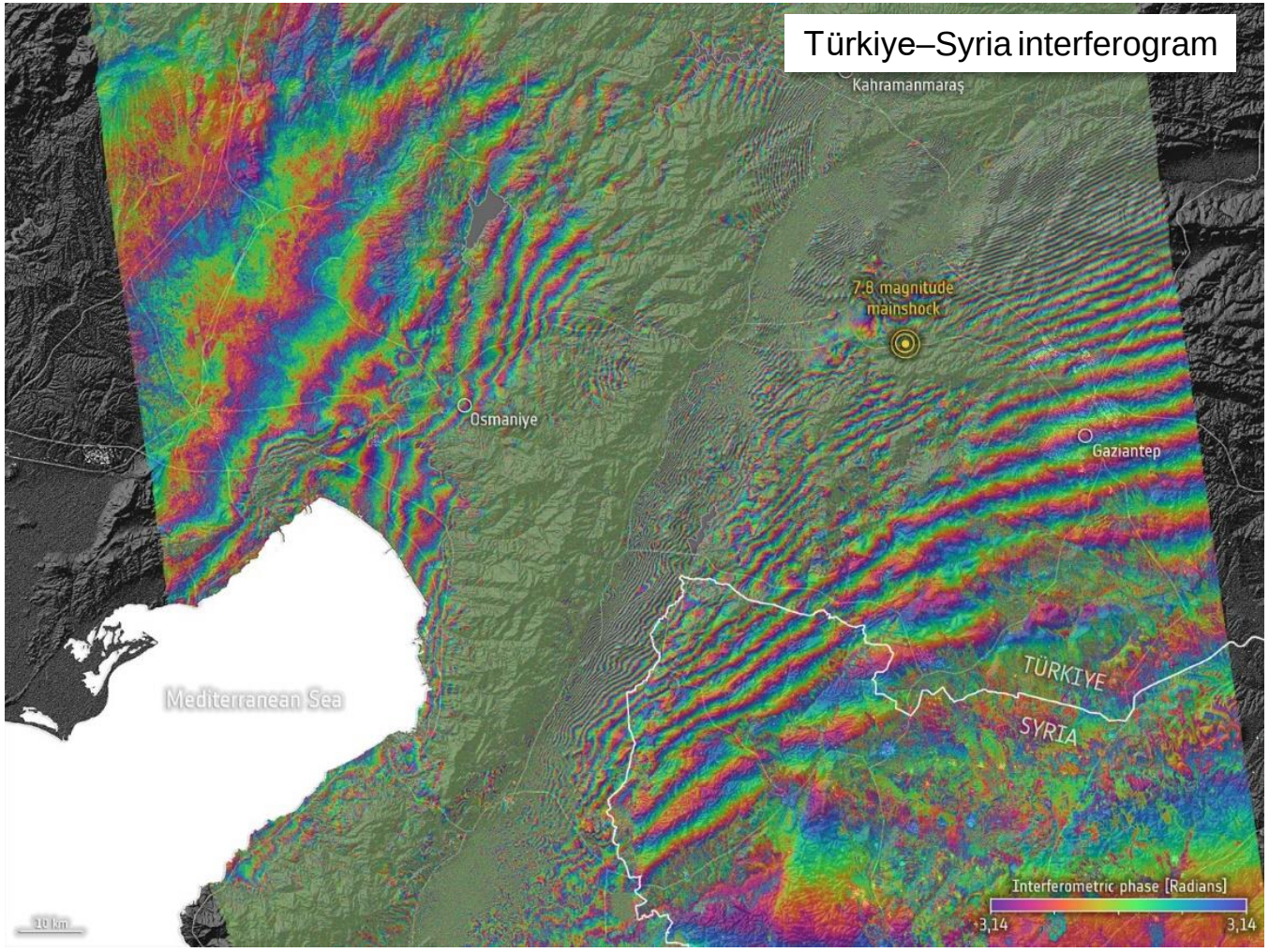


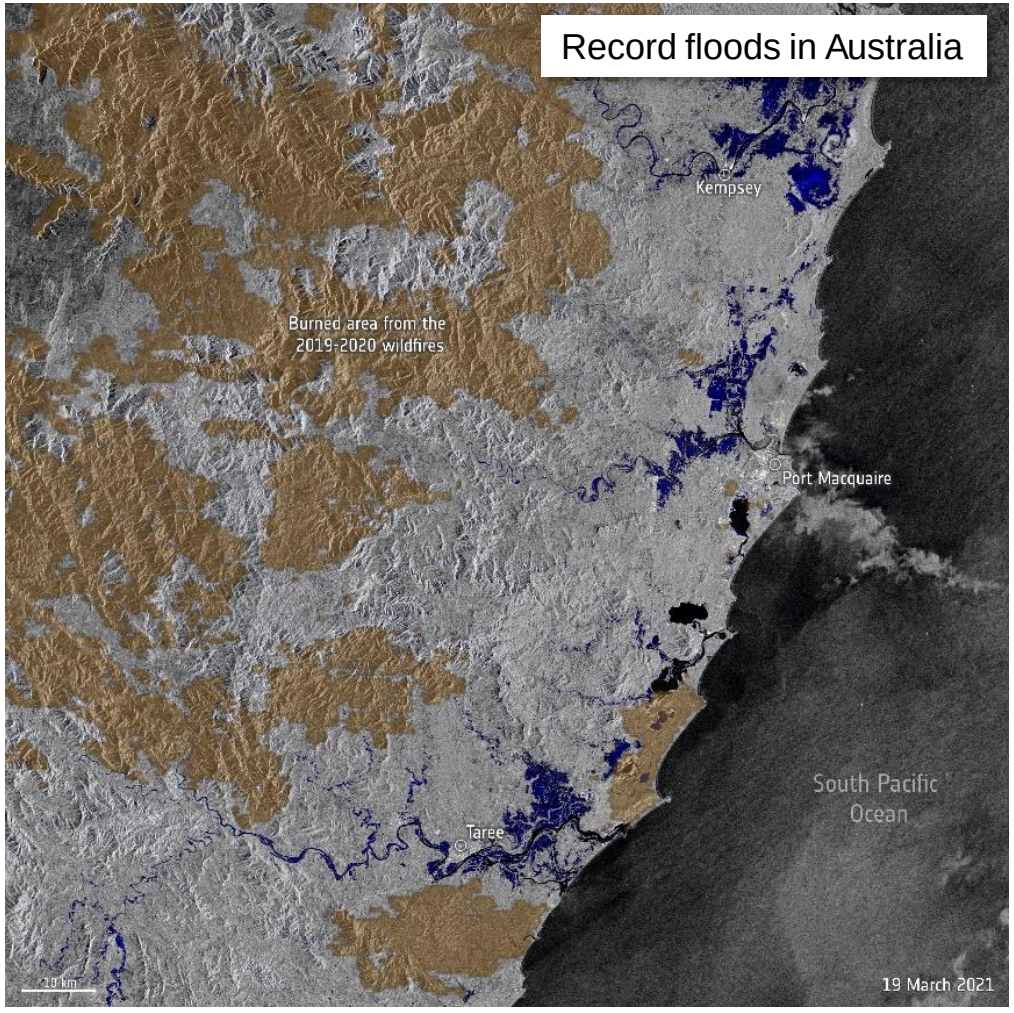
Sentinel-1 – Applications





Sentinel-1 – Applications





ESA EO Data Access and resources

ESA Earth Observation Data Policy

- To stimulate a balanced development of Science, Public Utility and Commercial Applications
- To maximize the use of data from ESA EO satellites

ERS and Envisat

Earth Explorers

- *Free datasets*

  (Free of charge; User registration and acceptance of ESA Terms & Conditions are required → Open access)

- *Restrained datasets*

  (Free of charge; User registration, submission of a "Project (Full) Proposal" and acceptance of the ESA Terms & Conditions are required, after its evaluation a quota will be assigned)

ESA Third Party Missions

- Data Policy of individual data providers

  In some case, a reproduction cost (e.g. ALOS) or Specific Restrictions (limitations of quota, geographical restrictions, etc.) to the use of data may be applied for TPM

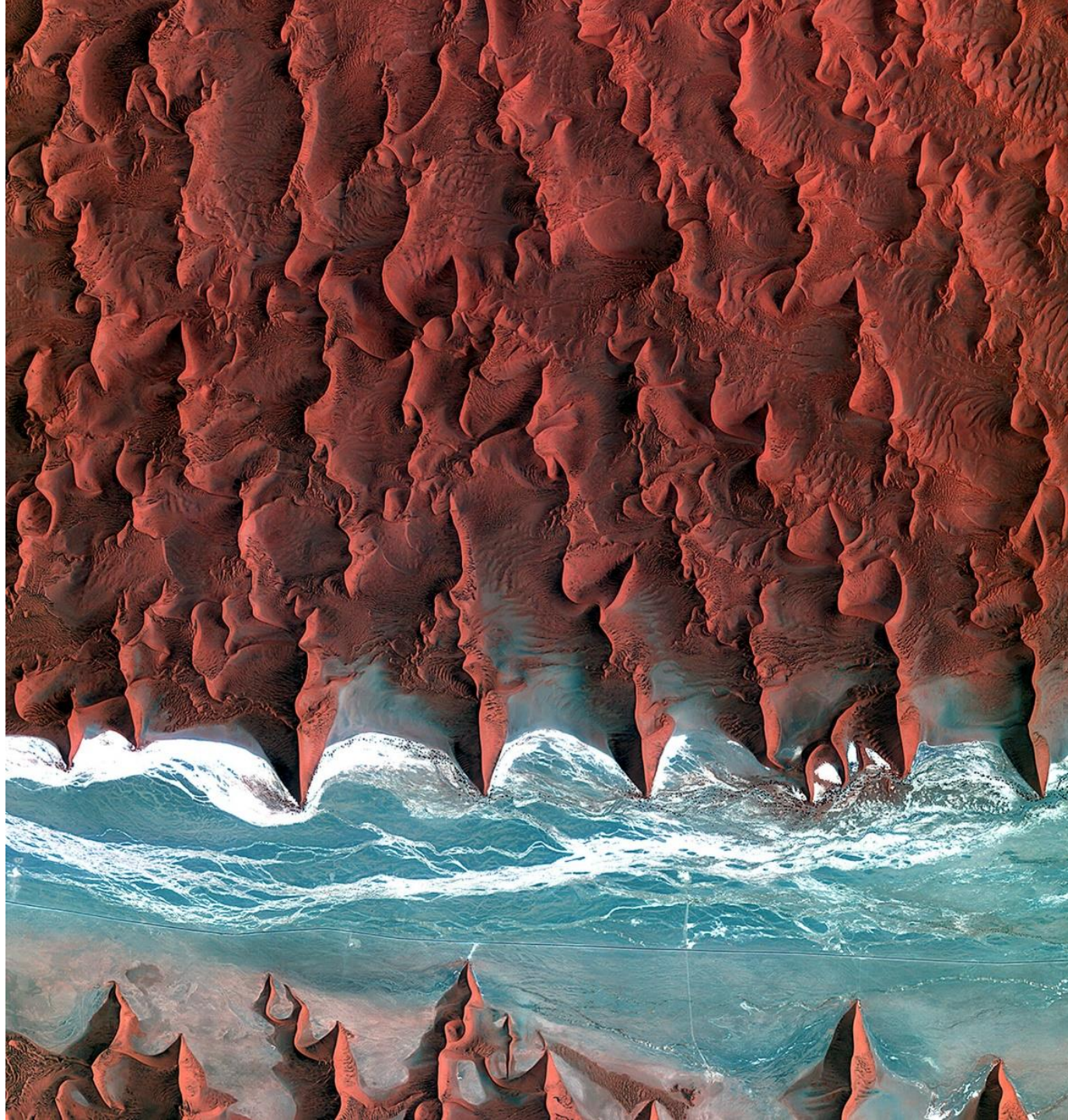
Source: https://www.esa.int/Applications/Observing_the_Earth/Envisat/ESA_declares_end_of_mission_for_Envisat, https://earth.esa.int/eogateway/news/esa-s-excellent-earth-explorer-missions-extended-to-2025/esa-s-ice-mission , https://www.esa.int/ESA_Multimedia/Images/2012/12/Pleiades#.XoNYGqecnA8.link

EO data access

Free open source platforms

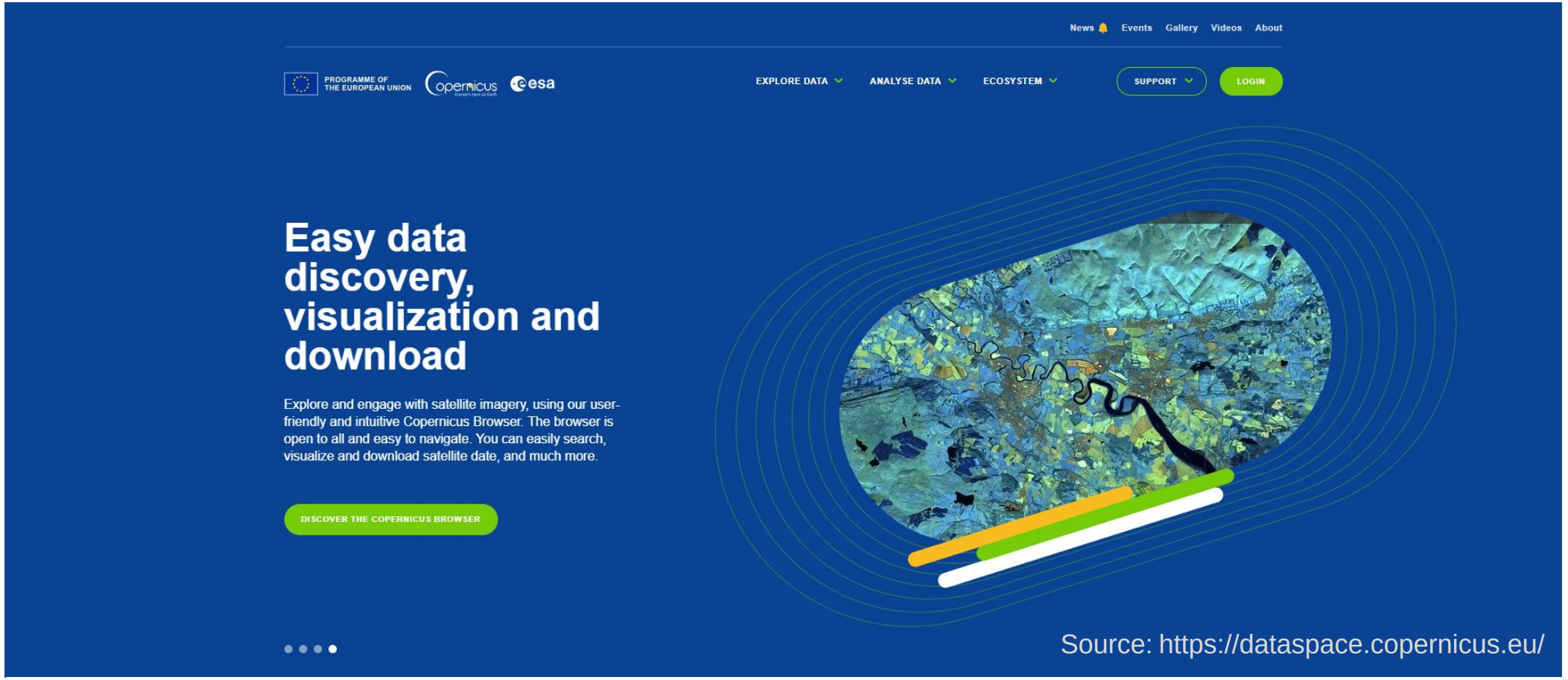
- **Copernicus Open Access Hub**
- Earth System Lab
- ESA Thematic Exploitation Platforms
- Alaska Satellite Facility
- Copernicus Global Land Service
- **Copernicus Data Space Ecosystem**
- **Sentinel Data Access Service**
- USGS Earth Explorer
- Sentinel Application Platform software
- Open Data Cube

Source https://business.esa.int/sites/business/files/Guide%20-%20Where%20to%20access%20EO%20data.pdf, https://www.esa.int/ESA_Multimedia/Images/2013/04/Namib_Desert:



Copernicus Data Space Ecosystem

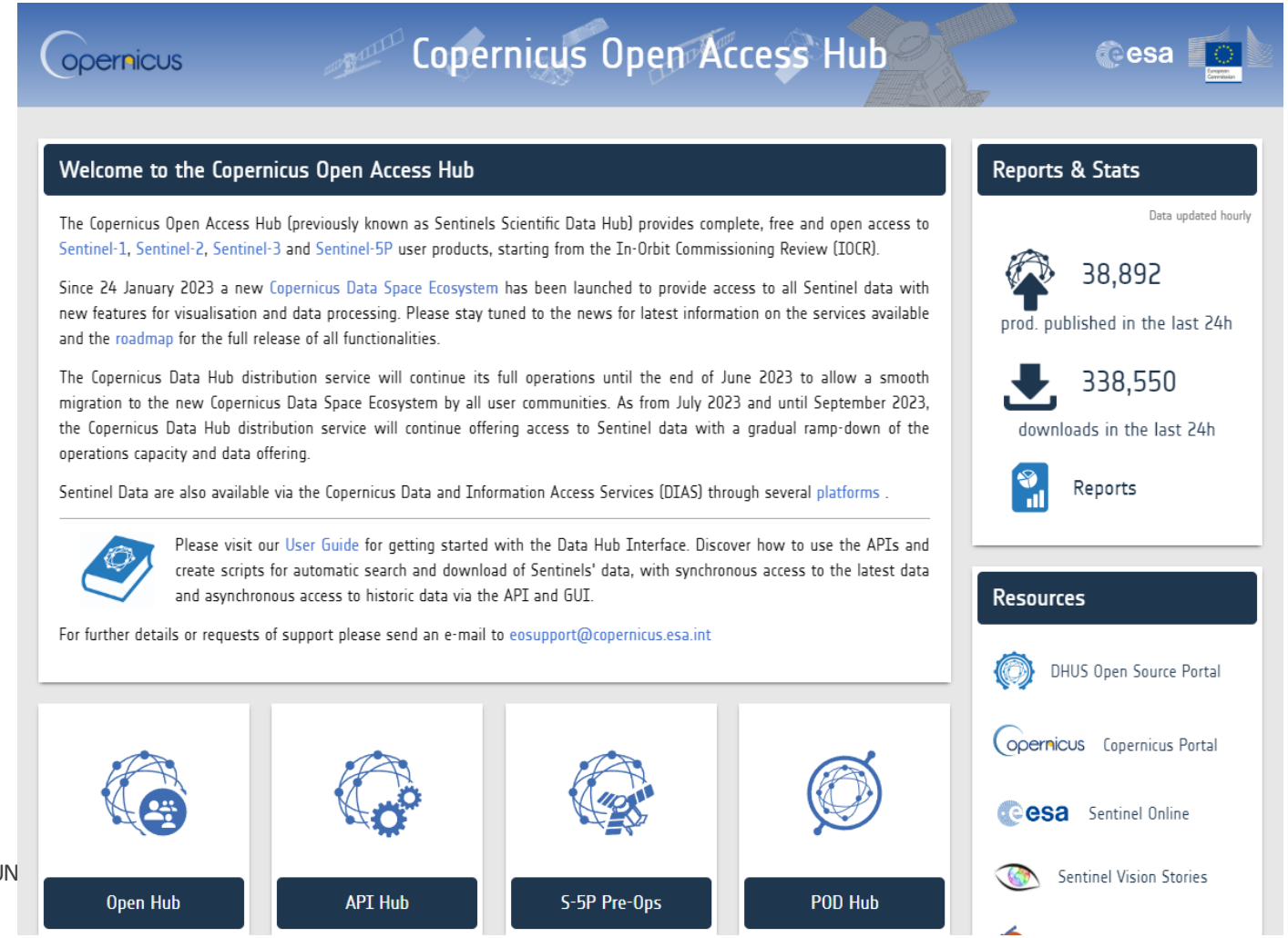
https://dataspace.copernicus.eu/



- Since 24 January 2023 a new Copernicus Data Space Ecosystem has been launched to provide free and open access to EO data from all Sentinel satellites with new features for visualisation and data processing.

Copernicus Open Access Hub

https://scihub.copernicus.eu/

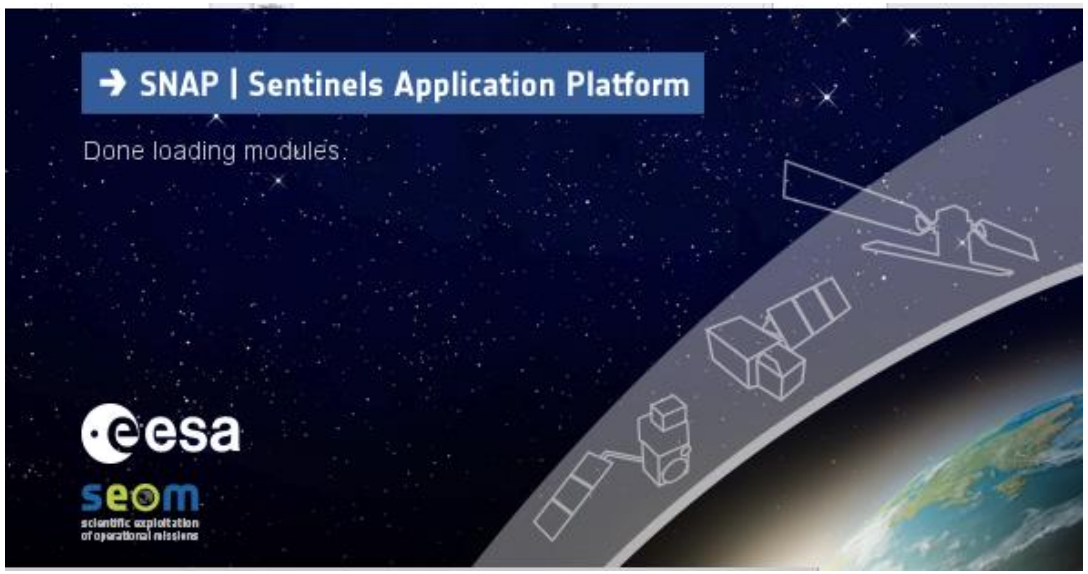


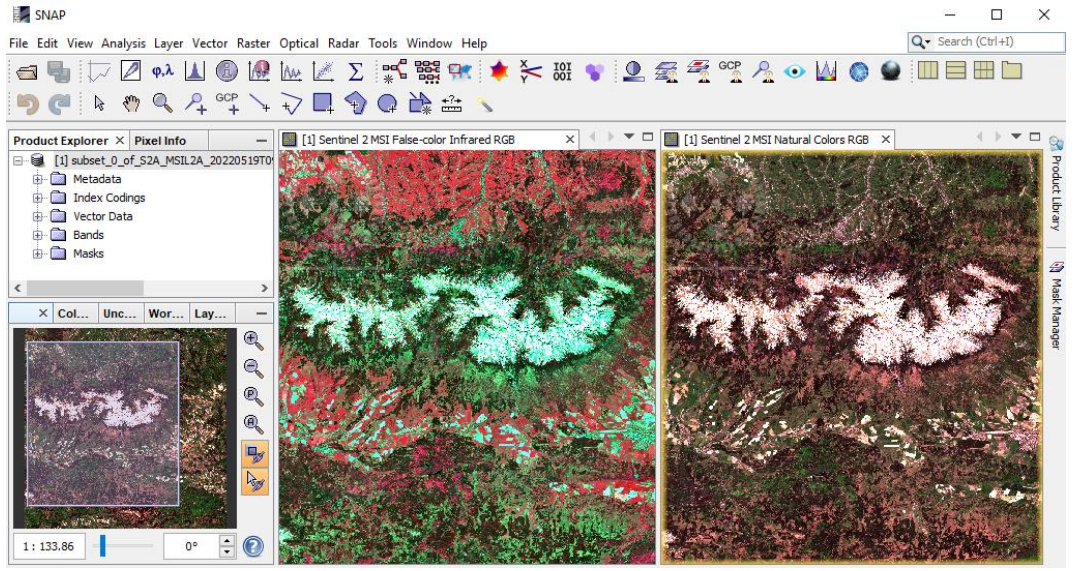
- The previous Copernicus Open Access Hub provided complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products

Source: https://scihub.copernicus.eu

SNAP (Sentinel Application Platform) software

http://step.esa.int/main/download/snap-download/





- ESA Sentinel Application Platform (SNAP) is a software toolkit developed by the ESA for processing and analyzing Earth observation data, particularly data from the Sentinel satellites. SNAP is part of the Sentinel Toolbox and is freely available to the public. It provides a user-friendly interface and a comprehensive set of tools also for working with a variety of other remote sensing data.

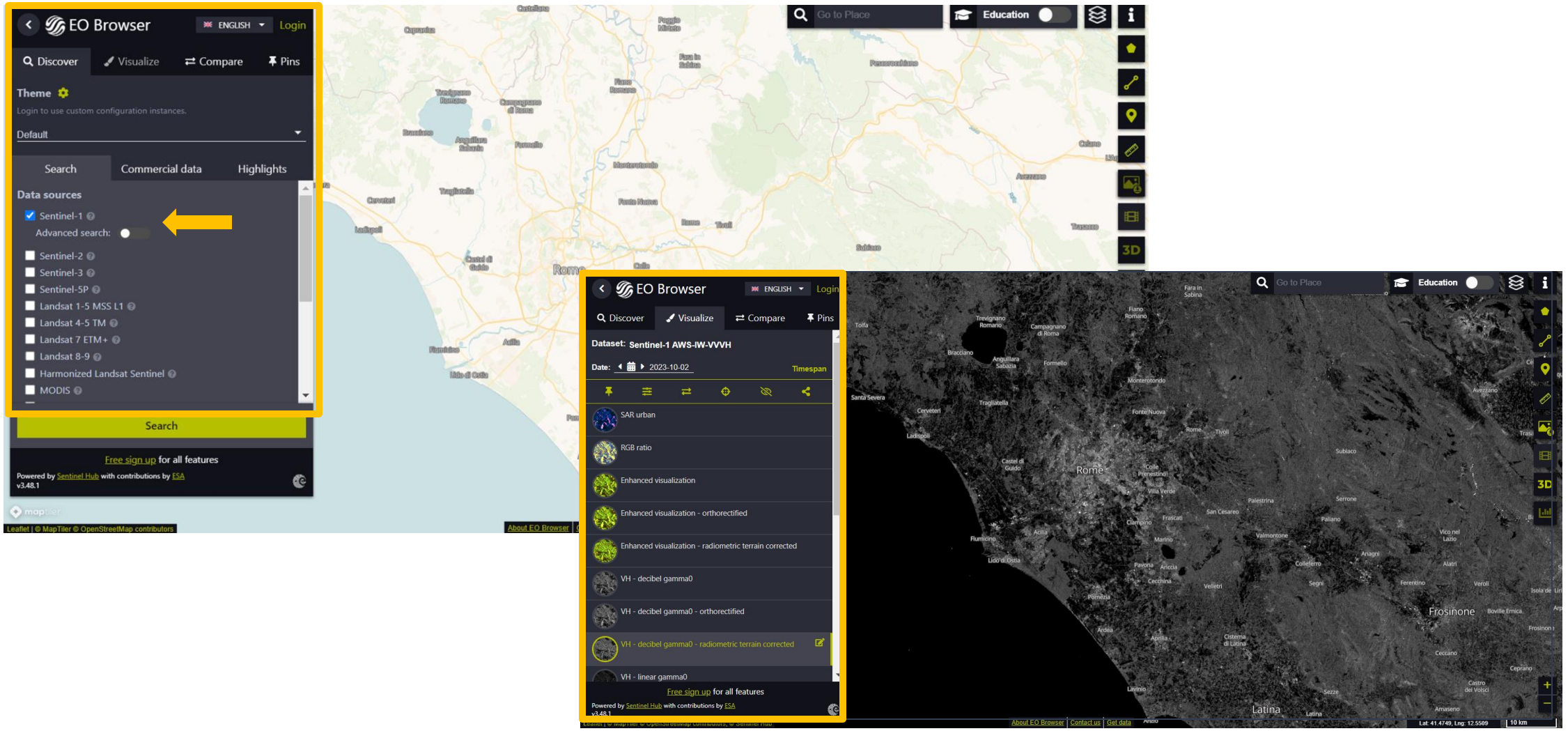
EO data access

Partially open-source EO platforms

- **EO Browser Sentinel Hub**
- DIAS - Copernicus Data & Information Access Services
- Google Earth Engine
- Earth on AWS

EO Browser - SENTINEL Hub

https://apps.sentinel-hub.com/eo-browser/

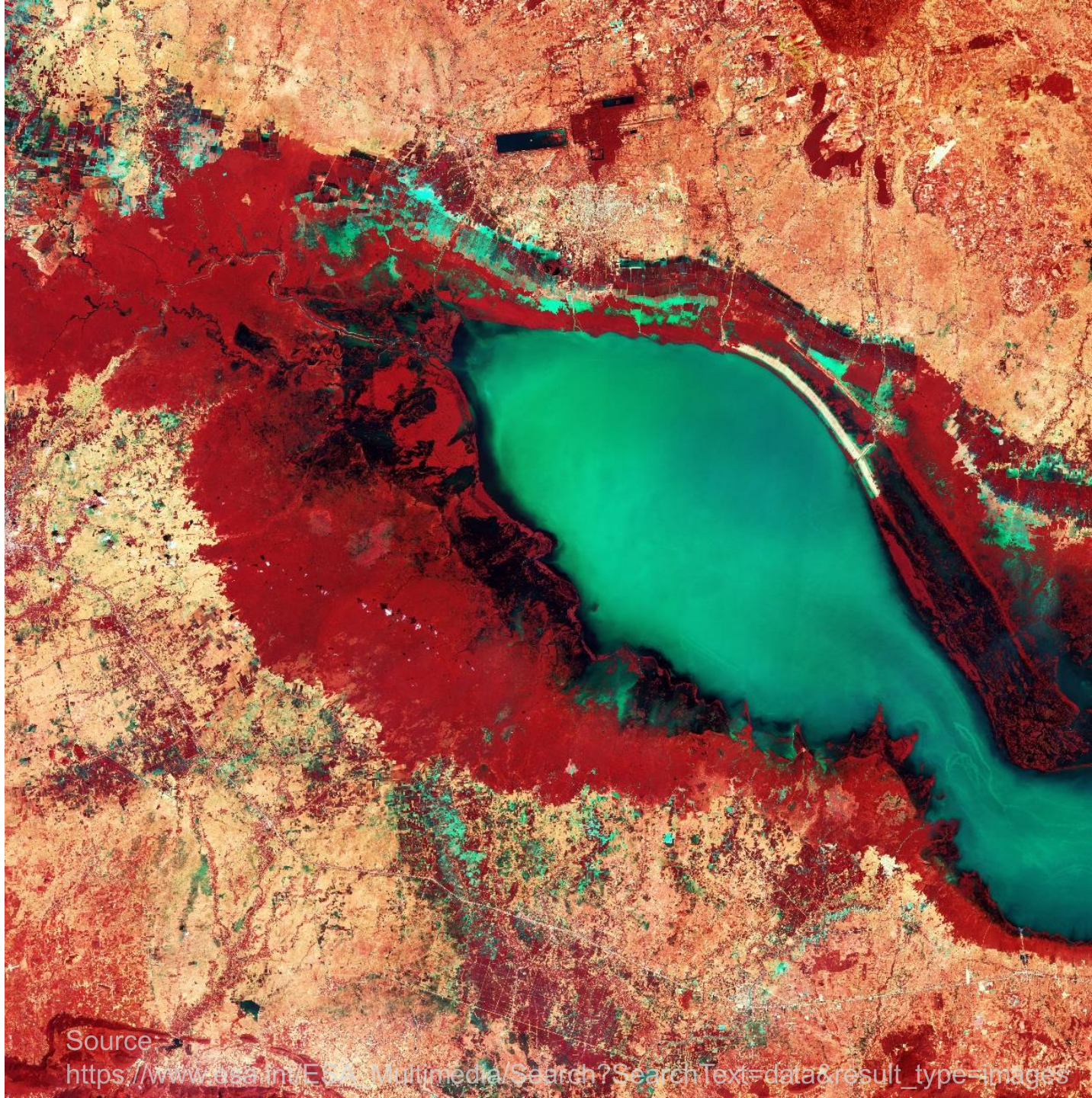


Source: https://apps.sentinel-hub.com/eo-browser

EO data access

Commercial EO platforms

- DigitalGlobe / Maxar
- OneAtlas
- Planet platform
- e-Geos
- Decartes Labs



esa space solutions

Copernicus Academy

ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach

Thank you for the attention