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.**"

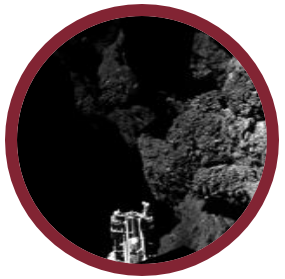
*Article 2 of the ESA Convention*


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

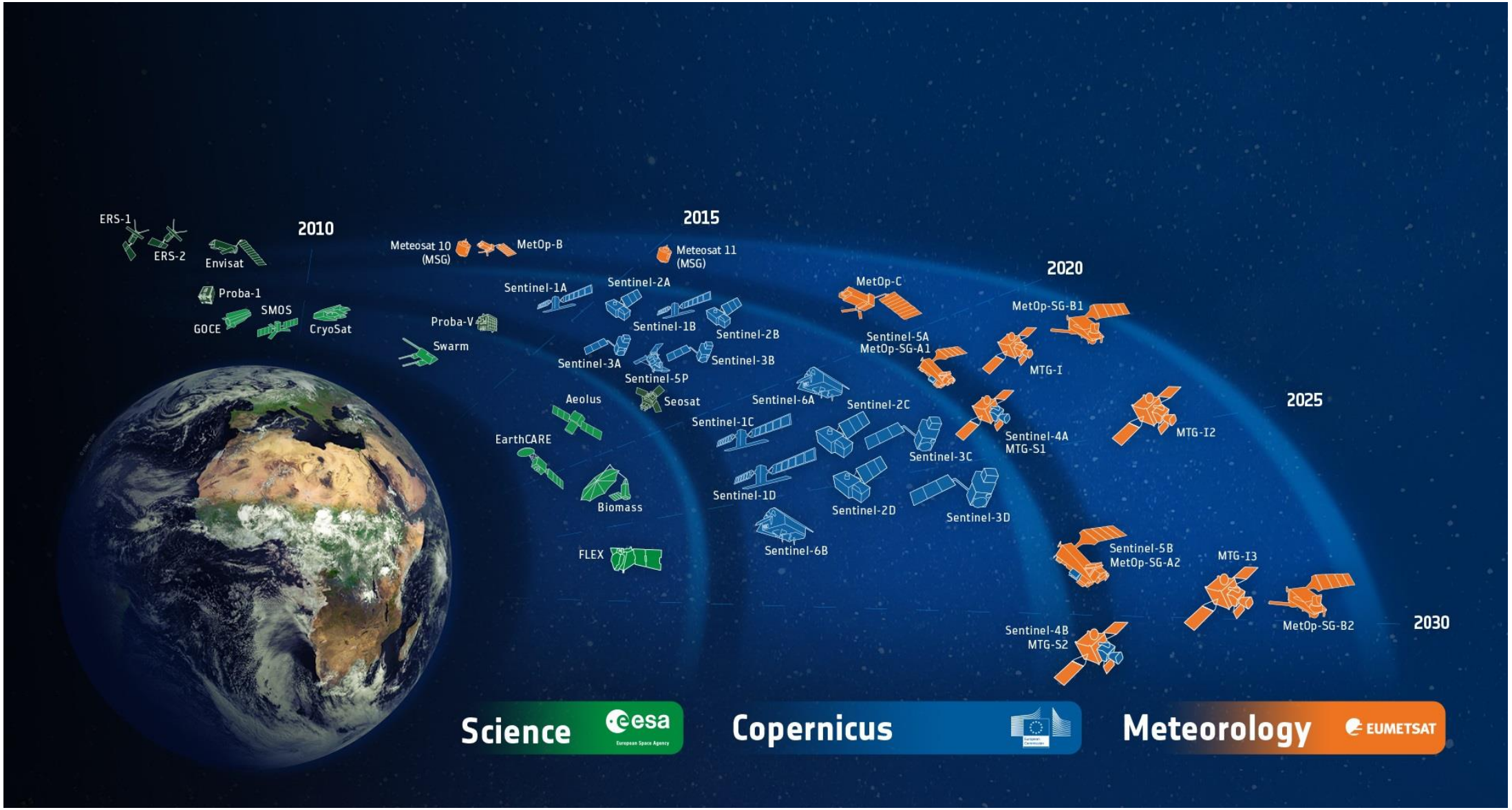

operations


technology


telecommunications

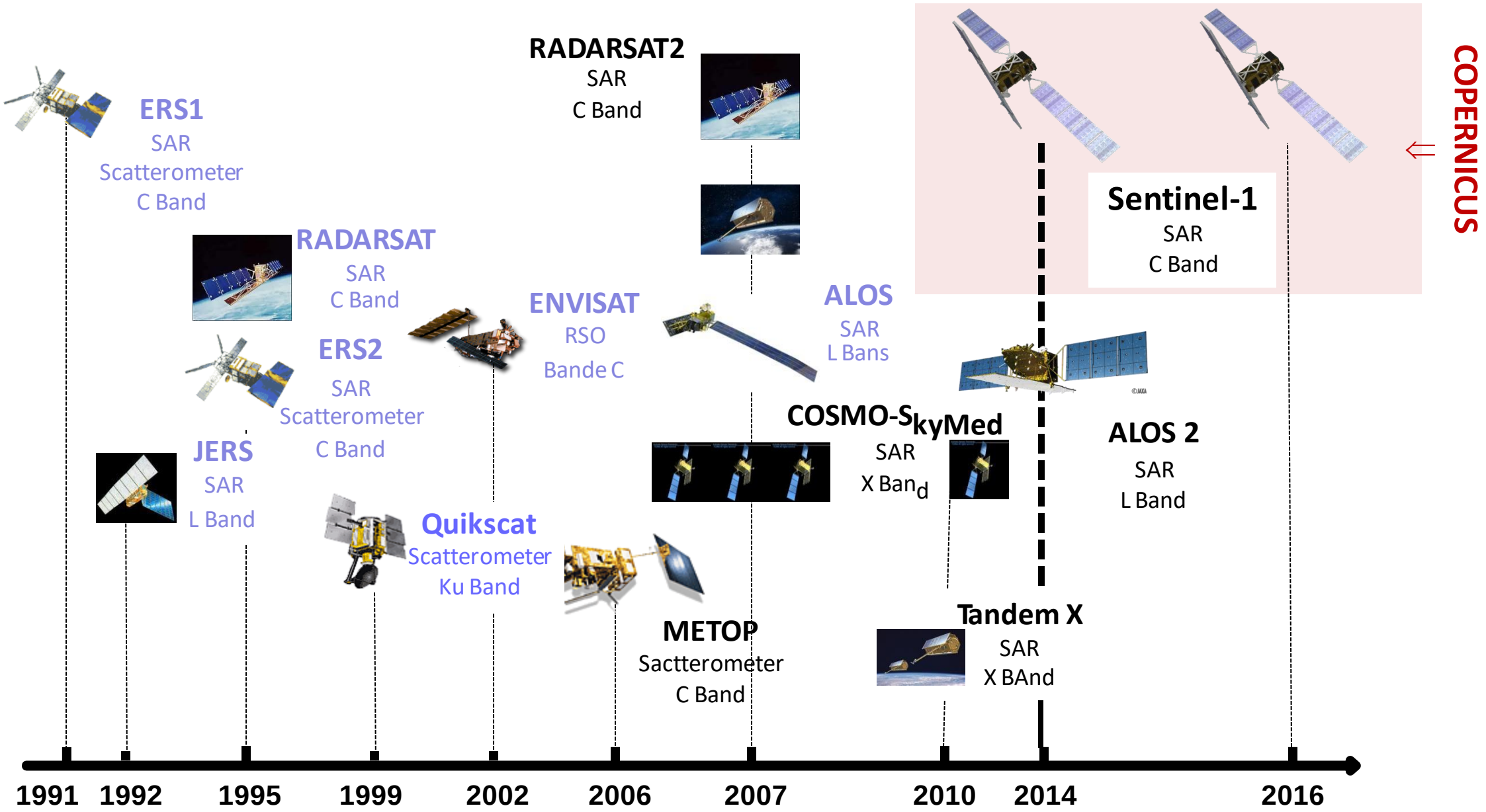
Source: https://esamultimedia.esa.int/docs/corporate/ESA_Corporate_Presentation_Fr.pdf

# 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- |

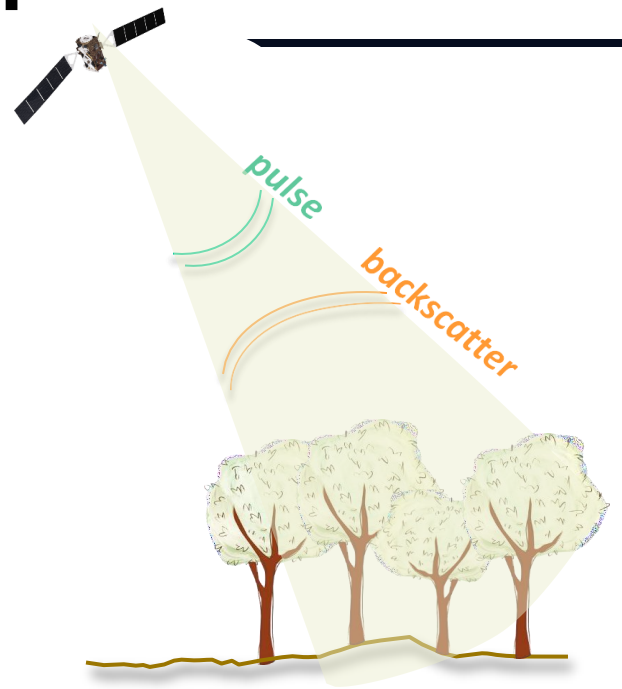
# Sentinel-1 – Radar vision

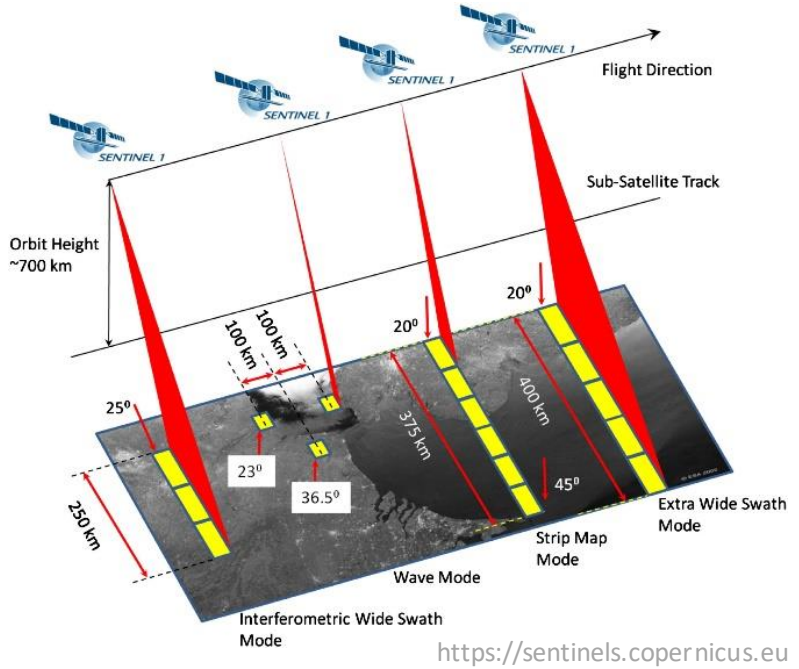
## Mission objectives:

- Marime and land monitoring
- Emergency management

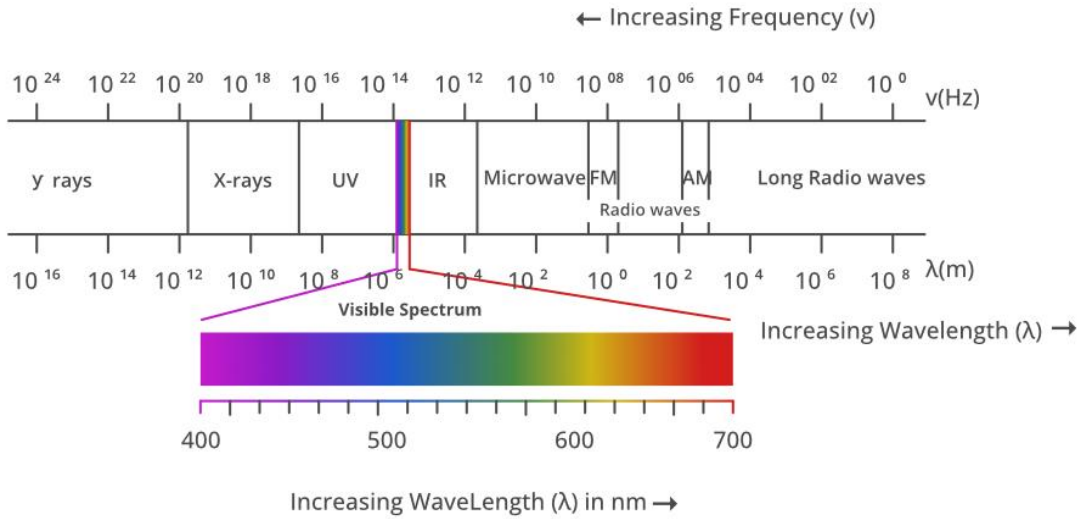
## Mission profile:

- 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



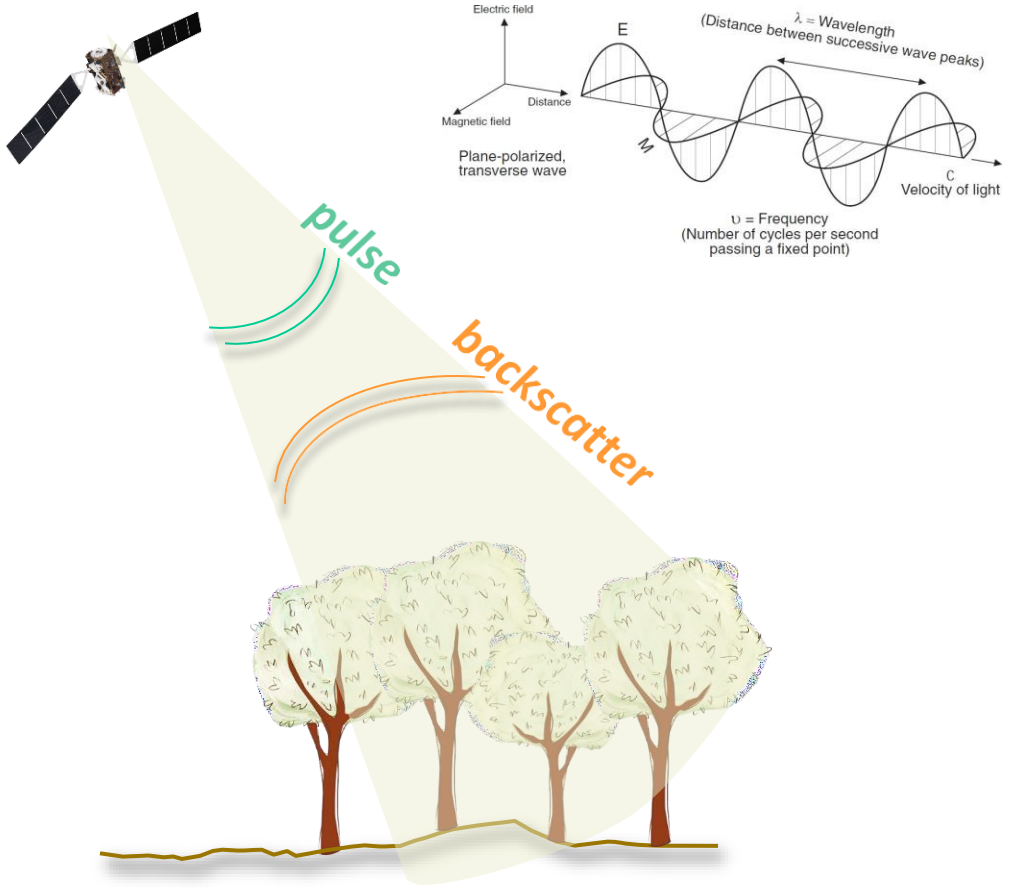

https://sentinels.copernicus.eu



# Active Radar Remote Sensing

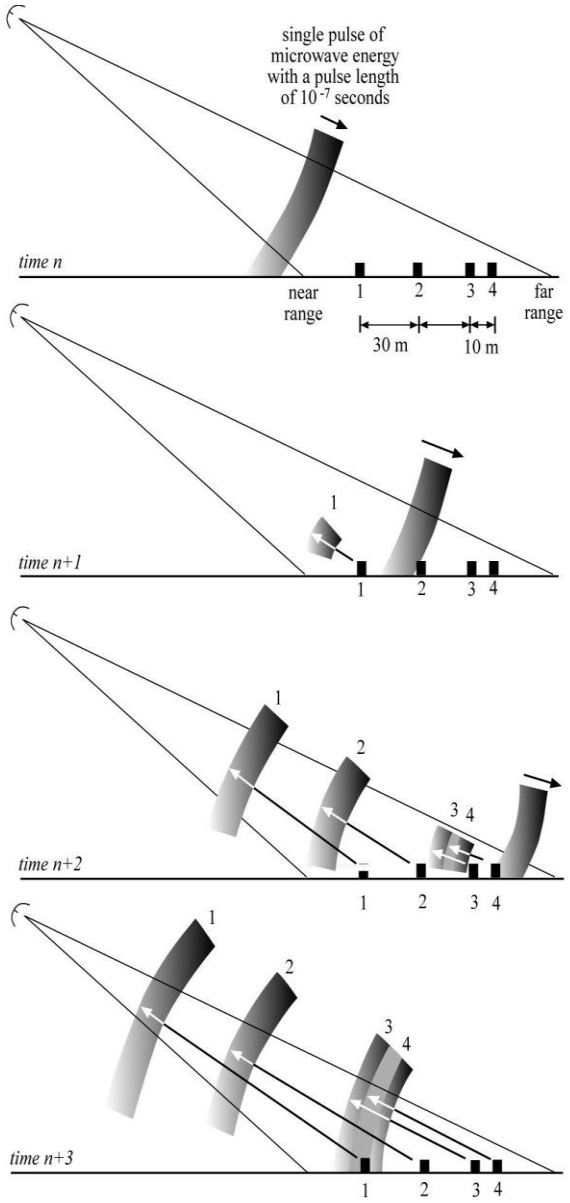
***Basic characteristics of radar systems/SAR sensors***

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










## Radar principle

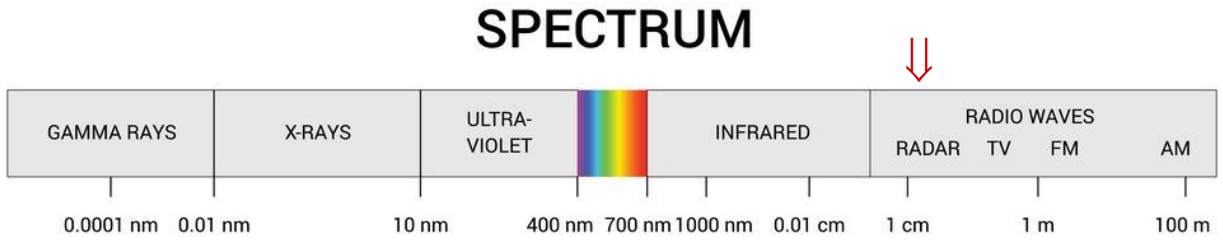
EMG transmitted in bursts of energy - pulses (approx. every 0.000 000 1 s)

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

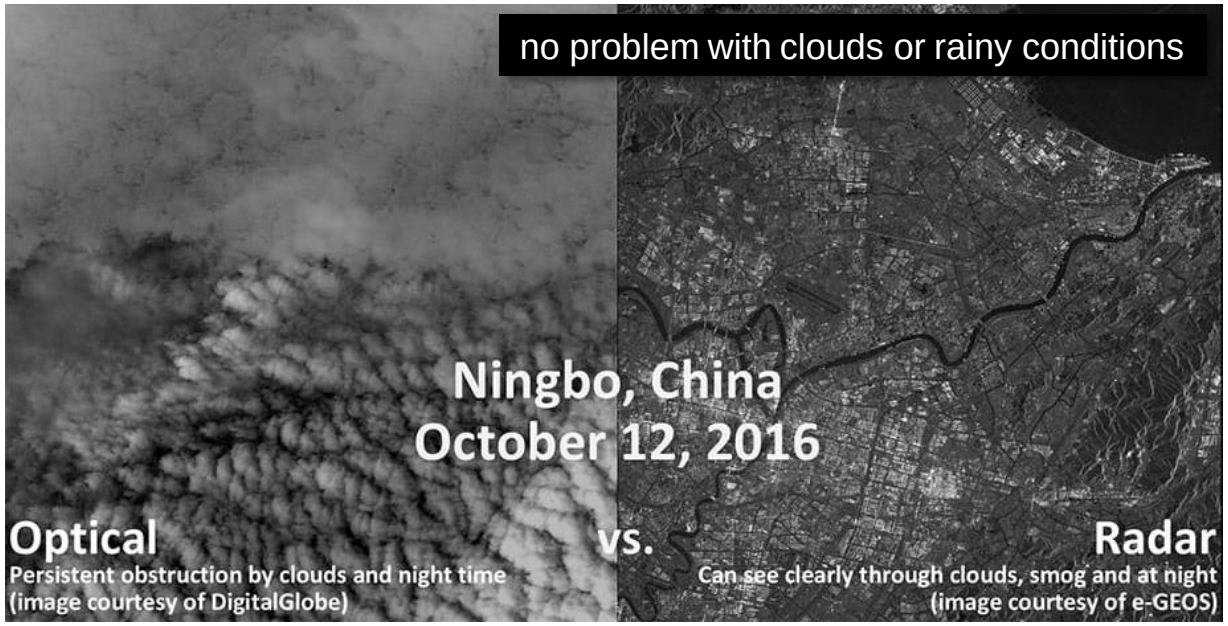
The intensity of the reflected energy and the time it takes for a given pulse to return are recorded

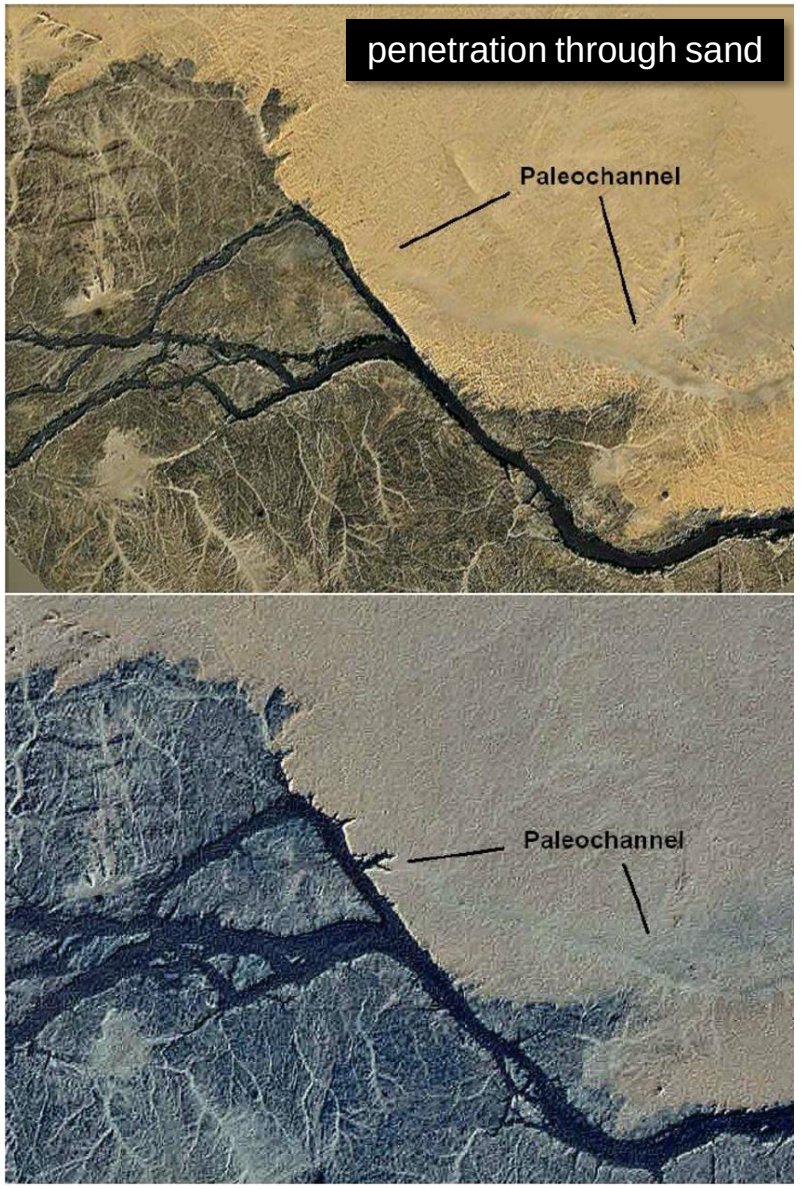
# Active Radar Remote Sensing

***Basic characteristics of radar systems/SAR sensors***




**Microwave ⇒ penetrates into/through objects**

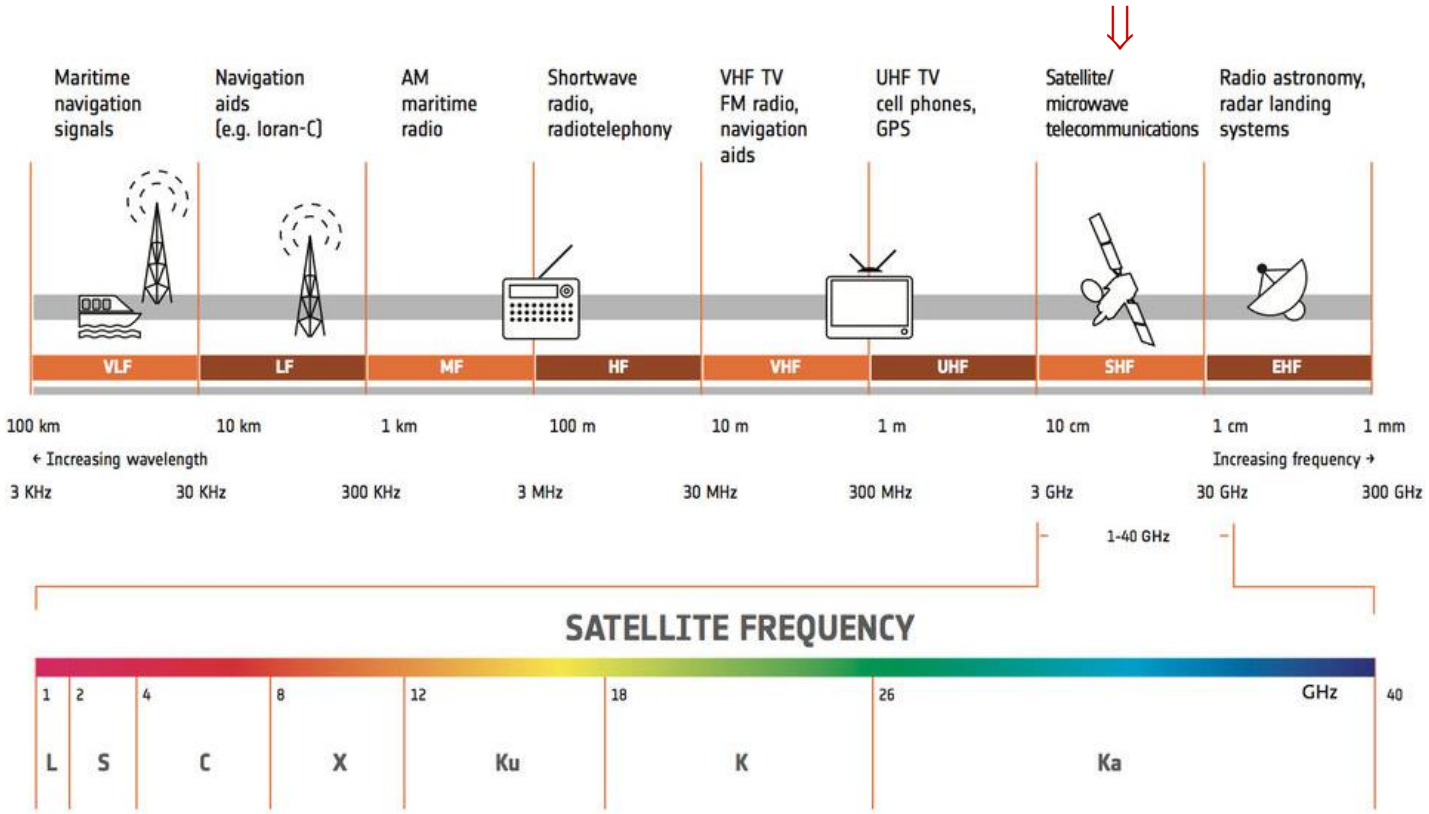


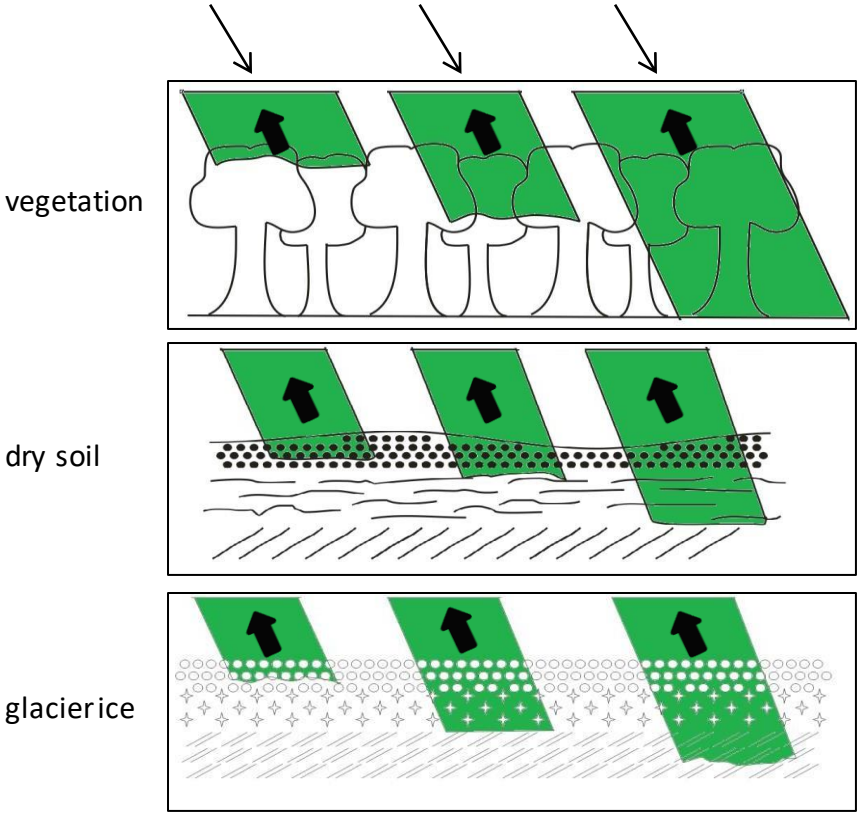



# Active Radar Remote Sensing

***RADAR band designations, wavelenghts and frequencies***

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

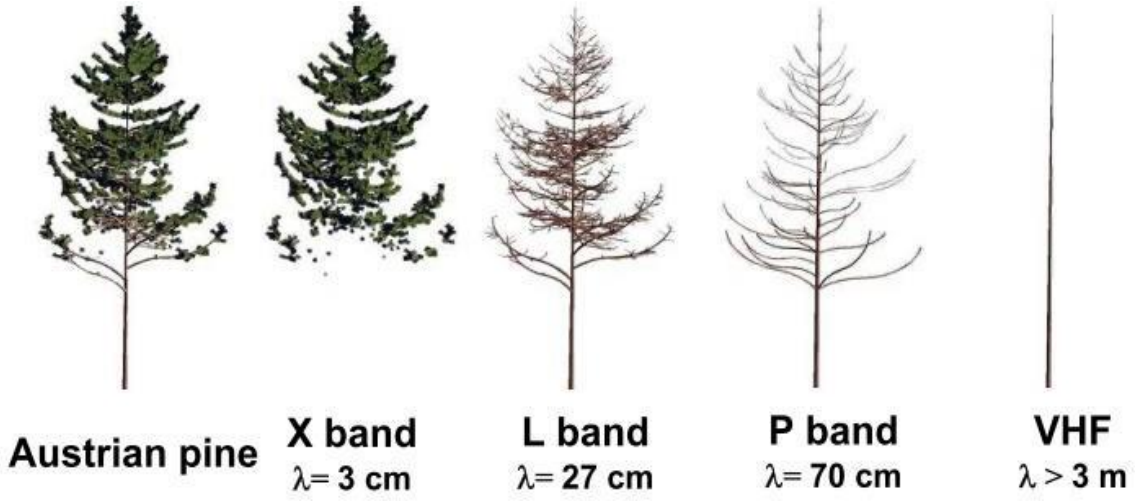


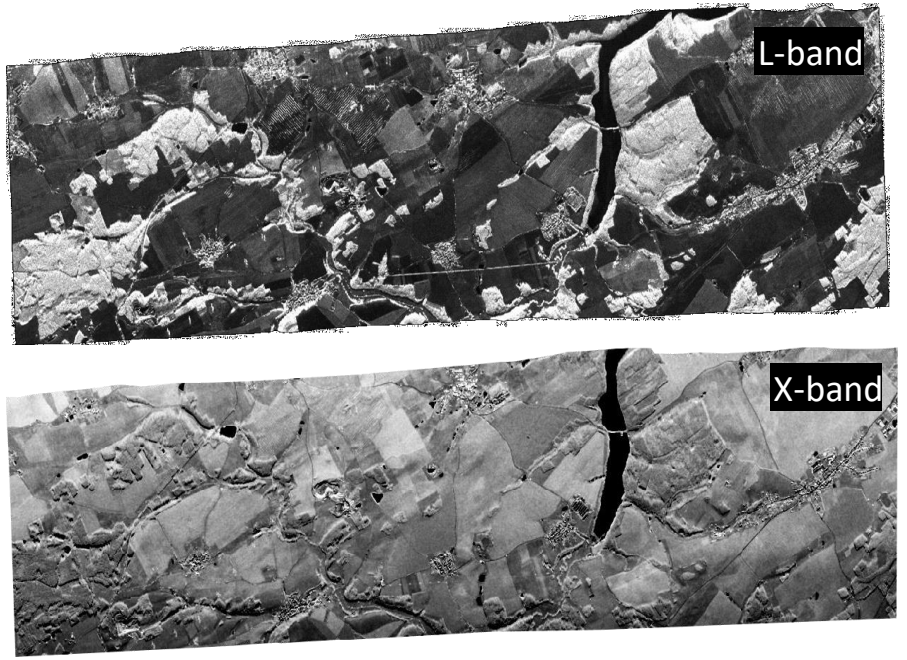



# Active Radar Remote Sensing

***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

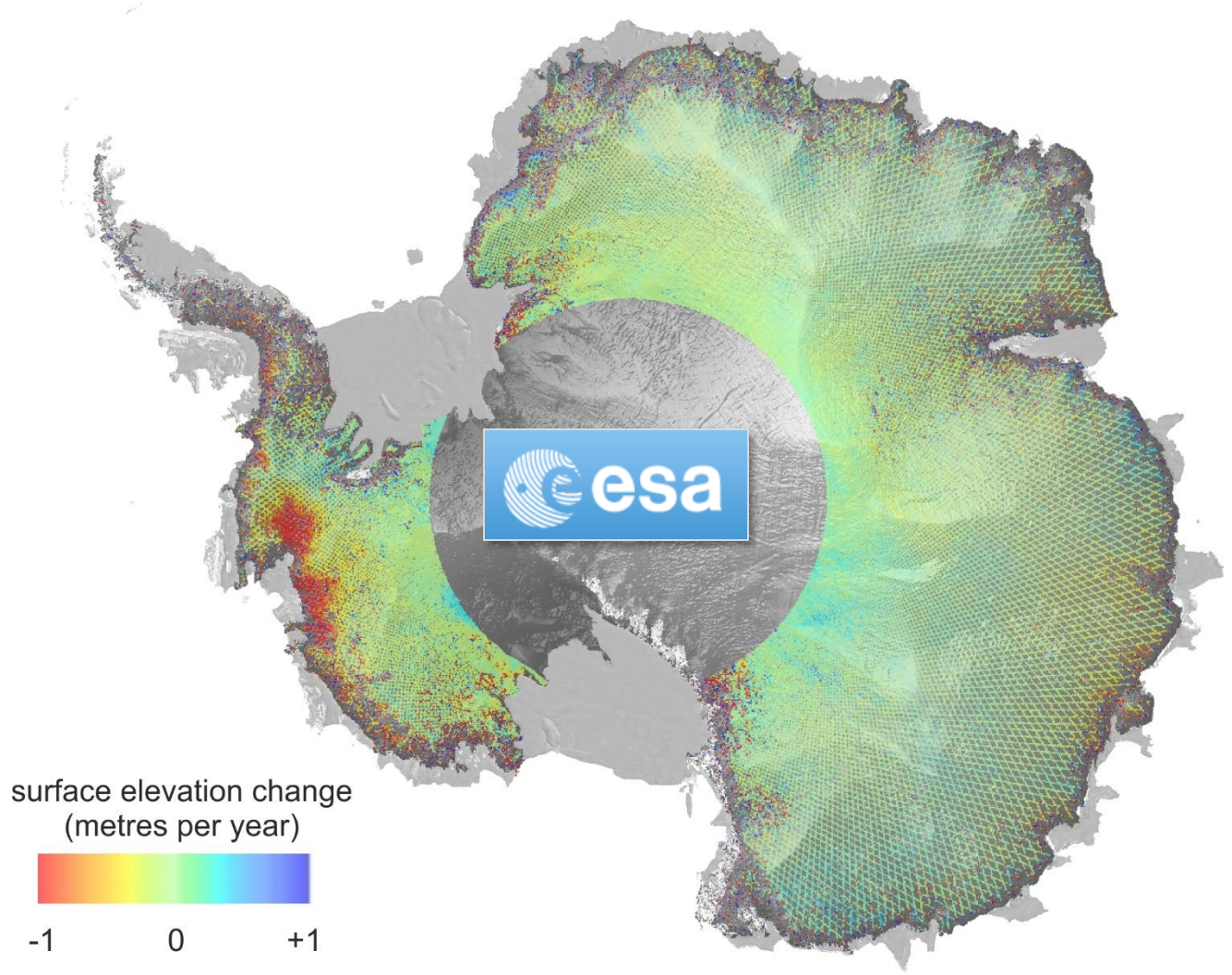
# Radar Altimetry = measuring altitude / vertical height


Article ESA

video

video 2

# Radar Altimetry = measuring altitude / vertical height



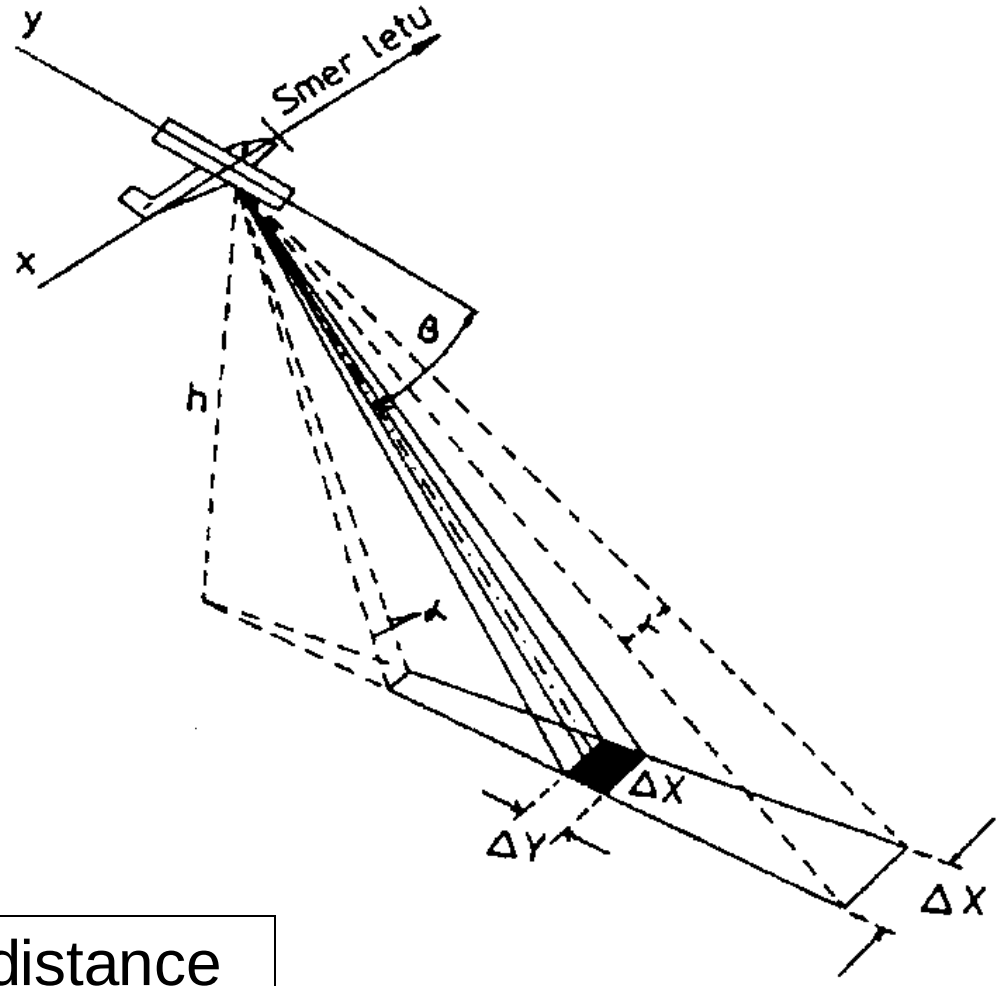

[Copernicus Sentinel-3 provides new measurements of Antarctic Ice Sheet
08 March 2019]

# 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



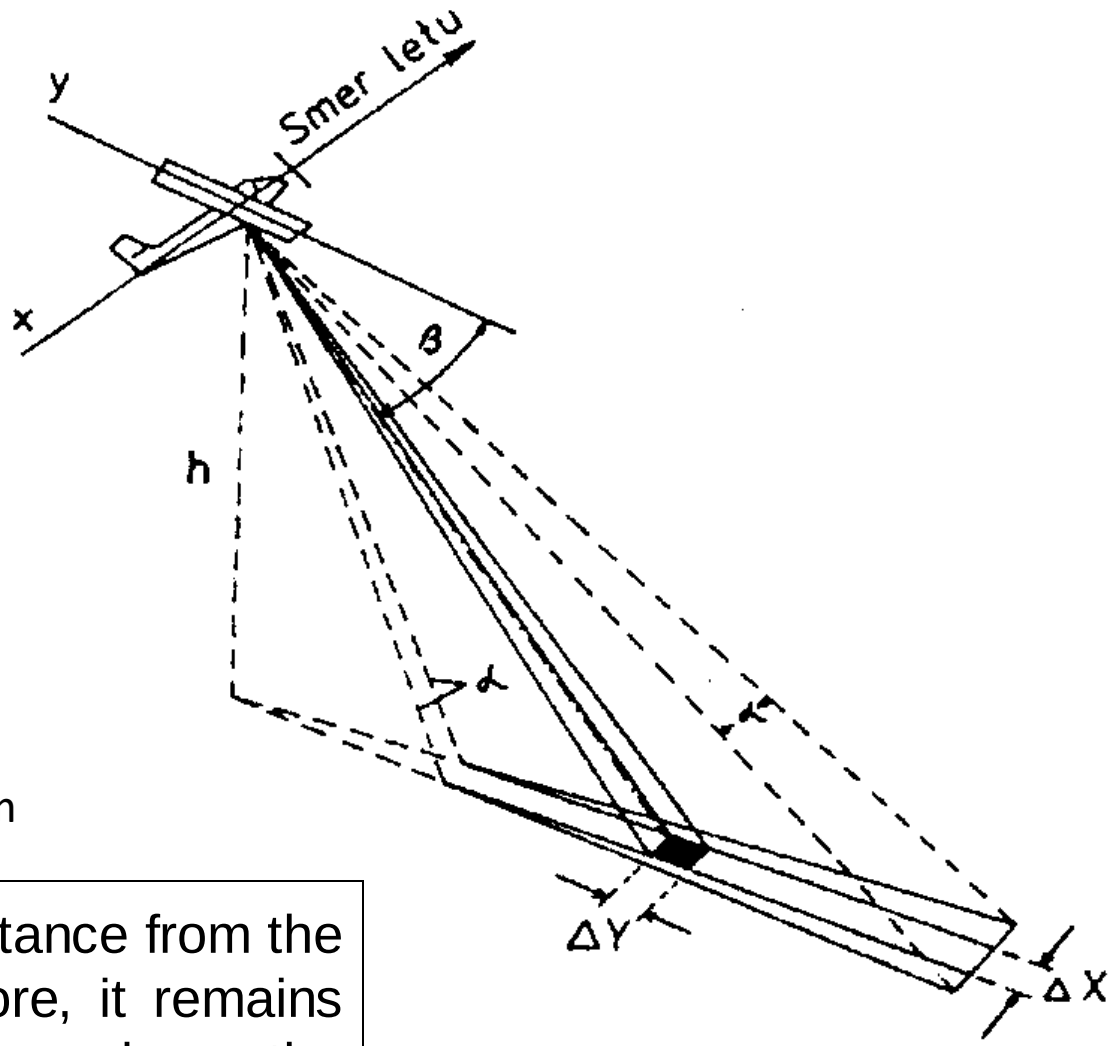

Spatial resolution deteriorates as the distance between the object and the antenna increases.

# 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



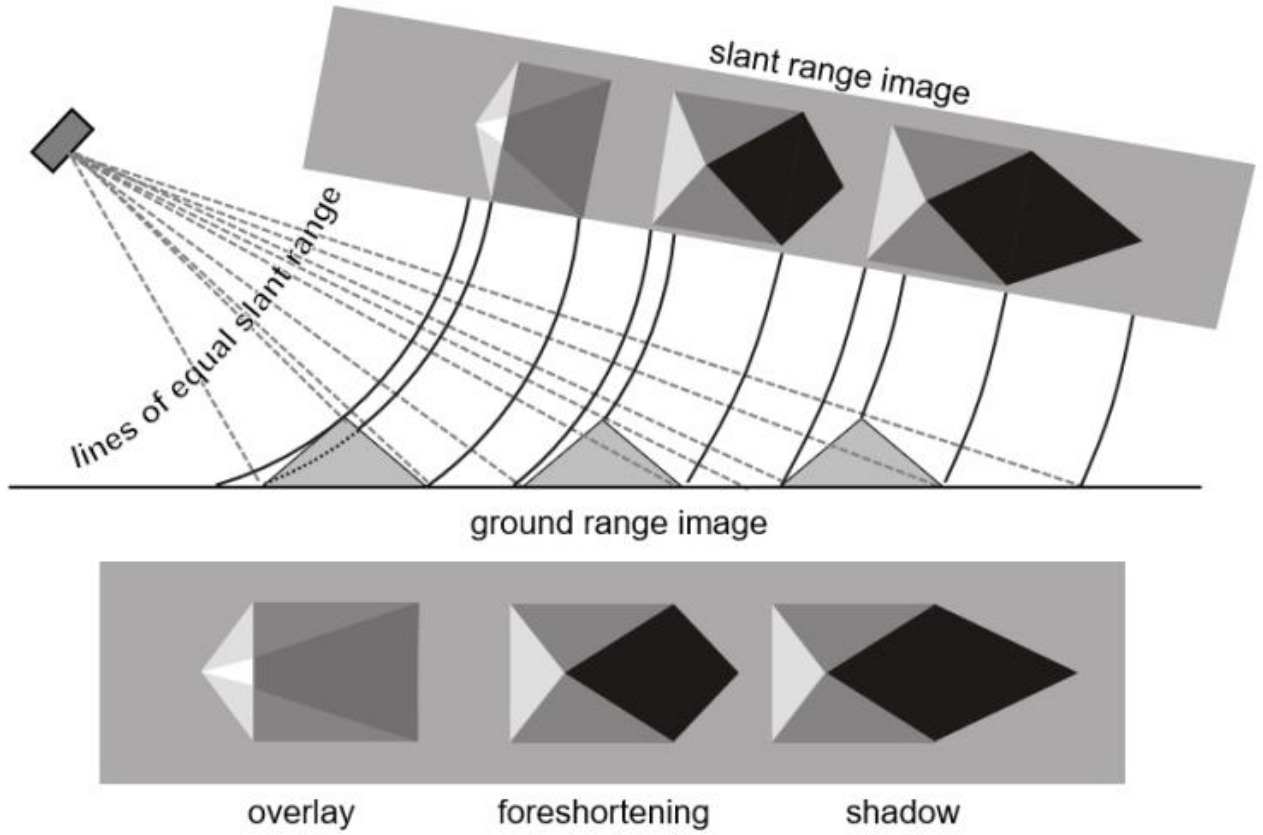

Spatial resolution is independent of the distance from the antenna in the direction of flight. Therefore, it remains constant in the flight direction, while it depends on the viewing angle perpendicular to the flight direction.

# Geometric Effects in SAR images

**Effects of side-looking geometry**

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

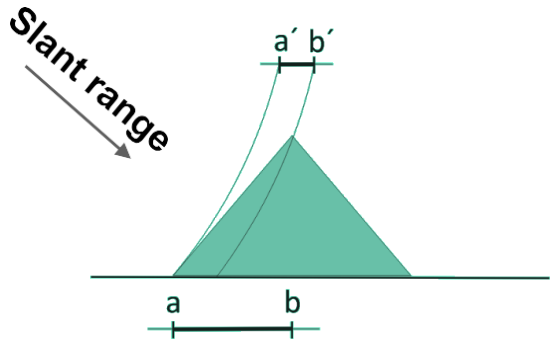
- The effects are:
  - ❖ Foreshortening
  - ❖ Layover
  - ❖ Radar shadow
- Controlled by:
  - ❖ Incidence angle
  - ❖ Topography




*Geometric distortions in radar images (Braun 2019)*

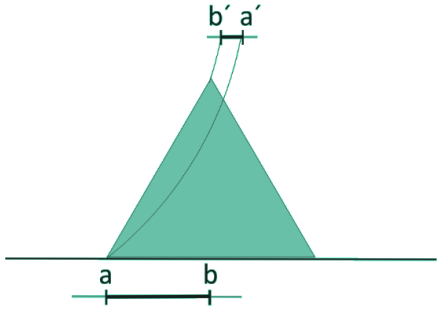
# Geometric Effects in SAR images

## Foreshortening



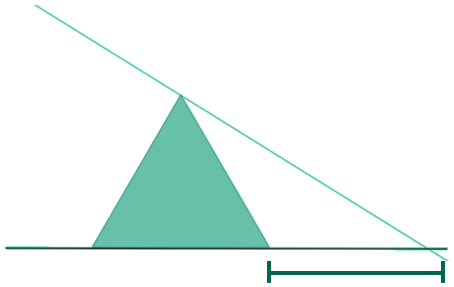

- Slopes oriented to the SAR appear compressed (Distance between a and b is shortened)
- Appears as very bright area
- More pronounced in near range (small incidence angle) than in far range (high incidence angles)

## Layover



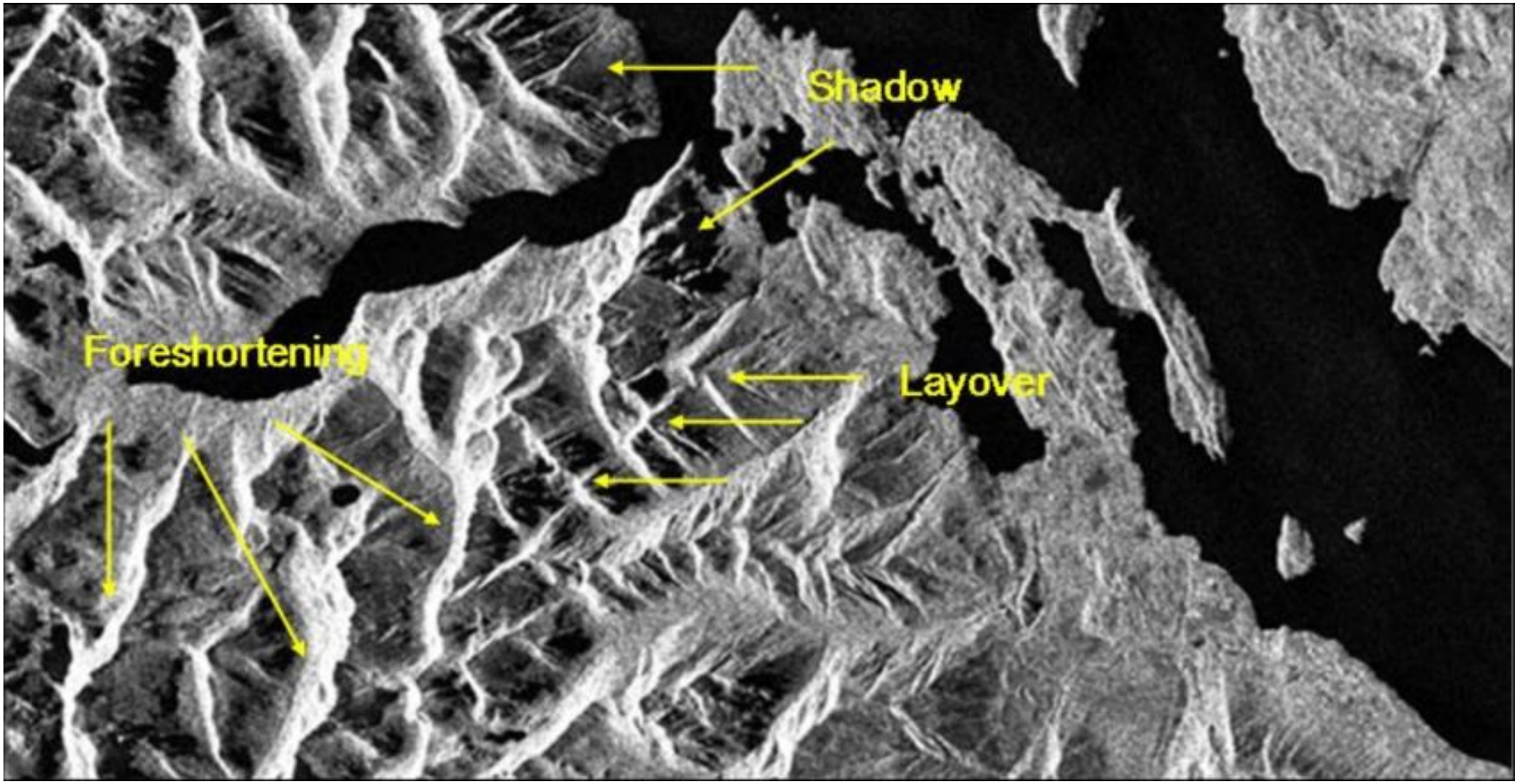

- Steep slopes oriented to the SAR lead to ghost images
- When radar beam reaches the top of a high feature (b) before it reaches the base (a)

## 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

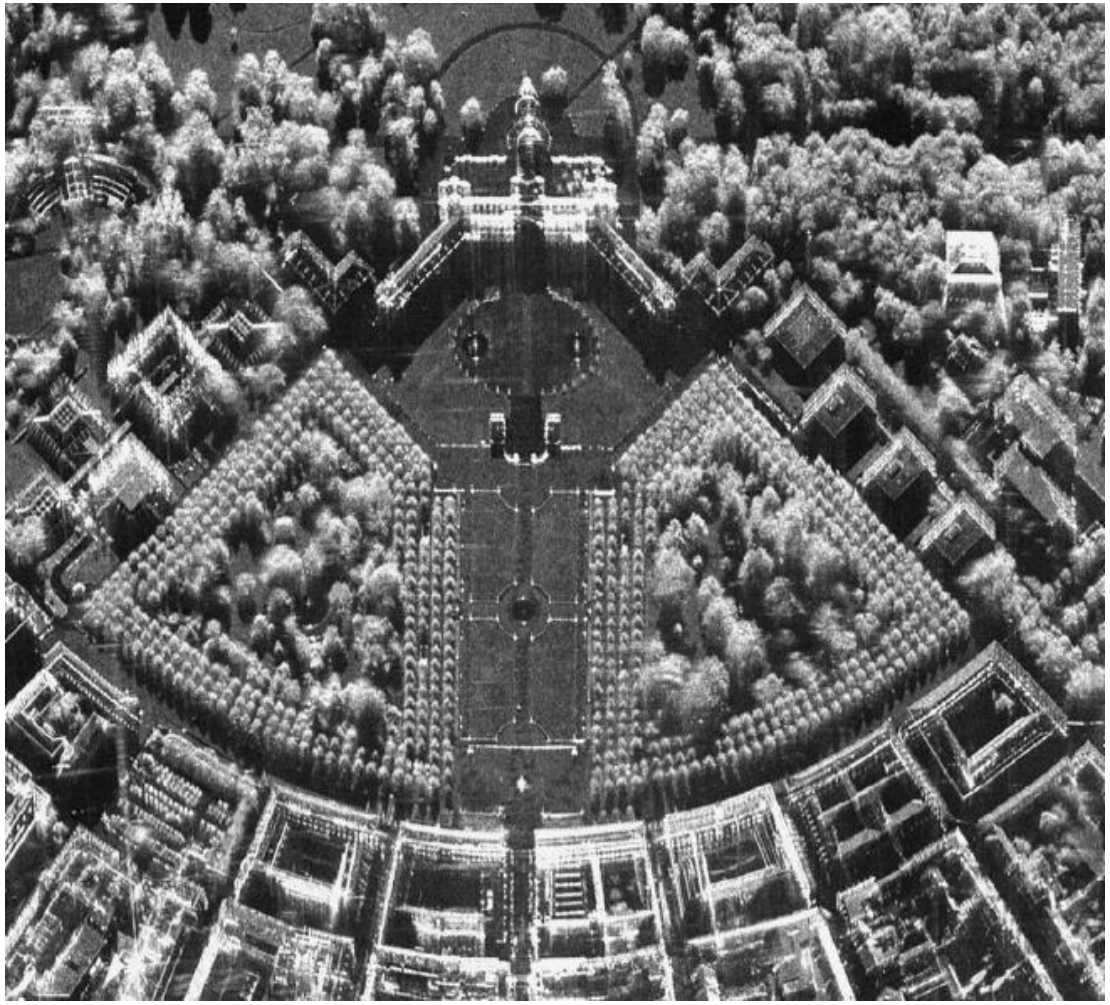



Source: https://www.researchgate.net/profile/M-Lenzano/publication/263124688/figure/fig23/AS:614356547039256@1523485423960/Figura-9-Efectos-de-shadowing-foreshortening-y-layover-en-una-imagen-SAR-de-RADARSAT-1.png

# Geometric Effects in SAR images

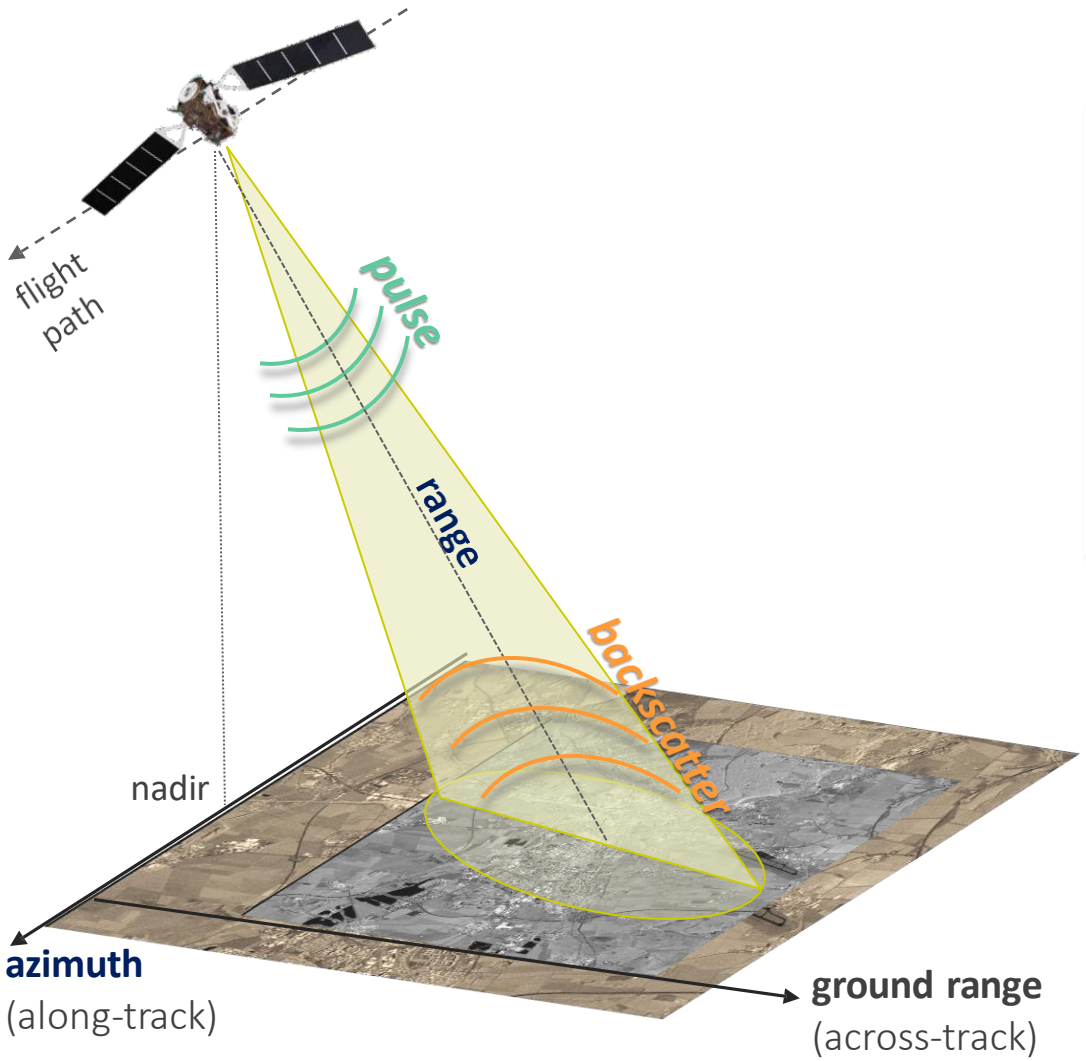
## Effects of side-looking geometry

Google maps

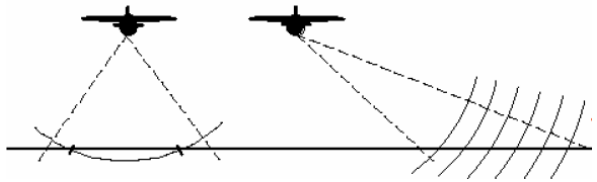


Andreas R. Brenner and Ludw ig Roessing, Radar Imaging of Urban Areas by Means of Very High-Resolution SAR and Interferometric SAR, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 46, NO. 10, OCTOBER 2008 (X-band)

# Radar side looking imaging geometry




## Is side looking really necessary?



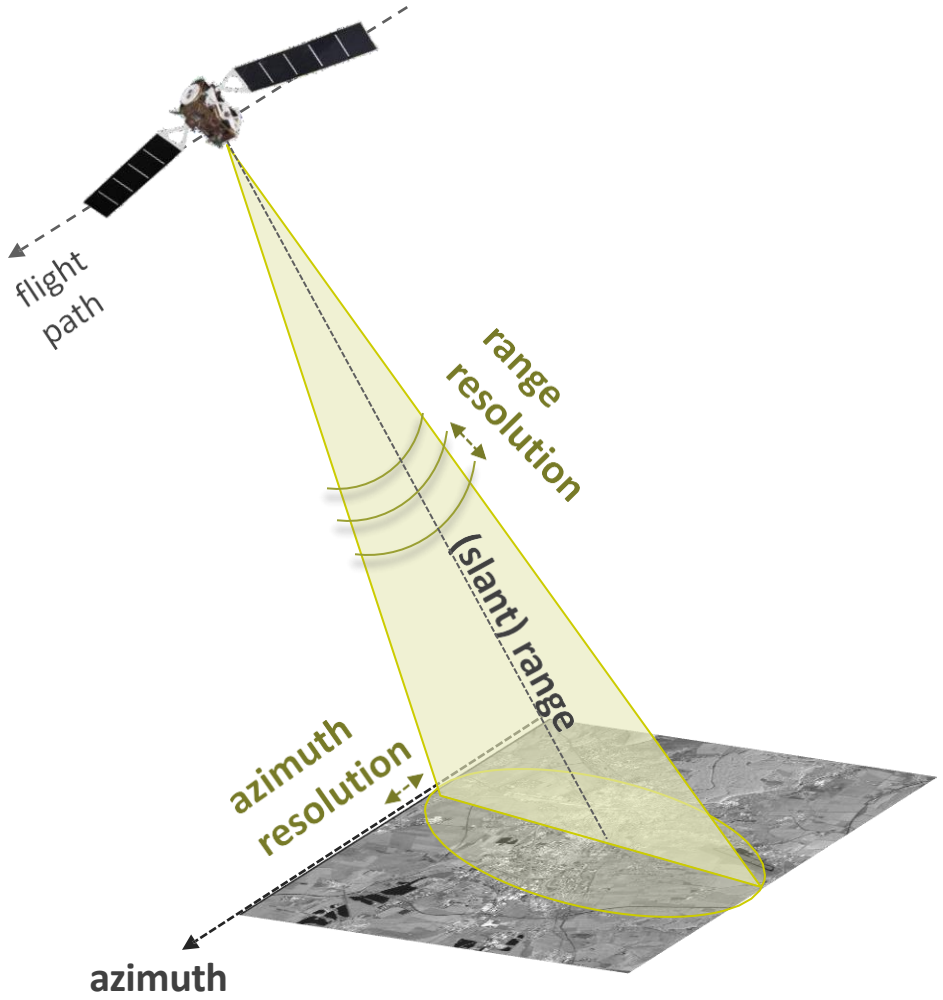
Nadir looking,
e.g. aerial photography

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



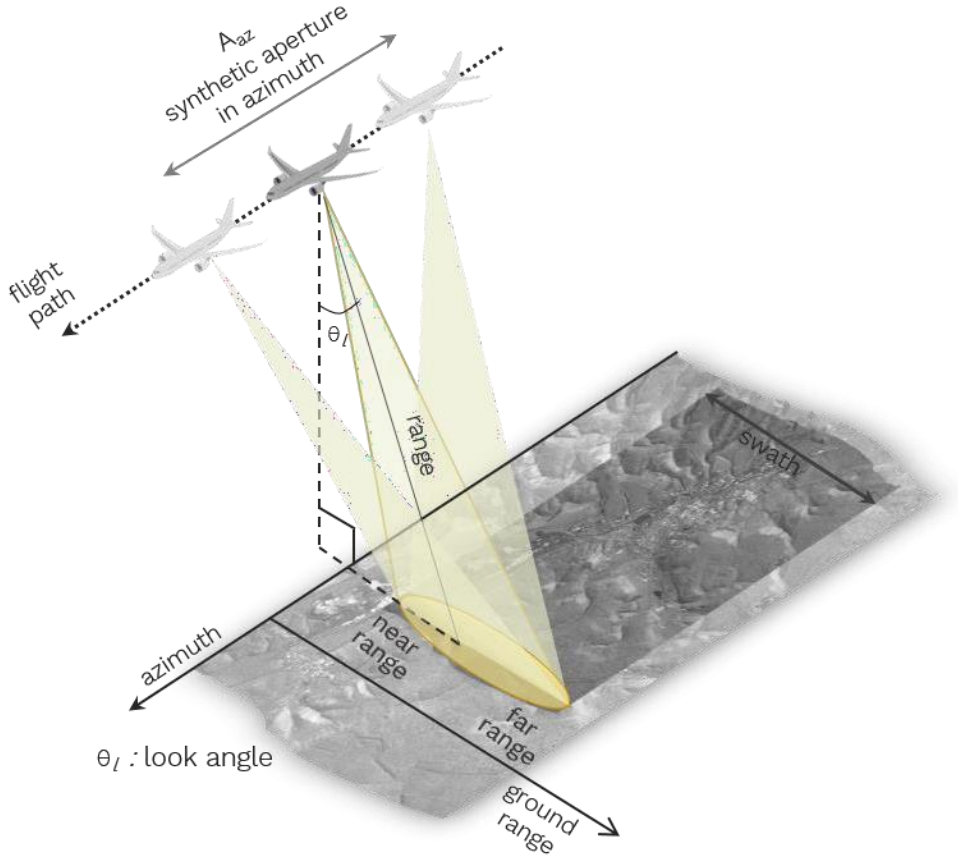

**slant-range resolution** depends on the **bandwidth of the system**

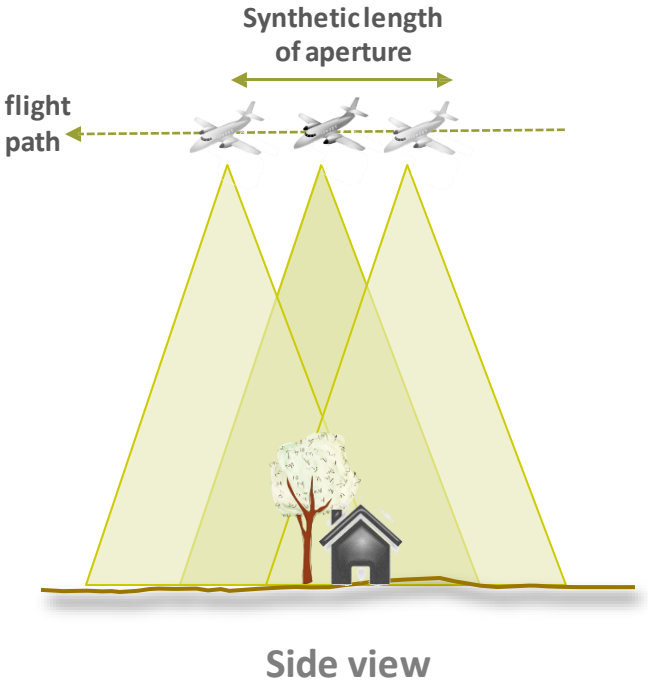
**azimuth resolution** is a function of the **antenna length** and **sensor height** over the Earth's surface

# Synthetic Aperture Radar (SAR)

**The principle of extending the antenna**

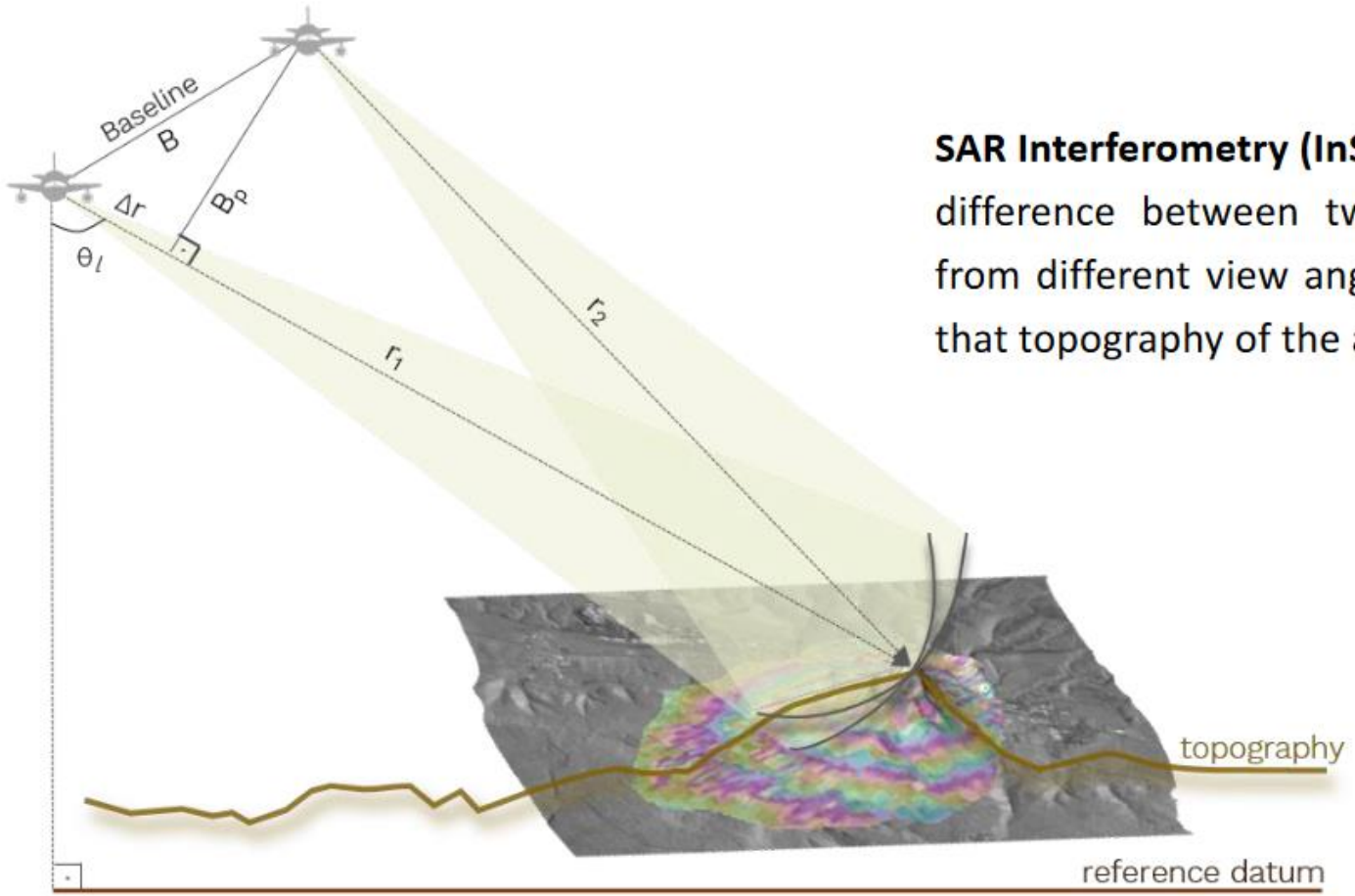
The key factor that is utilized in SAR is to synthesize a much longer antenna in azimuth direction by making use of the motion of the SAR sensor in order to achieve finer resolution.



# Synthetic Aperture Radar (SAR)

**Determining elevation**



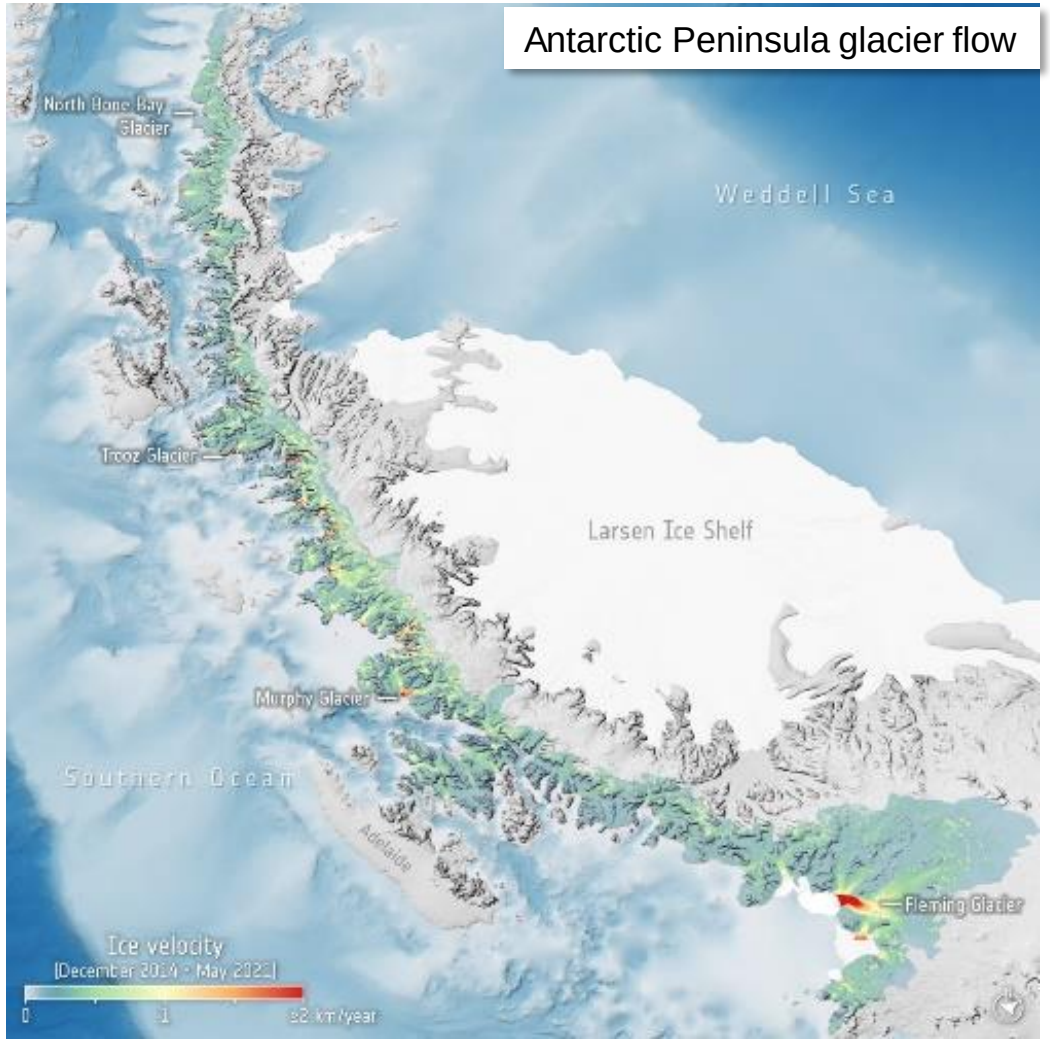

**SAR Interferometry (InSAR)** makes use of the phase difference between two complex valued images from different view angle, i.e. forming baseline, so that topography of the area can be imaged.

B : baseline
$B_p$ : perpendicular baseline
$\theta_l$ : look angle

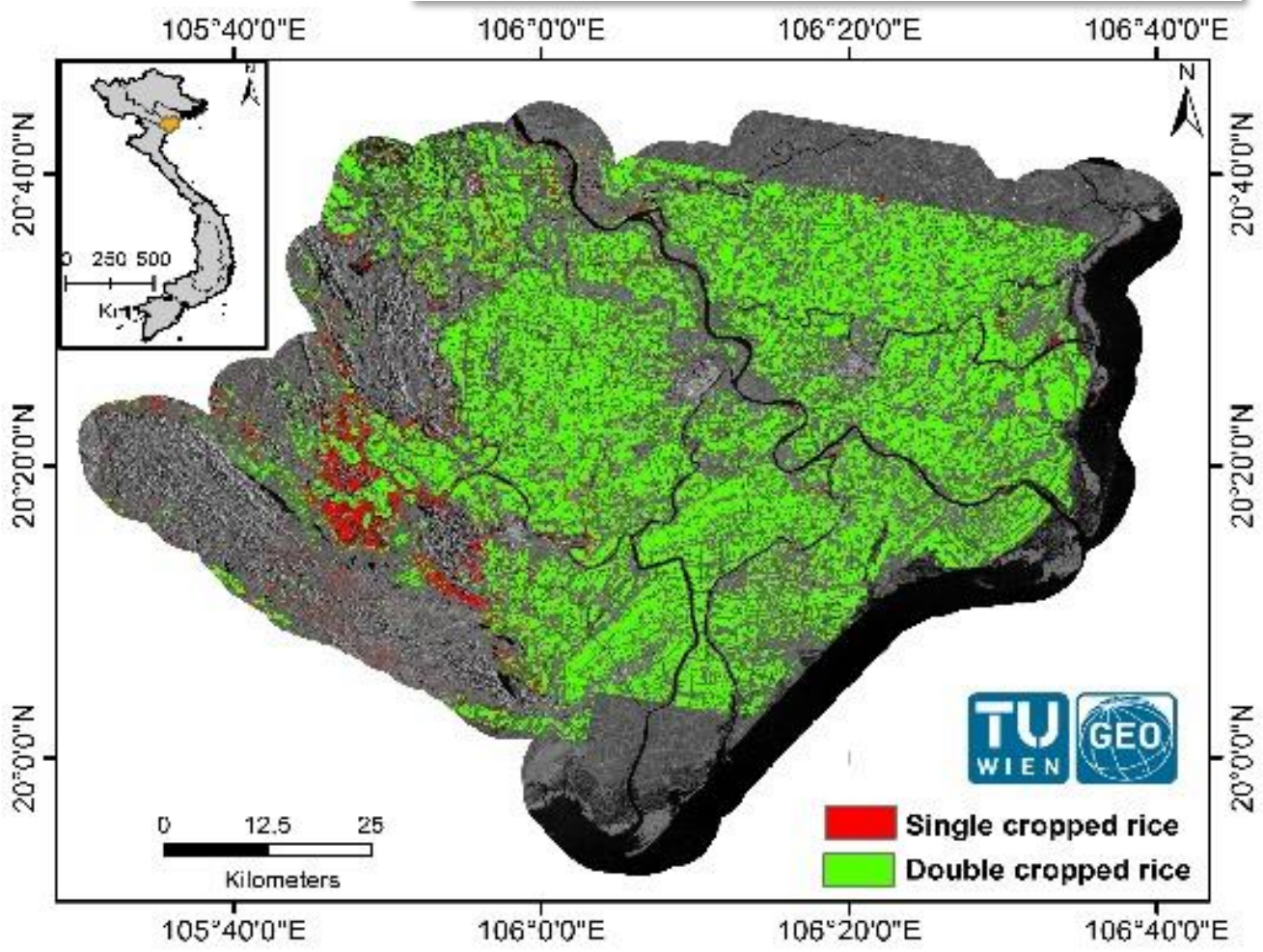
$r_1$ & $r_2$: range distance for the respective acquisitions
$\Delta r$ : range difference

# Sentinel-1 – Applications

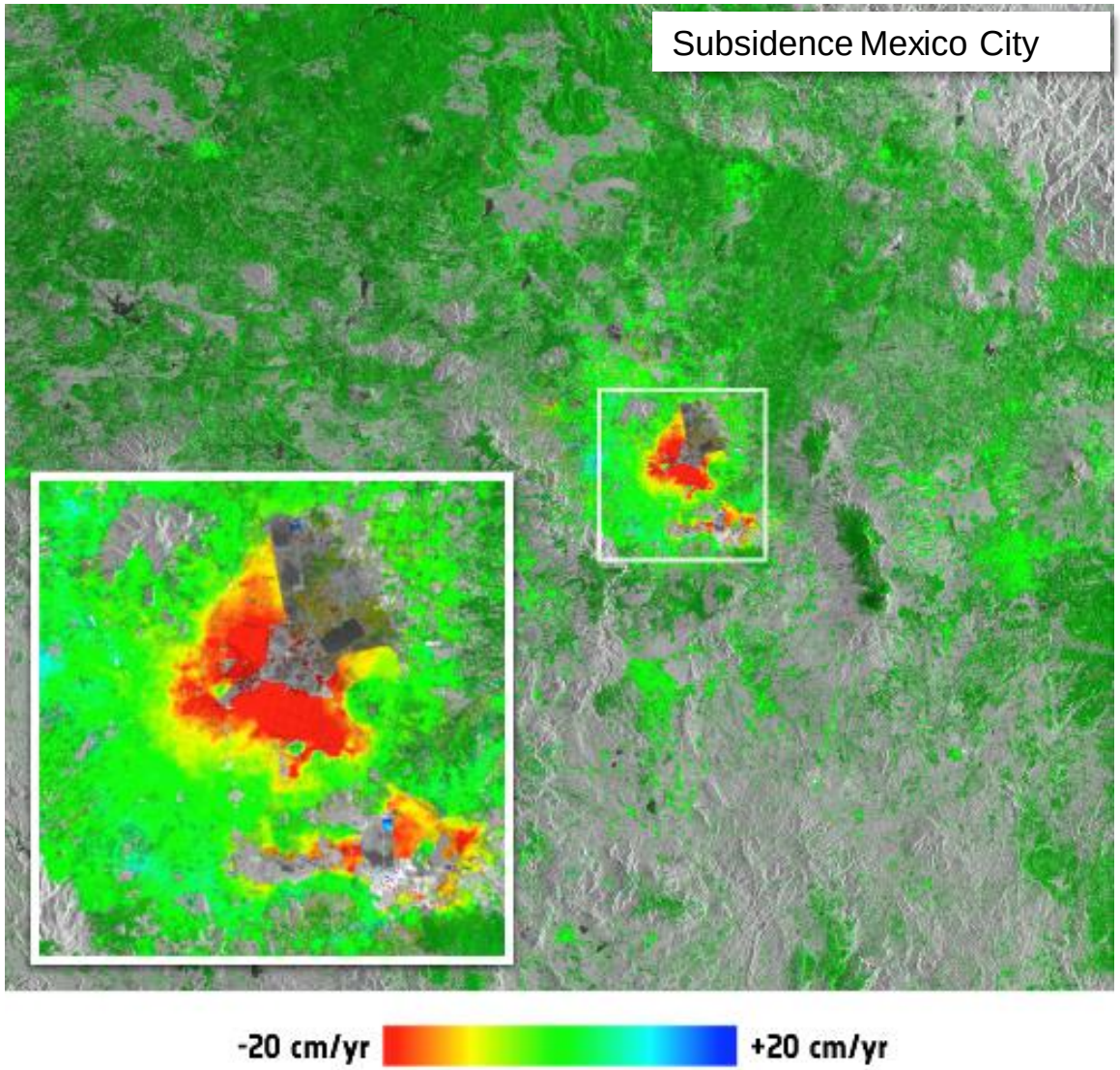
Antarctic Peninsula glacier flow

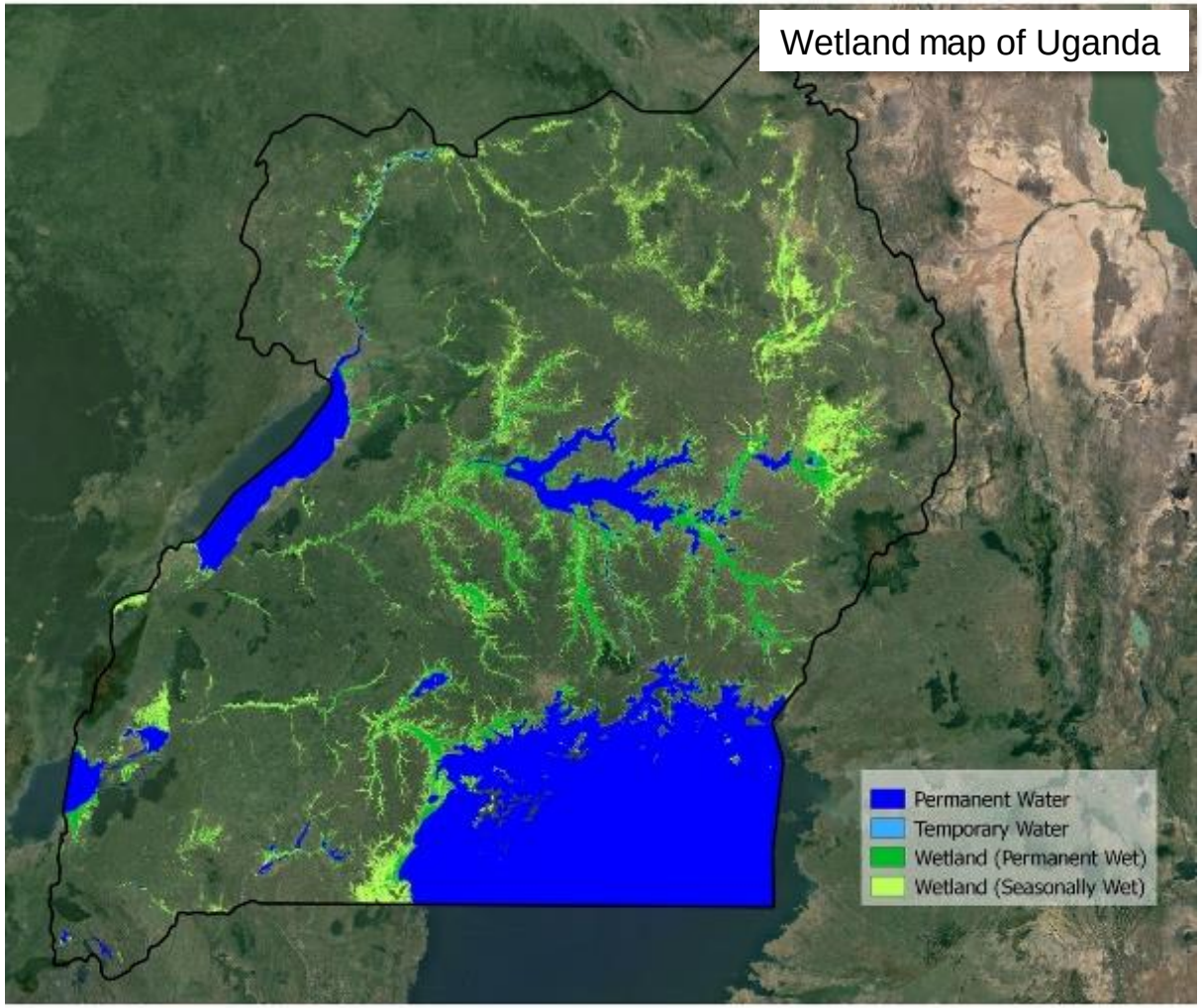



Rice-cropping systems in Vietnam's Red River Delta

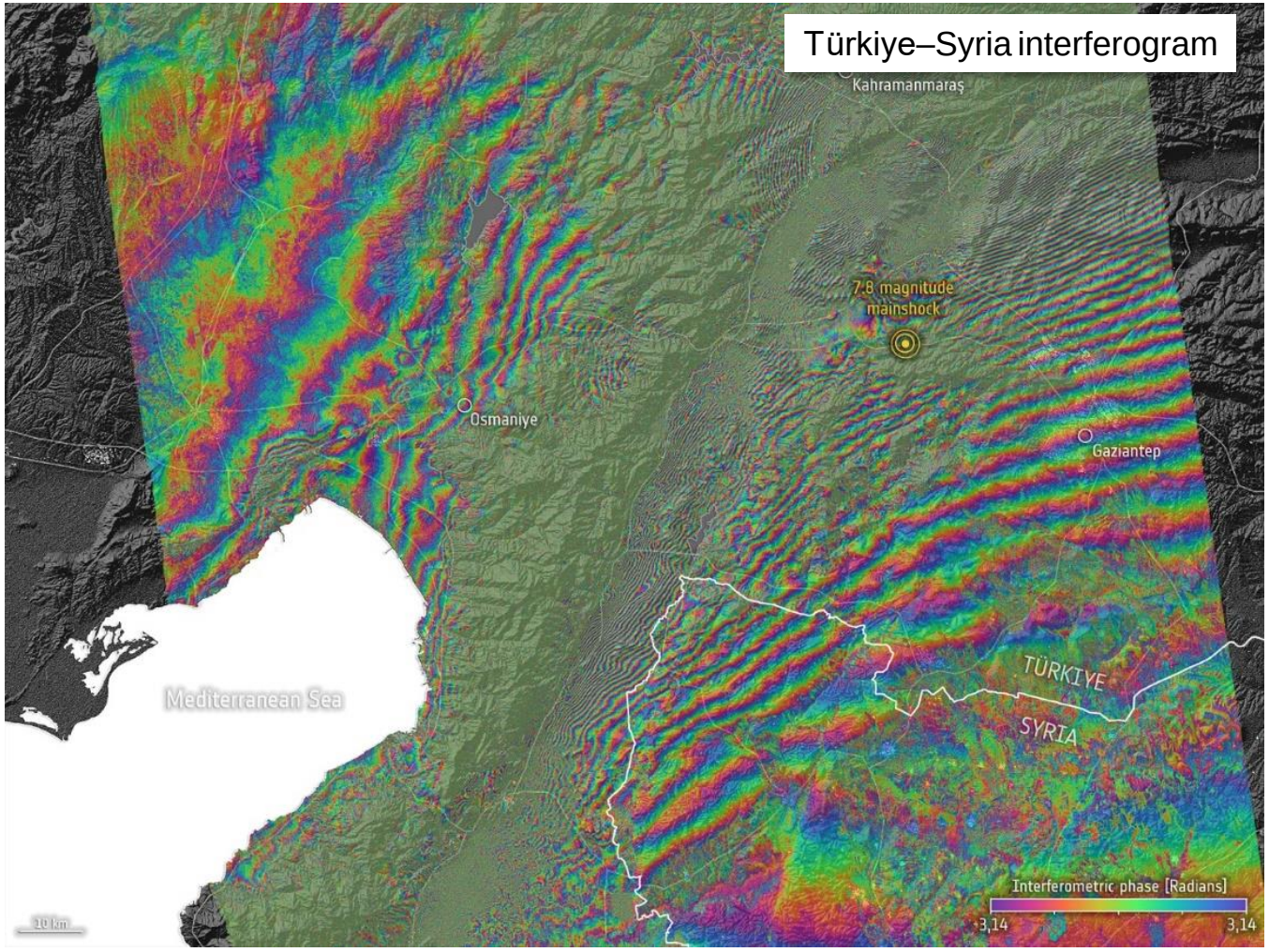


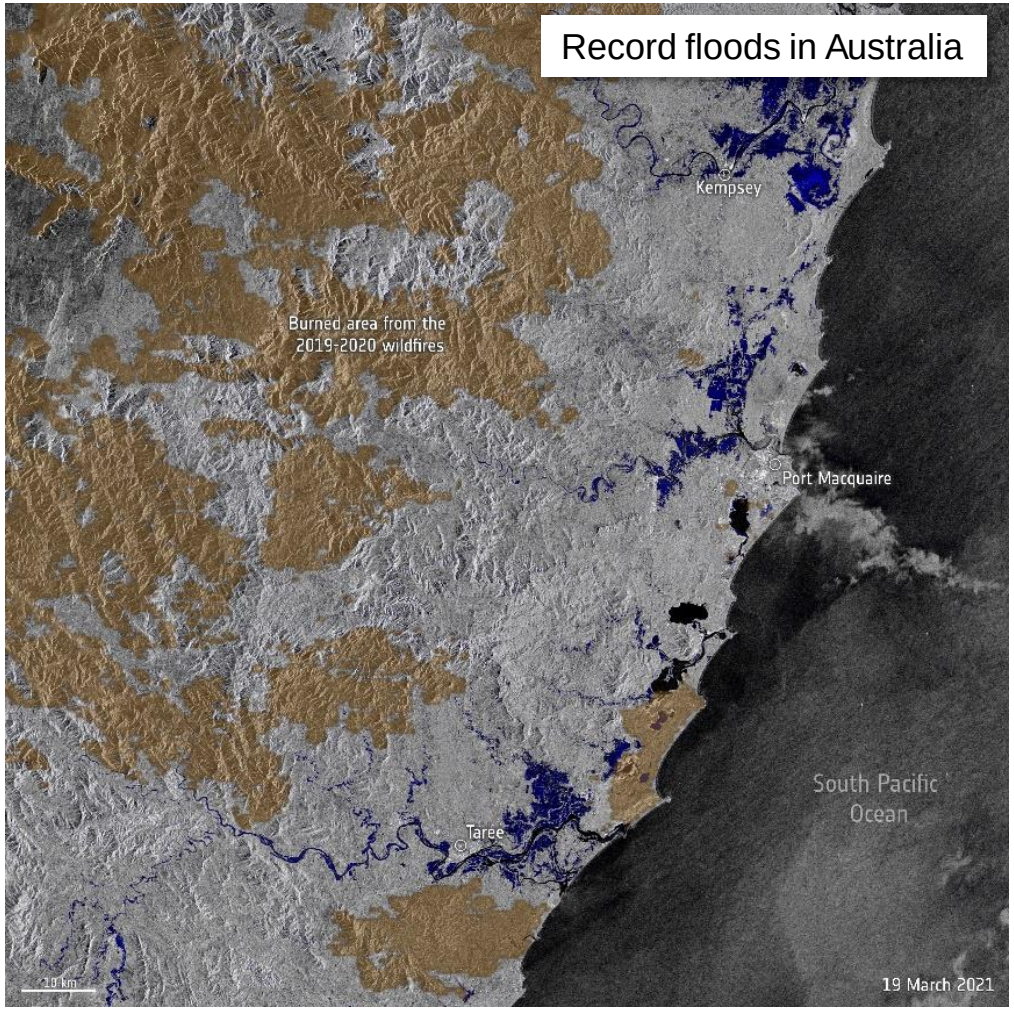
# Sentinel-1 – Applications



# 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

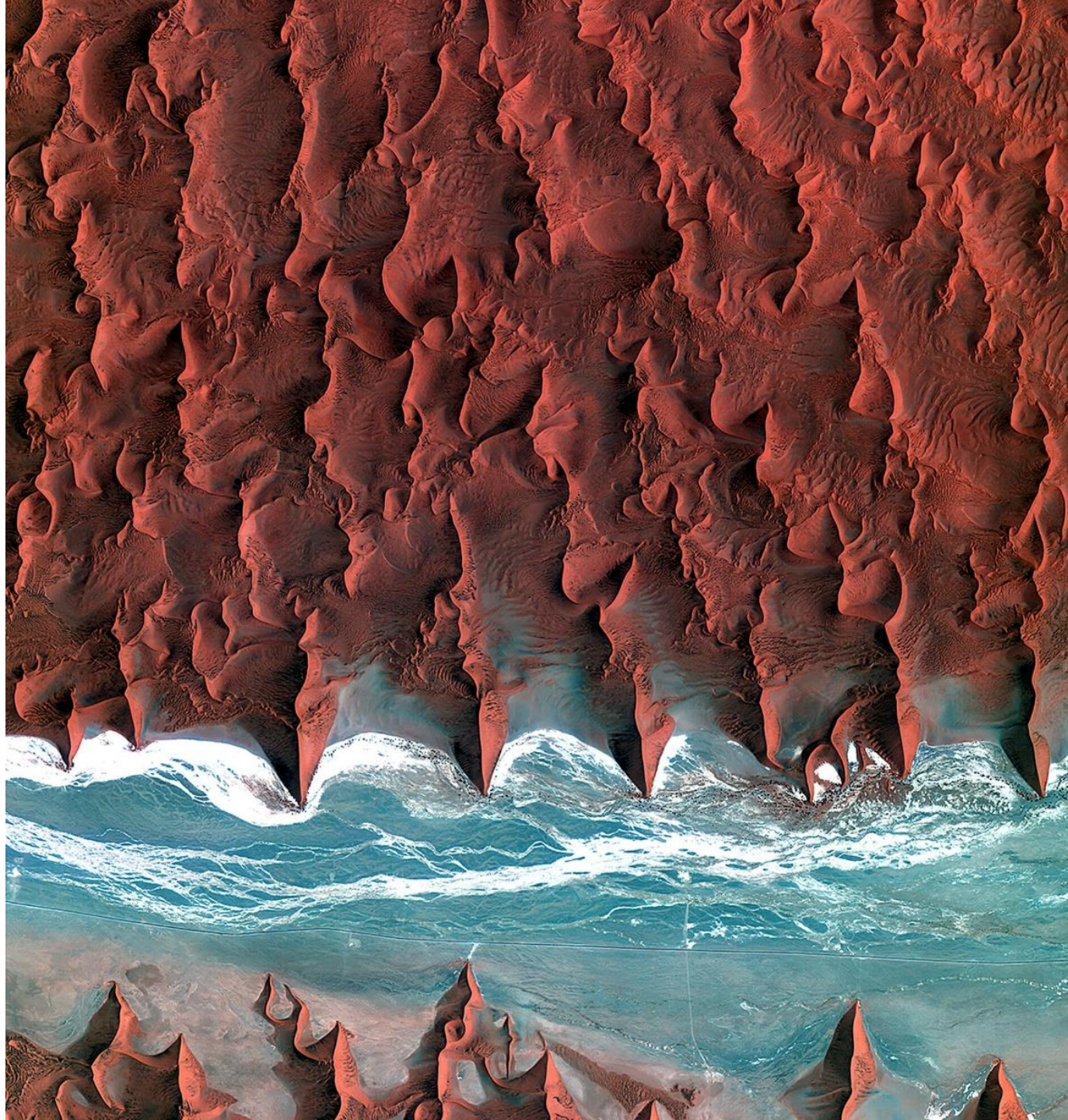
Source: https://www.esa.int/Applications/Observing_the_Earth/Envisat/ESA_declares_end_of_mission_for_Envisat, https://earth.esa.int/eogateway/news/esa-s-excellent-earth-explorer-missions-extended-to-2025/esa-s-ice-mission , https://www.esa.int/ESA_Multimedia/Images/2012/12/Pleiades#.XoNYGqecnA8.link

# EO data access

## Free open source platforms

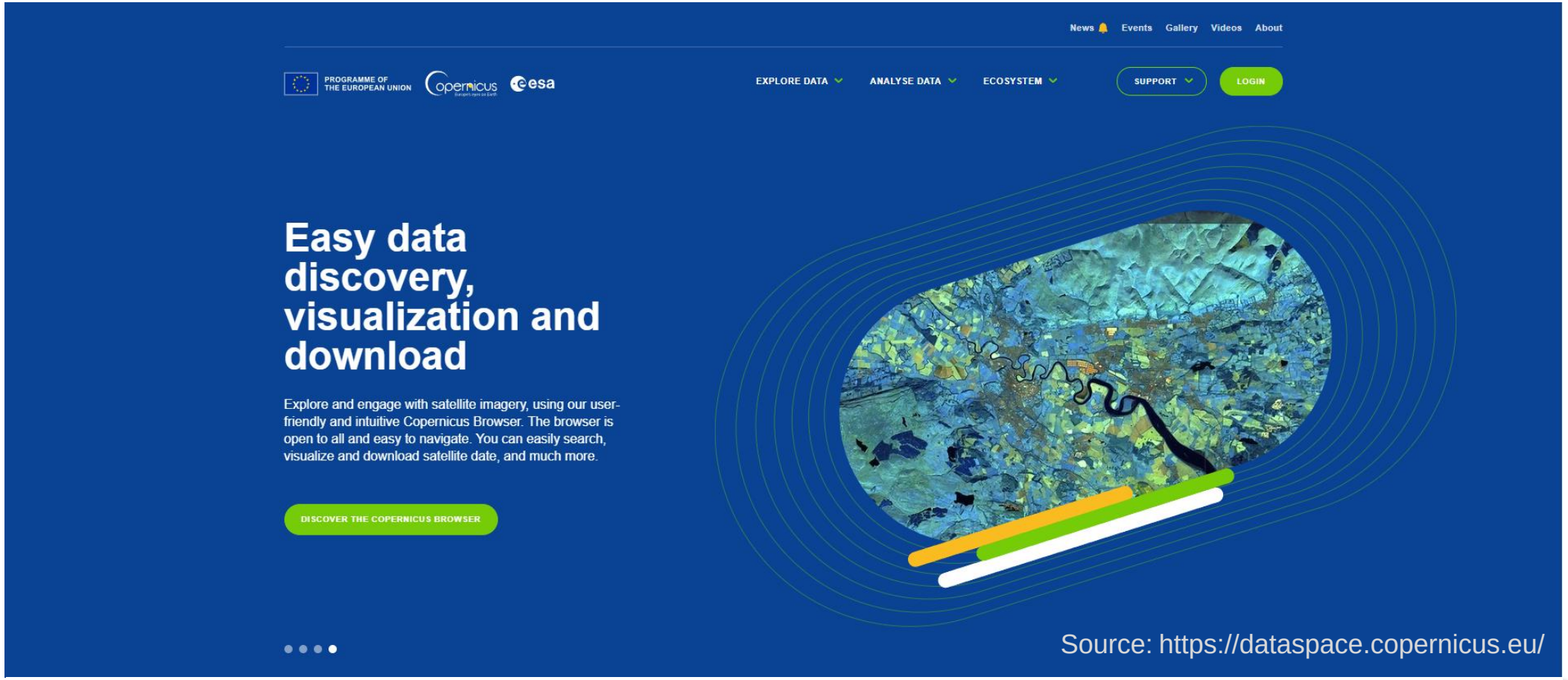
- **Copernicus Open Access Hub**
- Earth System Lab
- ESA Thematic Exploitation Platforms
- Alaska Satellite Facility
- Copernicus Global Land Service
- **Copernicus Data Space Ecosystem**
- **Sentinel Data Access Service**
- USGS Earth Explorer
- Sentinel Application Platform software
- Open Data Cube

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

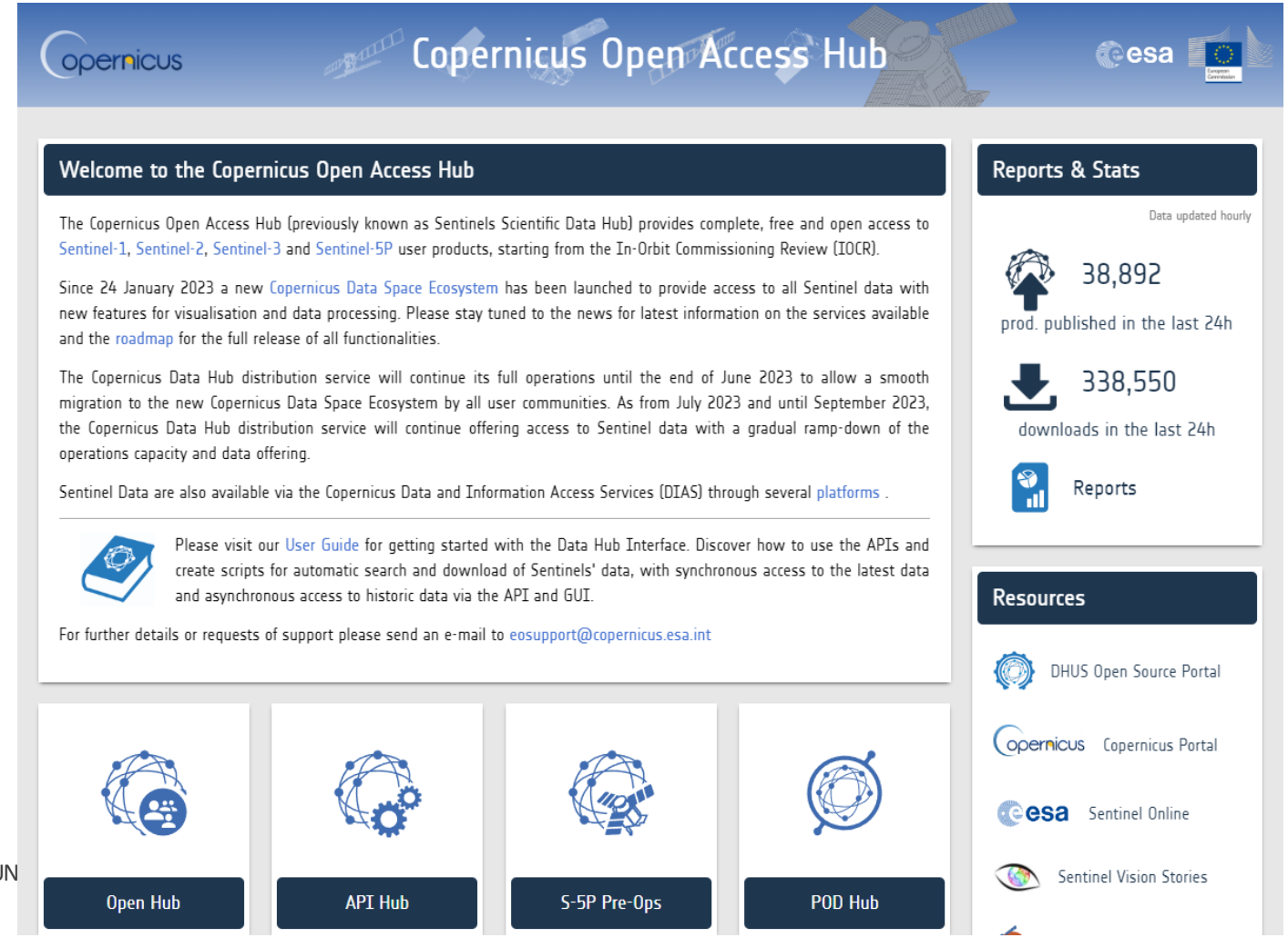
https://dataspace.copernicus.eu/




- 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/



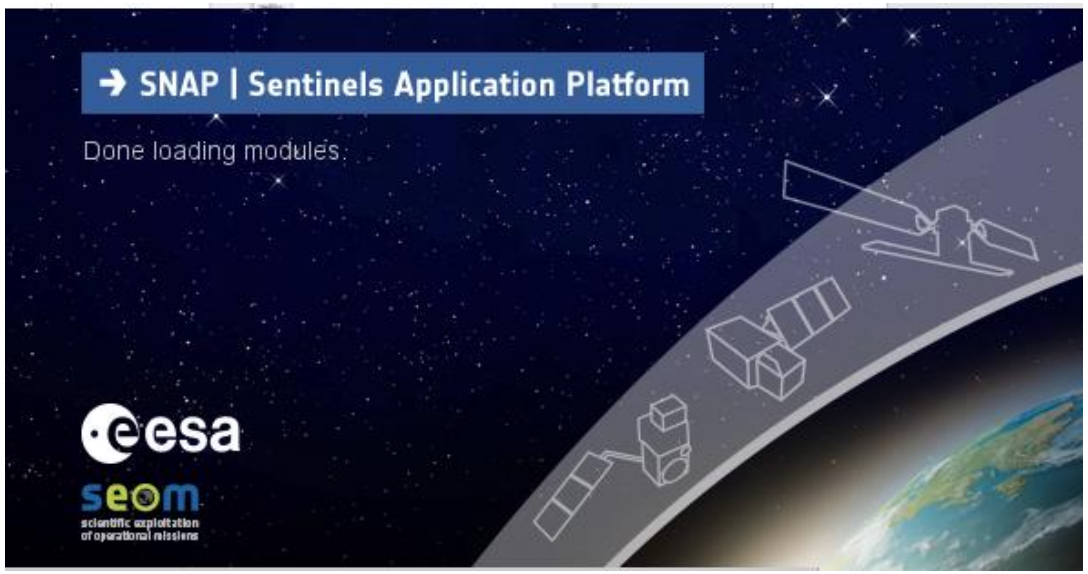

- The previous Copernicus Open Access Hub provided complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products

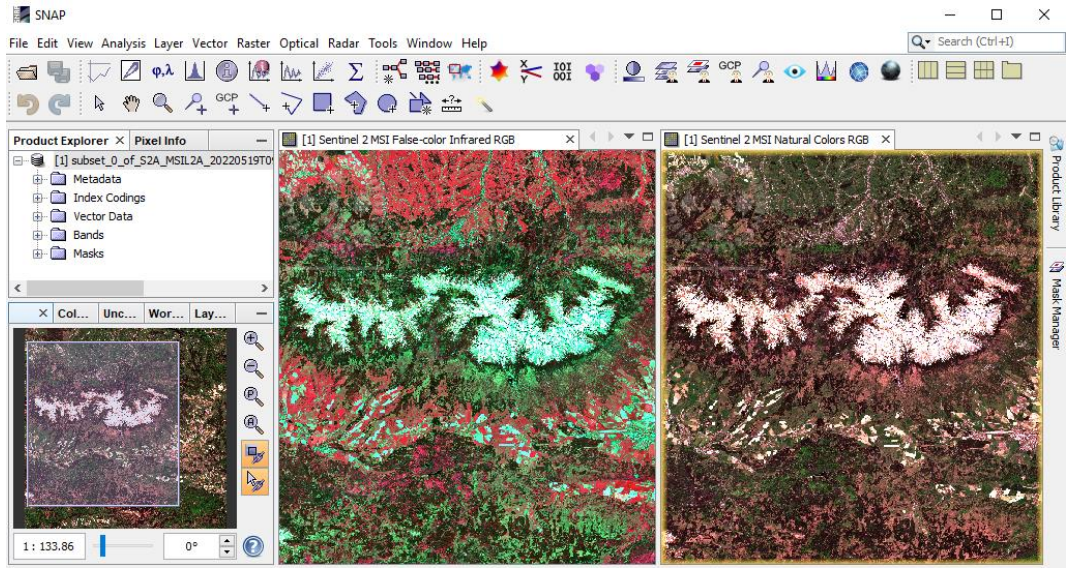


Source: https://scihub.copernicus.eu

# 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.

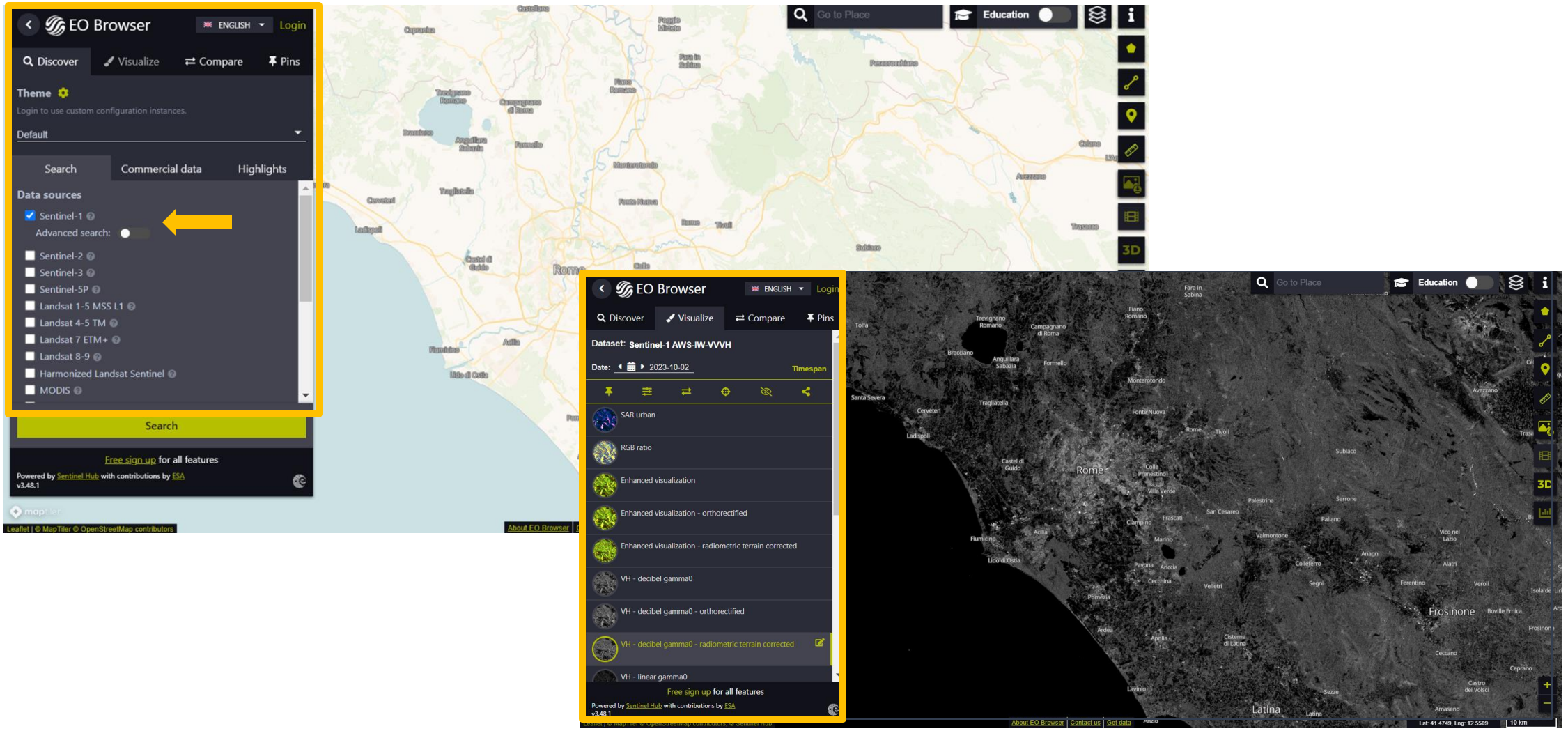
# EO data access

## 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/

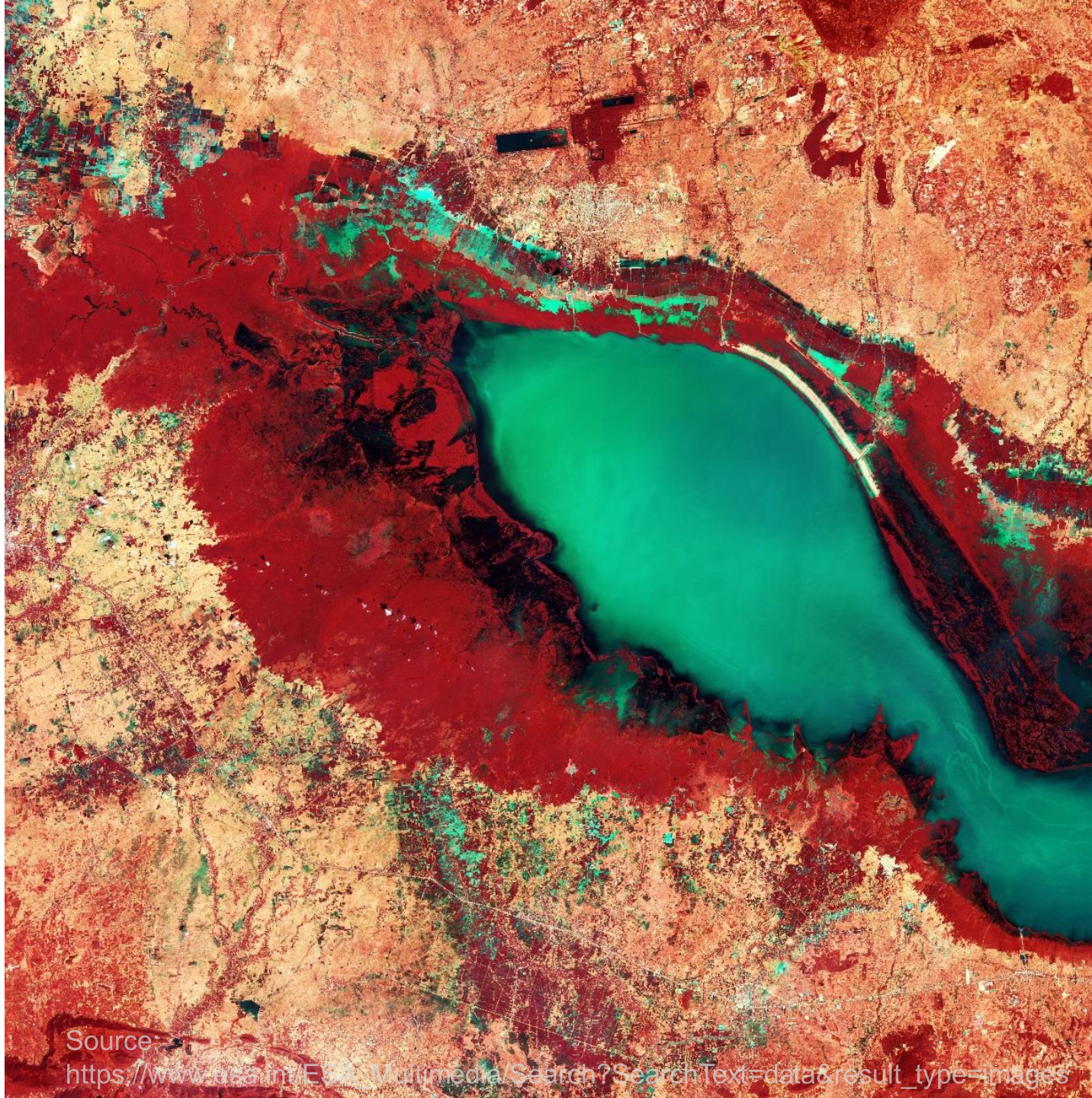



Source: https://apps.sentinel-hub.com/eo-browser

# EO data access

## Commercial EO platforms

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



esa space solutions

Copernicus Academy

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# Thank you for the attention