



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)

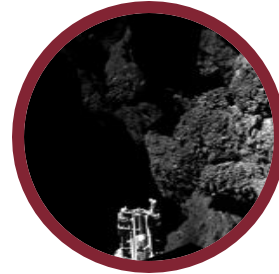
“To provide for and promote, for **exclusively peaceful purposes**, cooperation among European states in **space research** and **technology** and their **space applications.**”

Article 2 of the ESA Convention



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

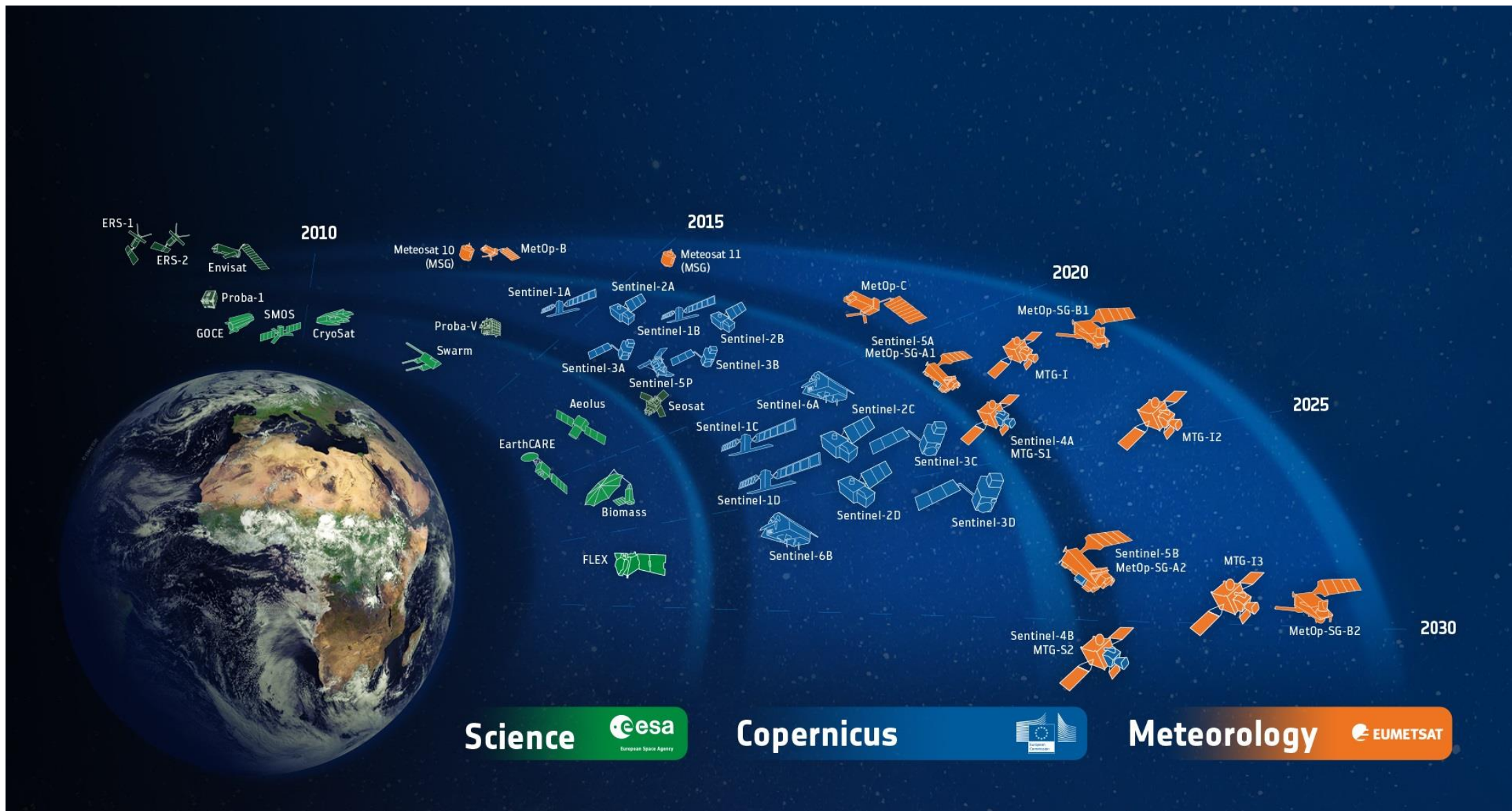


technology

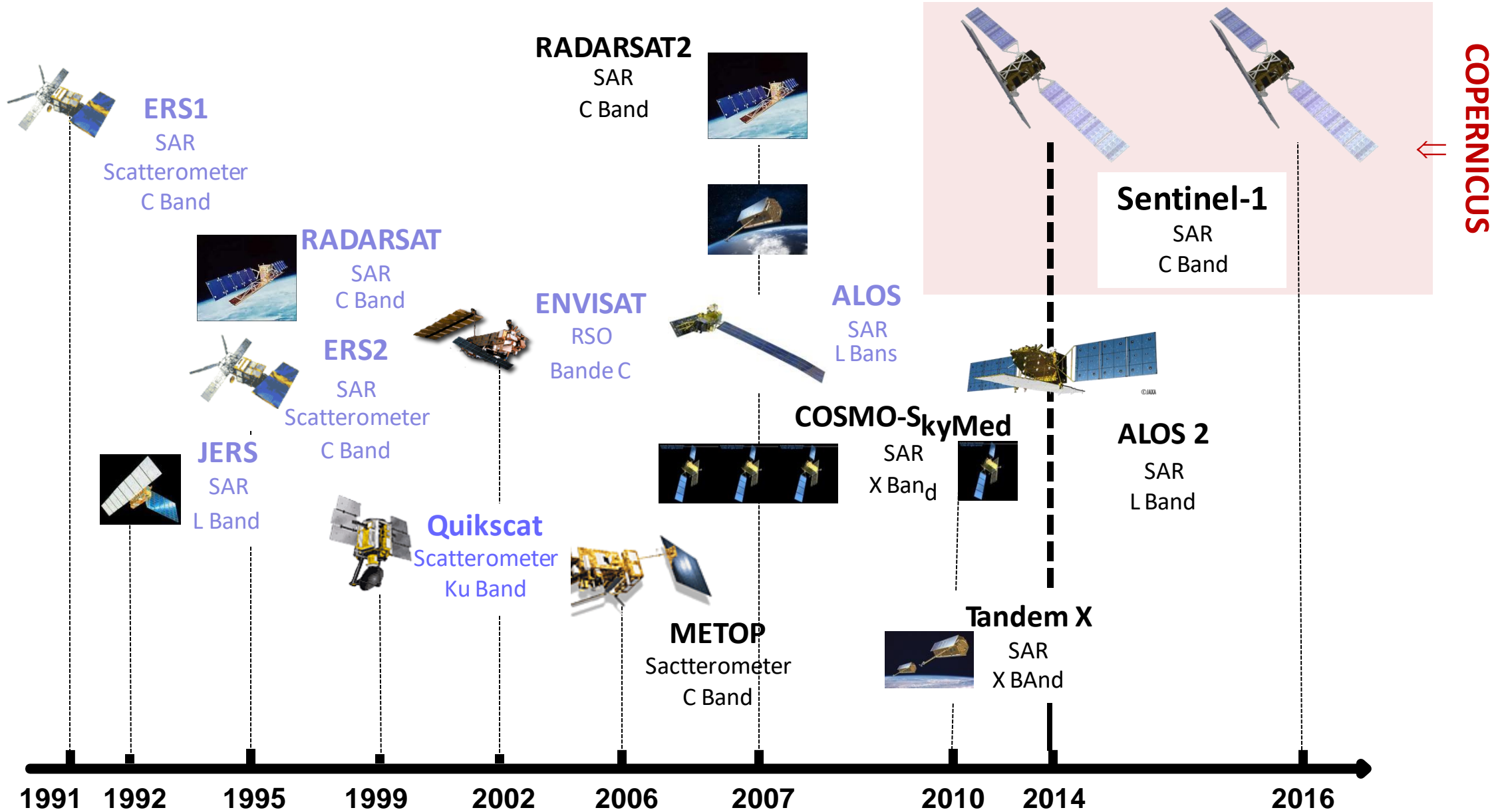


telecommunications

ESA-Developed Earth Observation Missions



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-

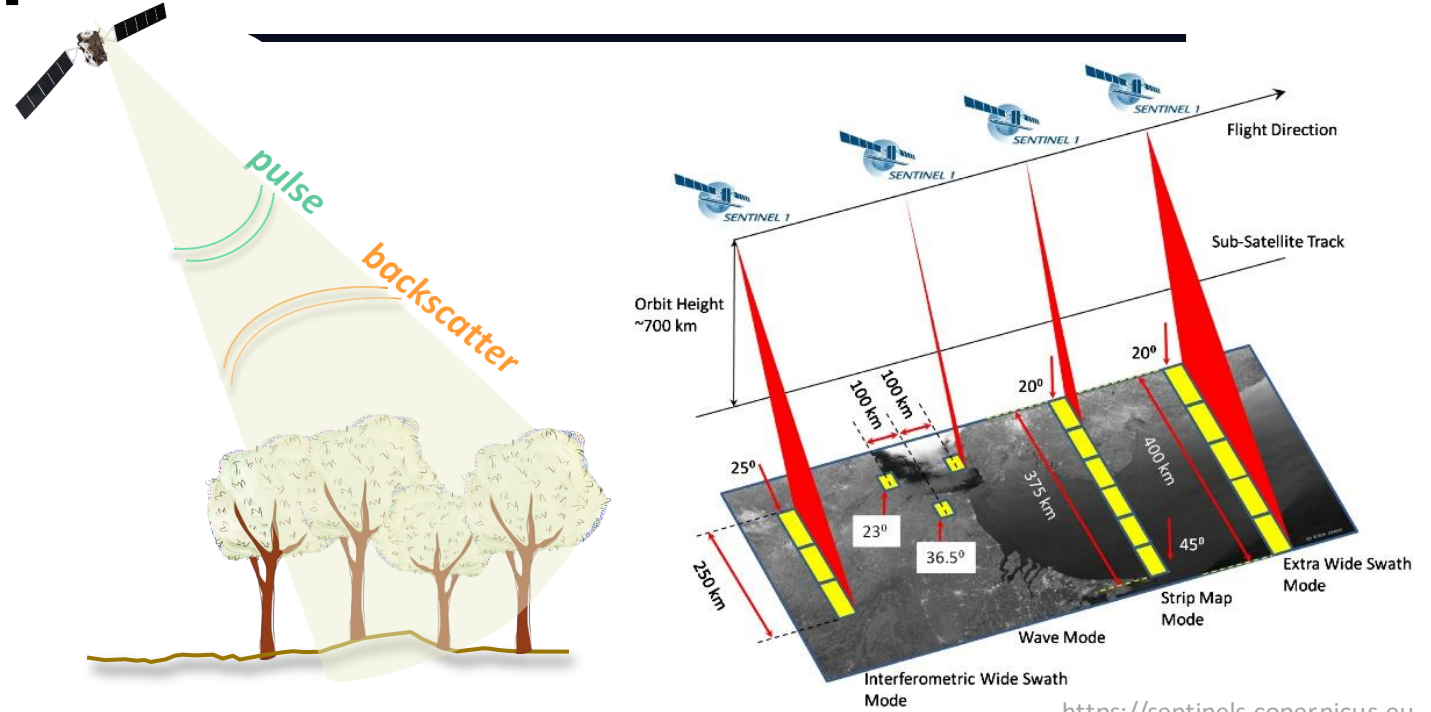
Sentinel-1 – Radar vision

Mission objectives:

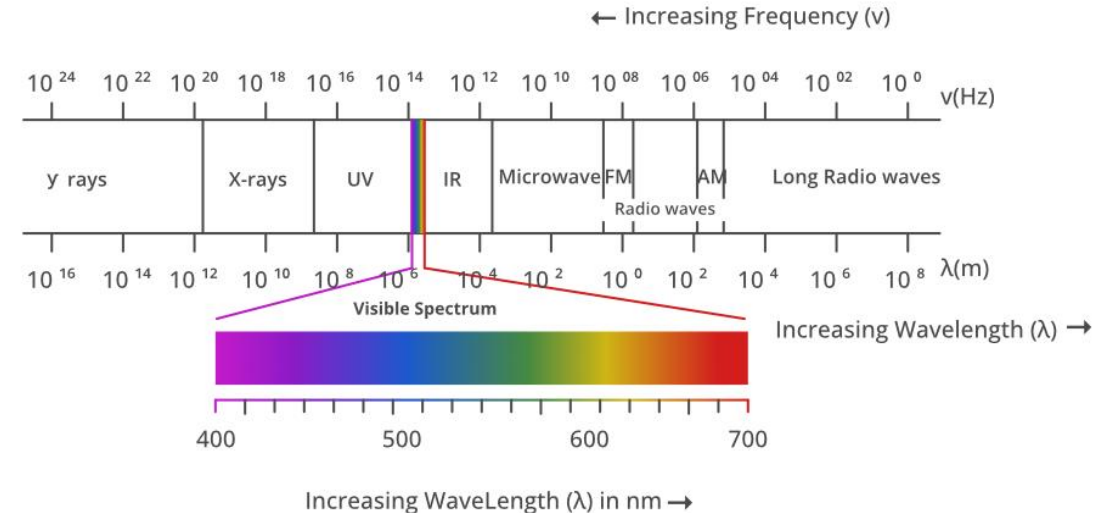
- Marine and land monitoring
- Emergency management

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



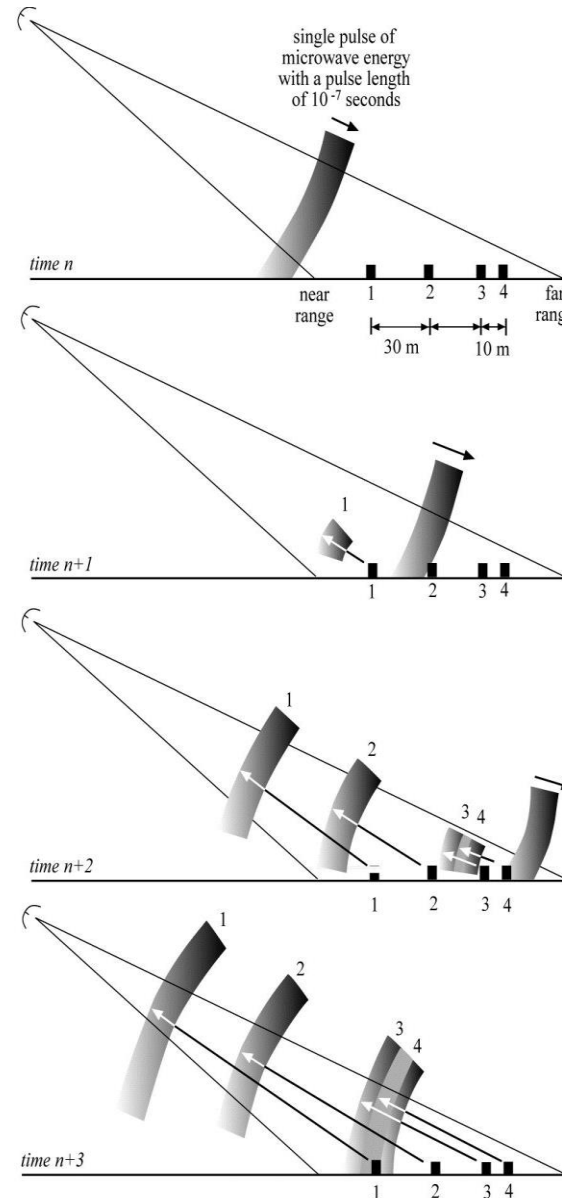
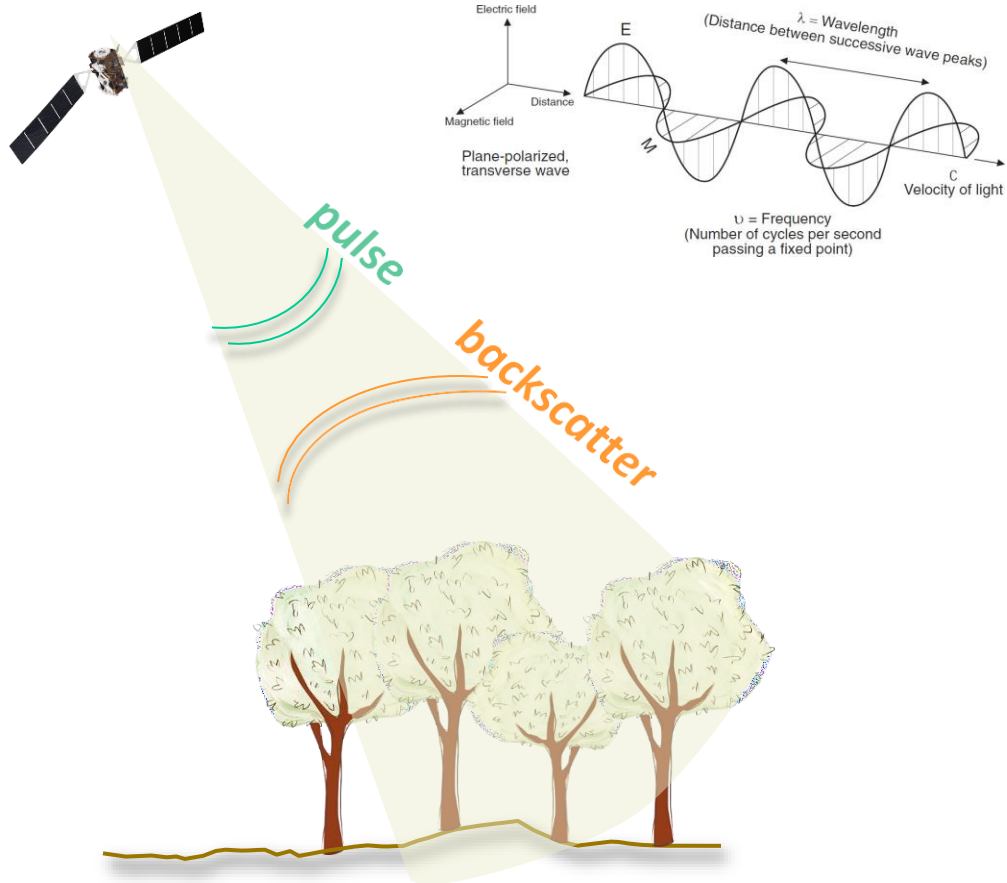
<https://sentinels.copernicus.eu>



Active Radar Remote Sensing

Basic characteristics of radar systems/SAR sensors

Active \Rightarrow independent of sun illumination
(generate EM-waves)



Radar principle

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

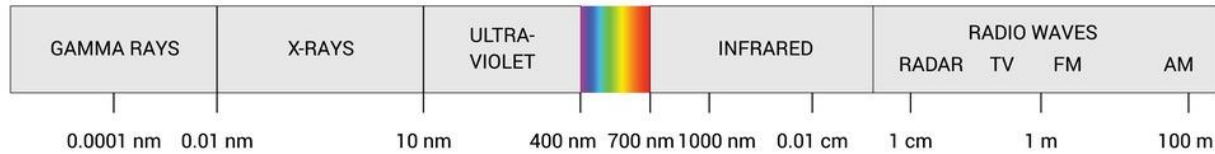
The energy of a single pulse is reflected from objects on the surface in order of distance from source/transmitter on board

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

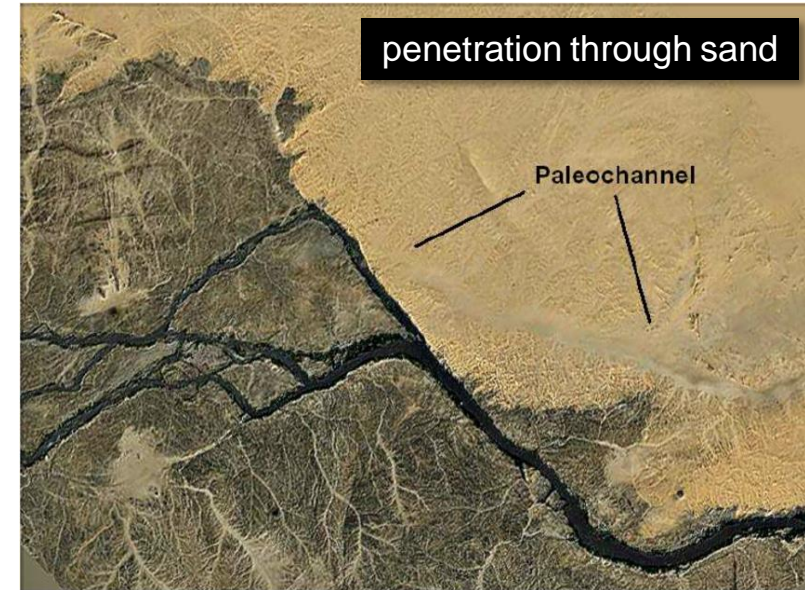
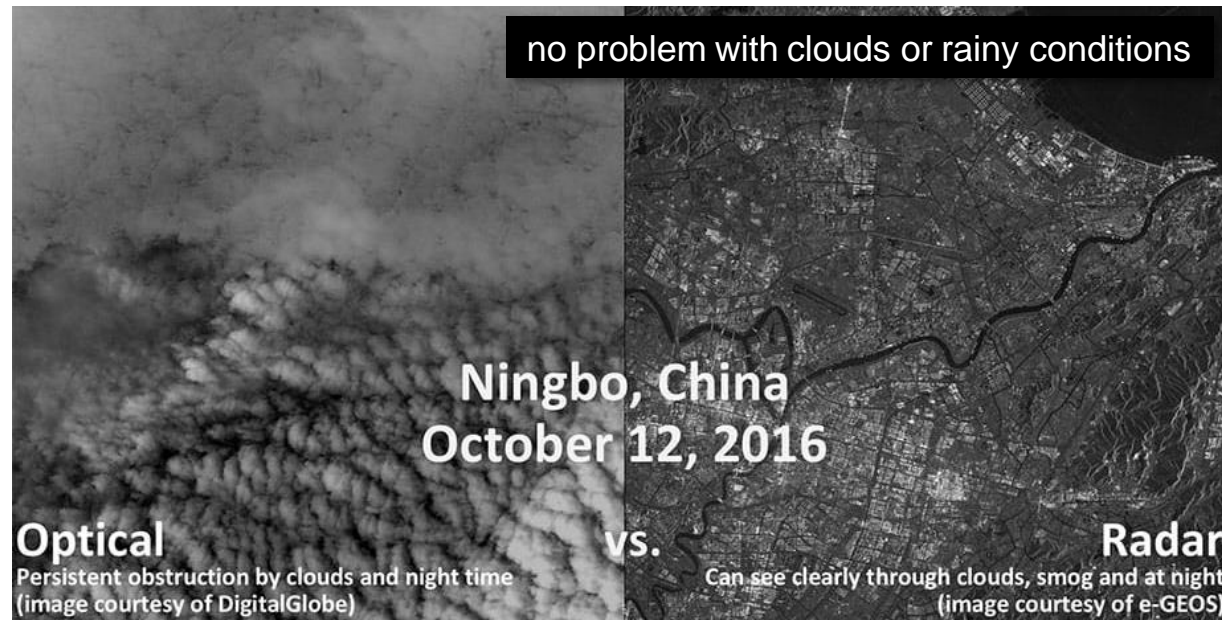
Active Radar Remote Sensing

Basic characteristics of radar systems/SAR sensors

SPECTRUM



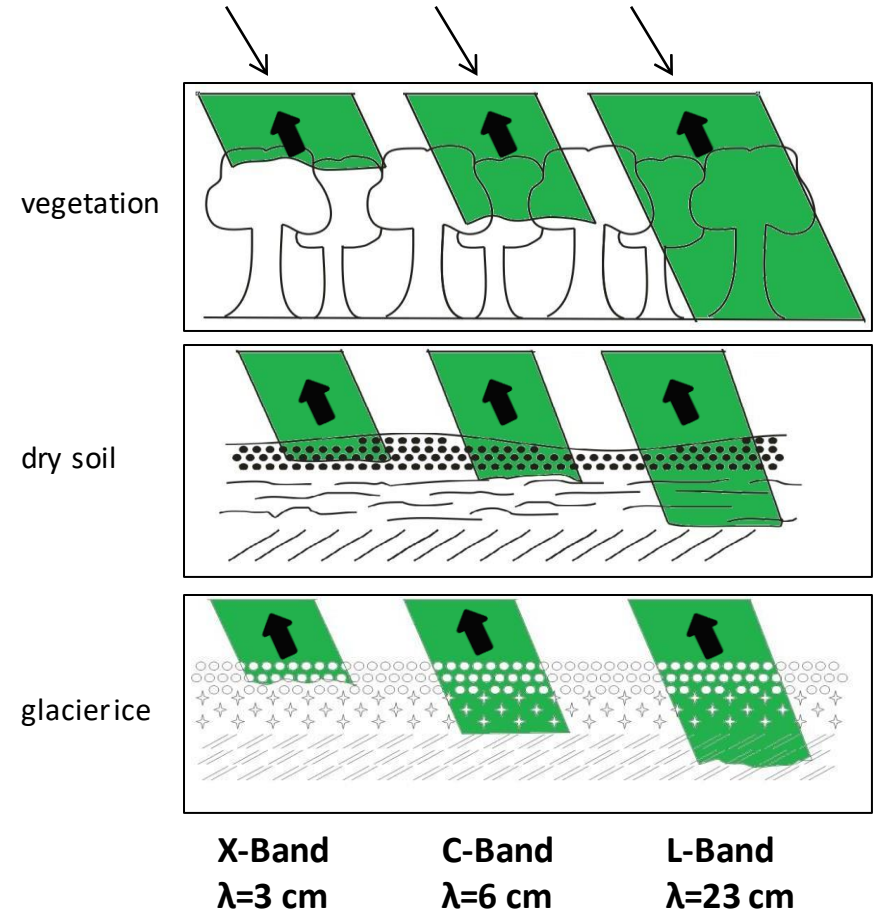
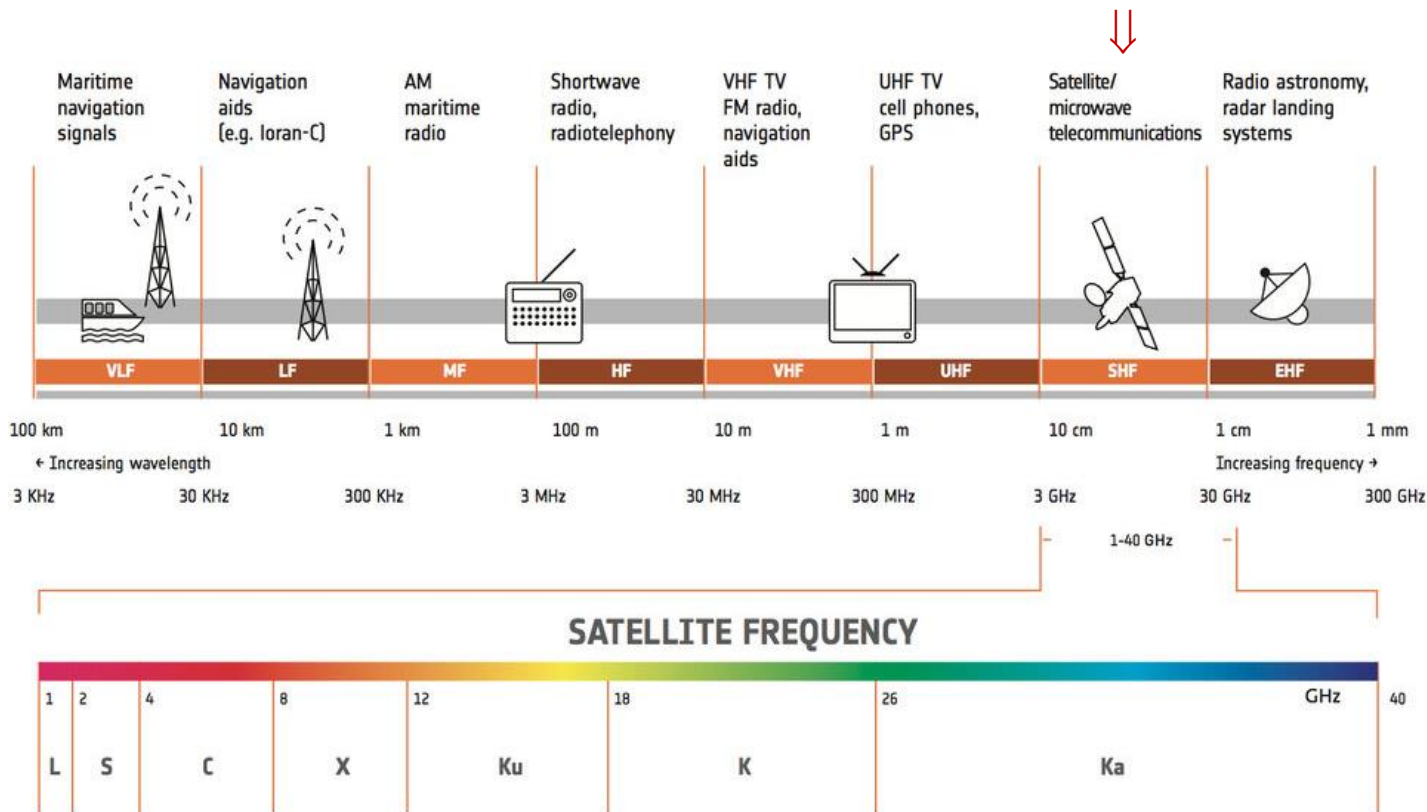
Microwave ⇒ penetrates into/through objects



Active Radar Remote Sensing

RADAR band designations, wavelengths and frequencies

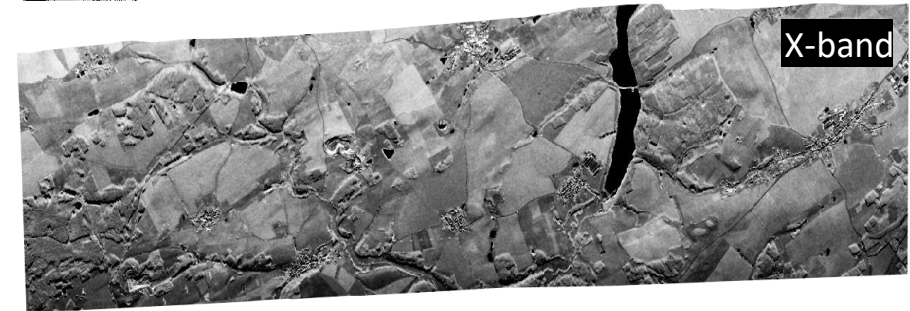
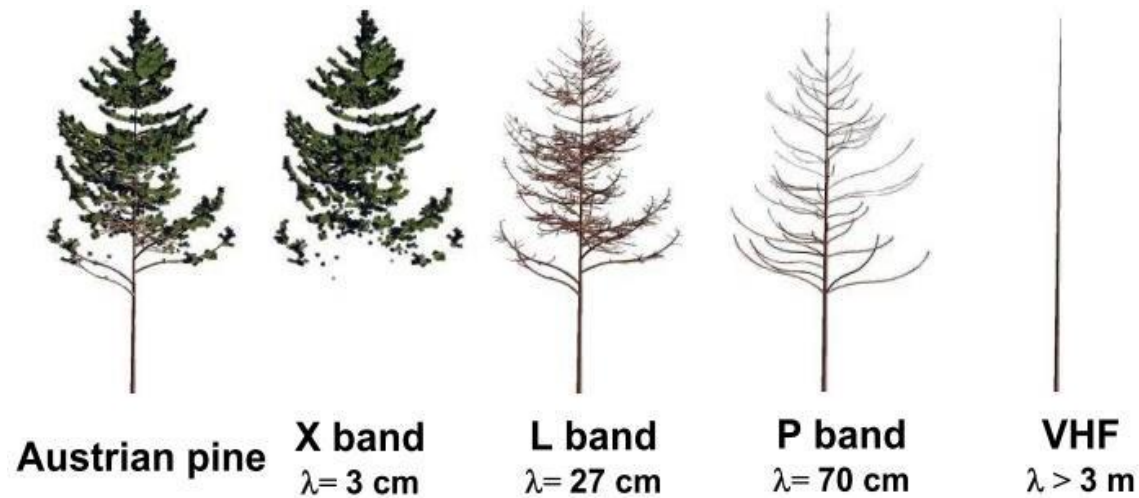
- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects



Active Radar Remote Sensing

RADAR band designations, wavelengths 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 – interferometric synthetic aperture radar
 - D-insar
 - PS-insar

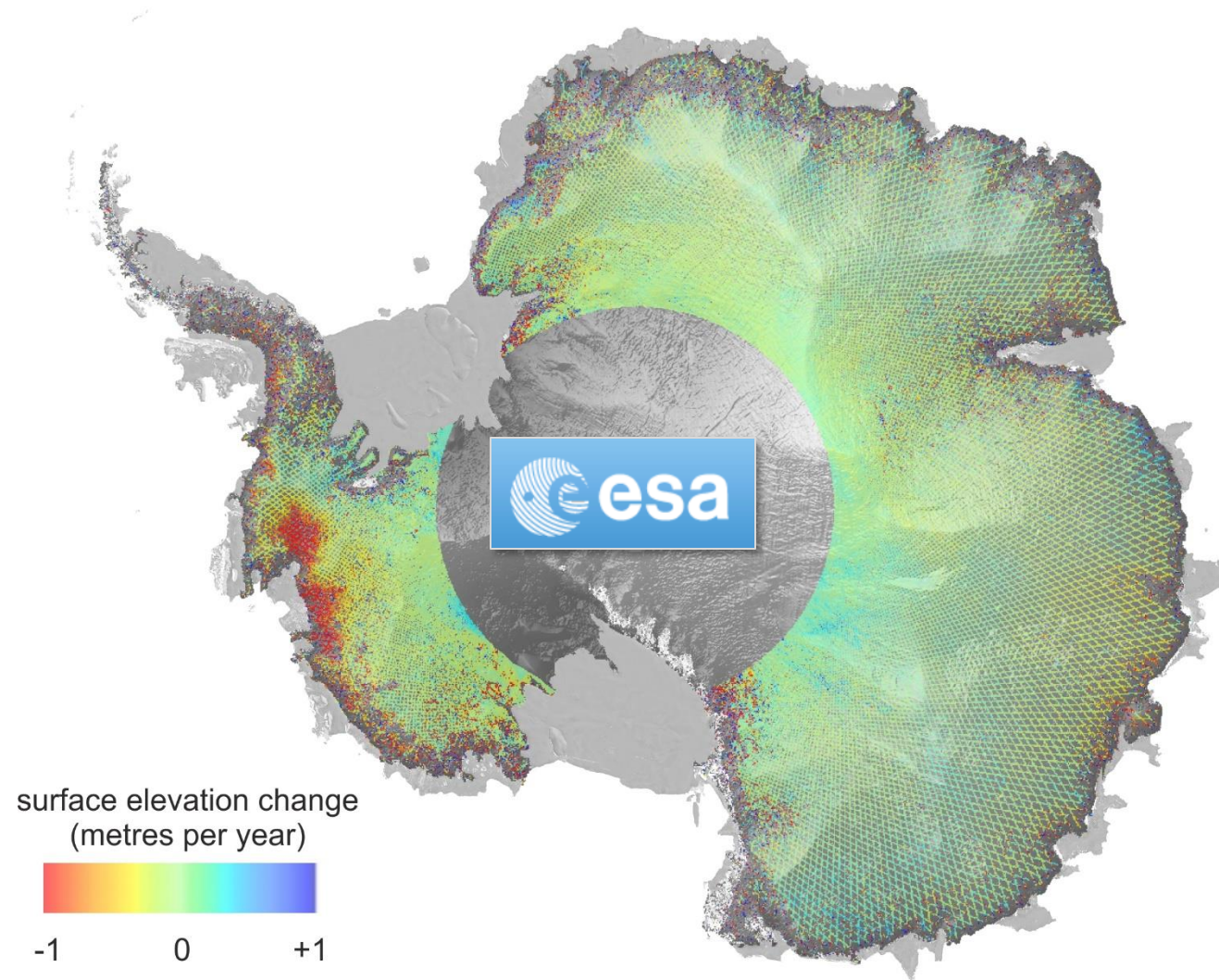
Radar Altimetry = measuring altitude / vertical height



[Article ESA](#)

[video](#)
[video 2](#)

Radar Altimetry = measuring altitude / vertical height



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

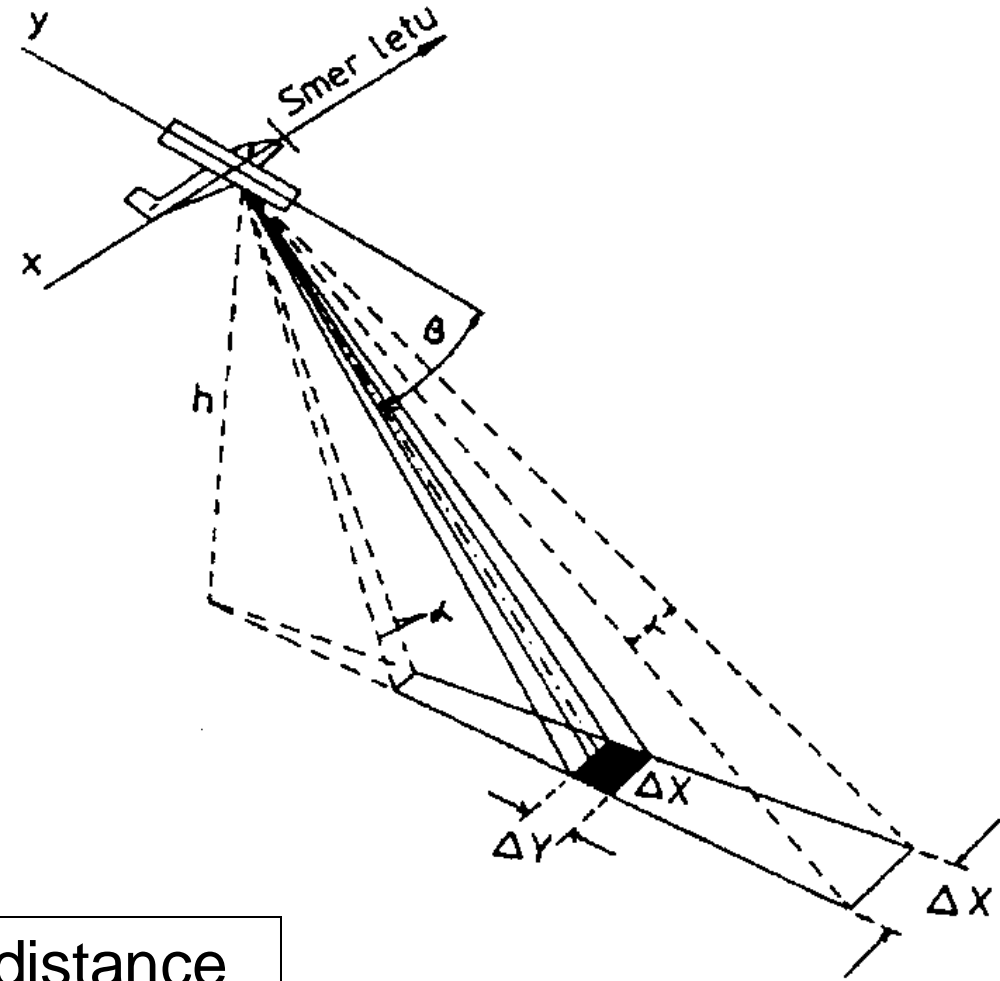
Side looking radar (SLAR)

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

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

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.



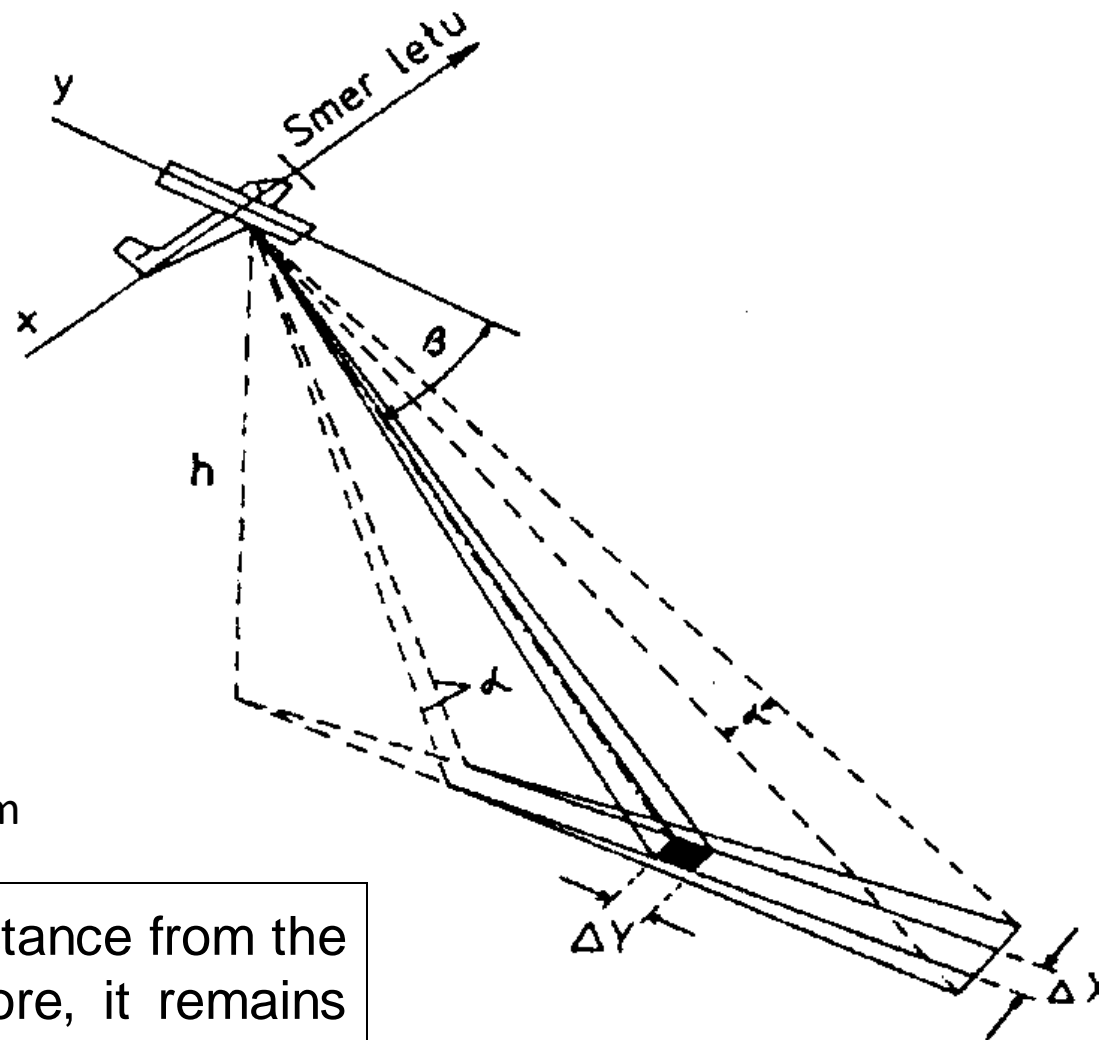
Synthetic aperture radar (SAR)

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

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

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.

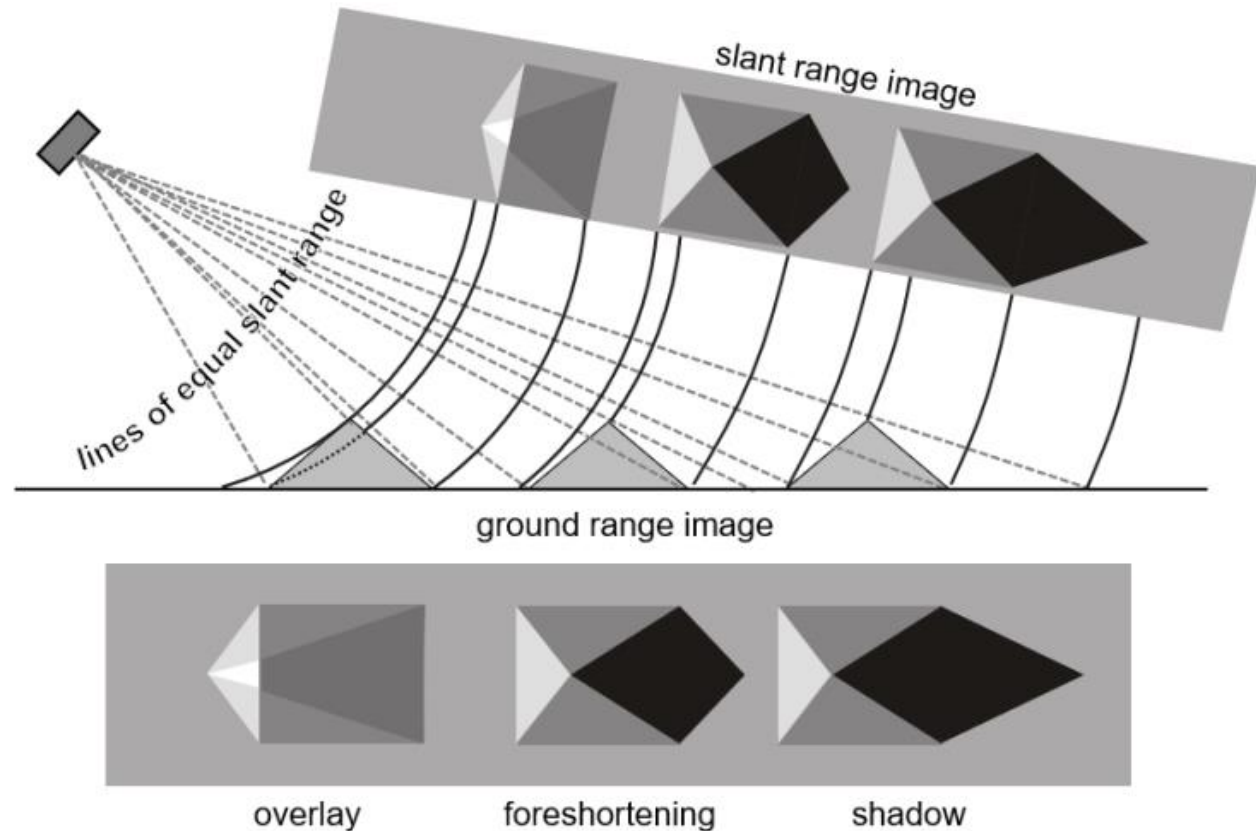


Geometric Effects in SAR images

Effects of side-looking geometry

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

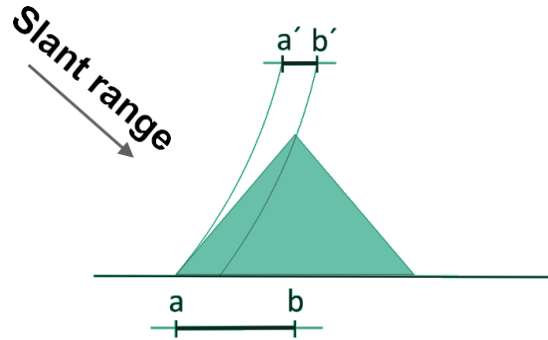
- The effects are:
 - ❖ Foreshortening
 - ❖ Layover
 - ❖ Radar shadow
- Controlled by:
 - ❖ Incidence angle
 - ❖ Topography



Geometric distortions in radar images (Braun 2019)

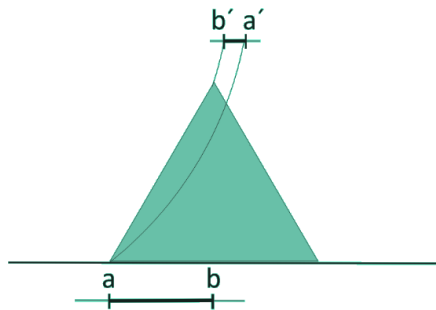
Geometric Effects in SAR images

Foreshortening



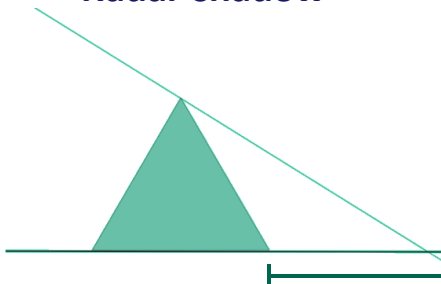
- Slopes oriented to the SAR appear compressed (Distance between a and b is shortened)
- Appears as very bright area
- More pronounced in near range (small incidence angle) than in far range (high incidence angles)

Layover



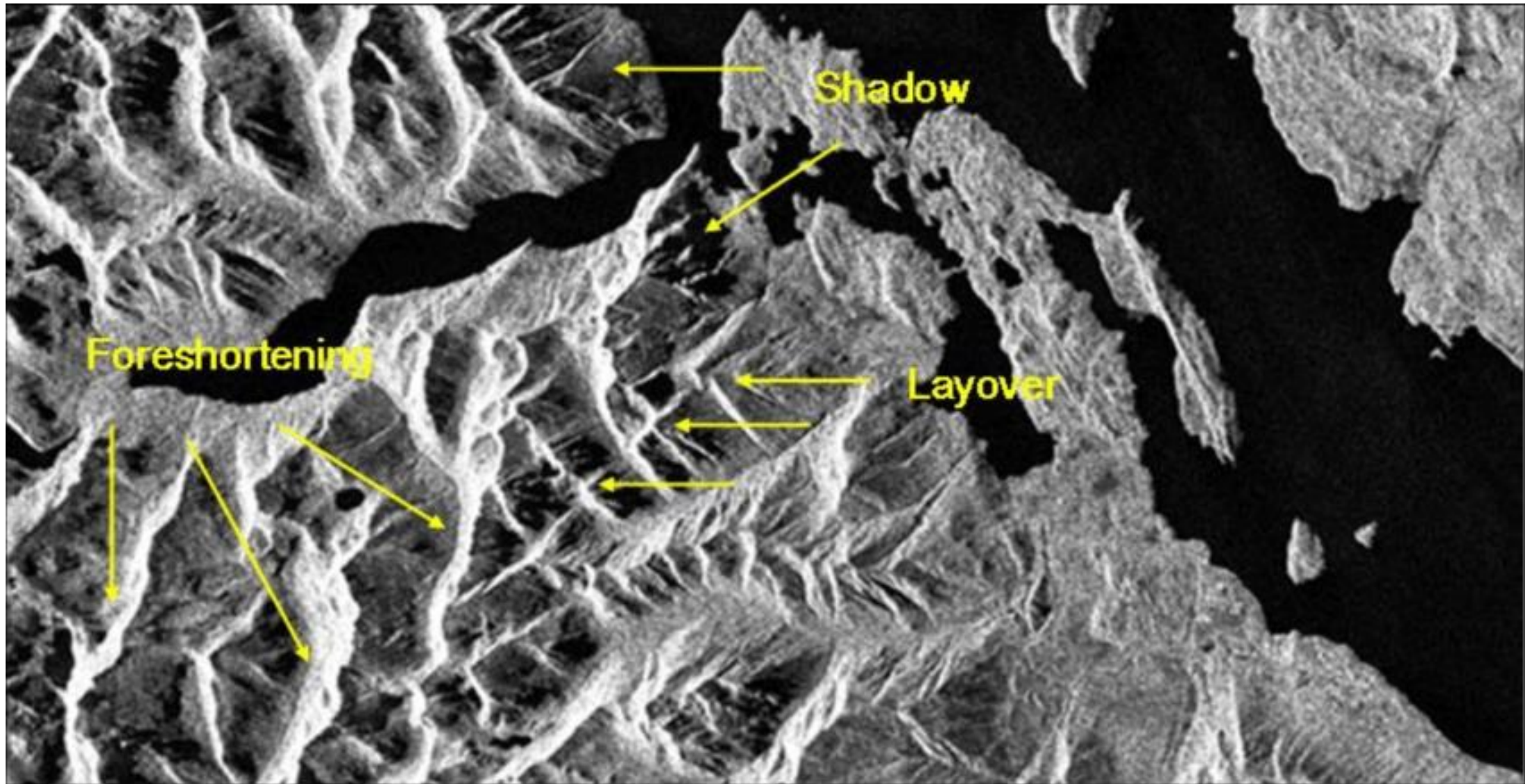
- Steep slopes oriented to the SAR lead to ghost images
- When radar beam reaches the top of a high feature (b) before it reaches the base (a)

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



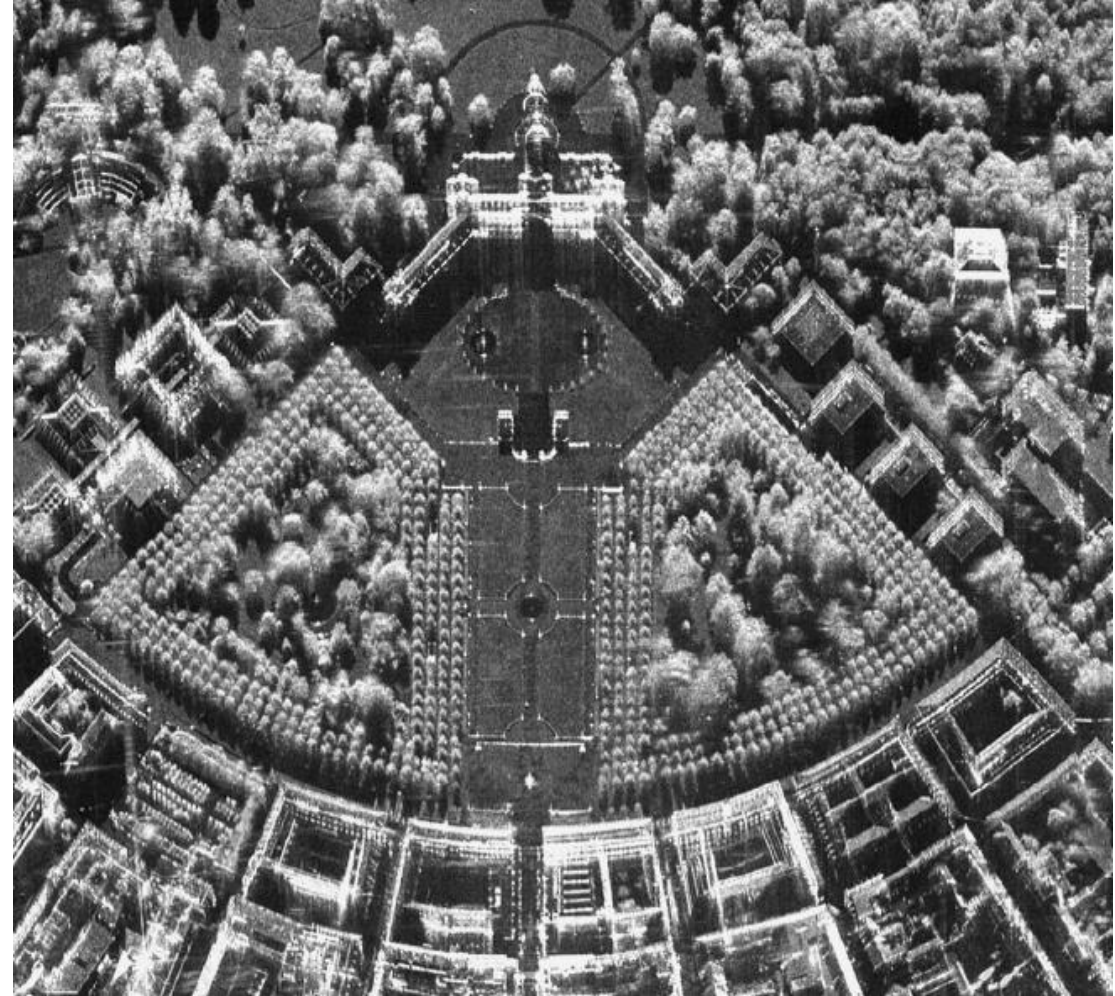
Source: <https://www.researchgate.net/profile/M-Lenzano/publication/263124688/figure/fig23/AS:614356547039256@1523485423960/Figura-9-Efectos-de-shadowing-foreshortening-y-layover-en-una-imagen-SAR-de-RADARSAT-1.png>

Geometric Effects in SAR images

Effects of side-looking geometry

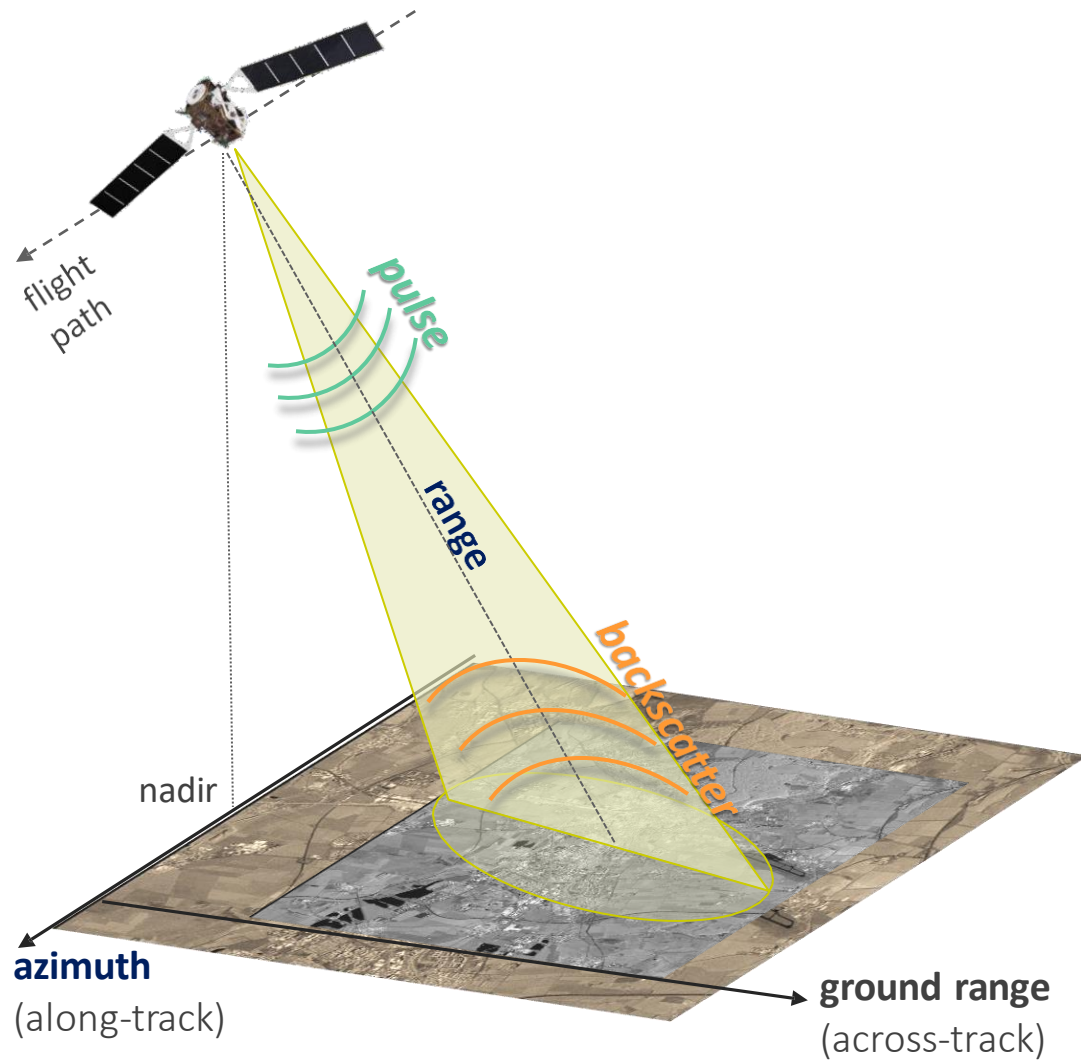


Google maps

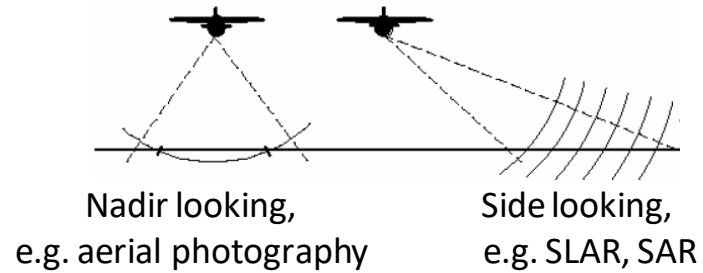


Andreas R. Brenner and Ludwig Roessing, Radar Imaging of Urban Areas by Means of Very High-Resolution SAR and Interferometric SAR, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 46, NO. 10, OCTOBER 2008 (X-band)

Radar side looking imaging geometry



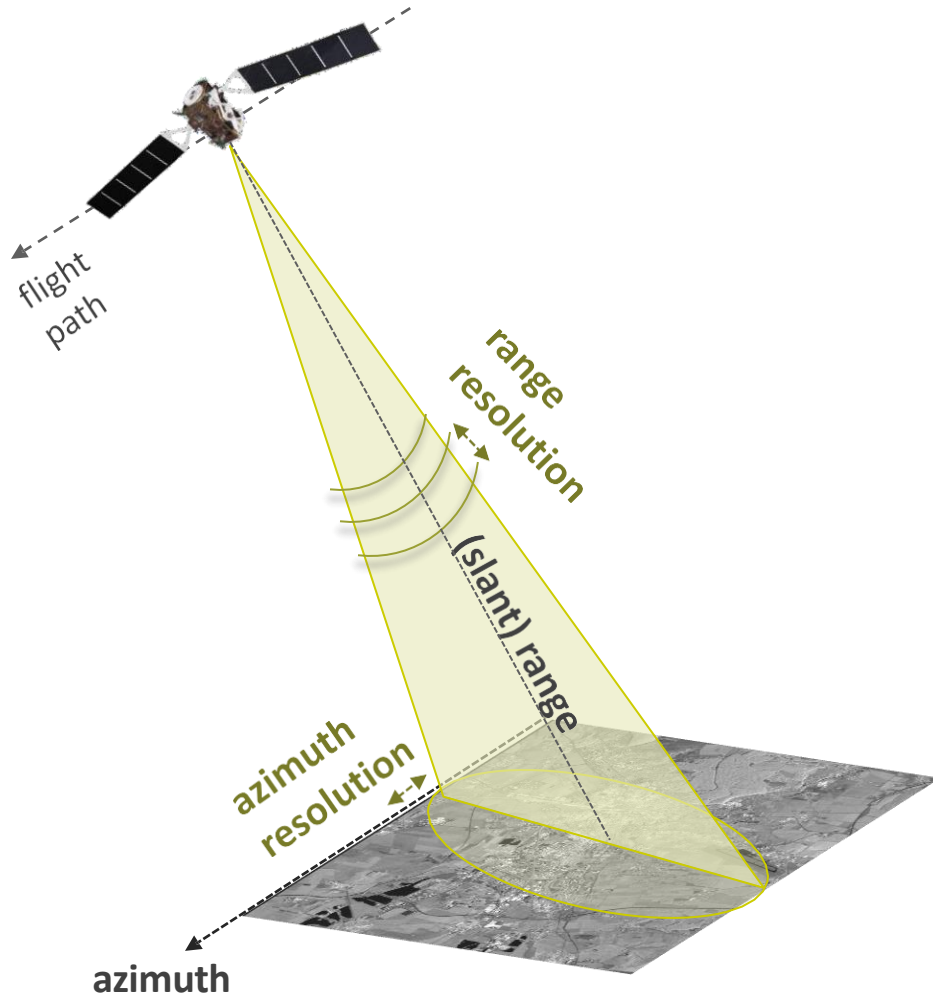
Is side looking really necessary?



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



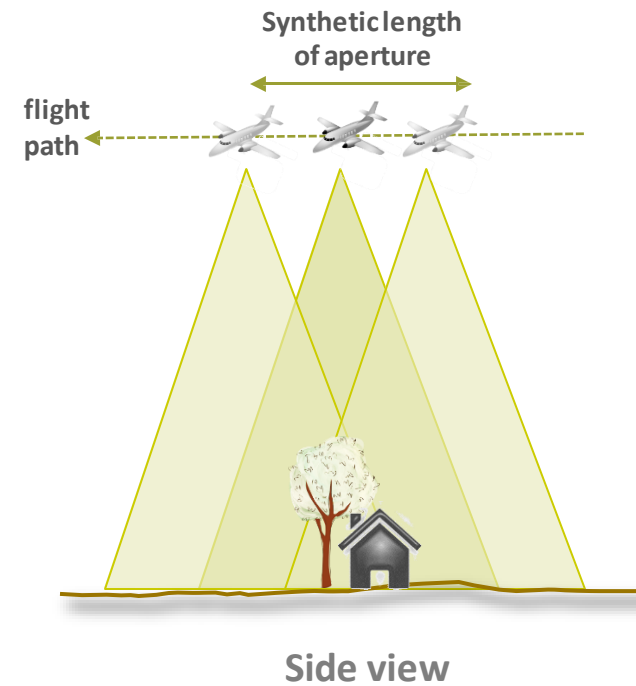
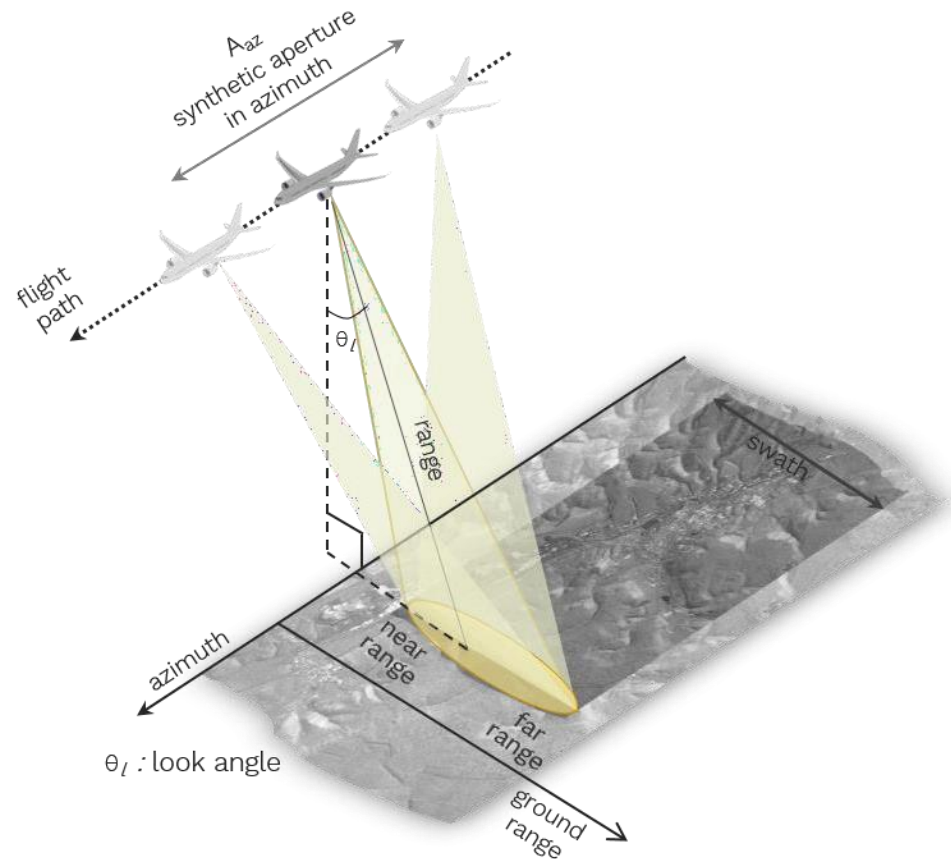
slant-range resolution depends on the bandwidth of the system

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

Synthetic Aperture Radar (SAR)

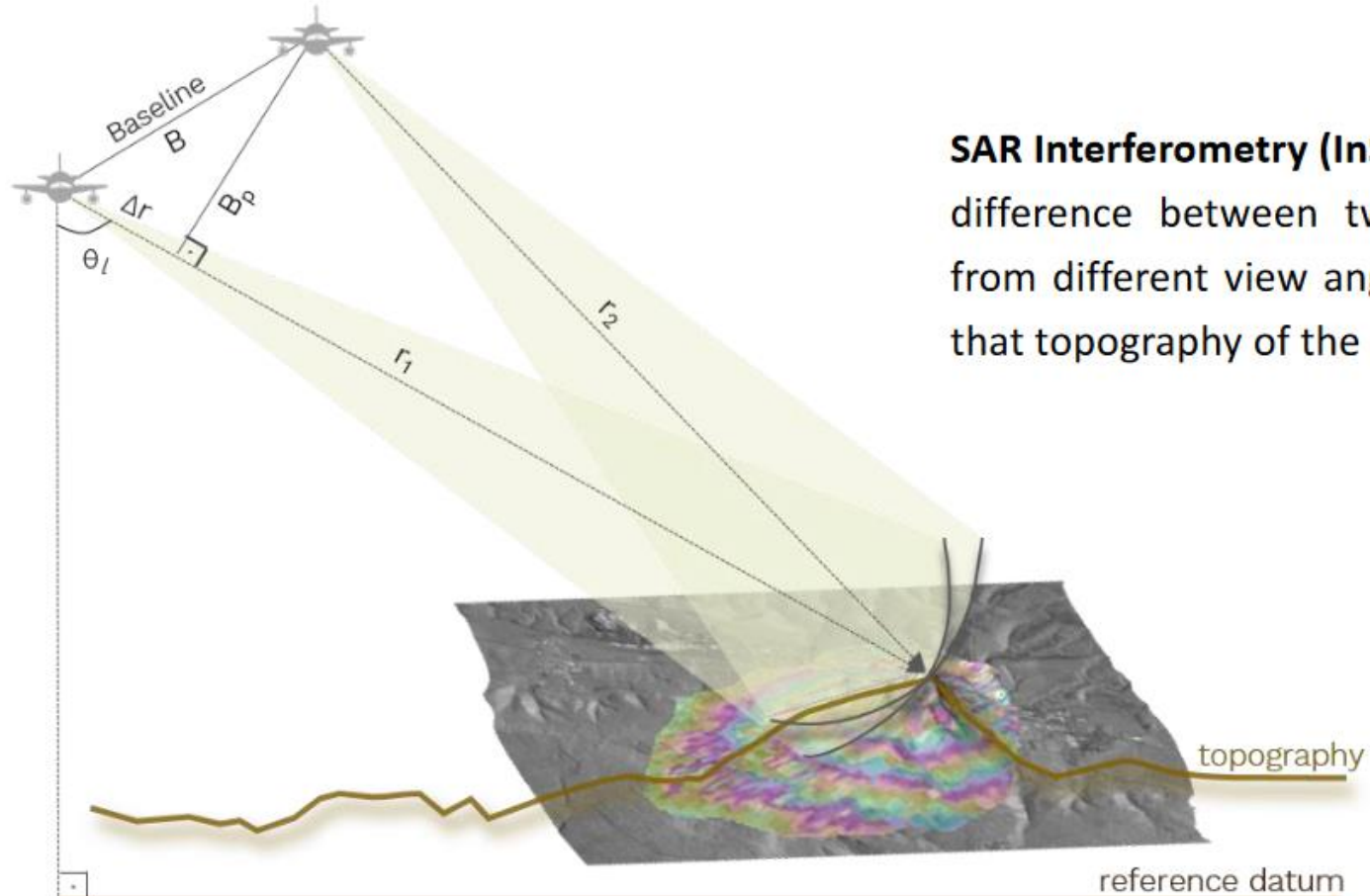
The principle of extending the antenna

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

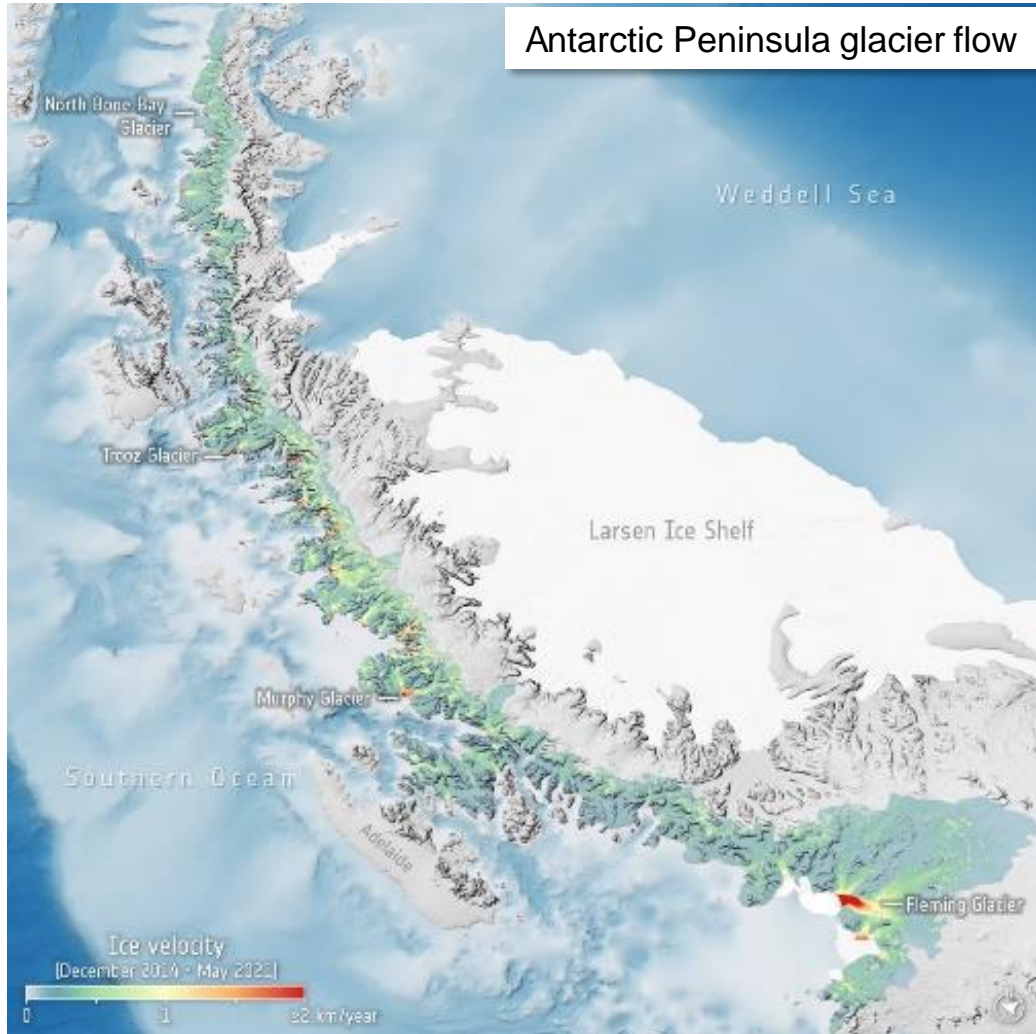
θ_l : look angle

r_1 & r_2 : range distance for the respective acquisitions

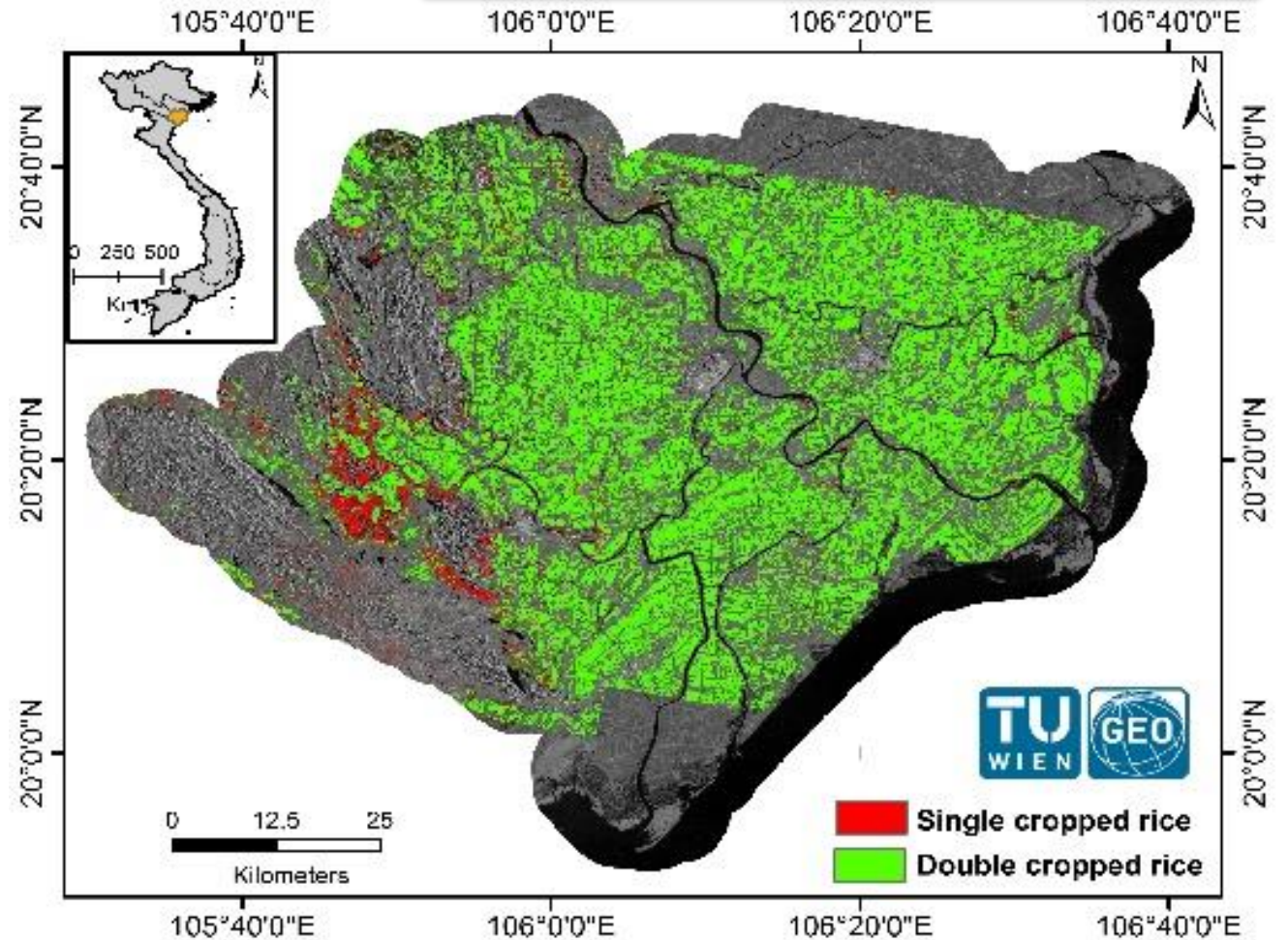
Δr : range difference

Sentinel-1 – Applications

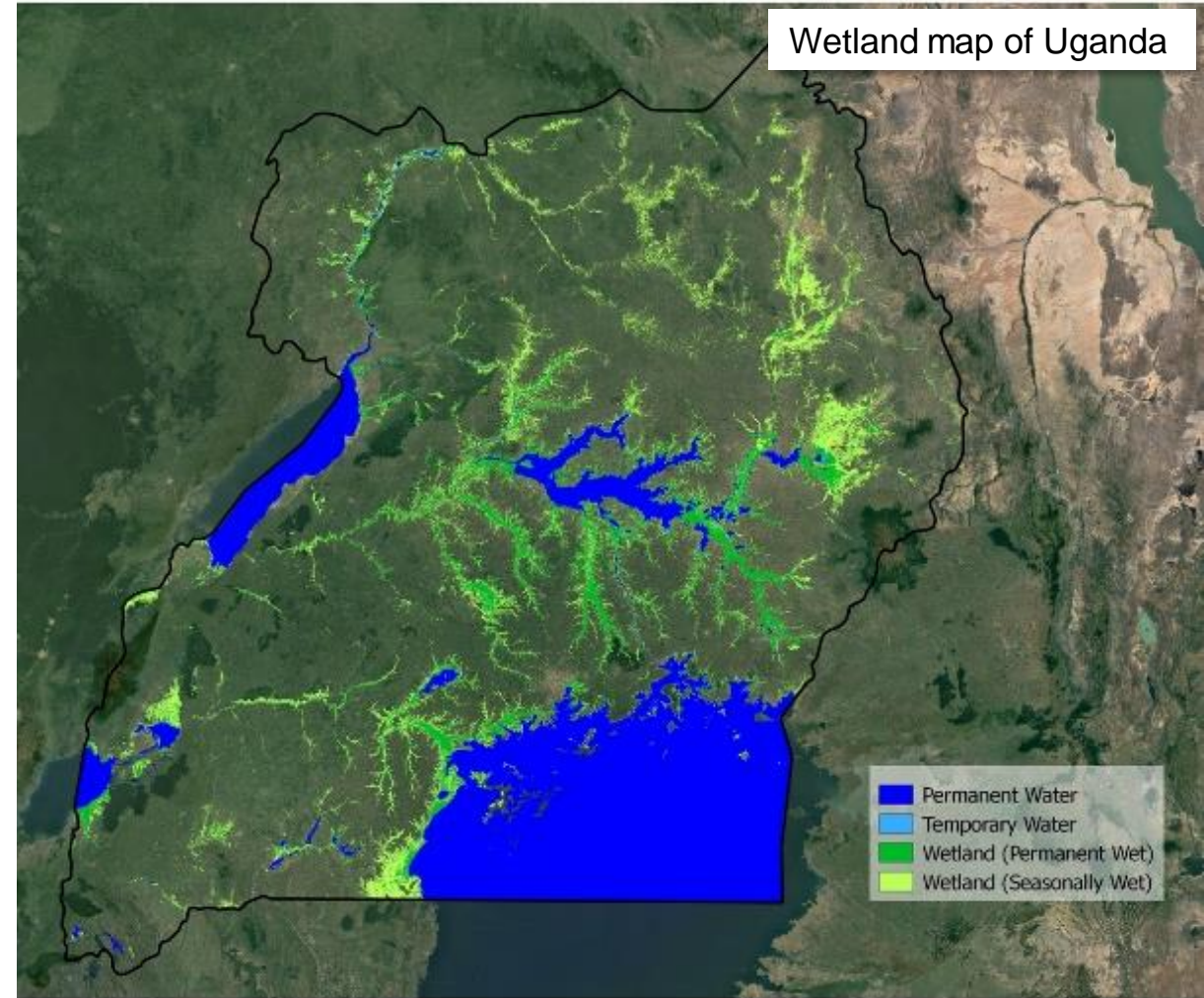
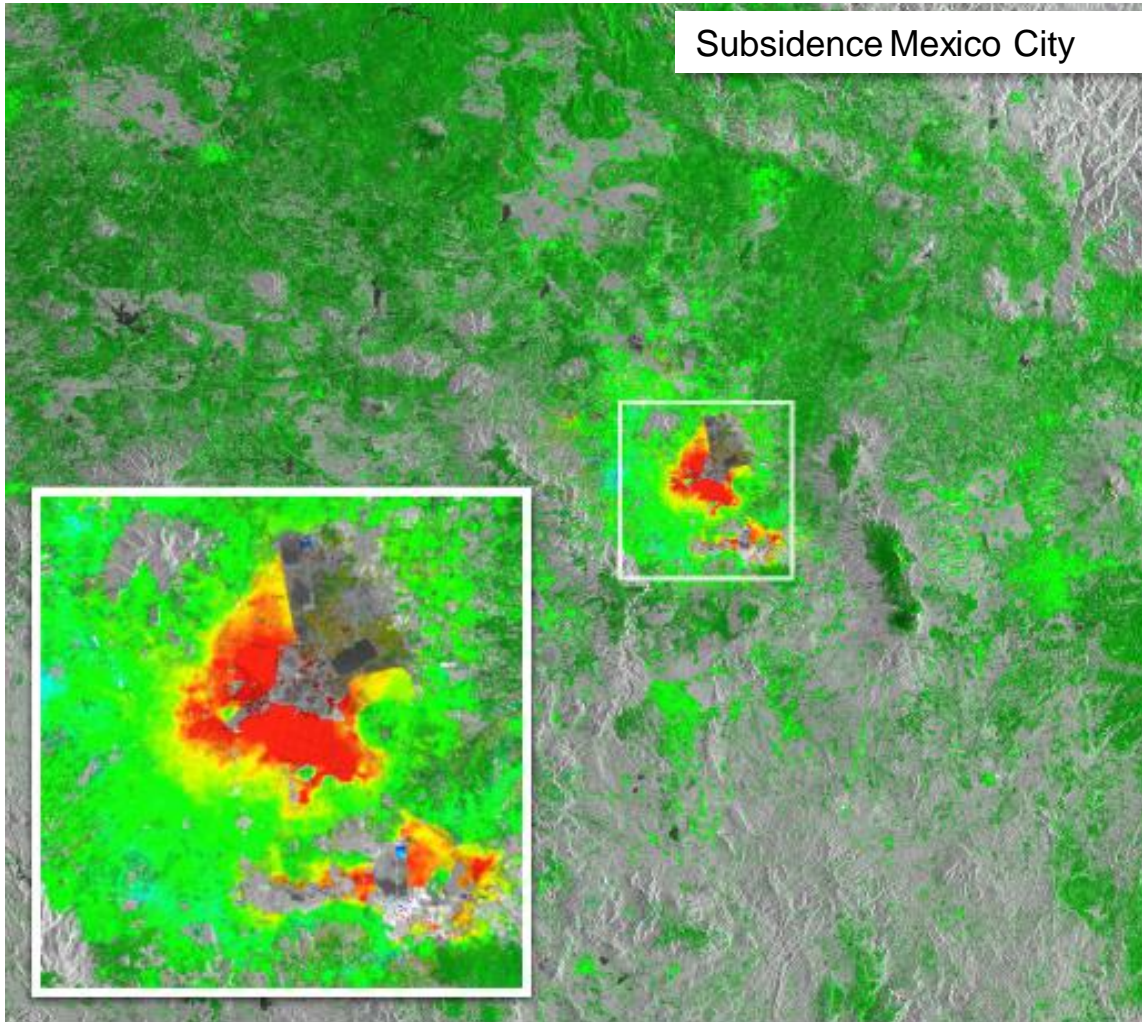
Antarctic Peninsula glacier flow



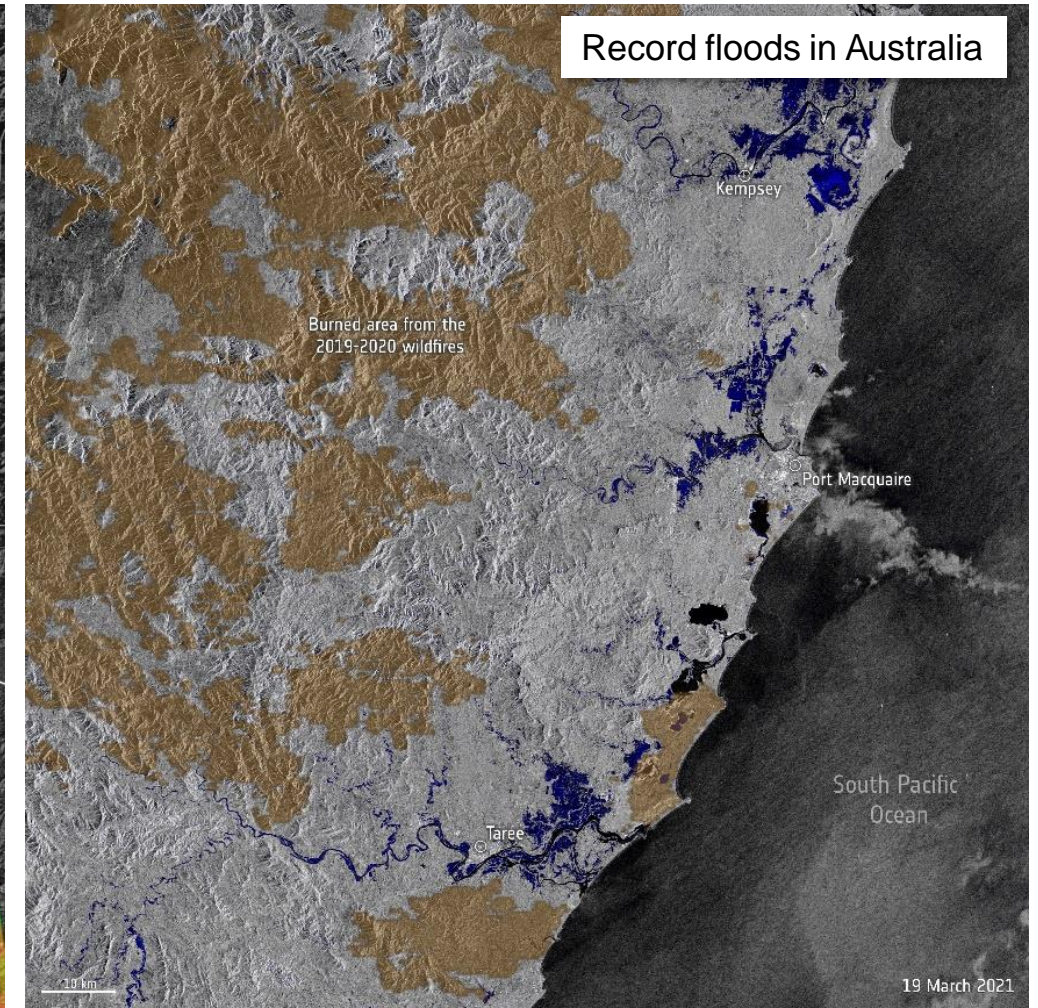
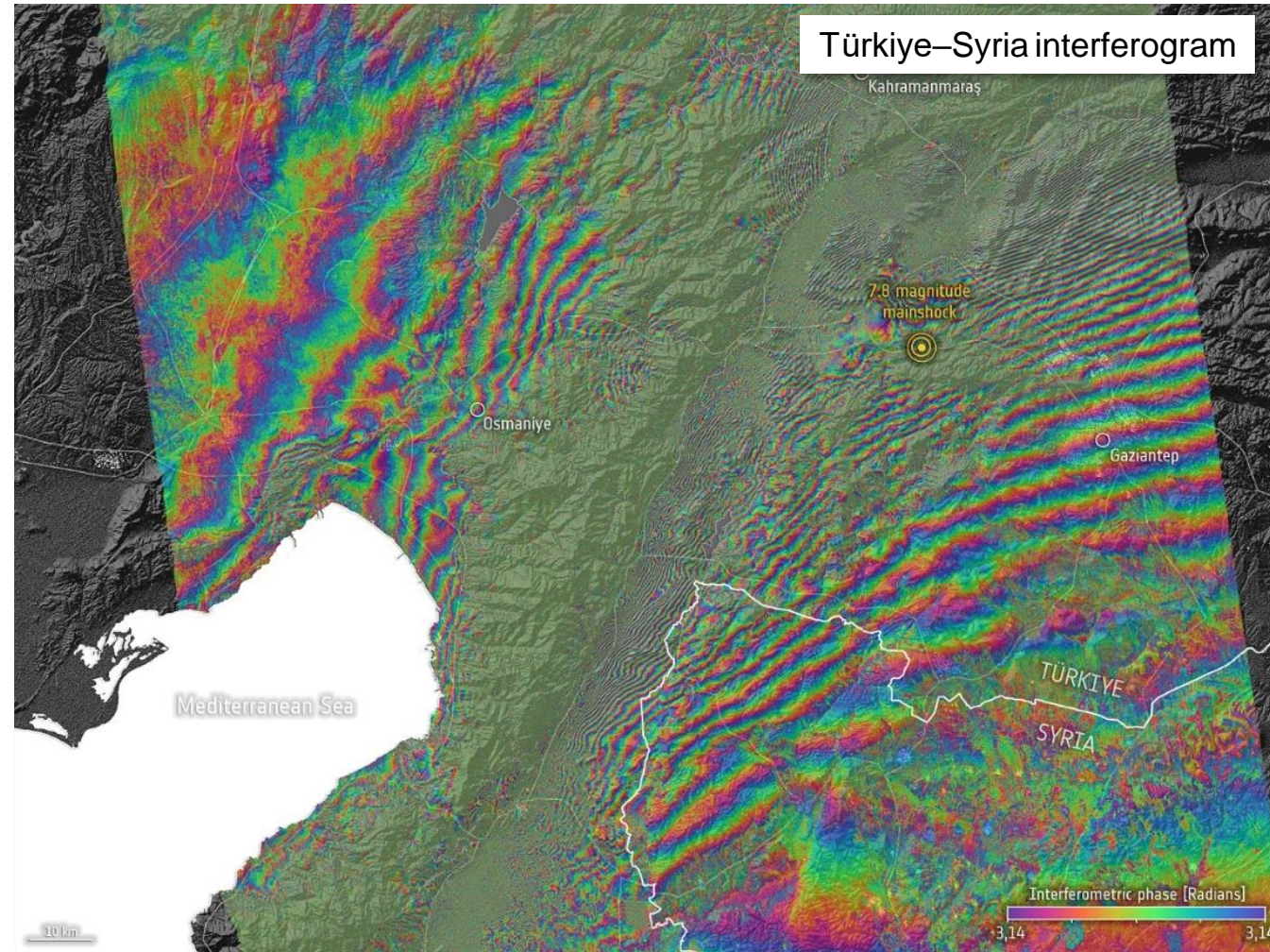
Rice-cropping systems in Vietnam's Red River Delta



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



ESA Third Party Missions

- 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)

- Data Policy of individual data providers

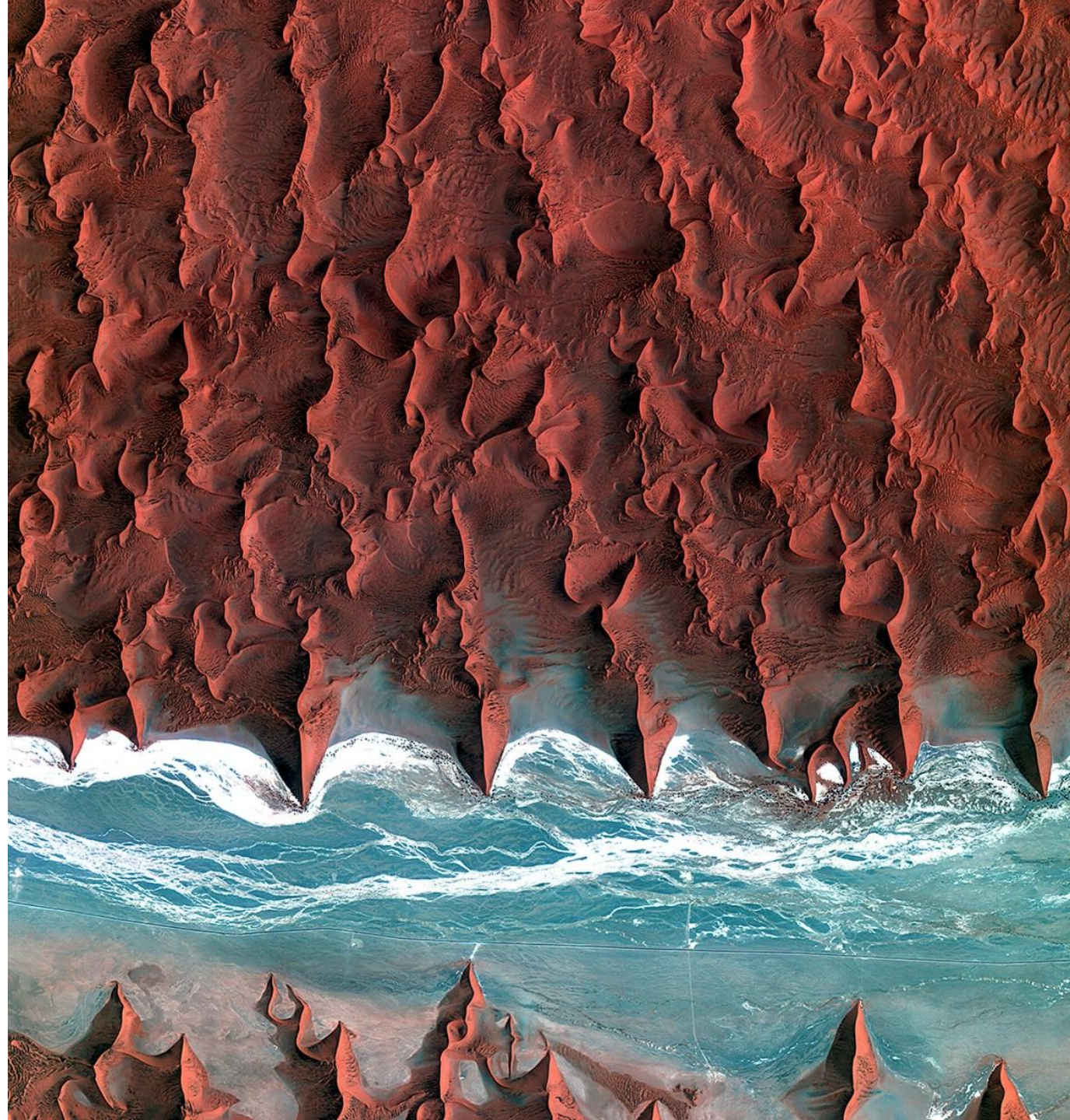
In some case, a reproduction cost (e.g. ALOS) or Specific Restrictions (limitations of quota, geographical restrictions, etc.) to the use of data may be applied for TPM

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:](https://www.esa.int/ESA_Multimedia/Images/2013/04/Namib_Desert)



Copernicus Data Space Ecosystem

<https://dataspace.copernicus.eu/>

The screenshot shows the homepage of the Copernicus Data Space Ecosystem. The background is a solid blue color. At the top right, there is a navigation menu with links for 'News', 'Events', 'Gallery', 'Videos', and 'About'. Below this, on the left, are the logos for the 'PROGRAMME OF THE EUROPEAN UNION', 'Copernicus', and 'esa'. In the center, there are three main navigation categories: 'EXPLORE DATA', 'ANALYSE DATA', and 'ECOSYSTEM', each with a dropdown arrow. To the right of these are two buttons: 'SUPPORT' and 'LOGIN'. The main content area features a large, stylized graphic of a satellite image of a landscape, framed by concentric blue circles. To the left of this graphic, the text reads: 'Easy data discovery, visualization and download'. Below this, a smaller paragraph states: 'Explore and engage with satellite imagery, using our user-friendly and intuitive Copernicus Browser. The browser is open to all and easy to navigate. You can easily search, visualize and download satellite data, and much more.' At the bottom left of this section is a green button that says 'DISCOVER THE COPERNICUS BROWSER'. At the bottom right, there is a source attribution: 'Source: <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 screenshot shows the Copernicus Open Access Hub website. At the top, there is a blue header with the Copernicus logo, the text 'Copernicus Open Access Hub', and logos for ESA and the European Union. Below the header, the main content area is divided into several sections:

- Welcome to the Copernicus Open Access Hub:** A dark blue header with white text. Below it, a paragraph explains that the hub provides complete, free, and open access to Sentinel-1, Sentinel-2, Sentinel-3, and Sentinel-5P user products. A second paragraph mentions the launch of the Copernicus Data Space Ecosystem on January 24, 2023, and provides information about new features and a roadmap. A third paragraph states that the Copernicus Data Hub distribution service will continue until the end of June 2023. A fourth paragraph mentions that Sentinel data is also available via DIAS through several platforms.
- Reports & Stats:** A white box with a dark blue header. It shows 'Data updated hourly' and two statistics: '38,892 prod. published in the last 24h' (with an upward arrow icon) and '338,550 downloads in the last 24h' (with a downward arrow icon). There is also a 'Reports' link with a bar chart icon.
- Resources:** A white box with a dark blue header. It lists several resources: 'DHUS Open Source Portal', 'Copernicus Copernicus Portal', 'ESA Sentinel Online', and 'Sentinel Vision Stories'.
- Navigation Buttons:** A row of four dark blue buttons with white text and icons: 'Open Hub' (with a globe icon), 'API Hub' (with a globe and gear icon), 'S-5P Pre-Ops' (with a globe and satellite icon), and 'POD Hub' (with a globe icon).

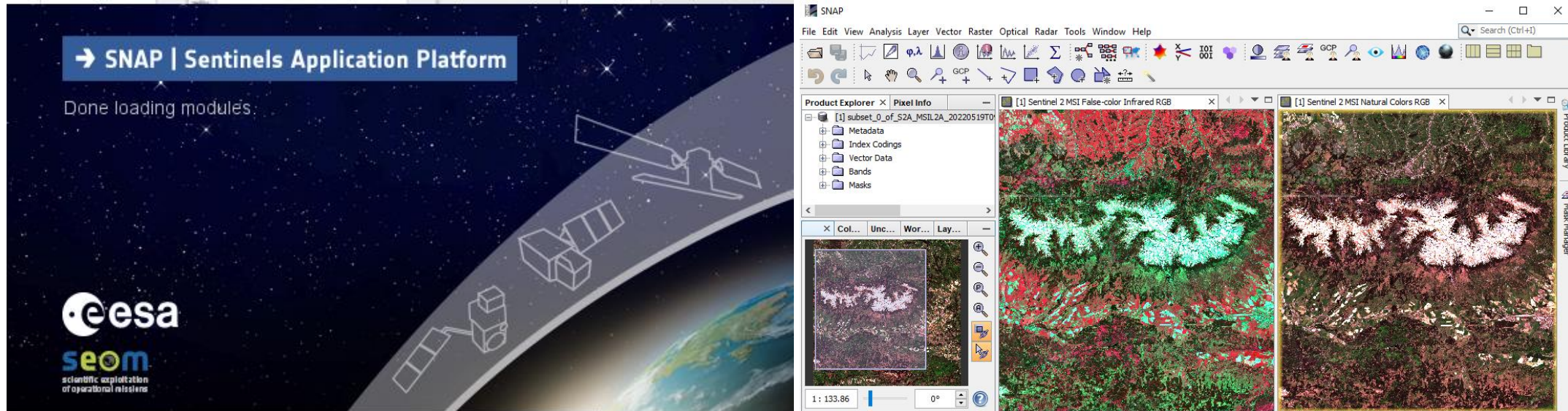
At the bottom left of the screenshot, there is a small 'ESA UN' logo.

- 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



Source:
https://www.esa.int/ESA_Multimedia/Images/2017/03/The_Karavasta_Lagoon_in_Albania_looks_spectacular/

EO Browser - SENTINEL Hub

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

The image displays two screenshots of the EO Browser interface, illustrating the process of selecting and visualizing Sentinel-1 data.

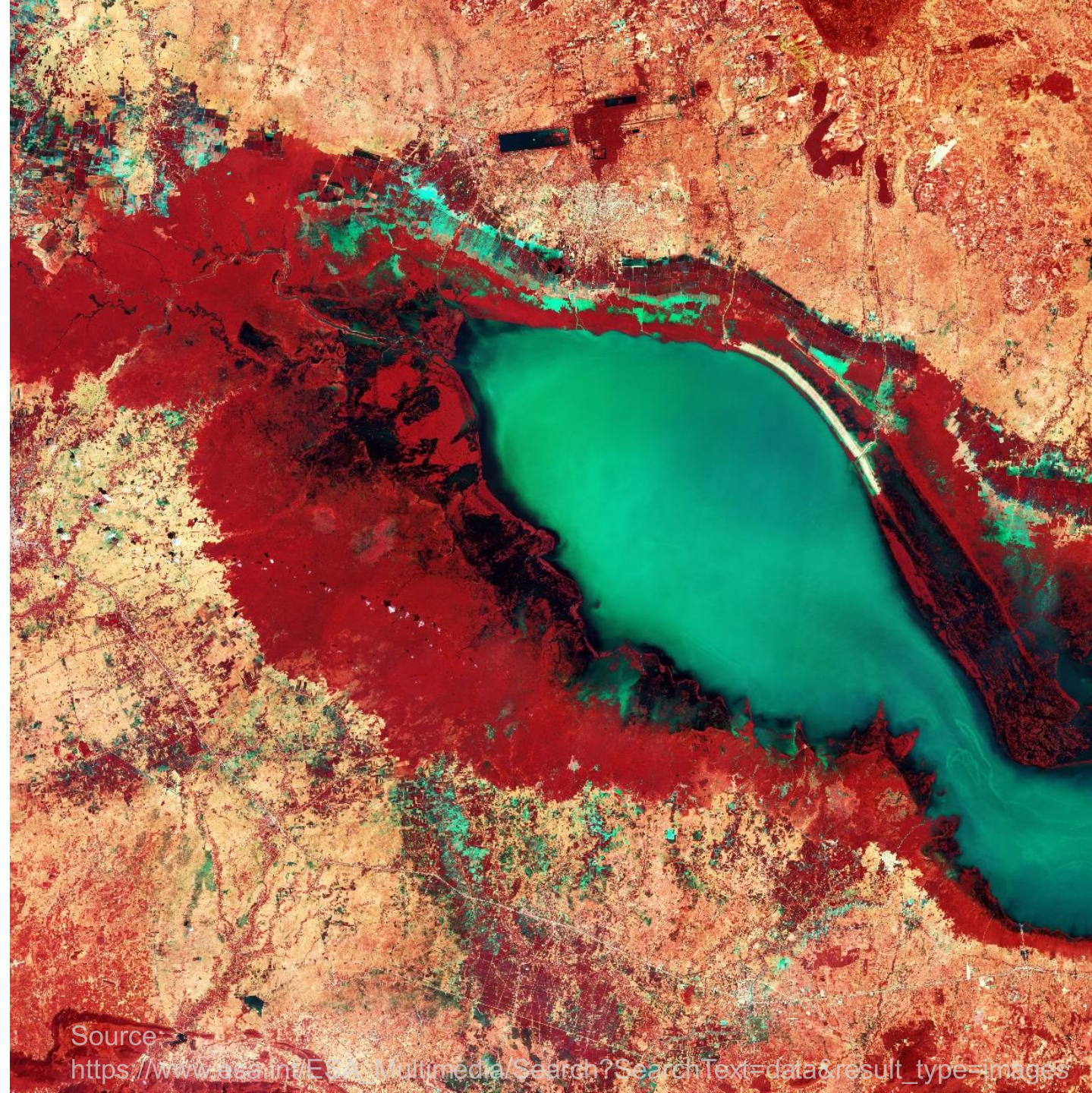
Top Screenshot: Shows the main interface with a map of Rome. The left sidebar is open to the "Data sources" panel. The "Sentinel-1" source is selected, and a yellow arrow points to the "Advanced search" toggle. Other data sources listed include Sentinel-2, Sentinel-3, Sentinel-5P, Landsat 1-5 MSS L1, Landsat 4-5 TM, Landsat 7 ETM+, Landsat 8-9, Harmonized Landsat Sentinel, and MODIS.

Bottom Screenshot: Shows the same map area but with a different visualization. The "Dataset: Sentinel-1 AWS-W-VVH" panel is open, displaying the date "2023-10-02" and a list of visualization options. The option "WH - decibel gamma0 - radiometric terrain corrected" is highlighted with a yellow circle. Other options include SAR urban, RGB ratio, Enhanced visualization, and various gamma0 and linear gamma0 options.

EO data access

Commercial EO platforms

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



Source:

https://www.esa.int/EOA/Multimedia/Search?SearchText=data&result_type=images

Thank you for the attention