



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)

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

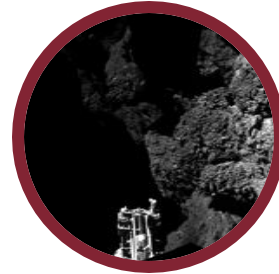
*Article 2 of the ESA Convention*



# Activities

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- 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**



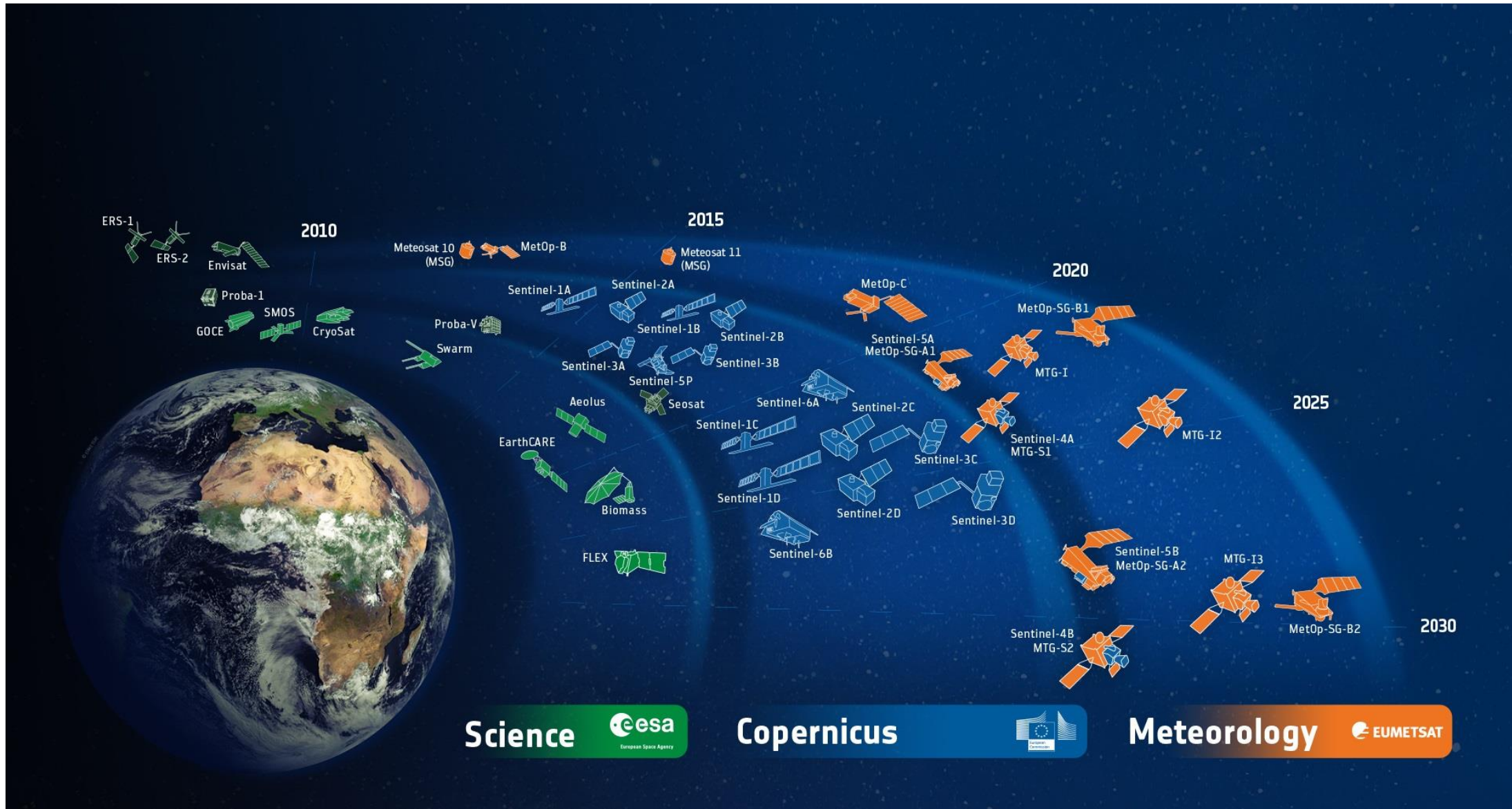
**technology**



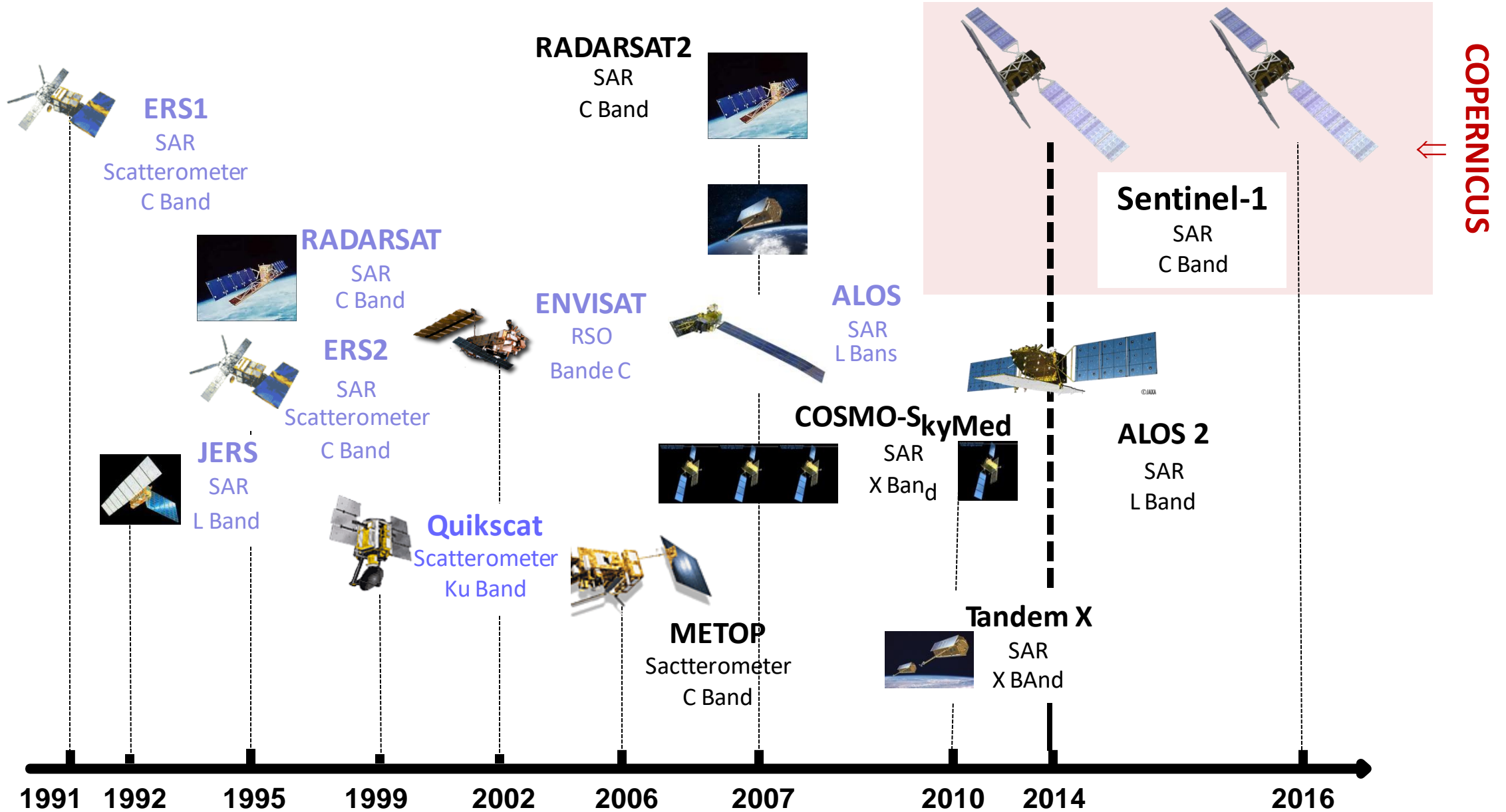
**telecommunications**



# 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-

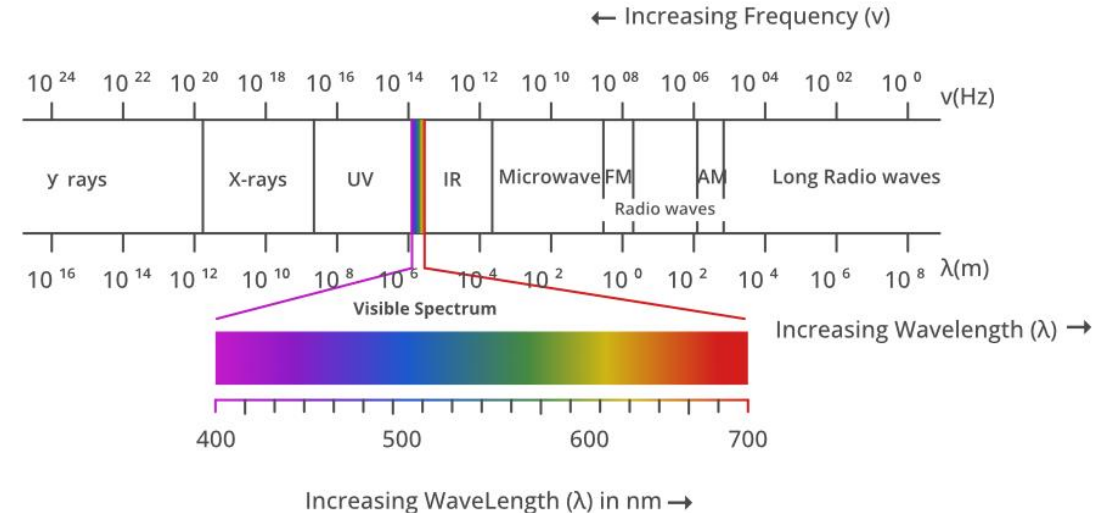
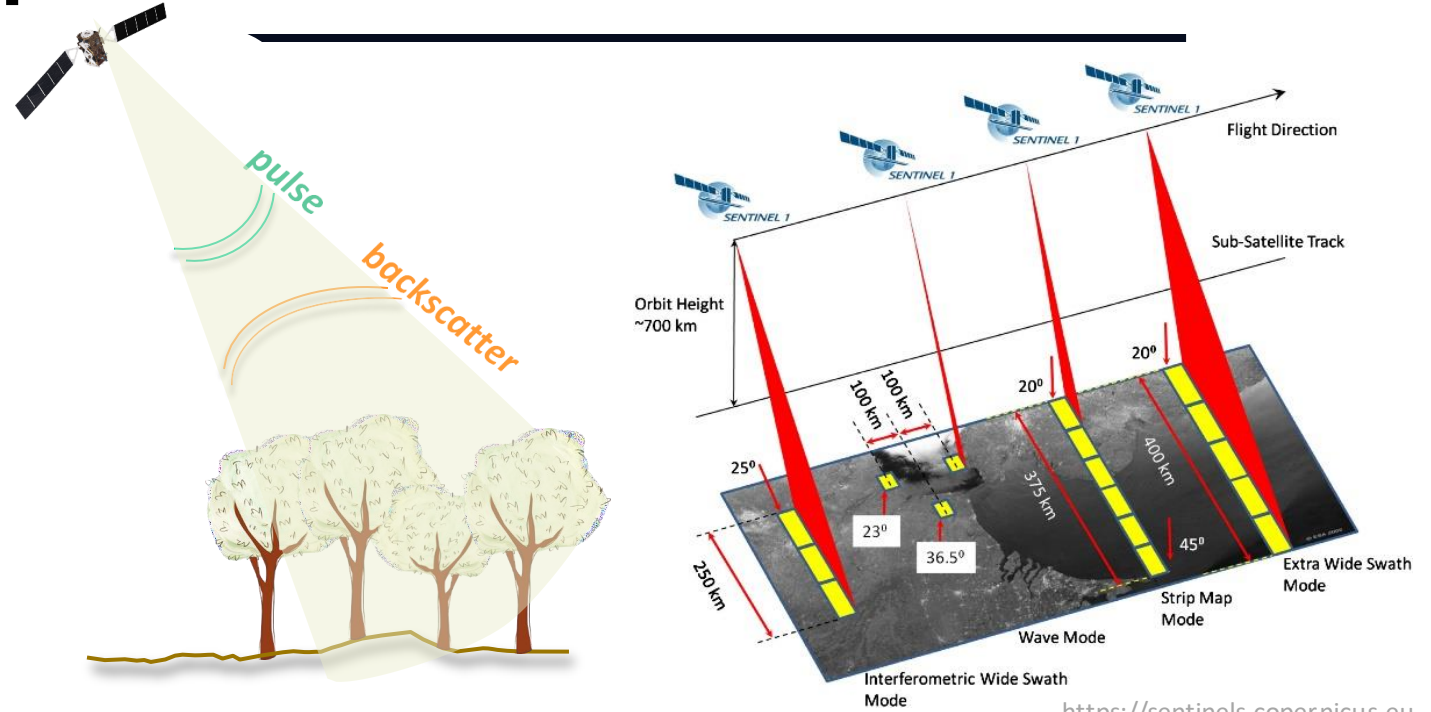
# Sentinel-1 – Radar vision

## 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

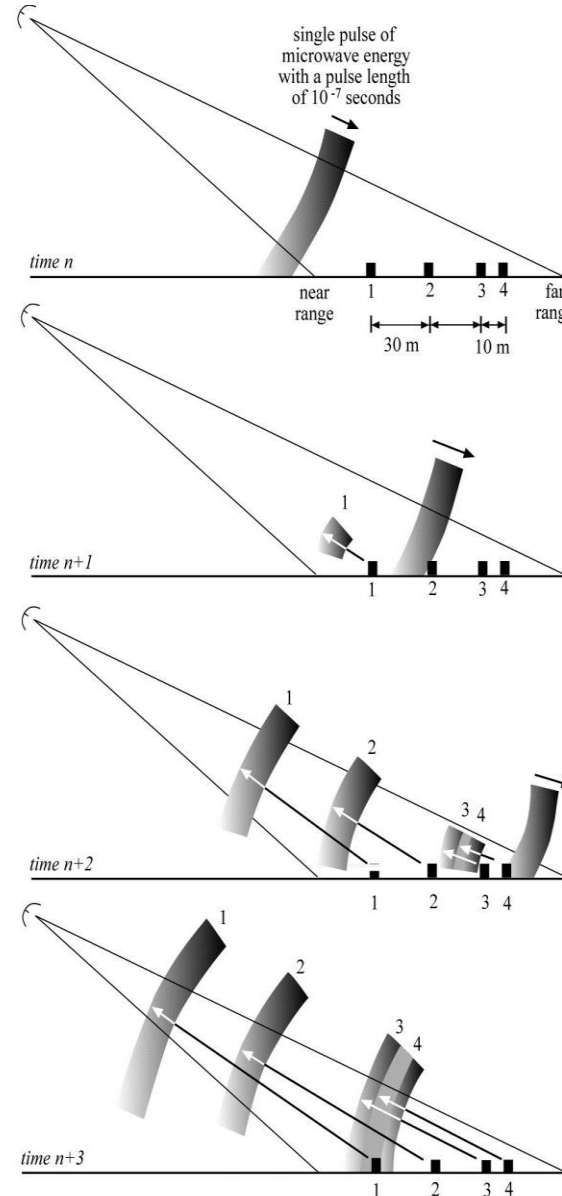
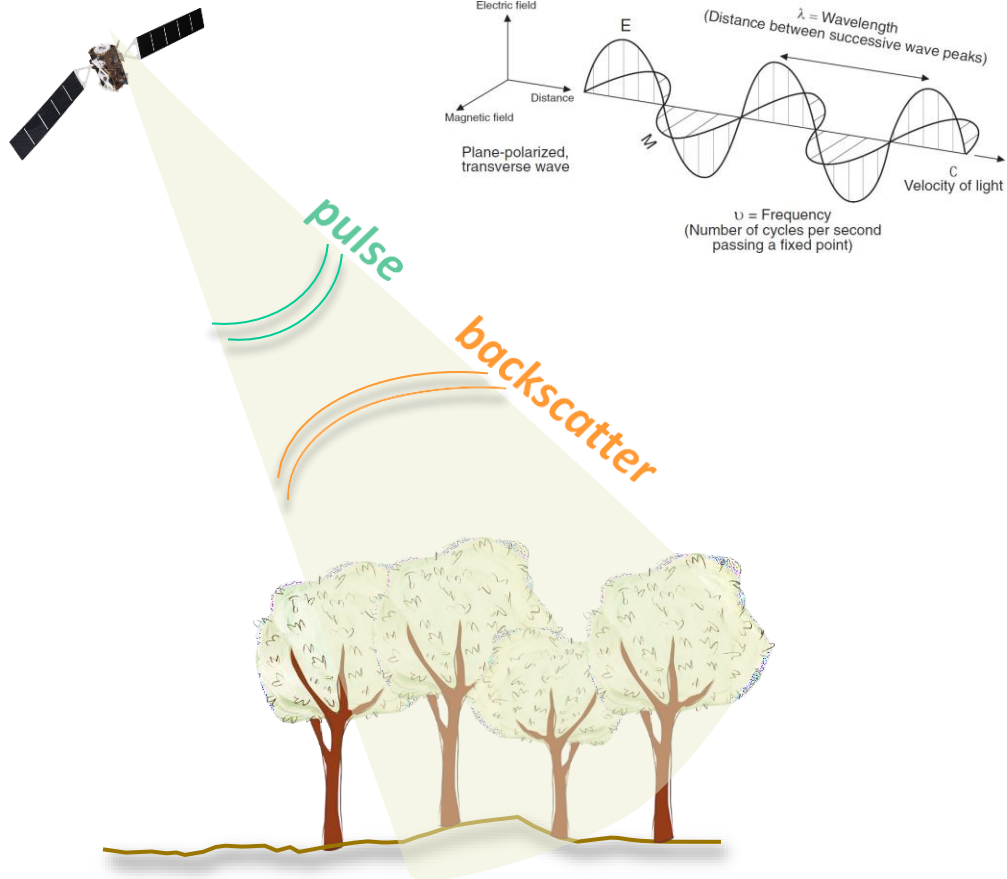




# Active Radar Remote Sensing

## 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

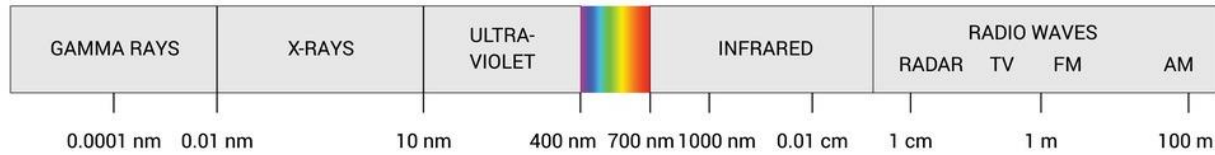
The intensity of the reflected energy and the time it takes for a given pulse to return are recorded



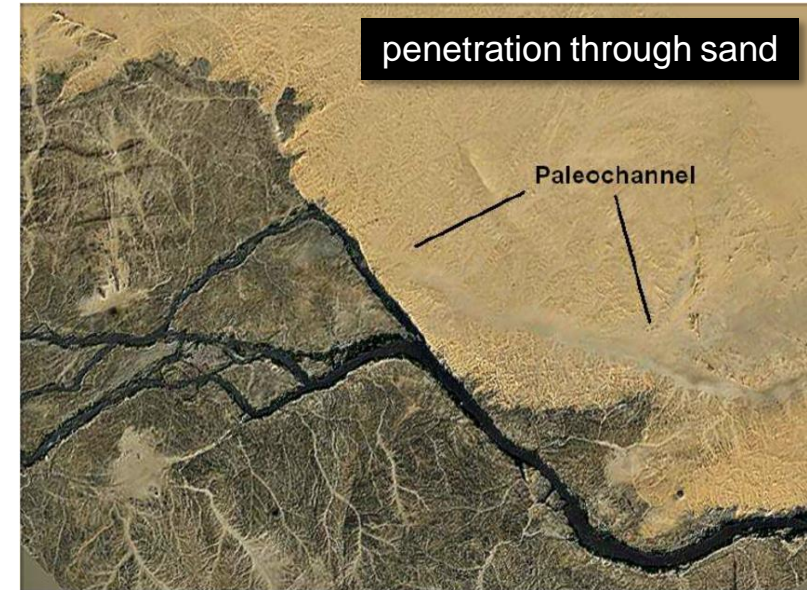
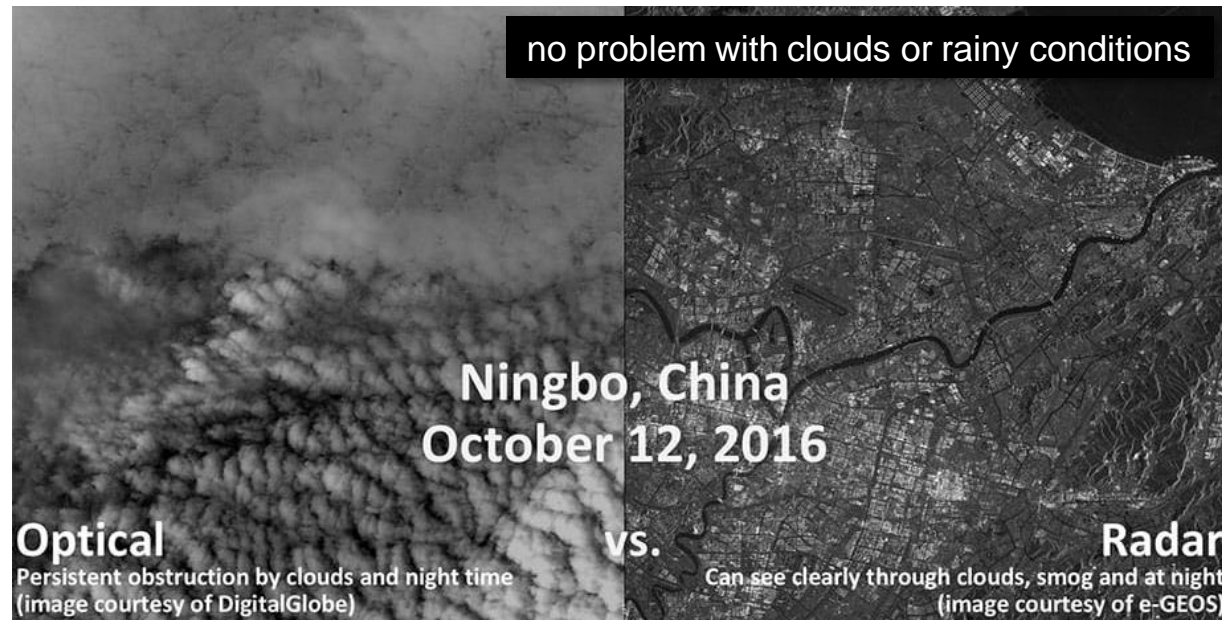
# Active Radar Remote Sensing

## Basic characteristics of radar systems/SAR sensors

### SPECTRUM



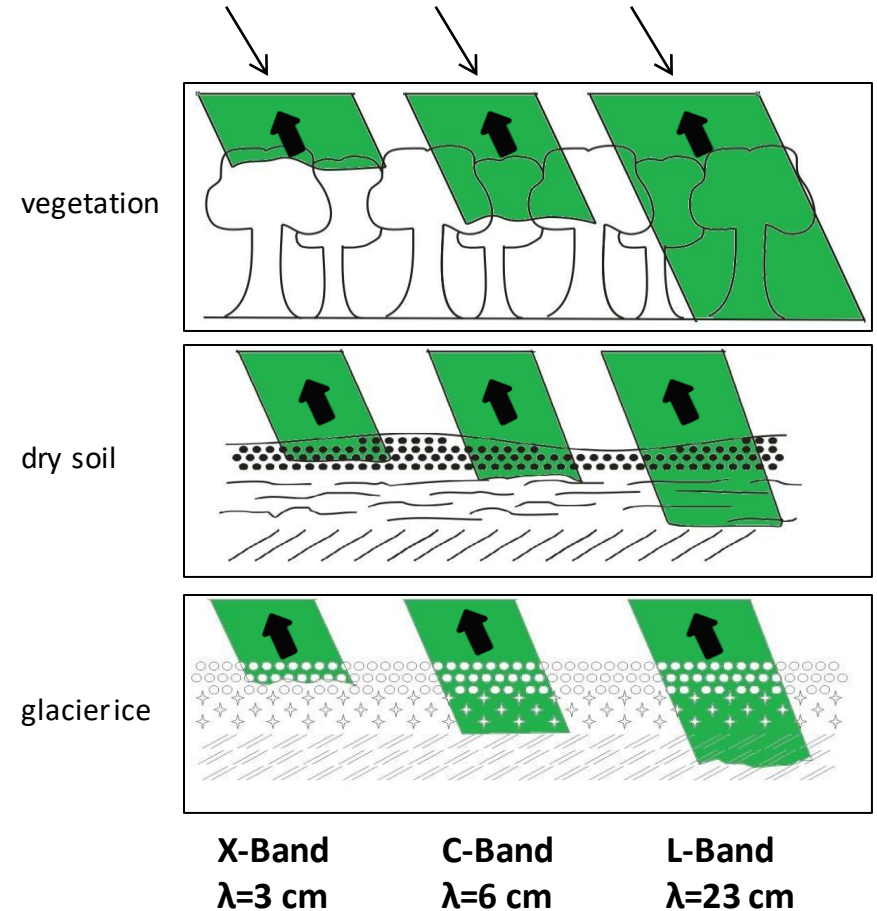
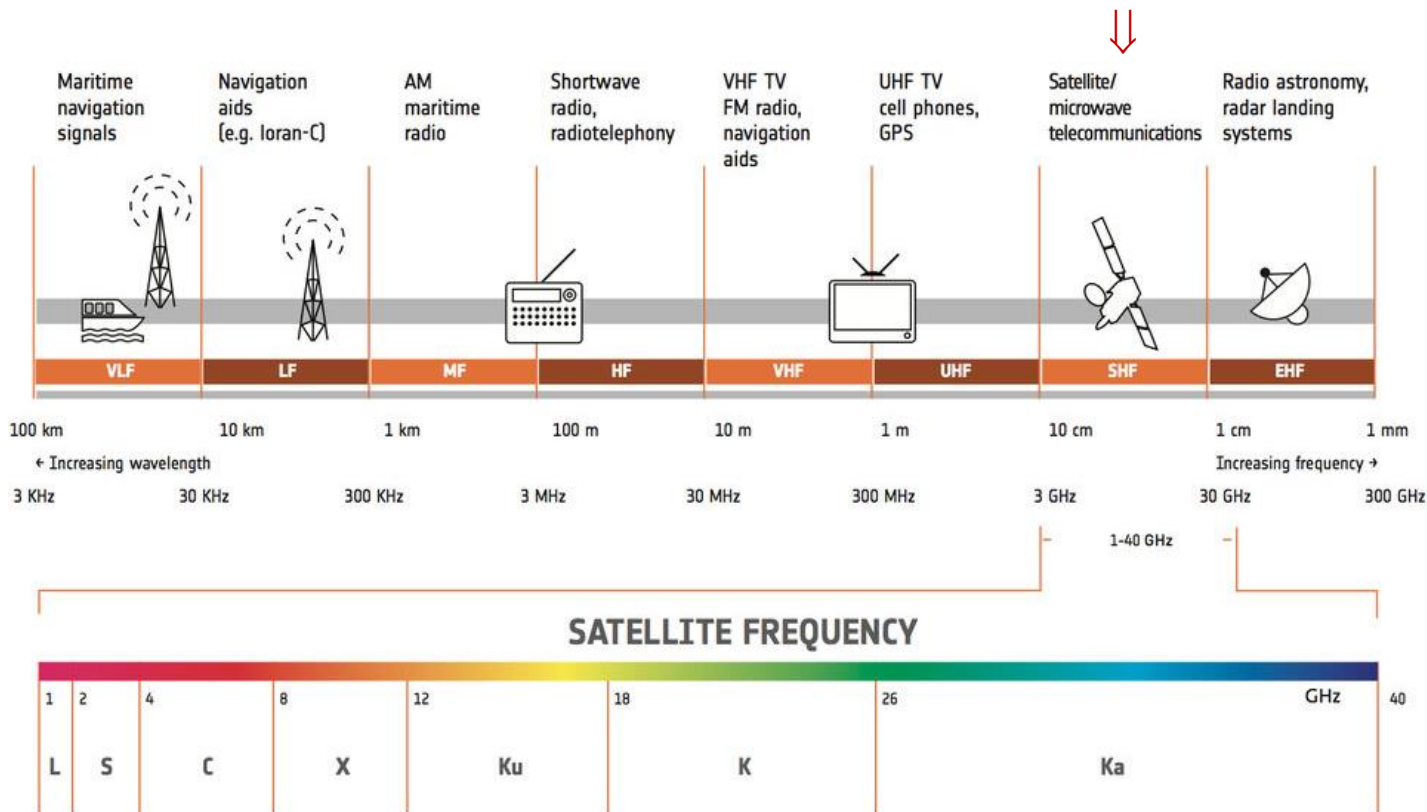
**Microwave** ⇒ penetrates into/through objects



# Active Radar Remote Sensing

## RADAR band designations, wavelengths and frequencies

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

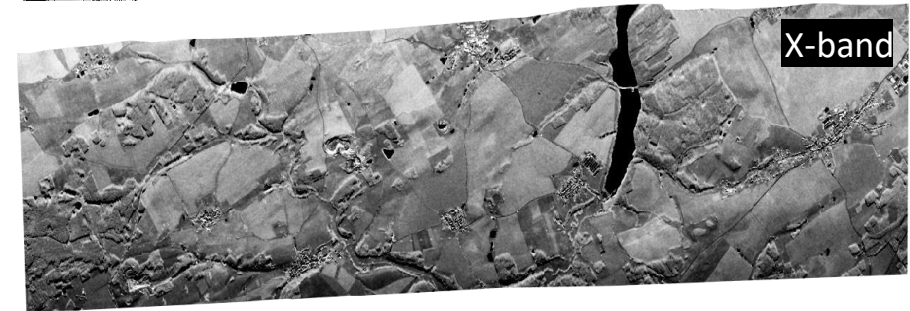
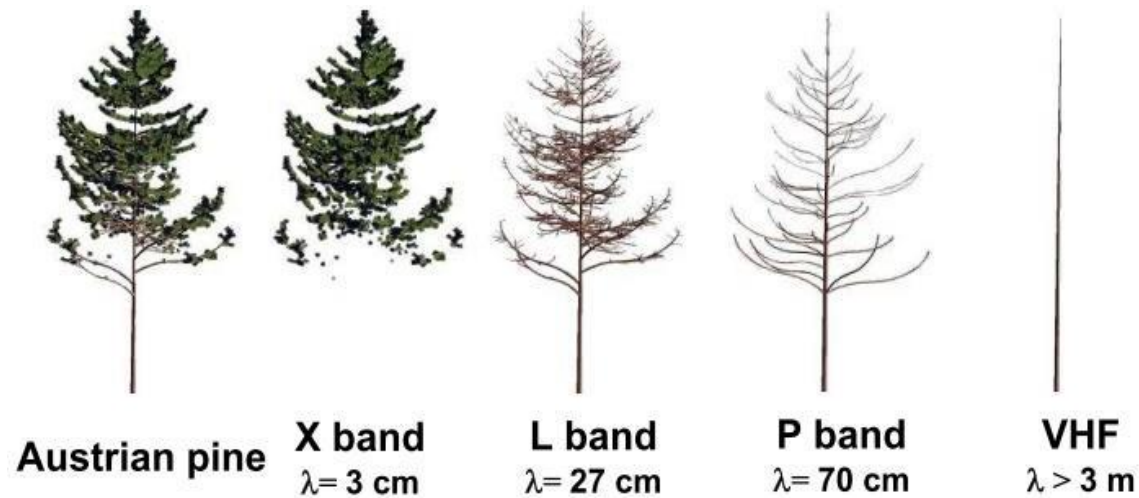




# Active Radar Remote Sensing

## *RADAR band designations, wavelengths and frequencies*

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



# Active Radar Remote Sensing

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



# Radar Altimetry = measuring altitude / vertical height

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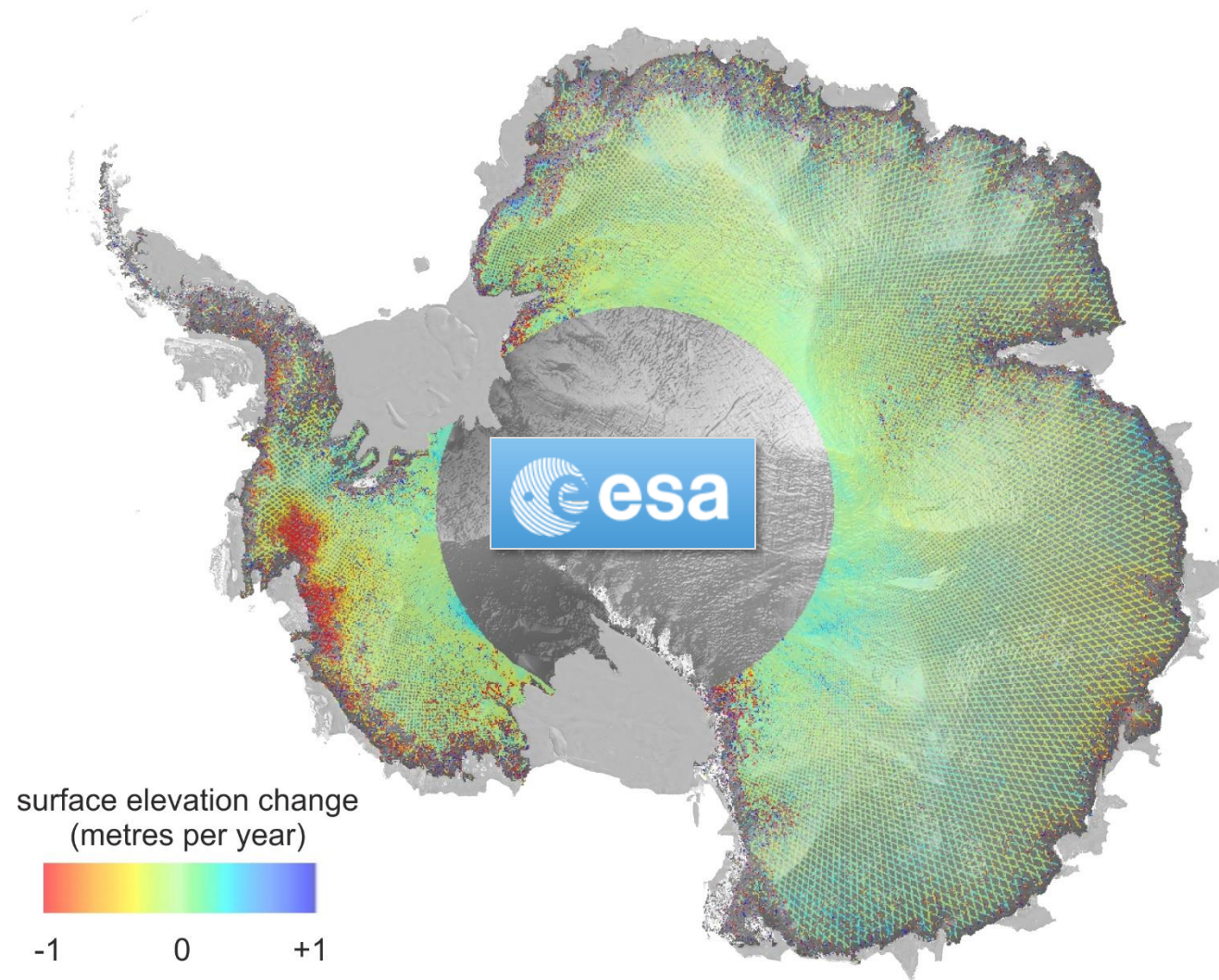


[Article ESA](#)

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

# Radar Altimetry = measuring altitude / vertical height

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

# Side looking radar (SLAR)

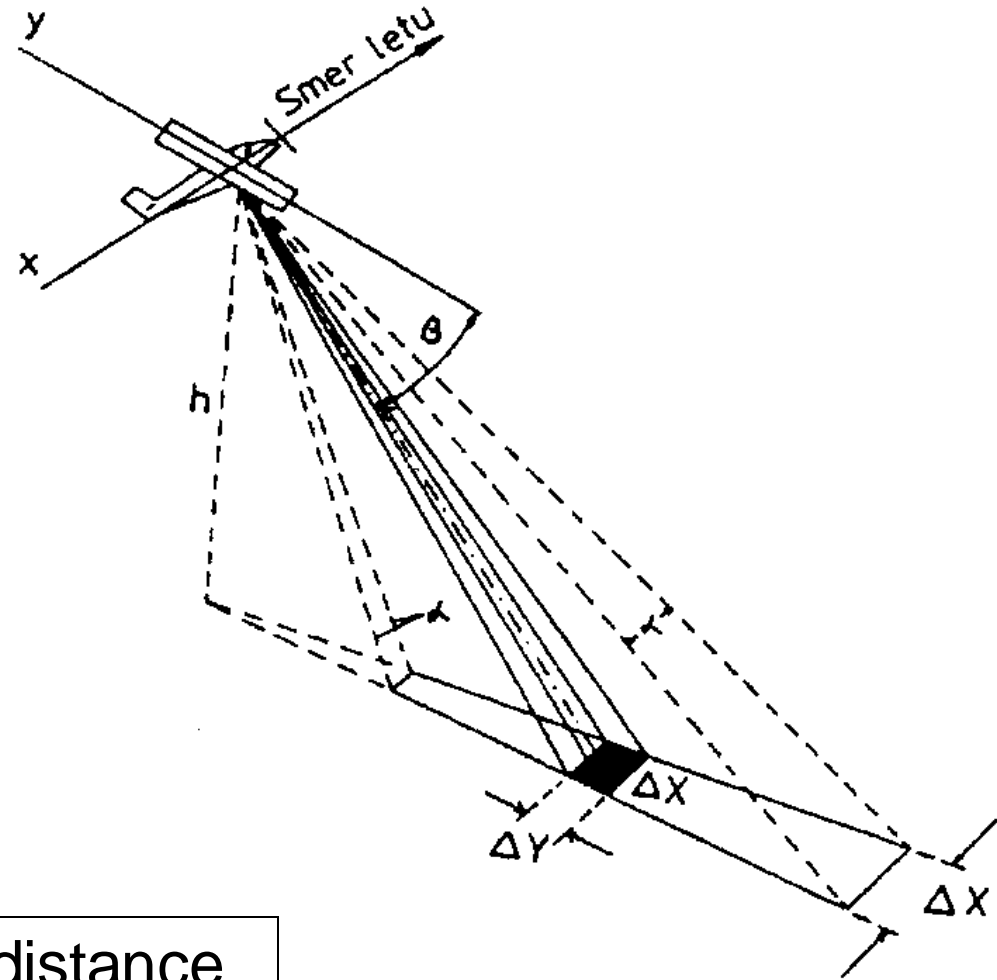
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$$\Delta x = \frac{h \cdot \lambda}{L \cdot \sin \beta}$$

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

$h$  – flight altitude,  $L$  – length of antenna,  $\beta$  - 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)

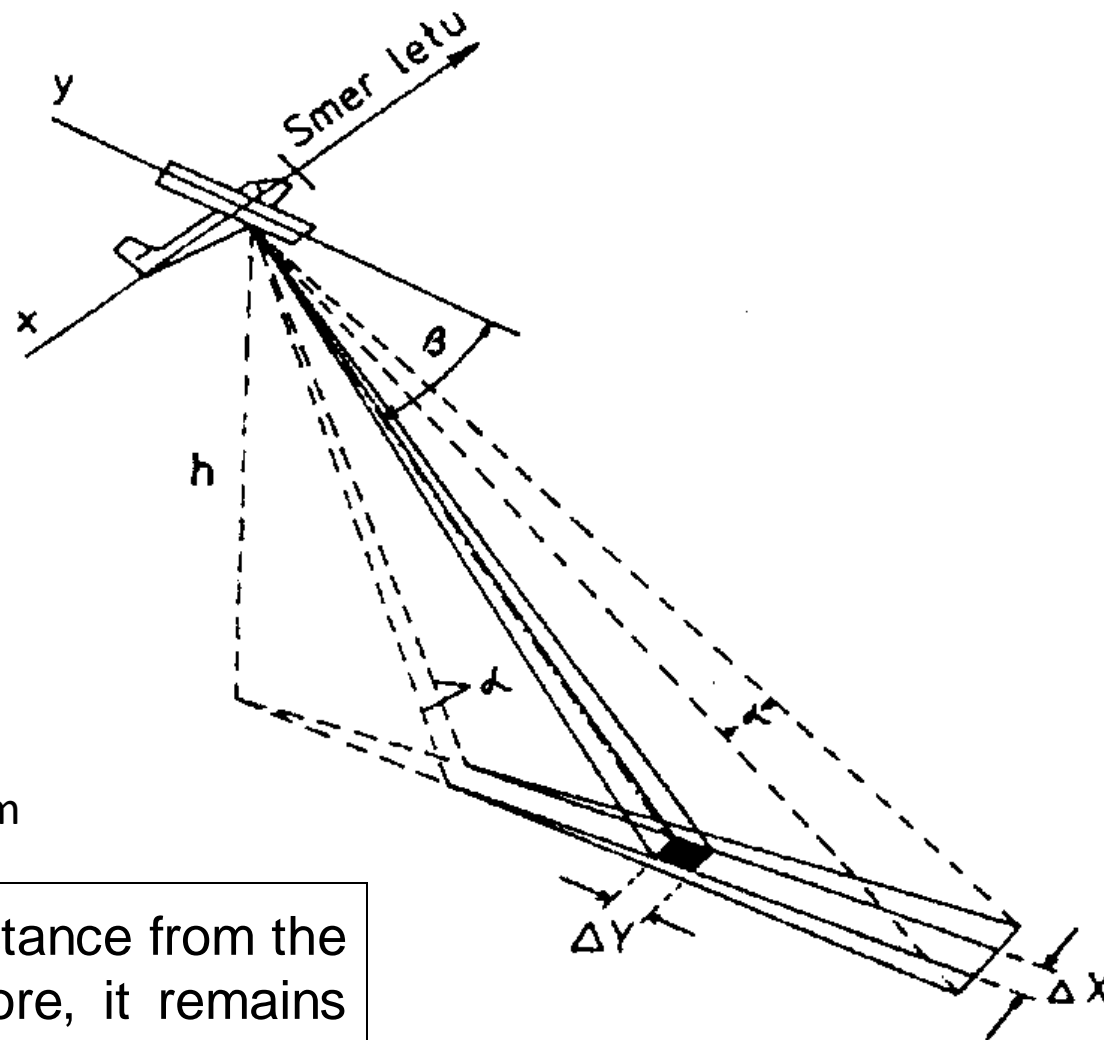
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$$\Delta x = \frac{L}{2}$$

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

$h$  – flight altitude,  $L$  – length of antenna,  $\beta$  - 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.



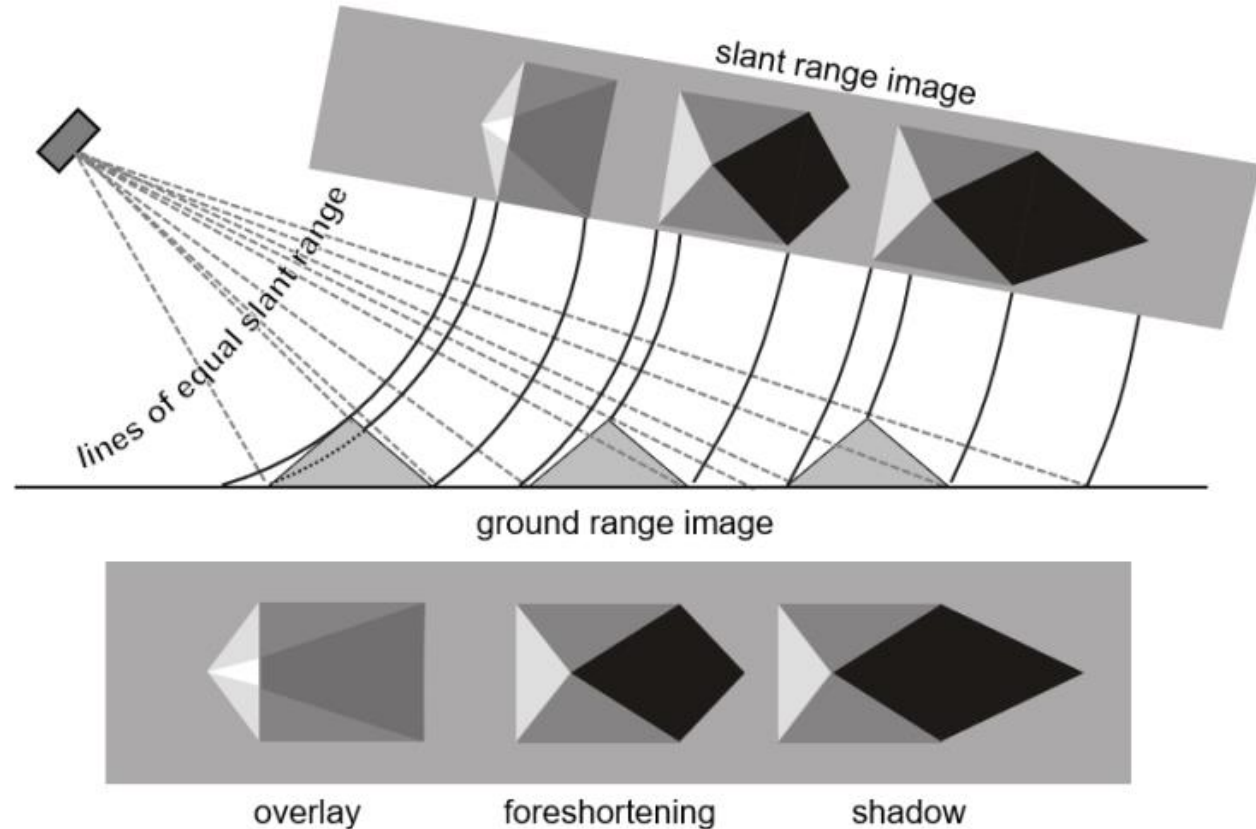


# Geometric Effects in SAR images

## Effects of side-looking geometry

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

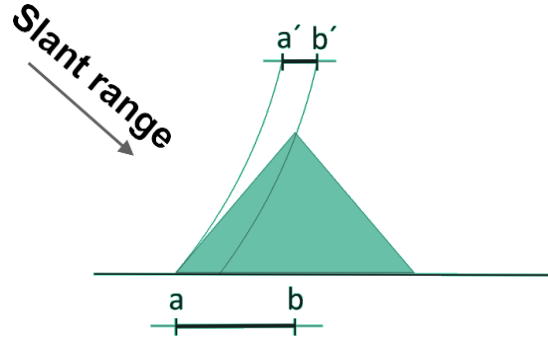
- The effects are:
  - ❖ Foreshortening
  - ❖ Layover
  - ❖ Radar shadow
- Controlled by:
  - ❖ Incidence angle
  - ❖ Topography



*Geometric distortions in radar images (Braun 2019)*

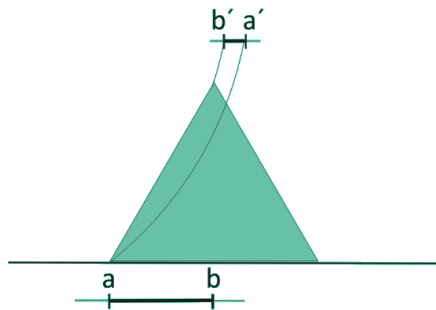
# Geometric Effects in SAR images

## Foreshortening



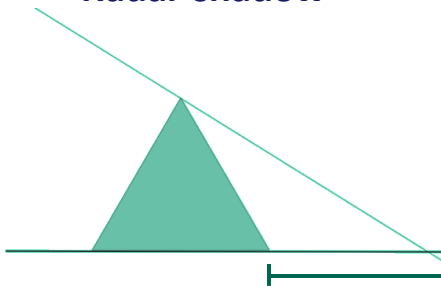
- Slopes oriented to the SAR appear compressed (Distance between a and b is shortened)
- Appears as very bright area
- More pronounced in near range (small incidence angle) than in far range (high incidence angles)

## Layover

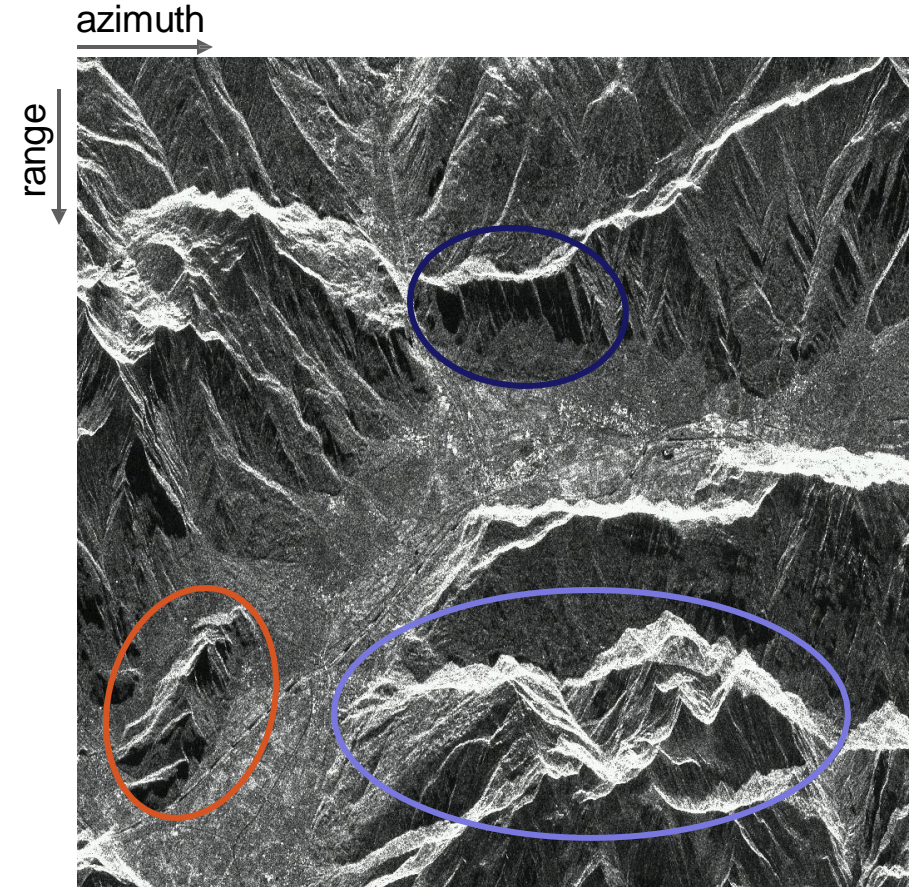


- Steep slopes oriented to the SAR lead to ghost images
- When radar beam reaches the top of a high feature (b) before it reaches the base (a)

## 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





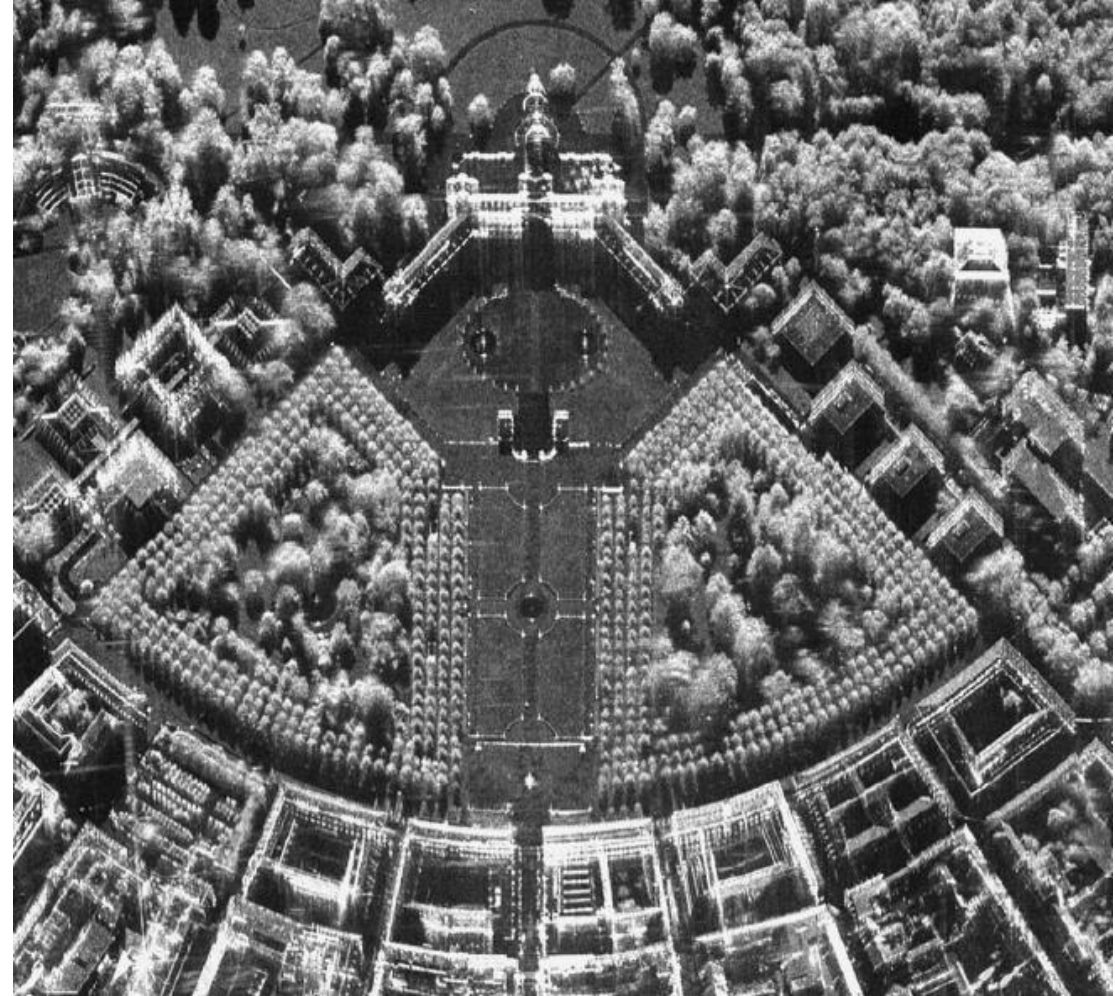
# Geometric Effects in SAR images

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## Effects of side-looking geometry

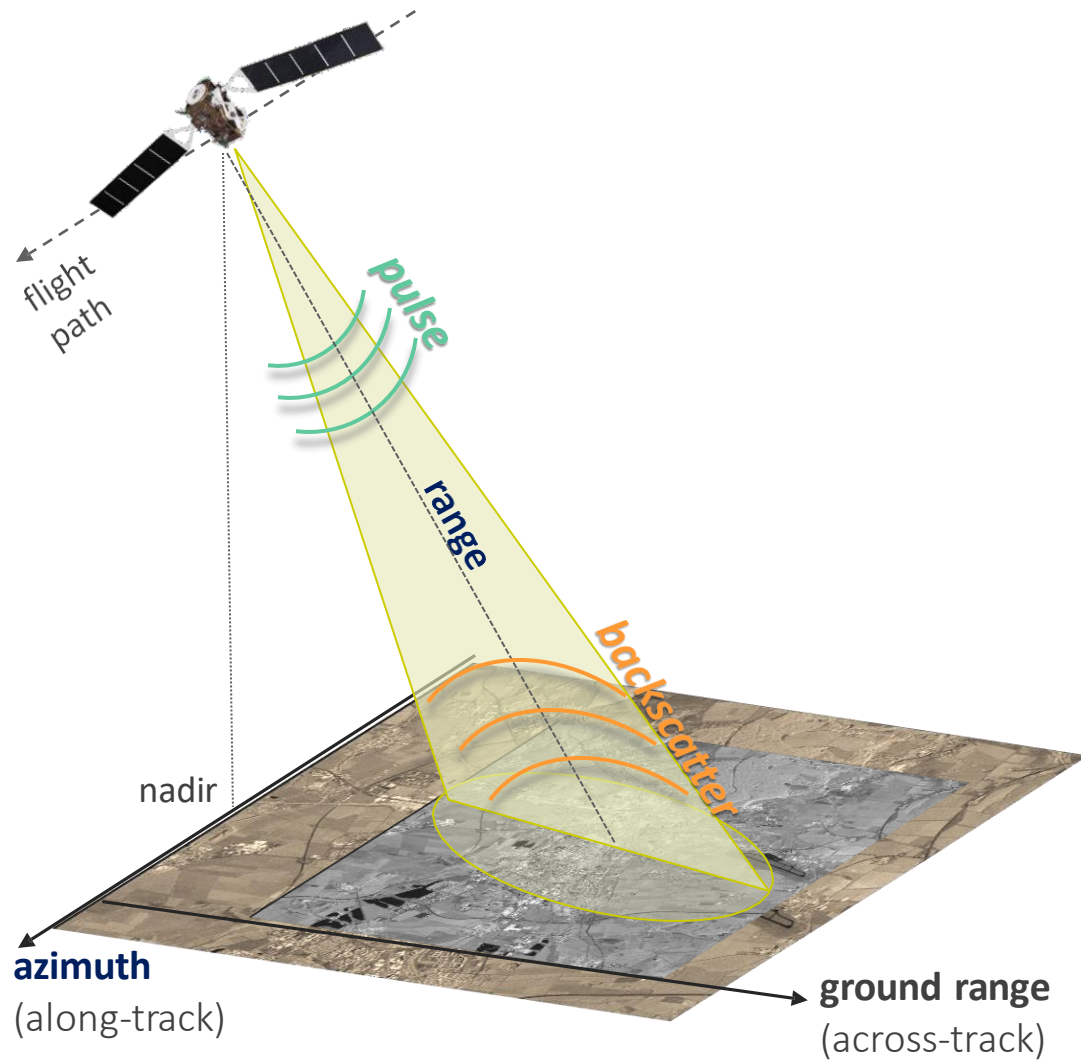


Google maps

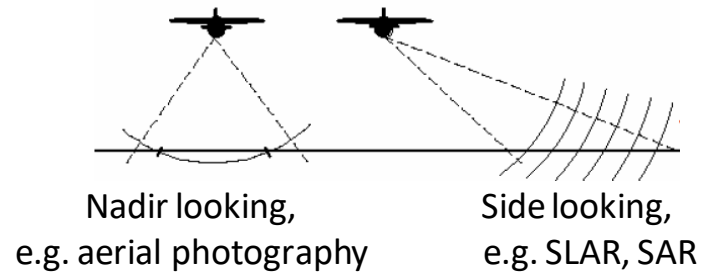


Andreas R. Brenner and Ludwig Roessing, Radar Imaging of Urban Areas by Means of Very High-Resolution SAR and Interferometric SAR, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 46, NO. 10, OCTOBER 2008 (X-band)

# Radar side looking imaging geometry



Is side looking really necessary?



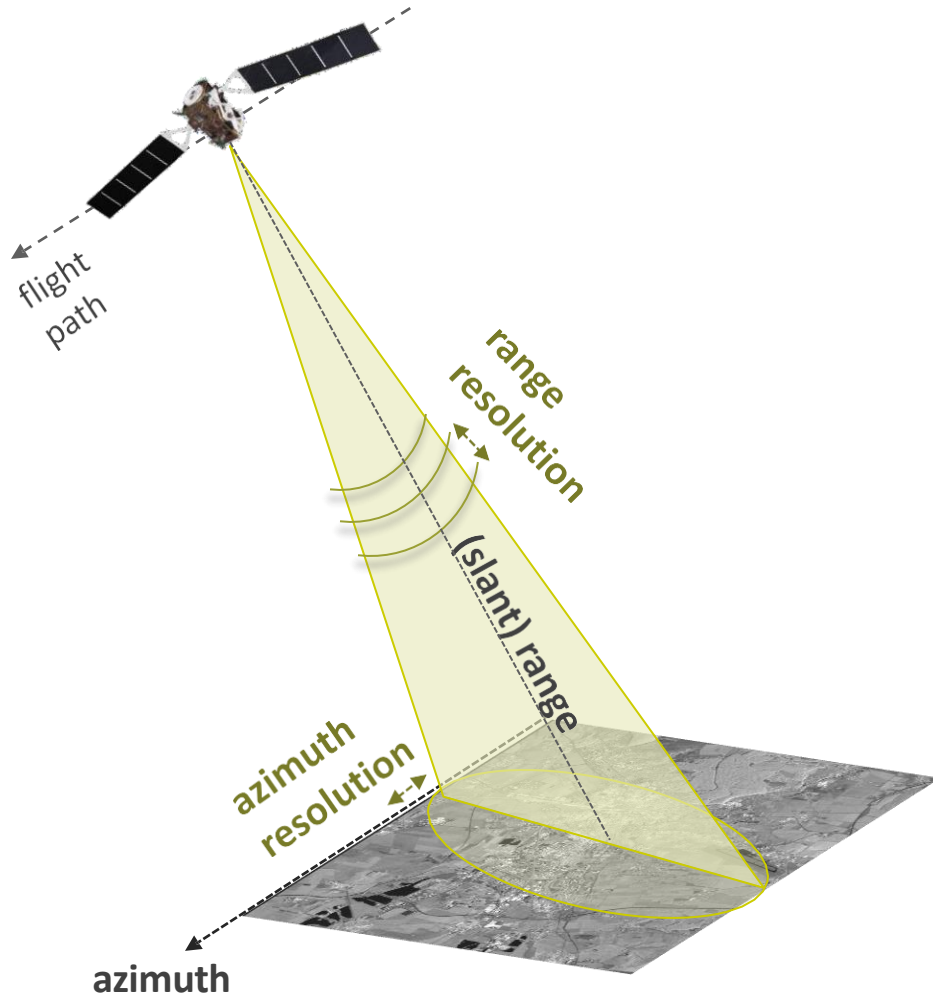
**range:** scanning in the look direction at the speed of light

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



# Radar side looking imaging geometry

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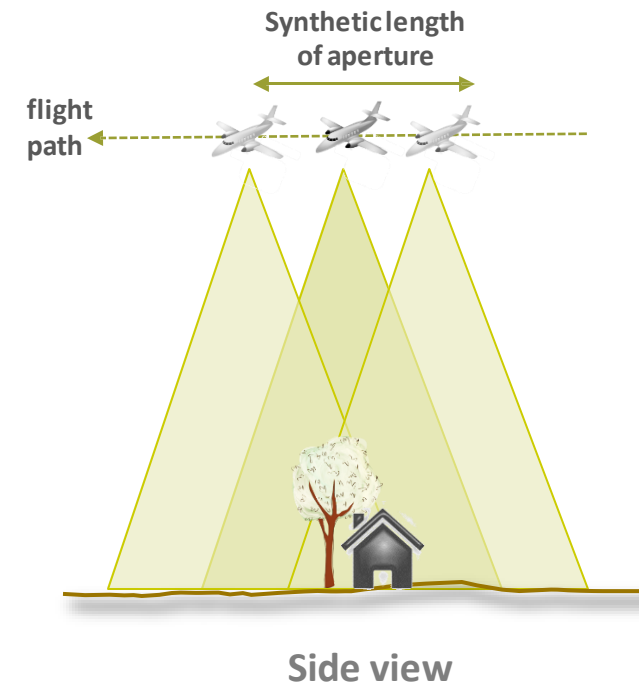
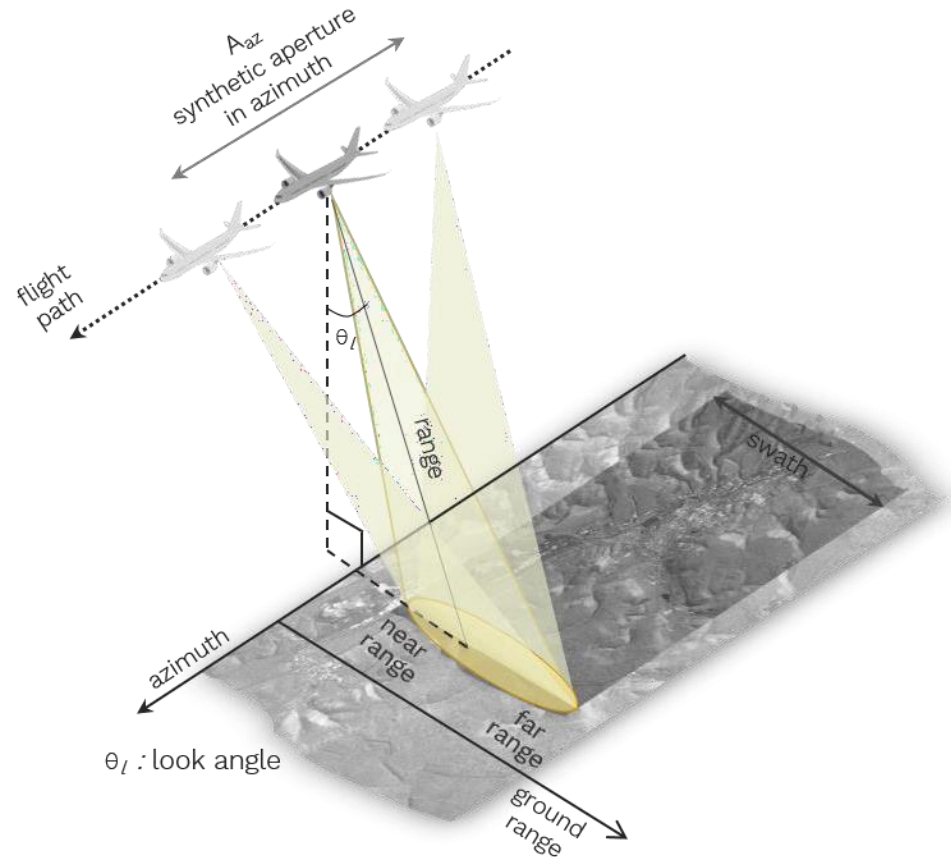
**slant-range resolution** depends on the bandwidth of the system

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

# Synthetic Aperture Radar (SAR)

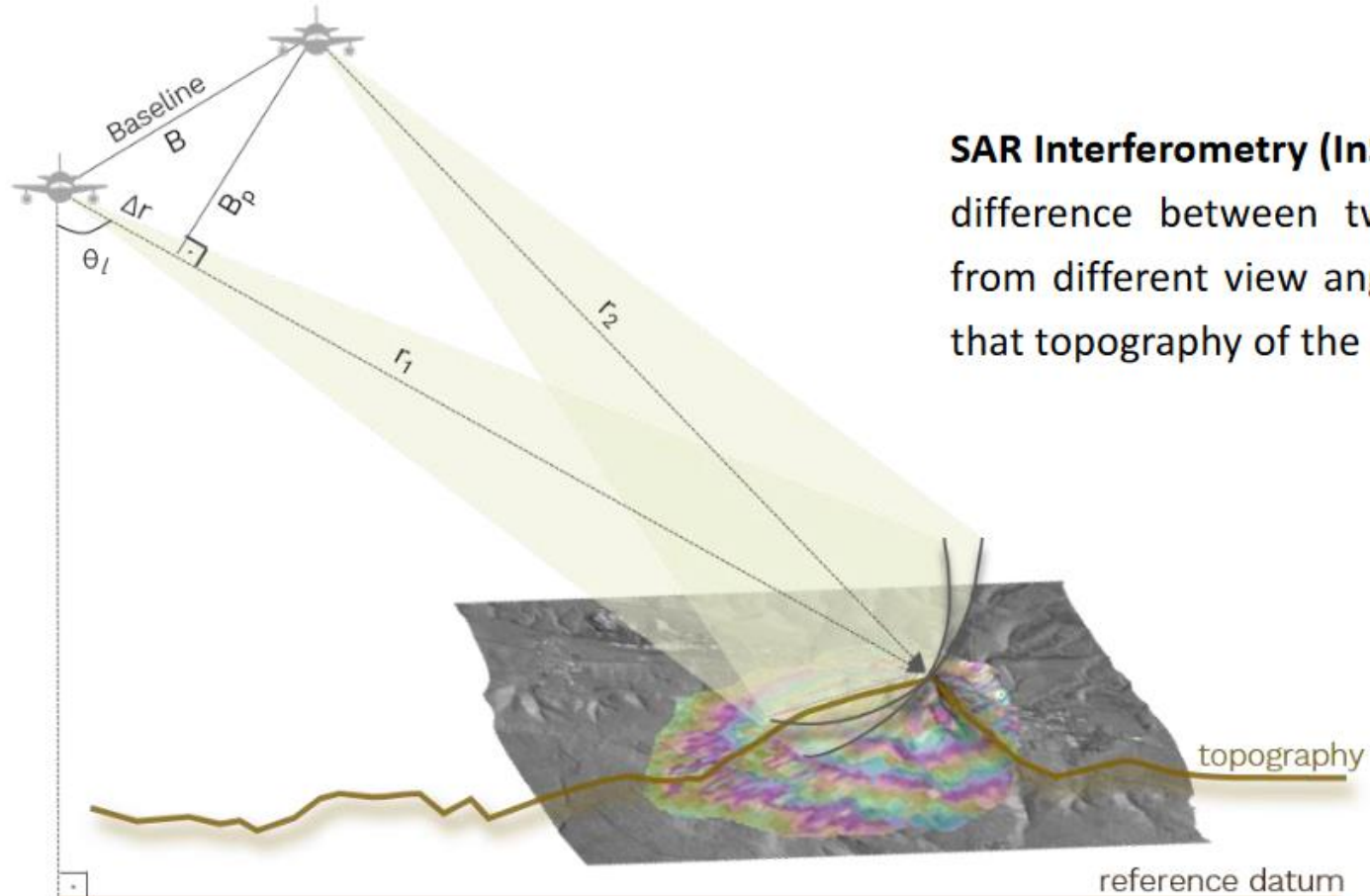
## The principle of extending the antenna

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

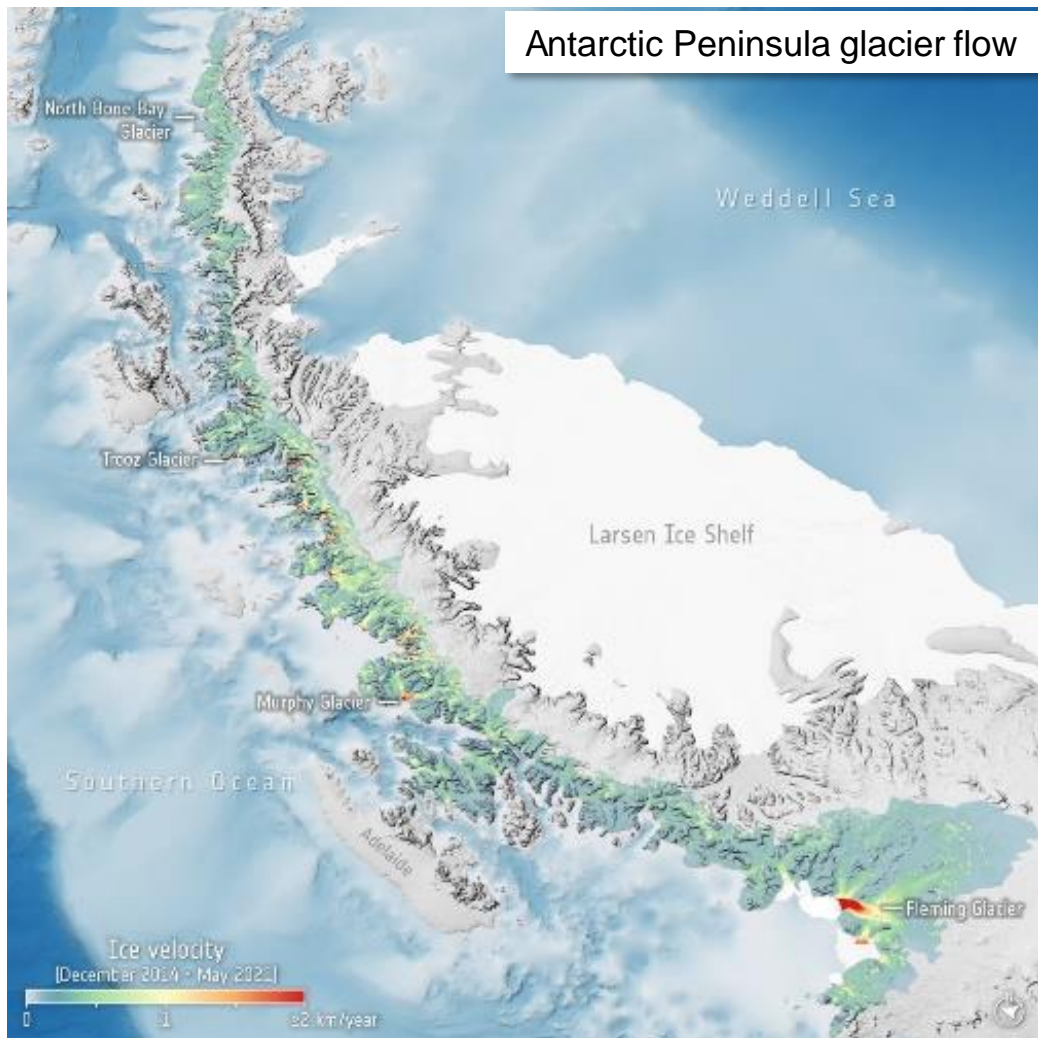
$r_1$  &  $r_2$ : range distance for the respective acquisitions

$\Delta r$  : range difference

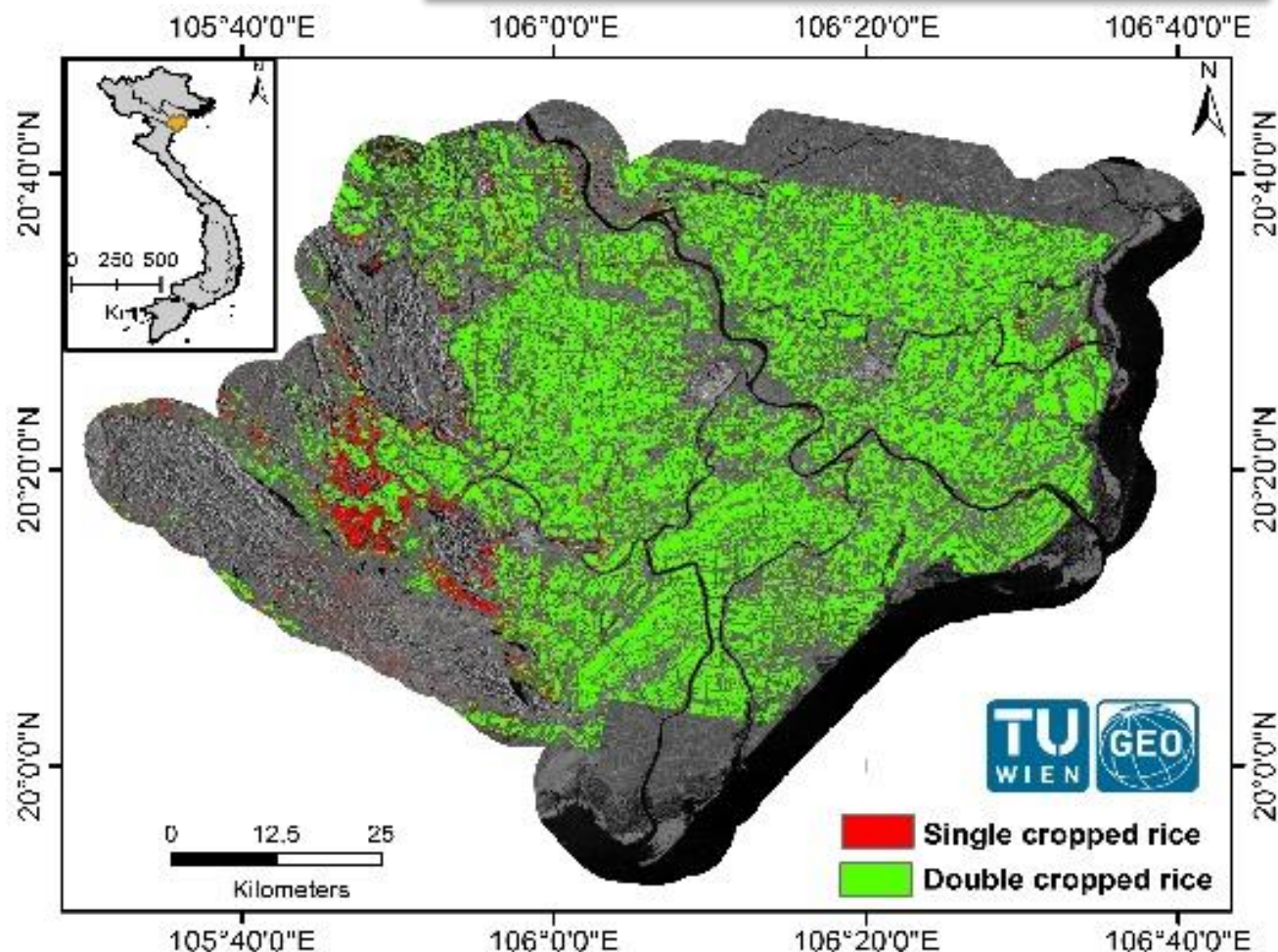


# Sentinel-1 – Applications

Antarctic Peninsula glacier flow

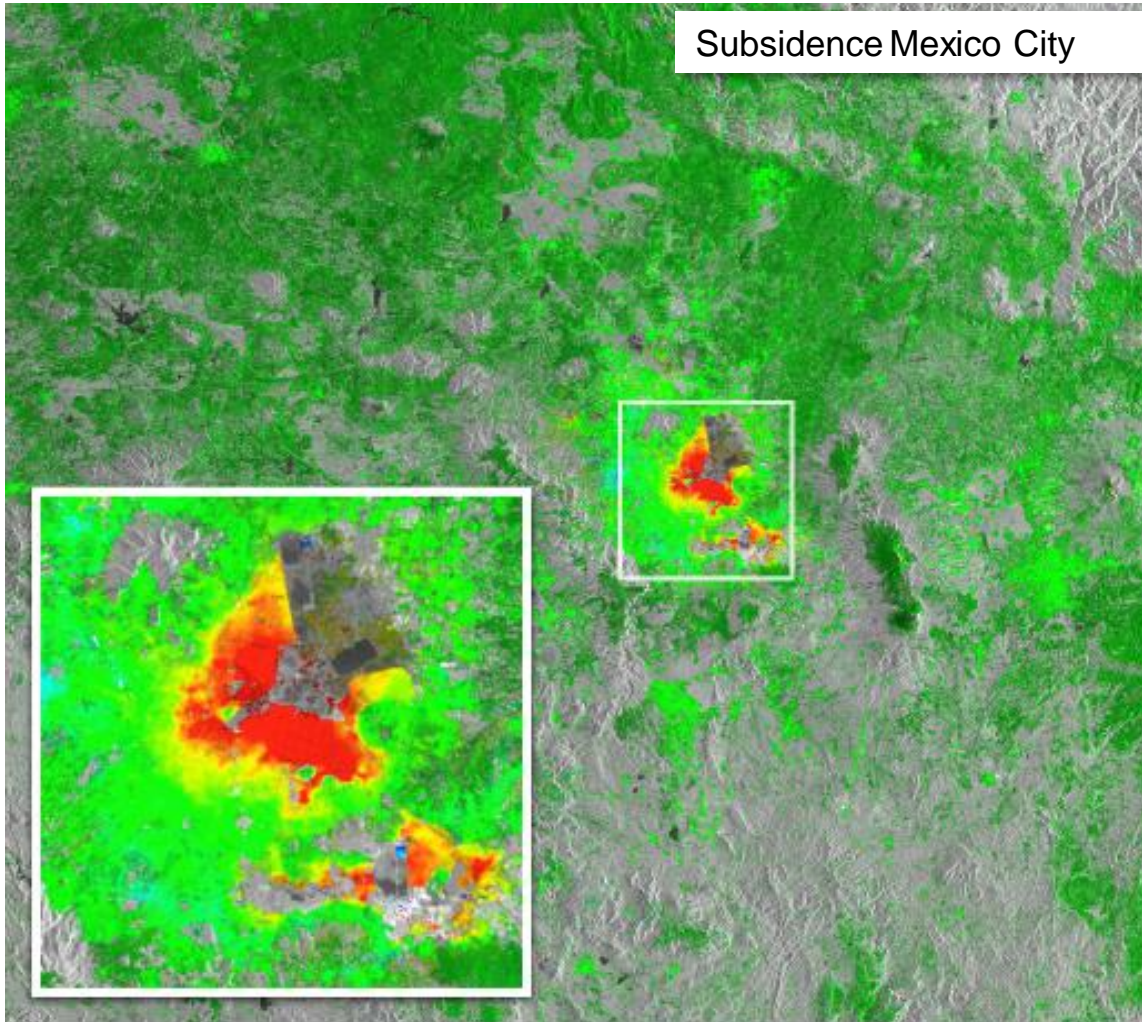


Rice-cropping systems in Vietnam's Red River Delta

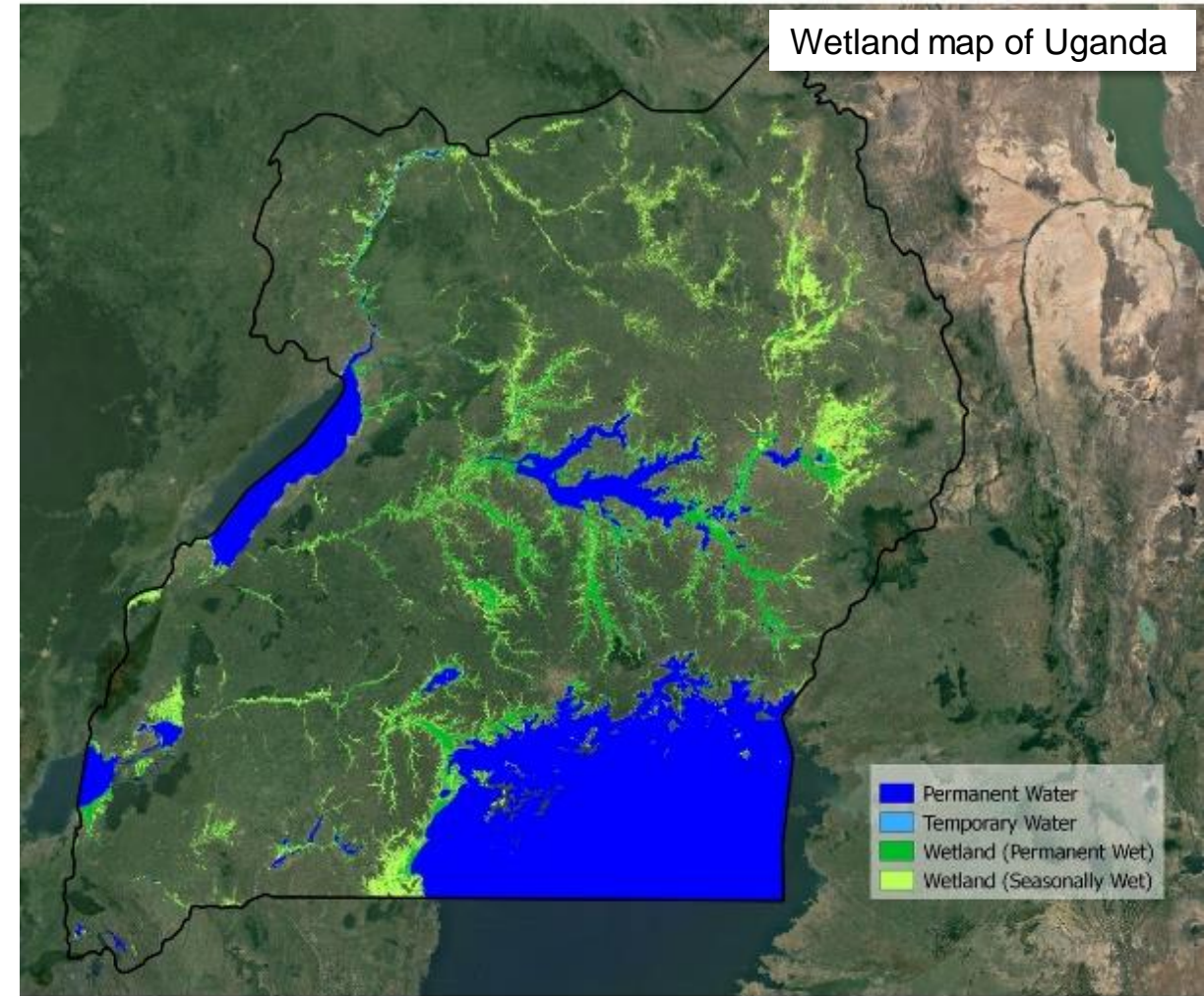




# Sentinel-1 – Applications

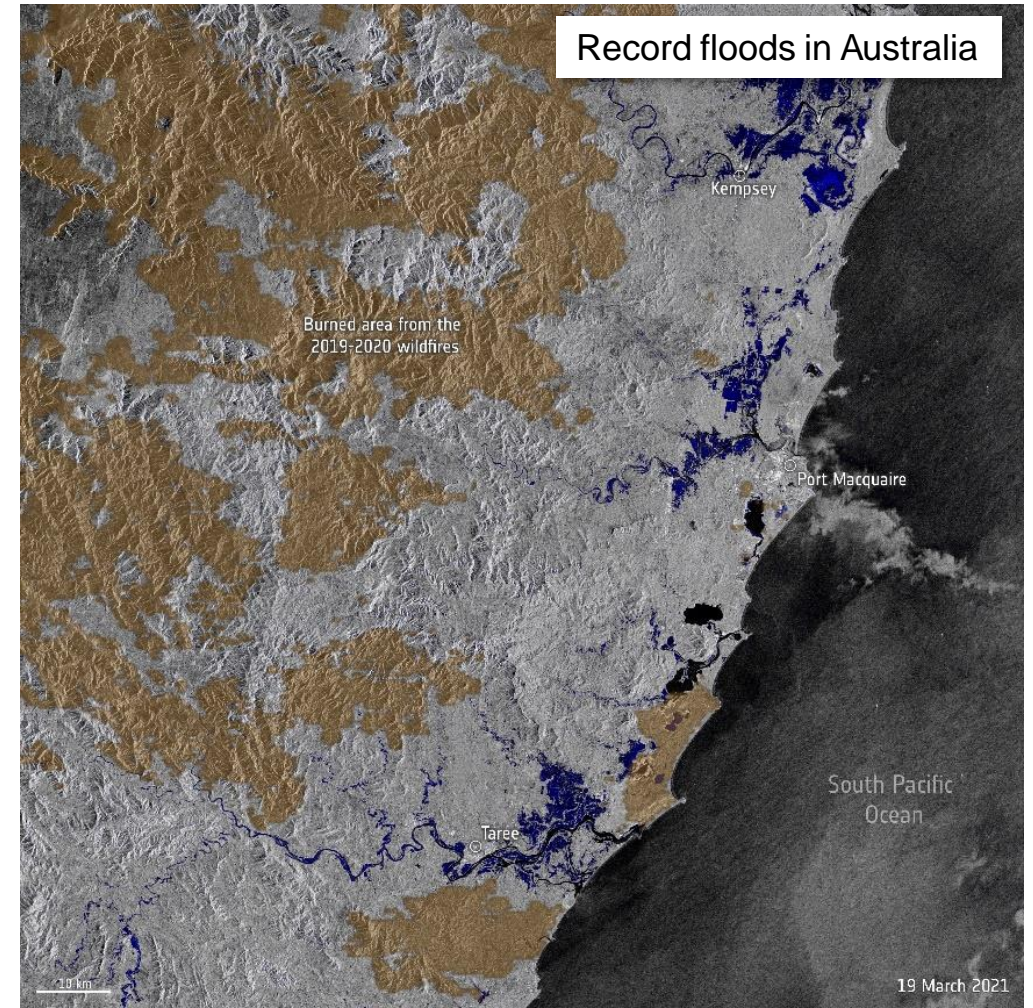
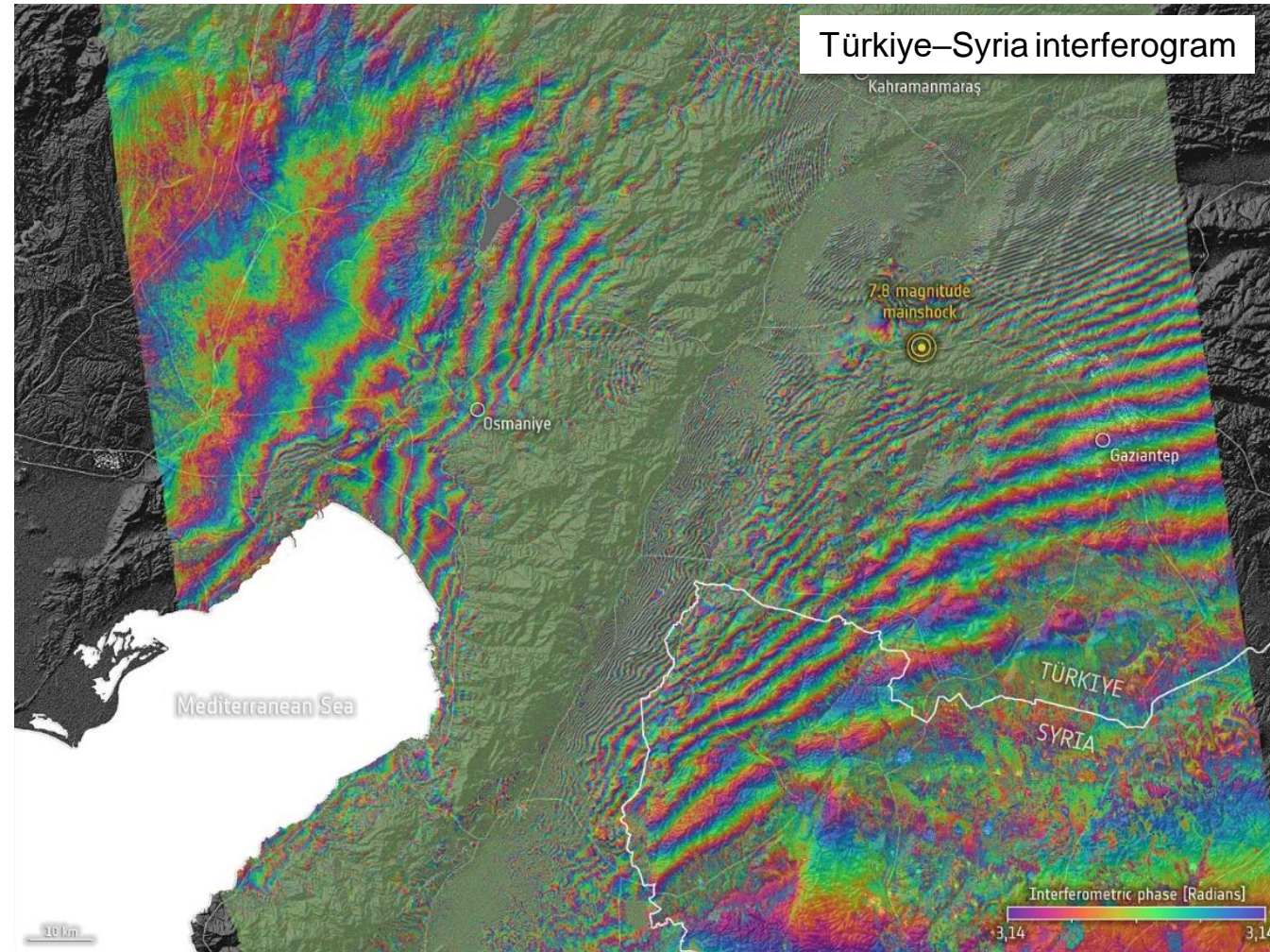


-20 cm/yr  +20 cm/yr





# 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



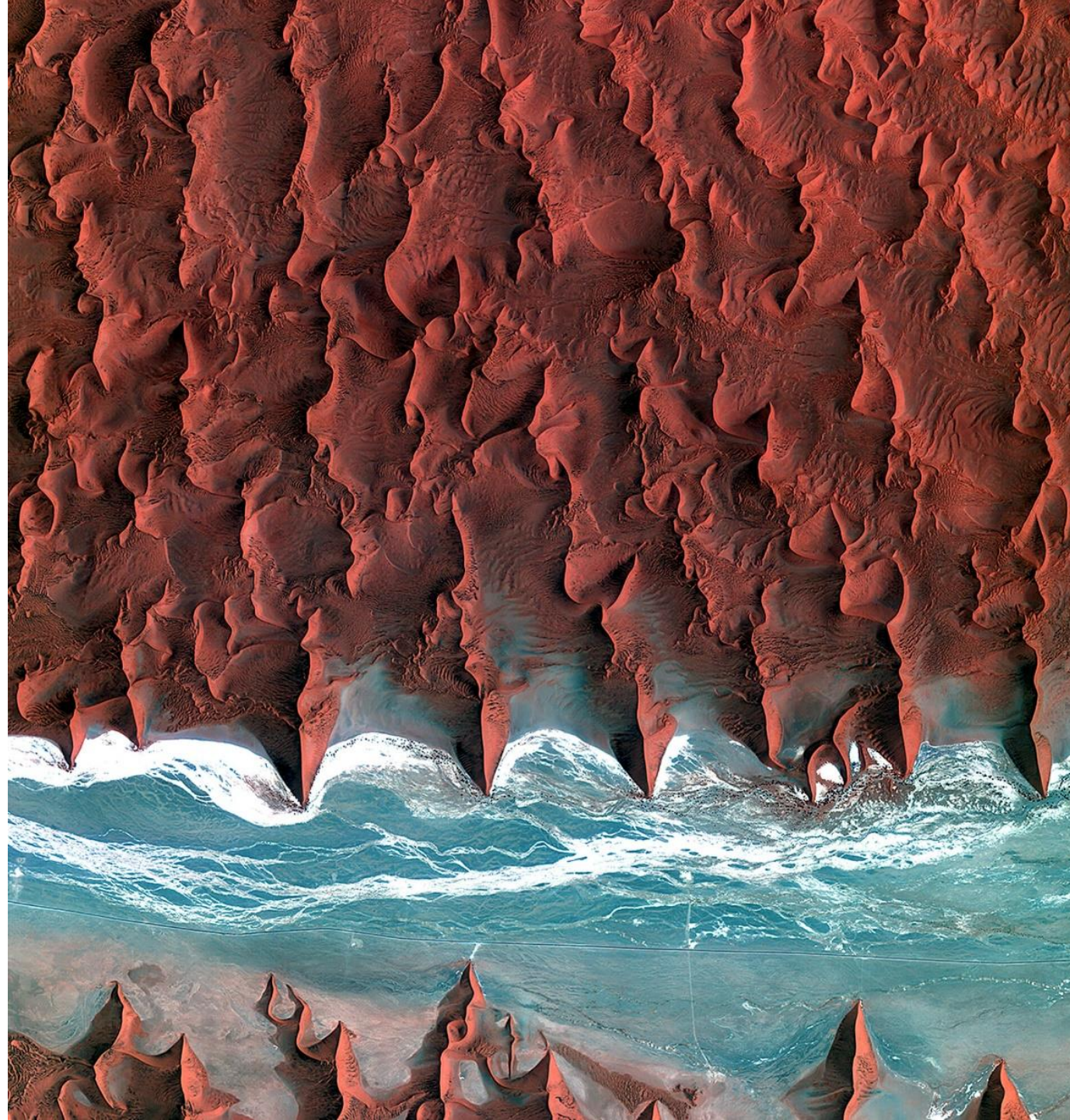
# EO data access

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## 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 items: '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 are logos for Copernicus, ESA, and the European Union. The main header reads "Copernicus Open Access Hub". Below this, there is a "Welcome to the Copernicus Open Access Hub" section with introductory text. To the right, a "Reports & Stats" section displays "38,892 prod. published in the last 24h" and "338,550 downloads in the last 24h". Below that is a "Resources" section with links to "DHUS Open Source Portal", "Copernicus Portal", "Sentinel Online", and "Sentinel Vision Stories". At the bottom, there are four buttons: "Open Hub", "API Hub", "S-5P Pre-Ops", and "POD Hub".

**Welcome to the Copernicus Open Access Hub**

The Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) provides complete, free and open access to [Sentinel-1](#), [Sentinel-2](#), [Sentinel-3](#) and [Sentinel-5P](#) user products, starting from the In-Orbit Commissioning Review (IOCR).

Since 24 January 2023 a new [Copernicus Data Space Ecosystem](#) has been launched to provide access to all Sentinel data with new features for visualisation and data processing. Please stay tuned to the news for latest information on the services available and the [roadmap](#) for the full release of all functionalities.

The Copernicus Data Hub distribution service will continue its full operations until the end of June 2023 to allow a smooth migration to the new Copernicus Data Space Ecosystem by all user communities. As from July 2023 and until September 2023, the Copernicus Data Hub distribution service will continue offering access to Sentinel data with a gradual ramp-down of the operations capacity and data offering.

Sentinel Data are also available via the Copernicus Data and Information Access Services (DIAS) through several [platforms](#).

Please visit our [User Guide](#) for getting started with the Data Hub Interface. Discover how to use the APIs and create scripts for automatic search and download of Sentinels' data, with synchronous access to the latest data and asynchronous access to historic data via the API and GUI.

For further details or requests of support please send an e-mail to [eosupport@copernicus.esa.int](mailto:eosupport@copernicus.esa.int)

**Reports & Stats**  
Data updated hourly

38,892  
prod. published in the last 24h

338,550  
downloads in the last 24h

Reports

**Resources**

- DHUS Open Source Portal
- Copernicus Portal
- ESA Sentinel Online
- Sentinel Vision Stories

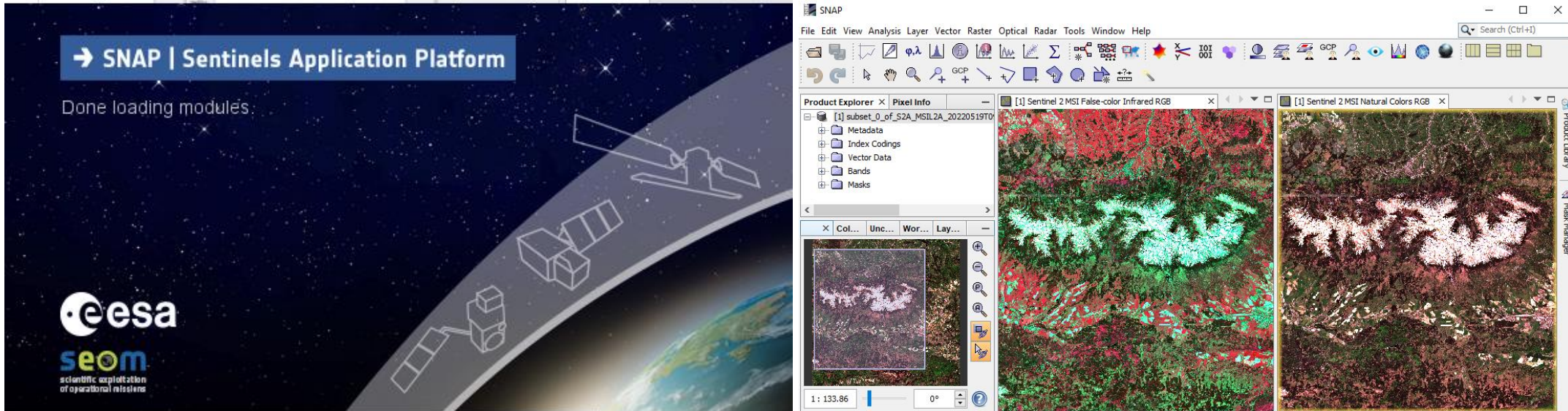
Open Hub   API Hub   S-5P Pre-Ops   POD Hub

- 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

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## 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/](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 web application interface. The top screenshot shows the main interface with a map of Rome, Italy, and a sidebar on the left. A yellow box highlights the 'Data sources' section in the sidebar, where 'Sentinel-1' is selected and indicated by a yellow arrow. The bottom screenshot shows the same interface but with a visualization panel open on the right, displaying a SAR urban image of Rome. The visualization panel lists various processing options, with 'VH - decibel gamma0 - radiometric terrain corrected' selected and highlighted by a yellow circle. The interface includes a search bar, a 'Go to Place' button, and a '3D' view toggle.

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

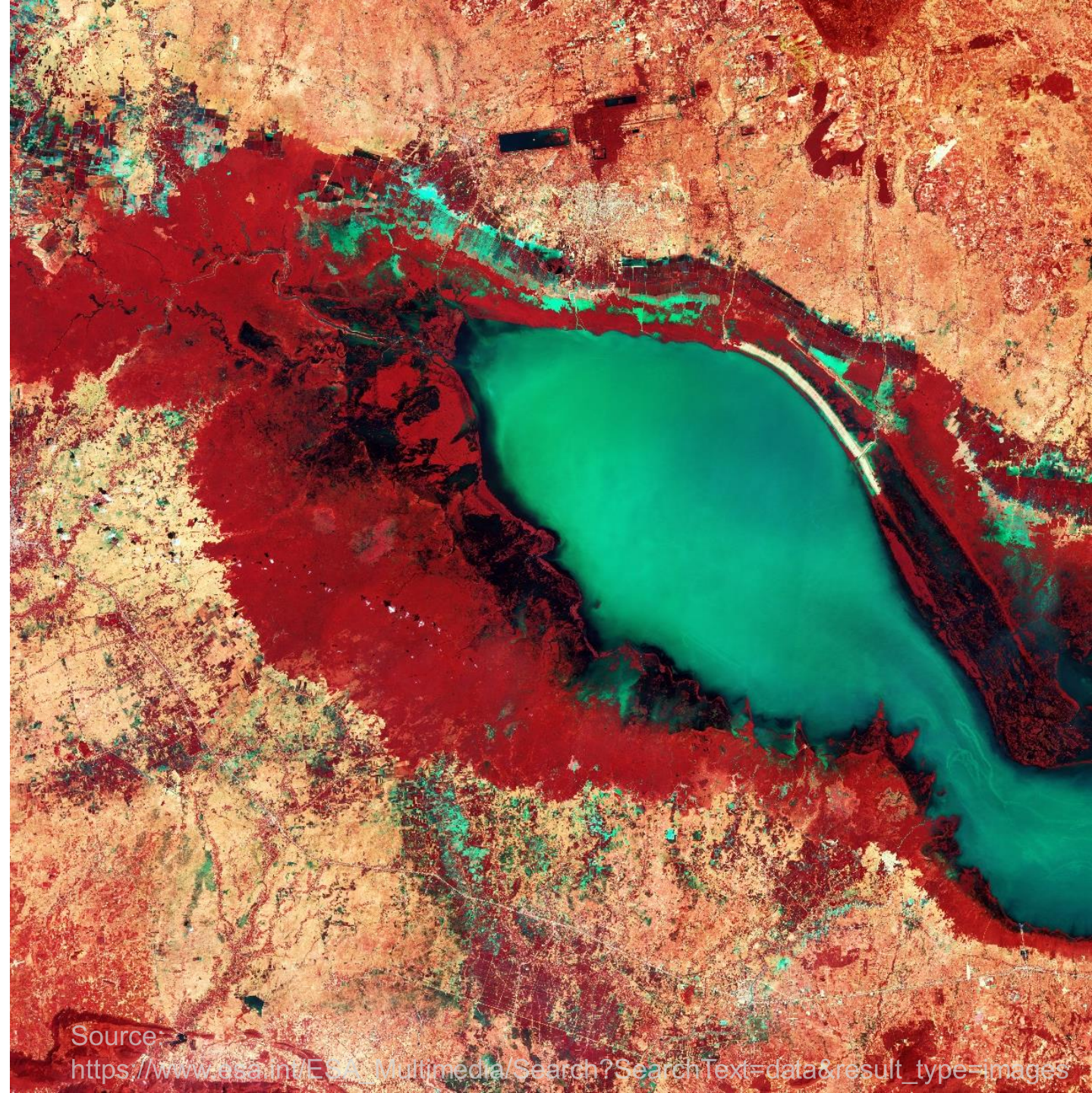


# EO data access

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



Thank you for the attention