2. SAR remote sensing for land applications 1 – SAR basics

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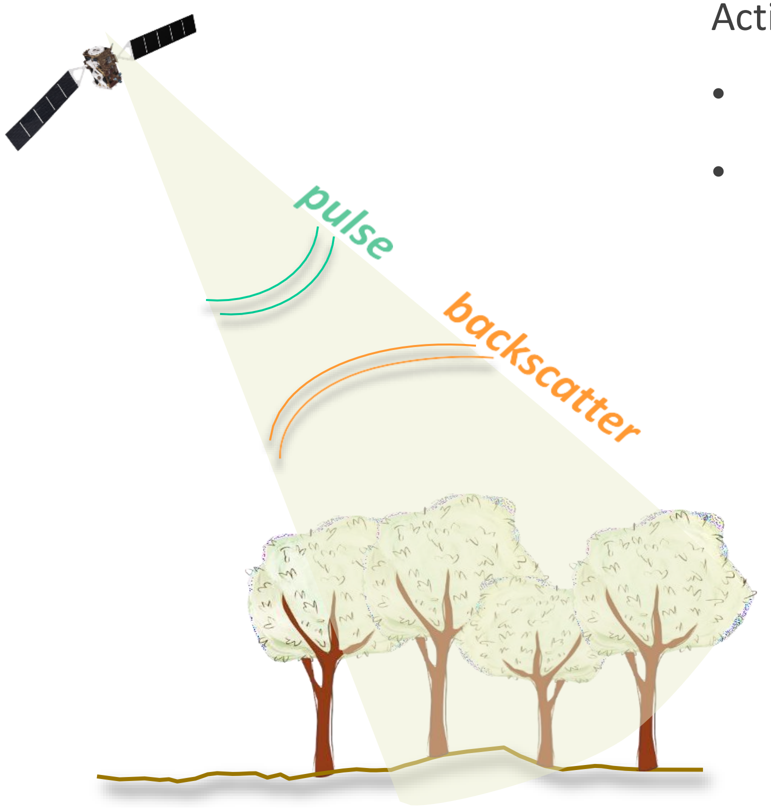
Synthetic Aperture Radar (SAR)

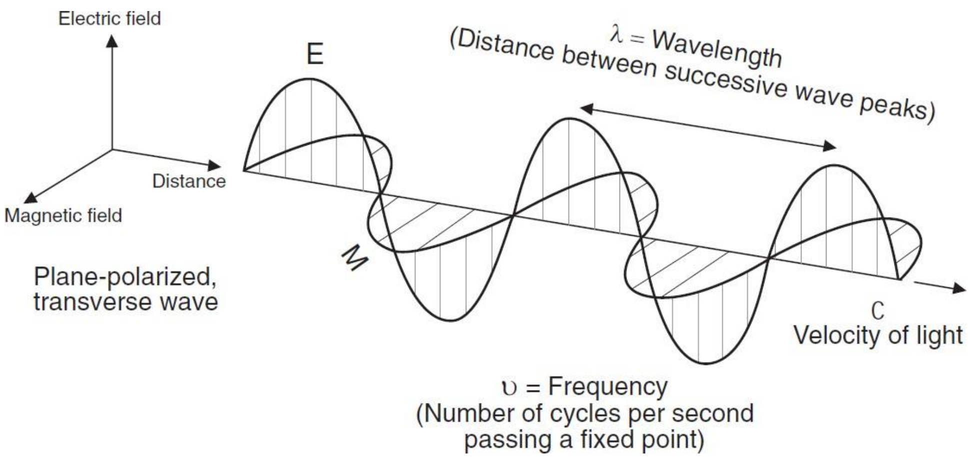
Basic characteristics of SAR (radar) sensors

- **active** $\Rightarrow$ **independent of sun illumination**



Active remote sensing sensors generate EM-waves

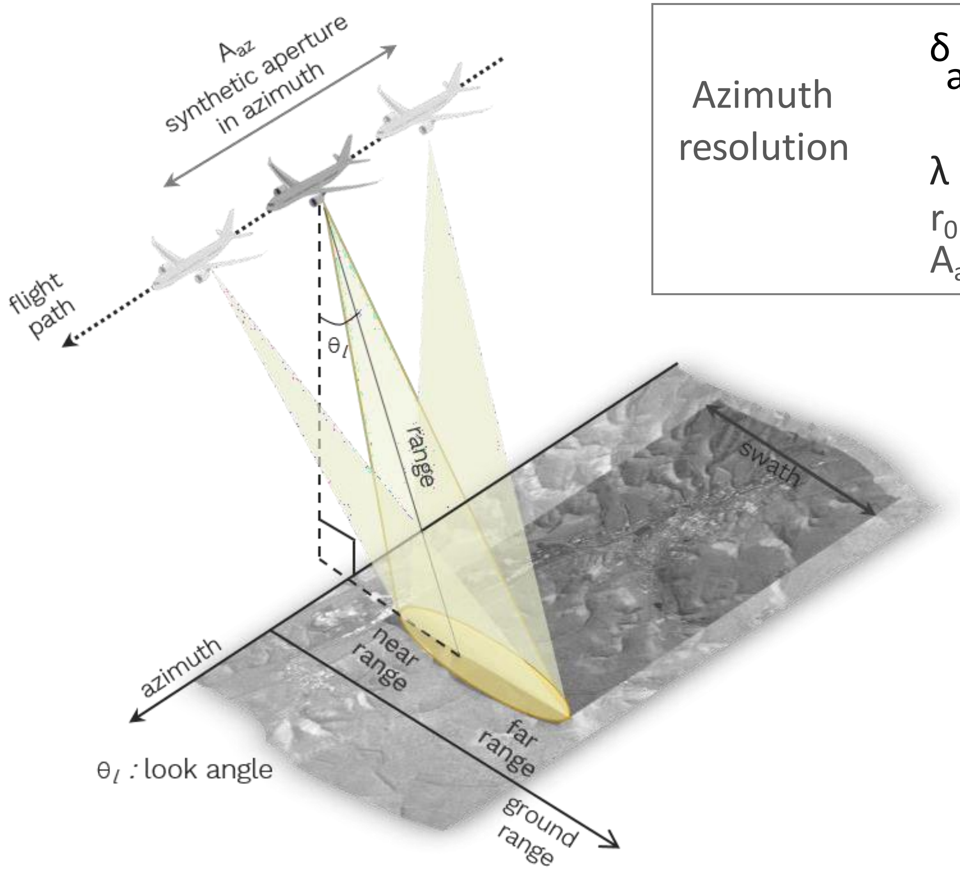
- no sunlight required night time acquisitions possible
- no problems due to bad illumination



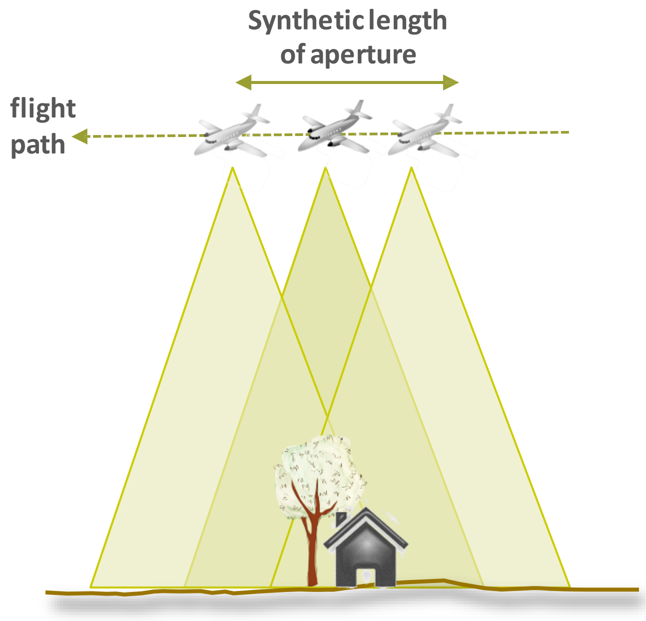
Synthetic Aperture Radar (SAR)

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.



Azimuth resolution	$\delta_{az} = \frac{\lambda r}{2A_{az}}$ λ : carrier wavelength r_0 : range distance A_{az} : azimuth aperture

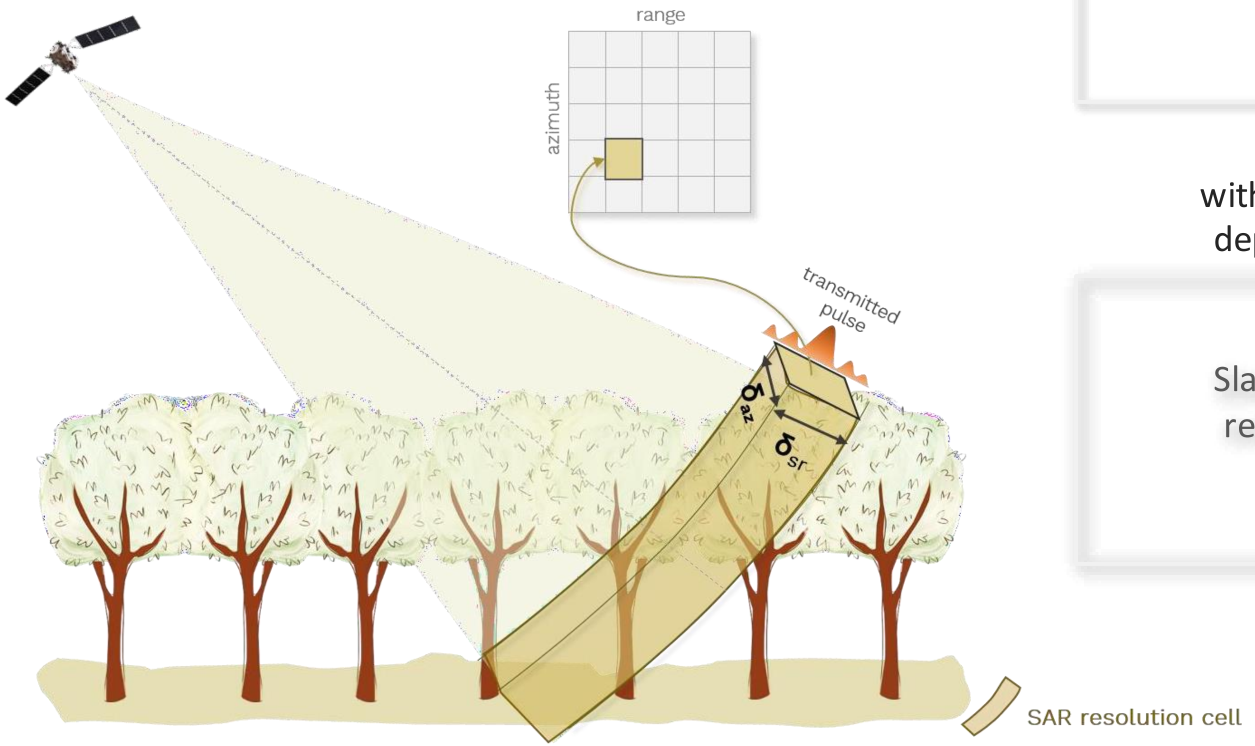


Side view

Synthetic Aperture Radar (SAR)

Cell resolution

A SAR pixel = sum of all contributions within the resolution cell



with the azimuth resolution being a function of the aperture in azimuth

Azimuth resolution

$$\delta_{az} = \frac{\lambda r_0}{2A_{az}}$$

λ : carrier wavelength
r_0 : range distance
A_{az} : azimuth aperture

with the slant-range resolution depending on the bandwidth

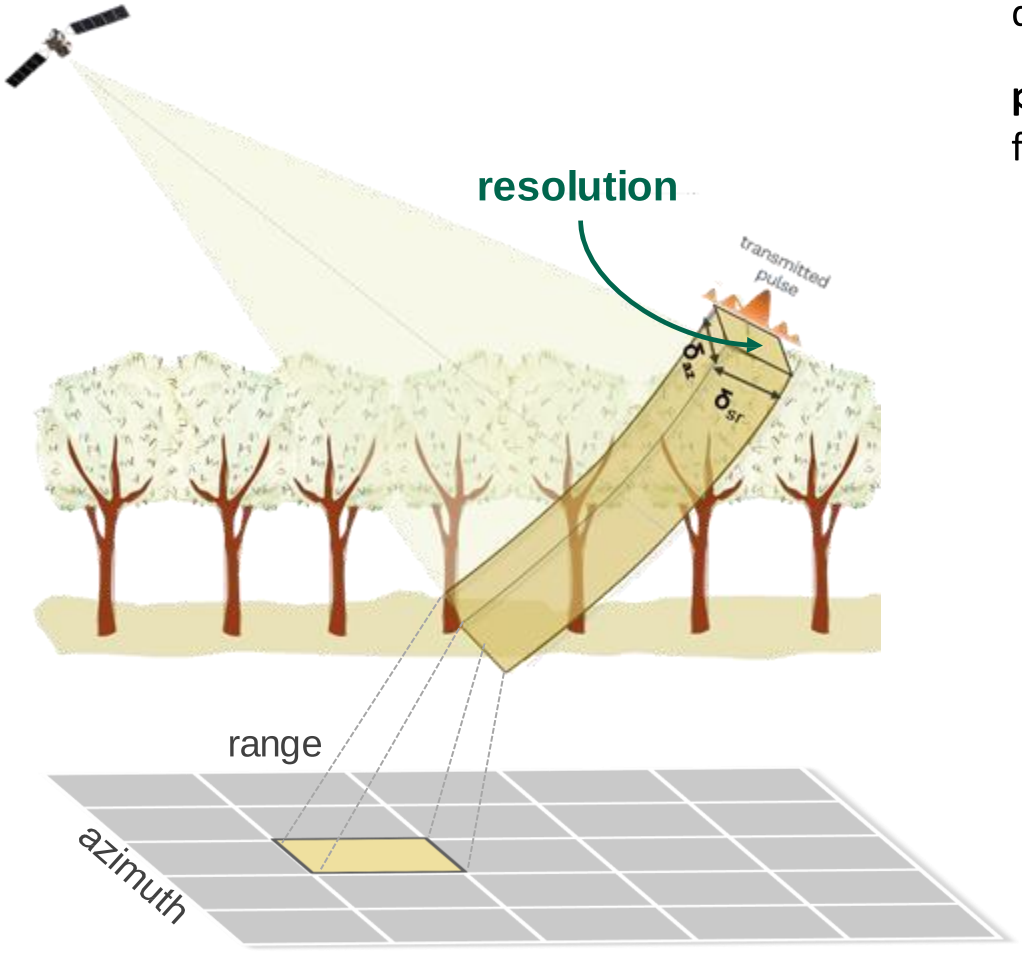
Slant-range resolution

$$\delta_{sr} = \frac{c}{2W}$$

c : speed of light
W : pulse bandwidth

Synthetic Aperture Radar (SAR)

Resolution vs. Pixel spacing



resolution is a measure of the system's ability to distinguish between adjacent targets

pixel spacing represents the distance on the ground for a pixel in the range and azimuth directions

E.g. Acquisition resolution of Sentinel 1 Level-1 SLC

Mode	Resolution rg x az	Pixel spacing rg x az
SM	1.7x4.3 m to 3.6x4.9 m	1.5x3.6 m to 3.1x4.1 m
IW	2.7x22 m to 3.5x22 m	2.3x14.1 m
EW	7.9x43 m to 15x43 m	5.9x19.9 m
WV	2.0x4.8 m and 3.1x4.8 m	1.7x4.1 m and 2.7x4.1 m

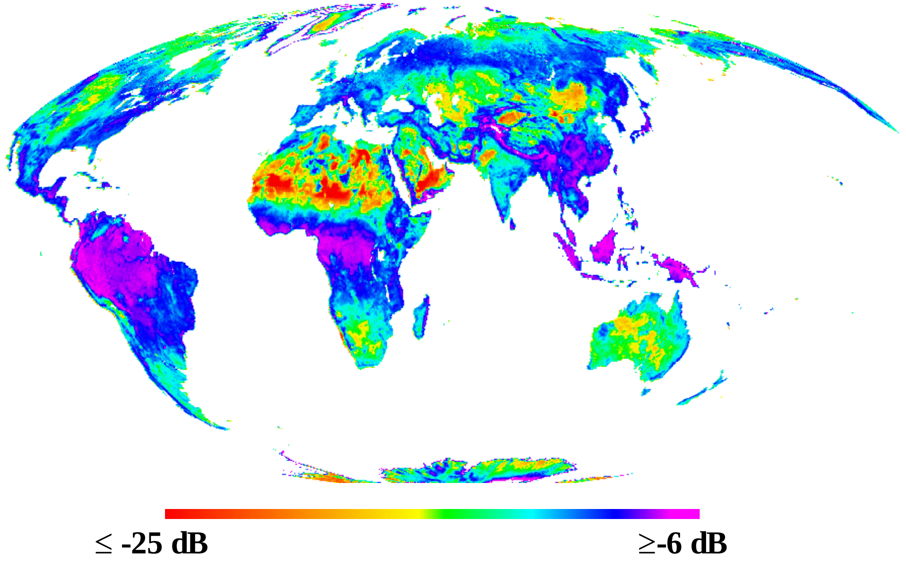
Synthetic Aperture Radar (SAR)

Scatterometers vs. SAR

***Scatterometers*:**

Radar eflectivity estimation (σ°)

- ***low spatial resolution***: *~ 10 – 50 km*
- ***high frequency of acquisitions (~ day)***

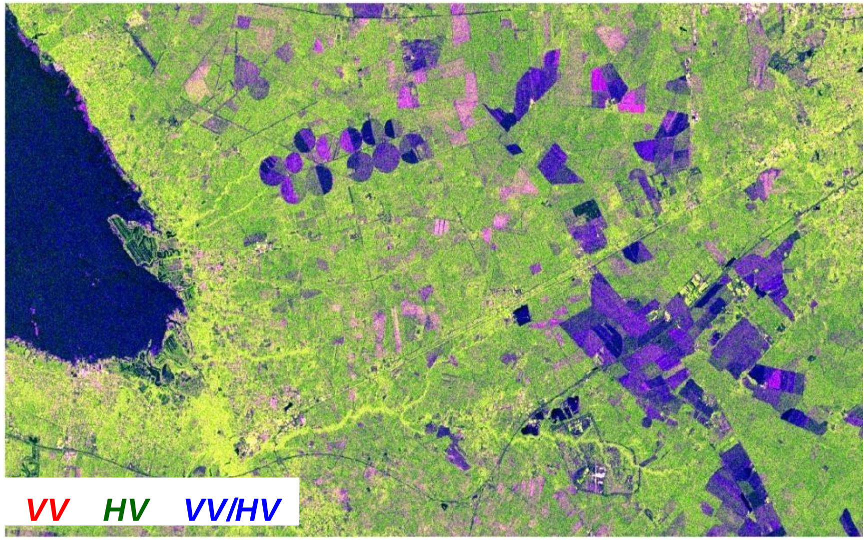


Scatt. ERS – May 1992

SAR:

Surface imaging

- ***high spatial resolution***: *~ 10 m*
- ***low frequency of acquisition (~ month)***

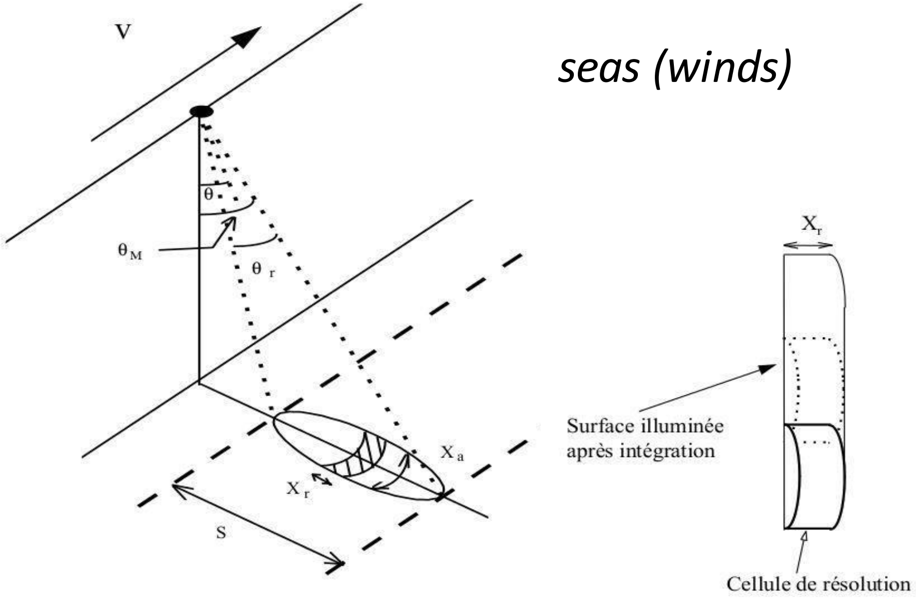


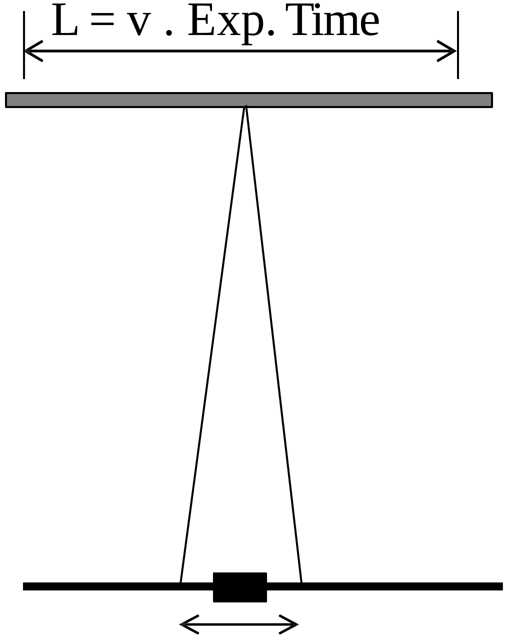
Sentinel-1 – March 2015

Synthetic Aperture Radar (SAR)

Scatterometers vs. SAR

Scatterometers		***SAR***
Incoherent sum *(I)*	**Raw echoes processing**	Coherent sum *(A, ϕ)*
Low (~ 10 – 50 km)	**Spatial resolution**	***Fine*** (1 - 30 m)
High (ENL ~ 400)	**Radiometic resolution**	***Low*** (speckle)
seas (winds)	**Originally designed**	*Land - seas*





Synthetic Aperture Radar (SAR)

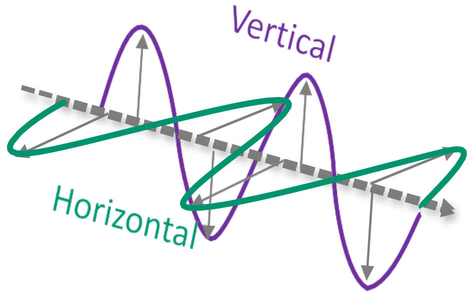
Polarisation

Important characteristics of cohetent EMW: Electromagnetic field evolution is predictable

Radar :

transmits a EMW in a given polarization

measures the backscattered wave contribution in a given polarization



The four combinations of SAR data polarizations:

HH: The emitted and backscattered signals have horizontal polarization

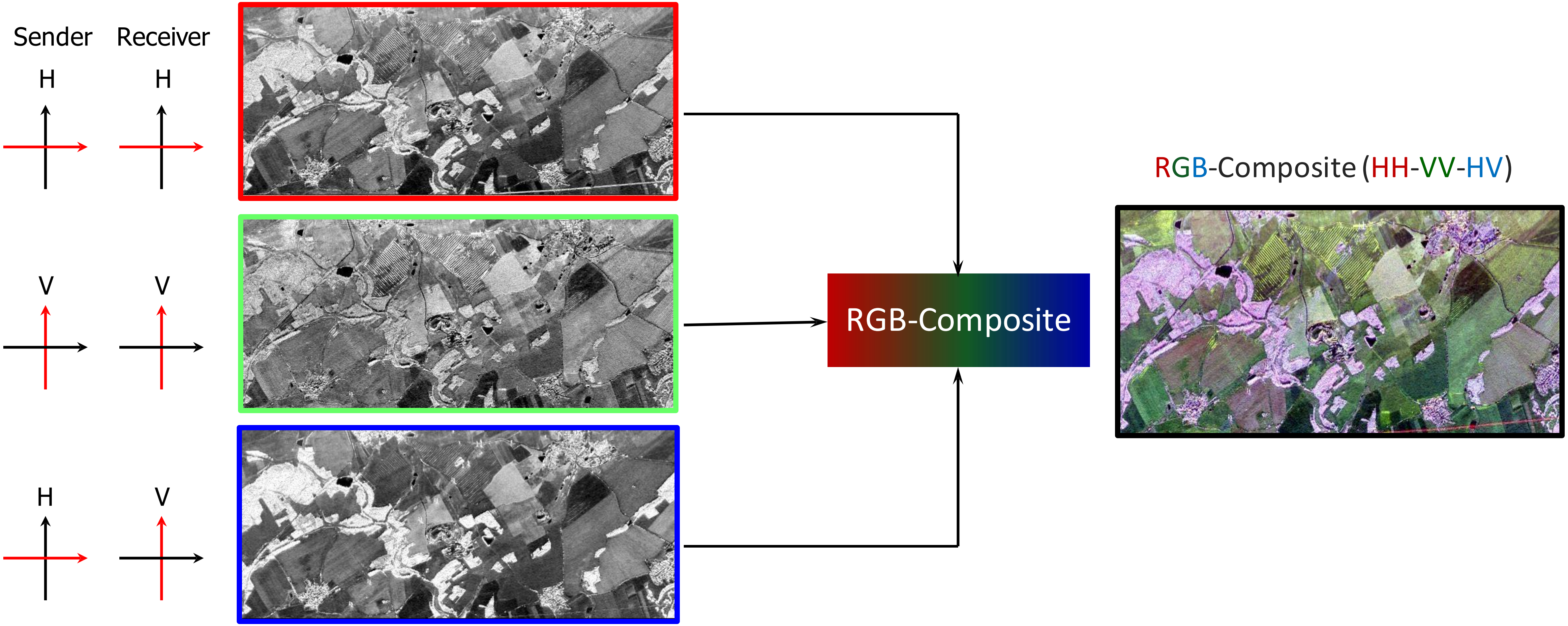
HV: The emitted signal has horizontal polarization, and the backscattered signal has vertical polarization.

VH: The emitted signal has vertical polarization, and the backscattered signal has horizontal polarization.

VV: Both emitted and reflected signals have vertical polarization

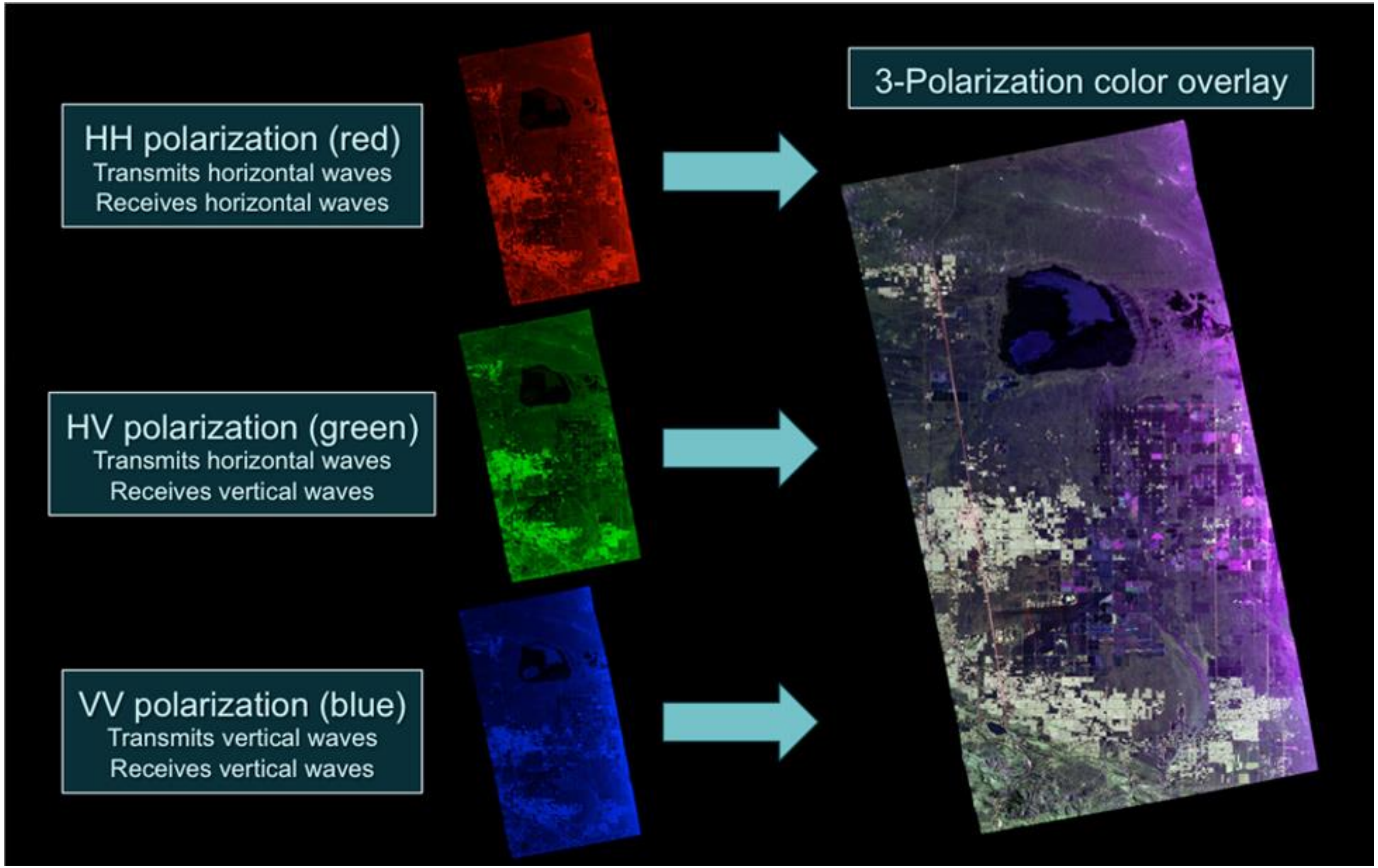
Synthetic Aperture Radar (SAR)

Polarisation



Synthetic Aperture Radar (SAR)

Polarisation



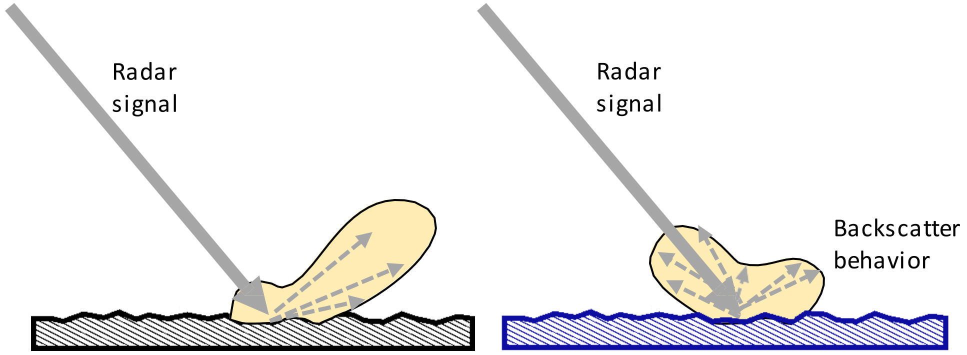
Synthetic Aperture Radar (SAR)

Target parameters : Dielectric Properties

Determined by dielectric constant ε_r:

• Strongly dependent on **water content** of natural media

•Controls reflection properties of natural media and thus the strength of radar backscatter (higher ε_r -> higher backscatter)



Effect of soil moisture on backscattering behavior

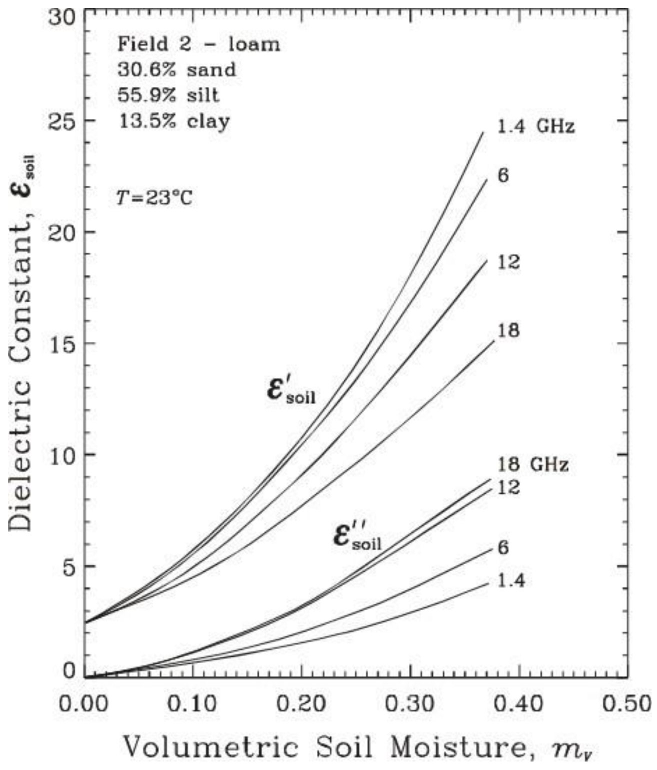
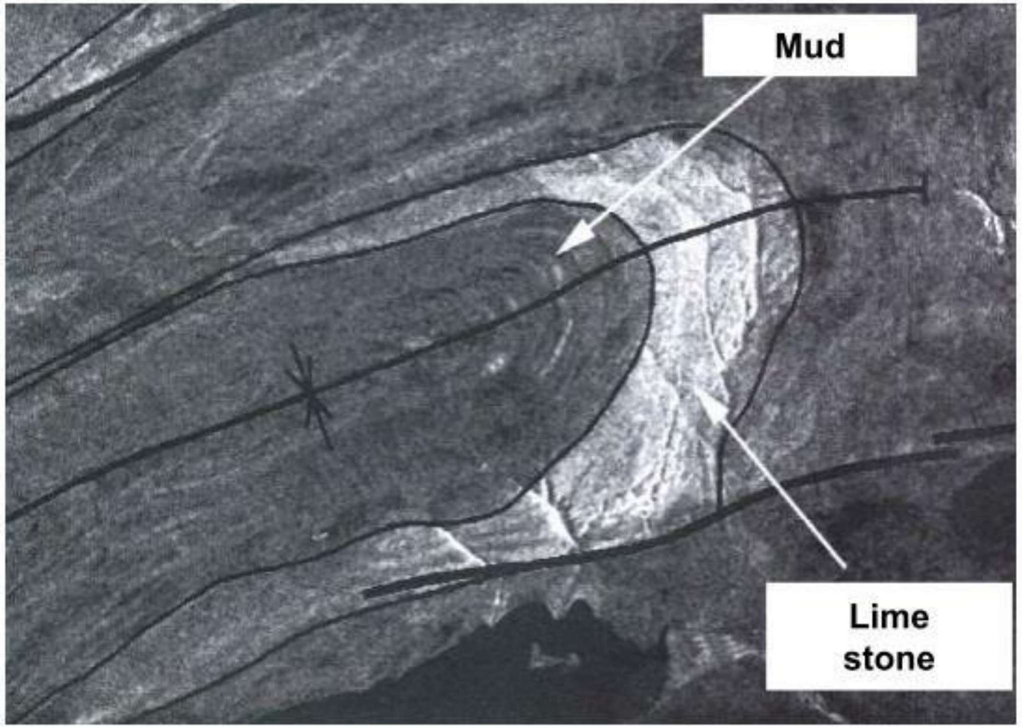


Fig.: Relationship between soil moisture and dielectric constant (Woodhouse, 2006)

Synthetic Aperture Radar (SAR)

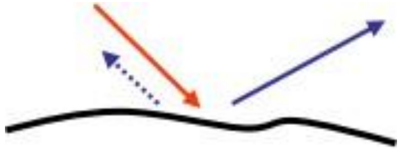
Target parameters : Surface Roughness



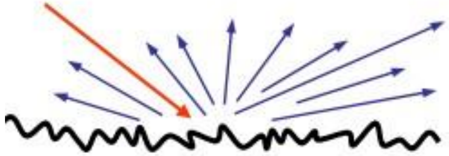
Radarsat, C-band, HH

Bathirst Island, Canada

mud, smooth surface, low radar backscatter



Lime stone, rough surface, high radar backscatter

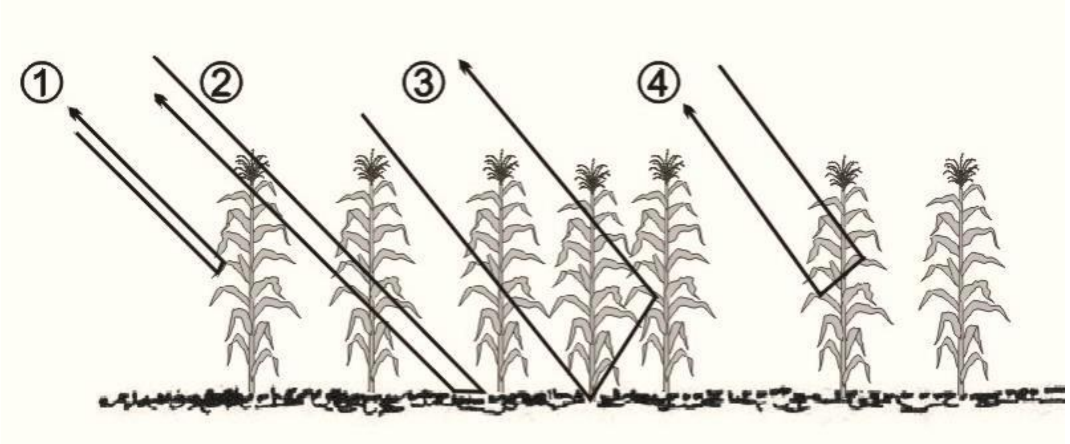


Synthetic Aperture Radar (SAR)

Target parameters : Scattering Mechanisms

The backscattered signal results from:

- surface scattering
- volume scattering
- multiple volume-surface scattering (double-bounce)



1) direct backscattering from plants
2) direct backscattering from underlying soil
3) multiple scattering between plants and soil
4) multiple scattering between plants,
5) leaves, stalks ect.

The relative importance of these contributions depend on

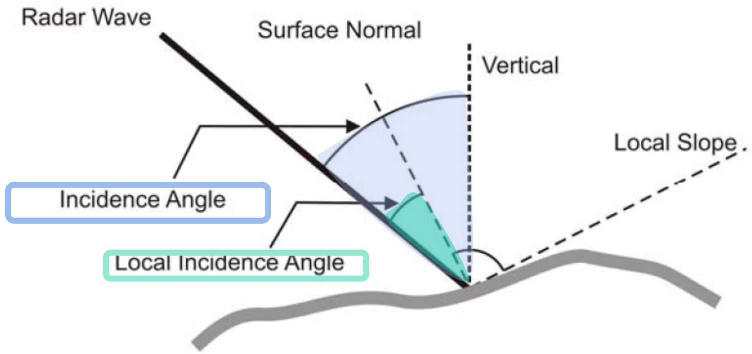
- surface roughness
- dielectric properties of the medium

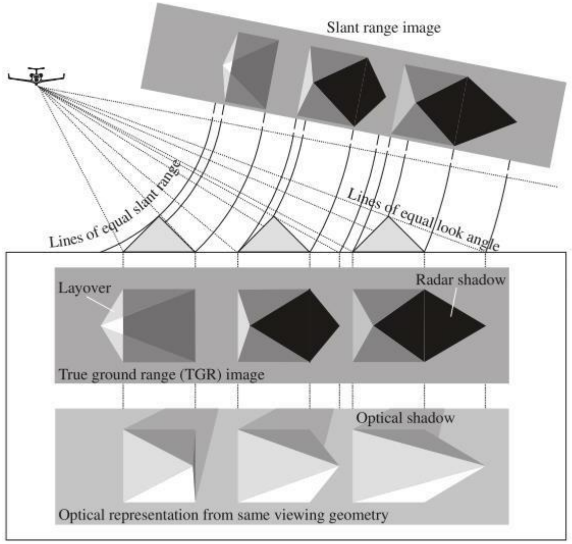
All of these factors depend on

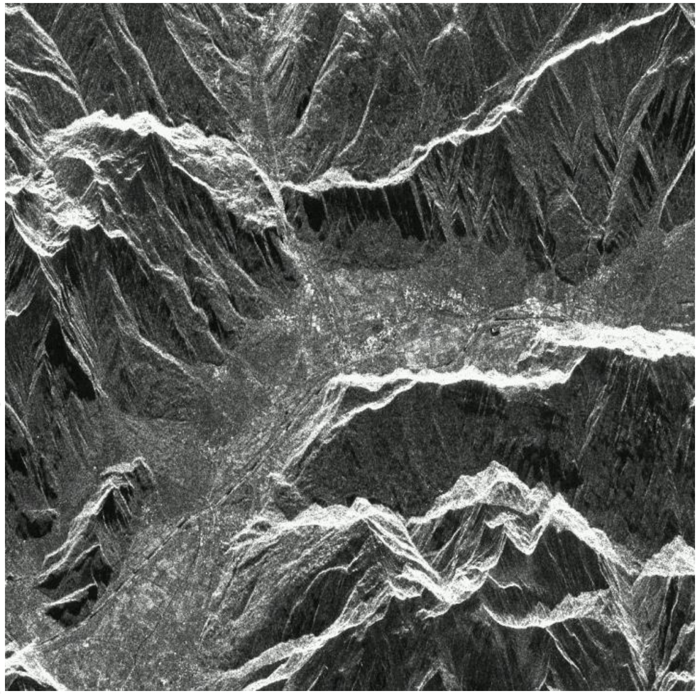
- the radar frequency
- the polarization
- the incidence angle

Synthetic Aperture Radar (SAR)

Target parameters : Local slope & orientation

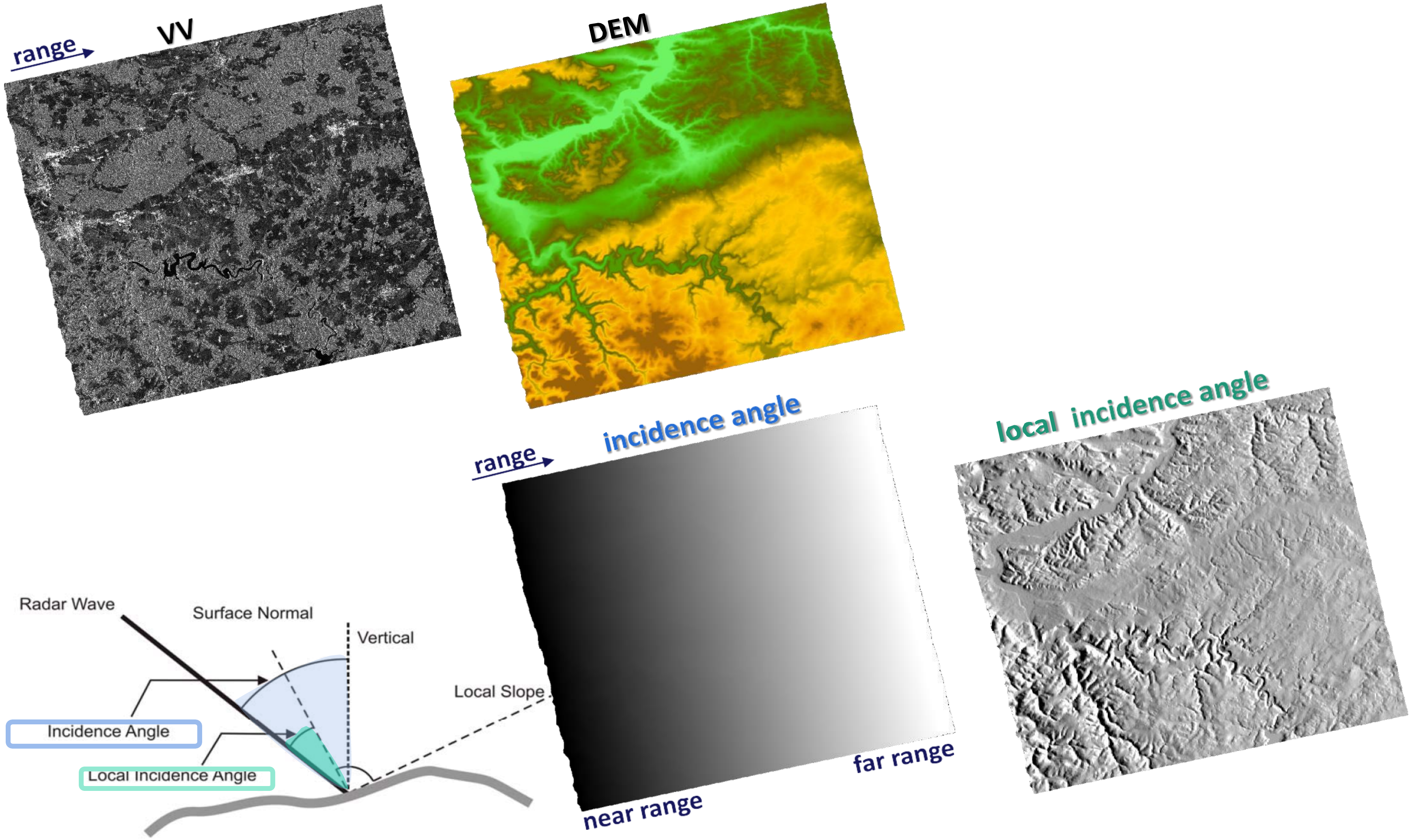






Synthetic Aperture Radar (SAR)

Target parameters : Local slope & orientation



Sentinel-1 – Radar vision

Mission profile:

- C-Band SAR mission at 5.4 GHz
- 4 operation modes
- Spatial resolution: 20 m
- Swath width: 250 km
- Two polarizations over land surfaces: VV and VH

Sentinel-1A: launched the 3rd April 2014
== > SAR data from March 2015

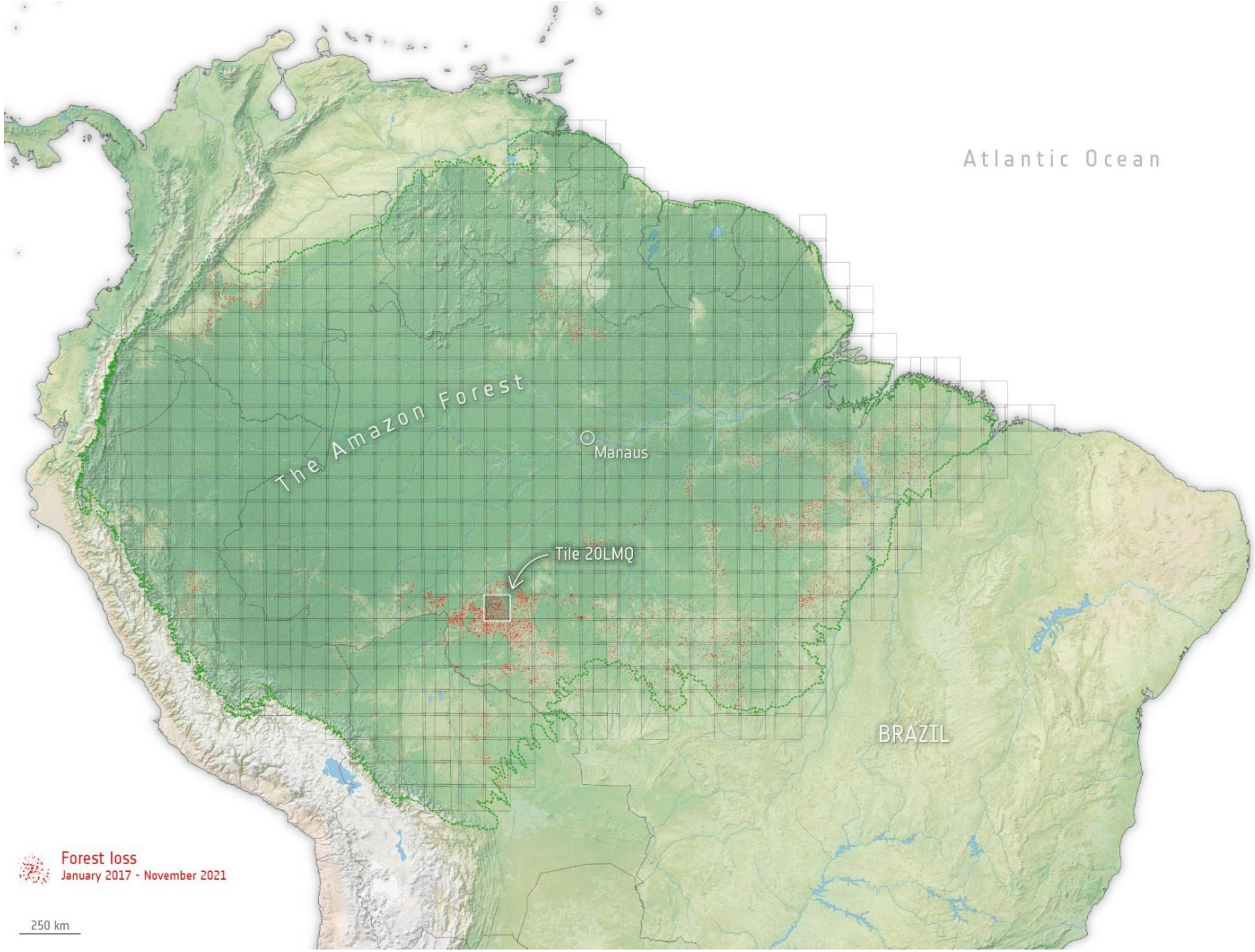
Sentinel-1B: launched the 22th April 2016
== > SAR data from September2016

Revisit time: 12 days
Revisit time: 12 days
} ***6 days***

- **High temporal frequency** of acquisition is necessary for seasonal variation of land surfaces
- Accessible now with **Sentinel-1** data at **local** scales

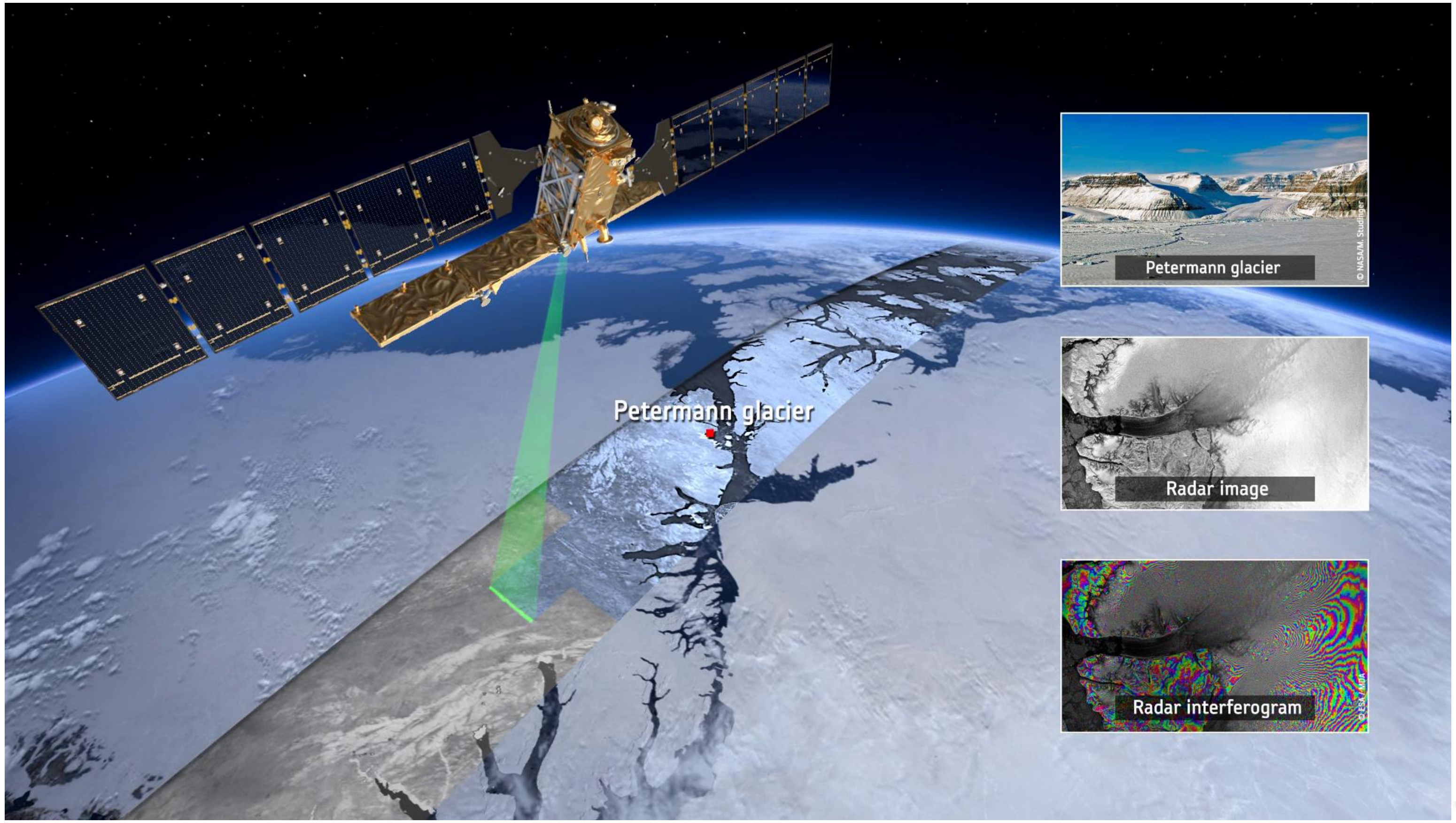
https://sentinels.copernicus.eu

Sentinel-1 - Forestry



Forest loss across the Amazon

Sentinel-1 – Topographic mapping

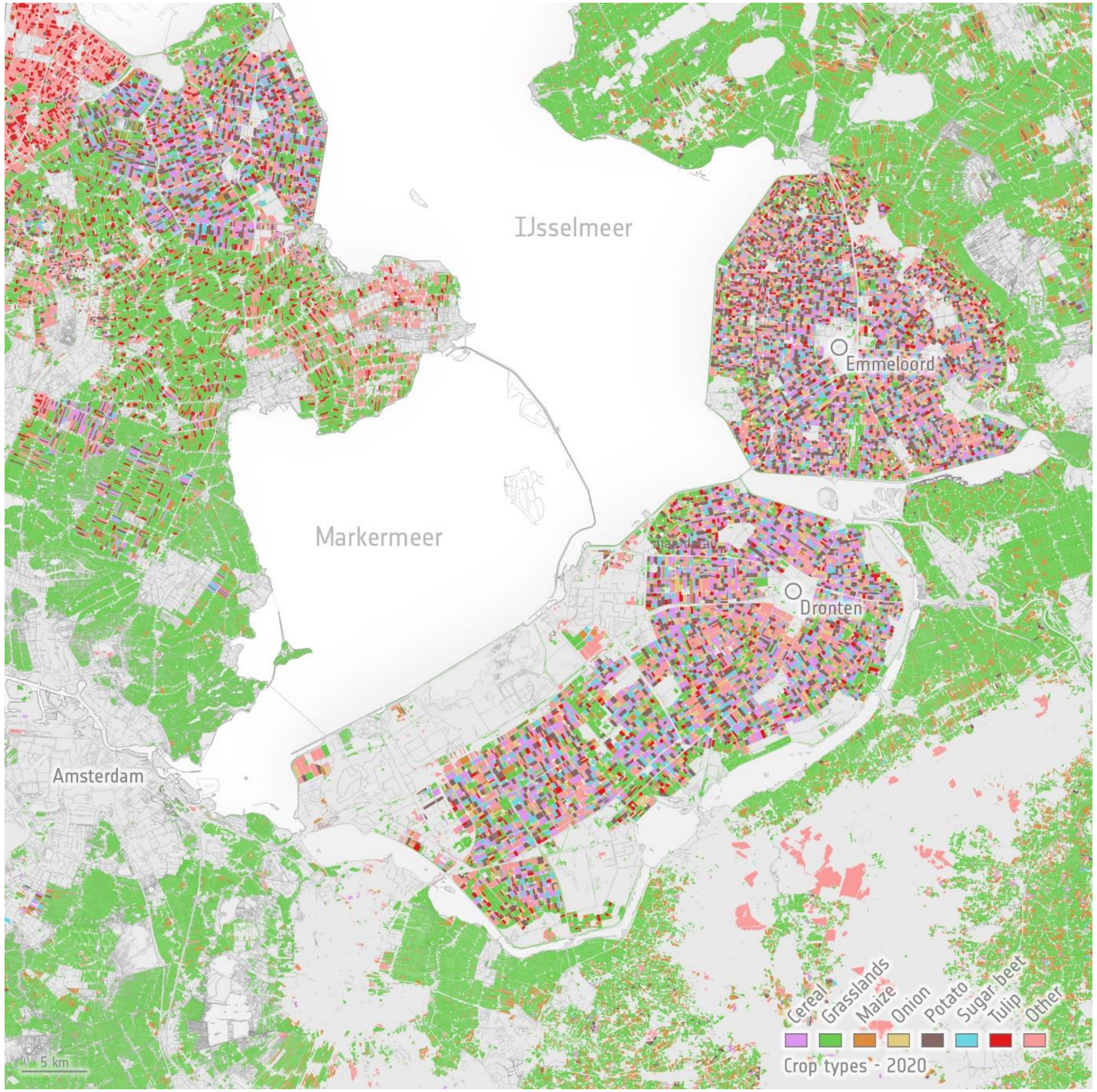


Sentinel-1 monitoring motion

Radar images from Sentinel-1 can be used to generate 3D models of Earth's surface and to closely monitor land and ice surface deformation. Synthetic aperture radar interferometry – or InSAR – is a technique where two or more satellite radar images acquired over the same area are combined to produce an interferogram. Small changes on the ground cause changes in the radar signal phase and lead to rainbow-coloured fringes in the interferogram. These products are important for mapping topography to produce 'digital elevation models' and to monitor surface deformation caused by, for example, mining, earthquakes, volcanic activity, melting permafrost and glacial flow.

Source: https://www.esa.int/ESA_Multimedia/Videos/2014/08/Sentinel1_monitoring_motion

Sentinel-1 - Crop monitoring

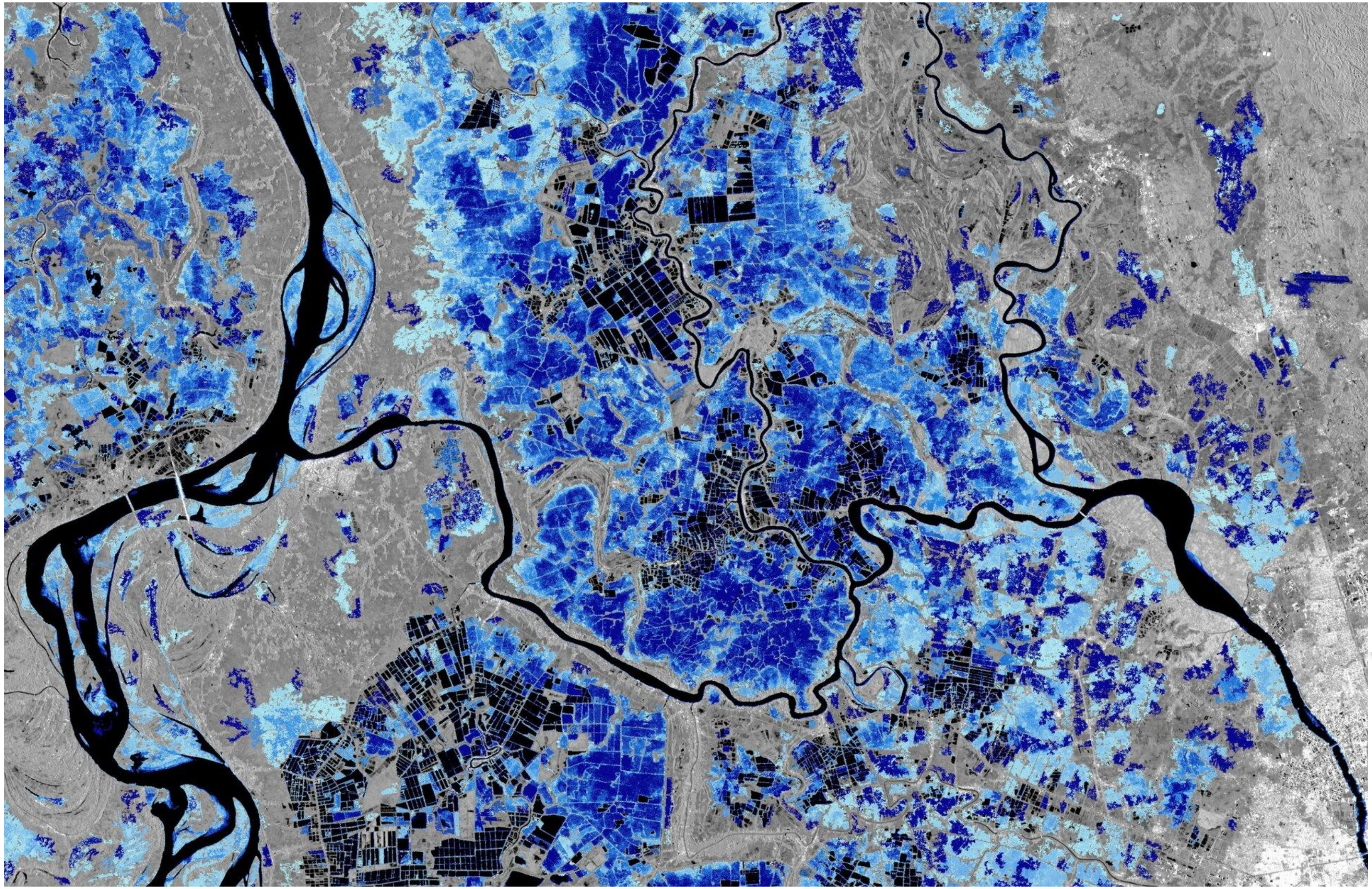


Crop type for all agricultural parcels Flevoland in the Netherlands

This figure zooms in on Flevoland in the Netherland to illustrate individual crop parcels. ESA worked with the Delft University of Technology in the Netherlands to develop Agricultural Sandbox NL, which makes use of radar data from Copernicus Sentinel-1 and optical, or camera-like, data from Copernicus Sentinel-2 and reduces terabytes of satellite data to just 10 gigabytes per year. Importantly, this dataset tool makes these data perfect for non-expert data users in the agriculture sector.

Source:https://www.esa.int/ESA_Multimedia/Images/2022/02/Crop_type_for_all_agricultural_parcels_Flevoland_in_the_Netherlands

Sentinel-1 – Flood mapping



Copernicus Sentinel-1 flood monitoring

Flood frequency mapping in Myanmar, using data from the Copernicus Sentinel-1 mission. Dark areas represent permanent water bodies or fields frequently or always covered by water, for example rice fields. Different shades of blue represent the flood occurrences frequency estimated from Copernicus Sentinel-1 data archive (light blue: less frequent; dark blue: more frequent).

Source:https://www.esa.int/Applicatios/Observing_the_Earth/Using_space_to_foster_development_assistance_for_disaster_resilience

Thank you for the attention