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1 Fundamentals of Remote Sensing

Sensors and their Characteristics, Active vs. Passive Sensing, Remote Sensing Platforms

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EARTH OBSERVATION RESEARCH

Sensors and their Characteristics

Sensors and their characteristics

- **A sensor** is defined as an instrument that detects and records electromagnetic radiation.
- Those sensors can be divided into **passive** and **active sensors**
- Sensors can be classified as **scanning** (imaging) and **non-scanning** (non-imaging) sensors. In Earth Observation we are interested in the first category – imaging sensors.
- Depending on what is the **object of your interest**, sensors vary in terms of their **geometric** and **spectral** properties.

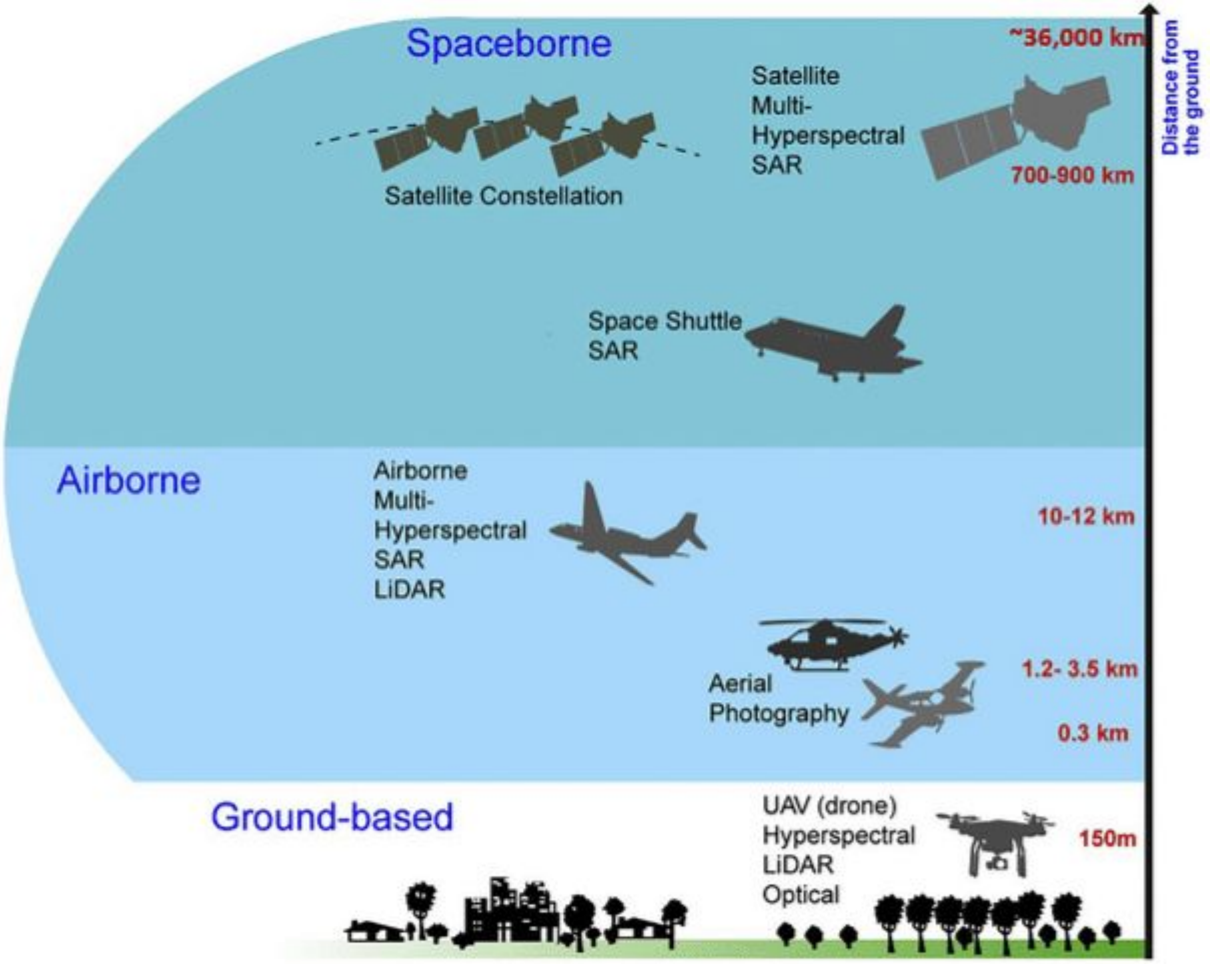
Sensors and their characteristics

- **Remote sensors** used to observe our planet and take measurements
- They operate at different altitude, **but: NO** direct contact with the object of study (do not touch the object)
- they vary from a **few centimeters** above the ground to
- those located far beyond the atmosphere up to **36 000 km above the ground** (satellites)

Sensors and their characteristics

- Sensors which observe the Earth’s surface are mounted on a **moving platform**
- Such platforms are airplanes or **satellites** which carry sensors
- **Static platforms** are also used, e.g., spectrometers, that are placed on a pole to measure the changing reflectance of a specific crop

Sensors and their characteristics



Common remote sensing platform and sensor combinations and remote sensing data platforms and most utilized sensors for specific platforms. Lechner et al., 2020.

Sensors and their characteristics

- **Different spectral resolution**: sensors also differ when we consider the scale in which they register the data, which depends also on their altitude.

- Each type of instrument used to measure **certain parameters** on the Earth's surface has its advantages and disadvantages.

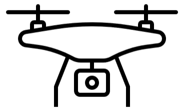
- **Different altitude** on which the sensing platform is placed have an **impact on the coverage** and **resolution of an image** it captures

- **Ground-based observation** collected by drones have their advantages in capturing data in **very high resolution**

Sensors and their characteristics

Drones (UAV): very high resolution

- One of the disadvantages is that UAV image covers a very small area



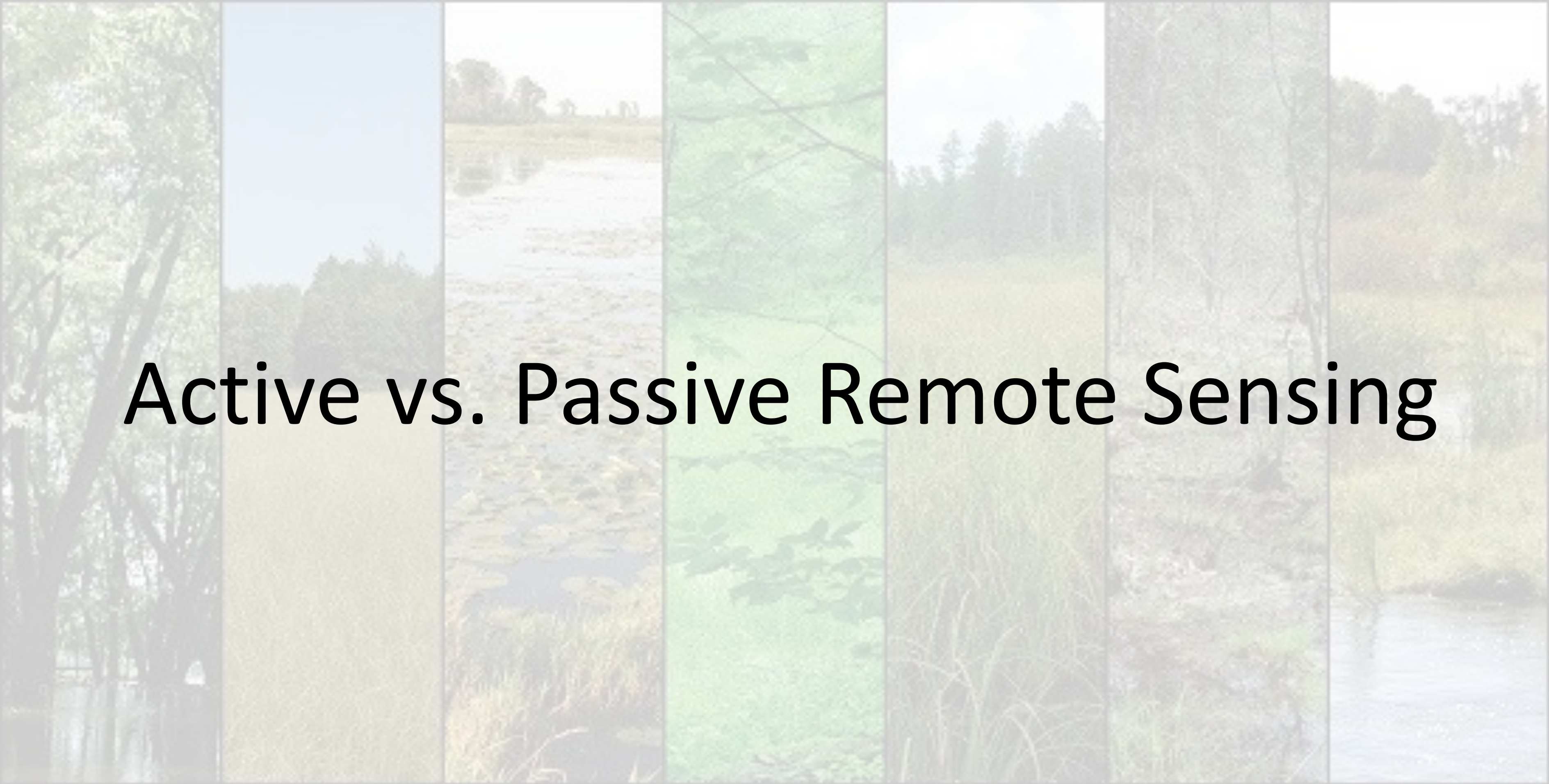
Images captured from **airplanes** have also high resolution

- Relatively small coverage extent, compared to spaceborne missions
- Very costly

Sensors and their characteristics

Satellites have a huge advantage over airplanes and drones because of their coverage

- The image covers **large extent** of the area
- Different instruments can be mounted on them **from high to coarse image resolution**
- For optical sensors **clouds** and **weather conditions** can be problematic
- Coverage is also restricted only to the **orbit track** and cannot be adjusted



Active vs. Passive Remote Sensing

Active vs. Passive Remote Sensing

Two main categories of Earth Observation systems can be differentiated – **Passive and Active**

Passive Instruments	**Active Instruments**
Multispectral sensors (e.g., Landsat, Sentinel-2)	RADAR / SAR (e.g., RADARSAT, TerraSAR-X, Sentinel-1)
Radiometers (e.g., MODIS, VIIRS)	Radar altimeters (e.g., TOPEX/Poseidon, Jason series)
Hyperspectral sensors	LiDAR sensors

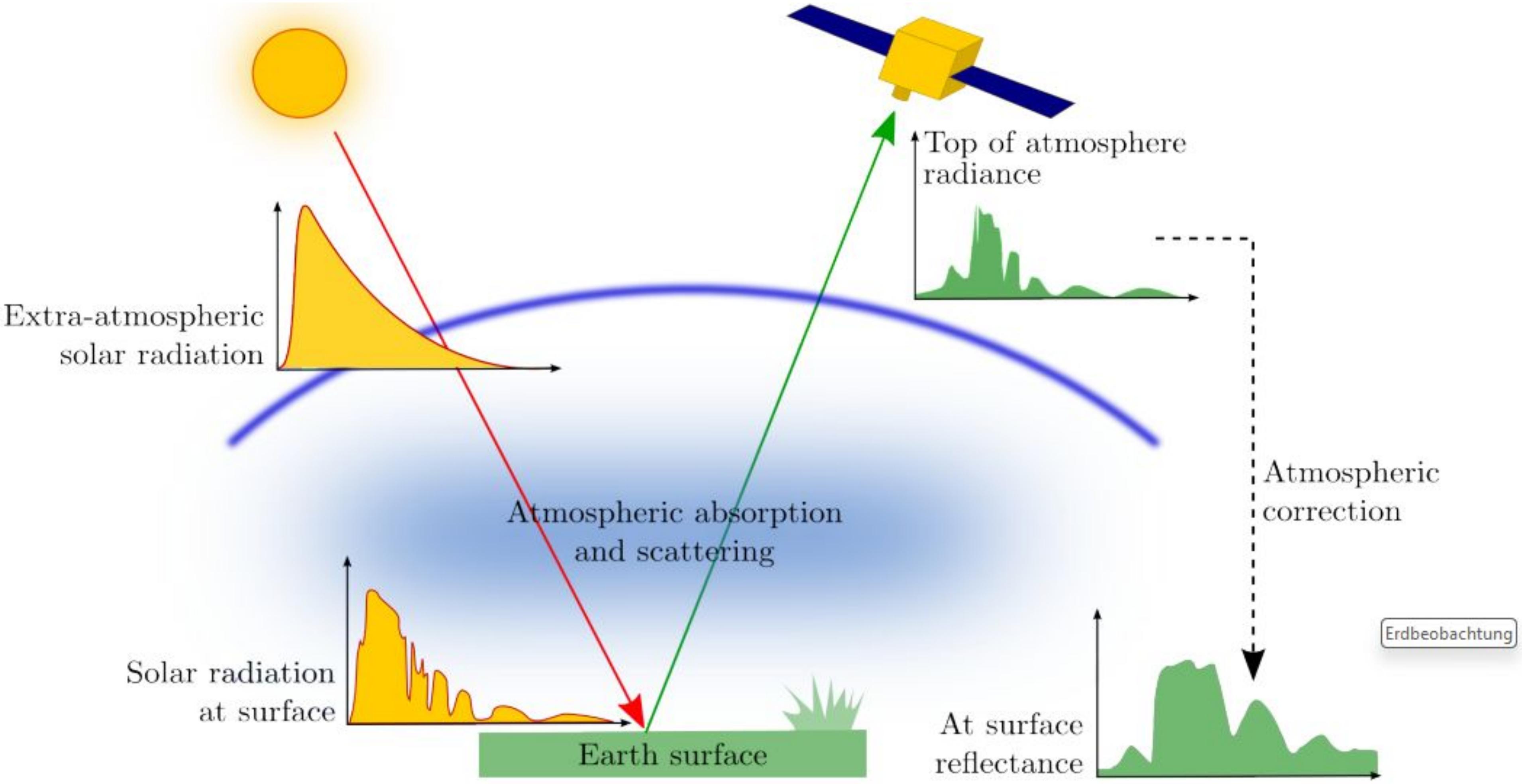
- **Sensors that use external sources of EM radiation** to “observe” an object, so usually rely on the sun but also the earth or atmosphere radiation are called **passive sensors**
- Passive sensors **record electromagnetic energy that is reflected** (e.g., blue, green, red, and infrared light) or emitted (e.g., thermal infrared radiation) from the surface of the earth
- What is important to remember that this kind of earth observation **will not work at night**, when there is no reflected energy coming from the sun

Active vs. Passive Remote Sensing

Two main categories of Earth Observation systems can be differentiated – **Passive and Active**

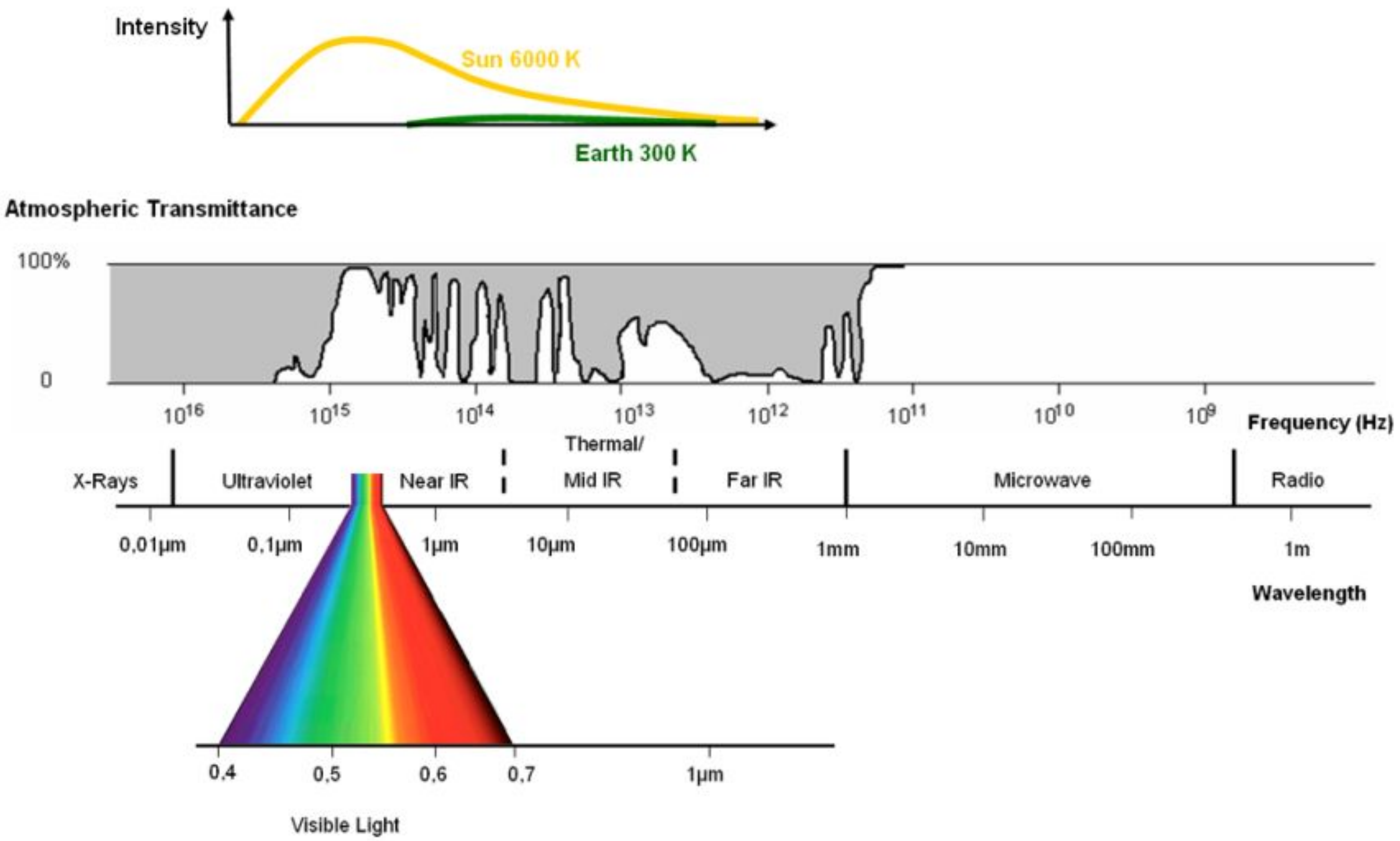
- Active remote sensing is **based on the sensor's own energy of light** (ilumination)
- The **sensor itself emits radiation** which is directed toward the target and then reflected back to the sensor to be recorded.
- This type of sensing and observing the Earth **does not require the sunlight** to measure an detect the radiation

Passive Remote Sensing - Basics



Basic physical principle of passive optical remote sensing

Passive Remote Sensing - Basics



A section of the electromagnetic spectrum used for remote sensing depicting atmospheric absorption features. The solar emission peaks falls right into the visible spectrum, which is not a coincidence: We can see where it is brightest – *Albertz 2007*

Passive Remote Sensing - Advantages

- Images captured by satellites provide information about large area at once. Satellites can acquire data also of **not easily accessible, remote regions** (such as far desert areas or glaciers)

- Moreover, images capture for a selected area are recorded continuously in a **repetitive way,** which leaves no gaps in information
   It is very important, especially when we would like to measure data on dynamic themes such as water, agricultural fields etc., as we do not need to come back to the field to collect the data.

- This capability enables assessment of any man- or nature-made changes in the landscape or environment.

Passive Remote Sensing - Advantages

- **Image acquisition is relatively cheap** compared to the ground-based data collection, taking into account the size of the area which can be investigated with considering imagery

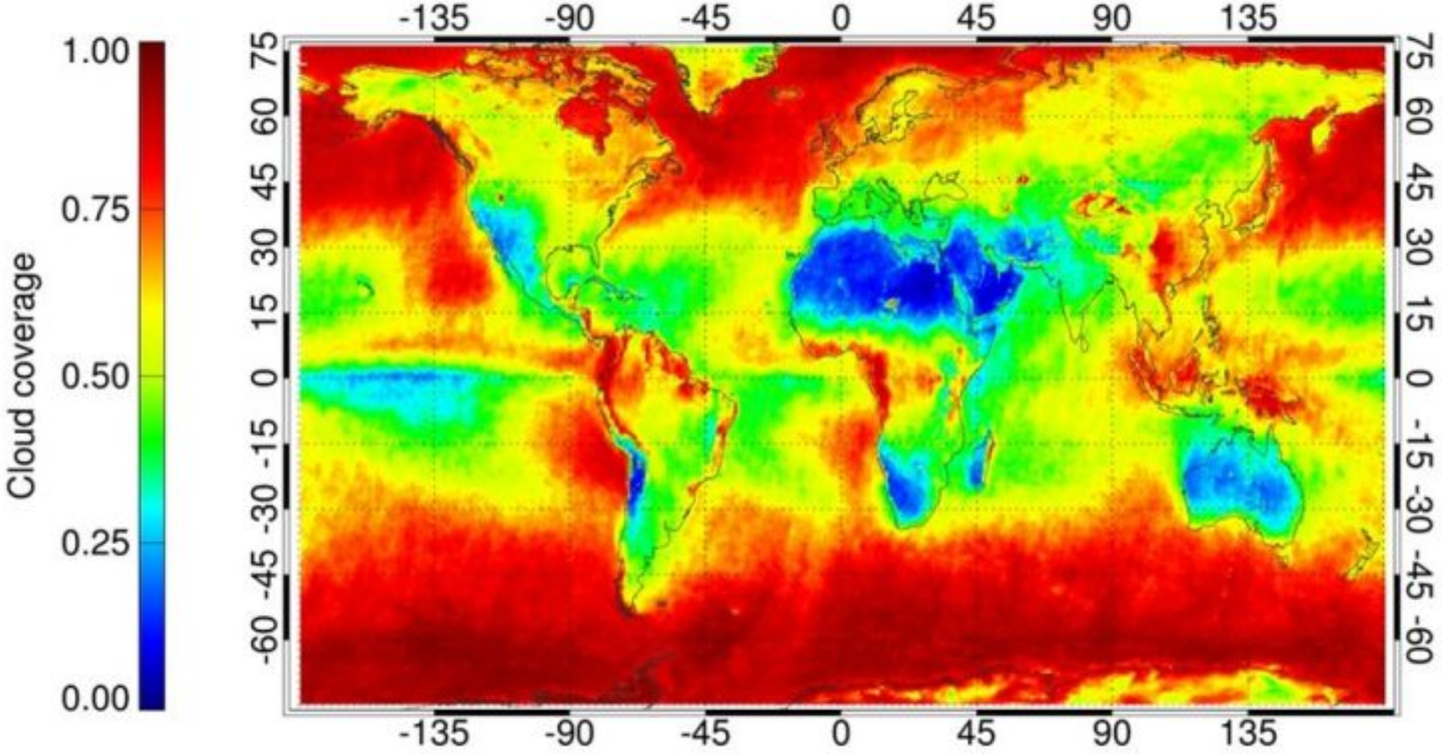
- **Data access and collection is easy** and relatively **quick**

- Different satellites offer a **variety of scales and resolutions** and therefore can be adapted to specific problem

- Maps can be produced in a fast and efficient way

Passive Remote Sensing - Limitations

- Clouds
- Atmospheric absorption
- Atmospheric scattering
- Reflection distribution of the surface
- Angular dependencies (visual/surface geometries)



Yearly cloud coverage per location on Earth (fractional coverage index)

Passive Remote Sensing - Limitations

- The first limitation is difficult data interpretation
- Preprocessing and analysis of satellite data require certain skills, and often requires a trained person or an expert in the field to interpret the data
- Data providers come across this challenge by providing already preprocessed visualizations of many areas around the globe
- Sentinel-Hub offering Sentinel 1 and 2, Landsat 8 data and MODIS imagery visualized using different band compositions, indexes and even classified images for a given area

Passive Remote Sensing - Limitations

- **Cross verification** (ground measurements) **is needed**, at least for randomly selected points spreading over the study area
- Data coming from different sensors using different bands and resolutions need **very good data handling skills**, as using several sensors may create confusion in image interpretation and further analyses
- We need to be also very careful in object classification as they can reflect differently in different time periods or can be affected by shadow or weather conditions. Therefore, **knowledge of study area** is always an added value.

Passive Remote Sensing - Limitations

- In **passive remote sensing clouds** may influence the reflectance of ground features or covering them completely
- A particular class we are interested in must be large enough with respect to the resolution of the imagery we have. There should be always a **balance between the size of an object to be detected and the spatial resolution** of an image cell
- **Some features cannot be separated only based on spectral signature** of target reflected in the image. It may be difficult to separate some certain tree species without supporting ground-truth data

Passive Remote Sensing – Optical Satellites


Shutterstock

Passive Remote Sensing – Multispectral Satellites

The Advanced Very High Resolution Radiometer (**AVHRR**) acquires measurements of land and sea surface temperature, cloud cover, snow and ice cover, soil moisture, and vegetation indices. Data are also used for volcanic eruption monitoring.

Specifications

Spatial Resolution: 1000 m
Temporal Resolution: 1 day

Spectral Bands: 5

Data available since: 1981

AVHRR consists of five different channels in which first two were red and NIR (0.6 mm and 0.9 mm respectively), third is located at 3.6 mm and remaining two channels are thermal radiation bands with wavelength 11 mm and 12 mm.

Passive Remote Sensing – Multispectral Satellites

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites.

Specifications

Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36)
Temporal Resolution: 1-2 days

Spectral Bands: 36

Data available since: 1999

MODIS data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

Passive Remote Sensing – Multispectral Satellites

The **Landsat program** is the longest-running enterprise for acquisition of satellite imagery of earth. It is a joint NASA / USGS program.

Specifications

Spatial Resolution: 30 m (bands 1-7; 9), 15 m (band 8), 100 m (bands 10-11)
Temporal Resolution: 16 days

Spectral Bands: 11

Data available since: 1972

Since 1972, Landsat satellites have continuously acquired images of the Earth's land surface, providing uninterrupted data to help land managers and policymakers make informed decisions about natural resources and the environment.

Passive Remote Sensing – Multispectral Satellites

The Copernicus **Sentinel-2** mission is based on a constellation of two identical satellites in the same orbit. Each satellite carries an innovative wide swath high-resolution multispectral imager with 13 spectral bands for a new perspective of our land and vegetation.

Specifications

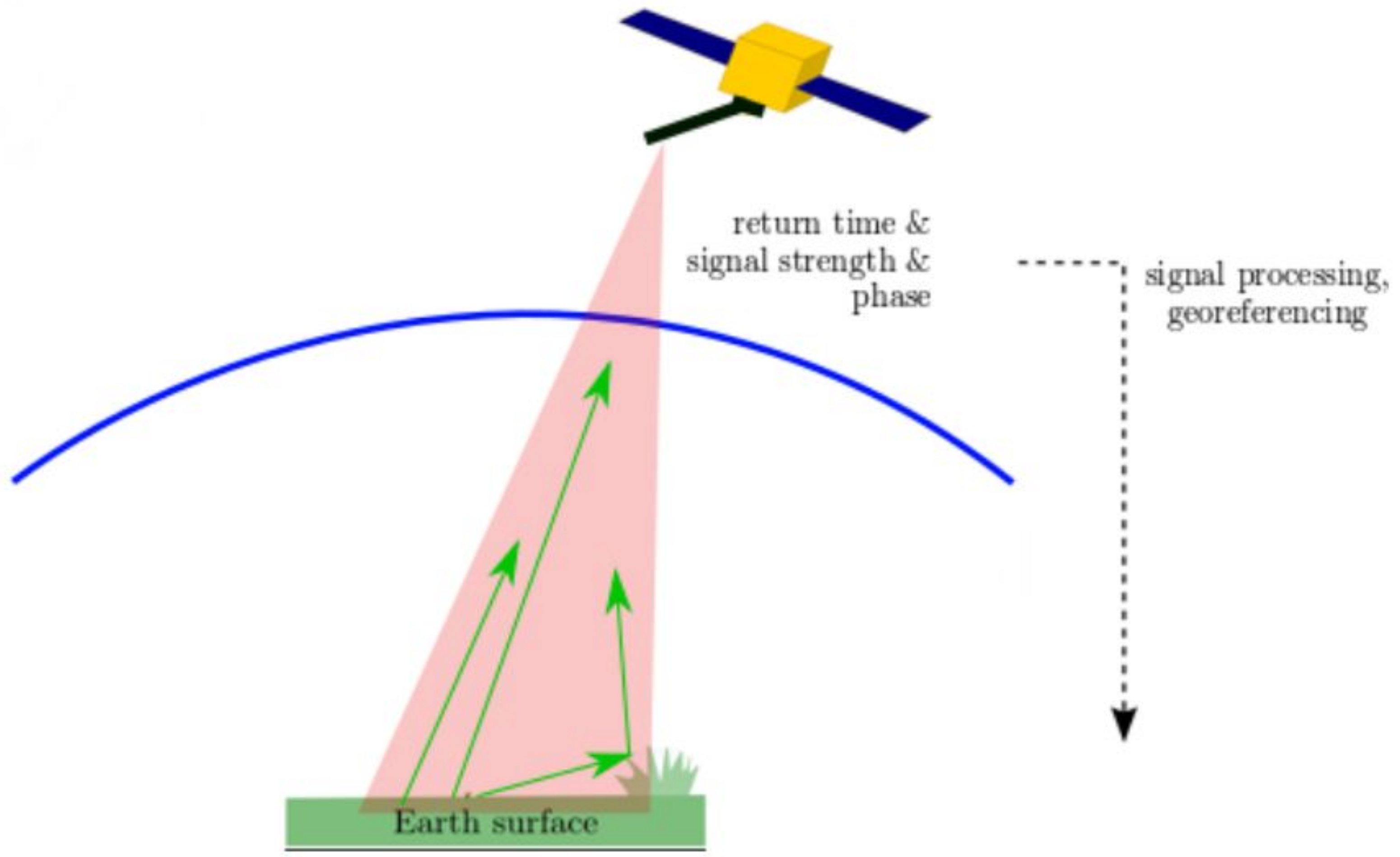
Spatial Resolution: 10 m (bands 2-4; 8), 20 m (band 5-7; 8A; 11-12), 60 m (bands 1; 9-10)
Temporal Resolution: 5-7 days

Spectral Bands: 13

Data available since: 2015

Its main applications are within agriculture, forests, land-use change, land-cover change, mapping biophysical variables such as leaf chlorophyll content, leaf water content, leaf area index, monitoring coastal and inland waters, risk and disaster mapping

Active Remote Sensing - Basics



Basic physical principle of active optical remote sensing

Active Remote Sensing - Advantages

- Weather independent: artificial microwave radiation can penetrate clouds, light rain and snow
- Sunlight independent: can be operated day and night
- Radar penetrates vegetation and soil: can gain information about surface layer from mm to m depth
- Can give information about moisture content of soil layer
- Various applications: oceanography, hydrology, geology, glaciology, agriculture and forestry services

Active Remote Sensing - Limitations

- The pulse power is mostly low and can be influenced or interfered by other radiation sources
- Radar signals contain no spectral characteristics
- Complicated analysis, cost-intensive

Active Remote Sensing – Synthetic Aperture (SAR) Satellites

The Copernicus **Sentinel-1** mission is designed as a two-satellite constellation. Each satellite carries an advanced radar instrument to provide an all-weather, day-and-night supply of imagery of Earth's surface. The mission **ended** for Sentinel-1B in 2022.

Specifications

Temporal Resolution: 6-12 days
Polarization: HH+HV, VV+VH, VV, HH

Instrument: C-band Synthetic Aperture Radar

Data available since: 2014

By offering a set of key information services for a broad range of applications, this global monitoring program makes a step change in the way we manage our environment, understand and tackle the effects of climate change, and safeguard everyday lives.

Remote Sensing Platform

Remote Sensing Platform

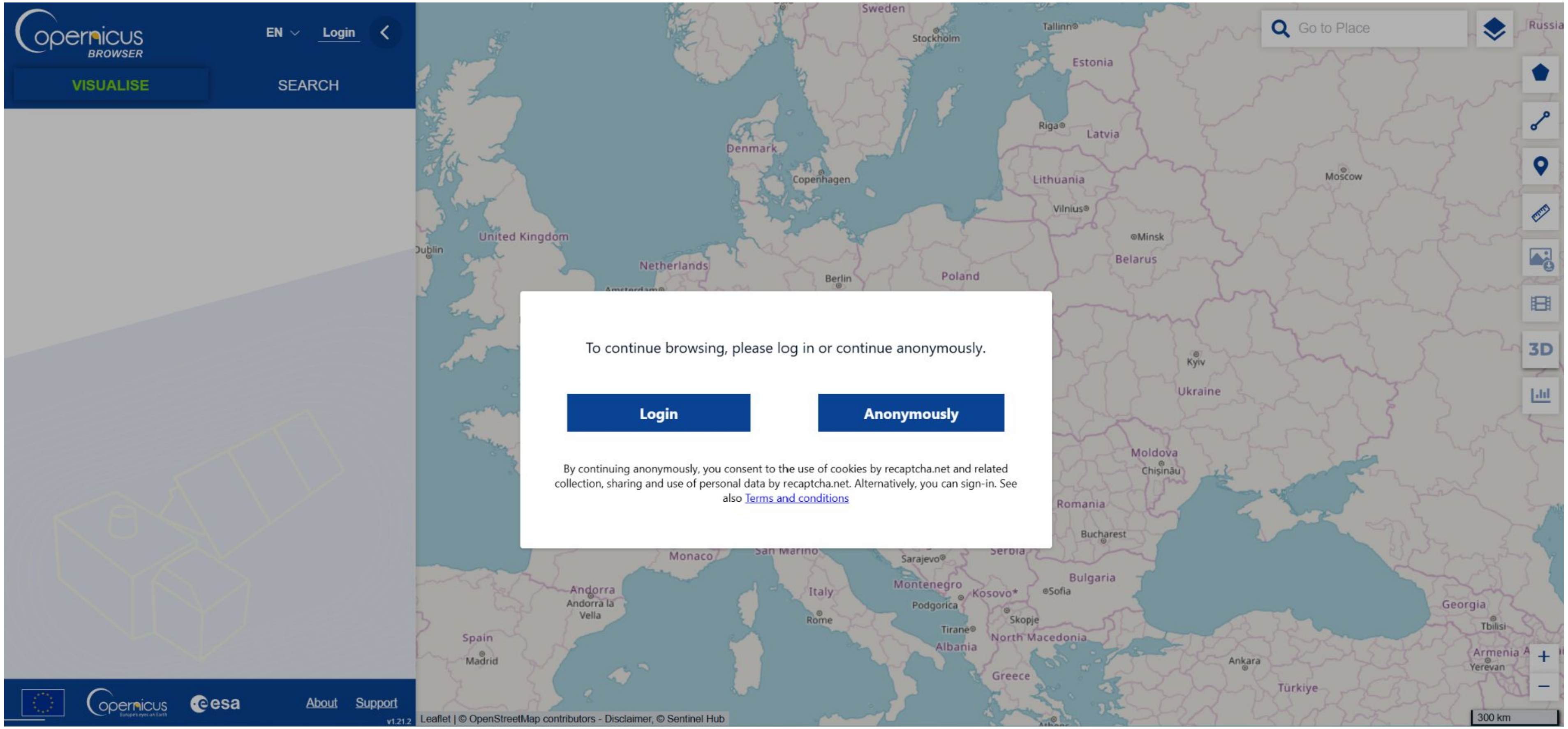
Copernicus Browser

- Access and download freely available data provided by ESA Sentinel missions at the **Copernicus Browser** which provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products.

- To **access the Copernicus Browser**, navigate to your **Internet browser** (e.g., Firefox Web Browser, Google Chrome, Microsoft Edge etc.) and type the Copernicus Open Access Hub address https://browser.dataspace.copernicus.eu/.

Remote Sensing Platform

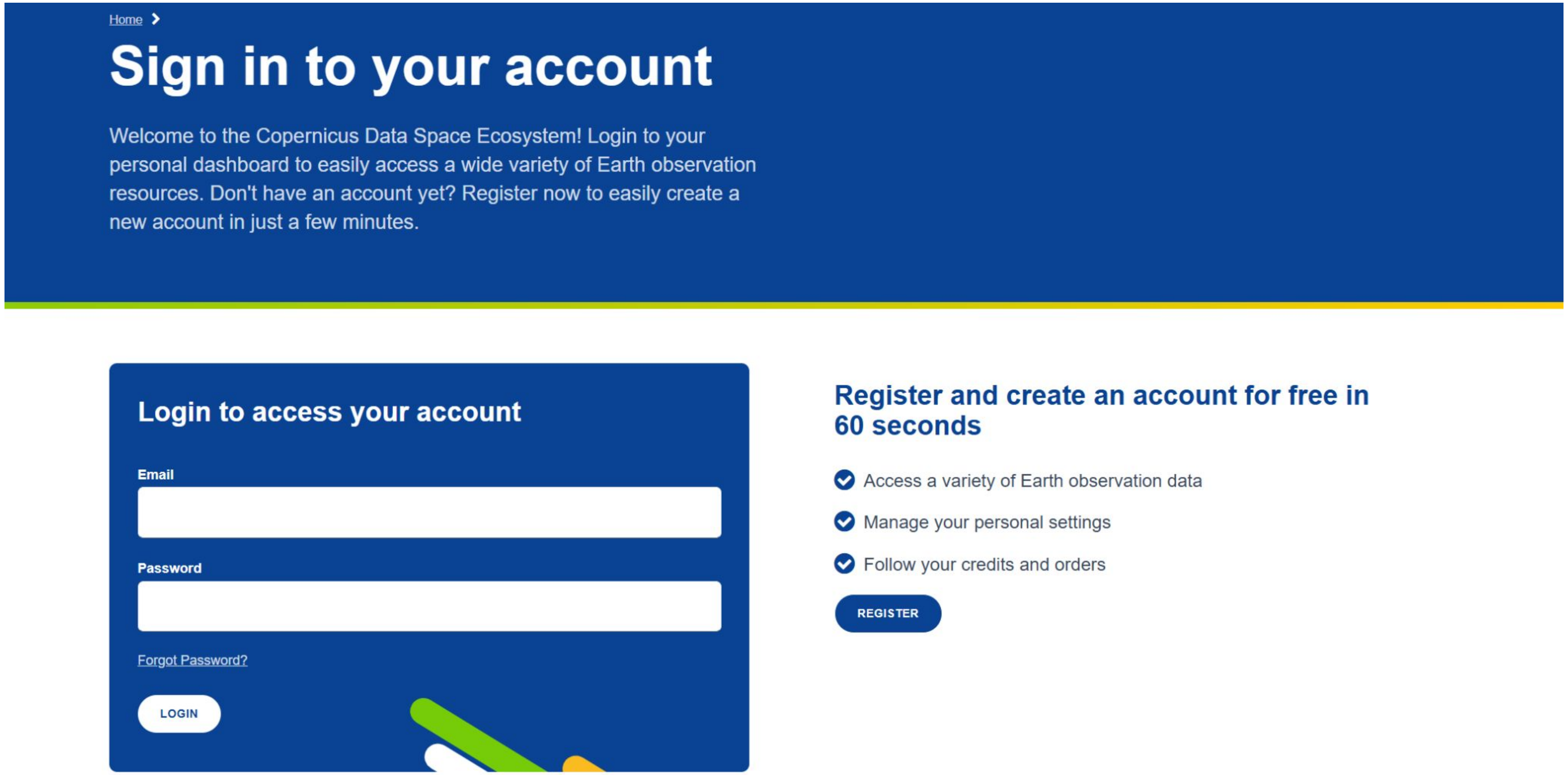
Copernicus Browser



- Choose **"Login".**

Remote Sensing Platform

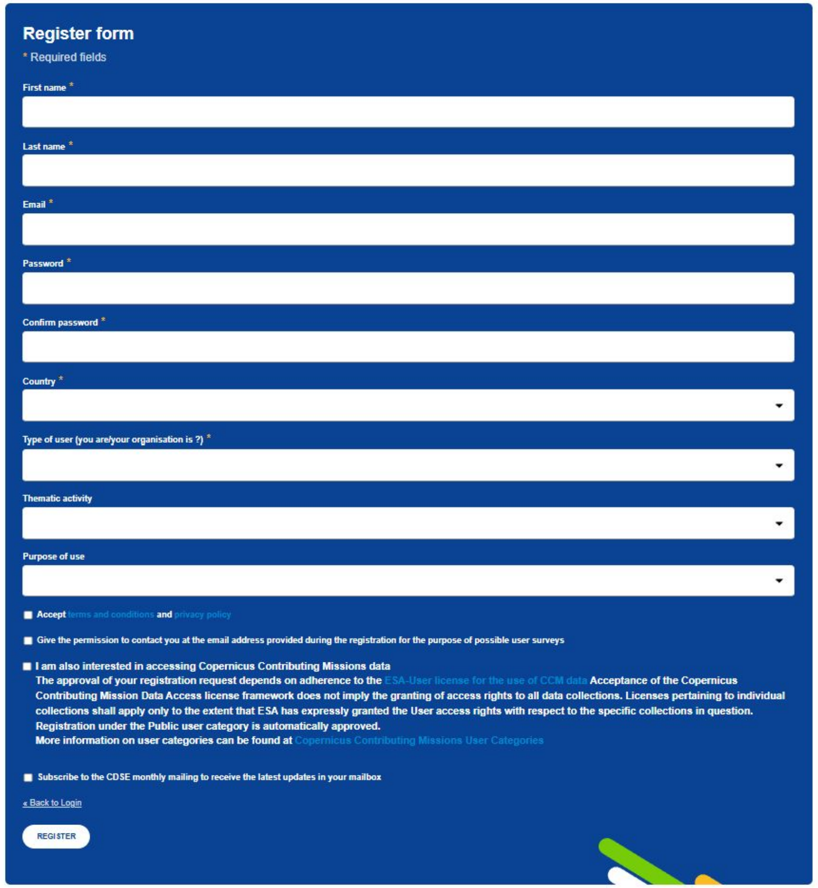
Copernicus Browser



- If you do not have an account, please register by going to “Register” after previously selecting “Login”.

Remote Sensing Platform

Copernicus Browser



Register form

* Required fields

First name *

Last name *

Email *

Password *

Confirm password *

Country *

Type of user (you are/your organisation is ?) *

Thematic activity

Purpose of use

Accept terms and conditions and privacy policy

Give the permission to contact you at the email address provided during the registration for the purpose of possible user surveys

I am also interested in accessing Copernicus Contributing Missions data
The approval of your registration request depends on adherence to the ESA-User license for the use of CCM data Acceptance of the Copernicus Contributing Mission Data Access license framework does not imply the granting of access rights to all data collections. Licenses pertaining to individual collections shall apply only to the extent that ESA has expressly granted the User access rights with respect to the specific collections in question.
Registration under the Public user category is automatically approved.
More information on user categories can be found at Copernicus Contributing Missions User Categories

Subscribe to the CDSE monthly mailing to receive the latest updates in your mailbox

« Back to Login

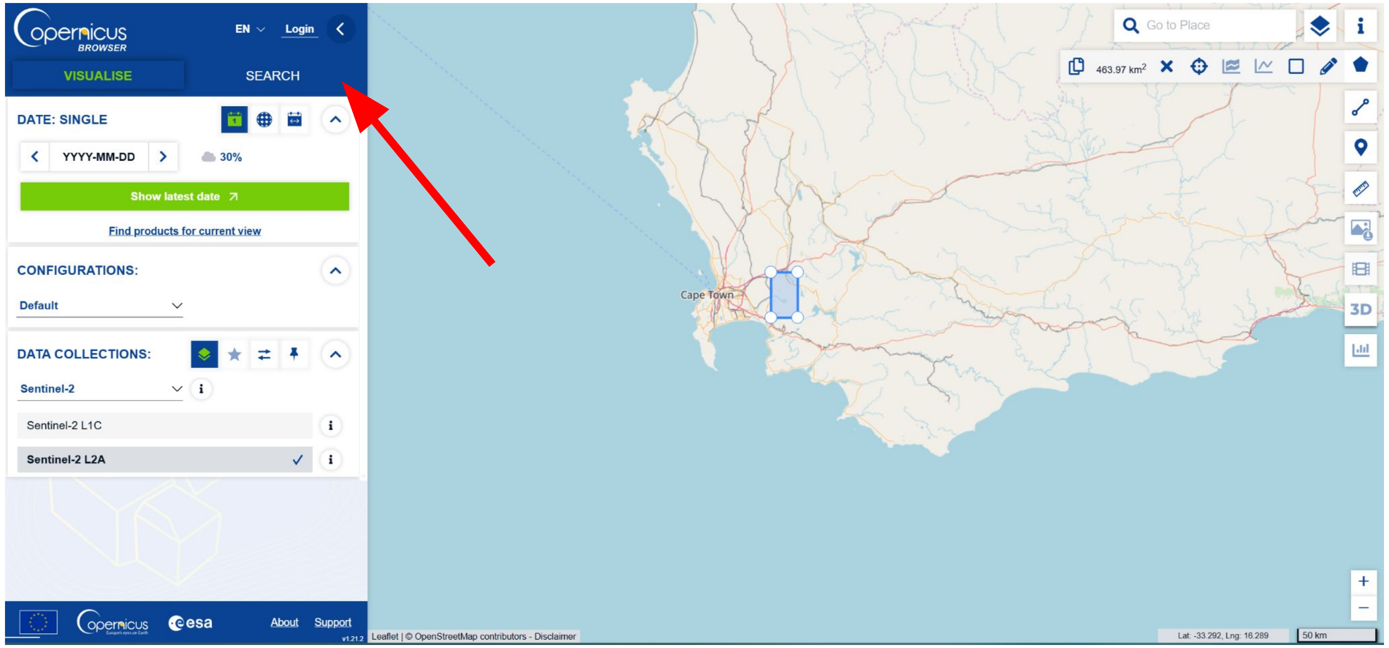
REGISTER

- After you have filled in the registration form, you will receive an activation link by e-mail.
- Once your account is activated - or if you already have an account - **LOGIN.**

Remote Sensing Platform

Copernicus Browser – Example of Download

- Navigate over the Cape Town province area (eastern side of Cape Town) in South Africa (approximate area - blue rectangle).
- For the demonstration purpose we will just download one selected product for this area of interest.
- Zoom in a bit more, switch from “navigation mode” to “drawing mode” (green circle) and draw a rectangle covering area of interest (approximately as indicated below).



Open the search menu by clicking to the left part of the **search bar** (as indicated by red arrow above).

Remote Sensing Platform

SciHub – Example of Download

For Sentinel-2 product:

- **Data Sources:** Sentinel-2
  - Select MSI
  - Set cloud cover to required percentage, for example 5%
  - Select L2A
- **Time Range:** From 2018/03/27 to 2018/03/27

Press search button.

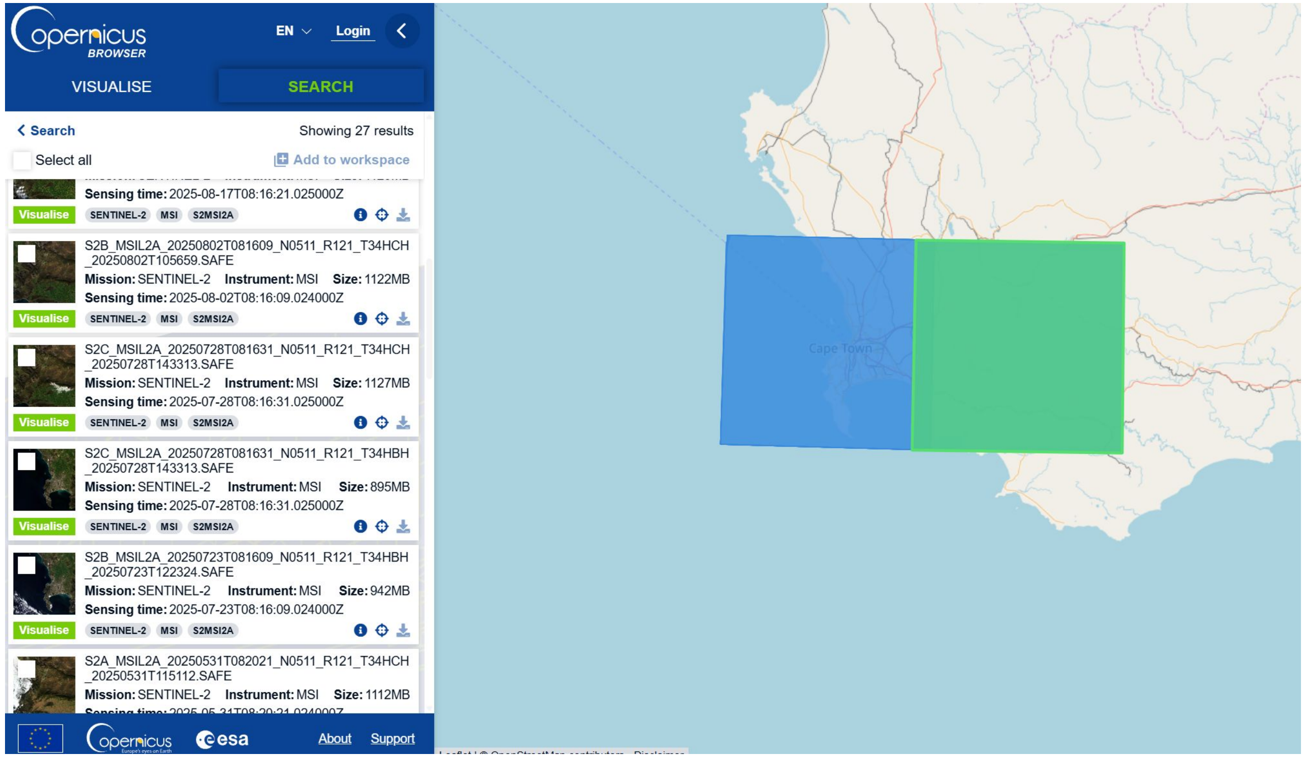
NOTE: Due to ESA policy on the availability of Sentinel data on Copernicus Open Access Hub and to ensure the continued access to all Sentinel data at all time, the Long-Term Archive (LTA) Access has been implemented to roll-out the oldest data from the online access.
More information about the LTA can be found in the following link:
https://www.copernicus.eu/en/access-data

Remote Sensing Platform

Copernicus Hub – Example of Download

Based on your search, Copernicus Browser will show you all available images fitting your search filters.

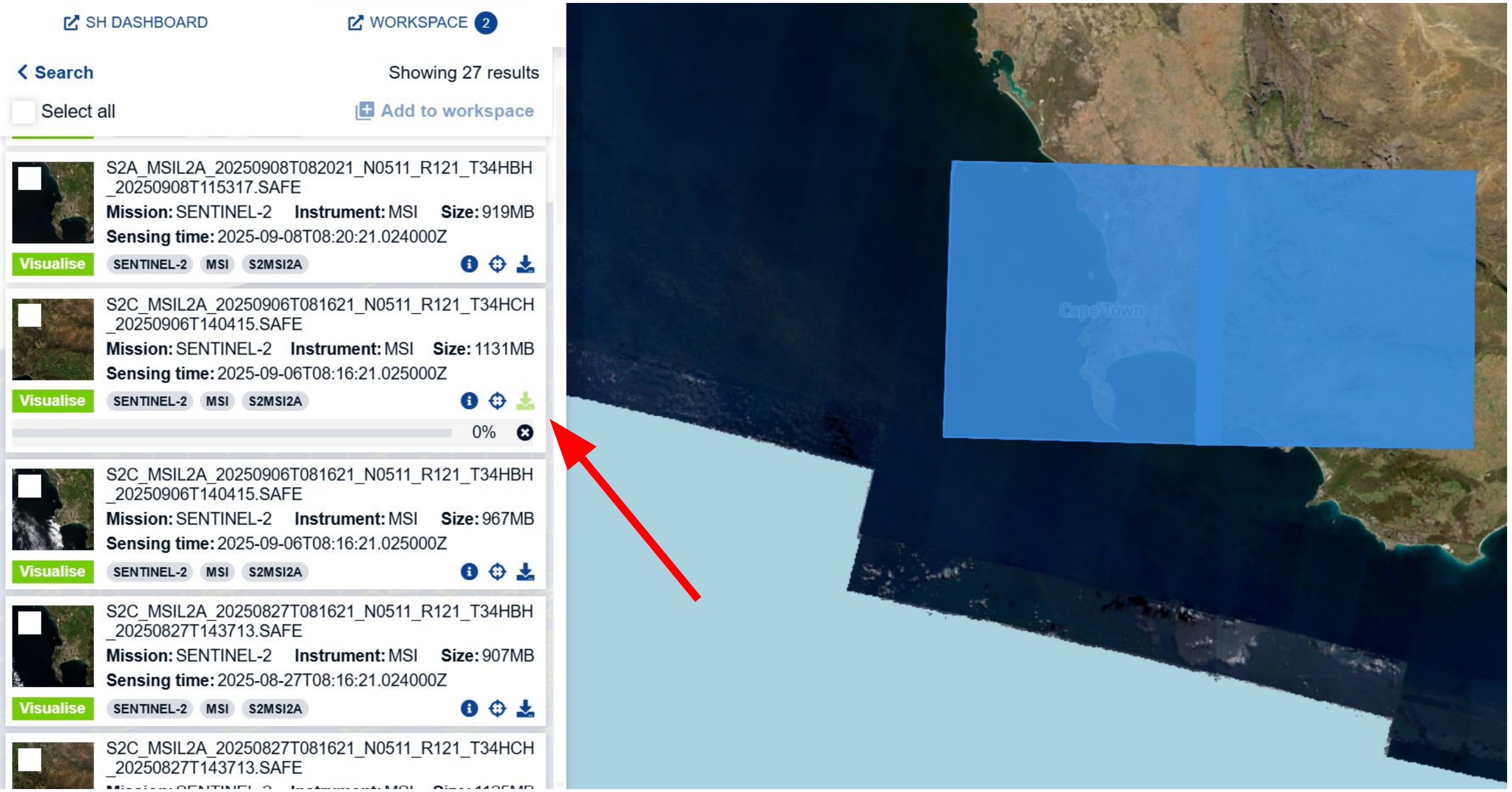
By hovering over a given image, its extend will be highlighted in green (see below).



Remote Sensing Platform

Copernicus Browser – Example of Download

To start downloading the scene, click on the download symbol, as indicated by the red arrow below.



A download bar will appear and indicate the progress of the download.

Recap and Take Home

Recap and Take Home

□ Understanding the difference between multispectral and SAR satellites

Multispectral Satellite

- Observes the state on the ground based on solar light reflected from target objects

SAR Satellite

- Illuminates radio signals onto the ground and receives reflected waves to obtain information on the ground surface to be observed.

Recap and Take Home

Observation Method

Multispectral Satellite

- Has onboard multispectral sensors to take pictures of the ground surface using solar light as the light source, like a typical digital camera.
- During nighttime, it can only observe the lights in cities. Targets that are covered by clouds cannot be observed even during daytime.

SAR Satellite

- Has an onboard microwave transmitter to illuminate the ground and a sensor to receive the reflected wave to obtain information on the ground surface.
- Regardless of time of day or weather conditions, can observe the ground surface 24 hours a day, 7 days a week.

Recap and Take Home

Image Data from Satellite

Multispectral Satellite

- Being full-color image data, the target object can be intuitively recognized.
- Compared to SAR satellites, more frequent observations are made by many satellites. Also, their data has higher spatial resolution.

SAR Satellite

- Being monochromatic, SAR images are difficult for humans to interpret.
- On the other hand, as the satellite observes reflected radio waves by emitting the source signals, it can always capture images in the same condition, making it easier to detect changes in the target object compared to optical images, which vary in appearance depending on sunlight conditions.

Recap and Take Home

Satellite Images can show

Multispectral Satellite

- Color, size, number, form, etc., of the object
- Land coverage condition (wood, farmland, city)
- Plant types and activity

SAR Satellite

- Structure and material of target objects (artifacts/natural objects)
- Existence/change of target objects
- Soil moisture content

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Thank you for your attention!

Dr. Insa Otte (on behalf of the EOCap4Africa Team) and colleagues

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