



University of Ljubljana  
Faculty of Civil and Geodetic Engineering



# Forestry from Space

## 13th ESA Training Course on Earth Observation 2023

prof. dr. Krištof Oštir

University of Ljubljana, Faculty of Civil and Geodetic Engineering

18 | 09 | 23 - 22 | 09 | 23

Osijek, Croatia

# Outline

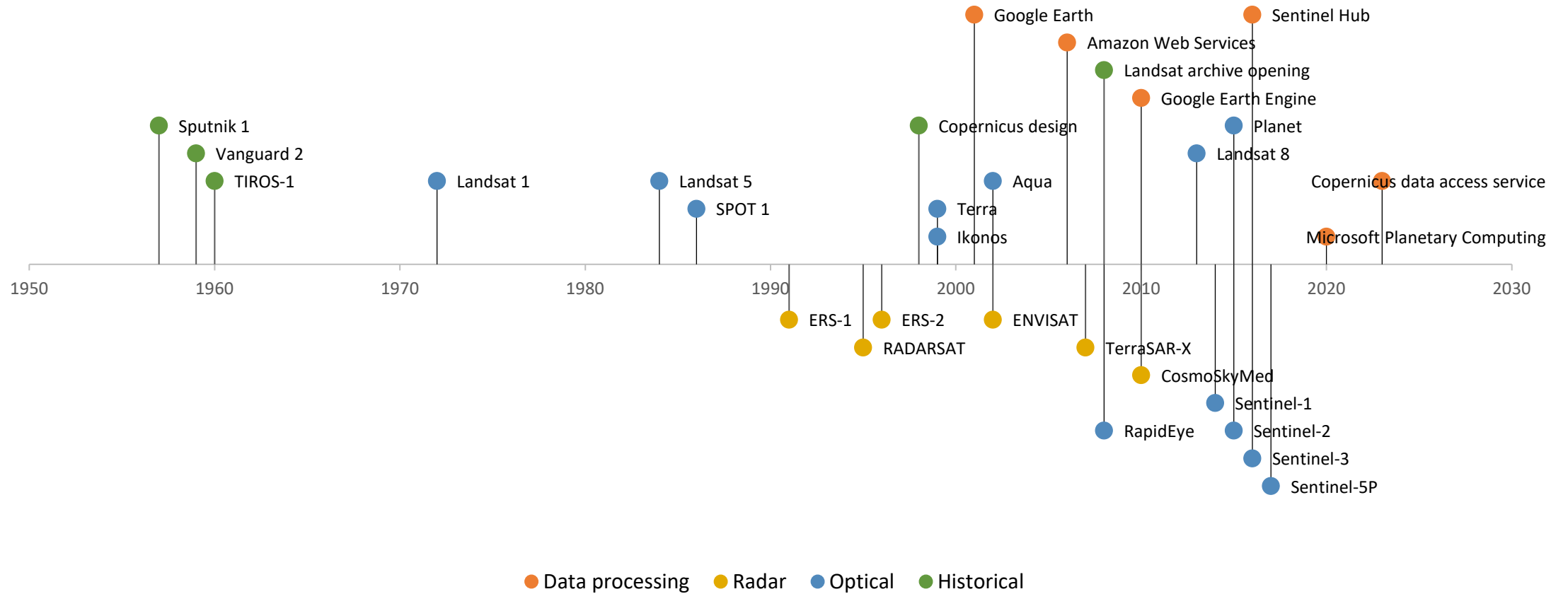
- Introduction
- Optical Remote Sensing and vegetation
- Synthetic Aperture Radar and vegetation
- Copernicus and the Sentinel satellites
- Time series – generation and analysis
- Analysis ready data
- Sentinel Hub – getting data ready
- Forestry application of time series analysis

# SUSTAINABLE DEVELOPMENT GOALS



[Space4SDGs: How space can be used in support of the 2030 Agenda for Sustainable Development \(unoosa.org\)](https://www.unoosa.org/)

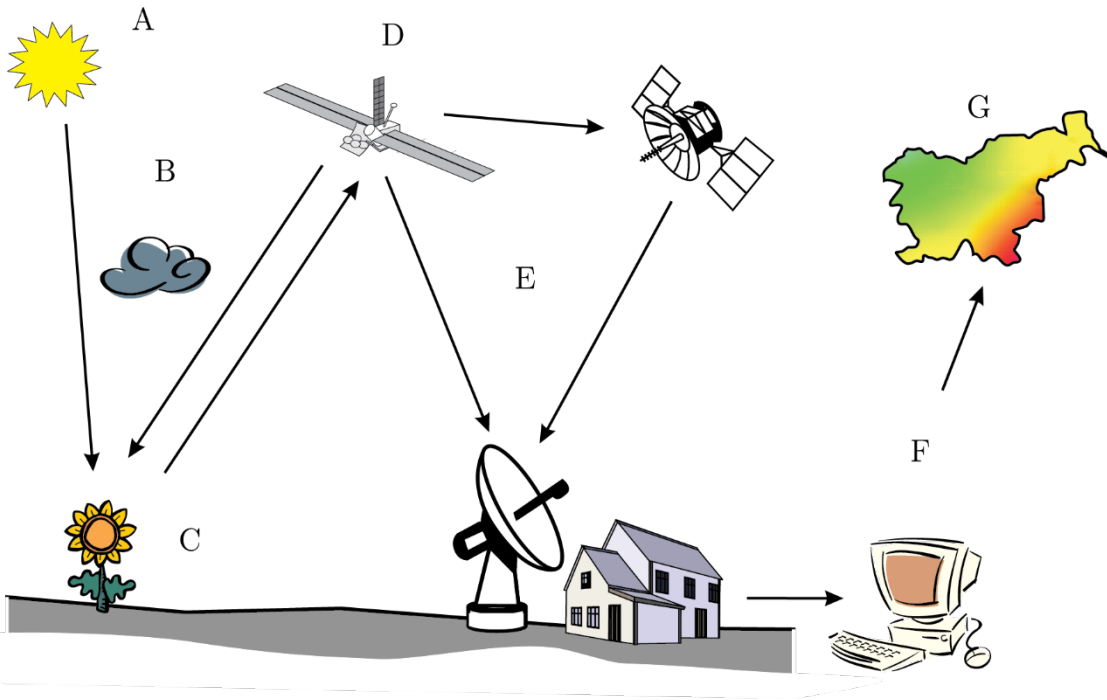
# Major milestones



Optical and radar remote sensing

# What is remote sensing?

- Remote sensing is the science of obtaining information on Earth's surface without coming into direct contact with it. In doing so, we detect and record a reflected or radiated electromagnetic waves, process them, analyse them and use this information in different applications.



Energy or Illumination Source (A)

Radiation and the Atmosphere (B)

Interaction with the Target (C)

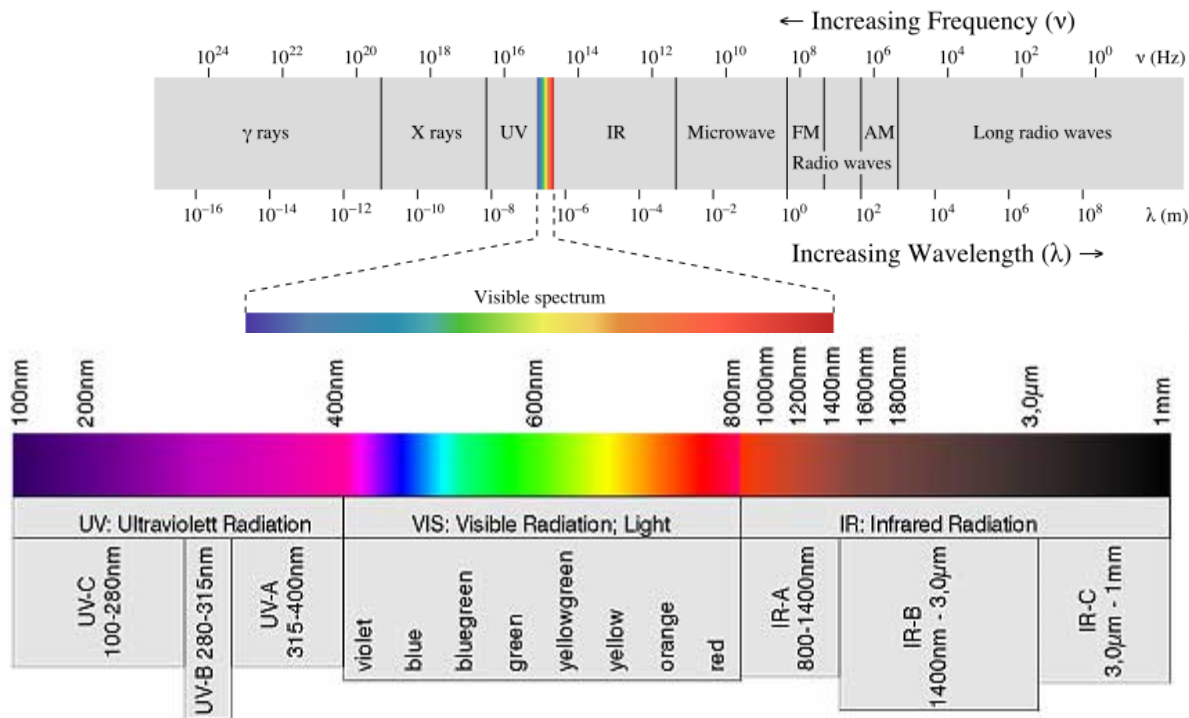
Recording by the Sensor (D)

Transmission, Reception, and Processing (E)

Interpretation and Analysis (F)

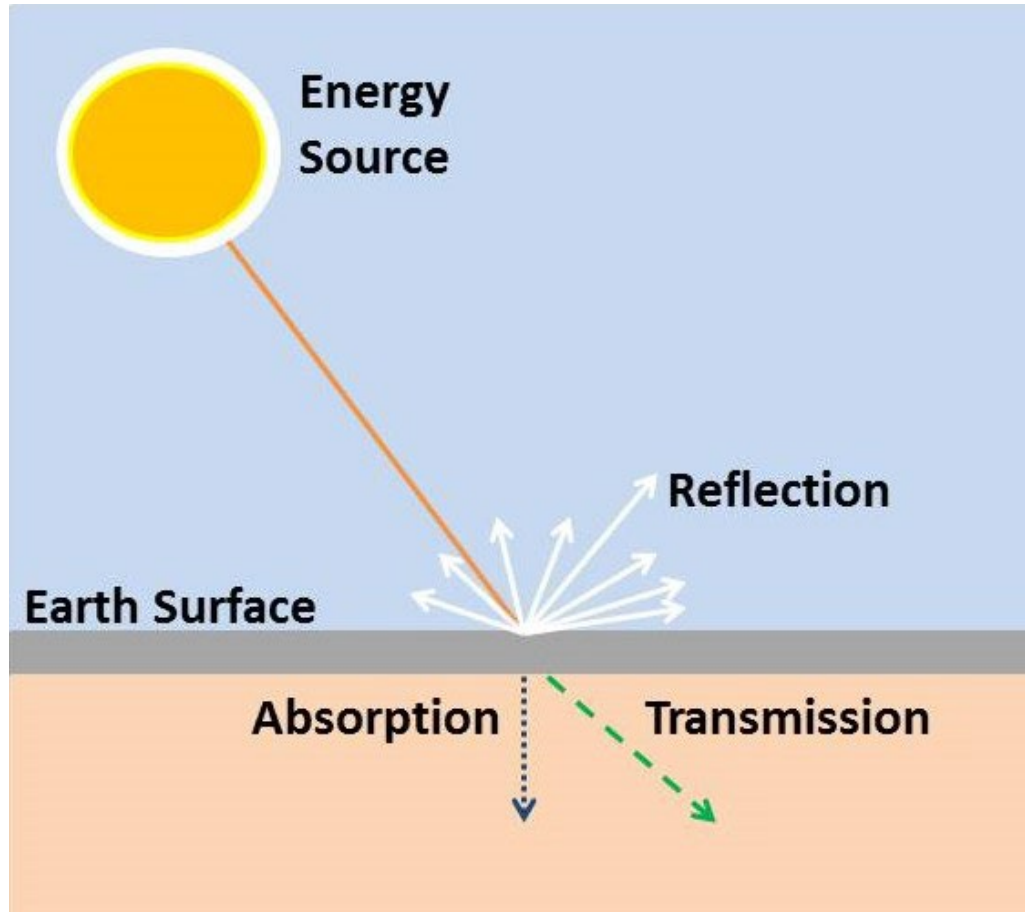
Application (G)

# Spectrum EMR



- Visible (VIS) 400 nm – 800 nm – perceived by the human eye
- Near infrared (IR) 1,55–1,75  $\mu$ m and 2,05–2,4  $\mu$ m
- Thermal 8,0–9,2  $\mu$ m and 10,2–12,4  $\mu$ m
- Microwave (SAR) 7,5–11,5 mm and 20 mm–

# Interaction with the surface

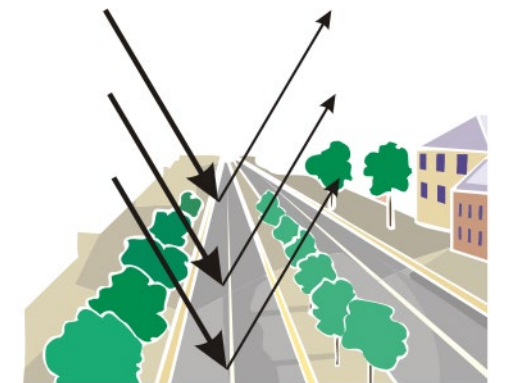
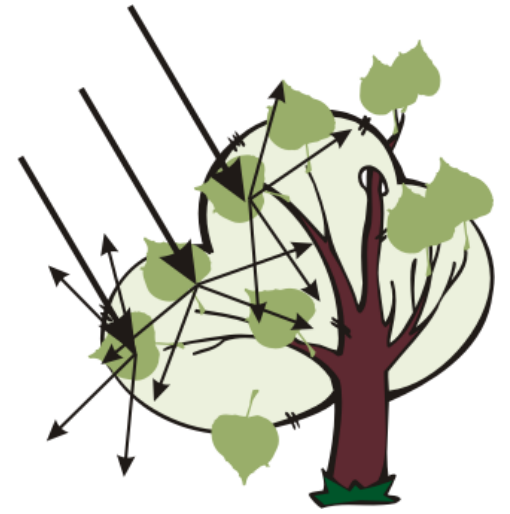


- The interaction of electromagnetic radiation with the surface is driven by three physical processes: reflection, absorption, and transmission of radiation.
- Reflection involves the returning or throwback of the radiation incident on an object on the surface.

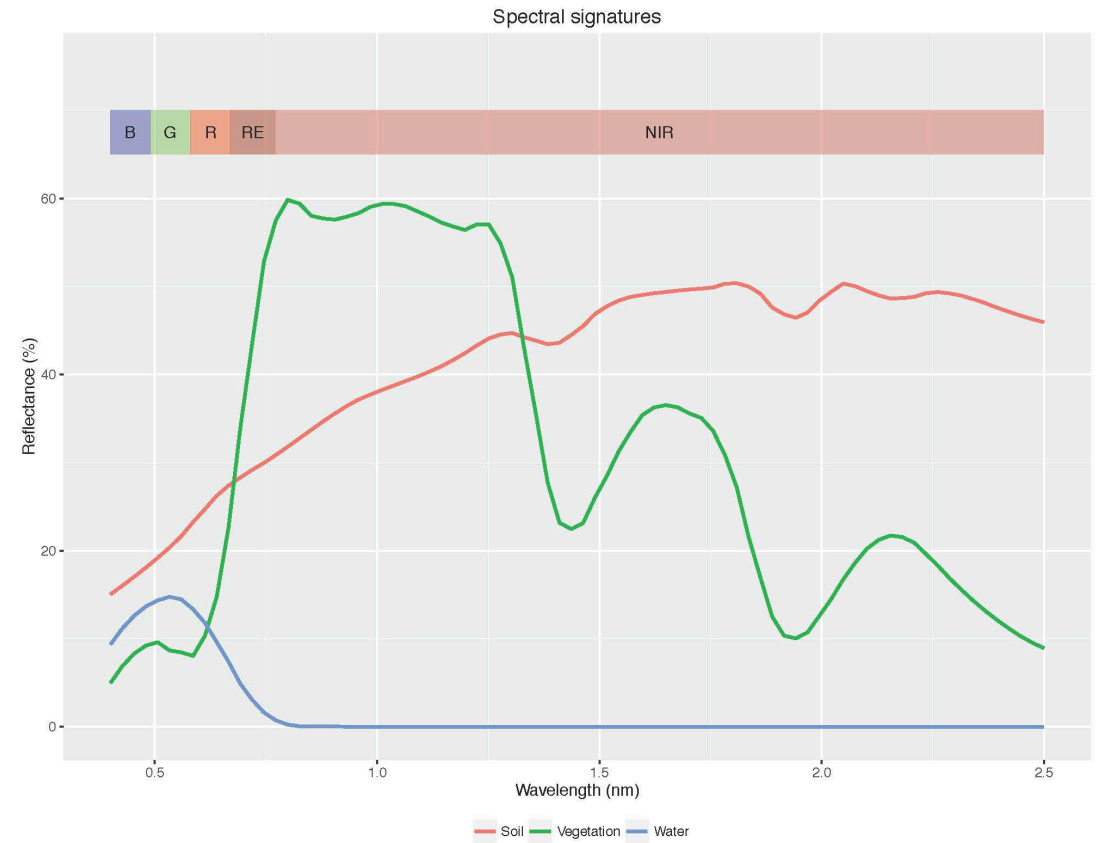
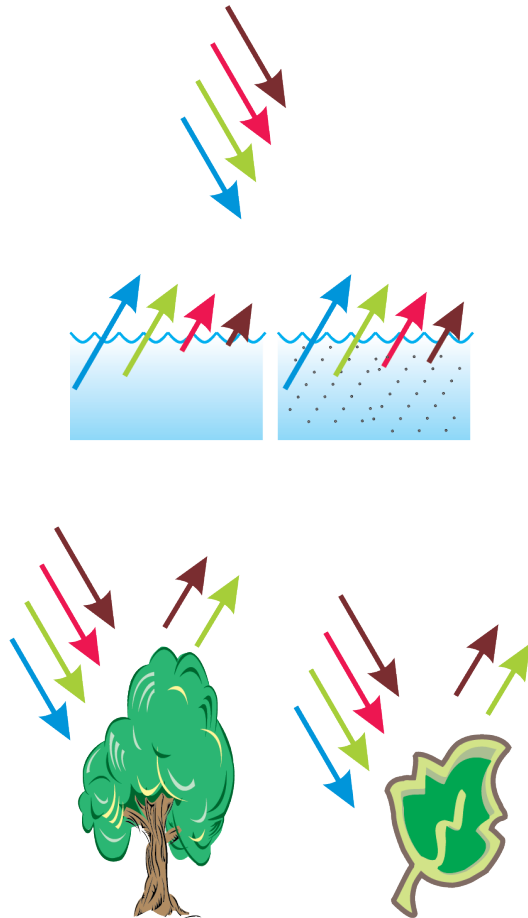


# Interaction with the surface

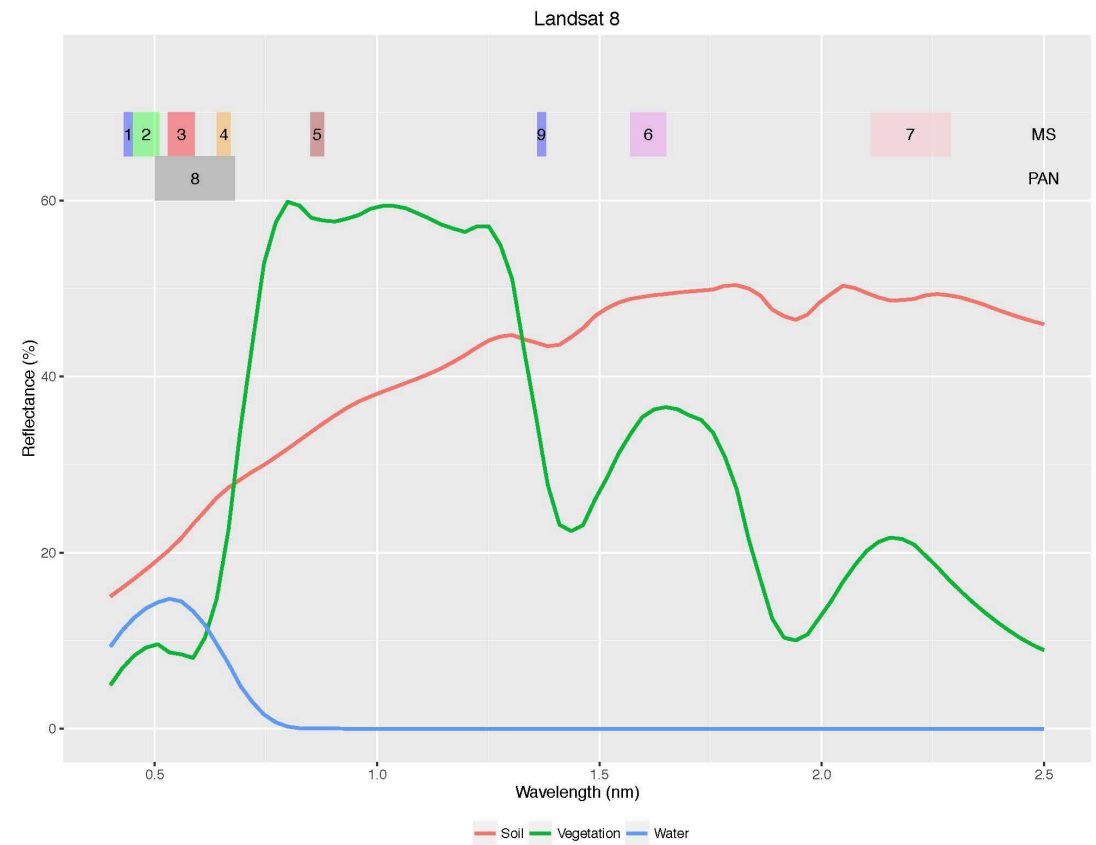
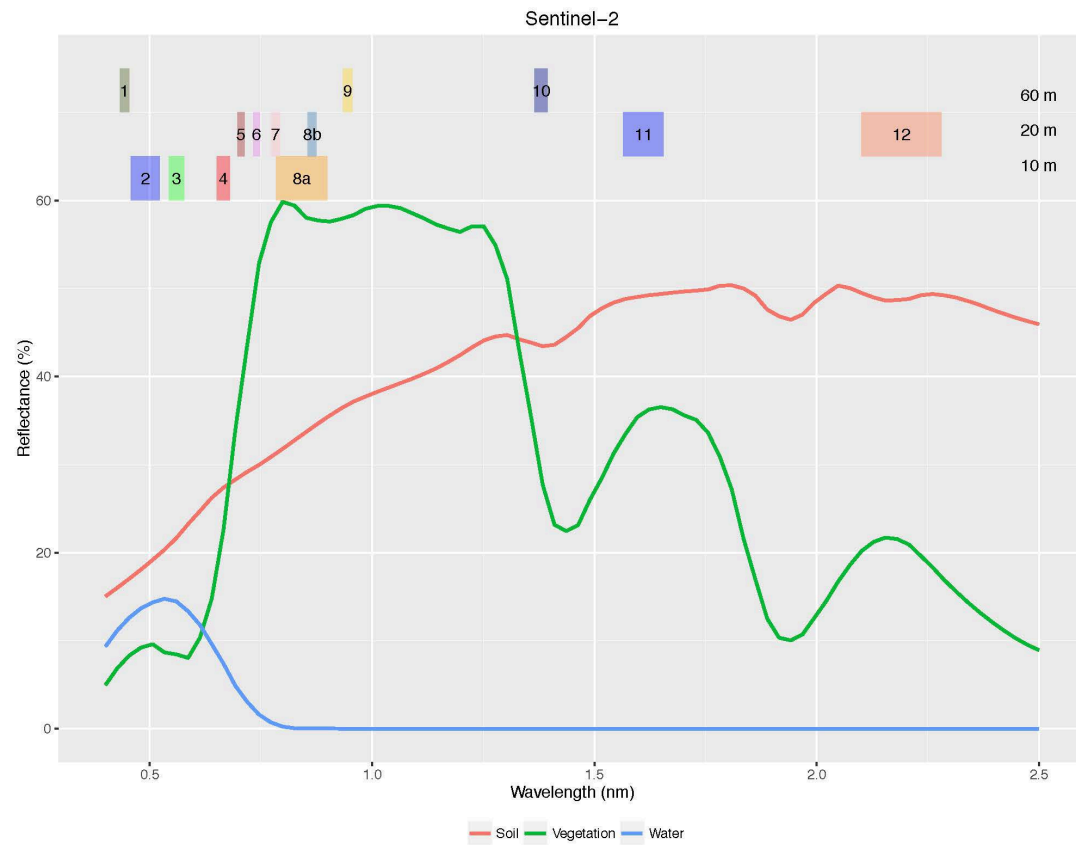
- Spectral reflectance refers to the amount of reflectance in a specified wavelength range.
- It depends on:
  - the type of material
  - the nature of the surface, particularly whether it is a rough surface or a smooth surface, diffuse and specular
  - the wavelength of the incident radiation
  - other factors, such as the slope of the surface, its condition ...



# Interaction with vegetation and water



# Landsat 8 and Sentinel-2 bands

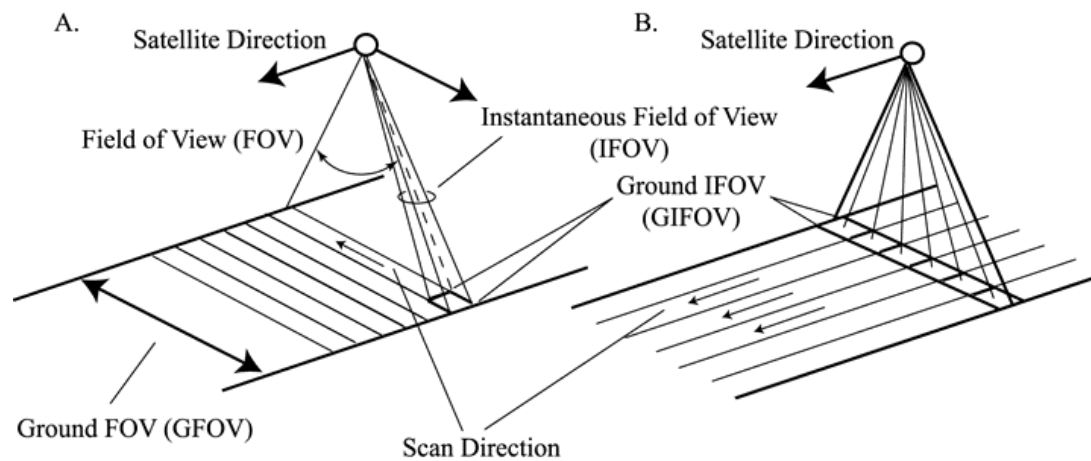


# Optical satellites

- Optical satellites are passive
- They use devices that are simpler – lens and detectors
- They observe the surface of the Earth across a varied spectrum of wavelengths
- The number of spectral channels/bands and bandwidth is different
- Optical imagery is more accessible and easier to interpret

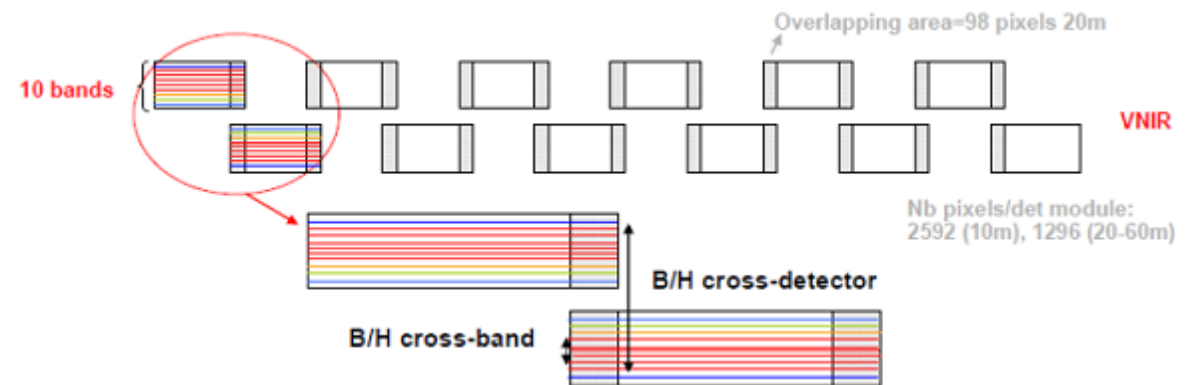
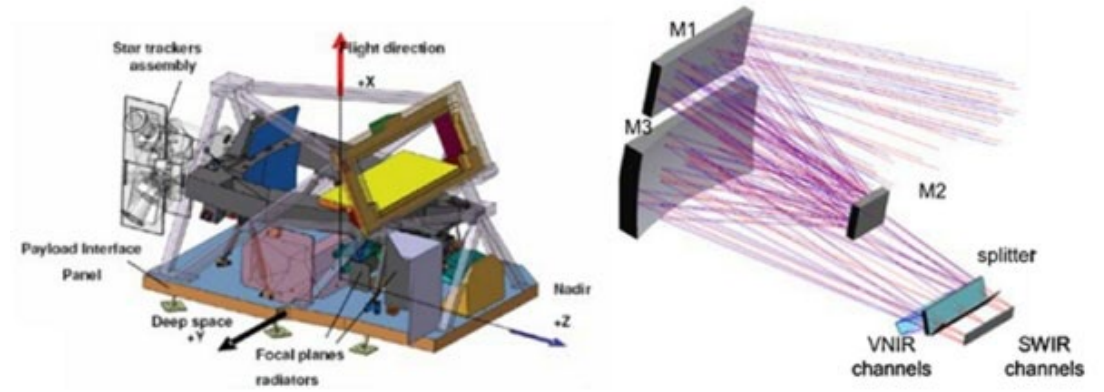
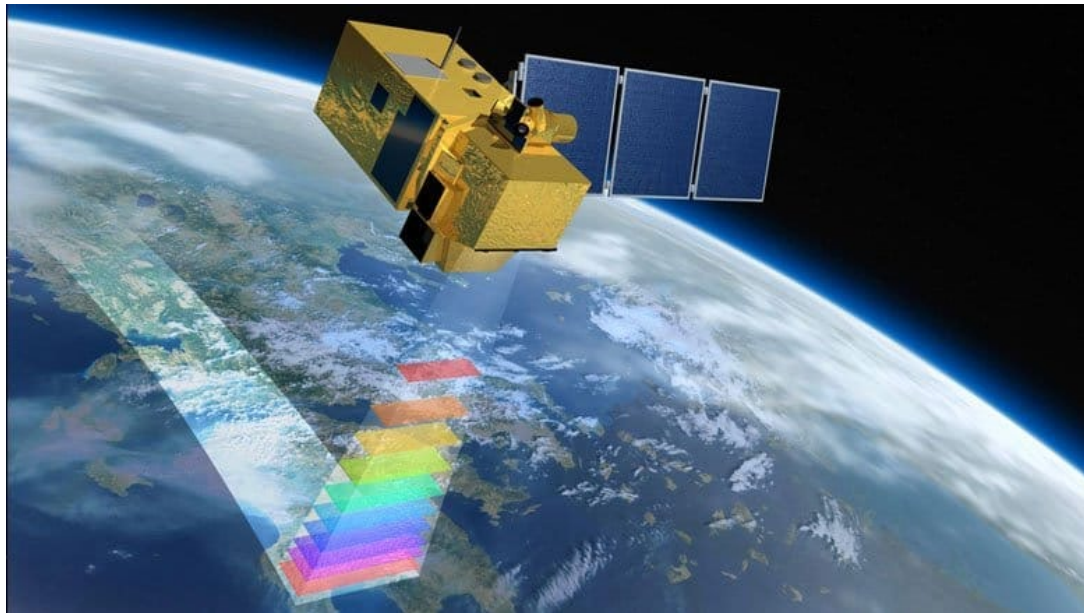


# Optical scanners



- Across track
  - Landsat – up to 7
- Along track
  - All HR and VHR
  - Sentinel-2
  - Landsat 8

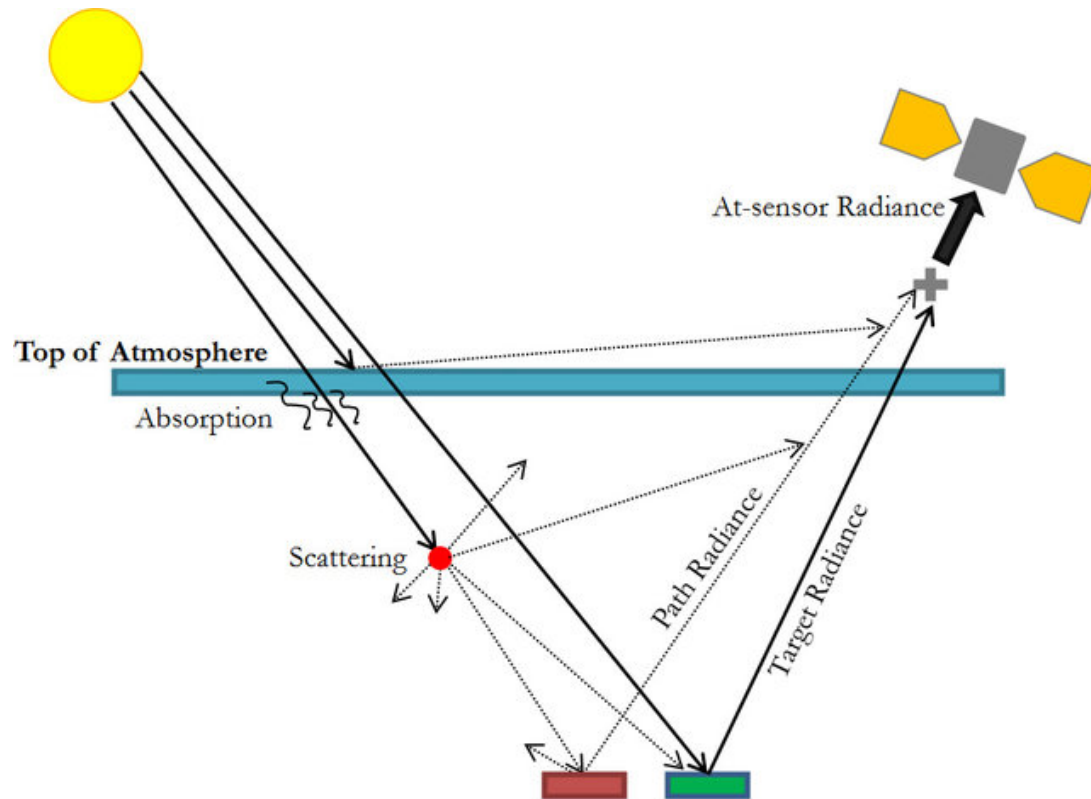
# Sentinel-2 imaging



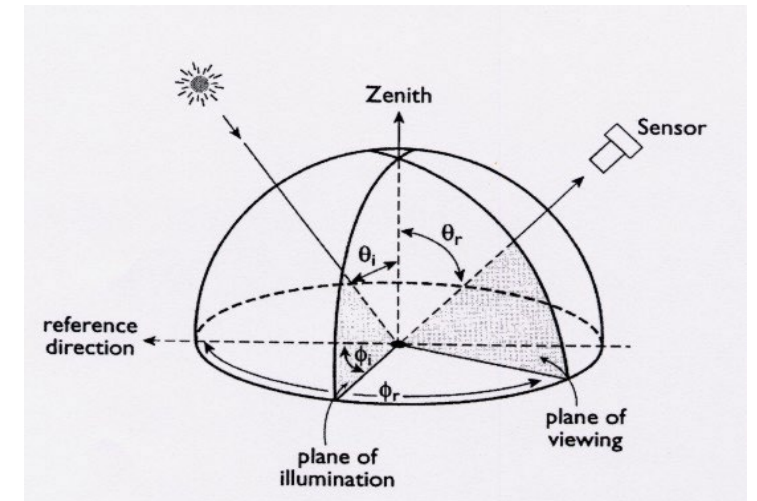
# Sentinel-2 imaging



# What is being measured?



- The quantity of radiation passing through or emitted from a surface and falls within a given solid angle in a specified direction.



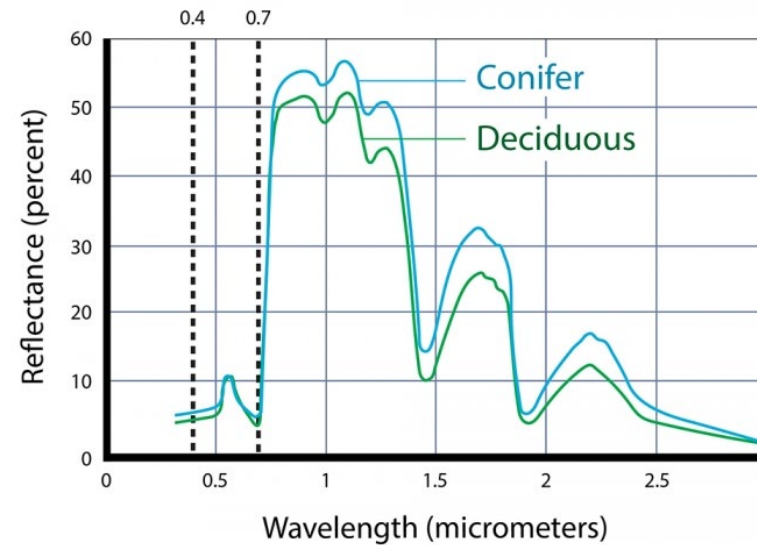
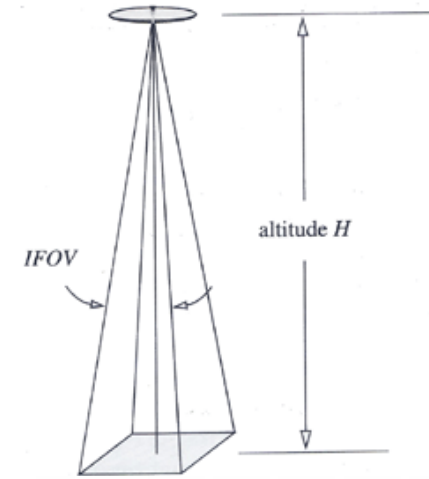
[PowerPoint Presentation \(ucdavis.edu\)](#)

[\(18\) \(PDF\) Estimation of PM10 Distribution Using Landsat5 and Landsat8 Remote Sensing \(researchgate.net\)](#)



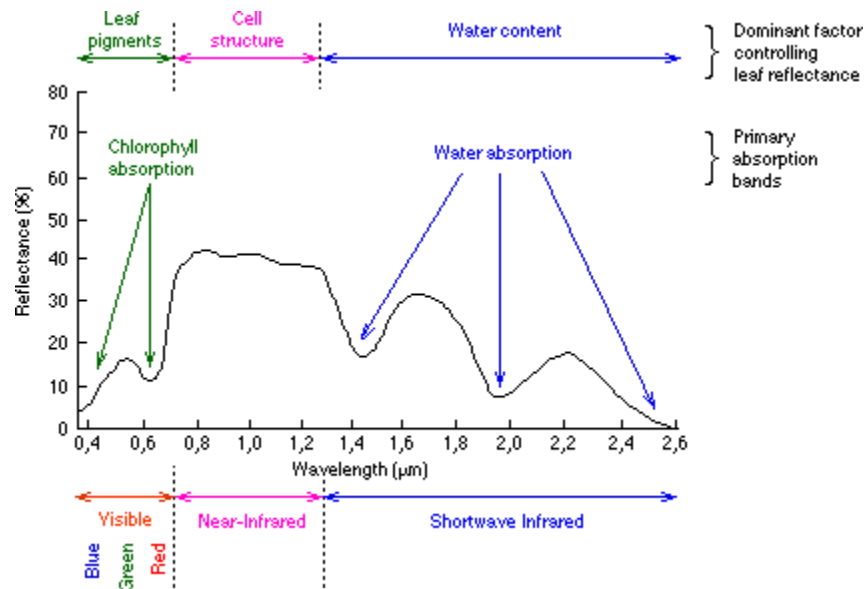
# Resolution

- Spatial resolution
- Spectral resolution
- Radiometric resolution
- Temporal resolution



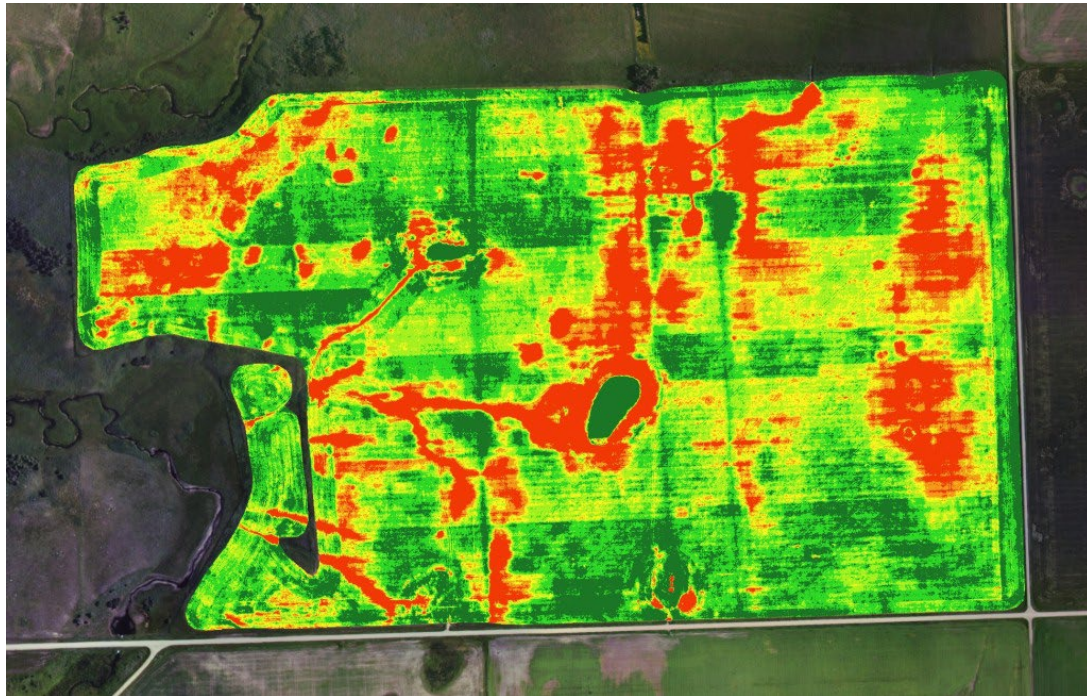
Sentinel-2  
10, 20, 60 m  
13 bands  
12-bit  
5 days

# Vegetation Spectra



- Particular wavelengths are sensitive to particular chemicals and compounds.
- Result in absorption features.
- Make measurements related to those compounds.
- Indices take advantage of these wavelength features.

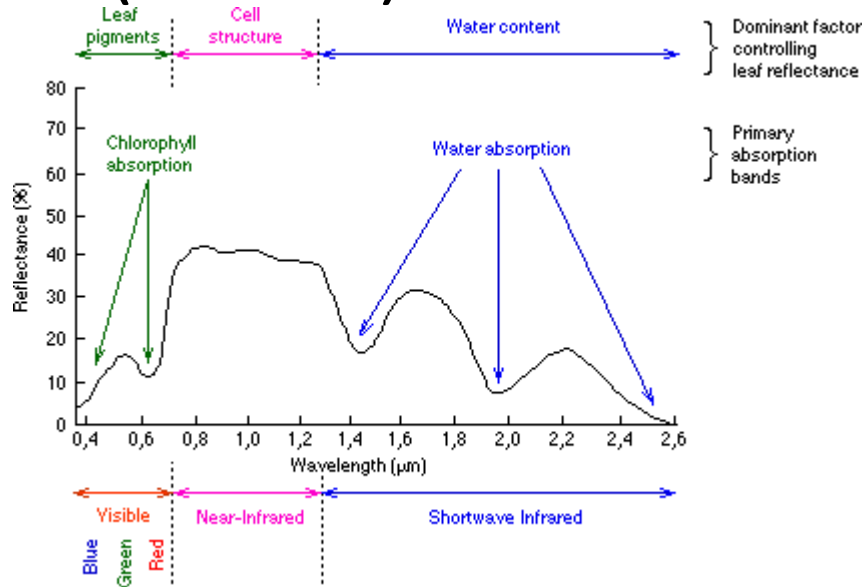
# Vegetation Indices



- VI - Vegetation Index
- NDVI - Normalized Difference Vegetation Index
- EVI - Enhanced Vegetation Index
- SAVI - Soil Adjusted NDVI
- AVI - Advanced Vegetation Index
- NDMI - Normalized Difference Moisture Index ...

[IDB - Index DataBase](#)

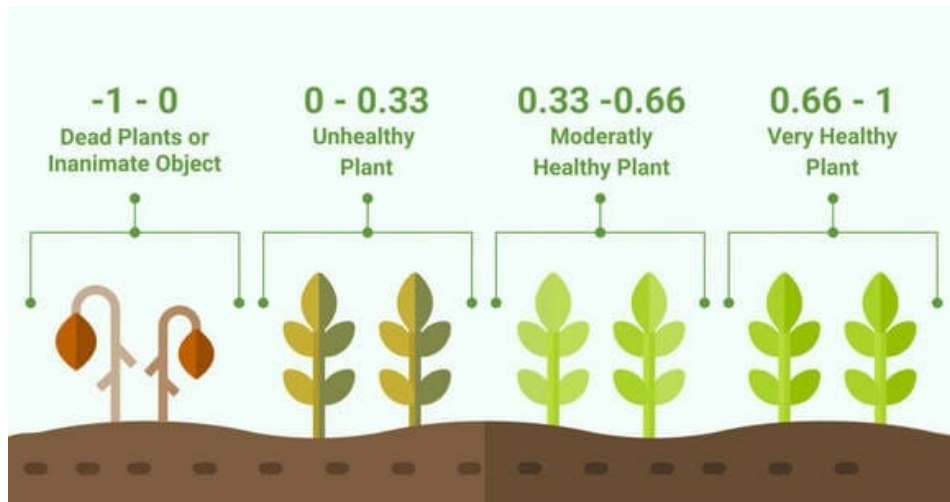
# Normalised Difference Vegetation Index (NDVI)



- Vegetation has high NIR and low Red reflectance.
- Other land cover have NIR and Red which are much close together

$$NDVI = \frac{IR - R}{IR + R}$$

- -1.0 to +1.0
- vegetation from 0.3 to 0.8, depending on health/intensity
- water (sea, lakes, rivers) low positive or even negative
- bare soil low positive values from 0,1 to 0,2



[NDVI FAQs: Frequently Asked Questions About The Index \(eos.com\)](https://eos.com/ndvi-faq/)

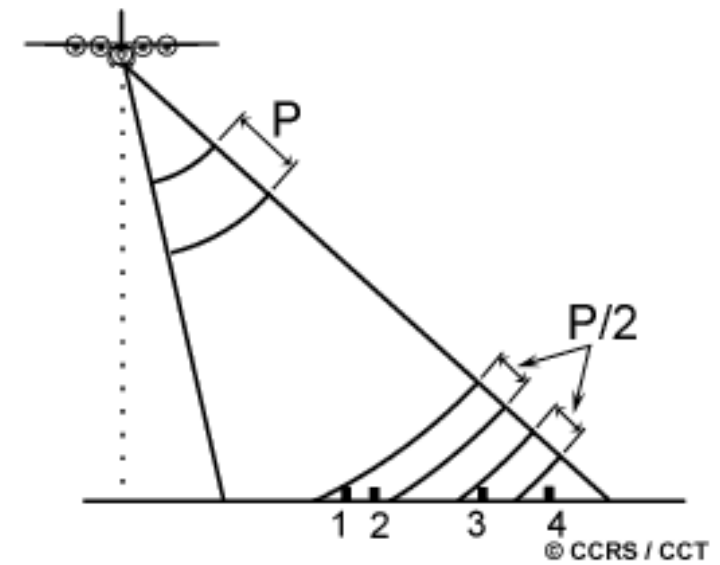
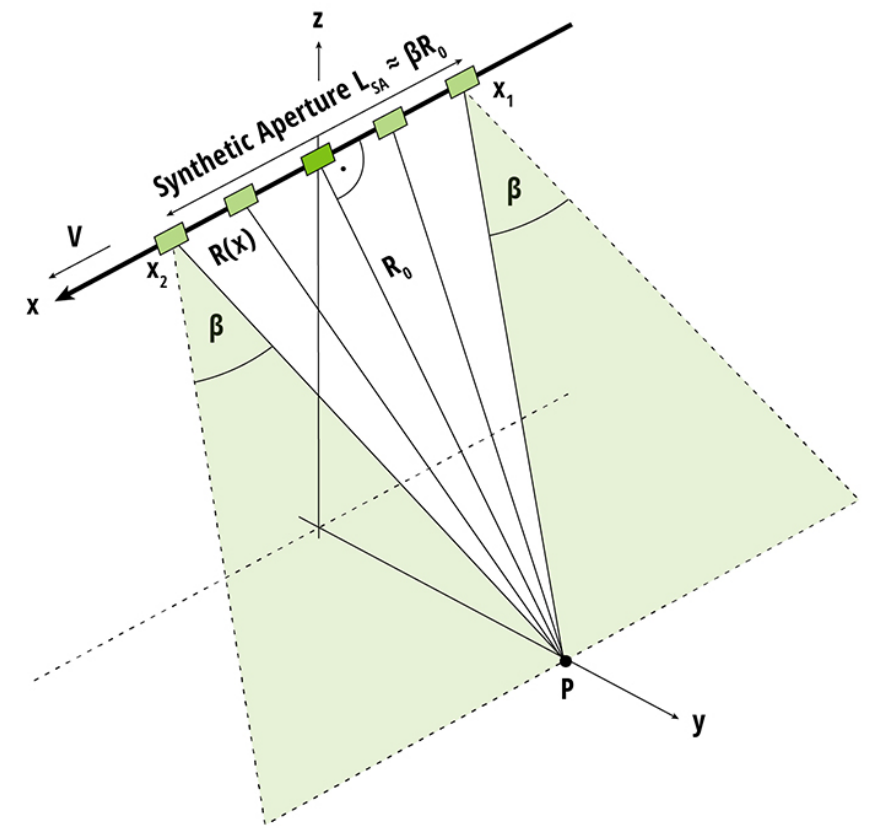
# Radar

- Radar (radio detection and ranging)
- It measures the strength of the microwave signal, which is emitted by the antenna and reflecting off the remote surfaces or objects on them.
- The radar system determines the position of the observed surface based on the time of the microwave travel to the Earth and back (or the slant range distance).



# Radar system resolution

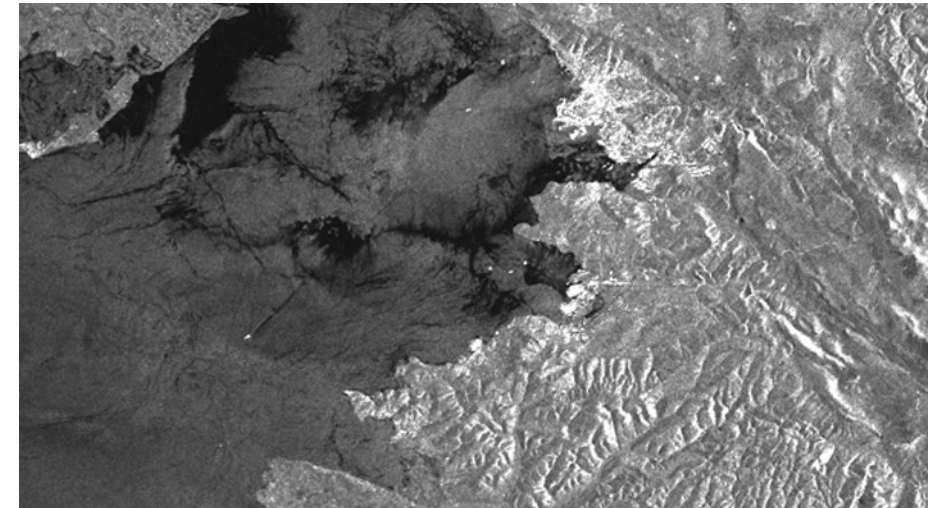
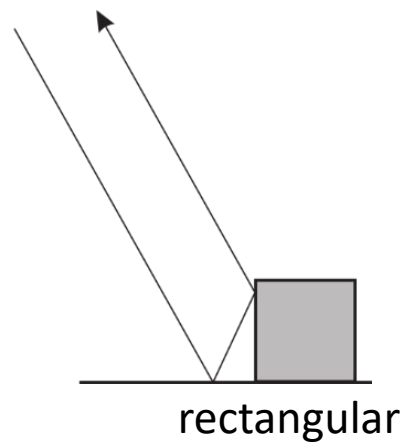
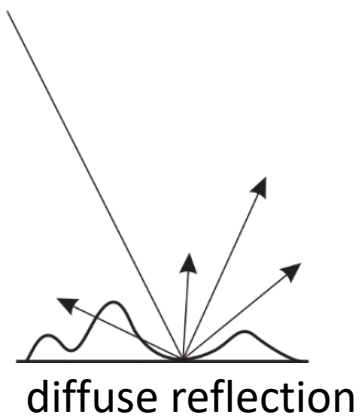
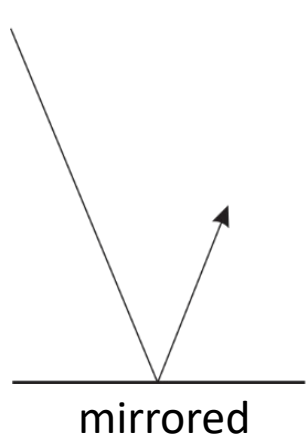
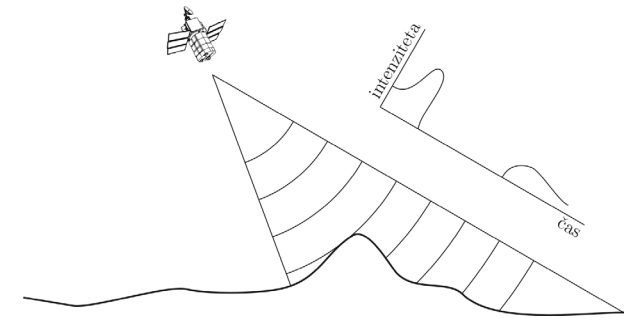
- Depends on the direction
- In the direction of looking -the length of the pulse
- In the direction of flight - antenna length
- In space the antenna can not be very long  $\rightarrow$  SAR



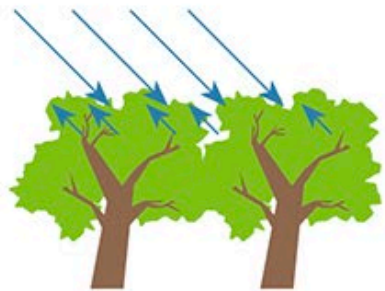
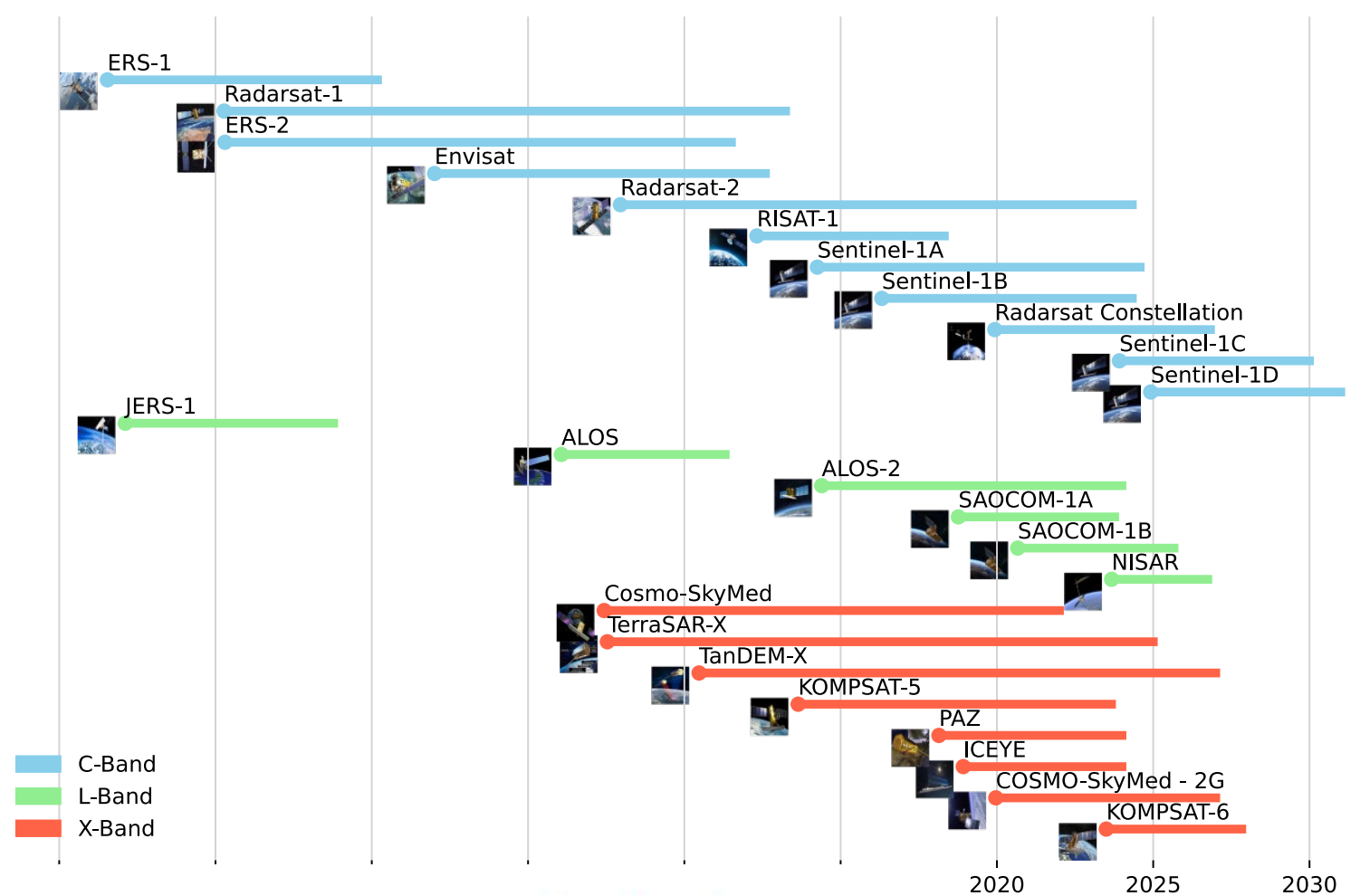
[What is Synthetic Aperture Radar? | Earthdata \(nasa.gov\)](https://earthdata.nasa.gov)

# Interaction with the surface

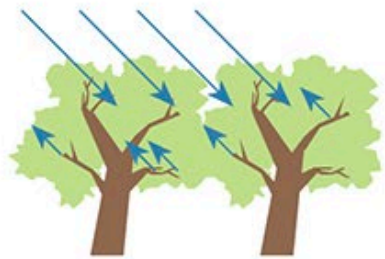
- Incidence angle
- Terrain roughness
- Conductivity and dielectricity of the surface



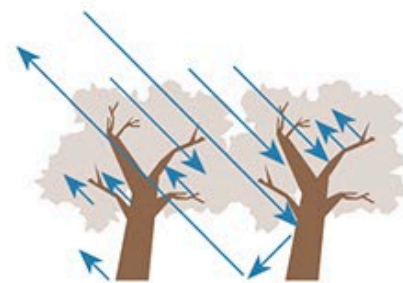
# Satellites



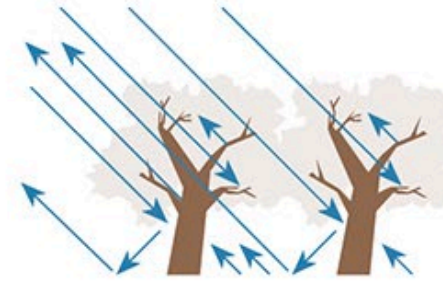
X-BAND 3 cm



C-BAND 6 cm



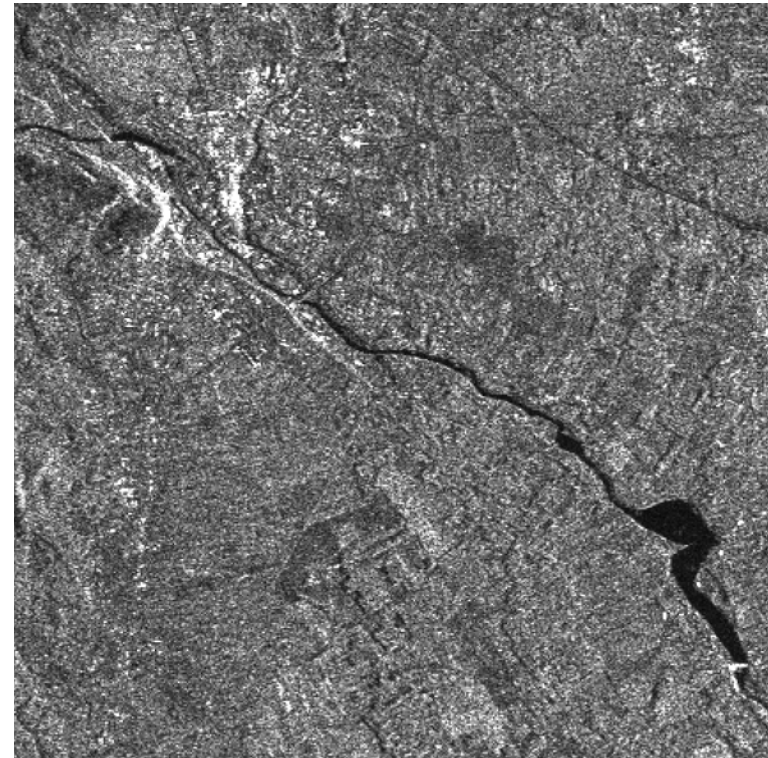
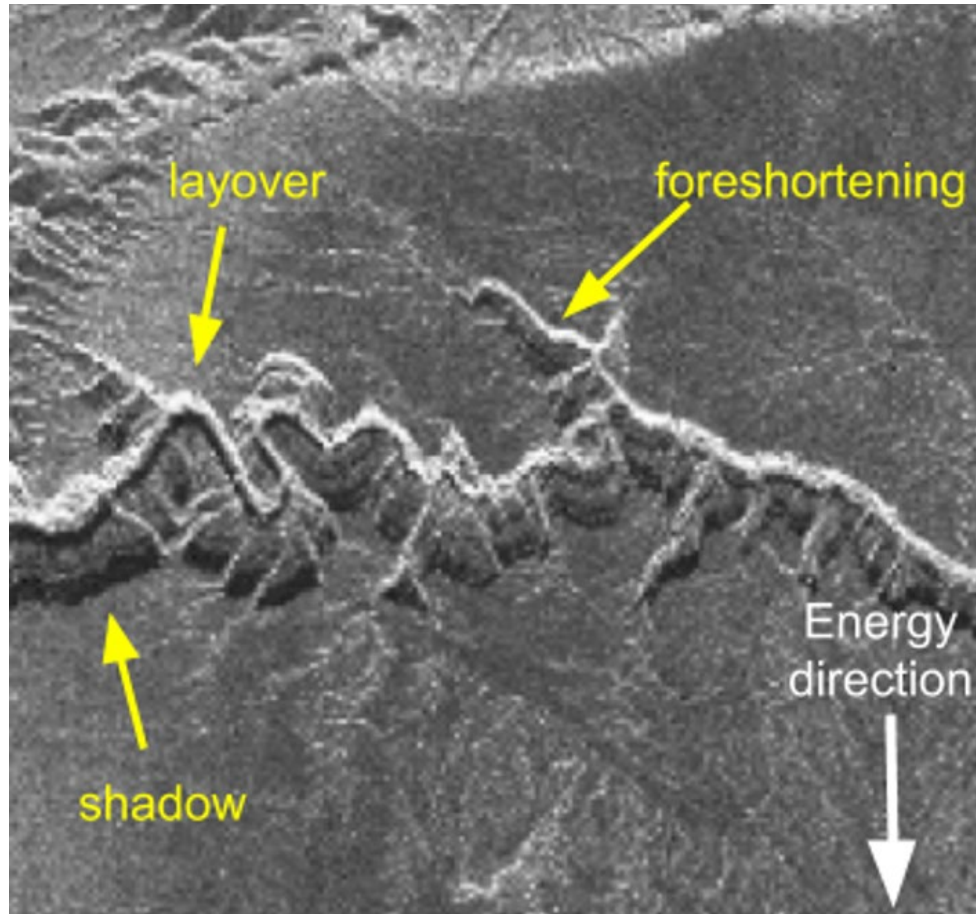
L-BAND 24 cm



P-BAND 65 cm



# Layover, shadows, speckle

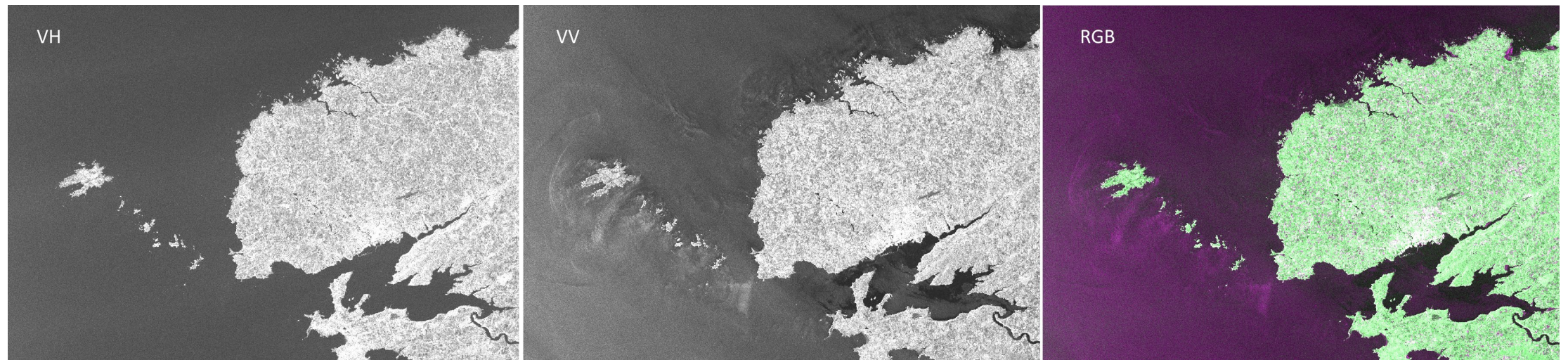


# Polarisation



colour composite

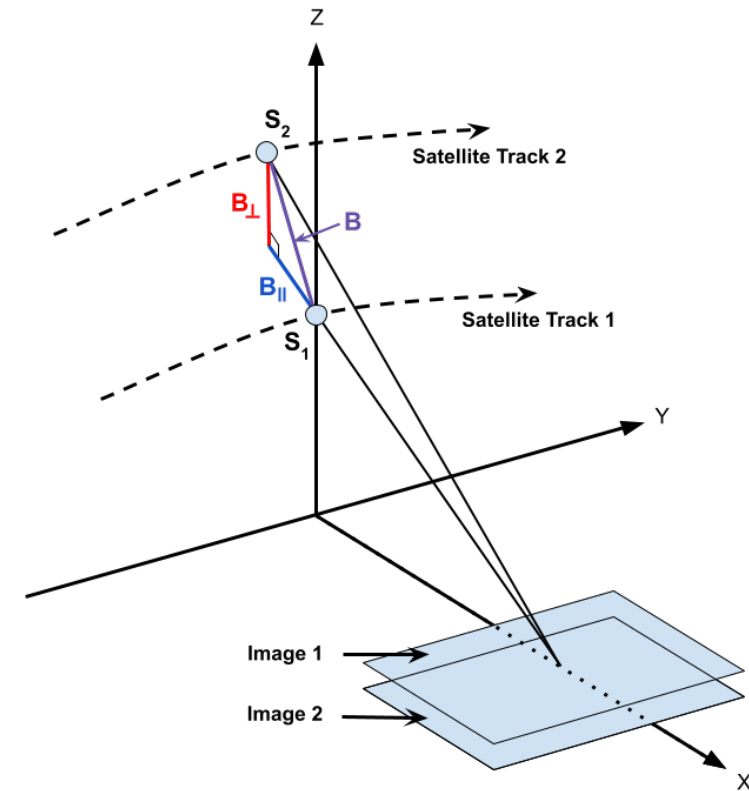
# Sentinel-1 polarimetry



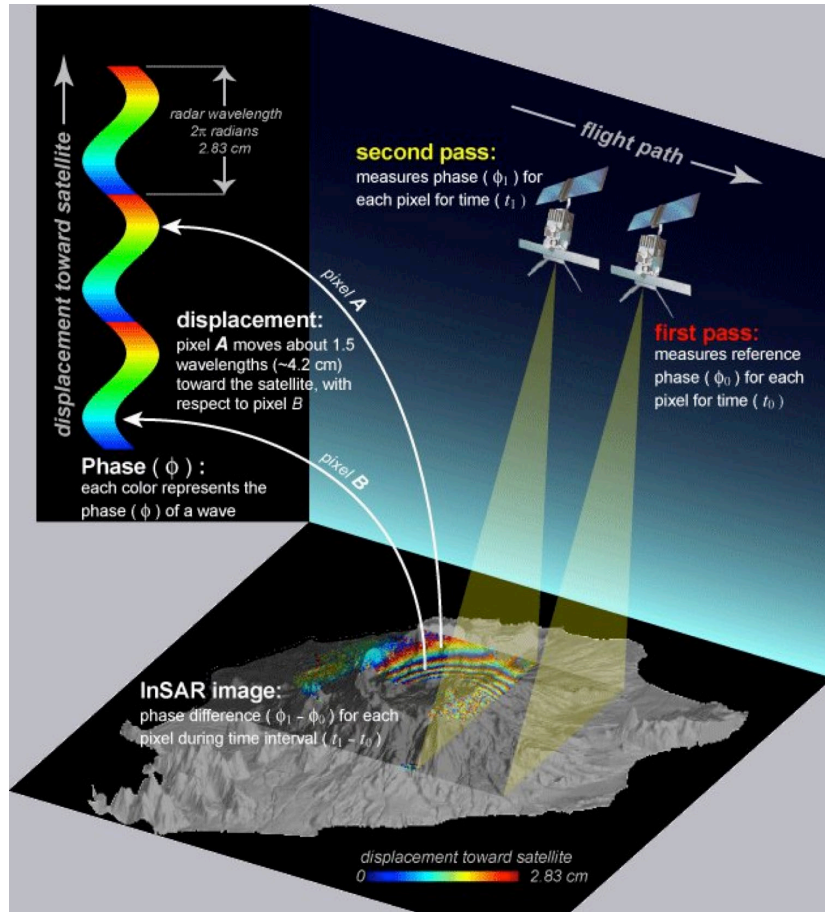
VV intensity image, VH intensity image, and RGB color composite

# Radar interferometry

- Two images from slightly displaced orbits
- Relief model
- Displacements
- Land cover classification
- Techniques
  - InSAR
  - DInSAR
  - PS InSAR
  - SBAS InSAR
  - SqueeSAR



# Radar interferometry



- Phase differences due to
  - Parallax
  - Elevation differences
  - Relief Surface movements
  - Atmospheric phenomena
- Elevations in m
- Displacements in mm

Copernicus and Sentinel

# Copernicus Programme

Europe's eyes on Earth



Programme Manager

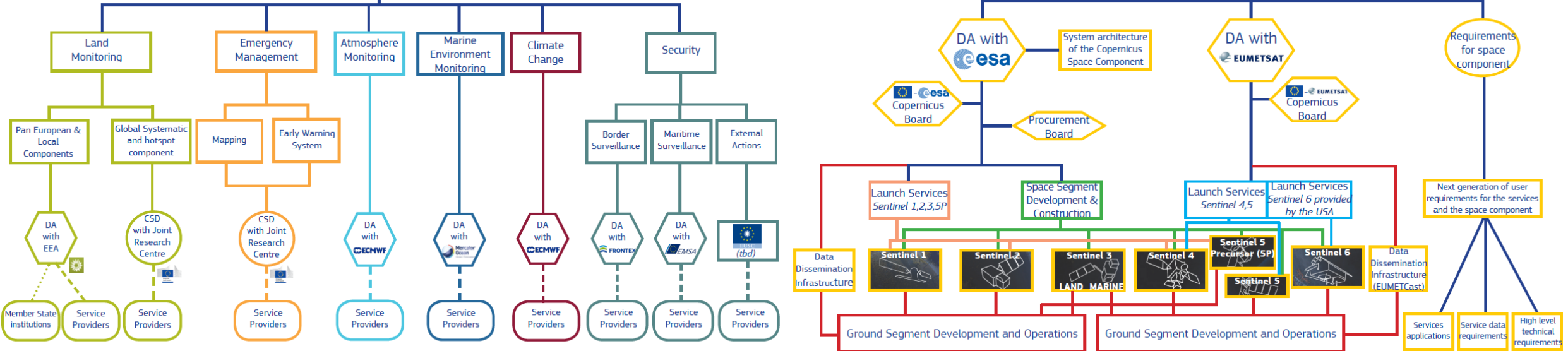
Copernicus  
Committee

User Forum

Copernicus  
Services

Copernicus  
Space Component

In-situ Component\*



# Copernicus Programme

Europe's eyes on Earth

Programme Manager

Copernicus Committee

User Forum

## Copernicus Space Component

DA with **esa**

System architecture of the Copernicus Space Component

DA with **EUMETSAT**

Requirements for space component

EU - **esa**  
Copernicus Board

Procurement Board

EU - **EUMETSAT**  
Copernicus Board

Launch Services  
*Sentinel 1,2,3,5P*

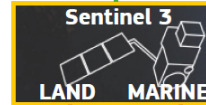
Space Segment  
Development &  
Construction

Launch Services  
*Sentinel 4,5*

Launch Services  
*Sentinel 6 provided by the USA*

Next generation of user requirements for the services and the space component

Data Dissemination Infrastructure



Data Dissemination Infrastructure (EUMETCast)

Ground Segment Development and Operations

Ground Segment Development and Operations

Services applications

Service data requirements

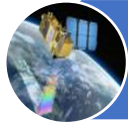
High level technical requirements



# Copernicus and Sentinel satellites



S1A/B: Radar observations



S2A/B: High-resolution optical observation



S3A/B: resolution imaging and altimetry



S4A/B: Observation of the atmosphere from the geostationary orbit



S5P: Observation of the atmosphere from low orbit - predecessor

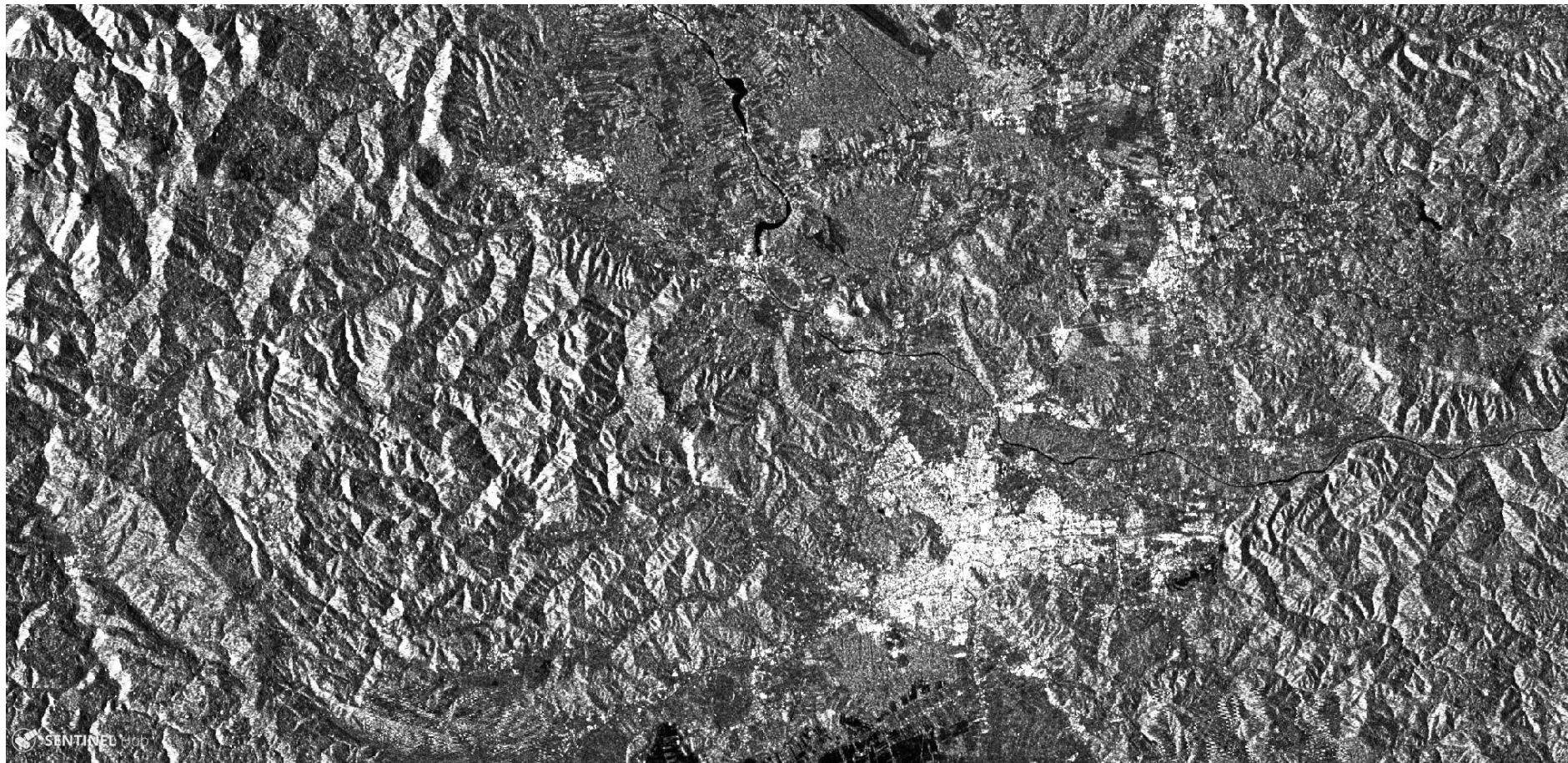


S5A/B/C: Observation of the atmosphere from low orbit

# Sentinel-1

- Sentinel-1A – 2014
- Sentinel-1B – 2016 – not working since 23.12.2021
- Observation of land, forests, water, soil and agriculture
- Rapid mapping in case of natural disasters
- Shipping traffic
- Observing ice at sea
- C-SAR (C-band Synthetic Aperture Radar)
- Resolution: 250 km – 5 x 20 m
- InSAR

# Sentinel-1



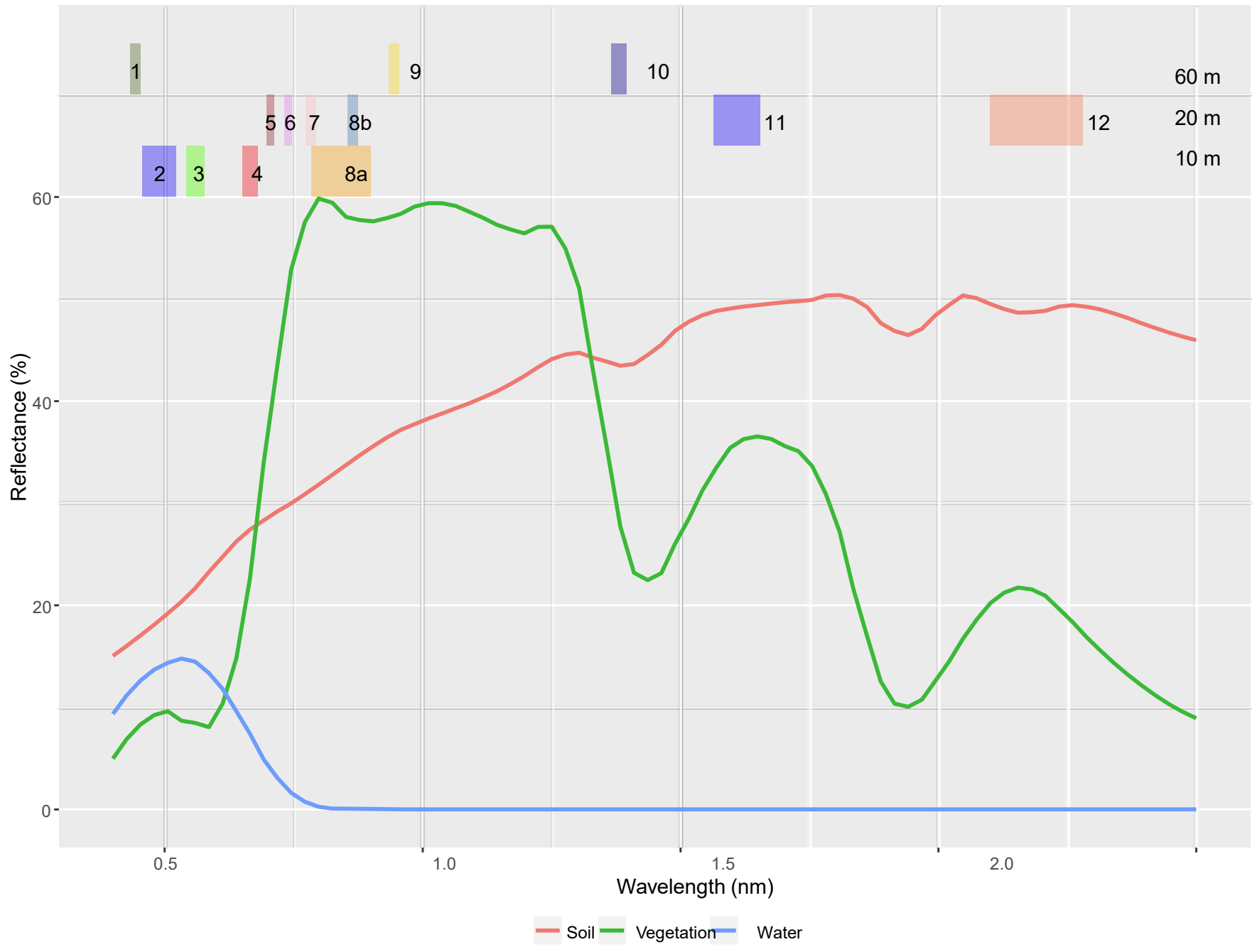
# Sentinel-2

- Sentinel-2A – 2015
- Sentinel-2B – 2017
- Observation of land, vegetation, soil, water surfaces, coastal bands
- Land cover detection and changes
- Rapid mapping in case of natural disasters
- Climate change observation
- Orbit repeatability 10 days, 5 days with two satellites
- MSI (Multispectral Imager)
- Resolution: 290 km – 10 m, 20 m in 60 m

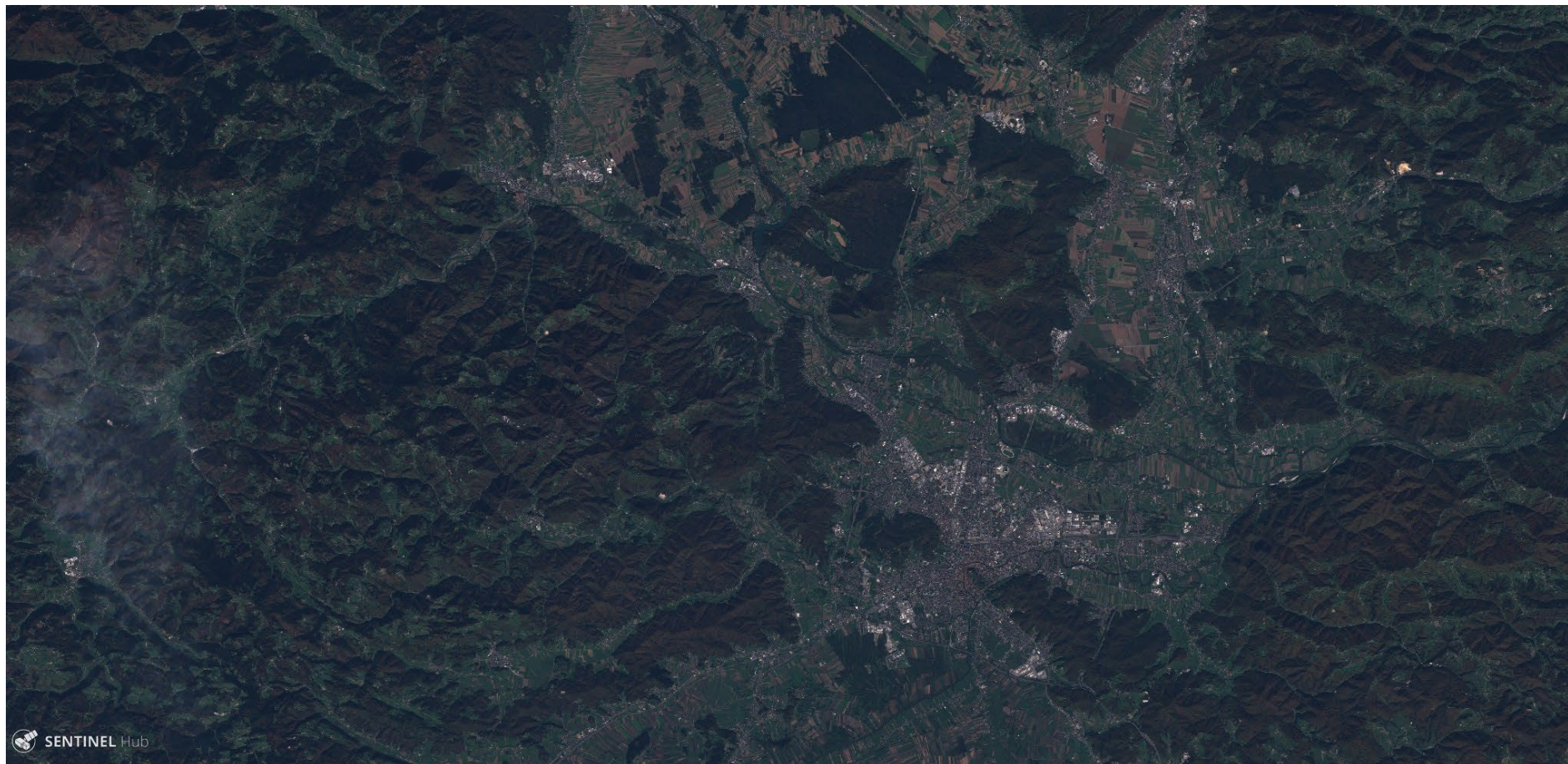
# Sentinel-2

	S2A		S2B		
Band Number	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
1	442.7	20	442.3	20	60
2	492.7	65	492.3	65	10
3	559.8	35	558.9	35	10
4	664.6	30	664.9	31	10
5	704.1	14	703.8	15	20
6	740.5	14	739.1	13	20
7	782.8	19	779.7	19	20
8	832.8	105	832.9	104	10
8a	864.7	21	864.0	21	20
9	945.1	19	943.2	20	60
10	1373.5	29	1376.9	29	60
11	1613.7	90	1610.4	94	20
12	2202.4	174	2185.7	184	20

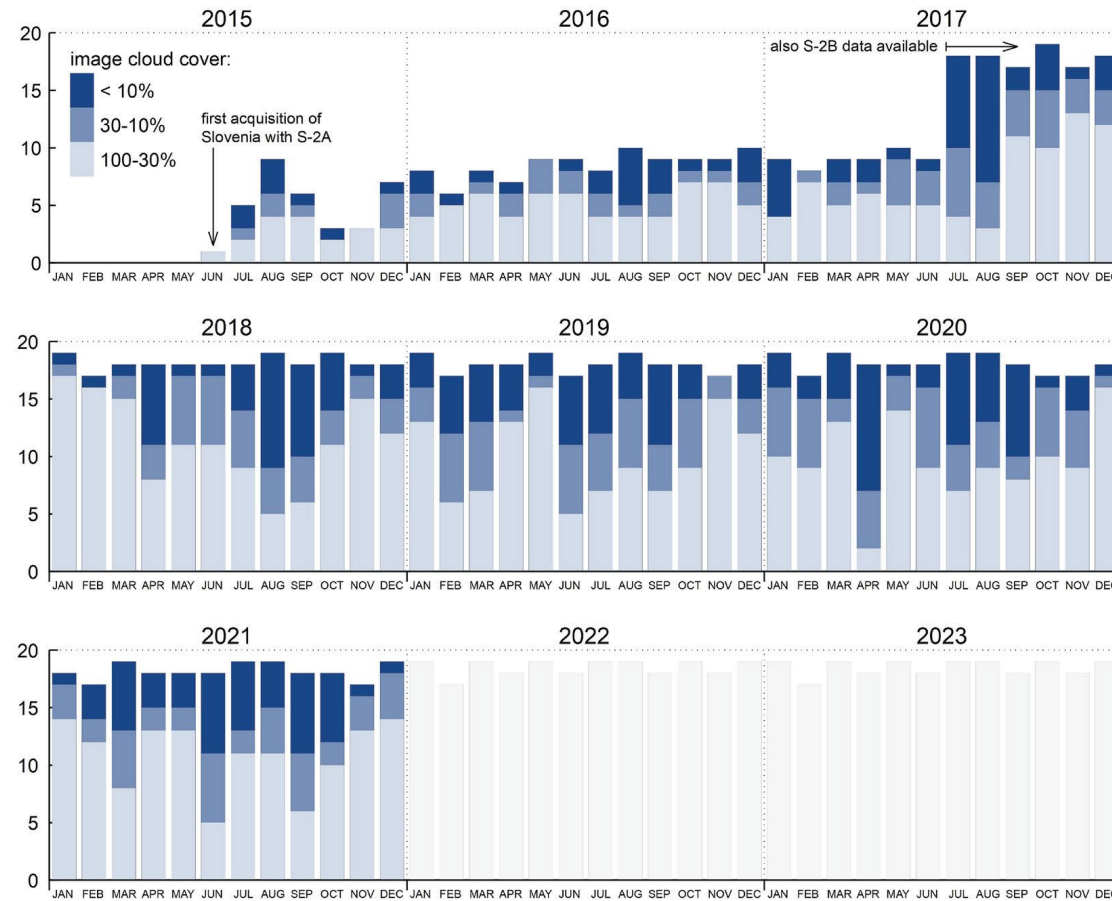
# Sentinel-2



# Sentinel-2



# Sentinel-2 archive





Long and dense time series

# Satellite Image Time Series – SITS

- Medium and high-resolution data is freely available
- Landsat archive – 2008
- Copernicus – complete, free and open
  
- Long SITS
  - 1972 –
- Dense SITS
  - weekly, daily
- Harmonized SITS
  - Landsat – Sentinel-2
  - Optical – radar
  - Sentinel-2 – Planet

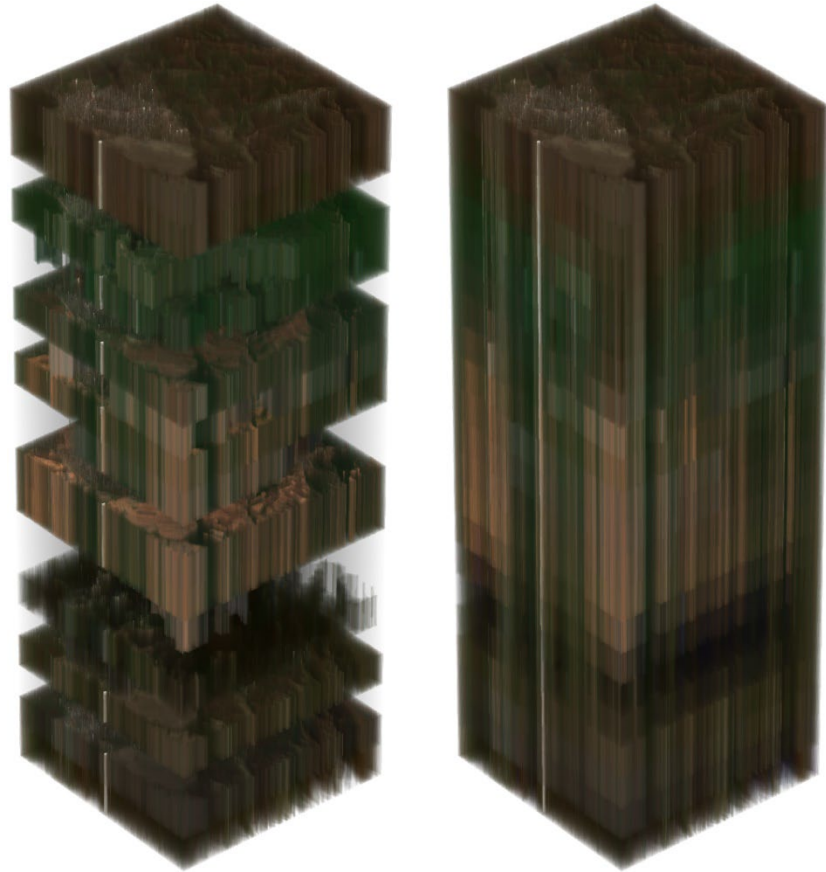
# Landsat SITS

- Landsat, 1972 –
- Thematic Mapper (TM), 1982 –
- Operational Land Imager (OLI), 2013 –
- Every 16 day
- Optical → clouds



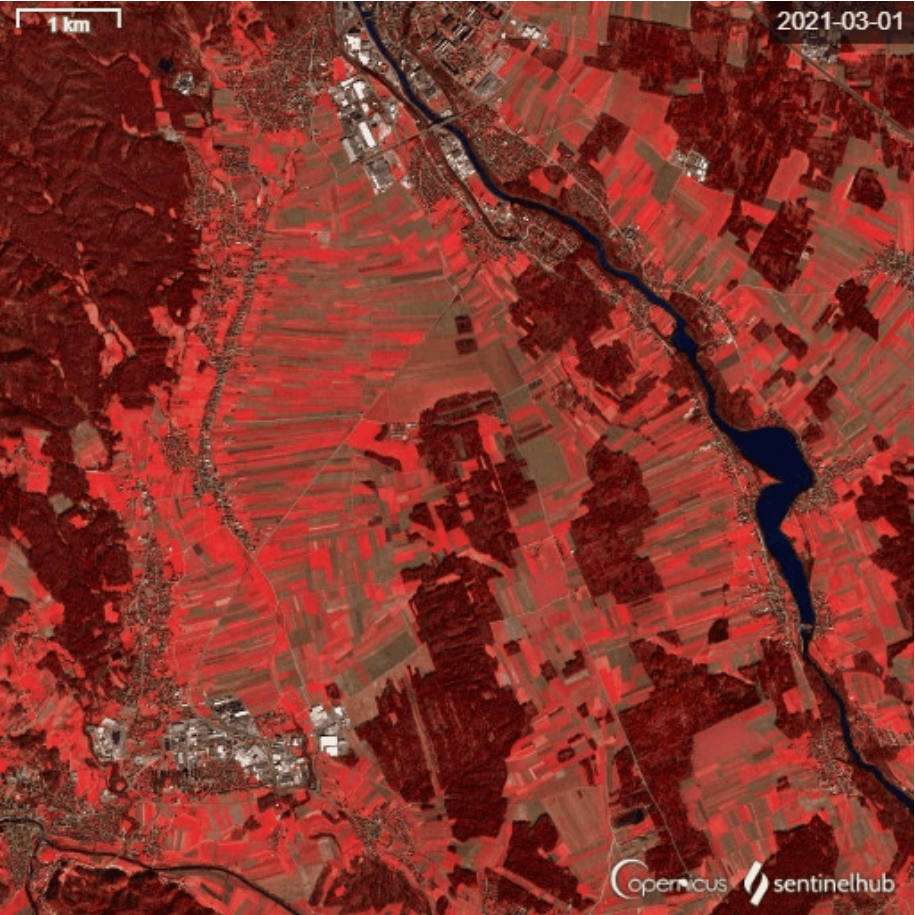
Time Series generation

# Time series

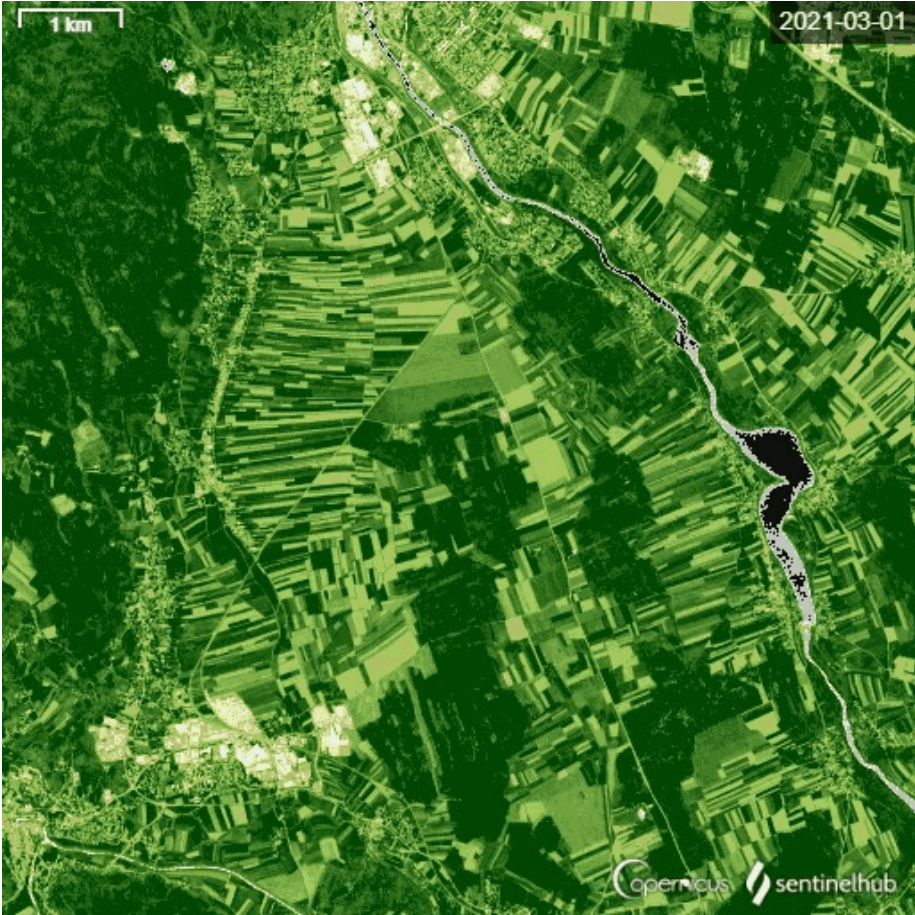


- Set of satellite images taken over the same area of interest at different times
- Same or multiple sensors
- Time Series:
  - understanding how Earth is changing
  - determining the causes of these changes
  - predicting future changes
  - discriminating features

# Time series - Sentinel-2

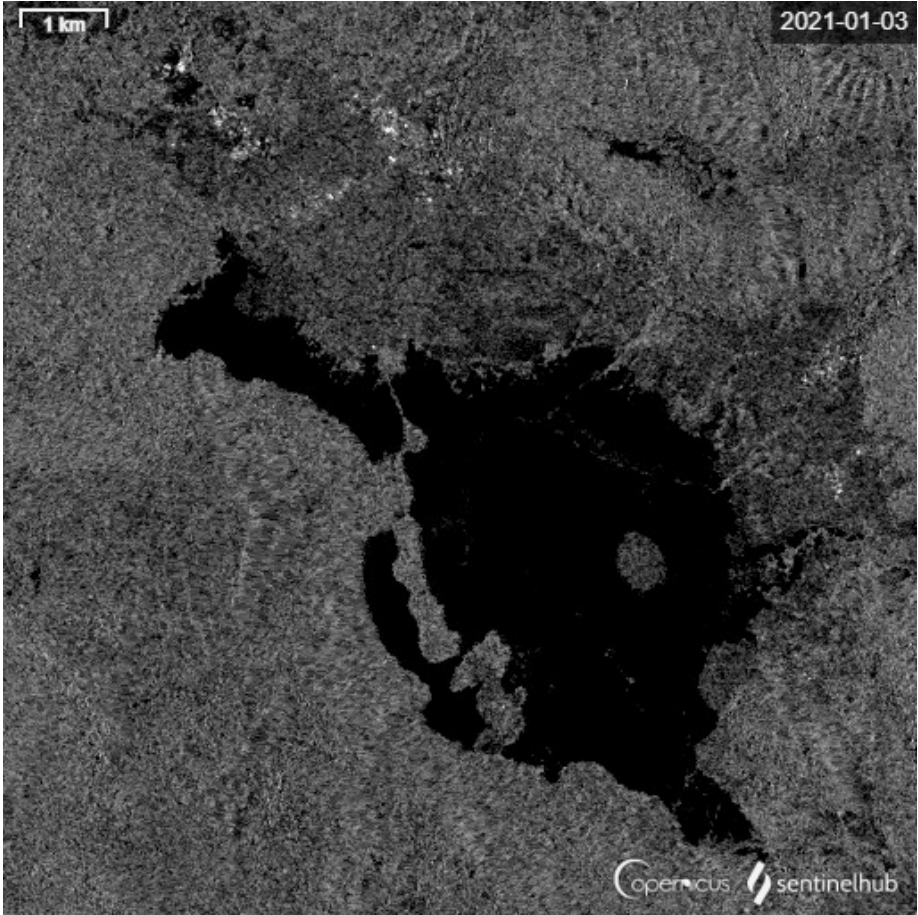


8, 4, 3

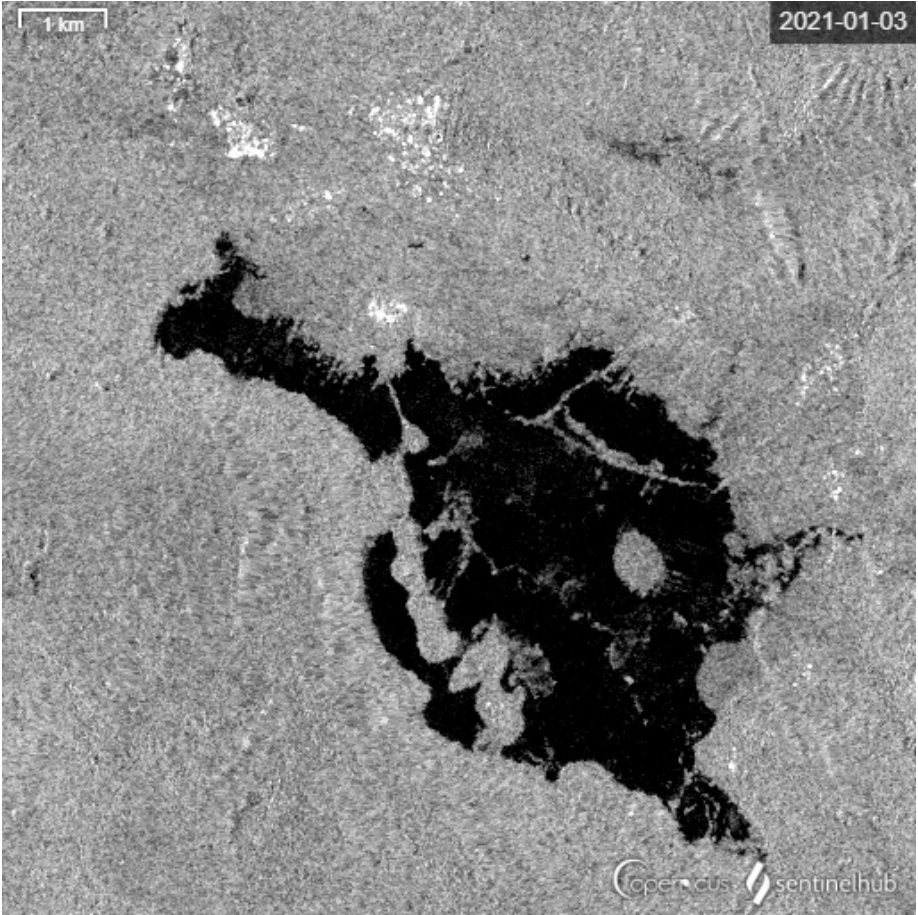


NDVI

# Time series - Sentinel-1

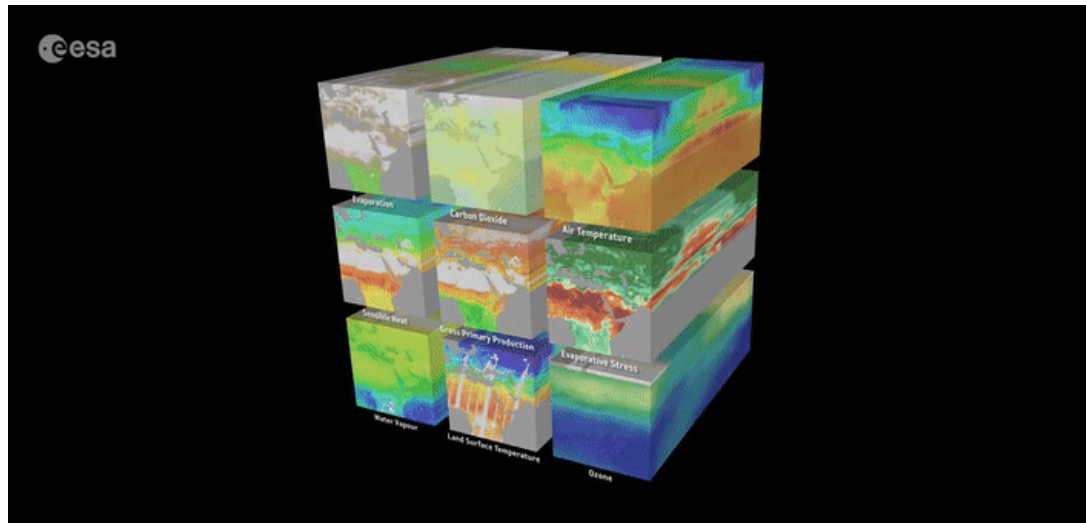


VH



VV

# Analysis Ready Data (ARD)



- CEOS – Committee on Earth Observation Satellites:
  - Analysis Ready Data are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.
- Data which is ready to use.

[CEOS Analysis Ready Data](#)

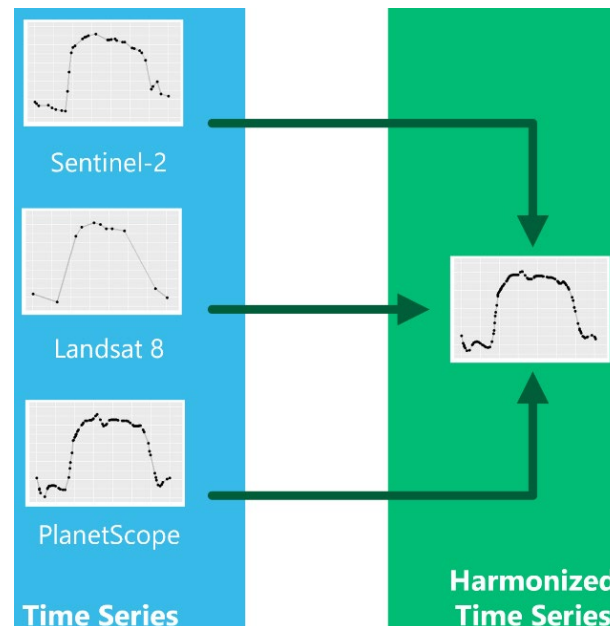
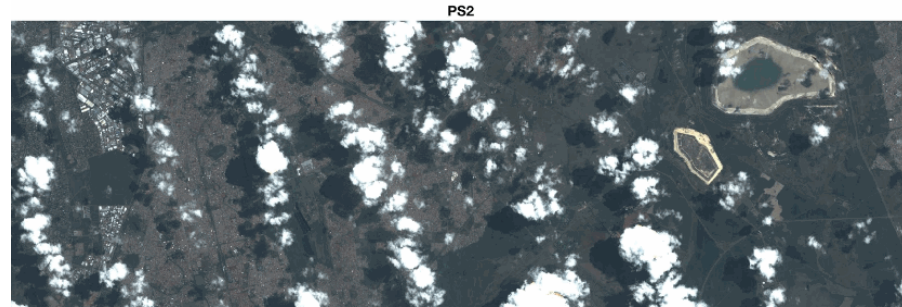
[Analysis Ready Data Defined. Cloud Native Geoprocessing Part 2 | by Chris Holmes | Planet Stories | Medium](#)

[Harness the power of Sentinel Hub, xcube, EOxHub, GeoDB and more in Euro Data Cube | by Dorothy Rono | Euro Data Cube | Medium](#)

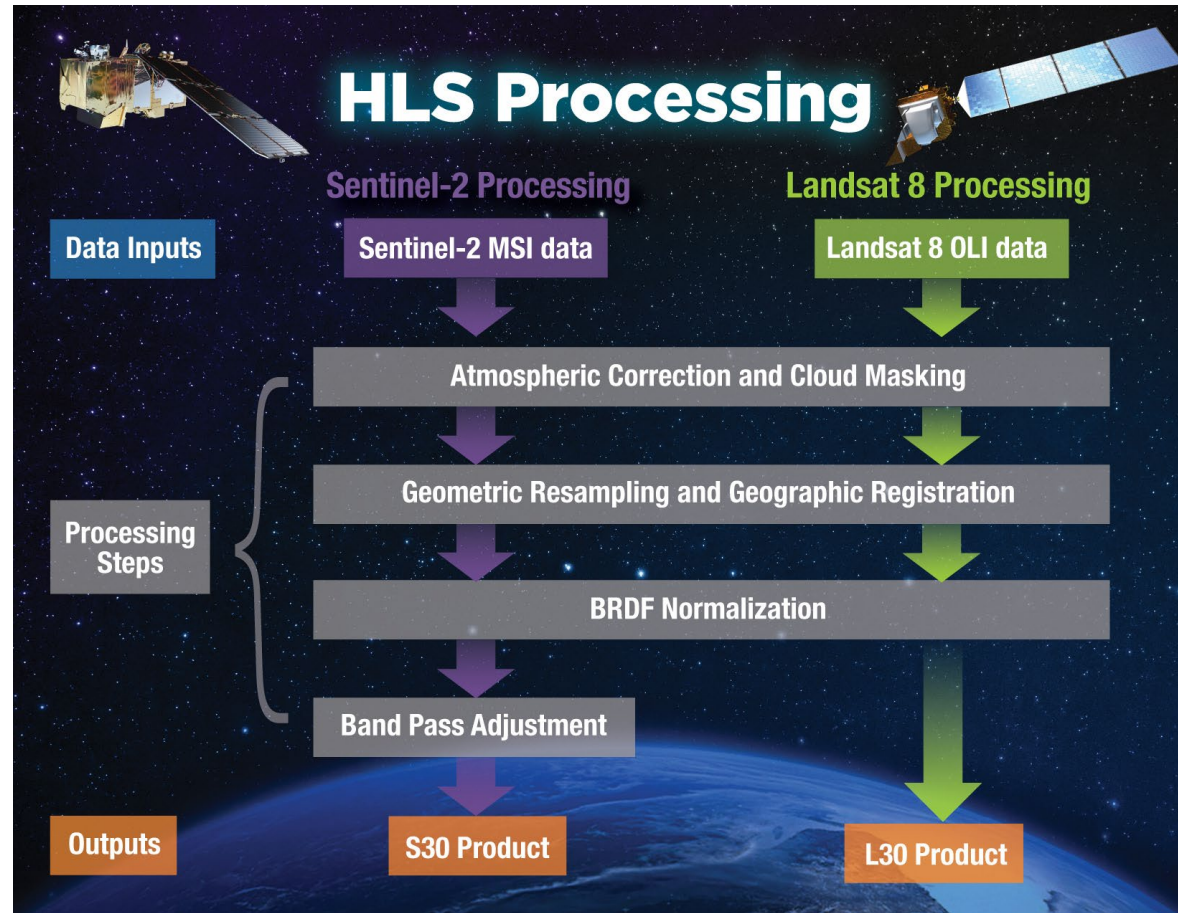


# Analysis Ready Data (ARD)

- ARD processing may differ between applications
- Image clipping
- Masking – Usable/Unusable Data Masks
- Atmospheric Correction
- Pixel Alignment
- Sensor Alignment

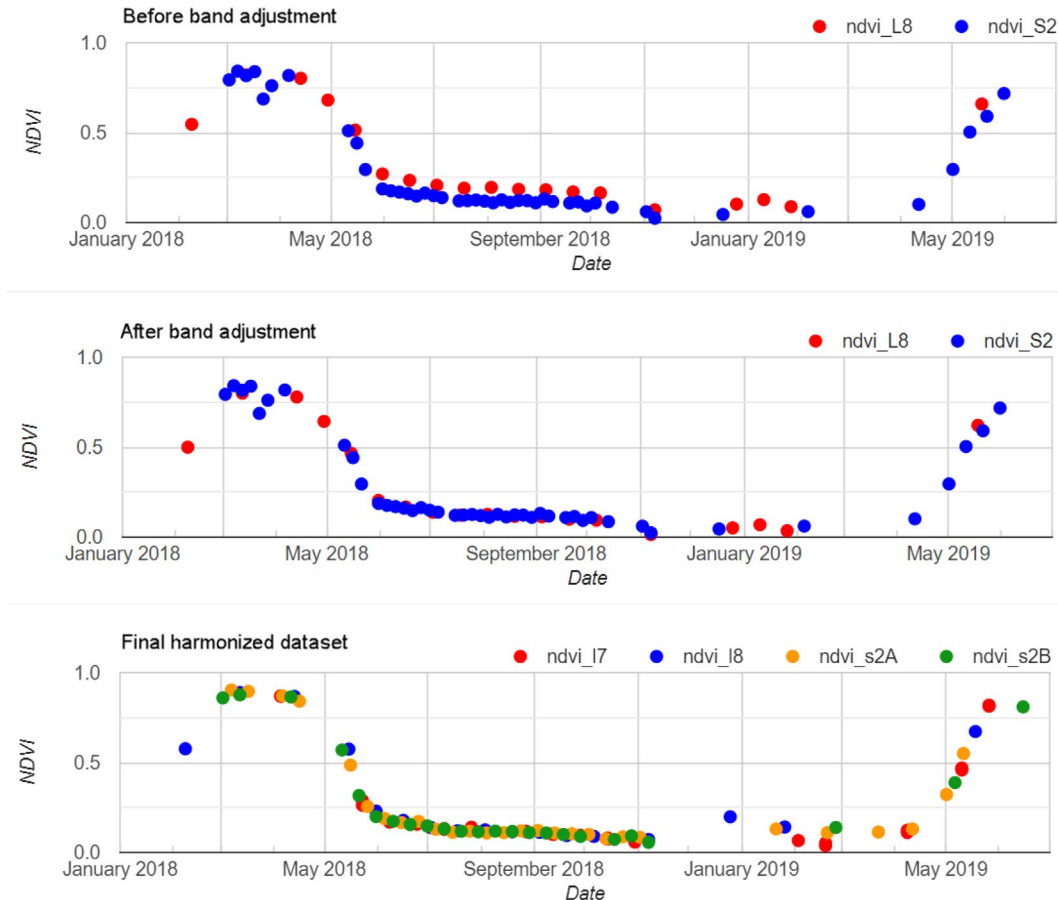


# Harmonization of the time series



[Algorithms « Harmonized Landsat Sentinel-2 \(nasa.gov\)](https://www.nasa.gov/algorithm/harmonized-landsat-sentinel-2)

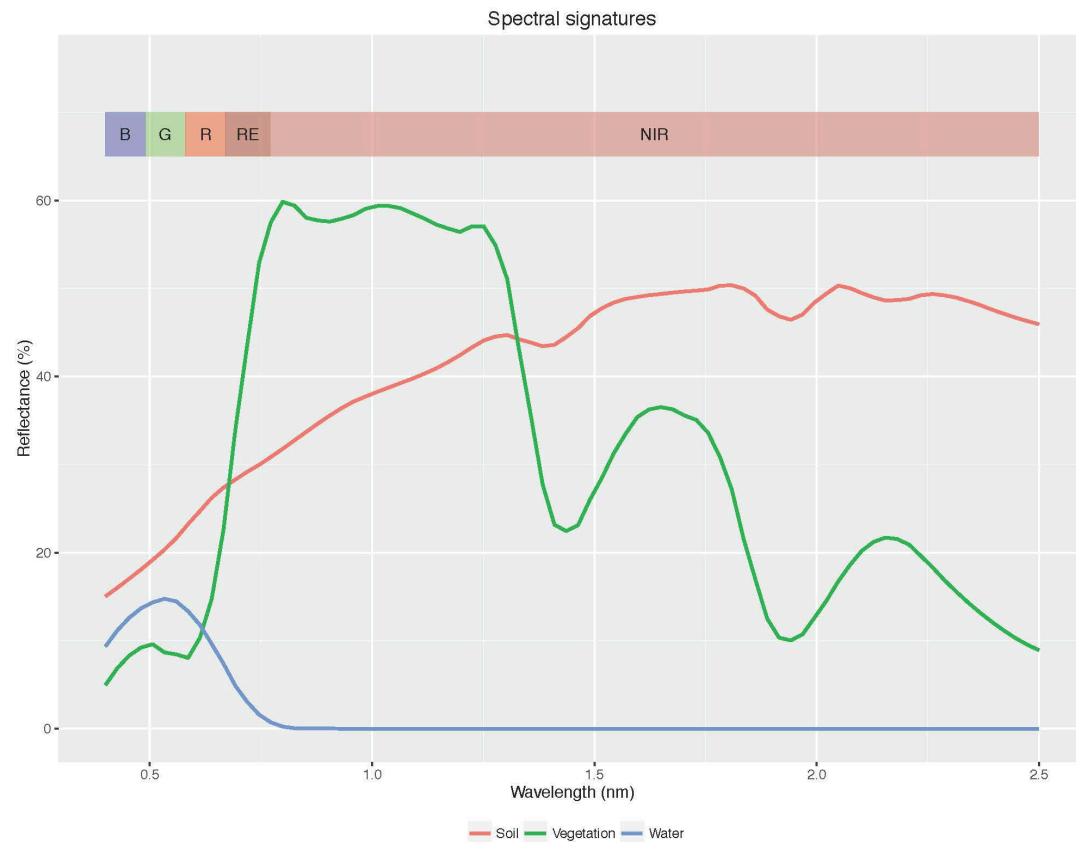
# Sentinel-2 – Landsat 7,8 – harmonization



[Remote Sensing | Free Full-Text | Harmonization of Landsat and Sentinel 2 for Crop Monitoring in Drought Prone Areas: Case Studies of Ninh Thuan \(Vietnam\) and Bekaa \(Lebanon\) \(mdpi.com\)](#)

# Vegetation on optical and radar images

# Vegetation Spectra – optical



- Certain wavelengths are sensitive to certain chemicals and compounds.
- They result in absorption characteristics.
- Make measurements in relation to these compounds.
- Indices make use of these wavelength features.

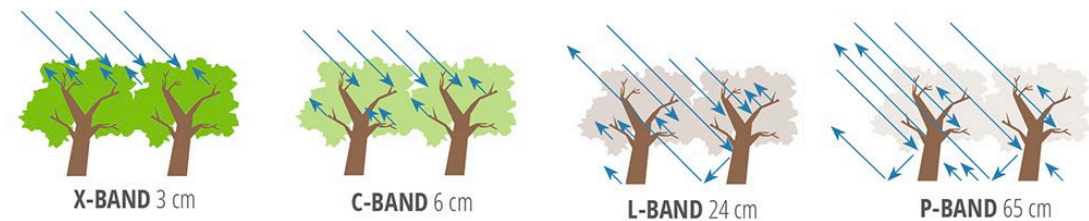
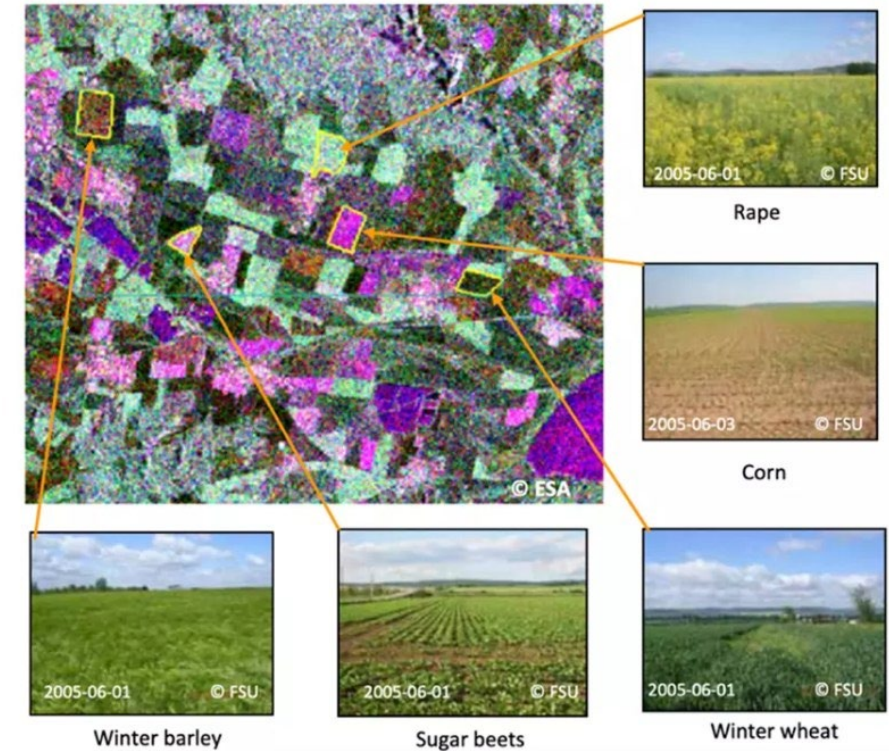
# Radar backscattering

- Wavelength/frequency
- Polarization (horizontal, vertical)
- Incidence angle
- Resolution

Radar

- Structure of the observed phenomenon
- Roughness (roughness) of the terrain
- The conductivity and dielectricity of the surface
- Orientation

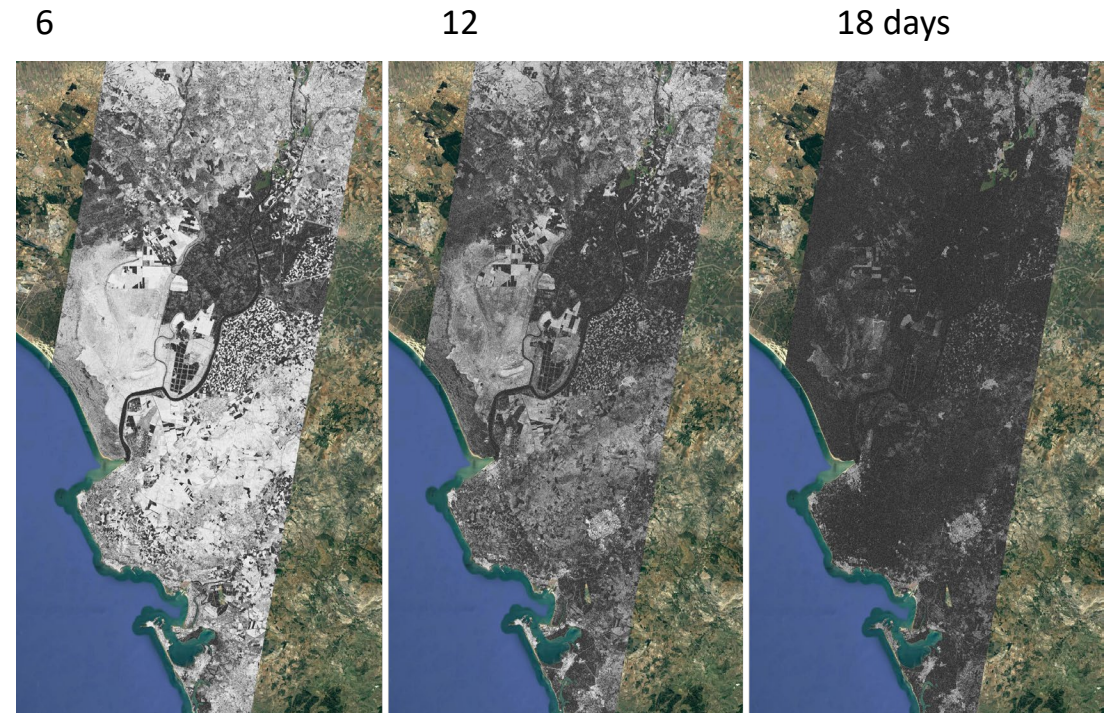
Surface



[What is Synthetic Aperture Radar? | Earthdata \(nasa.gov\)](https://earthdata.nasa.gov)  
[SAR Satellites for Agriculture - Groundstation](#)

# Coherence for vegetation mapping

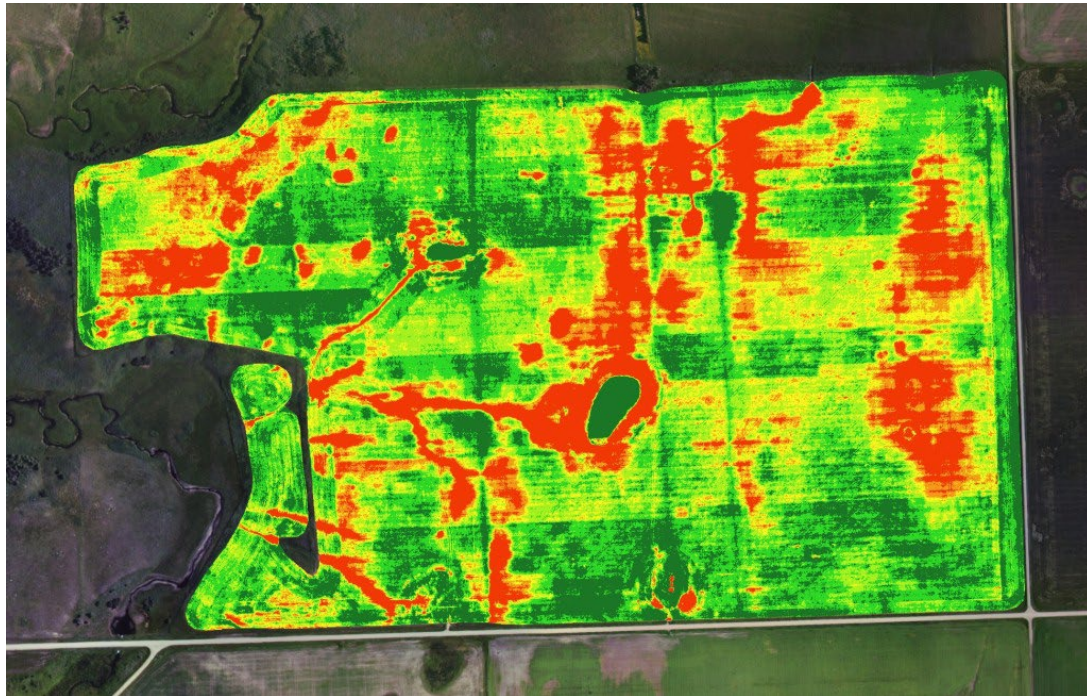
- The coherence of an InSAR data pair represents the magnitude of the complex correlation between two SAR images on a pixel-by-pixel basis.
- Is a quantitative measure of the amount of noise in the interferogram.



Is NDVI enough?



# Vegetation Indices



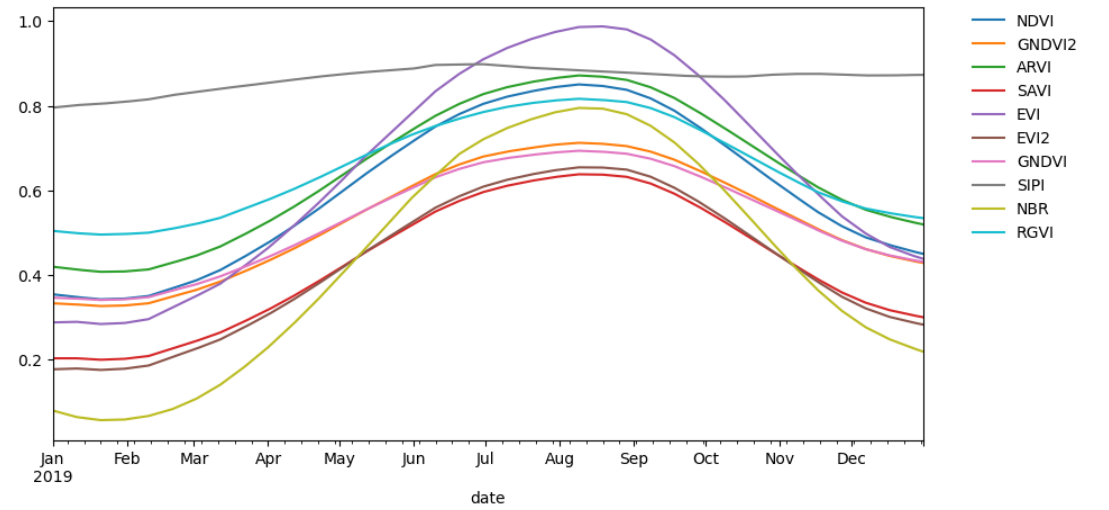
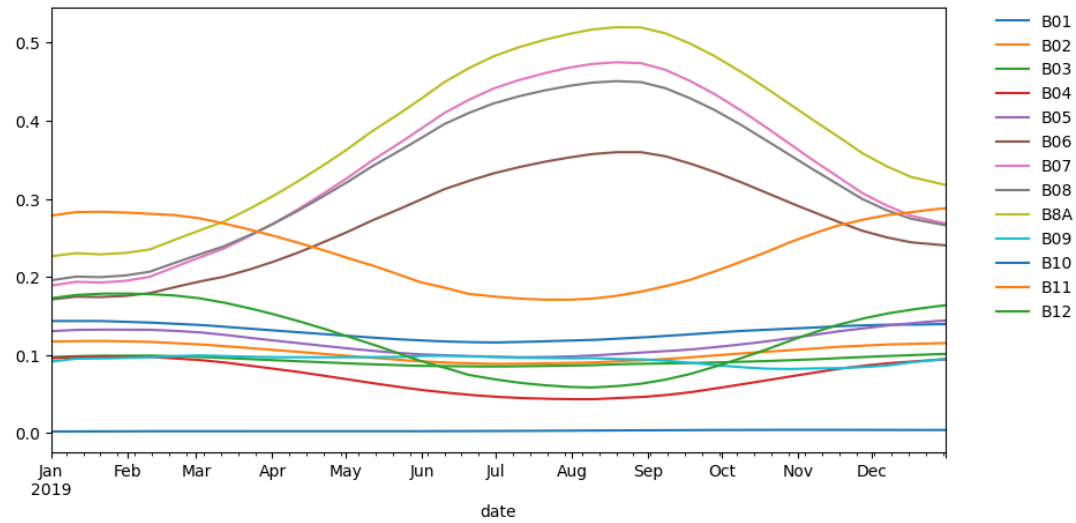
- VI - Vegetation Index
- NDVI - Normalized Difference Vegetation Index
- EVI - Enhanced Vegetation Index
- SAVI - Soil Adjusted NDVI
- AVI - Advanced Vegetation Index
- NDMI - Normalized Difference Moisture Index ...

[IDB - Index DataBase](#)

# IDB - Agriculture

Nr.	Name	Formula	Variables	Comment
1	Atmospherically Resistant Vegetation Index	$\frac{NIR-RED-y(REL-BLUE)}{NIR+RED-y(REL-BLUE)}$	NIR = [781:1399]	
2	Atmospherically Resistant Vegetation Index 2	$-0.18 + 1.17 \left( \frac{NIR-RED}{NIR+RED} \right)$		
3	Canopy Chlorophyll Content Index	$\frac{\frac{NIR-rededge}{NIR+rededge} - \frac{NIR-Red}{NIR+Red}}{\frac{NIR-Red}{NIR+Red}}$		
4	CASI NDVI	$\frac{((770:780)+[784:790]) - ((655:665)+[676:685])}{((770:780)+[784:790]) + ((655:665)+[676:685])}$		
5	CASI TM4/3	$\frac{[770:780] + [784:790]}{[655:665] + [676:685]}$		
6	Cellulose Absorption Index	$100 (0.5 (2030nm + 2210nm) - 2100nm)$		
7	Cellulose absorption index 2	$0,5 (2020nm + 2220nm) - 2100nm$		
8	Chlorophyll Absorption Ratio Index	$\left( \frac{700nm}{670nm} \right) \frac{\sqrt{(a-670+670nm+b)^2}}{(a^2+1)^{0.5}}$	b=(550nm-((700nm-550nm)/150*550)), a=(700nm-550nm)/150	
9	Chlorophyll Absorption Ratio Index 2	$\left( \frac{[(a \cdot [670] + [670] + b)]}{(a^2 + 1)^{0.5}} \right) \left( \frac{[700]}{[670]} \right)$	a=([700]-[550])/150, b=[550]-(a*[550])	
10	Chlorophyll Green	$\left( \frac{[760:800]}{[540:560]} \right)^{(-1)}$		
11	Chlorophyll Index RedEdge 710	$\frac{750nm}{710nm} - 1$		
12	Chlorophyll Red-Edge	$\left( \frac{[760:800]}{[690:720]} \right)^{(-1)}$		
13	Chlorophyll vegetation index	$NIR \frac{RED}{GREEN^2}$		
14	Crop water stress index	$\frac{C-A}{B-A}$		
15	Green leaf index	$\frac{2GREEN-RED-BLUE}{2GREEN+RED+BLUE}$		
16	Leaf Chlorophyll Index	$\frac{[850]-[710]}{[850]+[680]}$		

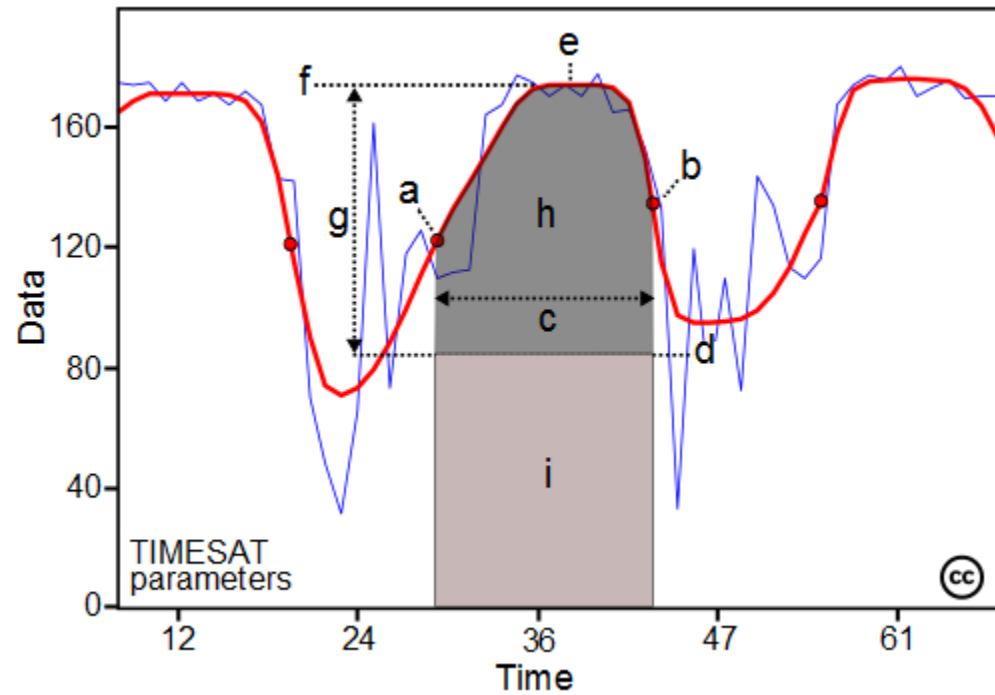
# Sentinel-2 – Bands and indices





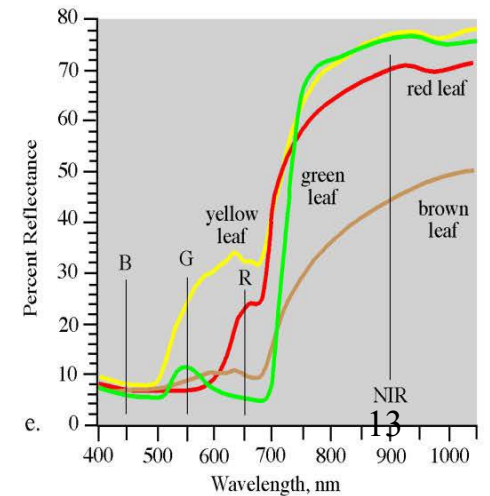
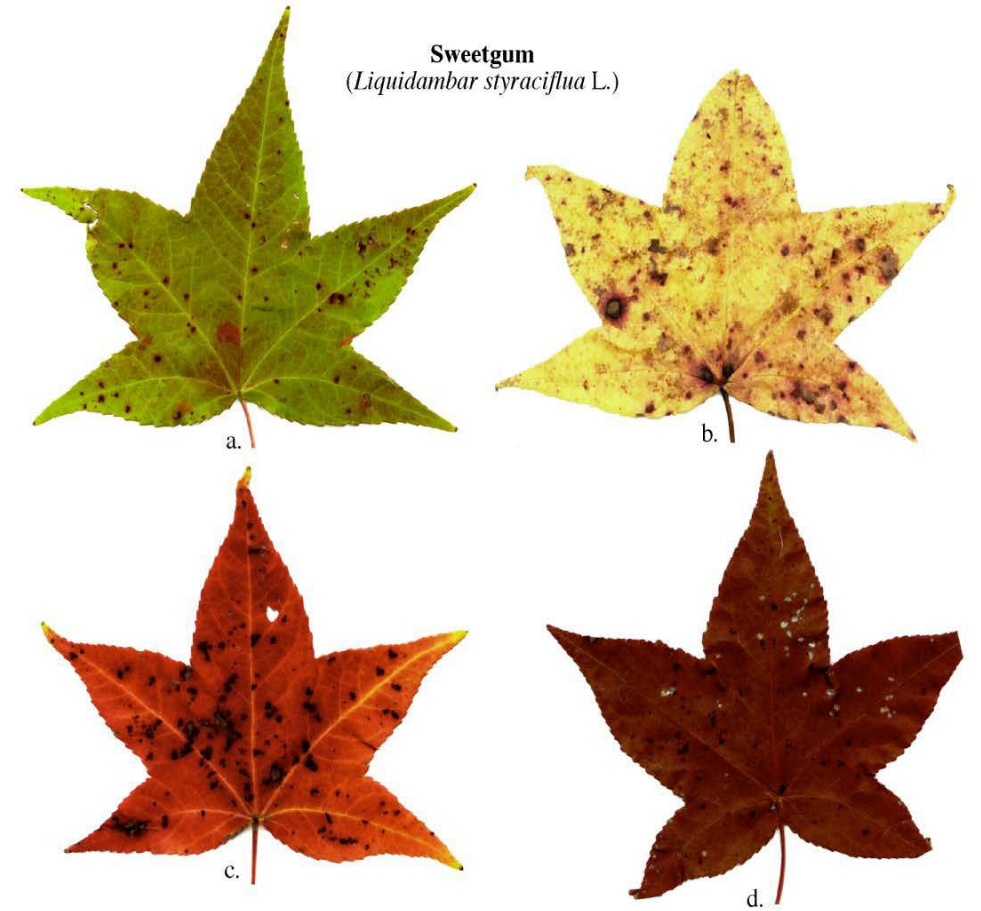
# Time series analysis

# Temporal development of vegetation

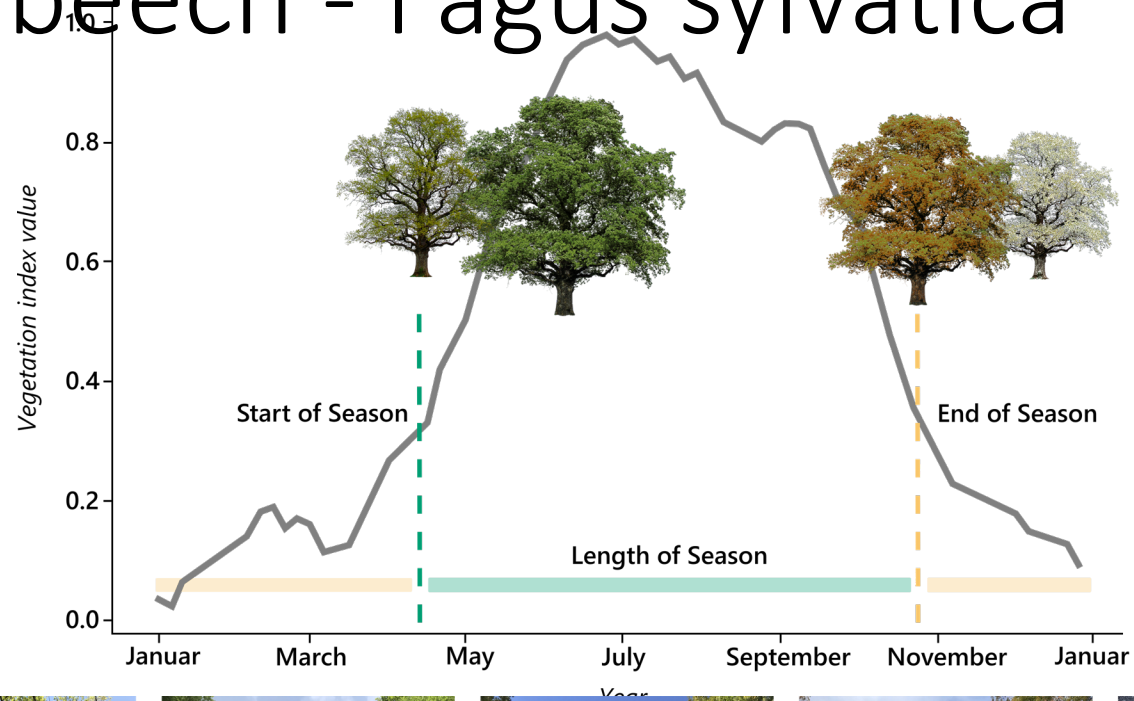


[Welcome to the TIMESAT pages! \(lu.se\)](http://lu.se)

# Sweetgum Leaves (*Liquidambar styraciflua* L.)



# European beech - *Fagus sylvatica*



11 April 2022



30 April 2022



23 May 2022



19 September 2022



13 October 2022



23 October 2022



23 January 2023



# Time series of images



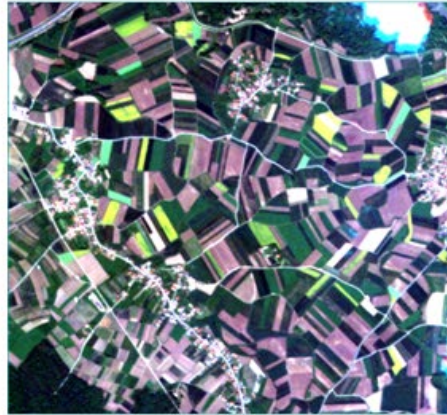
Apr



May



Jun



Jul



Aug



Sep

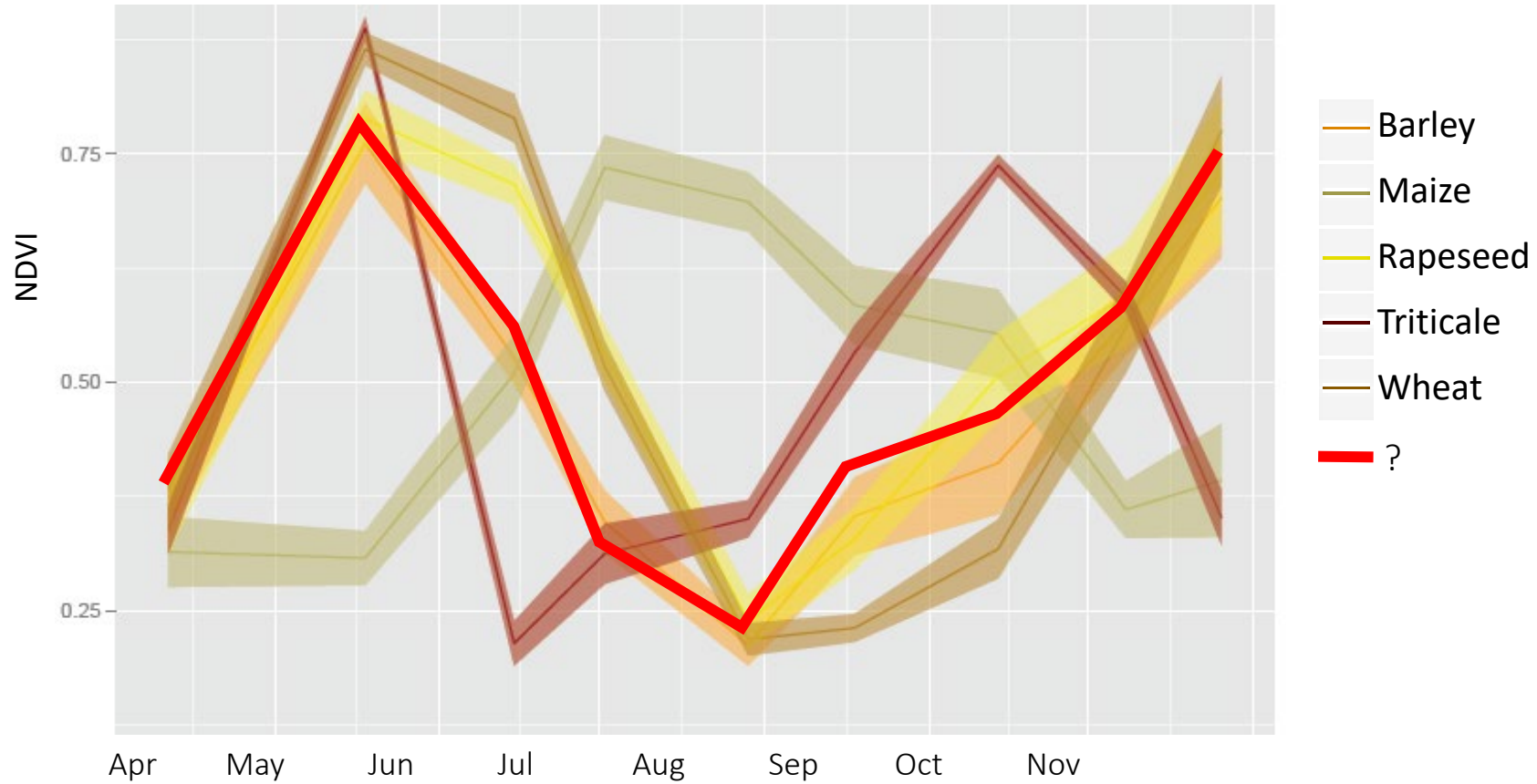


Oct

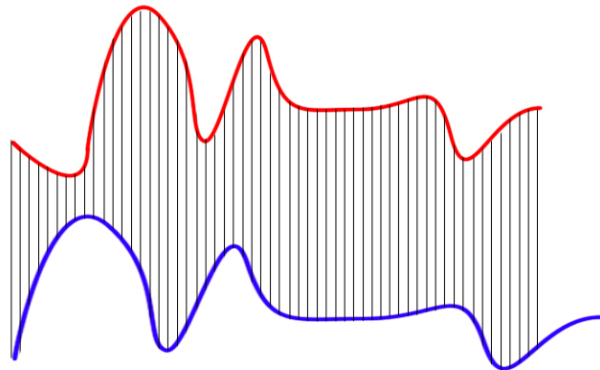


Nov

# Classification based on time series

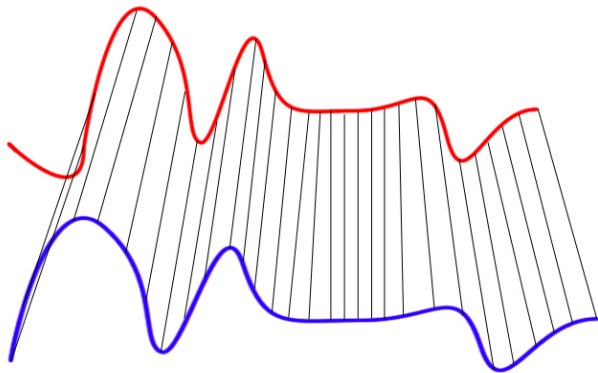


# Time series analysis



Euclidean distance

easy  
of the same length  
inflexible

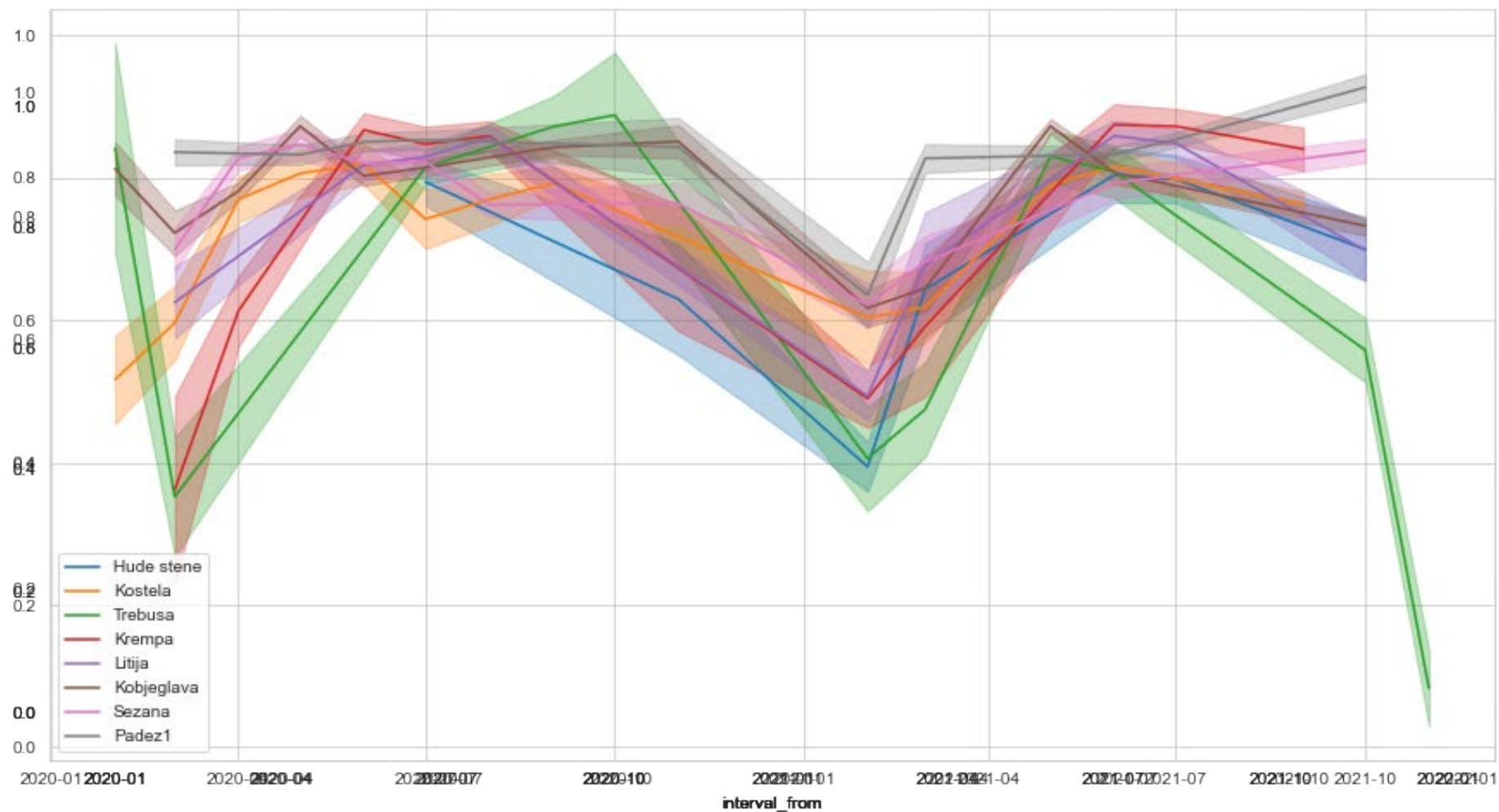


Dynamic time warping

flexible  
more computationally complex  
time-consuming

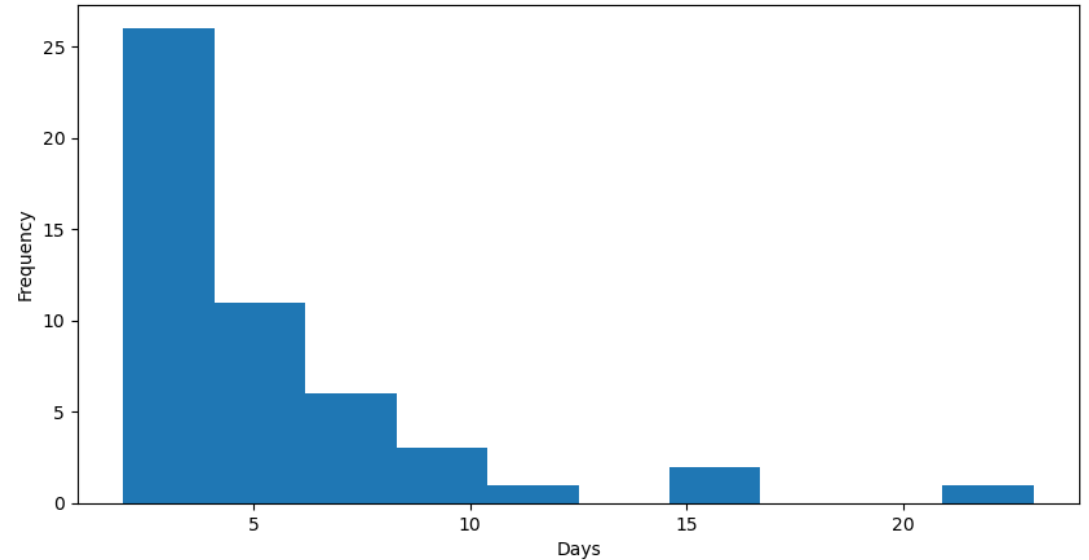
# Time interpolation/aggregation

- No
- 5 D
- 10 D
- 1 M

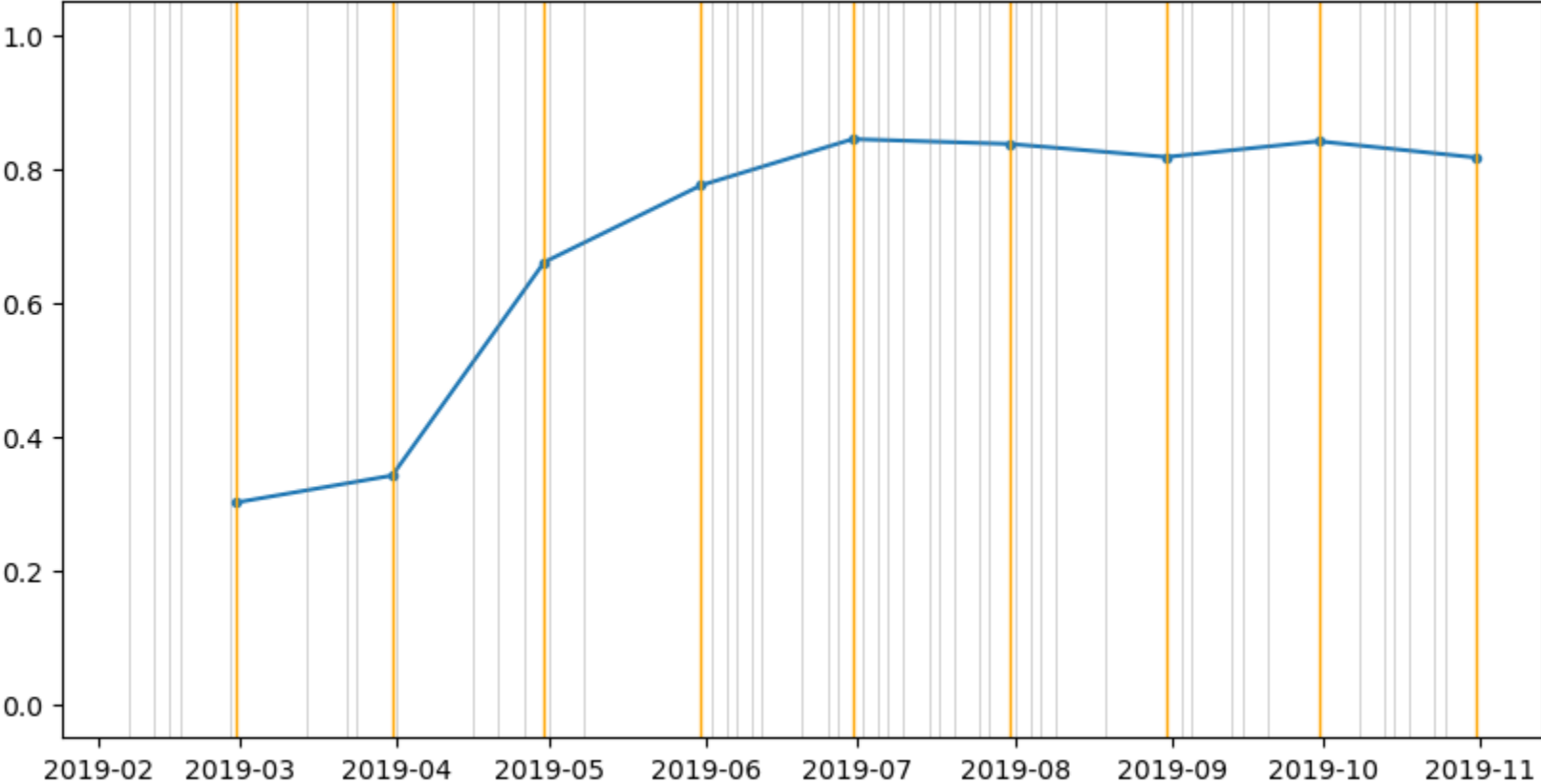


# Time synchronization

- Time series have different timestamps
- Time of image acquisition
  - Clouds
  - Different satellites
  - Different sensors
- Synchronize to the same timestamps
  - Week
  - 10 days
  - Month

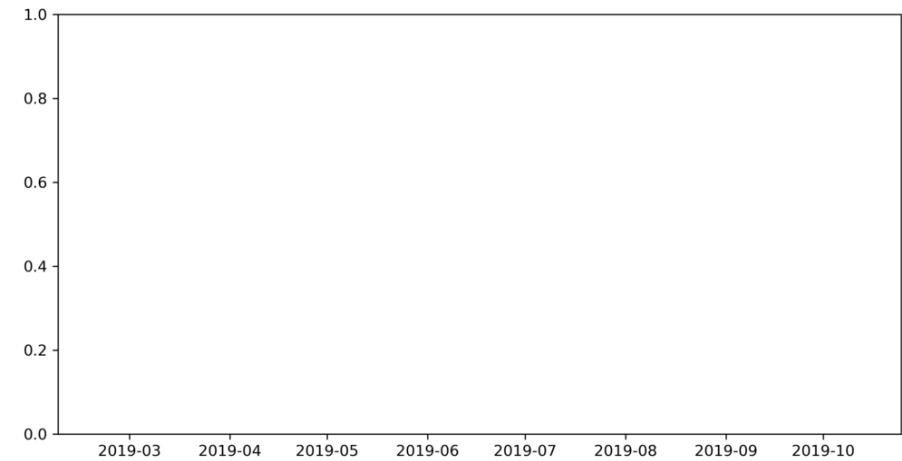


# Time synchronization



# How long must the time series be

- Yearly vegetation cycle
- Multiyear
  - Disturbances
- Beginning of the year



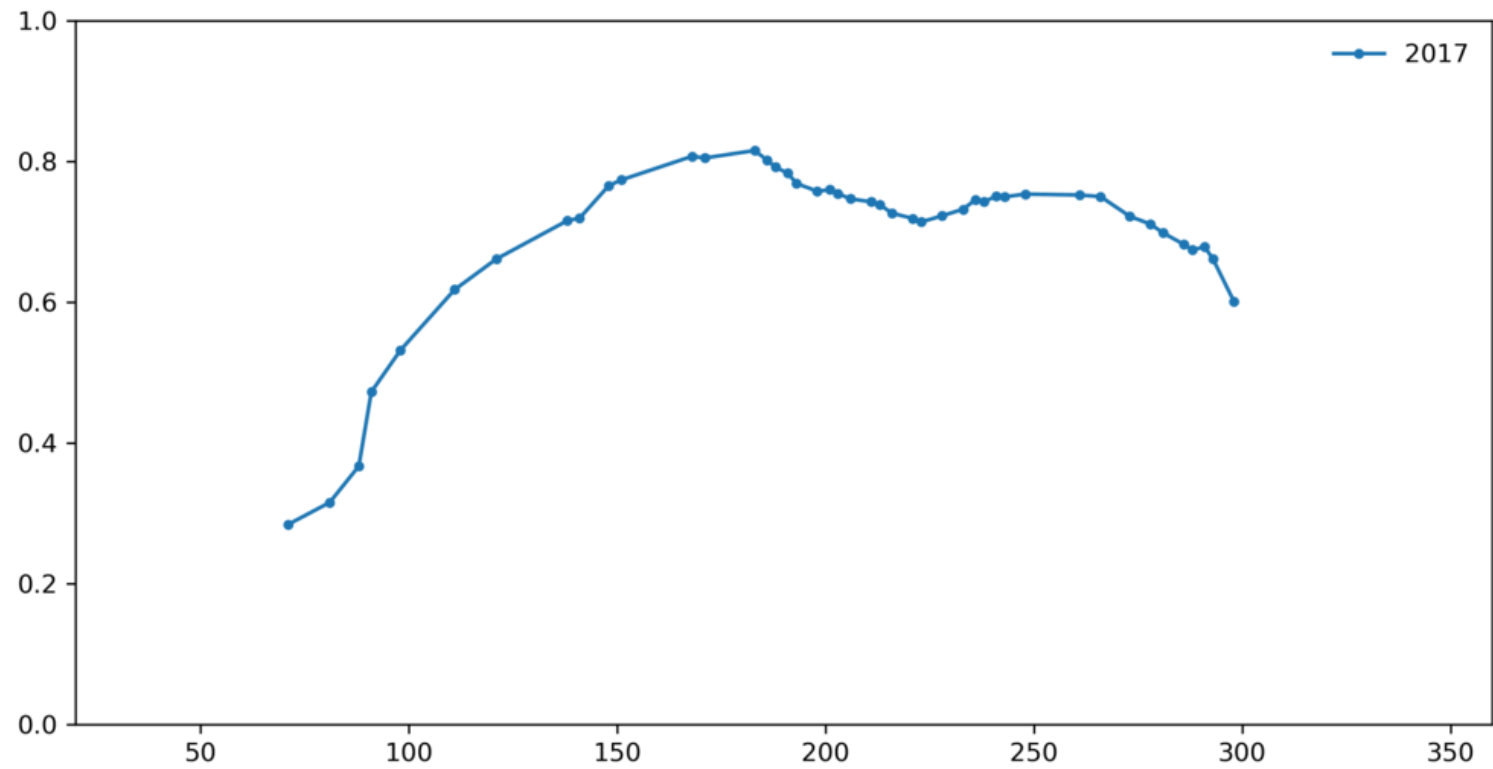
# How long must the time series be

- Yearly vegetation cycle
- Multiyear
  - Disturbances
- Beginning of the year

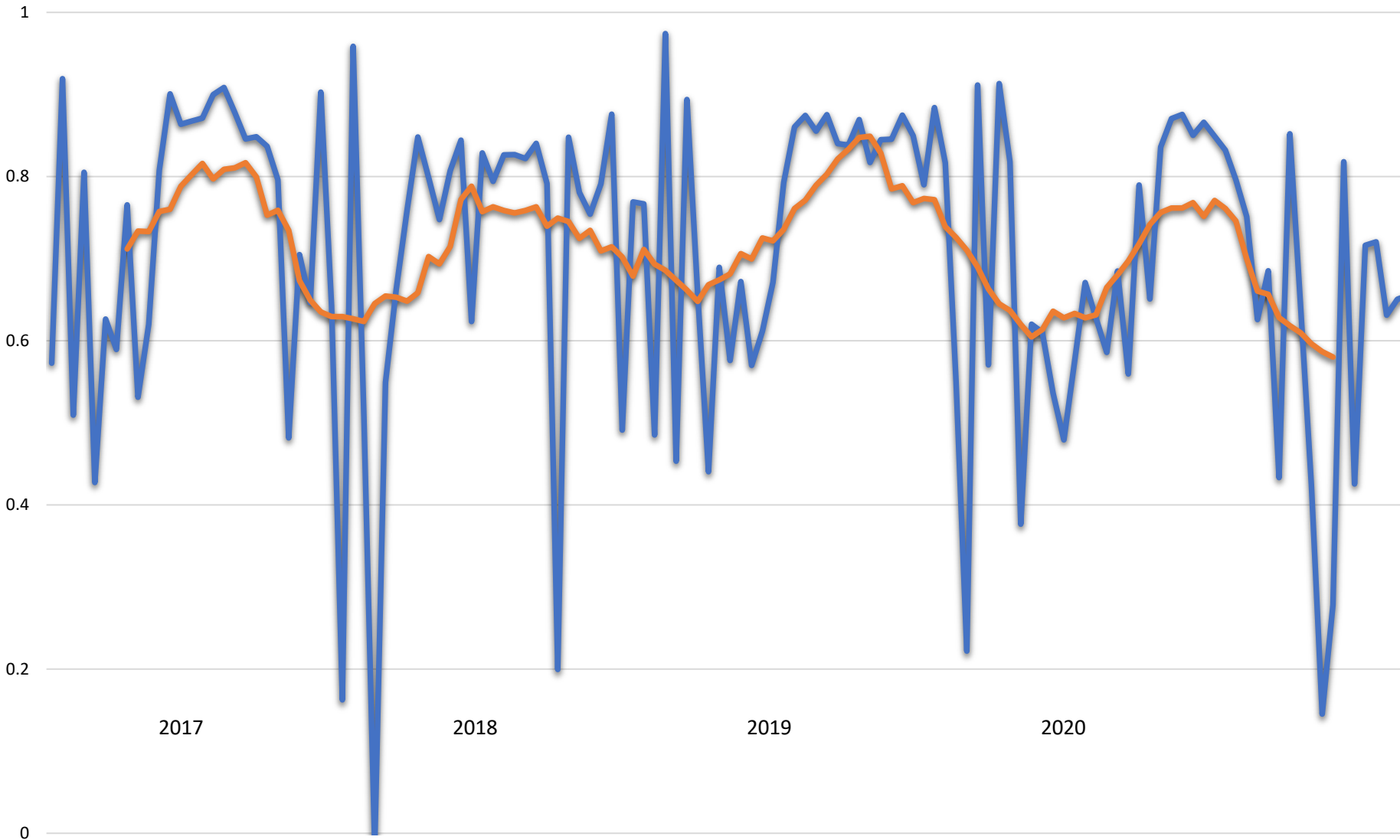




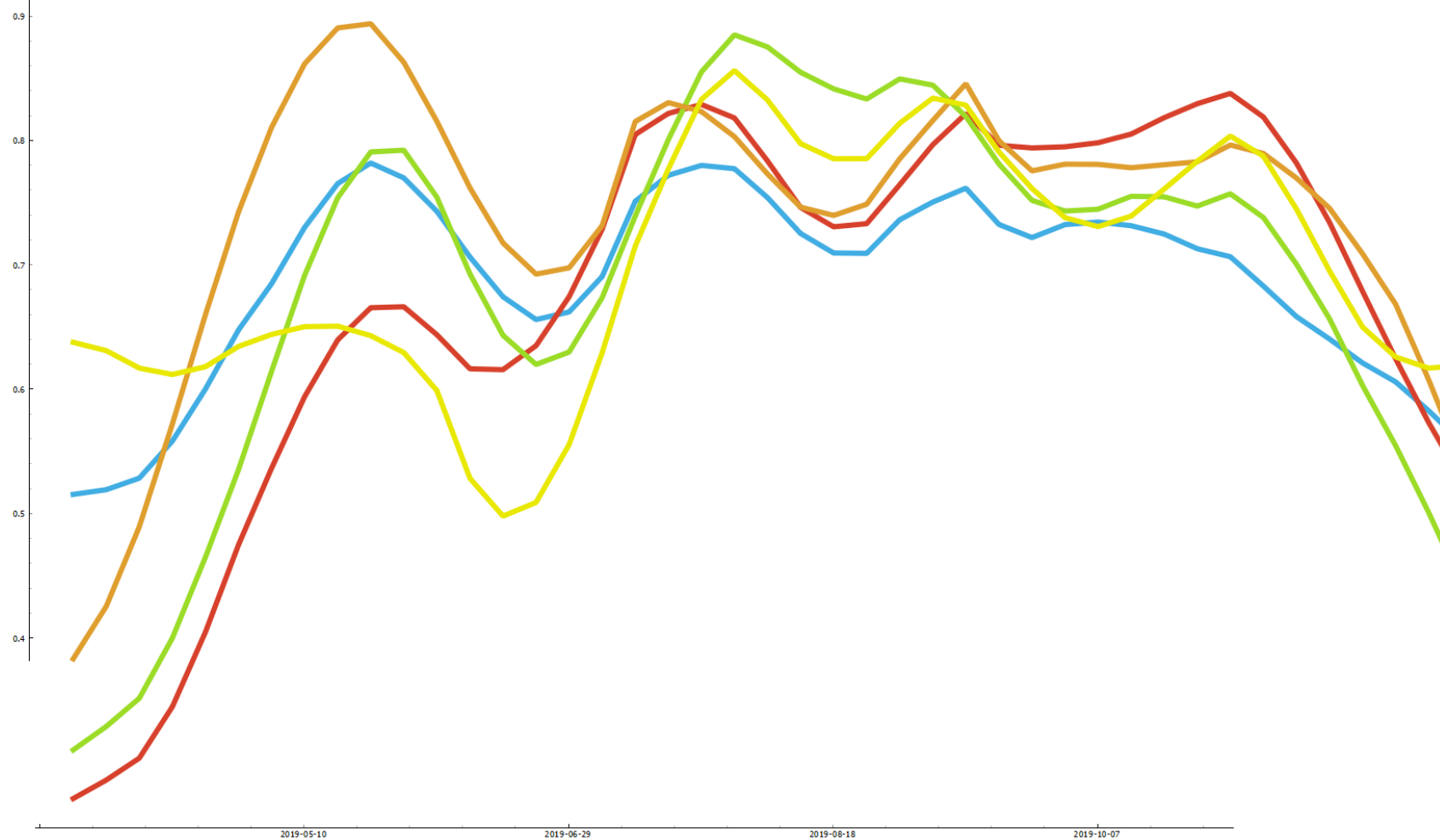
# Multiyear time series



# Beech – Multiyear development



# Different tree types



pine



beech



oak



robinia

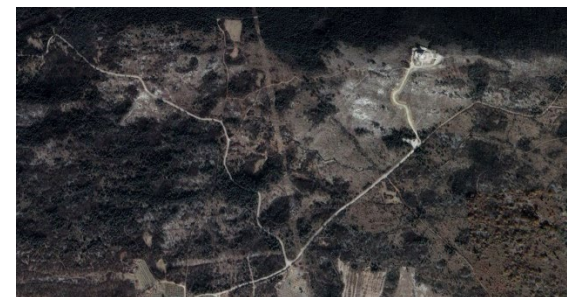
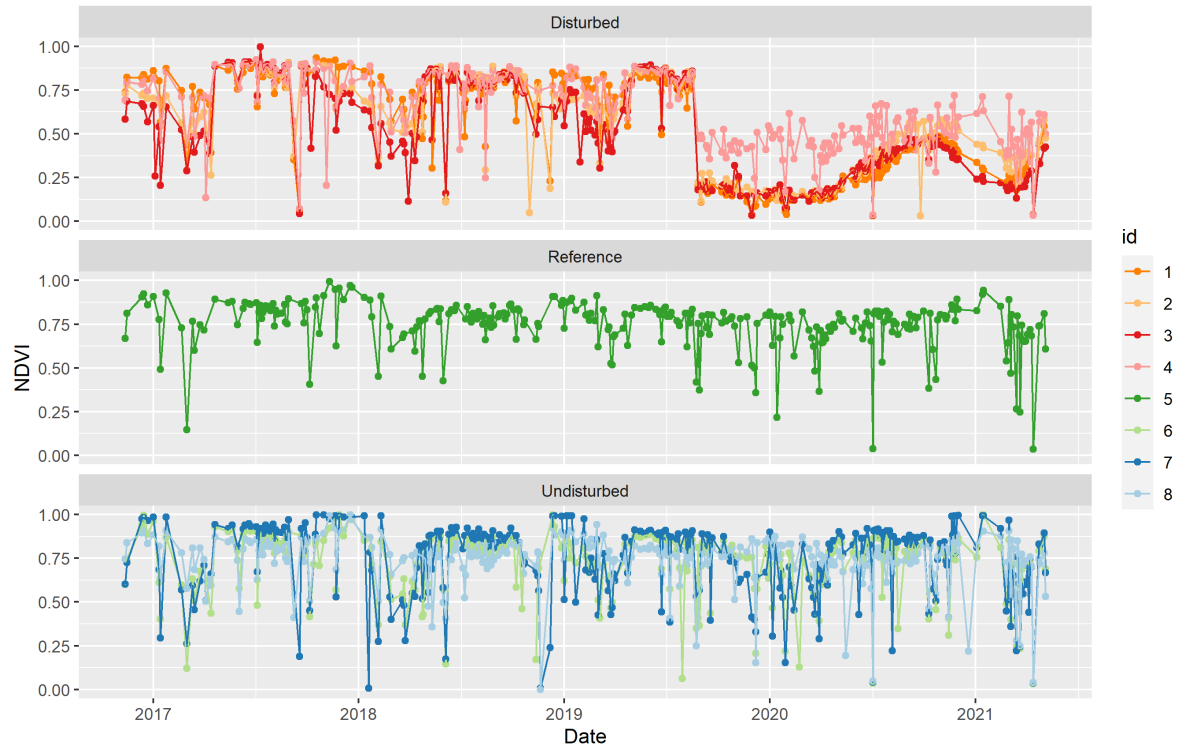


spruce



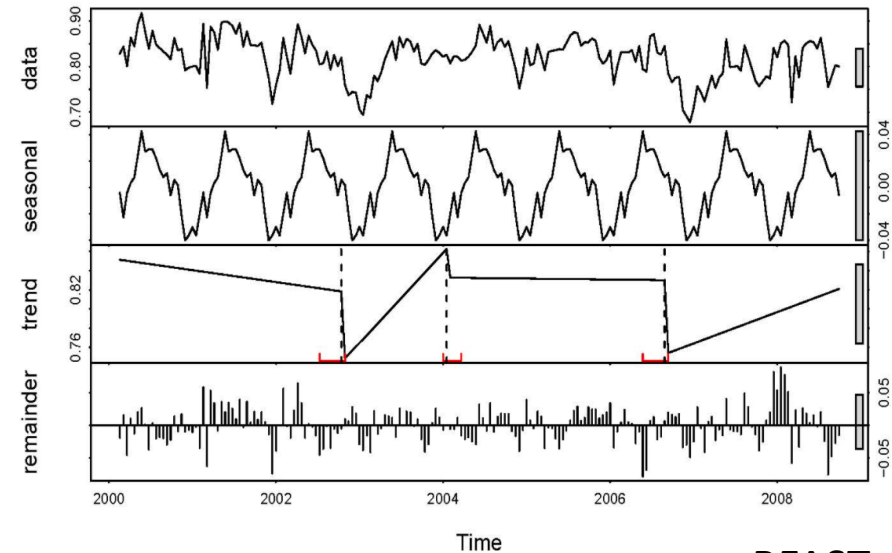
# Disturbances

Cerje, Slovenia (Sentinel-L2A)

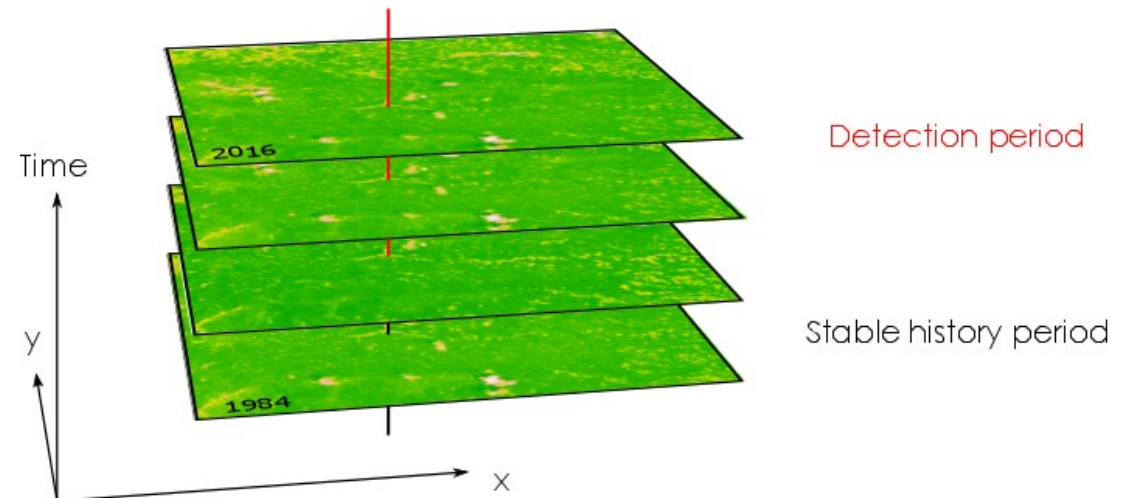


# Long term satellite image time series

- Identify changes over time with long term satellite data sets
- Normalised Difference Vegetation Index (NDVI) as an input variable
- Time series processing methods and algorithms
- Temporal changes in trend and seasonal components, breakpoint detection

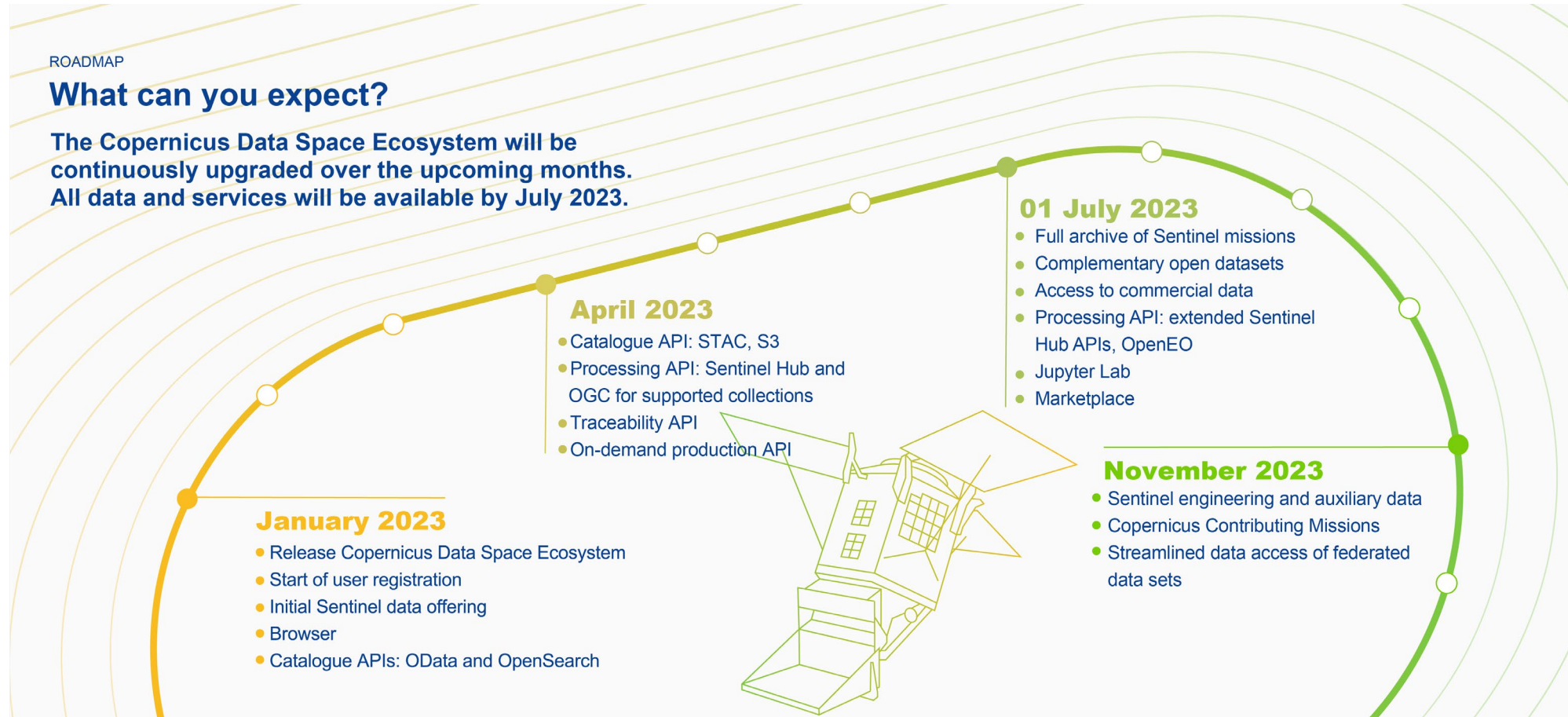


BFAST

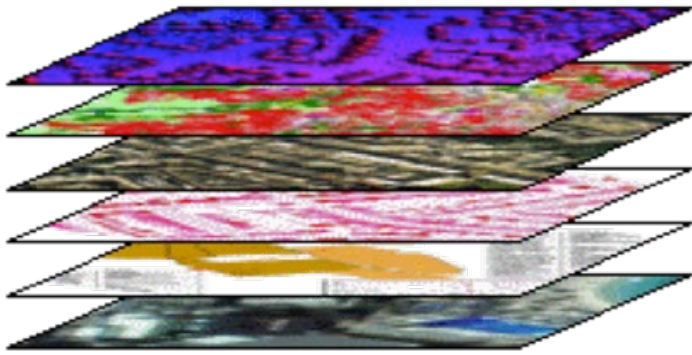


Sentinel Hub

# Copernicus Data Space Ecosystem



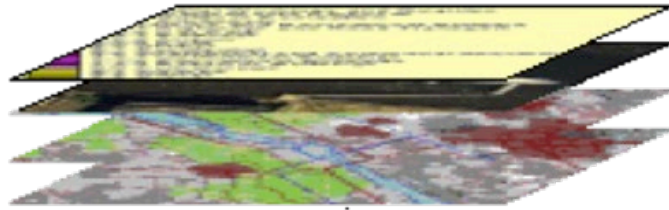
Open EO data - Sentinel-1, Sentinel-2, Landsat, ...



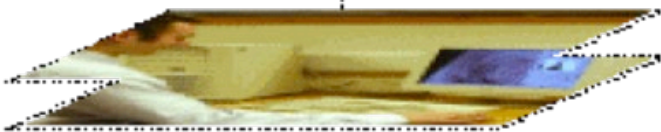
Commercial EO data – WorldWind, GeoEye, ...



Aerial imagery (drone, airplane)



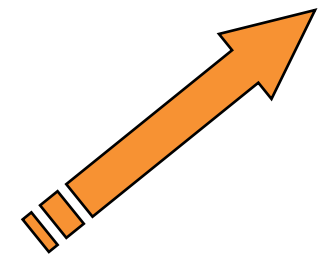
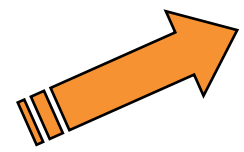
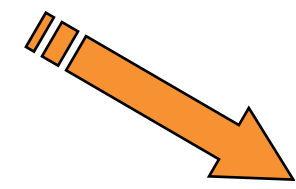
Other raster and vector data



Sinergise



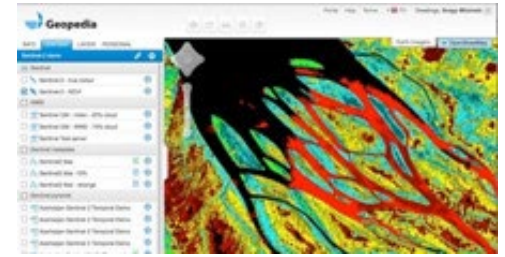
# SENTINEL Hub



WMTS

WMS

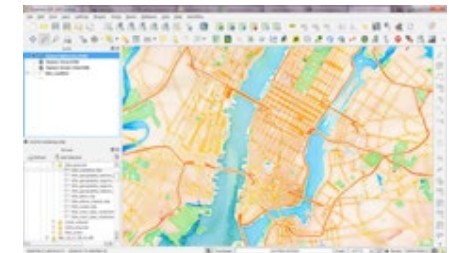
WCS



Cloud GIS



Web / Mobile apps



Desktop (QGIS, ArcGIS...)

```
2) path_out = "responces_small" if use_small_responces else "responces_large"
# Responce collection
responces = ResponseLoader([responces])
from data_loader import DataLoader
from data_loader import DataLoader

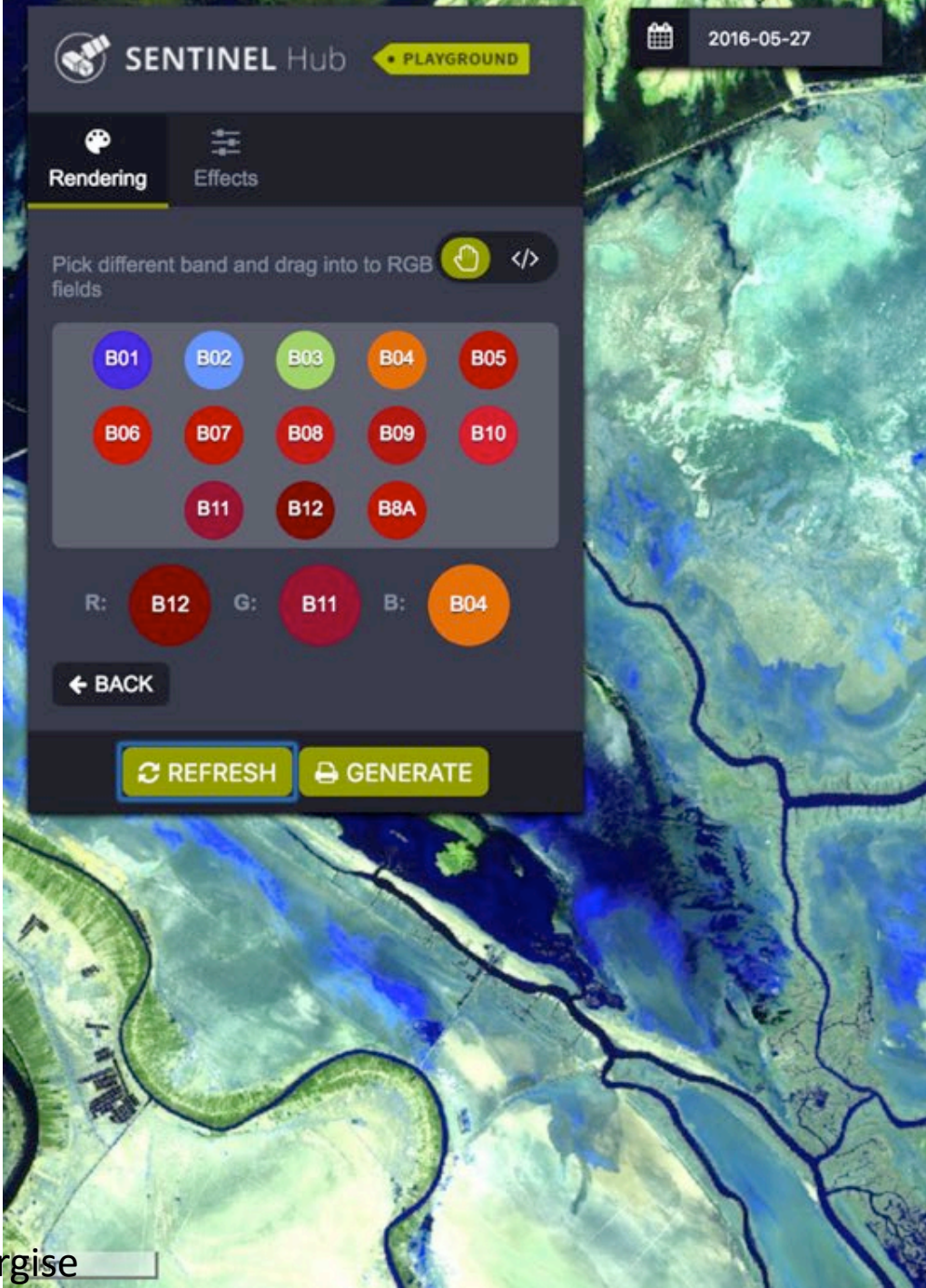
fig_name = get_model_name(responces, "responces", "small")

plot = DataCollection()
for i in range(responces.count()):
    responces = ResponseLoader([responces[i]])
    if use_small_responces else responces[i]:
        data_loader = DataLoader(responces[i])
        data_loader.load_data()
        data_loader.plot()
        data_loader.save()
        data_loader.close()
        data_loader = None
    plot.add_responce(i)

fig = Figure(figsize=(10, 10))
ax = fig.add_subplot(111)
ax.imshow(data_loader.get_data())
ax.set_xlabel("Longitude")
ax.set_ylabel("Latitude")
ax.set_title("Responces")
fig.savefig("responces.png")
```

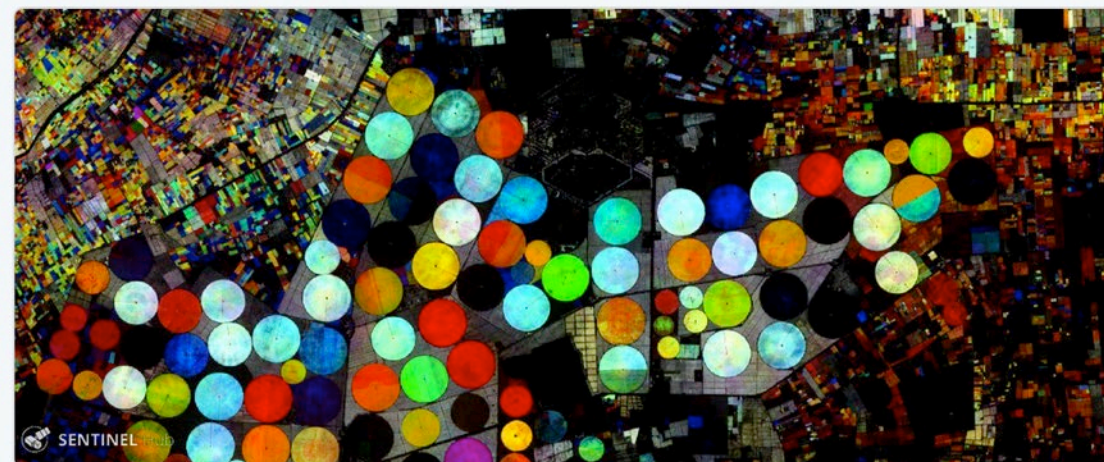
Scripting (Python, R, ENVI...)





HD @HarelDan · 24 Oct 2017

Tip: Blue field growing, Green fields maturing, Yellow Fields ripe, Red fields reaped/drying. Same place, 3 days ago [apps.sentinel-hub.com/sentinel-playg...](https://apps.sentinel-hub.com/sentinel-playg...)



4 comments 5 retweets 20 likes



**Stef Lhermitte**

@StefLhermitte

Following

Replying to @HarelDan @sentinel\_hub and 4 others

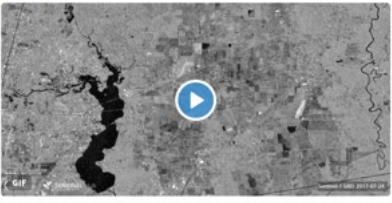
Wow! The moment even my mom can classify petabytes in seconds on her very old computer is getting closer. Just need to teach her Javascript

8:14 AM - 25 Oct 2017

1 Retweet 9 Likes



Simon Gascoin @sgascoin · Aug 30  
Flooded areas near Highway 90 and Dayton TX (July 24 vs. Aug 29) #Sentinel1 #HarveyFlood



Zack Labe @ZLabe · Sep 7  
Break in the satellite imagery for something a bit less intimidating than Hurricane Irma --> phytoplankton! (Barents Sea 9/5/17, Sentinel-2)



You, Copernicus EU, Copernicus Marine and 2 others  
4 31 92

Toño Fdez-Cañadas @TFCanadas · Aug 25  
Terrorífica e impresionante la imagen 3D del 23-08-2017 del incendio de Losadilla #sentinel2 obtenida de sentinel-hub.com



Denis Oštr @kricac · Aug 22  
Great images of #Croatia fires from #CopernicusEMS #Sentinel imagery, Hvar and Obrovac.



Latest relatively cloud free #sentinel2 L1C NDVI imagery shows extents of Landslides in #Inishowen #sentinel\_hub @donegalcouncil



1 9 11

Zack Labe @ZLabe · Sep 16  
How can you not find Earth science fascinating? Eddies, sediment, sand, etc from Hurricane Irma in the Florida Keys [Sentinel-2, 13 Sep '17]



GIS and Beers @GIS\_and\_Beers · Sep 4  
Ataque al corazón!! Heart attack in #Tokio using #sentinel\_hub #Infrared #copernicus #sentinel



You, Copernicus EU, Copernicus Marine and 2 others  
4 31 92

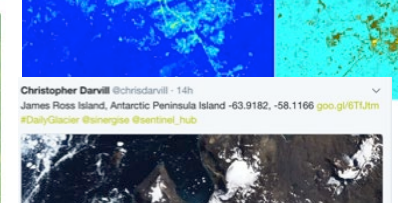
Tim Wallace @wallacetim · Jul 12  
This browser for Sentinel and Landsat constellations is kinda incredible. On the fly band combos and math. apps.sentinel-hub.com/geo-browser/#la...



Christopher Darvill @chrisdarvill · Sep 18  
James Ross Island, Antarctic Peninsula Island -63.9182, -58.1166 goo.gl/8T1Jtm #DailyGlacier #Sinergise #sentinel\_hub



3 14 41



Christopher Darvill @chrisdarvill · 14h  
James Ross Island, Antarctic Peninsula Island -63.9182, -58.1166 goo.gl/8T1Jtm #DailyGlacier #Sinergise #sentinel\_hub



Simon Gascoin @sgascoin · Sep 12  
Flood in #Luzon #Sentinel2 on Sep 04 and Sep 11



Toño Fdez-Cañadas @TFCanadas · Sep 4  
Replying to @Borvilba @Divulgameteo @JostMaffeo  
Isi se ve el embalse desde #Sentinel2 . A finales de agosto de este año y del año pasado #sentinel\_hub



You, Copernicus EU, Copernicus Marine and 2 others  
4 31 92

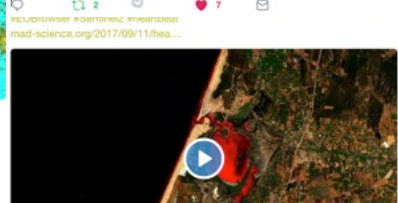
Pierre Markuse @Pierre\_Markuse · Sep 18  
Greece Turkey 9-months temporal mosaic using #sentinel\_hub #EOBrowser and some PS #Sentinel #Copernicus Big pic.kx/p/YBQkS2



Christopher Darvill @chrisdarvill · Sep 18  
Isman Glacier, New Zealand -43.6616, 170.1890 goo.gl/5373qb #DailyGlacier #Sinergise #sentinel\_hub

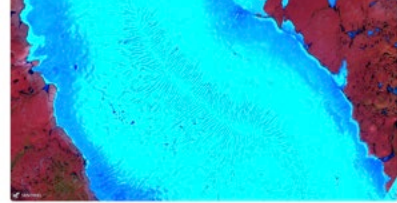


2 7

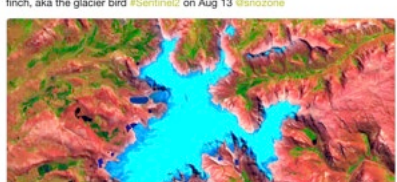


5 13

BABA Mohamed Wassim @MatarNissan · Aug 22  
A better view with NIR-SWIR-Blue



Simon Gascoin @sgascoin · Sep 10  
Replying to @IceOily @Sinergise  
Quelcaya ice cap. Largest glacier in the tropics. Home of white-winged diuca finch, aka the glacier bird #Sentinel2 on Aug 13 #soozone



You, Copernicus EU, Copernicus Marine and 2 others  
4 31 92

Zack Labe @ZLabe  
Clear view of the #WeddellPolynya (Antarctic) today by Sentinel-3 satellite. For more information about this feature twitter.com/seaice\_de/stat...



6:20 AM · 26 Sep 2017  
18 Retweets 41 Likes

Simon Gascoin @sgascoin  
#LarsenC : The Movie  
Made with 1 year of extra-wide swath single HH Sentinel-1 data available @sentinel\_hub @ESA\_EO @CopernicusEU



2 61 40



Copernicus EU @CopernicusEU · Aug 18  
sunarrows only credits @NASAEarth but uses lots of #Copernicus and #Sinergise Imagery @smccarty\_geo @Preme\_Markuse



AT Solutions @D2AT\_Solutions · Jul 31  
James-Les-Mimosas at La Bastide après #incendie vu par le satellite #sentinel2 #CopernicusEU #Sinergise (NIR, True, Moisture Index, NDVI)



You, Copernicus EU, Copernicus Marine and 2 others  
4 31 92

vely fluvial geomorphology revealed using the #sentinel\_hub playground, check out those braided channels!



almazara.forestry.es/2017/08/incend...  
Translate from Spanish



2 61 40



Pierre Markuse @Pierre\_Markuse · Aug 18  
Playing with the new temporal mosaicking abilities of @Sinergise #SentinelHub (Beta coming soon) - Nice so far! Lake Edward DRC #Uganda



You, EODetective and Copernicus EU  
1 8 13

Pierre Markuse @Pierre\_Markuse · Aug 21  
Playing with #Sentinel-1 #EO data visualization in the #Sinergise #EOBrowser, #Rottendam and surroundings, Netherlands



You, EODetective and EO OPEN SCIENCE  
1 8 14

Veeitee Amet  
February 13 at 4:35pm · E

Selline piit avaneb siis Eesti merealast ja jääoludest 800 km kõrguseilt, otse Sentinel-2 pardalt. Siit on ka hästi näha, kus jää juba paksem ja kus see veel õrnem on. Surfa ise ka satelliitidel siit: http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/.../ Aga täna teatas Maanteeamet melle, et nad on alustanud ettevalmistusi jäätee rajamiseks Vormsile. Niisil otsustasimegi meie peatada seal alates 20. veebruarist laevaliiklus. Laevaliiklus pannakse seega seisma kavan... See More See Translation



ed lmi  
2 7

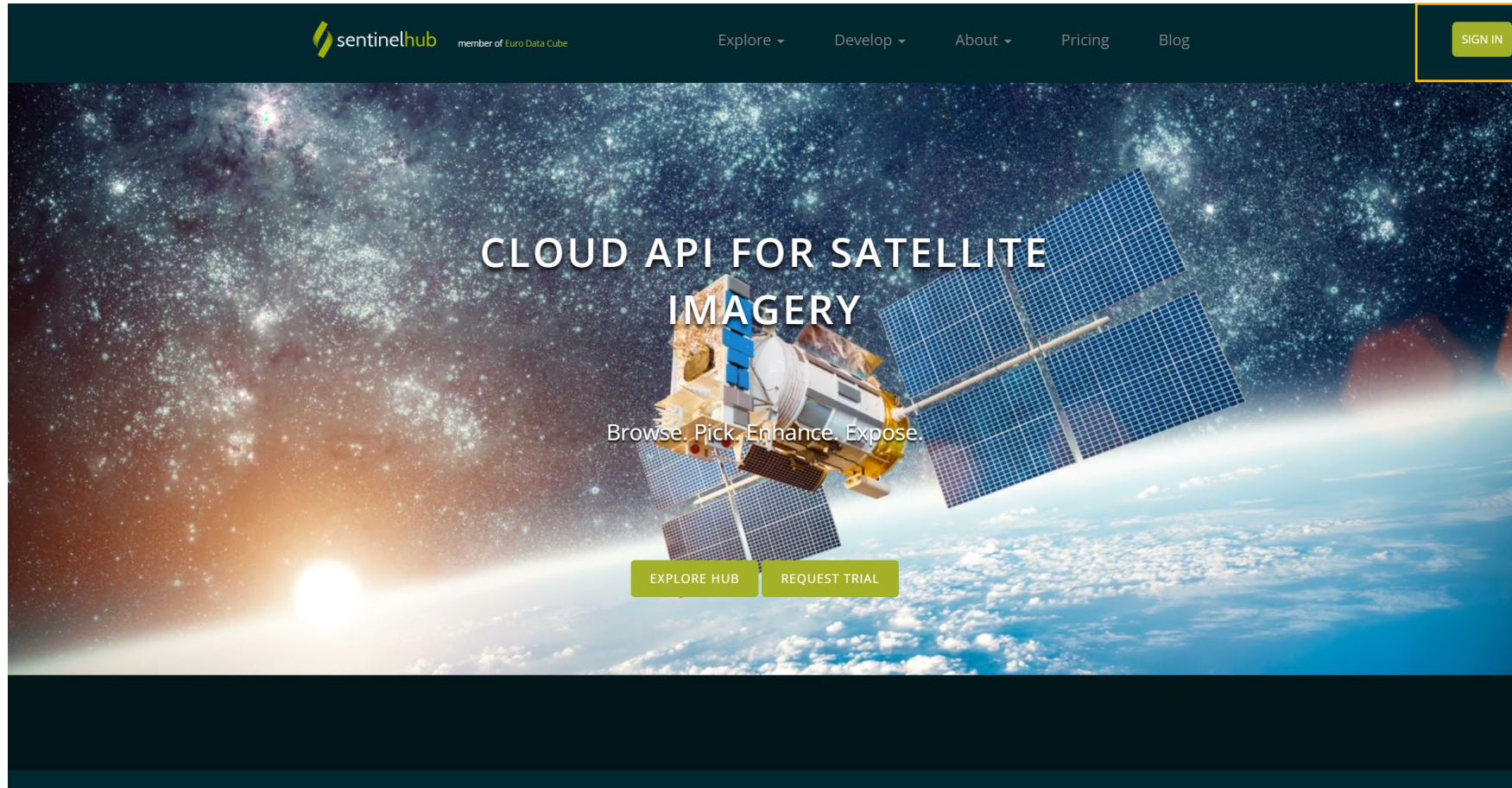


Amir Farhand @AmirFarhand · Sep 13  
Damage to vegetation after #irma on #jostvandyke #BVI Before & After satellite imagery @sentinel\_hub @BBCAmos @SCFGalagher @richardbranson



You, DonegalCountyCouncil, DEP and 4 others  
587 11 Comments 147 Shares

# Create Sentinel Hub account



# Create Sentinel Hub account



The image shows the Sentinel Hub login page. At the top is the Sentinel Hub logo (a green stylized 'S') and the text 'sentinelhub by SINERGISE'. Below the logo are two input fields: 'E-mail:' with a person icon and a password field with a lock icon. A link 'Forgot password?' is positioned below the password field. At the bottom of the form area, there are two buttons: a large green 'Sign In' button and a smaller white 'Sign Up' button. Below these buttons, the text 'Or sign in/sign up with:' is followed by five social login icons: CREODIAS, esi, mundi WEB SERVICES, COIH, and CODEDE.

sentinelhub  
by SINERGISE

E-mail:

Password:

Forgot password?

Sign In

Sign Up

Or sign in/sign up with:

CREODIAS esi mundi WEB SERVICES COIH CODEDE



The image shows the Sentinel Hub sign-up page. At the top is the Sentinel Hub logo (a green stylized 'S') and the text 'sentinelhub by SINERGISE'. Below the logo are four input fields: 'First name:' and 'Last name:' (each with a person icon), 'E-mail:' (with an envelope icon), and 'Password:' and 'Confirm password:' (each with a lock icon). Below the password fields are two checkboxes: 'I would like to receive the latest news and information about Sentinel Hub.' and 'I agree to the Terms of Service and Privacy Policy'. At the bottom of the form area is a large green 'Sign up' button. Below the button, the text 'Already have an account? Sign in' is displayed.

sentinelhub  
by SINERGISE

First name:

Last name:

E-mail:

Password:

Confirm password:

I would like to receive the latest news and information about Sentinel Hub.

I agree to the [Terms of Service and Privacy Policy](#)

Sign up

Already have an account? [Sign in](#)

# EO Browser

The screenshot displays the EO Browser interface. The main map shows a satellite view of a rural area with various settlements and roads. The left sidebar contains the following elements:

- EO Browser** header with language (ENGLISH) and user profile (Hello, Kristof Ostir).
- Discover** section with options: Visualize, Compare, Pins.
- Theme** dropdown menu set to Default.
- Data sources** section with a list of satellite and remote sensing data sources:
  - Sentinel-1
  - Sentinel-2
    - Advanced search:  L1C
    - L2A (atmospherically corrected)
    - Max. cloud coverage:
  - Sentinel-3
  - Sentinel-5P
  - Landsat 1-5 MSS L1
  - Landsat 4-5 TM
  - Landsat 7 ETM+
  - Landsat 8-9
  - Landsat (ESA Archive)
  - Harmonized Landsat Sentinel
  - Envisat Meris
  - MODIS
  - DEM
  - Copernicus Services
  - Proba-V
  - GIBS
  - Planet NICFI
  - Other

- Time range [UTC]** section with a date range from 2021-01-01 to 2021-12-31 and a **filter by months** option.
- Search** button.
- Footer: Powered by Sentinel Hub with contributions by ESA v3.38.0.

The right sidebar contains navigation and utility icons: Home, Location, Layers, 3D, and a scale bar. The bottom status bar shows the current location: Lat: 46.75209, Lng: 14.40139, 500 m.

# EO Browser

The screenshot displays the EO Browser interface. The top navigation bar includes the EO Browser logo, a language selector set to 'ENGLISH', and a user greeting 'Hello, Kristof Ostir'. Below the navigation bar are tabs for 'Discover', 'Visualize', 'Compare', and 'Pins'. A search bar on the right contains the text 'Go to Place'. The main content area shows a list of search results for Sentinel-2 L2A images, with 'Showing 24 results' indicated. The list includes the following items:

- 2021-12-31, 10:08:02 UTC, 0.8% cloud cover, 33TVL. A yellow 'Visualize' button is present.
- 2021-10-27, 10:08:11 UTC, 8.6% cloud cover, 33TVL. A yellow 'Visualize' button is present.
- 2021-10-17, 10:08:12 UTC, 2.8% cloud cover, 33TVL. A yellow 'Visualize' button is present.
- 2021-09-12, 10:08:03 UTC, 0.5% cloud cover, 33TVL. A yellow 'Visualize' button is present and highlighted with a yellow border.
- 2021-09-02, 10:08:03 UTC, 1.9% cloud cover, 33TVL. A yellow 'Visualize' button is present.
- 2021-08-18, 10:08:09 UTC, 2.9% cloud cover, 33TVL. A yellow 'Visualize' button is present.

The interface also features a vertical toolbar on the right with icons for home, location, edit, layers, 3D, and print. At the bottom, there is a footer with 'Powered by Sentinel Hub, with contributions by ESA v3.38.0', 'About EO Browser | Contact us | Get data', and a status bar showing 'Lat: 45.77874, Long: 14.44147 | 500 m'.

# EO Browser

The screenshot displays the EO Browser interface. The main window shows a satellite map of a rural area with various fields and roads. The sidebar on the left contains the following elements:

- Header: EO Browser, ENGLISH, Hello, Kristof Ostir
- Navigation: Discover, Visualize, Compare, Pins
- Dataset: Sentinel-2 L2A (Show L1C)
- Date: 2021-08-18 (Timespan)
- Visualization Options:
  - True color (Based on bands 4,3,2)
  - False color (Based on bands 8,4,3)
  - Highlight Optimized Natural Color (Enhanced natural color visualization)
  - NDVI (Based on combination of bands (8B - 84)/(8B + 84))** (highlighted with a yellow box)
  - False color (urban) (Based on bands 12,11,4)
  - Moisture index (Based on combination of bands (8BA - B11)/(8BA + B11))
  - SWIR (Based on bands 12,8A,4)
  - NDWI (Based on combination of bands (83 - 89)/(83 + 88))
  - NDSI (Based on combination of bands (83 - B11)/(83 + B11))
  - Scene classification map (Classification of Sentinel2 data as result of ESA's Scene classification algorithm.)
  - Custom (Create custom visualization)
- Footer: Powered by Sentinel Hub with contributions by ESA v3.38.0

The map shows a landscape with fields, roads, and some buildings. Labels on the map include: Ponikve, Jeršanova, Malni, Storovo, Lepi Vrh, Sveta Trojica, Mramorovo pri Pajkovem, Rožanče, Hribarjevo, Podslivnica, Sleme, Ravnik, Škufče, Lahovo, Škrabče, Sveti Duh, Zakraj, Lužarji, Godičevo, Mramorovo pri Lužarjih, Kotel, Radlek, Volčje, Bloke, Nemska vas na Blokah, Nova vas, Veliki Vrh, Studeno na Blokah, Grahovo, Glina, Fara, Veliki Vrh, Studenec na Blokah, Benete, Blošča Polica, Žerovnica, Blošča, Bločice, Hudi Vrh, Fara, Hudi Vrh, Topol, Ravne na Blokah, Metulje, Lipsenj, and Goričice.

MapTiler logo is visible in the bottom left corner. Footer text includes: About EO Browser, Contact us, Get data, Lat: 45.77852, Lng: 14.49193, 500 m.

# EO Browser

The screenshot displays the EO Browser interface. The main map area shows a satellite view of a rural landscape with various vegetation indices overlaid. A yellow location pin is placed on the map with a tooltip that says "Click to place marker".

**Left Sidebar:**

- Dataset: Sentinel-2 L2A [Show L1C](#)
- Date: 2021-08-18 [Timespan](#)
- Visualization options:
  - True color (Based on bands 4,3,2)
  - False color (Based on bands 8,4,3)
  - Highlight Optimized Natural Color (Enhanced natural color visualization)
  - NDVI** (Based on combination of bands (B8 - B4)/(B8 + B4))
  - False color (urban) (Based on bands 12,11,4)
  - Moisture index (Based on combination of bands (B8A - B11)/(B8A + B11))
  - SWIR (Based on bands 12,8A,4)
  - NDWI (Based on combination of bands (B3 - B8)/(B3 + B8))
  - NDSI (Based on combination of bands (B3 - B11)/(B3 + B11))
  - Scene classification map (Classification of Sentinel2 data as result of ESA's Scene classification algorithm.)
  - Custom (Create custom visualization)

**Top Bar:**

- EO Browser logo
- Language: ENGLISH
- Search: Go to Place
- Navigation icons: Home, Layers, Settings, Info

**Right Panel:**

- Location pin icon (highlighted with a yellow box)
- Measurement tool icon
- 3D view icon
- Full screen icon

**Bottom Bar:**

- MapTiler logo
- Map data: © MapTiler © OpenStreetMap contributors, © Sentinel Hub
- Location: Gorčice
- Coordinates: Lat: 45.78843, Lng: 14.44071
- Scale: 500 m



# EO Browser

The screenshot displays the EO Browser interface. The top navigation bar includes the EO Browser logo, a language dropdown set to 'ENGLISH', and a user greeting 'Hello, Krištof Oštir'. Below this, there are tabs for 'Discover', 'Visualize', 'Compare', and 'Pins'. The main content area is a satellite map of a rural region with numerous village names labeled, such as Otonica, Hribarjevo, Sveta Trojica, Mramorovo, Škofče, Lahovo, Krampilje, Godičevo, Mramorovo pri L..., Bloke, Nemška vas na Blokah, Studeno na Blokah, Glina, Nova vas, Veliki Vrh, Runarsko, Studenec na Blokah, Hudi Vrh, Topol, Ravne na Blokah, Metulje, Podlož, Lož, Knežja Njiva, Klance, Gorenje Jezero, Goričice, Lipsenj, Žerovnica, Bloška Polica, Bločice, Radlek, Ulaka, Velike Bloke, and Grahovo. A yellow location pin is placed on the map. The left sidebar is titled 'Dataset: Sentinel-2 L2A' and 'Date: 2021-10-17'. It lists several visualization options: True color (Based on bands 4,3,2), False color (Based on bands 8,4,3), Highlight Optimized Natural Color (Enhanced natural color visualization), NDVI (Based on combination of bands (B8 - B4)/(B8 + B4)), False color (urban) (Based on bands 12,11,4), Moisture index (Based on combination of bands (B8A - B11)/(B8A + B11)), SWIR (Based on bands 12,8A,4), NDWI (Based on combination of bands (B3 - B8)/(B3 + B8)), and NDSI. The bottom of the interface shows the text 'Powered by Sentinel Hub with contributions by ESA v3.36.0' and a footer with links for 'About EO Browser', 'Contact us', and 'Get data'. The bottom right corner displays the coordinates 'Lat: 45.79625, Lng: 14.53923' and a scale bar for '1 km'.

# EO Browser

The screenshot displays the EO Browser interface. On the left, a sidebar contains a list of visualization options for the Sentinel-2 L2A dataset. The 'NDVI' option is selected, showing a green color scale. The main map area shows a satellite view of a rural landscape with various fields and roads. A data visualization window is overlaid on the map, displaying a line graph of NDVI values over time. The graph shows a peak in late July, a sharp drop in early August, and a recovery by mid-August. The interface includes a search bar, a language selector (English), and various map controls like zoom and pan.

**Dataset:** Sentinel-2 L2A **Show L1C**

**Date:** 2021-08-18 **Timespan**

- True color (Based on bands 4,3,2)
- False color (Based on bands 8,4,3)
- Highlight Optimized Natural Color (Enhanced natural color visualization)
- NDVI (Based on combination of bands (B8 - B4)/(B8 + B4))**
- False color (urban) (Based on bands 12,11,4)
- Moisture index (Based on combination of bands (B8A - B11)/(B8A + B11))
- SWIR (Based on bands 12,8A,4)
- NDWI (Based on combination of bands (B3 - B8)/(B3 + B8))
- NDSI (Based on combination of bands (B3 - B11)/(B3 + B11))
- Scene classification map (Classification of Sentinel2 data as result of ESA's Scene classification algorithm.)
- Custom (Create custom visualization)

**Sentinel-2 L2A - 3. NDVI**

5 years 2 years 1 year 6 months 3 months 1 month

Date	NDVI Value
23. Jul 21	0.25
28. Jul 21	0.85
3. Aug 21	0.05
9. Aug 21	0.15
15. Aug 21	0.75

Export CSV

Powered by Sentinel Hub with contributions by ESA v3.38.0

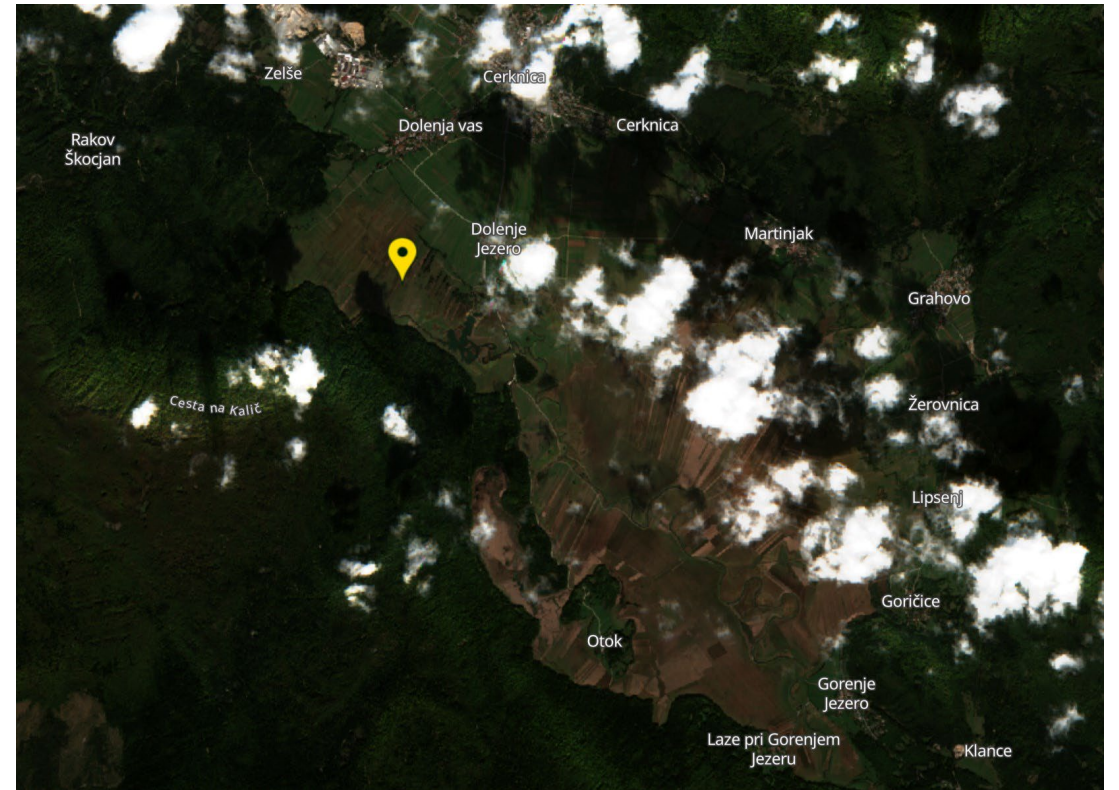
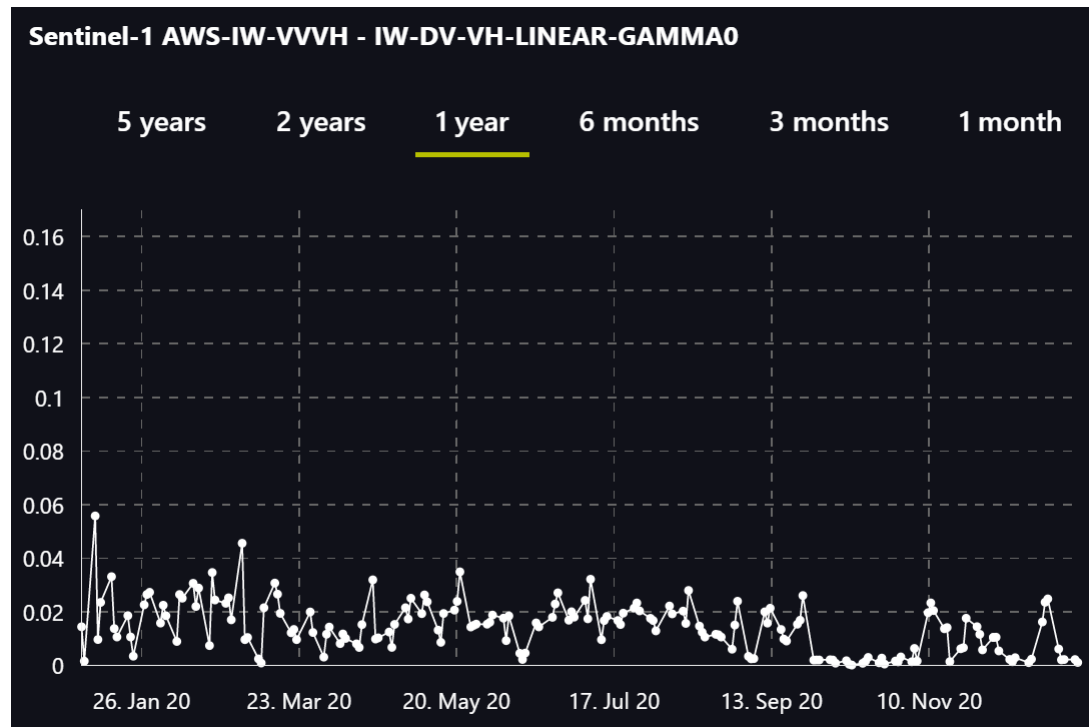
maptiler

© MapTiler © OpenStreetMap contributors, © Sentinel Hub

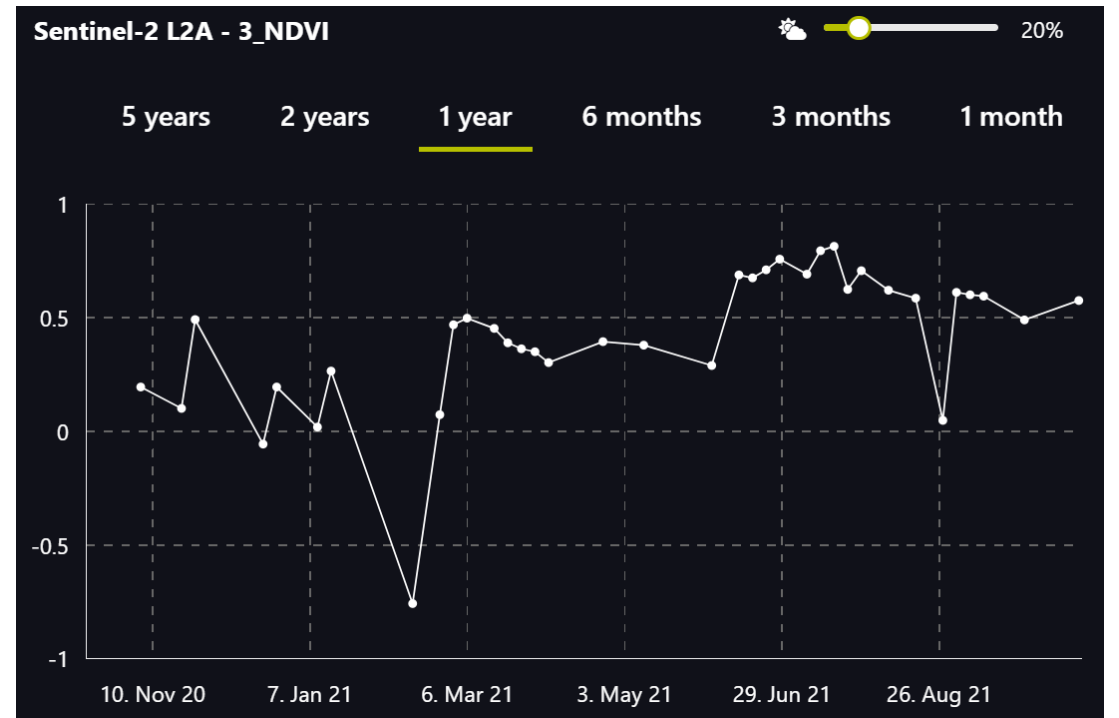
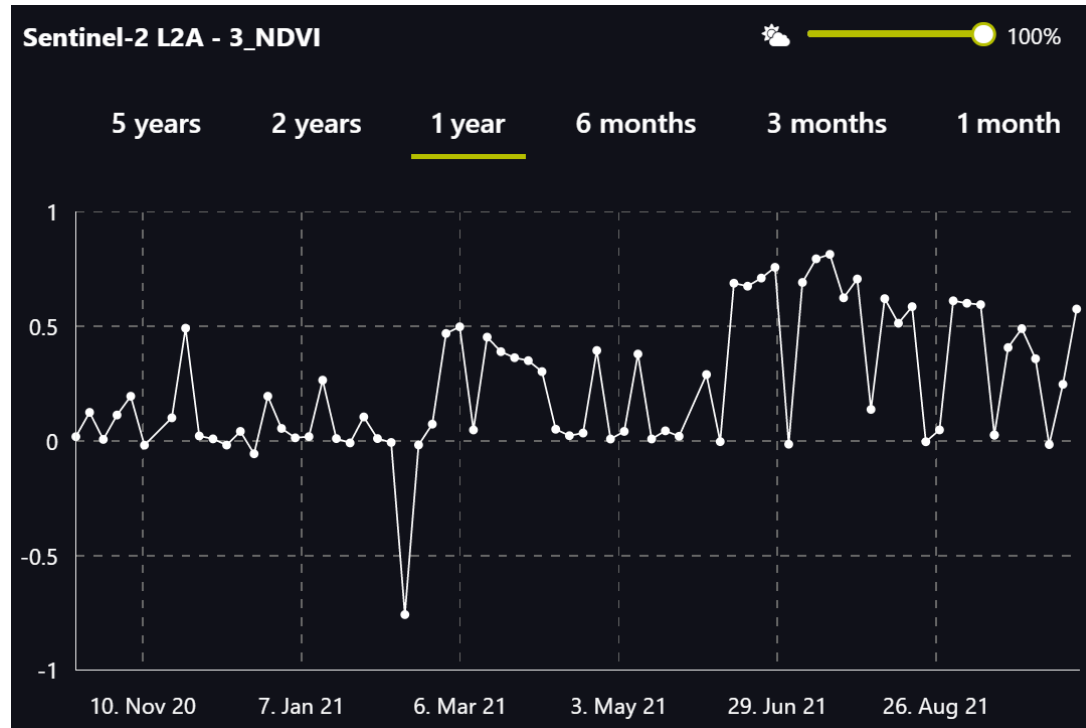
About EO Browser | Contact us | Get data

Lat: 45.80982, Lng: 14.50281 500 m

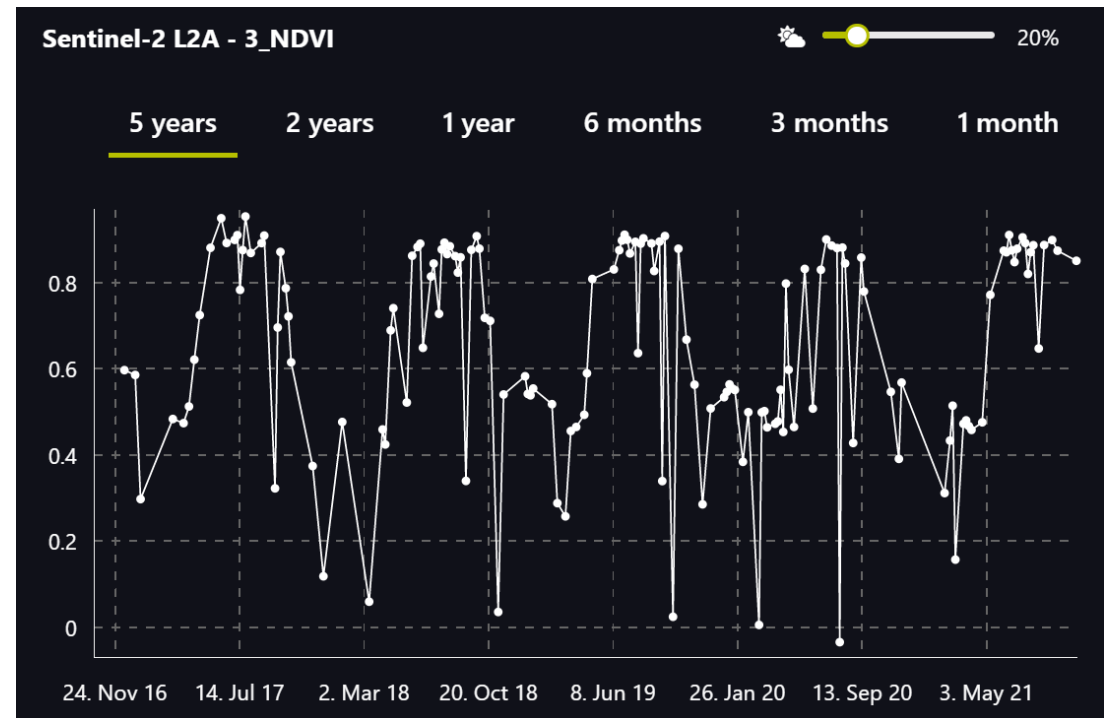
# EO Browser



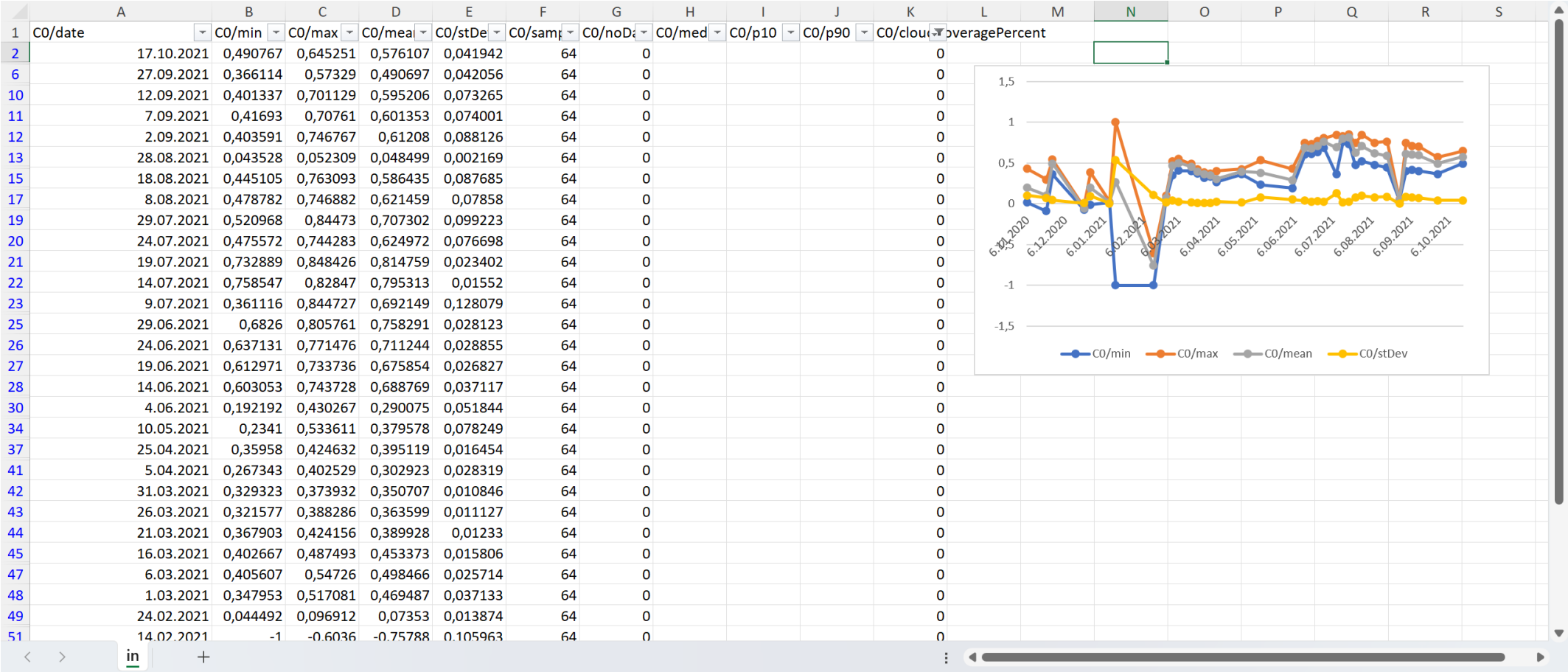
# EO Browser



# EO Browser



# EO Browser





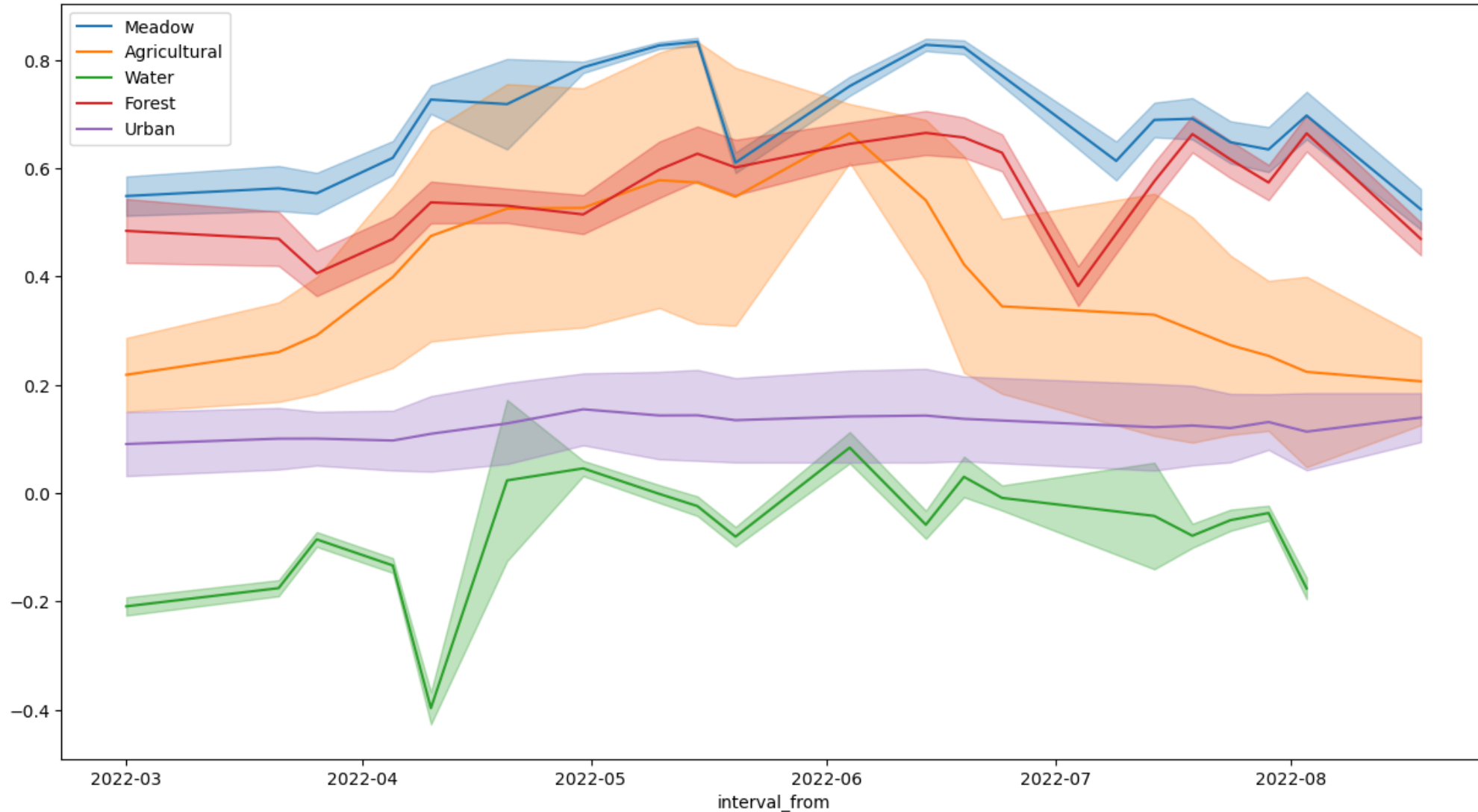
# Sentinel-hub – Statistical API – data – GEOJSON



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  ]
}
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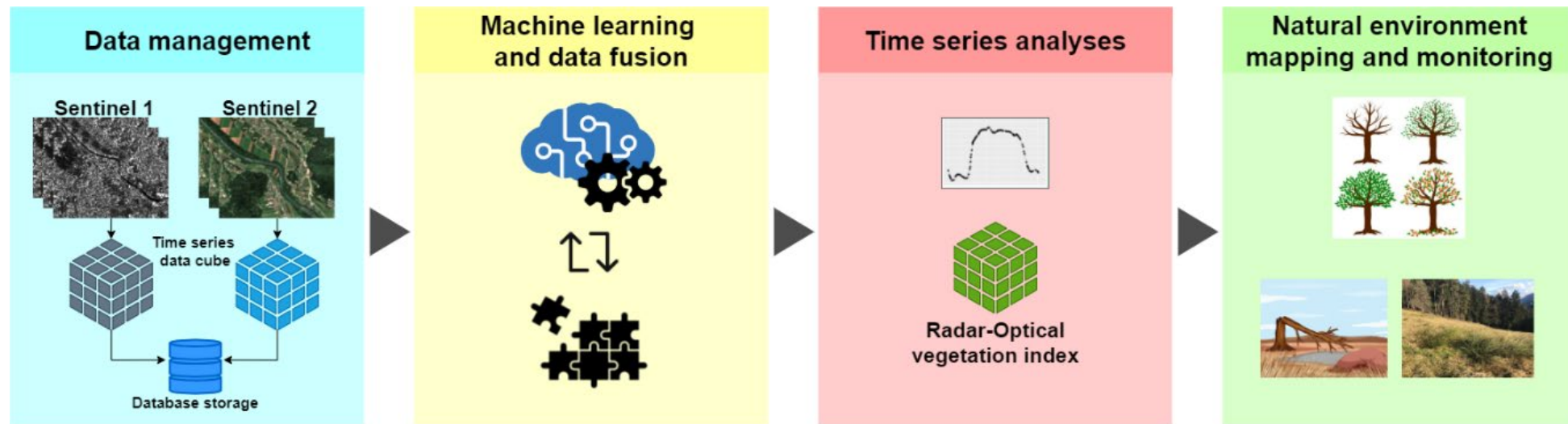


# Sentinel-hub – Statistical API

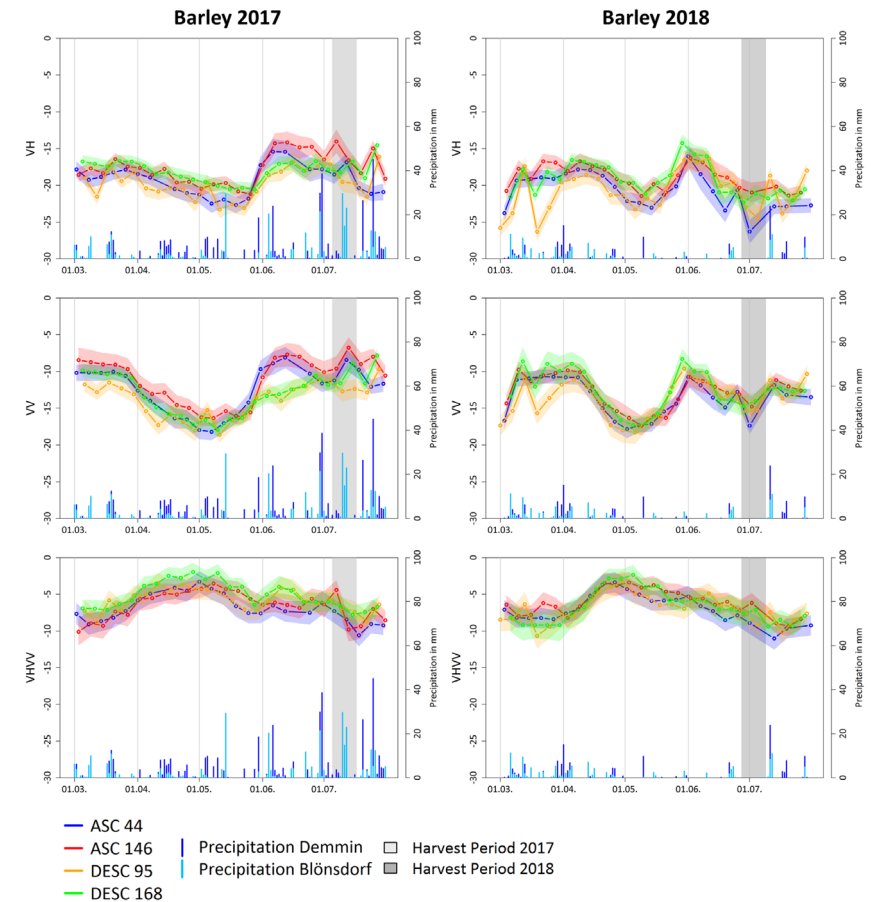
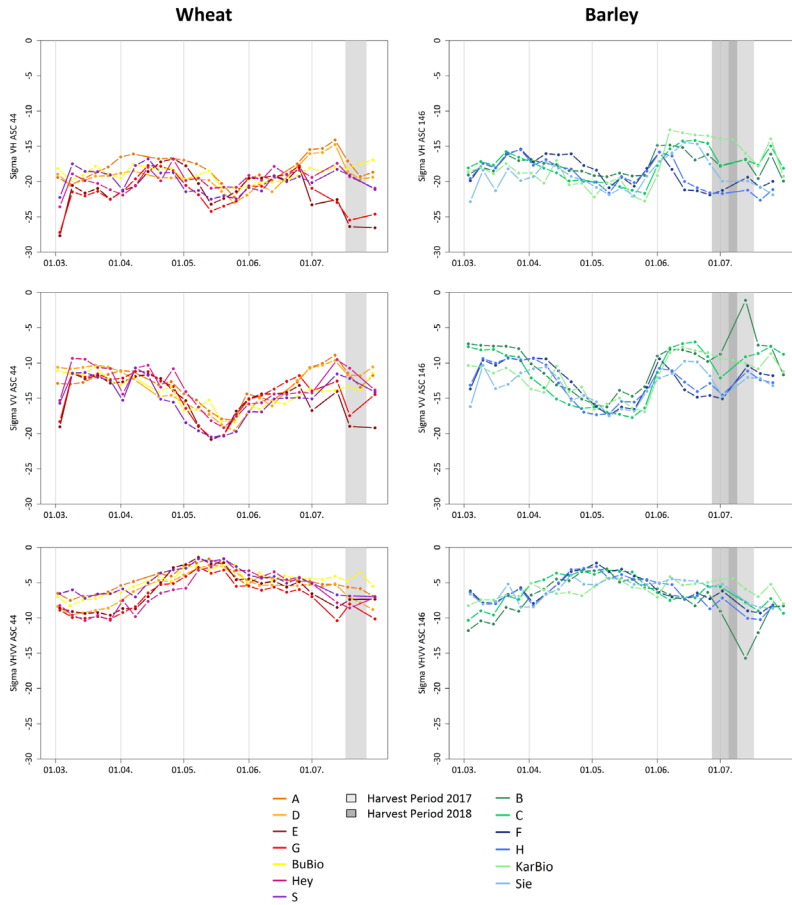


Radar and optical integration

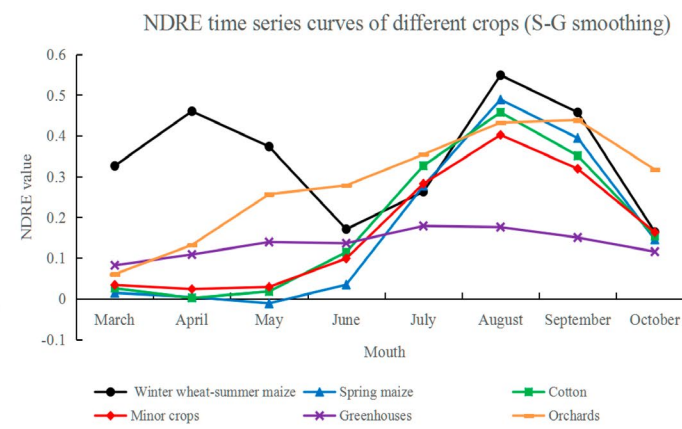
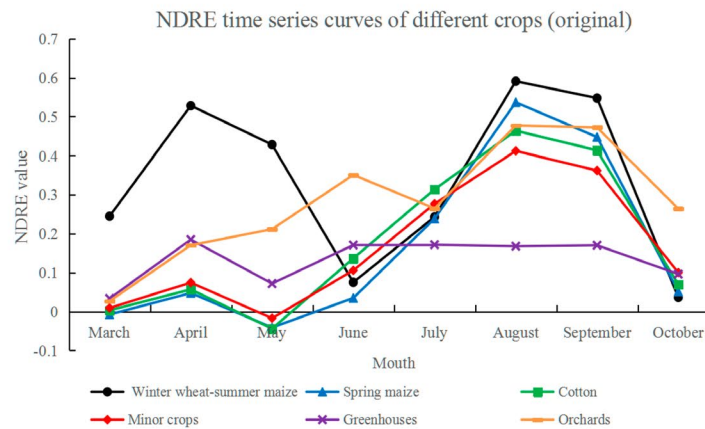
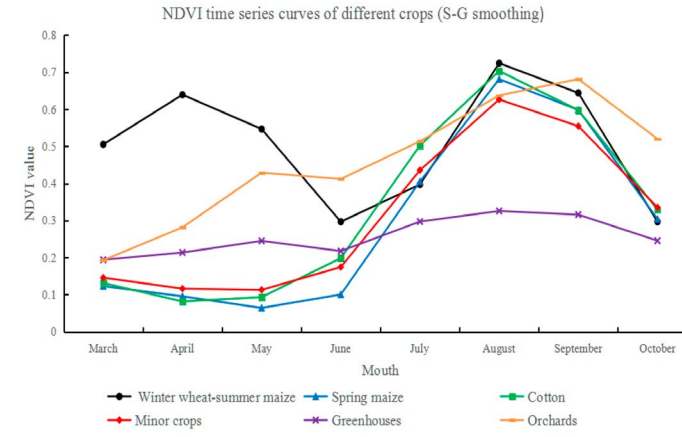
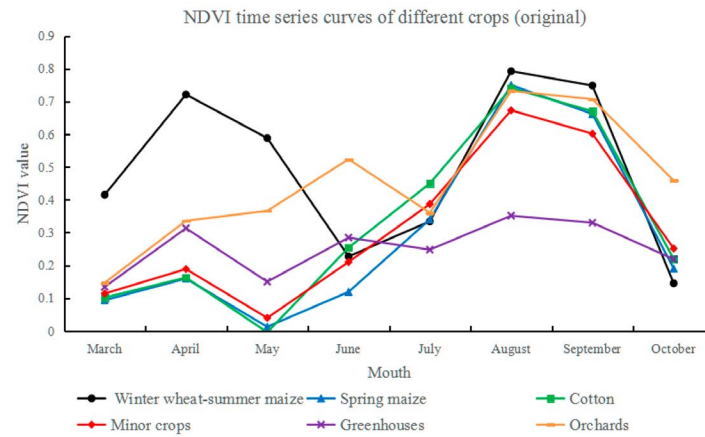
# SAR/Optical integration



# Radar backscatter



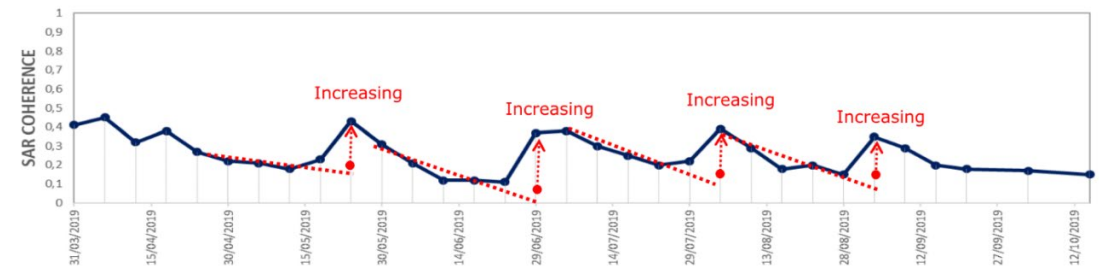
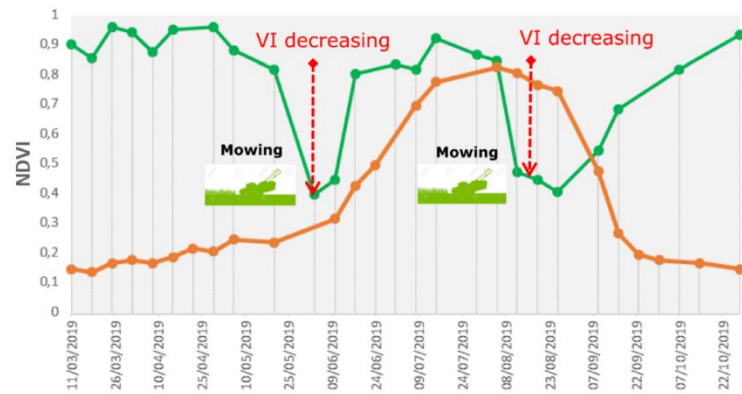
# NDVI and NDRE

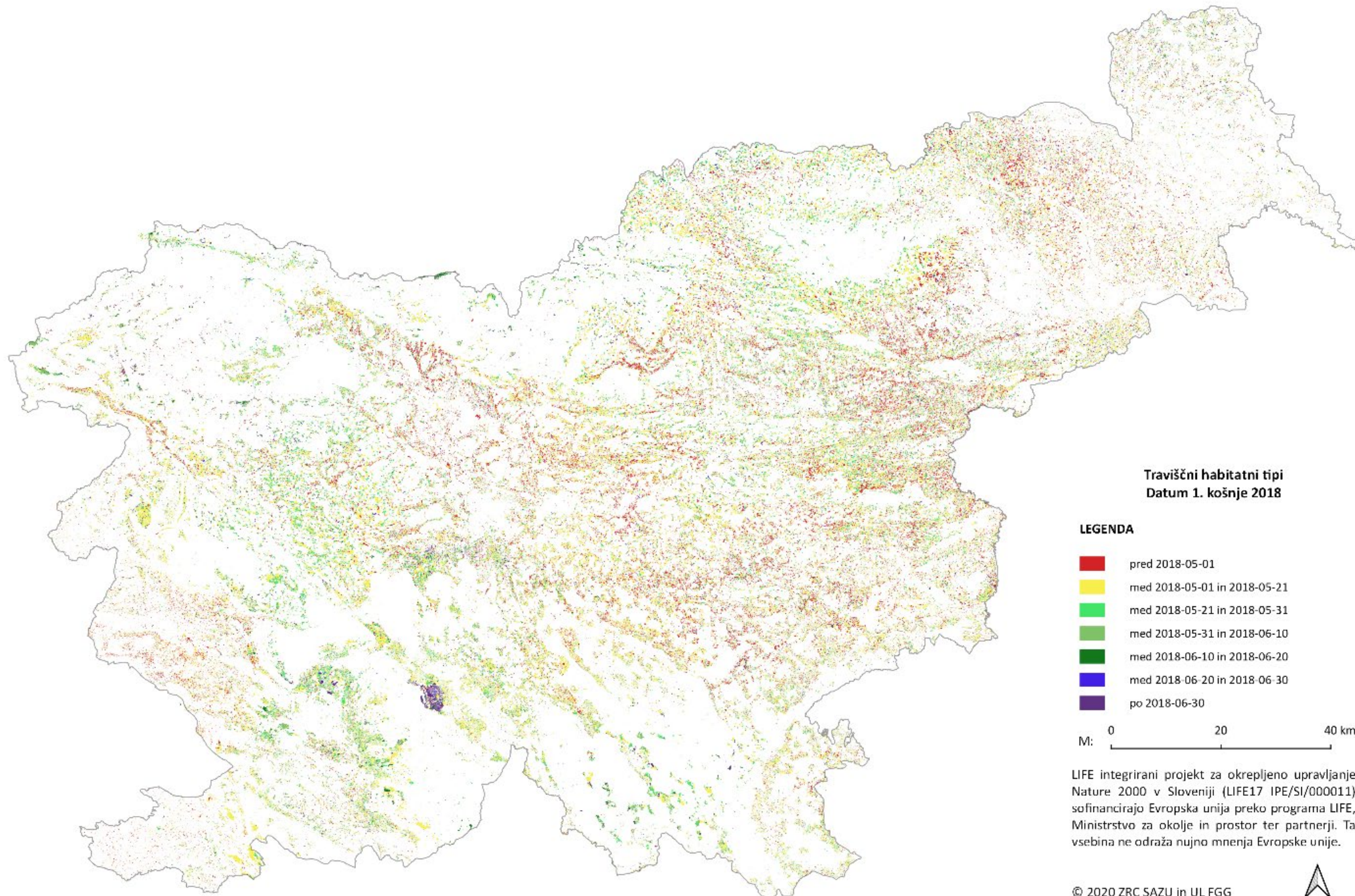


# Mapping grassland – intensive/extensive



# Optical (NDVI) and radar (coherence)

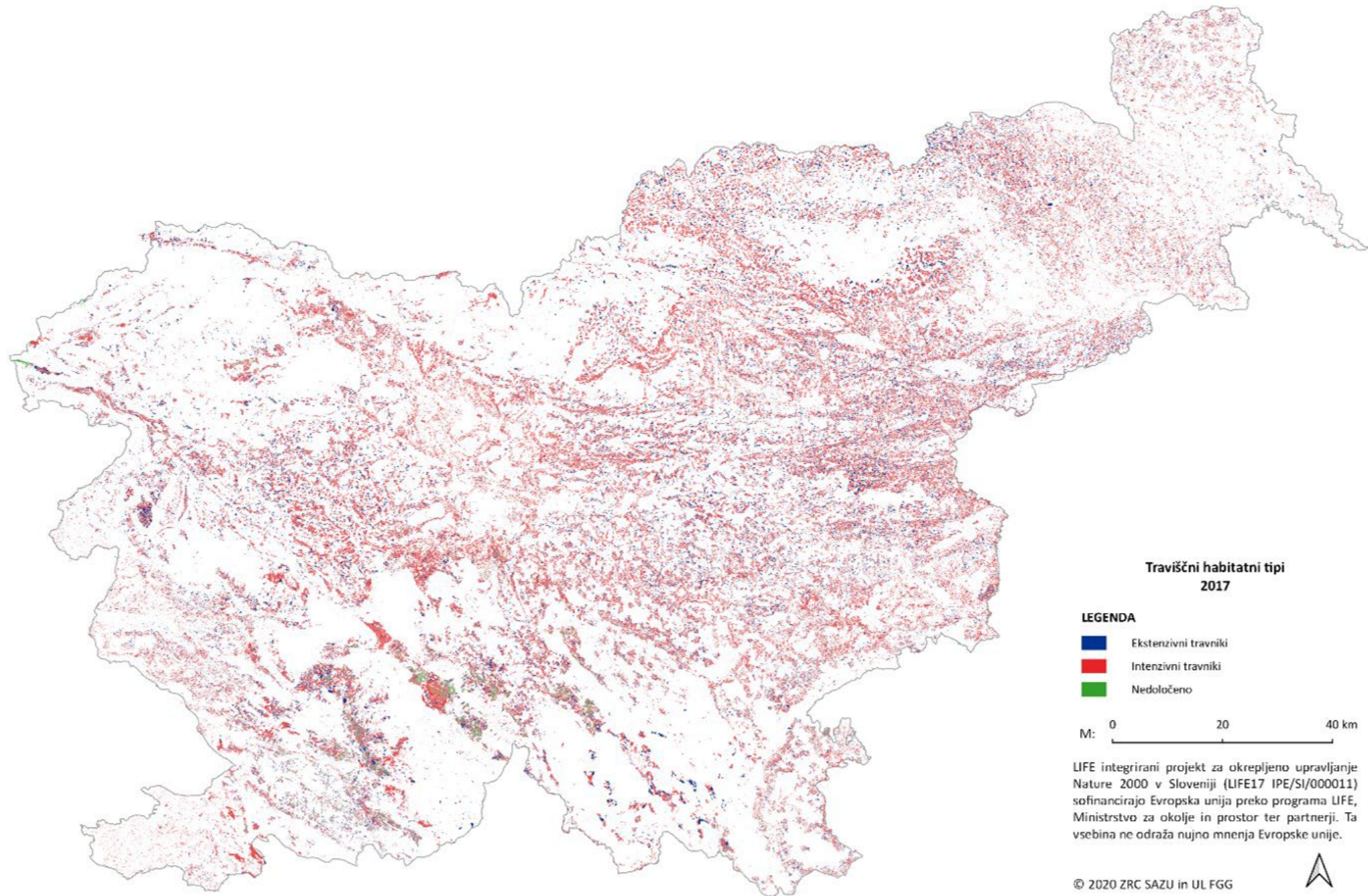




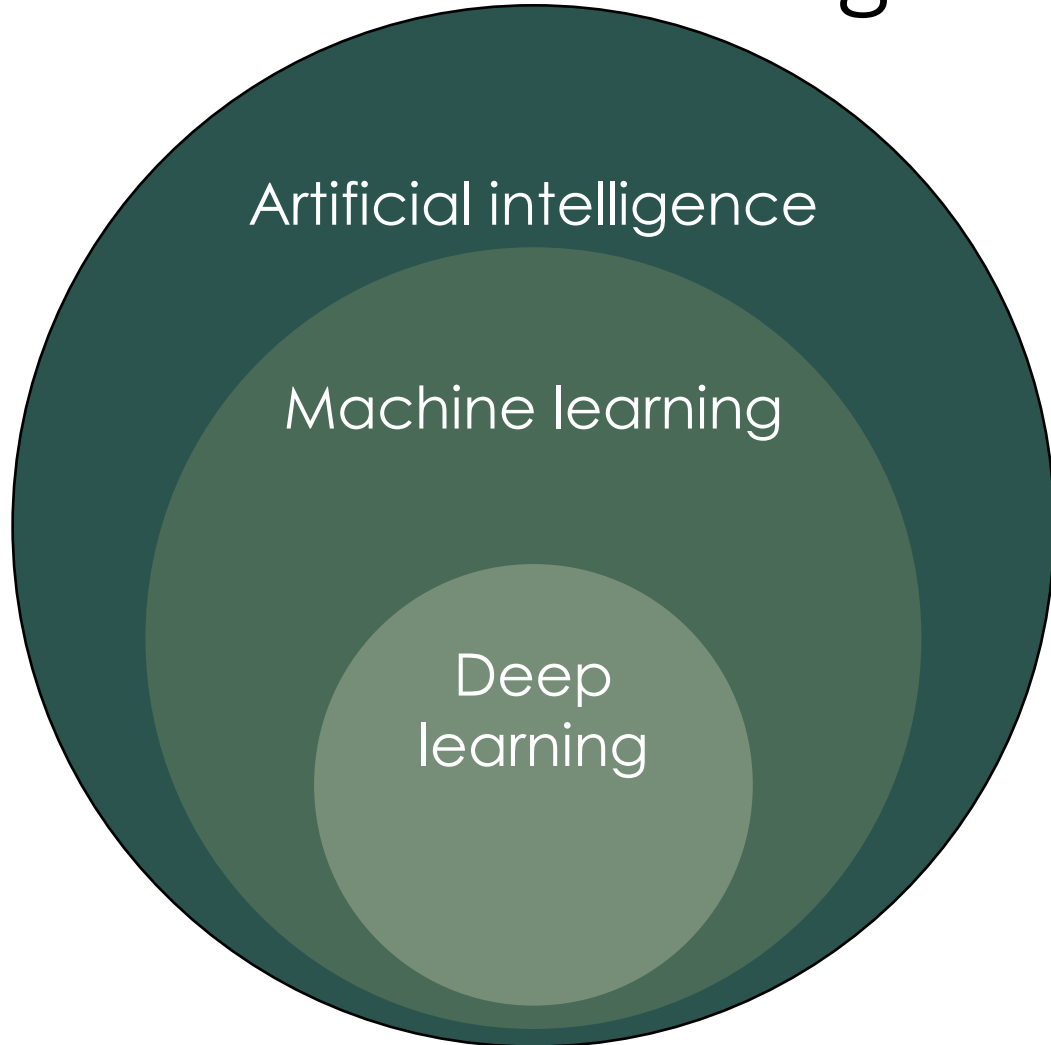
LIFE integrirani projekt za okrepljeno upravljanje Nature 2000 v Sloveniji (LIFE17 IPE/SI/000011) sofinancirajo Evropska unija preko programa LIFE, Ministrstvo za okolje in prostor ter partnerji. Ta vsebina ne odraža nujno mnenja Evropske unije.







# Machine learning

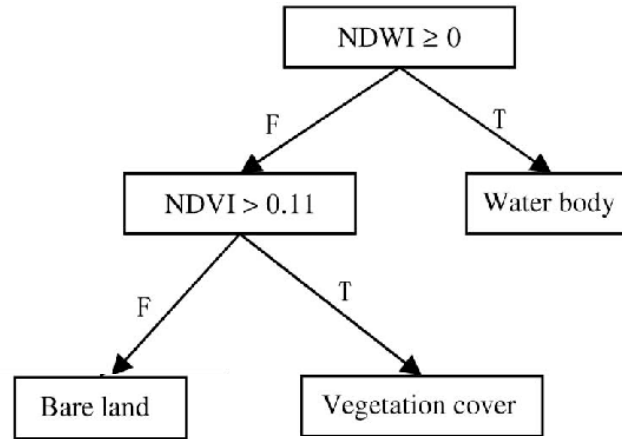


- Scene classification
- Object detection
- Segmentation
- Pixel classification

# Machine learning – SITS

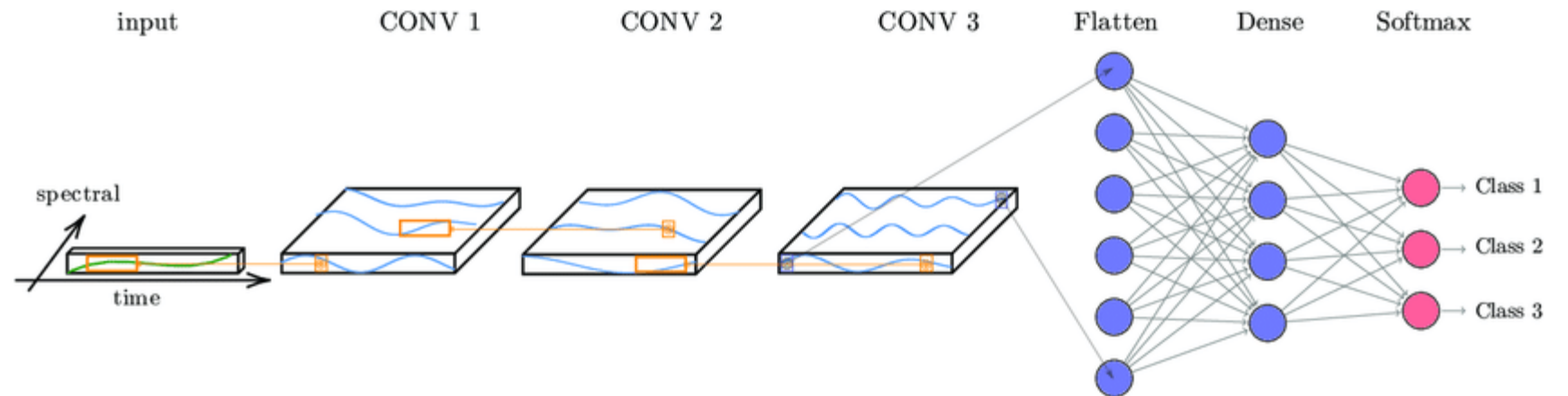
- Machine learning

- Decision tree
- Random Forest
- LightGBM



- Deep learning

- RNN
- CNN
- Transformers



# Conclusions

- We have dense (weekly, multispectral) time series from multiple satellite systems
- Freely and openly available
- ARD is needed, but generating the ARD products is challenging
- It is likely that in the future ARD data will be prepared by the data providers
- Vegetation observation benefits with time series of optical and SAR data
- Time series analysis is complex and requires knowledge from several disciplines
- Artificial intelligence is providing answers to some of the problems
  
- Applications are limited only by imagination

# Contacts

- Prof. Krištof Oštir

[kristof.ostir@fgg.uni-lj.si](mailto:kristof.ostir@fgg.uni-lj.si)

- Ana Potočnik Buhvald

[ana.potocnikbuhvald@fgg.uni-lj.si](mailto:ana.potocnikbuhvald@fgg.uni-lj.si)