Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

University of Ljubljana

UNIVERSITY of STIRLING

esa

APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Crop Mapping using Synthetic Aperture Radar (SAR) and Optical Remote Sensing

April 6, 2023

Training Outline

April 4, 2023

Crop Classification with Time Series of Polarimetric SAR Data

April 6, 2023

Crop Classification with Time Series Optical and Radar Data

April 11, 2023

Monitoring Crop Growth Through SAR-Derived Crop Structural Parameters

Homework and Certificate

- Homework Assignment:
  - Answers must be submitted via Google Form
  - Due Date: April 25, 2023
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - Complete the homework assignment by the deadline (access from website)
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Training Objectives

After participating in this 3-part training, attendees will be able to:

- Explain how polarimetric parameters are used for crop condition assessment
- Demonstrate how to perform Sentinel-1 SAR preprocessing to derive quasi polarimetric parameters
- Perform a calibration of a SAR-based vegetation index to NDVI
- Monitor crop growth with multitemporal polarimetric SAR (PolSAR) data from Sentinel-1
- Examine crop growth using a canopy structure dynamic model and time series of Sentinel-1 imagery
- Classify crop type using a time series of radar and optical imagery (Sentinel-1 & Sentinel-2)

Agriculture and Agri-Food Canada

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Monitoring Crop Growth Through SAR-Derived Crop Structural Parameters

Prof. Krištof Oštir, Asist. Matej Račič

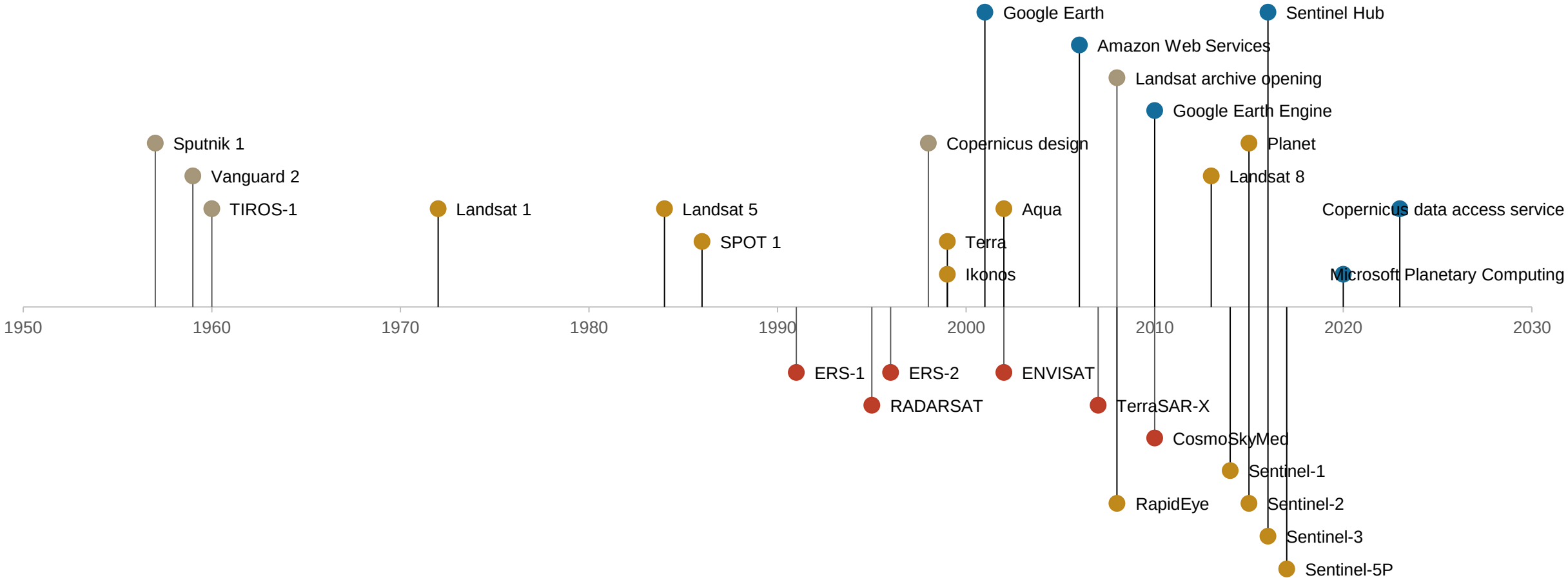
April 6, 2023

Outline

- Satellite Image Time Series
- Copernicus and the Sentinels
- Time series generation
- Analysis ready data
- Time series analysis
- Sentinel Hub
- Statistical API
- Machine learning
- eo-learn
- eo-workflow

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

Major Milestones



Long and dense time series

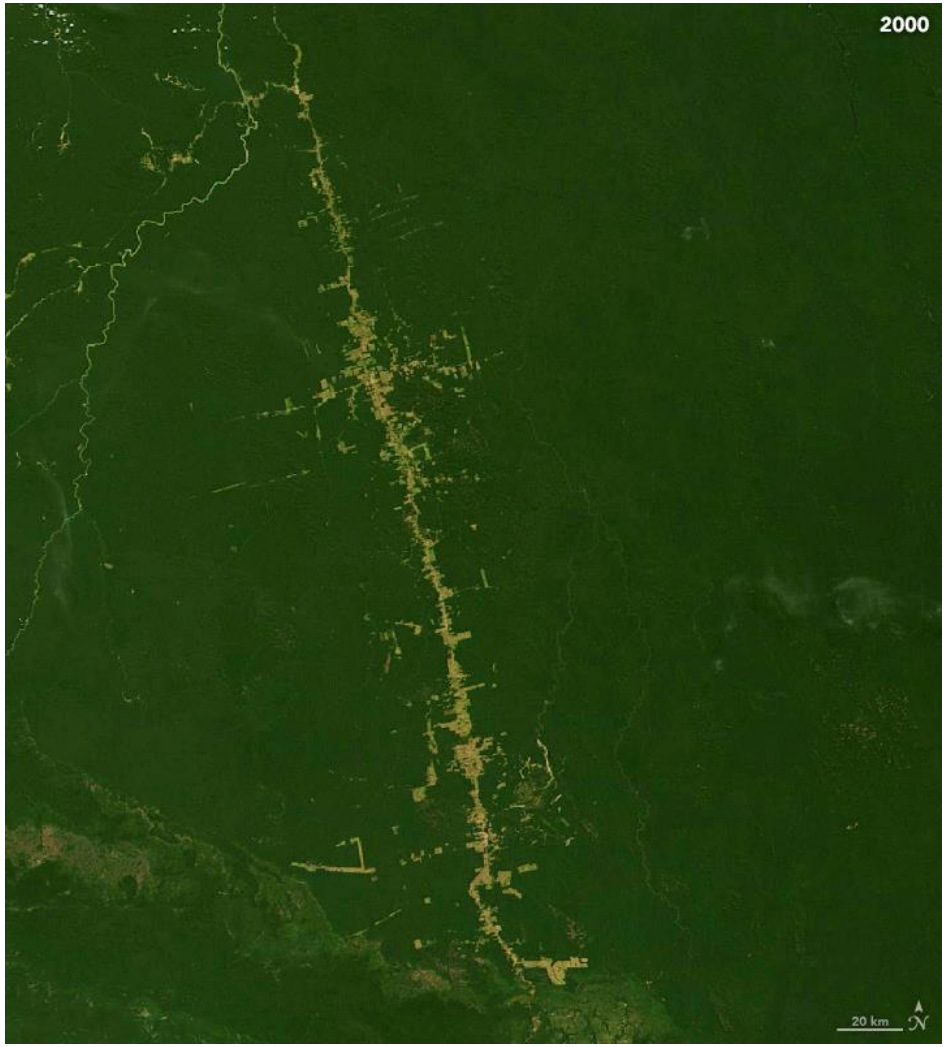
Satellite Image Time Series – SITS

- Medium and high-resolution data is freely available
- Landsat archive – 2008
- Copernicus – complete, free and open

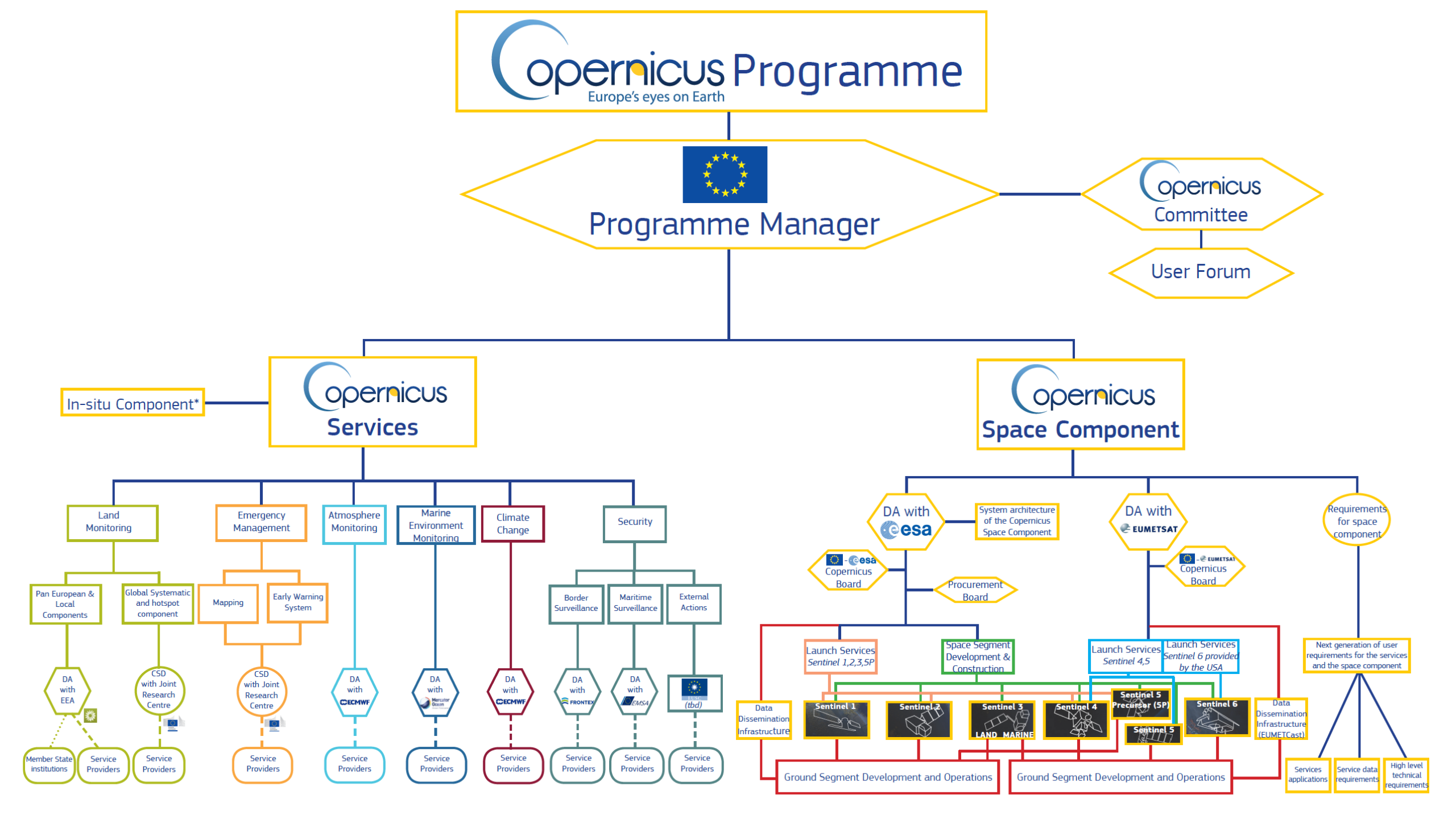
- Long SITS
  - 1972 –
- Dense SITS
  - weekly, daily
- Harmonized SITS
  - Landsat – Sentinel-2
  - Optical – radar
  - Sentinel-2 – Planet

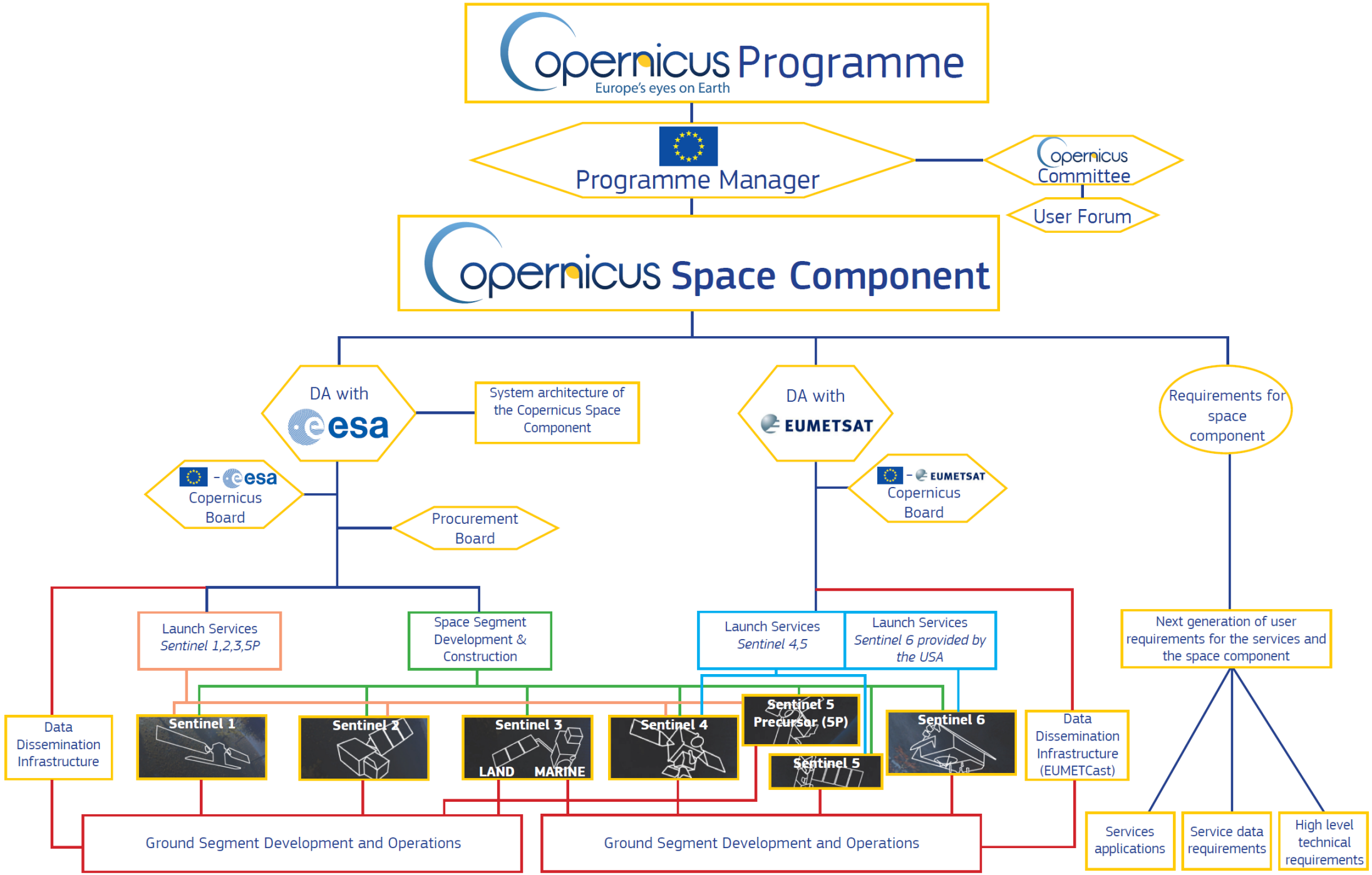
Landsat SITS

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



Landsat Image Gallery - Making Sense of Amazon Deforestation Patterns (nasa.gov)


Copernicus Programme
Europe's eyes on Earth
Programme Manager
Copernicus Committee
User Forum
In-situ Component*
Copernicus Services
Land Monitoring
Pan European & Local Components
Global Systematic and hotspot component
DA with EEA
Member State institutions
Service Providers
CSD with Joint Research Centre
Service Providers
Emergency Management
Mapping
Early Warning System
CSD with Joint Research Centre
Service Providers
Atmosphere Monitoring
DA with ECMWF
Service Providers
Marine Environment Monitoring
DA with Mercator Ocean
Service Providers
Climate Change
DA with ECMWF
Service Providers
Security
Border Surveillance
DA with FRONTEX
Service Providers
Maritime Surveillance
DA with EMSA
Service Providers
External Actions
(tbd)
Service Providers
Copernicus Space Component
DA with esa
System architecture of the Copernicus Space Component
Copernicus Board
Procurement Board
DA with EUMETSAT
Copernicus Board
Requirements for space component
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
Sentinel 1
Sentinel 2
Sentinel 3
LAND MARINE
Sentinel 4
Sentinel 5 Precursor (5P)
Sentinel 5
Sentinel 6
Data Dissemination Infrastructure (EUMETCast)
Ground Segment Development and Operations
Ground Segment Development and Operations
Services applications
Service data requirements
High level technical requirements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Sentinel 5
Sentinel 6
Data Dissemination Infrastructure (EUMETCast)
Ground Segment Development and Operations
Ground Segment Development and Operations
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Service data requirements
High level technical requirements

Sentinel Satellites

S1A/B: Radar observations — 2014, 2016–2021

S2A/B: High-resolution optical observation — 2015, 2017

S3A/B: resolution imaging and altimetry — 2016, 2018

S4A/B: Observation of the atmosphere from the geostationary orbit — 2022

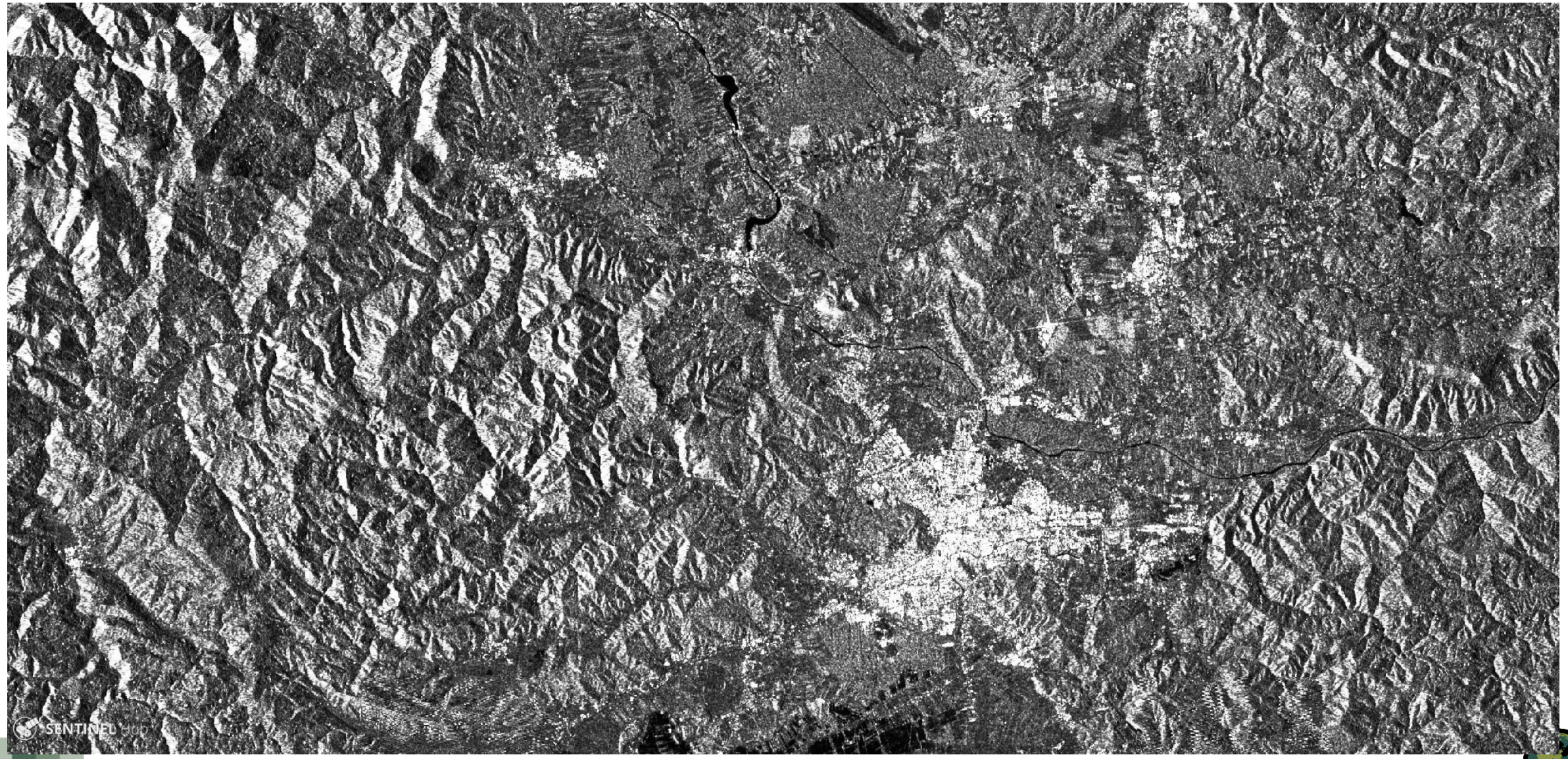
S5P: Observation of the atmosphere from low orbit - predecessor — 2017

S5A/B/C: Observation of the atmosphere from low orbit — 2015, 2017

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

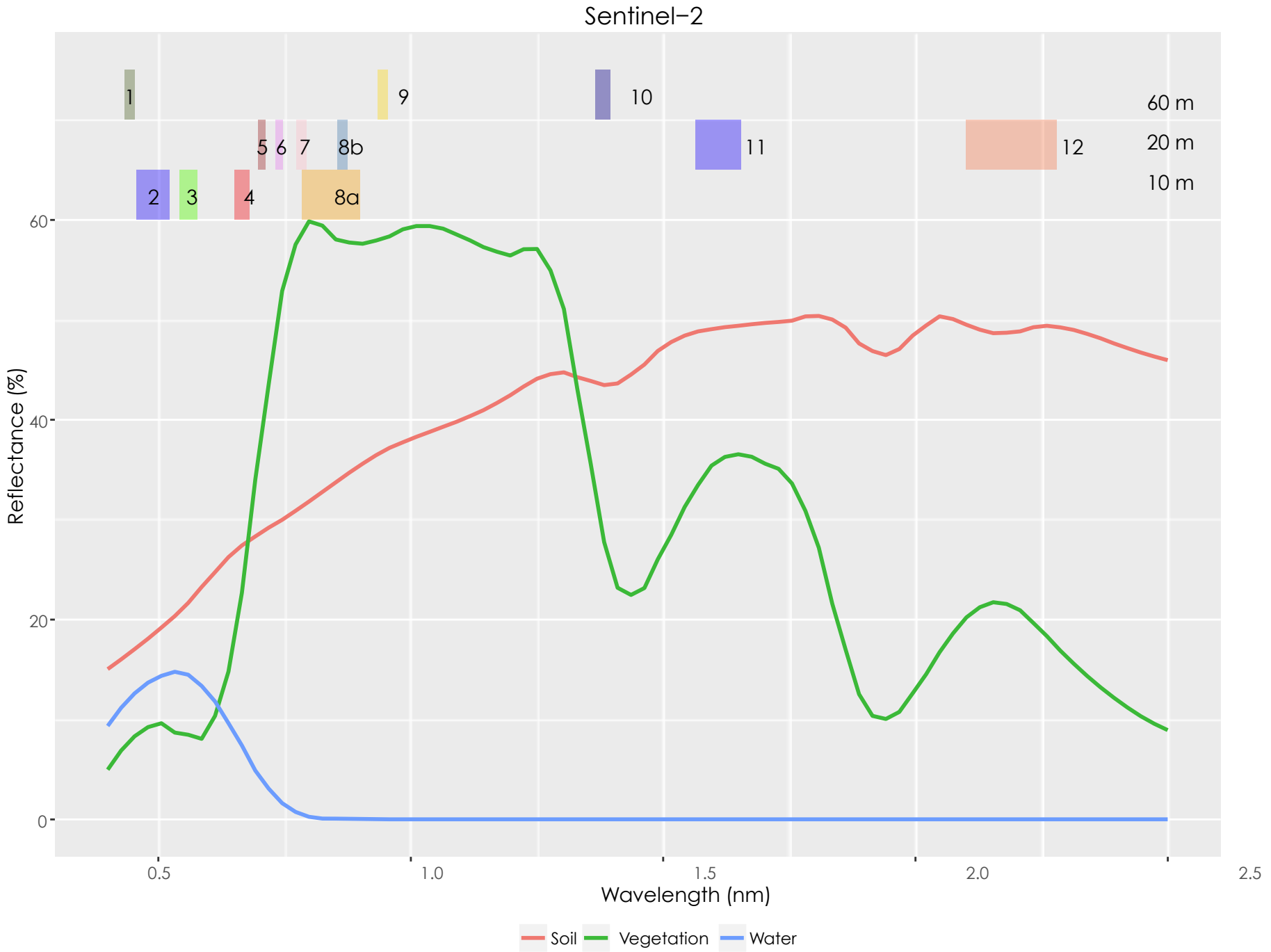


Sentinel-2

- 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, and 60 m

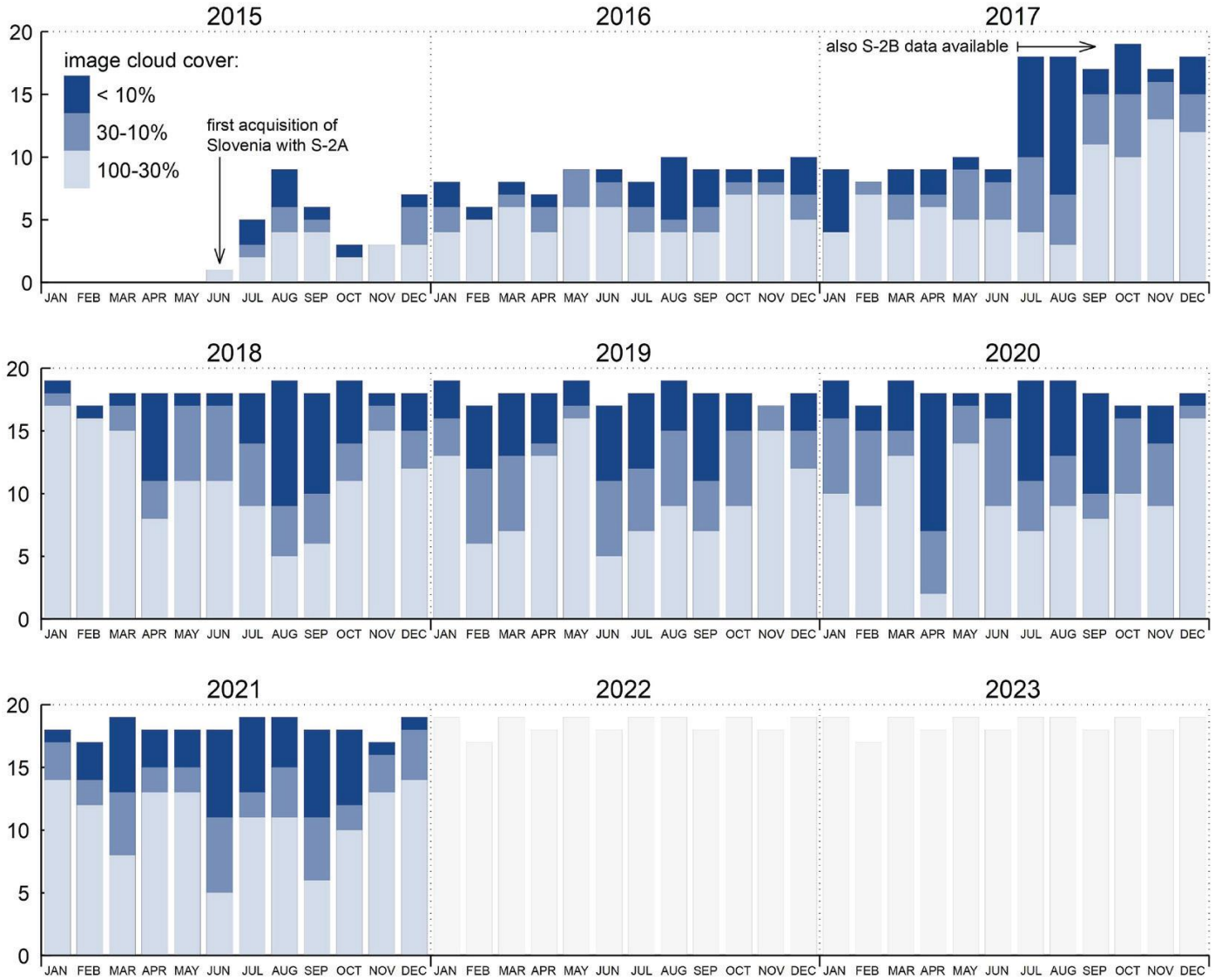
Sentinel-2

	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
1
9
10
5 6 7
8b
11
12
60 m
20 m
10 m
2
3
4
8a
60
40
20
0
Reflectance (%)
0.5
1.0
1.5
2.0
2.5
Wavelength (nm)
Soil
Vegetation
Water

Sentinel-2

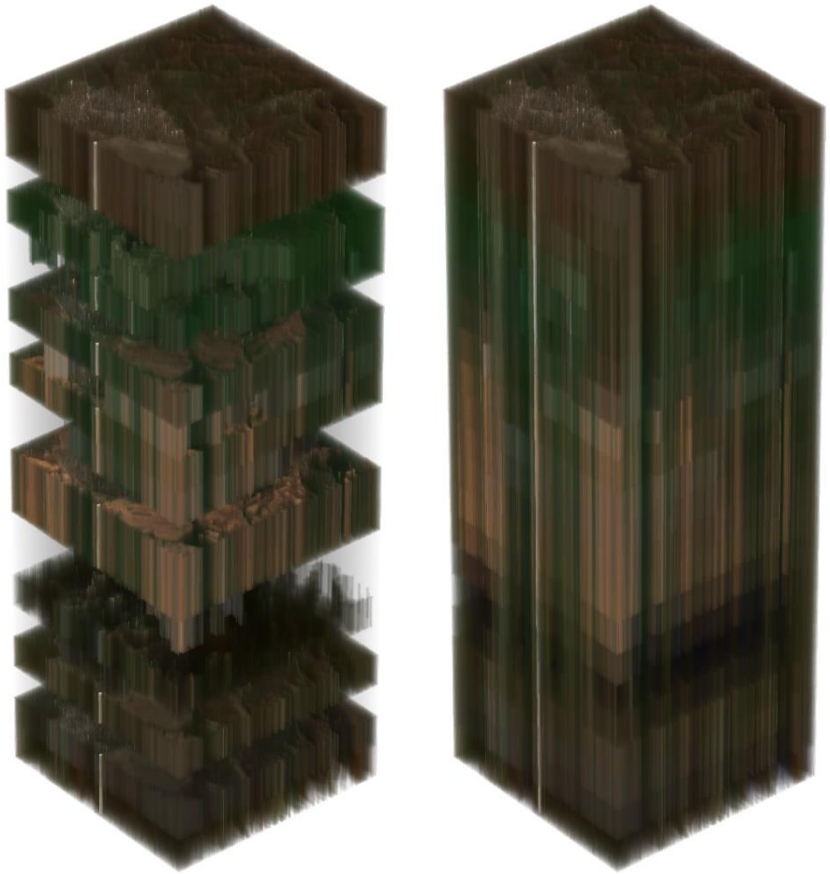
Sentinel-2 Archive



 Paper: Six years of Sentinel-2 archive of Slovenia | Geodetski vestnik (geodetski-vestnik.com)

Time Series Generation

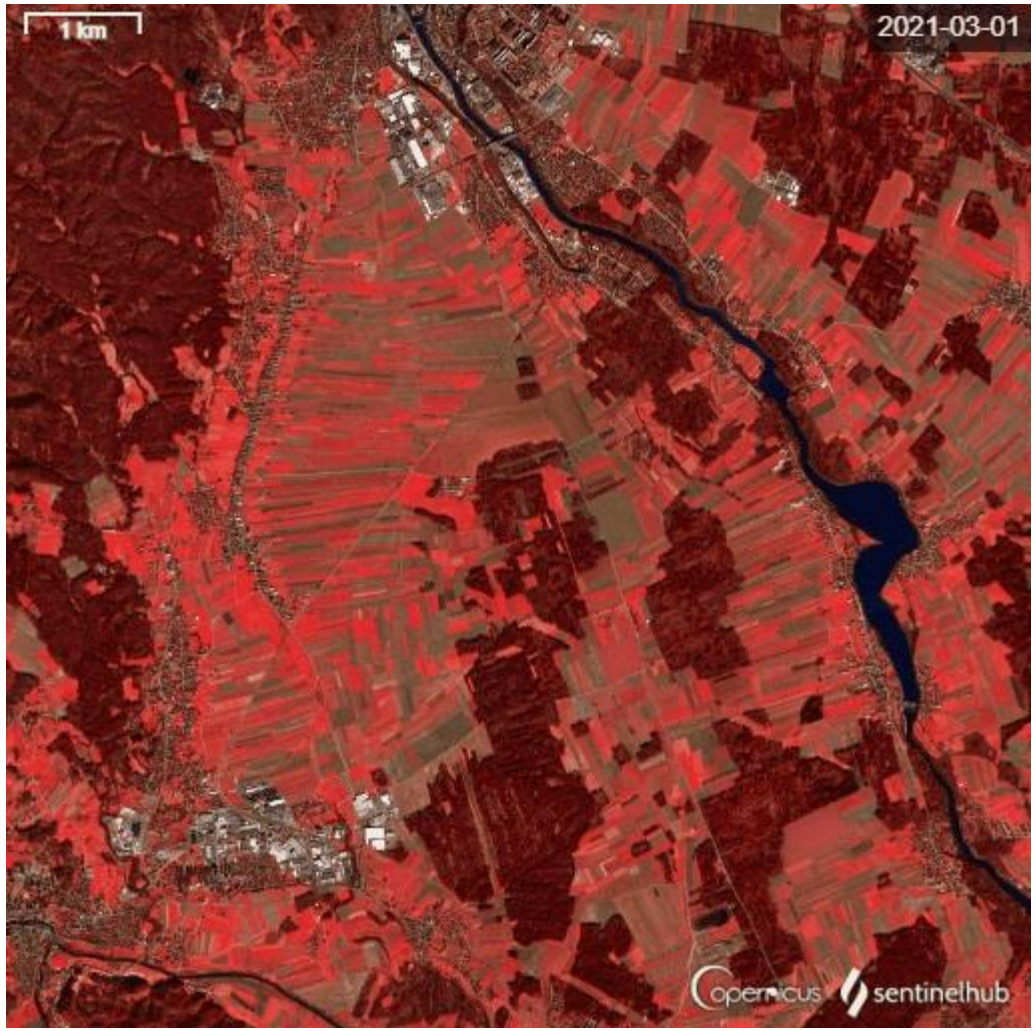
Time Series



- 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

Land Cover Classification with eo-learn: Part 2 | by Matic Lubej | Sentinel Hub Blog | Medium

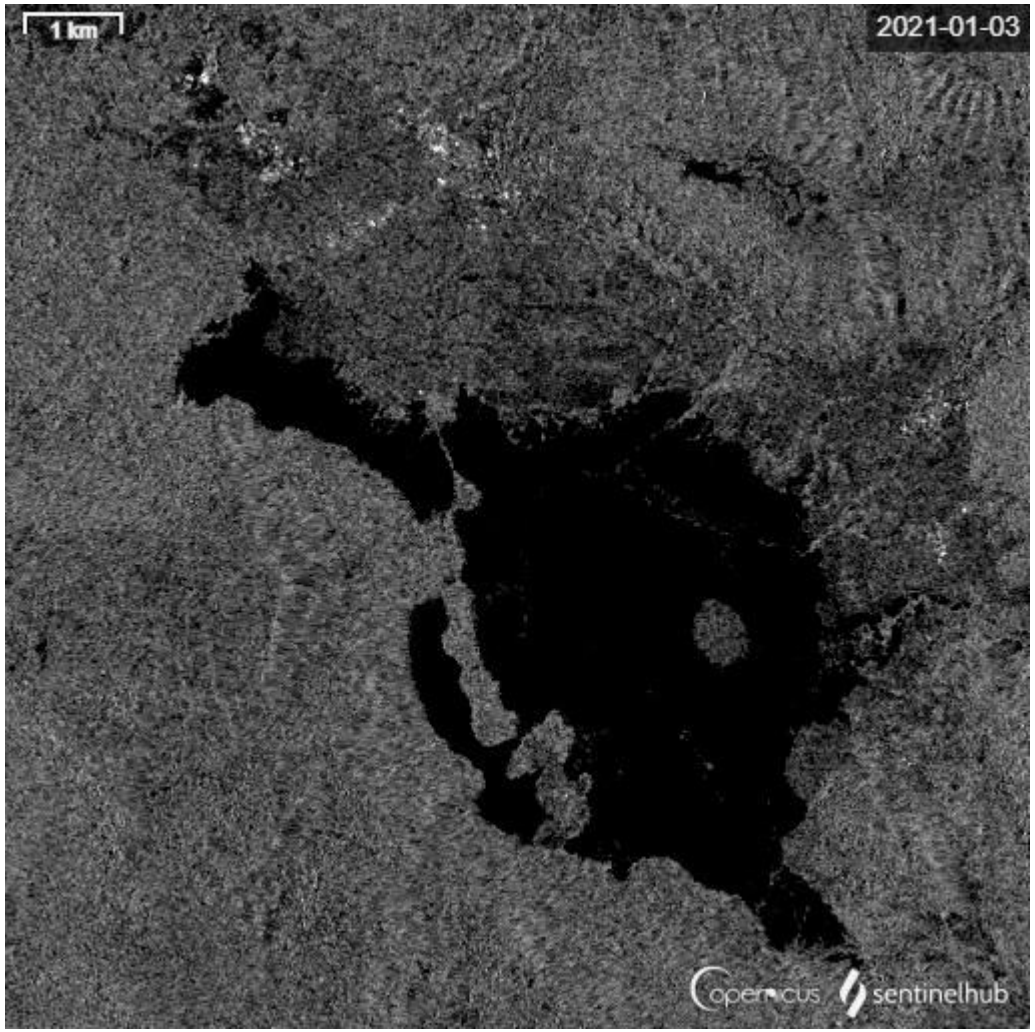
Time Series - Sentinel-2



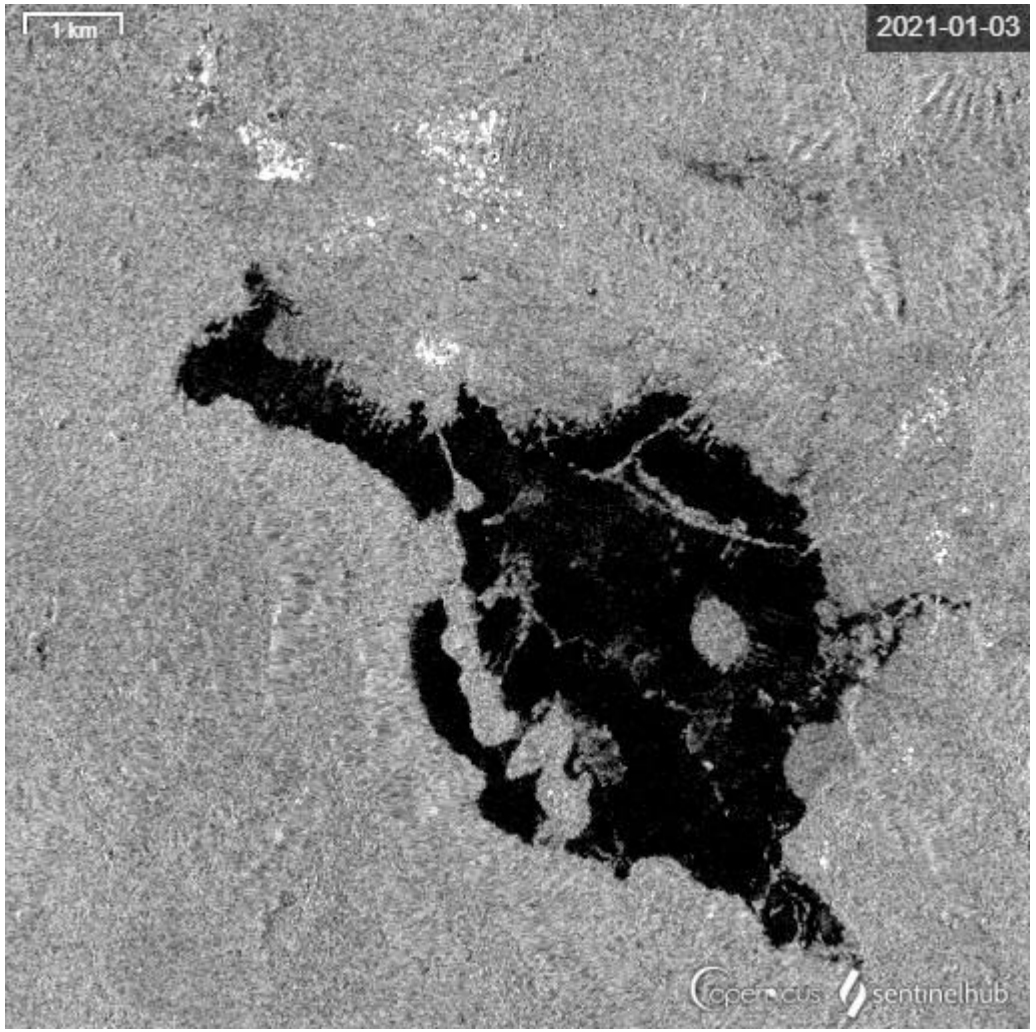
8, 4, 3

NDVI

Time Series – Sentinel-1

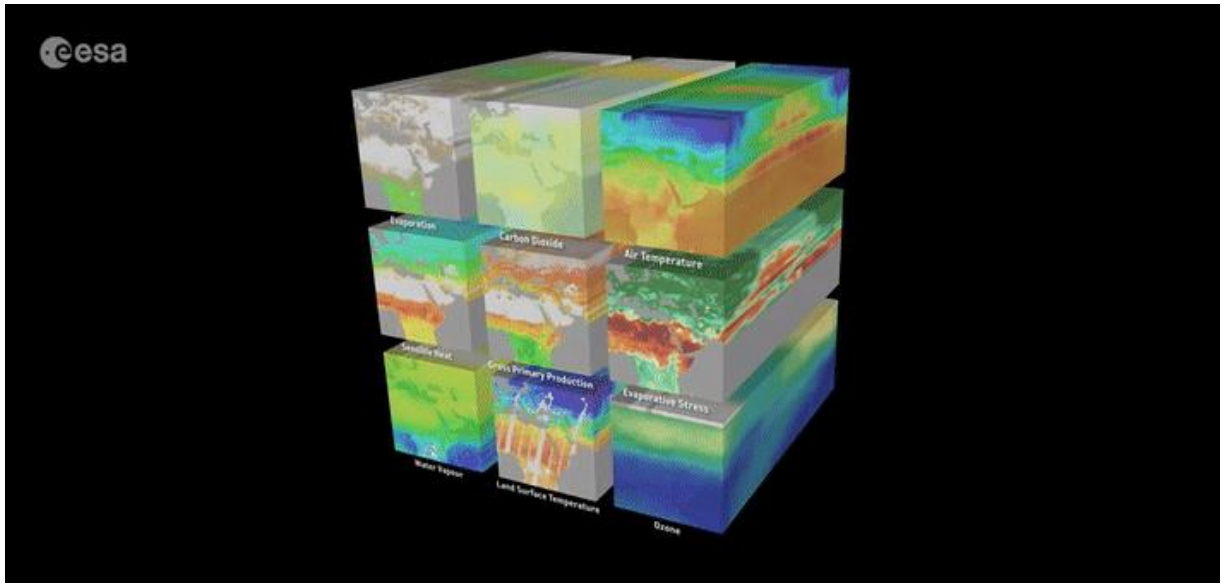


VH



VV

Analysis Ready Data (ARD)

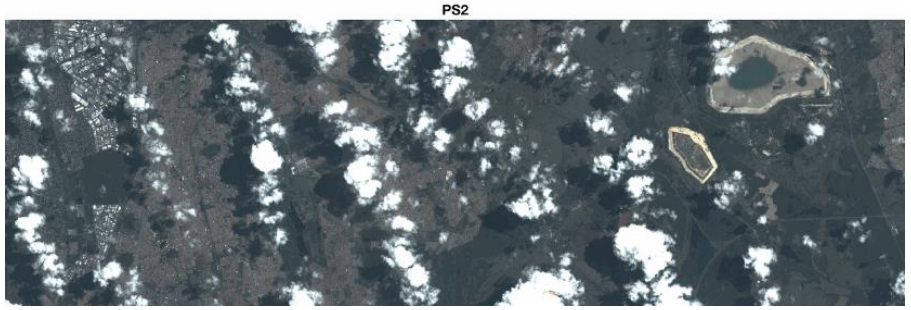


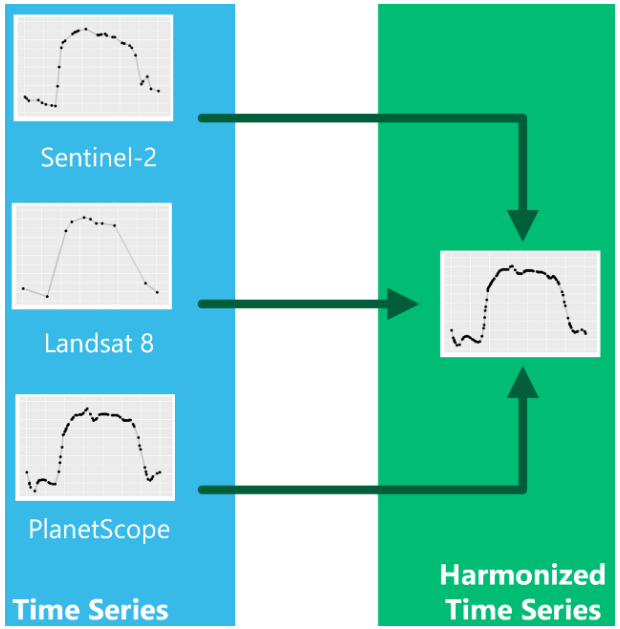
- CEOS – Committee on Earth Observation Satellites:
  - Analysis Ready Data (ARD) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with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

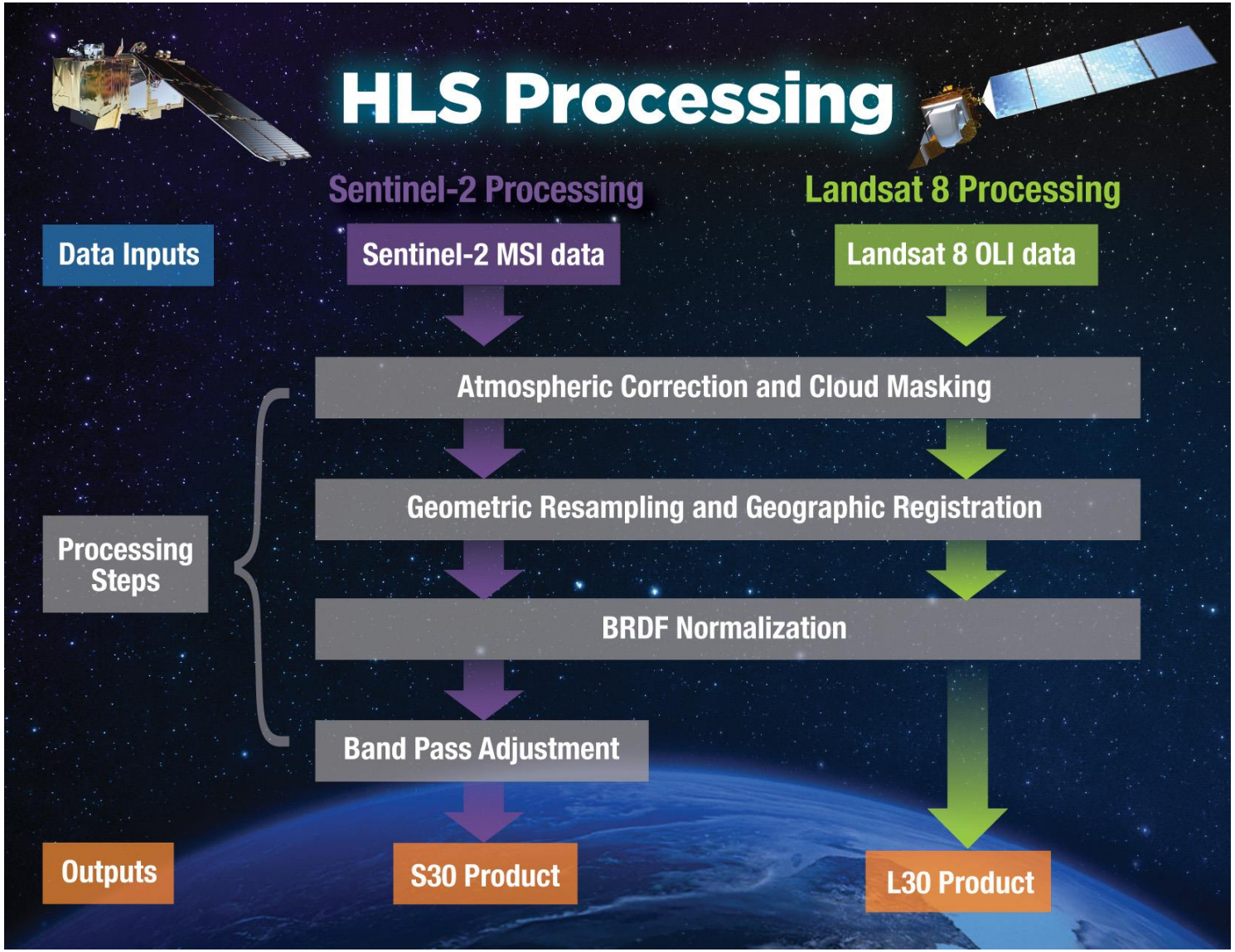
- ARD processing may differ between applications.
- Image clipping
- Masking – Usable/Unusable Data Masks
- Atmospheric Correction
- Pixel Alignment
- Sensor Alignment





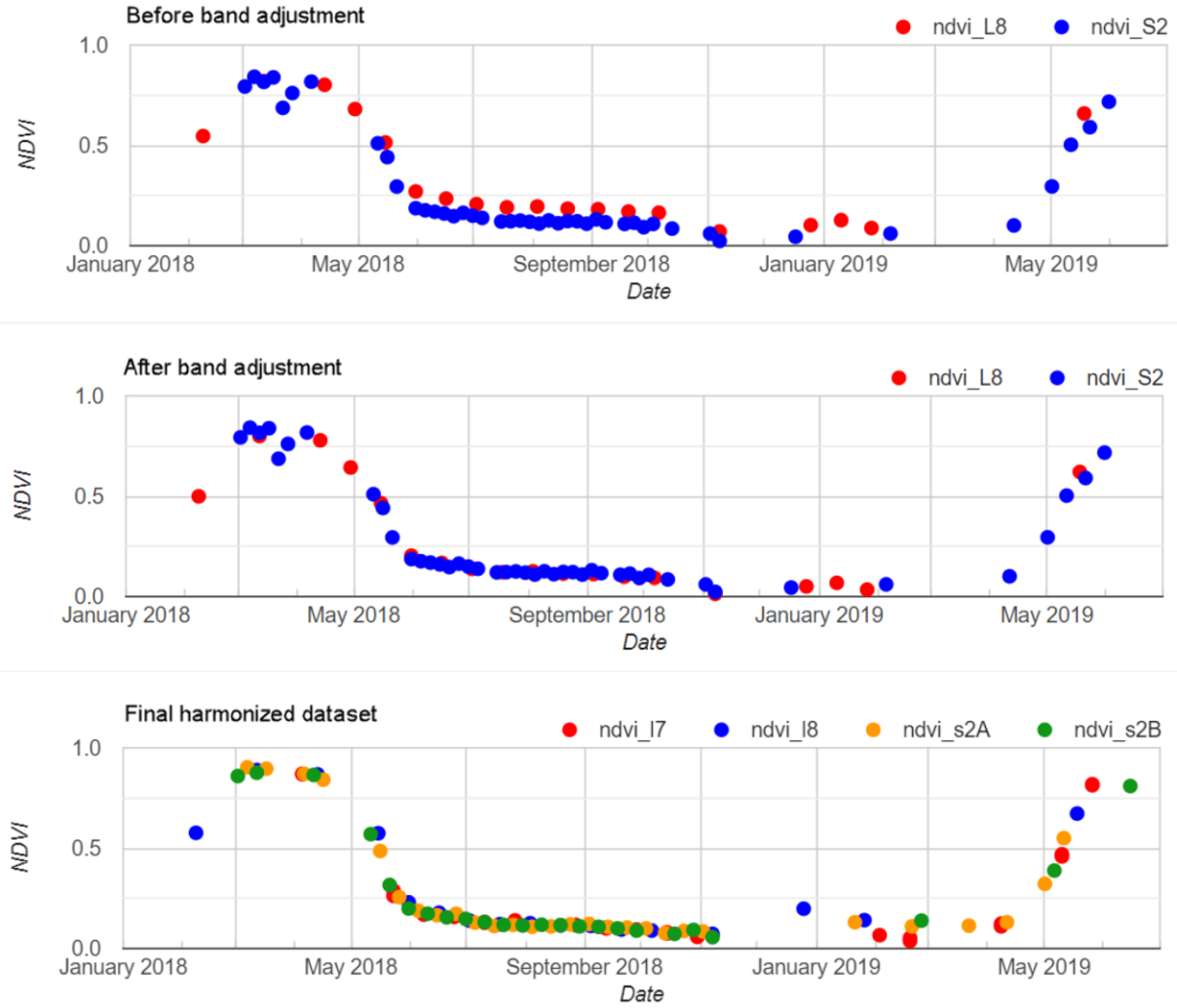
Analysis Ready Data Defined. Cloud Native Geoprocessing Part 2 | by Chris Holmes | Planet Stories | Medium

Harmonization of the Time Series



Algorithms « Harmonized Landsat Sentinel-2 (nasa.gov)

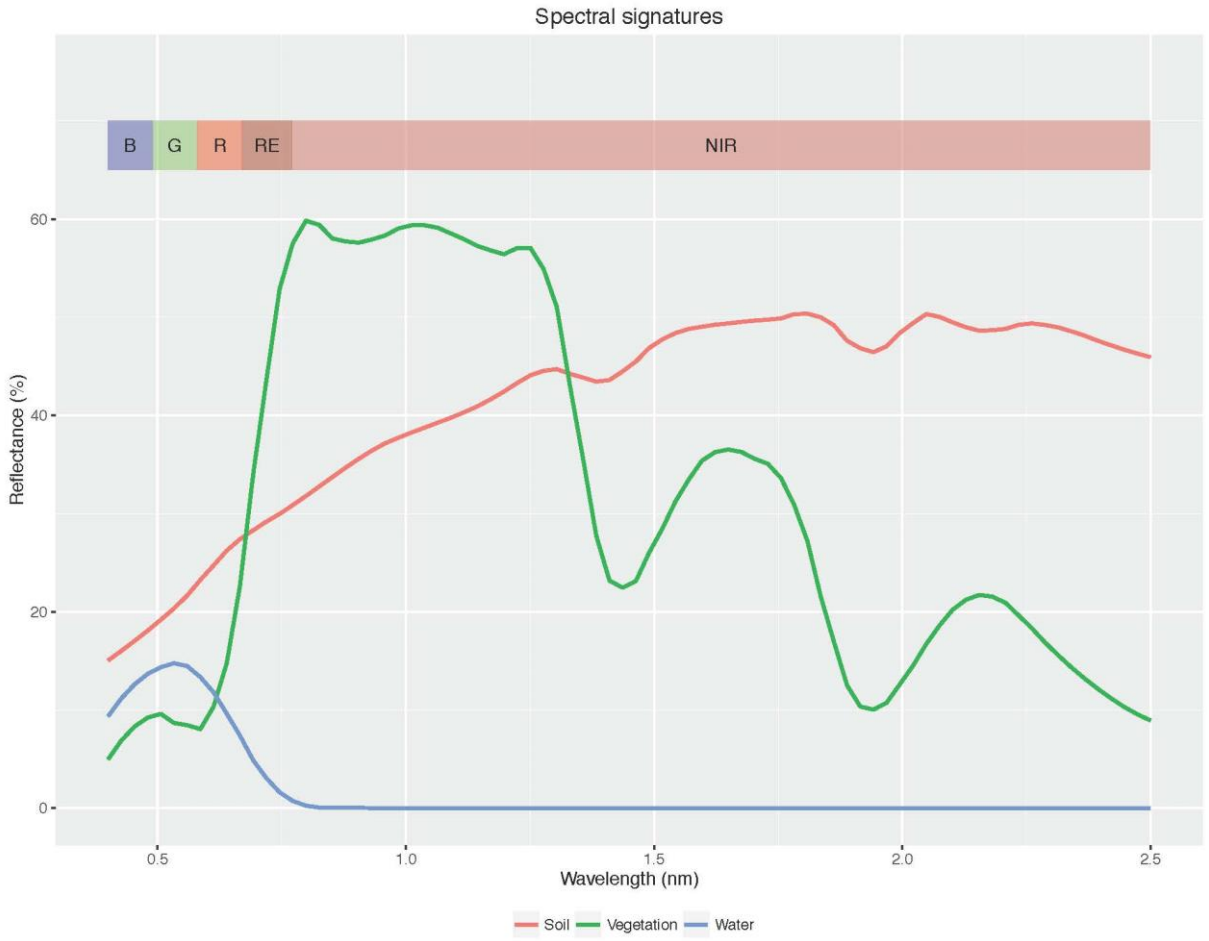
Sentinel-2 – Landsat 7,8 – harmonization



[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.

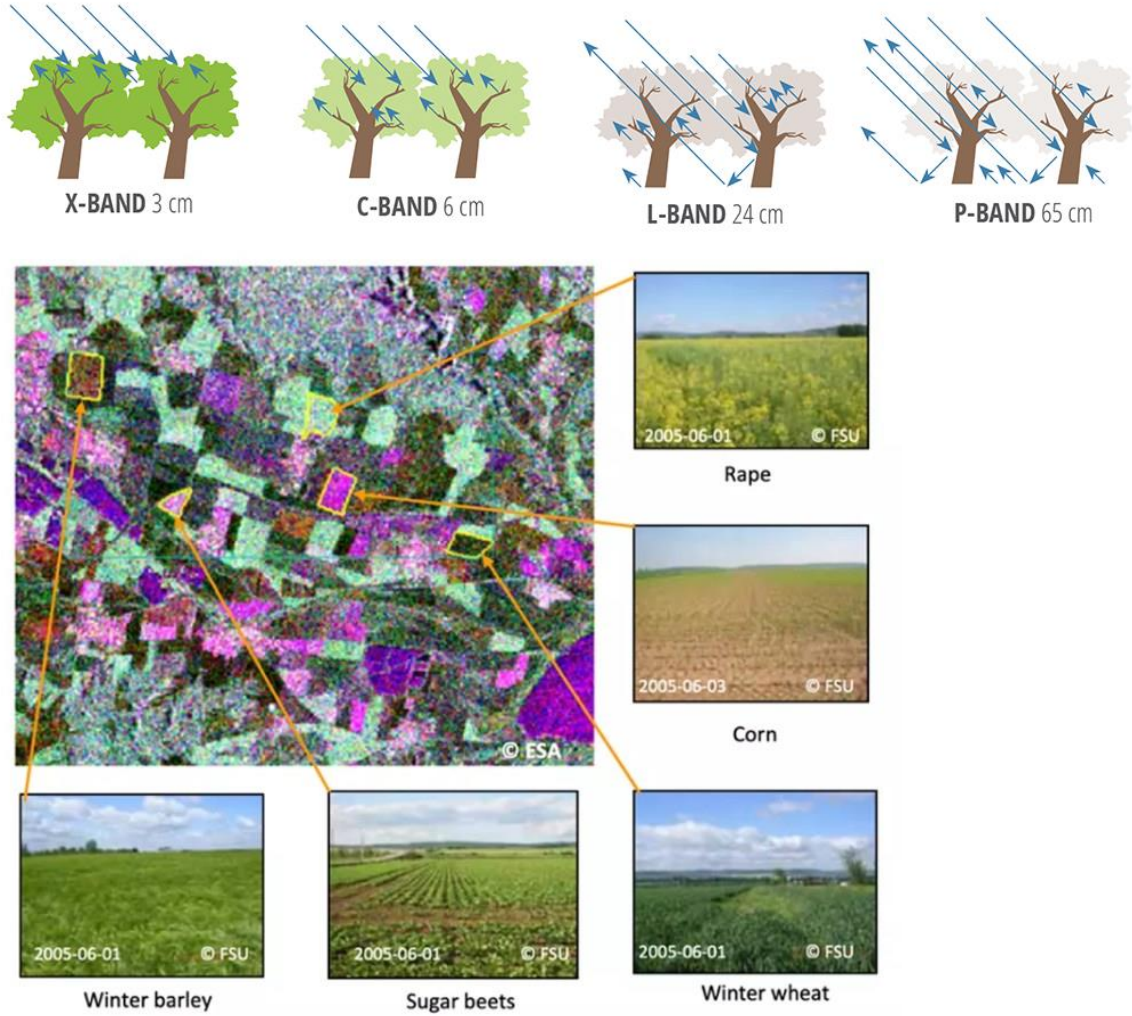
Radar backscattering

Radar

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

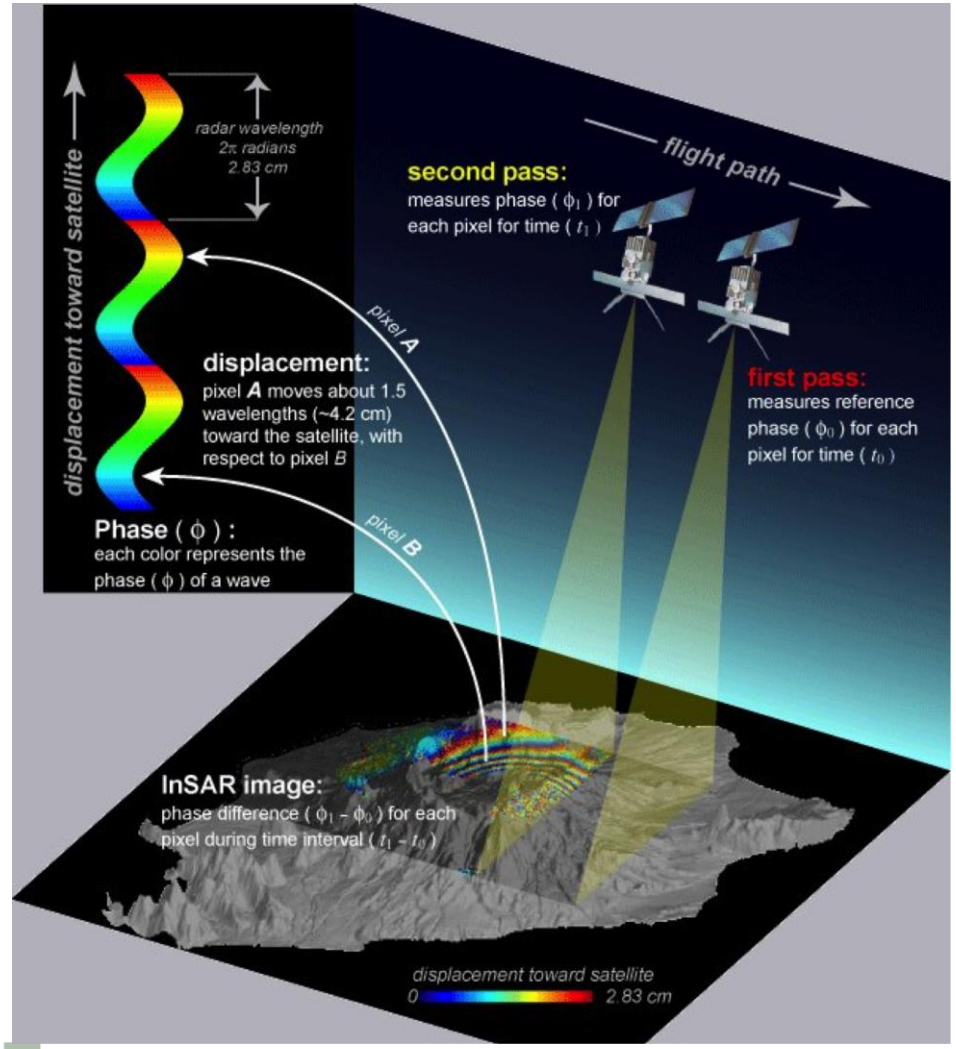
Surface

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



[What is Synthetic Aperture Radar? | Earthdata (nasa.gov)]
[SAR Satellites for Agriculture - Groundstation]

Radar Interferometry

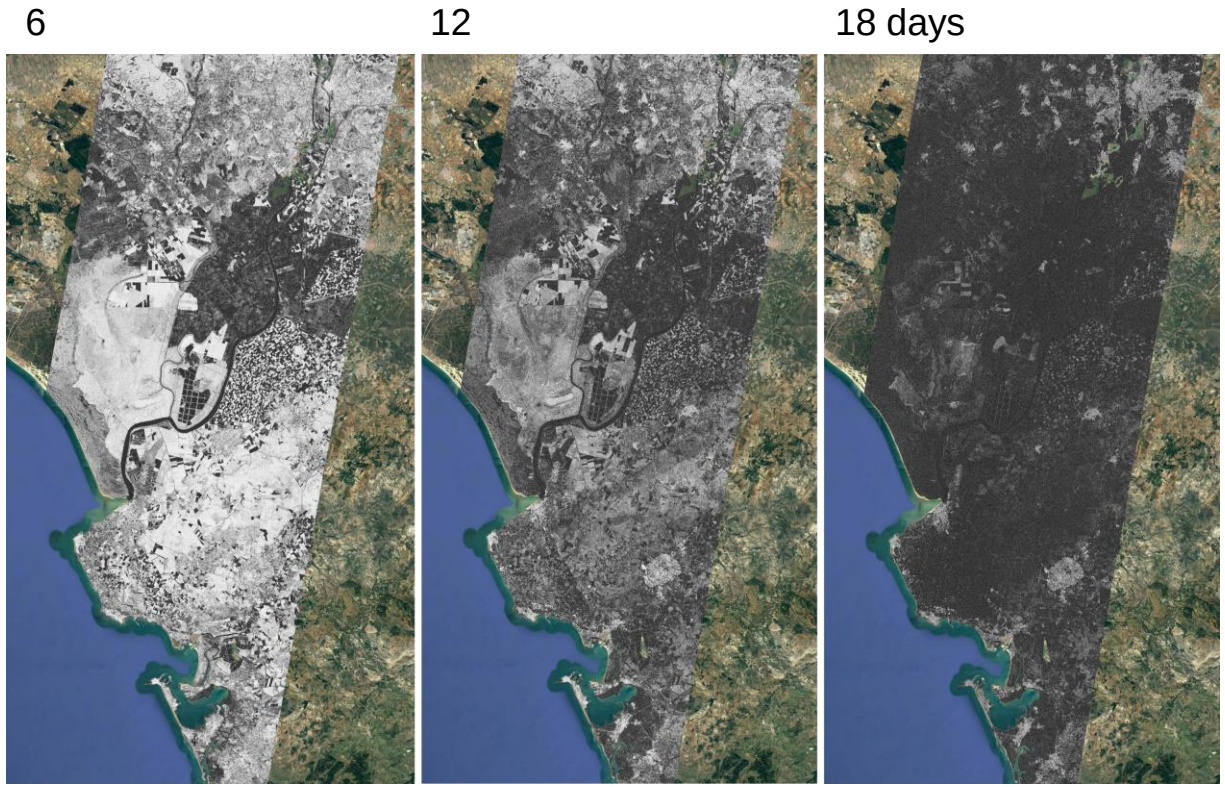


- Two images from slightly displaced orbits
- Phase differences due to
  - Parallax
  - Elevation differences
  - Surface movements
  - Atmospheric phenomena
- Elevations in m
- Displacements in mm
- Coherence

[Elastic Earth science for global monitoring | Elastic Blog]

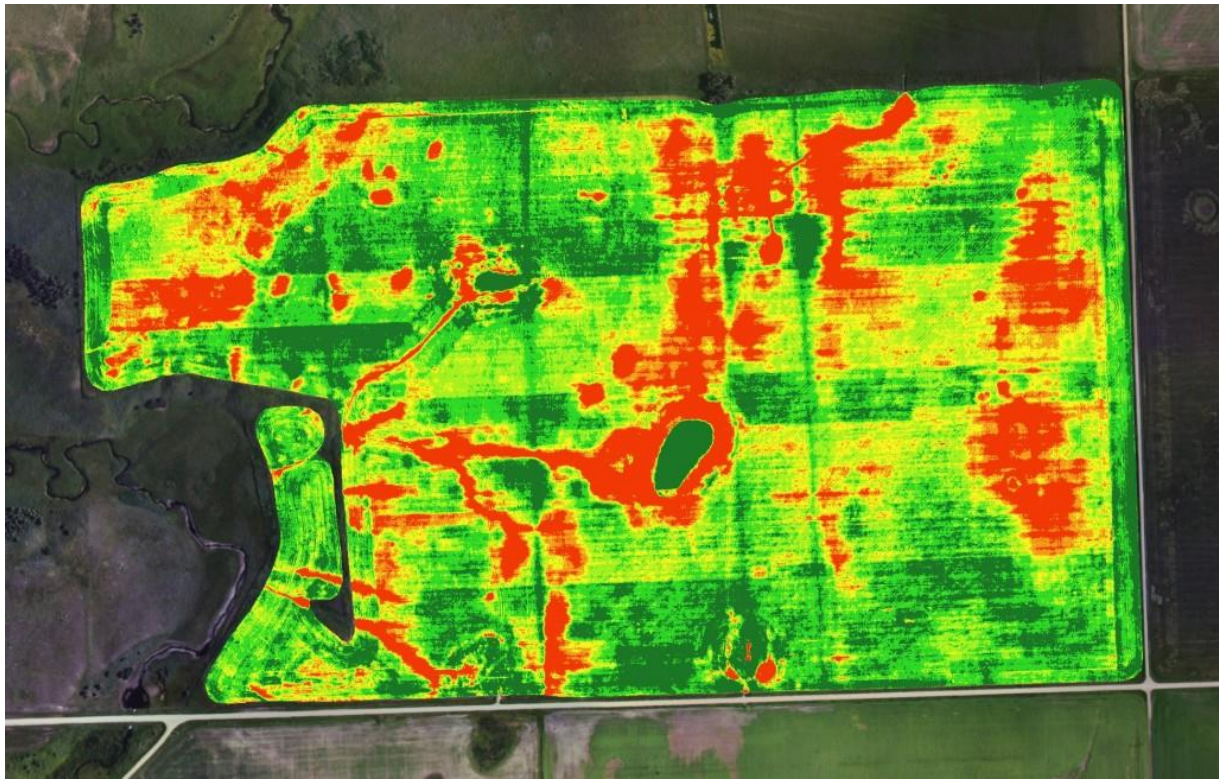
Coherence for Vegetation Mapping

- 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



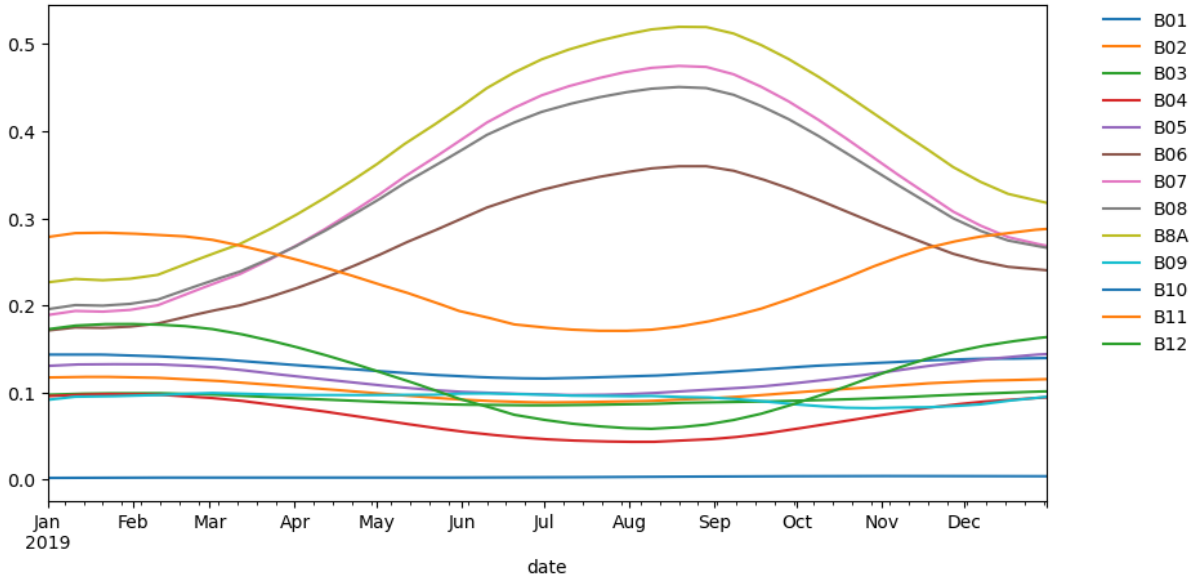
- VI - Vegetation Index
- NDVI - Normalized Difference Vegetation Index
- EVI - Enhanced Vegetation Index
- SAVI - Soil Adjusted NDVI
- AVI - Advanced Vegetation Index
- NDMI - Normalized Difference Moisture Index ...

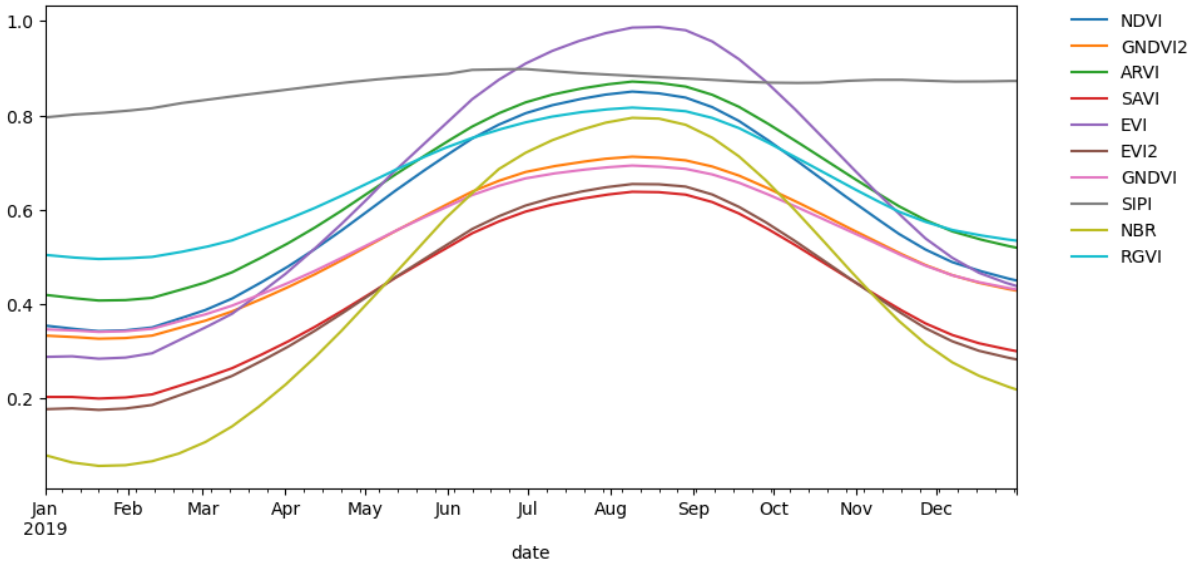
IDB - Index DataBase

IDB - Agriculture

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

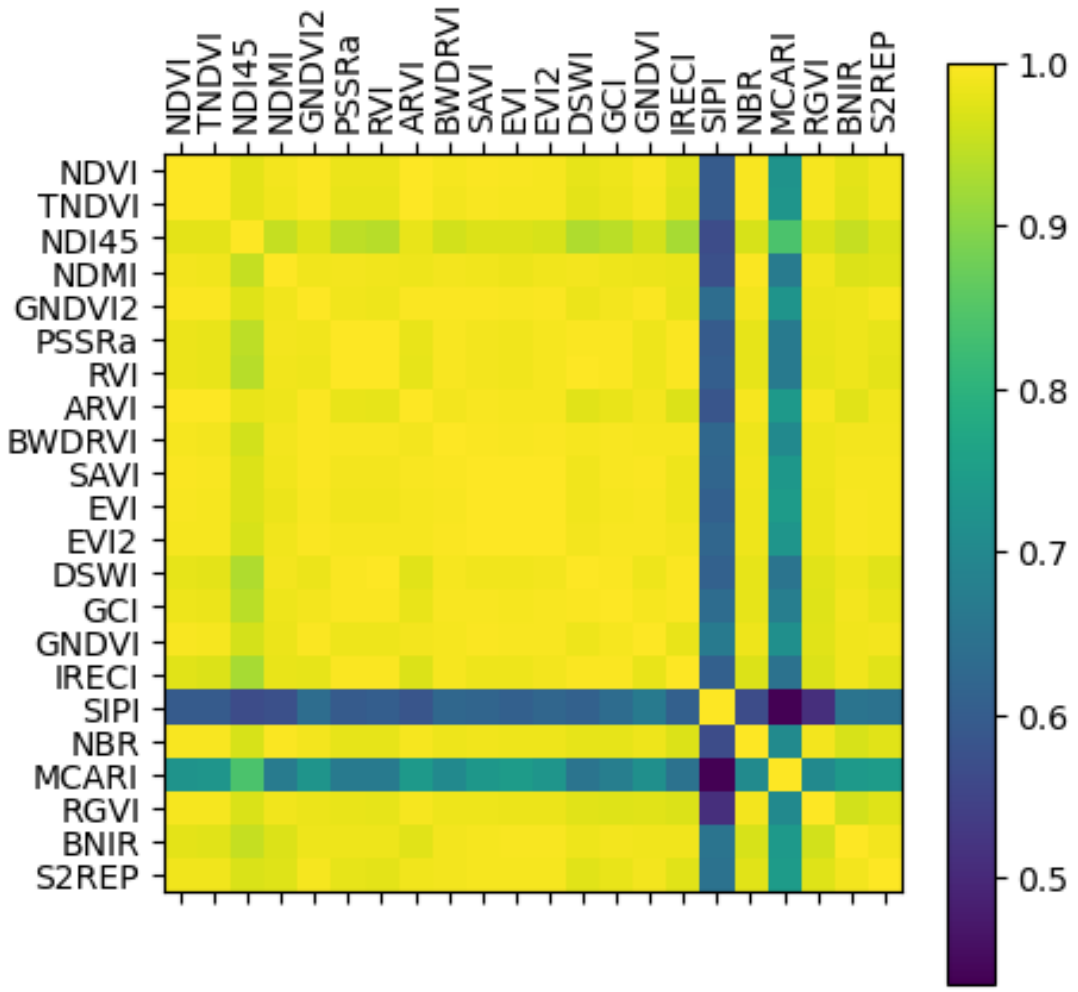
Sentinel-2 – Bands and indices





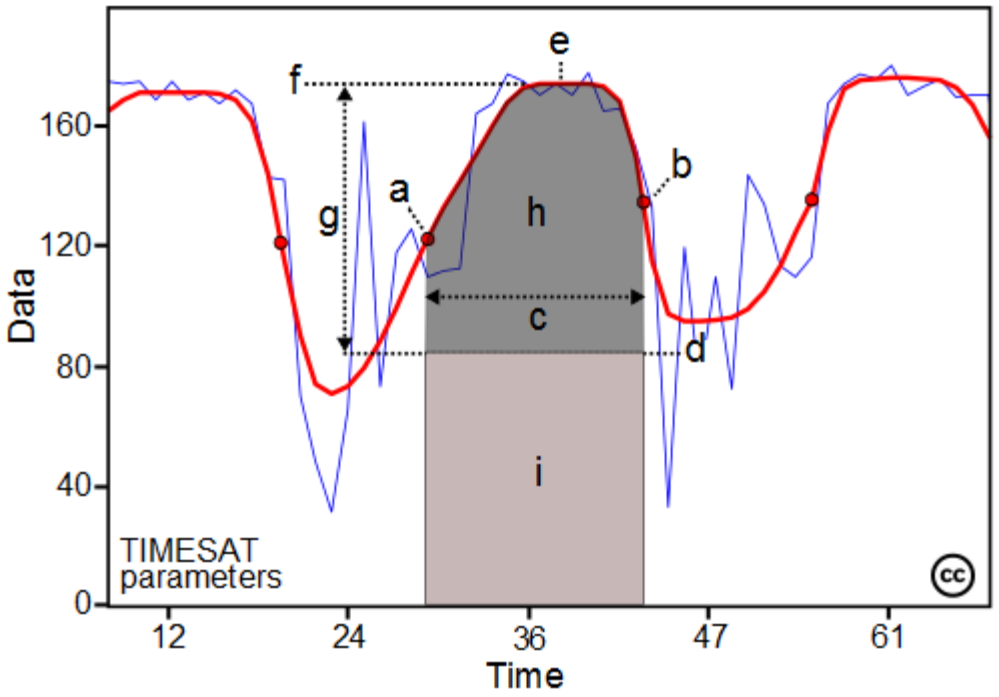
Correlation with NDVI

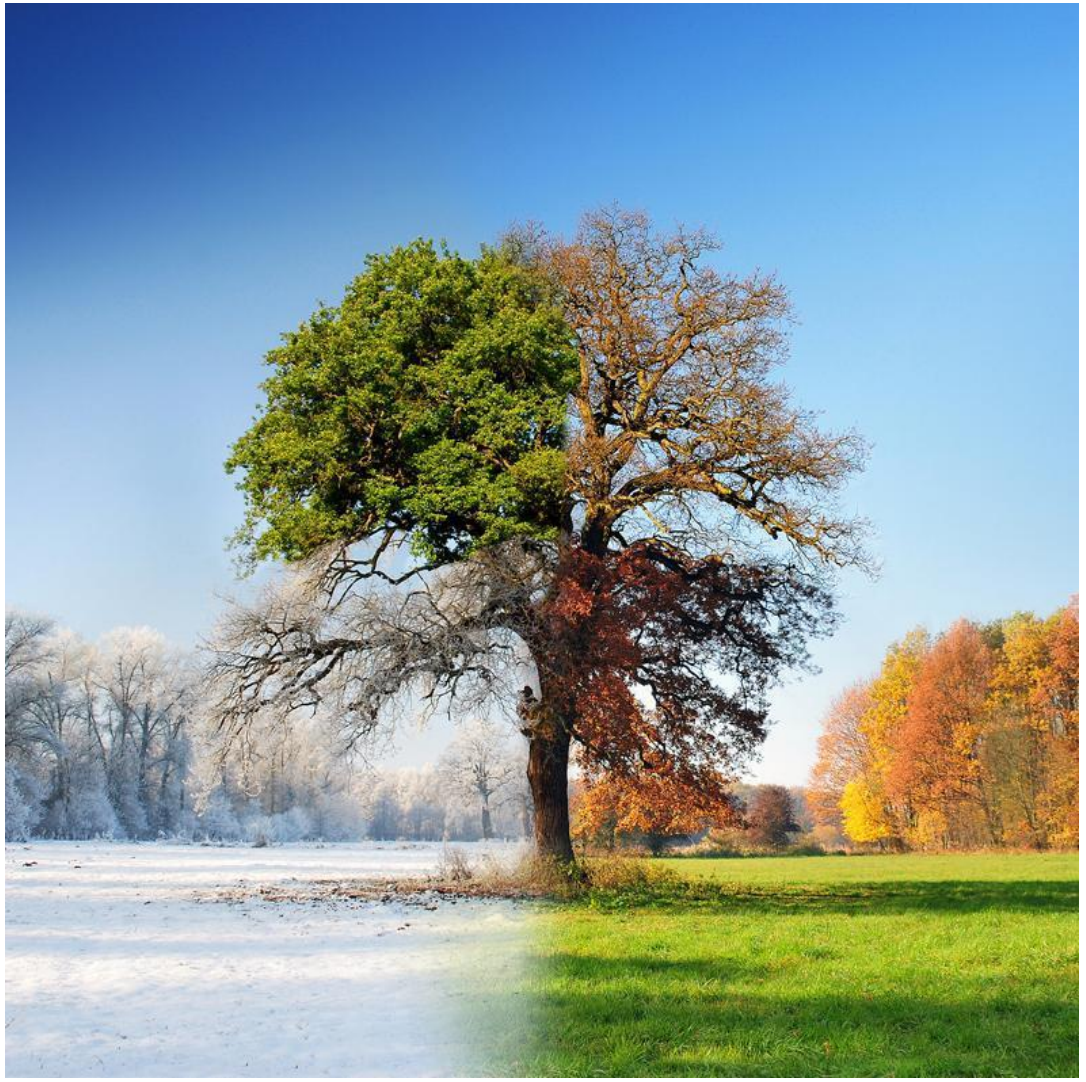
NDVI	1.000000
TNDVI	0.999901
ARVI	0.999040
GNDVI2	0.996843
SAVI	0.995774
NBR	0.994418
GNDVI	0.993543
EVI	0.993383
EVI2	0.993084
BWDRVI	0.992537
RGVI	0.992294
NDMI	0.989918
S2REP	0.988046
GCI	0.984749
PSSRa	0.984149
RVI	0.982727
DSWI	0.980093
BNIR	0.976743
NDI45	0.976497
IRECI	0.973852
MCARI	0.725447
SIPI	0.596313



Time Series Analysis

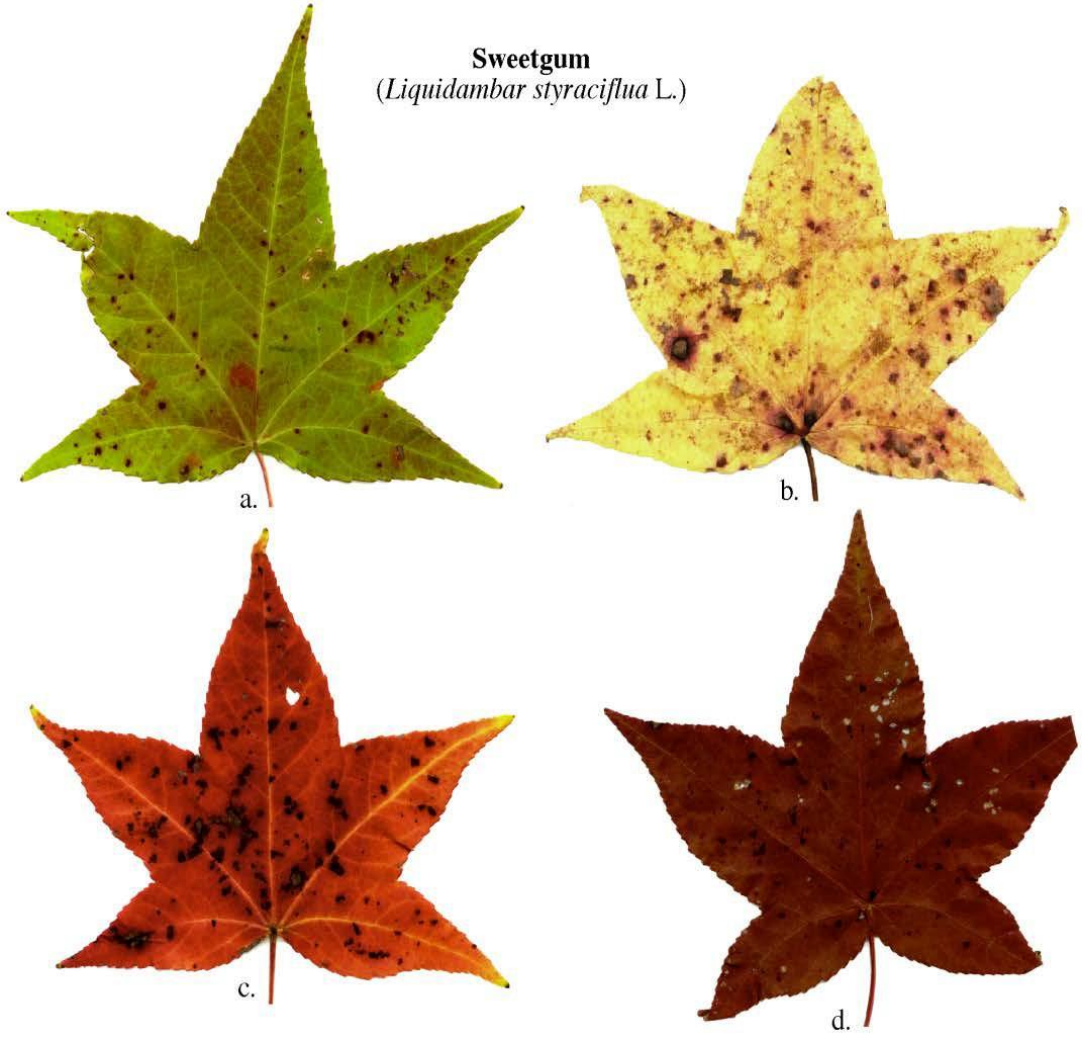
Temporal Development of Vegetation

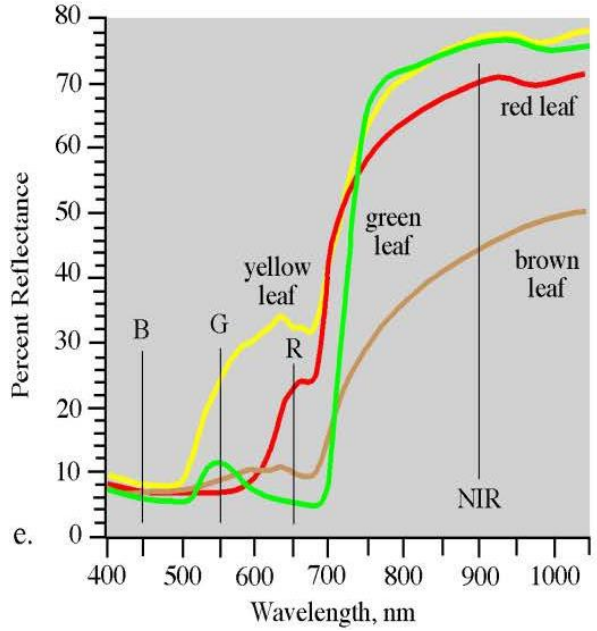




[Welcome to the TIMESAT pages! (lu.se)]

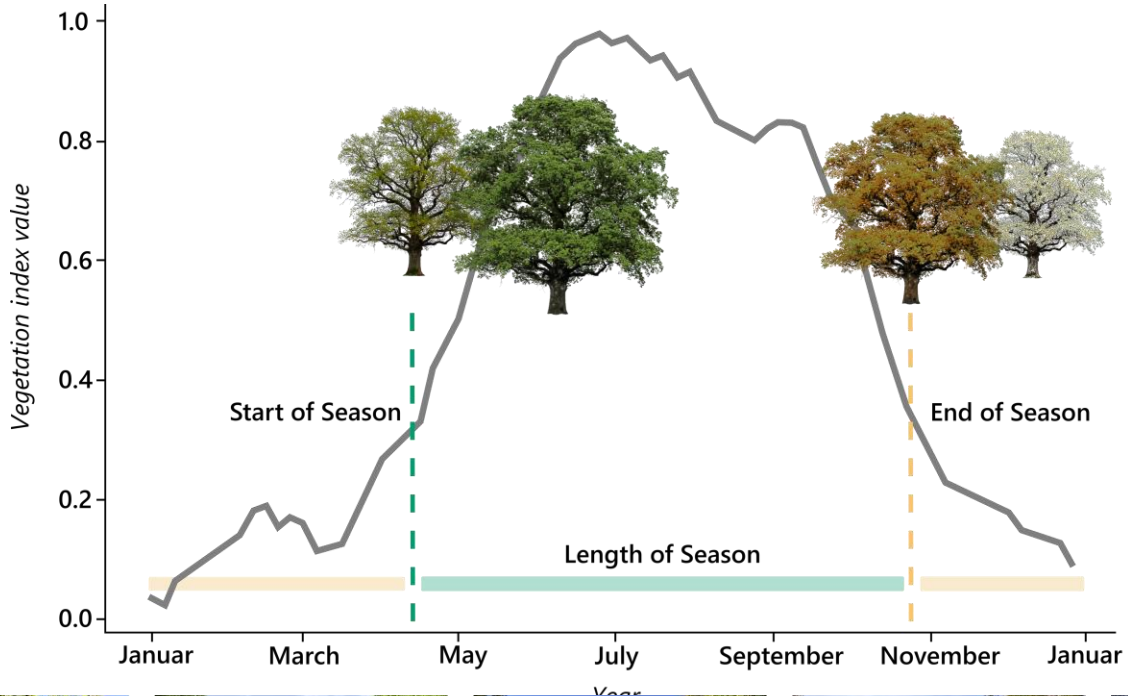
Sweetgum Leaves - (Liquidambar styraciflua L.)

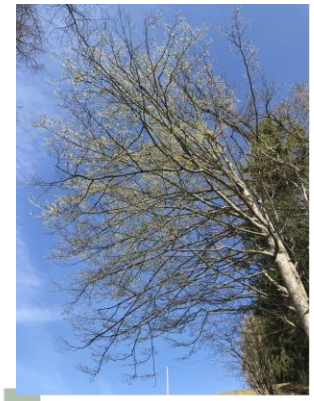


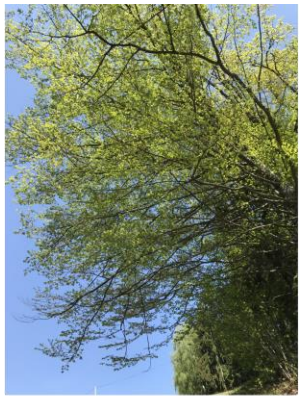


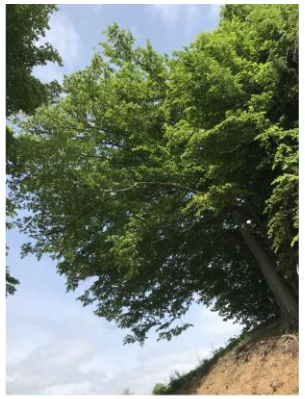
[PowerPoint Presentation (ucdavis.edu)]

European Beech - Fagus sylvatica




11 April 2022


30 April 2022


23 May 2022

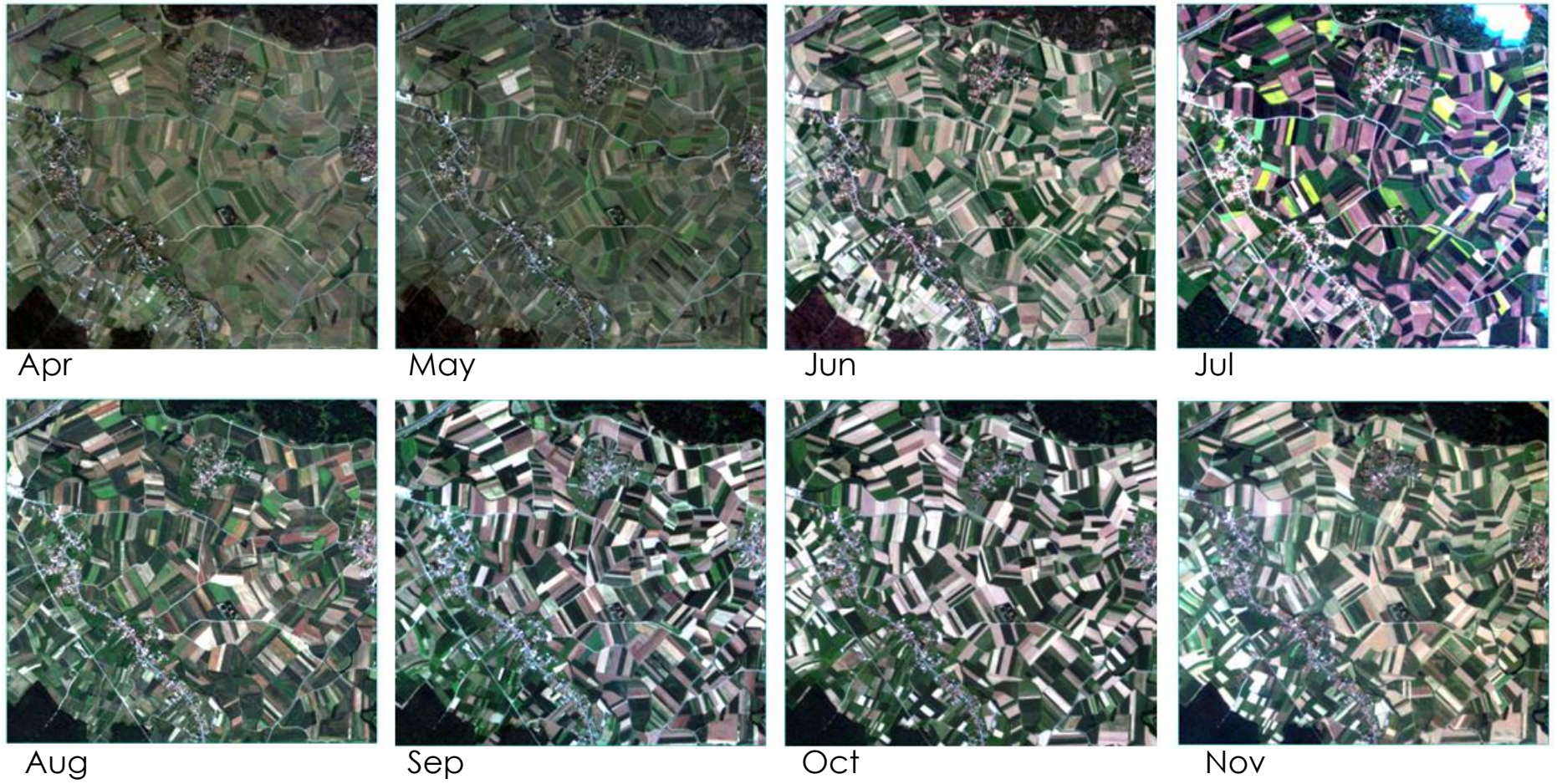
19 September 2022

13 October 2022

23 October 2022

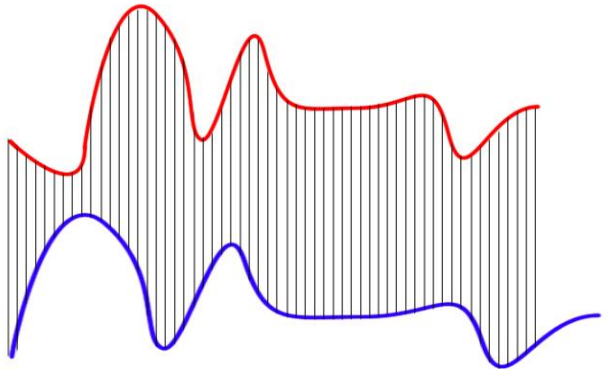
23 January 2023

Time Series of Images

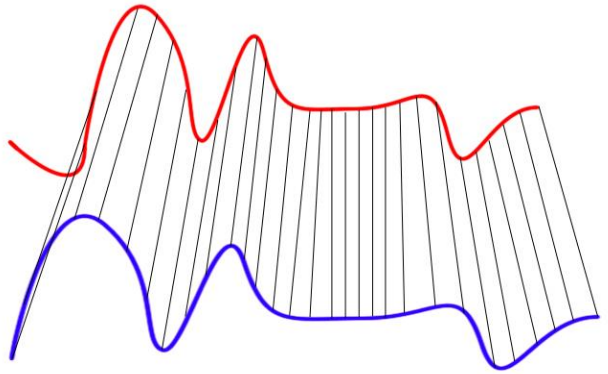


Time series classification

- Quasi time series classification
  - Images are attributes
  - Multidimensional classification, time sequence not considered
- Full time series classification
  - uses information about the development



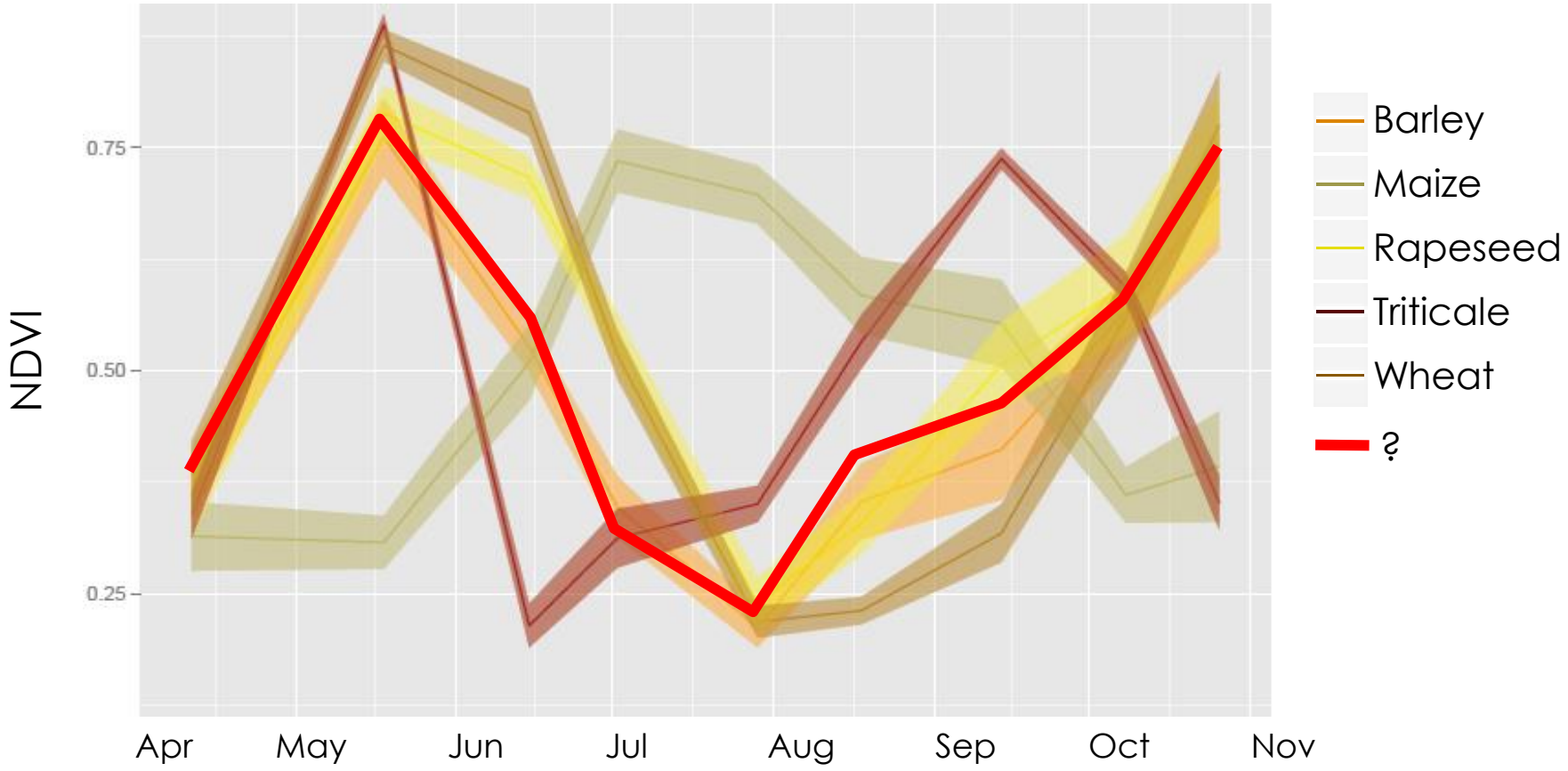
Euclidean distance



Dynamic time warping

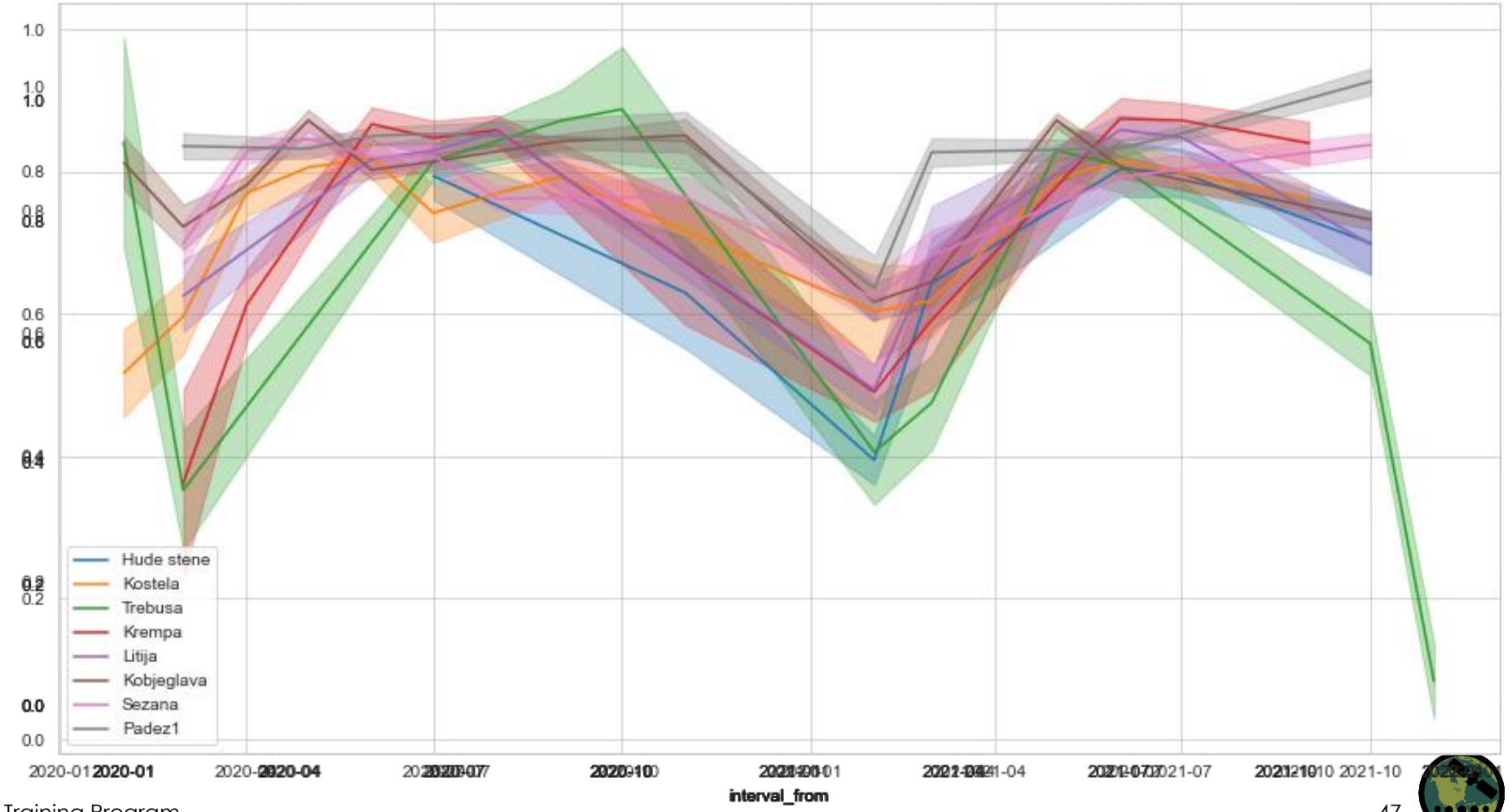
[Dynamic time warping - Wikipedia]

Classification based on time series



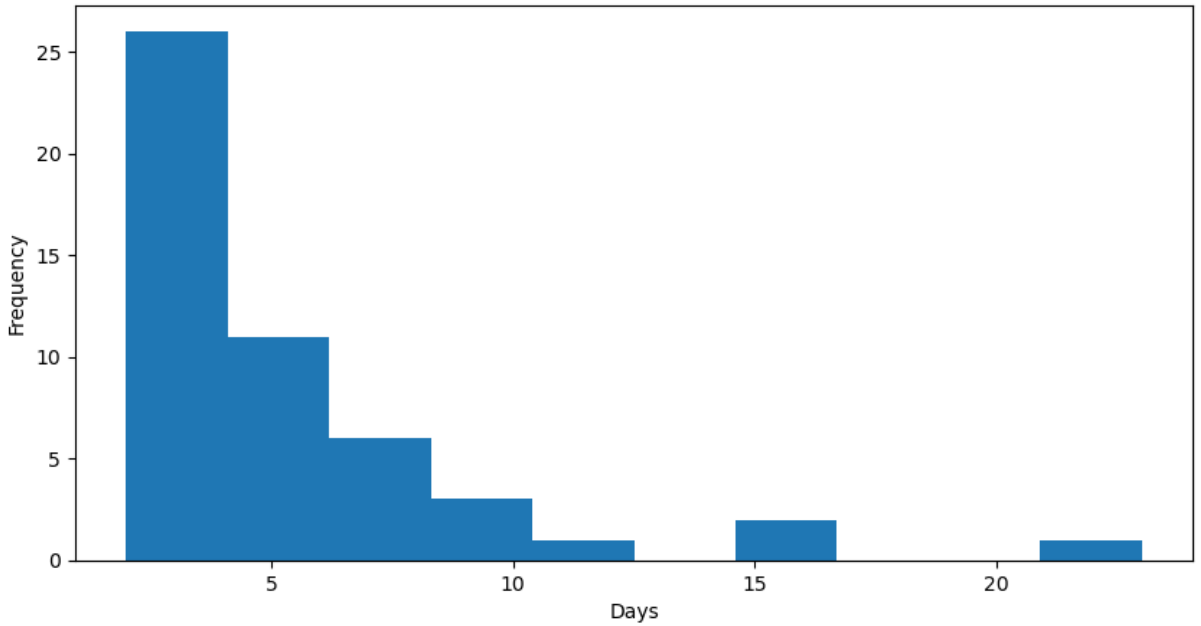
Time Interpolation/Aggregation

- No
- 5 D
- 10 D
- 1 M

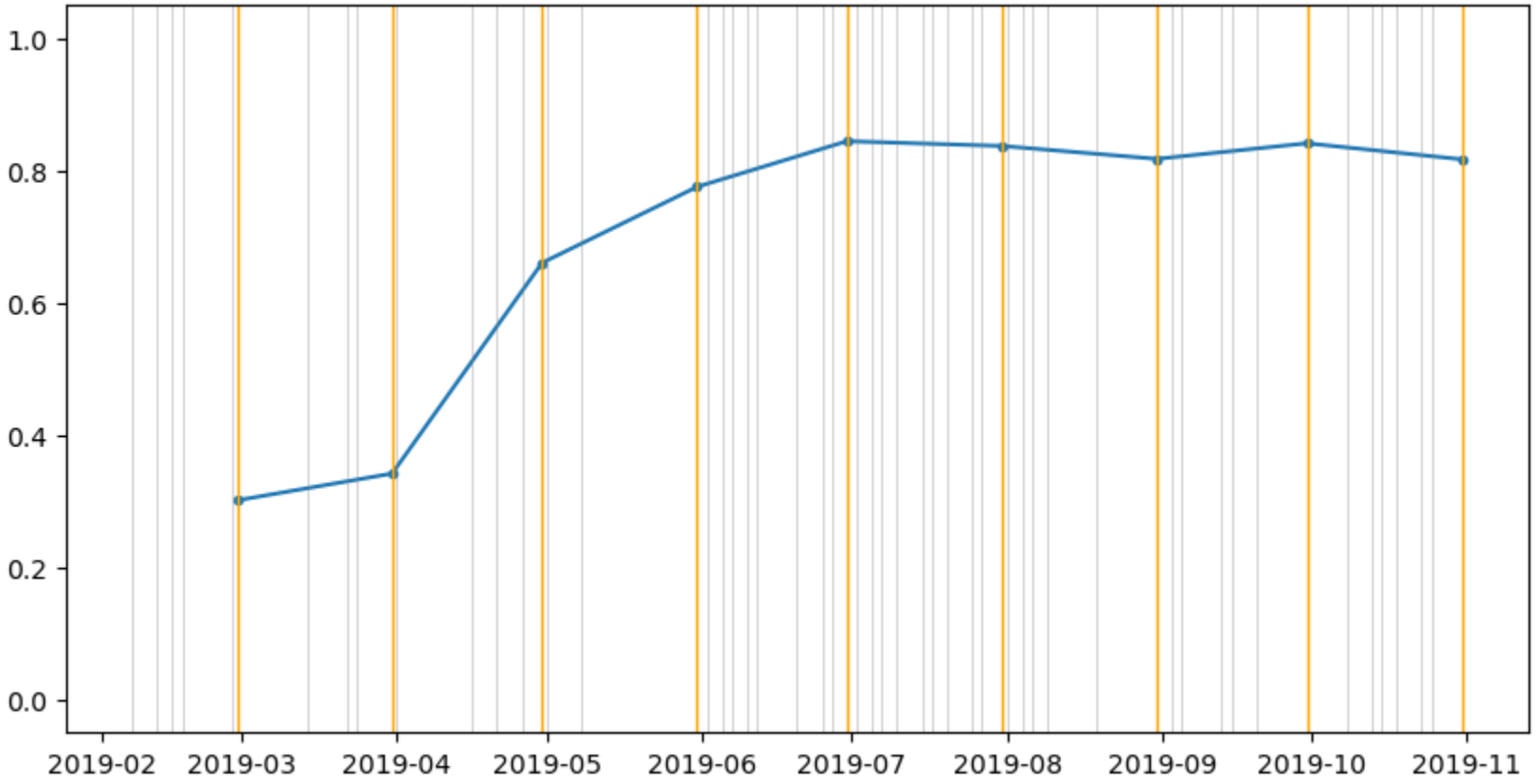


Time synchronization

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

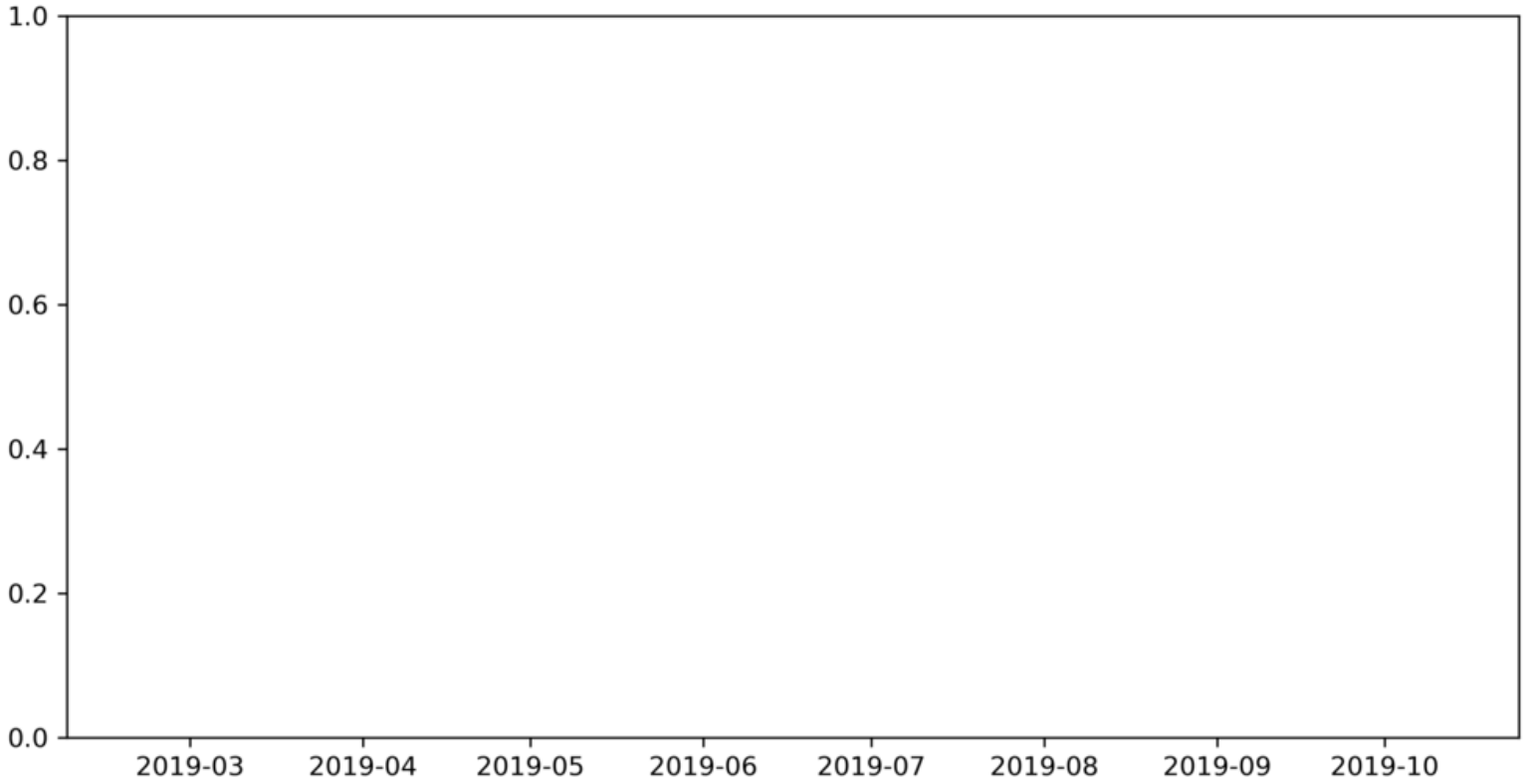


Time synchronization

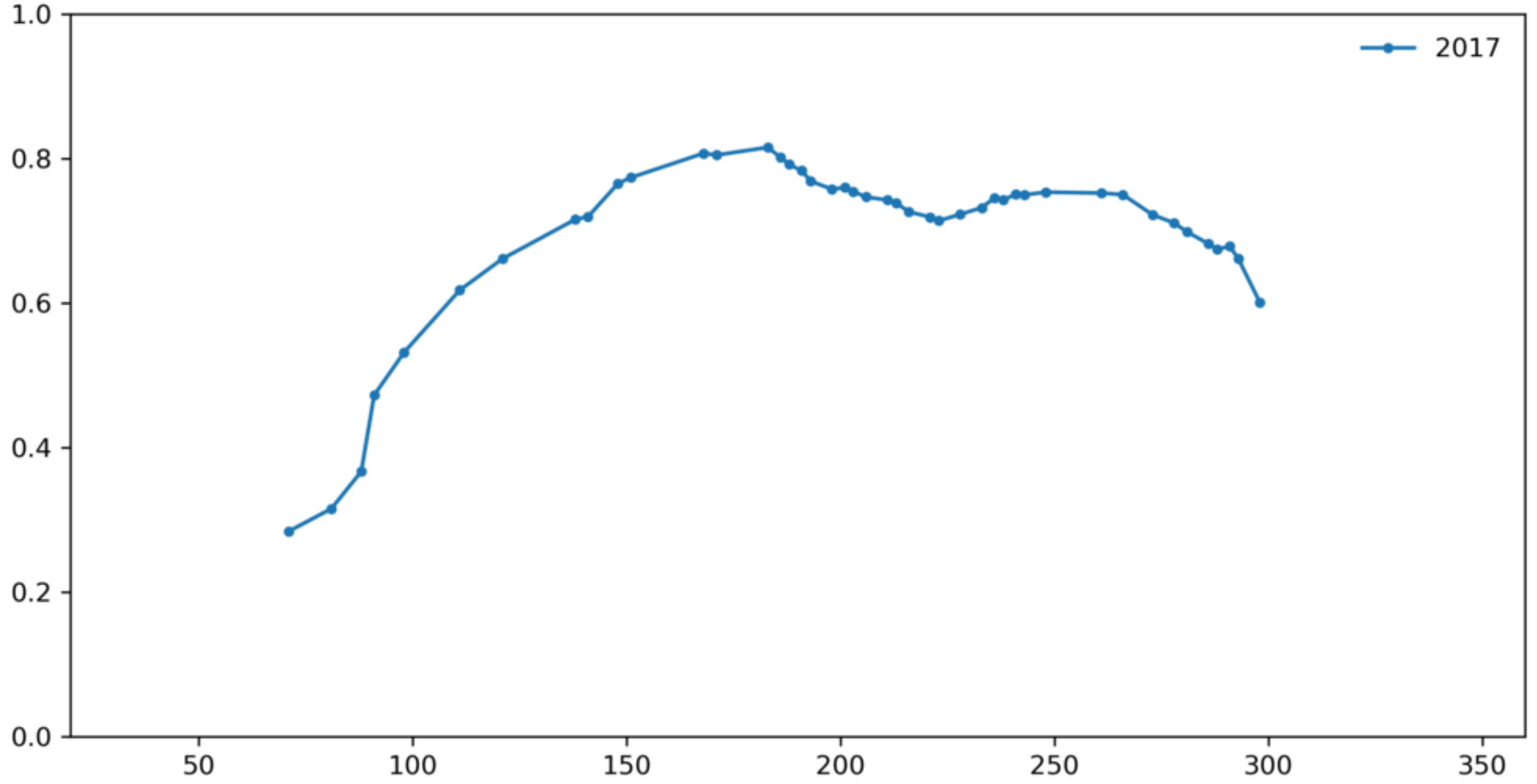


How long must the time series be

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



How long must the time series be



Sentinel Hub

Copernicus Data Space Ecosystem

ROADMAP

What can you expect?

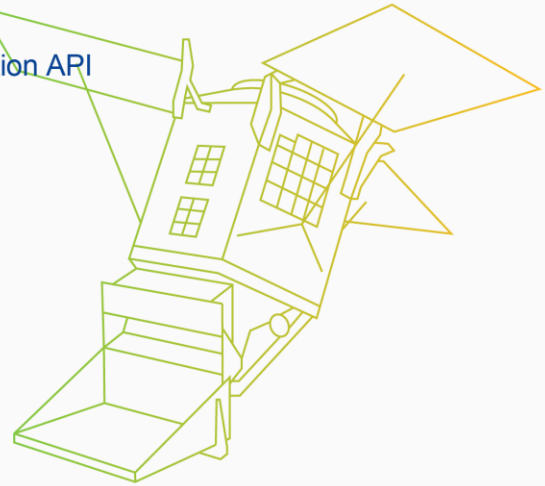
The Copernicus Data Space Ecosystem will be continuously upgraded over the upcoming months. All data and services will be available by July 2023.

January 2023

- Release Copernicus Data Space Ecosystem
- Start of user registration
- Initial Sentinel data offering
- Browser
- Catalogue APIs: OData and OpenSearch

April 2023

- Catalogue API: STAC, S3
- Processing API: Sentinel Hub and OGC for supported collections
- Traceability API
- On-demand production API



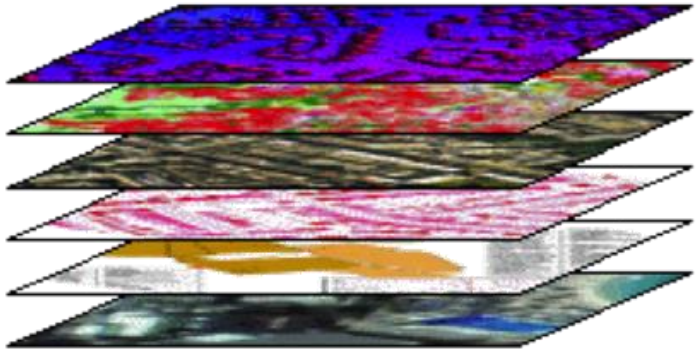
01 July 2023

- Full archive of Sentinel missions
- Complementary open datasets
- Access to commercial data
- Processing API: extended Sentinel Hub APIs, OpenEO
- Jupyter Lab
- Marketplace

November 2023

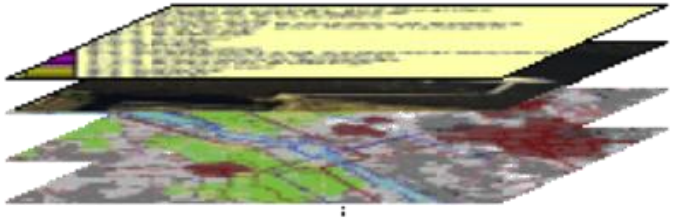
- Sentinel engineering and auxiliary data
- Copernicus Contributing Missions
- Streamlined data access of federated data sets

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

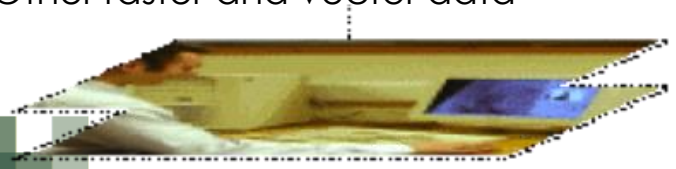


Commercial EO data – WorldWind, GeoEye, ...

Aerial imagery (drone, airplane)



Other raster and vector data



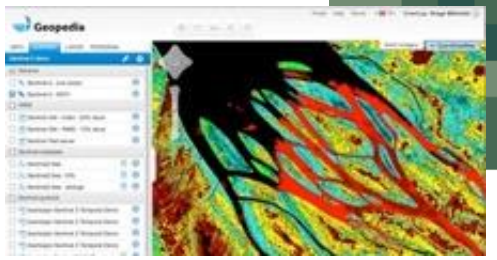
SENTINEL Hub

WMTS

WMS

WCS

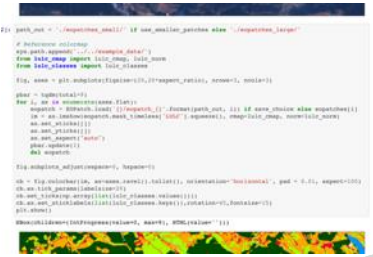
Sinergise



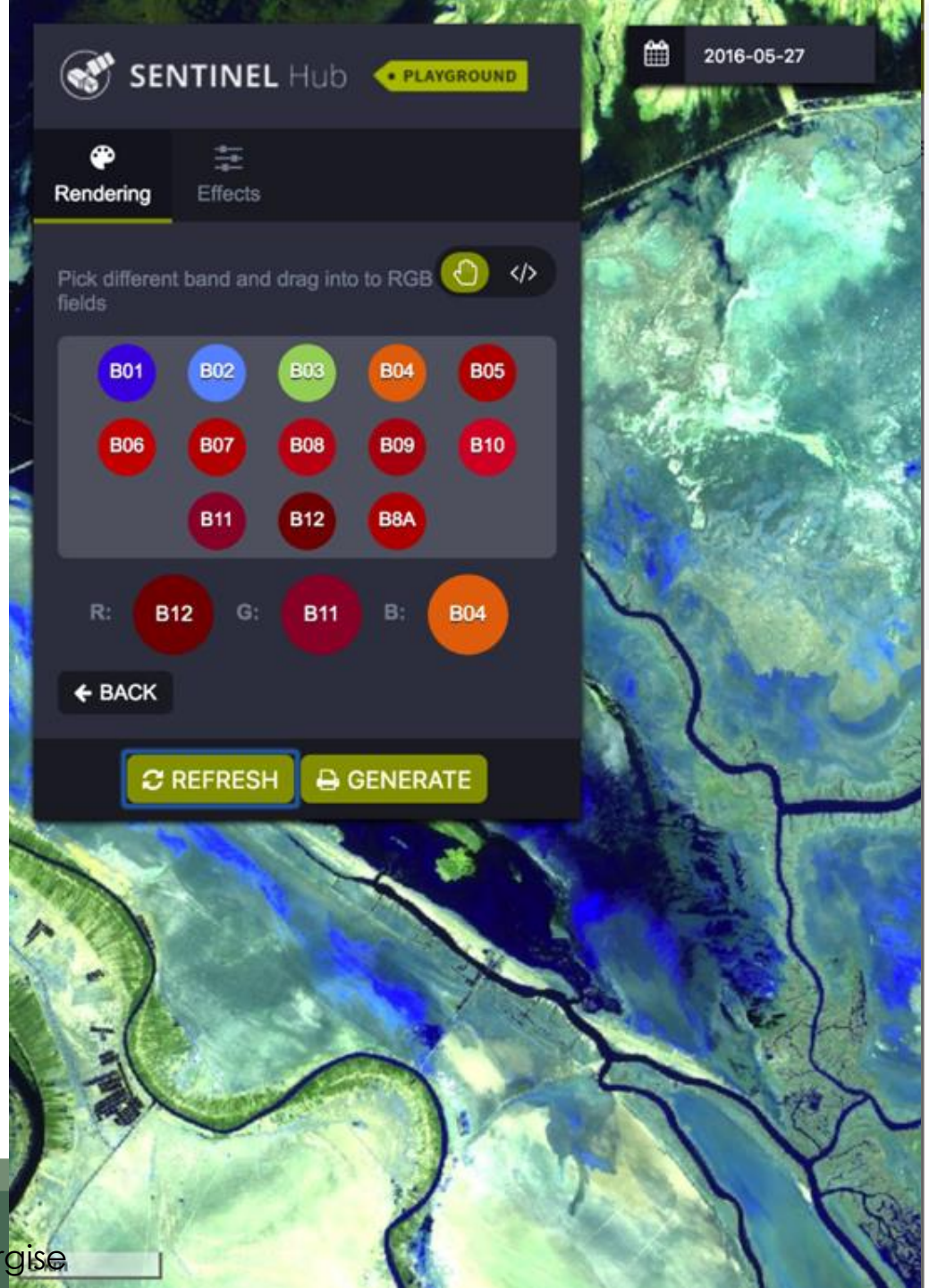
Cloud GIS

Web / Mobile apps

Desktop (QGIS, ArcGIS...)

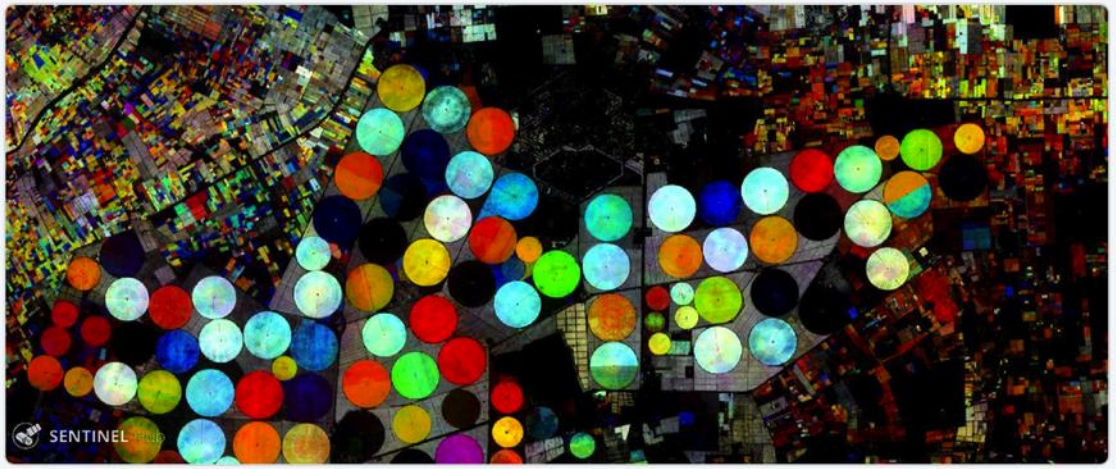


Scripting (Python, R, ENVI...)



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…



4 5 20

Stef Lhermitte
@StefLhermitte

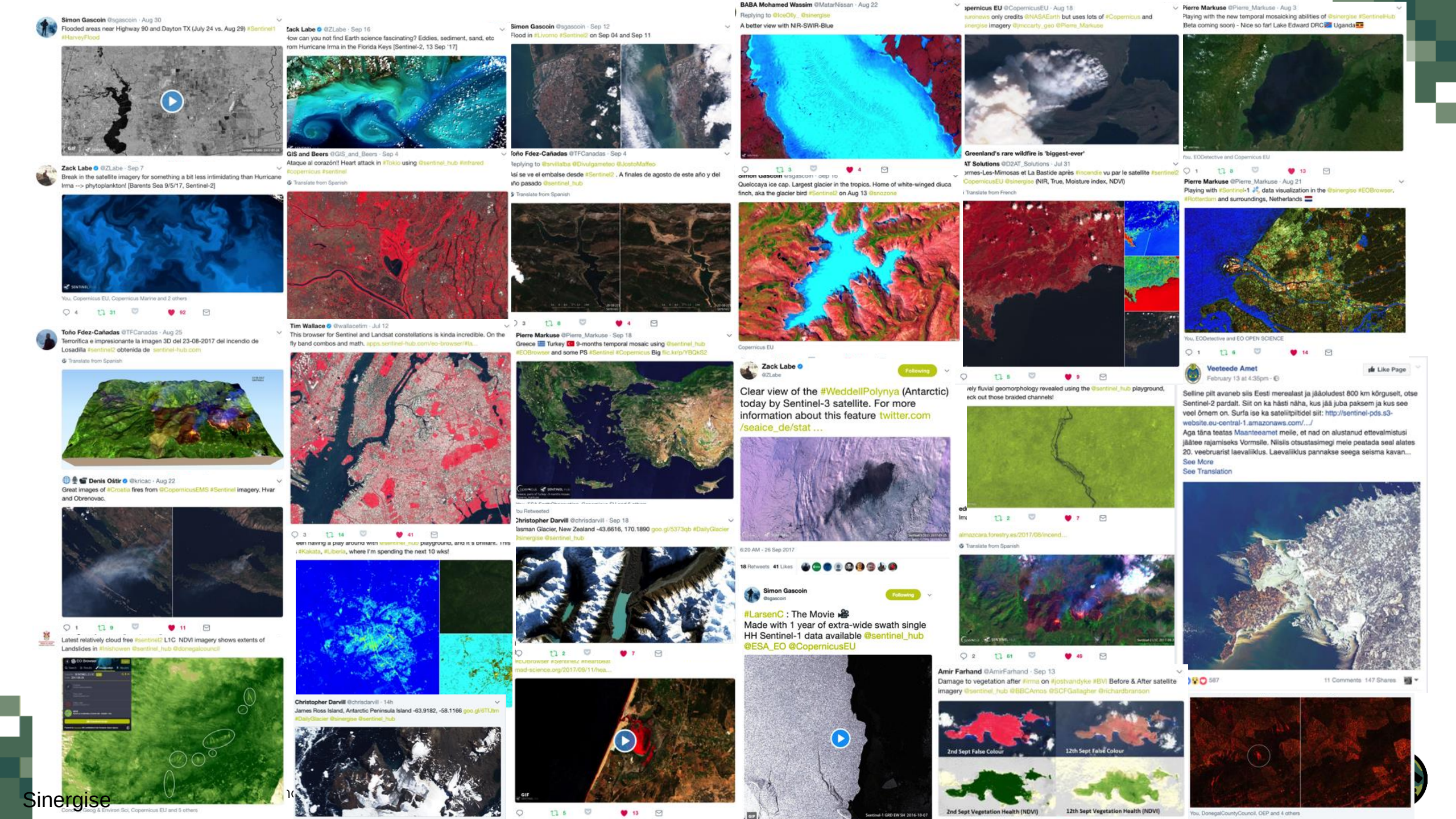
Following

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

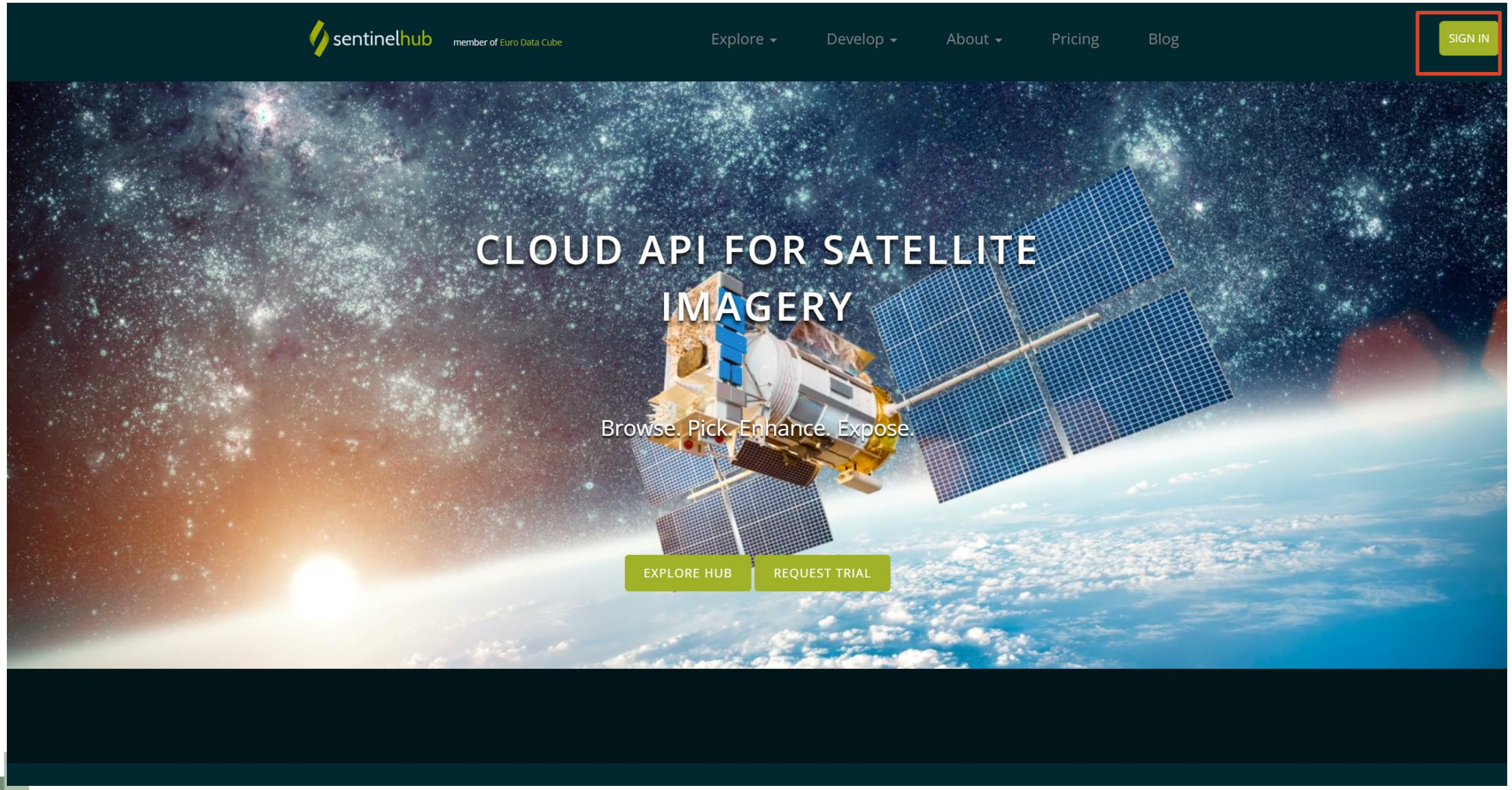
8:14 AM - 25 Oct 2017

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 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]
Simon Gascoin @sgascoin · Sep 12
Flood in #Livorno #Sentinel2 on Sep 04 and Sep 11
BABA Mohamed Wassim @MatarNissan · Aug 22
Replying to @IceOlly_ @sinergise
A better view with NIR-SWIR-Blue
Pierre Markuse @Pierre_Markuse · Aug 3
Playing with the new temporal mosaicking abilities of @sinergise #SentinelHub (Beta coming soon) - Nice so far! Lake Edward DRC Uganda
GIS and Beers @GIS_and_Beers · Sep 4
Ataque al corazón!! Heart attack in #Tokio using @sentinel_hub #infrared #copernicus #sentinel
Translate from Spanish
Toño Fdez-Cañadas @TFCanadas · Sep 4
Replying to @srvillalba @Divulgameteo @JostoMaffeo
Así se ve el embalse desde #Sentinel2 . A finales de agosto de este año y del año pasado @sentinel_hub
Translate from Spanish
Greenland's rare wildfire is 'biggest-ever'
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]
Quelccaya ice cap. Largest glacier in the tropics. Home of white-winged diuca finch, aka the glacier bird #Sentinel2 on Aug 13 @snazone
Translate from French
Pierre Markuse @Pierre_Markuse · Aug 21
Playing with #Sentinel-1 data visualization in the @sinergise #EOBrowser, #Rotterdam and surroundings, Netherlands
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/eo-browser/#la...
Pierre Markuse @Pierre_Markuse · Sep 18
Greece Turkey 9-months temporal mosaic using @sentinel_hub #EOBrowser and some PS #Sentinel #Copernicus Big flic.kr/p/YBQkS2
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
Translate from Spanish
Zack Labe @ZLabe
Following
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
Veeteede Amet
February 13 at 4:35pm
Like Page
Selline pilt avaneb siis Eesti merealast ja jääoludest 800 km kõrguselt, otse Sentinel-2 pardalt. Siit on ka hästi näha, kus jää juba paksem ja kus see veel õrnem on. Surfa ise ka sateliitpiltidel siit: http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/.../
Aga täna teatas Maanteeamet meile, et nad on alustanud ettevalmistusi jäätee rajamiseks Vormsile. Niisiis otsustasimegi meie peatada seal alates 20. veebruarist laevaliiklus. Laevaliiklus pannakse seega seisma kavan...
See More
See Translation
Denis Oštir @kricac · Aug 22
Great images of #Croatia fires from @CopernicusEMS #Sentinel imagery. Hvar and Obrenovac.
Christopher Darvill @chrisdarvill · Sep 18
Tasman Glacier, New Zealand -43.6616, 170.1890 goo.gl/5373qb #DailyGlacier #sinergise @sentinel_hub
Simon Gascoin
Following
#LarsenC : The Movie
Made with 1 year of extra-wide swath single HH Sentinel-1 data available @sentinel_hub @ESA_EO @CopernicusEU
Latest relatively cloud free #sentinel2 L1C NDVI imagery shows extents of Landslides in #Nishowen @sentinel_hub @donegalcouncil
Christopher Darvill @chrisdarvill · 14h
James Ross Island, Antarctic Peninsula Island -63.9182, -58.1166 goo.gl/6TIJtm #DailyGlacier @sinergise @sentinel_hub
Amir Farhand @AmirFarhand · Sep 13
Damage to vegetation after #irma on #jostvandyke #BVI Before & After satellite imagery @sentinel_hub @BBCAmos @SCFGallagher @richardbranson
2nd Sept False Colour
12th Sept False Colour
2nd Sept Vegetation Health (NDVI)
12th Sept Vegetation Health (NDVI)

Sinergise

Create Sentinel Hub Account



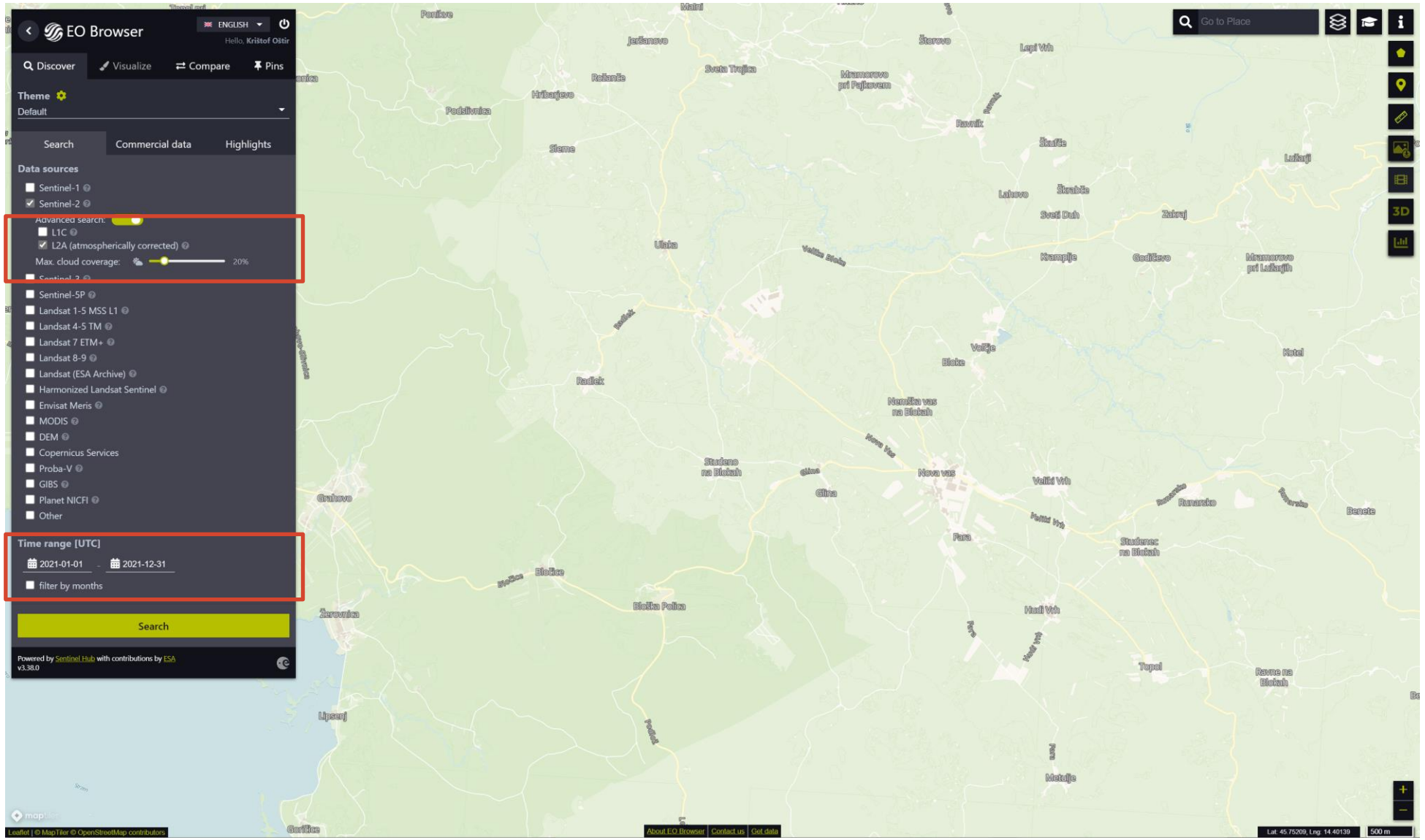
Create Sentinel Hub Account

Create Sentinel Hub Account

- After you create an account, you enter the trial mode
- Send the Sentinel Hub registered email to matej.racic@fgg.uni-lj.si
- You will get credits for processing and advanced use

- ESA (Network of Resources) and Sinergise are sponsoring the use for ARSET participants

EO Browser


EO Browser
ENGLISH
Hello, Krištof Oštir
Discover
Visualize
Compare
Pins
Theme
Default
Search
Commercial data
Highlights
Data sources
Sentinel-1
Sentinel-2
Advanced search:
L1C
L2A (atmospherically corrected)
Max. cloud coverage:
20%
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]
2021-01-01
2021-12-31
filter by months
Search
Powered by Sentinel Hub with contributions by ESA
v3.38.0
Go to Place
3D
Leaflet | © MapTiler © OpenStreetMap contributors
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Hello, Krištof Oštir
Discover
Visualize
Compare
Pins
Back to search
Showing 24 results
Sentinel-2 L2A
2021-12-31
10:08:02 UTC
0.8%
33TVL
Visualize
Sentinel-2 L2A
2021-10-27
10:08:11 UTC
8.6%
33TVL
Visualize
Sentinel-2 L2A
2021-10-17
10:08:12 UTC
2.8%
33TVL
Visualize
Sentinel-2 L2A
2021-09-12
10:08:03 UTC
0.5%
33TVL
Visualize
Sentinel-2 L2A
2021-09-02
10:08:03 UTC
1.9%
33TVL
Visualize
Sentinel-2 L2A
2021-08-18
10:08:09 UTC
2.9%
33TVL
Powered by Sentinel Hub with contributions by ESA
v3.38.0
Go to Place
3D
About EO Browser
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Get data
Lat: 45.77874, Lng: 14.44147
500 m

EO Browser

EO Browser
ENGLISH
Hello, Krištof Oštir
Discover
Visualize
Compare
Pins
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
Powered by Sentinel Hub with contributions by ESA
v3.38.0
Go to Place
3D
Ponikve
Jeršanovo
Štorovo
Lepi Vrh
Rožanče
Sveta Trojica
Mramorovo pri Pajkovem
Hribarjevo
Podslivnica
Ravnik
Škulče
Sleme
Lužarji
Lahovo
Škrabče
Sveti Duh
Zakraj
Ulaka
Velike Bloke
Krampije
Godičevo
Mramorovo pri Lužarjih
Radlek
Volčje
Bloke
Kotel
Nemška vas na Blokah
Studeno na Blokah
Glina
Nova Vas
Veliki Vrh
Grahovo
Runarsko
Benete
Fara
Studenec na Blokah
Bločice
Žerovnica
Bloška Polica
Hudi Vrh
Topol
Ravne na Blokah
Lipsenj
Podlož
Metulje
Goričice
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500 m

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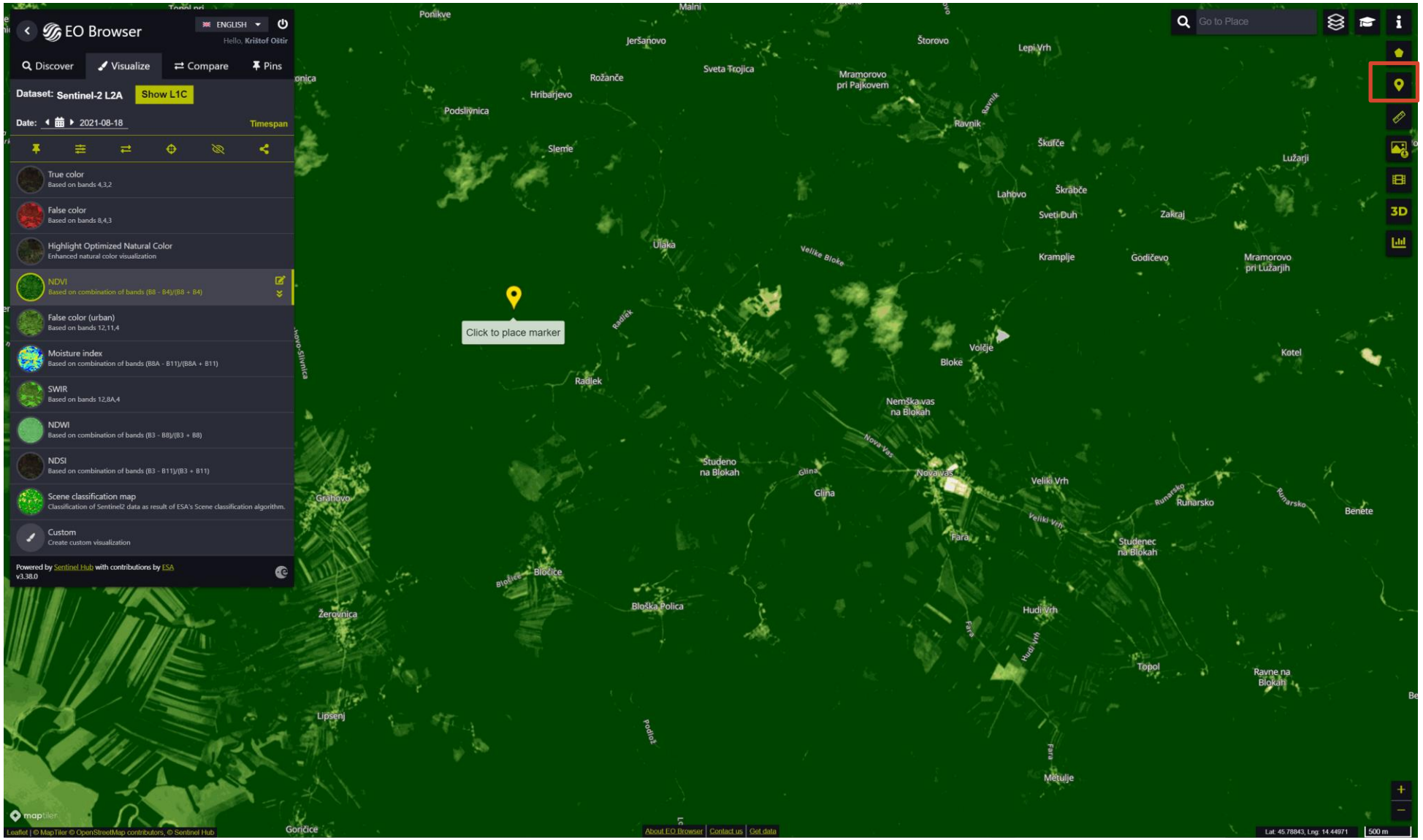
EO Browser
ENGLISH
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Compare
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Dataset: Sentinel-2 L2A
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Based on combination of bands (B3 - B11)/(B3 + B11)
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Hribarjevo
Podslivnica
Ravnik
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Sleme
Lužarji
Lahovo
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Sveti Duh
Zakraj
Ulaka
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Bloke
Kotel
Nemška vas na Blokah
Studeno na Blokah
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Glina
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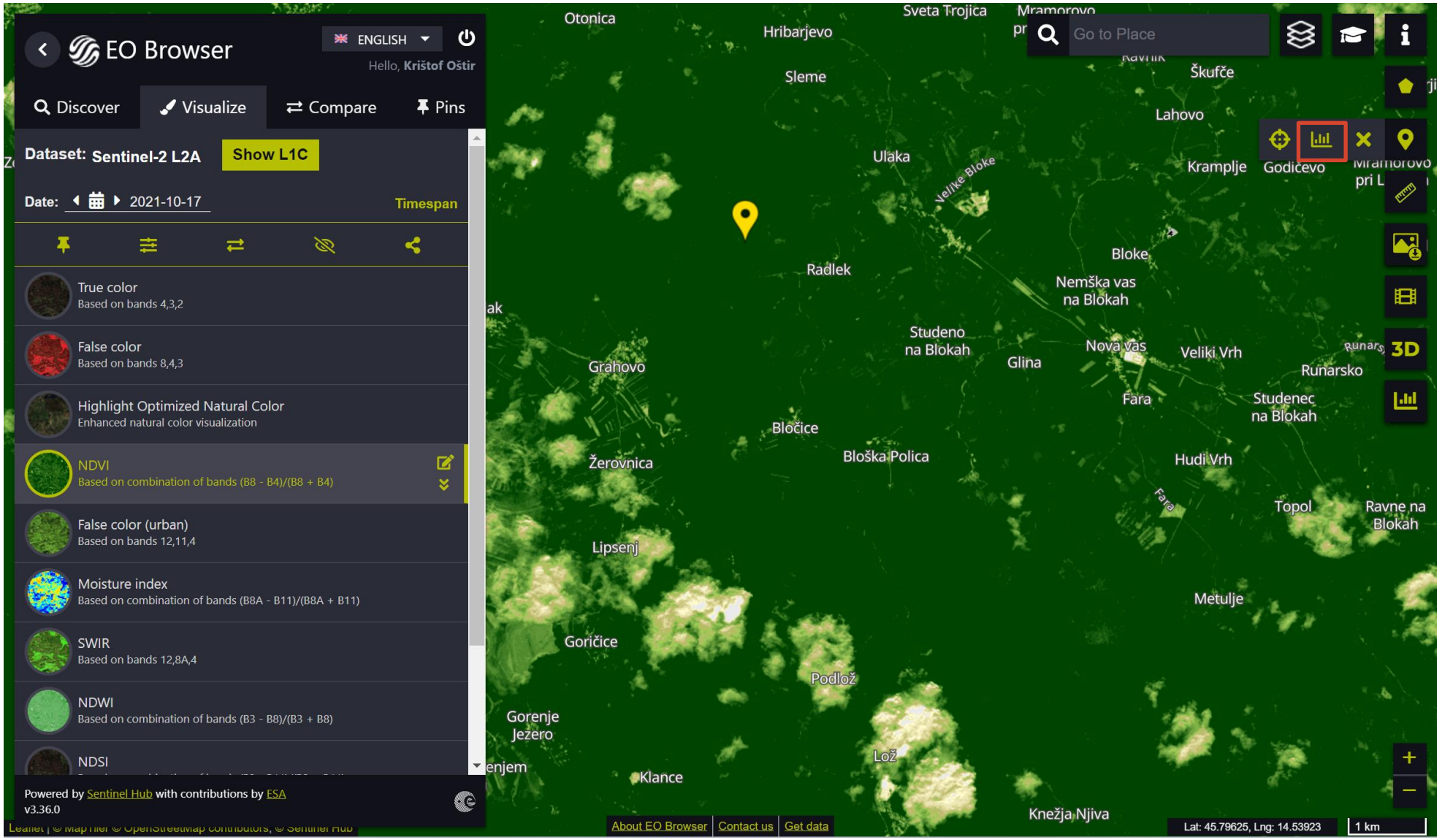
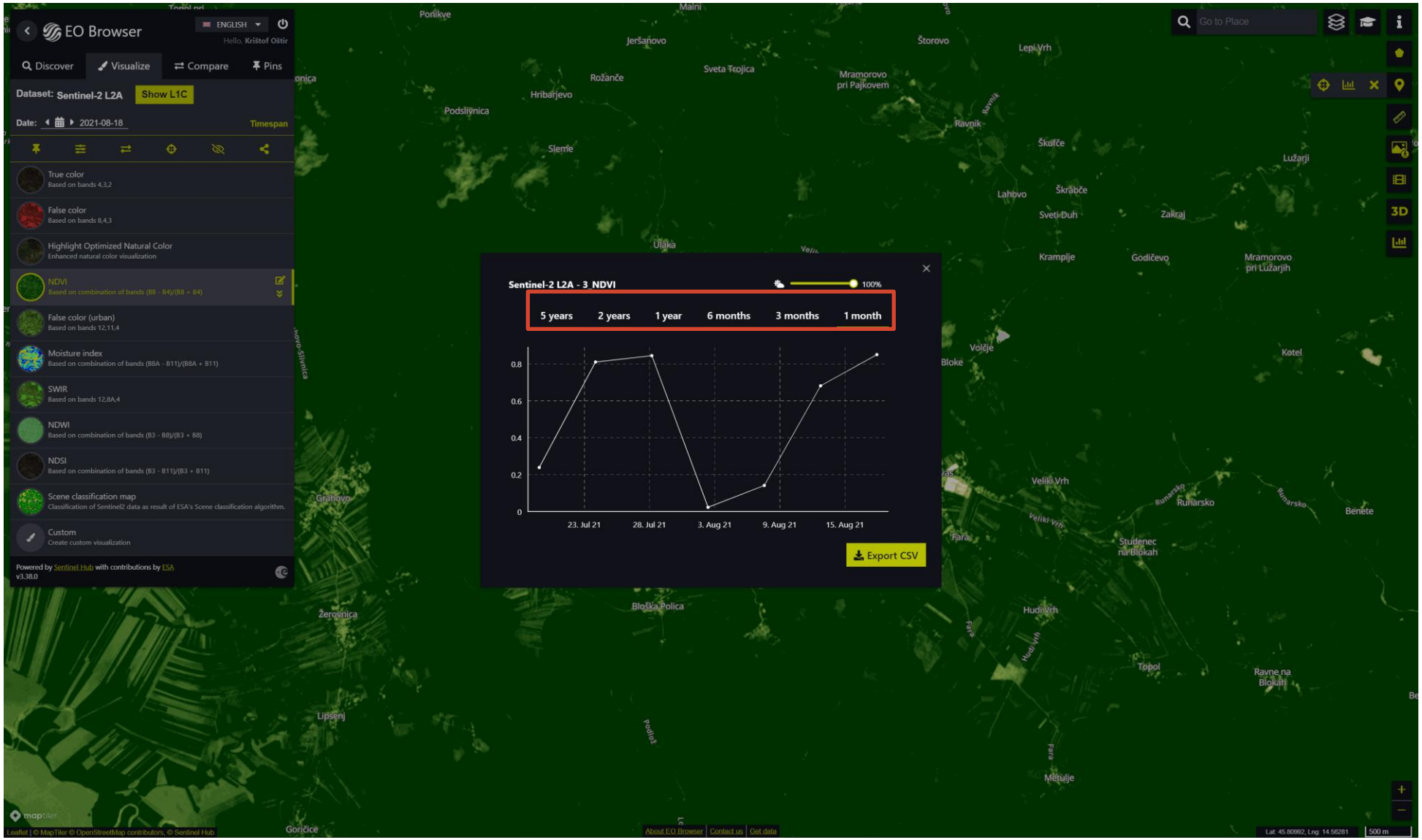
500 m

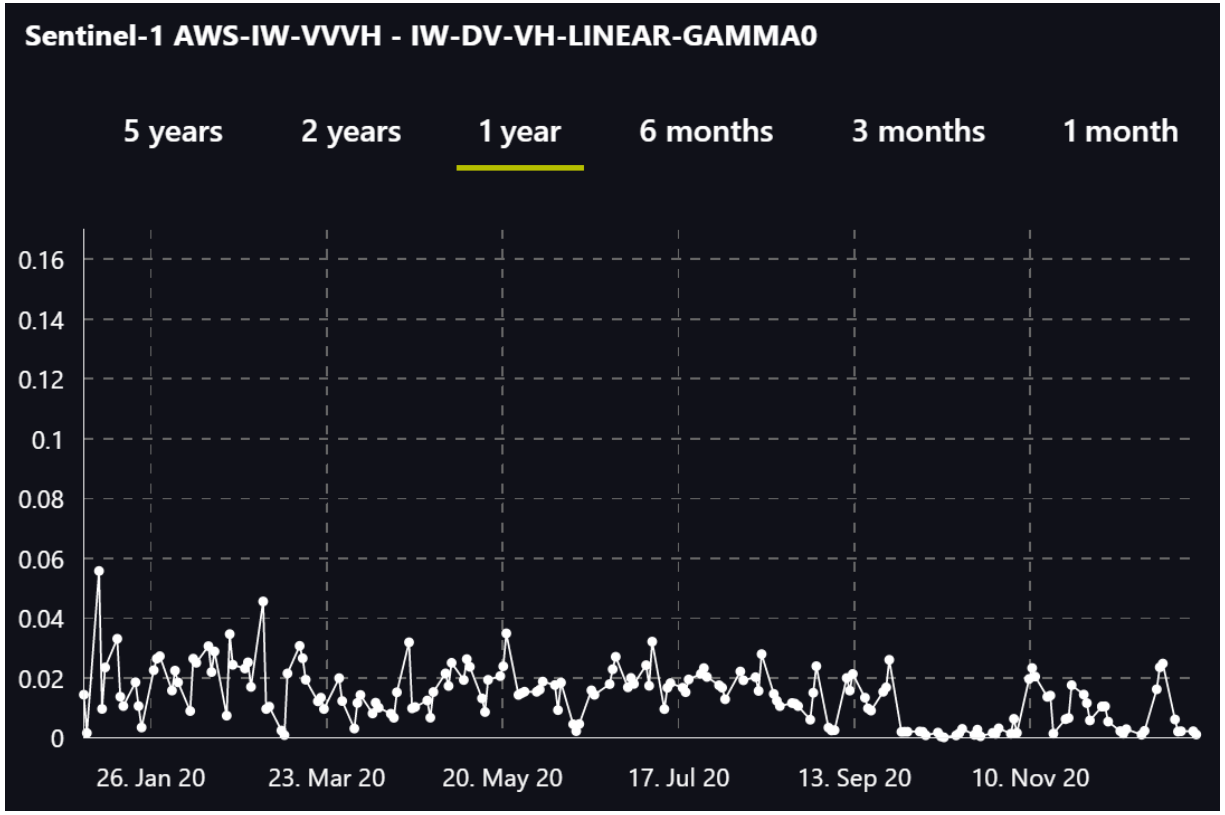
EO Browser

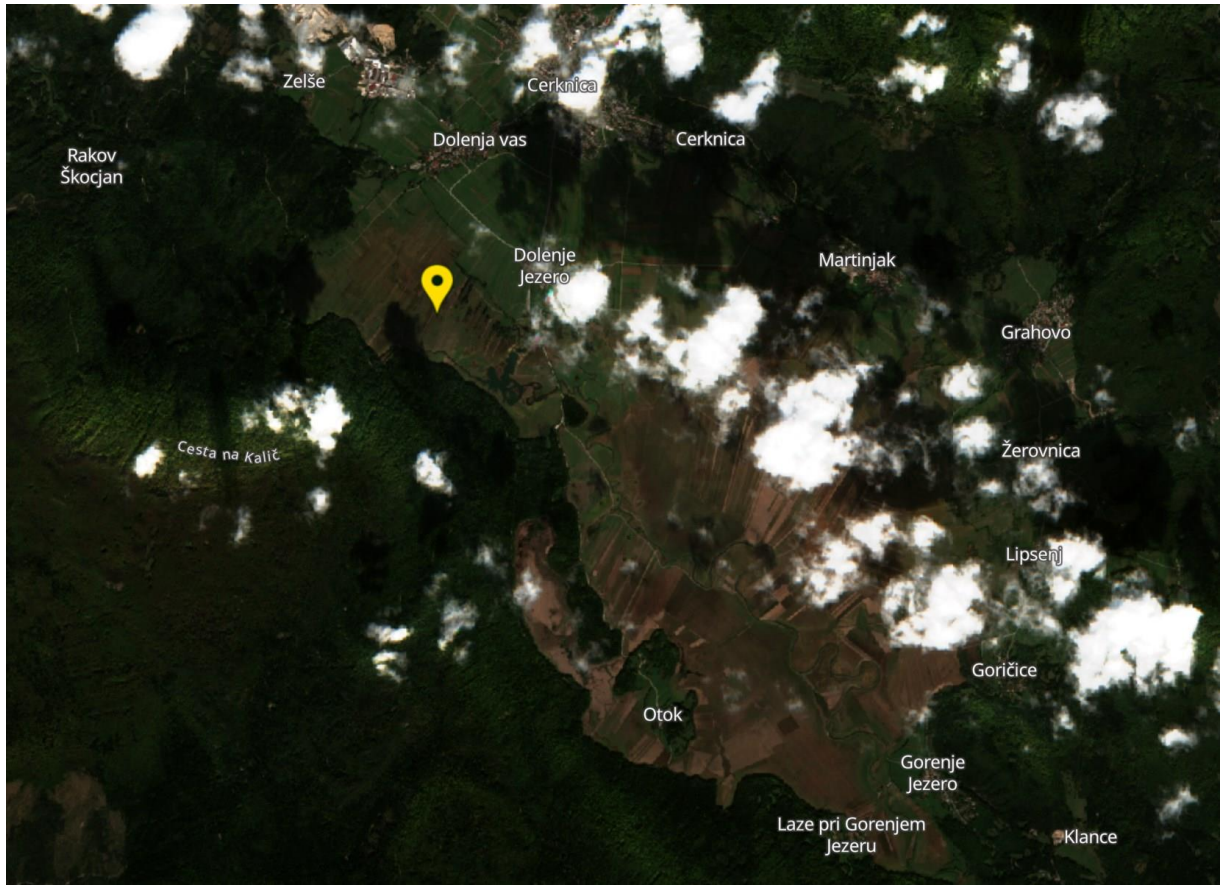

EO Browser
ENGLISH
Hello, Krištof Oštir
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date: 2021-10-17
Timespan
True color
Based on bands 4,3,2
False color
Based on bands 8,4,3
Highlight Optimized Natural Color
Enhanced natural color visualization
NDVI
Based on combination of bands (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
Powered by Sentinel Hub with contributions by ESA
v3.36.0
Go to Place
Otonica
Hribarjevo
Sveta Trojica
Sleme
Škufče
Lahovo
Ulaka
Kramplje
Godičevo
Radlek
Bloke
Nemška vas na Blokah
Studeno na Blokah
Nova vas
Veliki Vrh
Runarsko
Grahovo
Glina
Fara
Studenec na Blokah
Bločice
Žerovnica
Bloška Polica
Hudi Vrh
Topol
Ravne na Blokah
Lipsenj
Metulje
Goričice
Podlož
Gorenje Jezero
Lož
Klance
Knežja Njiva
3D
About EO Browser
Contact us
Get data
Lat: 45.79625, Lng: 14.53923
1 km

EO Browser

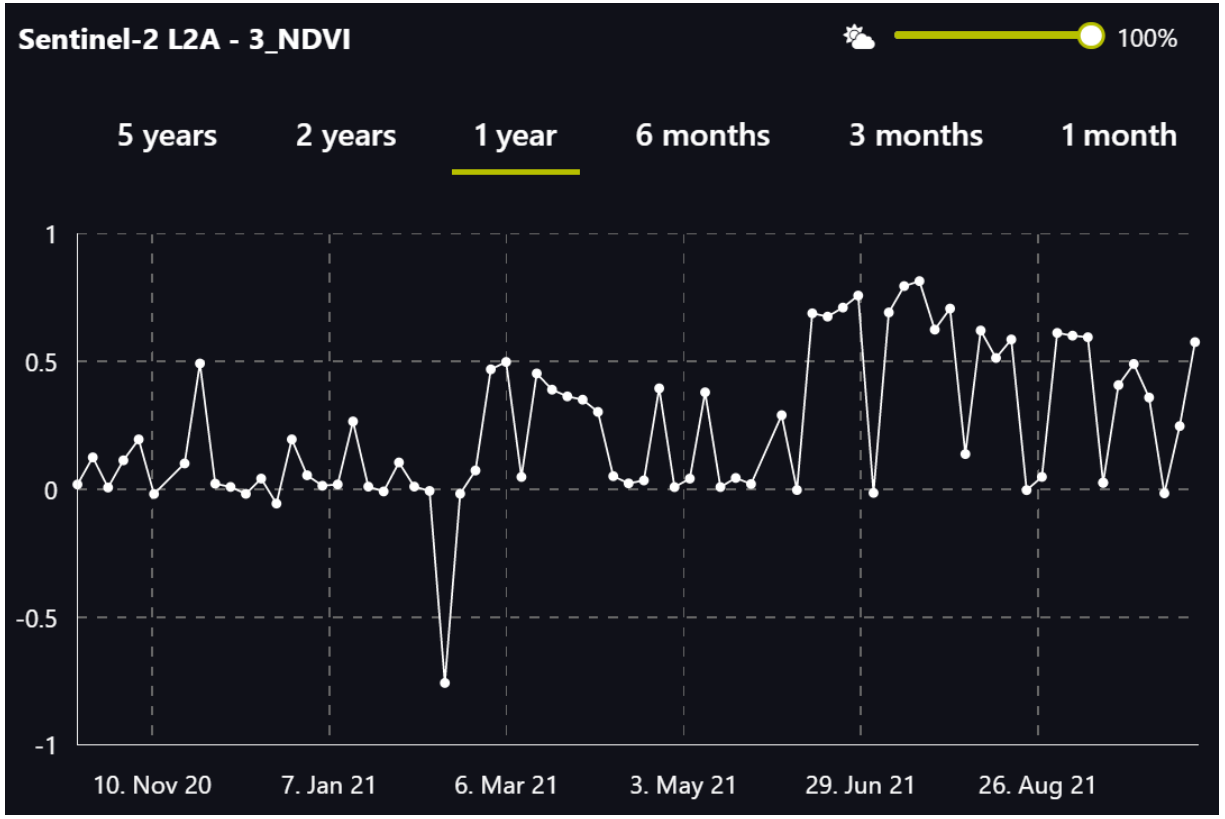

EO Browser
ENGLISH
Hello, Kristof Ostir
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date: 2021-08-18
Timespan
True color
Based on bands 4,3,2
False color
Based on bands 8,4,3
Highlight Optimized Natural Color
Enhanced natural color visualization
NDVI
Based on combination of bands (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
Powered by Sentinel Hub with contributions by ESA
v3.38.0
Sentinel-2 L2A - 3_NDVI
100%
5 years
2 years
1 year
6 months
3 months
1 month
0.8
0.6
0.4
0.2
0
23. Jul 21
28. Jul 21
3. Aug 21
9. Aug 21
15. Aug 21
Export CSV
Go to Place
3D
Ponikve
Jeršanovo
Štorovo
Lepi Vrh
Sveta Trojica
Rožanče
Mramorovo pri Pajkovem
Hribarjevo
Podslivnica
Ravnik
Škofče
Lužarji
Slemše
Lahovo
Škrabče
Sveti Duh
Zakraj
Ulaka
Krmplje
Godičevo
Mramorovo pri Lužarjih
Volčje
Bloke
Kotel
Veliki Vrh
Runarsko
Benete
Grahovo
Studenec na Blokah
Bloška Polica
Hudi Vrh
Žerovnica
Topol
Ravne na Blokah
Lipsenj
Podlisk
Metulje
Goričice
maptiler
Leaflet | © MapTiler © OpenStreetMap contributors, © Sentinel Hub
About EO Browser
Contact us
Get data
Lat: 45.80992, Lng: 14.56281
500 m

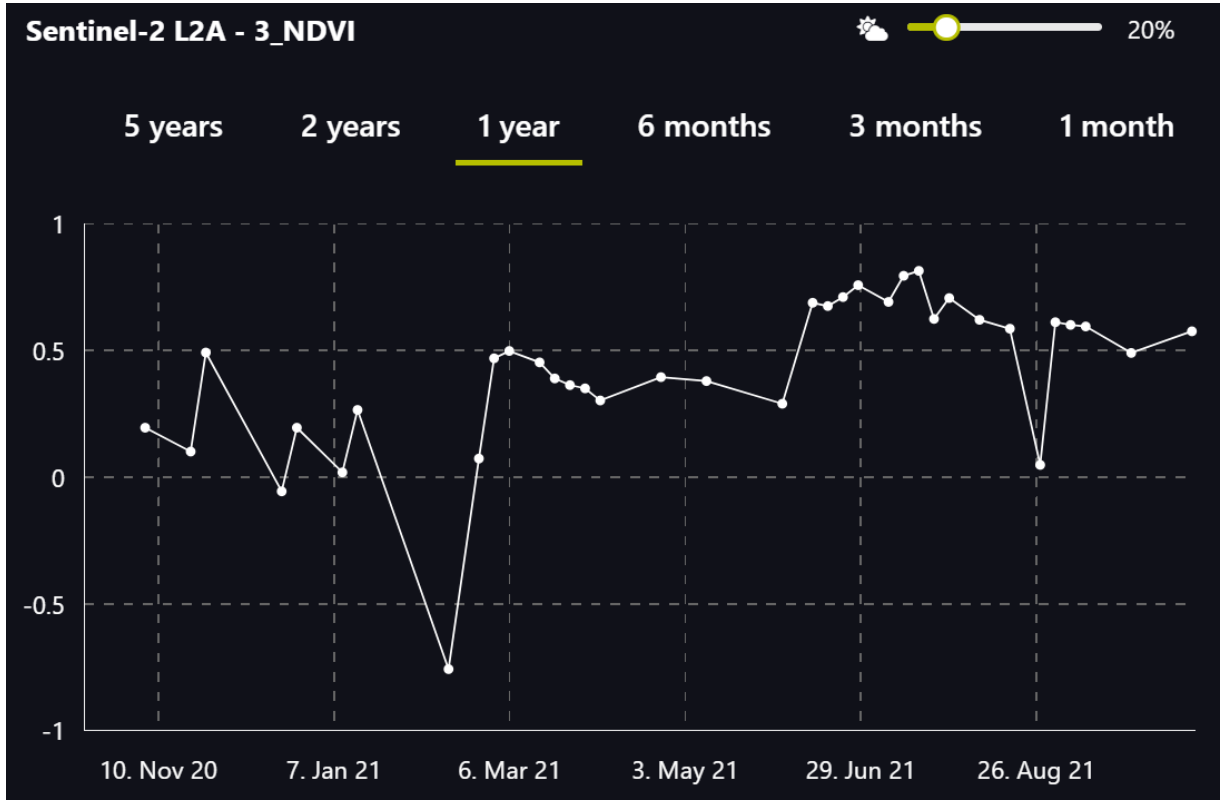
EO Browser


Sentinel-1 AWS-IW-VVVH - IW-DV-VH-LINEAR-GAMMA0
5 years
2 years
1 year
6 months
3 months
1 month
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
26. Jan 20
23. Mar 20
20. May 20
17. Jul 20
13. Sep 20
10. Nov 20


Zelše
Cerknica
Dolenja vas
Cerknica
Rakov Škocjan
Dolenje Jezero
Martinjak
Grahovo
Cesta na Kalič
Žerovnica
Lipsenj
Goričice
Otok
Gorenje Jezero
Laze pri Gorenjem Jezeru
Klance

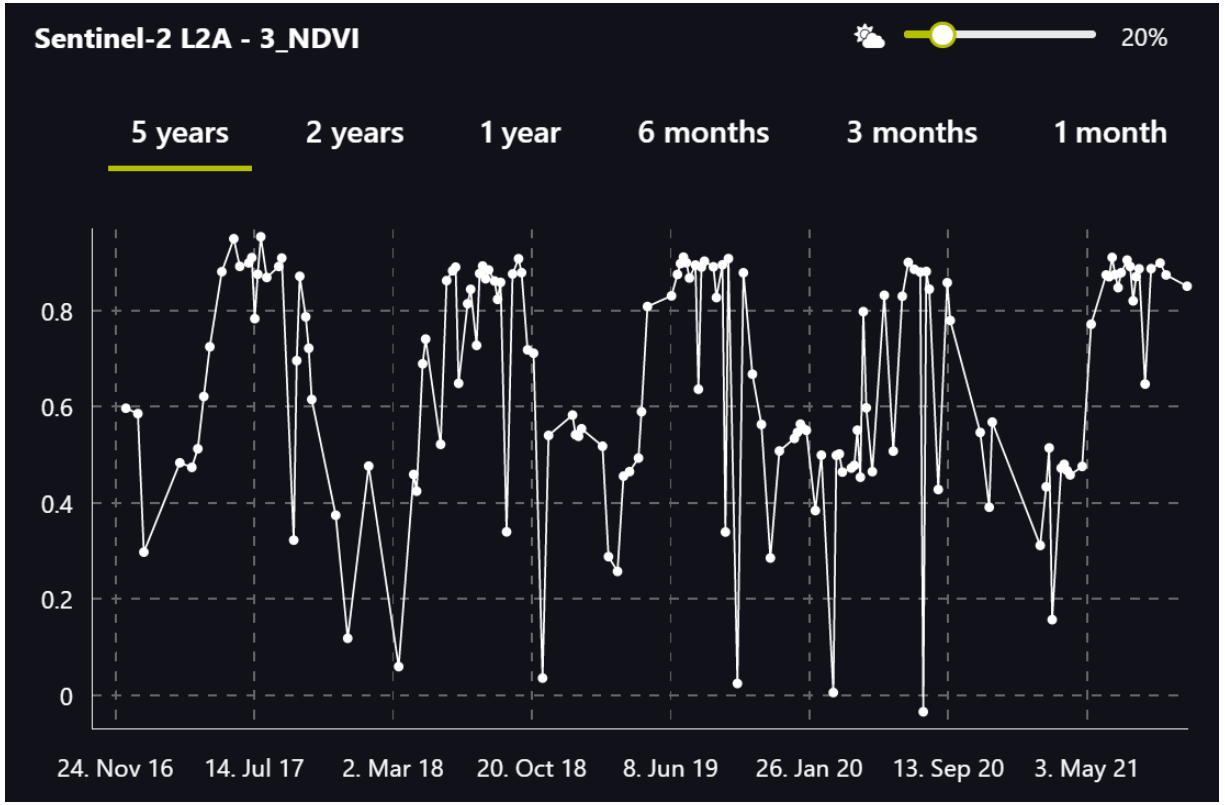
EO Browser


Sentinel-2 L2A - 3_NDVI
100%
5 years
2 years
1 year
6 months
3 months
1 month
1
0.5
0
-0.5
-1
10. Nov 20
7. Jan 21
6. Mar 21
3. May 21
29. Jun 21
26. Aug 21


Sentinel-2 L2A - 3_NDVI
20%
5 years
2 years
1 year
6 months
3 months
1 month
1
0.5
0
-0.5
-1
10. Nov 20
7. Jan 21
6. Mar 21
3. May 21
29. Jun 21
26. Aug 21

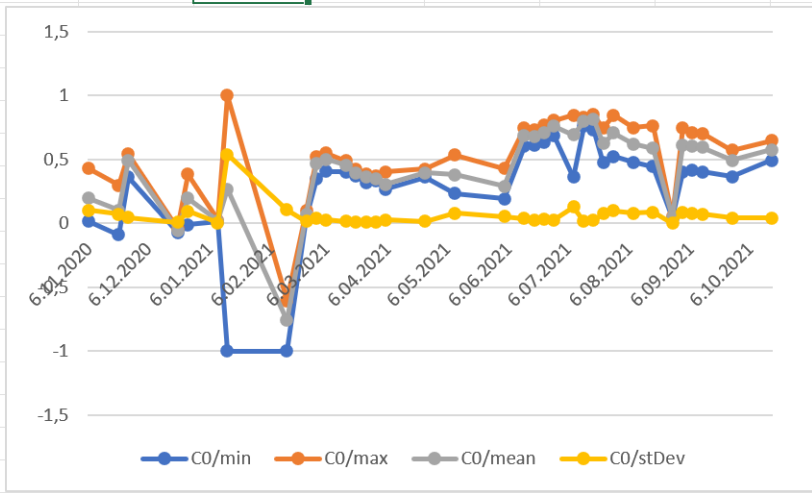
EO Browser

Zelše
Cerknica
Dolenja vas
Cerknica
Ulaka
Radlek
Dolenje Jezero
Martinjak
Studeno na Blokah
Grahovo
Bločice
Žerovnica
Bloška Polica
Lipsenj
Goričice
Otok
Podlož
Gorenje Jezero
Laze pri Gorenjem Jezeru
Klance
Lož


Sentinel-2 L2A - 3_NDVI
20%
5 years
2 years
1 year
6 months
3 months
1 month
0.8
0.6
0.4
0.2
0
24. Nov 16
14. Jul 17
2. Mar 18
20. Oct 18
8. Jun 19
26. Jan 20
13. Sep 20
3. May 21

EO Browser

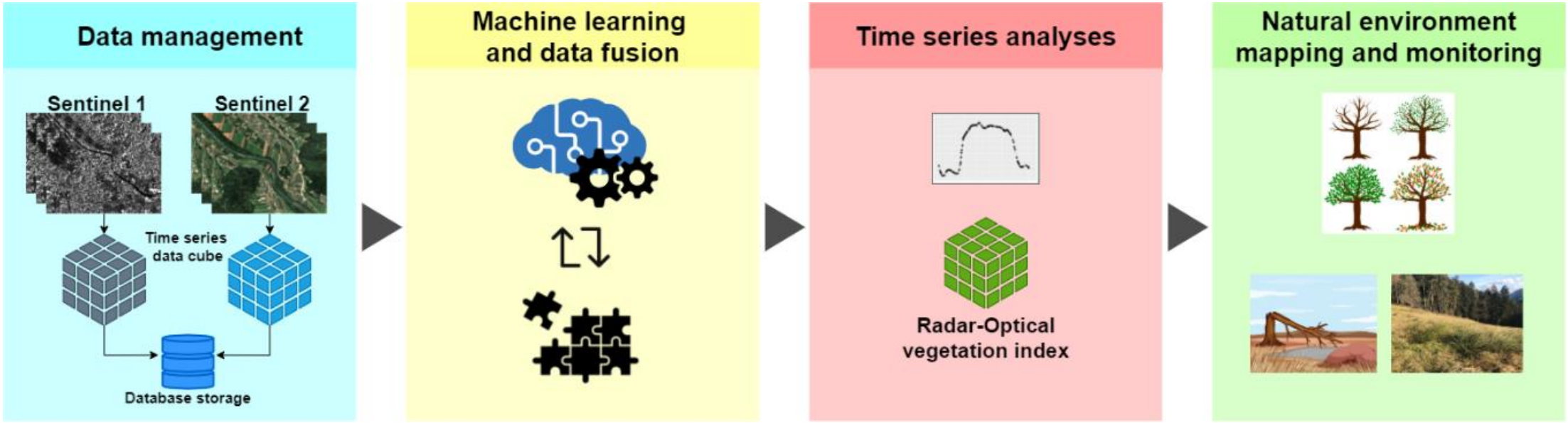
	A	B	C	D	E	F	G	H	I	J	K	L
1	C0/date	C0/min	C0/max	C0/mea	C0/stDe	C0/samp	C0/noDa	C0/med	C0/p10	C0/p90	C0/clou	overagePercent
2	17.10.2021	0,490767	0,645251	0,576107	0,041942	64	0				0	
6	27.09.2021	0,366114	0,57329	0,490697	0,042056	64	0				0	
10	12.09.2021	0,401337	0,701129	0,595206	0,073265	64	0				0	
11	7.09.2021	0,41693	0,70761	0,601353	0,074001	64	0				0	
12	2.09.2021	0,403591	0,746767	0,61208	0,088126	64	0				0	
13	28.08.2021	0,043528	0,052309	0,048499	0,002169	64	0				0	
15	18.08.2021	0,445105	0,763093	0,586435	0,087685	64	0				0	
17	8.08.2021	0,478782	0,746882	0,621459	0,07858	64	0				0	
19	29.07.2021	0,520968	0,84473	0,707302	0,099223	64	0				0	
20	24.07.2021	0,475572	0,744283	0,624972	0,076698	64	0				0	
21	19.07.2021	0,732889	0,848426	0,814759	0,023402	64	0				0	
22	14.07.2021	0,758547	0,82847	0,795313	0,01552	64	0				0	
23	9.07.2021	0,361116	0,844727	0,692149	0,128079	64	0				0	
25	29.06.2021	0,6826	0,805761	0,758291	0,028123	64	0				0	
26	24.06.2021	0,637131	0,771476	0,711244	0,028855	64	0				0	
27	19.06.2021	0,612971	0,733736	0,675854	0,026827	64	0				0	
28	14.06.2021	0,603053	0,743728	0,688769	0,037117	64	0				0	
30	4.06.2021	0,192192	0,430267	0,290075	0,051844	64	0				0	
34	10.05.2021	0,2341	0,533611	0,379578	0,078249	64	0				0	
37	25.04.2021	0,35958	0,424632	0,395119	0,016454	64	0				0	
41	5.04.2021	0,267343	0,402529	0,302923	0,028319	64	0				0	
42	31.03.2021	0,329323	0,373932	0,350707	0,010846	64	0				0	
43	26.03.2021	0,321577	0,388286	0,363599	0,011127	64	0				0	
44	21.03.2021	0,367903	0,424156	0,389928	0,01233	64	0				0	
45	16.03.2021	0,402667	0,487493	0,453373	0,015806	64	0				0	
47	6.03.2021	0,405607	0,54726	0,498466	0,025714	64	0				0	
48	1.03.2021	0,347953	0,517081	0,469487	0,037133	64	0				0	
49	24.02.2021	0,044492	0,096912	0,07353	0,013874	64	0				0	
51	14.02.2021	-1	-0,6036	-0,75788	0,105963	64	0				0	



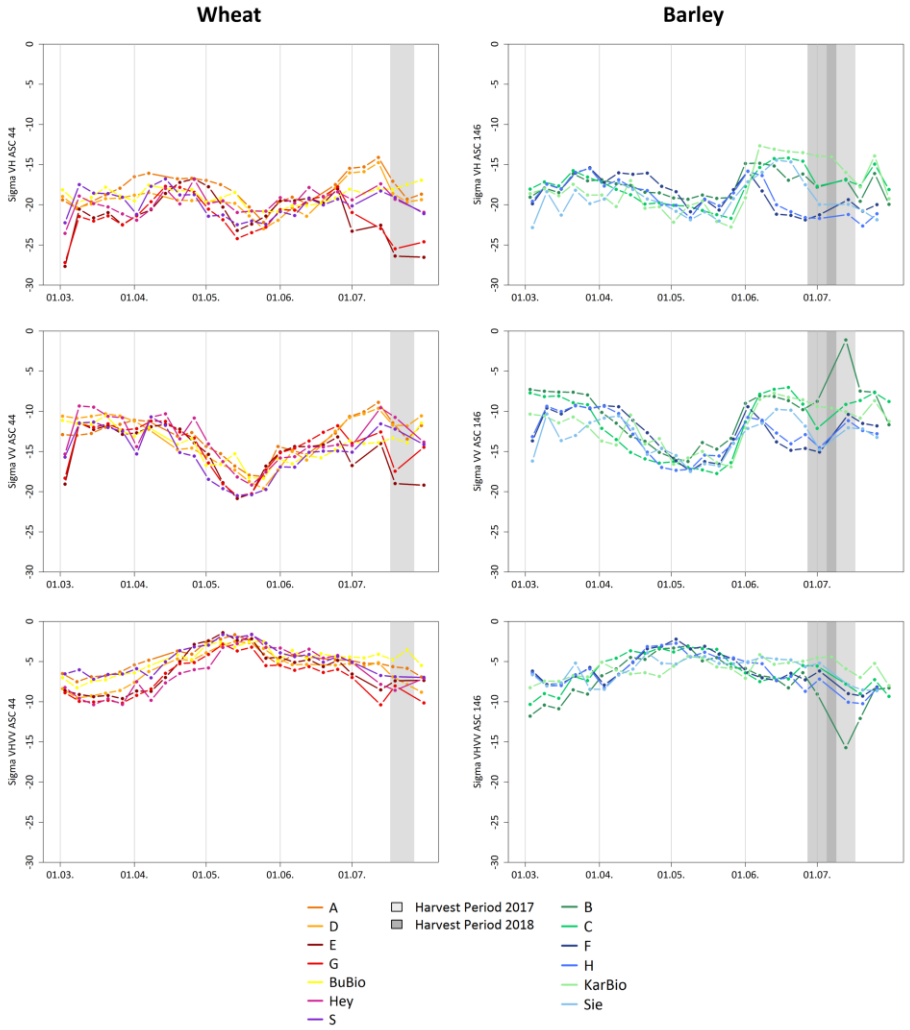
in

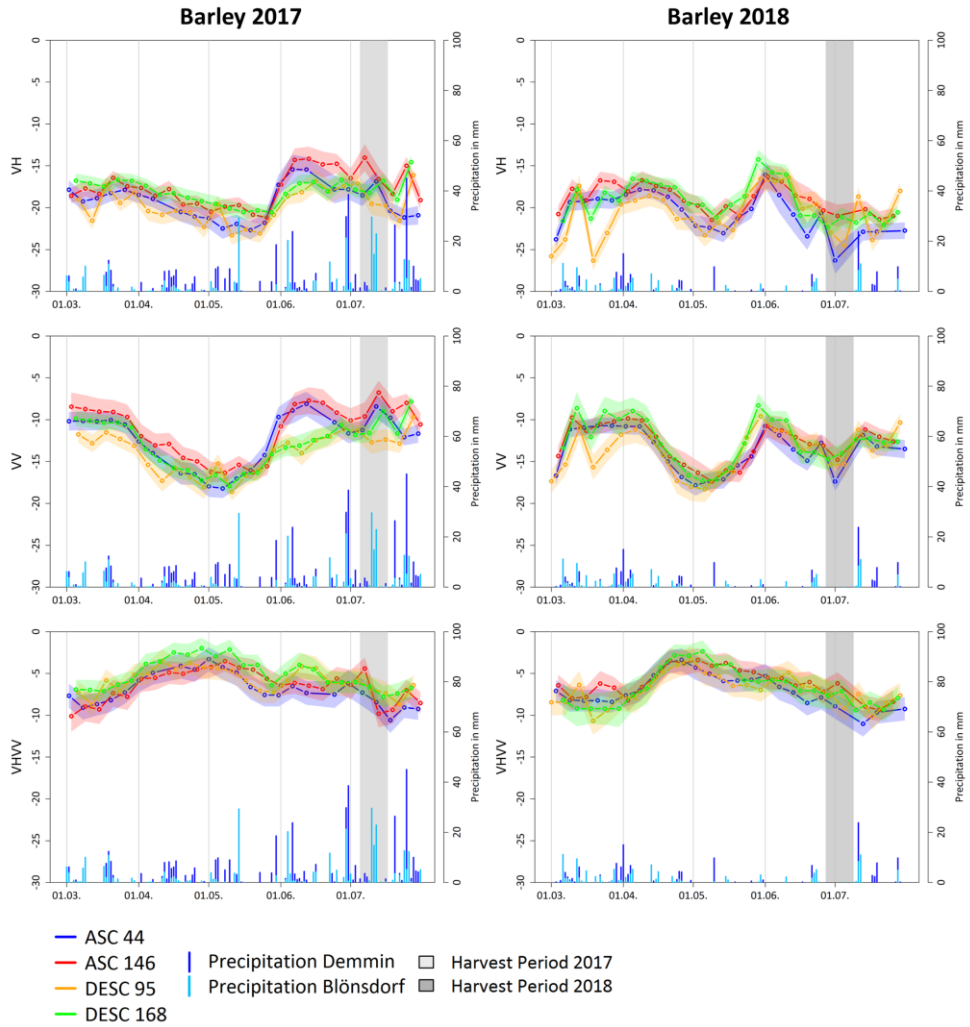
Radar and optical Integration

SAR/Optical Integration



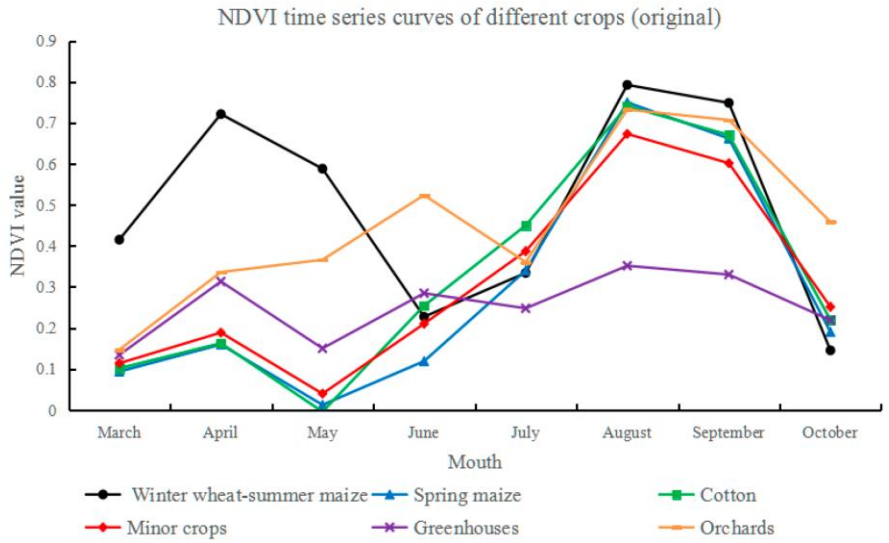
Radar backscatter

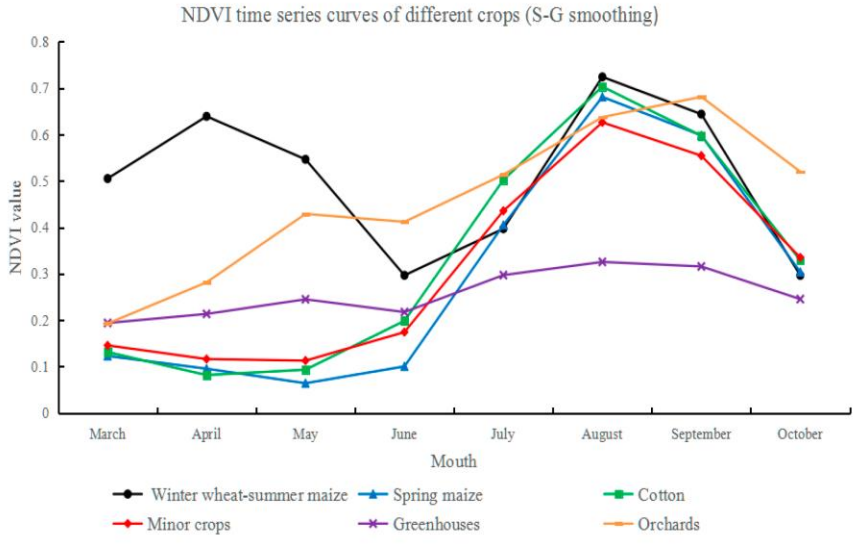


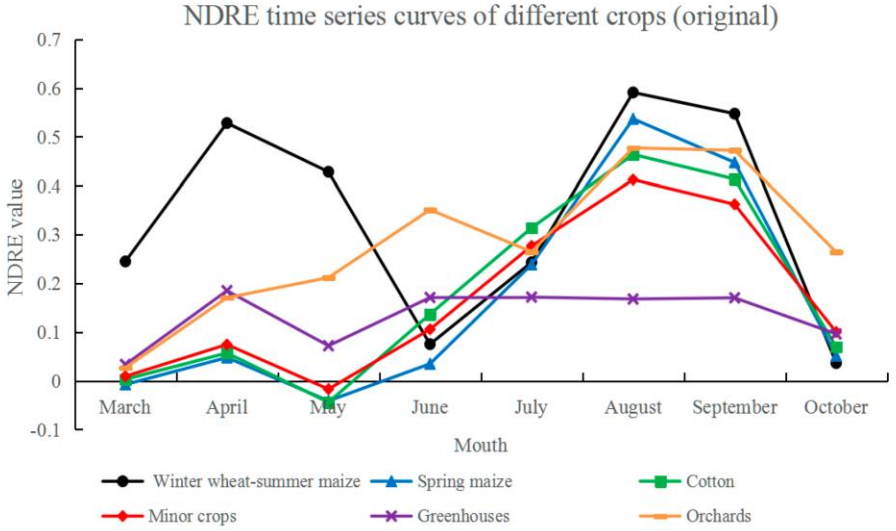


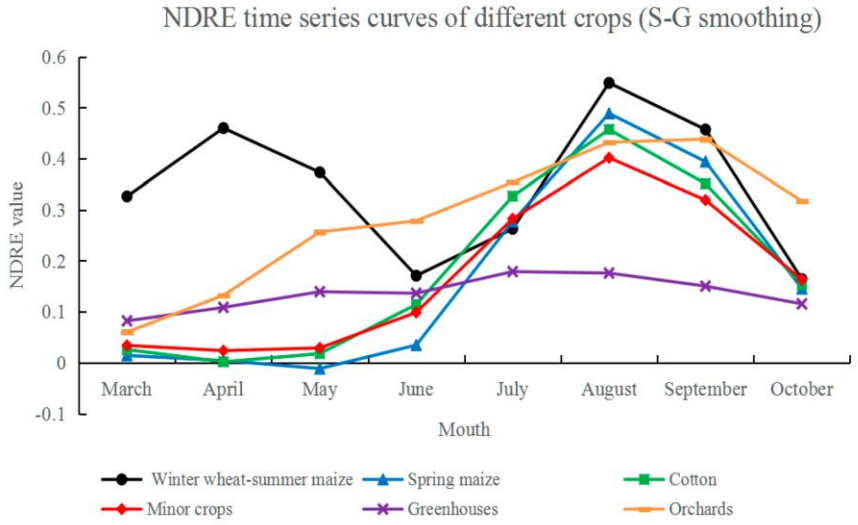
[Remote Sensing | Free Full-Text | Analyzing Temporal and Spatial Characteristics of Crop Parameters Using Sentinel-1 Backscatter Data (mdpi.com)]

NDVI and NDRE



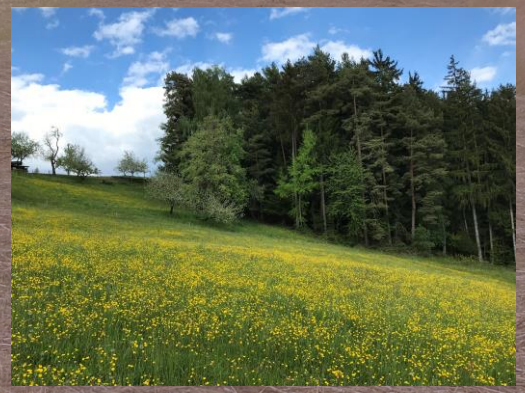




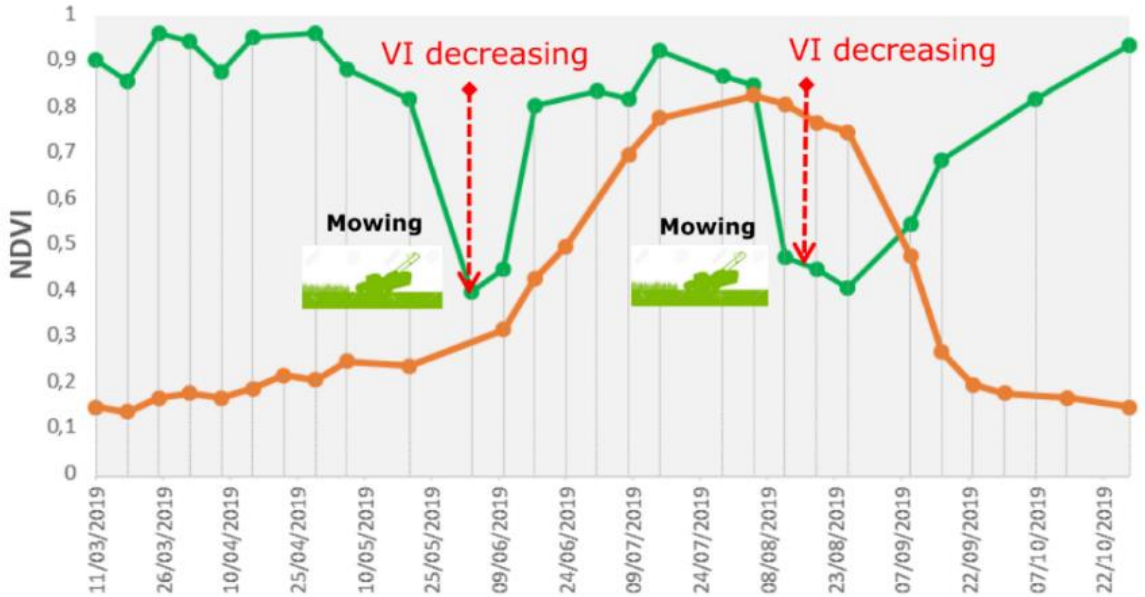


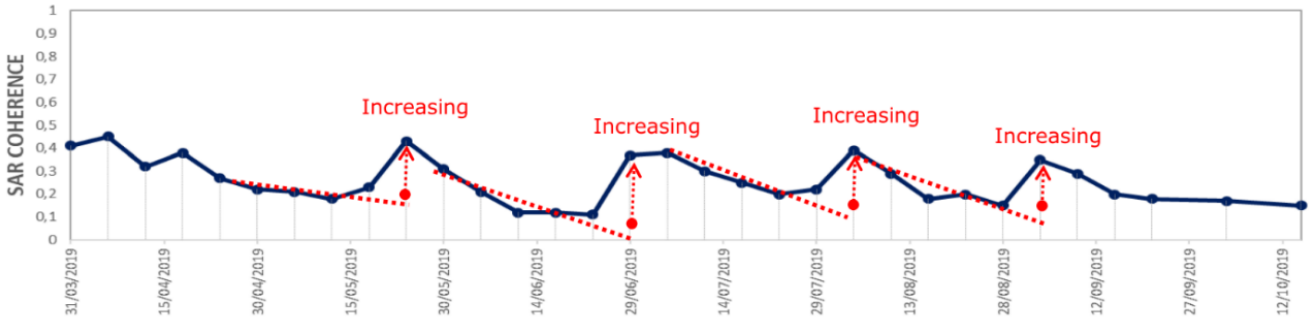
[Remote Sensing | Free Full-Text | Land Cover and Crop Classification Based on Red Edge Indices Features of GF-6 WFV Time Series Data (mdpi.com)]

Mapping Grassland – Intensive/Extensive



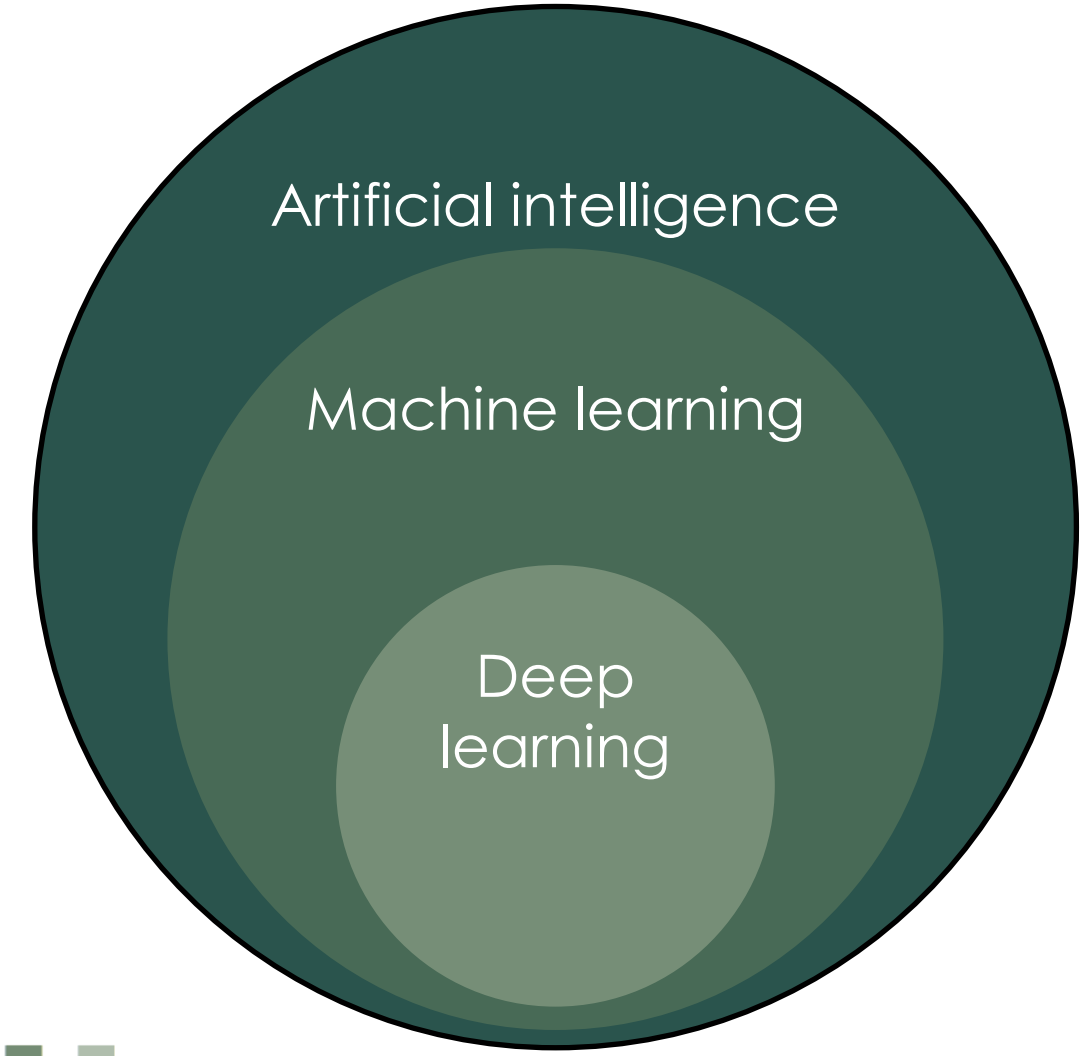
Optical (NDVI) and radar (coherence)



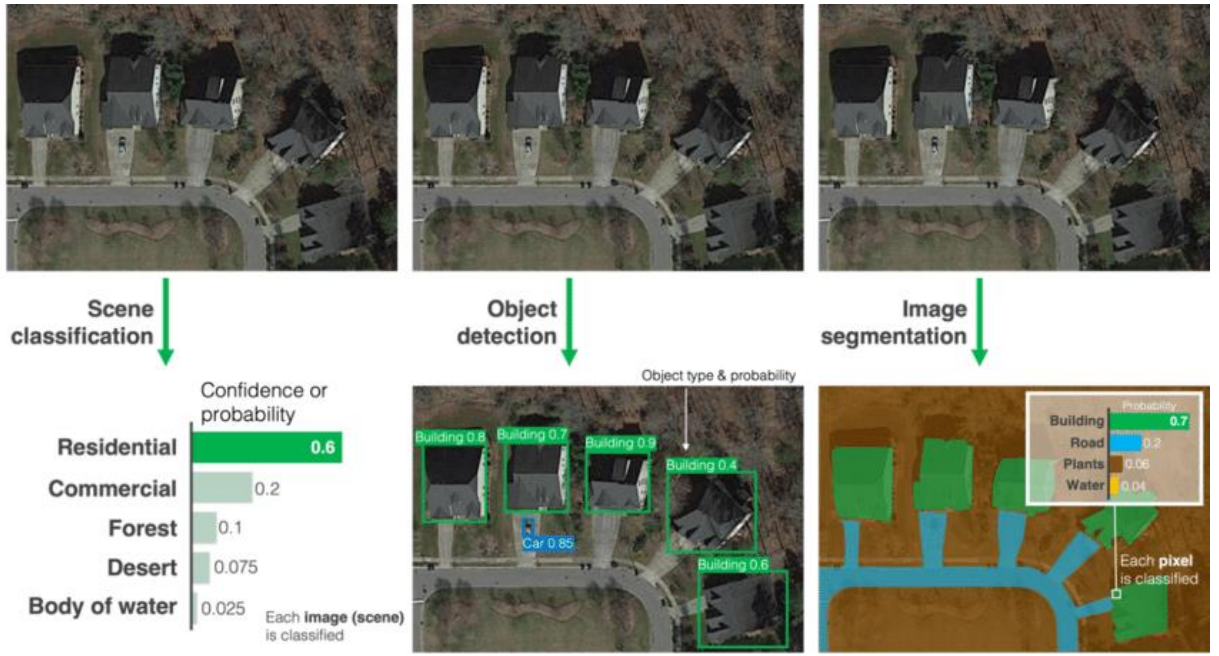


[Sen4Cap (esa-sen4cap.org)]

Machine learning



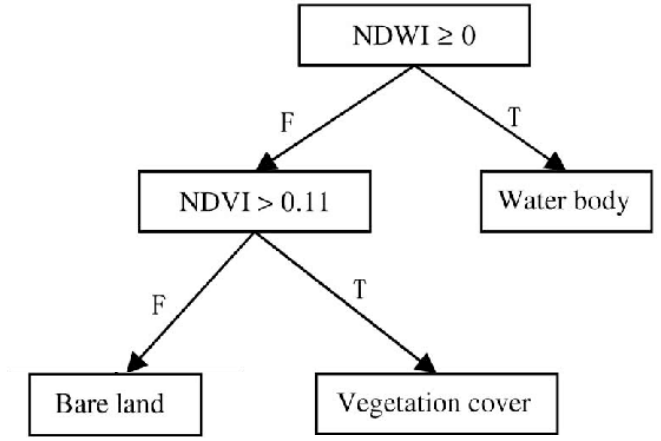
- Scene classification
- Object detection
- Segmentation
- Pixel classification



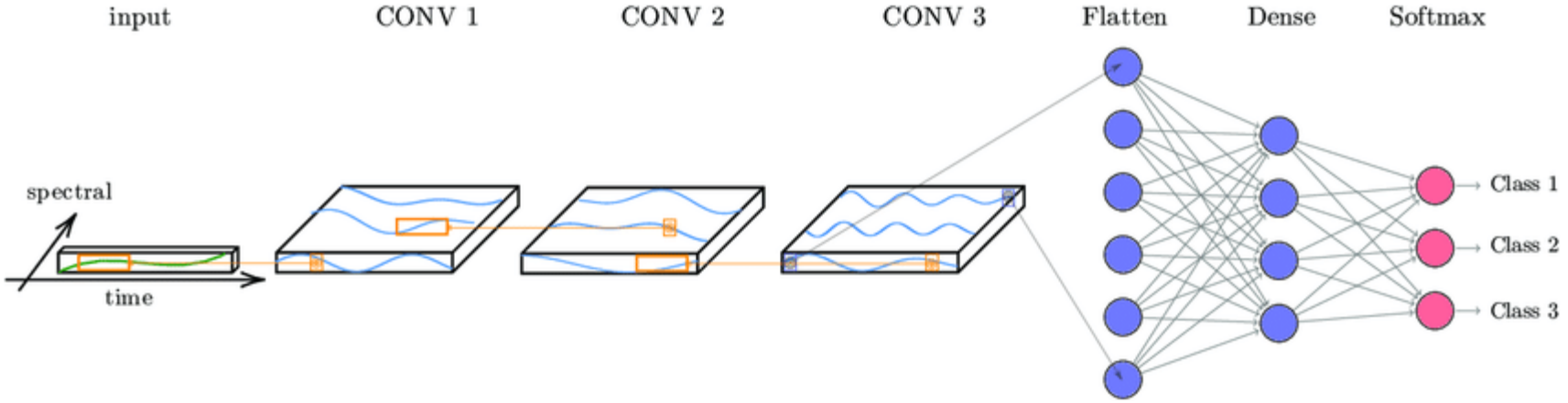
[Automated Extraction of Energy Systems Information from Remotely Sensed Data: A Review and Analysis]

Machine learning – satellite image time series

- Machine learning
  - Decision trees
  - Random Forest
  - LightGBM



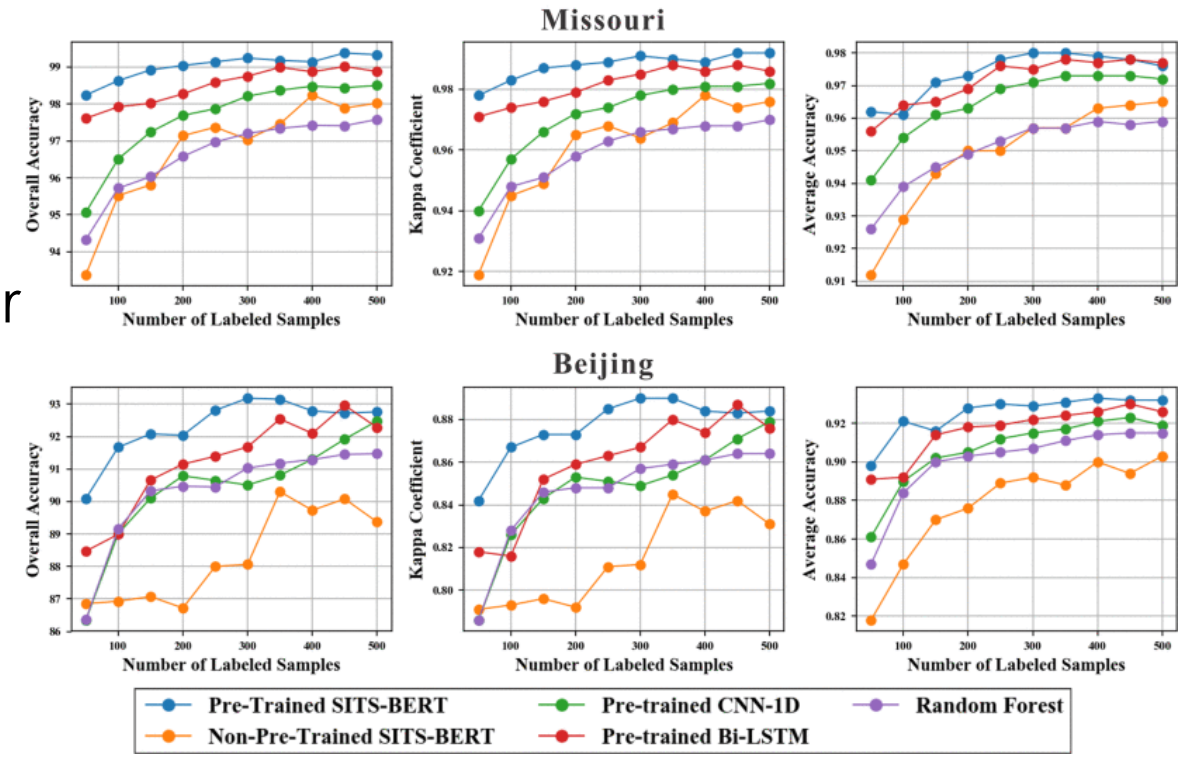
- Deep learning
  - RNN
  - CNN
  - Transformers

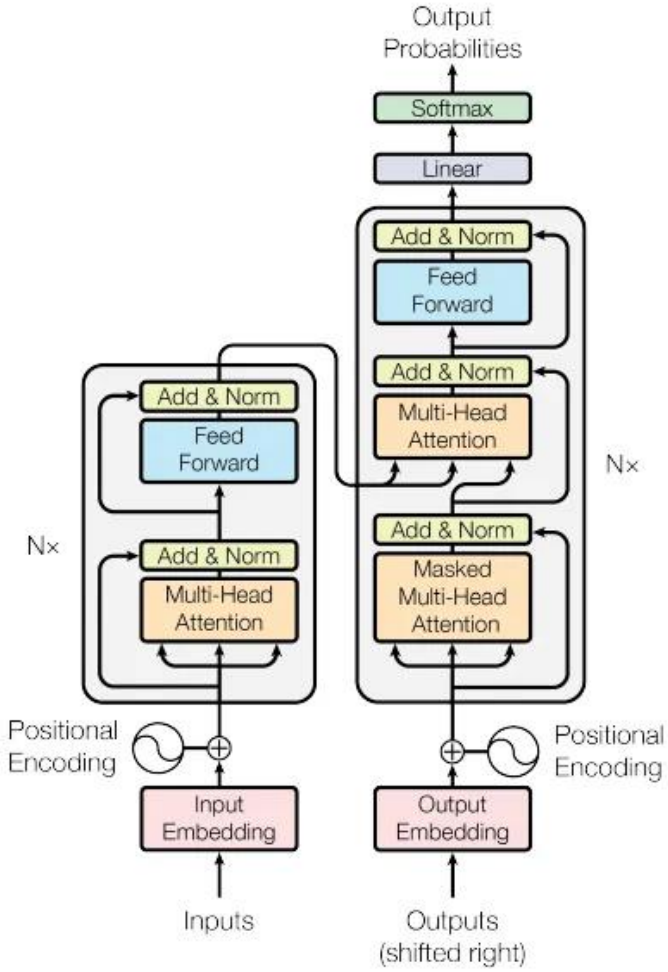


[A Decision-Tree Classifier for Extracting Transparent Plastic-Mulched Landcover from Landsat-5 TM Images]
[Temporal Convolutional Neural Network for the Classification of Satellite Image Time Series]

Transformers – Satellite image time series

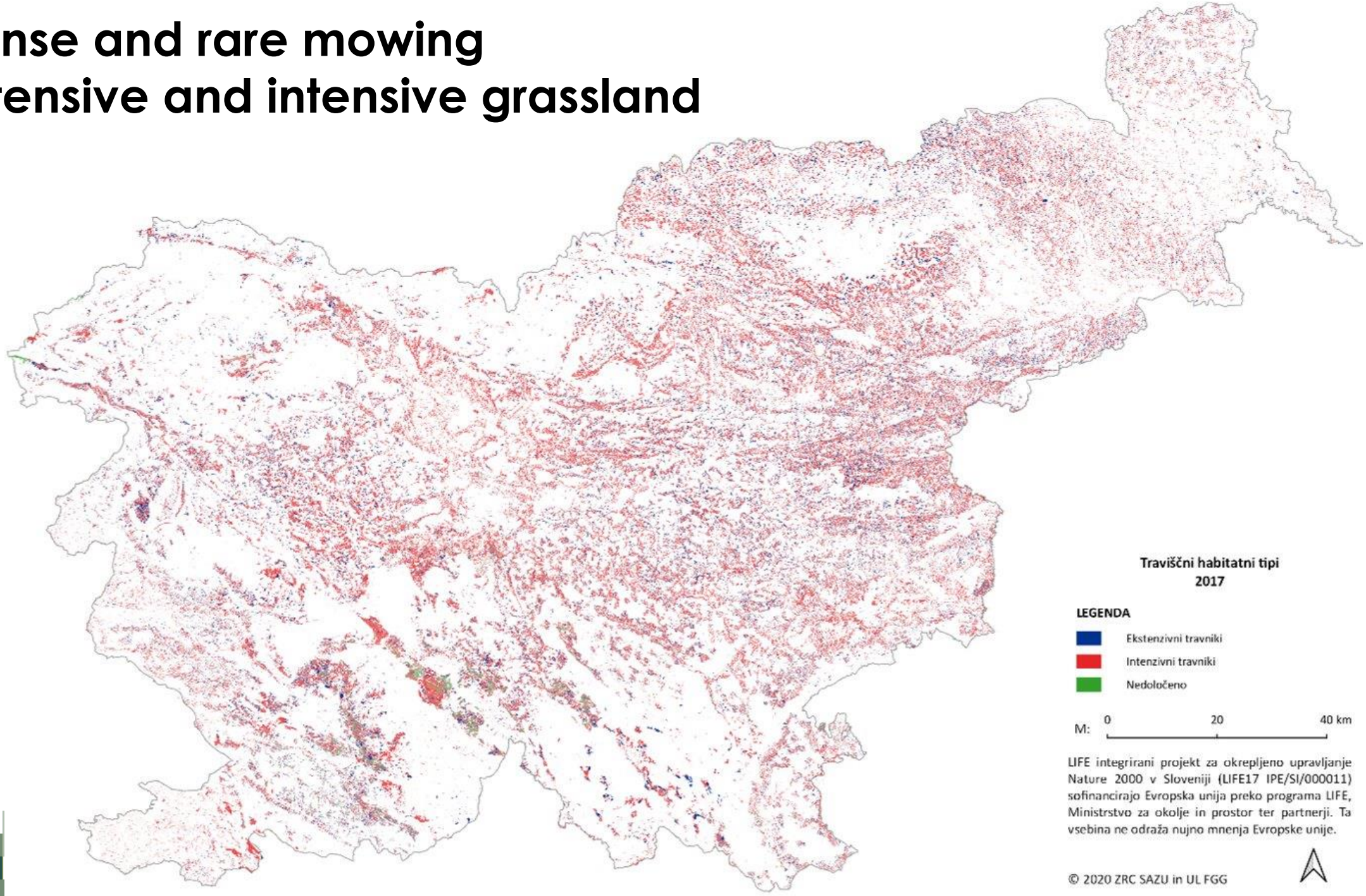
- Pre-processing is not mandatory but can improve results
- Models can infer:
  - Interpolation
  - Cloud mask
- Knowledge transfer
  - Domain
  - Year
  - Season



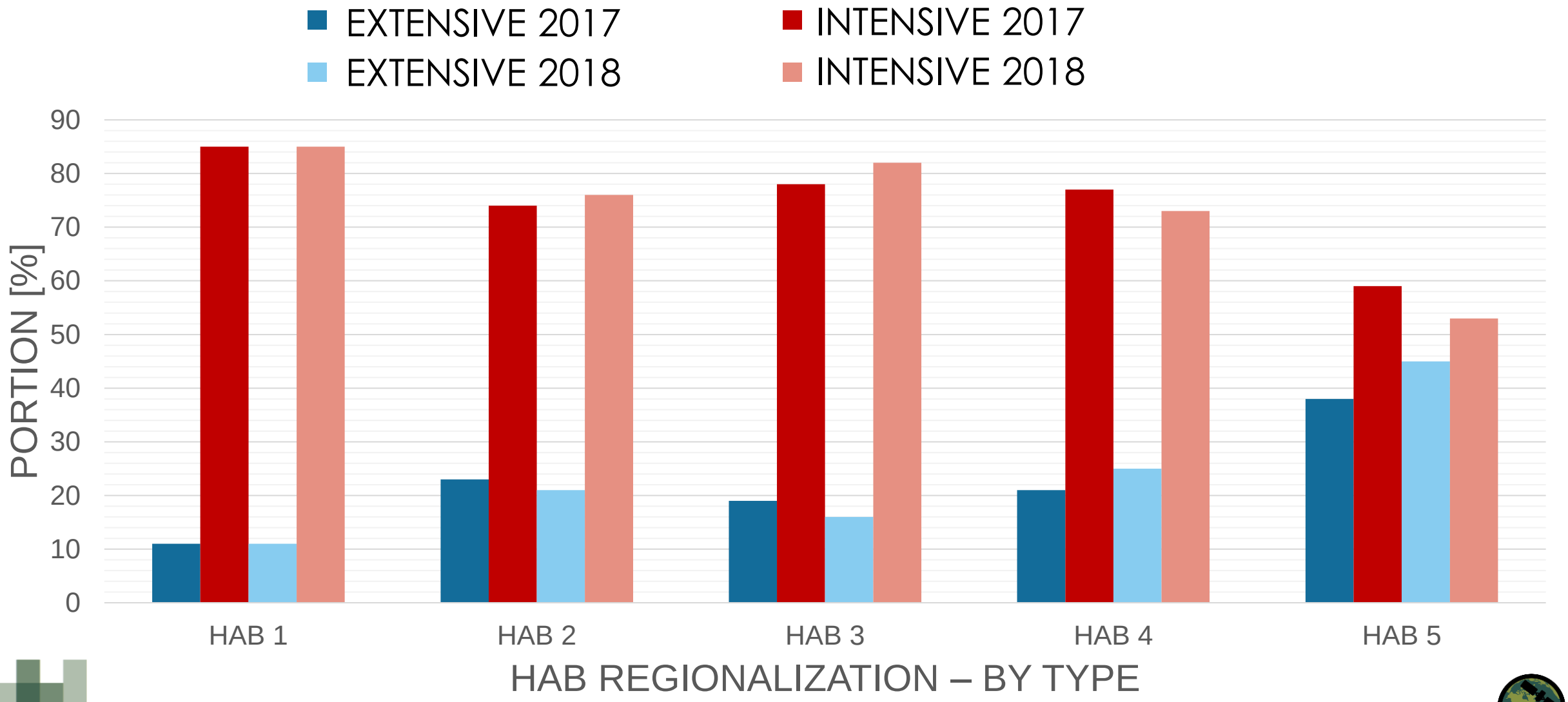


[Attention Is All You Need]
[Self-Supervised Pretraining of Transformers for Satellite Image Time Series Classification]

Dense and rare mowing
Extensive and intensive grassland



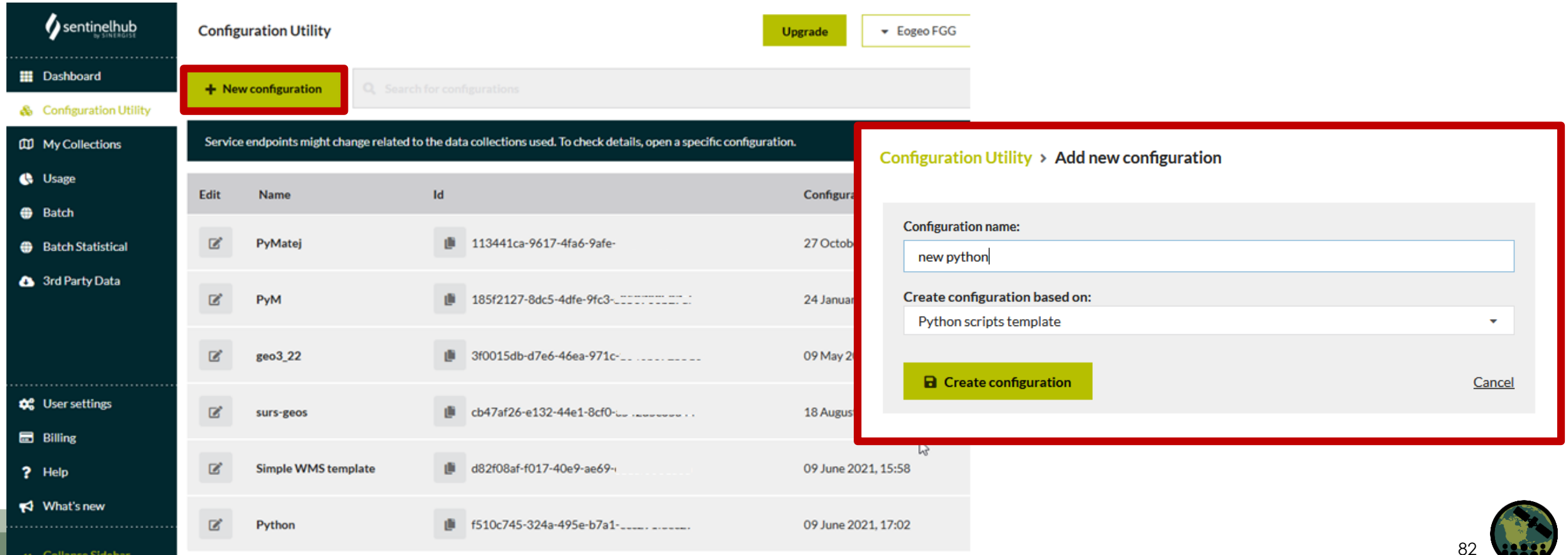
Extensive and intensive grassland – statistics



Practical

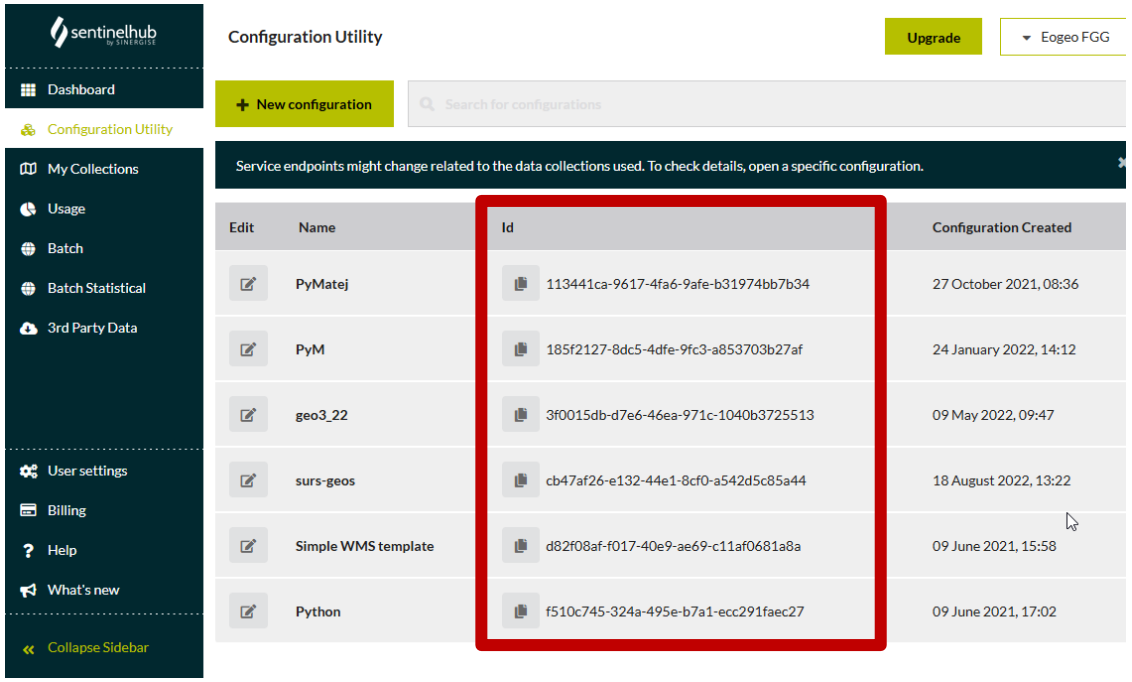
Credentials

1. INSTANCE_ID: Configuration Utility > Id
2. CLIENT ID: User settings > Oauth clients > ID (Client credentials)
3. CLIENT_SECRET: „secret“

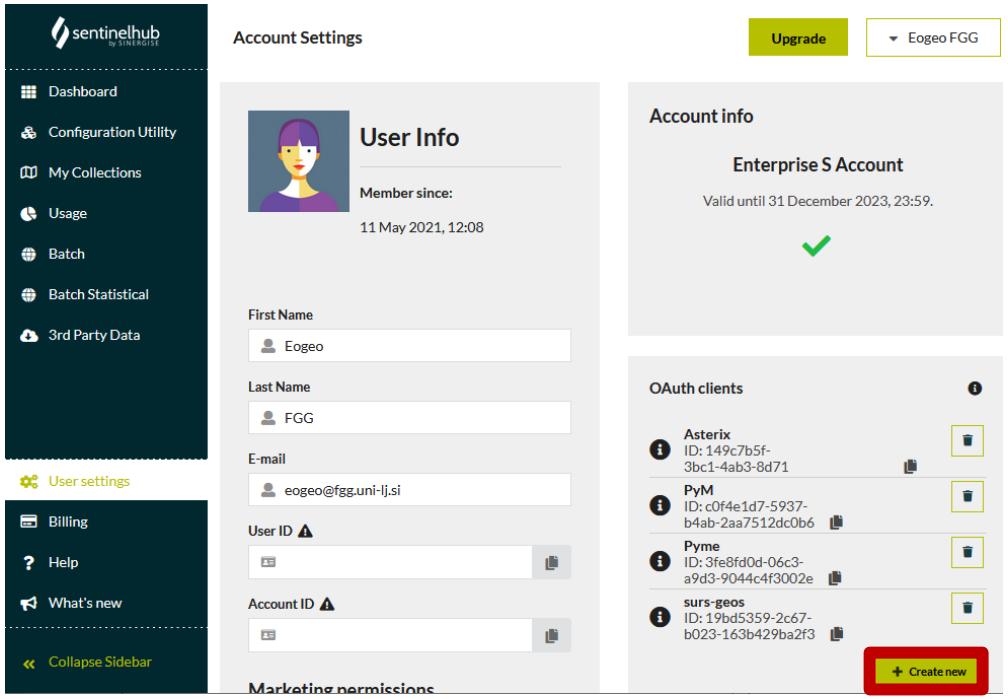


Credentials

- Configuration Utility – INSTANCE_ID

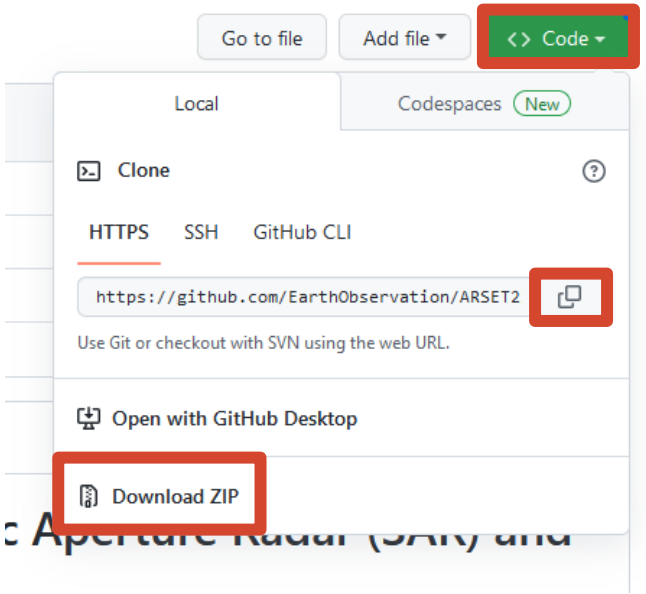


- OAuth clients – CLIENT_ID
- Save the secret key – CLIENT_SECRET



GitHub - ARSET23

- https://github.com/EarthObservation/ARSET23
- Repository
  - Theory
  - Practical
- Git clone https://github.com/EarthObservation/ARSET23.git



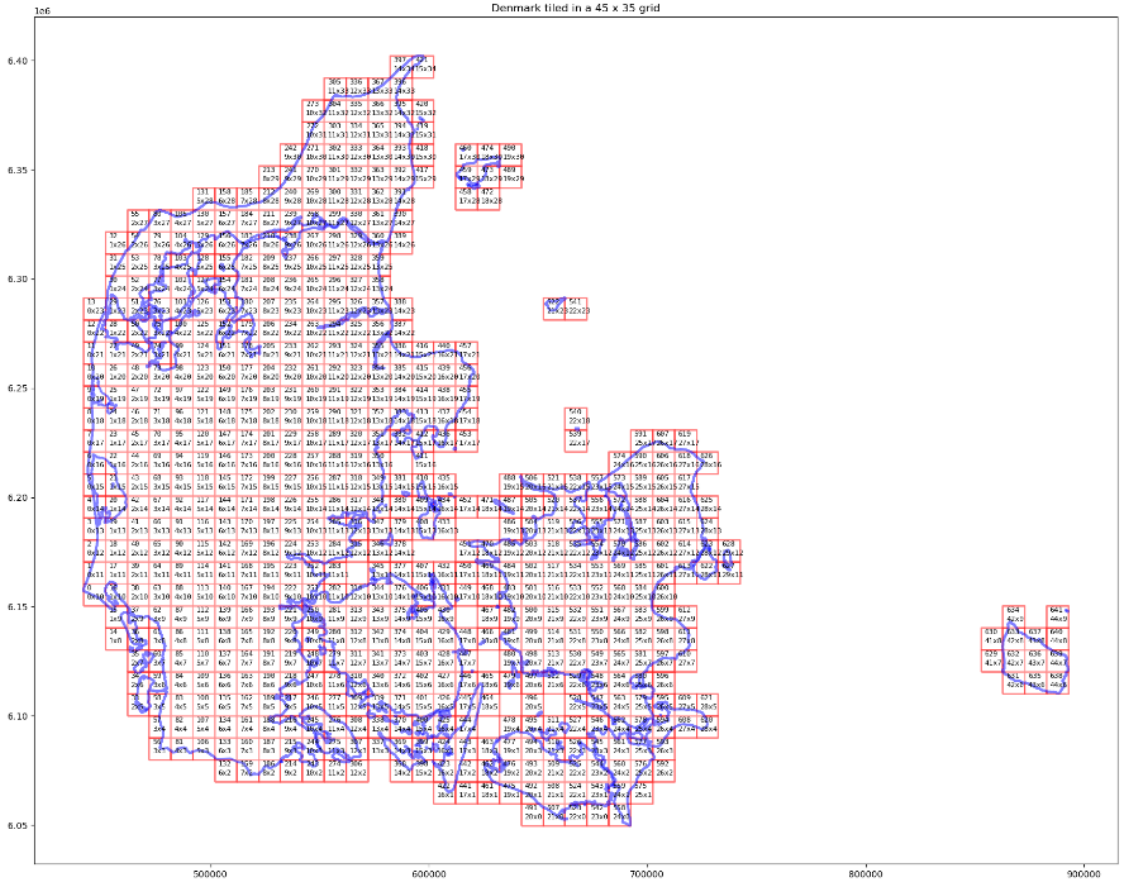
GitHub - ARSET23

Practical - Notebooks

- credentials_SH.ipynb
  - Sign Up
  - sentinelhub.id
  - config
- data_sources_explorer.ipynb
  - DataCollection
  - evalscript
  - Imagery retrival
  - Visualisation
- earth_observation_with_StatAPI.ipynb
  - Inspecting AOI
  - Statistical API
  - Time series visualisation
- extra_land_cover.ipynb
  - EO workflow
    - Splitting AOI
    - Data download
    - Adding reference
    - Machine learning

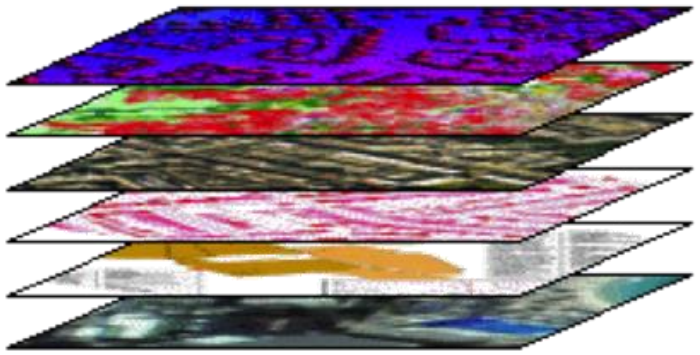
Practical - Data

- Region of Interest (ROI)



- Country outline
- Divided into smaller regions
  - 1000 x 1000 pixels
- Denmark splitted into 45x35 patches

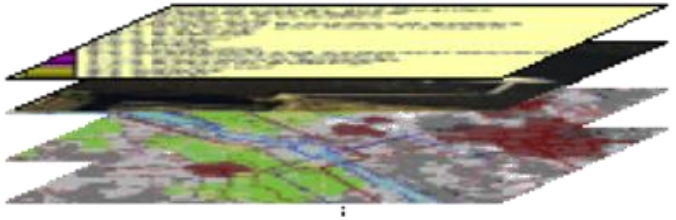
Open EO data - Sentinel-1, Sentinel-2, Landsat, ...



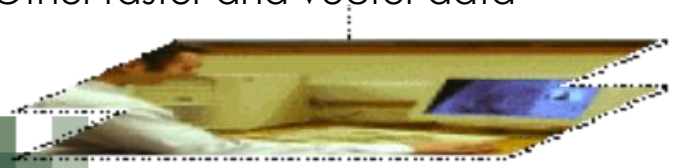
SENTINEL Hub

Commercial EO data – WorldWind, GeoEye, ...

Aerial imagery (drone, airplane)



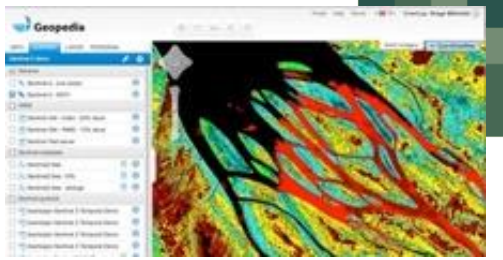
Other raster and vector data



WMTS

WMS

WCS



Cloud GIS

Web / Mobile apps

Desktop (QGIS, ArcGIS...)

Scripting (Python, R, ENVI...)

Sentinel-hub – Statistical API – Data – GEOJSON

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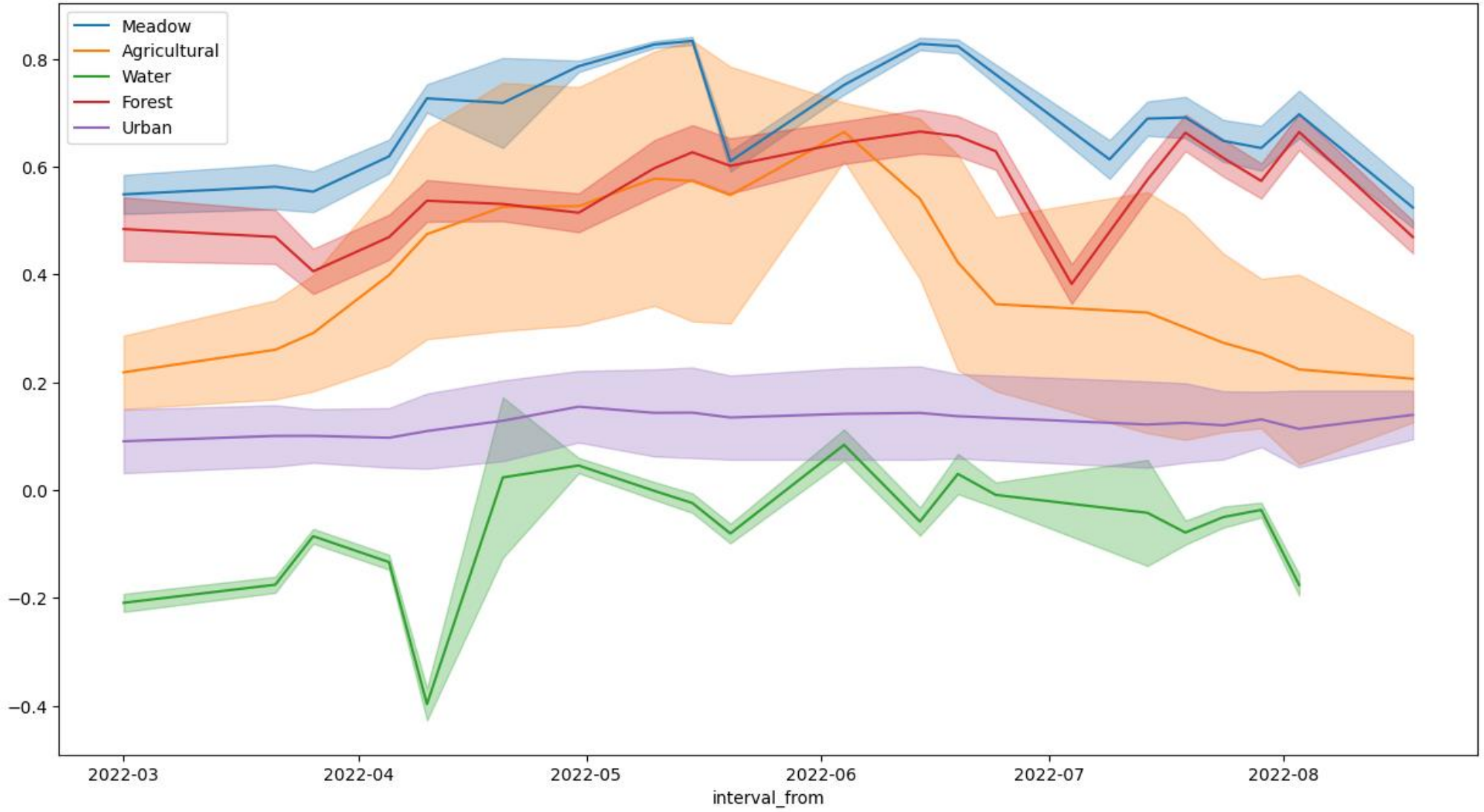
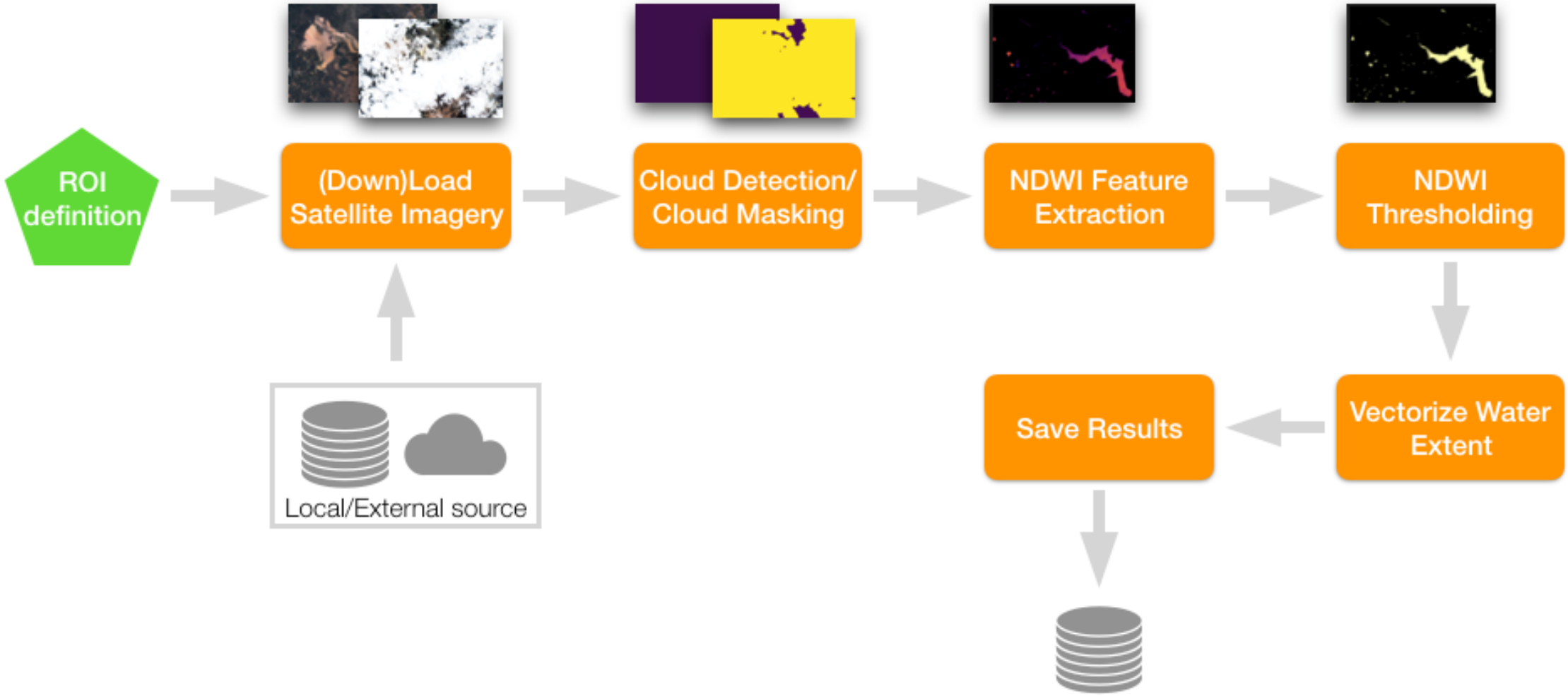
Sentinel-hub – Statistical API



eo-learn


ROI definition
(Down)Load Satellite Imagery
Cloud Detection/ Cloud Masking
NDWI Feature Extraction
NDWI Thresholding
Vectorize Water Extent
Save Results
Local/External source

eo-workflow

extra_land_cover.ipynb

- Region-of-Interest (ROI)
  - Outline (geojson, or similar)
  - Split into smaller tiles
- Download patch (sentinelhub-py)
  - Time interval, bands, masks
- Machine learning
  - Prepare training data
  - Model training
  - Validation
- Visualisation of results

More materials:

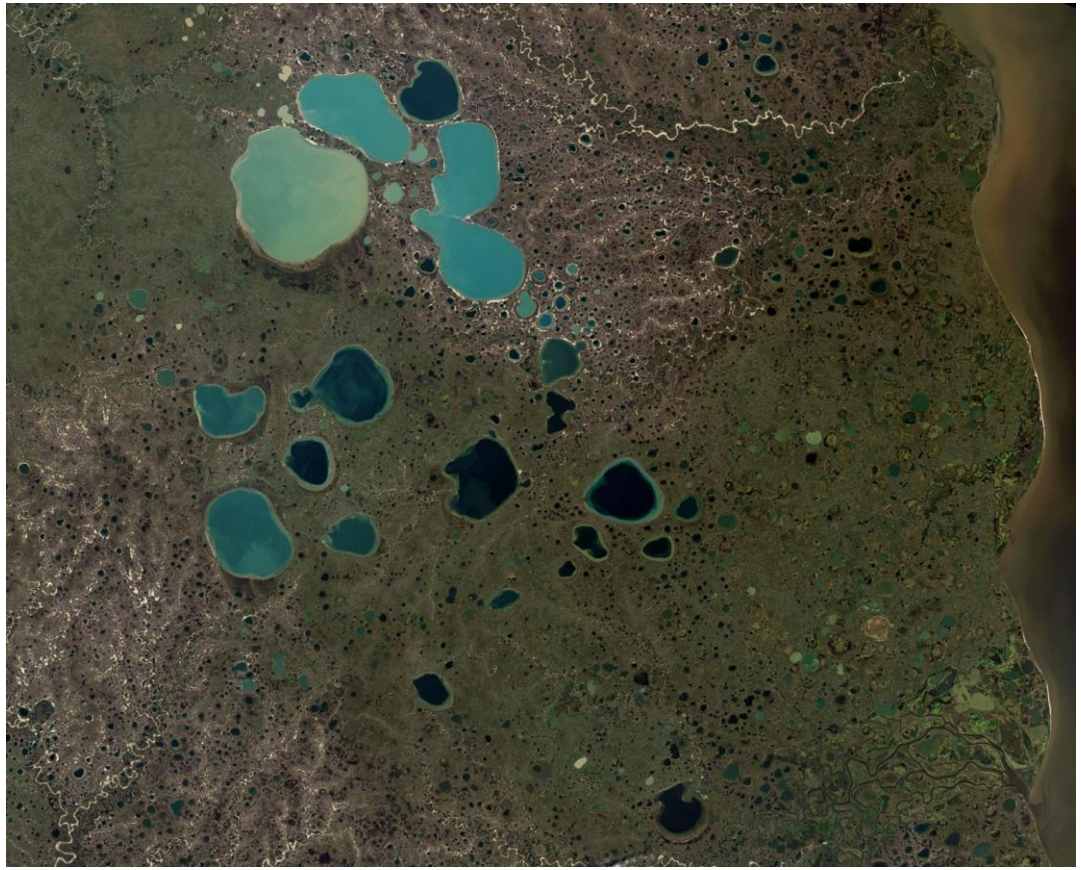
- https://github.com/sentinel-hub/eo-learn-examples
- https://github.com/sentinel-hub/eo-learn-workshop

APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!

Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.



https://earthobservatory.nasa.gov/images/6034/pothole-lakes-in-siberia

Contacts

- Trainers:
  - Prof. Krištof Oštir: kristof.ostir@fgg.uni-lj.si
  - Matej Račič: matej.racic@fgg.uni-lj.si

- https://github.com/EarthObservation/ARSET23

- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-crop-mapping-using-synthetic-aperture-radar-sar-and-optical-0
- ARSET Website:
  - https://appliedsciences.nasa.gov/arset

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Thank You!