ARISTOTLE UNIVERSITY
OF THESSALONIKI

TRANS-ATLANTIC TRAINING 2024 – CHANIA, GREECE

Earth Observation and Machine Learning for Disaster Mapping

Earth Observation Platforms for Land Motion and Earthqaukes

Michael Foumelis | Assoc. Professor AUTh

Contributor(s)

Fabrizio Pacini | Terradue

TAT 2024 Training

14-17 July 2024

EO.Lab
Earth Observation
& Geospatial Applications Lab

CIRI-AUTH
CENTER FOR INTERDISCIPLINARY RESEARCH AND INNOVATION
Aristotle University of Thessaloniki

TERRADUE

Earth Observation & Geospatial Applications Lab (EO.Lab)

- The Aristotle University of Thessaloniki (www.auth.gr) is the largest public University in Greece established in 1925.
- The Earth Observation and Geospatial Applications Lab of AUTh (EO.Lab, https://eolab.geo.auth.gr) resides within the Department of Physical and Environmental Geography, School of Geology, Faculty of Sciences.
- The expertise of **EO.Lab** members spans across a variety of Earth Observation and Geospatial Information Science-Technology domains, including Optical, Radar and Aerial remote sensing, SAR Interferometry, Photogrammetry, Surveying and Geodesy, GNSS, LiDAR and Sonar.
- The application areas of EO.Lab extent in natural resources mapping and monitoring, geohazards, inland water bodies, coastal areas monitoring and climate change.

Interdisciplinary R&D and Service Provision

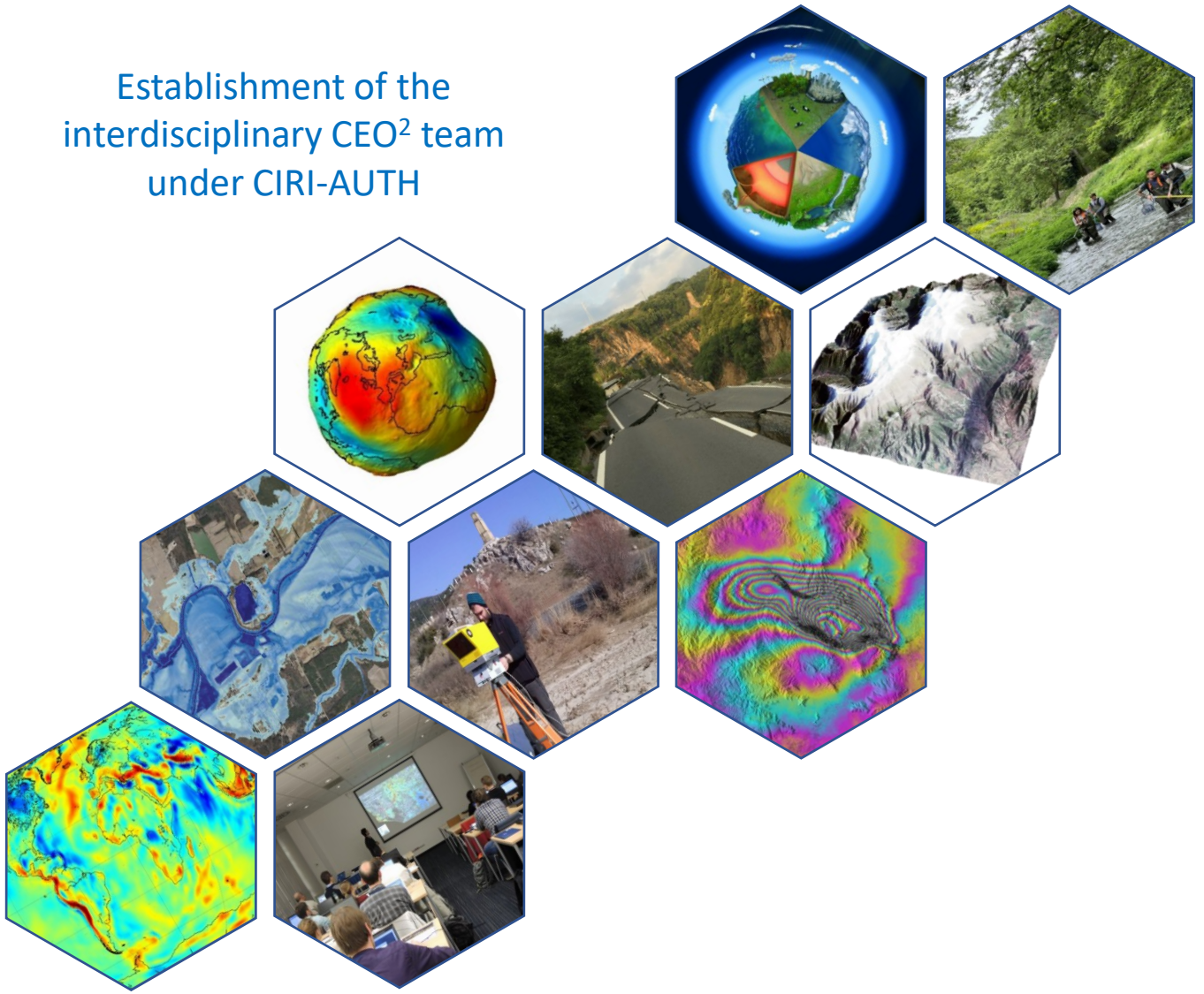
Center of **E**arth and **O**cean **O**bservation (**CEO²**)

CIRI-AUTH
CENTER FOR INTERDISCIPLINARY RESEARCH AND INNOVATION
Aristotle University of Thessaloniki

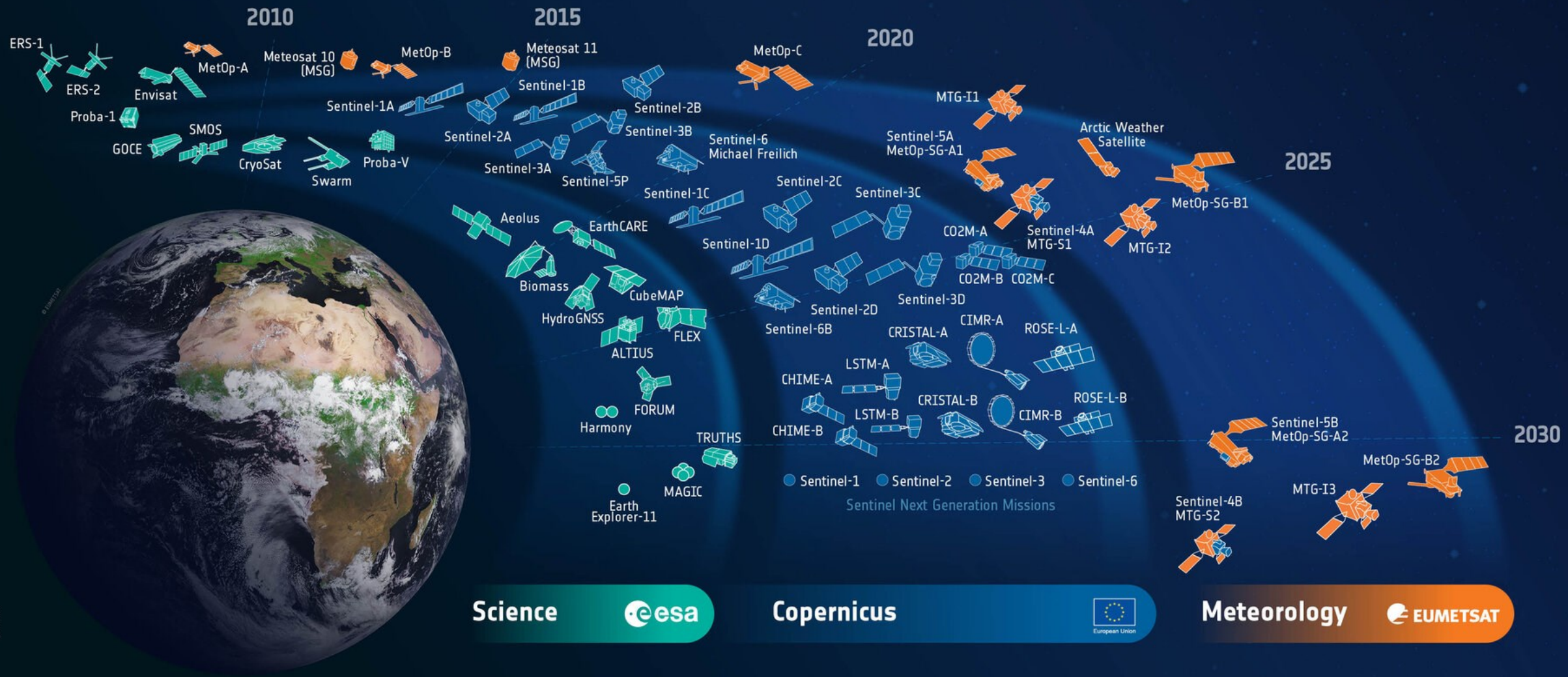
https://kedek.auth.gr

The main mission of **CIRI** is the promotion and development of interdisciplinarity in an open and collaborative environment of excellence, which utilizes the research infrastructures of AUTH at the local, national and European level, expands the University's synergy with society and contributes to the economic and social development of the country.

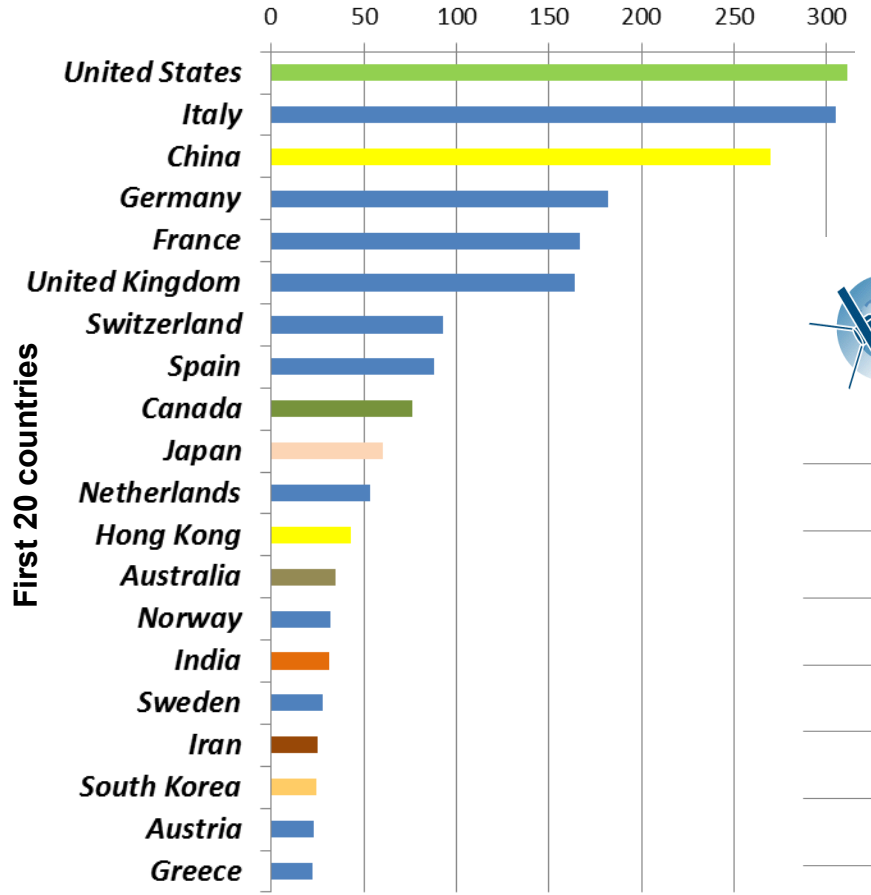
Establishment of the interdisciplinary CEO² team under CIRI-AUTH



ESA-developed Earth Observation Missions

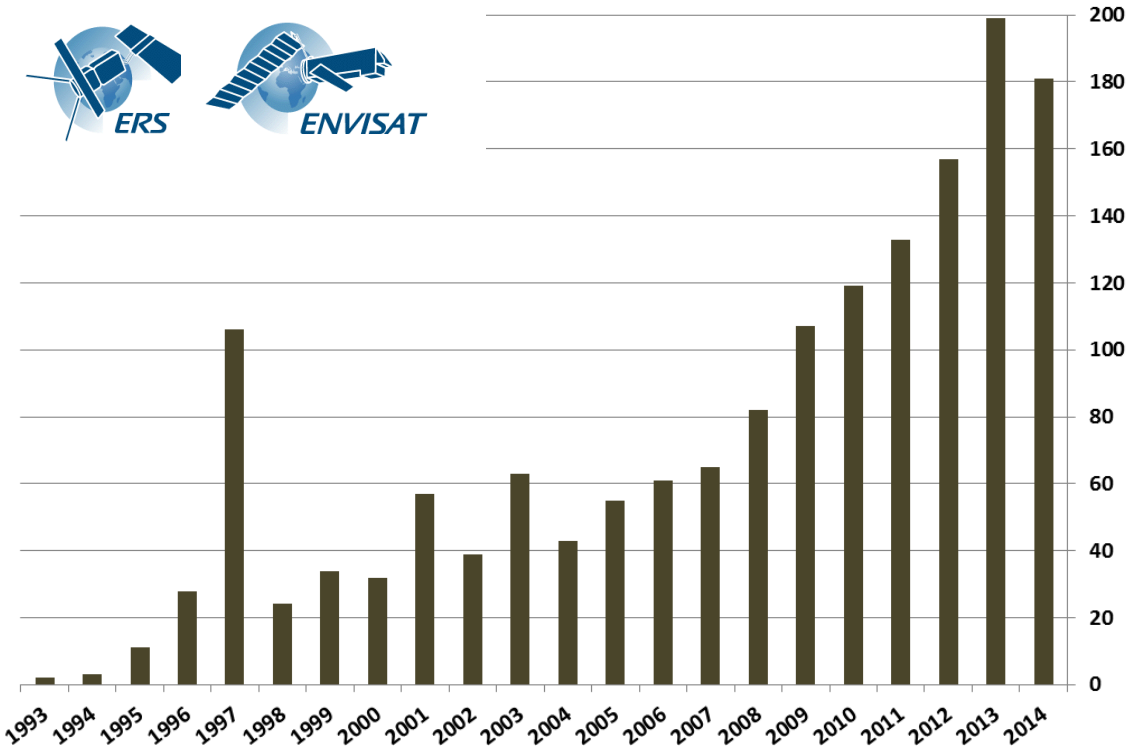


Large Impact on Scientific Literature



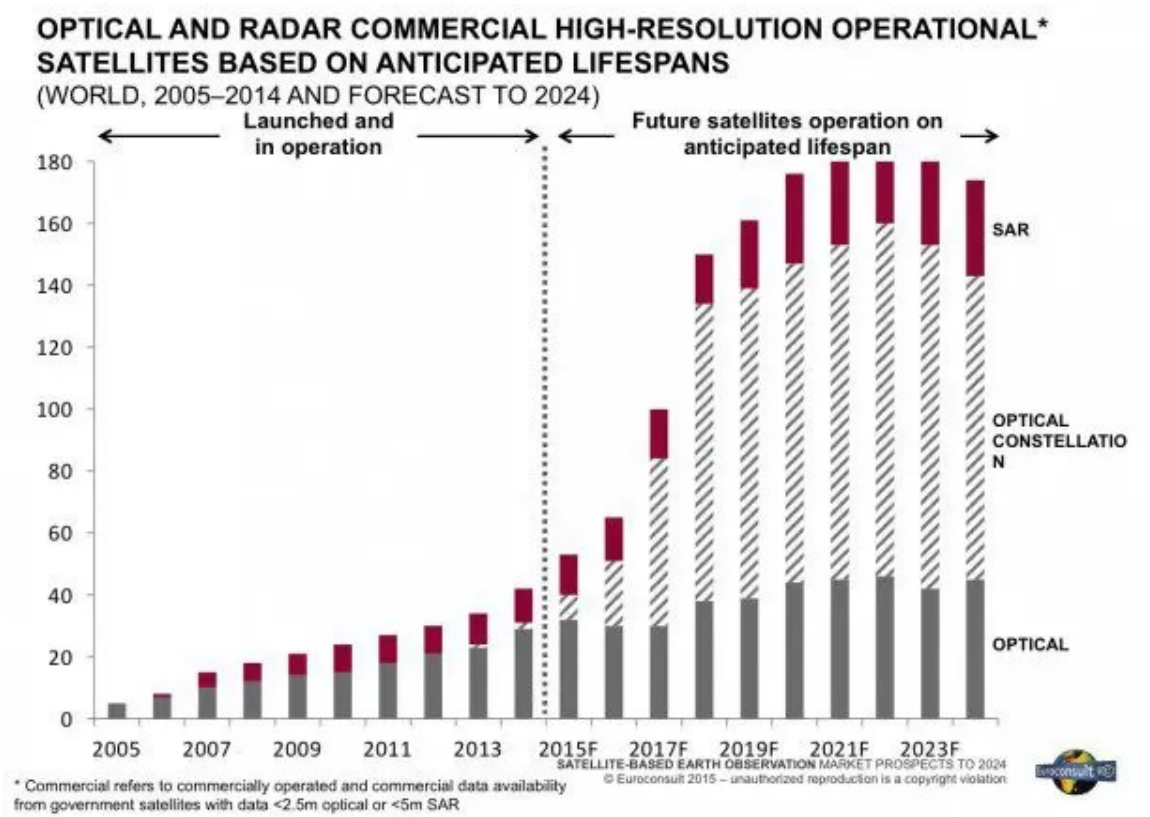
Scopus database, Journal papers with search on: “ERS or Envisat and SAR Interferometry”

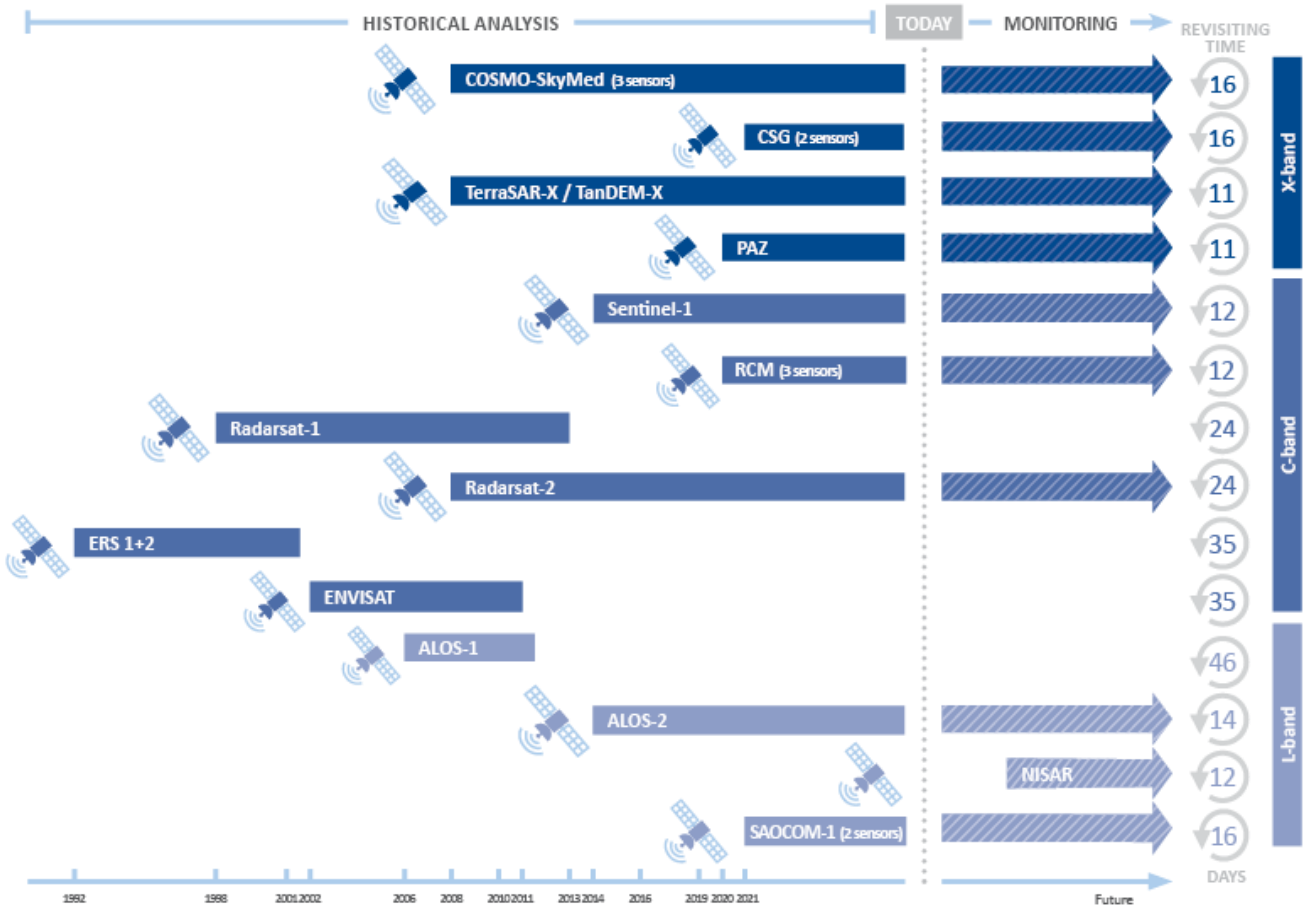
Peer-reviewed journal papers based on SAR interferometry and on ERS or Envisat data



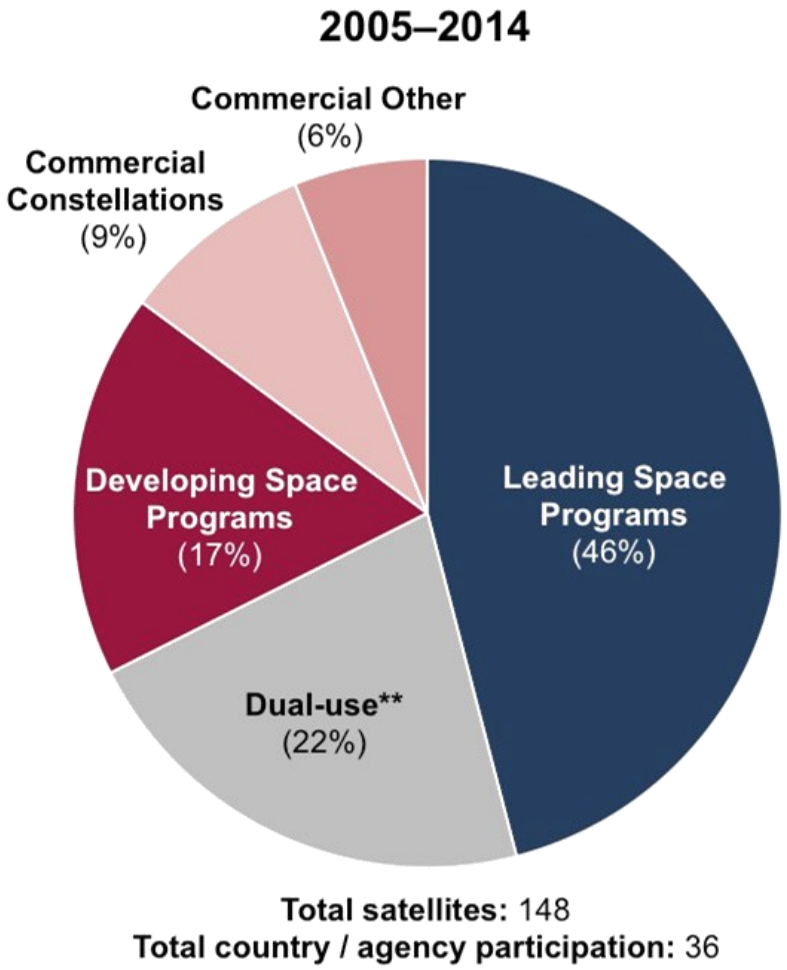
Significant Supply Expansion for EO Industry:

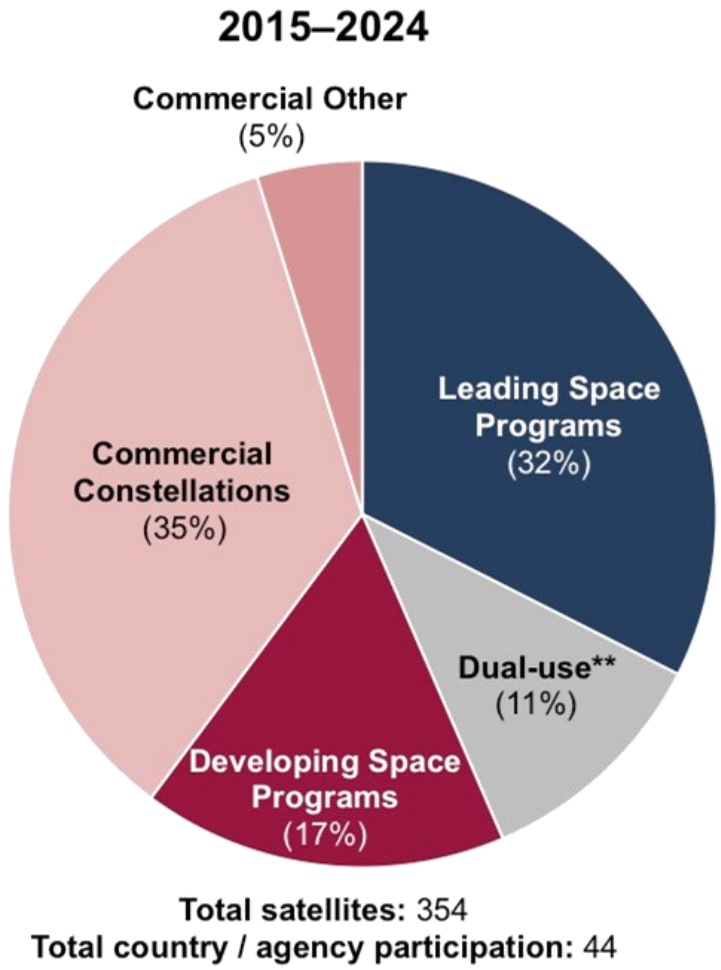
Data Demand Driven by Defense and Emerging Markets





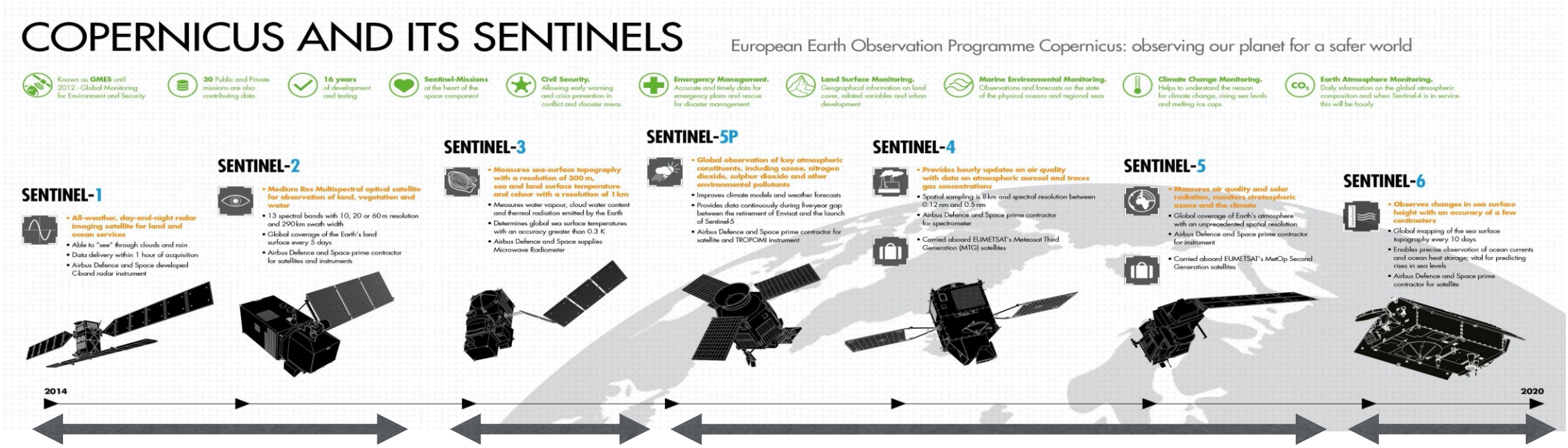
Earth Observation Satellites Launched by Operator type





Copernicus Sentinel-1 mission

Long-term Ensured Monitoring Capability

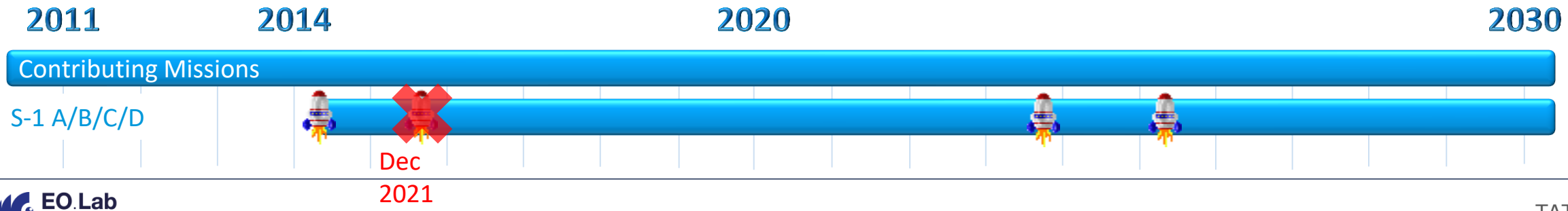


Ground Motion Monitoring

Sea Topography Sea and Land Temperature

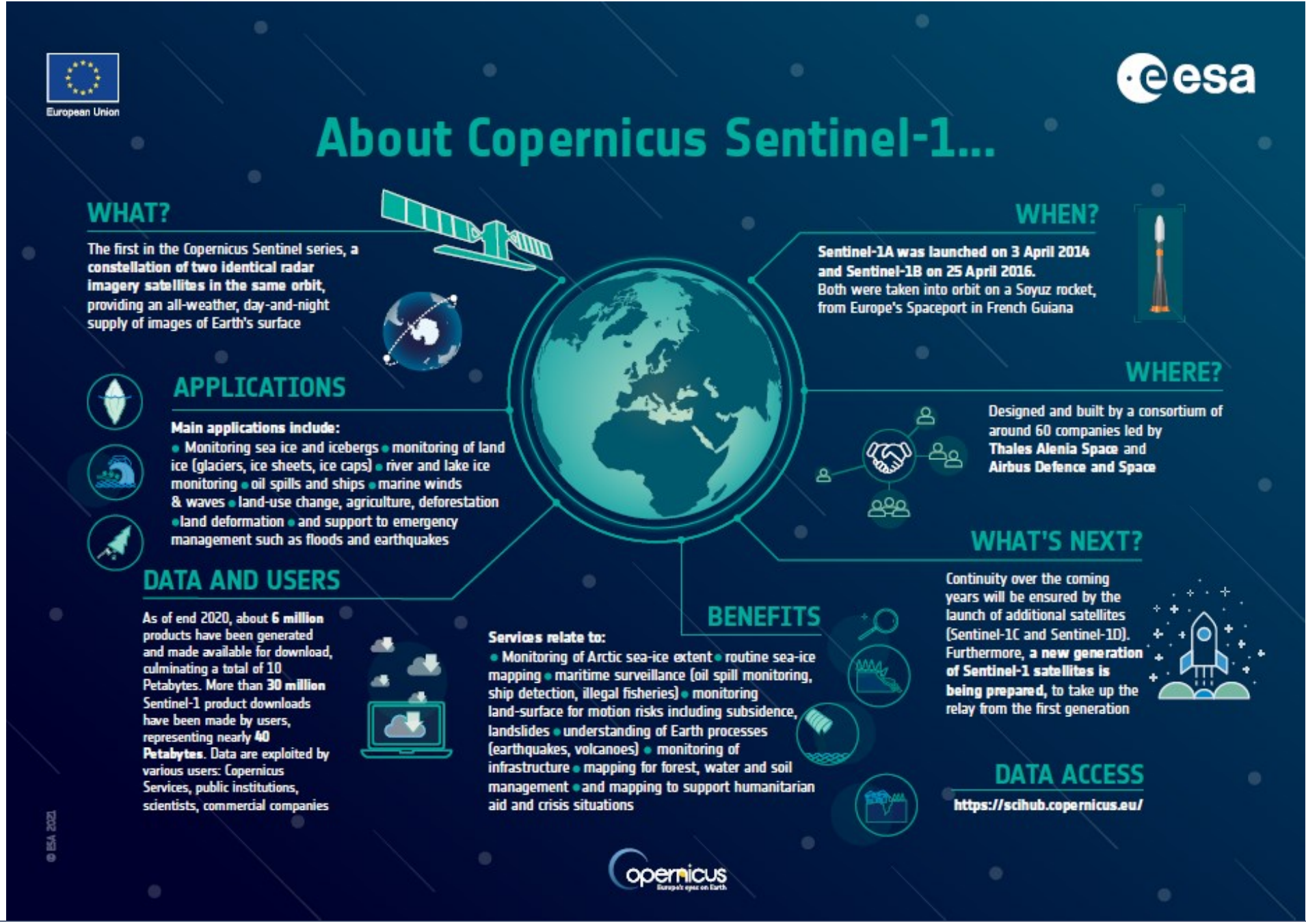
Atmospheric composition

Sea Surface Height Changes



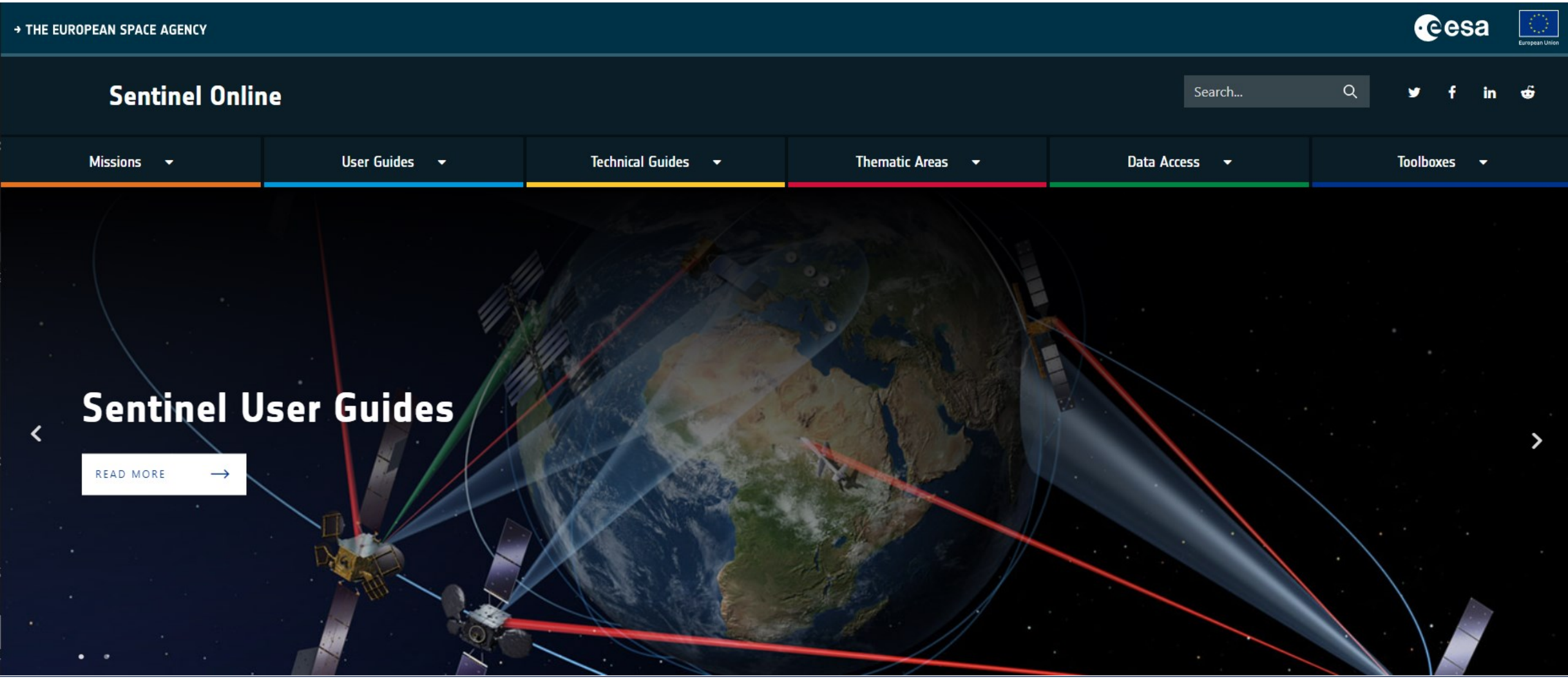
EU Copernicus

Sentinel-1 mission



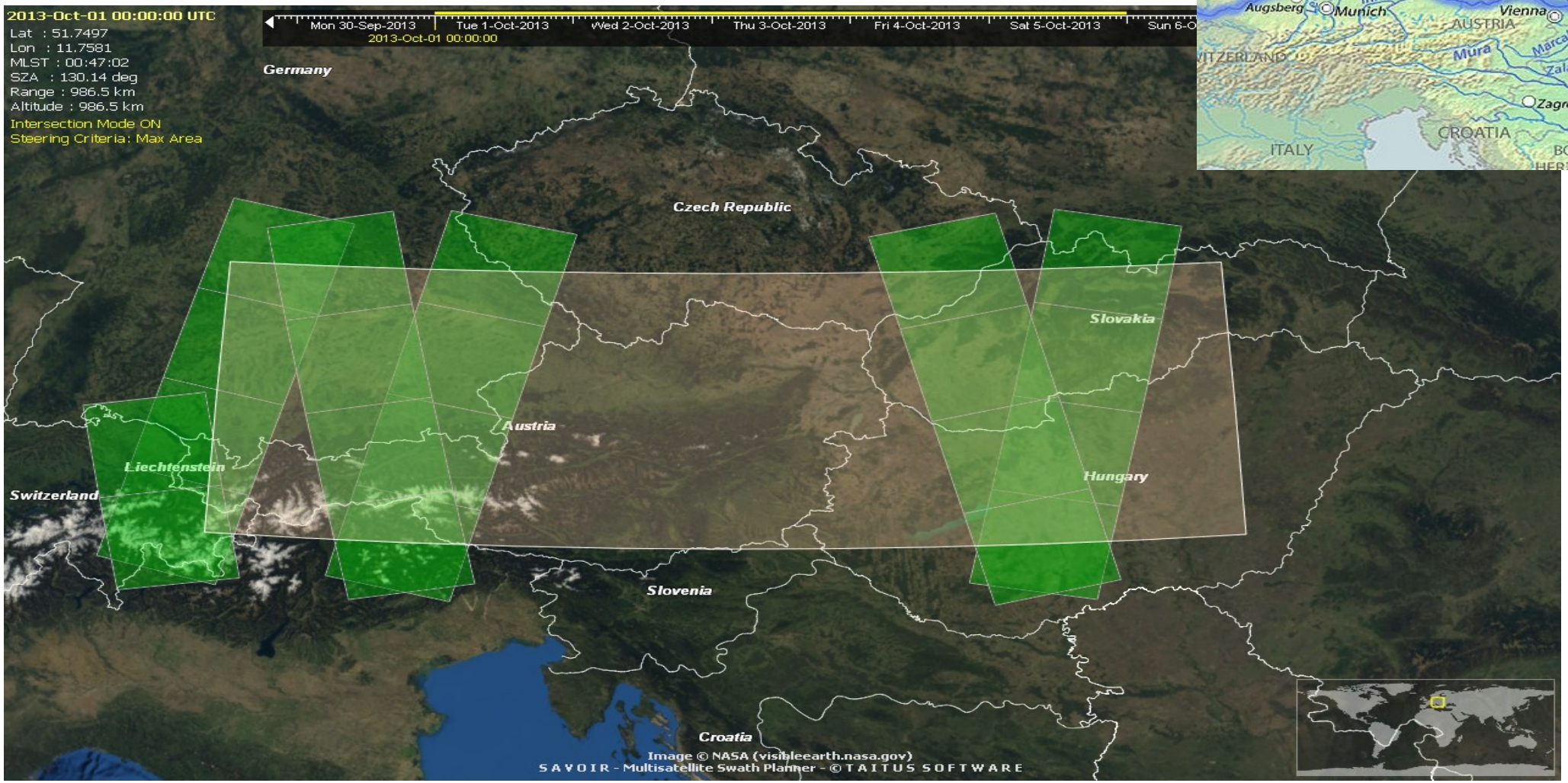
Sentinel Online

https://sentinels.copernicus.eu



Copernicus Sentinel-1 | **Improved Spatial Coverage**

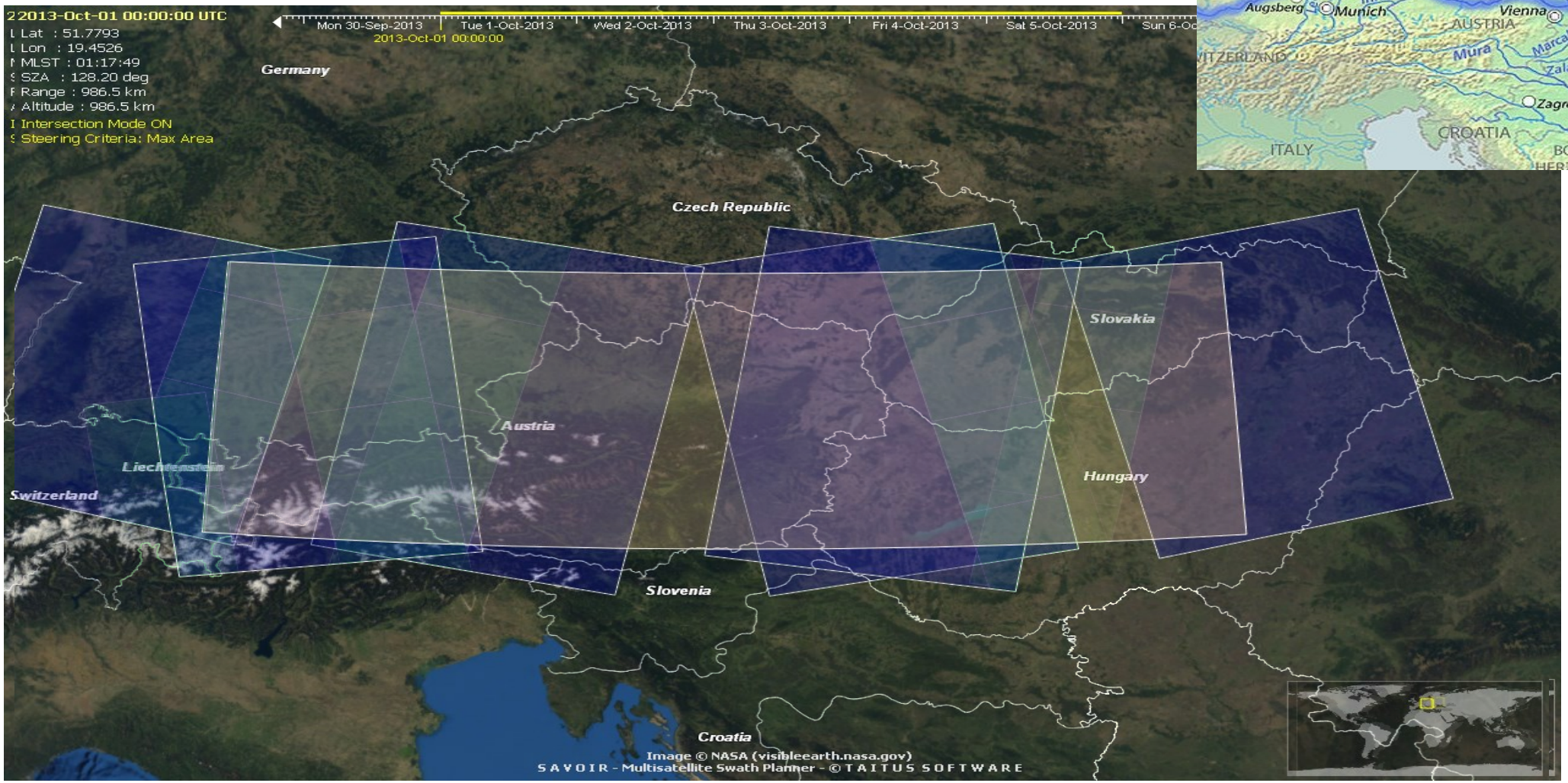
Sentinel-1 vs ENVISAT 5-day coverage



Until 2012:
ENVISAT

Copernicus Sentinel-1 | **Improved Spatial Coverage**

Sentinel-1 vs ENVISAT 5-day coverage

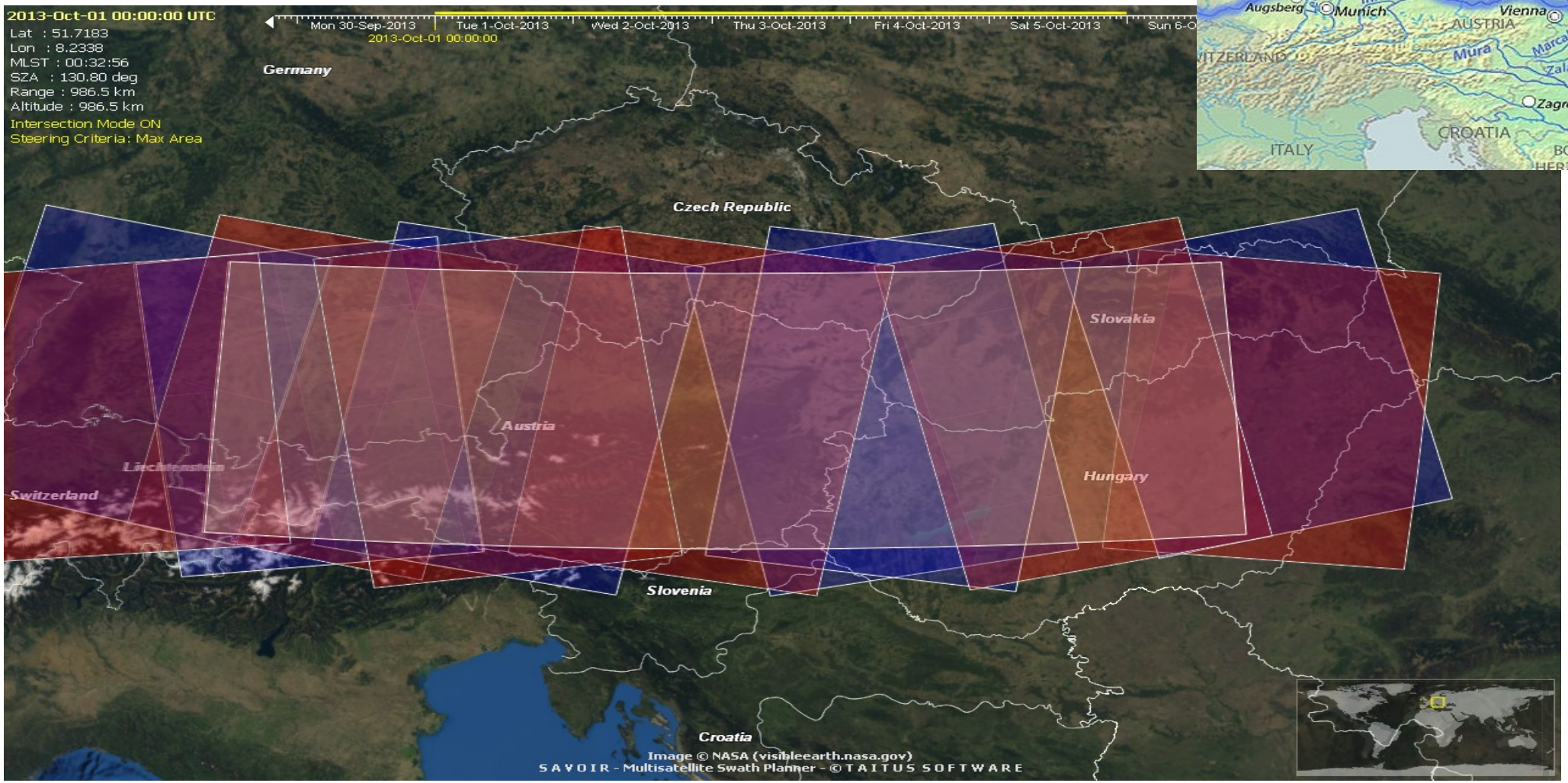


Until 2012:
ENVISAT

2014+:
Sentinel1A

Copernicus Sentinel-1 | **Improved Spatial Coverage**

Sentinel-1 vs ENVISAT 5-day coverage



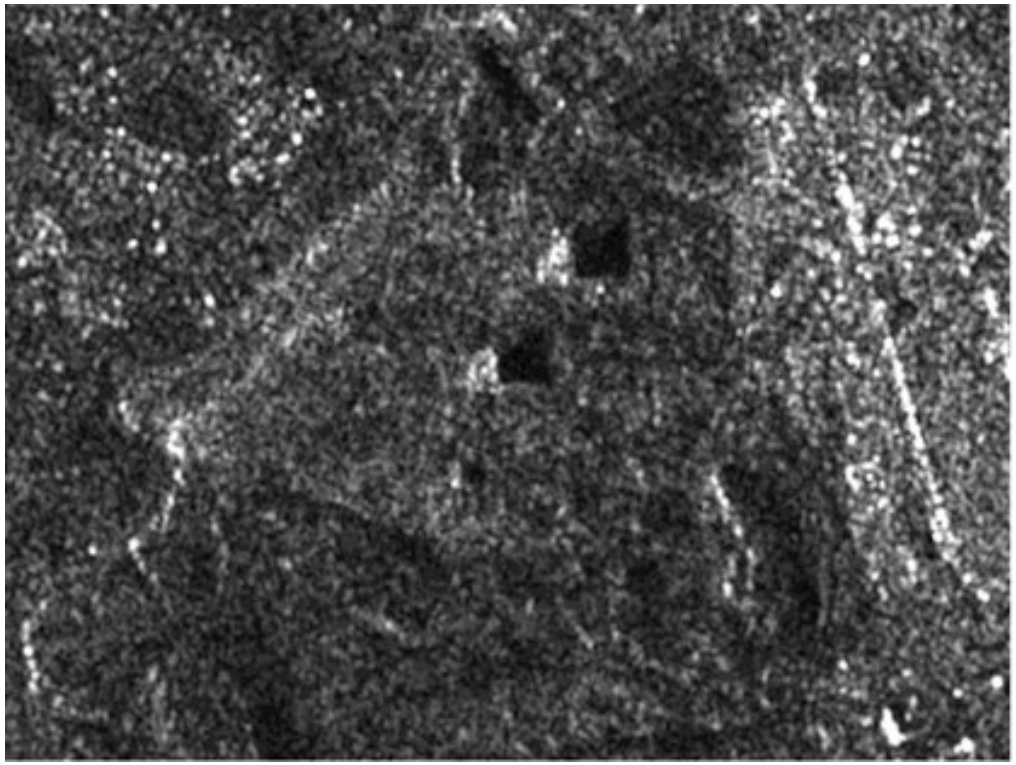
Until 2012:
ENVISAT

2014+:
Sentinel1A

2016+:
Sentinel1A/B

From Medium to High Resolution Spaceborne RADARs

Comparison of a SAR image corresponding to the state of the art during the 90s [ca. 20 m resolution, C-band, radar illumination from the left] and the generation of SAR satellites available since 2007 [1 m resolution, X-band, radar illumination from the right].



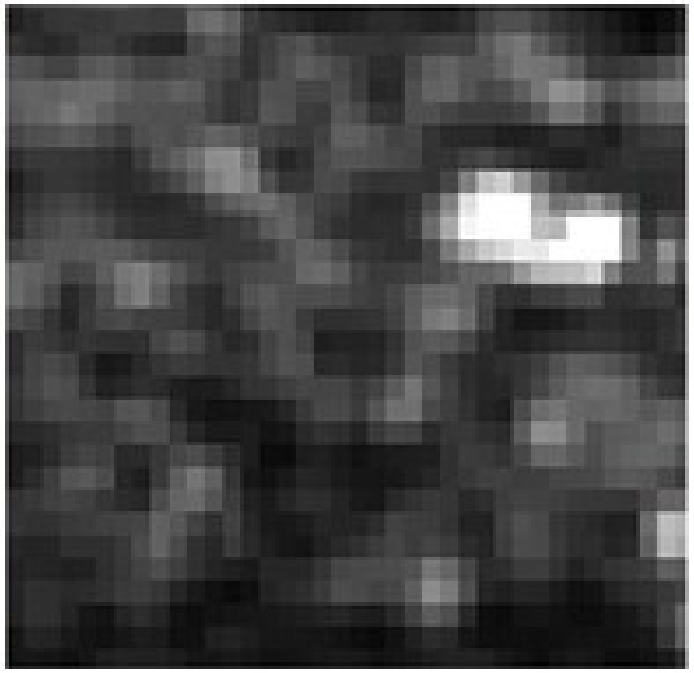
The images show the pyramids of Giza, Egypt.

From Medium to Very High Resolution Spaceborne RADARs

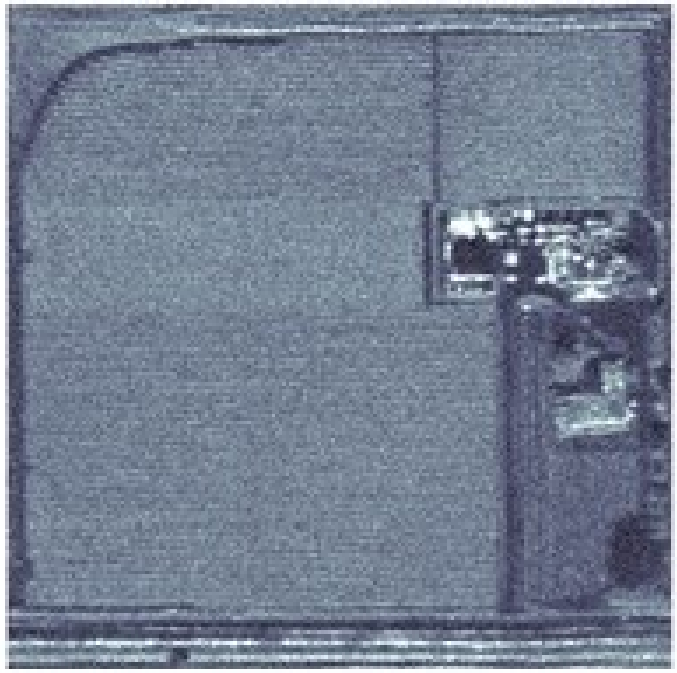
Comparison of a SAR image from Copernicus Senintinel-1 (ca. 20 m resolution C-band in IW mode) and new generation of SAR satellites reaching 0.5 m (Capella X-band in Spotlight mode).

Google Reference Image

Copernicus Sentinel-1



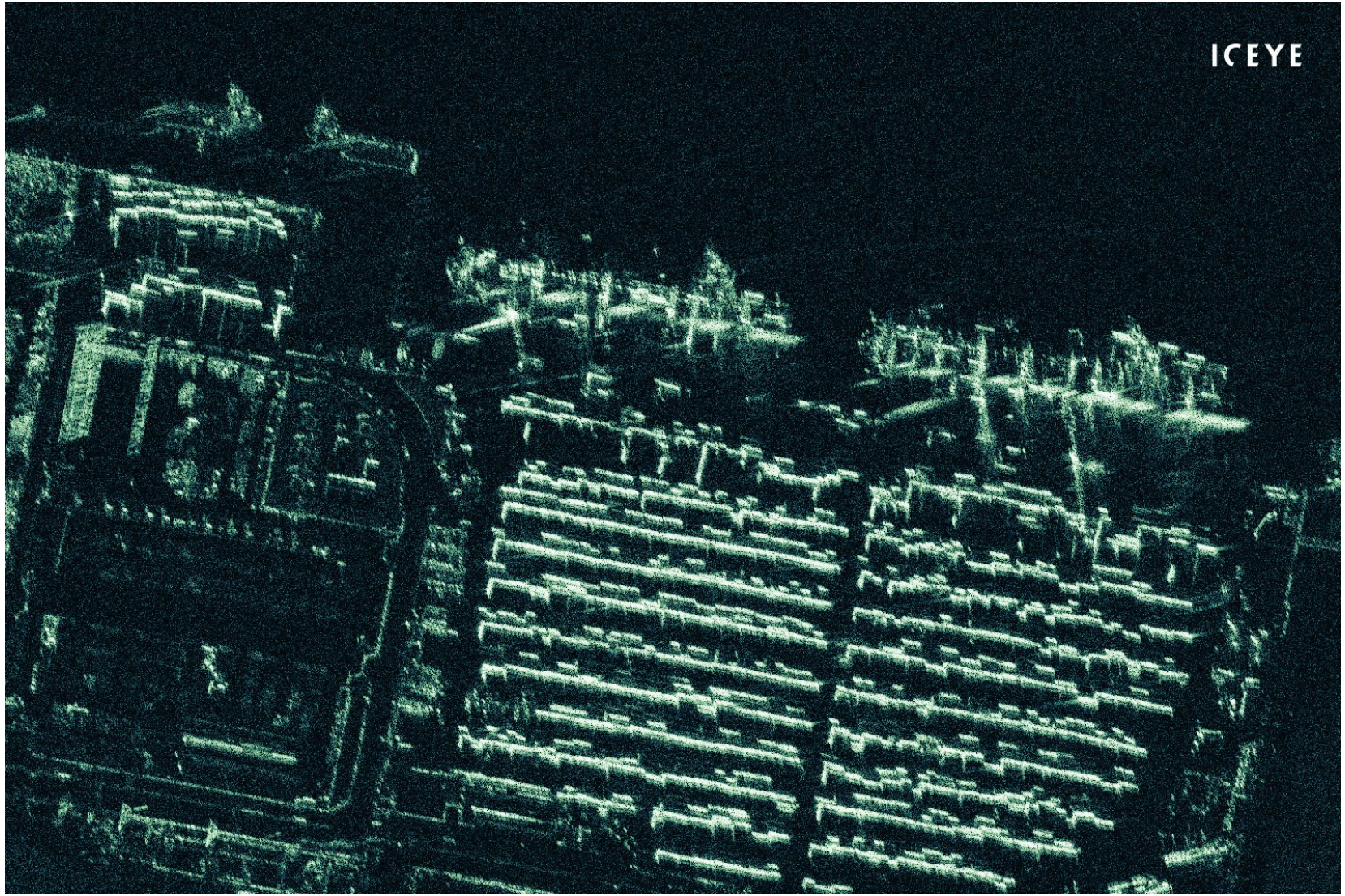
Cappella

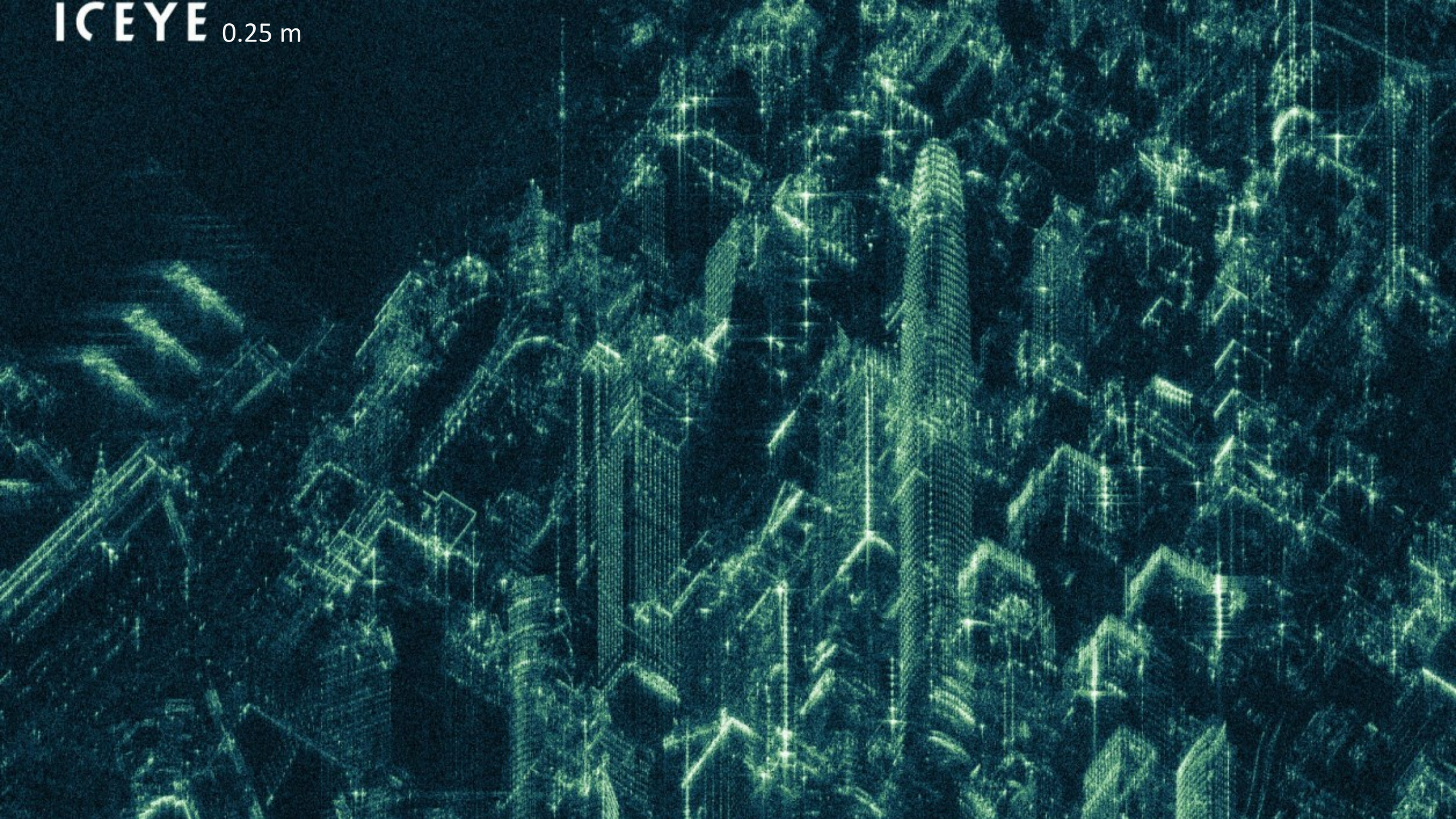



Sentinel-1 ~20 m

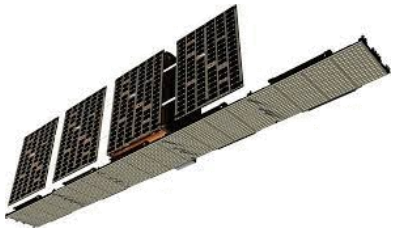

Capella 0.50 m

ICEYE Releases World-First Under 1-Meter Resolution Radar Imagery from SAR Microsatellites




ICEYE 0.25 m

ICEYE SAR | Moving from Imagery to Video Capture



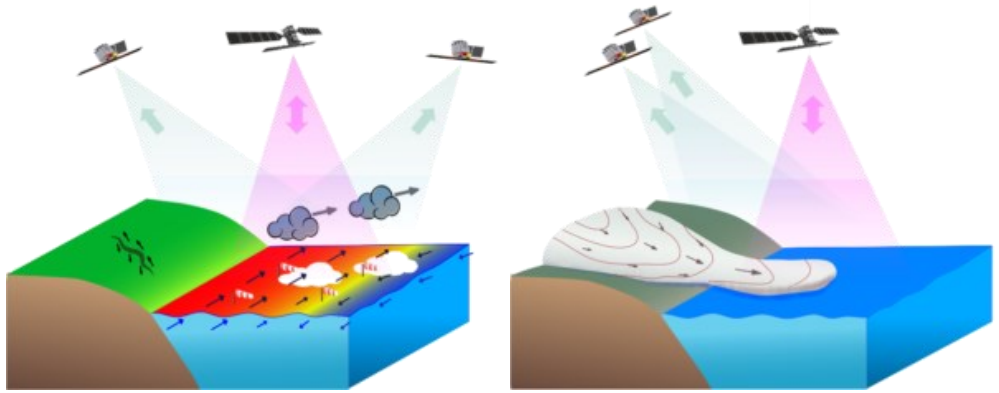
ESA Earth Explorer 10 | HARMONY

Expected launch 2029

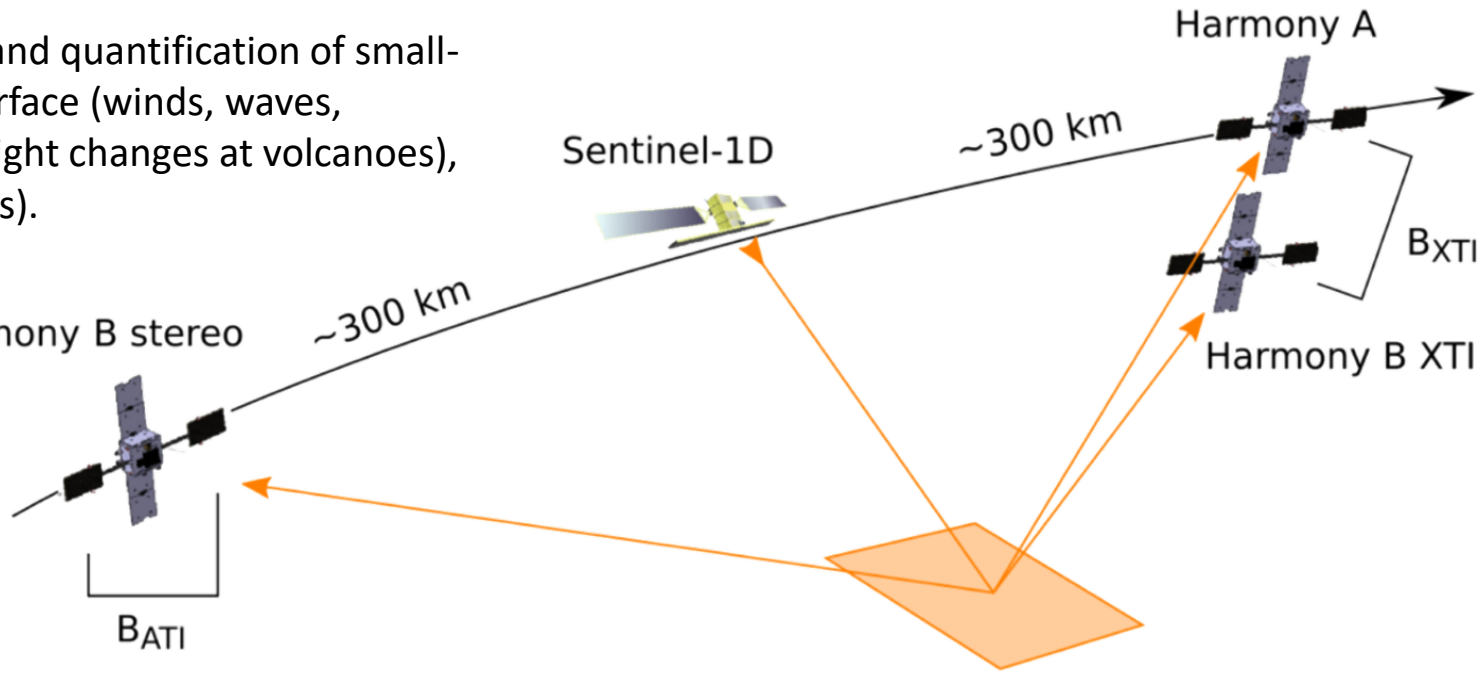
Mission approved by ESA member states in Sept 2022

The Harmony mission is dedicated to the observation and quantification of small-scale motion and deformation fields at the air-sea interface (winds, waves, surface currents), of solid Earth (tectonic strain and height changes at volcanoes), and in the cryosphere (glacier flows and height changes).

In order to achieve the different mission goals, the Harmony mission shall deploy two companion satellites following one of ESA's Copernicus Sentinel-1 satellites. The companions will be flying in two different formations.



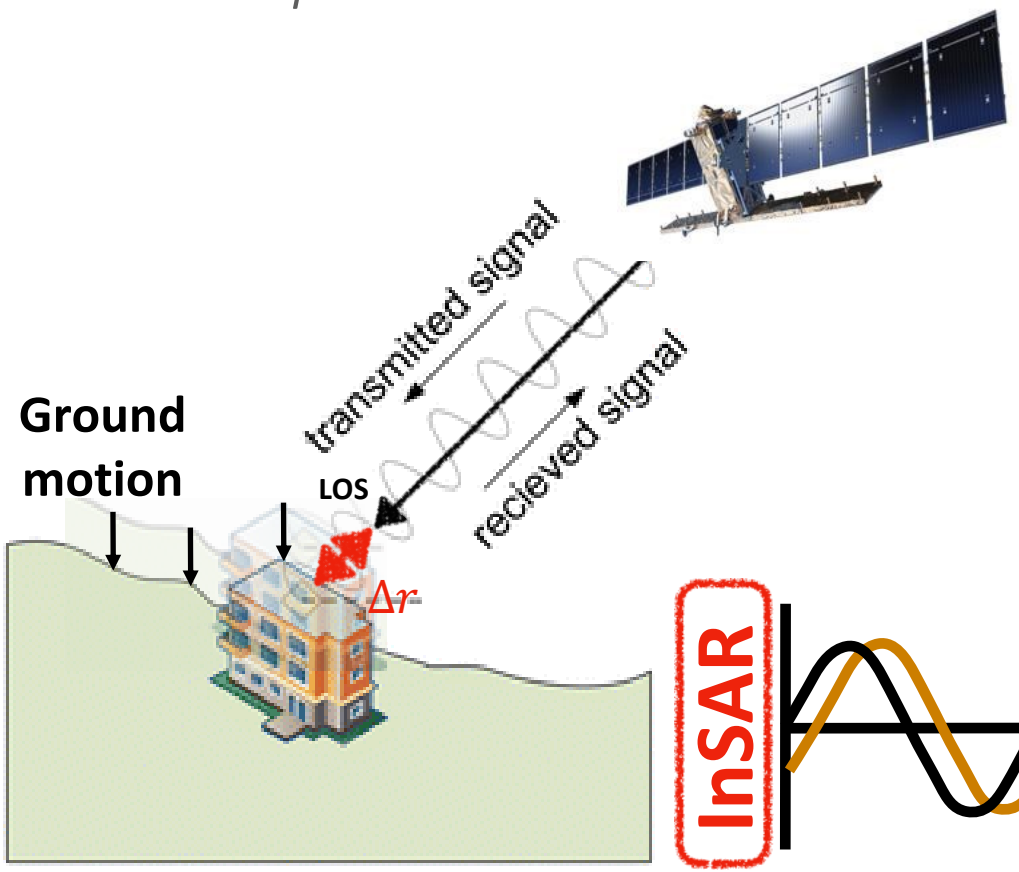
Copyright: Harmony Mission Advisory Group.

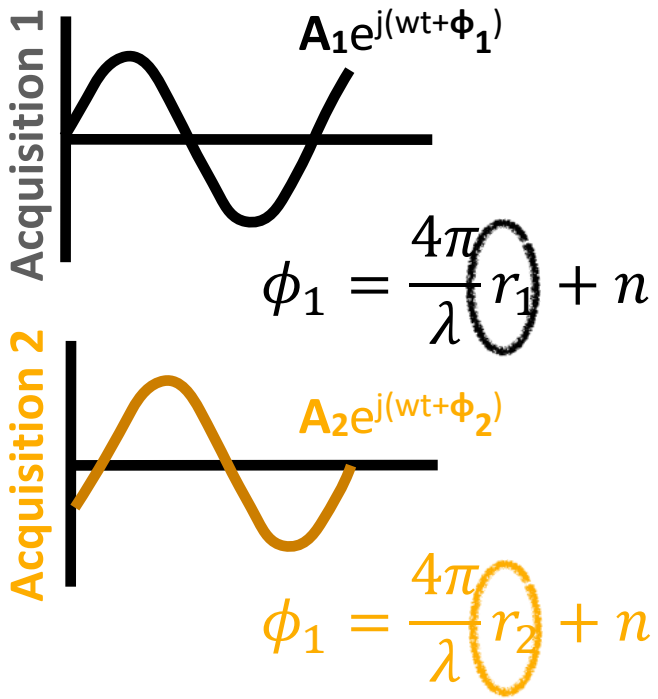


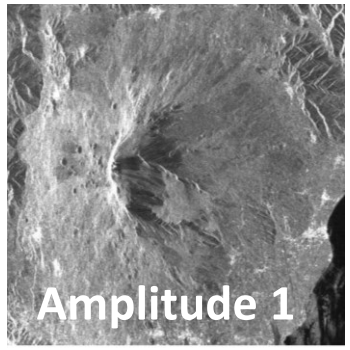
The angular diversity provided by the Harmonies in combination with Sentinel-1 will allow the retrieval of deformation measurements of the sea and earth surface with unprecedented accuracy, while the cross-track configuration will allow the accurate measurement of elevation changes for land-ice and volcanic applications.

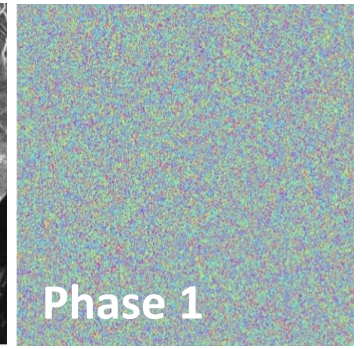
What is SAR Interferometry (InSAR)?

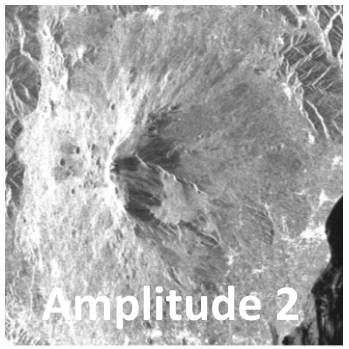
SAR interferometry consists in computing the phase difference of two SAR acquisitions

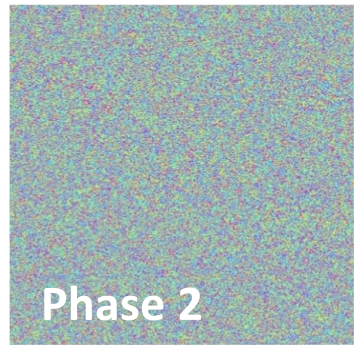




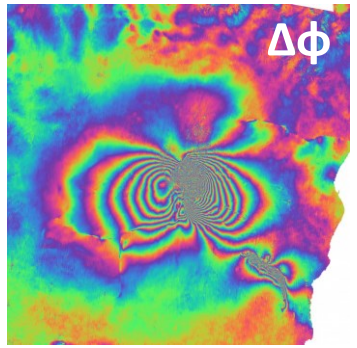






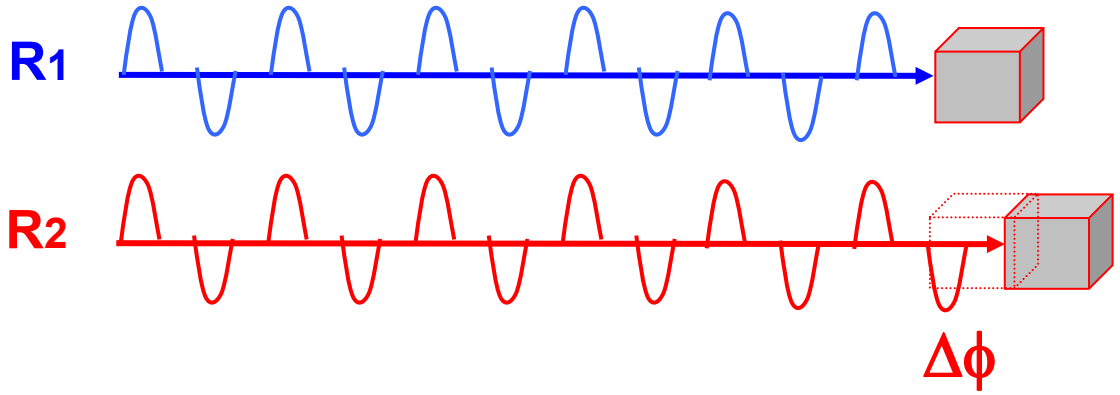


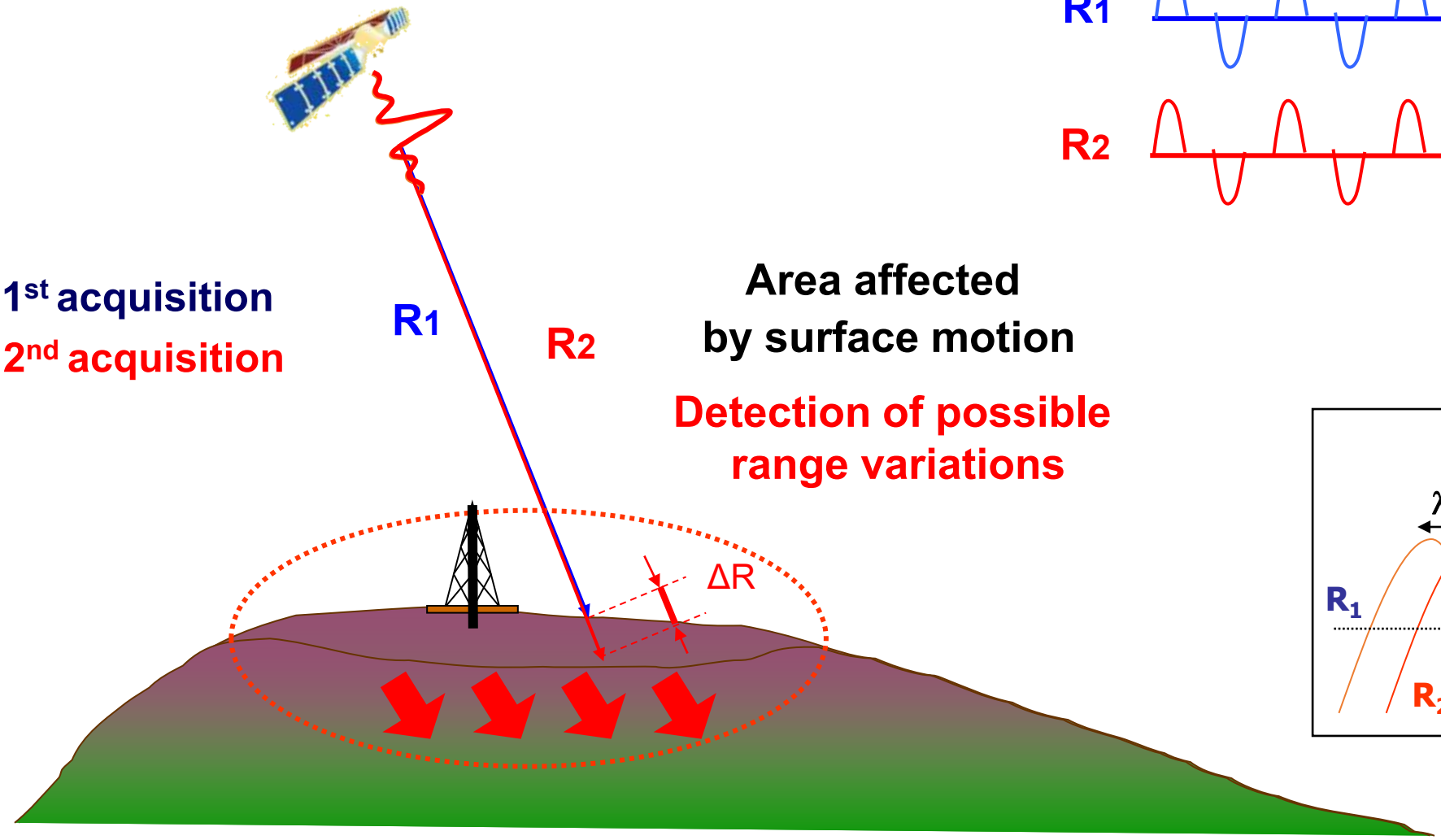
$$\Delta\phi = \phi_2 + \phi_1 = \frac{4\pi}{\lambda}(r_2 - r_1) + n \quad (\Delta r)$$



InSAR for Surface Motion

The ***unit of length*** used in InSAR is the wavelength:

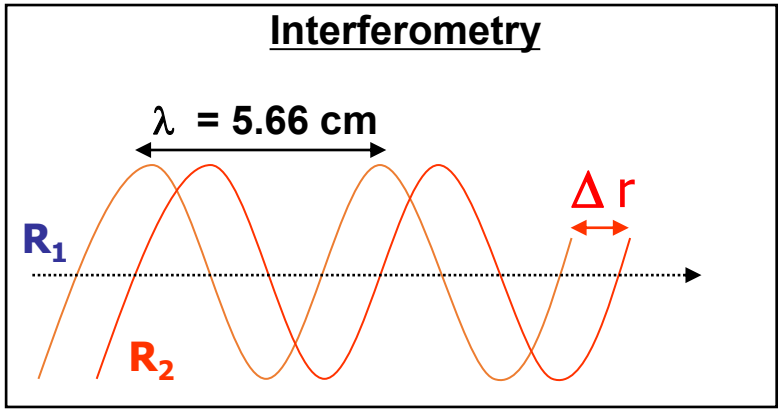




Area affected by surface motion

Detection of possible range variations

$$\Delta R = c \cdot \Delta\phi$$



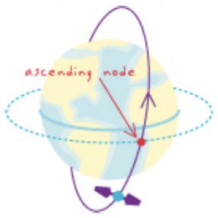
InSAR products | Differential Interferograms

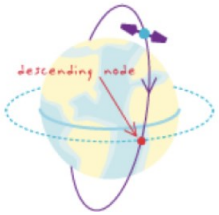
WRAPPED INTERFEROGRAM

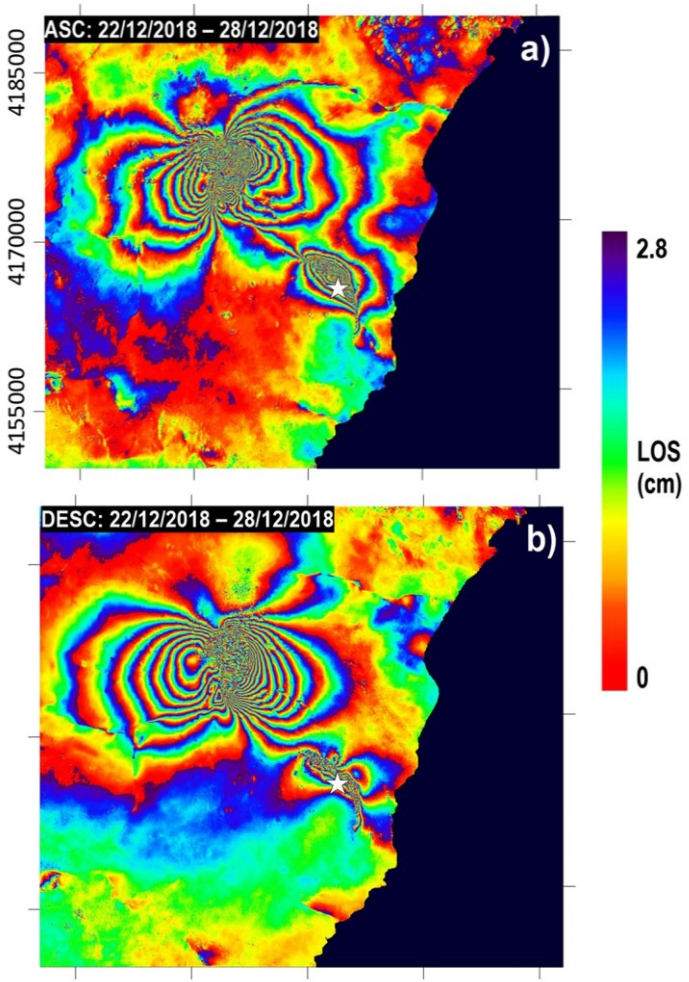
UNWRAPPED INTERFEROGRAM

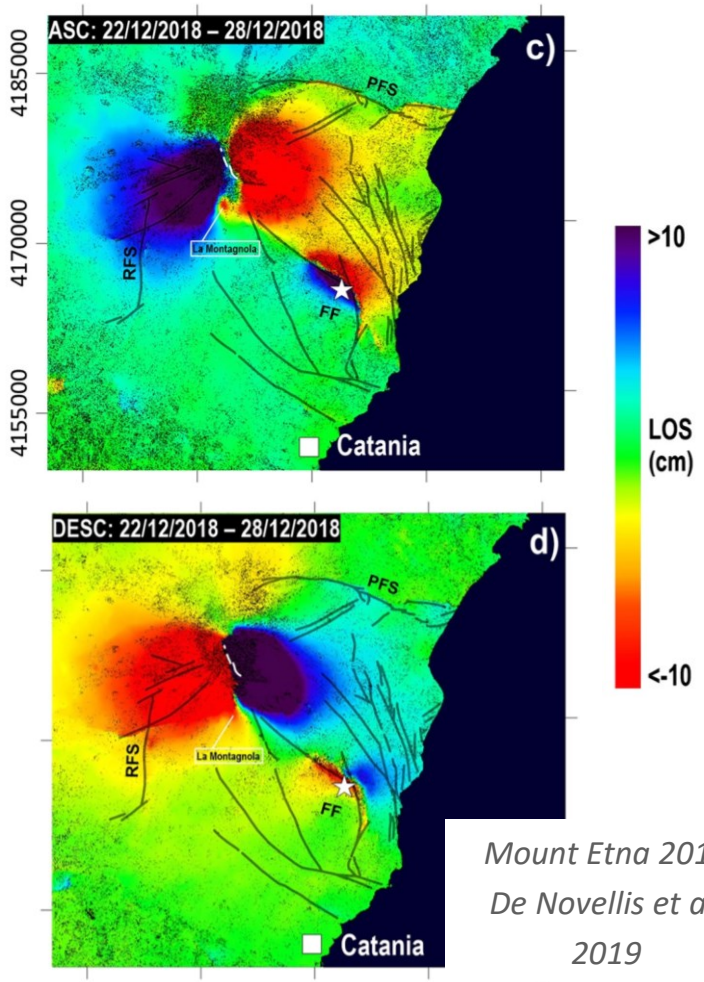
Ascending orbit

descending orbit









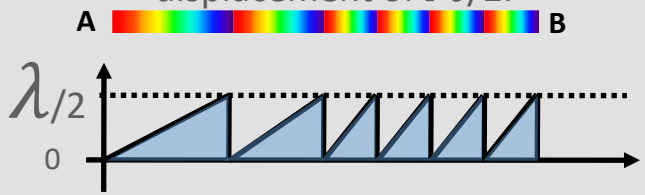
Mount Etna 2018
De Novellis et al, 2019

It shows the phase difference Δϕ

It shows the ground displacement in the LOS direction

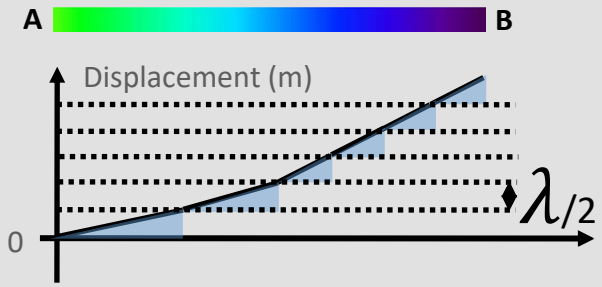
WRAPPED INTERFEROGRAM

One can estimate the displacement by counting the number of fringes. One fringe corresponds to a ground displacement of $\lambda/2$.



UNWRAPPED INTERFEROGRAM

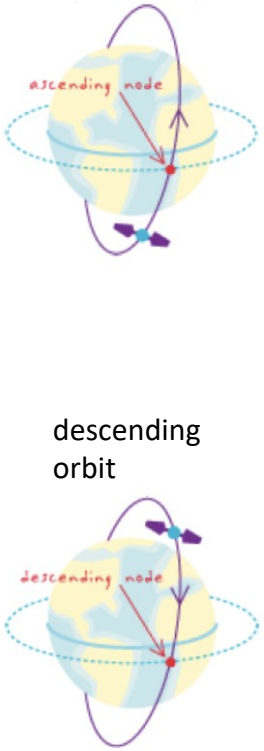
Unwrapping automatized this step to retrieve the ground displacement.

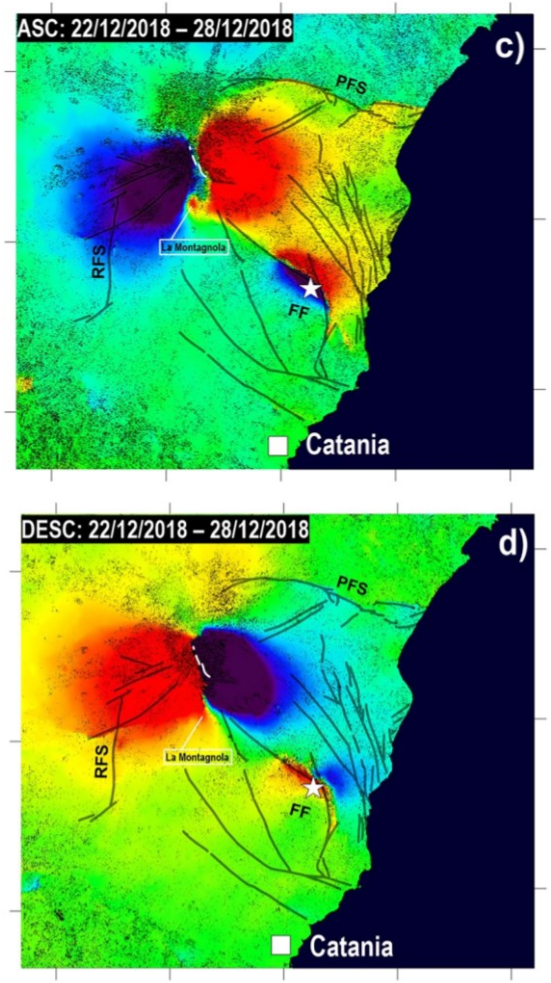


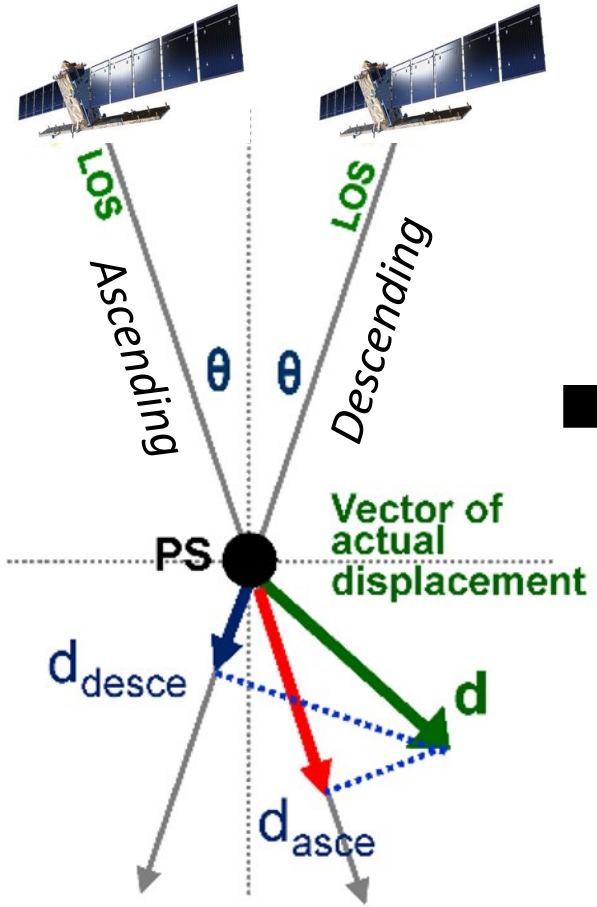
InSAR Motion Decomposition

Ascending orbit

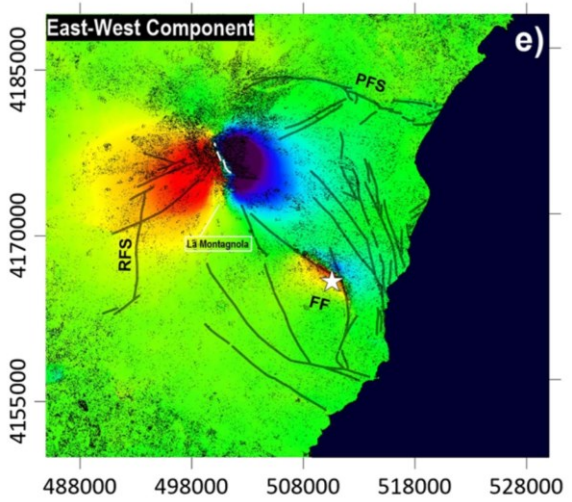
descending orbit



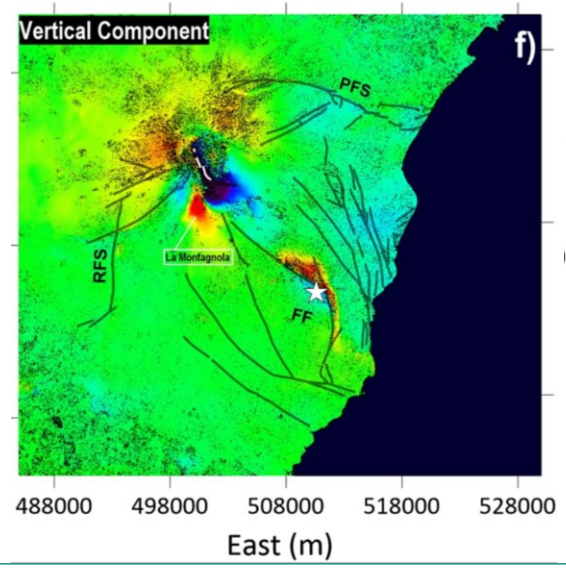


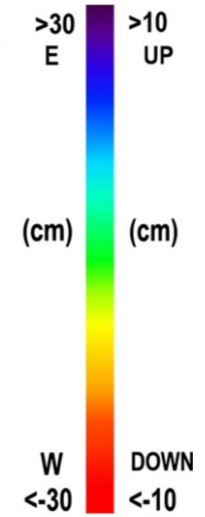


EAST-WEST MOTION



VERTICAL MOTION





Mount Etna 2018
De Novellis et al, 2019

Operational **Copernicus Sentinel-1** mission & Maturity of Synthetic Aperture Radar Interferometry (**InSAR**)

1992

First demonstration using ESA SAR data, over the M7.3 Landers earthquake by Massonnet et al. 1992;

2002

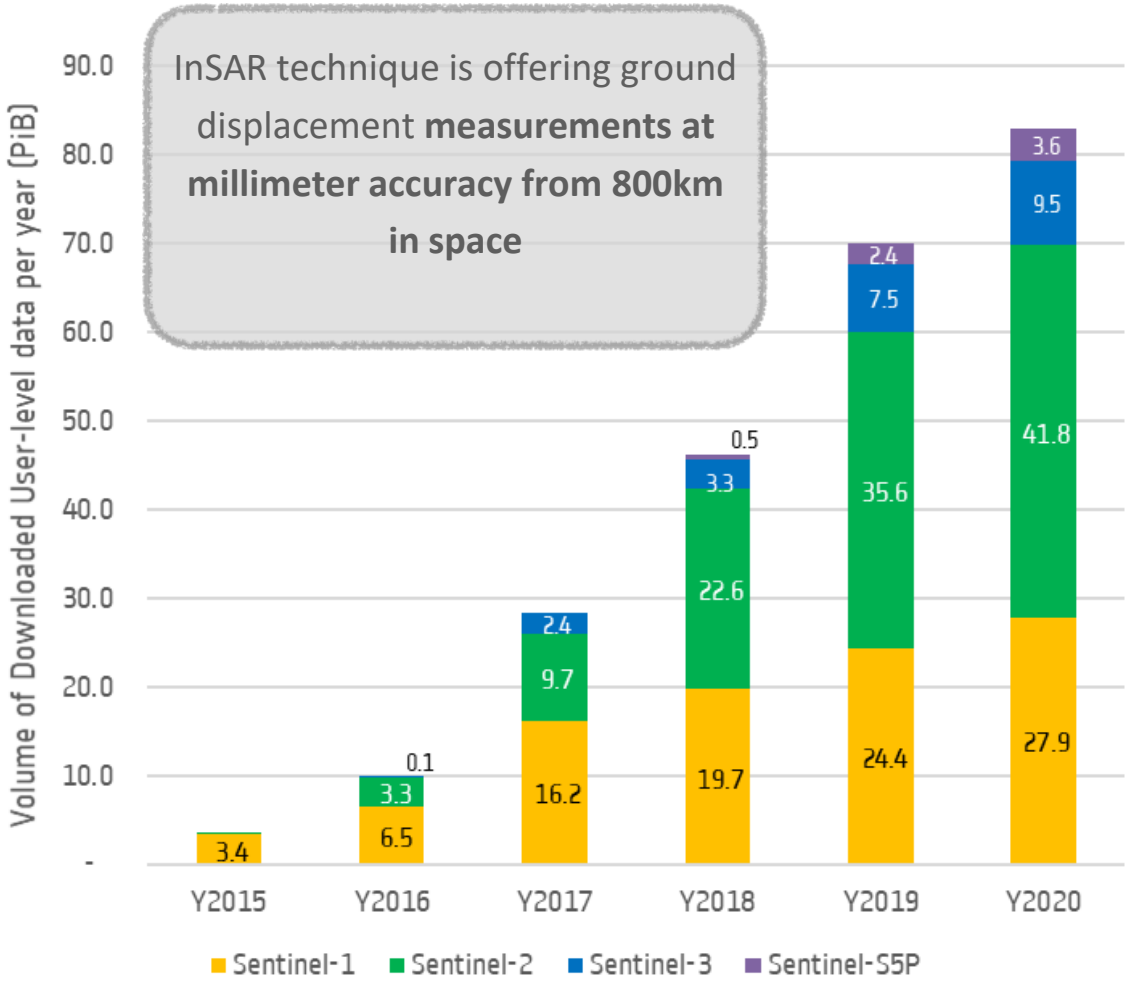
Revolutionized for ***processing of long data stacks*** to obtain millimeter level accuracy (Ferretti et al. 2002);

2010-2020

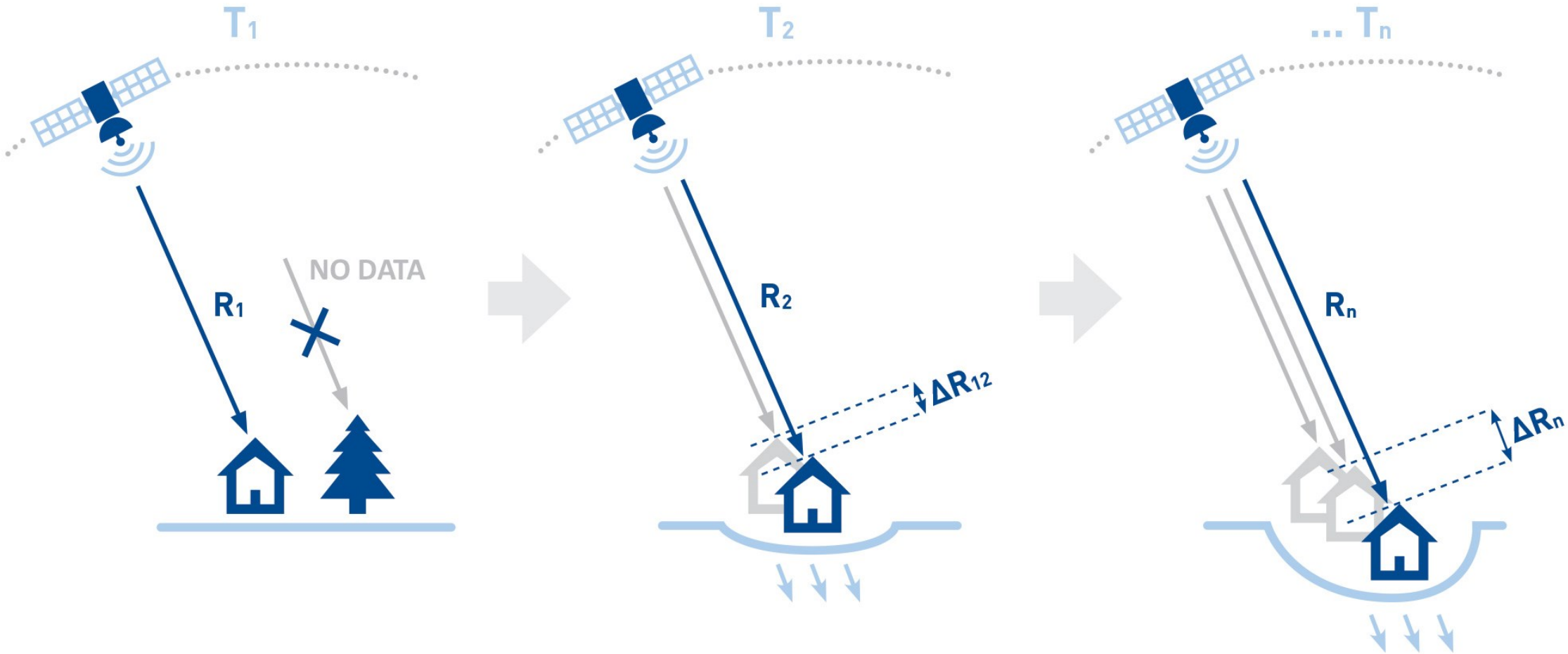
Reached ***maturity*** and validated over ~20 years (e.g. ESA Terrafirma project)

2020-2030

Made ***operational*** via Copernicus Sentinel-1 constellation and other national and commercial SAR missions

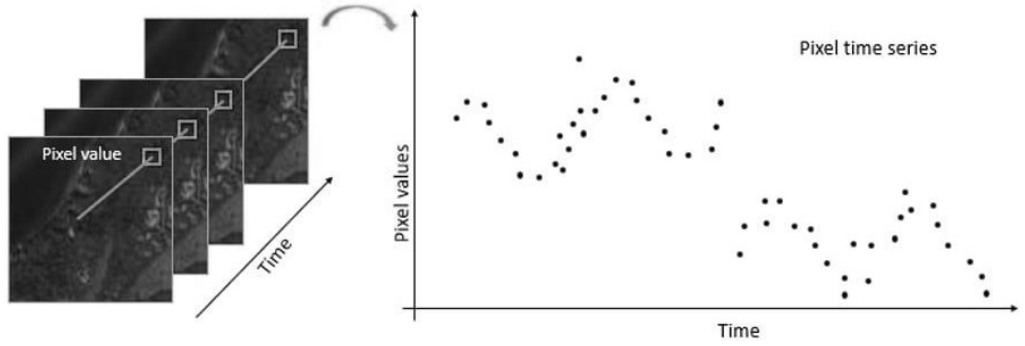


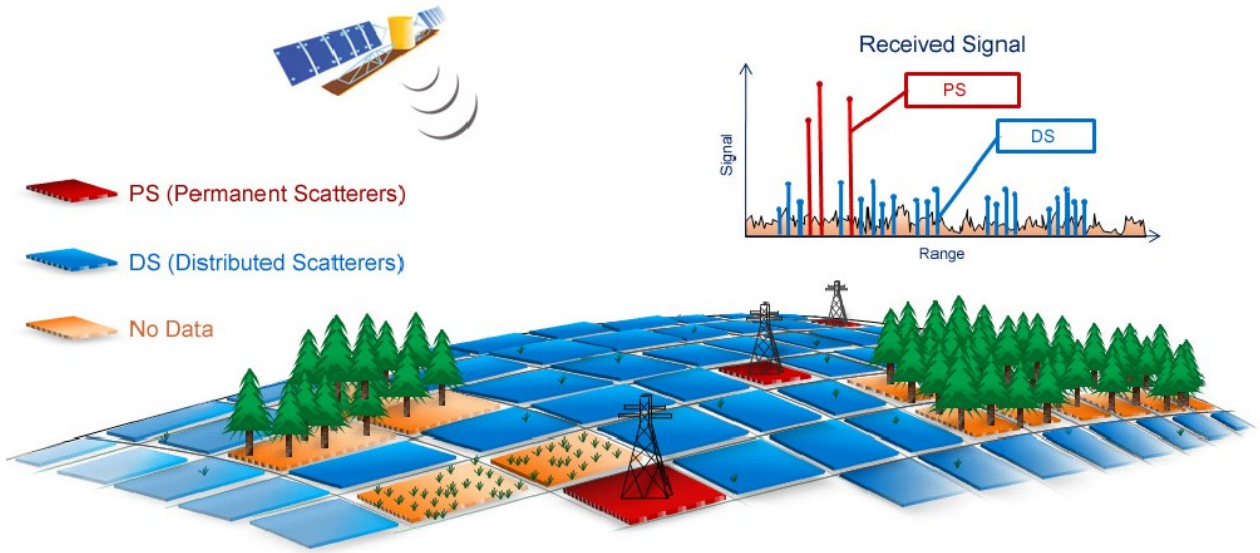
Conventional InSAR vs. Advanced Multi-Temporal InSAR

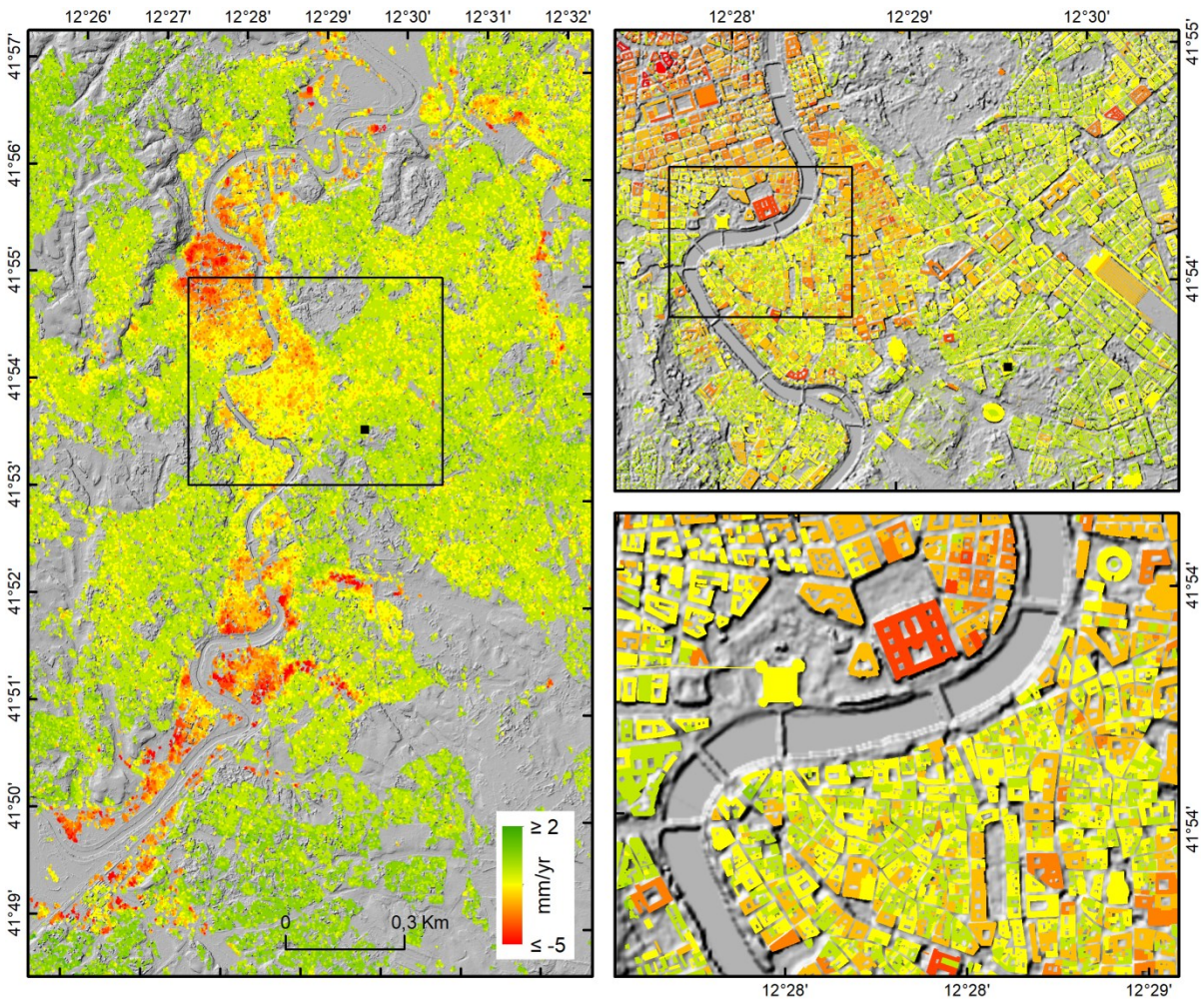


Multi-Temporal SAR Interferometry

Exploit temporal and spatial characteristics of interferometric signatures from point targets remaining 'stable' over time



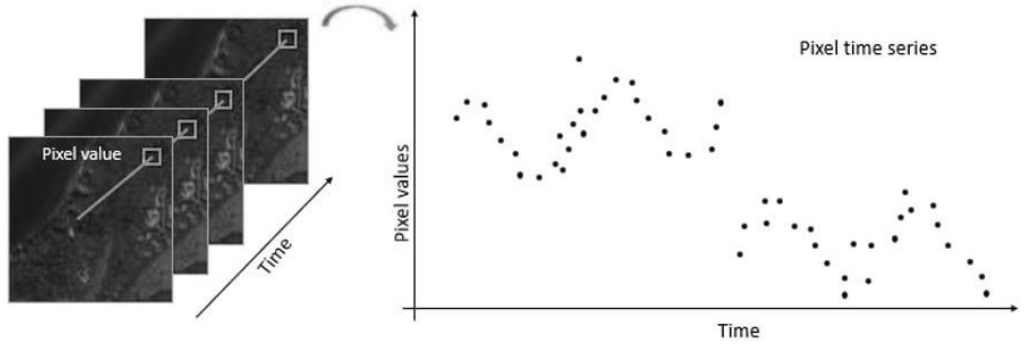


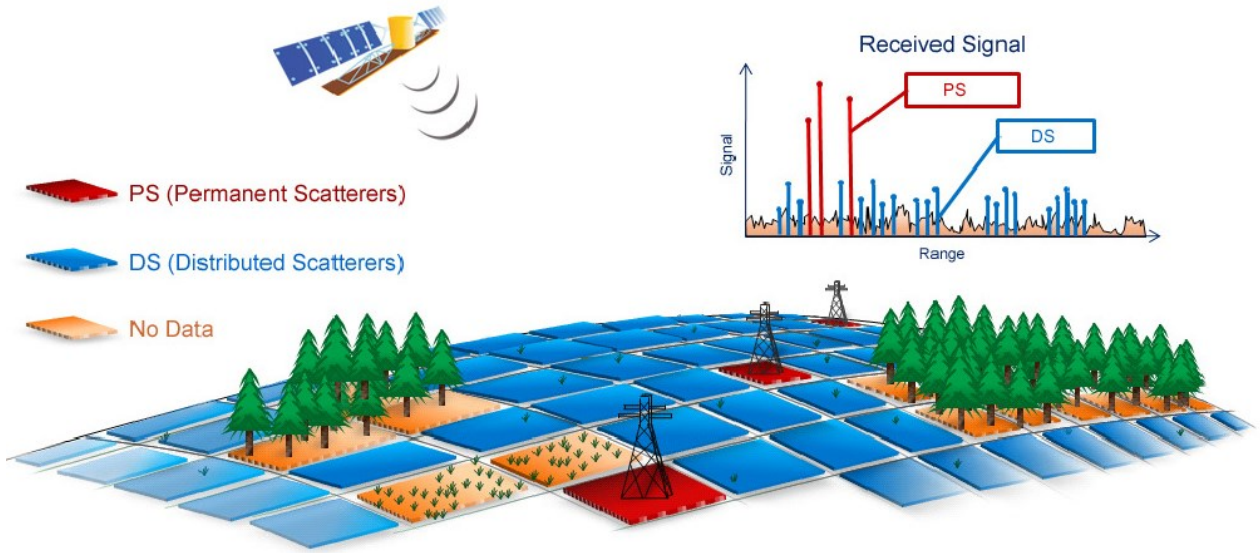


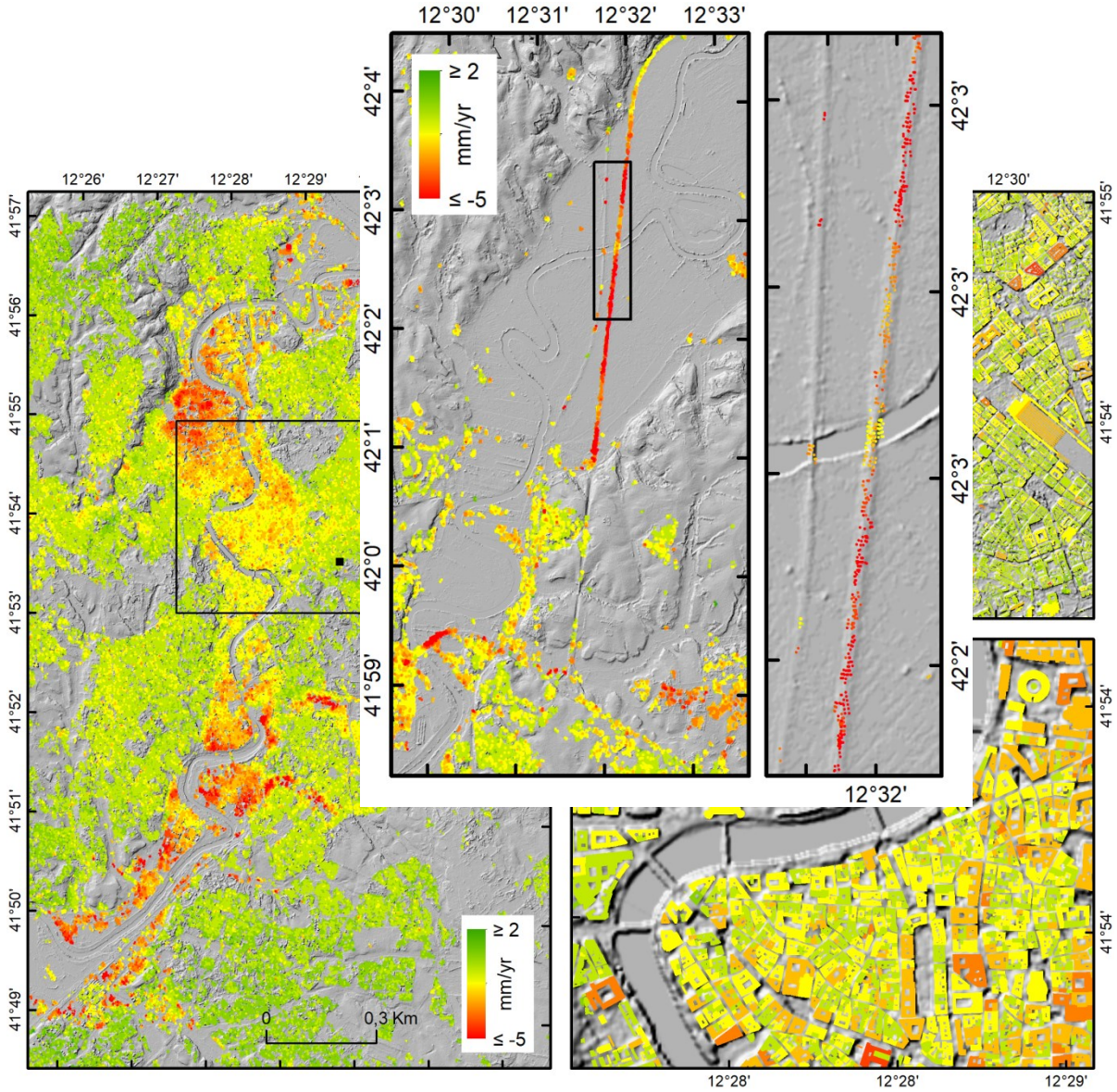
Delgado Blasco, J.M.; Foumelis, M.; Stewart, C.; Hooper, A. Measuring Urban Subsidence in the Rome Metropolitan Area (Italy) with Sentinel-1 SNAP-StaMPS Persistent Scatterer Interferometry. *Remote Sens.* **2019**, *11*, 129. https://doi.org/10.3390/rs11020129

Multi-Temporal SAR Interferometry

Exploit temporal and spatial characteristics of interferometric signatures from point targets remaining 'stable' over time

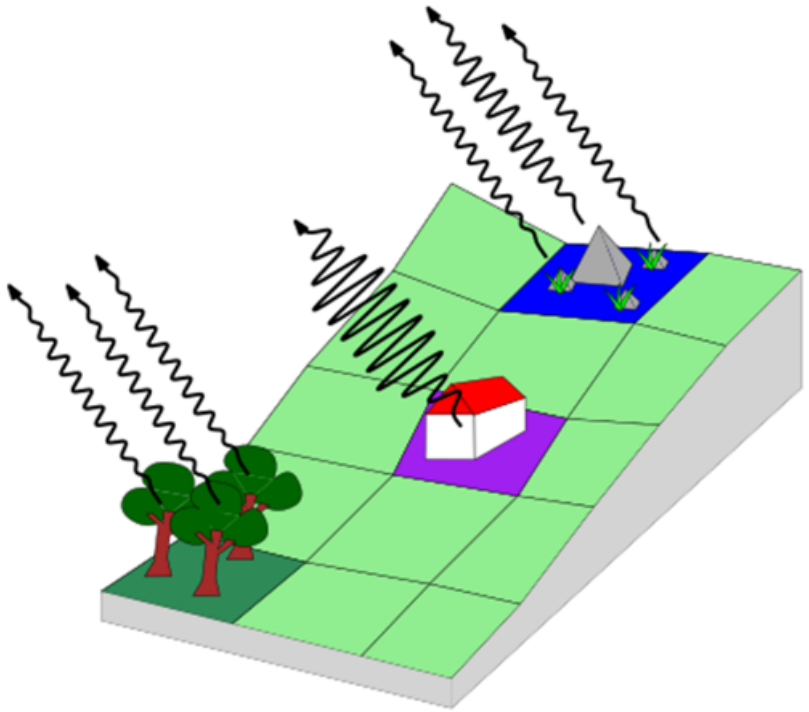


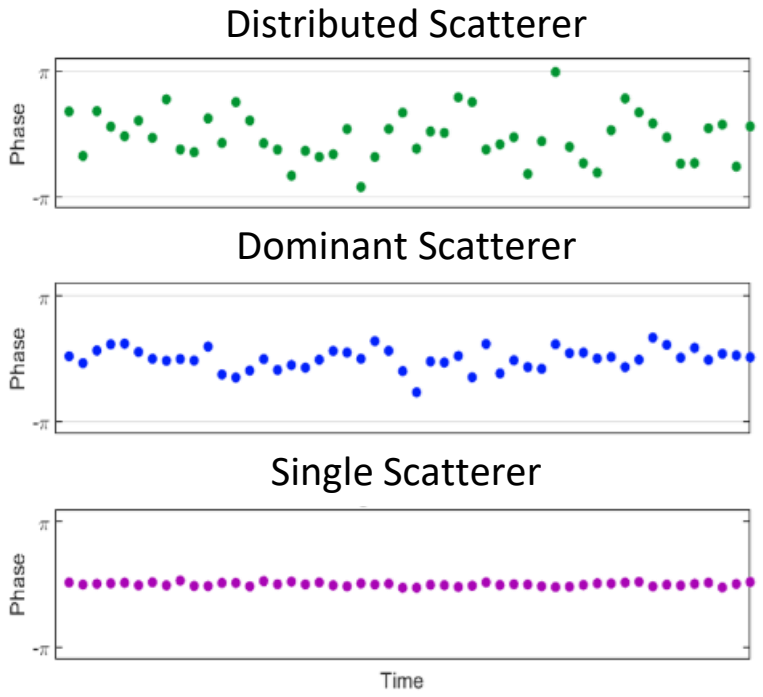


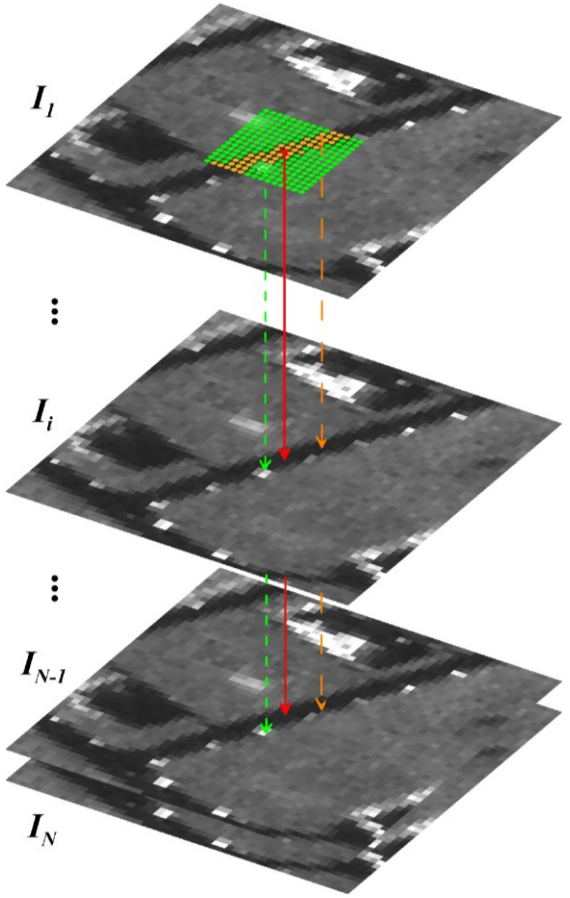


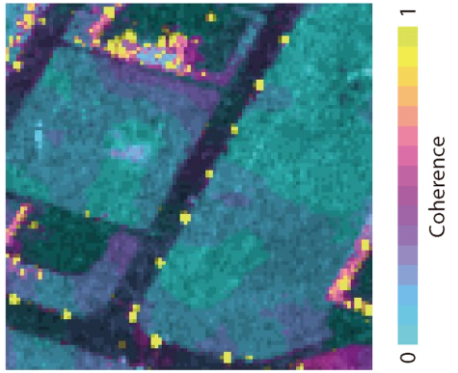
Delgado Blasco, J.M.; Foumelis, M.; Stewart, C.; Hooper, A. Measuring Urban Subsidence in the Rome Metropolitan Area (Italy) with Sentinel-1 SNAP-StaMPS Persistent Scatterer Interferometry. *Remote Sens.* **2019**, *11*, 129. https://doi.org/10.3390/rs11020129

Detection of Targets | PS vs DS points



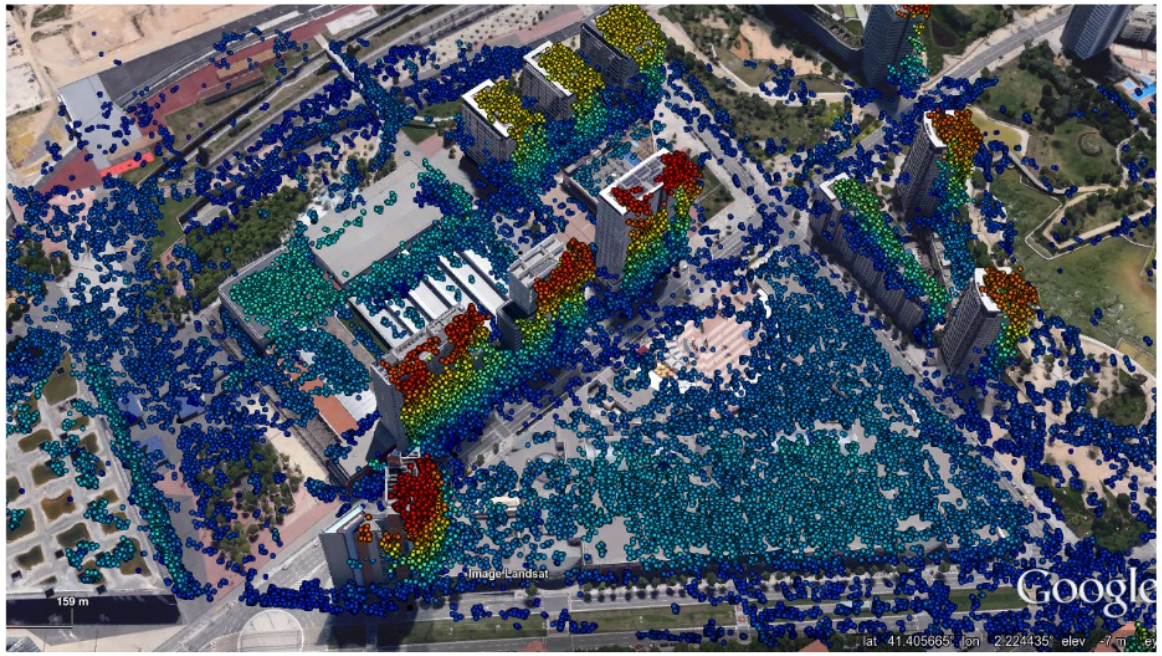


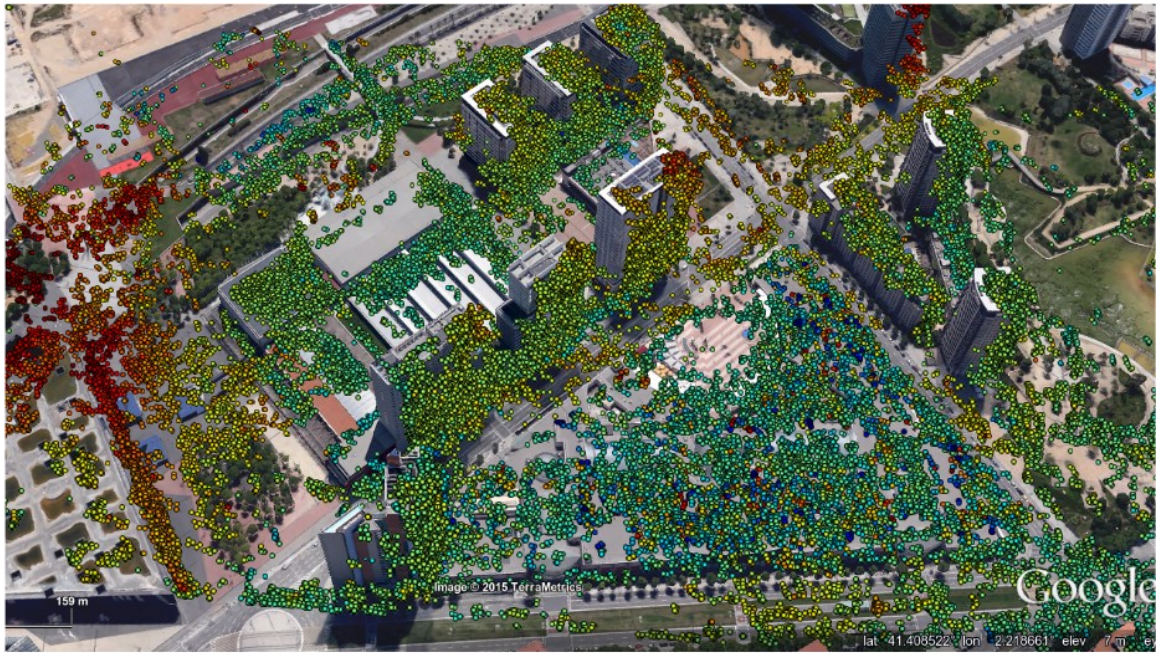


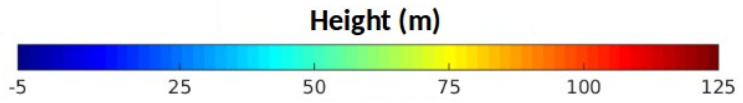


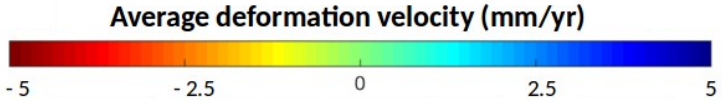
Persistent Scatterers (PSs)

PS refers to point-like objects on the Earth's surface that reflect radar waves consistently over time, despite changes in the scene such as surface deformation, vegetation growth, or seasonal changes.



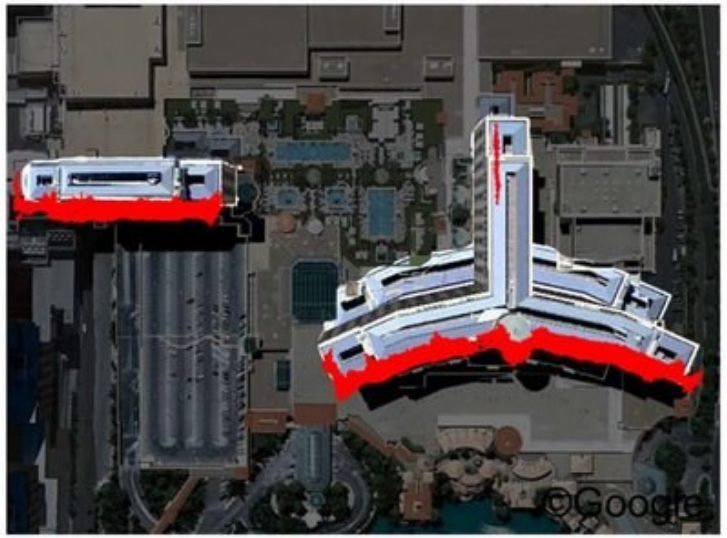


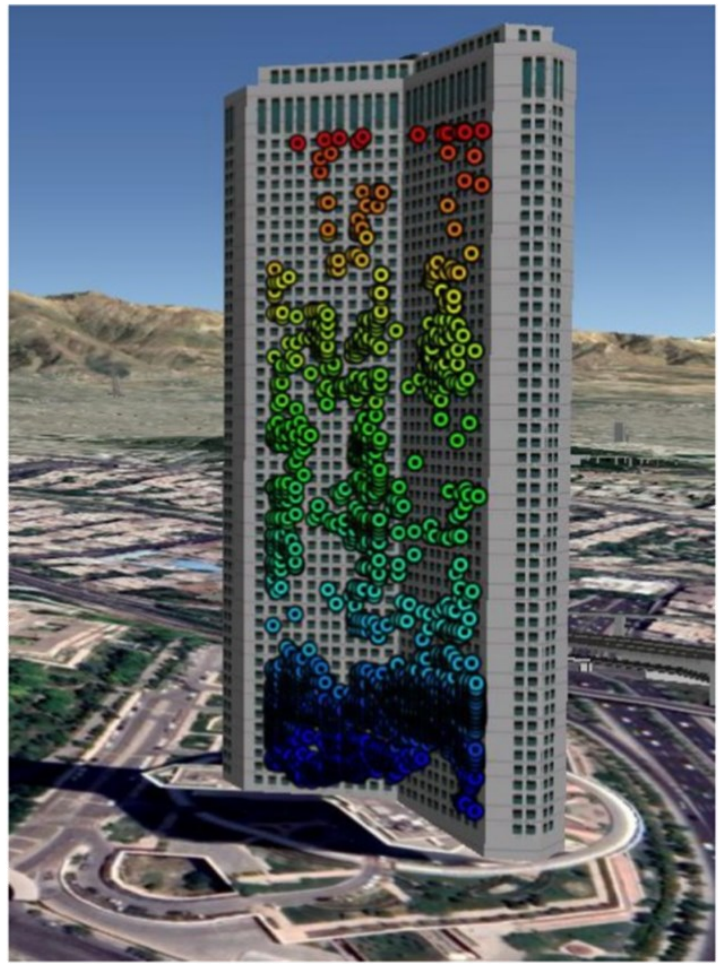




Persistent Scatterers | Geolocation based on SAR Viewing Angle

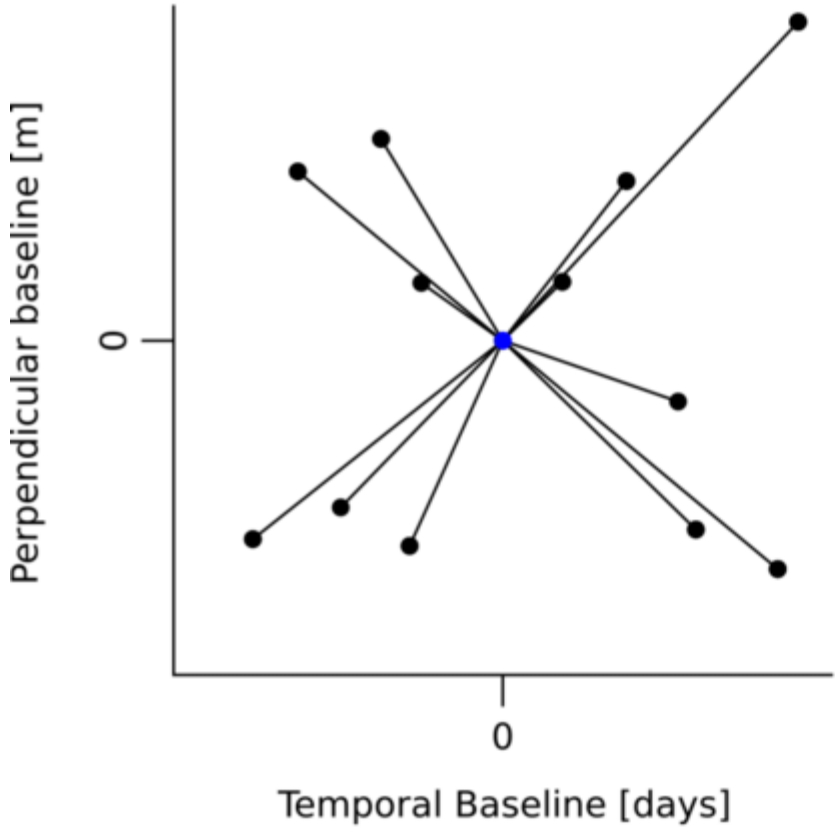
The geolocation of PS targets can be affected by the SAR viewing angle, which is the angle between the direction of the SAR antenna and the ground surface. To mitigate the effects of SAR viewing angle, it is often necessary to acquire SAR data from multiple viewing angles along the ascending and descending satellite orbits.



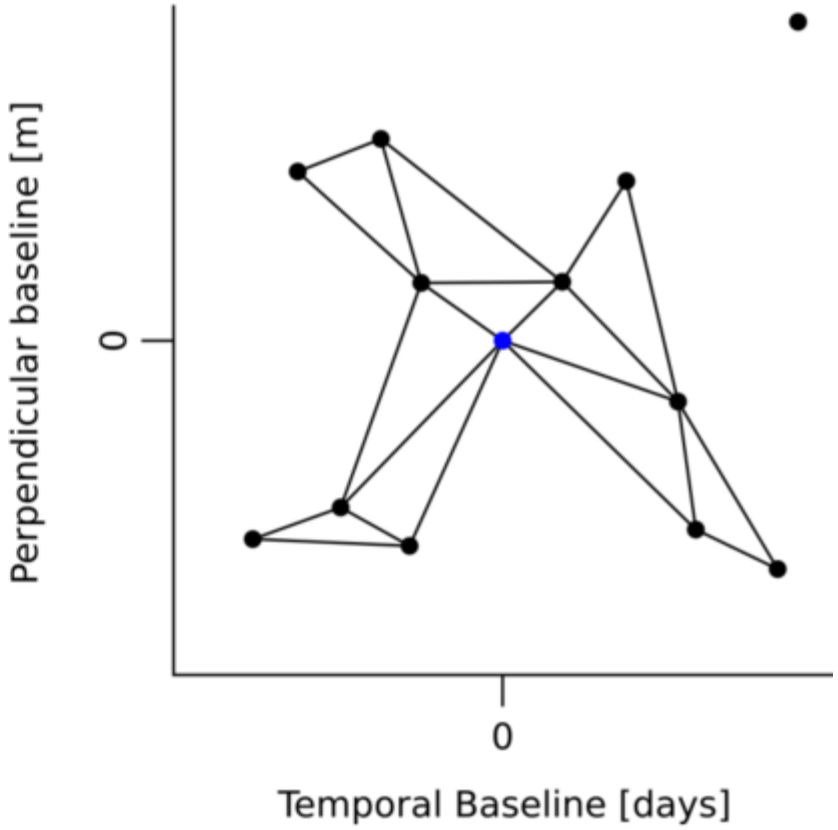


Multi-Temporal InSAR Analysis | Interferometric Pairs Selection

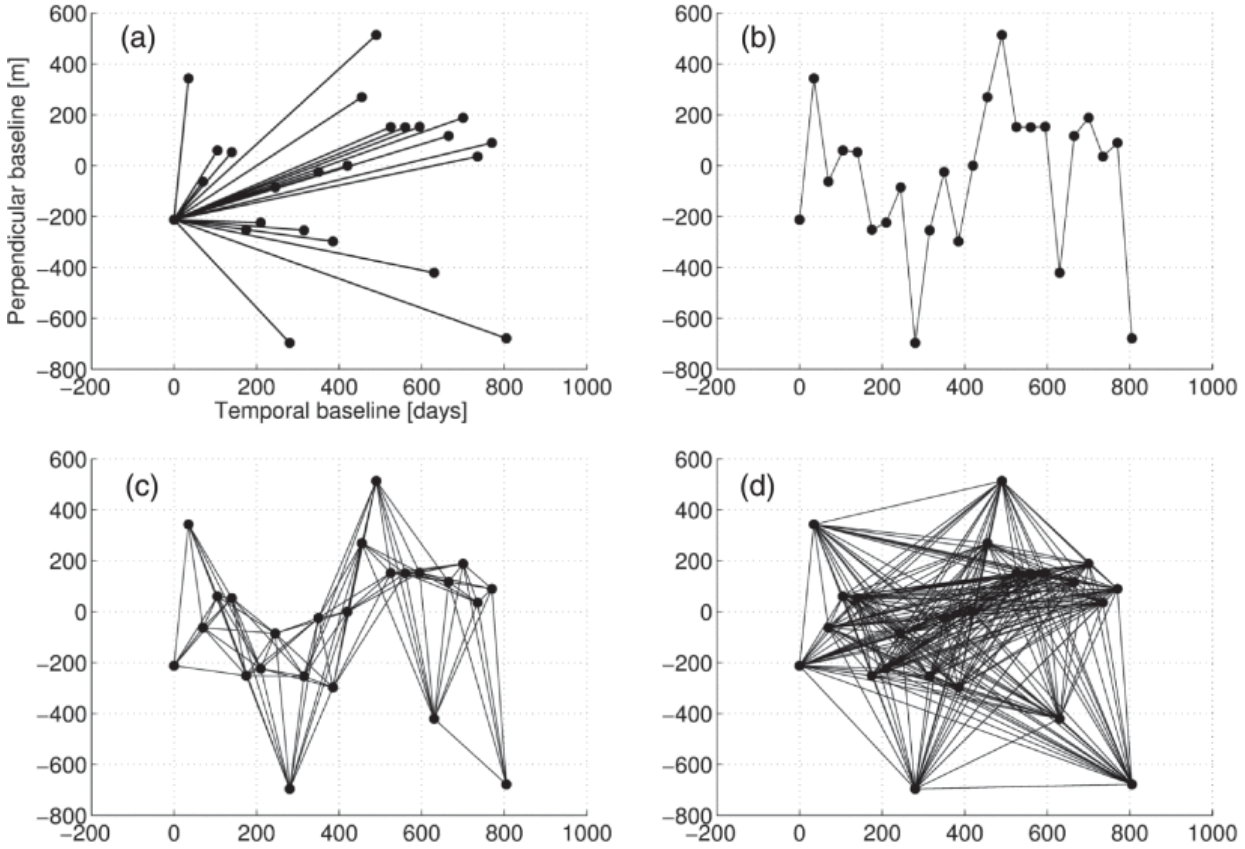
Persistent Scatterer Interferometry (PSI)

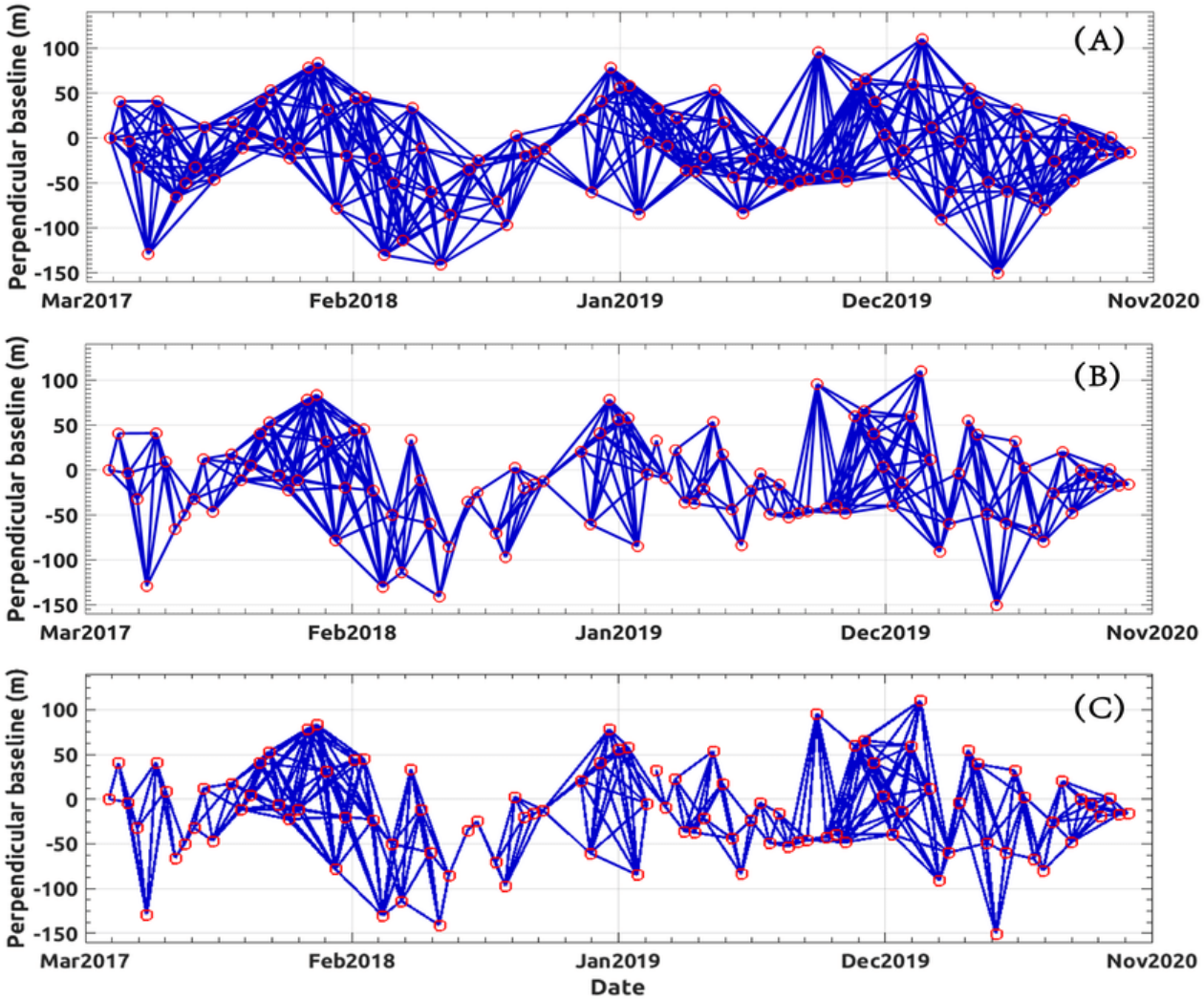


Small BAseline Subset Interferometry (SBAS)

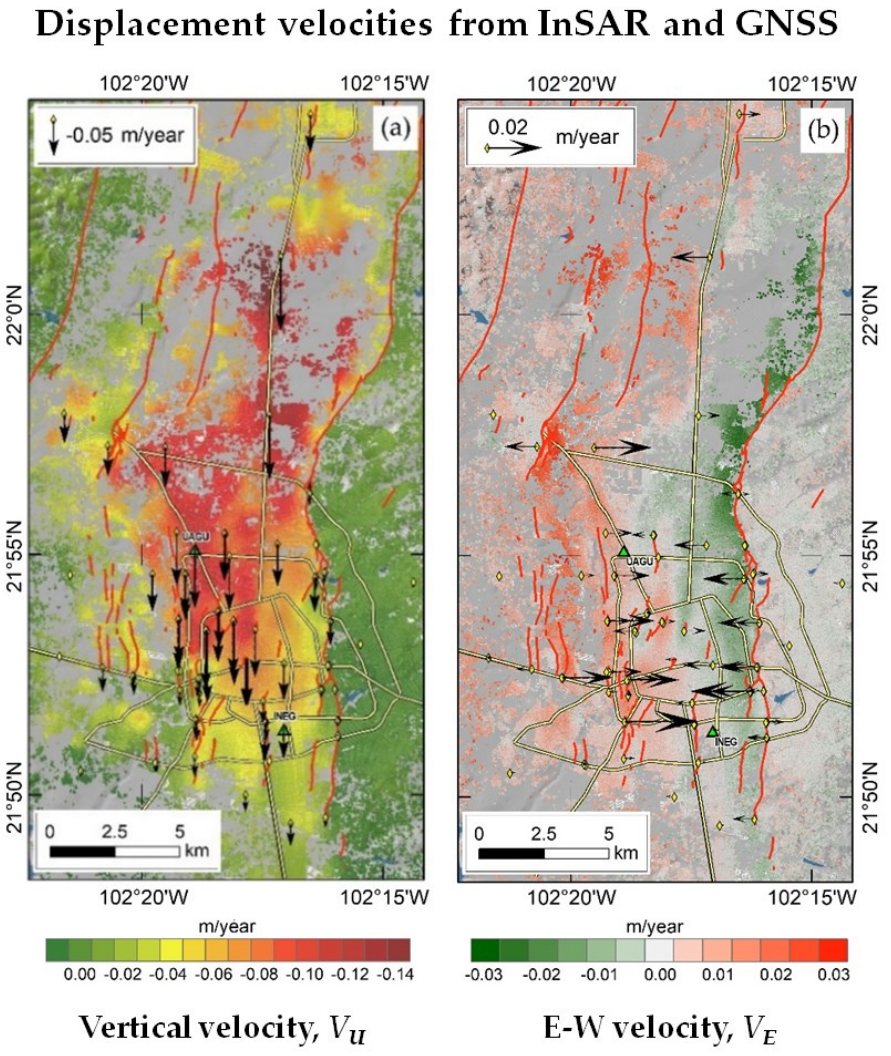


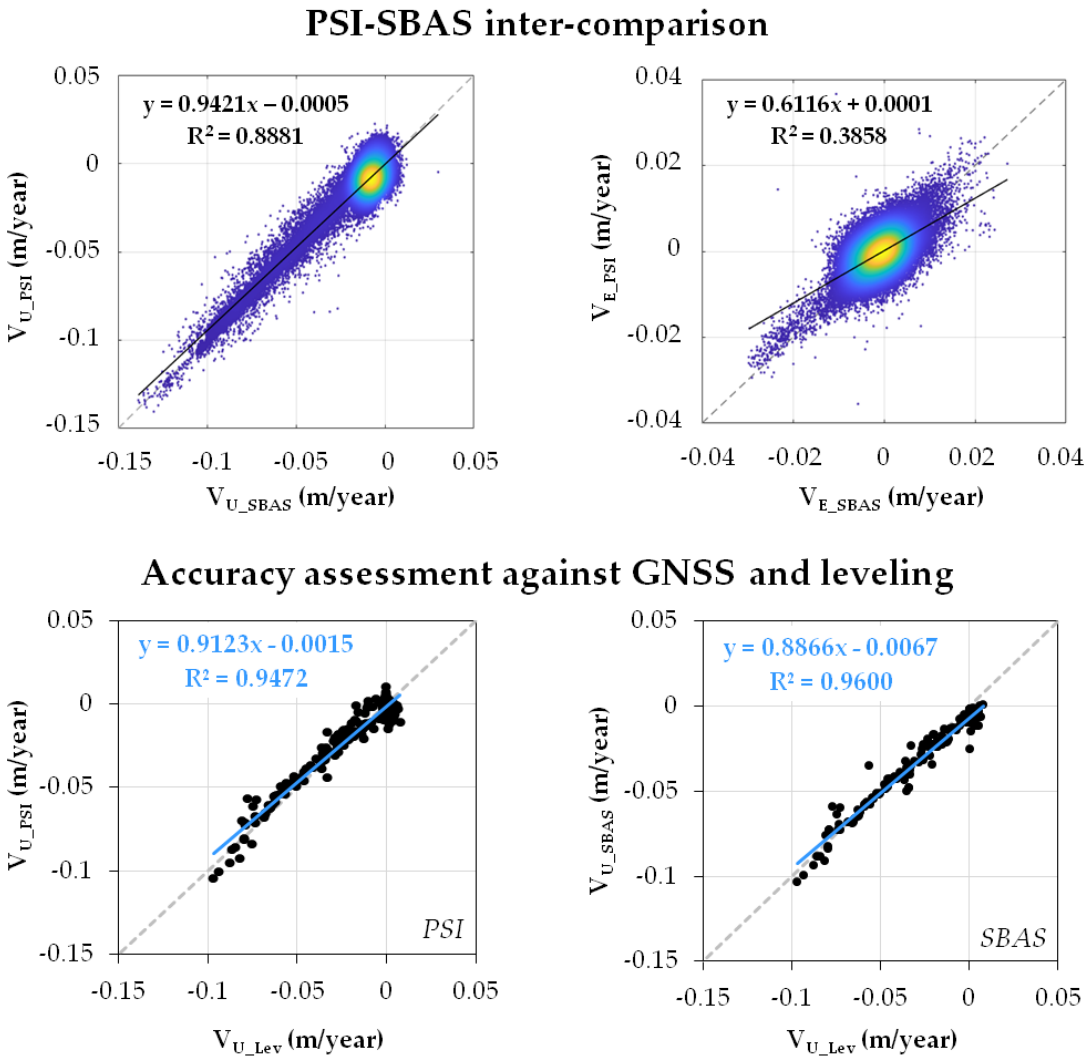
Multi-Temporal InSAR Analysis | Interferometric Pairs Selection



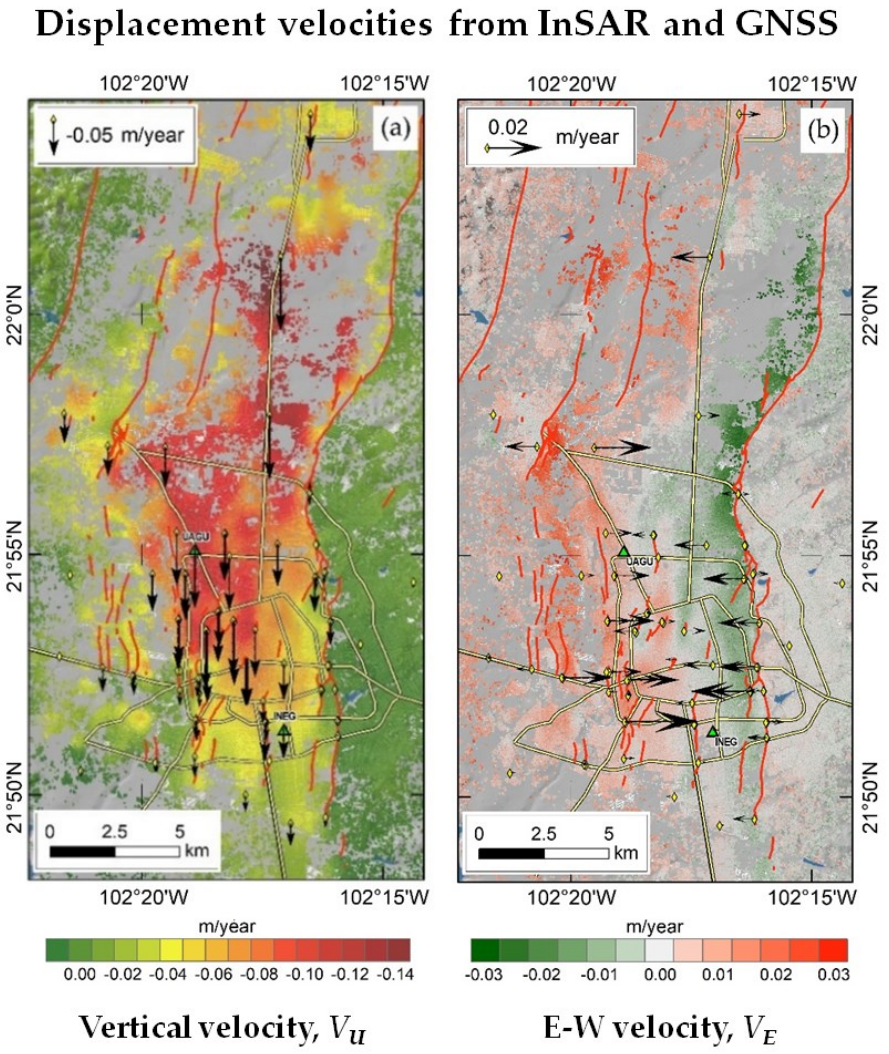


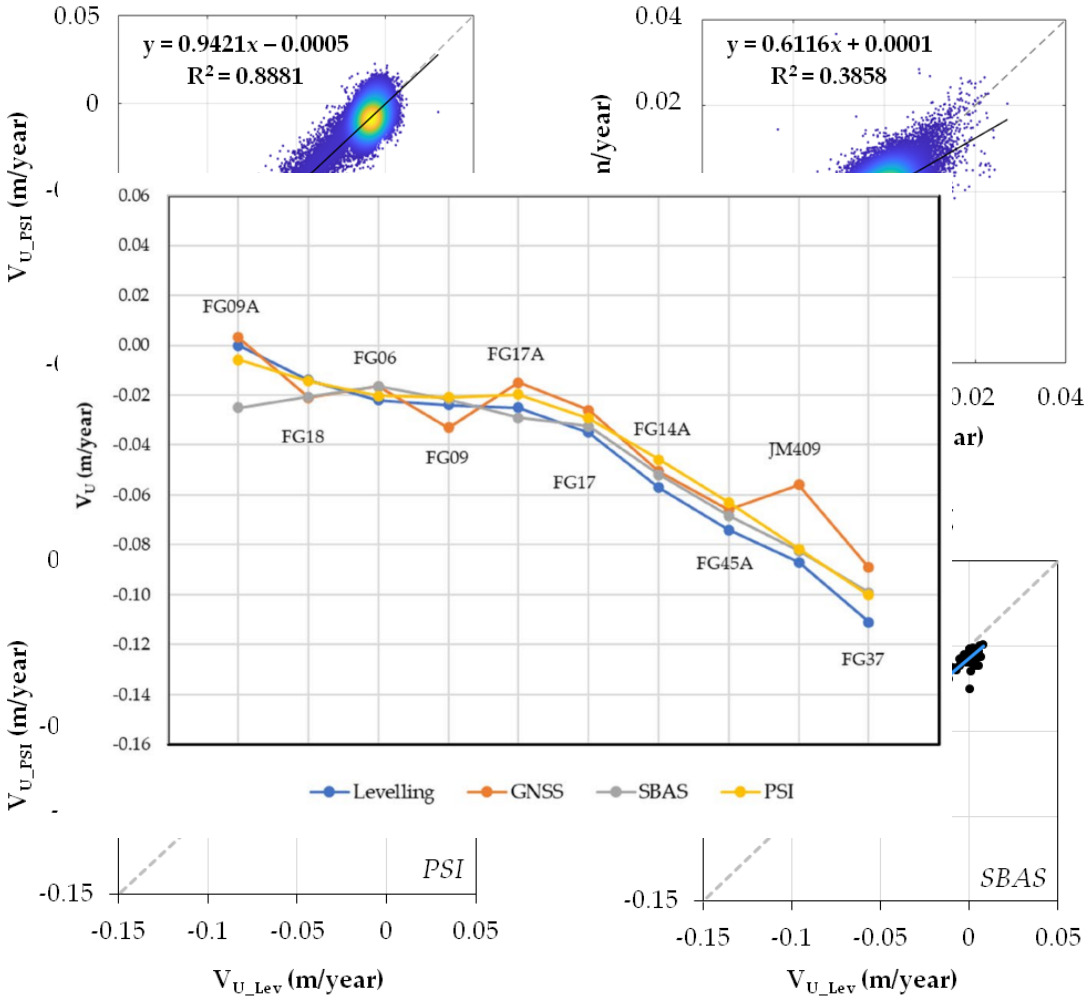
Inter-Comparison Between PSI and SBAS approaches





Inter-Comparison Between PSI and SBAS approaches

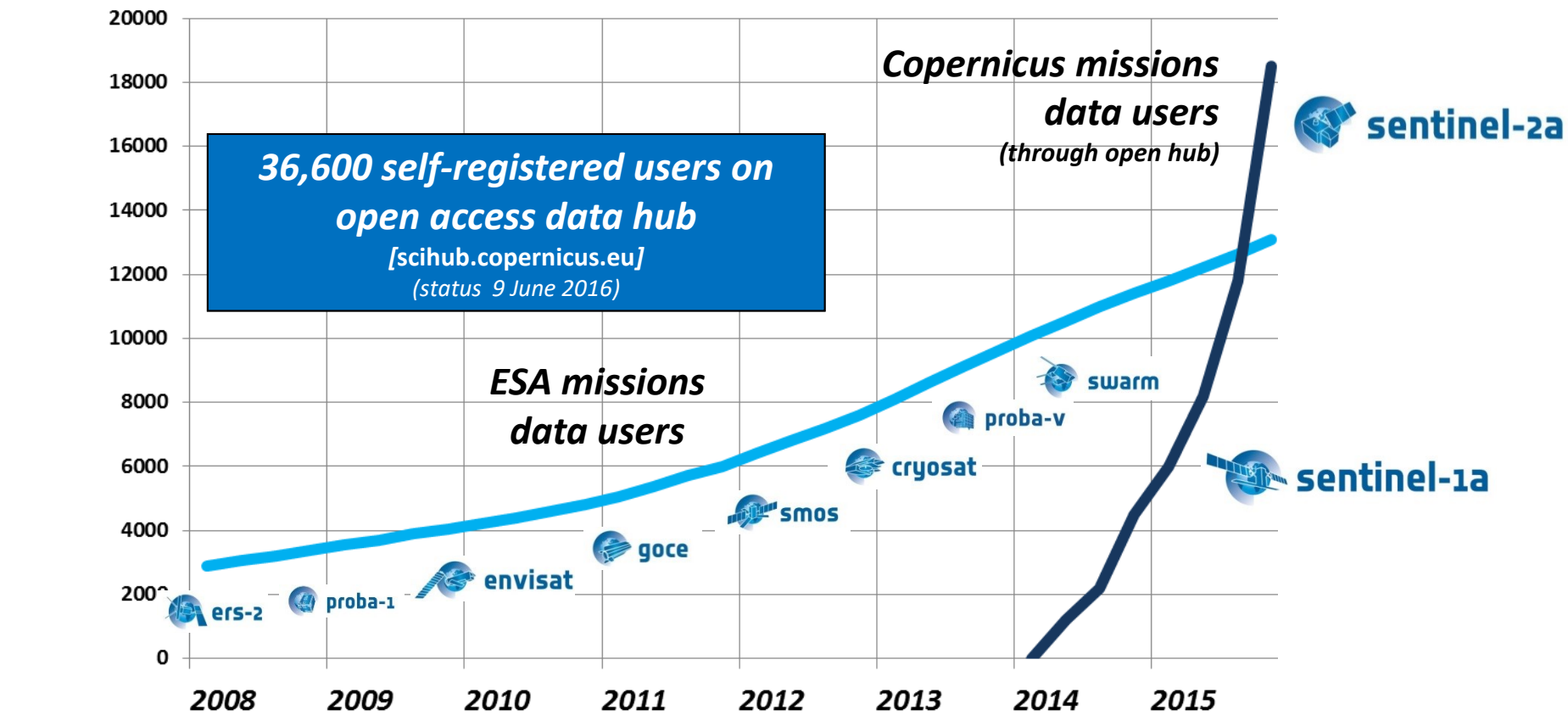




Sentinel Missions | Big Data Era

Users' registration on Open Access Data Hub

A steady sharp increase of users
as a consequence of Data Policy and Mission Operations Concept:
systematic observation, acquisition, processing and dissemination



Registered Users

695,085

Users Downloads Volume

539.34 PB

Published Products

61,633,707

Open Access Hub Availability over the past Month

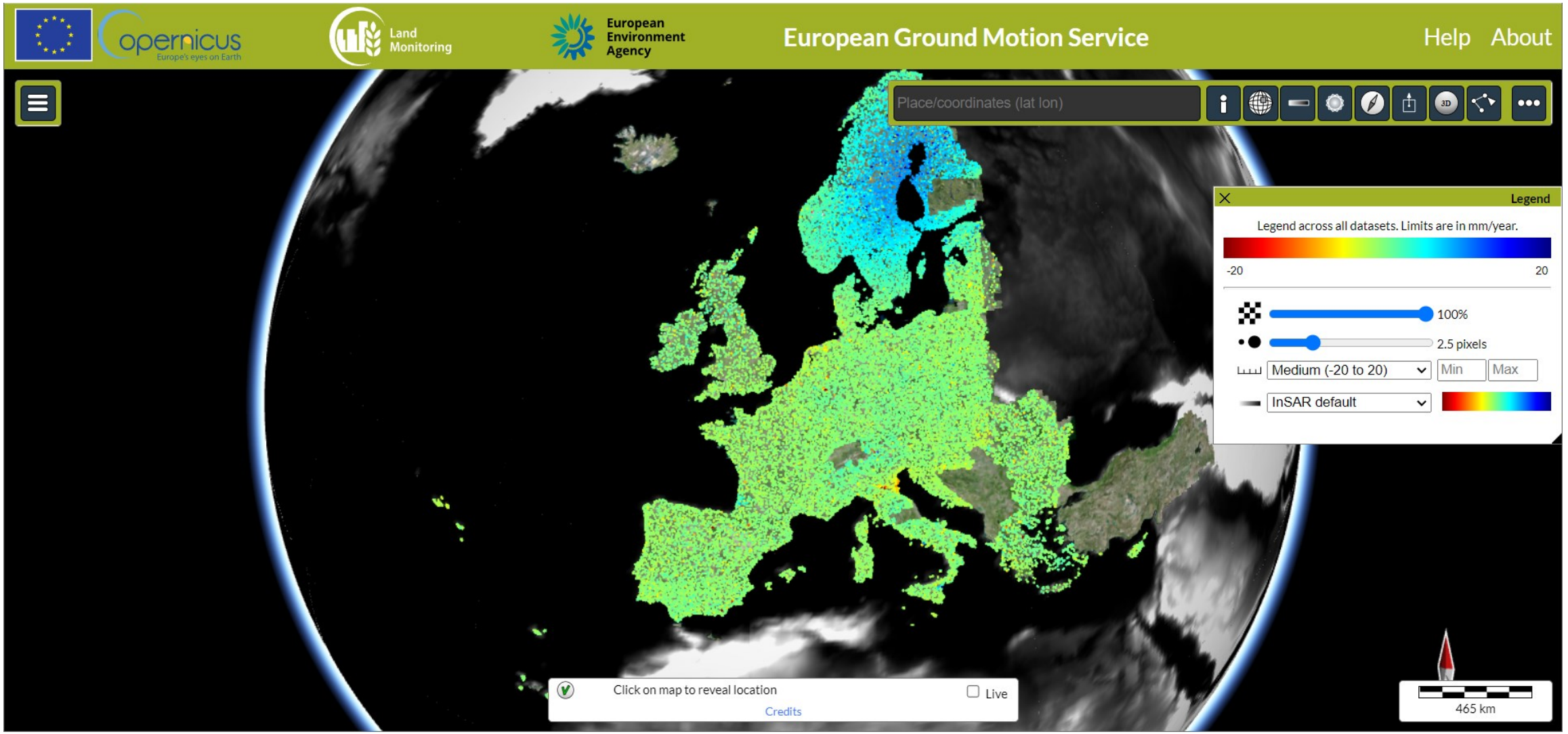
99.9%

Statistics of Data Hub Services since start of operations (05/2023)

Analysis Ready Dataset

European Ground Motion Service (EGMS)

https://egms.land.copernicus.eu

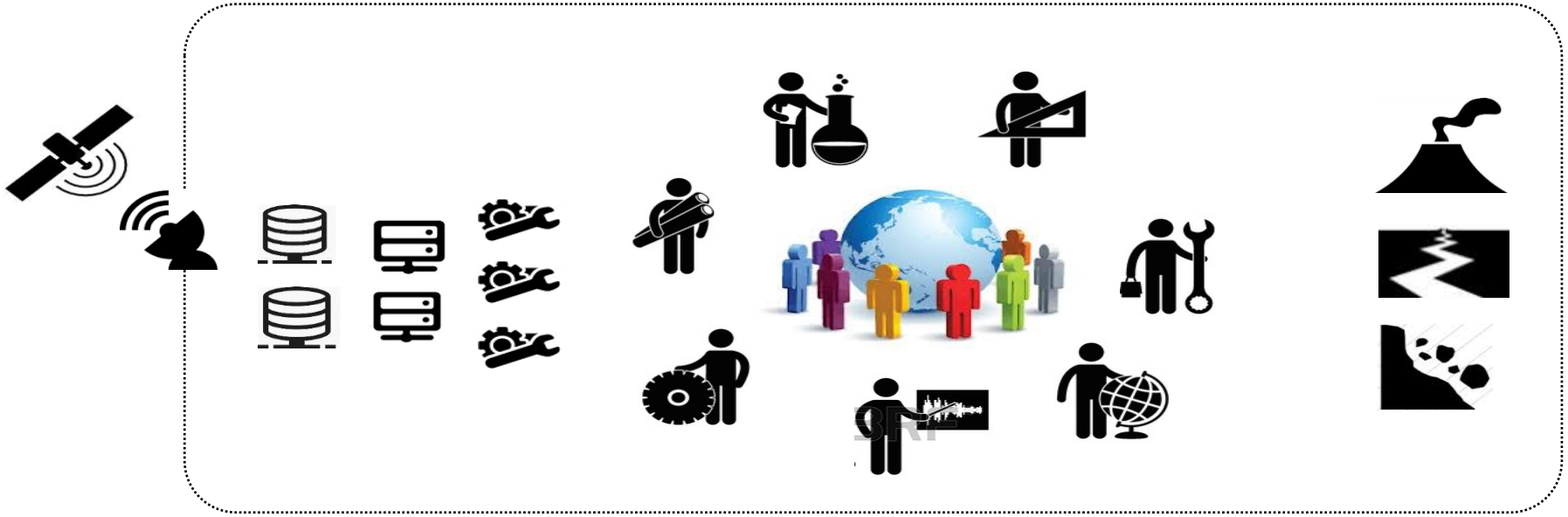


Thematic Exploitation Platforms | TEPs

Geohazards Exploitation Platform | GEP

https://geohazards-tep.eu

The GEP is a cloud-based environment providing a set of EO processing services that allow mapping hazard prone land surfaces and monitoring terrain motion.



International Forum on Satellite EO and Geohazards organized by ESA and GEO in Santorini in 2012 (140+ participants)

tep thematic exploitation platform

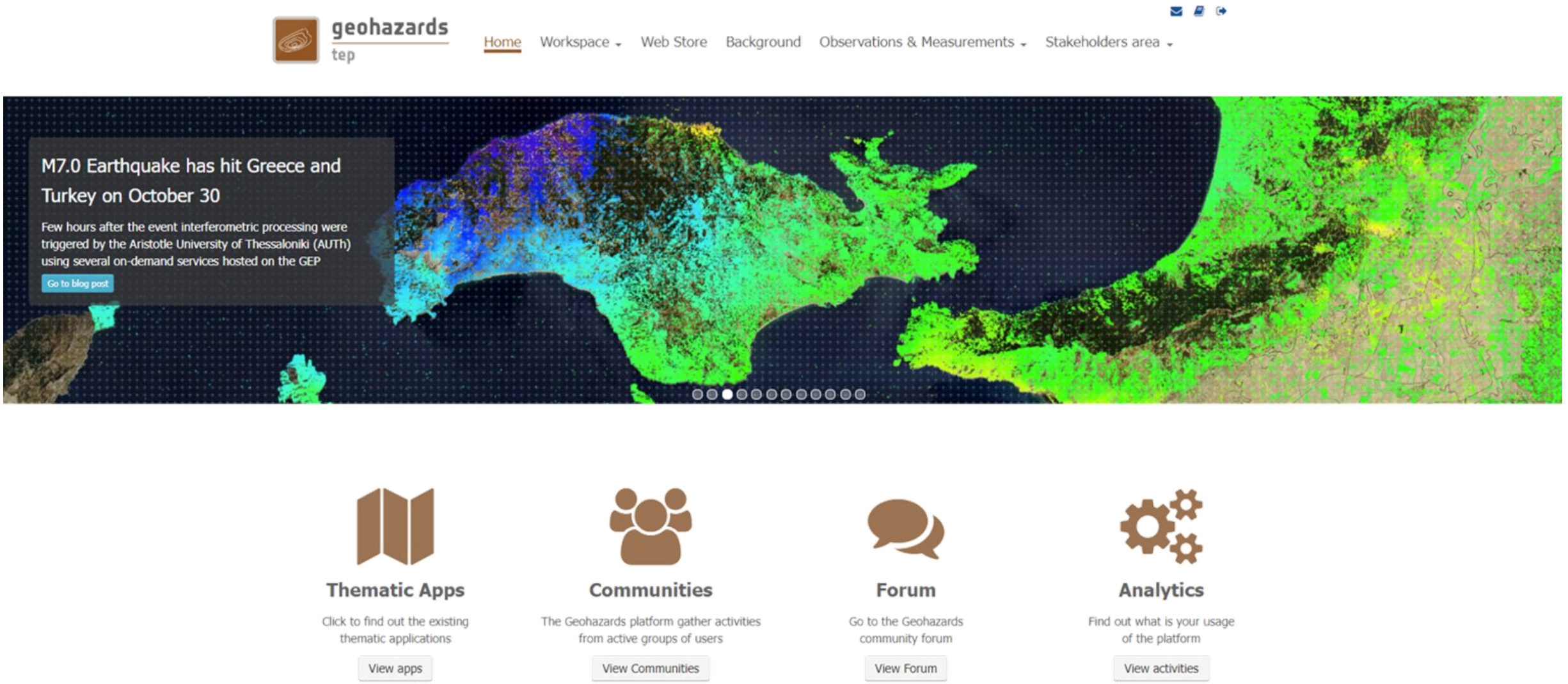
https://tep.eo.esa.int

geohazards tep | polar tep | coastal tep | hydrology tep | urban tep | forestry tep

geohazards tep

Geohazards Exploitation Platform | GEP

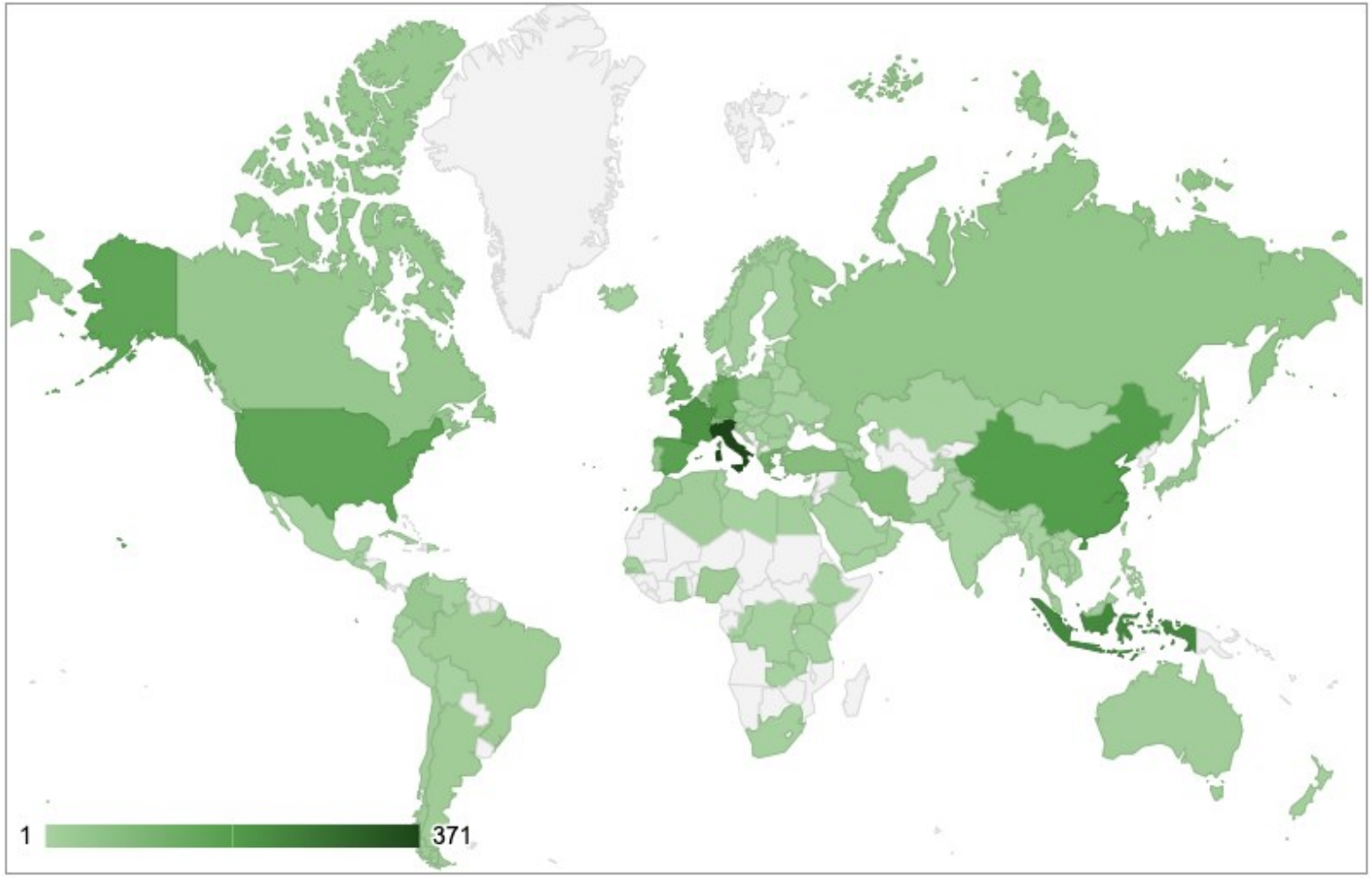
https://geohazards-tep.eu



GEP | Users Uptake

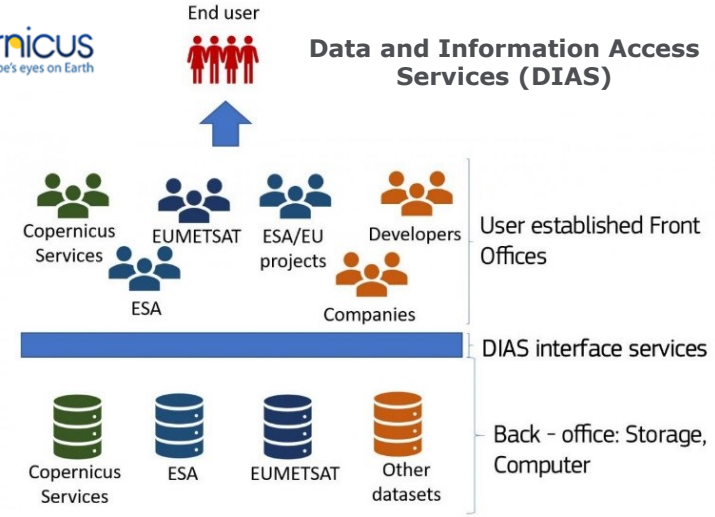
geohazards tep

Operations Reporting May 2023



#	Country	#users
1	Italy	371
2	Indonesia	230
3	France	206
4	China	185
5	Spain	169
6	USA	160
7	Germany	146
8	United Kingdom	136
9	India	111
10	Greece	106
11	Iran	80
12	Switzerland	74
13	Turkey	70
14	Russia	46
15	Netherlands	38
16	Canada	37
17	Colombia	36
18	Morocco	30
19	Japan	30
20	Austria	30
21	Portugal	29
22	Poland	29
23	Thailand	24
24	Belgium	23
25	Philippines	22
26	Norway	22
27	Uganda	19
28	Nigeria	19
29	Mexico	19
30	Brazil	19
31	Argentina	19
32	Romania	18
33	South Korea	17
34	Pakistan	17
35	Chile	15
36	Australia	15
37	Algeria	15
	...	
	Grand Total	**2950**

GEP | Cloud Platform - Data



Enhanced Data Gateway using OpenSearch

- Automatic multi-sourcing to optimize data access
- Programmable and systematic data caching
- Data usage accounting
- Personal cloud storage (repository)

Catalogue synchronized with Copernicus Open Access Hub:

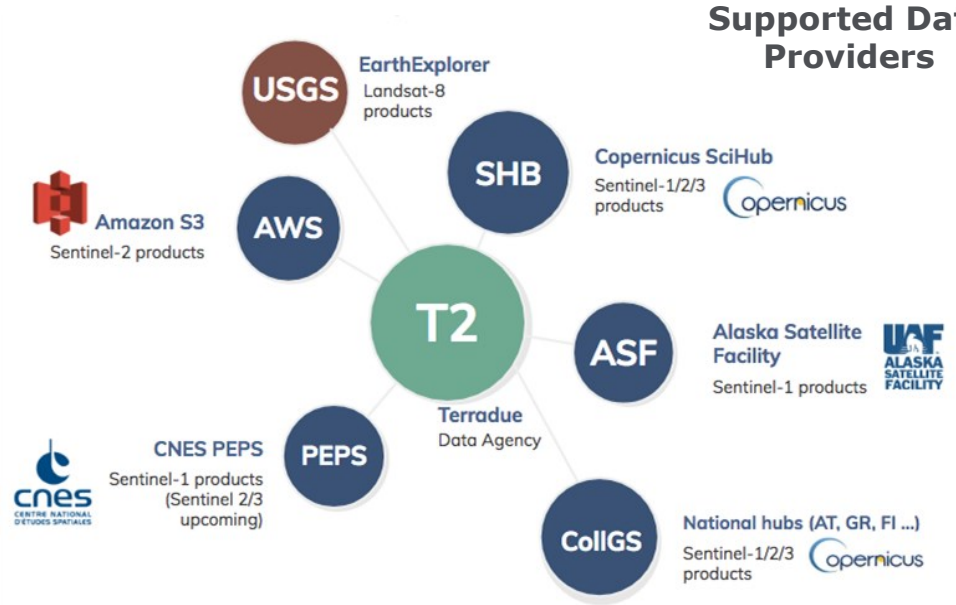
- Sentinel-1A/B: (RAW, SLC, GRD and OCN)
- Sentinel-2: (MSI L1C)
- Sentinel-3: (OLCI, SLSTR)

Catalogue synchronized with USGS EarthExplorer:

- Landsat-8: (OLI and TIRS)

Access to ESA heritage SAR missions:

- ERS (SAR IM Level-0)
- ENVISAT (ASAR IM Level-0)

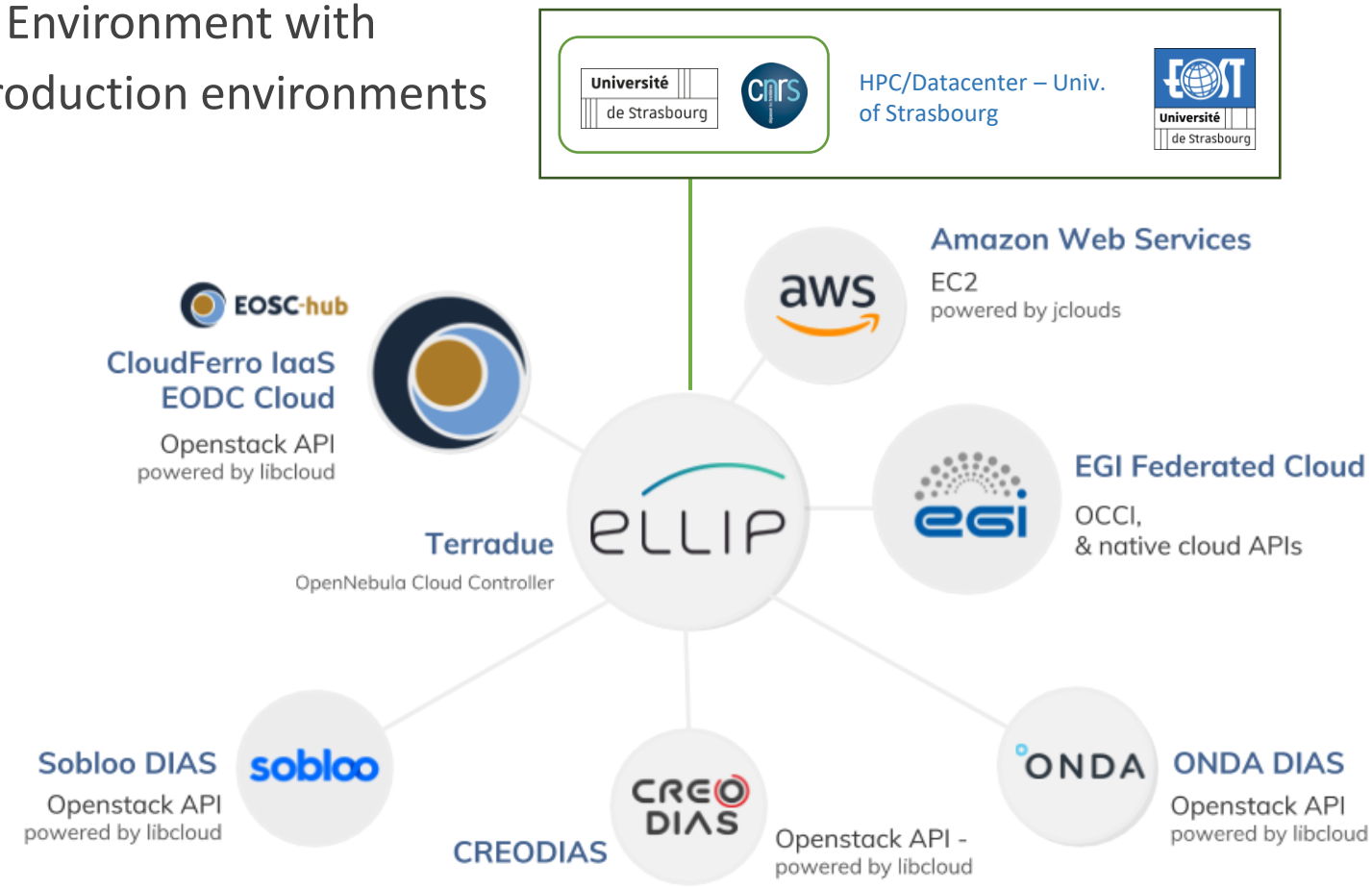


GEP | Cloud Platform - Computing

Continuous Integration and Deployment Environment with automatic packaging & deployment in production environments

Improved Production Center, with (auto)scalability allowing cost-effective data processing on Cloud Computing

Deployment in multiple Cloud-based processing environments with no lock-in on a Cloud provider

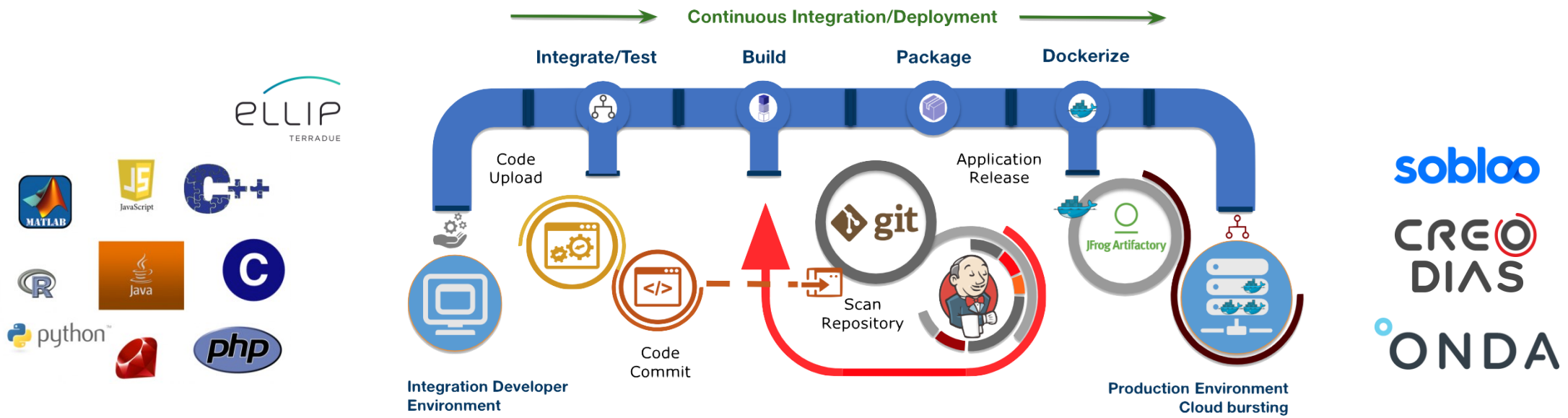


GEP | Application Integration

Applications developed in any programming language supported

C/C++, Java, Python, Matlab and IDL

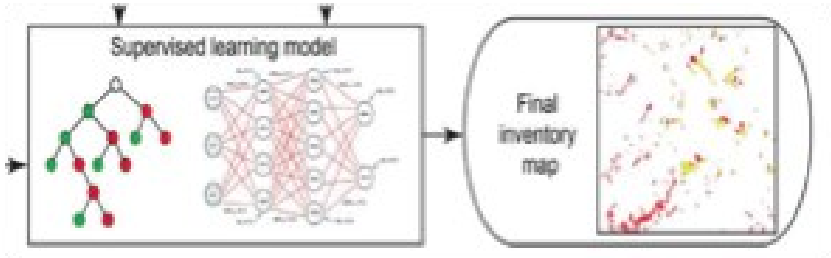
Continuous Integration and Deployment Environment with automatic packaging and deployment in production environments

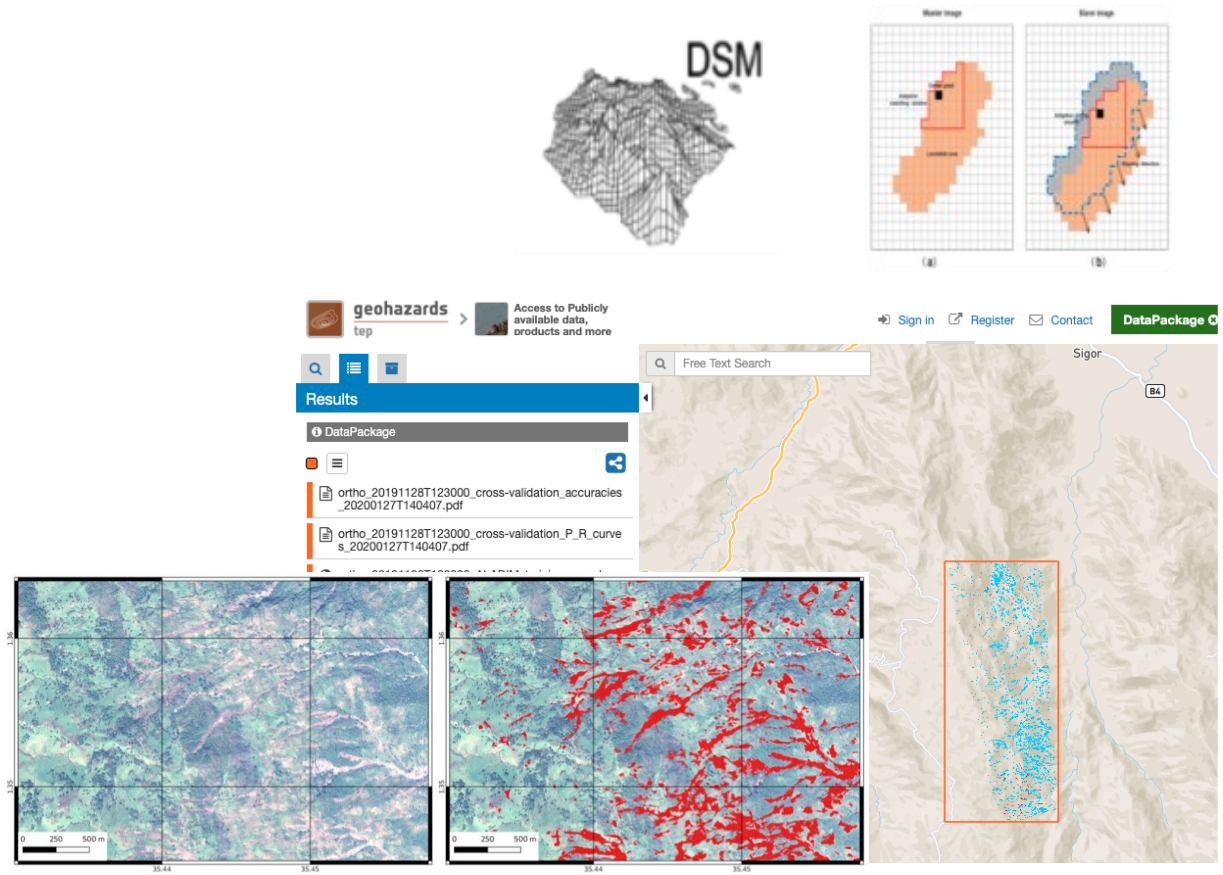


GEP | Algorithm Hosting

CNRS-EOST Strasbourg developed several services for landslide monitoring using Sentinel-2 and Pléiades data measuring:

- Earth surface deformation
- Digital Surface Model
- Automatic landslide detection based on Machine Learning



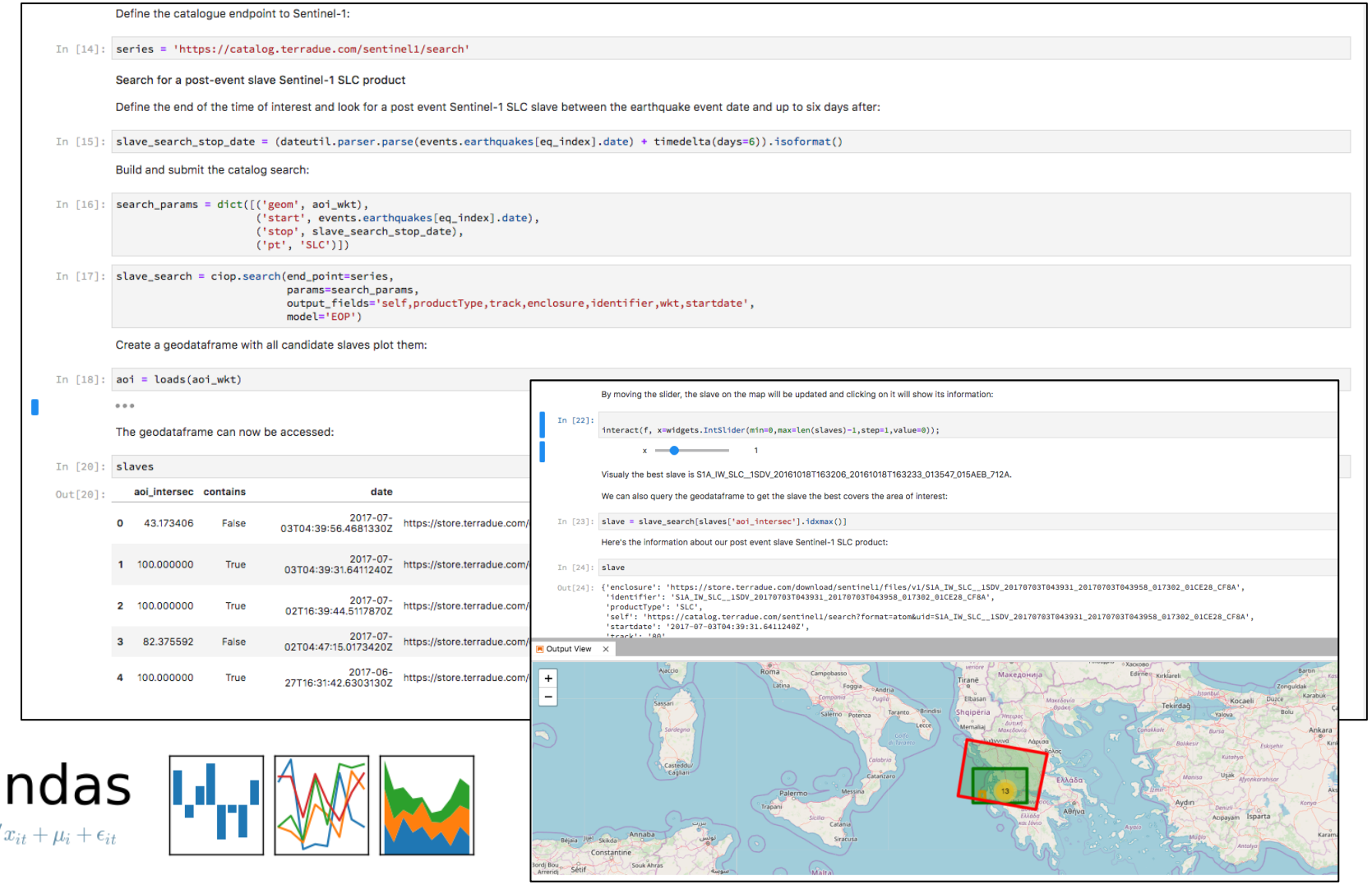


GEP | Data Exploitation: Target Reproducibility

Exploring the Earth Observation Catalogues from a **Jupyter Notebook** accessing open APIs

Analyse results as data structures

Interactive processing and post-processing services enabling users to exploit and share the processing results



pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$

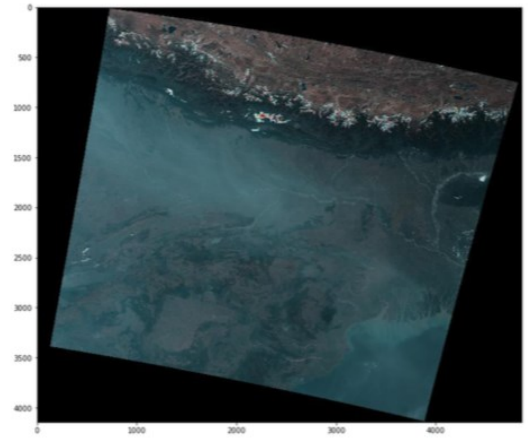
GEP | Data Exploitation: Access to EO Products

Notebooks documenting how to plot and analyse Sentinel data

```
In [5]: import numpy as np
        import matplotlib
        import matplotlib.pyplot as plt
        import matplotlib.colors as colors

        %matplotlib inline

        def plotBand(product, band, vmin, vmax):

            band = product.getBand(band)

            w = band.getRasterWidth()
            h = band.getRasterHeight()

            band_data = np.zeros(w * h, np.float32)
            band.readPixels(0, 0, w, h, band_data)

            band_data.shape = h, w

            width = 12
            height = 12
            plt.figure(figsize=(width, height))
            imgplot = plt.imshow(band_data, cmap=plt.cm.binary, vmin=vmin, vmax=vmax)

            return imgplot

        plotBand(terrain, 'Sigma0_' + polarization, 0, 0.3)

Out[5]: <matplotlib.image.AxesImage at 0x7f6e2370e990>
```

- Step 4: Plot an RGB image

```
In [6]: red_radiance = reproject.getBand('Oa08_radiance')
        green_radiance = reproject.getBand('Oa05_radiance')
        blue_radiance = reproject.getBand('Oa04_radiance')

        w = red_radiance.getRasterWidth()
        h = red_radiance.getRasterHeight()

        red_radiance_data = np.zeros(w * h, np.float32)
        red_radiance.readPixels(0, 0, w, h, red_radiance_data)
        red_radiance_data.shape = h, w

        green_radiance_data = np.zeros(w * h, np.float32)
        green_radiance.readPixels(0, 0, w, h, green_radiance_data)
        green_radiance_data.shape = h, w

        blue_radiance_data = np.zeros(w * h, np.float32)
        blue_radiance.readPixels(0, 0, w, h, blue_radiance_data)
        blue_radiance_data.shape = h, w

        xmax=200
        red = (red_radiance_data*256/(xmax-np.amin(red_radiance_data)))
        green = (green_radiance_data*256/(xmax-np.amin(green_radiance_data)))
        blue = (blue_radiance_data*256/(xmax-np.amin(blue_radiance_data)))

        rgb_uint8 = np.dstack((red, green, blue)).astype(np.uint8)

        width = 12
        height = 12
        plt.figure(figsize=(width, height))
        img = Image.fromarray(rgb_uint8)
        imgplot = plt.imshow(img)
```

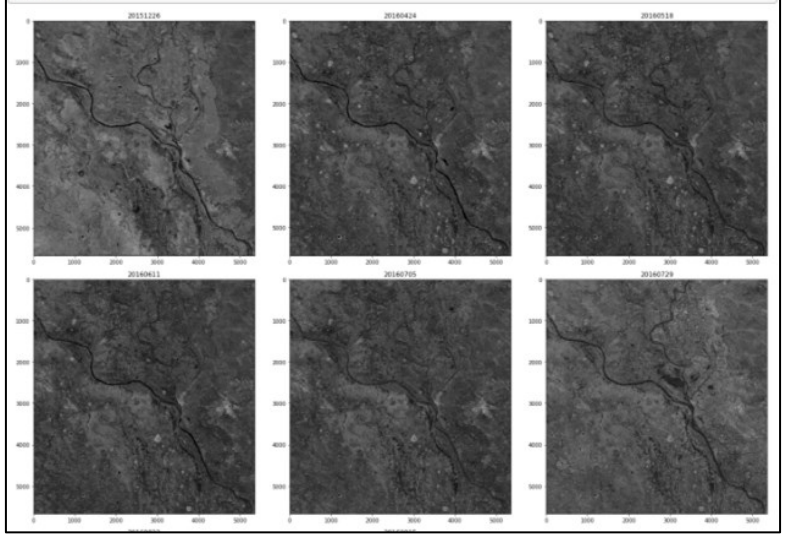


GEP | Data Exploitation: Time Series Analysis

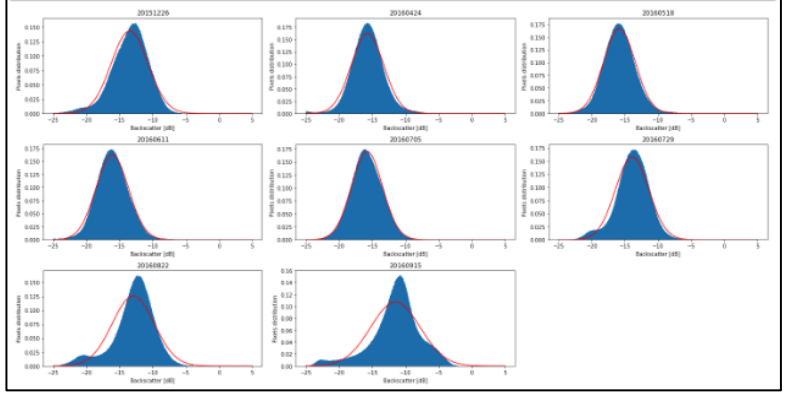
Notebook analysis of a stack of Sentinel-1 data

Backscatter profiles for reference image used in flood analysis

```
    band_data.shape = h, w

    imgplot = plt.imshow(band_data, cmap=plt.cm.binary_r, vmin=vmin, vmax=vmax)


    return imgplot


fig = plt.figure(figsize=(20,20))
i = 1

for lineartodb in lineartodbs :

        a=fig.add_subplot(330+i)
        imgplot = plotBand(lineartodb, 'Sigma0_VV_db', -25, 5)
        name = lineartodb.getName()
        timestamp = name.split("_")[5]
        date = timestamp[:8]
        a.set_title(date)
        i = i+1

plt.tight_layout()
fig = plt.gcf()
plt.show()

fig.clf()
plt.close()
gc.collect()
```



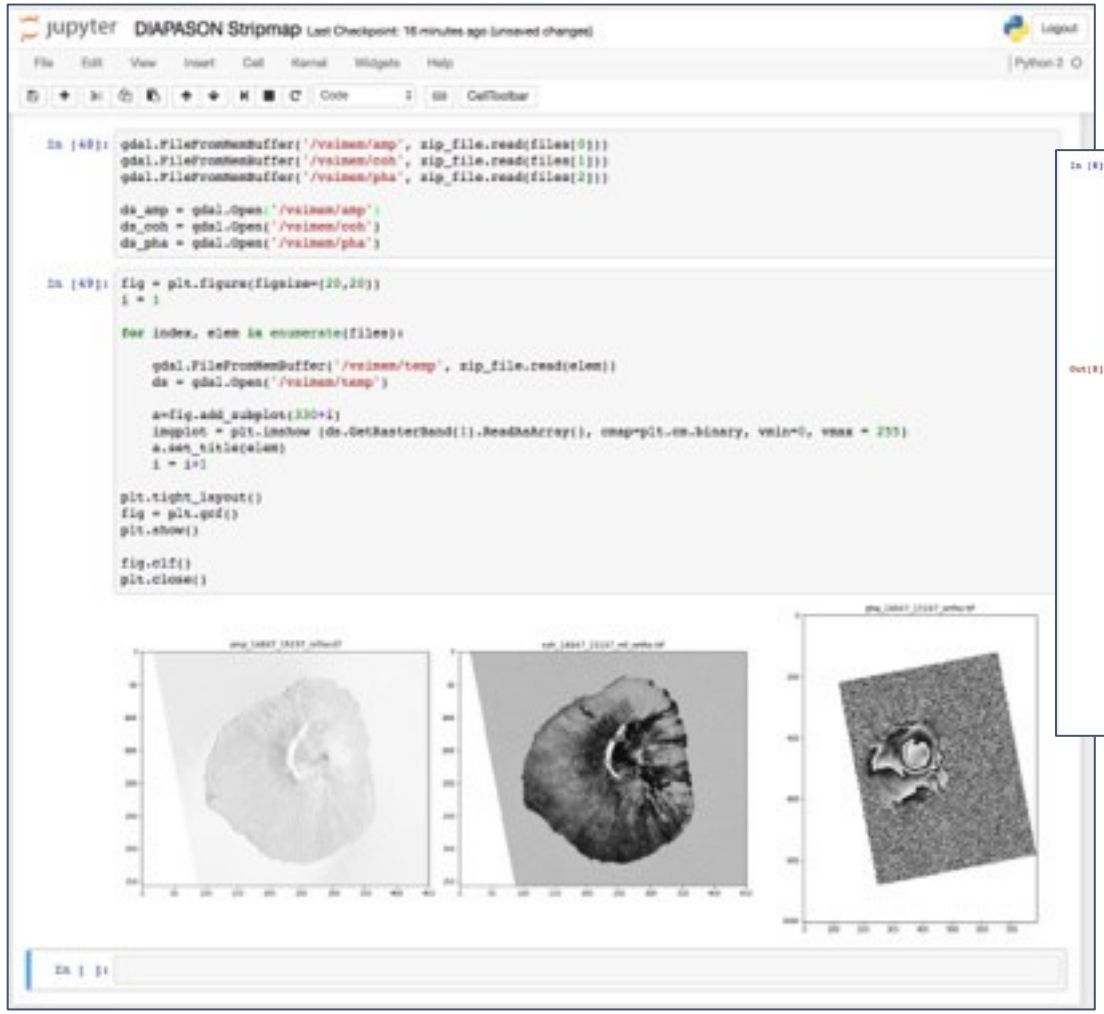
```
    band_data.shape = h * w

    ser = np.asarray(band_data, dtype='float')

    m, s = stats.norm.fit(ser) # get mean and standard deviation
    pdf_params.append([m,s])
    p5 = np.percentile(ser, 5) # return 5th percentile.
    p95 = np.percentile(ser, 95) # return 95th percentile.
    index1 = p95 - p5 # anomaly index 1
    index1s.append(index1)

    hist = plt.hist(ser, bins=2048, range=[-25, 5], normed=True)
    pdf_g = stats.norm.pdf(lnspc, m, s) # now get theoretical values in our interval
    pdf = plt.plot(lnspc, pdf_g, label="Norm", c='r') # plot it
    plt.xlabel('Backscatter [dB]')
    plt.ylabel('Pixels distribution')

    return hist

index1s = []
fig = plt.figure(figsize=(20,10))
i = 1

for lineartodb in lineartodbs :

        a=fig.add_subplot(330+i)
        a.patch.set_alpha(0.7)
        plotHistdB(lineartodb, 'Sigma0_VV_db')
        a.set_title(dates[i-1])
        i = i+1


plt.tight_layout()
fig = plt.gcf()
plt.show()
fig.clf()
plt.close()
gc.collect()
```

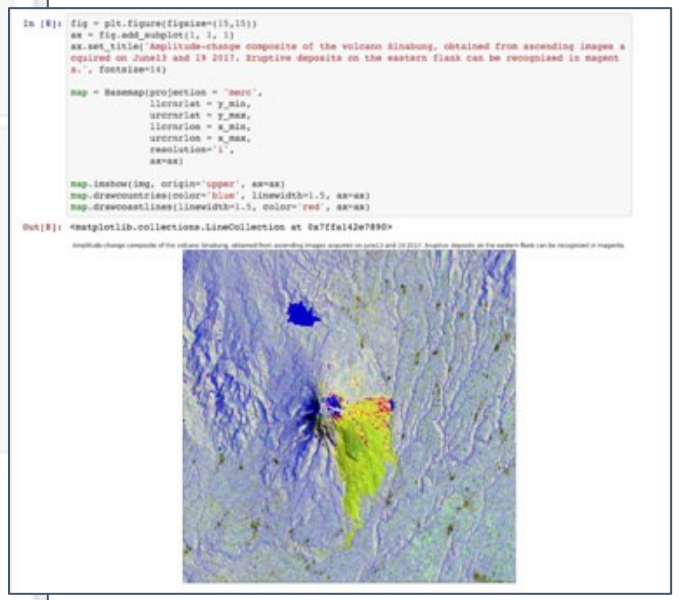


GEP | Data Exploitation: Invoking Services

Invoking GEP services from a notebook

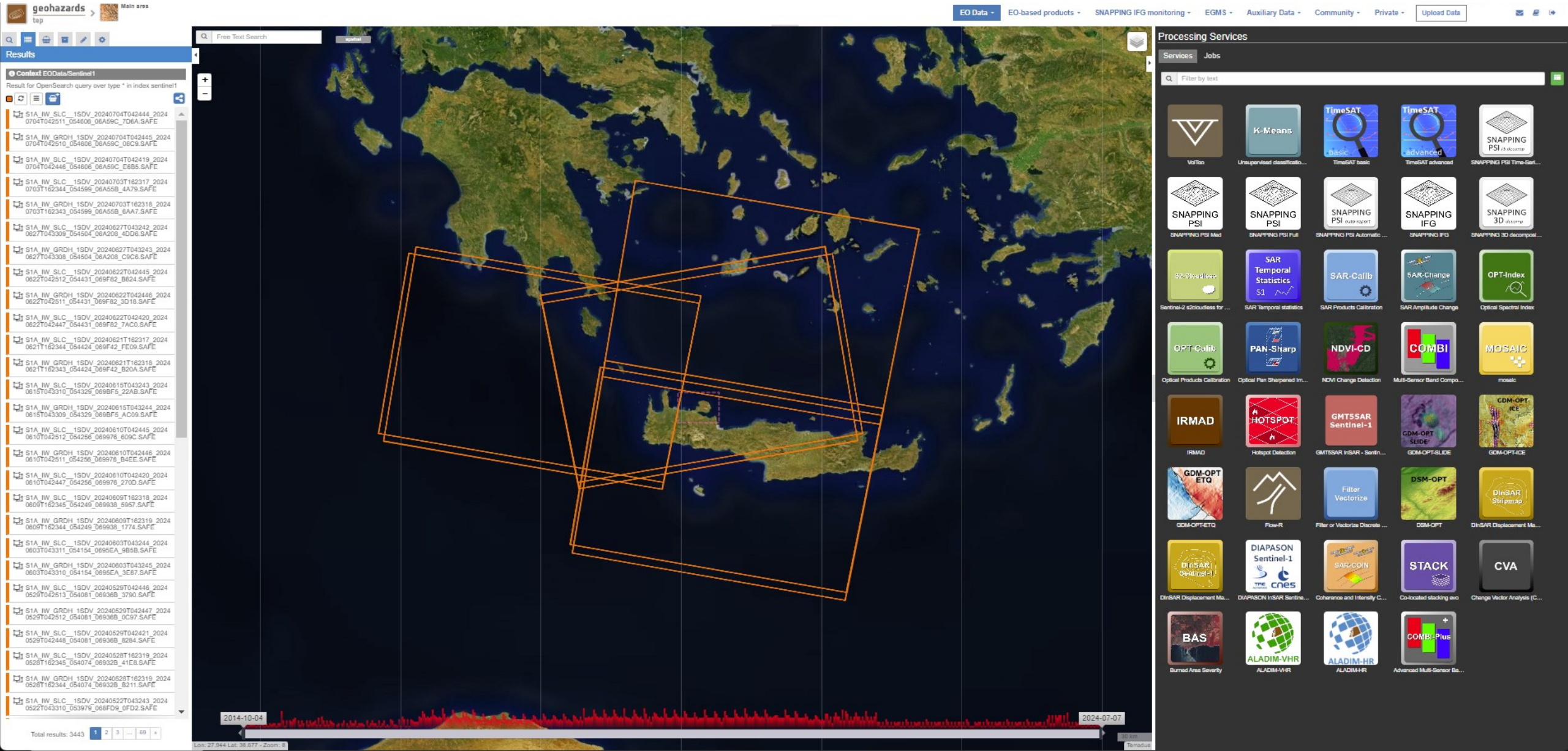
GEP Processing Service over active volcano (Fogo)\through a OGC API





Geohazards Exploitation Platform | GEP

https://geohazards-tep.eu



TerraDue
Advancing Earth Science

GEP offering
published in April 2023

GEP Services Portfolio

Basic

Access to Data screening services
Publisher credentials
Jupyter Notebook workspace
Result data persisted (*)
Professional support
Account management

Monthly subscription (+) per team (**)

€150
includes €50 pay-per-use monthly voucher

Essentials

Access to Event response services
Publisher credentials
Jupyter Notebook workspace
Result data persisted (*)
Professional support
Account management

Monthly subscription (+) per team (**)

€250
includes €150 pay-per-use monthly voucher

Advanced

Access to Area monitoring services
Publisher credentials
Jupyter Notebook workspace
Result data persisted (*)
Professional support
Account management

Monthly subscription (+) per team (**)

€550
includes €450 pay-per-use monthly voucher

Flex

Accessible via sponsoring institutions

per-use budget for running processing jobs

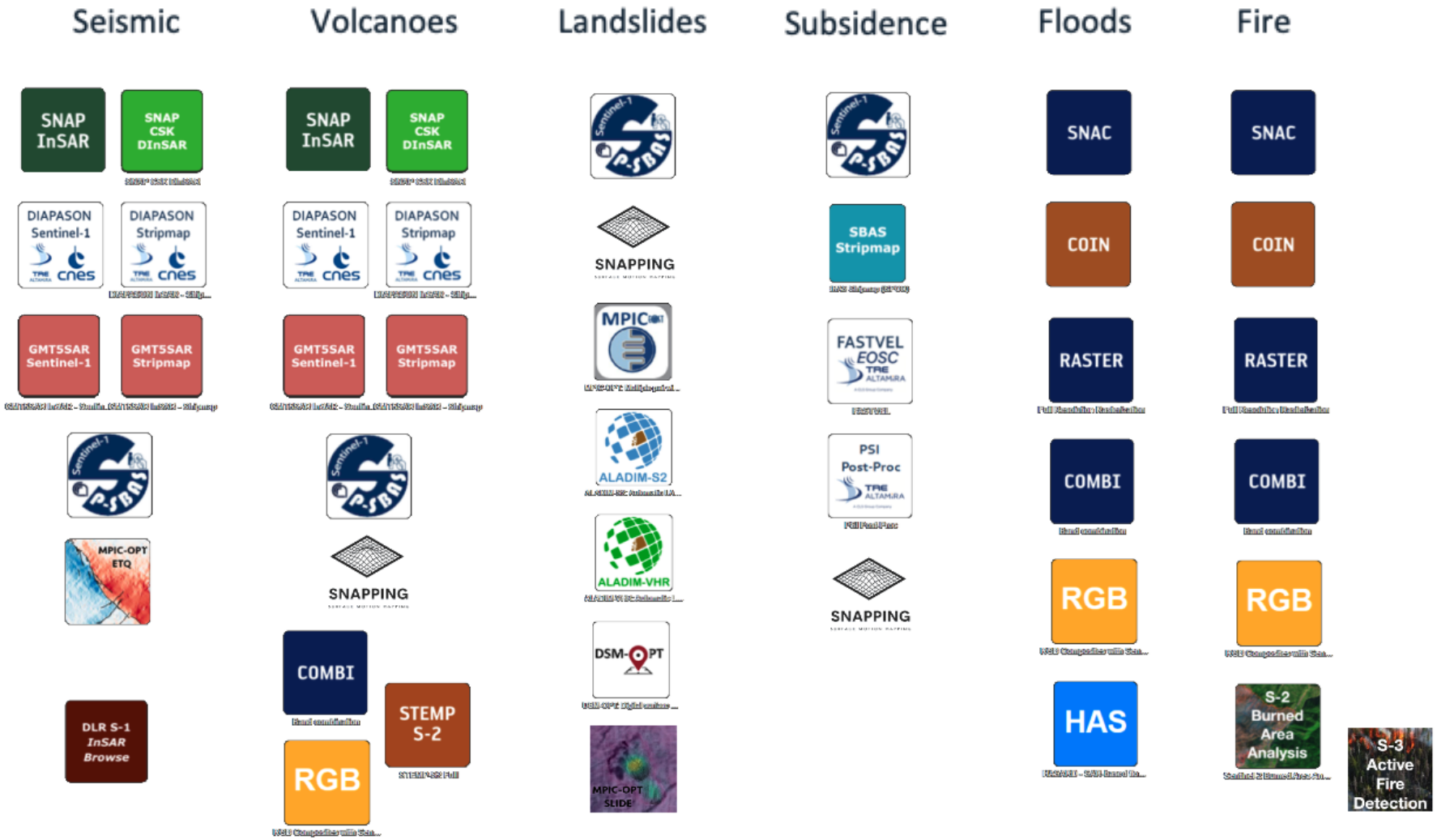
subscription end

ry, up to 5 users for research labs, up to 20 students for universities and training sessions

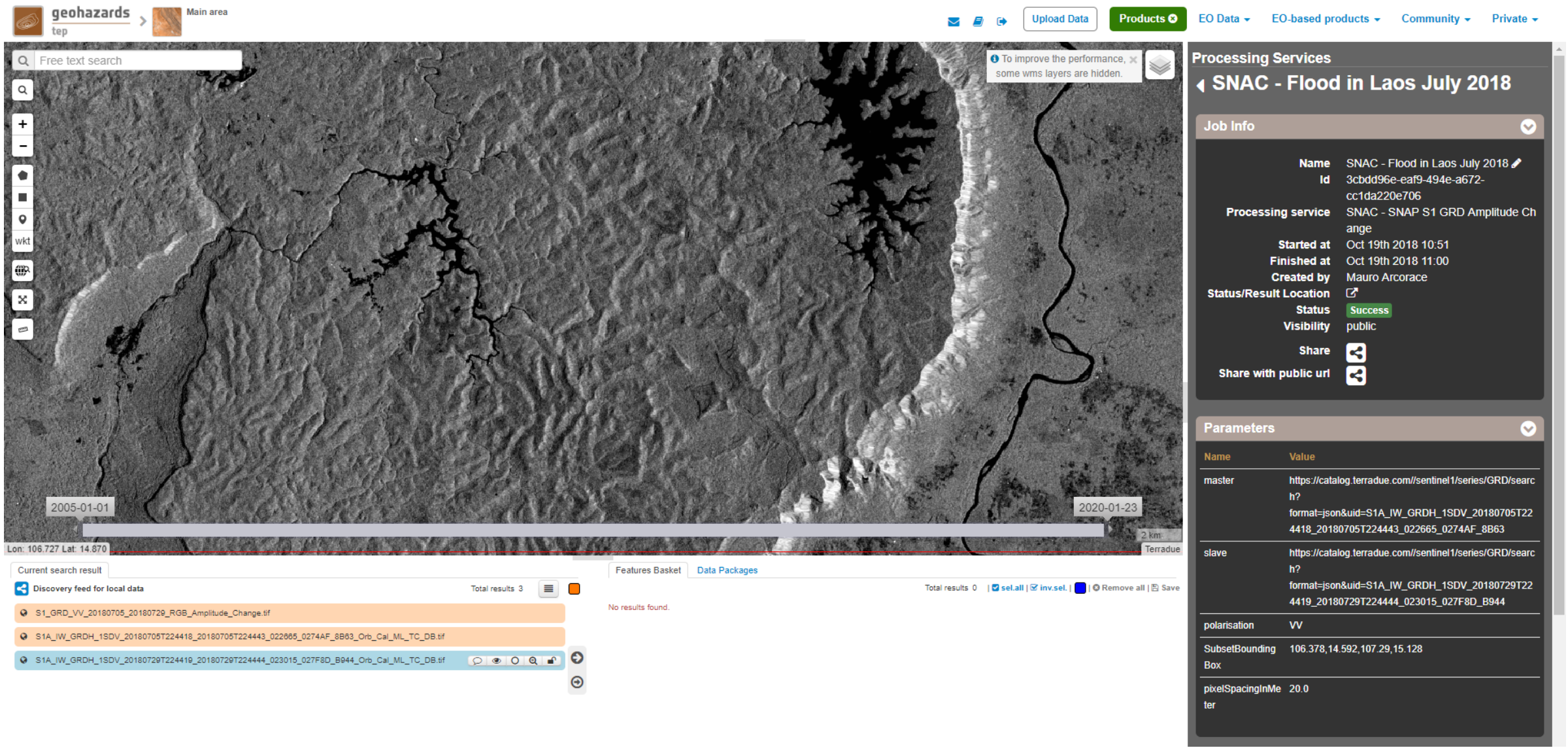
ervices ("as of April 2023") are described **here**.

GEP Hosted Processing Services

geohazards tep



Examples of GEP Services | SNAC (Floods in Laos)



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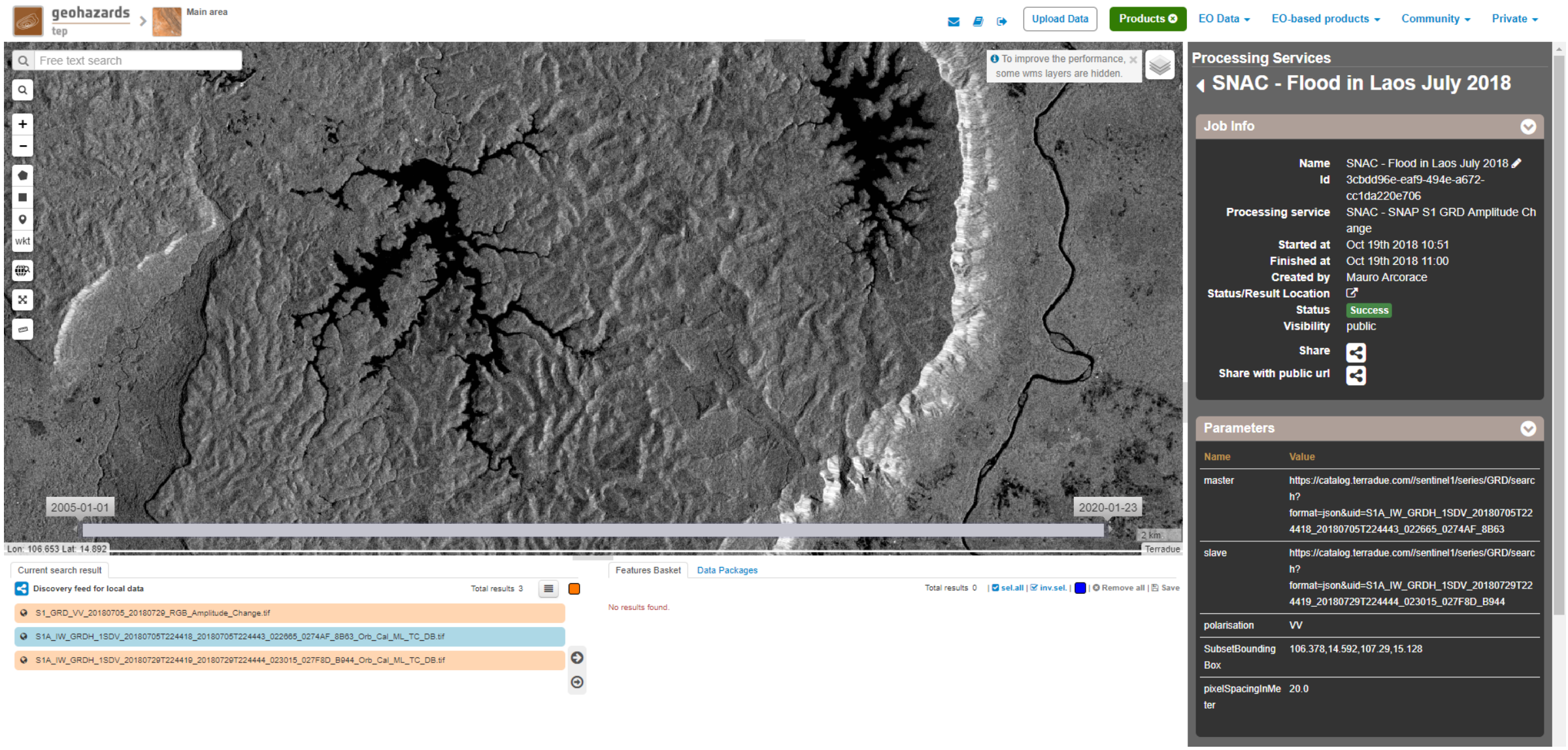

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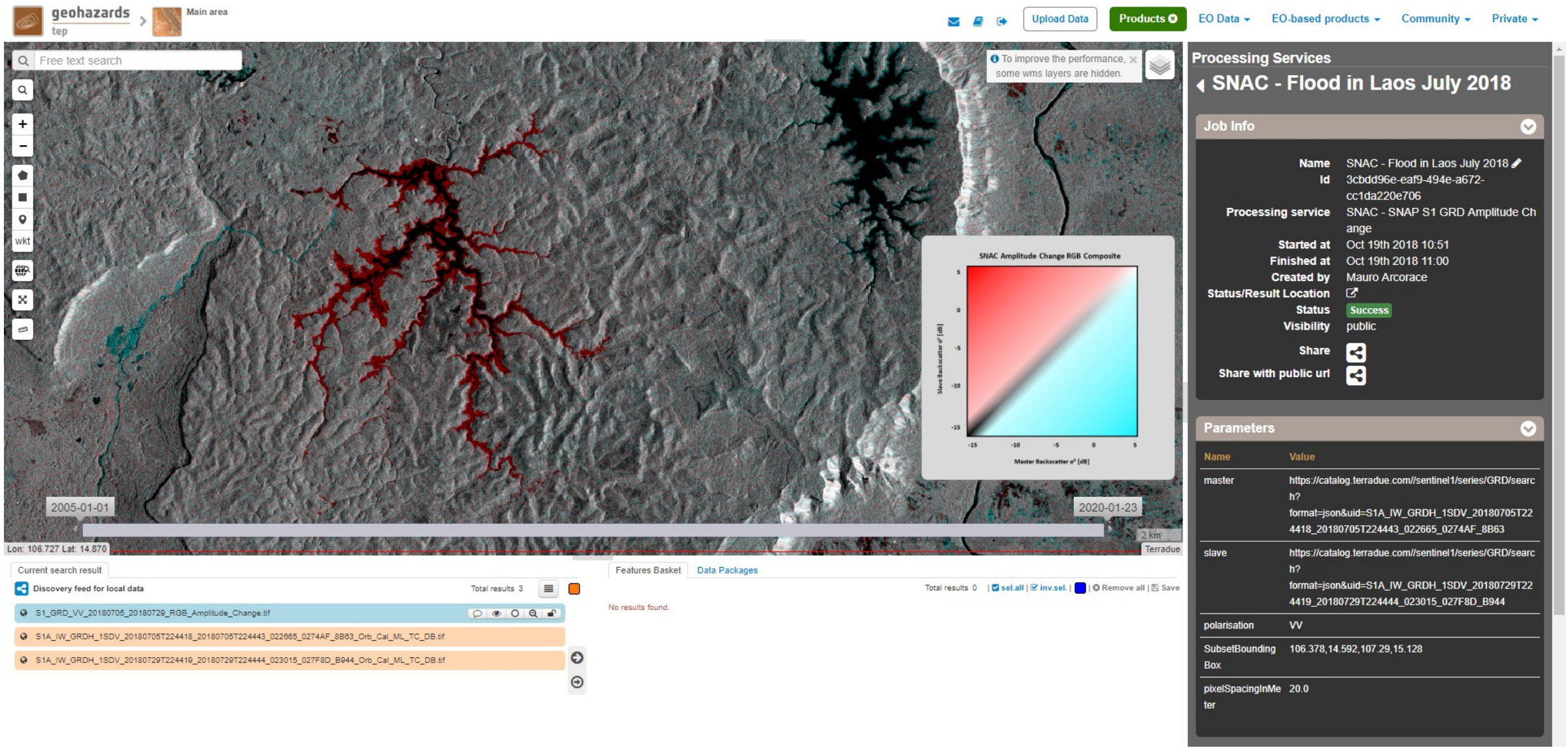

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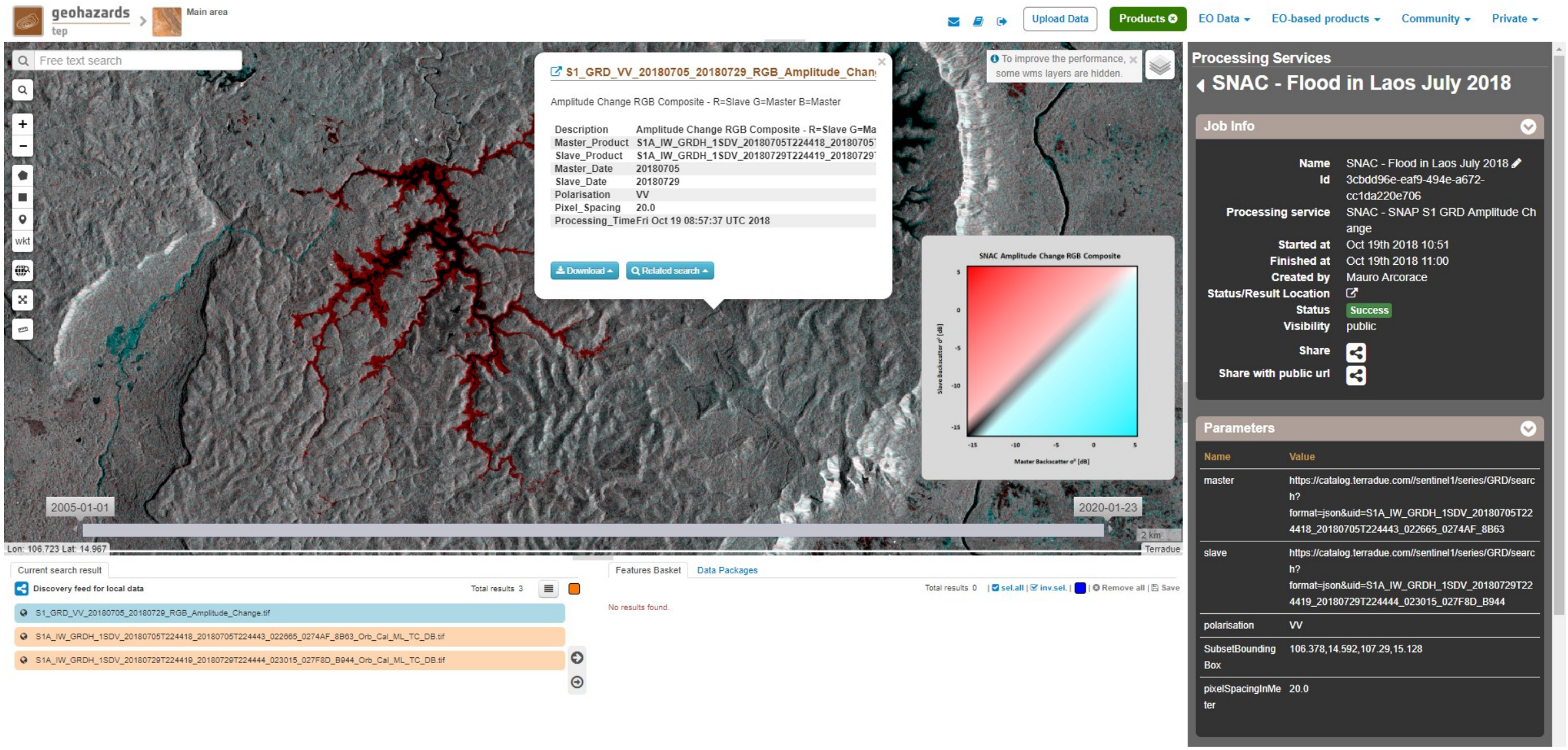
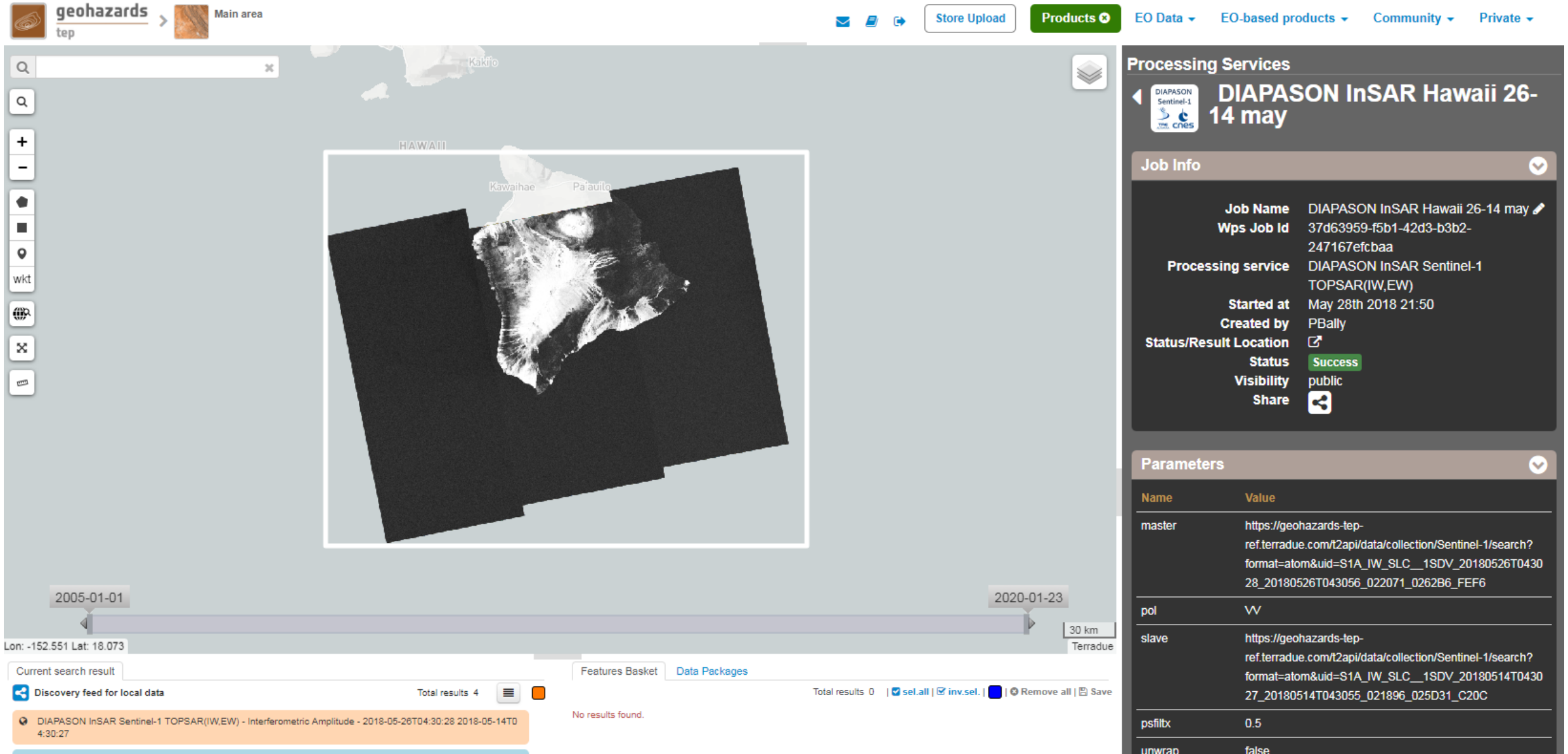


Examples of GEP Services | DIAPASON (Kilauea Eruption)



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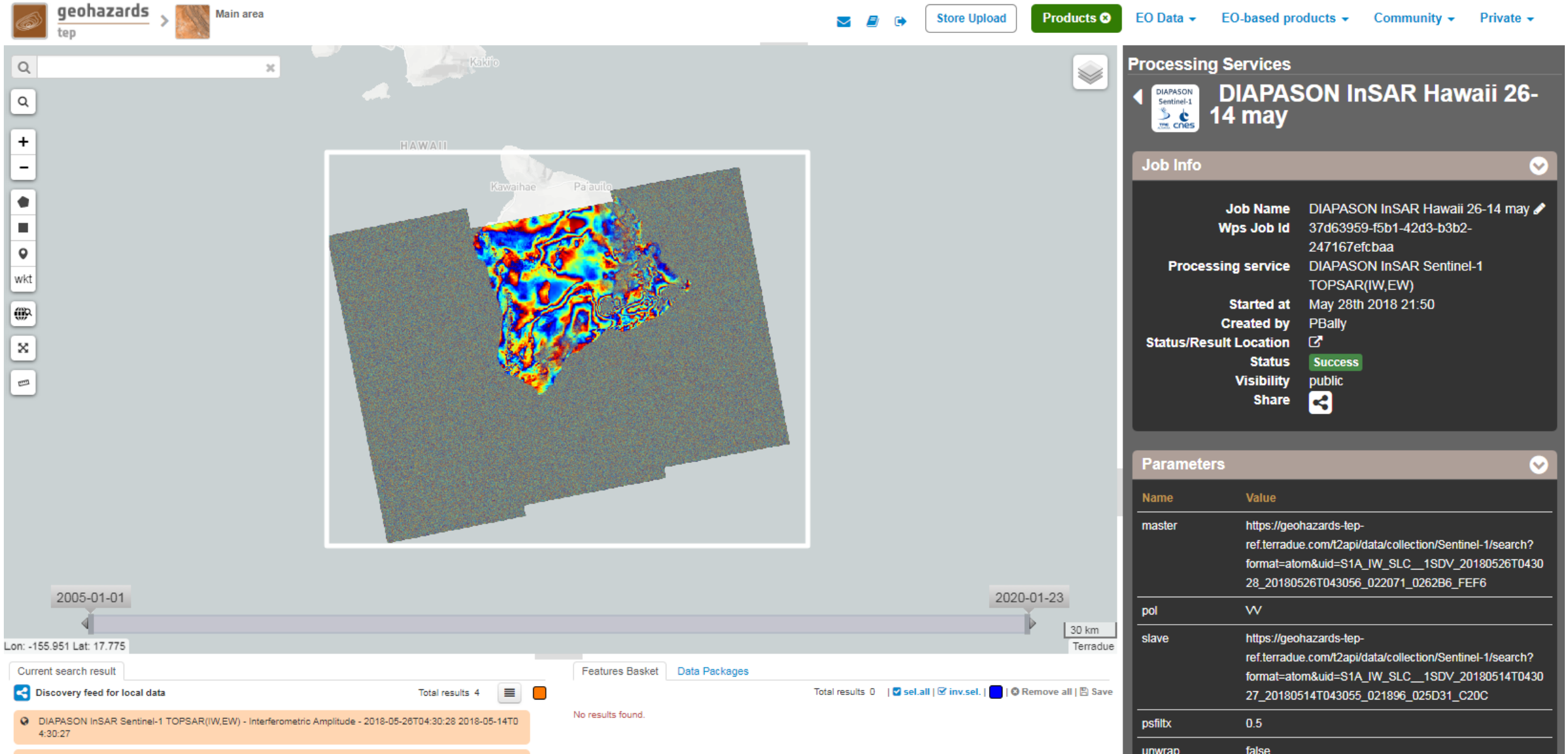

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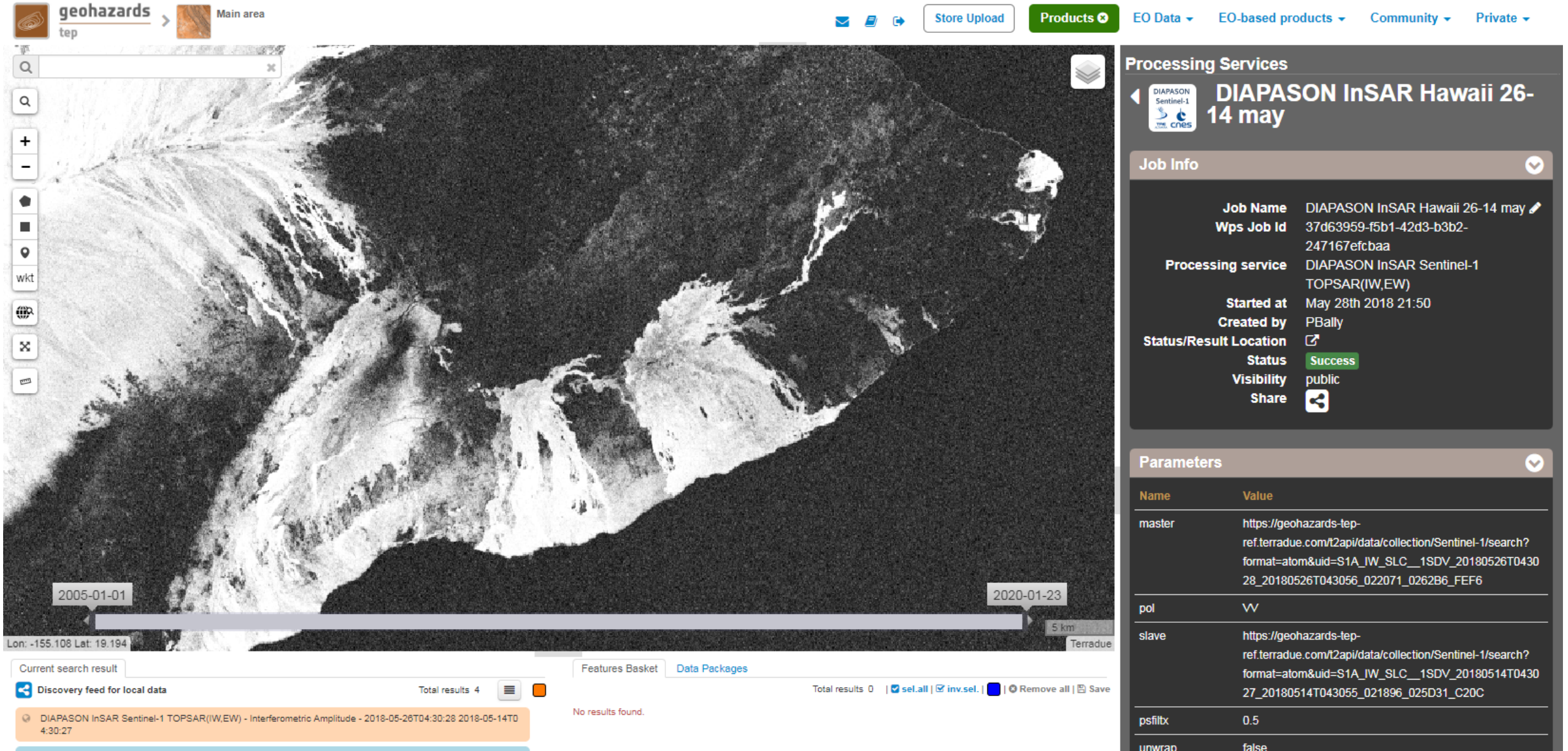

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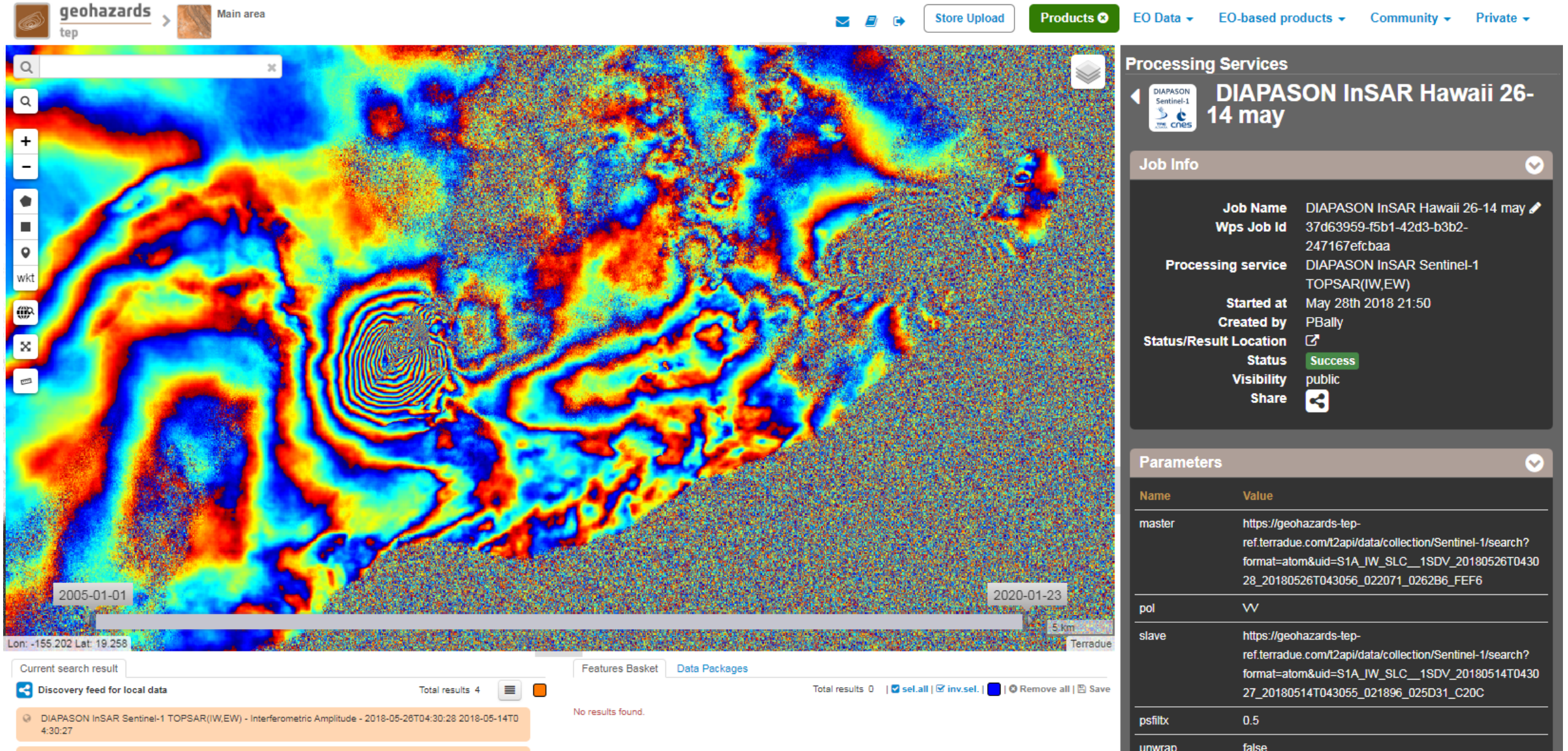
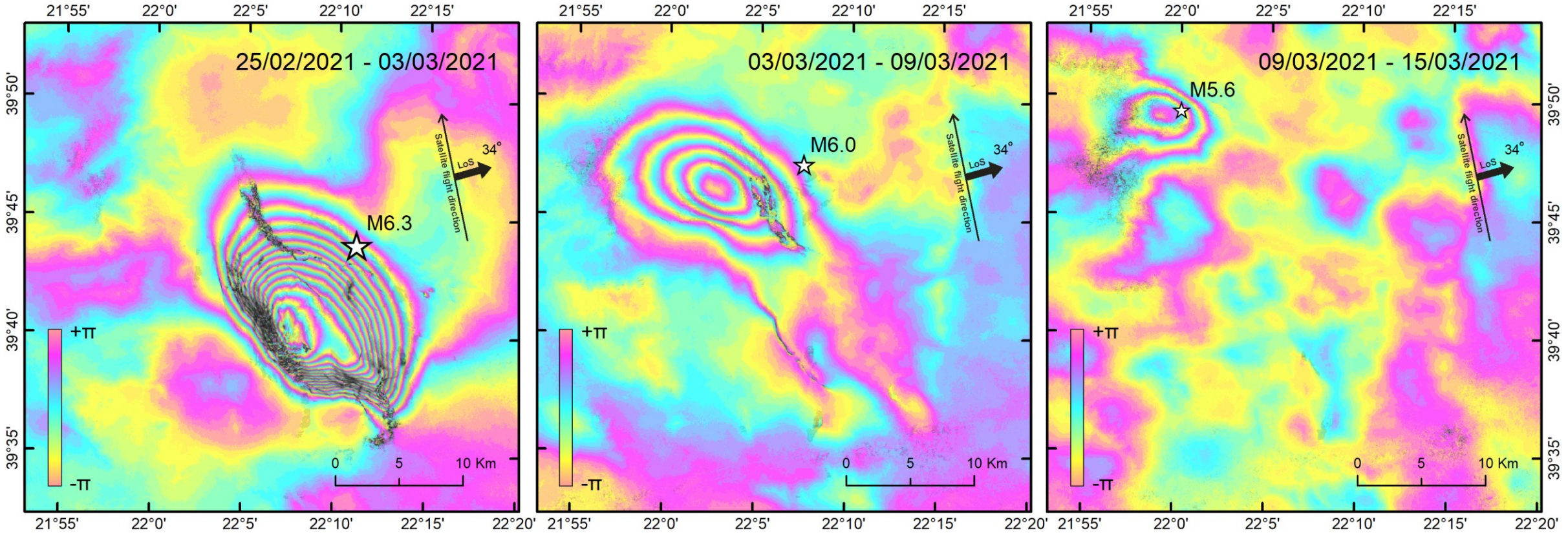


Surface Motion | Tyrnavos (Greece) Earthquake Sequence (March 2021)

Sentinel-1 Co-Seismic Differential Interferograms

Observed surface displacements for the major seismic events: -38 cm (M6.3), -12 cm (M6.0;) and -9 cm (M5.6)



Contains modified Copernicus Sentinel data [2020], processed by AUTh

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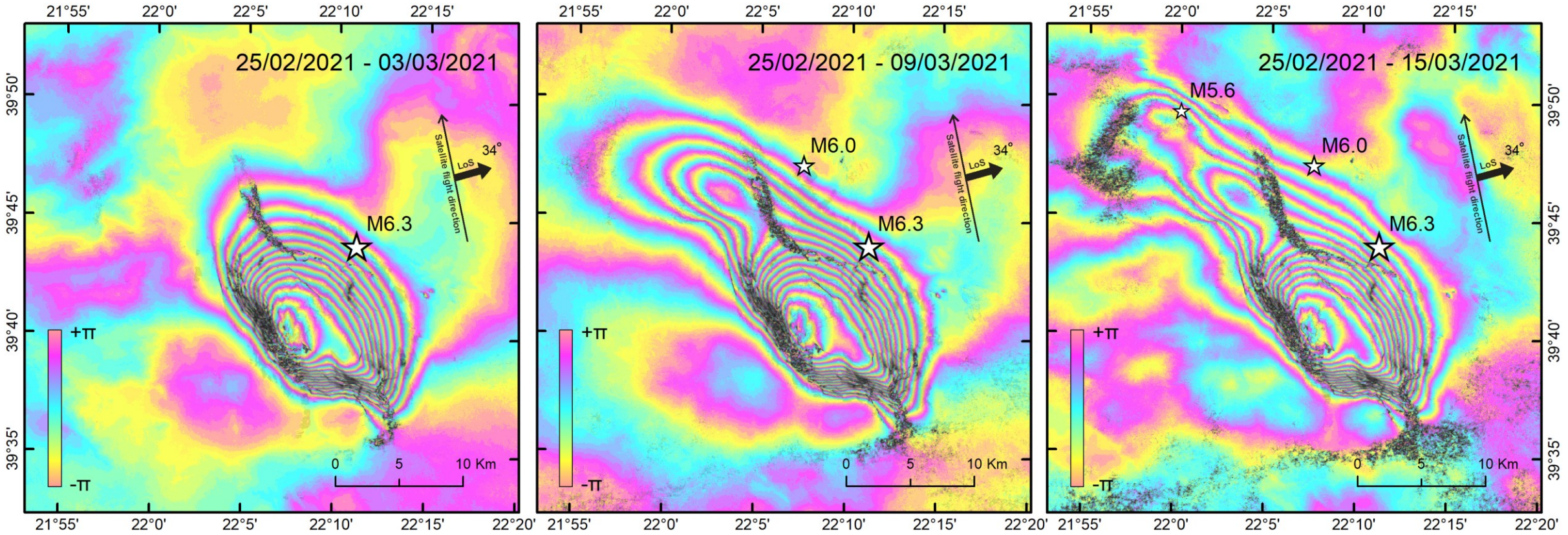


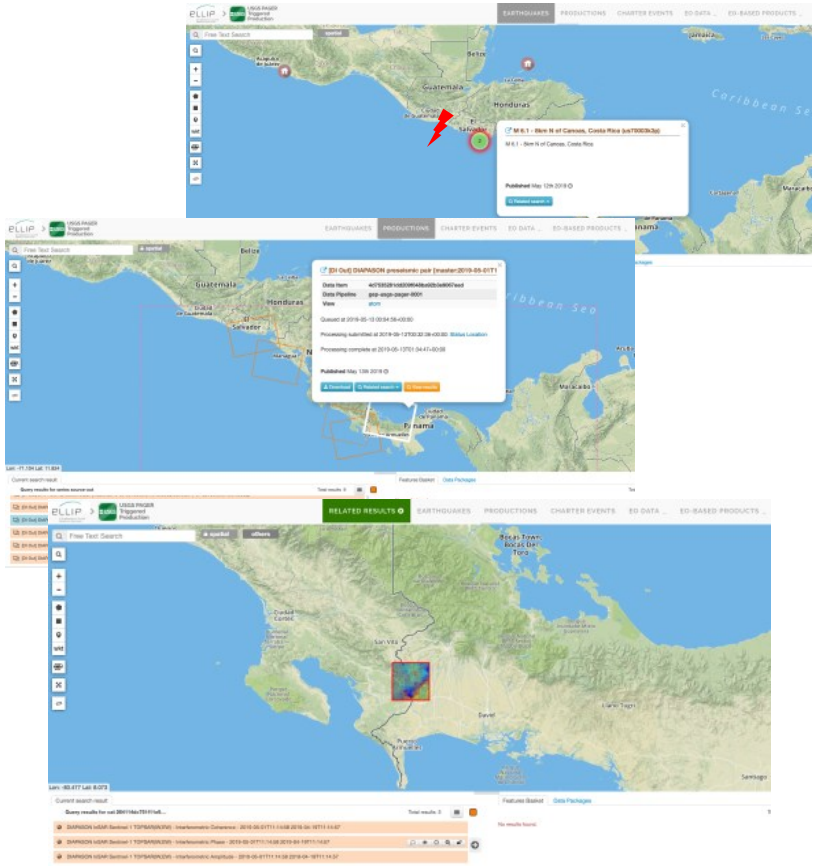
Contains modified Copernicus Sentinel data [2020], processed by AUTh

GEP | Automatic Alerting System

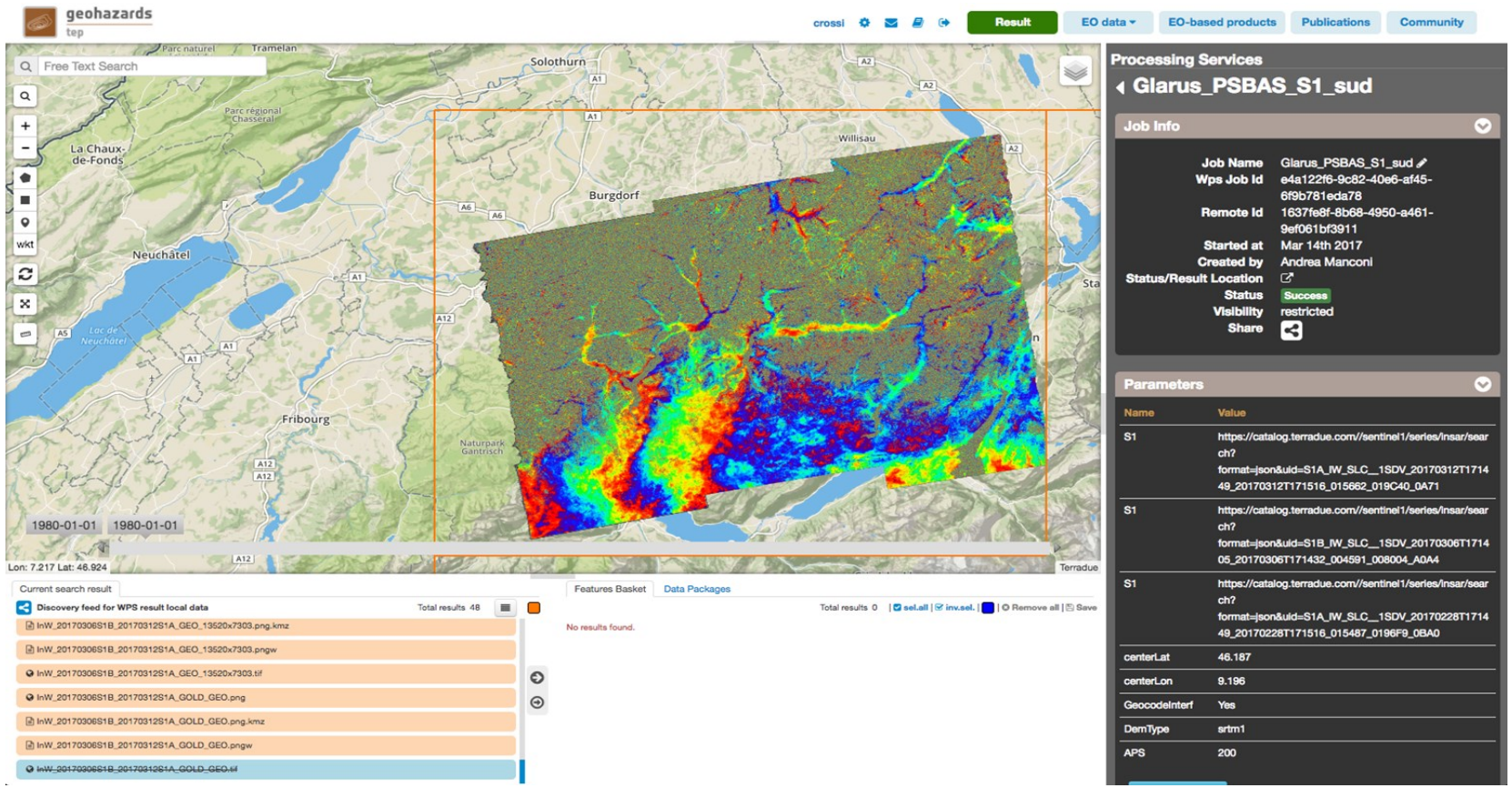
New GEP functionality under implementation:
Triggering services based on seismic events polled from external systems

- **Automatic production** of **deformation maps** with different GEP processing services
  - **Actuators** are event-based components able to start specific data discovery, ingestion, caching and processing workflows (**USGS pager**, **@INGVterremoti** twitter feed based on the earthquake magnitude, **Copernicus EMS** rapid mapping and risk & recovery feeds and **UNOSAT/GDACS** disaster feed)
  - Services shall be triggered for each earthquake with a magnitude > X, based on the actuators feed

- **Publication** of generated maps in a specific index in the GEP catalogue linked to the originating event



GEP | P-SBAS On-demand Processing Service



https://geohazards-tep.eu

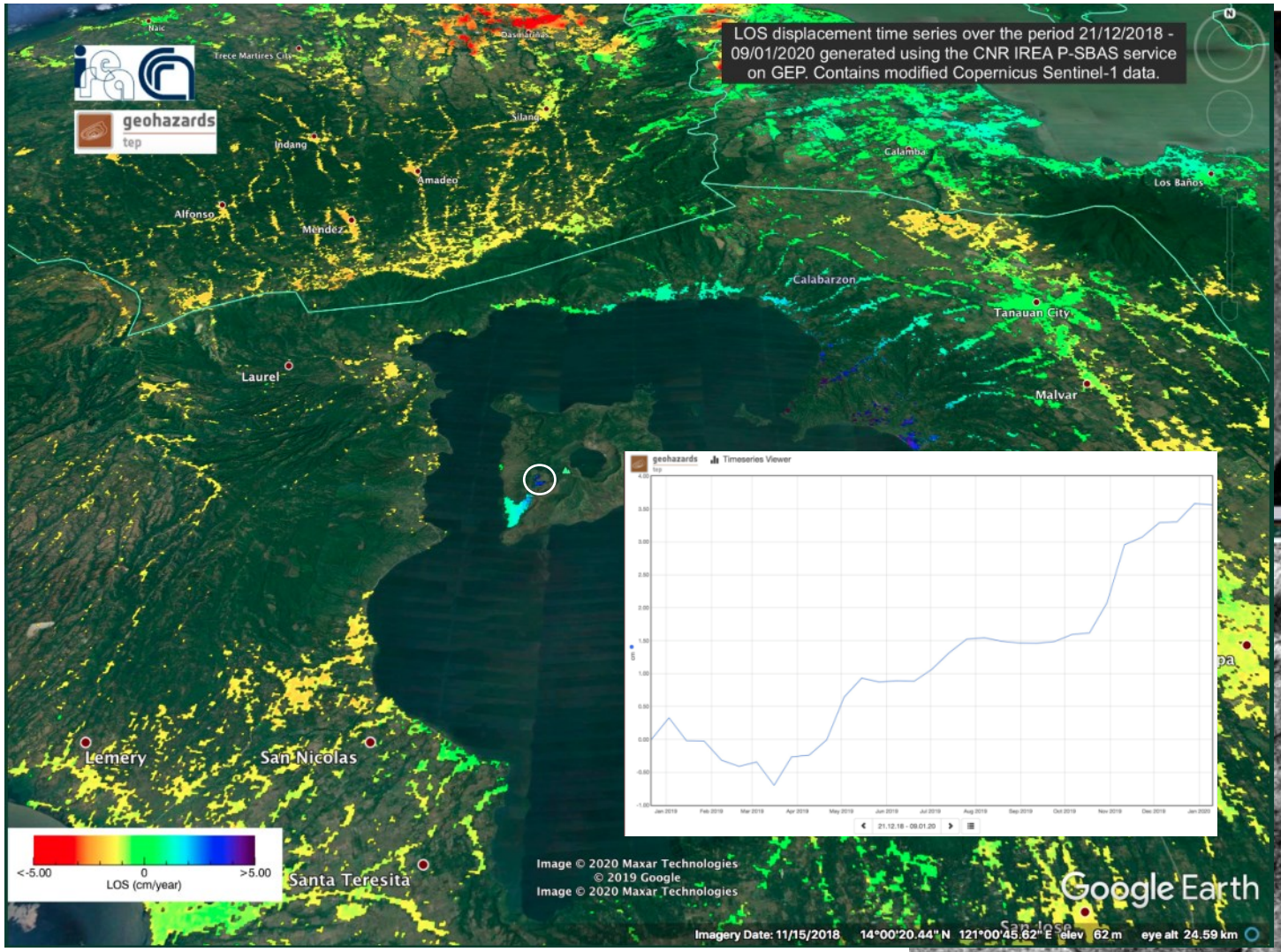
Will be supported by EGI BELNET-BEGRID (Belgium)

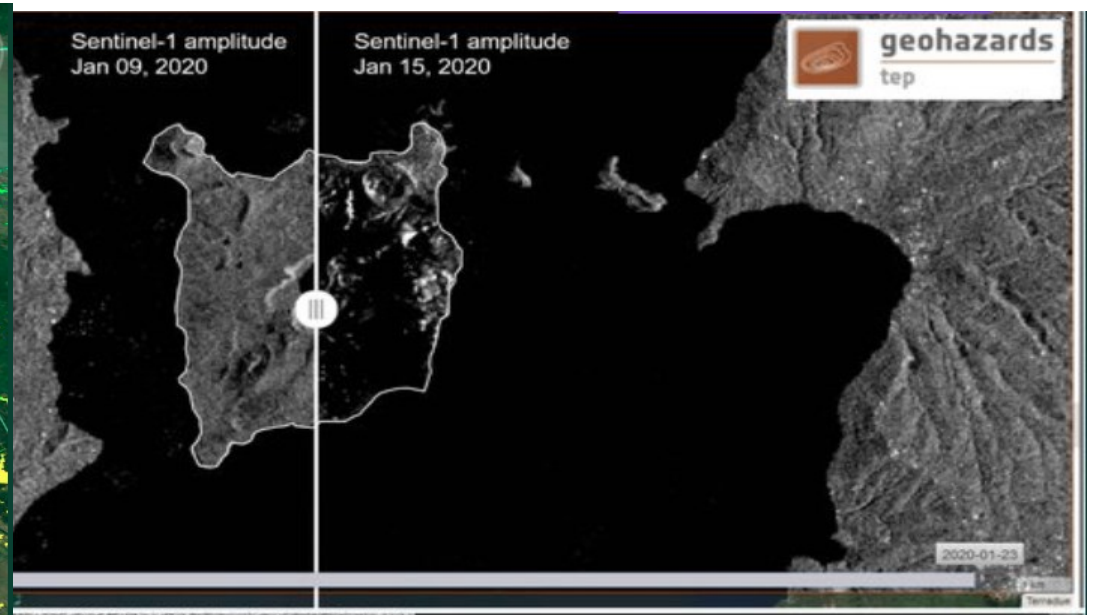
ONDA

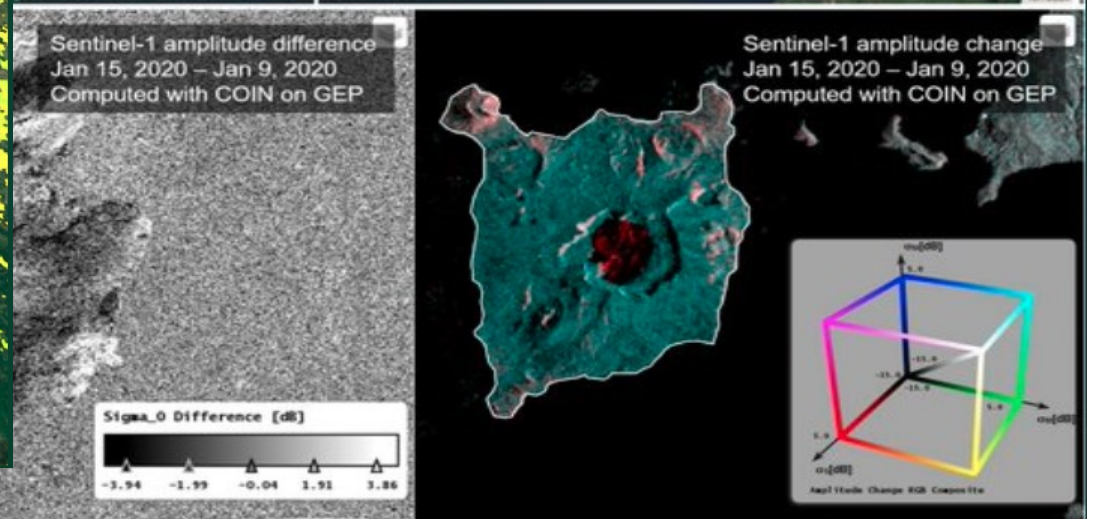
CNR-IREA P-SBAS Sentinel-1 processing on-demand

P-SBAS stands for Parallel Small BAseline Subset and it is a DInSAR processing chain for the generation of Earth deformation time series and mean velocity maps. Input: SLC (Level-1) Sentinel-1 data.

GEP | P-SBAS Taal Volcano (Philippines)

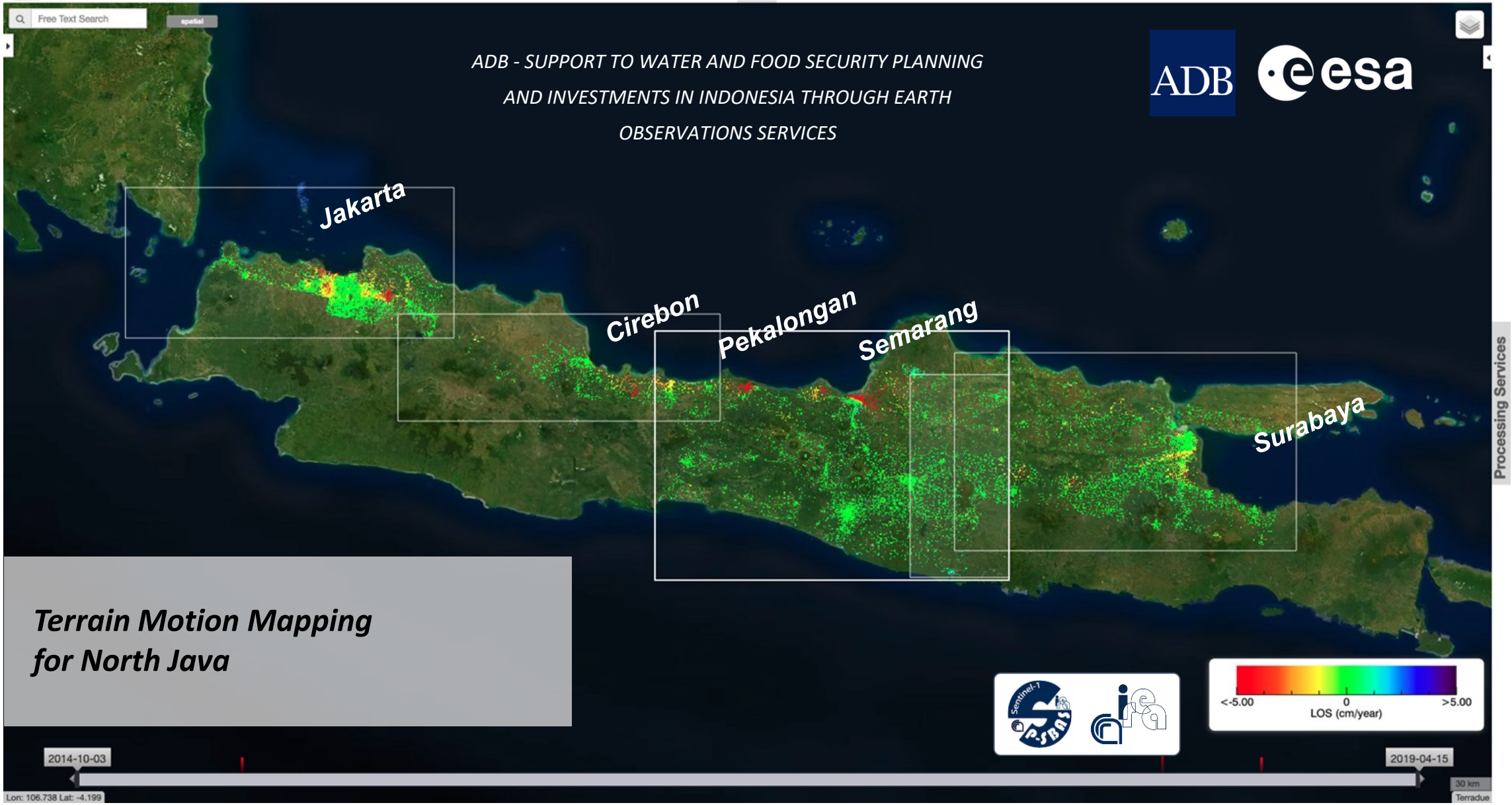






ADB - Support to Water & Food Security Planning & Investments in Indonesia through EO Services

North Java | GEP P-SBAS On-Demand InSAR Service



Contains modified Copernicus Sentinel-1 data (2015-2020)

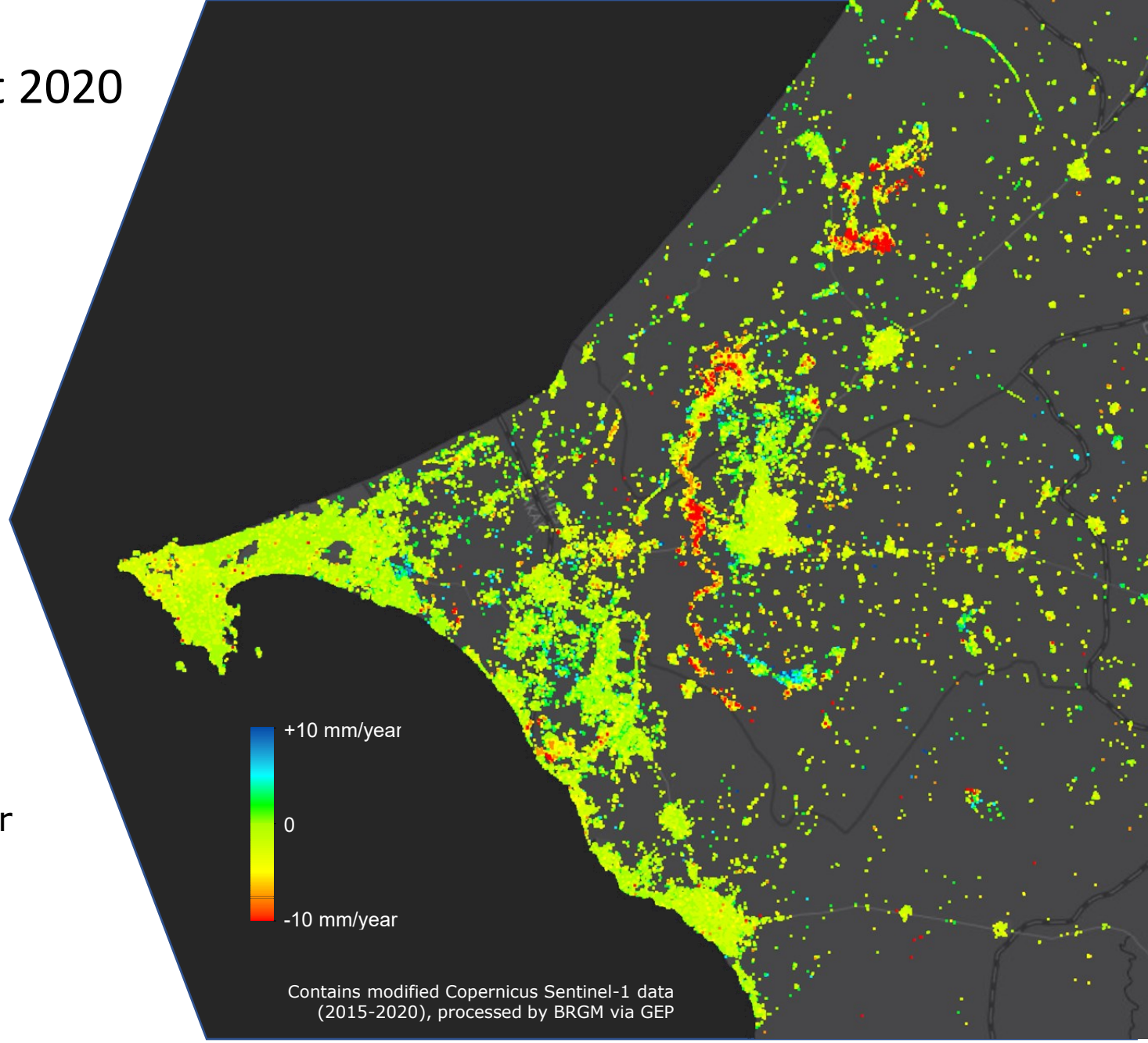
West Africa State of the Coast Report 2020

Terrain deformation of Dakar (Senegal) via GEP online services. Ground displacements for the period April 2015 – August 2020 based on InSAR processing of Copernicus Sentinel-1 mission data using the CNR-IREA P-SBAS on-demand service implemented on GEP (10.1109/JSTARS.2014.2322671, 10.1109/TGRS.2019.2904912)

More than **90.000** measurement points using **352** Sentinel-1 acquisitions over the period **04/2015-08/2020** (~5yr)

Precision of the measurements 1-2 mm/year (10.1109/TGRS.2019.2904912)

Production completed in **~30hrs**



SURFACE MOTION MAPPING | SNAPPING SERVICE ON GEP

A multi-temporal interferometric service that produces measurements of surface displacements based on ESA SNAP and StaMPS software packages

SNAPPING IFG

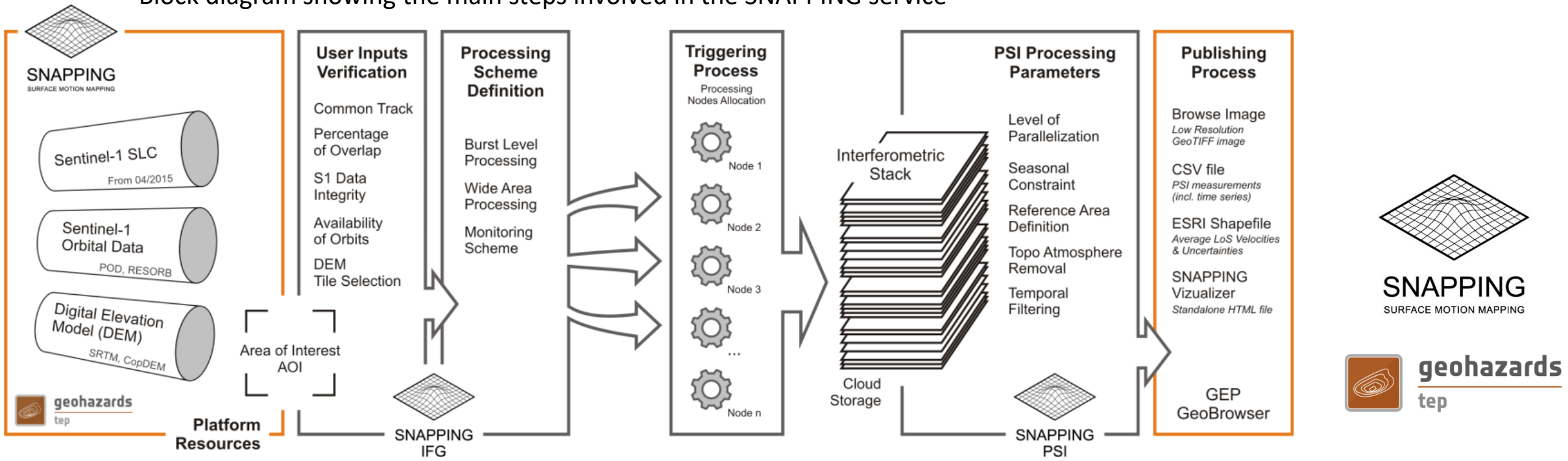
SNAPPING PSI

Two step process

The first consists in setting-up **SNAPPING IFG** processing pipeline to generate the interferogram stack

In the second step the interferogram stack is channeled to the **SNAPPING PSI** pipeline for time series analysis

Block diagram showing the main steps involved in the SNAPPING service



SNAPPING
SURFACE MOTION MAPPING

geohazards tep

Family of SNAPPING Services

SNAPPING
SURFACE MOTION MAPPING

SNAPPING PSI Med

A service focusing on the delivery of PSI measurements at reduced spatial resolution (spatial averaging of point targets within a 100x100 meters radius to allow wide-area coverage in a relatively short time. The SNAPPING PSI Med service is proposed for inspection of areas of large extent to identify sites where more dedicated analysis is required.

SNAPPING PSI Full

Full sensor resolution PSI service applicable for a detailed regional investigation of surface motion, as well as for building-level and infrastructure monitoring. Persistent Scatterers (PS) targets represent surface features stable over the observation period, mainly man-made objects and non-vegetated natural terrain.

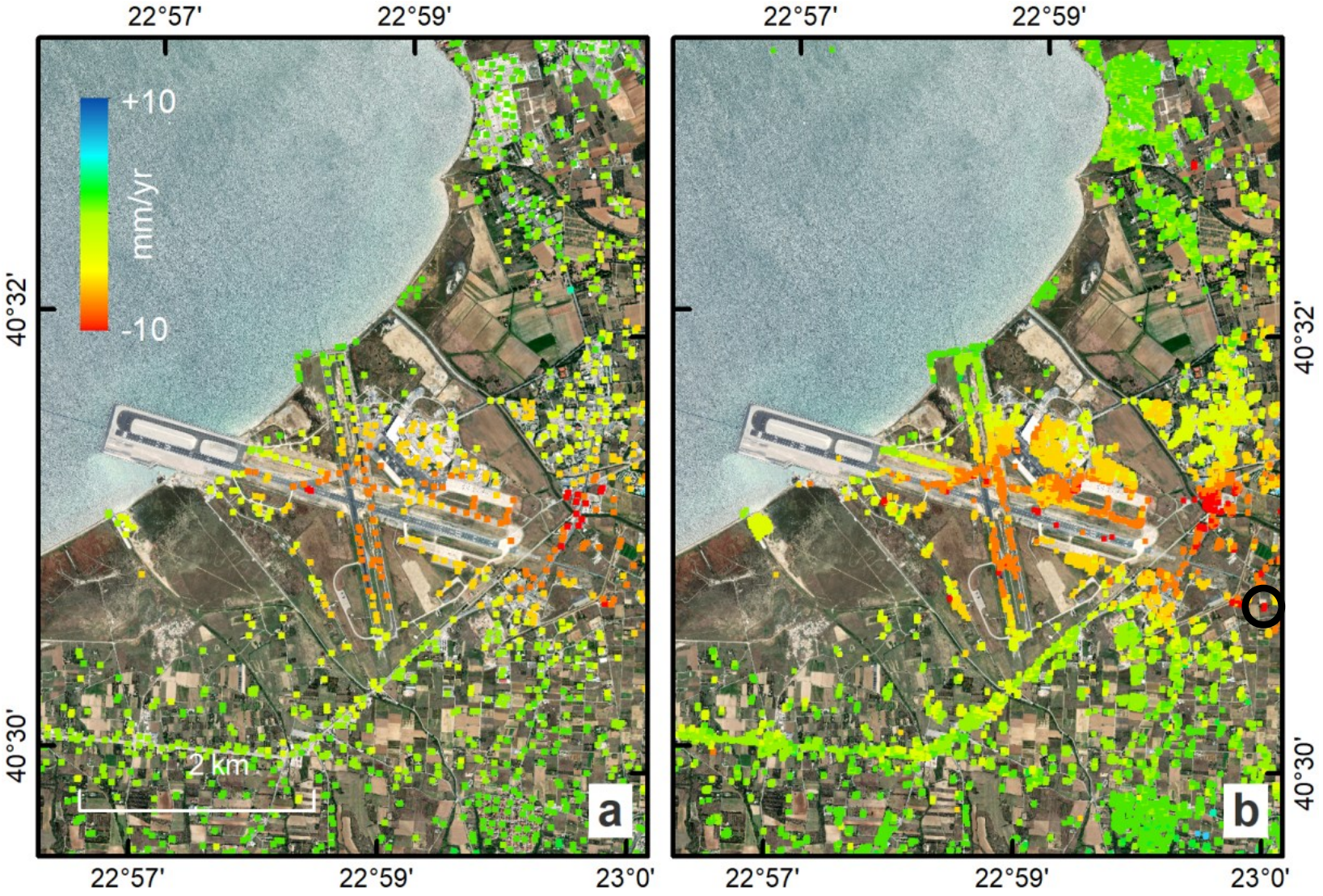
SNAPPING PSI+ (PS/DS)

Tailored interferometric processing on both PS and Distributed Scatterers (DS), providing optimum measurement densities. DS are typically identified over homogeneous ground, non-cultivated lands and deserted areas.

SNAPPING PSI | Υπηρεσίες Μέσης (Med) και Υψηλής (Full) Χωρικής Ανάλυσης

Ετήσιοι ρυθμοί μετακίνησης για την περίοδο 2015-2020 στον Διεθνή Αερολιμένα Θεσσαλονίκης χρησιμοποιώντας τις υπηρεσίες SNAPPING PSI Med και PSI Full. Παρατηρείται η αύξηση της πυκνότητας των μετρήσεων με την χρήση της υπηρεσίας PSI Full.

Η υπηρεσία SNAPPING PSI Full οδήγησε σε αύξηση κατά ~1500% των μετρήσεων (συνολικά 16500 ανακλαστήρες) σε σύγκριση με την αντίστοιχη λύση PSI Med (1120 ανακλαστήρες).



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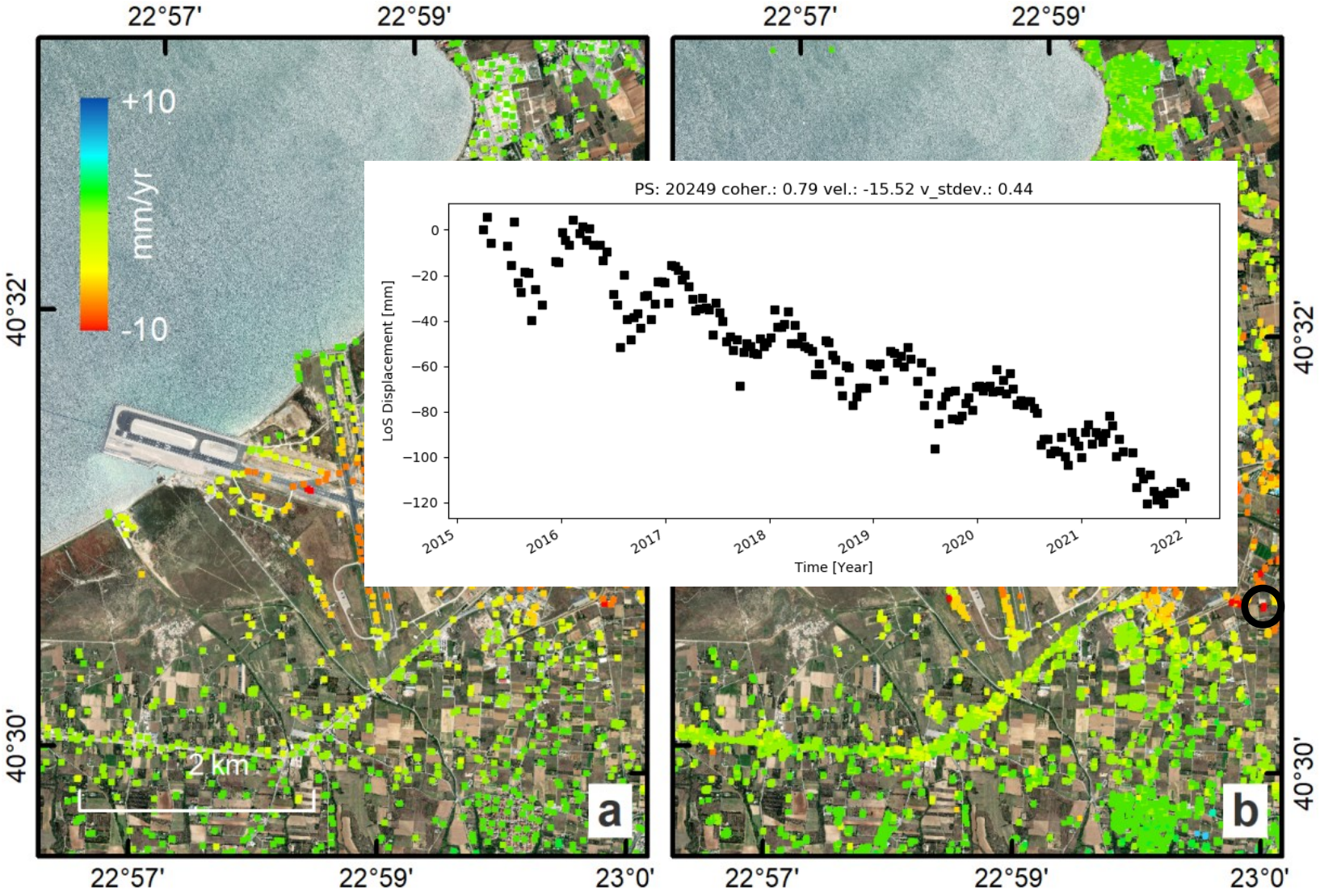
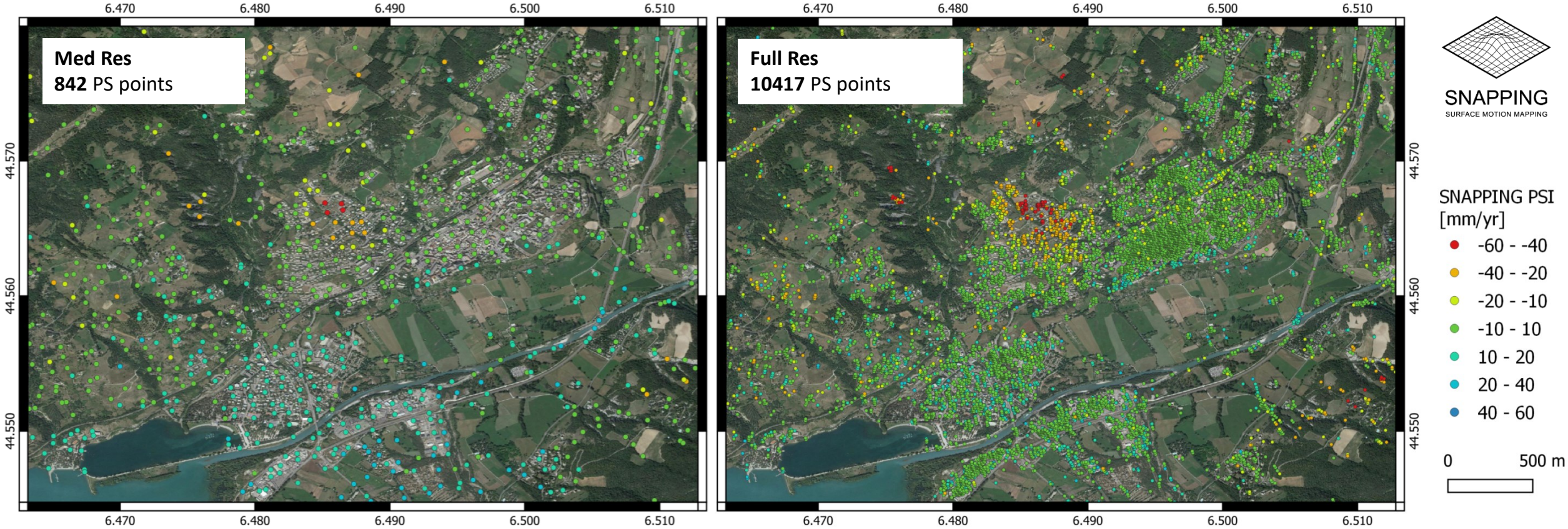


SNAPPING PSI services

Landslide site in the French Alps captured by SNAPPING on-demand service on the Geohazards Exploitation Platform (GEP) using Copernicus Sentinel-1 mission data (observation period 2020-2021)



Contains modified Copernicus Sentinel-1 data (2020-2021), processed on GEP by AUTh

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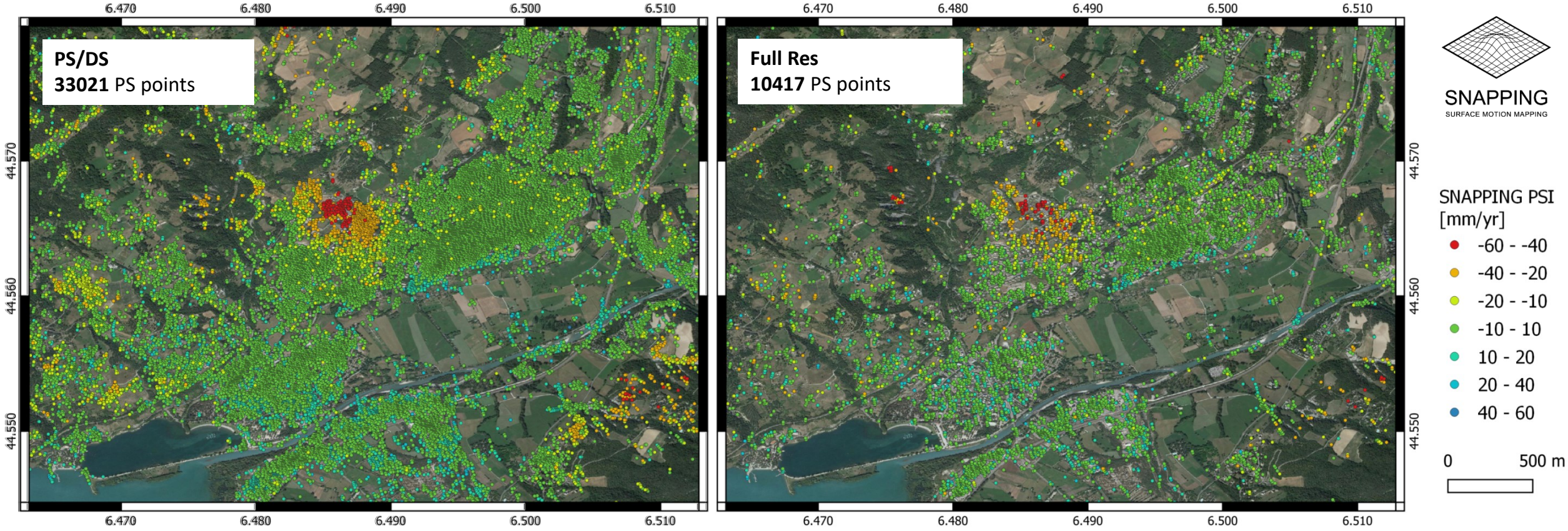
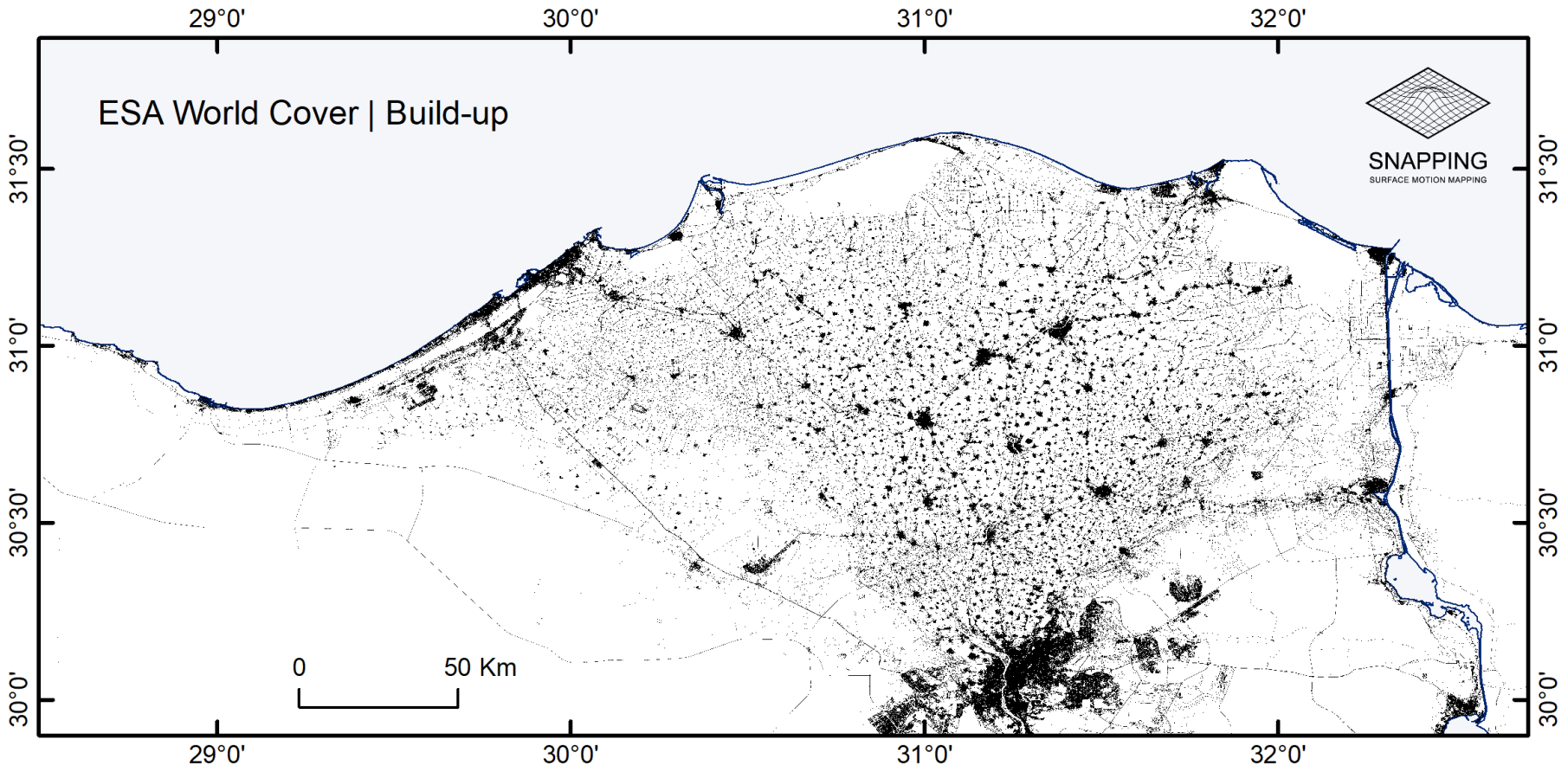


Contains modified Copernicus Sentinel-1 data (2020-2021), processed on GEP by AUTh

Wide Area InSAR Processing | Nile Delta (Egypt)

Terrain motion over build-up areas of the Nile Delta

Build-up area of the Nile Delta as outlined by the ESA WorldCover 2020 product



Contains modified Copernicus Sentinel-1 data (2015-2020), processed on GEP by NARSS/AUTh

Project supported by ESA NoR sponsorship involving the National Authority for Remote Sensing & Space Sciences (**NARSS**) of Egypt, the Aristotle University of Thessaloniki (**AUTh**) in Greece and the French Geological Survey (**BRGM**)

Sentinel-1 Tracks:
Descending 065 & 167

Observation Period:
2015-2020 (~6 years)

Nu of Sentinel-1 Scenes:
517

Nu of PS points:
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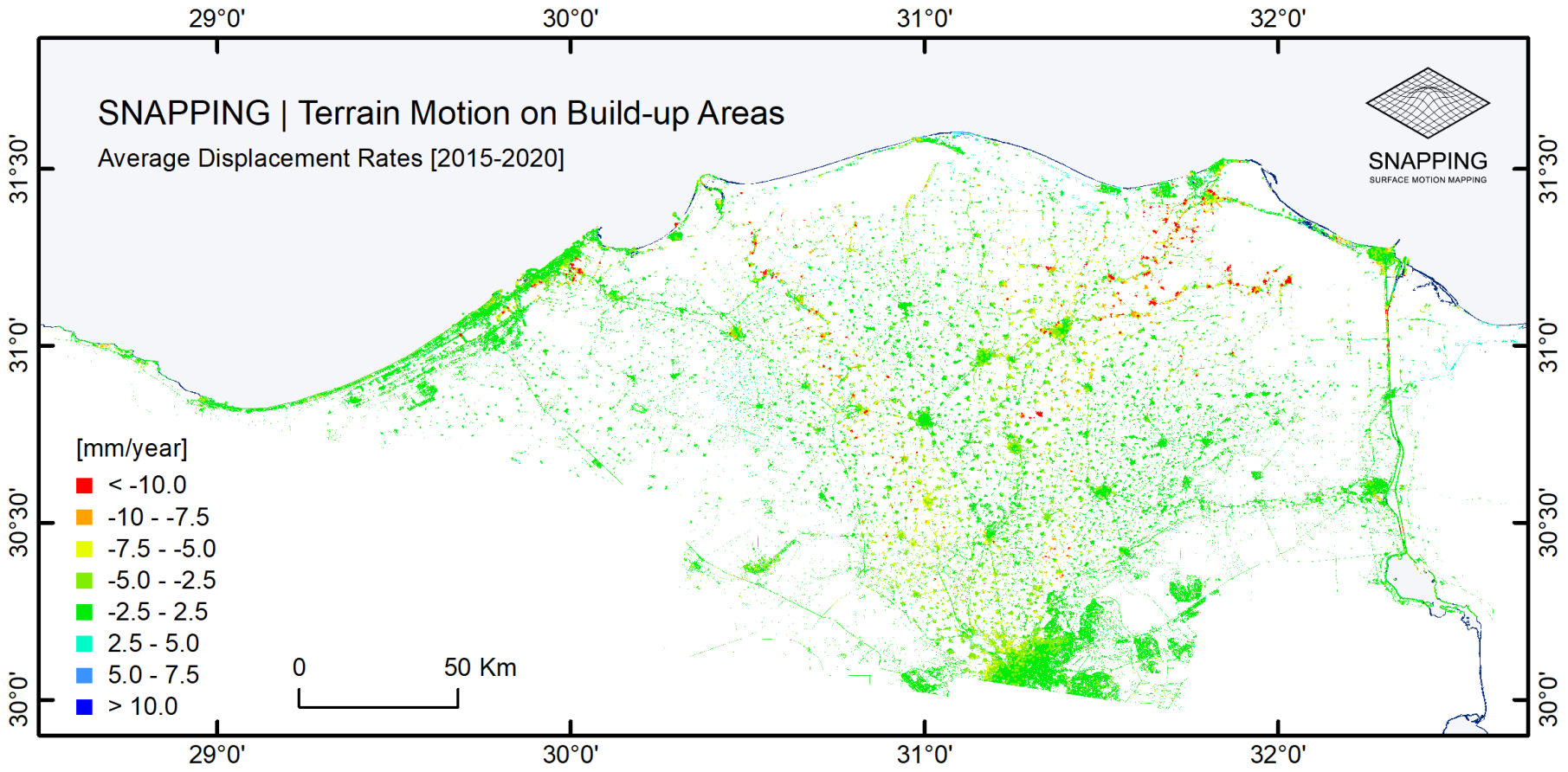

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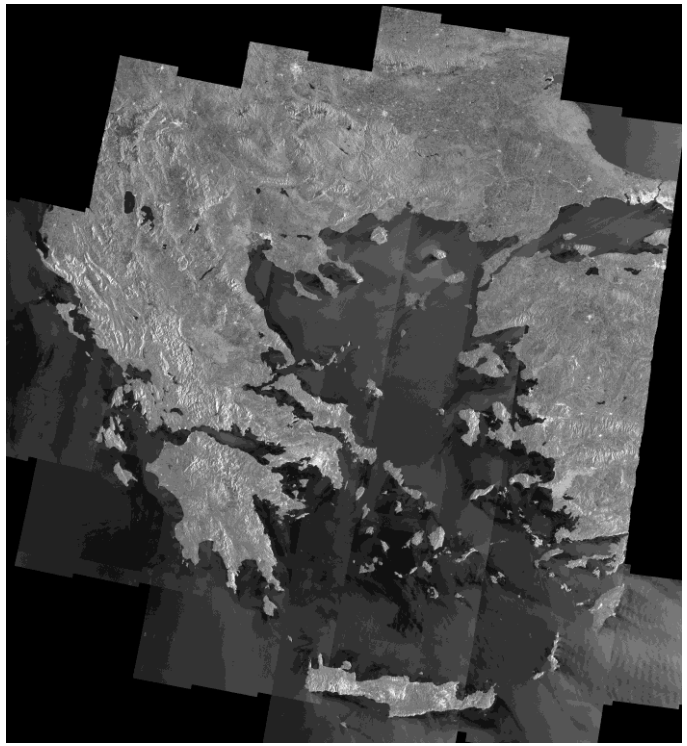
SNAPPING InSAR GReece

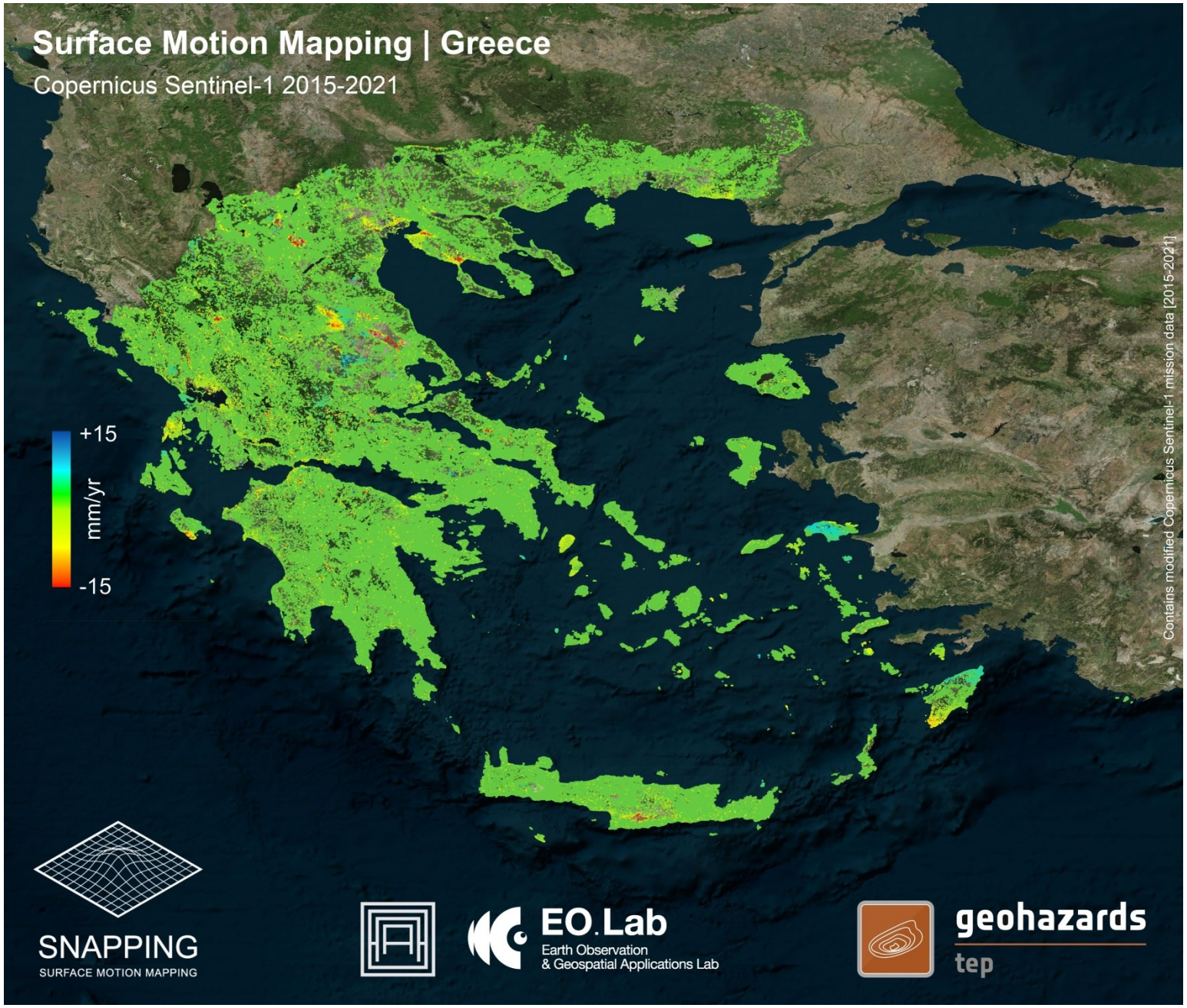
Copernicus Sentinel-1 Tracks

D153 | D080 | D007 | D109 | D136 | D138

4180 SLC scenes



A total of ~4M point measurements at medium resolution covering 132k sq.km2



SNAPPING InSAR GReece

Copernicus Sentinel-1 Tracks

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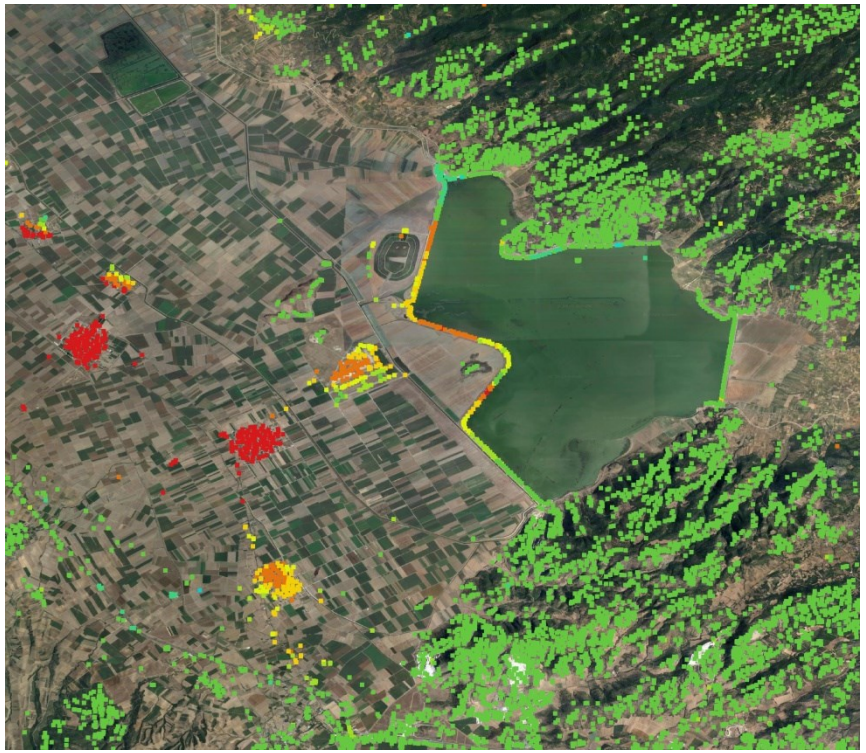

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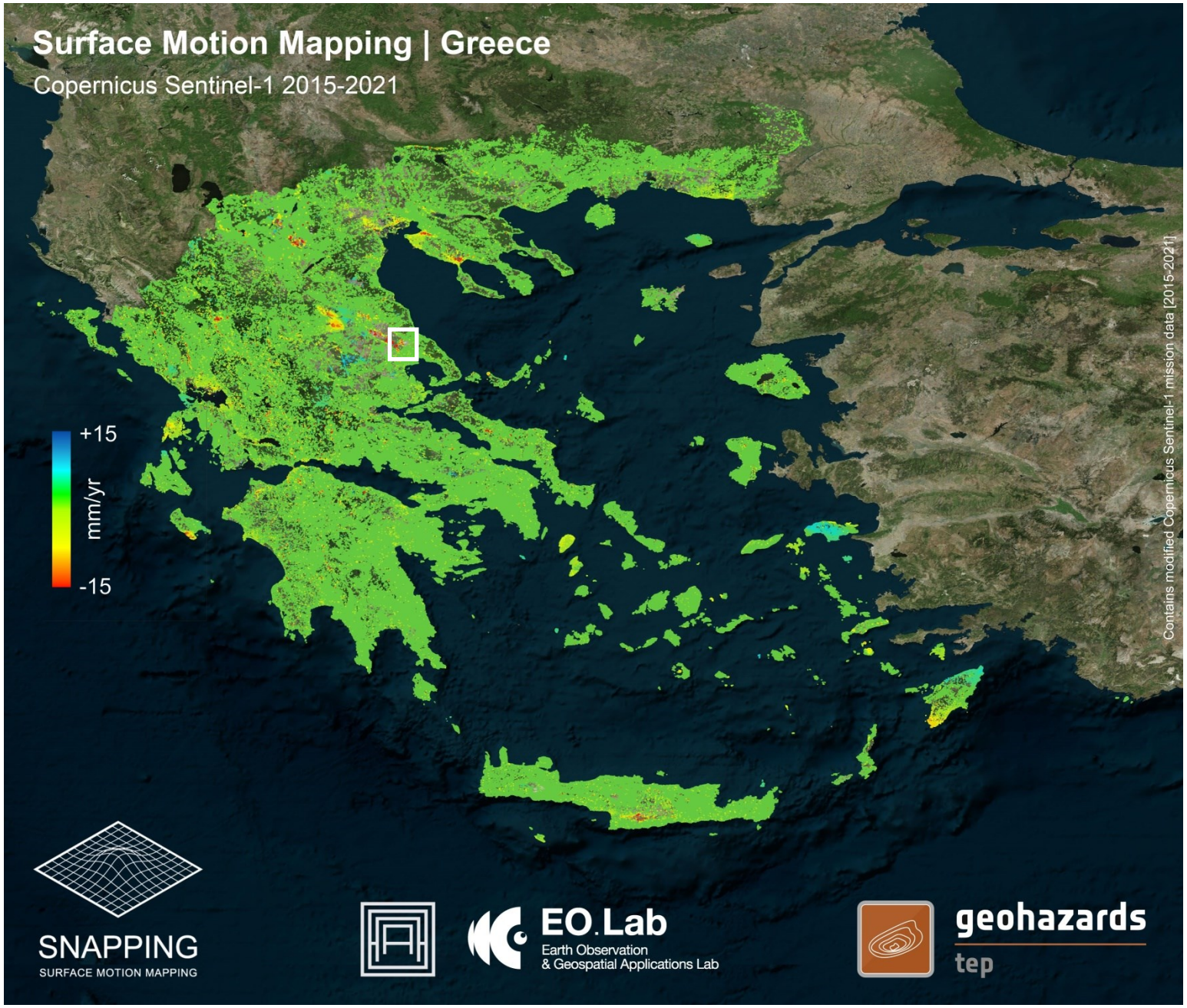

SNAPPING PSI Outputs

The SNAPPING measurements are provided as a text file in **Comma Separated Values (CSV) format** containing information about each point target.

code;	latitude;	longitude;	vel;	vs;	coh;	height;	inc_angle;	D20150404;	D20150416;	D20150428;	...
1;	40.231686;	23.72987;	-0.39;	0.44;	0.85;	50.33;	0.676172;	0.0;	10.15;	-10.15;	...
2;	40.232704;	23.722376;	-0.95;	0.45;	0.81;	50.52;	0.676749;	0.0;	10.3;	-10.3;	...
3;	40.2337;	23.715092;	-0.8;	0.38;	0.73;	61.56;	0.677298;	0.0;	9.72;	-9.72;	...
4;	40.242413;	23.650858;	0.31;	0.3;	0.7;	141.27;	0.682141;	0.0;	4.82;	-4.82;	...
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SNAPPING PSI Outputs

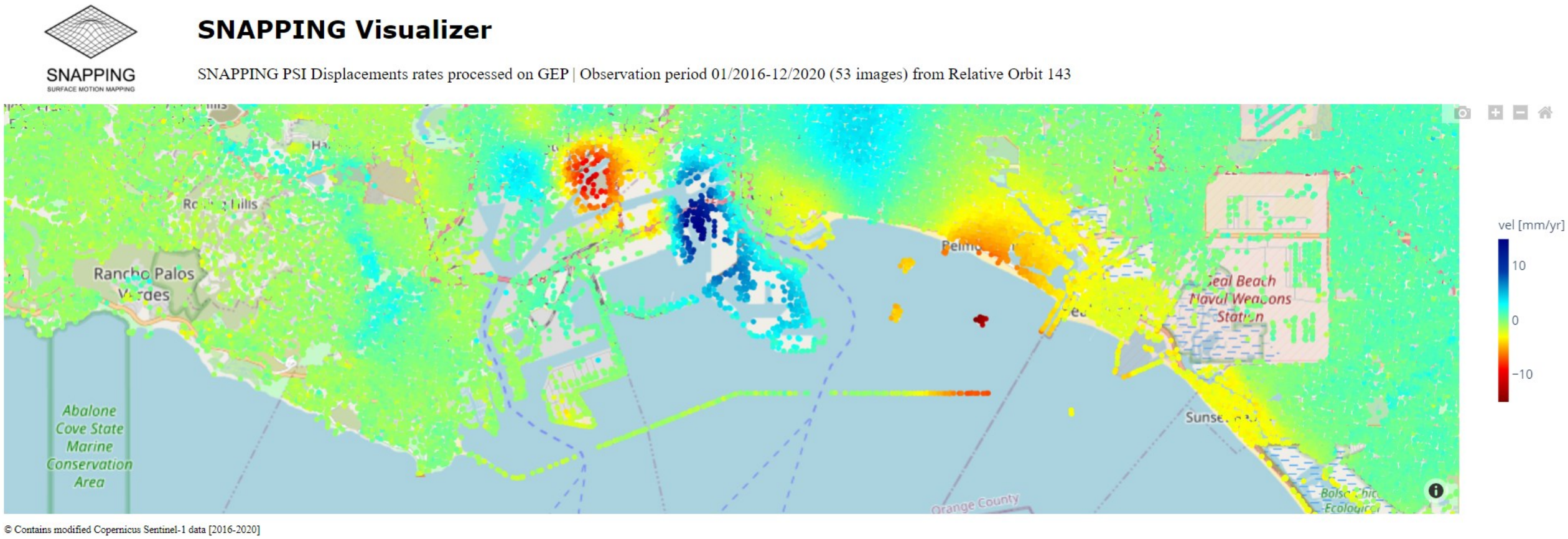
The SNAPPING measurements are provided as a text file in **Comma Separated Values (CSV) format** containing information about each point target.

Furthermore, PS displacement rates and corresponding uncertainties are provided in standard vector format (i.e. ESRI shapefiles).

File	Format	EPGS	Description
<Filename>.csv	Standard Comma-Separated Values file	4326 (WGS 1984)	Tabulated surface motion measurements with following attributes: ID, Latitude, Longitude, Vel, Vs, Coh, Height, Inc_Angle, YYYYMMDD (as YYYY: year; MM: month & DD: day).
<Filename>.txt	Standard text file that contains plain text	Not applicable	Processing metadata, including detailed information on the version of the service used, production date, EO sensor, start/end of the measurements, number of images etc.
<Filename>.shp	Standard ESRI vector file format to be accessed with proprietary (ESRI) or other open source software (e.g. QGIS)	4326 (WGS 1984)	Surface motion measurements as point vector data containing same attributes as CSV file (see above).
<Filename>.rgb.tif	Standard GeoTIFF file	4326 (WGS 1984)	Low resolution browse image.
<Filename>.legend.png	Standard Portable Network Graphics raster file	Not applicable	Colour scale (as raster image) corresponding to browse image file (i.e. Filename.rgb.tif).
<Filename>.html	Standard file in Hypertext Markup Language	Not applicable	Standalone visualization file showing surface motion point measurements (average motion rates in mm/yr) as overlaid on OpenStreetMap background.

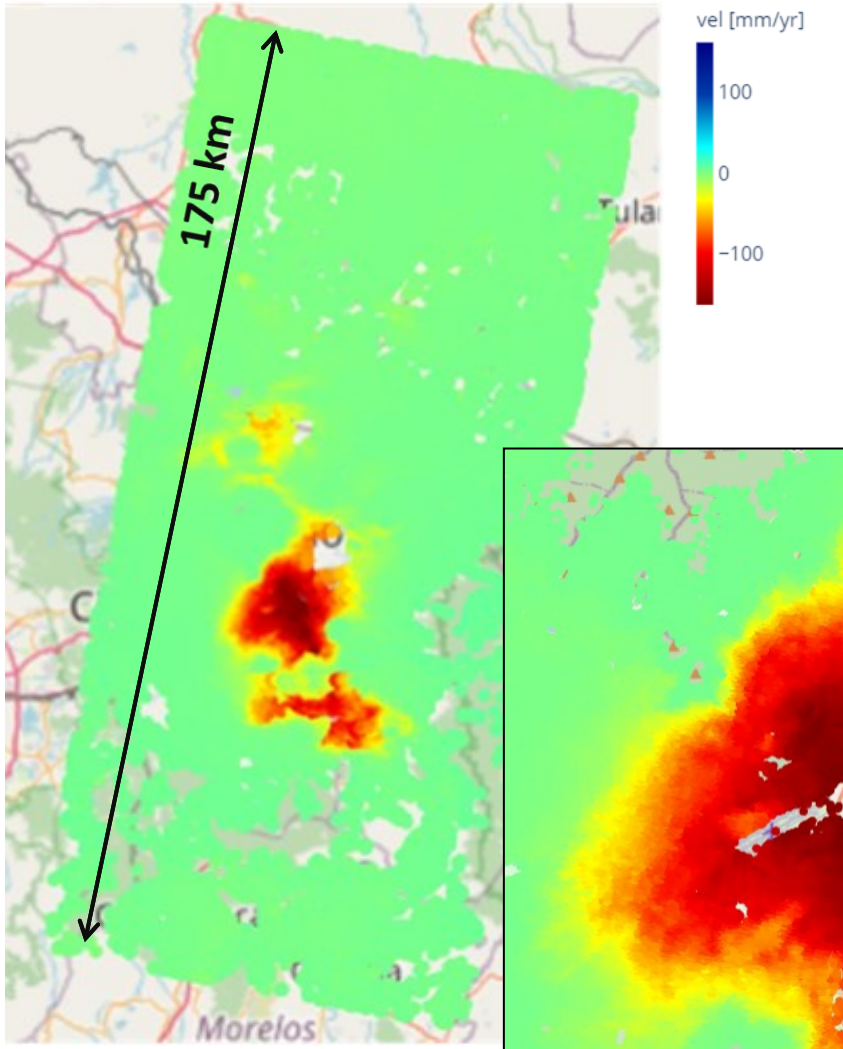
SNAPPING VISUALIZER | Los Angeles (USA)

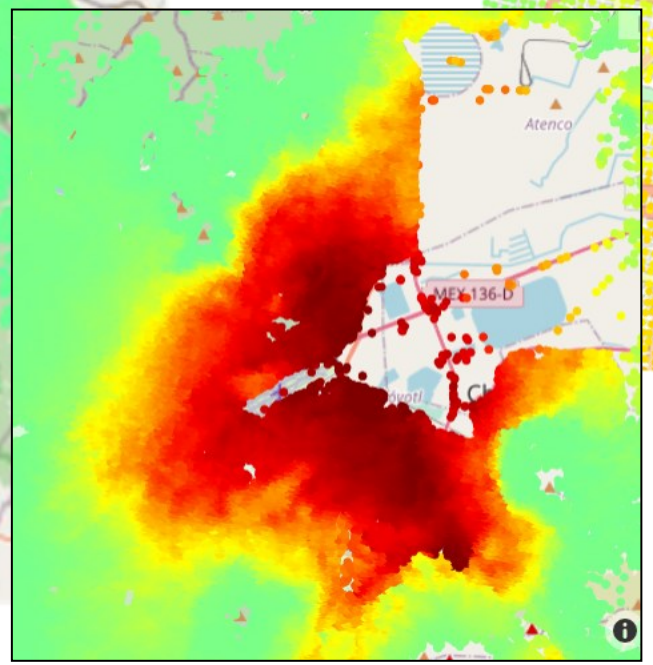
A standalone HTML (off-line) visualization file is also provided to facilitate proper inspection of data by end-users without the need for ingestion into any geospatial database.

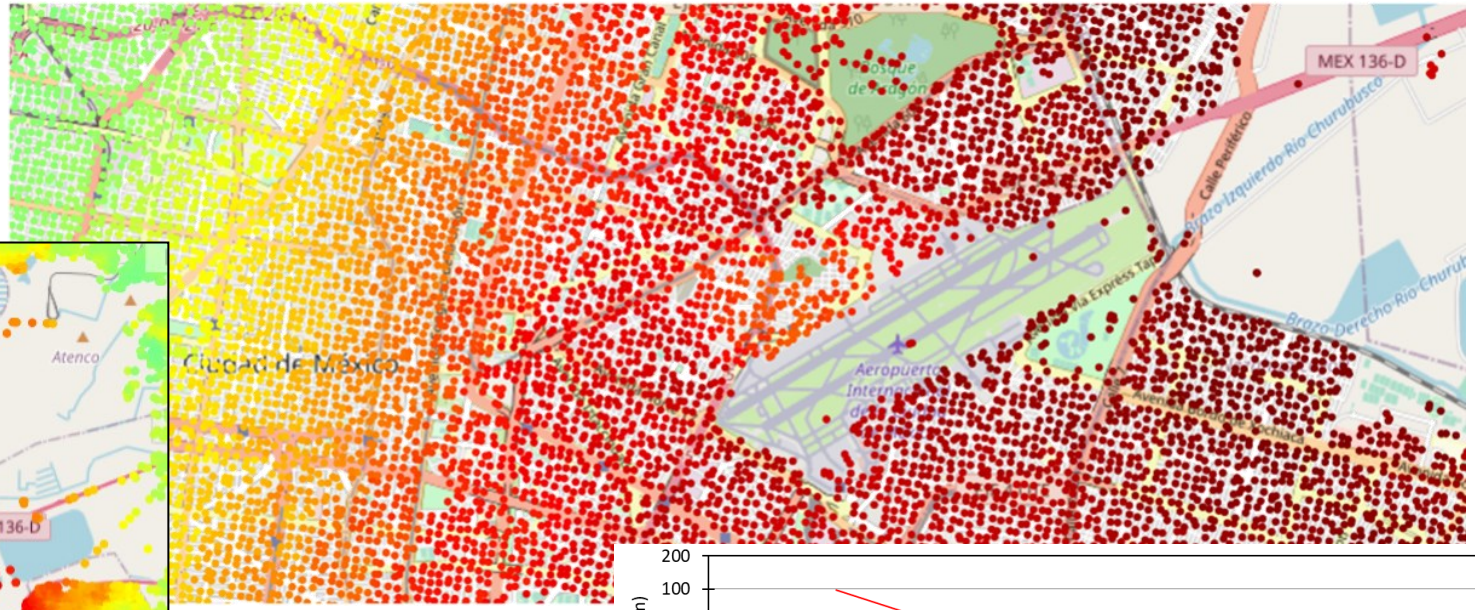


World Bank| SNAPPING PSI Terrain Motion processed on GEP for Mexico Valley

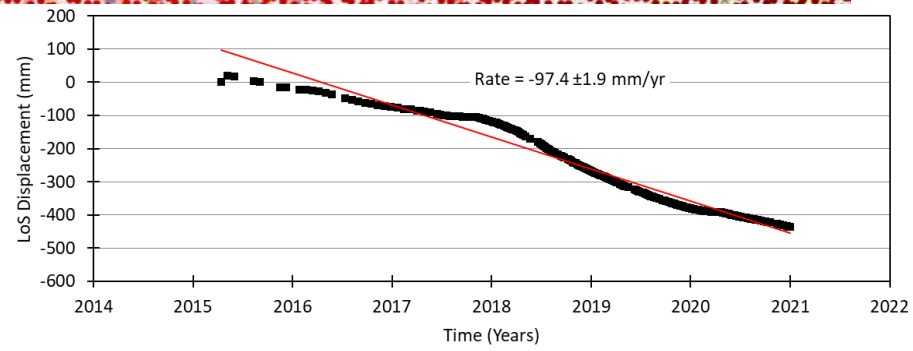
Observation period 04/2015-12/2020 (205 images) from Relative Orbit 143







A total number of **~245k** point measurements



geohazards tep

WORLD BANK GROUP

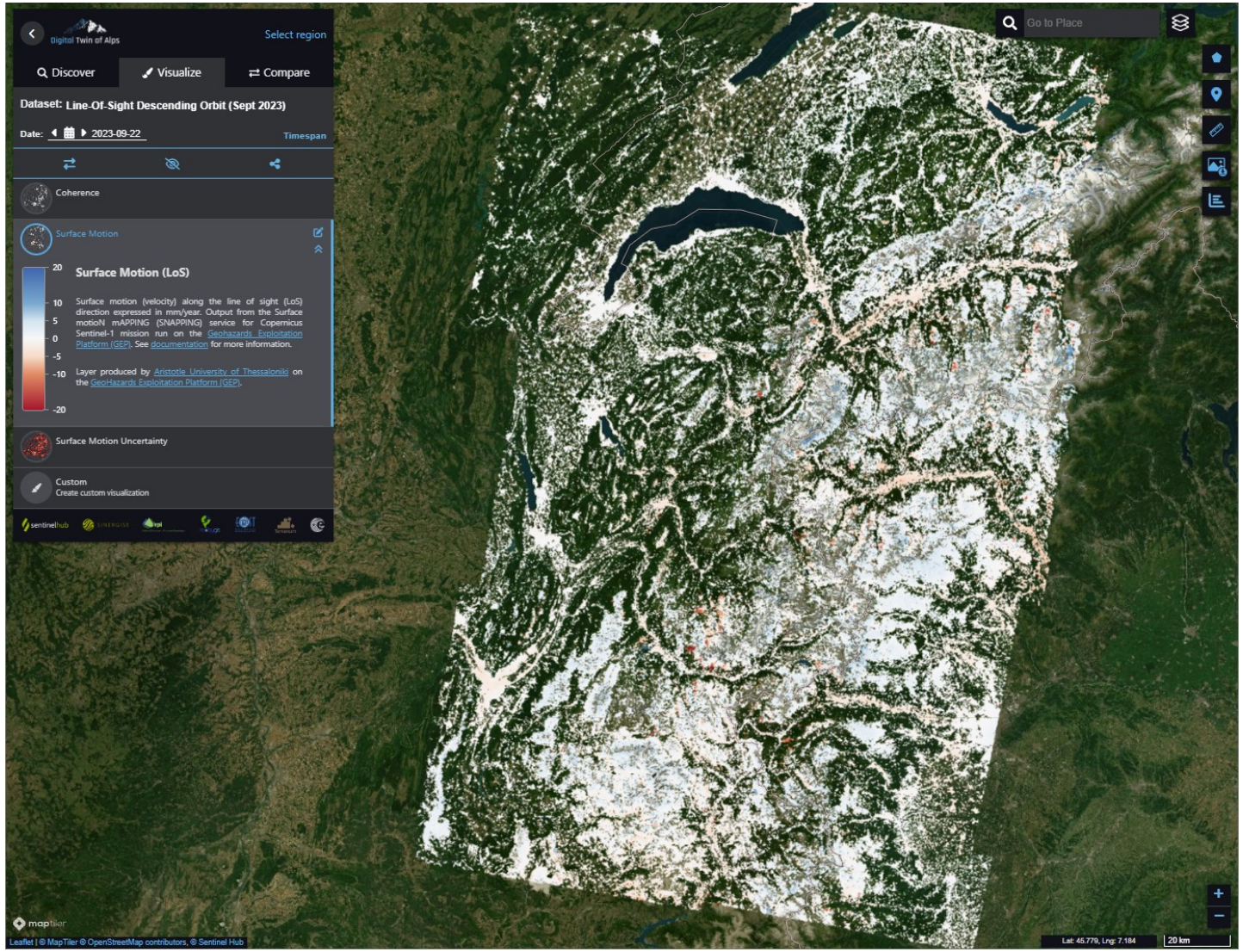
indra

EO.Lab Earth Observation & Geospatial Applications Lab

TERRADUE Advancing Earth Science

Digital Twin Alps (DTA) | Surface Motion Component

In the ESA DTA demonstrator you can access ground motion products for glaciers and landslides monitoring have been processed over the eastern Alps with the GEP services. The services were used to process the full archive of Sentinel-1 and Sentinel-2 for an AOI of 20,000+ km^2 and allow for monitoring very slow (0.005-0.1 m/year) and rapid (> 1 m/year) movement, giving a thorough overview of the unstable slopes in the Alps.



https://demonstrator.digitaltwinalps.com

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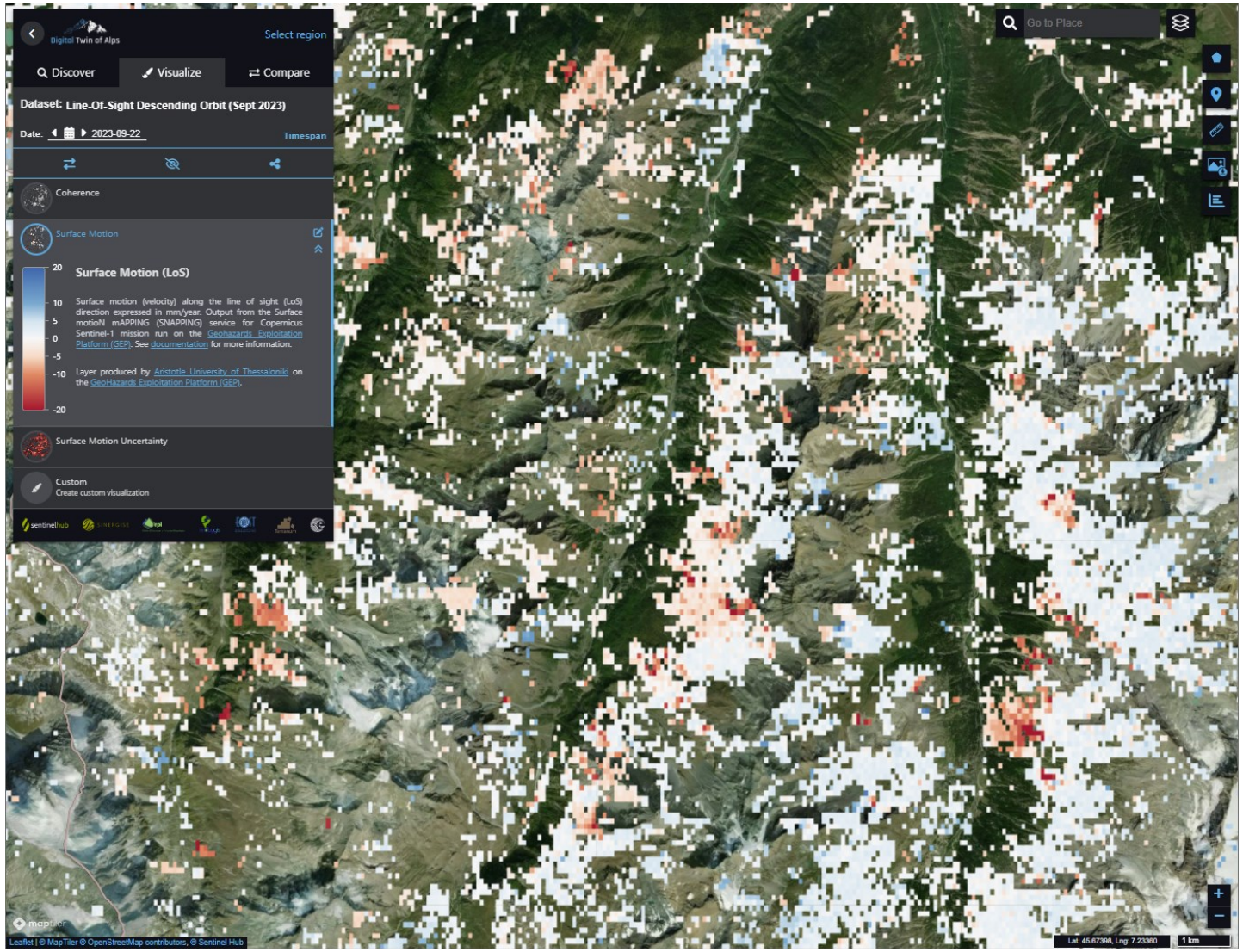

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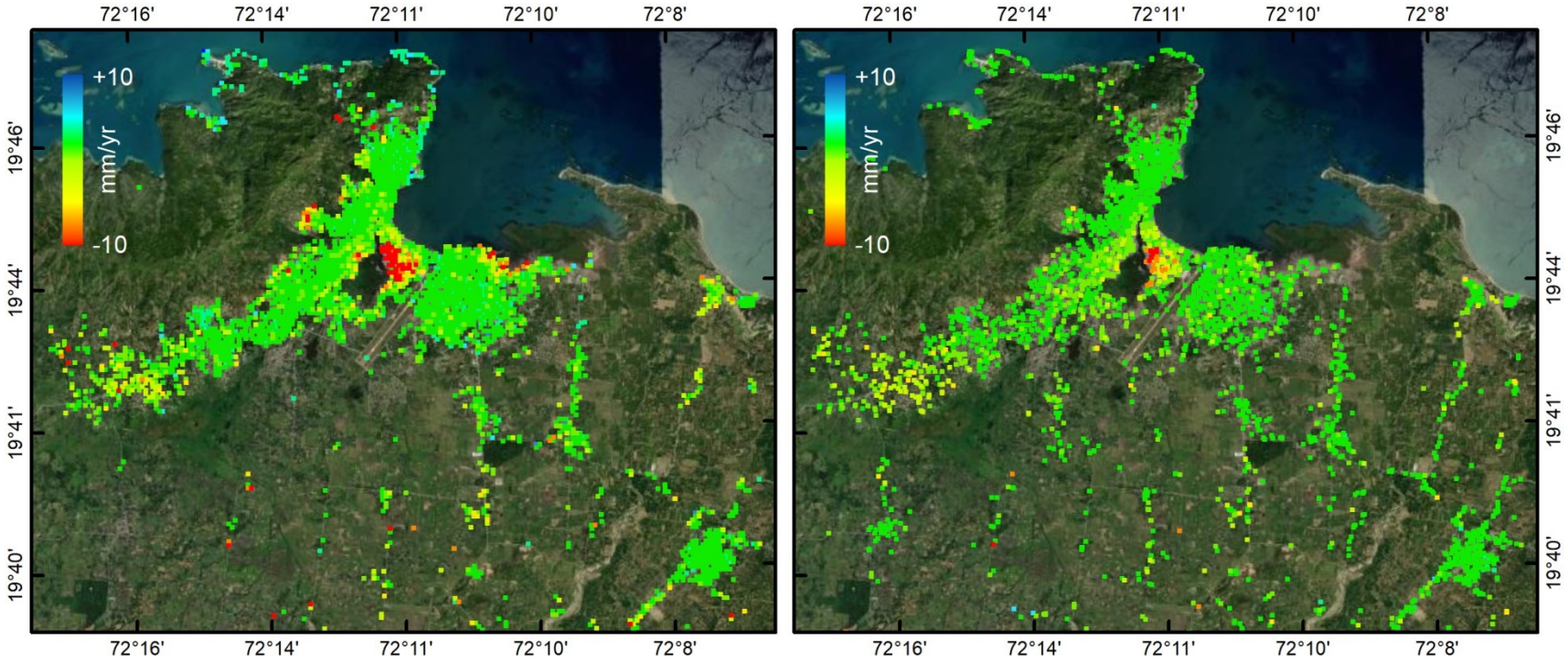
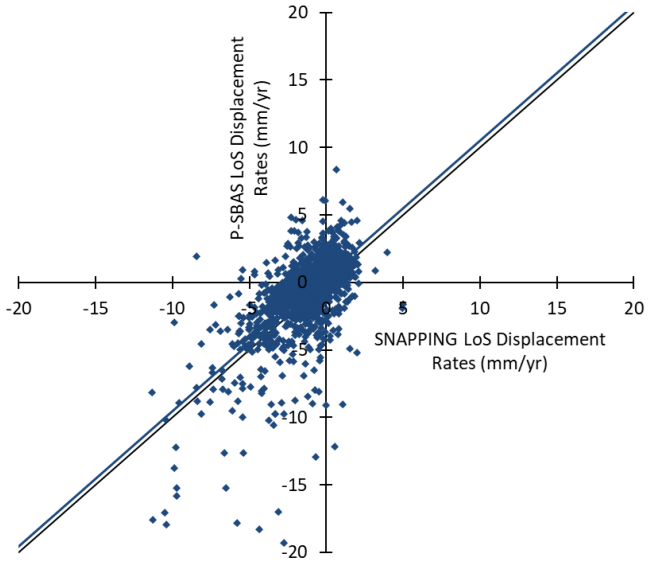
Inter-Verification of EO-Based Measurements

Inter-verification of Sentinel-1 terrain motion measurements using different operational services on GEP. Example over **Cap-Haïtien** by P-SBAS & SNAPPING services.

CNR-IREA P-SBAS

SNAPPING (AUTh)

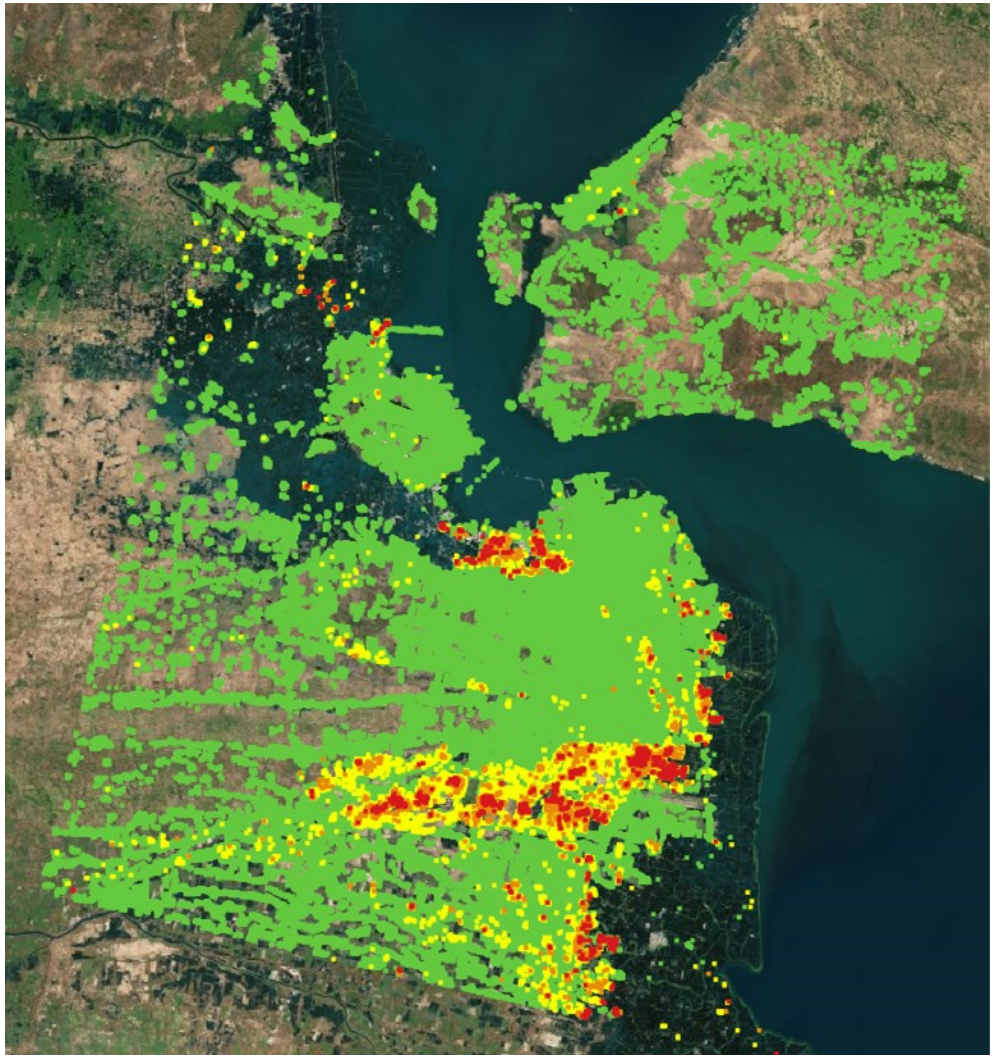




ADB - Support to Water & Food Security Planning & Investments in Indonesia through EO Services

Surabaya Terrain Motion | GEP On-Demand Advanced InSAR Services

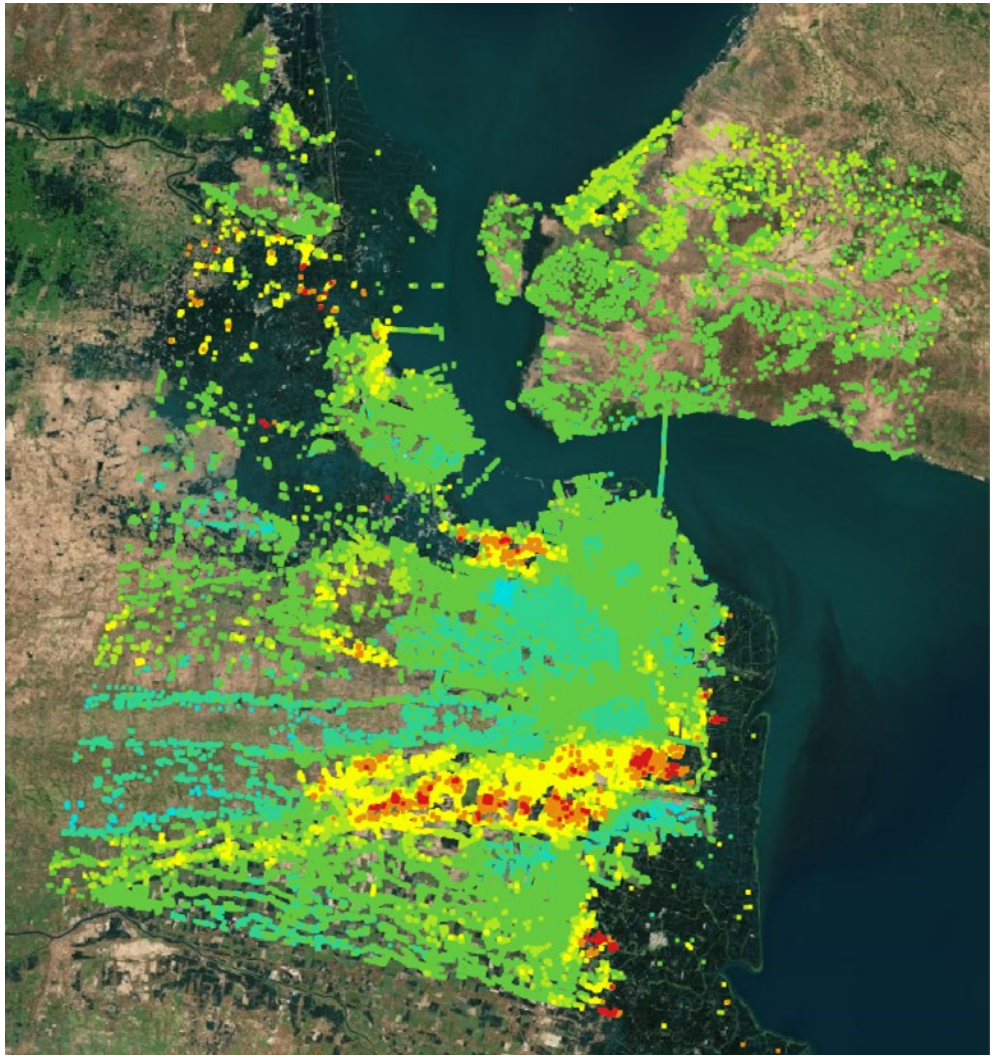
P-SBAS



Access GEP Public Job

SNAPPING

SNAPPING
SURFACE MOTION MAPPING

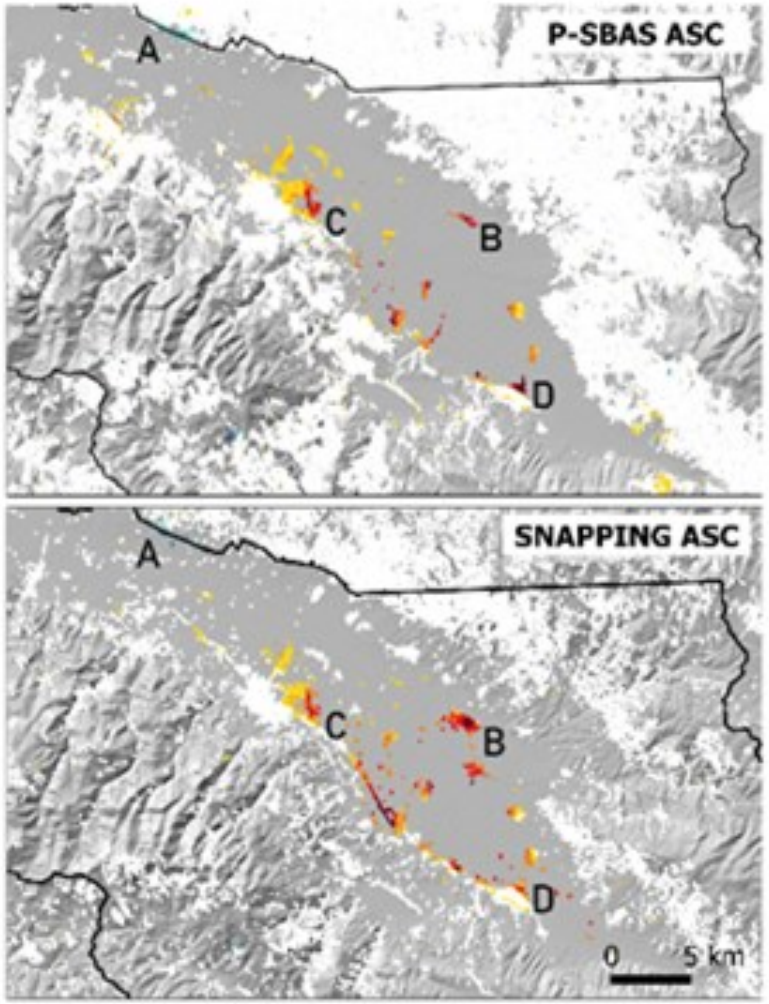


Access GEP Public Job

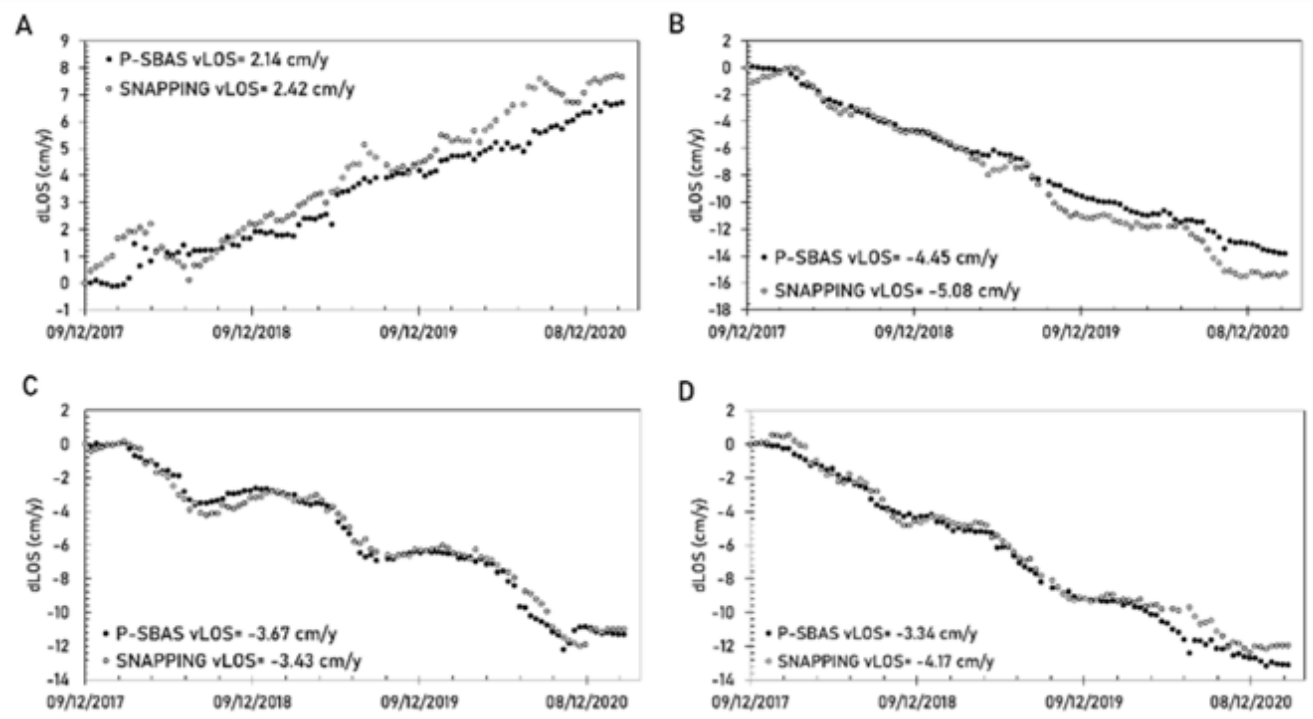
Contains modified Copernicus Sentinel-1 mission data (2015-2020)

User Inter-Verification of GEP EO-Based Measurements

Investigation of terrain motion at **Eastern Gediz Basin (Turkey)**



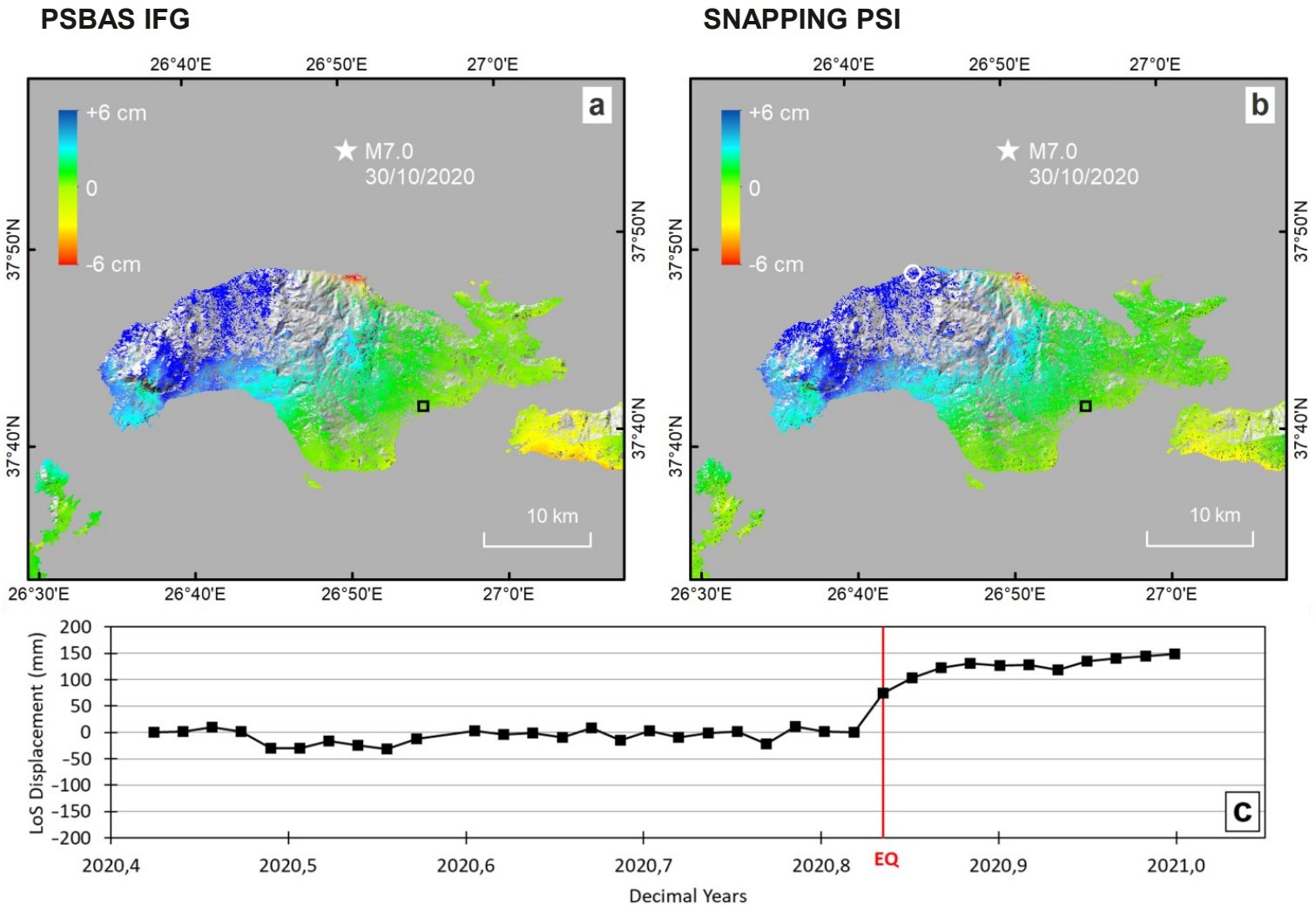
P-SBAS and SNAPPING detected comparable motion patterns and higher subsidence rates of -6.4 and -7.6 cm/year, respectively. SNAPPING point density is higher in the valley (human settlements), whereas P-SBAS over surrounding mountainous regions. More details



The work has been presented at ESA LPS2022 under the title “Exploring Land Subsidence with A-DInSAR Thematic Apps of the Geohazards Platform”

Verification | Moderate Co-seismic Motion

SNAPPING
SURFACE MOTION MAPPING

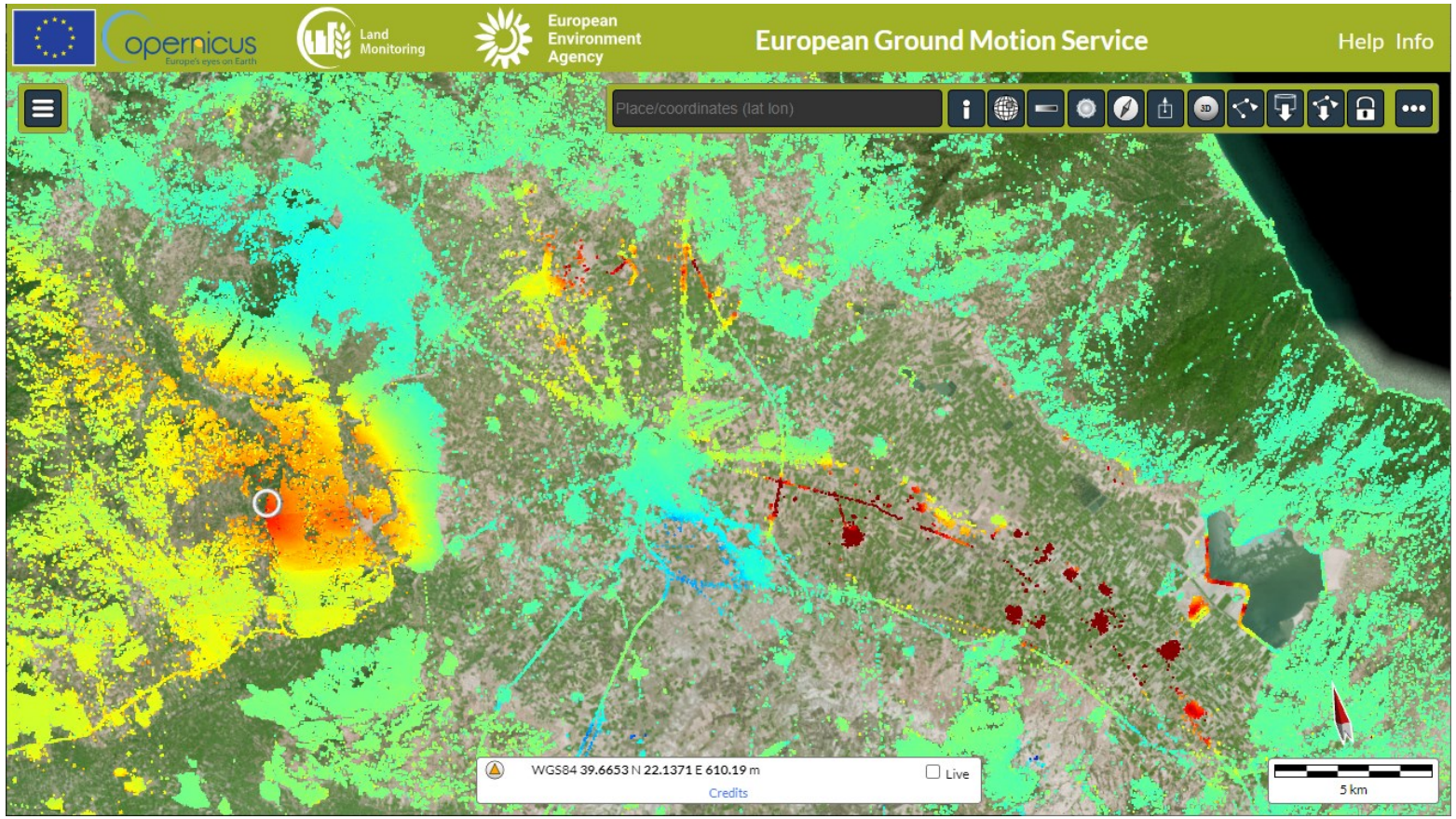


Co-seismic Sentinel-1 displacement field (24 October 2020–30 October 2020; ascending track 131) for the Samos M7.0 earthquake-based P-SBAS service (in IFG mode) at 100 m resolution (unwrapped and converted to LoS displacements) and corresponding displacements as extracted from SNAPPING PSI time series at medium resolution.

SNAPPING point measurements are averaged to 100 m grid for consistent representation among the techniques.

SNAPPING PSI Med vs EGMS | Tirnavos M6.3 Earthqauke

In March 2021, an earthquake of magnitude 6.3 struck central Greece, close to Tyrnavos a town about 230 km north of Athens. It was felt across the country damaging a number of houses but drawing no casualties.



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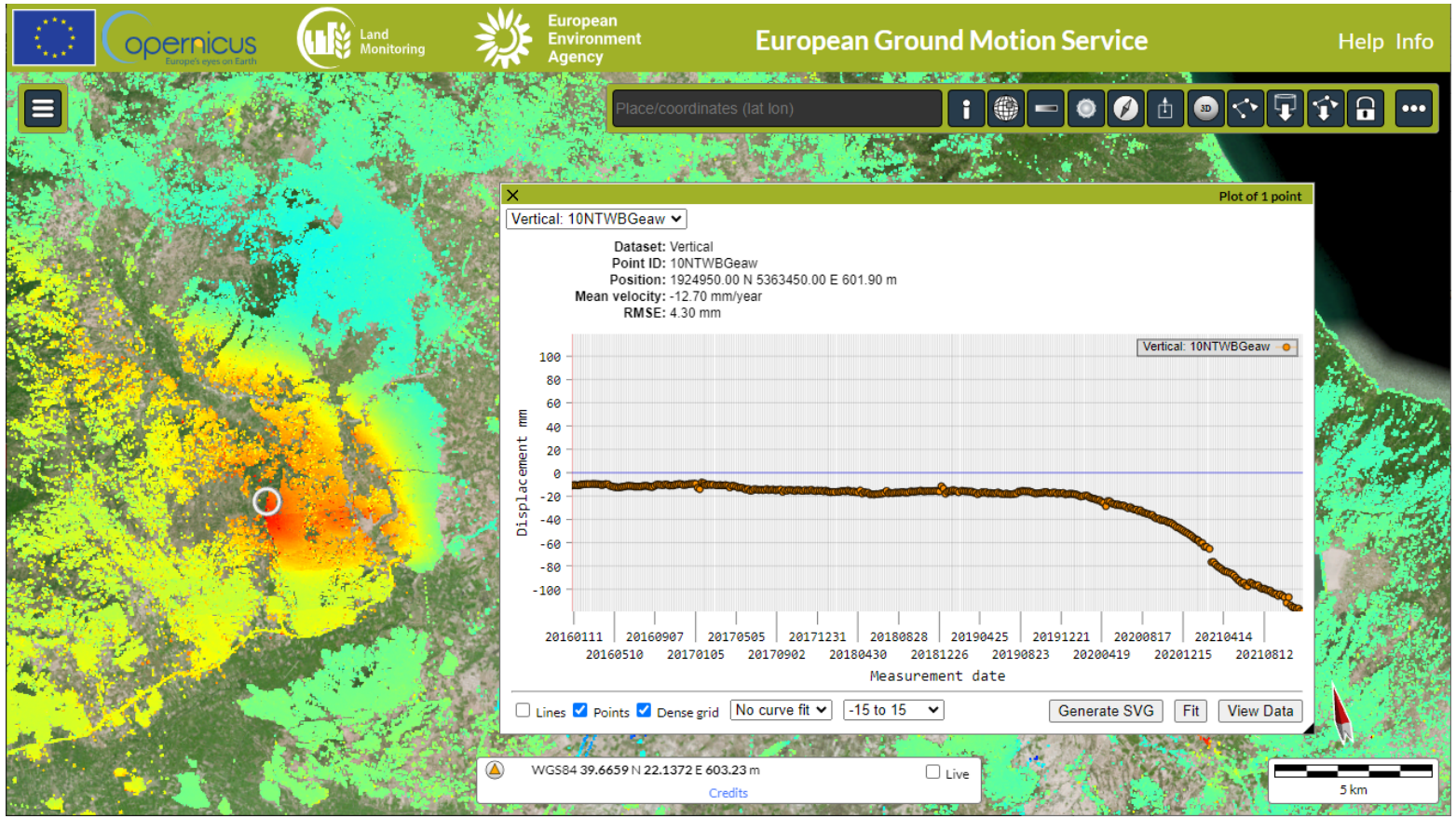

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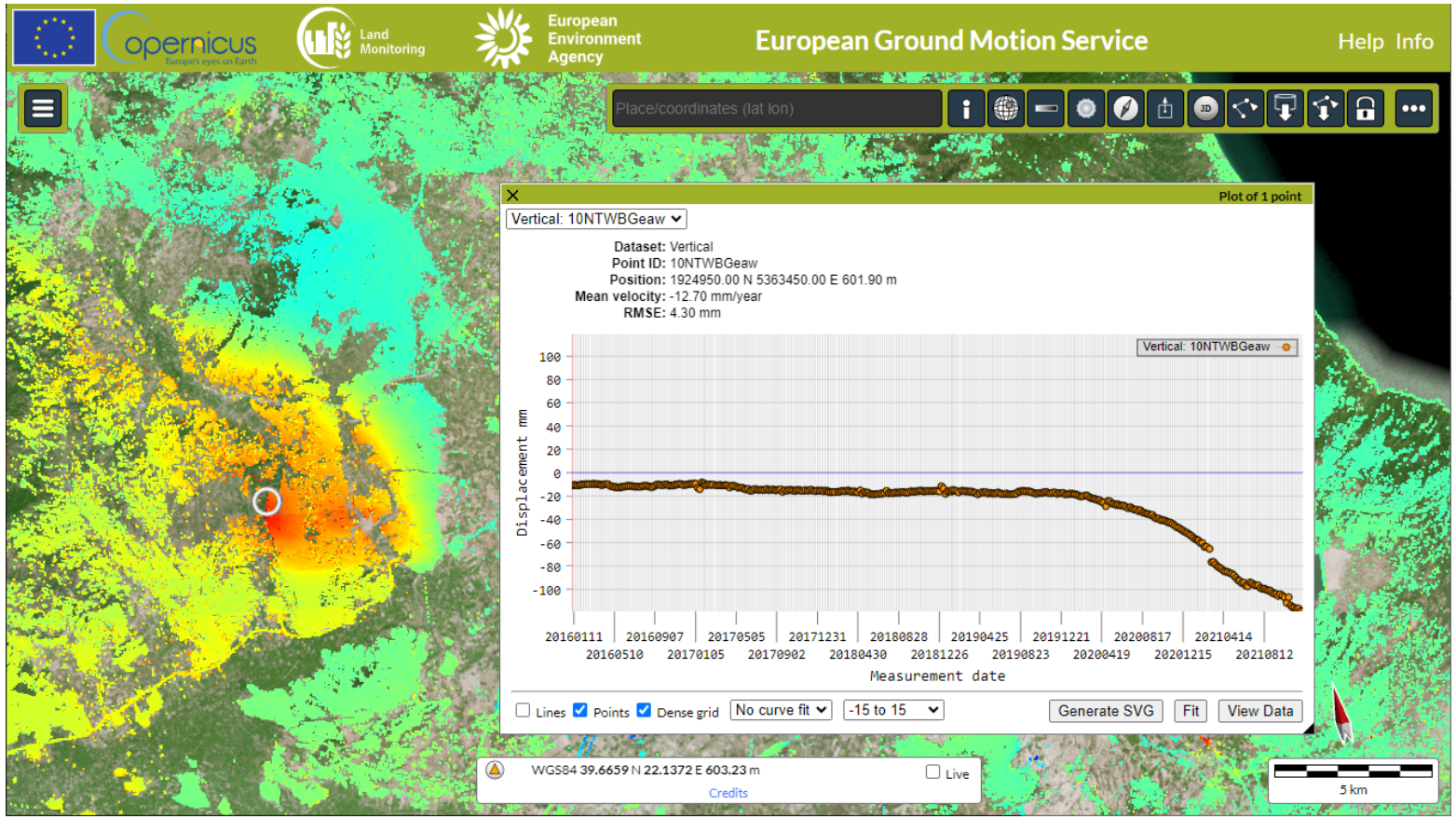
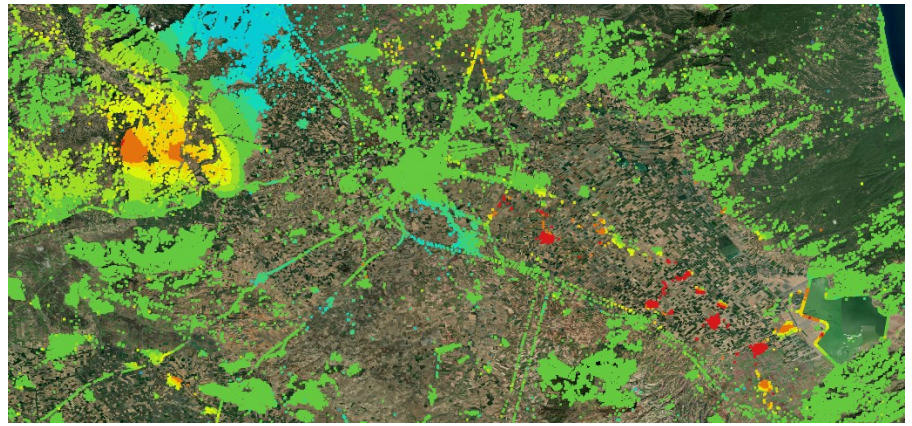
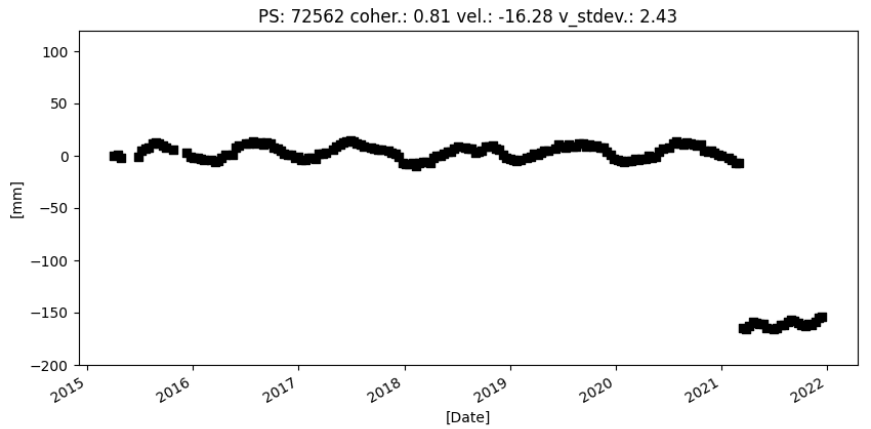
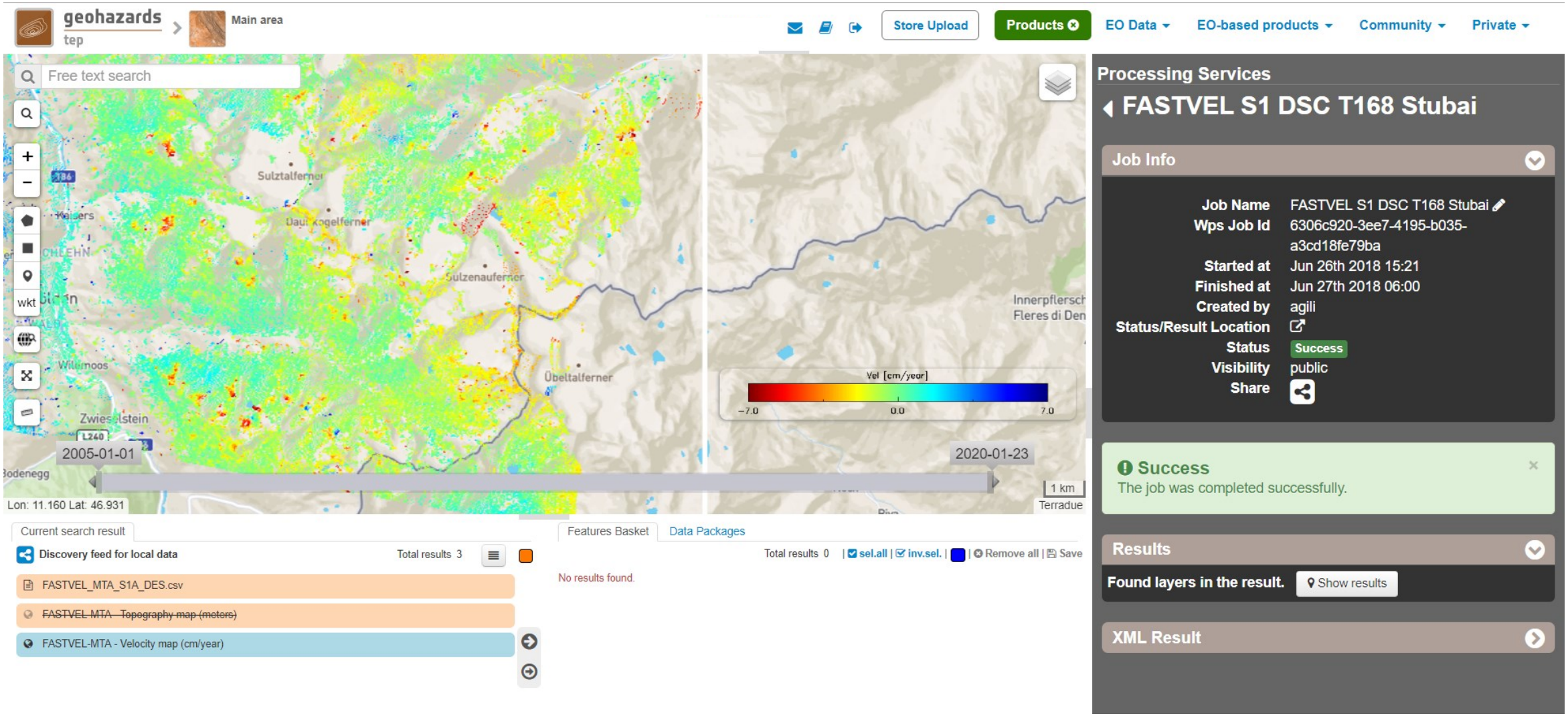






GEP | FASTVEL Landslides over French Alps



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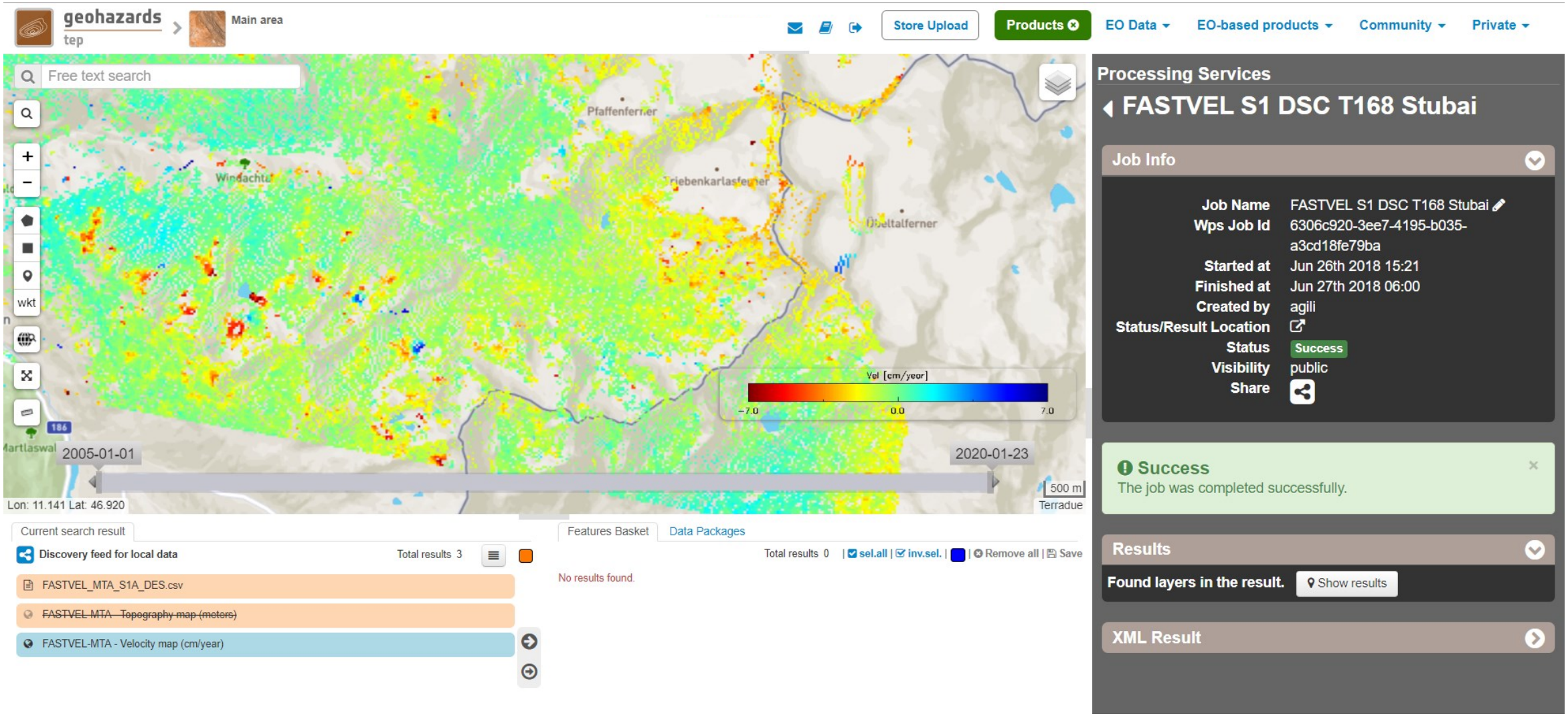

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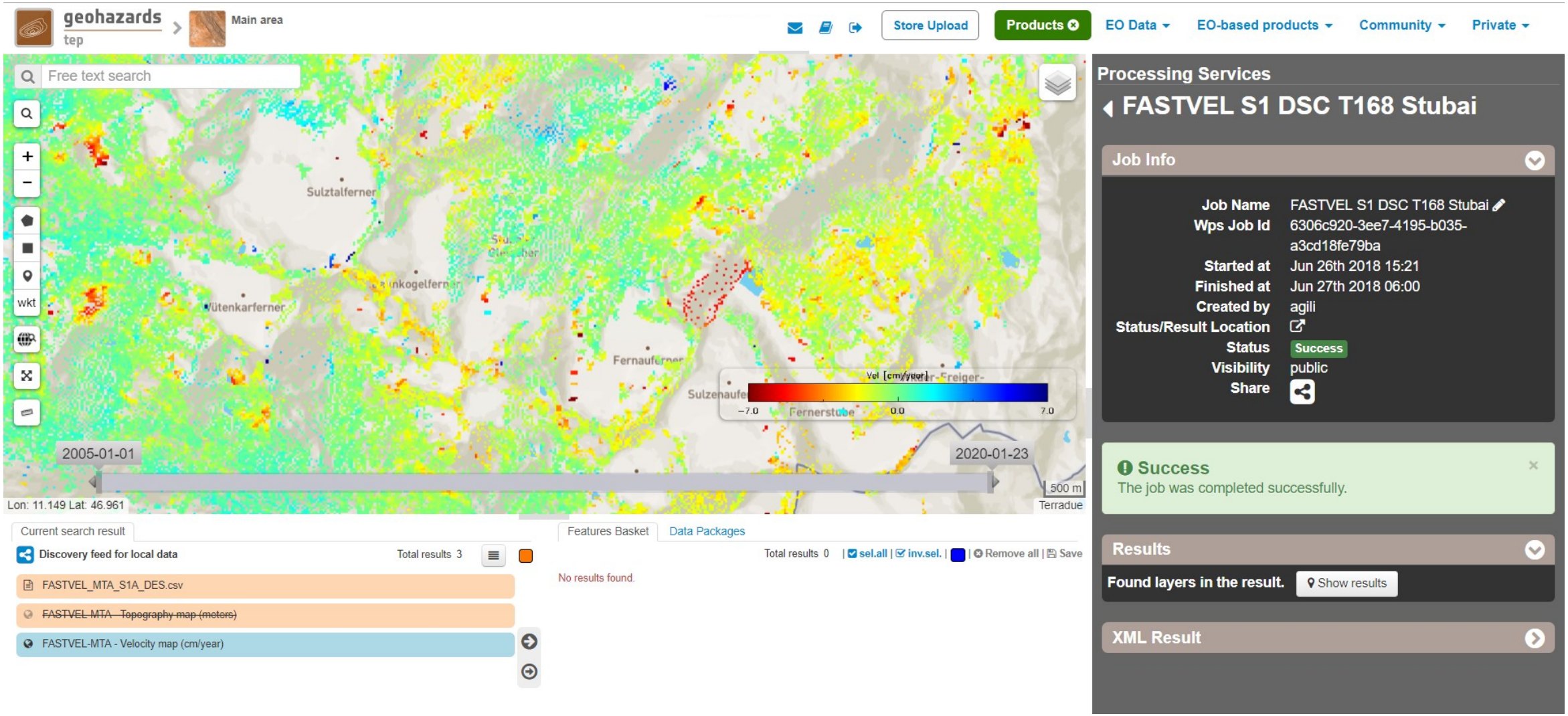


Interactive Web Interface | Visualization of SNAPPING measurements

Interactive Web Interface | Visualization of SNAPPING measurements

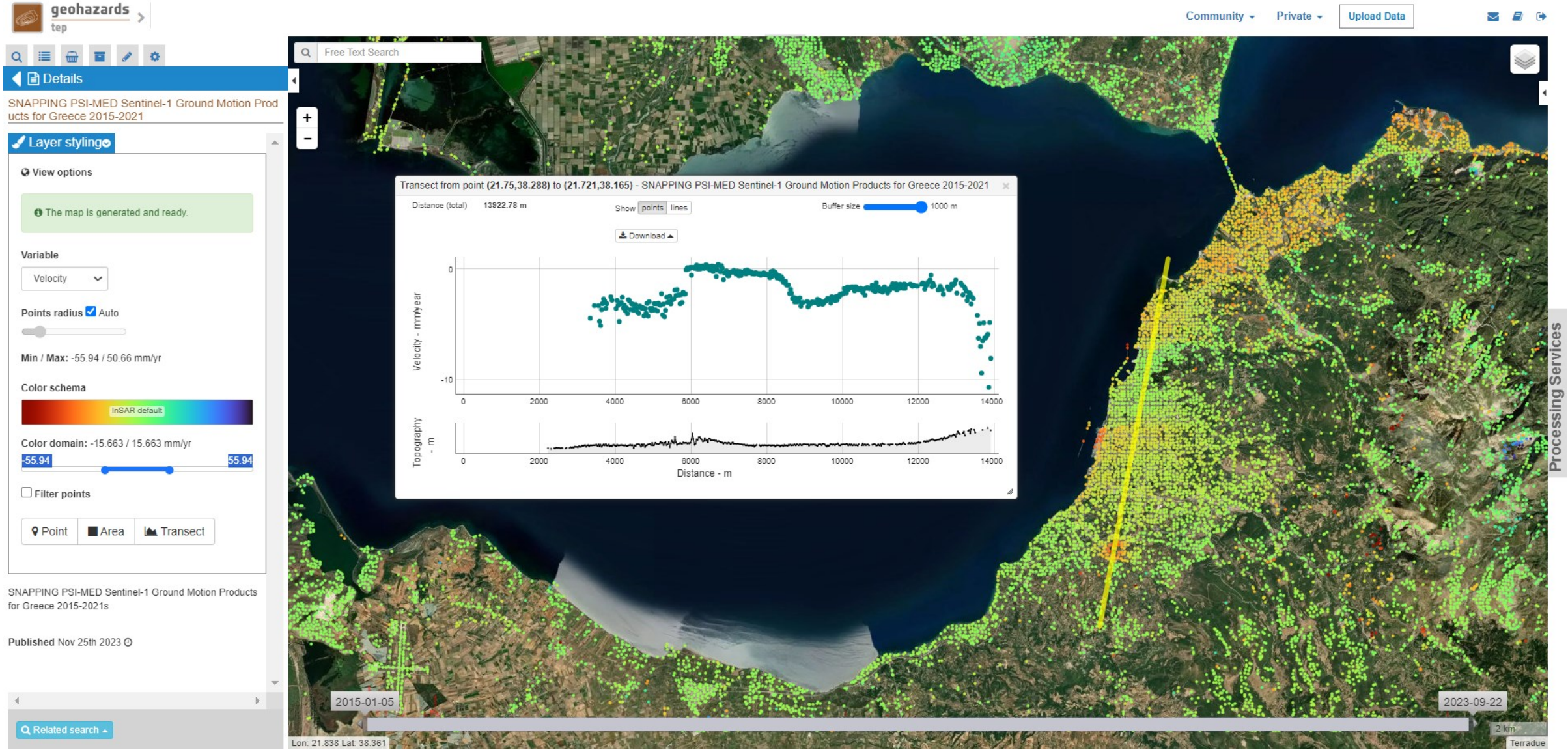
Contains modified Copernicus Sentinel-1 data (2015-2020), processed on GEP by AUTh

Not only a **visualization** portal, but also for **dissemination** purposes

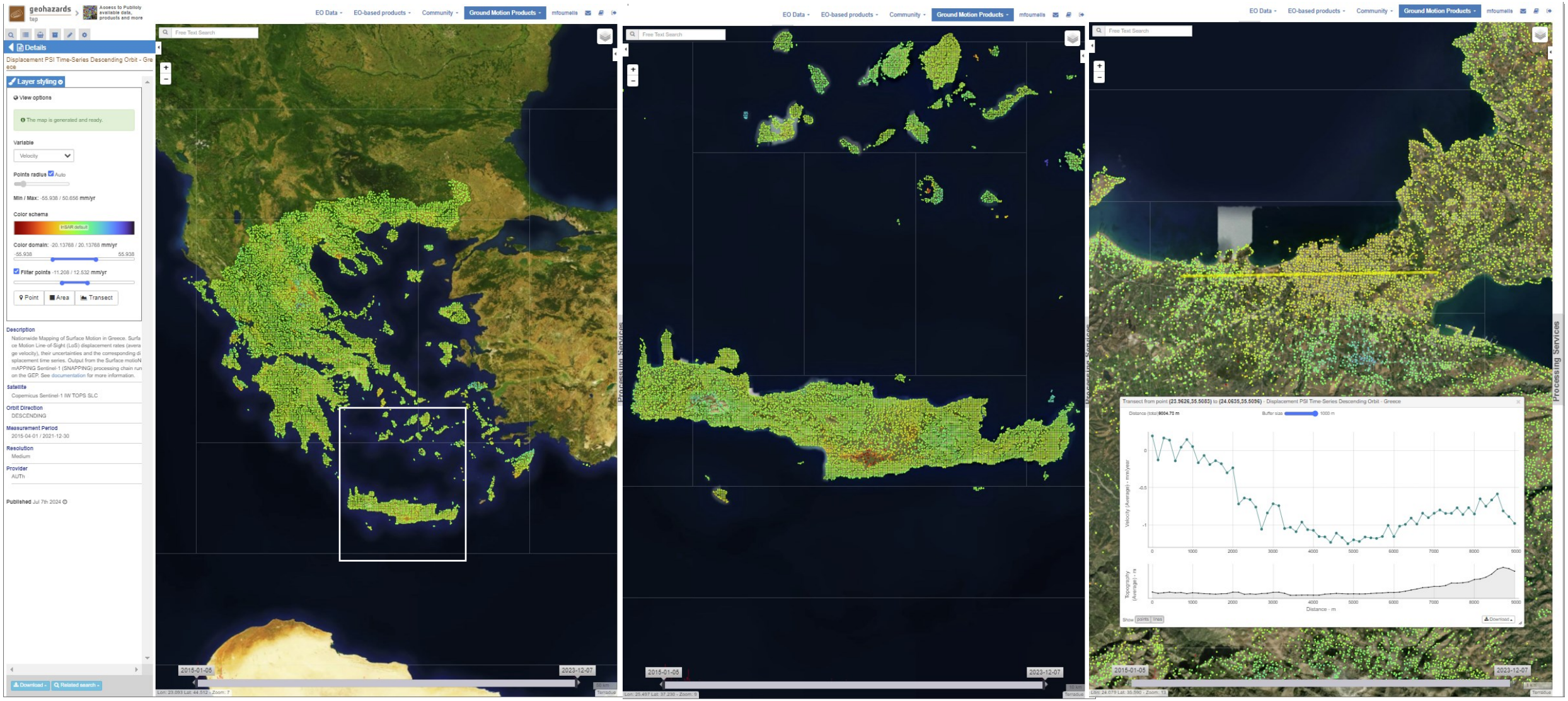
Open dataset (CC BY-NC-SA 4.0) for investigation of various geohazards

Facilitates **intercomparison** with other open datasets

Surface Motion | Active Fault zone buried under Urban cente (Patras, Greece)



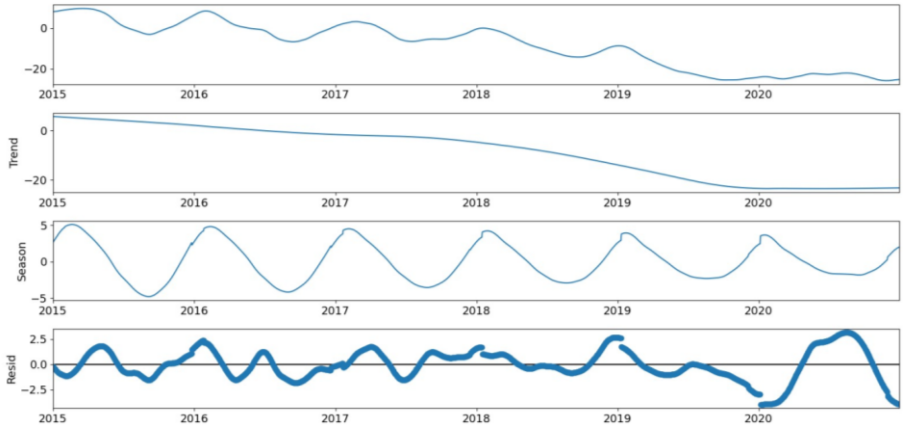
GEP | Interactive Visualization Interface

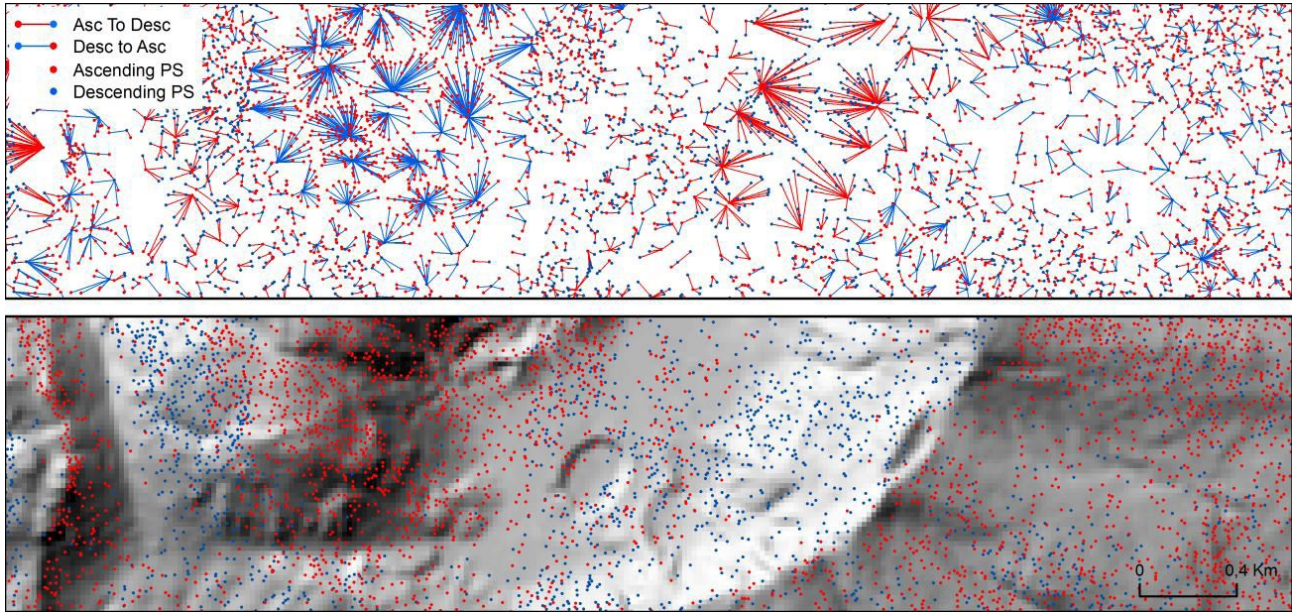


GEP | On-going Developments

- Improved on-the-fly visualization interface
- SNAPPING InSAR geometric decomposition
- SNAPPING Time series decomposition
- SNAPPING Automatic Reporting
- Implement an AI processor

Decomposition of displacement time series



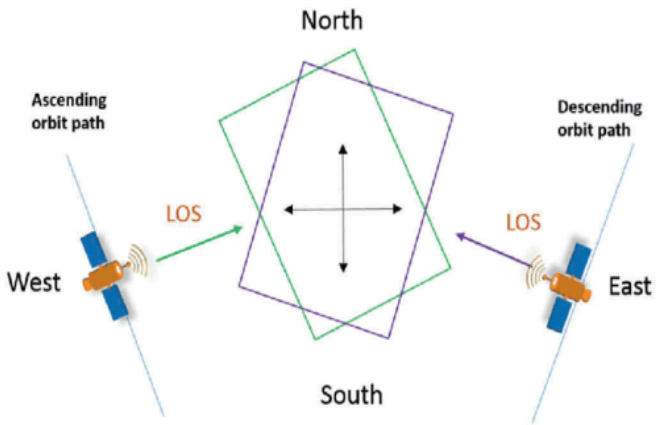


Foumelis, M., 2016. Vector-based approach for combining ascending and descending Persistent Scatterers Interferometric point measurements. *Geocarto International*, doi:10.1080/10106049.2016.1222636.

Family of SNAPPING services | Post-Processing & Reporting

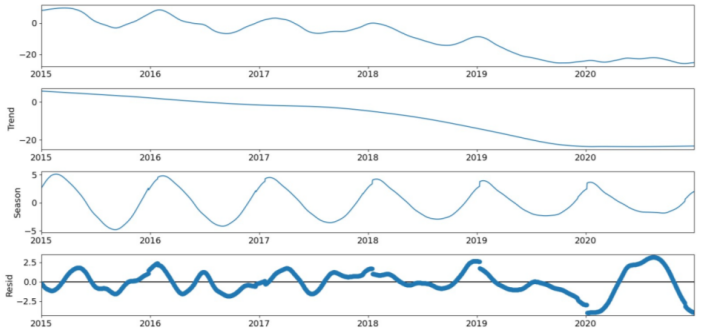
SNAPPING 3D *decomp*

Combination of ascending and descending Line-of-Sight surface motion measurements to calculate the actual E-W and Vertical motion components.



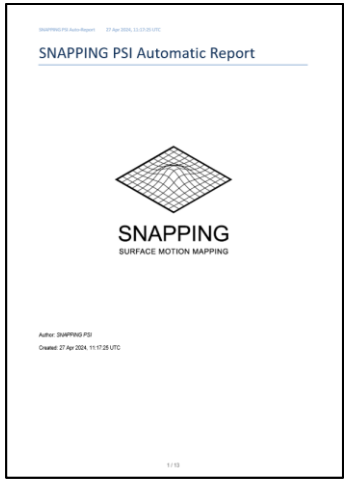
SNAPPING PSI *TS decomp*

Decomposition of observed temporal motion into trend, seasonal component and residual.

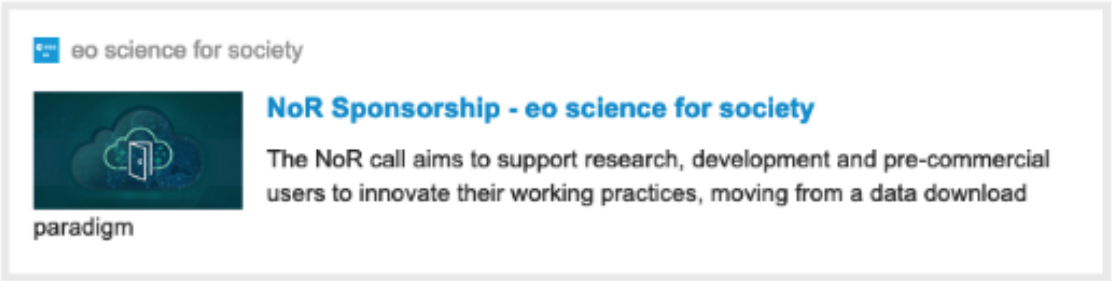


SNAPPING PSI *auto report*

High level report generated automatically based on SNAPPING outputs, highlighting the observed surface motion statistics and regions of interest (i.e. highest motion) as well as local patterns and temporal evolution of motion.



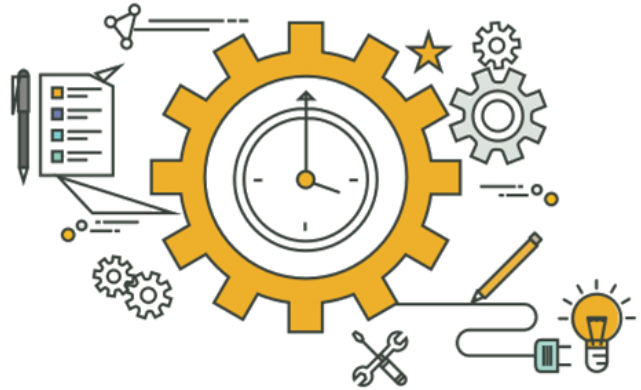
Sponsorship Opportunities



- ESA NoR
  - Privileged channel providing science support for:
    - Geohazards analysts (i.e. principal investigator, researcher, scientific engineer, PhD student, trainee) with EO data processing goals
    - Service providers or data providers, interested to connect their resources to be used via the Platform
    - Organizations interested in running user community trainings
- Via GEP, parties can request NoR sponsorship (vouchersinterested) for their forthcoming GEP activities

  https://bit.ly/GEP-NOR

Take Home Messages



- Space-born InSAR is a mature technique
- InSAR has already been validated through various initiatives and proven valuable for surface motion measurements
- Systematic availability of satellite data supports operational service development for geohazard applications
- The ever-increasing availability of SAR data from different sensors together with the systematic acquisition strategies allows for understanding complex phenomena
- Capacity building activities are required for reaching the operational utilization of measurements


TRANS-ATLANTIC TRAINING 2024 – CHANIA, GREECE

Earth Observation and Machine Learning for Disaster Mapping

Thank you

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mfoumelis@geo.auth.gr


EO.Lab
Earth Observation
& Geospatial Applications Lab

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