



**ARISTOTLE UNIVERSITY
OF THESSALONIKI**



TRANS-ATLANTIC TRAINING 2024 – CHANIA, GREECE
Earth Observation and Machine Learning for Disaster Mapping

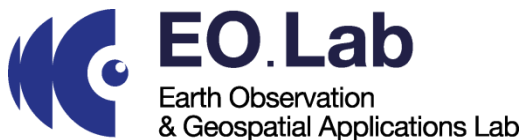
Earth Observation Platforms for Land Motion and Earthquakes

Michael Foumelis | Assoc. Professor AUTh

TAT 2024 Training
14-17 July 2024

Contributor(s)

Fabrizio Pacini | Terradue



- 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.



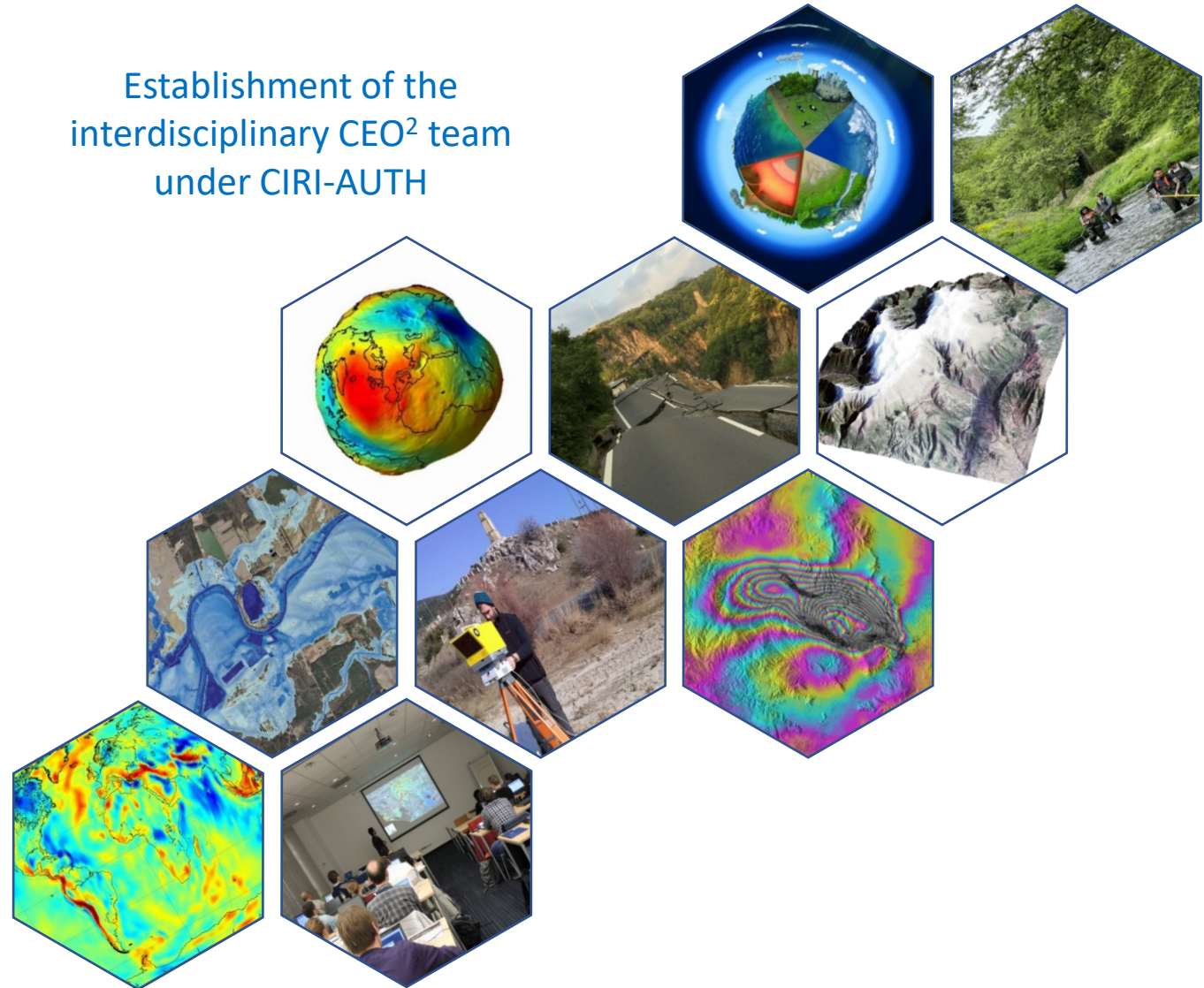
Interdisciplinary R&D and Service Provision Center of Earth and Ocean Observation (CEO²)



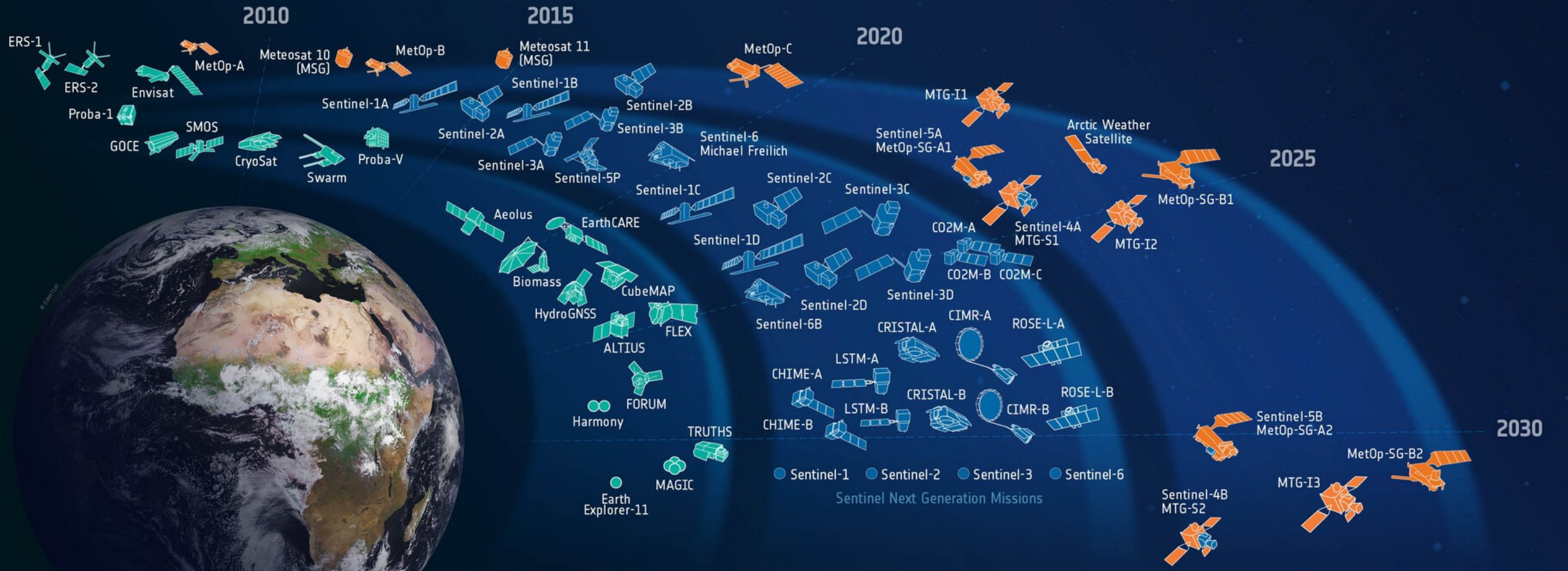
<https://kedek.auth.gr>

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.

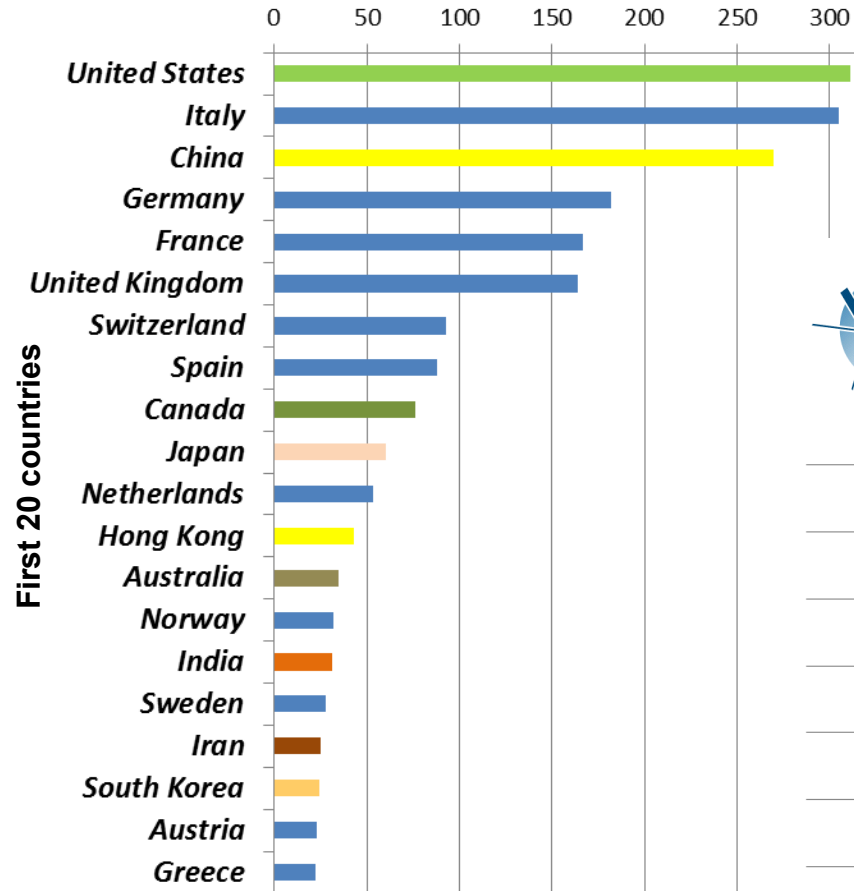
Establishment of the
interdisciplinary CEO² team
under CIRI-AUTH



ESA-developed Earth Observation Missions

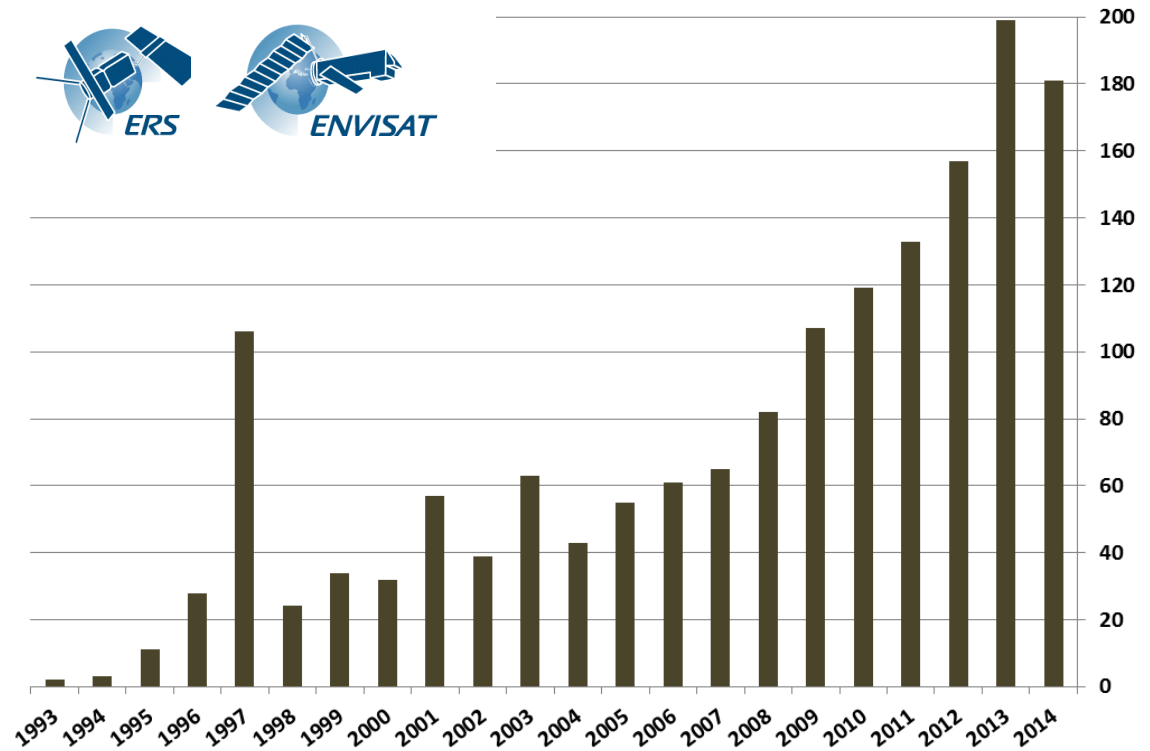


Large Impact on Scientific Literature



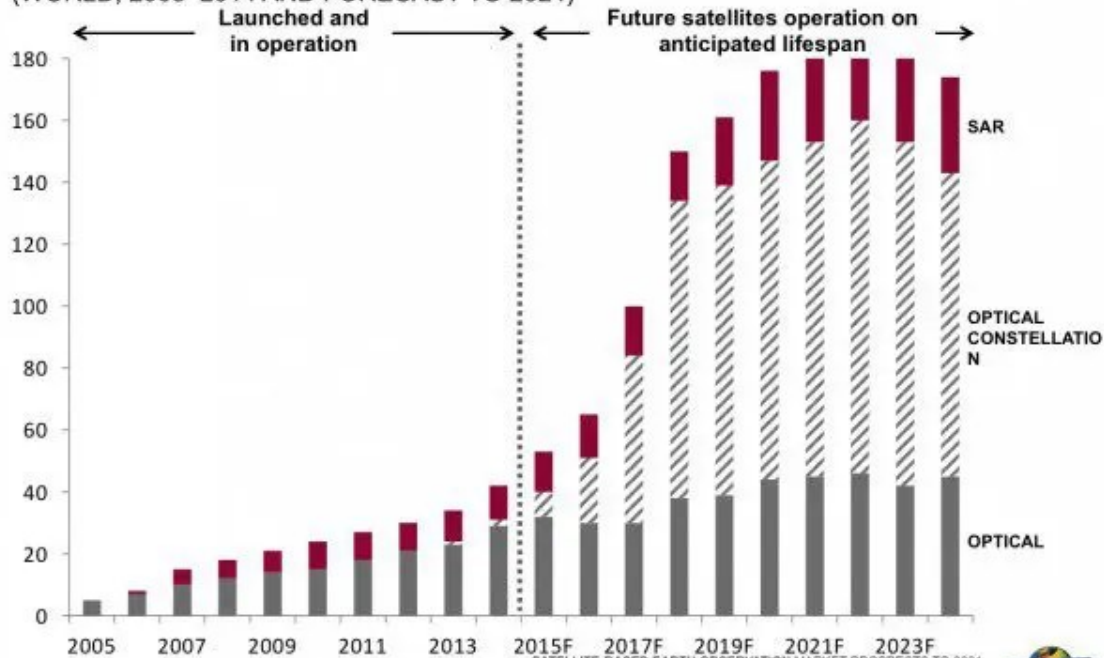
Scopus database, Journal papers with search on: "ERS or Envisat and SAR Interferometry"

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

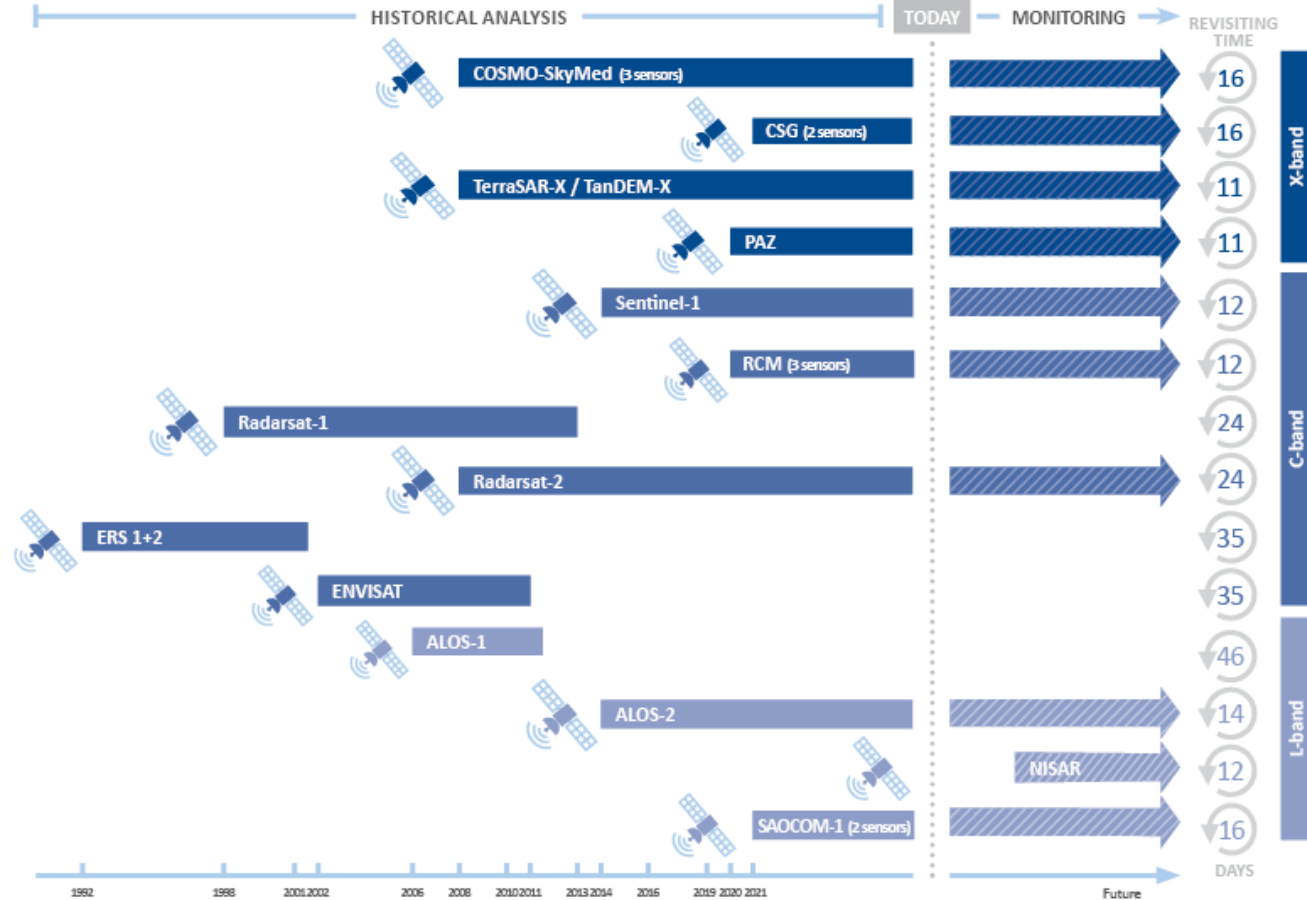


Significant Supply Expansion for EO Industry: Data Demand Driven by Defense and Emerging Markets

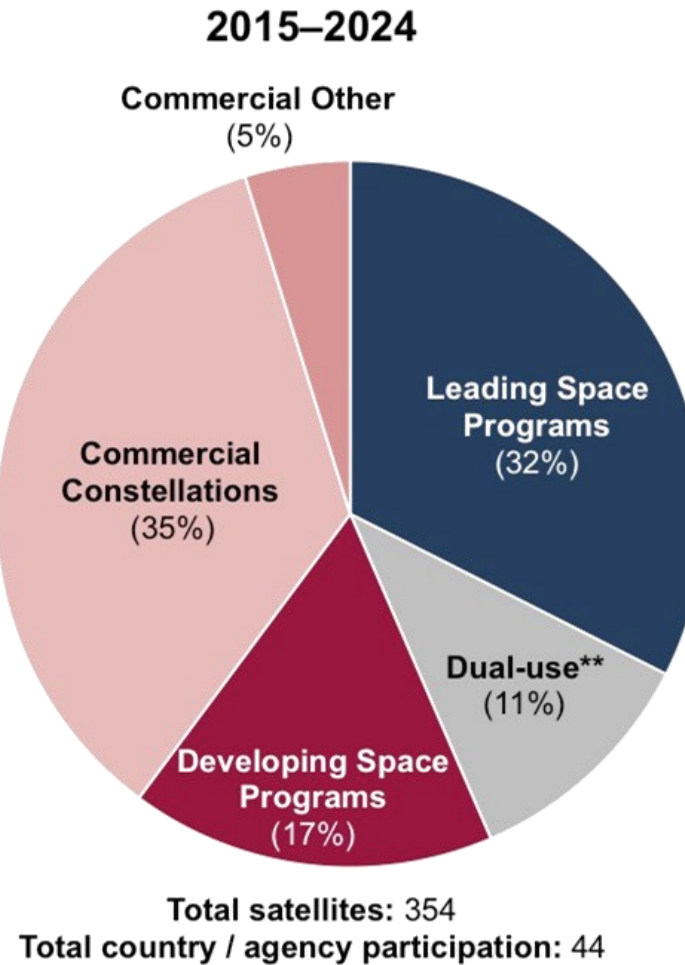
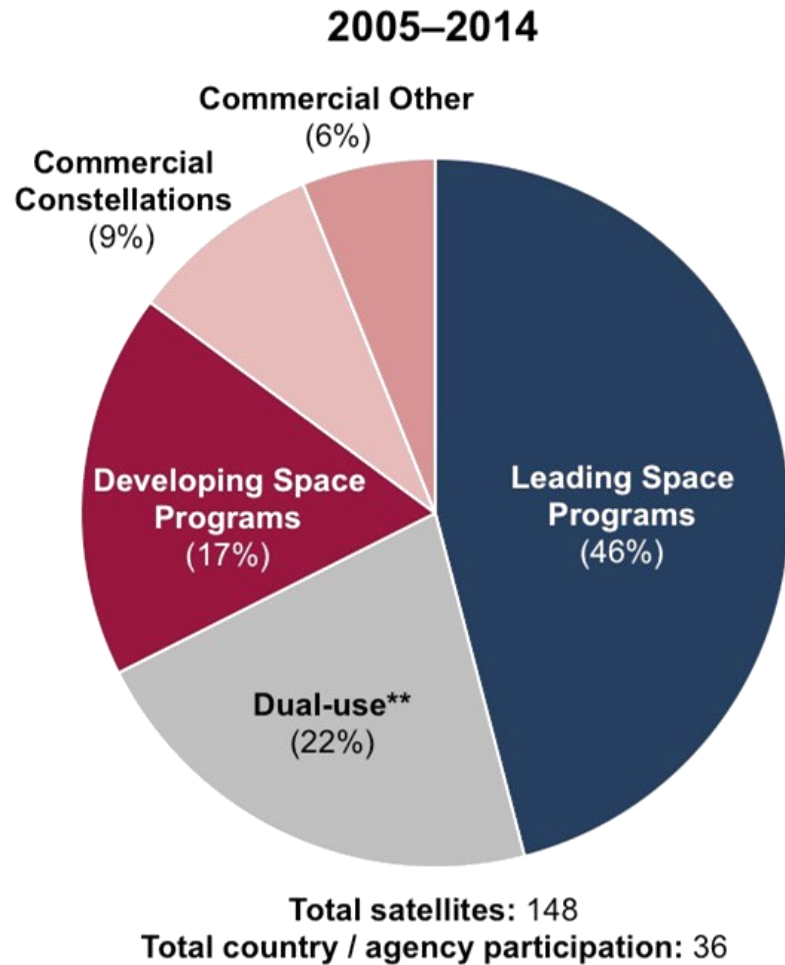
OPTICAL AND RADAR COMMERCIAL HIGH-RESOLUTION OPERATIONAL* SATELLITES BASED ON ANTICIPATED LIFESPANS
(WORLD, 2005–2014 AND FORECAST TO 2024)



* Commercial refers to commercially operated and commercial data availability from government satellites with data <2.5m optical or <5m SAR
© Euroconsult 2015 – unauthorized reproduction is a copyright violation



Earth Observation Satellites Launched by Operator type



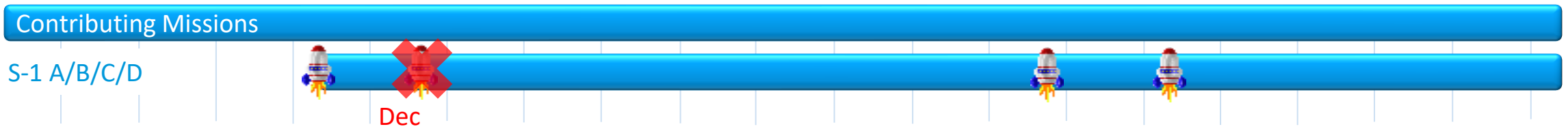
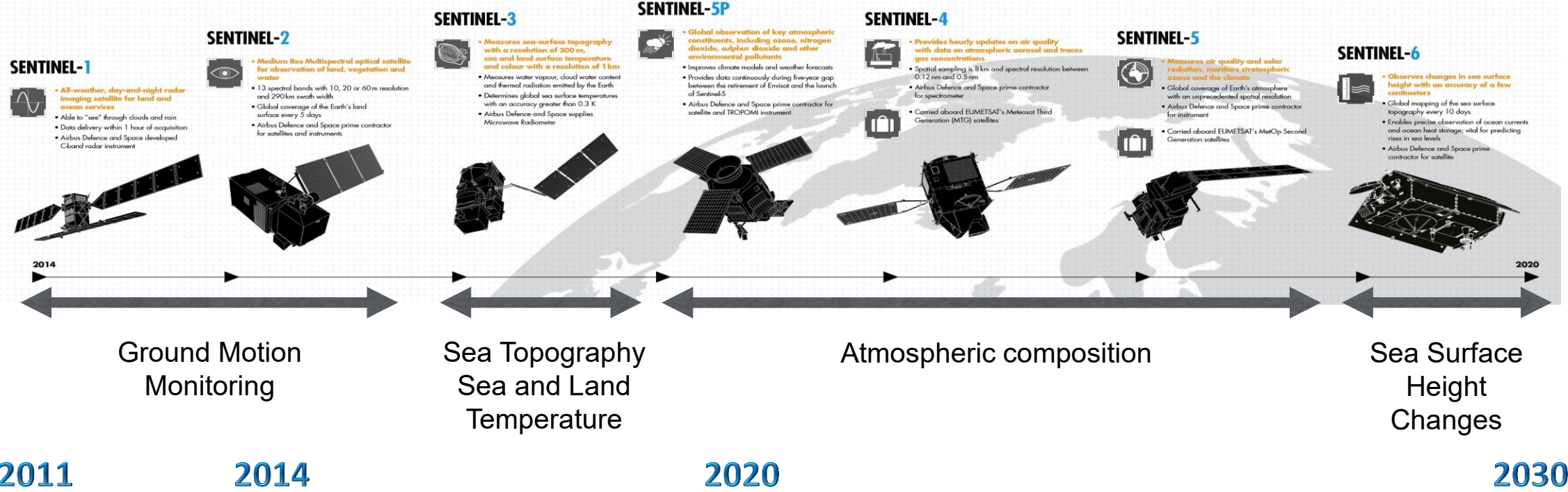
Copernicus Sentinel-1 mission

Long-term Ensured Monitoring Capability

COPERNICUS AND ITS SENTINELS

European Earth Observation Programme Copernicus: observing our planet for a safer world

- Known as GMES until 2012 - Global Monitoring for Environment and Security
- 30 Public and Private missions are also contributing data
- 16 years of development and testing
- Sentinel-Missions at the heart of the space component
- Civil Security. Allowing early warning and crisis prevention in conflict and disaster areas
- Emergency Management. Accurate and timely data for emergency plans and rescue for disaster management
- Land Surface Monitoring. Geographical information on land cover, related variables and urban development
- Marine Environmental Monitoring. Observations and forecasts on the state of the physical oceans and regional seas
- Climate Change Monitoring. Helps to understand the reason for climate change, rising sea levels and melting ice caps.
- Earth Atmosphere Monitoring. Daily information on the global atmospheric composition and when Sentinel-4 is in service this will be hourly



EU Copernicus Sentinel-1 mission



European Union



About Copernicus Sentinel-1...

WHAT?

The first in the Copernicus Sentinel series, a constellation of two identical radar imagery satellites in the same orbit, providing an all-weather, day-and-night supply of images of Earth's surface



WHEN?

Sentinel-1A was launched on 3 April 2014 and Sentinel-1B on 25 April 2016. Both were taken into orbit on a Soyuz rocket, from Europe's Spaceport in French Guiana



WHERE?

Designed and built by a consortium of around 60 companies led by Thales Alenia Space and Airbus Defence and Space



APPLICATIONS

Main applications include:

- Monitoring sea ice and icebergs
- monitoring of land ice (glaciers, ice sheets, ice caps)
- river and lake ice monitoring
- oil spills and ships
- marine winds & waves
- land-use change, agriculture, deforestation
- land deformation
- and support to emergency management such as floods and earthquakes



WHAT'S NEXT?

Continuity over the coming years will be ensured by the launch of additional satellites (Sentinel-1C and Sentinel-1D). Furthermore, a new generation of Sentinel-1 satellites is being prepared, to take up the relay from the first generation



DATA AND USERS

As of end 2020, about 6 million products have been generated and made available for download, culminating a total of 10 Petabytes. More than 30 million Sentinel-1 product downloads have been made by users, representing nearly 40 Petabytes. Data are exploited by various users: Copernicus Services, public institutions, scientists, commercial companies



BENEFITS

Services relate to:

- Monitoring of Arctic sea-ice extent
- routine sea-ice mapping
- maritime surveillance (oil spill monitoring, ship detection, illegal fisheries)
- monitoring land-surface for motion risks including subsidence, landslides
- understanding of Earth processes (earthquakes, volcanoes)
- monitoring of infrastructure
- mapping for forest, water and soil management
- and mapping to support humanitarian aid and crisis situations



DATA ACCESS

<https://scihub.copernicus.eu/>

© ESA 2021



Sentinel Online

Search...



Missions ▾

User Guides ▾

Technical Guides ▾

Thematic Areas ▾

Data Access ▾

Toolboxes ▾

Sentinel User Guides

READ MORE

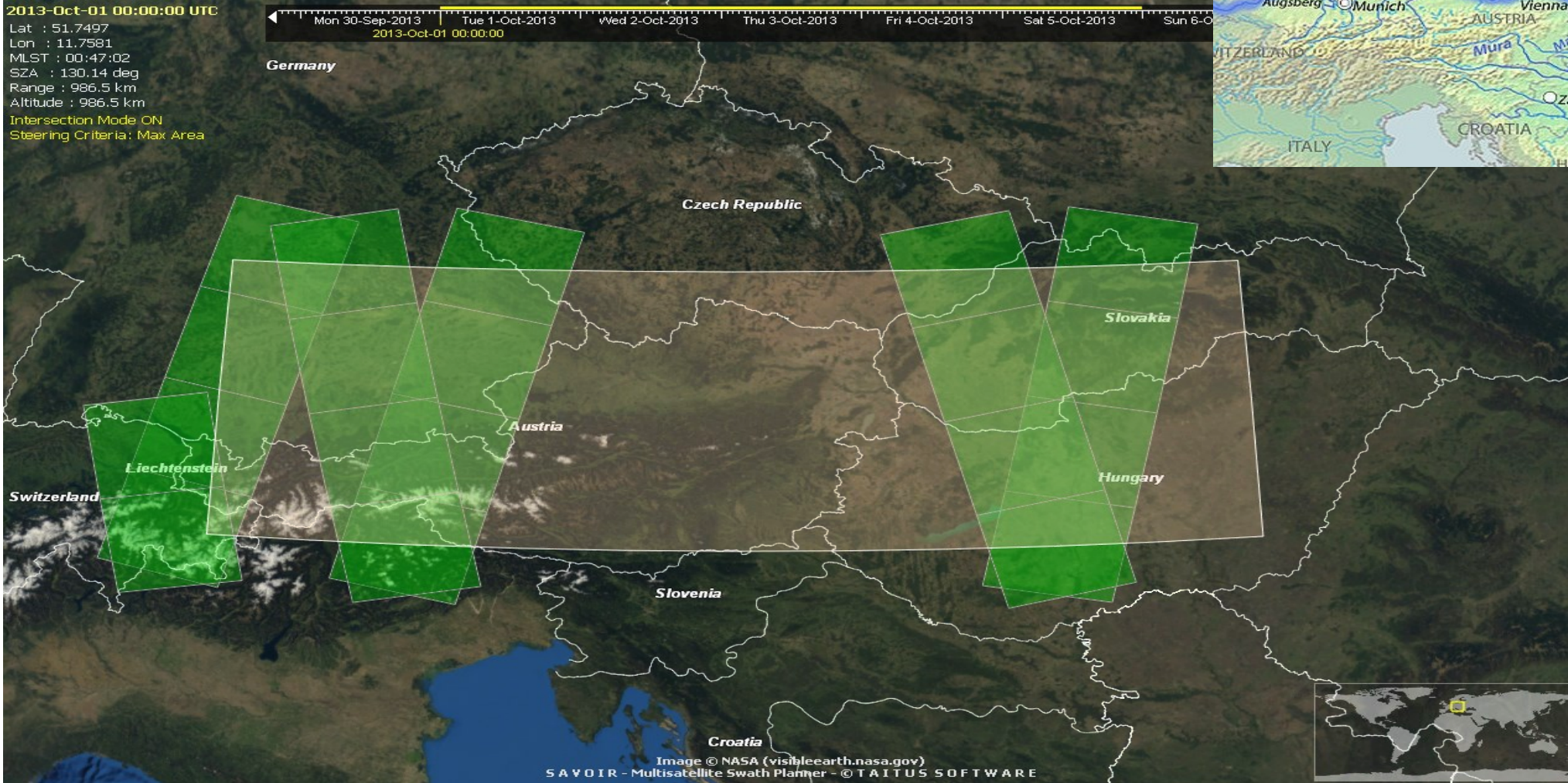


Copernicus Sentinel-1 | Improved Spatial Coverage

Sentinel-1 vs ENVISAT 5-day coverage



Until 2012:
ENVISAT



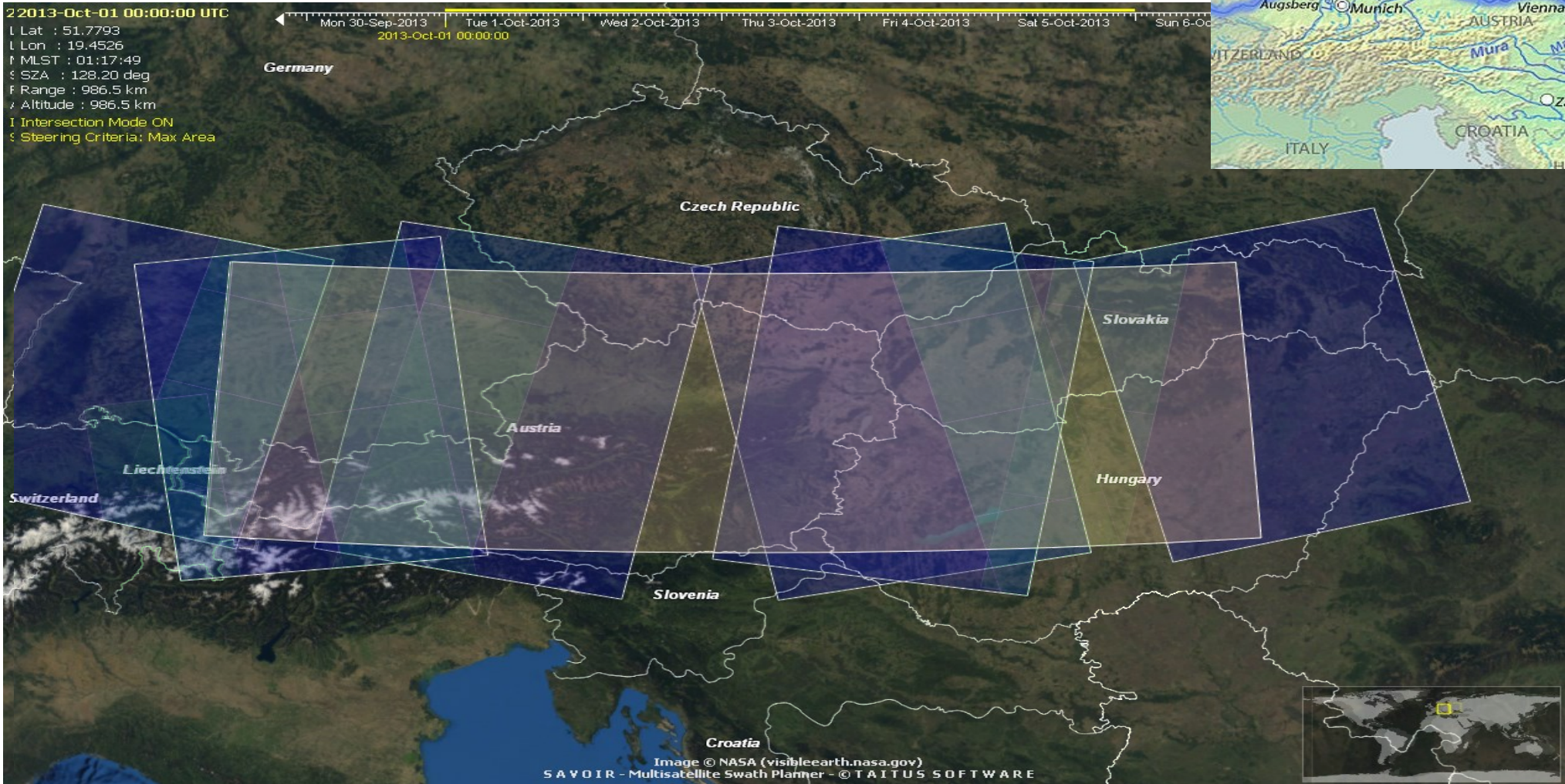
Copernicus Sentinel-1 | Improved Spatial Coverage

Sentinel-1 vs ENVISAT 5-day coverage



Until 2012:
ENVISAT

2014+:
Sentinel1A



Copernicus Sentinel-1 | Improved Spatial Coverage

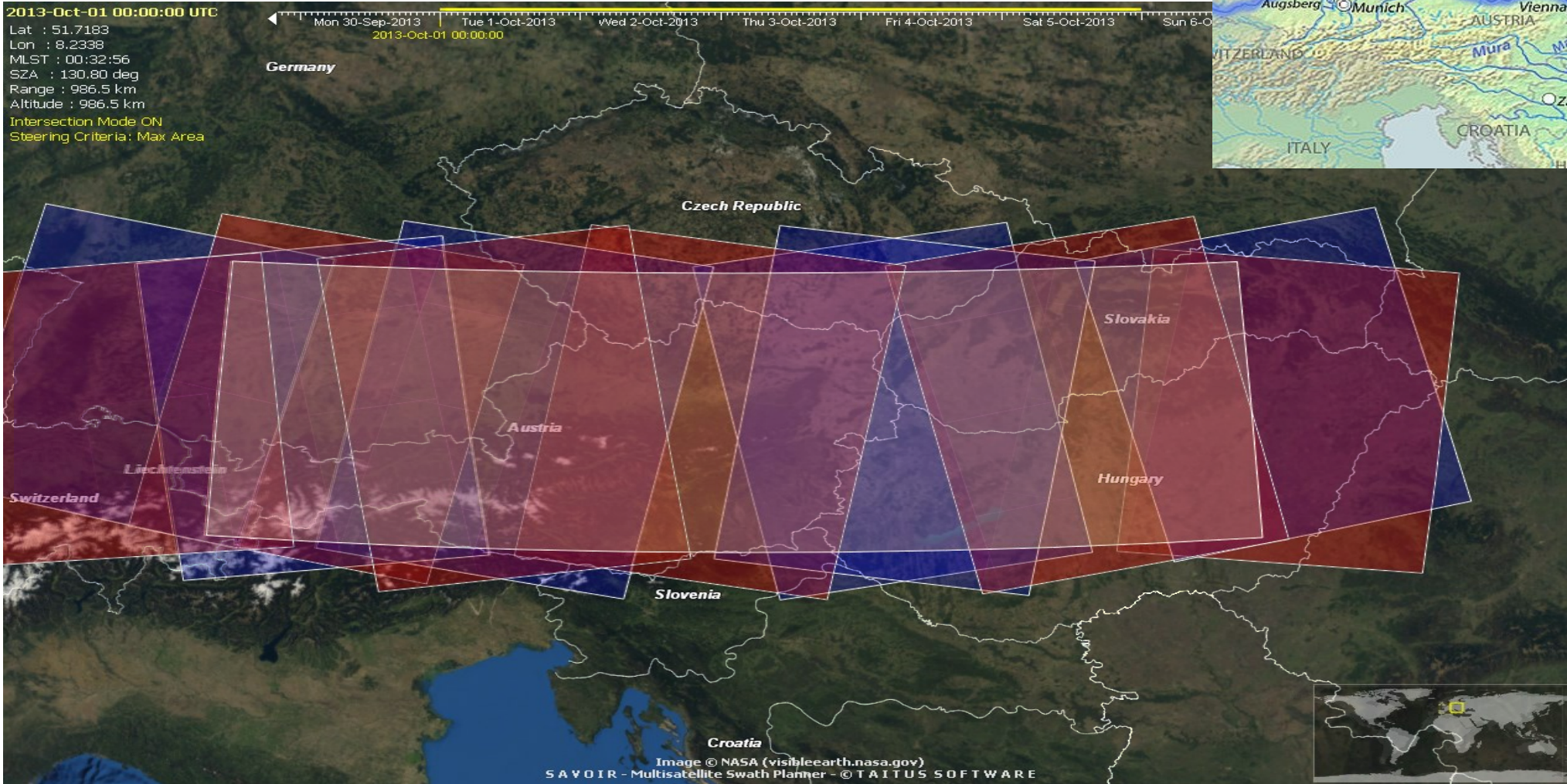
Sentinel-1 vs ENVISAT 5-day coverage



Until 2012:
ENVISAT

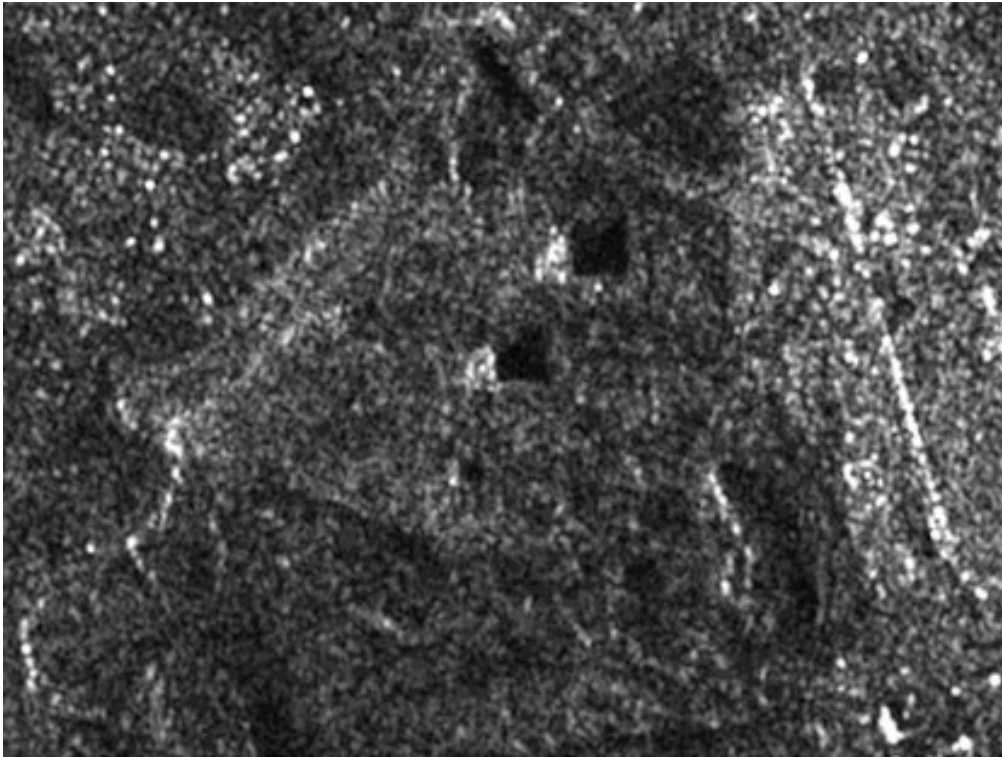
2014+:
Sentinel1A

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.

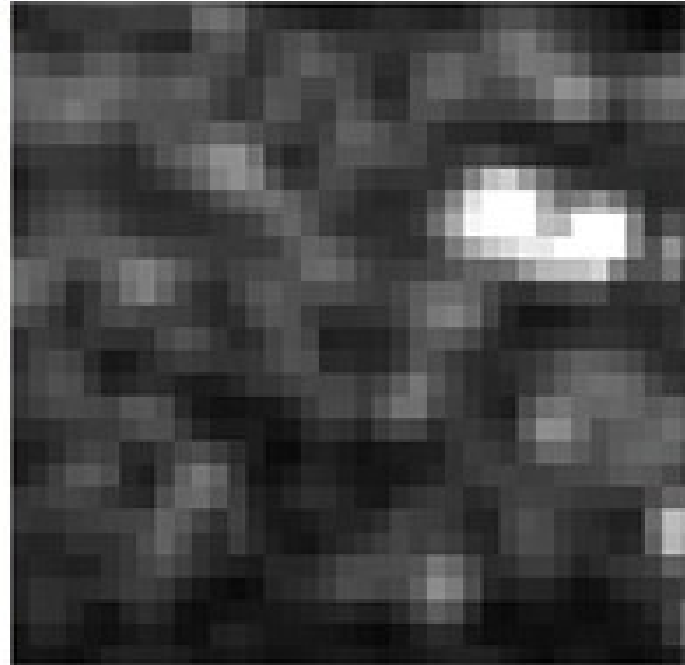
From Medium to Very High Resolution Spaceborne RADARs

Comparison of a SAR image from Copernicus Sentinel-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).

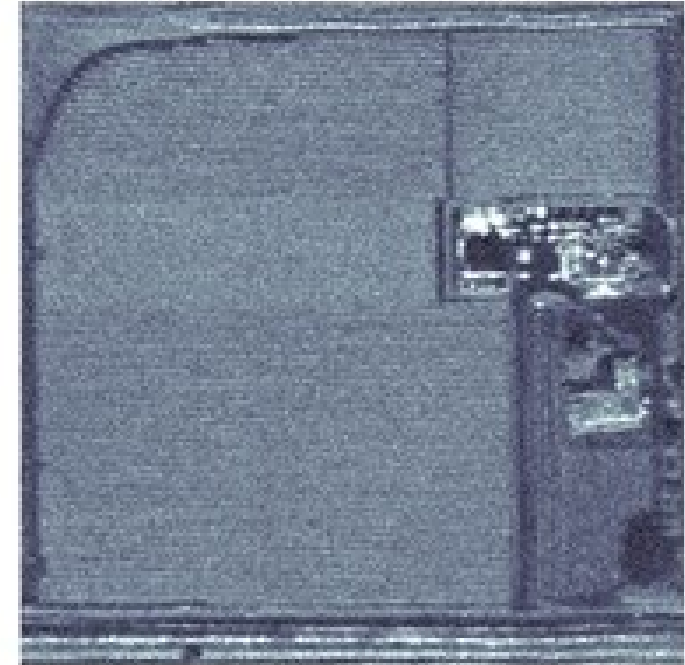
Google Reference Image



Copernicus Sentinel-1



Cappella



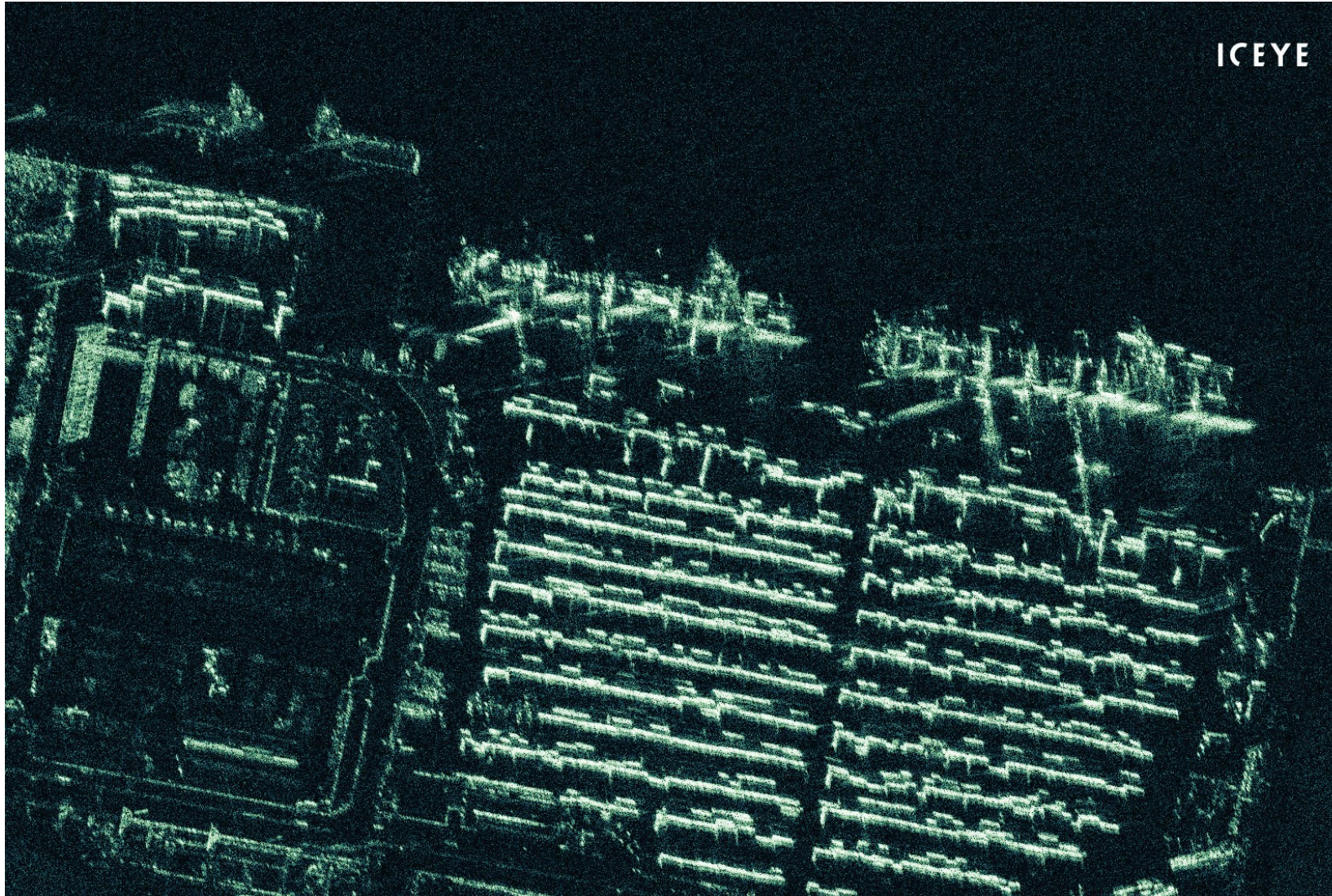


Sentinel-1 ~20 m

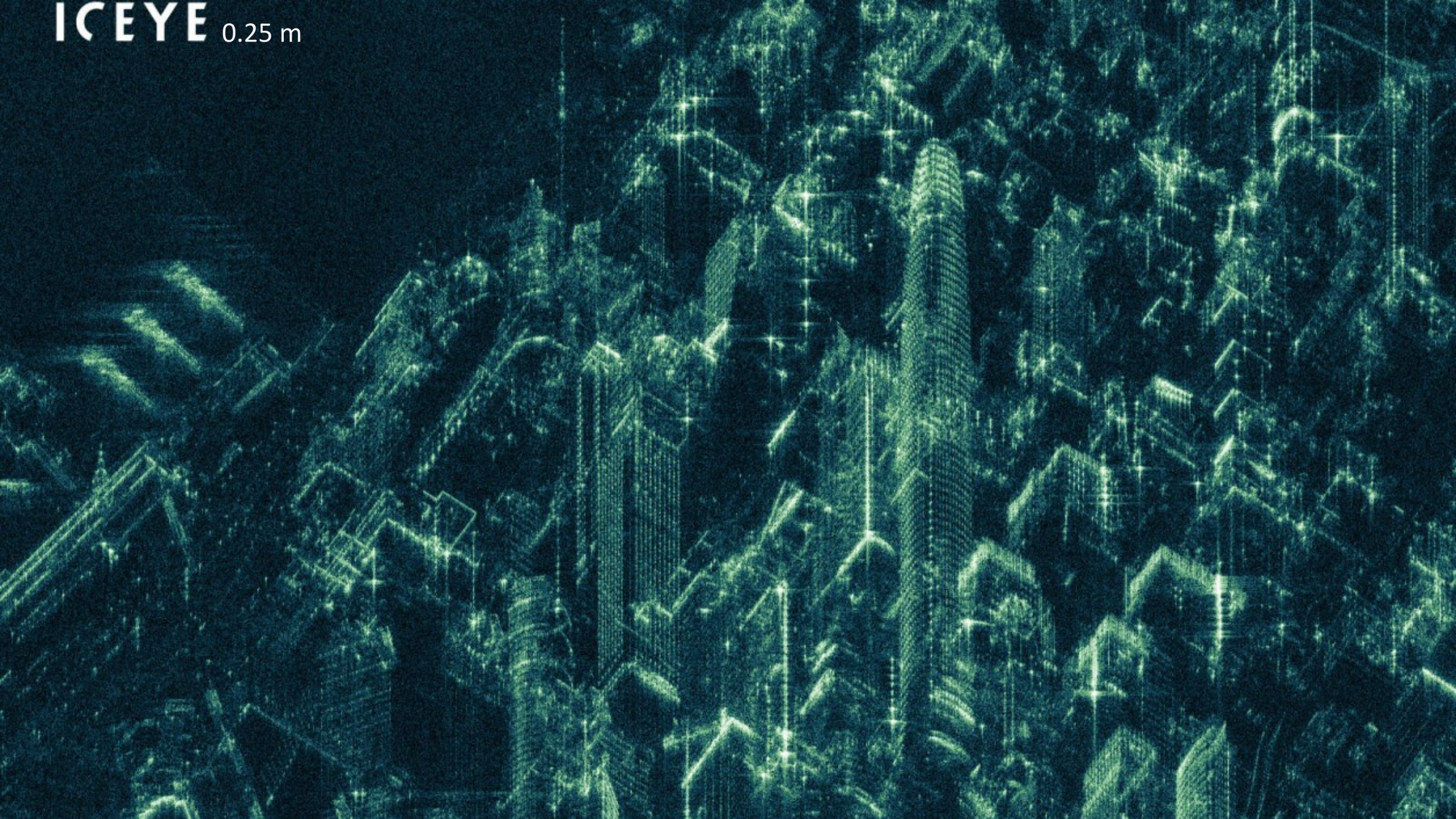


Capella 0.50 m

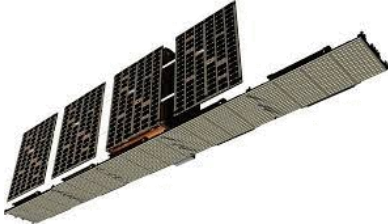
ICEYE Releases World-First Under 1-Meter Resolution Radar Imagery from SAR Microsatellites



ICEYE 0.25 m



ICEYE SAR | Moving from Imagery to Video Capture



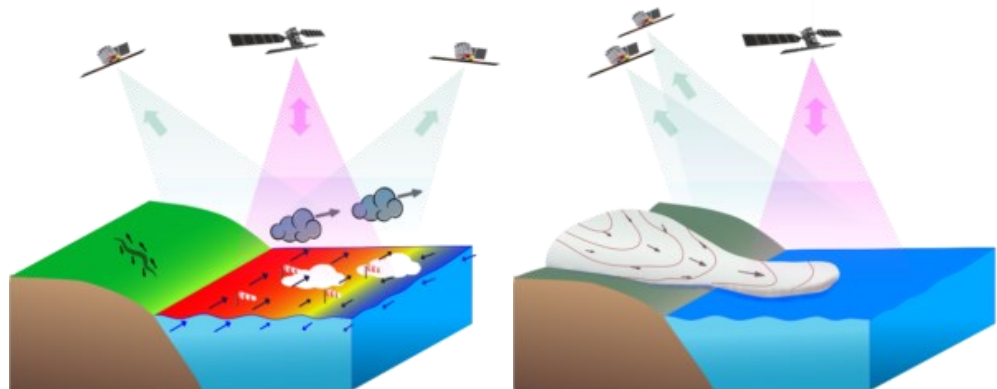
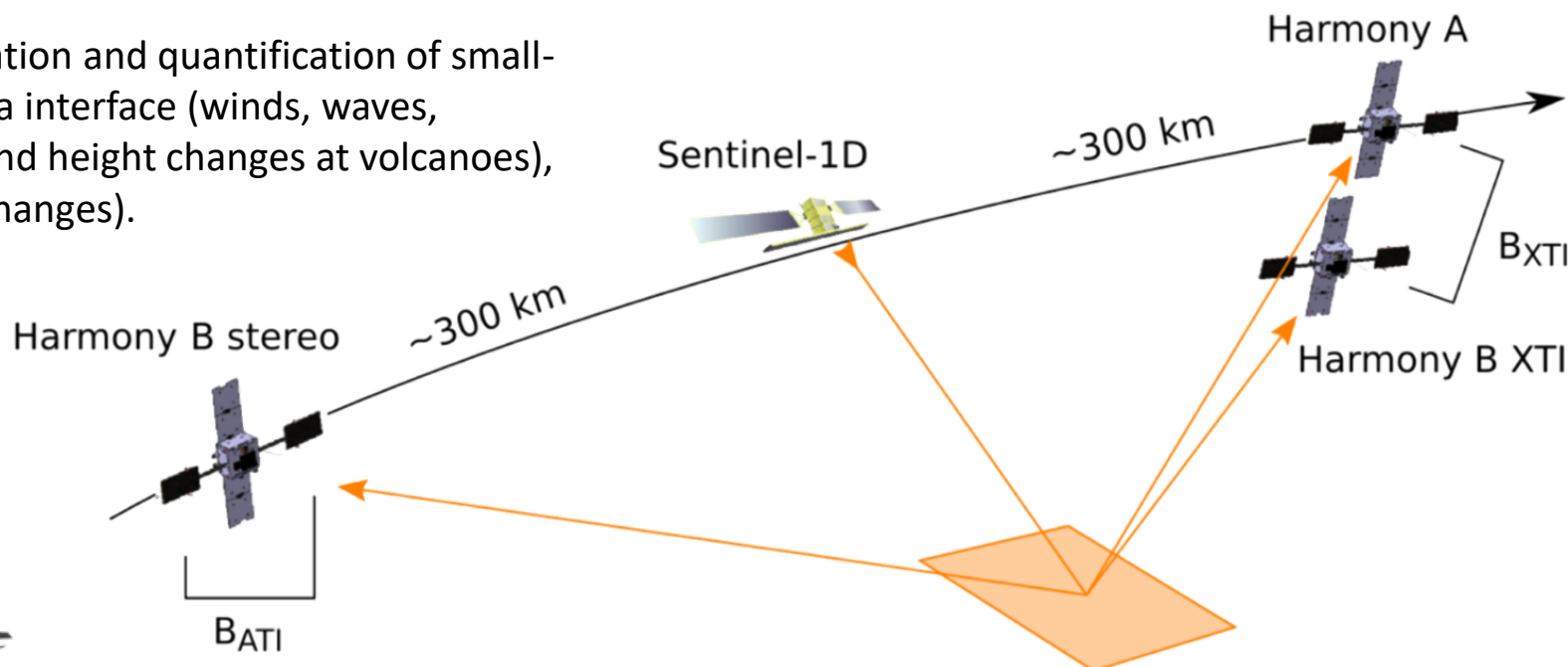
ESA Earth Explorer 10 | HARMONY

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.

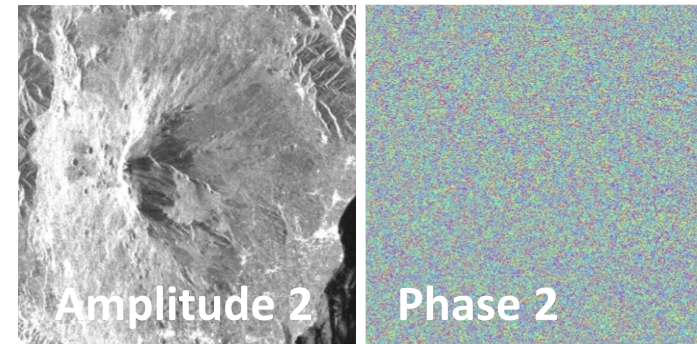
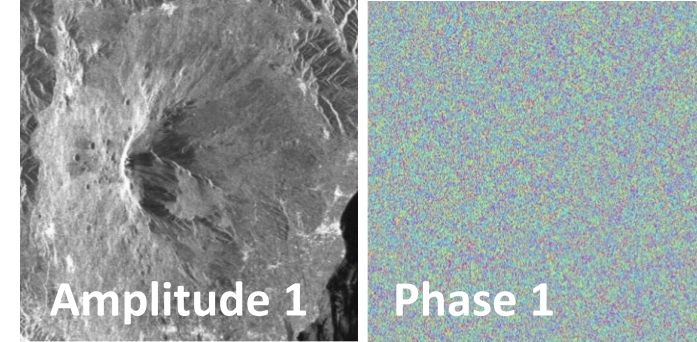
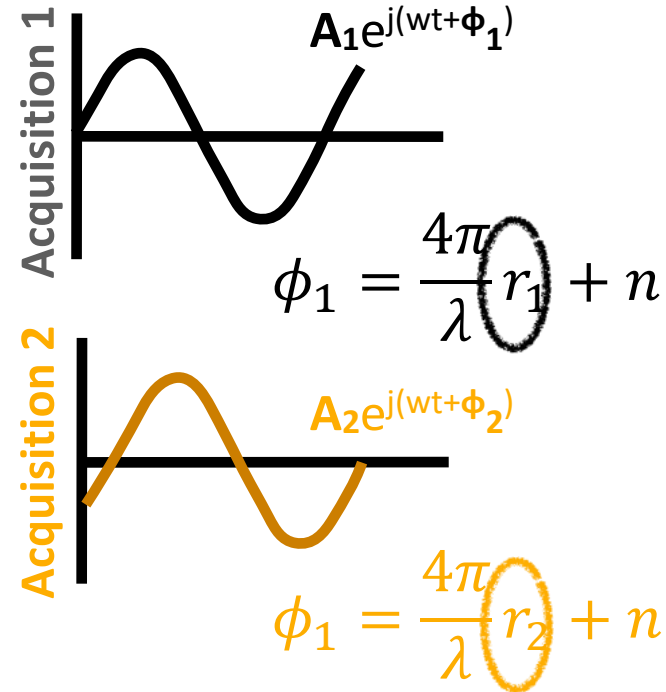
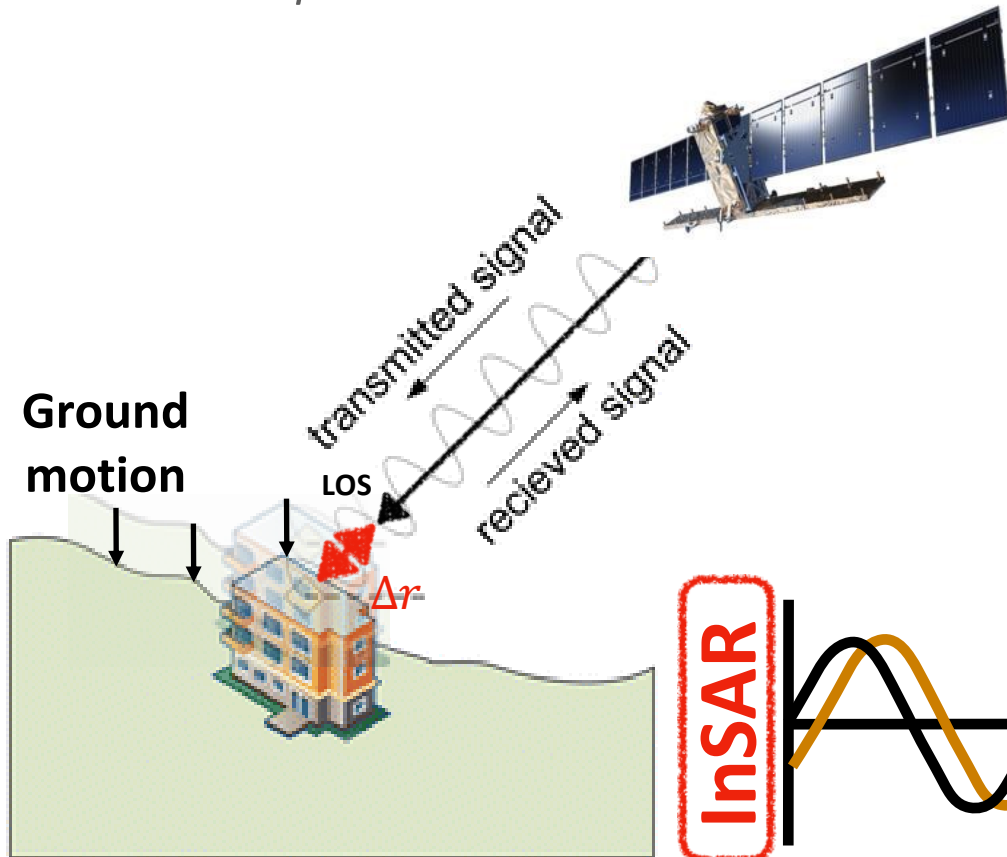


The angular diversity provided by the Harmonies in combination with Sentinel-1 will allow the retrieval of deformation measurements of the sea and earth surface with unprecedented accuracy, while the cross-track configuration will allow the accurate measurement of elevation changes for land-ice and volcanic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

Copyright: Harmony Mission Advisory Group.

What is SAR Interferometry (InSAR)?

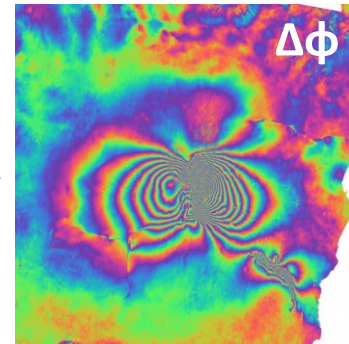
SAR interferometry consists in computing the phase difference of two SAR acquisitions



InSAR

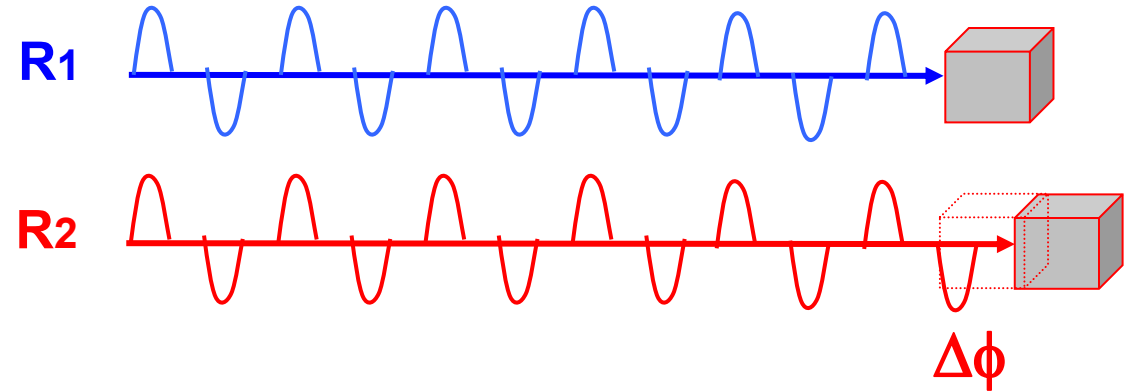
$$\Delta\phi = \phi_2 - \phi_1 = \frac{4\pi}{\lambda} (r_2 - r_1) + n$$

$\Delta\phi = \phi_2 - \phi_1 = \frac{4\pi}{\lambda} \Delta r + n$



InSAR for Surface Motion

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



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

1st acquisition
2nd acquisition

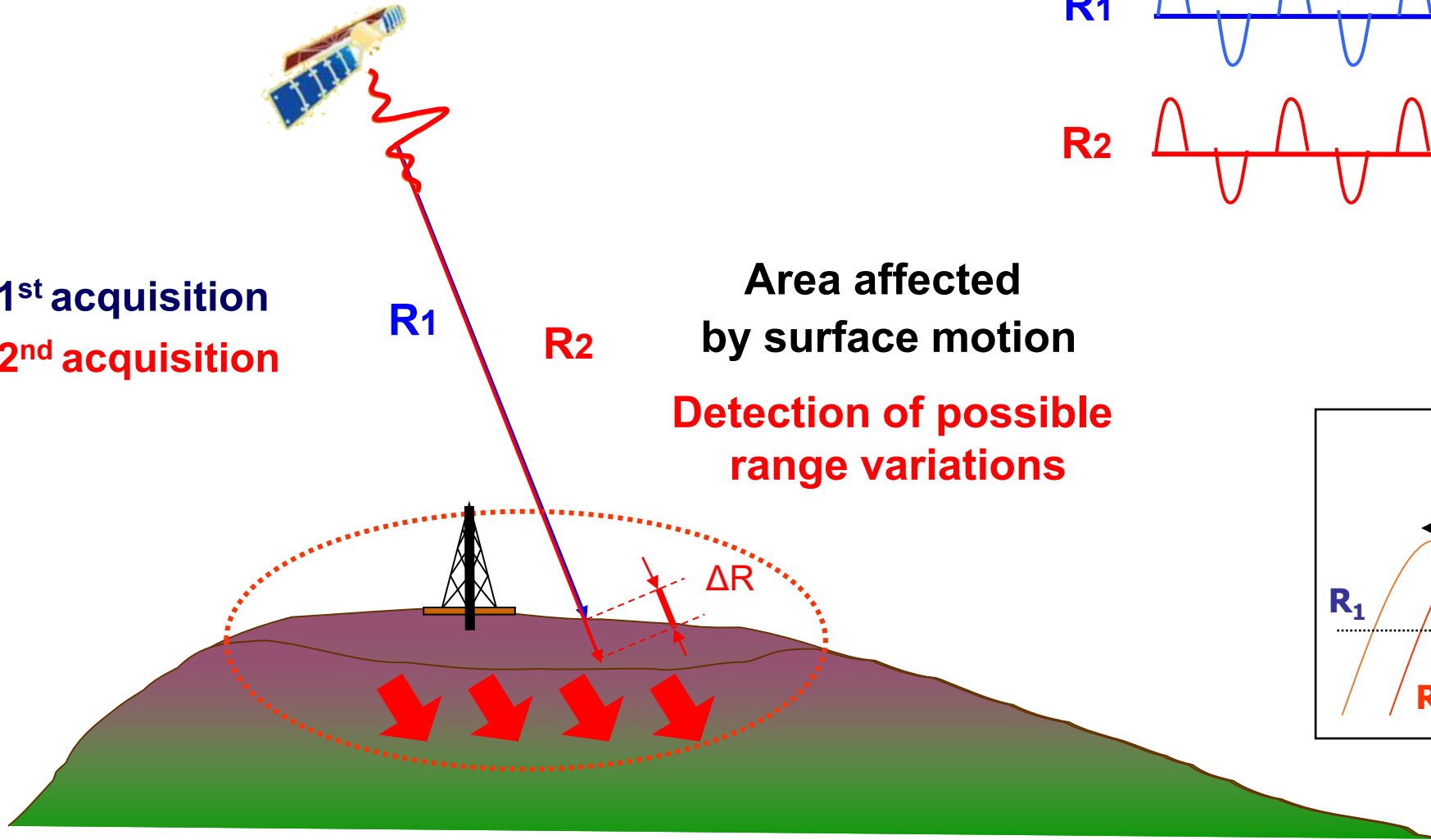
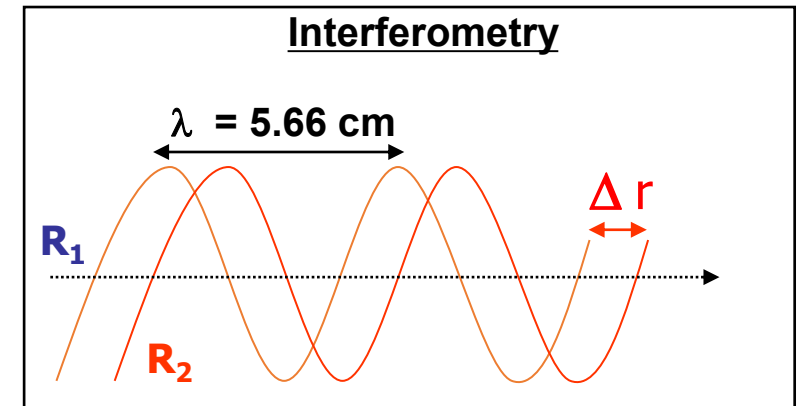
R_1

R_2

Area affected
by surface motion

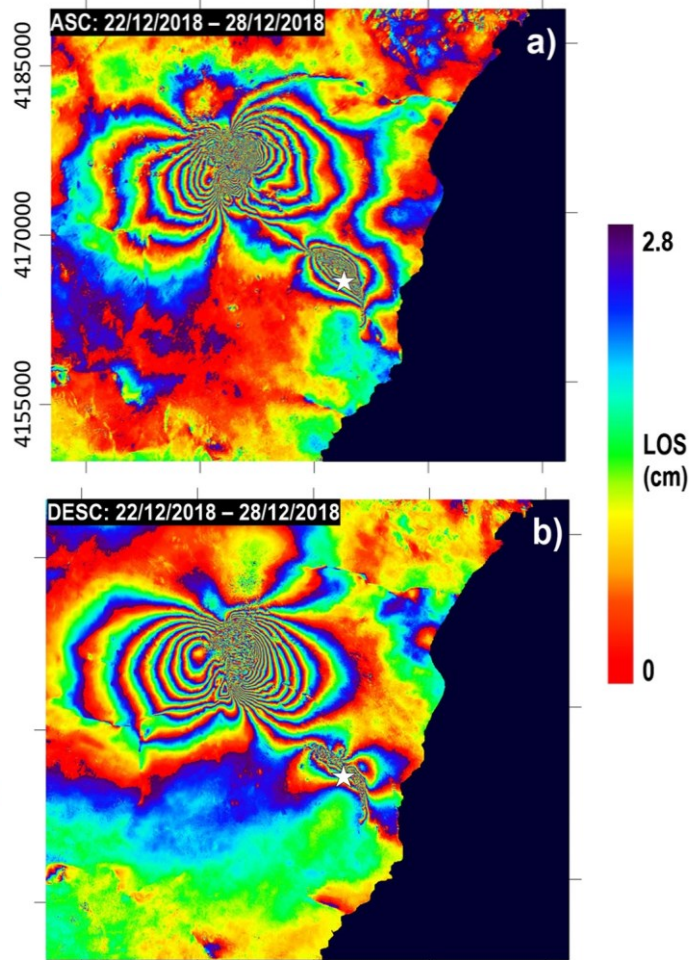
Detection of possible
range variations

ΔR



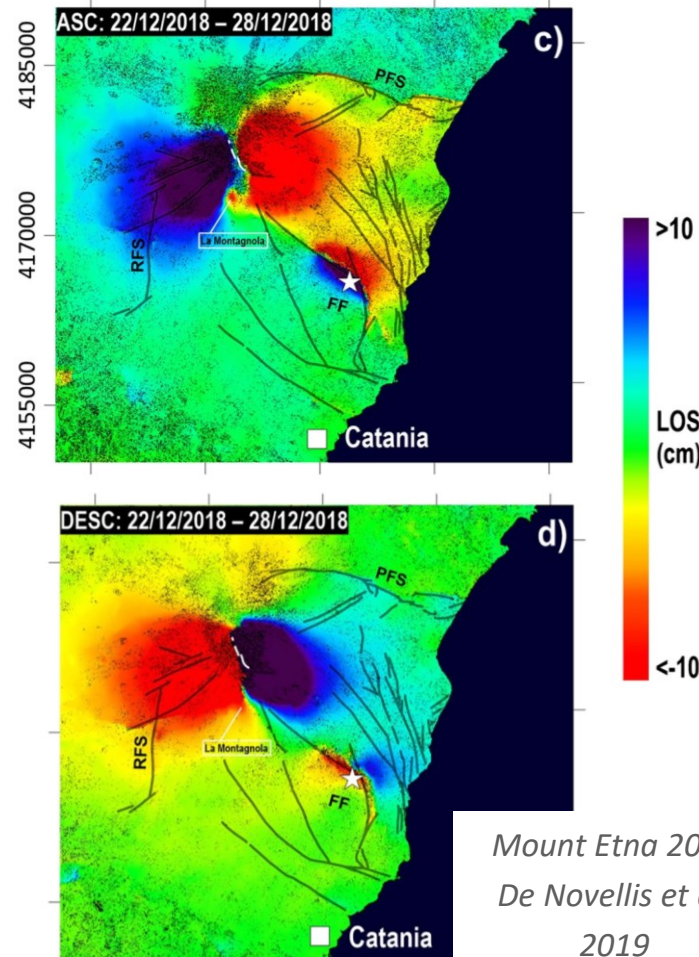
InSAR products | Differential Interferograms

WRAPPED INTERFEROGRAM



It shows the phase difference $\Delta\phi$

UNWRAPPED INTERFEROGRAM

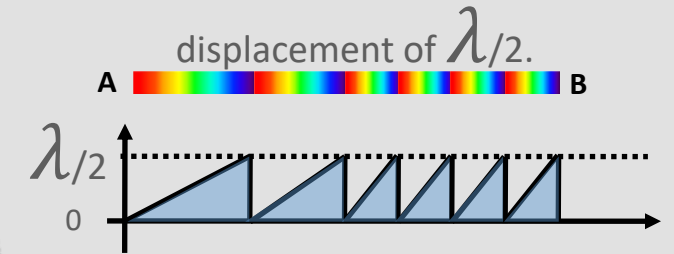


It shows the ground displacement in the LOS direction

Mount Etna 2018
De Novellis et al,
2019

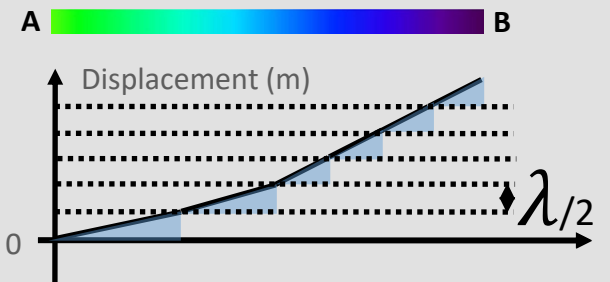
WRAPPED INTERFEROGRAM

One can estimate the displacement by counting the number of fringes. One fringe corresponds to a ground

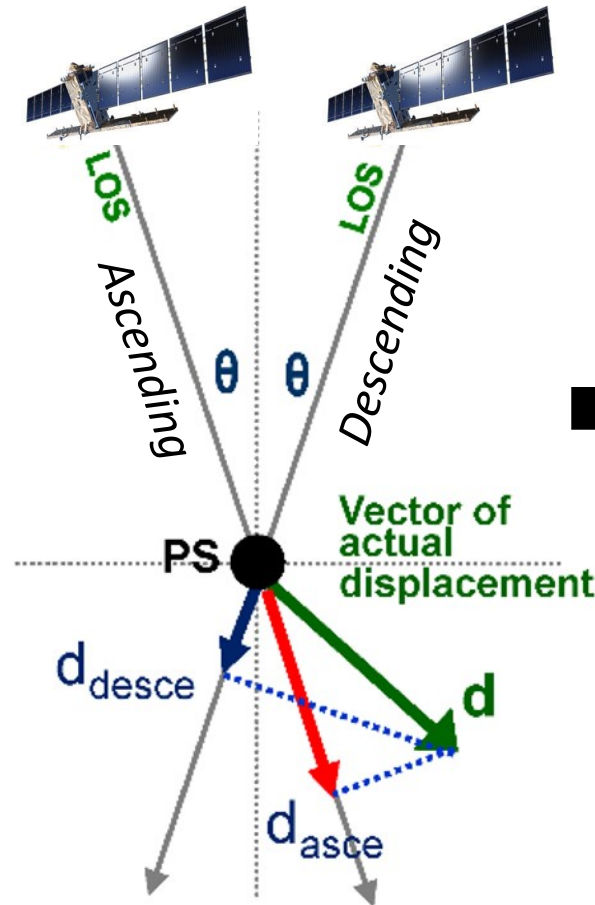
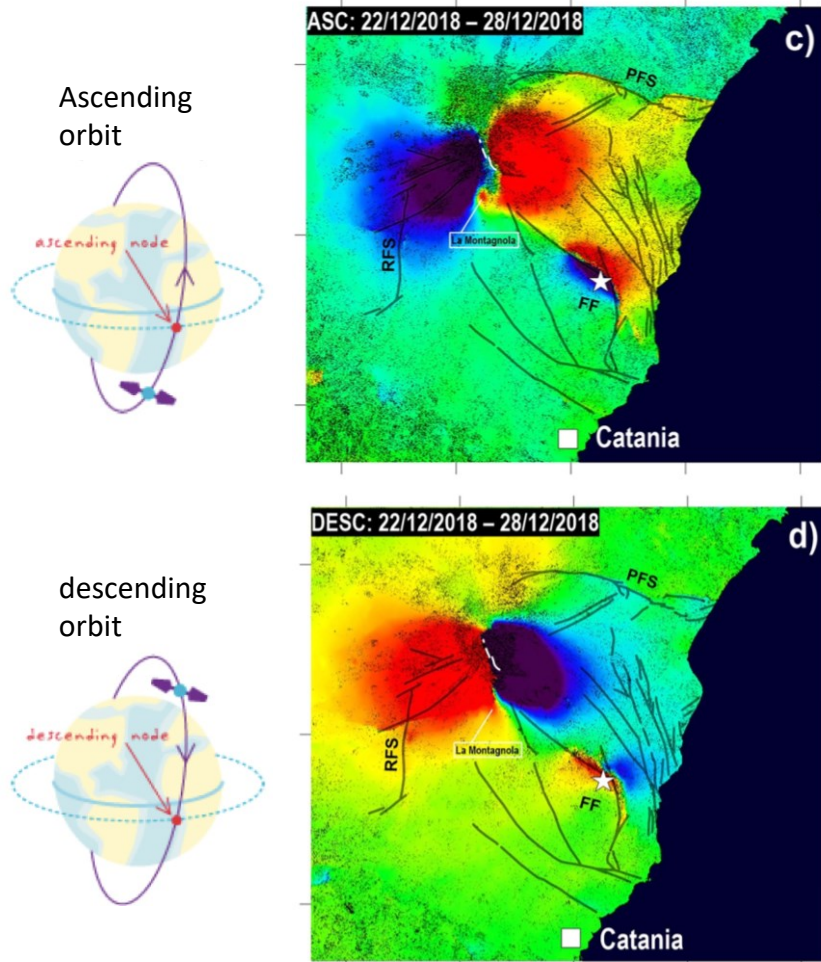


UNWRAPPED INTERFEROGRAM

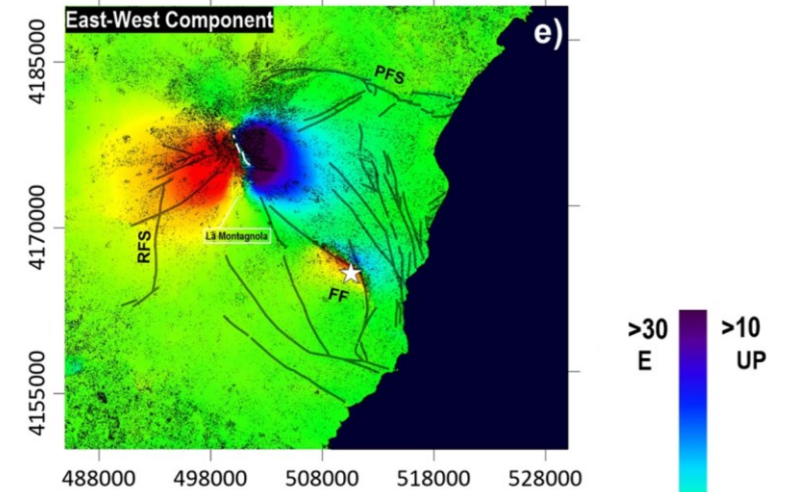
Unwrapping automatized this step to retrieve the ground displacement.



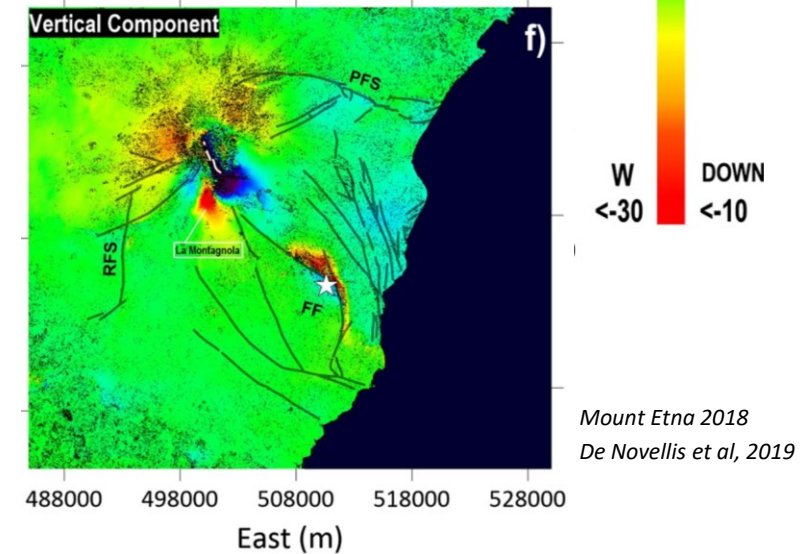
InSAR Motion Decomposition



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

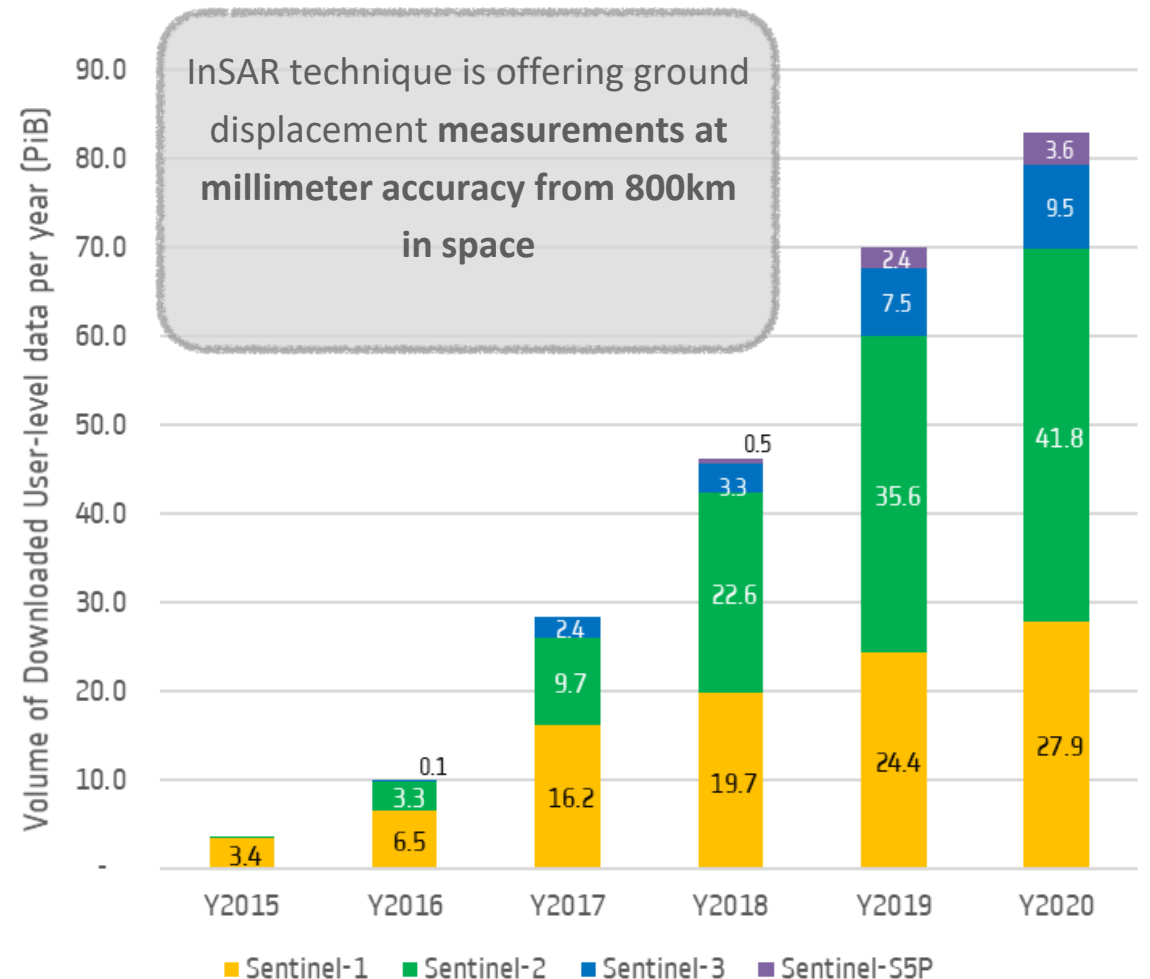
Revolutionized for *processing of long data stacks* to obtain millimeter level accuracy (Ferretti et al. 2002);

2010-2020

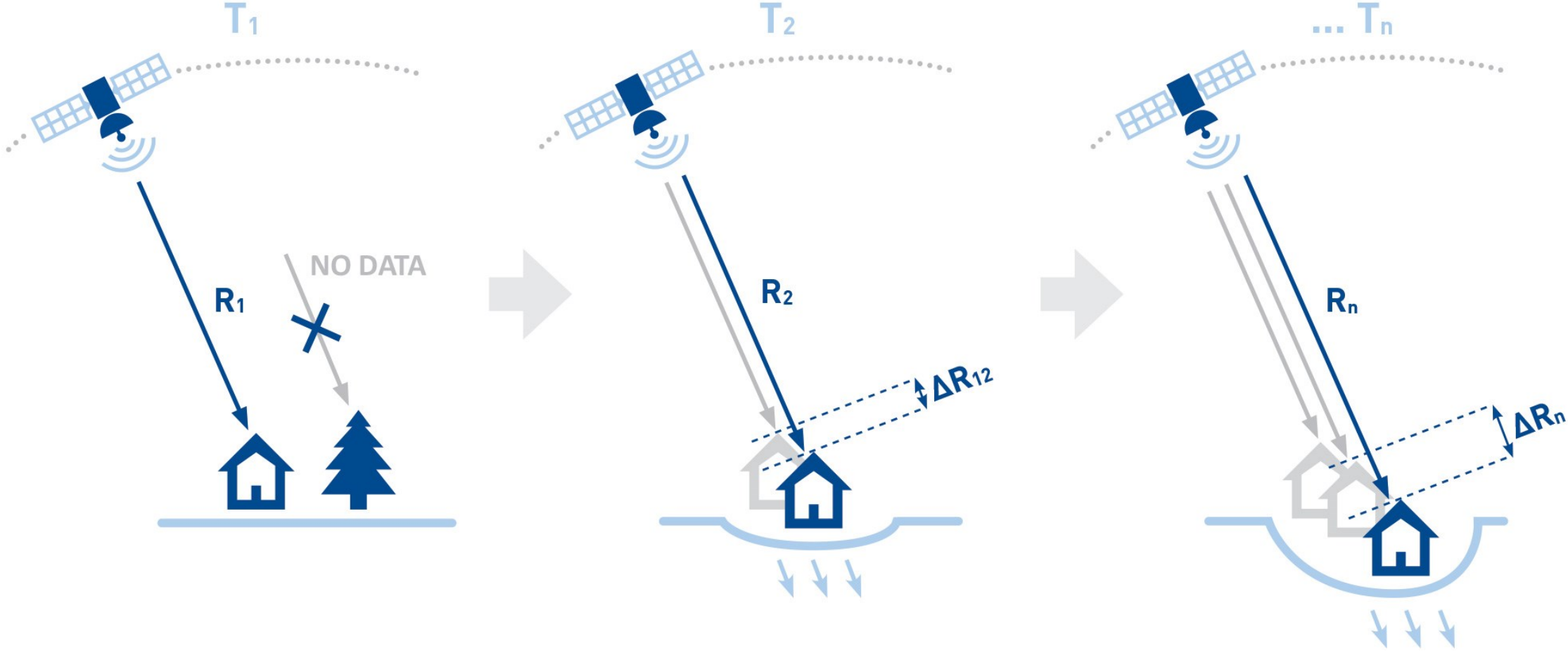
Reached *maturity* and validated over ~20 years (e.g. ESA Terrafirma project)

2020-2030

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

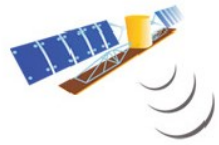
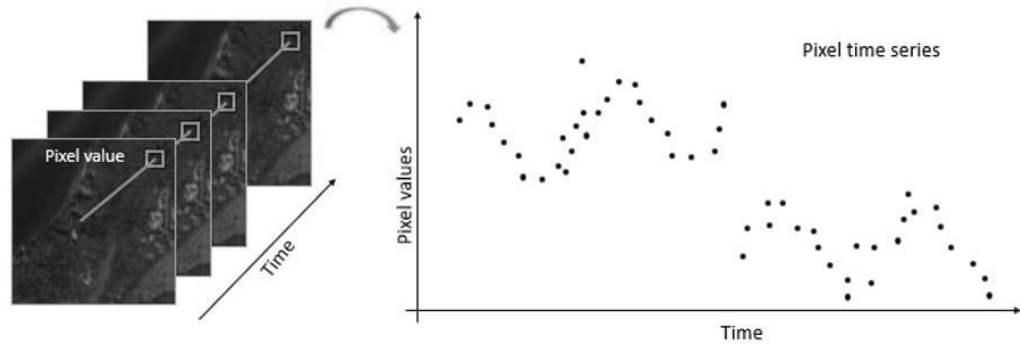


Conventional InSAR vs. Advanced Multi-Temporal InSAR

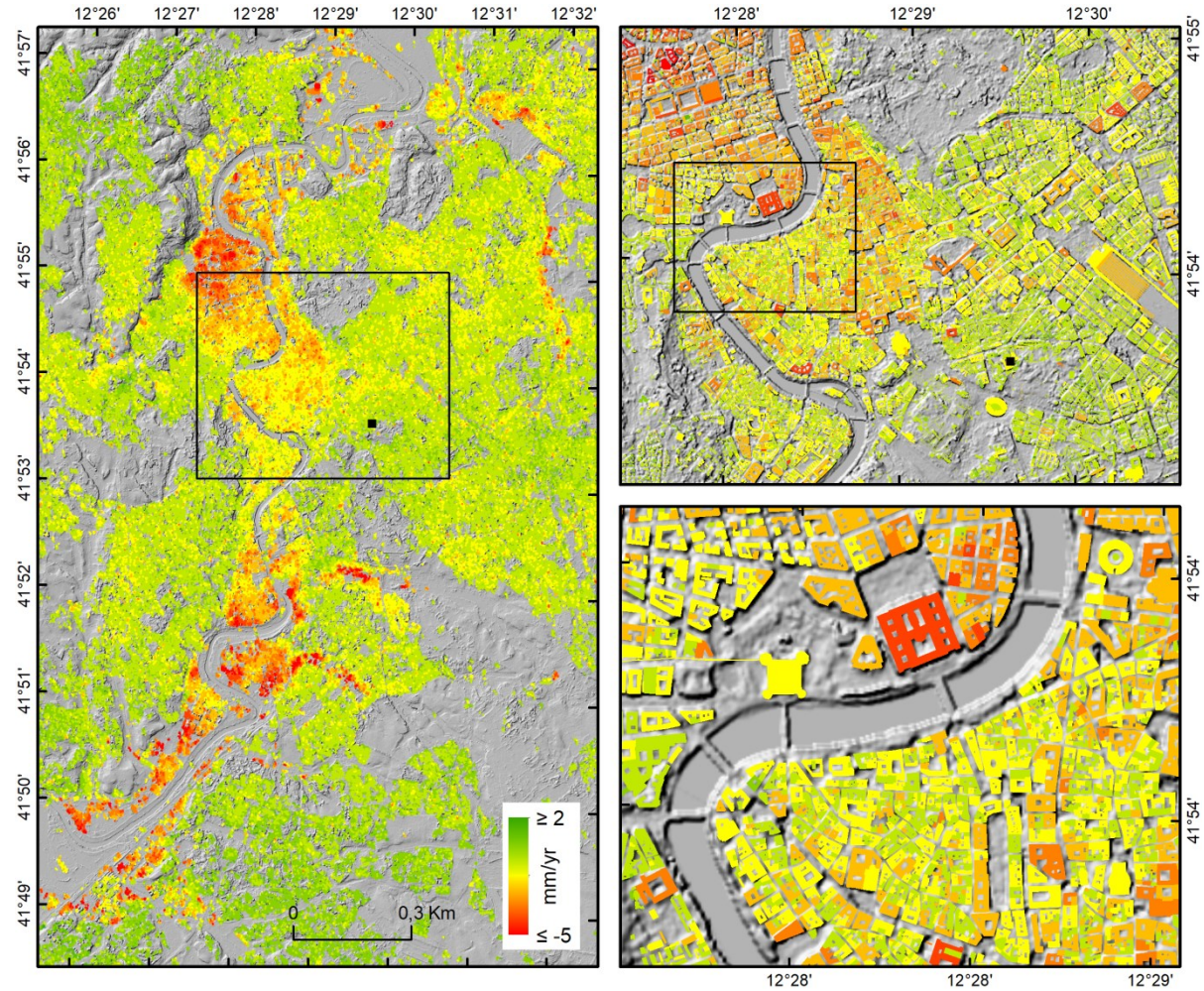
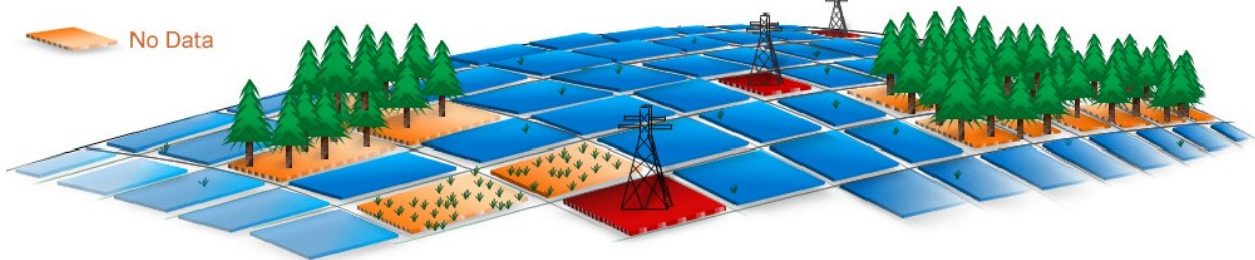
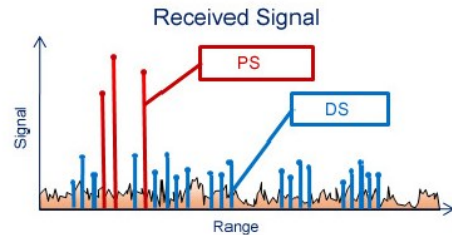


Multi-Temporal SAR Interferometry

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



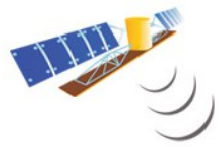
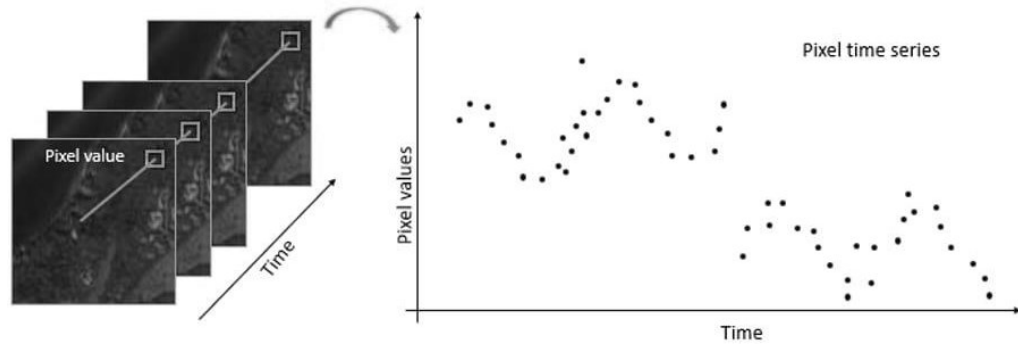
-  PS (Permanent Scatterers)
-  DS (Distributed Scatterers)
-  No Data



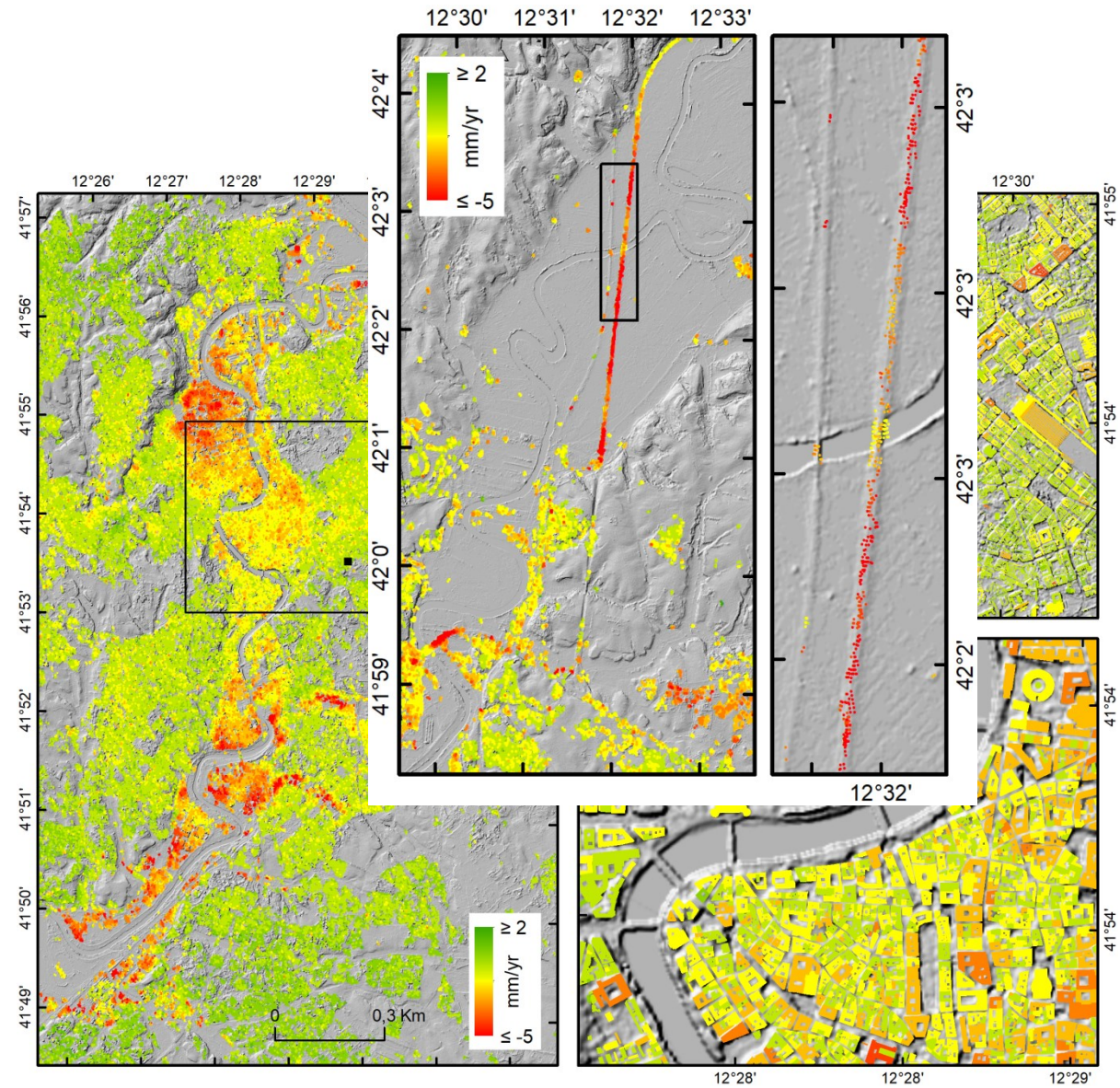
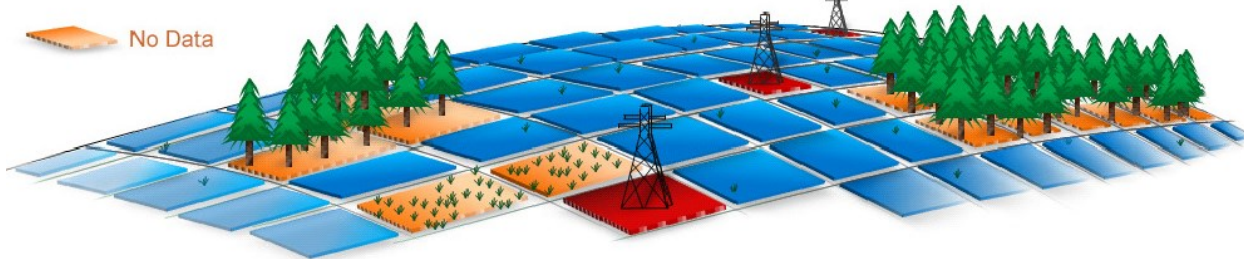
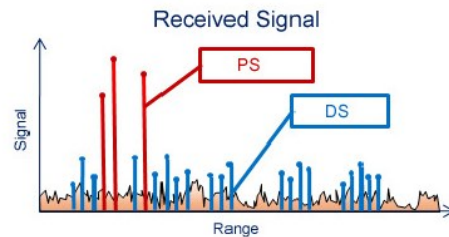
Delgado Blasco, J.M.; Fomelis, M.; Stewart, C.; Hooper, A. Measuring Urban Subsidence in the Rome Metropolitan Area (Italy) with Sentinel-1 SNAP-StaMPS Persistent Scatterer Interferometry. *Remote Sens.* **2019**, *11*, 129. <https://doi.org/10.3390/rs11020129>

Multi-Temporal SAR Interferometry

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

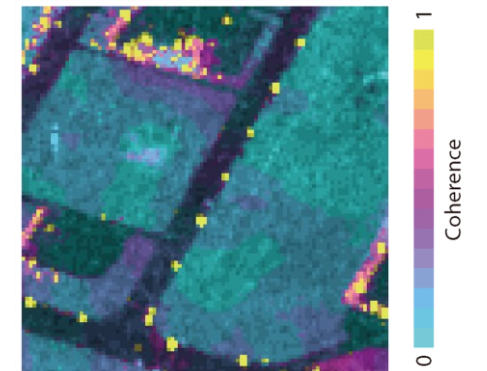
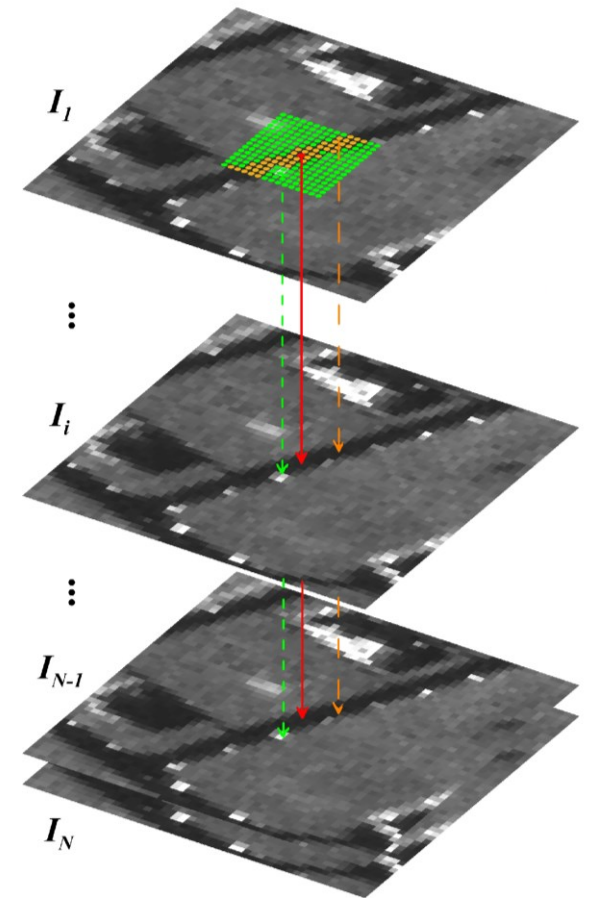
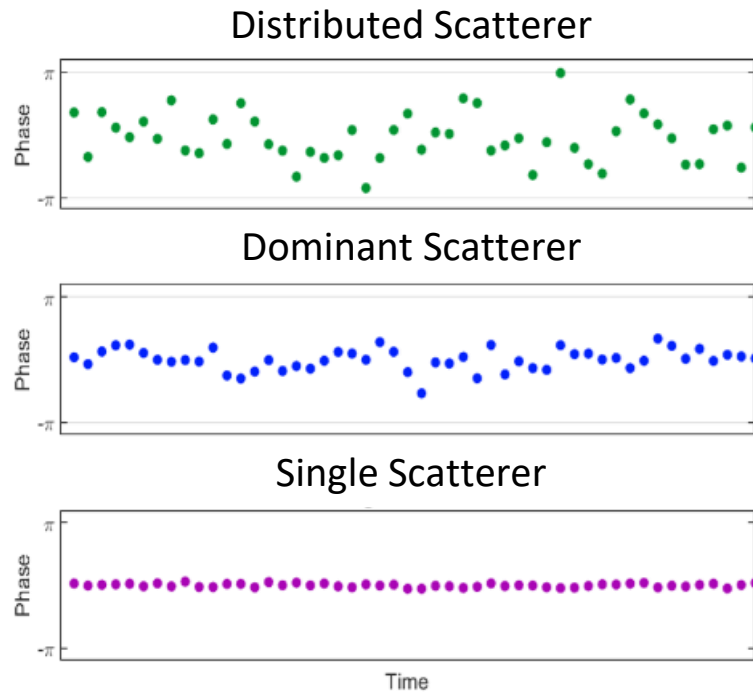
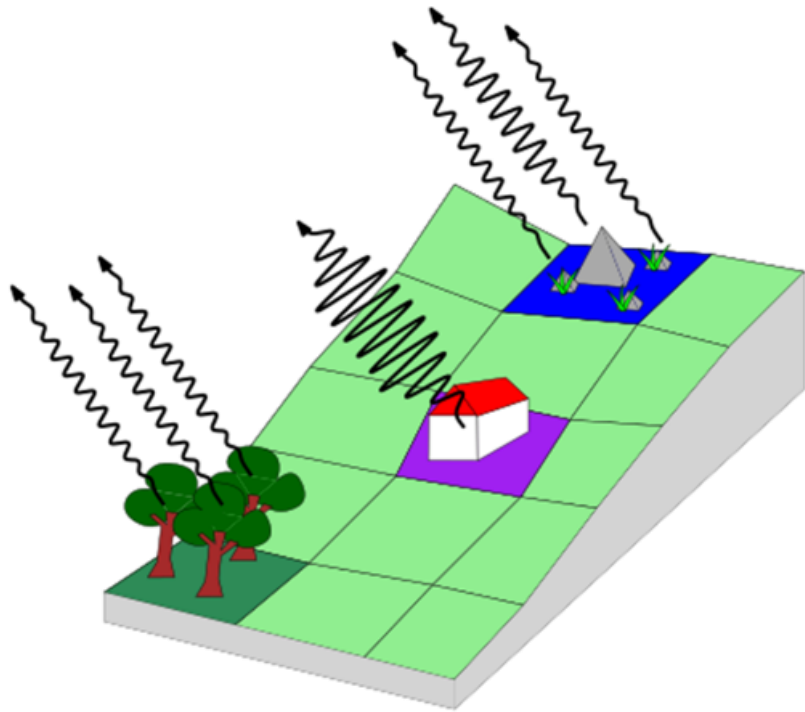


-  PS (Permanent Scatterers)
-  DS (Distributed Scatterers)
-  No Data



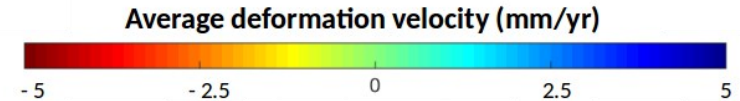
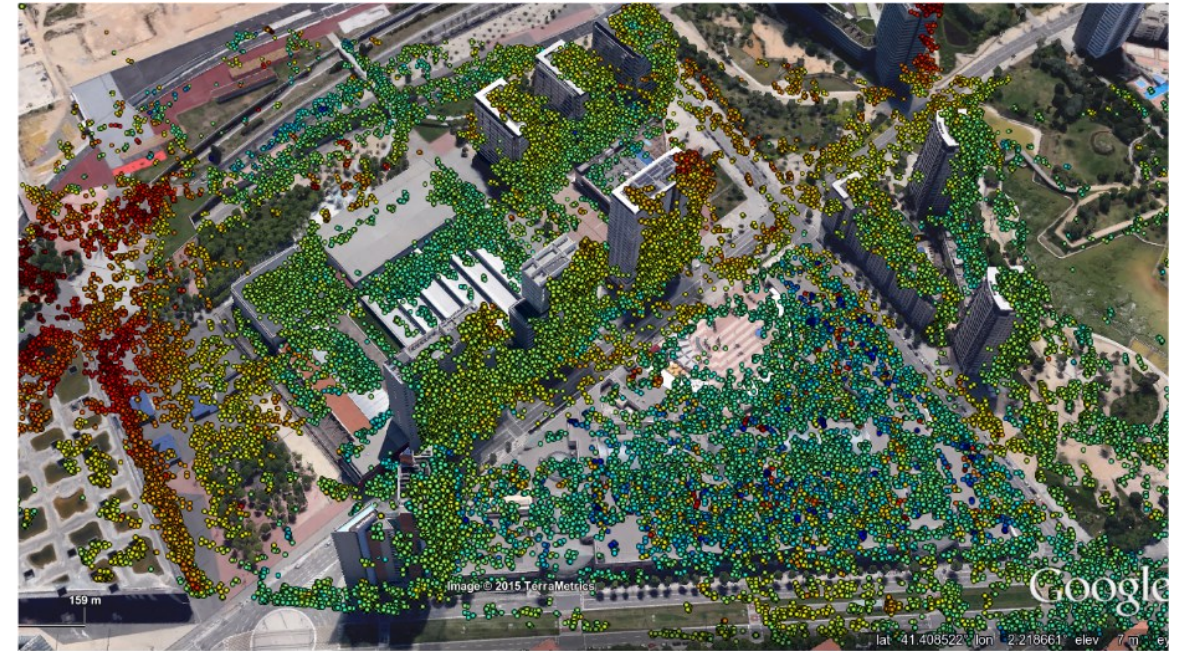
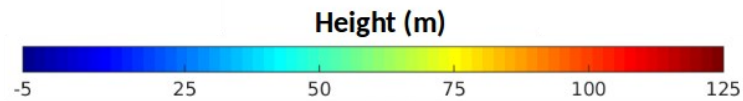
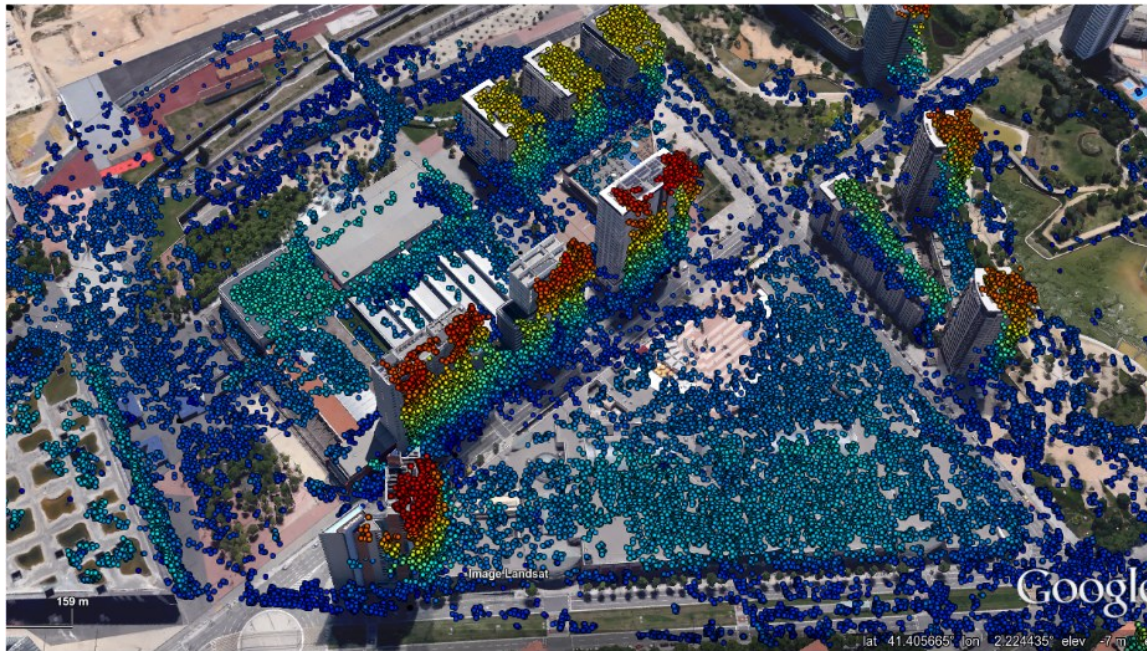
Delgado Blasco, J.M.; Fomelis, M.; Stewart, C.; Hooper, A. Measuring Urban Subsidence in the Rome Metropolitan Area (Italy) with Sentinel-1 SNAP-StaMPS Persistent Scatterer Interferometry. *Remote Sens.* **2019**, *11*, 129. <https://doi.org/10.3390/rs11020129>

Detection of Targets | PS vs DS points



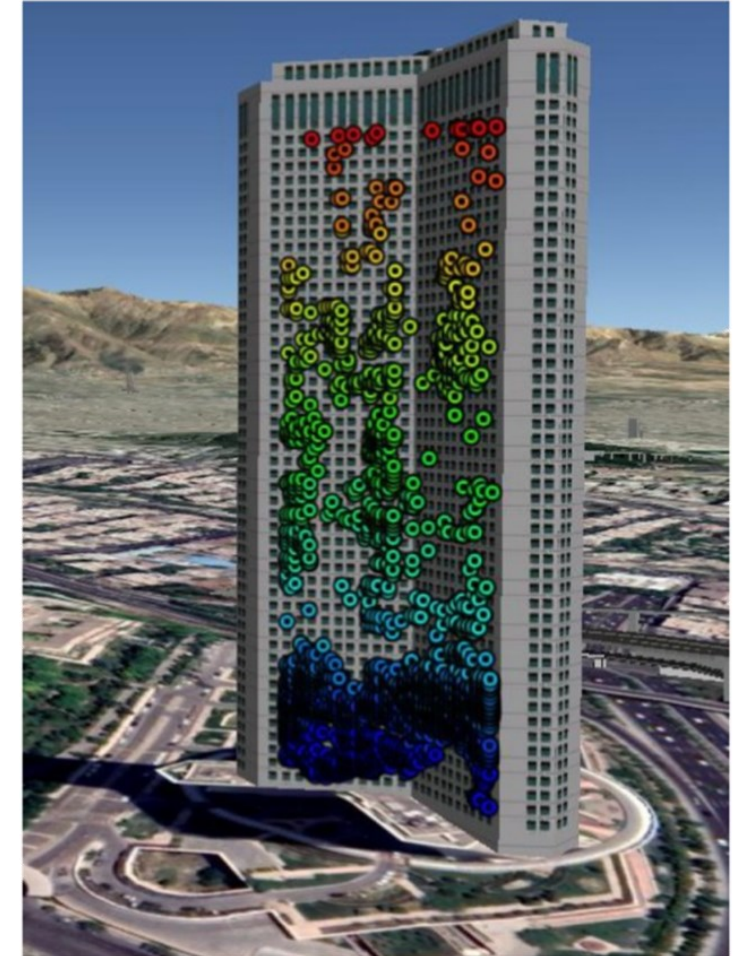
Persistent Scatterers (PSs)

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.



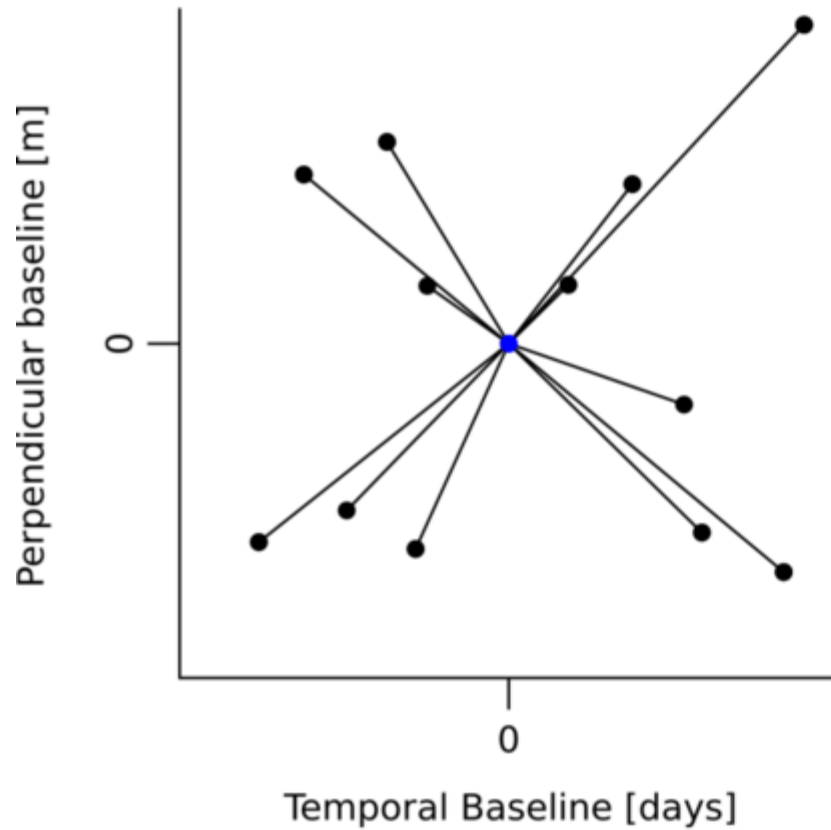
Persistent Scatterers | Geolocation based on SAR Viewing Angle

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.

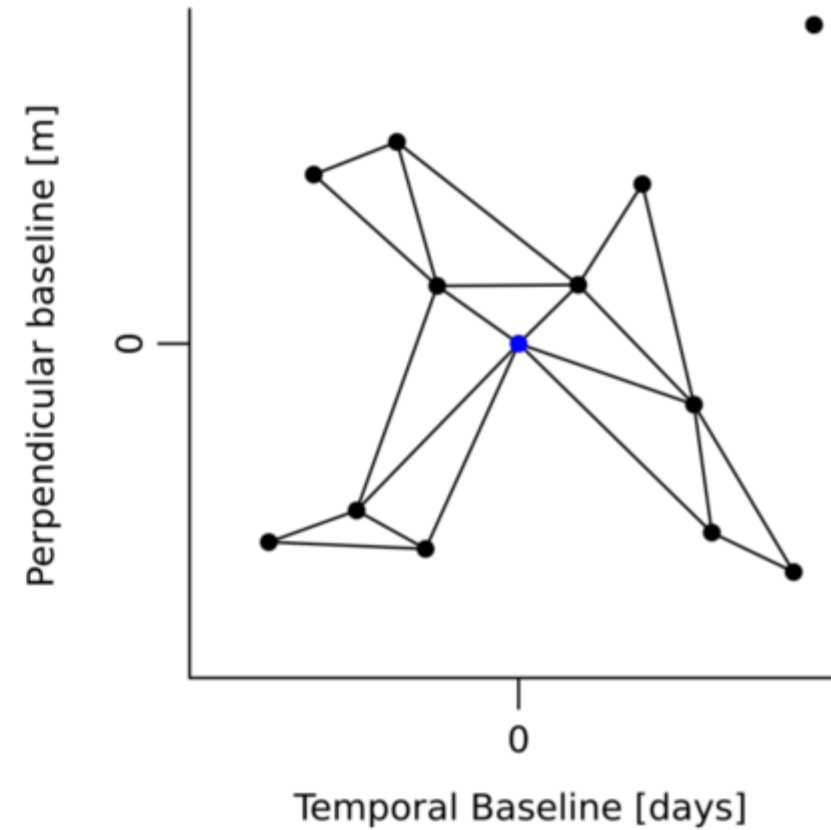


Multi-Temporal InSAR Analysis | Interferometric Pairs Selection

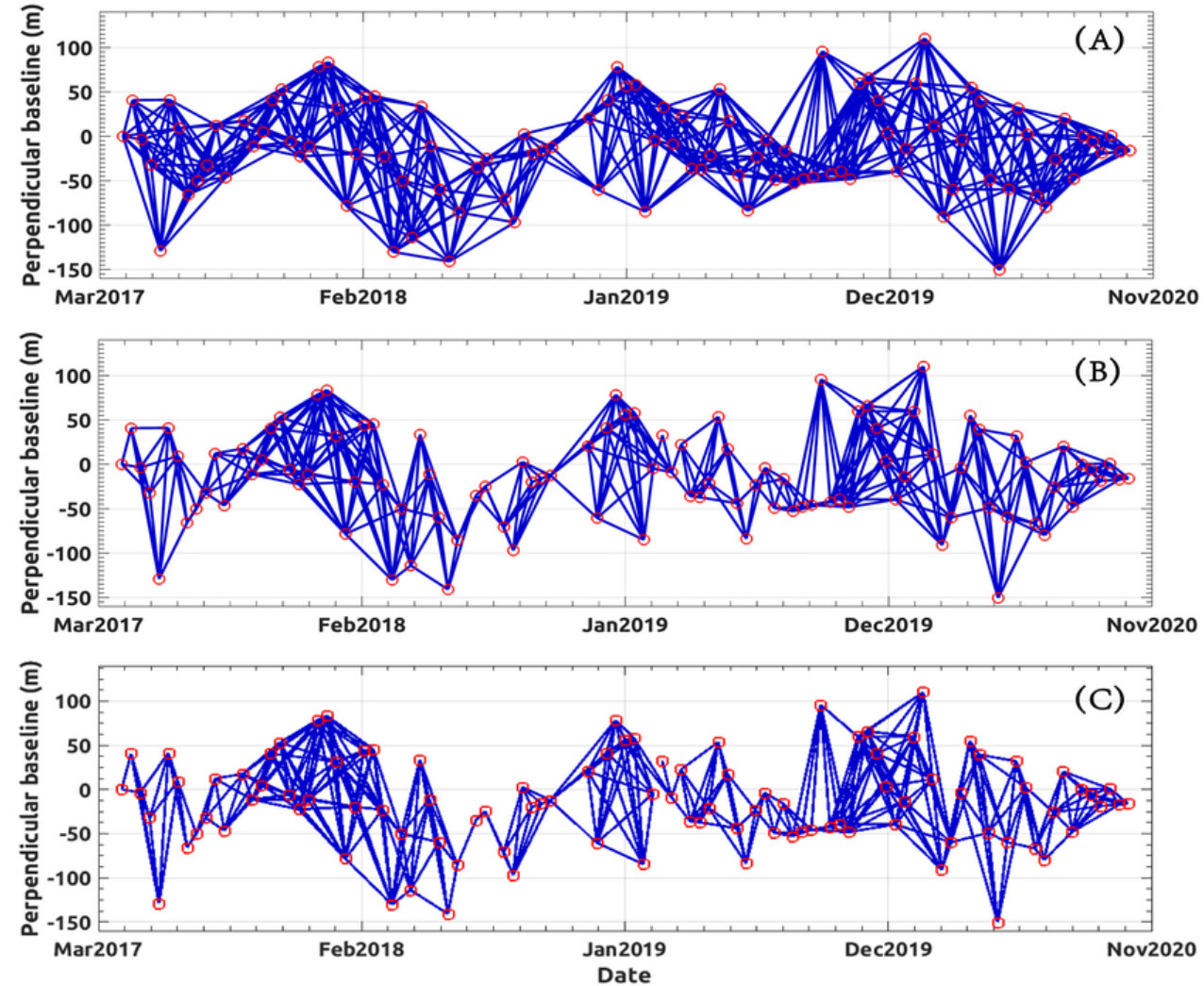
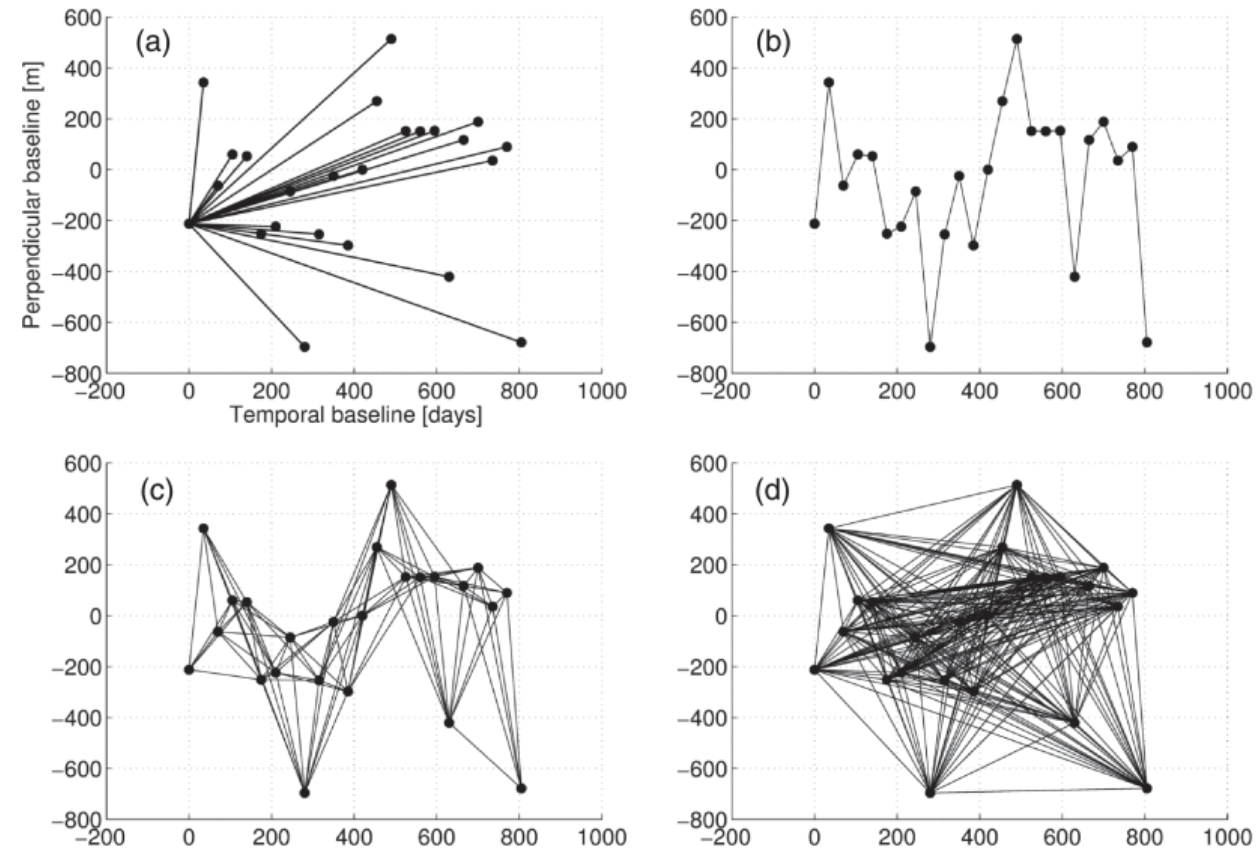
Persistent Scatterer Interferometry (PSI)



Small BAseline Subset Interferometry (SBAS)

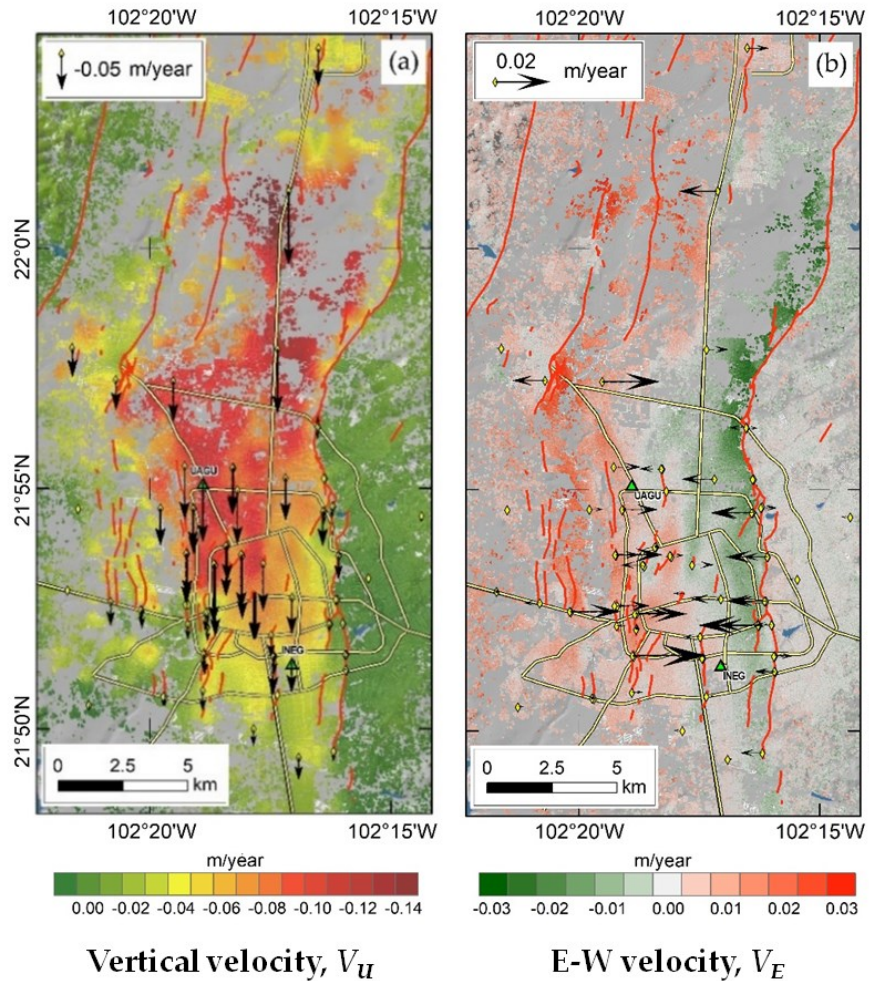


Multi-Temporal InSAR Analysis | Interferometric Pairs Selection

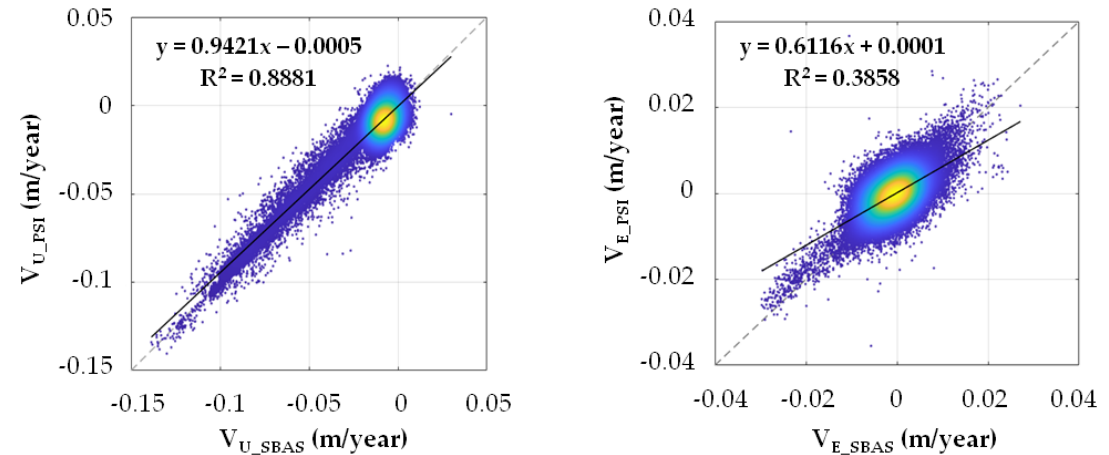


Inter-Comparison Between PSI and SBAS approaches

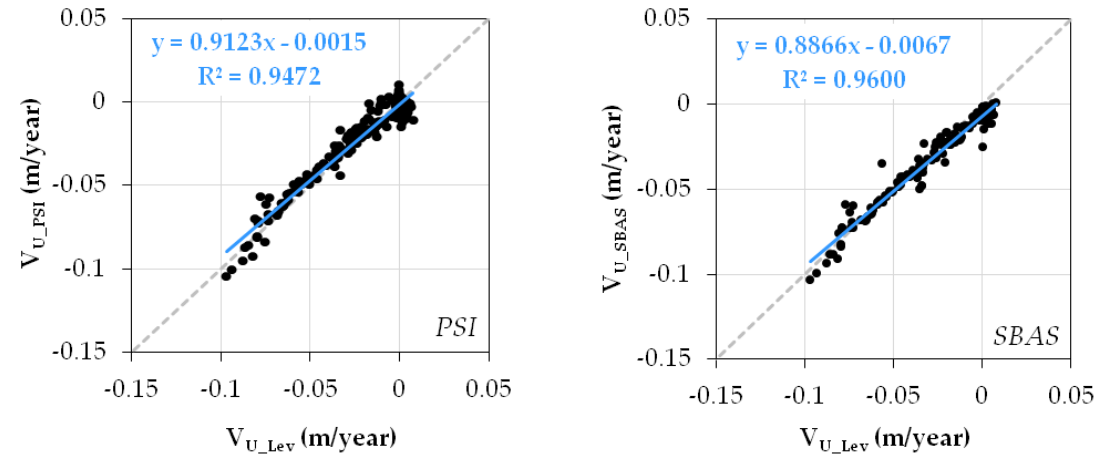
Displacement velocities from InSAR and GNSS



PSI-SBAS inter-comparison

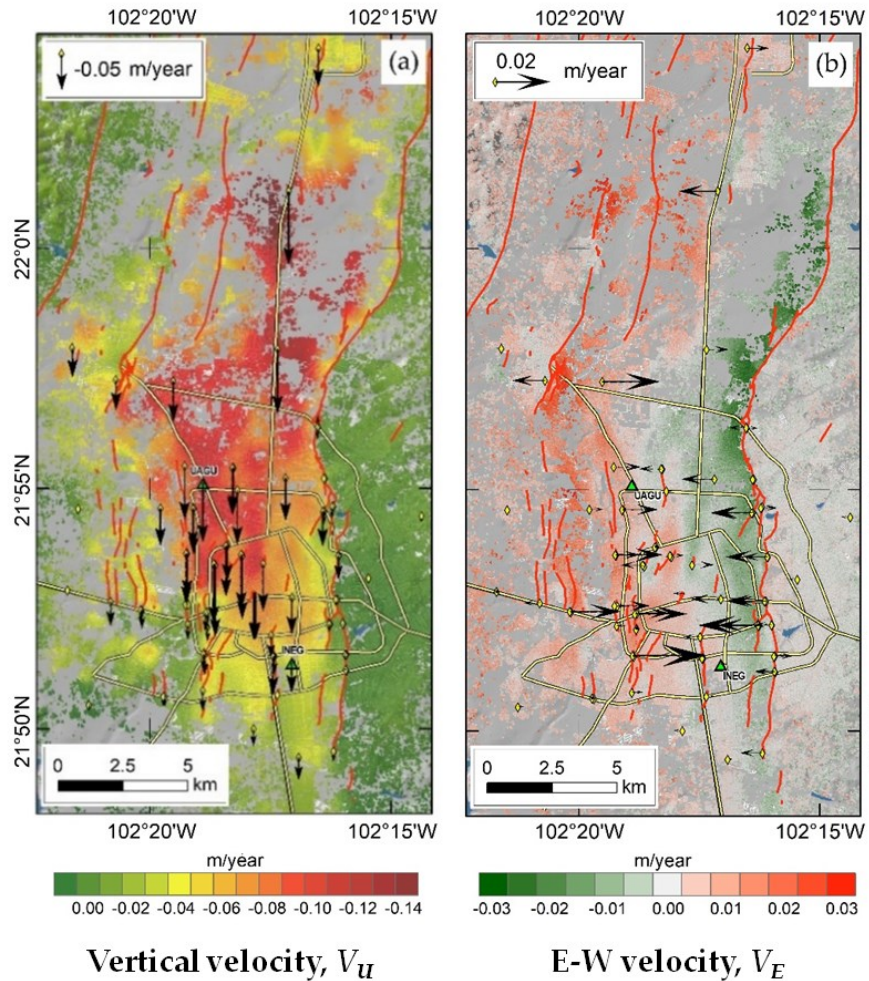


Accuracy assessment against GNSS and leveling

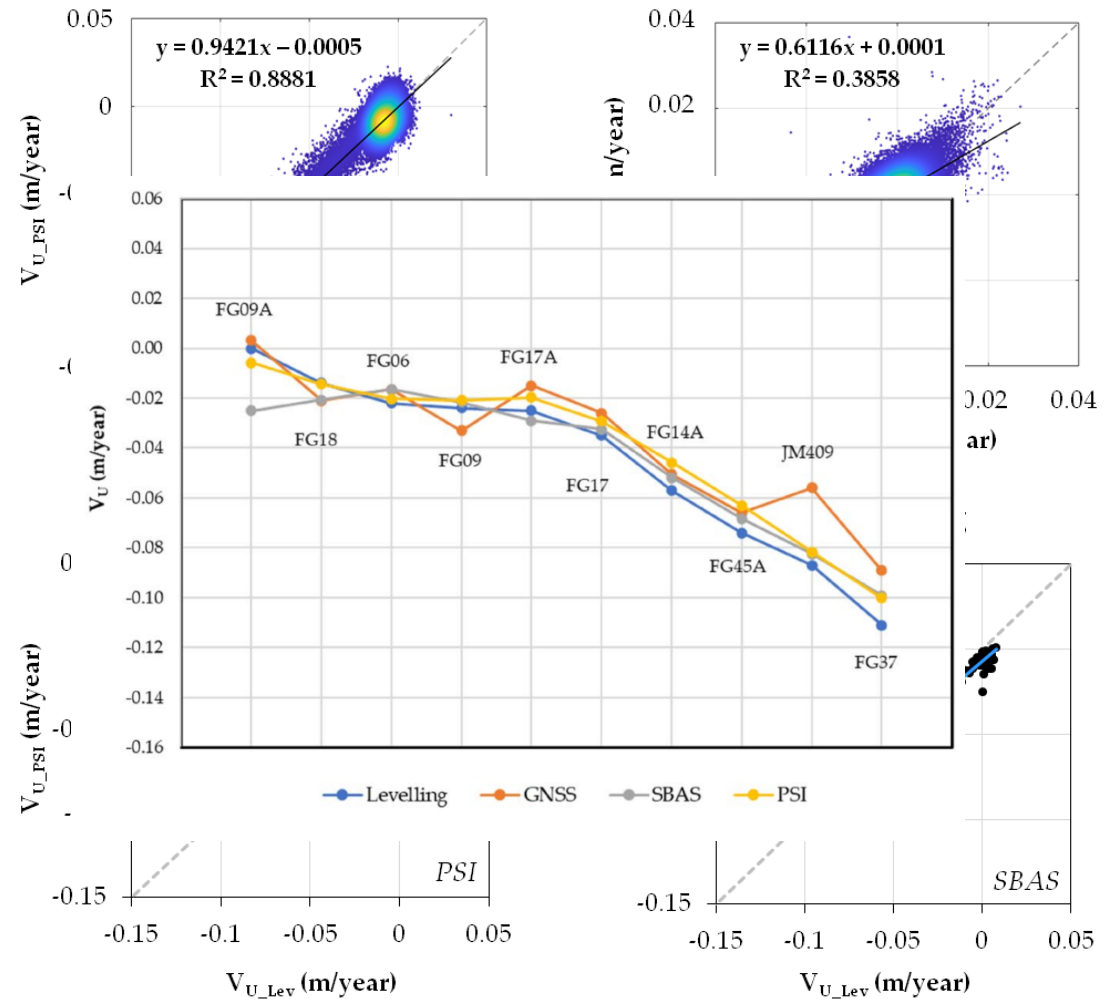


Inter-Comparison Between PSI and SBAS approaches

Displacement velocities from InSAR and GNSS



PSI-SBAS inter-comparison

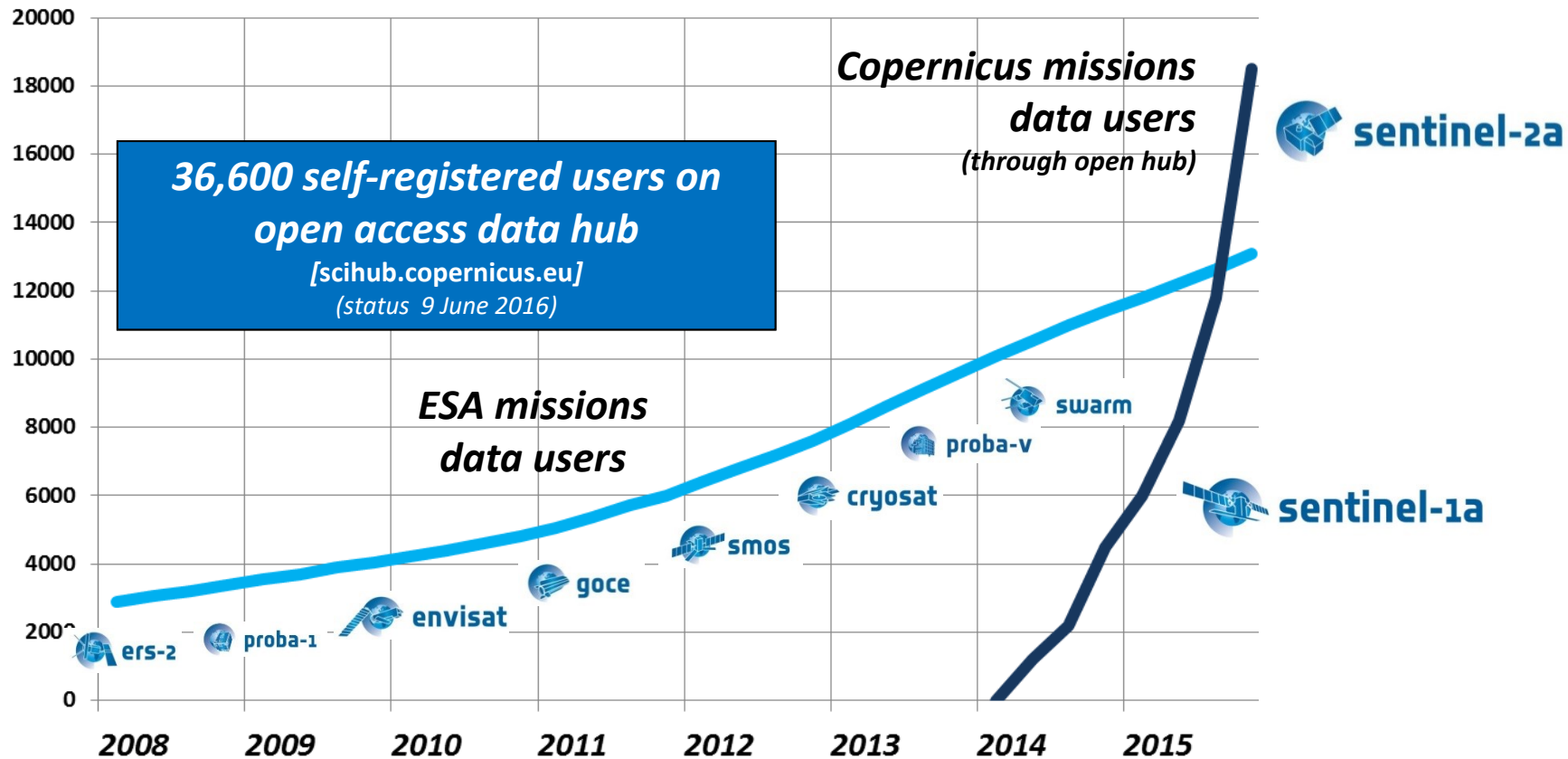


Sentinel Missions | Big Data Era

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***

Number of registered users



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)

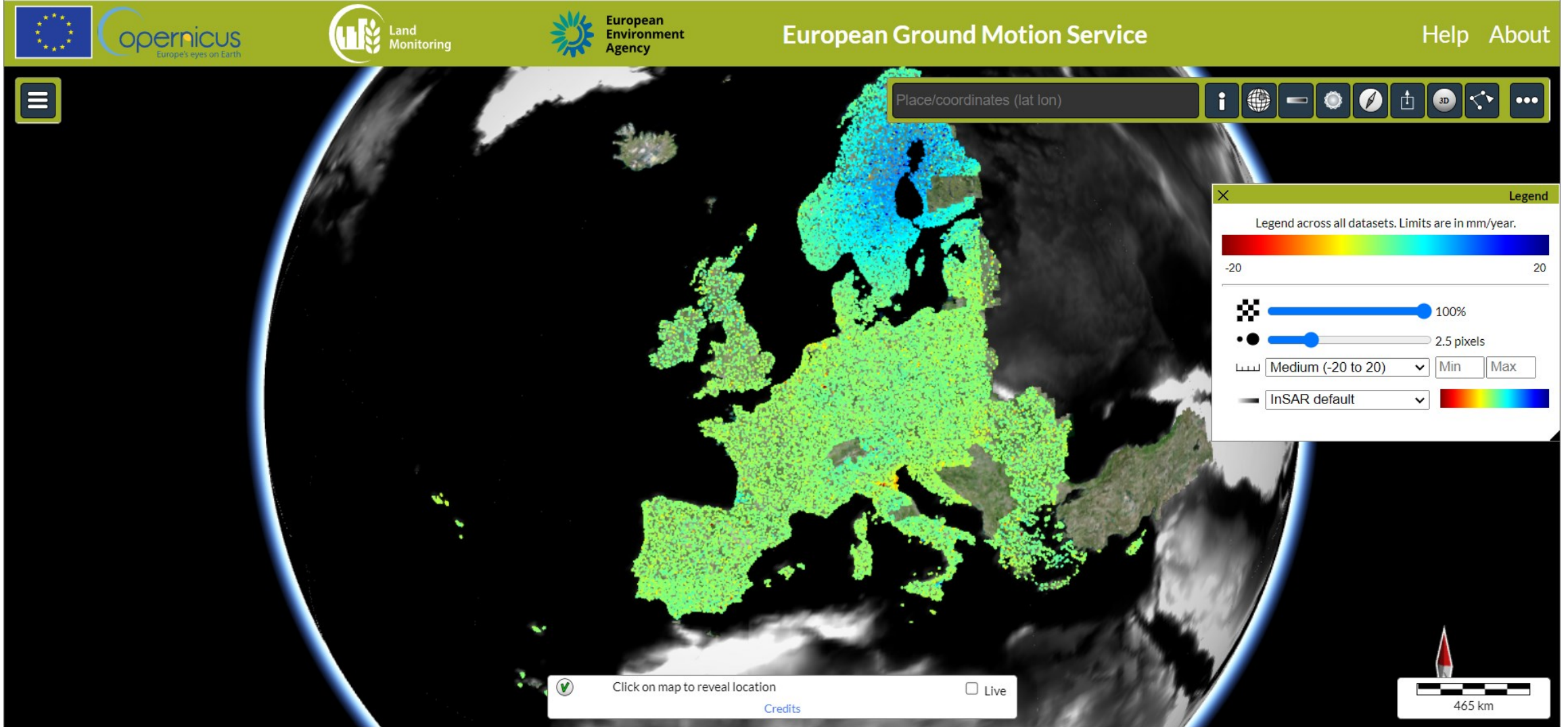
Analysis Ready Dataset

European Ground Motion Service (EGMS)

<https://egms.land.copernicus.eu>



European Environment Agency



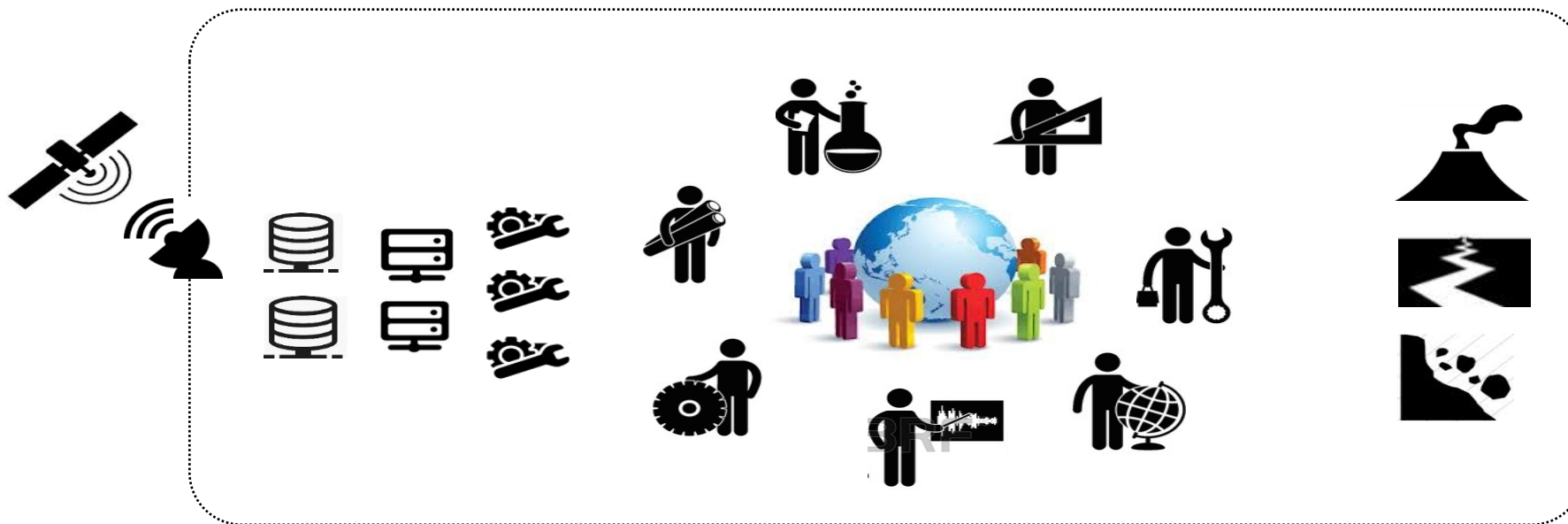
Thematic Exploitation Platforms | TEPs










Geohazards Exploitation Platform | GEP

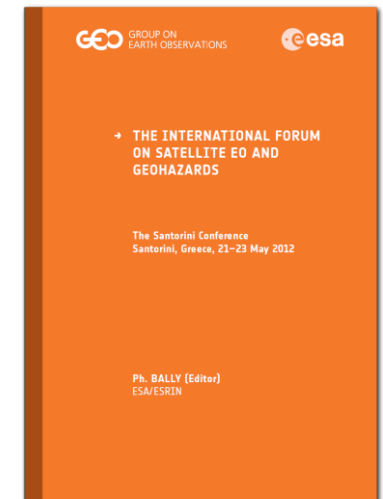
<https://geohazards-tep.eu>

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)

 thematic exploitation platform https://tep.eo.esa.int	 geohazards tep	 polar tep	 coastal tep
	 hydrology tep	 urban tep	 forestry tep

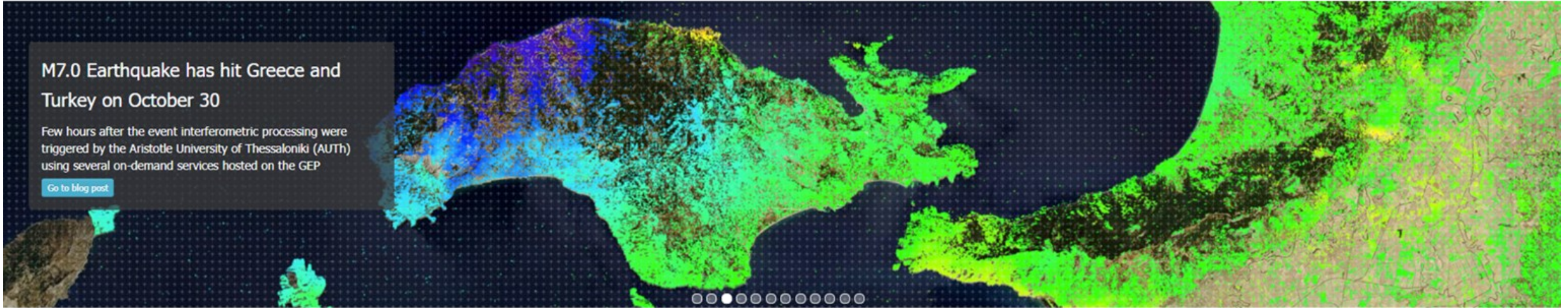


Geohazards Exploitation Platform | GEP

<https://geohazards-tep.eu>



[Home](#) [Workspace](#) [Web Store](#) [Background](#) [Observations & Measurements](#) [Stakeholders area](#)



Thematic Apps

Click to find out the existing thematic applications

[View apps](#)



Communities

The Geohazards platform gather activities from active groups of users

[View Communities](#)



Forum

Go to the Geohazards community forum

[View Forum](#)



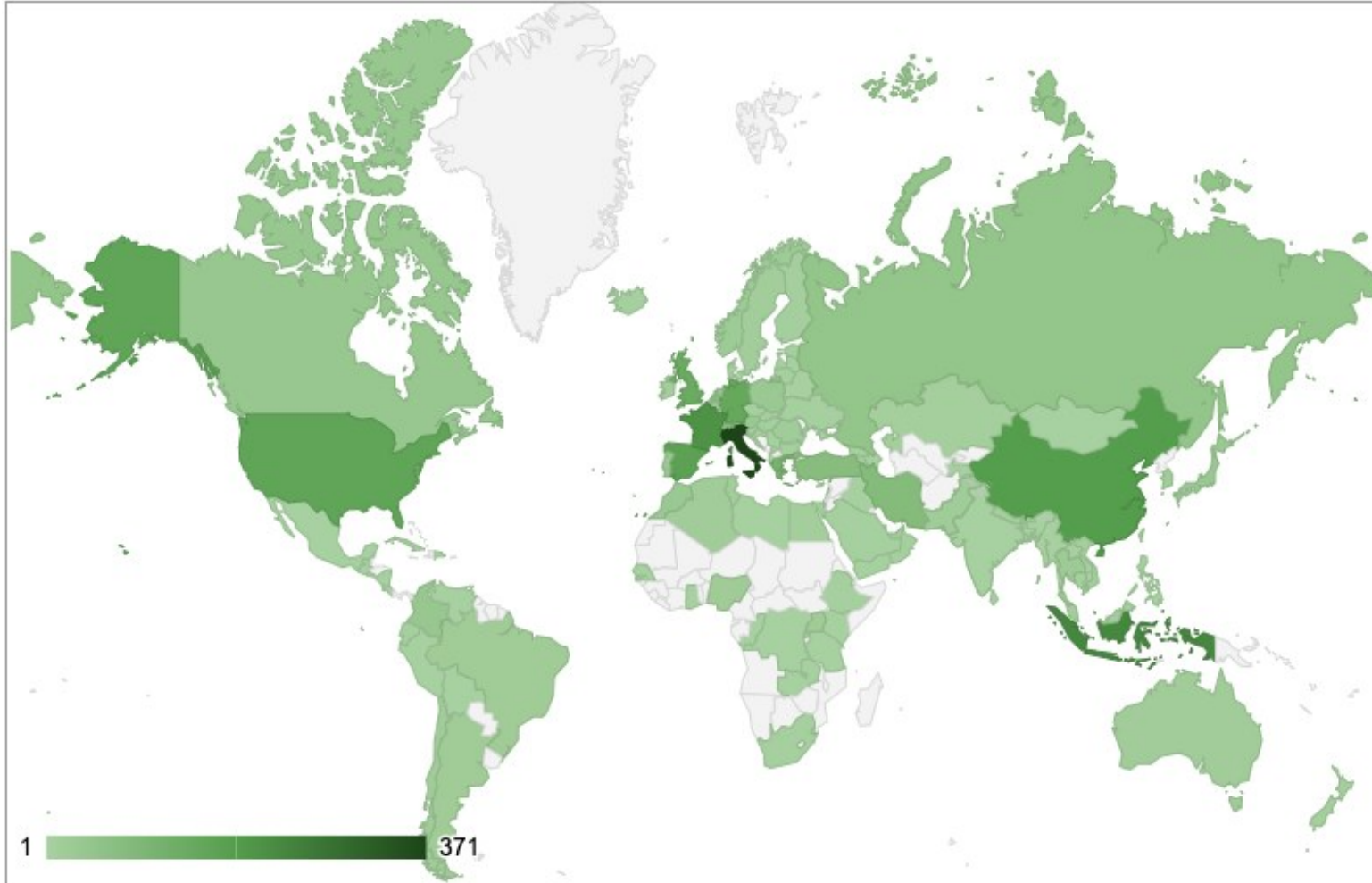
Analytics

Find out what is your usage of the platform

[View activities](#)

GEP | Users Uptake

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

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:

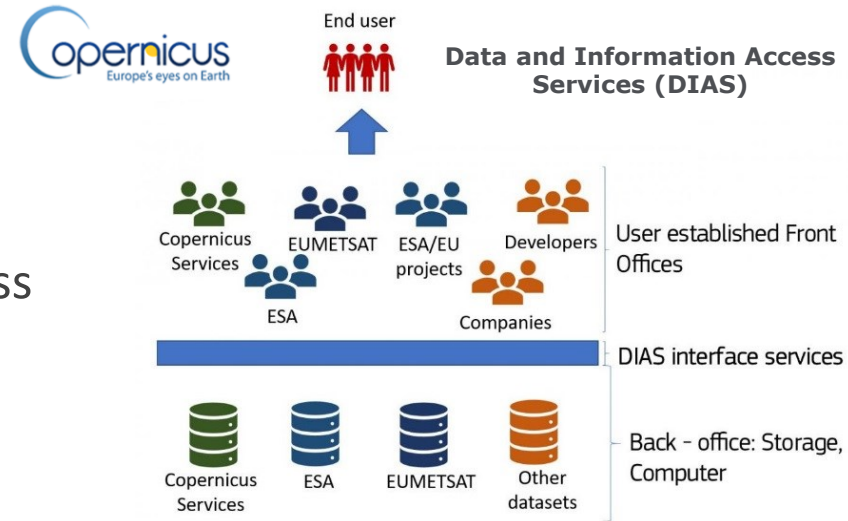
- **Sentinel-1A/B:** (RAW, SLC, GRD and OCN)
- **Sentinel-2:** (MSI L1C)
- **Sentinel-3:** (OLCI, SLSTR)

Catalogue synchronized with USGS EarthExplorer:

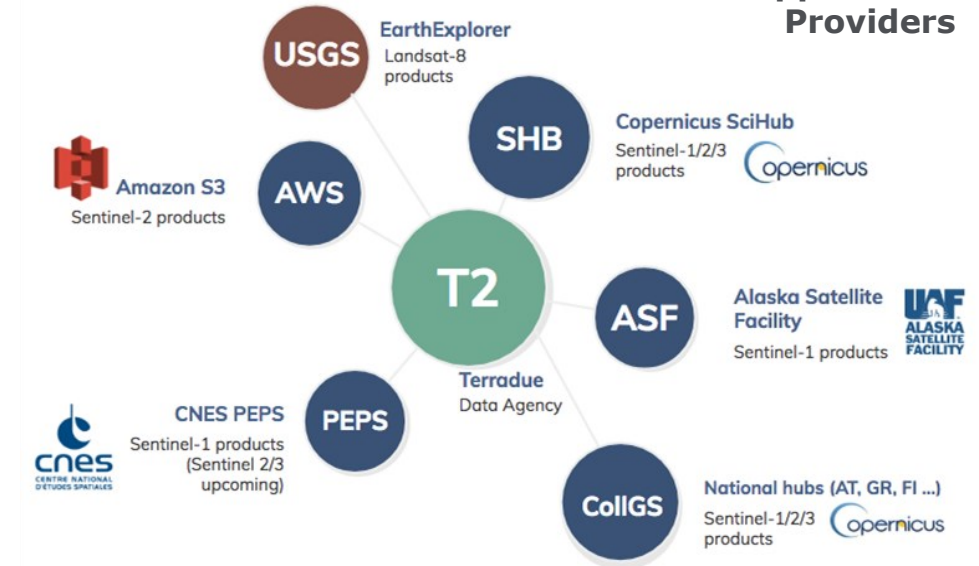
- **Landsat-8:** (OLI and TIRS)

Access to ESA heritage SAR missions:

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



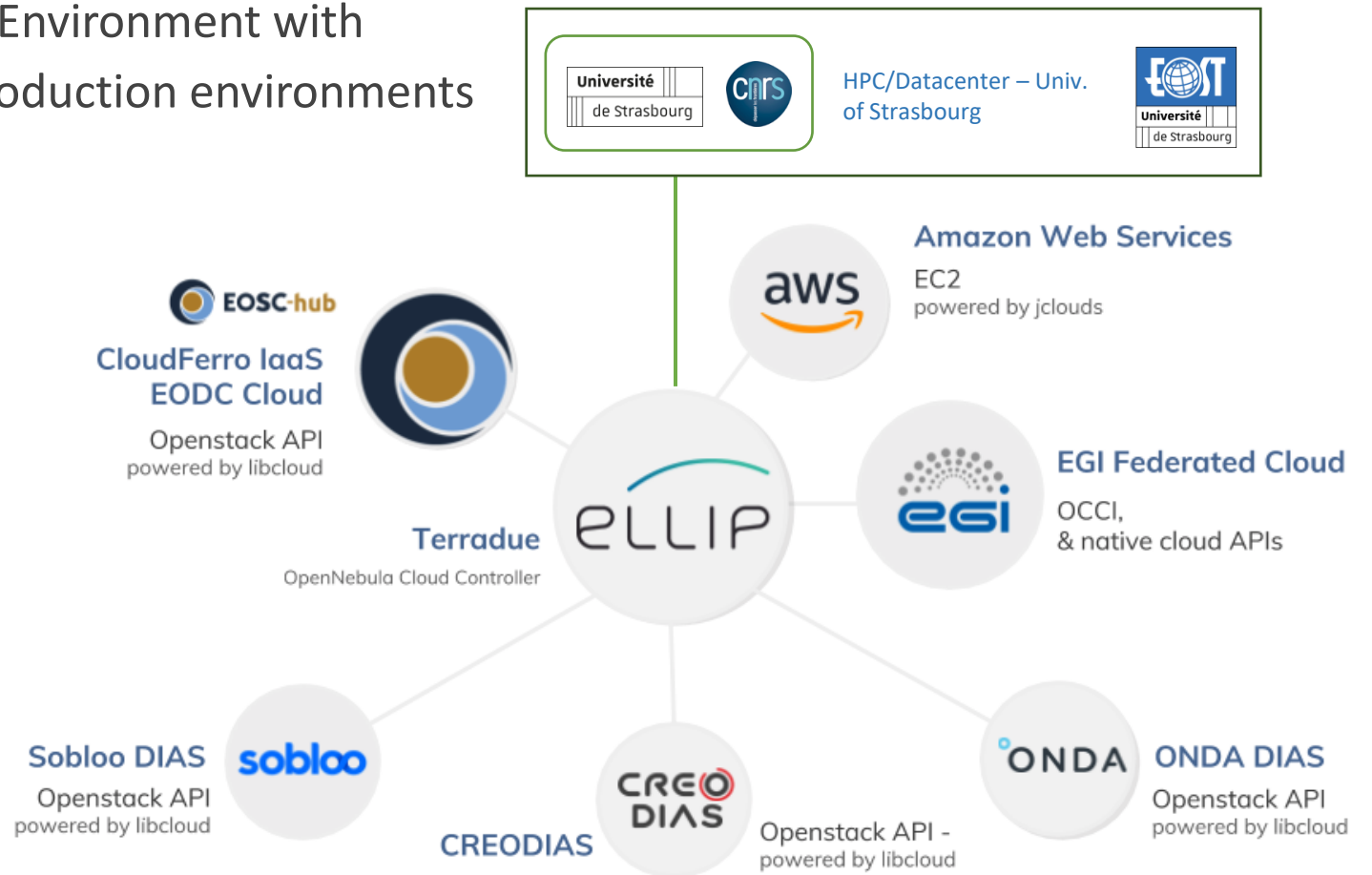
Supported Data Providers



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

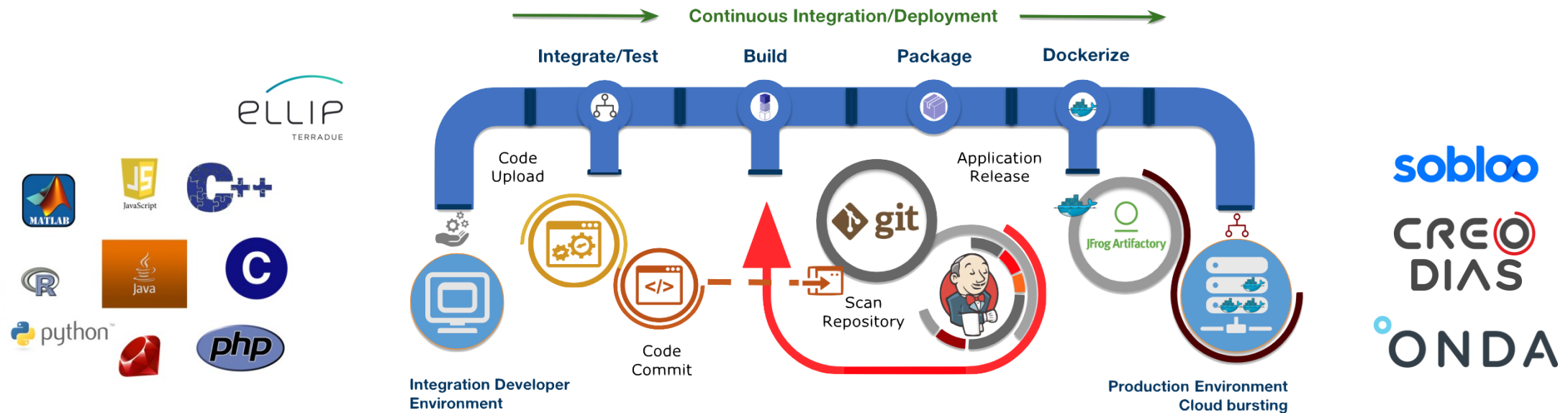


GEP | Application Integration

Applications developed in any programming language supported

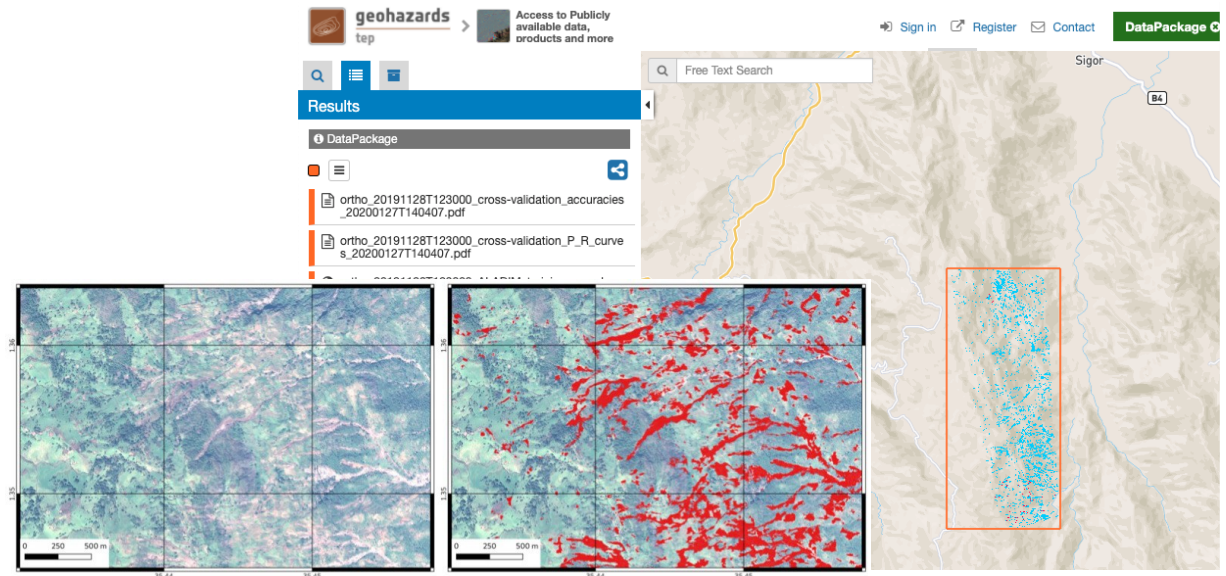
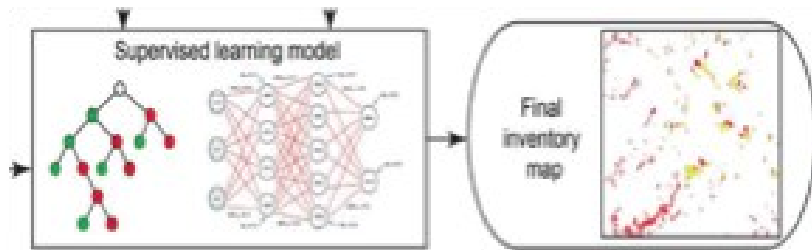
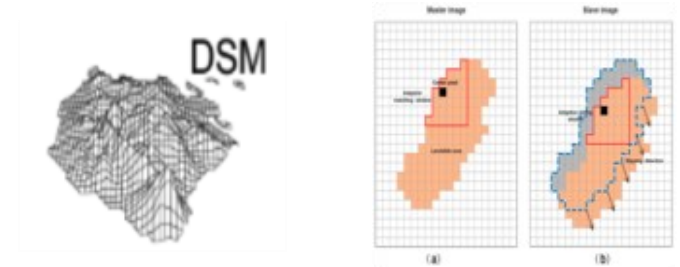
C/C++, Java, Python, Matlab and IDL

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



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



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

```

Define the catalogue endpoint to Sentinel-1:
In [14]: series = 'https://catalog.terradue.com/sentinel1/search'

Search for a post-event slave Sentinel-1 SLC product
Define the end of the time of interest and look for a post event Sentinel-1 SLC slave between the earthquake event date and up to six days after:
In [15]: slave_search_stop_date = (dateutil.parser.parse(events.earthquakes[eq_index].date) + timedelta(days=6)).isoformat()

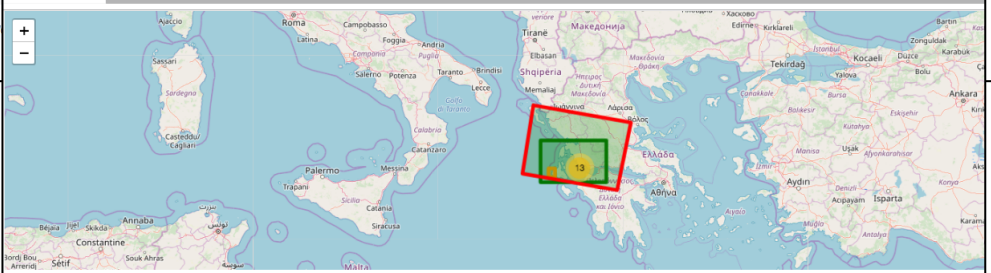
Build and submit the catalog search:
In [16]: search_params = dict(['geom', aoi_wkt),
                              ('start', events.earthquakes[eq_index].date),
                              ('stop', slave_search_stop_date),
                              ('pt', 'SLC')]

In [17]: slave_search = ciop.search(end_point=series,
                                   params=search_params,
                                   output_fields='self,productType,track,enclosure,identifier,wkt,startdate',
                                   model='EOP1')

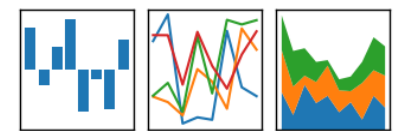
Create a geodataframe with all candidate slaves plot them:
In [18]: aoi = loads(aoi_wkt)
***
The geodataframe can now be accessed:
In [20]: slaves
Out[20]:
  aoi_intersec  contains  date
0  43.173406  False     2017-07-03T04:39:56.4681330Z https://store.terradue.com/
1  100.000000  True      2017-07-03T04:39:31.6411240Z https://store.terradue.com/
2  100.000000  True      2017-07-02T16:39:44.5117870Z https://store.terradue.com/
3  82.375592  False     2017-07-02T04:47:15.0173420Z https://store.terradue.com/
4  100.000000  True      2017-06-27T16:31:42.6303130Z https://store.terradue.com/

By moving the slider, the slave on the map will be updated and clicking on it will show its information:
In [22]: interact(f, x=widgets.IntSlider(min=0,max=len(slaves)-1,step=1,value=0));
x 0 1

Visually the best slave is S1A_IW_SLC__1SDV_20161018T163206_20161018T163233_013547_015AEB_712A.
We can also query the geodataframe to get the slave the best covers the area of interest:
In [23]: slave = slave_search[slaves['aoi_intersec'].idxmax()]
Here's the information about our post event slave Sentinel-1 SLC product:
In [24]: slave
Out[24]: {'enclosure': 'https://store.terradue.com/download/sentinel1/files/v1/S1A_IW_SLC__1SDV_20170703T043958_017302_01CE28_CF8A',
          'identifier': 'S1A_IW_SLC__1SDV_20170703T043958_017302_01CE28_CF8A',
          'productType': 'SLC',
          'self': 'https://catalog.terradue.com/sentinel1/search?format=atom&id=S1A_IW_SLC__1SDV_20170703T043958_017302_01CE28_CF8A',
          'startdate': '2017-07-03T04:39:31.6411240Z',
          'track': '13'}
    
```



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



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)

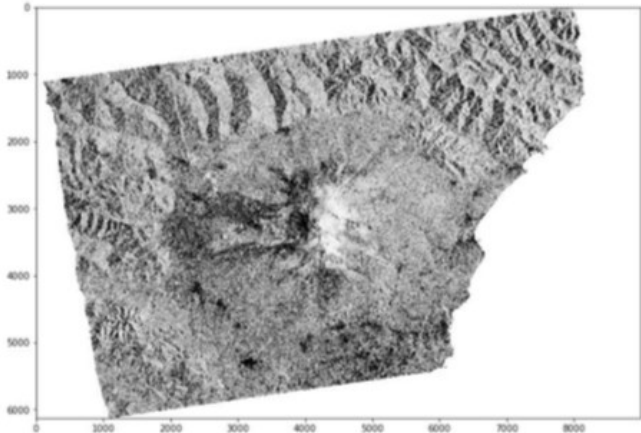
    band_data.shape = h, w

    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

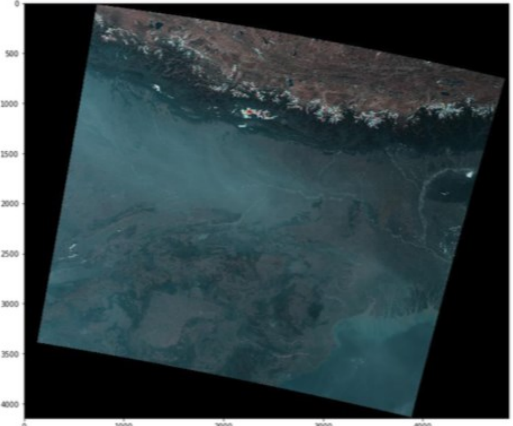
green_radiance_data = np.zeros(w * h, np.float32)
green_radiance.readPixels(0, 0, w, h, green_radiance_data)
green_radiance_data.shape = h, w

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)))

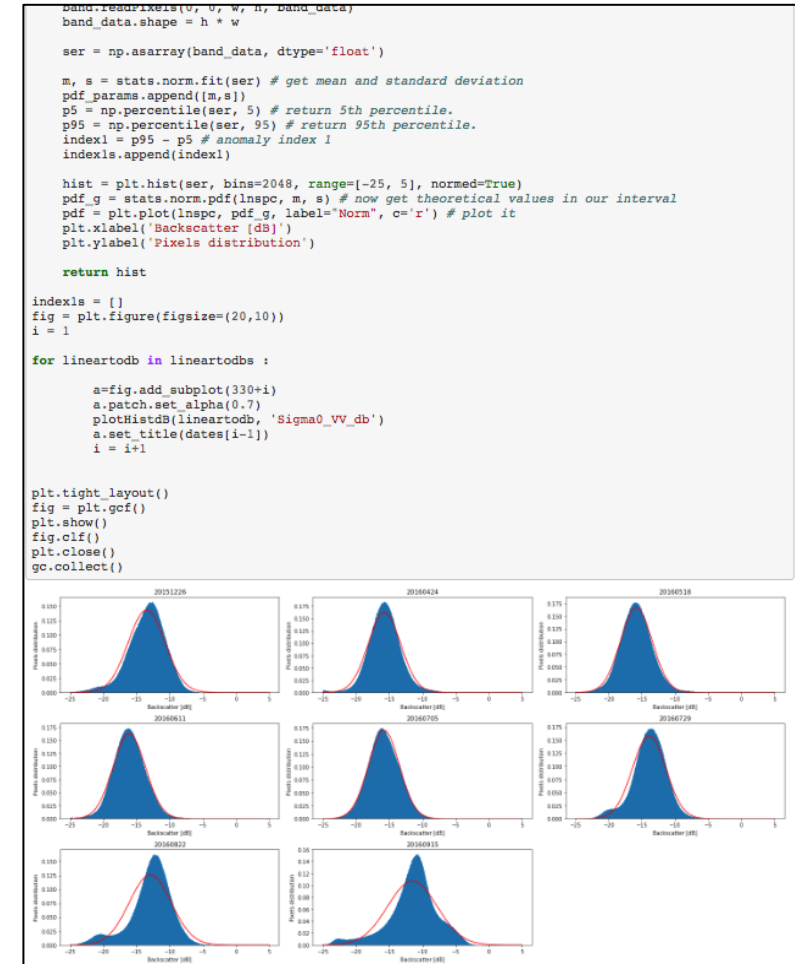
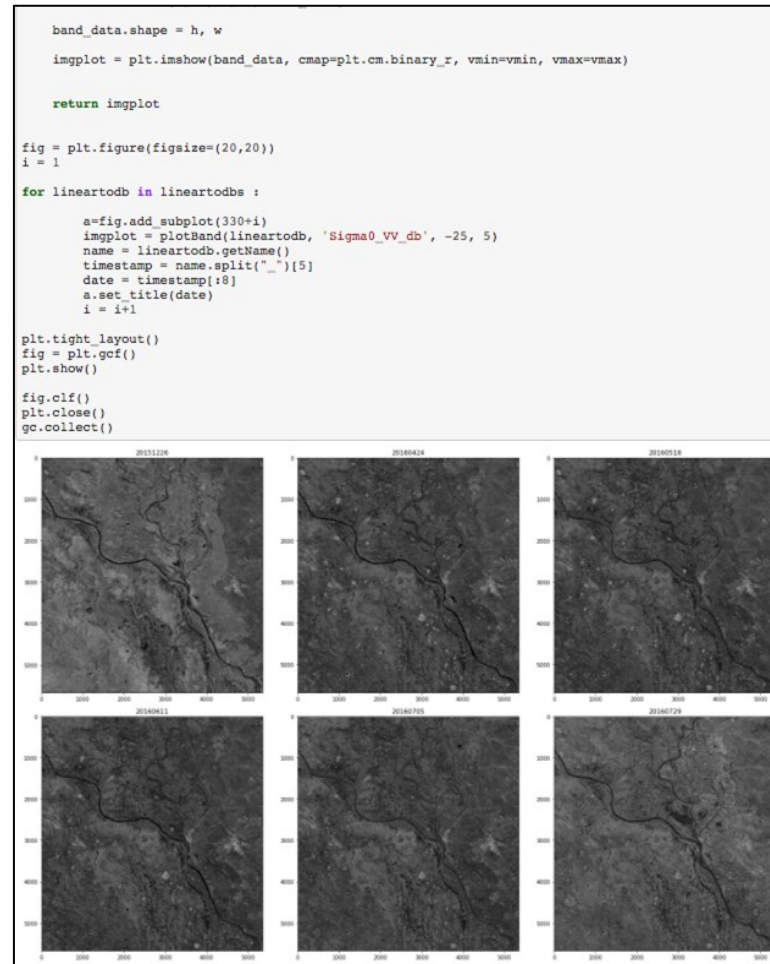
rgb_uint8 = np.dstack((red, green, blue)).astype(np.uint8)

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



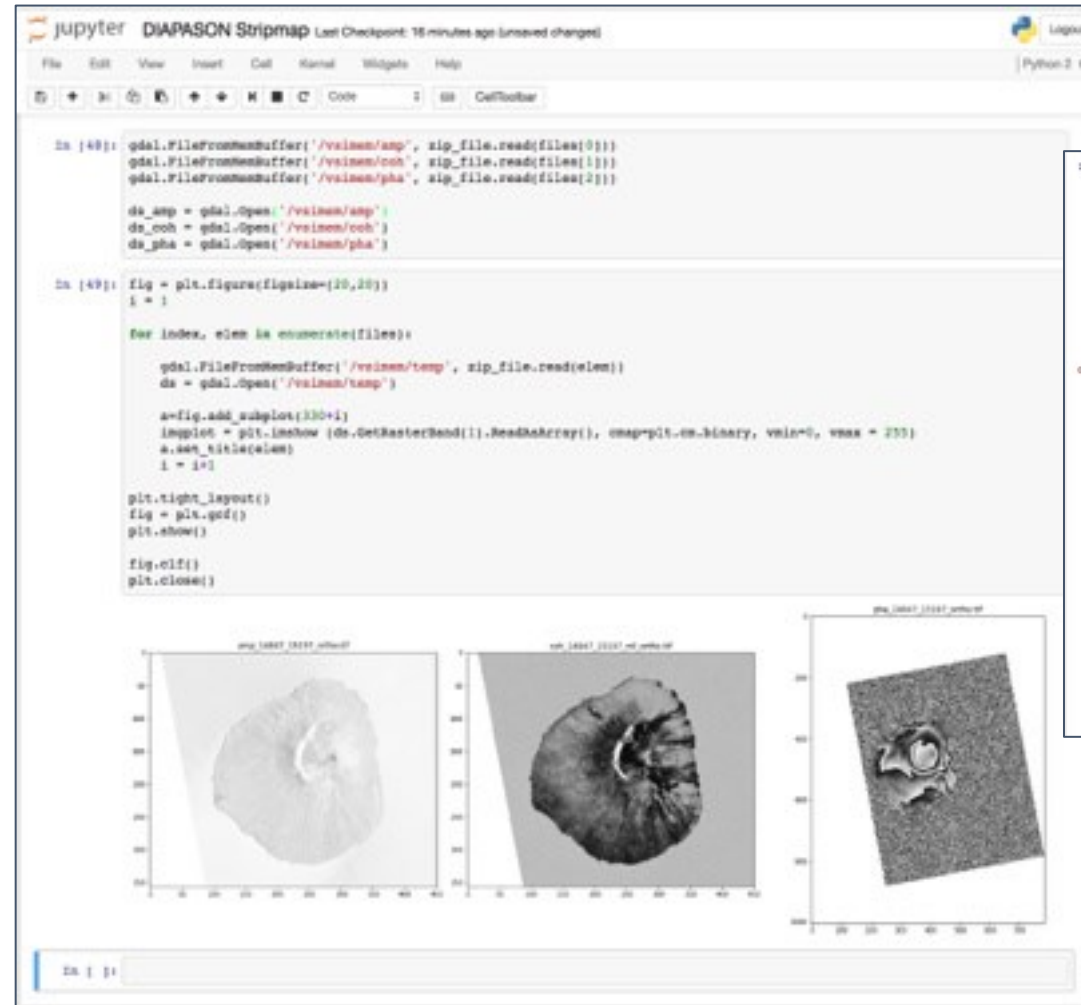
Notebook analysis of a stack of Sentinel-1 data

Backscatter profiles for reference image used in flood analysis



Invoking GEP services
from a notebook

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



```
In [48]: gdal.FileFromMemBuffer('/vsinem/amp', zip_file.read(files[0]))
gdal.FileFromMemBuffer('/vsinem/coh', zip_file.read(files[1]))
gdal.FileFromMemBuffer('/vsinem/pha', zip_file.read(files[2]))

ds_amp = gdal.Open('/vsinem/amp')
ds_coh = gdal.Open('/vsinem/coh')
ds_pha = gdal.Open('/vsinem/pha')

In [49]: fig = plt.figure(figsize=(20,20))
i = 1

for index, elem in enumerate(files):

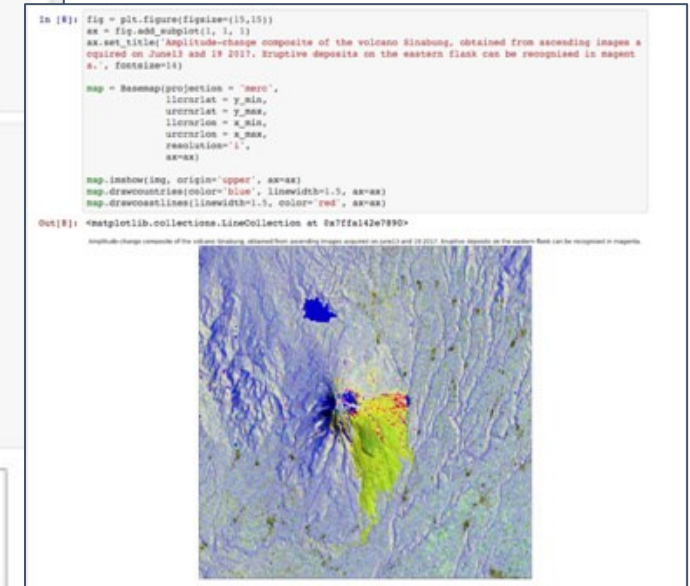
    gdal.FileFromMemBuffer('/vsinem/temp', zip_file.read(elem))
    ds = gdal.Open('/vsinem/temp')

    a=fig.add_subplot(330+i)
    imgplot = plt.imshow(ds.GetRasterBand(1).ReadAsArray(), cmap=plt.cm.binary, vmin=0, vmax = 255)
    a.set_title(elem)
    i = i+1

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

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

The notebook displays three subplots at the bottom, each showing a different satellite image of a volcano. The first subplot is titled 'amp 16857 2017 07h00', the second 'coh 16857 2017 07 00h00', and the third 'pha 16857 2017 07h00'. Each plot shows a grayscale image of a volcanic crater with a central vent.



```
In [8]: fig = plt.figure(figsize=(15,15))
ax = fig.add_subplot(1, 1, 1)
ax.set_title('Amplitude-change composite of the volcano Sinabung, obtained from ascending images aquired on June13 and 19 2017. Eruptive deposits on the eastern flank can be recognized in magent a.', fontsize=14)

map = Basemap(projection = "merc",
              llcrnrlat = y_min,
              urcrnrlat = y_max,
              llcrnrlon = x_min,
              urcrnrlon = x_max,
              resolution='1',
              ax=ax)

map.imshow(img, origin='upper', ax=ax)
map.drawcountries(color='blue', linewidth=1.5, ax=ax)
map.drawcoastlines(linewidth=1.5, color='red', ax=ax)

Out[8]: <matplotlib.collections.LineCollection at 0x7f6a142e7890>
```

The notebook displays a satellite image of a volcano with a color scale. The image shows a central vent and surrounding terrain. The color scale ranges from blue (low amplitude change) to red (high amplitude change). The title indicates that the image is an amplitude-change composite of the volcano Sinabung, obtained from ascending images acquired on June 13 and 19, 2017. Eruptive deposits on the eastern flank can be recognized in magenta.

Geohazards Exploitation Platform | GEP

<https://geohazards-tep.eu>



geohazards tep Main area

EO Data - EO-based products - SNAPPING IFG monitoring - EGMS - Auxiliary Data - Community - Private - Upload Data

Free Text Search

Results

Context EOData/Sentinel1

Result for OpenSearch query over type * in index sentinel1

- S1A_IW_SLC__1SDV_20240704T042444_20240704T042511_054606_06A59C_7D6A.SAFE
- S1A_IW_GRDH_1SDV_20240704T042445_20240704T042510_054606_06A59C_06C3.SAFE
- S1A_IW_SLC__1SDV_20240704T042419_20240704T042446_054606_06A59C_E6B5.SAFE
- S1A_IW_SLC__1SDV_20240703T162317_20240703T162344_054599_06A558_4A79.SAFE
- S1A_IW_GRDH_1SDV_20240703T162318_20240703T162343_054599_06A558_6AA7.SAFE
- S1A_IW_SLC__1SDV_20240627T043242_20240627T043309_054504_06A208_4D06.SAFE
- S1A_IW_GRDH_1SDV_20240627T043243_20240627T043308_054504_06A208_C8C6.SAFE
- S1A_IW_SLC__1SDV_20240622T042445_20240622T042512_054431_069F82_B624.SAFE
- S1A_IW_GRDH_1SDV_20240622T042446_20240622T042511_054431_069F82_3D18.SAFE
- S1A_IW_SLC__1SDV_20240622T042420_20240622T042447_054431_069F82_7AC0.SAFE
- S1A_IW_SLC__1SDV_20240621T162317_20240621T162344_054424_069F42_FE09.SAFE
- S1A_IW_GRDH_1SDV_20240621T162318_20240621T162343_054424_069F42_B20A.SAFE
- S1A_IW_SLC__1SDV_20240615T043243_20240615T043310_054329_0698F5_22AB.SAFE
- S1A_IW_GRDH_1SDV_20240615T043244_20240615T043309_054329_0698F5_AC09.SAFE
- S1A_IW_SLC__1SDV_20240610T042445_20240610T042512_054256_069976_6D9C.SAFE
- S1A_IW_GRDH_1SDV_20240610T042446_20240610T042511_054256_069976_B4EE.SAFE
- S1A_IW_SLC__1SDV_20240610T042420_20240610T042447_054256_069976_270D.SAFE
- S1A_IW_SLC__1SDV_20240609T162318_20240609T162345_054249_069938_5957.SAFE
- S1A_IW_GRDH_1SDV_20240609T162319_20240609T162344_054249_069938_1774.SAFE
- S1A_IW_SLC__1SDV_20240603T043244_20240603T043311_054154_0695EA_9B5B.SAFE
- S1A_IW_GRDH_1SDV_20240603T043245_20240603T043310_054154_0695EA_3E87.SAFE
- S1A_IW_SLC__1SDV_20240529T042446_20240529T042513_054081_069368_3790.SAFE
- S1A_IW_GRDH_1SDV_20240529T042447_20240529T042512_054081_069368_OC97.SAFE
- S1A_IW_SLC__1SDV_20240529T042421_20240529T042448_054081_069368_B284.SAFE
- S1A_IW_SLC__1SDV_20240528T162319_20240528T162345_054074_069329_41E8.SAFE
- S1A_IW_GRDH_1SDV_20240528T162319_20240528T162344_054074_069329_B211.SAFE
- S1A_IW_SLC__1SDV_20240522T043243_20240522T043310_053979_068FD9_0FD2.SAFE

Total results: 3443

2014-10-04 2024-07-07

Lon: 27.944 Lat: 38.677 - Zoom: 8

Processing Services

Services Jobs

Filter by text

- Vit3oo
- K-Means
- TimeSAT basic
- TimeSAT advanced
- SNAPPING PSI 3D decompos...
- SNAPPING PSI Mad
- SNAPPING PSI Full
- SNAPPING PSI automatic
- SNAPPING IFG
- SNAPPING 3D decompos...
- S2-Flowline
- SAR Temporal Statistics SI
- SAR-Callib
- SAR-Change
- OPT-Index
- OPT-Calib
- PAN-Sharp
- NDVI-CD
- COMBI
- MOSAIC
- Optical Products Calibration
- Optical Pan Sharpened Im...
- NDVI Change Detection
- Multi-Sensor Band Compo...
- mosaic
- IRMAD
- HOTSPOT
- GMTSSAR Sentinel-1
- GDM-OPT SLIDE
- GDM-OPT-ICE
- GDM-OPT-ETQ
- Flow-R
- Filter or Vectorize Discrete...
- DSM-OPT
- DInSAR Stripmap
- DInSAR Displacement Ma...
- DIAPASON Sentinel-1
- SAR-COIN
- STACK
- CVA
- DInSAR Displacement Ma...
- DIAPASON InSAR Sentin...
- Coherence and Intensity C...
- Co-located stacking avo
- Change Vector Analysis (C...
- BAS
- ALADIM-VHR
- ALADIM-HR
- COMBI-Plus
- Burned Area Severity
- ALADIM-VHR
- ALADIM-HR
- Advanced Multi-Sensor Ba...

Basic	Essentials	Advanced	Flex
<p>Access to Data screening services</p> <p>Publisher credentials</p> <p>Jupyter Notebook workspace</p> <p>Result data persisted (*)</p> <p>Professional support</p> <p>Account management</p> <p>Monthly subscription (+) per team (**)</p> <p>€150 includes €50 pay-per-use monthly voucher</p>	<p>Access to Event response services</p> <p>Publisher credentials</p> <p>Jupyter Notebook workspace</p> <p>Result data persisted (*)</p> <p>Professional support</p> <p>Account management</p> <p>Monthly subscription (+) per team (**)</p> <p>€250 includes €150 pay-per-use monthly voucher</p>	<p>Access to Area monitoring services</p> <p>Publisher credentials</p> <p>Jupyter Notebook workspace</p> <p>Result data persisted (*)</p> <p>Professional support</p> <p>Account management</p> <p>Monthly subscription (+) per team (**)</p> <p>€550 includes €450 pay-per-use monthly voucher</p>	<p>Accessible via sponsoring institutions</p>

COMBI	RASTER	S-1 GRD RGB composite	+	ALADIM	ALADIM-VHR	COIN	+	FASTVEL	GDM-OPT ICE	GDM-OPT SLIDE
S-2 Burned Area Analysis	S-2 L1C and L2A RGB composite	S-3 Active Fire Detection		DIAPASON Stripmap	DIAPASON Sentinel-1	SNAPP IFG		SNAPP IFG	SNAPPING PSI	SNAPPING PSI
S-3 OLCI composites	SETAP			GMTSSAR Stripmap	SNAC	SNAP CSK DInSAR		SNAPPING PSI		
				SNAP InSAR	STEMP S-2					































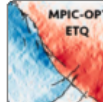










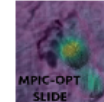



per-use budget for running processing jobs

subscription end

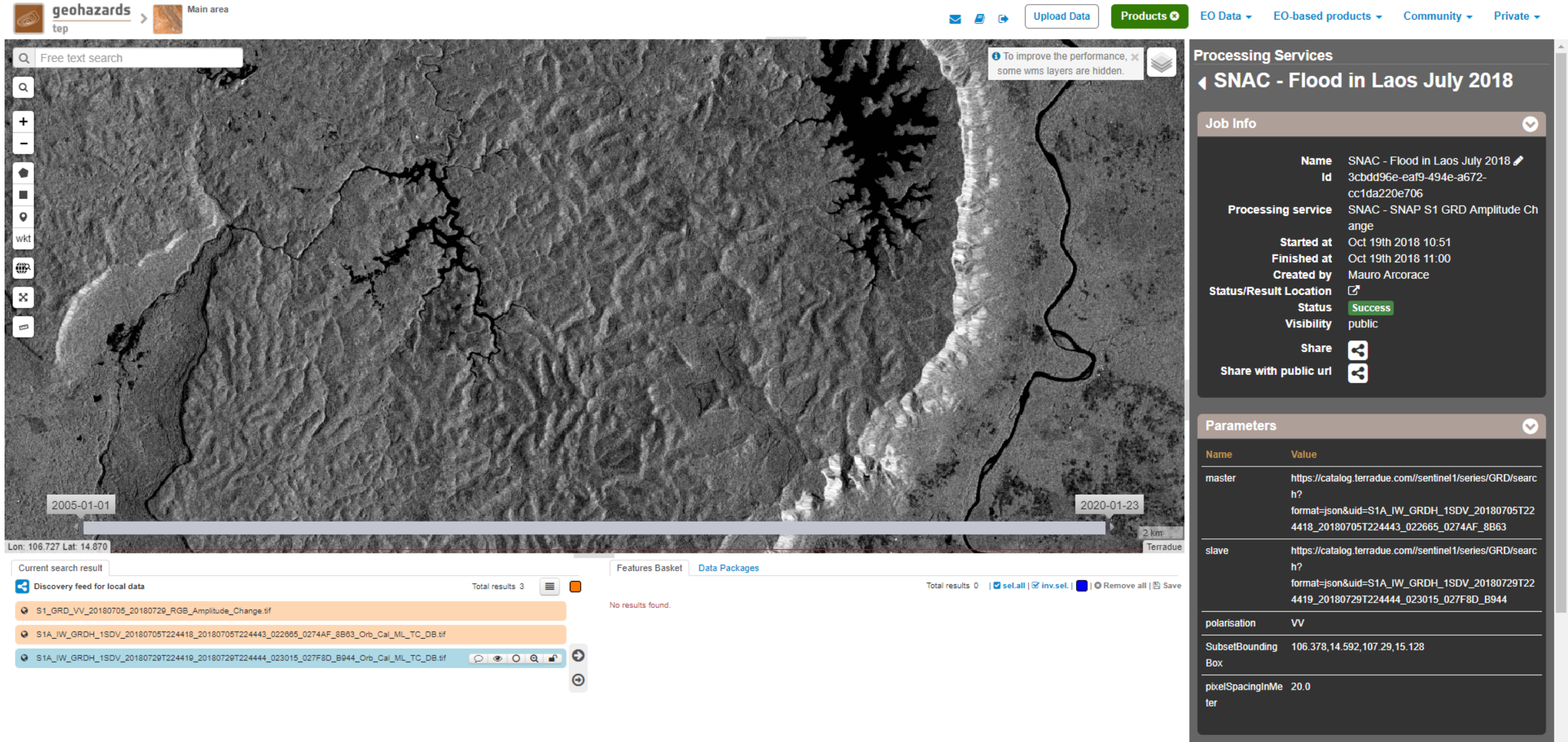
ry, up to 5 users for research labs, up to 20 students for universities and training sessions

services ("as of April 2023") are described [here](#).

GEP Hosted Processing Services

Seismic	Volcanoes	Landslides	Subsidence	Floods	Fire
 	 				
 	 				
 	 				
					
					
	  	 			 

Examples of GEP Services | SNAC (Floods in Laos)



Processing Services

SNAC - Flood in Laos July 2018

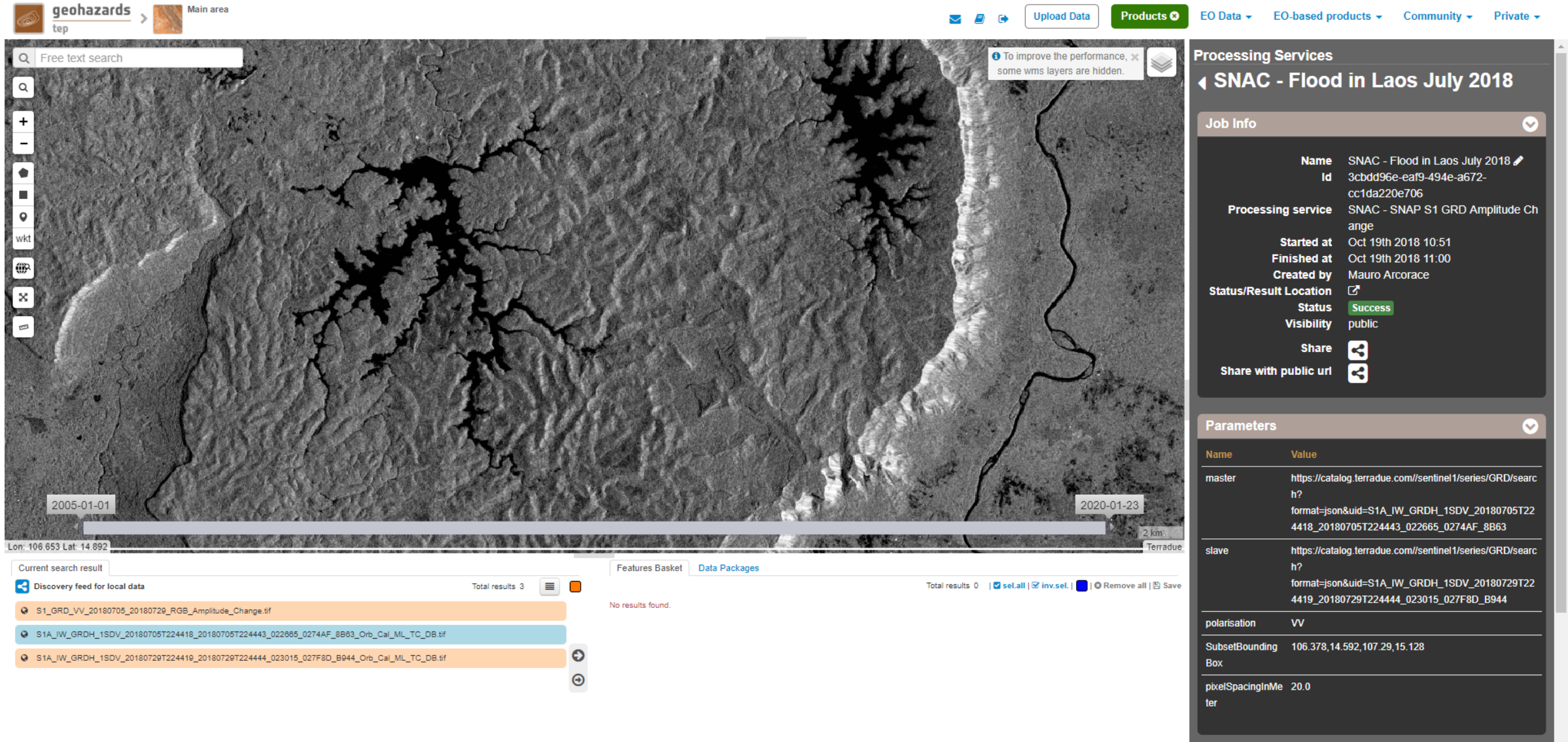
Job Info

Name	SNAC - Flood in Laos July 2018
Id	3cbdd96e-eaf9-494e-a672-cc1da220e706
Processing service	SNAC - SNAP S1 GRD Amplitude Change
Started at	Oct 19th 2018 10:51
Finished at	Oct 19th 2018 11:00
Created by	Mauro Arcorace
Status/Result Location	📄
Status	Success
Visibility	public
Share	🔗
Share with public url	🔗

Parameters

Name	Value
master	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63
slave	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180729T224419_20180729T224444_023015_027F8D_B944
polarisation	VV
SubsetBounding Box	106.378,14.592,107.29,15.128
pixelSpacingInMeter	20.0

Examples of GEP Services | SNAC (Floods in Laos)



Processing Services

SNAC - Flood in Laos July 2018

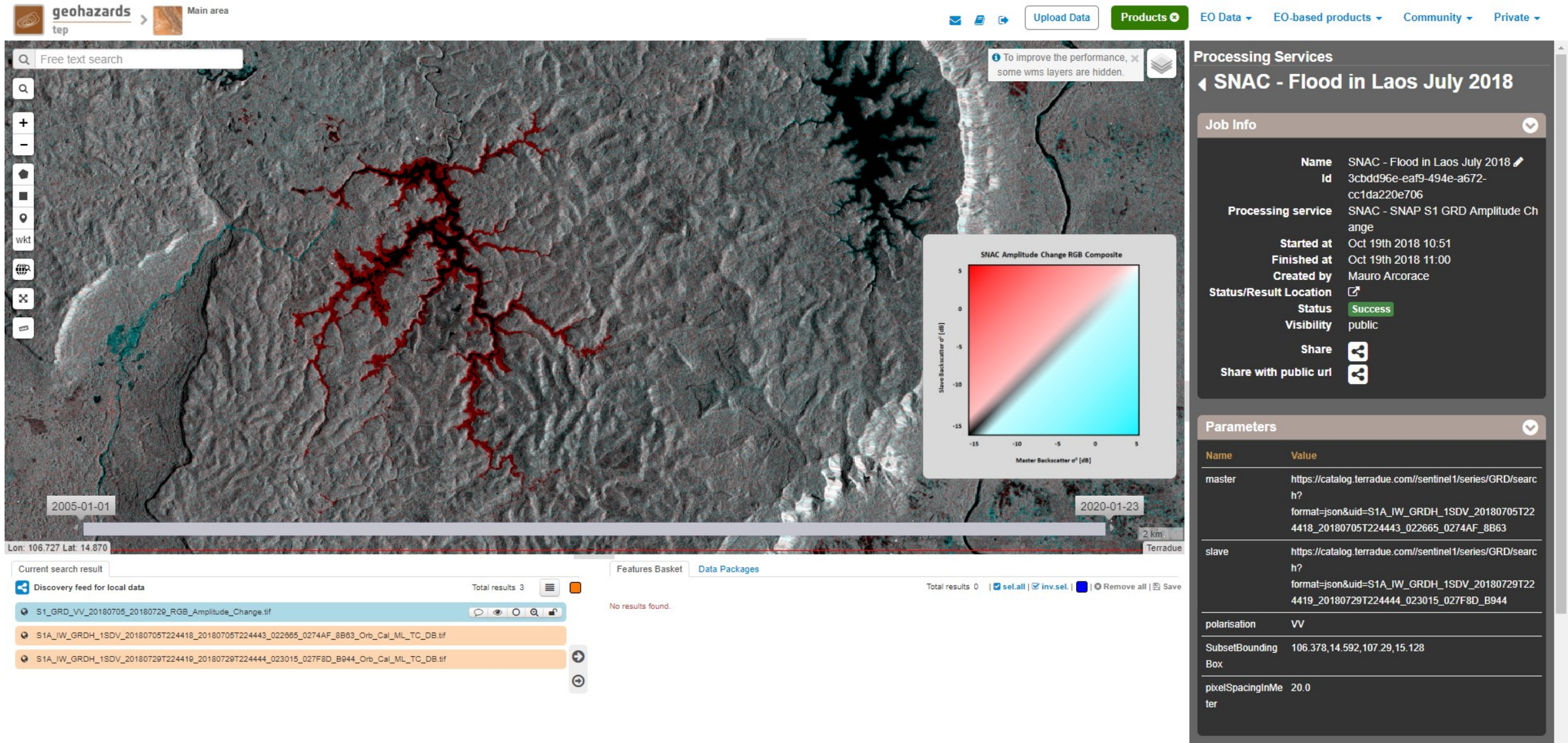
Job Info

Name	SNAC - Flood in Laos July 2018
Id	3cbdd96e-eaf9-494e-a672-cc1da220e706
Processing service	SNAC - SNAP S1 GRD Amplitude Change
Started at	Oct 19th 2018 10:51
Finished at	Oct 19th 2018 11:00
Created by	Mauro Arcorace
Status/Result Location	📄
Status	Success
Visibility	public
Share	🔗
Share with public url	🔗

Parameters

Name	Value
master	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63_Orb_Cal_ML_TC_DB.tif
slave	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180729T224419_20180729T224444_023015_027F8D_B944_Orb_Cal_ML_TC_DB.tif
polarisation	VV
SubsetBounding Box	106.378,14.592,107.29,15.128
pixelSpacingInMeter	20.0

Examples of GEP Services | SNAC (Floods in Laos)



The screenshot displays the geohazards tep web interface. The main map shows a grayscale satellite image of a region in Laos, with a red-colored area indicating a flood. A legend titled "SNAC Amplitude Change RGB Composite" is overlaid on the map, showing a color scale from dark blue (-15 dB) to red (5 dB). The interface includes a search bar, navigation tools, and a processing service panel on the right.

Processing Services
SNAC - Flood in Laos July 2018


Job Info

Name	SNAC - Flood in Laos July 2018
Id	3cbdd96e-eaf9-494e-a672-cc1da220e706
Processing service	SNAC - SNAP S1 GRD Amplitude Change
Started at	Oct 19th 2018 10:51
Finished at	Oct 19th 2018 11:00
Created by	Mauro Arcorace
Status/Result Location	Success
Status	Success
Visibility	public
Share	[Share icon]
Share with public url	[Share icon]

Parameters

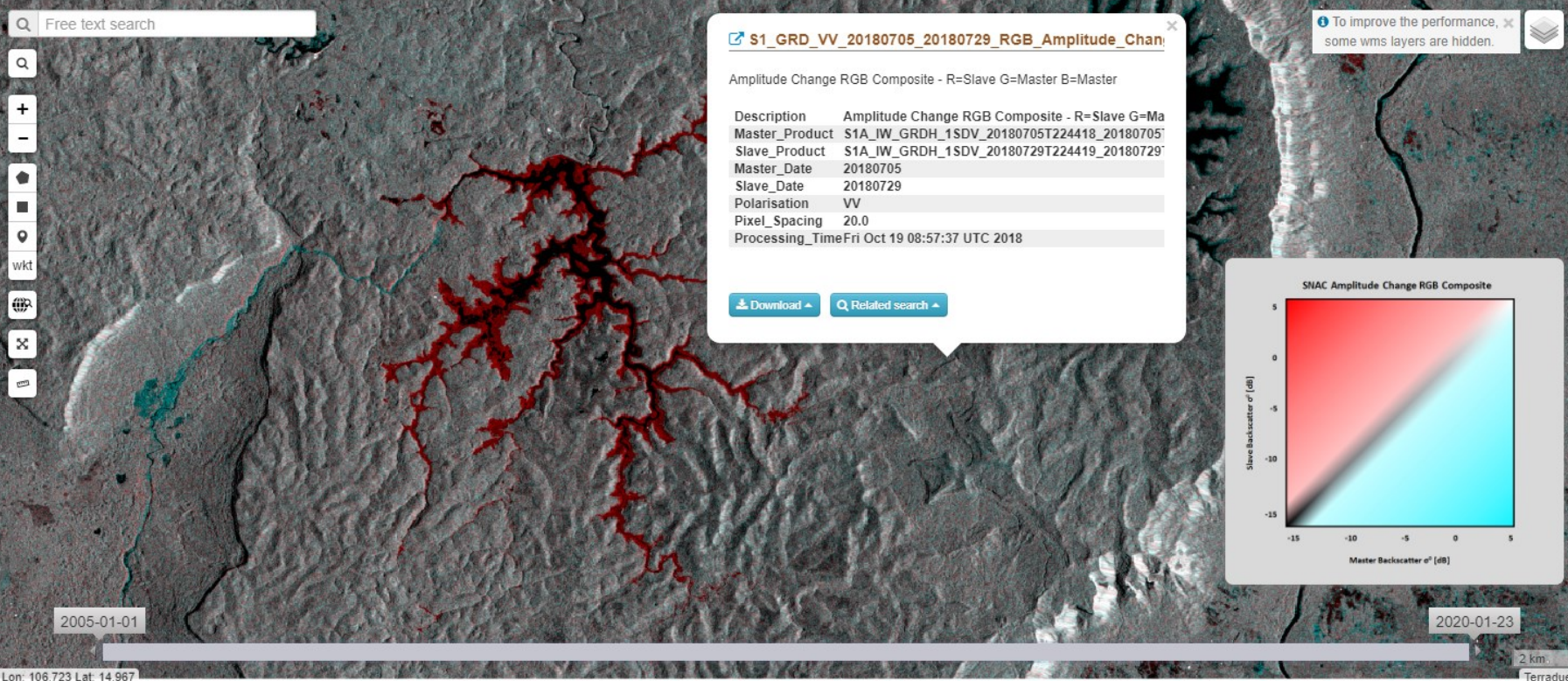
Name	Value
master	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63_Orb_Cal_ML_TC_DB.tif
slave	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180729T224444_023015_027F8D_B944_Orb_Cal_ML_TC_DB.tif
polarisation	VV
SubsetBounding Box	106.378,14.592,107.29,15.128
pixelSpacingInMeter	20.0

Examples of GEP Services | SNAC (Floods in Laos)


Main area

Upload Data
Products
EO Data
EO-based products
Community
Private

To improve the performance, some wms layers are hidden.

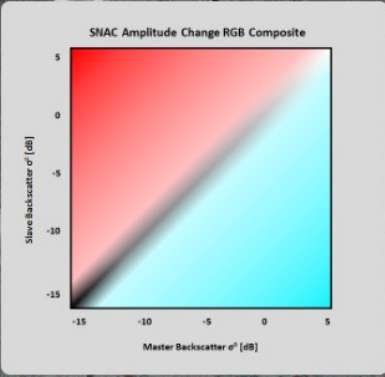


S1_GRD_VV_20180705_20180729_RGB_Amplitude_Change

Amplitude Change RGB Composite - R=Slave G=Master B=Master

Description	Amplitude Change RGB Composite - R=Slave G=Master B=Master
Master_Product	S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63_Orb_Cal_ML_TC_DB.tif
Slave_Product	S1A_IW_GRDH_1SDV_20180729T224419_20180729T224444_023015_027F8D_B944_Orb_Cal_ML_TC_DB.tif
Master_Date	20180705
Slave_Date	20180729
Polarisation	VV
Pixel_Spacing	20.0
Processing_Time	Fri Oct 19 08:57:37 UTC 2018

Download Related search



SNAC Amplitude Change RGB Composite

Slave Backscatter⁰ [dB]

Master Backscatter⁰ [dB]

Processing Services

SNAC - Flood in Laos July 2018

Job Info

Name	SNAC - Flood in Laos July 2018
Id	3cbdd96e-eaf9-494e-a672-cc1da220e706
Processing service	SNAC - SNAP S1 GRD Amplitude Change
Started at	Oct 19th 2018 10:51
Finished at	Oct 19th 2018 11:00
Created by	Mauro Arcorace
Status/Result Location	Success
Status	Success
Visibility	public
Share	Share icons
Share with public url	Share icon

Parameters

Name	Value
master	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63
slave	https://catalog.terradue.com/sentinel1/series/GRD/search?format=json&uid=S1A_IW_GRDH_1SDV_20180729T224419_20180729T224444_023015_027F8D_B944
polarisation	VV
SubsetBounding Box	106.378,14.592,107.29,15.128
pixelSpacingInMeter	20.0

Current search result

Discovery feed for local data Total results 3

- S1_GRD_VV_20180705_20180729_RGB_Amplitude_Change.tif
- S1A_IW_GRDH_1SDV_20180705T224418_20180705T224443_022665_0274AF_8B63_Orb_Cal_ML_TC_DB.tif
- S1A_IW_GRDH_1SDV_20180729T224419_20180729T224444_023015_027F8D_B944_Orb_Cal_ML_TC_DB.tif

Features Basket Data Packages

No results found.

Total results 0

sel.all inv.sel Remove all Save

Examples of GEP Services | DIAPASON (Kilauea Eruption)

The screenshot displays the geohazards tep web application interface. The main map shows a 3D visualization of Kilauea volcano in Hawaii, with labels for Kilauea and Pa'uilo. The interface includes a search bar, navigation tools, and a sidebar with job details and parameters.

Processing Services

DIAPASON InSAR Hawaii 26-14 may

Job Info

Job Name	DIAPASON InSAR Hawaii 26-14 may
Wps Job Id	37d63959-f5b1-42d3-b3b2-247167efcbaa
Processing service	DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW)
Started at	May 28th 2018 21:50
Created by	PBally
Status/Result Location	Share
Status	Success
Visibility	public
Share	Share

Parameters

Name	Value
master	https://geohazards-tep-ref.terradue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180526T043028_20180526T043056_022071_0262B6_FEF6
pol	VV
slave	https://geohazards-tep-ref.terradue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180514T043027_20180514T043055_021896_025D31_C20C
psfiltx	0.5
unwrap	false

Current search result: DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW) - Interferometric Amplitude - 2018-05-26T04:30:28 2018-05-14T04:30:27

Discovery feed for local data: Total results 4

Features Basket: Data Packages: Total results 0 | sel.all | inv.sel | Remove all | Save

No results found.

Examples of GEP Services | DIAPASON (Kilauea Eruption)

The screenshot displays the geohazards tep web application interface. The main map shows an InSAR map of Hawaii, with a color-coded area indicating ground deformation. The map includes labels for 'Kilauea', 'Kawaihae', and 'Pa'aulo'. A search bar at the top left contains 'Kilauea'. The interface includes navigation controls on the left, a top navigation bar with 'Store Upload', 'Products', 'EO Data', 'EO-based products', 'Community', and 'Private' options, and a right-hand panel for processing services.

Processing Services

DIAPASON InSAR Hawaii 26-14 may

Job Info

Job Name	DIAPASON InSAR Hawaii 26-14 may
Wps Job Id	37d63959-f5b1-42d3-b3b2-247167efcbaa
Processing service	DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW)
Started at	May 28th 2018 21:50
Created by	PBally
Status/Result Location	Share
Status	Success
Visibility	public
Share	Share

Parameters

Name	Value
master	https://geohazards-tep-ref.terradue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180526T043028_20180526T043056_022071_0262B6_FEF6
pol	VV
slave	https://geohazards-tep-ref.terradue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180514T043027_20180514T043056_021896_025D31_C20C
psfiltx	0.5
unwrap	false

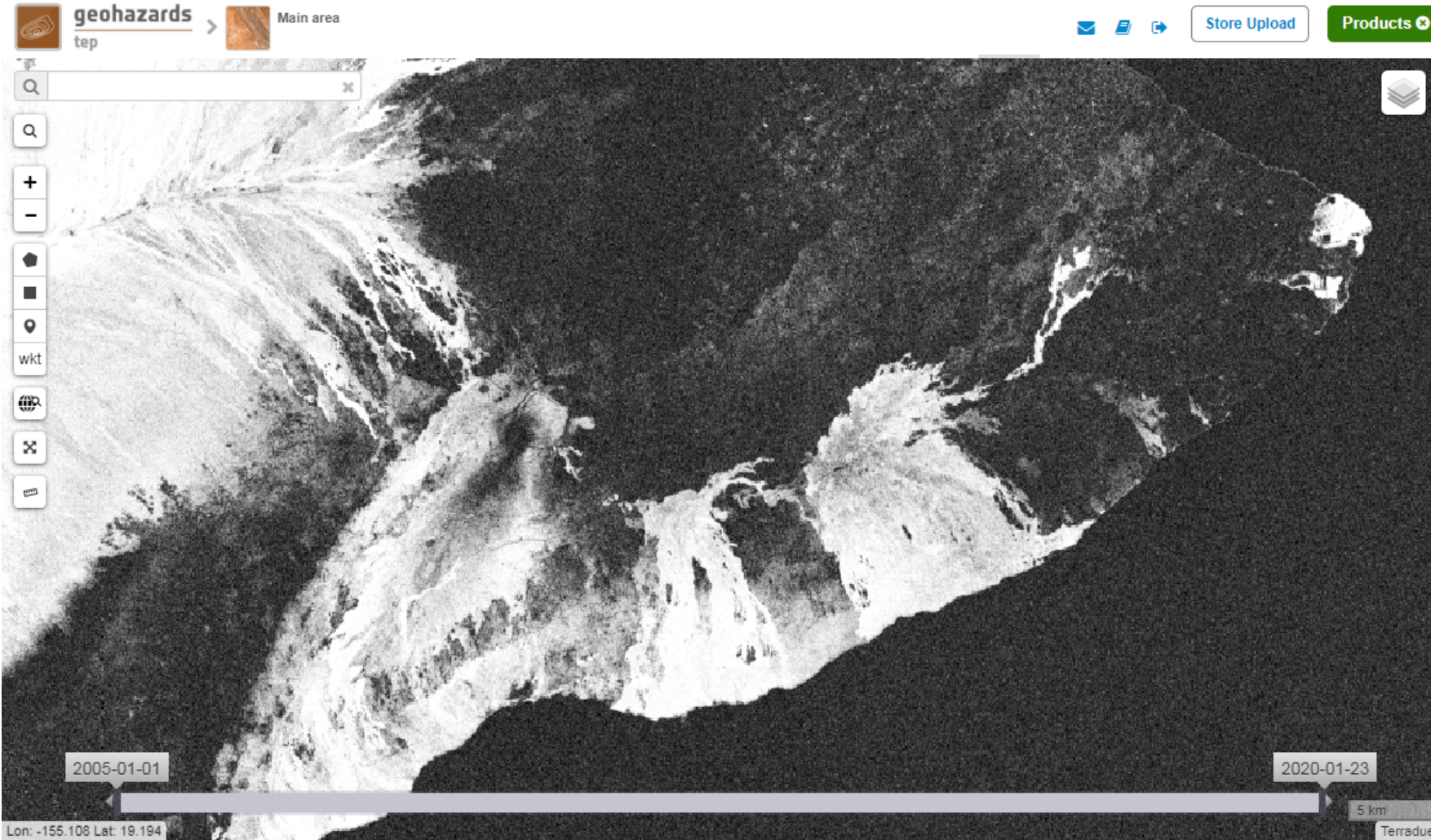
Discovery feed for local data Total results 4

- DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW) - Interferometric Amplitude - 2018-05-26T04:30:28 2018-05-14T04:30:27

Features Basket **Data Packages** Total results 0 | [sel.all](#) | [inv.sel](#) | [Remove all](#) | [Save](#)

No results found.

Examples of GEP Services | DIAPASON (Kilauea Eruption)



Processing Services

DIAPASON InSAR Hawaii 26-14 may

Job Info

Job Name	DIAPASON InSAR Hawaii 26-14 may
Wps Job Id	37d63959-f5b1-42d3-b3b2-247167efcbaa
Processing service	DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW)
Started at	May 28th 2018 21:50
Created by	PBally
Status/Result Location	Share
Status	Success
Visibility	public
Share	Share

Parameters

Name	Value
master	https://geohazards-tep-ref.terraeue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180526T043028_20180526T043056_022071_0262B6_FEF6
pol	VV
slave	https://geohazards-tep-ref.terraeue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180514T043027_20180514T043055_021896_025D31_C20C
psfiltx	0.5
unwrap	false

Current search result

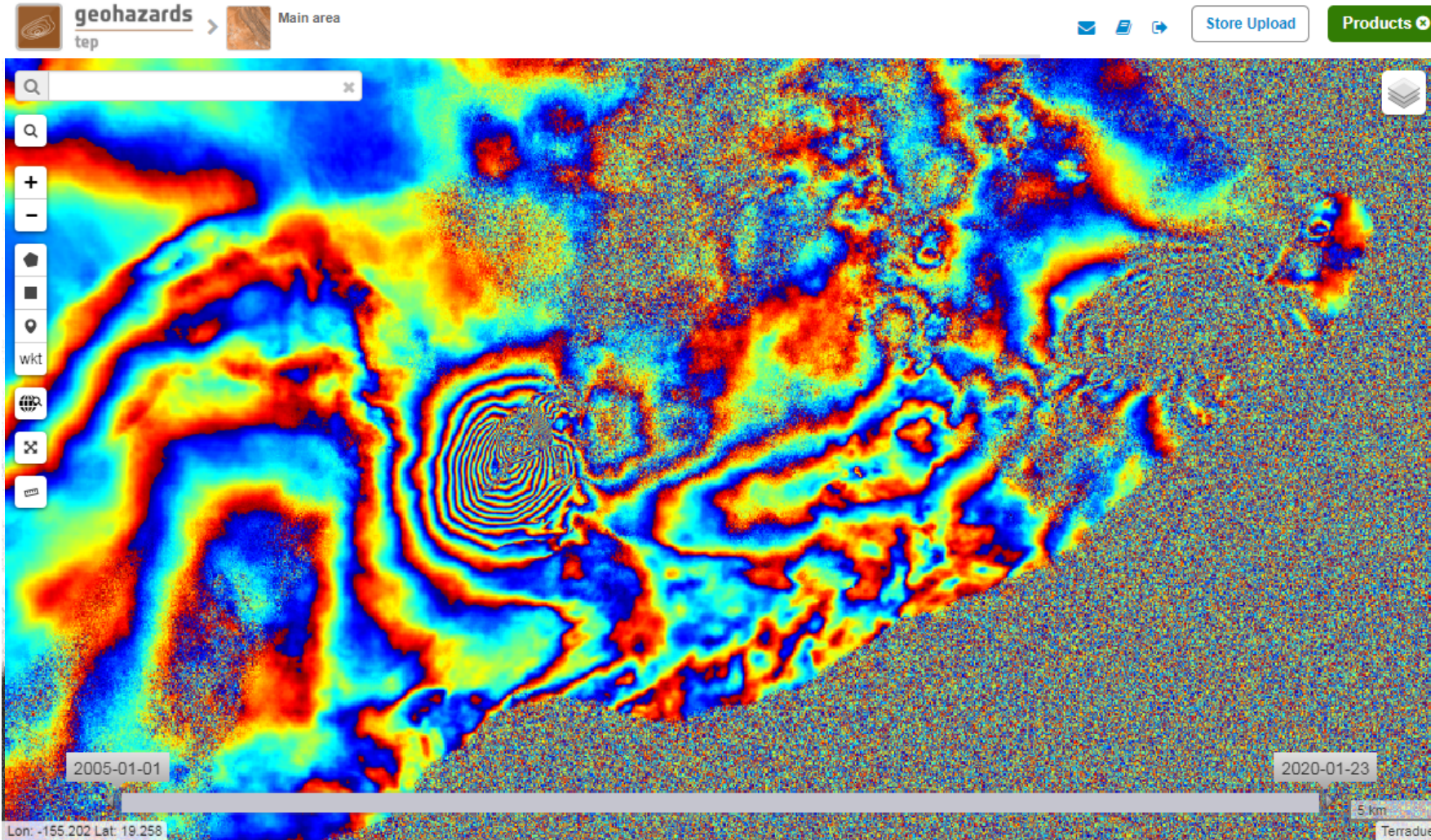
Discovery feed for local data Total results 4

DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW) - Interferometric Amplitude - 2018-05-26T04:30:28 2018-05-14T04:30:27

Features Basket Data Packages Total results 0 [sel.all](#) [inv.sel](#) [Remove all](#) [Save](#)

No results found.

Examples of GEP Services | DIAPASON (Kilauea Eruption)



Processing Services

DIAPASON Sentinel-1
DIAPASON InSAR Hawaii 26-14 may

Job Info

Job Name	DIAPASON InSAR Hawaii 26-14 may
Wps Job Id	37d63959-f5b1-42d3-b3b2-247167efc6aa
Processing service	DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW)
Started at	May 28th 2018 21:50
Created by	PBally
Status/Result Location	Share
Status	Success
Visibility	public
Share	Share

Parameters

Name	Value
master	https://geohazards-tep-ref.terraeue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180526T043028_20180526T043056_022071_0262B6_FEF6
pol	VV
slave	https://geohazards-tep-ref.terraeue.com/t2api/data/collection/Sentinel-1/search?format=atom&uid=S1A_IW_SLC__1SDV_20180514T043027_20180514T043055_021896_025D31_C20C
psfiltx	0.5
unwrap	false

Current search result

Discovery feed for local data Total results 4

Features Basket Data Packages Total results 0

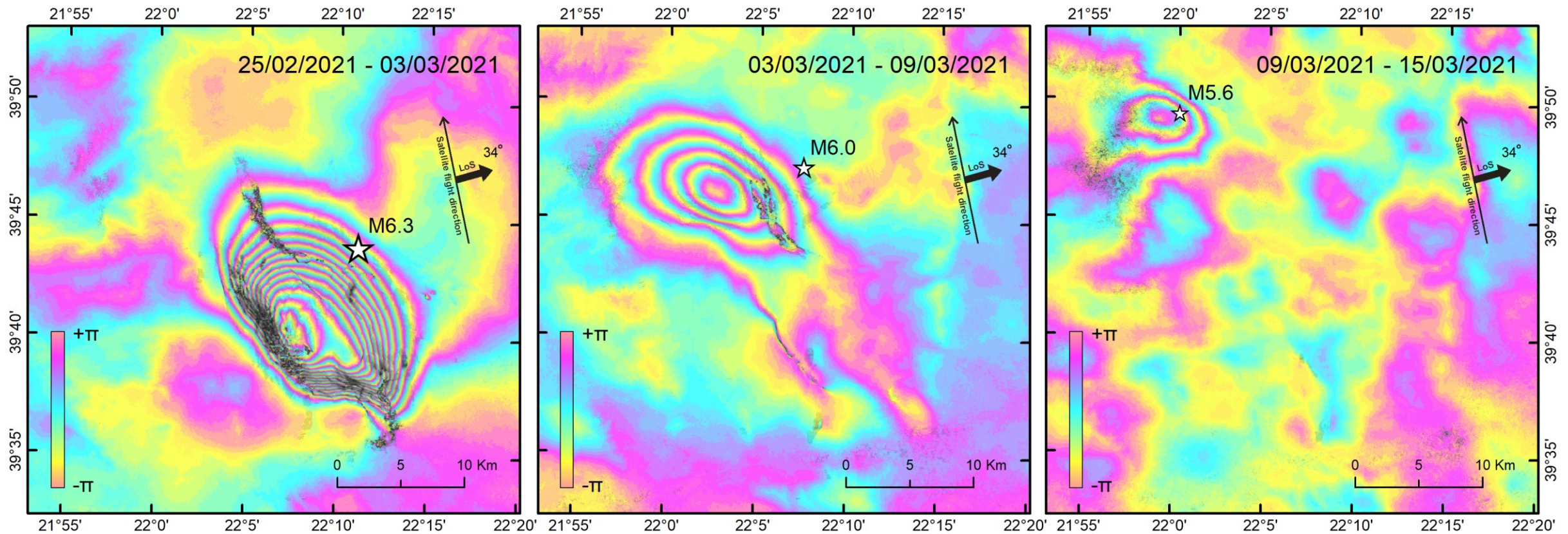
DIAPASON InSAR Sentinel-1 TOPSAR(IW,EW) - Interferometric Amplitude - 2018-05-26T04:30:28 2018-05-14T04:30:27

No results found.

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)

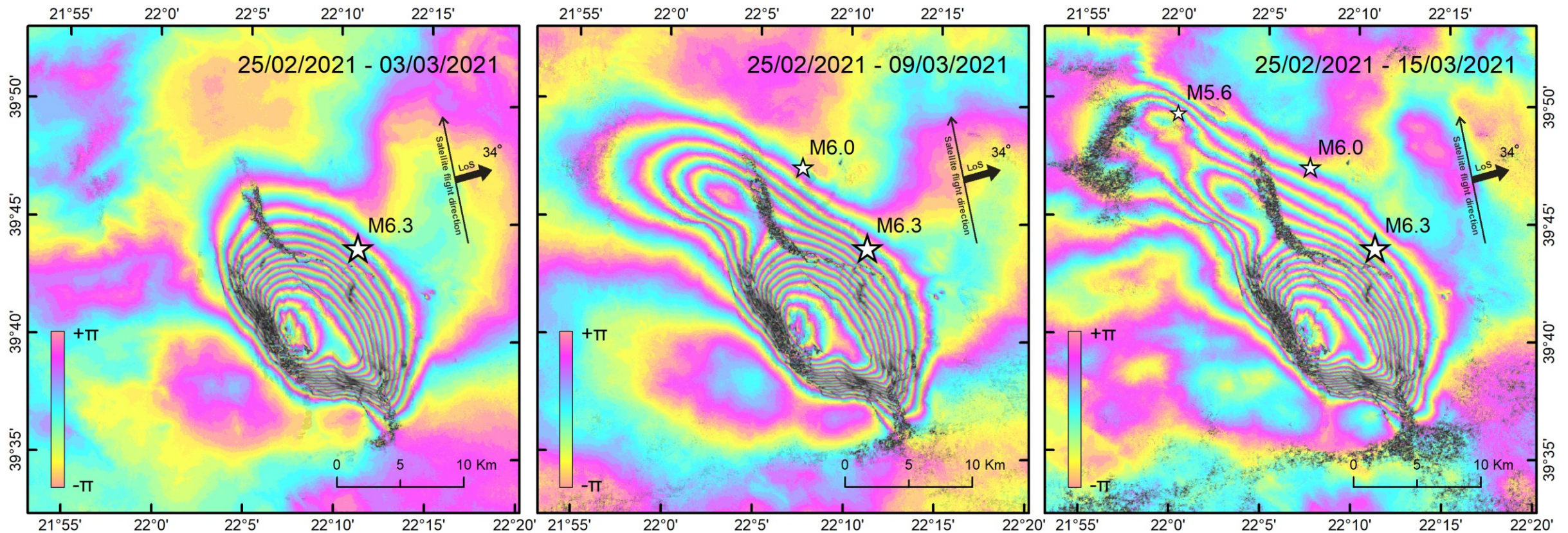


Contains modified Copernicus Sentinel data [2020], processed by AUTH

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

Sentinel-1 Co-Seismic Differential Interferograms

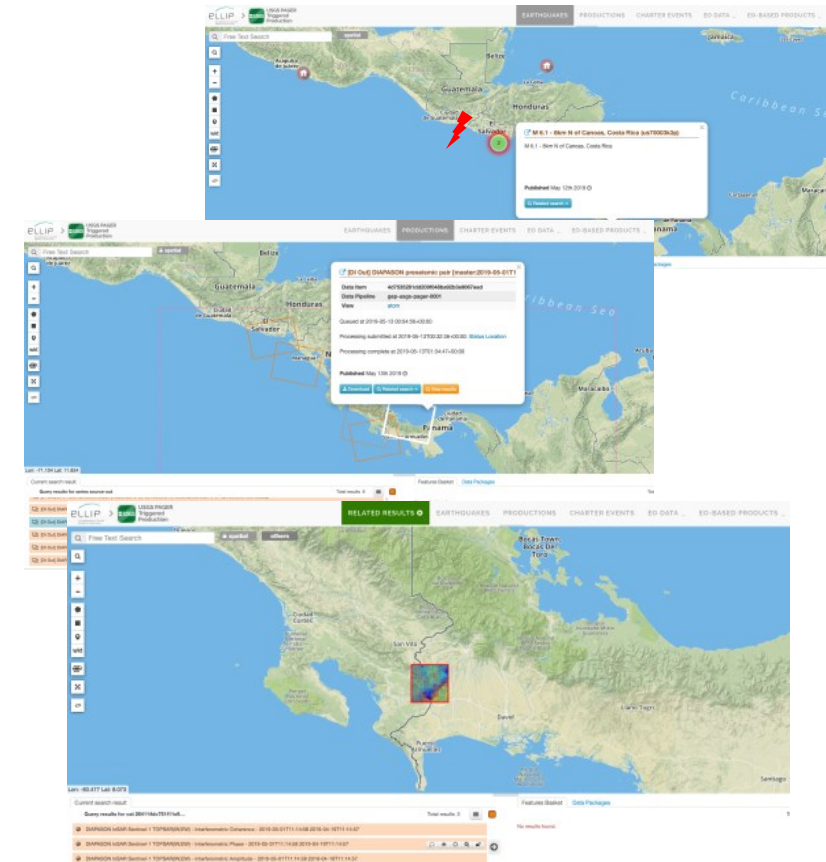
Observed surface displacements for the major seismic events: -38 cm (M6.3), -12 cm (M6.0;) and -9 cm (M5.6)



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

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

The screenshot shows the geohazards tep web interface. The main map displays a color-coded deformation map over a geographical area including Solothurn, Burgdorf, Willisau, and Neuchâtel. The interface includes a search bar, map navigation tools, and a sidebar with processing service details.

Processing Services
← Glarus_PSBAS_S1_sud

Job Info

Job Name	Glarus_PSBAS_S1_sud
Wps Job Id	e48122f6-9c82-40e6-af45-6f9b781eda78
Remote Id	1637fe8f-8b68-4950-a461-9ef061bf3911
Started at	Mar 14th 2017
Created by	Andrea Manconi
Status/Result Location	View
Status	Success
Visibility	restricted
Share	Share

Parameters

Name	Value
S1	https://catalog.terradue.com/sentinel1/series/insar/search?format=json&uid=S1A_IW_SLC__1SDV_20170312T171449_20170312T171516_015662_019C40_DA71
S1	https://catalog.terradue.com/sentinel1/series/insar/search?format=json&uid=S1B_IW_SLC__1SDV_20170306T171405_20170306T171432_004591_008004_A0A4
S1	https://catalog.terradue.com/sentinel1/series/insar/search?format=json&uid=S1A_IW_SLC__1SDV_20170228T171449_20170228T171516_015487_0196F9_0BA0
centerLat	46.187
centerLon	9.196
GeocodeInterf	Yes
DemType	srtm1
APS	200

Will be supported by  **ESI**
 BELNET-BEGRID (Belgium)



ONDA

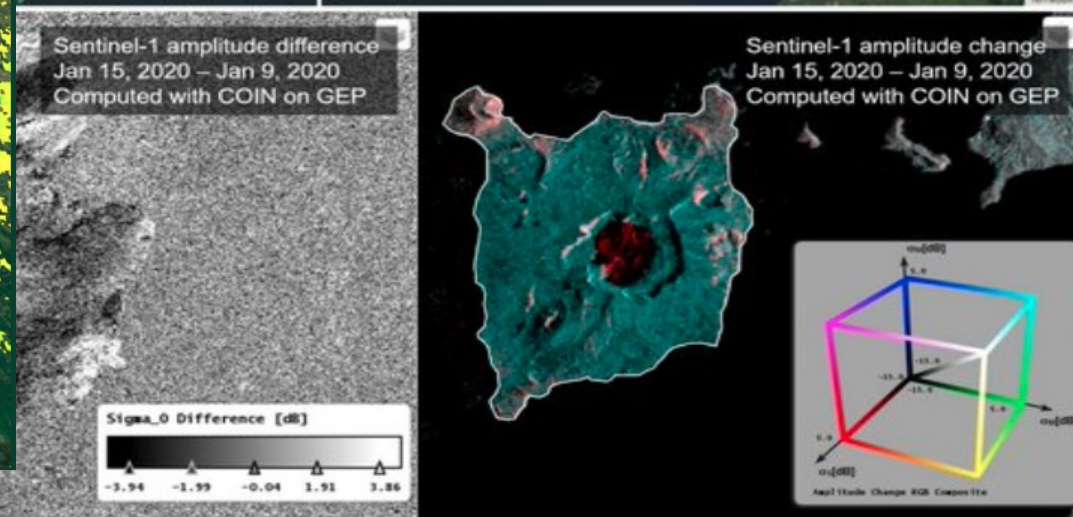
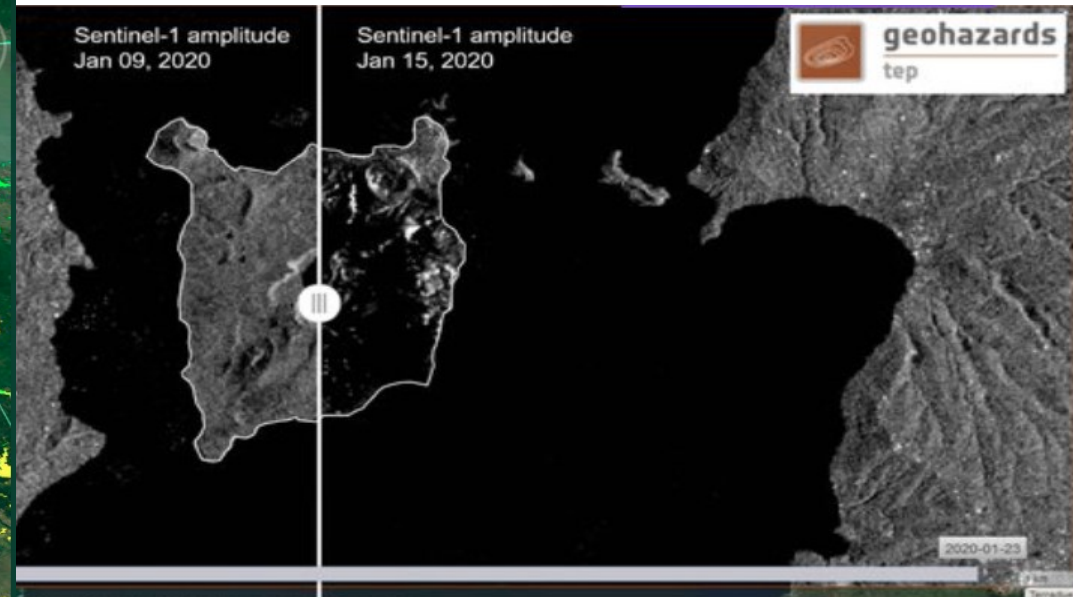
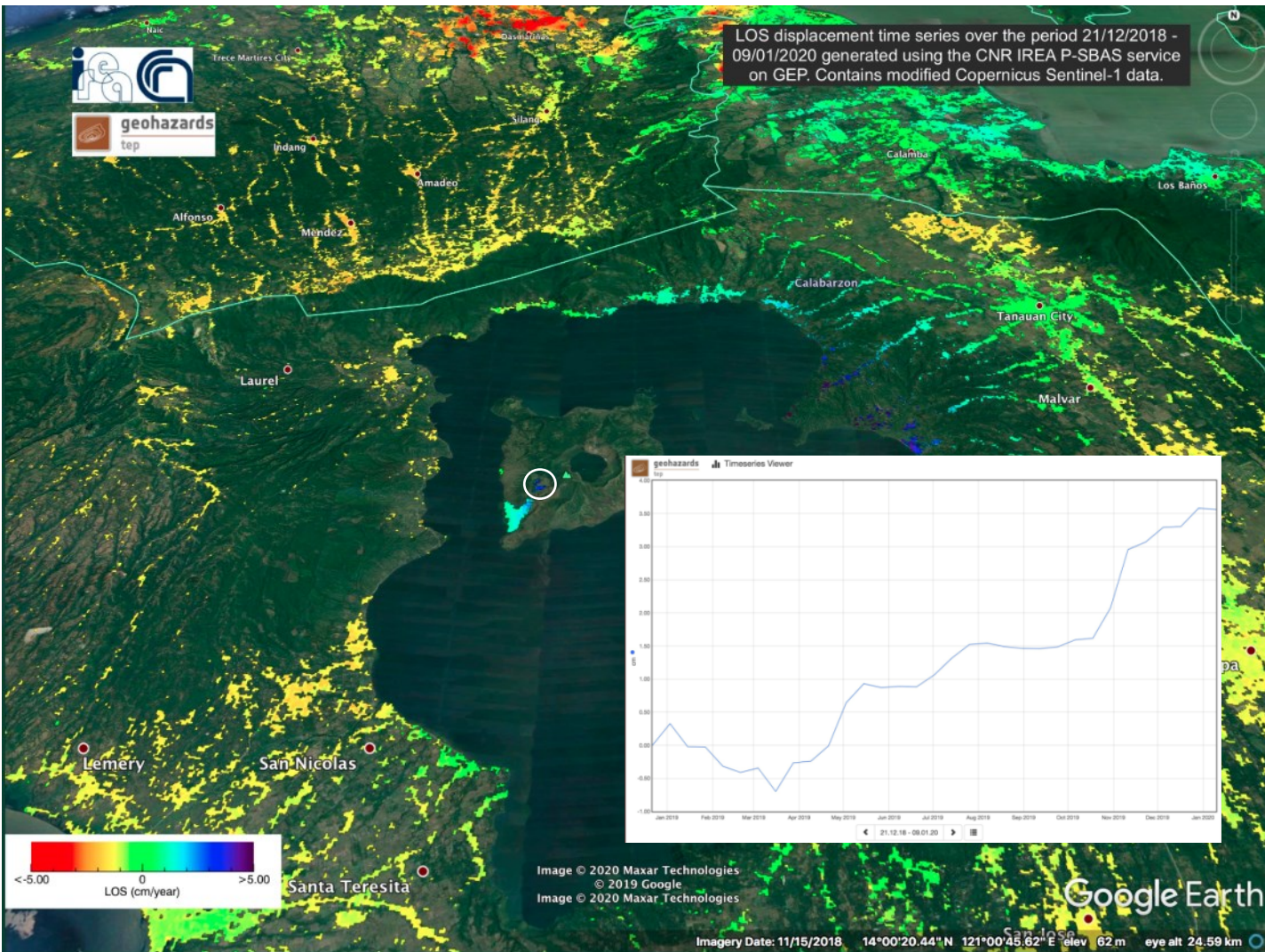
CNR-IREA P-SBAS Sentinel-1 processing on-demand

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.



<https://geohazards-tep.eu>

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



West Africa State of the Coast Report 2020

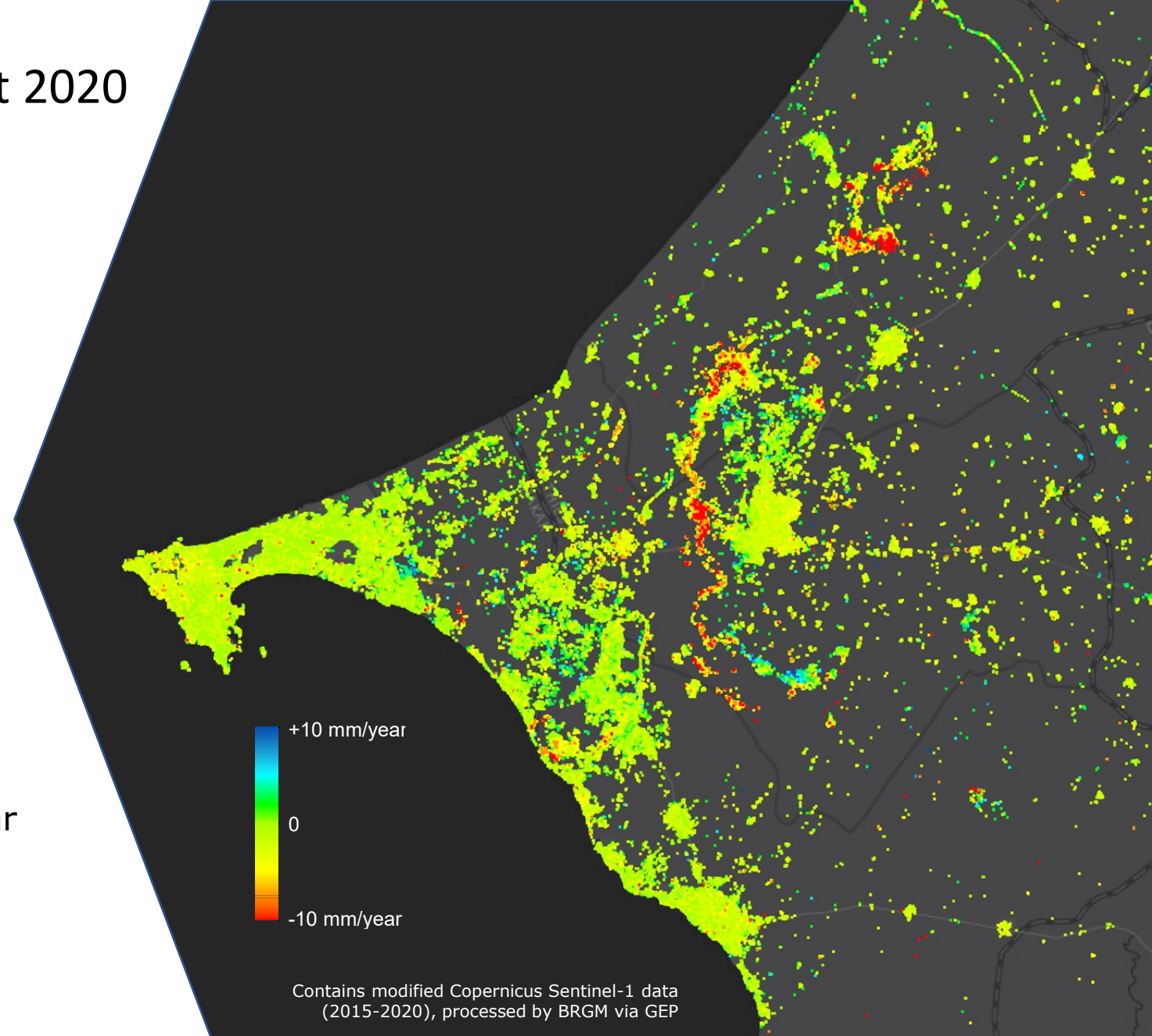
Terrain deformation of Dakar (Senegal) via GEP online services. Ground displacements for the period April 2015 – August 2020 based on InSAR processing of Copernicus Sentinel-1 mission data using the CNR-IREA P-SBAS on-demand service implemented on GEP

([10.1109/JSTARS.2014.2322671](https://doi.org/10.1109/JSTARS.2014.2322671),
[10.1109/TGRS.2019.2904912](https://doi.org/10.1109/TGRS.2019.2904912))

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

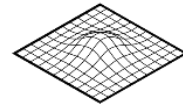
Precision of the measurements 1-2 mm/year
([10.1109/TGRS.2019.2904912](https://doi.org/10.1109/TGRS.2019.2904912))

Production completed in **~30hrs**

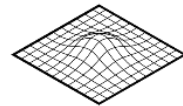


SURFACE MOTION MAPPING | SNAPPING SERVICE ON GEP

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



SNAPPING IFG



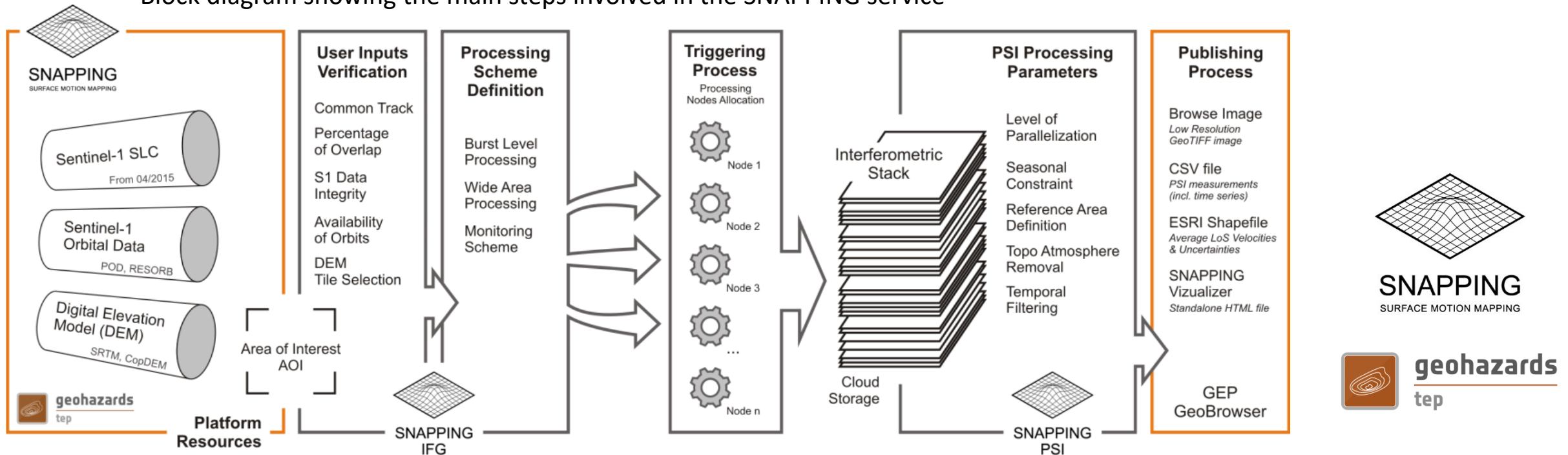
SNAPPING PSI

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



Family of SNAPPING Services



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.

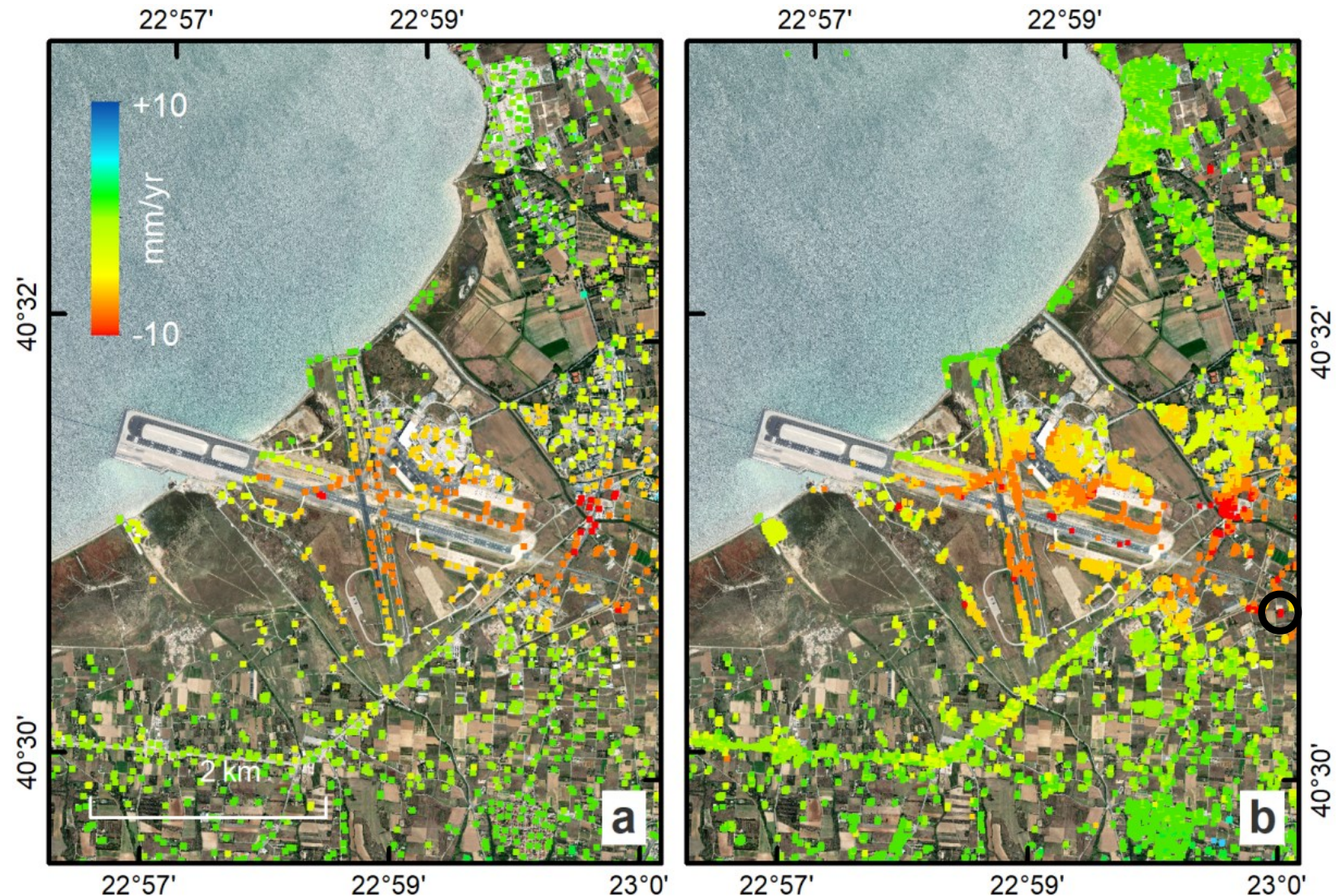
SNAPPING PSI+ (PS/DS)

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.

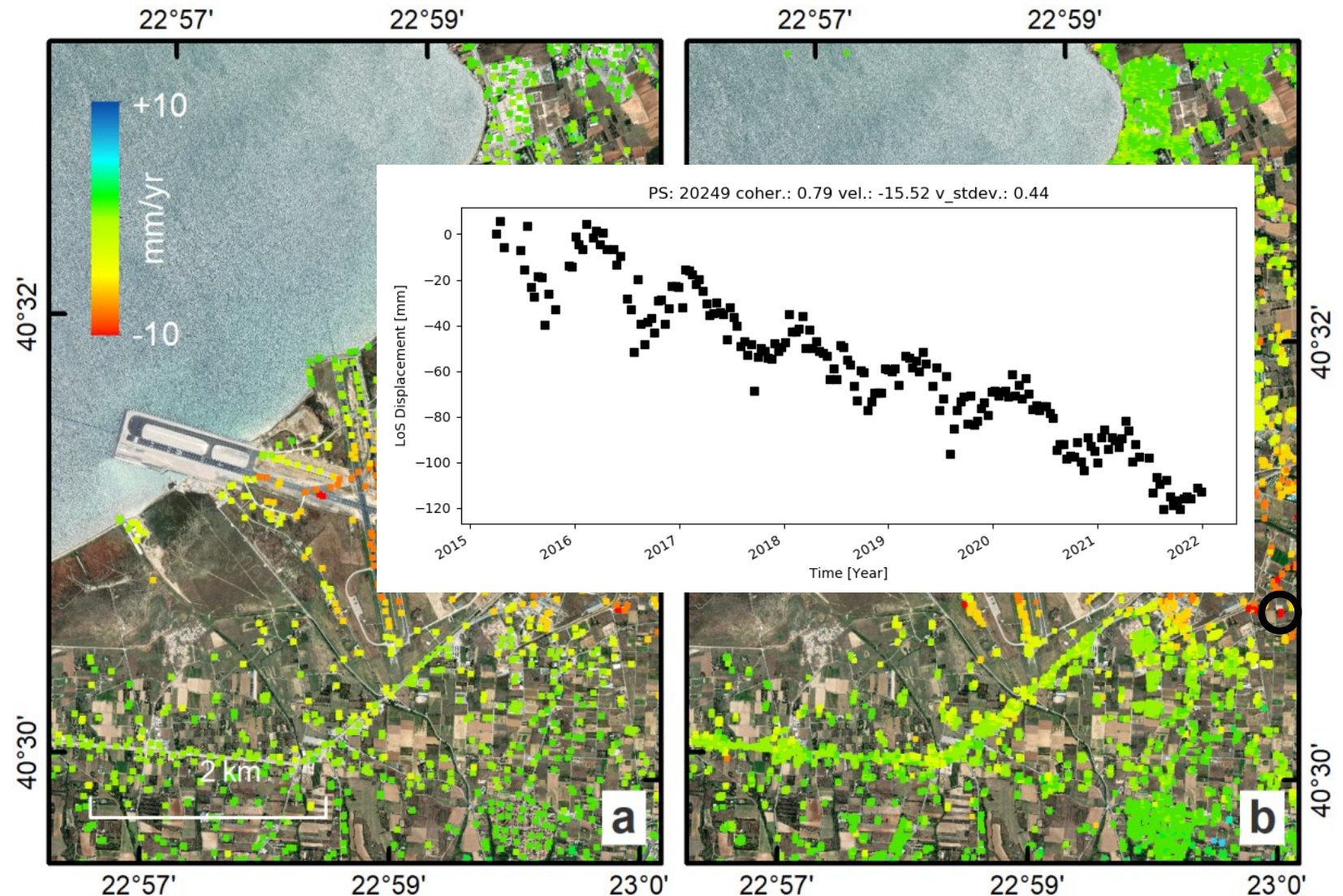
Η υπηρεσία SNAPPING PSI Full οδήγησε σε αύξηση κατά ~1500% των μετρήσεων (συνολικά 16500 ανακλαστήρες) σε σύγκριση με την αντίστοιχη λύση PSI Med (1120 ανακλαστήρες).



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

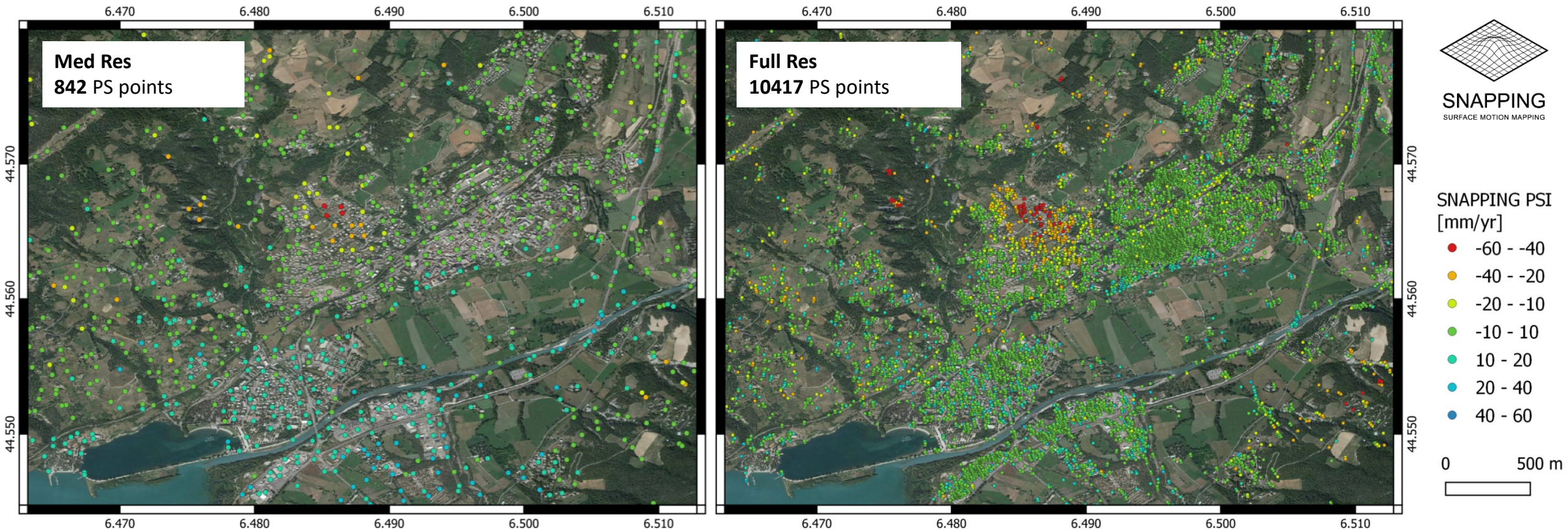
Ετήσιοι ρυθμοί μετακίνησης για την περίοδο 2015-2020 στον Διεθνή Αερολιμένα Θεσσαλονίκης χρησιμοποιώντας τις υπηρεσίες SNAPPING PSI Med και PSI Full. Παρατηρείται η αύξηση της πυκνότητας των μετρήσεων με την χρήση της υπηρεσίας PSI Full.

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).



SNAPPING PSI services

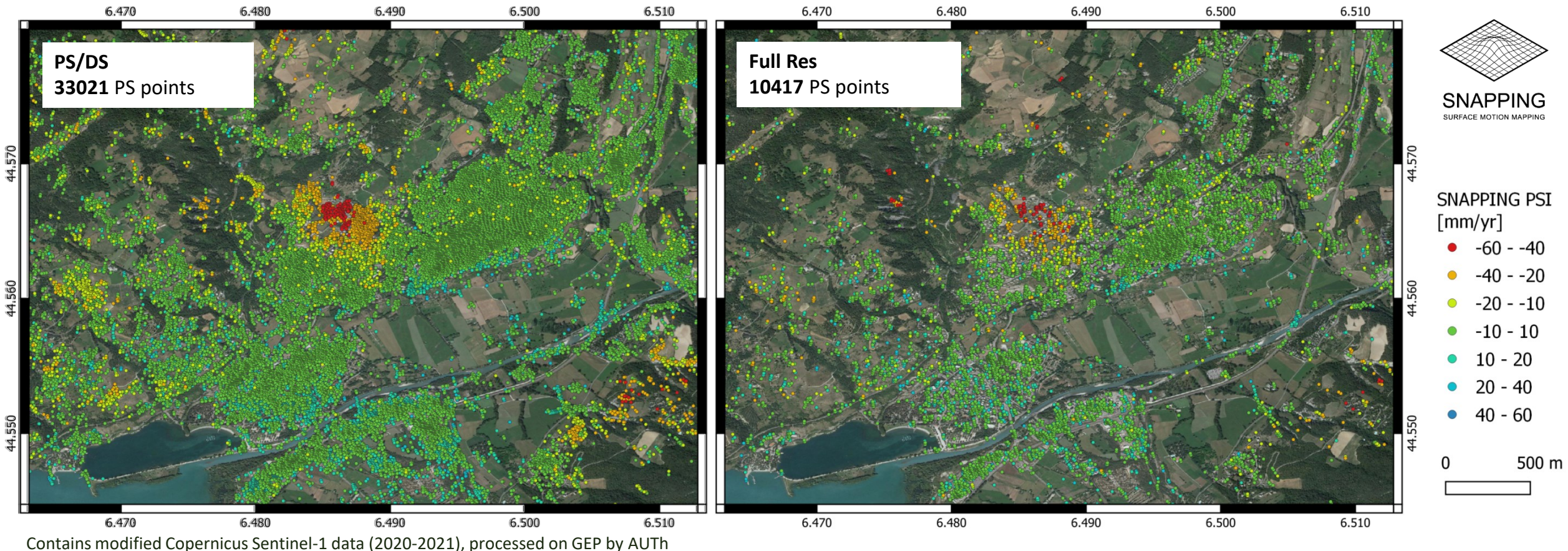
Landslide site in the French Alps captured by SNAPPING on-demand service on the Geohazards Exploitation Platform (GEP) using Copernicus Sentinel-1 mission data (observation period 2020-2021)



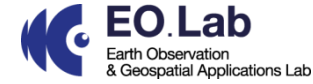
Contains modified Copernicus Sentinel-1 data (2020-2021), processed on GEP by AUTH

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)

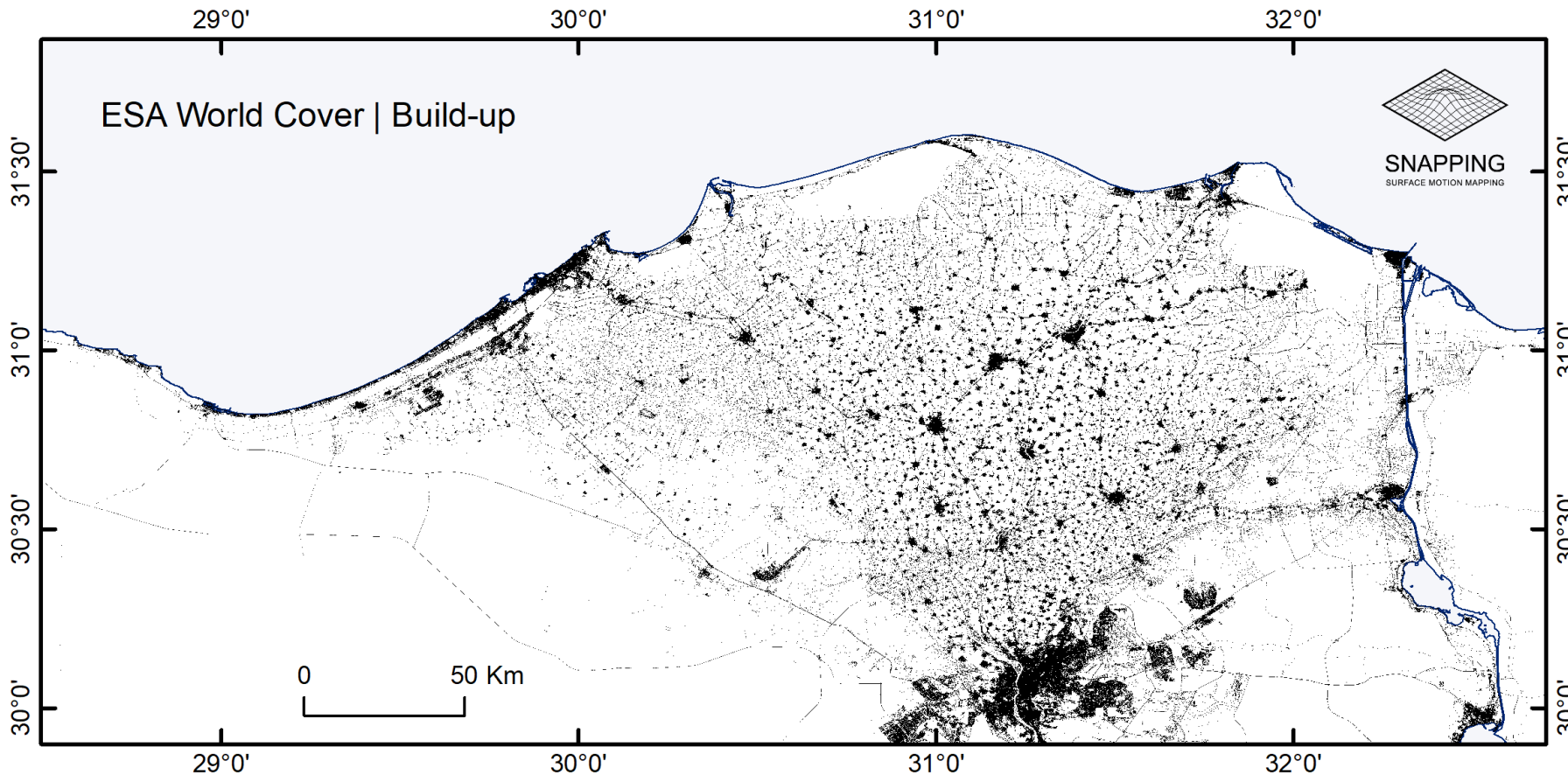


Wide Area InSAR Processing | Nile Delta (Egypt)



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**)

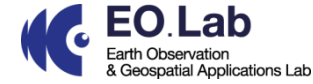
Sentinel-1 Tracks:
Descending 065 & 167

Observation Period:
2015-2020 (~6 years)

Nu of Sentinel-1 Scenes:
517

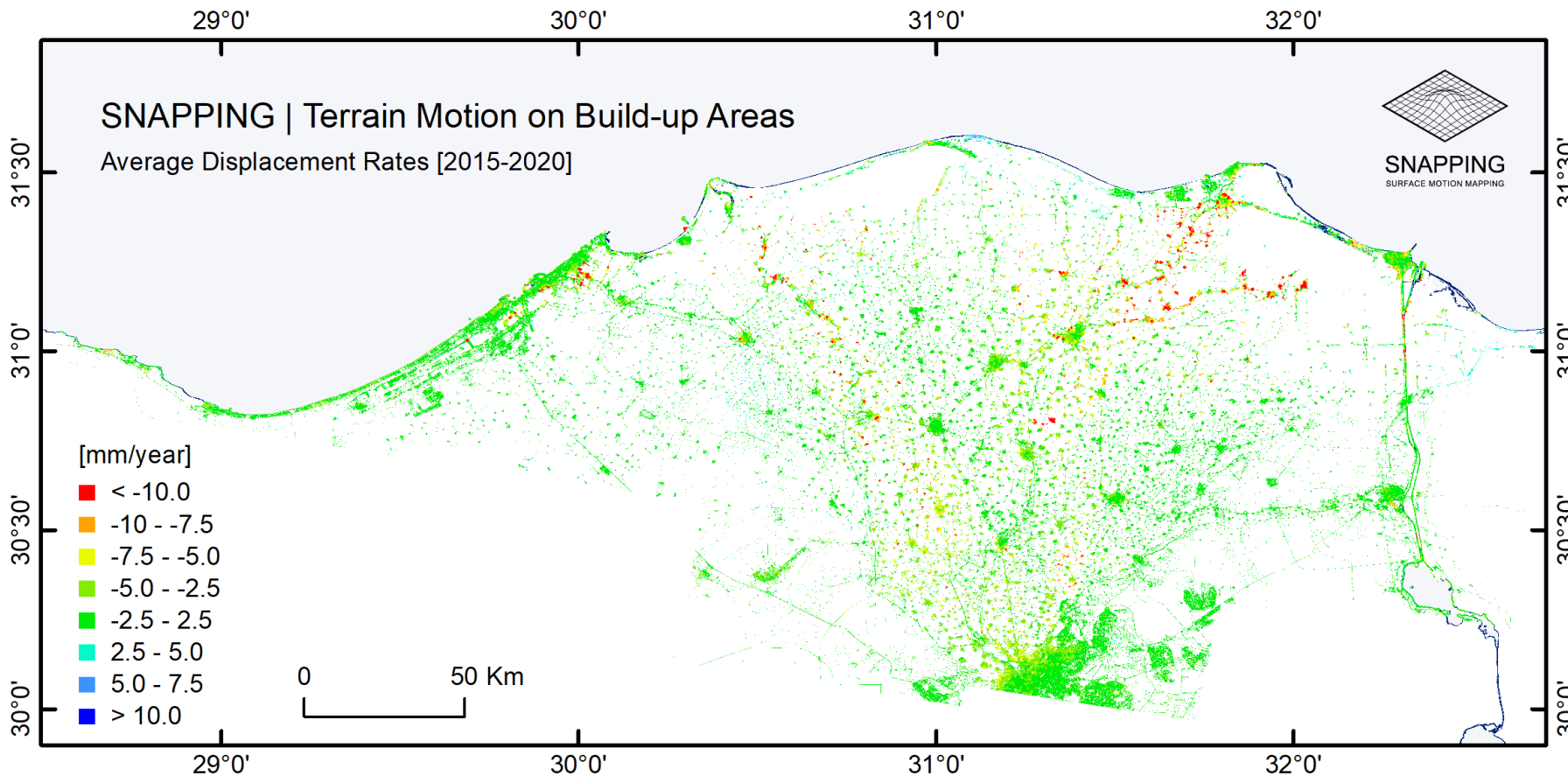
Nu of PS points:
~516k

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

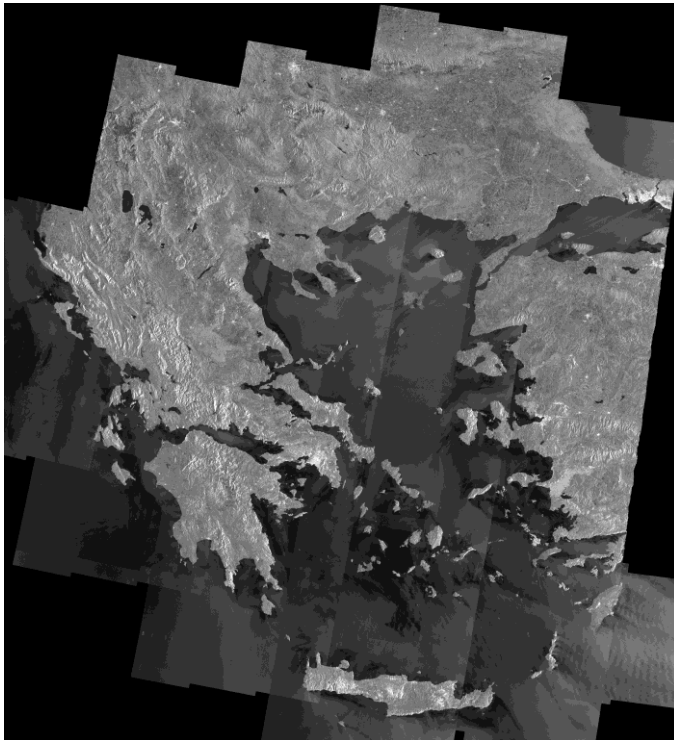
Nu of PS points:
~516k

SNAPPING InSAR GRreece

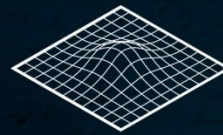
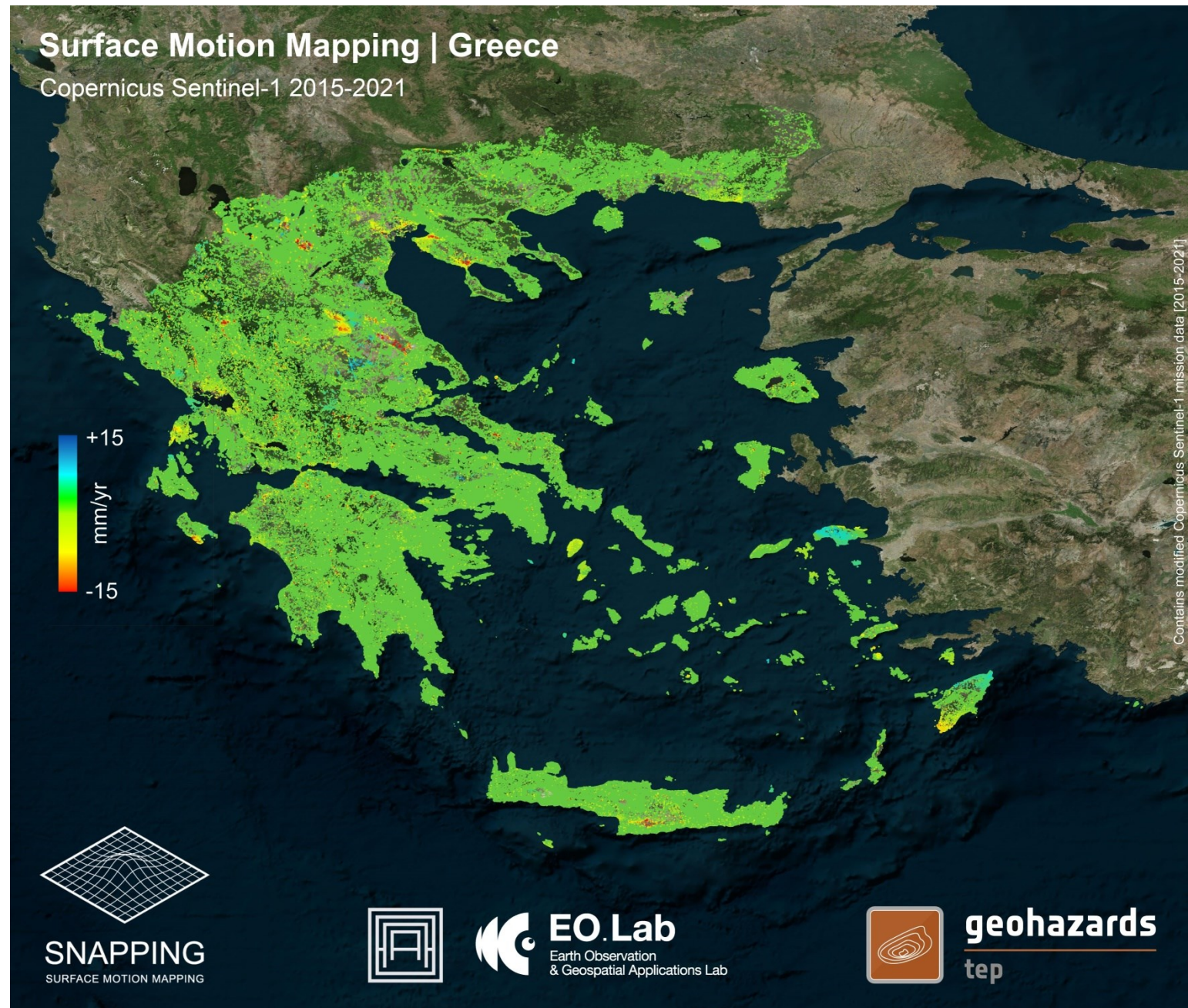
Copernicus Sentinel-1 Tracks

D153 | D080 | D007 | D109 | D136 | D138

4180 SLC scenes



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



SNAPPING
SURFACE MOTION MAPPING



EO.Lab
Earth Observation
& Geospatial Applications Lab



geohazards
tep



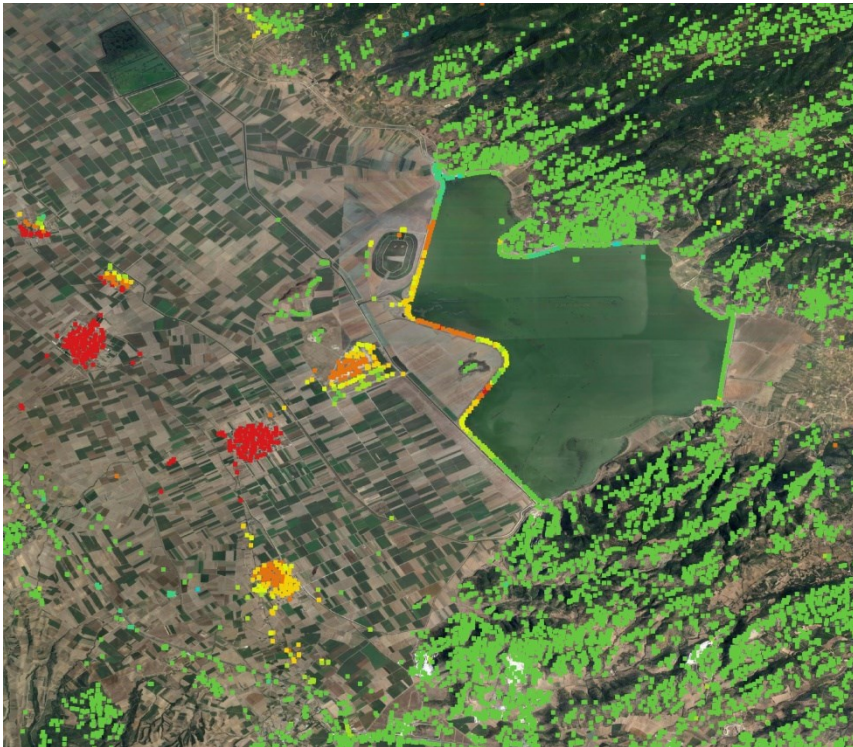
EO.Lab
Earth Observation
& Geospatial Applications Lab

SNAPPING InSAR GRreece

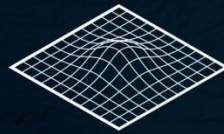
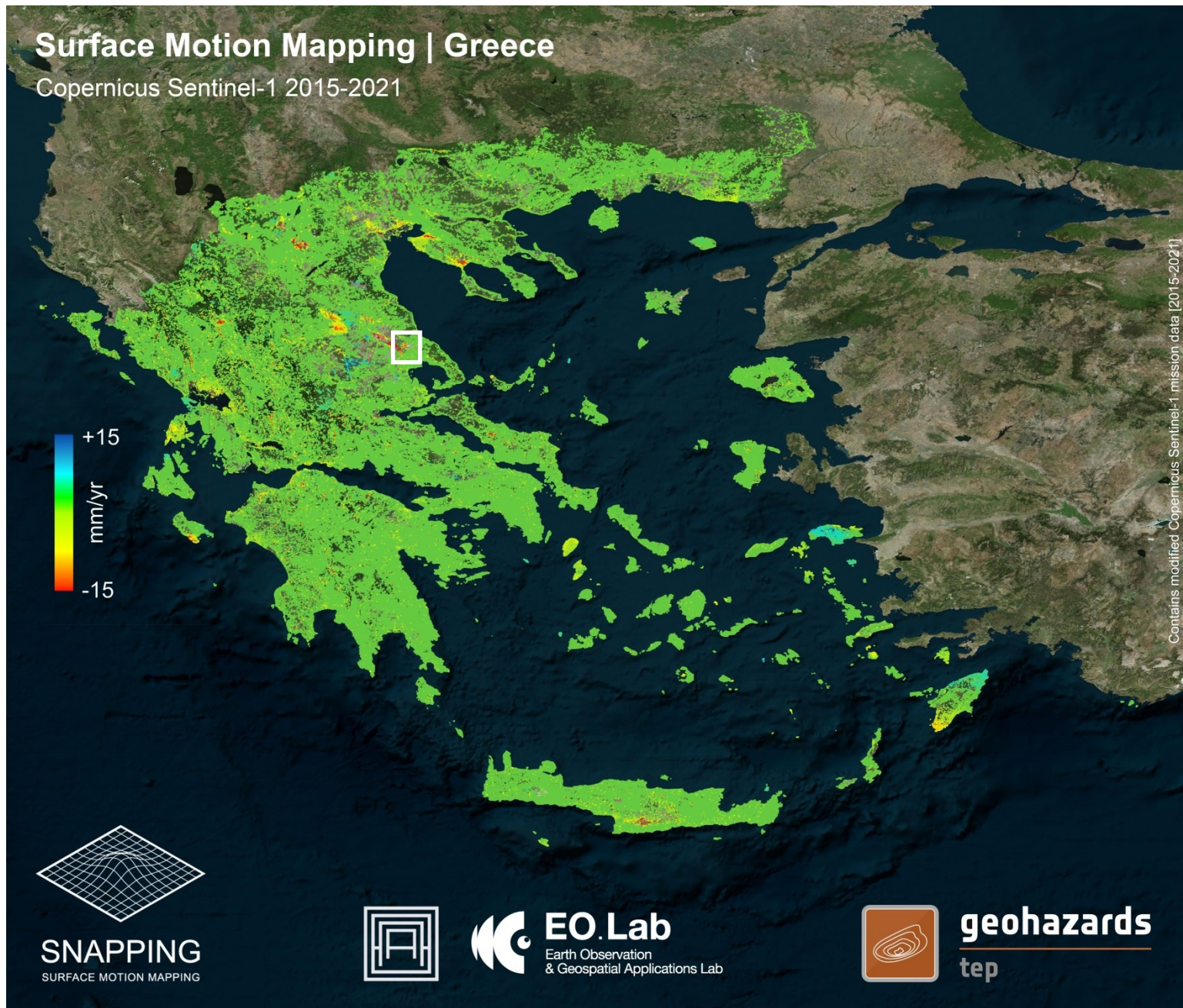
Copernicus Sentinel-1 Tracks

D153 | D080 | D007 | D109 | D136 | D138

4180 SLC scenes



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



SNAPPING
SURFACE MOTION MAPPING



EO.Lab
Earth Observation
& Geospatial Applications Lab



geohazards
tep

Contains modified Copernicus Sentinel-1 mission data [2015-2021]



EO.Lab
Earth Observation
& Geospatial Applications Lab

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; ...
. . . . . . . . . . . .
. . . . . . . . . . . .
. . . . . . . . . . . .
```

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.

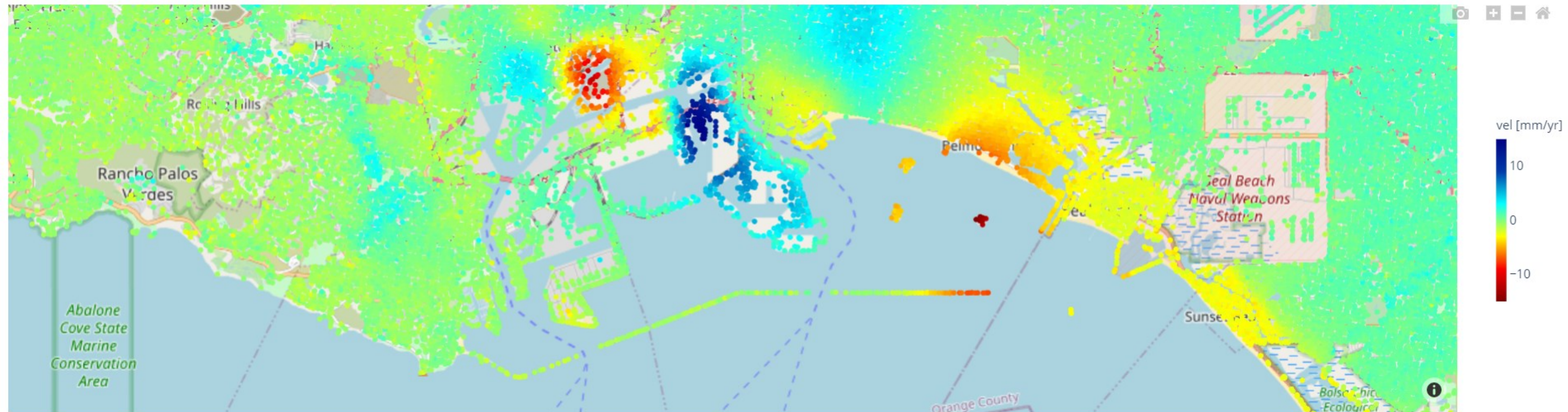
SNAPPING VISUALIZER | Los Angeles (USA)

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.



SNAPPING Visualizer

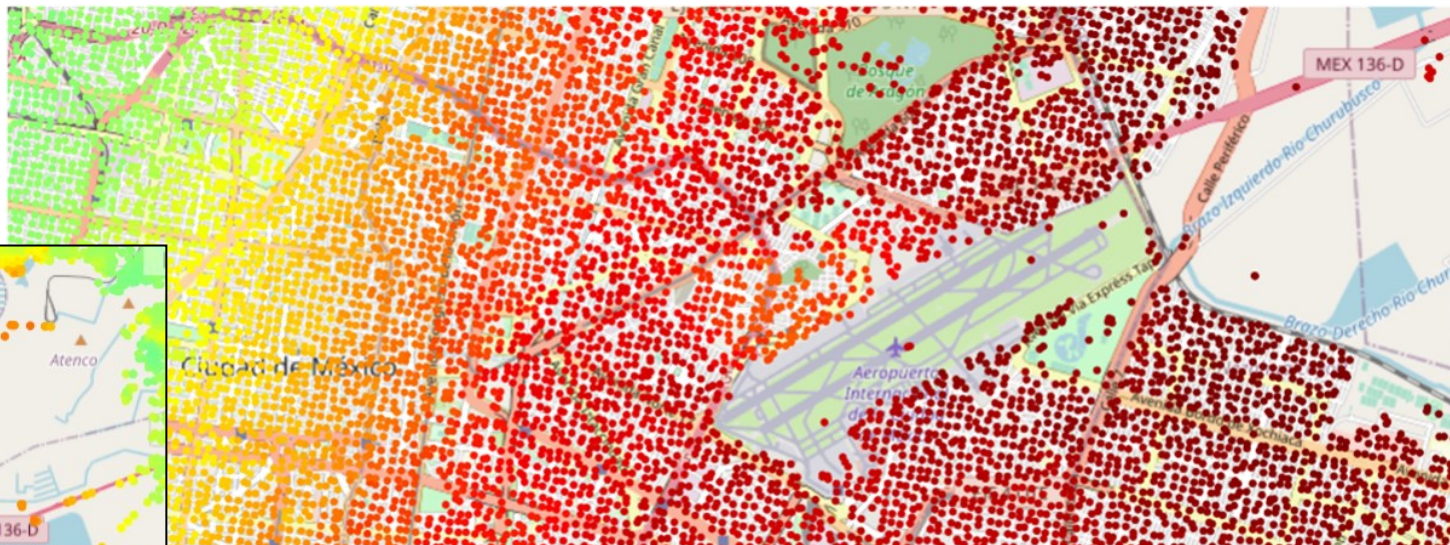
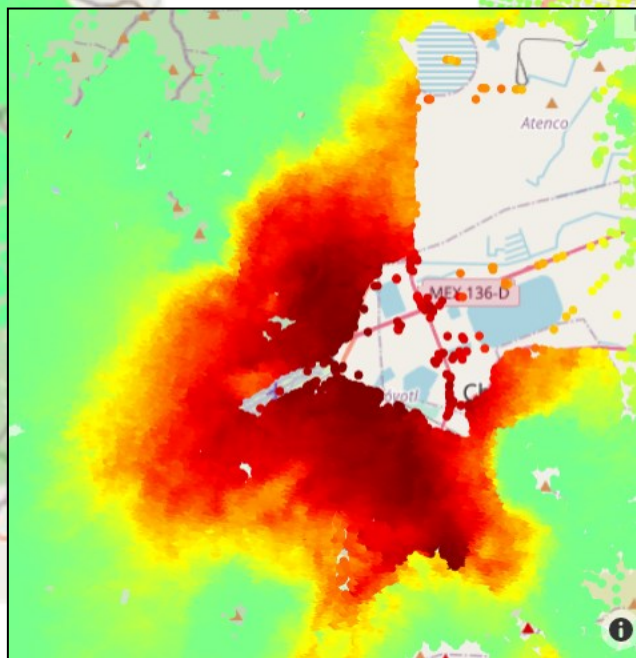
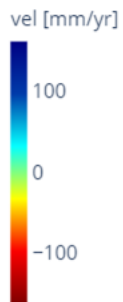
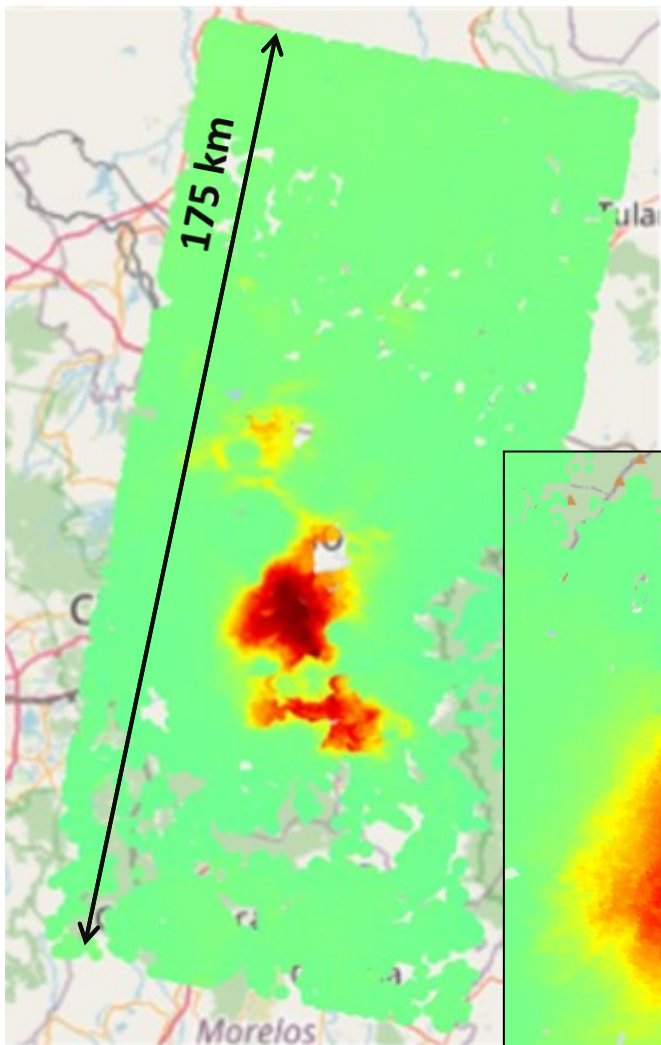
SNAPPING PSI Displacements rates processed on GEP | Observation period 01/2016-12/2020 (53 images) from Relative Orbit 143



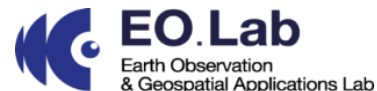
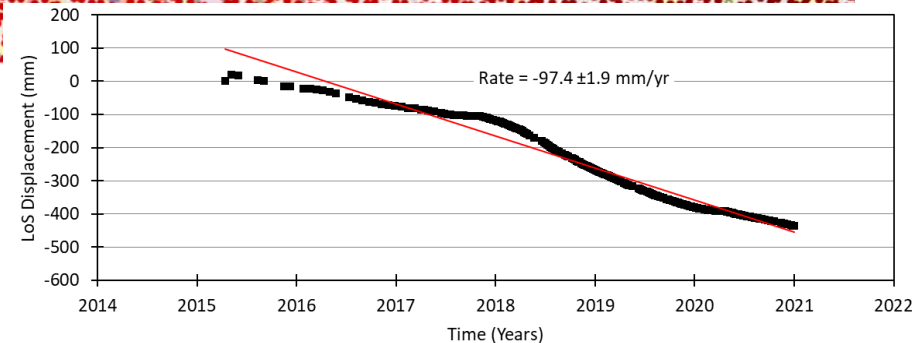
© Contains modified Copernicus Sentinel-1 data [2016-2020]

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

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

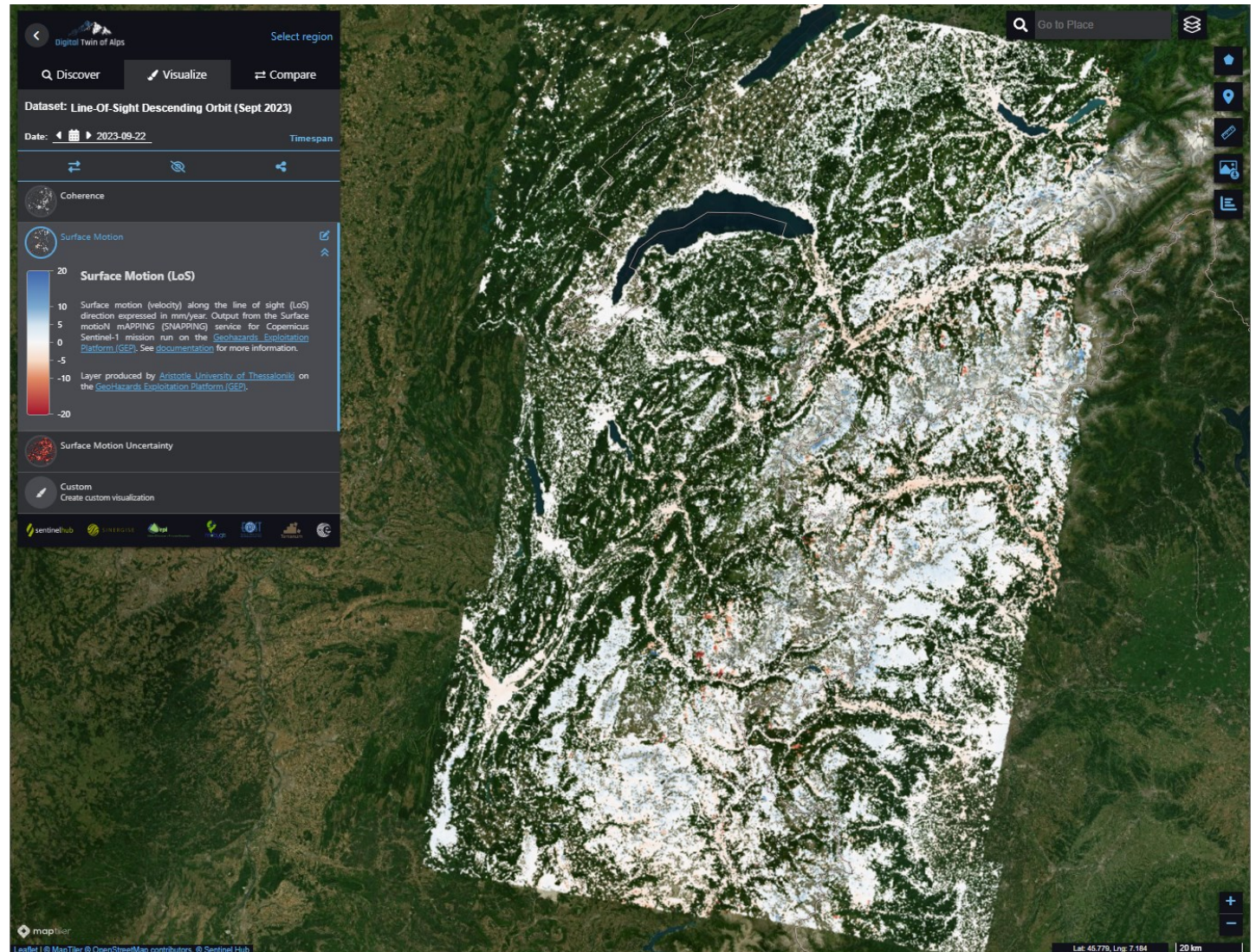


A total number of
~245k point
measurements



Digital Twin Alps (DTA) | Surface Motion Component

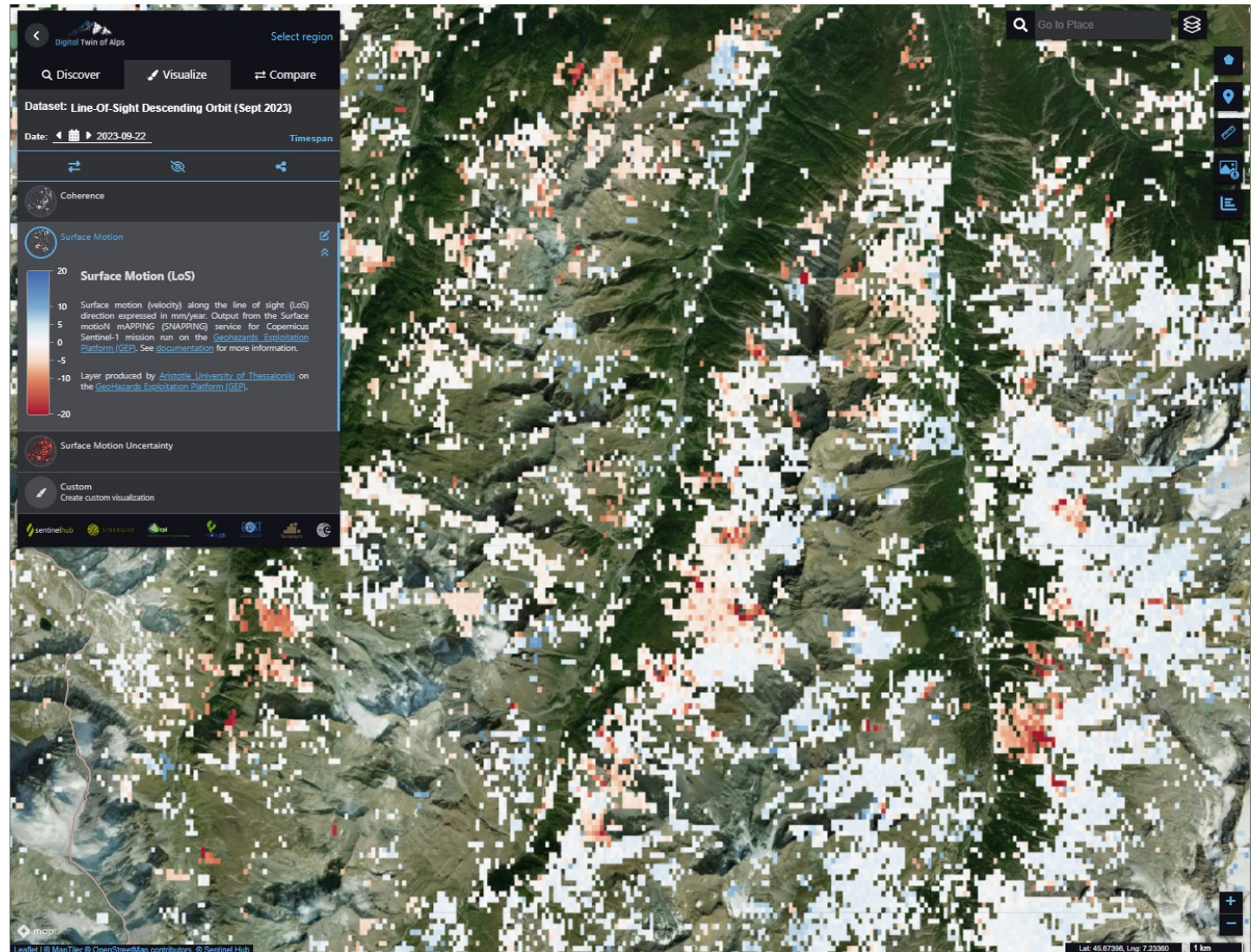
In the ESA DTA demonstrator you can access ground motion products for glaciers and landslides monitoring have been processed over the eastern Alps with the GEP services. The services were used to process the full archive of Sentinel-1 and Sentinel-2 for an AOI of 20,000+ km² and allow for monitoring 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.digitaltinalps.com>

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+ km² 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>

Inter-Verification of EO-Based Measurements

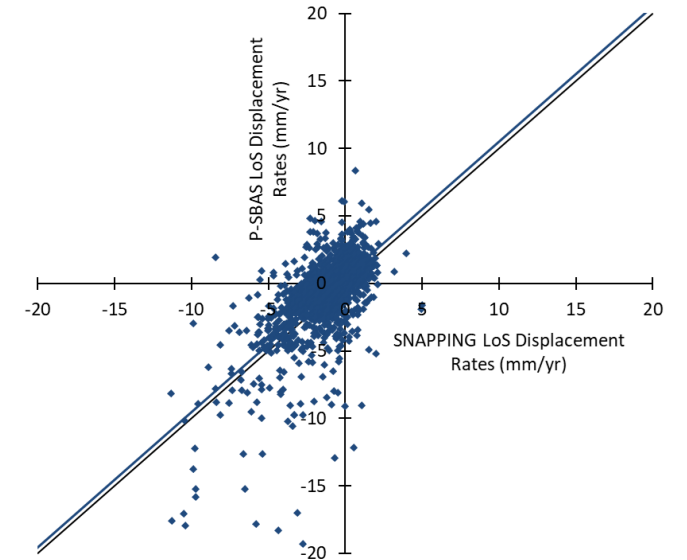
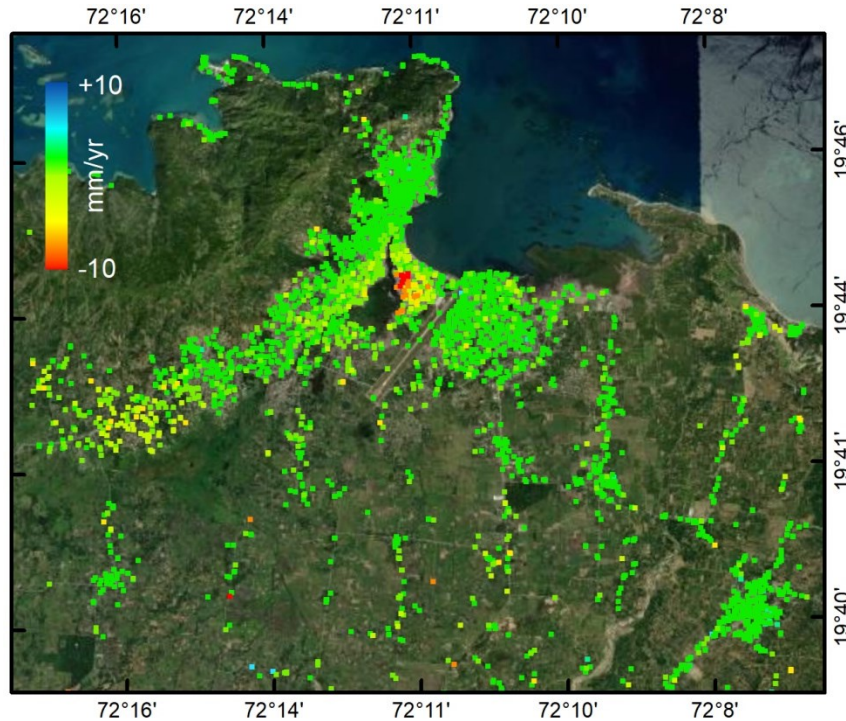
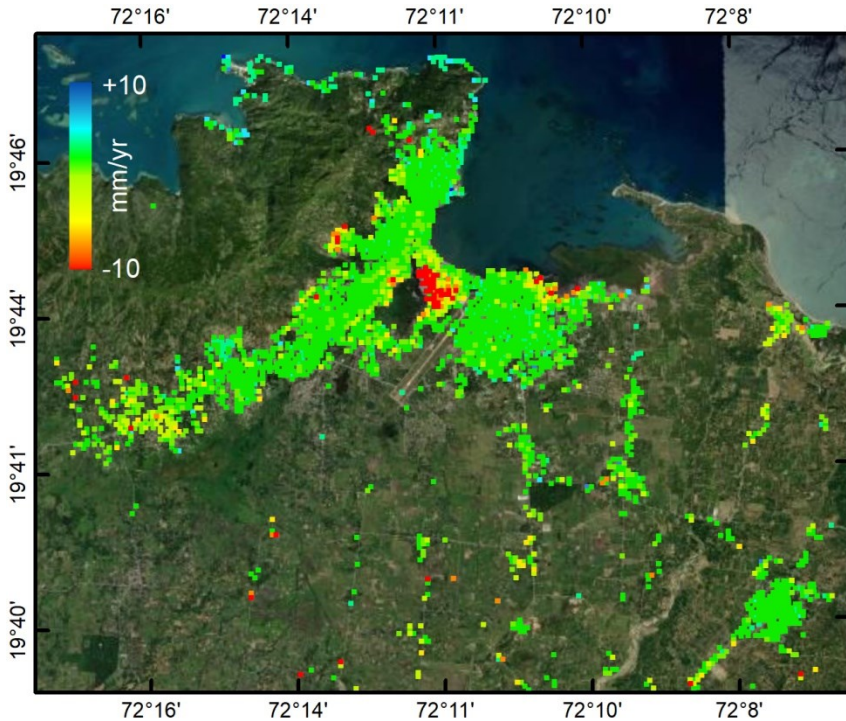
Inter-verification of Sentinel-1 terrain motion measurements using different operational services on GEP. Example over **Cap-Haïtien** by P-SBAS & SNAPPING services.



CNR-IREA P-SBAS



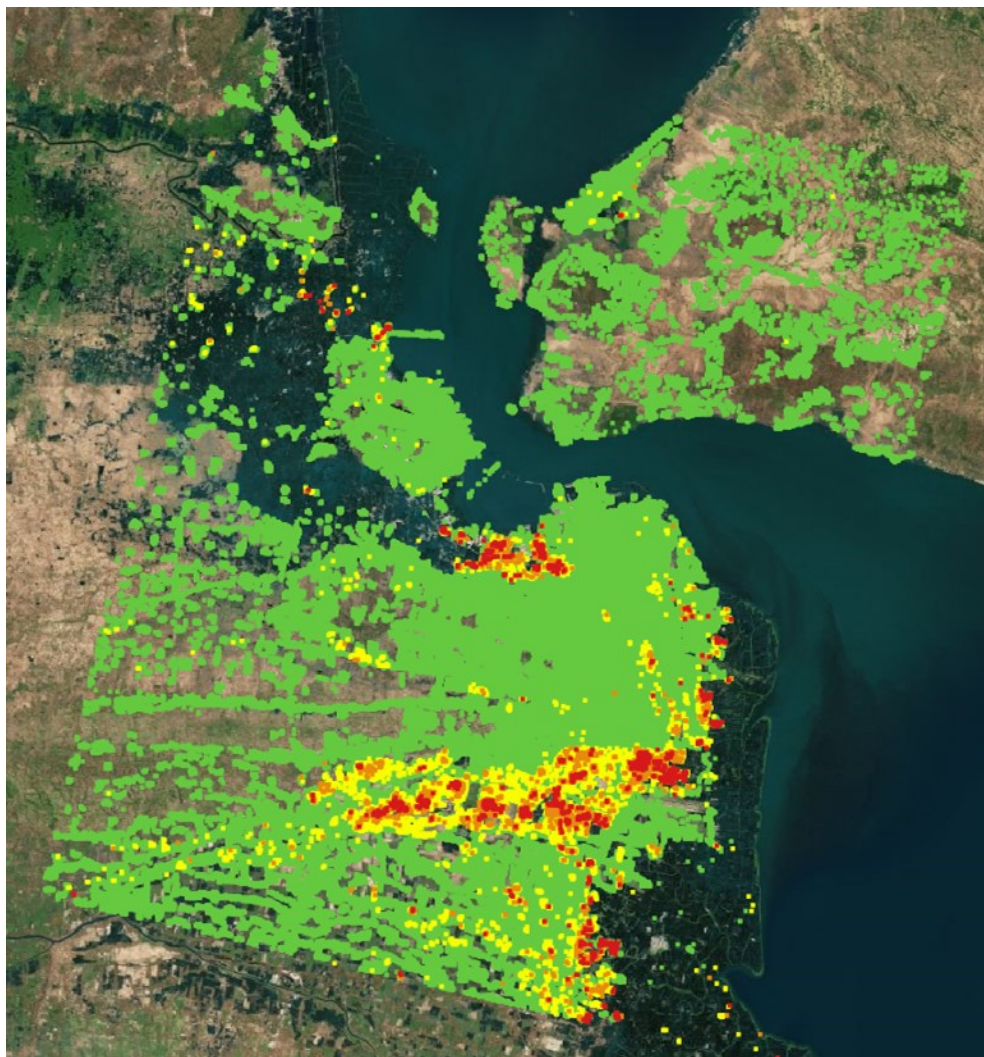
SNAPPING (AUTH)



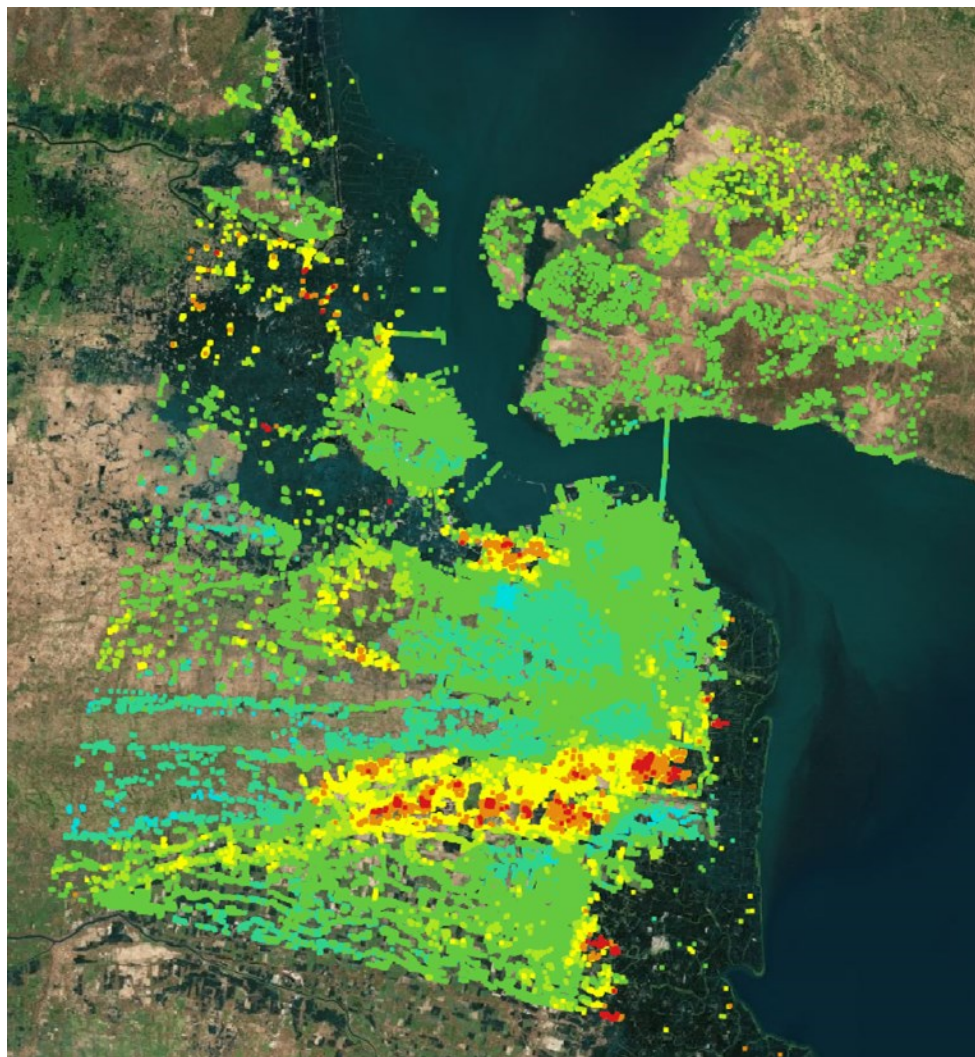
ADB - Support to Water & Food Security Planning & Investments in Indonesia through EO Services Surabaya Terrain Motion | GEP On-Demand Advanced InSAR Services



P-SBAS



[Access GEP Public Job](#)



[Access GEP Public Job](#)

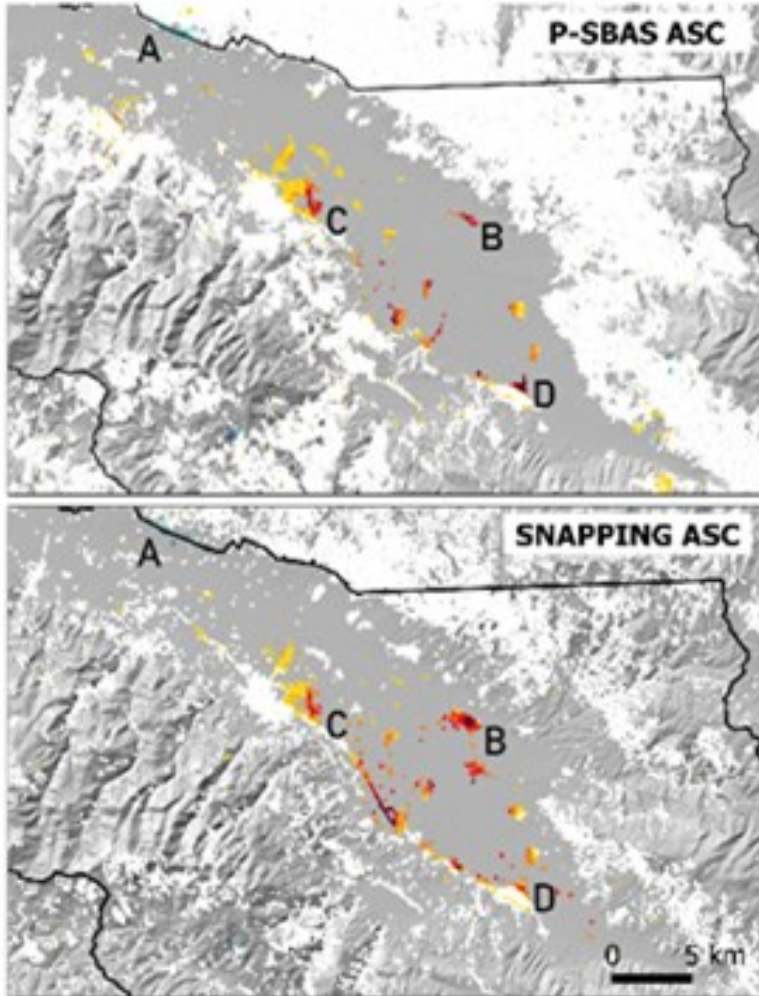
Contains modified Copernicus
Sentinel-1 mission data (2015-2020)

SNAPPING

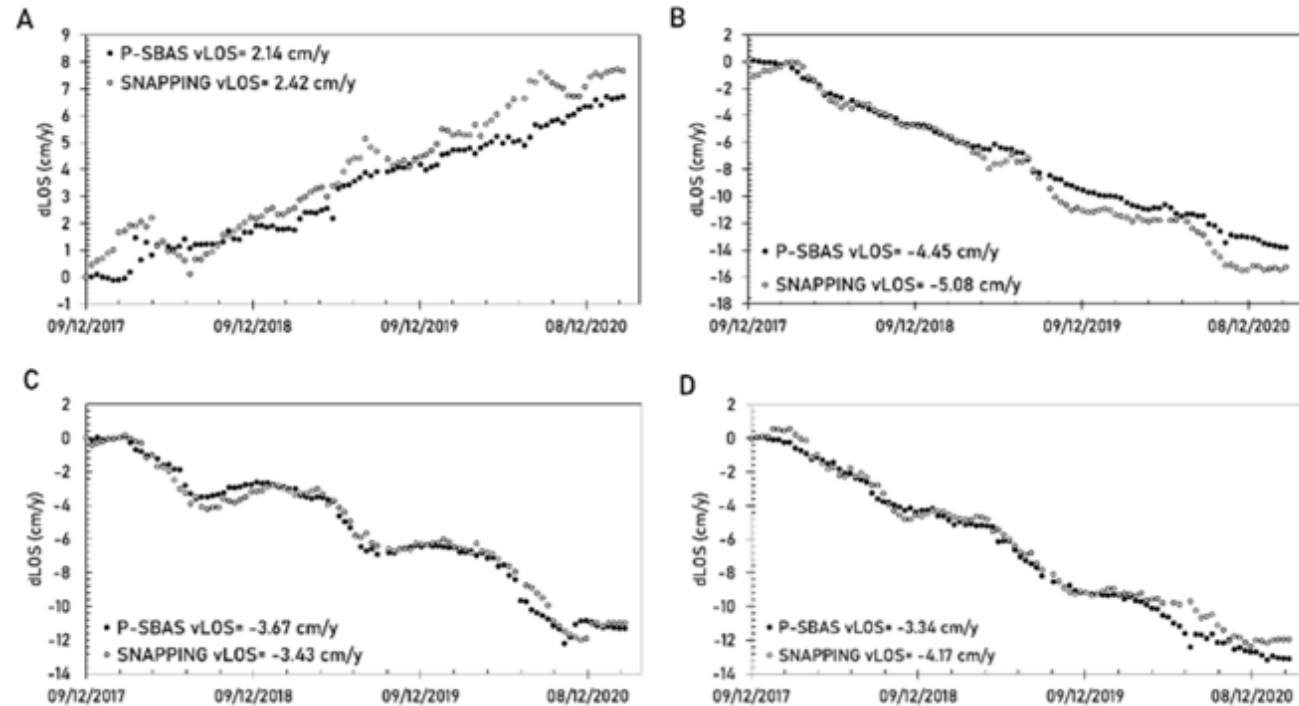


User Inter-Verification of GEP EO-Based Measurements

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

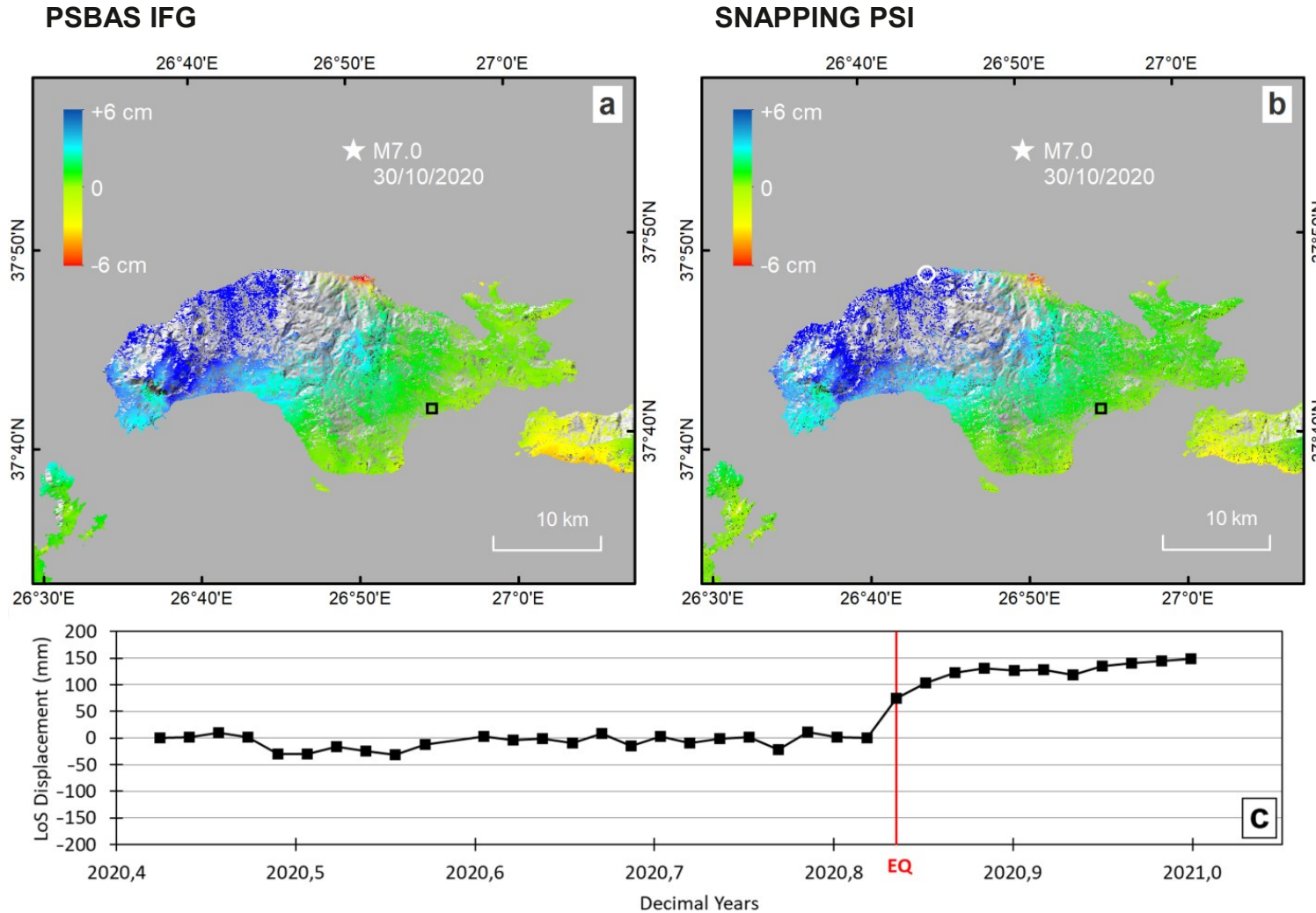


P-SBAS and SNAPPING detected comparable motion patterns and higher subsidence rates of -6.4 and -7.6 cm/year, respectively. SNAPPING point density is higher in the valley (human settlements), whereas P-SBAS over surrounding mountainous regions. More details



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

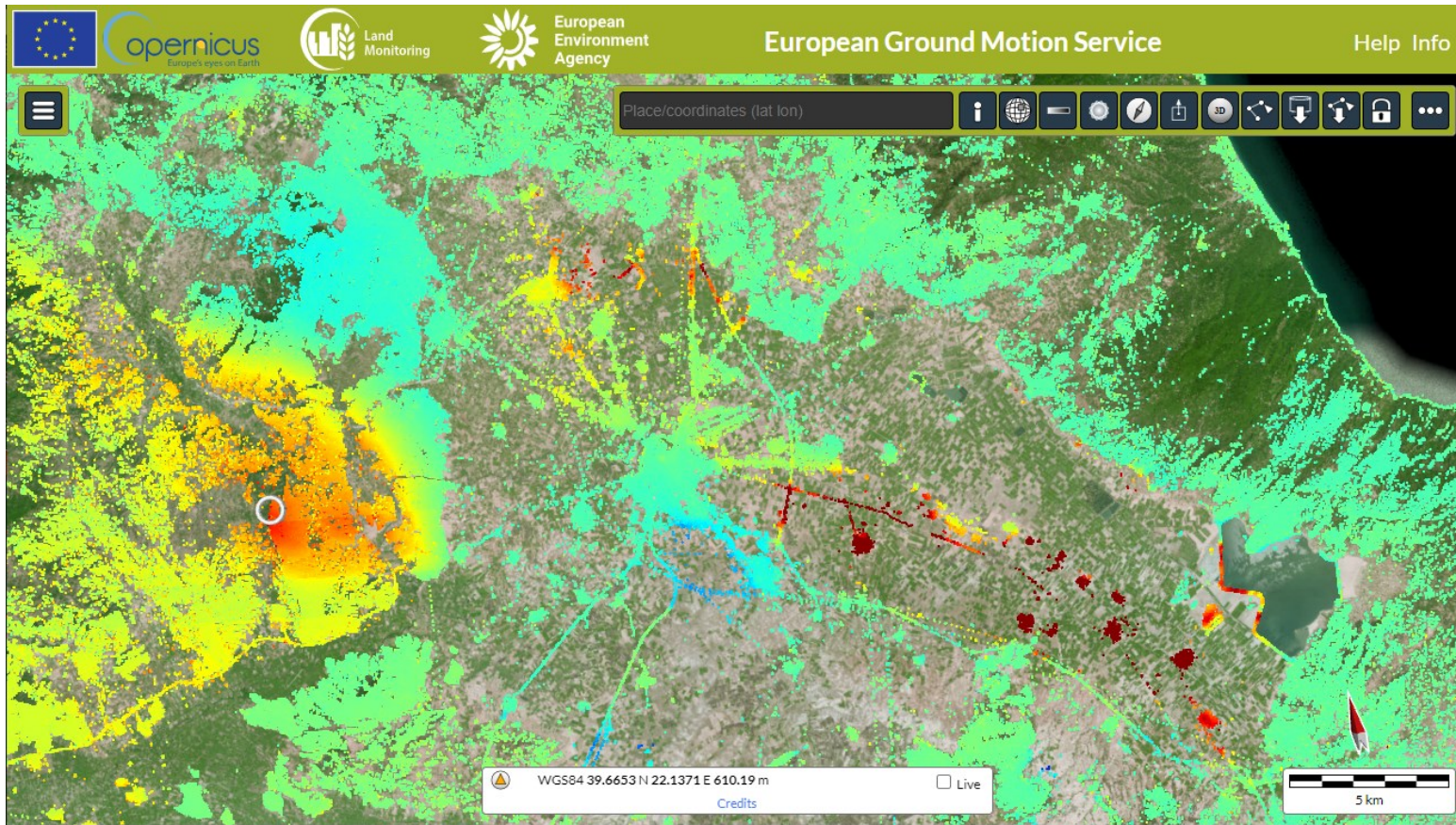


Co-seismic Sentinel-1 displacement field (24 October 2020–30 October 2020; ascending track 131) for the Samos M7.0 earthquake-based P-SBAS service (in IFG mode) at 100 m resolution (unwrapped and converted to LoS displacements) and corresponding displacements as extracted from SNAPPING PSI time series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

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

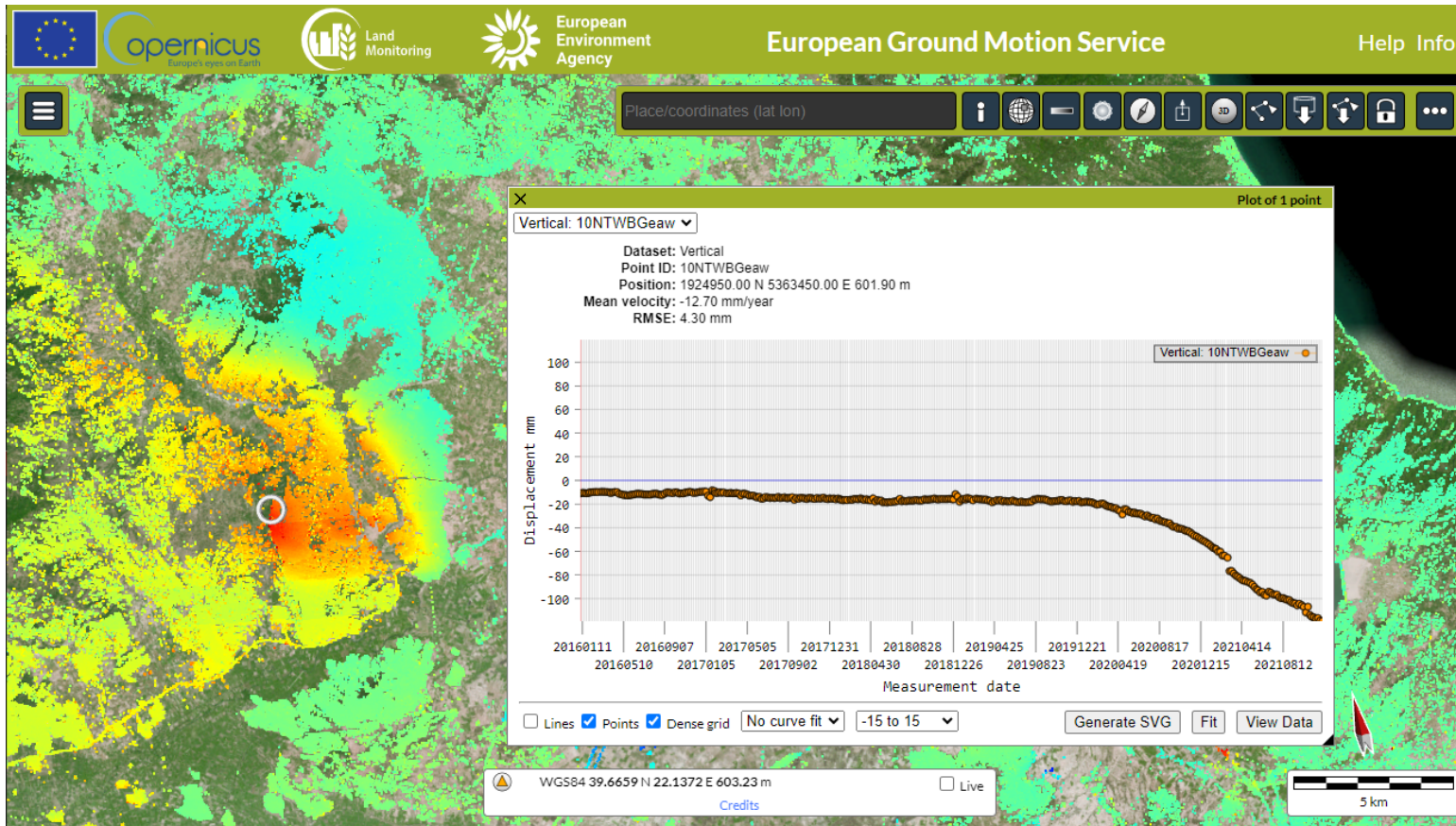
SNAPPING PSI Med vs EGMS | Tirnavos M6.3 Earthquake

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.



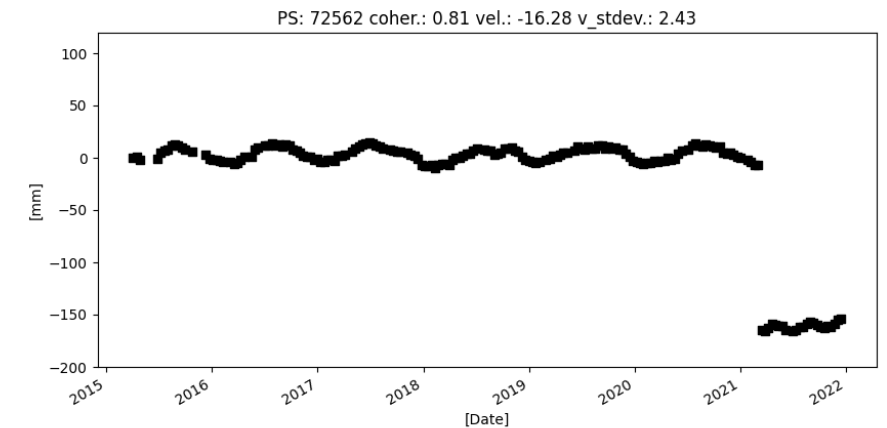
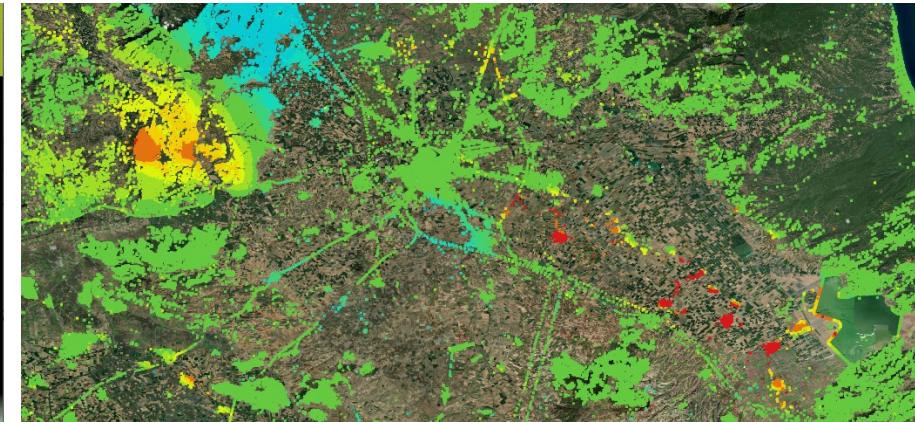
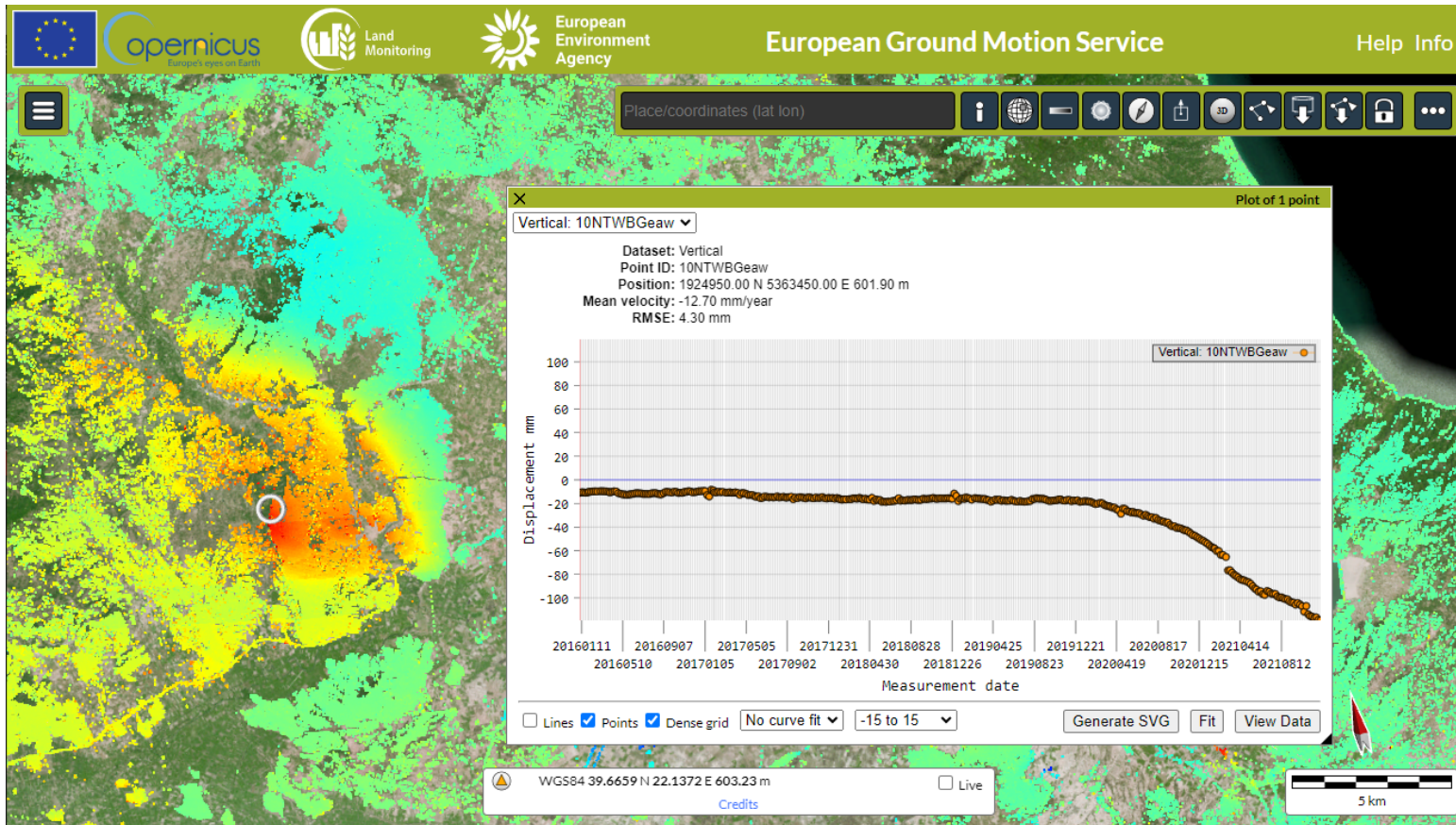
SNAPPING PSI Med vs EGMS | Tirnavos M6.3 Earthquake

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.



SNAPPING PSI Med vs EGMS | Tirnavos M6.3 Earthquake

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.



GEP | FASTVEL Landslides over French Alps

The screenshot displays the geohazards platform interface. The main map area shows a velocity map of the French Alps, with a color scale ranging from -7.0 to 7.0 cm/year. The map is overlaid with a topographic map. The interface includes a search bar, a map navigation toolbar, and a job details panel on the right. The job details panel shows the job name 'FASTVEL S1 DSC T168 Stubai', the job ID '6306c920-3ee7-4195-b035-a3cd18fe79ba', the start and finish dates (Jun 26th 2018 15:21 and Jun 27th 2018 06:00), the creator 'agili', and the status 'Success'. A success message indicates that the job was completed successfully.

geohazards tep Main area

Free text search

Store Upload Products EO Data EO-based products Community Private

Processing Services

FASTVEL S1 DSC T168 Stubai

Job Info

Job Name	FASTVEL S1 DSC T168 Stubai
Wps Job Id	6306c920-3ee7-4195-b035-a3cd18fe79ba
Started at	Jun 26th 2018 15:21
Finished at	Jun 27th 2018 06:00
Created by	agili
Status/Result Location	
Status	Success
Visibility	public
Share	

Success
The job was completed successfully.

Results

Found layers in the result. Show results

XML Result

Current search result

Discovery feed for local data Total results 3

- FASTVEL_MTA_S1A_DES.csv
- FASTVEL_MTA_Topography map (meters)
- FASTVEL-MTA - Velocity map (cm/year)

Features Basket Data Packages

No results found. Total results 0

sel.all inv.sel. Remove all Save

Lon: 11.160 Lat: 46.931

2005-01-01 2020-01-23

1 km

Terradue

GEP | FASTVEL Landslides over French Alps

The screenshot displays the geohazards platform interface. The main map shows a velocity map of the French Alps, with a color scale ranging from -7.0 to 7.0 cm/year. The map includes labels for Pfaffenferrier, Windacht, Triebenkarlasferrier, and Dibeltalferrier. A timeline at the bottom of the map shows dates from 2005-01-01 to 2020-01-23. The interface includes a search bar, a navigation menu, and a processing services panel on the right.

Processing Services

FASTVEL S1 DSC T168 Stubai

Job Info

Job Name	FASTVEL S1 DSC T168 Stubai
Wps Job Id	6306c920-3ee7-4195-b035-a3cd18fe79ba
Started at	Jun 26th 2018 15:21
Finished at	Jun 27th 2018 06:00
Created by	agili
Status/Result Location	Share
Status	Success
Visibility	public
Share	Share

Success
The job was completed successfully.

Results

Found layers in the result. [Show results](#)

XML Result

Discovery feed for local data Total results 3

- FASTVEL_MTA_S1A_DES.csv
- FASTVEL_MTA_Topography map (meters)
- FASTVEL-MTA - Velocity map (cm/year)

Features Basket Data Packages Total results 0 | [sel.all](#) | [inv.sel](#) | [Remove all](#) | [Save](#)

No results found.

GEP | FASTVEL Landslides over French Alps

geohazards tep Main area

Free text search

2005-01-01 2020-01-23

Lon: 11.149 Lat: 46.961

Vel [cm/year] -7.0 0.0 7.0

Processing Services

FASTVEL S1 DSC T168 Stubai

Job Info

Job Name	FASTVEL S1 DSC T168 Stubai
Wps Job Id	6306c920-3ee7-4195-b035-a3cd18fe79ba
Started at	Jun 26th 2018 15:21
Finished at	Jun 27th 2018 06:00
Created by	agili
Status/Result Location	
Status	Success
Visibility	public
Share	

Success
The job was completed successfully.

Results

Found layers in the result. Show results

XML Result

Discovery feed for local data Total results 3

- FASTVEL_MTA_S1A_DES.csv
- FASTVEL_MTA_Topography map (meters)
- FASTVEL-MTA - Velocity map (cm/year)

Features Basket Data Packages

No results found. Total results 0

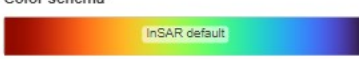
Interactive Web Interface | Visualization of SNAPPING measurements

Free Text Search

Details

Displacement PSI Time-Series Descending Orbit - Greece

Color schema



Color domain: -15.663 / 15.663 mm/yr

-55.938 55.938

Filter points

Point Area Transect

Description

Nationwide Mapping of Surface Motion in Greece. Surface Motion Line-of-Sight (LoS) displacement rates (average velocity), their uncertainties and the corresponding displacement time series. Output from the Surface motion MA PPING Sentinel-1 (SNAPPING) processing chain run on the GEP. See [documentation!](#) for more information.

Satellite

Copernicus Sentinel-1 IW TOPS SLC

Orbit Direction

DESCENDING

Measurement Period

2015-04-012 2015-04-010 2015-04-012 2015-04-011 2015-04-011 2015-04-011 2015-04-012 2015-04-011 2015-04-013 2015-04-010

Resolution

Medium

Provider

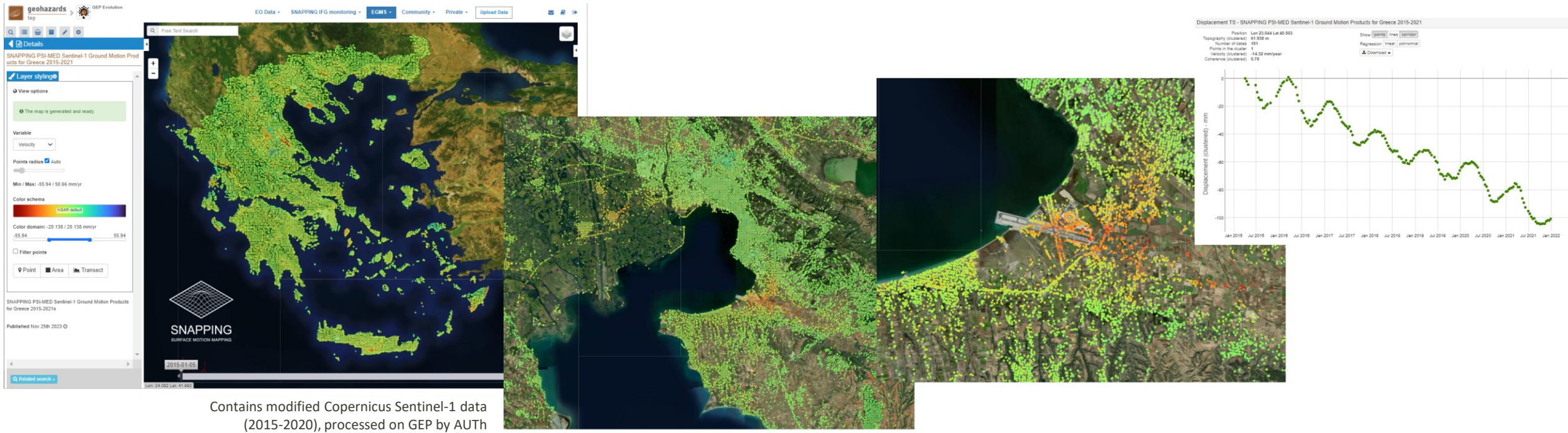
AUTH

Published Apr 4th 2024

Download - Related search -



Processing Services

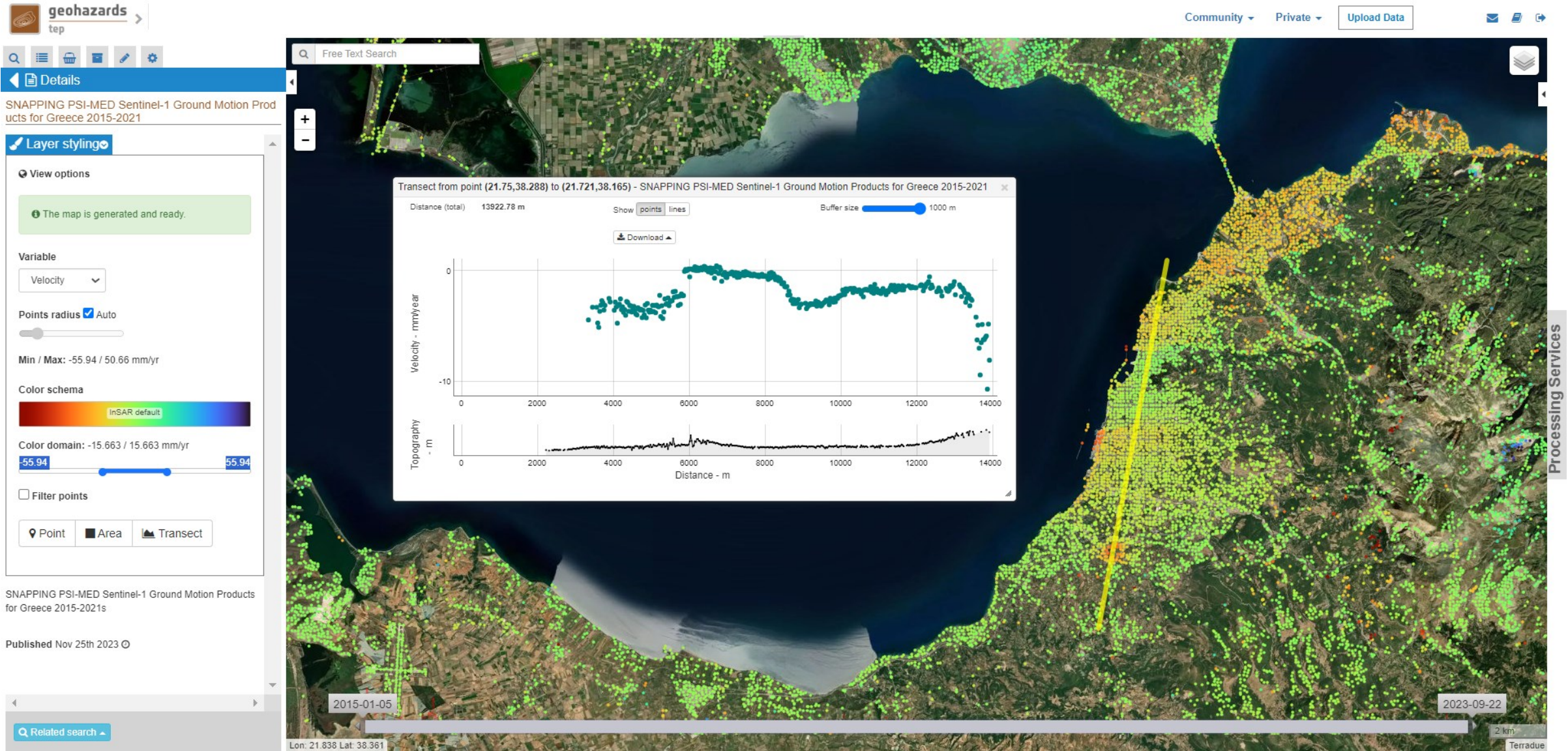


Not only a **visualization** portal, but also for **dissemination** purposes

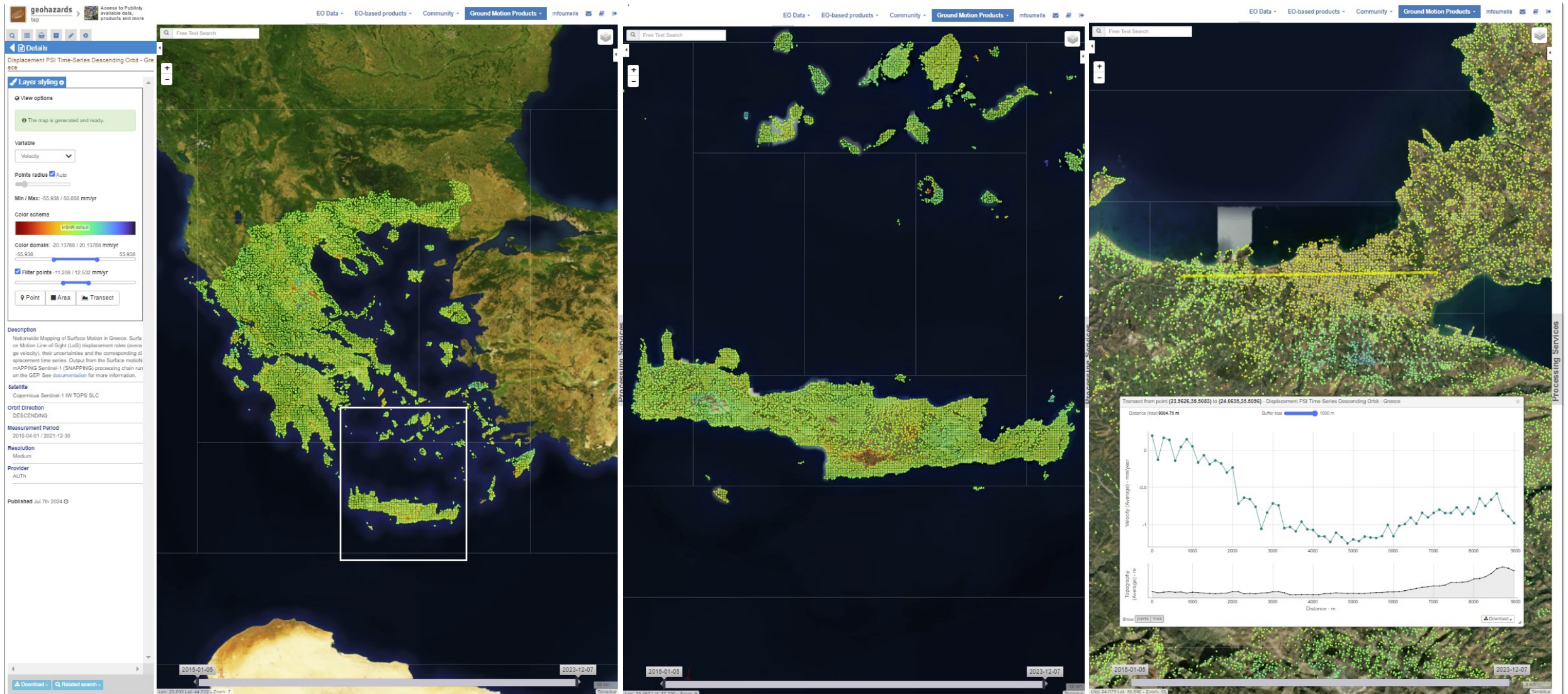
Open dataset (CC BY-NC-SA 4.0) for investigation of various geohazards

Facilitates **intercomparison** with other open datasets

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



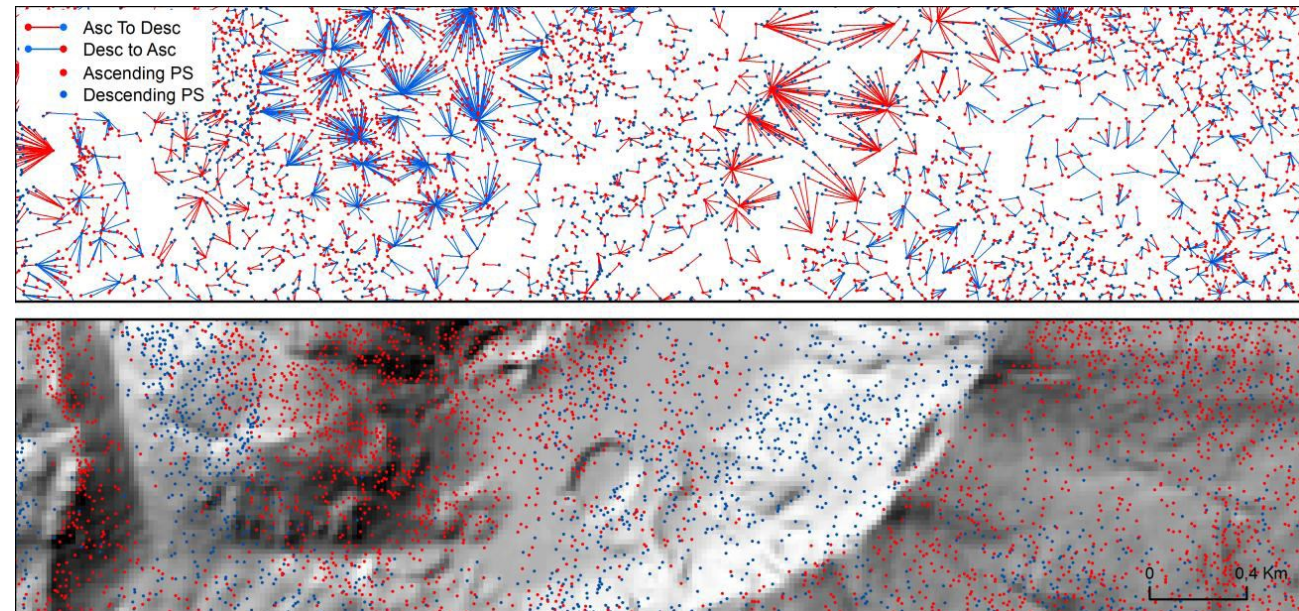
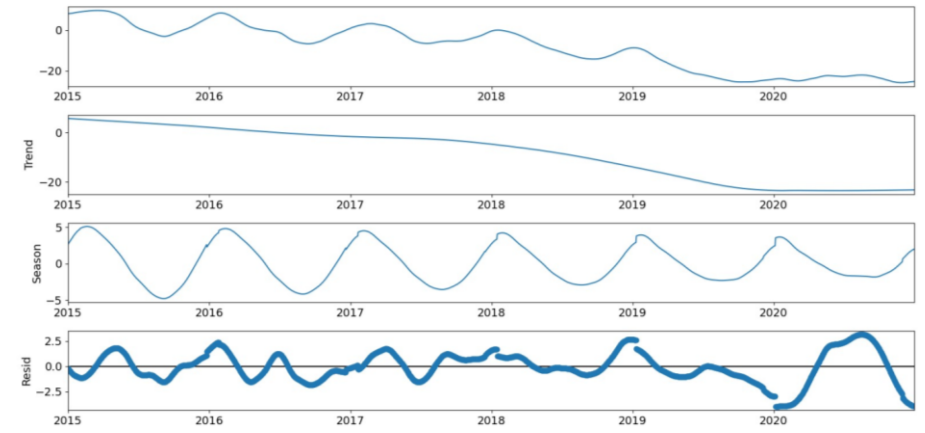
GEP | Interactive Visualization Interface



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

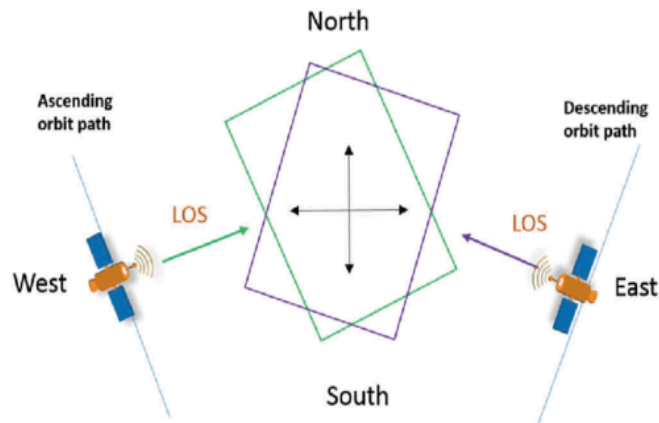


Foumelis, M., 2016. Vector-based approach for combining ascending and descending Persistent Scatterers Interferometric point measurements. *Geocarto International*, doi:10.1080/10106049.2016.1222636.

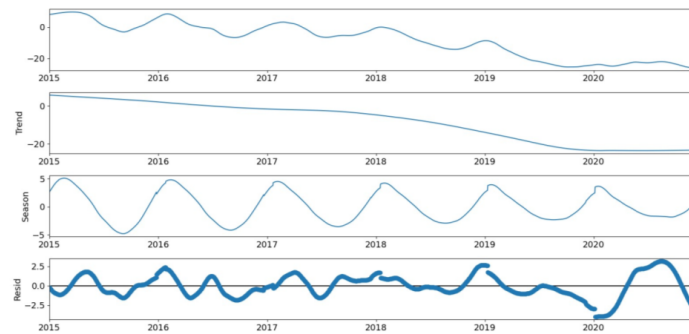
Family of SNAPPING services | Post-Processing & Reporting



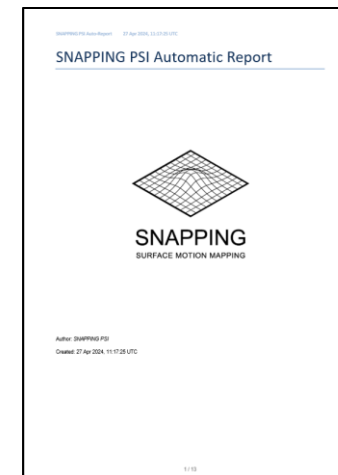
Combination of ascending and descending Line-of-Sight surface motion measurements to calculate the actual E-W and Vertical motion components.



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



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.



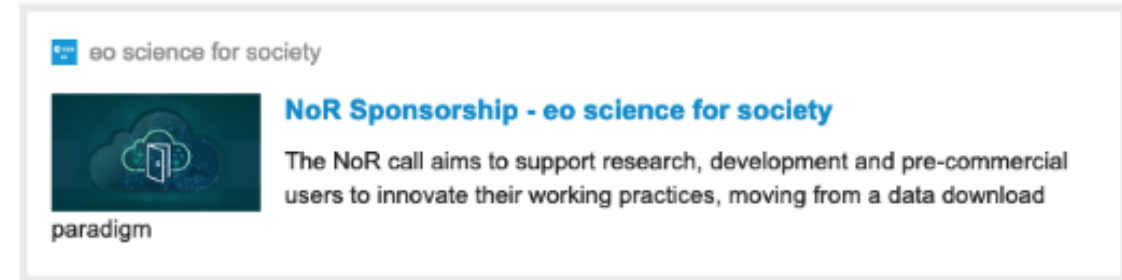
- ESA NoR

- Privileged channel providing science support for:

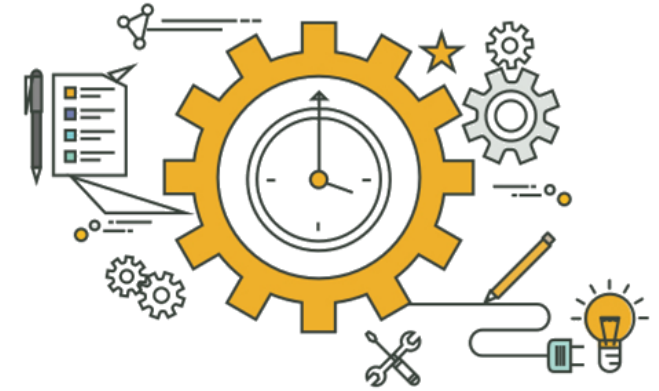
- Geohazards analysts (i.e. principal investigator, researcher, scientific engineer, PhD student, trainee) with EO data processing goals
- Service providers or data providers, interested to connect their resources to be used via the Platform
- Organizations interested in running user community trainings

- 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

Michael Foumelis
mfoumelis@geo.auth.gr



EO.Lab
Earth Observation
& Geospatial Applications Lab



CIRI-AUTH

CENTER FOR INTERDISCIPLINARY RESEARCH AND INNOVATION
Aristotle University of Thessaloniki