

The Contribution of Earth Observation to Disaster Risk Management

Online access to EO data



Philippe Bally, Roberto Biasutti (ESA)

Zachary Foltz (ARGANS)

Earth Observation Programmes Directorate,

European Space Agency



Developing a better understanding of risk through hazard and exposure mapping

Provides useful geo-information:

1) Hazard Impact mapping:

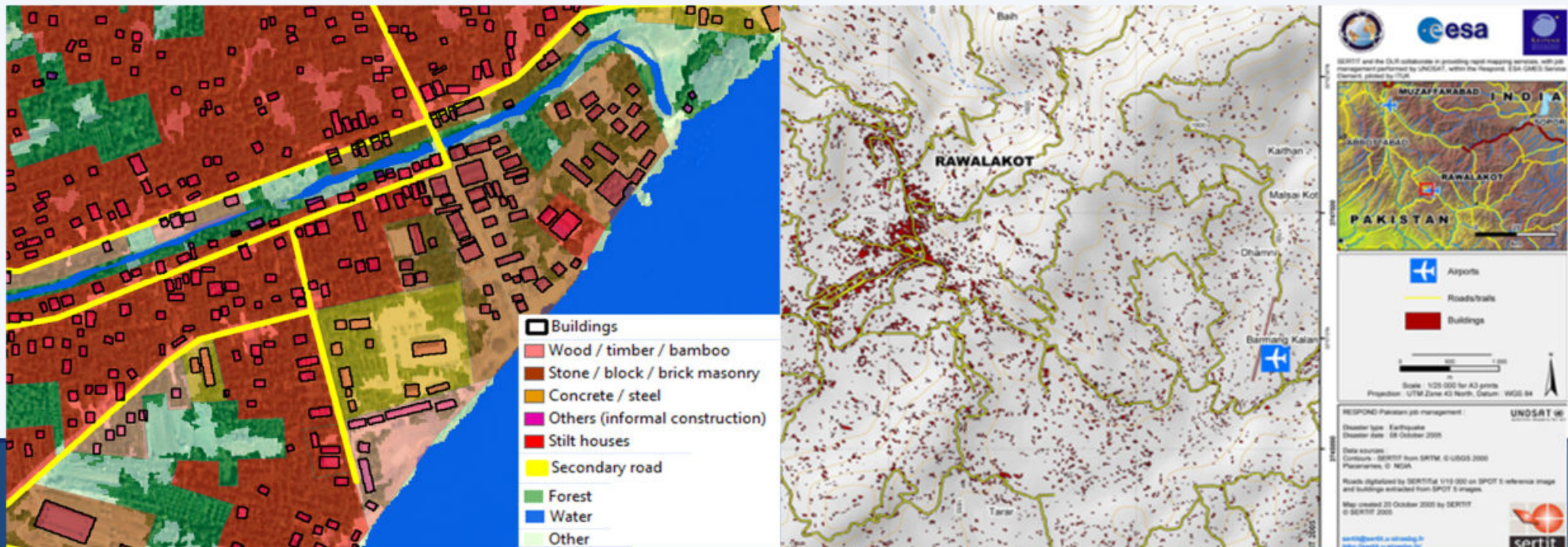
Response phase

*Low level of sophistication but rapid provision of information
(hazard impact, location of damaged areas)*

2) Exposure & Asset mapping/modeling

Risk assessment – prevention & preparedness

Detailed information on hazard & risk, including scientific data



- Emergency Response:

- Rapid Crisis Mapping
- Damage identification
- Situational Mapping

- Prevention, Preparedness, Recovery, and Reconstruction:

- Detailed Damage Mapping
- Risks Assessment

- All phases:

- Reference Mapping
- Digital Elevation and Terrain models
 - LU/LC Mapping
 - Asset Mapping

EO IS AVAILABLE GLOBALLY



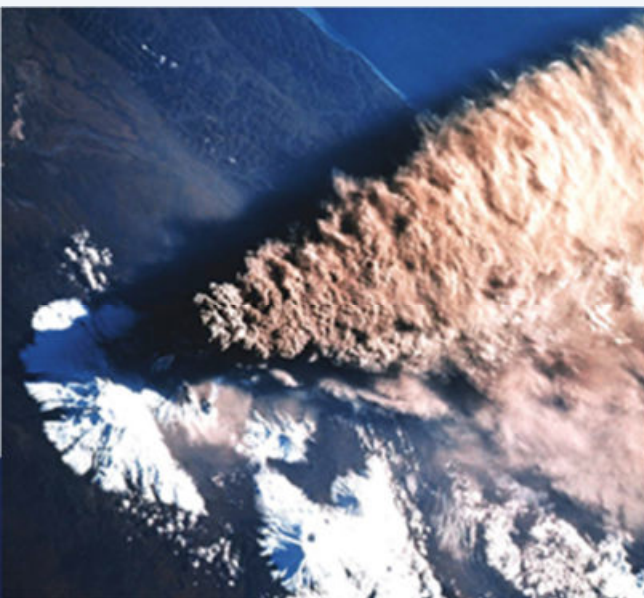
The Copernicus Sentinel missions & DRM



Meeting **user requirements** (availability, timeliness, accuracy) generally requires a combination of different EO missions.

The **Sentinel missions** allow for regular provision of very large, open access data collections in a systematic fashion to support operational applications globally.

- **Sentinel-1** provides repeat observations in all weather and enables bi-weekly observations for millimetric precision terrain motion monitoring (C-SAR).
- **Sentinel-2** with its two platforms, provides complete optical coverage of 100% of global land masses once every 5 weeks.
- **Sentinel-3, 4, & 5** operate in different complementary domains of remote sensing.



The International Charter 'Space & Major Disasters'



- Initiated in **2000** by CNES, ESA, and CSA
- **Agencies joined since:** NOAA, ISRO, CONAE, JAXA, USGS, UKSA, CNSA, ROSCOSMOS, INPE, DLR, KARI, EUMETSAT, ABAE, UAESA
- Unified system of EO data acquisition & delivery for natural or human-made disaster response (no cost, best effort basis)
- Cooperation agreements with UNOOSA, UNITAR/UNOSAT, and Sentinel Asia (escalation procedure)
- Only **Authorized Users (NDMAs)** can request the services of the Charter
- **Universal Access:** nationally mandated users from any country may apply to be an **Authorized User (AU)**, provided simple criteria are met
- **Charter activations** – Averaging 42/year over the last 10 years
- Processing environment – **ESA Charter Mapper**



792
Activations

154
Countries

17
Charter Members

270
Contributing Satellites

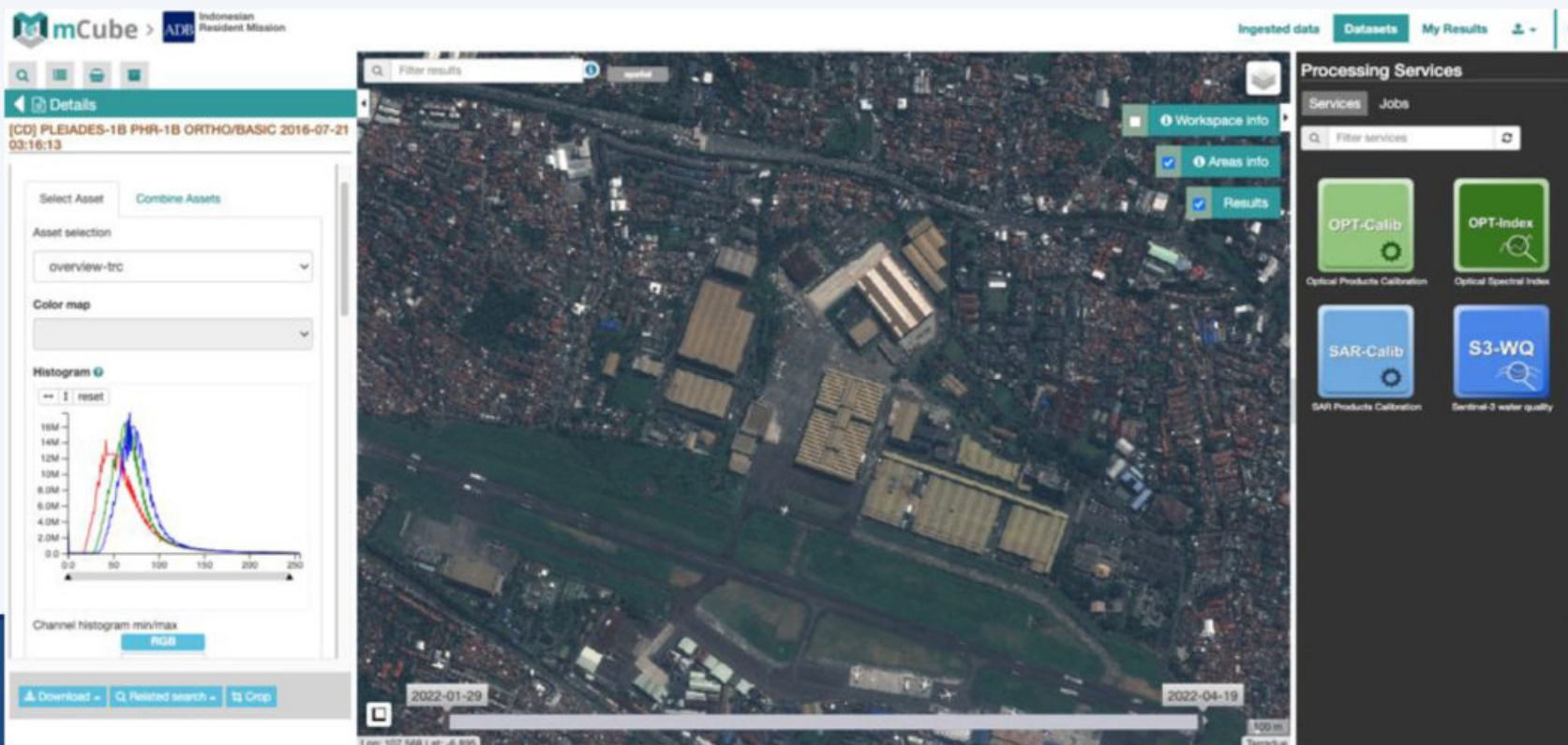
mCube: Multi-Mission Mapper

- A **processing environment** used in ESA disaster risk reduction (DRR) projects, such as the GDA disaster resilience project.
- **mCube** is the light version of the **ESA Charter Mapper**, the cloud platform for disaster response mapping of the International Disaster Charter
- **On-demand services** for Data Screening, Event Response, and Area Monitoring
- Offers processing chains and tools for online **EO data visualisation and analysis**



www.mcube.terradue.com

<https://docs.mcube.terradue.com>



Multi-Mission Algorithm and Analysis

- Ingestion, hosting, and cataloguing of data (metadata extraction and publication)
 - Data calibration and creation of true and false color composites at full resolution.
 - Preserved lineage and access to native format
- Multi-sensor Calibration processors with standard parameters
 - Gain, offset, ESUN, incidence angle, etc.
- Unified Datasets with common band name method (CBN)
 - Optical: pan, coastal, blue, green, red, nir, swir
 - Radar: amplitude, phase, sigma nought
- Process Ready Data as (STAC+COG)



+

**COG**CLOUD OPTIMIZED
GEOTIFF

+



Supported Missions



A single access to multi-mission EO data at Medium, High, and VH resolution.

mCube supports 46 satellites (37 EO missions) from 20 space agencies and data distributors.



ALOS-2	Landsat-8/9
ALSAT-1B	Planetscope
BlackSky	Pleiades
CartoSat-2	RCM
COSMO-SkyMed	ResourceSat-2, 2A
Gaofen-1	SAOCOM-1A/1B
Gaofen-2	Satellogic Newsat
Gaofen-3	Sentinel-1A/B
Gaofen-4	Sentinel-2A/B
GeoEye-1	SPOT-6, 7
ICEYE-X2, 4, 5, 7	TerraSar-X,
Kanopus-V-IK	TanDEM-X
Kanopus-V	UK-DMC-2
KOMPSAT-3, 3A	Vision-1
KOMPSAT-5	VRSS-1, 2
	WorldView-1, 2, 3

EO processing services

On-demand

Systematic

Optical and SAR calibration



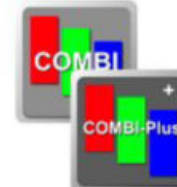
Spectral index



Pan Sharpening



Band combination



Unsupervised Classifier



Change detection



Co-location and co-registration



Water quality & Vegetation health



InSAR



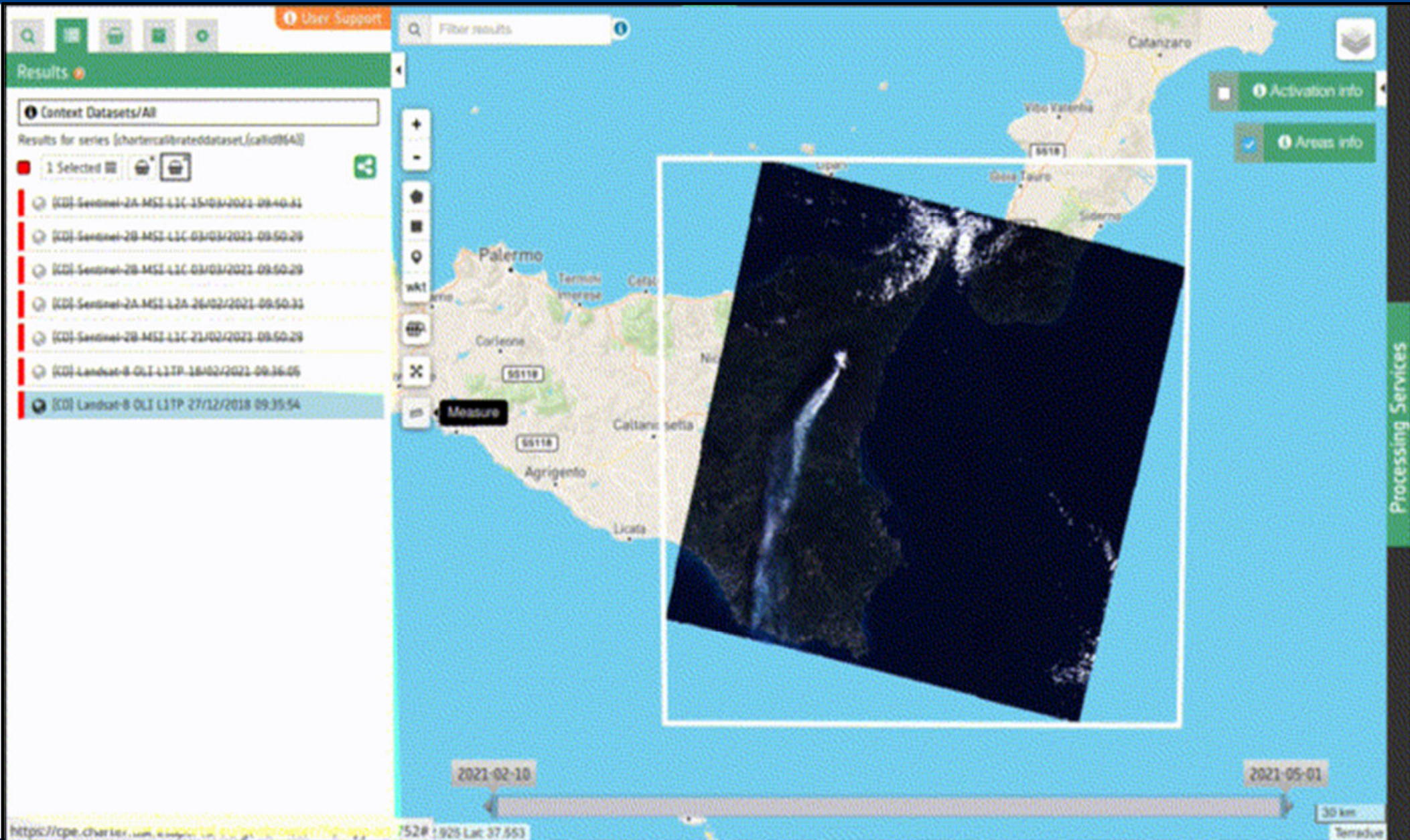
Hotspot and Burnt area



TERRAUE

planetek
italia

NHAZCA
NATURAL HAZARD CONTROL AND ASSESSMENT



The screenshot displays the mCube web interface. On the left, a sidebar shows search results for a specific series. The main area features a map of Sicily with a satellite image overlay. A timeline at the bottom indicates the date range from 2021-02-10 to 2021-05-01. The interface includes various navigation and information tools.

Results

Context Datasets/All

Results for series [chartercalibrateddataset_calid064]

1 Selected

- [X] [CD] Sentinel-2A MSI L1C 15/03/2021 09:40:31
- [X] [CD] Sentinel-2B MSI L1C 03/03/2021 09:50:29
- [X] [CD] Sentinel-2B MSI L1C 03/03/2021 09:50:29
- [X] [CD] Sentinel-2A MSI L2A 26/02/2021 09:50:33
- [X] [CD] Sentinel-2B MSI L1C 21/02/2021 09:50:29
- [X] [CD] Landsat-8 OLI L1TP 18/02/2021 09:36:05
- [X] [CD] Landsat-8 OLI L1TP 27/12/2018 09:35:54

Map labels: Palermo, Agrigento, Licata, Caltanissetta, Termini Imerese, Cefalù, Nicosia, Gela Tauro, Vibo Valentia, Catanzaro, Siracusa.

Timeline: 2021-02-10 to 2021-05-01

Scale: 30 km

Coordinates: 752# 1925 Lat: 37.553

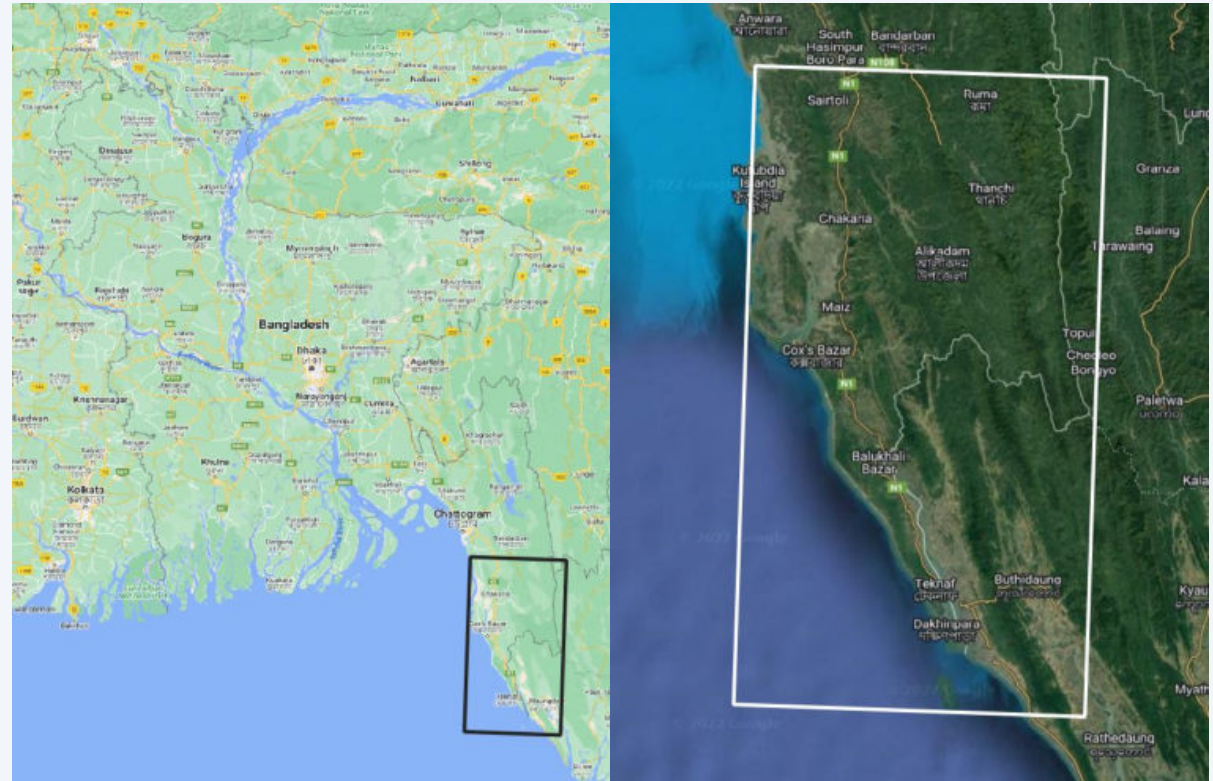
Processing Services

mCube: Example



Medium Resolution Ground Motion Map

- **AOI:** South-eastern part of Bangladesh, covering approximately 15,590 km².
- The ground motion products were derived exploiting the entire archive of Copernicus Sentinel-1 mission over the period 2015-2022.
- The temporal resolution of the Copernicus Sentinel-1 mission over the AOI is 12 days (i.e. repeat cycle).



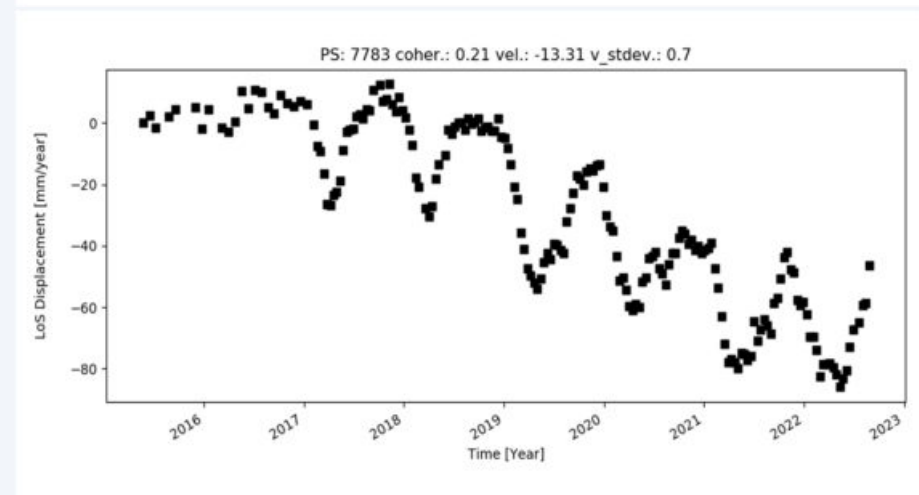
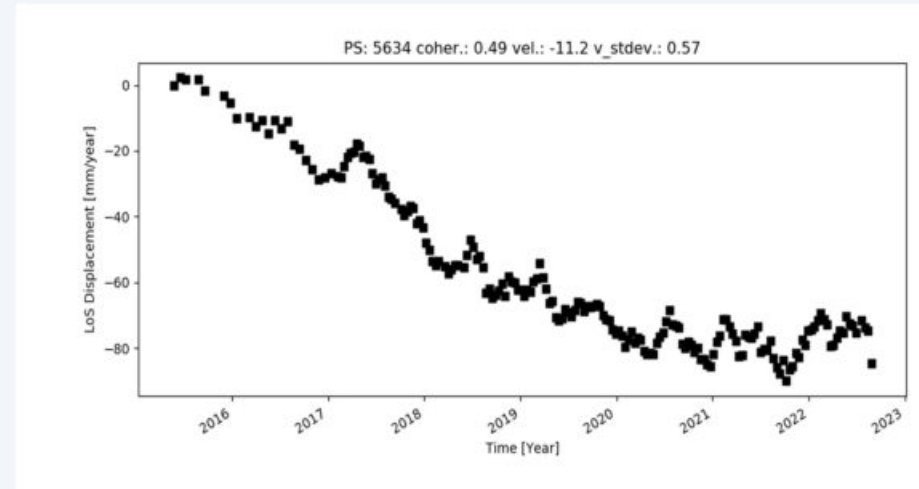
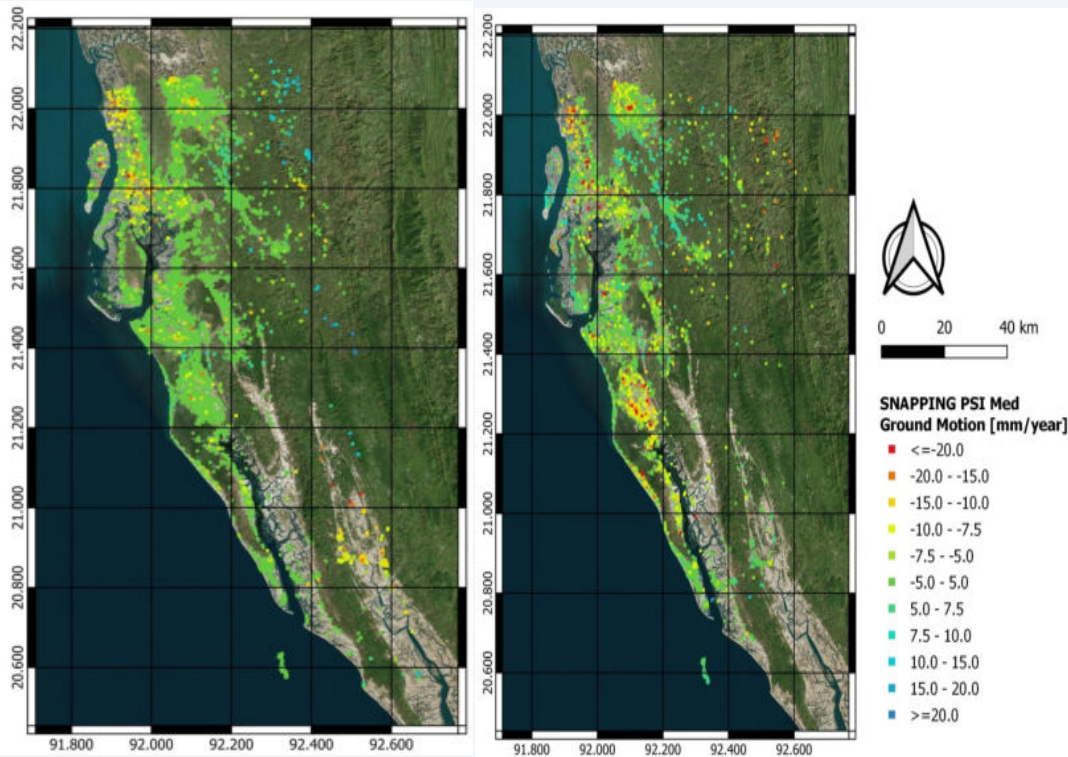
Geo-positional accuracy	Approximately 15m (half of the reference pixel DEM used in the processing; SRTM 1 Arc-Second)
Thematic accuracy	The expected measurement accuracy is 1-2 mm/year for displacement rates and 2-5 mm for displacement time series.
Visual inspection	Products were visually assessed by independent staff

mCube: Example



Medium Resolution Ground Motion Map

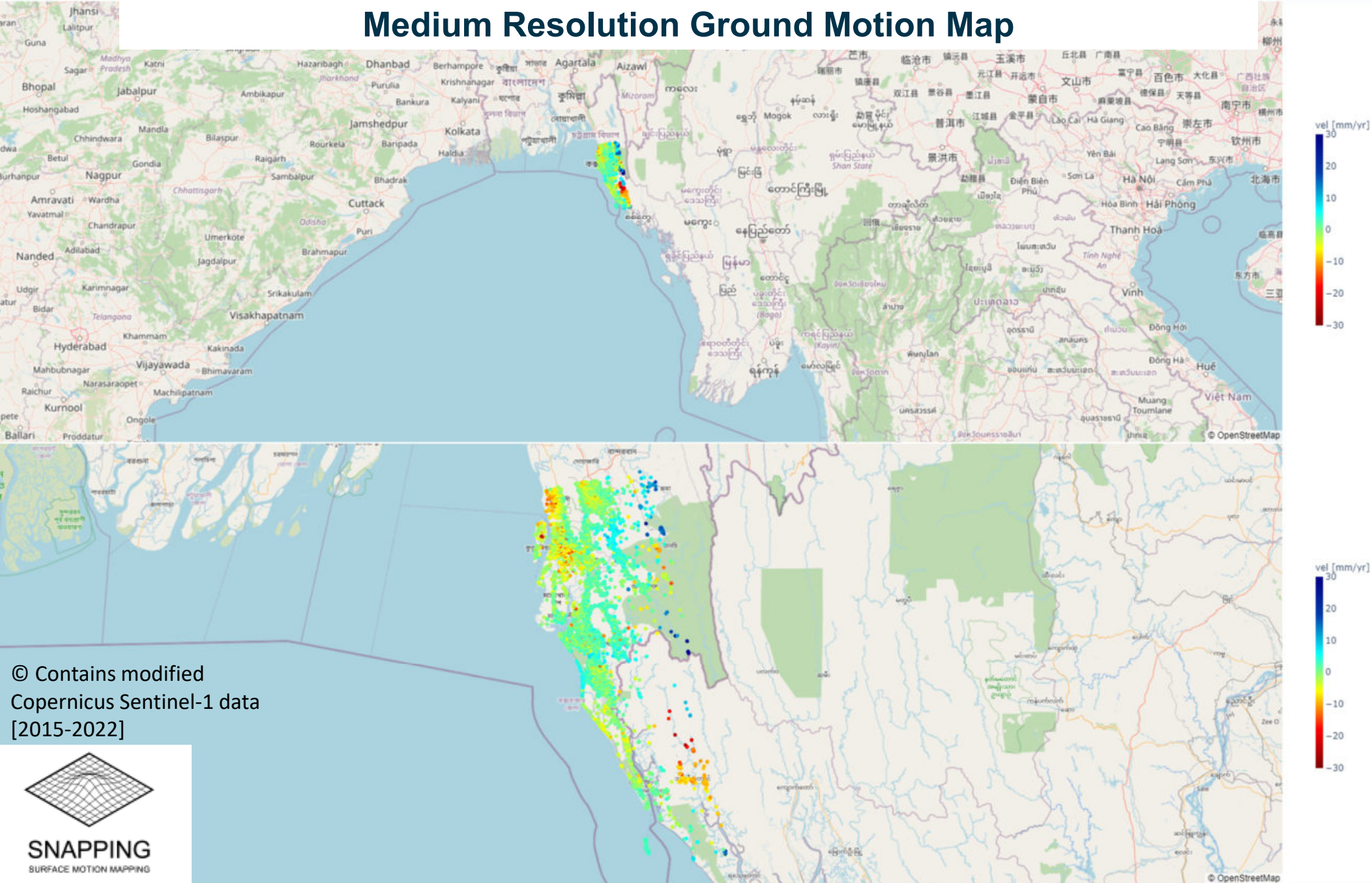
Over the region of interest **376** and **313** Sentinel-1 SLC products were available, along the ascending track 41 (A041) and the descending track 77 (D077), respectively, for the period **between 05/2015 and 08/2022**.



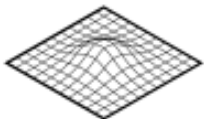
mCube: Example



Medium Resolution Ground Motion Map



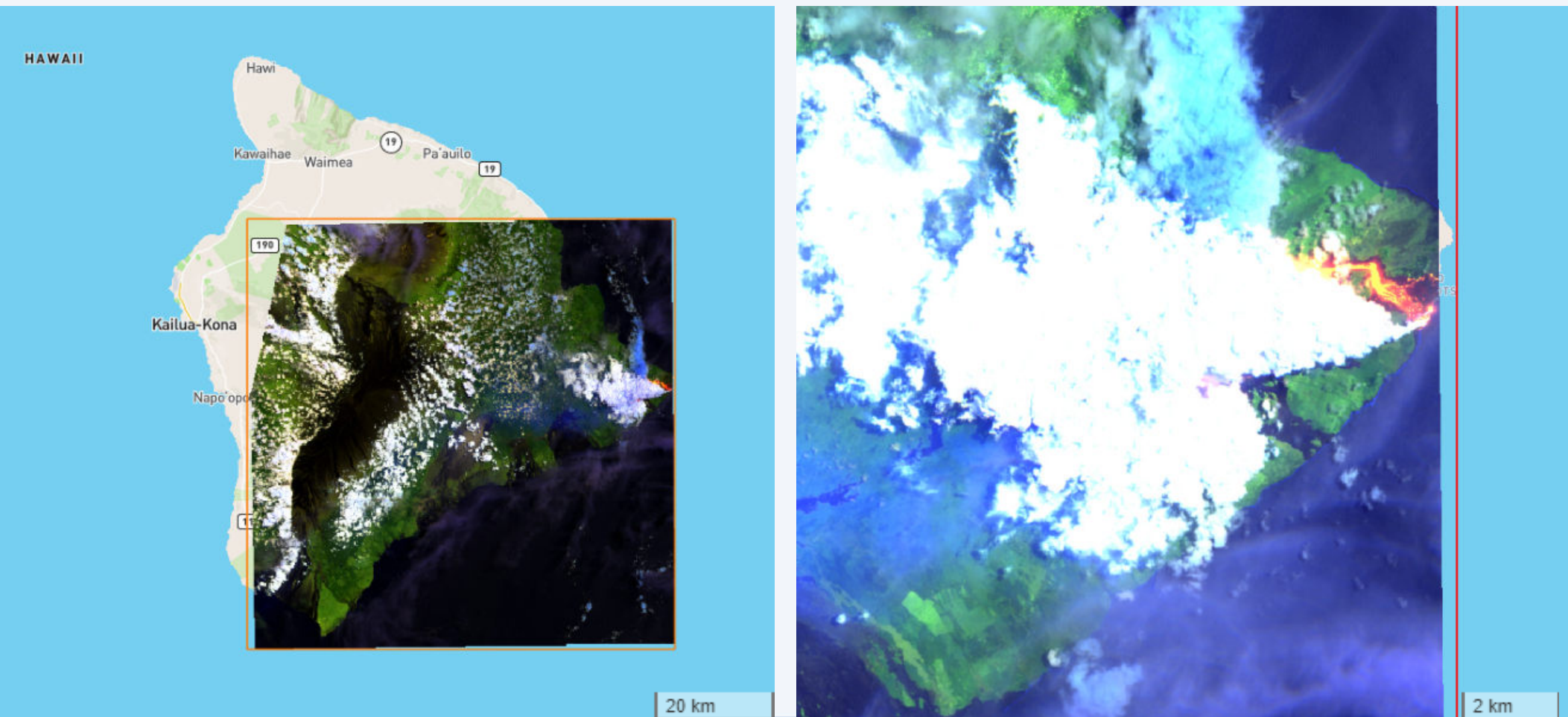
© Contains modified
Copernicus Sentinel-1 data
[2015-2022]



SNAPPING
SURFACE MOTION MAPPING

Example of Optical image viewing in mCube

- Kīlauea Volcano, Hawaii, United States
- RGB composite with Sentinel-2 Bands 11 and 12, which are sensitive to temperature



Example of Radar image viewing in mCube



Semeru Volcano, Indonesia

Results

Filter Criteria

AoI:

Satellite:

Sensor type: Radar

Date Range: From To

Resolution: very low low medium high very high

Search

Sort: Sensing date

Context Datasets

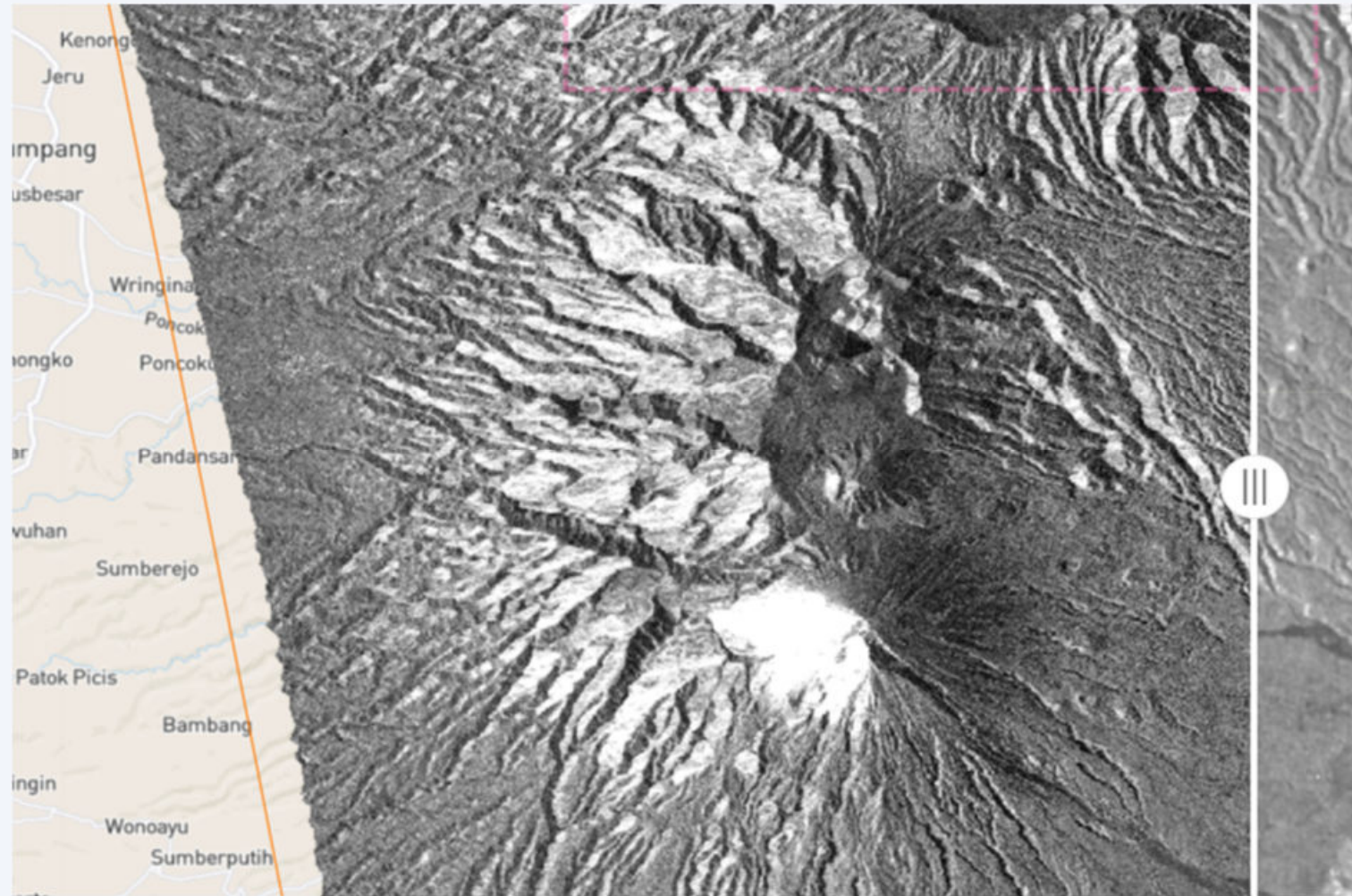
Results for series [chartercalibrateddataset,{callid913}]

- [CD] ICEYE-X2 GRD STRIPMAP VV 21867 2022-12-05 14:33:30
- [CD] SENTINEL-1A GRD IW VV/VH 54 2022-12-02 10:50:23

Close compare layers

Sentinel-1

Semeru Volcano, Indonesia



ICEYE

Example of Radar image viewing in mCube



[CD] ICEYE-X7 GRD STRIPMAP VV 17800 2022-10-06 18:30:30

overview-vv

Color map

Histogram

← | reset

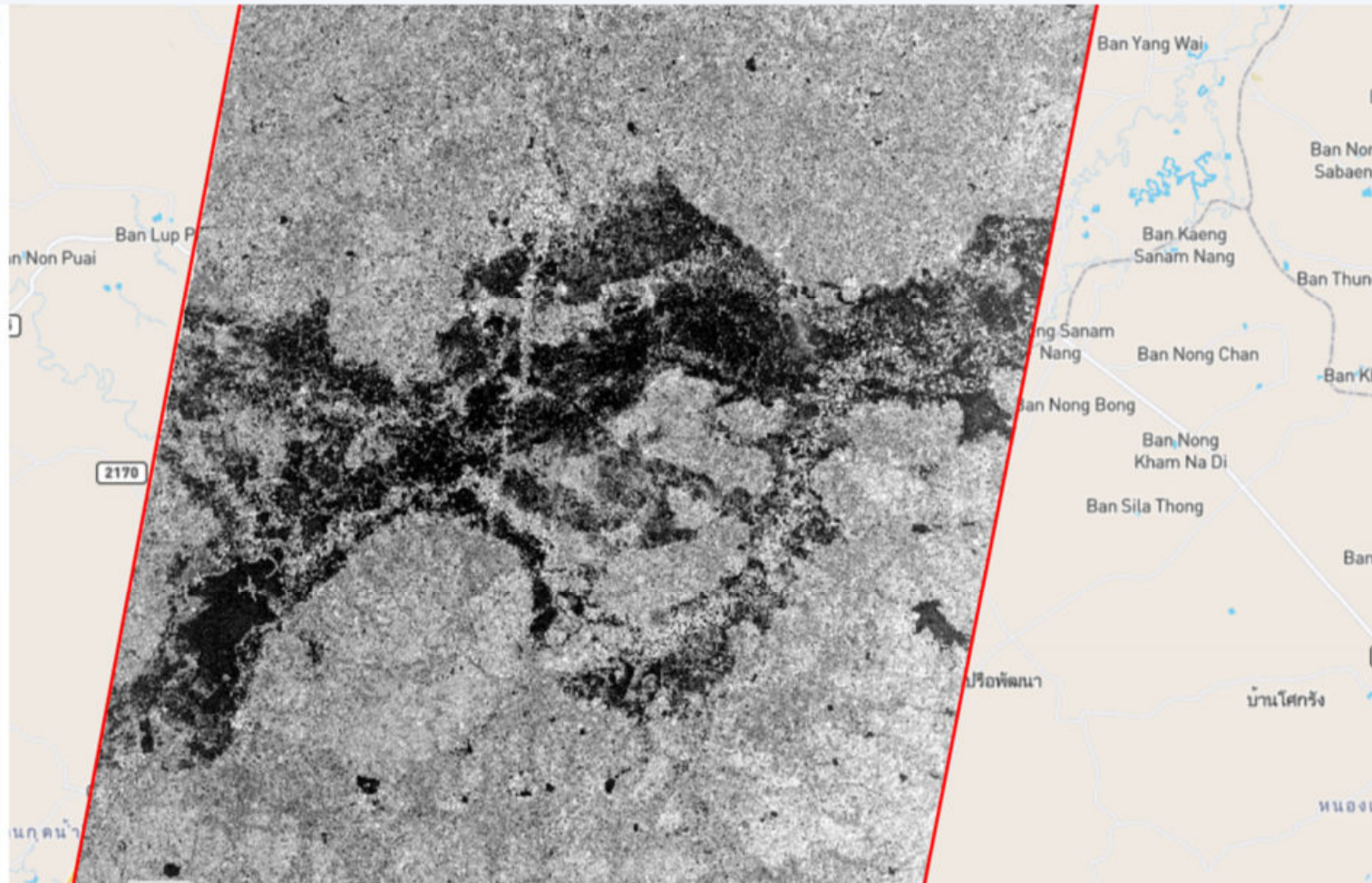
4.0M
3.5M
3.0M
2.5M
2.0M
1.5M
1.0M
500k
0.0

40 60 80 100 120 140 160 180

Channel histogram min/max

min	max
30,88	184,28

Use the same min/max value for all channels



Current users of the platform

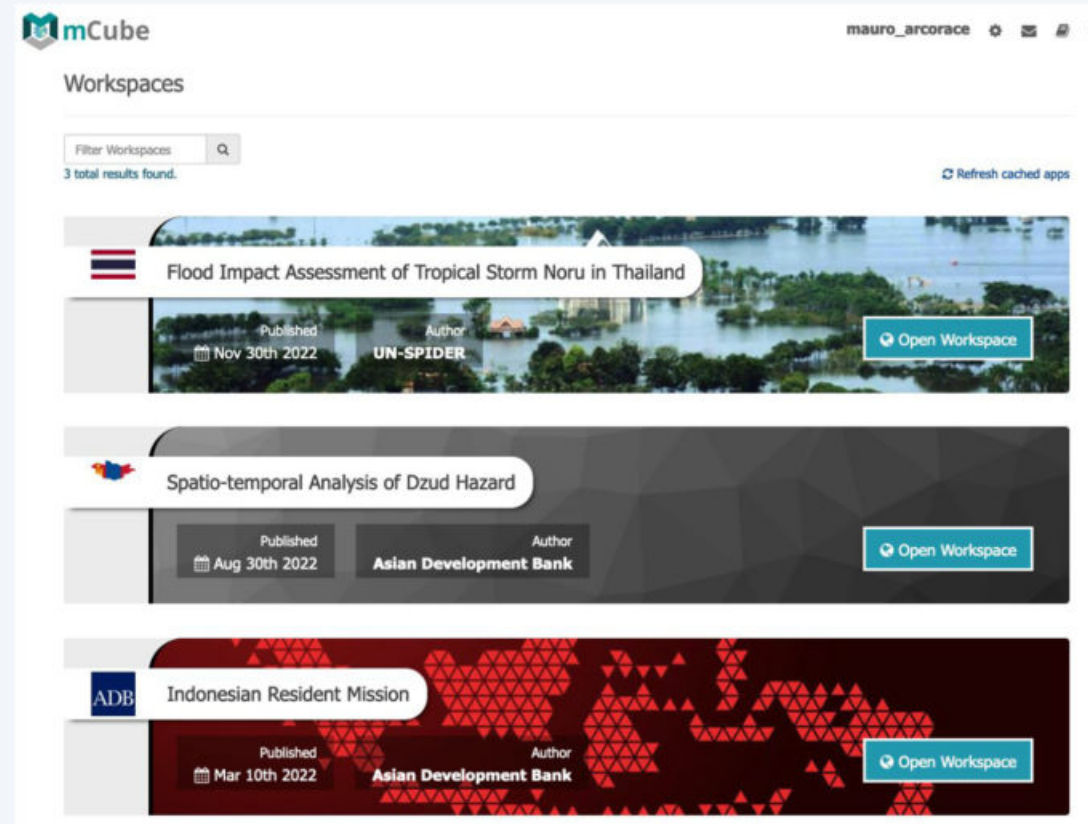
- **Southeast Asia (Asian Development Bank)**
 - Year-long contracts to support for emergency assistance on rehabilitation and reconstruction (Asian Institute of Technology) and for water and food security planning and investments (LAPAN)
 - Ongoing discussions to expand the usage of the platform for capacity building across the region
- **Governmental Agencies**
 - MITMA/ IGN (Spain): volcanic monitoring and geological risk
 - Alberta Geological Survey (Canada): landslides in abandoned coal mines
 - INGV (Italy): ground deformation due to both human and seismic activities
- **Private companies**
 - Climate-X: ground deformation and shrink-swell risk across the United Kingdom



mCube - Conclusion



- mCube is the light version of the ESA Charter Mapper, however it is used for general DRM applications
- ESA is exploring mechanisms to provide DRM organisations access to mCube.
- Multi-mission processing environment that can be used for various thematic applications



- In addition to the large number of **government missions**, a growing sector of “**new space**” missions has emerged, many of which can support DRM applications.
- **Disaster Response:** The International Charter and Sentinel Asia provide relevant services, the latter also provides services for all phases of DRM
 - The **user base** is growing (both NDMAs and the International Humanitarian community), and rapid mapping methods are being adopted by more and more end users
- **Risk prevention/preparedness (risk assessment):** There are more EO based services providing risk information used by mandated organisations
 - In Europe, 50+ **Geological Surveys** are routinely using satellite-based terrain motion maps for geo-hazard risk assessment, but in many countries of the world, users are not aware or cannot afford EO based solutions
- A link exists between **risk reduction and response:** By achieving greater acceptance & use of EO for risk assessment users will be better equipped to exploit EO for disaster response.

An aerial photograph of a river delta, showing a complex network of channels and distributaries. The water is a deep blue, and the surrounding land is a mix of green and brown, indicating a mix of forest and agricultural or natural land. The overall scene is a dense, intricate web of waterways.

Thank you

mCube: Technology



- Users access through customized Workspaces, (i.e. Web-based dashboards)
- Storage and processing of EO datasets
- Leverages the latest Cloud-Native Geospatial technologies
- EO platform provides seamless access to multi-mission data thanks to STAC and COG technologies and the usage of Common Band Names (CBN)

The screenshot displays the mCube Workspaces interface. At the top, the mCube logo is on the left, and the user name 'mauro_arcorage' with settings, mail, and profile icons is on the right. Below the header, there is a search bar labeled 'Filter Workspaces' with a magnifying glass icon and a search button. Below the search bar, it says '3 total results found.' and a 'Refresh cached apps' button. The main content area shows three workspace cards, each with a title, a thumbnail image, a published date, an author, and an 'Open Workspace' button.

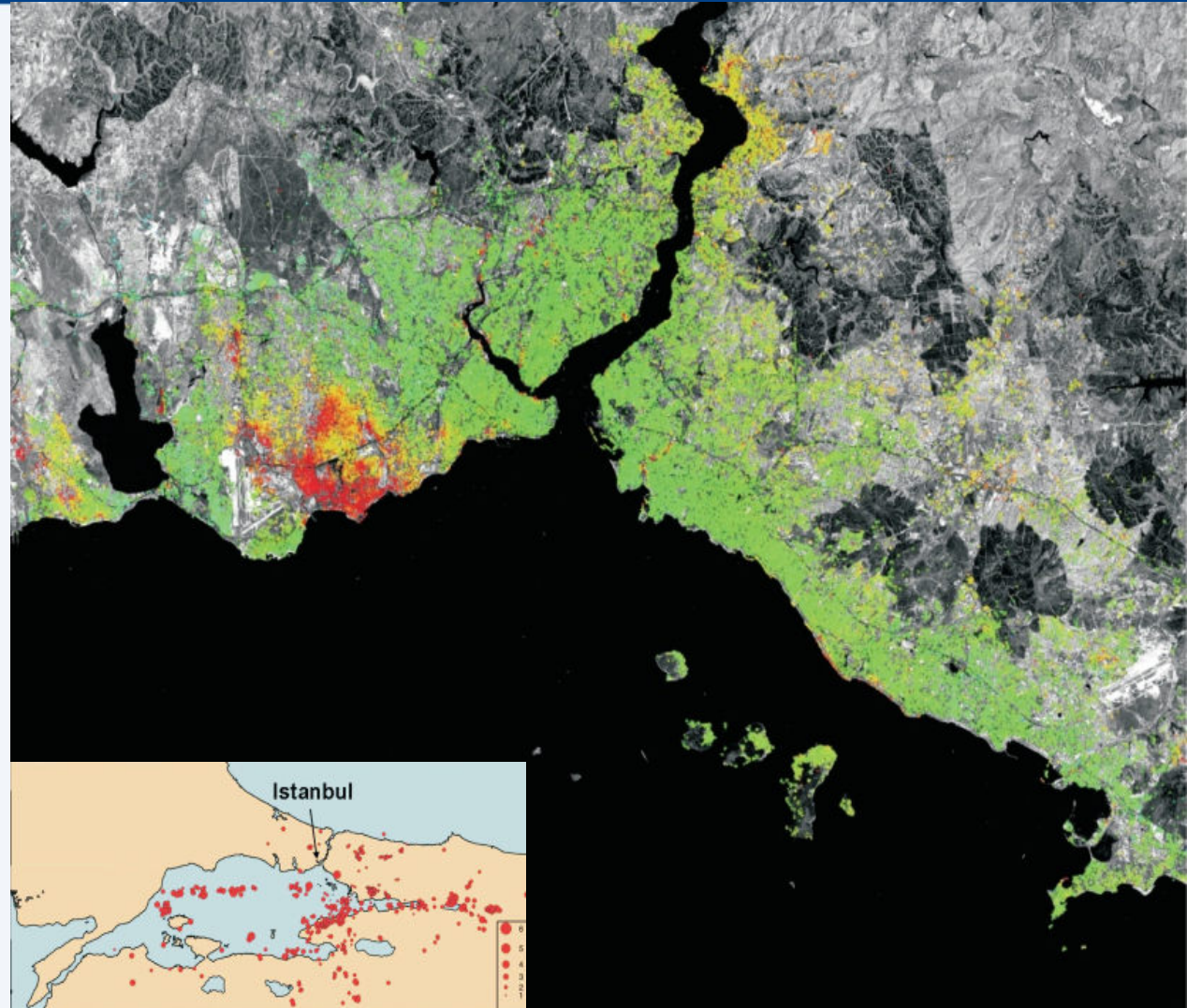
- Workspace 1:** Title: Flood Impact Assessment of Tropical Storm Noru in Thailand. Published: Nov 30th 2022. Author: UN-SPIDER.
- Workspace 2:** Title: Spatio-temporal Analysis of Dzud Hazard. Published: Aug 30th 2022. Author: Asian Development Bank.
- Workspace 3:** Title: Indonesian Resident Mission. Published: Mar 10th 2022. Author: Asian Development Bank.

Seismic risk mapping: 1999 Izmit Earthquake

- Seismic ground motion study : a soil vulnerability service for tectonics
- The product combines a time series of 50+ ERS SAR acquisitions to estimate terrain motion over several years

Analysis:

- Much of the destruction was concentrated to the west of the city. By contrast the eastern city is built mostly on solid rock and is generally stable, though critical zones are revealed by the terrain motion study. This is a clear sign of unconsolidated soft sediments that can severely amplify seismic ground motion.

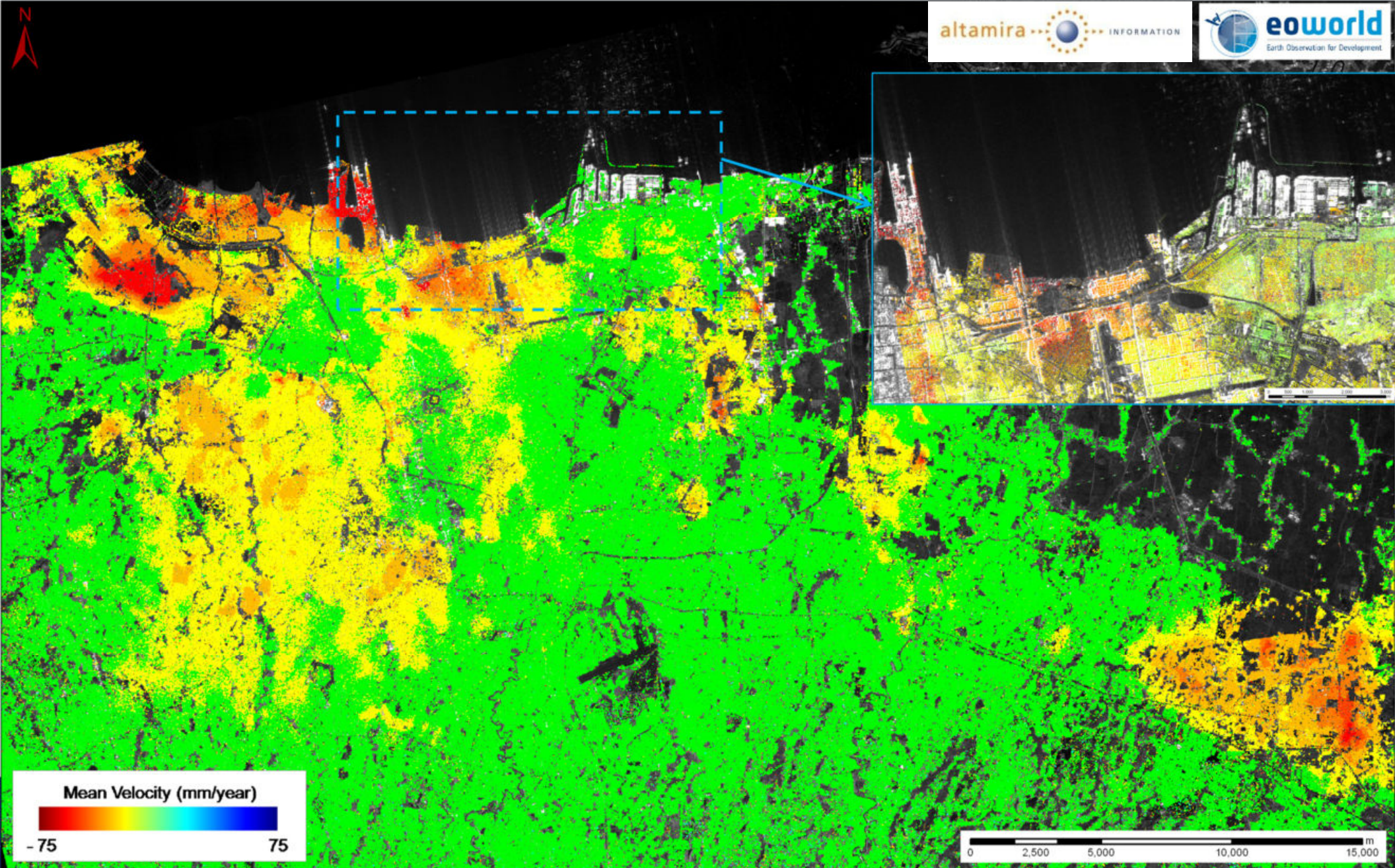


“Terrafirma data indicates where we should focus on our efforts in earthquake preparation.” Kandilli Observatory and Earthquake Research Institute (KOERI).

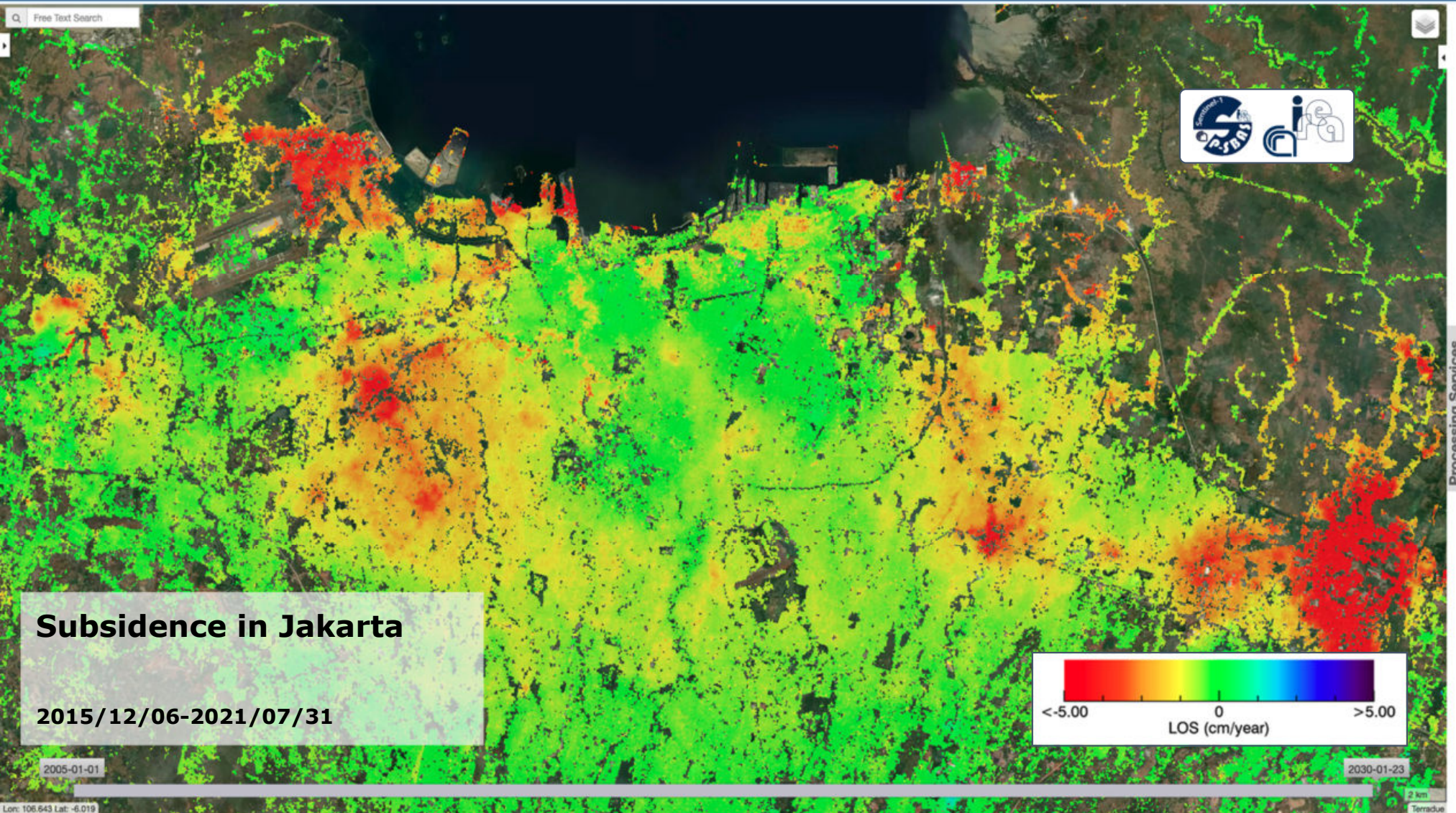
Understanding hazards to support mitigation



Analysis of Land Subsidence in Jakarta



Understanding hazards to support mitigation

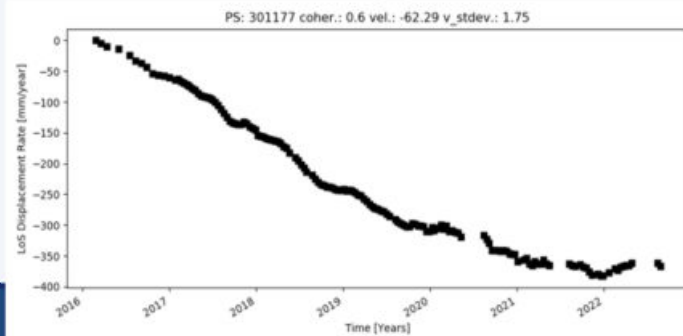
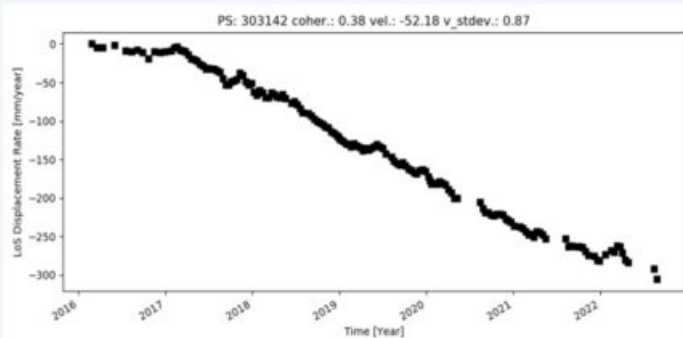


Contains modified Copernicus
Sentinel-1 mission data (2015-2021)

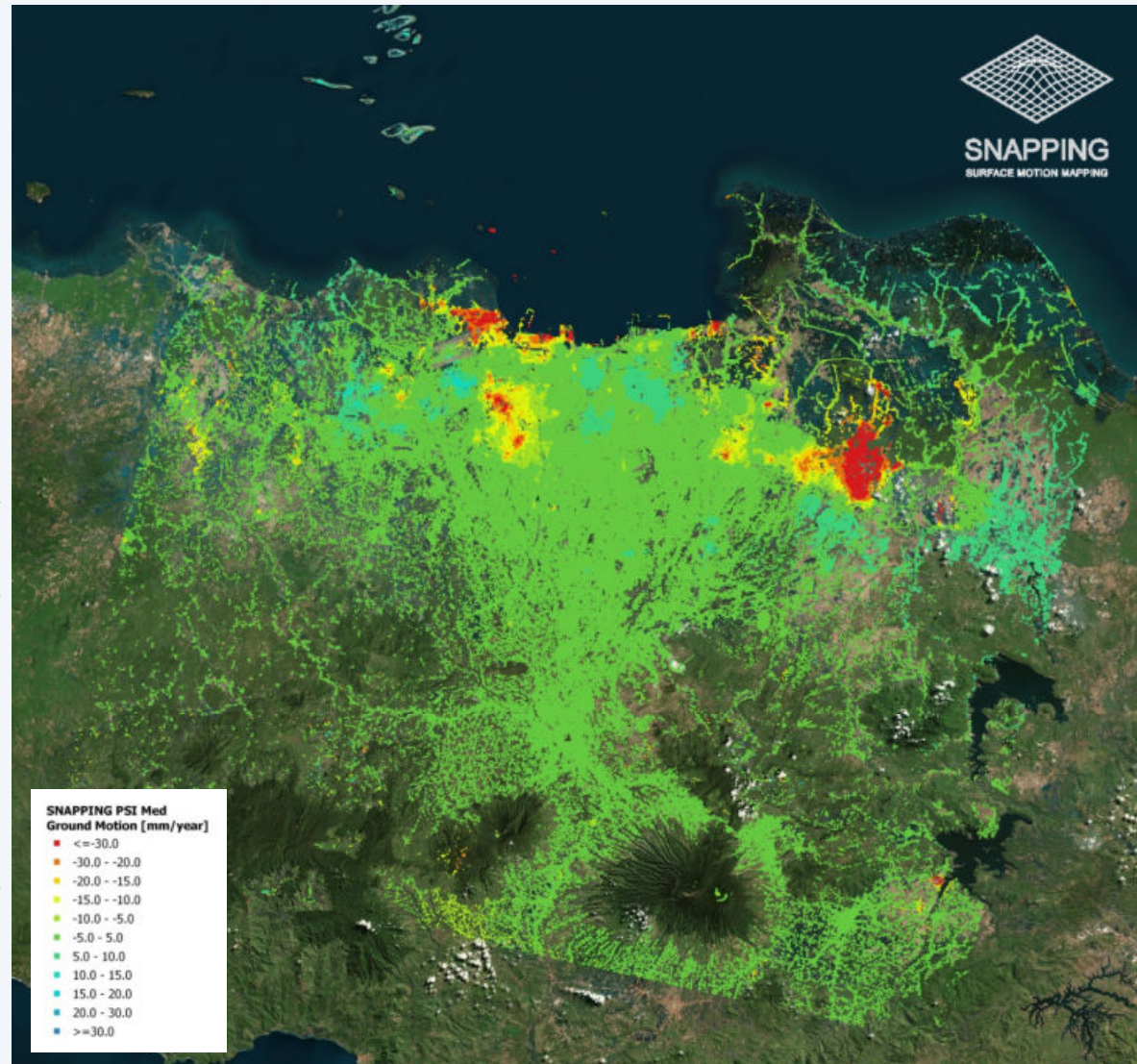
GEP | SNAPPING service

Terrain motion over **Jakarta** (~14750 sq.km) using Copernicus Sentinel-1 data (descending track 47) for the **period 2016-2022** (156 observation dates).

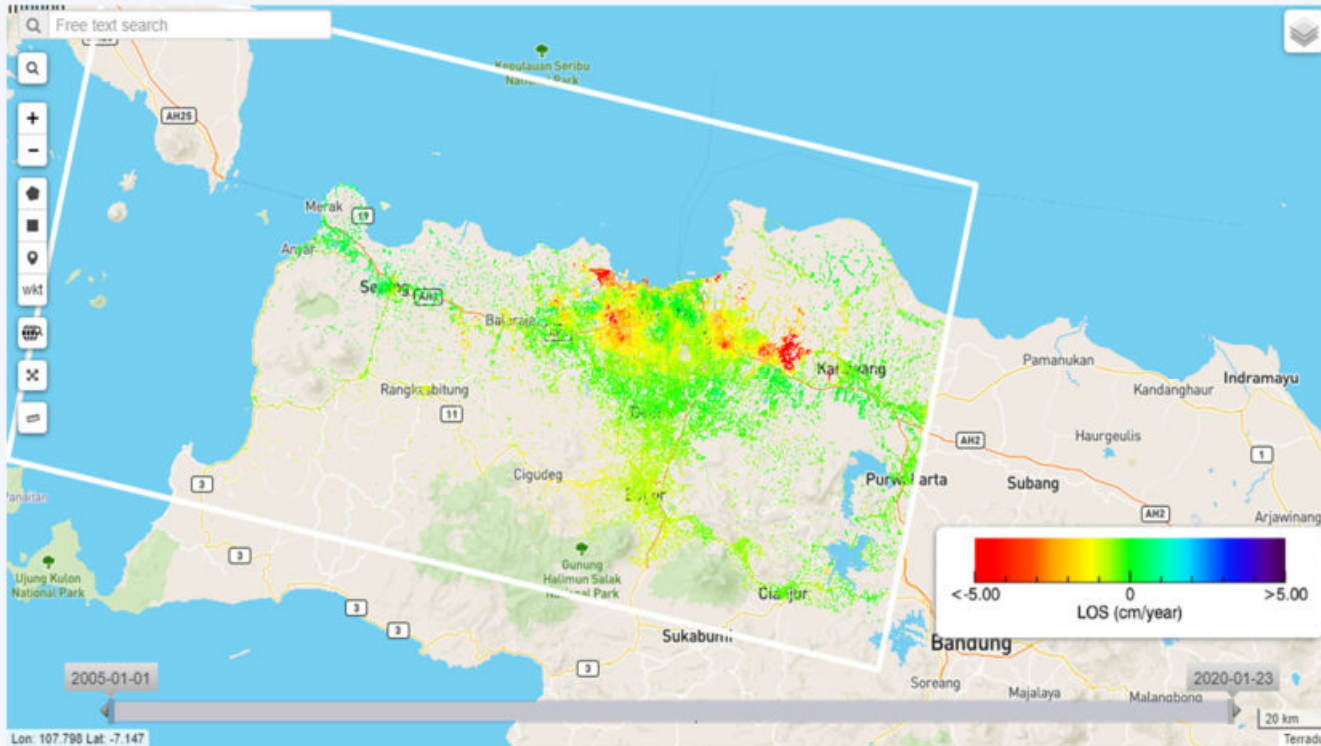
A total of ~320k point measurements were detected showing maximum motion at -93 mm/year.



Contains modified Copernicus Sentinel-1 data (2016-2020), processed by AUTH on GEP



GEP | P-SBAS On-demand Processing Service

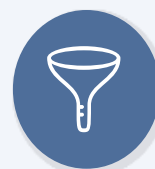


Will be supported by 
BELNET-BEGRID (Belgium)

 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.



THE DISASTER RISK MANAGEMENT CYCLE



DISASTER RISK MANAGEMENT CYCLE (DRMC) DIAGRAM

Definitions:

Mitigation/Prevention:

Activities which eliminate or reduce the chance of occurrence or the effects of a disaster.

Preparedness:

Planning on how to respond to disasters should they occur. This includes the provision of legislation, trained personnel

3 stages of DRMC

PRE-DISASTER

- Risk Assessment
- Mitigation/Prevention
- Preparedness

DISASTER RESPONSE

- Warning/Evacuation
- Saving People
- Providing Immediate Assistance
- Assessing Damage

POST-DISASTER

- Ongoing Assistance
- Restoration of Infrastructural Services
- Reconstruction (Resettlement /Relocation)
- Economic & Social Recovery
- Ongoing Development Activities
- Risk Assessment Mitigation/Prevention