CEOS
Committee on Earth Observation Satellites

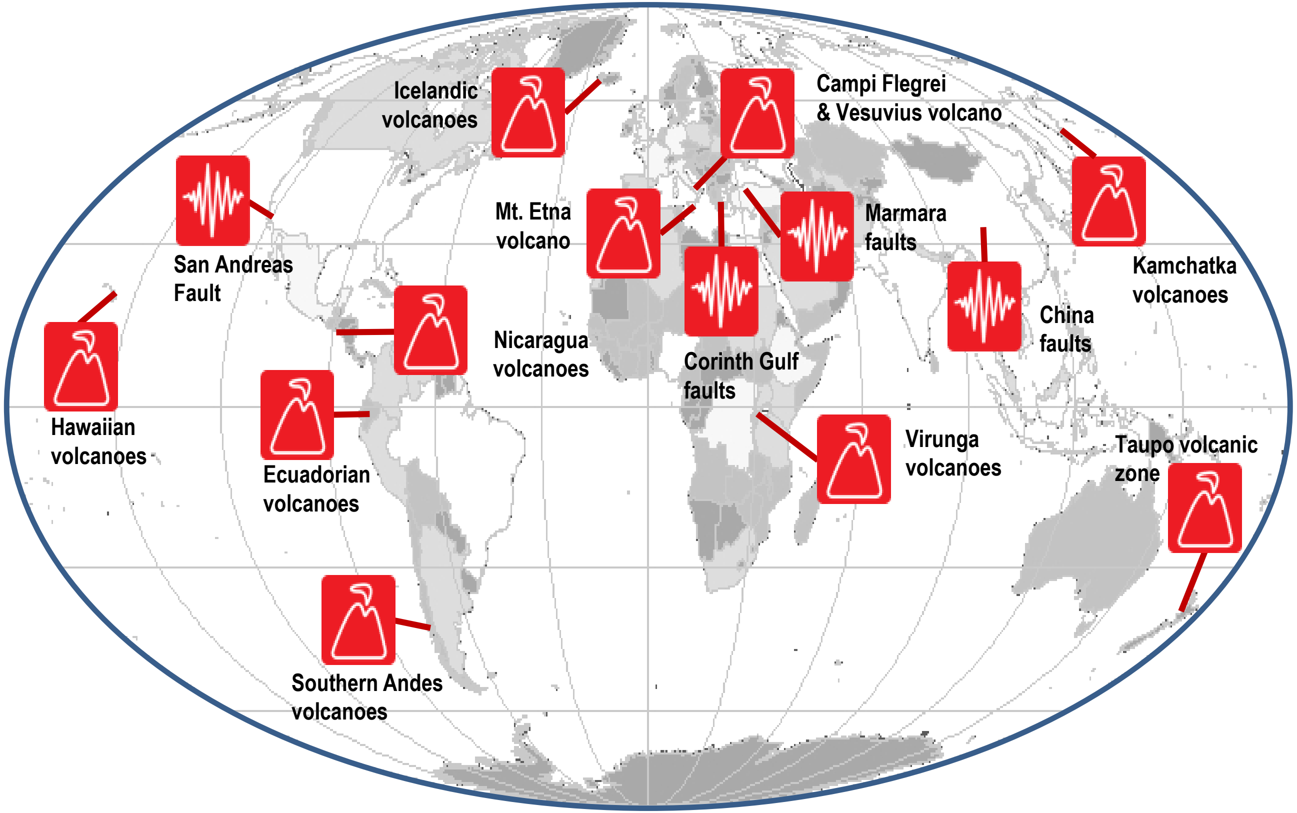
Geohazard Supersites and Natural Laboratories (GEO-GSNL)

Stefano Salvi - Chair of the GEO-GSNL initiative

WG Disasters 20, Yellowstone, MT, USA
5-9 September, 2023

Active permanent Supersites

GSNL is presently a network of 14 Supersites/NL



The GSNL partnership

- **Satellite data providers** (Space Agencies)
- **In situ data providers:** The Supersite Coordinators belong to the local hazard monitoring Institutes
- **The Supersite scientific community**, including over 150 scientists worldwide

Results from Supersites

Some results from

- Hawaii
- Ecuador
- Taupo
- Campi Flegrei
- Virunga
- China
- Nicaragua
- Kahramanmaraş Event Supersite

Active event Supersites

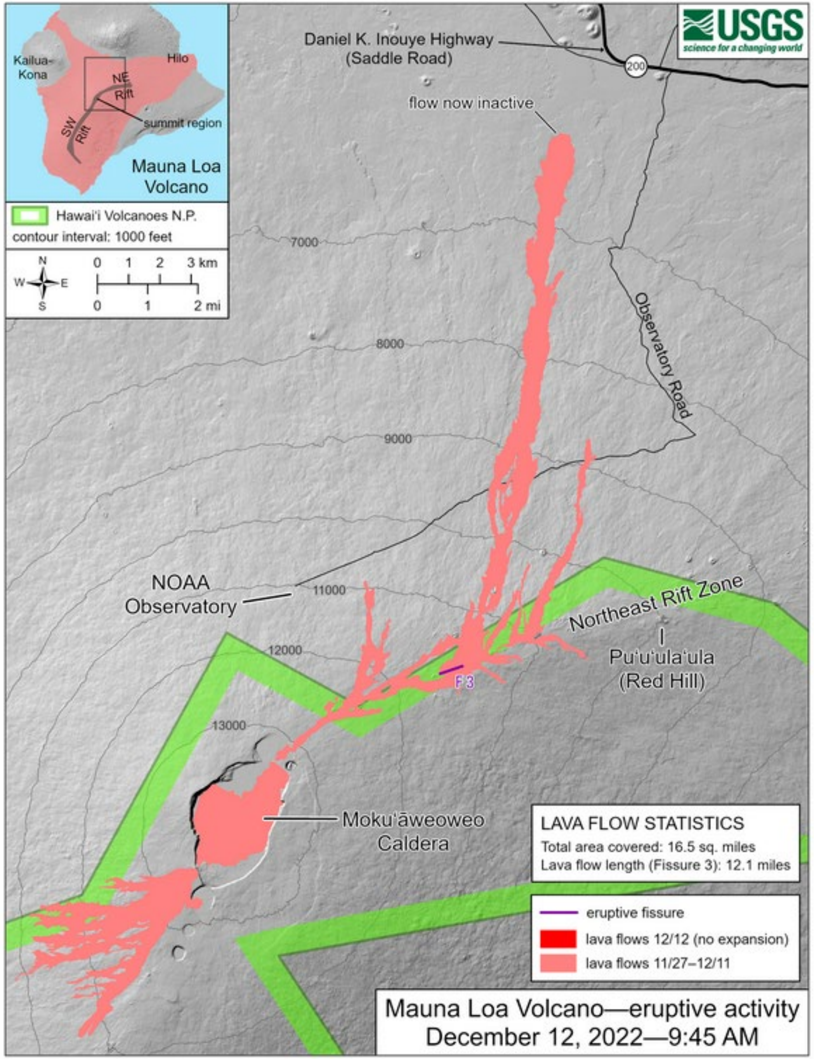
Kahramanmaraş Event Supersite

Coordinated by researchers from the Istanbul Technical University and KOERI

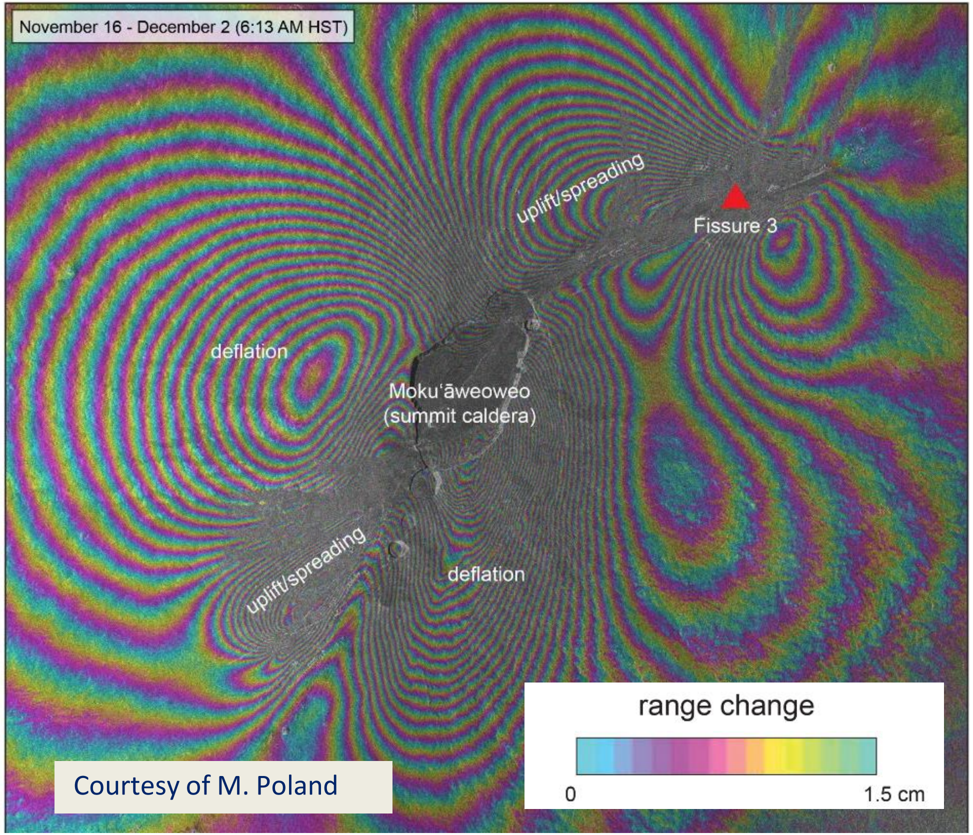
CEOS support to the Supersite is ending in March 2024.

Hawai‘i volcano Supersite

Mauna Loa, Hawai‘i, eruption, November-December 2022



Hawai‘i volcano Supersite



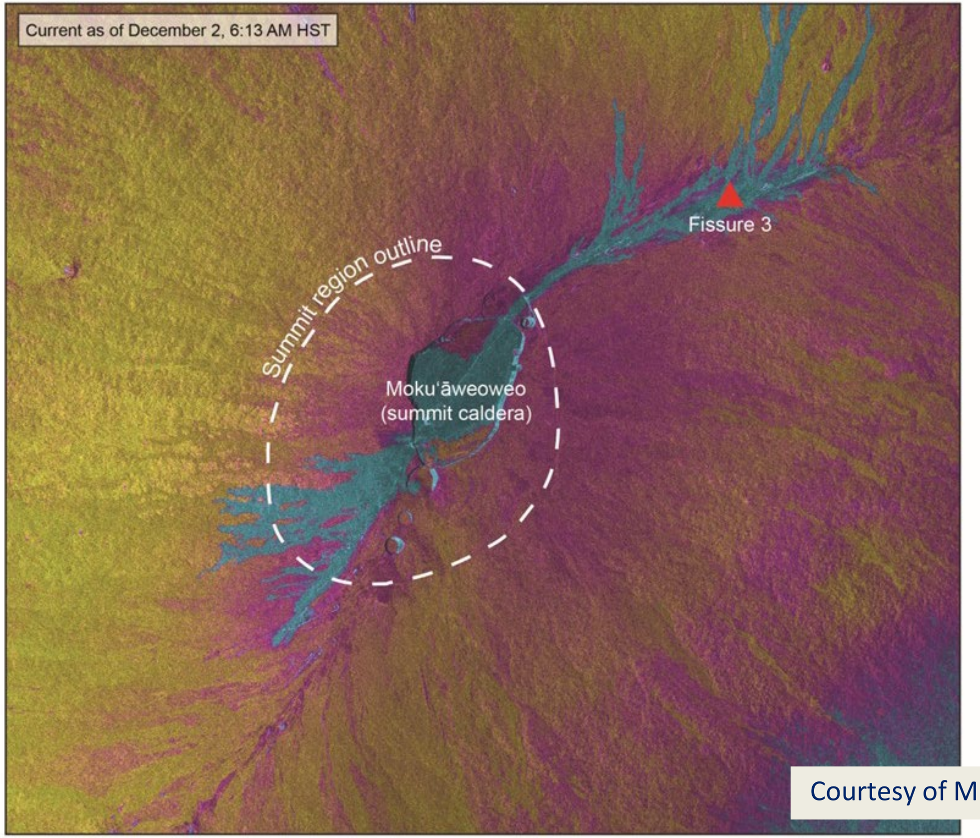
2022 Mauna Loa, Hawai‘i, eruption

CSK interferogram

November 15 – December 2

A complex pattern of ground deformation, including inflation, deflation zones and fractures, is clearly visible.

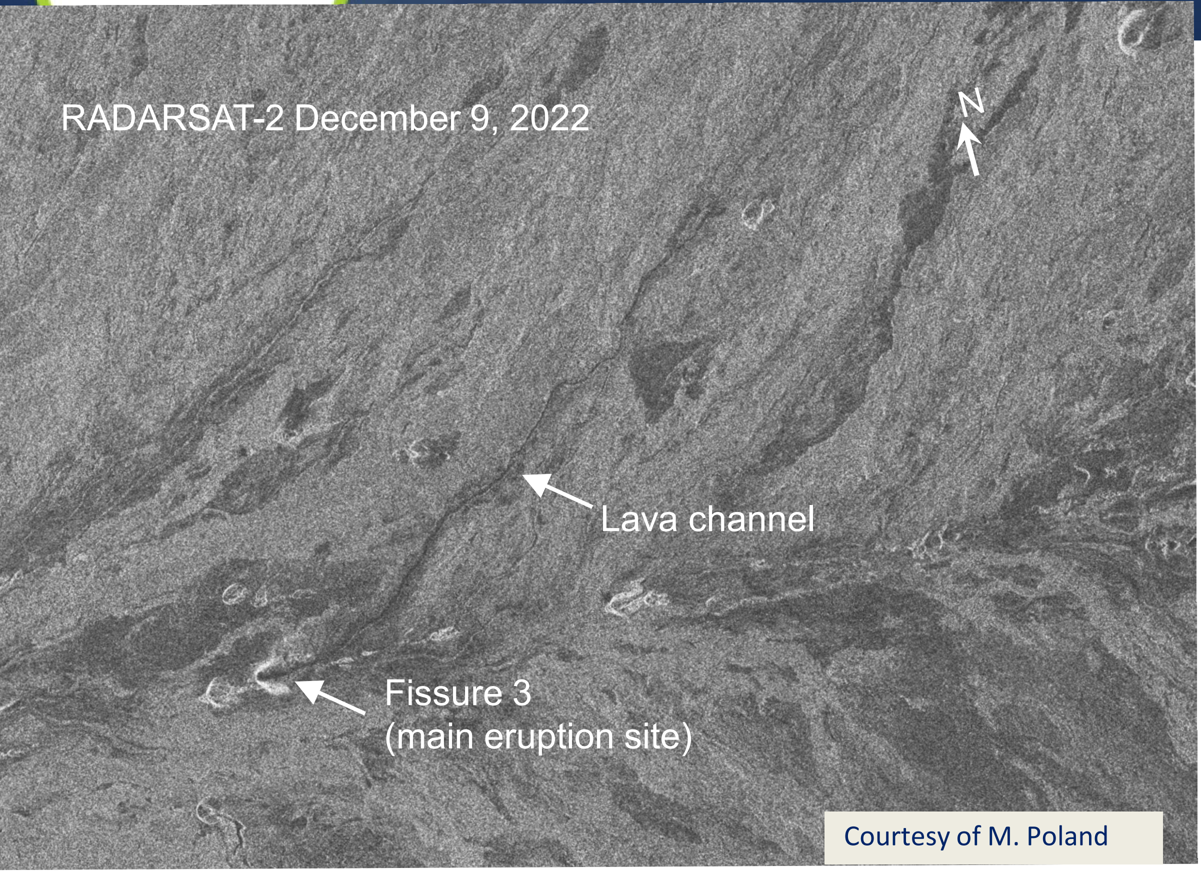
Hawaiʻi volcano Supersite



Courtesy of M. Poland

The CSK coherence was used to map lava flows during the last Mauna Loa eruption, in late 2022

Hawai‘i volcano Supersite



Radar amplitude of a C-band Radarsat-2 image of Mauna Loa, used to monitor the fractures and lava flows at high resolution during the 2022 eruption.

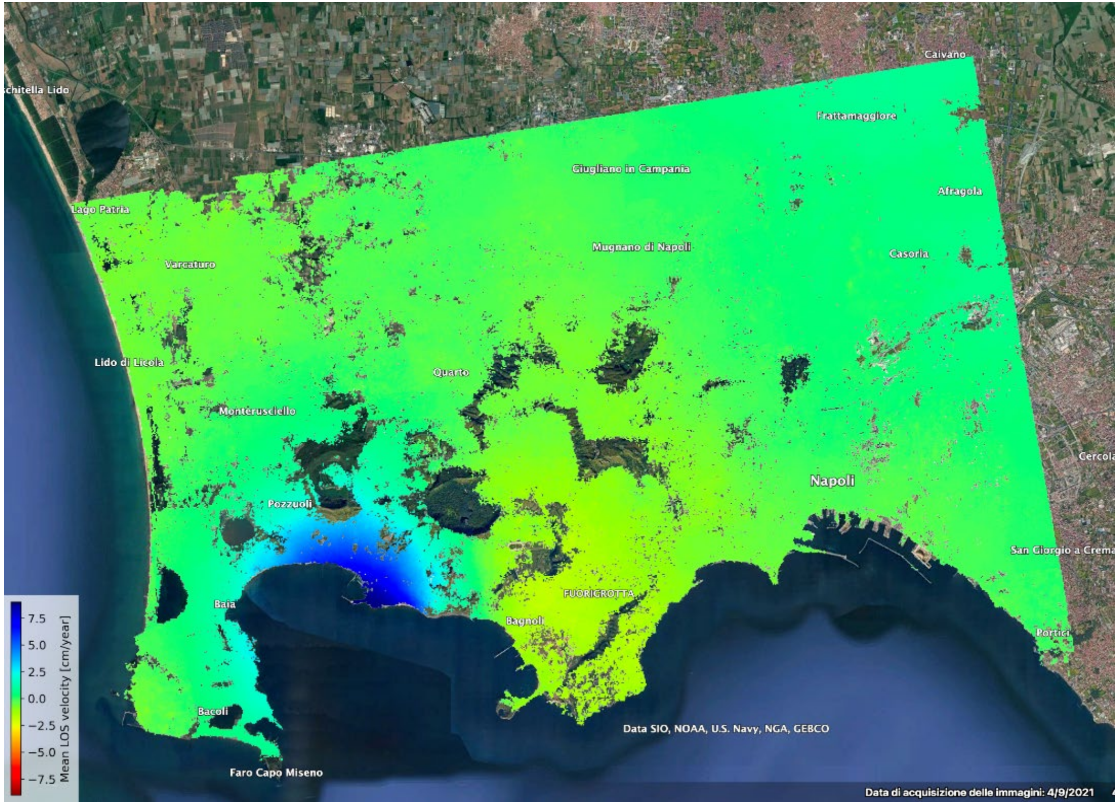
Campi Flegrei – Vesuvius Supersite

Integration of TSX/TDX/PAZ data over Campi Flegrei

- TSX/TDX asc data from "Vesuvius - Campi Flegrei" Supersite (39 images)
- PAZ asc data from AO-003-021_sven.borgstrom (16 images)
- Time span 2022.01.08 - 2023.04.15
- 55 images, 574 interferograms, $4 \leq$ Btemp (days) ≤ 117, $2 \leq B\perp$ (m) ≤ 250
- Presented at IGARSS 2023 (TanDEM-X session) by the INTA (National Institute of Aerospace Technology) Spanish team

(courtesy: Sven Borgstrom – INGV-OV)

Campi Flegrei – Vesuvius Supersite



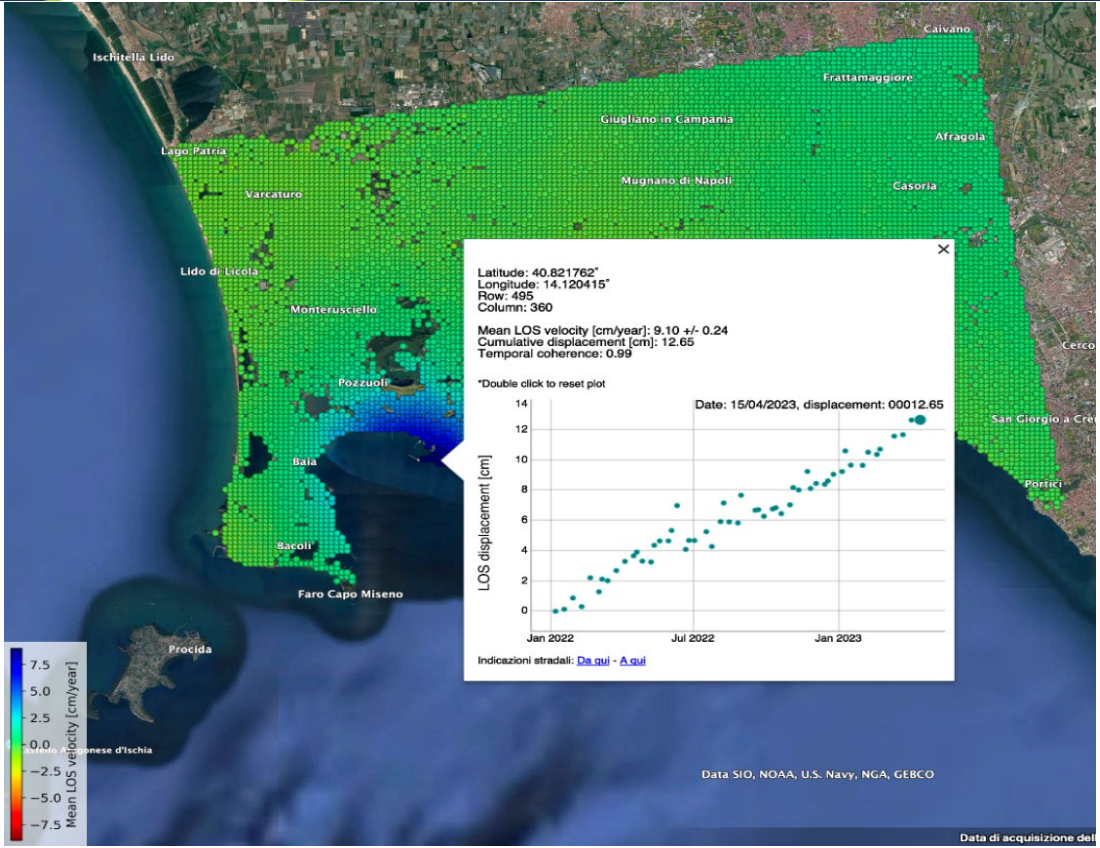
TSX/TDX/PAZ ascending track

Mean LoS velocity map (2022.01.08 - 2023.04.15) over the Campi Flegrei caldera.

Max uplift 9 cm/yr in the Pozzuoli village

(courtesy: Sven Borgstrom – INGV-OV)

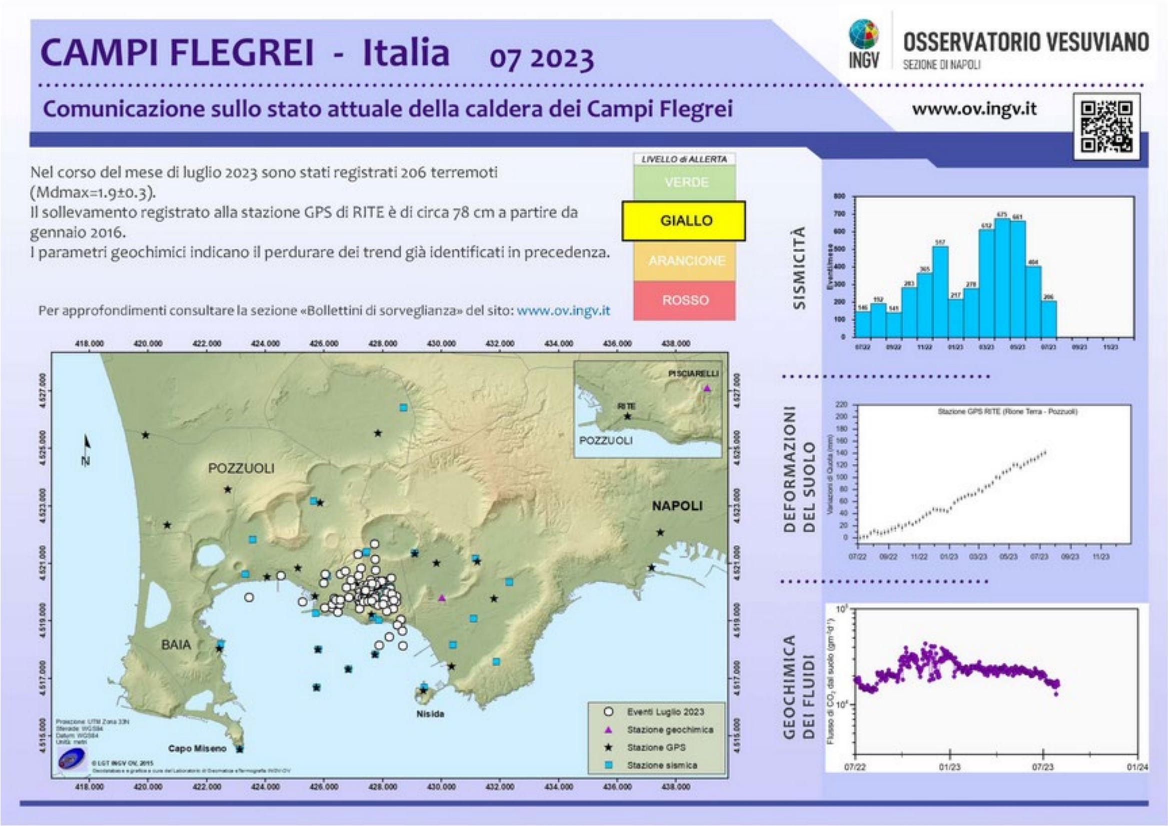
Campi Flegrei – Vesuvius Supersite



Ground deformation time-series (2022.01.08 - 2023.04.15) for a coherent target close to a cGNSS station in Campi Flegrei

(courtesy: Sven Borgstrom – INGV-OV)

Campi Flegrei – Vesuvius Supersite

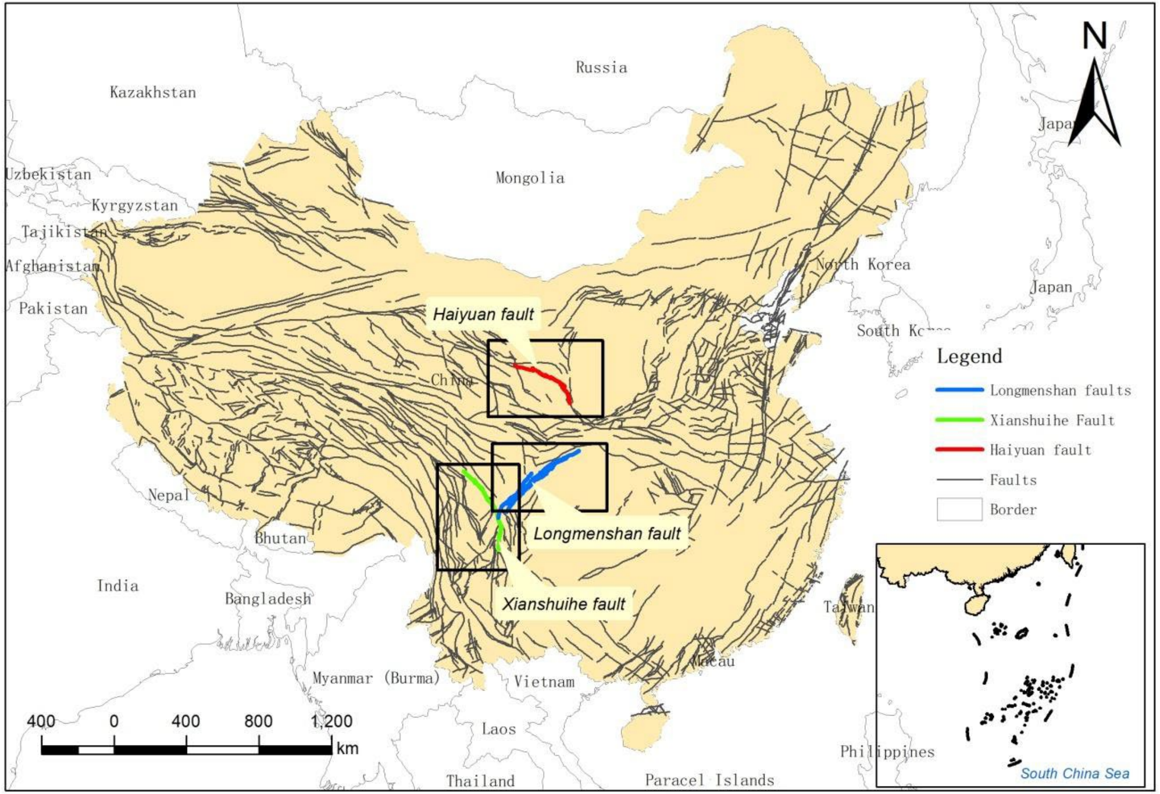


Current state of the volcano, information for the public from INGV website

As of July 2023 – Yellow alert level:

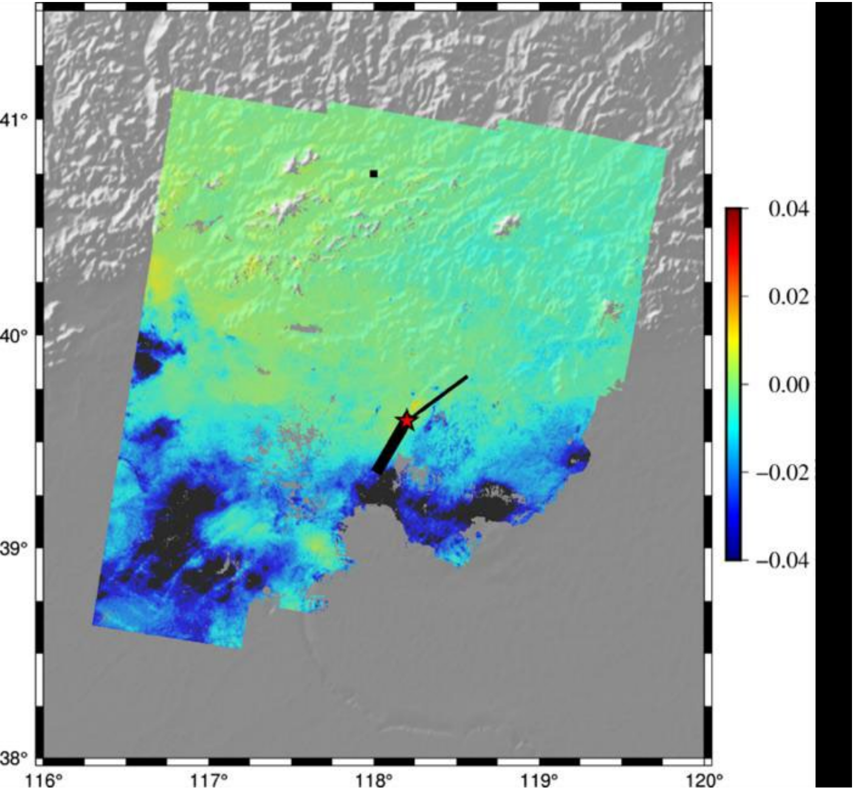
- 206 eqs with max magnitude 1.9±0.3, located between 2-4 km.
- Ground deformation centered in the Pozzuoli village, max velocity 15±3 mm/month (111 cm since 2005).
- Geochemical parameters follow the trend of the last 10 years.
- CO_2 flux from the Solfatara is 3000 tons/day.

China Seismic Supersite



Main AoIs of the China Supersite

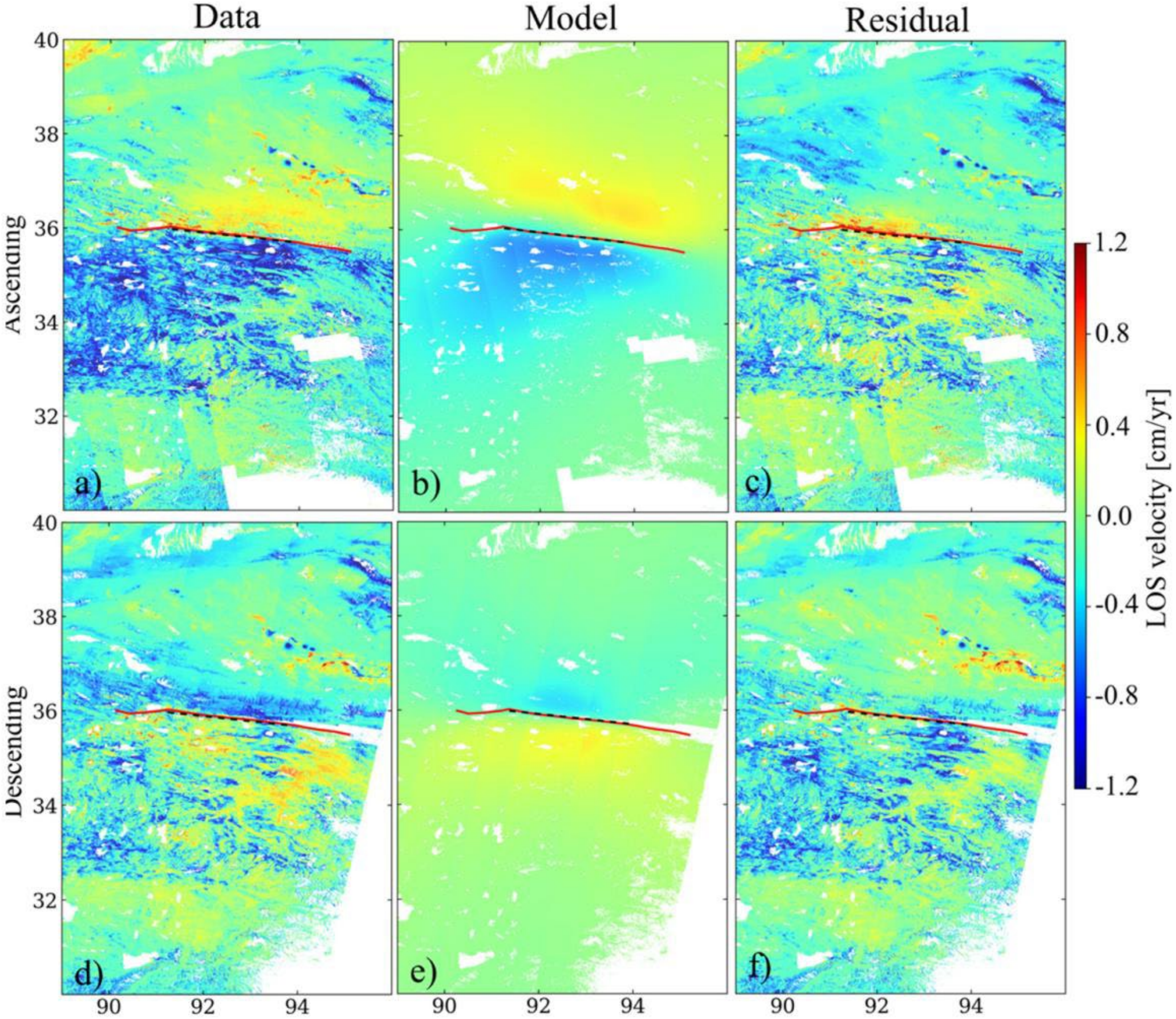
China Seismic Supersite



Using Sentinel 1 data the post-seismic deformation of various earthquakes of the 20° century, were studied.

This is the mean velocity 2014-2022 in the area of the 1976 Tangshan earthquake of Mw 7.6
Strong non-tectonic deformation components are present and mask a possible post-seismic signal.

Courtesy of Y. Shao



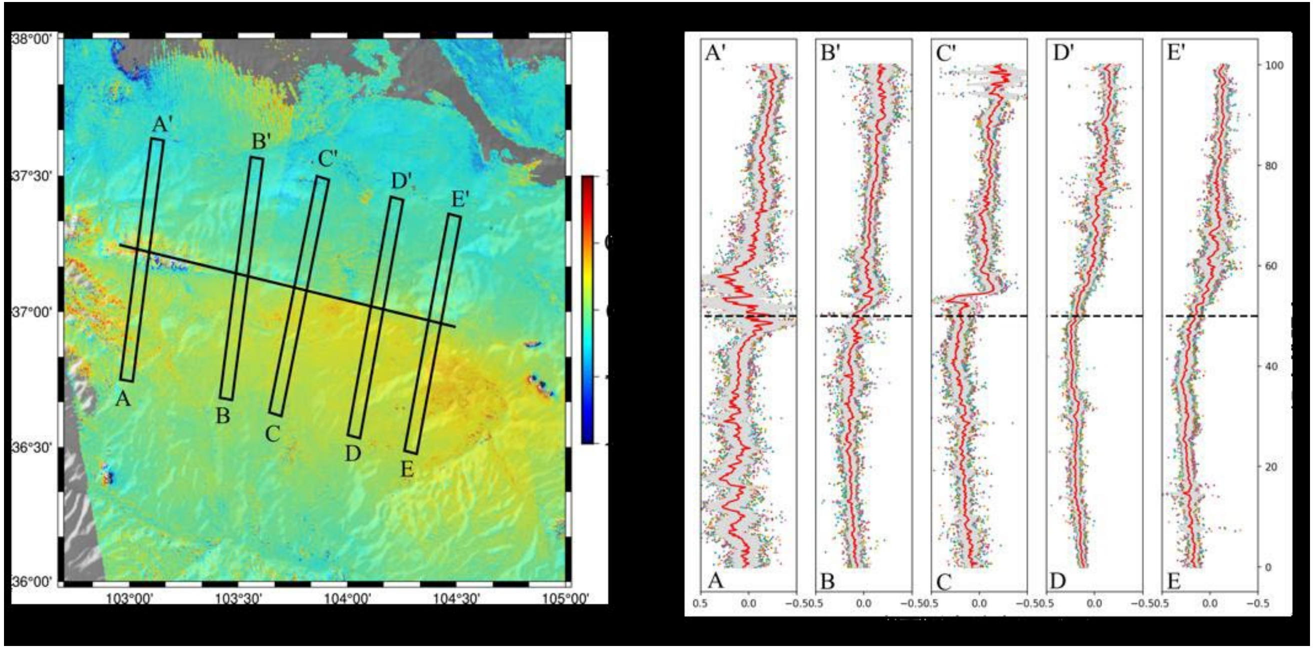
China Seismic Supersite

Mean velocity 2014-2021 in the area of the 2001 Kokoxili Mw7.8 earthquake.

A clear ground displacement signal is present across the fault and was modeled to estimate the lower crust viscosity.

(Lv and Shao, 2022)

China Seismic Supersite

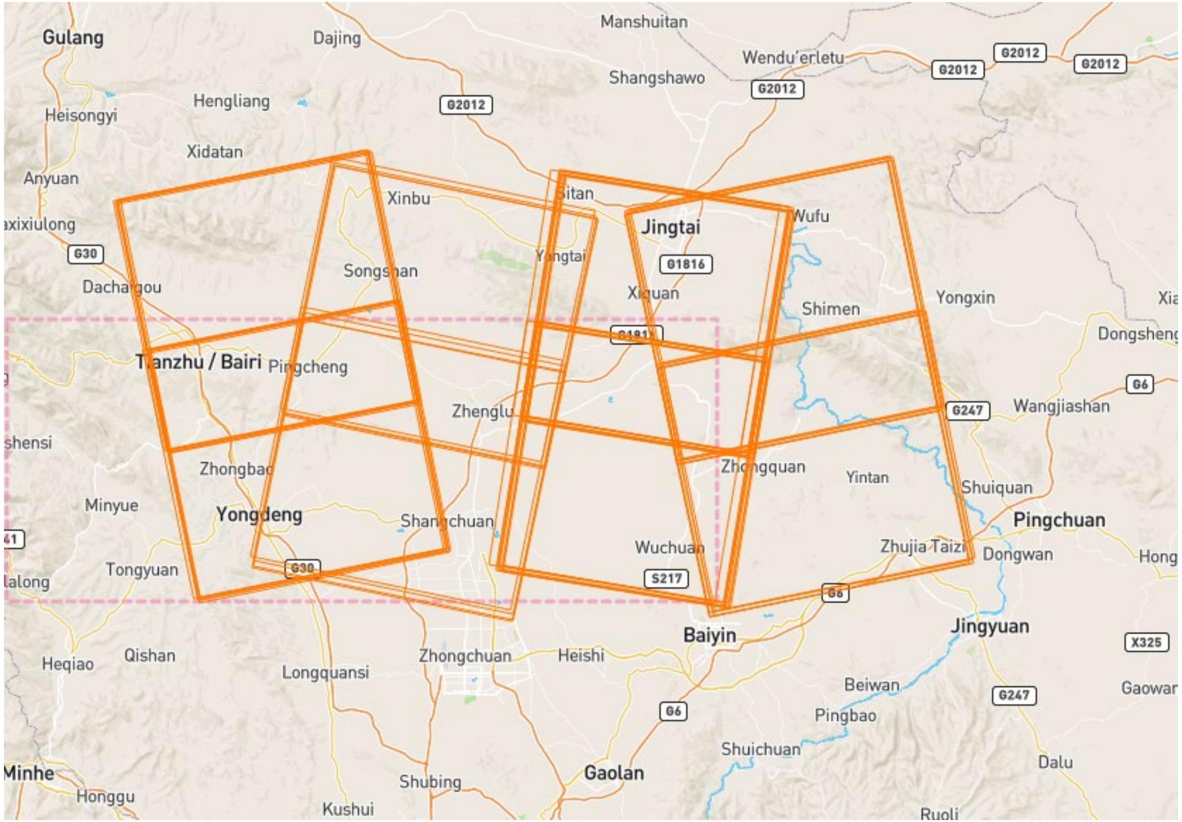


Mean E-W 2014-2020 velocity field in the area of the Haiyuan fault, from Sentinel 1 data.

A clear ground deformation signal is visible in the interseismic strain accumulation phase.

Courtesy of Y. Shao

China Seismic Supersite



Nearly 300 CSK images have been acquired over the Haiyuan Fault, but have not yet been processed

Ecuador volcano Supersite

TerraSAR X *data are used for monitoring Cotopaxi and Chiles-Cerro Negro volcanoes. There are no processing issues.*

COSMO-SkyMed *data are used to monitor Cayambe and Guagua Pichincha volcanoes. The interferograms however, suffer from long spatial baselines and often do not allow to reach a good deformation measurement accuracy.*

Sentinel-1 *imagery is easy to access and is downloaded every week for processing, producing very good results.*

Ecuador volcano Supersite

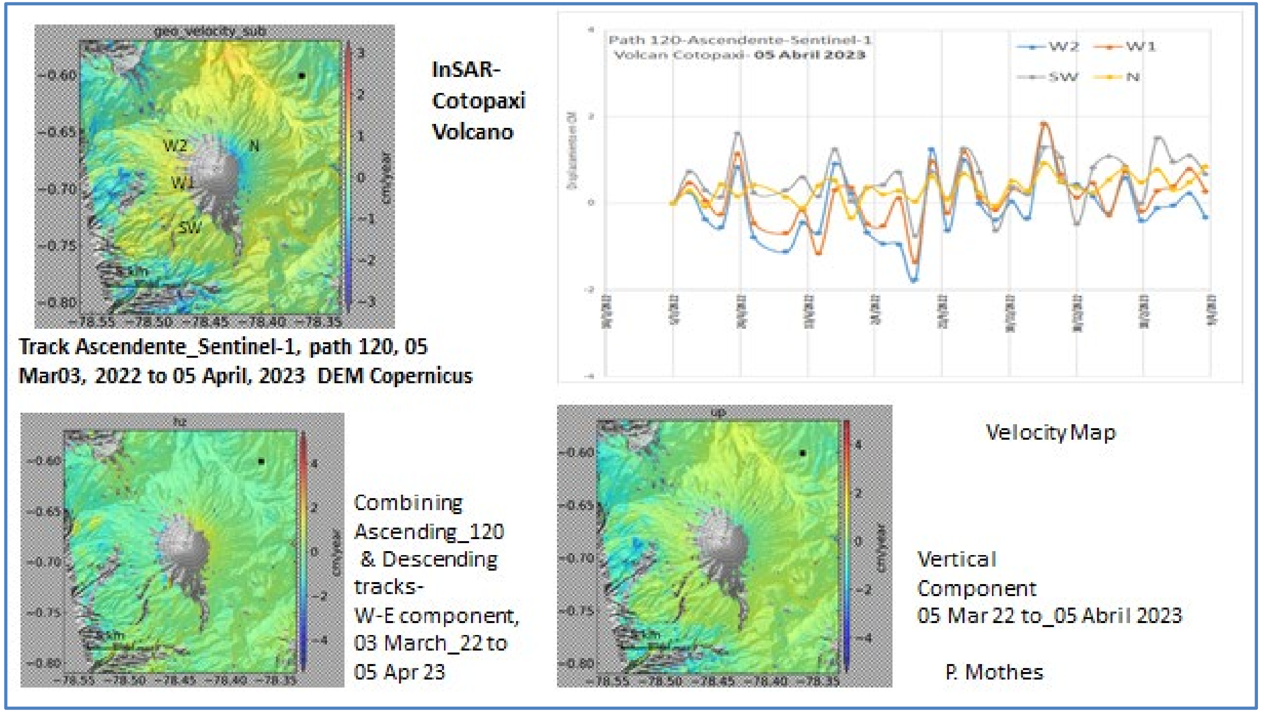
IGEPN has strongly benefited from the Supersite establishment.

Through new collaborations they have learnt how to process and interpret the satellite data (S1, CSK, TSX) provided by the CEOS.

Now they use EO data to monitor the most hazardous active volcanoes (15 out of 45).

All the monitoring information (from EO and in situ data) is discussed internally and then released to the National Risk Management organization.

Ecuador volcano Supersite



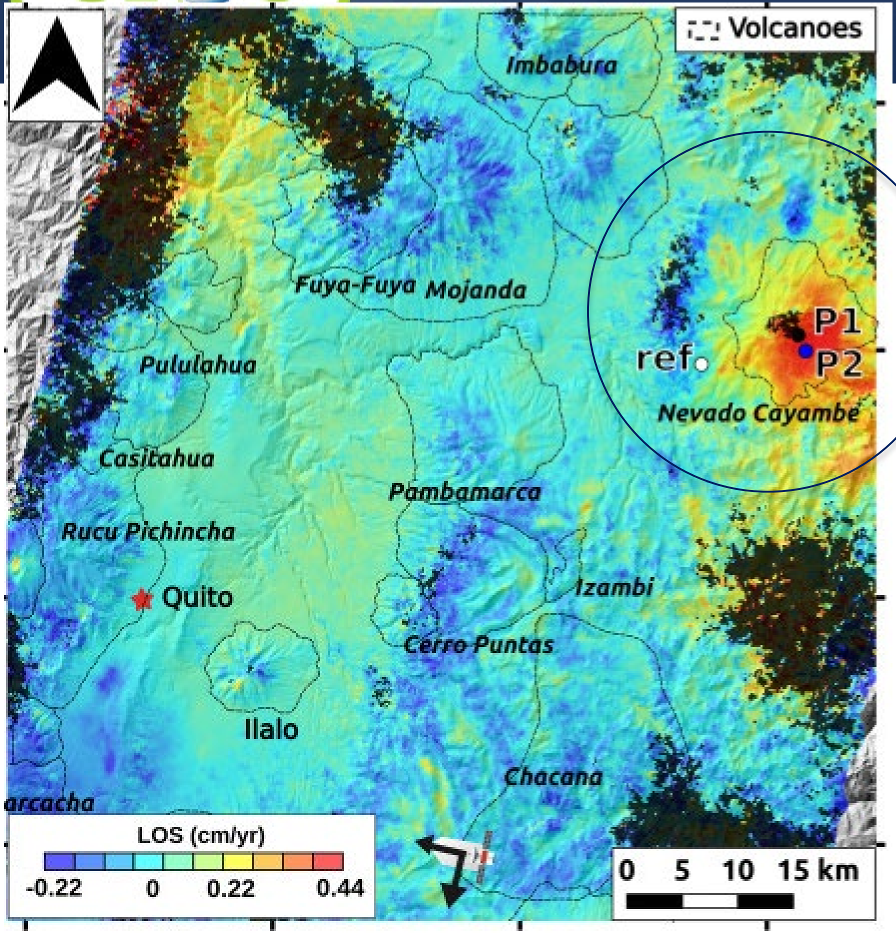
Cotopaxi volcano is being monitored mainly with Sentinel 1.

It is in the yellow alert level since October 2022.

Presently there is only minor ground motion.

Courtesy of P. Mothes

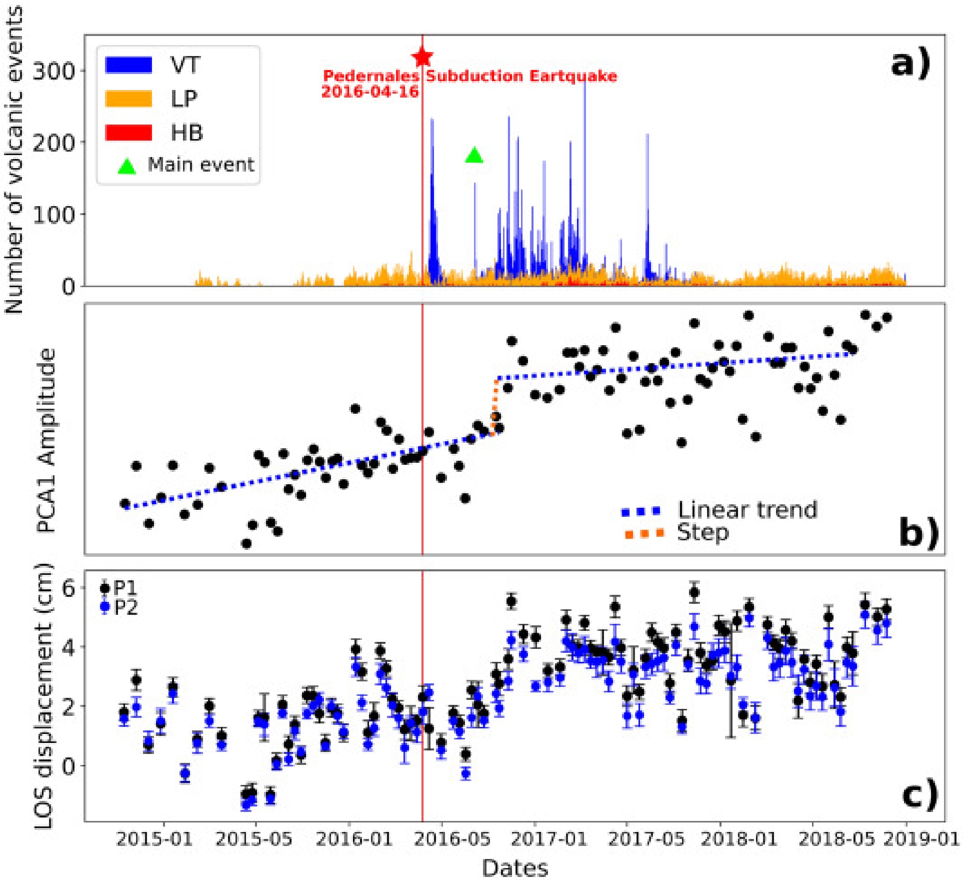
Ecuador volcano Supersite



Sentinel 1 2014-2018 descending velocities at Cayambe volcano.

(Espín Bedón et al., 2022)

Ecuador volcano Supersite

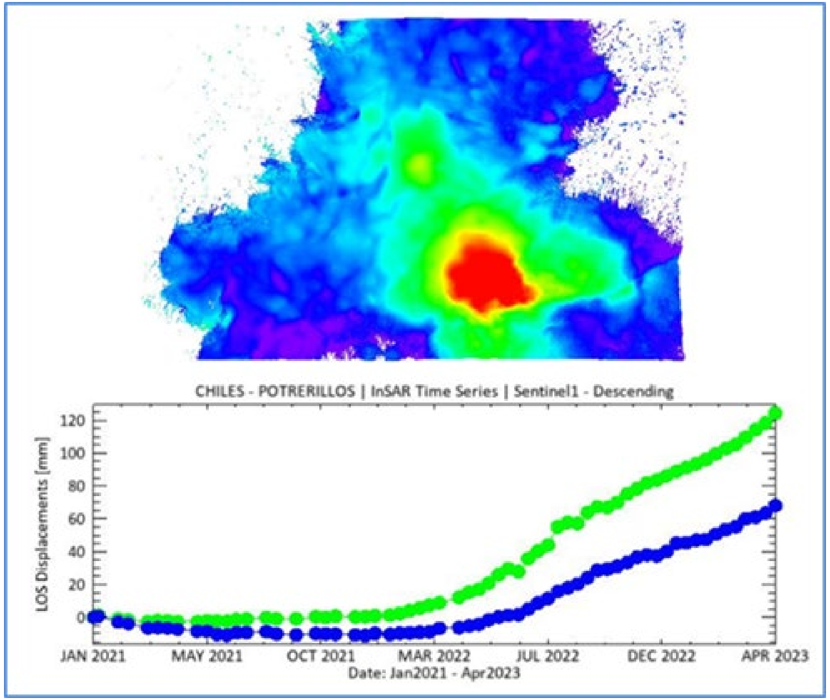


Seismicity and displacement time series 2014-2018 at Cayambe volcano.

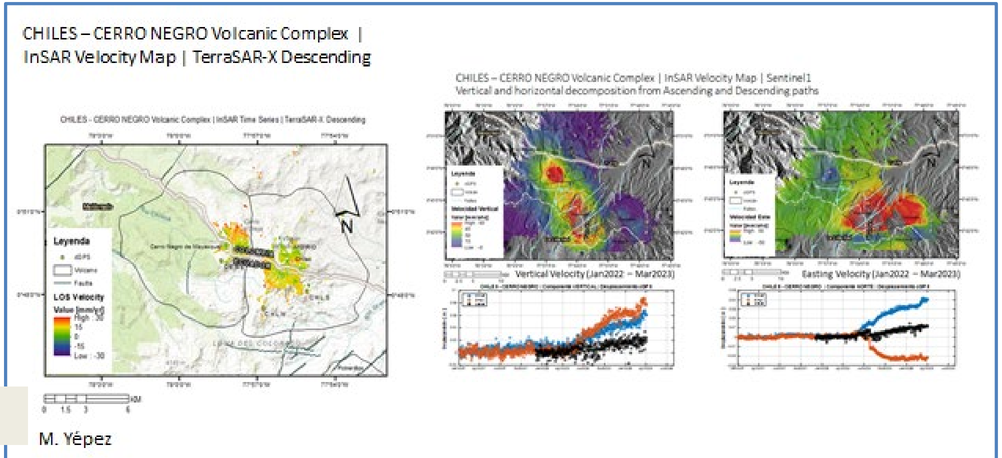
Seismicity rate increase, inflation and magma recharge started after the 2016, Mw 7.8 Pedernales subduction earthquake.

(Espín Bedón et al., 2022)

Ecuador volcano Supersite



A rapid ground deformation increase is also observed using Sentinel 1 and TerraSAR X at the Chiles-Cerro Negro - Potrerillos volcanoes, since May 2022.



Courtesy of P. Mothes

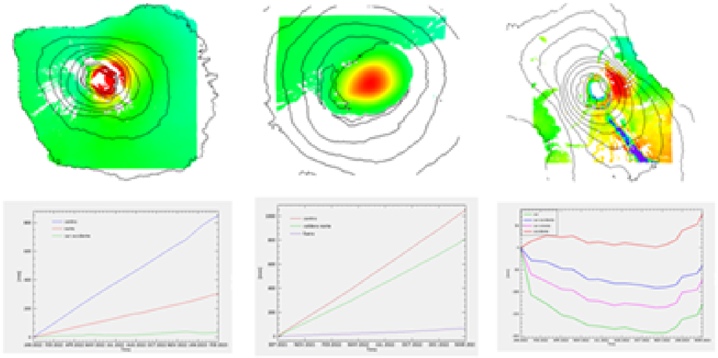
Ecuador volcano Supersite

Galapagos volcanoes map

With the use of VM and SARSCAPE software we monitore the deformation trends of volcanoes in Galapagos Islands

Sentinel_1 Processing

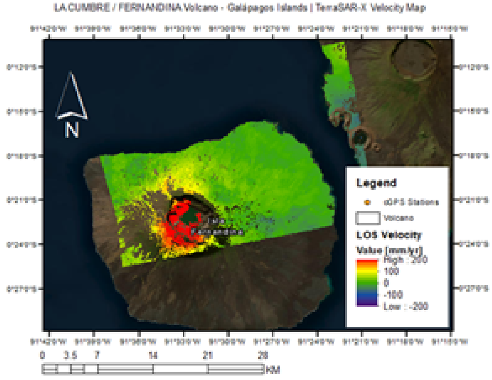
FERNANDINA Ascending orbit January 2022 – March 2023	SIERRA NEGRA Ascending orbit September 2021 – March 2023	WOLF Ascending orbit January 2022 – March 2023



Courtesy of S. Aguaiza

Galapagos volcanoes are always very active and are closely monitored using Sentinel 1 and TSX.

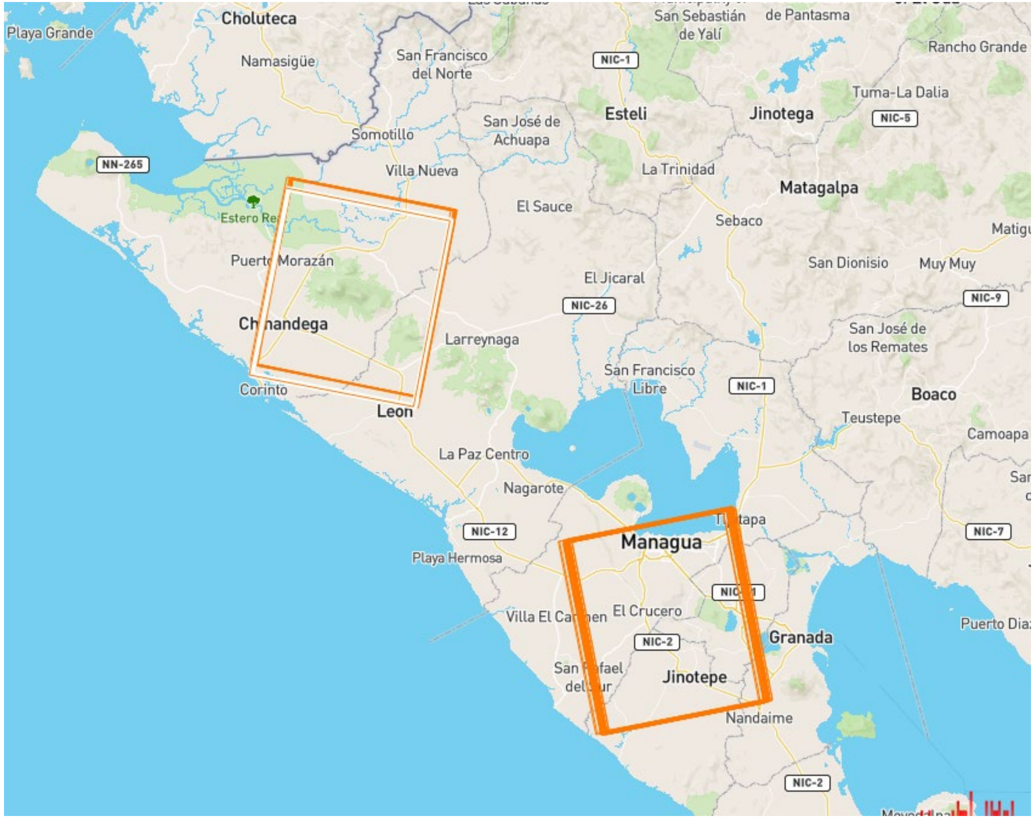
LA CUMBRE – FERNANDINA Galápagos Islands | InSAR Velocity Map | TerraSAR-X Ascending



LOS Velocity (Dec 2022 – Apr 2023)

Courtesy of M. Yepez

Nicaragua volcano Supersite



There are no results yet, due to limited local capacities in EO data use.

The CSK image request activities have started.

Request for TSX coverage should be submitted soon.

GSNL is seeking support for the training of at least one INETER researcher on InSAR data processing.

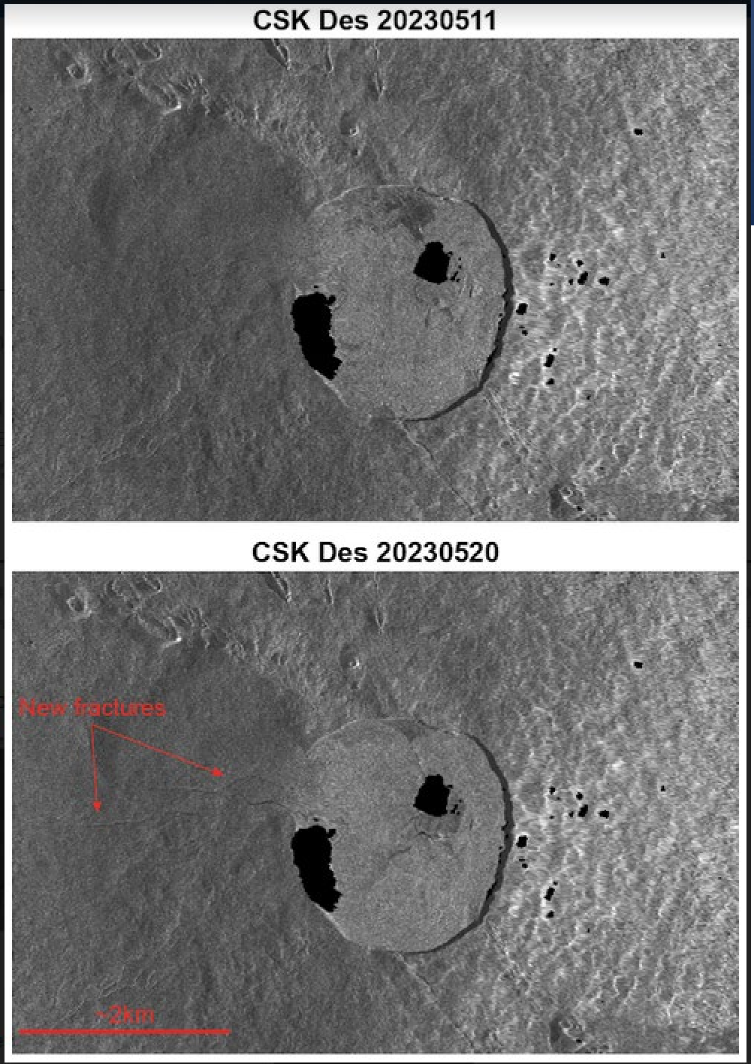
Virunga volcano Supersite

In April 2023 the Nyamulagira volcano started to erupt.

Through GSNL, the Goma Volcano Observatory requested support to monitor the vents, fractures and lava flows, using EO data.

A number of researchers responded with different products, generated using CSK and S1 data

Virunga volcano Supersite



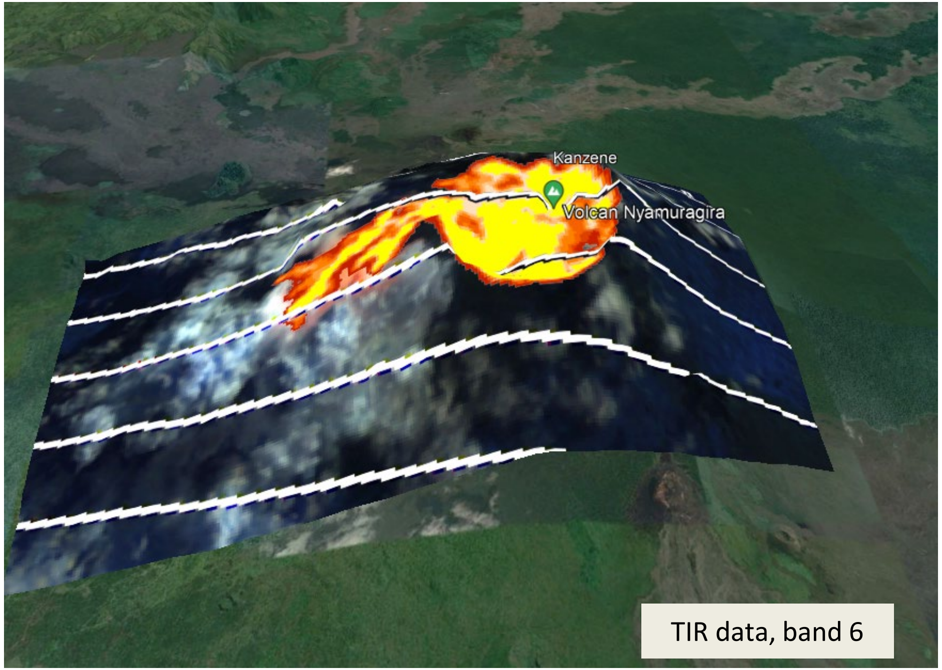
Most of the products consisted in change detection images obtained from CSK and Sentinel 1 or optical imagery.

This is a simple CSK amplitude image comparison by A. Nobile, at King Abdullah University of Science and Technology, Saudi Arabia

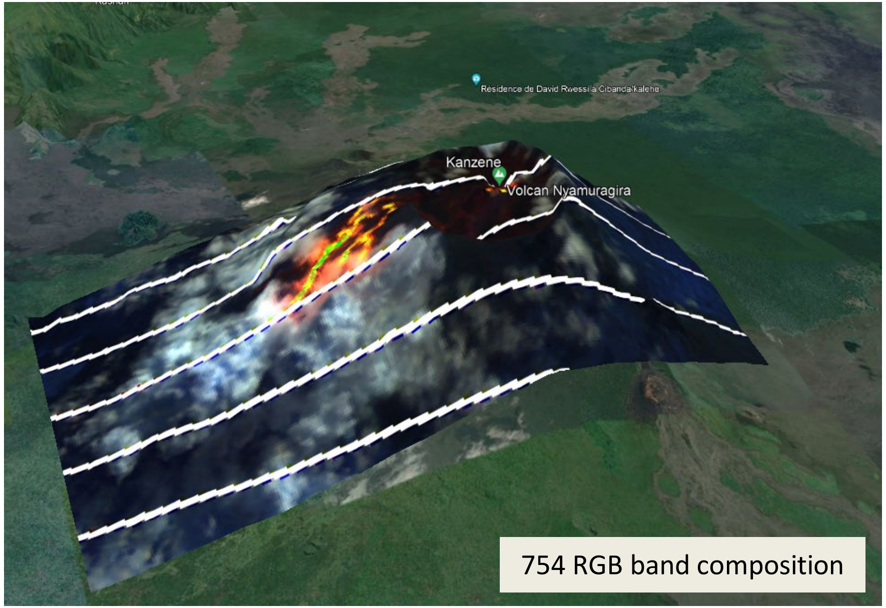
Virunga volcano Supersite

Landsat 7 visible (754) and TIR images of May 22, 2023.

By G. Ganci at INGV Catania.



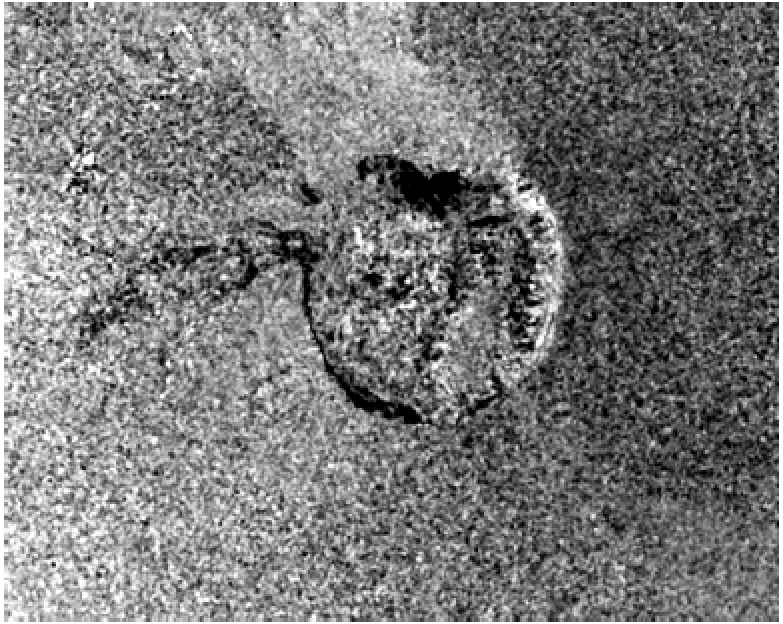
TIR data, band 6

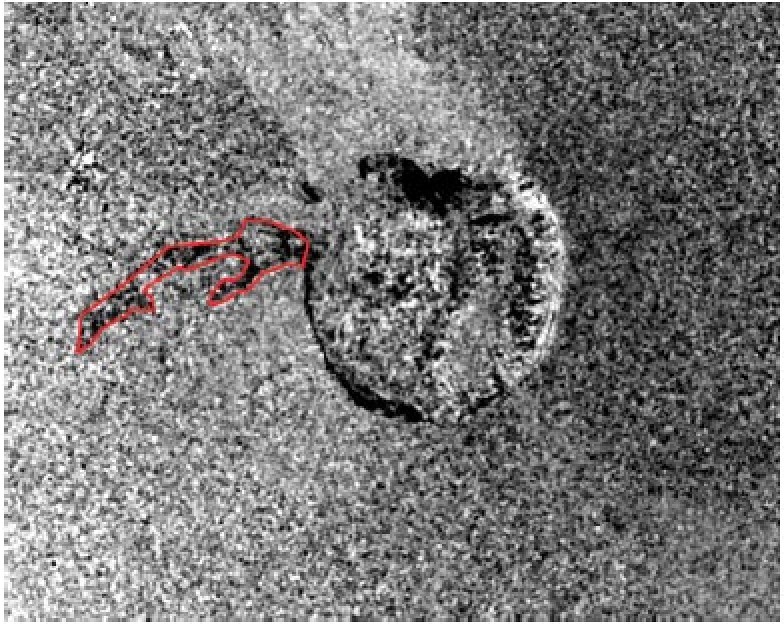


754 RGB band composition

Virunga volcano Supersite

Change detection using May 14 and May 22 CSK images. The lava flow extent is clearly visible

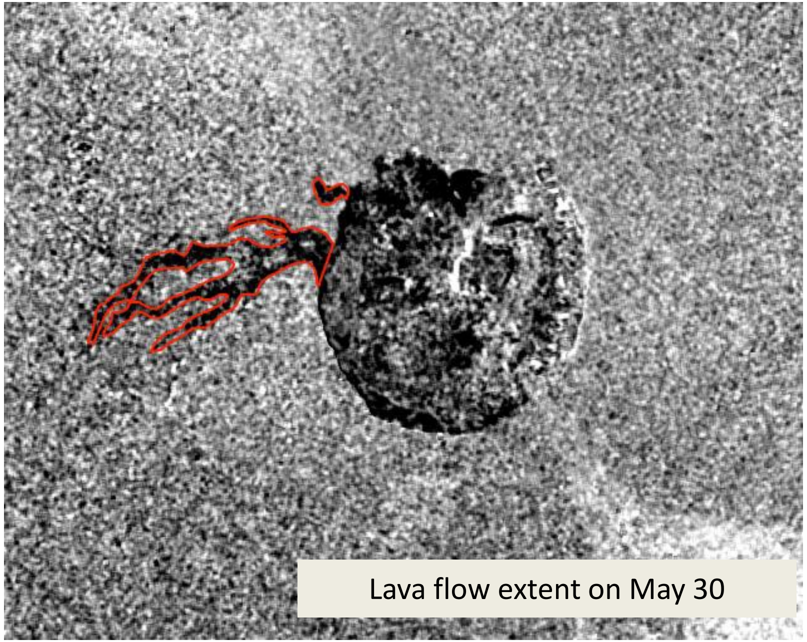




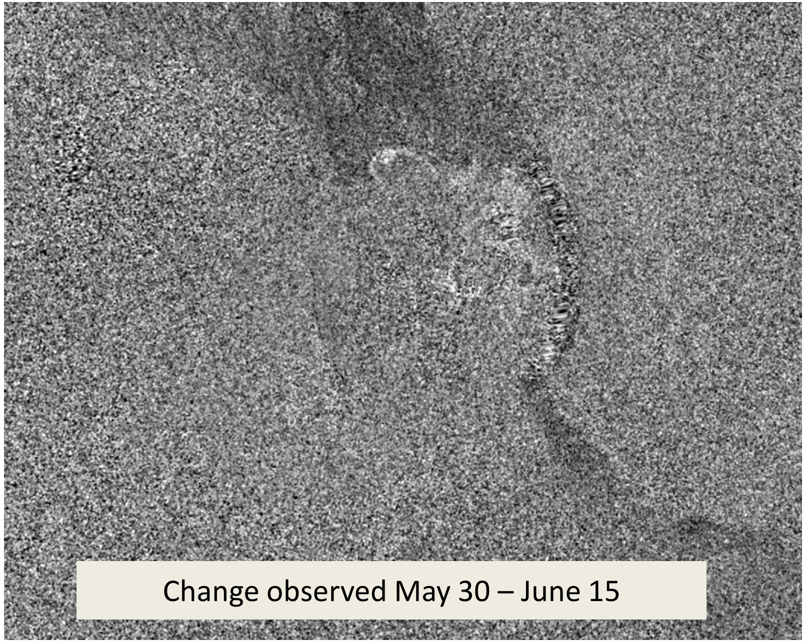
GeoSAR Lab, INGV-ONT

Virunga volcano Supersite

CSK change detection shows that the eruption ended shortly before May 30.



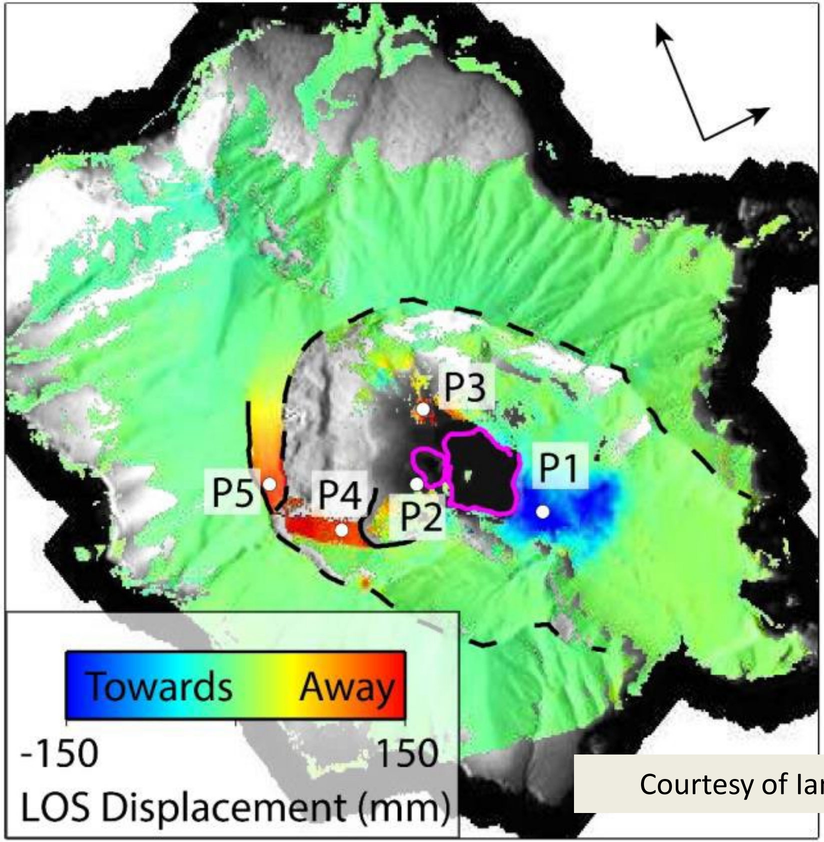
Lava flow extent on May 30



Change observed May 30 – June 15

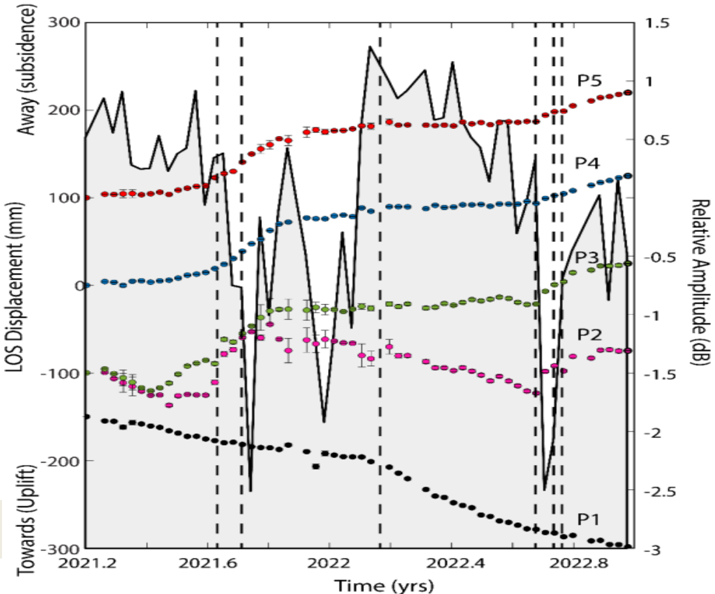
GeoSAR Lab, INGV-ONT

Taupo volcano Supersite

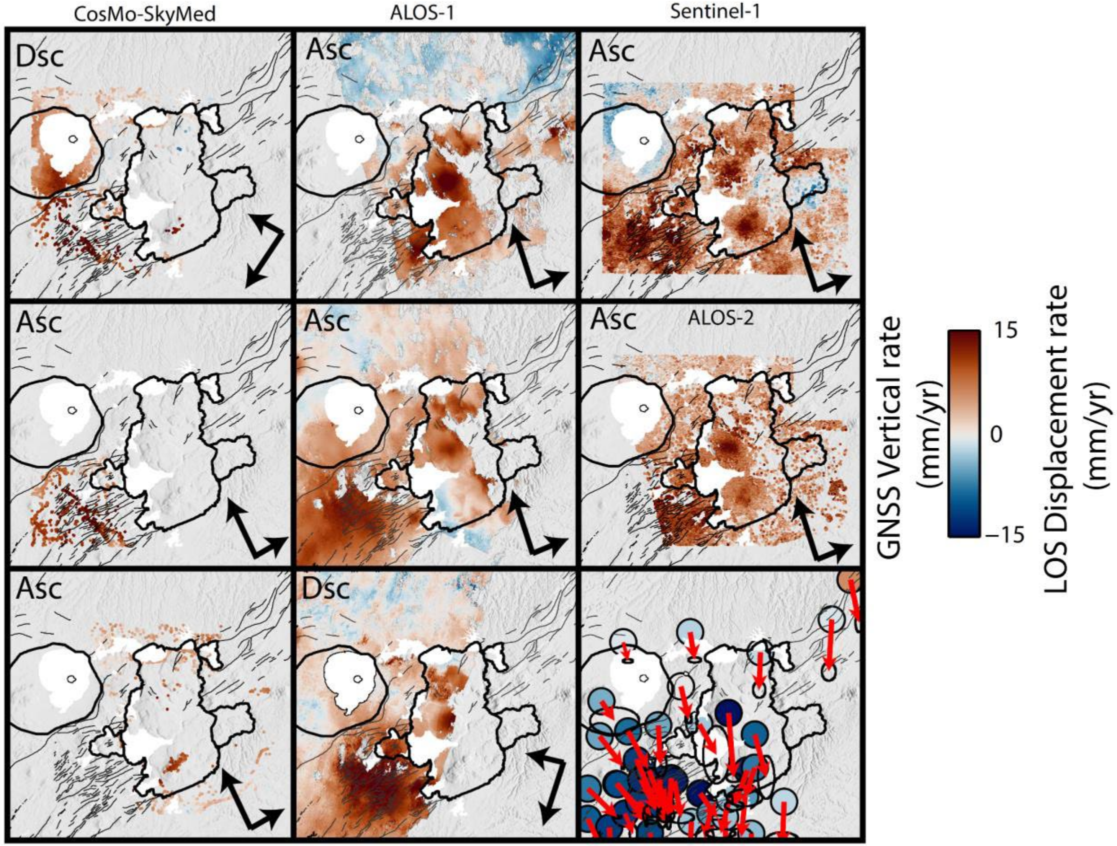


Courtesy of Ian Hamling

Total ground displacement 2021-2022 over White Island crater from Staring Spotlight TSX data. These are fundamental data, since there is no ground network operating in White Island, and access is banned.



Taupo volcano Supersite

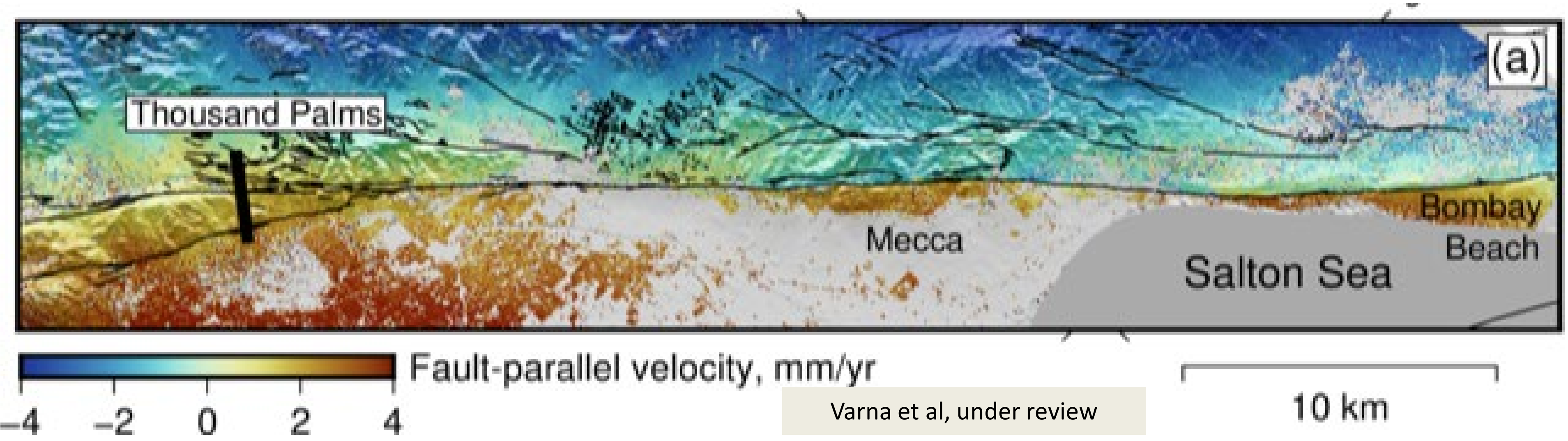


Ground velocity 2014-2020 in the Okataina volcanic system, obtained from multiple SAR data (CSK, S1, ALOS-1) and GNSS.

Courtesy of Ian Hamling

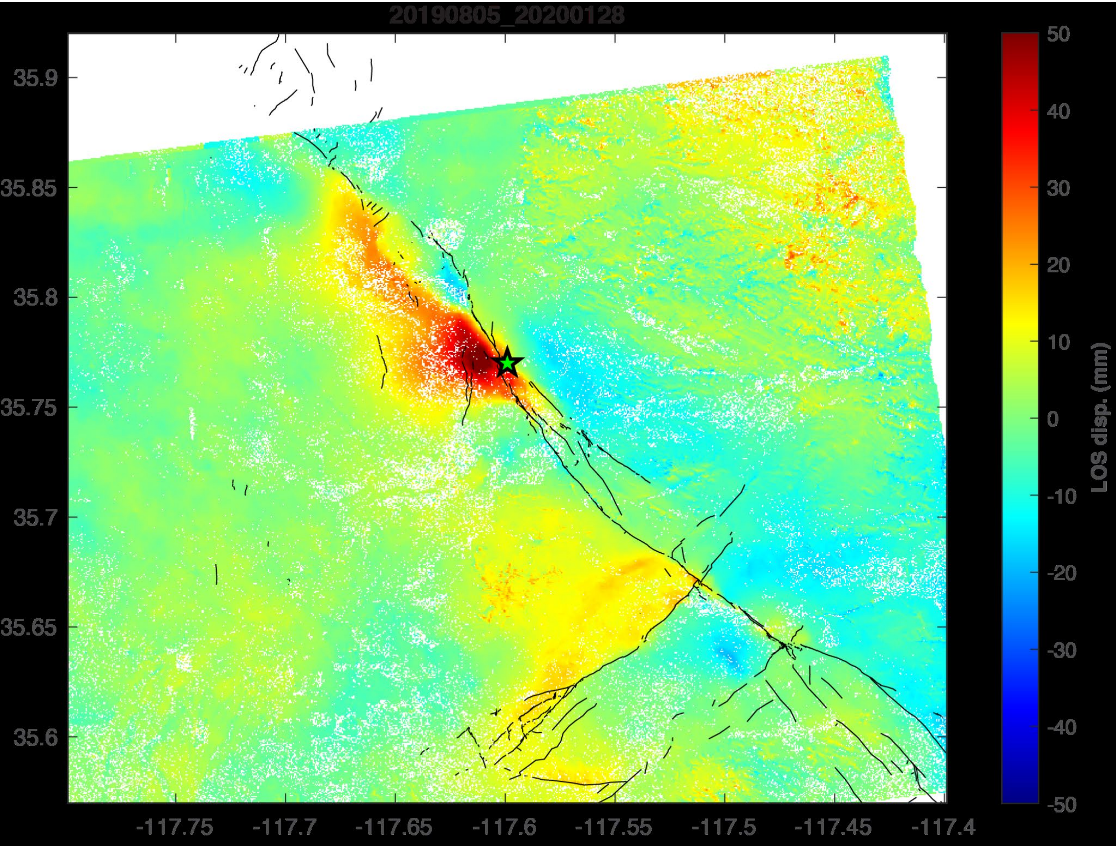
San Andreas Fault Nat. Lab.

S1 data were used to map the fault-parallel velocity of the Southern SAF. Together with local seismic data, they showed that the fault is dipping to the N and it is not vertical, posing new challenges for the seismic hazard assessment in this area.



Varna et al, under review

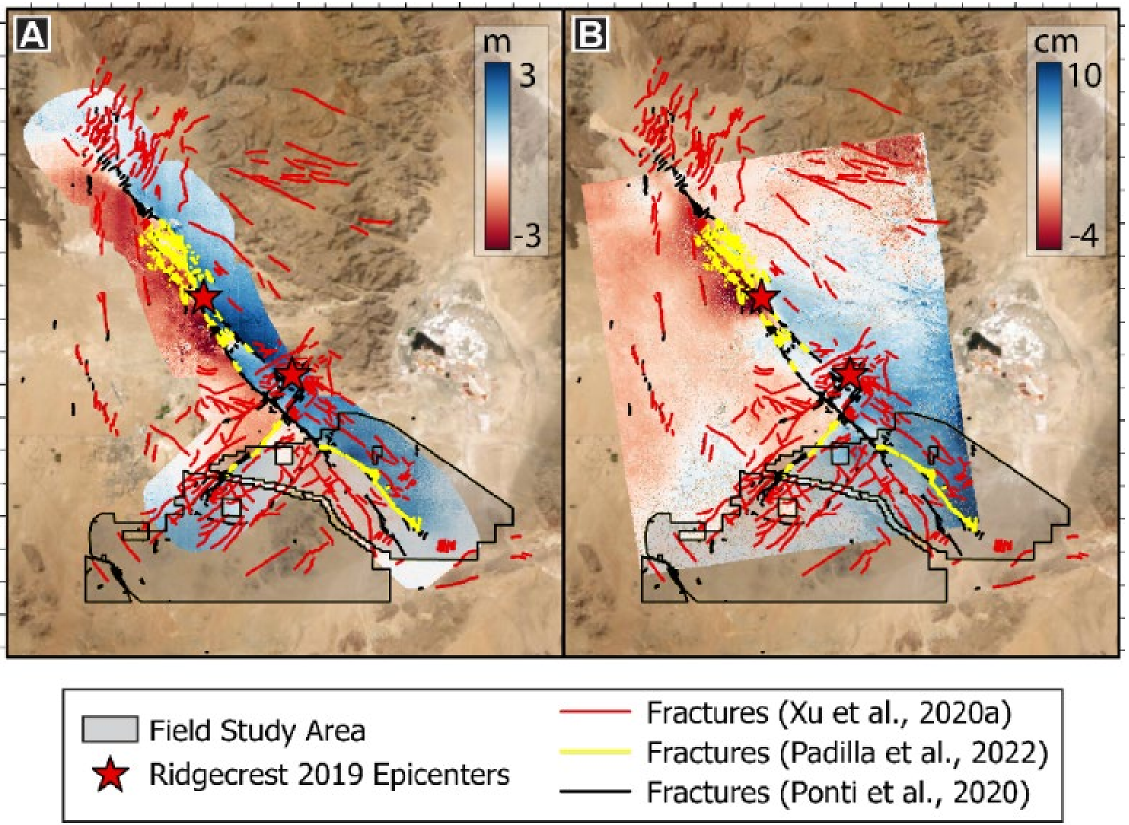
San Andreas Fault Nat. Lab.



CSK data were used to map the post seismic deformation of the 2019 Mw 7.1 Ridgecrest earthquake, revealing the important role of poroelastic rebound following seismic perturbations in the shallow crust.

Courtesy of W. Barnhart

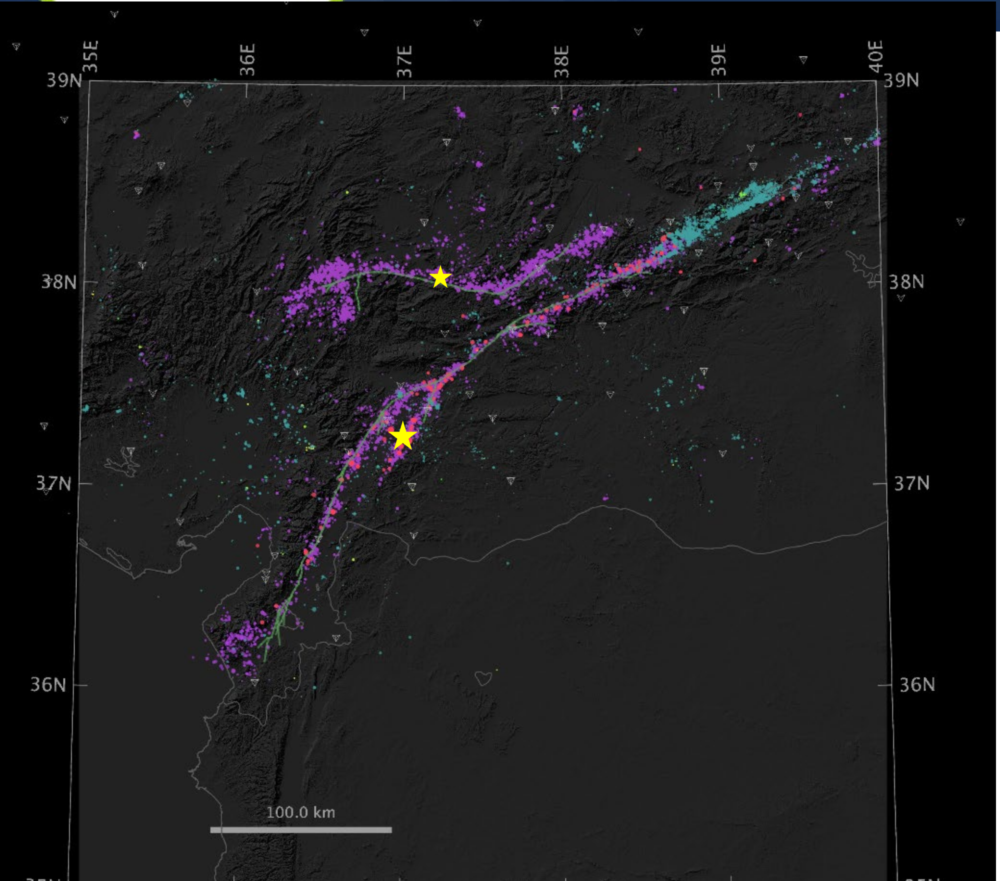
San Andreas Fault Nat. Lab.



CSK data are also used to map the brittle deformation (surface fractures) due to the Ridgecrest earthquake, combining high-resolution InSAR displacement and phase gradient maps with field observations.

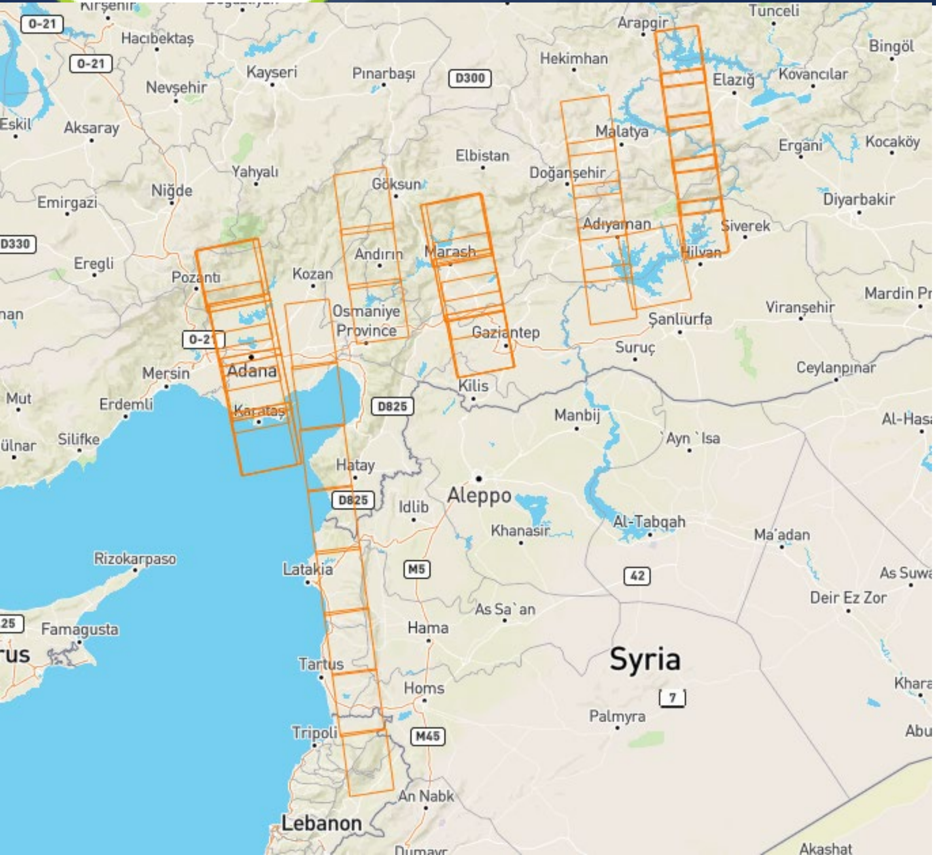
Courtesy of W. Barnhart

Kahramanmaraş Event Supersite



- Mw 7.8 mainshock on the NE-SW East Anatolian Fault on Feb. 6, 2023. followed by a Mw 7.6 eq on an E-W branching fault
- Over 30,000 aftershocks , up to Mw 6.7
- Final death toll >59,000
- About 1.5 million people were displaced
- 165,000 buildings were destroyed or strongly damaged

Kahramanmaraş Event Supersite



Over 600 CSK images already acquired.

Acquisitions will end in March 2024.

Kahramanmaraş Event Supersite

TSX Supersites Download Service

Type to search...

/supersites/files/Kahramanmaras/

File Name ↓	File Size ↓	Date ↓
Parent directory/	-	-
TSX_20230219T152329.533_Kahramanmaras_C521_O130_A_R_SM004_SSC.tar.gz	1.4 GiB	2023-05-09 00:00:51
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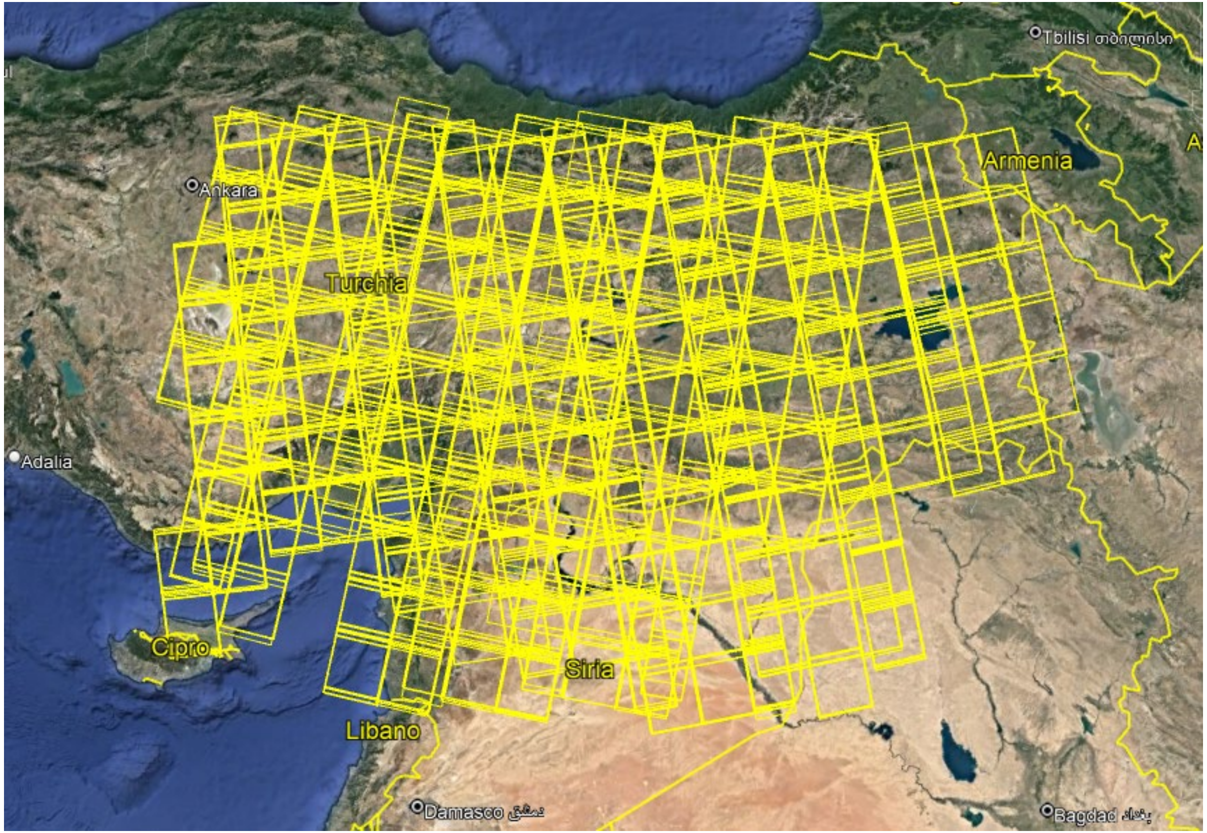
Over 16 TSX images have been acquired for the Supersite in the framework of a scientific AO

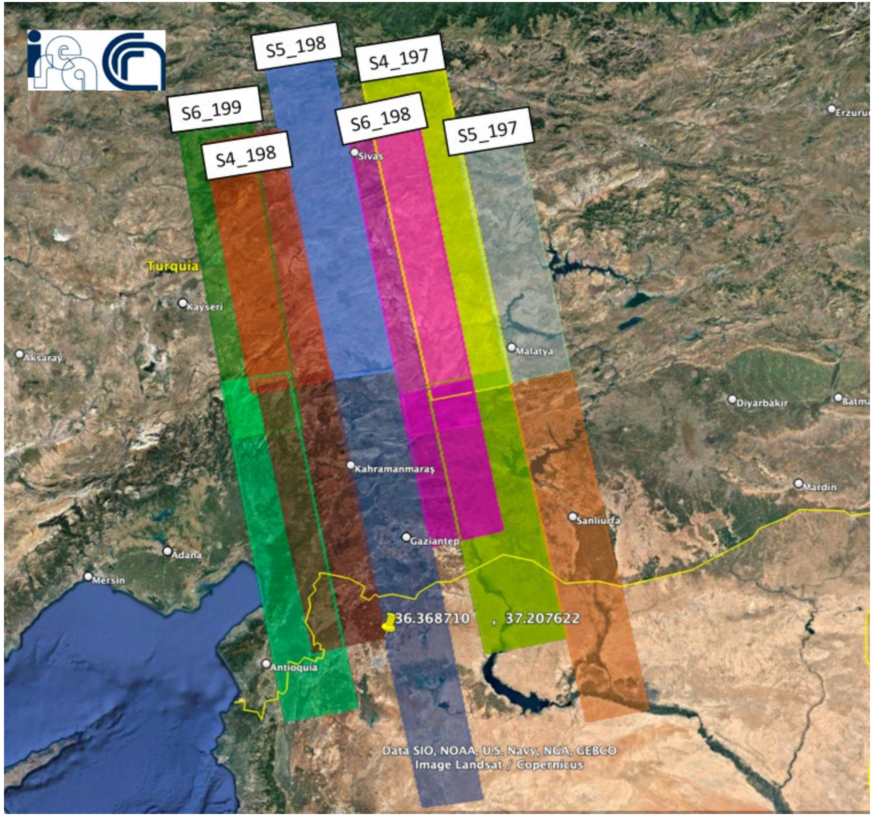
Kahramanmaraş Event Supersite



Thanks to ASI and CONAE we rapidly put in place a dense post-seismic acquisition plan for SAOCOM L-band SAR imagery.

To date, over 2300 SAOCOM images have already been acquired over the Supersite AoI.

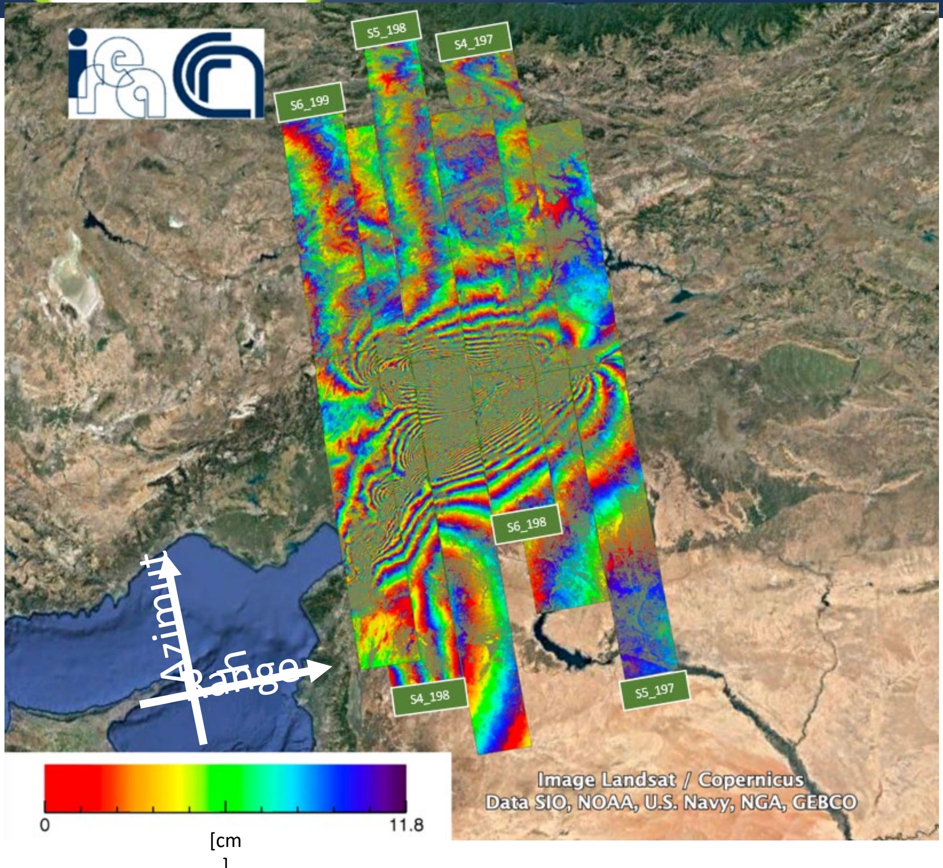
Kahramanmaraş Event Supersite



Using pre-event data SAOCOM L-band images acquired from ascending orbits (Tracks 197 and 198, Swaths S4, S5 and S6), IREA-CNR was able to generate a nearly full coverage of the coseismic displacement field.

Courtesy of R. Lanari

Kahramanmaraş Event Supersite



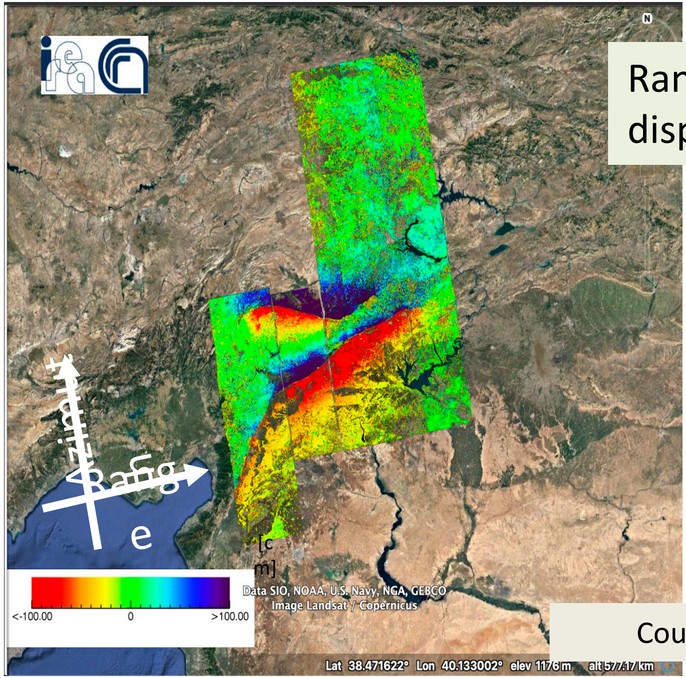
Twenty six SAOCOM pre- and post-event scenes have been processed.

The resulting interferograms have incidence angles between 33 and 44 degrees.

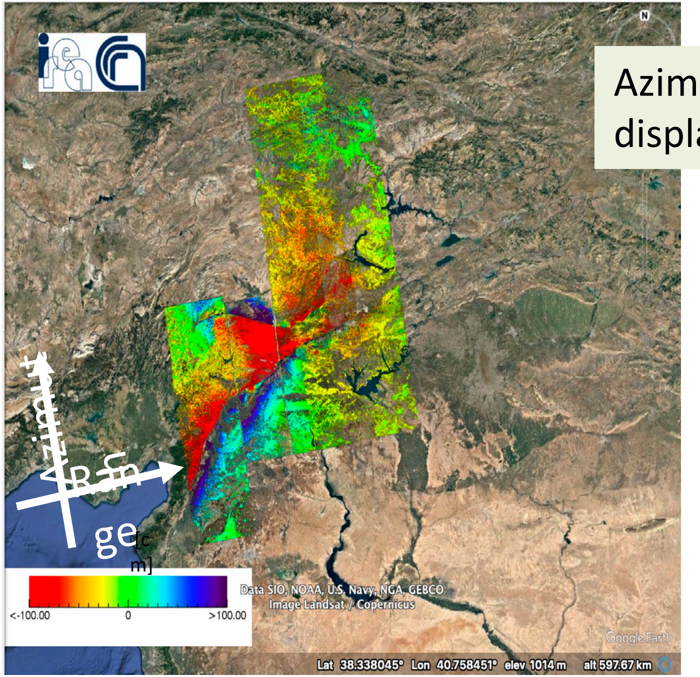
Courtesy of R. Lanari

Kahramanmaraş Event Supersite

Using pixel offset tracking on amplitude data of SAOCOM pre- and post-event images, IREA-CNR generated a detailed map of the co-seismic ground displacement fields.



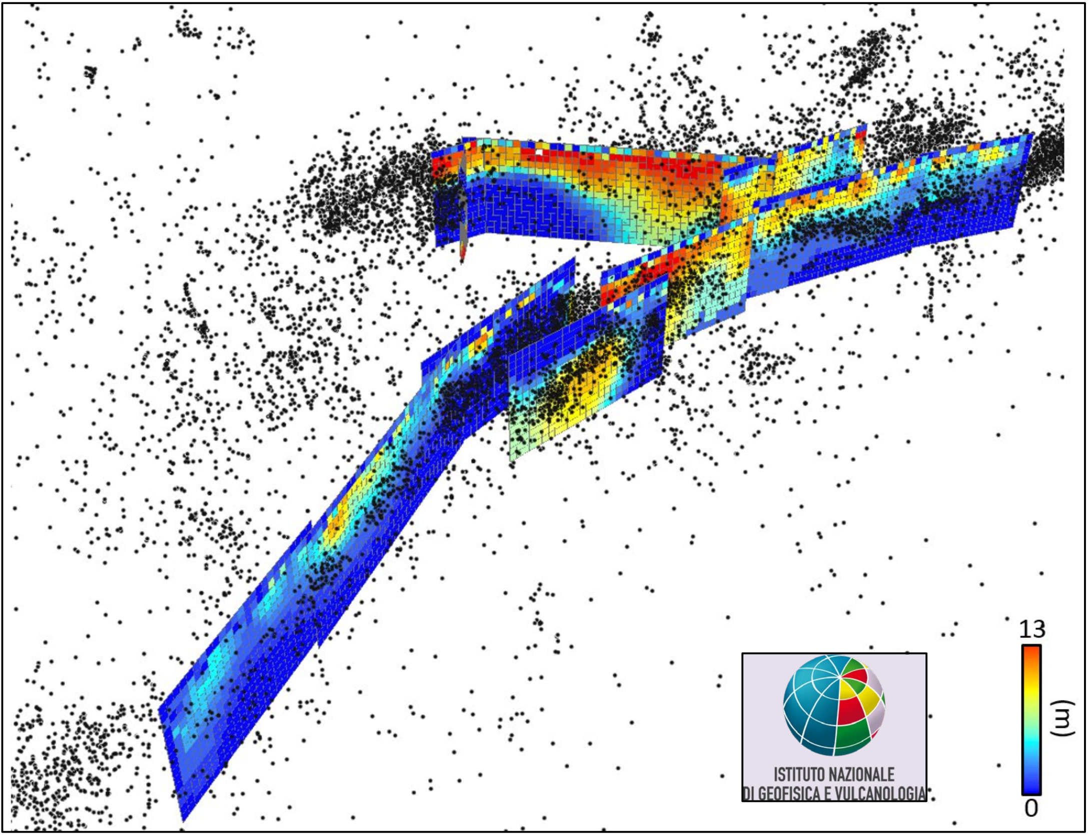
Range displacements



Azimuth displacements

Courtesy of R. Lanari

Kahramanmaraş Event Supersite



Using the co-seismic ground displacement fields from SAOCOM, Sentinel 1 and ALOS 2, together with geological and seismological data, INGV created a dislocation model for the two mainshock ruptures.

[c
m]

Courtesy of S. Atzori

Kahramanmaraş Event Supersite

Kahramanmaraş Supersite science page

This page reports the contributions from the scientific community and various local reports (some of them may be in Turkish).

You can send us your results using this **Google Form**. We will progressively update the table below with all received results.

Scientific/situational awareness reports

Co-seismic displacement field

Co-seismic surface faulting

Coulomb stress transfer

Instrumental seismicity

Historical seismicity

Finite fault inversion model

Pre-seismic ground deformation

Post-seismic ground deformation

Damage proxy maps

Soil liquefaction

HR monitoring of critical infrastructures

On the GSN wesite we collect scientific material produced by the scientific community before and after the earthquake, covering a number of different subjects.

http://geo-gsnl.org/kahramanmaras-supersite-science-page/

Capacity development

- INGV provided SAR data modeling seminars within a CD initiative organized annually in Latin America by USGS VDAP together with the GEOVOL (Latin America volcano geodesists group)
- GSNL donated 5 GNSS stations to the Goma Volcano Observatory to improve its in situ monitoring system, and INGV will be providing training for operation and data processing
- VDAP has supported the Virunga Supersite with geochemical measurements instruments and consumables
- GSNL is continues to provide access to cloud resources with commercial software for satellite data processing

Reports to be assessed

The following biennial reports were recently delivered to Laura and await assessment from the Agencies

- Ecuador Supersite 4th report
- China Supersite 1st report
- Nicaragua Supersite 1st report

Incoming reports (mid-November)

- Iceland Supersite 5th report
- Southern Andes Supersite 3rd report
- Virunga Supersite 3rd report

We warmly thank the CEOS agencies for the continuous support to GEO-GSNL since 2012 !