Committee on Earth Observation Satellites

The International Virtual Volcano Observatory

A proposal for CEOS WG Disasters

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CEOS WG Disasters 20

Yellowstone National Park

September 5–9, 2023

The impacts of volcanic eruptions

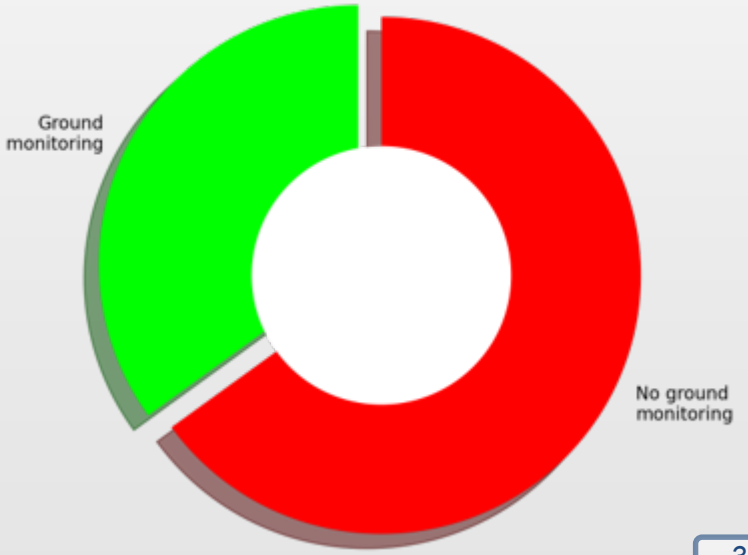
Krakatau, Indonesia, 2018
437 dead

Eyjafjallajökull, Iceland, 2010
$4.7US billion losses

La Palma, Canary Islands, 2021
3000 structures destroyed

Volcano Monitoring: The Problem

- Volcanic eruptions threaten life, infrastructure, and the global economy, but eruptions can be forecast if monitoring data are recorded and analyzed before the onset of unrest
- Only about 35% of the ~600 volcanoes that have erupted since 1500 CE have continuous ground monitoring
- Satellite data can make up for some of this gap, BUT:
  - We need the right types of data at the right volcanoes at the right times
  - Data should be freely accessible
  - Acquisition plans should be flexible (especially during a crisis)
  - Data latency should be low
  - Capacity building is critical



The Santorini Report

- Global background observations at 1400 volcanoes
- Weekly observations at restless volcanoes (~200/year)
- Daily observations at erupting volcanoes (70–80/year)

GEO GROUP ON EARTH OBSERVATIONS

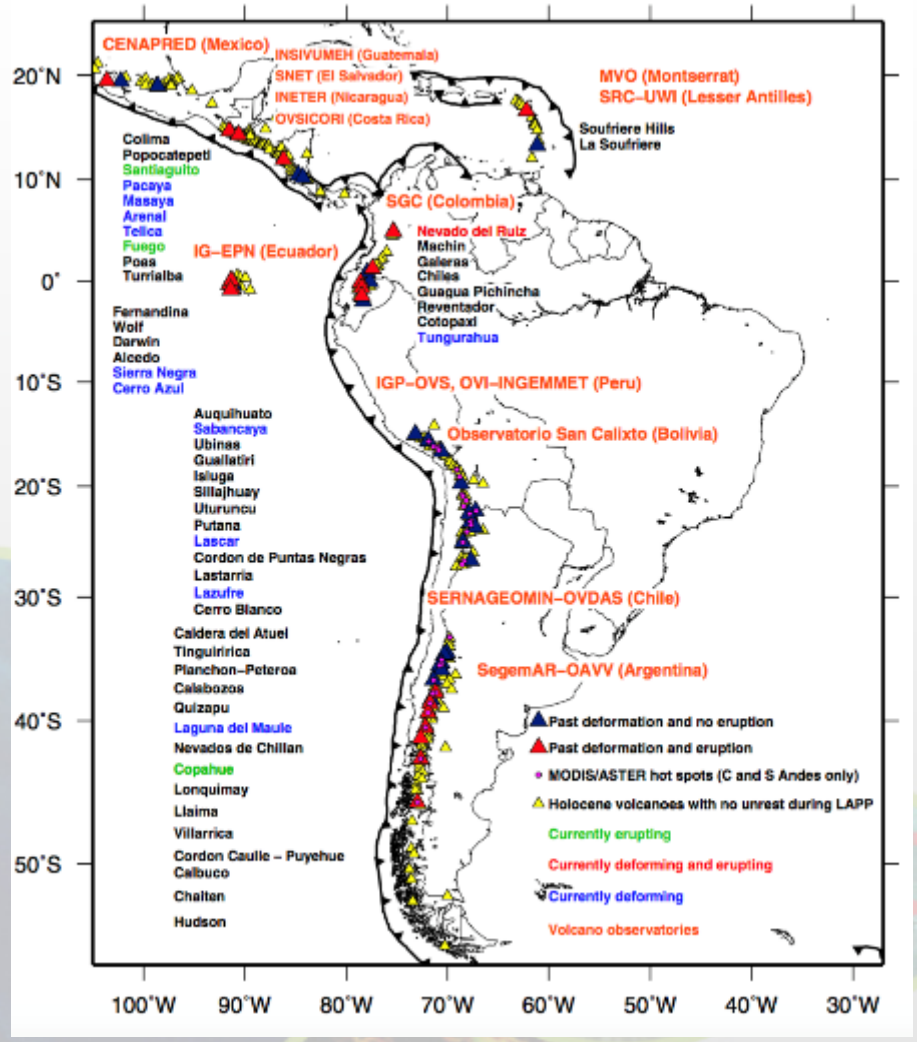
esa

→ THE INTERNATIONAL FORUM ON SATELLITE EO AND GEOHAZARDS

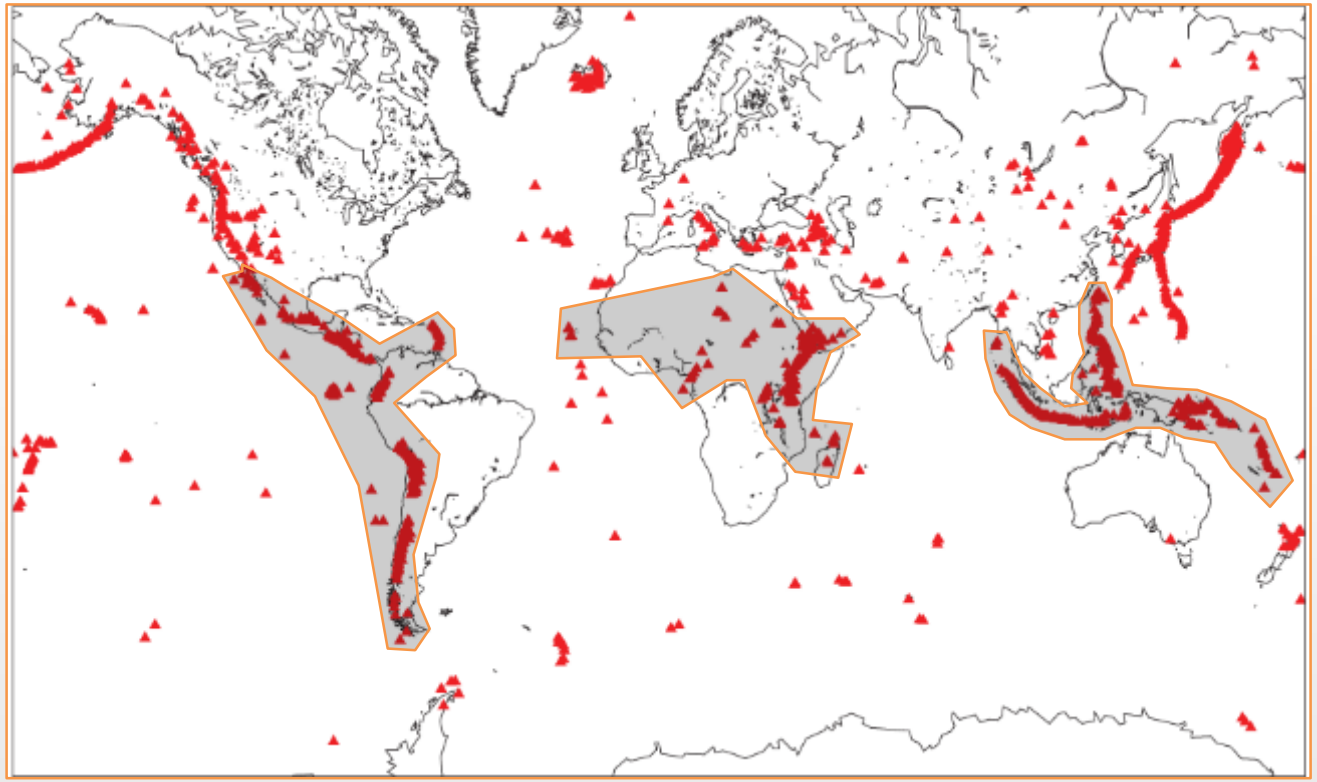
The Santorini Conference
Santorini, Greece, 21–23 May 2012

CEOS WG Disasters and Volcano Monitoring

Pilot (2014–2017)

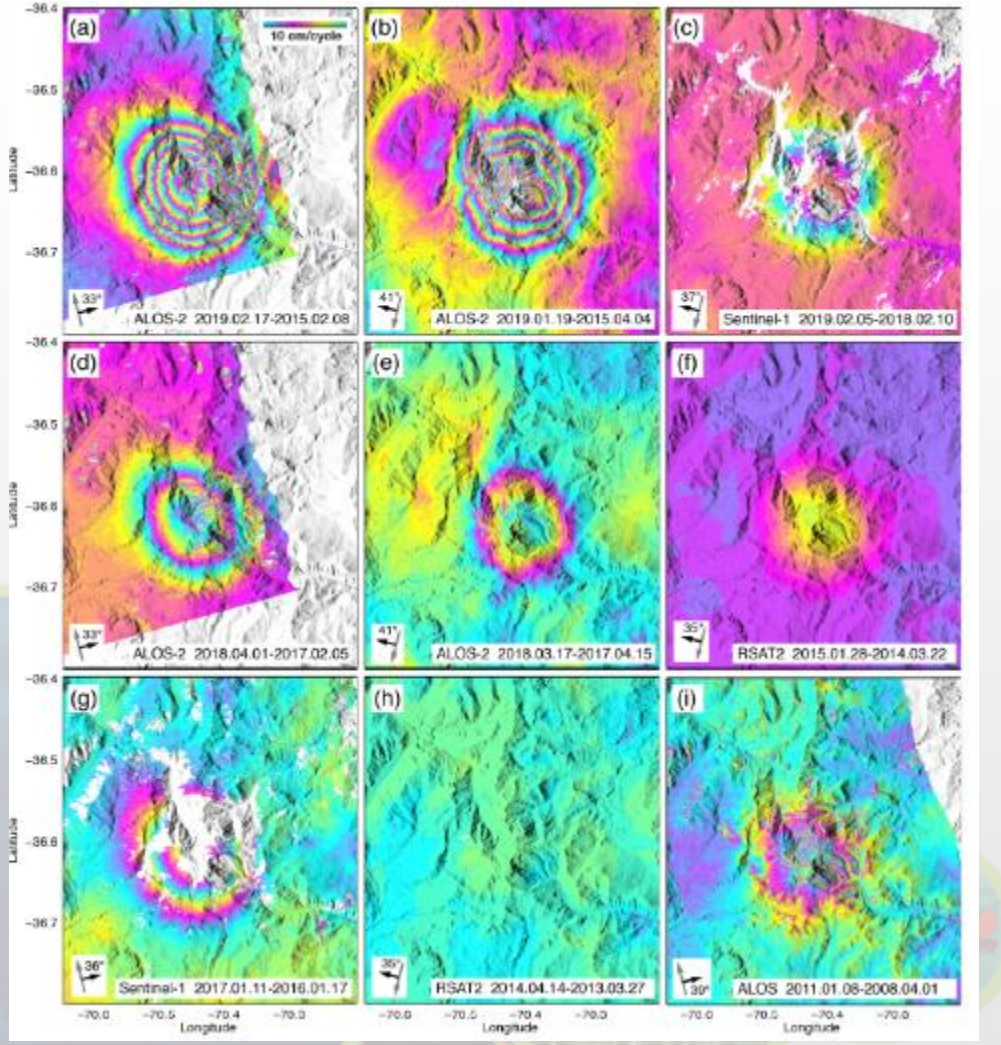


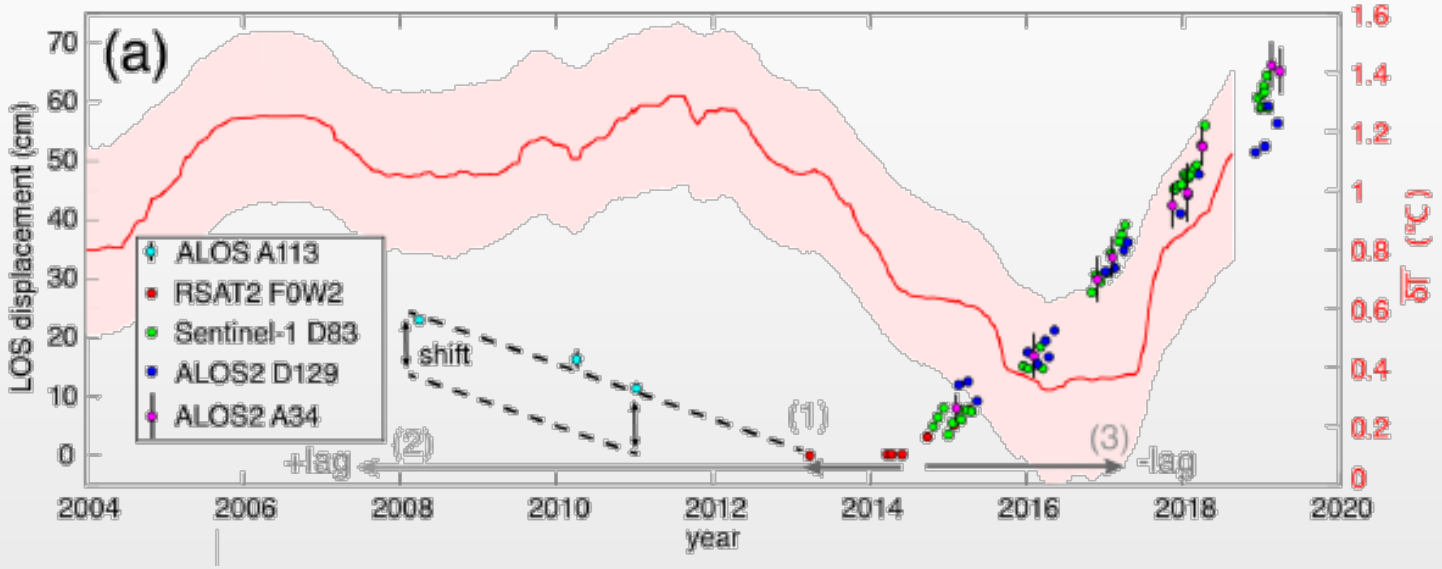
Demonstrator (2019–2023)



Long term goal: to demonstrate the necessity and viability of international coordination of satellite tasking for volcano monitoring

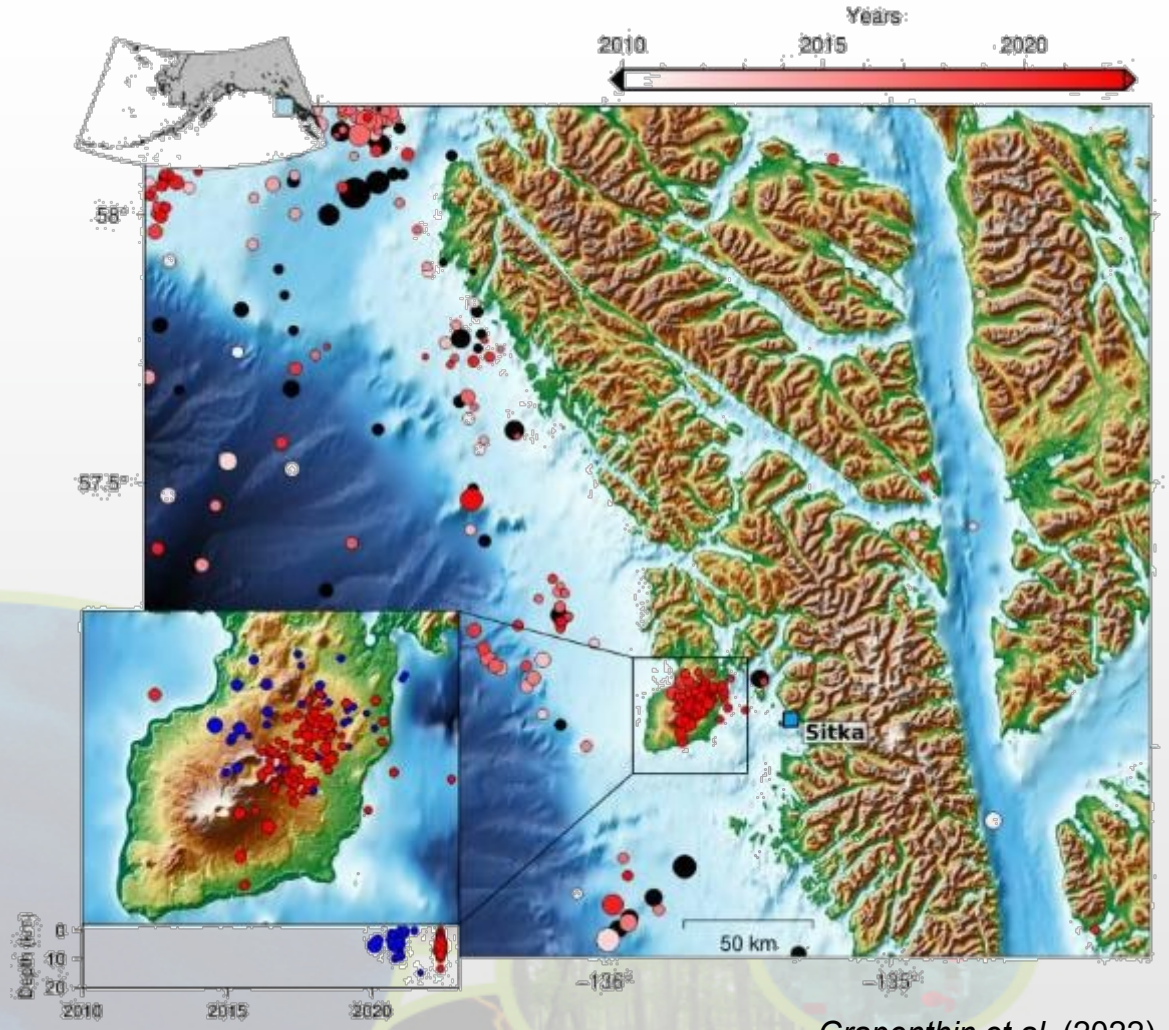
QUIESCENT: Domuyo, Argentia

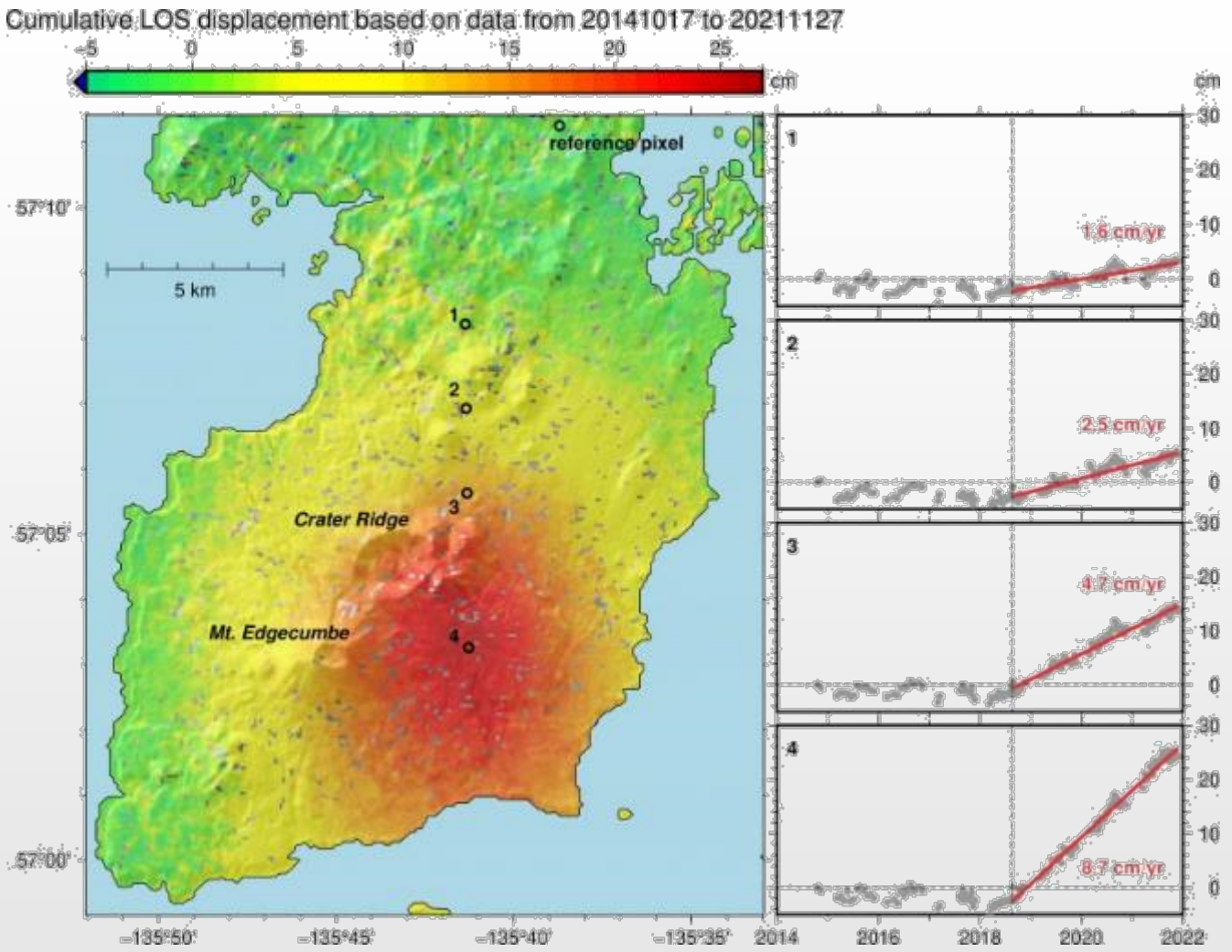




Lundgren et al. (2020)

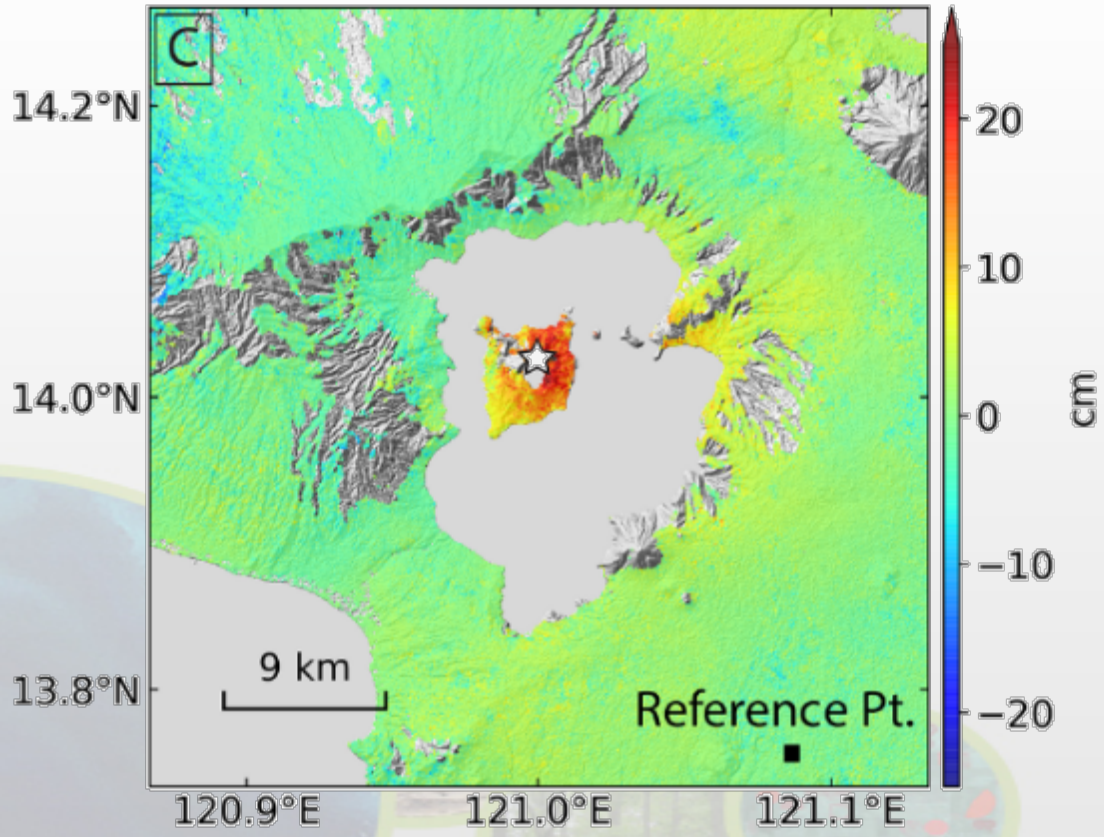
QUIESCENT : Edgecumbe, Alaska

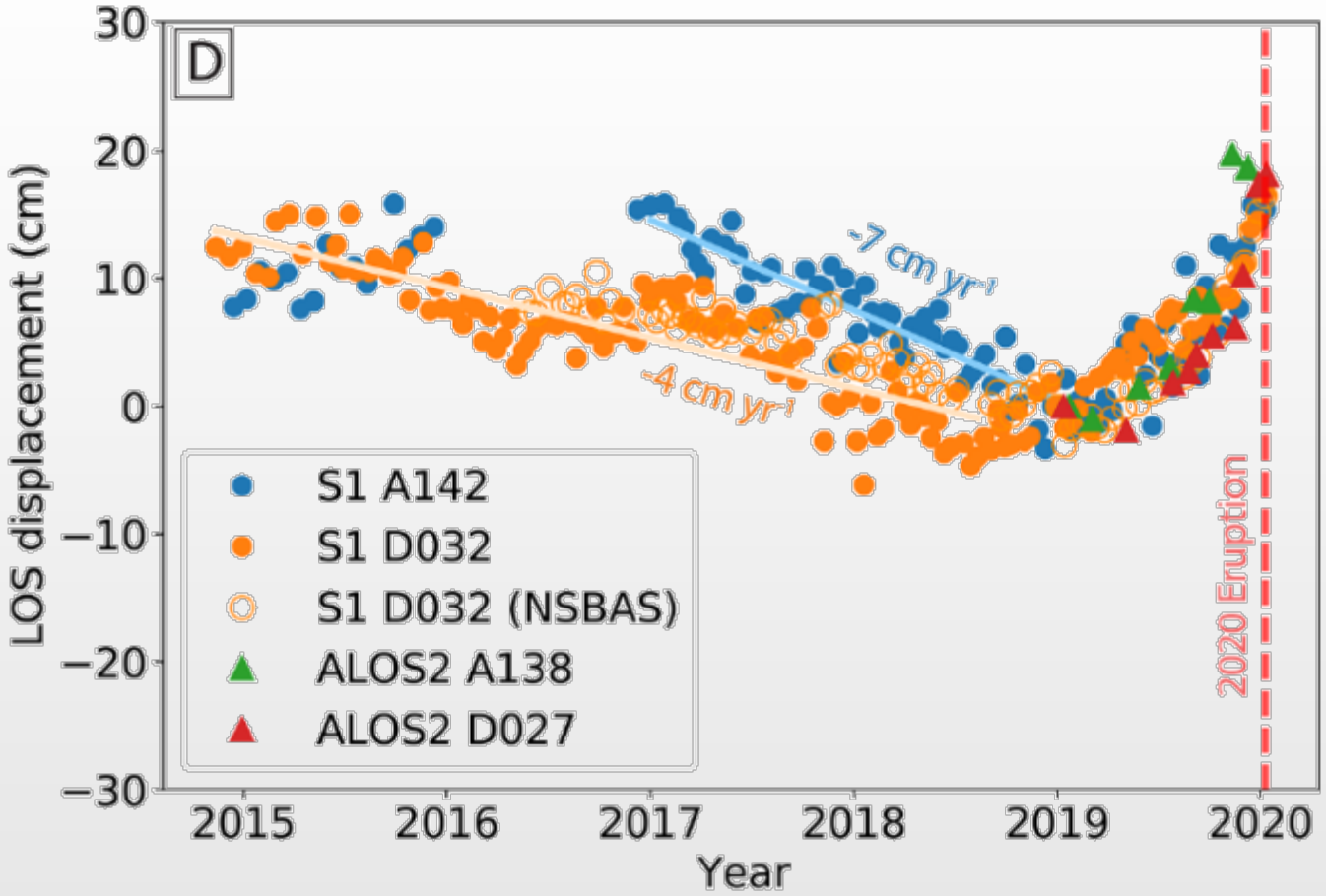




Grapenthin et al. (2022)

RESTLESS: Taal, Philippines



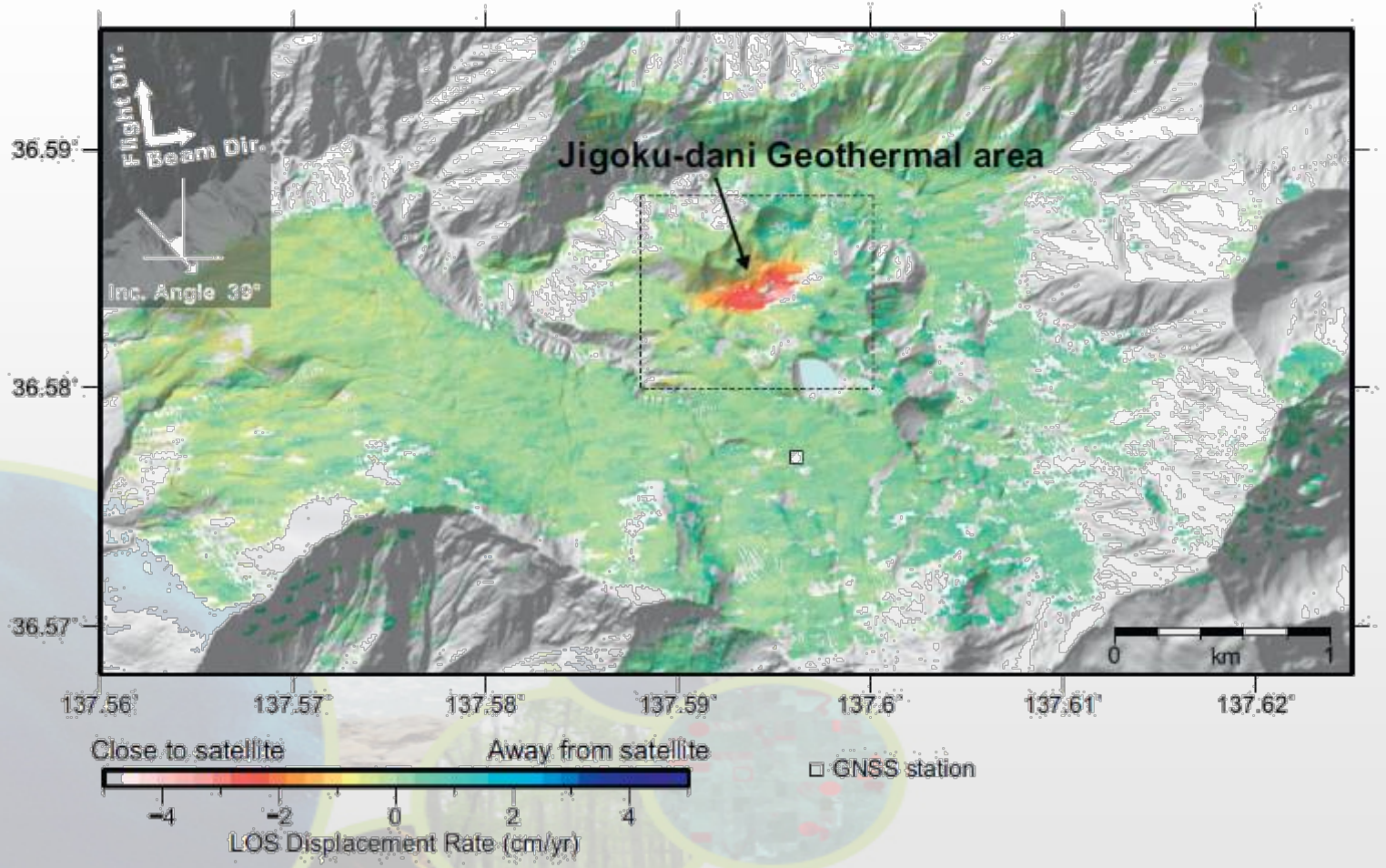


Bato et al. (2021)

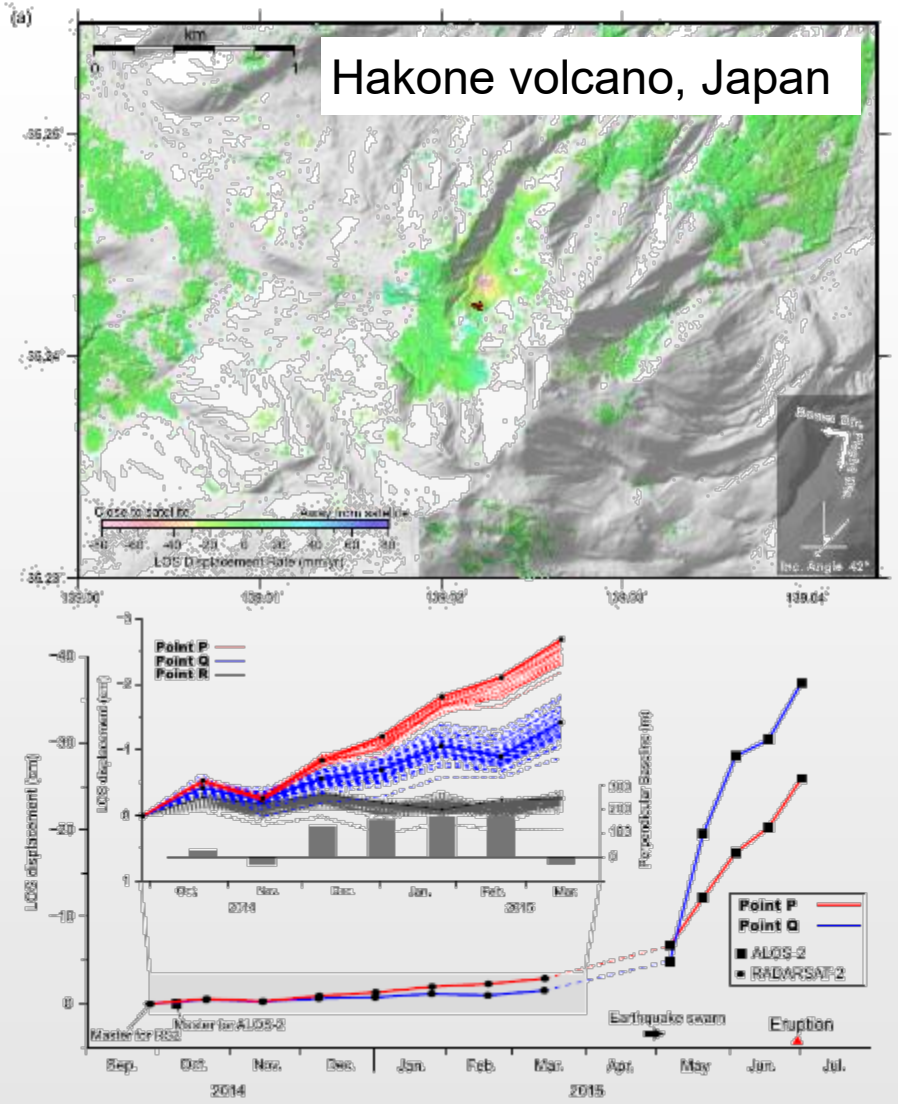
RESTLESS: Localized deformation in Japan

Midagahara volcano, Japan

Kobayashi (2018)



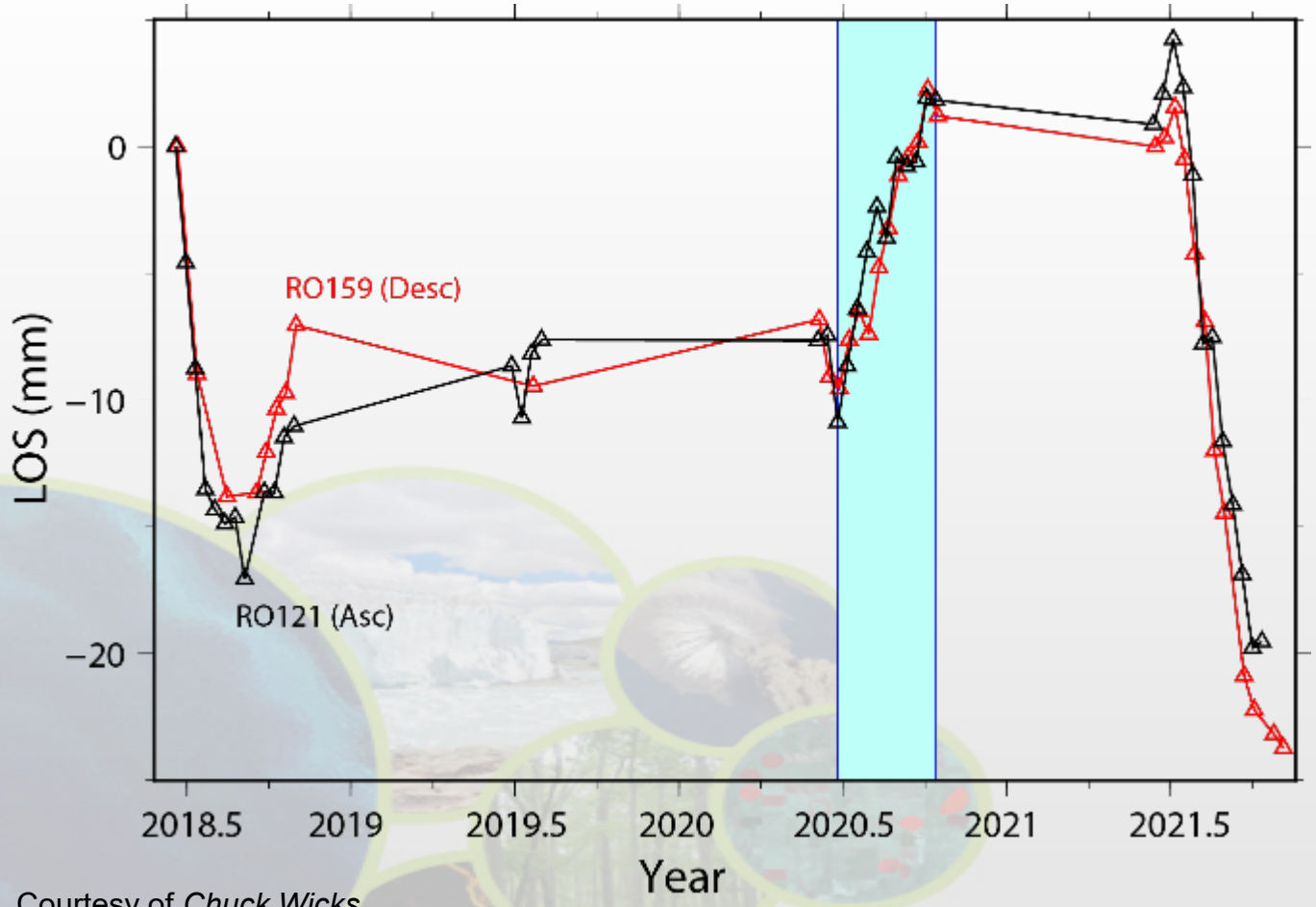
Hakone volcano, Japan



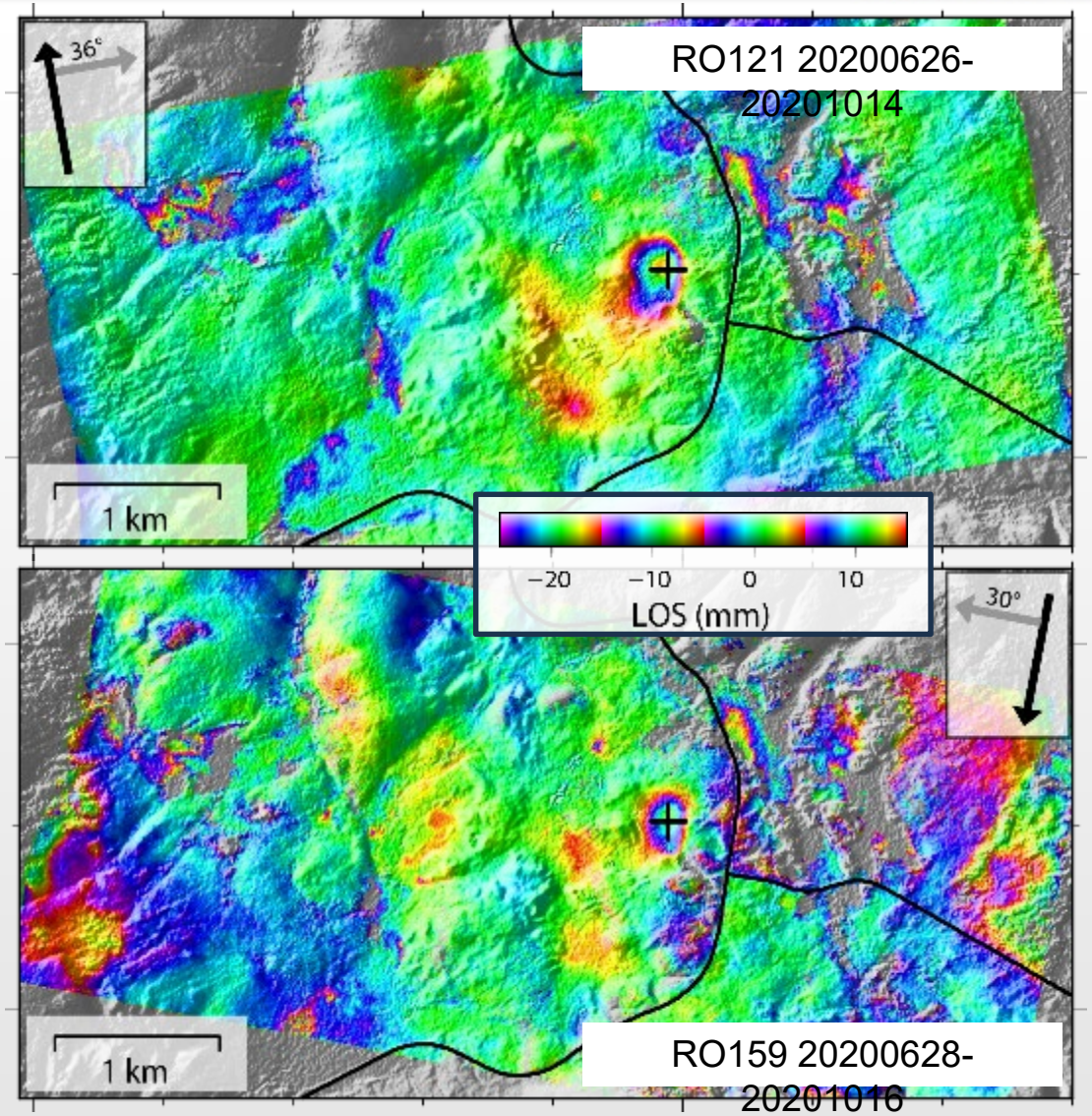
Kobayashi et al. (2018)

RESTLESS: Yellowstone caldera, USA

TSX Staring Spotlight



Courtesy of *Chuck Wicks*



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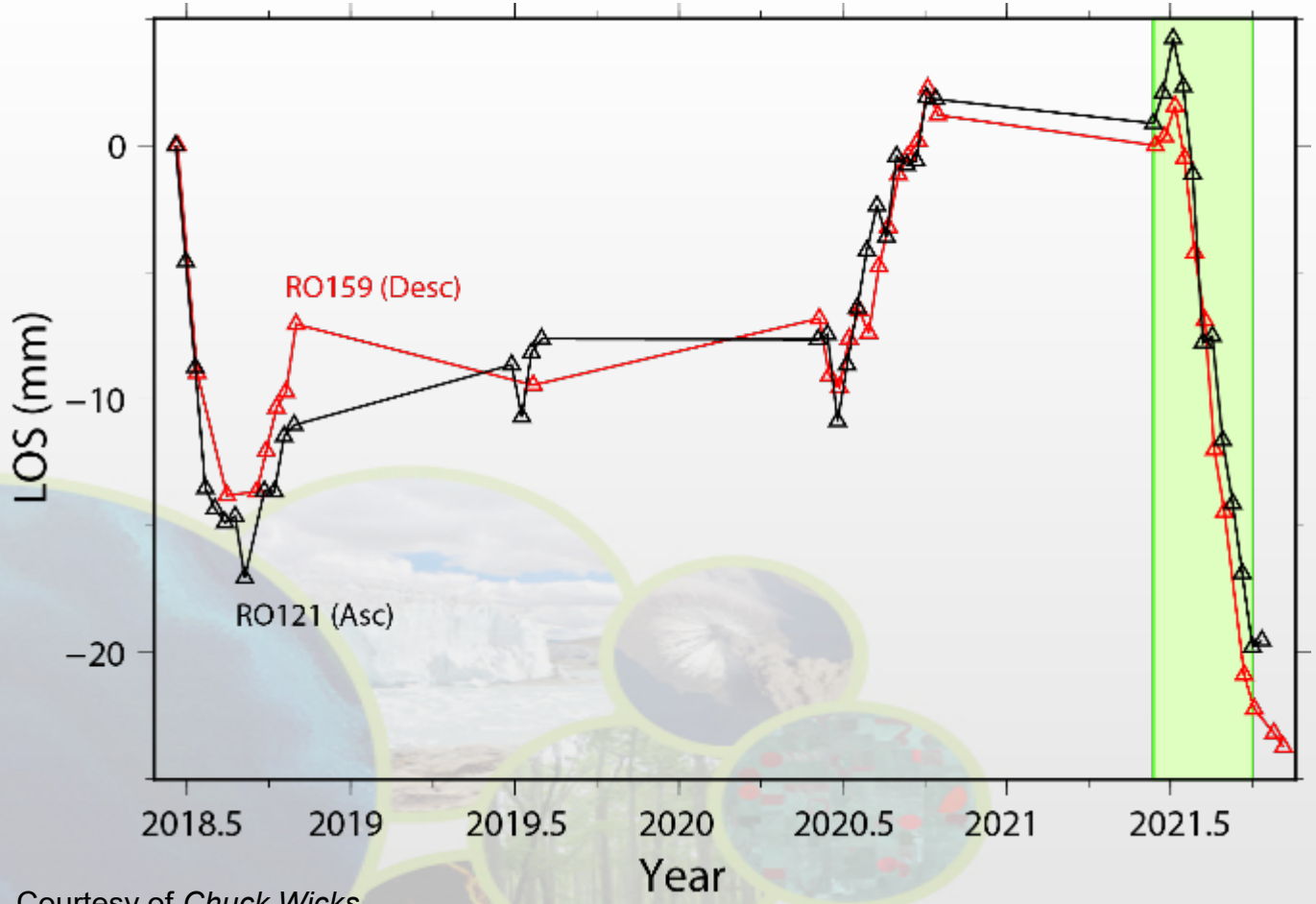
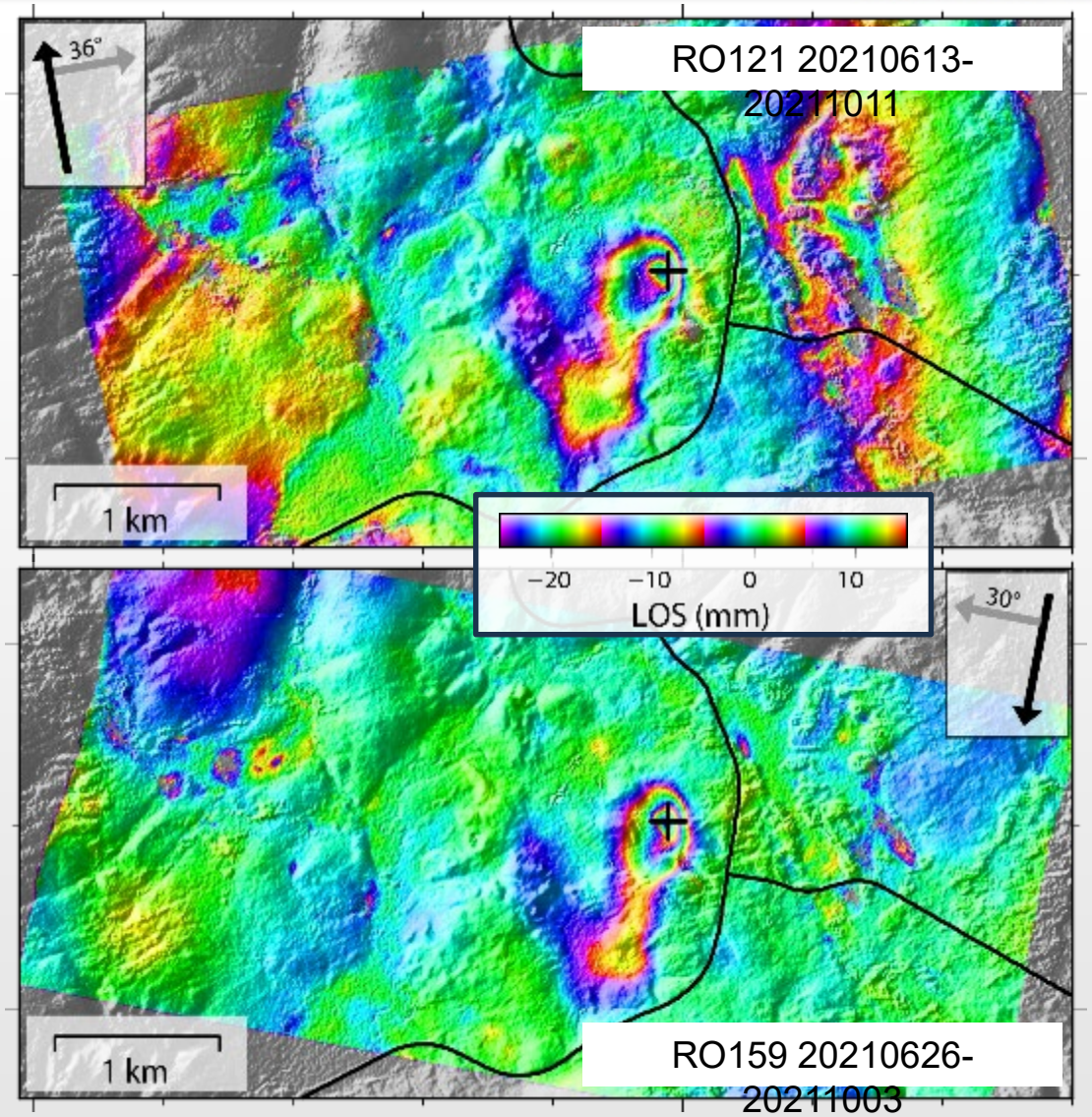
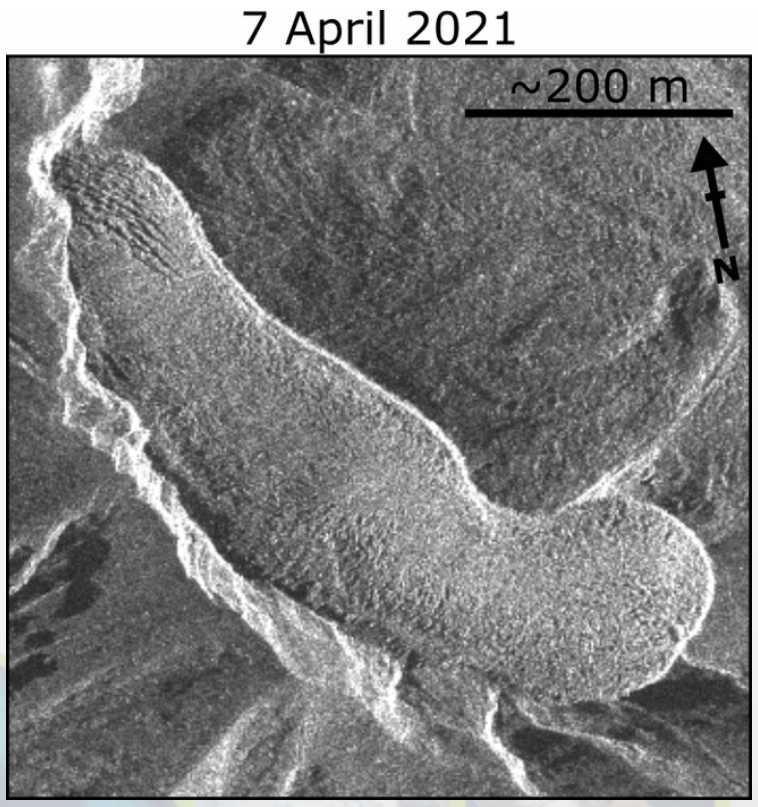
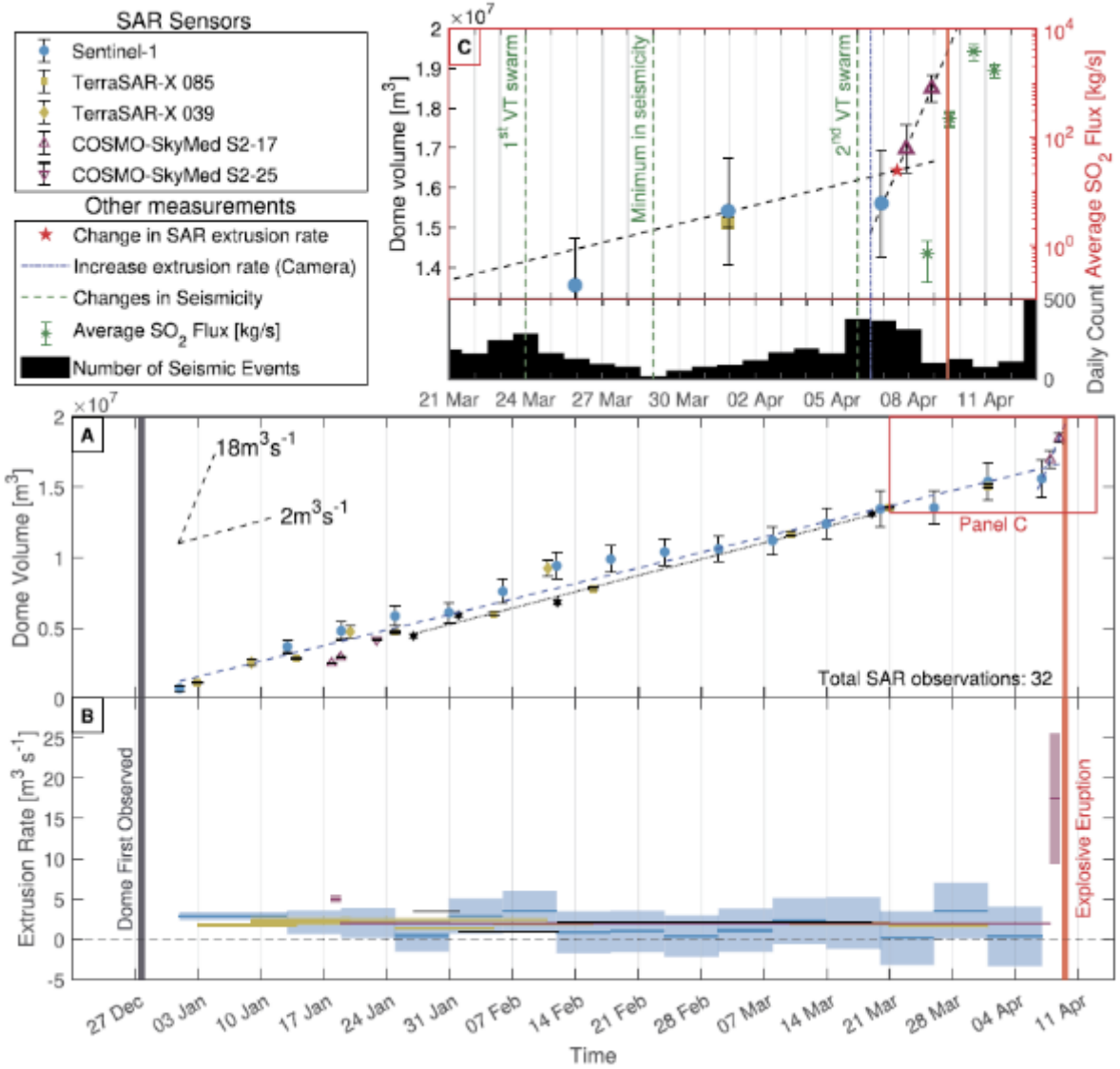


Courtesy of *Chuck Wicks*



ERUPTING: Soufrière, St. Vincent

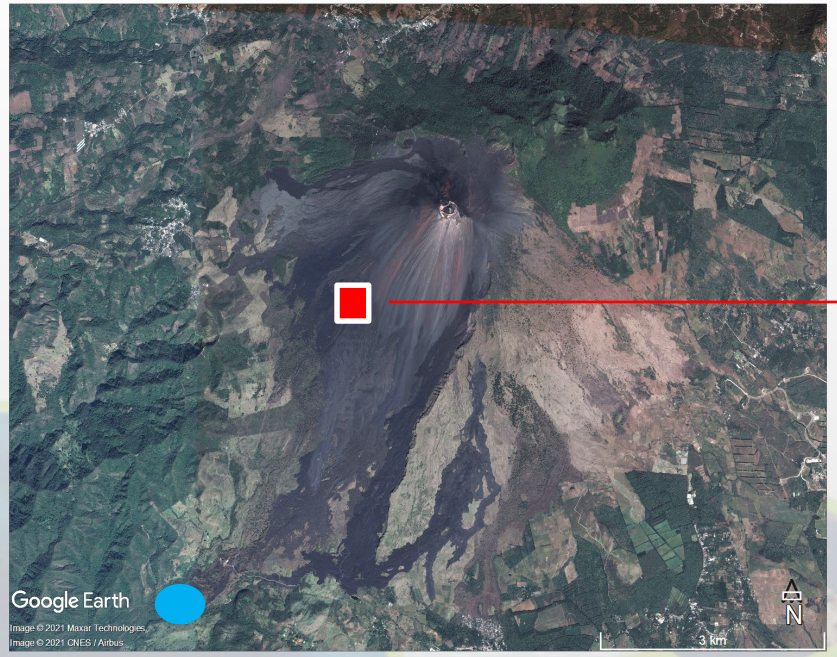


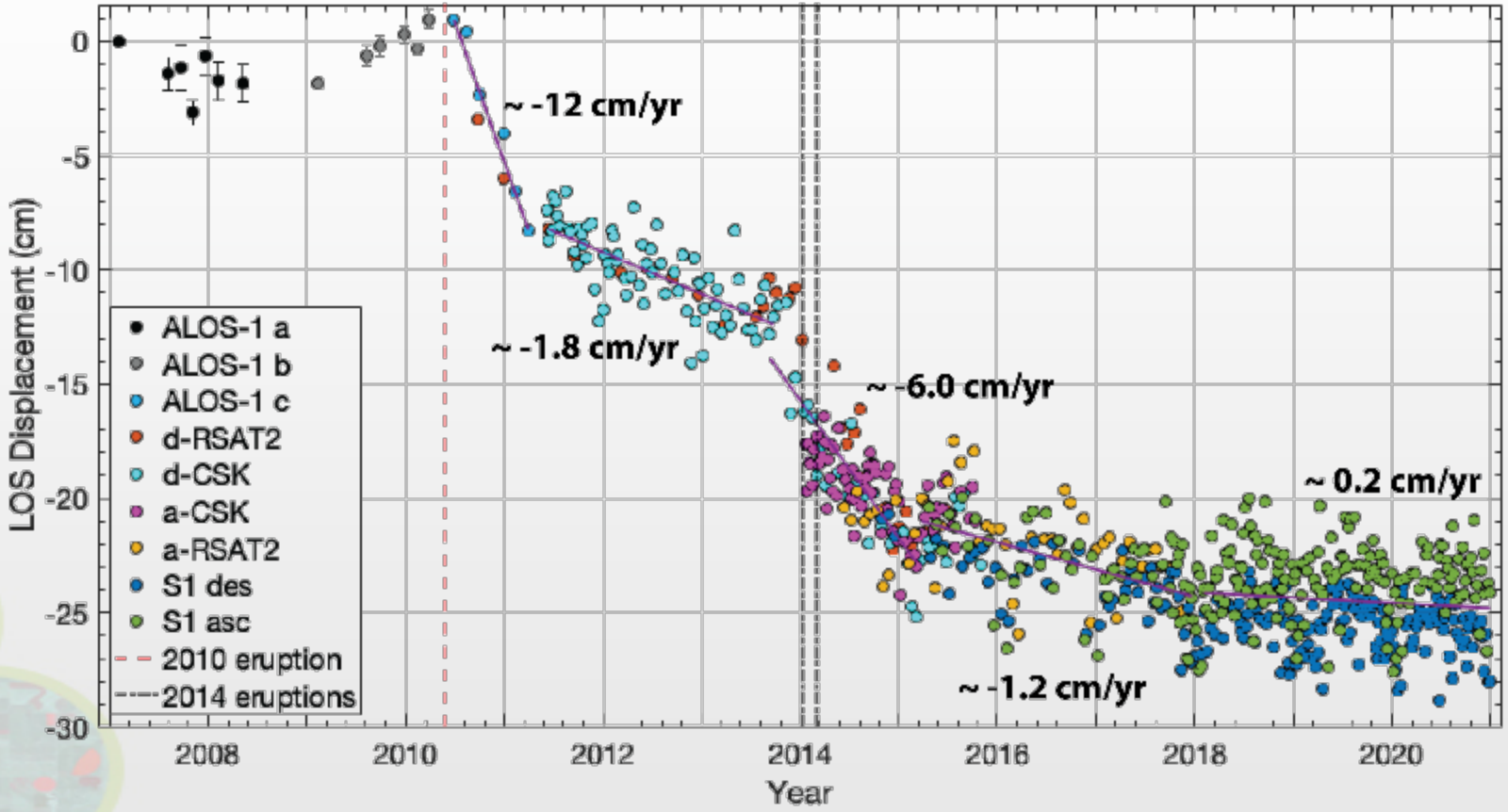


10x increase in extrusion rate 48 hours before onset of explosive eruption

Dualeh et al. (2023)

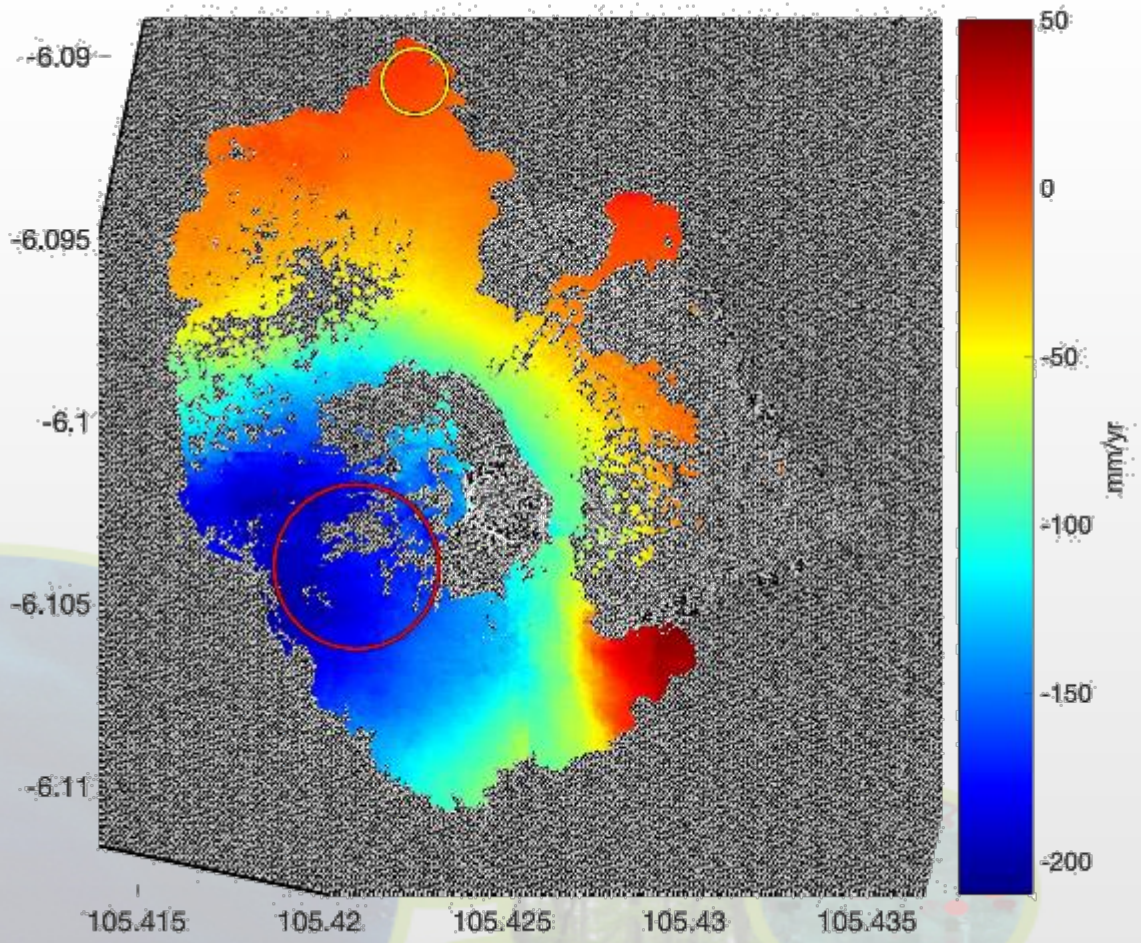
ERUPTING: Pacaya, Guatemala





Gonzalez-Santana et al. (2022)

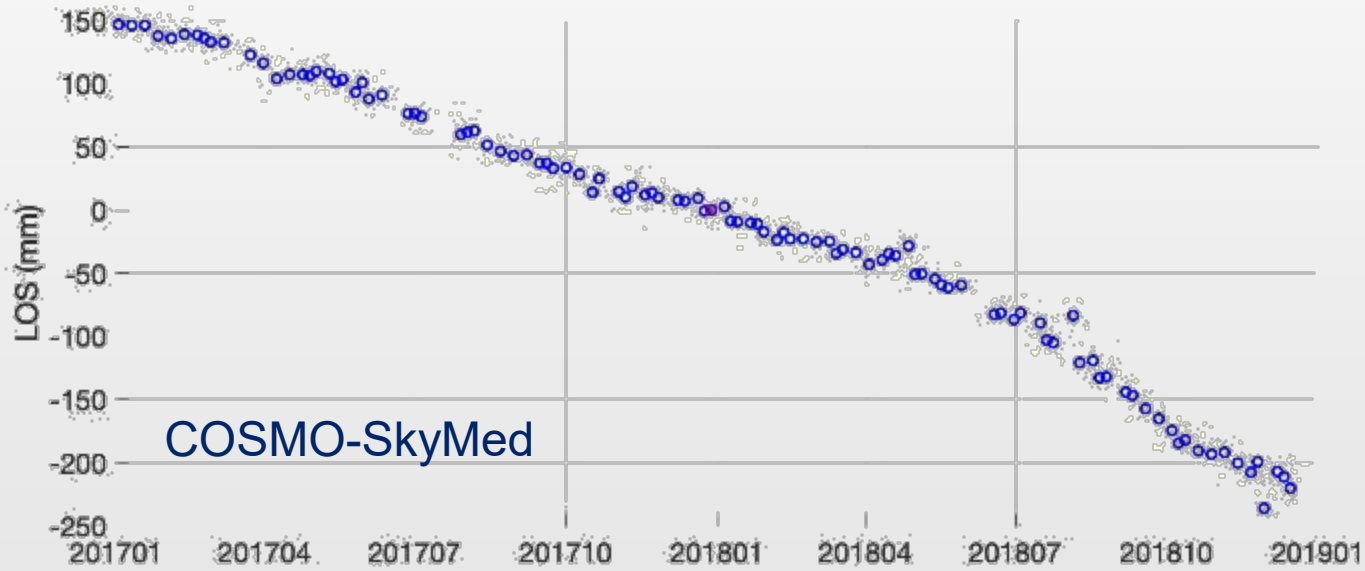
ERUPTING: Krakatau, Indonesia



Deformation

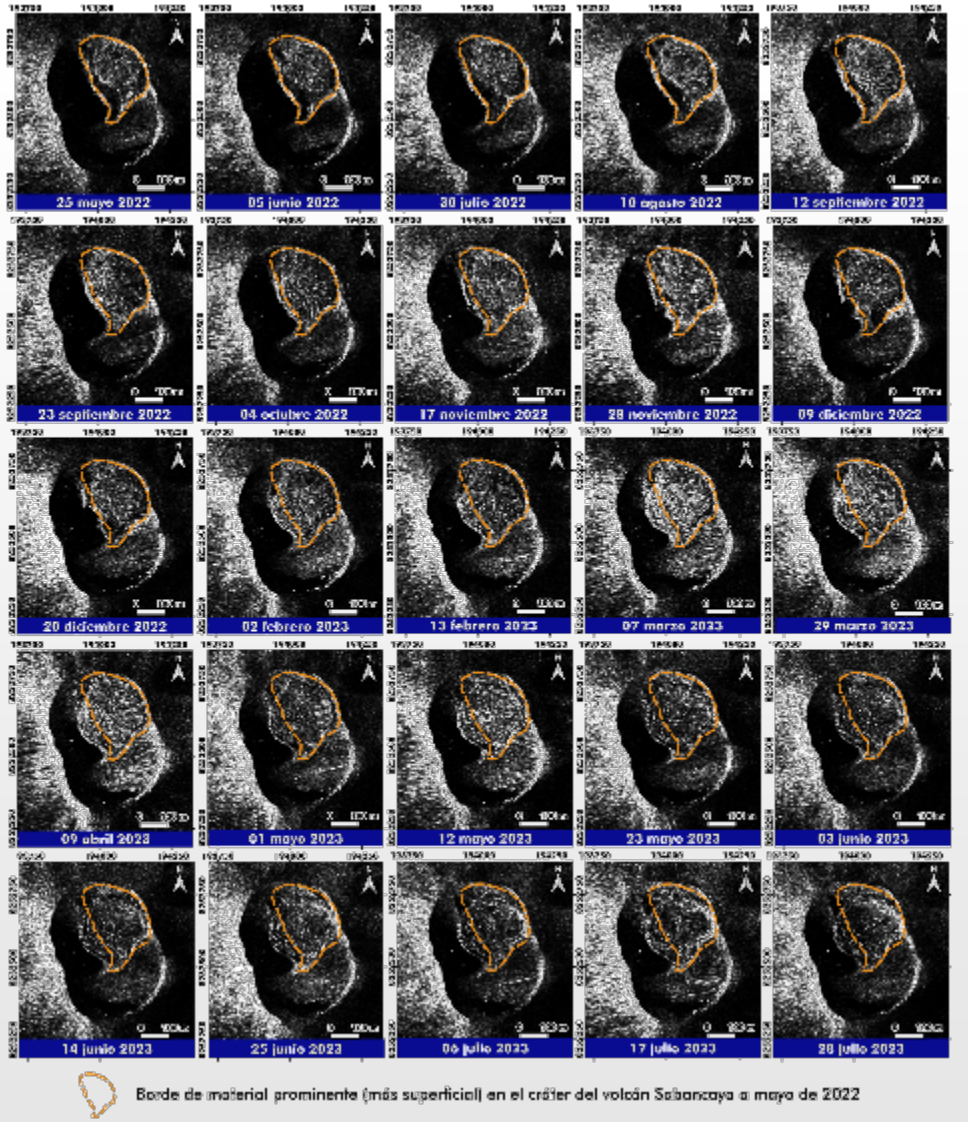
Reference

Courtesy of *Christelle Wauthier*

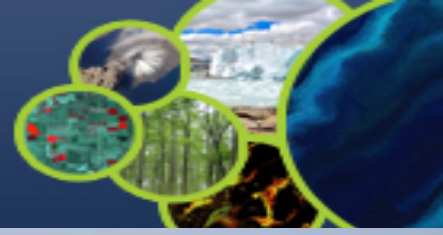


ERUPTING: Sabancaya, Peru

Courtesy of *Katherine Andrea Vargas Alva*

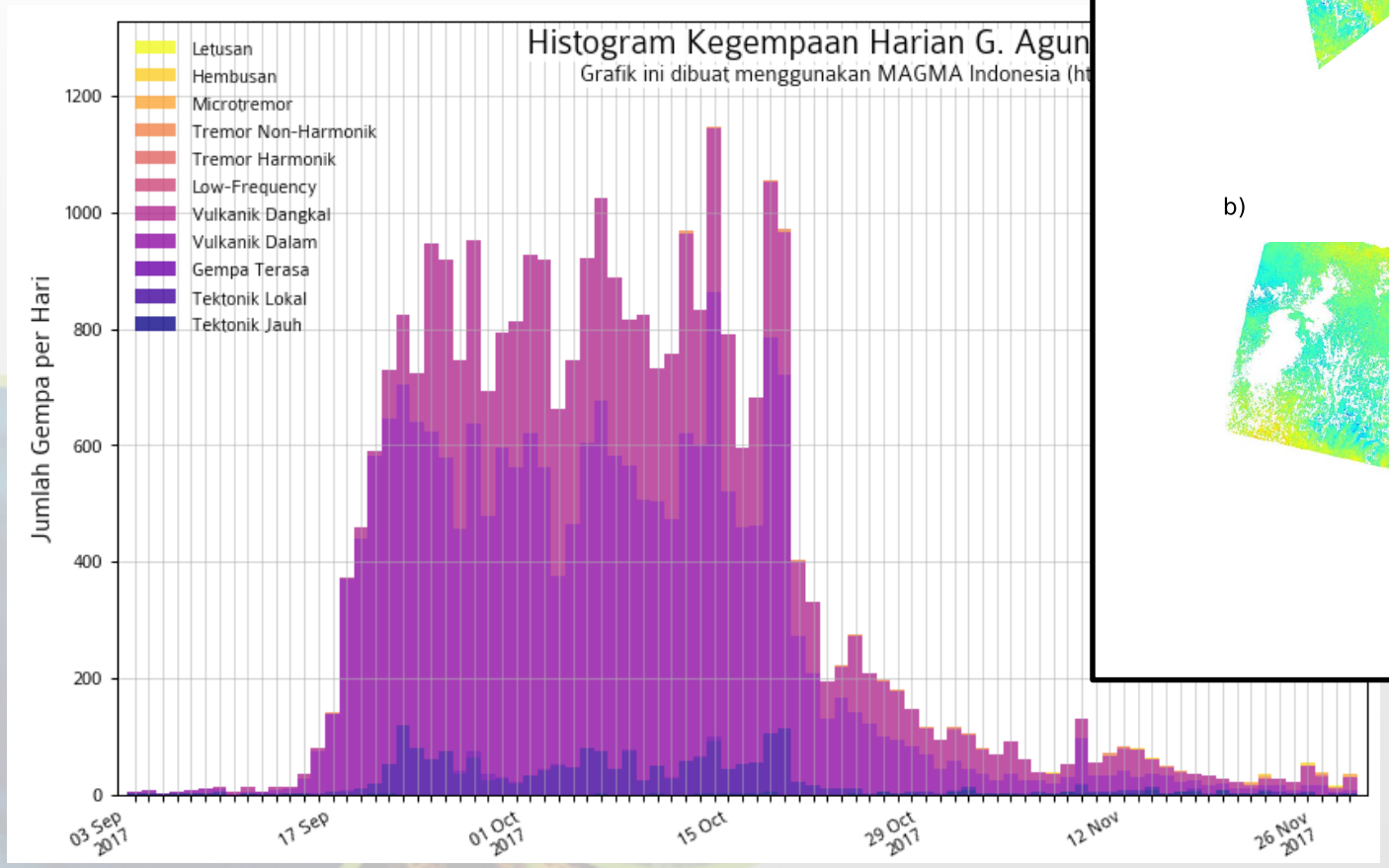


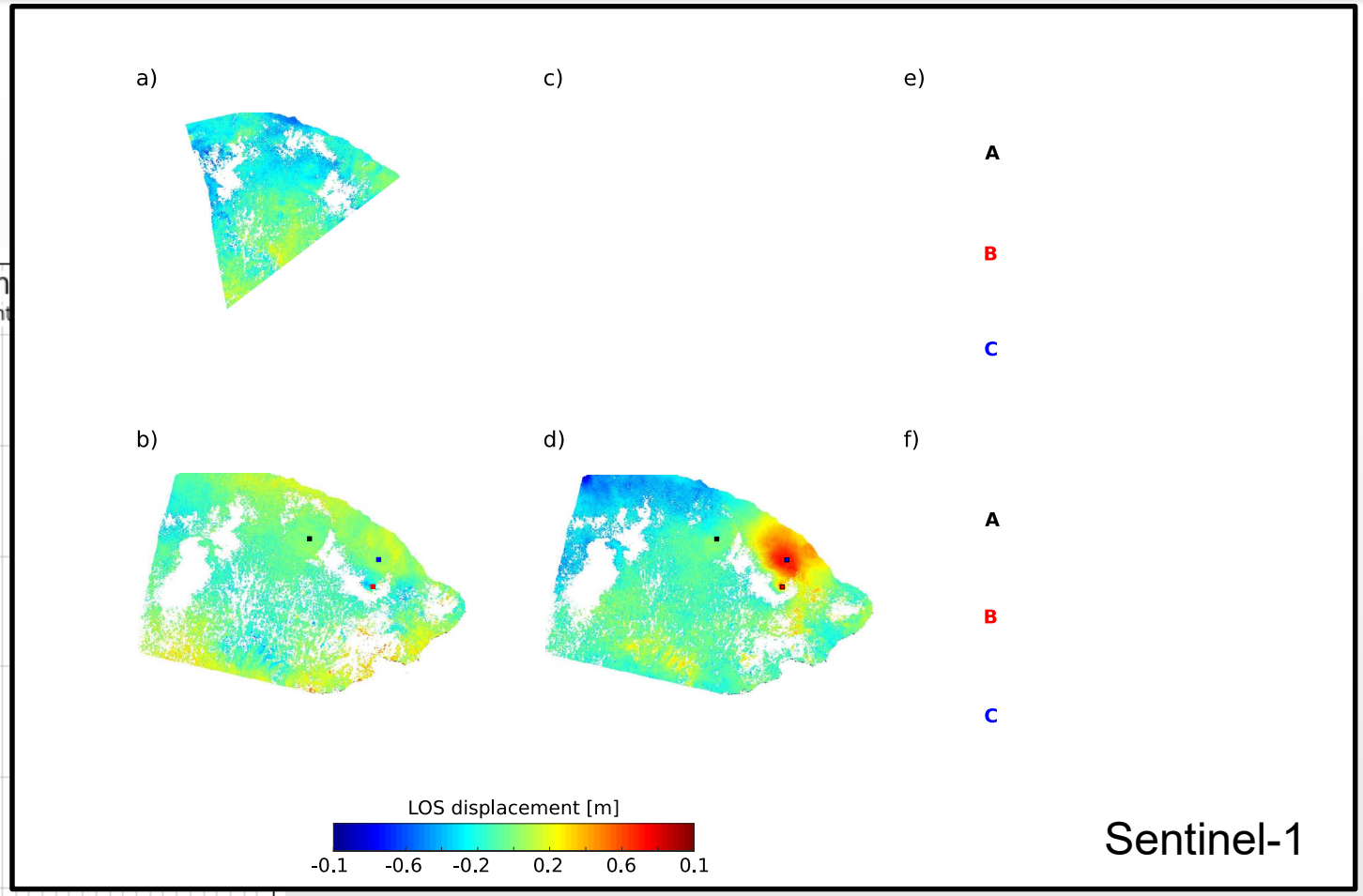
QUIESCENT, RESTLESS, ERUPTING: Agung, Bali



- Erupted in 1963–64, caused 2000 deaths and had a major impact on global climate
- Seismic swarm starting in September 2017 resulted in the evacuation of ~100,000 people
- Seismicity waned in October, but elevated levels of earthquake activity persisted
- Phreato-magmatic eruptions began in mid-late November, eruption of lava in the crater in late November with occasional discrete explosions
- Intense socio-political pressure on CVGHM
- No direct access to satellite data

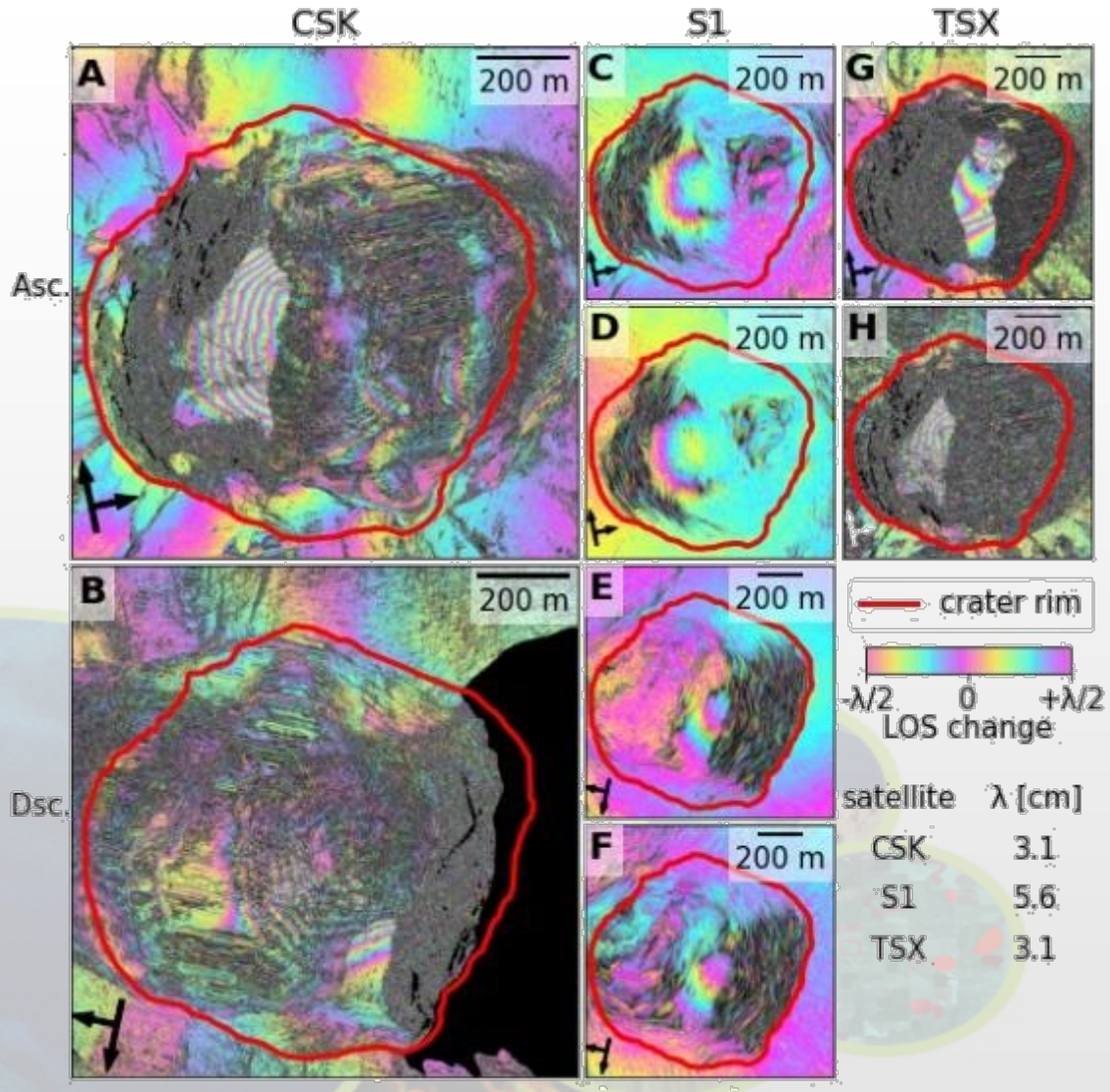
Agung, Bali, 2017: Seismic Crisis

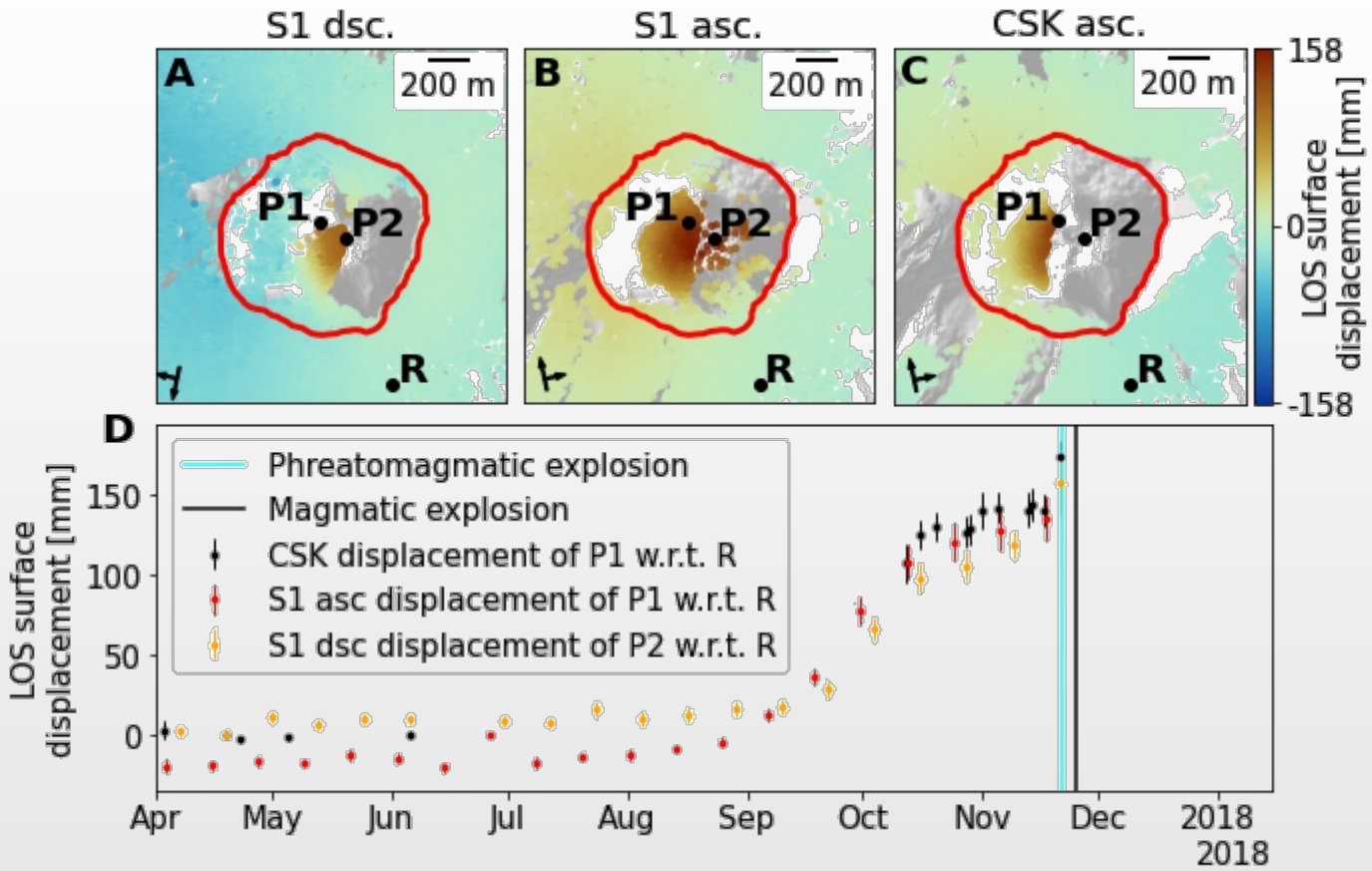




Albino et al. (2019)

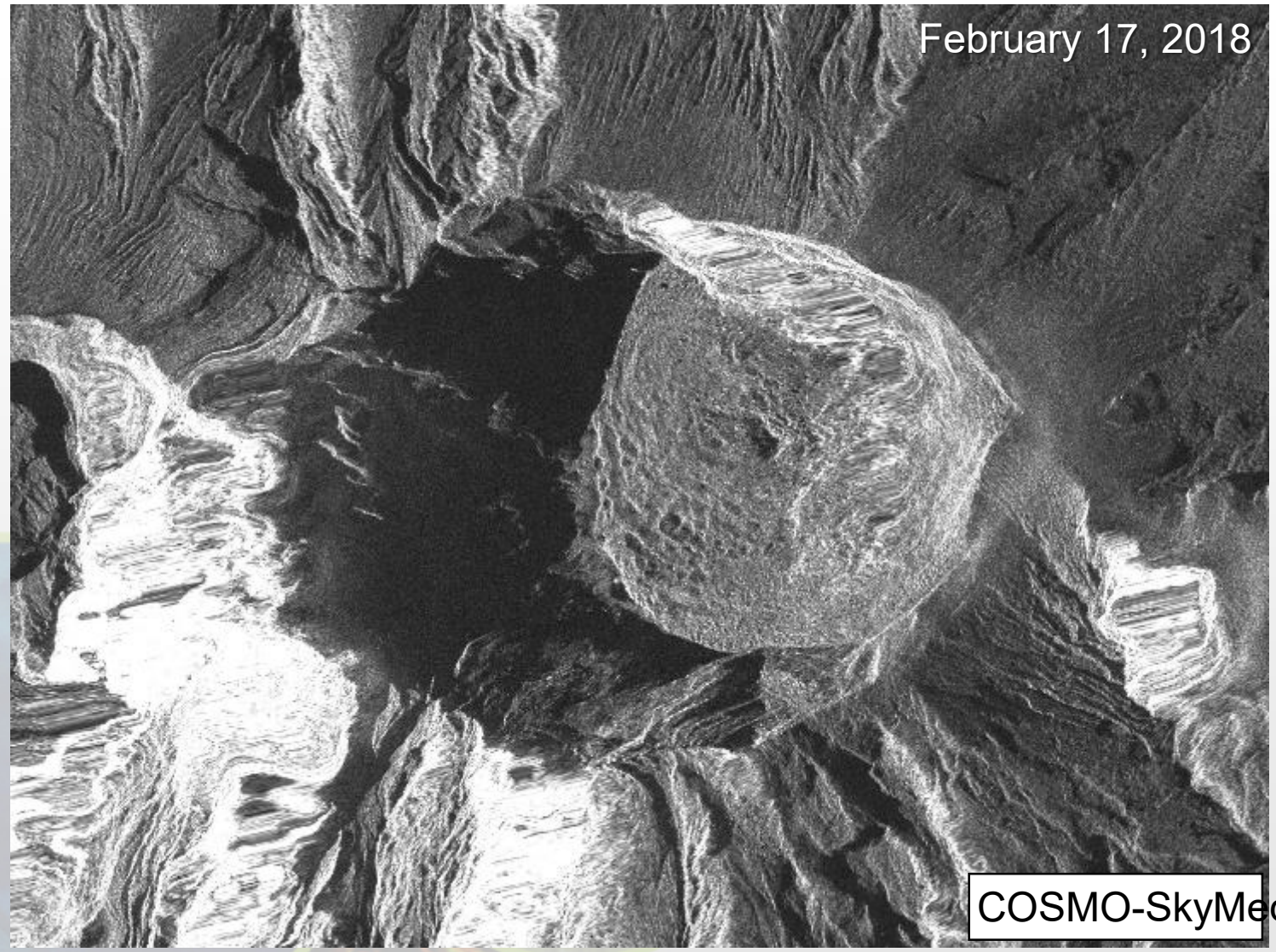
Agung, Bali, 2017: Eruption!

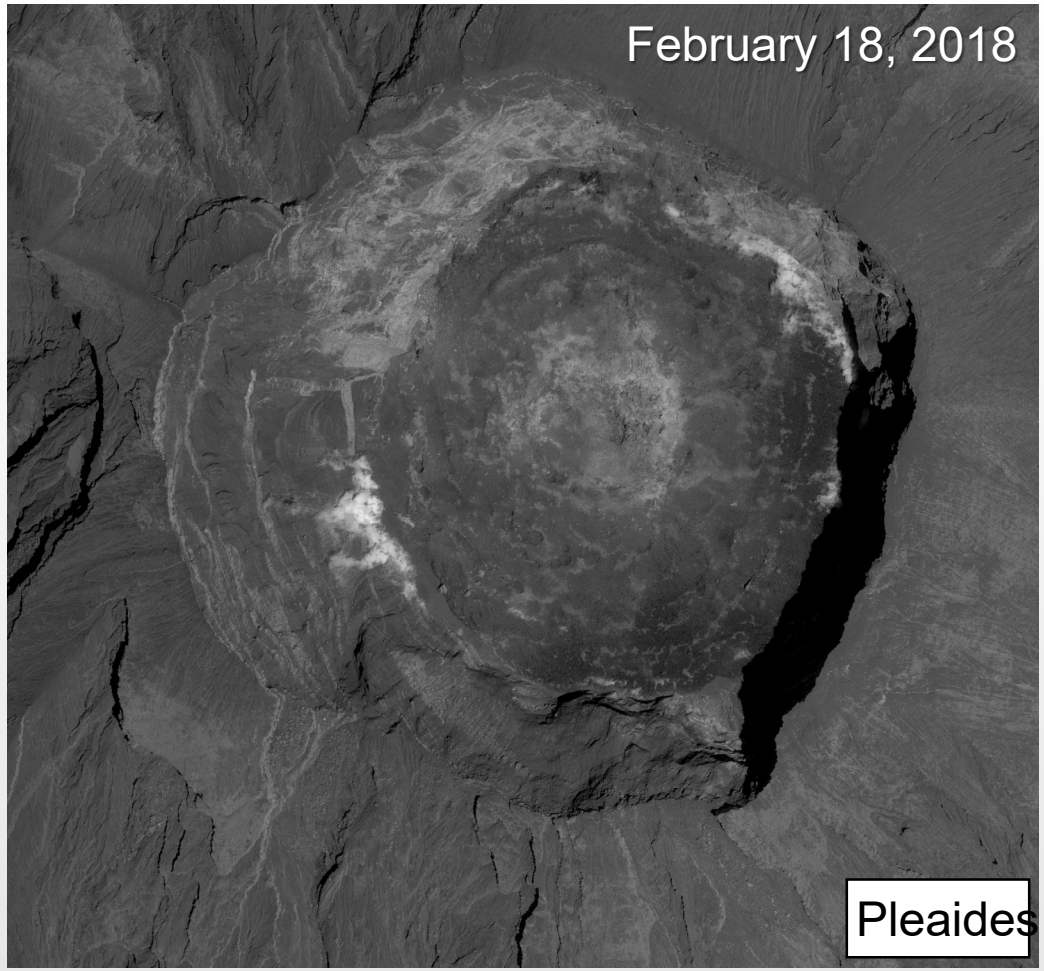




Bemelmans et al. (2023)

Agung, Bali, 2017: Lava flow fills crater



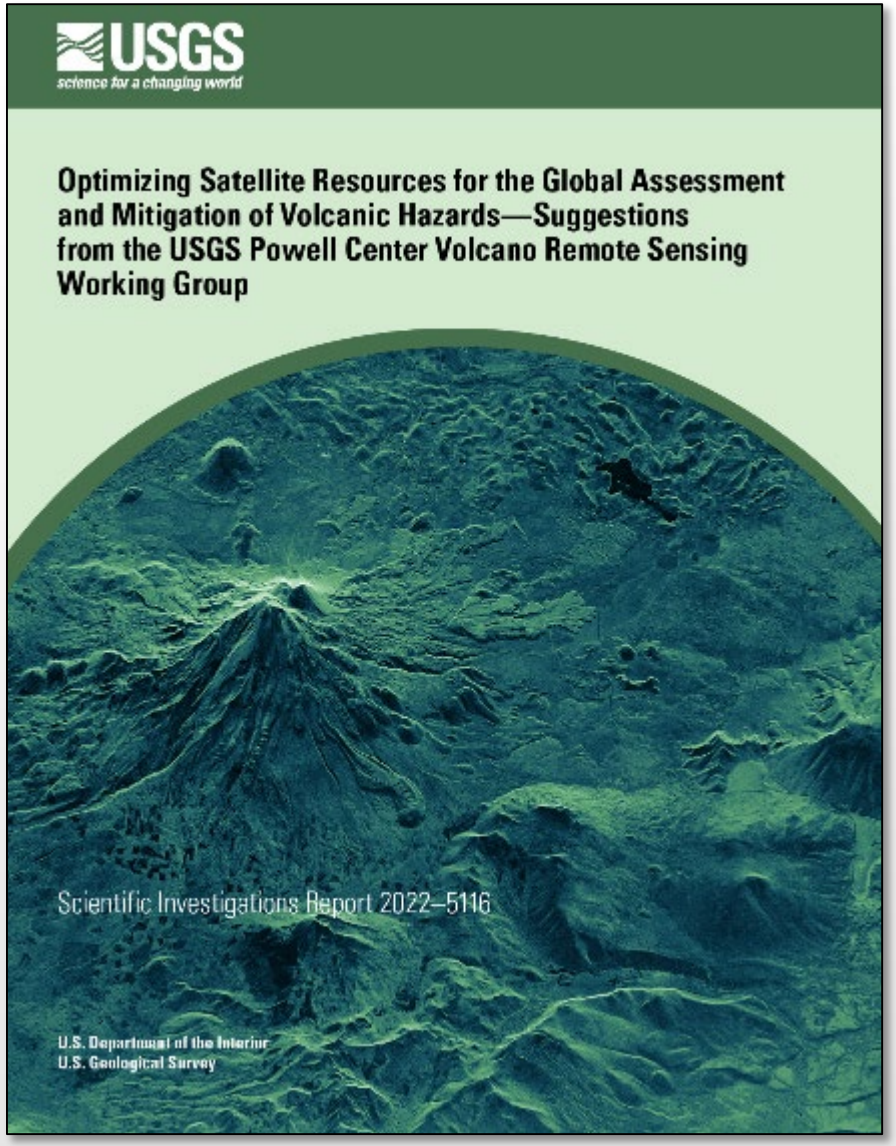


The message…

- These examples demonstrate what we can do if we have access to low-latency SAR and high-resolution optical/multispectral satellite data from volcanoes around the world.
  - Track the awakening of volcanoes currently at “quiescent” levels
  - Track the activity of restless volcanoes, especially as they progress toward eruption
  - Track eruptive activity and identify changes that might lead to hazardous conditions
- “The right data, at the right times, from the right places.”
- Most of the cases mentioned previously were detected after the fact. If someone were tracking these cases in real time, satellite data alone could have first detected, or potentially forecast these sorts of changes.

We are beginning to achieve our goals!

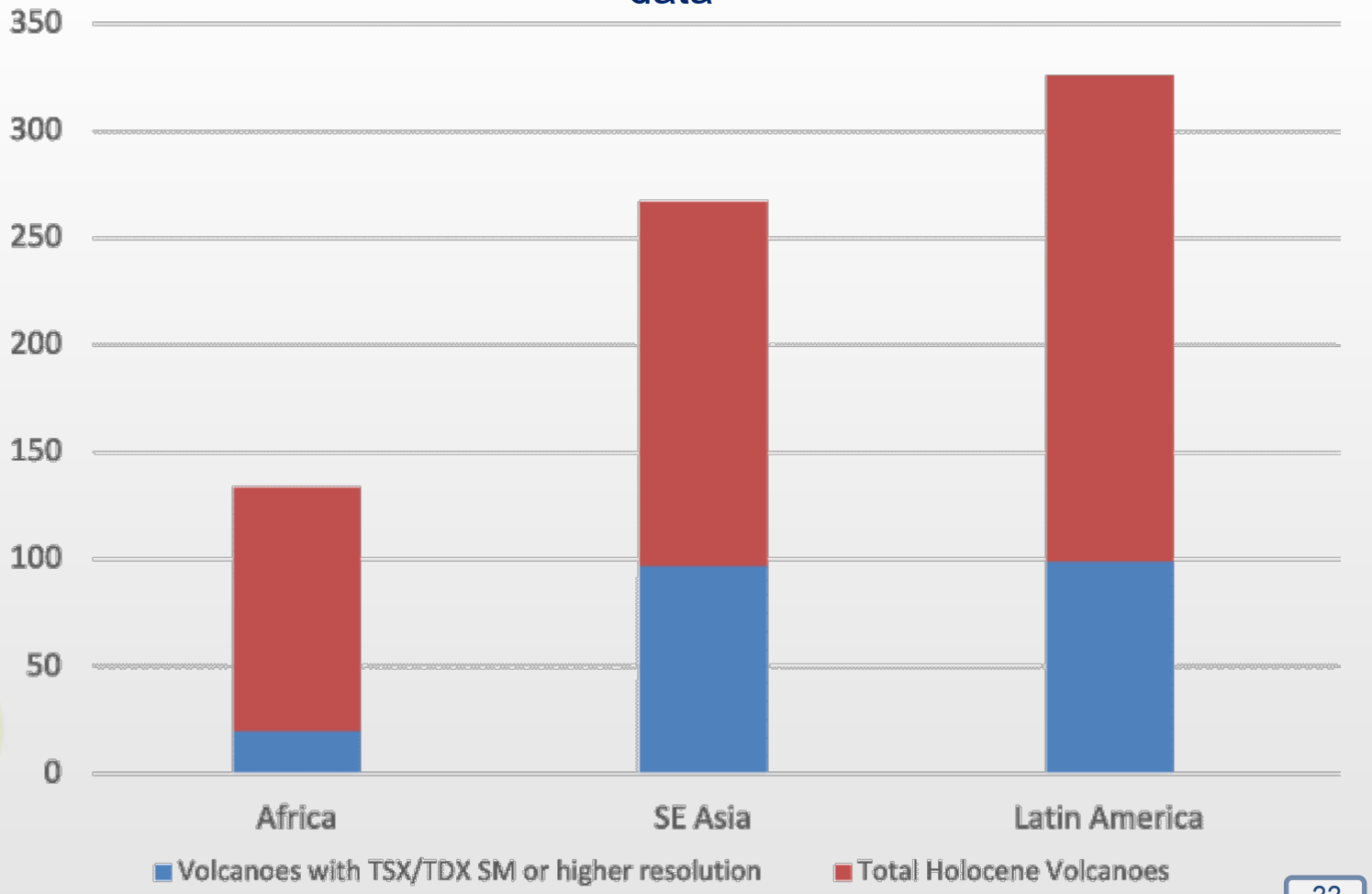
- Incredible uptake of data by observatories in developing countries
  - Peru
  - Ecuador
  - Colombia
- Developing a global partnership to coordinate communication, satellite tasking, and crisis response
- Rapid responses to societally important eruptions
  - Taal, Philippines
  - Soufriere, St. Vincent
  - Nyiragongo, Democratic Republic of the Congo
- Established a basis for coordination and collaboration
- ESA is using PowellVolc classification to prioritize Sentinel-1a tasking since the failure of Sentinel-1b



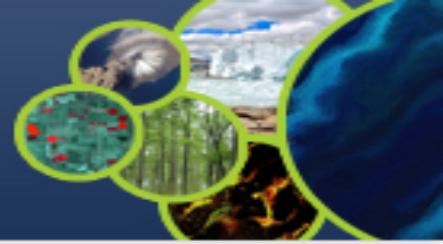
How are we doing so far?

- **Global background monitoring achieved for Sentinel SAR (and thermal and degassing) but not other SAR missions**
- **Weekly observations at restless volcanoes—68–85% achieved for SAR**
- **Daily observations at erupting volcanoes—10% achieved with SAR**

Number of potentially active CEOS Volcano Demonstrator Volcanoes with/without high spatial resolutions TSX/TDX/PAZ data



Proposal: International Virtual Volcano Observatory



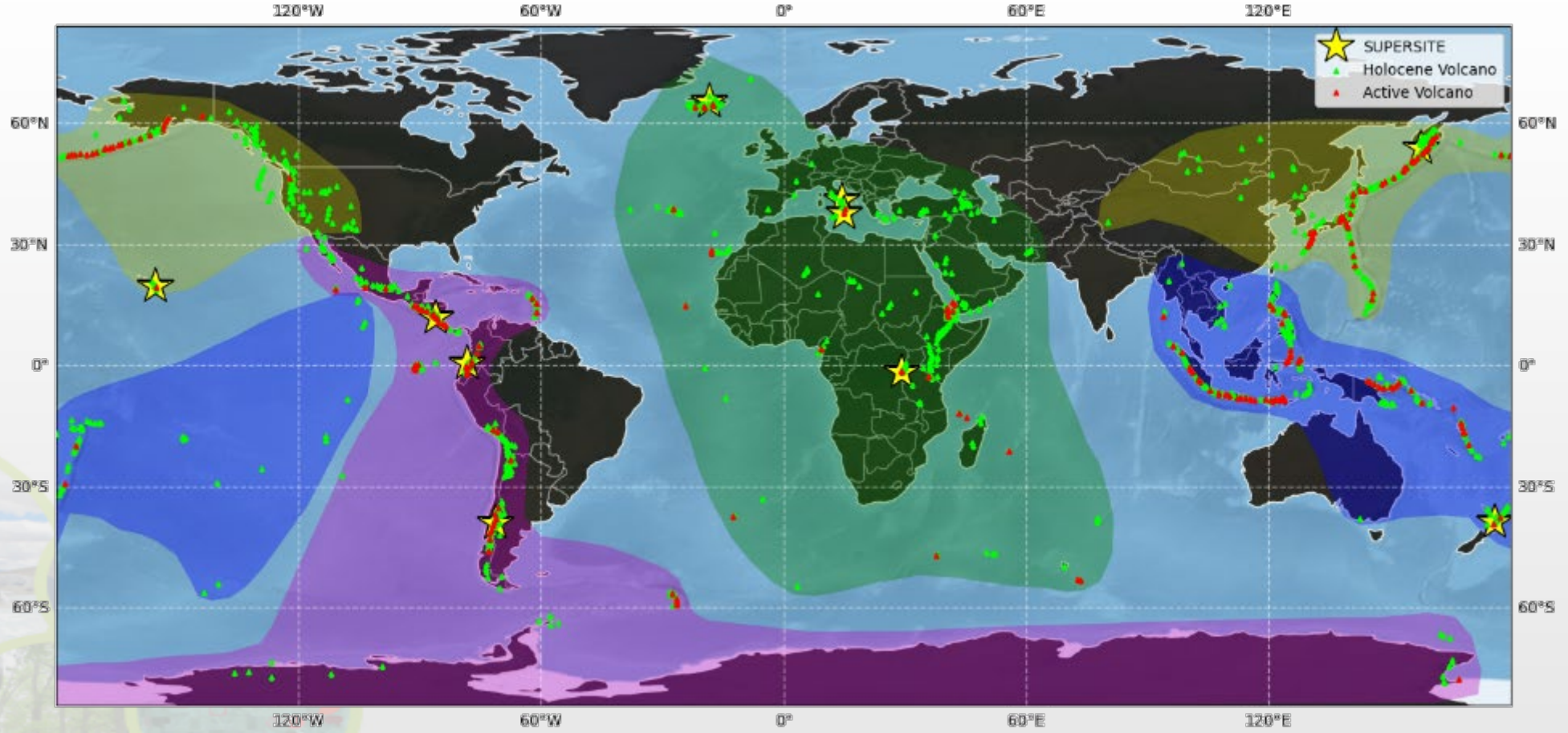
Q: How do we achieve the goals of the Santorini Report and the global volcano community to better monitor volcanoes and mitigate their hazards?

A: Create a permanent International Virtual Volcano Observatory (IVVO)!

- IVVO is the natural evolution of the CEOS Volcano Pilot/Demonstrator
- Permanent virtual facility for remote volcano monitoring
- Biennial renewable quotas (akin to Supersites)
- Supported by USGS, which will aid with global coordination
- Made possible by best-effort contributions from academic institutions, volcano observatories, and space agencies
- Leverage local capacity for monitoring and support local needs

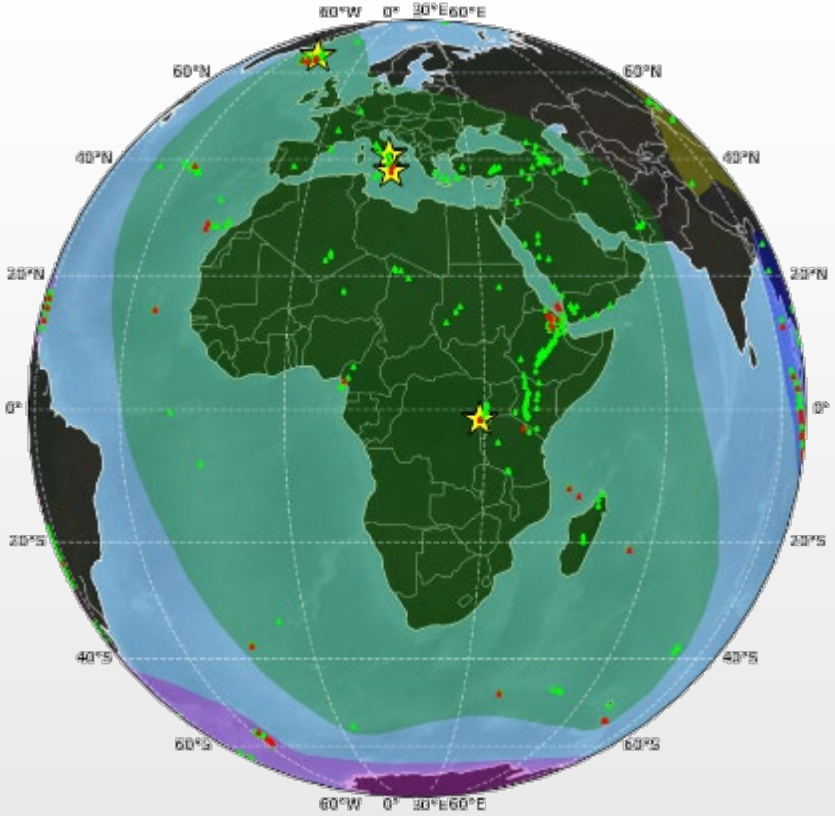
IVVO: Volcano Regions

1. Latin America, Caribbean, and Antarctica
2. Southeast Asia and South Pacific
3. Europe, Africa, and Middle East
4. North Pacific and East Asia



IVVO: Objectives and Strategy

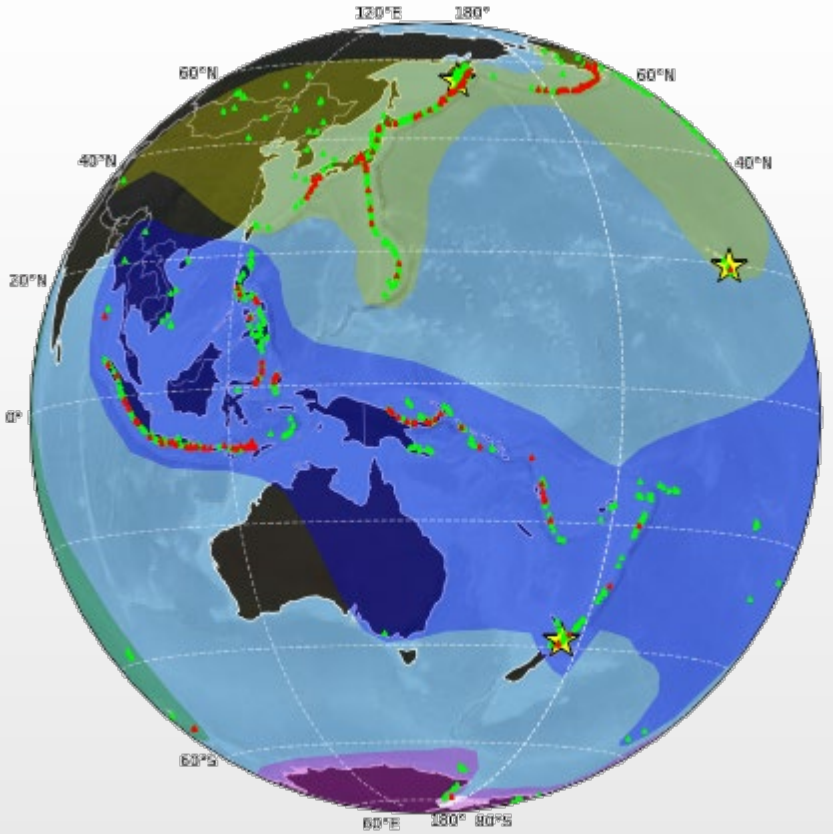
- Primary Objective: Global Volcano Observation
  - SAR
  - High-resolution optical and multispectral
- Timely response to hazardous volcanic eruptions (dozens per year, daily monitoring needed)
- Tracking of restless volcanoes (~200 per year, weekly monitoring needed)
- Background monitoring of quiescent volcanoes (~1400, quarterly to every few years needed)
  - Powell Center classification is a guide
  - Exploit vast existing archives of data
- Introduce strategy for prioritization of global volcano observation (Fagradalsfjall vs. Bagana)



Europe, Africa, and Middle East region

IVVO: Requested Data Quotas

- 4000 scenes/year each for TSX and CSK (divided evenly between the four regions) for monitoring going forward
  - Daily monitoring of erupting volcanoes; assume 30 VEI2 eruptions per year, averaging 75 days each is 2300 scenes per year
  - Weekly monitoring of 230 restless volcanoes is 6000 scenes per year
  - Background monitoring (quarterly to every few years) of quiescent volcanoes is 300 scenes per year
- TDX access for DEM generation
- 1000 scenes/year for SAOCOM (divided evenly)
- 1000 scenes/year for RSAT2/RCM (divided evenly)
- Archive SAR scenes as needed (hundreds per year)
- 20,000 km^2/year for Pleiades
- Access to SPOT6–7



Southeast Asia and South Pacific region

IVVO: Partners

IVVO is a partnership

- Data providers
- Academic institutions
- Volcano Observatories

Cornell University Founded A.D. 1865

esa European Space Agency

cnes

University of Bristol

USGS science for a changing world

Department of Science and Technology PHIVOLCS Philippine Institute of Volcanology and Seismology

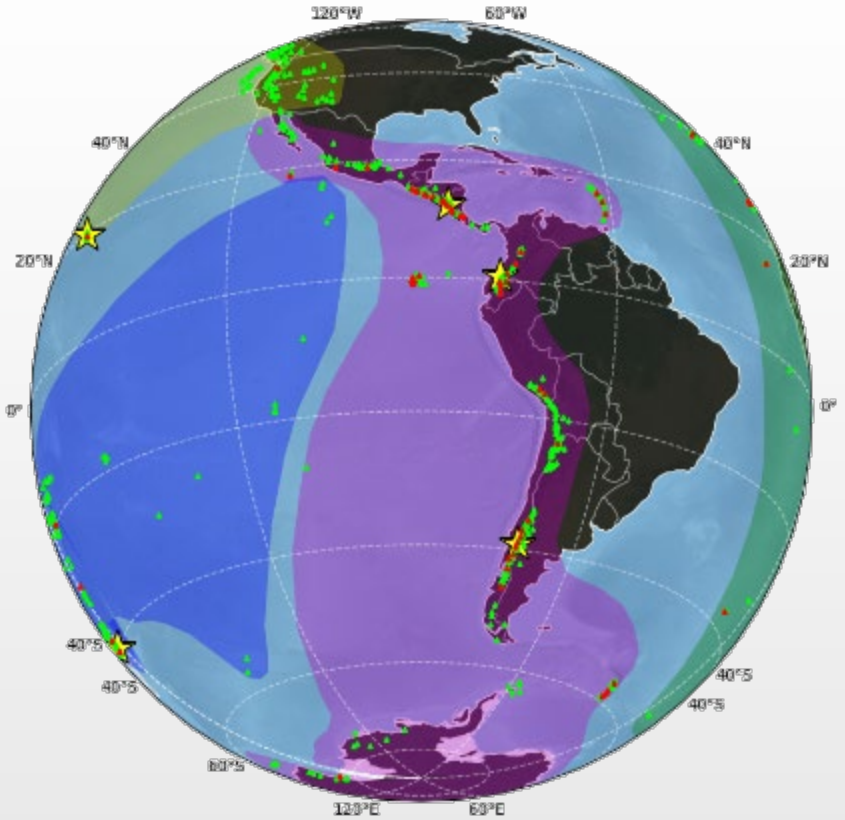
CONAE

asi agenzia spaziale italiana

NASA

IVVO: Deliverables

- Two-year cycles, akin to the Supersites
- Reports from each of the 4 global zones with showcases on responses to active eruptions
- Presentations at academic conferences
- Publications in academic journals
- Capacity building projects
  - Site visits
  - Workshops at international meetings



Latin America and Caribbean region

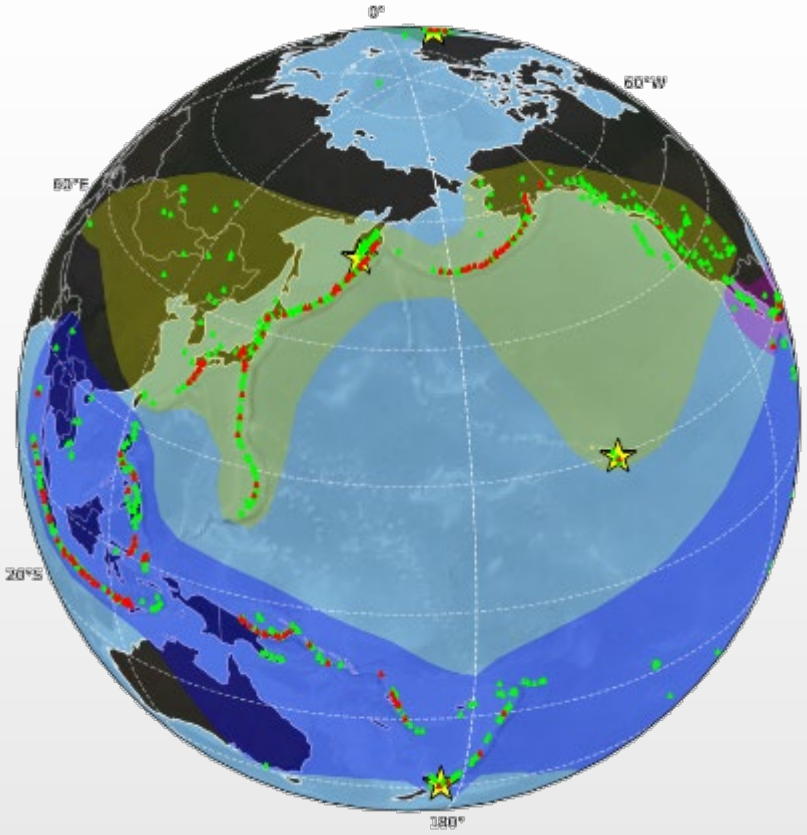
IVVO: Outcomes

- Showcase how CEOS data can be used to enhance public safety around the world
- Empower local volcano observatories and academic institutions to develop new skills and capabilities
- Create a new community of active users of satellite data
- Serve as a model for hazards assessment and mitigation

Ultimate outcome is a safer global society due to a better understanding of volcanic activity and volcanic hazards

IVVO: Open Questions

- How do the Supersites factor in to this plan?
  - Hawai‘i is largely independent
  - Chile relies on Demonstrator tasking of TSX
- Where will the data be hosted?
  - GEP? HDDS? ASF?
  - Considering an NSF proposal for funding to go to Earthscope for rejuvenating their SAR archive
  - All users must sign space agency license agreements
- How will NISAR impact the project?
  - First two years will explore how NISAR will be useful
  - Subsequent years will integrate NISAR with other data
- Any potential for commercial SAR?



North Pacific and East Asia region