Volcano Demonstrator Update Sept 2019

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Yosuke Aoki, Ian Hamling

UNIVERSITY OF LEEDS

COMET
Centre for the Observation and Modelling of Earthquakes, Volcanoes & Tectonics

CEOS

Powell Volcano Working Group

USGS Powell Center for Analysis & Synthesis

Powell Center

USGS science for a changing world

NERC SCIENCE OF THE ENVIRONMENT

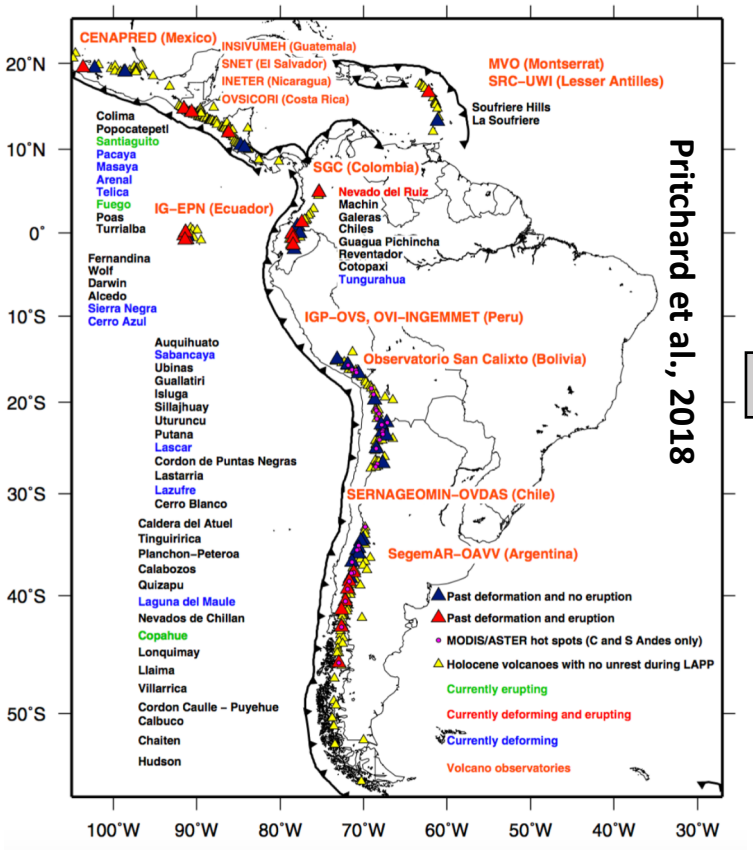
University of BRISTOL

General Aims

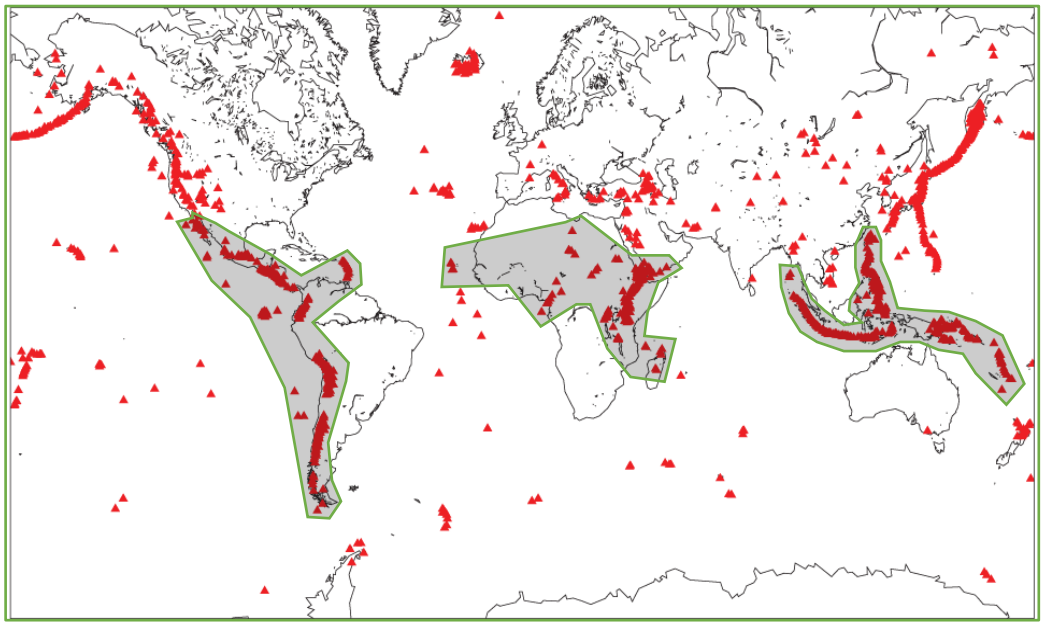
1. Expand use of satellite remote sensing for volcano monitoring
2. Research link between volcanic unrest and eruption from satellite observables
3. International coordination of satellite tasking to maximise its usefulness to volcano observatories
4. Supporting capacity building initiatives to increase the uptake of satellite imagery

Focus on use of diverse wavelengths - supplementing C-band with X and L.

Pilot (2014-2017)



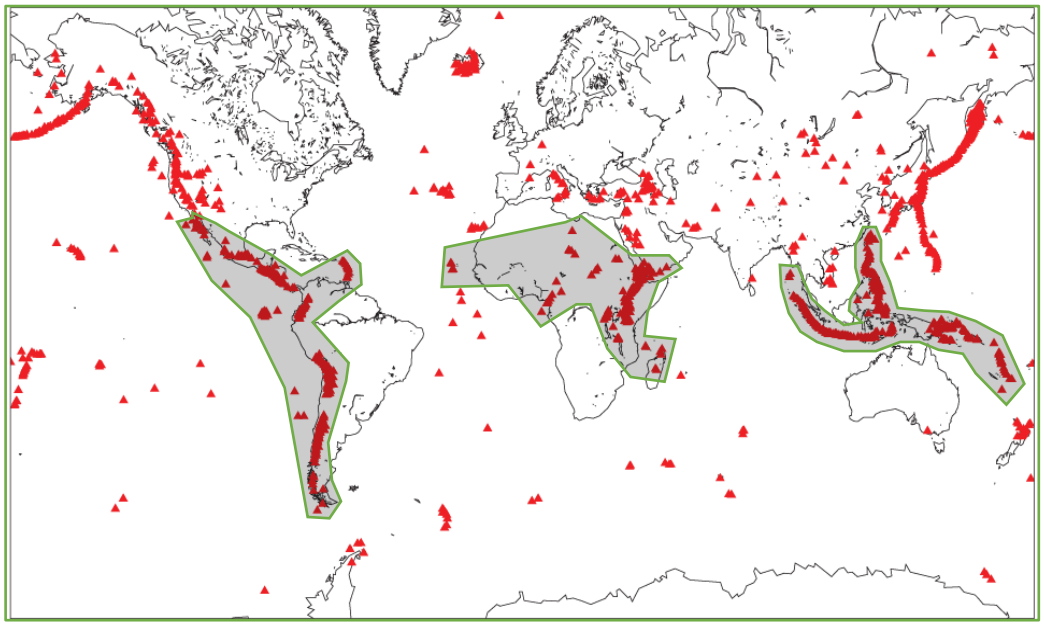
Demonstrator (2019 -)



1. Progress since March 2019 2. Powell Centre Results. 3. Future Plans.

Demonstrator (2019 -)

- Extension of project to African and SE Asian volcanoes
- Fill gaps in current monitoring
- Long term goal: to demonstrate the necessity and viability of international coordination of satellite tasking for volcano monitoring (after polar science community)



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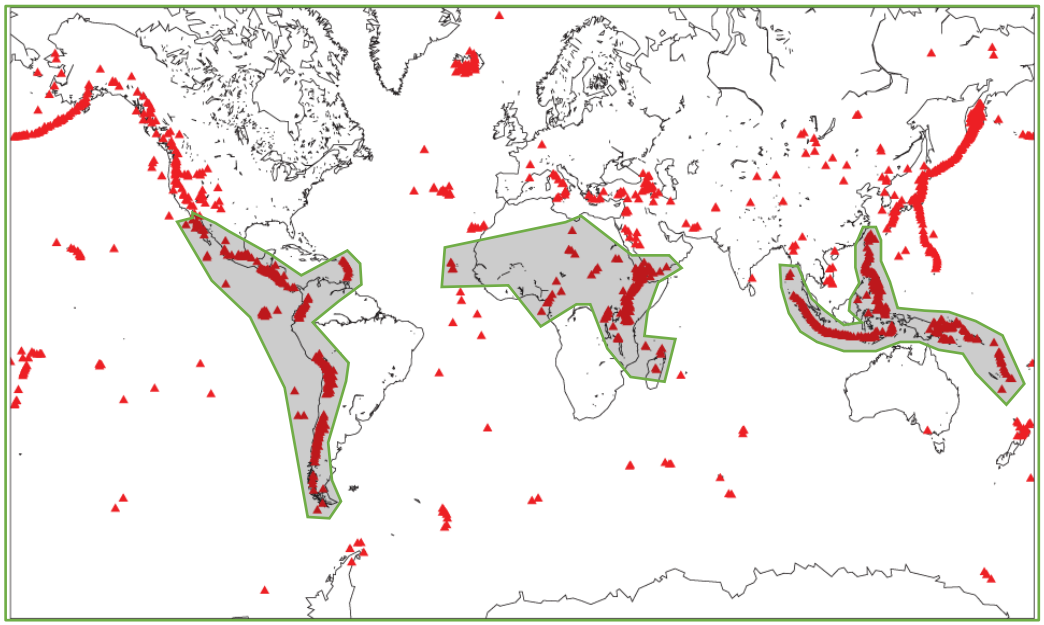
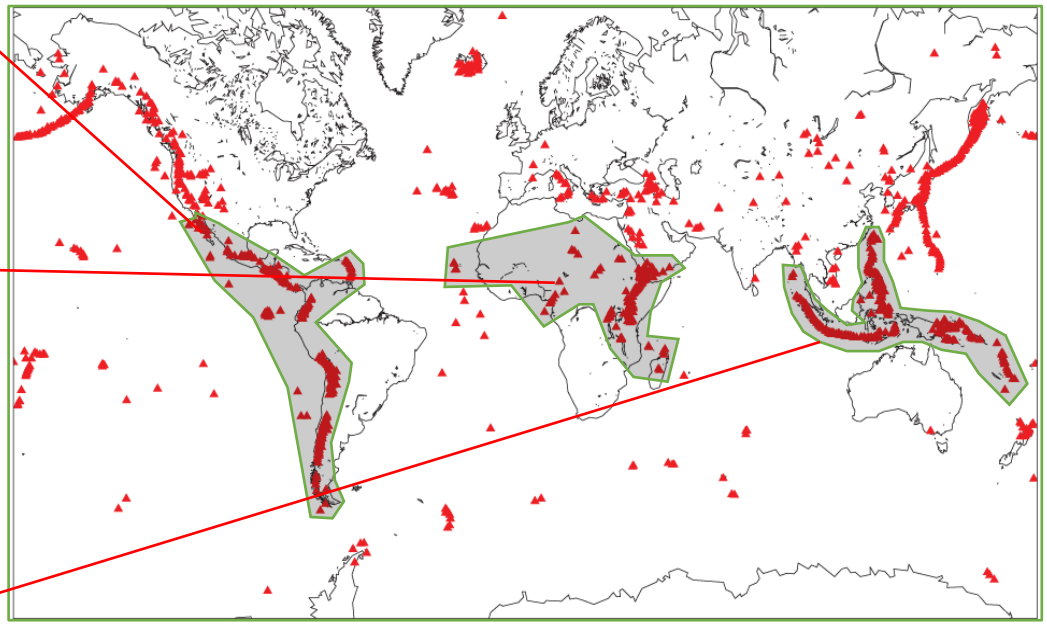


Demonstrator (2019 -)

Latin America:
Matt Pritchard
Cornell University

Africa:
Juliet Biggs
University of Bristol

SE Asia:
Yosuke Aoki
University of Tokyo
Ian Hamling
GNS New Zealand

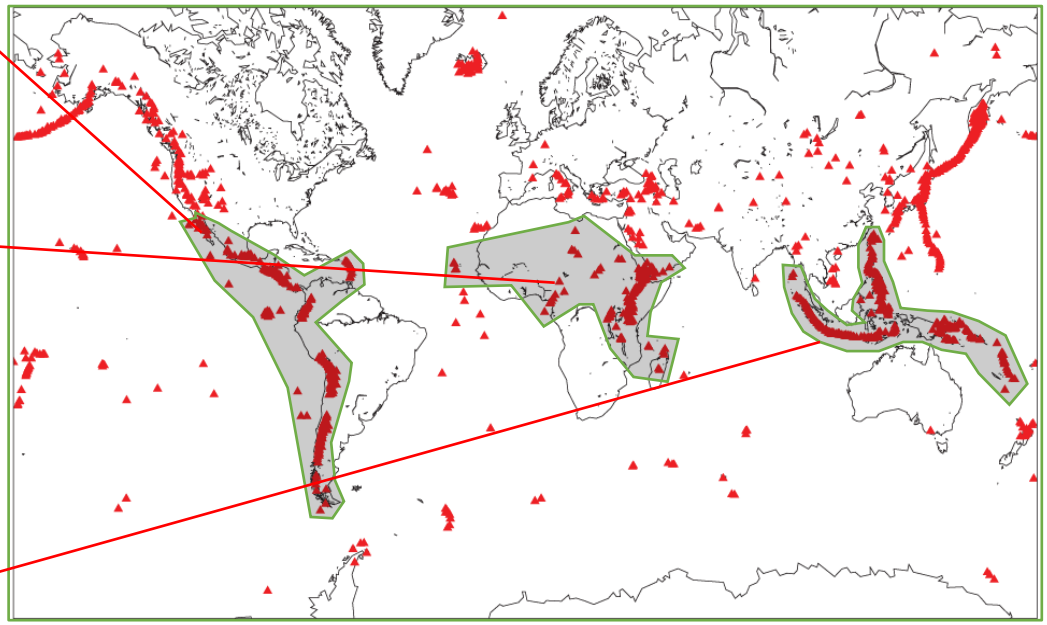


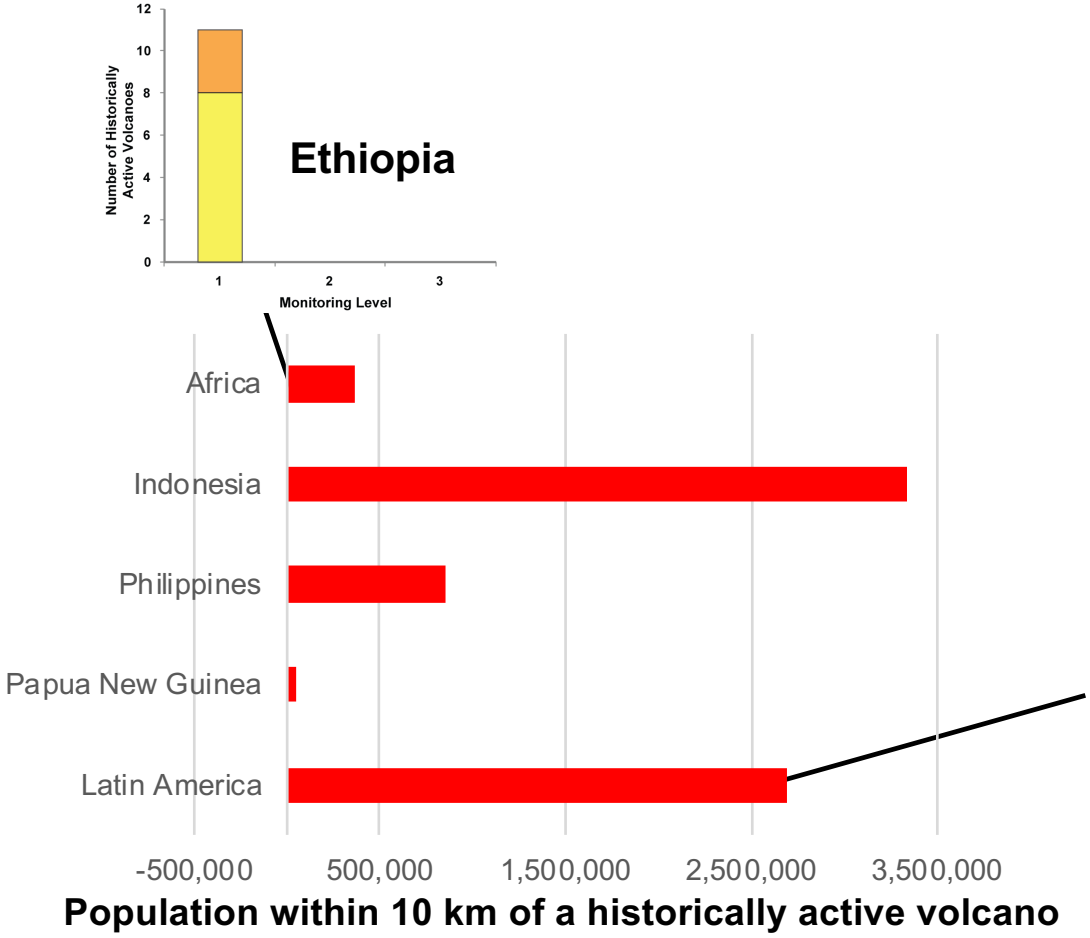
Demonstrator (2019 -)

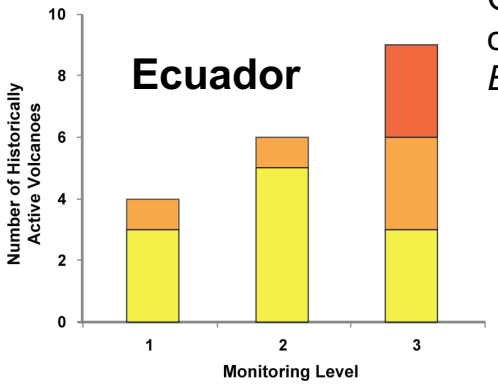
Latin America:
- 13 volcano observatories
- International collaborators for pilot in USA, UK, Italy

Africa
- 4 volcano observatories, most volcanoes unmonitored
- Major associated research projects in East Rift in UK, Belgium, France

SE Asia
- In Indonesia >3.2 million people live with 10 km of an active volcano (more than in the whole of Latin America in that regard)
- Important observatory partners likely to be PHIVOLCS, CVGHM, RVO
- International collaborators may include colleagues in Japan, New Zealand, Australia, Singapore







United Nations Global Assessment of Risk Report
Brown et al., 2015

2019 progress and outcomes

- Implementation plan submitted to Working Group in June 2019
- First data orders in for Latin America and SE Asia (Fuego, Uluwan & others)
- Regional leads in place (and initial discussions regarding SE Asia in Tokyo, August 2019, and Leeds, October 2019)
- Emails to scientific and volcano observatory community to promote engagement
- Teleconferences to define strategy for data ordering are in progress

Monitoring, data orders and strategy

- Quota for this year has been under-used, especially for the new regions

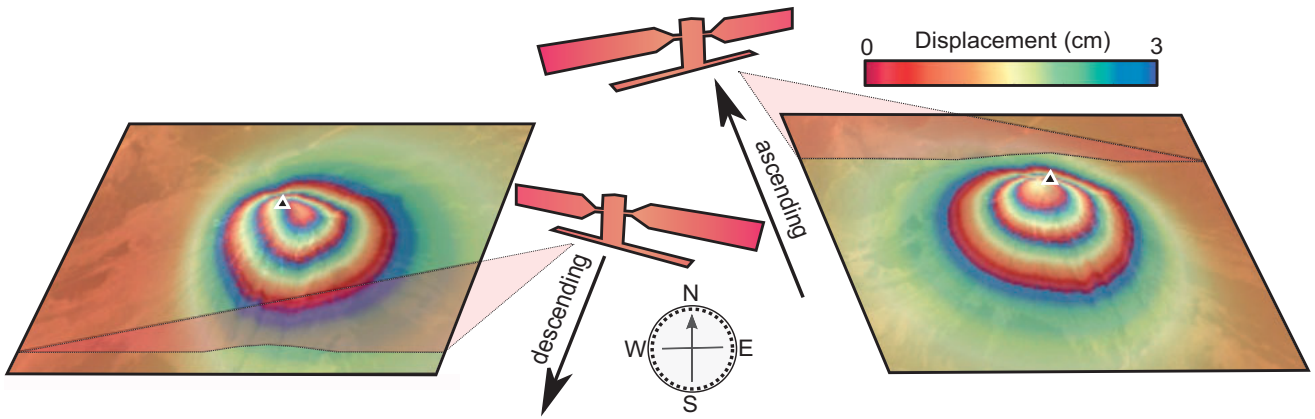
- Introductory emails to past collaborators and potential interested parties have been sent, with positive responses, but teleconference has been delayed until after Iceland CEOS meeting

- Sentinel-1 processing is increasingly automated by multiple projects (see later slides), so focus of CEOS should be on the benefits brought by multiple wavelengths.

- Why focus on SAR/InSAR?

50% of InSAR detections relate to pre-eruptive unrest, and deformation provides fundamental information about magma storage conditions (Ebmeier et al., 2018).

Deformation is more likely to precede eruption than detected degassing or thermal alerts, which are more likely to occur during eruption (Furtney et al., 2018)



- The importance of diversity of wavelength and resolution for volcano monitoring

A constellation approach to monitoring was found to be most successful for monitoring volcanoes in Latin America (Pritchard et al., 2018).

Sentinel-1 is now the 'workhorse' for volcano monitoring, and the first port of call for most scientists and volcano observatories

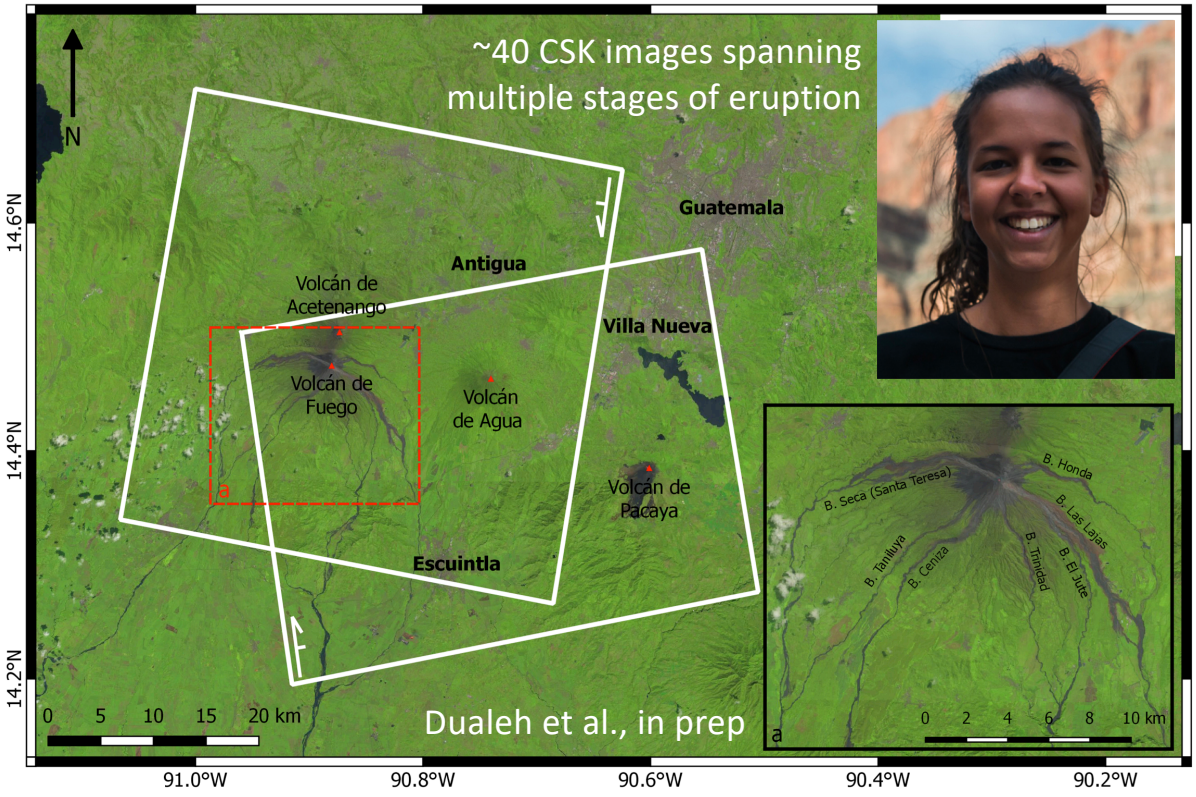
-> Our priorities should be to demonstrate the advantage of multiple instruments with different strengths available through CEOS

-> To do what we can to make X-band imagery as useful as possible in a volcanic crisis, e.g., describe background displacement, degassing etc. process/order 'pre-event' images

2018 eruption of Fuego, Guatemala

Application of radar backscatter to detect fresh deposits and quantify co- and post-eruptive changes

Edna Dualeh, PhD researcher, Leeds



Fresh pyroclastic flow deposits altered by successive lahars (volcanic mud flows)

• backscatter analysis requires high quality geometric corrections and understanding of pre-flow topography

- **but**, not limited by phase decorrelation like displacement measurement

• Contact with INSIVUMEH volcano observatory through colleagues with established relationship (Matt Watson, Bristol)

esa
European Space Agency

Fresh pyroclastic flow deposits altered by successive lahars (volcanic mud flows)

• backscatter analysis requires high quality geometric corrections and understanding of pre-flow topography

- **but**, not limited by phase decorrelation like displacement measurement

TanDEM-X imagery provided through demonstrator

Fabien Albino,
Univeristy of Bristol

University of BRISTOL

Relevance of backscatter studies to CEOS demonstrator:

- ‘Baseline’ CEOS data orders aimed at collecting pre-event images for backscatter analysis at very active volcanoes, especially with long-lasting eruptions. [aim to get these set up by the end of the 2019]

- Important to add in this avenue to capacity building efforts in addition to InSAR-derived displacements.

Capacity Building developments:

• Proposal put together by Matt Pritchard & others accepted for Cities on Volcanoes 11, May 2020. Funded by VDAP, WOVODAT, UK NERC & GLOVOREMID with joint goals of increasing capacity in remote sensing and cataloguing monitoring capacity

- Workshop aims to build understanding of current monitoring capacity from ground and space, and solicit feedback on online tools designed to make satellite imagery accessible
- Supported places for volcano observatory scientists.

Pre-Conference Workshop #4
Workshop on volcano monitoring infrastructure on the ground and in space

Duration: 21-22 May 2020

LEAD CONVENERS:

Juliet Biggs *University of Bristol, UK* | *Juliet.Biggs@bristol.ac.uk*,
Fidel Costa *WOVOdat, Earth Observatory of Singapore* | *fcosta@ntu.edu.sg*
Susana Ebmeier *University of Leeds, UK* | *S.K.Ebmeier@leeds.ac.uk*,
Matt Pritchard *Cornell University, USA* | *pritchard@cornell.edu*

CO-CONVENERS:

Mariano Agusto *ALVO and Universidad de Buenos Aires, Argentina*,
Ben Andrews *Global Volcanism Program, Smithsonian Institution, USA*,
Sarah Brown *University of Bristol, UK*
Simon Carn *Michigan Technological University, USA*
Hugo Delgado *UNAM, Mexico*,
Nico Fournier *WOVO and GNS, New Zealand*,
Eisuke Fujita *National Research Institute for Earth Science & Disaster Prevention, Japan*,
Julie Griswold *Cascades Volcano Observatory, US Geological Survey, USA*,
Gill Jolly *WOVO and GNS, New Zealand*,
Sue Loughlin *British Geological Survey, UK*,
Paul Lundgren *Jet Propulsion Laboratory, California Institute of Technology, USA*,
Chris Newhall *Mirisbiris Garden and Nature Center, Philippines*,
Natalie Ortiz *UNAM, Mexico*,
Giuseppe Puglisi *Istituto Nazionale di Geofisica e Vulcanologia, Italy*
Elise Rumpf *Astrogeology Science Center, US Geological Survey, USA*
Christina Widiwijayanti *WOVOdat, Earth Observatory of Singapore*

Workshop Description:

The goal of this 2-day workshop is to improve the understanding of the current capabilities and limits of volcano monitoring from the ground and space. By the end of the workshop, participants will contribute to the development of a Global Volcano Monitoring Infrastructure Database (GVMID) to be hosted at WOVOdat, and develop a roadmap to improve the utility of satellite data. We also hope to open more channels of communication among volcano observatories, space agencies, and the remote sensing/database community. We anticipate future workshops will be needed to further advance these goals.

On one day, we will discuss the motivations for the GVMID and the potential benefits of an infrastructure database for volcano observatories. A database of current infrastructure will provide a snapshot/baseline view of what techniques/instrumentation are in place at other similar/analogous volcanoes, which can help justify expanded networks by volcano observatories. These data will allow identification of what gaps exist that can be targeted by remote sensing and/or targeted deployments. In addition, we will discuss existing volcano-monitoring databases (e.g. GLOVOREMID, EPOS, VMID, INeVRH, and WOVOdat) and how we can improve or build upon those efforts.

On the other day, we will discuss the roles played by satellite systems in augmenting ground-based networks. Through presentations by participants, demonstrations of open-source resources, and case-studies of recent crises, we will address the following questions: 1) What satellite data are currently available? 2) What is the value of satellite data for volcano observatories and how are the data currently being used? 3) What is required to improve data use? One goal is to develop a global remote sensing observation strategy to ensure that the right satellites are collecting the right data at the right volcanoes. The recommendations will be communicated to the space agencies through the Committee on Earth Observing Satellites.

Core connection between the proposed session and societal risk mitigation:

The workshop is focused on improved monitoring of volcanoes from the ground and space. Increased monitoring has been shown to improve hazard forecasts for society (e.g., Winson et al., 2014).

Capacity Building developments:

- Early stage discussions about IAVCEI remote sensing workshop (New Zealand, 2021).
- 'Tomorrow's Cities' funded PhD student from IG-EPN Ecuador to start at Leeds January 2020
- Collaborative visits and development of web tools through NERC Innovation Fund (aim is to test these at COV workshop)

Powell Volcano Working Group

USGS Powell Center for Analysis & Synthesis

USGS science for a changing world

Lead by Matt Pritchard and Mike Poland

Upcoming publication: USGS Scientific Investigations Report: Powell Center Volcano Remote Sensing. This will be circulated to CEOS WG Disasters when it is finalised.

"Optimizing satellite resources for the global assessment and mitigation of volcanic hazards: Recommendations from the USGS Powell Center Volcano Remote Sensing Working Group"

- There is value in combining multiple types of remote sensing
- Remote sensing data complements ground monitoring (even at volcanoes with lots of sensors) but won't replace it
- Remote sensing data are not yet fully exploited

Key points for space agencies (USGS Scientific Investigations Report)

• An international group should **optimize volcano observation strategies from the international constellation** as done by the cryospheric community.

• We need to collect the **correct types of data** (wavelength, repeat interval, spatial resolution) at the right volcanoes. We describe in this report a draft observation plan for ~1414 subaerial volcanoes, based primarily on levels of past activity.

• **Background observations are critical** for producing long time series and global coverage, but not all satellites acquire data at all volcanoes of interest nor are all these data available to the communities that need them.

• **Free access** to **sustainable systematically acquired global datasets** are enhancing the work of volcano observatories and contributing to decisions regarding alert levels. Advances in processing and analysis strategies including automation will increase uptake of the data and should be supported.

Key points for space agencies (USGS Scientific Investigations Report)

• Restricted datasets that provide a **diversity of wavelengths and higher resolutions have been critical** in some instances to save lives during an eruption through evacuation and should be more widely available.

• During volcanic crises, it is important that the acquisition plans are sufficiently **flexible** to accommodate additional tasking and provide information with short latency.

• Increases in the availability and quality of satellite imagery are leading to **important advances in our understanding of volcanic and magmatic processes** and the potential contribution made by satellite imagery to forecasting volcanic hazards.

Class	# volcs	Definition	Recommended Timescale of Observation (SAR)
A1 “Active”	172	eruption since 1990 in populated regions with PEI ≥ 2 (Loughlin et al. 2016), eruptions in all PEI regions in last 5 years (in other words 2014)	weekly
A2 “Active”	55	eruption from 1990, but not in last 5 years (i.e. before 2014) with a PEI of 1-2	monthly to weekly to maintain coherence
B1 “Quiescent”	153	Satellite detected unrest since 1990 without eruption (Furtney and others, 2018; Reath and others, 2019b)	monthly to weekly to maintain coherence
B2 “Quiescent” (Ground-based)	116	Ground or GVP (2013) report of unrest since 1990 without eruption; Seismic swarm database from: White and McCausland (2016). and Phillipson et al. (2013).	monthly to weekly to maintain coherence as needed
C “Inactive”	917	No satellite unrest detections or eruptions since 1990	quarterly

Powell Centre draft observation plan

- This is the background for CEOS Implementation plan!

- Considers (1) how recent the last eruption was (2) Population Exposure Index (PEI), (3) Satellite/Ground detections of unrest

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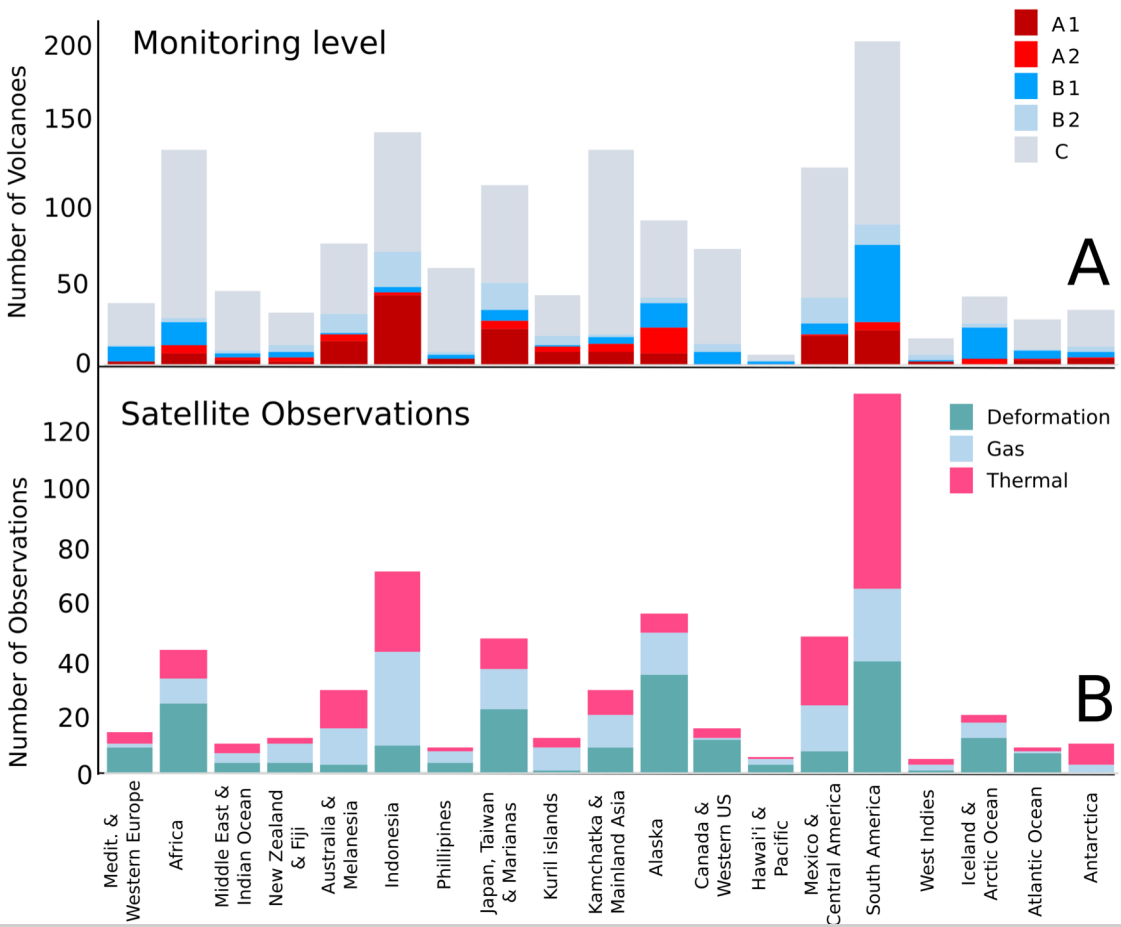

Pritchard et al., in prep

- Regions with more volcanoes generally have more satellite detections – but relationship with most dangerous volcanoes is less clear

- Relationships are less clear for deformation than for degassing and thermal measurements

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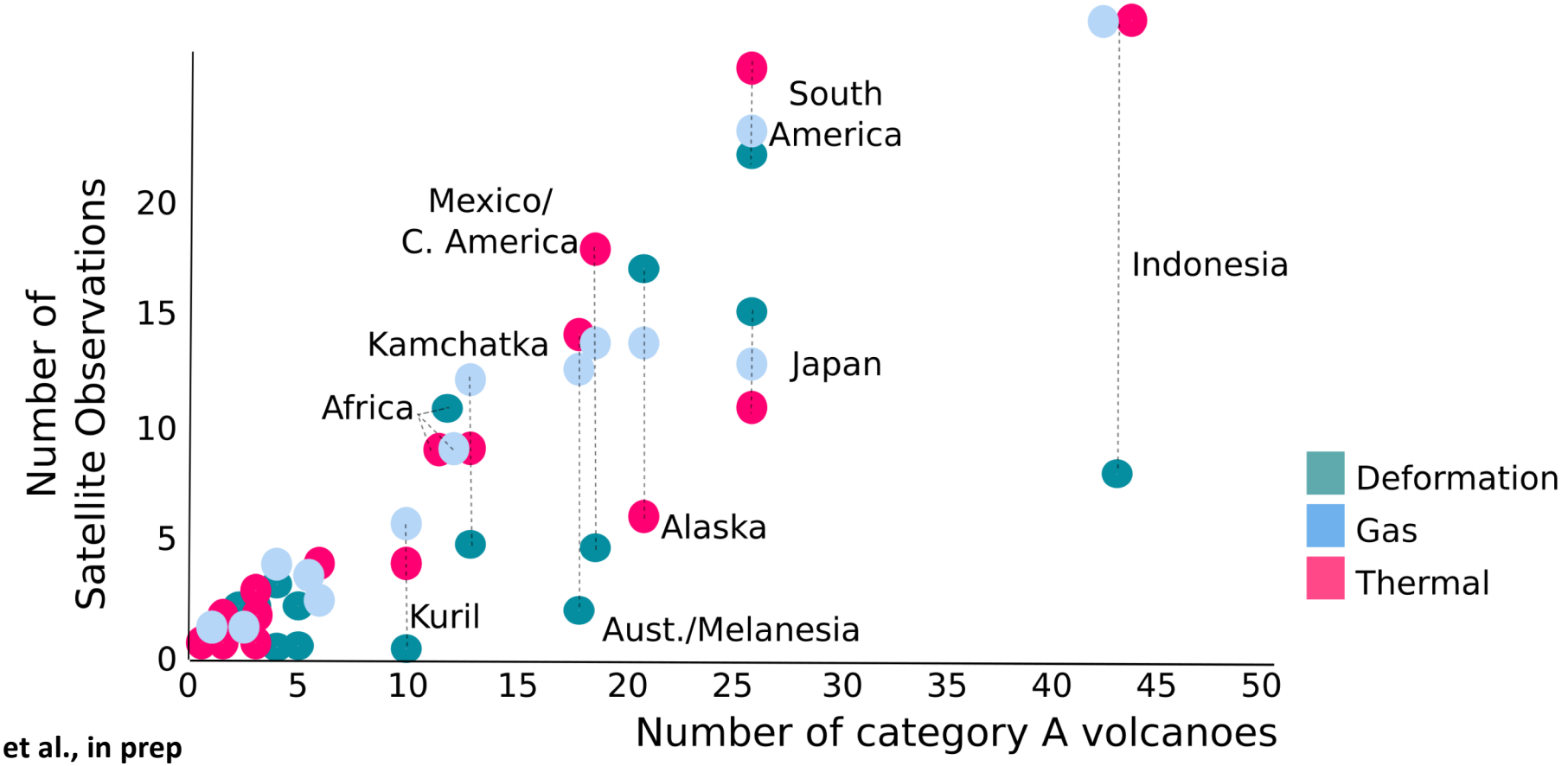

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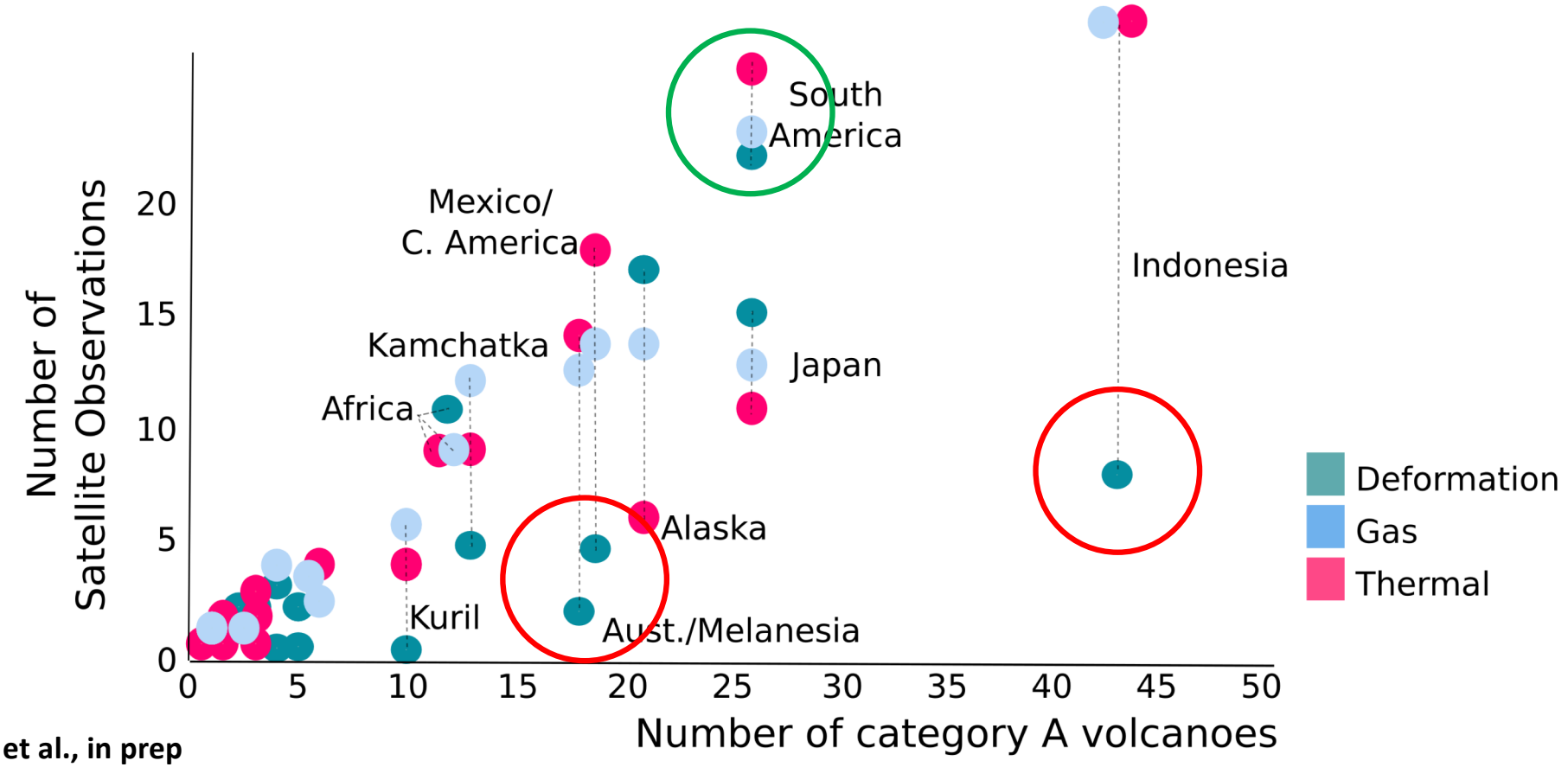

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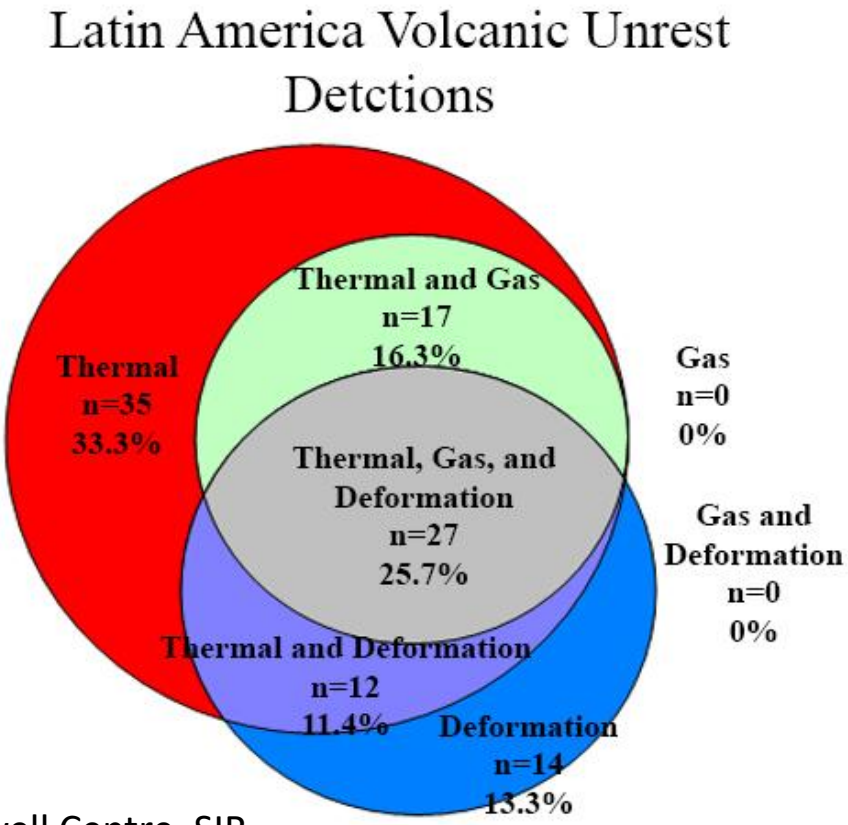
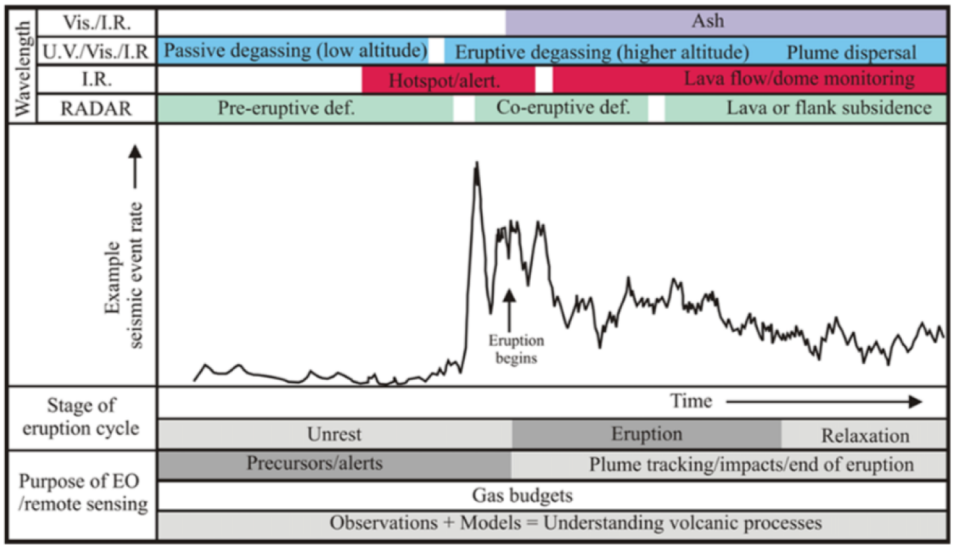


Powell Centre, SIR

Different parameters have different relationships with unrest and eruption (e.g., Furtney et al., 2018) and provide distinct information about volcanic processes.



Pyle et al., 2013

- Comparison of time series satellite observables for 47 most active volcanoes in Latin America

- Classify timeseries as 'open' or 'closed' and find that 28% of volcanoes do not fit this definition, many switched between behaviours over the seven years of observations

Reath et al., 2018

The Sentinel-1 context: automated processing

• projects at JPL (NASA), University of Alaska Fairbanks, COMET and many others

(I've illustrated with COMET example)

Automated processing/analysis

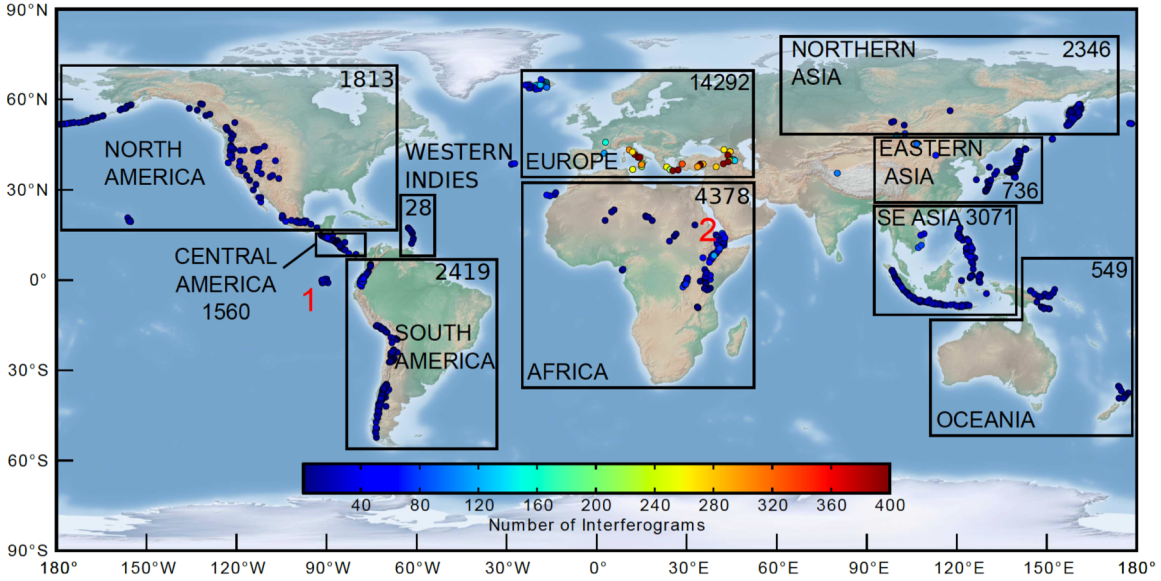
- Handling global data sets
- Near-real-time monitoring

Signal extraction

- Distinguishing between physical mechanisms
- Using redundancy to identify and remove noise
- Automatic alerts for volcanic deformation

Juliet Biggs, Tim Wright, Fabien Albino, Marco Bagnardi, John Elliott, Pablo Gonzalez, Emma Hatton, Andy Hooper, Milan Lazecky, Yu Morishita, Karsten Spaans, Richard Walters, Jonathan Weiss

The LiCSAR-volcano database

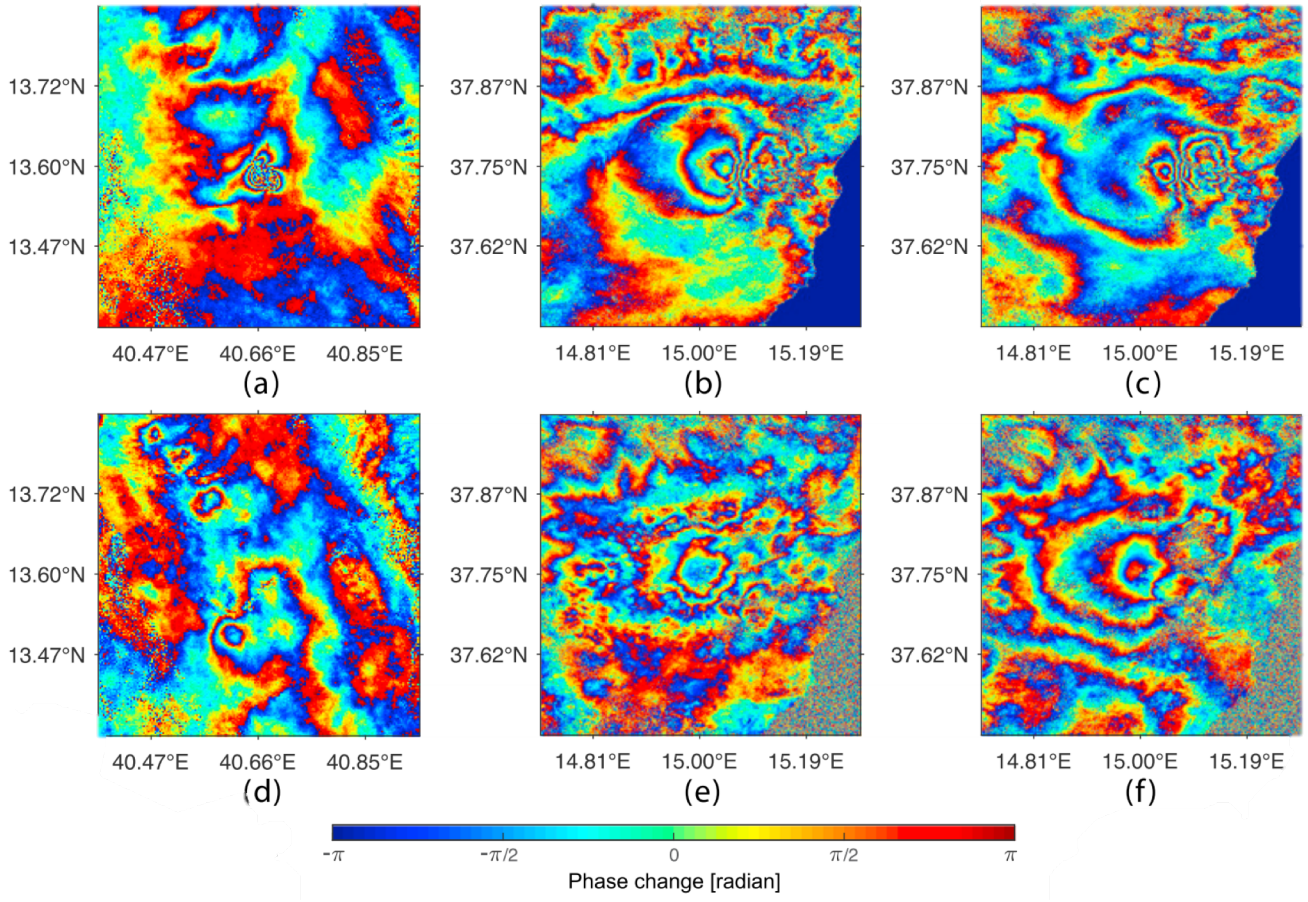


http://comet.nerc.ac.uk/ COMET-LiCS-portal/).

COMET

Centre for the Observation and Modelling of Earthquakes, Volcanoes & Tectonics

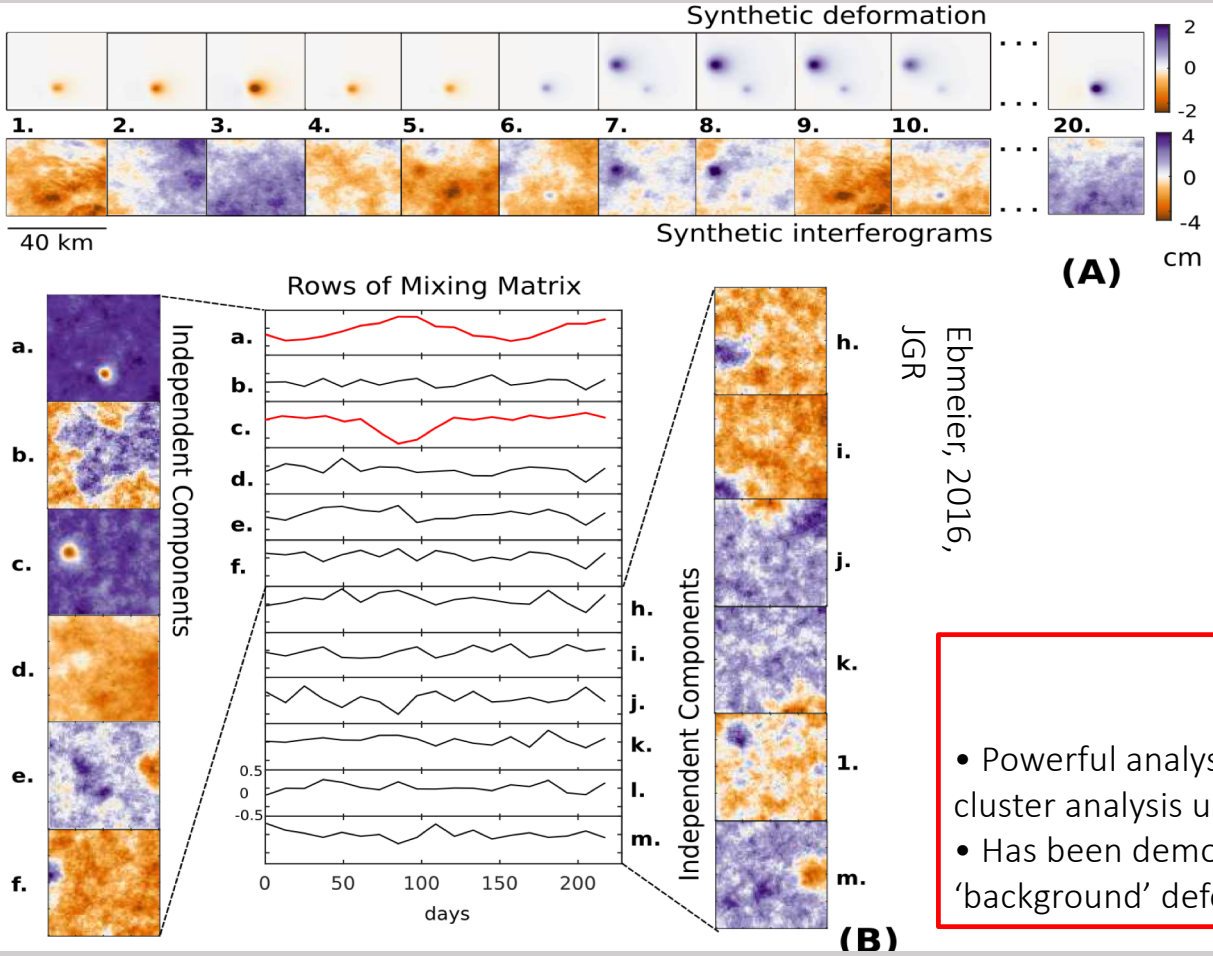
- Test dataset of ~100,000 interferograms at >900 active volcanoes produced by LiCSAR
- Anticipate 1 million images per year when fully operational.



The LiCSAR-volcano database

http://comet.nerc.ac.uk/ COMET-LiCS-portal/).

Volcanic?
Atmosphere?
Unwrapping error?
Background?



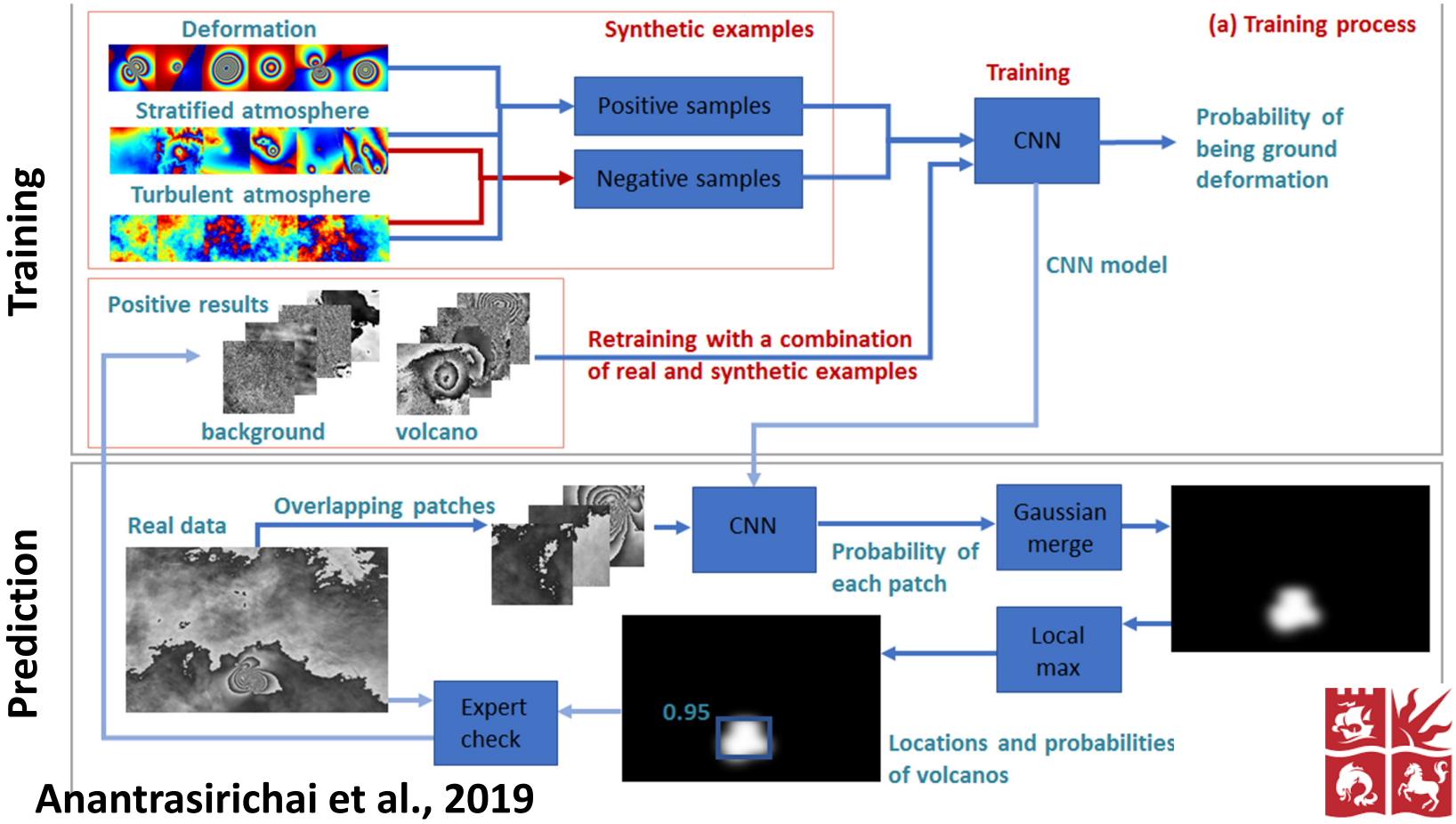
Ebmeier, 2016, JGR

ICA for InSAR Analysis

- Sources that are statistically independent in space are retrieved as separate components
- Volcanic deformation can be separated from atmospheric noise and other geophysical sources

Outlook

- Powerful analysis tool – relies on statistical independence only, cluster analysis used to test significance (Ebmeier et al., 2016)
- Has been demonstrated as a tool for detecting deviation from 'background' deformation (Gaddes et al., 2018)



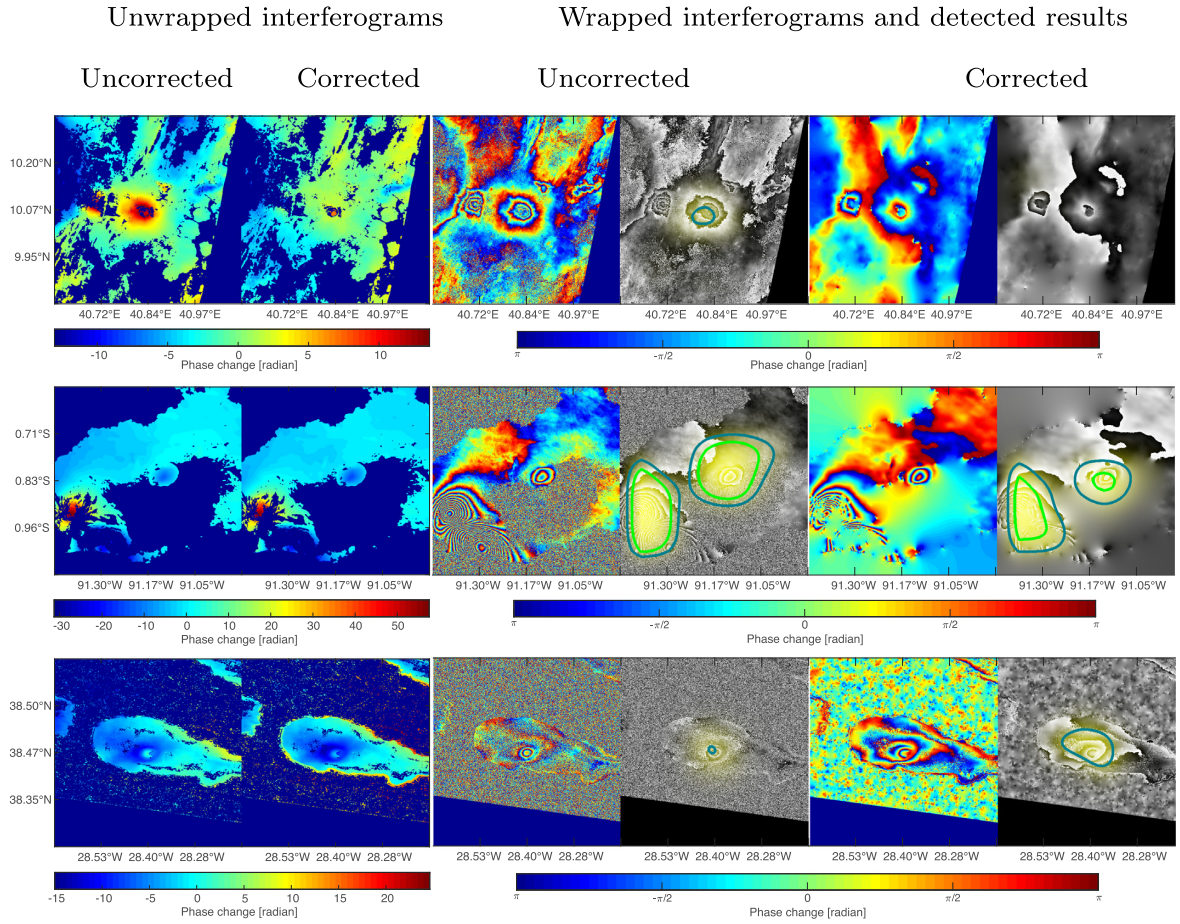
Anantrasirichai et al., 2019

Deep learning:

Automatic feature extraction and modelling

Juliet Biggs
Pui Anantrasirichai
Fabien Albino

University of BRISTOL



Anantrasirichai et al., 2019

Applying atmospheric correction, training with real & synthetic data, and retraining with false positives all improve detection rate

Outlook

- Provides true 'automatic' detection of volcanic signals with potential for NRT application
- slow signals can be detected by rewrapping at a higher rate

Implications of automated processing for CEOS Demonstrator

- Reduction in necessity for local processing in observatories, as automatic products become available?

- How important is it to tailor processing to specific volcanoes, and data presentation to observatory capacity?

- Eventually, we could aim to use automatic alerts to trigger acquisition or ordering of X-band or L-band imagery at volcanoes

Challenges:

- International processing capacity to provide support for volcano observatories is all voluntary, so we rely on complementary funded projects and good will

- Developing relationships with new volcano observatories takes time and investment.

In progress:

- Advertising for CEOS-linked PhD projects, in part to support demonstrator work
- Preparation for COV (2020) and IAVCEI (2021) remote sensing workshops
- Teleconference with current and potential participants in mid-October (> 30 institutes).

Interaction with other CEOS projects:

- Volcano Demonstrator has overlapping contributors and leaders with several of the supersites

- We have some potentially overlapping interests with Seismic and Landslide pilots/demonstrators, which we aim to deal with on a regional basis.