

# Synthesis of volcano deformation from global SAR datasets – implications for volcano monitoring

Ebmeier SK; Andrews BJ; Araya MC; Arnold DWD; Biggs J; Cooper C;  
Cottrell E; Furtney M; Hickey J; Jay J; Lloyd R; Parker AL; Pritchard ME;  
Robertson E; Venzke E; Williamson JL (2018)



The Leverhulme Trust



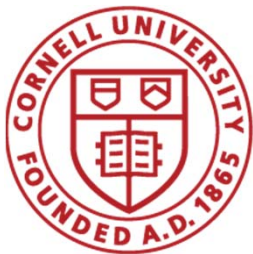
European Space Agency



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STREVA



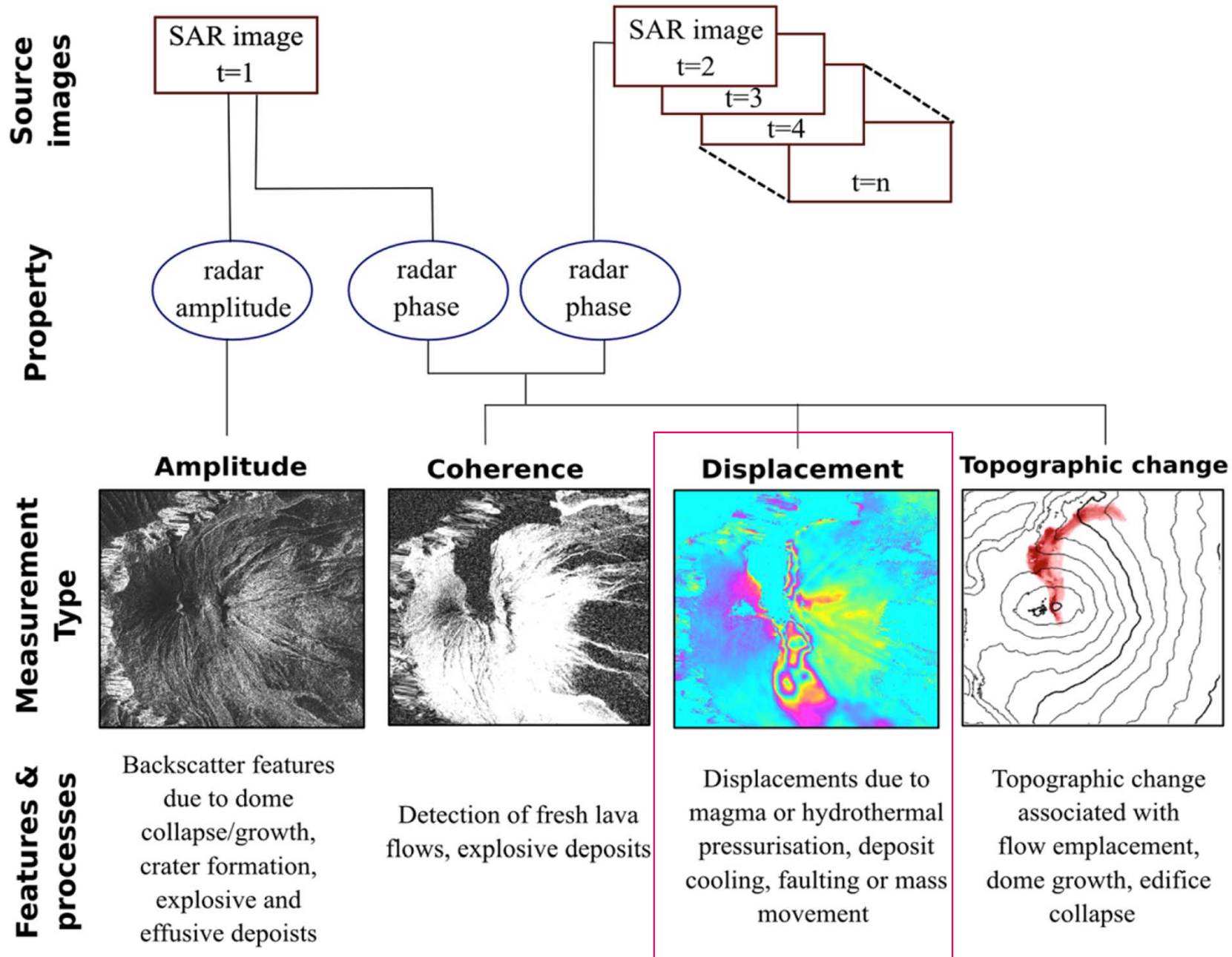
Smithsonian



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COMET



Examples from El Reventador, Ecuador, David Arnold

Smithsonian Institution  
National Museum of Natural History  
Global Volcanism Program

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### Aniakchak

Country	United States
Volcanic Region	Alaska
Primary Volcano Type	Caldera
Last Known Eruption	1931 CE
Latitude	58.88°N
Longitude	158.17°W
Summit Elevation	1341 m 4388 ft
Volcano Number	312090

Map Satellite

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### COMET Volcano Deformation Database

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### Aniakchak

Observations of Deformation Latest Sentinel-1 Data Export as CSV

Volcano number: 312090

Region: Alaska

United States

AR

2010

340 episodes of deformation at 160 volcanoes

Deformation during 1992 - 2010 [Subsidence; Observed by InSAR]

Start Date: 1992	Stop Date: 2010	Direction: Subsidence	Method: InSAR
Magnitude: Unknown	Spatial Extent: Unknown	Latitude: Unknown	Longitude: Unknown

Remarks: Variable rates of subsidence are observed at Aniakchak.

(a) Observed - ERS Descending 086

(b) Modeled - ERS Descending 086

*a* Observed and *b* best-fit synthetic descending-track ERS interferograms of Aniakchak Caldera; ? marks location of best-fit Mogi source. *c* Time-series showing cumulative source-volume change based on modeling ERS and Envisat interferograms from track 086. Observed Envisat interferograms are averaged deformation-rate maps for 1992-2010. Synthetic interferograms were produced using a Mogi (1958) source at about 4 km depth beneath the center of Aniakchak Caldera. Areas lacking interferometric coherence are uncolored. A full cycle of colors (i.e., one

Inferred cause of deformation: Hydrothermal, Magmatic

Characteristics of deformation: InSAR measurements show that the caldera subsidence decreased from ~12 mm/yr during 2005 - 2010. The deformation rate is ~1 mm/yr (km). Evidence from melt inclusions show subsidence may therefore be due to a decrease in pressure. Another possible cause is a decrease in pressure due to a hydrothermal system.

**Global Volcano Programme Database**, hosted by the Smithsonian Institution. Jennifer Jay, Matt Pritchard, Maria Furtney, Ben Andrews, Ed Venzke

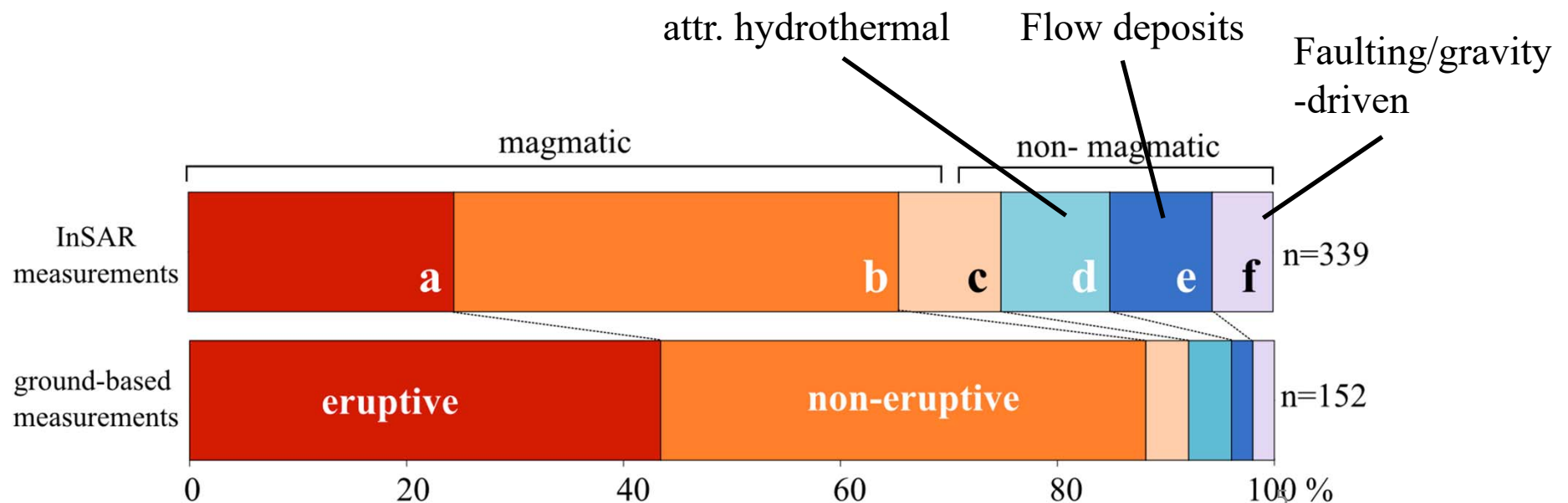
**COMET catalogue:** Susanna Ebmeier, Juliet Biggs, Amy Parker, James Hickey, David Arnold, Ryan Lloyd & Elspeth Robertson – Sentinel-1 images from 2010-2018  
Fabien Albino

1. What type of deformation is detectable using InSAR and what are we missing?
2. What are the 'baseline' characteristics of InSAR-measured volcano deformation?

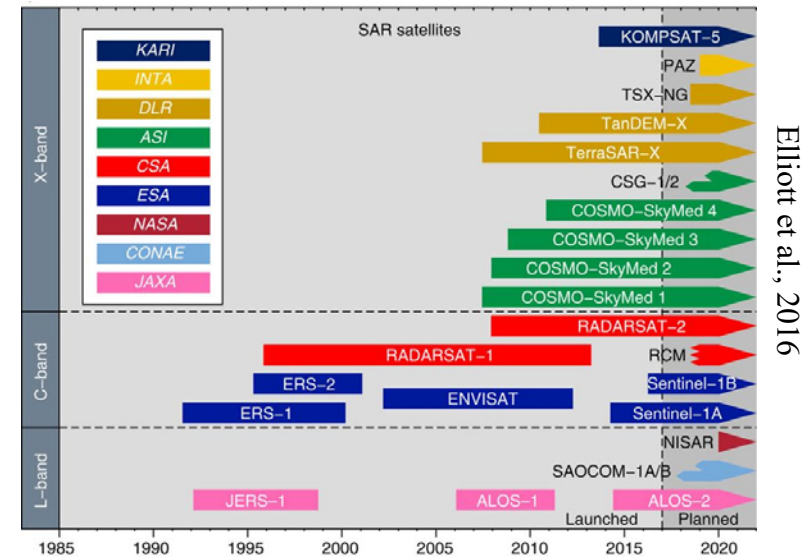
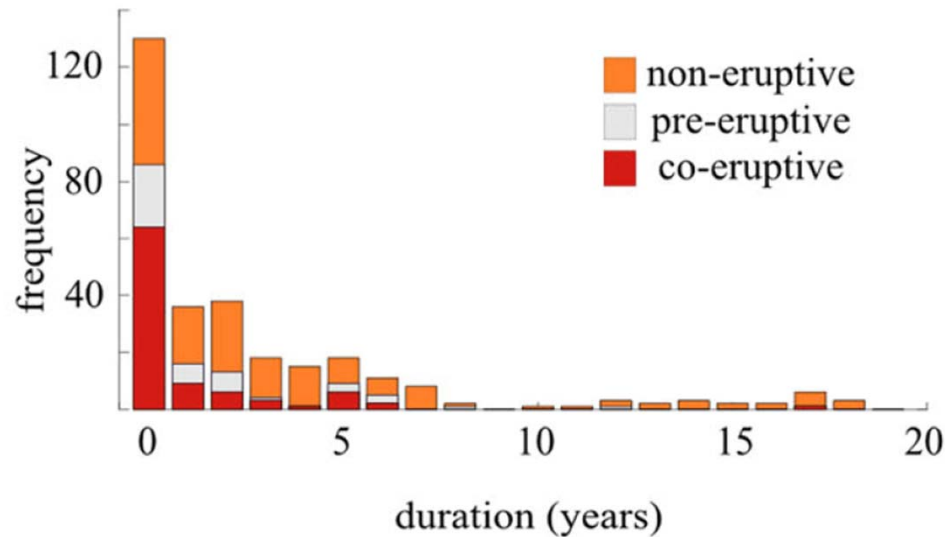
# InSAR measurement record completeness

## *Comparison to ground-based measurements*

- Higher proportion of InSAR measurements capture non-magmatic and non-eruptive processes than ground based measurements

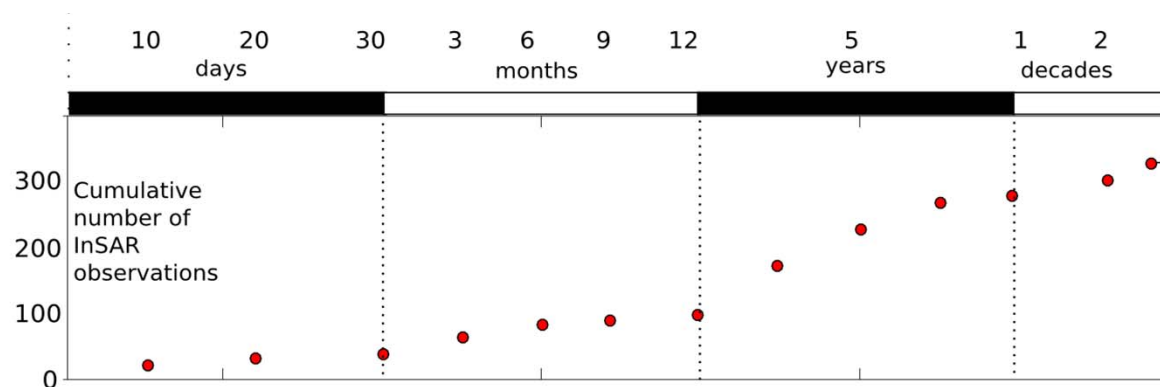




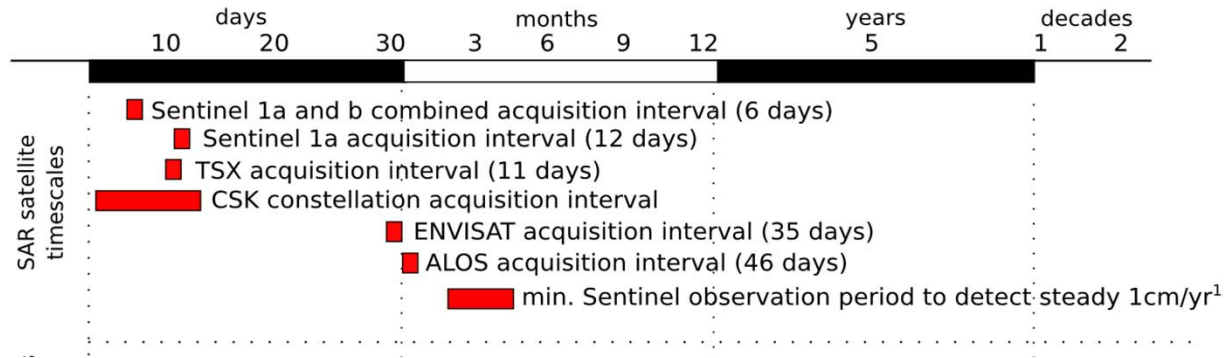


Elliott et al., 2016

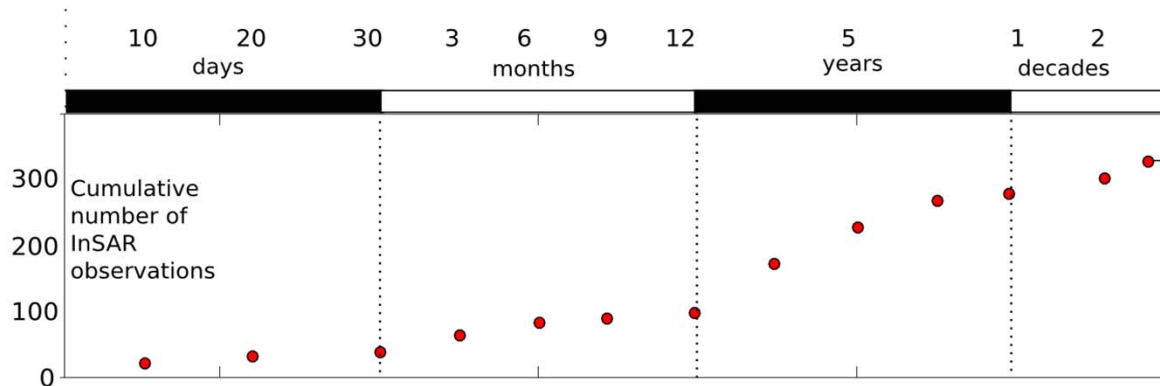
- 20% of deformation events thought to last longer than measurement window
- Long duration (> decades) and short (< month) events are under-sampled



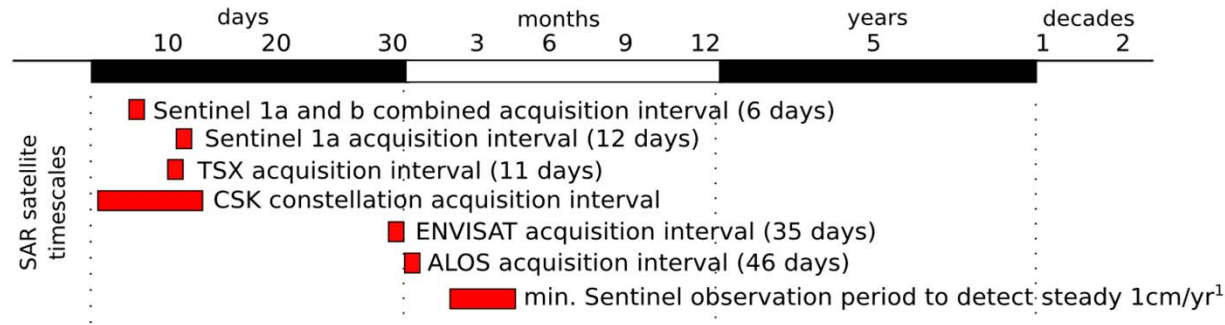
Satellite radar repeat intervals



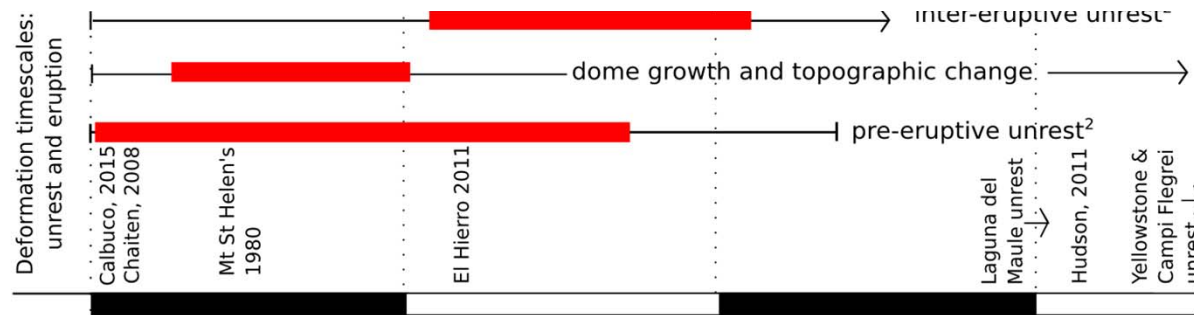
Number of InSAR measurements



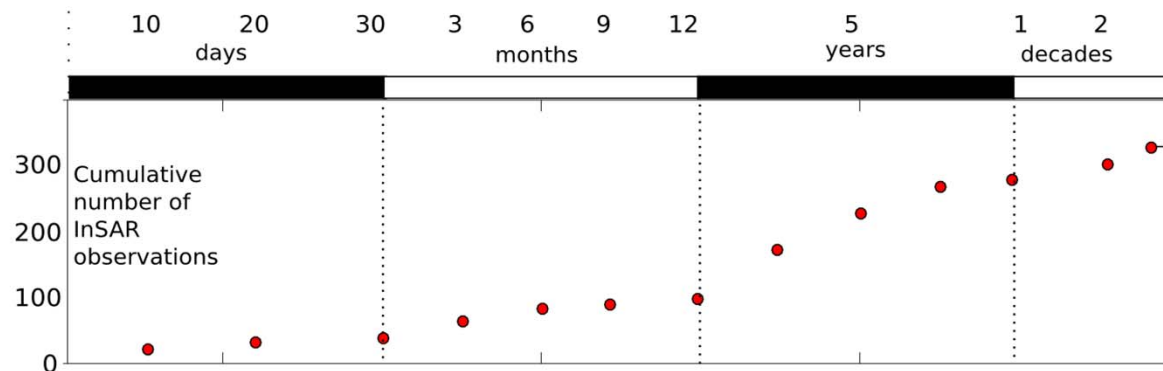
Satellite radar repeat intervals



timescales for unrest and eruption

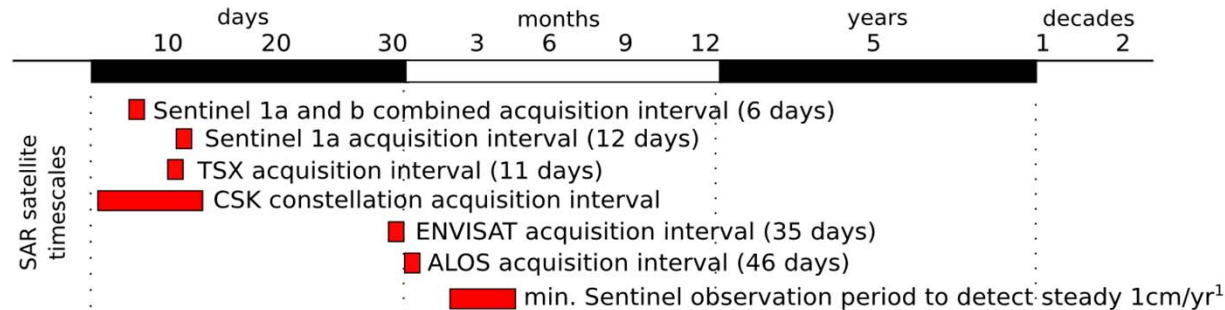


Number of InSAR measurements





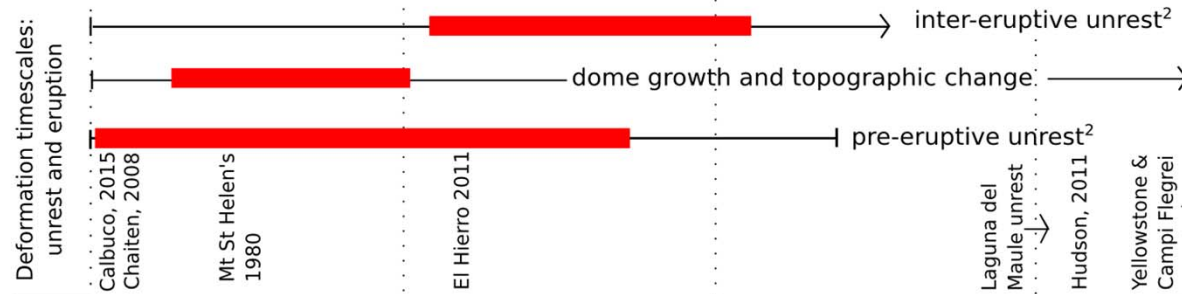
Satellite radar repeat intervals



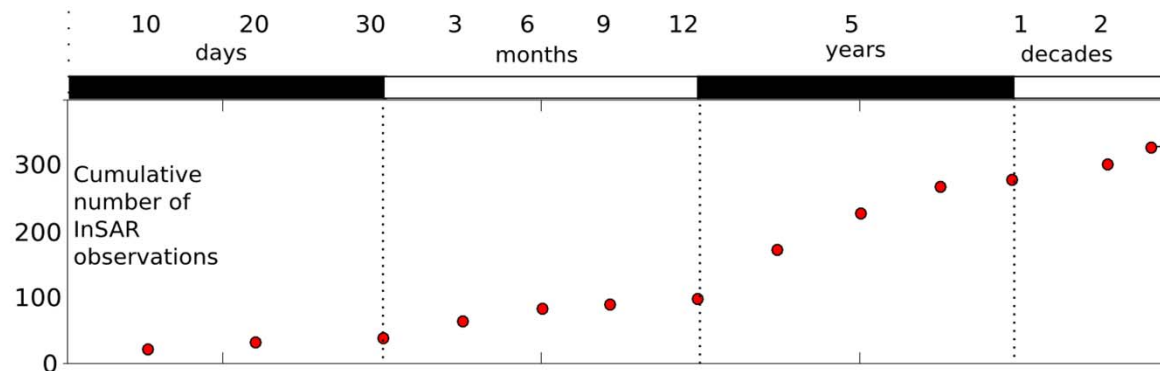
timescales for decision making



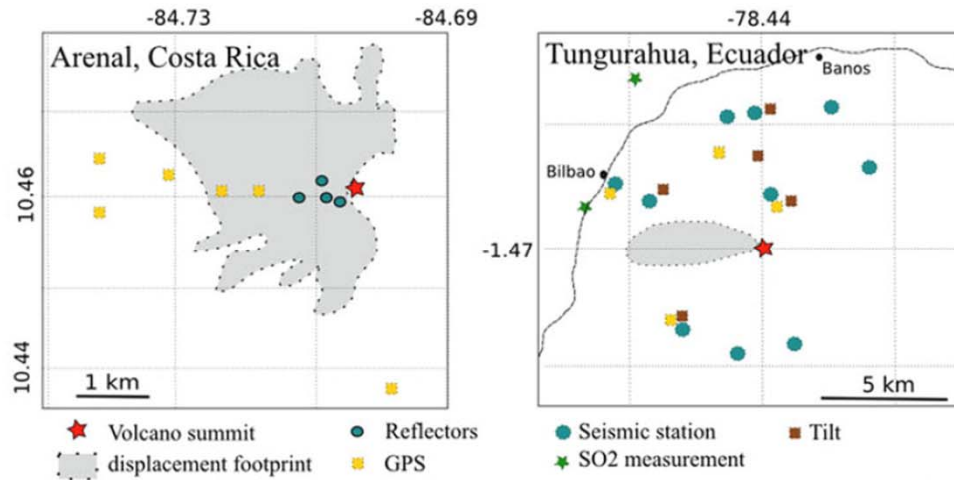
timescales for unrest and eruption



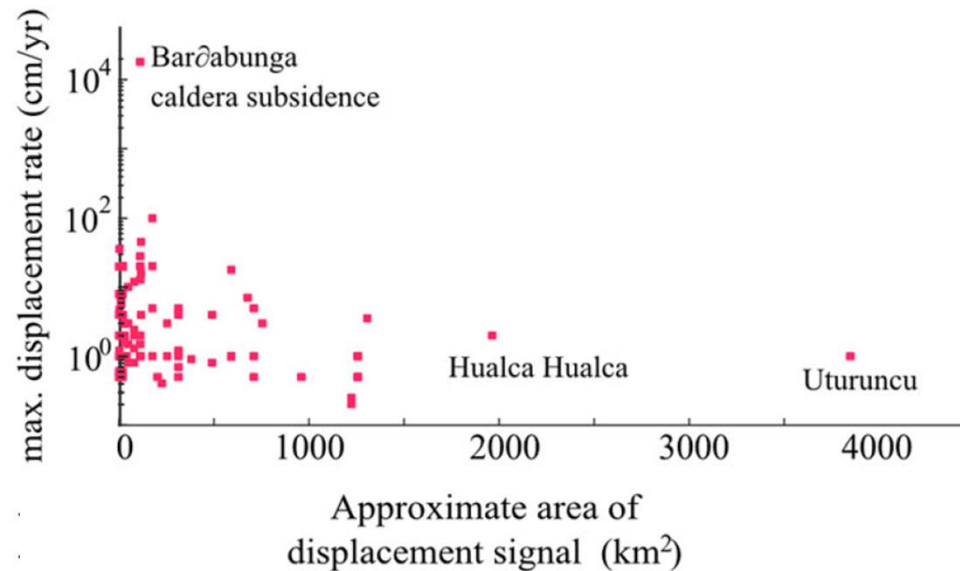
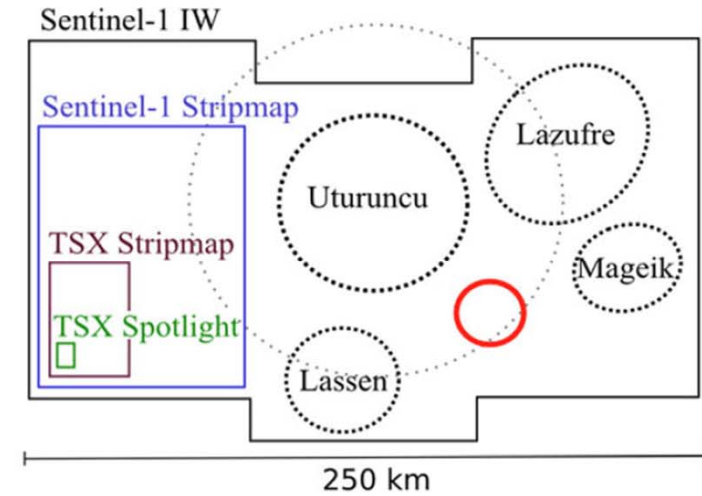
Number of InSAR measurements



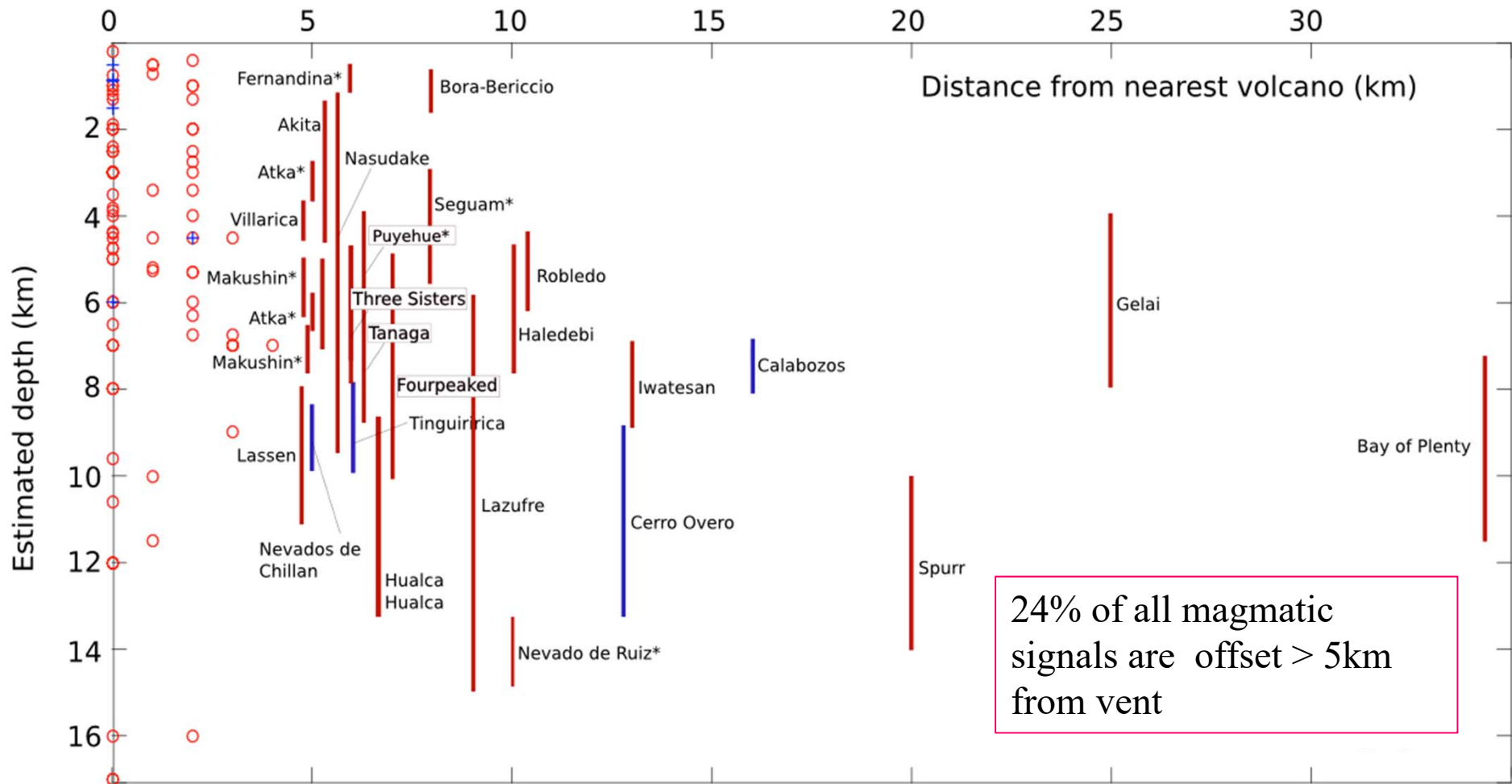
Deformation footprint within monitoring network

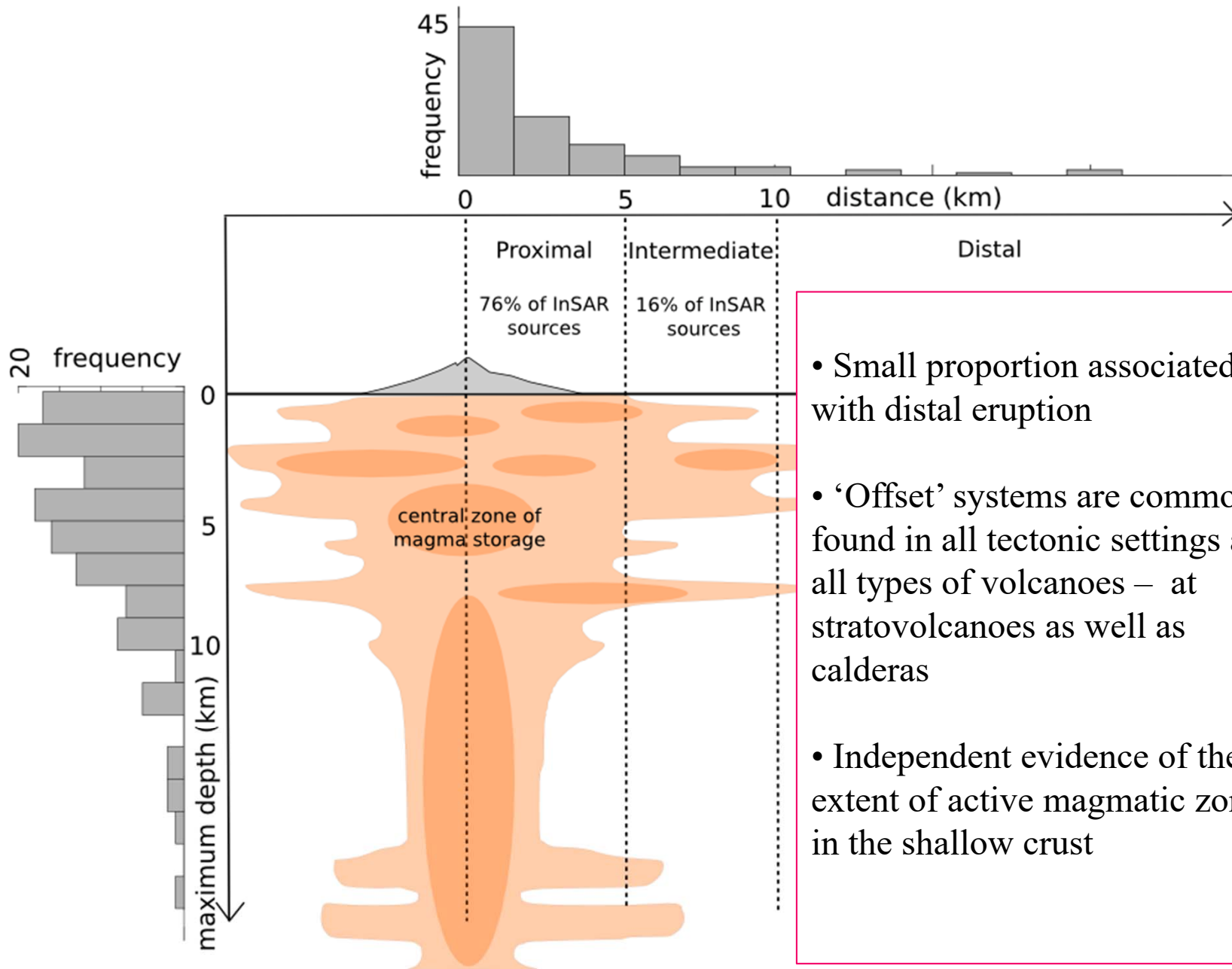


Deformation area > satellite swath



# Laterally 'offset' deformation





- Small proportion associated with distal eruption
- ‘Offset’ systems are common, found in all tectonic settings and all types of volcanoes – at stratovolcanoes as well as calderas
- Independent evidence of the extent of active magmatic zones in the shallow crust

## Implications for volcano monitoring

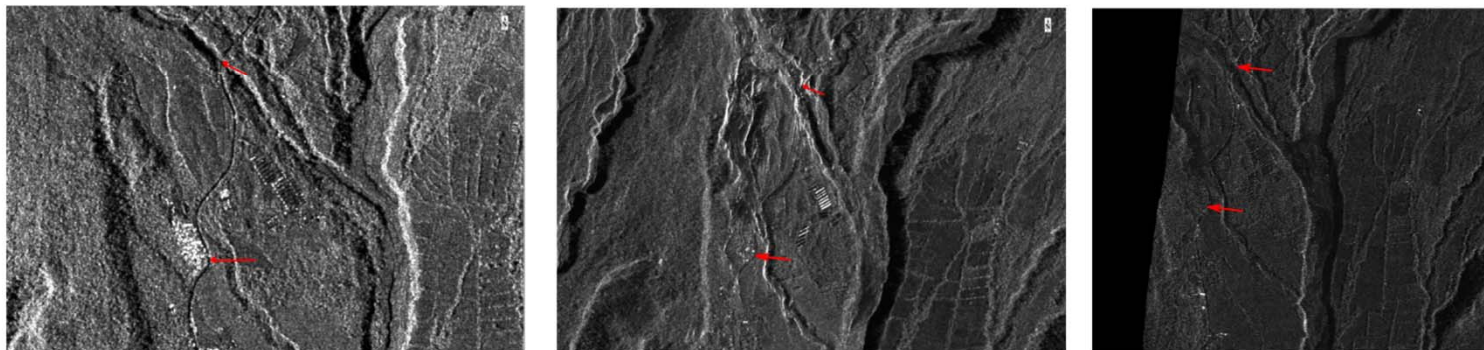
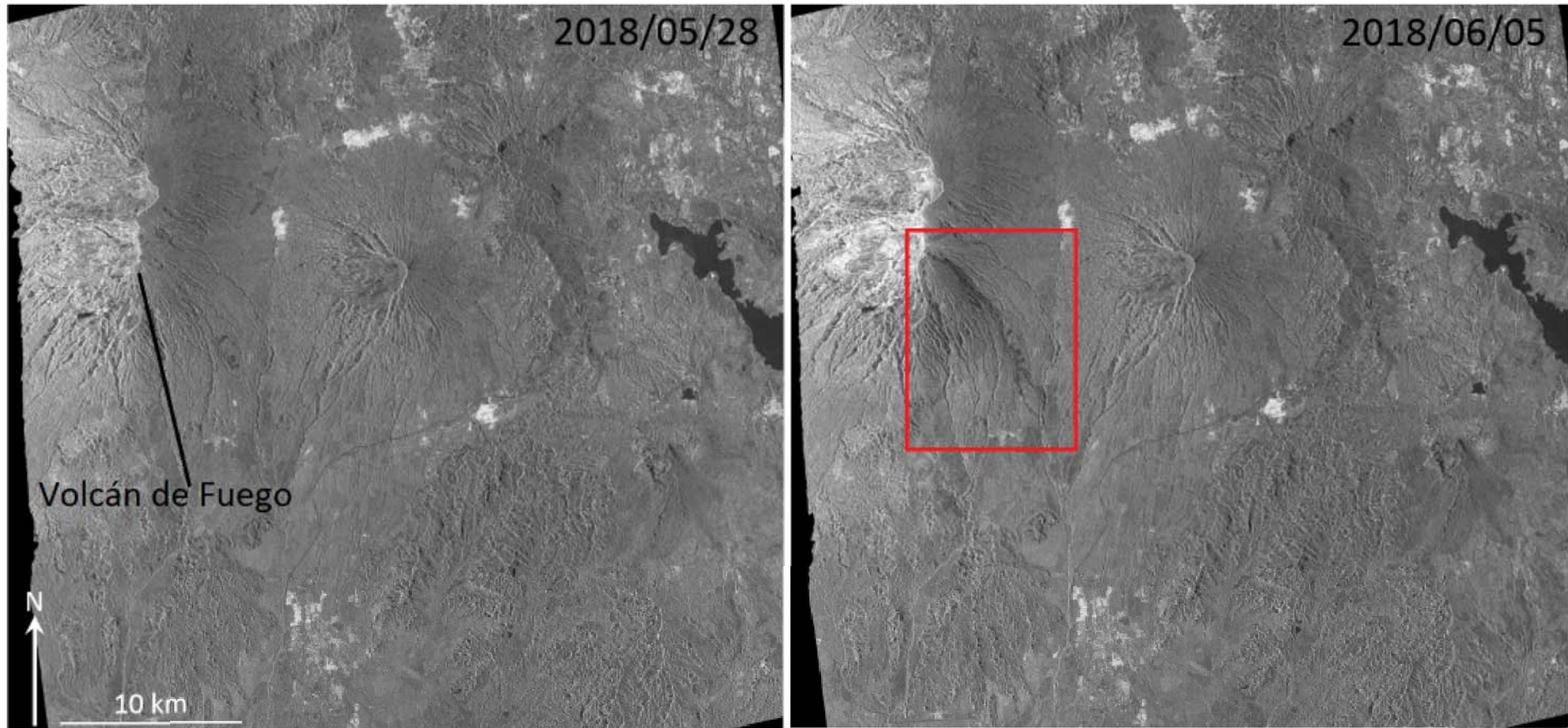
‘Modal’ historical volcanic InSAR signal has been:

- (1) located in the shallow crust, < 5 km
- (2) area < 100 km<sup>2</sup>, rate cm/yr
- (3) attributed to magmatic/hydrothermal fluids
- (4) not linked to eruption

Observation	Recommendation
24% magmatic/hydrothermal deformation offset by > 5km	‘Survey-mode’ measurements or Search radii > 20 km would have discovered 90% of database observations
Rapid near-vent deformation is under-represented in InSAR record	Data from constellations or multiple satellite needed for monitoring



# CSK imagery spanning Fuego eruptions



Susanna Ebmeier, s.k.ebmeier@leeds.ac.uk

Reference:

- Ebmeier SK; Andrews BJ; Araya MC; Arnold DWD; Biggs J; Cooper C; Cottrell E; Furtney M; Hickey J; Jay J; Lloyd R; Parker AL; Pritchard ME; Robertson E; Venzke E; Williamson JL (2018) Synthesis of global satellite observations of magmatic and volcanic deformation: implications for volcano monitoring & the lateral extent of magmatic domains, *Journal of Applied Volcanology*, 7.
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