InSAR Examples the Americas

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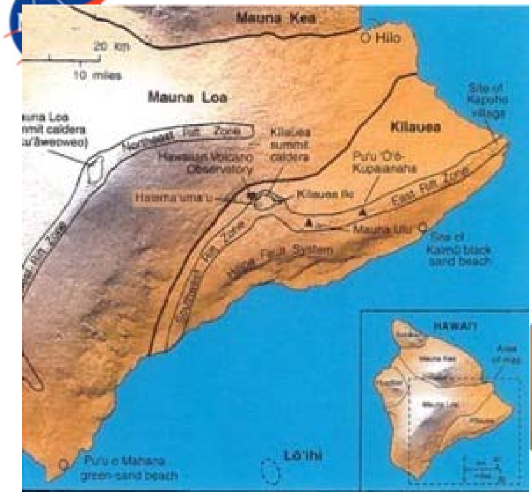
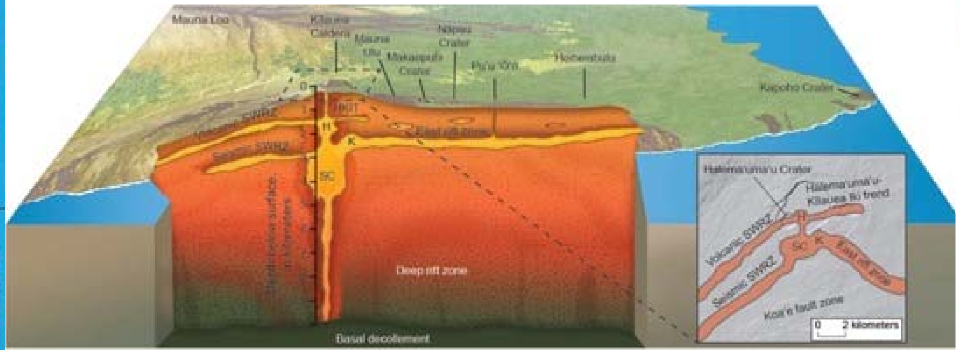
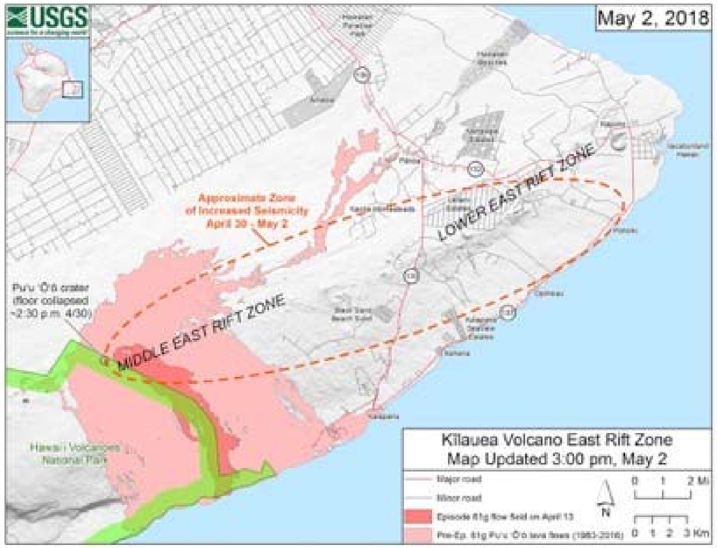
2018 Kilauea Eruption



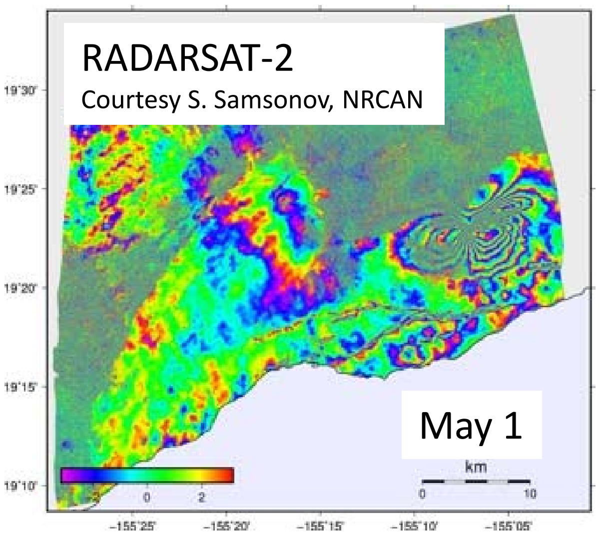


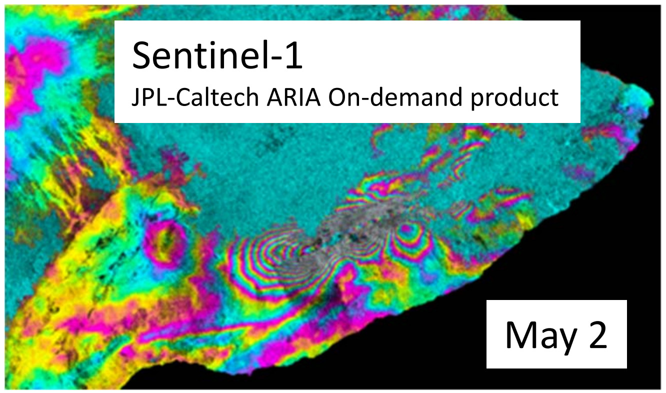


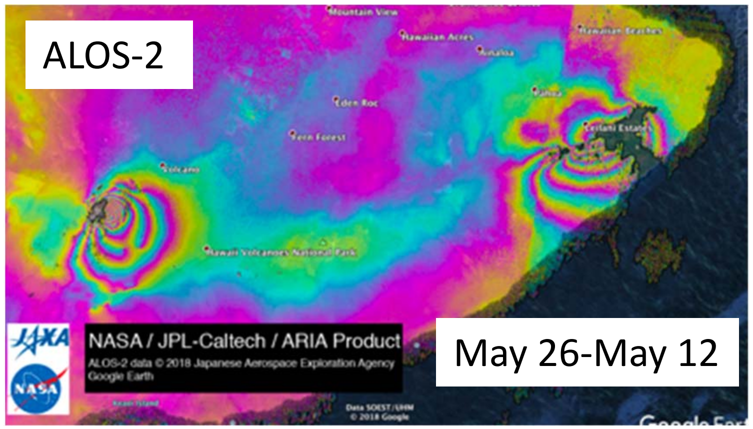
- Largest eruption in 200 years.
- Activity began late April with increased seismicity in East Rift Zone
- On May 1, active fissure opened in Leilani Estates Since eruption began May 4, there have been 24 new fissures – some combining.
- At least 533 homes destroyed
- Eruption stopped August 4, 2018

Satellite InSAR response – prior to first lava May 3

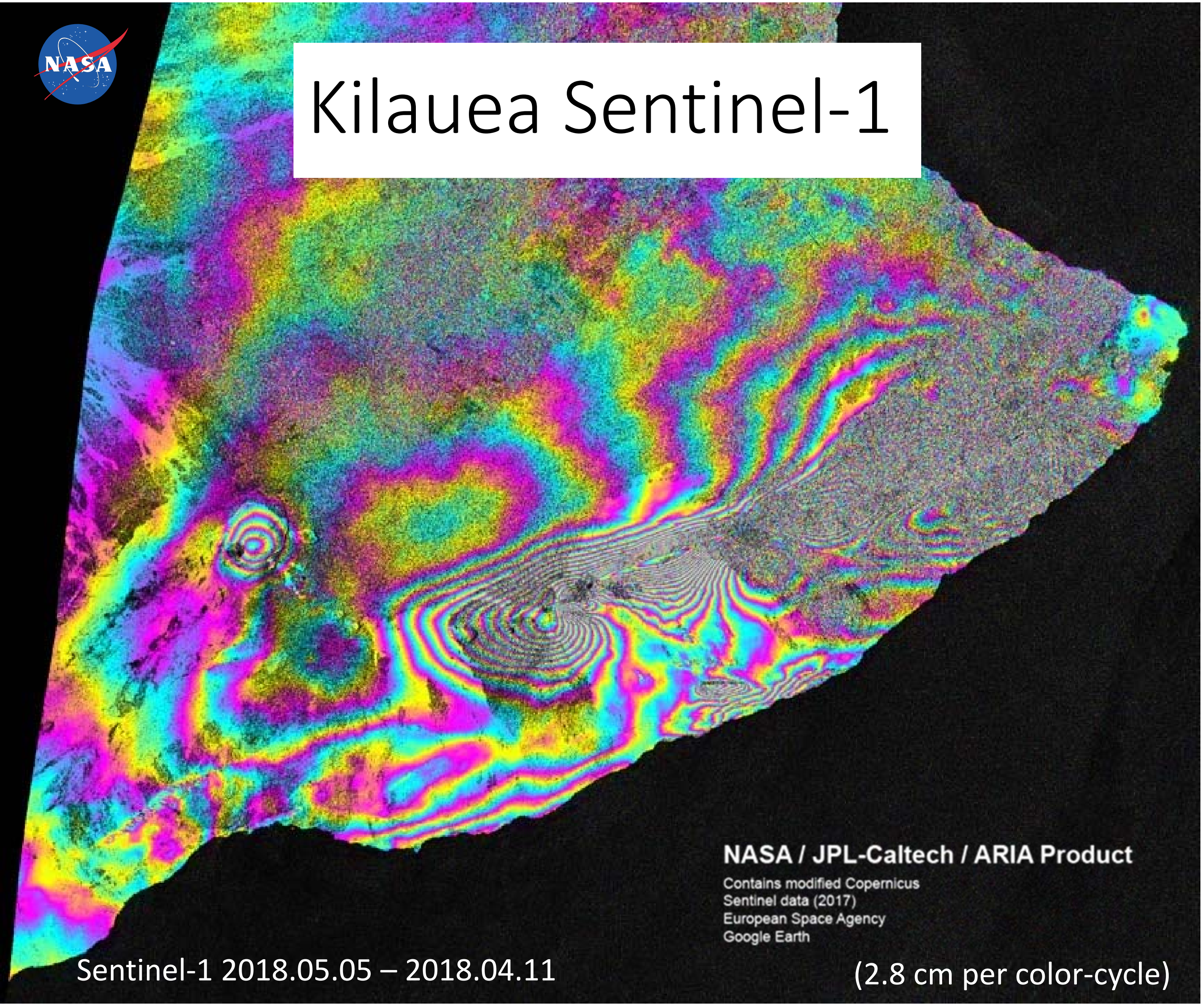
- Satellite InSAR observations of surface deformation constrained where changes in magma plumbing were occurring
- SAR interferograms constrained where the magma was moving down-rift, constraining the dike tip as it propagated



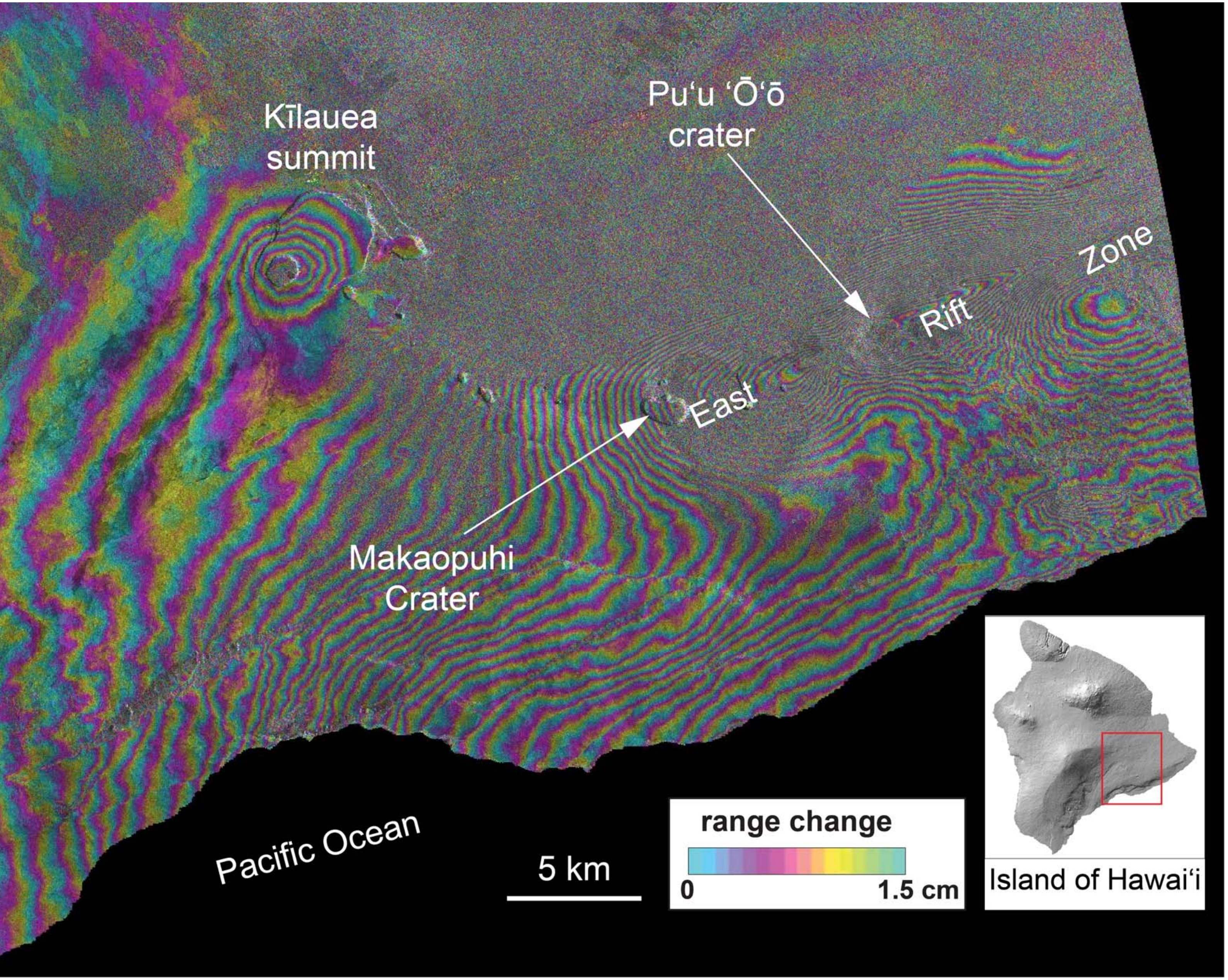




ALOS-2: Only SAR with good coherence in the Lower East Rif Zone.

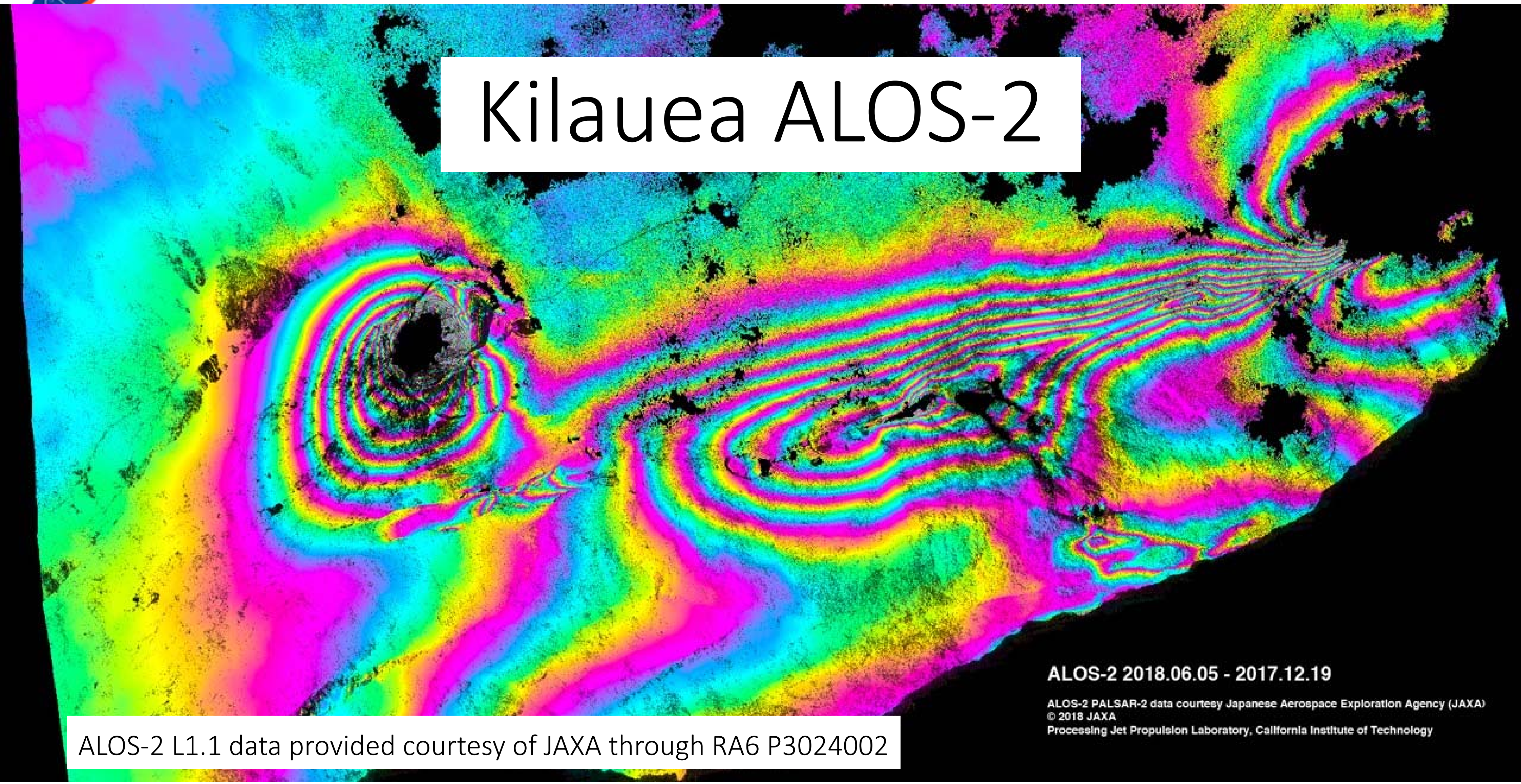


JPL-Caltech ARIA system produced Sentinel-1 InSAR products



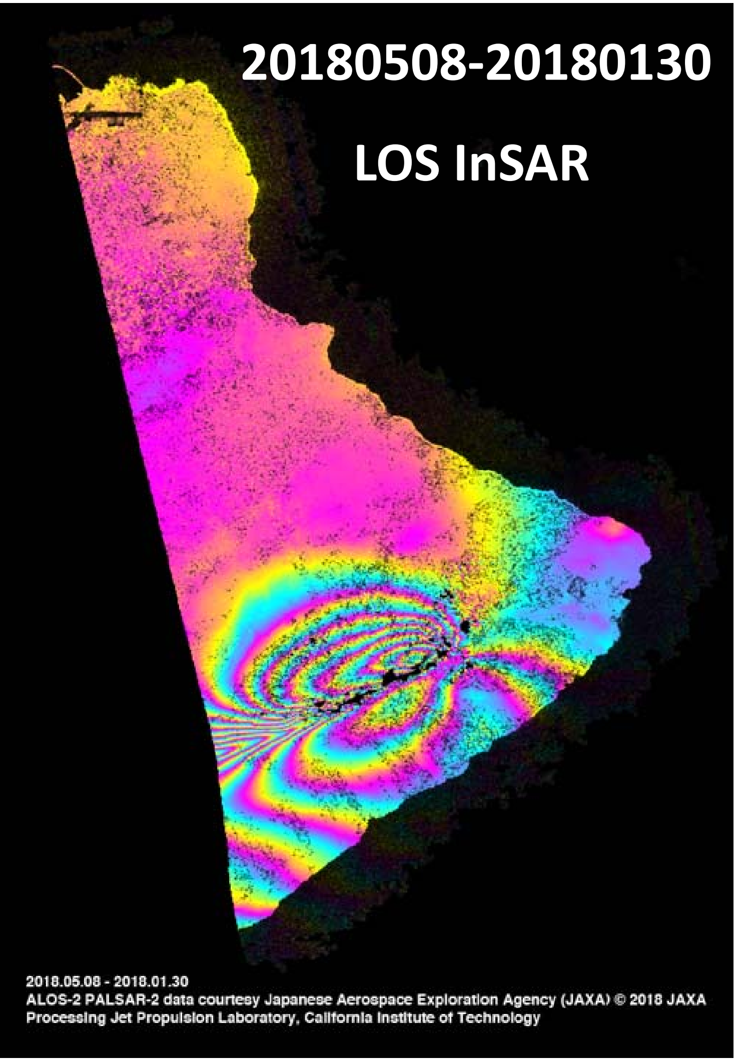
Volcano Demonstrator intensified image acquisition as soon as eruption became more severe; Sentinel-1 and CSK data (shown here) allow rapid mapping of deformation

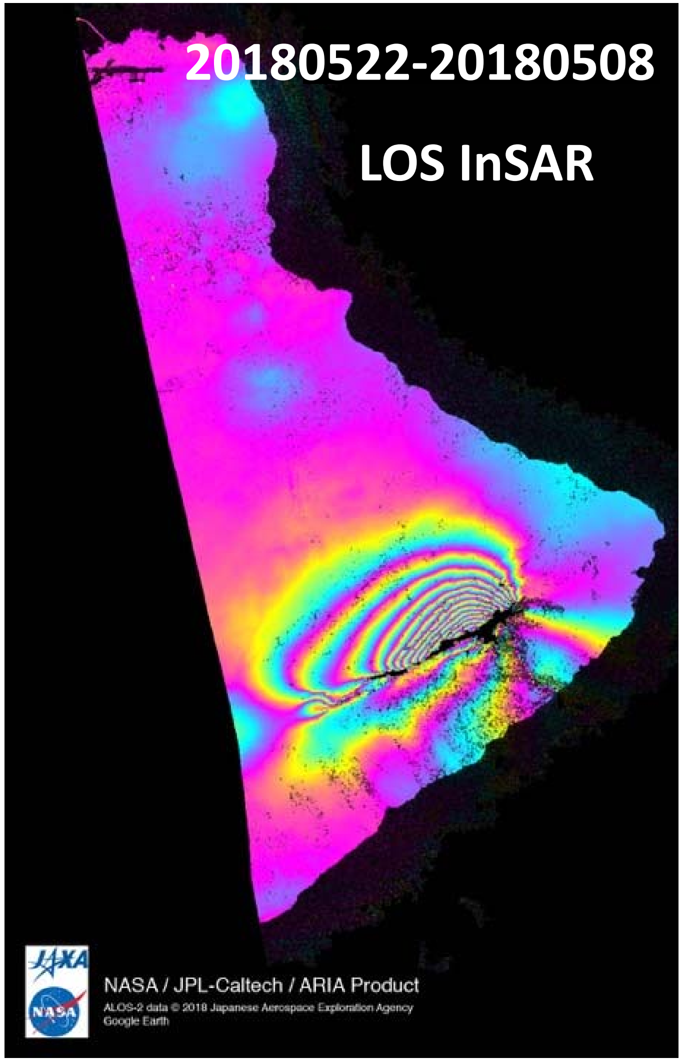
Kilauea ALOS-2

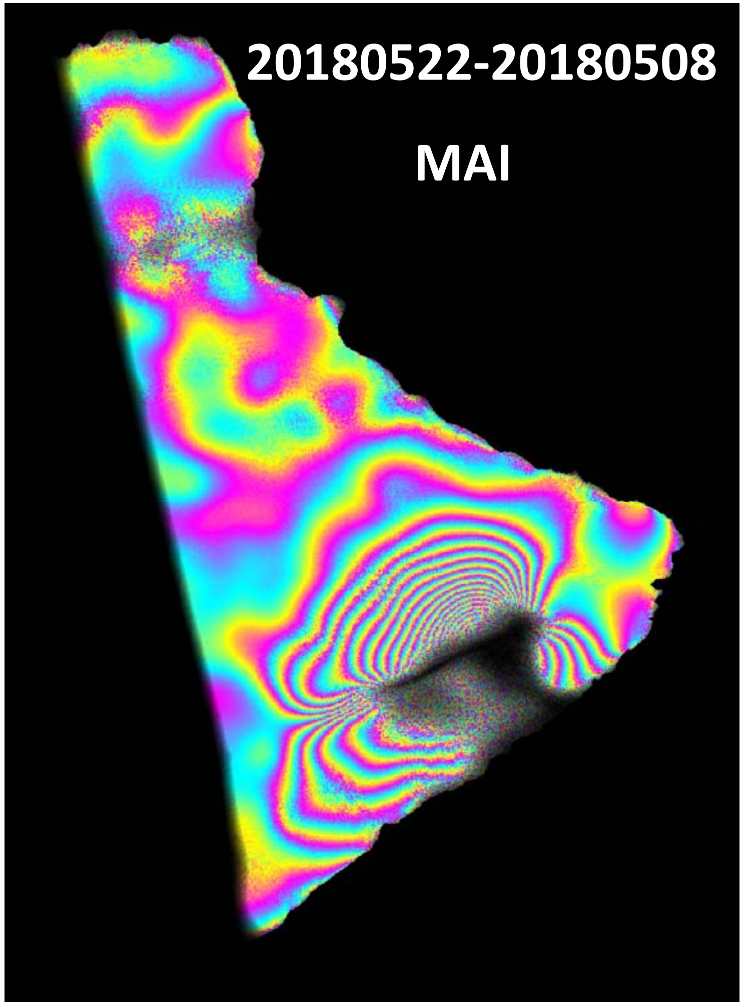


ALOS-2 L1.1 data provided courtesy of JAXA through RA6 P3024002

ALOS-2 of high value to USGS and NASA





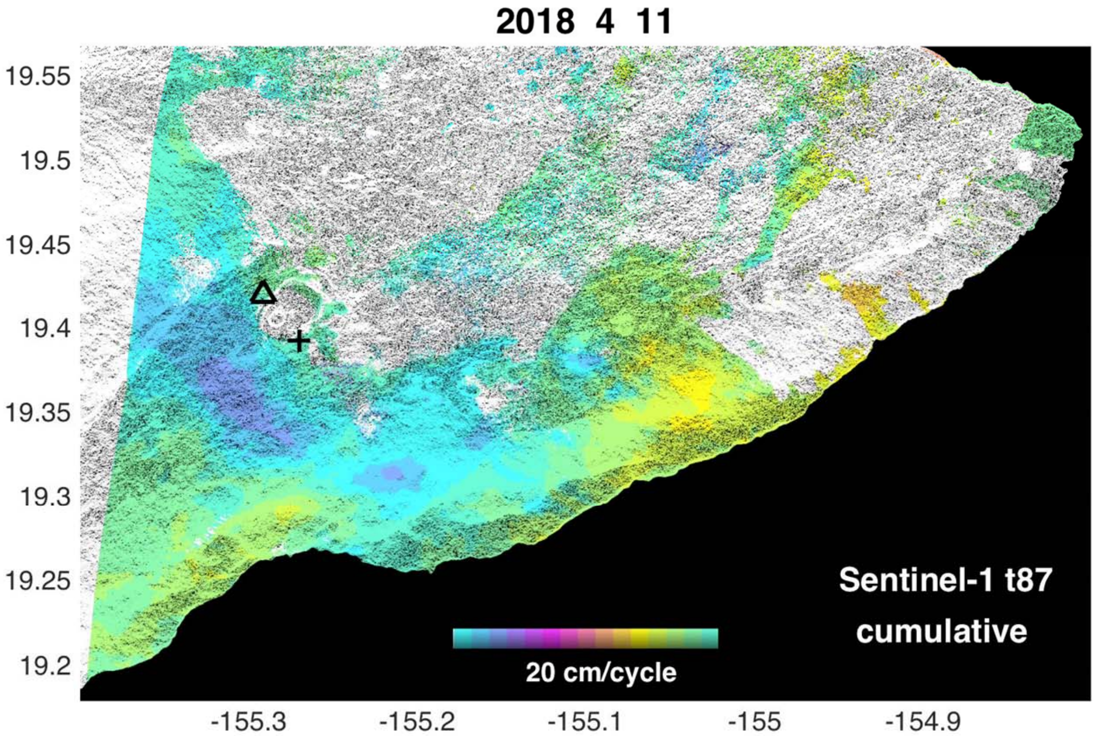


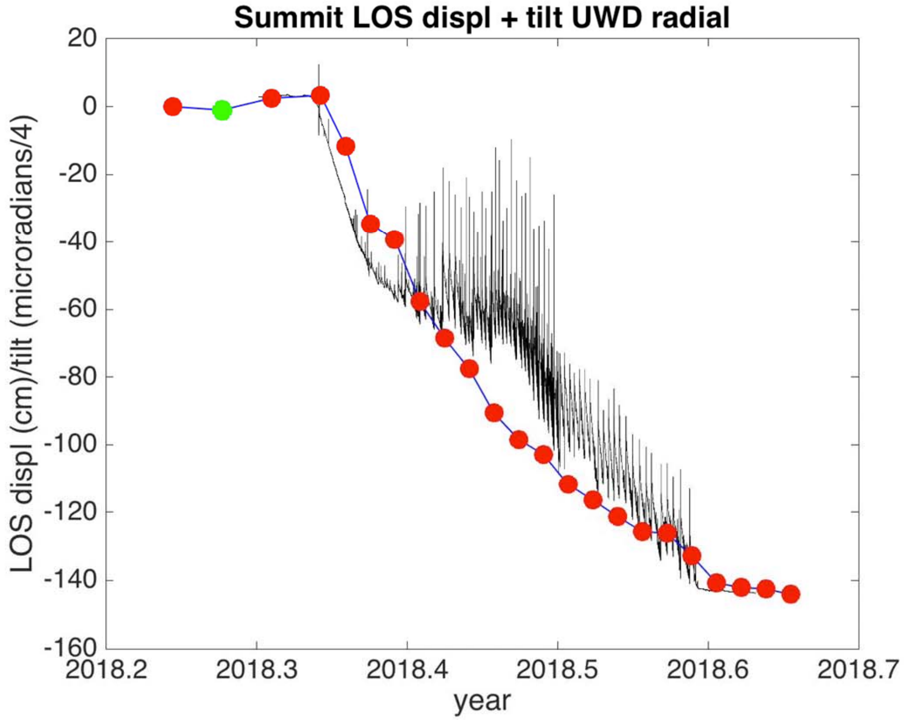
Time variable behavior

- InSAR time series from Sentinel-1 combined with tilt and GPS
- Lava effusion volume from repeat GLISTIN and other (in-situ) estimates

Sentinel-1 InSAR time series: Track 87

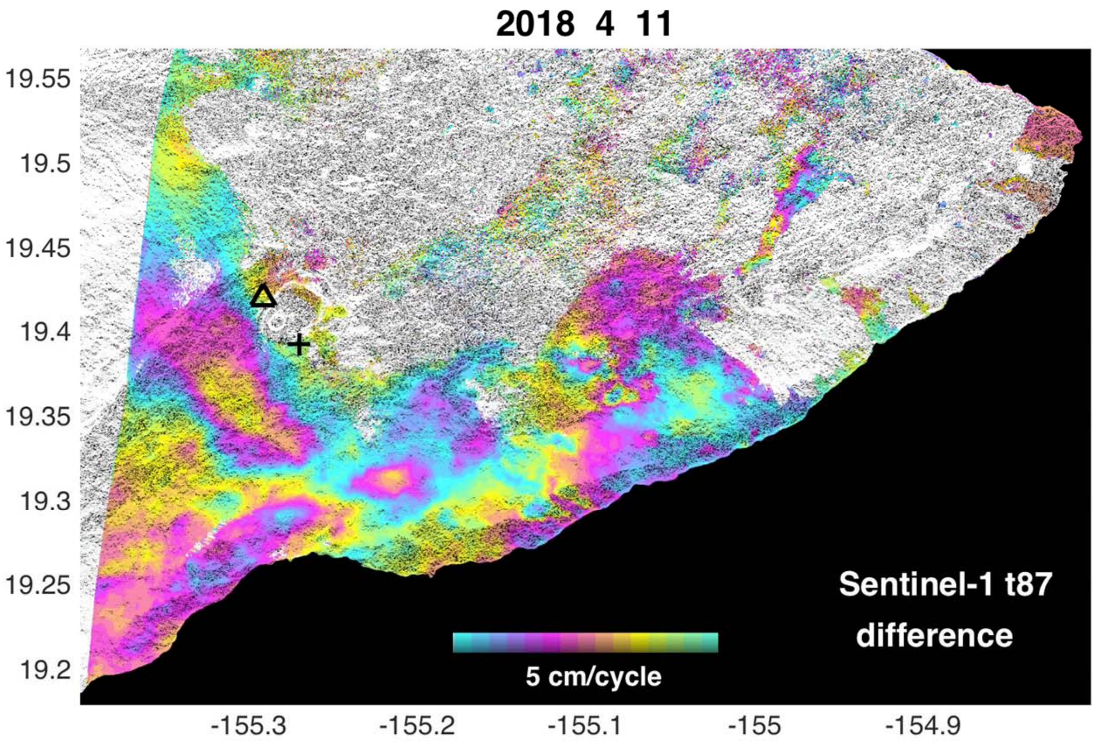
interferograms processed by the JPL/Caltech ARIA project

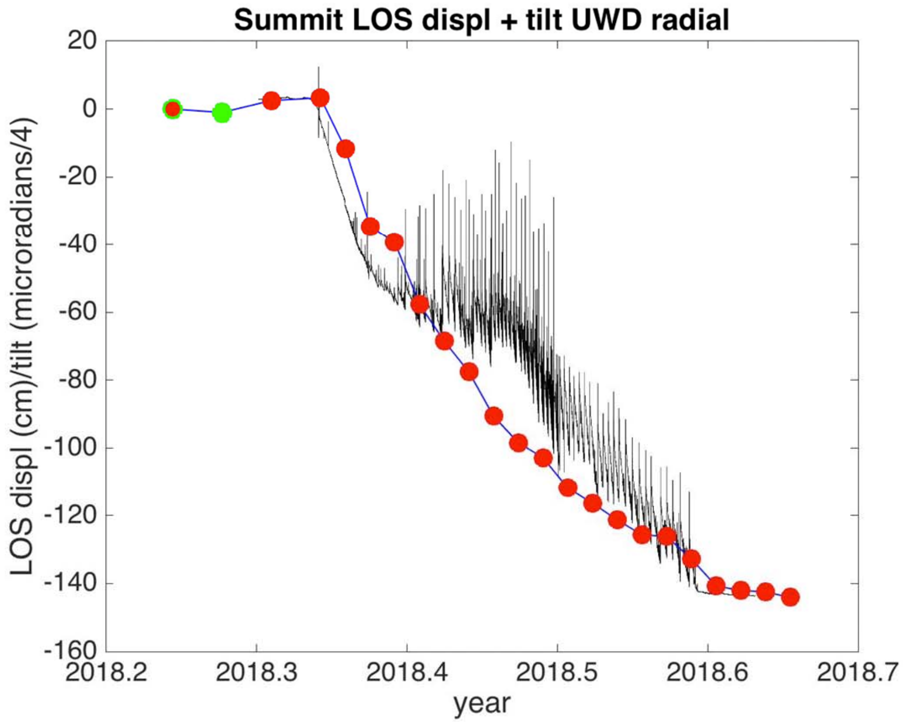




Sentinel-1 InSAR time series: Track 87

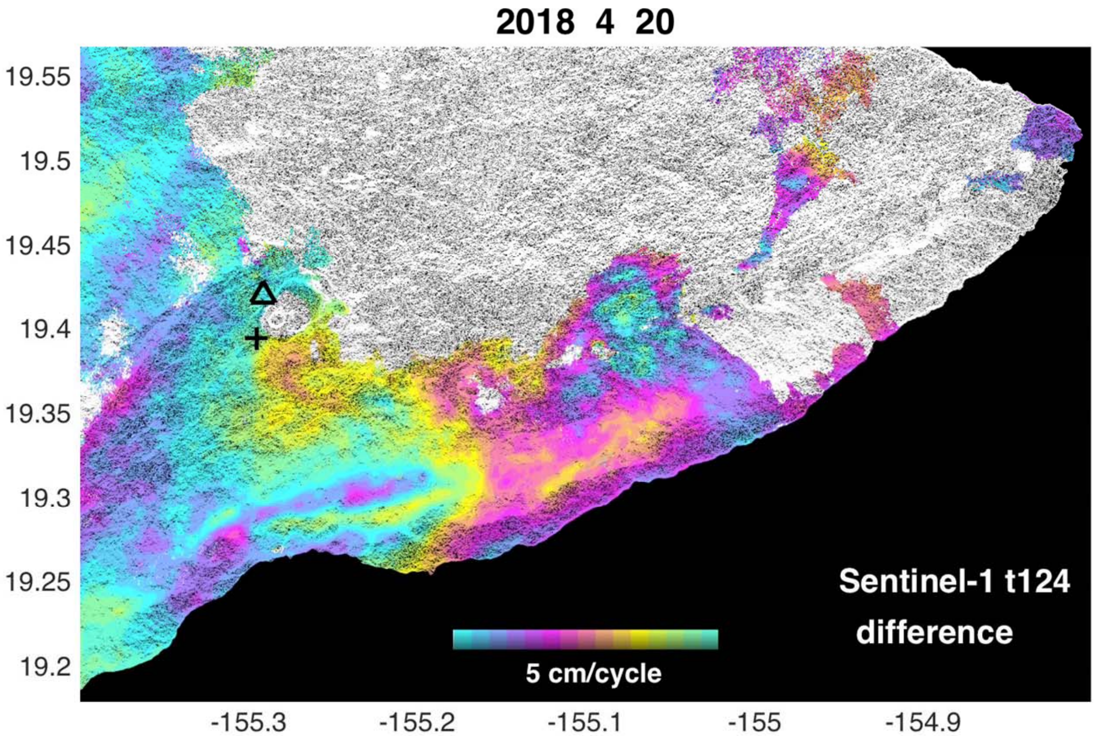
interferograms processed by the JPL/Caltech ARIA project

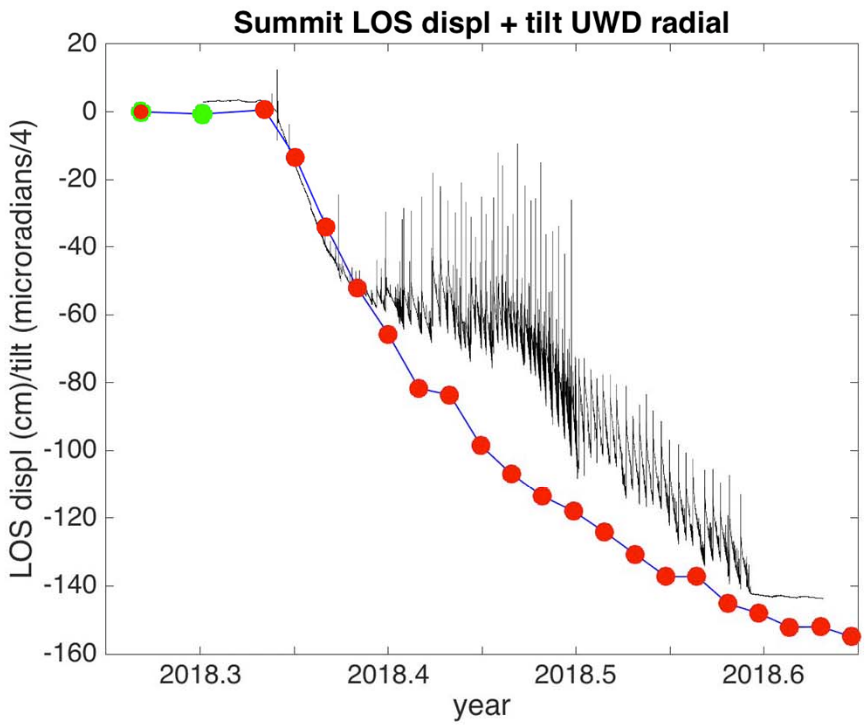




Sentinel-1 InSAR time series: Track 124

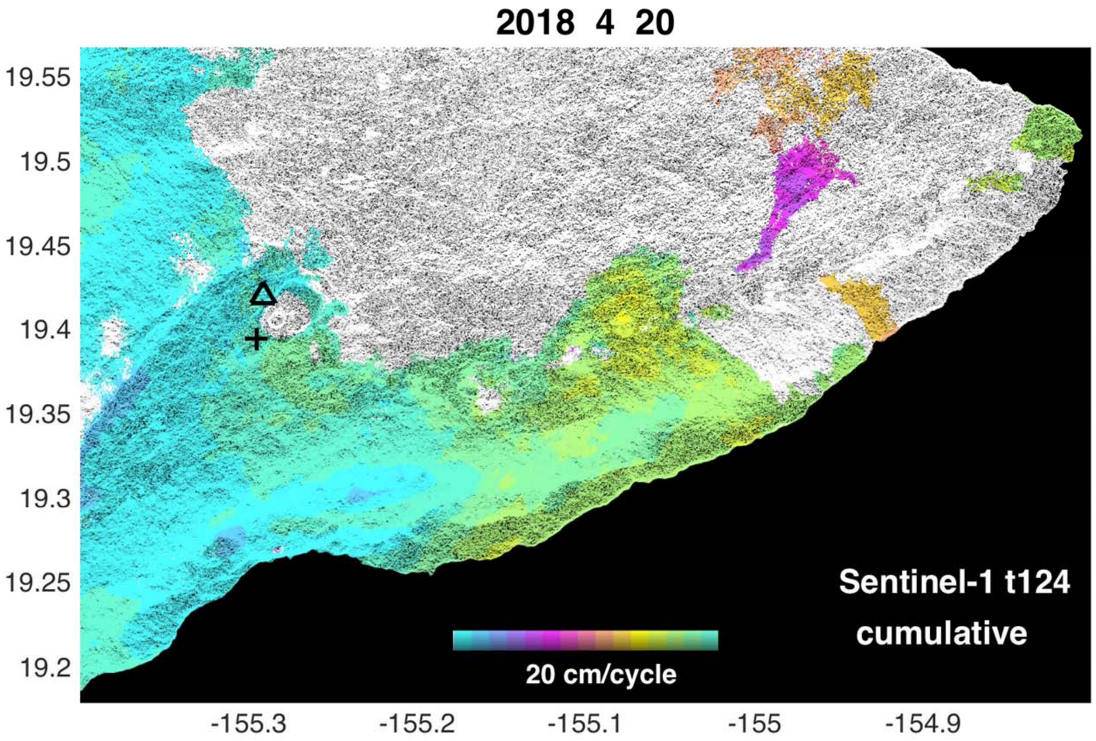
interferograms processed by the JPL/Caltech ARIA project

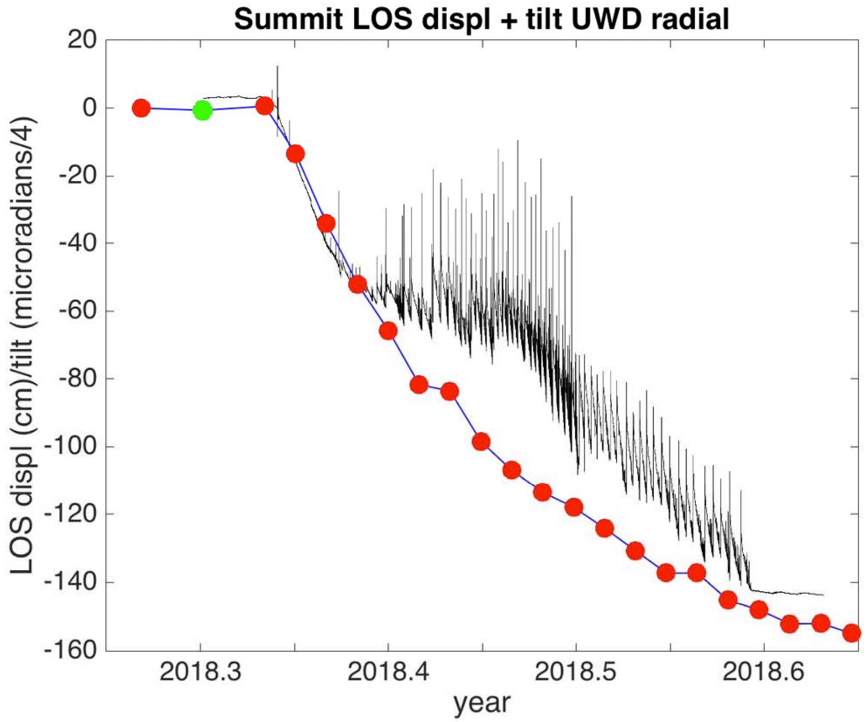




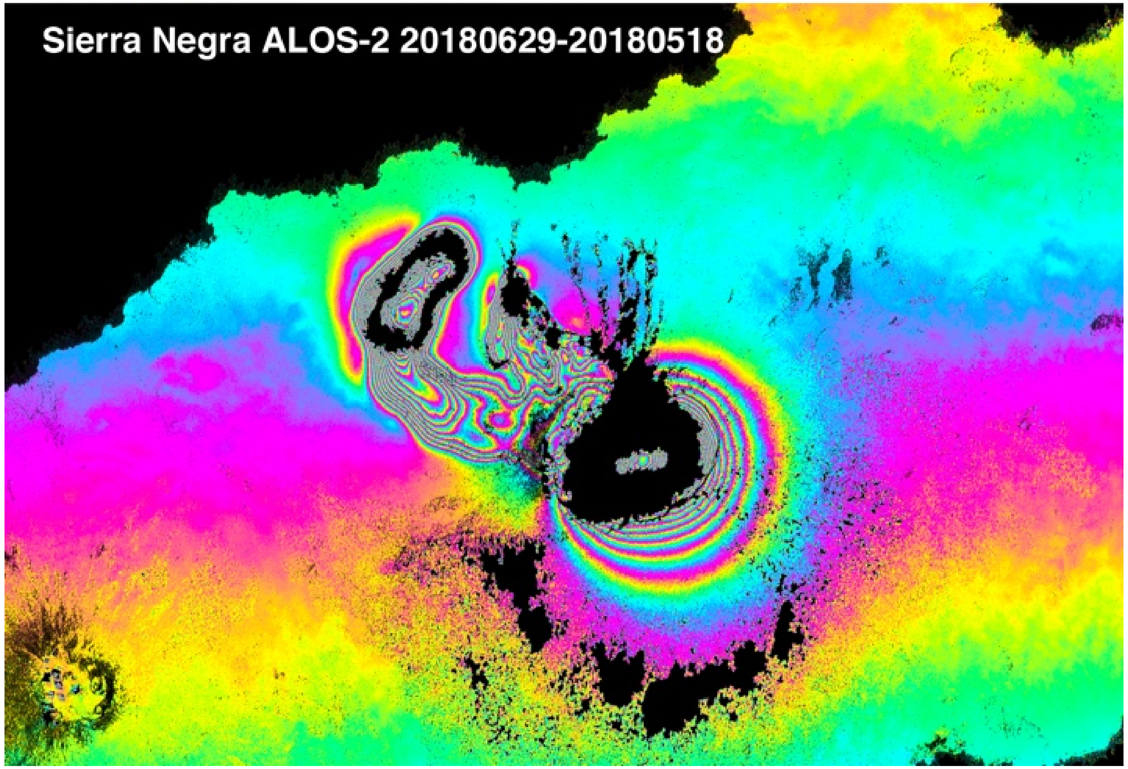
Sentinel-1 InSAR time series: Track 124

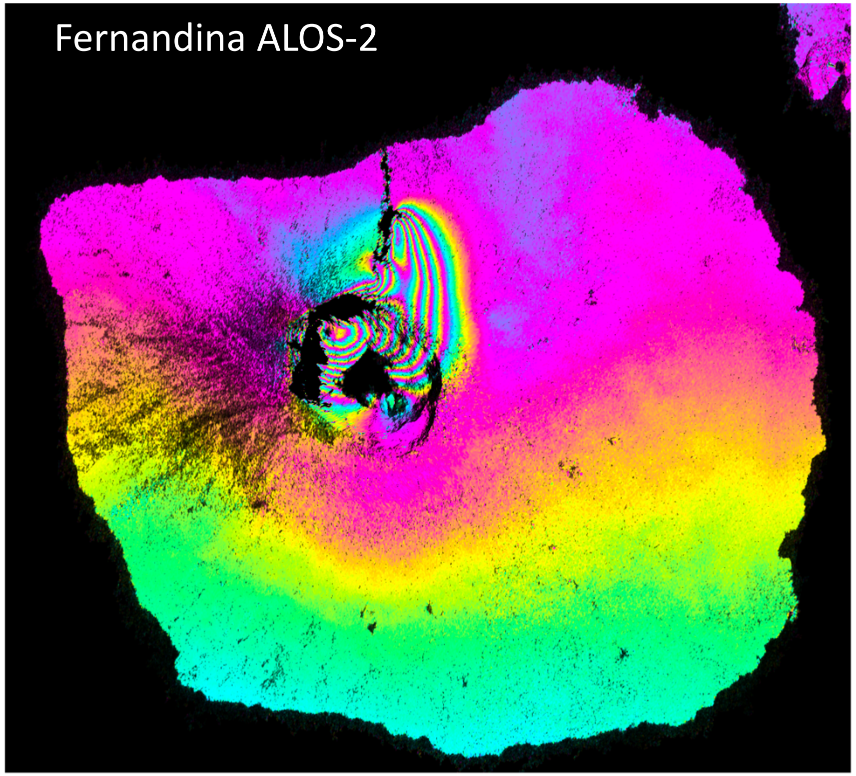
interferograms processed by the JPL/Caltech ARIA project

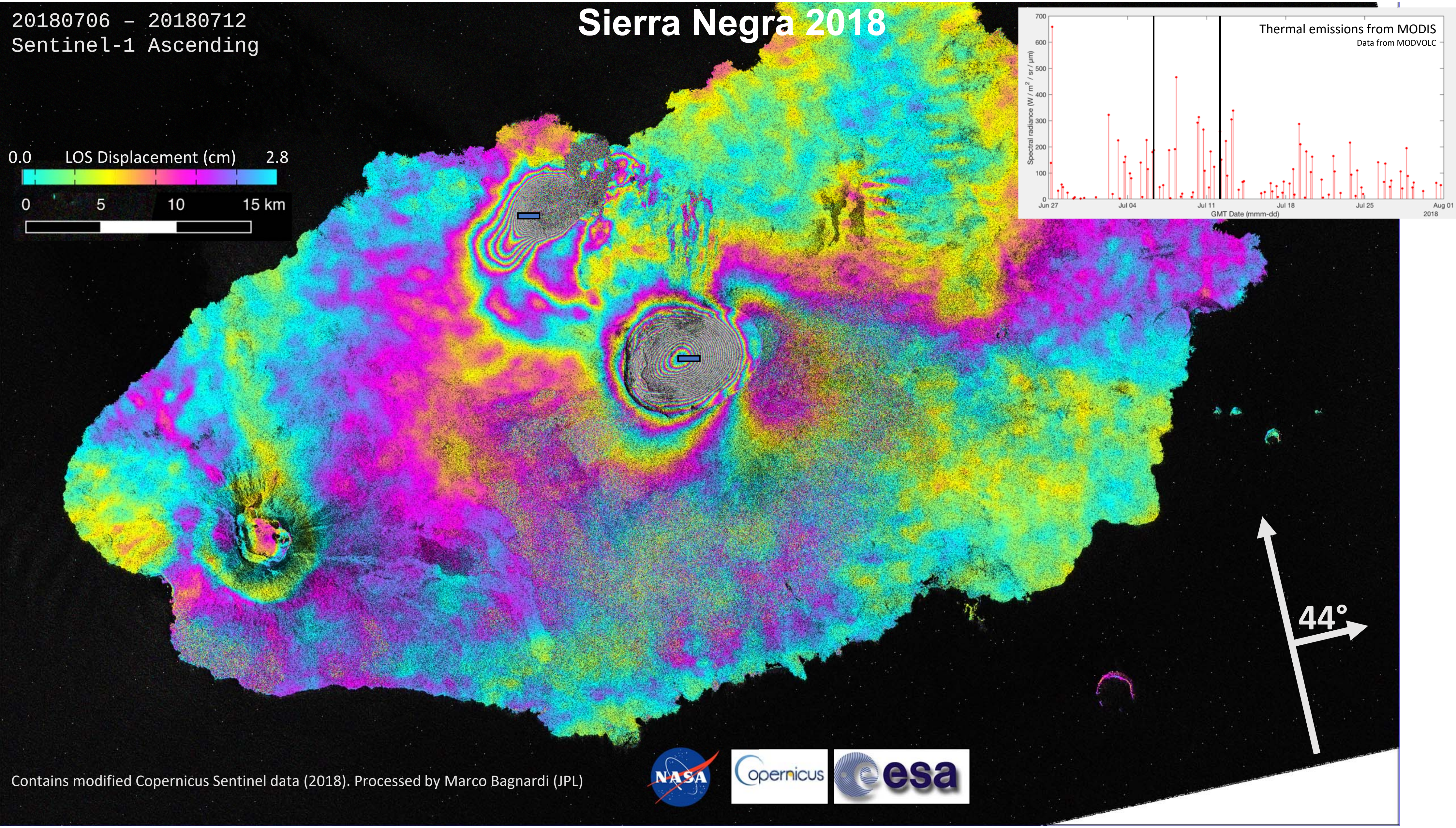


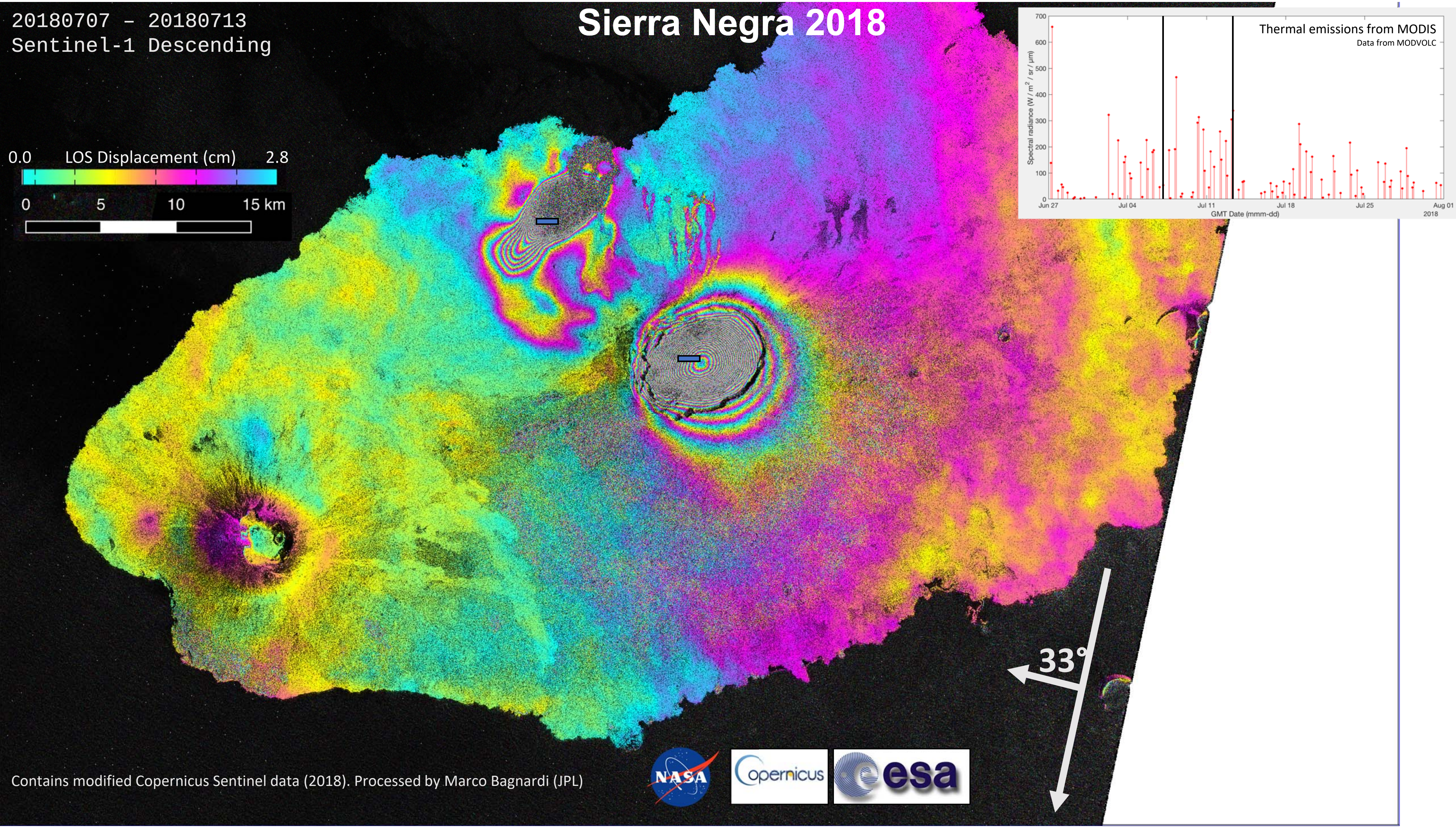


Galapagos: Sierra Negra & Fernandina eruptions, June 2018



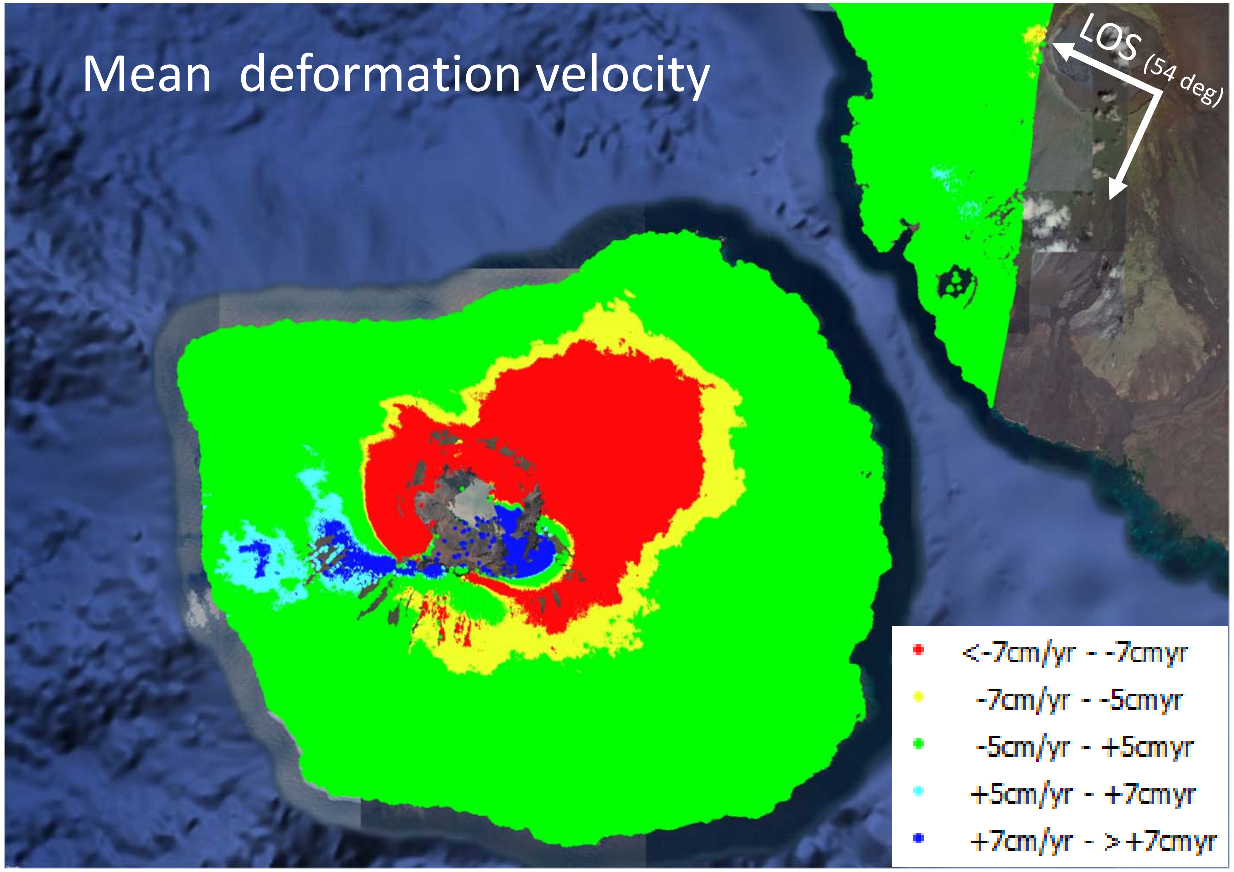



Sierra Negra 2018
20180706 – 20180712
Sentinel-1 Ascending
0.0
LOS Displacement (cm)
2.8
0
5
10
15 km
Thermal emissions from MODIS
Data from MODVOLC
Spectral radiance (W / m2 / sr / µm)
0
100
200
300
400
500
600
700
Jun 27
Jul 04
Jul 11
Jul 18
Jul 25
Aug 01
2018
GMT Date (mmm-dd)
44°
Contains modified Copernicus Sentinel data (2018). Processed by Marco Bagnardi (JPL)



20180707 - 20180713
Sentinel-1 Descending
Sierra Negra 2018
0.0
LOS Displacement (cm)
2.8
0
5
10
15 km
Thermal emissions from MODIS
Data from MODVOLC
Spectral radiance (W / m^2 / sr / μm)
700
600
500
400
300
200
100
0
Jun 27
Jul 04
Jul 11
Jul 18
Jul 25
Aug 01
GMT Date (mmm-dd)
2018
33°
Contains modified Copernicus Sentinel data (2018). Processed by Marco Bagnardi (JPL)

Fernandina (Galapagos) - September 2017 Eruption

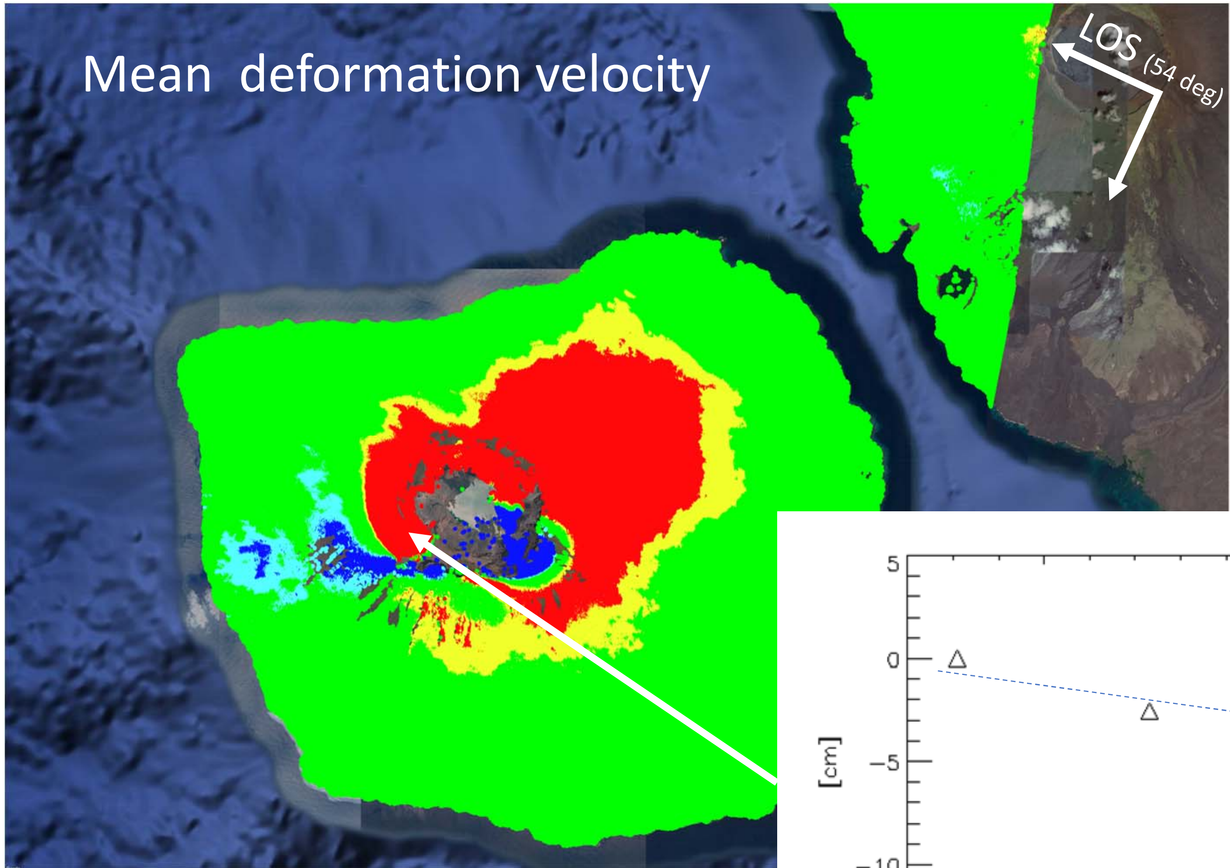


Dataset
CSK data – **descending** orbit
Incidence angle: about **54 deg**
6 acquisitions
From **29 Jul** to **17 Oct 2017**

Eruption on **04 Sept 2017**, lasted **one week**

Information loss on the summit due to decorrelation or too fast deformation

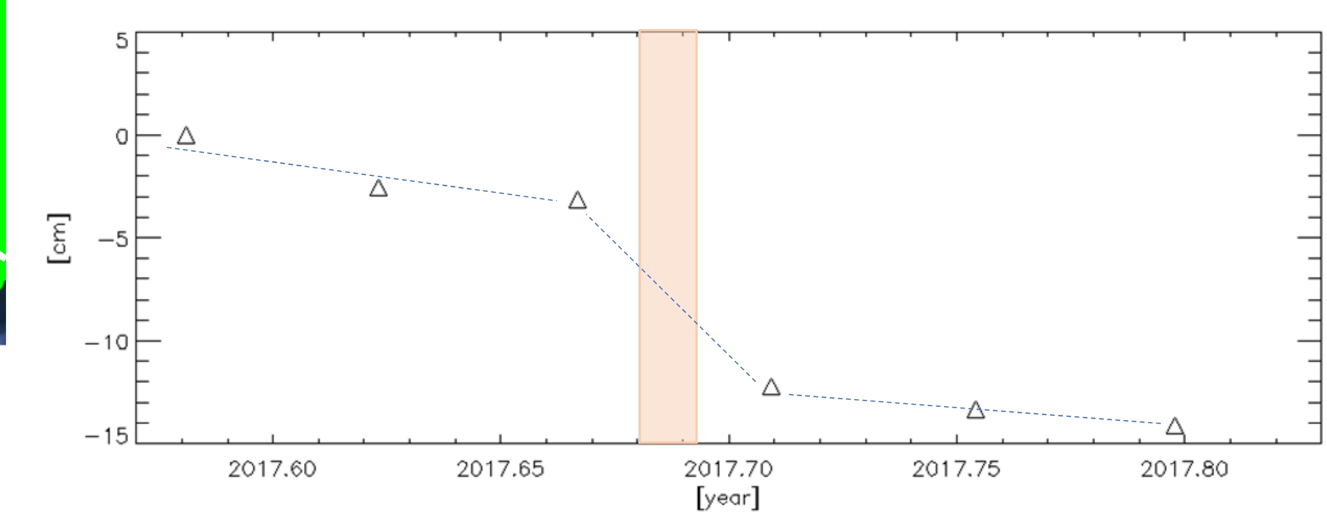
Fernandina (Galapagos) - September 2017 Eruption



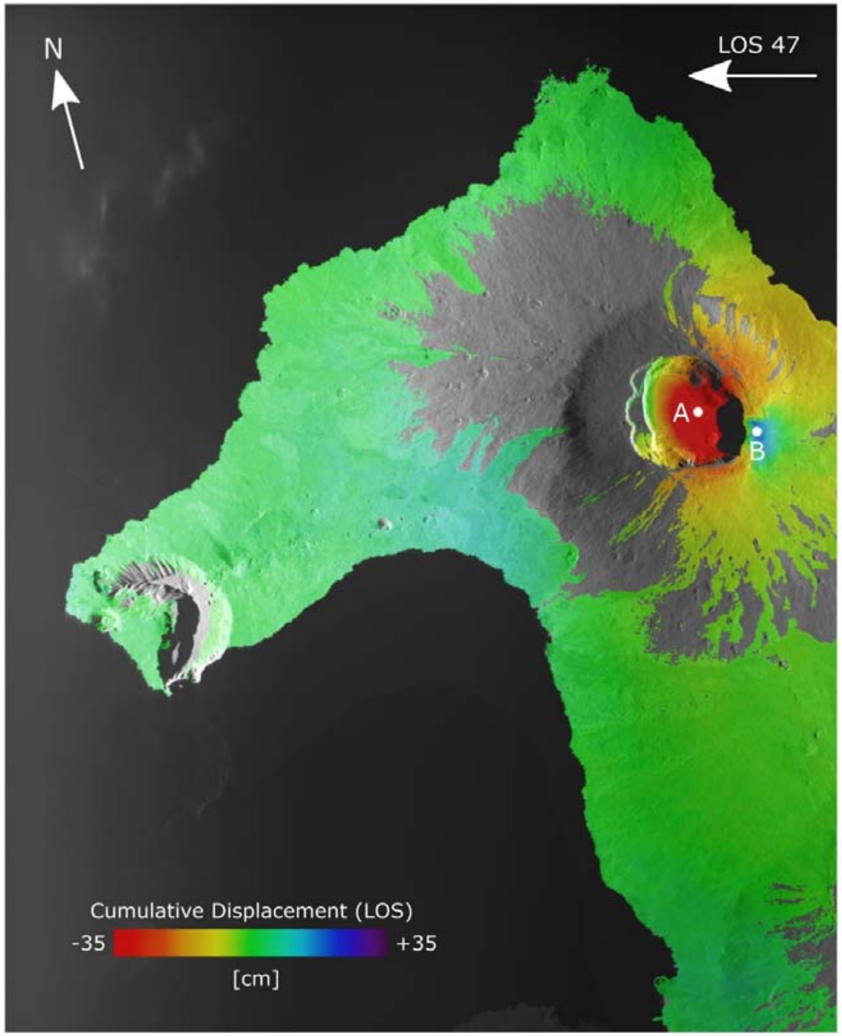
Time series very **preliminary**

Deformation occurred mainly across the eruption time.

Max deformation about **10-15 cm** (where measurable)



Wolf (Galapagos) – 2015 Eruption



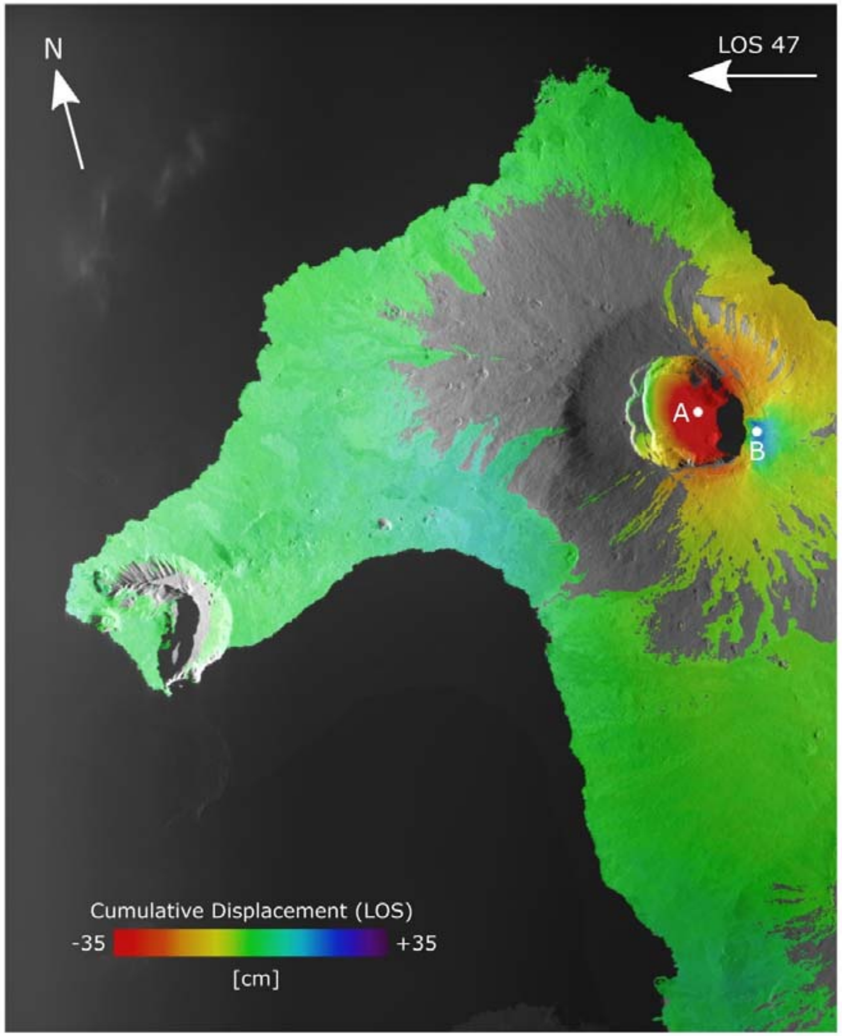
Dataset
CSK data – **descending** orbit
Incidence angle: about **47 deg**
30 acquisitions
From **16 Apr 2014** to **25 Aug 2015**

Eruption activities between **22 May 2015** and **11 Jul 2015**

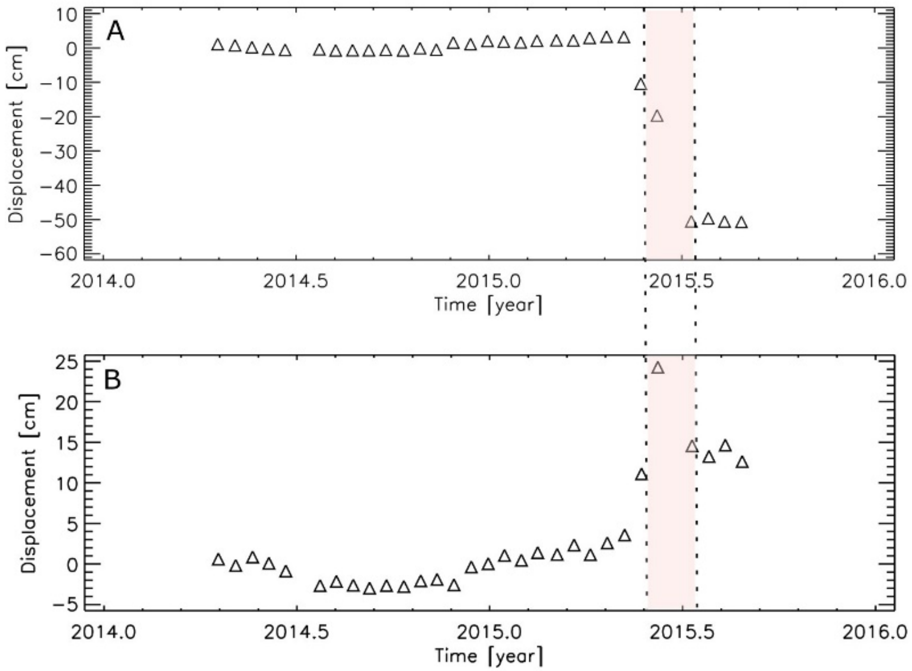
Information loss on the summit due to decorrelation or too fast deformation

From: Pritchard et al., Journal of Applied Volcanology (2018) 7:5 DOI: 10.1186/s13617-018-0074-0

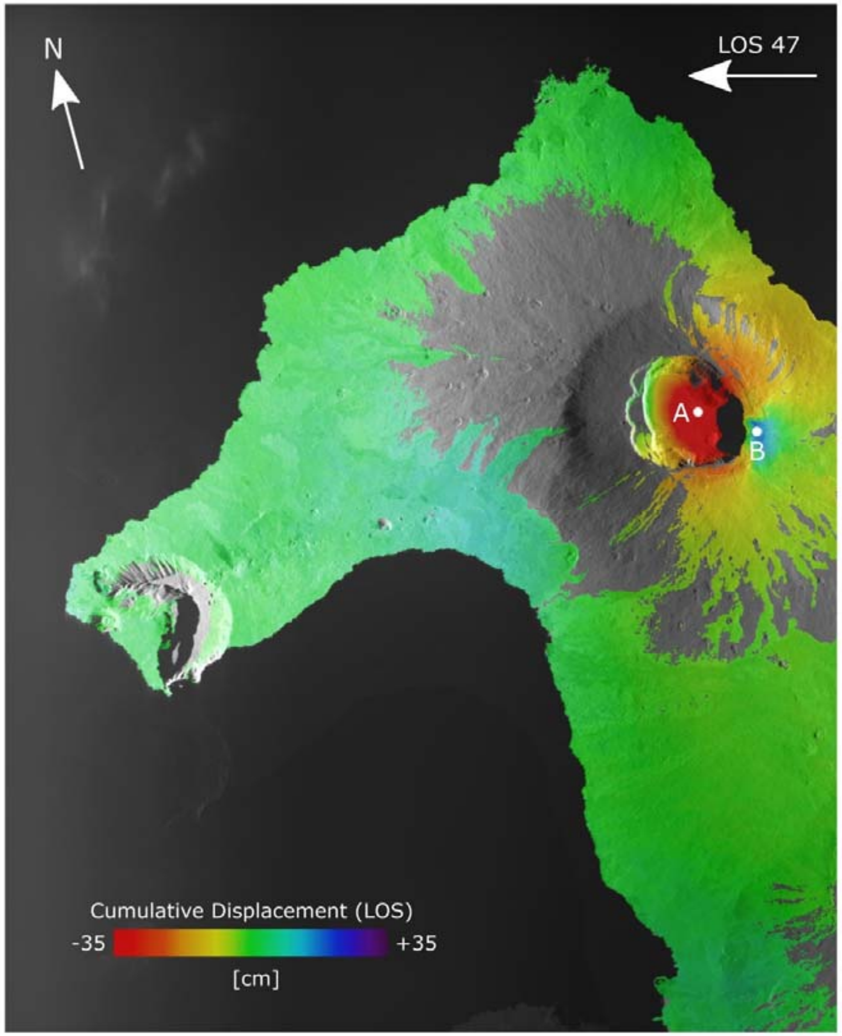
Wolf (Galapagos) – 2015 Eruption



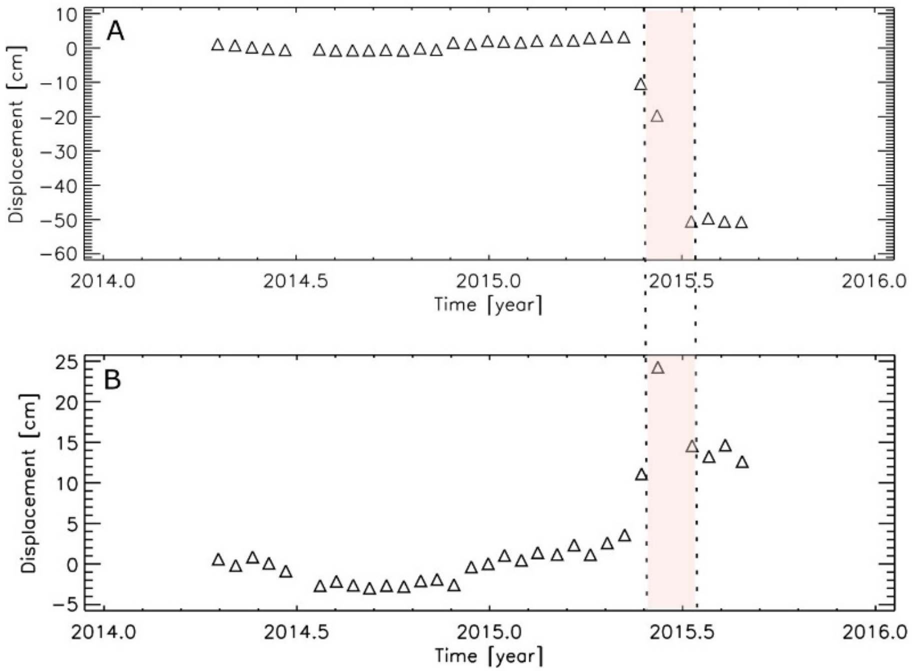
- Most of deformation **across** eruption
- No (or little) deformation before
- Atmospheric filter may have smoothed out some smaller deformation before eruption



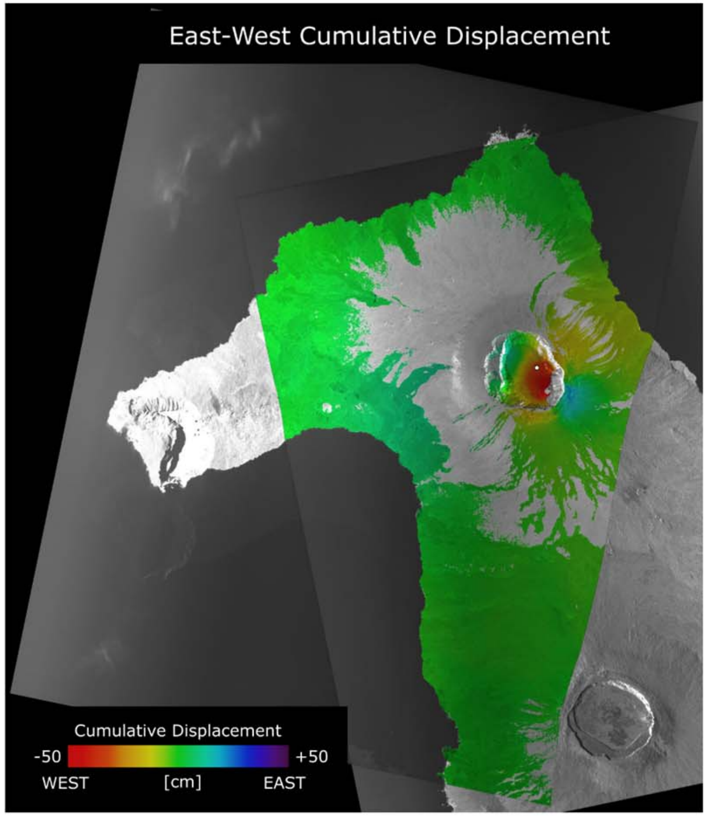
Wolf (Galapagos) – 2015 Eruption

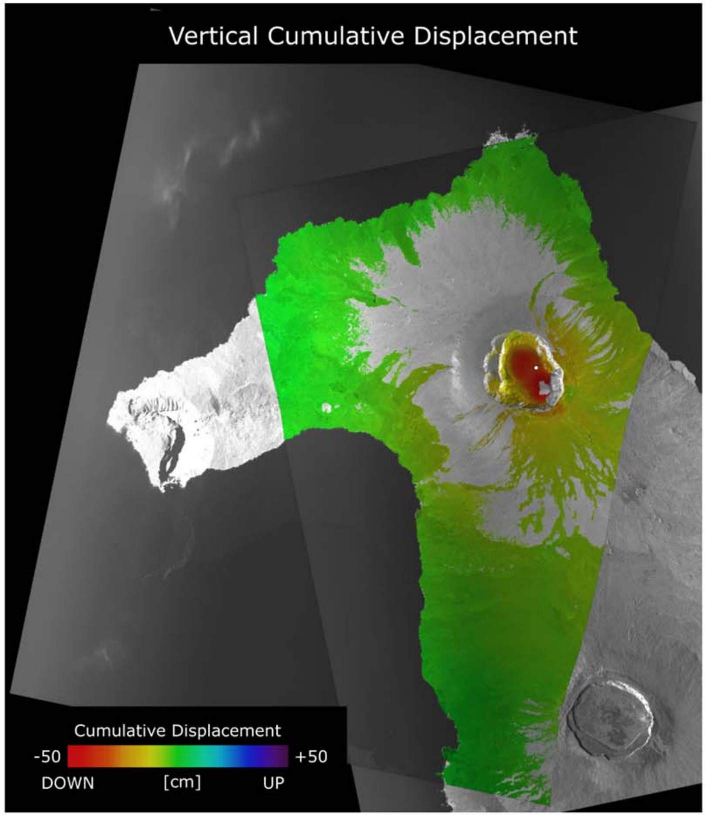


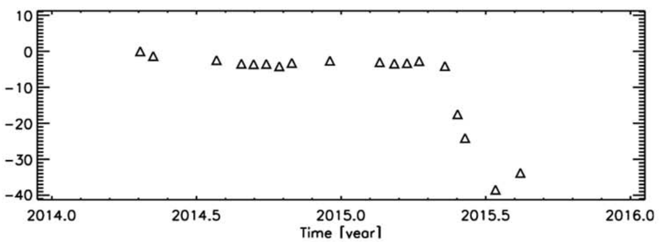
- Maximum (LOS) deformation about 50 cm
- Clear opposite sign deformation on the top
- Area B: recover some deformation or residual (unfiltered) atmospheric effect?

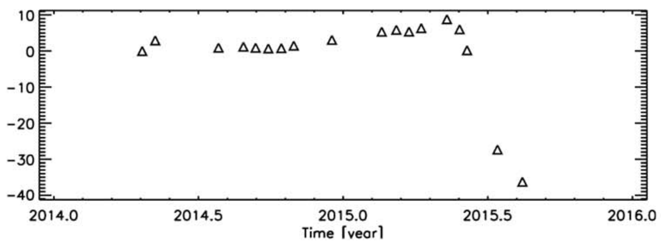


Wolf (Galapagos) – 2015 Eruption









CSK **ascending** and **descending** orbit combination.

Retrieval of **horizontal** (E-W) and **vertical** deformation.

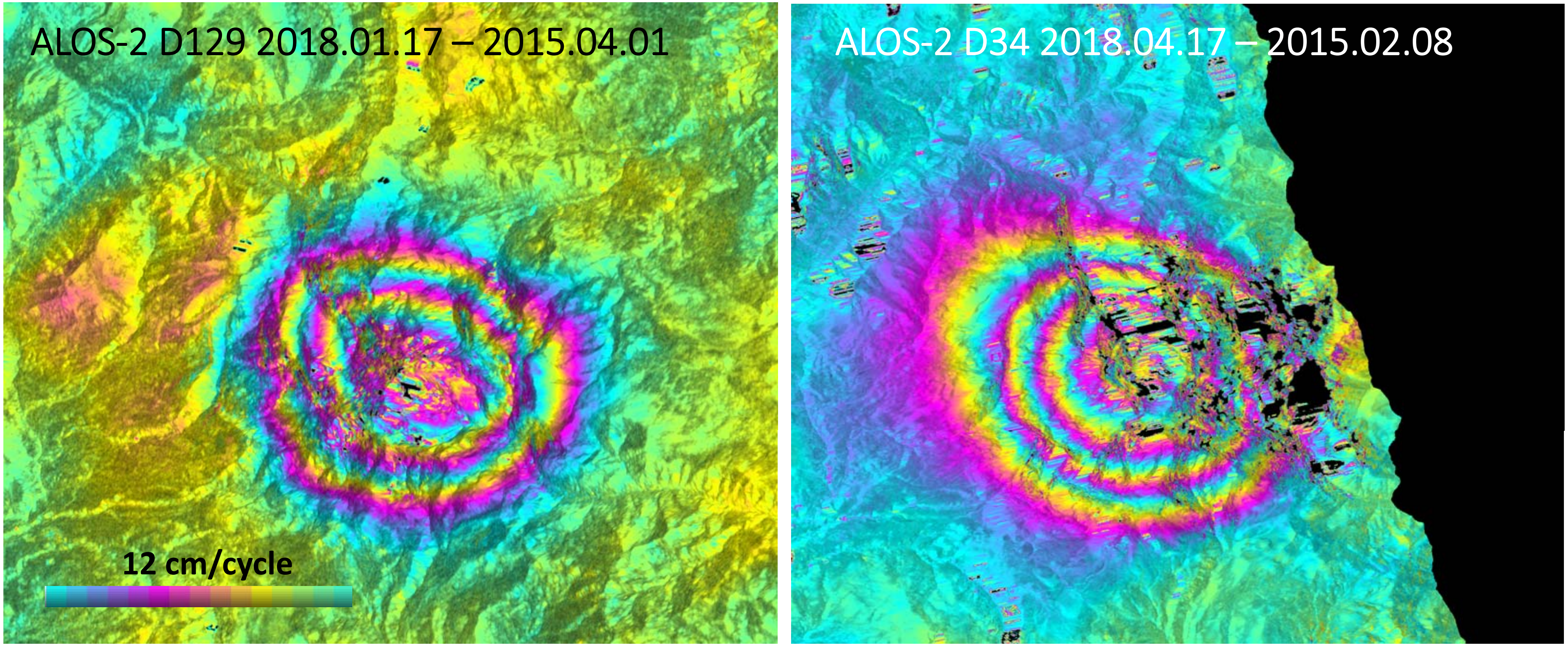
Data show subsidence and “closure*” of the summit caldera

* Eastern part goes west and western goes east

Volcano examples from Latin America

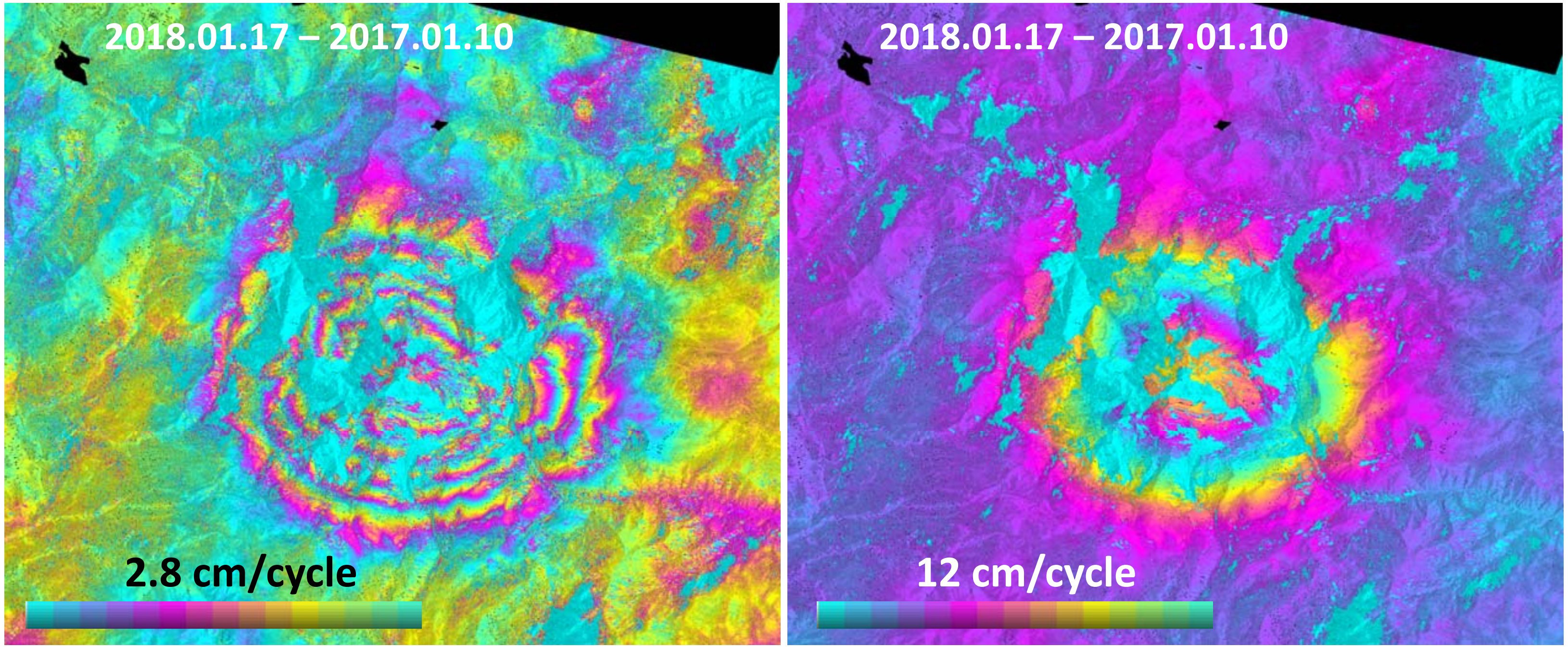
- 2018 eruptions in the Galapagos, Ecuador
- 2014-present inflation of Domuyo, Argentina

New volcano unrest: Domuyo, Argentina ALOS-2 ~3 yeaer interferograms

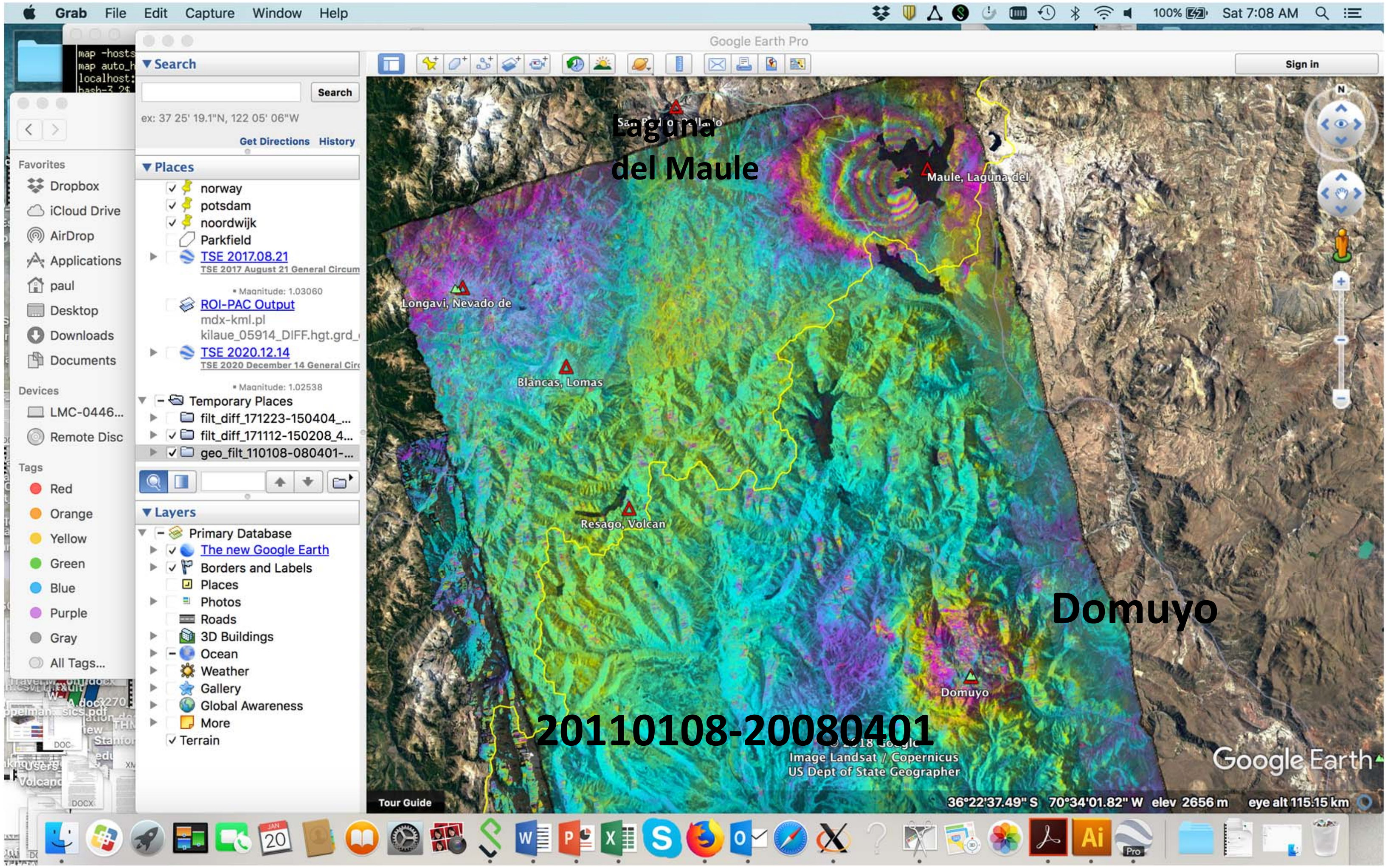


Sentinel-1 D83 1-year interferogram

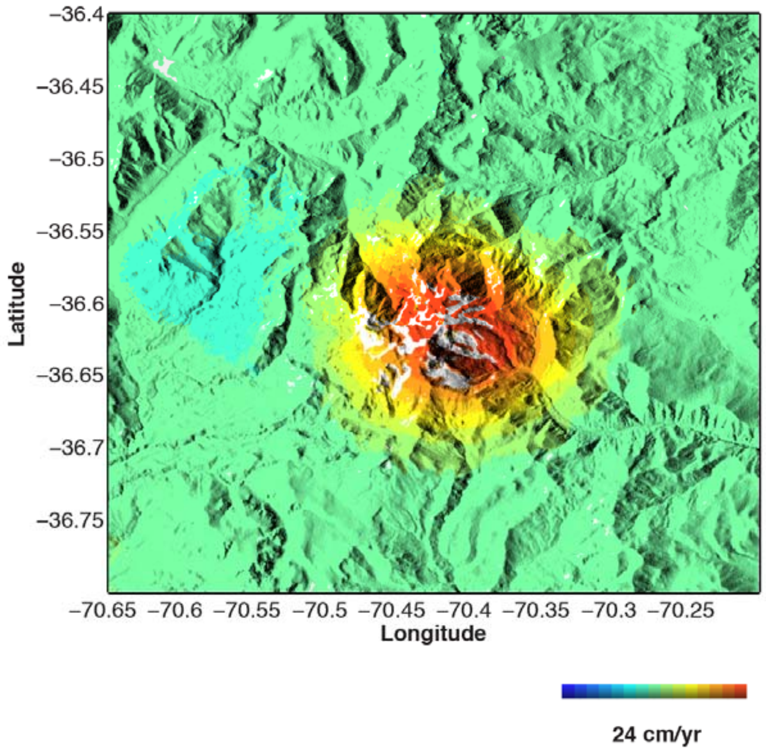
ARIA project performed a rapid response to request for data. Within a few days interferograms spanning 3 years confirmed the ALOS-2 results (special thanks to Hook Hua and Lan Dang at JPL)



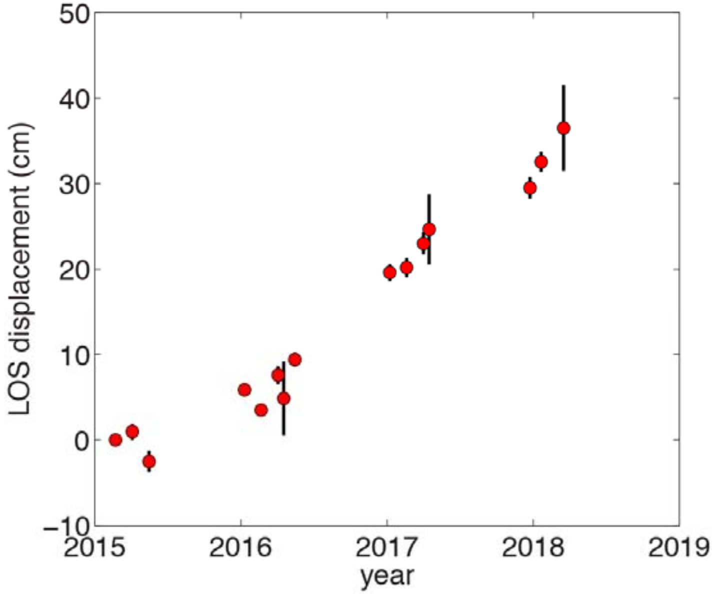
Domuyo ALOS results: Need for deep archives



ALOS-2 D129

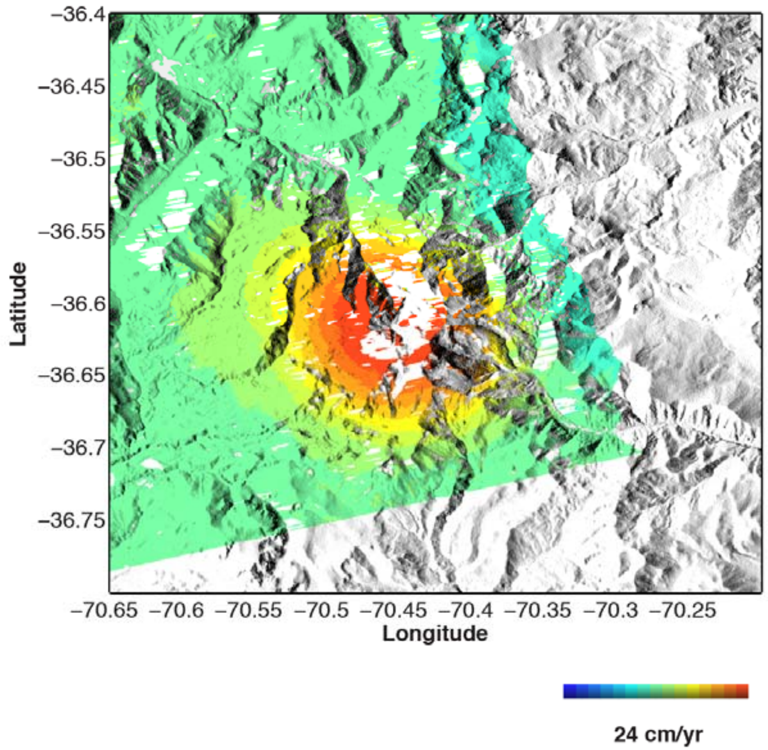


-36.4
-36.45
-36.5
-36.55
-36.6
-36.65
-36.7
-36.75
Latitude
-70.65 -70.6 -70.55 -70.5 -70.45 -70.4 -70.35 -70.3 -70.25
Longitude
24 cm/yr

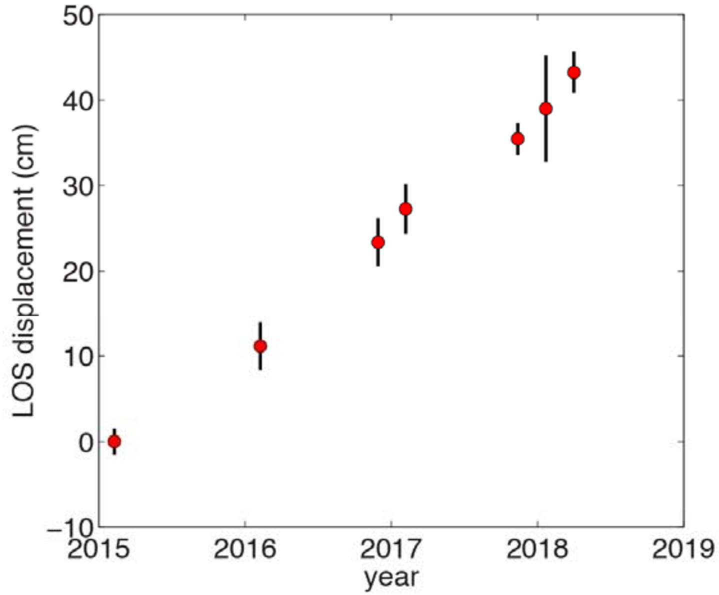


50
40
30
20
10
0
-10
LOS displacement (cm)
2015
2016
2017
2018
2019
year

ALOS-2 A34



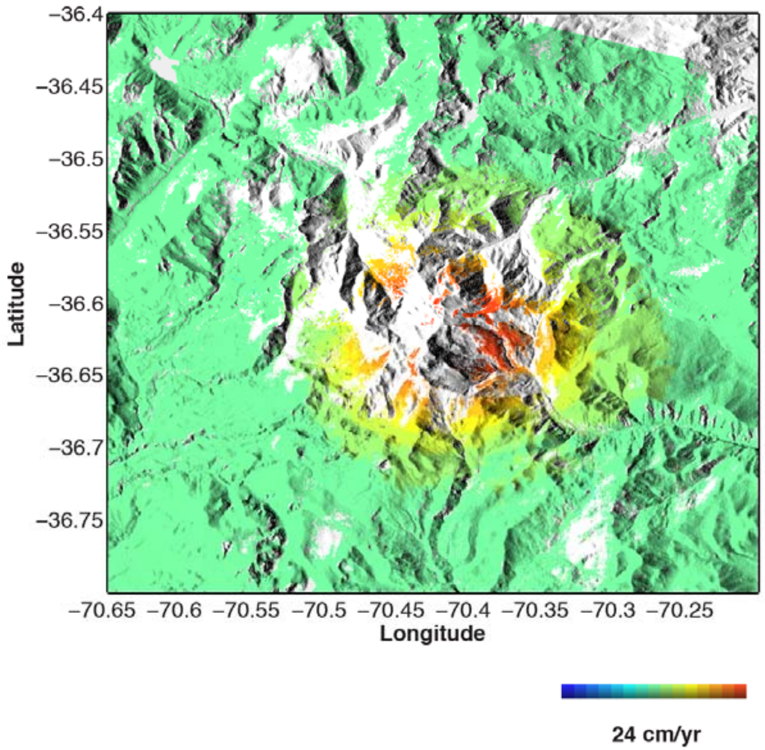
−36.4
−36.45
−36.5
−36.55
−36.6
−36.65
−36.7
−36.75
Latitude
−70.65 −70.6 −70.55 −70.5 −70.45 −70.4 −70.35 −70.3 −70.25
Longitude
24 cm/yr

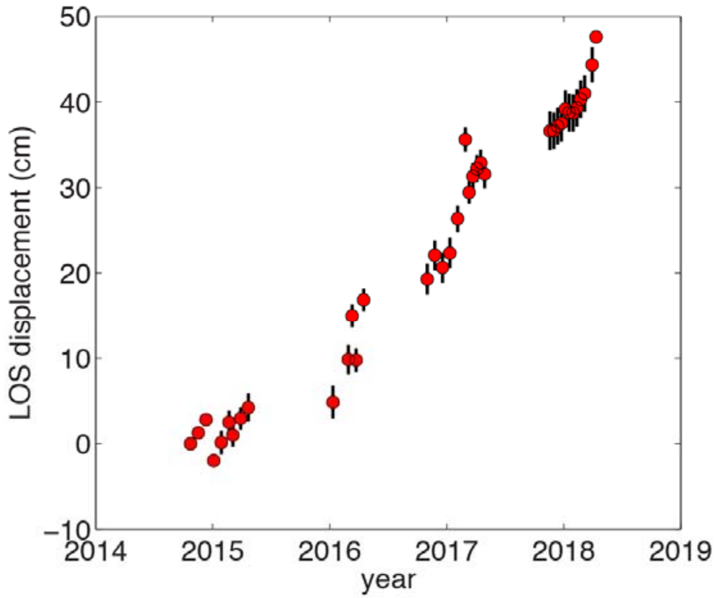


50
40
30
20
10
0
−10
LOS displacement (cm)
2015
2016
2017
2018
2019
year

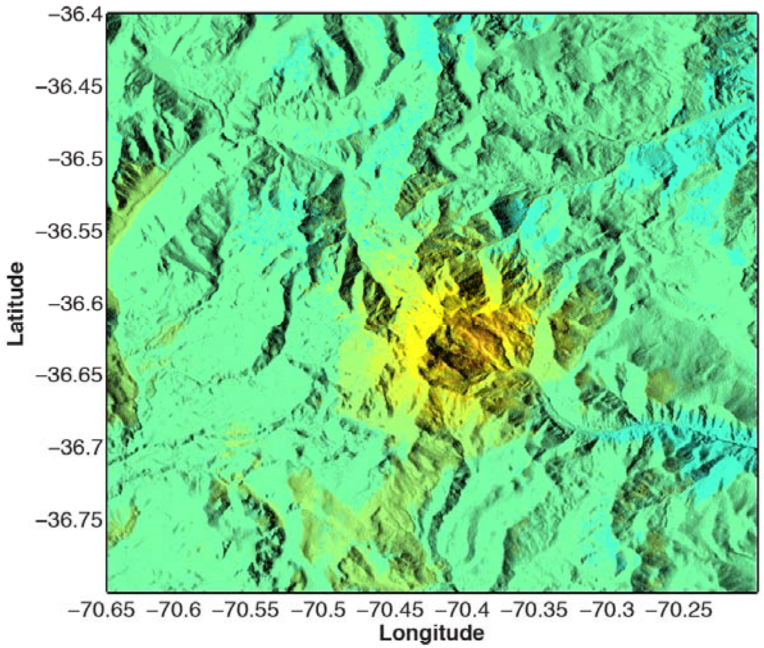
InSA

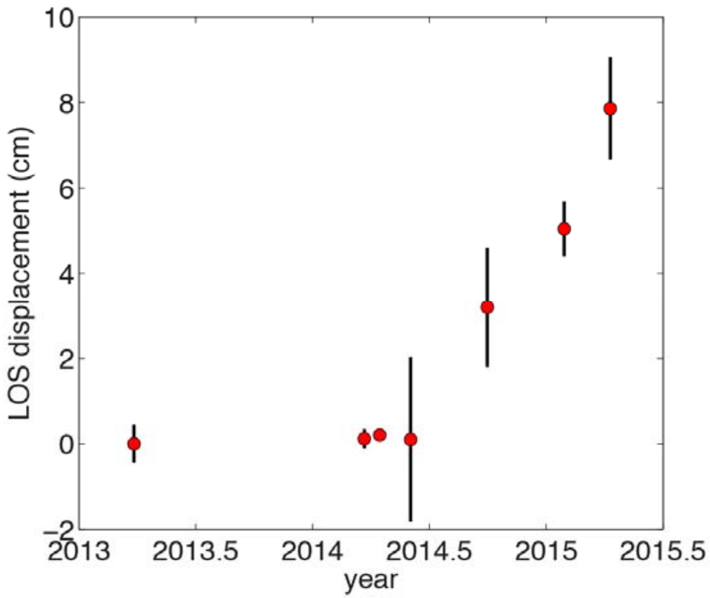
Sentinel-1 D83





RADARSAT-2 F0W2





RADARSAT-2 interferograms provided by Sergey Samsonov, Canada Centre for Mapping and Earth Observation, Natural Resources Canada

Nevado del Ruiz, Colombia

- InSAR showed that deformation was centered 10 km SW of summit
- All in-situ GPS stations were moving together to the NE
- InSAR can give broad-scale awareness of deep source activity

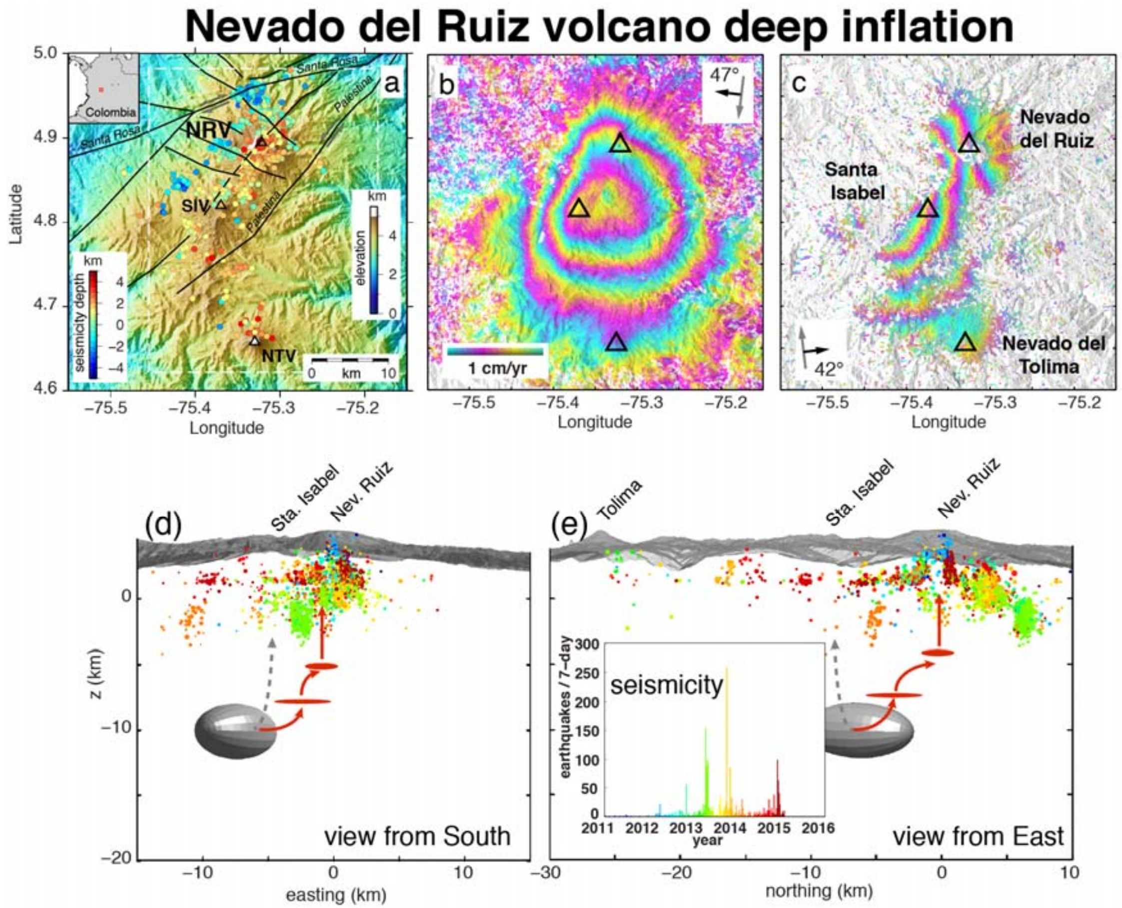


Figure 1. Nevado del Ruiz volcano, Colombia (a) Inflation and summit activity began in early 2012 and continues into 2015. RADARSAT-2 InSAR time series and interferogram data (b-c) revealed a broad pattern of inflation centered well south of Ruiz. Markov chain Monte Carlo (MCMC) modeling found a source 10 km SSW of Ruiz at over 14 km beneath the 4.2 km average of the InSAR data elevation (d-e). Stress analysis suggests that propagating dikes would be trapped as sills (red ellipses), thus favoring lateral transport as magma buoyancy eventually overcomes background compressive stresses (red arrows). Seismicity is much shallower than this source, with early activity near Ruiz, and later activity occurring at both Ruiz and farther SW.