Towards global InSAR deformation monitoring of volcanoes

insarmaps.miami.edu

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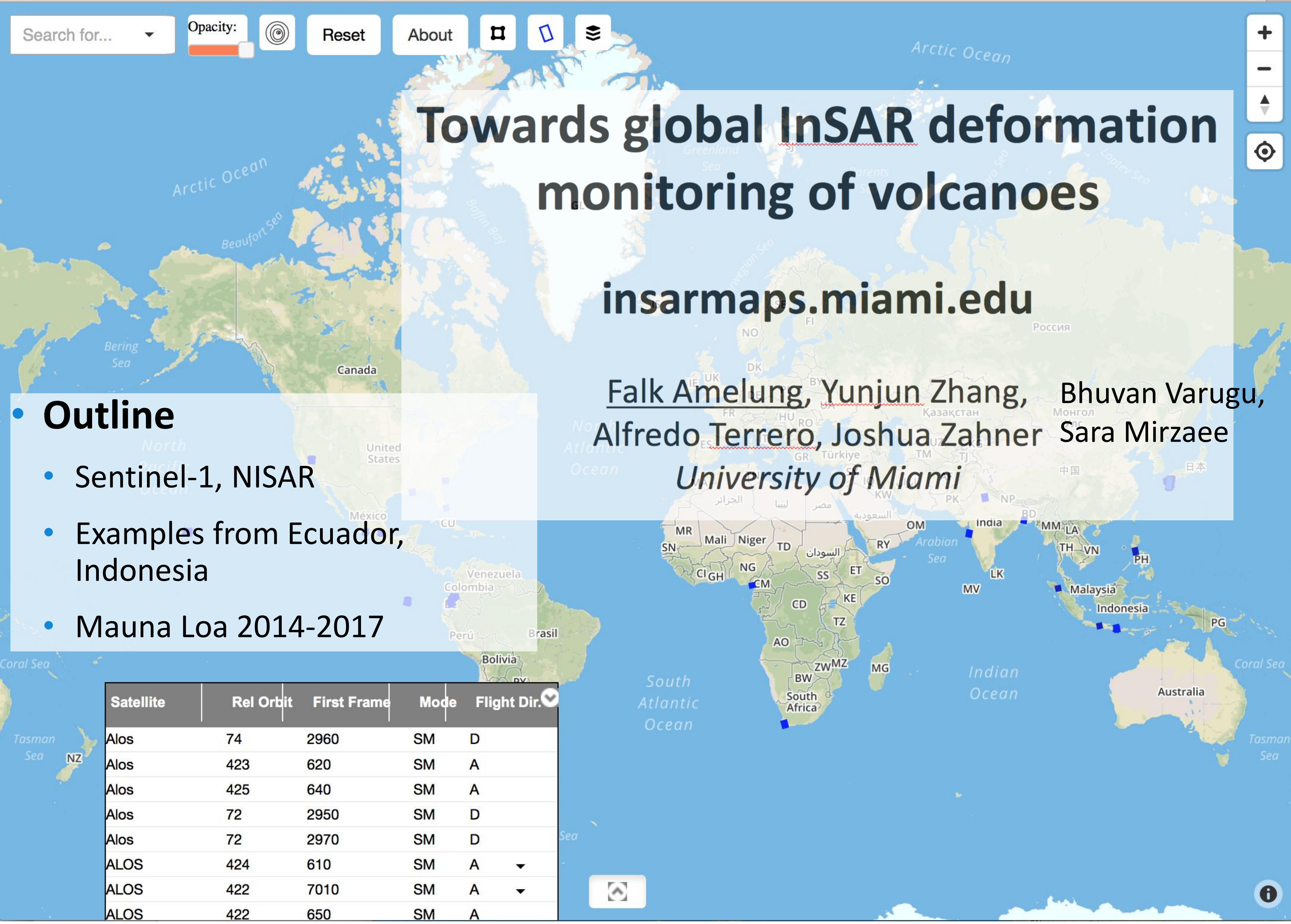
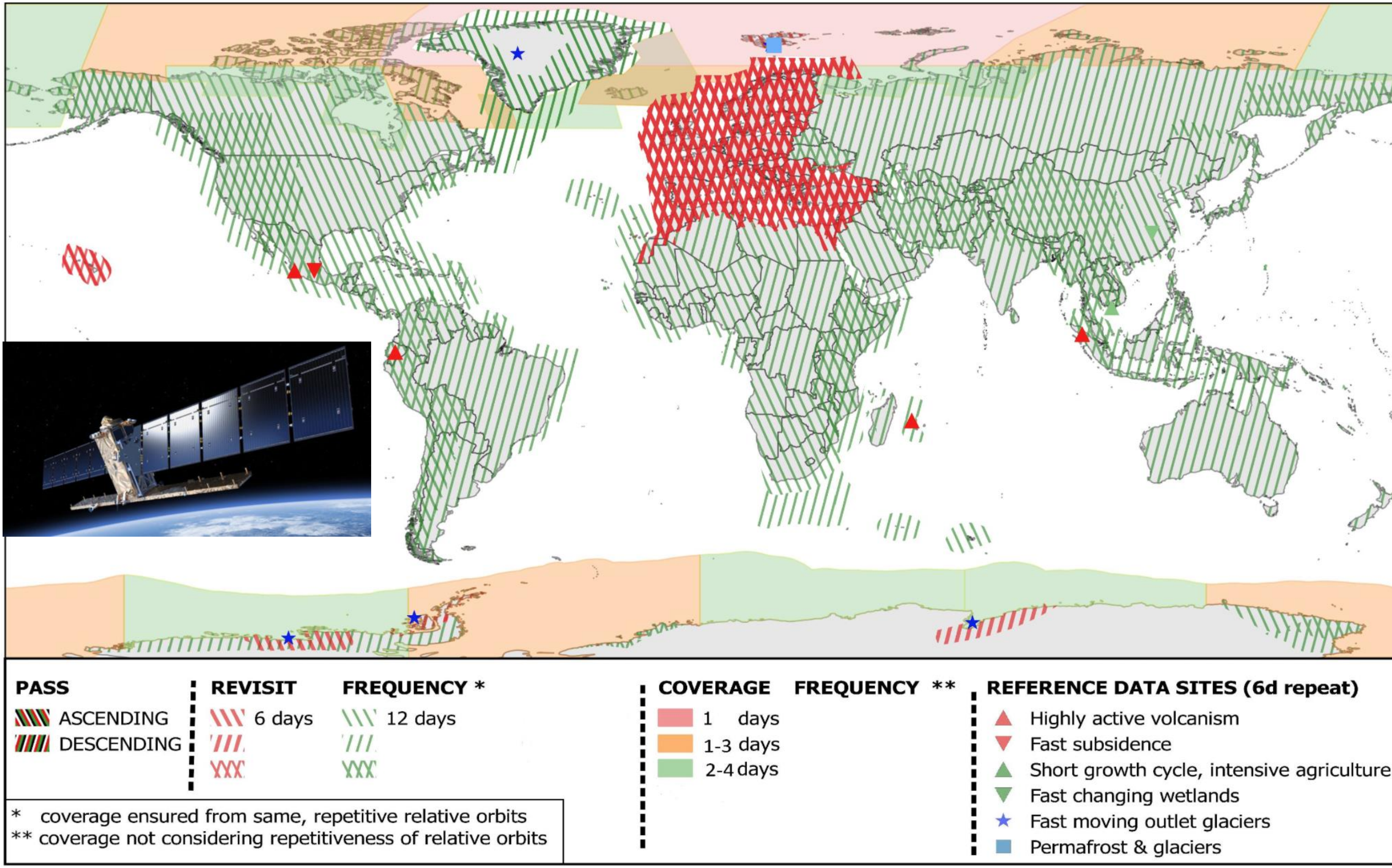
- **Outline**
  - Sentinel-1, NISAR
  - Examples from Ecuador, Indonesia
  - Mauna Loa 2014-2017



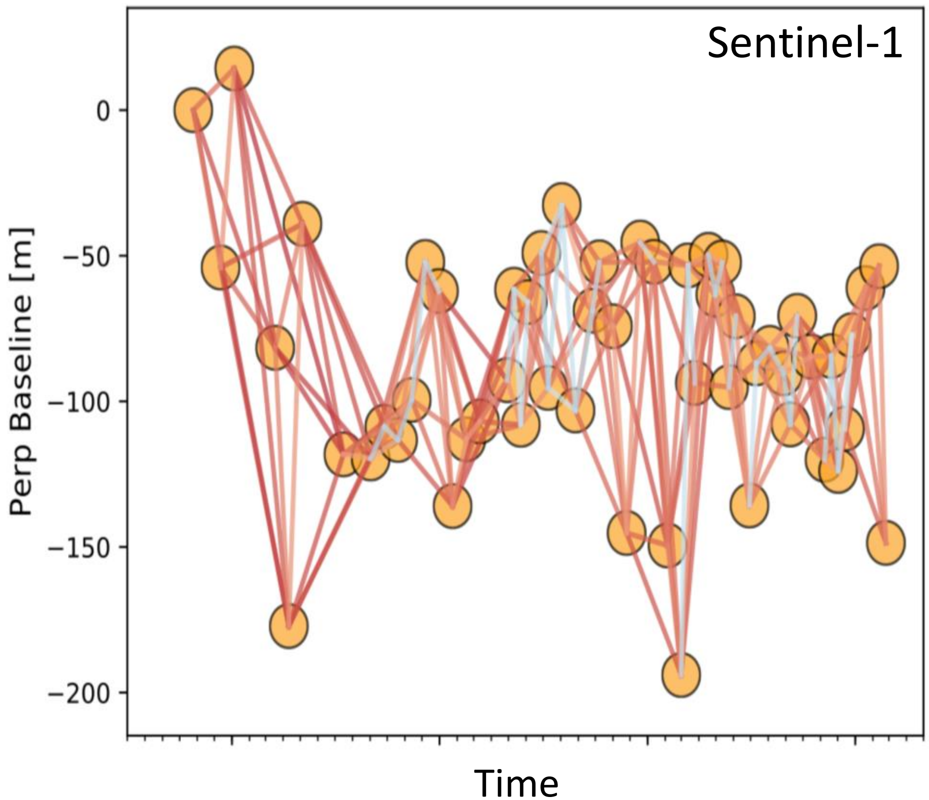
Satellite	Rel Orbit	First Frame	Mode	Flight Dir.
Alos	74	2960	SM	D
Alos	423	620	SM	A
Alos	425	640	SM	A
Alos	72	2950	SM	D
Alos	72	2970	SM	D
ALOS	424	610	SM	A
ALOS	422	7010	SM	A
ALOS	422	650	SM	A

Global SAR coverage with Sentinel-1



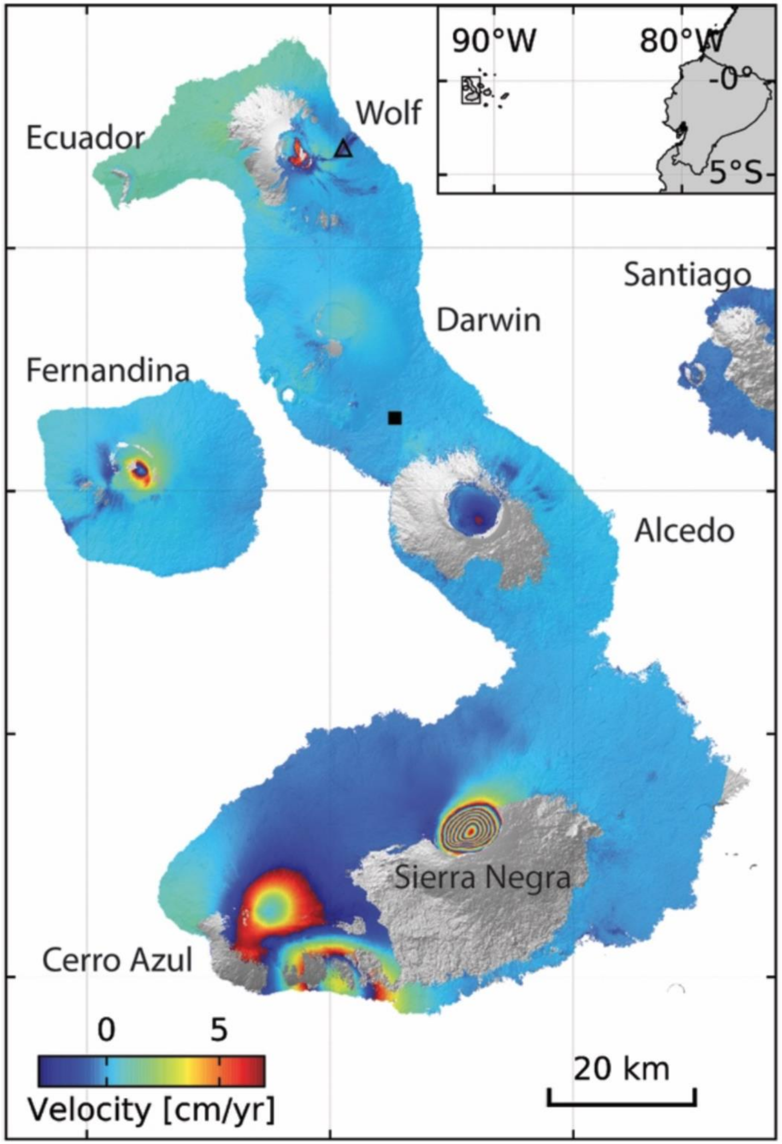
InSAR time series analysis

Network of SAR acquisitions



Distributed Scatterer Method

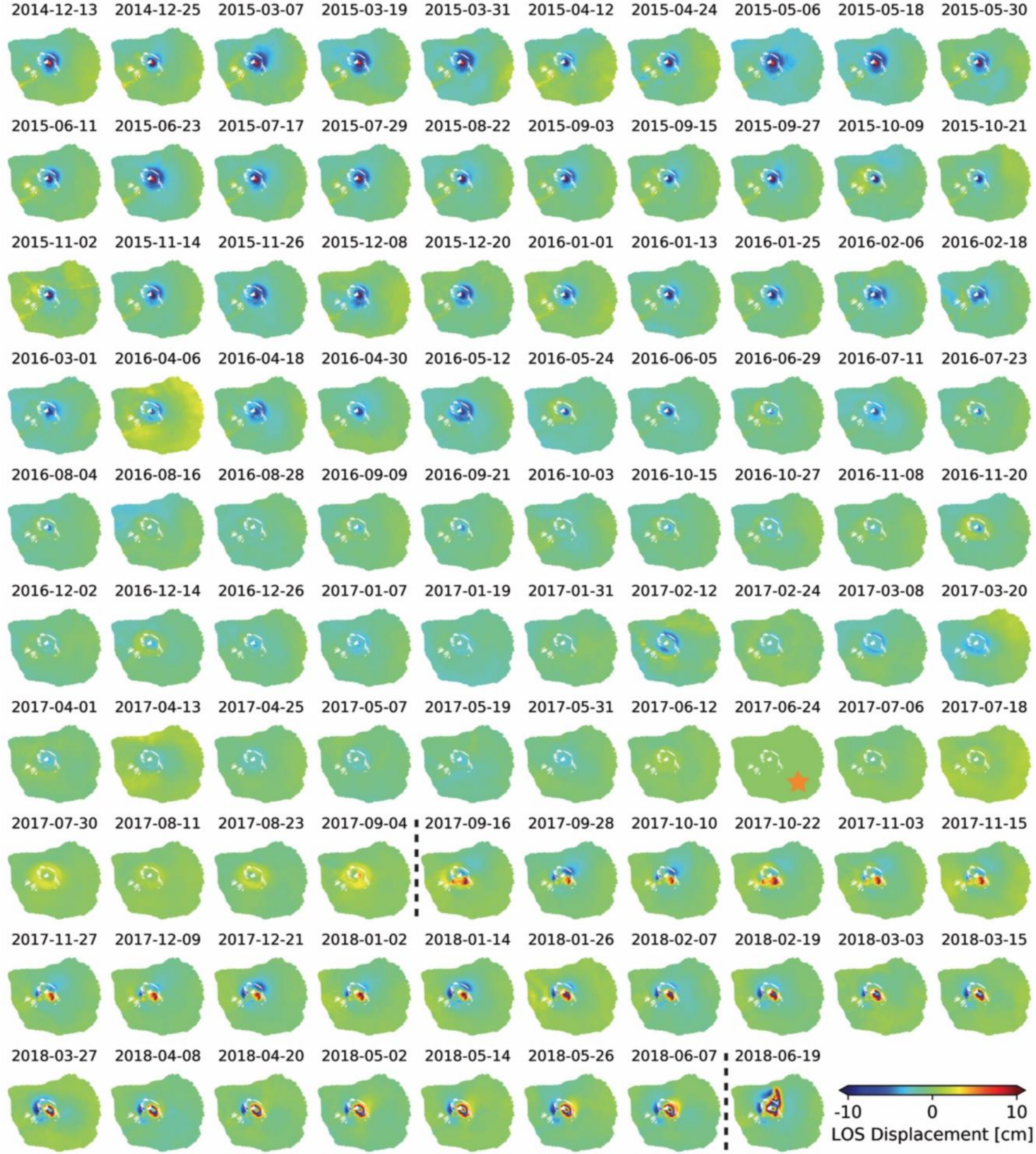
LOS velocity (and time series)



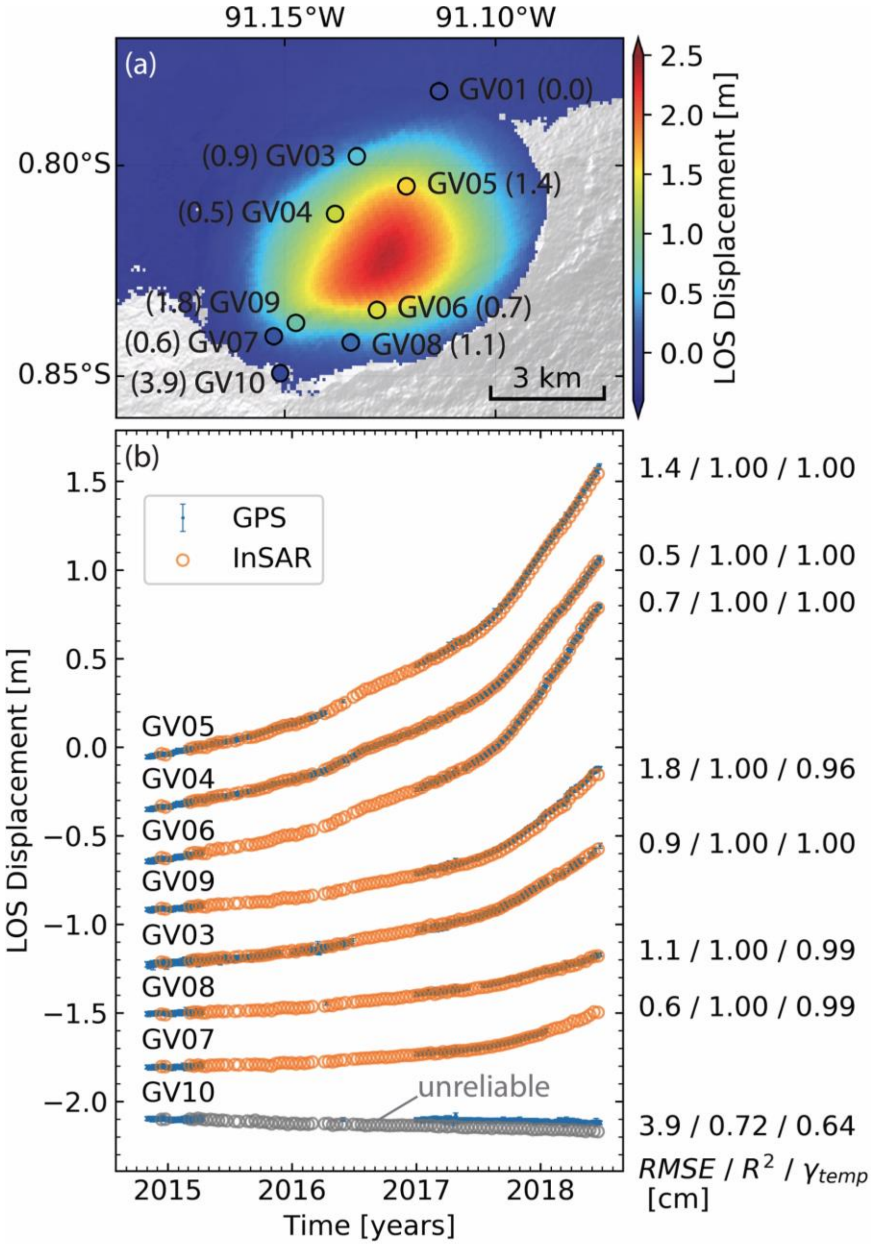
One measurement every 6-12 days

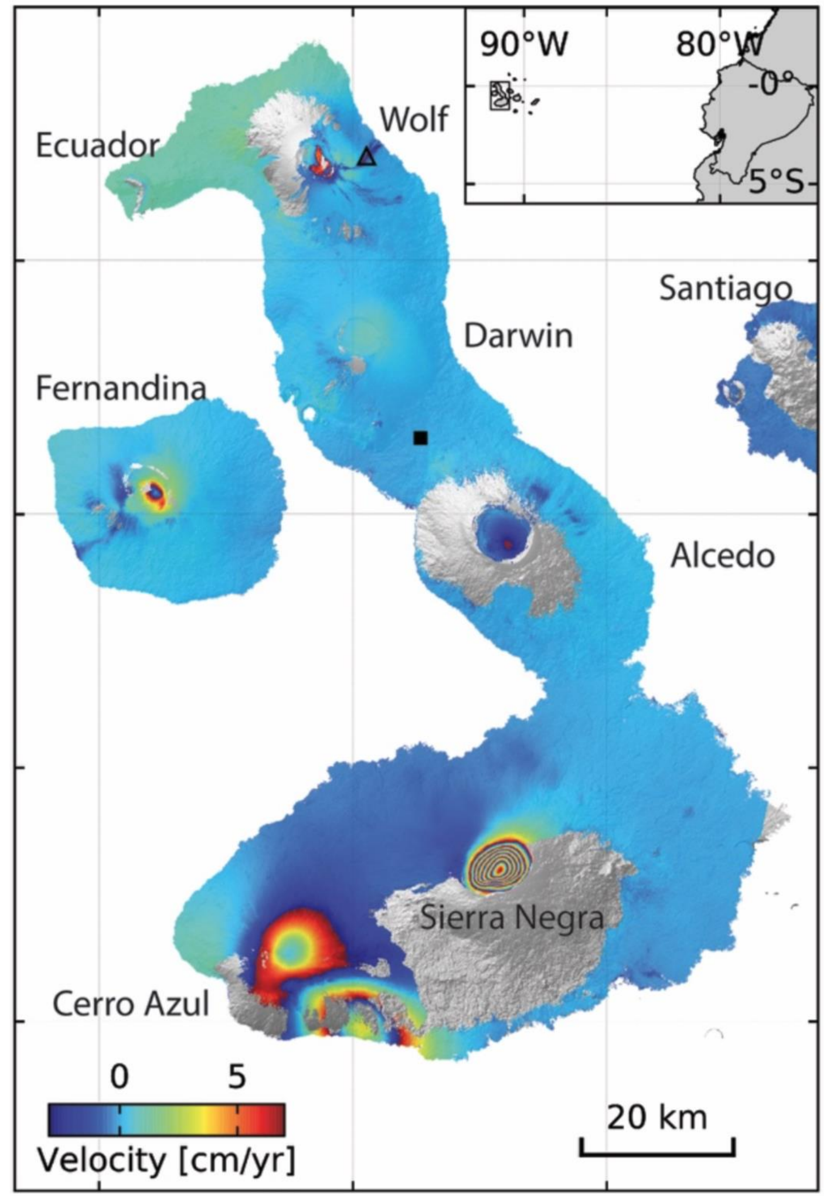
Continuous InSAR Timeseries (C-InSAR)

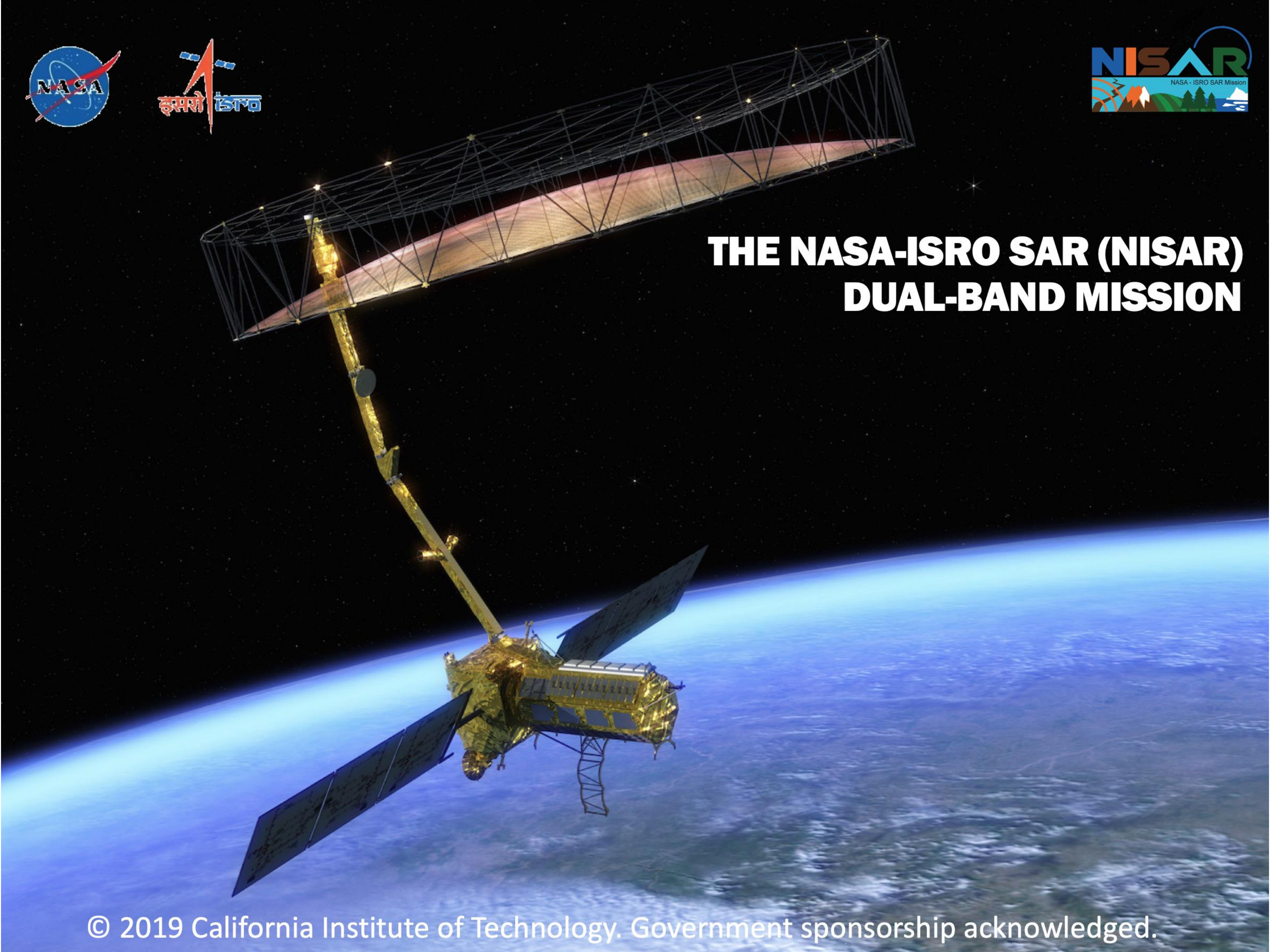
200 acquisitions acquired for Europe (ascending plus descending)



InSAR time series analysis






THE NASA-ISRO SAR (NISAR)
DUAL-BAND MISSION
NASA - ISRO SAR Mission
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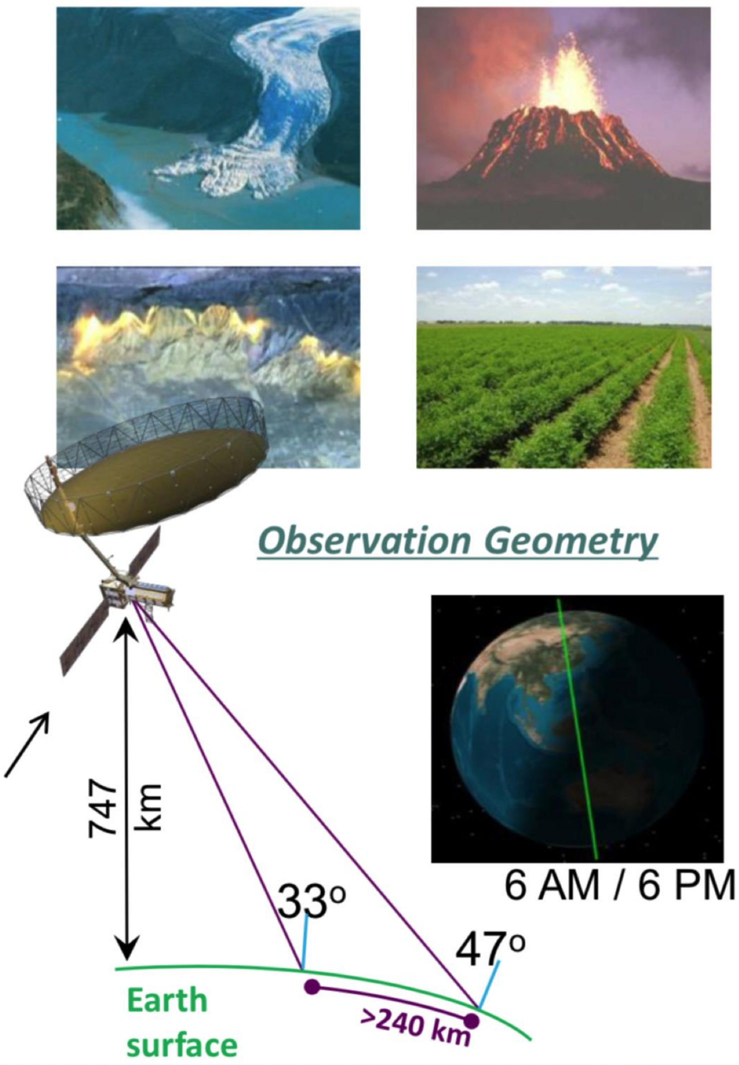
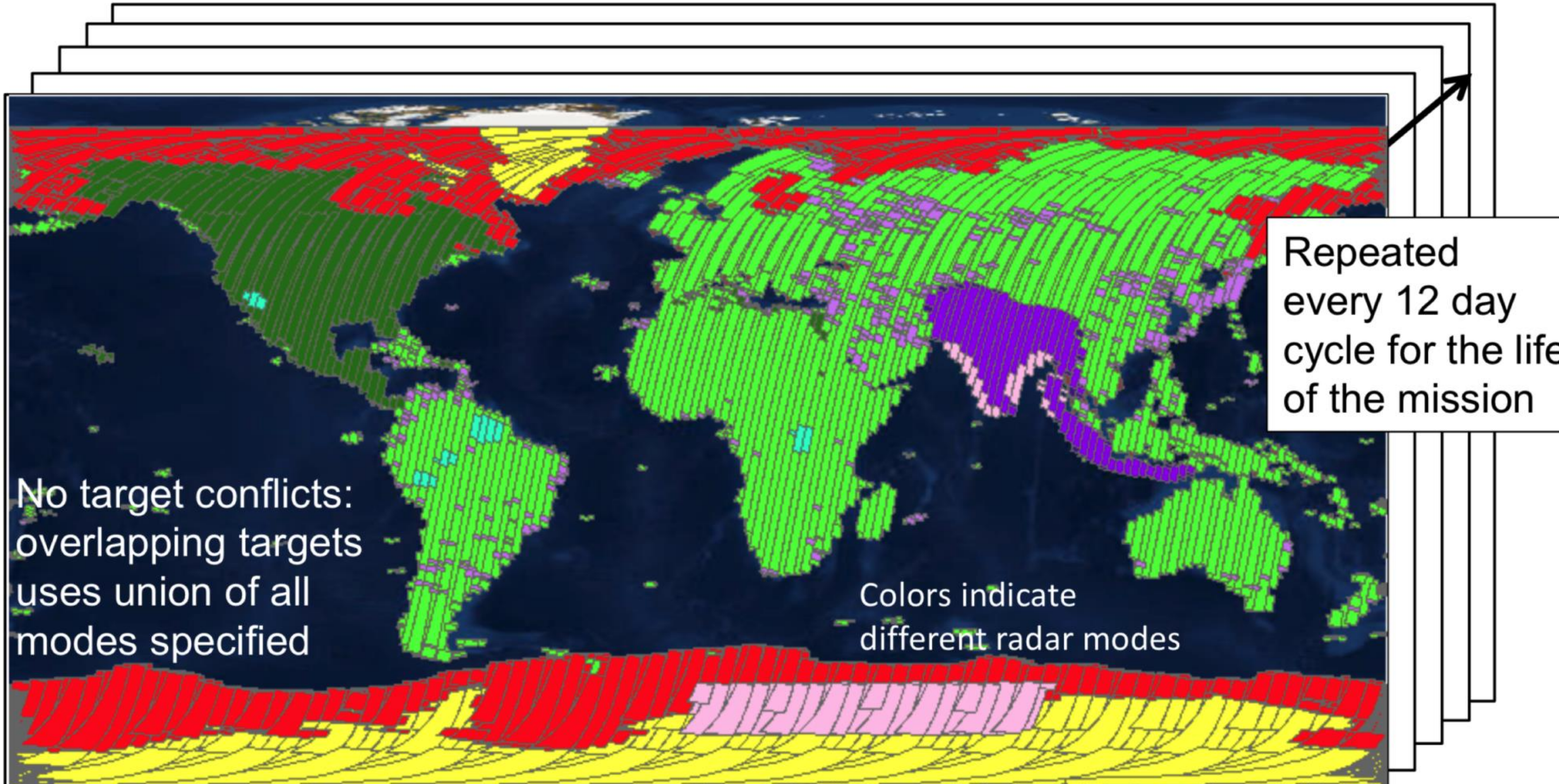
NISAR Science Observations Overview

NISAR Characteristic:	Enables:
L-band (23 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 yrs (NASA) / 5 yrs (ISRO) science operations	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 10% (S) / 50% (L) observation duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series Rely on Sentinel-1 for Arctic

NISAR Will Uniquely Capture the Earth in Motion



NISAR Systematic Observations
L-band globally – S-band over selected areas



J. Doubleday
P. Sharma, JPL

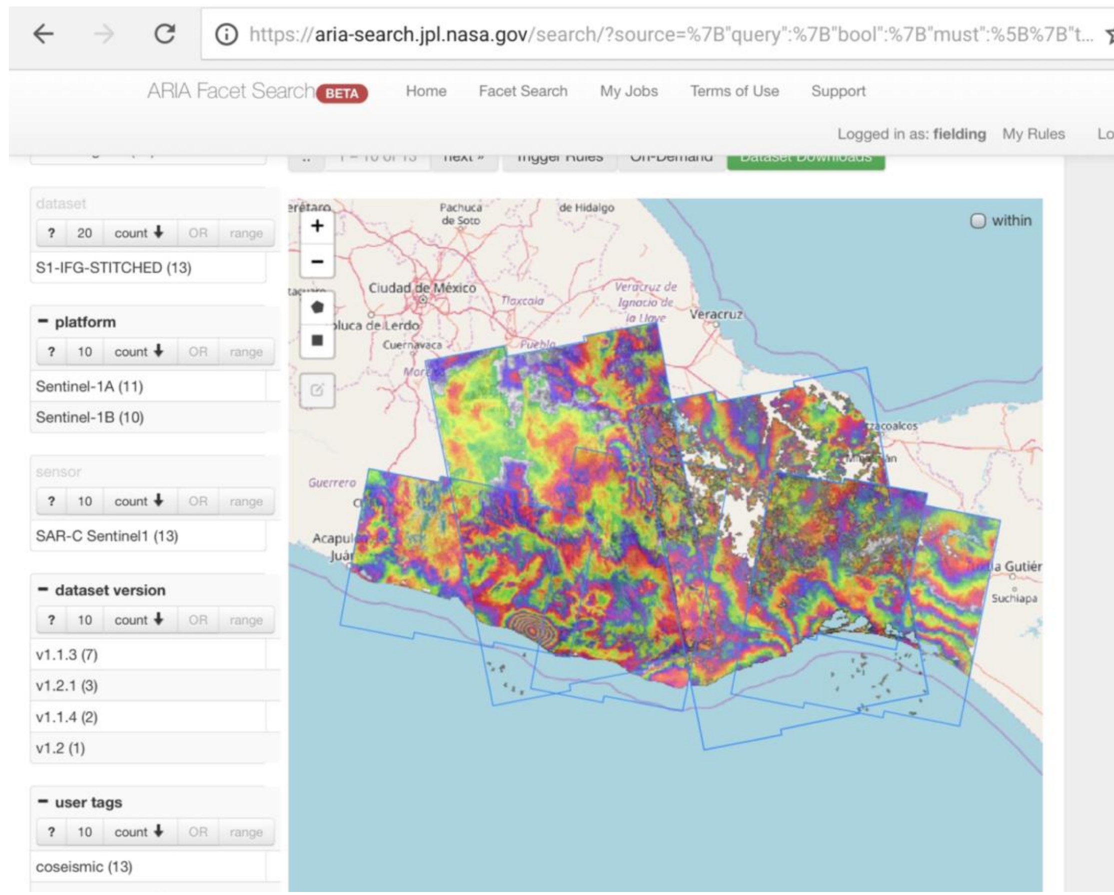
Persistent updated measurements of Earth
41 Tbits / day total L+S band science data downlink
120 Tbytes / day total L+S band L0-L2 data products

NISAR Data Products: Available from the Cloud

- L0, L1, L2 data products: SLCs, terrain-corrected SLCs, interferograms (unwrapped).
- Open and Free. From the Cloud (distributed by the ASF).

New for NiSAR:

- Geocoded SLCs and interferograms.
- On-demand processing on the Cloud: allows users to satisfy their needs
- (Custom-on-demand capability)



Relevance of GPS

- Cal-Val of geod. measuremnts
- Tropospheric correction (Ionospheric correction?)

Rosen

NISAR Science User’s Handbook

Describes:

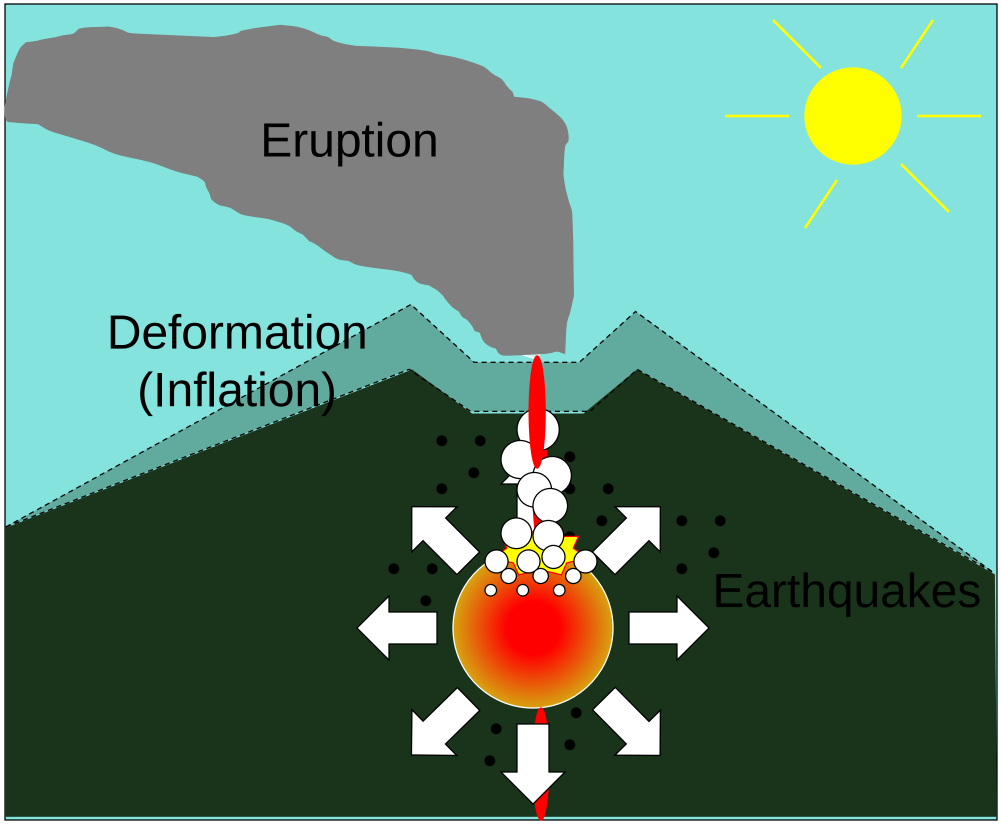
- Science and Applications
- Mission Science Requirements
- Mission Design and CONOPS
- Flight System Characteristics
- Radar and Measurement Principles
- Data Products
- Will be revised prior to launch or as necessary

Other major documents:

- Cal/Val Plan
- Utilization Plan
- Application Workshop Reports
- 21 science and applications white papers

What happens before an eruption?

- Deformation can be one of the first signs of impending eruptions, along with earthquakes and degassing



Ecuador's Cotopaxi volcano may threaten 325,000 people

18 August 2015 | Latin America & Caribbean

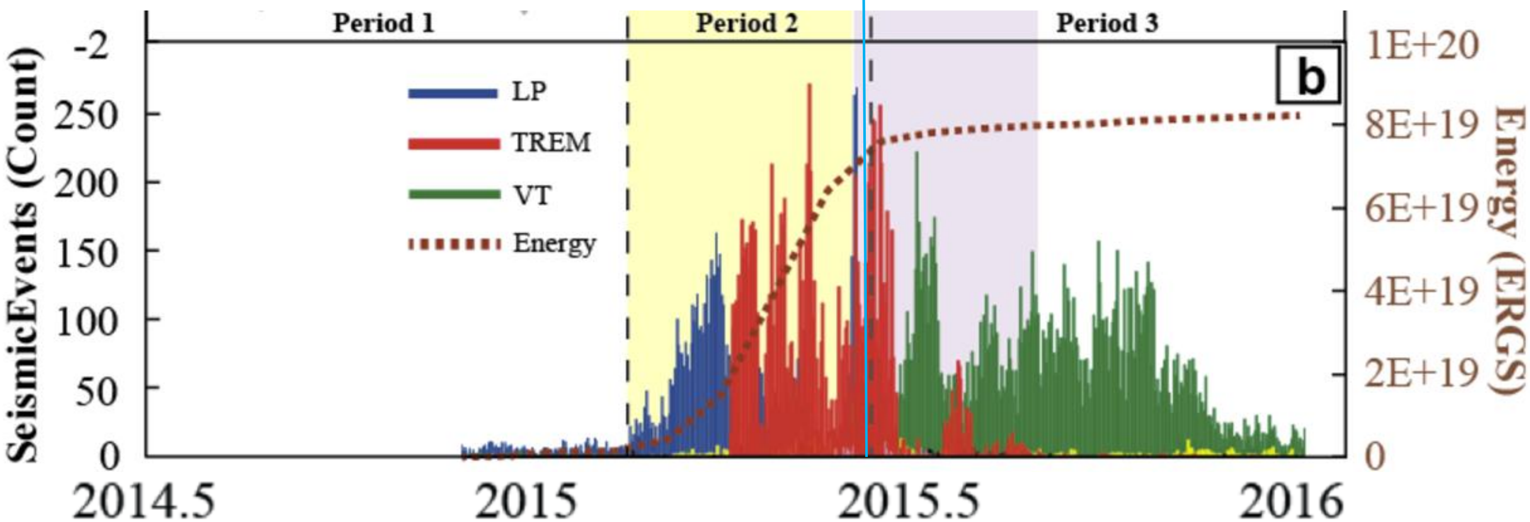
The 2015 crisis of Cotopaxi volcano,

<u>Concerns:</u>

- many fatalities from 1877 eruption
- lahars (can go to the coast)

Seismicity

Start of
eruption

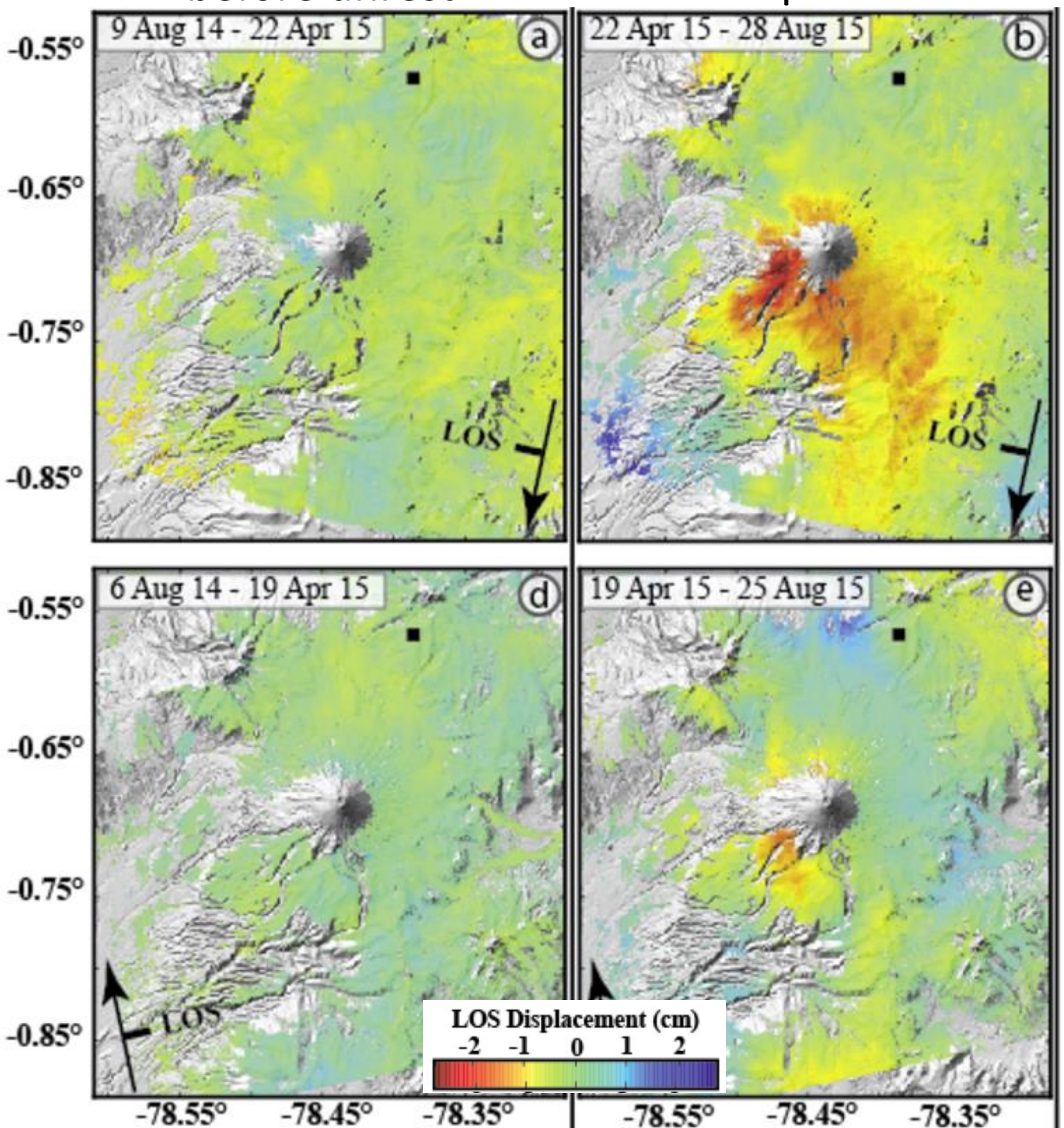


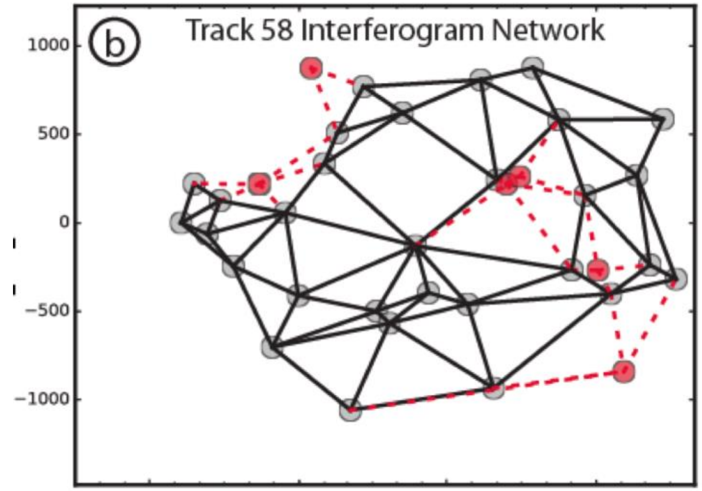
Concurrent seismicity increase and inflation at station MORU (InSAR and GPS)

Morales Rivera et al., 2017

Precursory inflation from InSAR time-series

before unrest | unrest period





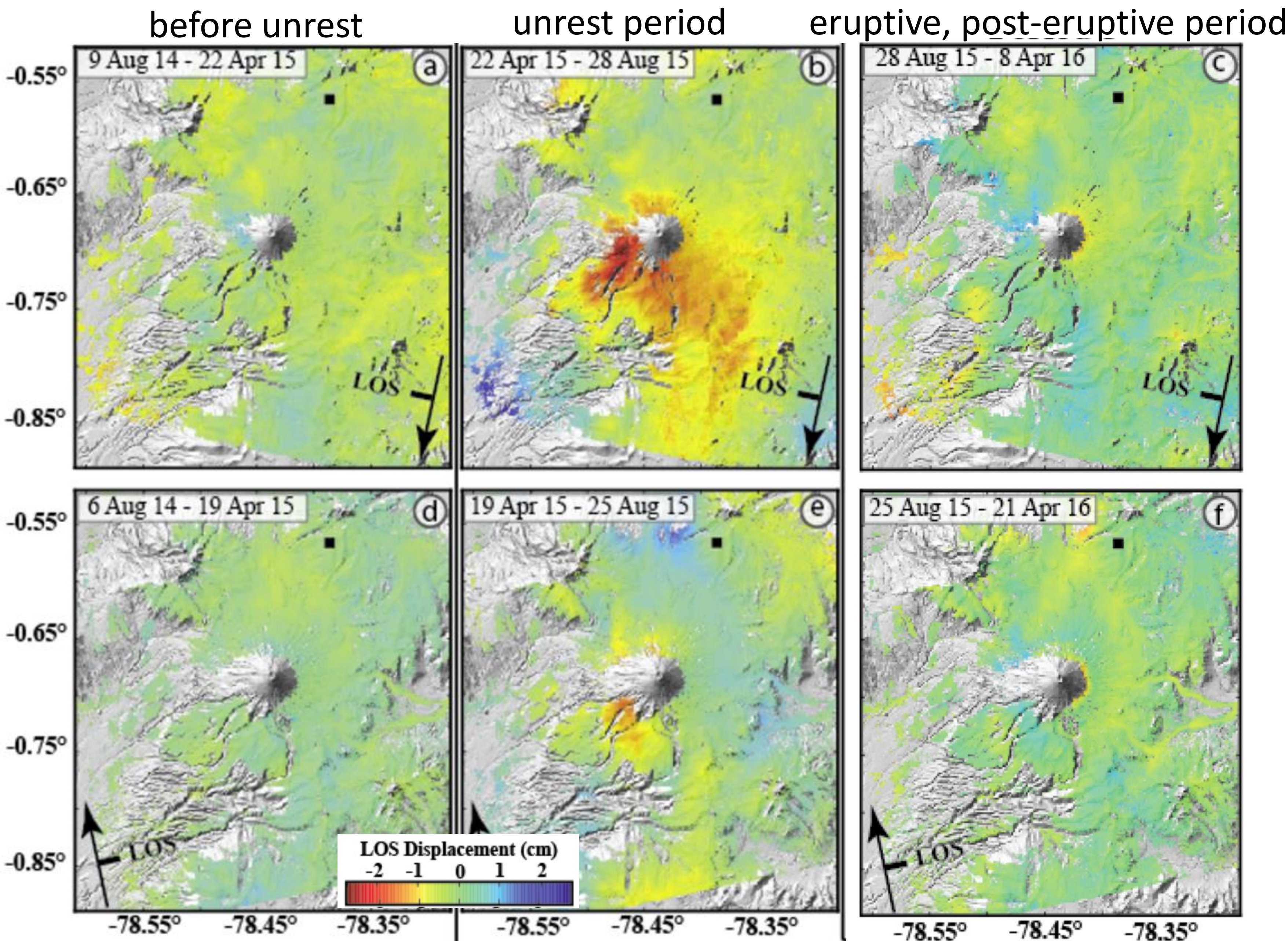
Data used: 70 Cosmo-Skymed SAR images from Geohazard Supersites initiative

Morales Rivera, Amelung et al., GRL in review

<u>Key findings:</u>

- InSAR detects 3 cm inflation on SW flank **before** eruption.

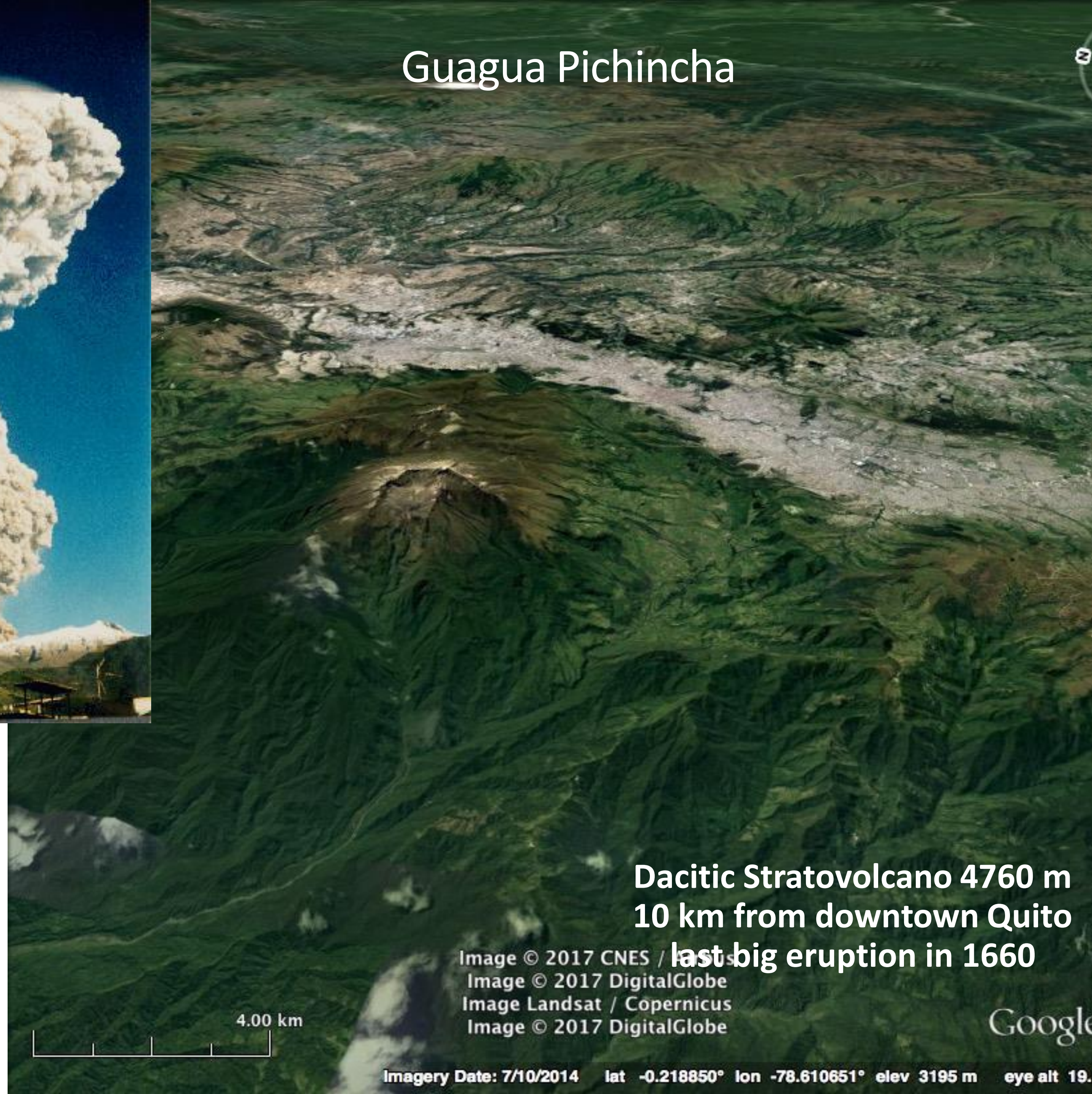
Precursory inflation from InSAR time-series



Morales Rivera, Amelung et al., GRL 2017

Guagua Pichincha

October 7
1999



Dacitic Stratovolcano 4760 m
10 km from downtown Quito
last big eruption in 1660

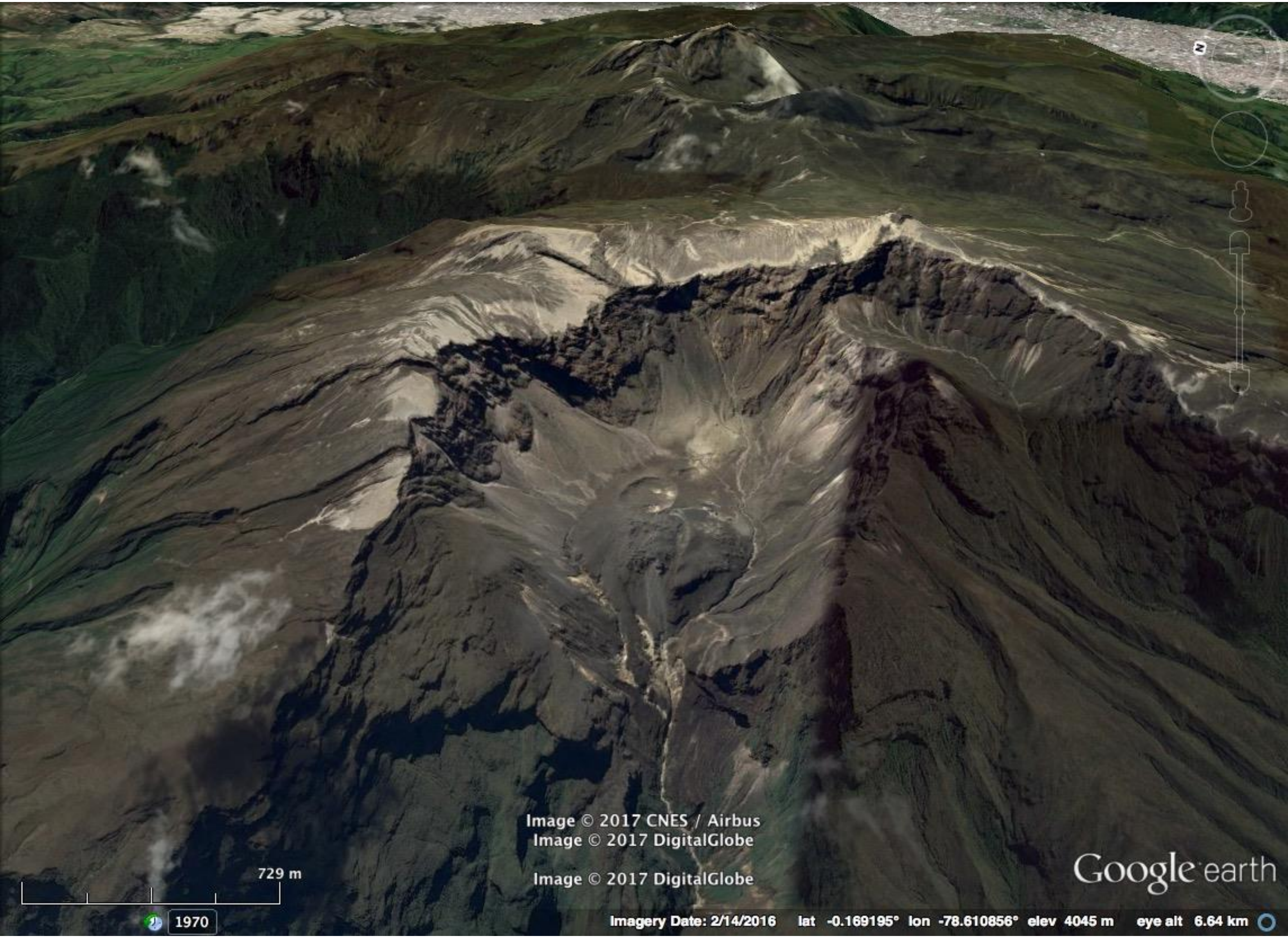
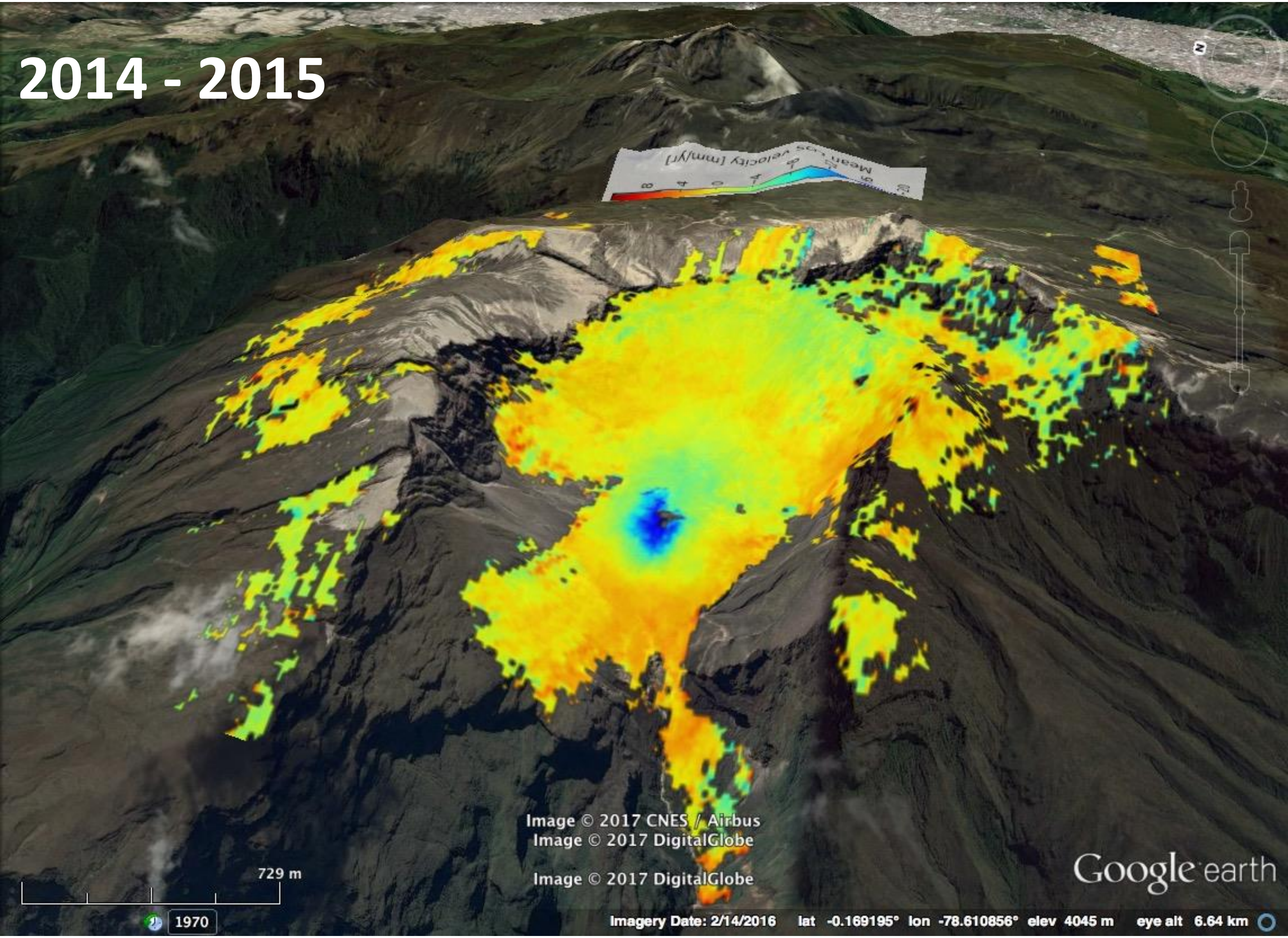
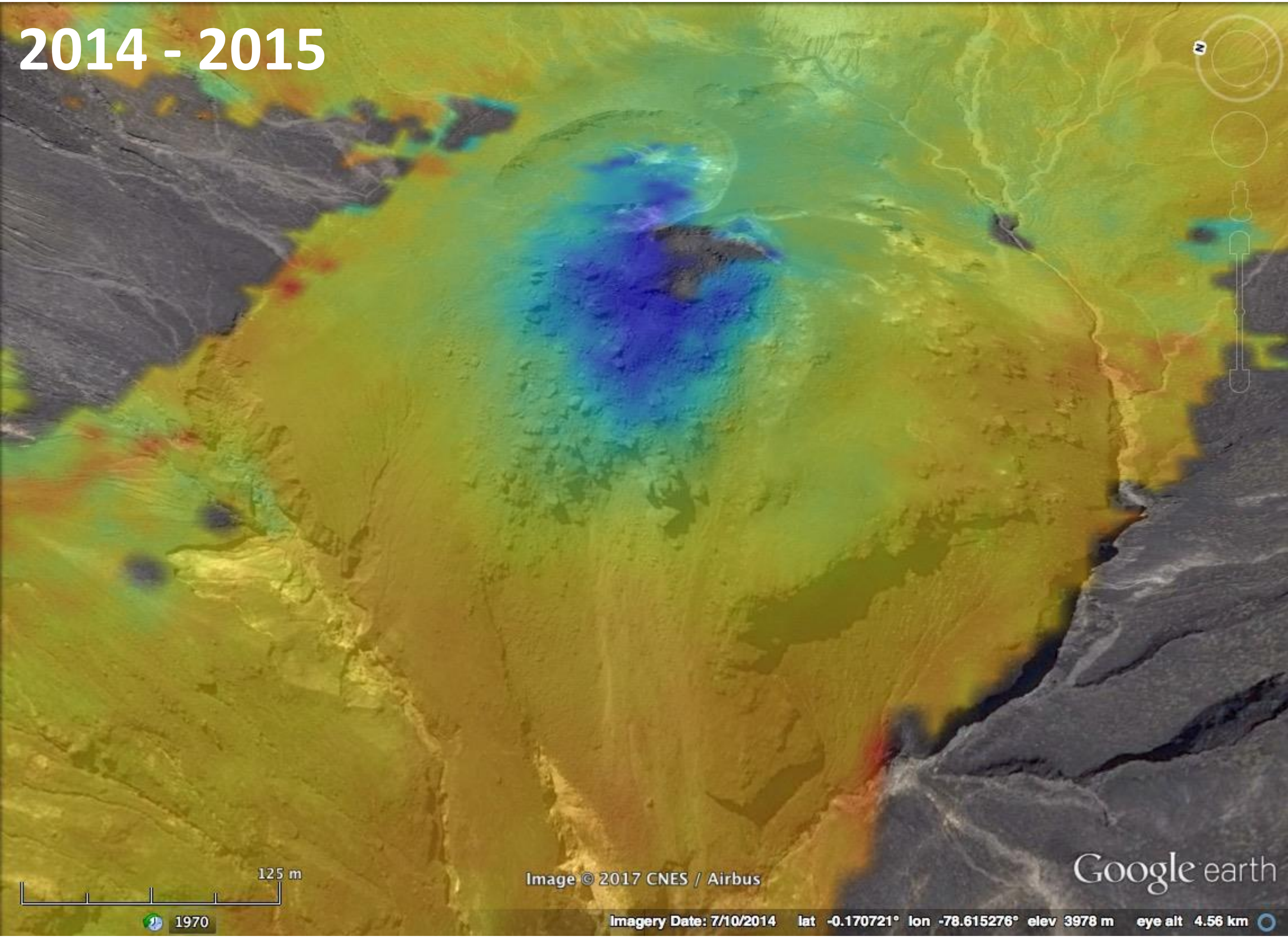
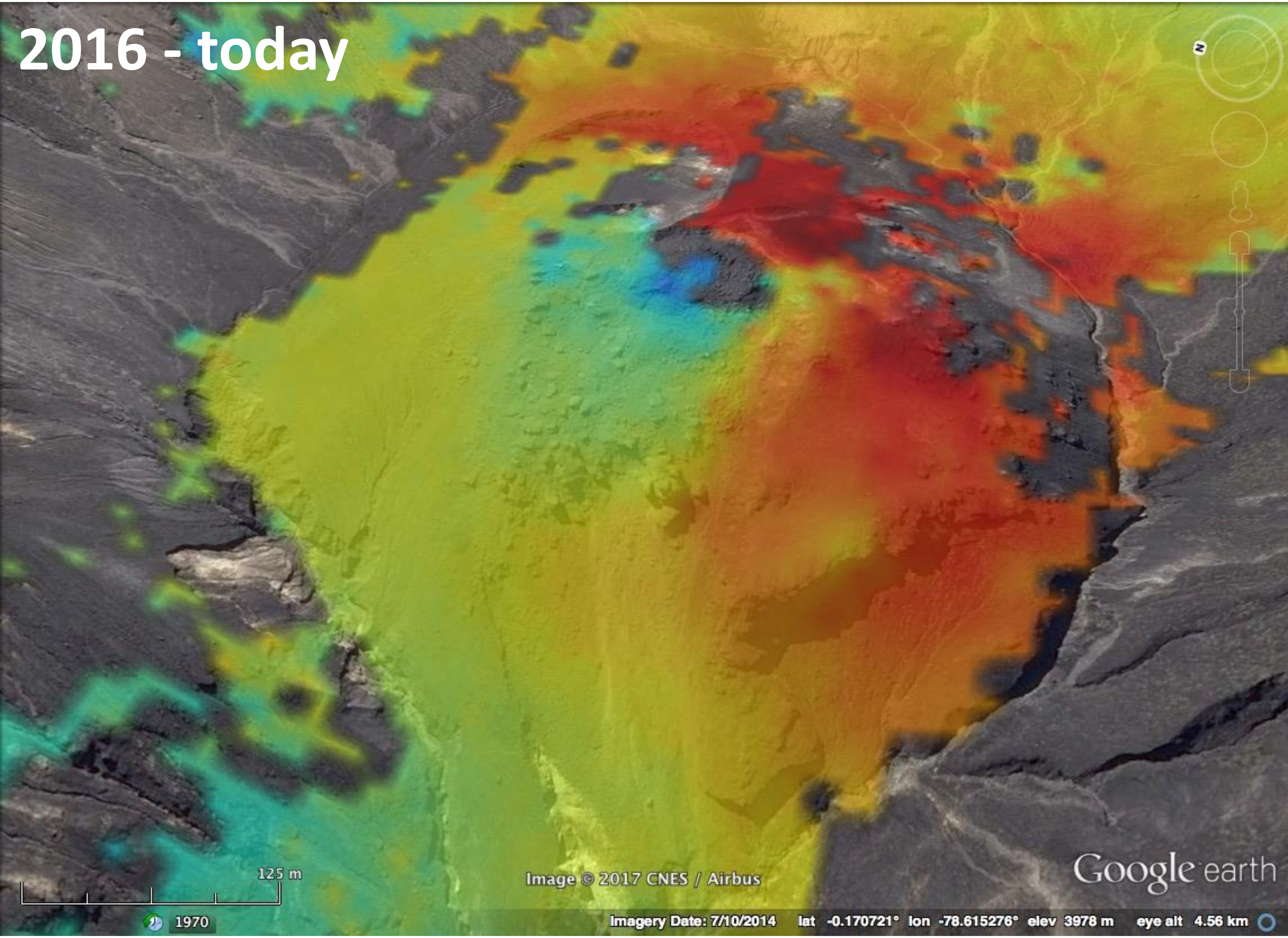


Image © 2017 CNES / Airbus
Image © 2017 DigitalGlobe
Image © 2017 DigitalGlobe
729 m
1970
Imagery Date: 2/14/2016 lat -0.169195° lon -78.610856° elev 4045 m eye alt 6.64 km
Google earth

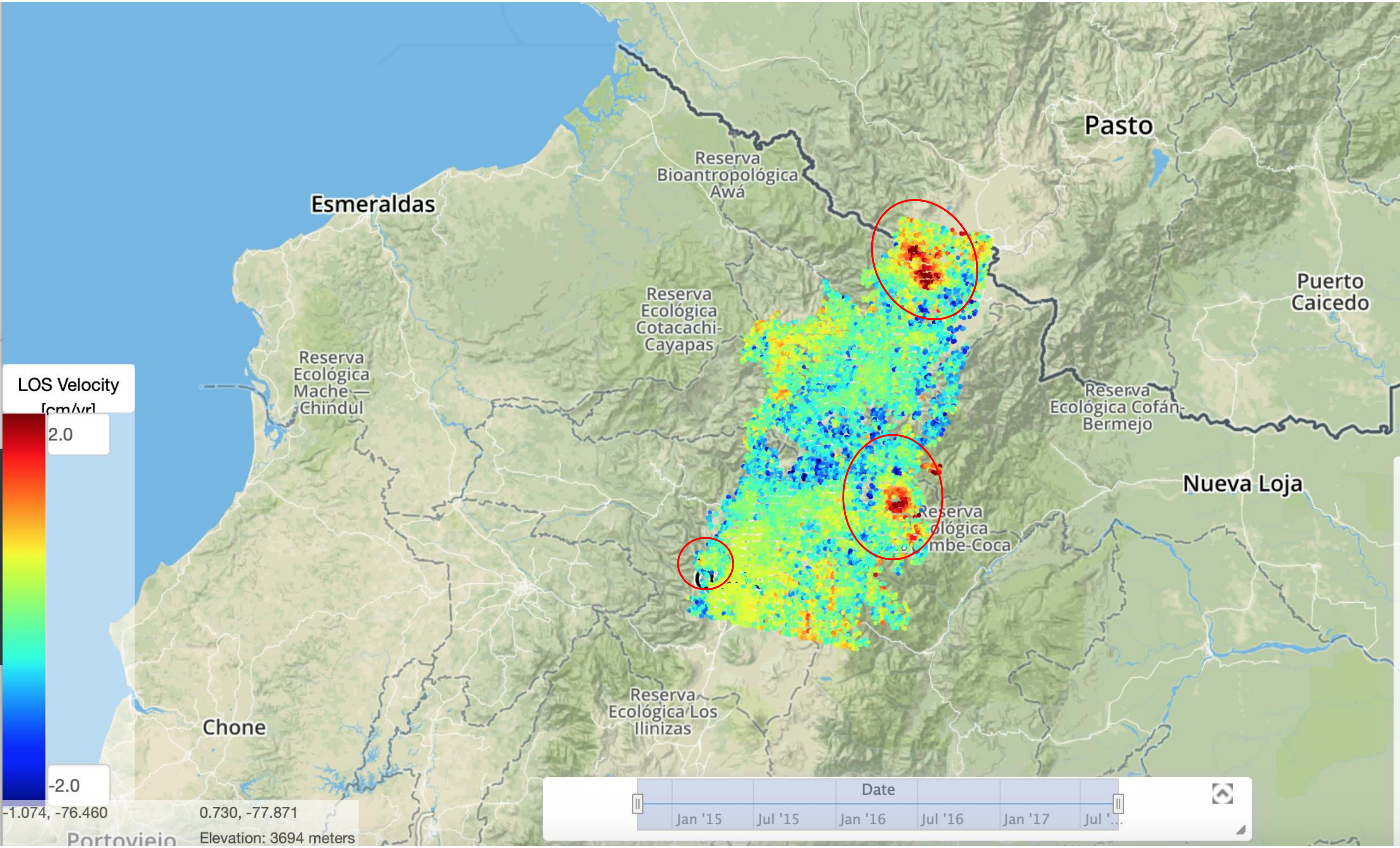

2014 - 2015
Mean LOS velocity [mm/yr]
Image © 2017 CNES / Airbus
Image © 2017 DigitalGlobe
Image © 2017 DigitalGlobe
729 m
1970
Google earth
Imagery Date: 2/14/2016 lat -0.169195° lon -78.610856° elev 4045 m eye alt 6.64 km

125 m
1970
Image © 2017 CNES / Airbus
Google earth
Imagery Date: 7/10/2014 lat -0.170721° lon -78.615276° elev 3978 m eye alt 4.56 km

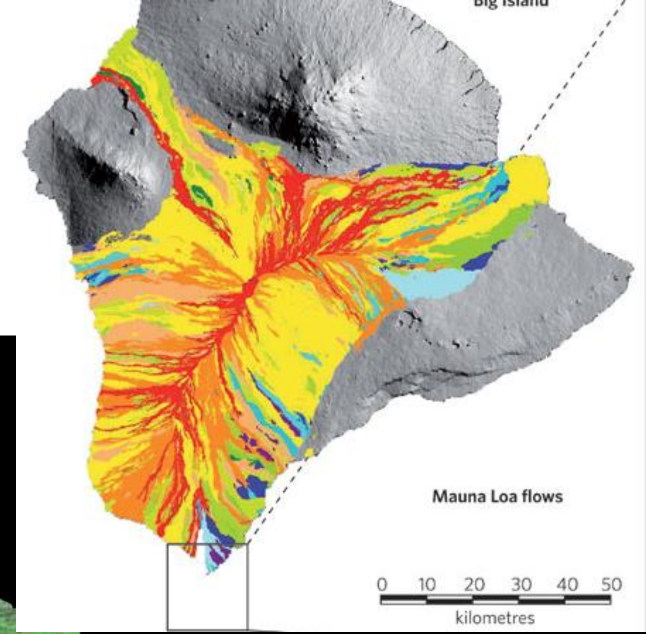

2014 - 2015
125 m
Image © 2017 CNES / Airbus
Google earth
1970
Imagery Date: 7/10/2014 lat -0.170721° lon -78.615276° elev 3978 m eye alt 4.56 km

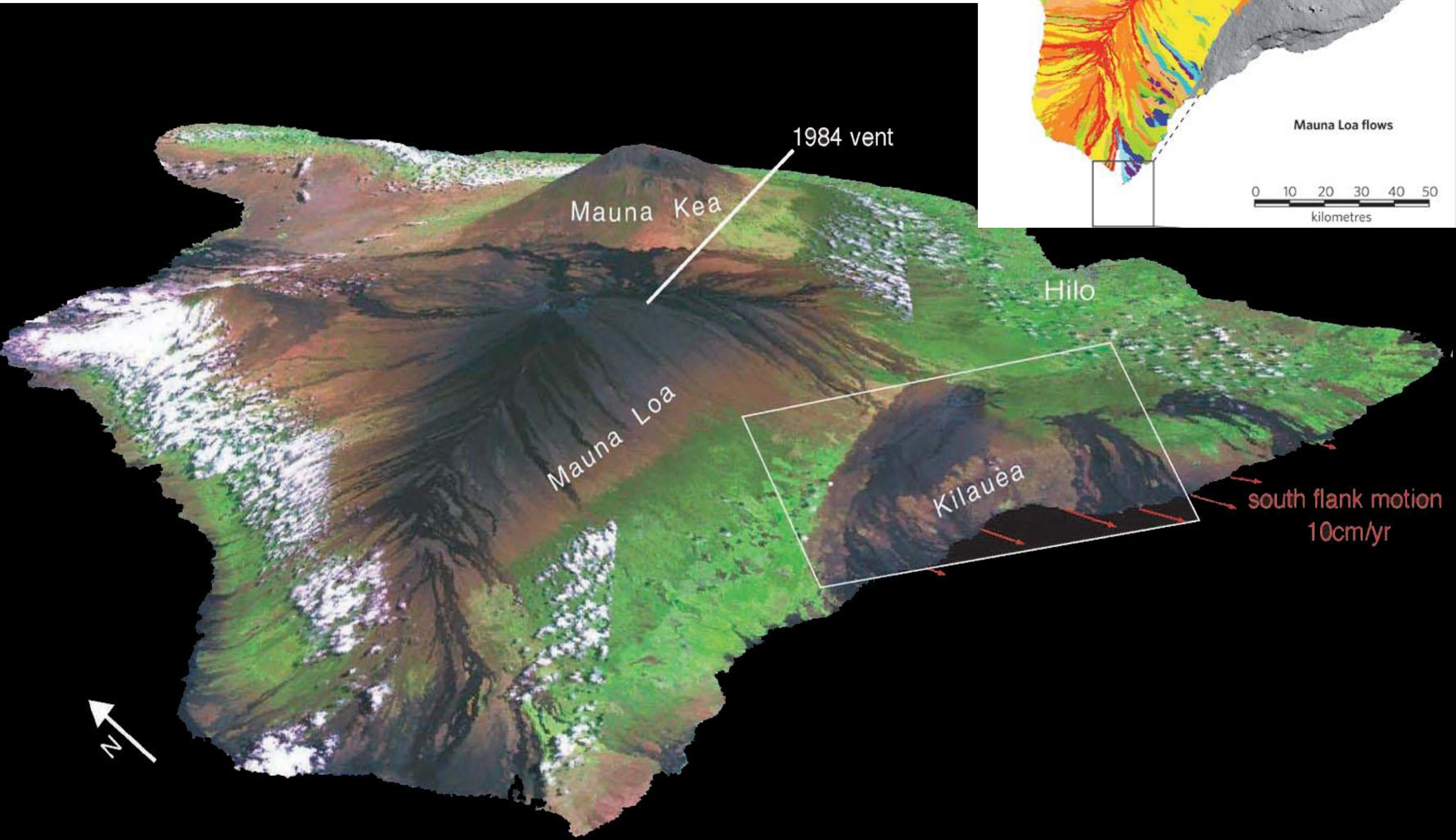

2016 - today
125 m
Image © 2017 CNES / Airbus
Google earth
1970
Imagery Date: 7/10/2014 lat -0.170721° lon -78.615276° elev 3978 m eye alt 4.56 km

Inter-Andean Valley, Ecuador, Sentinel, 2015-2019



Eruptions of Mauna Loa and Kilauea volcanoes commonly occur from the rift zones





Lava flow hazards of Mauna Loa eruptions

Fissure eruptions from dikes intruded into rift zone (1950, 1975, 1984).

Hilo Hawai'i, 1984

Lava flow hazards of Mauna Loa eruptions

Fissure eruptions from dikes intruded into rift zone (1950, 1975, 1984).

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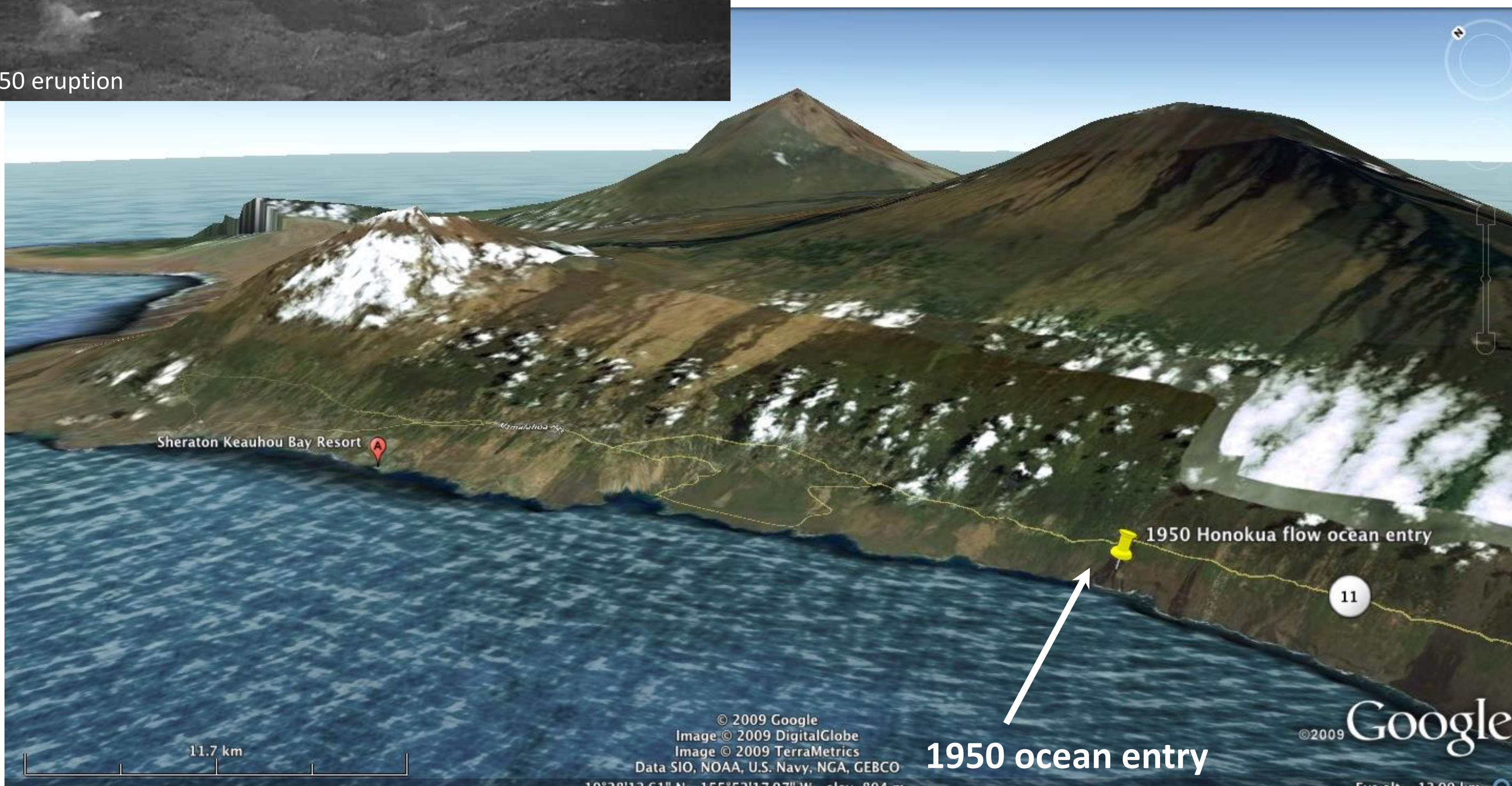
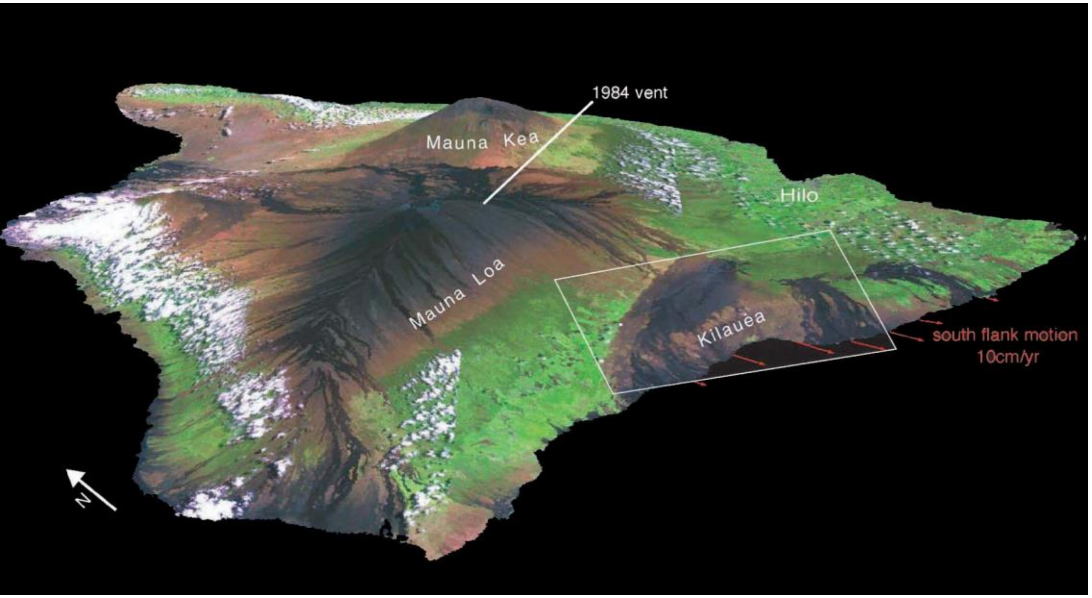


Lava flows from Mauna Loa threaten developments along the coast

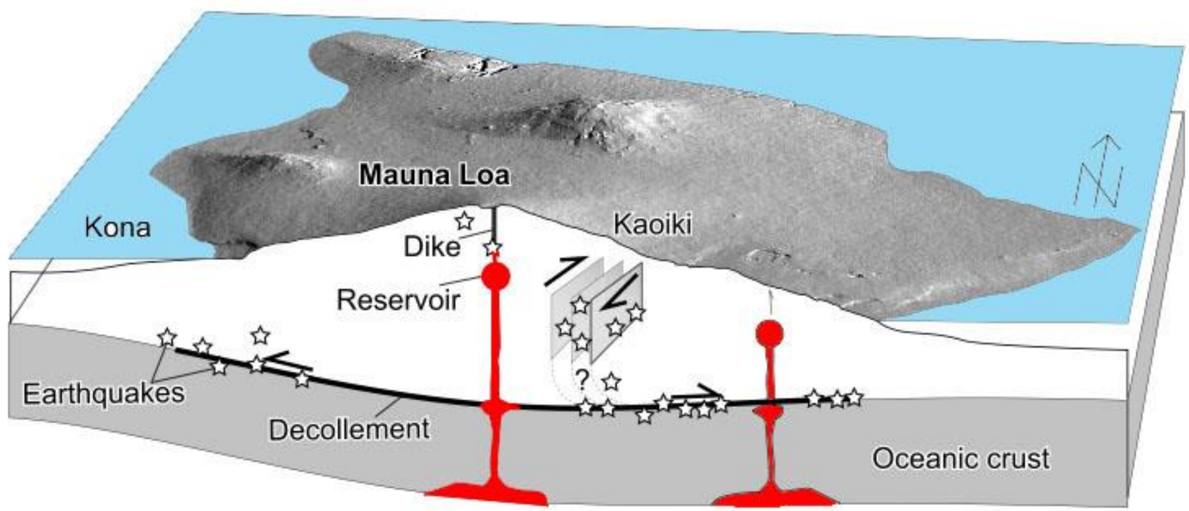
The 1950 flow took only 3 hours from eruption initiation to ocean entry. A repeat could lead to disaster.

The eruption was preceeded 2 days by a M6.5 quake

The Hawaiian Volcanoes: Rift intrusion and decollement motion



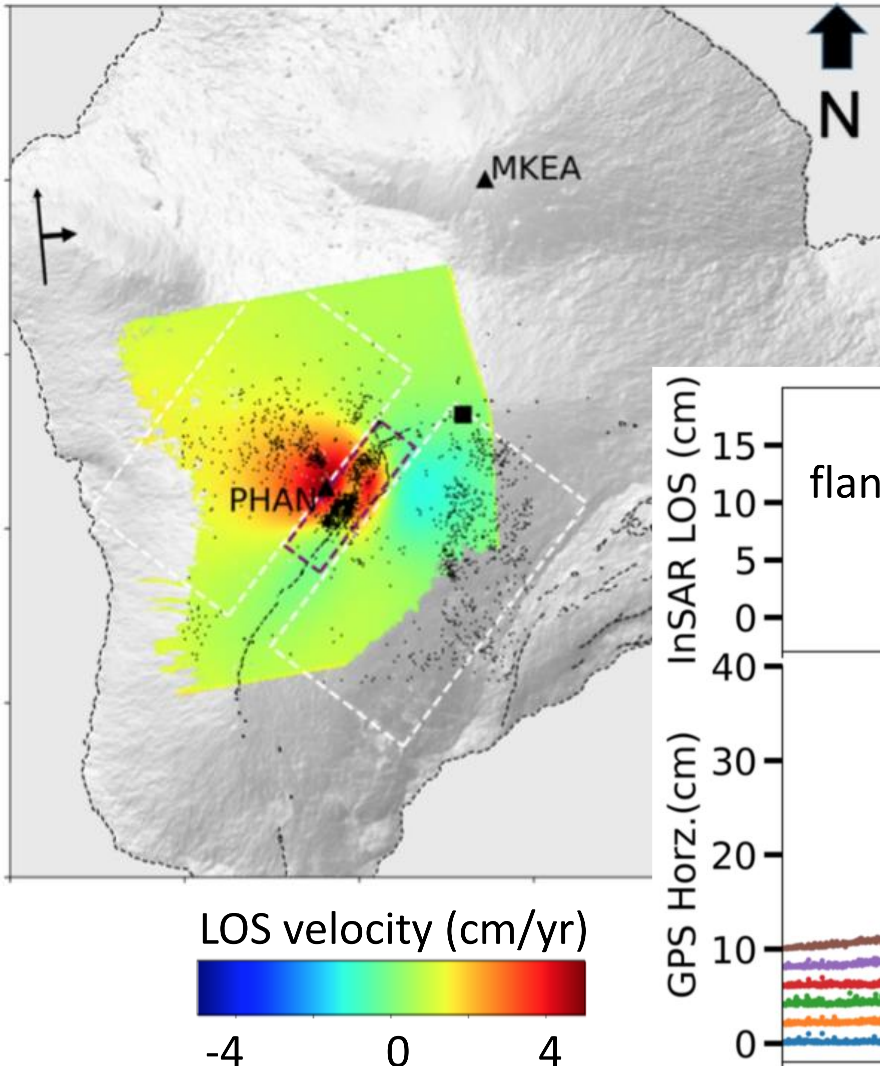
The modes of deformation:
- ❑ rift intrusion
- ❑ seismic/aseismic decollement slip
- ❑ flank motion
- ❑ magma chamber inflation/deflation



Photos: HVO

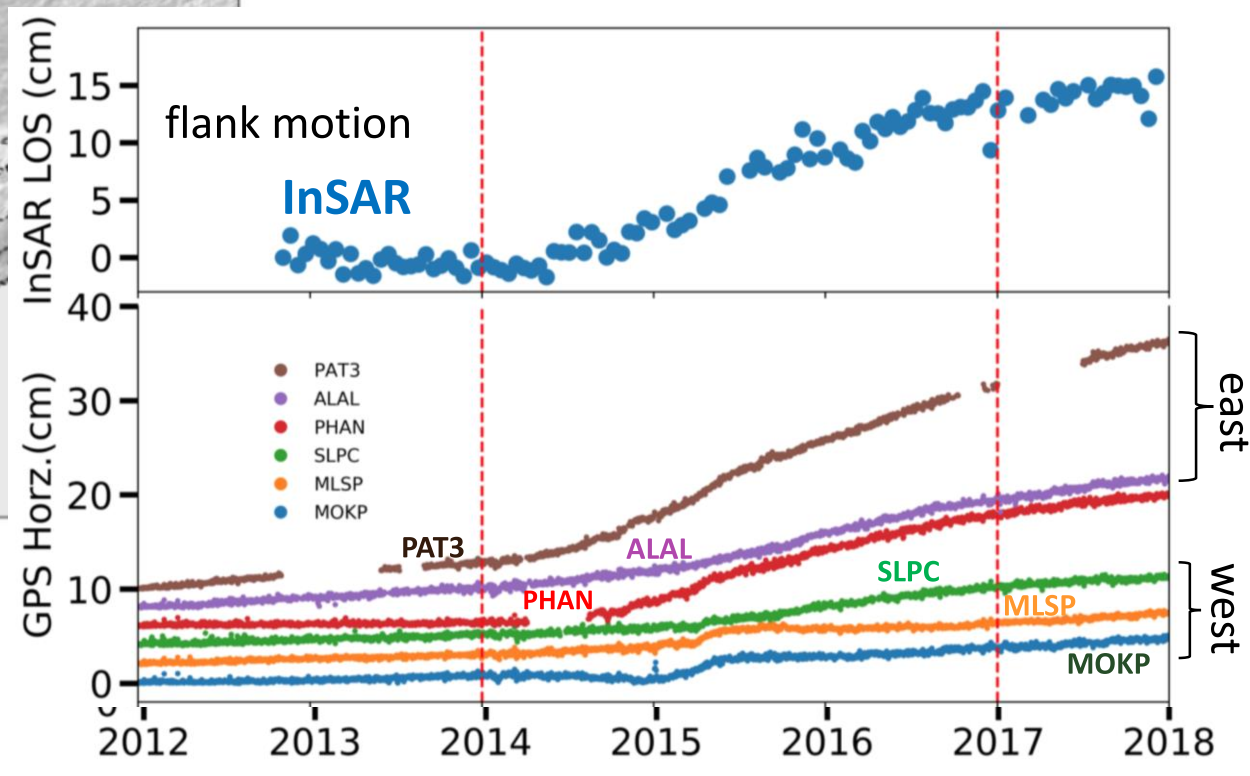
Mauna Loa, Hawaii, 2014-2017 unrest period

LOS displacement from 110 Cosmo-Skymed images



Ground deformation during 2013-2017 unrest period:

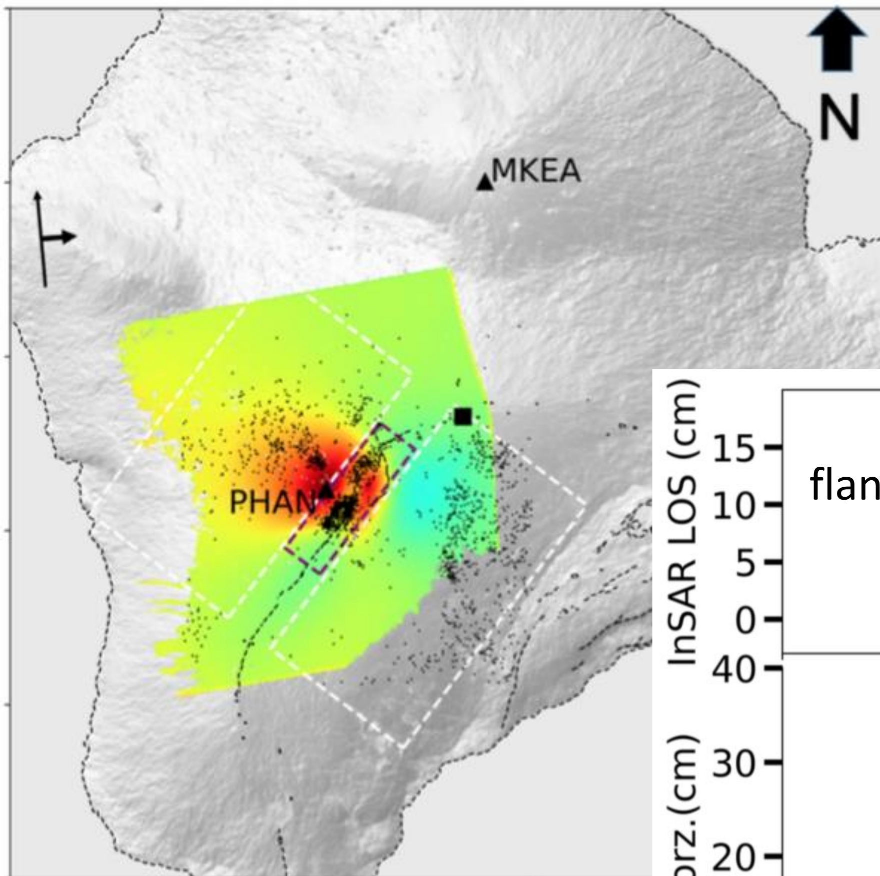
- 15 cm LOS decrease (uplift)
- 20 cm flank motion

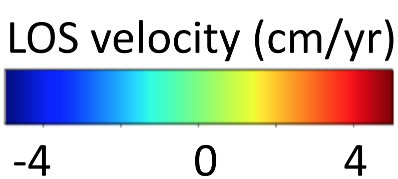


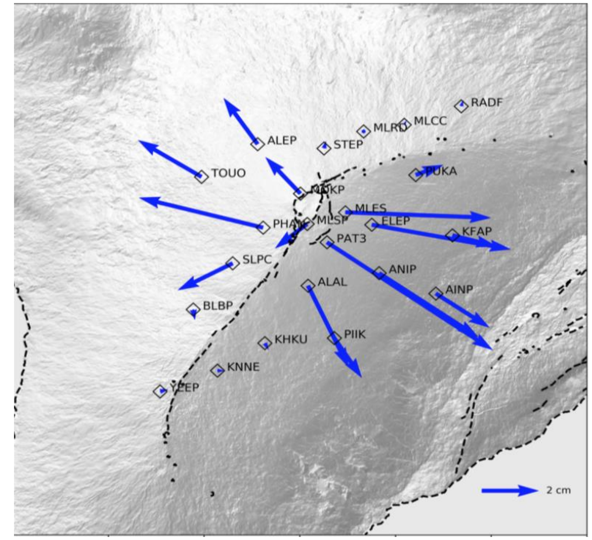
unrest period started with east flank motion

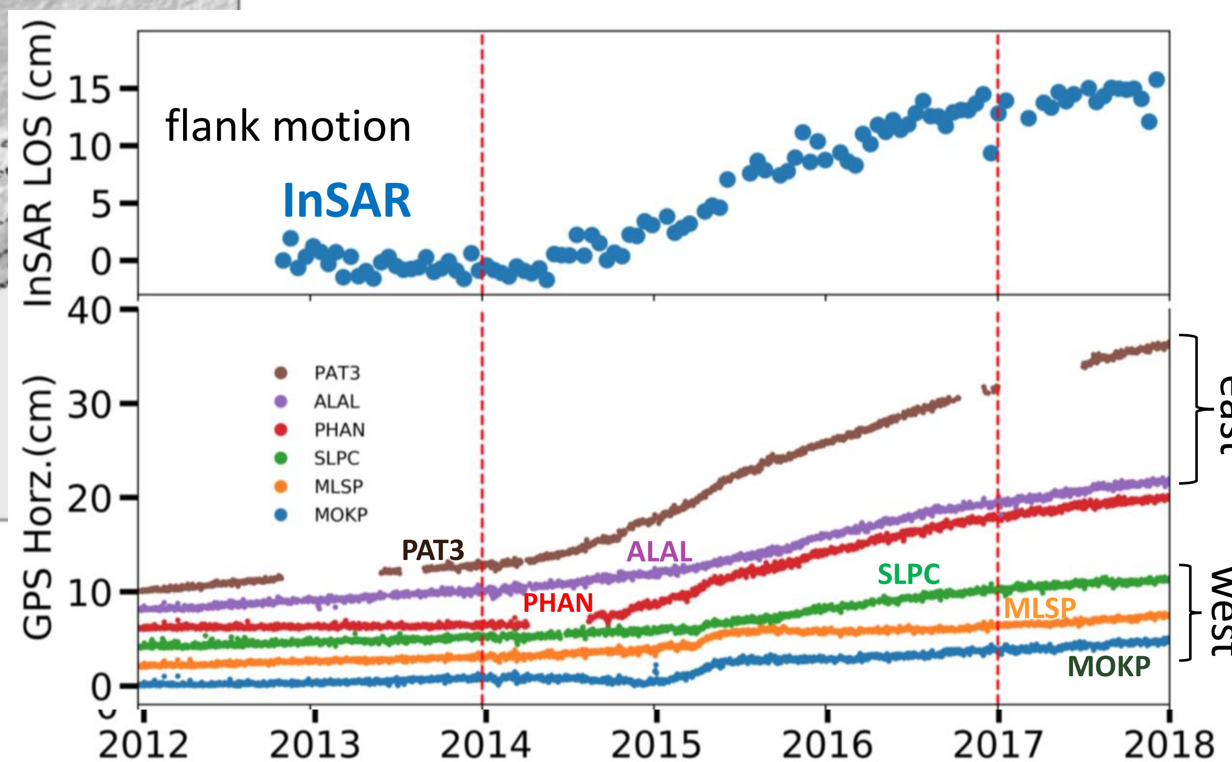
Mauna Loa, Hawaii

LOS displacement from 110 Cosmo-Skymed images







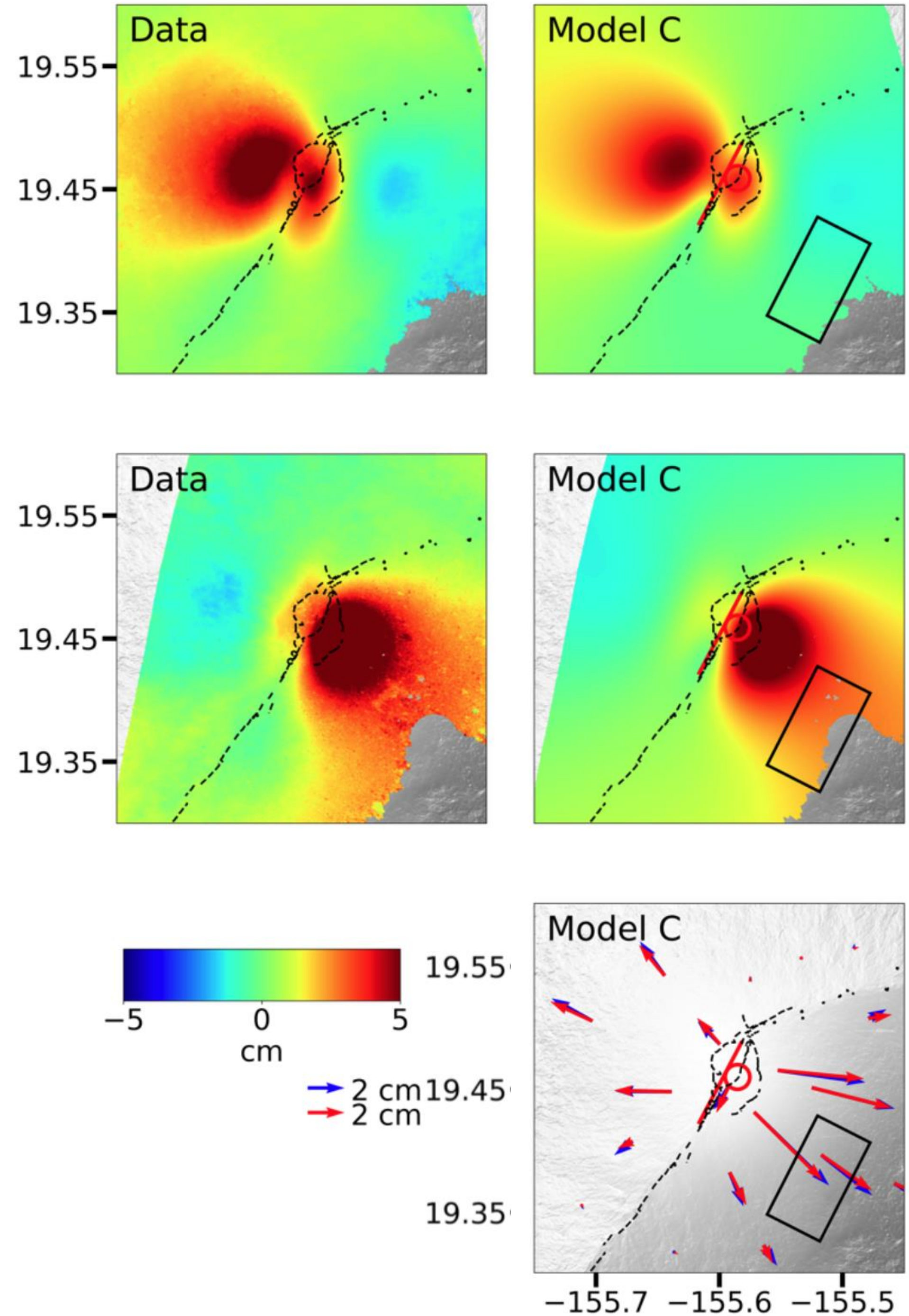


unrest period started with east flank motion

Mauna Loa Source Model

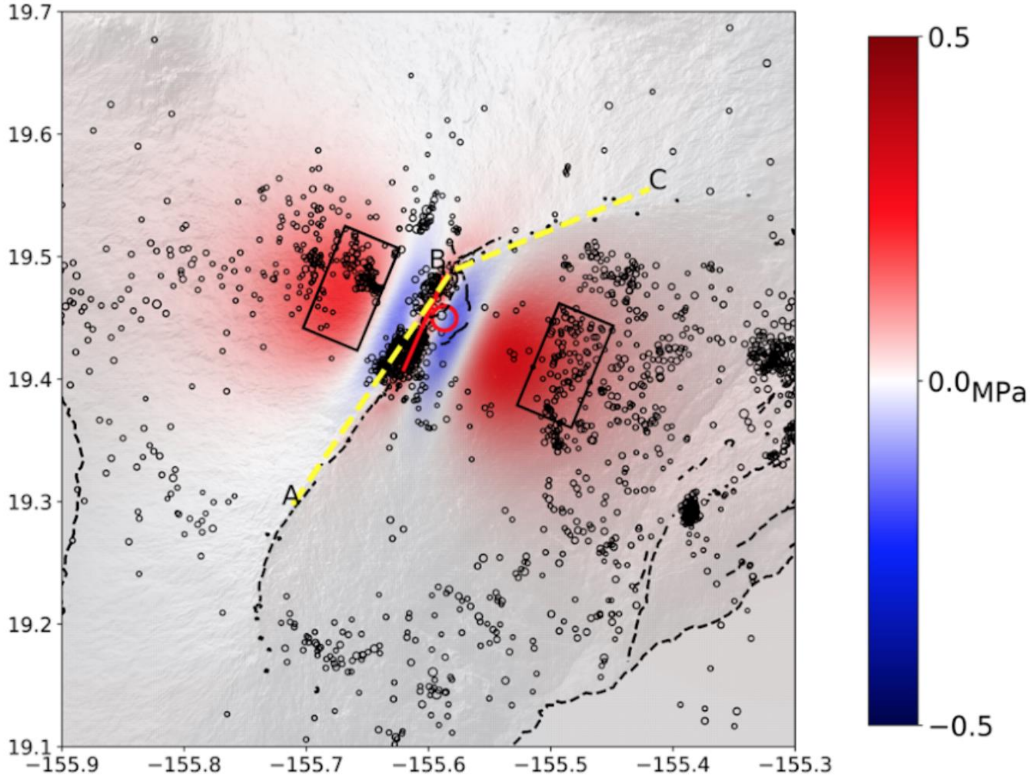
- Dike-like magma body
- Mogi source
- Slip along eastern decollement

No slip
along
western
decollement!

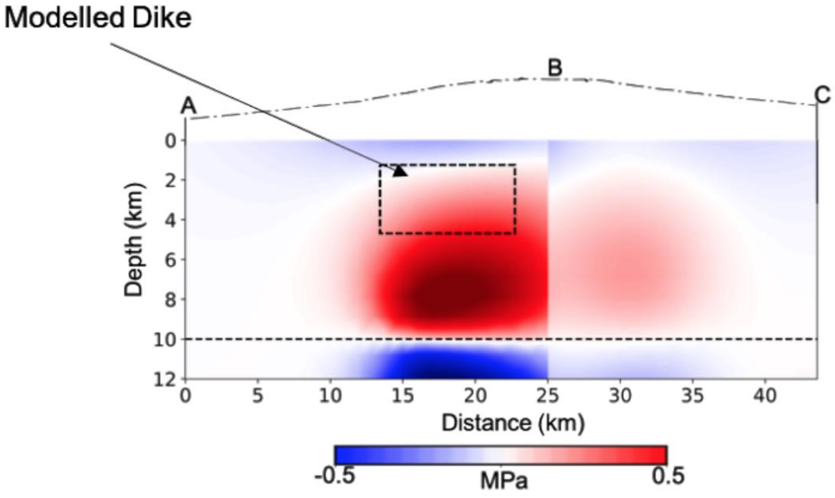


Coulomb stress changes

Along decollement due to magma source



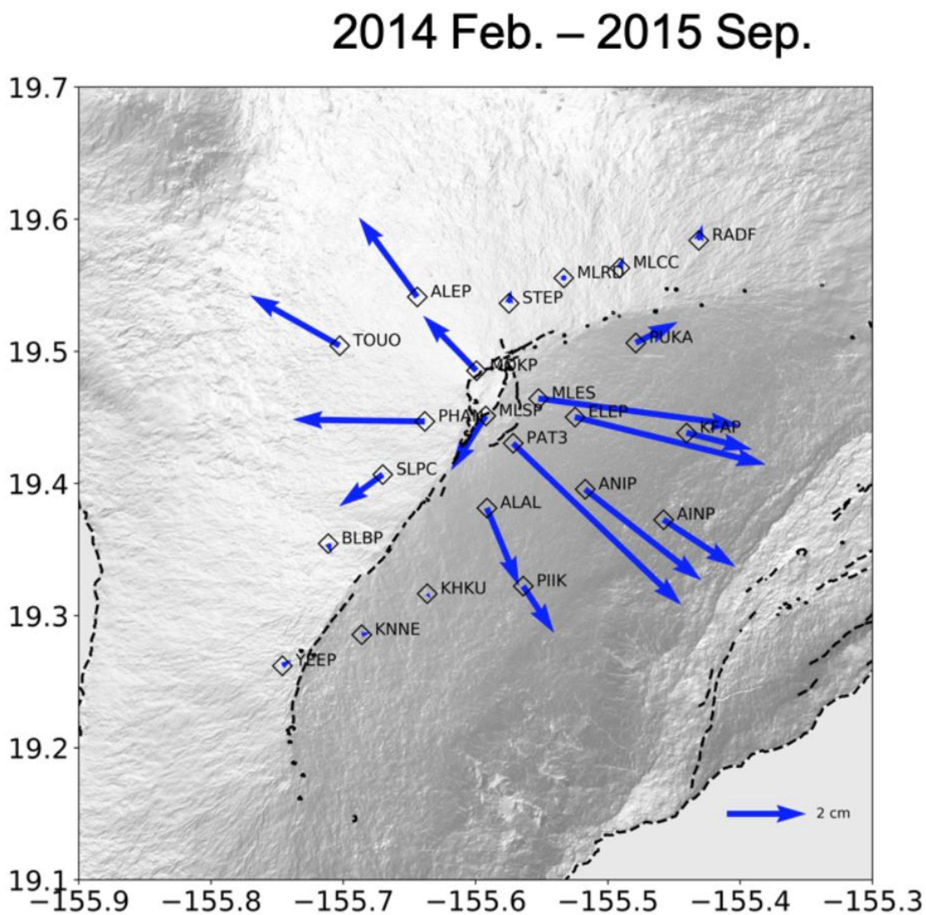
Along rift due to decollement slip

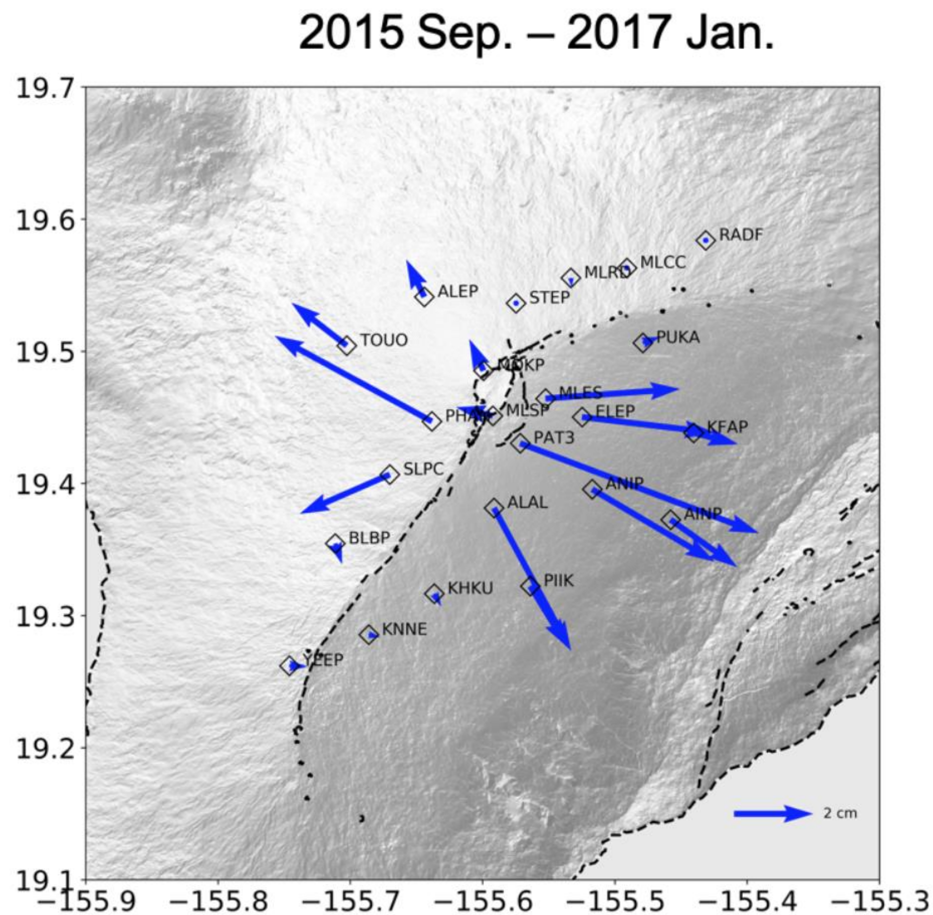


Feedback between dike inflation and decollement slip:

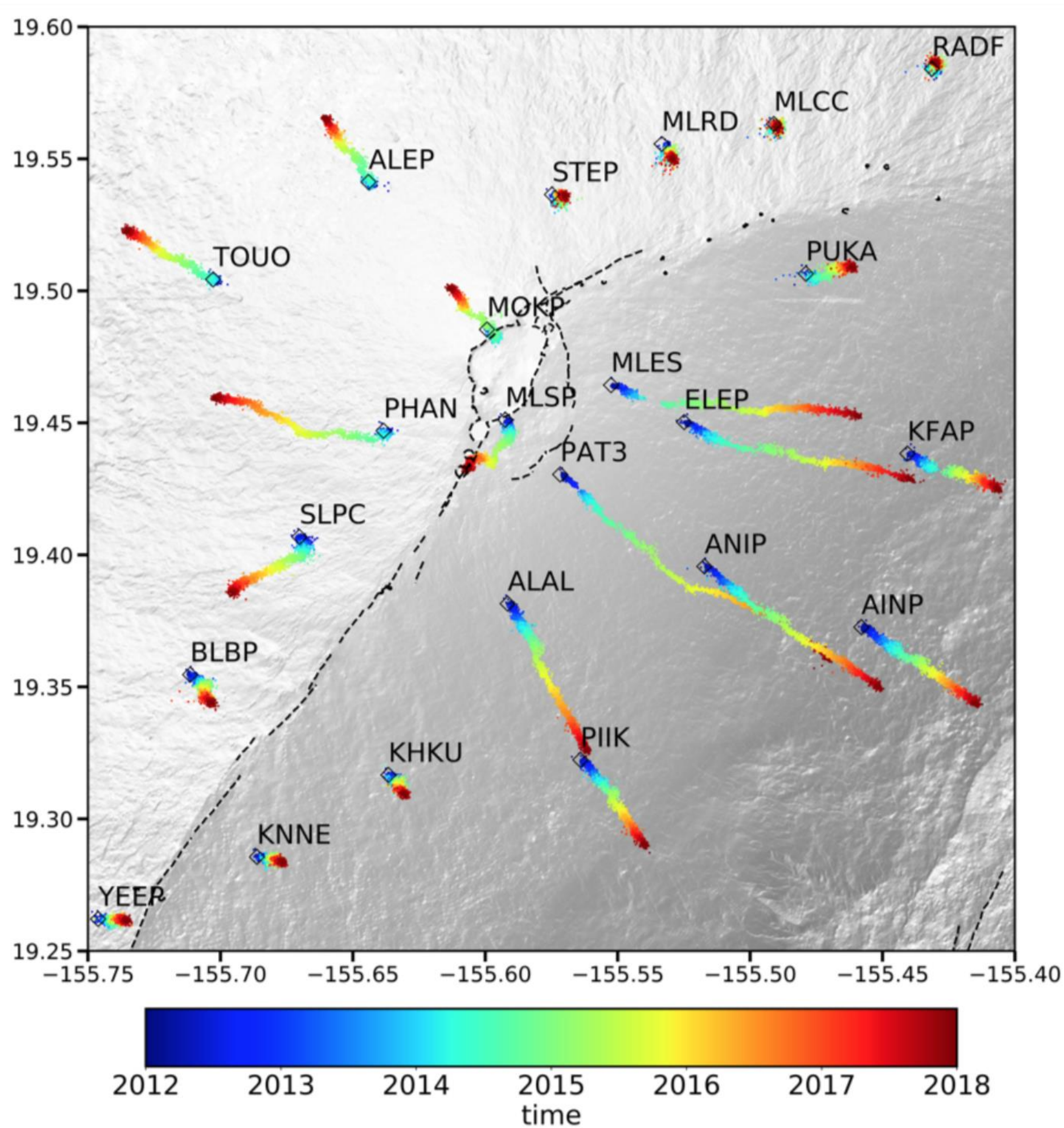
- dike inflation encourages decollement slip
- decollement slip encourages dike inflation

Temporal Variation





Is dike inflation variable with time?



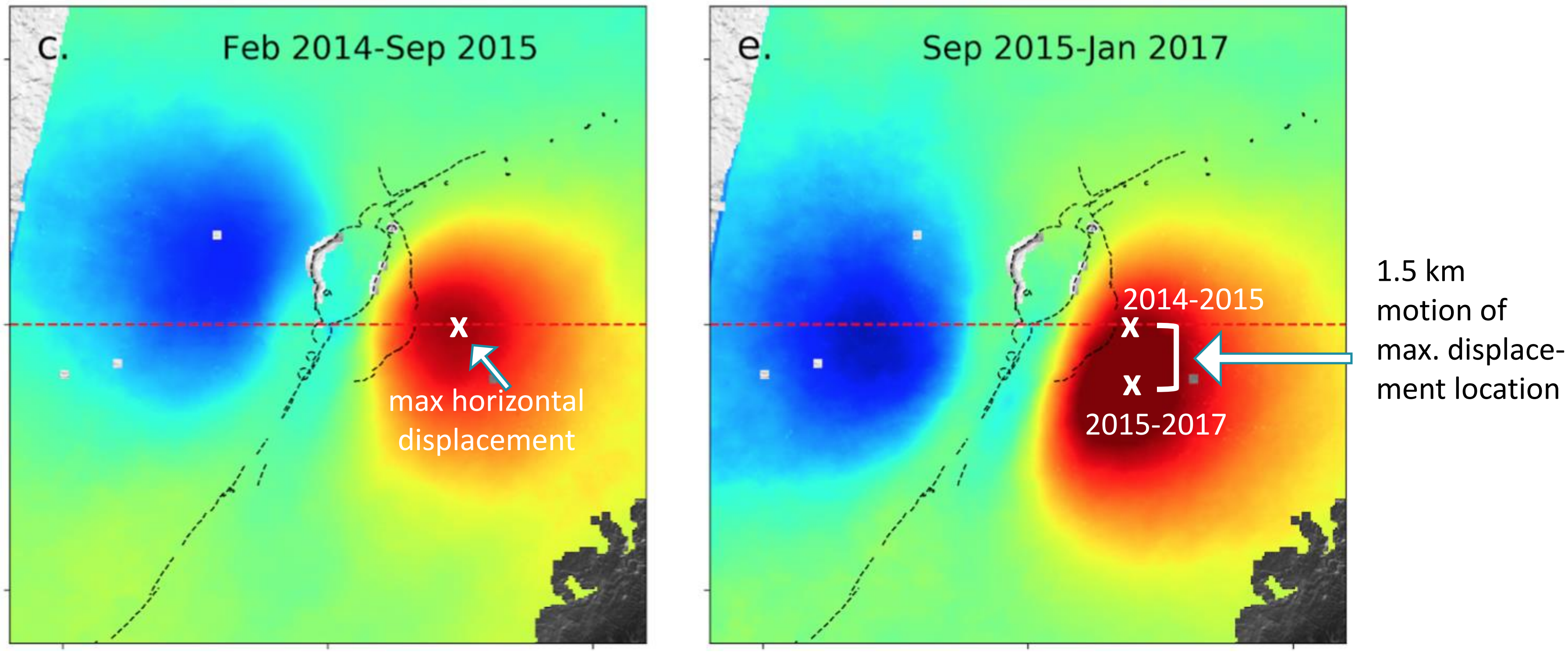
GPS positions as
as a function of time

- Little motion in West

- Change in Aug-Sep 2016

Southward propagation of dike in Sep 2015

East-west displacement from combining ascending and descending imagery



- Inflating dike is located 1.5 km further south during later time period
- southward motion is predicted by stress change models

Forecast:

There will be additional southward motion of the dike-like magma body and eventually it will erupt from the southflank

Questions?