The 2022 eruption of Mauna Loa volcano, Hawai'i: Precursors and re-inflation

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Topics:
- 20 years of deformation data
- stress change models
- "prediction" of eruption location
- 2021 summit earthquake
- ~2 month-long pre-cursor

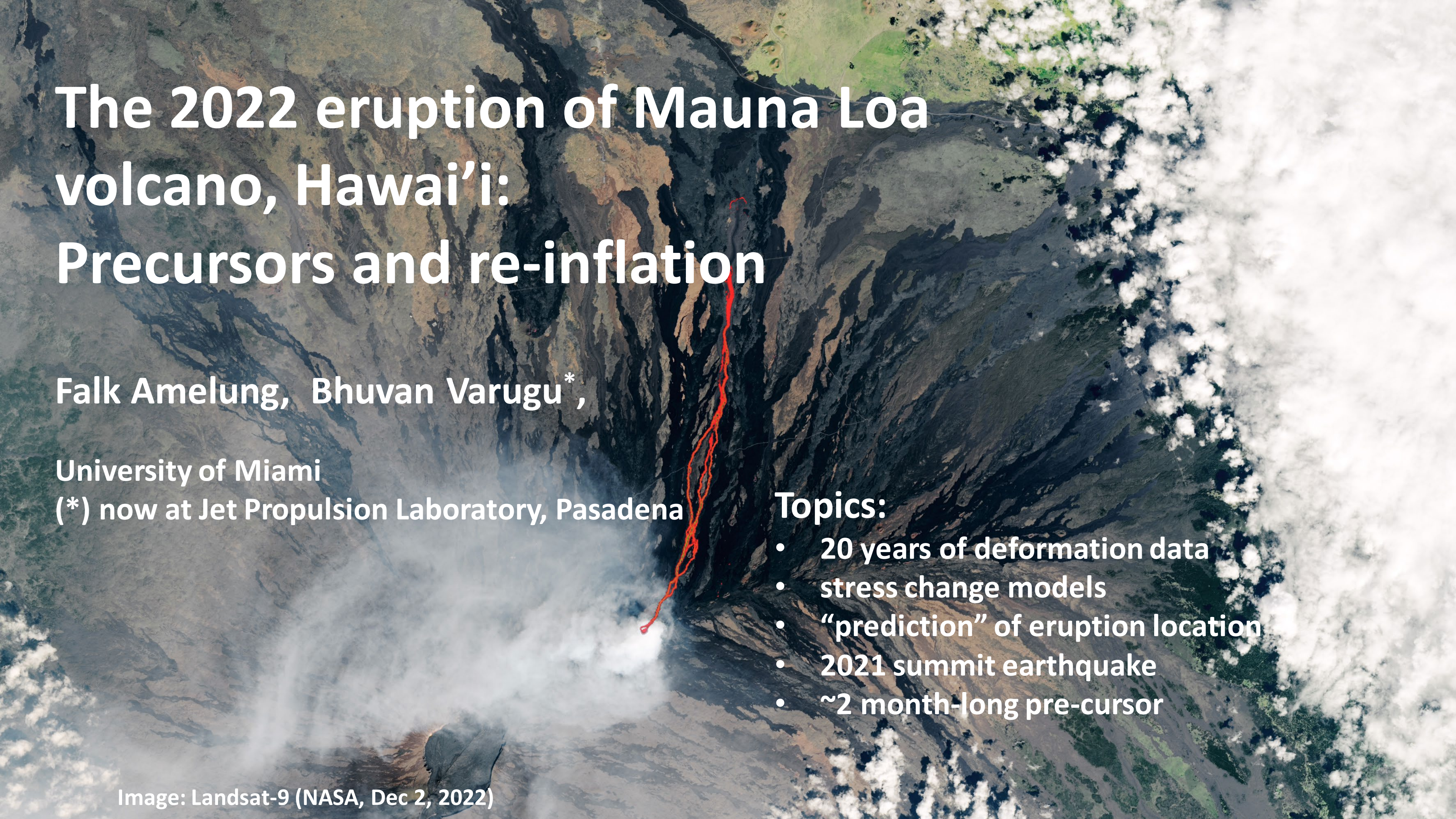
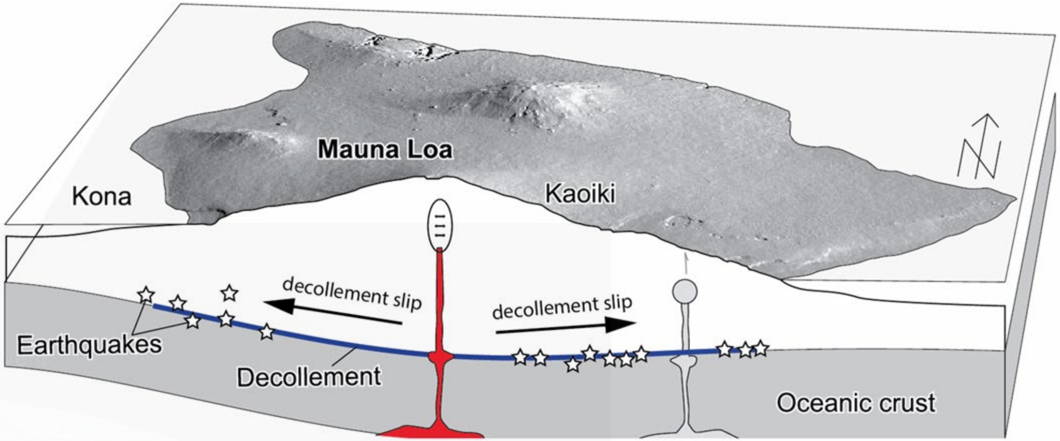
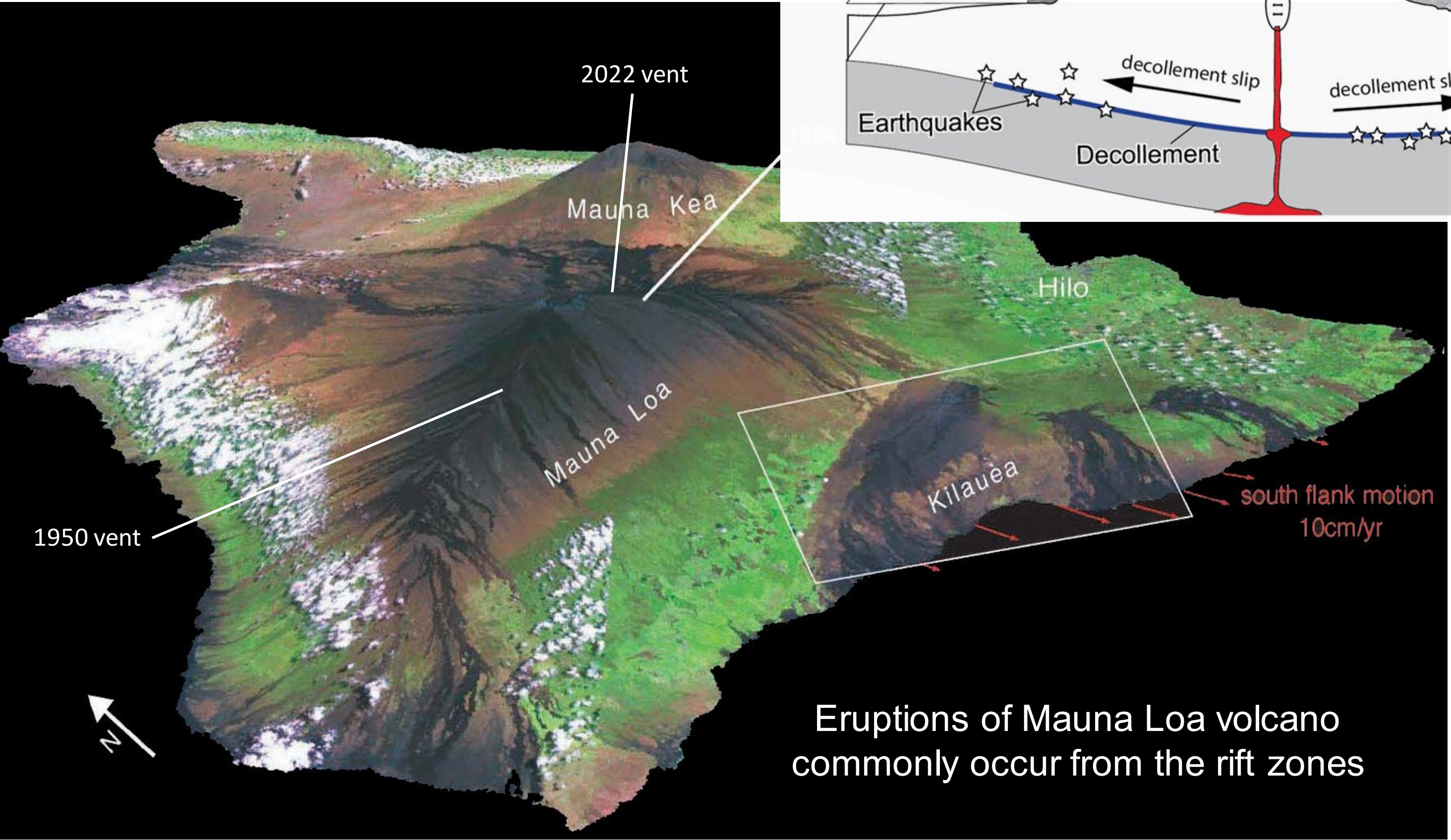


Image: Landsat-9 (NASA, Dec 2, 2022)

Mauna Loa

- 33 eruptions since 1843
- Previous eruptions in 1950, 1975 & 1984



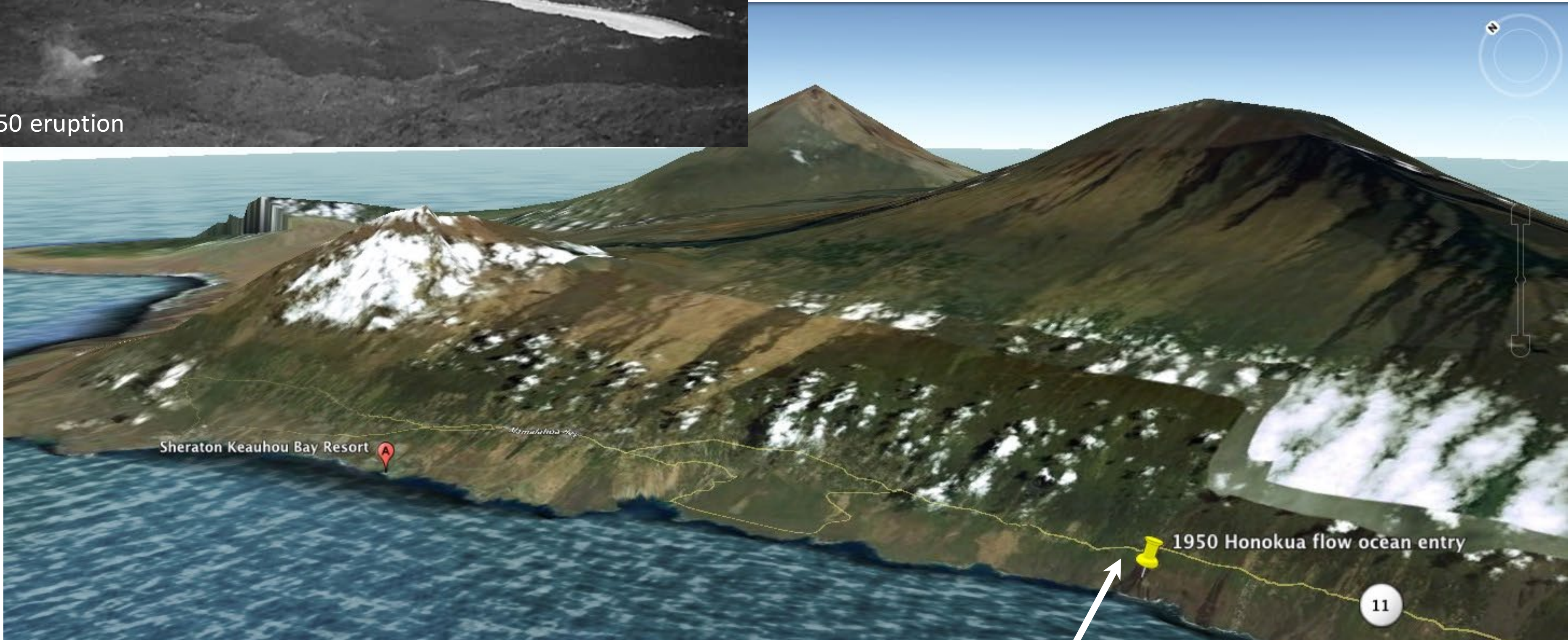


Eruptions of Mauna Loa volcano commonly occur from the rift zones

- Moku'aweoweo summit caldera
- Southwest Rift Zone (SWRZ) & Northeast Rift Zone (NERZ)
- Low angle decollement faults under both flanks

Eruptions from the Southwest rift zone can have rapid flows because of steep slopes.

1950 eruption



1950 eruption

Eruptions from the Southwest rift zone can have rapid flows because of steep slopes.

Threat to coastal developments

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

NWRZ eruptions produce slow flows on gentle slopes

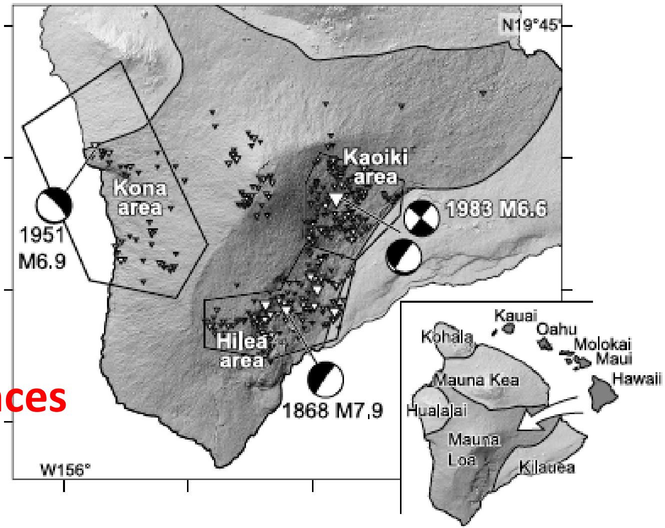
Kailua Kona, Dec 1 2022

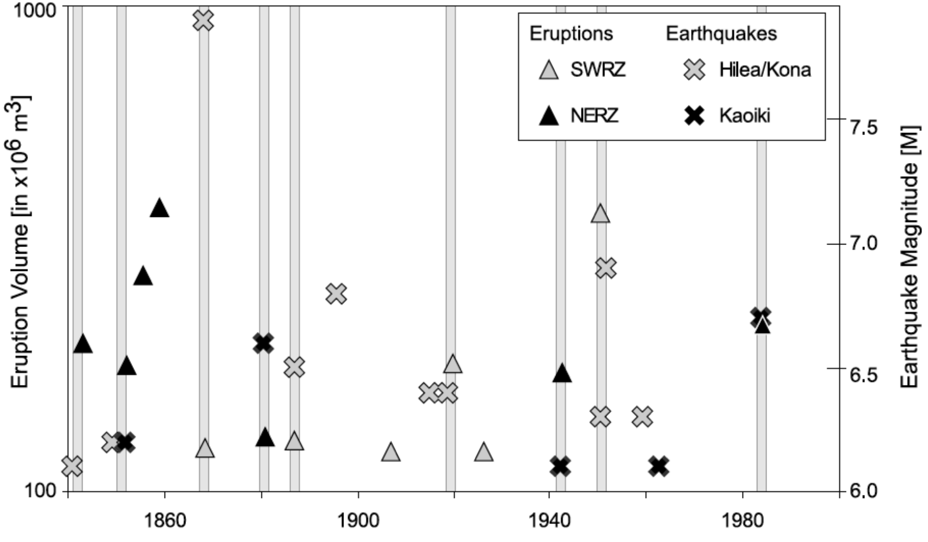
Source: some news media

Earthquake-volcano interaction

Since 1841:

- 17 large eruptions (volume >0.1 km^3)
- 15 earthquakes (M>6)
- **75% of eruptions and earthquakes are part of 2-yr sequences**



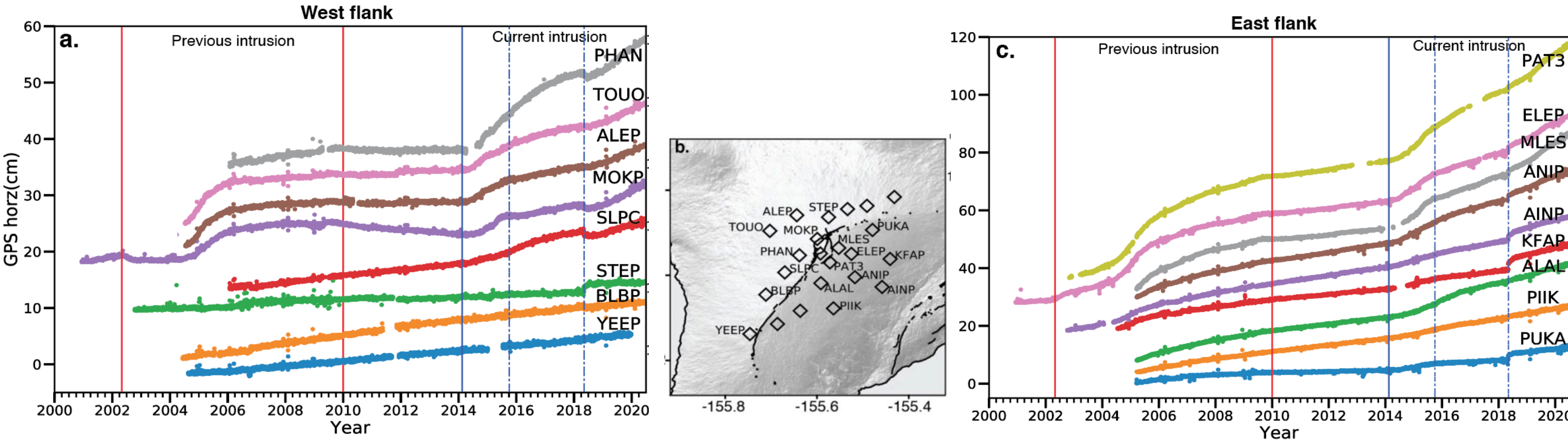


Pairs of:

- NERZ eruptions and Kaoiki earthquakes
- SWRZ eruptions and Kona or Hilea quakes

Walter & Amelung, 2006

2002-2021 horizontal GPS displacement



Varugu & Amelung, 2021

2004 – 2010: intrusion

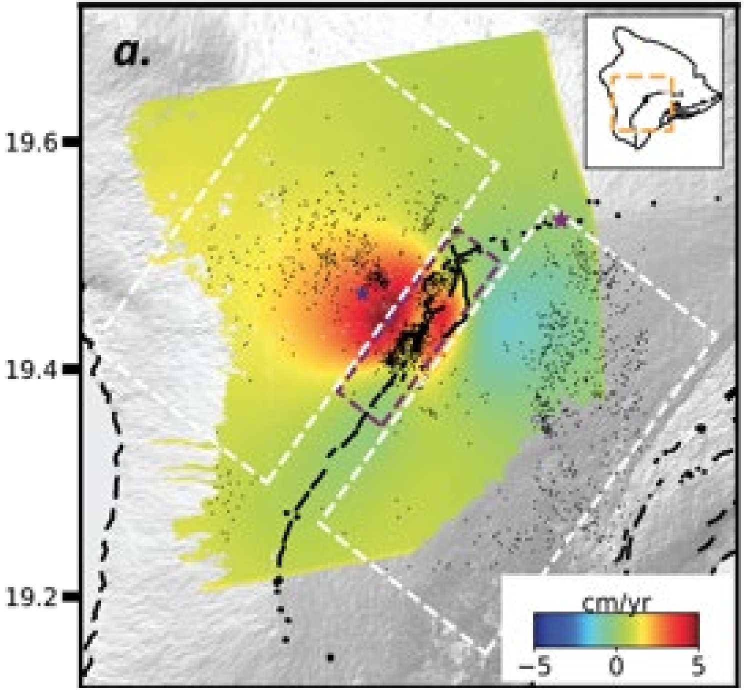
2010 – 2014 : flank motion [~1 cm/yr]

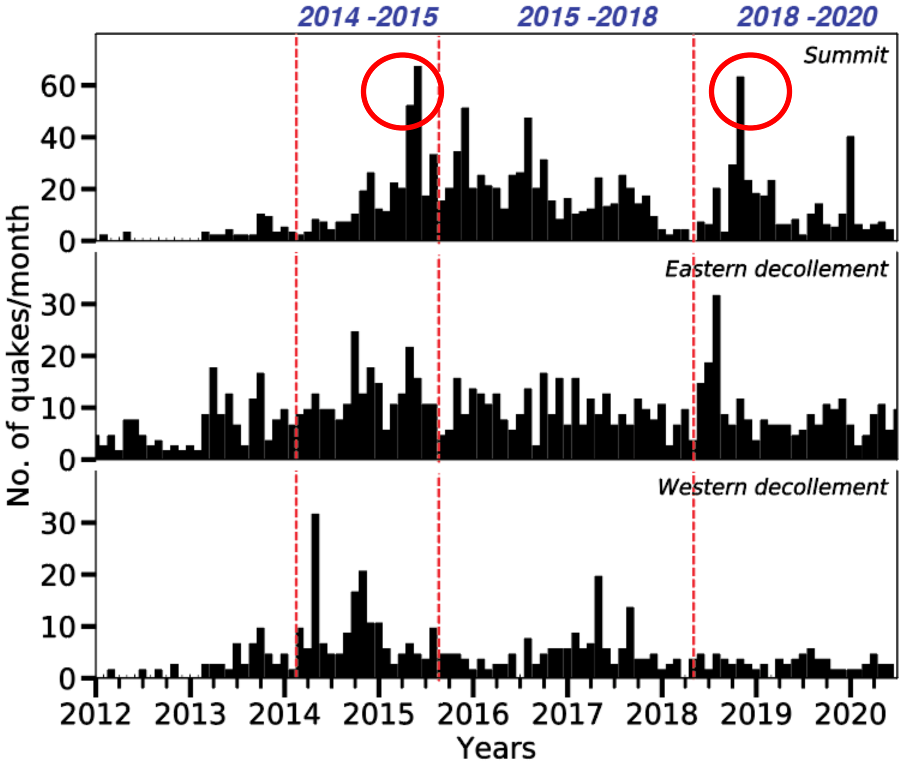
2014 – 2022 : intrusion

Different y-axis scales: east flank moves twice as fast.

The 2014-2020 intrusion period

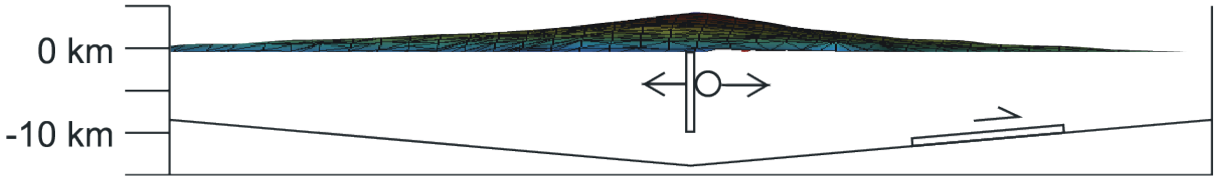
Cosmo-Skymed InSAR



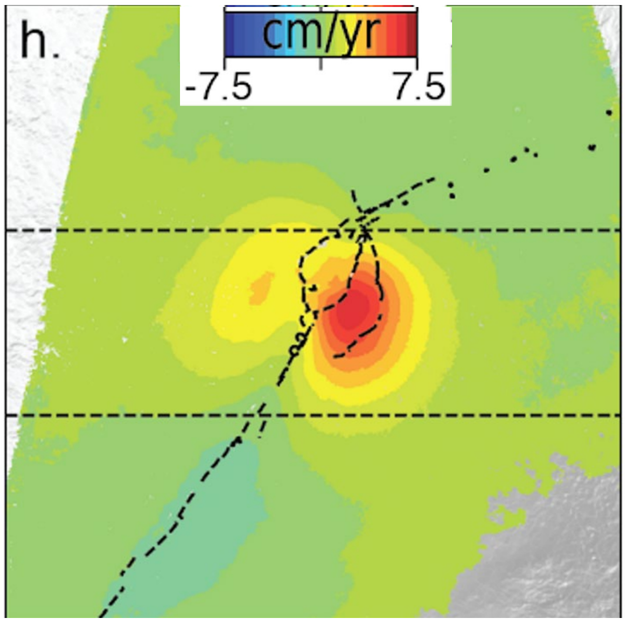


- Up to 7 cm/yr in radar line-of-sight (LOS) direction [2014 - 2020]
- Secular deformation around the summit – typical Mauna Loa inflation

Preferred geodetic model



2014-2015 vertical displacement



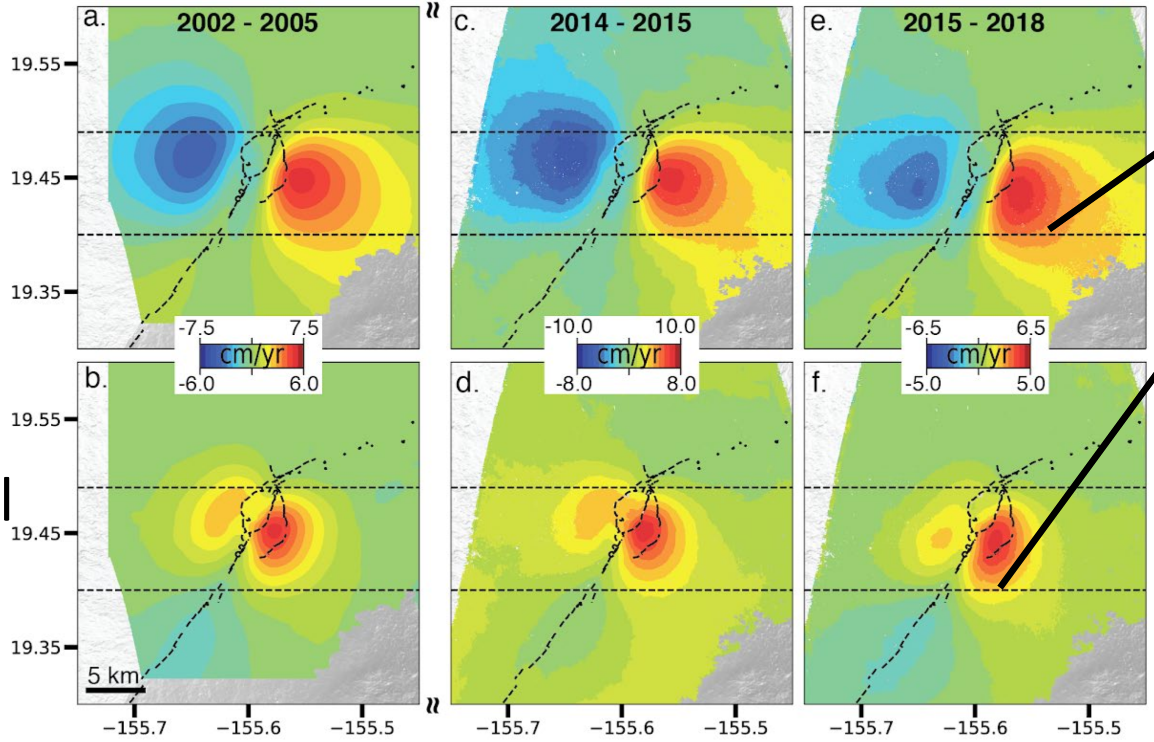
- Dike + Mogi source (complex magma body)
- Decollement slip under east flank

Dual-body magma reservoir explains asymmetry in vertical displacements.

Shift of deformation pattern in 2015

East-west

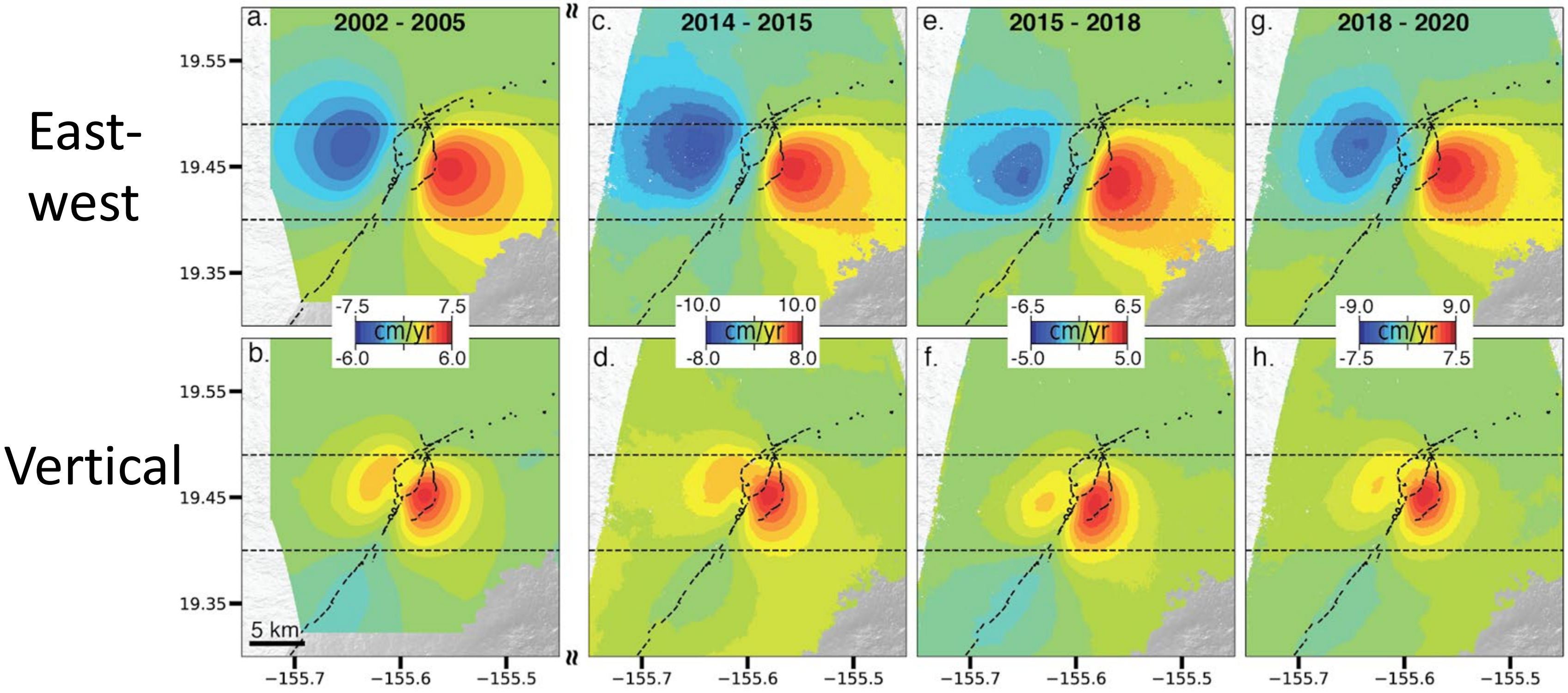
Vertical



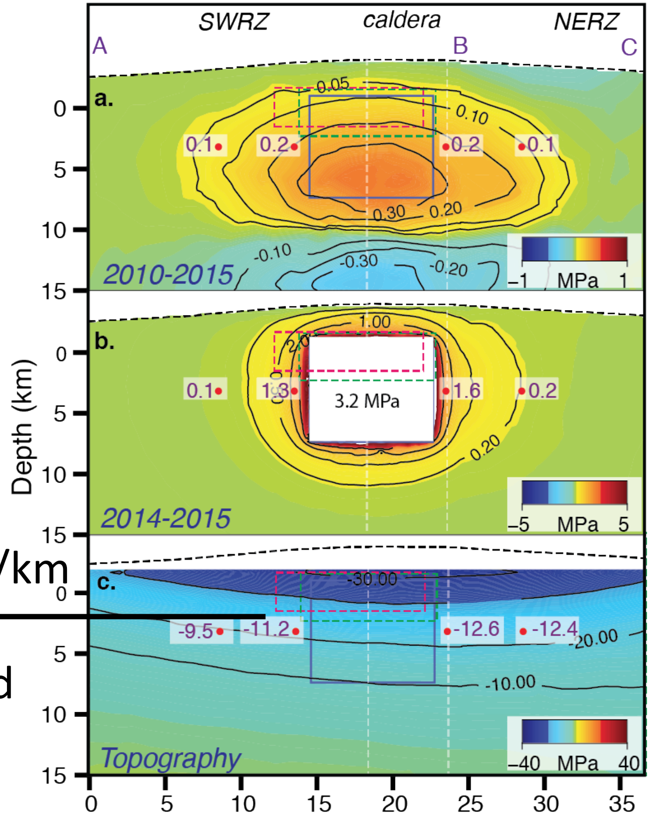
Southward shift of inflation sources in August 2015

Shift of deformation pattern in 2015

Same as
2002-2005 and 2014-2015



Why did the magma body migrate south? Analysis of normal stress in the rift zone.



0.34 MPa/km

southward gradient

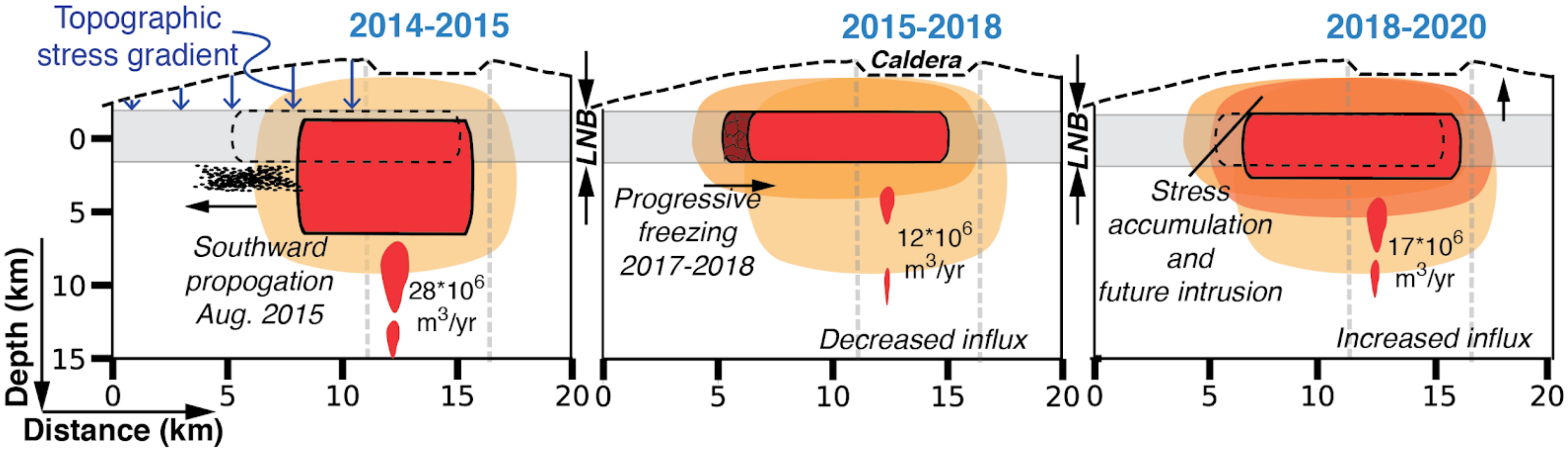
Decollement slip → small

Magma over pressure → uniform around the dike

Topographic compression → decreasing in south

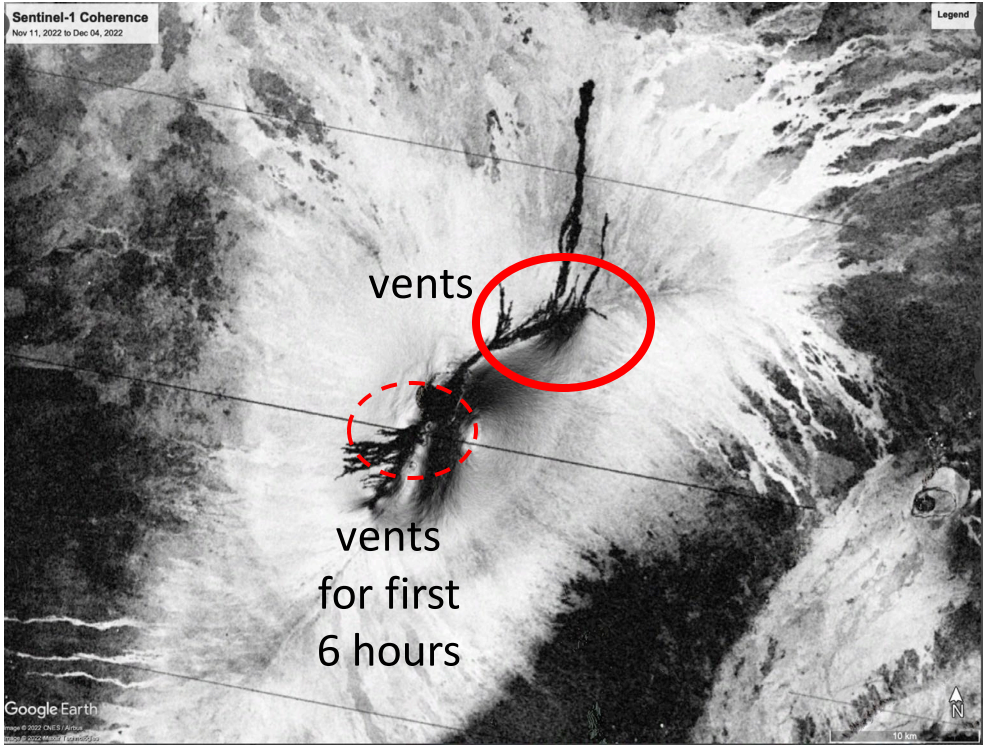
Southward propagation is consistent with topographic stress gradient!

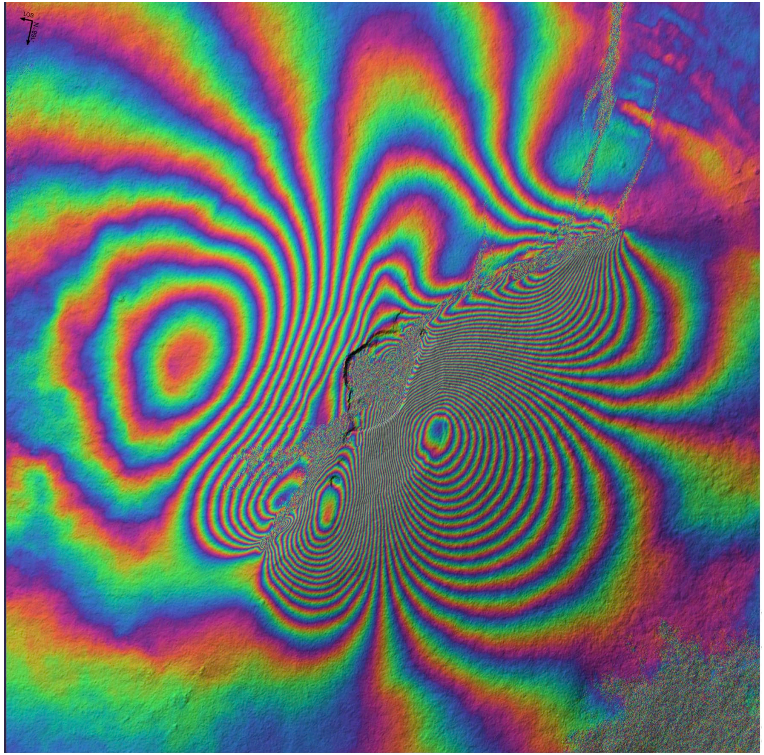
Summary from 2002-2020 data



- Down-rift propagation of magma body in 2015 in response to topographic stress
- Stress change suggest dike injection towards north and/or up.
  (Varugu & Amelung, 2021)

2022 eruption primarily from Northeast rift zone



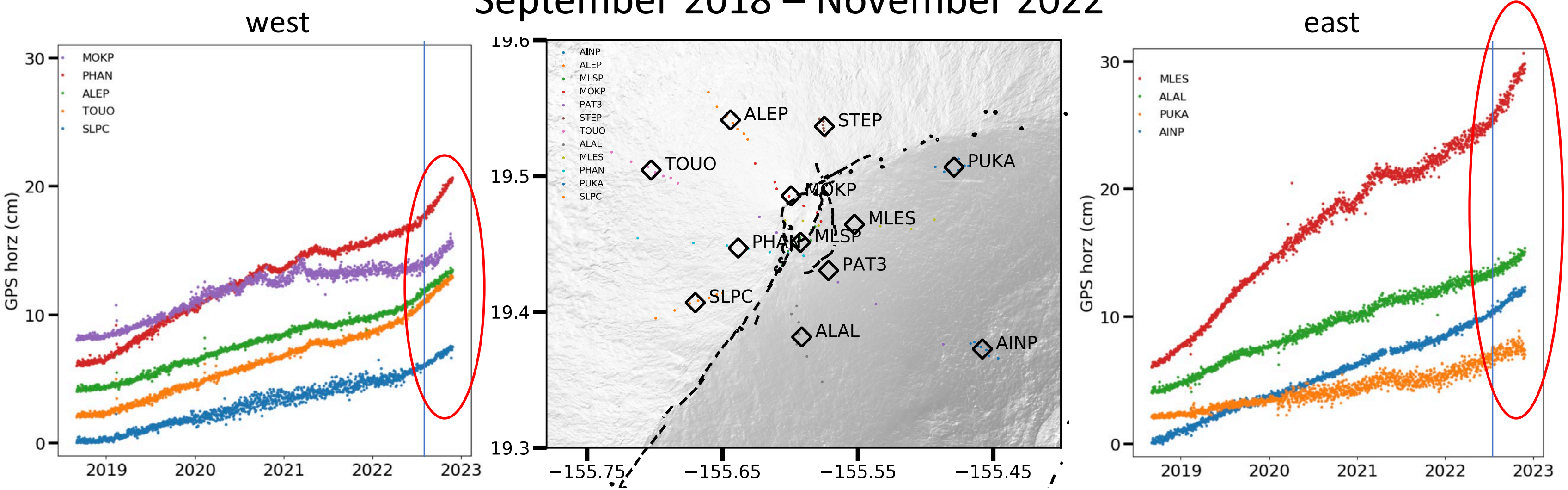


Location of eruption successfully "predicted" based on stress change models.

Pre-eruptive, co-eruptive and post-eruptive deformation

Pre-eruption: horizontal displacements

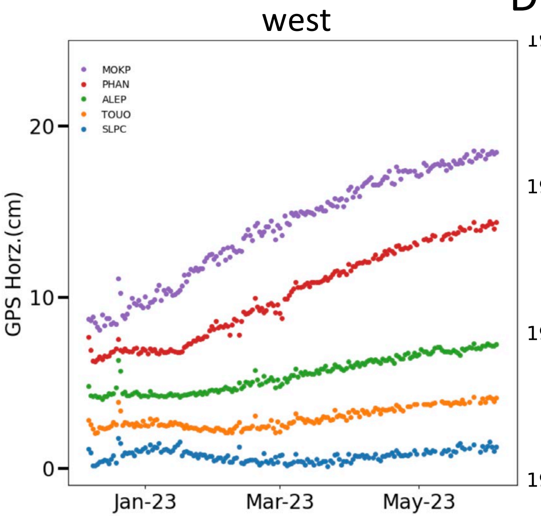
September 2018 – November 2022

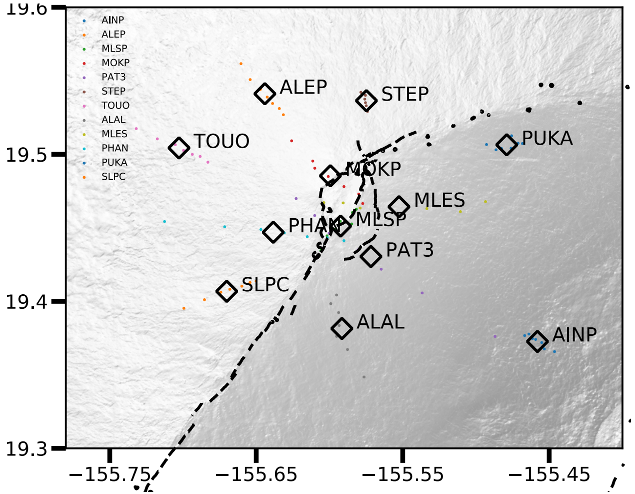


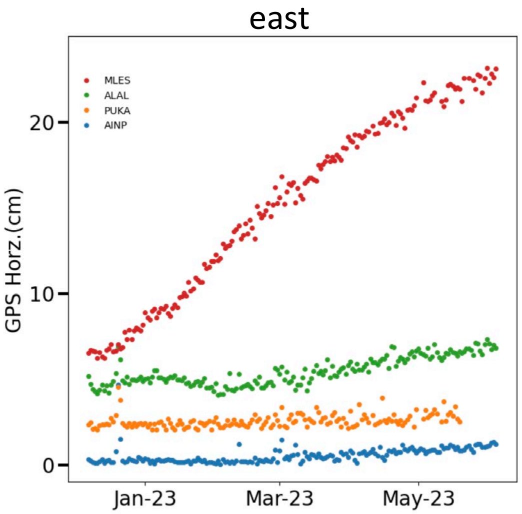
Acceleration of inflation in ~August 2022

Post-eruption: horizontal displacements

December 2022 – June 2023

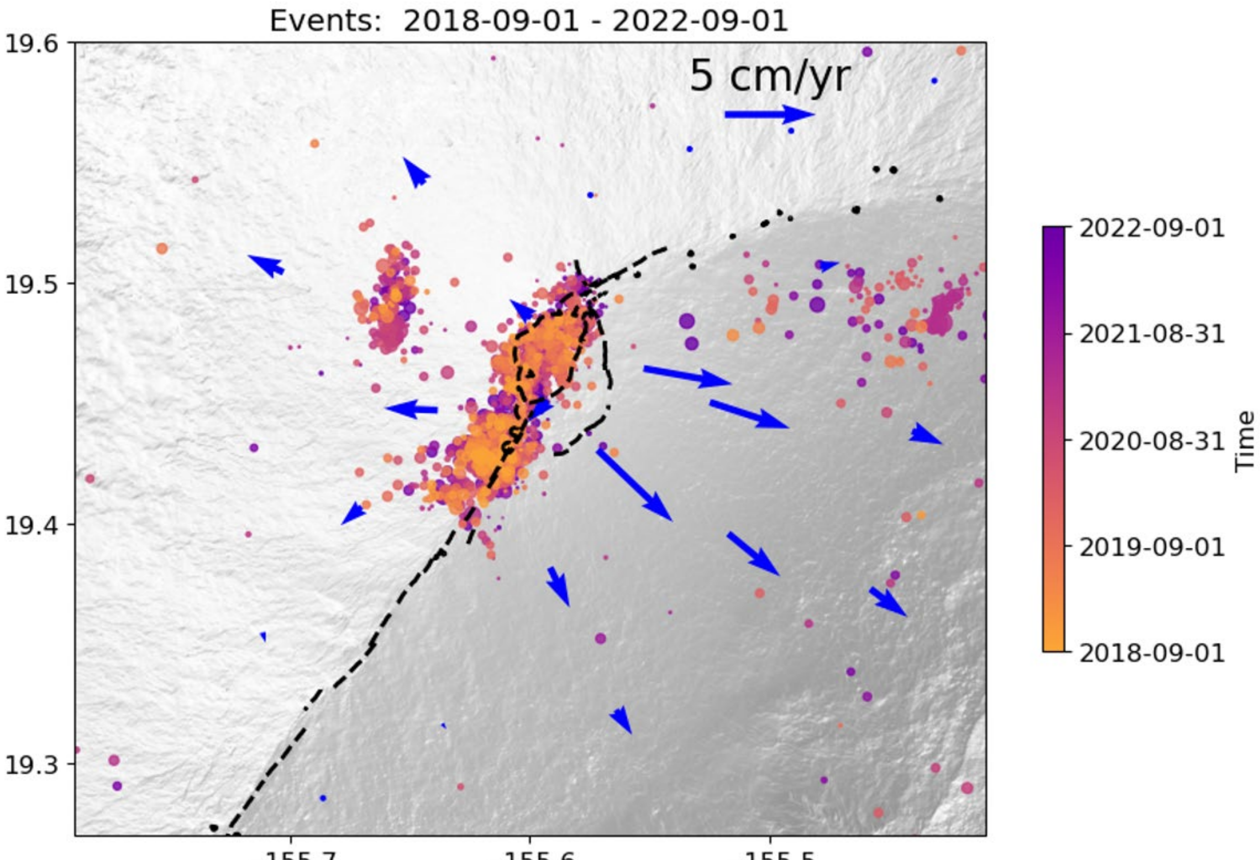






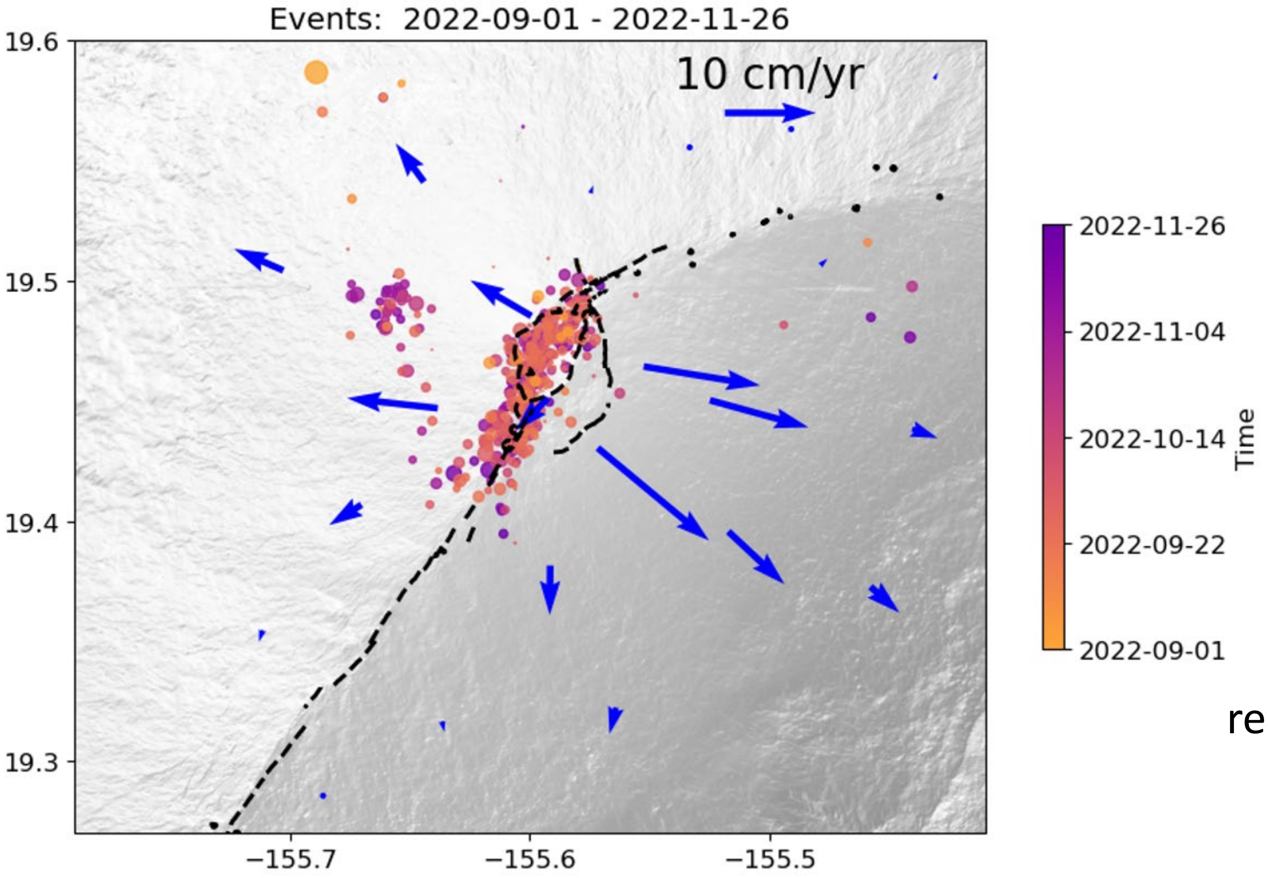
Decay of re-inflation rate since eruption

September 2018 - September 2022 (pre-eruption)



typical inflation pattern

September 2022 - 26 November 2022 (precursory)

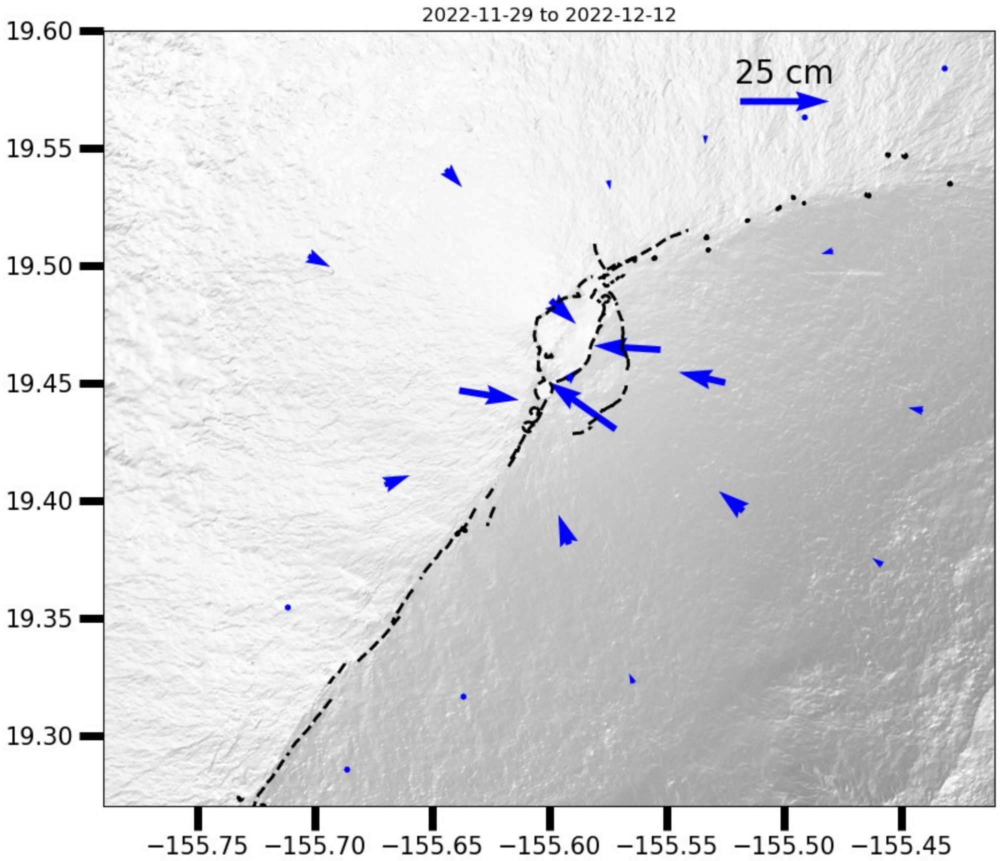


typical inflation pattern

twice the rate
(see scale)

relatively more summit deformation
→ shallow source

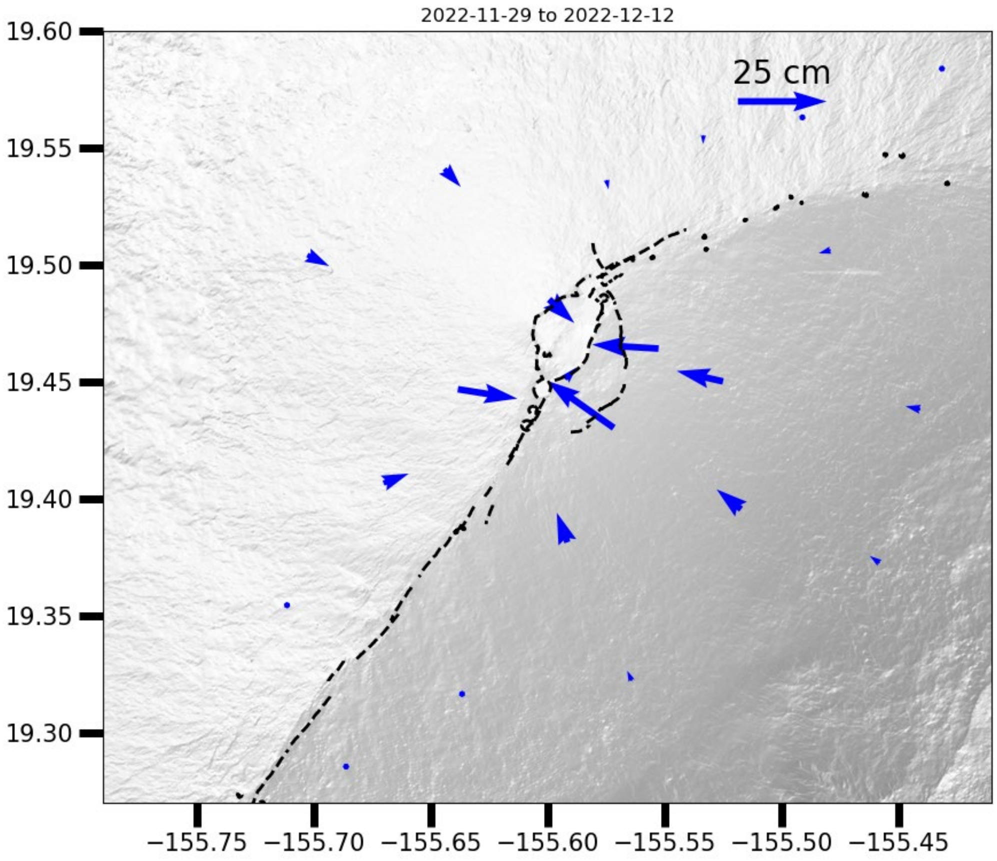
26 Nov 2022 - 29 Nov 2022 (dike propagation)



displacements (~1 meter) from:

- intruded dike
- reservoir evacuation

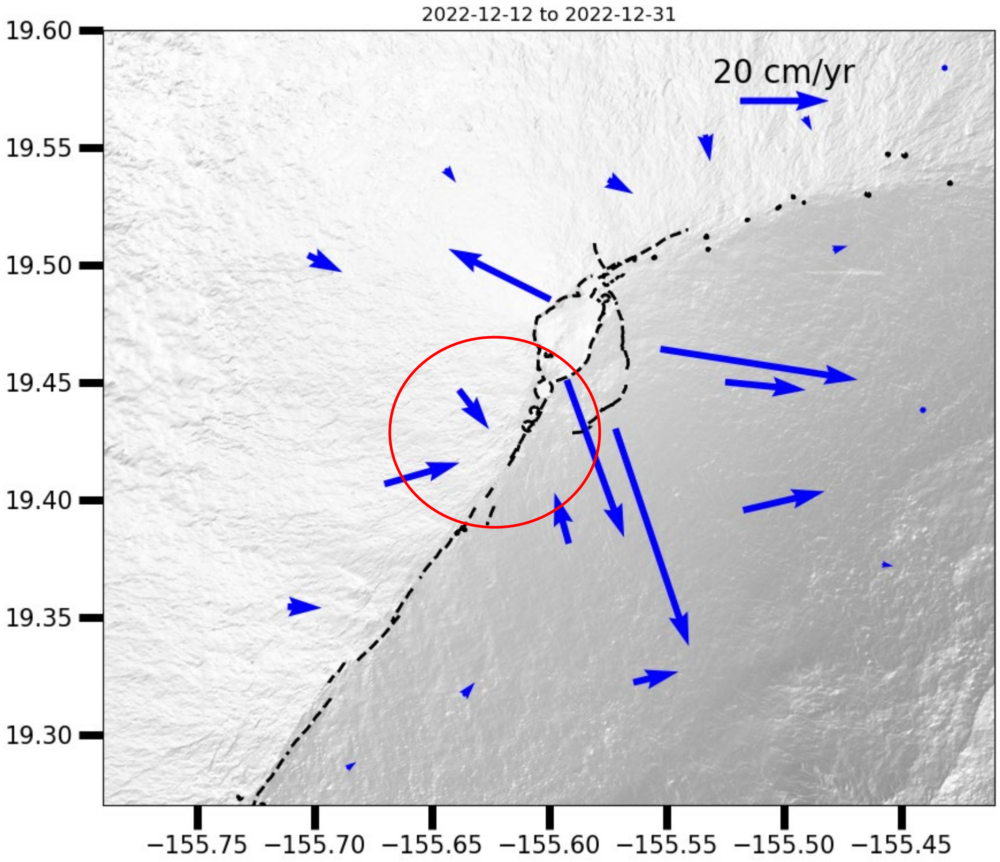
29 November 2022 - 12 December 2022 (co-eruptive)



deflation (~25 cm) from:

- reservoir evacuation

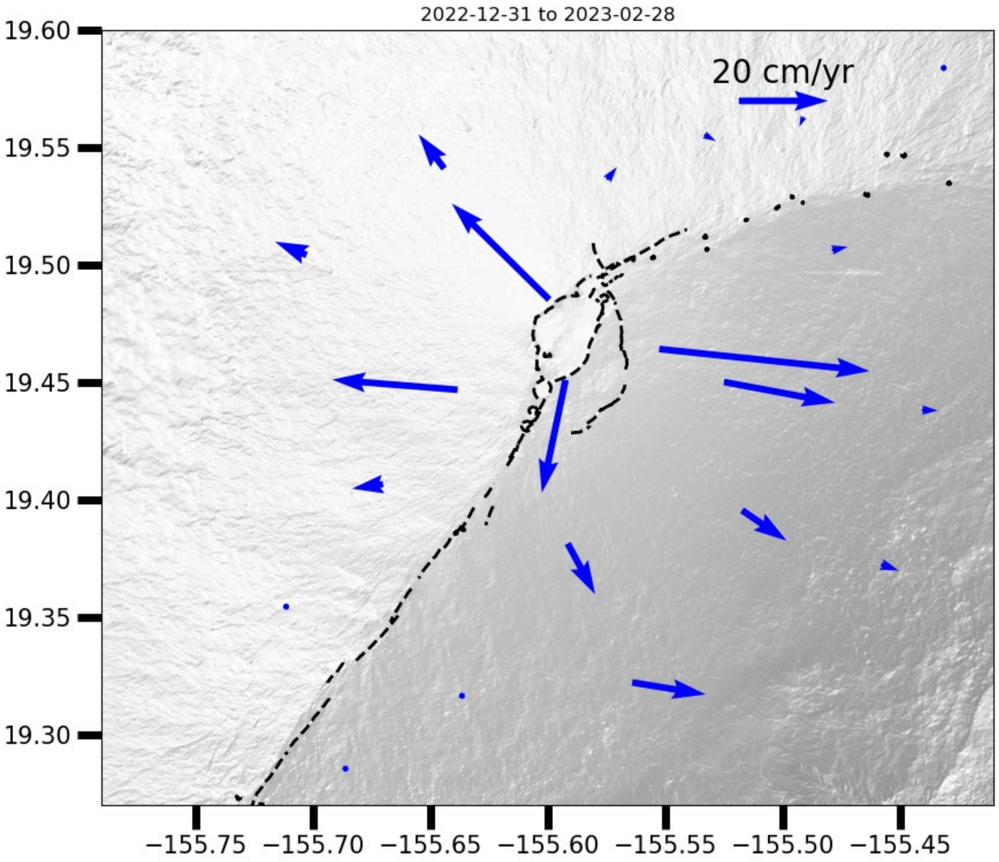
12 – 31 December 2022 (early post-eruptive, period 1)



- reinflation under central caldera (~20 cm/yr):
  → shallow source
- deflation under south caldera

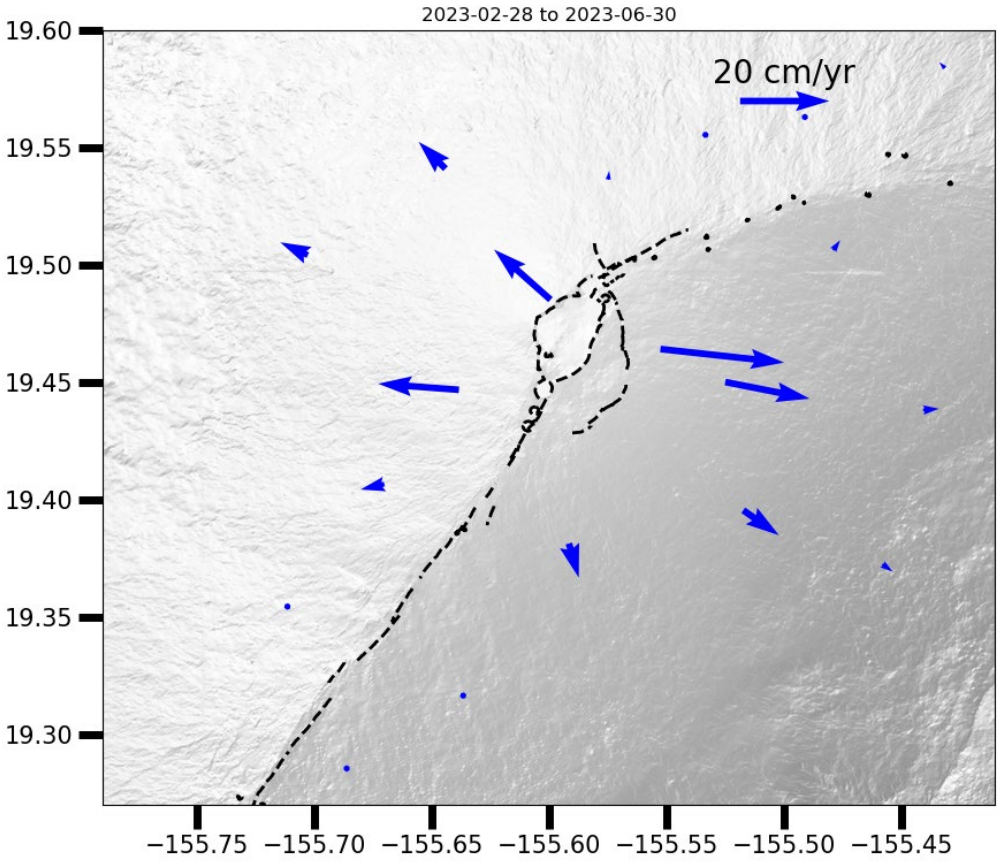
→ magma migration within reservoir

31 December 2022 – 28 February 2023 (post-eruptive period 2)



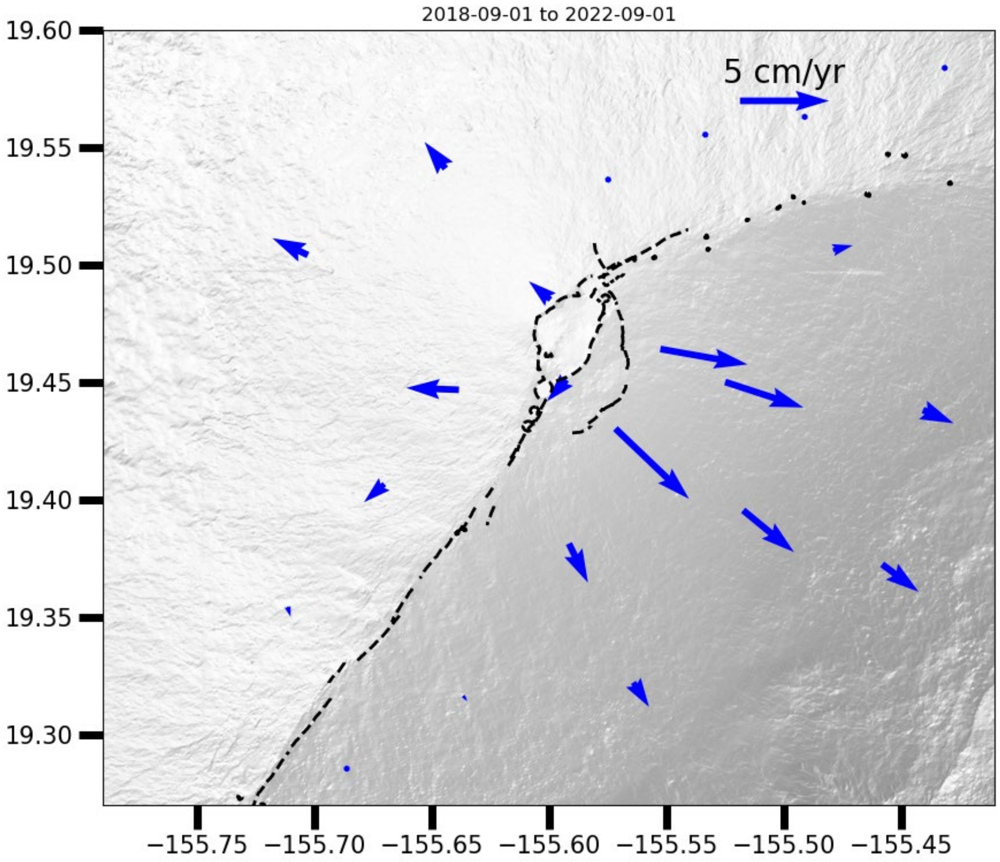
reinflation under summit
(~40 cm/yr)

28 Feb 2023 – June 2023 (post-eruptive period 3)



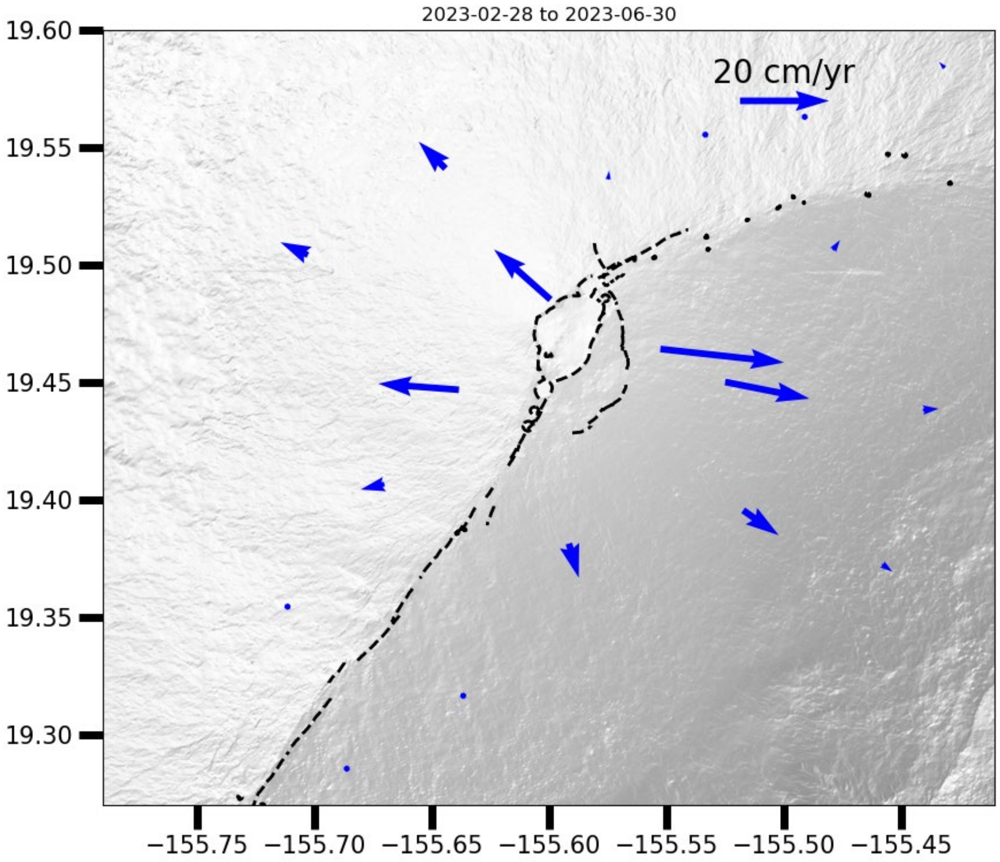
reinflation under summit
(~25 cm/yr)

Compare with-pre-eruption inflation (2018-2022)



typical inflation pattern

28 Feb 2023 – June 2023 (post-eruptive period 3)



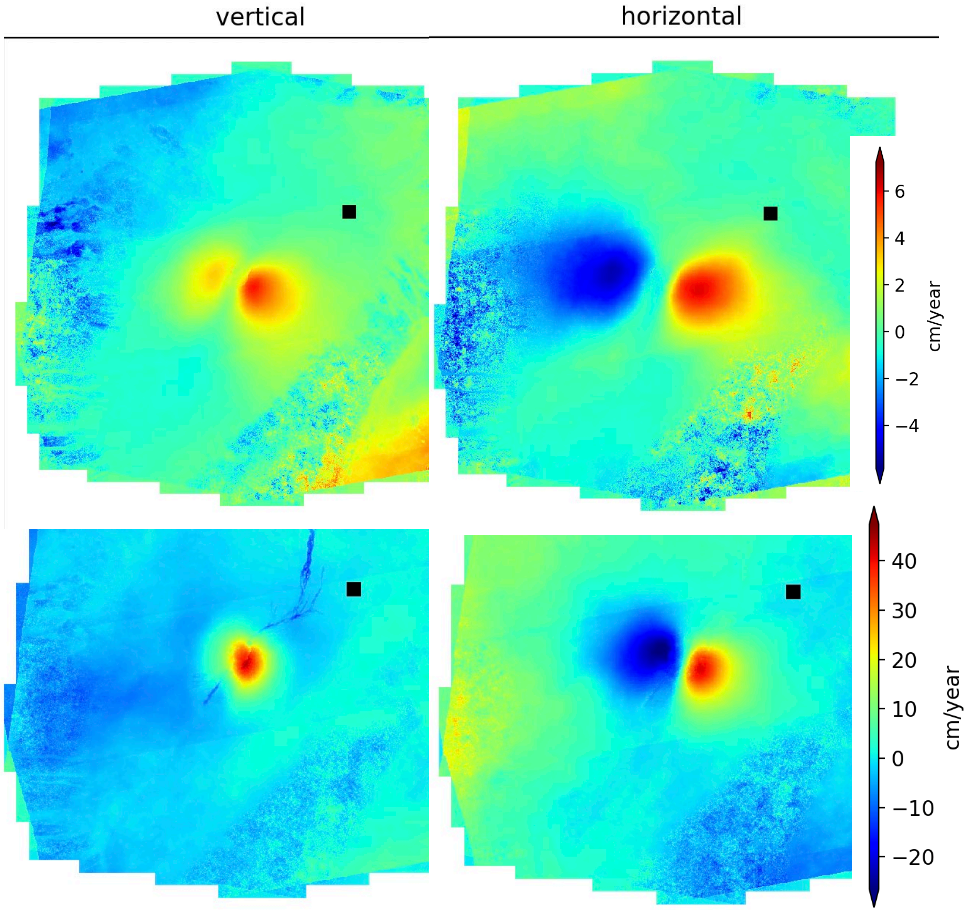
reinflation under summit
(~25 cm/yr)

relatively more summit
Inflation
→ shallow source

Vertical and Horizontal from InSAR

Pre-eruptive
(2018-2022)

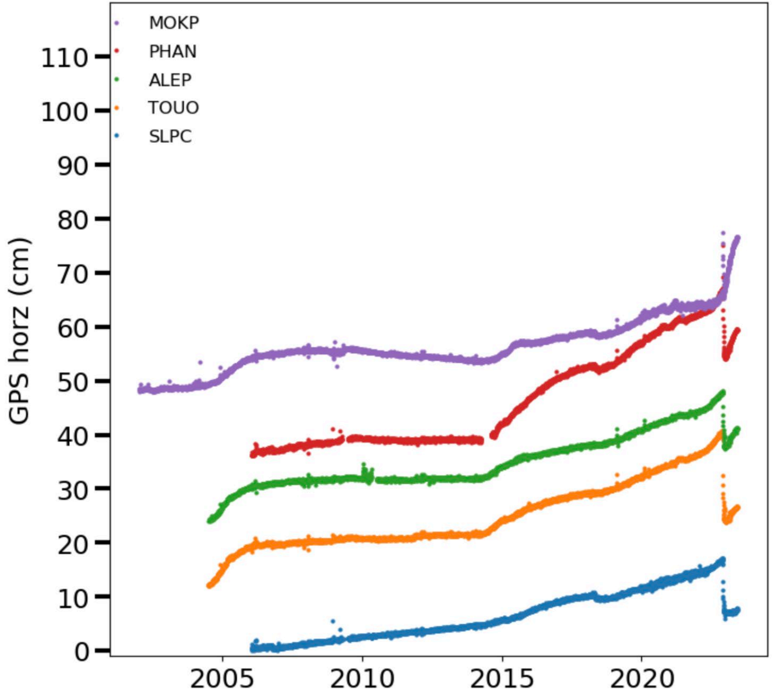
Post-eruptive
Dec 2022- June 2023

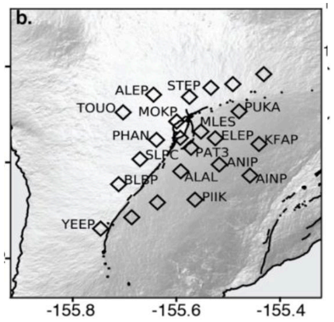


Relatively more summit deformation
→ shallow reinflation source

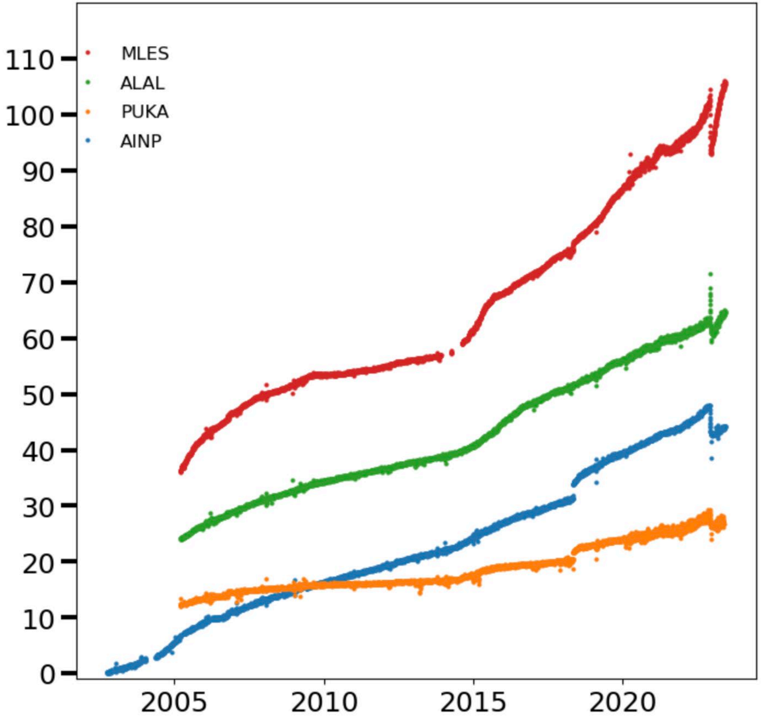
2002-2023 horizontal GPS displacements

western flank



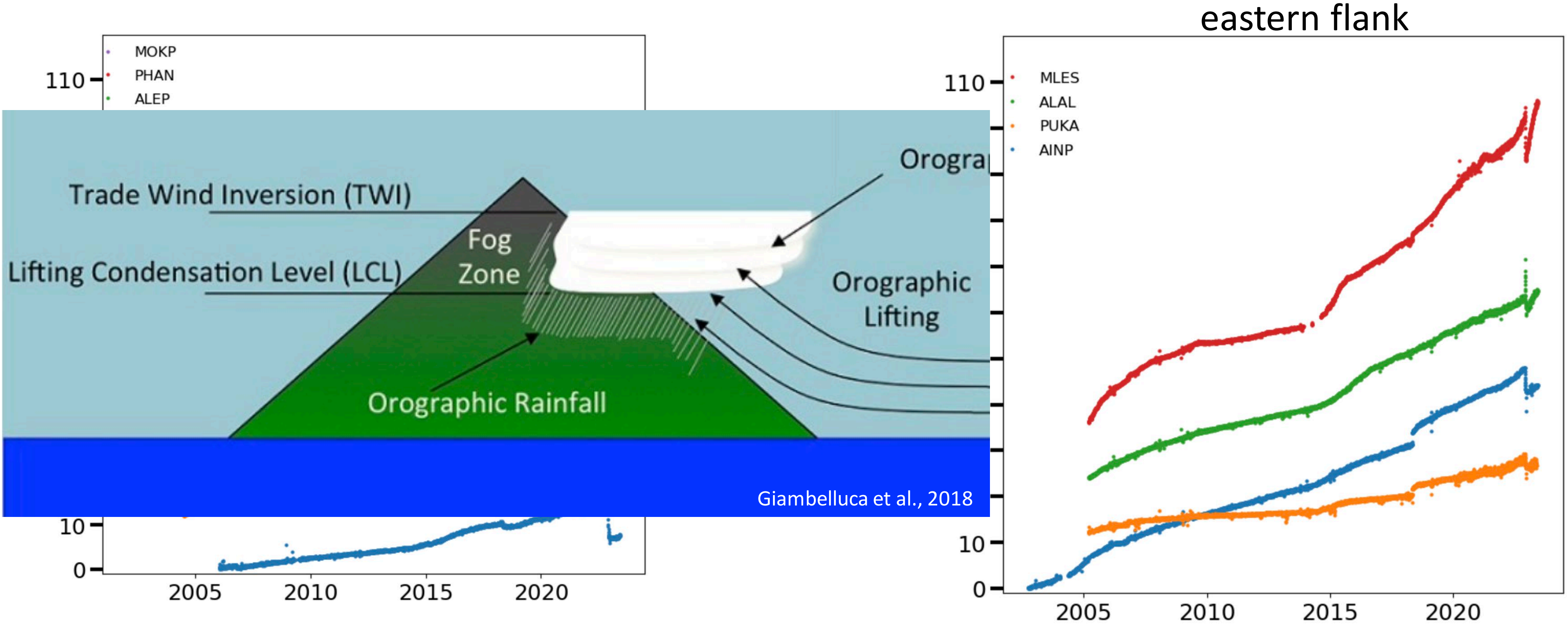


eastern flank

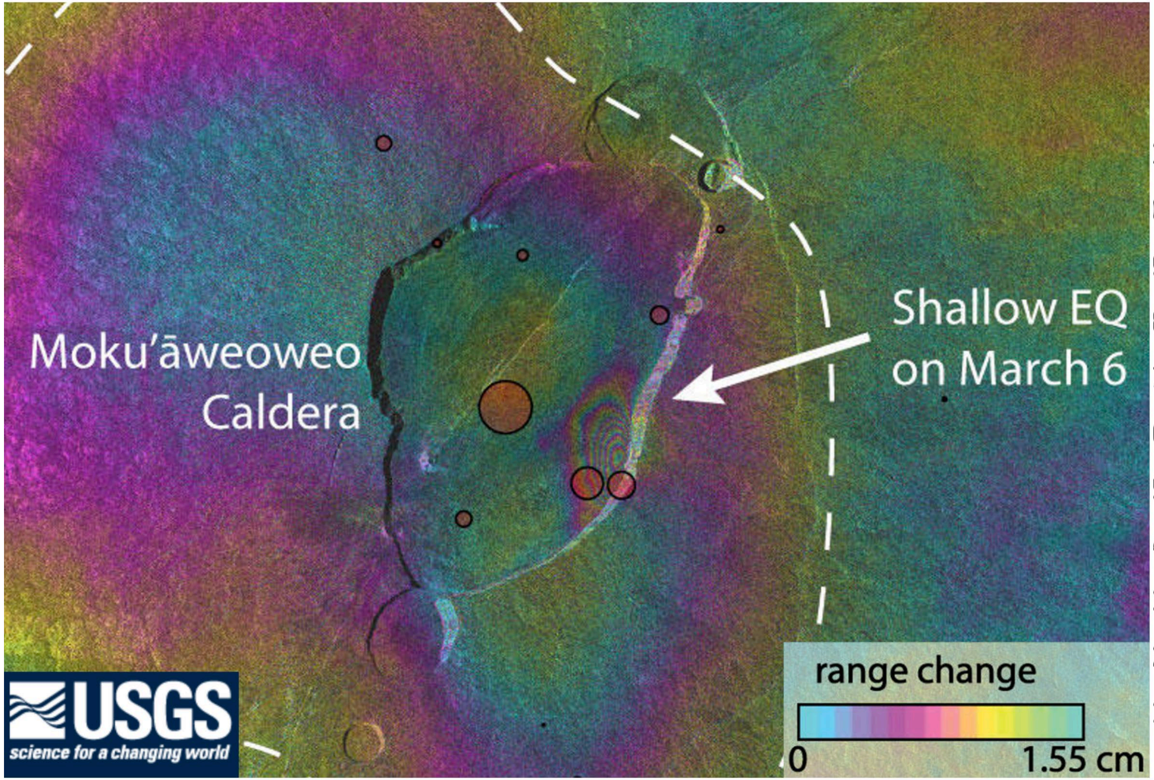


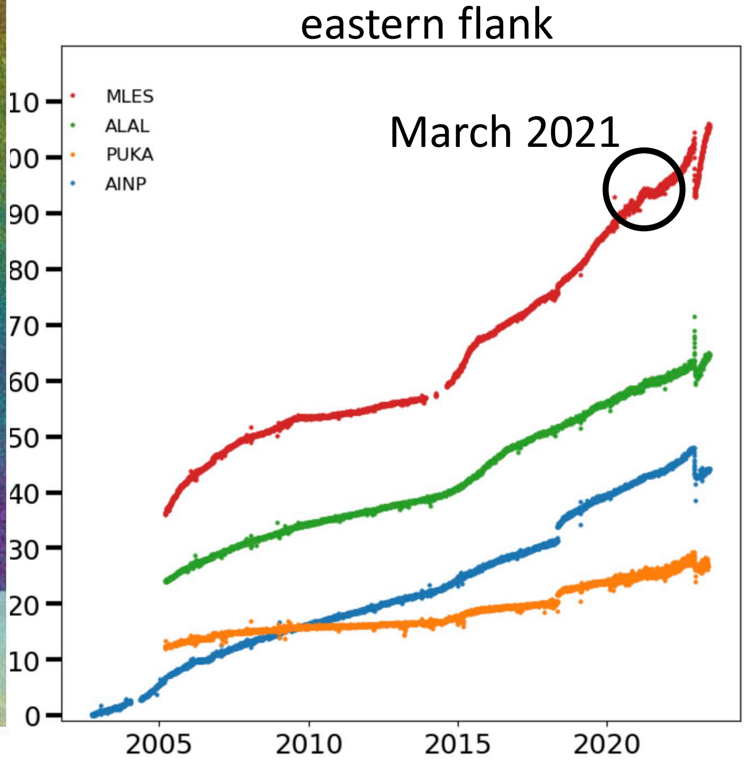
The 2022 eruption was just a blip….

Could orographic precipitation be an alternative explanation for the mobility of the eastern flank?



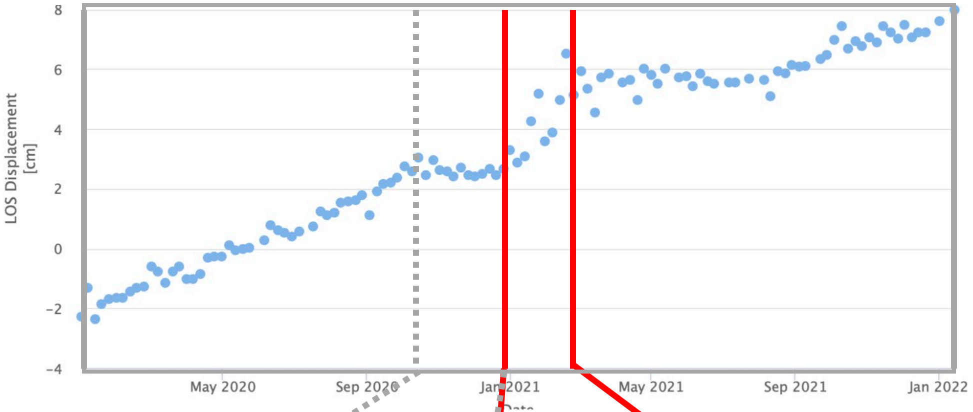
March 2021 M3.6 earthquake

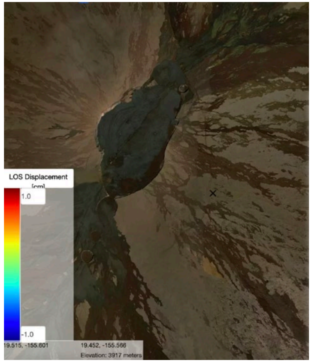




Sentinel-1 descending

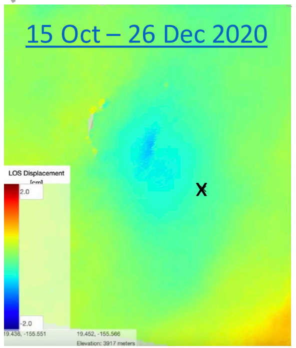
Jan-Feb 2021

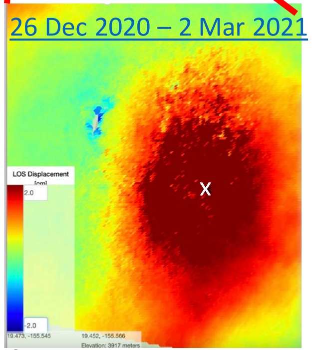




lull

rapid inflation





2 cm

2 cm

x

increased intrusion during Jan-Feb 2021

Floods on Maui , Island (1 day after quake)

The Guardian

Hawaii governor declares emergency after floods and landslides

Move came after heavy rains and dam overflowed on island of Maui, forcing evacuations and destroying homes

160 km distance from Mauna Loa

- Rainfall-triggering of Kilauea 2018: Farquharson & Amelung, Nature 2020

~40 % of 14-months precipitation during 2 months prior to quake

Floods on Maui , Island (1 day after quake)

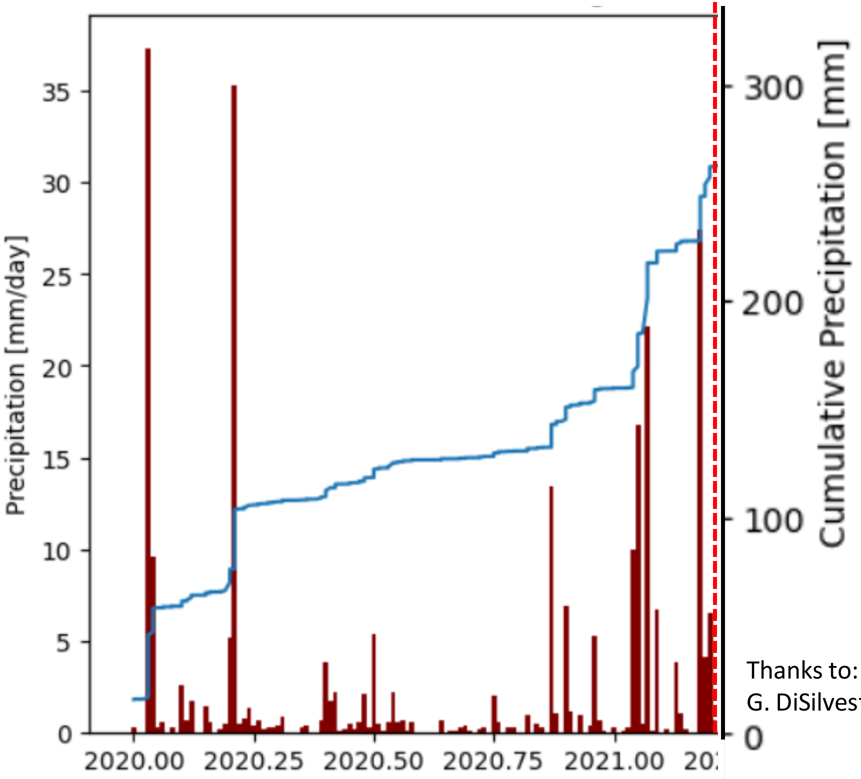

The Guardian

Hawaii governor declares emergency after floods and landslides

Move came after heavy rains and dam overflowed on island of Maui, forcing evacuations and destroying homes

01:38

6 March 2021



Thanks to: G. DiSilvestro

- Rainfall-triggering of Kilauea 2018: Farquharson & Amelung, Nature 2020

Conclusions

- Mauna Loa was inflating for > 20 years prior to 2022 eruption
- Eruption from northeast rift zone because of southward dike migration in 2015
- Two months of rapid precursory inflation
- Top-down reinflation after eruption

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Back-up slides