Photo by Parque National Galápagos

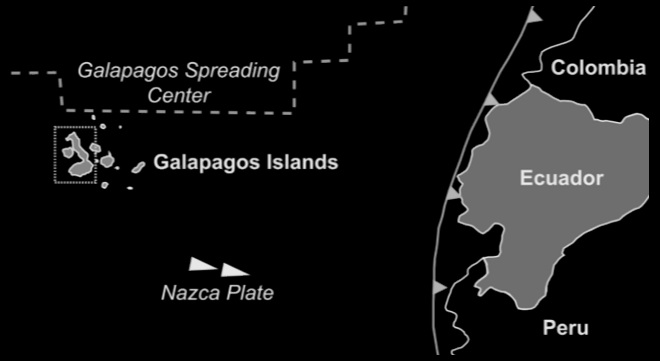
Chasing a "*Magma Gopher*"

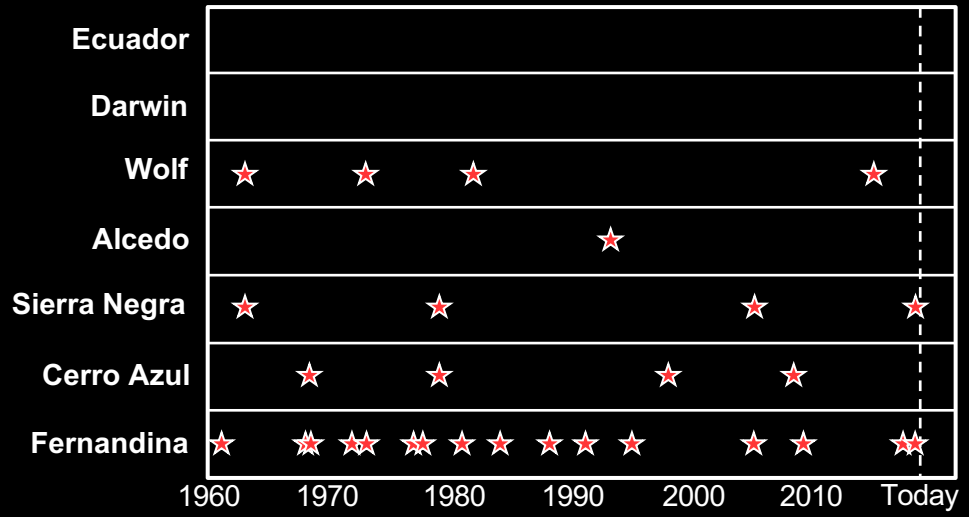
Insights on Intricate Subsurface Magma Pathways at Sierra Negra Volcano, Galápagos

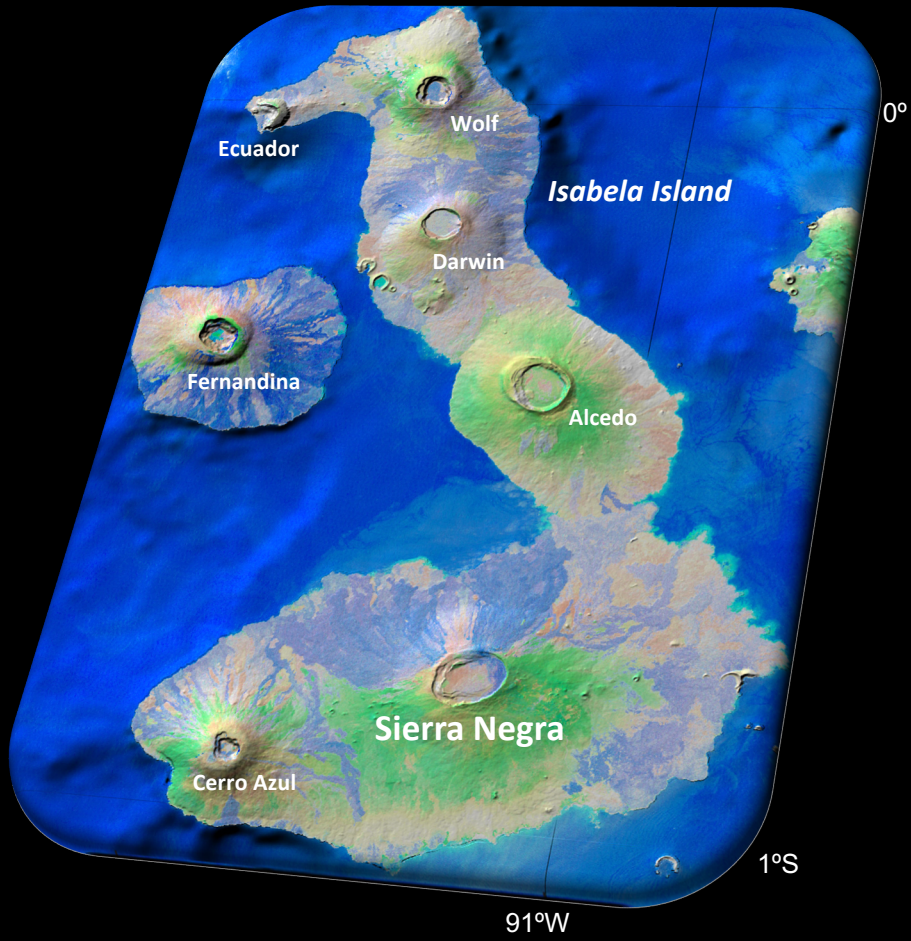
Marco Bagnardi and Paul Lundgren

Jet Propulsion Laboratory
California Institute of Technology

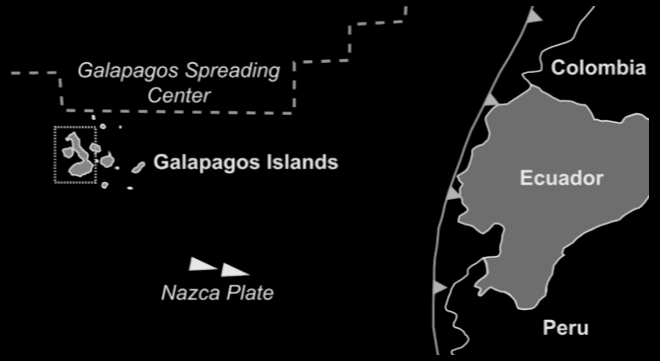
Sierra Negra Volcano – Galápagos Islands

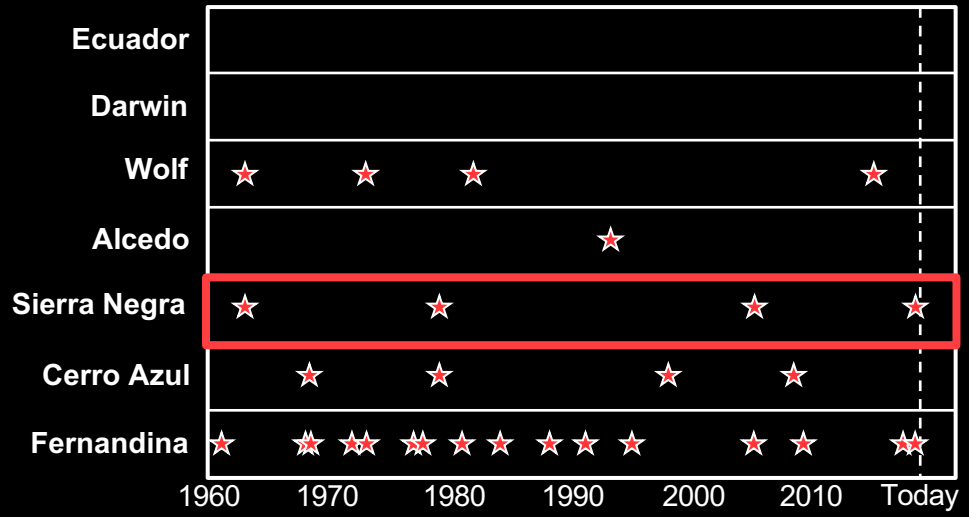


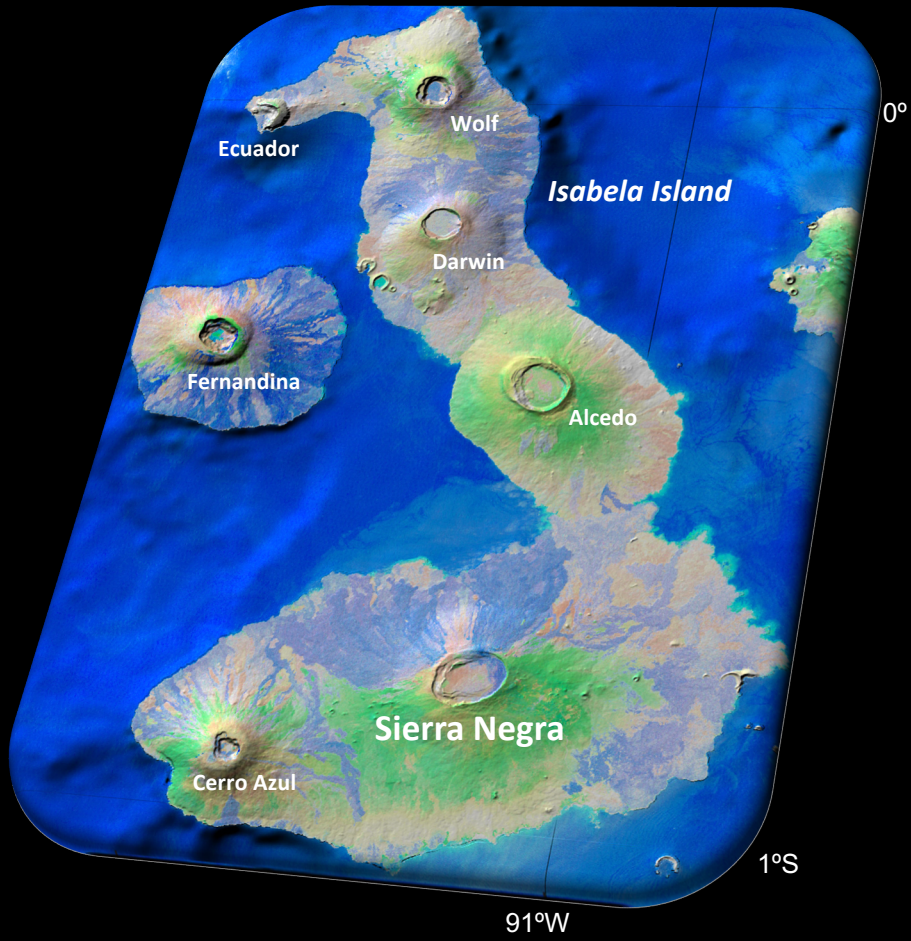




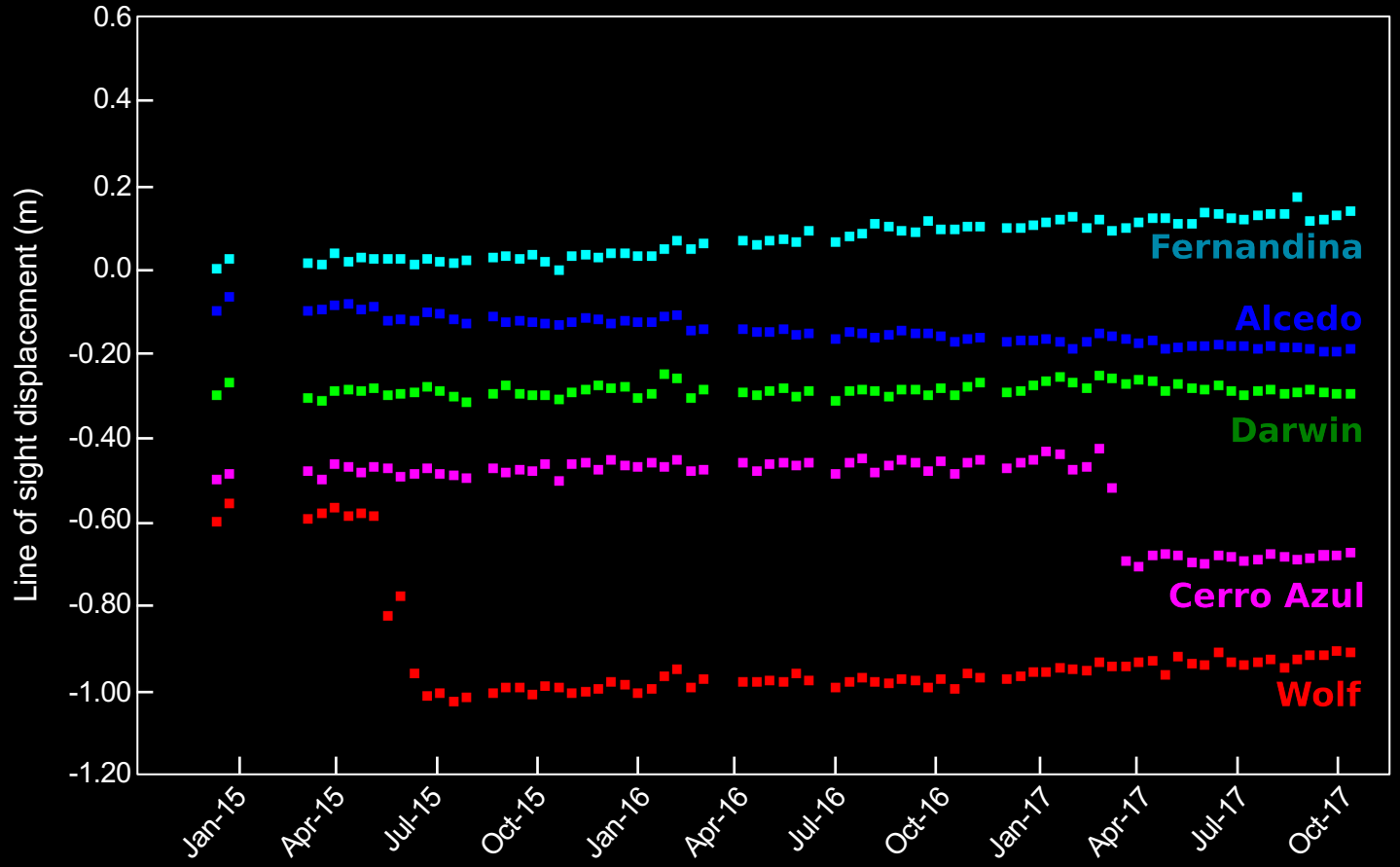
Sierra Negra Volcano – Galápagos Islands

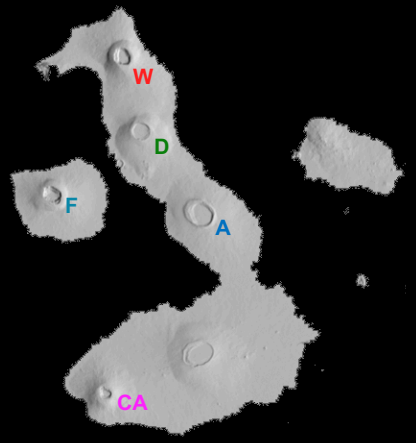


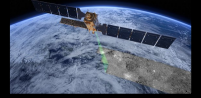




Deformation – InSAR time series 2015 – 2017







Sentinel-1 data: derived from Copernicus SAR data

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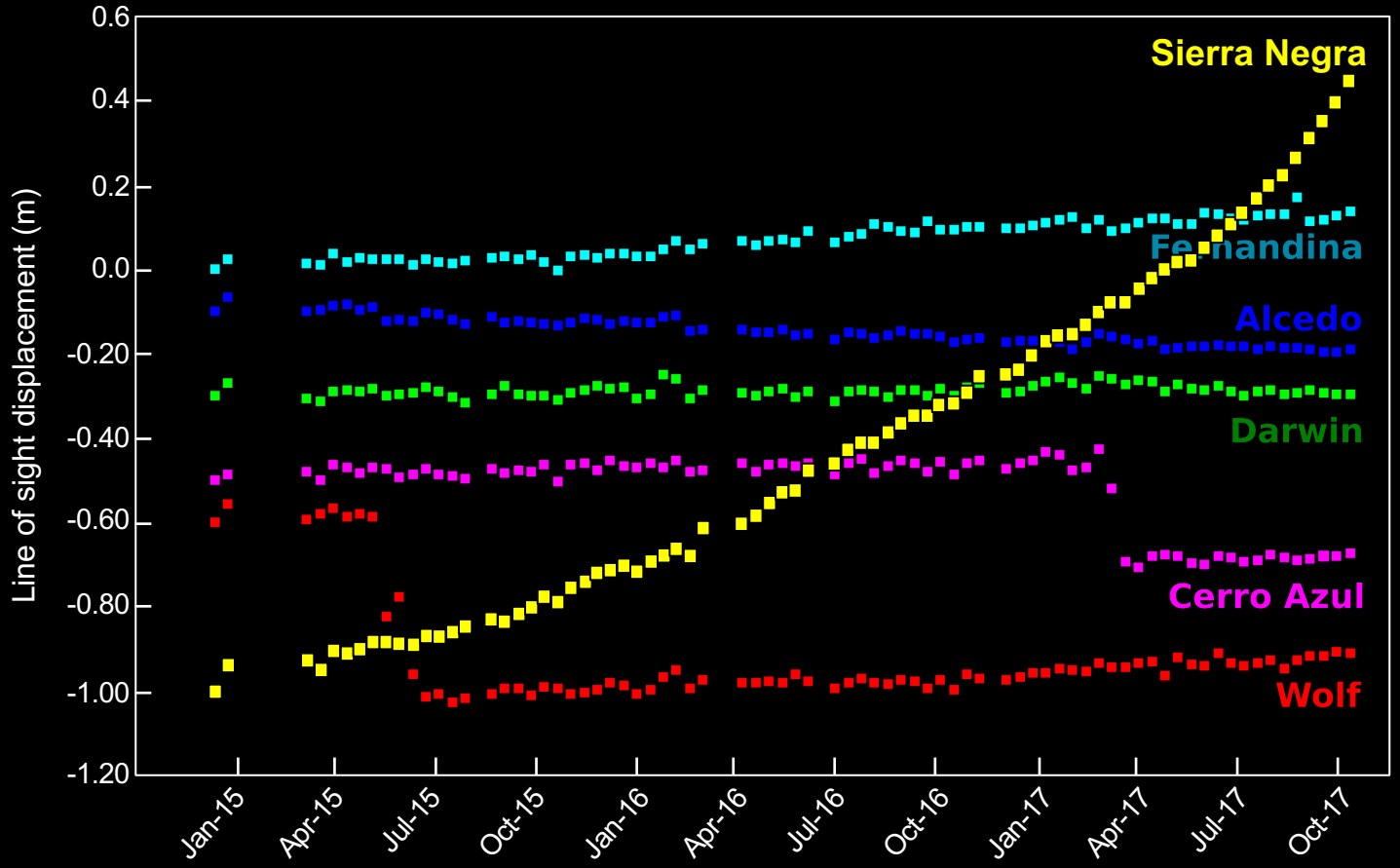

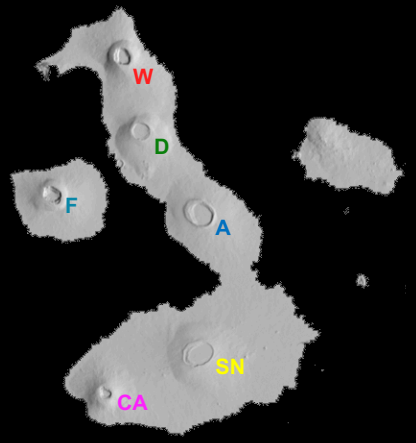

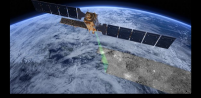

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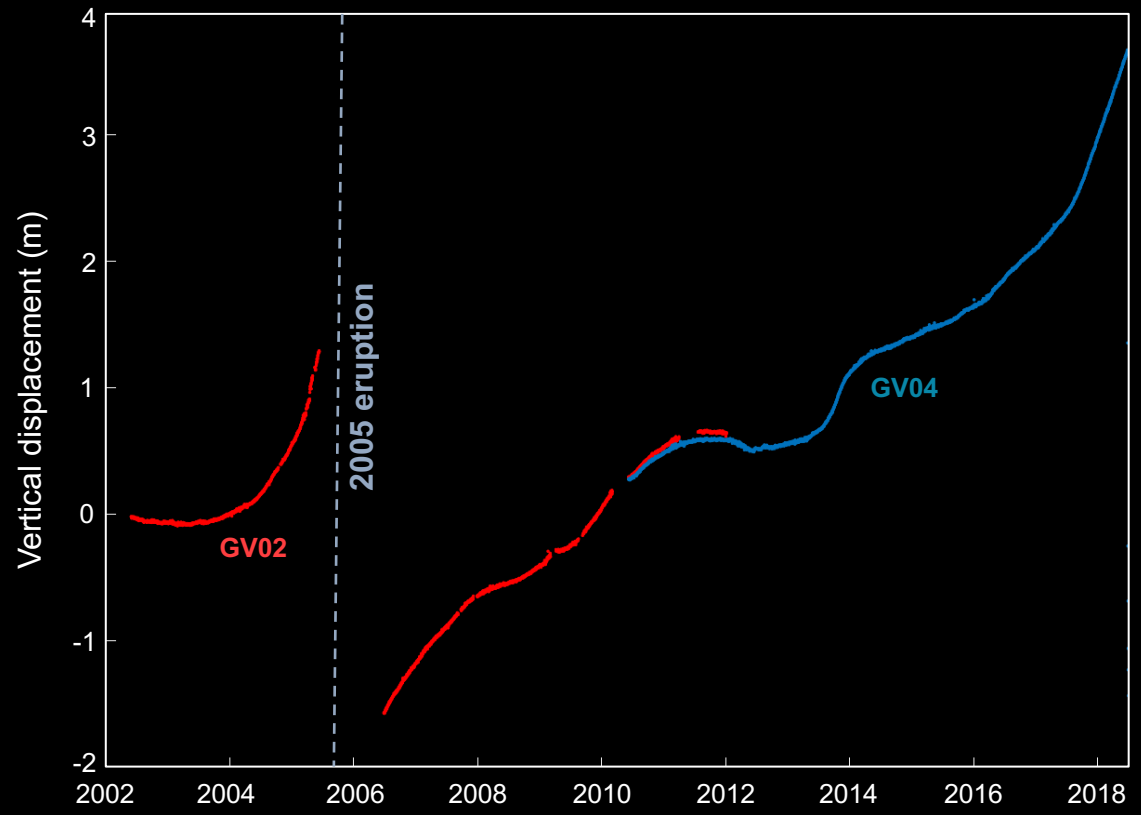
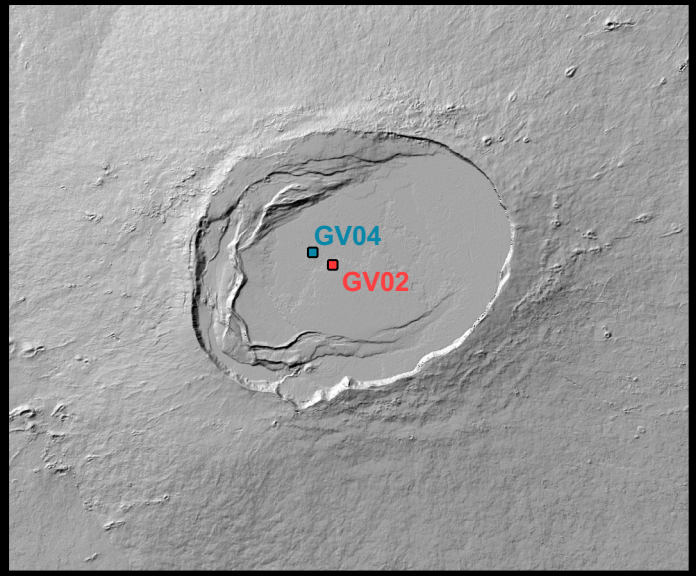
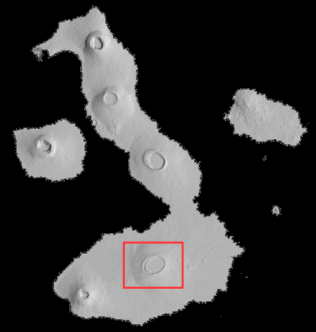
Long-term deformation (GNSS) 2002 – 2018



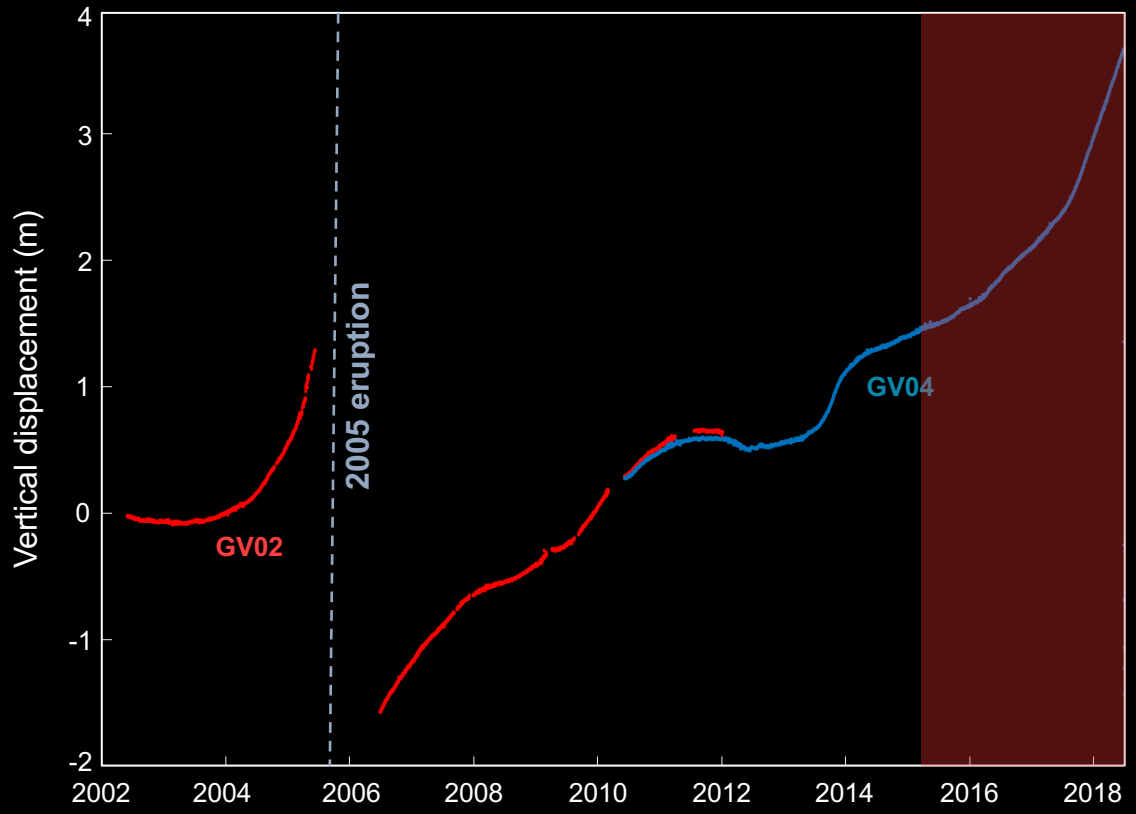


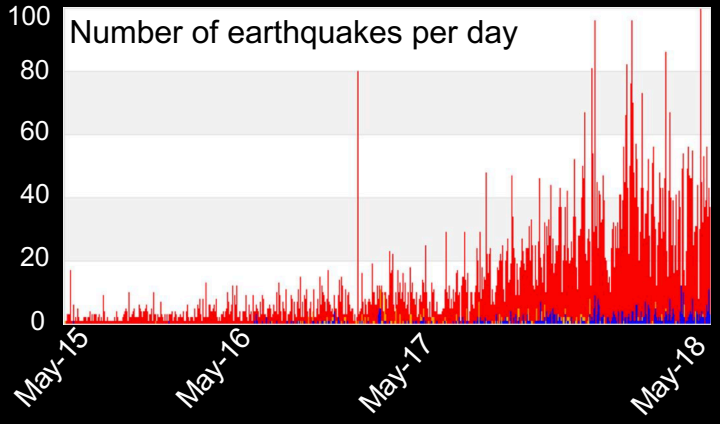
DEM: TanDEM-X



GNSS data: Nevada Geodetic Laboratory

Long-term deformation vs. seismicity

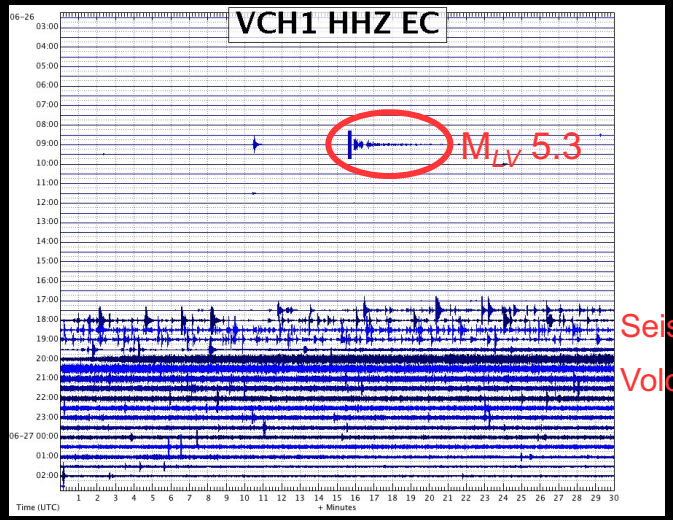




Modified from IGEPN, Informe Especial No. 4, 06/08/2018

GNSS data: Nevada Geodetic Laboratory

June – August 2018 eruption chronology



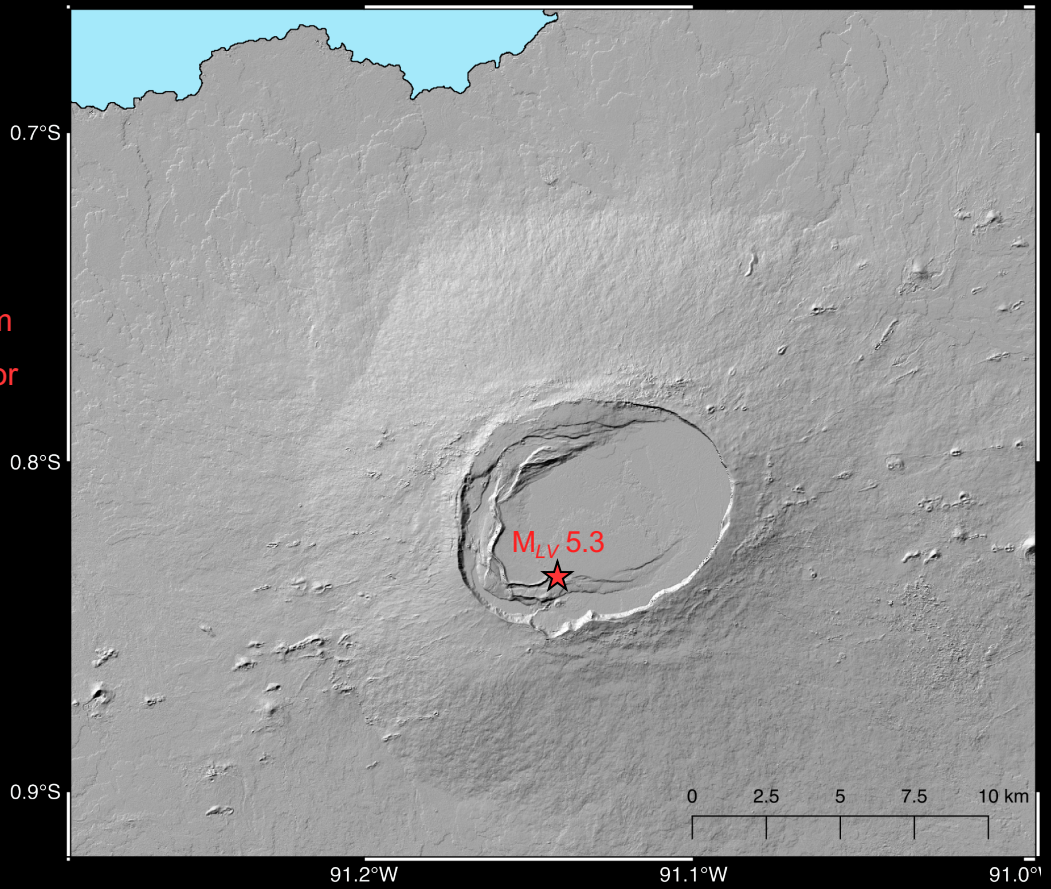
From IGEPN, Informe Especial No. 3, 12/22/2017

09h15 (UTC): M_{LV}5.3 trapdoor-faulting earthquake

17h17 (UTC): onset of seismic swarm

19h40 (UTC): onset of volcanic tremor

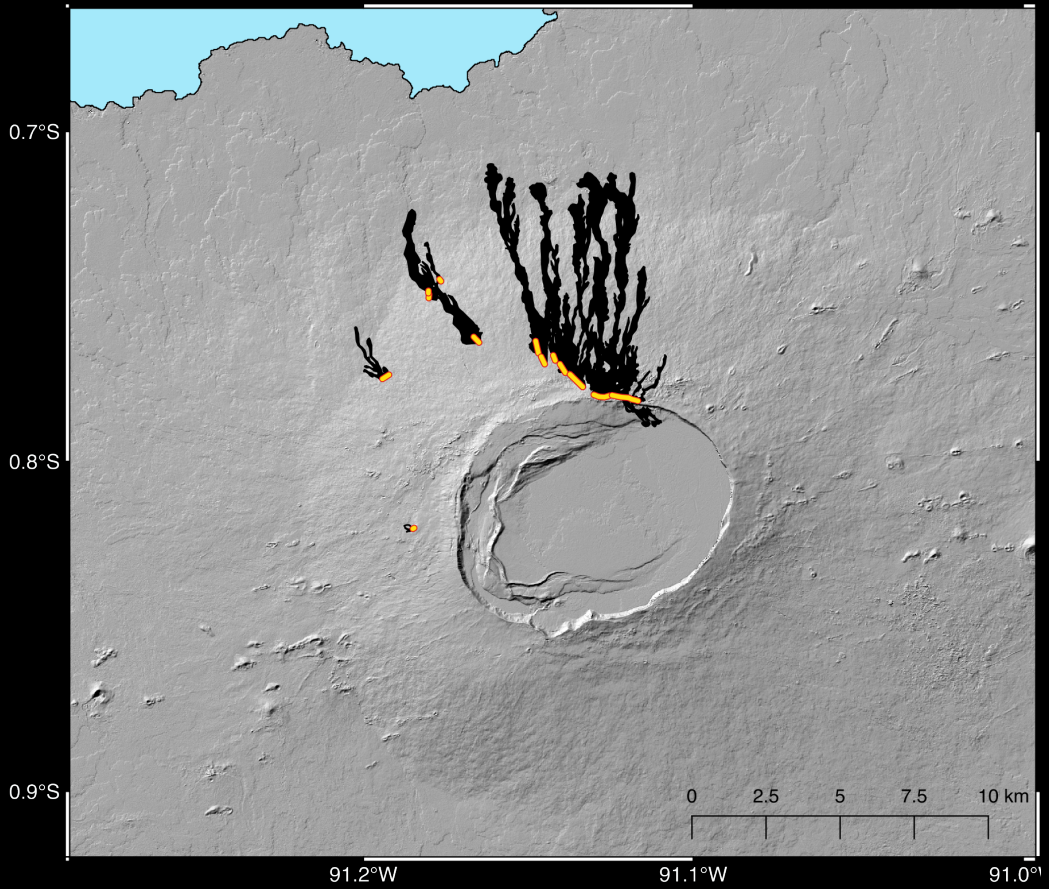
From *Vasconez et al.*, 2018



June – August 2018 eruption chronology

PHASE 1: lasted < 1 day; Area covered > 17 km^2
[*Vasconez et al.*, 2018]

Photo by Parque National Galápagos – Xavier García.
Taken at 18:25 LT, 00:25 UTC.



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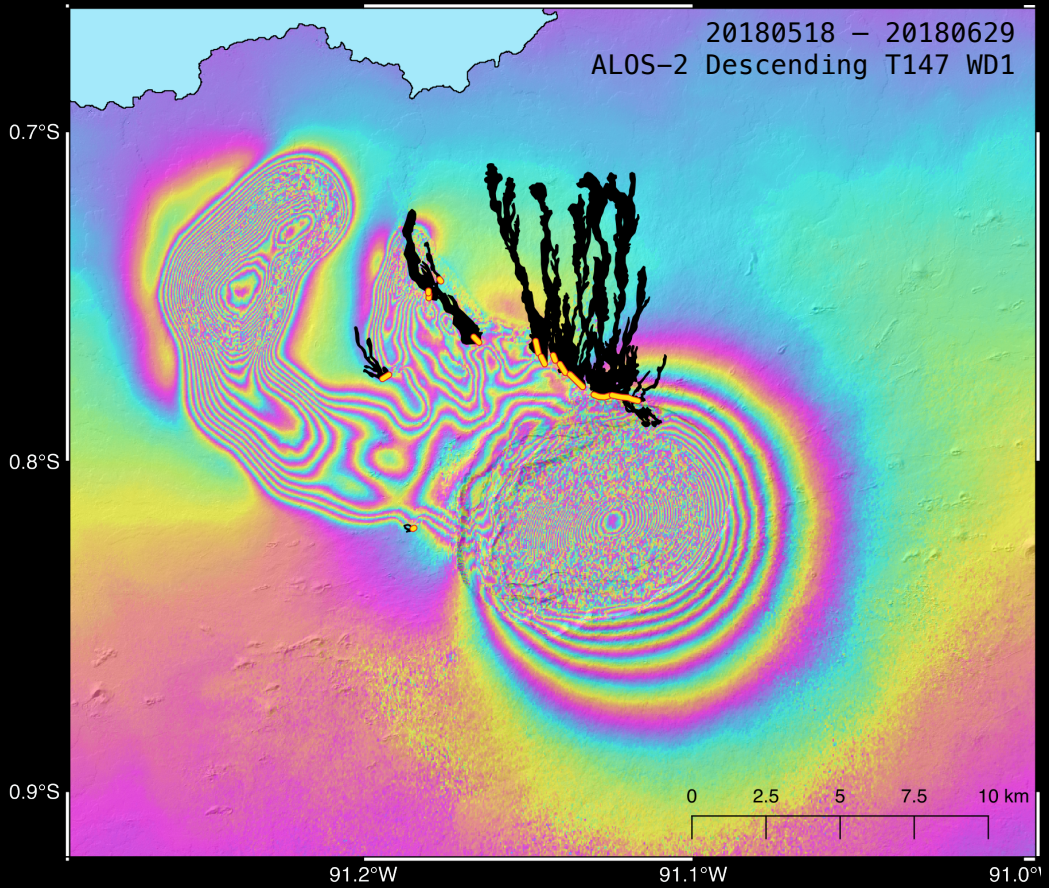


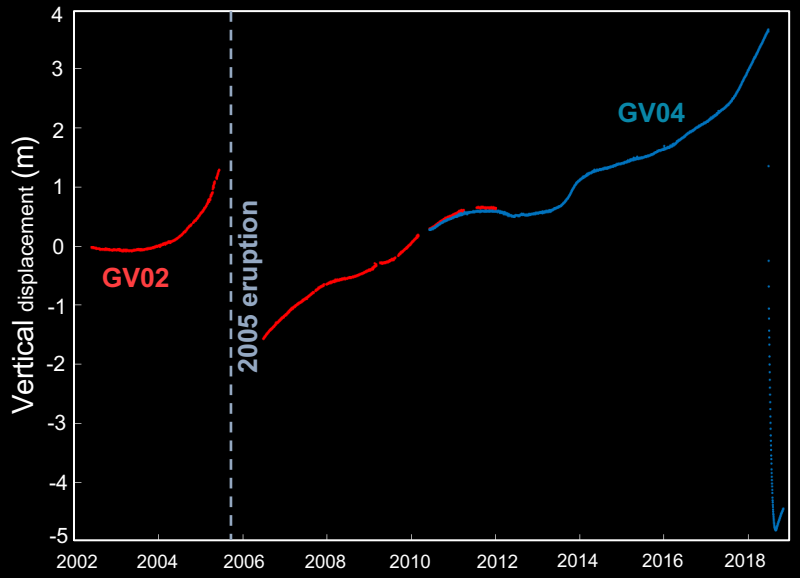
ALOS-2 data: from JAXA

June – August 2018 eruption chronology

PHASE 2: lasted 57 days; Area covered > 13 km^2

Total area covered: 30.6 km^2

[*Vasconez et al.*, 2018]



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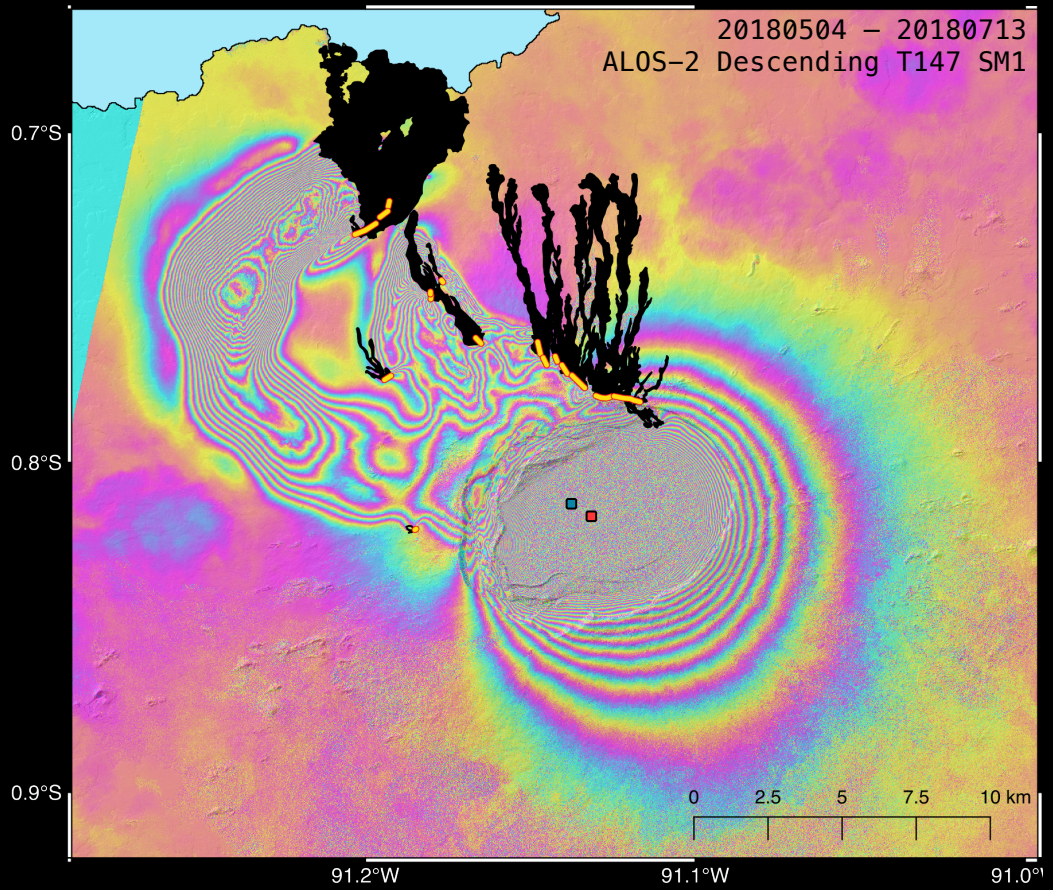

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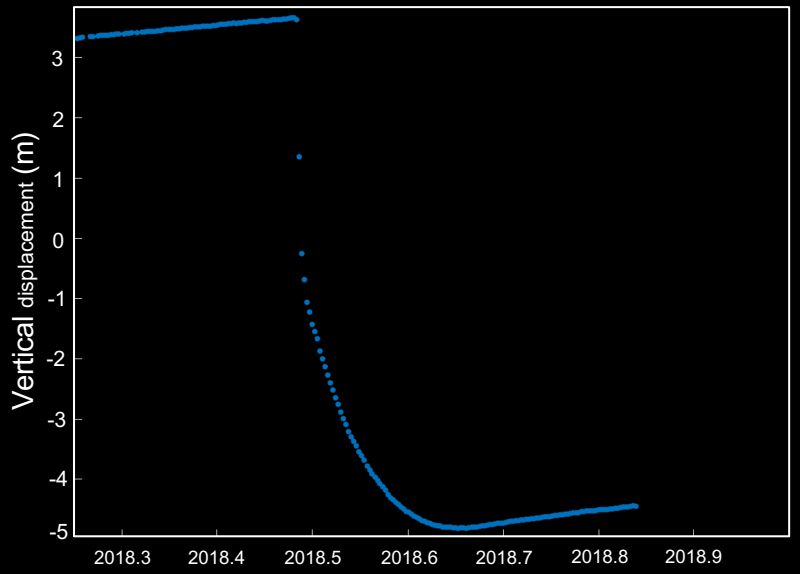

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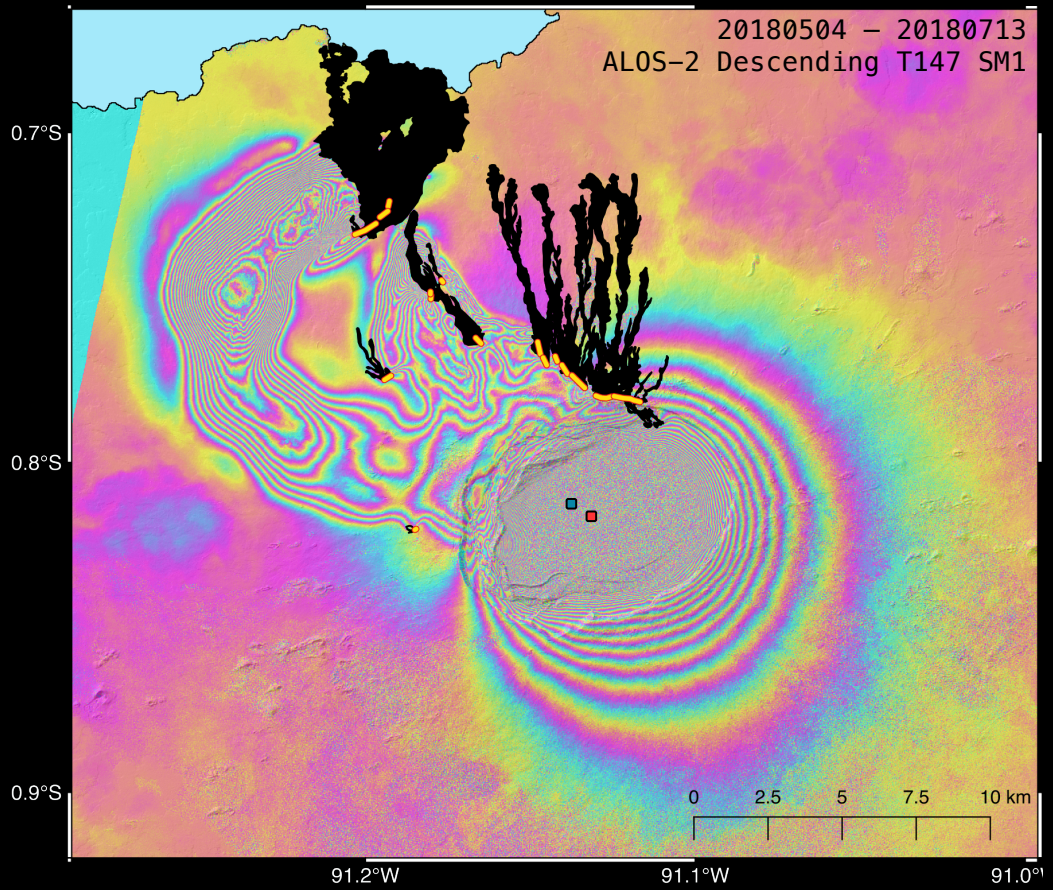

ALOS-2 data: from JAXA

Intrusion velocity

INTRUSION 1

Length: ~ 7 km

Max. propagation time: ~ 7 hours

Min. propagation velocity: 1 km/h or 0.28 m/s

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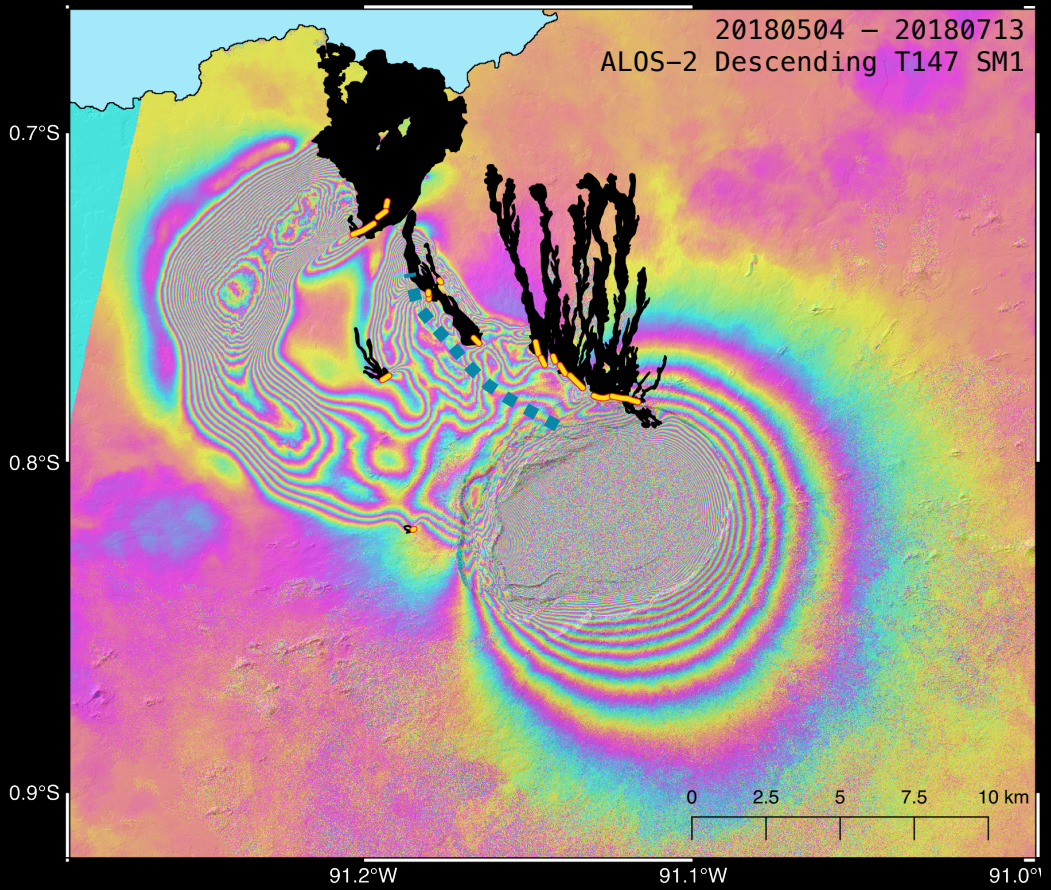

ALOS-2 data: from JAXA

0.0 LOS Displacement (cm) 11.45

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INTRUSION 2

Length: ~ 19 km

Max. propagation time: ~ 77 hours

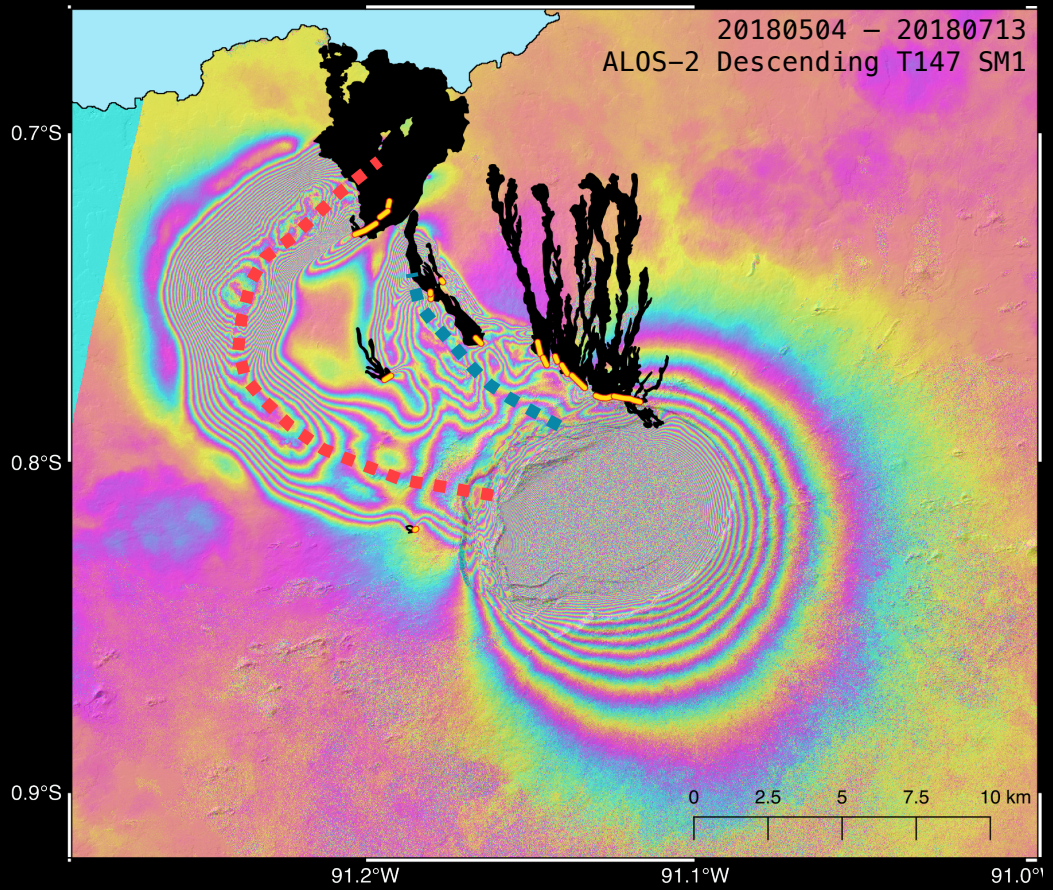
Min. propagation velocity: 0.25 km/h or 0.07 m/s

*** If northernmost fissure erupting at the same time as upper fissures** (e.g., *Vasconez et al.*, 2018)**:**

Length: ~ 19 km

Max. propagation time: ~ 7 hours

Min. propagation velocity: 2.7 km/h or 0.75 m/s



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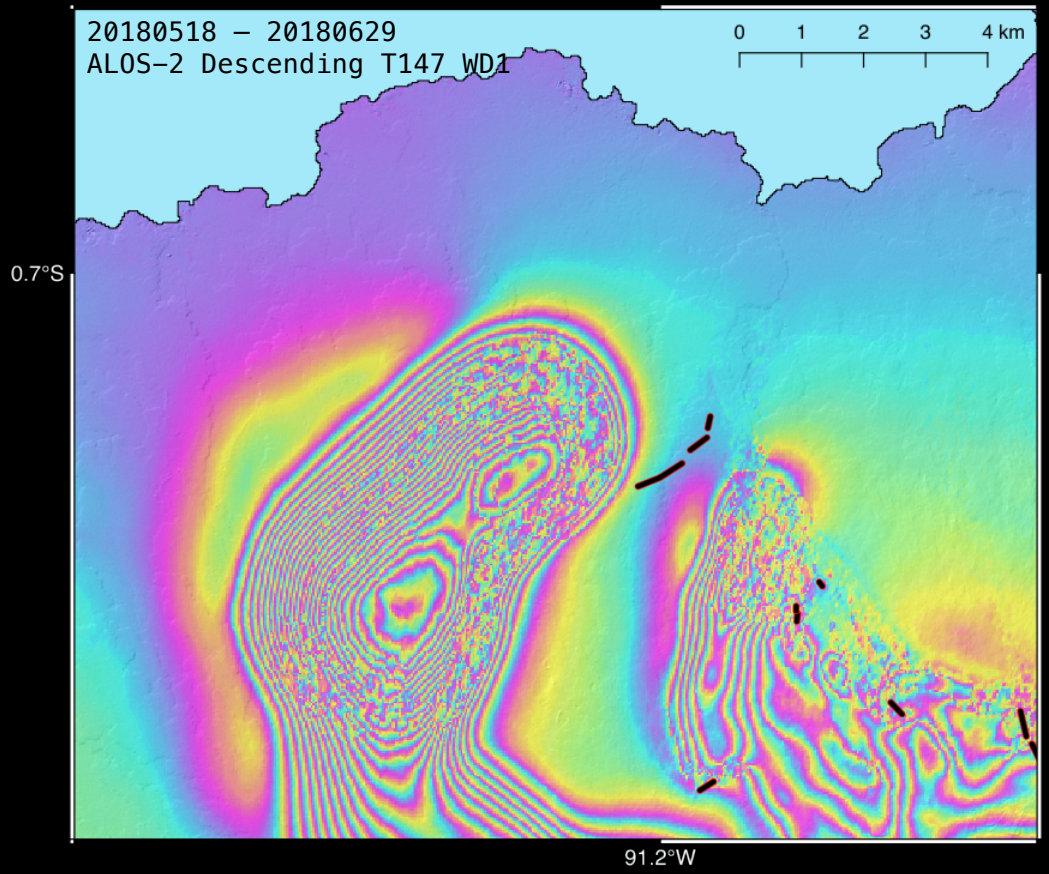

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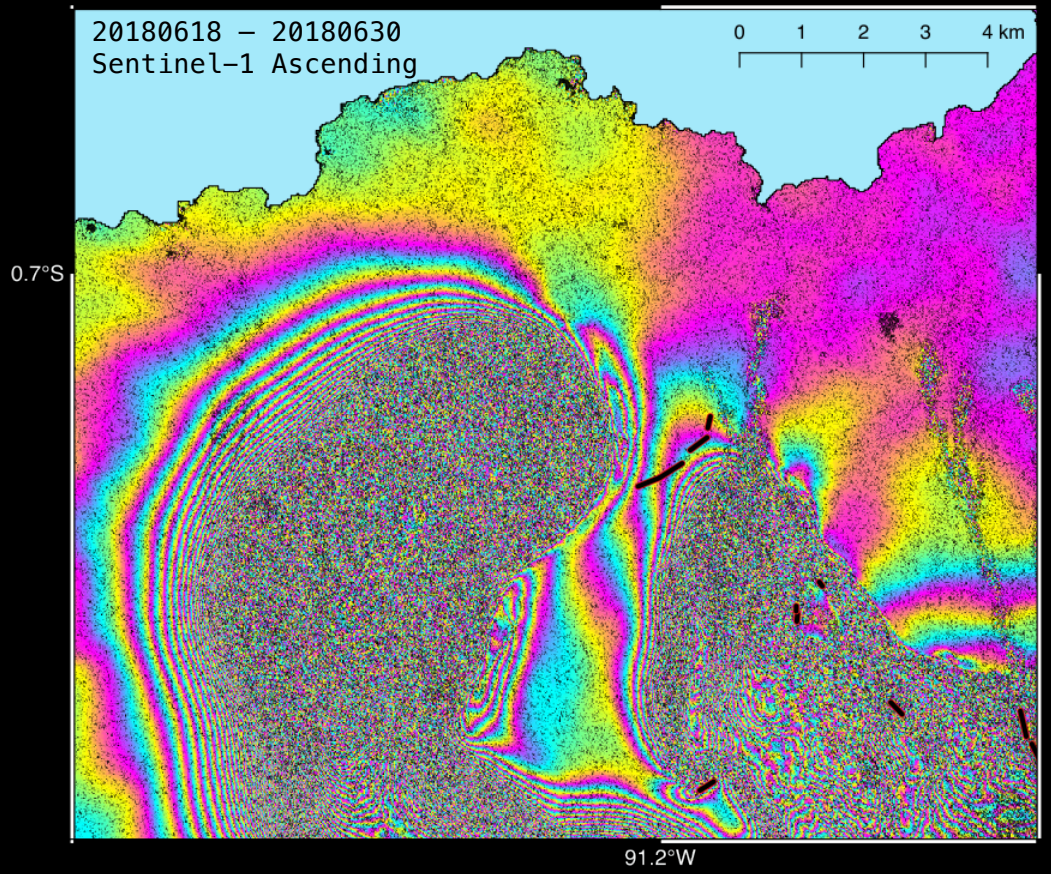

Sentinel-1 data: derived from Copernicus SAR data

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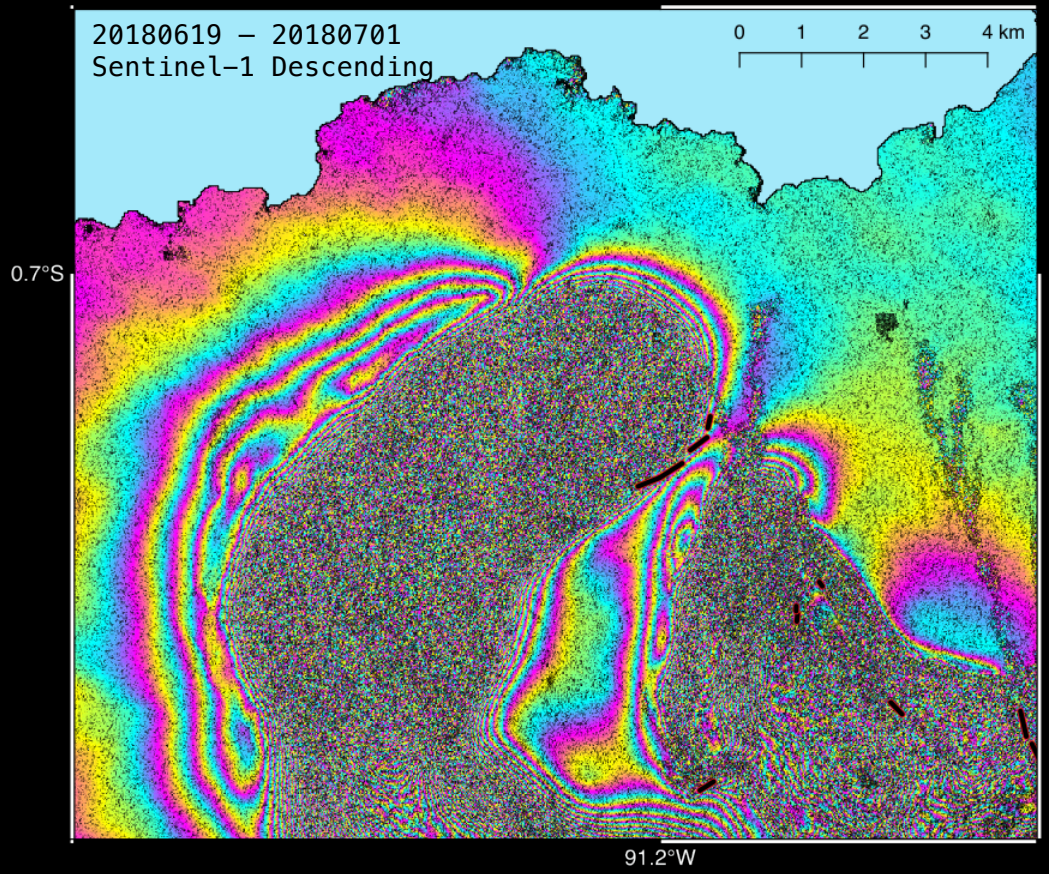

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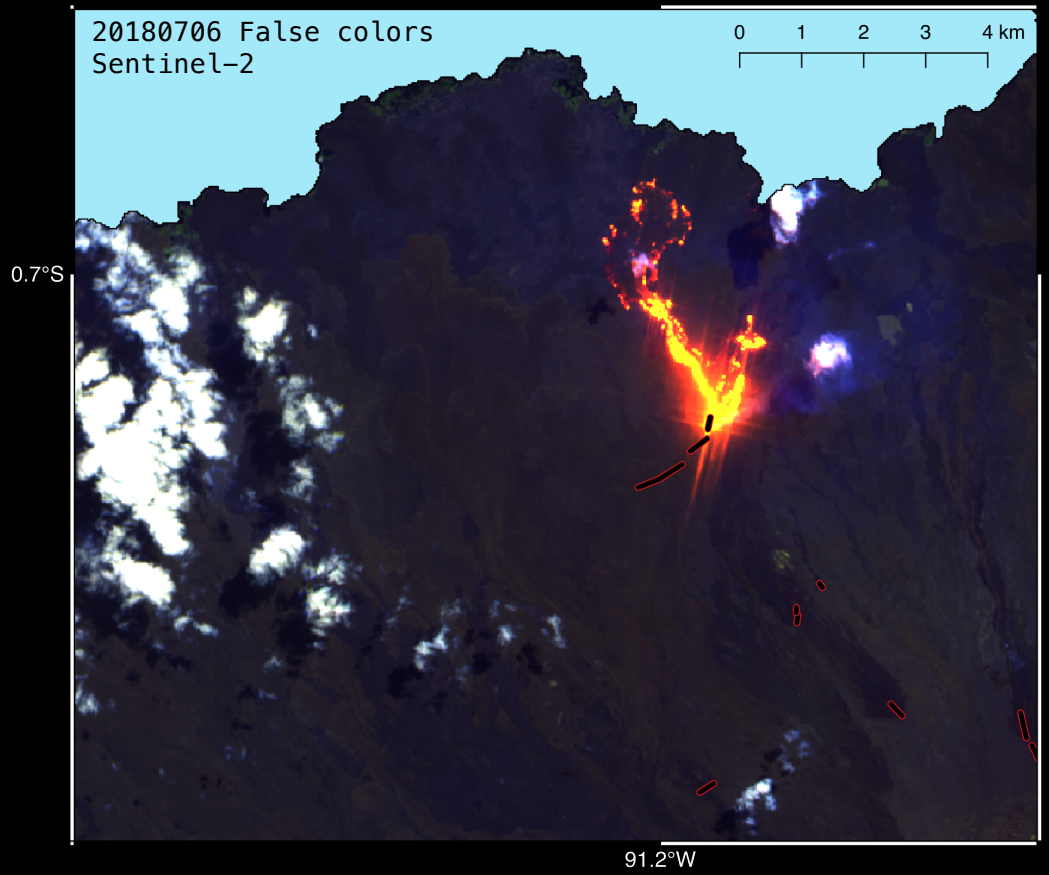
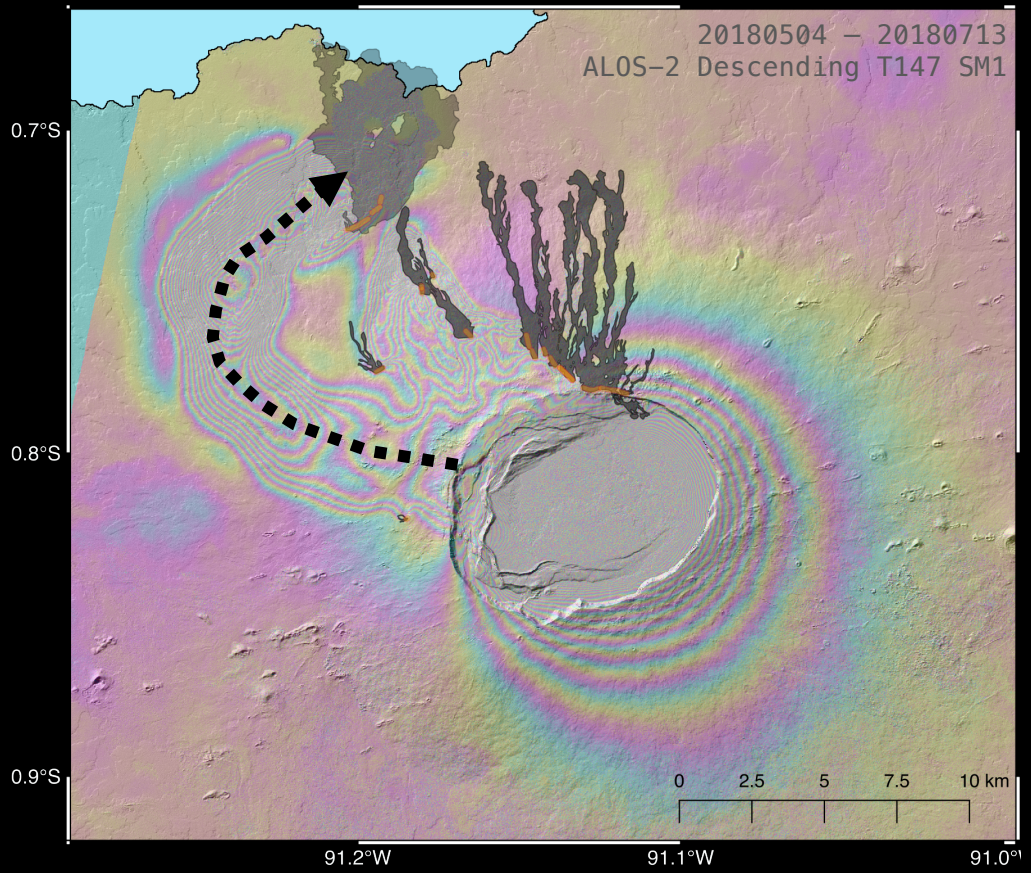


Sentinel-2 data: from Copernicus data

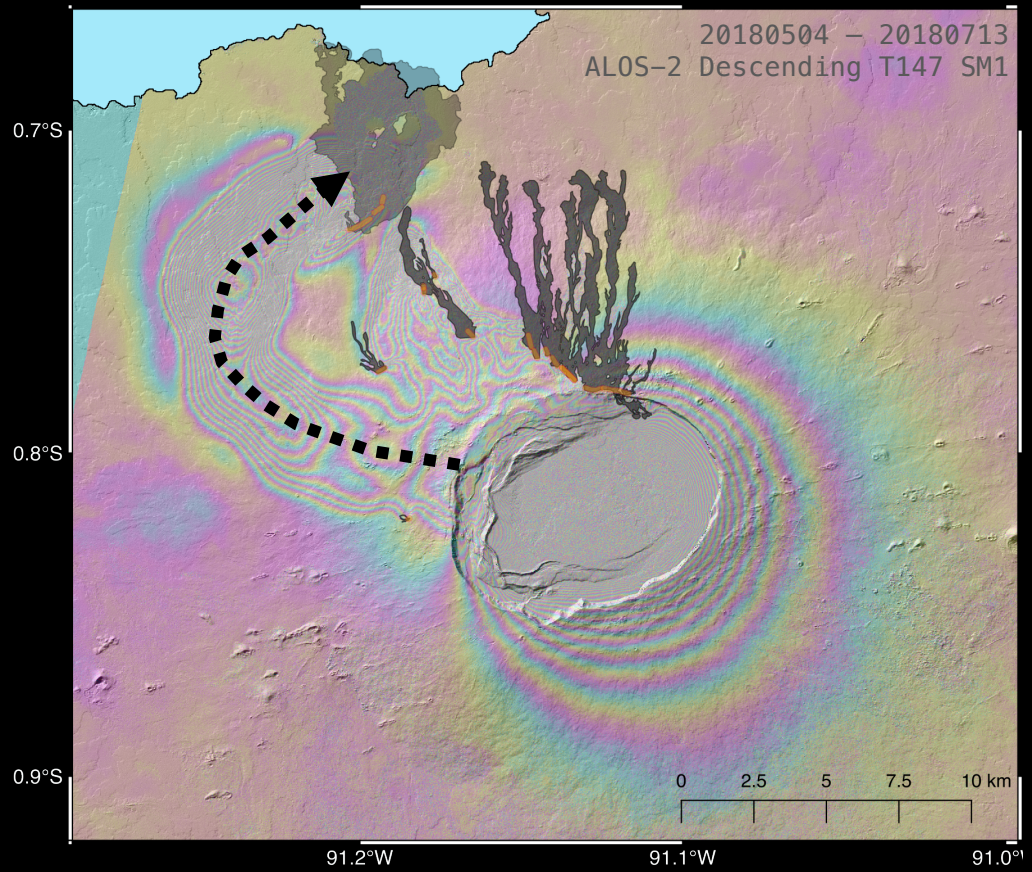
Intrusion trajectory



ALOS-2 data: from JAXA

Intrusion trajectory

Work in collaboration with Tim Davis and Eleonora Rivalta (GFZ – Potsdam)

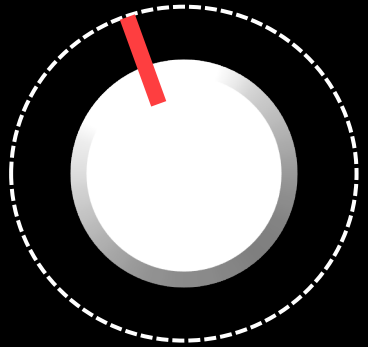


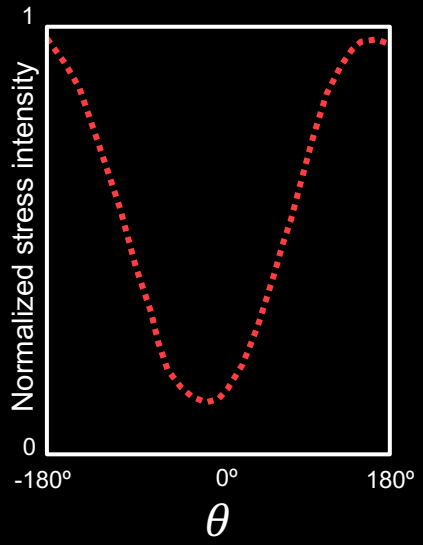
ALOS-2 data: from JAXA

Numerical method

[Davis et al., in review]

Using a 3D displacement discontinuity code we approximate the **stress intensity** at the tip of a **pressurized fracture**.





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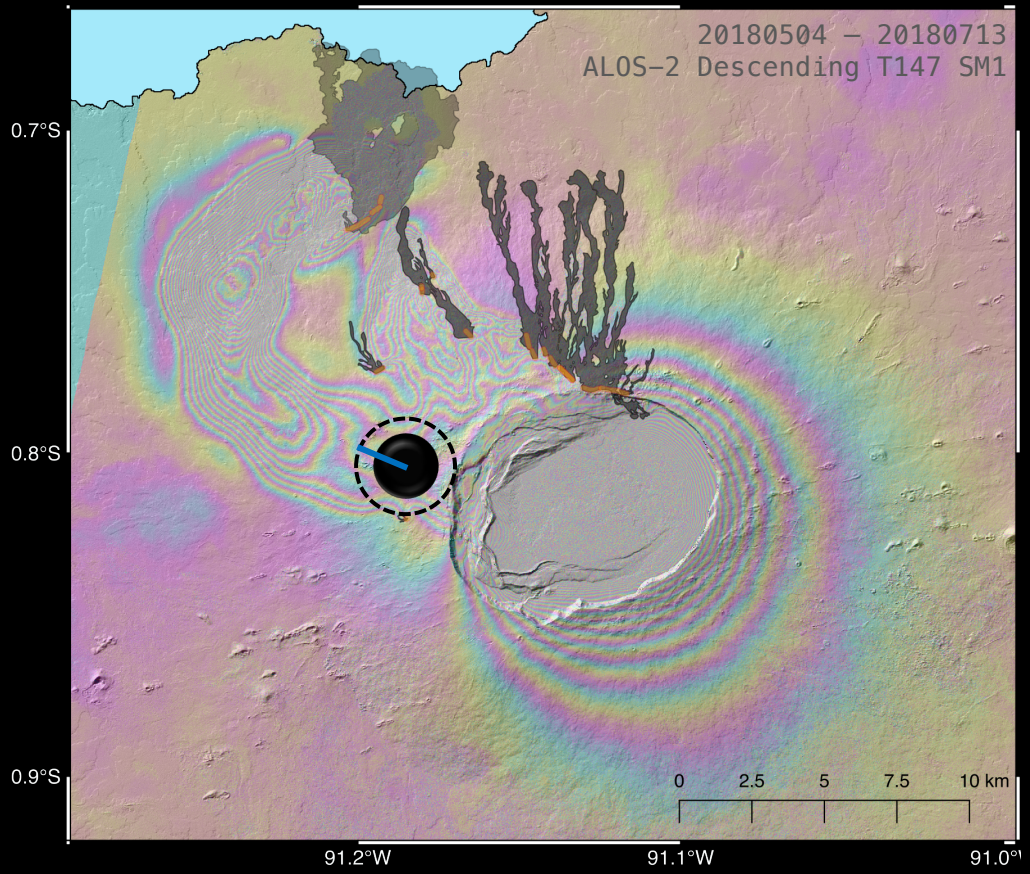
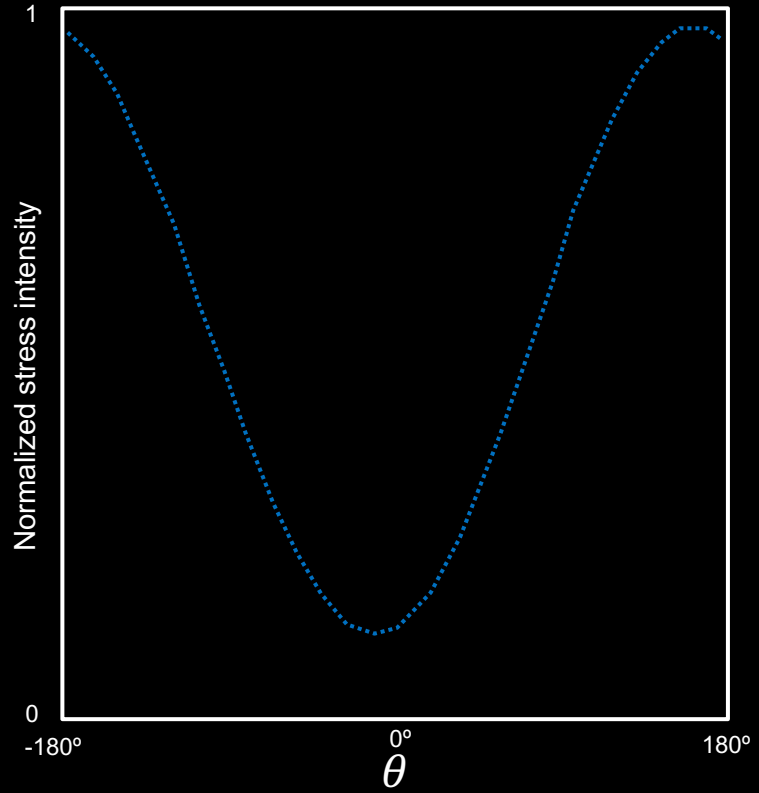


Effect of topography



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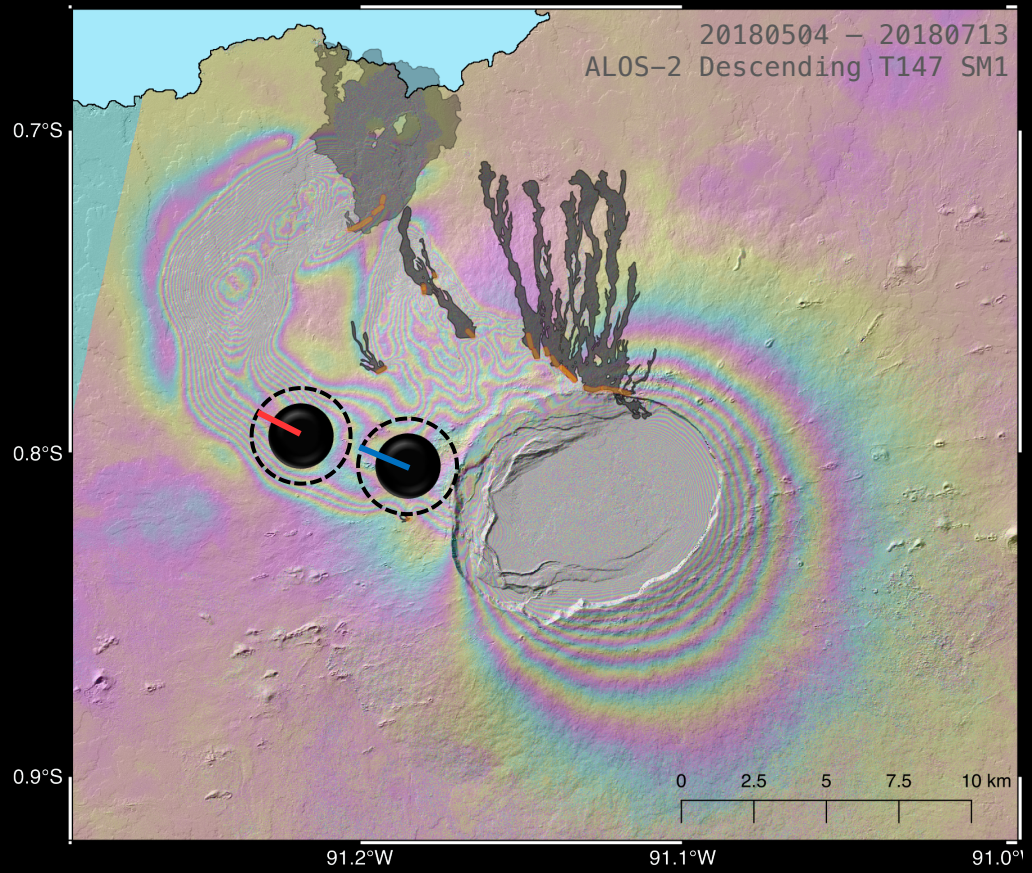

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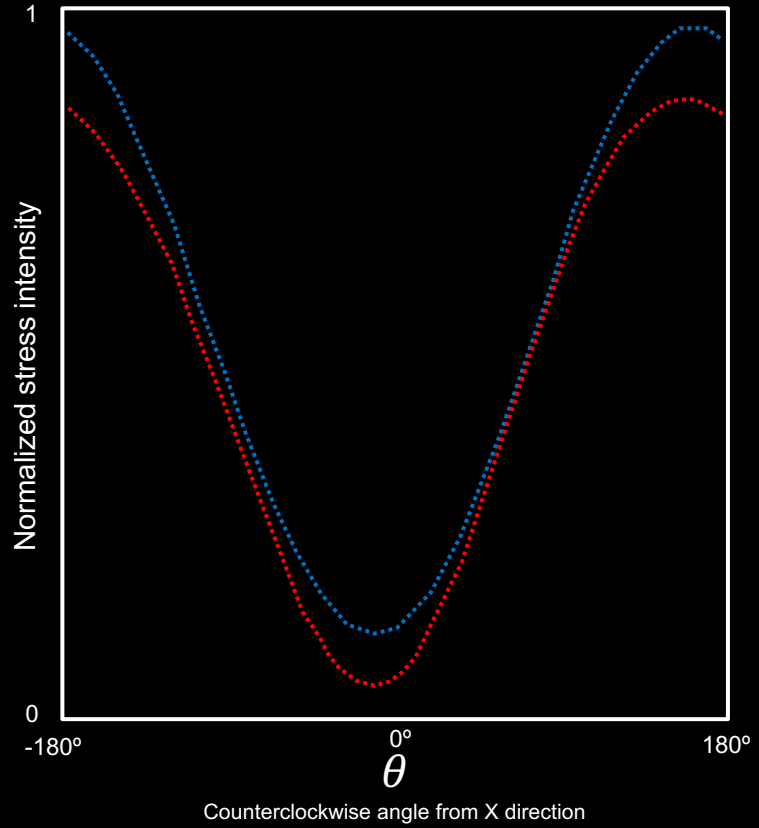

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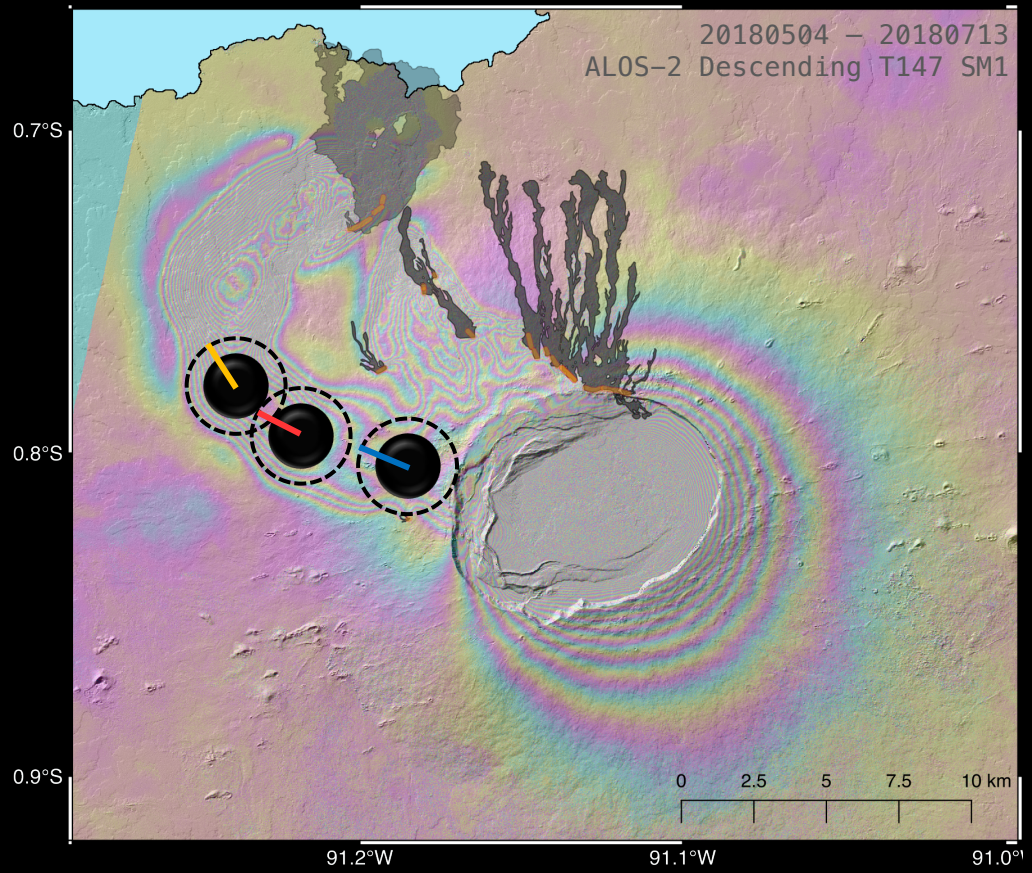

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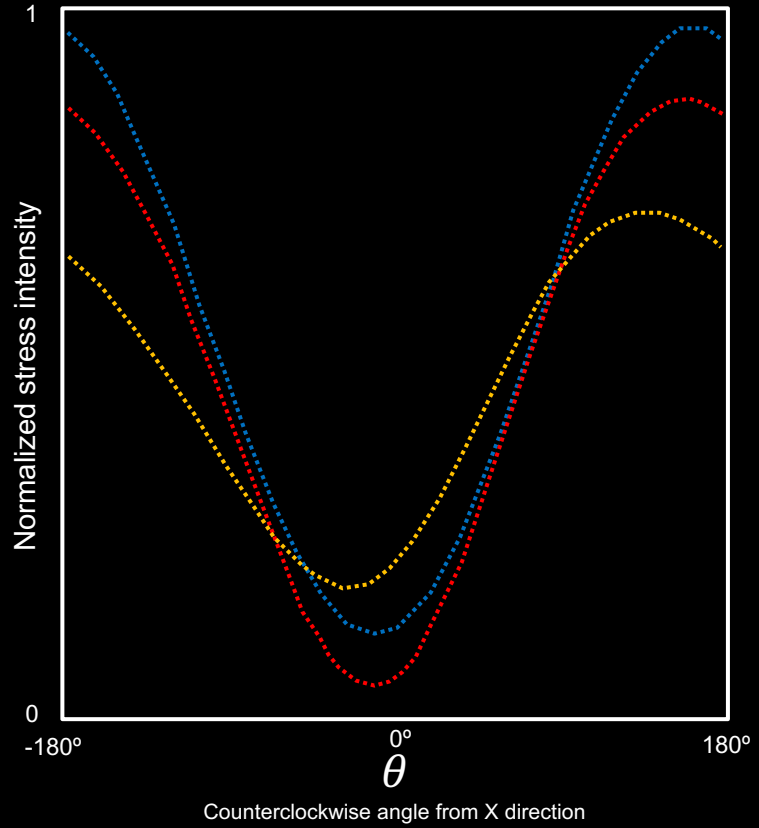

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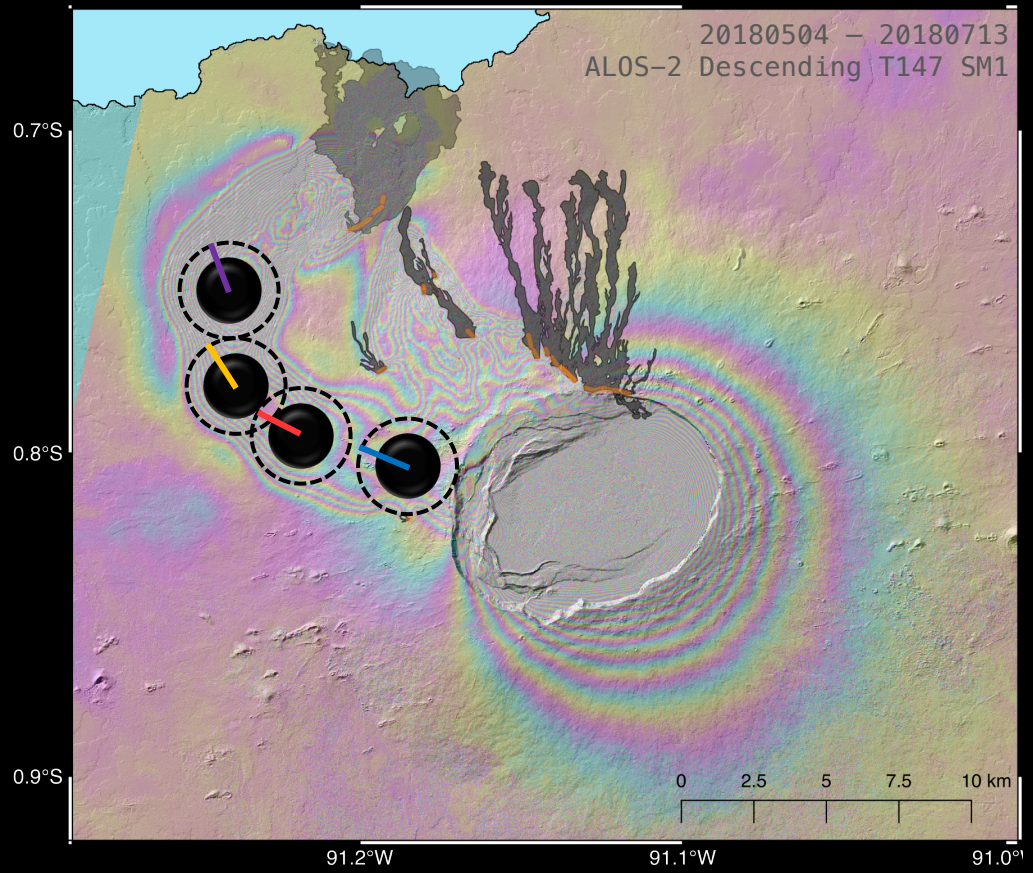

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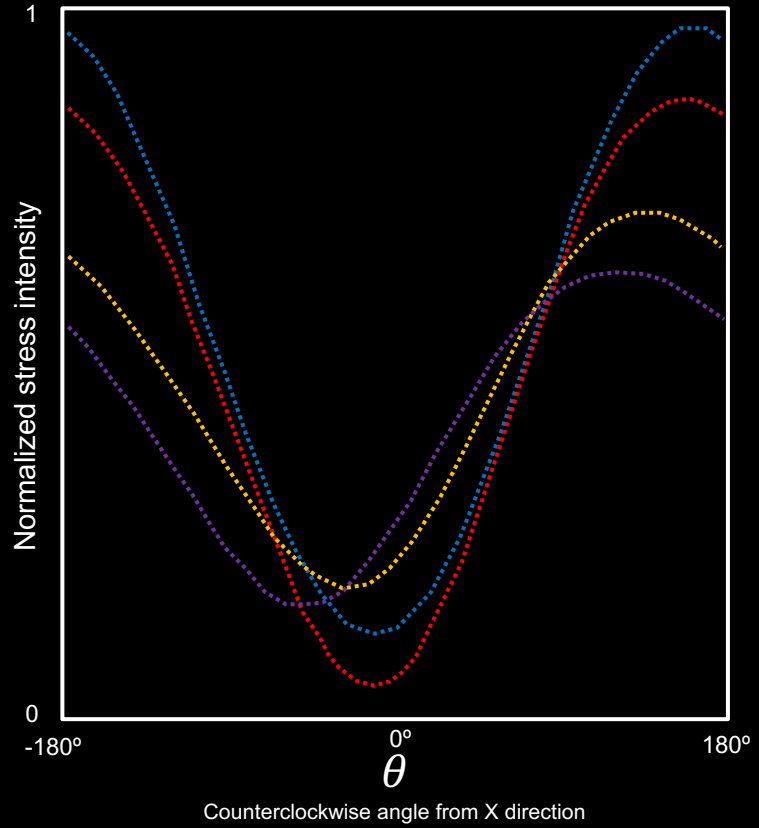

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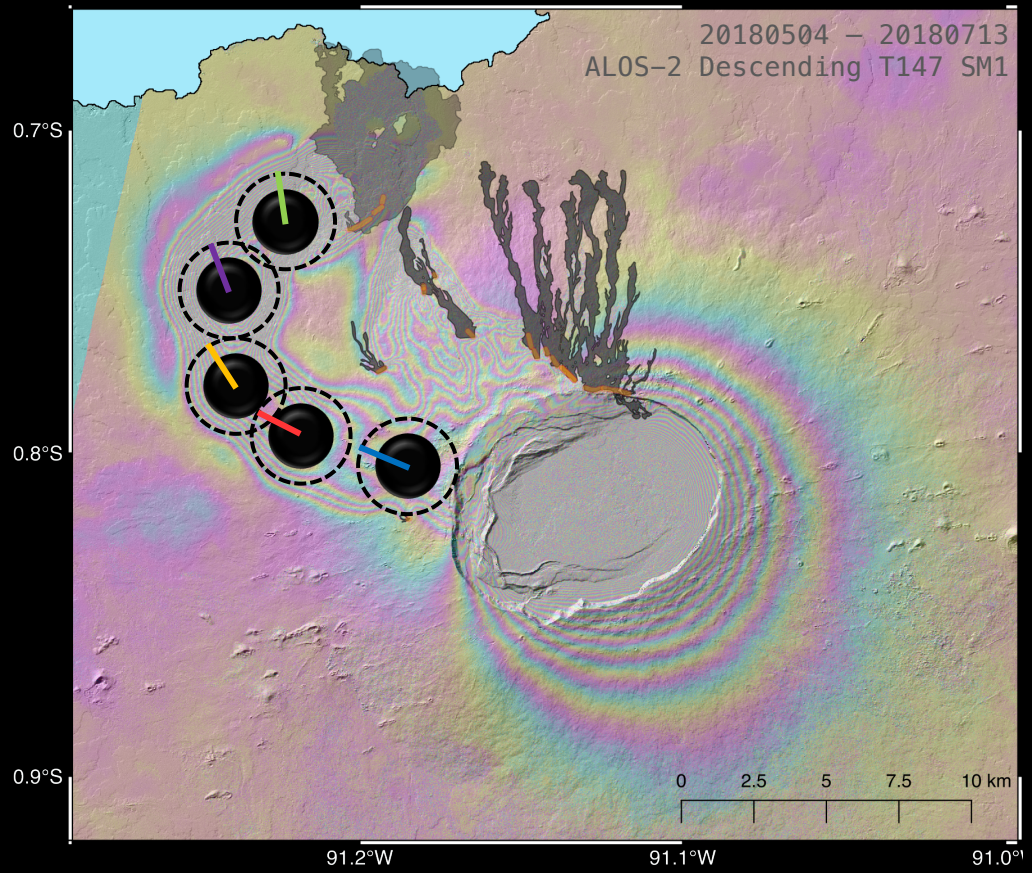

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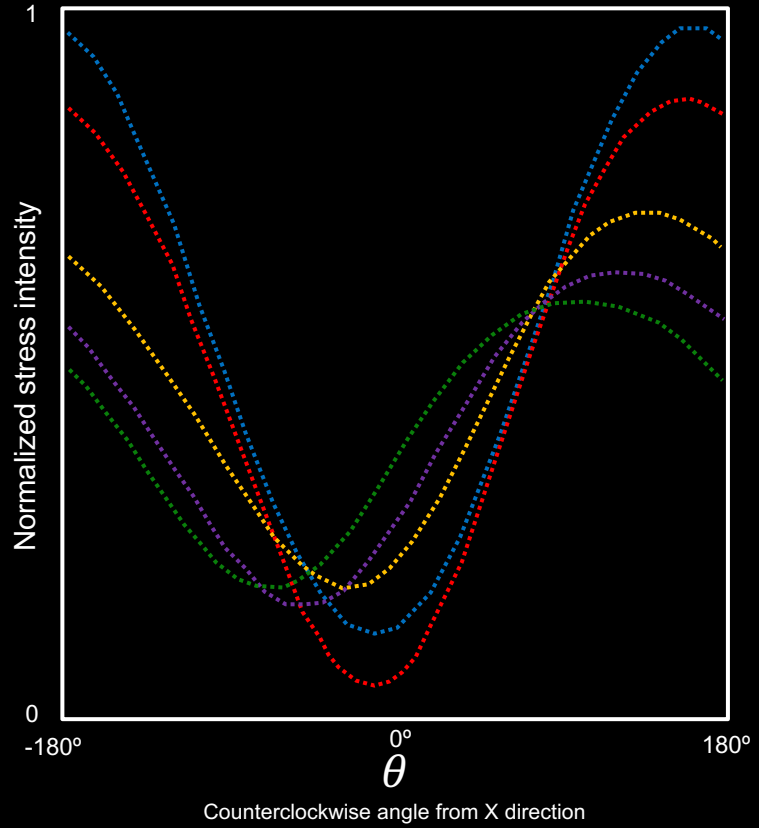
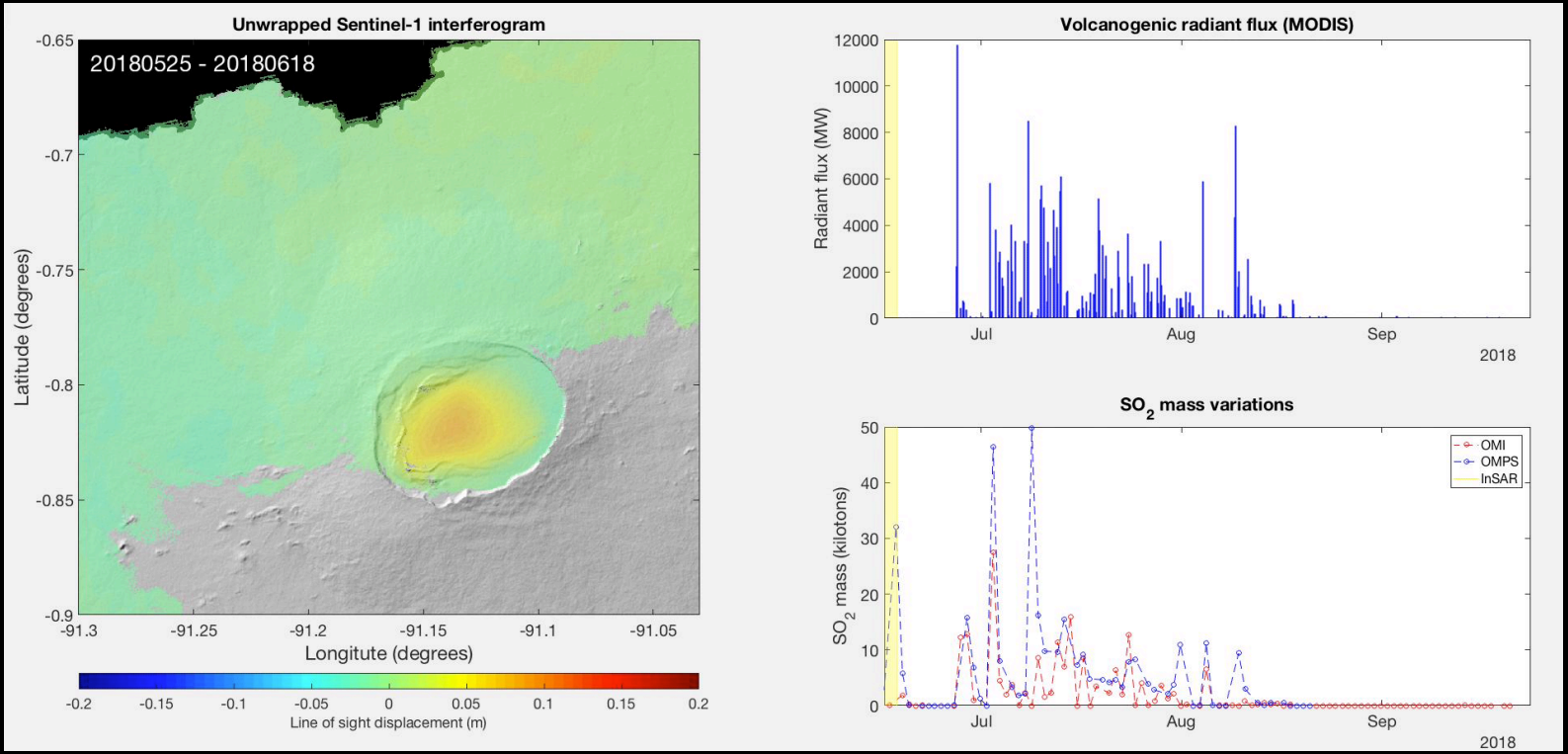


ALOS-2 data: from JAXA

Temporary magma storage and eruption



InSAR: Sentinel-1 (contains modified Copernicus data, 2018), processed by M.Bagnardi at NASA/JPL-Caltech

Thermal: data from MODVOLC (modis.higp.hawaii.edu)

SO2 emissions: data from NASA Global Sulfur Dioxide Monitoring Home Page (so2.gsfc.nasa.gov)

Concluding remarks

- June – August 2018 eruption was fed by two sill intrusions:
  - The first intrusion propagated at ~ 1 km/hr and fed Phase 1 of eruption (duration < 1 day)
  - The second intrusion propagated for ~19 km at a minimum speed of 0.25 km/hr and fed Phase 2 of eruption (duration 57 days)

- Second intrusion took > 90 degree turn during propagation. No clear cause for this change in trajectory.

- Magma withdrawal from shallow reservoir caused > 8 of caldera subsidence;

- Magma was temporarily stored beneath northernmost vent during the eruption and fed Phase 2.

- Caldera inflation resumed as soon as eruption ended.

Photo by Parque National Galápagos – Xavier García.

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov