Volcano monitoring using ALOS-2 and Sentinel-1 satellites

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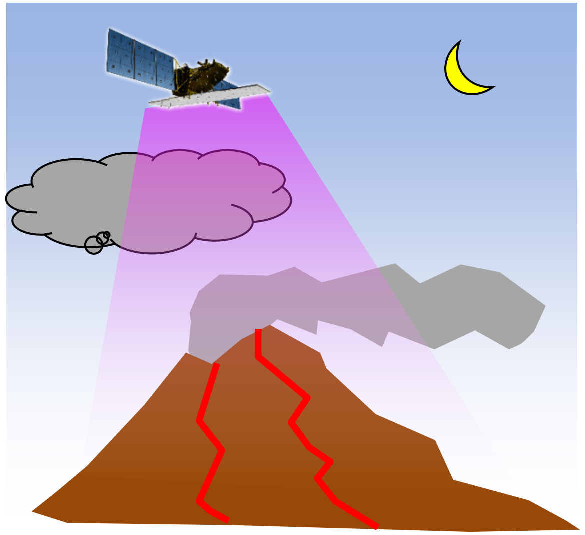
Outline

- Background: ALOS-2 for volcano monitoring
- 2018 Kīlauea eruption
- 2021 Nyiragongo eruption
- Comparisons with Sentinel-1
- Conclusions

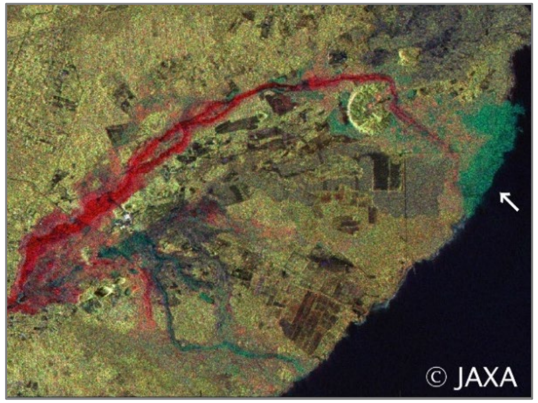
Background: ALOS-2 for volcano monitoring

- Advantages of SAR observation for volcano monitoring
  - observing land surface around volcanoes regardless of day/night, weather, or ash plumes
  - observing volcanoes without ground instruments
  - measuring displacement of land surface by interferometry (InSAR)
- Roles of ALOS-2
  - responding to emergency observation requests from disaster management agencies, international cooperation frameworks, and scientists
  - providing the observation data and/or analysis results
- ALOS-2 capabilities
  - L-band SAR observation with various observation modes:

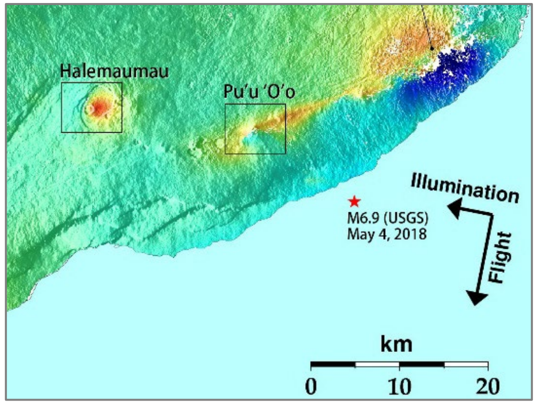


(1) Spotlight
- Highest resolution (1x3 m)
- Small-scale changes

(2) Stripmap
- Dual/Quad-polarimetry
- Local changes or displacement

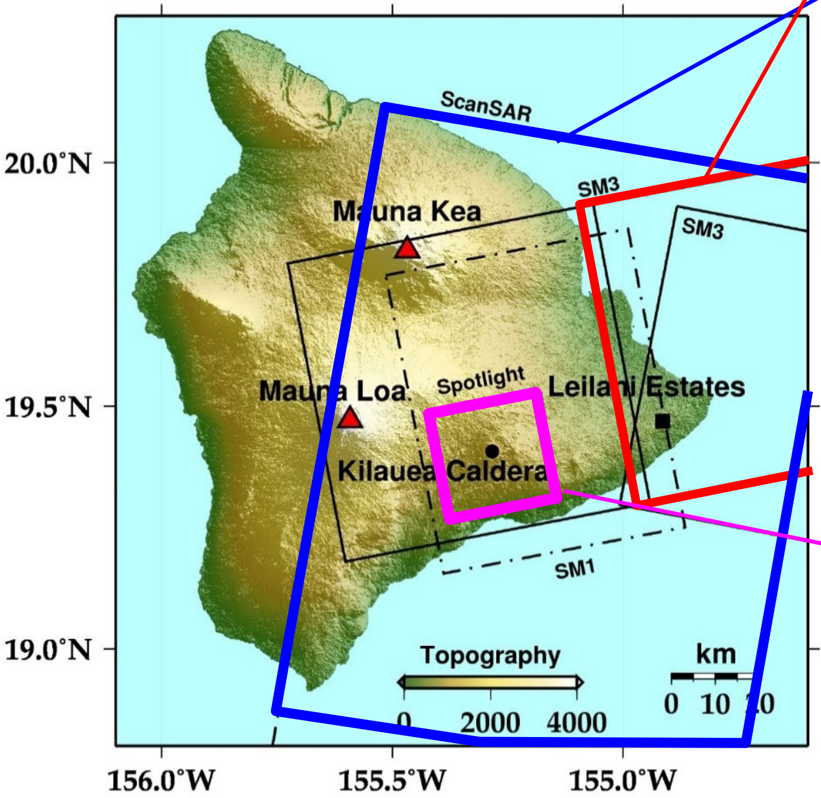


(3) ScanSAR
- Wide swath (350-490 km)
- Whole picture of displacement



2018 Kīlauea eruption

- Kilauea Volcano in Big Island, Hawaii began erupting on May 3, 2018
- Lava flows caused severe damages to the residential area (Leilani Estates)
- JAXA conducted a series of ALOS-2 emergency observations based on the requests from the International Disaster Charter
- Analysis performed:
  - InSAR
  - MAI (multi-aperture interferometry)
  - Offset tracking
  - Multi-temporal multi-polarimetric image interpretation

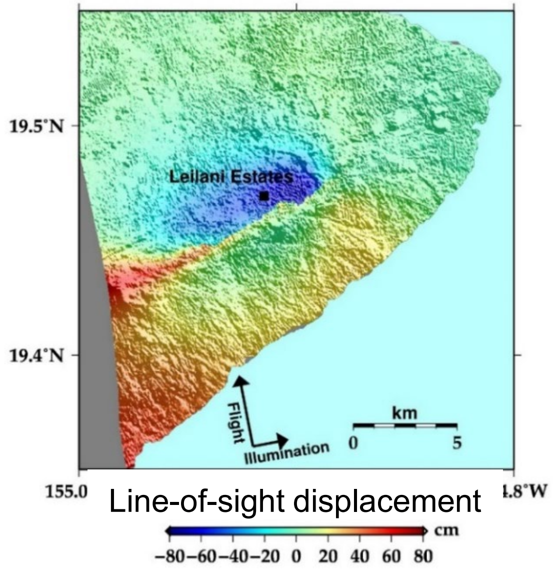


ALOS-2 Observations

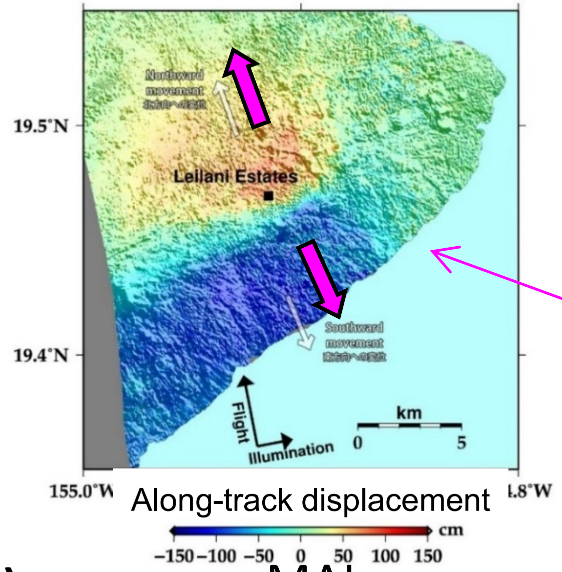
Date	Mode	Area
May 8	Strip (10m)	Leilani
May 12	ScanSAR	Whole
May 17	ScanSAR	Whole
May 22	Strip (10m)	Leilani
May 26	ScanSAR	Whole
May 30	Strip (3m)	Caldera
May 31	ScanSAR	Whole
June 5	Strip (3m)	Whole
June 9	ScanSAR	Whole
June 13	Spotlight	Caldera
June 14	Strip (10m)	Leilani
June 19	Strip (10m)	Leilani
June 23	ScanSAR	Whole

⋮

Interferometry of Stripmap data

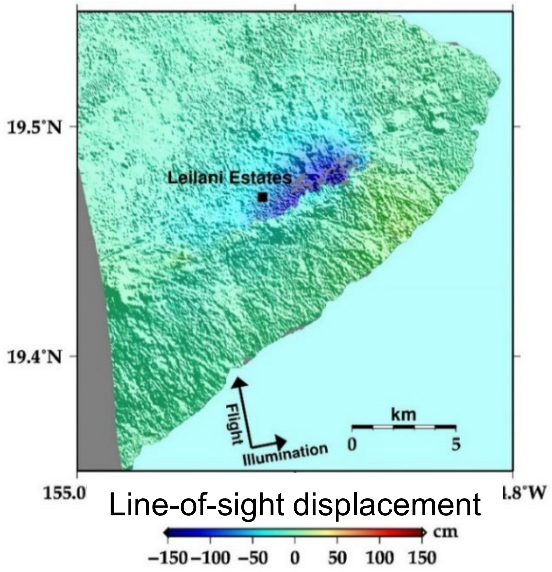


InSAR

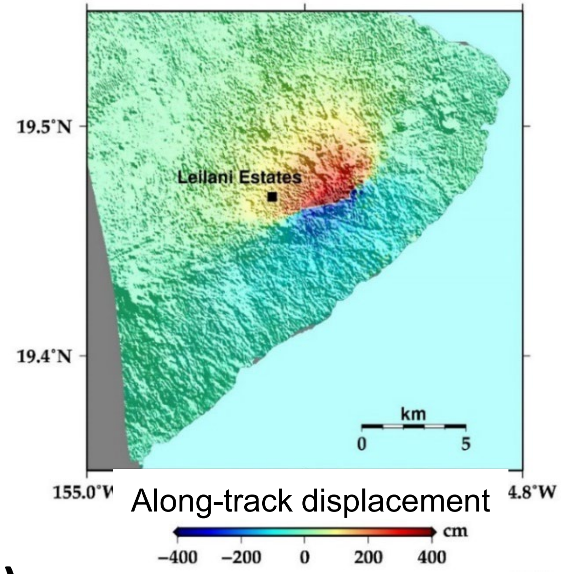


MAI

(1)



InSAR



MAI

(2)

(1) 2018-02-27→2018-05-08

- Dyke intrusion (3.9 m thickness and 4.9 × 10^7 m^3 volume*) was estimated under the residential area

*Estimated by the Geospatial Information Authority of Japan (GSI)

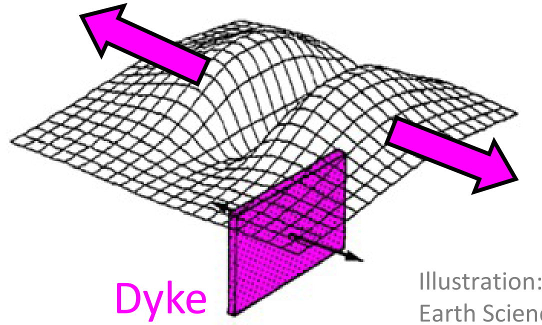


Illustration: National Research Institute for Earth Science and Disaster Resilience

(2) 2018-05-08→2018-05-22

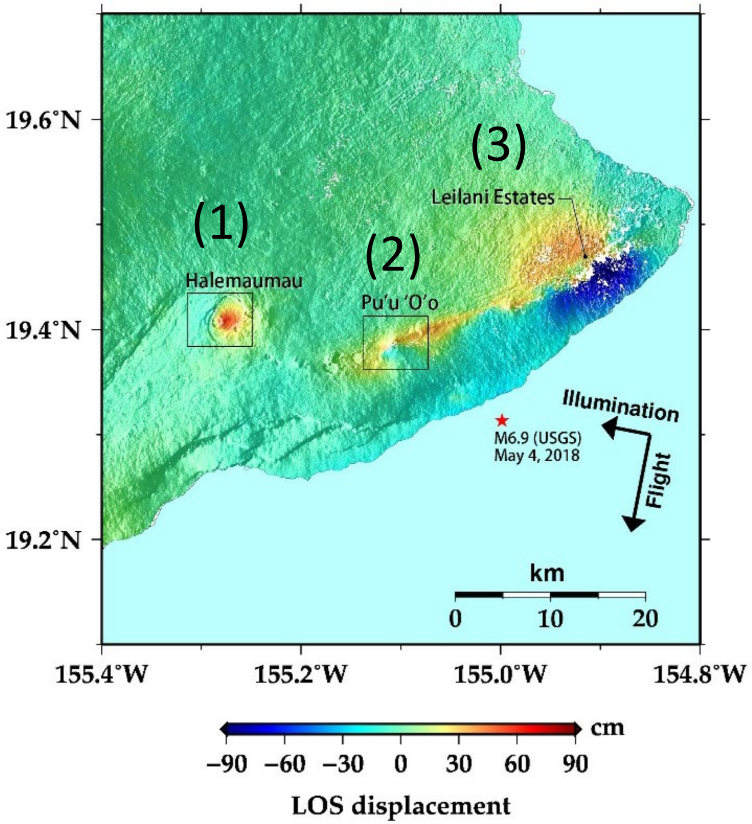
- The deformation area moved to the east
- Suggested that underground magma moved eastward as it erupted from fissures in the residential area

https://www.theatlantic.com/photo/2018/05/photos-of-kilaueas-newest-lava-fissures-on-hawaiis-big-island/559751/

Interferometry of ScanSAR data

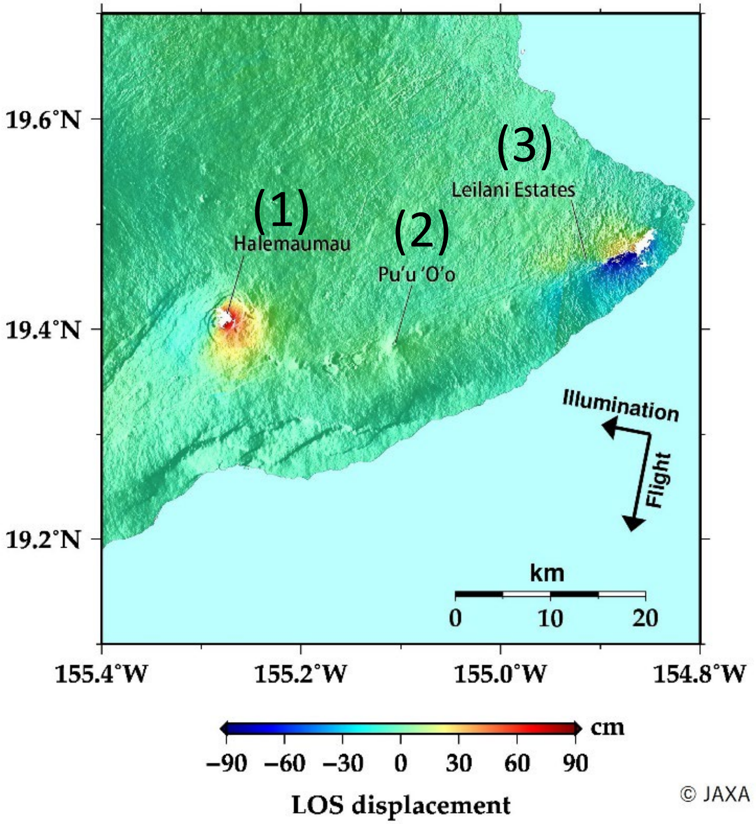
- ScanSAR data showed the whole picture of the volcanic activity

2018-01-20→2018-05-12



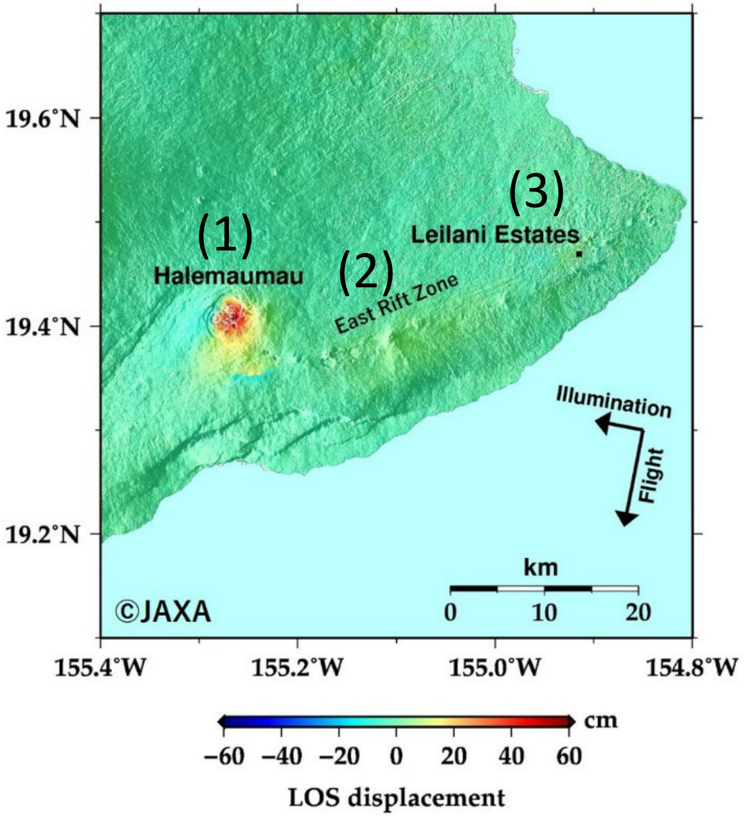
(1) Kilauea Caldera: >50 cm subsidence
(2) East Rift Zone (ERZ): >30 cm subsidence
(3) Leilani Estates: >1 m expanding
→Magma moved from (1) to (3) via (2)

2018-05-12→2018-05-26



(1) Kilauea Caldera continued to subside
(2) Deformation in ERZ ceased

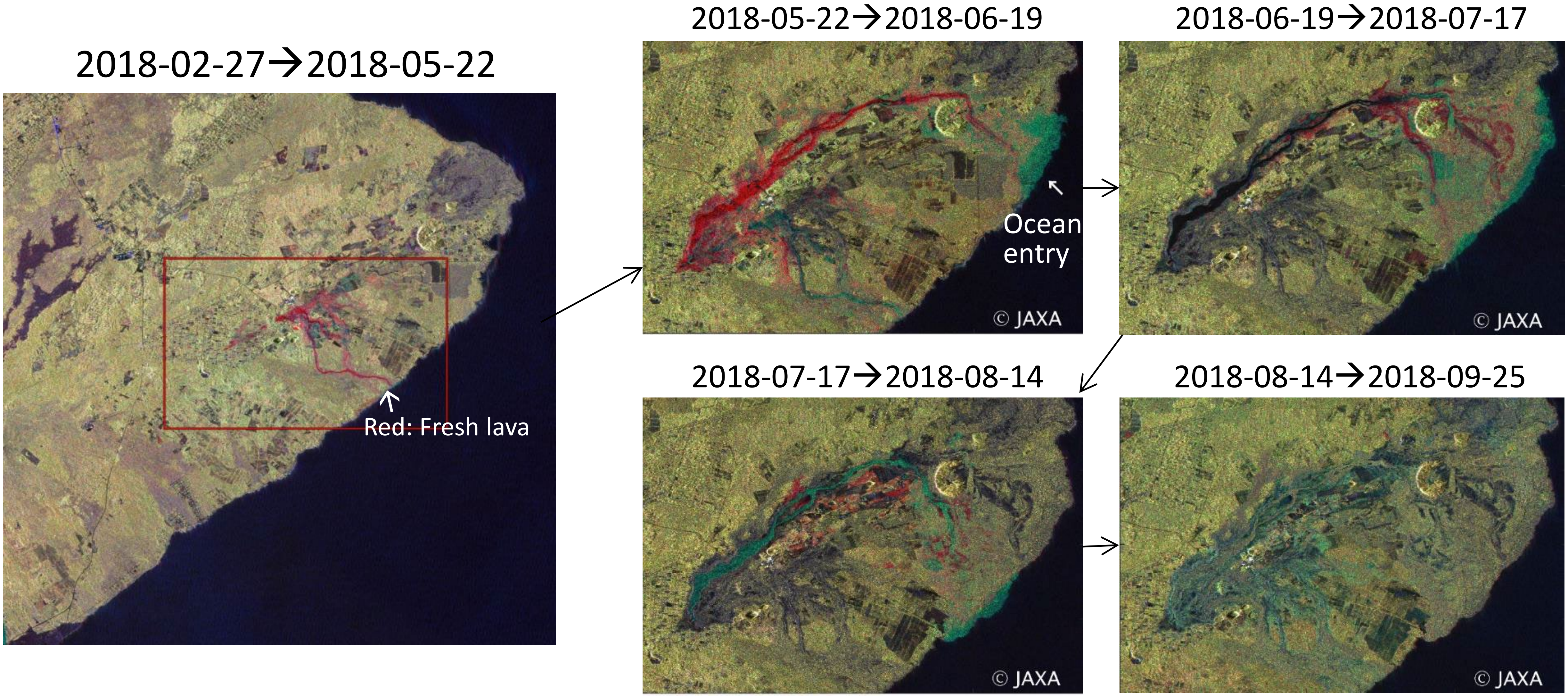
2018-05-26→2018-06-09



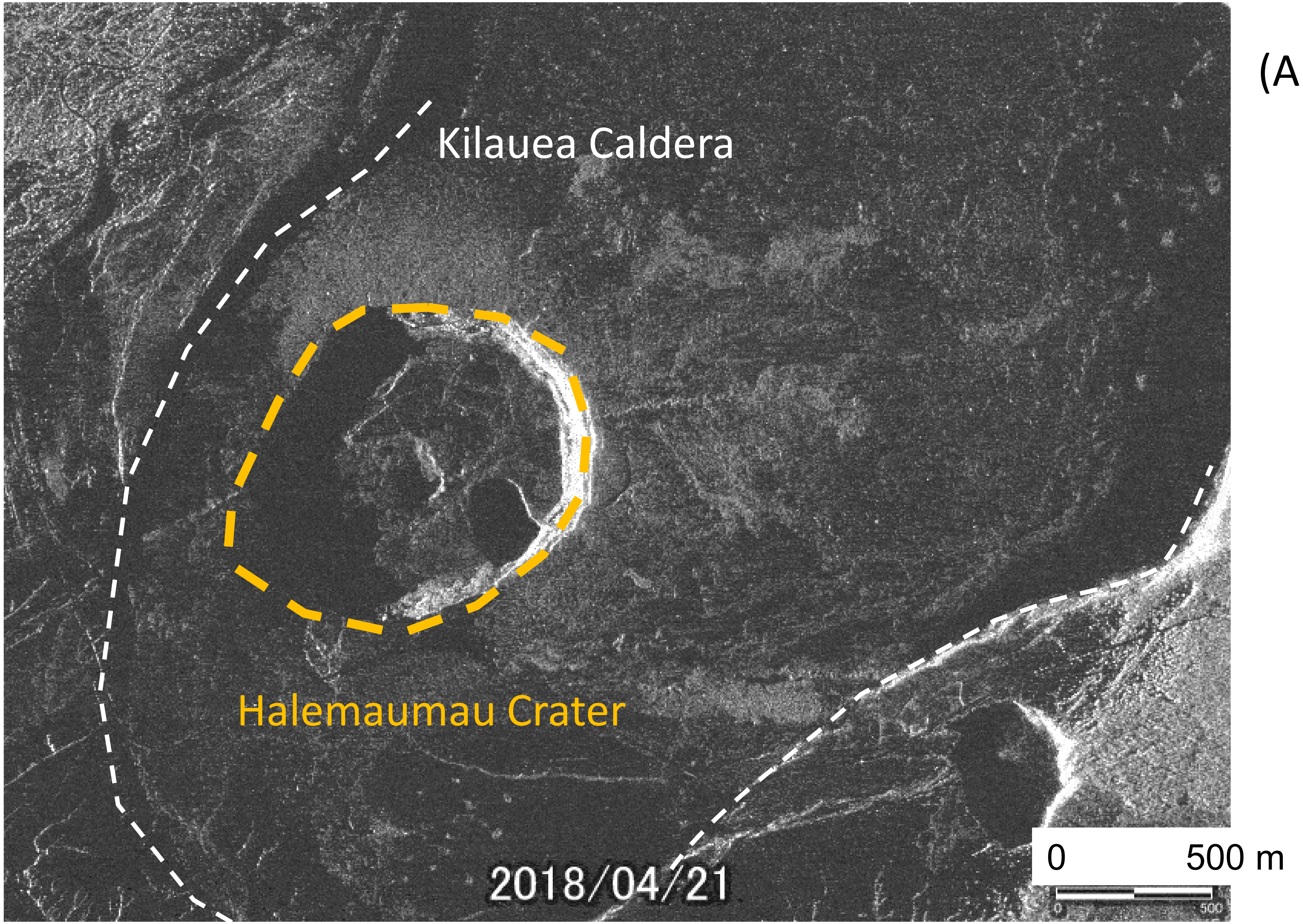
(1) Kilauea Caldera continued to subside
(3) Deformation in the residential area ceased

Lava flows by dual-polarization data

- Multi-polarimetric multi-temporal color composite (R:G:B = HV before: HV after: HH after)
- Fresh lava flows are clearly visible (red area)



Collapse of Kīlauea Caldera by Spotlight mode

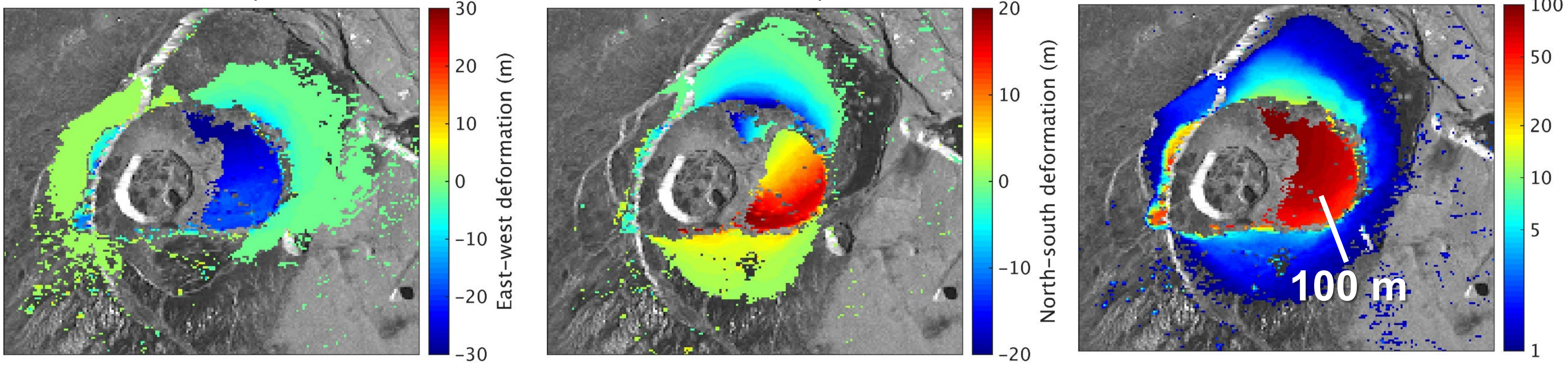


(Animation)

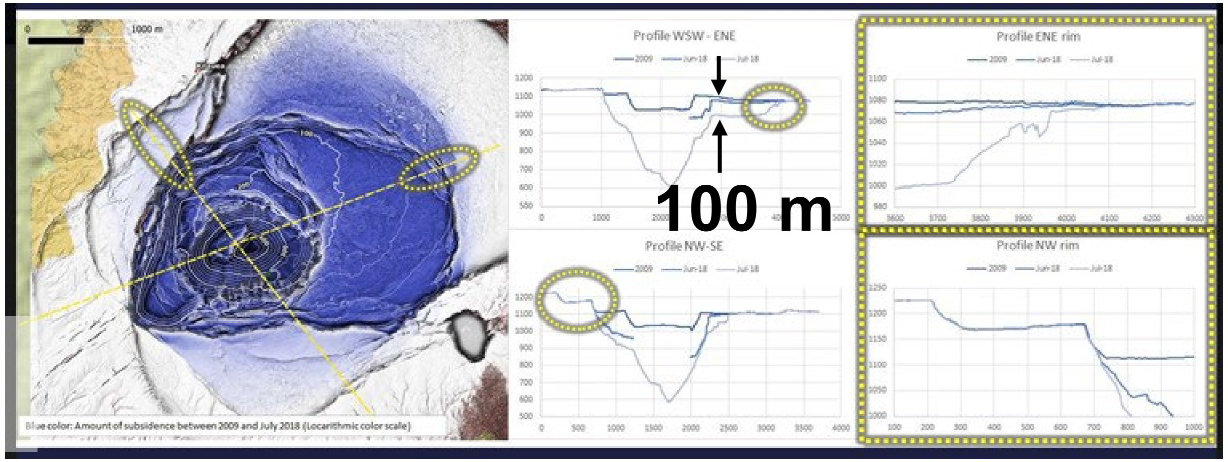
Three-dimensional deformation of Kilauea Caldera

- Offset tracking using Spotlight data provided small-scale 3-D displacements

East-west component | North-south component | Subsidence



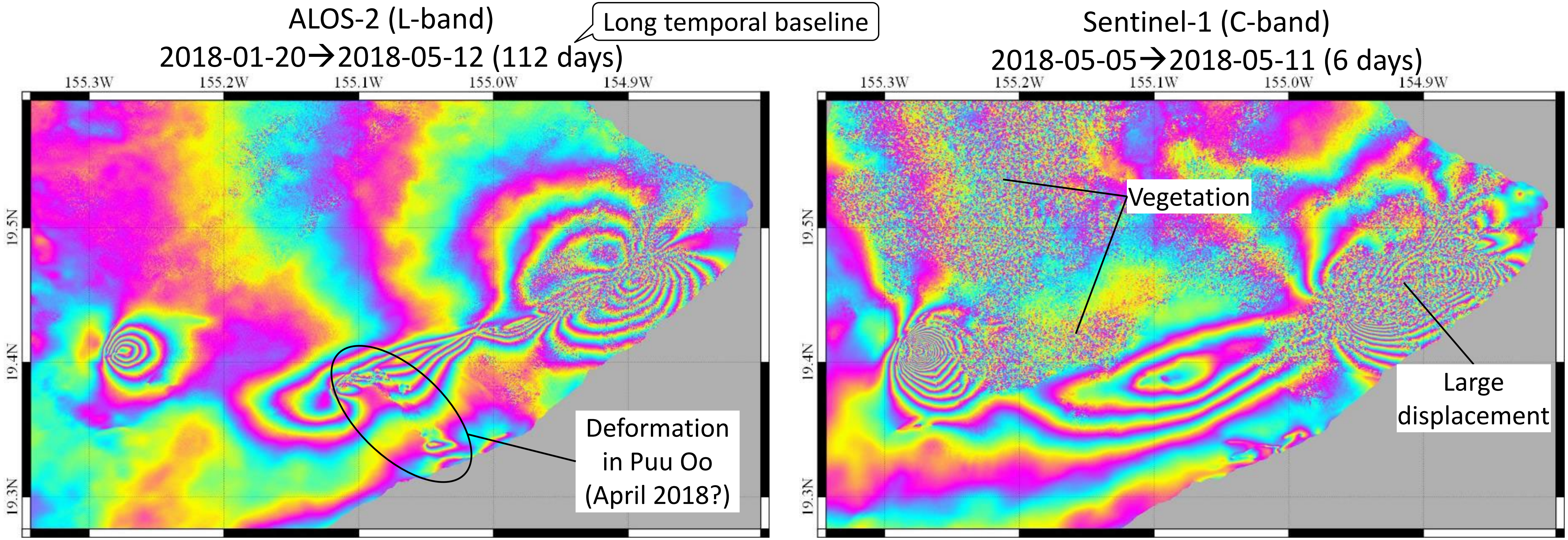
- Good agreement with airborne LiDAR data (~100 m subsidence)



LiDAR measurements (USGS)

Comparison: ALOS-2 and Sentinel-1

- ALOS-2 (L-band)
  - Higher coherence even in densely vegetated and largely displaced area despite of the long temporal baseline
  - The large temporal baseline (non-frequent observation) leads to contaminations in the results
- Sentinel-1 (C-band)
  - The small temporal baseline (frequent observation) is adequate for monitoring rapid volcanic activities



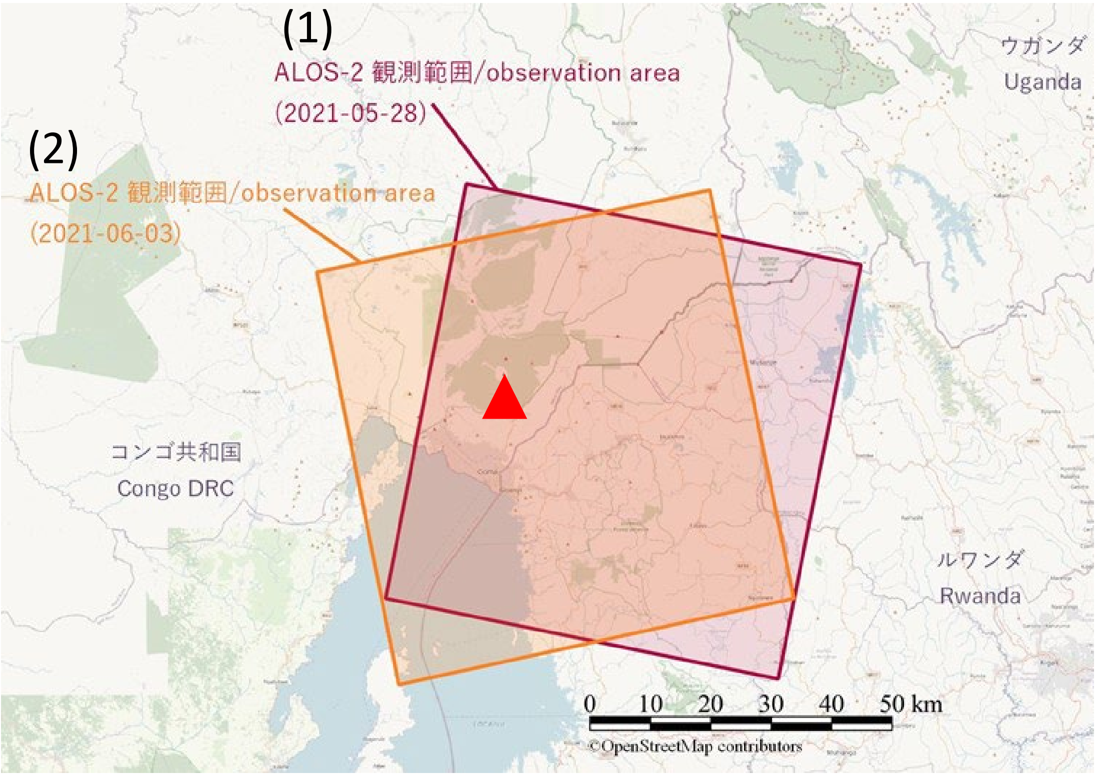
Wrapped interferogram of 2018 Kilauea eruption

2021 Nyiragongo eruption

- Mount Nyiragongo, the Democratic Republic of the Congo erupted on May 22, 2021
- Lava flow reached the residential areas and caused severe damage
- JAXA conducted a series of ALOS-2 emergency observation based on the requests of the International Disaster Charter
- Analysis performed:
  – InSAR
  – Multi-temporal multi-polarimetric image interpretation

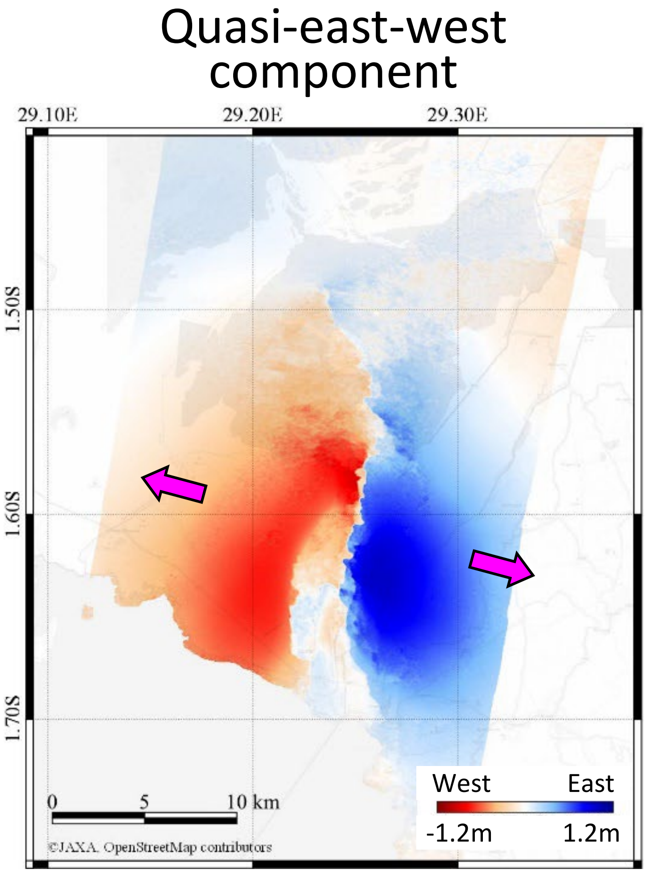
Observations

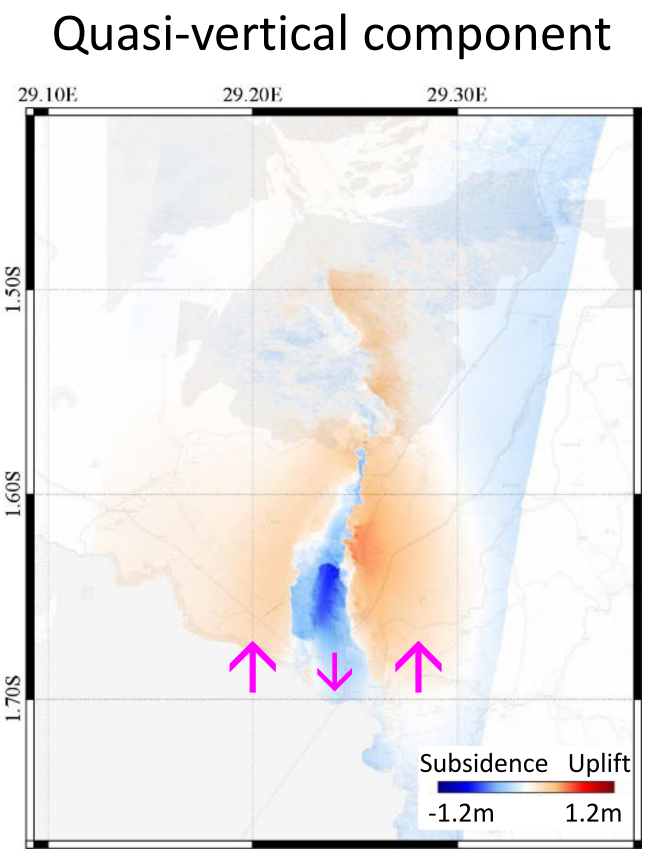
(1) 2021-05-28 Strip(10m), descending, right-looking
(2) 2021-06-03 Strip(10m), ascending, right-looking

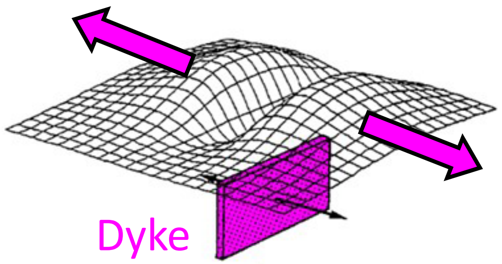


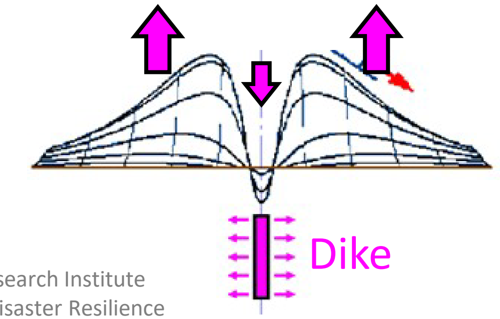
Displacement obtained from multi-angle interferometry

- Multi-angle interferometry (2.5-dimensional analysis) using the ascending/descending data provided quasi-vertical and quasi-horizontal (east-west) components of displacements around the volcano
  - Horizontally, ground was expanded in the direction of the east-west splitting
  - In vertical direction, only the center of the deformation area subsided, while the surrounding areas uplifted
- These results implied the occurrence of dyke intrusion









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Lava flows by dual-polarization data

- Multi-polarimetric multi-temporal color composite (R:G:B = HV before: HV after: HH after)
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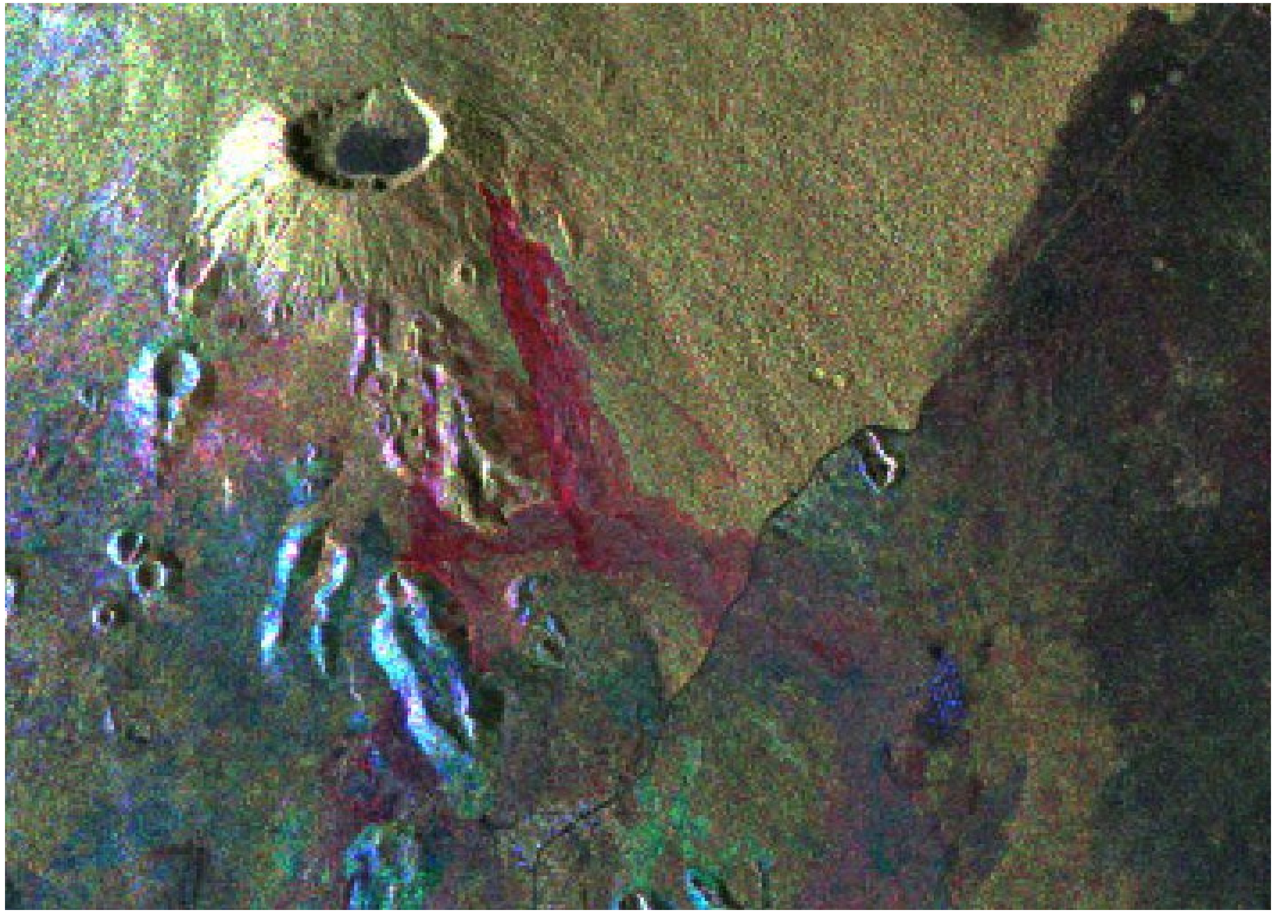
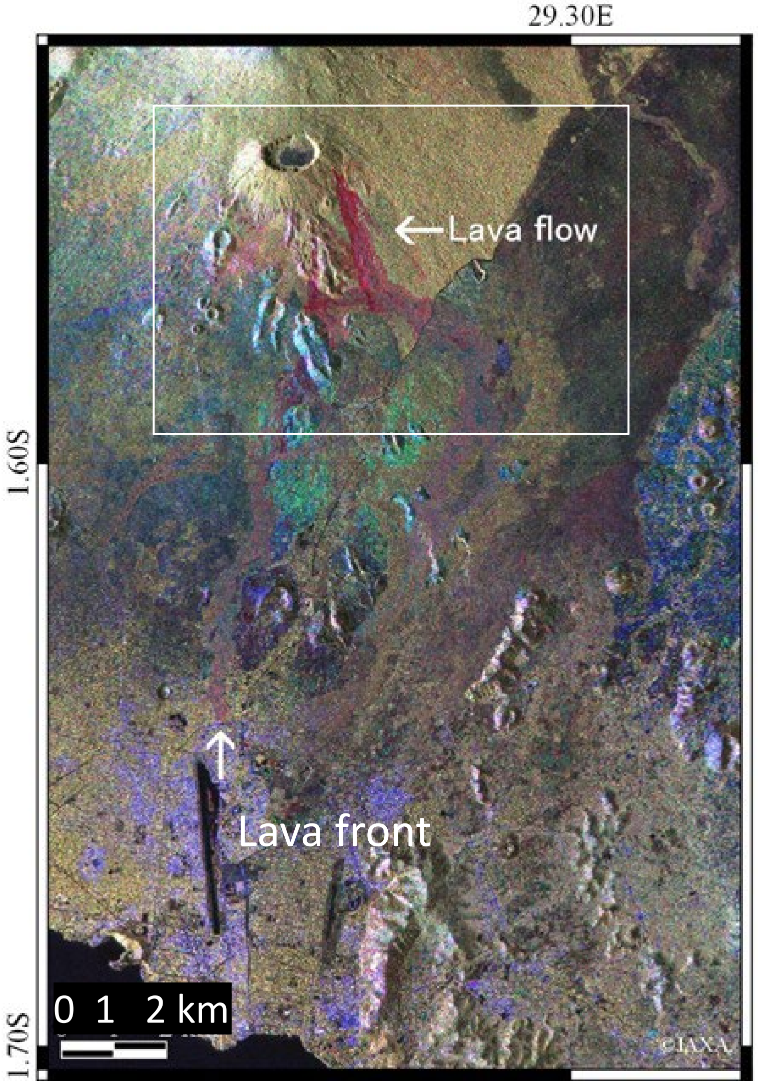


2020-03-06 and 2021-05-28 data

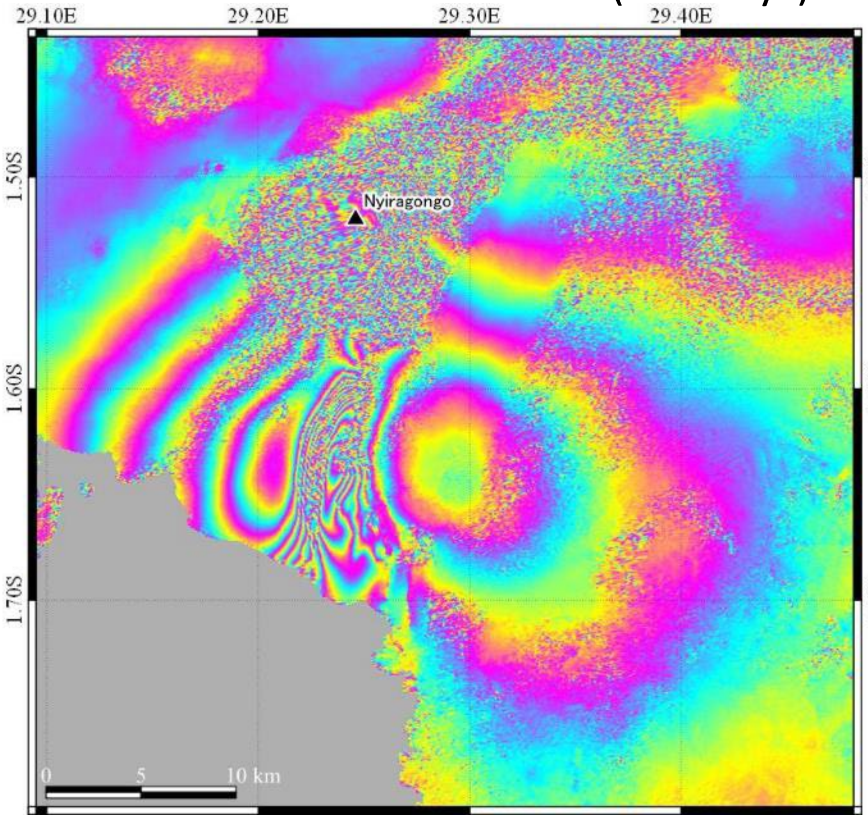


Comparison: ALOS-2 and Sentinel-1

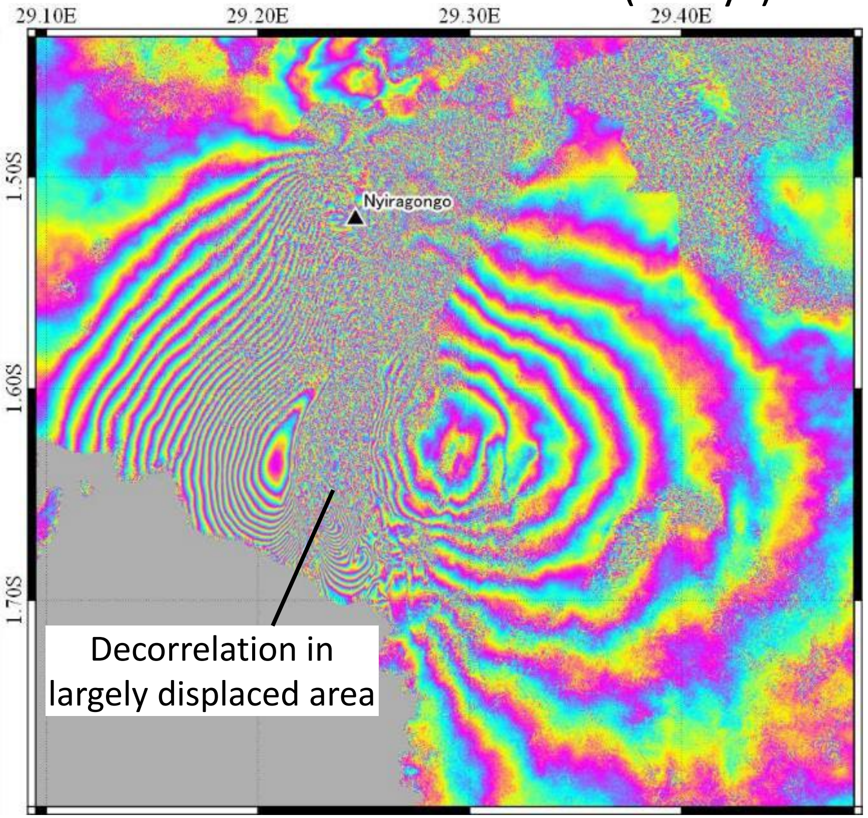
- ALOS-2 (L-band)
  - Higher coherence even in densely vegetated and largely displaced area despite of the long temporal baseline
  - Fewer fringes, i.e., higher sensitivity to larger displacements
- Sentinel-1 (C-band)
  - More fringes, i.e., higher sensitivity to small displacements

Wrapped interferogram of 2021 Nyiragongo eruption

ALOS-2 (L-band)
2020-07-30→2021-06-03 (308 days)



Sentinel-1 (C-band)
2021-05-19→2021-05-25 (6 days)

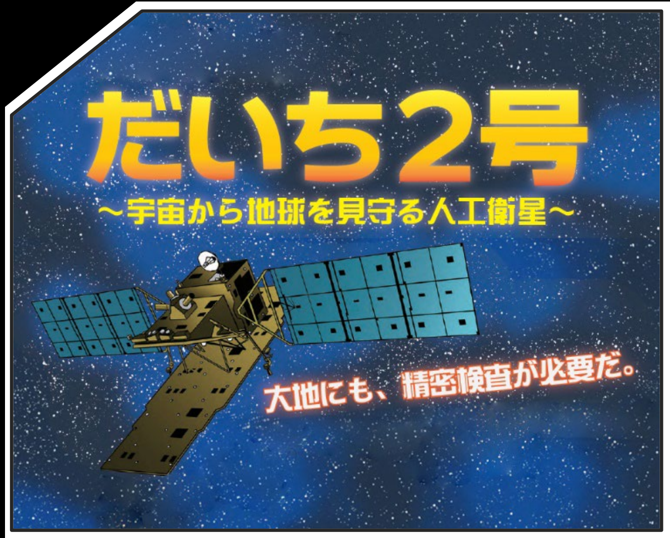


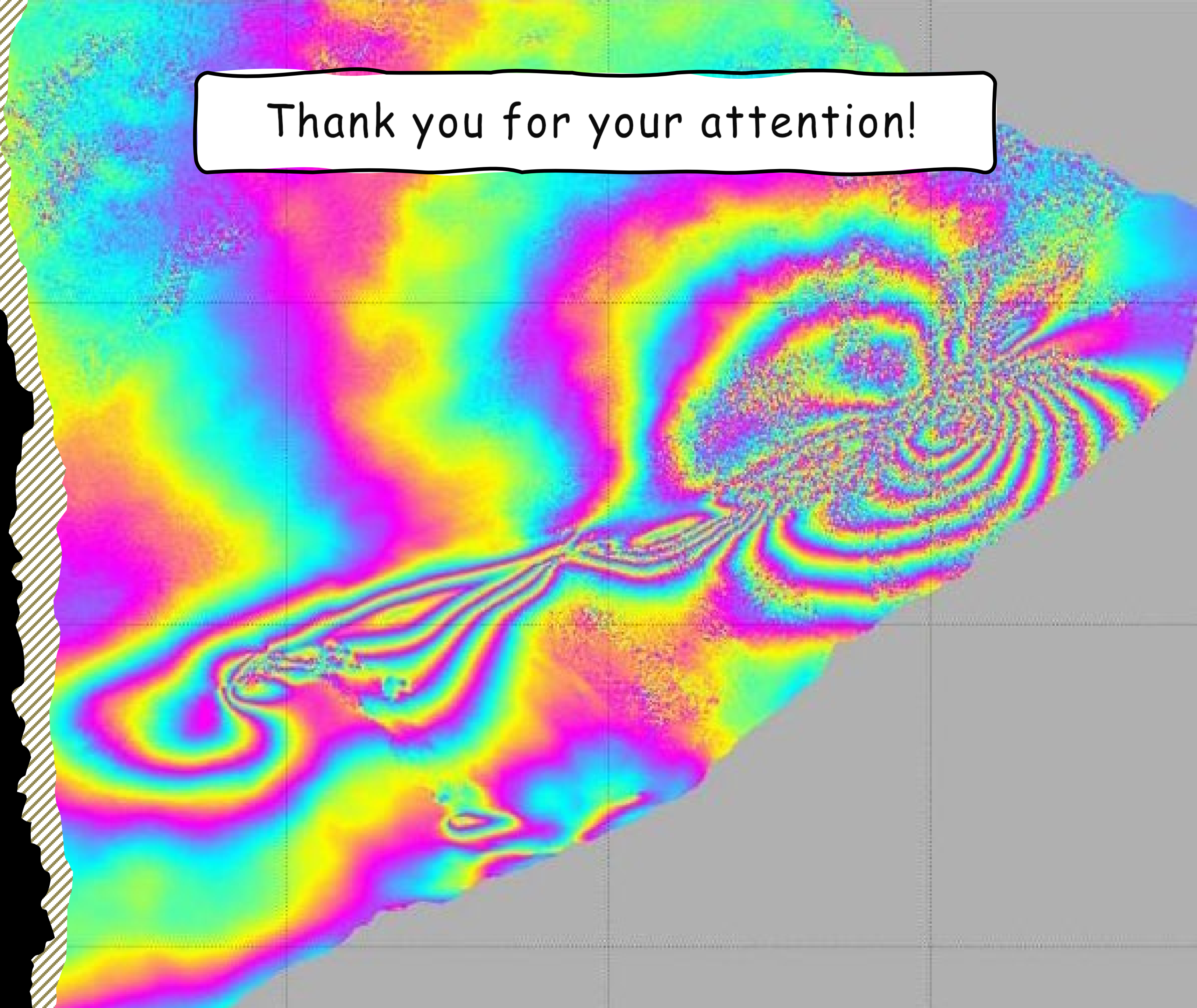
Conclusion

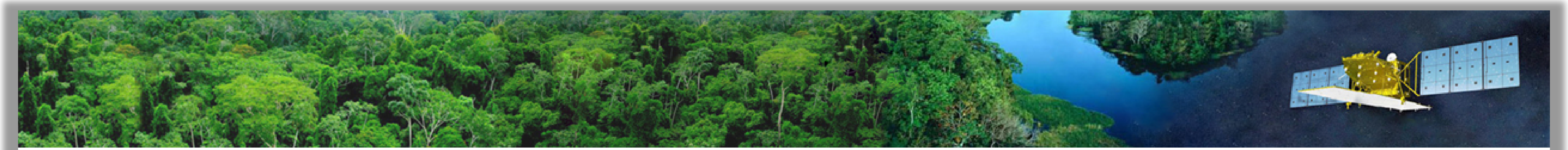
- We presented ALOS-2 results for 2018 Kilauea and 2021 Nyiragongo eruptions
  - Interferometry of Stripmap mode data revealed surface displacements associated with the volcanic activities
  - ScanSAR data provided the whole pictures of the large-scale deformations
  - Spotlight data provided highly detailed pictures of the crater collapse in Kilauea Caldera
  - Multi-polarimetric multi-temporal images clearly showed the lava flows

- Compared to Sentinel-1, ALOS-2 has
  - Higher coherence even in densely vegetated and largely displaced area in a long temporal baseline
  - Higher sensitivity to larger displacement (0.1-100 m)
    --> Sentinel-1 is needed for small displacement
  - Larger temporal baseline causing contaminations in results
    --> More frequent observation by Sentinel-1 (and possibly ALOS-4) is needed
  - ALOS-2/4 and Sentinel-1 are effective when used complementarily

Thank you for your attention!







ALOS-2: Groundbreaking Achievements of the First L-band SAR Long-term Pantropical Forest Monitoring Mission

A3.12 Forest Monitoring - 5
Friday, 03:15 pm

Living Planet Symposium 2022

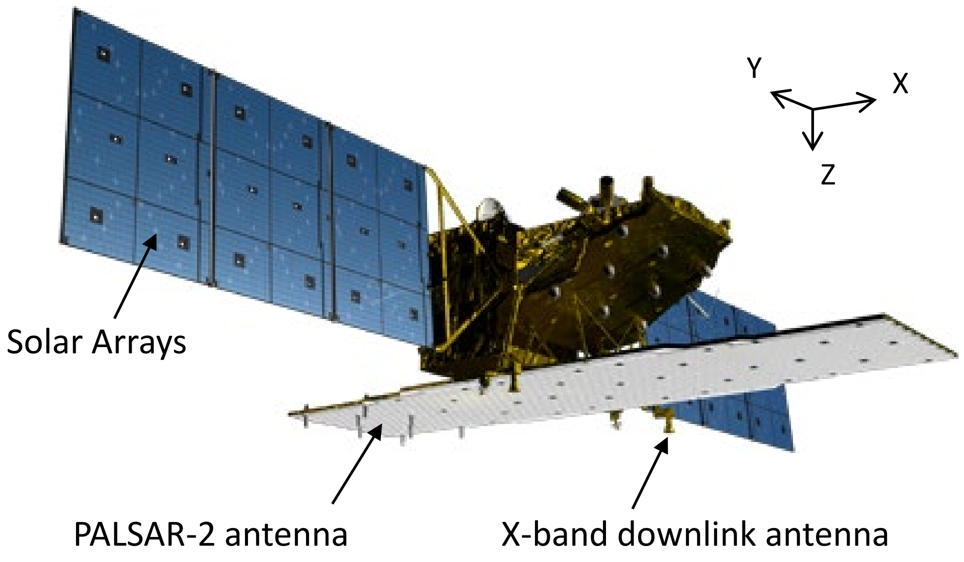
WCC Bonn, 27 May 2022

JAXA Explore to Realize

Backup

ALOS-2 Specification and mission

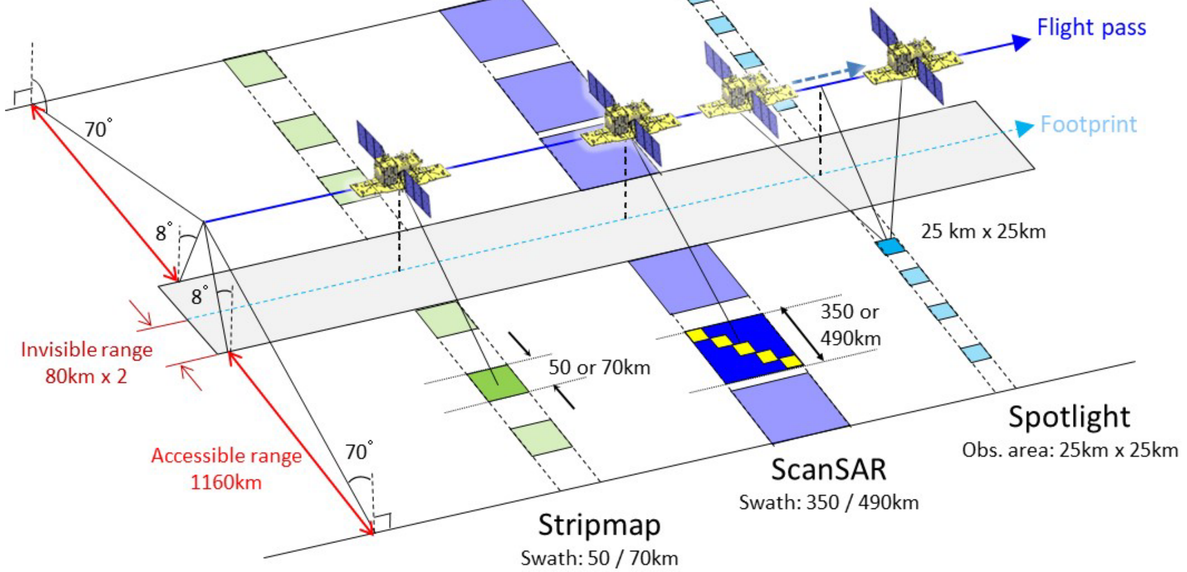
- Primary objectives:
  - Disaster monitoring: earthquake, volcano, flood, landslide, forest fire
  - Environmental monitoring: forest, mangrove, ice
  - Land applications: agriculture, natural resources
  - Ocean monitoring: sea ice, ocean wind, maritime
  - Radar and satellite technology development



ALOS-2 specification		
Mission sensor		PALSAR-2 (L-band synthetic aperture radar)
	Resolution, swath	Spotlight: 1x3m, 25x25km Stripmap: 3/6/10m, 50/70km ScanSAR: 100m, 350/490km
Launch		May 24, 2014 / H-IIA rocket
Mass		2.1 tons
Mission lifetime		5 years (target: 7 years)
Orbit		Sun-synchronous sub-recurrent: 628 km altitude, 14 days revisit, Orbit control within ±500 m. 12:00±15 min local Sun time
Mission data transmission		800 Mbps (X-band 16 QAM), 200/400 Mbps (X-band QPSK)

ALOS-2 observation modes

- Target applications:
  - Fine (dual-pol): Forest and land cover monitoring, InSAR
  - ScanSAR (dual-pol): Rapid deforestation, wetlands, InSAR
  - Spotlight (single-pol): Emergency observations
  - Ultra Fine (single-pol) : Mapping (Japan area), InSAR base-ma
  - High Sensitive (quad-pol): Mapping (Specific area)
  - ScanSAR Wide (single-pol) : Polar ice, ocean



		Spotlight	Stripmap			ScanSAR		
			Ultra Fine (3m)	High Sensitive (6m)	Fine (10m)	ScanSAR Nominal		ScanSAR Wide
Bandwidth		84MHz	84MHz	42MHz	28MHz	14MHz	28MHz	14MHz
Resolution		Rg × Az : 3 × 1m	3m	6m	10m	100m (multilook)		60m (multilook)
Swath		Rg × Az : 25 × 25km	50km	50km	70km	350km (5-scan)		490km (7-scan)
Polarization*		SP	SP/DP	SP/DP/QP/CP		SP/DP		
NESZ		-24dB	-24dB	-28dB	-26dB	-26dB	-23dB	-23dB
S/A	**Rg**	25dB	25dB	23dB	25dB	25dB		20dB
	Az	20dB	25dB	20dB	23dB	20dB		20dB

*Polarization SP : HH or VV or HV , DP : HH+HV or VV+VH , QP : HH+HV+VH+VV , CP : Compact pol (Experimental)

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