InSAR解析によるトゥングラワ火山噴火に伴う地殻変動

The Ground Deformation associated with the Eruption of Tungurahua Volcano, Ecuador detected by InSAR analysis

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Acknowledgements

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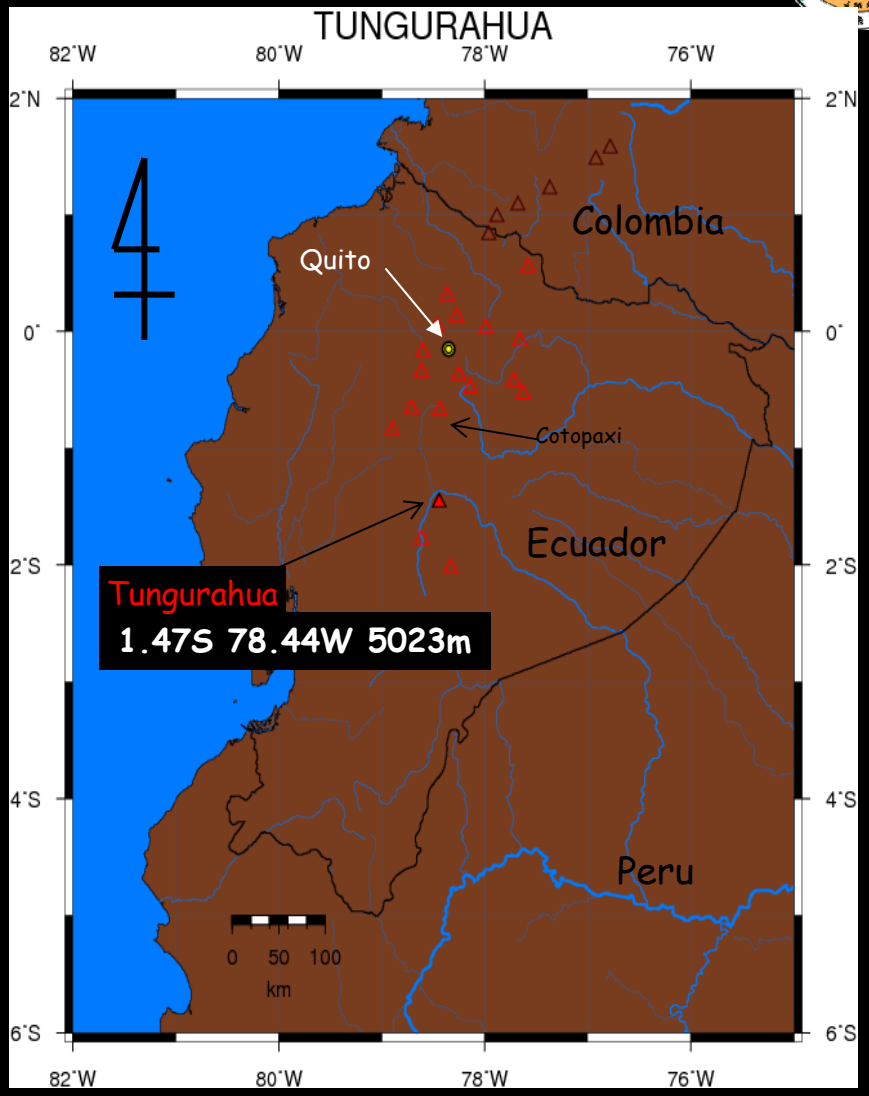
- The ownership of PALSAR data belongs to METI and JAXA.
- We would like to thank Dr. Shimada (JAXA) for the use of his SIGMA-SAR software.
- Some figures were made using GMT (P.Wessel and W.H.F.Smith, 1999).
- We are also grateful to Dr. Okuyama (AIST) and Dr. Miyagi (JAXA) for their advice on the drawing method by GMT.

Location


Venezuela
Guyana
Suriname
Guiana
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Uruguay
Argentina


TUNGURAHUA
82°W
80°W
78°W
76°W
2°N
0°
2°S
4°S
6°S
Colombia
Quito
Cotopaxi
Ecuador
Tungurahua
1.47S 78.44W 5023m
Peru
0 50 100
km

Tungurahua volcano

Photo by Nov. 2004 from wikipedia.

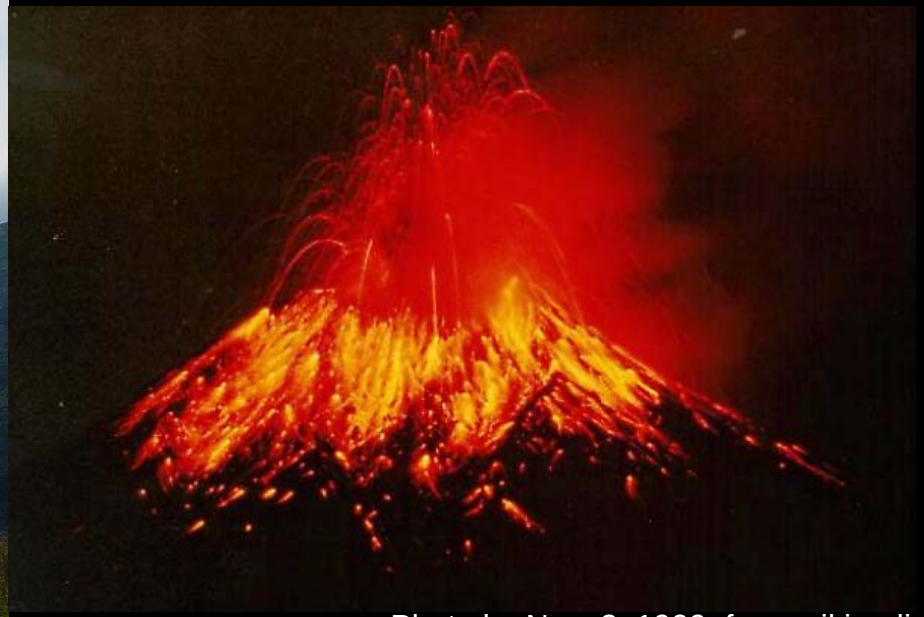


Photo by Nov. 2. 1999 from wikipedia.

- Lat : 1.47S Lon : 78.44W Elevation : 5023m
- 140 km (87 miles) south of the capital Quito.
- Type : strombolian
- With its elevation of 5,023 m Tungurahua just over tops the snow line (about 4,900 m). Tungurahua's top is snow covered and did feature a small summit glacier which melted away after the increase of volcanic activity in 1999.

Eruption History

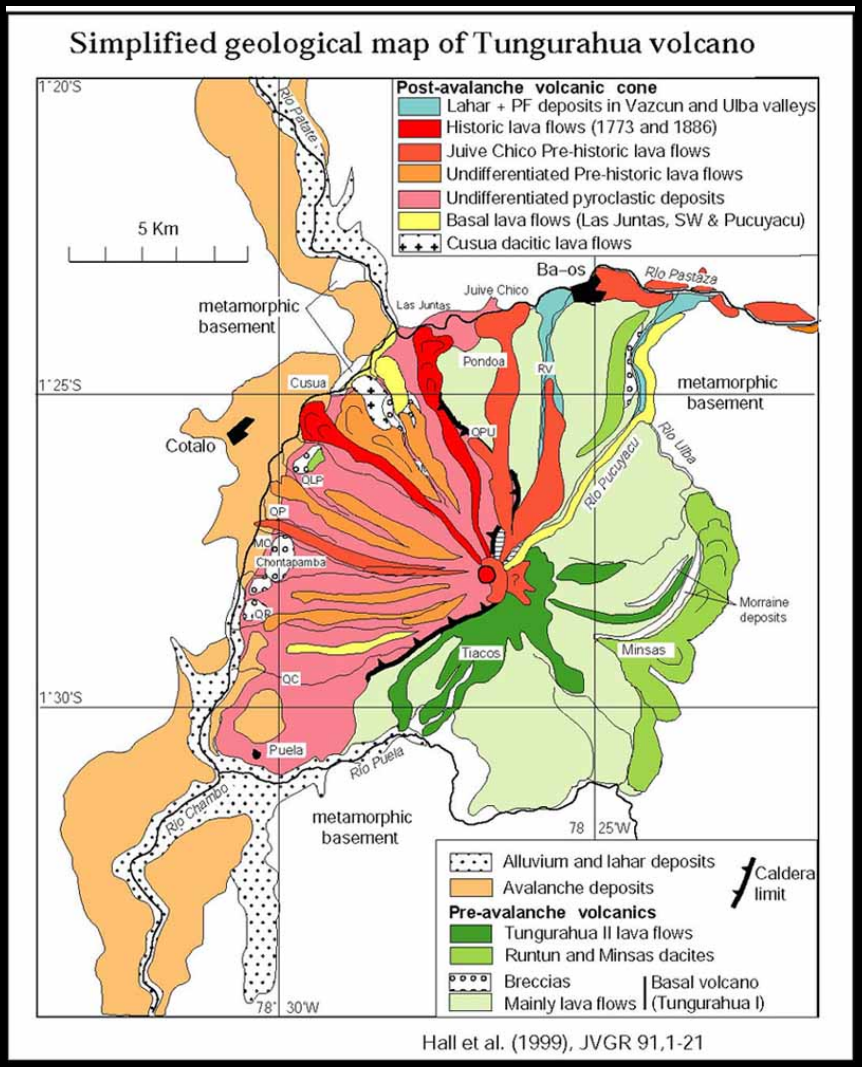
Area of Activity	Start Year	Start MoDy	Stop Year	Stop MoDy	Eruptive Characteristics	VEI	Volume L / T
Pyroclastic flows	1999	1005	2009>	....	x --- ---- x -- ?-- x x -	3?	
Lava flows	1993	0506	1993	0506	x --- ---- x -- --- ---	1?	
Mudflows (lahars)	? 1944	....	....	....	x --- ---- ? -- --- ---	2	
	1916	0303	1925	1201p	x --- ---- x x- --- -x -	4	
	? 1900	....	....	....	x --- ---- ? -- --- ---	2?	
	1886	0111	1888a	....	x --- ---- x -- --- x x -	4	7 / –
	1885	01 ..?	1885	1016	x --- ---- x -- --- ---	2?	
	1857	0910?	....	....	x --- ---- x -- --- ---	2?	
	? 1781	....	....	....	x --- ---- -- -- --- ---	2	
	? 1777	....	....	....	x --- ---- ? -- --- ---	2	
	1776	0103	....	....	x --- ---- x x- --- ---	2	
(P2 tephra; eruption began in 1773, not 1772)	1773	0204	1773	07 ..?	x --- ---- x -- --- -x -	3	8 / –
	? 1757	....	....	....	x --- ---- ? -- --- ---	2	
	1644	....	1646?	....	x --- ---- x -- --- -x	2	
	1640	....	1641	....	x --- ---- x -- --- -x	3?	
	1557	....	....	....	x --- ---- x -- --- ---	2	
	G 1350t	....	....	....	x --- ---- x -- --- ---	3?	
	G 1250t	....	....	....	x --- ---- x -- --- ---		
(tephra layer F)	C 1030u	....	....	....	x --- ---- x -- --- ---		
	C 0800?	....	....	....	x --- ---- x -- --- ---		
(P1 tephra unit)	C 0730x	....	....	....	x --- ---- x -- --- ---	4?	– / 7
	C 0600?	....	....	....	x --- ---- x -- --- ---	3?	
	C 0480u	....	....	....	x --- ---- x -- --- ---		8 / –
	C 0350?	....	....	....	x --- ---- x -- --- ---	3?	
	C 0200?	....	....	....	x --- ---- x -- --- ---		
	C 0100?	....	....	....	x --- ---- x -- --- ---	3?	
	C -0050?	....	....	....	x --- ---- x -- --- ---	3?	
	C -0100?	....	....	....	x --- ---- x -- --- ---	3?	
	C -0270v	....	....	....	x --- ---- x -- --- ---		
	C -0500?	....	....	....	x --- ---- x -- --- ---	3?	
(collapse of Tungurahua II edifice)	C -1010v	....	....	....	x --- ---- x -- --- x x -	5	– / 9
	C -7750?	....	....	....	x --- ---- x -- --- ---	4	– / 8

From Smithsonian Institution

Sometimes
cause big damage

Sometimes
- Lava flow
- Pyroclastic flow
- Mudflow

Pyroclastic deposits & lava flows



Hall et al. (1999), JVGR 91,1-21

Magma composition	Sequence name / deposits	Eruptive stages, major eruptions and datings	
Andesitic	1916-1918 eruption		SECOND MAIN PERIOD OF TUNGURAHUA III
Dacitic --> acid andesite -->andesitic	1886 eruption		
Dacitic --> acid andesite	1773 eruption ← P2	Mainly pyroclastic activity	
	← Unknown activity		
		← 890+/-135 BP (ash dep.)	
Dacitic	La Rea and Las Juntas upper pyroclastic flows	955 +/- 80 y. BP	
Basic andesite & andesitic	Bomb-rich pyroclastic flows in La Rea and upper Las Juntas sections (layer F)		
dacitic --> acid andesite	Las Juntas pyroclastic flow sequence (middle part of the section) ← P1	← 1230 +/- 30 y. BP	
		← 1470 +/- 85 y. BP in an ashfall deposit	
Andesitic	Juive Chico and Vazcun Lava flows	Construction stage	FIRST MAIN PERIOD OF TUNGURAHUA III
Basic andesite & andesitic	lower Las Juntas pyroclastic flows, La Piramide and Motilones pyr. flows, and lower, mainly andesitic, fallout deposits	Pyroclastic activity	
Basic andesite	Lower Las Juntas series + Rio Chambo (mainly lava flows)	Construction stage ← 2215 +/- 90 y. BP	
Dacitic	Cusua dacites		
	Main avalanche event	~2955+/-90 y. BP	
Mainly acid andesite	Tungurahua II		
Basic andesite to dacitic	Tungurahua I	Age : up to ~ 0.7 Ma	

Fig. 10. Generalized stratigraphy of Tungurahua volcano with special emphasis to the post avalanche Tungurahua cone.

Hall et al. (1999), JVGR 91,1-21

These have principally descended the cone's western.

Eruption History (recently)

Before and after the eruption on Feb. 6, 2008

On 30 January, incandescence at the summit was observed at night and incandescent blocks that were propelled from the summit by explosions rolled 600 m down the W flank. Explosions rattled windows as far away as the Tungurahua Observatory (OVT) in Guadalupe, about 13 km NW. A lahar descended the Mandur drainage, to the NW. On 1 and 4 February, incandescence at the summit was again noted and incandescent blocks traveled down the flanks. On 4 February, heavy ashfall to the SW was reported and explosions rattled windows in near-by areas. On 5 February, ashfall was reported in areas to the NW.

On 6 February, IG reported that pyroclastic flows from Tungurahua descended multiple NW and W drainages and tephra fall 3 cm in diameter was reported in areas to the SW. Based on information from the IG and satellite imagery evaluation, the Washington VAAC reported that ash plumes rose to estimated altitudes of 7.3-14.3 km (24,000-47,000 ft) a.s.l. and drifted S and NW. Ashfall was reported in areas downwind and to the SW and W, including Riobamba (30 km S). Precursory seismicity saturated local stations and presented similar patterns seen prior to intense episodes in July and August 2006. According to news articles, several hundred to 2,000 people were evacuated.

On 7 February, ash plumes rose to altitudes of 7-10 km (23,000-32,800 ft) a.s.l. and drifted mainly NW. Ash and tephra fell in areas to the SW and W. Strong roaring noises, explosions, and +ACI-cannon shots+ACI- were heard and windows vibrated, as far away as the Tungurahua Observatory (OVT) in Guadalupe, about 13 km NW. Incandescent material was propelled from the summit and fell on the flanks at about 3.5 km elevation, below the crater. Pyroclastic flows were detected in the Chontapamba ravine to the W and in the Juive and Mandur drainages to the NW. According to news articles, residents were evacuated again, hours after being allowed to return home.

During 8-11 February, ash plumes rose to altitudes of 6-10 km (19,700-32,800 ft) a.s.l. and drifted mainly W and E (on 10 February, only). Ashfall was reported from areas to the NW, W, and SW and was 3-4 mm thick in Choglontus to the SW on 8 February. Incandescence at the summit was also observed on 8 February. Ground vibrations were reported all four days. On 11 February, Strombolian activity was seen at the summit and material that was propelled out rolled 1.2 km down the flanks.

From Smithsonian weekly Report

ALOS/Daichi data

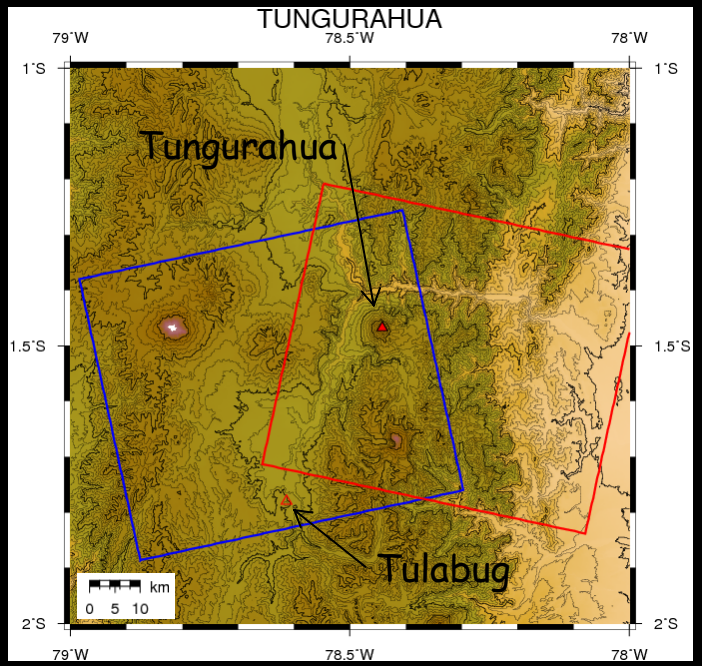
ALOS launched in Jan. 24, 2006

- **Ascending**
  - **Path-Flame:110-7150**
    - ✓2006:12.23
    - ✓2007:06.25, 08.10, ***12.26***
    - ✓2008:***03.27***, 05.12, 06.27, 08.12, 12.28
    - ✓2009:06.30

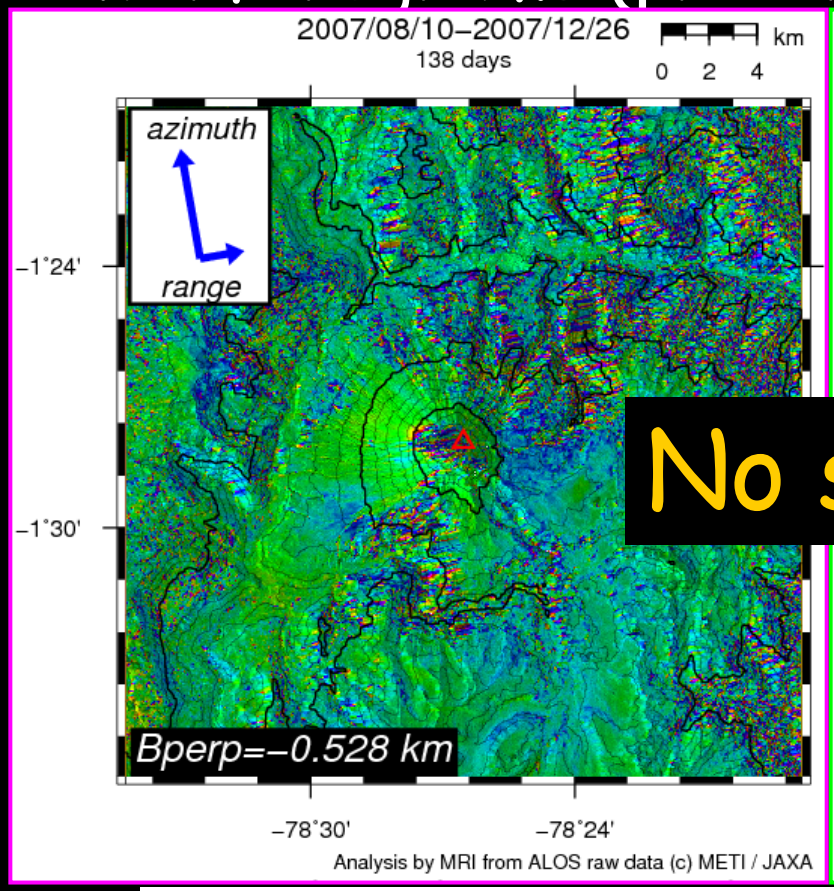
} 10 scene

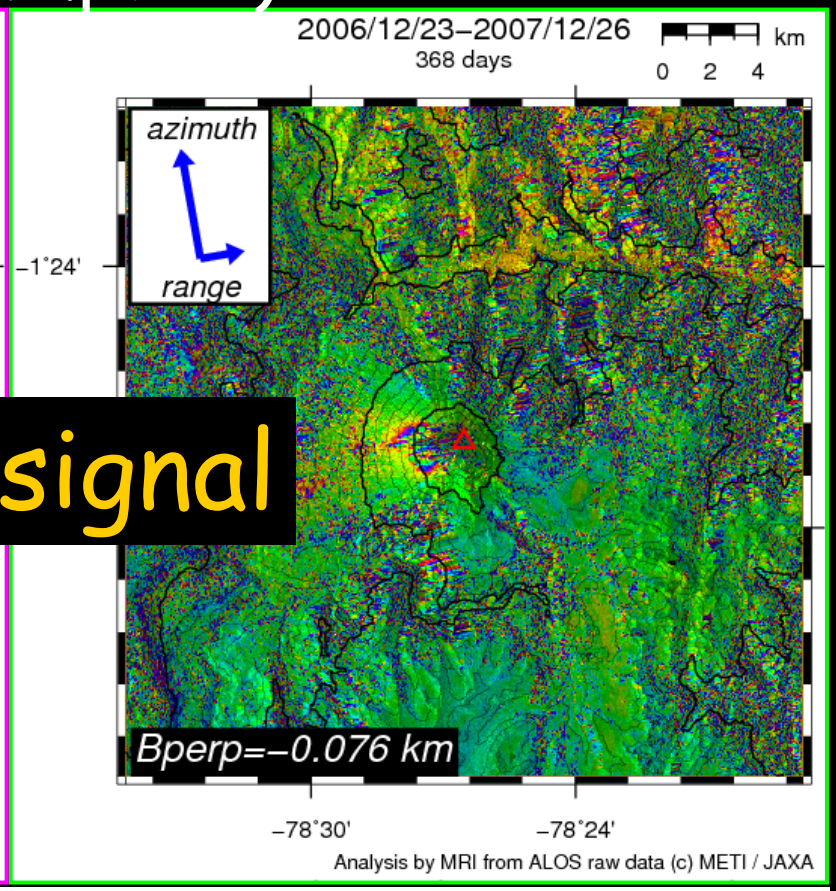
- **Descending**
  - **Path-Flame:450-3650**
    - ✓2007:***12.10***
    - ✓2008:***03.11***, 07.27

} 3 scene

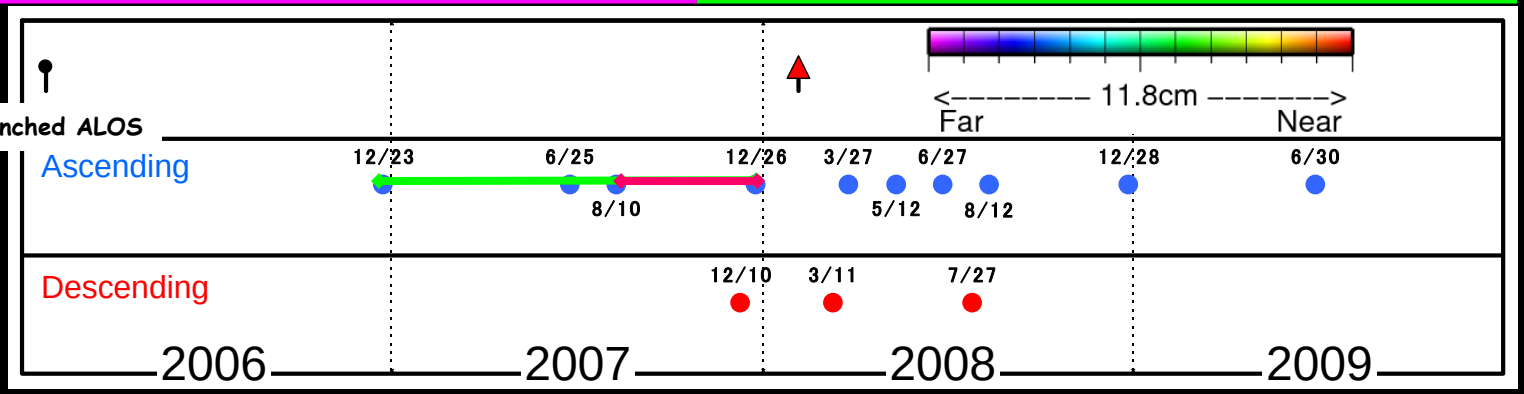


Interferograms (pre-eruptive)





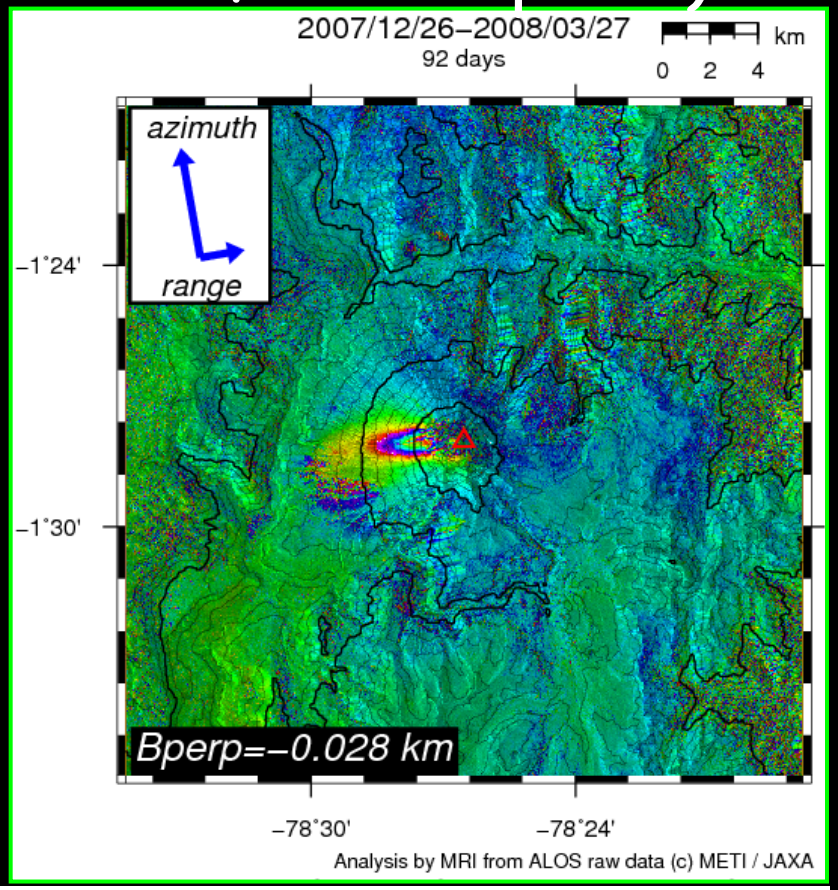
No signal

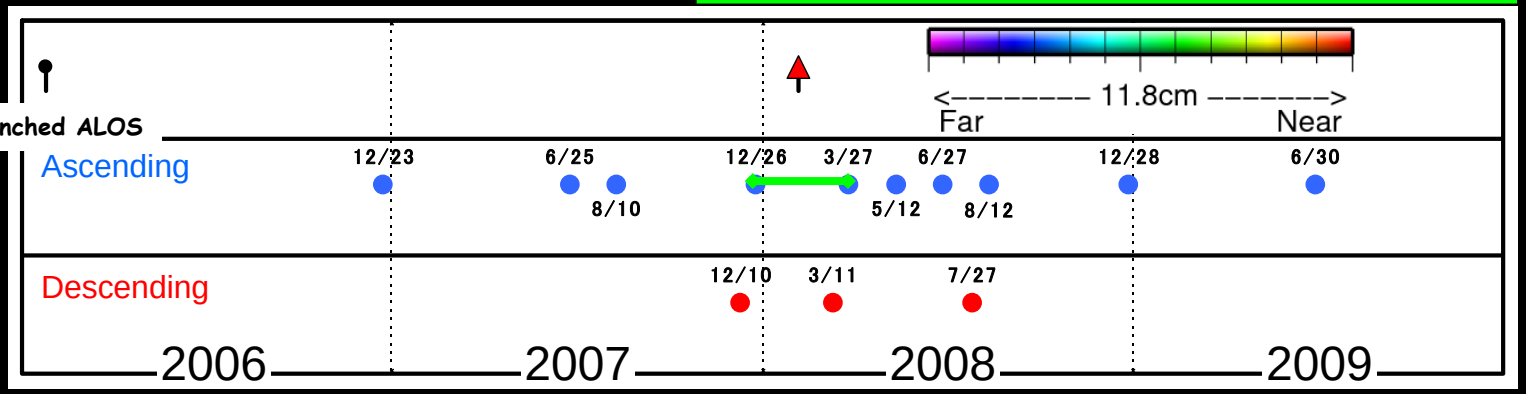


Interferogram (before and after eruptive)

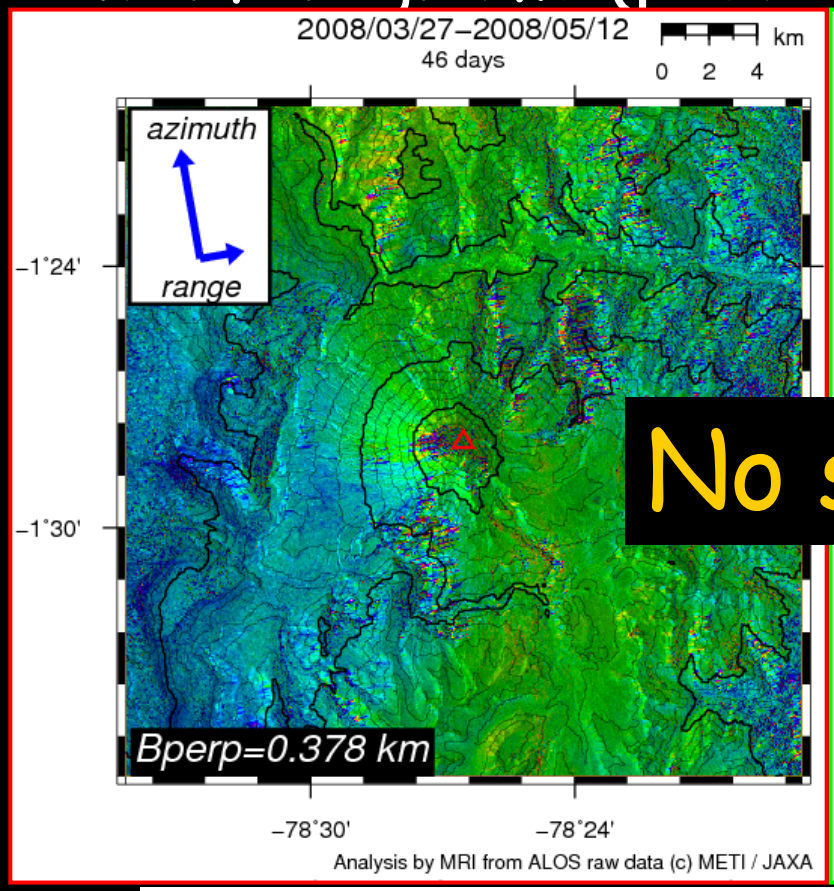
- In the western side of summit
- Incandescent blocks
  - were expelled from the summit
  - rolled down the flanks
- Ash plumes rose to altitudes of max 14.3 km (47,000 ft) a.s.l.

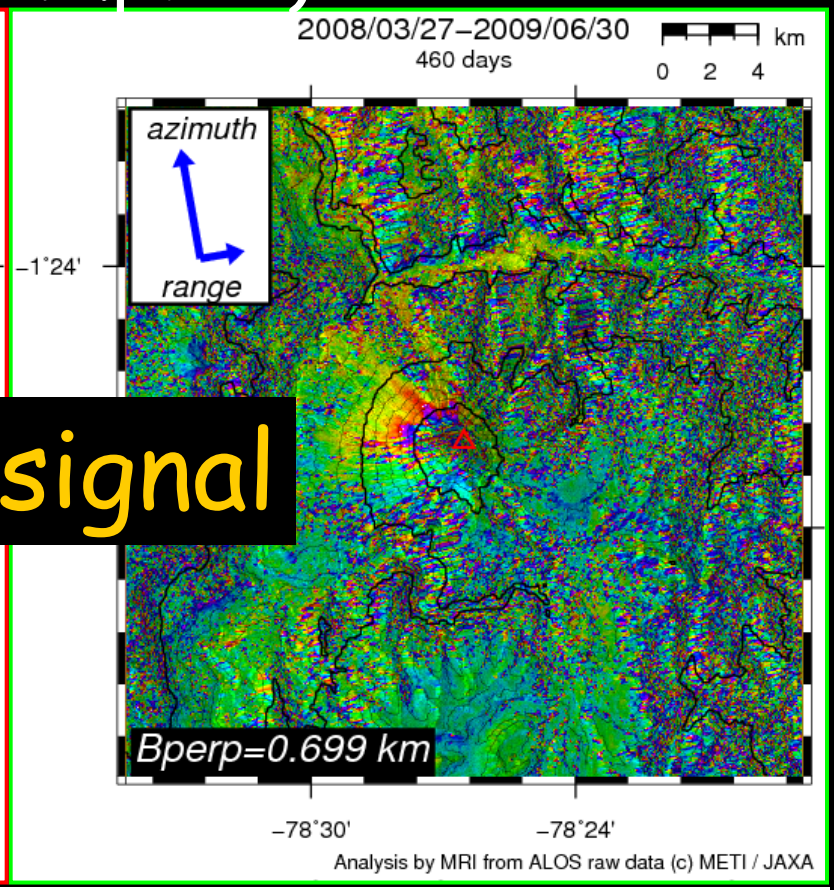
Clearly signal



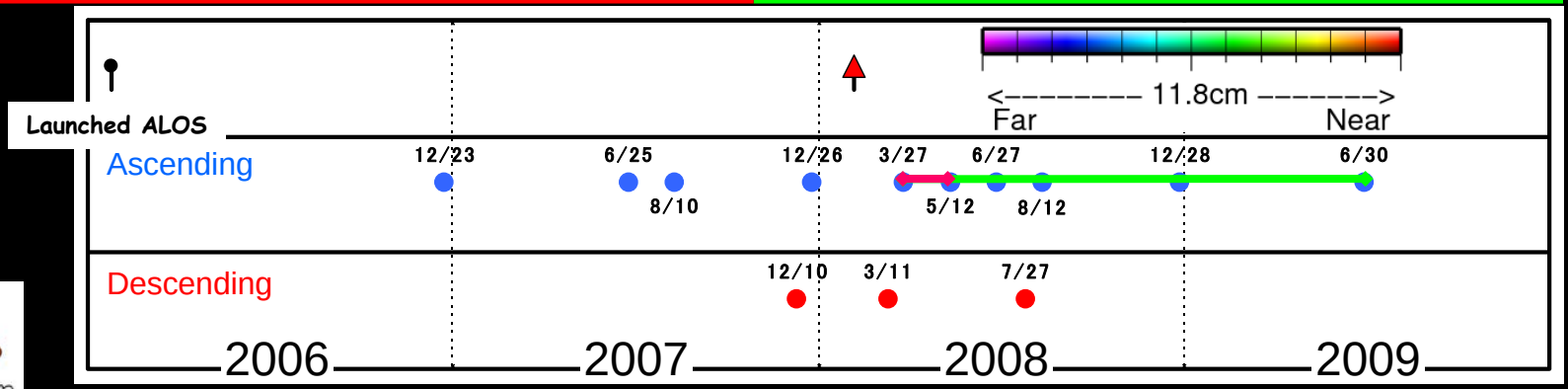


Interferograms (post-eruptive)

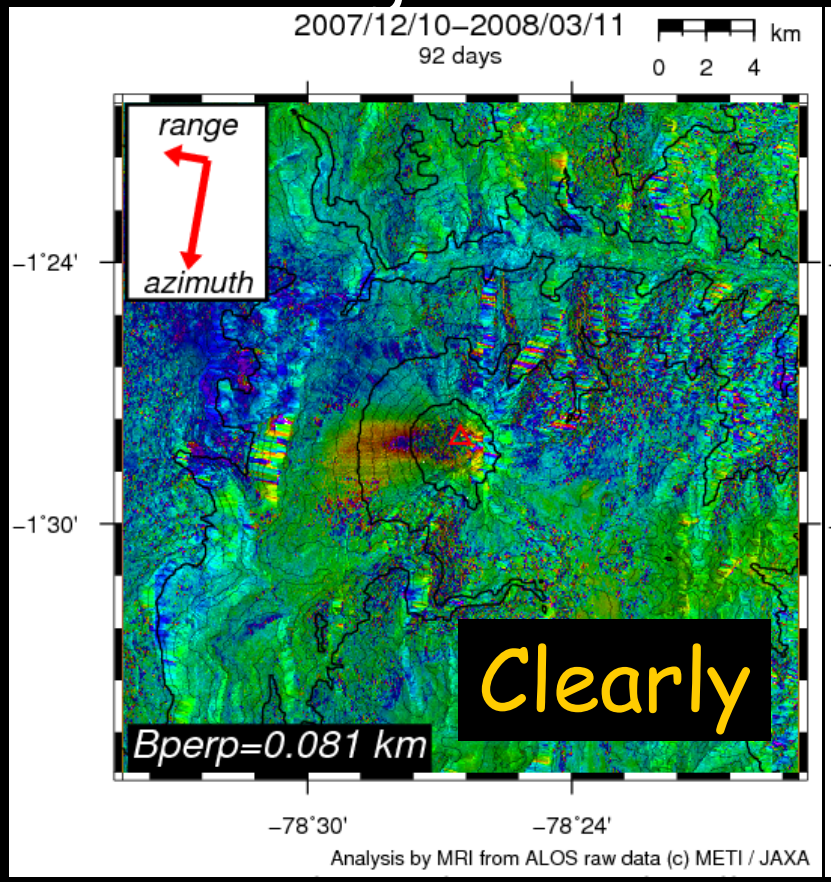


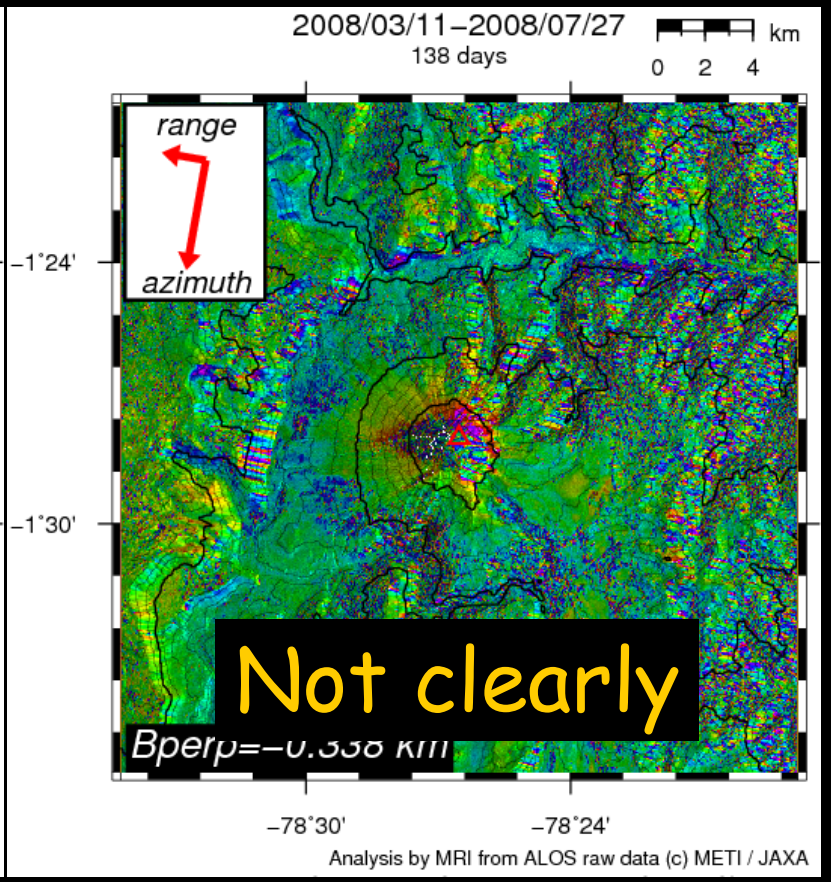


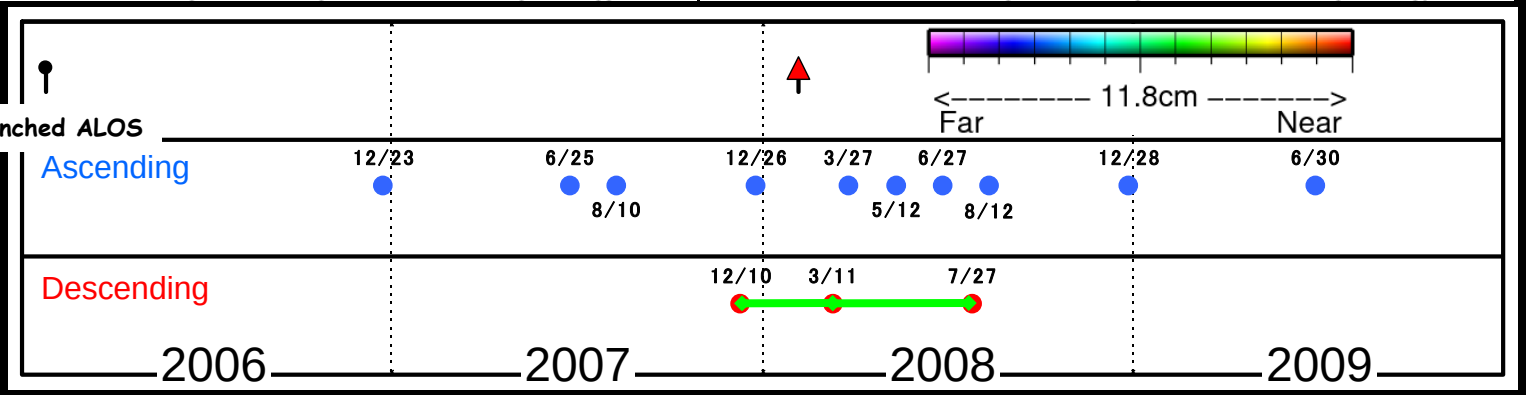
No signal



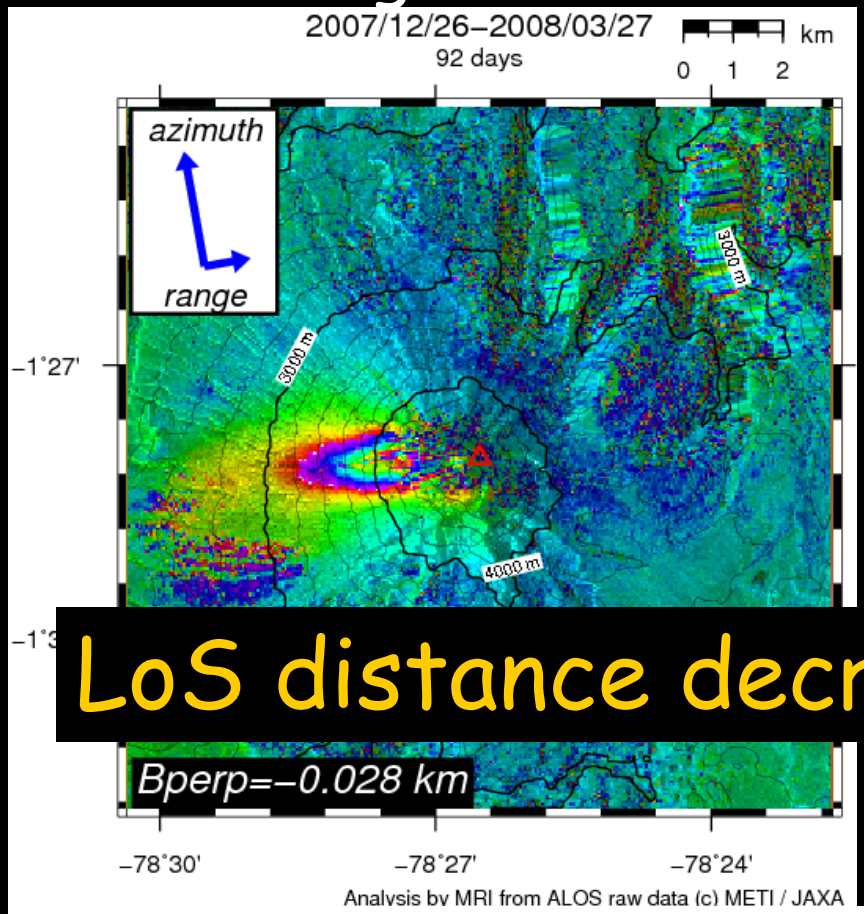
Interferograms

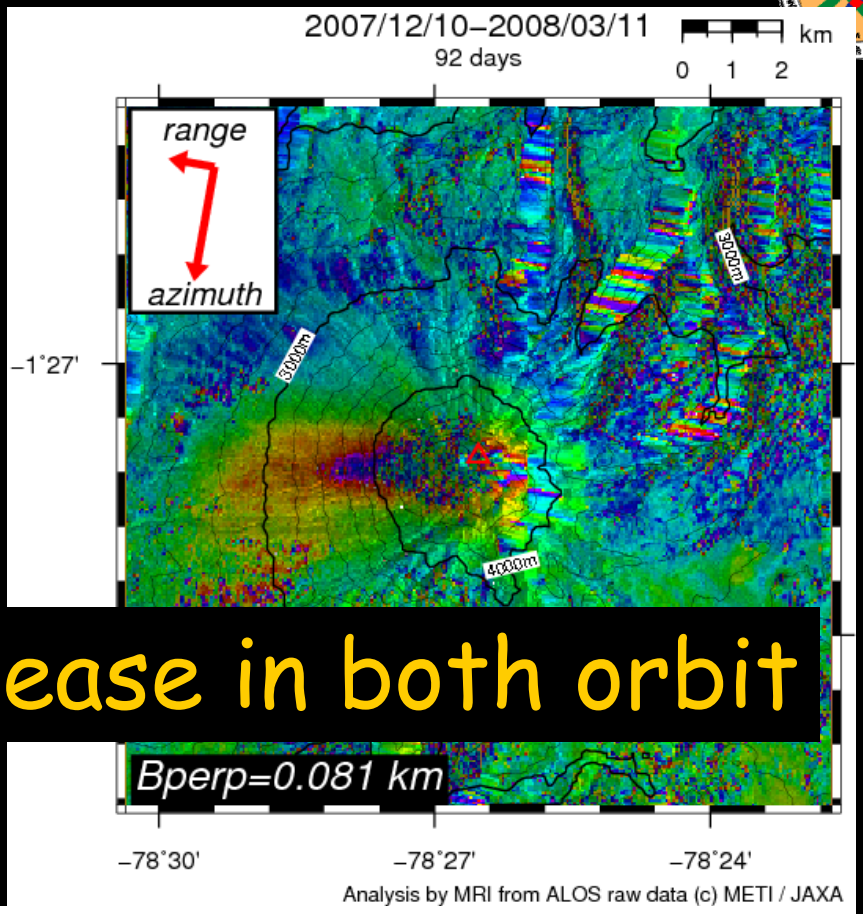




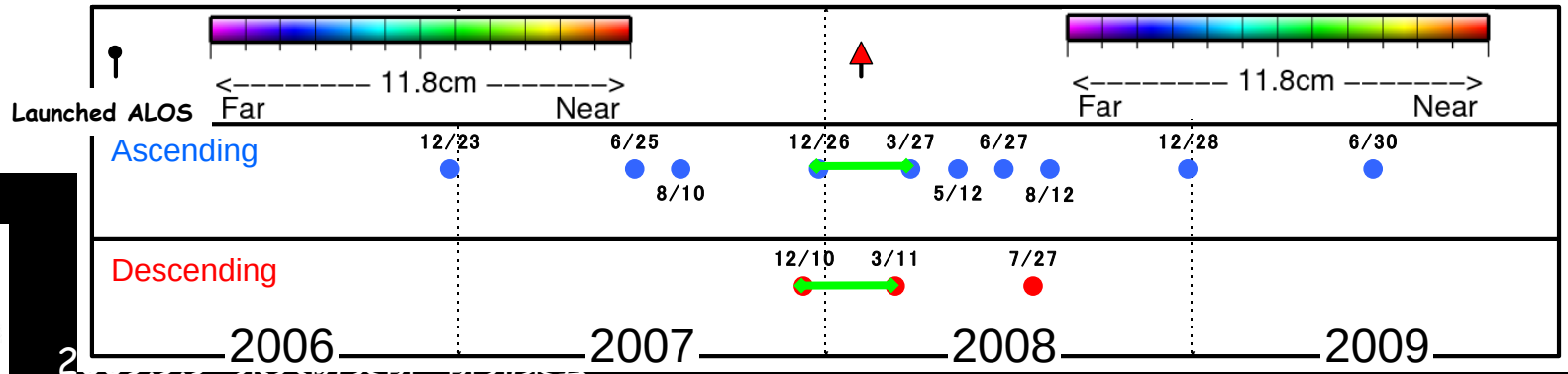


Interferograms

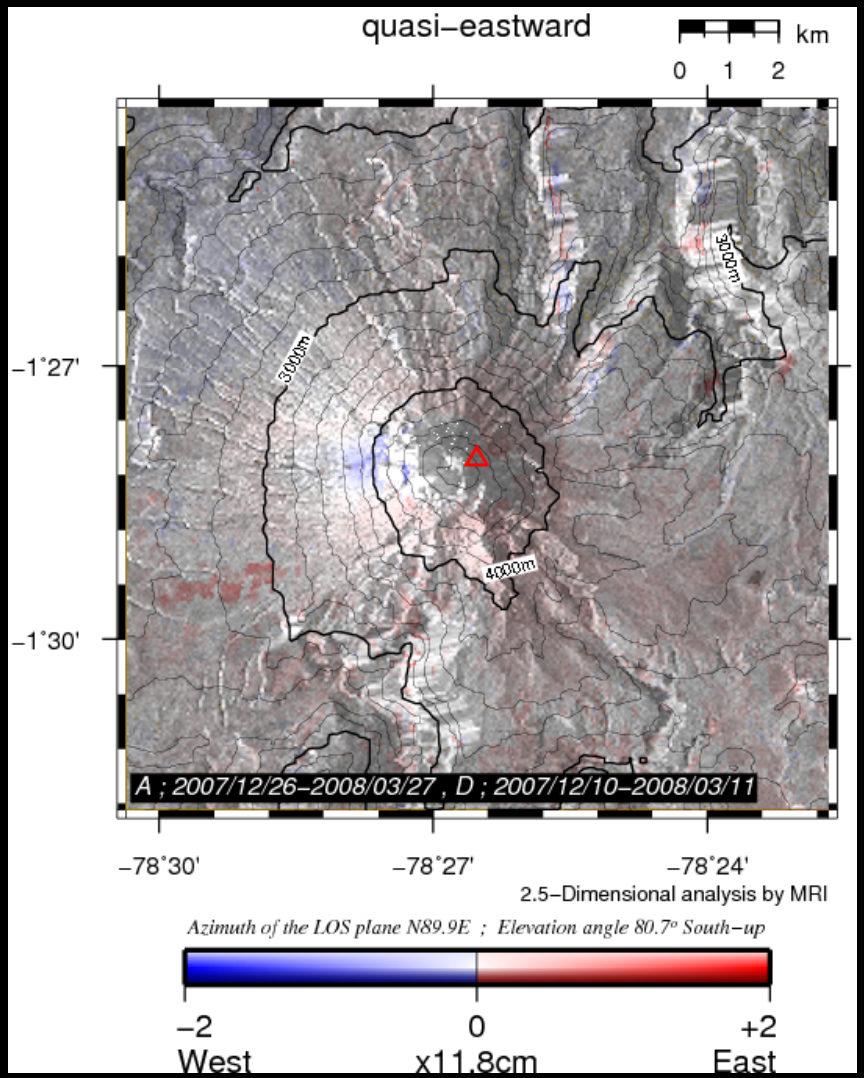


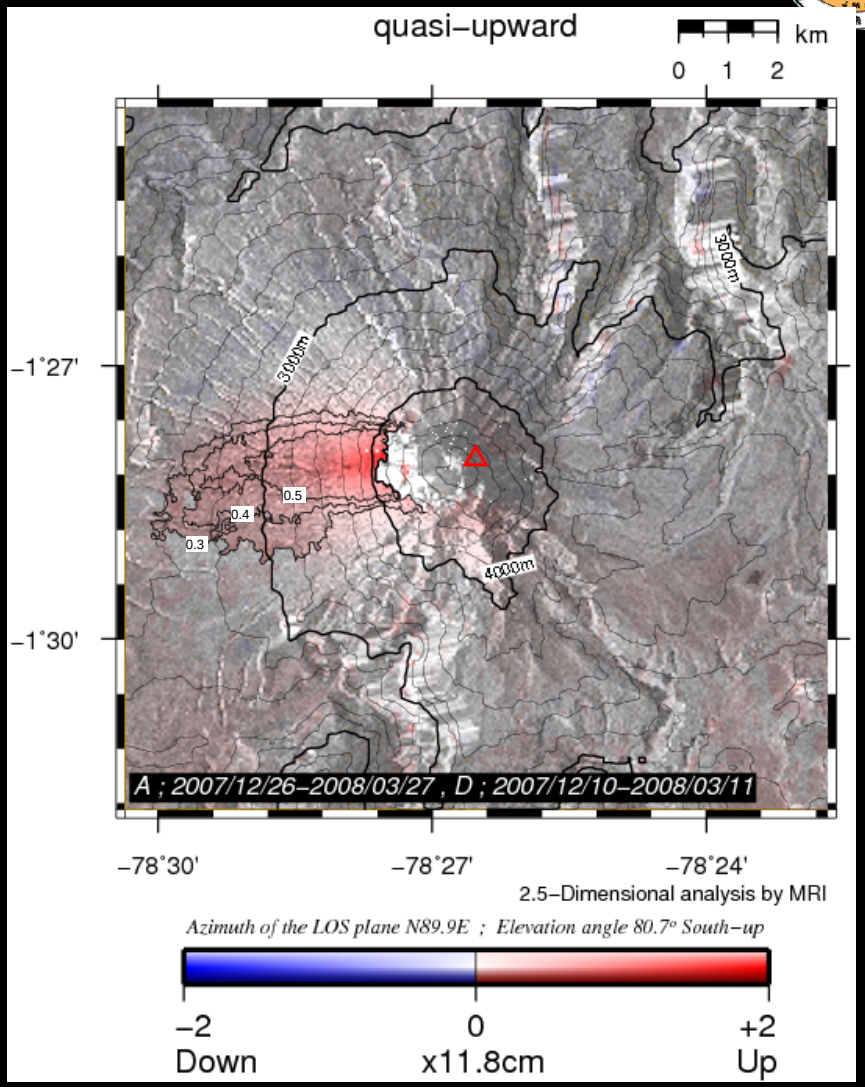


LoS distance decrease in both orbit



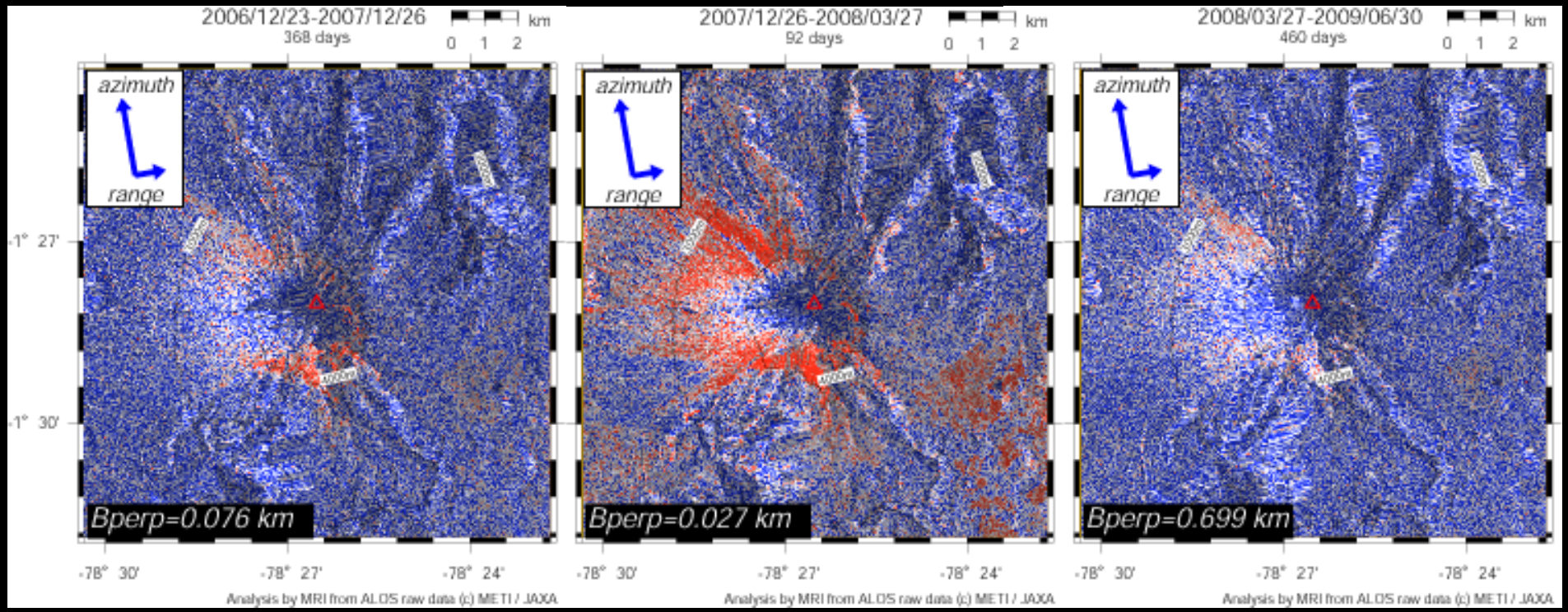
2.5-dimentional analysis

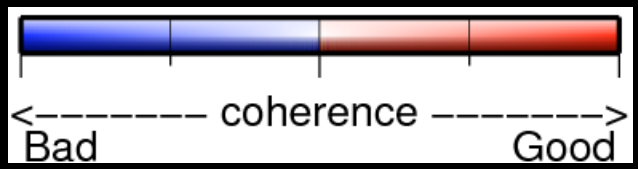




Coherence images

Pre-pair | Inter-pair | Post-pair





Coherence is high in the western side of the summit.

Interpretation

Report:

Incandescent material was propelled from the summit and fell on the flanks at about 3.5 km elevation, below the crater.

Result:

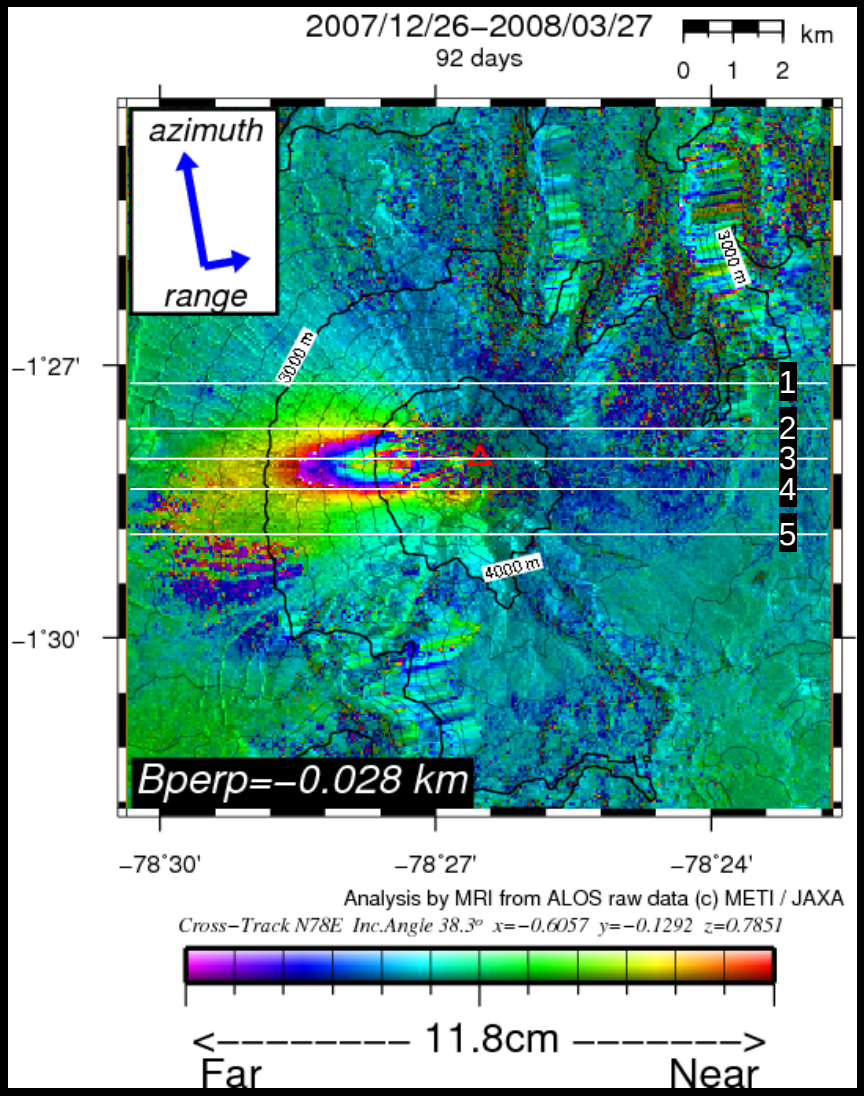
- Uplift of the ground deformation is observed only at west flank.
  But these deformation isn't clear in pre-eruptive and post-eruptive pair.
- Coherence is high at west flank.
  But these correlation isn't clear in pre-eruptive and post-eruptive pair.

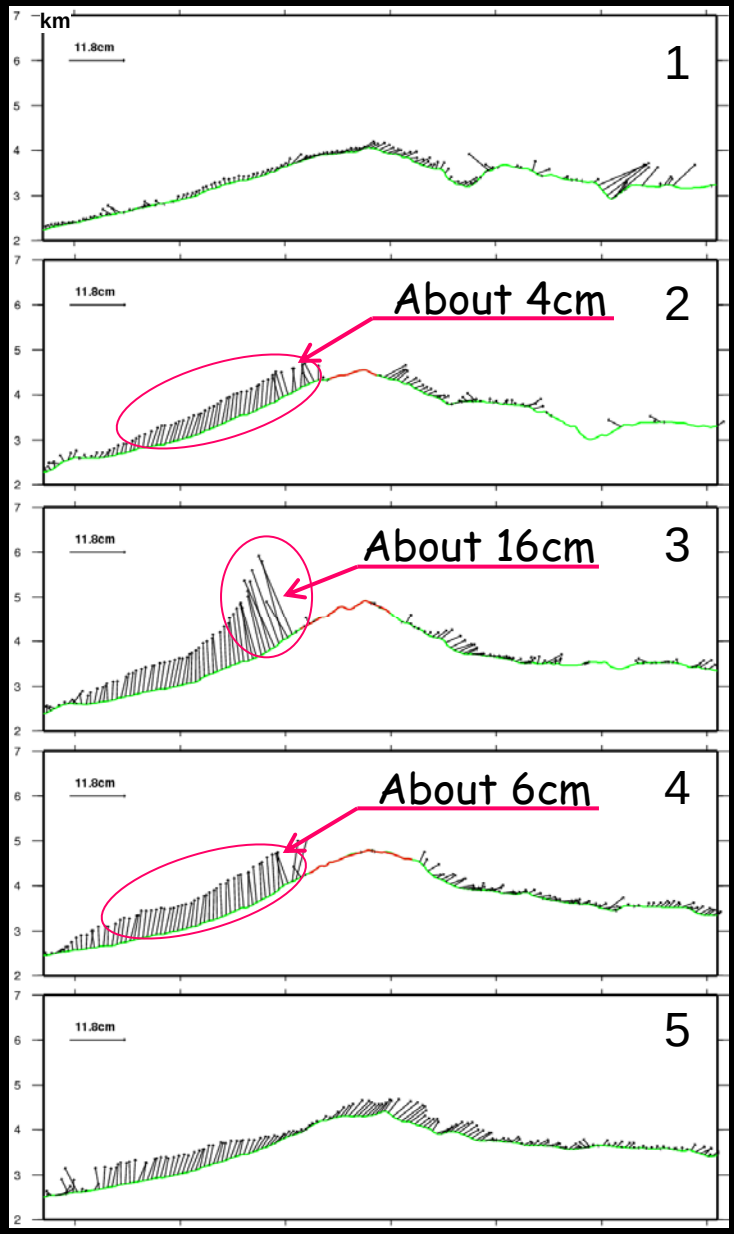
In general:

Uplift of the ground deformation is observed before eruption.
And then, it subsides after eruption.
Correlation is higher in the lava zone than the forest area.

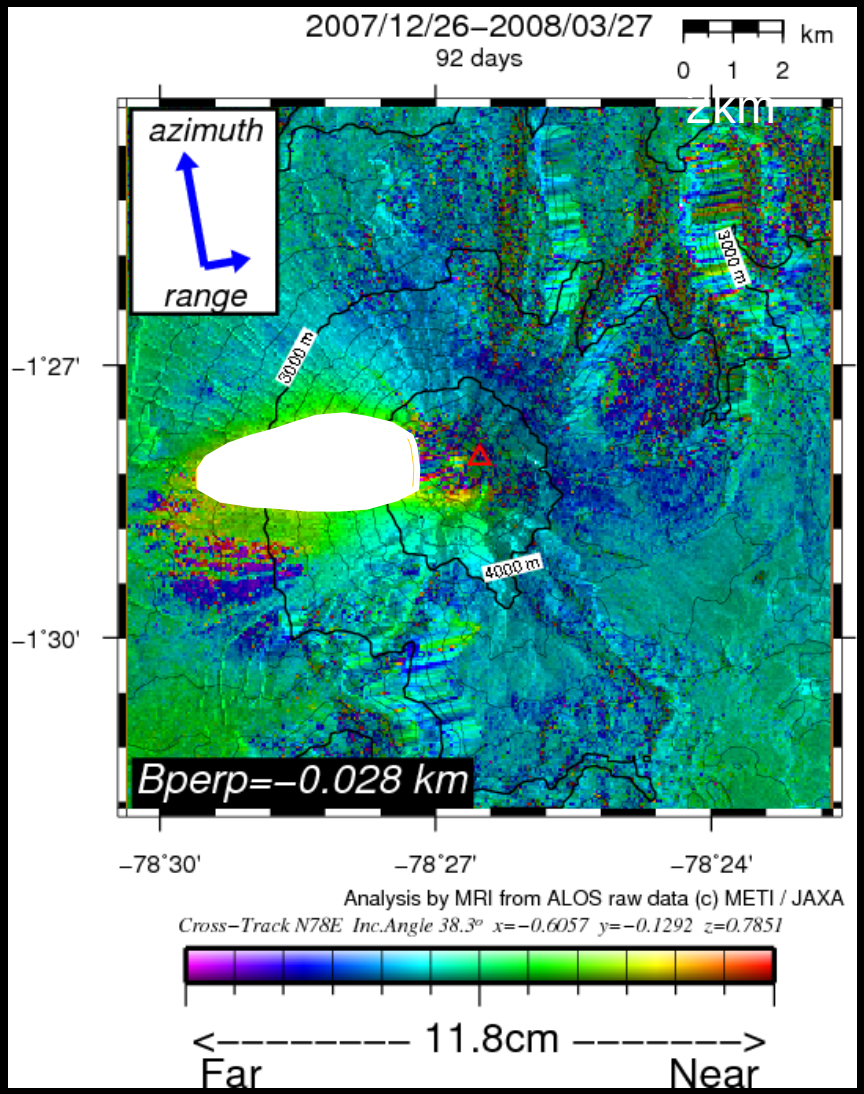
This is possibility of the lava flow or the volcanic blocks caused by eruption.

2-dimentional displacement vectors





Estimation of lava flows or volcanic blocks



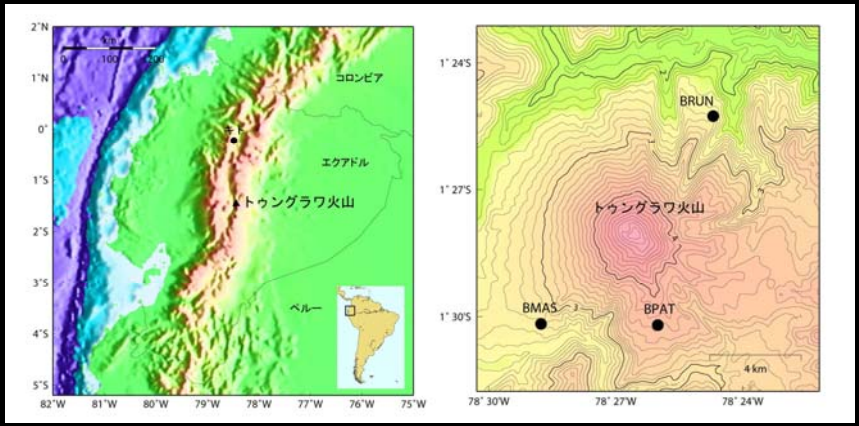
If this shape is an ellipse …

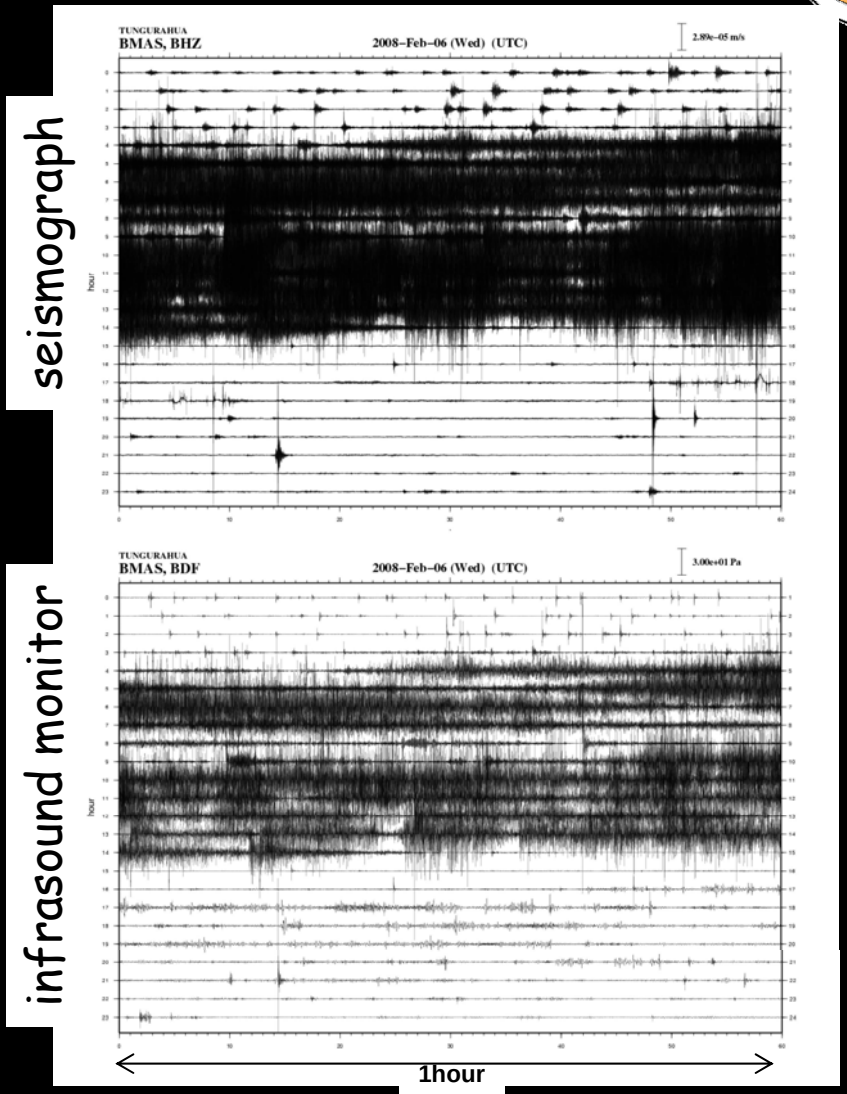
- $S = 2km * 1km * \pi * h$
- Thickness of layer :2~16cm
  ∴ h (Average) : ~ 7cm
- Volume = $0.43 * 10^6$ m^3
  where lava's density is $2*10^3$ kg/m^3
  →$0.86 * 10^9$ kg

cf.:
Washington VAAC reported that
ash plumes rose to estimated altitudes
of 7.3-14.3 km (24,000-47,000 ft) a.s.l.
and drifted S and NW.

Erupted volume (kg)
= K * altitude $(km)^4$ * continuation time (hr)
where K = 2.4～10 × 10^5 $Kg/km^4/hr$
If continuation time is 30 min and altitude is 10km…
∴ Erupted volume > $1.2～5 * 10^9$ kg
from suzuki(1990)

Seismograph & infrasound monitor

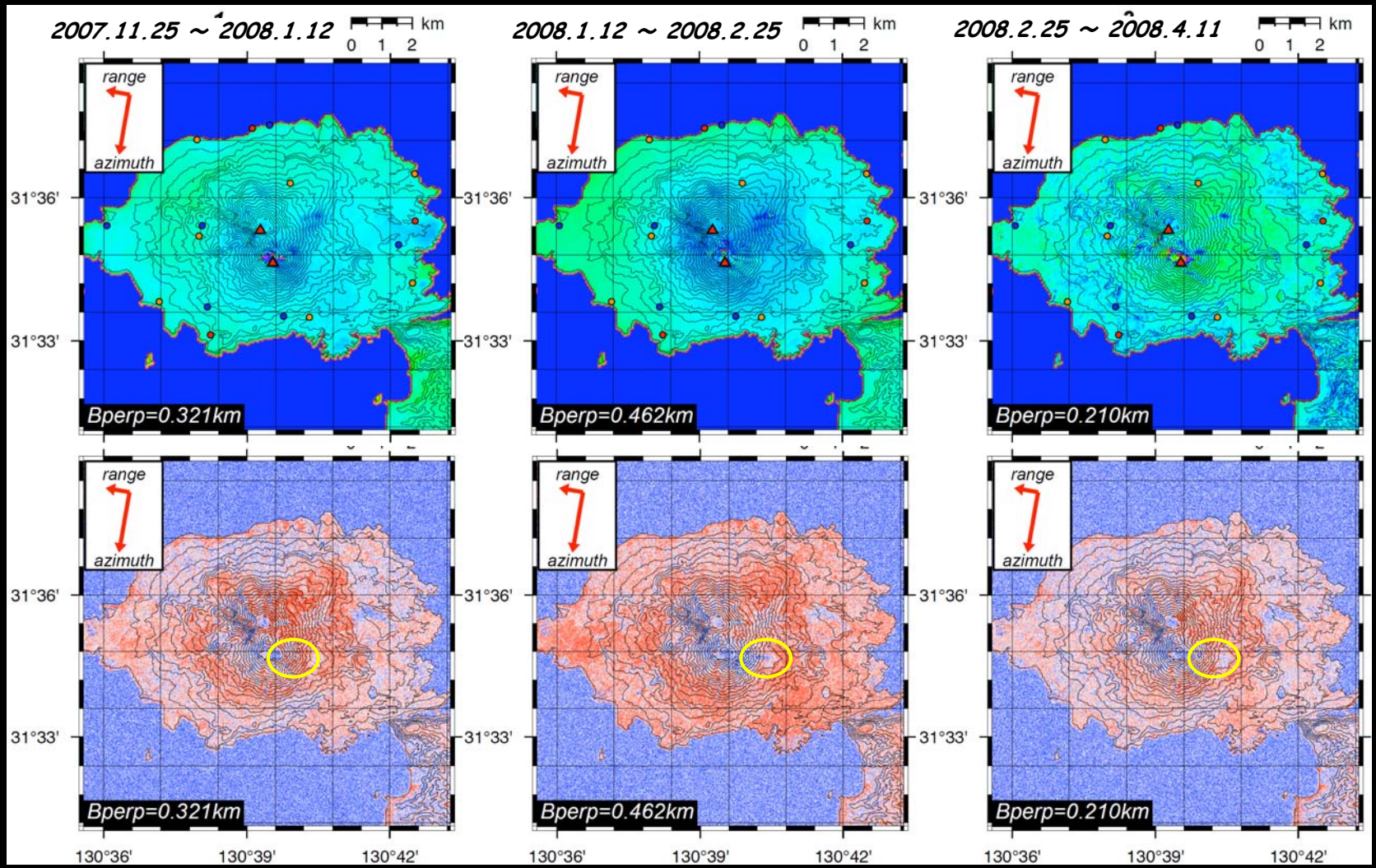




The eruption activity
continued for about 10 hours.
(include a vibration
caused by pyroclastic flows etc.)

From Home Page of NIED (National Research Institute for Earth Science and Disaster Prevention)

Pyroclastic flow (for example Sakurajima)



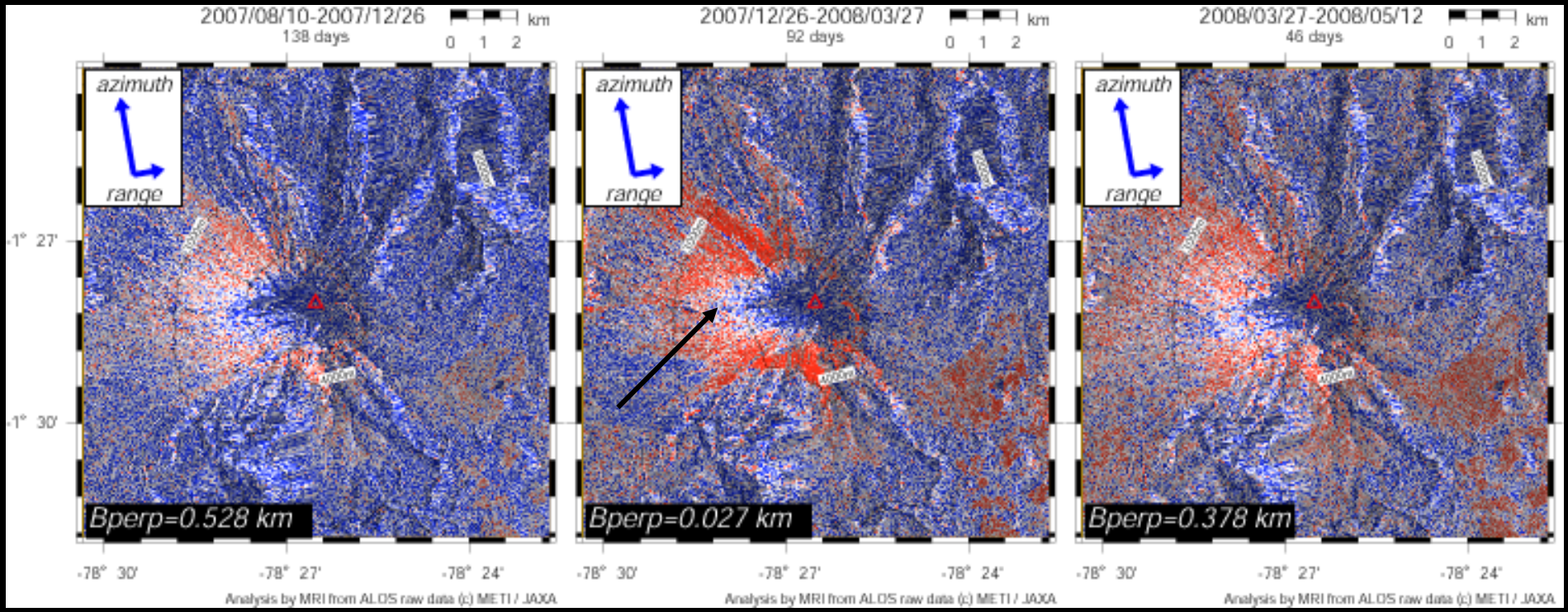
Interferograms

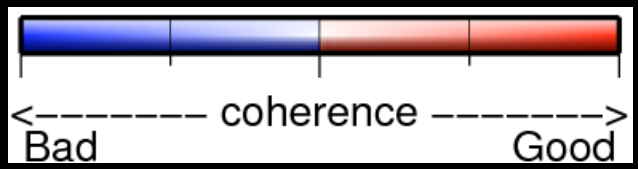
Coherence images

Pre-eruptive pair | Before and After | Post-eruptive pair

Coherence images

Pre-pair | Inter-pair | Post-pair





Coherence is high in the western side of the summit.
But not clearly (arrow point). Because it is ash or pyroclastic flow.

Summary

- We detected the ground deformation in Tungurahua volcano.
- This deformation rose toward the satellite in the radar LoS direction before and after the eruption on Feb. 2008.
- According to the 2.5-dimensional analysis using both orbits, this deformation was mostly at a quasi-upward direction.
- This deformation is possibility of the lava flow or the volcanic blocks caused by the eruption.