Detecting Topographical Change around the Summit of Mt. Merapi by InSAR Technique

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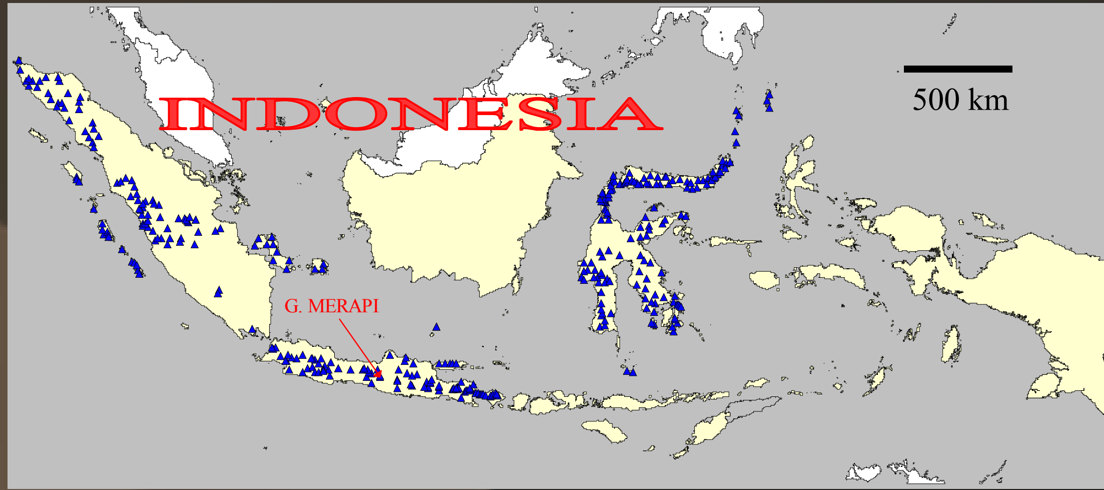
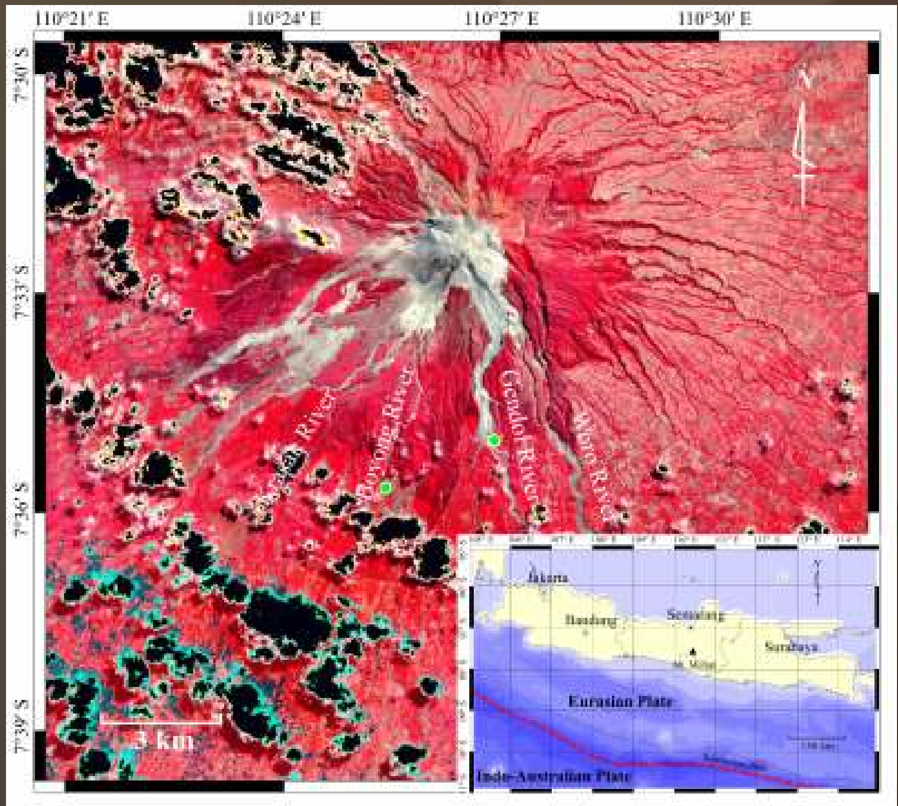
Introduction



Study area:

Mt. Merapi located in Central Java, Indonesia is one of 129 the most active volcanoes in Indonesia.



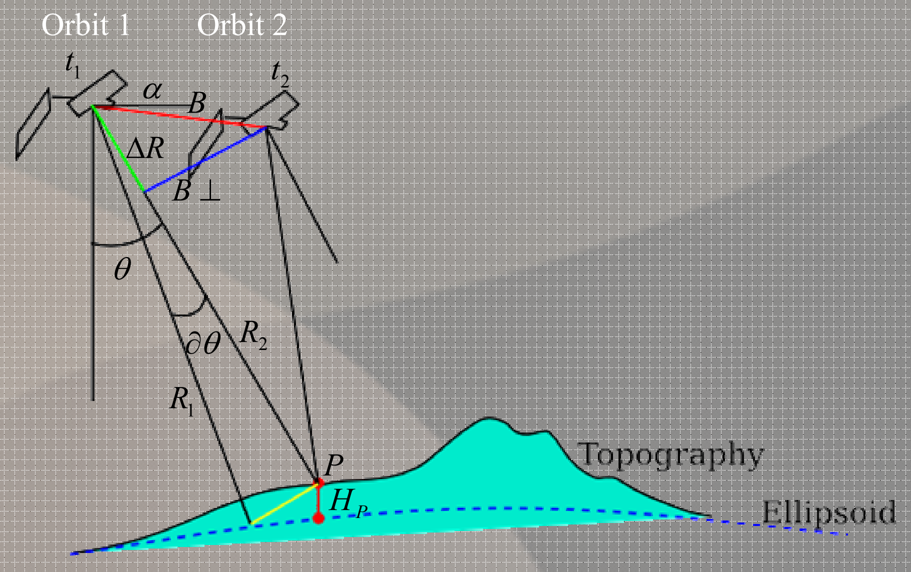
Objectives:

- To obtain topographical change around the summit
- To identify the change related with magma ascent and/or lahars generation
- To characterize surface change in the time of lava dome growth

ASTER image of Mt. Merapi for Band 3,2,1 in R,G,B and the subduction zone in the southern part.

InSAR Processing overview

- Image pair from two scenes time (t_1 and t_2).
- Perpendicular baseline ($B_{\perp}$) affected to phase different.
- Complex multiplication.
- Phase different for each pixel ($\partial \phi_p$) including topography (D_p) and Deformation (H_p) effect.
- Deformation effect is larger than topographic effect.



$$y_1 = |y_1| e^{j\varphi_1}$$

$$y_2 = |y_2| e^{j\varphi_2}$$

$$y_1 y_2^* = |y1||y2| e^{j(\varphi_1 - \varphi_2)}$$

$$\partial\phi_p = \varphi_{1p} - \varphi_{2p}$$

$$\partial\phi_p = -\frac{4\pi}{\lambda}\left(D_p - \frac{B\perp}{R_{1p}\sin\theta} H_p\right)$$

InSAR Processing Common Problem

1. Low coherence;

Distance between two satellites (Baseline): The long baseline leads the low correlation.

Time Interval between two observations.

2. Atmosphere condition;

Delay caused by water vapor in the atmosphere: The difference of the water vapor conditions in two observations produces the extra phase pattern.

3. Large changes of the earth surface;

Too large deformation caused high decorrelation between two data, e.g. eruption of an active volcano.

4. Orbital ambiguity;

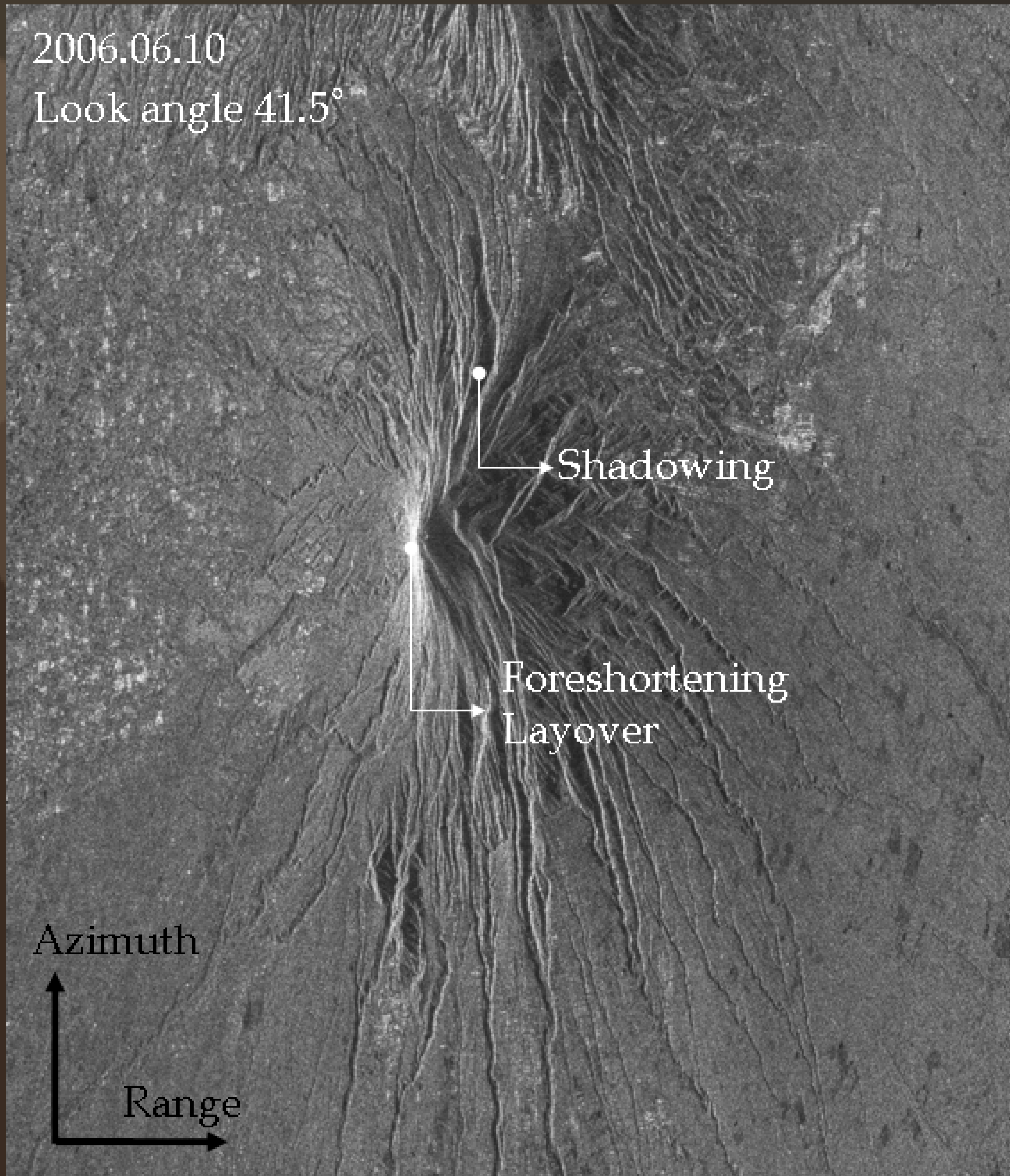
The fringes aligned toward to spacecraft direction (azimuth).

ALOS-PALSAR

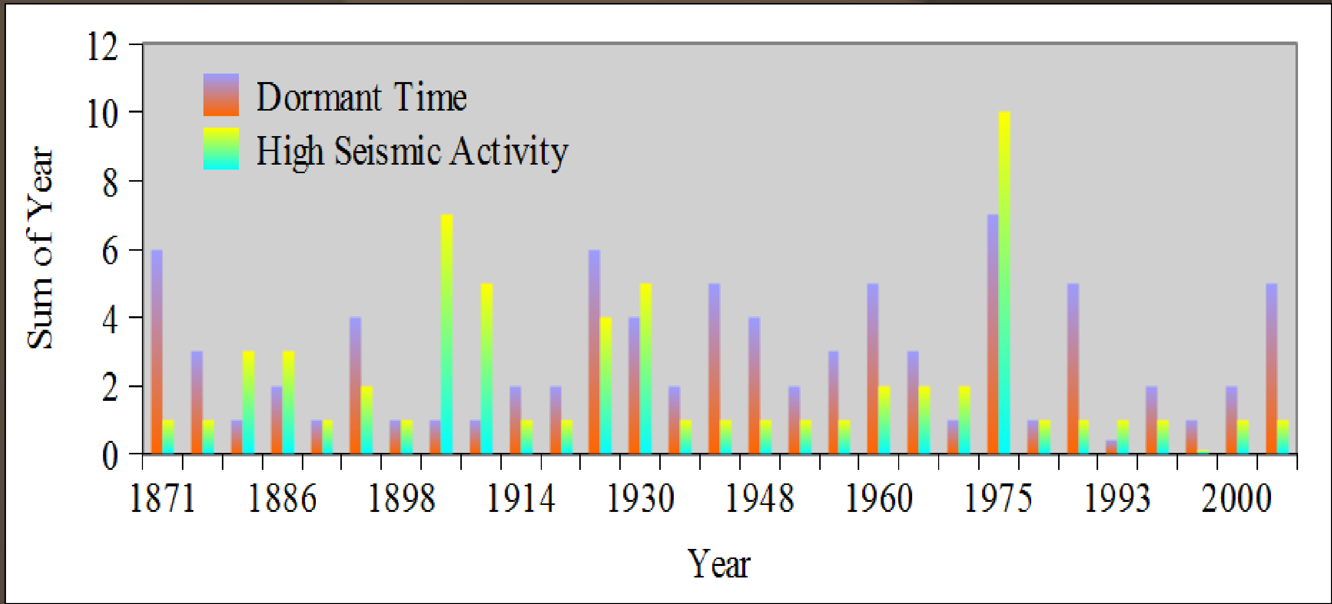
Radar signal return to the receiver depend on:

- Slope
- Roughness
- Dielectric constant

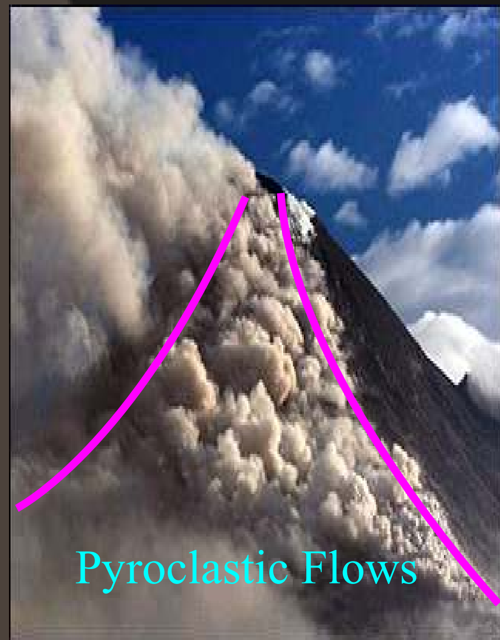
Intensity image showing the geometry distortion caused by off nadir angle view



The History of Mt. Merapi Eruption Period

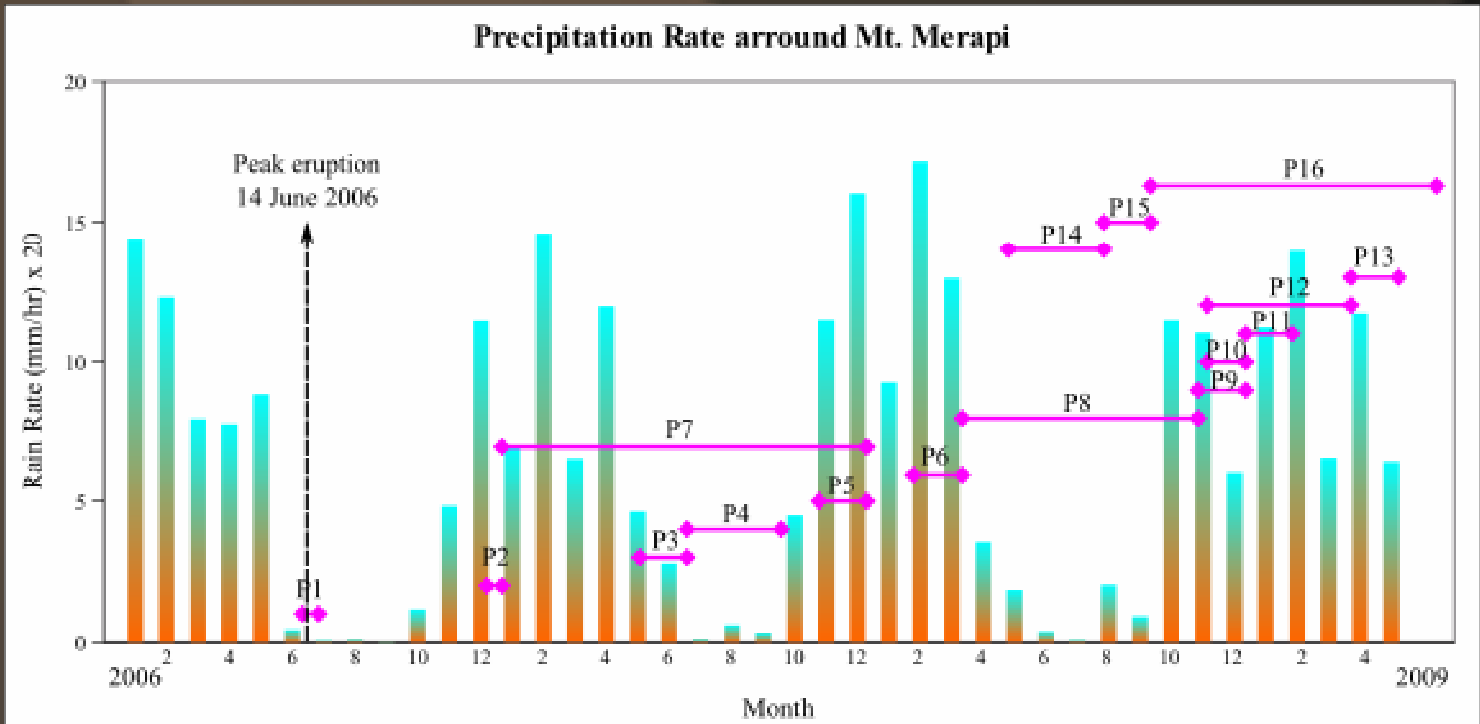


The latest eruption on May-June 2006



Mt. Merapi has short intervals of eruptions characterized by dome explosion and accompanied large amount of pyroclastic flow deposits (source: VSI, 2008).

Pair Line of ALOS/PALSAR 2006-2009



Three years observation data of ALOS/PALSAR were combined by a monthly precipitation rate with grid size 0.25º x 0.25º from Tropical Rainfall Measuring Mission (TRMM) data covered around the summit of Mt. Merapi

Overview of Sigma-SAR Software

ALOS/PALSAR Level 1.0 in JAXA Format

SAR Imaging+Calibration

- *Select a machine*
- *Input full directories*
- *SAR Imaging (InSAR)*
- *Sensor selection*
- *Processing algorithm selection*

InSAR Processing Software

- *Co-registration*
- *Interferometry 1st trial*
- *Slant range tuning*
- *Interferometry 2nd trial*
- *D-InSAR (prepare co-registration)*
- *Orbit tuning*

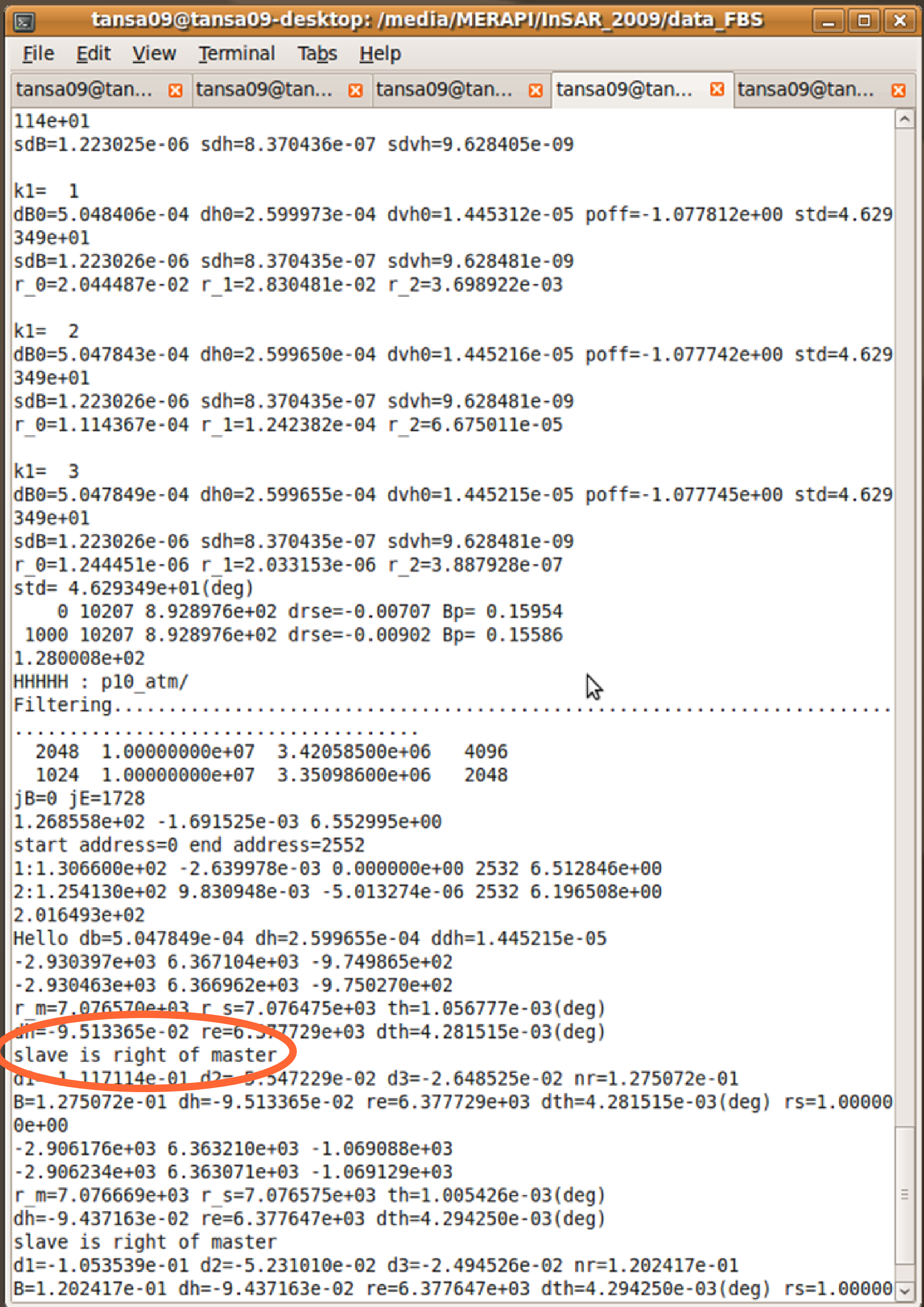
Atm. Corr:

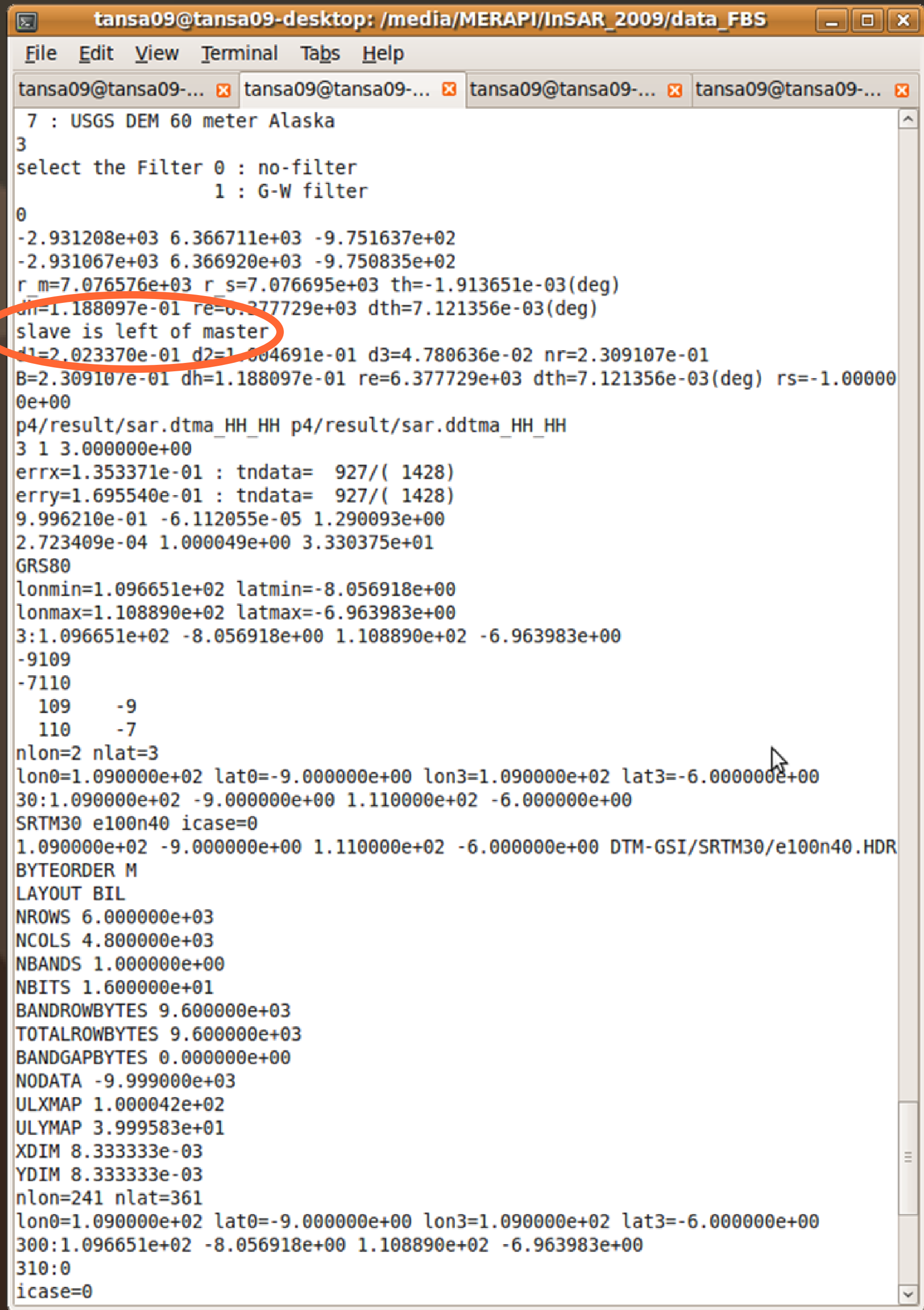
0: coarse
1: detailed
2: no
3: self_correction (DDTM)

- *Filtering*
- *Geocoding*

An Inconsistency...?
Master and Slave Position change automatically when running the program

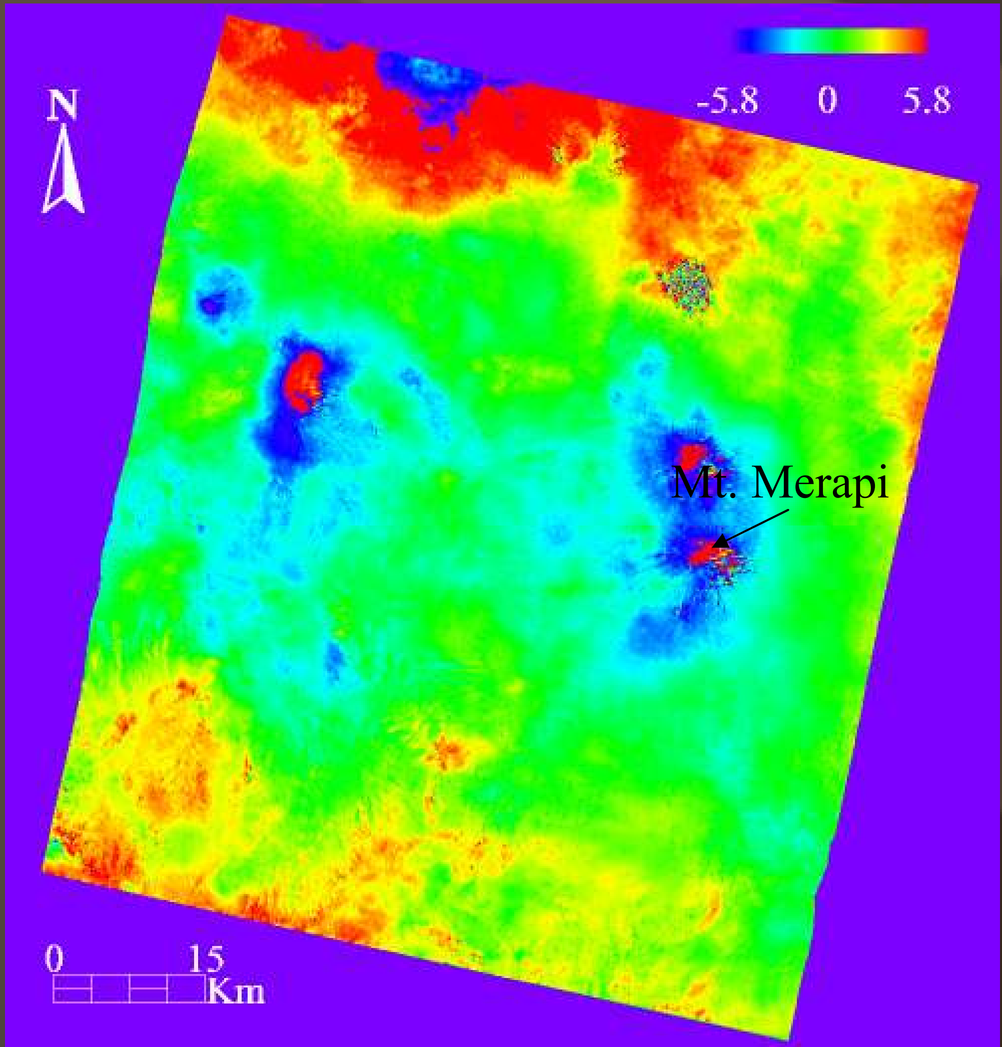
Slave Image is Older than Master



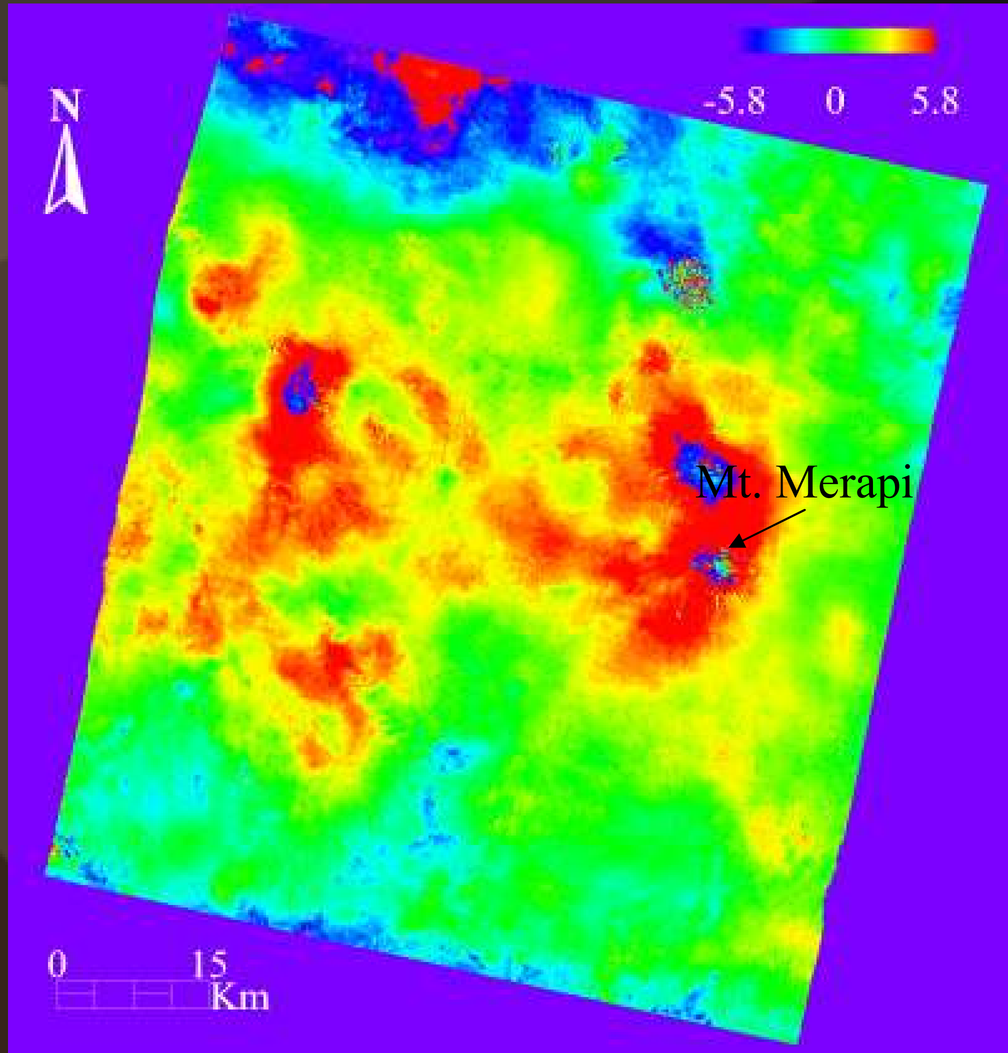


Master and Slave Image Position

P3 slave is right of master

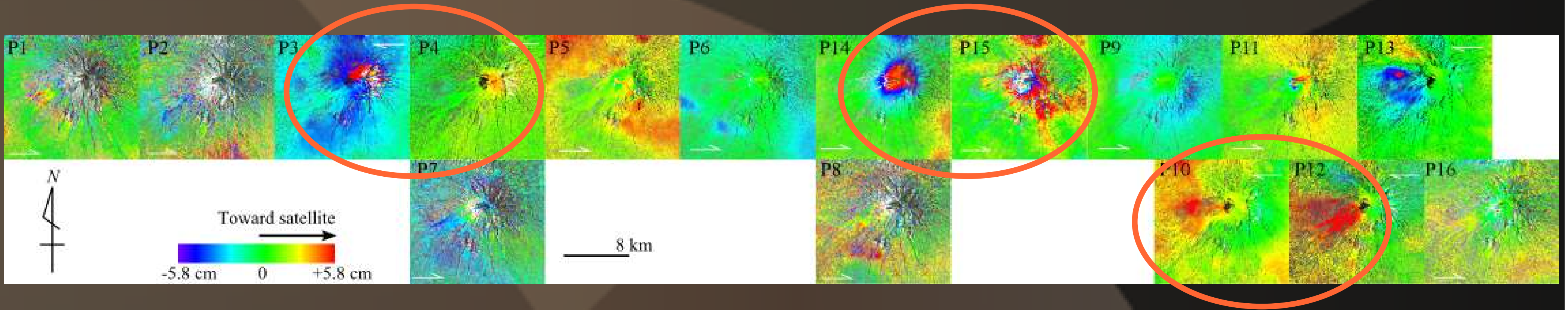


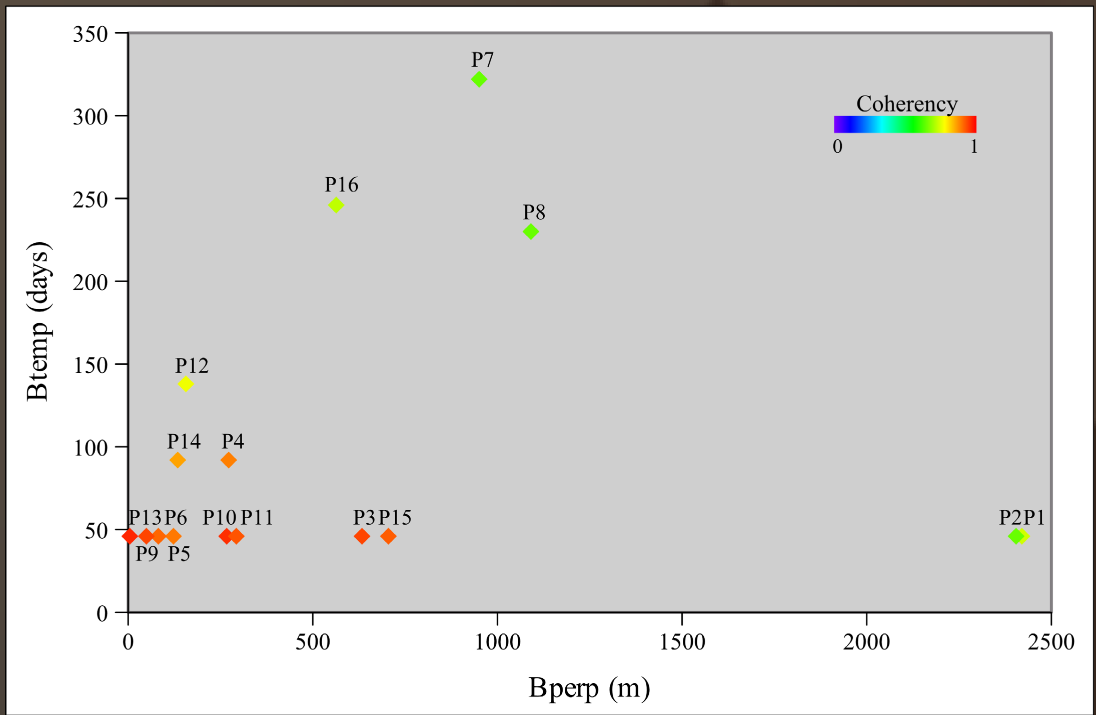
P3 slave is left of master



In particular case the Sigma-SAR change the master and slave position. The examination of log report is needed to know their correct position.

The Interferograms Generated from ALOS/PALSAR

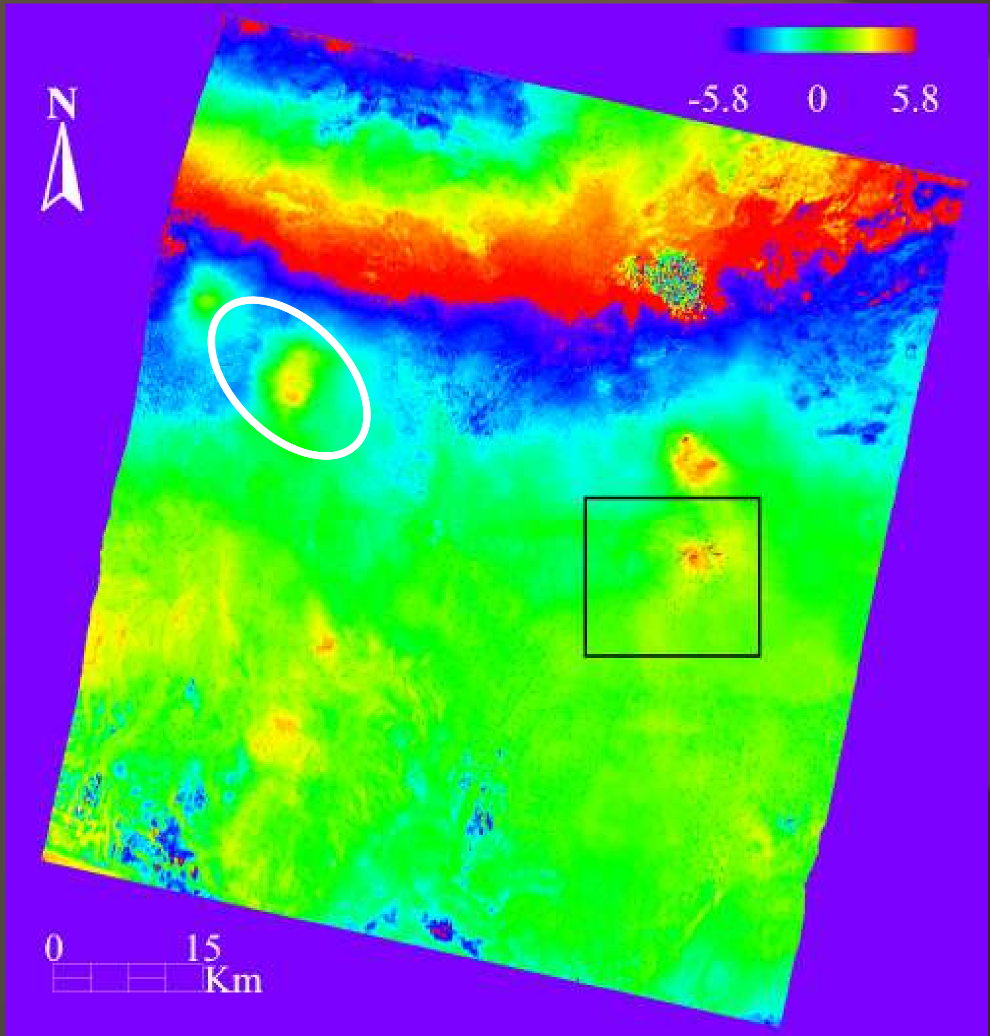




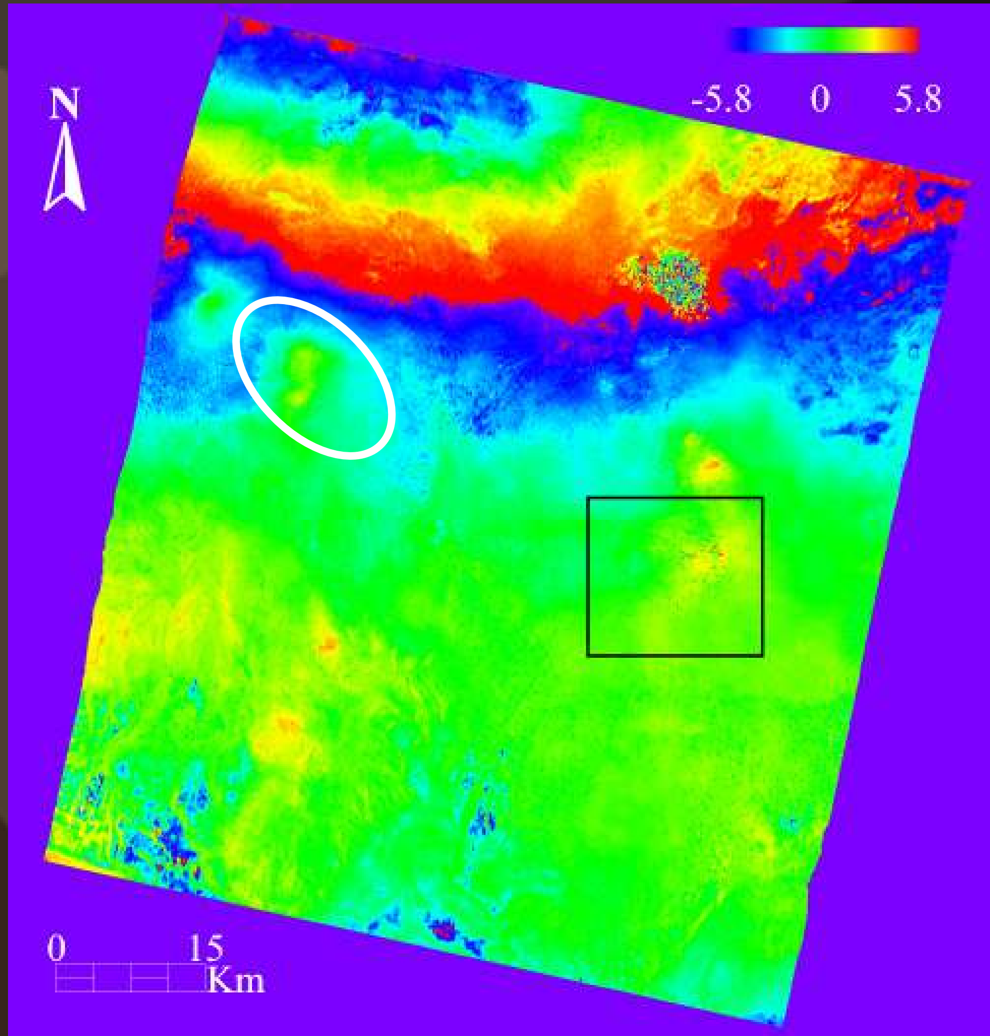
- The Interferograms were generated after removing the topographical and orbital error.
- Two typical patterns are notable: the ground surface is changed about 10 cm in the radar's line of sight to the surface at the eastern flank and the western flank from the summit.
- Baseline and coherence condition of ALOS/PALSAR is getting better in recent time.

Atmospheric Effect

P4 sar.ddtmaf_g

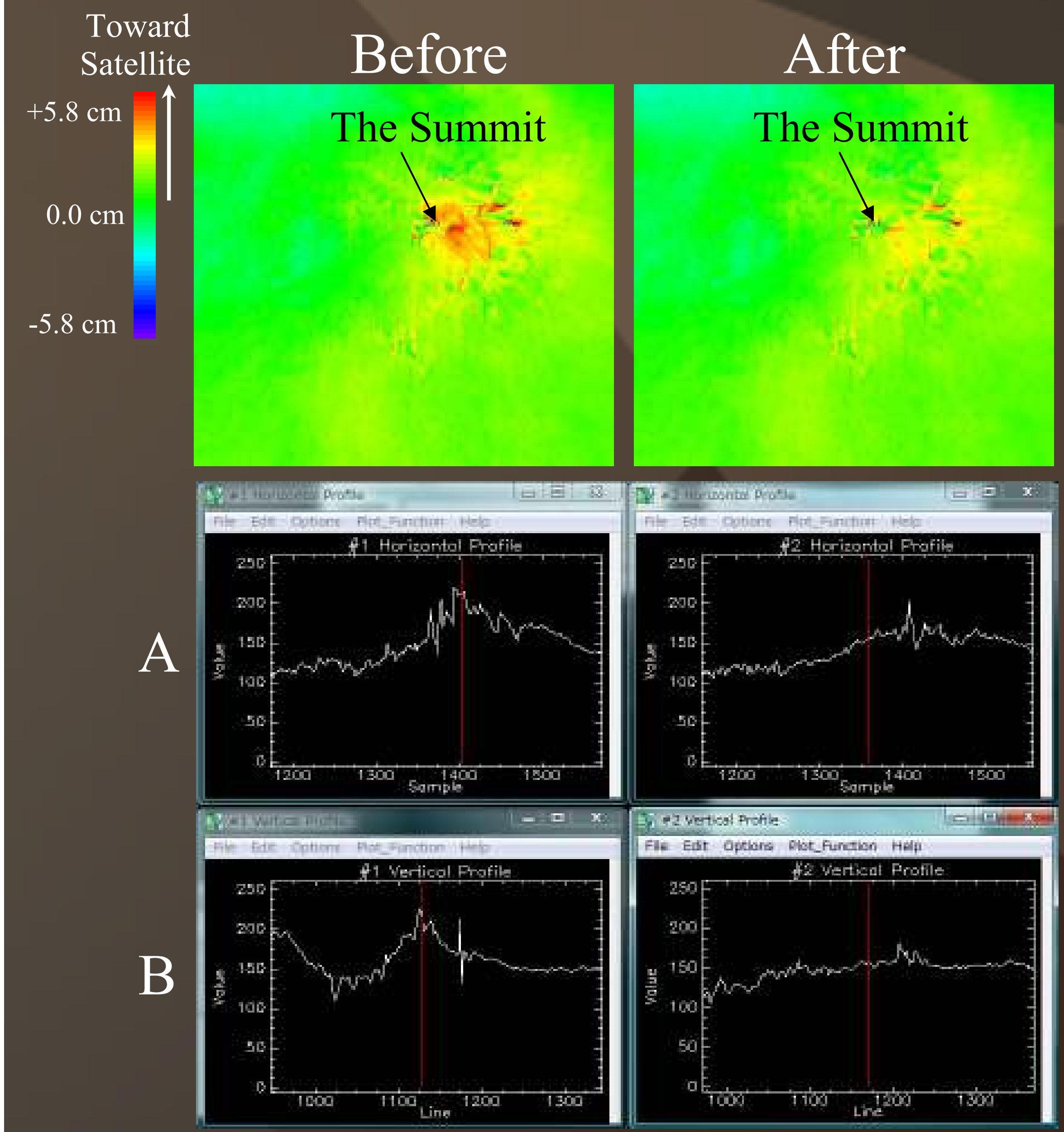


P4 sar.ddtmaf_g



The effect of atmospheric delay can be seen by the different before (left) and after (right) atmospheric correction.

Profile Before and After Atmospheric Correction

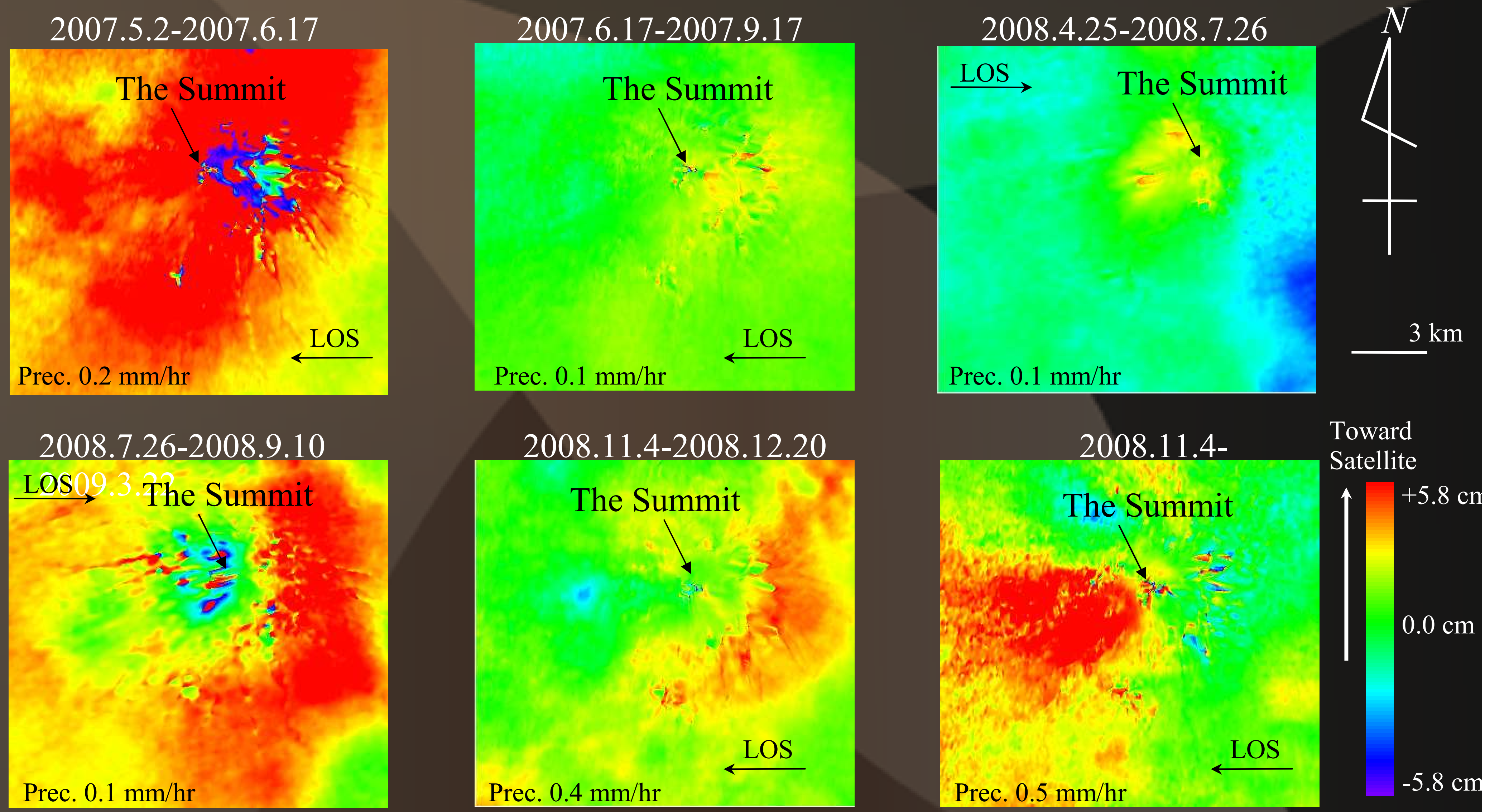


The deformation signals on the left image are contaminated by atmospheric delay that may lead to the mis-interpretation.

Interferogram profile for the west-east (A) and north-south (B) direction before and after atmospheric correction.

The profiles are supposed to be the topographical change around Mt. Merapi

Topographical Change of Mt. Merapi



The fringe pattern with low precipitation at the eastern flank is supposed to be related with magma ascent to the shallow reservoir and the western flank is caused by lahars generation due to high precipitation in rainy season.

Conclusion

- The topographical changes around Mt. Merapi might be caused by two factors: internal factor related with magma ascent and external factor related with lahars in rainy season.
- The precipitation data can be used to estimate the lahars generation, however the high precision GPS measurement is important to validate the topographical change related with magma ascent .
- The ground surface is uplifted about 10 cm in the radar's line of sight to the surface at the eastern flank and the western flank from the summit.
- The pattern at the eastern flank is supposed to be related with magma ascent to the shallow reservoir and the western flank is caused by lahars generation in rainy season.

Acknowledgments

The ALOS/PALSAR data level 1.0 were provided by PALSAR Interferometry Consortium to Study our Evolving Land and Surface (PIXEL). The raw SAR data were processed using JAXA/SIGMA-SAR (M. Shimada, 1999).