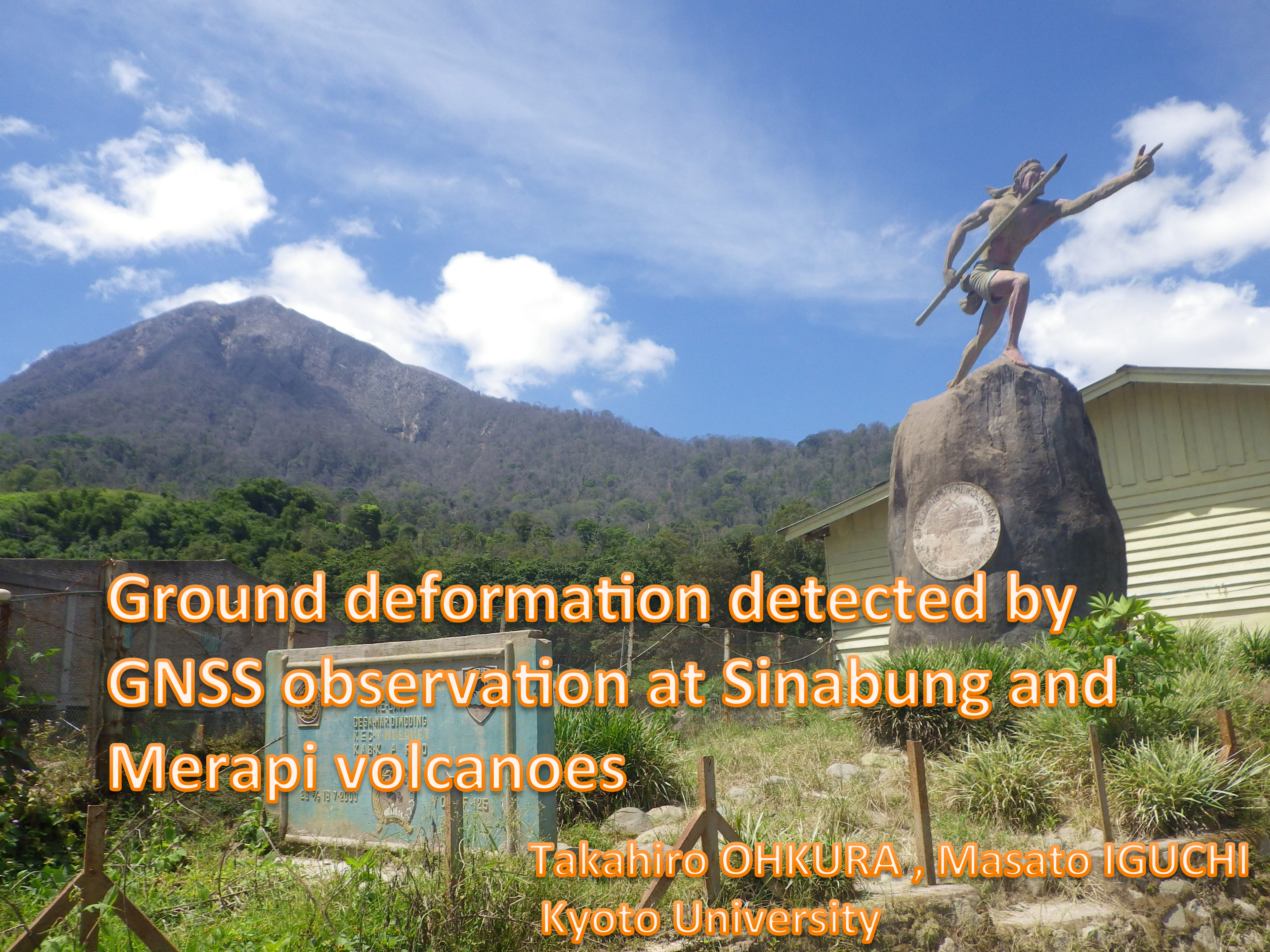

Ground deformation detected by GNSS observation at Sinabung and Merapi volcanoes

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Kyoto University

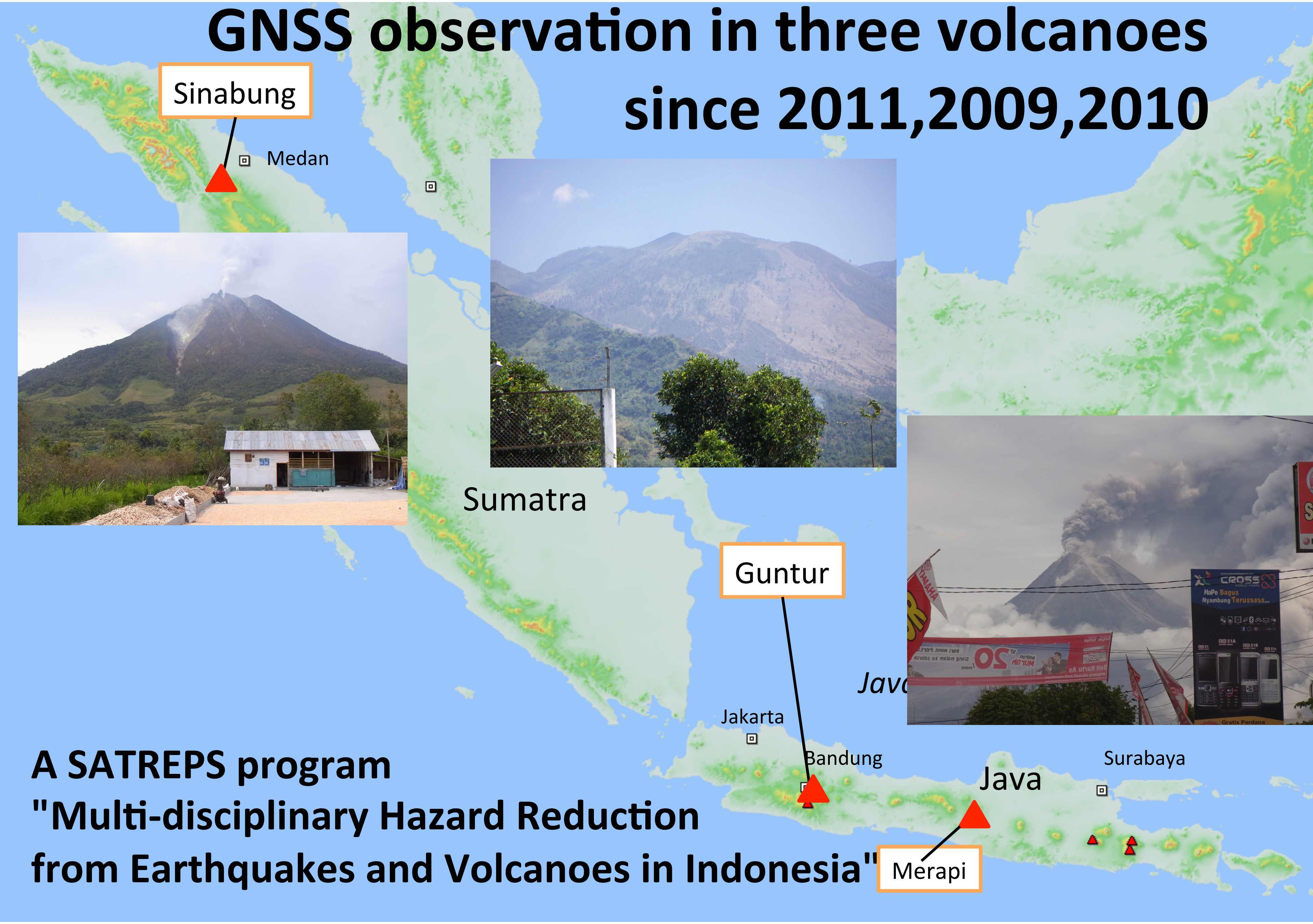
Objectives of G1-1 Volcano Monitoring

Develop observation system for prediction and real-time estimation of discharge rate of volcanic products.

GNSS receivers, 3-components short period seismometers and a tiltmeter were installed at each volcano.

Ground deformation detected by GNSS will be used for evaluation of volcanic activity.

GNSS observation in three volcanoes since 2011,2009,2010



A SATREPS program
"Multi-disciplinary Hazard Reduction from Earthquakes and Volcanoes in Indonesia"

GNSS Data analysis

*Hourly solutions for a real time monitoring

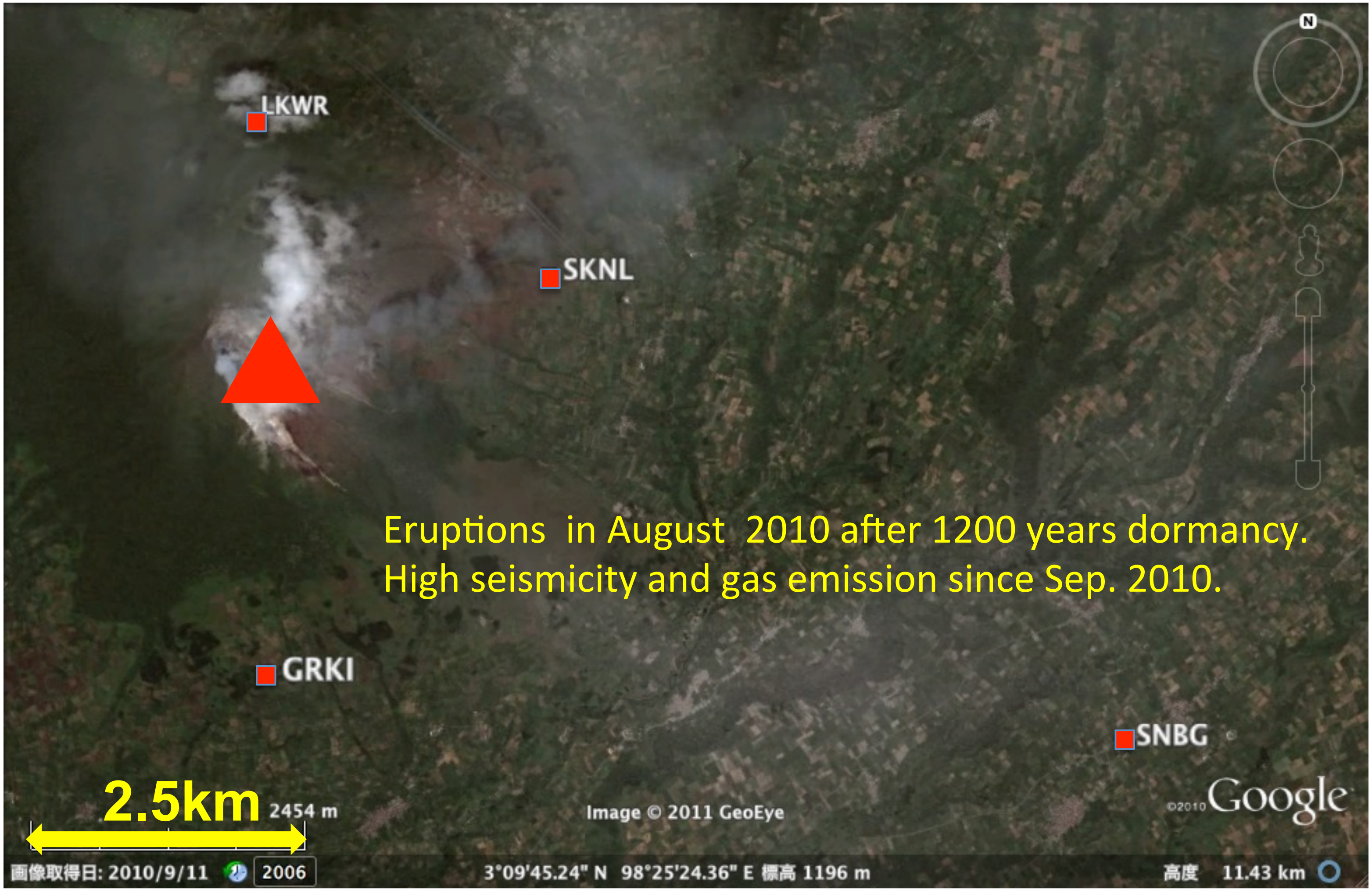
- Automatic quick static analysis to get baseline length using a GNSS software, Leica Spider

For a better evaluation of volcanic activity

*Post processing to get precise daily coordinates

-Precise point positioning(PPP) using GIPSY-OASIS II Ver.6.1.2 (JPL, NASA)

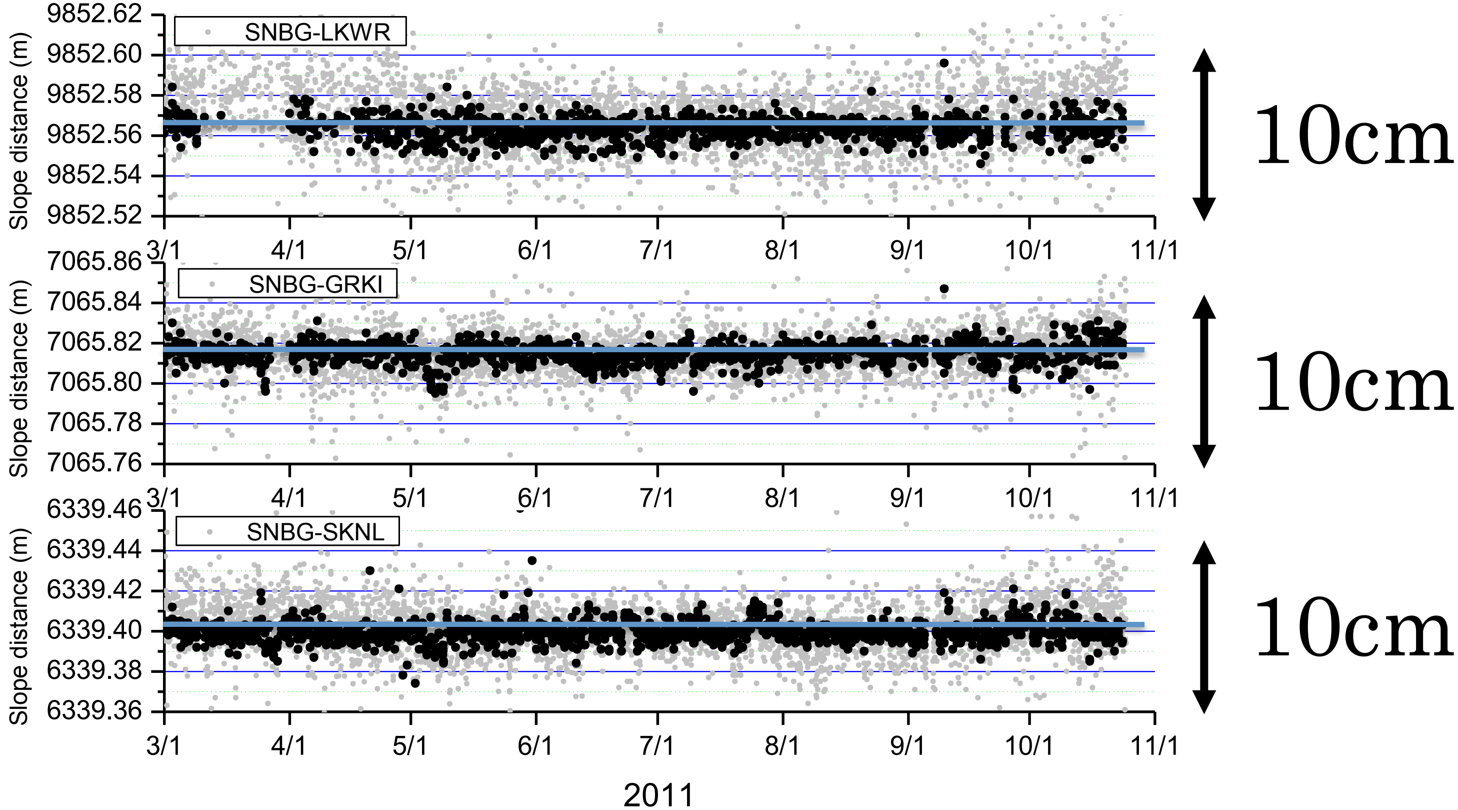
GNSS stations in Sinabung since Feb. 2011



3 stations around the summit(3-5 km apart)
6-10 km away from the base station.

Temporal change of slope distance, Sinabung (2011.03-2011.10)

No deformation detected.
No volume change of the magma chamber.



FIX SNBG (POS Sinabung)

Analysis every 1 hour
Solid dots: night time observation (22:00-03:00)

Evaluation of activity of Sinabung as of Nov. 2011

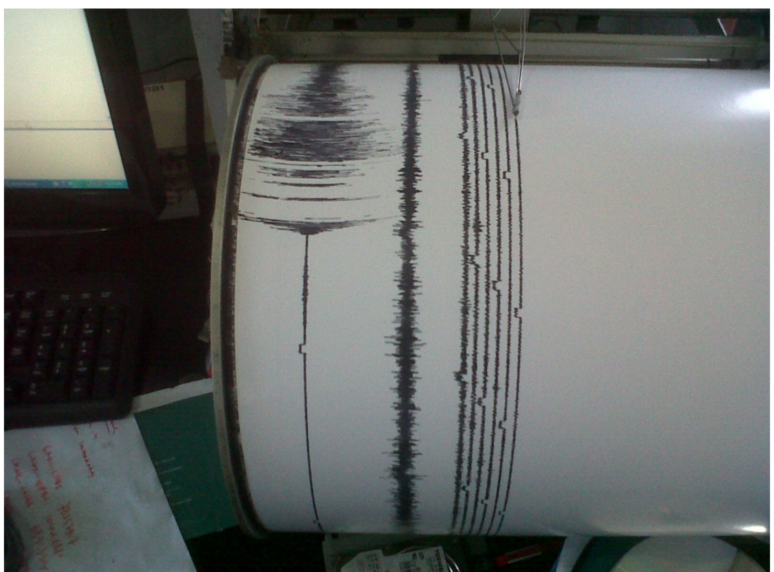
- No significant deformation was detected although many volcanic earthquakes occurred and volcanic gas emission continued.

- It is possible that magma supply magma chamber is almost ec consumption rate of magma (e.g. 300 ton/day SO_2 emissi $1\sim2*10^6 m^3$ /year magma co depth in Aso volcano, Japan)

Magma supply on go

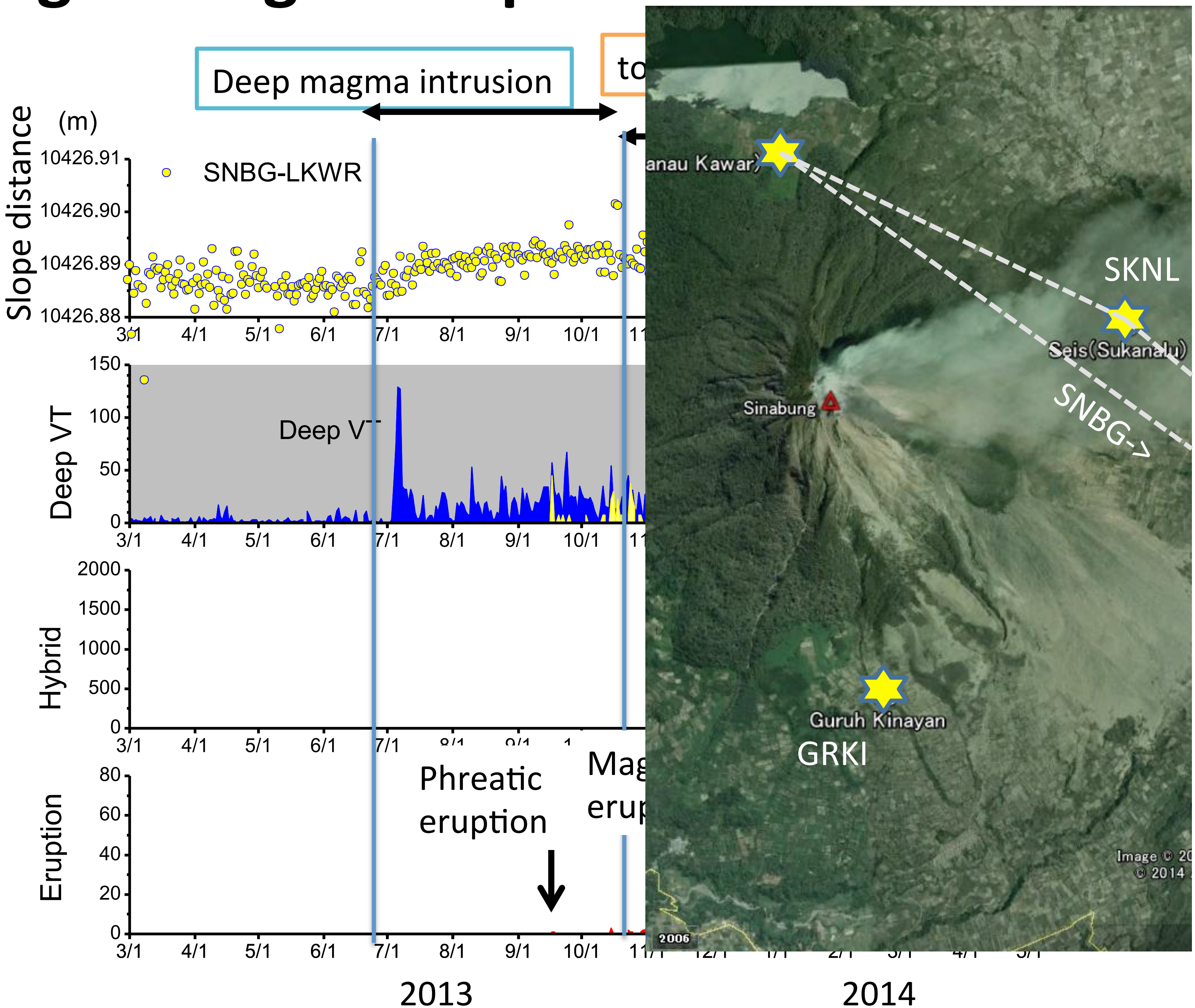
To be monitored carefully.

Resume of Phreatic eruption Sep. 2013

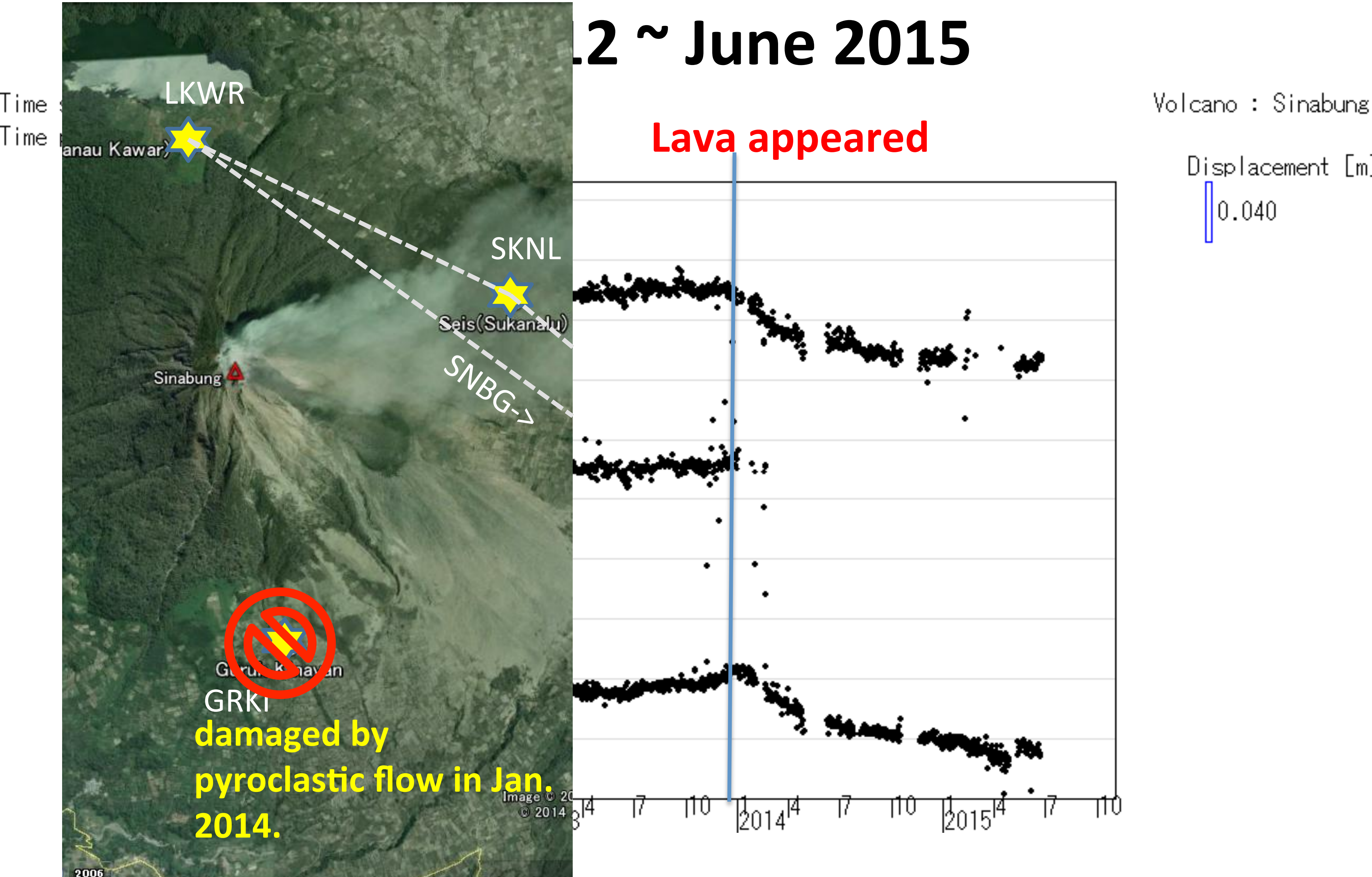


Eruption on Sep. 17, 2013

Magma migration process

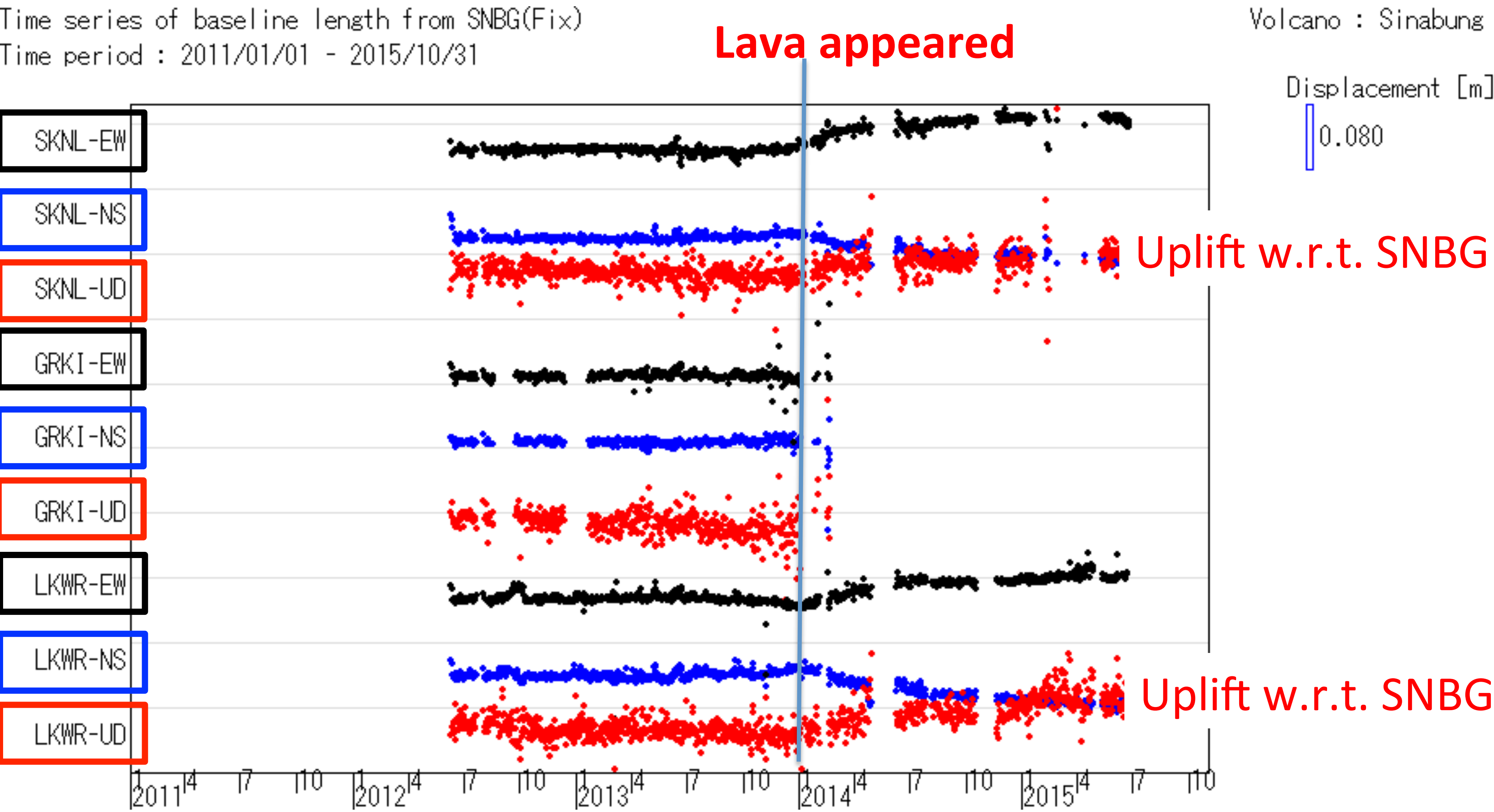


Baseline length from SNBG
2 ~ June 2015

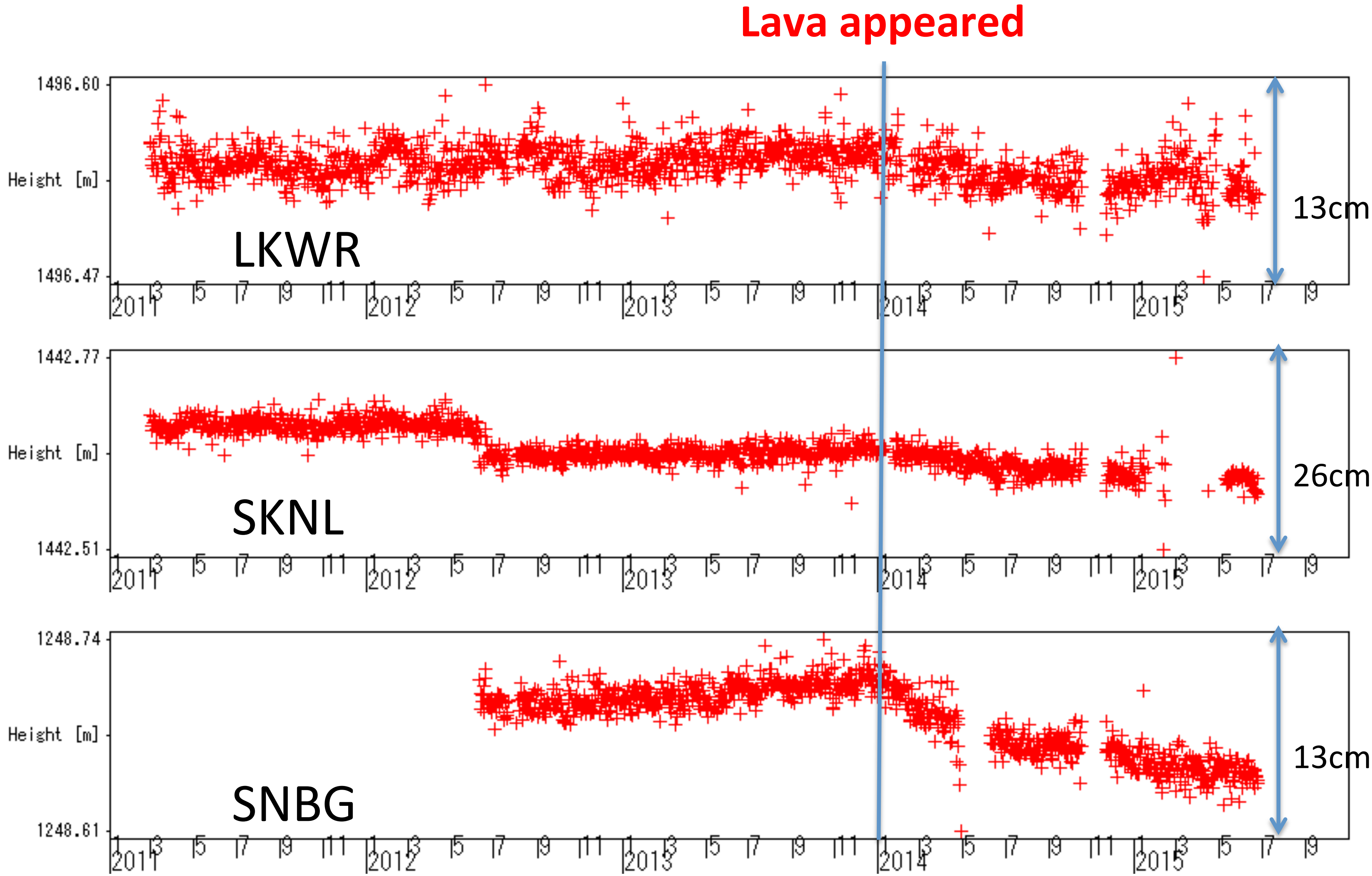


2014

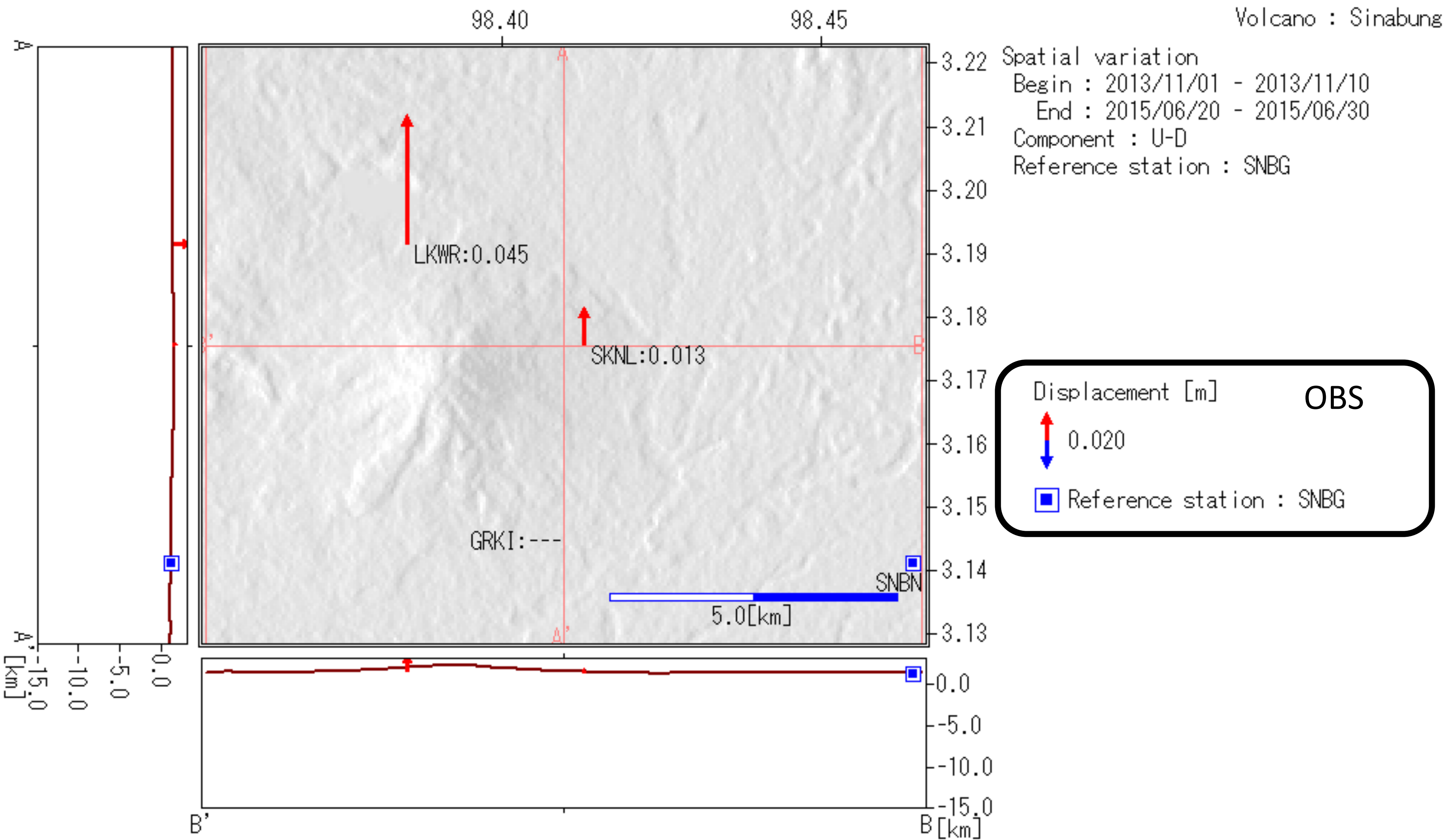
Displacement w.r.t. SNBG
June 2012 ~ June 2015



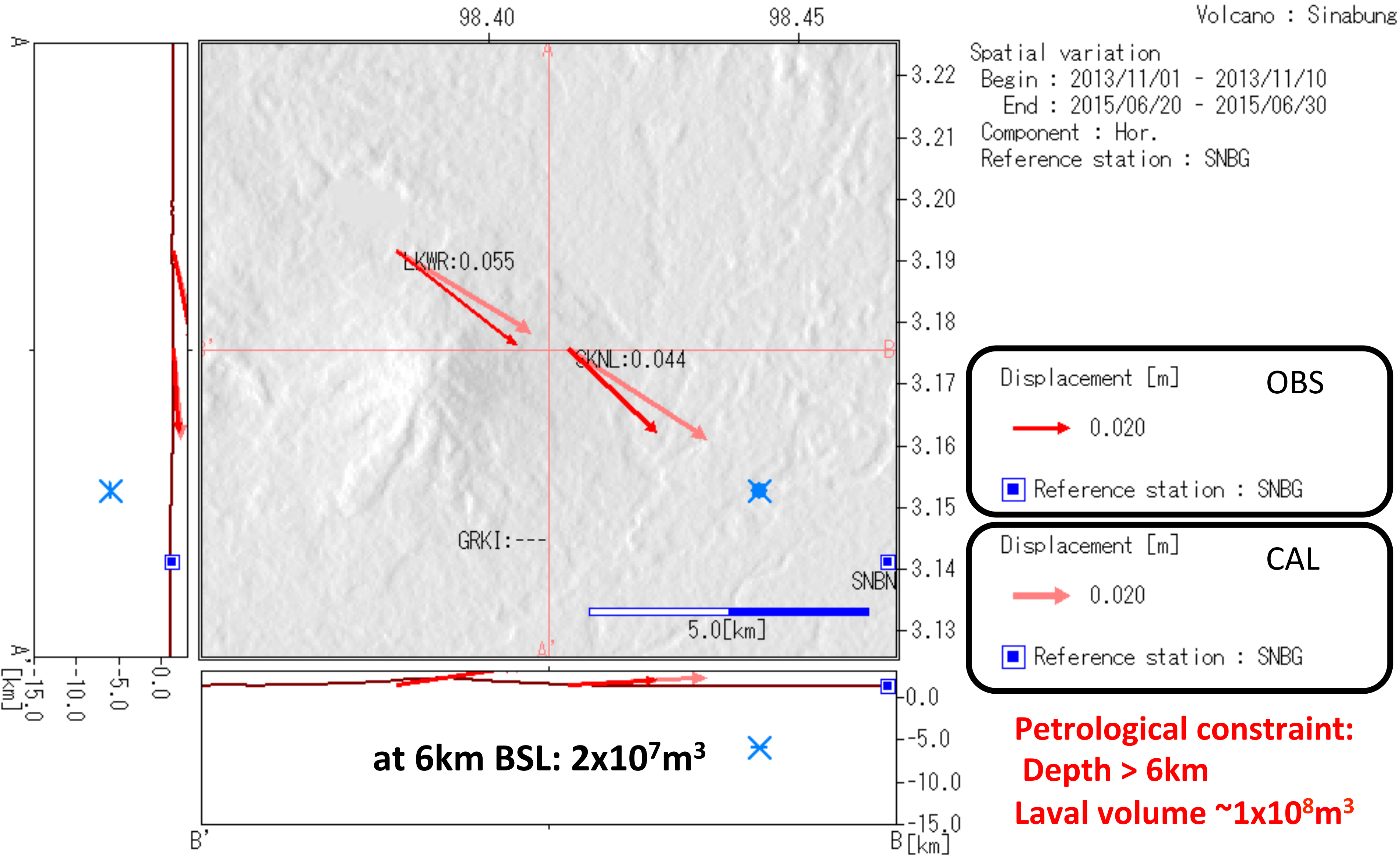
Station elevation
Jan 2011 ~ June 2015



Displacement w.r.t. SNBG
Nov. 2013 ~ June 2015

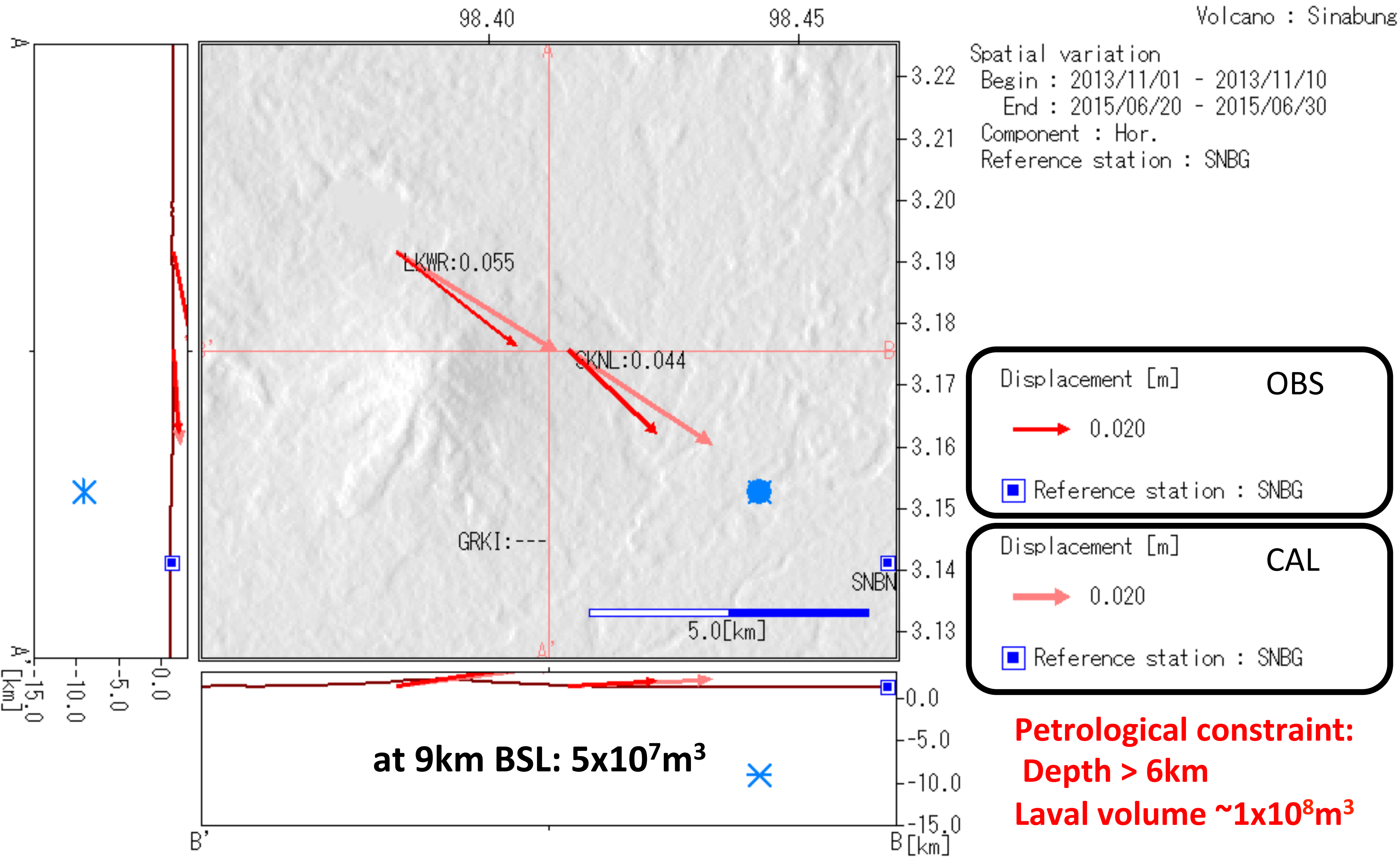


Deformation source location assuming single Mogi source



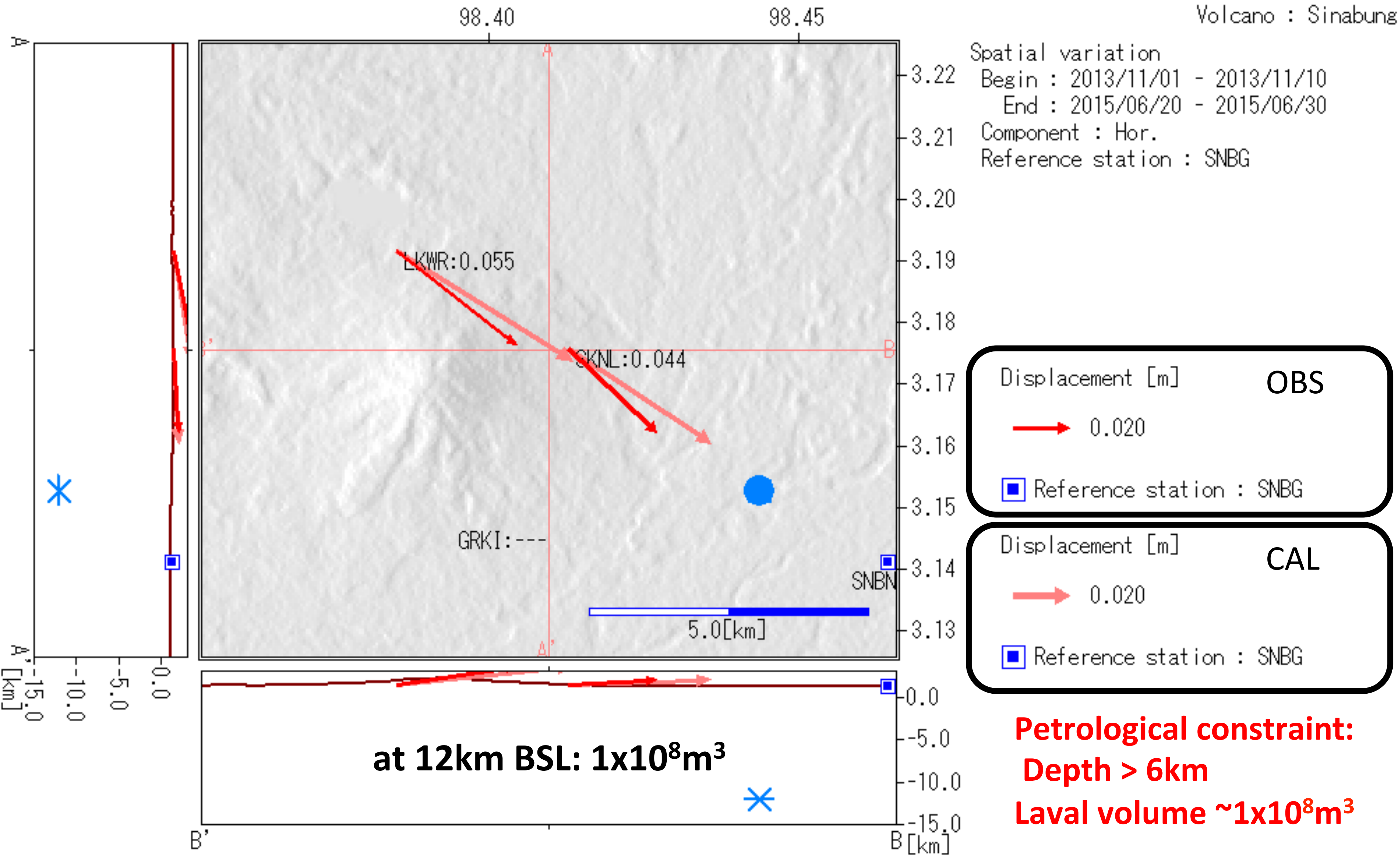
Petrological constraint:
Depth > 6km
Laval volume ~1x10^{8}m^3

Deformation source location assuming single Mogi source



Petrological constraint:
Depth > 6km
Laval volume ~1x10^{8}m^3

Deformation source location assuming single Mogi source



Petrological constraint:
Depth > 6km
Laval volume ~1x10^{8}m^3

Results of GNSS observation

- **Merapi:**

  Inflation of deep magma reservoir just after 2010 eruption

  ~2*10^6m^3 of magma accumulated Potential for small eruptions

- **Sinabung:**

  Inflation accompanied with deep VT Eq. activity and increase in inflation rate prior to magmatic eruptions and emergence of Lava dome.

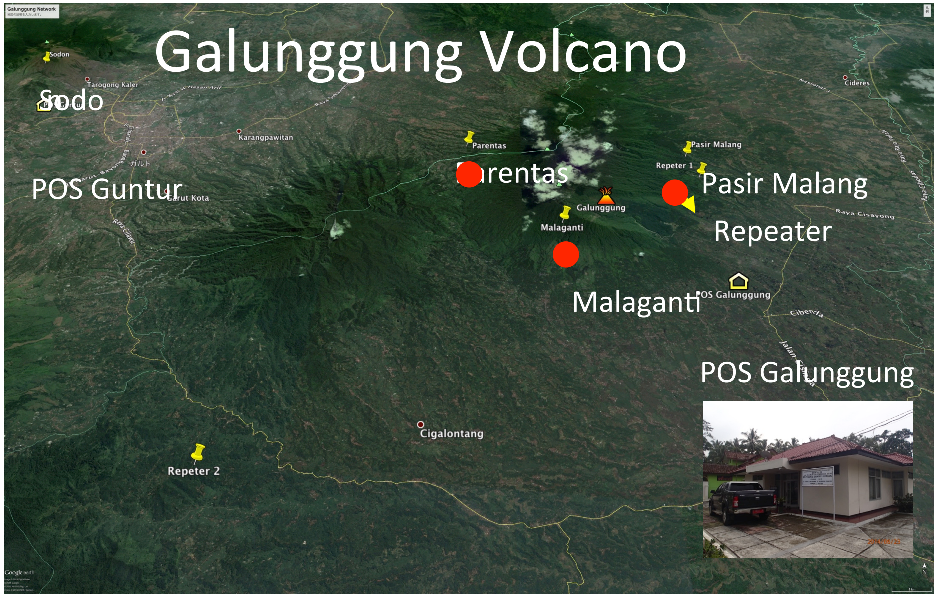
  At Lava flow stage: discharge rate ~ GPS baseline length.

  Source: 5km ESE from the summit

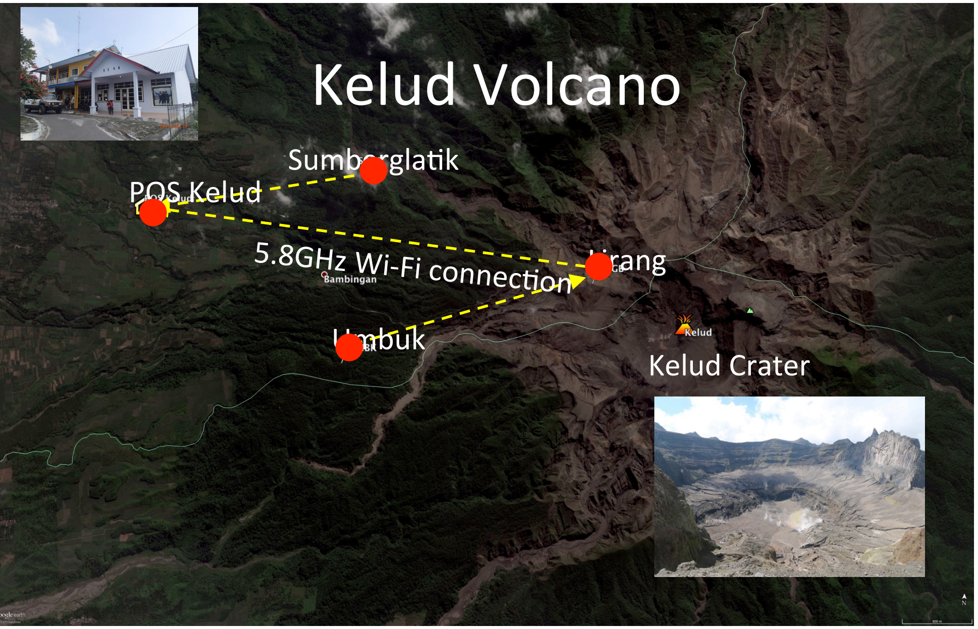
  depth 6~12 km

  Deflation 20~100x10^6m^3

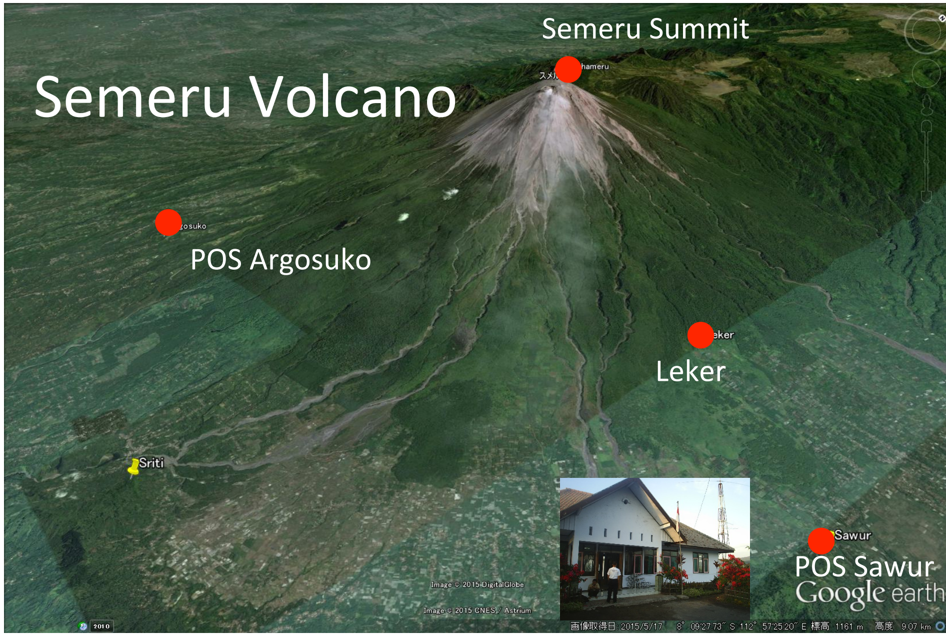
GNSS Observation started at other three Volcanoes in 2015



Construction Finished in April 2015



Construction Finished in March 2015

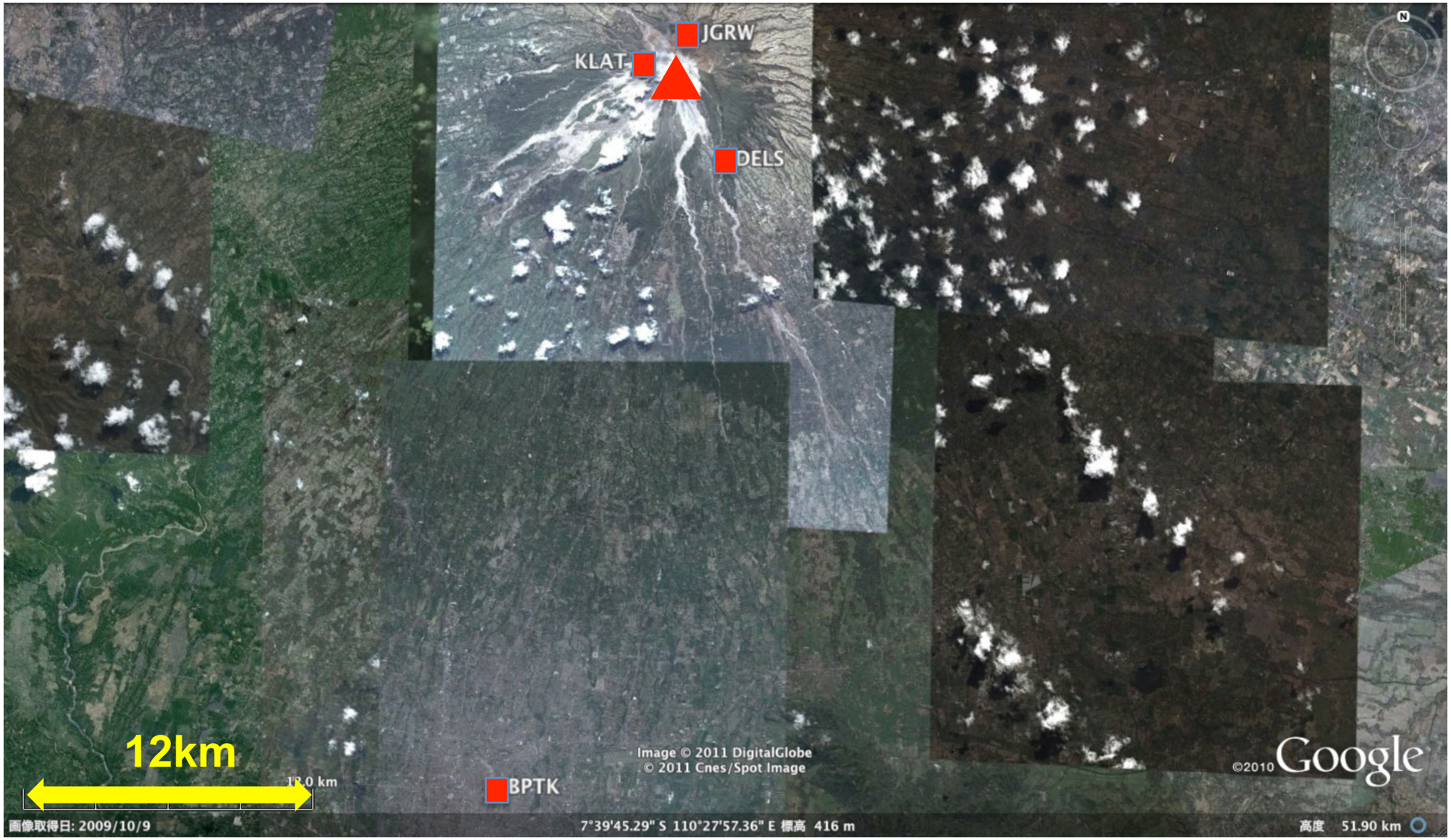


Construction Finished in September 2015

GNSS observation: 6 volcanoes covered

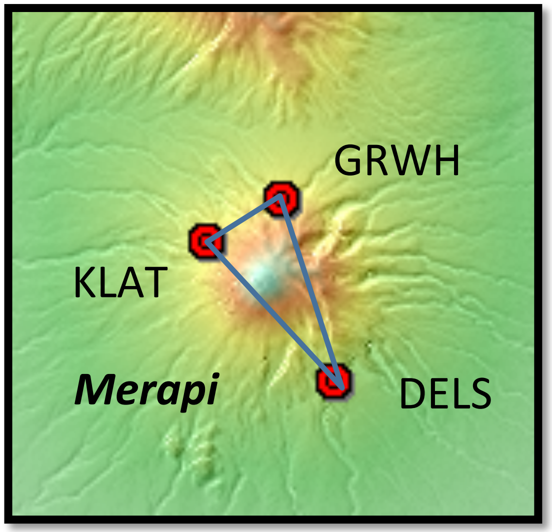
For a better evaluation of volcanic activity

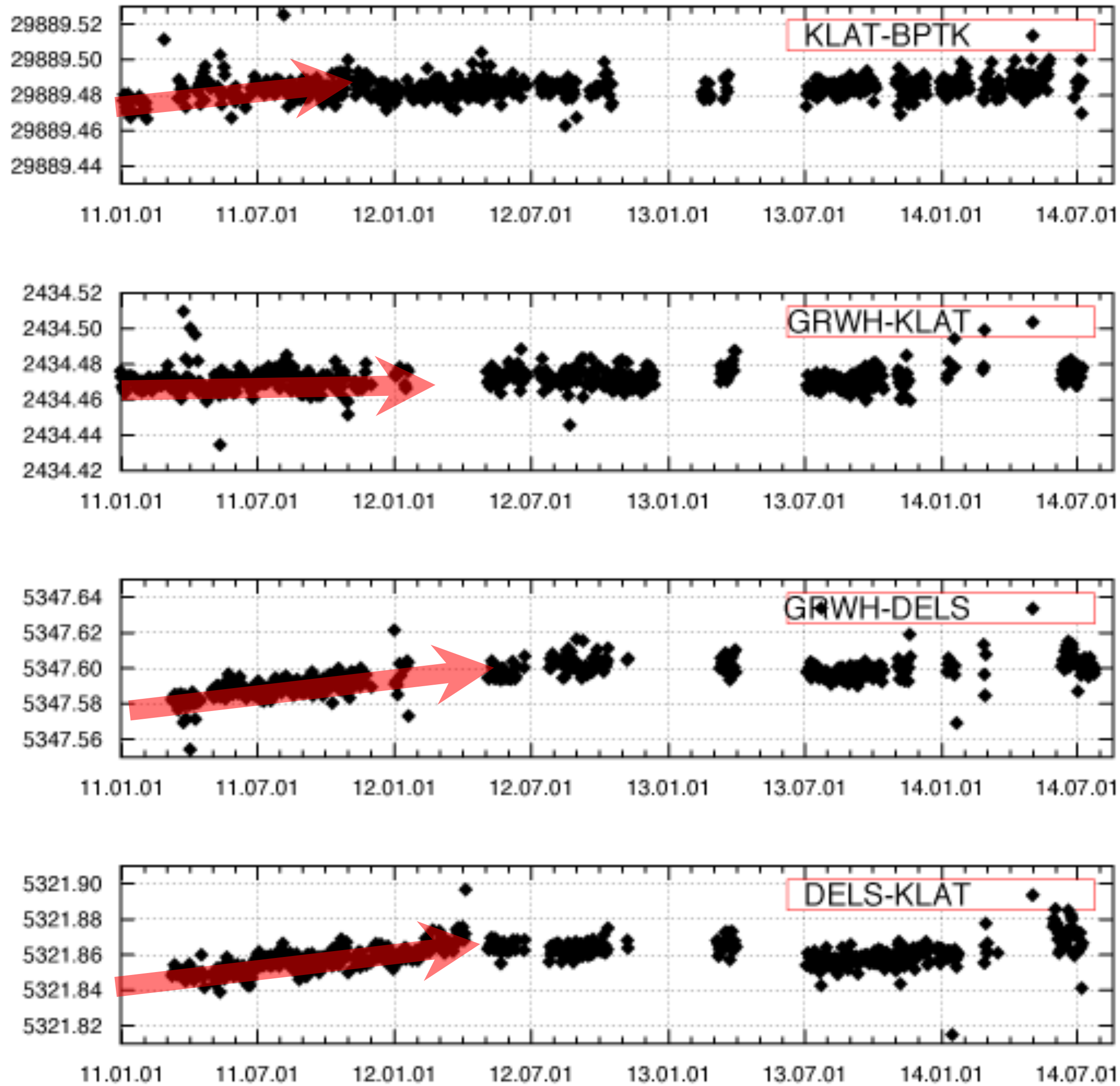
GPS stations in Merapi(since Dec. 2010)



3 stations around the volcanoe(2-5km apart)
27-32 km away from the base station.

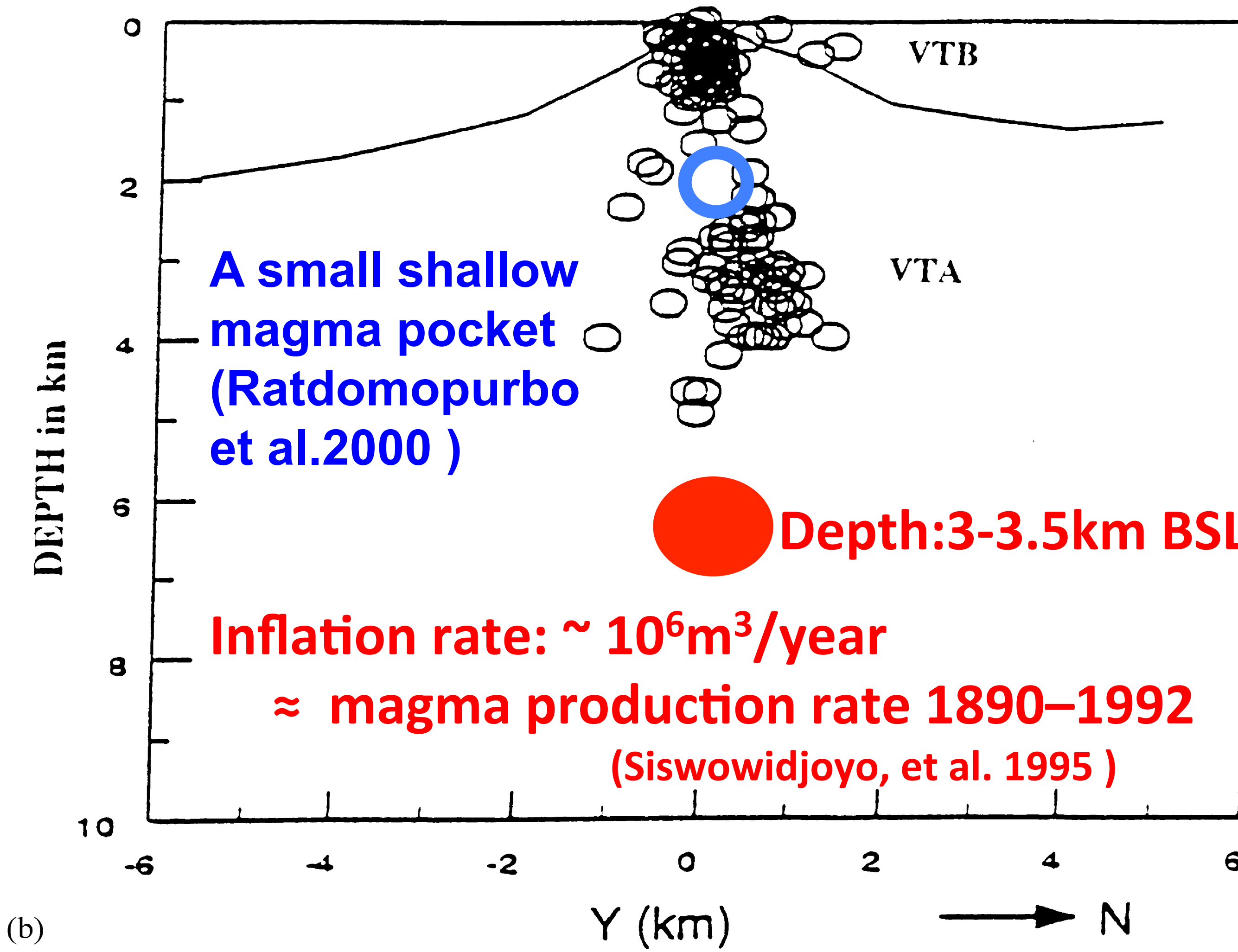
Detection of inflation of Merapi volcano





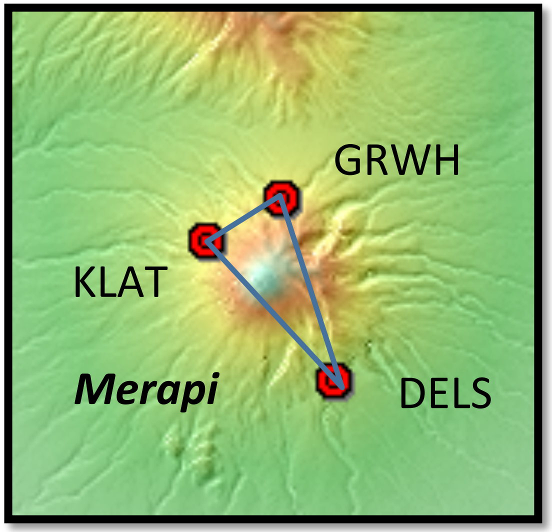
Temporal change of slope distances after 2010 eruption

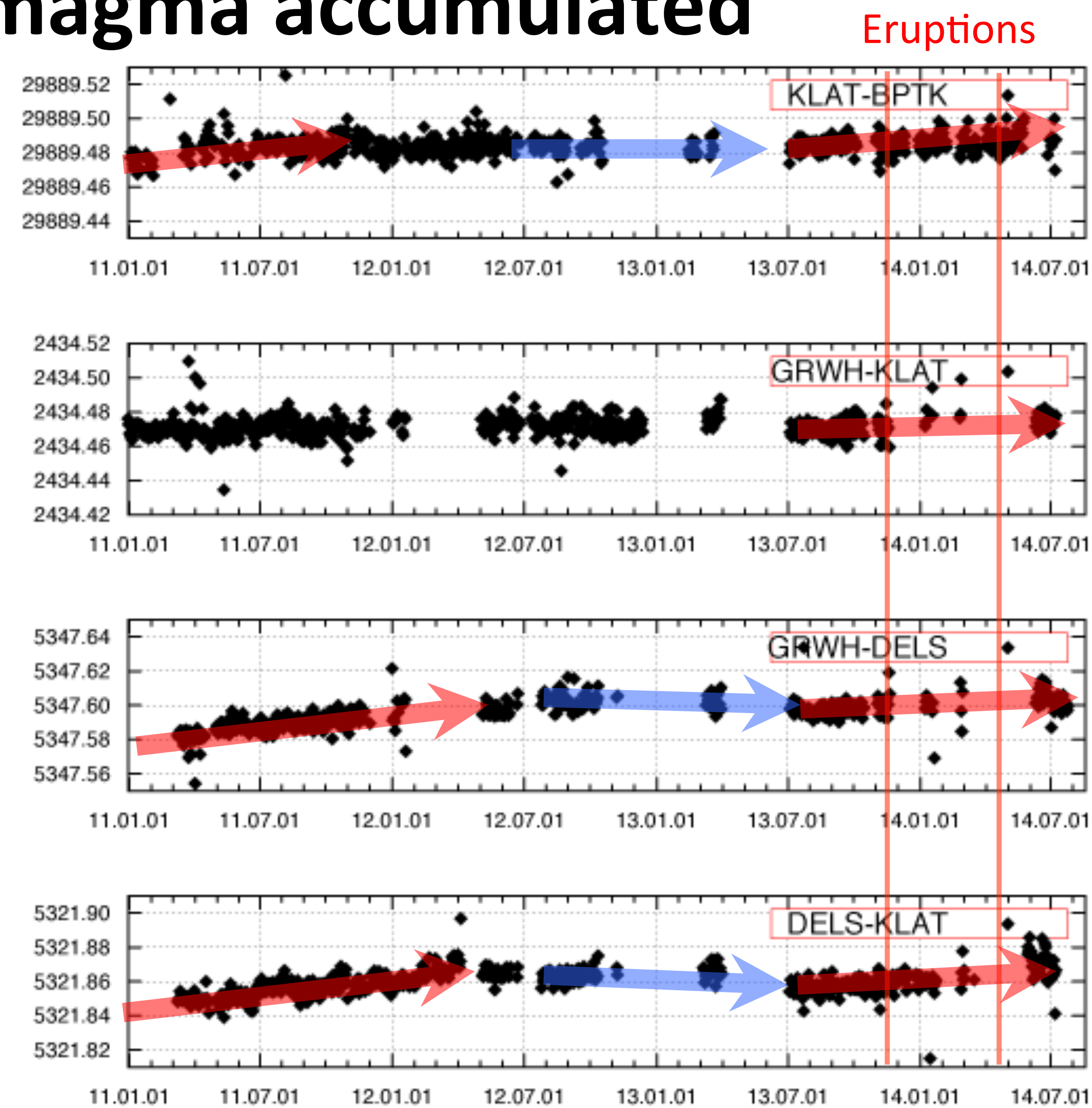
Deformation source location



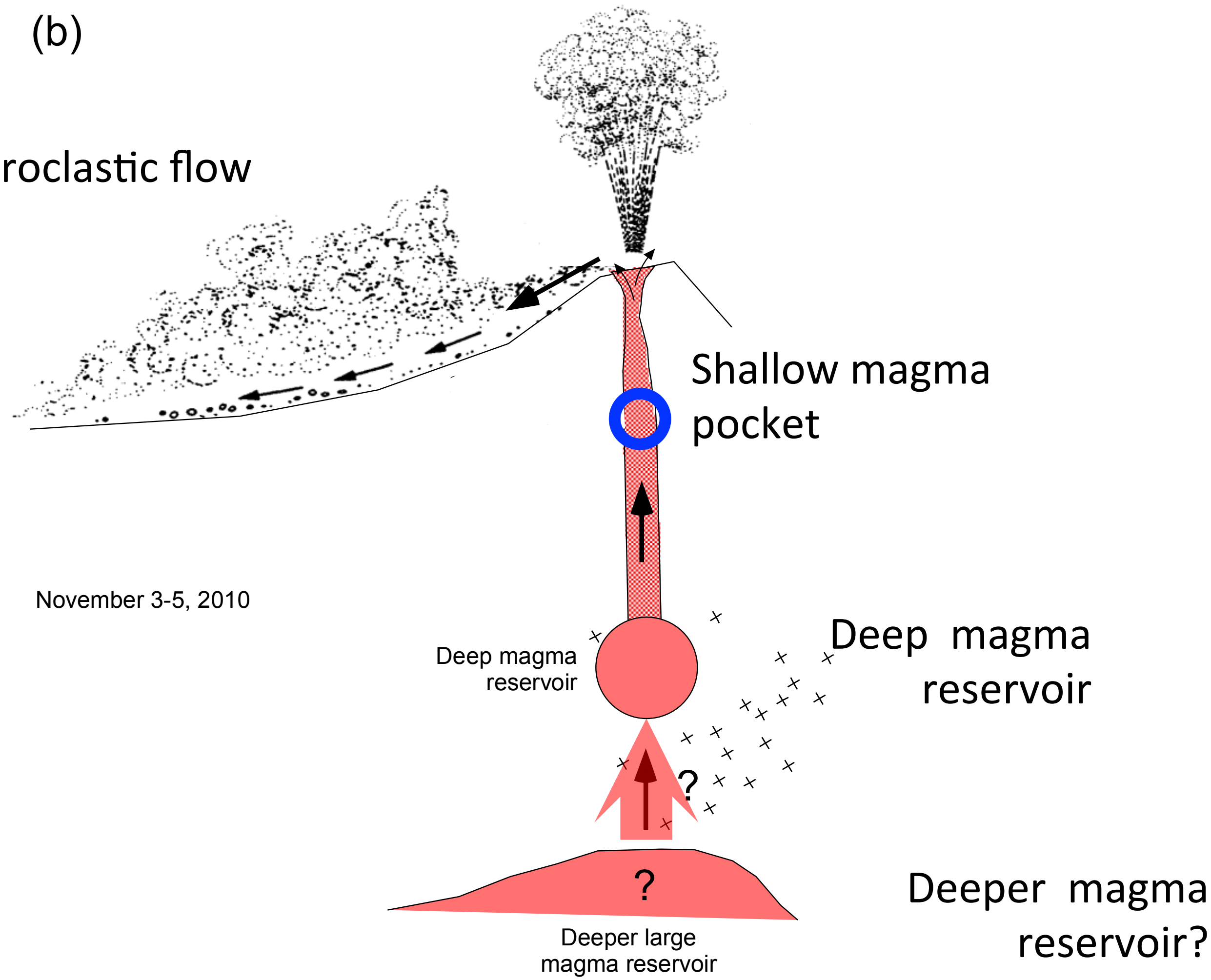
Cross-section of the seismicity in Merapi volcano in 1991

Occurrence of small eruptions; ~2*10^{6}m^3 of magma accumulated



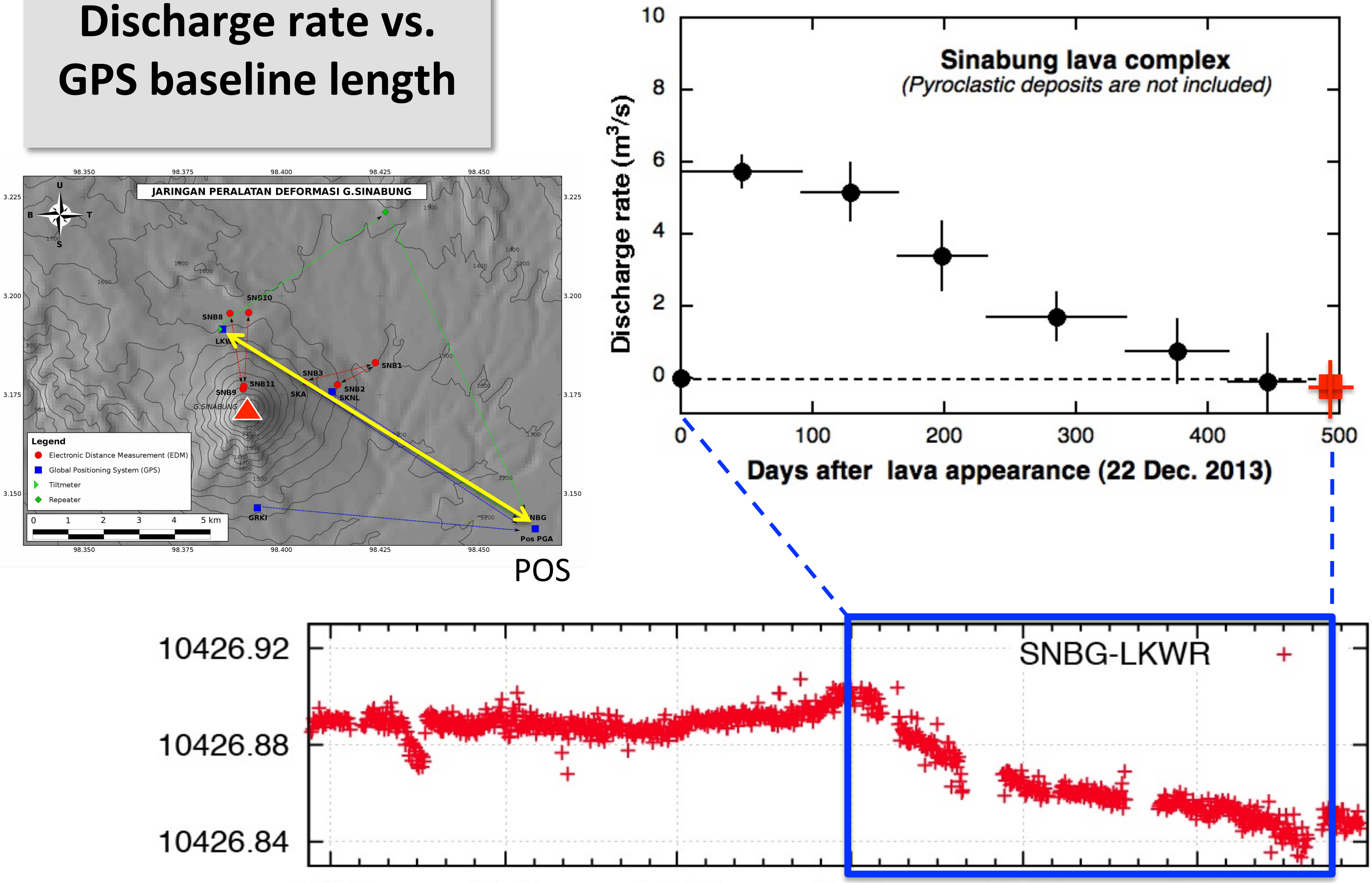


Magma supply system in Merapi

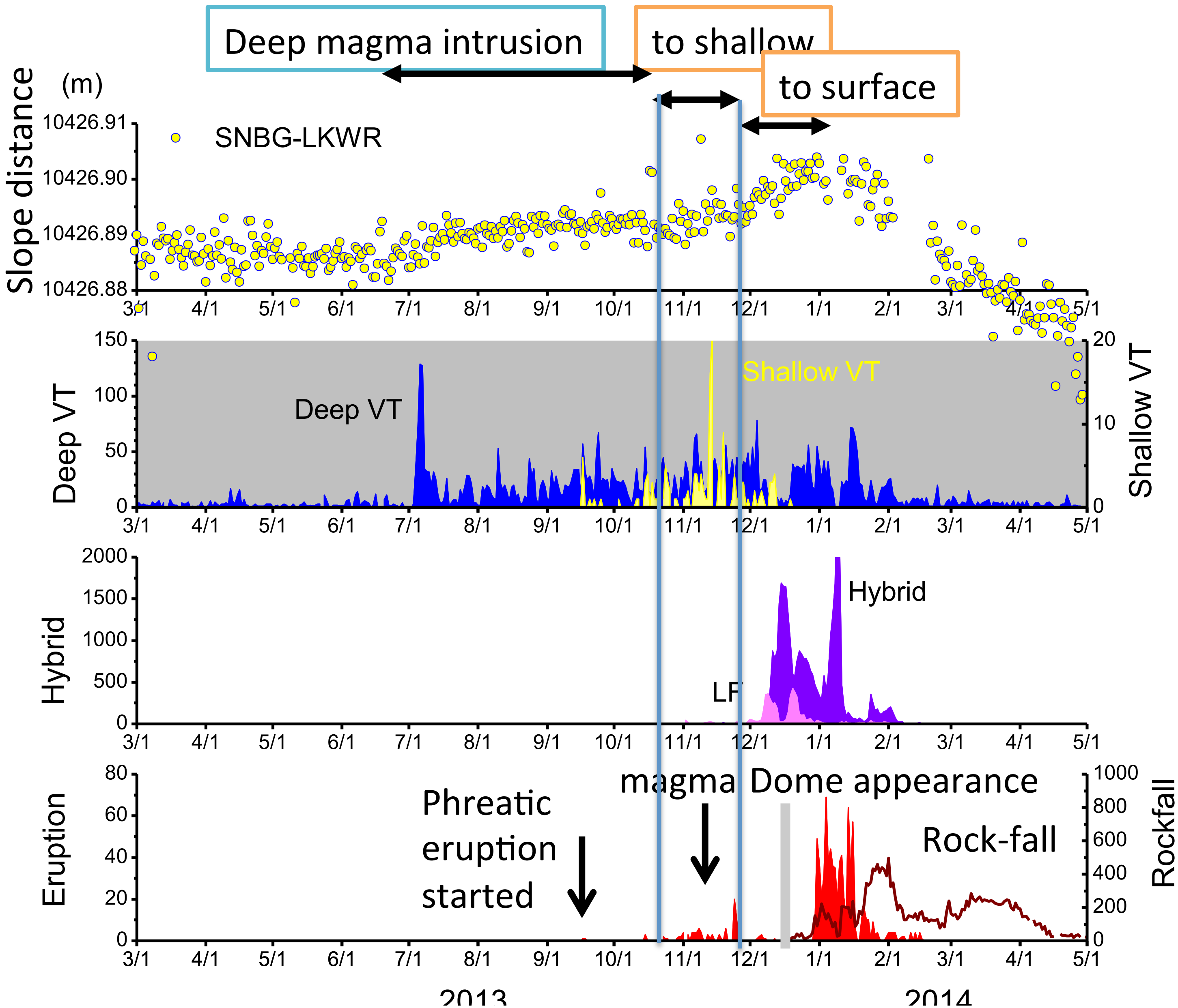


Inflation of deep magma reservoir suggests an existence of another deeper magma reservoir.

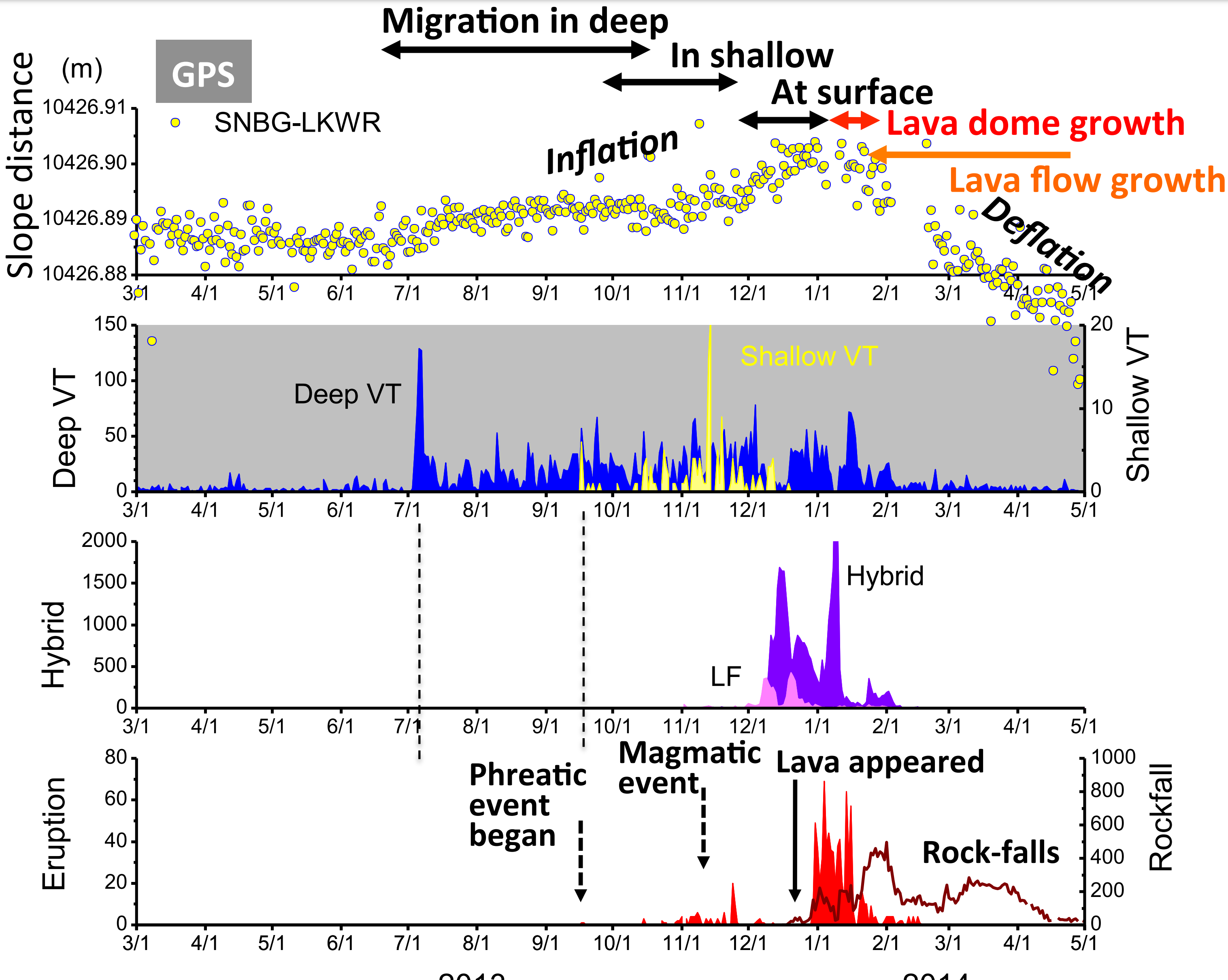
Discharge rate vs. GPS baseline length



Magma migration process



Geophysical monitoring (Sinabung)



Displacement w.r.t. SNBG
Nov. 2013 ~ June 2015