Pre-eruptive deformation of Shinmoe-dake in Kirishima volcano, Japan: geodetic observations and modeling

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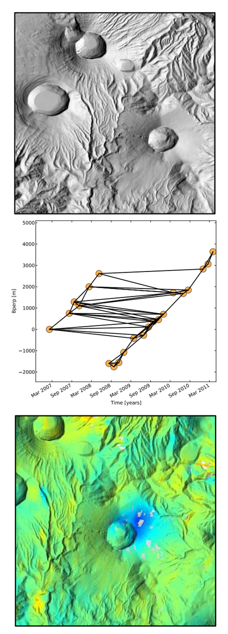
ABSTRACT

Ryukyu volcanic arc is Japan's triple junction formed by the subduction of the Philippine Sea Plate beneath the Eurasian Plate. Lying on the north of this arc, Kyushu Island volcanoes could severely disrupt over 110 million people's everyday life (Tatsumi and Suzuki, 2014, PJA Ser.B) due to potential catastrophic caldera-forming eruption. 2011 Shinmoe-dake eruption is the latest magmatic eruption on Kyushu Island. GPS based modeling has been conducted, but no InSAR research has been done on its pre-eruptive deformation yet.

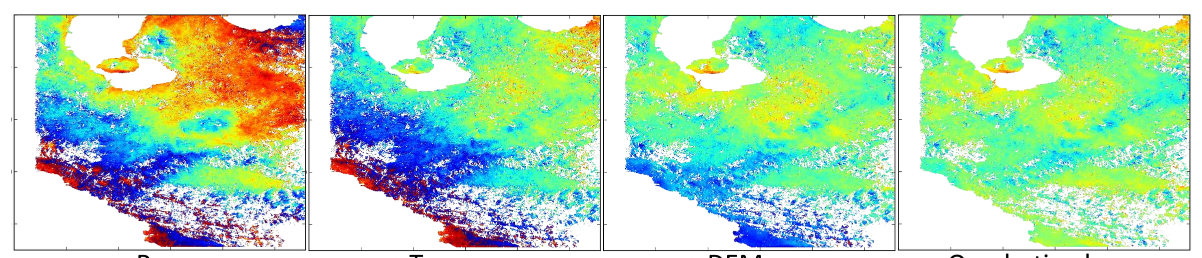
We processed three tracks of ALOS L-band SAR data covering Shinmoe-dake crater using time series InSAR technique. All show deflation on and around the crater. A shallow source of about 800 m below the sea level is estimated using a spherical model with 3D finite element modeling technique. This confirms that shallow source is preferential on strike-slip tectonic settings (Chaussard and Amelung, 2014, G3). Deflation and inflation activities are also detected on Kuju volcano and Sakurajima caldera.

METHODOLOGY

- SAR Focusing (GAMMA)
- InSAR Processing (ROI_PAC)
- Time Series processing (PySAR)
  - SBAS Network selection
  - Remove Tropospheric effect (PyAPS), DEM error & phase ramp
  - Inversion of velocity and time series
- Magma source modeling (COMSOL)



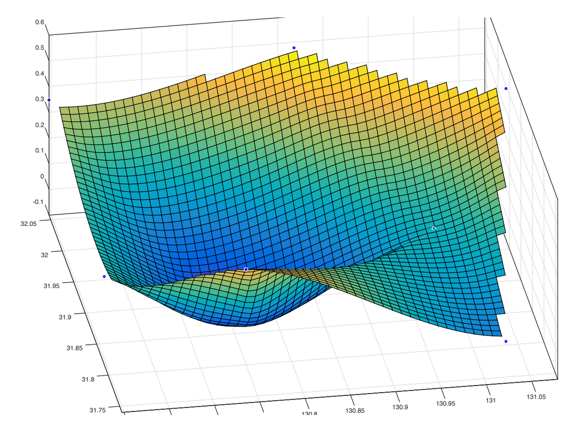
- Data: 4 tracks (2 Asc, 2 Desc) 276 ALOS images (2006-2011) from JAXA, and 0.4 arc-second (~10 m) Digital Ellipsoidal Height Model from GSI, Japan [Tobita et al., 2002]
- InSAR processing: 331 interferograms (Ifgs) produced after generating SLCs with Gamma.
- Time series InSAR: Small Baseline Subset (SBAS) [Berardino et al., 2002, TGRS] using PySAR developed at Univ of Miami.



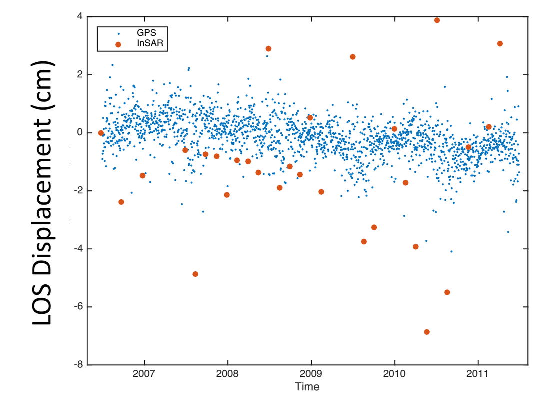
  - o Pairs selection: threshold (1000 days and 1 km), drop low coherent Ifgs manually.
  - o Phase correction: tropospheric phase estimation using ECMWF weather re-analysis data with PyAPS [Jolivet et al., 2011, GRL], DEM error correction [Fattahi and Amelung, 2013, TGRS] and quadratic ramp removal.
- Source modeling: Spherical source embedded in an elastic homogeneous medium with 3D Finite Element Modeling (FEM)

2) GPS

GEONET data from the Geospatial Information Authority of Japan (GSI) F3 solution during 2003~2014.

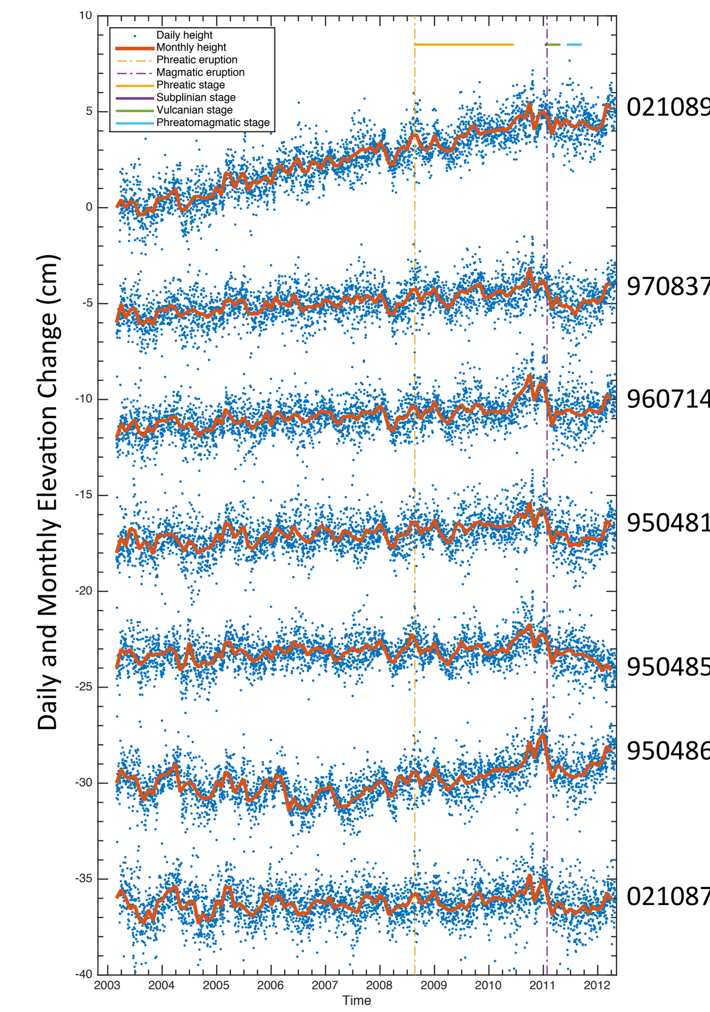


Simulated LOS Velocity of Kirishima area from GPS data (200303-200904)

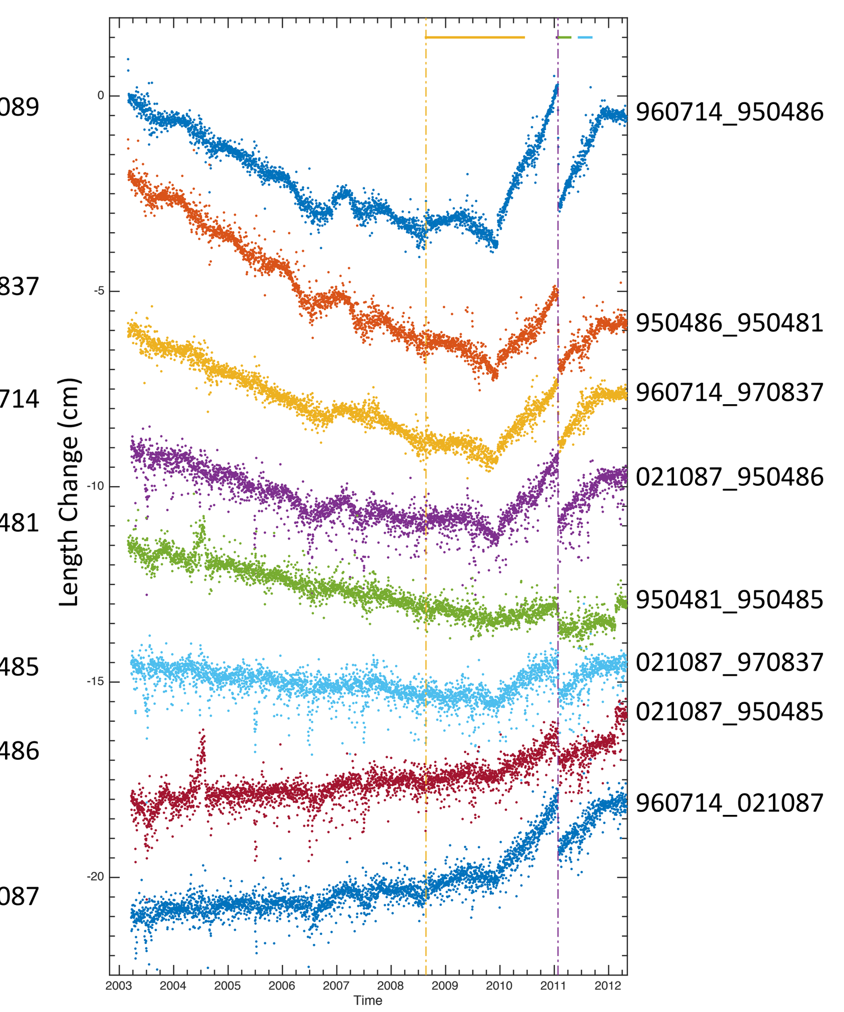


Time series comparison between GPS and InSAR

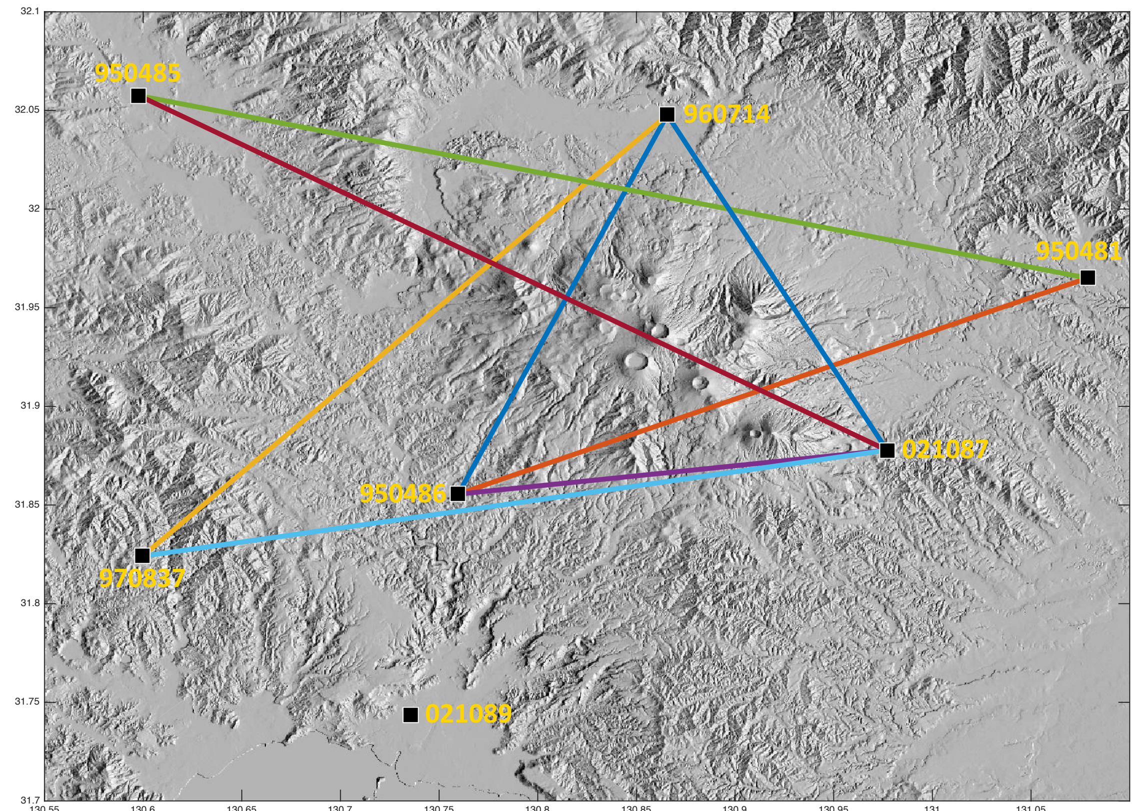
Vertical Displacement



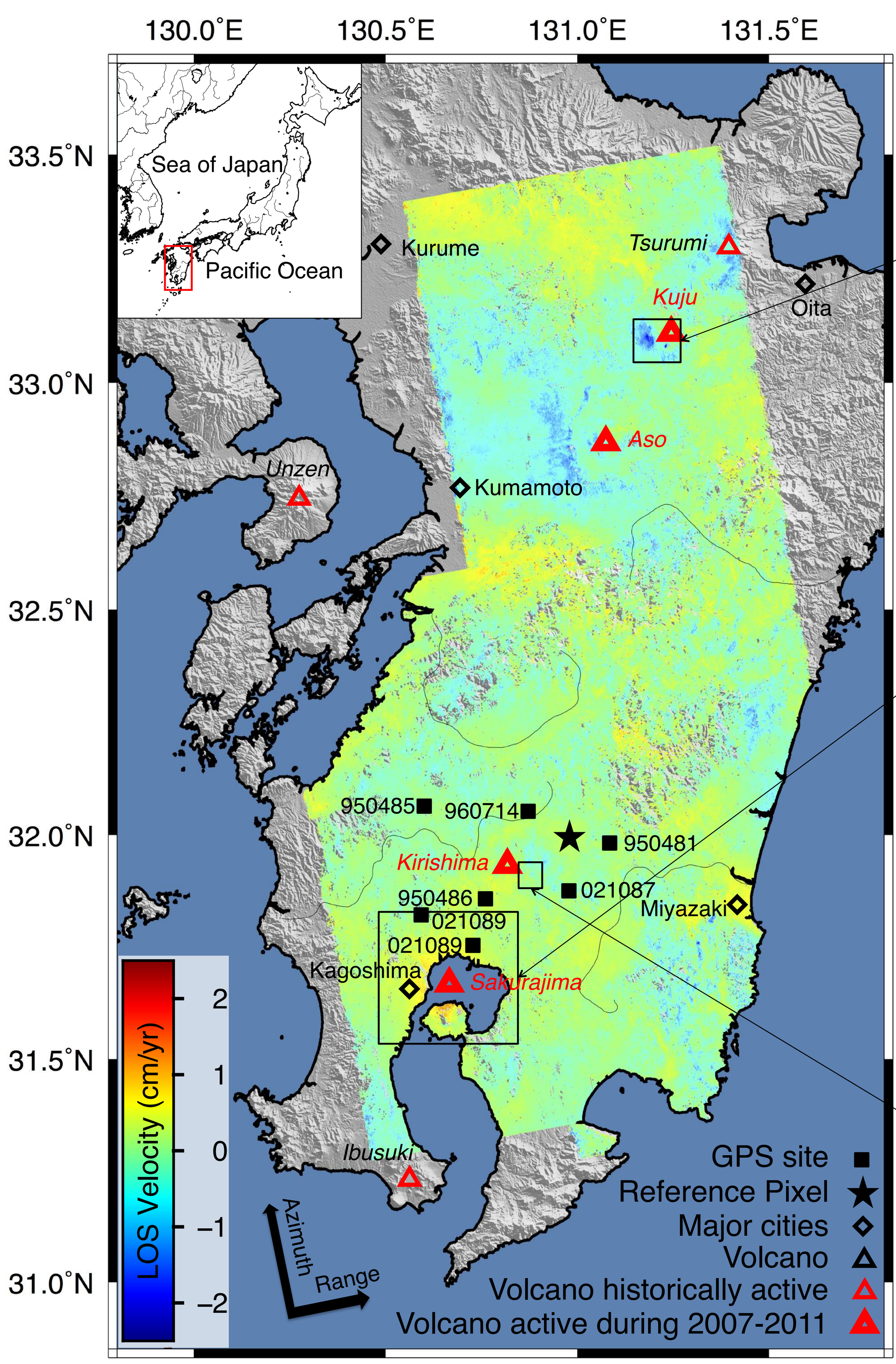
Length Change



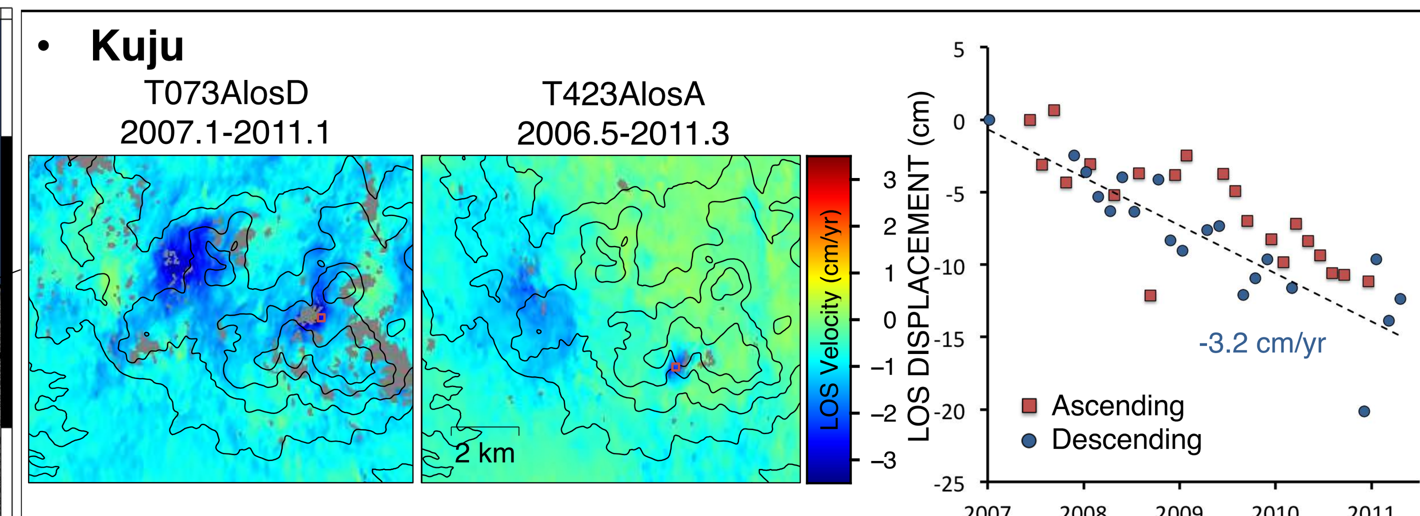
GPS Location and Baseline



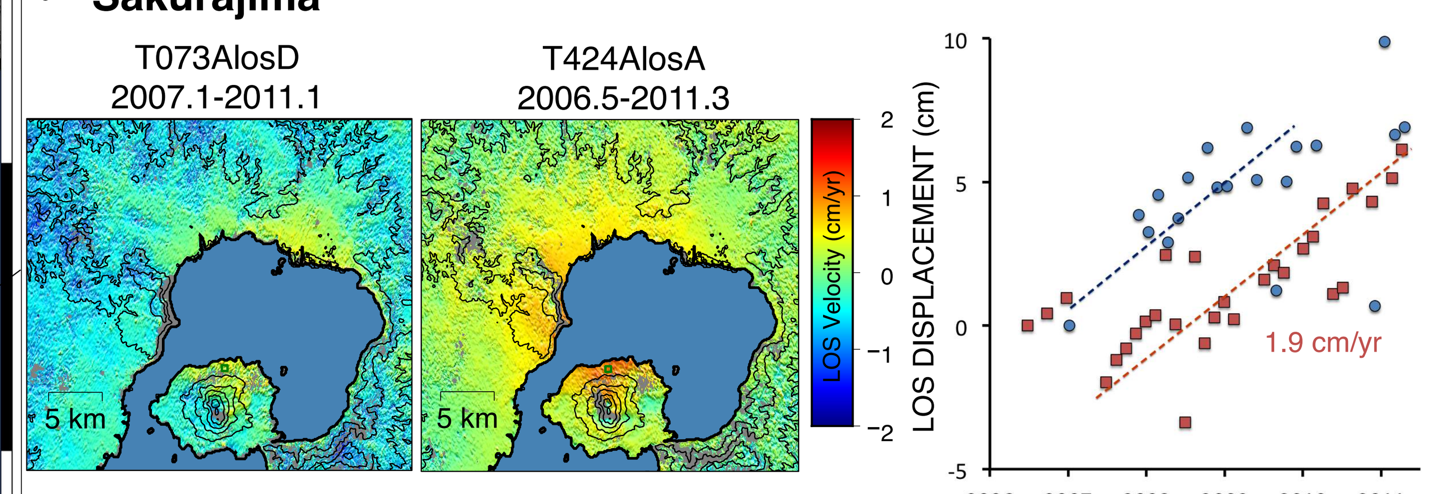
1) TIME SERIES INSAR



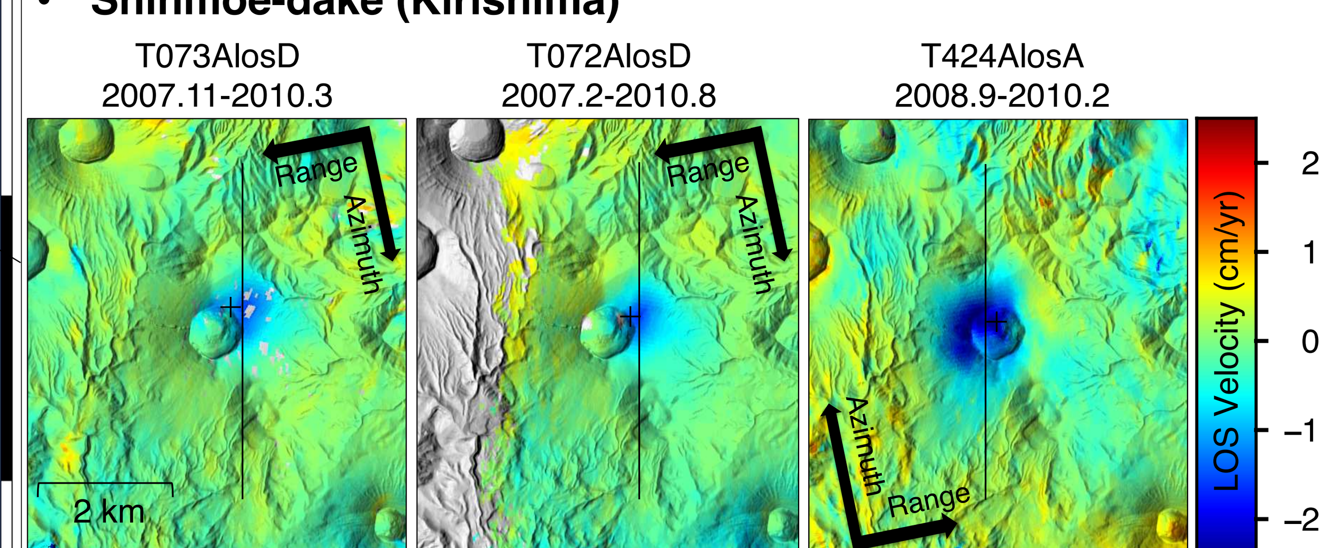
- **Kuju**

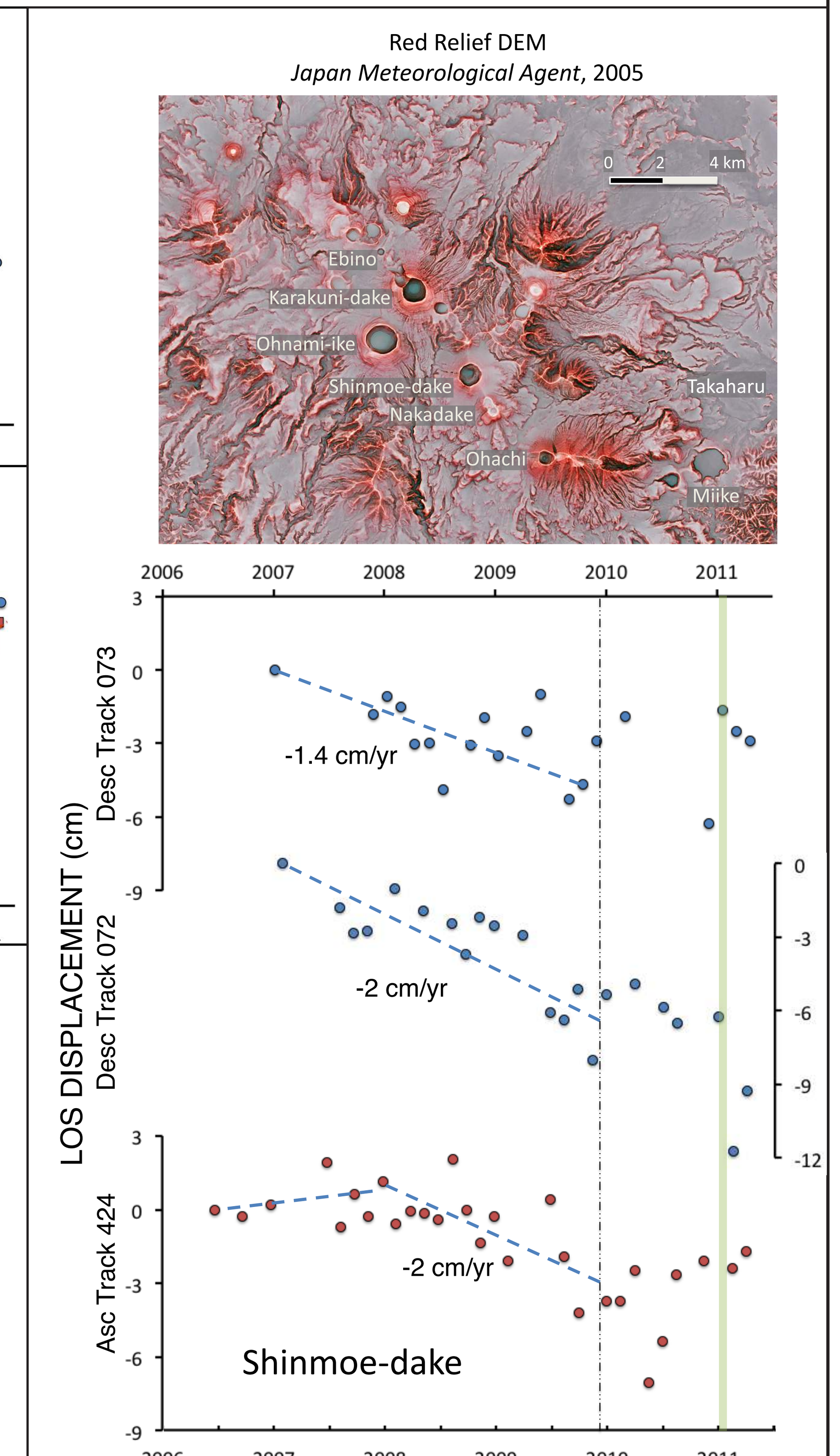


- **Sakurajima**



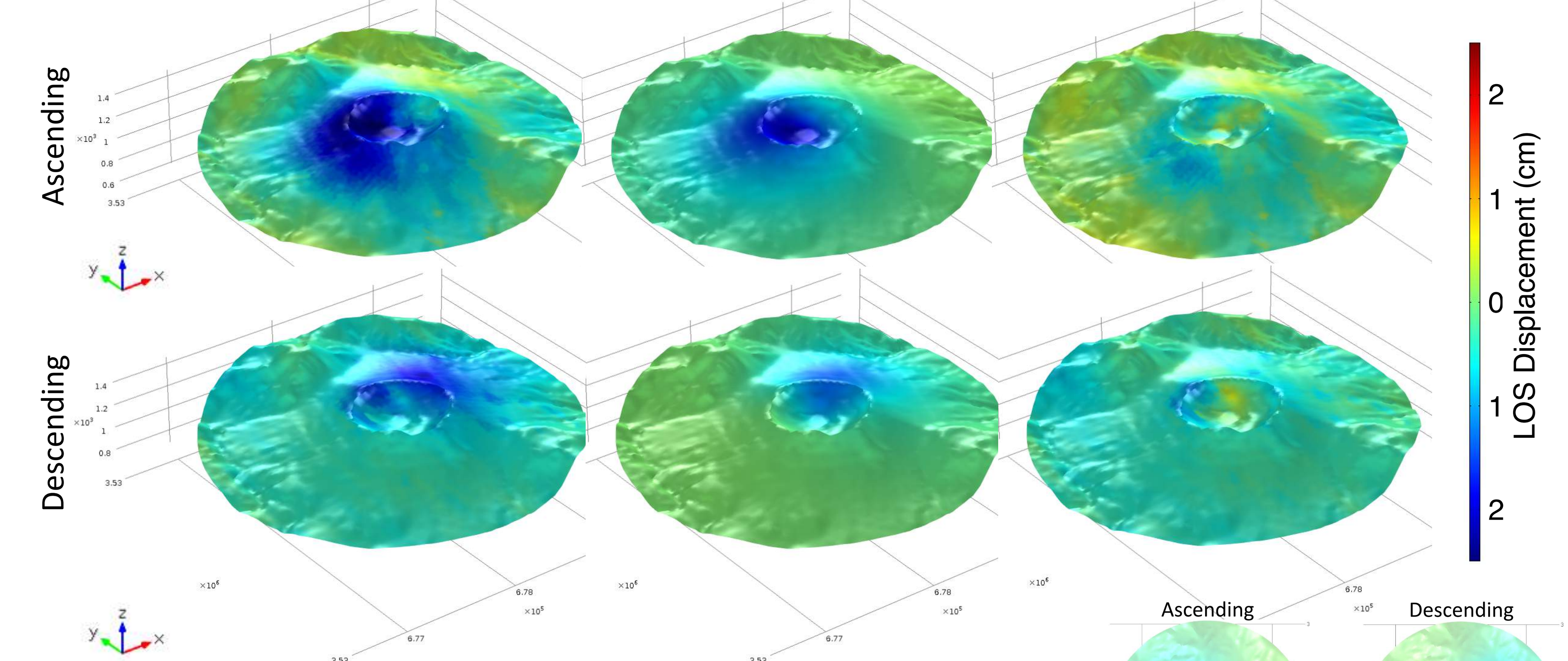
- **Shinmoe-dake (Kirishima)**





3) SOURCE MODELING

We use **3D Finite Element Modeling (FEM)** to model to the ground deformation of the volcano. Taking into account the **topography**, we consider a **spherical source** embedded in an **elastic homogeneous medium**, to retrieve the position (Es, Ns, Zs) and radius (Rs) of the source. Elastic parameters and source overpressure are fixed in the model.



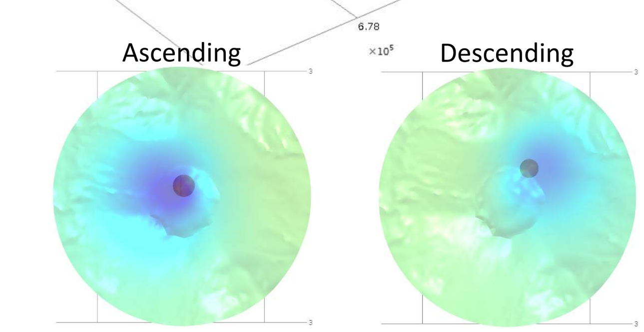
Parameter for best fit model:

	Radius (m)	Depth (m)	East	North
Ascending:	134	-724	678035	3532342
Descending:	112	-801	678272	3532558

Note: depth is relative the sea level; coordinate system is UTM-WGS-84.

Constant parameter:

Shear modulus G = 12e9 Pa
Poission's ratio v = 0.25
Overpressure DP = 20e6 Pa



Source Location

CONCLUSIONS

- Obivious pre-eruptive deformation is observed in both InSAR and GPS result:
  - three independent tracks of InSAR data
  - GEONET continuous GPS data.
- The source responsible for pre-eruptive deformation of Shinmoe-dake is shallow and small.
  - It could be related to magma cooling process or a hydrothermal system?
- Questions in the future:
  1. 200 m disagreement (EW and NS) of source position between ascending and descending InSAR data modeling;
  2. Double source system: deep source observed by GPS and shallow source observed by InSAR

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- Tatsumi, Y., and K. Suzuki-Kamata (2014), Cause and risk of catastrophic eruptions in the Japanese Archipelago, Proceedings of the Japan Academy. Series B, Physical and biological sciences, 90(9), 347.