Volcanic Unrest of the 2011 Eruption at Shinmoe-dake (Kirishima), Japan, revealed by InSAR and GPS data and modeling

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1- Summary

Study Area: Kirishima volcano group in southern Kyushu Island, southwest Japan.

Problem: How did the volcano deform in time and space durint this volcanic active period in 2008-2012? How deep is the source (magmatic and/or hydrothermal)?

Data: InSAR time series deformation from 3 tracks of ALOS-PALSAR over ascending and descending orbit from 2006 to 2011; 13 continuous GPS sites with data from 2006 to 2012.

Key findings:
1) **Two deformation sources** are identified: a deep magmatic chamber at ~10 km depth ~5 km away to the west of Shinmoe-dake's summit, which corresponds to the 2011 eruptive event, it started inflating ~1 year before the eruptive; and a shallow source at ~1.4 km depth beneath the summit, which corresponds to the 2008-2010 phreatic events.

2) The volume change associated to the **pre-eruptive ground deformation is close in amplitude** to the volume change relative **to the co-eruptive signal**. It means that the amount of new magma that enters into the magma chamber was transfered to the surface to fed the eruption. We can conclude that the shallow reservoir is not a large magma storage zone but it acts more as a **transfer zone** between deep source and surface.

2- InSAR Processing

Kirishima (霧島山, *i.e.* Foggy Mountain in Japanese), which means a lot of tropospheric delay!

Data: ALOS-PALSAR ascending track 424 and descending track 72 and 73 from 2006 to 2011 provided by JAXA; 0.4 arc-second (~10 m) resolution DEM provided by the Geospatial Information Authority of Japan (GSI) [Tobita *et al.*, 2002].

Time series InSAR: Small BAseline Subset (SBAS) [Berardino *et al.*, 2002, TGRS] using PySAR.
1) Network selection: threshold (1200 days and 12 km), then drop low coherent ifgrams manually (Fig 2.2)
2) Phase correction:
a) tropospheric delay using ECMWF weather re-analysis with PyAPS [Jolivet *et al.*, 2011, GRL];
b) DEM error correction [Fattahi and Amelung, 2013, TGRS];
c) Linear ramp removal;
d) Drop dates with obvious tropospheric turbulence using normalized sum of displacement for each epoch, as shown on Fig 2.3.

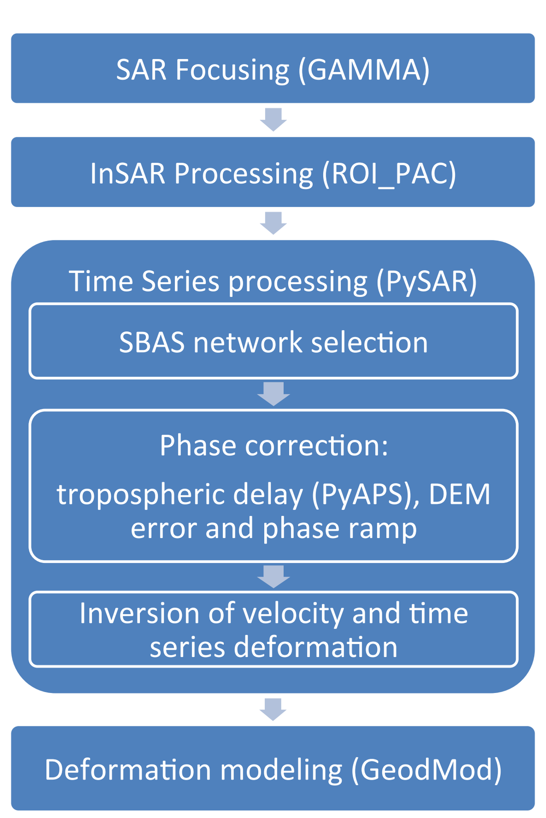
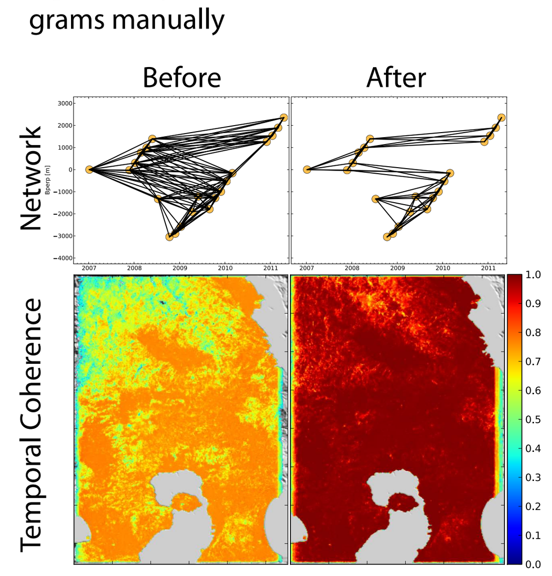


Fig 2.2 Drop low coherent interferograms manually

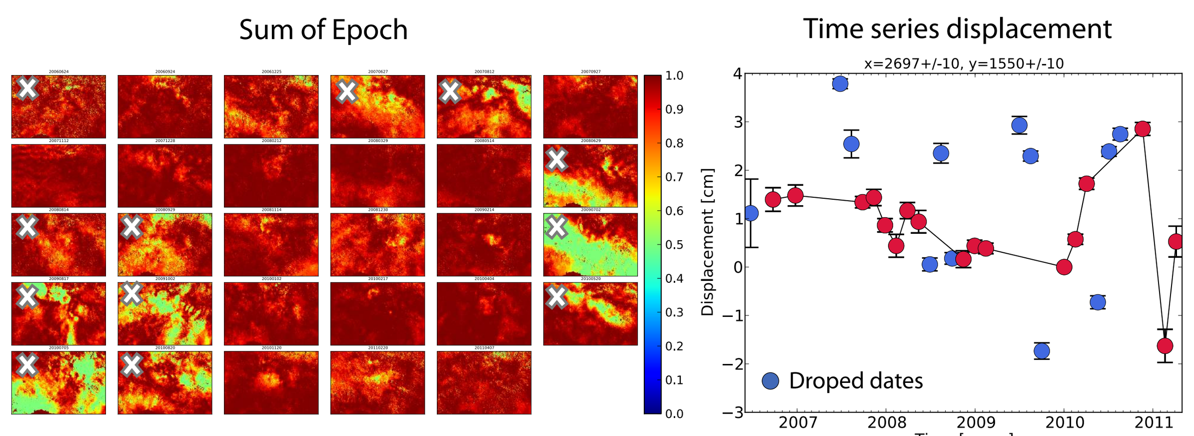


ALOS-PALSAR Track 73 Frame 2970_2980

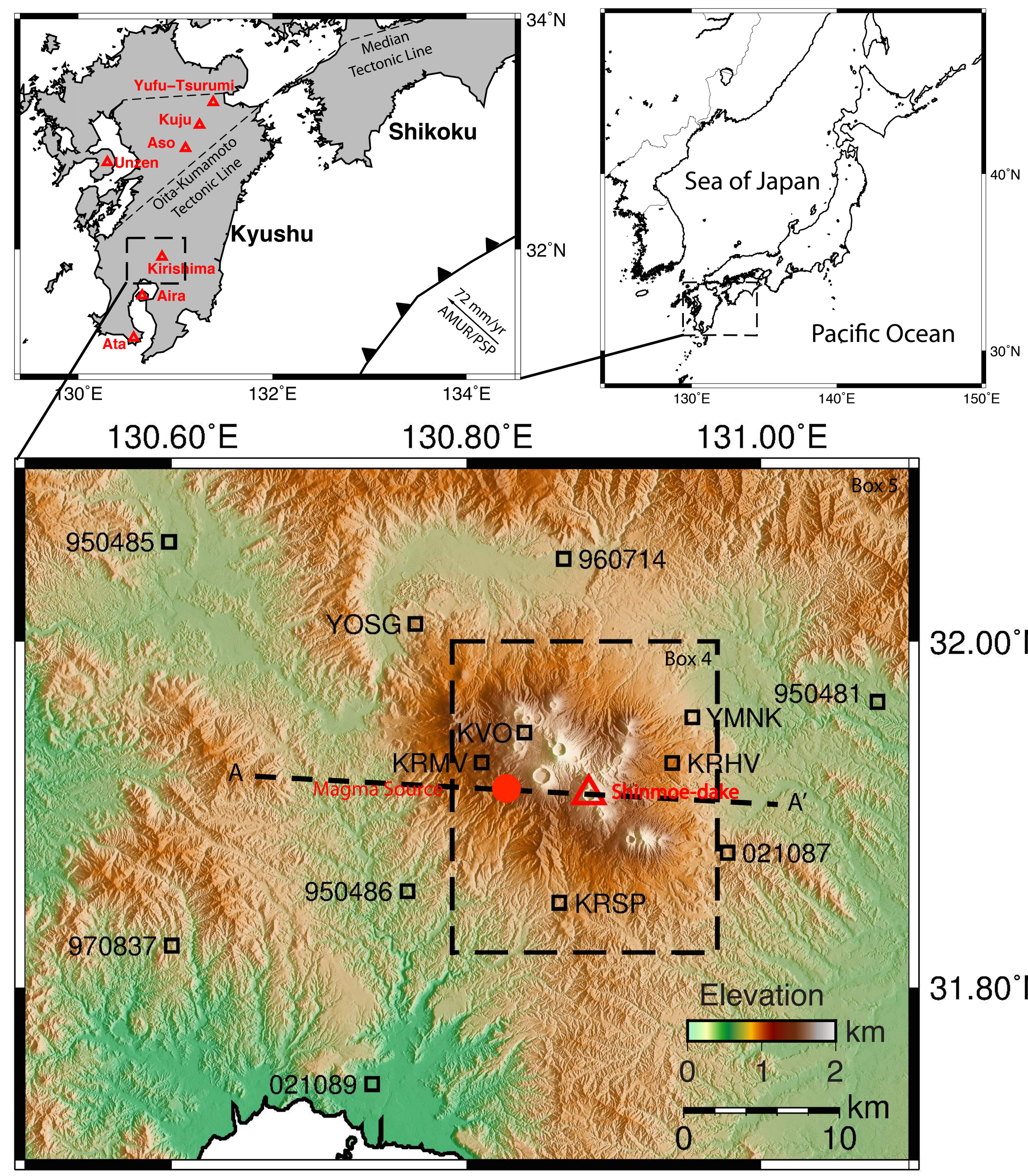
Fig 2.3 Drop dates with obvious tropospheric turbulence

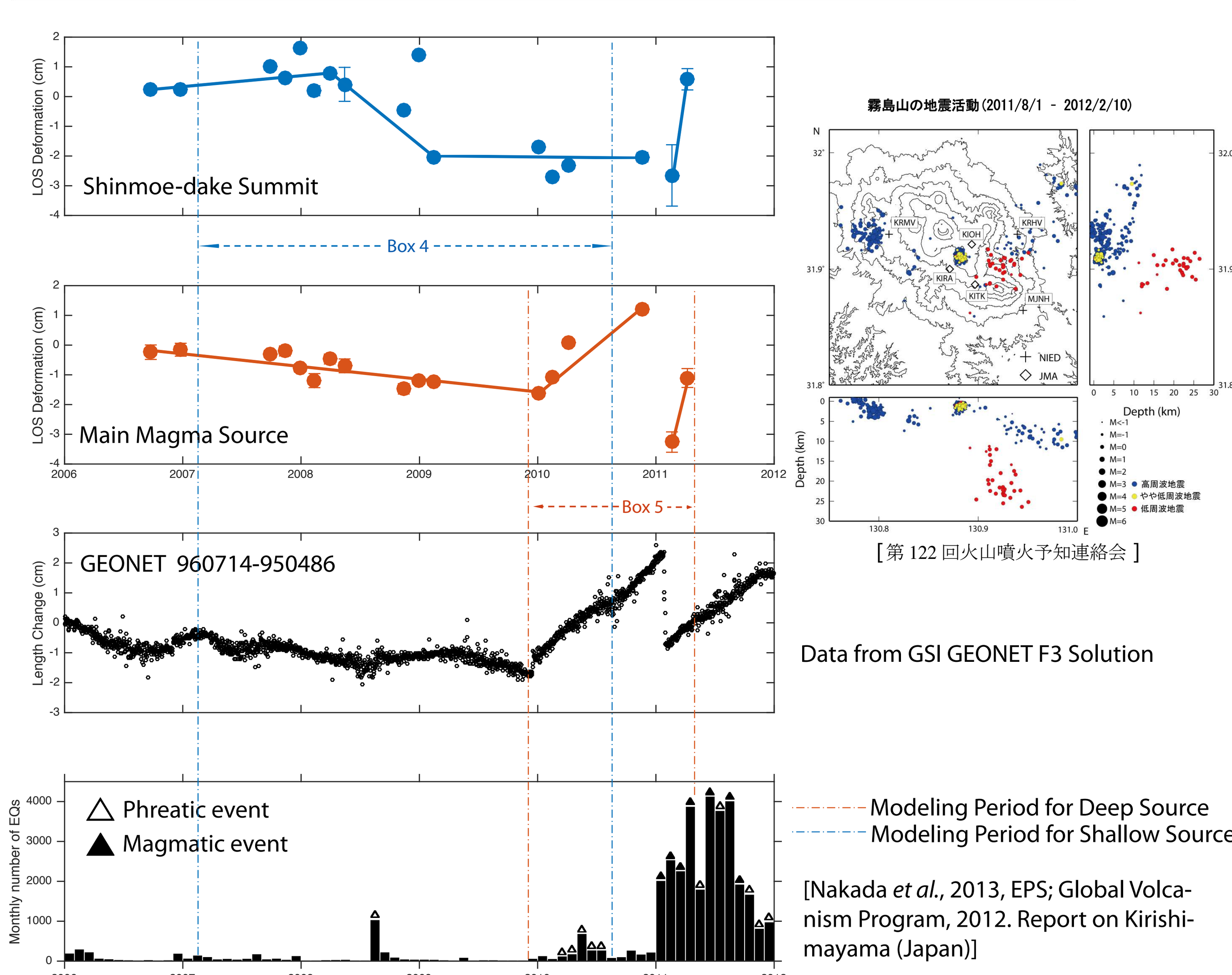
$$dSum_i = \frac{1}{N}\sum_{j=1}^{N}|d_j - d_i| \qquad dSum_i = \frac{\max(dSum) - dSum_i}{\max(dSum)}$$

where d_i is the ith epoch displacement, N is number of epoches [Fattahi and Amelung, 2015, JGR].



3- Time Series Displacement

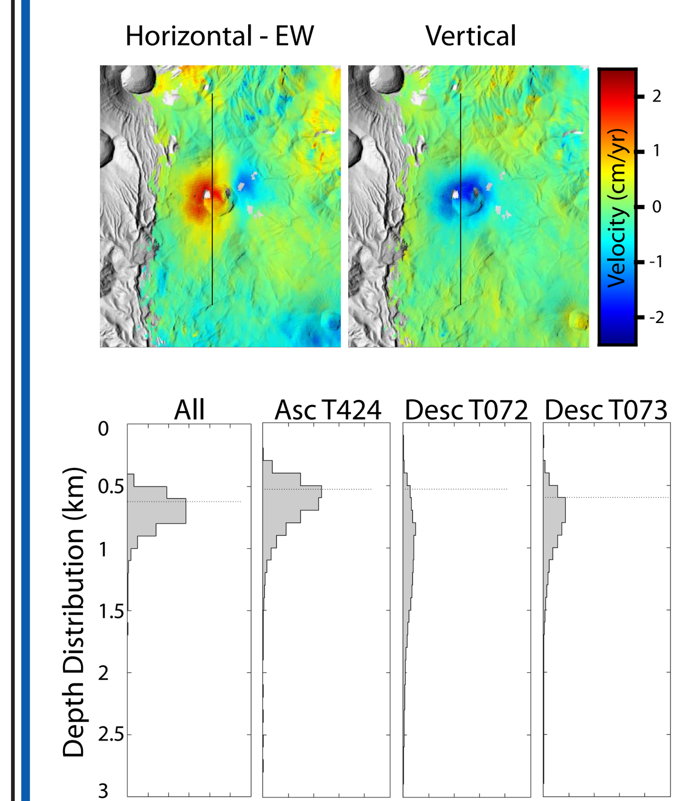


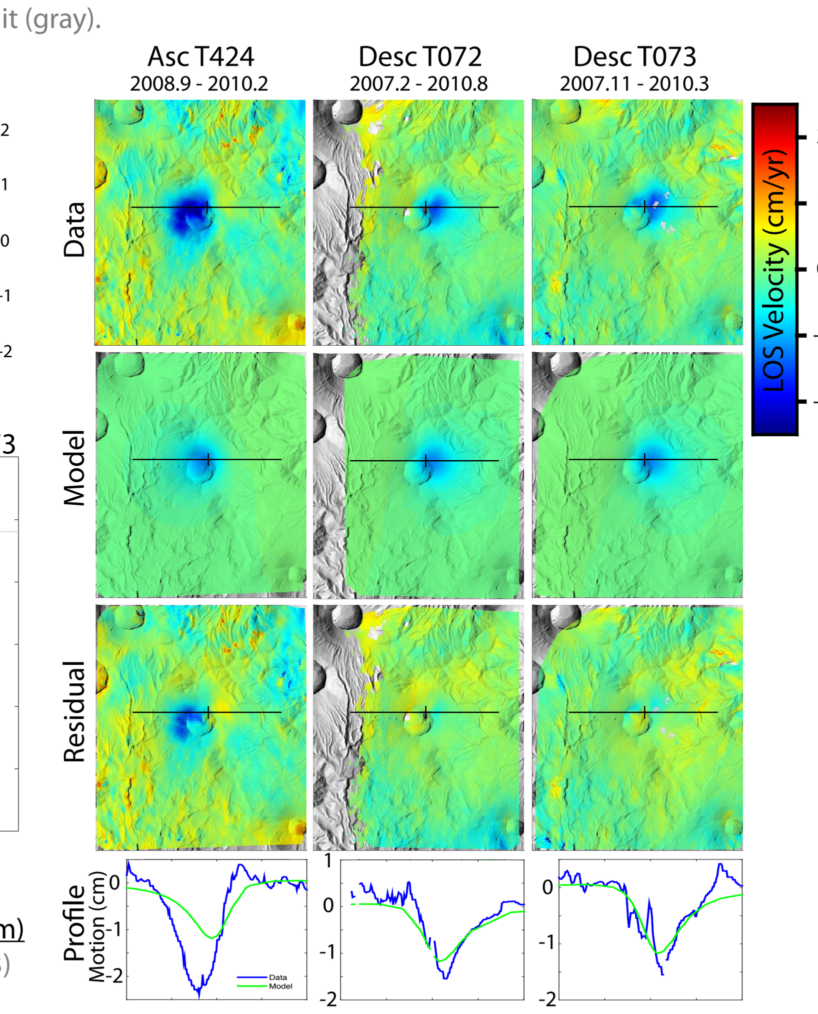


[Nakada *et al.*, 2013, EPS; Global Volcanism Program, 2012. Report on Kirishimayama (Japan)]

4- Pre-eruptive Deflation at Shallow Source

Deflation at Shinmoe-dake's Summit caused by the **phreatic explosion** occured in August 2008 (VEI=1) and March, April, May, June and July 2010. We choose elastic homogeneous, isotropic half-space **McTigue sphere model** with **Gibbs sampling** method to inverse source's geometry using **GeodMod** software. Depths are shown relative to the half space (black) and to the summit (gray).



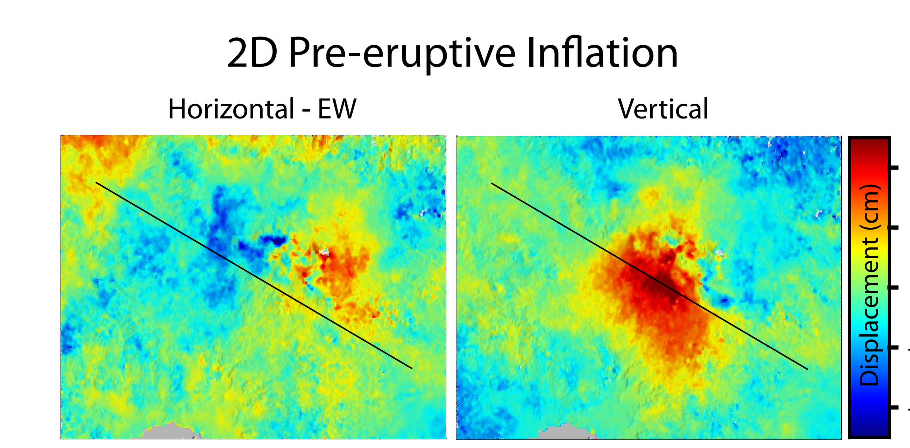


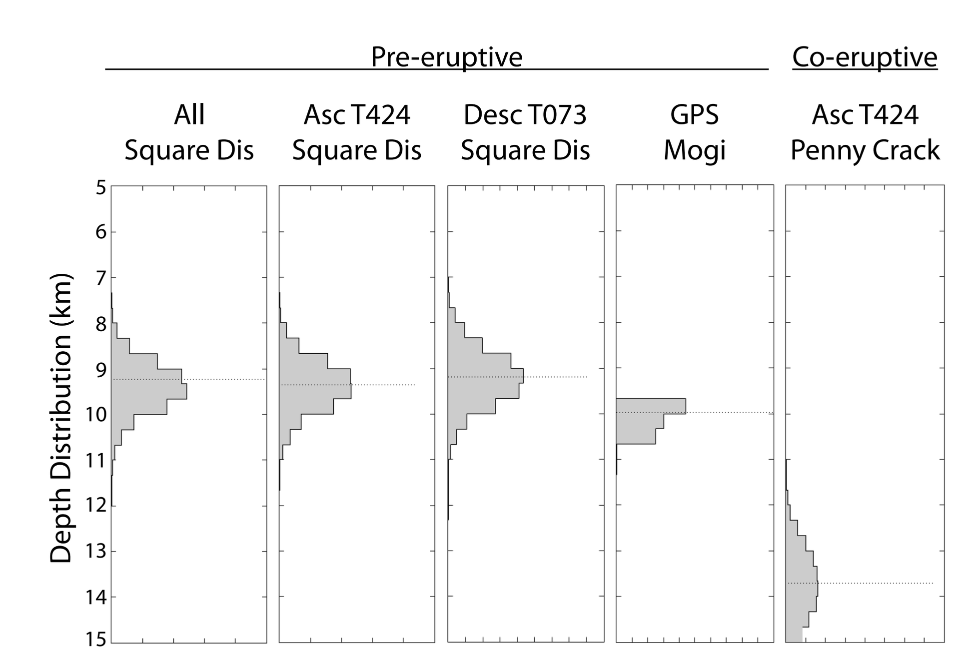
Best fitting model

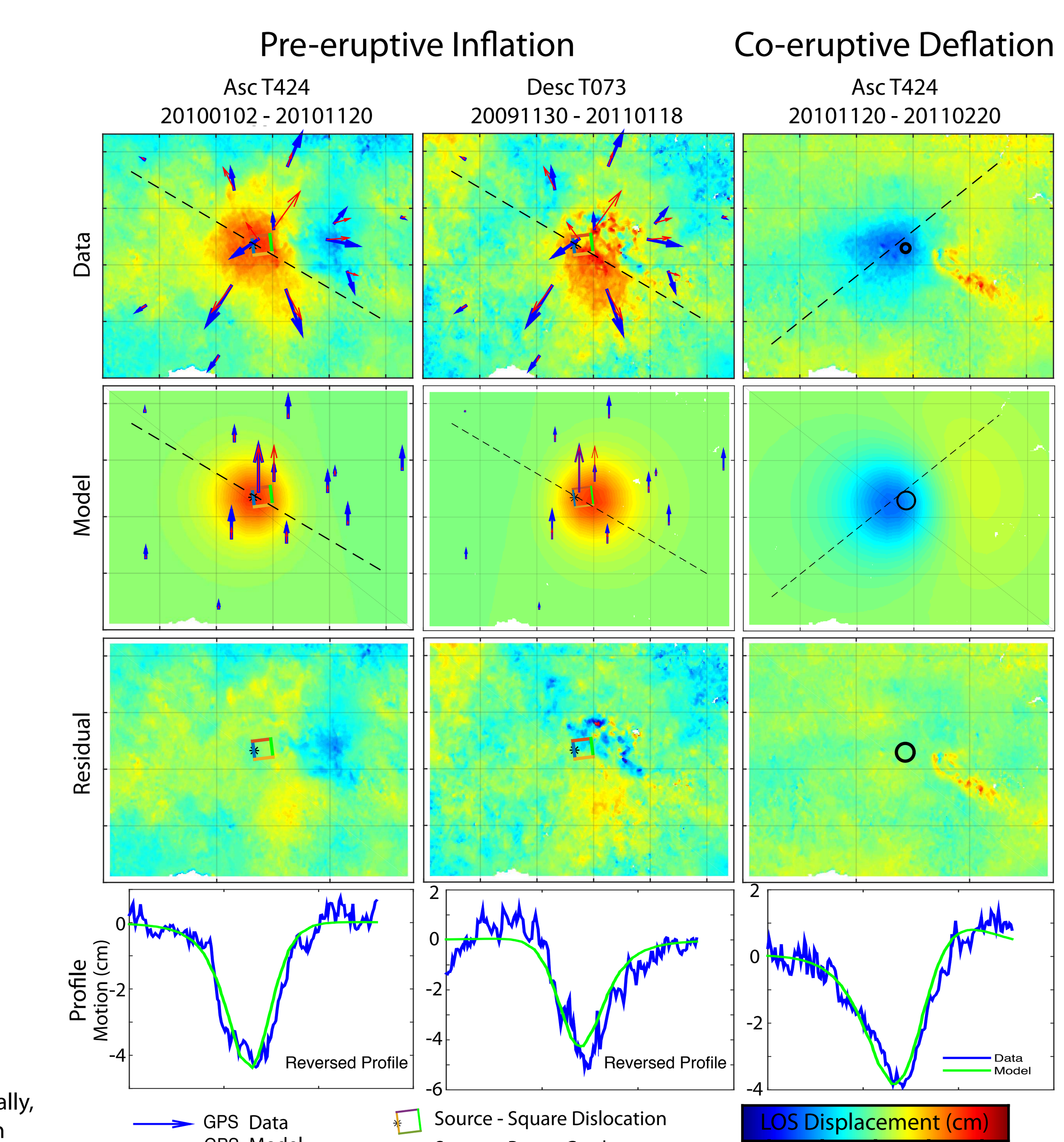
Latitude	Longitude	Radius (km)	Depth (km)
31.9146	130.8851	0.059	0.65 (1.43)
			0.01 r.s.l.

5- Pre- and Co-eruptive Deformation at Deep Source

Magmatic eruption (VEI=2) occured in 2011 with peak activity between Jan 26 and 31. The volcano edifice started to inflate about a year prior to the climax event. Here we use InSAR Descending and Ascending data with noise-corrected GPS (from Nakao et al., 2013, EPS) for pre- and co-eruptive modeling.





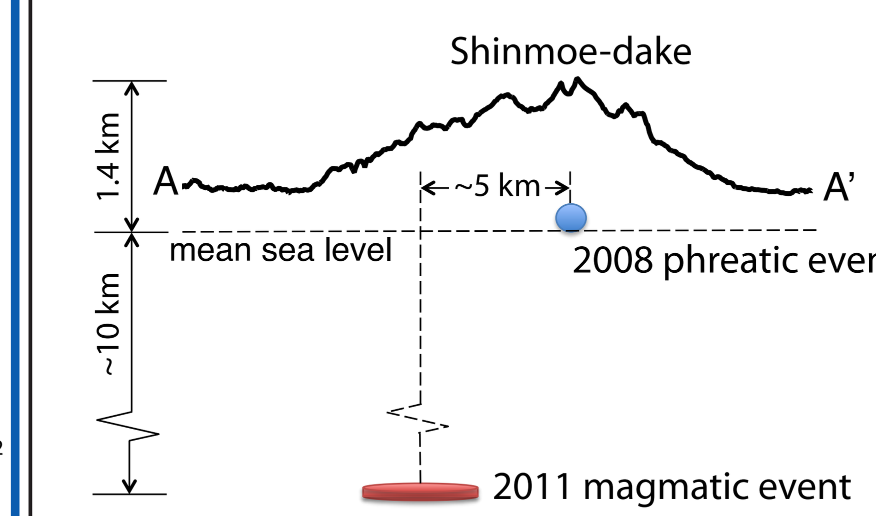


Best fitting model

	Latitude	Longitude	Radius/Len (km)	Depth (km)
Pre-climax	31.9195	130.8254	3.23	9.3 r.s.l.
During-climax	31.9203	130.8225	1.57	13.7 r.s.l.

Depth change for inversed model is mainly because of different model used. Generally, square dislocation gives shallower depth compared with penny crack. For GPS, both penny and square dislocation cannot be well constrained, so we use Mogi.

6- Source Model



7- Reference

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