Interpretation of InSAR images by FEM: Effects of topography

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Synthetic Aperture Radar (SAR) plays very important role in detecting volcanic deformation all over the world. Recently, in Japan, volcanic deformation associated with eruption and/or dike intrusion at Mt. Sakurajima, Mt. Kirishima, and Mt. Ontake etc. has been elaborated by using SAR interferometry. The spatial resolution of SAR satellites has been increasing with time, by which we can grasp more detailed surface deformation at the flank and the summit of volcanic edifices. Also, airborne SAR technique is developed to attain higher spatial resolution.
To quantitatively interpret the SAR images of higher resolution, we need improved numerical modelling scheme. Especially for volcanoes with steep edifice, the surface deformation due to shallow dike intrusions should be affected by surface topography. In this study, I develop an improved model of dike intrusion considering realistic topography, and apply it to the InSAR images of Mt. Sakurajima to evaluate the effect of surface topography.
On August 2015, the Japan Meteorological Agency raised volcanic alert level for Mt. Sakurajima to 4, following increased volcanic activities. The InSAR images of Mt. Sakurajima acquired by ALOS2 indicate clear Line-of-Sight (LOS) length change in the island exceeding the noise level. The displacement pattern seems well explained by crack opening. The crack locates in the central part of the island where surface altitude is high. As the crack sits quite shallow depth, it is very likely for InSAR images to be affected by surface topography. I calculated surface deformation by finite element method using COMSOL Multiphysics fully considering the surface topography derived from SRTM (Shuttle Radar Topography Mission) data (Figure). I set a rectangular crack in an elastic medium corresponding to a dike. Given crack opening, the finite element model well explains the InSAR image of surface deformation during August 10 and 24, 2015.
Next, I ran the calculation setting surface altitude as 0 m everywhere, and noticed that the surface deformation gets too large. To explain the InSAR image without considering realistic topography, we have to increase the crack depth by over 500 m. The calculated LOS displacement with such “flat topography” correction still differs from the finite element analysis about 1cm around the summit area. The difference shows positive and negative pairs, which may be identified by further noise reduction. In the presentation, I mention on the model application to other InSAR pairs, and expected topographic effects for shallower crack.

Keywords: SAR, FEM, Sakurajima, Surface topography

Finite element model and dLOS of Sakurajima