Spatial and temporal crustal deformation analysis by the comparison of precise DEM - A case study of Mt. Usu

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1. Shallow inflation and deep deflation sources

The edifice-scale deformation associated with the 2000 eruption of Mt. Usu can be explained by a multiple spherical source model, with shallow inflation and deep deflation. It provides better fitness to the data when the deflation volume at 10km to the inflation at 2km is nearly equivalent (Okada, 2004c). Similar result is obtained for horizontal model. Distinct deformation characteristics of Mt. Usu are found, comparing with the other well studied volcanoes in the world. The model difference of Mt. Usu may partly indicate the difference of magma intrusion processes between basaltic effusive magma system like Kirauea and dacitic doming magma system like Mt. Usu.

2. Model evaluation using rational misfit values

For the purpose of quantitative evaluation of data fitness, the residual misfit values SUM(Dobs -Dmodel)/N defined by the conventional linear data fitting are generally used for evaluating the edifice-scale deformation models of Mt. Usu. But there is apparently little difference between the single source model and the multiple source model. This indicates the difficulties to estimate the deeper source when only residual misfit value is minimized. So, in this study we defined the rational misfit values SUM(Dobs -Dmodel)/N/Dmodel which is the ratio (%) of the residual to the data is introduced. The rational misfit value of 49% of the multiple source model, which value is much less than the 104% of the single source model is obtained. Here, we could successfully evaluste quantitatively the deeper source contribution to the shallower one by comparing the rational misfit values. Similar result is obtained for horizontal model. Rational misfit value is considered as useful value for the evaluating the fitness of the models, especially for over wide rage deformation (1mm to 1m deformation) or edifice wide scale deformation.

3. Precise DEM analysis

We have yet to understand the precise deformation patterns at the summit area, where repeated magma intrusion was known to happen in the past reported eruptions. There are many characteristic structures there, such as lava domes, crypto-domes, faults, a somma caldera and some craterlets. For any deformation study in Mt. Usu, it is very important to examine how the summit area had been deformed at every eruption. However, there have not been enough geodetic data sets until now to discuss complicated deformation patterns of the summit excepting for Usu-shinzan formation in 1977-82. In this study, for the purpose of comprehensive understanding of the shallow magma intrusion process, deformation analyses utilizing precise DEM were done. These precise DEMs were generated from large scale topographic maps (e.g. 1983.10:Kokusai-Kogyo; 2000.4:GSI) by STRIPE method (Noumi et al., 2002). The original height information and contour line patterns in the base map are faithfully reproduced in generating DEMs. Precise DEM were created for Ko-usu, West-somma, Nishiyama and Kitabyobu-yama. Assuming their characteristic topography is reserved in the different periods, the 3-D displacement vectors (height changes and translations) can be obtained by comparison of the DEMs (Okada, 2004b). A few m scale of significant displacements both for vertical and horizontal are recognizable at the summit using 1993 and 2000 DEMs, which is mainly due to the deformation associated with the 2000 eruption. Preliminary results indicate the existence of shallower dike intrusions beneath the NW summit along weak fault zones, the orientation of which correspond to those pre-studied by Okazaki et al. (2002). It is confirmed that the 3-D deformation analysis using precise DEMs could be very useful tool for widely grasping of the deformation field in the volcanic region. Not only spatial distributions but also temporal changes of the deformations are needed to discuss by the comparison of many kind of DEMs at different periods in Mt. Usu.