

# Temporal relationship between seismic activity and ground deformation by GNSS data with applying the stacking method

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For understanding processes of volcanic activities, it is important to clarify the temporal relationship between ground deformation and seismic activities including their depth. It is reported that baseline changes seem to have started several weeks-to-months prior the earthquake swarms in recent studies. These results show that it is possible to detect volcanic activity changes before an eruption or earthquake swarms.

During the 2007 and 2014 Ontake volcano activity, the changes of stacked GNSS data began in the long stacked data moved to the short stacked data over time. Miyaoka and Takagi (2019) inferred that these data revealed movements of a pressure source to a shallower region from a deeper region (about 5km depth). The same case was reported during the 2013 Hakone volcanic activity, the changes of long stacked data (source depth about 5-10km depth) seem to have started several months prior to the earthquake swarms. Similar cases were reported in the earthquake swarms of Izu-Tobu volcanoes and the changes of GNSS data seem to have about half a day prior to the earthquake swarms (JMA, 2010). It was assumed that only ground deformation were detected when magma ascended in the hot and ductile part at the depth, and the earthquake occurred when magma reached to the shallower part (The headquarters for earthquake research promotion, 2010). Takagi (2019) reported volcanic ground deformation events that were detected at 9 volcanoes in Japan by applying the stacking method to strain measurements along baselines of GEONET, the GNSS network managed by the Geospatial Information Authority of Japan. On the other hand, the relationships between the ground deformation and earthquake activity were still not investigated in Takagi (2019).

In this study, for the purpose of detecting movement of a pressure source, we checked the relationship between earthquake activities and the occurrence of ground deformation based on events caused by deep pressure sources revealed by Takagi (2019). As a result, ground deformations prior to seismic activities were observed at many volcanoes, not only Ontake volcano and Hakone volcano but also Meakandake volcano, Niigata-yakeyama volcano, Asama volcano, Shinmoedake volcano and Aso volcano. Although no eruptions have been observed, it was also observed that ground deformation prior to swarm activity at Zao volcano and Azuma volcano, which had swarm activities in recent years. In particular, at Meakandake volcano and Azuma volcano, it is possible that the slight baseline changes from the long stacked data to the short baseline be seen by using the stacking method of Miyaoka and Takagi (2016). The results of an investigation of the relationship between ground deformation and seismic activity for several volcanoes including above will be shown.

Keywords: Ground deformation, Earthquake activity, GNSS, Stacking method