Theory on tidal groudwater oscillation on a circular island - application to analysis of gravity variation on volcanic islands

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Continuous gravity observations have been performed in volcanic areas to detect mass transport and ground deformation beneath volcanoes such as Mt. Etna (Panepito et al. 2008), Asama volcano (Okubo et al. 2012), and so on. During the processing of the gravity records, it is now conventional to apply the corrections for solid earth tide, oceanic loading, and barometric disturbance. However, even after accurately correcting for these effects, we still find oscillations with tidal frequencies in the gravity records on a small island or nearly circular peninsula such as Sakurajima. These oscillations must be adequately eliminated based on physical modeling so that we can detect short-term (time scale<12 hours) signals of volcanic origins in the gravity records.

The tidal oscillations are most likely due to groundwater variation in an unconfined aquifer. In this presentation, we give an analytic solution for the height of water table beneath a circular island driven by oceanic tide on the coast. The result is compared with the record of water level in a well on the Sakurajima to derive hydraulic conductivity of K˜1 cm/sec. The result enables us to estimate long-term disturbance of gravity arising from groundwater. When corrected for such disturbance, the gravity signal on Sakurajima during 2009 through 2018 exhibits reasonable variation even after heavy rainfalls (eg. 500-1000 mm in a month).

We conclude from theoretical and observational viewpoints that (1) tidal variation of groundwater level can be observed on volcanic islands and (2) tidal oscillation of groundwater brings about significant gravity variations with tidal frequencies.

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