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Gravity correction of groundwater-derived noise for high-accuracy monitoring of volcanic activities

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The basis of geodesy is to measure physical quantities accurately, and to monitor solid-earth activities, such as earthquakes and volcanic eruptions. Fluctuations from outside the solid earth (earth tide, atmospheric disturbance and so on) are considered as noises, and have been eliminated effectively. The groundwater-derived noise, however, have not been corrected adequately, since only little has been known on the mechanism of the noise for a long time. Consequently, geodesists have corrected groundwater noises with empirical methods, such as tank models and regression curves. These methods, however, are not based on hydrological background, and are very likely to eliminate solid-earth signals excessively. The correction method of groundwater noise has to be developed with hydrological and quantitative approach.

We thus investigate how to correct groundwater-derived noise from gravity data effectively. Groundwater noise is corrected in the following procedure: (1) Groundwater distributions are simulated on a hydrological model, utilizing groundwater flow equations. (2) Groundwater-derived gravity value is estimated for each instant of time, by integrating groundwater distributions spatially. (3) The groundwater-derived gravity, as the correction value, is subtracted from observed gravity data. In this study, we simulated groundwater flow and groundwater-derived gravity value on the east part of the Asama volcano, central Japan, with a simple hydrological model, consisting of homogeneous soil, lying on a flat impermeable basement. We also observed time variations of watertable height, soil moisture and gravity during the summer of 2006 at Asama volcano, and compared the observations with the theoretical values.

Both simulated groundwater distributions and gravity changes agree fairly well with observed values. On variations of water level and moisture content, rapid increase at the time of rainfalls and exponential decrease after rainfalls were illustrated. Theoretical gravity changes explained 90% of observed gravity increase at the heavy rainfall of mid-July 2006. These facts showed that even a simple hydrological model can reproduce characteristic variations of groundwater and gravity at the same time. We believe that hydrological simulation with more sophisticated model (such as 3D inhomogeneous soil lying on a curved basement) provides an effective and physically appropriate scheme for eliminating ground noise from geodetic data. Improved groundwater correction will reveal detailed solid-earth activities such as volcanic eruptions.