Measuring vertical gravity gradients in volcanic areas using an interferometric gravity gradiometer

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Gravity measurements, using mechanical and absolute gravimeters, have been carried out in various volcanic areas to infer the subsurface density variations caused by volcanic activities. Measured values of gravity are not only influenced by the density variations due to volcanic activities, but also by movements of groundwater and diastrophism. These non-volcanic effects have to be modelled and removed from the gravity values. However, large uncertainties in the modelling tend to hinder accurate identification of the volcanic effects. In order to improve the accuracy of identifying the volcanic effects, we propose simultaneous measurements of gravity and vertical gravity gradients. The vertical gravity gradients are obtained by taking the differences of two gravity values (g_A and g_B), simultaneously measured at different heights (A and B). By taking the difference of g_A and g_B, the common effects to the both values are cancelled out. Such common effects are originated from, for example, seismic vibrations and diastrophism at the observation point; the values of vertical gravity gradients are not severely affected by height changes of the observation point. Also, unlike gravity, which is proportional to the square of the distance from the source of gravity, gravity gradients are proportional to the cube of the distance. This indicates that the measurements of gravity gradients are likely to be more sensitive to the movement of nearby groundwater than those of gravity. Because of these intrinsic differences, the simultaneous measurements could be useful for more accurate identification of the sources of density variations.

A new type of gravity gradiometer, employing technologies for the fifth-force search, had been developed at the Institute for Cosmic Ray Research (ICRR) of the Tokyo University from 2009 to 2012. In this gravity gradiometer, a pair of test masses, set at different heights, is thrown up at the same time in vacuum and their differential acceleration is measured by interferometer. Laboratory tests at the ICRR showed that this type of gravity gradiometer was capable of measuring vertical gravity gradients to a level of a few μGal (=10^{-8} m/s^2) per meter. This resolution is comparable to that of commercial absolute gravimeters, widely used in the field of geodesy. We intend to use the gravity gradiometer for the simultaneous measurements. We have moved a prototype of the gravity gradiometer to the Aso Volcanological Laboratory of Kyoto University (AVL) and carried out further improvements and trail measurements. We report the current status of the development and future prospects of the gravity-gradients measurements in volcanic areas.