Determination of instrumental tilts of portable relative gravimeters using image analyses

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Continuous gravity measurement is one of the most effective methods to understand spatiotemporal mass variations associated with volcanic activities, but the volcanic gravity signals are often masked by artificial gravity change due to instrumental tilt. In the case of the 2015 rapid inflation event at Sakurajima Volcano, Kazama et al. (2016) succeeded in retrieving the volcanic gravity signal of about 6 micro-Gal from the continuous gravity time series collected by a CG-3M gravimeter, after correcting the tilt-derived artificial gravity change using the tilt time series simultaneously collected by the gravimeter. However, most of gravimeters which have been used in volcanic areas cannot measure instrumental tilt values electronically; for example, analog tiltmeters (needle- and/or bubble-type) are just put on LaCoste relative gravimeters to check instrumental tilts manually. In monitoring continuous gravity variations at volcanoes using typical relative gravimeters such as LaCoste gravimeters, instrumental tilt values should be determined from the analog tiltmeters to correct the tilt-derived gravity changes accurately.

Thus we developed a method to quantify instrumental tilt from photographs of analog tiltmeters, and applied the method to the photograph data taken during the tilt experiment for the D58’s feedback-type relative gravimeter. At the tilting experiment, we first put the D58 gravimeter on a tilt table, and tilted the table from -100 arc-sec to +100 arc-sec intermittently. We then took photographs of the D58’s analog (needle and bubble) tiltmeters every 10 sec, along with the digital data of relative gravity and electronic tilt values transmitted from the D58 gravimeter continuously. The tilt value was estimated from each photograph of the needle tiltmeter, by digitizing the positions of the needle using the original Python software. The tilt value of the bubble tiltmeter was also digitized, by measuring the position of a bubble in each photograph relative to the reference bubble using the cross correlation technique.

We found that the tilt values digitized from the photograph data of the analog tiltmeters were clearly correlated with the one of the electronic tiltmeter embedded in the D58 gravimeter. Correlation coefficients between digitized and electronic tilt values are calculated to be +0.9999 and +0.995 for needle and bubble tiltmeters, respectively. This result shows that instrumental tilt values of relative gravimeters can be precisely obtained by applying the above image analyses to the photograph data of analog tiltmeters. We will verify how accurate the tilt-derived artificial gravity change can be corrected by using the tilt values digitized from the photographs of the analog tiltmeters. We will also install LaCoste relative gravimeters at several volcanoes in Japan to monitor gravity and tilt changes associated with volcanic activities continuously.

Keywords: gravity, tilt, continuous observation, volcano, image analysis, Python

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