Permanent gravity changes caused by The 2007 Noto Hantou Earthquake and The 2007 Niigataken Chuetsu-oki Earthquake

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The high sensitivity and stability of the superconducting gravimeter (SG) allow us to observe changes in gravity acceleration of the order of 1 x 10^{-8} ms^{-2} or smaller. Permanent gravity changes associated with earthquakes are one of the signals to be investigated by means of the SG. The first successful observation of coseismic gravity changes with the SG was made by Imanishi et al. (2004), who analyzed the data from three SGs in Japan to detect signals associated with The 2003 Tokachi-oki Earthquake (M8.0). This was followed by Nawa et al. (2008) who used the SG at Inuyama to retrieve gravity changes caused by The 2004 off the Kii peninsula earthquakes (M7.1, M7.4). In these studies, the earthquakes are typical thrust events along subduction zones, and are energetic enough to induce permanent gravity changes which are observable with SGs even at far fields. Such events are, however, relatively infrequent. Other cases in more 'common' earthquakes must be examined so that the potential usefulness of the SG in the tectonic studies can be evidenced.

In 2007, there occurred two interesting earthquakes in the central part of Japan. One is The Noto Hantou Earthquake (M6.9) on March 25 and the other is The Niigataken Chuetsu-oki Earthquake (M6.8) on July 16. Although these earthquakes are much less energetic than The 2003 Tokachi-oki Earthquake, there are two of good SG stations in this region, Matsushiro and Kamioka, with epicentral distances ranging from 1.1 to 1.5 degrees. These events have provided us with good opportunities for a challenge of retrieving coseismic gravity changes with SGs at intermediate epicentral distances.

Calculations based on the dislocation theory (Okubo, 1992) predict gravity changes of -0.196 x 10^{-8} ms^{-2} at Matsushiro and -0.136 x 10^{-8} ms^{-2} at Kamioka, respectively, for The Noto Hantou Earthquake (the minus sign denotes a decrease in gravity acceleration). For the Niigataken Chuetsu-oki Earthquake, the predicted gravity changes are +0.185 x 10^{-8} ms^{-2} at Matsushiro and +0.179 x 10^{-8} ms^{-2} at Kamioka, respectively. Here we have assumed fault models estimated by Geographical Survey Institute (2007). Considering that a signal of the order of 10^{-9} ms^{-2} was marginally observable at Matsushiro in the case of The 2003 Tokachi-oki Earthquake, the predicted magnitude of the coseismic signals will be fairly observable with the SGs.

The gravity data are corrected for tides, atmospheric effects, hydrological effects, polar motion effects and instrumental drifts. Coseismic changes are estimated by fitting a step function of time to the short segment of residual series including both before and after the earthquake. One of the improvements of this study over Imanishi et al. (2004) is that the discarded portions of data are only a few hours long, so that ambiguities in the step estimation may be smaller.

Out of a total of four possible combinations of the source and the receiver, two cases produced plausible signals. The SG at Matsushiro registered -0.021 x 10^{-8} ms^{-2} of gravity change for The Noto Hantou Earthquake, which should be compared with the theoretical prediction of -0.196 x 10^{-8} ms^{-2}. The SG at Kamioka yielded +0.080 x 10^{-8} ms^{-2} for the Niigataken Chuetsu-oki Earthquake, while the theory predicted +0.179 x 10^{-8} ms^{-2}. In these two cases, observed gravity changes are in fair agreement with theoretical predictions, but the differences between them are left unexplained. For the remaining two cases, the gravimeters suffered from instrumental offsets.

This result indicates the difficulty in identification of small coseismic signals caused by typical inland earthquakes with the current design and methodology of the SG. Future improvements on the instrumental design as well as on the correction of environmental effects on gravity will be necessary so that coseismic signals can be more stably observed.