No identification of predicted earthquake-induced prompt gravity signals in data and its interpretation based on the principle of gravimetry

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Dynamic earthquake rupture causes density changes of the medium and, in theory, induces prompt gravity perturbations at all distances before the arrival of seismic waves. Detection of the prompt gravity signal before the seismic one is a challenge in seismology. In this study, we searched gravimetric data for such prompt gravity changes induced by the 2011 Tohoku-Oki earthquake. However, significant changes predicted by a theoretical model were not identified even though the data had sufficient signal-to-noise ratios. We also analyzed broadband seismograph and tiltmeter array data. Again, we could not detect the expected changes although smaller trends before *P* wave arrival were found in multi-station stacked traces. To interpret the absence of expected signals in the data, we investigated the self-gravity effect on the measurement of gravitational acceleration, which has been ignored in the existing theory. For this purpose, we calculated the displacement of the observation station before *P* wave arrival and showed that each point in an infinite homogeneous medium moves at an acceleration identical to the applied gravity change. This means that the above gravity sensors do not have sensitivity to the prompt gravity change and can explain the absence of the expected signals in the data. In a realistic finite Earth, however, its free surface alters the ground acceleration because additional deformation occurs in order to satisfy the traction-free boundary condition. As a result, the perfect cancelation between the gravity change and the ground acceleration breaks, and the observability of the difference is expected to remain. Recent research reported that numerically simulated waveforms in a half-space were identified in observed data. In this context, the slight trends we found in the stacked traces may reflect this surface effect and correspond to the signals found in the recent research. In terms of gravity-gradient or spatial strain, there also remains a possibility of detection. Toward future research, we derived an analytical expression for the theoretical gravity gradients from a general seismic source.

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