Efficient simulation of prompt elasto-gravity signals (PEGS) based on a spherical self-gravitating earth model

Rongjiang Wang¹, Shenjian Zhang¹,², Torsten Dahm¹,³, and Sebastian Heimann¹
¹GFZ German Research Centre for Geosciences, Potsdam, Germany (wang@gfz-potsdam.de)
²School of Earth and Space Sciences, Peking University, Beijing, China
³Institute of Geosciences, University of Potsdam, Germany

An earthquake causes a sudden rock-mass redistribution through fault rupture and generates seismic waves that cause bulk density variations propagating with them. For a large earthquake, both processes can induce global gravity perturbations, whose signals propagate with the speed of light and therefore can arrive at remote stations earlier than the fastest elastic P wave. In turn, the gravity perturbations generate secondary seismic sources overall within the earth, a part of which can cause ground motion prior to the direct P wave arrival, too. Recently, these prompt elasto-gravity signals (Vallée et al. 2017) for large earthquakes like Tohoku 2011 Mw 9.1 have been detected in records of broadband seismometers and superconducting gravimeters. Though the physics of the PEGS has been well understood, the tools used so far for a realistic modelling of them are complicated and computationally intensive. In this study, we present a new and rather simple approach that solves the full-coupled elasto-gravitational boundary-value problem more accurately, but no more complicated than to compute synthetic seismograms in a conventional way. Using the new tool, we simulate the PEGS of the 2011 Tohoku earthquake in both temporal and spatial scales, based on a realistic kinematic finite-fault source model. The temporal results show clearly how the ground motion is inspired by the gravity change in short- and long-term as well as how the combined PEGS behave at different epicentral distances from 400 to 3000 km. The spatial patterns of PEGS, especially that of gravity change, reveal the relationship between the PEGS and the focal mechanism. We also compare our simulation results with the predictions made before and with the observed waveforms and find a good agreement. Furthermore, we show particularly that the moment magnitude, rupture duration and focal mechanism of the 2011 Tohoku earthquake can be estimated robustly using the PEGS measured at a dozen selected stations, which could be helpful for the earthquake and tsunami early warning in the future.