Development of semi-real-time tsunami monitoring and calculation system for pressure gauge stations in southwestern Japan

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Ocean-bottom observatory systems provide powerful means to monitor geophysical phenomena in ocean areas, such as seismic activity, geodetic deformations, submarine eruptions and landslides, turbidity and bottom currents, tides, and tsunamis. Such observations develop our understanding of the dynamics of the Earth through the ocean. In 2011, JAMSTEC (Japan Agency for Marine–Earth Science and Technology) deployed 20 sets of ocean-bottom stations, namely DONET1 (Dense Oceanfloor Network System for Earthquakes and Tsunamis), in water depths of 1,900–4,400 m off the Kii Peninsula in southwestern Japan (Kawaguchi et al., 2011, 2015; Kaneda et al., 2015). In 2016, JAMSTEC also deployed 31 sets of stations, DONET2, in water depths of 1,100–4,400 m on the western side off the Kii peninsula. We refer to these ocean-bottom observatory systems, DONET1 and 2, as "DONET". Each station in DONET has strong-motion and broadband seismometers, hydrophones, differential and quartz pressure gauges, and thermometers. DONET pressure sensor data are expected to be useful for detecting tsunamis and for issuing tsunami warnings as reviewed by Rabinovich and Eblé (2015).

In this study, we developed a semi-real-time calculation and data monitoring system that measures pressure perturbations at the DONET pressure-gauge stations in order to identify tsunami signals associated with earthquakes (Nakamura and Baba, 2016). The system automatically calculates geodetic deformations and tsunami propagation immediately after getting seismic source information on hypocenter, magnitude, and mechanism. We use the list of point source mechanisms from the Global Centroid Moment Tensor (Global CMT) solution (Dziewonski et al., 1981; Ekström et al., 2012). The rupture duration and the fault size are estimated from the seismic moment via a scaling law. We implemented a hybrid MPI/OpenMP parallelization into the code to enable efficient parallel computation. The code was optimized by paying careful attention to the order in which elements in array variables are accessed, avoiding subroutine calls in the innermost loop iteration, and avoiding the use of unnecessary conditional branches in loop iterations, where processors spend much time.

The calculation results for transoceanic tsunamis can be available in approximately 20 s after getting source information to output waveform data by executing the optimized parallel calculation code on our computer server SGI UV2000 with a 32-core processor unit. The system also provides tide-removed and filtered waveform data at ocean-bottom stations, enabling the calculation results to be compared with actual tsunami arrivals. System operations began in July 2015 and have been applied to tsunamigenic earthquakes in the Pacific Ocean. At the 2015 Illapel, Chile, earthquake (Mw 8.2), the calculated waveforms show a good reproduction for the observations. At the 2015 earthquake (Mw 6.8) off the west coast of southwestern Japan, the calculated waveforms show the maximum tsunami amplitude of 0.3 mm, indicating quantitatively that tsunamis at the DONET pressure-gauge stations are of lower amplitude than the noise levels of the observations. These results demonstrate that the system is effective in identifying tsunami signals and automatically predicting tsunami propagation in offshore areas, which may be useful for further data analyses on tsunami propagation.

Keywords: tsunami, DONET, pressure gauge, early warning

