Data assimilation of high-density offshore pressure gauge observations for tsunami forecast simulation of the 2012 Haida Gwaii earthquake

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Here, we use a total of 57 tsunami waveforms recorded on the DARTs and a dense array off Oregon and California from the 2012 Haida Gwaii, Canada, earthquake (Sheehan et al., 2015, SRL) to simulate the performance of two different real-time tsunami-forecasting approaches. In the first approach, the fault slip distribution of the earthquake is estimated by inversion of recorded tsunami waveforms. In the second approach, the recorded waveforms on the dense tsunami array are continuously assimilated to produce tsunami wave fields within the vicinity of the stations. These tsunami source model and tsunami wave fields are then used to estimate the tsunami along the coast of Oregon and California. The dense array provides critical data for both methods to produce timely (> 30 minutes lead time) and accurate (> 94% confidence) in both timing and amplitude of tsunami forecasts.

In the first approach, we use tsunami waveform inversion (Satake et al., 2013, BSSA; Gusman et al., 2015, GRL) to estimate the slip distribution of the 2012 earthquake. The fault geometry is based on the W phase solution for the earthquake. Large slip amounts (4 –5 m) are located near the Haida Gwaii trench. The synthetic tsunami waveforms of the fault slip distribution match well the tsunami observations. Therefore, the fault model is suitable for tsunami warning purposes.

In the second approach, the tsunami waveforms are used in tsunami data assimilation method (Maeda et al., 2015, GRL), which does not require any assumption about the tsunami source mechanism. Tsunami wave field is created at every 1 sec, and it can be used as an input for tsunami forward modeling. Realistic tsunami wave fields begin to emerge after the tsunami passes through 5 stations. As more tsunami data are assimilated, the wave fields from this method are gradually become similar to that produced in the first approach that utilized tsunami waveform inversion.

High accuracies of more than 94% in average are produced from data-assimilation wave field at stations near the shoreline. As an example, using the 130 min data-assimilated wave field, the tsunami waveforms at station FS12B is forecasted with an accuracy of 98% about 30 min in advance. The tsunami data assimilation method that we present can be run continuously in real-time and does not require a fault model. Remarkably, the tsunami forecast accuracy from the tsunami data assimilation method is as good as that from the traditional tsunami forecasting method that assumes a fault model. Real-time tsunami data on dense arrays and data assimilation delivers a new generation tsunami warning system.

Keywords: Tsunami data assimilation, Dense tsunami array, The 2012 Haida Gwaii earthquake tsunami, Tsunami forecast, Earthquake source model

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