Real-time tsunami forecast based on simultaneous estimation of tsunami source and non-tsunami signals from offshore tsunami data

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A lot of offshore tsunami-meters such as cabled ocean-bottom pressure sensors and GPS buoys are deployed around Japan and the observed data are used in the JMA’s operation of tsunami early warning. For more accurate tsunami forecast, we are developing tsunami-forecast method that is based on real-time inversion of offshore tsunami-waveform data (tFISH: Tsushima et al., 2009, 2012, JGR). In the method, we assume that offshore tsunami-meter record can be expressed by linear combination of tsunami waveform and coseismic offset due to the permanent seafloor deformation at each pressure sensor. In the actual pressure records, however, coseismic offset and long-wave-period variation which are difficult to be interpreted as coseismic seafloor deformations and tsunamis are sometimes measured (Wallace et al., 2016, JGR; Tsushima and Hino, 2008, ASC Meeting). When the offshore data including such non-tsunami signals are fed into the tFISH, tsunami-source artifacts will be estimated, resulting in degrading accuracy of coastal tsunami predictions. To improve it, Tsushima and Yamamoto (2017, SSJ Meeting) proposed a revision of the tFISH inversion. In this paper, we tested tsunami-forecasting performance of the revised tFISH by conducting numerical simulations in which various interplate earthquakes were assumed. In addition, we propose indices to evaluate reliability of tsunami-forecasting results in real time, because tsunami source artifacts due to non-tsunami signals will not be always reduced sufficiently even by the application of the revised tFISH.

Tsushima and Yamamoto (2017, SSJ Meeting) revised the observation equation of the tFISH inversion to simultaneously estimate not only initial sea-surface height distribution and coseismic seafloor deformations at pressure sensors, but also coseismic offset and linear trend in record of each tsunami-meter (non-tsunami signals). Here, we show an example of the results of the performance tests. In the test, a Mw 8.0 interplate earthquake occurring Off Miyagi was assumed to produce synthetic observation data at S-net and GPS-buoy stations. Maximum amplitudes of non-tsunami signals (i.e. coseismic offset and long-wave-period pressure variations) were assumed to be 0.5 m. When the original tFISH is applied to the synthetic observations in which non-tsunami signals are not included, the accurate source model and the coastal tsunami-height predictions were obtained by inversion of the first 10-min offshore data. However, non-tsunami signals are included in the observation data, the original tFISH inversion provides significant source artifacts and the coastal tsunami heights are over-predicted. This misestimation of source model and coastal tsunami predictions are dramatically improved by applying the revised tFISH. The results show good agreement with the observed ones.

We next propose two kinds of indices to evaluate reliability of tsunami-forecasting results in real time: one is agreement of observed and calculated tsunami waveforms that are used in the inversion. It can be measured by variance reduction (waveform VR). The other index is agreement between a tsunami source that is estimated by the present execution of the inversion and that estimated by the previous execution (10-min before). When tsunamis are observed by offshore tsunami-meters substantially enough to accurately estimate all of the tsunami, seafloor deformation and others, the source estimate is expected to become stable: i.e. the same spatial distribution will be obtained even when more time-length data are used in the inversion. We measure it by using cross-correlation and variance reduction between the two source models (source VR). When all the indices exceed the pre-defined thresholds, we provide score of

“GOOD” for the forecasting results. Otherwise, score of “BAD” will be provided. We set to 0.95 and 0.8 as tentative thresholds for waveform VR and source VR, respectively, and then applied these indices to the forecasting results of Mw 8.0 earthquake mentioned above. As a result, the obtained scores are consistent with accuracies of the tsunami predictions.

Keywords: tsunami forecast, inversion, tsunami warning

