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Effect of offshore tsunami station array configuration on accuracy of near-field tsunami forecast

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1. Introduction

Tsunami forecast based on offshore tsunami data is effective to adequately update tsunami warnings. Several methods have been proposed by recent studies (e.g., Baba et al., 2004; Titov et al., 2005; Tsushima et al., 2009; Hayashi, 2010). Tsushima et al. (2011) applied the tFISH algorithm (Tsushima et al., 2009) retrospectively to the offshore tsunami data from the 2011 Tohoku earthquake, and showed that tFISH is able to contribute to improvement of the forecasts for the coastal sites in the Sanriku region, northern Honshu where many offshore stations were operated at the time of the 2011 Tohoku event. They pointed out that poor azimuthal coverage of offshore stations should degrade forecasts at some coastal sites where no offshore station is located in somewhere along tsunami ray paths to there. In this study, we discuss how an array configuration of offshore tsunami stations affects coastal tsunami forecasts provided by tFISH.

2. Simulation Procedure for Forecasting Tsunami

As a test case, we simulated tsunami forecast of the 2011 Tohoku earthquake. The simulation was carried out as follows: (1) Tsunami waveforms, computed for observation points by assuming a fault model, were regarded as the observed tsunami waveforms. (2) Coastal tsunami waveforms were then estimated from offshore tsunami data by using tFISH. (3) The results of the tsunami forecast were evaluated by comparing the observed waveforms at coastal sites (100 m in water depth) with the predictions from Hokkaido to Kanto.

For calculation of the observed waveforms, we assumed the fault model of Fujii et al. (2011). In the tFISH algorithm, offshore tsunami waveform data are inverted for initial sea-surface height distribution in source region, and then prediction of coastal tsunami waveforms are synthesized by using the estimated height and pre-computed tsunami Green functions.

We here assumed three different array configurations. First consists of the cabled OBPG and GPS buoy stations that were operated during the 2011 Tohoku earthquake, called the existed array configuration. Second consists of the existed array and three additional OBPG stations that are supposed to locate on the inner slope of the Japan Trench, called the IT array configuration. These stations are distributed from off Aomori to off Fukushima with a spacing of ˜200 km nearly parallel to the trench. Third consists of the existed array and three additional OBPG stations that are supposed to locate on the outer part of the Japan Trench, called the OT array configuration.

3. Results

We forecasted coastal tsunami waveforms at 20 min after the mainshock using the observed tsunami data at offshore stations in each configuration. In the case of the existed array configuration, the first peaks of the tsunamis were observed at the two OBPG stations, resulting in a good agreement between the observed and the predicted waveforms at the coastal points near Miyako and Kamaishi. At the other coastal points, however, predicted tsunami amplitudes were halves of the observations. In the case of the IT array configuration, the forecasting results improved dramatically. At the time of 20 min after the event, the pressure variation due to the coseismic seafloor deformation appears on the records at two additional IT array stations. We consider that in this case four offshore OBPG data constrained the source strongly, which make tsunami forecasts accurate. Similar improvements were found in the results for the OT array case. The additional OBPG stations are located far from the source, but the most part of the first tsunami wave was observed there until 20 min after the event because the almost all path run much deep ocean. The present results indicate that when strong tsunami energy were observed at offshore stations, the forecasting accuracy would be improved greatly, even though offshore station was not located between a source region and a coastal point where tsunami should be forecasted.

Keywords: real-time tsunami forecasting, near-field tsunami, ocean bottom pressure gauge, GPS buoy, DART