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Tsunami early warning using high-frequency ocean radar system in the Kii Channel, Japan

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The high-frequency (HF) ocean radar system is a shore-based remote sensing system that monitors sea surface currents, waves, and wind over large areas. It can measure tsunami-induced surface current velocity and provide information for tsunami early warning. An HF ocean radar system, installed by the Ministry of Land, Infrastructure, Transport, and Tourism in Japan, measured the tsunami velocity in the Kii Channel during the 2011 Tohoku earthquake. The Kii Channel is a strait that separates the Japanese island of Shikoku from the Kii Peninsula on the main island of Honshu. It connects the Osaka Bay with the Pacific Ocean.

We adopted the tsunami data assimilation approach to predict coastal tsunami waveforms. It is a method that reconstructs the tsunami wavefield using offshore data without the need for source information (Maeda et al., 2015). To process the HF radar data as the input, we initially converted the current velocity along the beam direction to into u, v directions (i.e., EW, NS directions). This process also involved the spatial interpolation of observational points from the beam of two HF radar land stations. In addition, recognizing the tradeoff between the sampling rate and velocity resolution, we applied a 10-min moving average to enhance data quality. The processed velocity data exhibited consistency with numerical simulations derived from the source model of Satake et al. (2013). The data assimilation started at 08:05 (UTC, hereafter) on March 11, 2011.

We predicted coastal tsunami waveform at Kobe, located in the Osaka Bay, and compared it with real observation recorded by the tide gauge. The forecast at 08:10 underestimated the tsunami amplitude, achieving an accuracy of 50.1% with a mean squared prediction error (MSPE) of 0.0101. However, the forecast at 08:20 matched well with the real observation, boasting an accuracy of 82.9% and a reduced MSPE of 0.0098. At 08:30, it continued to perform similarly, maintaining consistency between the predicted and observed waveforms. The accuracy was 81.3% and the MSPE further decreased to 0.0093. Given that the tsunami arrived in Kobe at 09:10, our approach can make an accurate prediction at least 50 min before its arrival.

To summarize, we demonstrated the effectiveness of the HF ocean radar system in tsunami early warning. The case study of the 2011 Tohoku tsunami yielded a remarkable accuracy of over 80% at Kobe station. In the future, we will investigate the relationship between the number and location of HF radar observational points and the forecast accuracy.