Data assimilation using high-frequency radar for tsunami early warning: A case study of the 2022 Tonga volcanic tsunami

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High-frequency (HF) radar monitors the sea surface current velocity and provides information for tsunami early warning. SeaSondeR, an HF ocean radar system in the eastern Tsugaru Strait, Japan, measured the tsunami-induced current velocity during the 2022 Tonga volcanic tsunami. This event was triggered by the eruption of the Hunga Tonga-Hunga Ha’ apai volcano on January 15, 2022. As an air-coupled tsunami, the generating mechanism was complex, making it difficult to predict coastal tsunamis using traditional early warning methods.

We adopted the tsunami data assimilation approach, which reconstructs the tsunami wavefield using offshore data and does not require source information, to forecast the coastal tsunami waveforms. Observations from the HF radar and offshore bottom pressure gauges (OBPGs) were used as the input for tsunami data assimilation. The assimilation process started at 09:00 (UTC, hereafter) and forecasts were made at 14:00 and 15:00. The surface current velocity recorded by the HF radar reached the maximum (˜0.25 m/s) at 13:00, which corresponded to a negative phase of ˜2 cm sea level variation observed by OBPGs.

The forecasted waveforms were compared with the observed waveforms at Hakodate and Shimokita tide gauges. The assimilation results using OBPG accurately forecasted the tsunami waveforms at Shimokita, especially for the next 2 h after the forecast. However, the forecast underestimated the waveforms at Hakodate. The assimilation results using HF radar matched well with the observations at both Shimokita and Hakodate. Furthermore, for quantitative analysis, we adopted an accuracy index that considers the maximum amplitude in the next 2 h and 6 h after the forecast. At 14:00, the accuracy indices were 91% and 67% for the next 2 h and 6 h, respectively. At 15:00, it was 63% and 70% for the next 2 h and 6 h, respectively. The accuracy indices of the forecast using HF radar were higher than those using OBPG. Thus, we demonstrated the applicability of HF ocean radar system in tsunami data assimilation. This study is the first to apply tsunami data assimilation to early warning using real HF radar observations. The HF ocean radar system could be a good supplement to OBPG for monitoring tsunamis and providing information for data assimilation.