Tsunami Early Warning Using Data Assimilation of Offshore Tsunami Data for Tonga Volcanic Eruption

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Hunga Tonga-Hunga Ha’apai is a submarine volcano in the South Pacific, which is part of the highly active Kermadec-Tonga subduction zone. A large eruption of the volcano occurred at approximately 04:15 UTC, 15 January 2022. It generated tsunami waves across the Pacific Ocean that was recorded by coastal tide gauges and offshore tsunameters. According to the report of Japan Meteorological Agency, the first tsunami wave reached Japan at around 11:30 UTC and the second wave arrived at approximately three hours later. The tide gauge at the Amami Islands recorded a maximum wave height of 1.2 m. No casualties or injuries were reported in Japan, but some boats were damaged in Kochi and Iwate Prefectures.

This event has a complicated mechanism of both eruptive tsunami and air-coupled tsunami, which poses difficulty for traditional tsunami early warning approaches based on source inversion. Tsunami data assimilation is a method of tsunami early warning that does not consider source information (e.g., Maeda et al., 2015). It directly assimilates offshore observed data to reconstruct the tsunami wavefield through optimal interpolation. Then, it makes a forecast by conducting forward simulation. Tsunami data assimilation has been successfully applied to seismogenic tsunamis such as the 2016 Fukushima earthquake (Mw 6.9; Wang et al., 2021).

In this study, we used tsunami records of two offshore observatory networks in Japan: Dense Oceanfloor Network system for Earthquakes and Tsunamis (DONET) and the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net). We employed 44 and 135 available stations of DONET and S-net, respectively, and retroactively predicted the tsunami waveforms at 10 coastal stations in Nankai and Tohoku regions. The waveforms at coastal stations were accurately forecasted by data assimilation at 60 min before arrival, which proves the validity of data assimilation in early warning of volcanic tsunami events. In addition, our method had a better performance in Tohoku region than Nankai region because the stations of S-net are more evenly distributed and thus the wavefield was more accurately reconstructed.

Keywords: Data assimilation, Tonga volcano, Tsunami forecast

