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Spatial-Temporal Rupture Characterization of Potential Tsunamigenic Earthquakes Using Beamforming: Faster and More Accurate Tsunami Early Warning

Amin Aghaee-Naeini[1,2], **Bill Fry**[2], and Jennifer D.Eccles[1]
[1]School of Environment, University of Auckland, Auckland, New Zealand (aagh670@aucklanduni.ac.nz)
[2]GNS Science, Wellington, New Zealand

The Vanuatu Trench hosts tsunamigenic earthquakes exceeding magnitude 7. For these source locations, current tsunami early warning systems in Aotearoa - New Zealand are based on earthquake point-source parameters and as tsunamis propagate, initial forecasts are refined by DART (Deep-ocean Assessment and Reporting of Tsunamis) sea-level analysis. This study, which is part of the R-CET (The Rapid Characterization of Earthquakes and Tsunami) project led by GNS Science, aims to seismologically characterize the spatio-temporal behavior of the regional tsunamigenic ruptures in near real-time. This transition from basic point sources to 4-D rupture propagation could enhance the accuracy of initial tsunami threat maps and hazard response. A new array of broadband seismic stations, designated as the R-CET array, has been strategically deployed in New Zealand to support this analysis for events in the South Pacific.

In this proof-of-concept study, we applied a beamforming array seismological technique to analyze the R-CET array recordings from a recent tsunamigenic earthquake (M_w 7.7) in the Vanuatu region, the Loyalty Islands, on May 19, 2023. We use sliding window fk-analysis beamforming, which can simultaneously measure backazimuth and slowness. Incorporating the sliding window, in conjunction with the fk diagrams, helps to observe temporal azimuthal changes, which facilitates tracking the rupture length and direction over time. Preliminary results showed the azimuthal and temporal variation of the rupture is in alignment with post-processing estimates of the finite fault solution for this event reported by USGS. We test the utility of this analysis in tsunami forecasts by comparing threat maps generated from the beamforming source and initial response maps used in real-time response on the day. We further compare our results to actual measured coastal cancellation gauges (tide gauges) and DART observations. We show that this analysis has the potential to improve initial tsunami forecasts prior to the onset of tsunami waves at deep ocean tsunamimeters. We further present the technique as an enticing path to meet UN Ocean Decade tsunami warning goals within our framework of ensemble and time-dependent forecasting.