Combining Tsunami Waves Reflected at the Coast with the Direct Tsunami Waves: Fault Modelling of the 2016 Te Araroa Earthquake, New Zealand

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The Te Araroa earthquake occurred in the subducting plate in the Hikurangi subduction zone on September 1, 2016 (UTC) (Mw 7.1, GCMT). When this event occurred, ocean bottom pressure gauges (OBPs), installed ~170 km south of the source area, clearly recorded tsunami from the source to OBPs and from coastal-reflections (Figure 1). We estimated the finite fault model of the Te Araroa earthquake using the both direct and reflected tsunami waveforms. We note that the coastal reflected tsunamis have not been explicitly used for earthquake source modelling, although they have been found by the previous researches (e.g., Saito et al., 2013; Gusman et al., 2017).

We first searched the centroid location (longitude and latitude) and source dimension (length and width) to best reproduce the OBP waveforms. When using the direct tsunami alone, the horizontal location was poorly constrained (uncertainty of ~100 km), whereas by adding the reflected waves we obtain a centroid near the GCMT centroid with smaller uncertainty (~40 km). We also found a smaller source dimension (L < ~30 km) is not plausible. We also conducted the finite fault inversion for the slip distribution (Figure 1). We obtained the maximum slip of 0.9 m and $M_o = 4.3 \times 10^{19}$ Nm (Mw 7.03; μ = 40 MPa). Using this model, we calculated the energy-based stress drop $\Delta\sigma_E$ (e.g., Noda et al., 2013) as 1.0 MPa, which is consistent with the typical stress drop values (~1 – 10 MPa) [e.g., Ye et al., 2016], but larger than the values for tsunami earthquakes, characterized by extremely low stress drops (< ~ 1 MPa) [e.g., Ye et al., 2016].

We could constrain the finite fault model of the Te Araroa earthquake by utilizing the direct and coastal reflected tsunami waves observed by offshore OBPs, which was difficult to obtain from the onshore seismic data alone. The additional information provided by coastal reflected tsunami coda, recorded using OBPs, will improve earthquake source modelling.

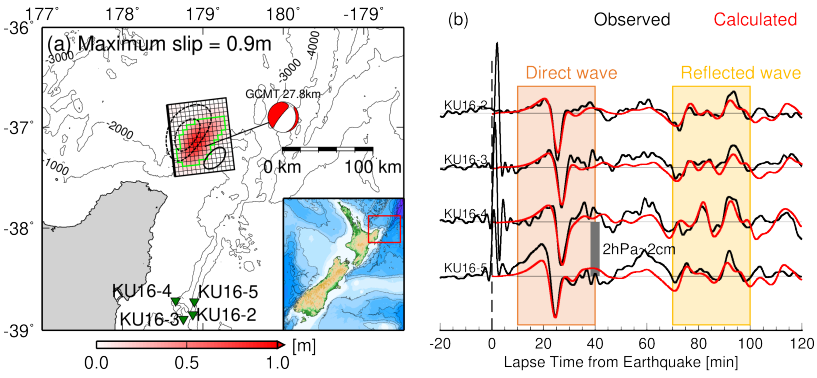

Figure 1. (a) Result of the finite fault inversion. The areas surrounded by green rectangles are the subfaults slip larger than 20% of the maximum slip. (b) Comparison of the observed (black) and calculated (red) waveforms.