Fault model of the Te Araroa earthquake, New Zealand, using ocean bottom pressure records

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On September 1, 2016 (UTC), the Te Araroa earthquake (Mw 7.0), with a normal-faulting mechanism, occurred in the subducting plate in the Hikurangi subduction zone. By comparing the regional onshore seismograms of this event and the smaller precursor events, Warren-Smith et al. (2018) suggested that this event is possible to have a larger source dimension (i.e., larger fault length and width) than that expected from typical fault scaling relationships. However, they could not discuss it in detail since this earthquake occurred far from the coast and the azimuthal coverage of the seismic stations was poor. When this event occurred, ocean bottom pressure gauges (OBPs) were installed ~170 km south of the source area and they clearly observed tsunamis from the source to OBPs (direct waves) and from coastal-reflections (reflected waves) (Figure 1). Since tsunami data contain unique information about the area of seafloor deformation (the extent of the tsunami source) and the tradeoff between the fault dimension and the rupture velocity is much less significant than the seismic waves, tsunami data have an advantage in constraining earthquake source dimensions. In this study, we investigated the tsunami data associalted with the Te Araroa earthquake to estimate the finite fault model, in order to discuss the fault dimensions. We note that we used the reflected waves, which have not been explicitly used by the previous researches, for earthquake source modelling, in addition to the direct waves.

We first constrained the centroid horizontal location and source dimension, based on the grid-search approach. As a result, we obtained a centroid near the GCMT centroid and found that the models using coastal reflections require a source dimension larger than ~ 30 km long. Using these results as a prior information, we then estimated the slip distribution by inverting tsunami waveforms (Figure 1a). We obtained the maximum slip of 0.9 m and Mo = 4.3×10^{19} Nm (Mw 7.03; μ = 40 MPa). Using this model, we calculated the shear stress change distribution (Figure 1b) and obtained the energy-based stress drop $\Delta\sigma_E$ (e.g., Noda et al., 2013) as 1.0 MPa. This value was consistent with the typical stress drop values (~ 1 – 10 MPa) (e.g., Ye et al., 2016) although is on the low end of these, and was consistent with the large fault dimension suggested by Warren-Smith et al. (2018).

Using the tsunami waves from both the direct and the coastal reflected waves observed by offshore OBPs, we could constrain the stress drop value of the Te Araroa earthquake in detail. This study shows that the information from the direct and the coastal-reflected tsunami data observed by the offshore OBPs provides us tighter constraints on the source parameter estimation of offshore moderate earthquakes, which is usually difficult to obtain from the onshore seismic data alone.

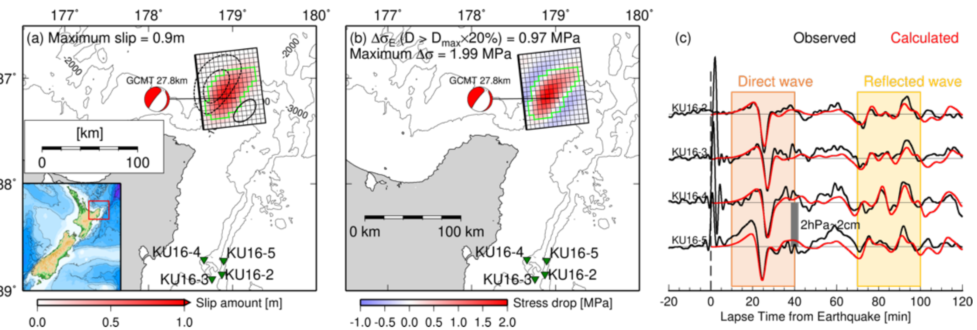

Figure 1. (a) Slip distribution obtained from the finite fault inversion. The area surrounded by green lines is the subfaults with slip larger than 20% of the maximum slip. The iso-depth contour lines are drawn at 1000 m interval. (b) Distribution of the shear stress change on the fault. Positive value denotes the stress reduction. (c) Comparison of the observed (black) and calculated (red) waveforms.