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Constraints on the Properties of Subduction-Related Earthquakes Using Array Data

Miaki Ishii[1*], Eric Kiser[1]

[1]Harvard University

Recent occurrence of giant earthquakes has been captured by large-aperture arrays such as the High Sensitivity Seismograph Network (Hi-net) in Japan and the Transportable Array component (TA) of the USArray project in the United States. These data provide unprecedented opportunity to constrain properties of these events with the back-projection technique. Unlike conventional finite-fault source modelling, the back-projection method requires very little a priori information, allowing robust estimates of parameters such as rupture speed and spatio-temporal distribution of energy release.

We have analyzed a subset of shallow and intermediate depth earthquakes that occurred between 2001 and 2010 using the back-projection technique applied to the Hi-net and TA data. For some of the events, the spatial and temporal resolution achieved either by the combination of arrays or seismic phases allows detailed imaging of the energy release process of these giant earthquakes. For example, the rupture process of the 2010 Mw 8.8 Maule, Chile earthquake can be obtained using the TA array data. The back-projection results show that this earthquake consists of three segments with very different characteristics. The northernmost segment is characterized by high rupture speed and strong energy release at high frequency. The latitudinal extent of this segment is consistent with that of the 1985 Valparaiso Mw 8.0 Valparaiso earthquake. The central segment is the region around the epicentre which ruptures bilaterally away from the epicentre. The energy release is uneven, and is much stronger to the north than to the south. The northern rupture propagates with a speed of about 2.2 km/s. The boundary between the north and central segments is represented by a gap in rupture and break in aftershock distribution. The timing of the terminus of the rupture of the central segment and initiation of the northern rupture is such that continuous rupture is unlikely, and that dynamic triggering is involved. The third segment is the southernmost segment, and is characterized by very slow rupture speed of 0.8 km/s, and highest relative energy release at low frequency. The central and south segments cover the region that is thought to have broken during the 1835 Charles Darwin earthquake.

Based upon analysis of a number of giant earthquakes, we conclude that dynamic triggering and segmentation of fault are common features. For shallow megathrust events, the locations of breaks in rupture appear to correlate well with change in seismic coupling of the slab interface. The back-projection analysis also indicates that each segment has very different properties. Released energy from segments peaks at various frequencies, implying that seismic hazard assessment requires source studies spanning a wide range of frequencies.