

Stress drop variations among small earthquakes in the Tohoku-oki region - implications for the 2011 megathrust event

UCHIDE, Takahiko^{1*} ; SHEARER, Peter² ; IMANISHI, Kazutoshi¹

¹Geological Survey of Japan, AIST, ²Scripps Institution of Oceanography, UC San Diego

It is important to assess the likely rupture characteristics of future megathrust earthquakes. One approach is to study the spatio-temporal variation of geophysical properties in active subduction zones. We explore this idea by examining stress drops of 1536 small earthquakes (Mw 3.0 - 4.5) shallower than 80 km in the Tohoku-oki region before the 2011 Tohoku-oki earthquake. We estimate stress drops using the spectral analysis method described by Shearer et al. [2006], which isolates source, path, and receiver terms and then applies an empirical Green's function (EGF) correction before computing corner frequencies and stress drops using the Madariaga [1976] model.

We find an overall increase in stress drop with depth, as well as lateral variations in stress drop along strike. Higher-than-average stress drops are found in East Aomori-oki and Miyagi-oki, whereas Sanriku-oki is a moderate stress-drop area. The high stress-drop zone in Miyagi-oki is located just south of the large slip area of the 2011 Tohoku-oki earthquake, and possibly acted as a barrier to further rupture propagation during the event. The Miyagi-oki high-stress-drop zone is located on west of the 1978 Miyagi-oki earthquake rupture area.

Stress drops of earthquakes in the large slip patch of the 2011 Tohoku-oki earthquake are comparable to the mainshock stress drop. Since studies [Hasegawa et al., 2011; Yagi and Fukahata, 2011] indicate that the 2011 Tohoku-oki earthquake released nearly all the stored shear stress, our findings suggest that small earthquakes prior to the mainshock also released a large fraction of the accumulated shear stress. Note that the absolute values of the stress drops of small earthquakes are not well constrained due to assumptions such as the choice of source models, whereas the relative values among the stress drops of small earthquakes are better resolved. Therefore the hypothesis of nearly complete stress drops for the small earthquakes needs to be confirmed by other approaches.

In addition, the frequency dependence of the seismic radiation observed during the mainshock, with proportionally higher frequencies coming from the deeper parts of the fault, mimics the depth dependence we see in small earthquakes in the same region.

These results imply that smaller pre-mainshock earthquakes can provide insights into the fault properties and consequent rupture processes of future megathrust earthquakes.

Keywords: The 2011 Tohoku-oki earthquake, Stress drop, Miyagi-oki, Spatial Heterogeneity of Fault Properties