Geophysical Research Abstracts
Vol. 20, EGU2018-10955, 2018
EGU General Assembly 2018

The Hidden Simplicity of Large Subduction Earthquakes and its Implications for Rupture Dynamics

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The largest observed earthquakes occur on subduction interfaces and come in an impressive diversity of shapes and forms. In particular the rupture evolution of the largest events, Mw>=8, seem to have little in common with one another, raising the question of whether or not they can be efficiently described by a single basic model. We perform a statistical analysis of the temporal evolution of more than 100 large subduction zone thrust earthquakes, using three independent compilations of earthquake source time functions (STFs) with Mw>=7, derived from teleseismic data with three different methods. We find that, despite the large variability of individual events, large ruptures share a typical universal behavior. The typical STF is nearly triangular and symmetric. We compare STFs in a range of magnitude bins and find that, after re-scaling, the median STFs are nearly identical. This scalability, however, is different than that implied by conventional self-similar rupture models. In fact, the observed linear moment rate growth stands in contrast to the quadratic growth predicted by self-similar pulse and crack models. This discrepancy suggests that these large events behave differently from the smaller Mw<7 events for which self-similar scaling is well established with abundant data. Furthermore, the deviations from the median STF behavior are multiplicative rather than additive, i.e. they are directly proportional to the STF amplitudes and, consequently, larger for larger events. Smaller and larger earthquakes are statistically indistinguishable until the smaller events reach peak moment rates, which has implications for earthquake early warning efforts. We discuss how these observations provide constraints for various aspects of earthquake rupture physics.