Geophysical Research Abstracts
Vol. 18, EGU2016-12062, 2016
EGU General Assembly 2016

Evolution of earthquake rupture potential along active faults, inferred from seismicity rates and size distributions

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One of the major unresolved questions in seismology is the evolution in time and space of the earthquake rupture potential and thus time-dependent hazard along active faults. What happens after a major event: is the potential for further large events reduced as predicted from elastic rebound, or increased as proposed by current-state short-term clustering models? How does the rupture potential distribute in space, i.e. does it reveal imprints of stress transfer? Based on the rich earthquake record from the Pacific Plate along the Japanese coastline we investigate what information on spatial distributions and temporal changes of a normalized rupture potential (NRP) for different magnitudes can be derived from time-varying, local statistical characteristics of well and frequently observed small-to-moderate seismicity. Seismicity records show strong spatio-temporal variability in both activity rates and size distribution. We analyze 18 years of seismicity, including the massive 2011 M9 Tohoku earthquake and its aftermath. We show that the size distribution of earthquakes has significantly changed before (increased fraction of larger magnitudes) and after that mainshock (increased fraction of smaller magnitudes), strongest in areas of highest coseismic slip. Remarkably, a rapid recovery of this effect is observed within only few years.

We combine this significant temporal variability in earthquake size distributions with local activity rates and infer the evolution of NRP distributions. We study complex spatial patterns and how they evolve, and more detailed temporal characteristics in a simplified spatial selection, i.e. inside and outside the high slip zone of the M9 earthquake. We resolve an immediate and strong NRP increase for large events prior to the Tohoku event in the subsequent high slip patch and a very rapid decrease inside this high-stress-release area, coupled with a lasting increase of NRP in the immediate surroundings. Even in the center of the Tohoku rupture, the NRP for large magnitudes has not dropped below long-term average values and is now not significantly different from conditions a decade before the M9 event.