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Size dependent rupture growth at the scale of real earthquake

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When an earthquake starts, the rupture process may evolve in a variety of ways, resulting in the occurrence of different magnitude earthquakes, with variable areal extent and slip, and this may produce an unpredictable damage distribution around the fault zone. The cause of the observed diversity of the rupture process evolution is unknown. There are studies supporting the idea that all earthquakes arise in the same way, while the mechanical conditions of the fault zone may determine the propagation and generation of small or large earthquakes. Other studies show that small and large earthquakes are different from the initial stage of the rupture beginning. Among them, Colombelli et al. (2014) observed that the initial slope of the P-wave peak displacement could be a discriminant for the final earthquake size, so that small and large ruptures show a different behavior in their initial stage.

In this work we perform a detailed analysis of the time evolution of the P-wave peak amplitude for a set of few, co-located events, during the 2008, Iwate-Miyagi (Japan) earthquake sequence. The events have magnitude between 3.2 and 7.2 and their epicentral coordinates vary in a narrow range, with a maximum distance among the epicenters of about 15 km. After applying a refined technique for data processing, we measured the initial Peak Displacement (Pd) as the absolute value of the vertical component of displacement records, starting from the P-wave arrival time and progressively expanding the time window. For each event, we corrected the observed Pd values at different stations for the distance effect and computed the average logarithm of Pd as a function of time.

The overall shape of the Pd curves (in log-lin scale) is consistent with what has been previously observed for a larger dataset by Colombelli et al. (2014). The initial amplitude begins with small values and then increases with time, until a plateau level is reached. However, we observed essential differences in the time evolution of Pd between small and large earthquakes, with very rapid time variations for small-to-moderate events, and a smoother evolution of the curve for the large events, even at the very beginning of the rupture process. Our observations, along with previous laboratory rupture experiments, support the evidence for a characterizing size of the earthquake nucleation zone, which plays a key role in the following rupture evolution, affecting the fate of the earthquake in terms of final rupture extent.

Using the Iwate-Miyagi sequence data, we investigated how to quickly measure the initial slope variation of the recorded signals, in order to rapidly distinguish a small event from a large earthquake. The proposed approach could be used in real-time, in the context of Earthquake Early Warning Applications, to quickly infer the expected size of the ongoing event and possibly activate the issuance of a warning.