Probabilistic Prediction of Rupture Length, Slip and Seismic Ground Motions for an Ongoing Rupture

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Earthquake Early Warning (EEW) predicts future shaking based on presently available data. Long ruptures present the best opportunities for early warning since many heavily shaken areas are distant from the epicenter. However, prediction of shaking for long ruptures requires some estimate of the likelihood of future rupture of an on-going rupture. An EEW system based on the Gutenberg-Richter (G-R) frequency-size statistics will likely never predict a large earthquake, because of their rare occurrence. For instance, according to the G-R relationship, the probability that an earthquake that is currently measured at M 5.5 will eventually grow into a M > 7.5 is only 1%. However, in the Characteristic Earthquake (CE) model, the occurrence of a "Big One" may be far more likely if the rupture is occurring on a fault that experiences large characteristic earthquakes. In order to further explore this issue, we simulate slip on faults using a simple 1-d slip pulse model of rupture in which slip amplitude varies stochastically along the fault (a kind of random walk), the degree of spatial heterogeneity is characterized by the spectral decay $k^{-\alpha}$ of the Fourier amplitude spectrum of slip $\tilde{D}(k)$ vs. wavenumber k. That is, $\tilde{D}(k) = D_0 \tilde{R}(k)(1+k)^{-\alpha}$, where D_0 is a normalization factor designed to match observed rupture data and $\tilde{R}(k)$ is the Fourier transform of Gaussian white noise. Smaller values of α produce spatially irregular slip distributions, whereas larger values of α produce smoother distributions. We declare the end of the rupture to occur when the slip changes sign as a function of position on the fault; that is, when the slip goes to zero. Rough slip distributions $(\alpha \sim 1.1)$ produce many small earthquakes, similar to a G-R distribution. In contrast, smooth distributions $(\alpha \sim 1.5)$ produce mostly large events, similar to a characteristic earthquake.

We study the statistics of many earthquakes simulated with this simple model. In particular, what is the probability of remaining rupture as a function of present slip amplitudes, D_p , of the ongoing rupture? We find that large present slip amplitudes increase the probability for the continuation of a rupture and the possible evolution into a large earthquake. More important, however, is the choice of the spatial roughness parameter α. If faults can be characterized *a priori* by their smoothness, then we conclude that recognition that rupture is occurring on a smooth fault results in a higher probability of a long rupture. For example, recognizing that an event is occurring on the Carrizo segment of the San Andreas Fault should result in a higher probability of a long ultimate rupture than if the same size slip were recognized on a more irregular fault. This line of reasoning indicates the importance of robustly recognizing slip on a few key through-going faults. This might be accomplished by monitoring the difference in displacement vectors from stations on opposite sides of key faults.