Harvard University -- Solid Earth Physics Seminar

From Stable to Destructive: How Creeping Fault Segments Can Join Earthquakes and Implications for Seismic Hazard

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Thursday 5 April 2012, 2:30 pm
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Seismic and aseismic fault slip is often assumed to be separated in space and to occur on two different types of fault segments: one with stable friction properties and the other with potentially unstable, weakening, friction that leads to stick-slip. The 2011 Mw 9 Tohoku-Oki earthquake shook such assumptions by accumulating its largest seismic slip in the area that was assumed to be creeping. We propose a model in which stable, rate-strengthening behavior at low, aseismic slip rates is combined with co-seismic weakening due to rapid shear heating, allowing unstable slip to occur in segments which can also creep between events (Noda and Lapusta, 2012). The model parameters are constrained by lab measurements on samples from the fault of 1999 Mw 7.6 Chi-Chi earthquake in Taiwan. The long-term slip behavior of the model is examined using a numerical approach that simulates both earthquake sequences and stable slip while including all wave effects. The model explains how the largest slip in Tohoku-Oki earthquake could occur in a creeping segment as well as reproduces the overall pattern of large events in the area. The model also reproduces one of the most puzzling observations from both Chi-Chi and Tohoku-Oki earthquakes, that areas of lower slip radiate more high-frequency energy than areas of higher slip. The implication that seismic slip may break through large portions of creeping segments - currently perceived as barriers – requires re-evaluation of seismic hazard in many areas, including the creeping segment of the San Andreas fault next to Parkfield. We will present indirect evidence for enhanced co-seismic weakening during repeating earthquakes in the creeping segment (Chen and Lapusta, 2012). Understanding if and when this weakening may extend to the surrounding creeping areas is an important area of further laboratory, paleoseismic, and theoretical studies.