Modeling moment-duration relation of aseismic slip events in subduction zones

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Observations of the "slow earthquake" phenomena, including aseismic slow slip events, afterslips, and low-frequency earthquakes at different tectonic settings, suggest a linear relation between their moments and characteristic durations [*Ide et al.*, 2007]. Following *Liu and Rice* [2007], we study the moment duration relation by applying rate and state friction to model short-period aseismic transients, which occur spontaneously in the times between great subduction earthquakes when pore pressure is near lithostatic around the stability transitional depth. Specifically, we assume a constantly low effective normal stress $\bar{\sigma}$ ($= \sigma - p$) within a zone extending W up-dip and down-dip, respectively, from the stability transition, and much higher $\bar{\sigma}$ beyond. By varying W and $\bar{\sigma}$ independently and keeping W/h^* in the range where occurrence of spontaneous transients is allowed, we can produce abundant aseismic transients with moments and durations spanning several orders of magnitude.

There are three major features noticed from the collection of moment (M) and duration (T) of the modeled transients. First, all events lie within a well defined band that follows the linear trend of $M \propto T$. Second, events of a fixed width of low $\bar{\sigma}$ follow a more strictly defined linear trend, even with moderate variations in W/h^*. For the same W/h^*, moment and duration increase linearly with $\bar{\sigma}$. Third, as the region of low $\bar{\sigma}$ decreases in size, the linear trend $M \propto T$ migrates toward regimes of smaller moment and shorter duration. Temperature profiles of friction parameter $a-b$ of granite under wet [*Blanpied et al.*, 1998] and dry [*Lockner et al.*, 1986] conditions are applied and both consistently show the three features. If the existence of near-lithostatic pore pressure around the stability transition is the origin of multiple episodes of slow slip events observed worldwide, our simulation shows that the level of pore pressure and the spatial extent of the high pore pressure zone contribute to the linear relation between events moment and duration. Moment and duration here are determined when the moment rate exceeds the steady-state rate within the low $\bar{\sigma}$ zone, where aseismic slip takes place. An alternate criterion of choosing moment and duration when the maximum slip rate exceeds the steady-state rate results in a similar linear relation. The along-strike width of fault involved in transient slips are not included in this current 2D model; we used a nominal $W_{strike} = 100$ km in the moment calculation. The modeled linear band would only shift slightly in the vicinity of the empirical M/[N-m] $= 10^{12-13}T$/[s] given the variance in the observed W_{strike}.