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Modeling earthquake occurrence and recurrence for supercycles and clusters

James Neely[1], Leah Salditch[1], Seth Stein[1], and Bruce Spencer[2]
[1]Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL, USA
[2]Department of Statistics, Northwestern University, Evanston, IL, USA

Long records often show large earthquakes occurring in supercycles—temporal clusters of seismicity, cumulative displacement, and cumulative strain release separated by less active intervals. Presently used earthquake recurrence models do not account for the time dependence and clustering. Poisson models assume that earthquake recurrence is time-independent, but seismicity studies have shown that time is needed to accumulate strain along a fault before another large earthquake. Seismic cycle/renewal models account for this time-dependence but assume that all strain is released after large earthquakes and fail to replicate clustered earthquake behavior. The resulting probability estimates for recurrence of the next earthquake thus depend crucially on whether the cluster is treated as ongoing or over.

In this study, we have reformulated our previously developed Long-Term Fault Memory (LTFM) earthquake model as a Markov process to better quantify long-term earthquake behavior and the probability of future earthquakes. In the LTFM model, the probability of a large earthquake reflects accumulated strain rather than elapsed time. The probability increases with accumulated strain (and time) until an earthquake happens, after which the probability decreases, but not necessarily to zero. This simple, strain-driven recurrence model yields realistic sequences of large earthquakes with periods of elevated activity followed by longer quiescence. Using the Markov formulation, we explore long-term earthquake behavior and how to use paleoseismic records to better estimate the recurrence and probability of future large earthquakes.