Large Earthquake Cycles and Intermittent Criticality On Heterogeneous Faults Due To Evolving Stress And Seismicity

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We analyze evolving stress and seismicity generated by three realizations of a discrete model of a strike-slip fault in a 3D elastic half-space using five functions of stress and five functions of seismicity. The first model (F) has realistic dynamic weakening (static minus dynamic frictions), the second (FC) has zero critical dynamic weakening, and the third (SYS) is constrained to produce only system-size events. The results for model F show cyclical development, saturation, and destruction of fluctuations and long range correlations on the fault, punctuated by the system-size events. The development stage involves evolution of stress and seismicity to distributions having broad ranges of scales, evolution of response functions toward scale-invariant behavior, increasing seismicity rate and event sizes, and increasing hypocenter diffusion. Most functions reach asymptotically stable values around 2/3 of the cycle and then fluctuate until one event cascades to become the next large earthquake. In model FC the above evolution is replaced by scale-invariant statistical fluctuations, while in model SYS the signals show simple cyclic behavior. The results suggest that large earthquake cycles on heterogeneous faults with realistic positive dynamic weakening are associated with intermittent criticality, produced by spontaneous evolution of stress heterogeneities toward a critical level of disorder having a broad range of scales. The stress evolution and development of large earthquake cycles may be tracked with seismicity functions. Continuing analysis of evolving stress and seismicity signals can provide a better understanding of earthquake dynamics and suggest new target signals for statistical forecasting of large events.