Earthquake Precursors: Activation or Quiescence, or Something Else?

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We discuss the long-standing question of whether the probability for earthquake occurrence is highest during time periods of smaller-event activation, or highest during time periods of smaller-event quiescence. The physics of the activation model are based on an idea from the theory of nucleation, that a small magnitude earthquake has a finite probability of growing into a large earthquake. The physics of the quiescence model is based on the idea that the occurrence of smaller earthquakes may be due to a mechanism such as critical slowing down, in which fluctuations in systems with long range interactions tend to be suppressed prior to large nucleation events. To illuminate this question, we construct two end-member forecast models illustrating, respectively, activation and quiescence. These models are in fact a means of filtering the seismicity time series to compute probabilities. We have considered two types of forecast models for large earthquakes. Both use the rate of occurrence of small earthquakes to forecast the occurrence of large earthquakes. The first is an activation model, in which a high recent rate of activity of small earthquakes is assumed to imply a high probability of a future large earthquake. The second is a quiescence model, in which a low recent rate of activity of small earthquakes is assumed to imply a high probability of a future large earthquake. For the activation model, the occurrence of a large earthquake is typically immediately followed by a large increase in probability for a future large earthquake (the highest probability for the large earthquake is seen immediately after it happens). For the quiescence model, the occurrence of a large earthquake typically leads to a sudden drop in probability for a future large earthquake (the lowest probability for the large earthquake is seen immediately after it happens). Models of the activation type include the ETAS (Ogata, 2005), BASS (Holliday et al., 2007), and STEP (Gerstenberger et. al, 2005) models. While quiescence as a precursor has been proposed (Wyss et al., 1996), there are apparently no quiescence models in the literature comparable to the quiescence model described here. We compared the two models using standard verification tests described in the literature. We also computed errors using the standard bootstrap methods. Using 25 years of catalog seismicity data for California and Nevada, we find that there is a small preference for the quiescence model, although the difference in computed verification values is typically near the noise level.