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A composite model of expected earthquake rates in California based on intermediate-term precursory patterns

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During last years a significant progress in developing and testing earthquake forecasting models was demonstrated, especially due to the activity of the Collaboratory for the Study of Earthquake Predictability (SCEP). Large number of forecasting models have been installed for testing in SCEP centers, most of them forecasting earthquakes rates in various time scales (from days to years). The models demonstrating the best accordance with reality are based on spatial and/or temporal clustering of seismicity. Those models, however, deal with very low probabilities of large earthquakes, the only exception is short-term forecasting right after largest earthquakes.

A different paradigm of earthquake prediction is based on the idea to look for symptoms of instability in a complex system, lithosphere. The group of Vladimir Keilis-Borok and his followers developed methods of the recognition of a pre-earthquake state, studying various precursory seismicity patterns. Earthquake prediction algorithms of this kind usually are based on pattern recognition techniques and do not estimate earthquake probabilities or expected rates.

Recently Shebalin et al. (2012, 2014) have proposed a method to convert non-probabilistic prediction models into rate-based ones and to combine such prediction algorithms or single precursors with existing rate-based forecasting models. The method is based on the idea that even non-probabilistic models have probabilistic properties due to the statistics of their application. Our Differential Probability Gain approach employs actual relation between errors of the to kinds, false alarms and failures to predict.

Here a propose a first attempt to combine several precursory seismicity patterns with a simple time-independent reference rate-based model of relative intensities. The output model is aimed to forecast the rates of earthquakes of magnitude M=5 and above in cells in CSEP California testing region, with a time step 3 months. The precursory patterns I use are 4 out of 8 patterns previously used in the Reverse Tracing of Precursors (RTP) algorithm (Shebalin et al., 2003, 2006; Keilis-Borok et al., 2002, 2004): “Activity”, “Gamma”, “Acceleration”, and “b-micro”. The period 1960 to 1984 was used to estimate parameters for combining, an independent retrospective test was performed in the period 1985-2016.

The composite model demonstrates high performance relative to a smoothed seismicity reference model. The log likelihood gain per target earthquake in the testing period is equal to 2.8. The output model is characterized by strong redistribution of the expected rates in comparison to the reference model. For example, for the interval April 1 to June 30, 2010 50% of expected earthquake rates were concentrated in 0.46% of the testing area (including epicenter of El Mayor – Cucapah M=7.3 earthquake of April 4, 2010), while for the reference model 50% of the total rate are in 8.2% of highest rate cells.

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