GLOBAL EARTHQUAKE FORECASTS AND HOW TO TEST THEM

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Rigorous testing of earthquake forecasts is challenging for several reasons: (1) Earthquakes cluster strongly, and one event can change radically change the probabilities of following ones. (2) Overlapping shaking from multiple near-simultaneous earthquakes makes it impossible to identify individual events. (3) Earthquake forecasts come in many forms, including contour maps of earthquake probability, fault based forecasts, and forecasts that are only activated when prescribed geophysical anomalies are detected. Many forecasts prescribe probabilities of a finite set of scenario earthquakes without clear rules on how to associate future earthquakes to events in the set.

We compare several tests, including likelihood ratio tests and measures based on the error diagram and the receiver operating curve. We apply these tests to synthetic earthquake catalogs and to our 1999 forecast of earthquakes in the NW Pacific and SW Pacific plate boundary zones.

The Collaboratory for the Study of Earthquake Predictability proposes to test several forecast hypotheses on a global scale against future earthquakes. We propose strategies for testing both long-term and short-term forecasts. One suggestion is to separate temporal behavior from space and magnitude dependence, replacing a variable-mean Poisson hypothesis with an empirically derived substitute. Another is to use a magnitude-dependent mask on a time-space interval following any large earthquake to account for short-term catalog incompleteness.

The algorithm FORMA for the short-term prediction of the mainshock from foreshocks

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ABSTRACT

During periods of intense earthquake activity, one of the main issues is to identify features of the time-dependent seismic hazard in near real-time conditions. Of special importance is the evaluation of the nature of a particular earthquake sequence, that is the discrimination between foreshocks-mainshock-aftershocks. We present the progress made to build up, calibrate and test the self-learning automated system FORMA (FOReshock-Mainshock-Aftershock). The system consists of earthquake data bases, an algorithm which performs the statistical tests, and a decision matrix which indicates the level of alert. The data basis is automatically updated from the results of the daily analysis of the national monitoring seismograph system. The algorithm updates calculations regarding seismicity rate and b-value changes and performs statistical tests for the significance of change. The decision matrix calculates the level of alert by companying together the level of significance for both the seismicity rate change and the b-value change. The development of the system incorporated three stages. Stage 1 is devoted to the design and construction of the system. Stage 2 includes the development of the “learning” phase of the system based on testing several earthquake sequences in Greece. Finally, stage 3 includes the validation on past earthquakes, while applications are performed in real time conditions of the Greek seismicity. We present the last progress and show prospects for further testing not only in Greece but also in other seismogenic areas. This is a contribution to the EU research project SAFER, contract n. 036935, FP6-2005-Global-4, Reduction of Seismic Risks.

GERASSIMOS A. PAPADOPOULOS’ BIOGRAPHY

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Mixture models for improved earthquake forecasting

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ABSTRACT

Earthquake likelihood models based on a single idea or methodology may capture certain, but not all, elements of earthquake occurrence. Therefore, in prospective testing, such models may forecast some earthquakes relatively well, but not others. The effect of the latter earthquakes can be very detrimental to the model's overall likelihood score. For this reason, hybrid models, which combine several ideas or methodologies, are likely to perform better than models based on a single method, provided that each of the individual methods is informative to some degree. A simple way to generate hybrid models is by forming mixtures – convex linear combinations of the rate densities of the individual models.

The short-term earthquake probability (STEP) forecasting model applies the modified Omori-Utsu aftershock-decay relation and the Gutenberg-Richter frequency-magnitude relation to clusters of earthquakes. It is intended mainly to forecast aftershock activity, and depends on a time-invariant background model to forecast most of the major earthquakes. On the other hand, the long-range earthquake forecasting model EEPAS – "Every Earthquake a Precursor According to Scale" exploits the precursory scale increase phenomenon and associated predictive scaling relations to forecast the major earthquakes months, years or decades in advance, depending on magnitude. Both models have been shown to be more informative than time-invariant models of seismicity. By forming a mixture of the two, we aim to create an even more informative short-term forecasting model. Using the ANSS catalogue of California over the period 1984 – 2004, the optimal mixture for forecasting earthquakes with magnitude $M \geq 5.0$ is a convex linear combination consisting of 0.42 of the EEPAS forecast and 0.58 of the STEP forecast. This mixture gives an average probability gain of more than 2 compared to each of the individual models. The optimal mixture model will be submitted to the CSEP Testing Center at the Southern California Earthquake Center to ascertain whether this result is borne out by real-time tests of the models against future earthquakes.

When fitting the EEPAS model to a catalogue, the likelihood surface is often rather flat near its optimum, indicating near-optimal performance over a range of parameter values. Also a number of variations on the EEPAS model now exist, taking into account different weighting strategies and parameterizations. We show examples where a mixture of EEPAS models, with different weighting strategies and/or sets of parameter values, give a better fit to the data than a single optimal version of the model, and where the mixture also performs better in tests on an independent catalogue with an average probability gain up to 1.3.

These examples suggest that when prospective tests have been carried out of many regional earthquake likelihood models based on different methodologies, there will be wide opportunities for forming mixtures which can outperform any individual model.

Key words: Earthquake forecasting, regional earthquake likelihood models

PRESENTER'S BIOGRAPHY

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24h High-Resolution Earthquake Forecasts for California

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We implemented a daily forecast of m > 4 earthquakes for California in the format suitable for prospective testing in the community-based earthquake predictability experiment: the Collaboratory for the Study of Earthquake Predictability (CSEP). The forecast, also available online, uses near-real time seismicity data from the ANSS above magnitude 2 and is updated every 24h at midnight UTC. The model is based on the Epidemic-Type Earthquake Sequence (ETES) model, a stochastic model of clustered and triggered seismicity [Ogata, 1988]. Our particular implementation builds on earlier work by Helmstetter et al. (2006, 2007), but we extended the forecast to all of California, use more data to calibrate the model and its parameters, and made some modifications. We summarize results from the calibration of the model and the maximum likelihood estimation of its parameters. Confirming a previous finding, retrospective tests suggest that including small earthquakes with magnitude m > 2 significantly improves the spatial forecast of m > 4 earthquakes. In contrast to other, relatively smooth models in the next-day testing class of CSEP, our forecasts have high resolution. We illustrate our forecasts with examples and evaluate the performance of the forecasts up to the present using the likelihood score.