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Short-term earthquake forecasting based on an epidemic clustering model

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The application of rigorous statistical tools, with the aim of verifying any prediction method, requires a univocal definition of the hypothesis, or the model, characterizing the concerned anomaly or precursor, so as it can be objectively recognized in any circumstance and by any observer. This is mandatory to build up on the old-fashion approach consisting only of the retrospective anecdotic study of past cases. A rigorous definition of an earthquake forecasting hypothesis should lead to the objective identification of particular sub-volumes (usually named alarm volumes) of the total time-space volume within which the probability of occurrence of strong earthquakes is higher than the usual. The test of a similar hypothesis needs the observation of a sufficient number of past cases upon which a statistical analysis is possible. This analysis should be aimed to determine the rate at which the precursor has been followed (success rate) or not followed (false alarm rate) by the target seismic event, or the rate at which a target event has been preceded (alarm rate) or not preceded (failure rate) by the precursor. The binary table obtained from this kind of analysis leads to the definition of the parameters of the model that achieve the maximum number of successes and the minimum number of false alarms for a specific class of precursors. The mathematical tools suitable for this purpose may include the definition of Probability Gain or the R-Score, as well as the application of popular plots such as the Molchan error-diagram and the ROC diagram. Another tool for evaluating the validity of a forecasting method is the concept of the likelihood ratio (also named performance factor) of occurrence and non-occurrence of seismic events under different hypotheses.
Whatever is the method chosen for building up a new hypothesis, usually based on retrospective data, the final assessment of its validity should be carried out by a test on a new and independent set of observations. The implementation of this step could be problematic for seismicity characterized by long-term recurrence. However, the separation of the data base of the data base collected in the past in two separate sections (one on which the best fit of the parameters is carried out, and the other on which the hypothesis is tested) can be a viable solution, known as retrospective-forward testing.
In this study we show examples of application of the above mentioned concepts to the analysis of the Italian catalog of instrumental seismicity, making use of an epidemic algorithm developed to model short-term clustering features. This model, for which a precursory anomaly is just the occurrence of seismic activity, doesn't need the retrospective categorization of earthquakes in terms of foreshocks, mainshocks and aftershocks. It was introduced more than 15 years ago and tested so far in a number of real cases. It is now being run by several seismological centers around the world in forward real-time mode for testing purposes.