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Proposal of correlation-based evaluation methods for earthquake forecasts

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Earthquake forecasting experiments are currently being conducted at CSEP regional centers. In these programs, many methods evaluating the performance of various forecasting models are based on the assumption that earthquakes will occur independently of each other. Therefore, the degree of correlation has been examined to confirm the validity of those methods.

Here, we consider the all-Japan area designated by the Japanese center of CSEP and earthquakes with a magnitude 4 or greater. The area consists of 20062 rectangular cells, each with a size of 0.1 by 0.1 degrees in latitude and longitude, and depths from the surface to 100km. The numbers of cells indicating a specific frequency of earthquakes in a year are then counted from 2001 to 2010. Differences from previous activities are also considered, because the expected activity in the next year will be considerably affected.

For example, among the cells in which only one earthquake occurred from 1965 through the previous year (i.e., 21561 cells for ten years), there were 498 cells with one event in the next year, 59 cells with two events, and 10 cells with three events. Considering that the average expectation of earthquakes for this data set was 0.03627, the expected number of cells will be 754, 14, and 0.17, if the process follows a Poisson distribution. This result suggests that evaluation tests essentially based on the Poisson distribution or the Poisson process are questionable.

The CSEP experiments examine both various forecasting models and various evaluation methods. The marked correlation between earthquakes makes it desirable to adopt and examine, if possible, methods that do not assume the Poisson process. A summation of squares of residuals between observed and forecasted numbers of events, or rather the logarithm of its inverse or root mean square, will be a simple measure for representing the distance from a perfect forecast.

In order to advance a probabilistic analysis, it is necessary to prove a reasonable correlation-based distribution function that replaces the Poisson distribution. For example, a function such as N(x)/N(x-1)=exp(-C/xˆD) may be a candidate for this purpose. Here, N(x) is the number of cells in which events occur x times or more, C is a constant defined by C=-ln(N(1)/N(0)), and D is an additional parameter. Further studies will be valuable for a significant evaluation.

Keywords: earthquake forecast, CSEP, evaluation method, Poisson process, Poisson distribution, root mean square