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Research towards practical earthquake forecasting

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Earthquakes occur because of abrupt slips on faults due to accumulated stress in the Earth's crust. Because most of these fault and their mechanisms are not readily apparent, deterministic earthquake prediction is difficult. For effective prediction, complex conditions and uncertain elements must be considered, which necessitates stochastic prediction. In particular, a large amount of uncertainty lies in identifying whether abnormal phenomena are precursors to large earthquakes, as well as in assigning urgency to the earthquake. Any discovery of potentially useful information for earthquake prediction is incomplete unless quantitative modeling of risk is considered. Therefore, this talk aims the prospect of earthquake predictability research to realize practical operational forecasting in the near future. More specific summaries are as follows:

To predict the future under complex and diverse earthquake generation process, the probability forecasting cannot be avoided. The likelihood (log-likelihood) is rational to measure the performance of the prediction. To provide a standard stochastic prediction of seismic activity in long term and short term, it is necessary to construct proper point process models and revise them that conform to each region.

By the appearance of the anomaly, we need to evaluate the probability that it will be a precursor to a large earthquake. Namely, we need to forecast that the probability in a space?time zone will increase to an extent, relative to those of the reference probability. For this, we make use of a point process model for the causality relationship. Thus it is desired to search any anomaly phenomena that enhance the probability gain that is ratio of the predicted probability relative to the baseline earthquake probability. A comprehensive physical study between precursory phenomena and earthquake mechanisms is essential for composing useful point process models. These elements must be incorporated to achieve predicted probability exceeding predictions of typical statistical models.

The key for progress of research for practical probability earthquake forecasting is to make use of multiple prediction formula that is derived through the Bayes formula. According to the formula, total probability gain is approximately the product of individual probability gains. The probability gain for an individual anomaly to be a precursor is basically its success rate divided by the precursor time. The success rate can only be determined from the accumulation of data with actual earthquakes. In this talk, I would like to start with the important suggestions by Utsu (1979) and Aki (1981), and then to provide some examples toward better probability gain modeling.

Furthermore, numerous research examples on earthquake processes must be accumulated. On the basis of these examples, probable prediction scenarios must be presented. Furthermore, to adapt well to diversity of earthquake generation, it is useful to adopt hybrid predictions taking account of period- and region-specific models.

My experiences thus far confirm that the method of statistical science is essential to elucidate movement leading to prediction of a complex system of global phenomena. There is a need for development of a forecasting model that reflects diversity of the vast amount of information on the basis of seismicity of various data by incorporating a hierarchical Bayesian model. Space?time models for seismicity have become increasingly complicated. A similar evolution is required for statistical models of geodetic GPS data. Thus, I believe that statistical seismology is essential for the study of complex systems of Earth. Moreover, educating citizens on understanding the forecast probability of complex phenomena is also the duty of researchers and practitioners who engage in statistical science.

Keywords: probability forecast, probability gains, multiple prediction formula, point process models, space-time models, hierarchical Bayesian models