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Earthquake forecasting as an example of forecasting of instability

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A catastrophe (bifurcation) is understood as something unexpected and terrible. Earthquakes are not only a spectacular example of bifurcation but also a good example of research. Earthquakes are numerous and have been studied for a long time. The global scientific community has come a long way in this area, from initial hopes of receiving of a forecast, through the idea that forecasting was impossible [1], to real-time monitoring that the best forecasting algorithms yield results better than random guessing [2; and others]. The main obstacles to obtain an effective earthquake forecasting are believe to be strong background variability of the seismic regime, the absence of the developed physical model of the seismic process and the lack of data [2; 3; and others]. Strong background variability complicates the timely identification of forecast anomalies, and the absence of a developed physical model of the earthquake complicates the selection of informative forecast features. New results have been obtained recently on these issues.

As a result of the analysis of the scaled (by the size of the source of a given strong earthquake) summation of data on a large number of strong earthquakes (the method of constructing and analyzing the generalized vicinity of a strong earthquake, GVSE), typical (average) forecast anomalies were described in details [4; 5]. It was also shown [6; 7] that a number of features and forecast effects differ for different depth earthquakes. These differences correspond to theoretically expected differences for ordinary shallow earthquakes, intermediate-depth events associated with the presence of the deep fluids, and the deep earthquakes explained by phase transitions in subducting lithospheric plates.

For typical earthquake catalogs (when the hypocenter, time, and magnitude of the event are known), three GVSE anomalies can be observed. The first one corresponds to a power-law increase in the foreshocks' intensity. The second corresponds to an increase in the proportion of stronger events (b-value decrease). The third typical anomaly corresponds to a change in the average earthquake depth; the nature of this anomaly varies for earthquakes at different depths.

The first two GVSE anomalies correspond to the development of system instability regardless of the mechanism of development of instability. The third characterizes the instability development mechanism (connection with the fluid regime). Predictive features in geophysical fields (seismo-ionospheric, hydrological, deformation, etc.) also characterize the physical mechanism of origin of instability.

The question arises: how often are typical GVSE anomalies can be detected in the foreshock zones of individual strong earthquakes? Data from global ISC-GEM, GCMT, and regional (Kamchatka and Japan) earthquake catalogs shows that the probability of detecting of the GVSE anomalies increases with completeness of the catalog. A high (80% or more) probability of detecting of at least one of the GVSE anomalies in the foreshock vicinity of target Mo + events take place in catalogs with completeness $Mc = Mo - 4$.

Experience of earthquake forecasting in terms of the first and second GVSE anomalies shows that similar anomalies can be used to predict the development of instability (bifurcations) in systems of various physical natures, such as finance, ecology, and others.

References

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