Anomalies of aftershock activities in space and time measured by the ETAS model and relations to stress changes

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I am concerned with precise prediction of time- and history-dependent occurrence rate of an aftershock sequence in order to test the hypothesis that abrupt stress-change due to the aseismic slip preceding a large aftershock triggers seismicity-rate-change in the aftershock volume. In principle, it should be always expected that seismic activity is enhanced in the zones where increment of the Coulomb failure stress (CFS) is positive, and also that the activity is reduced (seismic quiescence) in the stress-shadow zones of negative CFS. In fact, however, the stress changes in a region are very frequently affected by the nearby events, which trigger further aftershock clusters. Unfortunately, such stress transfers are too difficult to be computed due to unknown complex fault system with a fractal feature.

In order to extract an exogenous stress-change transferred from outside or boundaries of the main aftershock volume, we have to remove the effect of such complex, proximate triggering mechanics occurring within the aftershock volume. As a practical solution, we rely on the statistical empirical laws of aftershock activity. That is to say, the statistical model, such as the Omori-Utsu (the modified Omori) formula and its extension, the epidemic-type aftershock sequence (ETAS) model, is fitted to the sequence of events from the volume in order to precisely mimic the normal activity there. If the seismicity-rate-change (enhancement or reduction) relative to the predicted rate by the model is revealed, we explore matching it with the pattern of Coulomb's stress-changes due to the aseismic slip suspected somewhere around the aftershock volume.

If the aftershock activity is not affected by the exogenous stress-changes, we expect that the space-time aftershock point pattern should be uniform with respect to the transformed time according to the expected cumulative curves of the ETAS model. Therefore, a non-uniform pattern with time suggests the regions and periods of the anomalies of quiescence or activation in the aftershock region. I would like to show a number of such examples from the recent aftershock activities in Japan. These lead us to a summarized observation that even a small size of the CFS increment of the order of millibars can trigger such seismicity-rate-change, which is also supported by the Dieterich's seismicity-rate-equation. Thus, I expect that the anomalous seismic activity relative to the ETAS rates is sensitive enough to detect and measure a slight stress-change.

References

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