Resolving Stress Singularities: a Retrospective Japan Rate-and-State Earthquake Forecast

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Retrospective evaluations of rate-and-state Coulomb stress transfer have shown consistent associations between increased Coulomb stress and seismicity rates. However, stress singularities occurring at the ends of fault dislocation patches tend to provide an unrealistic calculated stress field near active faults, where most earthquakes occur. The effects of such stress calculation artefacts
may be mitigated through implementation of an inverse rate-and-state model, where seismicity rate variations are inverted to obtain Coulomb stress steps over time. The resulting stress variations, from which expected seismicity rates are derived, show potential near the Tohoku rupture plane in a short-term prospective Japan forecast due to low magnitude completeness thresholds, which allow for comprehensive delineation of the Coulomb stress field. An additional advantage of the stress inversion model is that it does not require receiver plane orientations or focal mechanisms, which add uncertainty to the calculated stress field and are not always available, limiting the reliability
of applying the forward model in a global earthquake forecast. We retrospectively test our forecast within all Japan CSEP (Collaboratory for the Study of Earthquake Predictability) testing regions, just after the 2011 Tohoku earthquake. To determine whether the observed seismicity rate variations are sufficient to define Coulomb stress field variations, we combine our forecast with ETAS forecasts currently being tested in the Japan CSEP testing center. At the 95% significance level, the rate-and-state forecast displays potential in defining the magnitude distribution of future earthquakes, but does not yet reliably constrain the number, or the spatial distribution of earthquakes away from the mainshock, indicating that the inverse forecast may be most effectively applied in an ensemble earthquake forecast model, where it contributes more to forecasted seismicity rates near areas with recent seismicity.

Keywords: forecast, seismology, Coulomb stress

