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The modified ETAS analysis on earthquake swarms induced by the Tohoku earthquake

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The ETAS model provides a good estimate of earthquake intensity when the underlying mechanism is uniform, or stationary. Any diversions of it from the data hence imply seismicity anomalies involved temporally into the focal region. Activation and quiescence caused by stress changes from outside are one of such anomalies. Relatively long-lasting changes can be treated by the ETAS model with one or a few change-points; in which framework all or part of ETAS parameters are estimated separately and independently across those change-points. This method, however, has troubles when changes occur gradually over time or kicks in for a short period of time, or appears repeatedly. For such cases, alongside the change-point framework, we consider the following more flexible form of misfit functions q(t)'s which estimate the misfits of the ETAS model from data.

We here adopt two forms of misfit functions. Both of them are to be estimated as the best modifications of the ETAS model to data, evaluated at each occurrence time of event. Because of this large parameterized nature, we use the Bayesian smoothing method to estimate them. The first misfit function modifies the overall reference ETAS intensity itself;

lambda'(t)=lambda(t)∗q(t). (model1)

Any large diversions of q(t) from unity reveals misfit of the ETAS model and hence suggests anomalies in seismicity. The second misfit function re-estimate the background component of the ETAS intensity: mu, which is originally constant, as a time-varying function mu(t) in the form

mu'(t)=mu∗q(t), (model2)

so that the estimated function let us follow the change in the background seismicity which is most susceptible to certain causes among the ETAS parameters. We check the characteristics of these functions with simulated data first, then applied them to some of inland earthquake clusters triggered by the Tohoku Earthquake as well as the data sets with swarm events, to which the normal ETAS model poorly fits. The data sets include earthquakes on Nagano-Niigata prefecture boundary (M6.7), eastern Shizuoka (M6.4), Fukushima Hamadori (M7.0) and swarm events in north-west of Lake Inawashiro.

Keywords: Touhoku earthquake, ETAS model, swarm, Bayesian smoothing, misfit