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Pseudo-Prospective Forecasting Experiments with Spatially Variable ETAS Models

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The Epidemic Type Aftershock Sequence (ETAS) model is widely employed to model the spatio-temporal distribution of earthquakes, generally assuming spatially invariant parameters. We propose an efficient method for the estimation of spatially varying parameters, using an Expectation Maximization (EM) algorithm and spatial Voronoi tessellation ensembles. We use the Bayesian Information Criterion (BIC) to rank inverted models given their likelihood and complexity, and select the best models to finally compute an ensemble model at any location. Using synthetic catalogs, we also check that the proposed method correctly inverts the known parameters.
We then select our best ETAS model and compare its skill to smooth seismicity models based on other popular declustering algorithms: Reasenberg declustering algorithm, Zaliapin declustering algorithm, and a window-based declustering algorithm, using the standard framework developed by the Collaboratory for the Study of Earthquake Predictability (CSEP) in five year long and one year long pseudo-prospective forecasting experiments. Our results, so far, indicate that the smoothed seismicity model based on smoothing the observed declustered seismicity (background earthquakes) coupled with simulated clustered seismicity (obtained by simulating catalogs in the forecast window using spatially variable parameters of the ETAS model), tends to outperform other smooth seismicity models; the latter are based on smoothing only the observed declustered seismicity obtained by, respectively, stochastic declustering, Reasenberg declustering and Zaliapin declustering. The success of our best ETAS model can be attributed to the two components of the model: the background component, which captures the spatially variable rate of the future background earthquakes based on past background event rates, and the triggered component, which captures how the future background earthquakes would trigger their own cascade of aftershocks, which would further trigger their aftershocks, and so on. On the other hand, solely declustering based smoothed seismicity models are only able to capture the background component, which could be suboptimal due to self-inconsistent declustering methodologies.
With our model, we can now obtain a more resolved picture of the seismic hazard in the study region. Our model further allows us to differentiate regions in terms of potential of the type of hazard (long term or short term), which is of key importance for probabilistic seismic hazard assessment.