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Estimating Spatially Variable Parameters of the Epidemic Type Aftershock Sequence (ETAS) in California

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The ETAS model is widely employed to model the spatio-temporal distribution of earthquakes, generally using spatially invariant parameters, which is most likely a gross simplification considering the extremely heterogeneous structure of the Earth's crust. We propose an efficient method for the estimation of spatially varying parameters, using an expectation maximization (EM) algorithm and spatial Voronoi tessellations. We assume that each Voronoi cell is characterized by a set of eight constant ETAS parameters. For a given number of randomly distributed cells, Vi=1 to N, we jointly invert the ETAS parameters within each cell using an EM algorithm. This process is progressively repeated several times for a given N (which controls the complexity), which is itself increased incrementally. We use the Bayesian Information Criterion (BIC) to rank all the inverted models given their likelihood and complexity and select the top 1% models to compute the average model at any location. Using a synthetic catalog, we also check that the proposed method correctly inverts the known parameters.

We apply the proposed method to earthquakes (M>=3) included in the ANSS catalog that occurred within the time period 1981-2016 in the spatial polygon defined by RELM/CSEP around California. The results indicate significant spatial variation of the ETAS parameters. Using these spatially variable estimates of ETAS parameters, we are better equipped to answer some important questions: (1) What is the seismic hazard (both long- and short-term) in a given region? (2) What kind of earthquakes dominate triggering? (3) are there regions where earthquakes are most likely preceded by foreshocks? Last but not the least, a possible correlation of the spatially varying ETAS parameters with spatially variable geophysical properties can lead to an improved understanding of the physics of earthquake triggering beside providing physical meaning to the parameters of the purely statistical ETAS model.