ETAS-positive: extracting unbiased epidemic-type aftershock forecast models from incomplete earthquake catalogs

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Earthquake catalogs provide the core data of statistical seismology but are typically incomplete records of the earthquakes that occur. Incomplete detection results from sparse network coverage and saturation of the network during periods of high activity. Traditional attempts to address incompleteness center on modeling the time-varying sensitivity of the network, characterized by a completeness magnitude, but such models are non-unique and introduce additional uncertainty.

I previously presented methods for estimating the true magnitude-frequency distribution of the earthquakes in an incomplete catalog using the b-positive method, which uses the distribution of magnitude differences between successive earthquakes where the second is larger than the first. This approach was then elaborated to measure unbiased earthquake rates using a-positive, which focuses on the time to the next larger earthquake. Both approaches obviate the need for a completeness magnitude, instead leveraging the fairly conservative assumption that catalog completeness improves monotonically, or at least does not degrade, in the quiet periods between any two earthquakes. Here I demonstrate how to extend this approach to the epidemic-type aftershock sequence (ETAS) model, by defining and optimizing the non-homogeneous Poisson likelihood exclusively over intervals between pairs of earthquakes where the second is larger than the first. This modification allows for the unbiased estimation of the ETAS parameters in incomplete catalogs without recourse to an incompleteness model.

When applied to aftershock sequences, the ETAS-positive method reproduces the findings of a-positive, revealing essentially no evidence for an early-time plateau in the early aftershock rate. ETAS-positive places an upper bound on the Omori c-parameter of a minute or less following magnitude 6 and larger mainshocks, which is on the order of the earliest resolved aftershocks in the catalog.