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Estimating ETAS: the effects of truncation, missing data, and model assumptions

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The Epidemic-Type Aftershock Sequence (ETAS) model is widely used to describe the occurrence of earthquakes in space and time, but there has been little discussion of the limits of, and influences on, its estimation. What has been established is that ETAS parameter estimates are influenced by missing data (e.g., earthquakes are not reliably detected during lively aftershock sequences) and by simplifying assumptions (e.g., that aftershocks are isotropically distributed). In this article, we investigate the effect of truncation: how do parameter estimates depend on the cut-off magnitude, M_{cut}, above which parameters are estimated? We analyze catalogs from southern California and Italy and find that parameter variations as a function of M_{cut} are caused by (i) changing sample size (which affects e.g. Omori's $c$constant) or (ii) an intrinsic dependence on M_{cut} (as M_{cut} increases, absolute productivity and background rate decrease). We also explore the influence of another form of truncation—the finite catalog length—that can bias estimators of the branching ratio. Being also a function of Omori's p-value, the true branching ratio is underestimated by 45% to 5% for 1.05$<$ p $<$1.2. Finite sample size affects the variation of the branching ratio estimates. Moreover, we investigate the effect of missing aftershocks and find that the ETAS productivity parameters (α and K_0) and the Omoris c-value are significantly changed only for low M_{cut}=2.5. We further find that conventional estimation errors for these parameters, inferred from simulations that do not account for aftershock incompleteness, are underestimated by, on average, a factor of six.