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Estimation of the maximum magnitude in the framework of a doubly-truncated Gutenberg-Richter model: Limits of statistical inference from earthquake catalogs

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We discuss to which extent a given earthquake catalog and the assumption of a doubly-truncated Gutenberg-Richter distribution for the earthquake magnitudes allow for the calculation of confidence intervals for the maximum possible magnitude M. We show, that without further assumptions, like the existence of an upper bound of M, only very limited information may be obtained. In a frequentist formulation, for each confidence level α the confidence interval diverges with finite probability. In a Bayesian formulation, the posterior distribution of the upper magnitude is not normalizable. We conclude that the common approach to derive confidence intervals from the variance of a point estimator fails. Technically, this problem can be overcome by introducing an upper bound $\widetilde{M}$ for the maximum magnitude. Then, the Bayesian posterior distribution can be normalized and its variance decreases with the number of observed events. However, since the posterior depends significantly on the choice of the unknown value of $\widetilde{M}$, the resulting confidence intervals are essentially meaningless. The use of an informative prior distributions accounting for pre-knowledge of M is also of little use, because the prior is only modified in the case of the occurrence of an extreme event. The results suggest that the maximum possible magnitude M should be replaced by M_T, the maximum expected magnitude in a given time interval T. For this quantity the calculation of exact confidence intervals becomes straightforward. From a physical point of view, numerical modelsof the earthquake process adjusted to specific fault regions may be a powerful alternative to overcome the shortcomings of purely statistical inference.