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A Bayesian Framework for Aftershock Forecasting and Testing

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Earthquakes trigger subsequent earthquakes. They form clusters and swarms in space and in time. This is a direct manifestation of the non-Poisson behavior in the occurrence of earthquakes, where earthquake magnitudes and time intervals between successive events are not independent and are influenced by past seismicity. As a result, the distribution of the number of earthquakes is no longer strictly Poisson and the statistics of the largest events deviate from the GEV distribution. In statistical seismology, the occurrence of earthquakes is typically approximated by a stochastic marked point process. Among different models, the ETAS model is the most successful in reproducing several key aspects of seismicity. Recent analysis suggests that the ETAS model generates sequences of events which are not Poisson. This becomes important when the ETAS based models are used for earthquake forecasting (Shcherbakov et al., Nature Comms., 2019). In this work, I consider the Bayesian framework combined with the ETAS model to constrain the magnitudes of the largest expected aftershocks during a future forecasting time interval. This includes the MCMC sampling of the posterior distribution of the ETAS parameters and computation of the Bayesian predictive distribution for the magnitudes of the largest expected events. To validate the forecasts, the statistical tests developed by the CSEP are reformulated for the Bayesian framework. In addition, I define and compute the Bayesian p-value to evaluate the consistency of the forecasted extreme earthquakes during each forecasting time interval. The Bayesian p-value gives the probability that the largest forecasted earthquake can be more extreme than the observed one. The suggested approach is applied to the recent 2019 Ridgecrest earthquake sequence to forecast retrospectively the occurrence of the largest aftershocks (Shcherbakov, JGR, 2021). The results indicate that the Bayesian approach combined with the ETAS model outperformed the approach based on the Poisson assumption, which uses the extreme value distribution and the Omori law.