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# Editorial: Physical and statistical approaches to earthquake modeling and forecasting

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## KEYWORDS

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## Editorial on the Research Topic

Physical and statistical approaches to earthquake modeling and forecasting

Statistical seismology represents a promising and active research field in earthquake forecasting applications. It combines rigorous statistical methods and earth science, with the aim of improving the knowledge of the seismic phenomenon, the evaluation of the relative forecasts and the test of their reliability. The final scope is to enhance resilience and earthquake preparedness of threatened communities.

Short-term seismic hazard is of particular interest for societal safety reasons, as it is the scale implicated in case of emergency, when a precise decision-making table is needed (e.g., during an ongoing seismic sequence). On short-time scales of days or weeks, earthquakes are shown to cluster both in space and time, due to the high triggering capability of large earthquakes. Spatio-temporal clustering of earthquakes is one of the key features of seismic catalogs. Its modeling is essential for both long-term hazard and short-term forecasting of seismicity.

[Sedghizadeh et al.](#) study the microseismicity clustering in the Saskatchewan potash mine (Canada). This work can be framed in the way of community safety, as mining operations represent an example of workplace tasks for which security and efficiency are crucial. By implementing the Nearest-Neighbor technique, the authors find that earthquakes occur predominantly as (independent) background events, mostly driven by underground mining operations, and only a minor part of them cluster as “burst-type” seismicity. They also investigate the earthquakes frequency-magnitude distribution (FMD), obtaining a deviation from the decreasing exponential Gutenberg-Richter (GR) law, which is typically used in the literature. The GR law is ruled by the b-value parameter, which controls the proportion between small and large earthquakes. Some authors claim it may represent a precursor for an upcoming strong event. [Sedghizadeh et al.](#) estimate this parameter and link it to a low probability of strong earthquakes.

Earthquakes probabilities may vary over orders of magnitude, though typically remaining low, thus making the decision-making process a difficult challenge. This is indeed a relevant problem for the communication of short-term earthquake forecasts, which in turn plays a fundamental role in the Operational Earthquake Forecasting (OEF).

OEF represents one of the most important applications related to the short-term seismic hazard. It is implemented in several countries worldwide, such as Italy, New Zealand, United States of America and Switzerland. OEF allows to determine, in quasi real-time, the occurrence probability of an earthquake in a given space-time-magnitude domain and it commonly relies on the well-known Epidemic Type Aftershock Sequence (ETAS) model. The latter incorporates the GR law for earthquake magnitudes, the modified Omori law (MOL) for the aftershocks decrease in time and a spatial kernel (typically of Gaussian type) for describing the distribution of earthquakes in space. Although ETAS is a plain combination of basic laws of seismicity and requires a simplification of the phenomenon it models, in a large majority of applications it is shown to have a very good reliability and performance skill. An example is given in the paper by [Dong et al.](#), where the forecasting performance of ETAS vs. the single MOL is evaluated using statistical tests that implement the Markov Chain Monte Carlo (MCMC) sampling to account for the uncertainty in the model parameters. The forecasting skill results shown in this paper indicate that the ETAS model tends to perform consistently well according to most of the proposed statistical tests. Nevertheless, these comparison tests are not sufficient to determine whether ETAS is the best performing model.

A key strength of ETAS relies in its capability to account for earthquakes spatiotemporal clustering. Although seismic interevent times are known to be not independent, nor exponentially distributed, several applications in the literature still adopt the Poissonian assumption that foresees events to occur randomly in time. The large majority of OEF systems use the Poisson distribution to model the number of events in the short-term, but several authors have proved evidence against this assumption. In this regard, [Taroni et al.](#) present a statistical comparison between the Poisson and the Negative Binomial distribution (NBd) for modeling the number of observed seismic events in short-term time windows (from 1 day to 1 month) in case of both regional and global catalogs. By using the chi-squared test and the Akaike Information Criterion, the authors find a better performance of NBd against Poisson for almost all the catalogs and temporal windows considered. This work suggests then to use the more flexible and well performing NBd as a valid alternative of the Poisson distribution.

One key aspect of the OEF systems improvement is the development of more efficient techniques for the estimation of earthquake model parameters and their uncertainty. Indeed, a good practice in any study attempting to deliver reliable earthquake forecasts is to assess the uncertainty of the estimated parameters. A practical example is given in [Naylor et al.](#), where the authors present the R-package ETAS.inlabru, which implements integrated nested Laplace approximation (INLA) to model seismicity as a temporal ETAS model. Similarly to the Bayesian MCMC

implementations, INLA enables uncertainty quantification by returning joint posteriors on the ETAS parameters. However, this alternative approach offers substantial advantages both in terms of computational times and scalability. Besides analyzing the performance of ETAS.inlabru, the authors also discuss some key points that should be carefully addressed when inverting for ETAS parameters: (1) the importance of a period of relative quiescence in the chosen dataset; (2) the choice of starting parameters; (3) the impact of short-term incompleteness.

The paper by [Naylor et al.](#) allows us also to cite a general problem related to statistical seismology and its applications. Unfortunately, the majority of papers in this field are not equipped with free and easy-to-access metadata repositories with user-friendly codes, thus resulting in a general lack of available software tools; educational resources are also lacking, making it difficult for newcomers to learn about this discipline.

This Research Topic has been thought of exactly to promote excellence in statistical seismology. All the published papers are somehow related to short-term earthquake modeling and OEF. We therefore hope that this Research Topic will help to increase the knowledge and resources necessary to understand and implement the best practices in seismic hazard, and will help both expert and younger statistical seismologists in building better and more reliable earthquake forecasting models.

## Author contributions

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## Conflict of interest

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