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A physical constraint on smoothed-seismicity models and the stationary seismicity assumption in long-term forecasting

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In earthquake forecasting, smoothed-seismicity models (SSM) are based on the assumption that previous earthquakes serve as a guideline for future events. Different kernels are used to spatially extrapolate each moment tensor from a seismic catalog into a moment-rate density field. Nevertheless, governing mechanical principles remain absent through the model conception, even though crustal stress is responsible for moment release mainly in pre-existent faults. Furthermore, a lately developed SSM by Hiemer et al., 2013 (SEIFA) incorporates active-fault characterization and deformation rates stochastically, so that a geological estimate of moment release could also be taken into account. Motivated by this innovative approach, we address the question: How representative is the stochastic temporal/spatial averaging of SEIFA, of the long-term crustal deformation and stress? In this context, physics-based modeling provides insights about the energy, stress, and strain-rate fields within the crust due to discontinuities found therein. In this work, we aim to understand the required temporal window of SEIFA to satisfy mechanically its underlying assumption of stationarity. We build various SEIFA models within different spatio-temporal subsets of a catalog and confront them with a physics-based model of long-term seismic energy/moment rate. Following, we develop a method based on the moment-balance principle and information theory to compare the spatial similarity between these two types of models. These models are built from two spatially conforming layers of information: a complete seismic catalog and a computerized 3-D geometry of mapped faults along with their long-term slip rate. SEIFA uses both datasets to produce a moment-density rate field, from which later a forecast could be derived. A simple physics-based model is used as proof of concept, such as the steady-state Boundary Element Method (BEM). It uses the fault 3D geometry and slip rates to calculate the long-term interseismic energy rate and elastic stress and strain tensors, accumulated both along the faults and within the crust. The SHARE European Earthquake Catalog and the European Database of Seismogenic Faults are used as a case study, constrained to crustal faults and different spatio-temporal subsets of the Italy region in the 1000-2006 time window. The moment-balance principle is analyzed in terms of its spatial distribution calculating the spatial mutual information (SMI) between both models as a similarity measure. Finally, by using the SMI as a minimization function, we determine the catalog optimal time window for which the predicted moment rate by the SSM is closer to the geomechanical prediction. We emphasize that regardless of the stationarity assumption usefulness in seismicity forecasting, we determine a simple method that provides a physical boundary to data-driven seismicity models. This framework may be used in the future to combine seismicity data and geophysical modeling for earthquake forecasting.