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Historical seismicity as a proxy to physics-based long-term earthquake forecasts

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The frequency and size of destructive earthquakes are key elements of a seismogenic source model for use in seismic hazard assessment. Given an earthquake prone region, the spatial and temporal distribution of observed seismicity usually provide the basis to forecast the future seismicity. Often, the observed seismicity (i.e. instrumental and/or historical) spans over limited time intervals, which might not be representative for a complete seismic cycle of moderate to large magnitude events. Although using statistical approaches and extrapolation of small-to-moderate magnitude earthquakes are prevalent, number of recorded earthquakes, especially in low seismicity region, is not sufficient to have a reliable estimate and distribution of the time interval between large earthquakes are not clear. One way to overcome such challenges is to simulate physics-based earthquake catalogues, covering long time intervals. Considering stress interaction between active faults and providing a catalog based on active movement absorbed by the region are the most important advantages of physics-based simulations, which pave another path for earthquake rate forecasting besides statistical approaches.

The most important input for a long-term seismicity simulation is the fault information (i.e. geometric characteristics and slip rates of active faults), which can be combined with geodetic information and kinematic models to describe the seismic productivity in a given region. In this contribution, we present a procedure to evaluate the frequency and size of large earthquakes by use of different datasets, including historically recorded earthquakes, active faults, and tectonic deformation rates. First, starting with a given earthquake catalogue and an a-priori defined seismogenic source model, a fault model is built using magnitude-size scaling relationships. Next, the newly derived fault model, fully characterized in terms of geometry and location is augmented with slip-rates from tectonic deformation rates. Further, Green's functions are used to describe the stress interactions between the faults and imposing a back-slip method, the stress in the media is evaluated based on the prescribed fault slip rates. This loading process continue until the failure threshold on one fault is reached and rupture propagation is modeled by considering the static and dynamic failure criteria. Finally, the probable moderate-to-large earthquakes within the given region are provided in space and time domain.

The procedure is illustrated by the results of two cases studies: a region of a low-to-moderate seismicity, Valais, Switzerland; and a region of moderate-to-high seismicity, Dasht-e-Bayaz, Iran. The obtained results are compared with previous independent estimates of earthquake rates for the whole region and rates of small-magnitude earthquakes happened close to the modelled faults in terms of b-value. Hence, the procedure can be applied in any seismically active region, with or without identified faults, thus of great importance for seismic hazard and risk assessment.