Geophysical Research Abstracts
Vol. 21, EGU2019-16195, 2019
EGU General Assembly 2019

Physics-based earthquake simulators as a tool in Fault-PSHA: example for the Marmara region, Turkey.

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Proximity of the Istanbul megacity to the western branch of the North Anatolian Fault (NAF) constitutes a major challenge in earthquake risk assessment today due to the offshore location of the fault. In particular, two questions remain: what is the proportion of slip rate that is potentially accommodated by aseismic slip and what combination of multi-fault-ruptures are potentially possible. In order to tackle these questions, we first construct a fault hazard model for the western NAF composed of fault section geometries and associated slip rate estimates that are based on published data. We then implement two complementary modeling approaches to assess the rate and magnitude of earthquakes that can be expected in the fault system.

In the first approach earthquake rates are computed using the recently develop code SHERIFS (Seismic Hazard and Earthquake Rate In Fault Systems) which explores in a statistical manner an ensemble of rupture scenarios (user defined). The main assumption made in SHERIF is that the magnitude frequency distribution (MFD) should respect an imposed shape at the system level. This approach is computationally efficient, allowing for a wide exploration in a logic tree of the epistemic uncertainties associated with the input hypotheses and fault parameters.

In the second approach, earthquake rates are computed with RSQSim, a boundary element earthquake simulator based on the rate and state friction equation. RSQSim is computationally heavier, since it is modeling physical processes, consequently the epistemic uncertainties affecting the large number of input parameters cannot be easily explored.

Computed earthquake rates following the two approaches are then compared to the rates estimated on the basis of the local earthquake catalog and the available paleoseismological data.

In order to match the data, SHERIFS must impose a shape of the MFD that deviates from a Gutenberg-Richter distribution and the match is best when considering a maximum rupture size corresponding to an earthquake of magnitude 7.5 than when considering larger ruptures. The earthquake catalog generated with RSQSim shows a similar MFD shape and maximum magnitude, which suggest that the MFD shape modelled in SHERIFS has some physical grounds and the geometrical complexities of the western NAF system impede the occurrence of M> 7.6.

Joining approaches for setting up hazard models allows users to build on the strength of each approach. SHERIFS allows to explore the full range of epistemic uncertainties affecting the fault parameters and therefore the hazard and RSQSim sheds some light on the physically acceptable hypotheses consistent with the assumed friction law.

As the computation capacities increase, so will the use of physics based models in the seismic hazard assessment. The large number of poorly constrained parameters and the diversity of hypotheses concerning earthquake physics in the scientific community make it difficult to imagine purely physics-based seismic hazard assessments with exploration of the epistemic uncertainties in the near future. However, the inclusion of physics-based simulators such as RSQSim as a part of the hazard model building process can greatly improve the models quality and their physical representation of the natural phenomenon.