2022 SCEC Project Report
Predicting Ground Motions from Complex Fault Models

Understanding the cause of damaging high-frequency earthquake ground motions is important from both a fundamental physics perspective and to better prepare for earthquake hazards. However, there are a number of competing physical models for how these ground motions are produced within complex fault zones, with slip heterogeneity, structural impacts and damage creation being amongst those most debated. While ground motion predictions for these three models exist, it is challenging to directly compare the predictions and thus to have testable differences to compare with observations. We propose to systematically compare these predictions with the goal of having a better understanding of how observational tests of these models can be performed.

The major outcomes at this time answer the first-order question of what the impact model predicts in the most extreme situations of the simplest and most complex fault systems. Seismogenesis and creep are theoretical end members for ground motions. One of our findings is very straightforward but interesting: When faults are perfectly planar (i.e. there is zero fault complexity) and friction is stable (e.g. rate strengthening, or does not lead to stick-slip motion on its own), then the prediction of the impact model is that faults creep and do not exhibit seismogenic behavior. On the other hand, once there is non-zero fault complexity, stress is predicted to build up behind geometric barriers and result in a dynamic event once a yield stress is reached or once enough strain builds up that the geometric barrier is reduced enough for slip to occur. This prediction of creeping vs. locked/seismogenic behavior is interesting and can be tested against observations. Separate work not funded by SCEC funding is ongoing to test whether this simple prediction is borne out by observations. Preliminary findings suggest that the prediction is correct, and a manuscript that incorporates both the theoretical prediction and the empirical findings is currently being written up for publication.

Beyond the simple prediction for seismogenesis or not, we also find that the size of the geometric structures contributing to the fault network complexity is predicted to determine the magnitude of stress build up, and thus the magnitude of the largest earthquake that can be hosted on a given fault segment. Since fault structures are approximately self similar in that the structure sizes scale with fault system length, this yields the prediction that the magnitude of earthquakes scales with fault length but importantly that faults of the same length can have different seismogenic potential depending on their geometric complexity. Again, this is an interesting prediction that can be tested against previously observed earthquakes and fault complexity observations. Separate work not funded by SCEC is ongoing to test these predictions.