Epistemic uncertainty in fault geometry effects earthquake rupture behavior

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It is well established in the seismology community that geometric complexity plays an important role for a fault's seismotectonic behavior. It affects the initiation, propagation and termination of an earthquake as well as influencing the stress-slip relationship, the size of fault segments, and the probability of multi-segment rupture. Consequently, fault geometric complexity is studied intensively and increasingly incorporated into computational earthquake rupture simulations. These efforts reveal a problem: While we may be able to constrain a natural fault's geometry with a high level of detail at the surface (i.e., the fault trace), we cannot do the same for the buried portion of the fault - where most of the rupture takes place. How much does a fault's seismotectonic behavior vary as a result of this epistemic uncertainty?

We address this question computationally with a physics-based multi-cycle earthquake rupture simulator (MCQsim), enabling us to investigate how (for example) earthquake recurrence, slip accumulation, magnitude-frequency distribution, and fault segmentation vary (looking at the entire fault as well as individual locations on the fault) as function of our insufficient knowledge about the fault's geometric complexity. To simulate fault geometric complexity, we generate 2-D random fields, using the “random midpoint displacement” method (RMD), representing the fault's non-planar, self-similar geometry. The advantage of using RMD is that it allows us to create a 2-D random field while also keeping one or more of the field's edges at a prescribed value. Hence, this approach allows us to generate a random field to represent fault roughness while also allowing us to incorporate what is known about the fault geometry (i.e., the fault surface trace, representing one of the random field's edges). In doing so, we can investigate how the aforementioned seismotectonic parameters vary as a function of fault roughness uncertainty.

For this purpose, we create 5000-year long earthquake catalogs for a 150x18km large strike slip fault that is parameterized by more than 40k fault cells (average cell size 0.07km^2), containing earthquakes with 3.5 < M < 7.8. We create these catalogs for 100 roughness realizations while keeping the simulated fault's surface trace constant for all realizations. The results of these simulations will be presented in our presentation.