Geophysical Research Abstracts
Vol. 19, EGU2017-18689, 2017
EGU General Assembly 2017


# 3D fault curvature and fractal roughness: Insights for rupture dynamics and ground motions using a Discontinous Galerkin method

Thomas Ulrich and Alice-Agnes Gabriel
LMU Munich, Geophysics, Department of Earth and Environmental Sciences, Munich, Germany
(gabriel@geophysik.uni-muenchen.de)

Natural fault geometries are subject to a large degree of uncertainty. Their geometrical structure is not directly observable and may only be inferred from surface traces, or geophysical measurements. Most studies aiming at assessing the potential seismic hazard of natural faults rely on idealised shaped models, based on observable large-scale features. Yet, real faults are wavy at all scales, their geometric features presenting similar statistical properties from the micro to the regional scale.

Dynamic rupture simulations aim to capture the observed complexity of earthquake sources and ground-motions. From a numerical point of view, incorporating rough faults in such simulations is challenging - it requires optimised codes able to run efficiently on high-performance computers and simultaneously handle complex geometries. Physics-based rupture dynamics hosted by rough faults appear to be much closer to source models inverted from observation in terms of complexity. Moreover, the simulated ground-motions present many similarities with observed ground-motions records. Thus, such simulations may foster our understanding of earthquake source processes, and help deriving more accurate seismic hazard estimates. In this presentation, the software package SeisSol (www.seissol.org), based on an ADER-Discontinuous Galerkin scheme, is used to solve the spontaneous dynamic earthquake rupture problem. The usage of tetrahedral unstructured meshes naturally allows for complicated fault geometries. However, SeisSol's high-order discretisation in time and space is not particularly suited for small-scale fault roughness. We will demonstrate modelling conditions under which SeisSol resolves rupture dynamics on rough faults accurately.

The strong impact of the geometric gradient of the fault surface on the rupture process is then shown in 3D simulations. Following, the benefits of explicitly modelling fault curvature and roughness, in distinction to prescribing heterogeneous initial stress conditions on a planar fault, is demonstrated. Furthermore, we show that rupture extend, rupture front coherency and rupture speed are highly dependent on the initial amplitude of stress acting on the fault, defined by the normalized prestress factor R, the ratio of the potential stress drop over the breakdown stress drop. The effects of fault complexity are particularly pronounced for lower R.
By low-pass filtering a rough fault at several cut-off wavelengths, we then try to capture rupture complexity using a simplified fault geometry. We find that equivalent source dynamics can only be obtained using a scarcely filtered fault associated with a reduced stress level. To investigate the wavelength-dependent roughness effect, the fault geometry is bandpass-filtered over several spectral ranges. We show that geometric fluctuations cause rupture velocity fluctuations of similar length scale. The impact of fault geometry is especially pronounced when the rupture front velocity is near supershear. Roughness fluctuations significantly smaller than the rupture front characteristic dimension (cohesive zone size) affect only macroscopic rupture properties, thus, posing a minimum length scale limiting the required resolution of 3D fault complexity.

Lastly, the effect of fault curvature and roughness on the simulated ground-motions is assessed. Despite employing a simple linear slip weakening friction law, the simulated ground-motions compare well with estimates from ground motions prediction equations, even at relatively high frequencies.