EGU24-19294, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-19294
EGU General Assembly 2024

One-way linking of 3D long-term geodynamic models and short-term earthquake dynamic rupture models

Anthony Jourdon[1], Nicolas Hayek[1], Dave May[2], and Alice-Agnes Gabriel[2,1]
[1]Ludwig-Maximilian-Universität, Geophysics, Department of Earth and Environmental Sciences, Munich, Germany
[2]Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, UC San Diego, La Jolla CA, USA

Tectonic deformation plays a crucial role in shaping the Earth's surface, with strain localization resulting in the formation of shear zones in depth and faults on the surface. These structures accommodate a significant portion of the displacement between tectonic plates. While long-term deformation can be approximated as continuous visco-plastic processes, earthquakes involve cycles of stress loading and unloading that trigger rapid and catastrophic elasto-plastic deformation. Earthquake dynamic rupture models offer valuable insights into studying and comprehending earthquakes. However, these models heavily rely on initial conditions that are often challenging to obtain solely from observations. Particularly, a mechanically self-consistent prestress state loading a fault prior a seismic event and 3D fault geometry, especially in depth, are commonly poorly constrained. Nonetheless, the prestress state and the fault geometry significantly impact earthquakes initiate, propagate, and arrest and the associate radiation of seismic waves and ground shaking.

To address the lack of information on stress and fault geometry, one promising approach is to use long-term geodynamic numerical simulations. In this study, we employ pTatin3D, a visco-plastic finite element software, to simulate the evolution of strike-slip deformation in 3D over geological time scales. To ensure a physically consistent long-term model, the fault geometry is not prescribed but solved for based on the lithospheric rheology and tectonic plate velocities. However, the geodynamics model describes faults as continuous volumetric fields of finite deformation and strain-rate, rendering them 3D objects, while earthquake dynamic rupture models typically represent faults as 2D interfaces.

In this study, we outline a new and versatile method to link 3D geodynamic simulations to rupture dynamics earthquake and seismic wave propagation modelling. We first extract 3D volumetric shear zones from the geodynamic model and automatically convert them into surface representations. Next, we generate meshes including these as faults for dynamic rupture models. Finally, we showcase 3D dynamic rupture models utilizing the stress states and faults self-consistently as derived from the long-term geodynamic model as initial conditions.