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Coupled 3D Earthquake Dynamic Rupture - Tsunami Models & the ASCETE framework

Elizabeth Madden (1,2), Joern Behrens (3), Michael Bader (4), Ylona van Dinther (5,6), Alice-Agnes Gabriel (1), Leonhard Rannabauer (4), Sebastian Rettenberger (4), Thomas Ulrich (1), Carston Uphoff (4), Stefan Vater (3), Stephanie Wollherr (1), and Iris van Zelst (6)

(1) LMU-Munich, Geophysik, Seismology, Munchen, Germany (madden@geophysik.uni-muenchen.de), (2) University of Brasilia, Geosciences Institute, Brasilia, Brazil, (3) Universität Hamburg, Dept. of Mathematics, Numerical Methods in Geosciences, Hamburg, Germany, (4) Technische Universität München, Institut für Informatik, Garching, Germany, (5) Utrecht University, Tectonics, Department of Earth Sciences, Utrecht, the Netherlands, (6) ETH Zürich, Institute of Geophysics, Computational Seismology Group, Zurich, Switzerland

We present a coupled modeling approach of large-scale physics-based dynamic earthquake rupture simulations to tsunami propagation and inundation models. Two simple test cases are designed illustrating earthquake-tsunami interaction and establishing baselines for realistic coupled scenarios. The 3D earthquake models incorporate a planar fault, extending from the seafloor to 35 km depth, dipping 16 degrees, and surrounded by a homogeneous crust. They are run with SeisSol (www.seissol.org), which can incorporate many aspects of realistic source physics, such as geometrically complex fault systems, various modern friction laws and off-fault plasticity, all in the framework of efficient HPC computation. The modeled time-dependent seafloor displacements are used as the source in the tsunami model with the help of ASAGI, an open-source library with a simple interface to access Cartesian material and geographic datasets in massively parallel simulations. An accurate and efficient representation of the evolution of the tsunami and the following coastal inundation are achieved with an adaptive mesh discretizing the shallow water equations with a Runge-Kutta discontinuous Galerkin scheme. Across-model complexity is explored using earthquake sources both with and without elevated near-trench cohesion. We specifically compare tsunami models using static (final) versus dynamic (time-dependent) seafloor displacements as sources. In order to better constrain the initial conditions governing earthquake models, we further present the ASCETE framework, which couples a subduction zone seismic cycle model to the earthquake and tsunami models. The seismic cycle model is a 2D seismo-thermo-mechanical simulation of long term deformation. Slip instabilities that approximate earthquakes arise spontaneously within the subduction zone channel. Within this framework, we attain physically consistent initial conditions for a megathrust earthquake, capture the full dynamics of the rupture, and determine the resulting seafloor displacements to source the tsunami. This work is part of the project "Advanced Simulation of Coupled Earthquake and Tsunami Events" (ASCETE), funded by the Volkswagen Foundation.