WaveQLab3D: A Software Framework for Seismic Wave Propagation and Dynamic Earthquake Rupture

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Abstract

High fidelity numerical simulations of seismic wave propagation and spontaneously propagating dynamic earthquake ruptures in realistic geological models are essential for understanding nonlinear earthquake source processes and improving seismic hazard assessment. We present *WaveQLab3D*, a high-performance computing, open-source framework that solves the three-dimensional elastic wave equation on curvilinear multi-block grids, supporting non-planar fault interfaces, surface topography, and heterogeneous Earth structures. In this presentation we evaluate the accuracy of *WaveQLab3D* for simulating high frequency visco-elastic wave propagation in realistic 3D models with geometrically complex free surface topography. We will as well present stable and scalable perfectly matched layer (PML) when visco-elastic attenuation is present. Our current developmental contribution also includes a Python-based workflow that supports multiple visualization modes for fault-interface variables, including slip, slip rate, tractions, and stress perturbations, providing detailed insight into rupture dynamics on complex fault geometries.

Keywords: WaveQLab3D; seismic wave propagation; dynamic rupture; topography; elastic attenuation; Perfectly Matched Layer (PML); summation-by-parts (SBP); MPI parallelization; computational seismology