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AWP-ODC: A Highly Scalable HPC Tool for Dynamic Rupture and Wave Propagation Simulations

Kim Olsen[1], Daniel Roten[2], Te-Yang Yeh[1], Ke Xu[1], and Yifeng Cui[2]
[1]San Diego State University
[2]San Diego Supercomputer Center

AWP-ODC is an open-source dynamic rupture and wave propagation code which solves the 3D velocity-stress wave equation explicitly by a staggered-grid finite-difference method with fourth-order accuracy in space and second-order accuracy in time. The code is memory-bandwidth, with excellent scalability up to full machine scale on CPUs and GPUs, tuned on CLX, with support for generating vector folded finite difference stencils using intrinsic functions. AWP-ODC includes frequency-dependent anelastic attenuation Q(f), small-scale media heterogeneities, support for topography, Drucker-Prager visco-plasticity, and a multi-yield-surface, hysteretic (Iwan) nonlinear model using an overlay concept. Support for a discontinuous mesh is available for increased efficiency. An important application of AWP-ODC is the CyberShake Strain-Green-Tensor (SGT) code used for probabilistic hazard analysis in CA and other regions.

Here, we summarize implementation and verification of some of the widely-used capabilities of AWP-ODC, as well as validation against strong motion data and recent applications for future earthquake scenarios. We show for a M7.8 dynamic rupture ShakeOut scenario on the southern San Andreas fault that while simulations with a single yield surface reduces long period ground motion amplitudes by about 25% inside a wave guide in greater Los Angeles, multi-surface Iwan nonlinearity further reduces the values by a factor of two. In addition, we show assembly and calibration of a 3D Community Velocity Model (CVM) for central and southern Chile as well as Peru. The CVM is validated for the 2010 M8.8 Maule, Chile, earthquake up to 5 Hz, and the validated CVM is used for scenario simulations of megathrust scenario events with magnitude up to M9.5 in the Chile-Peru subduction zone for risk assessment. Finally, we show simulations of 0-3 Hz 3D wave propagation for the 2019 Mw 7.1 Ridgecrest earthquake including a data-constrained high-resolution fault-zone model. Our results show that the heterogeneous near-fault low-velocity zone inherent to the fault zone structure significantly perturbs the predicted wave field in the near-source region, in particular by more accurately generating Love waves at its boundaries, in better agreement with observations, including at distances 200+ km in Los Angeles.