AWM-Olsen Code Description

1. Code Overview

- **Code Version:** 2.6.4.
- **Type of code:** Finite Difference on a Regular Grid. The code is implemented in the message-passing interface (MPI) which is scalable to 40k+ processors, enabling high-performance execution for large-scale dynamic and kinematic rupture models.
- **Names of developers:** Olsen, Marcinkovich, Dalguer, Cui, Zhu, and Hu.
- **Special features used for spontaneous rupture problems:** Surface viscosity damping on the fault plane, where staggered-grid split-node (SGSN) are used to model surface contact between the two sides of the fault (Dalguer and Day 2007).
- **Funding source for code development:** Original FD code developed at the UTAM oil consortium (University of Utah), but support for implementation of rupture dynamics has been from SCEC

2. Technical Description

- The code solves a velocity-stress formulation of the first-order hyperbolic-system of the elastodynamic equations (Madariaga, 1976).
- It is based on a finite difference approach in a regular staggered grid with fourth order operators in space and explicit second order time integration (Olsen, 1994).
- The code includes inelastic attenuation by solving the viscoelastic wave propagation equations with a coarse-grained implementation of the memory variables for a constant-Q solid (Day and Bradley, 2001).
- The code has the Perfectly Matched Layer (PML) absorbing boundary conditions on every external face of the computational domain (Marcincovich and Olsen, 2003) except on the upper one where explicit free surface boundary conditions are implemented using the imaging formalism (Gottschammer and Olsen, 2001).
- The code models spontaneous dynamic rupture propagation for a fault plane, where the SGSN method developed by Dalguer and Day (2007) is used to model the fault rupture
- The SGSN implemented in the code considers viscous damping by adding terms to the elastodynamic equations that are proportional to the strain-rate components, leading to damping stresses of Kelvin-Voigt form. Such

terms are only included in the equations of motion for the split nodes of the dynamic rupture model (Dalguer and Day, 2007).

- The code considers either linear or non-linear slip-weakening friction models. The implementation of the rate- and state-dependent constitutive relationships is in development.

3. The SCEC Dynamic Rupture Problems

- All problem versions of the SCEC dynamic rupture benchmark have been solved considering a Courant number of 0.37 or smaller. In a typical run like those used for TPV8 and TPV9, the grid is 45.5 km long times 30.0 km wide times 38 km depth, with grid sizes of h=100 m and dt=0.0065 s. This makes a grid of about 50.7 million of nodes. These jobs were run in the San Diego Supercomputing Center (SDSC) DataStar parallel computer using 960 processors and last around 3.1 hours.

4. Bibliography

- Gottschammer, E. and K.B. Olsen (2001). Accuracy of the Explicit Planar Free-Surface Boundary Condition Implemented in a Fourth-Order Staggered-Grid Velocity-Stress Finite-Difference Scheme, Bull. Seis. Soc. Am. 91, 617-623.
- Marcinkovich, C., and K. Olsen (2003), On the implementation of perfectly matched layers in a three-dimensional fourth-order velocity-stress finite difference scheme, J. Geophys. Res., 108(B5), 2276, doi:10.1029/2002 JB002235.
- Olsen, K. B. (1994), Simulation of three-dimensional wave propagation in the Salt Lake basin, Ph.D. thesis, Univ. of Utah, Salt Lake City.
- Day, S. M., and C. R. Bradley (2001), Memory-efficient simulation of anelastic wave propagation, Bull. Seismol. Soc. Am., 91, 520– 531.
- Luis A. Dalguer,1 and Steven M. Day (2007), Staggered-grid split-node method for spontaneous rupture simulation, J. Geophys. Res., 112, B02302, doi:10.1029/2006JB00446.