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3D nonplanar dynamic rupture in a heterogeneous medium: the pre-stress effect

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Fundamental questions of seismic complexity have been answer thanks to the development of numerical tools allowing seismologists to simulate the dynamic rupture of earthquakes. Both, the increasing computational power and the high quality observations allow the insertion of new physical constrains on the available numerical models so as our comprehension of earthquake mechanics may be continuously enhanced. The integration of sophisticated laboratory-derived friction laws or real faults geometries has shown to be essential to explain recent observations. On that account, the numerical precision of the numerical approaches becomes nowadays a critical issue, reason why it should be carefully analyzed before studding real earthquakes in detail.

In the last year, numerous modellers of the spontaneous rupture problem have tackled the challenge of validating their numerical approaches through the benchmark promoted by R. Harris and R. Archuleta (2004). Consistency between solutions yielded by different numerical approaches is essential since it is the only way to have confidence in these kinds of complex 3D simulations for which no theoretical solutions are available. Essentially, this code comparison exercise revealed the strong dependency of numerical results on the way rupture boundary conditions are applied. Finite difference (FD) approaches in which source discretization spreads out beyond one mesh point in thickness are particularly important for us. These are models where the displacement discontinuity takes place over a zone, namely a fault zone, having a finite width. The "fault zone models" (FZM) have been widely used and present interesting scaling features allowing, for instance, the spontaneous rupture growth along nonplanar faults (Cruz-Atienza and Virieux, 2004). So, in this work we first analyse the convergence and precision of our numerical FD FZM which is basically an extension to 3D of the rupture model introduced by Cruz-Atienza and Virieux (2004) where the

fault zone is described by boundary cubic elements. When compared with the Traction at Split Node (TSN) FD method in the planar fault case(*), and with the Boundary Integral Equation Method (BIEM) in the case of nonplanar (curvilinear) fault geometries, our approach is precise if the grid size is small enough (litter or equal than 50m).

Previous studies have shown that rupture propagation along nonplanar faults is mainly governed by the shear stress field ahead the rupture front even when Coulomb failure criterion is considered. Dynamic variations on the static (and dynamic) friction associated with normal stress changes cause only second order effects. However, in this work we show that, if a smooth curvilinear fault is embedded inside a space loaded by a homogeneous biaxial stress field, rupture history strongly depends on the initial traction vector along the fault surface which gives not only the shear stresses, but also the initial static friction through the normal stresses. Depending on the curvature of the fault surface, bilateral ruptures triggered at the fault center may exhibit asymmetric evolutions going from subshear regimes in one direction to supershear propagation regimes in the opposite direction. Seismograms computed around theses sources become complex when rupture propagates trough a heterogeneous medium. This work shows that the effects of tectonic stress field and the velocity structure may strongly determine rupture history on nonplanar faults and hence observable ground motions.

(*)We thank Luis Dalguer for providing us the TSN results for The Problem, Version 3, of the SCEC/USGS code-comparison exercise (Harris and Archuleta, 2004).

References 1) Cruz-Atienza V.M. and J. Virieux (2004). Geophys. J. Int., 158, 939-954. 2) Harris, R.A., and R.J. Archuleta (2004), EOS, 85, 321.