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Boundary conditions for the numerical modelling of seismic ruptures

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Seismic ruptures are usually modelled by finite difference (FDM), finite element (FEM) and boundary integral equation (BIEM) methods that have substantially different domains of validity. The recent SCEC experiment proposed by Harris and Archuleta (AGU Fall 2004) and several other authors have recently pointed out that numerical results may be very different depending on the particular technique used to model the friction boundary conditions on the fault. For instance, Dalguer and Day (AGU Fall 2004) pointed out that three different ways of doing boundary conditions in FDM produce quite different rupture velocities for the same overall parameters. They studied thre types of boundary conditions : split nodes, where the fault is actually two lines in the finite difference mesh, and two variations of the ‘‘thick fault” boundary conditions of Madariaga et al (1998). These results are not at all astonishing but pose serious problems for the reproducibility of numerical dynamic faulting sismulations. We demonstrate that in well posed boundary value faulting simulations, there are two space variables that need to be taken into account, one is the size of the fault and the other is the length of the slip weakening zone that blunts the crack front. For the different boundary conditions to give similar results the time and space sampling have to be adapted to both the effective slip weakening zone size and the overal dimensions of the fault. Because the different versions of the boundary conditions are applied at different distances from the fault, they produce different sizes of the effective slip weakening zone. Thick fault boundary conditions are less efficient in modelling the rupture zone, but tend to be more stable than split nodes because they have stronger effective damping. We extend the comparison to BIEM and a version of the Spectral FEM where the boundary conditions are solved by a combination split nodes and BIEM. While BIEM are nominally the most efficient method for solving the boundary

conditions they produce very noisy wave propagation as shown earlier by Tada and Madariaga (1999). Spectral elements are also noisy but they require many more mesh points so that they produce excellent results. From the study of a simple flat antiplane rupture propagation we conclude that there is an important trade off between numerical accuracy and boundary condition stability that needs to be carefully studied for each numerical method.