# Solving dynamic rupture problem with different numerical approaches and constitutive laws

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We study the dynamic initiation, propagation and arrest of a 2–D in–plane shear rupture by solving the elasto–dynamic equation both by using a boundary integral equation method and a finite difference approach. For both methods we adopt different constitutive laws: a slip–weakening (SW) law, with constant weakening rate, and rate– and state–dependent friction laws (Dieterich–Ruina). Our numerical procedures allow the use of heterogeneous distribution of constitutive parameters along the fault for both formulations. We first compare the two solution methods with a SW law emphasizing the required stability conditions to achieve a good resolution of the cohesive zone and to avoid artificial complexity in the solutions. Our modeling results show that the two methods provide very similar time histories of dynamic source parameters. We point out that, if a careful control of resolution and stability is performed, the two methods yields identical solutions. We have also compared the rupture evolution resulting from a slip–weakening and a rate– and state–dependent friction law. This comparison shows that, despite the different constitutive formulations, similar behaviors are simulated during the rupture propagation and arrest. We observe a crack tip bifurcation and a jump in rupture velocity (approaching the P–wave speed) also with the Dieterich–Ruina (DR) law. The rupture arrest at a barrier (high strength zone) and the barrier–healing mechanism are also reproduced by this law. However, this constitutive formulation allows the simulation of a more general and complex variety of rupture behaviors. By assuming different heterogeneous distribution of the initial constitutive parameters, we were able to model a barrier–healing as well as a self–healing process. This result suggests that, if the heterogeneity of the constitutive parameters is taken into account, the different healing mechanisms can be simulated. We also study the nucleation phase duration $T_n$, defined as the time necessary for the crack to reach half–length $l_c$. We compare the $T_n$ values resulting from distinct simulations

calculated using different constitutive laws and different set of constitutive parameters. Our results confirm that the DR law provides a different description of the nucleation process than the SW law adopted in this study. We emphasize the DR law yields a complete description of the rupture process, which includes the most prominent features of SW.