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Numerical modelling of earthquakes and fault systems using a dynamic elasto-plastic frictional contact model and the finite element method

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Dynamic simulations of rupture propagation in crustal fault systems are presented. We demonstrate the applicability of our elasto-plastic fault model for modelling dynamic rupture and wave propagation in fault systems. We present results for both homogeneous and inhomogeneous fault systems, and demonstrate the rich array of dynamic properties that can be simulated by varying different model parameters. These include: demonstration of either the crack-like or pulse-like nature of rupture propagation depending on the spatial and material heterogeneity of the fault; sub-shear and super-shear rupture speeds depending primarily on the weakness of the fault, the strain loading of the system and the propagation direction; and asymmetric bi-lateral propagation of rupture along an inhomogeneous fault.

Rupture propagation on a fault is controlled by the constitutive properties of the fault. A dynamic elasto-plastic constitutive law for the interface friction at the fault is formulated based on the Coulomb failure criterion and applied in a way analogous to non-associated elasto-plasticity. A slip weakening frictional law is employed. We study numerical solutions of the dynamic wave equation using the finite element method, where the penalty method is used to enforce the fault boundary conditions. This is achieved using a high level computational modelling language, escript, an advanced geophysical simulation software package developed at ACcESS which includes parallel equation solvers, data visualisation and data analysis software.

This model represents one component of a software system designed to permit large-scale simulations of earthquake cycles within fault systems of arbitrary geometry and mechanical properties. The software system is highly flexible, permitting fault systems

of differing geometry and complexity to be easily incorporated without any changes to the implementation of the earthquake physics. Our goal is to provide a comprehensive fault system simulation package with applications to synthetic seismicity studies, seismic hazard assessment and forecasting; and a virtual laboratory for probing the physics of crustal fault systems.