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Earthquake models suggest high fluid pressures along the 2004 Sumatra-Andaman earthquake megathrust

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We present physically realistic models of the 2004 Sumatra-Andaman Earthquake using SeisSol (www.seissol.org), which solves the spontaneous dynamic earthquake rupture problem. Geological and geophysical data suggest low effective stresses. A simple mechanism for lowering the effective stress is increasing the fluid pressure.This has the effect of both decreasing the normal stress acting on the fault surface and decreasing the effective shear stress by decreasing the difference between the maximum and minimum principal stresses. A model with hydrostatic fluid pressure produces slip magnitudes that are double that captured by kinematic source inversions. A model with near-lithostatic fluid pressure produces more reasonable slip magnitudes, but seafloor displacements lower than observations captured by GPS data. A preferred model with pore fluid pressure between these two extremes produces slip that matches the GPS data in magnitude and orientation in most locations, particularly along the central and north-central part of the rupture. The height of the tsunami wave suggests slip on landward and possibly also seaward dipping faults splaying off the megathrust. This is supported by evidence for active splay faulting along the southern end of the ruptured megathrust from deep seismic reflection surveys, bathymetric data, and relocated seismicity. We evaluate two splay fault geometries on seafloor uplift along the southern end of the rupture in the SeisSol models: (1) one long forethrust dipping 45 degrees and (2) two short forethrusts and two short backthrusts dipping 45 degrees. Only the long forethrust is activated and changing the fluid pressure does not affect fault activation, but does affect slip magnitude. In the preferred model, the long forethrust has dip slip of 1.5 m and this transfers directly into 1.5 m of vertical seafloor displacement. In contrast, 12 m of dip-slip on the megathrust results in only 2-3 m of uplift. However, high slip is concentrated along the central part of the megathrust in all of our models. In light of recent evidence for high slip along the megathrust close to the surface, we critique our models and discuss whether splay fault slip is required to generate the devastating tsunami that followed the earthquake, or whether slip along the megathrust alone could serve as an adequate tsunami source.