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Characterizing a Complex Source: The Role of Splay Faults in Seafloor Deformation During the 2004 Sumatra-Andaman Earthquake

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Failure along 1300 km of the Sumatra-Andaman subduction zone on 26 December 2004 caused 8-10 minutes of violent shaking. The resulting M 9.1-9.3 megathrust earthquake generated a tsunami wave that was up to 30 m high along the northern coast of Sumatra. The height of this wave suggests slip on landward and possibly also seaward dipping faults dipping at a high angle to the megathrust. This is supported by evidence for activation of splay faults off the west coast of northern Sumatra from deep seismic reflection surveys, bathymetric data, and relocated seismicity. We review evidence for the presence of active splay faults along the southern extent of the rupture. We then evaluate the influence of two alternative splay fault geometries on surface uplift in physically realistic dynamic rupture simulations of the megathrust earthquake. To model the dynamic rupture process, we use SeisSol, a software package based on an ADER-DG scheme with high-order accuracy in space and time. An unstructured tetrahedral mesh accommodates the complex geometry of the non-planar megathrust and the potential splay faults. We compare seafloor displacements for three models: without splay faults, with one long forethrust dipping 45 degrees, and with two short forethrusts and two short backthrusts dipping 45 degrees. Only the long forethrust is activated, directly transferring 2 m of along dip slip into 2 m seafloor uplift. In contrast, 12 m of along dip slip on the 20 degree dipping megathrust results in only 2-3 m of seafloor uplift. These results are being used by colleagues at the University of Hamburg to compare tsunamis generated from the displacements in the framework of the ASCETE project ("Advanced Simulation of Coupled Earthquake and Tsunami Events", www.ascete.de).