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Large scale dynamic rupture scenario of the 2004 Sumatra-Andaman megathrust earthquake

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The Great Sumatra-Andaman earthquake of 26 December 2004 is one of the strongest and most devastating earthquakes in recent history. Most of the damage and the ∼230,000 fatalities were caused by the tsunami generated by the Mw 9.1-9.3 event. Various finite-source models of the earthquake have been proposed, but poor near-field observational coverage has led to distinct differences in source characterization. Even the fault dip angle and depth extent are subject to debate.

We present a physically realistic dynamic rupture scenario of the earthquake using state-of-the-art numerical methods and seismotectonic data. Due to the lack of near-field observations, our setup is constrained by the overall characteristics of the rupture, including the magnitude, propagation speed, and extent along strike. In addition, we incorporate the detailed geometry of the subducting fault using Slab1.0 to the south and aftershock locations to the north, combined with high-resolution topography and bathymetry data.The possibility of inhomogeneous background stress, resulting from the curved shape of the slab along strike and the large fault dimensions, is discussed. The possible activation of thrust faults splaying off the megathrust in the vicinity of the hypocenter is also investigated. Dynamic simulation of this 1300 to 1500 km rupture is a computational and geophysical challenge. In addition to capturing the large-scale rupture, the simulation must resolve the process zone at the rupture tip, whose characteristic length is comparable to smaller earthquakes and which shrinks with propagation distance. Thus, the fault must be finely discretised. Moreover, previously published inversions agree on a rupture duration of ∼8 to 10 minutes, suggesting an overall slow rupture speed. Hence, both long temporal scales and large spatial dimensions must be captured.

We use SeisSol, a software package based on an ADER-DG scheme solving the spontaneous dynamic earthquake rupture problem with high-order accuracy in space and time. SeisSol allows adaptive tetrahedral meshing that accommodates complex geometries such as the splay fault scenario explored here, as well as mesh refinement in areas requiring higher resolution. We aim to conduct petascale dynamic rupture simulations on modern supercomputers with SeisSol based on the developed scenario to resolve the influence of source dynamics on ground displacement and the potential impacts on tsunami generation and propagation in the framework of the ASCETE project (www.ascete.de).