COMBINED EFFECTS OF FAST-VELOCITY WEAKENING FRICTION AND STRESS HETEROGENEITY CONTROL MEGATHRUST EARTHQUAKE RE-ACTIVATION, HIGH-FREQUENCY RADIATION, AND ARREST IN 3D DYNAMIC RUPTURE SIMULATIONS OF THE 2011 TOHOKU-OKI EARTHQUAKE

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Megathrust earthquakes are devastating and often rupture in unexpected ways. For example, the 2011 Mw 9.0 Tohoku-Oki earthquake may have multiple rupture episodes with high-frequency seismic radiation concentrated near the down-dip edge and large, tsunamigenic slips close to the trench, highlighting the importance of resolving rupture complexities due to the faulting conditions.

We use 3D dynamic rupture simulations to examine the roles of fast-velocity weakening rate-and-state friction and multi-scale stress heterogeneity in controlling the observed complexities of the Tohoku earthquake in terms of (i) multiple rupture episodes due to reactivation of the same fault area; (ii) down-dip high-frequency radiation and (iii) spontaneous rupture arrest. Our models account for depth-dependent normal stress, realistic slab geometry (JIVSM), and high-resolution seafloor bathymetry.

Driven by fast-velocity weakening friction alone, we observe complex dynamic interaction of the rupture and healing front that can reactivate the hypocentral area and induce three rupture episodes (Nielsen & Madariaga, 2003; Gabriel et al., 2012). Our models demonstrate that downdip high-frequency slip pulses can be generated without prescribing local stress or frictional asperities. If incorporating additional initial stress heterogeneity, such as from kinematic finite-fault slip models (Wong et al., ESSOAr, 2023), our dynamic models can reproduce spontaneous rupture arrest without requiring frictional barriers. Our results highlight the combined effects of frictional and stress heterogeneity in governing megathrust earthquakes.

Note: Figure is on the next page.

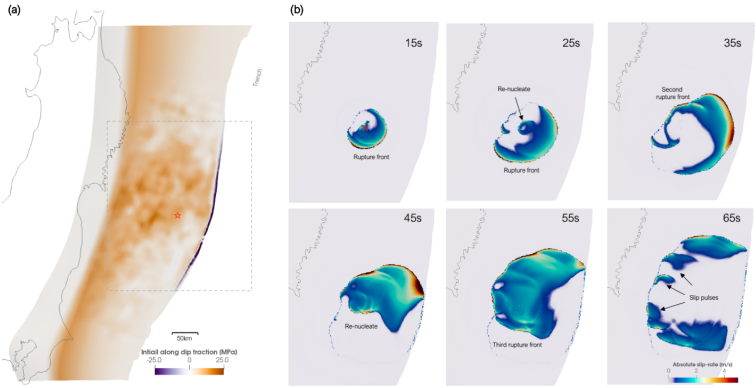

Figure: (a) Initial stress of the dynamic rupture simulation informed by median kinematic slip distribution (Wong et al., 2023). (b) Multiple-rupture front, downdip high-frequency radiation, and rupture arrest of the Tohoku-Oki earthquake simulation. Snapshot of the absolute slip-rate at an interval of 10s. Red star indicates the hypocenter location.