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Untangling the dynamics of the 2019 Ridgecrest sequence by integrated dynamic rupture and Coulomb stress modeling across an immature 3D conjugate fault network

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We present combined 3D dynamic rupture scenarios of the 2019 M_w6.4 Searles Valley and M_w7.1 Ridgecrest earthquakes closely constrained by observations, incorporating complex subsurface material properties, high-resolution topography and off-fault plastic deformation empowered by supercomputing. A detailed 3D non-vertical fault model of the active quasi-orthogonal intersecting fault network is built by integrating relocated aftershocks and surface ruptures constrained by space geodesy and field observations. All faults are exposed to a 3D SCEC community stress model as well as long- and short-term static and dynamic stress transfers, which impact rupture dynamics, particularly in the vicinity of complexities in fault geometry.

By assuming apparently weak faults due to the effect of rapid velocity-weakening friction and elevated fluid pressure, we determine initial stresses and fault strength. Multi-fault rupture directivity and velocity of both events are constrained by aftershock calibrated back-projection. In the presented scenario two conjugate faults simultaneously rupture in the M_w6.4 event, while only the SW-segment breaks the surface. The M_w7.1 event experiences the full final state of stress (dynamic plus static effects) of the Searles Valley scenario, leading to complex rupture including re-activation of the conjugate M_w6.4 segment, mixed crack and pulse-like propagation, tunneling beneath the fault intersection and choosing one Southern branch only. Both events exhibit a high dynamic stress drop reflecting the immature fault system. The foreshock induces a considerable Coulomb stress change in the M_w7.1 hypocentral region; however, not enough to trigger rupture across the stress-shadowed main fault. Both scenarios match key observations including magnitude, rupture speed, directivity, off-fault damage, slip distribution from kinematic inversion, teleseismic waveforms, GPS, and InSAR ground deformation; while shedding light on geometric, strength and stress factors governing the complex rupture evolution and interaction of the Ridgecrest sequence.