Supporting Information for "Precursory slow slip and foreshocks on rough faults"

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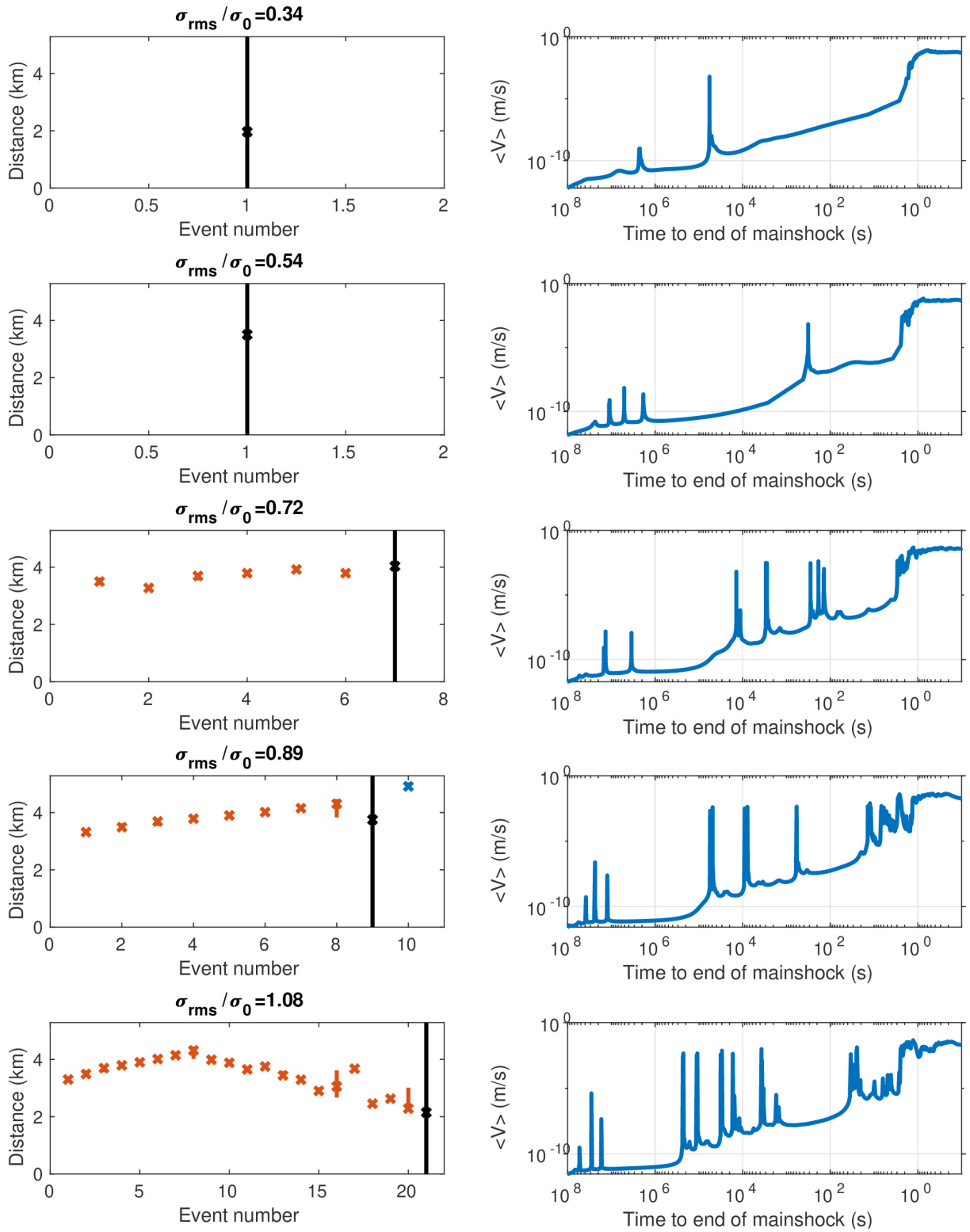
1. Figures S1, S2

1. Supplementary Figure: Other sequences

Supplementary Figure 1 shows the location of earthquakes and evolution of slip velocities in all simulated sequences.

2. Supplementary Figure: Effect of maximum wavenumber k_{max}

Since stress perturbations grow as k^2, they are dominated by the smallest wavelength (wavenumber k_{max}). In the simulation in the main text, $k_{max} \sim 2\pi/L_\infty$. To verify the impact of smaller wavelengths, we ran a simulation on a subset of the original domain, and increased k_{max} by successive factors of 2. Fig. S2 shows a cycle for a simulation with k_{max} increased by a factor of 4; for efficiency, we initialize the fault with an elliptical slip profile with $< S >= 17$cm, so that normal stress perturbations are already developed. The velocity at the beginning of the cycle is lower than in the earlier case, consistent with the dimension of the creeping patches decreasing linearly with k_{max},and creep velocities scaling as $V_{cr} \sim \dot{\tau} L_{cr}/\mu'$; we verified that V_{cr} early in the cycle scales with k_{max}^{-1} as expected. Since asperities with moderate $\Delta\sigma$ can now be significantly smaller than their local nucleation dimension, they rupture aseismically (peaks in velocity in Fig. S2 before $t \sim 10^6$s). Both seismic and aseismic failures contribute to a gradual unpinning of the fault, as described above: the size of creeping regions expands as more asperities fail and creeping patches merge. The temporal evolution of slip velocities, with an abrupt increase during bursts and an an overall $1/t$ trend, is analogous to the previous case.


σrms /σ0 =0.34
σrms /σ0 =0.54
σrms /σ0 =0.72
σrms /σ0 =0.89
σrms /σ0 =1.08
Distance (km)
Event number
<V> (m/s)
Time to end of mainshock (s)

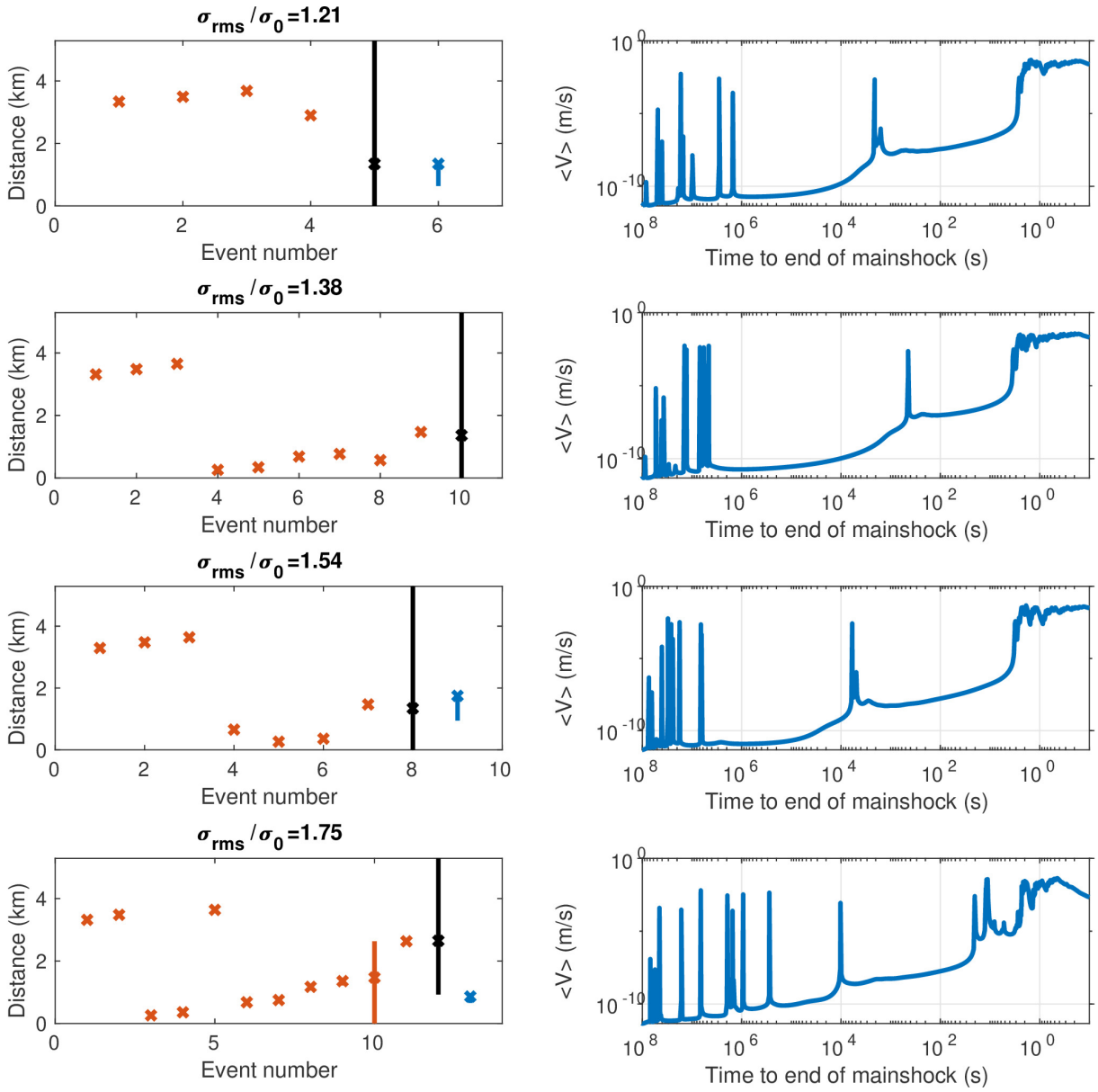


Figure S1. Spatio-temporal behavior of all simulated sequences. As time progresses, more slip accumulates and the root-mean-square amplitude of normal stress perturbations increases (appendix A). Left: crosses indicate the center of the nucleation region, and lines the rupture length. Red=foreshocks, black=mainshock, blue=aftershocks. Right: Average slip velocity on the fault vs. time to mainshock.

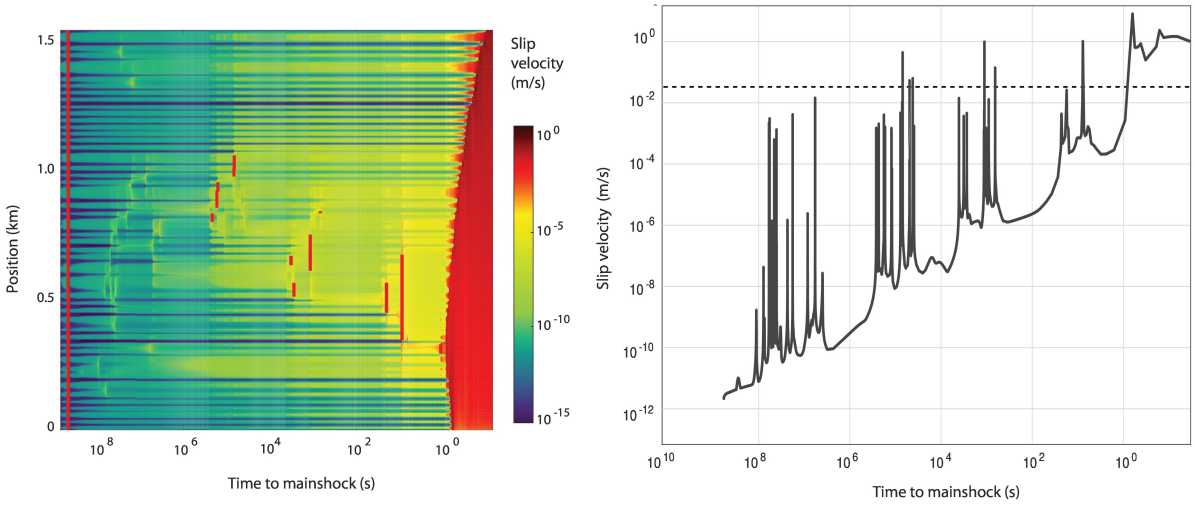


Figure S2. Left: slip velocity plot as in Fig.4, for a smaller fault with $L_{min} = 25m \sim L_\infty/4$ (4 times smaller than in the previous simulations) and $\Delta\sigma_{rms}/\sigma_0 = 2.9$. Right: maximum slip velocity leading up to the mainshock with $L_{min} = 25m$. The dotted line marks the threshold velocity used to define earthquakes (see methods section).