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Spatial Distributions of Foreshocks and Aftershocks: Static or Dynamic Triggering

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In recent years, the spatial distributions of foreshocks and aftershocks have been scrutinized for evidence supporting either triggering by static stress changes induced by the permanent deformation from prior earthquakes or triggering by the dynamic stresses from seismic waves. Felzer & Brodsky (2006) identified small (m<4) mainshocks and triggered aftershocks, stacked the distances between these pairs and observed a single power-law decay with distance that extends beyond the zone traditionally thought to be affected by static stress changes. On this basis, they argued that dynamic stresses are responsible for triggering earthquakes. Richards-Dinger et al. (2010) and other studies, however, have presented several lines of evidence that suggest otherwise. One crucial question is whether the stacked distances of pairs of earthquakes, representing either mainshock-aftershock or foreshock-mainshock pairs, are in fact correctly identified and not misattributed, unrelated earthquakes. This question is especially important in the critical distance range of several to tens of earthquake radii, over which static stresses are thought to be too small to affect seismicity. If earthquake pairs in this range are not causally related, then the histogram of foreshock-mainshock and mainshock-aftershock pairs should be identical, and the difference between the two histograms can be used to identify remote triggering. Results based on southern Californian seismicity suggest that (1) the existence of a single power-law with a particular exponent may not be a robust observation, (2) geothermal regions seem to play an important role over the relevant distances, (3) remote triggering seems to exist beyond the classical static stress influence zone (perhaps out to 15 km after mainshocks with magnitudes between 3 and 4), (4) simple ETAS model simulations cannot reproduce all observations, and (5) at most one-third of the remote aftershocks had received significant static Coulomb stress change from much earlier but nearby large (m>5) quakes, suggesting that a misattribution of aftershocks statically triggered by large quakes as remotely-triggered aftershocks seems unlikely. An analysis of the Japanese JMA catalog supports some of these results, but not all. In particular, while the full data set suggests remote triggering of aftershocks by small (m<4) mainshocks out to 15 km, a high-quality onshore data subset with low residual timing errors does not support remote triggering at all. However, if the remote triggering signal in the full JMA catalog is spurious and instead due to temporally larger location uncertainties after moderate earthquakes, these uncertainties need to persist beyond the first 10 minutes after each (3<m<4) 'mainshock' to explain the signal.