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Is the co-seismic slip distribution fractal?

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Co-seismic along-strike slip heterogeneity is widely observed for many surface-rupturing earthquakes as revealed by field and high-resolution geodetic methods. However, this co-seismic slip variability is currently a poorly understood phenomenon. Key unanswered questions include: What are the characteristics and underlying causes of along-strike slip variability? Do the properties of slip variability change from fault-to-fault, along-strike or at different scales? We cross-correlate optical, pre- and post-event air photos using the program COSI-Corr to measure the near-field, surface deformation pattern of the 1992 Mw 7.3 Landers and 1999 Mw 7.1 Hector Mine earthquakes in high-resolution. We produce the co-seismic slip profiles of both events from over 1,000 displacement measurements and observe consistent along-strike slip variability. Although the observed slip heterogeneity seems apparently complex and disordered, a spectral analysis reveals that the slip distributions are indeed self-affine fractal i.e. slip exhibits a consistent degree of irregularity at all observable length scales, with a 'short-memory' and is not random. We find a fractal dimension of 1.58 and 1.75 for the Landers and Hector Mine earthquakes, respectively, indicating that slip is more heterogeneous for the Hector Mine event. Fractal slip is consistent with both dynamic and quasi-static numerical simulations that use non-planar faults, which in turn causes heterogeneous along-strike stress, and we attribute the observed fractal slip to fault surfaces of fractal roughness. As fault surfaces are known to smooth over geologic time due to abrasional wear and fracturing, we also test whether the fractal properties of slip distributions alters between earthquakes from immature to mature fault systems. We will present results that test this hypothesis by using the optical image correlation technique to measure historic, co-seismic slip distributions of earthquakes from structurally mature, large cumulative displacement faults and compare these slip distributions to those from immature fault systems. Our results have fundamental implications for an understanding of slip heterogeneity and the behavior of the rupture process.