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Variability in coseismic and long-term slip along the El Mayor-Cucapah surface rupture assessed using terrestrial lidar

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We analyze high-resolution (>10^4 points/m^2) terrestrial lidar surveys of the 4 April 2010 El Mayor-Cucapah earthquake rupture (Baja California, Mexico), collected 12 to18 days after the event at three sites. Using point cloud-based tools in an immersive, virtual-reality environment, we quantify coseismic fault slip for hundreds of meters along strike and construct densely constrained along-strike slip distributions from measurements of offset landforms. Uncertainty intervals ranging from ±12-17% (2σ) for each offset or fault-perpendicular profile are determined empirically by repeatedly measuring each sequence of offsets. This analysis suggests that short wavelength (10^1-10^2 m) variations in displacement do not reflect recognizable earthquake mechanisms but rather are the result epistemic (interpretive) uncertainties that are difficult to quantify in the field. At all three sites, a linear slip gradient either satisfies all measurement distributions or accounts for unmeasured sagging of the hangingwall detected with differential airborne lidar. Conversely, fitting an envelope curve above the local slip maxima overestimates true fault slip by ~30% and along-fault strain by over an order of magnitude by favoring measurements with large, positive, epistemic errors. In aggregate, these datasets show that the true slip distribution at each site is likely to be smoother than that implied by a single set of field- or virtual reality-based measurements. In addition, we measured two populations of striations on exposed fault faces plunging ~25° and ~56° to the southeast. The shallower set of striations overlaps within error the ~30° plunge of the 2010 slip vector determined from offset measurements, implying that the steeper striations preserve the slip direction from the penultimate earthquake. Fault-perpendicular profiles across a paleoscarp that we interpret to have resulted from a single pre-historic earthquake reveal ~3.2 m of vertical displacement. Thus we find that the Borrego fault produced ~2.5 m of strike-slip dominated displacement in 2010, and ~4 m of dip-slip dominated displacement in the penultimate earthquake. Both interpretations suggest that the Borrego fault violates the common assumption that faults produce kinematically similar slip events.

Keywords: terrestrial lidar, surface rupture, slip distribution, El Mayor Cucapah, uncertainties

NOTE: This research was completed while first author Gold was at UC Davis.