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How Much Shallow Afterslip Are We Missing Immediately Following a Rupture? Capturing Rapid Postseismic Fault slip in the Hours Following the 2016 Mw 7.1 Kumamoto Earthquake, Japan Using a Dense Continuous GPS Network

Chris Milliner (1), Roland Burgmann (2), Teng Wang (3), Asaf Inbal (2), David Bekaert (1), Cunren Liang (1), and Eric Fielding (1)

(1) JPL, NASA, Earth Surface and Interior, Los Angeles, United States (christopher.milliner@jpl.nasa.gov), (2) Earth and Planetary Science, UC Berkeley, (3) EO Singapore

Capturing rapid afterslip in the minutes to hours following a surface rupturing event is challenging due to the latency of satellite observations (e.g., from SAR or optical imagery), and daily observations from sparse GPS networks. Consequently, whether the majority of shallow fault motion is a result of dynamic rupture, or rapid afterslip driven by possible slip gradients from vertical deficits in the initial coseismic slip is difficult to determine. What process is primarily responsible for shallow fault slip has significant implications for our understanding of faulting mechanics and frictional behavior in the shallow crust. Here, using a dense and continuous 5-minute sampled GPS network we constrain the spatiotemporal evolution of afterslip along the fault plane within the first hours following the 2016 Mw 7.1 Kumamoto earthquake. To isolate the aseismic transient tectonic signal from the noisy continuous GPS data ($\pm$ 5 mm) we apply both principal and independent component analysis, which helps identify and filter out common-mode error and noise, reducing the RMS by $\sim$60%. After inverting the filtered GPS time series epoch-by-epoch using an L1 inversion scheme, the time-varying slip models show no clear evidence of significant (< 30 cm) rapid, afterslip occurring within the first day in the top 3 km of the crust. Interferometry of ALOS-2 data in the week following the mainshock show aside from surface deformation related to volumetric changes from poroelastic processes, the majority of shallow slip on the ruptured fault was largely complete after rupture cessation. We suggest, the lack of early afterslip is possibly a result of the Kumamoto rupture occurring along 1) a mature, smooth, well-defined pre-existing fault structure that allowed for near-complete rupture towards the surface and, 2) the presence of well- consolidated volcanic material and lack of saturated, unconsolidated sediments. The latter which are typically strongly velocity-strengthening and thought to explain the anomalously large afterslip following the 2014 Mw 6.0 Napa earthquake. The use of geodetic data with the ability to resolve near-field, coseismic deformation and rapidly decaying postseismic processes will aid in our understanding of the ability of ruptures to penetrate fully towards the surface through the velocity- strengthening regime, enabling for more accurate simulations of expected dynamic ground motions and reliable seismic hazard assessment.