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# Rapid response of slow-moving landslides to extreme rainfall following historic drought in California

Alexander Handwerger (1), Eric Fielding (1), Mong-Han Huang (2), Georgina Bennett (3), and Cunren Liang (4)

(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, United States (alexander.handwerger@jpl.nasa.gov), (2) Department of Geology, University of Maryland, College Park, Maryland, United States (mhhuang@umd.edu), (3) School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom (Georgina.Bennett@uea.ac.uk), (4) Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, United States (cunrenl@caltech.edu)

Large, deep-seated, slow-moving landslides can remain active for decades or longer and move primarily during seasonal wet periods when infiltrating precipitation increases the pore-water pressure within the landslide body. Climate change, which is altering both the frequency and magnitude of precipitation worldwide, is therefore predicted to have a major impact on landslides. To better understand the hydrological controls on landslide behavior, we examine the relationship between precipitation, pore-water pressure, and landslide displacement for hundreds of active landslides in the Eel River catchment, northern California, USA, between 2016 and 2018. This time period is well suited for exploring the hydrological controls on landslide motion because over the last decade there have been rapid and extreme shifts in precipitation including a historic drought (2012-2016) and one of the wettest years on record (2017). We use precipitation data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group, ground-based measurements of precipitation and pore-water pressure from a USGS landslide monitoring station, and we quantify the landslide displacement using repeat-pass radar interferometry and pixel offset tracking techniques on data from the airborne NASA/JPL Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR).

We explored how spatial and temporal changes in precipitation affected the landslide activity across a 3,000 square kilometer area. Our field area is centered on Kekawaka Creek, which has an average annual precipitation of $\sim$1.55 m, 80% of which falls between October and May. Kekawaka Creek received 1.8 m of rainfall during 2016, 2.3 m during 2017, and 1.1 m during 2018. We found that these large changes in rainfall had a major impact on the landslide activity. In total, we identified 312 active landslides during our 2.5 year study period, 102 of which were previously unmapped and 87 that reactivated. We also found that 120 landslides were active during 2016, 312 during 2017, and 146 during 2018. Furthermore, the increased landslide frequency during 2017 was accommodated by the smaller and thinner landslides. Lastly, there was a large increase in landslide displacement and velocity during 2017. These changes in landslide activity are directly linked to the changes in precipitation and pore-water pressure. Our results show that slow-moving landslides are sensitive to rapid changes in precipitation, particularly the smaller and thinner landslides that experience stronger pore-water pressure changes. Based on future predictions of precipitation over the next century, we expect that there will be profound changes in landslide behavior and highlight the need for more observations and models that can help describe these behaviors.