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A shift from drought to extreme rainfall drives a stable landslide to catastrophic failure

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The addition of water on or below the earth's surface generates changes in stress that can trigger both stable and unstable sliding of landslides and faults. While these sliding behaviours are well-described by commonly used mechanical models developed from laboratory testing (e.g., critical-state soil mechanics and rate-and-state friction), less is known about the field-scale environmental conditions or kinematic behaviours that occur during the transition from stable to unstable sliding. Here we use radar interferometry (InSAR) and a simple 1D hydrological model to characterize 8 years of stable sliding of the Mud Creek landslide, California, USA, prior to its rapid acceleration and catastrophic failure on May 20, 2017. Our results suggest a large increase in pore-fluid pressure occurred during a shift from historic drought to record rainfall that triggered a large increase in velocity and drove slip localization, overcoming the stabilizing mechanisms that had previously inhibited landslide acceleration. Given the predicted increase in precipitation extremes with a warming climate, we expect it to become more common for landslides to transition from stable to unstable motion, and therefore a better assessment of this destabilization process is required to prevent loss of life and infrastructure.

Stress and fluid-pressure perturbations from changes in infiltrating precipitation and snowmelt[1–7], seasonal water storage[8], dehydration reactions[9], and wastewater and fluid-injection[10–12] can trigger diverse sliding behaviours of both landslides and faults, including stable sliding (e.g., slow-moving landslides or aseismic fault slip) and unstable sliding (e.g., fast-moving landslides or earthquakes). These various sliding behaviours are described by the laboratory-based critical-state soil mechanics[3–5] and rate-and-state friction[10–15] models. In general, stable sliding should occur if the frictional resistance increases during sliding and unstable sliding should occur if the frictional resistance decreases during sliding. These changes in the frictional resistance are controlled by material properties[10–16] and/or from shear-induced changes in pore-fluid pressure[3–5,17]. Although these mechanical models can be used to describe various sliding behaviours, less is known about the field-scale environmental conditions or kinematic behaviours that occur during the transition from stable to unstable sliding. In this manuscript, we present new remote sensing observations that show the behaviour of a landslide that transitioned from stable to unstable sliding.

Ongoing natural and man-made climate shifts (i.e., global warming) in response to increasing concentrations of greenhouse gases are predicted to increase the frequency and magnitude of geohazards such as landslides[18]. Recent studies have investigated the role of climate change on slope stability using historical records of temperature, precipitation, and landslide events with future predictions from downscaled Global Circulation Models[18–20]. These studies have found that the occurrence or activity of landslides is expected to increase in areas where the frequency and magnitude of precipitation is predicted to increase and decrease in areas where the frequency and magnitude of precipitation is predicted to decrease. However, interactions between ongoing climate shifts and landslide behaviour are difficult to assess due to uncertainties in both climate and landslide models. Documenting the behaviour of landslides in response to ongoing climate shifts is essential for improving our understanding of the mechanisms that control their velocity and our ability to forecast catastrophic failure.

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