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Controls on slow-moving landslides revealed by satellite and airborne InSAR

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Landslides display a wide variety of behaviors ranging from slow persistent motion to rapid acceleration and catastrophic failure. Given the variety of possible behaviors, improvements to our understanding of landslide mechanics are critical for accurate predictions of landslide dynamics. To better constrain the mechanisms that control landslide motion, we use recent SAR data collected by Copernicus Sentinel-1A/B, NASA UAVSAR, JAXA ALOS-2, and DLR TerraSAR-X to quantify the time-dependent kinematics of over 200 slow-moving landslides in the Central and Northern California Coast Ranges. These landslides are ideally suited for InSAR investigations due to their size (up to 5 km in length and 0.5 km in width), persistent downslope motion with low velocities (m/yr), and sparse vegetation. We quantify the seasonal and multi-year changes in velocity driven by changes in precipitation and find that landslide velocity varies over both timescales. Over seasonal timescales, each landslide displays a period of acceleration that occurs within weeks of the onset of seasonal rainfall suggesting that motion is governed by precipitation-induced changes in pore-water pressure. We also examine the effects of multi-year climate variations (i.e. recent historic California drought and the possible wet period that began in late 2016) on the activity of landslides. We find that the drought has led to a decrease in annual displacement over the past several years and predict that a resurgence in annual displacement will occur with an increase in annual rainfall. Lastly, we use UAVSAR data acquired at 4 different look directions to quantify 3D surface displacement of multiple landslides and invert for their subsurface geometry (i.e. basal slip surface) using recently developed 3D mass conservation techniques. The application of NASA's UAVSAR data represents a major advance from previous InSAR studies on landslides in this region and provides one of the first 3D dataset that contains numerous landslides occurring under nearly identical environmental conditions. We find that each landslide displays a heterogeneous (i.e. bumpy) basal slip surface with changes in thickness that can approach several meters along the landslide body. We propose that the slip surface roughness governs long term kinematics and helps prevent catastrophic failure of these landslides. Our future work is aimed at using these observations to test and develop predictive landslide models.