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Evolution analysis of the April 2019 Hoseynabad-e Kalpush landslide in Iran inferred from multi-sensor satellite remote sensing and in-situ measurements

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Following intense precipitation records between mid-March and the beginning of April 2019, thousands of slope failures affected the mountainous regions in northeast and south of Iran. In particular, a catastrophic landslide occurred in Hoseynabad-e Kalpush village, in Semnan province in the Northeast of Iran, where more than 300 houses were damaged, of which 163 houses had to be evacuated due to the severity of the destruction and the danger to their residents. Several questions were raised in the aftermath of the disaster as to whether the landslide was triggered by the heavy precipitation only or by other factors such as additional load due to the increase of the hydraulic gradient and seepage from a nearby artificial reservoir built in 2013 on the opposite side of the slope. This paper provides multi-scale and multi-sensor remote sensing investigation for the pre-, co-, and post-failure slope stability of the Hoseynabad-e Kalpush landslide and assesses the role of potential external factors in triggering the 2019 catastrophic failure. C-band Sentinel-1A Interferometric Synthetic Aperture Radar (InSAR) measurements and very-high-resolution Planet scope imagery cross-correlation show a clear precursory and transient deformation in the lower part of the slope that culminated in a slope failure of more than 35 m in the upper part of the landslide in April 2019. The lower and middle parts of the landslide continued to move with a maximum displacement rate of 10 cm in the first 6 months. Satellite remote sensing results are integrated with rainfall data and in-situ records of the reservoir water levels to evaluate the role of meteorological and anthropogenic conditions in promoting slope instability. The outcomes of this study highlight how the complex interaction between climate and anthropogenic factors influence unstable hillslope conditions in space and time and the need for more integration of remote sensing measurements into early warning systems at regional and national scales.