

30+ Yrs of Satellite-based Monitoring of Slow-moving Landslides in Central Nepal using Pixel Tracking

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Abstract:

The Himalayan Mountain hillslopes are affected by numerous and varied landslides. A specific type of landslide develops within the fragmented mass of old slid hillslopes. Associated displacement can reach several tens of mm/year, with potential high spatial and temporal variabilities, controlled by external factors including earthquake and monsoon. To understand the underlying dynamics and relationships between the displacement and external factors, the capability to monitor displacements over a large spatial and time range, as well as in difficult acquisition setups (high slopes, clouds and varying atmosphere) is needed. However, the upper range of displacement of these landslides reaches the application limits of commonly used methods such as InSAR, and cloud cover reduces the availability of optical images.

Here we demonstrate, in the Bhote Koshi Valley (Central Nepal), the capability of retrieving such displacements using both radar (Sentinel-1, PAZ) and high-resolution optical (Pléiades) image pixel tracking, and we present preliminary results on the dynamics of monitored landslides.

We found that pixel tracking of Sentinel-1 images needs large rectangular correlation windows and is better constrained both spatially and in amplitude using a frequency refinement. Preprocessing the images with a mask based on the amplitude dispersion index can further decrease the overall noise and blunders in adjacent areas. The perpendicular baseline does not impact the image's global errors, but can hinder signal detection in specific zones. Correlation is well preserved even for high temporal baselines, underlying smaller displacement values with higher S/N, and is therefore preferred for time series inversion. The minimal detected gradient is estimated around 1/6th of the pixel size (for Sentinel-1), higher than the threshold commonly agreed for pixel tracking of 1/10th. Furthermore, over the monitored area, the Bolde landslide shows a constant displacement to the North of 1–2 m/y at least since 1992 until now. The Tapgaon landslide, which shows no continuous displacement detectable by Sentinel-1 pixel tracking, exhibited a strong response to the 2015 Mw 7.8 Gorkha earthquake with more than 11 m of westward displacement. Pleiades' disparities show large displacement over the Bolde village and neighbouring farming fields, with displacement ranging from 0.27 m/y to 1.11 m/y to the North and divided into separate blocks. Decorrelation is observed at the river interface, highlighting high erosive flux.

This work shows that Sentinel-1 radar image pixel tracking can be crucial as it bridges the gap between InSAR and optical correlation, and allows landslides monitoring over large areas with high temporal coverage.

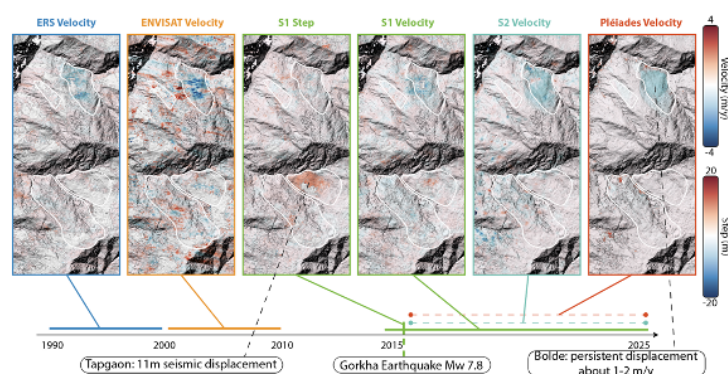


Figure 2: Continuous northward displacement of the Bolde landslide between 1992 and 2025 and the 2015 earthquake's response of the Tapgaon landslide