

Mapping and Monitoring of Slow-Moving Landslides in Upper Mustang (Nepal) Using Optical Images Correlation and InSAR

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Abstract:

Upper Mustang (Nepal) is a dry, high-altitude (>3000 m) sedimentary valley located between the high peaks of the Himalayas (Annapurna, Dhaulagiri) and the Tibetan plateau, destabilized by numerous large-scale slope deformations. Although these landslides have been recognized for a long time, their characteristics (location, extent, volume, speed, etc.) have never been systematically studied.

This project aims to determine the extent and kinematics of the slope deformations in Upper Mustang and evaluate their temporal and spatial controls using a combination of two remote sensing methods: Optical Images Correlation and InSAR. We use the correlation of very high-resolution Pleiades images (2013-2025) and InSAR of Sentinel-1 data to do an exhaustive inventory of the landslides. We generate time series of displacement with: PlanetScope images (2016-2025) for specific areas of slow velocity (from cm/y to m/y) and Sentinel-1 data (2014-2025) for areas with very slow velocity (mm/y to cm/y).

The results highlight the complementarity of InSAR and optical image correlation for mapping and monitoring deformations in Upper Mustang, which has so far enabled the detection of 85 landslides covering 42 km^2 , representing 4.5% of the study area. The speeds of the landslides range from 5mm/yr to 3.3m/yr. Their temporal evolution varies, with some areas showing slow and linear evolution (western Gayu) and others showing trends toward acceleration and deceleration (Dhe, eastern Gayu), which could point to different triggering and controlling factors (climate, human activity, geology).

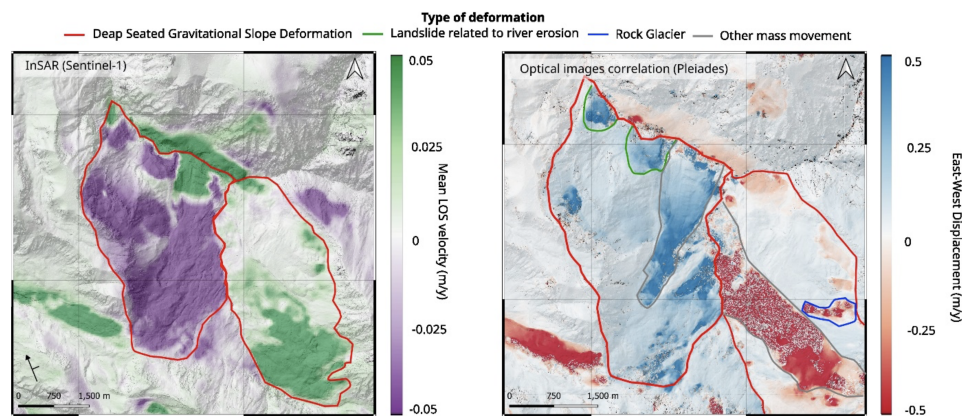


Figure 1: Complementarity of InSAR (left) and Optical Images Correlation (right) to detect different slope deformations in Upper Mustang (Gayu-Kharka area). InSAR (Sentinel-1, 2014–2025) is sensitive to very slow velocity, highlighting the deep-seated motion (red) of the two mountain slopes. Optical Image Correlation (Pleiades, 2013–2025) highlights the different types of landslides moving faster (m/y): the small deformations related to the river erosion (green), the rock glacier (blue) at the top of the deformation, and other slow-moving areas not yet related to a specific factor (grey)