PS-InSAR based Slope Deformation Monitoring in the Bhagirathi Valley, Uttarakhand Himalaya

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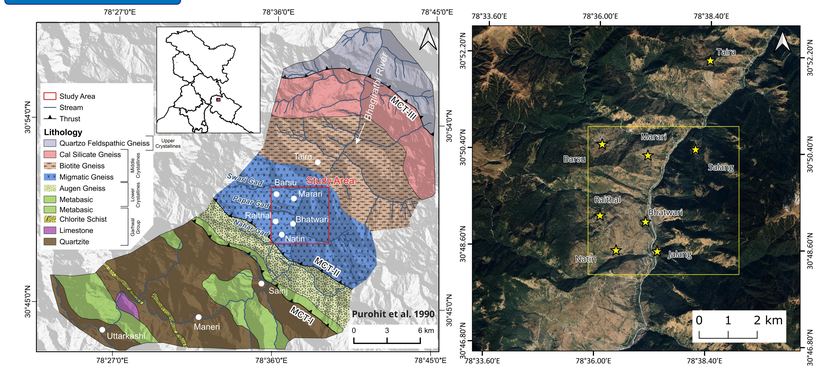
1. INTRODUCTION

Slow-moving landslides—often referred to as "silent disasters" — pose long-term threats to infrastructure, communities, and landscapes, with the potential to evolve into catastrophic events.

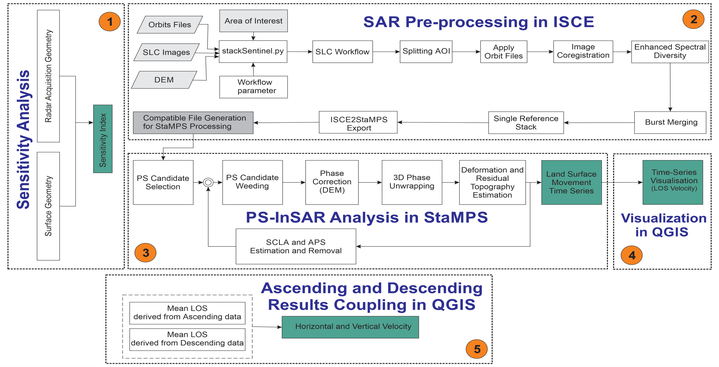
Therefore, it is vital to continuously monitor such landslides with the aim of reducing the risk posed by the failure, by comprehending the slope movement dynamics with the help of continuously monitoring the slope movement, as the knowledge of landslide deformation dynamics provides crucial insights into its characteristics and assist in reducing its detrimental impact on the society.

In this regards, satellite-based synthetic aperture radar (SAR) remote sensing provides reliable and continuous ground deformation over a wide area with its all-weather conditions and day-night imaging capabilities.

2. STUDY AREA



3. METHODOLOGY

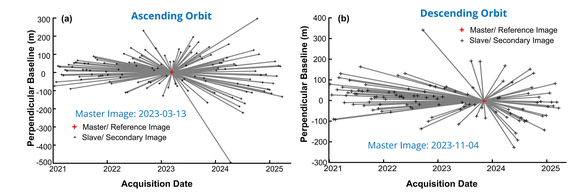


Dataset: Sentinel- 1A
Polarisation: VV
Ascending Orbit:
Path: 129
Frame: 97
First Image: 2021-01-10
Last Image: 2025-03-26
Reference/Master Image: 2023-03-13
Sub-swath: IW-2
No. of Bursts: 3
No. of Scenes: 129

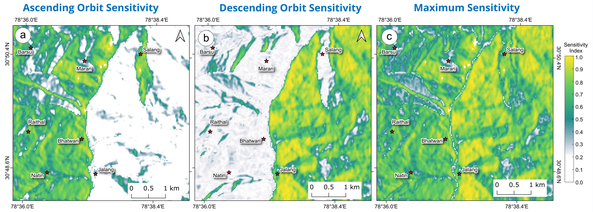
Descending Orbit:
Path: 63
Frame: 487 & 488
First Image: 2021-01-06
Last Image: 2025-03-22
Reference/Master Image: 2023-11-04
Sub-swath: IW-2
No. of Bursts: 2
No. of Scenes: 114

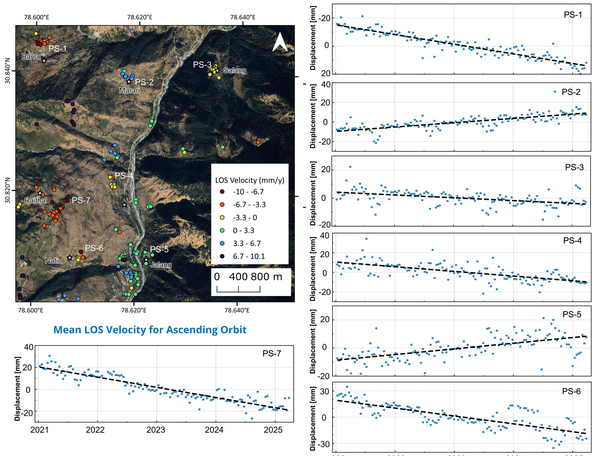
4.1 RESULTS

Star Plot

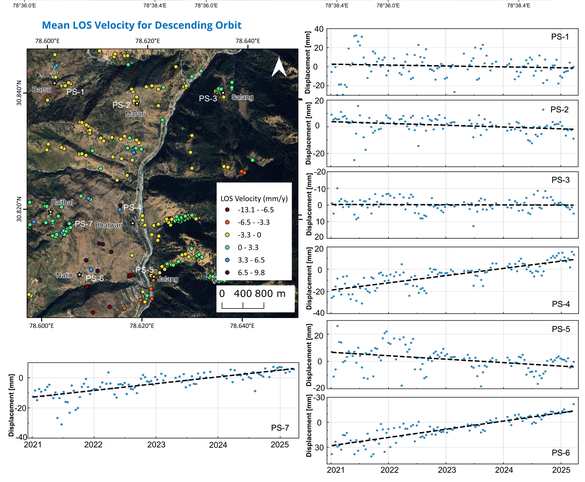


Sensitivity Index





The mean LOS velocity ranges between -10 mm/y and 10 mm/y. Natin, Raithal and Barsu are experiencing surface movement away from the satellite, with a mean velocity of greater than approximately -3.0 mm/y. Furthermore, the time-series plot for the PS pixels PS-1, PS-6, and PS-7 shows a consistent negative deformation trend. In contrast, settlements located closer to the valley floor are revealing a positive mean LOS velocity. PS-2, PS-2, and PS-5 are exhibiting a positive deformation trend with a mean LOS velocity greater than ~ 3 mm/y.



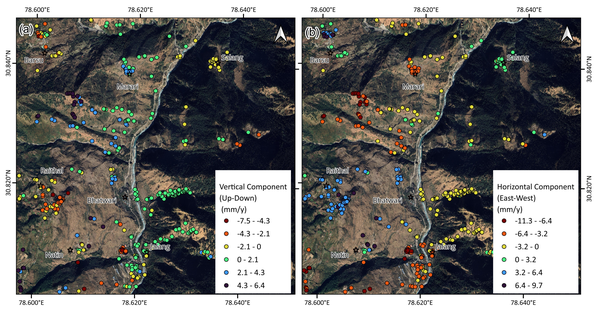
For the descending orbits, the mean LOS velocity are ranging between ~ -13 mm/y and ~10 mm/y . Raithal, Salang and Bhatwari are showing positive mean LOS velocity accounting for > ~ 3mm/y, and similarly the time-series deformation plot for the PS pixels PS-3, PS-4 and PS-7 also showing positive trend. Whereas Barsu, Marari and Jalang are creeping at the rate of > ~ -3 mm/y and the PS pixels PS-1, PS-2 and PS-5 are showing negative trend for the observed time-period.

4.2 RESULTS

2-D Velocity Components

The results demonstrate that the settlements on the upper reaches of the slope are experiencing vertically downward movement with mean velocity upto ~ -7mm/yr, while the lower reaches are predominantly showing vertically upward movement with mean velocity ranging between ~ 2 mm/yr and ~ 6.5 mm/yr.

The settlements such as Natin, Raithal, Barsu, and Salang are primarily creeping eastwards with mean velocity reaching up to ~ 10mm/y, whereas the southern extent of Bhatwari, Marari, and the surrounding area are showing mean negative velocity greater than ~ -3 mm/y, suggesting westward movement.



5. FIELD PHOTOGRAPHS

The impact of slow movement is well evident in the field in the form of cracks developed in the houses, tiled pillars and trees, undulated ground surfaces, tension cracks, land subsidence and landslides as well.

6. CONCLUSIONS

1. The spatial distribution of mean LOS velocity for the ascending pass shows that the upper slope settlements such as Natin, Raithal and Barsu shows negative mean LOS velocities upto -10mm/y while lower valley settlements show positive LOS velocities (> ~ 3 mm/y). Whereas for the descending satellite orbit, Raithal, Salang and Bhatwari show positive mean LOS velocities (> 3 mm/y) and Barsu, Marari and Jalang show negative mean LOS velocities (> -3 mm/yr).

2. The 2-D realistic mean velocity shows that the upper-slope settlements such Natin, Raithal and Barsu are predominantly moving vertically downward (upto ~ 7mm/y) and eastward (upto ~ 10mm/yr), whereas lower valley settlements such as Marari Bhatwari township are showing vertically upward movement (~ 2 to 6.5 mm/y) combined with westward movement (> ~ -3 mm/yr).

3. The region is persistently observing slow movements, which may serve as a precursor to a possible disaster. Therefore, there is a need for a comprehensive investigation integrating the PS results with the slope stability analysis that assesses the role of geology, rainfall, and earthquakes, and geophysical mapping. This integration shall assist in estimating the risk posed by the failure and further help in mitigation planning.

ACKNOWLEDGEMENT

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