Multi-Temporal GNSS, RTS, and InSAR for Very Slow-Moving Landslide Displacement Analysis

Taraka V. PATTELA[1], **Leonardo DISPERATI**[1,*], **Enrico D'ADDARIO**[1], and **Daniele RAPPUOLI**[2]

[1] *Department of Earth, Environment and Physical Sciences, University of Siena, Siena, Italy, (taraka.pattela@unisi.it, disperati@unisi.it, enrico.daddario@unisi.it)*

[2] *Unione dei Comuni Amiata Val d'Orcia, Piancastagnaio, Italy, (d.rappuoli@uc-amiatavaldorcia.si.it)*

[*] *corresponding author*

Abstract

Very slow-moving landslides threaten infrastructures and safety, yet detecting their subtle, long-term displacements remains challenging. The eastern slope of Mount Amiata, Tuscany, Italy, where high-precision geodetic monitoring is required to control the very slow-moving landslides affecting the area, represents an example of this issue. Namely, in this study we assess whether the joint exploitation of multi-temporal GNSS (continuous and periodic), Robotic Total Stations (RTS), and Persistent Scatterer InSAR techniques allows us to provide a coherent picture of very slow-moving landslide areas. While GNSS provides useful long-term displacement data, it may be affected by low signal-to-noise ratios, limiting precision to cm-mm level. Hence, to refine the outputs, we implement statistical time-series analysis, including weighted linear regression and 95% confidence intervals. RTS delivered high-precision 3D data associated to local-scale measurements, while InSAR extended coverage to wider areas, resolving East-West and Vertical components from Sentinel-1 data. We highlight that, since 2019, the monitoring network has recorded horizontal displacements averaging 8 mm/y and vertical movements reaching -6 mm/y, well correlating with local morphology and bedrock geology characteristics. We also perform a comparison of GNSS and RTS measurements with InSAR datasets, highlighting the limitations of InSAR in vegetated and geometrically complex terrains, while also confirming its value in capturing large scale displacement trends. The findings demonstrate that, despite their individual limitations, the joint exploitation of GNSS, RTS, and InSAR allow us to provide a comprehensive framework for very slow-moving landslide areas. The scalable, cost-effective multi-source system here developed represents a robust approach for monitoring very slow-moving landslides, supporting risk mitigation strategies in landslide-prone regions.

Keywords: Very slow-moving landslides, GNSS, RTS, PSInSAR, Statistical Time-series Analysis

This contribution was selected for publication as a peer-reviewed paper in the "Special issue Deformation Monitoring 2025" of the Journal of Applied Geodesy – https://www.degruyter.com/journal/key/jag/html.