YEG-Article-11/2025

Advanced Landslide Monitoring in Jebha Region (North Morocco) Using Persistent Scatterer Interferometry (PS-InSAR)

Rida Haddane

Geosciences laboratory, Department of Geology, Faculty of Sciences, Mohammed V University in Rabat, 4 Avenue Ibn Batouta, B.P. 1014-Morocco

rida_haddane@um5.ac.ma

Landslides are a significant hazard in mountainous regions like El Jebha, posing risks to life, infrastructure, and the environment. Traditional monitoring methods are often limited by accessibility, the vast area, and the complex nature of landslides. This study utilizes Persistent Scatterer Interferometric Synthetic Aperture Radar (PS-InSAR) analysis of 12 Sentinel-1A images acquired between January 17, 2019, and December 31, 2019, to assess the activity and intensity of suspected slow-moving landslides in El Jebha. The PS-InSAR technique effectively detected ground displacements ranging from 28 mm to -17 mm, highlighting the potential of Sentinel-1 data to identify regions with subtle, yet significant, movement, with uncertainty estimated to be within ±2 mm under optimal conditions. These results demonstrate the value of PS-InSAR in monitoring slow-moving landslides, even in challenging terrain, and contribute to a better understanding of landslide dynamics in El Jebha.

1. Introduction

Morocco faces significant risks from climatic, meteorological, geological, and biological phenomena, collectively posing threats that can severely impact socio-economic development in disaster-prone regions. Landslides are among these challenges, notably prevalent in the El Jebha region, where instances of land instability are increasingly common. These events disrupt sustainable development efforts, affect infrastructure, housing, agricultural lands, and can tragically result in human casualties.

The El Jebha region (Figure 1) is undergoing substantial socio-economic growth, marked by ongoing and upcoming large-scale infrastructure projects. These initiatives aim to stimulate tourism along the Mediterranean coast. However, the area's geological instability, characterized by frequent landslides, necessitates robust environmental protection measures. The occurrence and development of landslide events in El Jebha are influenced by many natural and anthropogenic factors, including topography, geology, hydrology, hydrogeology, rapid slope erosion, and urbanization.

Numerous studies in the El Jebha area have employed various methodologies and research techniques to understand landslide processes (Bouchra et al., 2020; Byou et al., 2021). Our

study focuses on utilizing Persistent Scatterer Interferometry Synthetic Aperture Radar (PS-InSAR) throughout 2019 to monitor landslides.

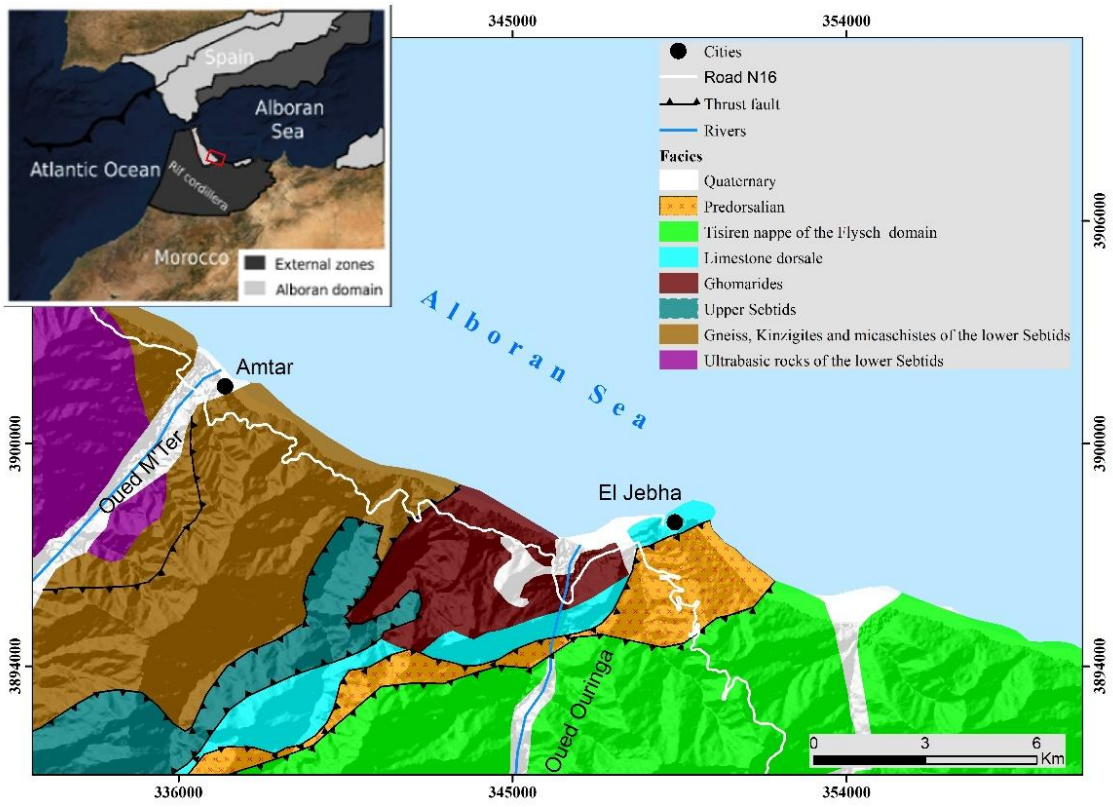

Figure 1 Geological map of the study area (modified from DIR. GEOL. MAROC, 2011; Kornprobst and Wildi, 1980).

2. Methodology

For this study, PS-InSAR was employed to monitor landslide activity in the Jebha region of North Morocco. This method is particularly effective in identifying and monitoring ground displacement in areas with stable reflectors, known as persistent scatterers, which provide consistent radar reflections over long periods (Ferretti et al., 2001; Hooper et al., 2004).

A total of 12 images from the Sentinel-1A satellite, all acquired in ascending mode, were utilized for this analysis. These images were acquired between January 17 and December 31, 2019, with an average frequency of one image per month.

Table 1 Data Used for PS-InSAR analysis

Satellite	Year of acquisition	Sensor	Type of product	Polarization	Mode of acquisition
Sentinel 1A	2019	SAR-C	SLC	VV et VH	IW

3. Results and discussion

In total, 167,399 Persistent Scatterer (PS) points were identified across the study, providing a detailed dataset for the PS-InSAR analysis. Cumulative ground movement over the 12-month observation period in 2019 ranges from 28 mm to −17 mm (rounded to nearest millimeter). Based on the coherence levels and standard PS-InSAR performance using Sentinel-1A data, the expected measurement uncertainty in this study is estimated to be within ±2 mm under optimal conditions, in line with values reported in Ferretti et al. (2001). Figure 2 shows the average Line-of-Sight (LOS) velocity in mm/year derived from cumulative displacements.

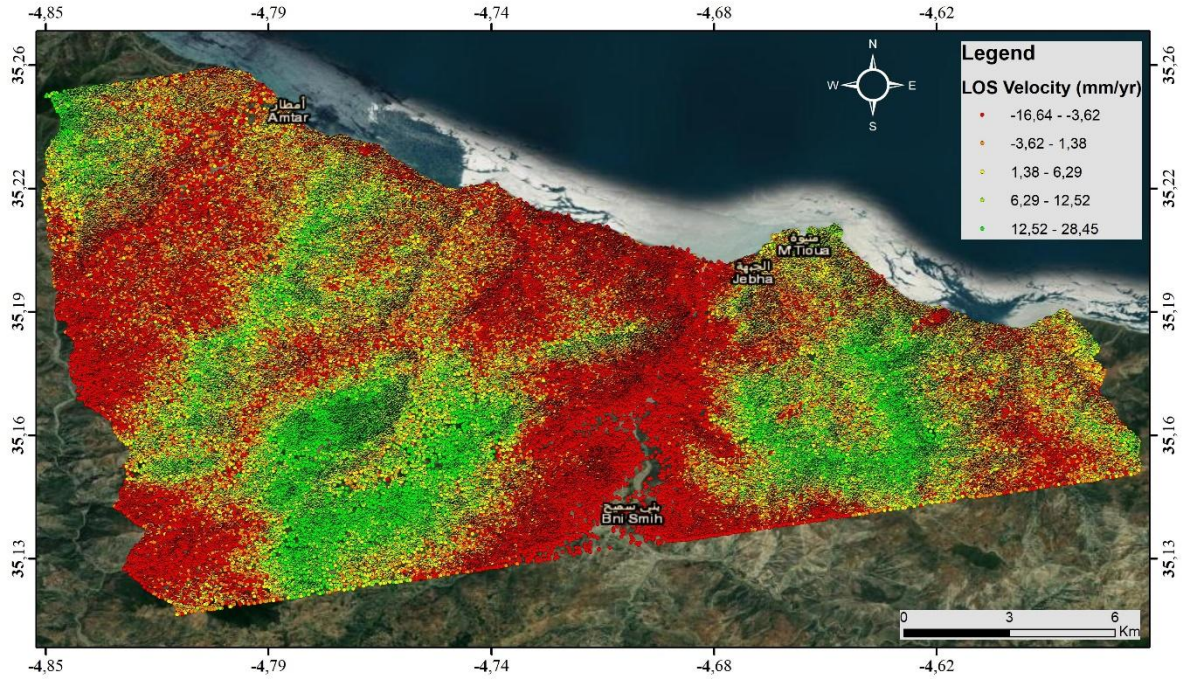

Figure 2 Average Line-Of-Sight Velocities (from the 2019 PS-InSAR dataset) for Ascending Mode in El Jebha (North Morocco).

4. Conclusion

This study successfully demonstrates the effectiveness of PS-InSAR analysis using Sentinel-1A data in monitoring slow-moving landslides in the challenging terrain of El Jebha. The identified ground displacements, ranging from 28 mm to -17mm over a 12-month period, highlight the ability of the technique to detect subtle movements often missed by traditional methods. The results underscore the potential of this approach for understanding landslide dynamics in the region, contributing to improved hazard assessment and mitigation strategies. Further investigation using a longer time series of Sentinel-1 data is recommended to refine our understanding of landslide behavior and potential future risks in El Jebha.

5. References

Bouchra, A., Mustapha, H., & Mohammed, R. (2020). D-InSAR Analysis of Sentinel-1 Data for Landslide Detection in Northern Morocco, Case Study: Chefchaouen. Journal of Geoscience and Environment Protection, 08(07), 84–103. https://doi.org/10.4236/gep.2020.87005

Byou, T., Obda, K., Taous, A., & Obda, I. (2021). Susceptibilité aux glissements de terrain dans la ville d'Al Hoceima et sa périphérie : Application de la méthode de la théorie de l'évidence. Geomatica, 75(1), 1–27. https://doi.org/10.1139/geomat-2019-0025

Ferretti, A., Prati, C., & Rocca, F. (2001). Permanent scatterers in SAR interferometry. IEEE Transactions on Geoscience and Remote Sensing, 39(1), 8-20.

Hooper, A., Zebker, H., Segall, P., & Kampes, B. (2004). A new method for measuring deformation on volcanoes and other non-urban areas using InSAR persistent scatterers. Geophysical Research Letters, 31(23).

Author Responsibility Disclaimer

During the preparation of this work, generative AI and AI-assisted technologies were not used in the writing process. The author takes full responsibility for the content of the publication and for properly referencing all figures, tables, and information included in the article.