



## Assessing the Impact of Stabilization Measures on a Slow-Moving Landslide in Arcos de La Frontera town (SW Spain) using InSAR

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The town of Arcos de la Frontera is a historical heritage ensemble located in Andalusia (SW Spain), perched on a nearly vertical 100 m calcarenites cliff and surrounded by gentle slopes characterized by being composed of weathered clayey soil from the Guadalquivir Blue Marls formation. This formation, extensively present in the region, poses significant geotechnical challenges, particularly when weathered, exhibiting low strength parameters. Between the end of the 20th and the beginning of the 21st century, the town underwent significant urban expansion. New building blocks were constructed in the head of a complex slow-moving earth slide, whose activity had been producing documented damages to linear infrastructures and urban assets since the 1970s. The most affected structures in this area by slope movements belong to La Verbena neighbourhood, which started to deteriorate soon after their construction in 2007. By October 2009, severe structural damage prompted the evacuation of 22 families, and one of the buildings was officially declared derelict in March 2010 following intense precipitation. Although local authorities commissioned geotechnical investigations and stabilization measures, these initiatives did not approach the complex landslide as a holistic problem. Instead, the works were applied locally with the objective of stabilizing La Verbena neighbourhood. These measures included jet grouting of cement-based injections and drainage and were implemented intermittently in La Verbena from 2011 to 2021, incurring a cost of €4.1 million.

In this investigation, we employed a long-term motion InSAR analysis landslide activity using Sentinel-1 data acquired in both ascending and descending orbit from January 2016 to March 2023. The primary focus was to evaluate the efficacy of local stabilization efforts and compare our InSAR results to in-situ monitoring surveys. Our results indicate a clear deceleration of the landslide head post-mid-2018, providing evidence of the effectiveness of the local stabilization measures. Before this period, the Line-of-Sight (LOS) mean velocity of the entire landslide head in ascending and descending orbits was 2.2 cm/year and 1.3 cm/year, respectively, decreasing to 0.43 cm/year and 0.23 cm/year.

The findings of our study demonstrate that the local stabilization works in La Verbena have

influenced a significantly larger area, extending beyond the directly intervened zone and effectively stabilizing the entire head of the landslide. By providing data beyond the boundaries of the in-situ monitoring area, InSAR has enriched our insights into the effects of stabilization works, emphasizing the benefits of integrating InSAR techniques as a complementary tool to traditional geotechnical monitoring methods.