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Mapping and monitoring ground deformations: Insights from a Sentinel-1 Persistent Scatterer Interferometry study in Northeastern Italy

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Persistent Scatterer Interferometry (PSI) is a valuable technique for investigating shallow ground displacement phenomena, such as slow landslides and subsidence. Its flexibility in time intervals and spatial scales allows to use PSI as an ideal tool for mapping and continuous monitoring over vast areas, ranging from regional to continental scales. In a four years collaboration (since 2019) between the University of Florence and the Veneto Region (Northeastern Italy), this study aims to enhance understanding of natural, gravity-induced phenomena while providing scientific support for geohazard management. The Veneto Region serves as an exemplary study site due to its complexity in terms of extent, geological setting, and geomorphological processes, challenging the PSI technique to prove its efficacy. For this work, ESA (European Space Agency) Sentinel-1 satellite constellation, with a revisiting time of 6 and 12 days (after the end of the operative life of Sentinel 1B in January 2022), were used. Radar data undergoes a set of different analysis: firstly, from Persistent Scatterer (PS)-derived deformation maps, clusters of high mean velocity were detected and classified using machine learning algorithms in order to mapping hotspot areas. Then, relevant displacement anomalies associated with periods of acceleration and deceleration of the deformation in the time series of each PS (Persistent Scatterer) were identified and classified to recognize the cause of deformation (e.g. landslide or subsidence). Furthermore, a Principal Component Analysis (PCA) and a machine learning clustering were done on up-down and east-west InSAR components to identify specific time series patterns on regional scale. The implementation of this methodology revealed significant outcomes, particularly in the Belluno province where, in Cortina d'Ampezzo municipality, hotspot areas associated with known landslides were accurately identified and in the Lozzo di Cadore municipality, where the analysis detected high anomalous displacement rates within a narrow time frame. Notably, four anomalous PS points exhibited peak displacement rates ranging from 56 mm/yr to 78 mm/yr from February 2023 to October 2023, where no landslides were previously inventoried. The PCA and clustering procedure was successfully applied over the whole Region and, in particular, Lamosano village (Belluno province) where a known landslide movement was recognized. This study underscores the efficacy of Sentinel-1 data for mapping and continuous, real-time ground displacement monitoring over wide areas. The cluster mapping and anomaly detection procedures proved to be crucial in identifying anomalies with high displacement rates, particularly

in areas lacking prior landslide inventory. The Cortina d'Ampezzo, Lozzo di Cadore and Lamosano case studies exemplify how the PSI technique can contribute to risk mitigation strategies by suggesting updates to landslides inventories based on hotspot mapping and anomalies detection and classification. In conclusion, this work demonstrates the potential of PSI in advancing the understanding of ground displacement and contributing to proactive geohazard management.