Paper ID: 87965
oral
student

IAF EARTH OBSERVATION SYMPOSIUM (B1)
Interactive Presentations - IAF EARTH OBSERVATION SYMPOSIUM (IP)

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REMOTE MONITORING OF GROUND MOTION EXPLOITING FUNCTIONAL DATA ANALYSIS AND NONPARAMETRIC PREDICTION ON MULTI-TEMPORAL DINSAR DATA

Abstract

The latest advancements in differential interferometric processing have resulted in techniques which continuously provide high-resolution ground displacement estimates with precision up to millimeter scale [1]. Such diffuse information on how the ground moves and changes offers the opportunity for monitoring multiple extensive areas susceptible to environmental risks at the same time. In this study, we use Synthetic Aperture Radar data processed with multi-temporal Differential Interferometric techniques to monitor the Phlegraean Fields, Italy, notably exposed to high seismic and bradisismic hazards. We adopt an anomaly detection methodology combininges principles and recent advances in the fields of functional data analysis and non-parametric statistics. The functional data analysis setting is convenient to jointly handle data high dimensionality and capture the natural smoothness of the observed physical phenomenon. The temporal sequence of displacement data can effectively be modeled as a time series of surfaces (i.e., functions defined on a two-dimensional spatial domain), evolving over time following an functional autoregressive process. The methodology thus considers the historical records of displacement surfaces and associates each new surface with a prediction band, identified by spatially varying upper and lower bounds. An anomaly is identified whenever the new surface falls outside the prediction set at a specific point. The upper and lower bounds are determined using conformal prediction, a non-parametric resampling statistical method that constructs the prediction band while controlling the risk of false alarms over the domain. The method results from a recent evolution of conformal prediction, which enables controlling false warnings in contexts where the data are bidimensional functions and exhibit temporal dependence [2]. The point predictor employed for the one-step-ahead prediction of the future surface is key to improve the efficiency of the resulting prediction bands. The outcome is a monitoring tool operating over time and continuously over space, which allows to identify localized anomalous evolutionary phenomena while ensuring a pre-specified probability of having one or more false alarms over the spatial domain. This type of information may play a crucial role in defining interventions and reducing the exposure to risk of social and material resources linked to the area of interest.

References

[1] Cigna F., Esquivel Ramírez R., Tapete D. (2021): Accuracy of Sentinel-1 PSI and SBAS InSAR Displacement Velocities against GNSS and Geodetic Leveling Monitoring Data. Remote Sensing, 13, 4800.

[2] Ajroldi, N. et al. (2023): Conformal prediction bands for two-dimensional functional time series, Computational Statistics Data Analysis 187 (2023), p. 107821.