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Methodologies for surface deformations analysis at regional scale

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Analysis of ground deformation is particularly demanding when displacement rates are in the range of some mm/y. This study integrates different statistical techniques to unravel the spatial and temporal patterns of vertical ground deformation in an alluvial basin. Beyond the identification of critical areas, this is also essential to delineate a conceptual model for the uplift and subsidence mechanisms in complex environments such as a layered aquifer suffering strong piezometric oscillations and land use changes due to human activities.

The study area covers about 4000 km^2 in the Lombardy region (N Italy) and includes the Milan metropolitan area and a part of the Po alluvial plain between the Como and Varese lakes. In this study, Sentinel-1A (C-band) PS-InSAR data with an average revisiting time 6 days and an average PS distance of 20 m, processed by TRE-Altamira, were analysed to investigate different movement styles in the study area.

The PS-InSAR data ranges from 2015 to 2020 and reveal a wide gently subsiding area oriented in NW-SE direction (average subsiding rate of nearly -1.5 mm/yr along the line of sight). Principal Component Analysis (PCA) and Independent Component Analysis (ICA) were applied on ground deformation and piezometric time series, showing analogue spatial patterns of the fluctuation styles. Then, from the correlations between the spatial patterns of ground motion, groundwater level changes and geological data, and between the temporal patterns of rainfall and groundwater abstraction rates, the main causes of ground motion were identified and summarized in a conceptual model.

Finally, after reconstructing the aquifer composition and the geo-hydro-mechanical properties, and by implementing the hydraulic stresses from the conceptual model, a hydro-mechanical coupled FEM numerical model was developed. This allowed verifying the hypotheses through the comparison between the simulated ground displacement and the measured one.