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A new multi-methodological and multi-disciplinary procedure for identifying hydrology-driven ground deformations in delta areas from geodetic datasets

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Deltas are crucial places for life and economic development of a country, harbouring small towns and megacities, feeding agricultural activities and fishing, and hosting important ecosystems. These complex natural systems, although modified over the centuries by human interventions, are founded on a delicate water-land balance that strongly depends on climatic variability. The seasonal and periodic components of the water cycle are well studied, but the influence of the hydrological processes on the periodic signals exhibited by the geodetic data is poorly understood.

The new procedure we propose aims at understanding the influence of climate-driven hydrological processes on the dynamics of the Earth's surface. It is part of a wider innovative methodological approach addressed to retrieve both periodic and permanent components of the vertical ground motion and aimed to predict more accurate subsidence rates, especially in the most vulnerable delta regions. It can be seen as a multi-step procedure: standard statistical methods and wavelet analysis are first applied to geodetic time series for extracting the permanent and periodic components (Step 1). Then, comparative analyses, performed through standard linear and non-linear techniques (e.g. cross-wavelet transform and wavelet transform coherence analyses), are used for comparing geodetic data with datasets of different nature (e.g., meteorological, hydrological, hydrogeological, mareographic and weather data), in order to find correlation between land and hydrologic system and to infer possible processes or sources (Step 2). Finally, the sources are validated through physically-based models (Step 3).

Compared to qualitative or semi-quantitative methods, the defined procedure allows to overcome the routinely used one-source investigation and improves the relation between data analysis and physically-based modelling. Moreover, differently from other approaches, that validate the source from the model findings, the procedure spots the relevance of the source from data analysis reducing the ambiguity in modelling.

The new methodology has been applied to geodetic and hydro-meteorological data of the Po Delta Area (Northern Italy) over 2009 - 2017 period. It has led to identify the main water-dependent processes that control the annual oscillation of the vertical ground movements. In particular, it turns out that the periodic annual component of the vertical ground motion exhibited by CGPS time series is explained by soil moisture mass change in the southern part of the Delta and by river water mass change in the central one.