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Evaluation of waterborne electromagnetic methods to delineate the salt wedge on Po di Goro river

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Global warming is rising the sea level, which increases the saltwater intrusion in coastal aquifers and the penetration into delta systems. The delta systems are sensitive areas due to complex hydrogeological dynamics between fresh and salt water. Such iterations have a significant impact on ecosystems and might lead to environmental problems, such as triggering processes of desertification and the increased vulnerability of soils. Moreover, seawater intrusion may have an economical and social impact due to scarce water resources and damages to agriculture that are caused by irrigation with salt water contaminated groundwater. Therefore, it is important to examine the spatial extent and the evolution of the salt wedge intrusion inland over time. Such intrusion involves the upward movement of saltwater along the riverbed correlated with both a scarce pressure of the river water and an increase of the upstream of the mixing zone in the surface waters. This phenomenon requires a new monitoring system that has to provide fast information for a manager boarding which plans the groundwater use. One of the chemical-physical parameters to define the water quality is the electrical conductivity (EC), which increases in saline water, with groundwater being commonly associated to much lower values. Hence, surveys using a moving boat with a multiparameter probe able to measure salinity and temperature is to date used as monitoring system with punctual collections. This approach is limited in its spatio-temporal resolution as it is time consuming and may lack the required resolution of the salt wedge for monitoring long rivers (> 5 km). To overcome these limitations, we propose the application of geophysical electromagnetic (EM) methods using fast acquisition system and high resolution. This work describes results for surveys collected along the Po di Goro River in the Po Delta system using frequency domain (FDEM) and time domain (TDEM) electromagnetic measurements. The FDEM method was able to detect the saltwater flow front observed during the summer of 2022, when a large salt water wedge contaminated the Po Delta system for several kilometres (around 20-25 kms from the sea). During the summer of 2023, an integrated survey with FDEM and TDEM system was used to obtain the distribution of EC along the Po di Goro River. Even if the salt wedge penetration was less intensive, it was observed close to the Goro village (ca. 7 km from the sea). The FDEM data were inverted using the EMagPy open-source software, that highlighted the EC distribution section along the investigated river path; while an open-source library based on empymod and pyGIMLi was used for the inversion of the TDEM data. The two methodologies were compared and integrated, to improve the EC distribution model of the Po di Goro River. Our results demonstrated the ability of both methods to detect the saltwater

wedge effect due to the tidal phenomenon. The results emphasize the significant potential of the proposed geophysical approach to monitor the salt wedge phenomenon during crisis period when fast and high-resolution information are necessary for hydrodynamical monitoring decisions.