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Quantitative hydro-geophysical monitoring and coupled modeling of a controlled irrigation experiment

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Geophysical surveys provide useful indirect information on vadose zone processes. However, the ability to supply a quantitative description of the subsurface phenomena remains to be proven. A controlled infiltration experiment is here extensively monitored by both ERT and GPR surveys. The experimental site is located nearby the campus of the Agricultural Faculty of the University of Turin, Italy, in Grugliasco. The experimental field is chosen for the plain and well-characterized subsoil geometry: the shallower vadose zone is composed by eolic sand with homogeneous isotropic properties. In these quasi-ideal conditions the geophysical data are accurately examined to achieve the potential knowledge on the water processes and to identify possible misleading information. Field ERT data have been compared with numerical simulations using both traditional uncoupled hydrogeophysical inversion and an innovative Bayesian framework for coupled hydrogeophysical modeling. The coupled data assimilation process is able to estimate reliable hydrological parameters and to reproduce the proper evolution of the water plume in the vadose zone. The uncoupled approach leads to misleading estimations of hydrological quantities, that are essentially due to the geophysical inversion procedure. The lack of knowledge in the inversion process may generate artifacts in the geophysical parameter distributions, which shall be translated in uncorrected hydrological states. GPR data are used separately to analyze capabilities and limitations of this technique in unsaturated environment. GPR surveys on the topographic surface could be wrong analyzed if a clear understanding of the wave propagation in the soil is not realized. So, where a straightforward interpretation of direct and reflected waves is not possible, the presence of guided modes of propagation must be deeply examined to achieve useful information on fluid flow dynamics. The results clearly demonstrate that two key points are fundamental in the hydrogeophysical inversion. The starting point is the proper understanding of the physical phenomena acting during the geophysical surveys, as misinterpretations cause a detachment from the true system. Second, an adequate choice of the hydrogeophysical approach may strongly reduce the propagation of errors and artifacts during the process of parameter estimation.