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Hydro-geophysical monitoring and stochastic inverse modeling of a controlled irrigation experiment

Gabriele Manoli (1), Matteo Rossi (2), Damiano Pasetto (2), Pietro Teatini (2), Rita Deiana (3), Stefano Ferraris (4), Mario Putti (1), and Giorgio Cassiani (2)

(1) Università di Padova, Dipartimento di Matematica, Padova, Italy , (2) Università di Padova, Dipartimento di Geoscienze, Padova, Italy , (3) Università di Padova, Dipartimento dei Beni Culturali, Padova, Italy , (4) Università di Torino, DIST, Torino, Italy

Ground-penetrating radar (GPR) and Electrical Resistivity Tomography (ERT) can provide useful indirect information on the dynamic processes occurring in the vadose zone. However, to achieve a quantitative description of soil moisture dynamics, the information content of geophysical observations has to be exploited in a hydrological modeling framework, that properly accounts for the physics of hydrological processes and geophysical measurements, with the relevant uncertainties related to both measurements and model errors. In this work we present the results and the interpretation of a controlled irrigation experiment monitored with both surface GPR and ERT in time-lapse mode. A first data analysis reveals that GPR provides detailed information on the depth of the infiltration front, but the information is apparently inconsistent with water mass balance calculations. This inconsistency is explained by the ERT results which provide a good qualitative image of the infiltration process and reveals a non-homogeneous distribution of infiltration. Both GPR and ERT data provide partial information on the system dynamics without ensuring a full quantitative description of the physical state, because of resolution and inversion characteristics. In order to overcome these limitations we propose a sequential data assimilation approach that combines geophysical observations with numerical simulations, aiming at hydraulic parameter identification. We use the Sequential Importance Resampling (SIR) method to assimilate ERT measurements in a coupled hydrogeophysical model: ERT resistances are blended in the simulation to update the state of the system, estimate the model parameters and quantify the model uncertainties. The limitations of traditional uncoupled inversion are quantified and compared with the sequential Bayesian approach. Perspectives of coupled hydrogeophysical data assimilation are discussed.