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Joint inversion of hydrogeophysical data for porous media characterization. A real case

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We present a multi-physical approach developed for the hydrodynamic characterization of real porous media using hydrogeophysical information. Several pumping tests have been performed in the Hydrogeosite, a controlled site designed and constructed at the CNR-IMAA laboratory, in Marsico Nuovo (Basilicata Region, Southern Italy). The facility consists of a pool ($10\times7\times3$ m^3) completely covered with a steel shed, used to study water infiltration processes, to simulate the space and time dynamics of subsurface contamination phenomena, to improve and to find new relationship between geophysical and hydrogeological parameters, to test and to calibrate new geophysical techniques and instruments. The pool, because of its dimensions, is made by reinforced concrete, representing an intermediate stage between laboratory experiments and field survey. Therefore, the Hydrogeosite has the advantage to carry out controlled experiments, like in a flow-cell or sand-box, but at field comparable scale. The data collected during the experiments have been used to validate the following joint inversion model.

Water flow in a variably saturated porous medium can be represented by the modified Richards equation (Richards, 1931; Panday et al., 1993):

$$\nabla \cdot [K(\theta)\nabla h] = (S_w S_s + C(\theta)) \frac{\partial h}{\partial t} \tag{1}$$

where K is the hydraulic conductivity, h is the hydraulic head [m], θ is the water content[·], S_w is the reduced water content [·], S_s is the specific storage coefficient [m^{-1}], and $C(\theta)$ is a function called "specific moisture capacity" [m^{-1}], defined as $C(\theta) = \partial\theta/\partial\psi$, and could be determined for different soil types using curve fitting and laboratory experiments measuring the rate of infiltration of water into soil column.

The Poisson equation provides a relationship between the self potential φ [V], which naturally occurs among points of the soil surface owing to the presence of an electric field produced by the motion of underground electrolytic fluids through porous systems, and the charge density J_e [Am^{-2}]:

$$\nabla \cdot [\sigma(S_w)\nabla\varphi - J_e] = 0 \tag{2}$$

where σ is the electrical conductivity.

Combining the equations (1) and (2), we obtain the Richards – Poisson model:

$$\begin{cases} \nabla \cdot [K(\theta)\nabla h] = (S_w S_s + C(\theta)) \frac{\partial h}{\partial t} \\ \nabla \cdot \left[\sigma(S_w)\nabla\varphi + \frac{C'\sigma_{sat}}{K(\theta)S_w} u\right] = 0 \end{cases} \tag{3}$$

Once the spatial distributions of the hydraulic head (h) and the self potential signal (φ), monitored during a pumping test, are known; once the electrical conductivity field of the medium (σ) has been reconstructed through ERT tests, and once the infiltration parameters of the soil have been measured, it's possible to estimate the hydraulic conductivity and the storage coefficient distributions by means of joint inversion of these data into the Richards - Poisson model.

Hydraulic conductivity obtained by means of this joint inverse model was able to reconstruct the drawdown measured in the boreholes, and this is a validation of the inversion strategy.

References

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