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Getting saturated hydraulic conductivity from surface Ground-Penetrating Radar measurements inside a ring infiltrometer

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Hydraulic properties of soils, described by the soil water retention and hydraulic conductivity functions, strongly influence water flow in the vadose zone, as well as the partitioning of precipitation between infiltration into the soil and runoff along the ground surface. Their evaluation has important applications for modeling available water resources and for flood forecasting. It is also crucial to evaluate soil's capacity to retain chemical pollutants and to assess the potential of groundwater pollution.

The determination of the parameters involved in soil water retention functions, 5 parameters when using the van Genuchten function, is usually done by laboratory experiments, such as the water hanging column. Hydraulic conductivity, on the other hand can be estimated either in laboratory, or *in situ* using infiltrometry tests. Among the large panel of existing tests, the single or double ring infiltrometers give the *field* saturated hydraulic conductivity by applying a positive charge on soils, whereas the disk infiltrometer allows to reconstruct the whole hydraulic conductivity curve, by applying different charges smaller than or equal to zero. In their classical use, volume of infiltrated water versus time are fitted to infer soil's hydraulic conductivity close to water saturation. Those tests are time-consuming and difficult to apply to landscape-scale forecasting of infiltration. Furthermore they involve many assumptions concerning the form of the infiltration bulb and its evolution.

Ground-Penetrating Radar (GPR) is a geophysical method based on electromagnetic wave propagation. It is highly sensitive to water content variations directly related to the dielectric permittivity.

In this study GPR was used to monitor water infiltration inside a ring infiltrometer and retrieve the saturated hydraulic conductivity. We carried out experiments in a quarry of Fontainebleau sand, using a Mala RAMAC system with antennae centered on 1600 MHz. We recorded traces at fixed time steps, during an infiltration of 5 cm of water, inside a ring infiltrometer. We used the ring to demarcate the infiltration area, and to create reflexions at known depths. GPR reflexions coming from the wetting front as well as the buried edges of the cylinder were recorded. Modeling of the infiltration were made using Hydrus-1D and Hydrus 2D/3D, GPR data of the infiltration were computed using GprMax suite programs. We generated water content profiles associated with a saturated hydraulic conductivity value, at each experimental time step with Hydrus1D. Then we convert those profiles to permittivity profiles using the Complex Refractive Index Method relation, to compute the reflexion time of the cylinder and the wetting front. We found the saturated hydraulic conductivity of soil by minimizing the differences between experimental and simulated data. Our retrieved saturated hydraulic conductivity from GPR data was compared to disk infiltrometer measurements. We investigated the limitations of the procedure due to initial water contents, flatness of the area and electrical conductivity (related to silt content of the soil). Furthermore, the possibility of inverting the other hydrodynamical parameters using a Monte Carlo Markov Chain algorithm is studied.

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