Geophysical Research Abstracts
Vol. 13, EGU2011-4779, 2011
EGU General Assembly 2011

Advances in borehole GPR data interpretation for hydrological purposes

Giorgio Cassiani (1), Matteo Rossi (1), Giulio Vignoli (1), Rita Deiana (1), and Andrew M. Binley (2)

(1) Università di Padova, Dipartimento di Geoscienze, Padova, Italy (giorgio.cassiani@unipd.it), (2) Lancaster Environment Centre, Lancaster University, Lancaster, UK

Borehole GPR has been frequently used as a technique to investigate the structure of the shallow subsurface and monitor therein the evolution of moisture content in time and space. The use of borehole techniques allow for a much higher resolution than achievable from the ground surface but, of course, requires the existence of one or more boreholes. In addition, specific techniques must be used for data processing and interpretation, linked also to the specific cross-hole geometry. In fact, the apparent simplicity with which borehole GPR data can be inverted and interpreted does not guarantee that the results are meaningful and correct for hydrological uses. This has been apparent for some years particularly by comparing the moisture content profiles obtained from borehole GPR against the predictions of vadose zone flow models, as the former appear in most cases to yield a smoothed image of reality. In this contribution we analyze in particular Zero Offset Profiles (ZOP) and Vertical Radar Profiles (VRP). The reconstruction of the GPR velocity vertical profile from VRP travel-time data is a problem with a finite number of measurements and imprecise data. The uncertainty in data accuracy and the error amplification inherent in deriving velocity estimates from gradients of arrival times make this an example of an ill-posed inverse problem. In the framework of Tikhonov regularization theory, ill-posedness can be tackled by introducing a regularizing functional (stabilizer). The role of this functional is to incorporate a-priori assumptions about the geometrical and/or physical properties of the solution. One of these assumptions could be the existence of sharp boundaries separating rocks with different physical properties. In order to overcome the smooth moisture content profiles often obtained from VRP data, we apply a method based on the minimum support stabilizer to the VRP travel-time inverse problem. We compare traditional smooth inversion results with our proposed sharp reconstructions. Using synthetic examples, we demonstrate that in case of profiles containing sharp discontinuities, the minimum support stabilizer allows for a correct recovery of the profile shape and velocity value of the target. We also applied the proposed approach to real-life cases where VPRs have been used to derive a moisture content profile as a function of depth. In these real cases, the derived sharp profiles are consistent with other evidence, such as GPR reflections and known locations of the water table. In the case of ZOPs, we also propose a method that overcomes the smoothing effect inherent in the simplest data inversion approaches. ZOP borehole measurements are very useful to detect subsoil dielectric properties, due to their simplicity in data collection, treatment and analysis. The easiest inversion of ZOP data is the direct-wave approach, where point ZOP travel times are converted into velocity and subsequently into dielectric constant and then moisture content estimates. This approach can be misleading as it does not take into account two essential factors: volume averaging (Fresnel zone) and critical wave refractions, that can occur in presence of sharp vertical boundaries. We apply an approach based on an electromagnetic (EM) wave simulator and a stochastic Monte Carlo framework. In this manner both averaging and critically refracted wave effects are taken into account. Results from synthetic and real ZOP datasets are statistically analysed to deduce what kind of moisture content distributions are resolvable what is the associated degree of uncertainty.