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3D Monte Carlo inversion of magnetic resonance measurements applied to karst conduit imaging

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Designed for groundwater exploration, the Magnetic Resonance Sounding (MRS) is a surface geophysical method used for water content imaging over large area with moderate cost. Earlier 2D or 3D MRS (MRT) applications have shown the method potential to detect complex water filled subsurface formations such as karst aquifers. However, theses recent applications are facing uncertainties issues due to the non-uniqueness of the inversion results typical for the majority of the surface geophysical methods. It has been reported that when applying MRT in 3D geological context solution provided by the Tikhonov regularization method could lead to erroneous estimate of the volume of water in the subsurface.
We propose to investigate the uncertainty in the inversion results using algorithms based on the Monte Carlo approach. We use the Simulated Annealing (SA) algorithm that samples the entire solution space and makes it possible computing the probability of the water content distribution that includes all the equivalent solutions.
We present two different realizations of the SA algorithm adapted to imaging of karstic conduits without prior knowledge on their location, geometry, orientation, and water content. The first realization provides continuous water content distribution in the whole area and the second realization represents the water distribution by blocks (blocky SA).
Modeling synthetic karst conduits confirm the ability of these algorithms to correctly locate water. However, probability density functions of water content shows substantial standard deviations, demonstrating the impossibility to estimate rigorously the water content of karst 3D targets without external constraints. Along these lines, the blocky SA scheme shows better performances (lower standard deviations) than the continuous SA, because of the underlying prior knowledge on the solution shape encoded in.
We applied these two algorithms to process data measured around the Poumeyssen karst conduit (south of France). Measurements have been performed with eleven coincident sounding loops under low-noise conditions. We show that the conduit was located in a maximum probability halo but, due to the non-uniqueness of the solution, the true 100% water content is only a minor possibility among many other solutions that all fit experimental data equally well.

Key words: Simulated Annealing, MRS, MRT, karst conduit imaging.