TorusMRS – MRS using a moveable helium-filled balloon

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SUMMARY

A concept is introduced to increase the MRS measurement progress in the field. The main idea is to install the circular measurement loop on a helium-filled donut-shaped balloon, which enables moving this system effectively along large profile lines. To take advantage of the fast positioning of the measurement loop, the duration of each sounding is reduced by decreasing the number of pulse moments at the expense of vertical resolution. However, using effective datasets and inversion schemes, i.e., MRS data collected using a pulse moment distribution optimized for identifying a specific target, we expect that the benefit of acquiring horizontal information compensates for the general loss in vertical resolution. For determining the optimum pulse distribution, a priori information at single fixing points in the area of investigation must be available, e.g. obtained from boreholes or common MRS measurement with higher vertical resolution.

Key words: Measurement progress, moveable MRS system, helium balloon, effective datasets

INTRODUCTION

Conducting magnetic resonance soundings (MRS) to survey subsurface groundwater has proven to lead to very valuable information for aquifer characterization. However, due to the slow measurement progress, the application of MRS in practice is often limited to only a few 1-D surveys in the area of investigation - too few for a reliable hydrogeological interpretation at the regional scale. A promising solution could be the combination of ground-based MRS and airborne electromagnetic (EM) methods (Siemon et al., 2015): the regional overview is given by the 3-D resistivity distribution, while MRS, in addition to borehole information, can help to overcome the natural ambiguity of resistivity data regarding the interpretation of lithology and groundwater salinity. On the other hand, increasing the measurement progress for MRS could be a less cost-intensive alternative for acquiring large hydrogeophysical datasets in 2-D or 3-D. Technical developments and improvements of the equipment might reduce the measurement duration in the future, e.g., shorter charging time for the capacitors or lesser number of stacks due to improved signal-to-noise ratios. With this paper, we focus on fasten the measuring progress by decreasing the logistical effort in the field, i.e., by reducing the time for moving the measuring loop. We want to introduce and discuss a concept how to apply a moveable MRS system using the currently available equipment.

This concept is based on a donut-shaped balloon (Figure 1) that carries a circular measurement loop with a diameter of 22 m. The system was originally developed for transient electromagnetic measurement (TEM) in arid areas (Steuer et al., 2014) and its handling was successfully tested in 2014 at a BGR test field near Berlin (TorusTEM, Schildknecht and Steuer, 2014). The balloon is connected to and moved by two cars, one in the front and one in the back considering the direction of motion. A feasibility test using the system for MRS measurements (TorusMRS) is planned in April 2015.

Figure 1. The measurement loop (diameter: 22 m) for TEM or MRS is installed on a donut-shaped helium-filled balloon, which is moved along the measurement profile by two cars (Schildknecht and Steuer, 2014).

CONCEPTIONAL CONSIDERATIONS

Typically, a complete MRS consisting of free induction decay (FID) experiments using at least 20 pulse moments lasts one to two hours, depending on the actual noise conditions. This is enough time for the staff to lay out the loop configuration for the next measurement position, so that the next MRS measurement can easily be started without too much delay. To take full advantage of a fast moveable measurement loop, the measurement duration must be decreased dramatically. Using the currently available equipment, this can only be realized by decreasing the number of stacks or pulse moments, which lowers the vertical resolution significantly. However, we expect that this loss of vertical resolution can be accepted for the benefit of an increased measurement progress if the distribution of pulse moments is optimized in such a way that the thickness and the depth of the target aquifer can nevertheless be observed along a profile line. Müller-Petke and Yaramanci (2007, 2008) introduced a resolution analysis based on singular value decomposition that allows for calculating resolution-optimized efficient datasets. Further approaches for effective data sets are recently presented for ERT measurement by Wagner et al. (2015). To determine this optimized pulse distribution the target aquifer must be identified at the beginning of the survey, which could be achieved by a borehole or a usual (extensive) MRS measurement with high vertical resolution. Such higher resolution MRS points should be sparsely but frequently distributed as fixing points along the profile to check and adjust the pulse moment distribution. To strengthen the significance of the MRS regarding lithological interpretation, the MRS measurement at these fixing points could even use pulse sequences for T_1 or T_2 measurements. Between the fixing points, the TorusMRS measurements consisting of FIDs with an optimized pulse moment distribution are used as a "fast interpolating tool" e.g. using LCI (Auken, and Christiansen, 2004) type of 2D inversion.

OUTLOOK

As already mentioned, the feasibility of TorusMRS and the applicability of the described concept of will be tested in April 2015. We hope to find the answer to some important questions regarding moveable MRS equipment: Is it possible to measure while driving (spatial stacking)? How dramatic is the influence of the cars on the homogeneity of the Earth's magnetic field in the vicinity of the loop? Is it possible to work with stationary noise reference loops?

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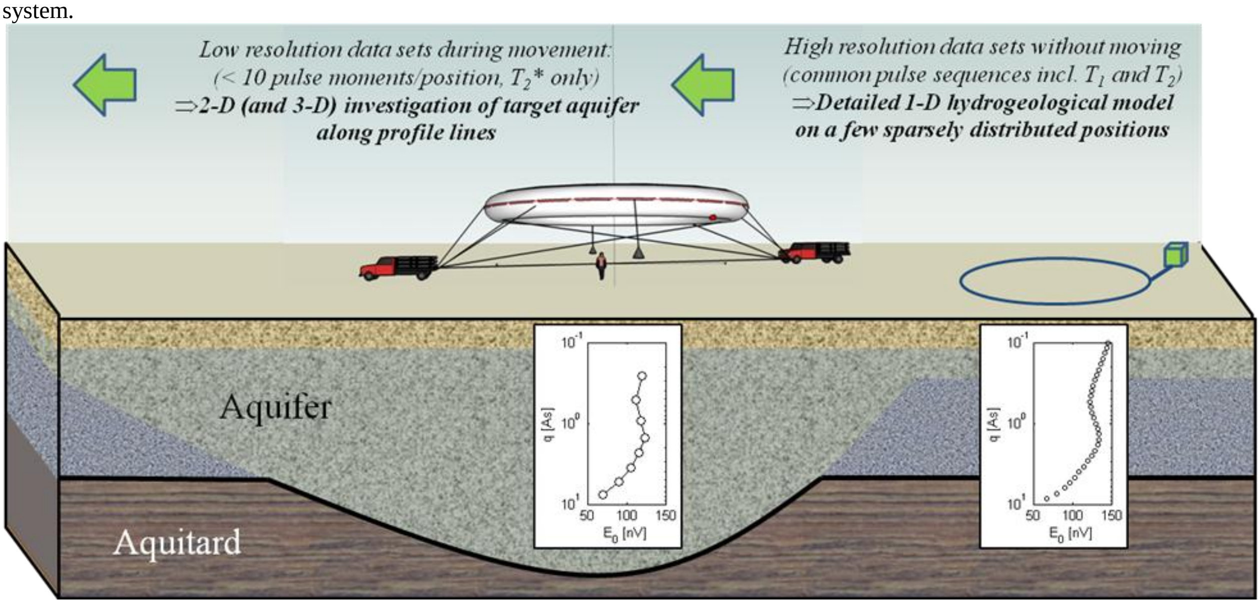

Figure 2. Concept of measuring MRS rapidly on large profiles using a moveable system: to take full advantage of the moveable MRS system, the measurement duration for each position on the profile is minimized by reducing the number of pulse moments (T_2* only) at the expense of vertical resolution. For adjustment, high-resolution measurements using much longer pulse sequences (including pulse sequences for measuring T_1 and/or T_2) are conducted on only on a few sparsely distributed positions along the profile.