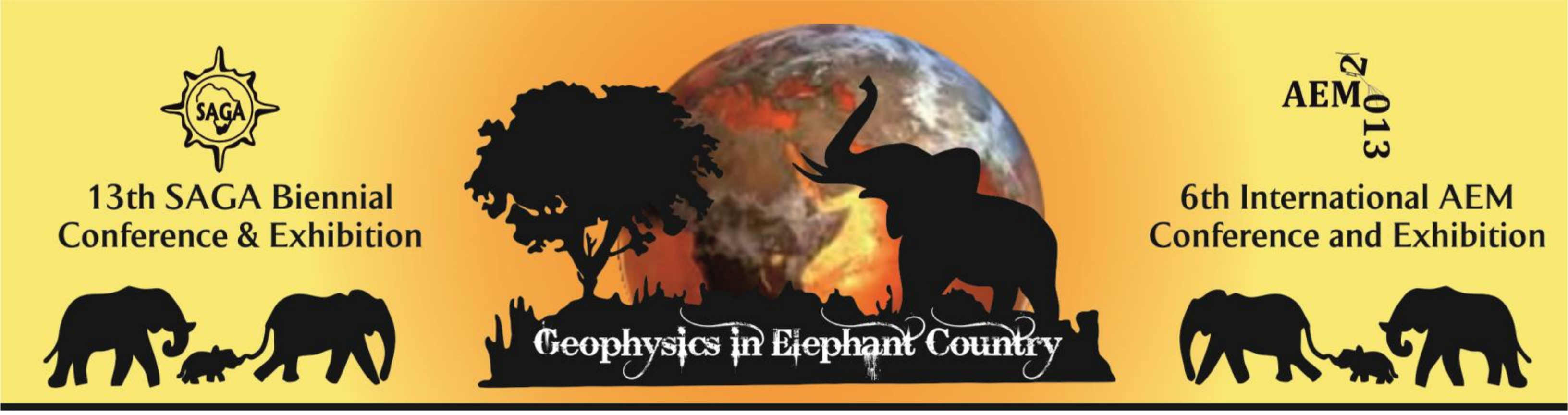

Very Early times in AEM - Resolution of the near-surface for hydrogeological applications

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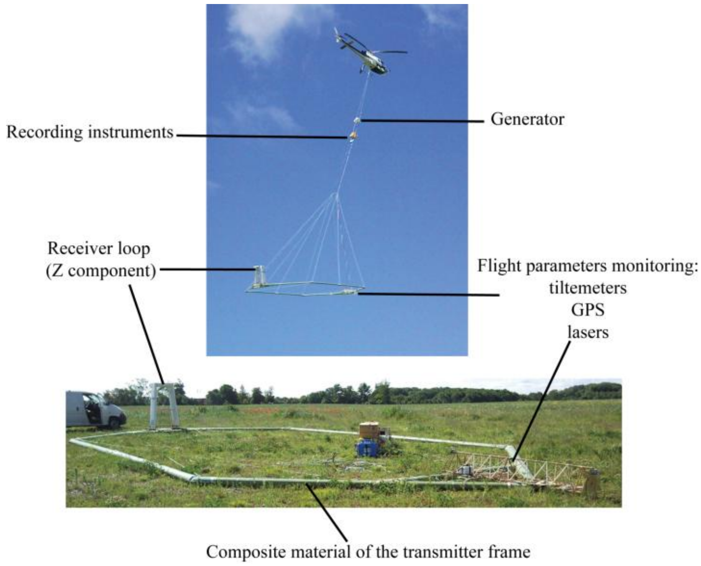
Airborne transient EM, very early times, near surface

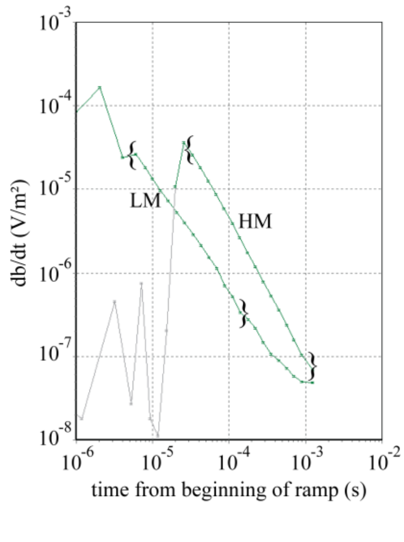
Mini-SkyTEM: a new transient AEM system for very early times interpretation

Since the 2000's helicopter transient electromagnetic (HTEM) systems have widespread in hydrogeological/environmental investigations. They are usually more limited in terms of near-surface resolution compared to helicopter frequency EM systems (HFEM). A new version of the SkyTEM system, called Mini-SkyTEM or SkyTEM 101, is now capable of measuring at very early times, only few µs after the turn-off of the current in the transmitter loop. The system payload is very light (350 kg) with a transmitter loop of only 130 m² (Figure 1a). The particularity of all SkyTEM systems is the measurement of both a low (LM) and a high (HM) moments (Figure 1b). This dual-moment configuration allows getting information both from near surface and deep layers. The HM gives a depth of investigation of ~100 m for an average resistivity of 50 Ωm, but the more interesting feature of the system is its earliest time in the LM which is only 2-3 µs from end of ramp (~ 3µs).

The very early times or the high frequency content can be interpreted only if two key points are handled. The first one is the calibration of the EM system. The AEM system has been calibrated following the procedure described by Foged et al. (2013) where a time and amplitude factor shifts are estimated above a well-known reference site to match the measurements and the modeled reference response. The accuracy of this calibration is critical in the present case, since a bad time shift estimation of less than 1 µs can cause non-negligible differences in the top 30 m. The second point to consider is the primary field residual, or coil response (CR), which affects the first gates right after the turn-off of the current. This CR is induced by small residual current in the transmitter wire and needs to be modeled especially when ground resistivity and/or flight altitude increase, reducing the strength of the ground EM response. This CR is measured at high altitude. Since measurements have confirmed its stable shape, only its amplitude, which varies due to small bending of the frame during the acquisition, has to be determined during the inversion as an amplitude correction factor. With the consideration of the CR, it is possible to interpret the very early times right after the turn-off of current (Schamper et al., 2012).

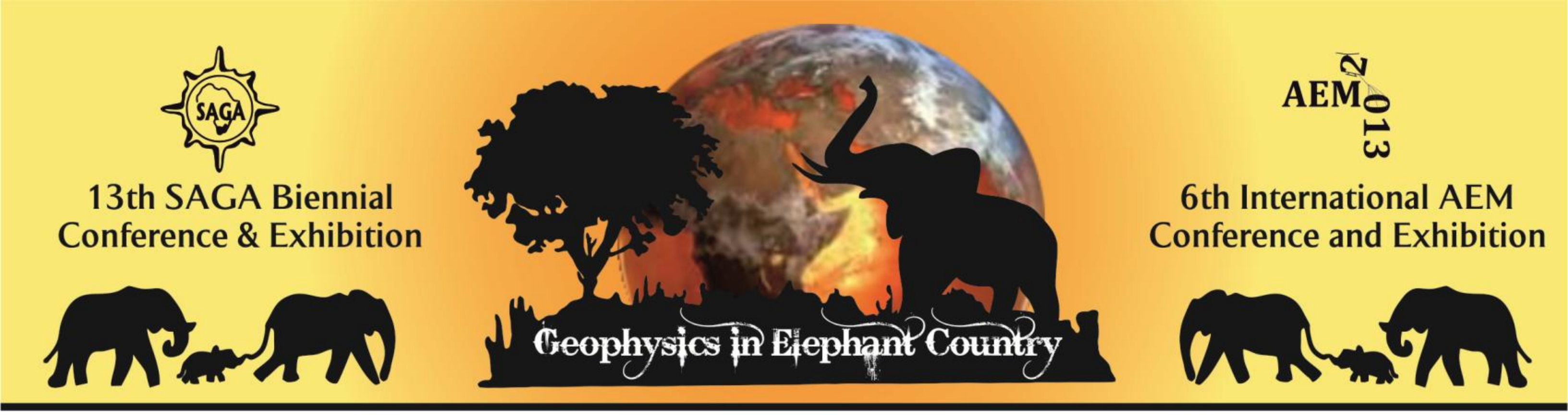


(a) Mini-SkyTEM system



(b) Typical sounding

Figure 1. Mini-SkyTEM (SkyTEM 101) system: (a) the system in the air with its 130 m² transmitter loop; (b) a typical dual-moment sounding with low-moment (LM) and high-moment (HM) curves. The zero timing is the beginning of the turn-off of the current, so the actual first time is only 2-3 µs after the end of the ramp. The brackets indicate the gates used for the interpretation.



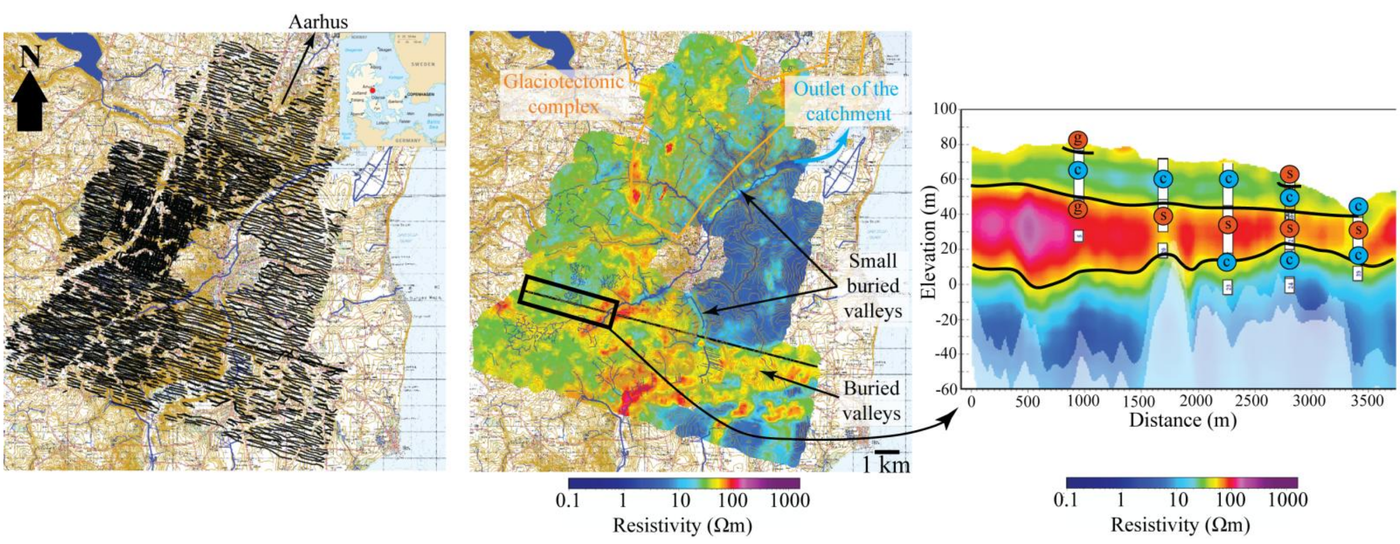
Application to the mapping of near-surface hydrosystems

The Mini-SkyTEM was developed and firstly employed within the NiCA project (www.nitrat.dk). The main objective of this project is to build a risk map at the scale of an entire catchment for applying adaptive regulation of nitrate leeching. The identification of the risky areas needs the modeling of the nitrates reduction which mainly lays in the top 20 m. This requires hydrogeological modeling based on a geological model, which is generated geostatistically to satisfy a priori information such as boreholes or local ground-based geophysical surveys. The spatial density of AEM data is used to reduce the uncertainties on this geological model thanks to the relation between the electrical resistivity and the clay content. Since the top 20 m is critical, pushing the limit of early time measurements to improve the near-surface resolution is the geophysical challenge of this project.

The pilot survey was flown in June 2011 above Norsminde catchment near the second main city of Denmark, Aarhus (cf. location in Figure 2a). About 2000 line km had been flown in one week, covering an area of 120 km². A large spatial density was obtained with a line spacing of 50 m in the western part of the survey where two sets of lines are combined (Figure 2a). The sedimentary context (mainly glacial sands and tills) is not simple due to past glaciotectonic and glacial activity, resulting in the presence of more or less narrow buried valleys and in rapid alternations of clay and sand lenses. This geological configuration is challenging for the diffusive method employed by the HTEM system.

The survey area also comprises a lot of man-made installations such as roads, farms, power lines *etc.* which implies a careful and time consuming cull of the coupled data. Once processing done, the data were inverted using a spatially constrained inversion (SCI) scheme (Viezzoli et al., 2008), a quasi 3D algorithm where resistivities of neighboring layered models are linked by spatial constraints. 40 CPUs during one week were necessary to invert the 100.000 AEM soundings (29 layers models). An example of depth resistivity slice is shown in Figure 2b.

The geophysical results show good correlation with borehole database, with almost 75% of the boreholes (within less than 15 m from the closest AEM sounding) showing at least an acceptable match. A resistivity section is shown in Figure 2c, illustrating the good correspondence between the resistivity transitions and the identified geological interfaces. More examples and detailed statistics will be shown during the presentation.



(a) (b) (c)

Figure 2. Resistivity results of the pilot survey: (a) The flight lines after culling of the coupled data; (b) Mean resistivity map at 15-20 m depth obtained after a SCI with 29 layers and kriging with a search radius of 150 m; (c) Resistivity section with borehole comparison, the shaded colors are resistivities below the estimated depth of investigation, *g* corresponds to gravels, *s* to sands and *c* to clays (mostly clay tills near the surface).

Cited Literature

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