An overview of airborne electromagnetics for 3D high-resolution mapping

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Introduction

Airborne electromagnetics (AEM) is an efficient tool for mapping the subsurface. AEM delivers a very high data coverage compared to the costs, and the direct outputs are high-resolution resistivity images of the subsurface. In particular the time domain methods (TEM) are well suited for mapping of the salt-fresh water boundary in coastal zones, aquifers, paleo-channels, mineralisations and general structural geological mapping.

The development of AEM systems and data processing systems has been intensive during the past 10–15 years because of better electronics and faster and more flexible computers. While most AEM systems in the 1980s were limited to detection of mineralisations, modern system generations measures full spectra, yields absolutely calibrated data and accurate descriptions of the system transfer function. This, in combination with much enhanced inversion and forward algorithms, makes AEM a suitable candidate for mapping targets which so far have not be possible.

The AEM systems work in either the frequency or the time domain. Generally speaking, a frequency domain system (HEM) measures the Earth's response in the presence of the primary field from the transmitter at typically 4–6 discrete frequencies, while TEM measures the Earth's response after the transmitter has been shut off. In principle, measuring the TEM decay is easier as the instrumentation need not compensate for a huge primary signal. However, in practice the challenge is to keep the receiver instrumentation from saturation since it is exposed to the primary signal, which in magnitude is larger than the signal from the Earth. Contrary to the TEM systems, all HEM systems suffer from drift in data because displacing the transmitter and receiver coils just one micrometer results in inaccurate compensation of the primary field from the transmitter.

Another major difference between the HEM and the TEM system is the depth of investigation which can be obtained. While HEM systems, in most cases, do not investigate deeper than 50–80 m into the ground, the TEM systems easily penetrates down to 300 m and some system even goes down to +500 m.

One of the new, commercially operated systems is the SkyTEM system, originally developed by the HydroGeophysics Group, Aarhus University, Denmark. As far as we know, the SkyTEM system is the only system giving absolutely calibrated data, i.e. data need no post-calibration and can be processed and inverted at once from the helicopter. It is also the only system giving data straight from the surface (12 microsek) down to great depth (10 ms, dependent on the noise and signal level).

Parallel to the SkyTEM system the HydroGeophysics Group has also developed a full data processing and inversion system. This system incorporates frame movement in the airspace and a complete modelling of the system transfer function (transmitter waveform, filters in the receiver system etc.). The inversion algorithm works with a 3D model and makes it possible to include geological a-priori information from e.g. boreholes or seismic as soft constraints.

In this presentation we will give an overview of the airborne electromagnetic systems and outline pros and cons. Special focus will be given to airborne TEM systems and SkyTEM in particular. We will also introduce the newest processing and inversion algorithms. To exemplify the use of these high-resolution 3D datar, we will show mapping results from different targets located around the world. They will be hydrological mapping in the Netherlands and geological mapping in Africa.