Towards inversion of large-scale semi-airborne EM data for mineral exploration in the Harz mountains, Germany

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SUMMARY

In recent years, exploration of raw minerals has gained increasing attention due to its growing demand. Whereas shallow deposits have been mostly well explored, deeper structures are often unknown or poorly resolved by electromagnetic measurements such as TEM or DC/IP. Combining the advantages of pure airborne and ground-based surveying, semi-airborne strategies can reach target depths of down to 1 km, while retaining the spatial resolution of airborne systems by a combination of grounded bipole transmitters and highly sensitive three-component magnetic field receivers in the air. The DESMEX research group developed such a system and applied it to a number of different deposits, also using drones as alternatives to helicopters. Extensive data processing is done to transfer the time series into transfer functions between current and magnetic fields that are further processed by the SAEM toolbox prior to sophisticated modelling. We developed the finite-element modelling toolbox custEM that is able to include arbitrary geometries of transmitters, multi-component receivers, topography, as well as complex subsurface structures. Together with the inversion capabilities of the pyGIMLi package we are able to build real-world three-dimensional subsurface conductivity images. Experimental design studies showed that coverage by multiple transmitters of varying orientation improves the resolution. As a consequence, large surveys use overlapping flight patches (flight area fixed to a single transmitter).

So far, examples with up to 5-7 patches have been presented as computing power has become increasingly available. However, for large-scale data sets this becomes prohibitive from RAM (3TB) and runtime (easily reaching days) point of view. We present a methodology where large data sets are subdivided into groups of first one, later two to four transmitters with overlapping areas. Those data are inverted separately and combined into a super-mesh using coverage-weighted logarithmic means. The subsets can be re-grouped and re-inverted using the existing models as starting model such that eventually a unique large-scale model is obtained.

We present results from a campaign carried out in 2022 in the West of the Upper Harz Mountains around Lautenthal, an ancient mining area for Zn-Pb-(Cu) ores. Data from 12 flight patches are used, with a total of more than 10000 receiver locations comprising complex-valued three-component magnetic transfer functions for eight frequencies covering a range from 5 Hz to 2 kHz. We used extensive processing to get rid of man-made noise, current and gas pipelines through several misfit plots. We demonstrate the increase in resolution through multiple transmitter coverage. The final 3D model shows conductive anomalies along fault lines, but also alternating stripes caused by syncline-anticline structures in a highly folded environment. The main conductor is related to geological cross section and can possibly be traced to much larger depths of about one kilometer. In total, the methodology provides a mean for efficient large-scale exploration of mineral deposits.

Keywords: Semi-airborne electromagnetics, 3D inversion, mineral exploration