AEM Data Quality Assurance and Control Procedures – A work in progress

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SUMMARY

Airborne electromagnetic data (AEM) are used in many and diverse applications such as mineral and energy exploration, groundwater investigations, natural hazard assessment, agriculture, city planning and defence. Unfortunately, many users do not have access to a simple workflow for assessing the quality of the data that they are using. This poster outlines the main quality assurance and quality control (QA-QC) procedures used by Geoscience Australia (GA) for our 2008-11 AEM surveys.

Geoscience Australia is embarking on a project to upgrade the National Airborne Geophysical Database to better manage the data from major AEM surveys. This will better preserve the data and associated documentation to allow users to access and take advantage of the data well into the future. The quality of historical data included in this endeavour will unfortunately be variable and dependent on the QA-QC standards of the time.

Awareness and implementation of standardised QA-QC techniques ensure future generations of AEM data captured in the National Airborne Geophysical Database will be to a higher standard.

Key words: Airborne electromagnetic data; National Airborne Geophysical Database; AEM; QA-QC.

INTRODUCTION

The Commonwealth Government through Geoscience Australia (GA) has funded regional AEM data acquisition in the Onshore Energy Security Program (OESP). Geoscience Australia also manages AEM surveys for other Commonwealth, state and territory government agencies. New users of AEM data have asked GA to provide the QA-QC checks and procedures we currently use and this is the motivation behind this poster.

AEM data are expensive to acquire and consequently should be treated as a valuable resource. Every effort should be made to ensure that maximum fidelity is preserved in the data during acquisition and processing. Data, at a minimum standard, should be fit-for-purpose and subsequent interpretation as well as being available for reprocessing, enhancements and modelling to ensure the usefulness and longevity of the data. With the increase in the numbers of AEM systems, the applications of the data and new clients, there is an increasing need for the standardisation of AEM data and reporting requirements.

Acquisition and processing errors can dramatically reduce the quality of AEM data to the point that interpreters will find the data unusable, or worse still be misled by features or characteristics produced during acquisition and processing. These scenarios not only impact the application at the time of interpretation, but can seriously impact the reputation and perceptions of the AEM industry. Many authors have documented AEM data acquisition, processing and interpretation methods including - but by no means restricted to - Palacky and West (1991), Lane *et al*. (2000), Smith (2001) and Auken *et al*. (2009), which have lead to current industry standard best practice.

There are more than 14 different AEM systems currently operating in Australia, including time domain (TEM) and frequency domain (FEM) methods. This poster is designed to highlight the minimum QA-QC requirements considered common to time domain systems.

Publically funded AEM data, in particular, should be fit for interpretation, inversion or transformation and archiving, to enable its use for a variety of purposes over a long period of time. To be able to quantitatively model and interpret AEM data GA adheres to the QA-QC procedures and minimum technical reporting as outlined in this poster. Industry funded data could also benefit from the standards used by GA.

Geoscience Australia is the custodian of the most comprehensive publicly available Australian airborne magnetic, gamma-ray, elevation model, electromagnetic and gravity databases. Geoscience Australia is embarking on a project to upgrade the National Airborne Geophysical Database (NAGD) to better manage the data from AEM surveys. Geoscience Australia plans to make available via the Geophysical Archive Data Delivery System (GADDS), AEM data in the future. It should be noted that with historical datasets the complexity entailed in data re-use increases with older acquisition systems and versions thereof, due to lack of fundamental information such as system geometry, waveform, window times, metadata and noise estimations.

Minimum technical metadata

Airborne electromagnetic responses are dependent on many factors such as levels of noise in the receiver coil measurements, terrain clearance, aircraft attitude, changes in the transmitter loop to receiver coil geometry, transmitter waveform, primary field removal, instability in the timing of the measurements as well as the conductivity of geological materials (Palacky, 1993; Green, 1998; Lane *et al*., 2000). Not only should the above factors be taken into consideration when working with AEM data, these variables should be measured or at least estimated and modelled.

Minimum technical specifications between GA and survey contracting companies are set out in Deeds of Standing Offer. The minimum technical metadata as outlined in the Deed should allow for the complete assessment of any particular AEM system for forward modelling, processing, transformation, inversion and interpretation. As a guide, aircraft and equipment information should, as a minimum, include the attributes listed in Table 1.

Aircraft Specifications
Capability
Nominal speed
Navigation
Make, model and registration
Transmitter System
Type and Version
Height above ground
Nominal loop axis
Loop physical mounting
Loop shape and area
Loop number of turns
Base frequency
Peak current
Digital current waveform
Receiver System
Type and version
Nominal position relative to transmitter
Number of receiver components
Nominal coil axes
Coil(s) physical mounting
Coils(s) shape
Coils(s) number of turns
Digital voltage waveform
Window details (start, end, width)
Auxiliary equipment
Noise Monitors
Navigation
Radar Altimeter
Laser Altimeter
Aircraft pitch and roll sensors
Magnetometer and base station
Other monitors

Table 1. Time Domain AEM minimum technical metadata.

Accurate and up-to-date digital data including time, transmitter current waveform and receiver voltage waveform with appropriate units is required. It is critical to know where time zero, relative to window times is defined on the waveforms, and how receiver sampling is synchronised with the transmitted pulse for modelling. It is also advantageous to know the receiver-measured waveform.

Delivery Products
To fulfil the requirements of being fit-for-purpose and suitable for modelling, interpretation and archiving GA request as a minimum from the contractor:

- Point located field processed data;
- Point located final processed data;
- Point located high altitude and repeat line data;
- Point located final conductivity data;
- Gridded data;
- Multiplots (displaying all deliverable data fields); and,
- Final Report which includes relevant processing and calibration information.

Information in the point located data includes, but is not restricted to: flight number, line number, line bearing, terrain clearance, ground elevation, transmitter position, receiver position, noise monitors, sferics monitor, window amplitude data, total magnetic intensity (TMI), location (easting/northing and longitude/latitude), projection, datum, time (fiducial and GPS time), altimeters, date and the unique GA project code.

The final report should include: operations and logistics, survey specifications, aircraft equipment and specifications, equipment calibrations, system monitoring, electromagnetic data processing (calibrations, stacking, primary field estimation), product creation details e.g. is B-field data a derived quantity or measured directly and other relevant information.

Input parameters required for EM Flow^{TM} software (Macnae *et al*., 1998; Stolz and Macnae, 1998) should be provided as metadata or in the final report so that earth conductivity predictions can be made to facilitate QA-QC and interpretation.

Additional products (and associated metadata) tailored to suit individual survey requirements and outcomes could include:

- Point located raw data, that is the earliest version of unfiltered and unlevelled data;
- Georeferenced JPEG images for GIS use;
- Additional conductivity models;
- Depth of investigation information; and,
- Interpretation report.

AEM QA-QC
Many QA-QC steps are basic, menial, time consuming and user intensive; however, it is essential as there is opportunity to learn a great deal about the geophysical signature of the survey area while completing the process.

The following QA-QC steps are undertaken at GA once contractor supplied data are delivered to ensure the data are fit-for-purpose and suitable for quantitative modelling, interpretation, archiving and for future use. The steps below are assessed against the detail contained within the Deed of standing offer.

Ensuring all the data and metadata have been delivered against the required contract specifications in the correct format and contain unit information, e.g., in ASEG-GDF2 format (Dampney *et al*., 1985; Pratt, 2003).

The minimum, maximum, mean and standard deviation of all fields including transmitter height, transmitter-receiver horizontal-separation distance and transmitter receiver vertical-separation distance by line, by flight and as a whole survey must be computed and tabulated to determine that each field contains data with plausible values.

A flight path map is created to check positioning, that all lines have been flown and unexpected deviations have not occurred. Parallax and or lag for magnetics, altimeters and EM data fields can also be checked at this time for spatial accuracy.

The altimeter data supplied are compared against contract specifications. The corrections made by contractors to the altimeters are recalculated using formulas found in the supplied metadata. The altimeter data are assessed for random spikes, noise and other errors, e.g., from tree tops where spurious reading can occur. Altimeter values are used in post-processing and if incorrect, can induce errors during the inversion process that look geologically plausible.

Terrain clearance measurements define part of the system geometry and are an input to the conductivity modelling. Shallow conductivity predictions are extremely sensitive to the terrain clearance of the transmitter loop and receiver coil elements of the system (Brodie and Lane, 2003). To ensure altimeter corrections have been undertaken correctly the elevation fields are cross-checked against an independent dataset e.g. the SRTEM DEM, GEODATA 9 second DEM (Hutchinson, 2008), or gravity spot heights.

Point located elevation, altimeters, magnetics, diurnal, EM window data, and noise monitor data are gridded to assess for coherency, level shifts, artefacts, features and anomalies. Errors in editing, filtering and levelling procedures applied to the data can be recognised in gridded data. Grids derived from the point located data are cross-checked with the gridded data provided by the contractor and if possible with independent data sources (national grids and topographic maps).

Additive noise calculated from high altitude flights represents random noise sources that are independent of the ground response. Multiplicative noise estimates are calculated from repeat (survey altitude) lines and represent ground response dependent noise. Noise estimate inputs into inversion and conductivity transform programs are made following the methodology of Green and Lane (2003).

AEM line are best represented in a multiplot. Multiplots are visual representations of relevant data and conductivity sections in one image frame at the highest possible resolution. The multiplot is a useful tool when determining if a response in the component data, or anomaly in the conductivity section, is geological in origin, or due to a variation in system geometry or noise. Often EM fields, noise monitors, terrain clearance and system geometry can be assessed collectively, as well as in individual data streams, an easy task with a multiplot.

The transformation of AEM data to conductivity depth sections should be used to assess the AEM data for consistency and to ensure it is consistent with plausible geological models in the survey area. Geoscience Australia uses forward modelling and inversions to check that data can be quantitatively fitted to within estimated noise levels. Geoscience Australia utilises the GA-Layered Earth Inversion code (Brodie and Fisher, 2008; Brodie and Sambridge, 2009) for these purposes. Further investigations are warranted if data cannot be adequately modelled.

Estimated conductivities should also be compared to other survey-specific geoscientific data, preferably down hole conductivity and drill hole data.

NATIONAL AEM REPOSITORY

Geoscience Australia has commenced work on an AEM data repository as a subset of the National Airborne Geophysical Database. Geoscience Australia has a role as the national geoscience agency to collect and archive AEM datasets acquired using public funds in a format that is maintainable and accessible. In addition, available open file AEM datasets will be archived in the repository.

As a part of this process GA is capturing historical AEM datasets. Additionally, auxiliary data including logistics reports, technical metadata, conductivity logging and interpretation reports will be collected where available. The quality of historical data included in this repository will be variable and dependent on the QA-QC standards of the time and the quality of available information for archiving may limit the usefulness of the data for modelling and interpretation purposes.

The immediate aim is to develop an AEM survey index map suitably attributed with relevant metadata in conjunction with releasing AEM data through GADDS. The long term aim is to create coherent regional compilations to be used to reduce exploration risk, support the work of the various industries that use AEM data and contribute to the development of government policy.

It is hoped that as current and future generations of AEM data are added to the NAGD they are processed and reported on considering the guidelines on this poster, so that new data and associated documentation will allow users to access and exploit this valuable resource well into the future.

CONCLUSIONS

The accuracy, integrity and useability of AEM data are reliant on many factors including topography, system geometry, noise and location. Successful QA-QC of these factors allows the data to be deemed fit for original purpose as well as fit for future use. The QA-QC steps outlined are suggested as a minimum standard to assess if AEM data are accurate and suitable to be interpreted, inverted and manipulated. It is important for the user to consider improvements to the QA-QC process as requirements, technology and AEM systems change.

The addition of AEM data to the NAGD, and in due course GADDS, will make it easier for government and private sectors to use the data in survey planning, interpretation, research and training projects.

Specific survey planning, forward modelling, inversion techniques, calibration tests, conductivity logging and depth of investigation methods and specifications fall outside the scope of this document. Successful assessment and completion of the above are required to complete a successful AEM project.

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