# Summarising AEM data for mapping applications

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## SUMMARY

AEM Geophysical surveys are excellent tools for mapping conductivity variation over large areas. Common workflows involve inverting data using 1D models on a per-station basis, then gridding those results over lines to produce maps. In the absence of other filtering, gridding operations must combine finely-sampled along-line data with sparsely-sampled between-line data. Independent of the choice of gridding technique and map cell dimension, such maps will obscure the two scales. Obtaining a spatially coherent map will often involve reducing the resolution along the survey lines. Indeed, it could be argued that if the goal of an AEM survey is mapping, then inverting the data on a station by station basis is not necessary.

We show that large-scale structures are preserved when data are summarised using the arithmetic mean over a number of stations. This allows practitioners to objectively determine map cell dimensions since it provides an indication of the distance over which 1D models which are typically used to process large data sets are valid. Practically, it makes little difference whether this summary takes place before data are inverted or after. Summarising data before inversion may provide a practical estimate of spatial and temporal variation of the data at a particular scale. In contrast, summarising inverted models may provide an estimate of model variability at a particular scale.

**Key words:** Airborne electromagnetic, inversion, mapping, filtering

## INTRODUCTION

Airborne electromagnetic (AEM) surveys are established methods of mapping conductivity variation over large areas. Because of the large volumes of data routinely collected, there is a requirement for rapid assessment of data. This requirement is generally met using approximate imaging (e.g. Macnae et al, 1998) or least-squares inversion (e.g. Lane et al 2000) methods. Despite algorithmic advances (e.g. Cox et al 2012), earth models underpinning both methods are generally 1D. Common workflows (e.g. Annetts et al 2014) involve treating data on a station-by-station, line-by-line basis, and results are placed in an areal context by gridding over a number of lines. Commonly such inversions of AEM data are used to map paleochannels or the boundaries of a regional aquifer.

However, unless limited to a small area surrounding a survey line, gridding operations must combine finely-sampled along-line data with sparsely-sampled between-line data; in most cases, the Nyquist frequency along the line is much higher than the Nyquist frequency between lines. When constructing a map, aesthetic imperatives favour broader features over fine scale ones. In this paper, we seek to understand the implications of treating AEM data at an appropriate scale for gridding. Generally, this will be at the line spacing. However, some applications may seek understanding at finer or coarser resolutions. In this work, we contrast averaging the data over several stations and then inverting for a 1D earth with inverting on a station by stations basis and then averaging the 1D models. We note that gridding 1D modelling results over a domain often implicitly involves averaging the 1D models over the grid cell that contains the 1D models.

## METHOD AND RESULTS

We illustrate these concepts using Tempest AEM system data collected in order to characterise the La Grange Catchment area, WA which is illustrated in Figure 1A along with a representative geological section (Figure 1B). Analysis of these data was described by Annetts et al (2014). These data form an excellent set for testing, since the geology is mostly horizontally layered. We focus on Line 1006601 which lies in in the southern half of the survey. Survey data are illustrated in Figure 2 (Panels A and B) along with a blocky (five-layer) inverted model (Panel D). Sea-water intrusion of the Broome sandstone is evident as the strong, wedge-like conductor in the west. The conductive basement was interpreted as the Jarlemai aquitard. The Broome Sandstone which is the region's aquifer overlies the Jarlemai. Cenozoic sediments form the near-surface (resistive) horizon which is underlain by a thin (conductive) clay horizon. Low errors (Panel C) suggest the model response is a good match to field data. Data were inverted using GA-LEI (Brodie and Richardson, 2015) and were unconstrained.

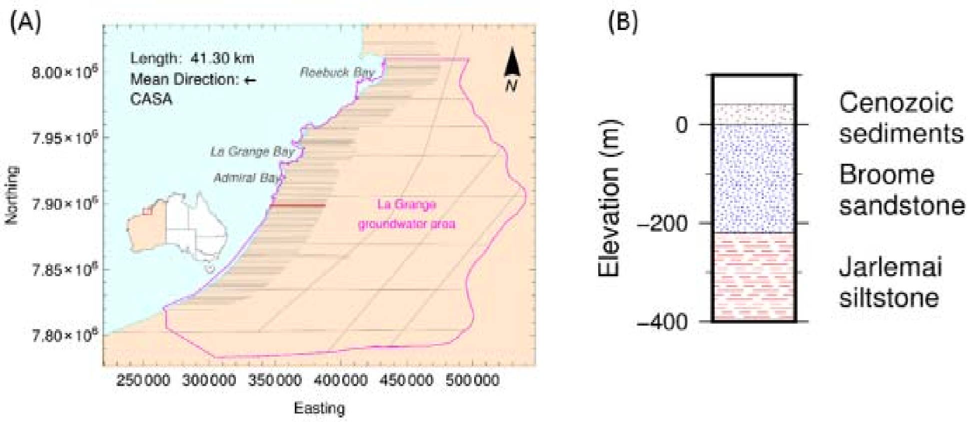


**Figure 1 The La Grange AEM survey (A) and representative geological section (B). Line 1006601 which is the subject of this abstract is highlighted in red. The survey was designed to characterise the La Grange groundwater area, especially near the coast where sea-water intrusion of the Broome sanstone is common.**

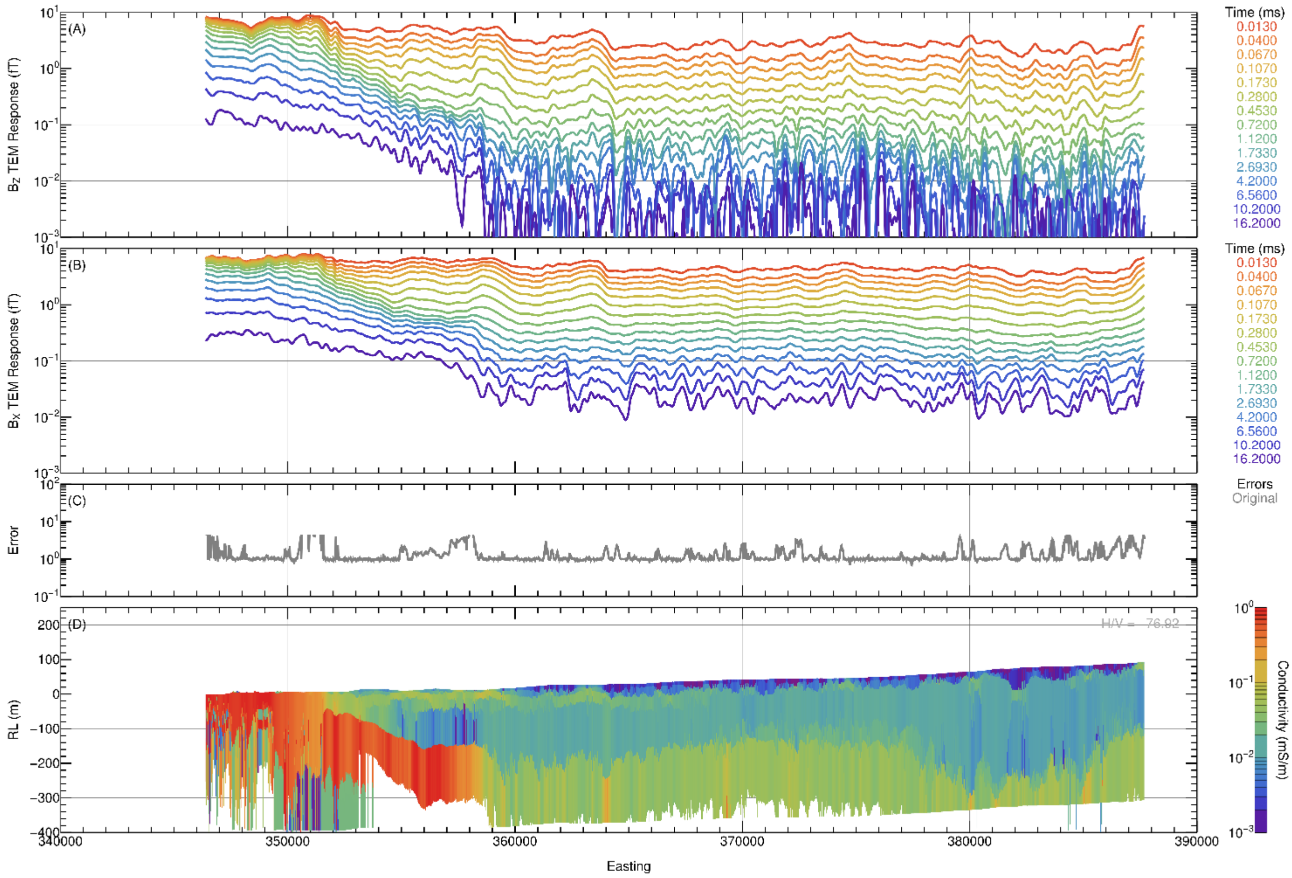


**Figure 2 Survey data and inverted model from Line 1006601. Data are good quality and are well modelled by a five-layer blocky model.**

Initially, we summarise data by their per-channel arithmetic mean over a number of stations. Alternative methods of summary, for example, moving mean or median, might be reasonable alternatives in some circumstances but, because of their non-linear nature, such methods would be more likely to misrepresent geological features at a particular scale. Figure 3 compares inversion results for different blocking levels. Panel A shows an unblocked section (where stations are spaced roughly 12.5 m apart) while Panels B, C and D show inversion results for blocks of 16 (with a mean block size of 218 m), 32 (449 m) and 64 (903 m) stations respectively. Dark grey lines on all panels show boundaries from Panel A. Clearly, there are differences between sections, especially near steeper-dipping structures such as 364000E. However, even at a coarse resolution (Panel D), the underlying structure is evident, suggesting that the blocking algorithm preserves dominant geological features at a particular scale. Indeed, it might be argued that if features are not preserved over different scales, then that is an indication of the scale over which a 1D approximation to the geology is no longer valid. Such an indication is critical to interpreting maps.

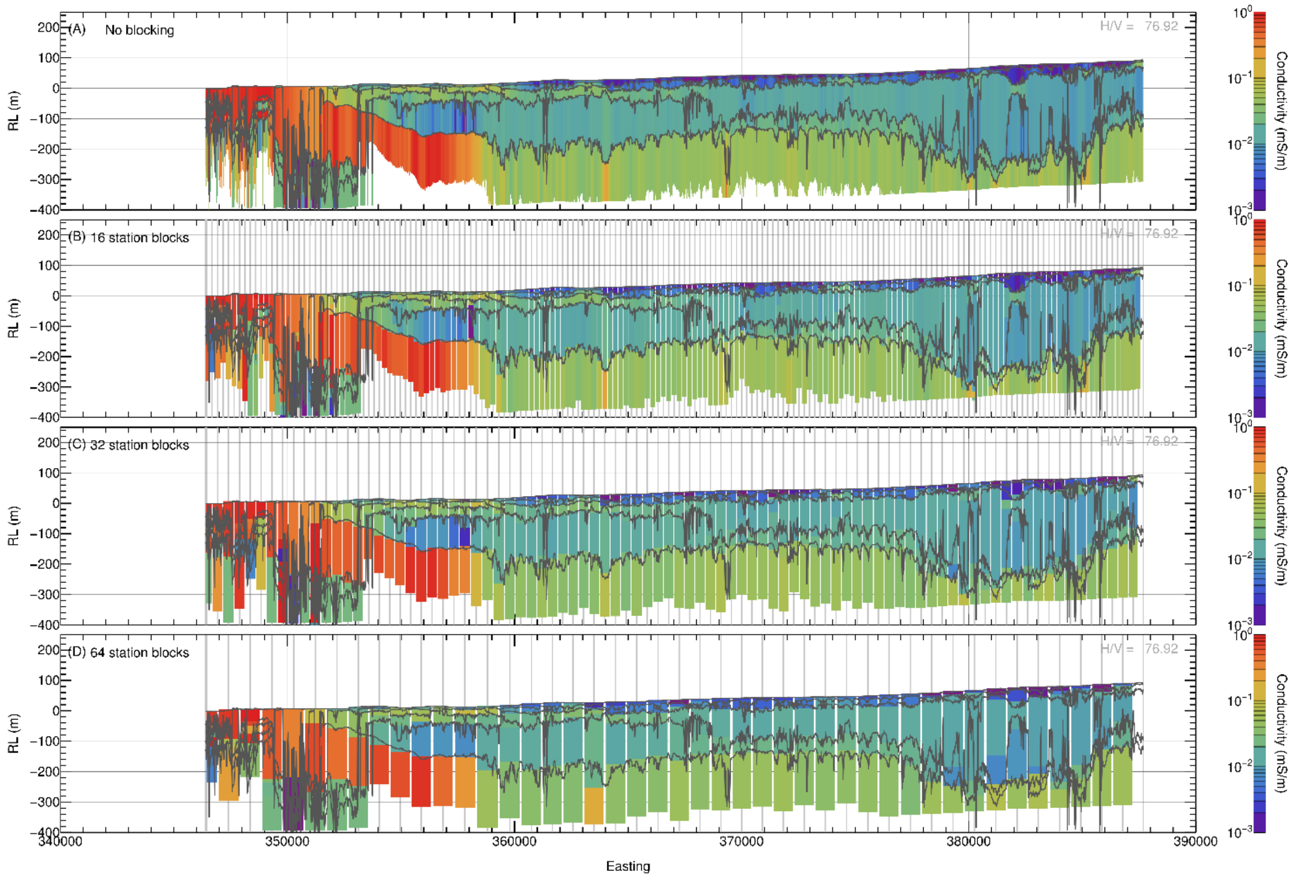


**Figure 3 Illustration of the effect of different summary rates on AEM inversion results. Although there are differences, large-scale features are preserved with increasing summary distances.**

It is interesting to continue this line of thought, and ask whether it is better to invert on a per-station basis, then summarise data at a particular scale, or summarise data first, then invert the summarised data. The first option is common. However, the second option, because of the ease of calculation of summary statistics over that block, would allow mapping with an estimate of data varability at a particular scale. Hauser et al (2015) show an application of the second option by summarising data variation using data covariance.

Figure 4 compares the two approaches for a mean block size of 449 m (blocking every 32 stations). Panels A and B compare field (grey) with blocked then inverted (red) and inverted, then blocked (blue to black) for vertical and inline components respectively. Panel C compares the inversion error of both approaches with unblocked data. Panels D and E compare inverted models using both approaches. Clearly, there are differences between the two approaches, and those differences are more pronounced over steeper resistive features (e.g. near 382000E) than flatter conductive ones (e.g. between 354000 and 358000 over the sea-water intrusion). However, inverted models are essentially similar, as suggested through a comparison of errors and responses.

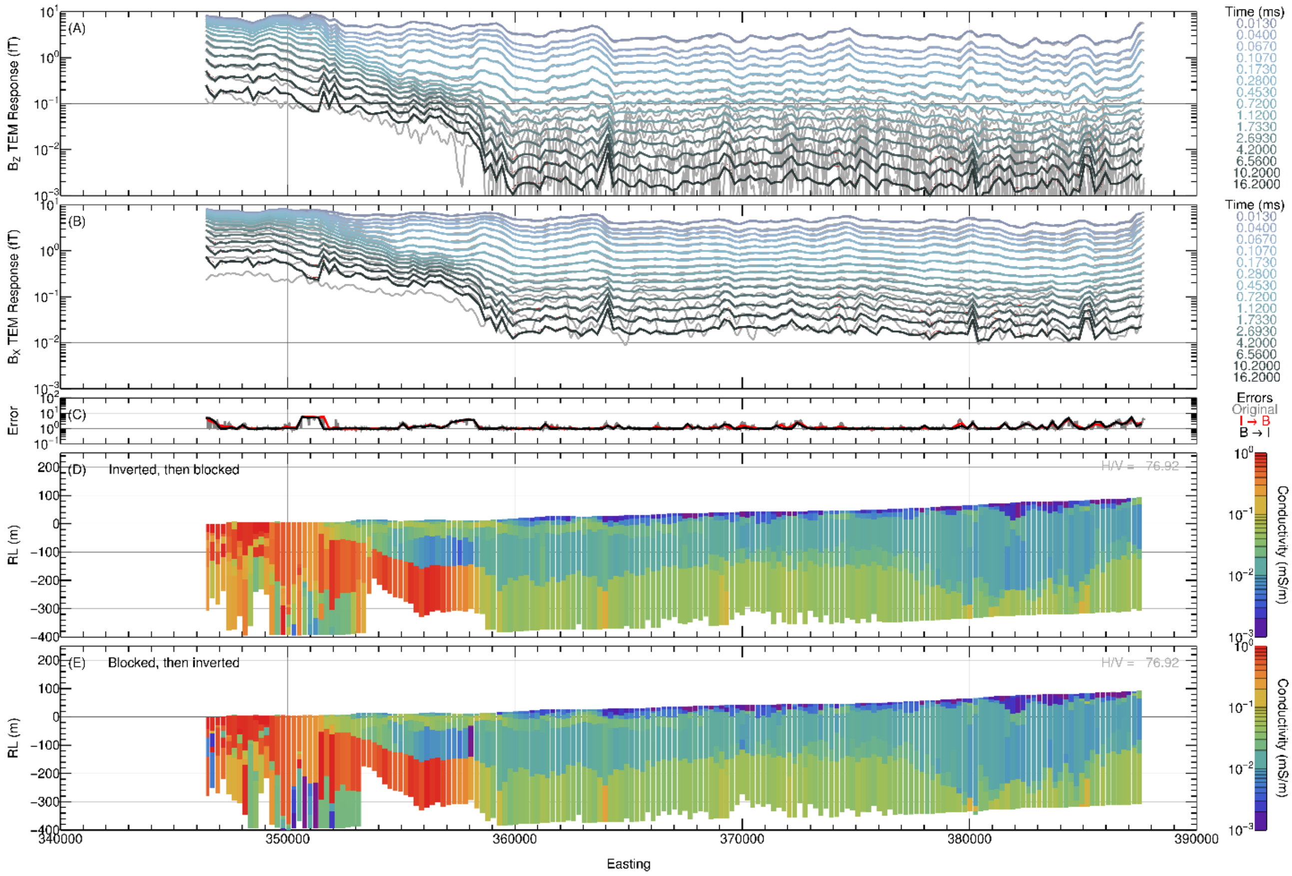


**Figure 4 Comparison of summary techniques. It makes little practical difference whether data are summarised then inverted, or inverted, then summarised.**

## CONCLUSIONS

We have shown that large-scale structures are preserved when data are summarised using the arithmetic mean over a number of stations. This allows practitioners to objectively determine map cell dimensions since it provides an indication of the distance over which 1D models which are typically used to process large data sets are valid. Practically, it makes little difference whether this summary takes place before data are inverted, or after. However, summarising data before inverting them may provide a practical estimate of spatial and temporal variation at a particular scale.

Ultimately the spatial resolution of an AEM survey is limited by the line spacing. Uncertainty is dominated by the fact that the further away one is from a survey line the less representative is the structure recovered at the nearest station. In this context the uncertainty in the inversion result at a single station is of lesser importance. Given a reconnaissance survey we can determine the critical block size along the survey line that is the block size above which we are no longer able to adequately recover the structure, i.e. there is a significant difference between the laterally blocked model and the station by station inversion. This critical block size can then be used as a guide for the line spacing of any follow up survey assuming the structure varies equally in all directions.

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