Correcting Drift Errors in HEM Data

Andy Green
OTBC Pty. Ltd. Australia
greenaa@ozemail.com.au

SUMMARY

Much HEM survey data suffers from low (spatial) frequency along-line variability in amplitude caused by slow changes in the system geometry and electronic drift. Even though the system is periodically taken up to a sufficient altitude to re-zero the primary field correction, the errors are not totally removed. This paper describes a procedure to reduce the effect of these errors.

Each flight line is corrected by subtracting a slowly varying function of time that has been chosen so that the between-line differences over the whole survey area are minimized. The parameters of the correction functions are estimated using weighted, damped least squares. The procedure produces a marked improvement in the quality of the images of low frequency, in-phase channels that have been corrupted by drift noise.

Key words: Airborne EM, Levelling, Noise.

INTRODUCTION

Much frequency domain HEM survey data suffers from low (spatial) frequency along-line variability in amplitude caused by slow changes in the system geometry and electronic drift. Even though the system is periodically taken up to a sufficient altitude to re-zero the primary field correction, the errors are not totally removed.

Valleau, (2000) and Huang and Fraser (1999) describe the processing of HEM data to remove these effects. Valleau states that, after corrections based on the high altitude reference data, further levelling is sometimes still required and “an EM expert” makes corrections to the In-phase and Quadrature data based on observation of “busts” in apparent resistivity images. Although such a process allows the possibility of very sophisticated correction it also has the potential to produce inconsistent results and it seems that suitable standard algorithm for making these adjustments would also be useful.

Although contractors usually level the data as part of their standard processing, some data, especially the vertical coaxial channels of older data sets, has not always fully levelled and it is necessary to apply further processing. The levelling procedure discussed in this paper was developed for this purpose.

THE LEVELLING PROCEDURE

As we are only seeking to estimate slowly varying effects the data is first smoothed along flight line with a median filter of length L. Then every Lth data point is extracted to provide the samples used in the procedure. Typically L might be between 10 and 30 and the samples represent 10% of the total data. Let this number be M and let the number of lines be N.

Let $X_{i,l}$ be the uncorrected response for the i^{th} sample of the survey which is on the l^{th} flight line. The model assumes that a simple linear correction provides better values for the samples on the l^{th} line

$$\hat{X}_{i,l} = X_{i,l} + a_l + b_l s_{i,l}$$

Here $s_{i,l}$ is the distance along the l^{th} line a_l and b_l are constants for line. In practice we could use any type of correction function that is linear in the unknown coefficients (a's and b's) but it is very rare that, in this application, anything more complex than the above is required.

A search procedure is used to find the neighbour nearest to $X_{i,l}$ on the adjacent line. Here it is expressed as the j^{th} sample on the n^{th} line with value $X_{j(i),n(i)}$. It's corrected value is similarly expressed,

$$\hat{X}_{j(i),n(i)} = X_{j(i),n(i)} + a_{n(i)} + b_{n(i)} s_{j(i),n(i)}$$

The cumbersome notation for j and n emphasises that they are a function of i but will be dropped in what follows.

We now assume that the differences between these neighbouring data values ($D_{i,l} = X_{i,l} - X_{j,n}$) can be explained in terms of the drift corrections and a random error term and we look for a way to estimate the correction parameters a_l and b_l for l =1,2,..N. We do this by looking for the values that cause the corrected data to have the smallest between-line differences. Thus we attempt to minimize $\sum_{i=1}^{M}\left(\hat{X}_{i,l} - \hat{X}_{j,n}\right)^2$. This amounts to solving the set of M equations of the form:

$$a_l + b_l s_{i,l} - a_n - b_n s_{j,n} = D_{i,l}$$

Recasting matrix form we have:

$$\mathbf{Gm} = \mathbf{d}$$

Where **m** is the column vector of the 2N correction parameters to be determined and **d** is the column vector of the M between line differences ($D_{i,l}$). The matrix **G** is large, sparse and dominantly diagonal with four terms on each row which are either ±1 or ±s-values depending on whether they multiply by an a or a b.

The solution of this problem is complicated by the fact that the system of equations is underdetermined. Because it is possible to add the same constant correction to all lines without affecting the between line differences, we can see that the additive terms will be undefined to the extent of a common constant. Other, more complicated, problems can occur with higher-order corrections. To overcome this non-uniqueness the must be constrained in some way. The usual method involves some form of damped least-squares that has the effect of minimizing the magnitude of the correction parameters.

The weighted, damped least squares solution this system is (Menke 1989)

$$\mathbf{m} = \left[\mathbf{G}^T \mathbf{W}_e \mathbf{G} + \mathbf{W}_m\right]^{-1} \mathbf{G}^T \mathbf{W}_e \mathbf{d} \qquad (1)$$

Here $\mathbf{W}_e$ is a diagonal matrix of M weights that make it possible to adjust the impact of each sample on the inversion. In this case it was found that making the weight on each sample equal to $1/(\sigma_{noise} + D_{i,l})^{1/2}$ down-weighted the largest between-line differences and improved the result. $\mathbf{W}_m$ is a diagonal matrix of 2N weights that determine the extent to which each correction parameter is allowed to vary from zero. Large weights (~10) restrict the extent to which a given line can be adjusted.

The solution using (1) is straightforward and rapid (a few seconds on a PC for a survey with 130,000 samples). This is fortunate because **G** is large (M may be of the order of 10^4) and it is not economical to use more robust procedures like Singular Value Decomposition on it directly.

RESULTS AND DISCUSSION

A Dighem data set acquired over the Chapman Valley in Western Australia is used to demonstrate the technique. The data was available in both “raw” and “final” forms. Other than some mild low-pass filtering on all channels only the 56kHz data were substantially changes in the “final” product.

If the weights $\mathbf{W}_m$ were set to allow all lines to be corrected, the results were satisfactory but showed some dependency on the data values. Thus, lines with isolated regions of very high values, tended to be made slightly too low after correction. However, if the weights were adjusted so that only those lines that were causing problems could be corrected these effects were not a problem.

Figure 1 illustrates the result of the correction procedure on the 56 kHz Quadrature channel. The image on the left is the “raw” data that has not had final drift correction. The image in the centre is the “final” data as supplied by the contractor and that on the right the result of applying the procedure described in this paper.

CONCLUSIONS

The procedure described here provides a useful method for levelling Frequency Domain HEM data. It works best when the lines with levelling problems can be identified beforehand. The procedure is rapid and can be tuned through the use of weights on both the data and individual flight lines.

REFERENCES

Huang, H. and Fraser, D.C., 1999, Airborne resistivity data levelling: Geophysics, 64, 378-385.

Menke, W., 1989, Geophysical Data Analysis: Discrete Inverse Theory, Academic Press,

Valleau, N.C., 2000, HEM data processing – a practical overview: Exploration Geophysics, 31, 584-594

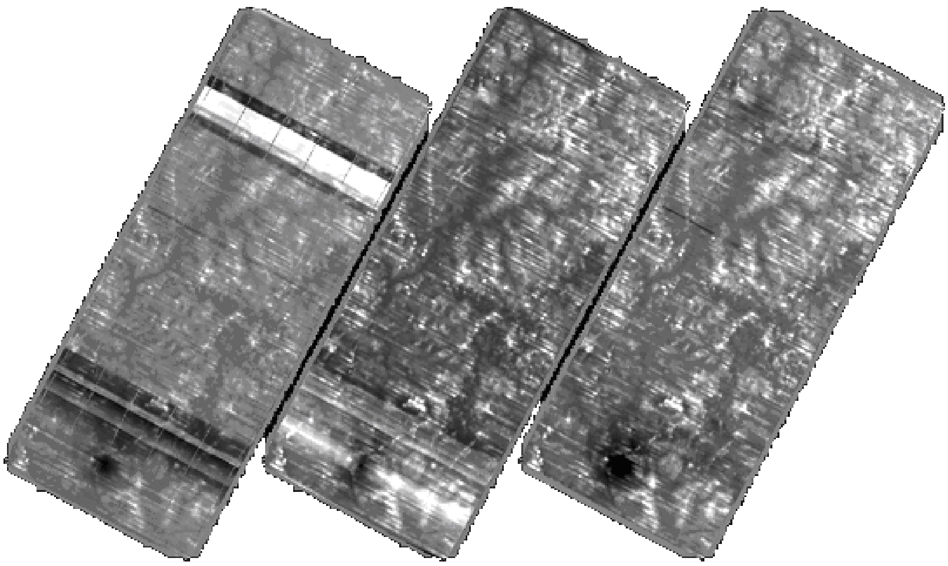

Figure 1. Illustrating the effect of the correction procedure on the 56 kHz Quadrature channel. The image on the left is the “raw” data that has not had final drift correction. The image in the centre is the “final” data as supplied by the contractor and that on the right the result of applying the procedure described in this paper.