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Digital Filtering of Sirotem Data

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Summary

Two dimensional Fourier Transforms and tailored filters can be applied to spatially collected electromagnetic data to provide better definition of anomalous responses. These can be applied quickly and easily to large data sets converted to a regular grid.

The residual or regional data can then be selected depending on the requirement and studied directly or further enhanced on an image processor.

Anomalous responses revealed in the filtered data can be processed and modelled directly or allocated for further definition in the field using more appropriate survey parameters.

Three methods described in this paper were applied to a Sirotem survey data set consisting of some 5000 data points. Anomalies that were known were better defined. Anomalies that were not previously identified were modelled and the results therefrom used to design detailed surveys to better define their source in the field.

Introduction

There has been much progress over the last 10–15 years in the processing and interpretation of potential field data, such as gravity and magnetics. It is obvious that some of these processing techniques can be applied to any data collected over a given surface on a regular or irregular grid. The author has studied the use of different transformation and filtering methods, widely applied to gravity and magnetic data , for large electromagnetic data sets. These techniques are computer based and are now available in conjunction with image processing systems.

The principal reasons for adopting a digital filtering approach to large data sets is to extract as much information as possible on anomalous responses which may be largely obscured by background or noise. A spectral approach was adopted due to its ready availability and relatively simple use.

Transforms and filters

There are a large number of transforms and filters that can be used to treat regularly sampled data. Simple multiple point weighted averaging filters can be used in the space domain and are adequate for some data sets. However a more versatile approach used here is the use of the Discrete Fourier Transform in conjunction with Spectral filters tailored to suit each data set.

The Z-Transform is also a popular approach because of its speed and easy implementation on computers. However certain side effects, such as phase shifts, can be experienced, which were thought better to avoid at this stage. The Discrete Fourier Transform can be implemented on computer by using a fast Fourier Transform which speeds up the conversion of data. The DFT and Z-Transform are in fact related.

Generalized filters were tailored to suit particular data sets and expected anomalous responses. This was achieved by obtaining the power spectrum of the transformed data and using this as a guide. Initially one-dimensional filters were tried on selected lines of data but because of the two-dimensional character of the anomalous responses a two-dimensional transform and filter approach was found to be more suitable.

Other methods of regional-residual separation had been tried prior to adoption of the Fourier filtering approach. These include simple background or half-space removal techniques. However due to the large variations in over burden thickness and conductivity that can occur over a survey area this approach was found to be inadequate. The use of five and seven point weighted averaging filters was discussed earlier. These tend to distort the anomaly signatures making it difficult to recognise them in the residual data. The Fourier filtering method was therefore considered more flexible and appropriate to the data set studied.

Filter application

The electromagnetic data set analysed consists of some 5000 data points distributed over a number of contiguous grids which are at different angles to each other. The method of collecting this data was by a moving 200 x 200 m displaced loop Sirotem mode. Readings were taken every 100 m this providing a 50% loop overlap. At each station between 16 and 28 channels of data were collected, thus providing a total of some 100 000 data values.

The data was initially interpreted by qualitatively studying stacked profiles and voltage contour maps. Anomalies were selected during this study and further processed by background removal and decay curve analysis. Finally the most interesting anomalies were selected and modelled using various numerical models. Follow-up work was then carried out on the basis of the modelling results.

It became apparent during the initial stages that certain anomalies stand out and are easily selected from a visual study of data. Anomalies which represent strong conductors at a shallow depth are in particular easy to pick because of their spectral resolution based on decay constants. That is, they are evident on channels representing intermediate to late time measurements. However anomalies relating to poor or deep conductors are more difficult to discern above the background response.

If the filter has been correctly designed it is possible to retain much of the symmetry and character of the actual anomalous response. This makes it possible to use available numerical modelling techniques to assess the anomaly.

Initially the filtering method was used in one dimension by treating individual lines of data. However due to the two dimensional character of both the background and anomalous response it is necessary to carry out the transformation and filtering in two dimensions. The radial spectrum and thereby the design of radial filters is used in the program MAGMAP (Patterson, Grant & Watson) was therefore employed to treat the whole data set.

Image processing

The transformation and filtering approach for multichannel EM data as described in the previous section can be used on available computers to produce stacked profiles and contours of the residual data. Alternatively the filtered data can be put on an image processor and further enhanced. Some of the more sophisticated commercially available image processors can handle 10 or more channels of data at a time. The less expensive systems can usually handle about 4 channels at once. In either case this is adequate to study the spatial and parametric characteristics of multichannel data.

The latest software on some systems enable the user to look at profiles on data on a vertical axis and the time variation on the horizontal axis, thus enabling the spatial and decay characteristics of TEM data to be studied simultaneously.

In addition to being able to manipulate the raw or filtered data on the image processor a large number of other filters can be applied. These include:

- edge enhancement (for picking up faults or discontinuities)
- log residual analysis (to further filter out unwanted background)
- stretching (linear, logarithmic, etc).

These can be used in addition to the various colour presentations.

A further presentation step after digital filtering is the application of a supervised classification technique to divide the area up into various anomalies and conductivity regimes based on both the spatial and spectral characteristics. However, this does not usually assist interpretation but helps the geophysicist to present the data to other members of the team.

Eventually it is necessary to return to the raw or filtered data to quantitatively analyse the anomalous responses. If confidence in the quality of the anomalous response is lacking, at worst a better designed survey can be performed to further enhance the anomaly in the field.