Empirical Mode Decomposition (EMD) of potential field data: airborne gravity data as an example

Hassan H. Hassan, GEDCO

Summary:

In this paper, we introduce a newly developed method to process potential field data as an alternative to Fourier and wavelet based techniques. This new method is called Empirical Mode Decomposition (EMD) and was developed by Dr. Norden E. Huang at the NASA Goddard Space Flight Center (Huang et al. 1998). The EMD method is different from Fourier and wavelet transforms because it handles nonlinear and non-stationary signals.

The Fourier transform (FFT) is designed to work with linear and stationary signals. The wavelet transform, on the other hand, is well-suited to handle non-stationary data but poor at processing nonlinear data. Since potential field data are in general nonlinear and non-stationary in nature we expect limitations in processing the data using FFT or wavelet methods.

This work is therefore designed to test this new technique on potential field data using airborne gravity over the Turner Valley area in the foothills of Alberta, Canada.

Introduction:

The use of airborne gravity surveys is growing in the oil and mining industry. However, the quality of the results is limited by the level of noise introduced into the data during acquisition. We lack a proper processing technique to remove effectively the noise from airborne gravity data. For this reason, we have tested the EMD technique because we feel that FFT is not well-suited to process this type of data.

The data selected to test the EMD method is derived from an AIRGrav survey flown over the Turner Valley region of Alberta in the summer of 2001 (Peirce et al. 2002). The data set consists of over 12,000 line km of airborne gravity data flown on 250 m spaced east-west lines, and 1000 m spaced north-south lines. The survey area, a well known oil and gas region, flanks the eastern edge of the Rocky Mountains where it is dominated by north-south trending faults associated with the foothills region (Fig. 1). The eastern side of the area consists of flat lying sediments.

The first vertical derivative of the filtered complete Bouguer gravity anomaly of the Turner Valley survey calculated at a reduction density of 2.67 gm/cc is shown in Figure 1. Figure 1 also shows the area selected to test EMD (purple box).

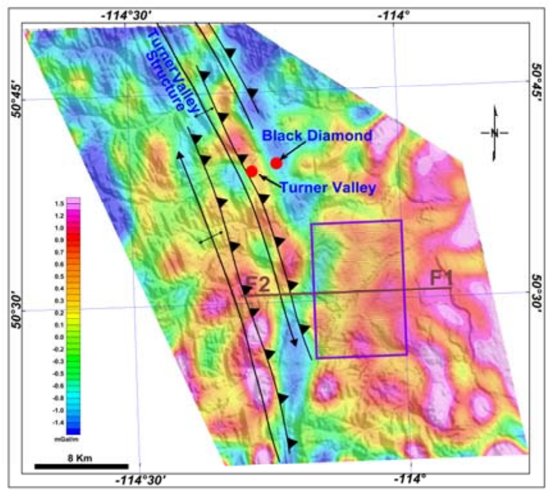

Figure 1. Map of first vertical derivative of filtered bouguer gravity anomaly of Turner Valley airborne gravity survey draped on northeast-shaded relief topography. The purple box is the EMD test area.

Methodology:

The EMD is an adaptive decomposition technique with which any complicated signal can be decomposed into a definite number of high-frequency and low frequency components by means of a process called sifting. These components are called intrinsic mode functions (IMF). These IMFs have well-behaved Hilbert transforms and are defined as functions which (1) have the same number of zero-crossings and extrema; and (2) the mean value of the upper and the lower envelopes is equal to zero. The EMD technique (Huang et al., 1998) is described in Figure 2.

The decomposition of the signal into IMFs is performed as follows (Fig. 2):

1. Identify the positive peaks (maxima) and negative peaks (minima) of the original signal.

2. Construct the lower and the upper envelopes of the signal by the cubic spline method.

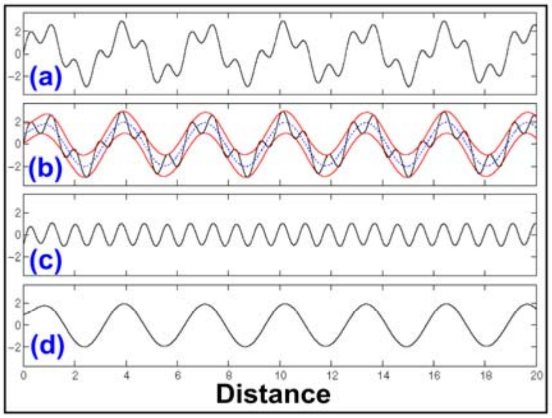

Figure 2. EMD of two component signal, (a) sum of two components, (b) lower and upper envelopes (red) and their mean (blue), (c) the first IMF and (d) the first residual (after Ooninckx and Hermand, 2004)

3. Calculate the mean values by averaging the upper envelope and the lower envelope.

4. Subtract the mean from the original signal to produce the first intrinsic mode function IMF1 component.

5. Calculate the first residual component by subtracting IMF1 from the original signal. This residual component is treated as new data and is subjected to the same processes described above to calculate the next IMF.

6. Repeat the steps above until the final residual component becomes a monotonic function and no more IMFs can be extracted.

We have used a Matlab code written by Dr. Patrick Flandrin of Centre National De Recherche Scientifique (CNRS) in Lyon, France (Flandrin et al. 2004) to compute EMD of the airborne gravity data.

Results:

We have used the EMD method to process the line data of the airborne gravity survey that covers the purple box area shown on Figure 1. The result of a single line (Line F1-F2) in the data set is displayed in Figure 3. Figure 3 shows that most of the noise in the data is contained in IMF1 and IMF2 components and can be easily separated from the gravity data. To illustrate the significance of the results obtained from the EMD method, plots of the complete Bouguer gravity signals prior to EMD processing (Fig. 4) and the IMF3 output of the same signals after EMD processing (Fig. 5) are displayed for comparison. Visual comparison between Figures 4 and 5 clearly indicates coherent and useful geological information in the data that is not evident using the FFT method.

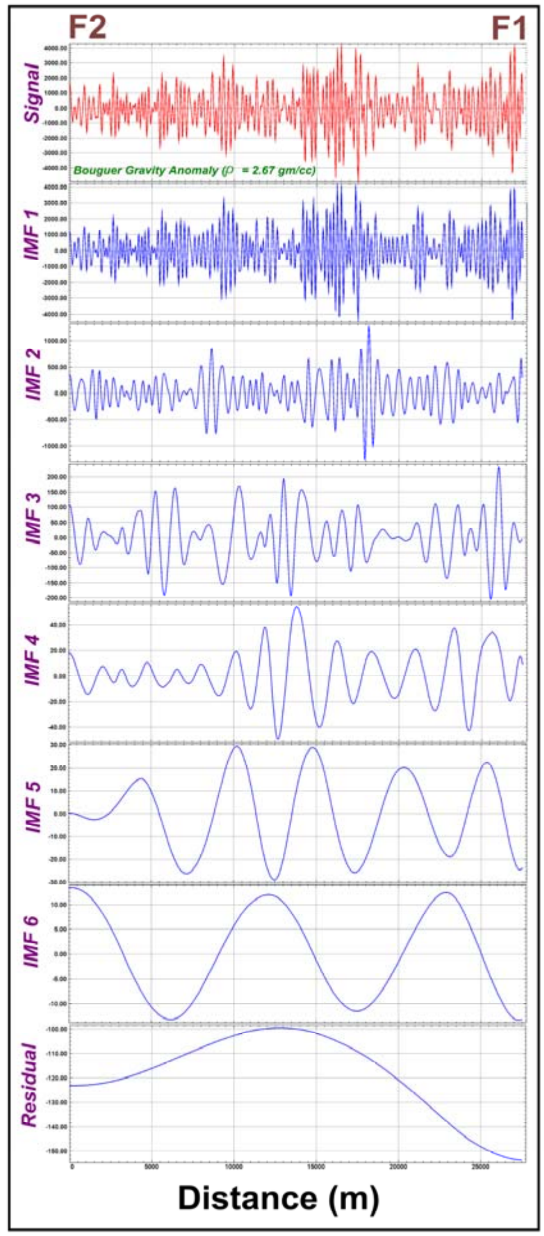

Figure 3. EMD decomposition of a single airborne gravity line (Line F1-F2 on Figure 1)

Concluding Remarks

A new technique to analyze airborne gravity data has been presented. The initial result is very encouraging and very promising. This new method would help in isolating noise from airborne gravity data and detects meaningful geological information that might have been masked by the amount of noise in the data.

References

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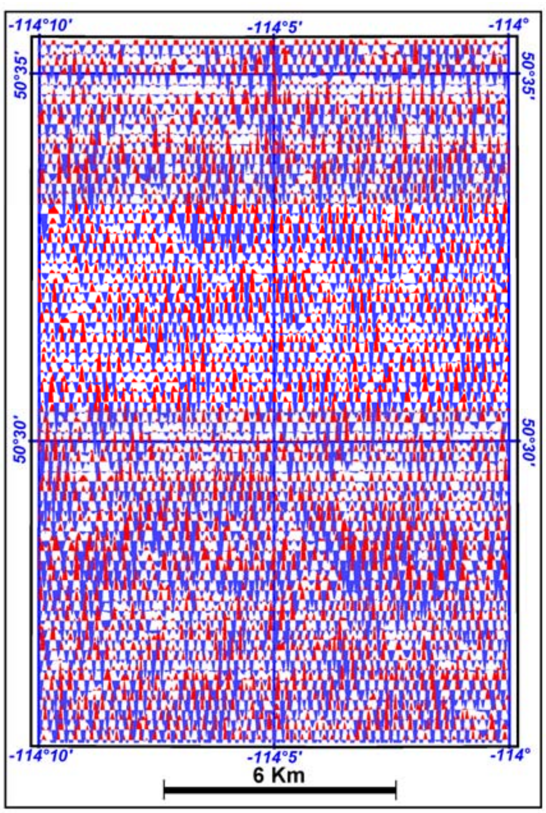

Figure 4. Plots of unfiltered Bouguer gravity data prior to EMD processing along the survey lines (same area as the purple box in Figure 1)

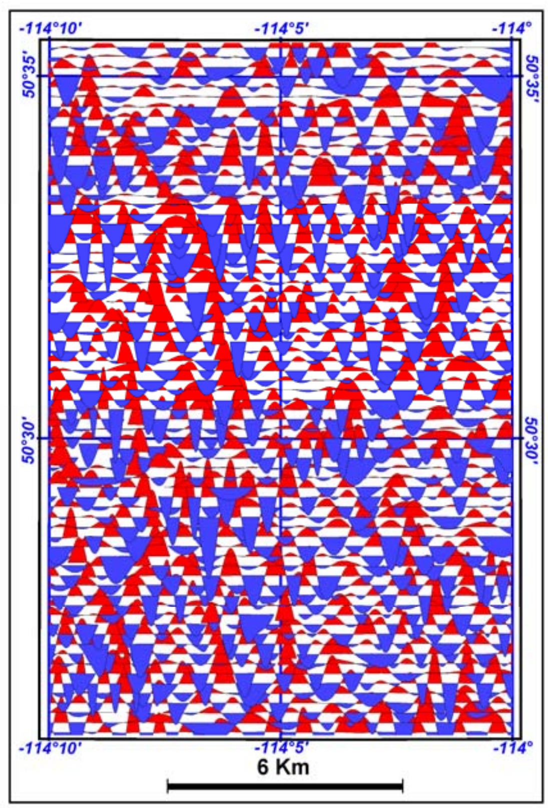

Figure 5. Plots of IMF3 after EMD processing of the Bouguer gravity data shown in Figure 4