Selecting optimal frequency range for estimating depth to magnetic sources

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The depth to the top of the deepest magnetic source is a proxy for the depth to basement under the assumption that basement is magnetic rock covered by non-magnetic sediment. Spectral domain methods allow for rapid estimation of the depth of magnetic sources from a magnetic anomaly map by analysing the power spectra calculated from a window of magnetic field data. The choice of an appropriate window size is critical when employing these methods, due to the trade-off between robustness and locality. Larger windows are desirable as they include more data to average out randomness and noise, and larger windows are needed to observe the low-frequency components which relate to the deepest sources. But they may also include multiple objects which can confuse analysis and spatially smear results, so smaller windows are desirable for improved spatial resolution.

The three properties typically estimated are the depth to the bottom of the layer z_b, the depth to the top of the magnetic layer z_t and the magnetic fractal parameter β, which describes how the magnetic source changes with scale. For our purposes we are not interested in the depth to the underside of the layer and consequentially can use smaller windows as we do not require the low frequencies to constrain the depth to the bottom of the layer. Hence the minimum window size is now limited by the expected depth to top of the layer.

A wide frequency range is critical to best separate the effects of z_t and β and obtain robust depth estimates. Above a certain frequency the spectrum is dominated by shallow sources and different types of noise; it no longer contains information about the deepest magnetic source. For a given window size we can obtain more robust estimates be carefully identifying this upper limit for the frequency range. The frequency at which the spectrum changes from being dominated by the magnetic layer to dominated by other sources can vary from location to location. Here we therefore introduce a methodology that selects a locally optimal upper limit for the frequency range by analysing the goodness of fit as a function of this frequency. For each location we identify candidate frequencies based on the R^2 value for a linear model for the power of the signal as a function of the frequency. From these candidate frequencies we chose the one resulting in the lowest root mean square error for the fitted spectral model.

We use synthetic tests to derive an empirical relationship between the recoverable depth to the top of the magnetic layer and the window size; and illustrate the degree of undesirable spatial smoothing caused by an unnecessary large window for a given recoverable depth. Recovered trends for the depth to basement for Australia are comparable to solutions obtained from different sources of information. The true value of our improved spectral method though lies in its suitability for application in a real-time environment due to its efficiency.