Modelling an Equivalent Layer in Magnetometry- A New Approach

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Abstract

This paper deals with the modelling of a thin fictitious equivalent layer with specific properties, capable of resemble in a reasonable verisimilitude, a given magnetic anomaly caused by a crustal source. This thin, magnetized and horizontal slab is obtained assuming that a three-dimensional body can be approximated by a collection of dipoles, smaller elements simple enough to possess analytical expressions for their magnetic fields. Its use is recurrent in magnetic interpretation and here we propose a method based upon the effect of magnetic shield as a reference for the layer's magnetization. In this physical phenomenon, the shield acquires a magnetization in such a way that, above it, the magnetic field is annihilated or strongly mitigated and this remarkable fact can be used to simplify mathematical modeling. This method was successfully tested on synthetic data sets and the results show that the method is effective in a variety of situations.

Introduction

The equivalent layer technique is an important tool in the process of interpolation of potential field data and has long been an issue in magnetic interpretation. This method focus on the calculation of a thin, magnetized and horizontal slab, formed by a collection of magnetic dipoles able to reproduce, with an acceptable reliability, the true source distribution and this study is based on synthetic virtual geomagnetical dipole distributions. However, this technique can be applied only in surveys with small number of datapoints, once it leads to a least-squares problem which involves a linear system whose order is the number of data (Mendonça, 1992). In spite of it, there are important scientific works developed in order to make the equivalent layer technique feasible in surveys with large data-sets, because of its remarkable importance in reduction of magnetic measurements (scattered datas collected in disparate altitudes, often from different surveys, can be merged and compared at a common level, for a simpler interpretation, leveled and analyzed following the same elevation pattern).

Method

The layer was modeled over a plane where the components of magnetic field (Bx, By, Bz) were measured and it consists of a collection of magnetic dipoles spread out the plane, establishing a regular grid. Each dipole has a moment directly proportional to field's intensity at this point and the magnetization direction will be the measured field projected on the layer's plane, which means that the magnetization will remain horizontal, behaving like a real shield, and the magnetization will be proportional to magnetic induction field. The forward method was developed generating synthetic data from a given distribution of sources. The inverse problem consists in settling the proportionality constant that associates the measured field with the magnetic moment of all the dipoles that compose the layer, so as to reproduce with the best reliability the effect caused by the sources above the equivalent layer.

For this purpose, the problem started being solved little by little: first of all, the model for a single dipole was studied and afterwards for two and so forth, which gives an idea of the problem's behavior and induces the first steps, once it's known that even bodies with sophisticated geometries can have its magnetic moment calculated by discretizing it into an array of small volume elements that, seen at a distance, can be approximately dipoles and finally sum the anomalies caused by each dipole (Blakely, 1995).

Once this approach may not be applicable when a survey counts on a large data set, the straightforward strategy employed is isolating the target anomaly in the data set (Dannemiller *et al*,2006), windowing the data so that only an area encompassing the target is used. This process must be carefully done in order not to select redundant data points, even if they belong to the target. In the case of other anomalies located in the surroundings, the method should not be used.

In order to estimate a magnetic field that would be measured in a higher elevation using measurements closer from all sources, we assumed continuity and applied upward continuation, once it's a typical low-pass filtering technique and it will attenuate the effect of smaller-scale anomalies located in target's neighborhood.

Field was also reducted to the pole (RTP) to transform an anomaly measured at any latitude into another one that would be generated at a magnetic pole, with a magnetization that has the same magnitude but is oriented in the vertical direction. Hence, anomalies from symmetrical bodies are symmetrical in this situation.

For many altitudes, the anomalies generated by true sources distributions were compared to those calculated and reproduced by equivalent layer and the results will be shown later, as well as the computed errors (root mean square).

After data processing and adequate removal of regional fields, data should be interpreted concerning other information, such as local geology and other geophysical data, in order to estimate source’s parameters, like thickness, spacial distribution, deepth and magnetization.

Results

The figures 1, 2 and 3 below, show for three different altitudes (1000m, 300m and 25m), comparisons between the anomalies caused by the true source distribution (a) and the same effect calculated by our algorithm, considering, for each altitude, the same comparisons for the RTP anomaly (b).

Conclusions

This method was widely tested on synthetic data sets with different distributions of sources and the algorithm was efficient for downward and upward continuations, showing that the methodology can be improved to be applied in the reduction and interpretation of magnetic measurements. Once it was modeled using upward continuation, anomalies caused by near-surface causative bodies are attenuated in relation to deeper sources (Blakely, 1996), due to differences in wavelength (the shorter the wavelength, the greater the attenuation). Therefore, our approach works in cases of near-surface sources (the distance between the surface and the slab plays an important role in generating derivatives on the anomaly) and with a small number of datapoints. If these assumptions are violated, the method will fail. This approach can be applied to both qualitative and quantitative interpretation techniques for a better comprehension of the subsurface.

Acknowledgments

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References

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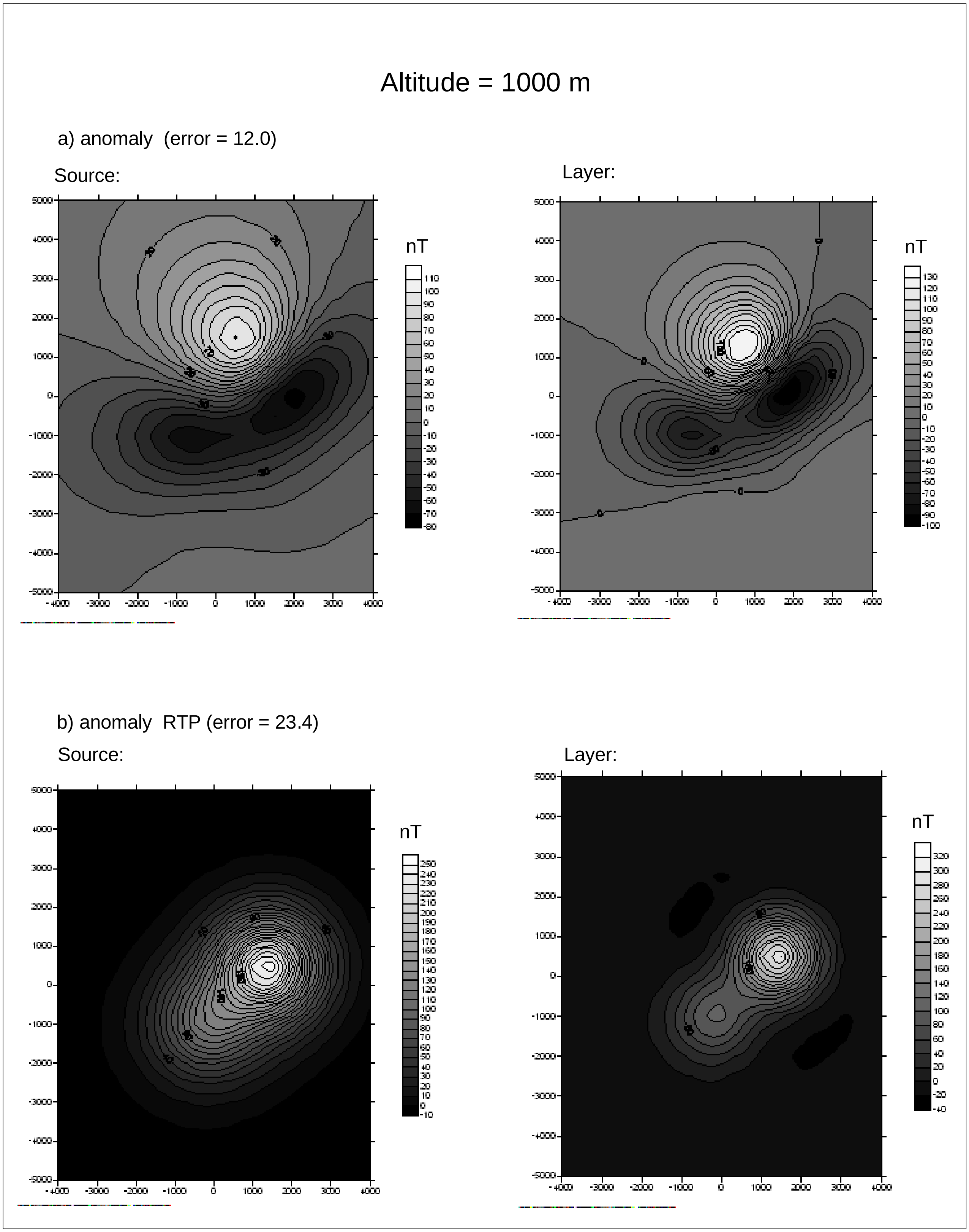
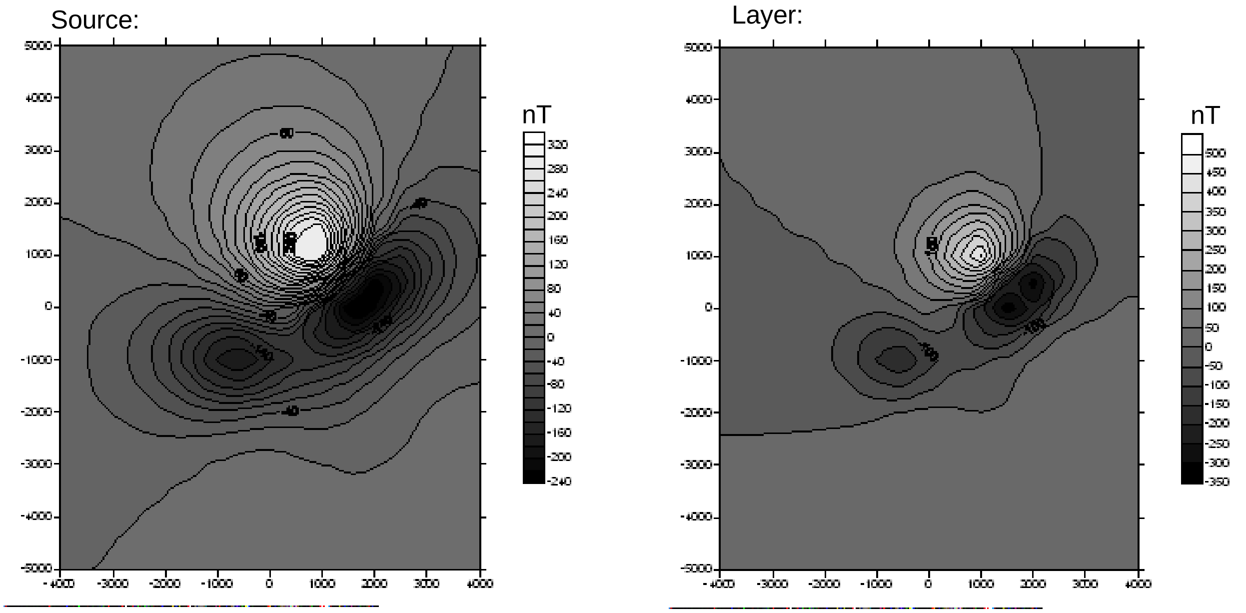


Figure 1. a) anomaly and b) anomaly RTP for 1000 meters.

Altitude = 300 m

a) anomaly (error = 28.4)



b) anomaly RTP (error = 50.9)

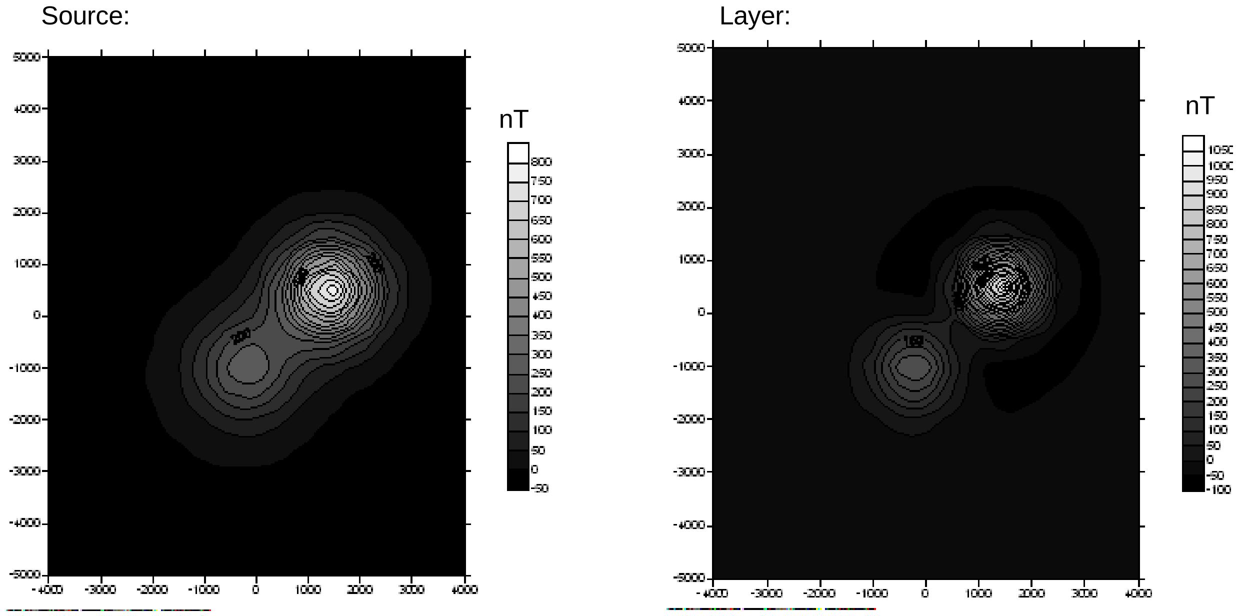
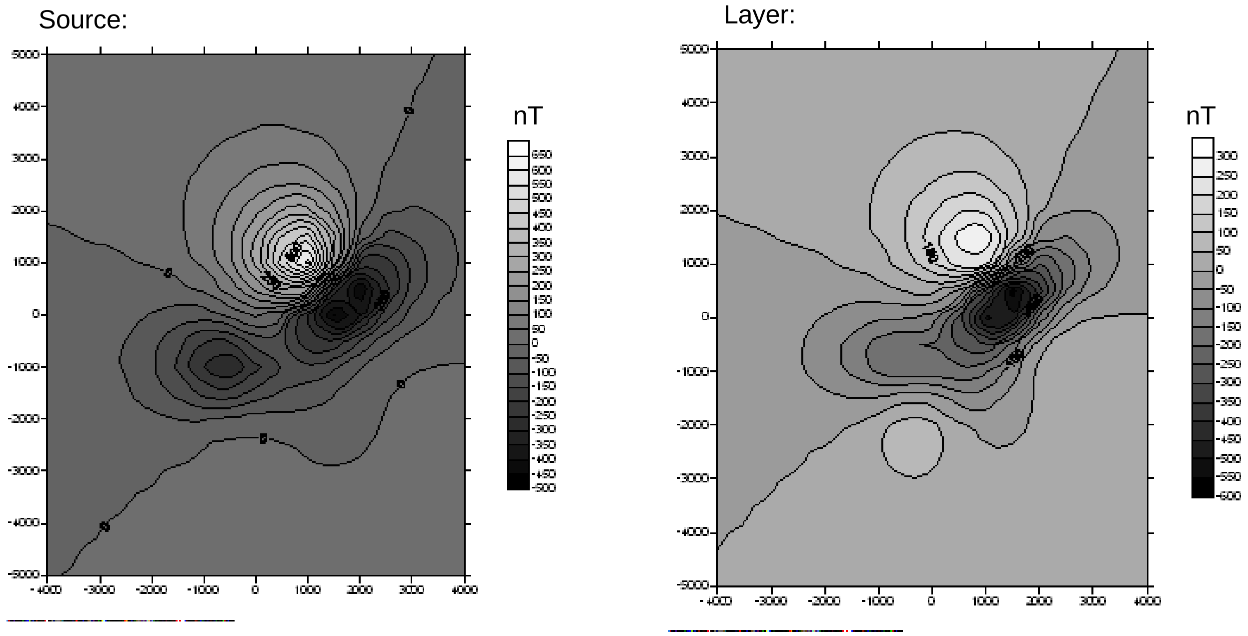


Figure 2. a) anomaly and b) anomaly RTP for 300 meters.

Altitude = 25 m

a) anomaly (error = 62.2)



Source:

Layer:

b) anomaly RTP (error = 150.9)

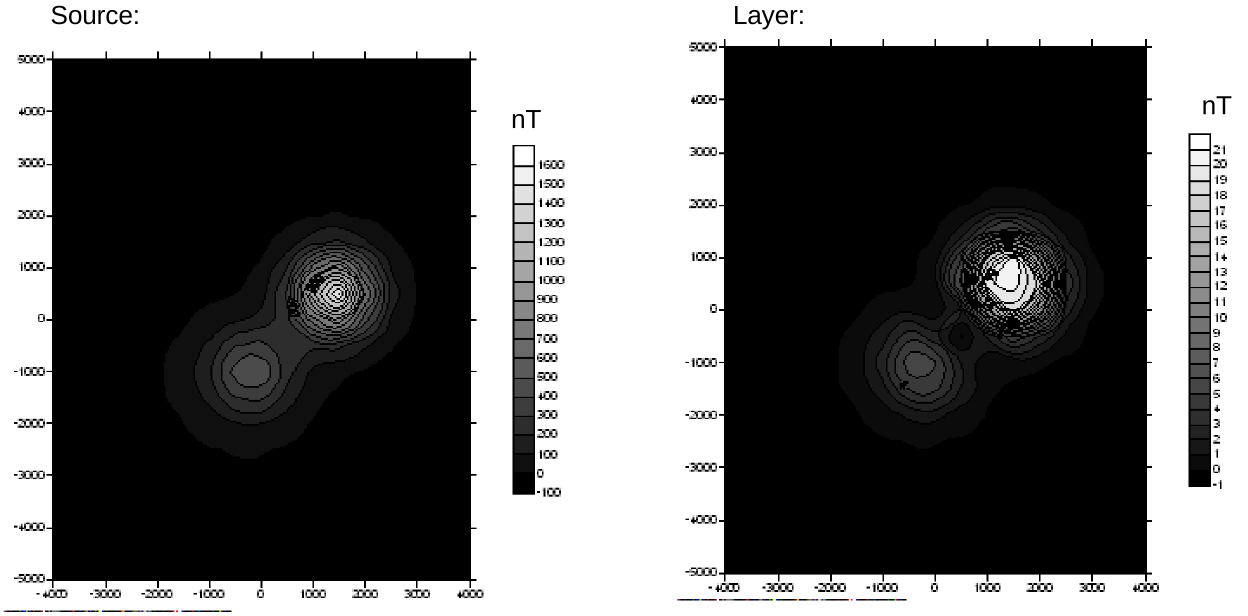


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Figure 3. a) anomaly and b) anomaly RTP for 25 meters.