A new RTP method via nonlinear thresholding at low latitudes

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Abstract

We present a stable reduction to the pole (RTP) strategy using a nonlinear threshold method with better RTP performance for magnetic data at low latitudes (RTP-L). It is tested on synthetic and field data and compared to other RTP methods. The proposed method yields more stable RTP result and estimates more accurate amplitudes than the existing methods we used in our study, especially for RTP at equator.

Introduction

Reduction to the pole (RTP) transforms an observed magnetic anomaly into an anomaly that would be measured at the north magnetic pole. This relocates extreme magnetic anomalies to be over their sources, thus making magnetic interpretation easier. However, magnetic RTP at low latitudes (RTP-L), especially RTP at equator (RTP-E), routinely computed in the wavenumber domain, is notoriously unstable.

To overcome this difficulty, the existing work has focused upon constructing a stable approximation of the RTP operator near these regions, and most of these methods are based upon filtering (Li, 2008). In order to overcome the unstableness of RTP at low latitudes, Yao et al (2004) presented a damper method which is called as RTP-Yao method. Because the RTP-L, especially the RTP-E is difficult to do, some researches use analytic signal amplitude (ASA) to identify magnetic anomalies (Keating, 2004; Ansari, 2009). But we know that the ASA needs to compute the derivatives of the field data, which is a high-pass filter, and is also unstable. So studying the stable RTP method at low latitudes is an interesting problem. In our study, we use a nonlinear threshold to suppress the high wavenumber nearby the narrow wedge-shaped segment centered along the direction of the declination.

Method

For the RTP processing, if there is no remnant magnetization or the direction of remnant magnetization is in the direction of the main magnetic field, the RTP operator can rewrite as:

$$Q = \frac{\left(\sqrt{u^2+v^2}\right)^2}{\left(i\cdot(u\cdot L_0 + v\cdot M_0) + N_0\cdot\sqrt{u^2+v^2}\right)^2}. \qquad (1)$$

Where (u, v) are wavenumbers in the x- and y-directions. $L_0 = \cos I_0 \cdot \cos D_0$, $M_0 = \cos I_0 \cdot \sin D_0$, $N_0 = \sin I_0$, I_0 and D_0 are the inclination and declination of the main magnetic field. For RTP at low latitude, when the points locate on or near the $u = -\tan D_0 \cdot v$, the operator will produce very large amplitudes which lead to instability.

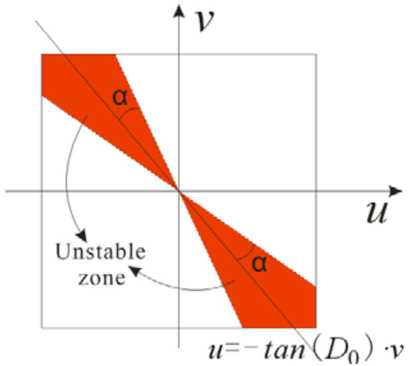

Figure 1. The character of RTP operator in the wavenumber domain. The filled red area will hold big values at low latitudes leading to be unstable.

For RTP-Yao (Yao, 2004), its operator is as follows:

$$Q(\theta) = \frac{1}{\left(\sin(I_0) + i\cos(I_0)\cdot\cos(D_0-\theta)\right)^2 + F}. \qquad (2)$$

where,

$$F = \begin{cases} 0, & abs(\alpha) \ge \beta \\ d\cdot 0.5\cdot(1+\cos(\frac{\pi\cdot\alpha}{\beta})), & abs(\alpha) < \beta \end{cases}, \qquad (3)$$

where d is a small value which is suggested to be set as d=0.01 in this paper. α is shown in Figure 1, β means the threshold angle.

In our study, we apply a nonlinear thresholding Q_0,

$$Q_0 = \begin{cases} 1, & abs(\alpha) \ge \beta \\ \left(\sin\left[\frac{\pi}{2}\cdot\frac{abs(\alpha)}{\beta}\right]\right)^N, & abs(\alpha) < \beta \end{cases}, \qquad (4)$$

where N means the attenuated coefficient, in this paper we set it as N=5. Then we obtain the operator of the RTP in the polar coordinate system, here we call it as magnetic RTP at low latitudes using nonlinear thresholding (RTP-NT):

$$Q(\theta)=\frac{Q_0}{\left(\sin(I_0)+i\cos(I_0)\cdot\cos(D_0-\theta)\right)^2}. \qquad (5)$$

Test Case Of Model Data

We use model tests to compare the proposed method with some existing methods. Figure 2a shows the magnetic response with an inclination of 0° and a declination of -5°. The model's location is indicated by the black lines. Figure 2b shows the magnetic response with an inclination of 90° and a declination of 0° with the same model. A perfect RTP should correspond to Figure 2b.

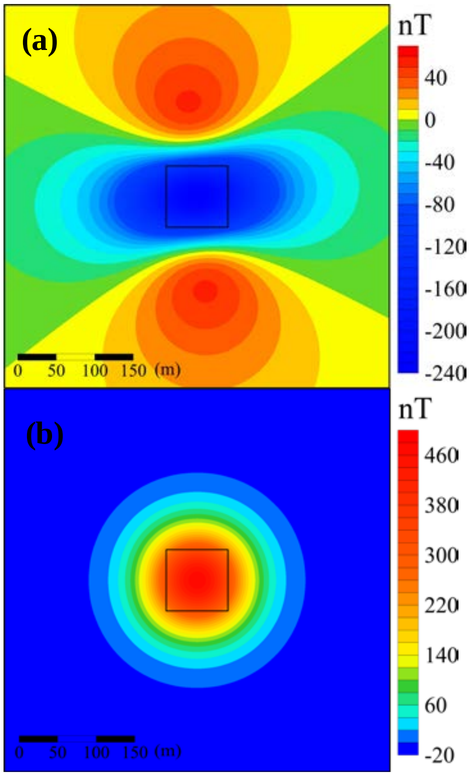

Figure 2. The simulated model data set. The grid interval is 5 m, with the size of 101 points by 101 points. Figure 2a shows the Magnetic response with an inclination of 0° and a declination of -5°. Figure 2b shows the Magnetic response with an inclination of 90° and a declination of 0°.

We use the RTP-Yao, the software of Oasis Montaj, as well as the proposed method to compute the RTP corresponding to Figure 2a. The results are shown in Figure 3. It is clear that the RTP-NT method performs better than the RTP-Yao method and the Oasis Montaj, the amplitudes (minimum value and maximum value), and the anomaly's shape of RTP-NT are more similar to Figure 2b.

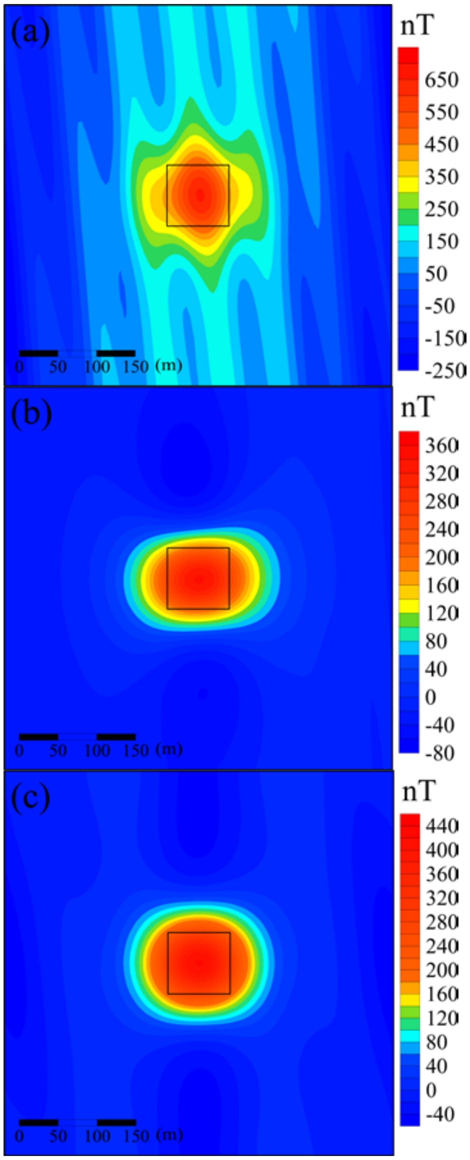

Figure 3. RTP results. Figure 3a, 3b, and 3c show the RTP by RTP-Yao, Oasis Montaj, and RTP-NT, respectively. For the RTP-Yao, the parameter d in equation 3 is set equal to 0.001.

Application To A Real Case

The case study is of the exploration of alkaline bodies and the area is located in the central portion of Brazil with an inclination of -25° and a declination of -19°. In this area, some of the alkaline bodies have a very high magnetic susceptibility, and the magnetic anomalies are caused mainly by them. But the magnetic anomalies do not over the known alkaline bodies very well because of the oblique magnetization, as shown in Figure 4a.

When comparing RTP-NT shown in Figure 4b with the existing methods shown in Figure 5, both the results via the RTP-Yao and Oasis Montaj are similar. In Figure 5 we can observe that the anomalies have an elongated format towards the south that is not absent when using RTP-NT. Combining these observations with the results of the model studies, it appears that the RTP-NT method's results are better and perhaps more interesting from the point of view of location information of the alkaline bodies.

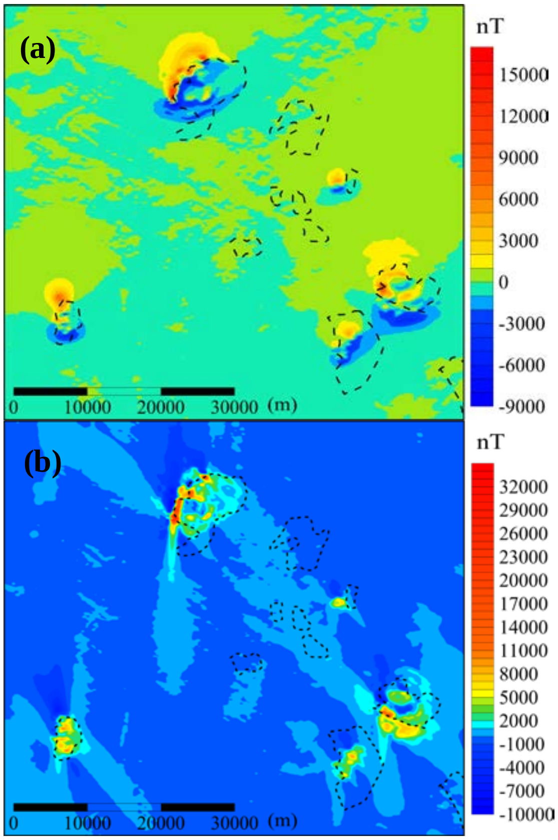

Figure 4. Figure 4a shows the magnetic data of a portion of Brazil with an inclination of -25° and a declination of -19°.Figure 4b shows the RTP result corresponding to Figure 4a via the proposed method, RTP-NT. The dotted lines shown on the map denote the known alkaline body's edge.

Conclusions

We have developed a new stable RTP-L method for magnetic data using a nonlinear threshold, which has been demonstrated that it yields more accurate RTP field than the existing methods shown in this study, especially for the magnetic data at equator.

Acknowledgments

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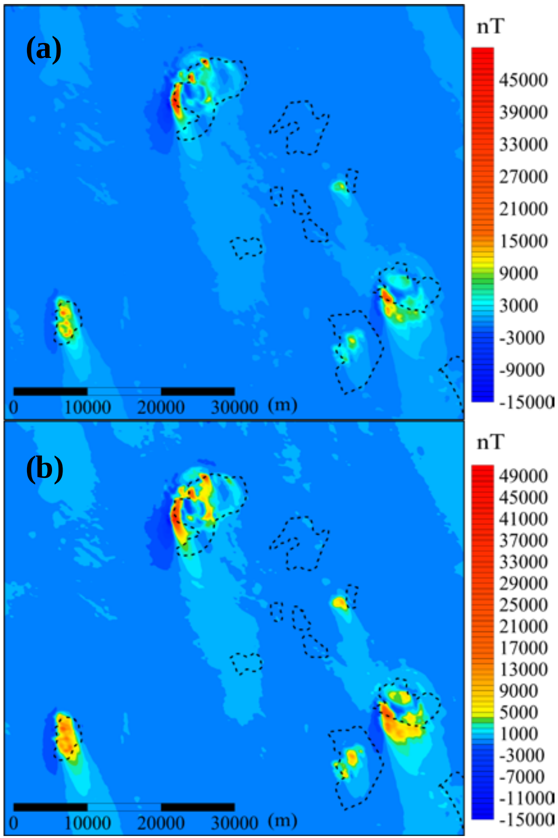

Figure 5. Figures a and b show the RTP results via the RTP-Yao and Oasis Montaj, respectively corresponding to the Figure 4a.

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