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Nonlinear Processes in Geophysics
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Discussions

Interactive comment on "Estimation of the total magnetization direction of approximately spherical bodies" *by* V. C. Oliveira Jr. et al.

V. C. Oliveira Jr. et al.

vandscoelho@gmail.com

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We would like to thank the Anonymous Referee for his/her constructive comments. Below we present our comments and responses to the Referees recommendations.

We have performed several new tests on synthetic data in response to the comments by all referees. We hope they will answer all of the points raised by the Referee. The results, figures, and source code for these tests are available online through the code hosting website Github at github.com/birocoles/Total-magnetization-of-spherical-bodies. Links to each specific synthetic test are provided in the relevant comments below.

General comments

Referee's comment: *"In addition, I appreciate what is, to my knowledge, a rather comprehensive literature review."*

Thank you for your review. In the revised version of the manuscript we have added some new references.

Referee's comment: *"The use of Euler Deconvolution to compute the center of the sources, however, I believe is a dubious method given the extension of the method to non-spherical sources. Their comments regarding the usefulness of the technique to horizontal location is appreciated, but the example only shows the technique applied to spherical bodies. I'd like an example of an off-center prism."*

That is a very good suggestion, thank you. This same concern was expressed by another referee (J. Ebbing). To address this suggestion, we have made a new test on synthetic data in which we applied our method to data generated form a model of a weekly magnetized sedimentary basin and an igneous intrusion formed by a sill which is fed by a vertical pipe. The results, figures, and numerical code used to produce these results can be found online in the IPython notebook (an interactive writing and programing environment) complex_test.ipynb.

The simulated geomagnetic field has inclination $-39.8°$ and declination $-22.5°$. The synthetic intrusion has a reversed magnetization with inclination $I = 39.8°$ and declination $D = 157.5°$. This intrusion is embedded in weakly magnetized sediments that are overlaying a basement which is magnetized by induction. In this example, the total-field anomaly predicted by the intrusion overlaps the one produced by the basement. Our method is applied to the noise-corrupted total-field anomaly produced by both the intrusion and the basement on a regular grid with constant vertical coordinate. The position of the synthetic intrusion is estimated by Euler Deconvolution. The synthetic intrusion is not an ideal source and then does not have a characteristic structural index.

In this case, we presume that the noise-corrupted total-field anomaly is produced by an spherical body and use a structural index equal to 3. The estimated location of the body obtained by Euler Deconvolution is placed outside the synthetic intrusion. This is an extreme case of an “off center prism”, as suggested by the referee.

Even using this poor estimate of the location of the source, our method estimated inclinations $\hat{I} = 37.50377° \pm 0.00035°$ and $\tilde{I} = 40.25973° \pm 0.04392°$ and declinations $\hat{D} = 167.61518° \pm 0.00060°$ and $\tilde{D} = 164.58968° \pm 0.09092°$. The caret (^) and tilde (~) denote the results computed by using, respectively, the least-squares and robust estimates. This numerical test shows the robustness of our method when applied to retrieve the magnetization direction of a complex source whose centre is poorly estimated by Euler Deconvolution. We also illustrate the use of the reduction to the pole to verify the quality of the estimated magnetization direction. The reduction to the pole calculated with the magnetization direction obtained by our method leads to a predominantly positive field, which is very close to the true pole field.

We have also run several additional tests showing the application of our method to estimate the magnetization direction of different synthetic sources with known and estimated centres (by using Euler Deconvolution). The figures, results, and source code of the additional tests obtained with the least-squares approach can be found in the IPython notebook synthetic_tests-L2.ipynb and the results obtained with the robust approach can be found in synthetic_tests-L1.ipynb. One of these tests show the influence of a superposed constant-regional field (50 nT) on the estimated magnetization direction. The regional field does not lead to wrong estimates of the centres of the sources by Euler Deconvolution because, in this case, this technique estimates a non-null base level. On the other hand, this regional-constant field misleads the magnetization direction obtained by our method. To overcome this problem, a regional-residual separation should be done prior to estimation. Finally, these additional tests also show the performance of our method in estimating the magnetization direction of synthetic models similar to the ones presented by Lelièvre and Oldenburg (2009) and Ellis, Wet and

Macleod (2012).

Referee's comment: *"It's fine to show the L2 results, but I'm not sure when one would not use the L1 in field data."*

We agree, thank you for your comment. In our opinion, the L1-norm approach should be used to interpret field data. We have stressed this aspect in the text of our manuscript.

The numerical results shown in our manuscript suggest the use of the L1 norm to interpret both interfering magnetic anomalies (section 3.2 - Robustness against interfering anomalies) and non-dipolar total-field anomalies (section 3.3 - Robustness against non-spherical sources). On the other hand, the results shown in section 3.4 (Robustness against errors in the centre location) suggest that the L2-norm approach is slightly better than the L1-norm approach if there are errors in the vertical position of the centre of the source (Figures 7e and 7f of our manuscript). The presence of errors in the horizontal position of the source misleads the results obtained with both L1- and L2-approaches.

Referee's comment: *"If there is room, I'd like to see the total field data in the field example reduced to pole as well, just for comparison."*

Sorry, we are not sure we understand this comment. Figure 10 of our manuscript shows the field data reduced to the pole using both the L1- and L2-norm solutions. Is this what you mean?

References

Lelièvre, P. G. and D. Oldenburg, 2009, A 3D total magnetization inversion applicable when significant, complicated remanence is present. Geophysics, 74(3), L21–L30, doi: 10.1190/1.3103249

Ellis, R. G., B. Wet and I. N. Macleod, 2012, Inversion of magnetic data from remanent and induced sources: 22nd International geophysical conferenceand exhibition, ASEG, Expanded Abrastracts, 1-4.

Interactive comment on Nonlin. Processes Geophys. Discuss., 1, 1465, 2014.