Dear Thorkild Rasmussen,

we are very grateful for your feedback and comments that much improve the quality of the manuscript. In particular, we consider your comment to discuss the equivalent source models in some more detail as very useful and have added now explanations a) why we chose dipoles as the equivalent sources and b) why we have not explicitly considered the remanent magnetization component in our model.

We address your various comments and questions individually, beginning with your review letter and subsequently the annotations made directly in the manuscript.

Best Regards

Björn Heincke

Responses to the main reviewer letter:

The manuscript by Heincke et al. on compilation of magnetic data for Greenland is a very important contribution and based on sound modelling and processing principles. I have attached an annotated version with suggestions for modifications (grammar mainly) and some questions/comments the authors should consider.

I would like to see some discussion on the actual "models " that are the output from the inversion, even though that they are not "true physical" geo-models. In particular, I note (see comments in annotated manuscript) that only induced polarization is assumed. What kind of equivalent source model is produced offshore where you have reversed polarity of the magnetic anomalies. What kind of pattern on equivalent source strength (positive/negative) is revealed? How does remanent magnetisation influence the inversion?

ANSWER:

- We chose dipoles as equivalent sources since they provide a more realistic physical representation of the true magnetic behaviour than monopoles (this benefit is mentioned now in Section 3.1) and their responses are much faster to compute than the ones of finite bodies as e.g. pillars.

  Moreover, the use of magnetic dipoles enables consideration of temporal variations in both the amplitude and direction of Earth's main magnetic field. This, in turn, allows to reduce during the inversion process inconsistencies between datasets that are associated with their different acquisition times. Such adjustments are not feasible when magnetic monopoles would be used.

  Since we did not describe this benefit before, we have now added a short subsection (Section 3.3.4) that describes how Earth's main magnetic fields at different times are

implemented in the inversion for both the equivalent sources and measurement locations.

- It is an interesting question, if it is needed to explicitly consider the contribution of the remanent magnetization in the equivalent source model (and inversion). We had a similar discussion among the authors at the beginning of the project and we concluded that the remanent part can be considered as negligible in very most cases.

  This can be explained as follows: A dipole component oriented orthogonally to the main geomagnetic field produces magnetic field vectors at nearby observation points whose directions deviate significantly from the one of the main geomagnetic field. Since the total magnetic anomaly is determined by projecting the dipole field onto the direction of the main geomagnetic field (see Eq. 3), the contribution of an orthogonally oriented dipole component is comparatively small.

  In practise, it can be checked whether dipoles used as equivalent sources adequately describe the magnetic field in areas dominated by remanent magnetization by considering the data misfits at nearby observation points. In our inversion test, we did not observe any elevated data misfits in areas that are dominated by magnetic remanence such as the ocean floor with its magnetic stripping patterns. This indicates that our model is able to properly fit the data, even though it does not explicitly consider the remanence.

  We have added now a discussion of this observation in Section 5.1.

Responses to comments made in the manuscript:

Line 12: change to "merging"

ANSWER: Done

Lines 21-22: The sentence needs rephrasing

ANSWER: We have changed the sentence to "Since areas insufficiently covered by airborne magnetic surveys can, moreover, be supplemented with lower-resolution satellite data, ... "

Line 26: change to "trace"

ANSWER: Done

Line 33: change to "exploration"

ANSWER: Done

Lines 40 – 45: I suggest to include a reference also to GEOPHYSICS, VOL. 67, NO. 2 (MARCH-APRIL 2002); P. 546–554, 6 FIGS., 3 TABLES.10.1190/1.1468615. Compatibility of high-altitude aeromagnetic and satellite-altitude magnetic anomalies over Canada. by D. Ravat, K. A. Whaler, M. Pilkington, T. Sabaka, and M. Purucker

ANSWER: We have added this reference in the introduction.

Line 49: change to "wavelength"

ANSWER: We have changed "frequency" to "wavenumber".

Line 89: change to "weight"

ANSWER: Both "regularization strengths" and "regularization weights" are commonly used terms in literature about inversion problems. We keep "regularization strengths" here.

Line 128: change to "acquired irregular"

ANSWER: We have replaced "unsystematically" with "irregularly".

Line 151: change to "magnetic"

ANSWER: We have changed "such as point masses and dipoles" to "such as magnetic monopoles and dipoles".

Lines 156-158: The ocean bottom has ages much less than the latest polarity reversal, so a reasonable assumption is that main contributions (or dominant) to the observed field offshore is remanent magnetization. Remember here that the magnetic response is zero for a horizontal slab (assuming flat Earth) with homogeneous magnetisation. Thus, provided that the continental drift is relatively small N-S, and mainly west-east wards, the induced field is in general small compared to the remanent field contribution.

ANSWER: We have addressed this aspect already in our reply to the main comment (see above).

Line 156: add "apparent"

ANSWER: Done

Line 157: change to "aligned along the direction of the main geomagnetic field"

ANSWER: Equation 2 assumes that all magnetization is induced and no remanence exists - even not along the direction of the core field. Therefore, we have changed the sentence slightly differently as proposed by the reviewer: "[...] This implies that all magnetization is assumed to be induced and thus aligned with the direction of the main geomagnetic field (no remanence and no field components orthogonal to the core field) [...]"

Line 157: add "orthogonal to core field"

ANSWER: See response to the previous comment

Line 187: delete "the"

ANSWER: Done

Line 242: Clearly, the Laplace equation is valid but is this a necessity for using equations 1-4? This is first of, all important /inherent for the use of spherical harmonics representation

ANSWER: The reviewer's comment is correct that the Laplace equation is not strictly required to apply equations 1 - 4, but the Laplace equation states that the field from equivalent sources fully represents the magnetic field generated by all sources located beneath the ES layers. To make this clear, we have added to the sentence: "[...] the complete magnetic field originating from the subsurface (underneath the ES layers) is represented by the fields from the equivalent sources and [...]".

Line 267: "first" is a somewhat arbitrary term although you do start up with estimation of C1. Use "lower most" instead.

ANSWER: Done

Line 272: delete “Typically”

ANSWER: Done

Line 298: change to “sufficiently”

ANSWER: Done

Line 300: change to “weights”

ANSWER: Both “regularization strengths” and “regularization weights” are commonly used terms in literature about inversion problems. We keep “regularization strengths” here.

Line 302: change to “sparsely”

ANSWER: Done

Line 324: the term "height" in the modelling is with reference to spherical earth so this introduce some thought for how to interpret data in relation to sea-level? I guess it becomes a little too philosophical to enter a discussion on this, but maybe something to consider for the future. Since the final data are only the anomalous field, I guess not of any concern here.

ANSWER: We agree with the reviewer and appreciate this comment – and in the most recent version of our program the flattening of the earth at the poles is considered. It would be even more appropriate to estimate the exact radius of the WGS84 ellipsoid at every equivalent source and measuring location. But then we need to find solutions that will not slow down calculations too much.

Line 324: change to “height”

ANSWER: Done

Line 327: change to “plane”

ANSWER: Done

Line 336: Any consideration on aliasing? any low-pass filter used prior to resampling?

ANSWER: The measured data typically have finer intervals than those obtained after resampling such that aliasing effects do not arise.

Lines 362 and 366: delete "(" and ")"

ANSWER: Done

Line 382: change to "heavily dependent on"

ANSWER: Done

Line 397: change to "low data density"

ANSWER: We have rephrased the sentence to become clearer.

Lines 402-403: I guess this would be interpolation across lines, not extrapolation?

ANSWER: Done. We agree with the reviewer that "interpolation" is the better suited term here.

Line 405: change to "in many places"

ANSWER: Done

Line 416: Remove line-break

ANSWER: Done

Line 421: magmatic or magnetic?

ANSWER: We have changed it to "magnetic".

Line 488: delete "now"

ANSWER: Done