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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Numerical Evaluation of magnetic absolute Measurements with arbitrary distributed DI-Fluxgate Theodolite Positions" *by* Heinz-Peter Brunke and Jürgen Matzka

Anonymous Referee #2

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1 General

The article presents a novel method to perform and evaluate absolute measurements at geomagnetic observatories. This seems to be an useful generalisation of the traditional method that can provide easier identification of outliers, allows analysing more measurements points at once to improve accuracy of the measurements and can give the observer some more insight about sources of problems. These are all welcome benefits of the method, very useful to the community.

In the light of "allowing fellow scientists reproduction of results" I slightly miss some supplementary material (an appendix) with either source code or a fully worked out

example of calculations with some raw measurement data and steps to the final result that can be used to validate new implementations of the algorithm done by readers of the article.

The article heavily promotes the ability to do measurements without the zenith ocular. It would be nice to see that claim supported by some numerical results.

The abstract feels a bit long. The list of references might be shorter than usual, but since this is mainly an original mathematical article rather than a review article, this is probably fine.

The English language needs some polishing. The symbols in mathematical formulae could be introduced more smoothly (it is not always clear what they are without some background knowledge, sometimes they are simply explained two paragraphs "too late" to allow a smooth reading experience).

2 General comments

- I believe that it is relatively difficult for a newbie to fully understand the procedure and follow all the steps correctly. I would find it enormously helpful if you would include an Appendix with a fully worked out example (or potentially even example source code). Say, provide 16 measurement points (including data from variometer and F), the first eight being the usual ones (at vertical angles 90 and 270 degrees), followed by a bunch more more at arbitrary angles. Include some proper outlier and one typo that could be corrected (say, a reading that's 10 arcminutes off) and compare the classical calculation with your method. I would find it important that someone who finds this article would be able to fully reproduce your results and verify that his/her implementation is 100% compatible with what you describe. While the article contains the formulas, they might feel a bit abstract, programming errors are easy to make and hard to debug.

- You claim that the method could be used at magnetic equator without the zenith ocular. While this is probably true, it might be interesting to see the comparison (either from a large set of simulated measurements, from mathematical analysis or from a measured dataset) between 8 points done using the traditional method (with the zenith ocular) and with another set where the four inclination measurements get replaced by a small number of measurements done at other angles. How does the uncertainty/error increase when we only measure at $90 \pm 60^\circ$ or only at $90 \pm 20^\circ$ (90° for declination plus some more measurements at other angles). Plus the 270° counterparts of course.

- It takes quite some time to understand what Figure 1 is trying to tell. Personally I would find it useful to see a simple 3D plot of F (with D and I angles marked somewhere), surrounded by a set of perpendicular arrows (perhaps also a formula) and a very short explanation saying that these perpendicular arrows represent all possible orientations of the magnetic sensor (and telescope) with $S = 0$. That is: orientations where we should be making our measurements. And explanation that the same (circle) is actually plotted in Figure 1 and 2.

  It would be nice to add (magnetic) latitudes of the three observatories next to Figure 1.

- Section 2.2 starts with a whole lot of equations, using symbols that have never been introduced before. Some are introduced after or with another equation. That makes the text more difficult to follow. You already use symbols $W \uparrow$ etc. in Figure 1 and don't even mention what that means. It would be more natural to me to introduce these symbols at the beginning of Section 2.1 where you introduce the traditional method and then continue using them throughout the article. In particular you never introduce $A_{W\uparrow}$ (A_X) (horizontal circle reading), ΔA_i, ...

3 Some notes about language

Please note that I'm not a native speaker, so please double-check any language-related comment yourself.

But the English used should be improved. Many commas are wrong, many "a" or "the" are missing. I'm slightly puzzled by the "German constructs" like "allows to get", "allows to evaluate", "allows to incorporate", ... I think that "evaluating" or "evaluation" sound better.

The title of the article sound capitalised by the German rules. Shouldn't all words be either lowercase or all uppercase (other than prepositions)?

Theodolite **orientation** sounds better than **position** to me (both in title and later in text). You are not moving the theodolite around the room, you are only rotating it.

I would replace "D" with "declination D" at a few more places, in particular at the beginning. It's sometimes nicer to spell the words inclination and declination explicitly (not always of course).

4 Minor issues

4.1 Abstract

- Line 1: missing "**the** so-called"
- Line 2: "allows to get" sounds weird
- Line 8-9 (For absolute ...): The sentence might not be grammatically incorrect, but it is difficult to understand. I would use a different word order.

- Lines 11-12: perhaps "allows evaluation of an arbitrary number of measurements (...) at "arbitrary" theodolite orientations ...". The orientations are not really arbitrary ones. Five readings at $E_\uparrow$ would certainly not help. The article doesn't explain anywhere to what extend these measurements are in fact arbitrary.
- Line 15: **the** least square
- Line 16: "Gauss–Newton method" (no dash in front of method)
- Line 19: perhaps "The calculated residuals give/provide a measure of quality of each individual measurement"?
- Line 20: "allows to incorporate": sounds weird, maybe "additional measurements may be seamlessly incorporated"
- Line 27: What levelling errors are avoided? The user still needs to read the angle at least? (I also have a slightly hard time buying the argument that using just one adjustment wheel is that much easier.)
- Line 30: I would say "possible even with theodolites without **the** zenith ocular" ("the" missing also two lines lower)

4.2 Introduction

- Line 12: You say that you took advantage of methods from geophysical inversion theory. Is there some appropriate reference you could mention here?

4.3 Section 2

- please use D and I (D, I) rather than plain D and I

- The first paragraph sounds like an appropriate place to introduce symbols $W \uparrow$ etc. that are later used in Eq. 1 and later.
- Lines 19, 22: Do any theodolites have the sensor mounted below the telescope at $\xi = 90°$? Unless that's common, why not explicitly mention sensor up and down at this point and say "sensor below the telescope" rather than "sensor on the other side of the telescope"?
- Lines 20, 24: w**h**ere
- Lines 21, 24: I would say: "where the magnetometer reading S is small or zero" and "where the field reading S vanishes" (that is: include the symbol)
- Line 22: why do you use index c for ϕ_{c1}? Why not

  $$\phi_1, \ldots, \phi_4$$

  (including comma)?
- Lines 23, 27: **the** magnetic North, **the** fluxgate, **the** telescope
- Shouldn't "eq. 1" be "Eq. 1", i.e. all uppercase, same for Figure N?
- Lines 31, 32: I would reword this.
- Figure 1 uses φ, while you refer to ϕ in the text. The same letter should be used.
- Symbols $W \uparrow$ etc. are already being used in the figure that should ideally be introduced earlier.
- I would make the x and y axis labels upright rather than italic.
- Figure description: I would say "The arrows indicate whether the sensor ..."

- The positions possible at a given observatory: "The sensor orientations at which one should measure at a given observatory should be . . . "
- Note the different ϕ values: this cannot be seen easily from the figures.

4.4 Section 2.2

- Line 4: I would say something like "Calculating declination D and inclination I from the conversional scheme is don by simply calculating mean values"
- I lack a gentler introduction to the variables and symbols being used in these equations. Some are not even defined/introduced or are introduced too late when the user has already lost focus and needs to come back.
- Page 4, line 3: Start the sentence with the names rather than parenthesis.
- Line 4: The sentence "In practice though ..." is suboptimal. We do repeated measurements all the time, they have to be done. You probably wanted to say that the entire measurement set is discarded along with the good readings?
- Line 5: **a** good reason

4.4.1 Typography

- Use `$\sin(x)$` and `$\cos(x)$` rather than `$sin(x)$` and `$cos(x)$` to get "$\sin(x)$" and "$\cos(x)$" rather than "$sin(x)$" and "$cos(x)$".
- Non-mathematical subscripts should not be typeset in math mode, use `\textnormal` to get $S_{\text{reading},i}$ rather than $S_{reading,i}$. Same is true for "$apriori$", "S_{off}" (use S_{off}), . . . (and blame the designer of this stylesheet for not matching the sizes of text and math to make even this look super ugly :)

- Degree sign in Eq. 1 and 2 should be in superscript.

4.5 Section 3

- Lines 9, 10: use symbols (D, I, S, δ, ϵ) next to descriptions
- Line 12: The general method described below allows evaluation of
- Line 13: even less **measurements** are possible
- Line 16: I would move "using the new method" at the end of the sentence

4.6 Section 3.1

- Line 20: allow calculating
- Eq. 3: I find it a bit confusing that you once use $f()$ with and once without S_{off}. But in any case I have troubles understanding how $c \cdot F \cdot f(\ldots, S_{\text{off}}) = \ldots + S_{\text{off}}$: what happens when $c = -1$ and why would F influence the final S_{off}? I believe that S_{off} should be strictly out of function f from the start.
- Please look at typographical notes for previous equations and reduce the spacing after $F\cdot$.
- Page 5, line 1: I would put "$c = 1$ if $S > 0$ when the telescope is pointing towards North" in parenthesis
- Line 2: S should be in math mode.
- Eq. 4: Shouldn't it be ΔD_i rather than just ΔD (same for I)?

- Line 12: what role does the word "respectively" play? (It's at a strange location anyway.)
- Eq. 6: you never defined f_i nor F_i. What exactly is $f_i(\mathbf{p}, \phi, \xi)$ and why not perhaps $f(\mathbf{p}, \phi_i, \xi_i)$? How do you get from f_i to partial derivatives of F_i and what is F_i? You used ΔD_i here, but not in the second line of Eq. 4 and 5.
- Line 20: Ideally are ...: weird sentence. Perhaps "Ideally we would have $r_i = 0$ for each measurement i."
- Line 21: the number . . . exceed**s**
- Line 22: **the** least square
- Eq. 7: the quantities used here are not explained or defined
- Page 6, line 2: **by** investigating
- Line 4: **the** first guess of D and I (use math mode)
- Line 6: "achieved" is not the right verb, "by" is missing
- Line 7: What exactly is a "3D pointing vector"? This reminds me of "Poynting vector" :)
- Use `\cos` and `\sin`
- Line 9: plan**e**
- Line 10: "D and I ar calculated accordingly.": it's difficult to explain what bothers me here, but I had a feeling I was supposed to know already how to do that after reaching the dot, but didn't know how. The next sentence explains how, but the flow of thoughts is broken and the last sentence is not even a standalone

sentence. You should probably at least change the dot after "accordingly" to a colon. Or do something else?

An image would help here. (It could be the same as I suggested adding to Figure 1.)

- Lines 11, 22, 24; page 7, lines 1, 2: capitalize "Equation"
- Line 15: **the** first guess
- Line 16: requires calculation of
- Line 17: known to have a quadratic convergence **which** is very fast
- Line 18: a or the? solution
- Line 20: Jacobian
- Line 21: with N **being** the number (use math mode)
- Line 24: "according" doesn't sound like the right word
- Page 7, lines 1-3: we should elaborate on this earlier
- Line 5: magnetometer**s** (plural)
- Line 8: mechanic is a noun (person who repairs machinery), use "mechanical" instead
- Line 10: is often referred to as **a** variometer
- Lines 18-17: use math mode for all: X, Z, Y, H, D, Z, use `\arcsin`, use `\left(` and `\right` for parenthesis in Eq. 11, "var" and "abs" should not be in math mode

- Eq. 11: I would remove "or D" and simply write the "is approximately" as a single equation.
- Eq.13: For me it would be less confusing to see a single equation

$$Z_{\text{abs}} = Z_B + Z_{\text{var}} = F \cdot \sin(I)$$

- Line 21: identified -> associated? not sure
- Page 8, Figure 2: mark the "x" axis with Y_{sensor} on both graphs and the "y" axis on the left.

5 Results

- Line 4: the word "according" sounds strange to me at this place.
- Use math mode for H.
- Line 9: don't put units (nT) in math mode or better: use `\mathrm`
- Line 12: **it** is worthwhile
- Lines 13, 14: not sure if dates should be in British or American style, but this format is weird.
- Line 13: each measurement **done at?** 16 positions
- Line 14: According to our explanation the problem was in . . .
- Page 9, Figure 4: "is could be": remove "is"
- Page 10, line 2: allows making DI

- Line 10: "scheme method" sounds weird
- **the** declination measurement
- The verb **note** can also mean "pay attention to". This sometimes makes it a bit non-straightforward that one has to write the values down. At least for me.
- Line 16: use math mode for D
- Line 23: At Niemegk the inclination is $I = 67.5°$.
- Line 25 (also page 11, line 3): remove a set of Set :), put parenthesis around $90° - \alpha$ and add the forgotten degree sign (also missing in many other lines)
- fix capitalization of "Set" after commas in many lines
- Line 26: finish sentence and start "Adjust" with a capital.
- fix the rest of copy-paste errors
- Line 13: magnet**ic** equator
- Lines 16-17: math mode for I, Else -> Other, closed -> close, angel -> angle, bee -> be (no mythical creatures and bee hives in the article, please :)

6 Discussion

- Line 21: We have been testing . . . **at** the Niemegk . . .
- Line 23: data is usually singular
- Line 25: **the** major advantage Line 26: **on** the same day; allows improving, allows assessing

- Line 28: remove "a" from "a problems"

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