Revision of the manuscript "Numerical Evaluation of Magnetic Absolute Measurements with Arbitrary Distributed DI-fluxgate Theodolite Positions" (gi-2017-3).

The manuscript "Numerical Evaluation of Magnetic Absolute Measurements with Arbitrary Distributed DI-fluxgate Theodolite Positions" deals with an alternative method to perform absolute measurements in geomagnetic observatories. This method is a more general one, and circumscribes the widely used 8-point scheme to a particular case of it. It takes advantage of the whole locus of perpendicular orientations of the DI-flux sensor with respect to the geomagnetic field vector, instead of restricting the observations to the meridian plane. An arbitrary number of readings corresponding to different theodolite orientations can then be introduced, which is meant to result in a higher accuracy of the target angles *D* and *I* by benefiting from a wider statistical population. The target angles are found by optimization in a least-squares sense by assuming a particular model of the instrument. Additional advantages of the method being argued by the authors are time saving and less error predisposition.

The manuscript might be useful to broaden the traditional scheme of observation, and especially for those low-latitude sites where it cannot be applied without specific (and perhaps difficult to find) and suitable (non-magnetic) theodolite accessories, but it lacks mathematical depth and conclusive arguments to support authors' theses.

From my point of view, the manuscript may be acceptable, but not before a substantial revision.

Major concerns:

- My main concern is that the presented model of the instrument is too simple: DI-flux theodolites, in general, are known to suffer from a number of drawbacks that make them imperfect instruments. The most popular ones are in fact the misalignment errors and the sensor offset, but there are others, like eccentricity of the graduated circles with respect to the rotation axes, non-orthogonality of these axes, or residual magnetizations (see, e.g., Marsal and Torta, 2007). Not accounting for them assumes that they are zero, resulting in biased values for the target angles *D* and *I*. From my point of view, the advantage of the conventional scheme is that the value of *D* is deduced from a set of 4 equations, while that of *I* is deduced from another set of 4 (virtually) *independent* equations. This allows, in practice, treating the misalignment/offset errors as independent in each set (even if we call them the same in both sets). This obviously does not guarantee that the *D* and *I* values deduced from the traditional method are the correct ones, but at least it allows for more degrees of freedom. I suggest the authors either extend their scheme to include these additional errors, or justify their simplification, but at least warn the reader that the presented method consists in a first approximation, not considering the whole complexity of real DI-flux instruments.

- If I'm not wrong, most equations have errors, showing a lack of rigor. Please, check them thoroughly:

- Eq. (1): I think the authors should subtract (or add) 180° in the r.h.s. For example, if D = 0°, one would obtain A_Eu = A_Wd = 90°, A_Ed = A_Wu = 270°, and the mean would be 180°.

- Eq. (2): a) The subscript of the last vertical reading should be N instead of S. b) The +90° serves only for the northern hemisphere; in the southern hemisphere a minus sign should be used.

- Eq. (3): Replace the occurrences of $\phi + \epsilon$ with $\xi + \epsilon$.

- Eq. (4): I think the factor cF is lost in the terms of the partial derivatives. The authors should also say that the partial derivatives are to be evaluated in D_0, I_0.

- Last line of eq. (6): What is F_i in the numerator of the partial derivatives? I think cFf_i should be used instead.

- Eq. (9): I'm not sure this expression is correct. Indeed, the authors are not using the vector S_i defined in eq. (6). I think the correct formula is $\mathbf{J}(\mathbf{p})\Delta\mathbf{p} - \left(\mathbf{S} - \mathbf{f}(\mathbf{p})\right) = \mathbf{r}$.

- Eq. (10): Again, I think the correct formula is $\Delta\mathbf{p} = \left(\mathbf{J}(\mathbf{p})^{\mathbf{T}}\,\mathbf{J}(\mathbf{p})\right)^{-\mathbf{1}}\mathbf{J}(\mathbf{p})^{\mathbf{T}}\left(\mathbf{S} - \mathbf{f}(\mathbf{p})\right)$.

Reference:

Marsal, S. and J.M. Torta (2007), An evaluation of the uncertainty associated with the measurement of the geomagnetic field with a D/I fluxgate theodolite, Measurement Science & Technology, 18, 2143-2156.

Minor points:

- English is not at the expected level. Please, revise it thoroughly. In the title, for example, I think the word "arbitrary" is an adjective rather than an adverb, so it should be replaced with "arbitrari**ly**". Also, punctuation is poor throughout the manuscript: commas, for example, are used where they should not, and are no longer used where they should. All these facts make it difficult reading through the manuscript.

- The title confused me the first time I read it. 'Position' for me can be understood as 'location', so I expected an article dealing with an ensemble of theodolites arbitrarily distributed. What about "reading positions", "orientations", "attitudes", "alignments", …? I would suggest the authors to ask a native English speaker.

- The abstract should be substantially reduced. Only information that is crucial for an overview of the article subject should be kept. Please, pass most of the abstract information to the Introduction and arrange it properly.

- Line 3: I think this not only applies to three-axis magnetometers, but also to others (like the dIdD coils) having 2 axes. What about using 'variometers' in general?

- Line 7: **nearly** parallel.

- Line 10: The use of the term "instrument parameters" sounds somewhat optimistic to me, especially when these parameters are said to be canceled out. Such "parameters" are usually

known as “errors” in the common language. As an intermediate solution, I suggest saying: “intrinsic errors (hereafter referred to as *instrument parameters*)”.

- Line 11: The authors use the word “measurement” throughout, but I think they should define this term, as it is too generic in this case: is it a single orientation of the theodolite, or the whole set of them? I think the authors refer to *measurements* as *reading positions* or *alignments* of the theodolite.
- Line 12: Replace “theodolite positions” with “orientation”.
- Line 17: Shouldn’t it be ‘D **and** I base values’?
- Line 27: I agree that the new procedure may be somewhat faster, but I guess not so much as the authors would like to suggest. They may save the time of computing the means for the magnetic meridian (1 minute or less for a skilled operator) and aligning the telescope exactly in the horizontal (meridian) position in the *D* (*I*) part, but in contrast, they must write down the angles corresponding to the vertical circle in each step of the *D* part (while they are known to be 90° 00’ 00’’ and 270° 00’ 00’’ in the conventional scheme), and the angles of the horizontal circle in each step of the *I* part (while they are known to be in the magnetic meridian in the traditional scheme). Can authors give a notion on how much faster is this procedure as compared to the conventional one?
- Line 28: As before, authors should give solid arguments to convince readers on the convenience of using this method. Please, compare the uncertainty that will be reached with this scheme to that of the traditional one.
- Combine sections 2.1 and 2.2 into one single section (so there are no sub-sections in Section 2). After that, try to arrange all the content in a more logical order. For example, the first paragraph is OK where it is; secondly, present the equations and define all the different variables; thirdly, put the current 2nd paragraph; then introduce Figure 1 in the text body (it should be clear what is it aimed at) and show it. The last paragraph in current section 2.2 is also OK where it is.
- First paragraph in section 2.1: Measurements are not necessarily done in this order: Eu, Wu, Ed, Wd, Nu, Sd, Nd, Su. If authors think this way of explaining allows being more precise, please say that this is an example of procedure, but that measurements can indeed be made in any order (provided that *D* measurements are made first).
- Lines 26-27 in section 2.1: to ease reading, mark the two referred advantages as a) and b).
- Eq. (1): the notation $i = 1 \ldots 4$ (as in eq. (8)) is normally used instead of $\in$. The same applies to the line above and eq. (2).
- Line 11 of section 2.2: Say that all the angles above are expressed in degrees.
- Line 13 of section 3.1.3: I think authors should put the subscript 0 in *D* and *I*.
- Eq. (7): Would it be suitable to introduce an equivalent additional equation for S_{off}?
- Line 20: Jacobi**a**n.
- In eq. (10), include an additional equation to calculate the error or uncertainty associated with the parameters in $\Delta\mathbf{p}$ according to the proposed method. I think the authors refer to

these error bars later in the caption of Figure 3 and in the Discussion, but the manuscript does not show how to calculate them.

- Line 5 of section 3.1.6: Again, why do the authors refer only to three-axis magnetometers?
- Line 20 in 3.1.6: I think it is a better practice to refer to *D*[nT] as the *E* component. See, e.g., https://www.ngdc.noaa.gov/IAGA/vdat/IAGA2002/iaga2002format.html.
- Eq. (13): include an equivalent equation for D_B (or rather E_B, see previous point).
- The Results section is presented before showing the details of the suggested procedure, which is not done until section 4.2 (almost at the end of the manuscript). This prevents the reader from judging the results, as he/she has not yet formed a concrete idea of the new scheme. I recommend placing the current sub-section 4.2 at least before 3.1.6.
- Line 6 of section 4, and line 26 in the Discussion: Could the method integrate measurements made in different days? If so, how many days can it integrate?
- Figure 3: It is not clear to me what is represented in the abscissa of Figures 3a and 4a. Is it S_i of eq. (6)? Please, explain in the text body what is exactly represented in each figure, and summarize it in the figure captions. Also, make axes labels greater.
- Last sentence in caption of Figure 4: Is the stated conclusion reached by interpretation of the green dots? (By the way, you would probably get the same effect with an eccentric vertical axis). If yes, state it; if not, what is the utility of the green dots?
- Line 5 of section 4.2: After struggling myself to understand what do authors mean by this sentence (and an equivalent one in the Abstract), I think I finally got it. However, I think "leveling" applies to surfaces, rather than lines (the telescope line, in this case). I would suggest saying that "the method tolerates imperfect alignment of the telescope with the horizontal".
- Paragraph starting in line 13 of section 4.2: Avoid repeating what has been sated in item 2) above.
- First line of section 4.2.1: "**In areas of the globe with a small** geomagnetic inclination, **i.e., typically** within …"