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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "How much solar wind data are sufficient for accurate fluxgate magnetometer offset determinations?" *by* Ferdinand Plaschke

Anonymous Referee #1

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General Comments

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This paper represents an interesting new statistical approach to determining how much data is required to calibrate a fluxgate magnetometer in the solar wind, leveraging the highly accurate data set available from MMS. The paper is well presented, and the methods used to create the results are appropriate and accurately described. Some additional details may help the reader understand both the instrumental and geophysical implications of the results. I question whether the conclusions of this paper might be altered slightly after a more careful assessment of the effect of the accuracy of the

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MMS data on the results. I hope this might be accomplished simply, by showing and discussing how the spin axis components and the spin plane components contribute individually to what is currently presented as "the upper limit estimate of the uncertainty in offset determination in any component".

Specific Comments

Page 3, lines 1-6:

I read the accuracy goal for MMS magnetic field measurements as a *relative* accuracy goal among the 4 spacecraft that comprise the tetrahedron (Torbert et al, 2016a), rather than an *absolute* accuracy goal, as stated here. In particular, AFG/DFG comparison ensures only relative accuracy, while the EDI comparison only claims to provide accurate FGM calibrations to 0.1 nT at best (Plaschke et al., 2014).

Furthermore, it is known that the MMS calibration accounts for temperature fluctuations on the spin-plane sensors on the order of +/- 0.2 nT, even on orbits with minimal temperature variations. It is likely that similar fluctuations exist on the spin axis component, although these offset variations are only corrected in the spin plane. Note that the temperature-dependent variations are effectively DC offsets at the 1-minute time scale (Bromund,et al., 2016). So I hesitate to agree that "additional offsets derived from these data should ideally vanish", except perhaps in the spin plane (see discusion of Page 4, line 1).

Page 3, line 12:

It is also important to note that the DMPA coordinate system is "Near GSE". Specifically, the spacecraft-sun vector is nearly aligned with the x-direction.

Page 4, line 1:

Regarding the choice of one-minute intervals, it is important to point out that corre-

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sponds to ∼3 complete spin periods of MMS (Tooley et al., 2015). This is significant, because the known, ∼0.1 nT inaccuracies in the spin-plane components are manifest in DMPA coordinates as oscillations at the spin period in Bx and By, and thus will average out over each 1-minute interval. The level of attenuation would be a factor of 10 or more (depending on the exact spin period). At the same time, any DC offset on the spin axis would remain unattenuated. Thus, I would expect that the offsets derived on 1-minute intervals from the MMS data should ideally vanish to the level of 0.01 nT or less in the spin plane, while they might be as large as 0.2 nT on the spin axis.

Page 4, lines 2-3

"vector estimates O are determined by minimization of the standard deviation of |B−O|". It would be helpful to mention that this is the Davis-Smith method, given that a few distinct methods were cited on Page 2, line 3 (Belcher, 1973; Hedgecock, 1975; Leinweber et al., 2008).

Page 4, lines 14-15

"Apparently, magnetic field fluctuations in Bx are slightly weaker than in the other components, so that Nx < Ny < Nz " Could this be a natural consequence of the fact that the Bx component in the DMPA system is closely aligned with the radial direction to the sun (see above note to page 3, line 12), and that the fluctuations of the solar wind are predominantly transverse to the radial (Belcher, 1973)?

Figure 3:

I would plot a vertical line at sigma_c = 0.15 nT to further emphasize that this represents the optimal choice for sigma_c, and to better illustrate the relationship between Figure 3 and Figure 5.

Page 6, lines 6-7:

It is interesting that further increase in sigma_c beyond 0.15 nT does not result in improved accuracy. The fact that this result is so close to the expected MMS FGM

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accuracy makes we wonder if this result is a function of the MMS FGM accuracy itself, or if it is inherent to the solar wind calibration process that is under evaluation. Some discussion would be helpful.

Page 8, line 2-5:

The conclusion that the results presented in Table 1 or Figure 5 are not MMS specific is not fully supported by the present analysis. Even if the absolute accuracy of the MMS data is always better than 0.1 nT as stated in this paper, this is a significant fraction of the best values of O_max,c at 0.12 nT, thus the flattening of the curve in Figure 5 at larger values of W may be due to the inherent inaccuracy of the MMS data.

Furthermore, as noted above, the spin axis likely includes temperature-dependent offset variations that are not corrected, thus I would expect O_max,c might be as large as a few hundred pT due to these effects alone, when calculated on a small number of intervals, W. These fluctuations would naturally average out as W increases, resulting in a trend that is similar to what we see in Figure 5, again calling to question the degree to which the results in Figure 5 are not MMS specific.

Inaccuracies due to the limitations of the solar wind calibration technique itself might tend to be larger in the spin plane, which includes the radial direction from the sun (Belcher, 1973). At the same time, inaccuracies in the MMS data would tend to manifest much more significantly in the spin axis. Thus, I believe it would be very useful to show the degree to which O_max,c is influenced by the spin axis and spin plane components separately. If the results of this additional analysis show that O_max,c is dominated by the spin plane components (Bx in particular), then I would be more confident that the results are not MMS specific.

Technical Corrections

Page 2, line 27-28 the wording "the MMS spacecraft carry most advanced instruments"

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is a bit awkward and vague...

Page 2, line 30-31 minor edit: replace "Each spacecraft is equipped with two magnetometers" with "Each spacecraft is equipped with two fluxgate magnetometers"

Additional References

C.R. Tooley, et al., The MMS observatory. Space Science Rev., 2015

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