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Comment on angeo-2022-4

Anonymous Referee #1

Referee comment on "The time derivative of the geomagnetic field has a short memory" by Mirjam Kellinsalmi et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2022-4-RC1, 2022

General Comments

This manuscript extends several previous studies by the FMI group of the geomagnetic perturbations that can cause geomagnetically induced currents, using multi-year observations from the IMAGE magnetometer network. An extension of previous analyses involves distinguishing internal and external parts of the observed vector magnetic field for events exceeding a |dH/dt| threshold of 1 nT/s (later extended to 0.5 nT/s) and analyzing separately both their amplitude and direction of their perturbations and that of their derivatives. As might be expected, the angular distributions of both the perturbations and their derivatives are larger for the internal part of the vector magnetic field, because of inhomogeneities in the underlying or regional conductivity at different stations. The main new result claimed is the large and quickly reached (~2 min) asymptotic value of the standard deviation of the time-averaged angle of dH/dt. However, no specific interpretation or mechanism for this result is provided.

The “main new result” of this paper, that the direction of the geomagnetic field time derivative has a very short “reset time,” was anticipated by Belakhovsky et al. (2018), as the authors note, but also in significant detail in a recent study of similar events in Arctic Canada by Weygand et al. (2021).

Weygand, J. M., Engebretson, M. J., Pilipenko, V. A., Steinmetz, E. S., Moldwin, M. B., Connors, M. G., et al. (2021). SECS analysis of nighttime magnetic perturbation events observed in Arctic Canada. *Journal of Geophysical Research: Space Physics*, *126*, e2021JA029839. https://doi.org/10.1029/2021JA029839

Specific Comments

- Line 150: The text incorrectly states that "Figures 10 and 11 show Δθ" but these figures and their captions make it clear that what is shown is the standard deviation of Δθ, not Δθ .
- Lines 152-153: Given the above confusion between Δθ and the standard deviation of Δθ, it is not clear to this reviewer whether or not "standard deviation" belongs in this sentence. It is also not clear what is meant by their "mean values" yielding similar results. Over what variable and range are these mean values (Δθ or std (Δθ)) calculated?
- Lines 185-186: The westward electrojet also produces southward magnetic field perturbations before magnetic midnight. See, for example, Table 3 of the SECS analysis of large (>6 nT/s) pre- and post-midnight magnetic field perturbations reported by Weygand et al. (2021).
- Lines 215-218: The time scale of 80 s to 100 s for the behavior of dH/dt is clear in the Pulkkinen et al. (2006) paper, but is asserted without any specific documentation or quantification as being a result of the analysis presented in this paper. This statement needs to either be adequately justified or removed.
- Lines 217-218: The manuscript does not provide any explanation for this time scale, other than that "The size, motion, and lifetime of the dH/dt structures may contribute to the observed time scale." The Weygand et al. (2021) paper provides detailed information at higher time resolution than provided in this study that may be helpful in developing such an explanation.

Figure 2 of Weygand et al. shows a histogram of the duration of all dB/dt derivative amplitudes above 6 nT/s observed at two Canadian stations during 2015. The peak of the distribution of the durations of derivative amplitudes |dB/dt| ≥ 6 nT/s, which are different from the duration of the magnetic perturbations (ΔB), was between 10 and 15 s, but the range was between a few seconds (most common for MPEs with peaks only slightly above 6 nT/s) up to 71 s.

This figure, based on 10x higher sampling rate data than was used in this manuscript, provides a corrective to the statement in lines 232-233 that "the amplitude of the derivative tends to decrease immediately after reaching the threshold value." The amplitude of course must increase immediately after reaching whatever threshold is used, whether 1 nT/s or 6 nT/s, if it is ever to reach a much higher value (which is often observed) but this figure quantifies the distribution of durations; it is short (not immediate) only relative to durations quantized by 10-s sampling. This rapid falloff of durations above 20 s provides a ready explanation (with a correction) for the statements in lines 230-233 and agrees with the statement on in lines 234-235 that it is rare for the derivative amplitude to remain at high values for long periods.

Weygand et al. (2021) also examined the dB/dt durations above 6 nT/s as a function of three categories of time delay Δtso after the most recent prior substorm. For Δtso ≤ 30 min category the mean duration was 19.0 ± 0.9 s, for 30 < Δtso < 60 min the duration was 17.7 ± 2.1 s, and for Δtso ≥ 60 min the mean duration was 12.8 ± 1.8 s where the uncertainty given is the error of the mean.

In addition, Weygand et al. (2021) presented several example events, combining multistation magnetometer observations with SECS analyses and in some cases auroral images, that showed that short-lived and highly localized vertical currents and associated localized ionospheric currents were associated with large perturbations and dB/dt values at individual stations. The location of these currents relative to the measuring stations determined details of the orientation of the observed magnetic perturbations and their vector derivatives as well as the extent of their duration. No issue of memory needs to be invoked.

Technical Corrections

Line 209: This line contains two minor errors. First, as in line 150, the words "standard deviation of" need to be added before "$\Delta\theta$." Second, the values "104 to 110" do not agree with the values of "105 to 109" stated in line 155 in reference to Figure 13.