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Comment on egusphere-2022-850

Mark Engebretson (Referee)

Referee comment on "Drivers of rapid geomagnetic variations at high latitudes" by Liisa Juusola et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-850-RC1, 2022

Review of Juusola et al., Drivers of rapid geomagnetic variations at high latitudes, submitted to EGUSphere, 2022

General Comments

This is a very well written study of five of the strongest geomagnetic variations observed by the IMAGE magnetometer array. It has a very good introductory review section, followed by tables showing the largest $\Delta \boldsymbol{H}$ and $|d\boldsymbol{H}/dt|$ at each of the IMAGE sites, separated into total (observed) and external and internal contributions. This is followed by a detailed analysis of five events that produced some of the most intense external $|d\boldsymbol{H}/dt|$ values. The authors provide plausible interpretations for the magnetospheric/ionospheric phenomena that drove these events, and also provide a careful discussion in section 4 of some of the limitations of this study (even though it is based on a large volume of data) and of continuing challenges to the successful prediction of intense (dangerous) $|d\boldsymbol{H}/dt|$ events. It concludes that the relevant scientific community is still far from a full understanding of the detailed physical pathway(s) leading to either modest or extreme $|d\boldsymbol{H}/dt|$ events, much less to the prediction of the time and place where these events will occur.

The content of this paper is of high quality and is certainly appropriate for publication in EGUsphere. This reviewer has only two substantive comments and four more minor comments.

Specific Comments

It is strongly suggested that throughout the paper the magnitude of the perturbations in the horizontal magnetic field that are denoted $|\boldsymbol{H}|$ should be replaced by $|\Delta\boldsymbol{H}|$. The magnitude of the total magnetic field or even its horizontal component (in a given coordinate system) is not what is physically important; it is rather the change in its value (during some appropriate time interval).

Lines 375-391: The manuscript cites a study by Viljanen et al. (2006b) that showed peaks in occurrences of large $|d\boldsymbol{H}/dt|$ events 5 minutes after both non-storm and storm-time substorm onsets at Sodankylä (63.92° MLAT) and Nurmijarvi (56.89° MLAT) during 1997 and 1999 (their Figure 3). However, there were no substorm onsets or sudden intensifications of the western electrojet during the five selected events. The authors may wish to contrast the observations of Viljanen et al. (2006b) with those of Engebretson et al. (2021), who showed in their Figure 2 plots of maximum dB/dt events (all > 6 nT/s) vs. time delay after substorm onsets for five stations in Arctic Canada during 2015 and 2017, with MLATs ranging from 75.2° to 64.7°. There was no significant peak near 5 minutes after onset at any of these stations (the distributions were relatively flat during the first 30 minutes). The distribution at each station had a gradual and extended falloff that was roughly consistent with those shown in most panels of Figure 3 of Viljanen et al. (2006b). The Engebretson et al. (2021) study also showed in panels B and C their Figure 11 that postmidnight dB/dt events that occurred greater than 30 minutes after substorm onsets at the lowest latitude station (KJPK, 64.7° MLAT) occurred during periods of gradual increases in the SML index (weakenings of the WEJ).

Engebretson, M. J., Ahmed, L. Y., Pilipenko, V. A., Steinmetz, E. S., Moldwin, M. B., Connors, M. G., et al. (2021). Superposed epoch analysis of nighttime magnetic perturbation events observed in Arctic Canada. *Journal of Geophysical Research: Space Physics*, *126*, e2021JA029465. https://doi.org/10.1029/2021JA029465

Technical Corrections

In line 185, the phrase "optimal temporal development" does not seem appropriate. "Optimal" approximates to "best," so this part of the sentence is confusing.

Figure 4 needs to be much larger in the final published paper, and some of the fine print in the figure could be moved to the figure caption. Figures 5, 6, 9, 11, 13, 14, 16, and 17 would also be easier to read if they made use of the full width of the available space on a page.

In line 285, "possible" should be changed to "possibly."

In line 375, remove “of” after “five.”