EGUsphere, referee comment RC3
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Comment on egusphere-2022-850

Anonymous Referee #3

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-RC3, 2022

A review of the manuscript entitled
"Drivers of rapid geomagnetic variations at high latitudes",
submitted to the journal EGUsphere by Liisa Juusola et al.

This is a very promising research paper. It exploits the large and comprehensive data resource that is the IMAGE archive. It employs an under-utilized, if not particularly new, analysis technique with 2-layer 2DSECS. It uses these to separate "internal" from "external" equivalent current sources driving geomagnetic disturbance at Earth's surface, and therefore to better understand the impact and scale of magnetosphere/ionosphere dynamical phenomena without worrying that "large" geomagnetic disturbances are simply due to much more localized earth conductivity structure. It is also very interesting to see how "internal" sources contribute to the interpretation of space weather phenomena, although perhaps this topic was covered in more detail by a recent paper by the same 1st author, and is only a secondary consideration in the present manuscript. Altogether, this manuscript offers a novel perspective on what influences ground magnetic disturbance the most, for the most impactful space weather events, and therefore should be published and added to the scientific literature base through EGUsphere.

That said, the presentation of this material lacks a certain focus, and is, at times, difficult to read, even for a scientist who is well-acquainted with the analysis techniques and scientific subject matter. The comments below are offered in the constructive hope that the overall clarity and readability of this research paper will be improved, and ultimately appeal to a wider and possibly more scientifically diverse audience.

These critiques/recommendations are offered in a loosely prioritized order:

- There is a considerable review of the underpinning theory in the Introduction. It ends with an overly brief statement of the question being asked/answered, and it is not

especially clear how this relates to the material presented prior to that.
  - most of the theory could be migrated into a more fleshed out Section 2.2, including Figures 1 and 2;
  - the introduction could then more clearly and succinctly articulate the motivation behind this study, possibly hinting at the more comprehensive explanation of techniques coming up later.
- There are too many figures (18!), and many figures include multiple labeled panels, sometimes up to the letter "l" (i.e., 12 panels!). This alone is very distracting, but the real problem is that it is not obvious that all the panels are discussed in the body of the manuscript. The authors should reconsider whether all these are necessary, and if so, could some be migrated to supplementary material. If the authors choose to keep most or all figures, they should make almost all of them larger, probably full-page.
- There are too many inline mathematical relationships. The authors should consider changing some of these to numbered equations that are visually separated from the main text, then cross-referenced when needed.
- Similarly, there are too many statistics and other data presented inline that would be more clearly presented in numbered, tables, then cross-referenced when needed.

(some specific comments and questions that should be addressed)

- Authors should expand on, or cite specific literature that justifies, the statement in the Introduction: "The down component (Bz) cannot be included in the fitting, because it cannot be represented in terms of ionospheric equivalent currents only".
- Authors should explain, or cite relevant literature justifying, why the internal 2DSECS was defined at only 1m depth? This certainly deviates from much of the previous literature (e.g., Pulkkinen et al., 2003 – EPS), and it seems likely to bias results toward nearby geomagnetic measurements.
- The authors should explain better how the results presented in Figures 7 and 8, and related discussion about the data's time resolution, tie into discussion of internal and external sources, and localization of |*dH/dt*|. Frankly, while this is an important point, it seems like a topic for a different paper.
- All references to the supplemental animations/movies should make it clear that these are supplemental material. If they could by hyperlinked, even better, at least for the online version of this manuscript.

(typos, grammatical errors, and ambiguities I noticed)

- Line 43 – "in order to be able to produce--d-- the highly structured…"
- Line 73 – "…by solar wind perturbations, or **internally**." Clarify "internally".
- Linen 87 – "…rapid *dB/dt* spikes…" – maybe quote *dB/dt*, assuming it is taken from the cited paper, since the authors consistently use |*dH/dt*| in this manuscript.
- Line 375 – "What is noteworthy in our five --of-- events is…"