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Reply on RC1

Sebastian Käki et al.

Author comment on "Spatio-temporal development of large-scale auroral electrojet currents relative to substorm onsets" by Sebastian Käki et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-37-AC1, 2021

We thank the anonymous referee for the helpful comments, and constructive remarks. Our replies are marked with *cursive* text. The supplement includes the same reply as pdf with color coding for the replies.

Scientific comments

Line 62–68: You mention CHAMP and Swarm here as examples of spacecraft orbiting above the current sheet that can identify the current systems, but mention of AMPERE (Anderson et al., 2000, 2002, 2014, 2018; Waters et al., 2001, 2004, 2020; Coxon, Milan and Anderson, 2018) might also be warranted in that context.

We will include a mention of AMPERE as it is indeed well warranted here.

Line 93–96: "only the largest areas in amplitude are defined as electrojets" – this is sensible, but the authors don't explain how this is done; an explanation of the selection criteria should be included to aid reproducibility.

We will include a small explanation of the method that is used in Swarm AEBS.

Line 104–109: The authors choose a separation of two hours as a method for interpreting the times between onsets as a "quieter baseline" than the times closer to the onsets. I have two comments here:

1. When discussing substorm recurrence and similar, the recurrence timescale is around 2.5 hours in a chain of substorms during sustained solar wind driving (Freeman and Morley, 2004). This means that using a criterion of under 2.5 hours means that periods which are during enhanced/sustained driving will be selected for analysis. This appears to be at odds with the desire for a quieter baseline, and is potentially a valid approach but which should be discussed here in the context of Freeman and Morley.

We plan to run the analysis again with the 2.5 hours limit and discuss this choice of limit in the context of Freeman and Morley, 2004. It is not expected that the results will change much.

2. The authors reference Forsyth et al. (2015) earlier in the manuscript and this dataset would provide a perfect way to disambiguate quiet interludes from sustained driving if the authors decide to do so. The SOPHIE technique described in that paper allows for expansion phases preceded by quiet times to be identified separately to expansion phases preceded by recovery phases, and if the authors decide to move away from two hour criterion in light of the potential contamination from periods of sustained driving, this would be a good method to capture the original motivation.

We agree that the SOPHIE technique would be capable of capturing quiet interludes. We believe that the 2- or 2.5-hour limit in the SuperMAG list is on its own enough to capture the intention to describe the statistical behavior of the electrojets after a quieter period. We think this is supported by the data as there is no clear evolution of the statistical values before the onset.

Line 132–133: While it may be true that the coordinate disparity is not the largest source

of error, eliminating the sources of error which are within the control of the authors is a necessary step in conducting scientific analyses. As such, I would ask the authors to present the SuperMAG data in QD coordinates in their next submission.

We will redo the analysis and use QD coordinates also for the SuperMAG data.

Line 142–143: "…we observe the dawn and dusk electrojets dominating the lower right portion of the panel (a) and lower left portion of panel (b), i.e. the pre-onset parts of sectors W1 and E1 respectively. A decrease (i.e. a strengthening in amplitude) in the WEJ median after the onset is clearly visible in sectors W1 and W2." I might be misinterpreting what the authors mean here, but I don't see this. The dominant portions of the panels appear to be toward the upper halves, not toward the lower half.

The intent was to indicate the trace of the electrojets in the plots before the onset. We will reword the expression to be clearer.

Line 143–144: "A decrease (i.e. a strengthening in amplitude) in the WEJ median after the onset is clearly visible in sectors W1 and W2." I don't understand how the strengthening in amplitude of the median is a decrease in the median. It looks to me like the current in the electrojets increases after onset from the plotted figure, and I am confused by the authors' interpretation here. It also seems to be at odds with the next sentence, on lines 144–147, in which it says that the current increases after onset.

As we have retained the sign in the median integrated values and the WEJ value is always negative. Therefore, more negative values and decreasing median correspond to stronger electrojets. We agree that the meaning of increase of current is ambiguous in this context, and we will reword the sentence.

Line 147–149: "The most remarkable feature in panel (b) is the strengthening of the eastward current median values in sector E2 after the onset. The values are roughly doubled in this sector and the intensification seems to reach the maximum eastward extent only after 15...30 min after the onset." It seems to me that the disparity of

the colour scale between before/after onset is similar between E1 and E2, and so I'm not sure I agree that E2 is the most remarkable feature. I'd consider plotting these as percentage differences from the onset value (perhaps as Figures 4c and 4d) so that it's easier to compare the relative strengths pre- and post-onset.

We can plot the percentage differences and take a closer look.

Figure 5–6: Instead of plotting quantities in units of 10^5 A, you might want to plot them in kA because you spend a lot of time discussing the units in kA. Mentally converting back and forth between the text and figures makes it more difficult for the reader to follow. Additionally, I would recommend plotting the locations of W1 and W2/E1 and E2 on the axes, which would also make the text easier to follow.

We will change the unit to kA and plot the location of the sectors on the axis.

Figure 7–8: I found it difficult to interpret what these graphs were showing. I initially assumed that the north/south WEJ were referring to the WEJ in the Northern and Southern Hemispheres observed by Swarm, but after some thought, I instead assumed that WEJ peak must be the peak of the WEJ, and that the WEJ north/south must be the northmost and southmost reach of the electrojet in the Northern Hemisphere.
It wasn't until seeing Figure 10 that I was confident of this interpretation. The north and south traces are not discussed in the text nor in the caption, but they do have some interesting implications for the shape of the electrojet and how that evolves over time, so I would recommend going into more detail on what this graph shows. I'd also recommend using "poleward" and "equatorward" instead of "north" and "south", since the former terms are much less likely to be misinterpreted.

We will change north and south to poleward and equatorward and add discussion of the plot within the limits of uncertainty provided by the SECS resolution.

Figure 10: Again, the larger spread on the dawn side than on the dusk side is interesting; it would be worth going into detail on this feature in the manuscript.

We agree with the referee that spreading in the dawn sector deserves some additional discussion in the paper. We believe the western jet has a larger extent in the north south direction in the dawn sector as the westward jet is naturally more established in this region. Our hypothesis is that signs of the Harang discontinuity can be seen in the dusk sector.

Line 195: Why use the 75% confidence interval? This seems low to me: is there a reason for this?

The confidence interval was chosen to present a coarse indicator of the uncertainty of the calculated values. We don't expect a larger value to change the interpretation, but we can choose a larger % confidence interval also.

Line 223–225: Coxon et al. (2017) looked further at the spatiotemporal development of substorms in AMPERE and found further evidence for the timescale here, but also found that the onset latitude was colocated with the R1/R2 field aligned current interface, which may be an interesting point of comparison to your finding that the peak WEJ coincides with the 0° line in QD coordinates (also relevant at lines 251–252).

This is an interesting point, and we will add discussion of this to the paper.

Line 231–234: To better make the link between W1, W2, and the substorm morphology described I would recommend including a schematic diagram which illustrates the proposed spacecraft passes and links them to Figure 5/7/9 to show how the results are what you would expect from passes through those currents.

We believe Figure 9 shows schematically the morphology and amplitudes. We also believe the addition of the sectors W1 and W2 in all the applicable figures will also illustrate this

link.

Line 245–250: How do you differentiate between a well-defined large-scale jet which moves in time, and a set of variable substructures which are poorly defined but do not move in time? I would argue that the R1/R2 current systems are well-defined, but because they move in latitude with the expansion and contraction of the polar cap an initial reading of this passage makes me think they would be considered disorganised/badly defined, which seems incongruous to me.

This is true and we plan to adjust the paragraph to take the view into account.

Line 255–257: It would be good to compare randomly selected SML values and the westward DF current, i.e. to repeat the analysis without the substorm consideration. Naïvely, I would have expected the correspondence to be high at all times and not just during substorm times.

We agree with the referee and we can investigate this.

Lines 269–280: It would be nice to see discussion here of the fact that the EEJ is less well-organised in the paradigm you're discussing and why that is.

We can add further discussion to the manuscript. We believe the ultimate reason is that the SML probes the westward electrojet by nature and choosing the origin of the coordinate system according to this index will thus lead to better organization of the WEJ data.

Typographical errors

In general in English style, "1...5" is not the style used to indicate a range; these should be replaced with "1–5" throughout.

We will check the indications of ranges in the text. While en dashes are mentioned in the English guidelines and house standards of the Copernicus manuscript preparation manual, there is also a point in the Mathematical notation section where it told that "A range of numbers should be specified as "a to b" or "a...b". The expression "a–b" is only acceptable in cases where no confusion with "a minus b" is possible."

Line 115: "close the poles" should be "close to the poles".

Figure 3: "(b) (corresponding to panel (a) in Fig. 4)" should be "(b) (corresponding to panel (b) in Fig. 4)".

Figure 8: "coveredby" in the caption needs a space.

Line 234: "over the part of SCW" should be "over the part of the SCW".

We will fix the typographical errors.

Please also note the supplement to this comment:
https://angeo.copernicus.org/preprints/angeo-2021-37/angeo-2021-37-AC1-supplement.pdf