

Interactive comment on “Multiscale estimation of the field-aligned current density” by Costel Bunescu et al.

Anonymous Referee #2

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The authors describe a technique which aims to disentangle the characteristics of FACs present in the auroral region at multiple scales. The scheme is a development of earlier work by Bunescu et al. (2015) and uses analysis of pre-processed magnetic field data with sliding windows at multiple scales to conduct analysis on observed disturbances in the time domain, using MVA to calculate characteristics such as current sheet orientation and to ultimately identify the relative contributions of various scales to make up a FAC system. The system is tested first on simple simulated FACs and then on real data observed using the Swarm satellite mission.

General Comments

The system performs remarkably well when tested on simulated data and I believe that the development path is a promising one – in particular the time domain nature

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of the method promises the potential of improved accuracy vs. frequency domain approaches. However when operating in the time domain, it is vitally important to somehow separate signals at various scales e.g. by zero-phase band-pass filtering. At the very least this direction should be explored and the results reported on. As things stand and as evident in Figures 1 and 2, even when running the system on simple test inputs, without appropriately suppressing large scales, small-scale parameters such as variance, dB etc. will be dominated by whatever is happening at those large scales. This is evidenced by the large error in calculated FAC in Figure 1 as the authors themselves admit to on page 11 lines 11-12 of the manuscript. When real data with multiple scales is analysed (e.g. Figure 5) the FAC contributions at various scales appear to bleed into each other to such a degree that disentangling the contributions from various scales becomes very difficult.

The authors attempt to correct for this as far as FAC density calculations are concerned by using weighting factors. In my opinion this can be potentially dangerous as then there is a risk of pre-supposing assumptions. Ultimately, we still do not know which scales are relatively the most important – this is what the methodology is designed to find out. By forcing weightings on scales there is a risk of the method presupposing its own conclusions. It is true that with the weighting factors the system does a good job of reconstructing the observed time series – however the aim is not to reconstruct the time series but to decompose them in a way that reflects the truth.

I would thus recommend a revision of the manuscript where some way of separating the scales, perhaps by selective zero-phase band-pass filtering, is carried out with the results reported on. I believe that simple additions such as these may greatly improve the system's capacity and look forward to seeing the results of the developments.

Specific comments:

Page 2 lines 3-4 “median of the scale distribution around 230 m in the range of fine and small scale auroral arcs (10 m – 1 km).” – please specify where the 10 m to 1

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km numbers are from, since they do not appear to be present in the reference (the minimum scale in the reference is 70 m).

Page 2 line 7 “large sampling frequency difference, maximum at about ~ 25 Hz for TV and ~ 0.3 Hz for ASI” – for clarification it would be sensible to add something to the effect of “as any arcs which did not exhibit quasi-stationarity at the exposure timescales would likely have had their optical signals smeared and integrated to appear as larger-scale structures”.

Page 2 lines 12-13 “Overall, the results of all these studies indicate a rather continuous scale spectrum” it may be better to write “Overall, the results of all these studies together indicate a rather continuous scale spectrum” since some of the individual studies alone certainly do not seem to indicate that!

Page 2 lines 23-24 “Karlsson and Marklund (1996) found a median scale of about 4.6 km for the diverging electric fields observed by Freja” – please specify where the referenced paper mentions that number, since I am unfortunately unable to find it

Page 4 lines 1-2 “Gillies et al. (2015) pointed out that the single-spacecraft FAC density provides better identification of the boundaries of auroral patches.” – Is this “better” as compared to the dual-spacecraft FAC density? Please specify. As I understand this paragraph advocates for the need to analyse multiple scales including small scales which may not be well-captured by the dual-spacecraft method or indeed by the 1 Hz single-spacecraft FAC product. In this context a valuable reference to add would be Miles et al. (2018) who studied an intense discrete auroral arc crossing observed by Swarm and e-POP, the paper vividly demonstrates the limitations of both the dual spacecraft FAC density product and the small-tilt assumption when analyzing small-scale auroral structures.

Page 5 lines 26-27 the authors state the Equation (3) was used for many single-spacecraft missions but then proceed to give only 1 reference (to Freja data). Please either amend the wording (e.g. “Equation (3) was used successfully to obtain partial

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estimates of the FAC density for some single-spacecraft missions”) or else add more references to where the single-spacecraft product was used (e.g. Swarm).

Page 5 line 21 “Thus, the cross-track separation defines the lower limit of the FAC scales” – authors should specify that the lower scale limit is in the cross-track direction. The scale limit in the along-track direction is determined by the inter-spacecraft along-track separation and the degree of quasi-stationarity of those FACs.

Page 15 lines 5-6 (also Figure 4) – the origin of the time shift is explained fine but it is visually difficult to compare the two results with the time shift in place. I would recommend factoring it out so that the two estimates are overplotted directly and the differences can be more clearly seen.

Technical corrections:

Page 8 line 4 please close the 2nd bracket

Page 15 line 27 "slightly" Please replace "associated to" to "associated with" (e.g. in lines 22-23 in page 1)

Figures:

Please label the plots in the figures (a1, b1 etc. . . are described in the figure captions but are not actually labelled by the sides of the plots). In Figures 1, 2, 5, 9 and 13 planarity (on the y-axis) appears to be mis-labelled as ‘scale’ in the plots.

References

Miles, D. M., Mann, I. R., Pakhotin, I. P., Burchill, J. K., Howarth, A. D., Knudsen, D. J., . . . Yau, A. W. (2018). Alfvénic dynamics and fine structuring of discrete auroral arcs: Swarm and e-POP observations. *Geophysical Research Letters*, 45. <https://doi.org/10.1002/2017GL076051>

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