Reviewer's comments on ANGEO-2018-70 (revised) by Bunescu et al.

Anonymous Referee #1
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1 Summary

This manuscript applies the minimum variance analysis (MVA) to in-situ magnetic field data during auroral crossings. MVA is applied to a set of sliding windows of across the data with differing window lengths to attempt to examine the orientation, planarity and field-aligned currents at different scales. The authors have made changes following earlier comments, however these changes reveal a deficiency in this analysis which is not fully resolved.

2 Technical Comments

The tabulation of the results in Section 4.3 shows that the current estimated from the MSMVA technique is 20-160% greater than that calculated from traditional FAC calculations. The manuscript indicates that this is due to the an alignment of the current system away from east-west. The table shows that the FACs are 20-25 degrees away from the east-west direction. However, such a deviation should mean that the true FAC is 13-20% greater than the single spacecraft approximation (the single spacecraft approximation is corrected by $1/cos^2(\theta)$). As such, the orientation does not account for a deviation of 160%. This discrepancy is not discussed in sufficient detail. While the other case study shows that the technique can give comparable results for simple current sheet configurations, the point of this technique is that it is designed to examine more complex scenarios with greater accuracy.

It is true that the orientation alone cannot account for the differences between the FAC estimates. The L2 single-sc FAC product and the MSMVA analysis provide estimates of the FAC density at different resolutions, are based on a slightly different computation procedure, and address the scale aspect in a different way.

The L2 single-sc FAC density is provided at 1 s resolution and thus enables a characterization of the current at scales larger than or equal to 1 s. This estimate typically takes into account only the magnetic perturbation in the east-west component (B_y).

The MSMVA FAC density estimate is computed using the 50 Hz magnetic field perturbation and is given at a resolution of 0.1 s ($\sim$760 m) in time (x-axis in the scalograms) and 0.04 s (highest resolution scanning) in the scale (y-axis in the scalograms). This estimate is based on the magnetic field perturbation in the FAC's tangential direction (B_η).

The estimates of the current density included in the previous manuscript for the event on 15 January 2015 correspond to mesoscale FAC signatures (upward current regions labeled by U2, U3, U4). The MSMVA estimates, selected based on $\partial_\xi \lambda_\eta$, were simply compared with the instantaneous values of the L2 single- and dual-sc FAC estimates. In order to properly compare the different FAC estimates, they should be computed at approximately the same scale. Whereas the scalograms of the FAC density provide the possibility to visualize/select the local average current at a certain scale, the L2 single-sc estimate is dependent on the local magnetic field perturbations present also at smaller scales. The MSMVA FAC estimates for U2-U4 structures (Table 2) correspond to the mesoscales delimited by the vertical lines in Figures 8 and 9. The selected values of the L2 single-sc FAC density (Table 2) reflect also the embedded smaller scale perturbations (internal structure of U2-U4 regions).

In order to clarify the differences we estimated the average L2 single-sc FAC density by using a boxcar running average (12 s width) over the L2 single-sc estimate. The 12 s window corresponds to the thickness of the U2-U4 FACs. Thus, we updated Table 2 by including a comparison of MSMVA estimates with this average estimate and shortly commented in the text about it and its relative percentage deviation with respect to MSMVA. We also slightly adjusted some of the MSMVA FAC estimates (see Table 2 and the text in section 4.3). To increase the visibility of smaller scale FACs we also updated Figure 9: the scalograms of $\partial_w \lambda_\eta$ and $j_\parallel$ for the linear and log scanning are now represented using a logarithmic color scale, similar to the last Swarm event (2014-09-27).

Figure 1 (this response) shows SwA magnetic field perturbation and the L2 single- and dual-sc FAC estimates. The vertical solid lines delimit the U2-U4 FACs. We notice that most of the mesoscale FACs (including U2 and U4) have an internal structure. For both U2 and U4 regions we have embedded perturbations visible through the slope change of $\Delta \boldsymbol{B}$ inside the respective intervals (panel-1). Panel-2 shows the L2 single-sc FAC (green), the L2 dual-sc product (black), and the average L2 single-sc FAC density (red) estimated by using the 12 s boxcar average window on the L2 single-sc FAC density. The internal structure provides distinct peaks in the L2 single-sc FAC product which are not visible in the average and the dual-sc current estimates. The comparison of the MSMVA FAC density with the average L2 single-sc current shows a significant decrease in the relative percentage differences (Table 2). A further inclusion of the orientation in the L2 single-sc product would probably lead to an even better agreement with the MSMVA result.

This example suggests that MSMVA can be indeed useful also for complex FAC signatures.

3 Suggestions for improvements

It may be useful to the reader if the manuscript included a step-by-step as to how the FAC scalograms are intended to be used and what information can be obtained/not obtained from them at each step. This could appear at the start of the Discussion and Summary section.

Section 6, Conclusions and outlook, was updated as suggested (second paragraph).

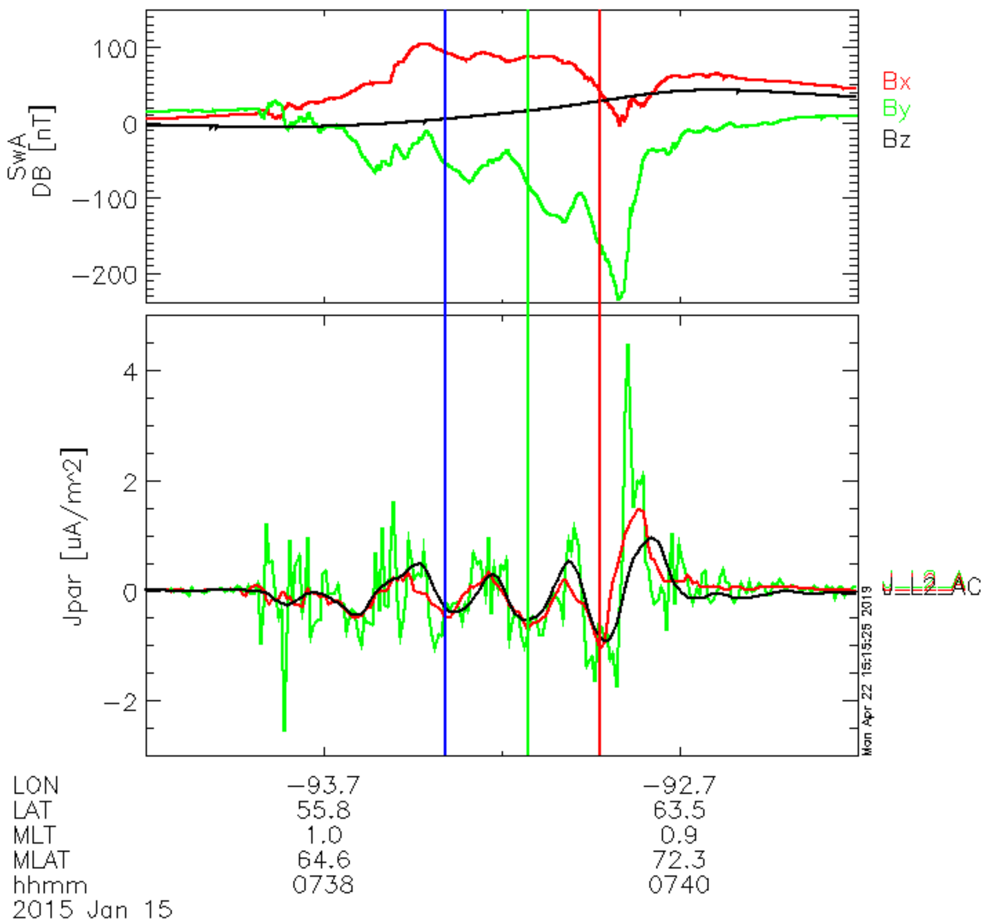

Figure 1. Upper panel: $\Delta\boldsymbol{B}$ from SwA. Bottom panel: FAC density estimates, L2 single-s/c (green), L2 dual-s/c (black), average L2 single-s/c (red).