Responses to the comments of Reviewer #1 on: “Properties of large-amplitude kilometer-scale field-aligned currents at auroral latitudes, as derived from Swarm satellites,” by Zhou and Lühr

We are very thankful to this reviewer (Bill Lotko) for his very positive rating of the manuscript. Furthermore, his very constructive comments and suggestions helped a lot to improve the quality of the manuscript and to make it clearer for the readers.

Below, we have repeated the comments and added our responses in blue text. In the revised manuscript the main changes are marked by bold text.

This study takes a major step in advancing knowledge of small-scale field-aligned currents (FAC) found at cusp and auroral latitudes with variations on 0.04 to 5 second time scales or 0.3-20 km spatial scales. The results are based on high-resolution, fluxgate magnetometer measurements from a special, two-week campaign in which the SWARM A and C satellites maintain separations of < 2.5 km cross-track and about 2 seconds along-track.

The study is well-motivated. The methodology is clear. The authors present new results pertaining to observed characteristics of small-scale field-aligned currents. Their presentation is well-organized and informative. The discussion of results offers interesting and plausible interpretations that suggest future research directions.

The manuscript will be of interest to the broader scientific community and is publishable. Before accepting it for publication in AG, I recommend implementing minor revisions to include some descriptive clarifications and improvements in language expression and syntax and in the font size in two figures. To facilitate revisions, I have sent a markup of the manuscript directly to the authors via email with embedded comments for their consideration (also attached with referee report).

New and noteworthy scientific methodology and results include:

1. Novel and rigorous analysis of two-point, high-resolution time-series from SWARM A and C, including cross-correlation, spectral distributions and polarization characteristics.
2. Resolution of spatiotemporal ambiguities using two-point measurements.
3. Determination of the preferred length scales for very large-amplitude FACs.
4. Characterization of waveform and amplitude persistence as a function of fluctuation length and time scales.
5. Analysis of relationships between fast and slowly varying fluctuations.
6. Determination of signal polarization, with more slowly varying signals exhibiting mostly elliptical polarization and faster varying signals exhibiting mostly (near) linear polarization.
7. MLAT–MLT distributions of signal characteristics.

An intriguing aspect of the study is its plausible interpretation of the data analysis in terms of Alfvénic turbulence. Building on a previous investigation of CHAMP satellite data (Rother et al., 2007) and appealing to results from previous theoretical and modeling studies, the authors assert that the observed magnetic fluctuations and attendant FACs on the dayside are a consequence of magnetopause disturbances that launch Alfvén waves earthward and become trapped in an F-region ionospheric Alfvén resonator (IAR). The guided waves achieve 5-20 km field-perpendicular scales upon reaching the ionosphere, i.e., the longer duration fluctuations in the data. With ongoing magnetopause stimulation of Alfvén waves flowing into the IAR, the resonator modes intensify until their dissipation within it balances the power flowing into it. The authors presume that nonlinear interaction between counterpropagating Alfvén resonator modes produces a turbulent cascade to smaller scales – the short duration, km-scale FACs identified in the data. The dissipation range of the cascade may be attributable to ionospheric Ohmic dissipation of sub-km-scale FACs according to cited modeling studies. Nightside Alfven wave activity originates from magnetotail processes and is more episodic than dayside activity, so its statistical properties differ from those on the dayside. However, the Alfven wave dynamics within the nightside ionosphere should be similar.

We have modified the Discussion and Summary sections in order to emphasize the facts listed above.

It is customary in turbulence analysis to determine the power spectral density of the fluctuations and identify a power law spectral index if one exists. An evaluation of the power spectral density and the energetics of the fluctuations across the spectral range might be a useful addition to the paper.

We have added a Figure 10 in the end showing the Power Spectral Density (PDS) curve of the magnetic field variations during bursty FAC event shown in the top frame of Fig. 9. Over large parts of a decay of the amplitude equal to the Kolmogorow curve with an index of -5/3 is found. This supports our interpretation that Alfvénic turbulence produces a cascade to smaller scales. We attribute the steeper spectral slope at higher frequencies to ionospheric Ohmic dissipation of sub-km-scale FACs.

The paper concludes with some unresolved questions for future study. What are the effects of the km-scale Alfven waves on ionosphere-thermosphere heating and neutral gas winds? What is the nature of the electric fields accompanying km-scale FACs? What are the effects on charged-particles, e.g., transverse acceleration of ions and field-aligned electron acceleration?

I would add to this list a key question posed by the authors' interpretations: If small-scale (5-20 km) and km-scale FACs are causally related, how is the elliptical polarization of small-scale FACs transformed into the linear polarization of km-scale FACs, and by what means do the km-scale FACs achieve much larger amplitudes than the presumed energy-containing population of 5-20 km-scale FACs?

Thank you for these suggestions. We have added the list of key questions at the end of the Summary section.

In addition to these listed modifications, a number of figures have been improved in order to make the labels better readable.