Response to Reviewer letter

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Manuscript Title: Magnetic local time asymmetries in precipitating electron and proton populations with and without substorm activity
https://www.ann-geophys-discuss.net/angeo-2019-49

Reviewer 2 (Comments)

The paper describes electron and proton differential number flux measured in various energy channels by detectors on POES and METOP from 2001-2008 in the radial direction away from Earth for electrons and 9 degrees from that in protons mapped to 110 km altitude, primarily using the APEX coordinate system and focusing on non-substorm and isolated substorm times, MLT and Kp index dependencies.

The paper is generally well written and presented well (with some exceptions noted below) and will provide useful contributions to the field with some minor modifications. The material is presented with reasonable background and within a reasonable context.

There are no major issues with the paper although there are several minor to mid-level issues that need to be addressed before publication.

In summary, with the relatively minor correction indicated: The conclusions of the paper are of reasonable significance and of importance to the community. The paper length is adequate. The language is fluent and the presentation clear and organized. The figures could be larger but are ok, but the text needs to be made significantly larger, and not at the expense of the size of the data presentation.

1. Comment

First, the abstract lists four findings a), b), c), and d). Strictly speaking neither b nor c are new results. b) (as pointed out later in the paper) is in agreement with conjectures in Newell et al. (2009), and c) has been presented before (although not with a focus on asymmetry) in plots by several authors, at least for some of the energy bands. The consistence of b) with previous results is still a useful finding, so should be included, just reworded. c) also is setup for d) and putting the numerical value on asymmetry is useful. So it is still a useful result, but should be reworded to indicate that it is not a completely new finding.

Reply: *The paragraph now reads:*
Some of the findings are: a) Substorms mostly increase particle precipitation in the night-sector by about factor 24 but can also reduce it in the day-sector. b) MLT dependence can be assigned to particles entering the magnetosphere at the cusp region and magnetospheric particles in combination with energy-specific drifts (in agreement with Newell et al., 2009). c) MLT flux differences of up to two orders of magnitude have been identified inside the auroral oval during geomagnetically disturbed conditions. Novelty here is the comprehensive coverage of energy bands and the focus on asymmetry. d) The maximum flux asymmetry ratio depends on particle energy, decreasing with Kp for low energetic particles and increasing with Kp for higher energy electrons, while high energy protons show a more complex dependency. While some aspects may already been known, the quantification of the flux asymmetry sheds new light on MLT variation.

2. Comment

The text in all of the figures is dramatically too small.

Reply: *The text size has been increased.*

3. Comment

The colors are missing on the color particle flux scale in Figure 2.

Reply: *High flux is colored in red, low fluxes in blue and between some fluxes are colored in white - but no colors are missing. Anyhow, the size of the color legend has been increased.*

4. Comment

Text (e.g a paragraph) needs to be added to discuss the limitations of the chosen color scaling in Figures 3 and 4. While the authors choice of scale is appropriate for examining and comparing asymmetry as described. It is atypical and many conclusions that can usually be drawn from color scales in figures do not apply with this choice. For example, the step jumps in the scale creates observable boundaries and structure in some places and plots that may also exist in other places and plots with the same magnitude, but in one case the variations happen to straddle the color boundary, while not in another. For example, the few orange colored pixels about 0 MLT in the upper right (TED4 substorm) plot of Figure 3, seem to indicate higher magnitude and definitive structure, and not having such pixels in the upper left (TED4 non-substorm) plot seems to indicate that structure structure does not exist in that case. But the color scale hard boundaries may be the only cause of these features. Additionally the color magnitudes between plots cannot be directly compared with each other as absolutes or even as relatives. Only the relative color changes/ranges within each given plot is comparable (as well as that variation pattern). The authors use the color scale appropriately and do not make any interpretations outside of the limitations of the color scale, but these limitations need to be expressly stated, at least briefly, to avoid readers from drawing inappropriate meaning from the presented data.

Reply: *The scaling is already discussed in detail. The aspect that the reviewer complaines about is color binning. But since any kind of color binning hides or pronounces flux steps (and almost every second paper uses color binning) we do not see why this should be discussed in detail. It is simply a question of accuracy (without color binning) vs. readability (with limited number of color/flux steps).*

5. Comment

A statement needs to be included that indicates how the limitations summed up in the final paragraph of section 3.1 (Page 10, lines 4-7) affect the findings and results of the study. That is, could it changes the findings entirely? Change the magnitude of the findings? or just have minor affects on the results, but not the overall findings and trends?

Reply: *Agreed, this should be clearified. In fact the better satellite coverage in high latitudes is just one part that limits the effect. The main aspect is that no longitudinal variations are seen the lat-long graph. The paragraph now reads:*
In sum the ascending and descending MLT paths cause the left edge of an equatorial crossing to be affected by the SAA, while the right edge is not. Any MLT analysis of latitudes that show longitudinal variations will suffer from the fact that longitudes contribute very unevenly to the MLT zones. Given that the SAA is the dominant flux source in low latitudes this hampers a MLT flux analysis here. Effects may also be seen in the drift loss cone, where longitudinal flux variations are expected. In high latitudes however, just minor longitudinal variations (in magnetic coordinates) are expected (see Fig. 1, bottom-left, auroral zone). Consequently it just has minor affects on the results, but not the overall findings and trends. Additionally this effect gets counterbalanced by broader MLT coverage and multiple satellites in high latitudes.

6. Comment

The reference at the end of the second paragraph of section 4.4 (page 15, line 26) should be Figure 14 of Dombeck et al. (2018) rather than Figure 4 of Newell et al. (2009)), and "Alfvén waves" immediately preceding the reference should be changed to "Alfvénic acceleration". There is no need for the authors to go into the depth of literature on Alfvén waves and Alfvénic acceleration of precipitating electrons by the likes of (Keiling, Chaston, Hatch, and Wygant, etc. etc.) But there has been significant work in this area, including many, many maps of Alfvén waves, etc. In short, precipitation is caused by some (and only some) Alfvén waves, and it is then called Alfvénic acceleration. Newell et al. (2009) does not investigate Alfvénic acceleration at all, instead analyzing "broadband" spectra, which Dombeck et al. (2018) indicate is a somewhat/rather imperfect proxy for Alfvénic acceleration. For the purposes of this paper it is better to use the Dombeck et al. (2018) figure reference, as it directly indicates the point the authors are attempting to make, i.e. Alfvénic accelerated precipitation is observed in the mentioned region.

Reply: *Both citations are mentioned now.*

References

Dombeck, J. ; Cattell, C. ; Prasad, N. ; Meeker, E. ; Hanson, E. ; McFadden, J.: Identification of Auroral Electron Precipitation Mechanism Combinations and Their Relationships to Net Downgoing Energy and Number Flux. In: *Journal of Geophysical Research (Space Physics)* 123 (2018), Dezember, S. 10. `http://dx.doi.org/10.1029/2018JA025749`. – DOI 10.1029/2018JA025749.

Newell, P. T. ; Sotirelis, T. ; Wing, S.: Diffuse, monoenergetic, and broadband aurora: The global precipitation budget. In: *Journal of Geophysical Research: Space Physics* 114 (2009), Nr. A9. `http://dx.doi.org/10.1029/2009JA014326`. – DOI 10.1029/2009JA014326.