

Response to Referee #1's report on "Relation between the asymmetric ring current effect and the anti-sunward auroral currents, as deduced from CHAMP observations" by Lühr and Zhou (MS#angeo-2020-3R)

The manuscript is revised according to the comments from the referees and is much improved. However, as stated below, there are a few points to be further considered before publishing in *Annales Geophysicae*.

We thank the referee for his/her effort in reviewing again our manuscript about asymmetric ring current and anti-sunward currents. We are pleased to note that only minor revisions are required for making it acceptable for publication. All the comments have been seriously considered, and in a point-by-point response we explain our motivation for the chosen phrases and presentations. Corresponding changes have been made in the manuscript, which make things clearer for the reader. Below, we first repeat the comments and then add our responses in blue text. Major changes in the manuscript are highlighted in bold face.

1. The revised manuscript refers to the previous papers studying the anti-sunward FAC current. Thus, reply is OK. But, the referee does not agree with the sentence "Conversely, our ring integral of the along-track component is a more straight-forward approach that return quantitative values for the net current passing the polar region.", because the method of authors includes a lot of assumptions to estimate the contributions from the unsampled parts and to calculate the ring integral.

Our chosen wording in the previous response to the referee's comments may not have been polite enough. But in the manuscript, no such decisive ranking of analysis techniques is expressed. We agree that a number of assumptions are made in our approach for calculating the ring integral from unsampled path elements. The resulting net currents, however, can be verified, at least in a statistical sense, by tracing them back to full-orbit integration, that does not require special assumptions. This validation chain is now described more clearly in lines 223ff, see also the response below.

2. Figure 4 is fundamentally the same as Figure 6 of paper by Zhou and Lühr [2017]. This figure is only stated and discussed in a very short paragraph (Lines 220–224). Thus, the referee is still uncomfortable in section 3. Either Figure 3 or Figure 4 is enough to demonstrate the full distribution of the net currents.

It is just the intension of Figure 4 to show the compatibility with Figure 6 in Zhou and Lühr [2017]. This is part of our line of arguments that the presented results are reliable. The average current density distribution presented here, although derived under more assumptions, agrees very well with that of Zhou and Lühr [2017], just the amplitudes are smaller by a factor of 2. This is expected since the dawn and dusk sectors are now sampled separately. In the Zhou and Lühr [2017] we have validated the separate results for the two hemispheres against the full-orbit net current results, which require practically no assumptions. Based on this chain of evidences we are quite convinced that the mean net current values presented here are reliable. For all these reasons we want to keep Figure 4, and have provided in lines 223ff the rational for it.

3. (a) Some tables are converted into figures, which greatly improve section 6. It becomes easier to understand the results of ground observations. However, Table 2 is yet something

redundant. If the authors want to show the numbers, please indicate in each panel of Figure 10.

We agree with the Referee that it is in principle possible to get mean magnetic field values from Figure 10. However, since the values listed in Table 2 are the basis of all subsequent calculations and considerations, we think, it is helpful for the reader to have the proper numbers when trying to verify the presented results. For that reason, we prefer to keep Table 2. These arguments are now outlined in the text, see lines 408ff.

(b) Reply is OK.

4. Reply is fine.

5. Replies are fine.

R1. The revised manuscript includes significant parts of addition in Lines 400–434 and Lines 493–502. In these additions, there are sentences “As a consequence, we have to state, our ground-based observations are not sufficient to reveal a possible seasonal effect of the storm-time disturbance asymmetry.” (Lines 430–432) and “However, our statistical study of recordings from a single European-African meridional chain is not sufficient to confirm the seasonal difference between hemispheres.” (Lines 493–494). This is a negative answer to a question raised in Lines 376–377, that is, “In order to obtain more information on the net current seasonal effects in ground observations we analysed magnetic field data from a meridional chain of observatories.”, indicating the analysis of the ground station data provides no useful information. The analysis result does not have any consequence in interpretation of the anti-sunward net current. Thus, the part of these ground stations (i.e., the latter part of section 6) and related figures and tables can be deleted.

The Referee is right in stating that the meridional chain of observatories is not sufficient for determining seasonal dependences. But there are a number of other quantities that can be derived from their data, e.g. the degree of storm-time disturbance asymmetry and its relation to the strength of anti-sunward net currents. For these reasons we prefer to keep the results of ground-based observations in the paper. For providing a better connection between space and ground-based results we have added some sentences in lines 439ff.

R2. In titles of sections 4 and 5, “anti-sunward net current” may be better to understand the contents of these sections.

Thank you for the advices. We have implemented them.

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