Dear Editor,

This is my review of the paper « Relative locations of the polar boundary of the outer electron radiation belt and the equatorial boundary of the auroral oval » by M. O. Riazanteseva et al. submitted to AnGeo.

This article addresses the problem of finding the position of the polar boundary of the outer electron radiation belt (ORB), relative to the position of the auroral oval (AO). The authors perform a statistical study using the data of the METEOR-M No1 auroral satellite for the period from 11 November 2009 to 27 March 2010. From it they deliver the respective position of the two structures.

I am the third reviewer of this article and I do recommend publications based on the following comments (A) and once the few additional changes I am asking (B) below are made.

A) As a third reviewer, I can see how this article has been improved since its submission. I agree with Reviewer 2 that this article provides a useful scientific step forward (now that some modifications have been made. Rewiever 1 asked to go a bit further in the analysis by trying to determine why d(lat) changes with increasing geomagnetic activity (from totally quiet to moderate activity). This has been done by the authors through Figure 4 and 5. Figure 4 showing the penetration of the ORB into the AO in terms of delta_Latitude is important. Reviewer 2 asked « new figure(s) that would provide clarity for the reader and confirm that the algorithm is producing results that are consistent with the previous work cited in paragraph 1&2, section 1 ». This has been done; figure 6 showing the distributions of the position of equatorial boundary of the auroral oval (green bins) and the polar ORB boundary (red bins) from the L different AE index is important. The authors have therefore accounted for the changes asked by both reviewers and their final figures are 1- clear to me, 2-bringing a statistical description for different geomagnetic activities, 3- support well the conclusions of the article.

B) There were issues on the energy range for the determination of the ORB and AO. In my review below, I come back on the energy-dependence that is a key point to discuss. The main modification I am asking should be fast to do as I only ask 1- to include a small discussion on the energy-dependence of the ORB (with a link to SAPS), 2- to account for recent publications.

My intension is to recommend publication in AnGeo and to see this article published within short delays.

Main corrections:

1- : On the energy-dependence

Although authors focus on the polar boundary of the outer belt, I ask here the question of the impact of energy dependence of the outer belt on its shape, and,

therefore, on its boundaries. The inner boundary of the outer belt is extremely energy dependent as shown very recently (e.g. Reeves et al. 2016; Ripoll et al. JGR 2017 and references in them) from the Van Allen Probes, from L~4 to 6. As L-increases above L~6 reaching now the polar boundary of the outer belts, in which the authors are working on, some of this energy-dependence will be kept, in particular for quiet times, for which the plasmasphere extends up to there. From Figure 6 of the authors, it is interesting to see that the probability is higher in the Southern hemisphere. (As a comment, the position of the plasmasphere is determinant on the energy-dependence of the ORB structure, but not only, as wave-particle interactions (WPI) from Chorus waves outside of the plasmasphere will also print an energy-dependence structure of the outer belt). What is interesting about quiet times, on which the authors focus on (but not only), is the great stability of the outer belt. For instance Ripoll et al. 2014 analyzing HEO data shown months of stability of the outer belt for E>100 keV, reinforcing the relevance of defining outer belt boundaries and positioning them onto known structures (aurora oval, ring plasma or current, plasma sheet, etc.). Still, the stability degrades as L-shell increases above 5-6. (As a comment, there must be more recent observations from the Van Allen Probes, which we let the authors find themselves). During, active times, because WPI are extremely energy-dependent, it is likely that the energy-dependence will also show up one way or the other, to print the whole outer belt structure. Accelerations for instance will contribute to redistribute the population (e.g. Reeves et al; 2013).

All of this energy dependence is left aside by the authors in their study, maybe because it will be another step, maybe because the measurements are not available from the Meteor satellite (with energy integrated sensors), etc. I understand that it is a limitation of the study that is perfectly admissible (because the authors conclusions are already interesting), however, I would like the authors to have a small paragraph on what they think their limitation is (due to energy-integrated measurement) and they comment the fact that their polar boundary is thus an averaged value of energy-dependent polar boundaries, that may vary quite a lot from the dynamic low energy seed population (~100 keV) up to the high (ultra-relativistic energies, >1 MeV).

About the energy-dependence, there is certainly two populations of the electron outer belts which I am asking the authors to distinguish in their discussions: the low energy electron seed, say around 100 keV, from 50 keV maybe up to 200 keV and higher energies, the core of the outer belt. The seed population is extremely dynamic and will penetrate deep (e.g. Zhao et al. 2013; Turner 2015b, 2016). In other words, it is probably harder to identify both inner and polar boundaries for the seed population. Though I believe that is probably what the authors may be observing. A second issue is that the entering of the seeds population in the outer belt does not occur at its boundary, as, for instance, substorm injections often locates around L=4.5 (Turner 2015b). A third point is that the density of the seed population is much higher than the high energy core, so that they probably dominate once one looks after an integrated outer belt boundary. What the polar boundary ends up to carry in terms of energy population is unknown. Its polar boundary surely does not carry all the information of the outer belt energy structure. The core population is expected to be more stable and, as such, to offer a clearer geometry (but less represented in proportion).

On the contrary, when the polar outer belt boundary is created by the simple effect of the magnetopause via magnetopause incursions and the Dst effect (i.e., magnetopause shadowing), the energy-dependence is totally removed and absent, and, as such, the polar boundary of the outer belts is expected to be this time fully energy-

independent. That is expected during disturbed times, that constitutes the second part of the authors' study. Such configuration makes the author's current analysis perfectly valid. It would be good to write it. But again, to observe it, would not it be better to have at disposal some energy resolution (rather than none). That last comment could be a good opening for future work.

In other words, if one tries to locate/study the polar boundary of the outer belts is seems today (with modern technology) more likely to be conclusive if the study is energy-dependent (or at least can be sustained additionally by some energy-dependent measurements), rather than a general global integral for all energies above 100 keV up to 13 MeV, as the authors do. I don't want to minimize the authors results either, as, as I wrote, has definitely its own merit, but I would like to see such opening to be made.

A last link I would like to see to be made is the link between the interactions of the aurora sub-region with the outer belt seed populations through SAPS (Subauroral polarization Streams, e.g. (Kunduri et al., 2017; Lejosne and Mozer, 2017)) potential drop. It has been recently shown that SAPS contribute to the injection (or deeper injections) of the energetic electrons (seed population of the outer belt, up to 200 keV) (Lejosne et al., 2018). This new point has direct implication to the authors' work; 1) it justifies more connecting all aurora associated phenomena and the outer belt dynamics, 2) on the other hand, it explains how fast transport (particularly during disturbed times) will bring more complexity to the outer belt structure, with necessary some implications on its boundaries, 3) it may simply affect the position of their respective boundary, 4) it may open new research angles. Again, it is directly related to the energy dependence of the outer belt, which, as I argue for long enough now here, is a consideration that I would like to see mentioned in this article.

To conclude, I concretely, ask the authors to account briefly for these aforementioned considerations in their discussions with proper citations (full references given below). For instance, Line 24-30 of the conclusions could be a good place for some of these points as the authors already open their discussion to 'acceleration' and 'transport of seed populations' (but I let the authors decide whether it is in the introduction, discussion, conclusion sections).

References

Kunduri, B. S. R., Baker, J. B. H., Ruohoniemi, J. M., Thomas, E. G., Shepherd, S. G., & Sterne, K. T. (2017). Statistical characterization of the large-scale structure of the subauroral polarization stream. Journal of Geophysical Research: Space Physics, 122, 6035–6048. https://doi.org/ 10.1002/2017JA024131

Lejosne, S. & Mozer, F. S. (2017). Subauroral Polarization Streams (SAPS) duration as determined from Van Allen probe successive electric drift measurements. Geophysical Research Letters, 44, 9134–9141. https://doi.org/10.1002/ 2017GL074985

Lejosne, S., Kunduri, B. S. R., Mozer, F. S.,& Turner, D. L. (2018). Energeticelectron injections deep into theinner magnetosphere: A result of thesubauroral polarization stream (SAPS)potential drop. Geophysical ResearchLetters, 45, 3811–3819. https://doi.org/10.1029/2018GL077969

Makarevich, R. A., A. C. Kellerman, Y. V. Bogdanova, and A. V. Koustov (2009), Time evolution of the subauroral
electric fields: A case study during a sequence of two substorms, J. Geophys. Res., 114, A04312,

doi:10.1029/2008JA013944.

Reeves, G. D., et al. (2013), Electron acceleration in the heart of the Van Allen radiation belts, Science, 341, 991, doi:10.1126/science.1237743.

Reeves, G. D., et al. (2016), Energy- dependent dynamics of keV to MeV electrons in the inner zone, outer zone, and slot regions, J. Geophys. Res. Space Physics, 121, 397–412, doi:10.1002/2015JA021569.

Ripoll, J.-F., Y. Chen, J. F. Fennell, and R. H. W. Friedel (2014), On long decays of electrons in the vicinity of the slot region observed by HEO3, J. Geophys. Res. Space Physics, 119, doi:10.1002/2014JA020449.

Ripoll, J.-F., O. Santolík, G. D. Reeves, W. S. Kurth, M. H. Denton, V. Loridan, S. A. Thaller, C. A. Kletzing, and D. L. Turner (2017), Effects of whistler mode hiss waves in March 2013, J. Geophys. Res. Space Physics, 122, doi:10.1002/2017JA024139.

Turner, D. L., T. P. O'Brien, J. F. Fennell, S. G. Claudepierre, J. B. Blake, E. K. J. Kilpua, and H. Hietala (2015a), The effects of geomagnetic storms on electrons in Earth's radiation belts, Geophys. Res. Lett., 42, doi:10.1002/2015GL064747.

Turner, D. L., et al. (2015b), Energetic electron injections deep into the inner magnetosphere associated with substorm activity, Geophys. Res. Lett., 42, doi:10.1002/2015GL063225.

Turner,D. L., et al. (2016), Investigating the source of near-relativistic and relativistic electrons in Earth's inner radiation belt, J. Geophys. Res. Space Physics, 121, doi:10.1002/2016JA023600.

Zhao, H., and X. Li (2013), Inward shift of outer radiation belt electrons as a function of Dst index and the influence of the solar wind on electron injections into the slot region, J. Geophys. Res. Space Physics, 118, doi:10.1029/2012JA018179.

Minor corrections:

- P1, Line 10: using the dat
- P1, Line 28: showed that the polar boundary
- P2, Line 27: rephrase "with pitch angle lower than 90°" because every p.a. is below 90°…. Do you mean below and close to 90°?
- P2, Line 28: "due to drift shell splitting (Shabansky effect)". Both are two different things in general. The second can cause the first. Rephrase according to what you want to say. The whole sentence from L25 to L29 is obscure.
- -P3, line 8: too strong "has not been properly studied yet". You could write something like "still requires careful studies" or "careful examination".
- P4, Line 4: make sure the definition "of the polar boundary of ORB, also known as the trapping boundary", of the trapping boundary is made the first time you mention the "trapping boundary". (It is not).
- P7, Line 7: …oval crossing of the ORB. For…
- P10, line 16: "…ring that surrounds.."
- P10, line 20: 'It contains closed
- P10, line 21: 'have drift'
- P10, line 23: "of the trapping"
- P10, line 25: feel free to include recent references from the Van Allen Probes observations (e.g. reference above)