Response to reviewers

Reviewer #1 Evaluations:
Summary: The work deals with improving the quantification of one of the main processes acting in the radiation belts: radial diffusion. It provides a variety of content of potential importance: It briefly describes how electric and magnetic field measurements from the three THEMIS inner probes (A, D, E) were processed to compute products equated with radial diffusion coefficients, DLLs. It discusses several dependencies of the database related to spatial location and magnetic activity. It compares and contrasts the database outputs with various published models. It also shows two numerical simulations of outer radiation belt dynamics: one where radial diffusion is parameterized by the data products introduced in this manuscript, and the other where radial diffusion is parameterized by the published model that best compares with the database (l.261-262). One of the main findings is that "all models underestimate the DLL during quiet times and at low L* values, while they overestimate the DLL during high levels of geomagnetic activity and at high L* values" (l.279-281).

General Comments: The work claims to provide a database of "accurately calculated" radial diffusion coefficients (l.4, l.12, l.71, l.216, l.246, l.265). Yet, it fails to be convincing. A much more rigorous treatment of both data processing and scientific presentation is required to demonstrate the validity and significance of the work.
Response: We agree with the reviewer that the expression "accurately calculated" may lead to misinterpretations. The term "accurate" intended to describe the detailed process we followed for the calculation of the DLL database, from the pre-processing of the data to final scientific product. Nevertheless, we acknowledge that any calculation of the DLL is an estimation based on several assumptions and, thus we have removed this term from the manuscript. Furthermore, we have included in the manuscript a detailed description concerning the entire data processing chain. To that end we have also discussed several assumptions DLL database which arise from the theoretical approach used in this study and the inherent limitations of the in-situ data.

Specific Comments:
Major comments:
1. The database does not provide radial diffusion coefficients:
A radial diffusion coefficient quantifies the long-term phase-averaged effect of small electromagnetic fluctuations on trapped particles' third adiabatic invariant (e.g., Schulz and Lanzerotti, 1974). Thus, a radial diffusion coefficient is independent of magnetic local time by definition. In this work, the products resulting from THEMIS data processing present significant variations with magnetic local time (section 3.2, Figure 4). This feature is enough to demonstrate that the database does not provide a time series of radial diffusion coefficients.
Response: We would like to thank the Reviewer for noting these points in the calculation of the radial diffusion coefficients. Indeed, the radial diffusion coefficient, DLL, quantifies the mean square displacement of radiation belt electrons across Roederer's L* as a result of fluctuations in the magnetic and electric fields. In the classic electromagnetic diffusion formulas proposed by Falthammar (1965), particle perturbations leading to diffusion result from variations in the magnetic field along the drift orbit and the electric fields induced by these magnetic field fluctuations as well as electric potential fluctuations, DLL,m and DLL,e.

In this manuscript, for the calculation of DLL, we have adopted the newer formulas for radial diffusion coefficients proposed by Elkington et al. (2003) and further developed by Fei et al. (2006) that consist of a component that quantifies radial diffusion driven by magnetic field disturbances in the direction of the background magnetic field, DLLB and a second component that quantifies radial diffusion driven by azimuthal electric field disturbances, DLLE. Since no coupling between wave magnetic and electric fields through Faraday's law is assumed, there are uncertainties introduced in the derivation of radial diffusion coefficients by Fei et al.(2006). We have noted that Lejosne (2019) has estimated that, in the presence of magnetic field disturbances, adopting the approach of Fei et al. (2006) leads to underestimation of the total radial diffusion coefficients by a factor of 2. However, as Sandhu et al. (2020) have suggested and as we demonstrate in section 4.1, this discrepancy is comparatively minor relative to the large variability of the calculated values which span orders of magnitude especially during magnetic storms.

Furthermore, spatial variations in the power of magnetic and electric field perturbations have been found to impart local time dependencies to calculated diffusion coefficients. In the following figure we demonstrate that wave power calculated based on measurements from three spacecraft of the THEMIS constellation is highly dependent on the limited MLT sector sampled.

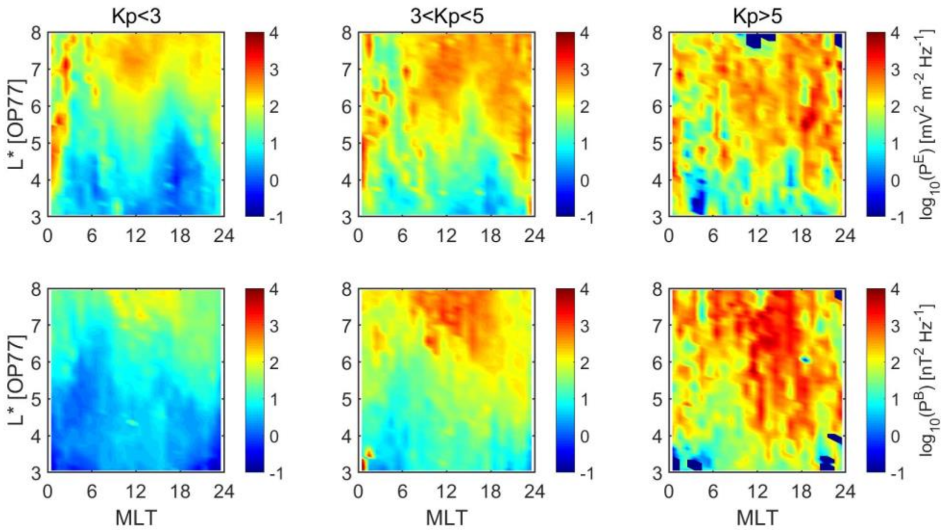

Figure 1: Logarithms of the mean ULF power with 1-min as a function of MLT (dMLT=1 hour) and L* (dL*=0.1) for three levels of geomagnetic activity: (left column panels) Kp<3, (middle column panels) 3<Kp<5 and (right column panels) Kp>5. Top and bottom row panels correspond to the power in the azimuthal electric field component and in the compressional magnetic field component, respectively.

Local time variations in wave power indicate sources of wave activity both internal (coupling with ring current ions and substorm particle injections) as well as external (solar wind driving). However, using measurements from a single spacecraft or from a single mission that sample a specific MLT sector can result to under- or over-estimates of radial diffusion coefficients, since spatial variations are neglected. In our case, the maximum MLT coverage from all three spacecraft does not exceed 6 hours per hour and per L*. This means that our DLL (and of course any other estimated by in-situ measurements) employs a small fraction of the full MLT coverage which would be required. Therefore, figure 4 in the manuscript reflects exactly the features presented in the above mentioned figure 1.

We emphasize that radial diffusion is a drift-averaged process and radial diffusion coefficients should describe an average over all local times and the possibility of combining measurements from missions and spacecraft sampling different parts of the magnetosphere needs to be explored. Our efforts have been currently focused on quantifying the magnitude of radial diffusion due to ULF waves observed solely by the THEMIS spacecraft since combining measurements from different missions will need intercalibration of measurements which is beyond the scope of this study.

A brief description has been added in the revised section 2 of the manuscript as follows: "Equations 2 and 3 also implicitly assume a uniform distribution of wave power in azimuth. In reality, the azimuthal distribution of the wave power in the Pc4-5 range depends on their generation mechanism, e.g. the wave power due to the Kelvin-Helmholtz instability is expected to be greater near dawn and dusk sectors, while due to the pressure pulses from the solar wind is expected to be greater near noon. Furthermore, the maximum MLT coverage from all three spacecraft does not exceed 6 hours per hour and per L*. This means that our DLL--and of course any other estimated by in-situ measurements [Jaynes et al. 2018, Olifer et al. 2019, Sandhu et al. 2021]--employs a small fraction of the full MLT coverage which would be required. We note that radial diffusion is a drift-averaged process and radial diffusion coefficients should describe an average over all local times. Nevertheless, in order to achieve a full MLT coverage, one would need a large multi-satellite dataset which would span several years. Our efforts have been currently focused on quantifying the magnitude of radial diffusion due to ULF waves observed solely by the THEMIS spacecraft since combining measurements from different missions will need inter-calibration which is beyond the scope of this study."

Another paragraph has been added in section 3.2 describing the physical meaning of figure 4 as follows: "We must note that the aforementioned MLT dependence reflects directly the azimuthal distribution of power for both the magnetic and the electric component of the DLL. This means that even though the radial diffusion coefficient is calculated with the drift-averaging assumption, in practice, the limited MLT coverage from single mission in-situ data introduce an azimuthal structure, which accounts for the coupling of external and internal ULF generation mechanisms and may be quite important for future modelling efforts."

Moreover, we have added a paragraph in the end of section 4.1 discussing how the aforementioned assumptions could affect the comparison of our database with the results of the semi-empirical models.

Finally, we have clarified in section 2 that our database consists of two parts: a) the ULF wave PSD, which is stored in daily CDF files with 1-min resolution for each spacecraft separately, and b) the drift-averaged DLL (grouped in bins with dt=1 hour and dL*=0.1).

2. THEMIS data processing, and its presentation, need improvement:
- Quantifying radial diffusion using satellite measurements is a challenging task. For instance, it requires differentiating spatial and temporal variations from a time series of field measurements sampled along spacecraft trajectory, often in the presence of strong spatial gradients. How this is achieved remains unclear.
Response: As mentioned in the previous comment response, we have included in the manuscript a detailed description concerning the entire THEMIS data processing chain.

Concerning the spatial gradients, we are not entirely sure what exactly the reviewer is referring to. We have included a paragraph in section 2.1 which refers to the magnetic field gradients as the spacecraft moves close to the Earth. This paragraph is as follows: "Note that as the satellites move inbound and outbound with high velocities at low L-shells, the magnetic field measurements exhibit, not only orders of magnitude increase, but very large gradients as well. These large gradients make it quite difficult to estimate the background trend, which has to be removed. Even if we filter the magnetic field time-series, the filtered signal's amplitude still grows significantly near perigee, which renders any PSD calculations erroneous. Therefore, we manually remove the corresponding part of the spectrum."

Furthermore, Fei's expressions are based on the assumption that the asymmetric background magnetic field leads to enhanced radial diffusion in the presence of broadband ULF waves. Following previous studies (Ozeke et al., 2012, Ali et al., 2015, Liu et al., 2016, Jaynes et al.,2018 and others), we have determined the power spectrum of ULF waves along each spacecraft orbit but, due to the limited coverage of THEMIS spacecraft measurements, it is not possible to determine the waves mode structure. In this light, we opted to use the weighted averaged power over the whole frequency range under study (i.e. Pc4-5 frequency range) in the place of waver power at a specific frequency. This procedure and its benefits are discussed in detail in section 2.2.

Finally, in order to extract field perturbations in the Pc4-5 frequency range, the background electric and magnetic field was identified by taking a running average over a 30 min sliding window (see also section 2.1). The power of magnetic field perturbations was calculated in the direction of the background magnetic field (compressional perturbations) and power in local electric field perturbations in the azimuthal direction. However, due to spacecraft motion, separation between spatial and temporal variations is not possible. Temporal variations may be introduced by the dynamics of the different wave sources and these have not been separated from spatial variations of ULF wave components due to weakening of the local magnetic field strength associated with an enhanced ring current population or an increase in the local plasma mass density.

- Fei et al. formulas apply at the magnetic equator only. Yet, THEMIS probes do not necessarily sample the magnetic equator. The manuscript does not explain how this feature is taken into account in the data processing.

Response: As mentioned in the revised section 2, Fei's approach considers equatorially mirroring particles only, while THEMIS satellites do not necessarily sample the magnetic equator. Nevertheless, they remain very close to the magnetic equator throughout their trajectories in the outer belt [Angelopoulos 2008, Turner et al. 2012] something that allows us to assume that the uncertainty in the DLL calculation will be rather small. This is also supported by the results shown in the following figure where we have plotted the mean power versus the Beq/Blocal ratio for different values of L*. As shown, both in the electric and magnetic field power, the variation of power versus Bratio is up to a factor of 2, at least for Bratio values larger than 0.8 (note that this threshold in Bratio is used in our study so all results correspond to DLL values at points with Bratio>0.8). Nevertheless, we should note that there is no straightforward comparison with the dataset used by Sandhu et al. 2020, since we have no information about whether they have sorted their dataset based on magnetic latitude or about the model used for the calculation of the magnetic ephemeris data.

Note that we have revised the corresponding paragraph of the manuscript as follows: "Finally, we emphasize the fact that our results on the MLT asymmetry are in good agreement with Sandhu et al. 2020 who used Van Allen probes data (different magnetic latitude) to infer the radial diffusion coefficients. This agreement also indicates that the uncertainty introduced by the magnetic latitude (and already discussed in section 2) is insignificant, even though there is no straightforward comparison with the dataset used by latter authors, since we have no information about whether they have sorted their dataset based on magnetic latitude or about the model used for the calculation of the magnetic ephemeris data."

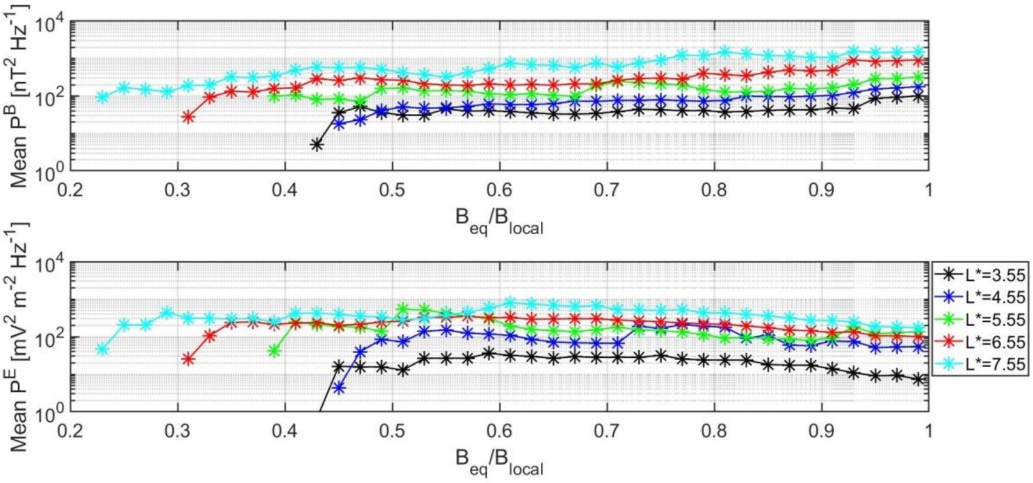

Figure 2: Logarithms of the mean ULF power with 1-min as a function of Beq/Blocal (dB=0.05) for 5 L* bins with dL*=0.1.

- Not all choices made during data processing are well explained or well justified. For instance, why the equation (4)? Why "cdelta" =0.76? What is the definition of "dj"?

Response: Indeed the data processing section was insufficient. Please note that we have revised section 2 in order to provide many more details to the reader concerning the entire data processing chain. Especially for the calculation of the ULF wave PSD, we have used the wavelet analysis as described in Torrence and Compo [1998]. The latter authors provide an in-depth analysis of the use of wavelet functions. This analysis is quite long and we believe that including it in the manuscript would be out of the scope of our study and would render the reading of the manuscript unnecessary difficult. Nevertheless, we have included the definitions of specific parameters.

For example, dj is the sampling scale of the wavelet analysis, which of course depends on the frequency range under study. Cdelta is a smoothing factor which depends on the non-dimensional frequency ω_0 of the Morlet wavelet:

$$\psi_0(\eta) = \pi^{-\frac{1}{4}} \cdot e^{i\omega_0\eta} \cdot e^{-\frac{\eta^2}{2}}$$

where η is a non-dimensional time parameter. For the Morlet wavelet ω_0 is taken as 6 to satisfy the admissibility condition (Farge 1992) and then Cdelta is empirically derived as 0.776.

- Farge, M., 1992: Wavelet transforms and their applications to turbulence. Annu. Rev. Fluid Mech., 24, 395–457.
- Torrence, C., and Compo, G. P.: A practical guide to wavelet analysis. Bulletin of the American Meteorological Society, 79(1), 61–78, 1998.

3. The claim that the data products are accurate is not justified:

Before being able to make any claim regarding the accuracy of the approach, it seems necessary to discuss the extent to which the outputs depend on the variety of choices made during data processing. Yet, this has not been done.

Response: As stated before the term "accurate" intended to describe the detailed process we followed for the calculation of the DLL database, from the pre-processing of the data to final scientific product, and in order to avoid any misinterpretations we have replaced it in the manuscript. Also we have included the subsection 2.3 (Assumptions) where we discuss all the assumptions used for the calculation of the PSD and DLL including the theoretical approach (Fei et al 2006) and the inherent limitations of our dataset. Furthermore, all the results presented in this study have been further discussed in the basis of these assumptions.

Minor comments:

* Table 1: Units are missing. The list of limitations provided is incomplete.

Response: Duly amended. We have now revised the table in order to included L* and Kp limitations for each model.

* While Falthammar's (1965) framework was developed in the non-relativistic case, the extension to relativistic particles is straightforward (e.g. Schulz and Eviatar, 1969). Thus, the claim that Falthammar's formulation is "valid for sub-relativistic particles, only" (l.32) is misleading.

Response: We thank the reviewer for the valuable information. The sentence has been removed from the manuscript.

References:

Schulz and Eviatar (1969), Diffusion of equatorial particles in the outer radiation zone, https://doi.org/10.1029/JA074i009p02182

Schulz and Lanzerotti, 1974, Particle Diffusion in the Radiation Belts, https://doi.org/10.1007/978-3-642-65675-0

Response to reviewers

Reviewer #2 Evaluations:
Summary: This work sets out an analysis of the SafeSpace electron diffusion coefficients database, comparing the magnitude of the magnetic and electric parts (relating to the formulation of Fei et al., 2006) under different environmental conditions parameterised by a number of indices. The method of calculating DLL using data from the THEMIS spacecraft is first described, followed by the main analysis. The time evolution of the ratio between DLLB and DLLE is discussed, and a comparison with various empirical models of DLL is then made, followed by an application of the SafeSpace coefficients using a physical model in order to simulate the outer electron belt over a month-long period. As part of the conclusion, the manuscript makes the claim that empirical models tend to underestimate DLL "at low levels of geomagnetic activity at all L*" based on results of the earlier comparison, and that DLLB can reach values comparable to, or in excess of, DLLE for periods following ICMEs.

General Comments: The authors show some interesting details about the time evolution of DLL following geomagnetic disturbances (Fig. 5). The authors also show correlations between changes in DLL and various indicies, and relate this to the physical processes driving each index (Fig. 3, 4). However, the method for calculating DLL from spacecraft data for the SafeSpace database is not clearly explained, and the authors do not clearly present evidence to support later claims that empirical models under/over-estimate just because they do not agree with SafeSpace. Some further discussion about the MLT-dependence of provided DLL is also required.

Major comments:
1. Section 2
As the authors are aware, DLL is used to quantify the time evolution of phase space density over many drift orbits due to small, repeated electromagnetic fluctuations. In this work DLL is presented as MLT-dependent (or perhaps, the authors' method of calculating DLL from THEMIS data is sensitive to the MLT at which data was collected). In any case, Section 2 should address the physical meaning of the MLT dependence of SafeSpace DLL, and where this arises from.
In addition, Section 2 jumps directly into describing measurements, without describing what these measurements are being used for. In general, the structure of Section 2 should be reworked. As a starting point, an example way to order things might be:
DLL was calculated directly from measurements in order to construct a database parameterised by solar wind and geomagnetic parameters. To calculate DLL, we used an approach based on the Fei et al. (2006) formulation. This approach involved considering "the compressional component of the magnetic field…" . The calculation of DLLB and DLLE depends on … These parameters were first determined using measurements from the THEMIS satellite.
[Then, describing how:] "We use 4-sec resolution measurements of the magnetic field vector…" "Complementary 1-min measurements of solar wind…" (etc.) "The THEMIS magnetic and electric field data were pre-processed by transforming them into a Mean 90 Field Aligned (MFA) coordinate system…" etc. [Then elaborate on the data processing method in more detail to put the MLT dependence in context.]
Response: We thank the reviewer for the suggestions. Indeed the data processing section was insufficient. Please note that we have revised section 2 according to the aforementioned suggestions in order to provide many more details to the reader concerning the entire data processing chain. To that end we have also discussed several assumptions of

our DLL database which arise from the theoretical approach used in this study and the inherent limitations of the in-situ data.

Especially, concerning the MLT dependence of the DLL, we have discussed that it reflects directly the azimuthal distribution of power for both the magnetic and the electric component. As we now state in section 2: “Equations 2 and 3 also implicitly assume a uniform distribution of wave power in azimuth. In reality, the azimuthal distribution of the wave power in the Pc4-5 range depends on their generation mechanism, e.g. the wave power due to the Kelvin-Helmholtz instability is expected to be greater near dawn and dusk sectors, while due to the pressure pulses from the solar wind is expected to be greater near noon. Furthermore, the maximum MLT coverage from all three spacecraft does not exceed 6 hours per hour and per L*. This means that our DLL--and of course any other estimated by in-situ measurements [Jaynes et al. 2018, Olifer et al. 2019, Sandhu et al. 2021]--employs a small fraction of the full MLT coverage which would be required. We note that radial diffusion is a drift-averaged process and radial diffusion coefficients should describe an average over all local times. Nevertheless, in order to achieve a full MLT coverage, one would need a large multi-satellite dataset which would span several years. Our efforts have been currently focused on quantifying the magnitude of radial diffusion due to ULF waves observed solely by the THEMIS spacecraft since combining measurements from different missions will need inter-calibration which is beyond the scope of this study.”

The aforementioned paragraph implies that any attempt to estimate the DLL from in-situ data (independent of the mission used) will introduce an MLT dependence due to the limited azimuthal coverage, which however may be important for future modeling efforts.

2. Section 4
The authors discuss the underestimation/overestimation by empirical models compared with the SafeSpace DLL. However, I feel it is important for the authors to also discuss the uncertainty in the SafeSpace DLL that may also be a cause of disagreement versus empirical models. This would strengthen the author’s claim that the SafeSpace DLL are accurate.
Response: We thank the reviewer for the constructive comment. We have now included a paragraph at the end of section 4.1 discussing these uncertainties and how they could affect our results. The paragraph is as follows:

“Finally, we have to consider the uncertainties in the SafeSpace calculated DLL that may also be a cause of disagreement versus the aforementioned semi-empirical models. As discussed in section 2, it has been shown that the Fei et al. 2006 approach can underestimate the radial diffusion coefficient by a factor of two compared with the Falthammar 1965 approach. This is sufficient to explain the difference exhibited by our DLL and the Brautigam & Albert 2000 and Boscher et al. 2018 models at L*>4, but it cannot explain the up to a factor of 10 difference at lower L-shells. Another uncertainty, also discussed in section 2, comes from the limited MLT coverage of THEMIS satellites used in this study. Nevertheless, the results of figure 6 are averaged values of the SafeSpace DLL for specific values of L* and Kp over 9 years of calculation, thus including several MLT values.”

We have further added significant discussion in section 4.1 discussing possible sources of the disagreement between the SafeSpace DLL and the various semi-empirical models.

Minor comments:
1. first paragraph

The first paragraph is vague. It is important to 'draw the reader in' at this stage. The authors could cut the first sentence down to something like, "The outer radiation belt exhibits electrons at energies from a few hundred keV to several MeV [reference]."
Then the authors could go straight to the topic of radial diffusion, e.g.: "Radial diffusion has been established as one of the most important mechanisms causing energization [references] and loss [references] of relativistic electrons."
Response: We have now changed this paragraph as follows: "The outer radiation belt exhibits electrons at energies from a few hundred keV to several MeV [Daglis et al. 2019]. Radial diffusion has been established as one of the most important mechanisms that contributes to this broad energy range of electrons since it can lead to both energization [Jaynes et al. 2015, Li et al. 2016, Katsavrias et al. 2019a, Nasi et al. 2020] and loss of relativistic electrons [Morley et al. 2010, Turner et al. 2012, Katsavrias et al. 2015, Katsavrias et al. 2019b]."

2. second paragraph
Again, the first sentence could be omitted. The second sentence could be expanded on like so:
"Ultra-Low Frequency (ULF) waves in the Pc4-5 band (1 and 22 mHz) can violate the third adiabatic invariant L* of…" Next sentence: "This drives radial diffusion by…"
This way the explanation comes first.
Response: We have now changed this paragraph as follows: "Ultra-Low Frequency (ULF) waves in the Pc4-5 band (1--22 mHz) can violate the third adiabatic invariant L* of the energetic electrons. This drives radial diffusion by conserving the first two adiabatic invariants under the drift resonance condition $\omega = m\omega_d$, where ω is the wave frequency, m is the azimuthal wave mode number and ω_d is the electron drift frequency [Elkington et al. 2003]."

3. line 34
The authors might consider replacing "something that runs counter to basic physical concepts of electromagnetism" with a more specific summary of the limitation. It is described well by Lejosne, 2019, and this paper is referenced in line 113. It can be referenced here as well.
Response: A brief explanation based on Lejosne (2019) has been included in the corresponding paragraph.

4. line 51
Replace "limitations of" with "dependence on" (and in line 219)
Response: Duly amended.

5. a general comment about repetition
The word "moreover" beginning line 58 is repeated at the beginning of the next sentence, and it is also in the previous paragraph. Use an alternative here, for example, "Furthermore, observed DLL have been shown…". It can be omitted in the next sentence too, for example: "Several case studies have demonstrated…"
"Moreover" is used yet again on line 66, try instead something like:
"…overestimated by the empirical model of Ozeke et al. (2014). At times, the difference between empirically modelled values and event-specific diffusion coefficients was shown to be multiple orders of magnitude."
The word "Nevertheless" is also used three times from line 100 to 115. As before, it would read better with a substitute.
Response: All sentences have been modified in order to avoid repetition.

6. line 75
There is a section 5 too, so don't use the word "finally" to describe section 4.
Response: Duly amended.

7. Figure 1
The Figure 1 font is difficult to read, try something like Arial, Calibri, etc. and use a darker red background for the white text.
Response: The figure colors and fonts have been modified.

8. line 139
The authors show that the CC between Psw and DLLE is weak. They then state that changes in Psw "are not really linked with the electric DLL component", yet mention that they are an important ULF wave generation mechanism. Are they implying the generation of ULF waves is not related to changes in DLLE? Be specific about this, rather than saying "not really linked".
Response: We apologize for the poor choice of words in this sentence. We have revised the manuscript as follows: "A possible explanation of this feature could be that, since solar wind pressure pulses produce mainly global magnetospheric oscillations [Kepko et al. 2002,Takahashi et al. 2012], they do not affect the azimuthal electric field variations and thus the electric DLL component."

9. line 152
The distribution is shown in terms of the magnetic coordinate L*, rather than a spatial coordinate. So if this is a spatial distribution, does it relate to the magnetic equator, or is there just no dependence on magnetic latitude, etc? Line 178 implies the dependence on latitude is weak, but, this should be clarified.
Response: As mentioned in the revised section 2, Fei's approach considers equatorially mirroring particles only, while THEMIS satellites do not necessarily sample the magnetic equator. Nevertheless, they remain very close to the magnetic equator throughout their trajectories in the outer belt [Angelopoulos 2008, Turner et al. 2012] something that allows us to assume that the uncertainty in the DLL calculation will be rather small. This is also supported by the results shown in the following figure where we have plotted the mean power versus the Beq/Blocal ratio for different values of L*. As shown, both in the electric and magnetic field power, the variation of power versus Bratio is up to a factor of 2, at least for Bratio values larger than 0.8 (note that this threshold in Bratio is used in our study so all results correspond to DLL values at points with Bratio>0.8). Nevertheless, we should note that there is no straightforward comparison with the dataset used by Sandhu et al. 2020, since we have no information about whether they have sorted their dataset based on magnetic latitude or about the model used for the calculation of the magnetic ephemeris data.

Note that we have revised the corresponding paragraph of the manuscript as follows: "Finally, we emphasize the fact that our results on the MLT asymmetry are in good agreement with Sandhu et al. 2020 who used Van Allen probes data (different magnetic latitude) to infer the radial diffusion coefficients. This agreement also indicates that the uncertainty introduced by the magnetic latitude (and already discussed in section 2) is insignificant, even though there is no straightforward comparison with the dataset used by latter authors, since we have no information about whether they have sorted their dataset based on magnetic latitude or about the model used for the calculation of the magnetic ephemeris data."

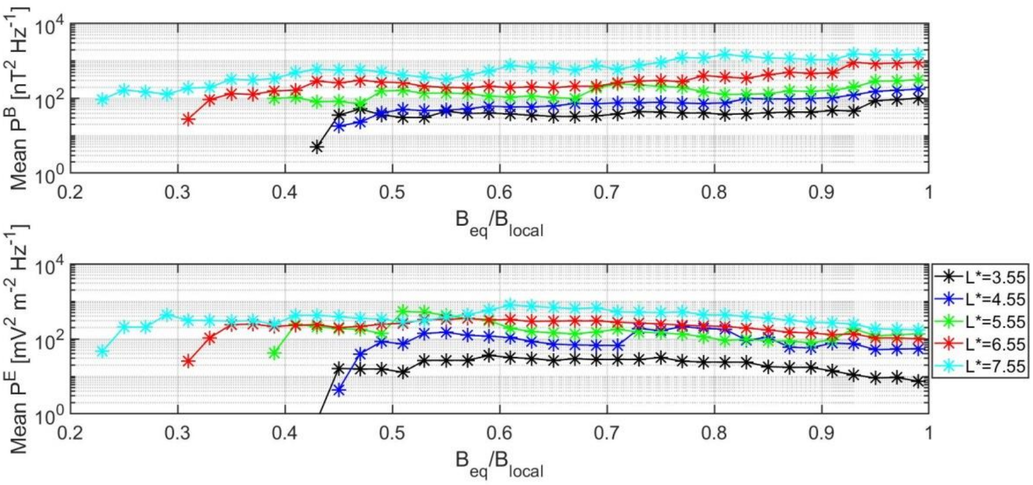

Figure 3: Logarithms of the mean ULF power with 1-min as a function of Beq/Blocal (dB=0.05) for 5 L* bins with dL*=0.1.

10. line 170
"On the other hand, the observed asymmetry in the electric component indicates that DELL is not only linked with solar wind speed but with internal mechanisms such as substorm activity, something that is also in agreement with the results of figure 2. "
Explain briefly why the asymmetry indicates a link with internal mechanisms.
Response: The intention of this sentence was to highlight the high values of DLLE at the nightside sector (0<MLT<3) shown in the upper panels of 4.

We have revised the corresponding text as follows: "On the other hand, the observed asymmetry in the electric component indicates that DLLE is not only linked with solar wind speed but with internal mechanisms such as substorm activity, especially during quiet or moderate magnetospheric activity. This is supported by the remarkable agreement of the DLLE MLT distribution (top row panels of figure 4) with Nose et al. 1998, who stated that substorms generate azimuthal ULF fluctuations at the nightside which peak at 1--2 MLT. Furthermore, this is also in agreement with the results of figure 2 and the significant correlation of DLLE with the AE index."

11. line 157 and line 190
"exceeds the value of 10…"
"a median value of 1000…"
Remember to always state units throughout
Response: Duly amended.

12. line 204 - 205
"up to two orders of magnitude compared with the magnetic component."
State that it is the ratio between the two which varies, from X up to ~100, etc.
Response: Duly amended.

13. line 212
"Also note that this feature present during SIR disturbances as well."
Where on Figure 5 is this shown? It's not as obvious as the change during ICMEs.
Response: We have revised this sentence as follows:

"Note that this feature, even though it is not that obvious, may be important during SIR disturbances as well. As shown in the bottom right panel of figure 5, the DLL ratio at L*>5.5

is decreased from approximately 100 to approximately 1 at +-3 hours from t0. We suggest that this difference in the DLL ratio between ICME and SIR--driven disturbances is probably attributed to the existence (or not) of shocks, which produce significant increase of the dynamic pressure and accompany, more often, the ICME--driven events."

14. end of Section 3
In Section 3.1, line 124, the authors explain how the energy/first invariant dependence of DLL does not significantly change the CCs shown in Figure 2. Can the same be said for the ratio of DLLE to DLLB shown in Figure 4, for example, if DLLB is energy dependent, does it still increase above DLLE at other energies? A few words addressing this would be sufficient. However it is also necessary to elaborate on the following:
"Furthermore, at L*> 6, the DBLL is comparable to the DELL up to approximately 12 hours after t0."
I am having trouble seeing this on Figure 5. What is meant by "comparable?" The conclusion on line 214 that DLL becomes energy dependent due to higher DLLB is only valid during the period following a disturbance, I presume. Therefore, it should be made clear how long this lasts, and what is the ratio of DLLE/DLLE, in order to show the reader this effect is important for radiation belt simulations.
Response: The following sentence has been added concerning the energy dependence of the DLLB:

"Furthermore, this feature is expected to be dependent on the first adiabatic invariant as well, since greater values of μ produce greater values of DLLB, which will consequently lead to changes in DLL ratio. It is also expected that, except the magnitude, the change in μ will affect both the duration and the L* coverage of this feature as well. In a future study we intend to investigate in greater detail these changes."

We have further clarified the duration of the DLLratio<1 as follows:

"This feature changes dramatically during ICME driven disturbances and around +- 6 hours from the maximum compression of the magnetetopause where the DLL ratio decreases below 1 at all L* values. Furthermore, at L*>6, the DLL ratio is approximately 1 up to 12 hours after t0."

15. section 4 / figure 7
"As shown in the 500 keV electron energy, simulation results exhibit more injections at high L* (4<L*<5.5) both during the relatively quiet period on early March and during the intense St. Patricks storm when using the calculated DLL…"
The injection events in Figure 7 seem to correspond to an external source of particles becoming trapped due to magnetic variability. Does this process involve diffusion? I am not sure why the different DLL leads to more injections.
The SafeSpace results do seem to show some improvement, but it would be better if the authors also addressed the disagreement between the MagEIS data and Salammbo results in either case, since it appears to be significant. I assume this disagreement is not just due to DLL, but rather a number of modelling factors.
Response: We thank the reviewer for the constructive comment. Indeed the word "injection" may have been misleading since it is more often than not used to describe the substorm injections. Here we are referring to transport/diffusion of low energy electrons from higher L-shells (beyond GEO), which of course is often combined with substorm injections. Therefore, we have replaced the term "more injections" with "more intense radial transport".

The disagreement between Salammbo and MagEIS data comes rather from the fact that we have not used the energy diffusion term in the simulations. As reported in several studies, the in-situ acceleration due to energy diffusion via chorus waves is usually more important for the enhancement of 1-2 MeV electrons. Therefore we have added the following sentence in the manuscript: “We note that the magnitude of the flux in the Salammbo simulation is not expected to agree with the MagEIS data due to the lack of the energy diffusion term (in-situ acceleration by VLF chorus waves), which for the St. Patrick's event of 2015 has been shown to be crucial especially for 1-2 MeV electrons (Li et al. 2016).

- W. Li, Q. Ma, R. M. Thorne, J. Bortnik, X.-J. Zhang, J. Li, D. N. Baker, G. D. Reeves, H. E. Spence, C. A. Kletzing, W. S. Kurth, G. B. Hospodarsky, J. B. Blake, J. F. Fennell, S. G. Kanekal, V. Angelopoulos, J. C. Green, and J. Goldstein. Radiation belt electron acceleration during the 17 March 2015 geomagnetic storm: Observations and simulations. Journal of Geophysical Research (Space Physics), 121:5520–5536, June 2016. doi: 10.1002/2016JA022400.