

Dear reviewers,

Happy holidays and thank you for taking your valuable time to read and evaluate this manuscript. I have addressed your comments and made the necessary changes to the manuscript. In this letter, my responses are marked in **green** and your simple suggestions that do not warrant a detailed response are marked **done**.

In addition to your comments we made a minor change to the appendix figure A1 that was requested by one of the authors. The scatter plot points and error bars in Figure A1, panels a and b, were updated using the identical method used in the Agapitov et al., 2018 study. This change does not affect the main results, and Figure A1 panel c is the same.

#### **Reviewer 1**

By using observations from the twin AC6 CubeSats, authors statistically studied the size of >35 keV electron microburst, which is typically considered as chorus-driven precipitations. The obtained size is a few tens km in low earth orbit (LEO) and within 200 km when mapping to the equator. This is roughly consistent with previously reported scale size of microburst (10s km) and chorus packets (100s km). To the reviewer's knowledge, this paper, for the first time, calculated the scale size of >35 keV electron microburst in a statistical sense, by taking the advantage of the high time resolution (10 Hz) and close conjunctions of a pair of AC6 CubeSats. The objectives are compelling and the manuscript is well-organized and well-written. This reviewer recommend the manuscript to be published in JGR after addressing the following comments.

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Major comments

Several essential technical details should be specified.

(a) Lines 151-155, Please define the burst parameter and how this parameter as well as the selected threshold value works in identifying microbursts.

**I defined and explained the burst parameter in the manuscript, closely following the arguments in O'Brien et al., 2003.**

(b) Lines 168-169, Please specify the time window for the CC and AC calculations?

**The AC window was two seconds wide and CC window was one second wide. This has been added to the manuscript.**

(b) Lines 182-185, Is there an overlapped time period between two successive CC calculations? Is there a time lag introduced to the CC calculation?

I tidied up that section and mentioned that the correlation value assigned to each microburst was the maximum of three correlations between the 1 and 1.2 second windows. Two correlations with the window start and end times aligned, and one with the windows centered.

(c) Lines 182-185, The time window to calculate the CC is 1 or 1.2s, which is small and can sometimes be smaller than the duration of one microburst event such as the example in Figure 2e. Is this time window good enough for these long duration microbursts? How is the result sensitive to the time window, for example, what is the statistical size of microburst if the authors apply a 2s time window?

Thank you for pointing out the ambiguity with our choice of the CC window sizes. We chose one second CC window to encompass at least one typical microburst while avoiding correlating the background as well. We took your advice and ran our analysis with a 2 and 2.2 second correlation windows and verified the resulting dataset by eye. While there were some microbursts that were highly correlated with 1 second window but not highly correlated with a 2 second window, the LEO distribution of microbursts as a function of separation was almost identical – the < 20 km drop off and the 60-70 km bump remain.

Lines 230-233, The second peak exists only at 70-80 km for different L ranges is surprising, considering the data samples are still large ( $> \sim 1000$ ; Figure 3c). If this is caused accidentally by limited events, it is not expected to exist in all the four L ranges. If this is due to a two-size microburst distribution, although this is not realistic, there should have more events within the 30-60 km separation bins, considering a huge number of samples in these bins. Do authors have a reason for it?

We apologize and there was no 70-80 km peak, the peak is at 60-70 km. This has been fixed. We believe the peak is likely a combination of multiple factors that contribute to an imperfect normalization. AC6 observed 101 microbursts in the 30-60 km separation bins and 53 in the 60-70 km bins so there was a significant number of microbursts observed. Many of the microbursts in the 60-70 km bin were observed during a small number of radiation belt passes during which AE was consistently above 400 nT - at one time above 700 nT. Thus, it may have been an unusually active period when AC6 separation was approximately 65 km which would bias the microburst distribution in a way that is difficult to normalize by the hours of observation at that separation. Unfortunately, we do not have enough microburst detections to split up the distributions by geomagnetic activity. In conclusion, the reality is that our normalization is not perfect.

Is it possible to add some discussion on how does the microburst scale size change versus L shells? The authors have already divided the results into four L shell ranges, but few descriptions are made regarding this point. It will be a valuable information to describe the microburst scale size vary as L shell changes and comparing it to the trend of chorus scale size.

Thank you for your comment, we added a sentence that says that the data does not show a clear trend in L on lines 236-237. The reason we looked for an L-dependent microburst size distribution is that recent studies of chorus wave sizes do not agree on if the chorus wave size increases at higher L shells. For example, Shen et al., 2019 found that chorus size is larger at larger L shell, but Agapitov et al., 2018 did not find such a trend. Unfortunately, these two papers cannot be directly compared because Shen et al., 2019 estimated the correlation size distribution, while Agapitov et al., 2018 estimated the amplitude

size distribution.

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Minor comments

Line 39 'complete loss'. Sub-second electron Microbursts are typically caused by wave-particle interactions due to chorus wave via pitch angle scattering process, whose efficiency has energy and pitch angle dependences. Without specifying the electron energy and pitch angle, I would recommend to reword 'complete' to other words like 'significant', 'dramatic', etc.

Done

Lines 175-177, Please explain why not include events that are only observed by one of the two satellites? Most of these events are caused by the s/c separation is larger than the microburst size. By including them may potentially make the Figure 3a drops faster.

We included the coincident microburst observations because we are certain that those microbursts were larger than the AC6 separation. For microbursts observed by only one spacecraft we have no size information whatsoever. For example, as Fig. 5d shows, 40 km microburst has only 20% probability of being observed by both spacecraft even when the AC6 separation is 20 km. This is the reason we developed the analytic and Monte Carlo models - to account for the random chance that microbursts are observed together by AC6 vs individually.

Figure 3a and 3b, Is it possible to shift each point to match the center of each bin in Figure 3c for an easier way to see the one-to-one correspondence? Same for Figure 4.

Done.

## Reviewer 2

This paper uses AC6 data along with model results to determine the likely size of microburst populations in the radiation belt. It is a useful study to the community, furthering knowledge of microburst populations and driving mechanisms, and could be published with some moderate clarifications and corrections.

### Moderate clarifications and corrections

Lines 139-140: Is the small precession in MLT a limitation of your study? If so, this should be discussed later in the paper.

I would not consider this a limitation; but rather a tradeoff. For three years AC6 sampled in the 8-12 MLT region where microbursts are most likely to be observed (from prior studies). As I mention towards the end of the manuscript, a homogeneous MLT coverage would be great as it can shed more light on the bimodal microburst population, but the tradeoff is poorer microburst size statistics in the region where microbursts are typically observed. I added a condensed version of this response to the manuscript.

Figures 3 & 4: Is it important that the AC6 microburst size histograms are divided into L bins? This doesn't seem to factor into the subsequent discussion.

Thank you for your comment, we added a sentence that says that the data does not show a clear trend in L on lines 236-237. The reason we looked for an L-dependent microburst size distribution is that recent studies of chorus wave sizes do not agree on if the chorus wave size increases at higher L shells.

For example, Shen et al., 2019 found that chorus size is larger at larger L shell, but Agapitov et al., 2018 did not find such a trend. Unfortunately, these two papers cannot be directly compared because Shen et al., 2019 estimated the correlation size distribution, while Agapitov et al., 2018 estimated the amplitude size distribution.

Lines 255-261: Consider expanding this paragraph greatly, or publishing Appendix A as a separate paper – doesn't seem associated with the rest of the work.

Thank you for pointing this out. Our intention with Appendix A was to motivate, and take the first step towards one possible future analysis that can build on these results.

Figures 3 & 4: Why are a) and b) shown as lone plots when they are histograms? This makes them appear to be continuous functions.

We made the choice just for esthetic reasons. We tried to use a bar plot, but all the bars overlap and are very messy.

Lines 276-277: Why is the microburst footprint assumed to be circular? Please clarify.

We assumed a circular footprint for simplicity, adding more free parameters quickly makes this problem extremely difficult to solve analytically. Furthermore, the numerical model will have unconstrained parameters that will diminish its usefulness.

Section 5.3: Are the microburst size model results at the equator or in LEO? This is not clear in the text.

The model results are for the LEO microburst size distributions. I clarified this in the subsection title and the subsection text.

Please make sure that all figure captions are fully explained and expanded in body text. Some of the figures appear to be most fully explained in the caption, and that makes reading the text a bit disjointed (see Figure 5).

We expanded the figure captions in main text, including Figure 5.

### **Minor clarifications and corrections**

Lines 74-90: Did these studies discuss the energies of their observed microbursts?

There is limited energy discussion in these papers since their X-ray instruments had an integral channel above e.g. 15 or 30 keV. Thus, they were most sensitive to sub-hundred keV X-rays microburst signatures. I mentioned this in the manuscript.

Lines 103-108: Does 'microburst size distribution' refer to microburst spikes, packets, or regions?

It refers to the distribution of individual microbursts. That sentence was tidied up.

Lines 154-155: What is 'good'?

We checked other burst parameter thresholds near 5, and we found that the LEO microburst distributions did not qualitatively change. We chose the threshold of 5 because it balances: a large number of microbursts identified and confirmed by two authors, while limiting the number of detections triggered by non-physical noisy spikes.

Lines 253-254: Is the PDF trend in Figure 3 and 4 actually similar?

We only intended to draw attention to the qualitative nature of the two plots. We have added this qualifier and changed the emphasis to the CDF curves.

Line 314: Small typo: “must less” -> “must be less”

Done

Line 432: Does nature prefer a microburst PDF? What do you mean? Maybe it's the PDF that nature most resembles?

Done