Electron Microburst Size Distribution Derived with AeroCube-6

Response to Reviewer Feedback

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21 December 2019

Dear reviewers,

Thank you for taking your 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.

**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 at 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. Two 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 70-80 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 (> ~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?

Here is my attempt

We are wondering the same thing and we think it is a combination of multiple factors. First, AC6 observed about the same number of events per bin, ~100 microbursts in the 30-60 km separation bins and ~50 in the 70-80 km bins. Thus AC6 observed roughly 33 microburst in each 10 km bin between 30 and 60 km separations. We looked at the AE index during the 30-60 km and 70-80 km microburst observations and we found that the median AE for the 70-80 km events was about 100 nT higher. Furthermore, many of the events in the 70-80 km bin were observed over a small handful of passes during which AE was high. Our point with these subtleties is that the normalization can never be perfect.

One explanation is that while AC6 were separated by 70-80 km they had a small number of outer radiation belt passes with high AE > 400. While AC6 were separated between 30 and 60 km there were relatively less microbursts observed at higher AE. Microburst occurrence rate increases with AE so AC6 may have been sampling a particularly active time period while it was separated between 70 and 80 km. AC6 observed these microbursts over a range of L shells because the entire radiation belt pass was active. We also can almost never normalize perfectly.

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 235-236. 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 at al., 2019 found that chorus size is larger at larger L shell, but Agapitov et al., 2018 did not find such a trend. These two papers cannot be directly compared because Shen at 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-partical 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 did not include every microburst observed by one or the other spacecraft because there are almost one hundred thousand microburst detections from observed by both spacecraft and it is very time consuming to visually confirm that each detection was a microburst.   
  
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.

**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 an obvious trend in L on lines 235-236. 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 at al., 2019 found that chorus size is larger at larger L shell, but Agapitov et al., 2018 did not find such a trend. These two papers cannot be directly compared because Shen at 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).

My apologies for the disjointed figure explanations and I expanded the main text around 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.

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

It refers to the distribution of individual microbursts. I changed the wording and I hope it is clearer.

Lines 154-155: What is ‘good’?

Not sure about this

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

Not sure how the reviewer wants me to respond. Manuscript says “The equatorial PDF trend is similar to LEO and most of the microbursts were observed when the AC6 equatorial separation was less than 200 km.” Maybe I should reword is to: “The equatorial F(s) drop off at small equatorial separations is similar but scaled to the similar feature in the LEO F(s). Most of the microbursts were observed when the AC6 equatorial separation was less than 200 km.”

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