

## Response to Reviewers

### Reviewer 1

This paper studies the response of the magnetotail and the auroral electrojet to geomagnetic storms driven by corotating interaction regions (CIR) or stream interaction regions. The wavelet and cross-wavelet analyses and Fourier transform of the IMF Bz, the magnetotail Bx, and the AE index show the characteristic periods of fluctuations of these parameters, the correlations between them, and the spectral index for the storm main and recovery phases, including the characteristic substorm cycles and the large spectral index during the storm recovery phase or possibly high-intensity long-duration continuous AE activities (HILDCAAs). The results are interesting and will potentially deepen our understanding of the coupling of the solar wind, the magnetosphere, and the ionosphere during storms. I think that the manuscript is relatively well organized and written. I, however, have a few concerns listed below to be considered before I can recommend accepting this paper for publication. In particular, I am concerned about the new points of this study, the magnetotail Bx, and the cone of influence for the wavelet analysis.

We thank reviewer 1 for the constructive comments that will help improve the quality of our paper. We have addressed each point below.

I think that the consistency with previous studies are well described, but it seems to me that it is necessary to describe or emphasize what are the new points or the differences, compared with previous studies.

Thank you for your consideration; we agree with your assessment. While our results align with previous findings regarding the periodic response of the magnetosphere (e.g., Korth et al., 2006; Echer et al., 2017), our study provides a broader statistical basis by analyzing 40 CIR-driven storms over a 15 year period (2001–2016). Furthermore, we distinguish the magnetotail response between the main and recovery phases and offer a quantitative comparison of turbulence levels. We have emphasized these novel contributions in the revised manuscript (lines 858–865).

Lines 91-96: In general, the observed magnetotail  $|B_x|$  increases during the substorm growth phase, associated with energy accumulation and plasma sheet thinning, while

$|B_x|$  decreases during the substorm expansion phase, associated with energy release and plasma sheet thickening. On the other hand,  $|B_x|$  has a spatial variation, that is, the polar-orbiting Cluster spacecraft observe the relatively small  $|B_x|$  in the plasma sheet and the large  $|B_x|$  in the lobe. This spatial variation is observed not only by the spacecraft motion but also by flapping motion of the magnetotail. To remove the spatial (Z-directional) variations in the magnetotail  $|B_x|$ , I suggest that instead of  $B_x$ , the lobe magnetic field be used, which can be estimated from the total pressure (the sum of the plasma (ion) and magnetic pressures), assuming the total pressure balance in the Z direction in the magnetotail:  $B_{\text{lobe}}^2/2 \mu_0 = NkT + B^2/2 \mu_0$ .

To address the spatial variations in  $B_x$  caused by spacecraft motion and magnetotail flapping, we implemented a detrending method based on the Haar wavelet transform (Bolzan et al., 2020). This approach decomposes the magnetic field time series into dyadic scales, allowing for the isolation of specific frequency components. By identifying and removing the scales associated with long-term periodicities and orbital trends, we effectively filter out the spatial 'noise' while preserving the high-frequency physical characteristics of the substorm events. We have included this information in the revised manuscript (lines 187-190).

Lines 249-251 (for all wavelet spectrograms): As the authors wrote, the wavelet power outside the cone of influence should be discarded due to edge effects. The discarded wavelet powers occur in the interval of interest (the interval of the plot) in the present analysis. Hence, to make the meaningful interval longer, particularly for long-period variations, I suggest that the interval of wavelet analysis be extended behind and ahead, from  $\sim 8$  hours or half a day before the beginning of the plot to  $\sim 8$  hours or half a day after the end of the plot (in the case of Figure 4, from 7 or 11 UT on August 31 to 16:40 or 20:40 UT on September 1 for the wavelet analyses), and then the additional intervals before and after the interval of the plot be cut (for Figure 4, show only the data from 19 UT on August 31 to 08:40 UT on September 1). Thus, this method will make the wavelet powers shown in the figures meaningful (inside the cone of influence).

The authors appreciate the reviewer's suggestion regarding the extension of the analysis interval to mitigate edge effects. We have performed tests with extended data windows for some cases and confirmed that the dominant periods remain the same. More importantly, we would like to clarify that all spectral peaks discussed and interpreted in this study are strictly located inside the cone of influence, where edge effects are negligible.

Minor comments:

Lines 101-103: What criterion (or minimum Dst or Sym-H) did this study adopt to define the geomagnetic storms? It should be written in the text.

The selection criterion followed the classification proposed by Gonzalez et al. (1994), where a moderate geomagnetic storm is defined by a minimum Dst peak value in the range  $-100\text{nT} \leq \text{Dst} \leq -50 \text{ nT}$ . We have added this definition to the manuscript (lines 203–206).

Figures 1 and 2: Please draw the line of IMF  $B_z=0$  in the top-left panel to identify the southward  $B_z$  easily.

Thank you for the suggestion. We have added a horizontal dashed line at  $B_z=0$  in Figures 1 and 2 to facilitate the identification of southward IMF intervals.

Lines 183-184: Please write the substorm signatures (AE increase and tail  $|B_x|$  decrease) specifically in the previous paragraph or somewhere.

Thank you for the recommendation; it will be included in the updated version of the manuscript (lines 345-347).

Line 246: The variation is not quasiperiodic but quasicontinuous?

Thank you for the correction. We have changed "quasiperiodic" to "quasicontinuous" in Line 246.

Line 265, Figure 5: The period ranges (or the maximum period range) for the histograms are different for different panels. For easier comparison between the three parameters and the two storm phases, it is better to make the format of the plot the same for all panels by showing all the period ranges, 0-2, 2-4,..., and 10-12 hours, even if the percentage is 0%.

Thank you for the suggestion; it has been included in the updated version of the manuscript.

Line 299 (Figure 6): What are the definitions of the four categories of local, intermittent, quasi-continuous, and continuous? They should be written in the text.

These classifications refer to the persistence of the correlation/power in the wavelet spectrum. Local: Power/correlation restricted to a short time interval. Intermittent: Appearing and disappearing at intervals. Quasi-continuous: Present for most part of the time. Continuous: Present throughout the entire duration of the analyzed interval. We have added this definition in the text (lines 258-268).

Figure 11: Do the upper panels show the results of event 7 of the storm main phase? And do the bottom panels show the results of event 1 of the storm main phase? These events should be mentioned in the text and in the figure caption. Confusingly, the authors discuss the mean values in the text, but Figure 11 seems to show the results of the specific events.

We apologize for the confusion. We have now clarified in the text (lines 767 and 832) and in the caption of Figure 11 that the upper panels refer to Event 7 and the bottom panels represent Event 1. Furthermore, we have made it clear that this figure serves

as an example of the applied method, whereas the discussion in the text is based on the mean values of all analyzed events (Tables 2 and 3).

Other minor corrections:

Throughout the text: Units should be written in roman, not in italic (for example, km s<sup>-1</sup> at line 30).

Done!

Line 15: both storm phases --> both storm main and recovery phases

Done!

Line 28: Add Schwenn (2006) to the references list.

Done!

Line 33: Add Sanchez-Garcia (2023) to the references list.

Done!

Line 42: Add Echer et al. (2013) to the references list.

Done!

Lines 83 and 86: I think "between" is better than "among".

Done!

Line 90: http --> https

Done!

Line 99: http --> https

Done!

Line 101: Leymory --> Iyemori

Done!

Lines 151 and 152: Write the units of Dst: -100 nT and -250 nT.

Done!

Line 255: Add Souza et al. (2018) to the references list.

Done!

Line 274: Add "For the magnetotail Bx," before "Although the range between 2 and 4 hours...."

Done!

Line 280: Delete "in the tail".

Done!

Line 317: Delete the comma after "both".

Done!

Line 387: MP and RP should be spelled out.

Done!

Line 466: Delete the comma after "Similarly".

Done!

Line 489: B= --> Bx

Done!

Line 525: Add "https://" before "wdc.kugi...".

Done!

Line 526: Add "https://" before "omniweb.gsfc...", and delete the space between "...gov/" and "form/...".

Done!

Line 554: Cite Chian et al. (2024) in the text, or delete it from the references list.

Done!

Line 618: Lyemori --> Iyemori

Done!

Line 646-647: The information of Runov et al. (2005) seems incorrect. Please correct it.

Done!

Figure 3, the middle panel: The title of this panel seems to be wrong. "IMF Bx" should be "Tail Bx" or something like that.

Thank you. We corrected it in the updated version of the manuscript.

Citation: <https://doi.org/10.5194/egusphere-2025-4911-RC1>

## Reviewer 2

The paper "Magnetotail response to corotating interaction region driven geomagnetic storms: Cluster observations" by Adriane M. de S. Franco et al. is a high standard statistical study of energetic fluctuations IMF Bz, magnetotail Bx and AE index, and their inter-correlations during CIR-driven storms. The manuscript is generally well written with clear structures. Important statistical results of wavelet and cross-wavelet analyses were shown and the conclusion is clear and interesting. I highly recommend the manuscript to be published with minor revisions.

The authors thank the reviewer for the positive evaluation and the recommendation for publication. We appreciate the recognition of the statistical analysis and have addressed the minor revisions suggested to improve the manuscript.

### 1. Figure 1 and Figure 2

1. The horizontal dash line is hard to see in the Bx panel. Adding a line indicating  $B_z = 0$  in IMF Bz penal will also help readers to observe the southward Bz.

Done.

2. It will be nice to see longer duration so one can have a full view of the storm

Done.

3. Similarly, including solar wind pressure and velocity will help readers with different backgrounds

Done.

4. Some color marks/boxes/indicators that correspond to the descriptions in the text should help the reader to follow the content. It is difficult to follow line 155-170 without a better indication of what is mentioned in the text.

Done.

2. Figure 6 and text mentioned it: What are the definitions of the continuous behavior category? What are their significance and physics meanings? Please include it in text.

Regarding Figure 6, we define the categories of wavelet power persistence according to their temporal duration and physical significance (Souza et al., 2016) : Local indicates power restricted to short intervals, representing transient phenomena like bursty bulk flows. The Intermittent characteristic describes features appearing and disappearing at intervals, reflecting recurrent or stochastic processes. The Quasi-continuous distribution denotes signals present for most of the duration, suggesting a sustained but modulated response to solar wind drivers. Continuous classification refers to power persisting throughout the entire interval, signifying a steady-state, stable coupling between the solar wind and the magnetosphere. We have incorporated these definitions into the revised manuscript to clarify the physics behind the magnetotail response (lines 258-268)

Citation: <https://doi.org/10.5194/egusphere-2025-4911-RC2>