

## Reply to Reviewer #1 comments:

Reviewer #1: angeo-2024-9

Title: A two-step geospace storm as a new tool for experimentally estimating the threshold condition for the formation of a substorm current wedge

Author(s): Leonid Chernogor

MS type: Regular paper

Iteration: Minor revision

Dear Anonymous Referee #1,

Thank you very much for your comments. Authors' reply and changes in the manuscript are marked **in green**.

The author is grateful to Anonymous Referee #1 for the valuable comments that have helped Author greatly improve the draft of his paper.

Sincerely,

Author.

Thank you for your revision following the previous comments. This manuscript has a great improvement. At the same time, some issues still need to be solved before publishing. Special issues are as follows:

1. Figure 3. I suggest using different colors for the line shapes of two sets of data in these figures.

Dear Anonymous Referee #1, Thank you very much for this comment. Figure 3 has been redone.

2. Section 4 Data analysis: I suggest merging this section into Section 5 Discussion.

Dear Anonymous Referee #1, Thank you very much for this comment. Sections 4 and 5 have been merged.

3. Reference: I suggest adding literature on the application of the results to reflect the possible application areas of the results and highlight the research significance of the paper.

Dear Anonymous Referee #1, Thank you very much for this comment. The following paragraph has been added at the end of Section 4 Discussion (Line 269–274):

The results obtained are of importance for both achieving the fundamental physical understanding and a quantitative assessment of energy storage in the ionosphere-magnetosphere system and its release via a partial diversion of the ring or tail current into the ionosphere through field-aligned currents. The ionospheric perturbations produced by the energy release can also be of importance to radio communications, including HF radio communications (CEDAR: The New Dimension, [https://cedarscience.org/sites/default/files/2021-10/CEDAR\\_October\\_V9.2.pdf](https://cedarscience.org/sites/default/files/2021-10/CEDAR_October_V9.2.pdf), last access October 15, 2024, 2010; Wang et al., 2022; Wang et al., 2023).

### References

CEDAR: The New Dimension, [https://cedarscience.org/sites/default/files/2021-10/CEDAR\\_October\\_V9.2.pdf](https://cedarscience.org/sites/default/files/2021-10/CEDAR_October_V9.2.pdf), last access October 15, 2024, 2010

Wang, J., Yang, C., and An, W.: Regional Refined Long-term Predictions Method of Usable Frequency for HF Communication Based on Machine Learning over Asia, *IEEE Trans. Antennas Propag.*, 70, 4040–4055, DOI: [10.1109/TAP.2021.3111634](https://doi.org/10.1109/TAP.2021.3111634), 2022.

Wang, J., Shi, Y., Yang, C., Zhang, Z., and Zhao, L.: A Short-term Forecast Method of Maximum Usable Frequency for HF Communication, *IEEE Trans. Antennas Propag.*, 71, 5189–5198, DOI: [10.1109/TAP.2023.3266584](https://doi.org/10.1109/TAP.2023.3266584), 2023.

Referee Report: [angeo-2024-9-referee-report.pdf](#)

Dear Anonymous Referee #1,

Author is deeply indebted to you for the numerous useful comments that have been fundamental for rewriting the manuscript.

Sincerely,

Author.

## Reply to Reviewer #2 comments:

Reviewer #1: angeo-2024-9

Title: A two-step geospace storm as a new tool for experimentally estimating the threshold condition for the formation of a substorm current wedge

Author(s): Leonid Chernogor

MS type: Regular paper

Iteration: Minor revision

Dear Anonymous Referee #2,

Thank you very much for your comments. Author's reply and changes in the manuscript are marked **in turquoise**.

Sincerely,

Author.

Dear author,

I am pleased to recommend the acceptance of this manuscript for publication after minor technical corrections. The study presented by the author significantly advances our understanding of the relationship between geospace storms and substorm current wedge formation. By analyzing data from the INTERMAGNET magnetometer network, the author effectively demonstrates the latitude dependence of geomagnetic field variations during the severe geomagnetic storm that occurred from April 23 to 24, 2023. This innovative approach provides valuable insights into energy transfer processes between the ionosphere and magnetosphere, highlighting the complexities of geosphere interactions.

The author has well organized the content structure of the article, clearly presenting the background, methods and results of the research, so that readers can smoothly understand the core ideas of the research. The experimental design of the paper is reasonable. By analyzing the severe geomagnetic storm data from April 23 to 24, 2023, it reveals the relationship between the change of the geomagnetic field and the formation of the substorm current wedge, which has important scientific value. At the same time, the data analysis in the paper is based on the INTERMAGNET magnetometer network (open data sources), which enhances the reliability and repeatability of the research.

The manuscript's strength lies in its rigorous analysis of geomagnetic fluctuations across different hemispheres, which reveals crucial threshold conditions for substorm current wedge formation. The identification of  $B_z$  values ranging from  $-(22-30)$  nT as critical for wedge formation significantly contributes to the existing body of knowledge regarding geomagnetic disturbances. Additionally, the paper successfully contextualizes its findings within the broader literature on space weather, laying the groundwork for future research in this area.

While the manuscript is well-crafted, I believe there are some areas where further refinement could strengthen its impact. For instance,

- it may be beneficial for the authors to explore the broader implications of their findings for space weather forecasting and how they may affect technological systems.

Dear Anonymous Referee #2, Thank you very much for your comment. Indeed, regarding the implications of the results of this study for space weather forecasting and how they may affect technological systems, we do understand the needs of users of space weather products, which are articulated best of all, as follows: "We have a lot of geophysical data, but we are really starving for impact data" (in the report "RESULTS OF THE FIRST NATIONAL SURVEY OF USER NEEDS FOR SPACE WEATHER" (published on Tuesday, October 01, 2024 16:42 UTC at <https://www.swpc.noaa.gov/news/results-first-national-survey-user-needs-space-weather>)). However, it is impossible to estimate the impact of our modest findings for sure.

Nevertheless, Author hopes that many results of the work would be of use for modeling and forecasting the effects of geospace storms and their impact on space- and ground-based technological systems. The results obtained complement information described in [Bothmer and Daglis, 2006; Daglis, 2001; Koskinen, 2011; Moldwin, 2022; Song et al., 2001] referenced to in the manuscript.

- Additionally, including a discussion that situates their work within the context of previous research on geomagnetic storms could help emphasize the contribution of their study to the field (The author have indeed discussed a substantial body of literature in the introduction, I just recommend the author do it in more detail in discussion, to make a more comprehensive comparison, if possible).

Dear Anonymous Referee #2, Thank you very much for your comment. The threshold IMF  $B_z$  estimated in this study and the technique identified for its determination complement the results obtained by the authors listed in the introduction.

To further enhance the manuscript, I would appreciate the opportunity to discuss a few questions/possibilities with the author:

- Maybe the identified critical  $B_z$  values contribute to future space weather prediction efforts?

Dear Anonymous Referee #2, Thank you very much for your comment. Author hopes so, yes. A further investigation of IMF  $B_z$  thresholds using the identified technique would contribute to the better understanding of storm dynamics and forecasting.

Besides, we have specified the paper title as follows:

A two-step geospace storm as a new tool of opportunity for experimentally estimating the threshold condition for the formation of a substorm current wedge

•Have the authors considered other factors, such as Seasonal Effects, that may influence the formation of substorm current wedges?

Dear Anonymous Referee #2, Thank you very much for your comment. We have made just a single estimate of the possible thresholds so far, therefore considering other factors would be just pure speculation.

•I am interested in the author's future research plan in this topic. Because I noticed the author has a lot of experience in this research direction. If the author is willing to give some discussion or suggestions in this regard, it will be very helpful and inspiring to scholars and readers in the same industry

Dear Anonymous Referee #2, Thank you very much for your comment. The future research on this topic is no doubt needed to confirm our conclusions, and the plan therefore includes (1) validation of the features discovered in this study, (2) determination of thresholds for other storms, and (3) modeling the formation of the current wedge. (Line 257–267 as well as 269–274).

I look forward to engaging with the authors on these points and contributing to the improvement of this important work. Overall, I commend the author for this important contribution and look forward to the minor technical revisions that will enhance its clarity and relevance.

Dear Anonymous Referee #2, I am pleased to thank you very much for your words of encouragement and kind offer of contributing to improvements to this work.

Author is grateful to Anonymous Referee #2 for the valuable comments that have helped Author greatly improve the draft of his paper.

Sincerely,  
Author.