

Dear Anonymous Referee #1,

Thank you very much for your comments.

Your comments are marked in yellow, Author's answers and changes in the manuscript are marked in green.

This paper has analyzed the characteristic features of a major two-step geomagnetic storm during 23–24 April 2023 based on the data available at the INTERMAGNET magnetometer network. This study is interesting and gets meaningful conclusions. This observation of the substorm current wedge phenomenon provides the basis for studies utilizing the datasets collected with ground-based magnetometers. Therefore this work can be acceptable after a major revision. Specific issues are as follows:

1. **Abstract:** The abstract should be organized into five aspects: background, purpose, methods, results, and conclusions. It should particularly emphasize explaining the research background, meaning and main achievements of this manuscript.

Dear Anonymous Referee #1, Thank you very much for this comment. We have added research background, meaning and main achievements of this manuscript at the very beginning of Abstract, which is given by

In the study of coupling processes acting within the upper atmosphere, a major challenge remains in quantifying the transformation of energy. One of the energy pathways between the ionospheric heights and the magnetosphere is the diversion of the cross-tail electric current into the ionosphere through the current wedge. This study suggests that there is an interplanetary magnetic field  $B_z$  component threshold for the formation of a substorm current wedge. Its magnitude may be estimated from observations with ground-based magnetometers in the case of a two-step geospace storm.

2. **Introduction:** There are numerous instances of multiple references cited together, such as

Line 47: "... a large number of studies (see, e.g., (Gonzalez et al., 1994; Laštovička, 1996; ..."

Line 53: "... affect human health (Daglis, 2001; Freeman, 2001; Song et al., 2001; Carlowicz and Lopez, 2002; Moldwin, 2008)"

...

Please provide a detailed explanation of the inspiration each of these references brings to the manuscript.

Dear Anonymous Referee #1, Thank you very much for this comment. We have provided information on why these references are relevant to the manuscript. They are marked in green in Introduction.

1. **Introduction:** To explain more clearly, the organizing structure of this paper should be explained at the end of the Introduction.

Dear Anonymous Referee #1, Thank you very much for this comment. The organizing structure of this paper is presented at the end of Introduction, as given by

The paper begins with a description of the data being analyzed and the state of space weather. Next, the main results of data analysis, performed in detail in Appendix, are summarized, and the principle achievement of this study, the suggestion that an interplanetary magnetic field  $B_z$  component threshold for the formation of a substorm current

wedge can be estimated with ground-based magnetometers, is stated. The paper ends with a discussion of the results obtained and conclusions drawn.

2. **Figure 1:** To highlight and avoid confusion, it is recommended to represent the site in different colors.

Dear Anonymous Referee #1, Thank you very much for this comment. We have represented the sites in different color.

3. Current Section 2 only introduces data sources and observation stations, the title and text is inconsistent. Therefore, I suggest revising the title “2 Instrumentation and techniques” as “2 Data and materials”. And a detailed observed instrumentation and its working parameters should be added.

Dear Anonymous Referee #1, Thank you very much for this comment. We have revised the Section 2 title “2 Instrumentation and techniques” as “2 Data and materials”. The vector magnetometers included into INTERMAGNET network must meet the following specifications: 0.1 nT strength resolution, 1 sample/sec sampling rate, 5 nT/year long term stability (St-Louis, B. (Ed.), INTERMAGNET Operations Committee and Executive Council, 2020, INTERMAGNET Technical Reference Manual, Version 5.0.0).

4. **Section 3** presents the results of the second section, and it is recommended to merge them into one section.

Dear Anonymous Referee #1, Thank you very much for this comment. Section 2 describes the data (from INTERMAGNET magnetometers) the present study is based on, whereas Section 3 is concerned with analyzing the state of space weather, which is performed using the data from instruments specified in the Section 3 first paragraph, as follows:

The data involved in the analysis of space weather include the temporal variations of solar wind parameters (<https://omniweb.gsfc.nasa.gov/form/dx1.html>), the interplanetary magnetic field (IMF), the storm-time variation,  $D_{st}$ , and the three-hour planetary,  $K_p$ , indices (<https://wdc.kugi.kyoto-u.ac.jp/>), as well as calculated solar wind dynamic pressure and the Akasofu energy function, all of which are presented in Fig. 2.

Thus, there is no rationale for the merger of Section 2 and Section 3.

5. The main achievement of this study is the issues concerning the threshold condition for the formation of the substorm current wedge; this accomplishment is at the end of the paper as a conclusion. To highlight this, I suggest renaming the paper as, for instance, “A two-step geospace storm as a new tool for experimentally estimating the threshold condition for the formation of a substorm current wedge”.

Dear Anonymous Referee #1, Thank you very much for this comment. We have renamed the paper “A two-step geospace storm as a new tool for experimentally estimating the threshold condition for the formation of a substorm current wedge”.

6. **Section 4** “Analysis of magnetometer data” is suggested to be moved to the Appendix. This rearrangement puts the principle accomplishment of this study at the center of the text.

Dear Anonymous Referee #1, Thank you very much for this comment. We have moved Section 4 to Appendix.

7. **Figures 3-11:** Most of the data in the figures are difficult to see clearly. It is recommended to revise the drawing method to be easily seen by readers.

Dear Anonymous Referee #1, Thank you very much for this comment. We study a two-step severe geomagnetic storm that occurred over the interval ~18:00 UT on 23 April 2023 to ~24:00 UT on 24 April 2023. Thus, the days of interest are 23 April 2023 and 24 April 2023, and the plots for these days are clearly seen in Figures 3–11. Regarding the rest of the plots, they are acquired during a quiet time period, and they form a quiet time background, which does not provide any information.

8. Throughout the text two designations of universal time can be found, UT and UTC. This should be fixed somehow. Figures 3-11, horizontal axis: UT (hours) is written, while (hh:mm) is indicated. Figures 12: horizontal axis: Universal Time (hours) is written, while (hh:mm) is indicated.

Dear Anonymous Referee #1, Thank you very much for this comment. We have corrected this untidiness. Now, the universal time is designated as UT throughout the manuscript.

9. Extensive English editing is required. Such as :

Line 13: replace “show” with “shows”

Line 40: replace “in Global Positioning System and in VLF navigation” with “in the Global Positioning System and VLF navigation”

Line 46: replace “storm” with “storms”

Line 95: replace “coordinares” with “coordinates”

Dear Anonymous Referee #1, Thank you very much for this comment. We have performed English editing of the text.

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

Sincerely,  
Leonid Chernogor.