# Response to Reviewer #1

**Manuscript Title:** *Atmospheric Tidal Variability and Gravity Wave Forcing During the January 19–21, 2026 Geomagnetic Storm*

Dear Reviewer,

We sincerely thank the reviewer for the careful and constructive evaluation of our manuscript. We greatly appreciate the comments regarding the physical interpretation, reproducibility of the SABER analysis, treatment of tidal and gravity-wave components, geographical and temporal sampling, and presentation of Figures 1 and 4–9.

We have carefully considered all comments and agree that the manuscript can be substantially improved by strengthening the methodological description, quantifying the quiet-time/storm-time differences more rigorously, ensuring better comparability of SABER observations, and distinguishing observational evidence from interpretation of the underlying physical mechanisms.

We have revised the manuscript accordingly. Our detailed responses to each comment are provided below. Reviewer comments are reproduced in **bold**, followed by our responses.

## General Comments

### Comment 1

This manuscript addresses an interesting and relevant topic by investigating the response of atmospheric tides and gravity waves to the January 19–21, 2026 geomagnetic storm using multiple observational datasets. The results are potentially valuable for understanding storm-time variability and thermosphere–ionosphere coupling. However, several of the physical interpretations appear stronger than what can be directly supported by the observations. In particular, the links to Joule heating, particle precipitation, enhanced dissipation, wave–mean flow interactions, and strong vertical coupling should be better supported and distinguished from observational correlations. I therefore recommend strengthening the quantitative analysis and clarifying the evidence supporting the proposed physical mechanisms before the manuscript can be considered for publication.

### Response

We thank the reviewer for this important observation. We agree that some statements in the original manuscript were stronger than could be directly supported by the available observations.

In the revised manuscript, we have therefore made a clear distinction between **observed responses** and **proposed physical mechanisms**. In particular, the observed changes in temperature, tidal amplitudes, gravity-wave activity, GWPE, heating flux, and radiative cooling are now presented as observational responses that are temporally associated with enhanced geomagnetic activity.

We have also moderated statements attributing these changes directly to Joule heating, particle precipitation, enhanced wave dissipation, and wave–mean-flow interactions. Where these processes are not directly measured, we now describe them as **plausible mechanisms that are consistent with the observations**, rather than as uniquely established causes.

For example, statements such as “directly indicate,” “confirm,” “definitive signature,” and “primarily attributed to” have been revised where appropriate to expressions such as “are consistent with,” “suggest,” “may reflect,” and “are temporally associated with.”

We have also added quantitative comparisons between quiet and storm periods, including [insert actual statistical measures: mean, median, standard deviation, percentage difference, and/or confidence intervals], to provide a more objective basis for the interpretation.

In particular, the revised manuscript now emphasizes that:

“The observations show measurable changes in atmospheric temperature, tidal-period variability, gravity-wave activity, and radiative cooling during the geomagnetically disturbed interval relative to the selected quiet-time intervals. These changes are temporally associated with enhanced solar-wind and geomagnetic activity and are consistent with storm-driven modifications of the thermospheric thermal and dynamical background. Because Joule heating and particle precipitation are not independently quantified in the present analysis, their individual contributions cannot be uniquely separated.”

This revision has substantially reduced the possibility of interpreting correlation as direct causation.

## Comment 2

The methodology is not sufficiently described to reproduce the analysis. The authors should clarify how the SABER profiles are selected and organized, how the FFT and CWT are applied, and how tidal and gravity-wave components are separated. In particular, the temporal sampling, altitude range, latitude/longitude coverage, and local-time coverage should be specified. It is also unclear how the latitude–altitude structures shown in Figures 4–9 are constructed from the individual SABER profiles**.**

## Response

We fully agree with the reviewer. The original description of the SABER data processing was too concise to permit complete reproduction of the analysis.

We have substantially expanded the **Data and Methods** section to describe the SABER data selection and processing procedure in detail. The revised manuscript now specifies:

1. SABER data product and version;
2. altitude range used in the analysis;
3. vertical sampling/resolution;
4. latitude range;
5. longitude range;
6. local-time range;
7. temporal sampling;
8. number of SABER profiles used;
9. quality-control criteria;
10. treatment of missing observations;
11. interpolation/gridding procedure;
12. construction of latitude–altitude distributions;
13. procedure used to obtain tidal-period components;

14. application of FFT;
15. application of CWT;
16. procedure used to obtain gravity-wave temperature perturbations; and
17. calculation of gravity-wave potential energy.

The revised methodology now explains that the individual SABER profiles are first screened according to the defined geographic, temporal, altitude, and quality criteria. The retained profiles are then organized according to latitude, altitude, and observation time. The latitude–altitude maps are constructed from these selected observations using the specified gridding/interpolation procedure.

We have also added the number of profiles contributing to each daily map and the relevant longitude/local-time ranges [insert exact values].

This revision is intended to ensure that another researcher can reproduce the data selection and processing steps.

## Comment 3

**I**n Figures 4–9, the panels in these figures are too small to clearly identify the amplitude values and other relevant details. Since the figures consist of 3 × 3 panels, a considerable amount of space between the subplots could be removed to enlarge each panel. I also recommend using the same color-bar limits for all subplots within each figure, which would allow a more direct visual comparison between the quiet and storm periods and better support the differences discussed in the text. This would also allow the figures to be simplified by using a single color bar for the entire figure. The altitude labels could be shown only on the left side of the complete figure, and the latitude labels only along the bottom**.**

## Response

We thank the reviewer for this useful recommendation and agree that the original figures were difficult to read.

Figures 4–9 have been reformatted to improve readability. Specifically:

- the spacing between subplots has been substantially reduced;
- the individual panels have been enlarged;
- common color-bar limits are now used for all panels within each figure;
- a single color bar is used for each complete figure;
- altitude labels are shown only along the left side;
- latitude labels are shown only along the bottom;
- the dates of the individual panels have been explicitly indicated; and
- unnecessary white space has been removed.

The revised presentation makes the quiet-time, storm-time, and post-storm structures more directly comparable.

## Comment 4

An important issue concerns the geographical and temporal sampling of the SABER observations used to construct the latitude–altitude plots. The manuscript should clearly indicate the longitude range represented in these figures and specify whether the corresponding times are given in UT or local time (LT). This is particularly important for the analysis of atmospheric tides and gravity waves, since differences in longitude and local time can produce significant changes in the observed structures independently of geomagnetic activity. The authors should clarify how the SABER profiles were selected and ensure that the quiet and storm-time observations are comparable in terms of longitude and local time**.**

## Response

We agree with the reviewer that this is a critical issue for interpreting tidal and gravity-wave variability.

In the revised analysis, we explicitly report the **longitude, latitude, UT, and local-time coverage** of the SABER profiles used to construct the latitude–altitude distributions. The revised manuscript now specifies [insert exact longitude range], [insert latitude range], [insert UT range], and [insert LT range].

More importantly, we have revised the profile-selection procedure to improve the comparability of the quiet and storm observations. The quiet-time observations are now restricted, as far as permitted by the available SABER sampling, to geographical and local-time intervals comparable to those represented during the storm period.

A new description has been added to the Methods section explaining this procedure.

We acknowledge that SABER does not provide continuous global temporal sampling at a fixed location. Therefore, we have also added an explicit limitation that residual differences in longitude/local time cannot be completely eliminated and may contribute to some of the observed spatial variability.

The revised manuscript therefore avoids attributing every spatial difference between quiet and storm observations exclusively to geomagnetic activity.

# Minor Comments

## Comment 1

**“**Punctuation: There are several instances where punctuation is missing or inconsistently used, particularly when listing multiple items. For example, this occurs in the final paragraph of the Introduction and in the first paragraph of the Conclusions. Please carefully check the manuscript and ensure that commas, periods, and other punctuation marks are used consistently throughout the text.”

## Response

Thank you for pointing this out. We have carefully proofread the entire manuscript and corrected punctuation errors and inconsistencies.

Particular attention was given to:

- commas in lists;
- periods at the ends of sentences;
- punctuation around equations;
- punctuation in figure captions;
- spacing between sentences and references;
- punctuation in the Introduction; and
- punctuation and formatting in the Conclusions.

We have also performed an additional language and formatting check throughout the revised manuscript.

## Comment 2

"Lines 160–161: The equation for the interplanetary electric field appears to be incorrect or incomplete after the equal sign. Please check and correct the equation and ensure that all terms are properly defined."

## Response

We thank the reviewer for identifying this error. We agree that the original expression was incorrectly written. The equation has been corrected and the coordinate/sign convention has been explicitly defined. The revised manuscript uses:

$E_y = -(V \times B)_y$ and, under the adopted GSM solar-wind approximation,
$E_y = -VxBz$.

The relevant variables and units are now explicitly defined in the text. Where solar-wind speed is expressed as a positive magnitude Vsw, the corresponding sign convention is also clearly stated. This correction has been incorporated into the revised manuscript.

## Comment 3

"Figure 1: I recommend showing the complete study period (16–30 January 2026), including both the quiet and storm periods, to provide a clearer overview of the data and geomagnetic conditions. I also suggest arranging all parameters in a single column to improve the figure layout and facilitate comparison."

## Response

We agree with this recommendation.

Figure 1 has been revised to display the complete study interval from **16 to 30 January 2026**, rather than focusing primarily on the storm interval. The revised figure now contains the following parameters in a single vertical column:

1. IMF components;

2. solar-wind velocity;

3. solar-wind dynamic pressure;

4. interplanetary electric field EyE_y;

5. Dst;

6. Kp;

7. ap; and

8. AE.

The storm interval of **19–21 January 2026** is explicitly identified in the revised figure, while the pre-storm quiet interval (16–18 January) and post-storm reference interval (28–30 January) are also shown. This provides a clearer overview of the geomagnetic conditions throughout the entire period used in the study.

## Comment 4

**"Figures 4, 6, 7, 8, and 9: These figures do not include data for January 19. Since January 19 corresponds to the beginning of the storm period considered in the study, the authors should clarify why this day is missing and, if possible, include the corresponding data."**

## Response

We thank the reviewer for identifying this inconsistency.

We have re-examined the SABER data availability and the profile-selection criteria for January 19, 2026. The original figures omitted January 19 because the SSC occurred at the end of the day and was considered as quiet time now we included in the revised one.

"We have now included the January 19 observations in Figures 4, 6, 7, 8, and 9. The revised figures therefore provide a complete representation of the three-day storm interval (19–21 January 2026)."

We believe that this clarification improves the transparency and reproducibility of the analysis.