Response to the Comments of Referees

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Title: Exploring the Mechanisms of Dust Emission and Transport based on Observations and GEOS-Chem Simulations

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We thank the reviewers and editor for providing helpful comments to improve the manuscript. We have revised the manuscript according to the comments and suggestions of the referees.

The referee's comments are reproduced (black) along with our replies (blue). All the authors have read the revised manuscript and agreed with the submission in its revised form.

Anonymous Referee #1

Review comments of "Exploring the Mechanisms of Dust Emission and Transport based on Observations and GEOS-Chem Simulations" by Zou et al., 2025

General comments

The authors present a detailed and well-documented case study of a dust storm originating in western Inner Mongolia that affected southern regions of China, including Hainan Island. The manuscript provides a thorough analysis of the physical processes driving dust emission, wet deposition, and long-range transport, and the comparison with historical records from the past 30 years as well as two recent dust storms is informative. However, while the results are clearly presented and internally consistent, many of the findings align closely with existing understanding of dust storm behavior. As a result, the study's broader scientific significance and novelty are somewhat limited.

The manuscript would benefit from improved conciseness. While the discussion of the physical factors controlling dust emission and transport (e.g., wind, temperature, soil moisture, and precipitation) is relevant and informative, this material is repeated in multiple sections of the paper (lines 143–154, 236–244, 247–248, 271–273, etc.). Consolidating these discussions would reduce redundancy and improve the overall flow of the manuscript.

We thank the reviewer for recognizing the detailed analysis and comparative work in this study, especially for the valuable suggestions to enhance the scientific significance and conciseness of the manuscript. In response to your suggestions, we have revised the manuscript while preserving the core scientific findings, as follows:

1. Highlighting the Scientific Significance and Novelty:

(1) Clarifying the Research Motivation: We have explicitly stated that the April 2025 dust event is a rare documented case of transport reaching Hainan Island, and that its ability to effectively transport southward under heavy precipitation conditions is distinctive (lines 78–84).

(2) Emphasizing Unique Findings: In section 4.3.2 and the Summary and Conclusion section., we have focused more on contrasting the fundamental differences in the combination of key driving factors between the 2025 event and two severe historical events. We highlight that the specific synergistic configuration of an abnormally southward-displaced and intensified Mongolian cyclone and an exceptionally strong and persistent Siberian High, along with the resulting special transport mode of “sustained strong northerly winds pushing dust and the rainband to move southward in coordination,” collectively constituted the key dynamic mechanism enabling the extreme southward transport. This specific configuration and process are uncommon in previously reported cases, thereby enhancing the uniqueness of the study.

2. Condensing Content and Eliminating Redundancy

We have systematically reviewed the entire manuscript and substantially consolidated or removed redundant discussions of controlling factors (wind, temperature, humidity, precipitation), particularly in the sections indicated by the reviewer.

(1) The text preceding Section 4.3.1 has been condensed, while the remaining relevant paragraphs have been retained and reorganized to ensure conciseness without compromising coherence.
(2) Subsequent chapters now focus on presenting data, conducting comparisons, and delving into the specific, underlying mechanisms behind the observed differences, thereby directing the reader’s attention to the new findings of this study.
(3) In the Conclusion section, we have reorganized and emphasized the distinctive aspects of this case that go beyond typical understanding and their underlying mechanisms, making the scientific contribution clearer.

We hope that through these revisions, the manuscript has been significantly improved in terms of highlighting novelty, enhancing logical flow, and increasing conciseness. Once again, we sincerely thank the reviewer for the highly constructive comments, which have greatly helped improve the quality and readability of the paper. All revisions have been highlighted or annotated in the revised manuscript for your review.

Specific comments

1. Line 87-91: Why do the authors use ERA5 instead of MERRA2 meteorological data in the analysis? It’s worth noting that the latter is the meteorological data used to drive the GEOS-Chem atmospheric chemical transport model simulations.

   We appreciate the reviewer’s comment. We agree that MERRA-2 is a widely used meteorological dataset for driving the GEOS-Chem model and has advantages in aerosol and radiation variables.

   In this study, we chose ERA5 for the following reasons:

   (1) Higher spatiotemporal resolution

   ERA5 has a horizontal resolution of ~31 km and hourly output, compared to ~50 km in MERRA-2. The finer resolution is beneficial for capturing detailed dust emission, transport, and boundary-layer processes in our case.

(2) ERA5's superior performance in representing large-scale circulation

Existing research demonstrates that ERA5 exhibits superior performance in representing large-scale circulation backgrounds and associated meteorological elements (e.g., temperature, pressure, humidity). This provides a more reliable foundation for analyzing processes dependent on circulation conditions, such as dust transport. Relevant references:

①Kara G T, Elbir T. (2025). Atmospheric Research, 325: 108233.

This study compares hourly ERA5 and MERRA-2 data over Turkey using 14 years of observations, showing that ERA5 outperforms MERRA-2 in simulating near-surface temperature, pressure, and humidity — indicating better representation of regional dynamic and thermodynamic structures.

②Hou C, Huang D, Xu H, et al. (2023). Theoretical and Applied Climatology, 151(1): 801–816.

Despite overestimating precipitation, ERA5 accurately captures the spatial patterns and long-term warming trends of temperature over northern China's desert regions, highlighting its strength in depicting large-scale thermal fields.

③Sun Y, Yang F, Liu M, et al. (2023). Atmospheric Research, 285: 106664.

Using radiosonde data, this work shows that ERA5's weighted mean temperature over China is significantly more accurate than MERRA-2, reflecting its superior ability to represent vertical profiles of temperature and humidity — key components of atmospheric thermal structure.

(3) Similar daily mean meteorological fields in the studied case

We evaluated the daily mean meteorological fields during the specific dust event, and found that differences between ERA5 and MERRA-2 were small, with both able to reasonably reproduce the synoptic situation (figure 1). Under this condition, we selected ERA5 for its higher resolution and superior performance in representing large-scale circulation.

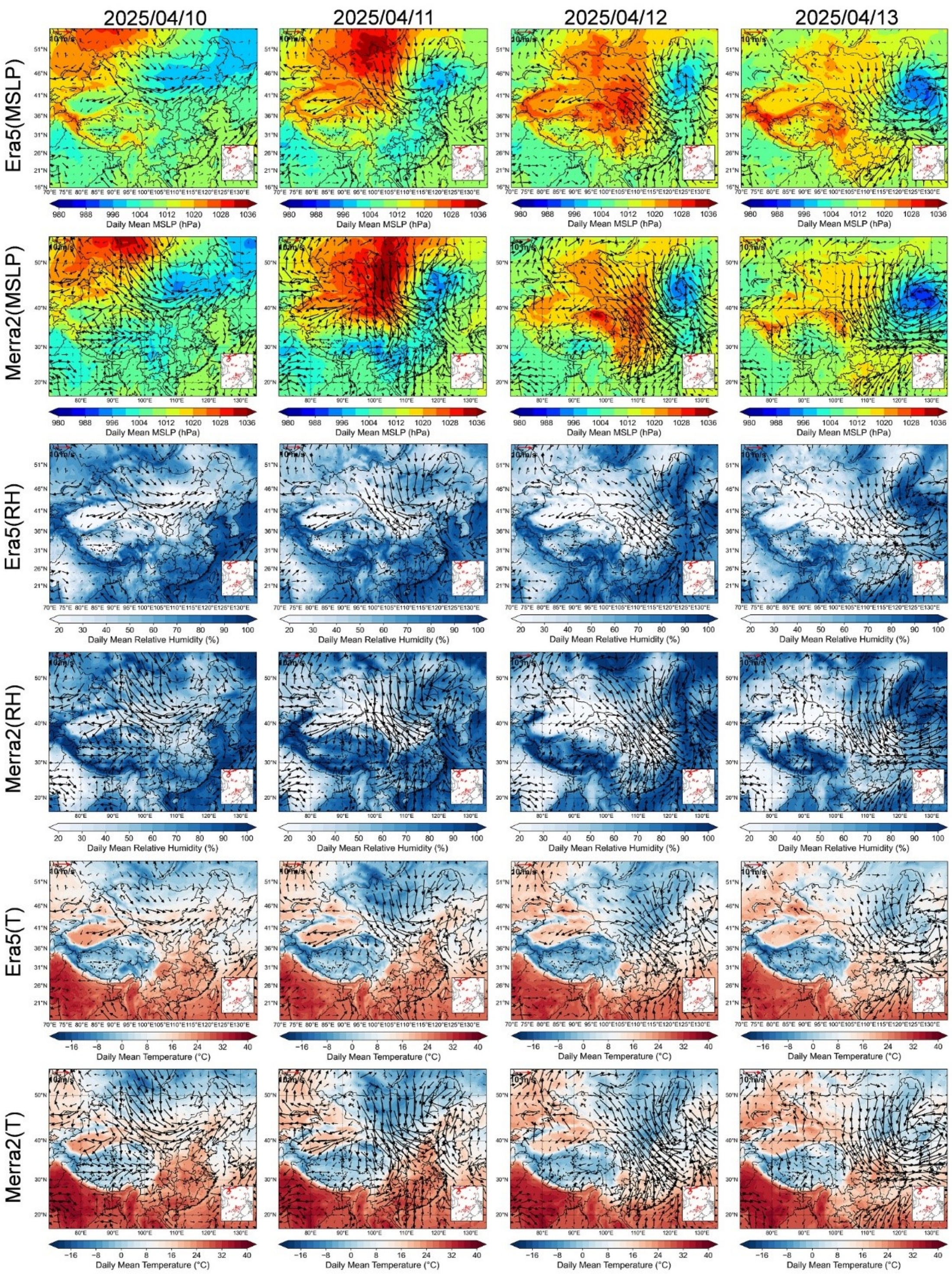

Figure 1. Spatiotemporal variations of daily mean temperature (°C), mean sea level pressure (MSLP, unit: hPa), relative humidity (%), and wind fields over China from ERA5 and MERRA-2 during 10–13 April 2025 (Beijing Time, BJT).

2. Figure 2: Why is the coverage of MODIS AOD so sparse in the China region? The data shown in the figure makes it difficult to distinguish between PM10 and AOD. Please change "scatter plot represents PM10 concentration" to "solid circles represent PM10 concentration".

We thank the reviewer for pointing out this issue. Regarding the sparse coverage of MODIS AOD in the China region, this is consistent with the limitations of passive satellite remote sensing noted by Jia et al. (2021, Nature Communications): under conditions of cloud cover, high surface reflectance, or complex terrain, AOD retrieval success decreases, and quality control filters out low-confidence pixels, leading to reduced data density. Concerning the difficulty in distinguishing between PM_{10} and AOD in the figure, we have revised the label from "scatter plot represents PM_{10} concentration" to "solid circles represent PM_{10} concentration", so that PM_{10} is now clearly differentiated from the AOD data points.

We have revised the figure captions.

3. Figures 2: Please explain that the wind speed scale is located in the upper right corner of each subplot, and explain what the small inset in the lower right corner represents.

   We have revised the caption of Figure 2 as suggested. The caption now states that the wind speed scale is located in the upper right corner of each subplot, and it describes the meaning of the small inset in the lower right corner.

4. Line 121 and Figure 3: If the PM10 and PM2.5 concentrations in the WIM region remain around 100 μg/m³ and 20 μg/m³, respectively (Figure 3), then why is the ratio of PM2.5 to PM10 0.3 instead of 0.2?

   We thank the reviewer for the careful identification of this issue. The value of 0.3 was a rough estimate based on the trend line; it is not precise in itself and, indeed, is numerically inconsistent with the PM_{10} (~100 μg/m³) and $PM_{2.5}$ (~20 μg/m³) concentrations given in the text, which could easily mislead readers. Therefore, we have revised the relevant statement in the main text, removing the inaccurate ratio and correcting it to describe its decreasing trend over time (lines 137–139).

5. Line 122 and Figure 3: Figure 3 shows that the dust storm began in the WIM region at 10:00 on April 11th, not at 17:00 as stated in line 122. In fact, the dust storm reached its peak at 17:00 at the WIM source region.

   Figure 3 shows that the dust storm started in the WIM region at 10:00 Beijing Time on 11 April, and reached its peak in the WIM source region at 17:00. We have corrected the time in line 122 from 17:00 to 10:00 in the revised manuscript to accurately reflect the onset time of the dust storm (line 138).

6. Line 126-127: Figure 4 does not show AOD values exceeding 2 in WIM.

   We have revised it as follows:

   "On April 12, the dust reached the Yangtze River Basin, where the PM_{10} concentration exceeded 1000 μg/m³ and the ratio of $PM_{2.5}$ to PM_{10} dropped below 0.2 (Figure 4). Meanwhile, the AOD in WIM exceeded 2 (Figure 2)."

   This revision ensures that the statement regarding AOD > 2 corresponds correctly to the spatial coverage in Figure 2, avoiding any confusion in the figure references (line 144).

7. Line 246-249: Please delete these two sentences, as they do not provide any necessary information.

   We have deleted the two sentences in lines 246–249.

8. Lie 275: What does "both" refer to?

The word “both” was inadvertently retained during the revision and led to ambiguous reference. We have removed it in the revised manuscript (line 292).

9. Figure 9: Please specify the geographical coverage in the caption.

   We have specified the geographical coverage in the caption of Figure 9 as suggested (line 312).

10. Figure 10: Please specify the geographical coverage for “western Inner Mongolia” in the caption.

    We have specified the geographical coverage for “western Inner Mongolia” in the caption of Figure 10 as suggested (lines 316–318).

11. Line 312-314: Please rephrase this sentence.

    We thank the reviewer for the suggestion. We have rephrased it to improve clarity and logical flow. The revised text now reads:

    “During the April 2025 dust event, a rainbelt was present over eastern China. However, because dust aerosols consistently remained behind the rainbelt, and thus their southward transport was not largely affected by wet scavenging. As a result, the dust storm was able to reach the far south of China, primarily owing to favorable meteorological conditions, namely strong and persistent northerly winds that enhanced both dust emission and long-range transport, combined with limited wet removal by precipitation.” (lines 330–334)

12. Figure 11: Please change “scatter plots” to be “filled circles”.

    We have already made the revisions.

Technique correction:

Figure 1: change “WIM” to “Western Inner Mongolia (WIM)” and change “western Inner Mongolia” to “WIM”.

We have already made the necessary technical modifications.
Line 271-272: Change “to compare” to “we compare”.

We have corrected this issue.

Anonymous Referee #2

Review comments of “Exploring the Mechanisms of Dust Emission and Transport based on Observations and GEOS-Chem Simulations” by Zou et al., 2025

General comments

The paper studied a severe dust storm originating in the Western Inner Mongolia (WIM) that was transported southward to southern China during April 11-14, 2025. Using ground observations, reanalysis (ERA5), satellite retrievals (MODIS/Aqua), and an improved GEOS-Chem model, the authors demonstrate that the emission and long-range transport of Inner Mongolian dust were mainly driven by anomalously strong northerly winds associated with the Siberian high and the Mongolian cyclone, along with reduced local precipitation, soil moisture, and high surface temperatures. The event is then compared with two other extreme dust events in northern China that occurred in March 2021 and April 2023. By comparing the meteorological conditions and PM10 evolution patterns, it is found that the absence of strong northerly winds is the primary reason why dust plumes during the other two events were not transported to Hainan Province in southern coastal China. The paper is generally well written and easy to follow. However, the study would be strengthened by better clarifying the motivation and novelty, justifying the use of the modeling approach, and providing a more detailed analysis in the multi-event comparison.

We thank the reviewer for their positive evaluation and careful review of our study. The suggestions to "further clarify the motivation and novelty, justify the use of the modeling approach, and provide a more detailed analysis in the multi-event comparison" are highly pertinent and crucial for enhancing the scientific depth and clarity of this paper. In response to these specific comments, we have systematically revised and expanded the manuscript as follows:

1. Strengthening the Motivation and Novelty: In both the Introduction and the summary section, we have expanded the discussion on the unique scientific value of the 2025 dust event. We explicitly highlight that this event represents a rare case documented to have reached Hainan Island and is distinctive for its effective southward transport despite the presence of heavy precipitation. By contrasting it with other severe East Asian dust events recorded in the literature, we emphasize its scarcity and research significance, thereby clarifying the motivation and novelty of this study.

2. Justifying the Use of the Modeling Approach: In Section 4.2 (Model Simulations), we have added a brief discussion explaining why the GEOS-Chem model was employed in addition to the available observational data. We explicitly state that model simulations can quantitatively resolve physical processes, such as the detailed emission fluxes, contributions of vertical and meridional transport, and the separation of dry and wet deposition processes, which is difficult to differentiate through observations alone—This clarifies the indispensable value of the model in diagnosing the underlying mechanisms of this study.

3. Deepening the Multi-Event Comparative Analysis: In Section 4.3.2 (Event Comparison) and the related figures, we have made the following important additions:

(1) Unified Analytical Framework: Wind speed data for comparison have been adjusted to anomalies relative to the 30-year climatological mean (Figure 10 has been updated), allowing a fair comparison of dynamical conditions across events from different years on a common baseline.

(2) Improved Evolution Representation: Additional timesteps closer to the dissipation stage for the 2021 and 2023 events have been added to Figure 11, providing a more complete life-cycle comparison.

(3) Enhanced Circulation Mechanism Analysis: Supplementary Figure S5 now includes sea-level pressure and wind fields during the peak phases of the two historical events. In the main text, we comparatively analyze key differences in the intensity, location, and configuration of the "Mongolian Cyclone–Siberian High" system across the three events, explaining the variations in transport pathways and intensity from the perspective of large-scale dynamical drivers.

We hope these targeted revisions have significantly strengthened the study in terms of focusing the scientific questions, justifying the methodology, and deepening the mechanistic analysis. We sincerely thank the reviewer again for their insightful comments, which have been instrumental in improving the quality of this paper.

Specific comments

1. Adding more information on the motivation of this study would further strengthen the manuscript. For example, beyond its unusual transport pathway, it would be helpful to clarify what unique features or mechanisms of this dust storm are revealed here that have not been addressed in previous studies.
   We thank the reviewer for the constructive suggestion. We have expanded the motivation of this study in the Introduction, emphasizing not only the unusual transport pathway of the April 2025 dust storm, but also its unique features and the scientific issues that have received limited attention in previous studies.
   Specifically, unlike typical dust events that are mostly confined to northern or northeastern China, this storm moved southward across the Yangtze River Basin and ultimately affected southwestern China and the South China Sea, indicating an exceptionally broad transport range. During the dust transport toward South China and Hainan Island, widespread precipitation occurred in the Yangtze River Basin. Such precipitation would normally lead to a marked reduction in aerosol concentration through wet scavenging, yet in this case, the dust maintained relatively high concentrations and successfully underwent ultra-long-range transport to Hainan Island (lines 75-83).
   These characteristics provide a valuable case for studying the processes of dust emission, transport, and deposition under extreme meteorological conditions, and help improve our understanding of the relative roles of dynamic forcing and wet scavenging in long-range transport, while addressing the lack of high-impact, strongly transported dust event cases in existing research.

2. In Section 4.2, including a brief discussion explaining why model simulations are used and what specific questions can be addressed through modeling (or cannot be addressed through observations alone) would highlight the added value of the modeling component.
   In response, we have added a brief discussion in Section 4.2 to clarify why model

simulations were employed and what specific questions they help address.
Observational data provide essential information on the spatiotemporal distribution of dust concentrations. However, due to limited observational coverage—especially the cessation of the CALIPSO satellite mission on 1 August 2023—it is difficult to fully resolve key aspects of the event, such as the detailed dust emission fluxes, vertical transport processes, and the relative contributions of different source regions.
By using the GEOS-Chem model, we were able to simulate dust emission and vertical transport under realistic meteorological conditions, perform sensitivity tests on factors such as soil moisture, surface wind, and vegetation cover, and examine processes that are challenging to observe directly, including the partitioning between saltation and suspension and the impact of wet scavenging along the transport pathway.
This combined approach of observations and model simulations not only enables a more complete depiction of the dust event's characteristics but also helps to elucidate the mechanisms responsible for its unusual intensity and long-range transport, thereby highlighting the added value of the modeling component.
The relevant additions are included in the revised Section 4.2.

3. Regarding modeling, are atmospheric circulation nudged to the GEOS-FP reanalysis? If not, it would be informative to show a comparison of modeled winds versus station observations or reanalysis, since winds are a key factor of dust emissions and transport.

We thank the reviewer for the important comment. In this study, the GEOS-Chem simulation did not apply nudging (assimilation-constraint) to align the atmospheric circulation with the GEOS-FP reanalysis data. The simulation was conducted in a free-running framework, with GEOS-FP data serving as initial and boundary conditions.
We fully agree that the wind field is a key factor influencing dust emission and transport. To evaluate the model's performance in simulating wind fields, Figure S1 in the supplementary material presents a comparison of the diurnal variations between observed and simulated wind fields. Additionally, we have supplemented Figure S2, which specifically presents a comparison of the simulated daily maximum wind speed in the WIM region with ERA5 reanalysis data and station observations. To further compare the reanalysis data with the model wind field, Figure 2 here provides an hourly variation comparison between the two. The results show that the model reasonably reproduces the characteristics of the wind field during the dust event.

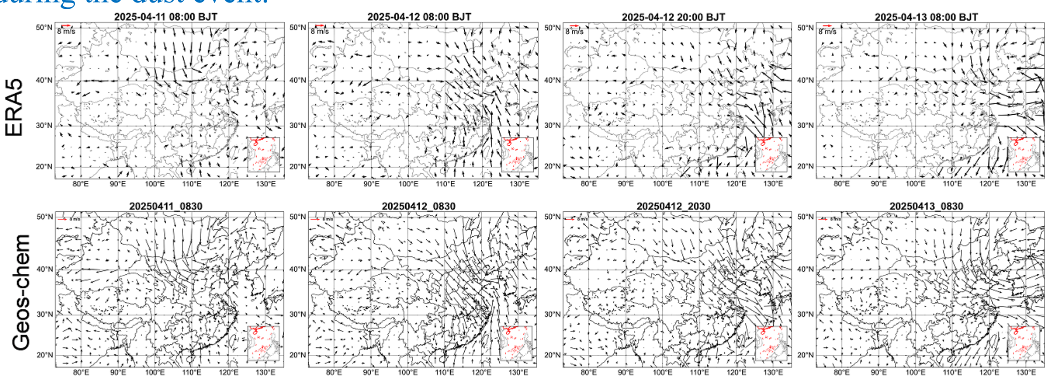

Figure 2. Comparison of simulated wind fields with ERA5 reanalysis data during 11–13 April 2025 (BJT).

4. Daily wind speeds are examined for the 2025 event (Fig. 8) and the other two springtime severe dust events in 2021 and 2023 (Fig. 10). Since dust emissions are more sensitive to high wind speeds at sub-daily time scales, it may be informative to display hourly wind speeds from the ERA5 reanalysis, station data, and model, or alternatively to show daily maximum wind speeds.

We thank you for the valuable suggestion. We fully agree that sub-daily time scales, especially peak wind speeds, are key factors for evaluating dust emission conditions. To better highlight the high-wind periods associated with dust activity, we have made corresponding revisions to the wind speed analyses in Figures 8 and 10.

The specific revisions are as follows:

Figure 8: The original daily mean wind speed time series has been replaced with daily anomaly time series of both daily mean and daily maximum wind speeds.

Figure 10: The wind speed analysis plot has similarly been updated to display the daily anomaly time series of daily maximum wind speed.

Furthermore, a detailed comparison of the simulated daily maximum wind speed in the WIM region with ERA5 reanalysis data and station observations has been provided in Figure S2 of the Supplementary Material. The corresponding figure captions and descriptions in the main text have been updated accordingly in the revised manuscript.

5. Section 4.3.2, additional clarification on how the two historical dust events were selected would be helpful. It is briefly mentioned that the two events were selected among "historical dust events in northern China since 2000" (Line 268). However, it is unclear which dataset was used to identify dust events and how a dust event is defined. The two events were referred to as "two most severe dust events" (line 268), but it was not clear whether severity refers to their magnitude (if so, the 2025 event is more severe), their impacts, or their duration. What's confusing is that later in the discussion, these events are referred to as "typical historical dust storms" (lines 323, 342). Clarifying the selection criteria and the purpose of using these events for comparison would help guide the reader.

With reference to Yu et al., Atmospheric Research, 2023, and Yang et al., Atmospheric Pollution Research, 2025, these two historical events were selected as benchmarks primarily for the following two reasons:

(1) To highlight the "extreme anomaly" of the 2025 event:

The 2021 event serves as a reference for "intensity and spatial extent": it demonstrates the theoretical maximum instantaneous intensity and broad horizontal impact (affecting about 17 provinces) that dust can achieve under the strongest Mongolian cyclone. However, it halted in central-eastern China. By comparing with it, we can ask: Why did the 2025 event, which also exhibited strong outbreak and wide impact, achieve southward transport, whereas the 2021 event resulted in broader lateral influence?

The 2023 event serves as a reference for "process and southward potential": it shows that dust can persistently affect North China and exhibit a southward trend (reaching Shandong), with a complex process (including secondary pollution). Yet it ultimately failed to penetrate deeply southward. By comparing with it, we can ask: Why, despite sharing a similar southward tendency, could the 2025 event overcome the precipitation barrier in the Yangtze River Basin and achieve stable

ultra-long-range southward transport, while the 2023 event could not?
(2) To control variables and focus on key differential mechanisms:

Given that both historical events and the 2025 event involved the influence of Mongolian cyclones, the factors leading to their distinct final transport pathways and outcomes must lie in the details of circulation configuration, such as the intensity, location, and persistence of synoptic systems.

We have revised Section 4.3.2 in accordance with your suggestions to further clarify the selection criteria for the two historical dust events and to unify the related terminology throughout the text, thereby improving the clarity and consistency of the manuscript.

Besides, we have uniformly used the term "severe" to describe the two historical events throughout the text to maintain consistency in context.

6. The comparison between the 2025 event and the other two events could be strengthened by discussing uncertainties, using similar evolution time frames, and adding analysis on circulation patterns. As mentioned in the text, these two events generally originated in northern China, so their emission areas are not exactly centered over the WIM (Fig. S3). Acknowledging these discrepancies helps explain their different magnitudes over the VIM and their paths. In addition, showing more time steps for the 2021 and 2023 events may provide a more complete picture of their evolution. For example, in Fig. 11 (bottom left), by 1200 BJT on March 16, 2021, the PM10 concentrations were still very high, with some areas above 1100 µg/m3, suggesting that the event had not yet fully dissipated (in contrast to the 2025 event, for which PM10 cementations decreased to around 200-400 µg/m3 by 0600 BJT on April 13, 2025). Similarly, by 0300 BJT on April 12, 2023 (Fig. 11, bottom middle), dust concentrations also remained very high, around 700-900 µg/m3. Including additional snapshots closer to the dissipation stage of these events would enhance the comparison. Lastly, including an analysis on circulation patterns would help understand wind directions and transport pathways (Fig. 11). For example, it is mentioned that both the March 2021 and April 2023 events were associated with Mongolian cyclones (line 270). Were they also associated with the Siberian High? What about other differences?

   We thank the reviewer for the detailed and constructive comments. We fully agree that enhancing the temporal evolution framework, supplementing key dissipation stages, and strengthening the analysis of circulation patterns can significantly improve the depth and clarity of the event comparison. Based on each of your specific suggestions, we have systematically revised the manuscript as follows:
   (1) Expanded Figure 11 to comprehensively depict the entire dust event process.
   (2) Added the circulation patterns of the historical events (Figure S5).
   (3) In the manuscript, we conducted a comparative analysis of the circulation fields of the three events, clearly highlighting the similarities and differences in circulation configurations — particularly the intensity, location, and synergistic relationships of the high-pressure and cyclone systems—and their decisive impacts on the transport pathways.

7. It is recommended to discuss the results in the context of previous studies. For instance, it is found that dust emissions in the WIM exceeded 400 µg/m² and the altitude of the dust plume reached 3.6 km. Are these values comparable to previous events, or are they substantially larger? Regarding the southward transport to Hainan province, was this the first occurrence of such a southward transport, or

has it documented previously? It was noted that about 50% of springtime dust events in Mongolia and northern China are associated with "the combined influence of Mongolian cyclones and cold high-pressure systems" (line 162). Was the combination of a Mongolian cyclone and the Siberian high found in the April 2025 event unique?

We have added the following content in the Discussion section (Section 5) of the manuscript:

(1) The dust emission flux in the WIM region and the height of the dust plume during this event are comparable to those reported for typical severe dust events in recent literature.

(2) The transport of dust from northern China to Hainan Island is extremely rare and may even represent the first systematically documented case of such an occurrence.

(3) The "Mongolian Cyclone–Siberian High" coupling that drove this event exhibited unique characteristics in terms of its intensity configuration (an exceptionally strong high-pressure system) and spatial configuration (a southerly displaced cyclone position). Together, these factors contributed to the rare dynamical conditions and extraordinary transport outcomes observed.

8. In Section 2.2, consider including a brief introduction to the dust emission scheme in the model.
   A brief introduction to the dust emission scheme has been added in Section 2.2.

9. Figs. 2, 4-5, 8d, 10a, and 11, are the wind fields surface winds? Please clarify in the figure captions.
   Yes, they are surface wind fields (10-m near-surface winds). This has been clarified in the figure captions.

10. Fig. 7, it would be helpful to also include modeled vertical and meridional winds in the figure.
    Simulated vertical and meridional winds have been added to Figure 7.

11. Fig. 8, is the time series of daily wind speed from the ERA5 or station observations?
    All data in Figure 8 are from ERA5, and a note specifying this has been added to the figure caption.

12. Fig. 10, it is preferred to show anomalies with reference to the long-term mean.
    We fully agree that using anomalies relative to the long-term mean can more clearly reveal abnormal signals and facilitate comparisons of relative changes across different periods and events. We have revised Figure 10 to display time series of anomalies relative to the 30-year climatological mean (1995–2024). The corresponding descriptions in the main text have also been updated accordingly.

Technique correction:

Fig. S2, although the figure caption refers to "AOD spatial distributions", MODIS data do not appear to be displayed in the top row.
We have corrected this technical issue.