Response to Reviewer 1 Comments

1. Summary

Thank you very much for taking the time to review our manuscript. We sincerely appreciate your constructive comments and suggestions, which have helped us improve the clarity, reproducibility, and scientific rigor of the manuscript. In response to your comments, we revised the manuscript by unifying the event information, rewriting the Introduction, clarifying the functions of HYSPLIT, ERA5, and tower observations, adding the anomaly baseline and spatial averaging definitions, improving the dynamic and thermal diagnostic analysis, revising the Discussion, standardizing terminology and figure captions, and removing overstated or insufficiently supported statements. The revised manuscript is provided with tracked changes, and the major textual changes are specified below by location, original wording, and revised wording.

2. Point-by-point response to Comments and Suggestions for Authors

Comments 1a

Reviewer comment: The study period and event sample are described inconsistently in the Abstract, Table 1, and the main text. Please unify the time span, total number of observed events, any excluded cases (with a brief reason), the final sample used for analysis, event numbering (Dust1–Dust8), and the definition of spring and summer throughout the manuscript.

Response: *Thank you very much for this important comment. We agree that inconsistent descriptions of the study period and event sample could cause confusion. We therefore revised the Abstract, Sect. 2.2, Table 1, the Results, and the Conclusion to use the same study period, event labels, excluded-event description, and seasonal grouping throughout the manuscript.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Abstract*

Original text: *Based on dual-gradient observational experiments in the central and peripheral regions of the TD, combined with ERA5 data and HYSPLIT analysis, eight dust storms from April to June 2024 were studied.*

Revised text: *This study combined dual-gradient tower observations from Tazhong (TZ) and Xiaotang (XT), ERA5 reanalysis, and HYSPLIT backward trajectories to examine eight dust-storm events in spring and summer 2024.*

Reason for this revision: *The wording was revised to avoid the inconsistent April–June description and to state the final sample as eight complete events in spring and summer 2024.*

Location in revised manuscript: *Sect. 2.2 "Observational Data"*

Original text: *Nine dust storm events were observed between April 3 and July 10, 2024 ... Therefore, the remaining eight observations became the primary samples for this study.*

Revised text: *Nine dust storm events were observed between 31 March and 18 June 2024, and the corresponding dust samples were collected from 3 April to 10 July 2024. However, during the second observation, data from the TZ station were missing, preventing a complete paired record. Therefore, the remaining eight complete dust storm events became the primary samples for this study.*

Reason for this revision: *The observation period, sample-collection period, excluded case, and final sample were separated and clarified.*

Location in revised manuscript: *Table 1*

Original text: *Tab. 1 Sample details; event IDs were shown as 1–9; dates were partly written as 2024.3.31, 2024.4.3, etc.; the excluded event was not clearly labelled in the table.*

Revised text: *Table 1. Summary of observed dust-storm events and sample collection information; event IDs are now shown as Dust1–Dust8, with one row labelled "Excluded event"; dates and times are standardized as YYYY-MM-DD HH:MM.*

Reason for this revision: *The table was revised so that the event numbering and time format are consistent with the Abstract, Methods, Results, and Conclusion.*

Location in revised manuscript: *Table 1, representative row examples*

Original text: *1 / TZ / 2024.3.31 / 22 / 2024.4.3; 2 / XT / 2024.4.5 / 5 / 2024.4.6; 9 / TZ / 2024.6.18 / 58 / 2024.7.9.*

Revised text: *Dust1 / TZ / 2024-03-31 12:00 / 22 / 2024-04-01 09:00; Excluded event / XT / 2024-04-05 01:00 / 5 / 2024-04-05 06:00; Dust8 / TZ / 2024-06-18 07:00 / 2 / 2024-06-18 09:00.*

Reason for this revision: *Representative rows were corrected to show the exact onset time, duration, sample-collection time, and event label.*

Location in revised manuscript: *Sect. 3.2 and Sect. 3.3*

Original text: *In summary, the pressure gradient before dust storms in March and April is significantly greater than in May and June ... dust storms occurring from March to June were categorized into two periods for analysis: spring (March and April) and summer (May and June).*

Revised text: *These background fields indicate a seasonal contrast in the pre-storm environment. The March–April events were more closely associated with stronger pressure-gradient and lower-tropospheric circulation signals, whereas the May–June events showed a more evident thermal* *background. Therefore, the analyzed events were grouped into spring cases and summer cases for the following dynamic and thermal anomaly analysis.*

Reason for this revision: *The seasonal grouping was retained but rewritten more cautiously and consistently.*

Location in revised manuscript: *Sect. 5 "Conclusion"*

Original text: *The conclusion previously referred to the dust-storm sample in a less consistent way and included broader statements based on the original event numbering.*

Revised text: *This study examined eight complete dust-storm events over the Taklimakan Desert using HYSPLIT trajectories, ERA5 reanalysis, and dual-gradient tower observations.*

Reason for this revision: *The conclusion now uses the same final sample definition as the Abstract and Methods.*

Comments 1b

Reviewer comment: *The Introduction provides a solid background, but the narrative could be made more coherent. I suggest refining the logical progression from motivation to knowledge gaps and then to the specific objectives/contributions of this study, and updating the citations with the most relevant literature published in the last five years.*

Response: *Thank you for your valuable suggestion. We rewrote the Introduction to improve its logical progression. The revised Introduction now moves from the regional importance of East Asian dust storms and the Taklimakan Desert, to dynamic and thermal forcing, transport pathways, topographic effects, and the remaining observational gaps. Recent studies published in the last five years were also added where they directly support the revised scientific logic.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Sect. 1, opening background*

Original text: *Dust storms are one of East Asia's most severe natural disasters, occurring frequently in arid and semi-arid regions such as the Taklamakan Desert in China and the Gobi Desert bordering Mongolia. These events are widespread in spring, impacting millions ...*

Revised text: *Dust storms are among the major natural hazards in arid and semi-arid regions of East Asia, where they are often accompanied by strong winds, air pollution, and reduced visibility, affecting transportation, agriculture, ecosystems, and public health ... Mineral dust can also influence atmospheric radiation, cloud processes, snow and ice albedo, and regional climate through long-range transport.*

Reason for this revision: *The opening was streamlined to introduce the regional relevance and scientific significance without excessive general descriptions.*

Location in revised manuscript: *Sect. 1, TD study-area motivation*

Original text: *The Taklamakan Desert is in Asia's arid and semi-arid regions, characterized by scarce precipitation, vast sandy terrain, and dry climatic conditions. Combined with the influence of Mongolian cyclones, these factors make the region prone to frequent dust storms in spring ...*

Revised text: *The Taklimakan Desert (TD) is located in the arid Tarim Basin and is surrounded by the Tianshan, Pamir, and Kunlun Mountains. Because of its extensive mobile sand surfaces, scarce precipitation, and unique basin topography, the TD is one of the major dust-source regions in East Asia.*

Reason for this revision: *The study-area motivation was rewritten to emphasize the TD as a major dust-source region shaped by surface and basin-topographic conditions.*

Location in revised manuscript: *Sect. 1, process framework paragraph*

Original text: *The formation of dust storms is a complex physical process driven by interactions between the atmosphere and surface soil, where dust source materials, dynamic conditions, and thermal factors play critical roles in influencing their occurrence ...*

Revised text: *The formation and development of dust storms are jointly controlled by atmospheric forcing and surface conditions. Among these controls, dynamic and thermal processes are particularly important because they determine whether surface particles can be lifted and whether the lifted dust can be transported vertically and horizontally ... Therefore, dust-storm processes cannot be explained by a single factor alone, but should be examined through the coupled effects of dynamic forcing, thermal instability, transport pathways, and terrain-modified local surface conditions.*

Reason for this revision: *The previous descriptive explanation was replaced by a clearer conceptual framework linking dynamic forcing, thermal forcing, transport pathways, and terrain effects.*

Location in revised manuscript: *Sect. 1, dynamic-forcing literature paragraph*

Original text: *In East Asia during spring, there is a significant positive correlation between strong winds and the frequency of dust storms. In East Asia, Mongolian cyclones frequently generate strong winds, which in turn lead to the formation of dust storms ...*

Revised text: *Previous studies have shown that dynamic forcing is a key driver of many spring dust storms in East Asia. Mongolian cyclones, cold fronts, cold high-pressure systems, and strong pressure gradients can generate strong near-surface winds and rapidly activate dust sources ... More recently, Mu et al. (2025) quantitatively assessed the role of atmospheric depressions and Mongolian cyclones in spring dust activity over East Asia ... However, many of them focus on northern China and the Gobi* *source region, whereas the pre-storm dynamic evolution over the Taklimakan Desert, especially its connection with local tower-based observations, remains less well documented.*

Reason for this revision: *Recent literature was added and the gap was clarified: dynamic evolution over the TD and its link to tower observations remain insufficiently documented.*

Location in revised manuscript: *Sect. 1, thermal-forcing literature paragraph*

Original text: *The original Introduction mentioned thermal factors mainly as general supportive conditions and did not clearly explain why thermal forcing is important for the TD or how it differs from dynamic forcing.*

Revised text: *Compared with the relatively well-recognized role of dynamic forcing, the influence of thermal forcing is more complex and is particularly important for inland desert regions such as the TD ... These findings suggest that distinguishing between dynamic and thermal controls is useful for understanding seasonal differences in dust-storm development. Nevertheless, how these seasonal differences are reflected in near-surface wind, temperature, and vertical meteorological profiles still requires further observational evidence ...*

Reason for this revision: *The revised paragraph explicitly introduces the thermal-forcing gap and connects it to vertically resolved observations.*

Location in revised manuscript: *Sect. 1, pathway and topography paragraphs*

Original text: *The original Introduction discussed dust transport and fluxes mainly from a broad transport or emission perspective, with less connection between pathways, dynamic–thermal forcing, and terrain constraints.*

Revised text: *Transport pathways provide an important way to connect dynamic and thermal forcing with dust-storm evolution ... These studies demonstrate the value of trajectory analysis, but pathway classification alone cannot fully explain why different dust storms develop under different dynamic or thermal backgrounds. Topography further modifies dust-storm occurrence, transport, and near-surface wind and temperature structures ...*

Reason for this revision: *The revised text now links pathway classification and terrain effects to the central dynamic–thermal interpretation of the study.*

Comments 1c

Reviewer comment: Please streamline the Methods and clarify how each method supports the study objectives and key conclusions. A short method–objective mapping paragraph at the beginning is sufficient. Briefly state the role of HYSPLIT (pathway classification and source indication), ERA5 diagnostics (dynamical: ΔP/wind/geopotential; thermal: ΔT/instability/BLH), and flux/profile calculations (vertical structure and terrain effects).

Response: *Thank you for this helpful suggestion. We revised the Methods and the corresponding Results structure to make the function of each method clearer. HYSPLIT is now used for pre-storm airflow pathway identification, ERA5 is used for synoptic background and dynamic–thermal anomaly diagnostics, and tower observations are used for near-surface vertical wind and temperature responses. The previous flux-centered Results section was replaced by tower-observed wind and temperature anomaly profiles to avoid overinterpretation of uncertain flux estimates.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Sect. 2.2 "Observational Data"*

Original text: *The gradient collection system gathers dust samples during dust storms using BSNE (Big Spring Number Eight) dust collectors installed at each layer, which are used to determine the horizontal dust flux at different heights.*

Revised text: *In the present analysis, the meteorological gradient observations were mainly used to examine wind-speed, wind-shear, and temperature-profile responses during dust-storm development.*

Reason for this revision: *The role of tower observations was redefined to support the revised profile-based analysis.*

Location in revised manuscript: *Sect. 2.3 title and opening*

Original text: *2.3 Remote Sensing Data. To further investigate the causes of dust storms, the study analyzed relevant meteorological conditions using the ERA5 reanalysis dataset.*

Revised text: *2.3 ERA5 Reanalysis Data. To further investigate the meteorological conditions associated with dust storm occurrence, this study used the ERA5 reanalysis dataset.*

Reason for this revision: *The section title and opening sentence were revised to accurately describe ERA5 rather than remote-sensing data.*

Location in revised manuscript: *Sect. 2.3, ERA5 role paragraph*

Original text: *The original Methods did not distinguish between original ERA5 fields and diagnostic anomaly indicators.*

Revised text: *In this study, ERA5 data were used in two ways. First, the original ERA5 fields were used to describe the synoptic-scale meteorological background ... Second, selected ERA5-derived diagnostic indicators were used for anomaly analysis after background removal.*

Reason for this revision: *The revised Methods now explicitly map ERA5 to the synoptic-background analysis and anomaly-diagnostic analysis.*

Location in revised manuscript: *Sect. 2.4 "HYSPLIT Model"*

Original text: *The study used the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to analyze the transport pathways of each dust storm event. This model utilizes grid data from the Global Data Assimilation System (GDAS) dataset to compute backward trajectories.*

Revised text: *The study used the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to analyze the transport pathways of each dust storm event ... For each event, backward trajectories were initialized at the dust-storm onset time ... Three starting heights, 100, 500, and 1500 m above ground level (AGL), were selected ... Each trajectory was traced backward for 48 h.*

Reason for this revision: *The HYSPLIT role and major settings were added to make the pathway analysis reproducible.*

Location in revised manuscript: *Sect. 2.5 and Sect. 3.4*

Original text: *2.5 The calculation of horizontal dust flux (Q) and vertical dust flux (F); 3.4 Dust Flux Analysis.*

Revised text: *The previous flux-calculation section was removed from the main analysis, and Sect. 3.4 was revised as "Tower-observed wind and temperature anomaly profiles".*

Reason for this revision: *The analysis was streamlined and made more directly supported by the available meteorological observations.*

Location in revised manuscript: *Sect. 3.4 revised analysis*

Original text: *The original section focused on horizontal dust flux (Q), vertical dust flux (F), and their height-dependent changes at TZ and XT.*

Revised text: *The tower observations further support the regional dynamic and thermal characteristics identified from the ERA5-based analysis. Figure 11 shows the composite evolution of 10 m wind-speed anomaly, 2–10 m wind-shear anomaly, 0.5–10 m air-temperature-difference anomaly, and 2 m air-temperature anomaly from −24 to +3 h relative to dust-storm onset.*

Reason for this revision: *The revised Results section links tower observations directly to the dynamic–thermal interpretation.*

Comments 1d

Reviewer comment: Please improve reproducibility by clarifying key definitions and settings. Define the anomaly baseline used for "anomalous wind/anomaly wind field". Specify whether the 24/12/6/3 h windows are referenced to event onset or storm time/peak. Provide the spatial averaging domain and essential HYSPLIT settings, including starting height, back-trajectory duration, and pathway classification criteria.

Response: *Thank you for this important comment. We revised Sects. 2.3 and 2.4 to specify the ERA5 anomaly baseline, lead-time definition, spatial averaging domains, latitude-weighted averaging, and*

HYSPLIT settings. We also clarified in Sect. 3.3 that the 24/12/6/3 h windows are referenced to dust-storm onset.

Detailed changes made in the manuscript:

Location in revised manuscript: *Sect. 2.3, ERA5 diagnostic indicators*

Original text: *The previous manuscript described anomalous wind fields and pressure/temperature changes but did not define the anomaly baseline or the spatial-averaging domains.*

Revised text: *The dynamic indicators included mean sea-level pressure-gradient magnitude, 850 hPa geopotential-height-gradient magnitude, and 10 m wind speed. These indicators were averaged over the regional domain of 70–100° E and 30–50° N ... The thermal indicators included 2 m air temperature, skin temperature, surface–air temperature difference, surface net shortwave radiation, and boundary-layer height ... The desert core was defined using a Taklimakan Desert polygon mask within 72–92° E and 35–43° N. Grid cells outside the desert mask were excluded from the thermal averaging.*

Reason for this revision: *The indicators and spatial domains were explicitly defined.*

Location in revised manuscript: *Sect. 2.3, anomaly baseline*

Original text: *The original manuscript did not explain how the ERA5 background state was calculated.*

Revised text: *For each dust-storm event and each lead time relative to storm onset, the corresponding 2024 ERA5 value was extracted. The background value was calculated from ERA5 records during 2015–2025, excluding 2024, using the same hour of the day within a ±3-day calendar window. The anomaly was then obtained by subtracting this background value from the corresponding 2024 event value. Area-mean values were calculated using latitude-weighted averaging with cos(latitude) as the weight.*

Reason for this revision: *The anomaly calculation is now reproducible.*

Location in revised manuscript: *Sect. 3.3, pressure-difference definition*

Original text: *Fig.6 and Fig.7 show the changes in average sea-level pressure over the 3, 6, 12, and 24 hours preceding the dust storms ...*

Revised text: *Figures 6 and 7 show the sea-level pressure differences at 24, 12, 6, and 3 h before dust-storm onset in spring and summer, respectively. The pressure difference was calculated as the sea-level pressure at onset minus that at each preceding time.*

Reason for this revision: *The reference time was clarified as dust-storm onset.*

Location in revised manuscript: *Sect. 3.3, surface–air temperature-difference definition*

Original text: *Figures 8 and 9 show the temperature changes 3, 6, 12, and 24 hours before the dust storms ...*

Revised text: *Figures 8 and 9 show the changes in surface–air temperature difference before dust-storm onset. The surface–air temperature difference was defined as Ts–T2m, and its change was calculated as the onset value minus the value at 24, 12, 6, and 3 h before onset.*

Reason for this revision: *The thermal diagnostic and its lead-time reference were clarified.*

Location in revised manuscript: *Sect. 2.4, HYSPLIT settings*

Original text: *The original HYSPLIT description did not include the complete model settings, start heights, endpoint, trajectory duration, or event ending times.*

Revised text: *The GDAS1 data have a horizontal resolution of 1° × 1° and a temporal interval of 3 h. Model vertical velocity was used for the vertical motion calculation. For each event, backward trajectories were initialized at the dust-storm onset time. The trajectory endpoint was set at 39.43° N, 85.97° E ... Three starting heights, 100, 500, and 1500 m above ground level (AGL), were selected ... Each trajectory was traced backward for 48 h. The trajectory ending times were 12:00 UTC on 31 March, 04:00 UTC on 12 April, 11:00 UTC on 17 April, 21:00 UTC on 26 April, 07:00 UTC on 12 May, 11:00 UTC on 20 May, 04:00 UTC on 4 June, and 07:00 UTC on 18 June 2024 for Dust1–Dust8, respectively.*

Reason for this revision: *The key HYSPLIT settings were added for reproducibility.*

Location in revised manuscript: *Sect. 3.1, pathway classification text*

Original text: *The original text described the pathways as east-to-west movement, transport across mountains, and west-to-east or thermal-factor-driven movement.*

Revised text: *Dust1, Dust3, Dust4, Dust5, and Dust6 mainly showed east-inflow transport, with air masses entering the TD through the northeastern opening of the Tarim Basin. Dust2 was characterized by a south-to-north pathway related to airflow crossing the Tibetan Plateau and Kunlun Mountains. Dust7 and Dust8 were associated with northwestern transport, with air masses passing over southern Russia and eastern Uzbekistan before crossing the Tianshan Mountains toward the TD.*

Reason for this revision: *The pathway categories were renamed and linked to actual airflow histories rather than interpreted as direct dust-source proof.*

Comments 1e

Reviewer comment: Please correct the inconsistency in Table 3 where ΔP appears in the header while the text discusses ΔT. Ensure the table title/header, in-text description, and any related figures/citations are consistent after revision, and confirm that Table 3 matches the variables plotted and discussed in the Results.

Response: *Thank you for pointing out this inconsistency. We agree that the previous Table 3 header was incorrect and could mislead readers. Instead of only changing the header, we removed the previous* *variance tables and replaced them with a more direct composite anomaly analysis in Fig. 10. The text and figure captions now consistently refer to dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Previous Table 3*

Original text: *Tab. 3 Variance and range 24h, 12h, 6h, and 3h before the dust storm; column headers included "Variance of ΔP24h", "Variance of ΔP12h", "Variance of ΔP6h", and "Variance of ΔP3h", although the surrounding text discussed temperature changes.*

Revised text: *The previous Table 3 was removed from the revised manuscript.*

Reason for this revision: *Removing the table avoided the variable mismatch between ΔP headers and ΔT interpretation.*

Location in revised manuscript: *Sect. 3.3, replacement diagnostic figure*

Original text: *The original text interpreted variance and range values in Tables 2 and 3 and emphasized a 12–6 h prediction window.*

Revised text: *Figure 10 further compares the composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset. The dynamic indicators are consistent with the spatial pressure-difference maps. The mean sea-level pressure-gradient anomaly and 850-hPa height-gradient anomaly remain higher in spring throughout the pre-onset period ...*

Reason for this revision: *The revised diagnostic analysis uses physically interpretable anomaly curves rather than variance/range tables.*

Location in revised manuscript: *Fig. 10 caption*

Original text: *No equivalent composite figure was provided in the original manuscript.*

Revised text: *Fig. 10. Composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset.*

Reason for this revision: *The new figure provides a consistent basis for dynamic and thermal comparison.*

Location in revised manuscript: *Sect. 3.3, thermal-anomaly interpretation*

Original text: *The original interpretation stated that temperature changes have a more significant impact on summer dust storms based mainly on Table 3 values.*

Revised text: *In summer, the net shortwave-radiation anomaly is strongly positive during the early pre-onset stage, and the surface–air temperature-difference anomaly is also positive before about −18 h. Meanwhile, the boundary-layer-height anomaly reaches approximately 200–300 m, indicating that stronger radiation and surface heating promoted boundary-layer growth before summer dust storms.*

Reason for this revision: *The revised text provides a clearer and more directly interpretable thermal diagnostic result.*

Comments 1f

Reviewer comment: Please strengthen the Discussion by adding comparisons with previous studies from the Taklimakan Desert and other deserts. Focus on seasonal dynamical and thermal controls, profile differences over flat and undulating surfaces, and transport-pathway classifications. Reduce repetition of the Results, and consider organizing Sect. 4 as: summary, highlights, limitations, and outlook.

Response: *Thank you for this constructive suggestion. We substantially revised the Discussion to reduce repetition of the Results and to emphasize interpretation. The revised Discussion now connects HYSPLIT pathways with ERA5 circulation patterns, interprets the seasonal dynamic–thermal contrast, discusses tower-observed differences between TZ and XT, and adds a limitations/outlook paragraph.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Old Sect. 4 structure*

Original text: *4.1 Dust Trajectory Analysis; 4.2 Discussion of Dynamic and Thermal Factors; 4.3 Key parameters are influenced by the terrain.*

Revised text: *4 Discussion, organized into integrated paragraphs on pathway–circulation linkage, seasonal dynamic–thermal differences, tower-observed vertical responses, and limitations/outlook.*

Reason for this revision: *The structure was simplified and repetition of Results was reduced.*

Location in revised manuscript: *Sect. 4, opening paragraph*

Original text: *The original Discussion repeated the main trajectory and pressure/temperature Results in separate subsections.*

Revised text: *The HYSPLIT pathway analysis, ERA5 diagnostics, and tower observations provide complementary evidence for interpreting dust-storm development over the Taklimakan Desert. HYSPLIT identifies the pre-storm airflow pathways reaching the observation sites, ERA5 explains the regional pressure, circulation, and thermal backgrounds behind these pathways, and the tower observations show how these regional conditions are expressed in near-surface wind, temperature, wind shear, and vertical profiles.*

Reason for this revision: *The revised opening explains how the three data sources jointly support the interpretation.*

Location in revised manuscript: *Sect. 4, transport-pathway interpretation*

Original text: *The original Discussion mainly stated that dust trajectories were complex and came from multiple directions.*

Revised text: *The pathway types are closely related to the ERA5 circulation patterns. East-inflow events are generally accompanied by clearer pressure differences between northern Xinjiang, surrounding high-pressure regions, and the Tarim Basin, together with organized 10 m winds entering the desert through the northeastern basin opening. Mountain-crossing events correspond more closely to lower-tropospheric circulation differences around the Tianshan–Pamir region, while the south-to-north pathway is related to pressure and wind configurations along the southern and southwestern margins of the desert.*

Reason for this revision: *The revised text links the pathway classification to circulation patterns and basin topographic constraints.*

Location in revised manuscript: *Sect. 4, seasonal dynamic–thermal interpretation*

Original text: *The original Discussion repeated that spring was more affected by pressure and summer by temperature, without enough integration of the new diagnostics.*

Revised text: *ERA5 further reveals a seasonal shift in the pre-onset conditions. Spring events show stronger and more persistent mean sea-level pressure-gradient and 850 hPa height-gradient anomalies, consistent with the more distinct dynamic pathways. Summer events show weaker pressure-gradient organization but stronger early thermal anomalies, including enhanced net shortwave radiation, surface–air temperature difference, and boundary-layer height.*

Reason for this revision: *The revised text uses the new anomaly diagnostics to support a more cautious seasonal interpretation.*

Location in revised manuscript: *Sect. 4, tower-profile interpretation*

Original text: *The original Discussion interpreted flux, temperature, and wind-speed differences in a more speculative way.*

Revised text: *The tower observations provide station-scale support for this interpretation. Summer events show more continuous vertical warming, while wind-speed and wind-shear anomalies strengthen closer to onset, indicating that thermal preconditioning alone is insufficient and that near-surface momentum enhancement remains necessary. The differences between TZ and XT further suggest that local terrain can modify the near-surface response to regional forcing. XT shows more regular vertical structures, whereas TZ exhibits more variable profiles, likely related to dune-induced flow disturbance and heterogeneous roughness.*

Reason for this revision: *The revised discussion emphasizes profile differences over relatively flat and undulating surfaces while avoiding overinterpretation of flux estimates.*

Location in revised manuscript: *Sect. 4, limitations and outlook*

Original text: *The original Discussion did not clearly state the limitations of the event sample and observational constraints.*

Revised text: *Several uncertainties remain. The analysis is based on eight events from one field season, and the identified pathway and seasonal characteristics need to be tested using longer-term samples. In addition, the lack of direct turbulence, vertical velocity, and lidar observations limits the interpretation of vertical transport processes. Future studies should combine multi-year observations, turbulence measurements, lidar data, and high-resolution simulations ...*

Reason for this revision: *A limitations and outlook paragraph was added to frame the results more appropriately.*

Technical comments

Comments 2a

Reviewer comment: Replace "HYSPIT" with HYSPLIT in the Sect. 2.4 title.

Response: *Thank you for pointing out this typographical error. We corrected the model name in the section title and checked the manuscript for consistency.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Sect. 2.4 title*

Original text: *2.4 HYSPIT model*

Revised text: *2.4 HYSPLIT Model*

Reason for this revision: *The spelling and capitalization of the model name were corrected.*

Location in revised manuscript: *Sect. 2.4 first sentence*

Original text: *The study used the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model ...*

Revised text: *The study used the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model ...*

Reason for this revision: *The full model name and abbreviation are now consistent with the corrected section title.*

Comments 2b

Reviewer comment: Standardize terminology throughout, e.g., use "850 hPa geopotential height" consistently. In the flux/parameter section, unify units, cm s−1 and m s−1, and clearly state any conversions where needed.

Response: *Thank you for this important comment. We standardized terminology throughout the manuscript and reduced the unit-related uncertainty by removing the previous flux-centered Results section from the main analysis. The revised analysis now focuses on ERA5 diagnostics and tower-observed wind-speed, wind-shear, and temperature anomaly profiles.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Figure captions and Results text*

Original text: *Fig.4 Mean sea level pressure, 10m wind vector, 850Phm altitude field; Fig.5 2m temperature, 10m wind vector, 850Phm altitude field.*

Revised text: *Fig. 4. Mean sea-level pressure, 10 m wind vectors, and 850 hPa geopotential height before the analyzed dust-storm events. Fig. 5. 2 m air temperature, 10 m wind vectors, and 850 hPa geopotential height during the analyzed dust-storm events.*

Reason for this revision: *Terminology, spacing, and units were standardized.*

Location in revised manuscript: *Sect. 2.3 and Sect. 3.3*

Original text: *The original manuscript used terms such as average sea-level pressure, altitude field, 850Phm, 2m temperature, and wind vector plume field inconsistently.*

Revised text: *The manuscript now consistently uses "mean sea-level pressure", "850 hPa geopotential height", "10 m wind speed" or "10 m wind vectors", "2 m air temperature", and "surface–air temperature difference".*

Reason for this revision: *The revised terminology is more standard and consistent with atmospheric-science usage.*

Location in revised manuscript: *Sect. 2.5 and old Sect. 3.4*

Original text: *The original manuscript contained a flux-parameter section involving horizontal dust flux (Q), vertical dust flux (F), friction velocity, cm s−1 and m s−1 units, and concentration conversions.*

Revised text: *The previous flux-calculation section was removed from the main Results and Sect. 3.4 was revised as "Tower-observed wind and temperature anomaly profiles".*

Reason for this revision: *This avoids unsupported or unit-sensitive interpretations and keeps the main analysis aligned with the directly available meteorological observations.*

Comments 2c

Reviewer comment: Several figure captions show numbering or formatting issues, e.g., "Fig.11 10 …". Please verify figure order/numbering and standardize caption style and wording.

Response: *Thank you for your careful observation. We checked the figure order, numbering, and captions throughout the manuscript. The captions were standardized, and the revised manuscript now uses consistent figure numbering and wording.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Fig. 1 caption*

Original text: *Fig. 1 Location and topography of the Taklimakan Desert, and the TZ and XT observation towers (maps and site photos)*

Revised text: *Fig. 1. Location and topography of the Taklimakan Desert, including the Tazhong (TZ) and Xiaotang (XT) observation towers and site photographs.*

Reason for this revision: *Caption style and station names were standardized.*

Location in revised manuscript: *Fig. 2 and Fig. 3 captions*

Original text: *Fig. 2 Schematic diagram of the backward trajectory of these dust storms; Fig. 3 10m wind vector plume field diagram.*

Revised text: *Fig. 2. Backward trajectories of the eight dust-storm events. Fig. 3. ERA5 10 m wind-vector fields during the eight dust-storm events.*

Reason for this revision: *Captions were revised for clarity and consistency.*

Location in revised manuscript: *Fig. 4 and Fig. 5 captions*

Original text: *Fig.4 Mean sea level pressure, 10m wind vector, 850Phm altitude field; Fig.5 2m temperature, 10m wind vector, 850Phm altitude field.*

Revised text: *Fig. 4. Mean sea-level pressure, 10 m wind vectors, and 850 hPa geopotential height before the analyzed dust-storm events. Fig. 5. 2 m air temperature, 10 m wind vectors, and 850 hPa geopotential height during the analyzed dust-storm events.*

Reason for this revision: *Terminology and figure-caption format were corrected.*

Location in revised manuscript: *Old Fig. 10–13 captions*

Original text: *Fig.10 Schematic Diagram of Horizontal Dust Flux during Sandstorms; Fig.11 10 Schematic Diagram of Vertical Dust Flux during Sandstorms; Fig.12 Schematic Diagram of Wind Speed and Temperature during Sandstorms; Fig.13 Schematic Diagram of Wind Speed and Temperature Changes ...*

Revised text: *Fig. 10. Composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset. Fig. 11. Composite evolution of tower-observed wind-speed, wind-shear, air-temperature-difference, and 2 m air-temperature anomalies from −24 to +3 h relative to dust-storm onset. Fig. 12. Vertical profiles of wind-speed anomalies at TZ and XT during spring and summer dust-storm events. Fig. 13. Vertical profiles of air-temperature anomalies at TZ and XT during spring and summer dust-storm events.*

Reason for this revision: *The revised figures and captions now match the revised analytical focus.*

Comments 2d

Reviewer comment: The reference list includes clearly irrelevant items and possible duplicates. Please remove unrelated references, merge duplicates where appropriate, and ensure one-to-one consistency between in-text citations and the reference list.

Response: *Thank you for this helpful comment. We checked the in-text citations and reference list, removed unrelated or duplicated references where appropriate, and added recent references closely related to East Asian dust storms, Taklimakan dust transport, dynamic and thermal forcing, boundary-layer processes, and terrain effects.*

Detailed changes made in the manuscript:

Location in revised manuscript: *References and in-text citations throughout the manuscript*

Original text: *The original manuscript contained possible duplicate citations, less relevant references, and some citation-format inconsistencies.*

Revised text: *The reference list and in-text citations were checked for one-to-one consistency. Recent and relevant studies were added or retained, including studies on East Asian dust events, Taklimakan dust transport, dynamic/thermal forcing, boundary-layer processes, and terrain effects.*

Reason for this revision: *The reference list was revised to better support the rewritten Introduction, Methods, Discussion, and Results interpretations.*

Location in revised manuscript: *Sect. 1 rewritten Introduction*

Original text: *The original Introduction relied more heavily on broad background references and did not sufficiently emphasize recent studies.*

Revised text: *Recent studies were incorporated into the dynamic-forcing, thermal-forcing, transport-pathway, and topographic-effect paragraphs, including recent work such as Bao et al. (2023), Chen et al. (2023a, 2023b), Li et al. (2023), Mu et al. (2025), Su et al. (2024), Xiong et al. (2023), and Zhang et al. (2025).*

Reason for this revision: *The added references place the study more clearly within recent dust-storm research.*

Comments 2e

Reviewer comment: The keywords include "Causation Analysis", but corresponding methods/results are not clearly presented. Please remove this term from the keywords and any related statements to avoid overstating the scope.

Response: *Thank you for this important suggestion. We agree that the term "Causation Analysis" may overstate the scope of the study. We revised the keywords and softened causal wording throughout the manuscript.*

Detailed changes made in the manuscript:

Location in revised manuscript: *Keywords below the Abstract*

Original text: *Keywords: Dust Storms, Backward Trajectory Analysis, Causation Analysis, Horizontal And Vertical Dust Flux Analysis.*

Revised text: *Keywords: Dust storm; Taklimakan Desert; HYSPLIT; ERA5; dynamic and thermal anomalies; vertical observation.*

Reason for this revision: *The unsupported keyword "Causation Analysis" was removed and the keywords were aligned with the actual data and methods used.*

Location in revised manuscript: *Abstract and Results/Discussion wording*

Original text: *The original manuscript used stronger causal expressions such as "caused", "triggered", and "dominated" in several places.*

Revised text: *The revised manuscript uses more cautious wording such as "is associated with", "suggest", "indicate", "is consistent with", and "may have enhanced" when interpreting dynamic and thermal processes.*

Reason for this revision: *This avoids overstating causation and makes the interpretation more consistent with observational evidence.*

Location in revised manuscript: *Abstract conclusion sentence*

Original text: *The original Abstract emphasized direct causes and a critical prediction window based on the original variance-table analysis.*

Revised text: *These findings provide observational evidence for seasonal differences in TD dust-storm processes.*

Reason for this revision: *The final statement was made more cautious and better aligned with the revised evidence.*

Additional note

In addition to the revisions listed above, the manuscript was revised according to suggestions from the other reviewers. These additional revisions mainly include weakening overgeneralized conclusions, replacing the previous flux-centered analysis with tower-observed wind and temperature anomaly profiles, adding ERA5-based quantitative anomaly diagnostics, clarifying the anomaly baseline and spatial averaging domains, adding detailed HYSPLIT settings, and adding a limitations and outlook paragraph. We believe these revisions have improved the clarity, reproducibility, and scientific rigor of the manuscript.

Mainly Added and Revised Figures and Tables

Table 1. Summary of observed dust-storm events and sample collection information

Event ID	Station	Start time of dust storm	Duration (h)	Sample collection time
Dust1	TZ	2024-03-31 12:00	22	2024-04-01 09:00
	XT	2024-03-31 12:40	17.3	2024-04-01 06:00
Excluded event	XT	2024-04-05 01:00	5	2024-04-05 06:00
Dust2	XT	2024-04-12 04:00	7.5	2024-04-12 14:00
	TZ	2024-04-14 04:00	11	2024-04-14 15:00
Dust3	XT	2024-04-17 11:00	23	2024-04-18 10:00
	TZ	2024-04-18 10:00	36	2024-04-19 22:00
Dust4	TZ	2024-04-26 21:00	16.5	2024-04-27 13:30
	XT	2024-04-26 02:00	31	2024-04-27 09:00
Dust5	TZ	2024-05-12 07:00	24	2024-05-12 14:30
	XT	2024-05-12 07:30	7	2024-05-12 14:30
Dust6	TZ	2024-05-20 11:00	14	2024-05-20 14:30
	XT	2024-05-20 11:00	3.5	2024-05-20 14:30
Dust7	TZ	2024-06-04 04:00	12	2024-06-04 16:00
	XT	2024-06-04 04:00	3	2024-06-04 07:00
Dust8	TZ	2024-06-18 07:00	2	2024-06-18 09:00
	XT	2024-06-18 07:20	3.7	2024-06-18 11:00

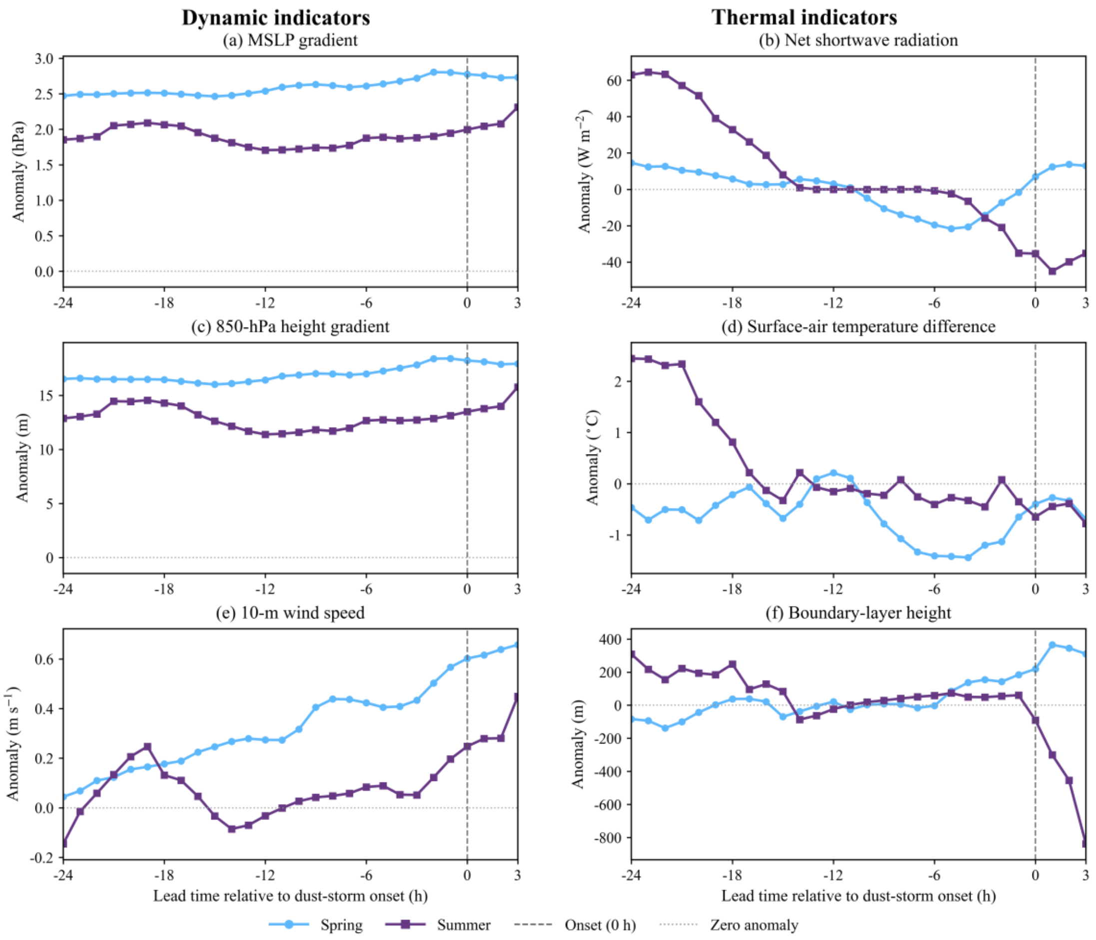

Fig. 10. Composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset.

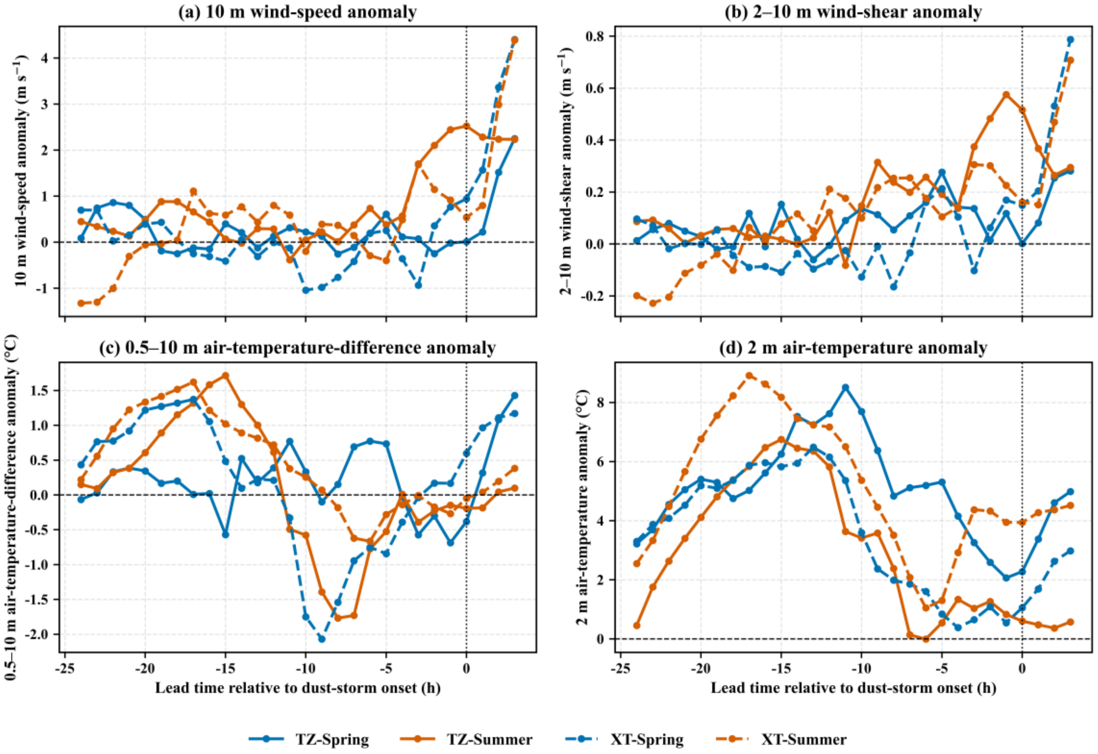

Fig. 11. Composite evolution of tower-observed wind-speed, wind-shear, air-temperature-difference, and 2 m air-temperature anomalies from −24 to +3 h relative to dust-storm onset.

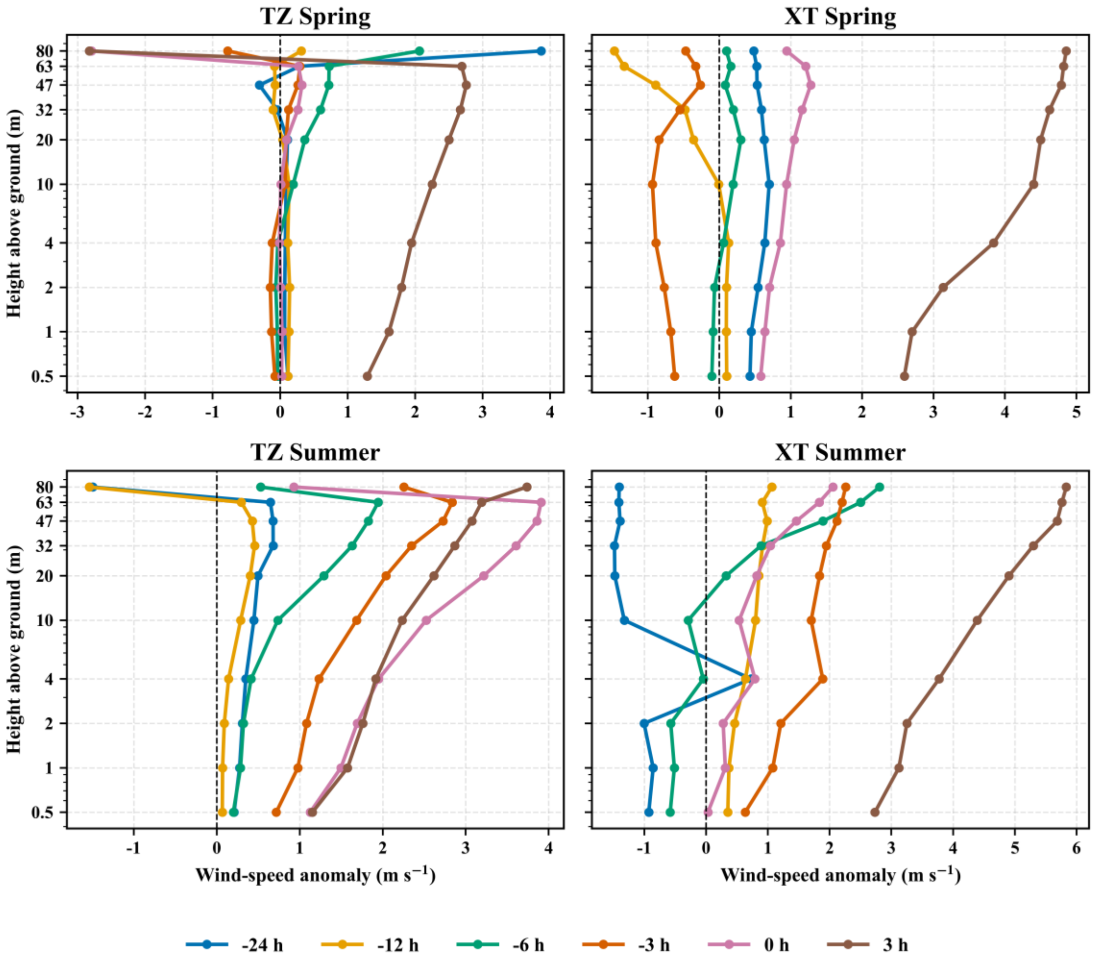

Fig. 12. Vertical profiles of wind-speed anomalies at TZ and XT during spring and summer dust-storm events.

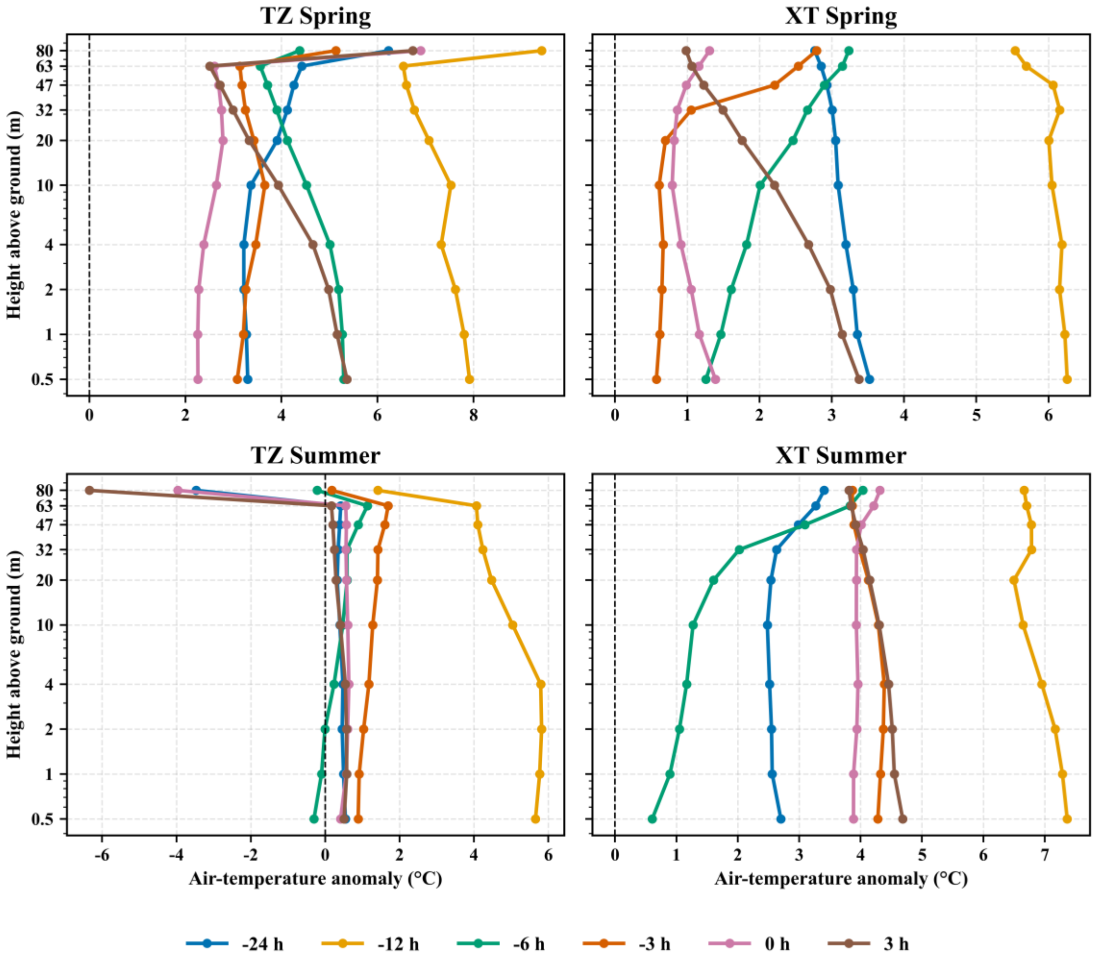

Fig. 13. Vertical profiles of air-temperature anomalies at TZ and XT during spring and summer dust-storm events.