Response to Reviewer 3 Comments

1. Summary

Thank you very much for taking the time to review our manuscript and for your positive evaluation of the topic and observational dataset. We sincerely appreciate your constructive comments and suggestions, which helped us improve the methodological clarity, diagnostic analysis, and technical presentation of the manuscript.

In response to your comments, we substantially revised the manuscript by adding quantitative ERA5-based dynamic and thermal anomaly diagnostics, removing the overstatement that the 12–6 h period represents a general "key prediction window", weakening causal language related to seasonal dynamic and thermal controls, removing the previous Q/F-centered flux analysis from the main Results and Conclusion because of uncertainties in flux calculation and sampling consistency, refocusing the tower-observation analysis on wind-speed, wind-shear, and air-temperature anomaly profiles, clarifying the ERA5 anomaly baseline, spatial averaging domains, and HYSPLIT settings, and correcting technical problems related to terminology, station names, Table 1, Table 3, formulas, units, and figure presentation.

The revised manuscript is provided with tracked changes. For clarity, the major textual and structural revisions are specified below by revision location, original wording, revised wording, and the reason for each change. In this response letter, the original text is shown in red italics, and the revised text is shown in blue italics.

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

Major issues

Comments a

Reviewer comment: The manuscript suggests that spring dust events are mainly controlled by dynamic forcing, whereas summer events are more closely related to thermal forcing, and it further identifies the 12–6 h period before onset as a key prediction window. At present, however, this interpretation is still supported mainly by descriptive evidence, and more direct diagnostic analysis would be needed to make the argument more convincing.

Response: Thank you very much for this important and helpful comment. We agree that the previous version relied too much on descriptive interpretation and did not provide sufficient direct diagnostic evidence to support the seasonal dynamic–thermal contrast. We therefore added quantitative ERA5-based anomaly diagnostics and revised the wording to avoid presenting the seasonal contrast as a strictly demonstrated causal separation. We also removed the statement that the 12–6 h period represents a general key prediction window.

Detailed changes made in the manuscript:

Location in revised manuscript: Abstract

Original text: *Spring dust storms (March–April) are dominated by dynamic factors, while summer storms (May–June) are influenced by thermal factors. Significant pressure and temperature changes 12–6 hours before a storm provide a critical prediction window.*

Revised text: *ERA5 anomaly diagnostics show that spring events maintained stronger mean sea-level pressure-gradient and 850 hPa geopotential-height-gradient anomalies throughout the pre-onset period, while 10 m wind-speed anomalies increased rapidly after approximately −12 h. In contrast, summer events showed stronger thermal signals before approximately −18 h, including enhanced surface–air temperature contrast, positive net shortwave radiation anomalies, and boundary-layer growth.*

Reason for this revision: The Abstract now presents quantitative diagnostic evidence and removes the unsupported "critical prediction window" statement.

Location in revised manuscript: Sect. 2.3 "ERA5 Reanalysis Data"

Original text: *The original manuscript described ERA5 mainly as a source of meteorological background fields and did not clearly define diagnostic indicators for dynamic and thermal analysis.*

Revised text: *The revised manuscript defines dynamic indicators as mean sea-level pressure-gradient magnitude, 850 hPa geopotential-height-gradient magnitude, and 10 m wind speed, and defines thermal indicators as 2 m air* *temperature, skin temperature, surface–air temperature difference, surface net shortwave radiation, and boundary-layer height.*

Reason for this revision: These definitions provide a more direct quantitative basis for evaluating the seasonal dynamic and thermal background before dust-storm onset.

Location in revised manuscript: Sect. 2.3, anomaly baseline and averaging method

Original text: *The original manuscript did not sufficiently explain how the background field and anomalies were 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: This addition makes the anomaly analysis reproducible and strengthens the diagnostic basis of the revised interpretation.

Location in revised manuscript: Sect. 3.3 "Analysis of Dynamic and Thermodynamic Factors"

Original text: *The original analysis mainly interpreted pressure and temperature maps and inferred that spring storms were dynamically dominated and summer storms were thermally influenced.*

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 mean sea-level pressure-gradient anomaly and 850 hPa height-gradient anomaly remain higher in spring throughout the pre-onset period, whereas summer cases show stronger early thermal preconditioning, expressed as enhanced surface–air temperature contrast, positive radiation anomalies, and boundary-layer growth.*

Reason for this revision: The revised text supports the seasonal contrast with quantitative anomaly curves rather than relying only on visual map-based interpretation.

Location in revised manuscript: Sect. 3.3 and Sect. 5 "Conclusion"

Original text: *The previous version stated that the 12–6 h period before onset could be regarded as a key prediction window.*

Revised text: *The revised manuscript removes the 12–6 h key-prediction-window conclusion and instead describes near-onset wind-speed and wind-shear enhancement as an observed feature of the analyzed events.*

Reason for this revision: The revision avoids overstating the forecasting significance of a limited event sample without a formal prediction or skill-assessment framework.

Comments b

Reviewer comment: The conclusion that 12–6 h represents a key time window is drawn largely from the contrasts in variance and range shown in Tables 2 and 3. However, the individual events do not show a fully consistent pattern, and some still display marked variability at shorter timescales. As a result, the broader applicability of this conclusion is not yet fully clear.

Response: Thank you for this valuable comment. We fully agree that the 12–6 h conclusion in the previous manuscript was too strong and was not supported by a formal predictive framework or sufficient event consistency. In the revised manuscript, we removed this conclusion and replaced the previous variance-based interpretation with composite dynamic and thermal anomaly curves from −24 to +3 h relative to dust-storm onset.

Detailed changes made in the manuscript:

Location in revised manuscript: Previous Tables 2 and 3

Original text: *Table 2 and Table 3 presented variance and range values at 24, 12, 6, and 3 h before the dust storm, and these values were used to infer that 12–6 h represented a key prediction window.*

Revised text: *The previous variance-based Tables 2 and 3 were removed from the revised manuscript.*

Reason for this revision: Removing these tables avoids using event-specific variance behavior as evidence for a general forecasting window.

Location in revised manuscript: Sect. 3.3, replacement analysis

Original text: *The original text stated that the pressure difference between ΔP12h and ΔP6h showed significant variation and that this period could represent a key window for spring dust-storm prediction.*

Revised text: *The revised text uses Fig. 10 to show the composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset. It describes stronger spring dynamic anomalies, stronger early summer thermal anomalies, and closer-to-onset wind-speed enhancement without defining a predictive window.*

Reason for this revision: The replacement analysis is more physically interpretable and avoids overgeneralizing from inconsistent event-level variance changes.

Location in revised manuscript: Sect. 3.4 "Tower-observed wind and temperature anomaly profiles"

Original text: *The original manuscript did not provide tower-based anomaly curves to support the temporal evolution near onset.*

Revised text: *Figure 11 was added to present the 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.*

Reason for this revision: The added tower-observation figure provides station-scale support for the near-onset wind and shear enhancement, while still avoiding the claim of a validated prediction window.

Location in revised manuscript: Sect. 5 "Conclusion"

Original text: *The original Conclusion stated that the 12–6 h period before dust-storm occurrence could be used as a key time window for prediction.*

Revised text: *The revised Conclusion removes this statement and instead emphasizes the staged evolution from early background adjustment or thermal preconditioning to near-surface wind and shear enhancement closer to onset.*

Reason for this revision: The revised conclusion better matches the evidence provided by the limited event sample and the new anomaly diagnostics.

Comments c

Reviewer comment: Section 2.5 provides the general framework for calculating Q, F, and u*, but several important methodological details remain insufficiently explained. In particular, the treatment of F, the assumptions used in estimating u*, the source of z0, the wind-speed averaging timescale, and the consideration of stability effects should be clarified, as these directly affect the reproducibility and reliability of the results.

Response: Thank you for this important and detailed comment. We agree that the previous description of Q, F, and u* was not sufficient to ensure reproducibility, especially because the calculation of vertical dust flux is sensitive to assumptions regarding concentration gradients, friction velocity, roughness length, wind-speed averaging, and stability effects. After carefully reconsidering the scope and reliability of the analysis, we removed the Q/F-centered flux calculation and interpretation from the main manuscript and refocused the analysis on directly observed tower meteorological variables.

Detailed changes made in the manuscript:

Location in revised manuscript: Previous Sect. 2.5

Original text: *The previous manuscript included "2.5 The calculation of horizontal dust flux (Q) and vertical dust flux (F)" and presented formulas for Q, F, dust concentration, and friction velocity.*

Revised text: *The original Sect. 2.5 on Q, F, and u* calculations was removed from the main manuscript.*

Reason for this revision: This avoids presenting flux estimates that require additional uncertainty analysis, clearer temporal matching, and more complete assumptions about u*, z0, and stability effects.

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

Original text: *The original text emphasized that the gradient collection system was used to determine 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 data-use description was revised to match the new profile-based analysis and to avoid overemphasizing uncertain flux calculations.

Location in revised manuscript: Sect. 3.4 revised title and content

Original text: *The original Results section focused on "Dust Flux Analysis" and interpreted Q/F structures at the two stations.*

Revised text: *Sect. 3.4 was revised as "Tower-observed wind and temperature anomaly profiles". The new section focuses on wind-speed anomaly, wind-shear anomaly, air-temperature-difference anomaly, 2 m air-temperature anomaly, and vertical profiles of wind-speed and air-temperature anomalies.*

Reason for this revision: The revised section is more directly supported by available tower measurements and better supports the dynamic–thermal interpretation of the study.

Location in revised manuscript: Sect. 4 and Sect. 5

Original text: *The original Discussion and Conclusion used Q/F differences to support terrain-effect interpretations.*

Revised text: *The revised Discussion and Conclusion no longer use Q/F as central evidence. Terrain-related differences are discussed in terms of wind and temperature anomaly profiles at TZ and XT.*

Reason for this revision: This revision reduces uncertainty and prevents flux-calculation assumptions from weakening the reliability of the manuscript.

Comments d

Reviewer comment: The manuscript states that BSNE samples were collected and weighed after each dust event, indicating that the measurements represent cumulative mass over a sampling interval. In contrast, the calculation of F requires a clearly defined concentration difference between two levels, together with the corresponding average wind speed and u* over the same period. At present, the sampling interval, event-based integration procedure, temporal consistency among sampling heights, and the matching with meteorological data are not sufficiently clear.

Response: Thank you for this careful and technically important comment. We agree that BSNE samples represent cumulative mass over sampling intervals, whereas calculating vertical dust flux requires strict temporal consistency between concentration differences, wind speed, and friction velocity. Because the previous manuscript did not adequately describe this matching procedure, we removed the vertical dust flux calculation and its interpretation from the main analysis.

Detailed changes made in the manuscript:

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

Original text: *The original text described the BSNE dust collectors and stated that dust samples were collected and weighed after each dust storm, but it did not fully explain the temporal matching between sampled mass, wind speed, and u* for flux calculation.*

Revised text: *The BSNE dust collection information is retained only as part of the observation-system description. The revised analysis focuses on meteorological gradient observations, including wind speed, wind shear, and temperature profiles.*

Reason for this revision: This revision keeps the observation-system description while avoiding insufficiently constrained flux calculations.

Location in revised manuscript: Previous Sect. 2.5 and flux-related Results

Original text: *The original manuscript calculated vertical dust flux using concentration differences and friction velocity, but the sampling interval and event-based integration procedure were not fully specified.*

Revised text: *The vertical dust flux calculation and the flux-centered Results were removed from the revised manuscript.*

Reason for this revision: The revision addresses the concern that temporal inconsistency between BSNE samples and meteorological variables could affect the reliability and reproducibility of F.

Location in revised manuscript: Sect. 3.4 "Tower-observed wind and temperature anomaly profiles"

Original text: *The original analysis used F to interpret vertical dust transport and terrain-related differences between the two sites.*

Revised text: *The revised analysis compares tower-observed wind-speed and air-temperature anomaly profiles at TZ and XT, together with wind-shear and temperature-difference anomalies from −24 to +3 h relative to onset.*

Reason for this revision: These variables have clearer temporal correspondence with the tower observations and are more appropriate for the revised dynamic–thermal interpretation.

Location in revised manuscript: Sect. 4 "Discussion" and Sect. 5 "Conclusion"

Original text: *The previous Discussion and Conclusion used F to support interpretations of summer variability and terrain effects.*

Revised text: *The revised Discussion and Conclusion no longer use F as supporting evidence. Differences between TZ and XT are discussed in terms of wind and temperature anomaly profiles.*

Reason for this revision: This change avoids overinterpreting cumulative dust-sample data without a fully documented temporal-matching procedure.

Comments e

Reviewer comment: The manuscript attributes the mid-level anomalies at TZ and the enhanced summer variability of F to secondary dust entrainment from surrounding dunes or to stronger topographic effects. However, these interpretations are not supported by sufficiently direct evidence, such as terrain parameters, wind-direction conditions, local turbulence characteristics, or surrounding geomorphological information.

Response: Thank you for this important comment. We agree that the previous interpretation of mid-level anomalies and enhanced summer F variability at TZ was too speculative, especially because direct evidence such as terrain parameters, local turbulence observations, detailed wind-direction analysis, or high-resolution geomorphological information was not available. We therefore removed the F-based interpretation and rewrote the terrain discussion more cautiously based on observed wind-speed and air-temperature anomaly profiles.

Detailed changes made in the manuscript:

Location in revised manuscript: Old Sect. 3.4 and flux-related interpretation

Original text: *The original manuscript attributed mid-level anomalies at TZ and enhanced summer F variability to secondary dust entrainment from surrounding dunes or stronger topographic effects.*

Revised text: *These F-based statements were removed from the revised manuscript.*

Reason for this revision: The revision removes speculative interpretations that were not supported by direct turbulence, wind-direction, terrain-parameter, or geomorphological evidence.

Location in revised manuscript: Sect. 3.4 revised profile analysis

Original text: *The original Results interpreted terrain effects mainly through horizontal and vertical dust-flux structures.*

Revised text: *The revised Results state that XT shows more regular vertical structures, whereas TZ shows more variable wind-speed and air-temperature anomaly profiles, which may reflect the modulation of regional forcing by local terrain heterogeneity.*

Reason for this revision: The revised interpretation is based on directly observed meteorological profile differences and uses cautious language.

Location in revised manuscript: Sect. 4 "Discussion"

Original text: *The original Discussion included stronger claims linking terrain and dunes to secondary dust entrainment and enhanced vertical dust flux.*

Revised text: *The revised Discussion states that local terrain heterogeneity may modulate the near-surface meteorological response to regional dynamic and thermal forcing, rather than directly concluding that dunes caused secondary entrainment or enhanced F.*

Reason for this revision: The revised wording better matches the available evidence and avoids unsupported causal claims.

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

Original text: *The original manuscript did not sufficiently acknowledge the lack of direct evidence for terrain-flow and vertical transport mechanisms.*

Revised text: *A limitations paragraph was added, noting that the lack of direct turbulence, vertical velocity, lidar observations, and detailed terrain-flow measurements limits the interpretation of local vertical transport processes. Future work should combine turbulence observations, lidar-based vertical profiling, high-resolution terrain data, and numerical simulations.*

Reason for this revision: This addition clearly separates supported findings from mechanisms that require further testing.

Technical issues

Comments a

Reviewer comment: The presentation of formulas and units is not sufficiently rigorous. The definition of c and the use of mixed units for u*, u, z, and z0 should be reviewed carefully to ensure dimensional consistency.

Response: Thank you for pointing out this problem. We agree that the previous formula presentation and unit definitions were not sufficiently rigorous. Because the Q/F flux calculation has been removed from the main manuscript, the previous formulas involving c, u*, u, z, and z0 have also been removed. The revised manuscript now focuses on ERA5 and tower-observed meteorological variables, and the text and figure captions use standard atmospheric-science terminology and SI units where applicable.

Detailed changes made in the manuscript:

Location in revised manuscript: Previous Sect. 2.5

Original text: *The original manuscript presented formulas for F, dust concentration c, and friction velocity u*, with mixed units such as cm s^{-1} and m s^{-1} for related variables.*

Revised text: *The previous formula section was removed from the main manuscript together with the Q/F-centered analysis.*

Reason for this revision: This eliminates unit inconsistency and avoids unsupported flux calculations without a full methodological and uncertainty description.

Location in revised manuscript: Sect. 2.3, Sect. 3.3, Sect. 3.4, and figure captions

Original text: *The original manuscript used inconsistent unit and variable expressions in parts of the flux and meteorological analysis.*

Revised text: *The revised manuscript focuses on mean sea-level pressure-gradient anomaly, 850 hPa geopotential-height-gradient anomaly, 10 m wind speed, surface–air temperature difference, net shortwave radiation, boundary-layer height, wind-speed anomaly, and temperature anomaly profiles.*

Reason for this revision: The revised variables are directly supported by ERA5 and tower observations and are described with clearer terminology and units.

Comments b

Reviewer comment: HYSPIT should be corrected to HYSPLIT.

Response: Thank you for identifying this typographical error. We corrected "HYSPIT" to "HYSPLIT" in the section title and throughout the manuscript.

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 model name was corrected and capitalization was standardized.

Location in revised manuscript: Abstract, Keywords, Sect. 2.4, Sect. 3.1, Sect. 4, and Sect. 5

Original text: *The original manuscript contained inconsistent HYSPLIT/HYSPIT spelling in several places.*

Revised text: *All occurrences were checked and standardized as "HYSPLIT".*

Reason for this revision: This correction removes a technical spelling error throughout the manuscript.

Comments c

Reviewer comment: X Station and XT Station are used inconsistently and should be unified throughout the manuscript.

Response: Thank you for this comment. We standardized the station names throughout the manuscript. The desert-interior station is consistently referred to as Tazhong (TZ), and the northern desert-margin station is consistently referred to as Xiaotang (XT). Inconsistent expressions such as "X Station", "XT Station", and "XiaoTang" were removed or revised.

Detailed changes made in the manuscript:

Location in revised manuscript: Abstract

Original text: *The original Abstract referred generally to dual-gradient observational experiments in the central and peripheral regions of the TD without clearly defining the station names.*

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 two station names and abbreviations are now introduced at the beginning of the manuscript.

Location in revised manuscript: Sect. 2.2 “Observational Data”

Original text: *The observational data were obtained from two stations: Xiaotang (XT)X Station … and TZ Station … At XT Station …*

Revised text: *The observational data were obtained from two stations: Xiaotang (XT), located on the northern edge of the TD, and Tazhong (TZ), situated in the desert interior.*

Reason for this revision: The station descriptions were revised to remove inconsistent forms and to clarify the geographic and terrain settings of the two sites.

Location in revised manuscript: Table 1, Sect. 3.4, Sect. 4, and Sect. 5

Original text: *The original manuscript used inconsistent station names and abbreviations in tables, captions, and interpretive text.*

Revised text: *The revised manuscript consistently uses “TZ” and “XT” after their first definition.*

Reason for this revision: Consistent station naming improves readability and avoids confusion between site identity and terrain setting.

Comments d

Reviewer comment: Table 1 contains obvious typographical errors such as XT(and XT).

Response: Thank you for pointing out these typographical errors. We carefully checked and corrected Table 1. The station names are now consistently written as TZ and XT, and typographical errors such as “XT(”, “XT)”, “TZ(”, and other station-name fragments have been removed.

Detailed changes made in the manuscript:

Location in revised manuscript: Table 1

Original text: *Examples of original entries included “TZ(”, “XT)”, “XTTZ”, and mixed event labels such as Dust32, Dust43, and Dust98.*

Revised text: *The revised Table 1 uses standardized station names “TZ” and “XT”, unified event labels Dust1–Dust8, one row labelled “Excluded event”, and date-time format YYYY-MM-DD HH:MM.*

Reason for this revision: The revised table now matches the event numbering, station naming, and timing used in the Abstract, Methods, Results, and Conclusion.

Location in revised manuscript: Sect. 2.2 “Observational Data”

Original text: *The original text and table mixed observation dates, sample-collection dates, and event labels.*

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: This revision clarifies the observation period, sample-collection period, excluded event, and final sample.

Comments e

Reviewer comment: The heading of Table 3 still refers to Variance of ΔP24h and related terms, which does not match the temperature-difference content of that table.

Response: Thank you for pointing out this inconsistency. We agree that the previous Table 3 heading was incorrect. In the revised manuscript, the previous variance tables were removed and replaced by a more direct composite anomaly analysis in Fig. 10.

Detailed changes made in the manuscript:

Location in revised manuscript: Previous Table 3

Original text: *The heading and column labels still referred to "Variance of ΔP24h", "Variance of ΔP12h", and related pressure terms, although the surrounding text discussed temperature differences.*

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

Reason for this revision: Removing the table avoids mismatch between the table heading, variable names, and the thermal-difference interpretation.

Location in revised manuscript: Sect. 3.3 and Fig. 10

Original text: *The original Results used Tables 2 and 3 to interpret pressure and temperature changes and to support the 12–6 h prediction-window statement.*

Revised text: *The revised Results use Fig. 10 to present the composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset.*

Reason for this revision: The revised figure provides a consistent set of diagnostic variables and avoids confusion between pressure and temperature indicators.

Comments f

Reviewer comment: The presentation of Figures 10–12 should be improved, especially with regard to image resolution, uniform font sizes, and the overly small subtitles in Figures 10 and 11.

Response: Thank you for this helpful comment. We agree that the previous figures had problems with resolution, font size, and subtitle readability. In the revised manuscript, the original flux-related figures were removed, and new or revised figures were prepared to support the updated analysis. These figures were redrawn with improved resolution, clearer labels, and more consistent font sizes.

Detailed changes made in the manuscript:

Location in revised manuscript: Old Figures 10–12

Original text: *The original figures included flux-centered panels and small subtitles, and the figure presentation did not sufficiently support the revised diagnostic analysis.*

Revised text: *The original flux-related figures were removed or replaced by new diagnostic figures.*

Reason for this revision: This revision improves both figure readability and consistency with the revised analytical focus.

Location in revised manuscript: Fig. 10

Original text: *No equivalent composite diagnostic 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: This new figure summarizes the ERA5-based dynamic and thermal anomaly diagnostics in a clearer and more quantitative form.

Location in revised manuscript: Fig. 11

Original text: *The original manuscript did not present a comparable tower-based composite anomaly figure.*

Revised text: *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.*

Reason for this revision: This new figure connects the regional dynamic–thermal background with the station-scale tower observations.

Location in revised manuscript: Figs. 12 and 13

Original text: *The original Figures 10–12 were not sufficiently clear in image resolution, font size, or caption wording.*

Revised text: *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 directly support the tower-observed profile analysis and use clearer figure presentation.

Additional note

In addition to addressing Reviewer 3's comments, the manuscript has also been revised according to suggestions from the other reviewers. These additional revisions mainly include rewriting the Introduction, clarifying the methodological framework, adding ERA5-based quantitative anomaly diagnostics, defining the anomaly baseline and spatial averaging domains, adding detailed HYSPLIT settings, removing unsupported Q/F flux-centered interpretations, revising figure captions and terminology, 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

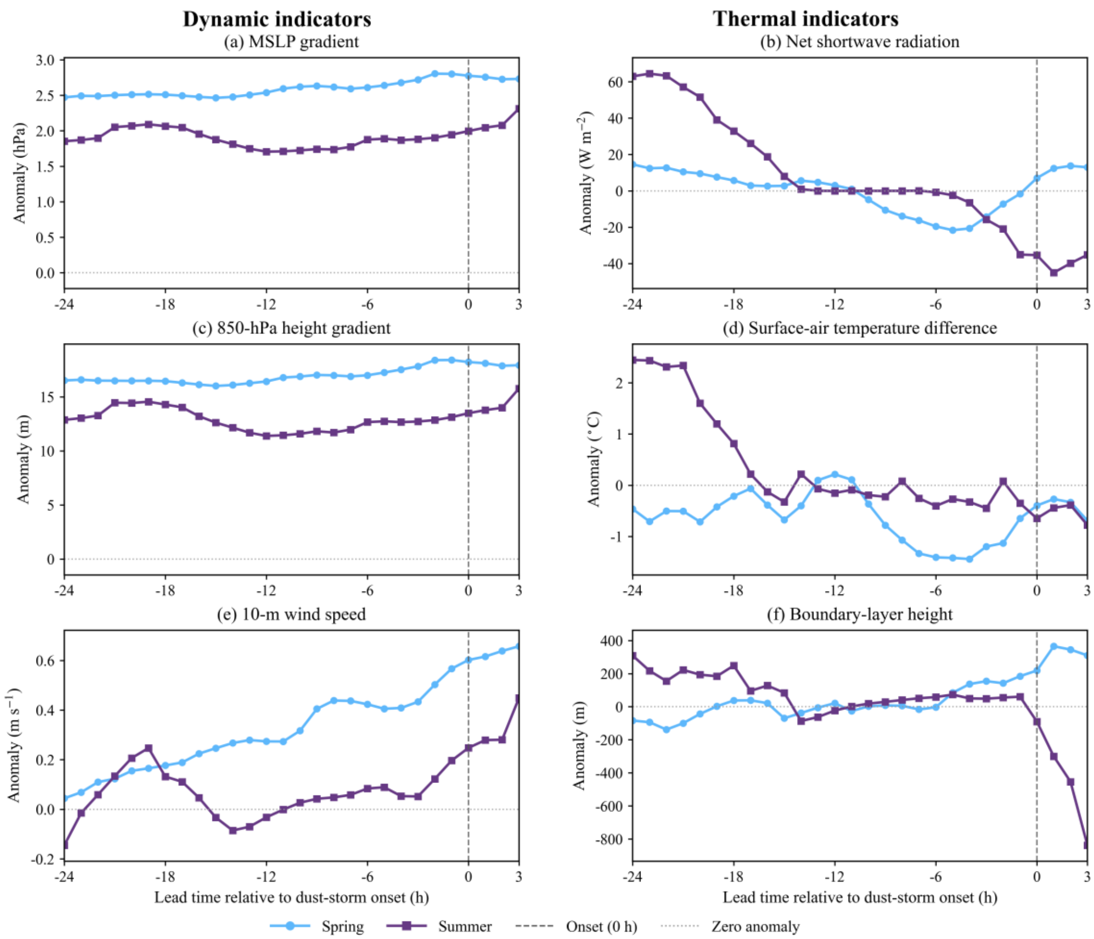

Fig. 10. Composite evolution of dynamic and thermal anomalies from −24 to +3 h relative to dust-storm onset.

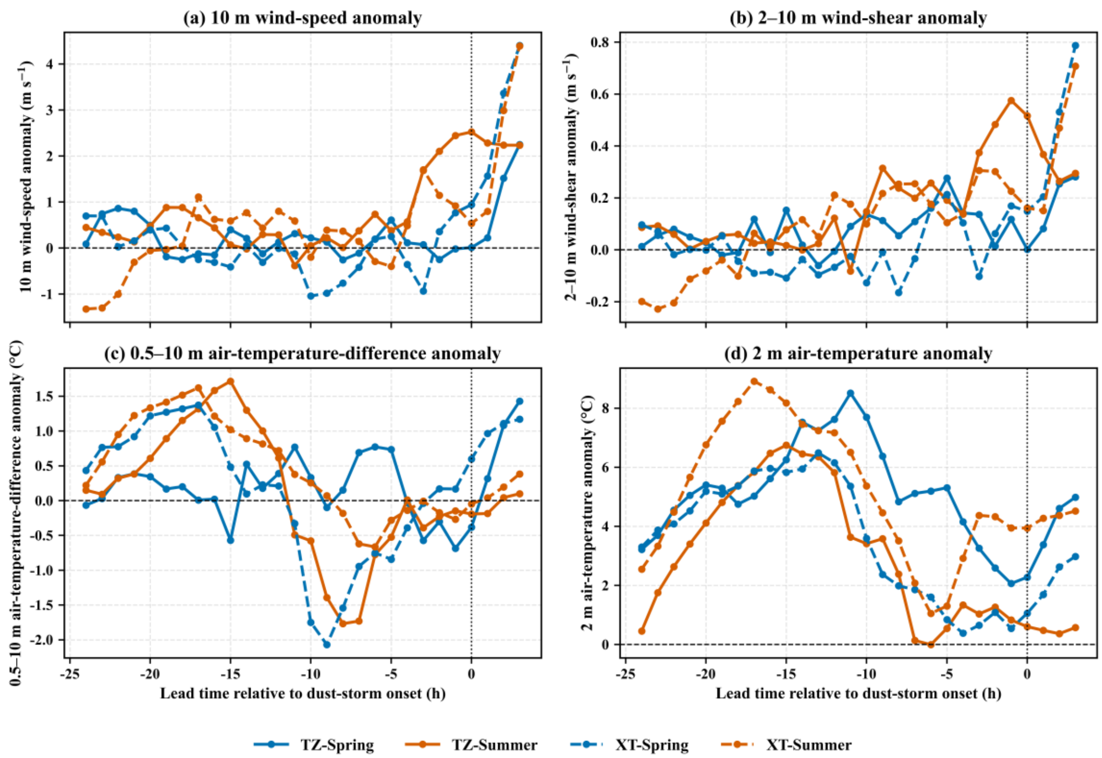

Fig. 11. Composite evolution of tower-observed wind-speed, wind-shear, air-temperature-difference, and 2 m air-temperature anomalies from −24 to +3 h relative to dust-storm onset.

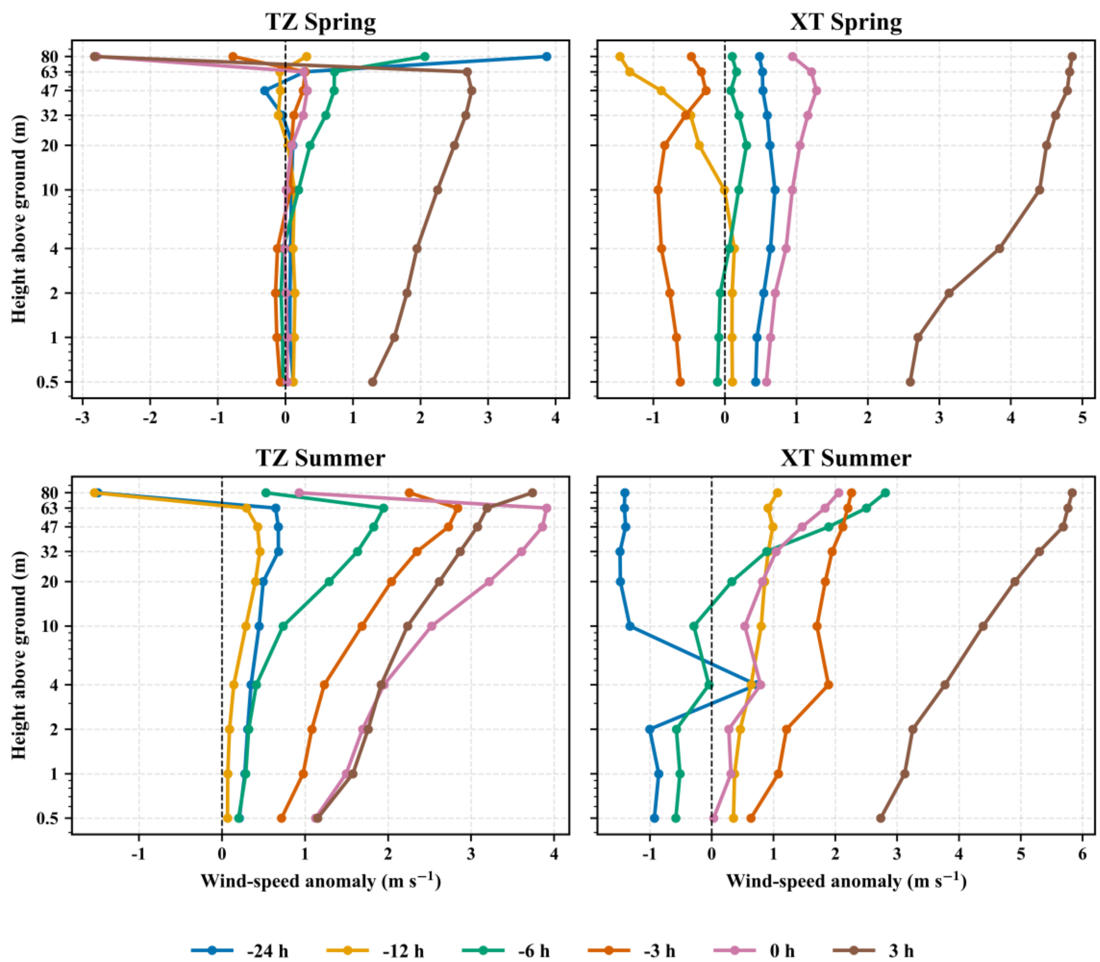

Fig. 12. Vertical profiles of wind-speed anomalies at TZ and XT during spring and summer dust-storm events.

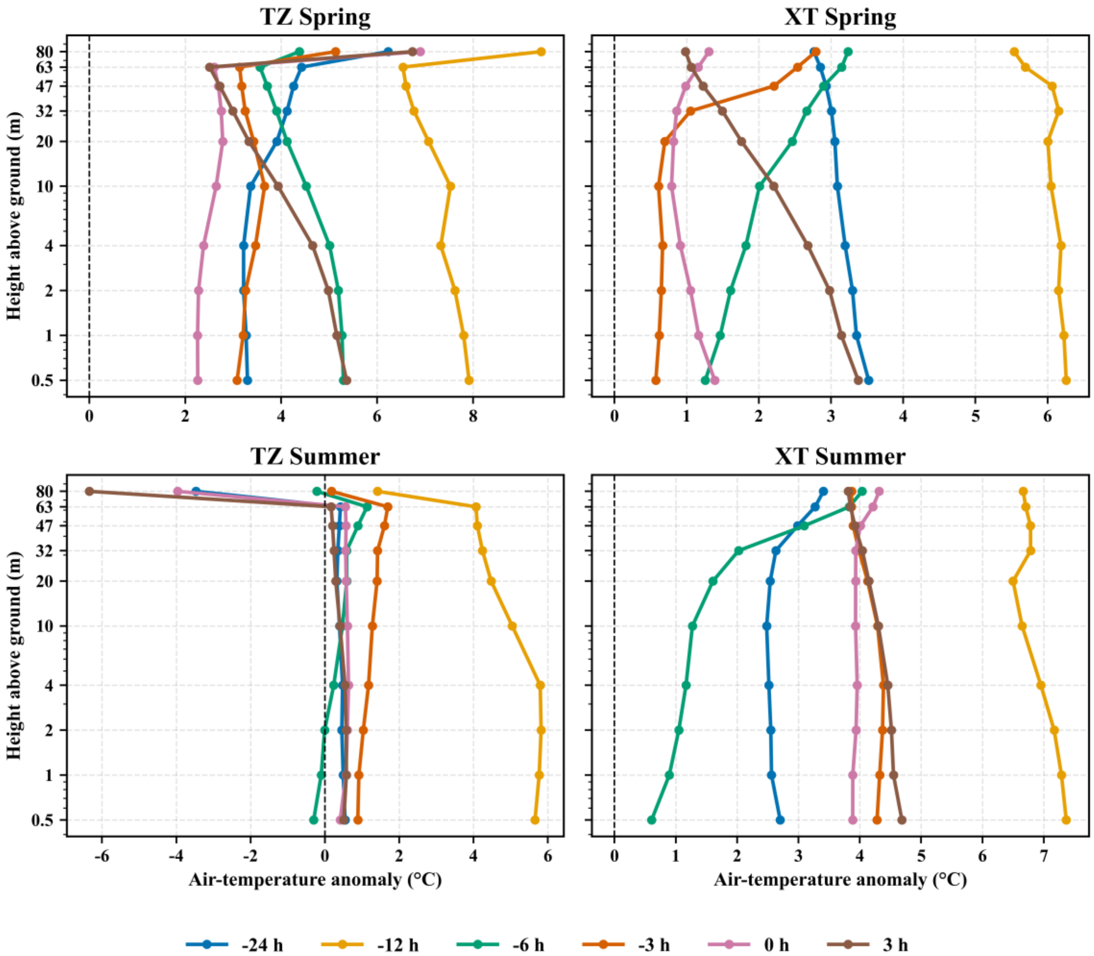

Fig. 13. Vertical profiles of air-temperature anomalies at TZ and XT during spring and summer dust-storm events.