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Article title: Response of Extreme Precipitation to Dust Aerosols in the Tarim Basin under Climate Warming

Manuscript number: egusphere-2025-5307

Dear Editors and Reviewers:

Thank you for your letter and for the reviewers' comments concerning our manuscript entitled "Response of Extreme Precipitation to Dust Aerosols in the Tarim Basin under Climate Warming (egusphere-2025-5307)". These comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made correction which we hope meet with approval. Revised portion are marked in the document named "Manuscript-R-with changes marked". The revised version is provided in the document named "Manuscript-R-with no changes marked". The point-to-point responses to associate editor and reviewer's comments are as follows.

Reviewer #1:

The interaction of aerosols and precipitation is an important issue in climate change and atmospheric sciences, especially for the arid and semi-arid lands. This article targeted the Tarim Basin with dry to explore the impact of dust aerosols on extreme precipitation over arid region with multi-source observation over past 50 years. The study provides the interesting results on response of extreme precipitation to dust aerosols over desert and surrounding region, improving our understanding on the interaction of aerosols and precipitation over arid region. The conclusions of this article on dust aerosols altering cloud physical properties are innovative to a certain extent. I recommend the article be published after the following comments are addressed.

Response: Thank you so much for your kindness and comments.

1. The main concerns are around the in-depth discussions and clarification on the results:

a) In Section 3.2.1, Dynamic Conditions: the synergistic effect of dynamic and thermodynamic processes establishes strong lifting conditions conducive to both dust event and extreme precipitation, which could ensconce a positive correlation between dust event and extreme precipitation in the macro process. Please give the discussions on this the macro process for response of extreme precipitation to dust aerosols.

Response: Thank you for your comments. We fully agree on the need to clarify the specific role of macro processes in linking dust with extreme precipitation. Following your suggestion, we have added a discussion at the end of Section 3.2.1 of the original manuscript. The specific revisions are detailed as follows:

The macroscale process of synergistic dynamical and thermodynamic lifting directly modulates the response of extreme precipitation to dust aerosols. It does so by providing the sustained ascent that simultaneously transports moisture and activates the microphysical effects of dust. Once activated, dust particles serve as efficient ice nuclei, enhancing ice-phase processes and latent heat release, which intensifies convection and precipitation efficiency (Xu et al., 2025; Sun et al., 2022). This interaction establishes a positive feedback loop, whereby the large-scale conditions amplify the microphysical impact of dust on precipitation.

Reference:

Xu, X., Cai, W., Zhao, T., Zhang, H., Guo, X., Liu, W., Zhang, T., Zhao, R., Wu, C., Li, Y., Wang, L., Yan, P., and Yang, C.: Understanding clouds and precipitation over the Mount Qomolangma: how does the aerosol activation effect exist? *Sci. Bull.*, 70, 3649–3658, <https://doi.org/10.1016/j.scib.2025.09.031>, 2025.

Sun, N., Fu, Y., Zhong, L., and Li, R.: Aerosol effects on the vertical structure of

precipitation in East China, *Npj Clim. Atmospheric Sci.*, 5, 60, <https://doi.org/10.1038/s41612-022-00284-0>, 2022.

b) Lines 201-202: Overall, the multi-year average contribution of D_EP frequency (amount) to total EP is 35.52% (34.34%). Please clarify how to estimate the contribution.

Response: Thank you for your comments. In Section 2.5 "Definition of EP events," EP is defined and categorized into D_EP events and N_EP events. Figures 3c and 3d present, for each station, the annual percentage contributions of D_EP frequency and precipitation amount to their respective totals for EP. The statement "Overall, the multi-year average contribution of D_EP frequency (amount) to total EP is 35.52% (34.34%)" was derived from the multi-year average across all stations. The specific revisions are detailed as follows:

By averaging the annual percentages of D_EP frequency and precipitation from each station relative to total EP, the multi-year average contribution is obtained as 35.52% (34.34%).

c) In Section 3.2.4 Cloud Microphysical Properties: Please add the supplementary with the Figures presenting the absolute values of Cloud physical (not only Microphysical) properties CTH, LWP, IWP, LWR and IWR for the complete discussion on D_EP events, which could support the mechanisms of dust aerosol effects on clouds and precipitation in Fig. 8.

Response: Thank you for your comments. We have incorporated the absolute values of cloud physical properties (CTH, LWP, IWP, LWR, and IWR) into Figure 7 and have supplemented the discussion on D_EP events accordingly. The specific revisions are detailed as follows:

The formation and intensity of precipitation are critically constrained by cloud microphysical properties, which govern the growth and conversion efficiency of hydrometeors within clouds and are macroscopically manifested in parameters such as

cloud-top height and cloud water path, both positively correlated with precipitation (Song et al., 2019; Zhao et al., 2024). Satellite observations reveal that during D_EP events, the average cloud top height (CTH) can reach approximately 8 km, exhibiting more pronounced vertical development compared to N_EP events (Fig. 7a, f). Accompanying this is a notable increase in hydrometeor content, with ice water path and ice-phase particle effective radius approximately twice their liquid counterparts (Fig. 7b–e). Further comparison with N_EP events shows that 63% of stations observed larger liquid water path values, while 85% of stations exhibited higher ice water path values (Fig. 7g, h). This enhancement can be attributed to the role of dust aerosols acting as efficient ice nuclei. Their insoluble surfaces provide a solid-liquid interface that facilitates the formation of ice embryos, thereby promoting the freezing of supercooled droplets (Zhang et al., 2012). The resulting ice crystals then grow through processes such as collision-coalescence, leading to a significant increase in the size of ice-phase particles, as indicated by the ice water radius (IWR; Fig. 7j). Notably, the mean liquid water radius (LWR) is also larger during D_EP events (Fig. 7i), which is likely attributable to strong updrafts supplying abundant moisture that enhances condensation concurrent with ice growth. This ultimately enhances precipitation efficiency by increasing the sedimentation velocity of precipitation particles. These microphysical processes can suppress the formation of light precipitation while promoting the occurrence of heavy precipitation, consequently leading to an increased frequency of extreme weather events (Shao et al., 2022; Zhao et al., 2025).

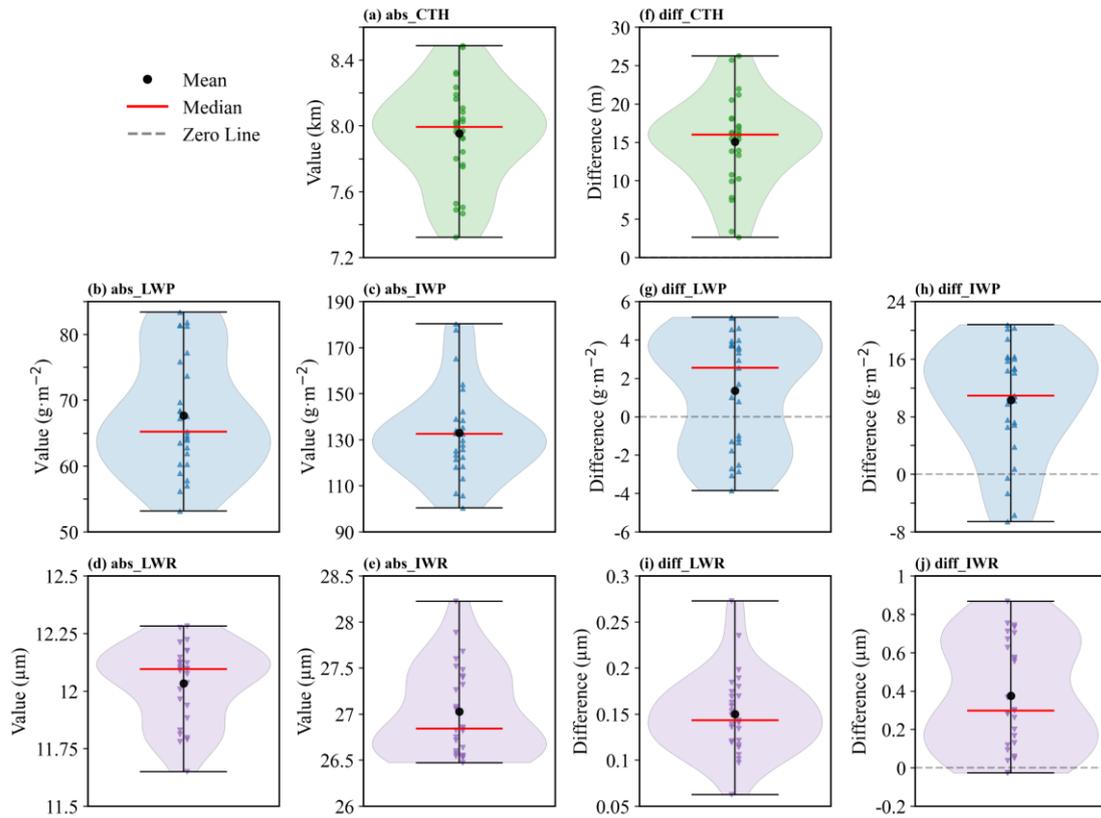


Figure 7. Cloud physical properties during D_EP events and their differences from N_EP events in March–August 2000–2024. (a–e) Absolute values during D_EP events: (a) CTH (km), (b) LWP ($\text{g}\cdot\text{m}^{-2}$), (c) IWP ($\text{g}\cdot\text{m}^{-2}$), (d) LWR (μm), (e) IWR (μm). (f–j) Differences (D_EP minus N_EP): (f) CTH (m), (g) LWP, (h) IWP, (i) LWR, (j) IWR. Black dots represent mean values, red solid lines indicate medians, and gray dashed lines denote the zero reference line.

Reference:

Shao, T., Liu, Y., Wang, R., Zhu, Q., Tan, Z., and Luo, R.: Role of anthropogenic aerosols in affecting different-grade precipitation over eastern China: A case study, *Sci. Total Environ.*, 807, 150886, <https://doi.org/10.1016/j.scitotenv.2021.150886>, 2022.

Song, H.-J., Lim, B., and Joo, S.: Evaluation of Rainfall Forecasts with Heavy Rain Types in the High-Resolution Unified Model over South Korea, *Weather Forecast.*, 34, 1277–1293, <https://doi.org/10.1175/WAF-D-18-0140.1>, 2019.

Zhang, D., Wang, Z., Heymsfield, A., Fan, J., Liu, D., and Zhao, M.: Quantifying the

impact of dust on heterogeneous ice generation in midlevel supercooled stratiform clouds, *Geophys. Res. Lett.*, 39, L18805, 2012.

Zhao, C., Li, J., and Yang, Y.: A Short Review of Microphysical Effects of Aerosols on Clouds and Precipitation, *Chin. J. Atmospheric Sciences*, 49, 949–963, 2025.

Zhao, P., Liu, X., and Zhao, C.: Potential Modulation of Aerosol on Precipitation Efficiency in Southwest China, *Remote Sens.*, 16, 1445, <https://doi.org/10.3390/rs16081445>, 2024.

d) It is suggested for the further study for another paper with the CMIP6 model projections of future changes in D_EP events under future climate. The current discussion and results are too simple and surplus with rough analysis.

Response: Thank you for your valuable comments. We have carefully considered your feedback and acknowledge that "The current discussion and results are too simple and surplus with rough analysis" indeed highlights a legitimate concern in our manuscript. However, another reviewer raised a key point: "The impact of dust aerosols on extreme precipitation is modeled under various emission scenarios, adding completeness to the paper. Nevertheless, the interpretation of the results is too succinct to convey the significance of these findings. The analysis and discussion of this part (Figures 9b and 9c) should be expanded." After synthesizing the suggestions from both reviewers, we have thoughtfully decided to expand the analysis in this section by adding more detailed interpretation and discussion. In addition, we will expand the "Results and Discussion" section by outlining prospects for future work, specifically the use of CMIP6 models to conduct deeper simulation analyses of how D_EP events may evolve under future climate change. The specific revisions are detailed as follows:

To further understand the impact of dust aerosols on EP, analyses of CMIP6 model projections are conducted for future changes in D_EP events under different emission scenarios. Historical simulations indicate that D_EP events were low probability occurrences prior to 1950, after which their frequency increased continuously and

gradually evolved into a regionally common weather phenomenon. This finding is consistent with the results of Zhou et al. (2025) based on ground-based observations, confirming the model capability to reproduce historical climate states. Under future scenarios, the frequency of D_EP events in the Tarim Basin shows a strong dependence on emission scenarios. Under the low-emission scenario (SSP126), the annual frequency exhibits a significant decreasing trend (trend = $-1.2 \text{ d} \cdot 10\text{a}^{-1}$), which is particularly pronounced in the near term (2021–2040; $-2.76 \text{ d} \cdot 10\text{a}^{-1}$). In contrast, under the medium- and high-emission scenarios (SSP245 and SSP585), the declining trend weakens considerably (-0.85 and $-0.19 \text{ d} \cdot 10\text{a}^{-1}$). Notably, the downward trend under SSP585 is statistically insignificant, and frequency remains high with fluctuations in the near term, reflecting the complex modulation of cloud microphysical processes by high aerosol concentrations. Correspondingly, a decreasing trend with diminishing rates (-4.77 , -4.36 , and $-3.46 \text{ mm} \cdot 10\text{a}^{-1}$) is observed for D_EP precipitation from 2015 to 2100 as the emission scenario intensifies. It is noteworthy that during the near-term period, only SSP126 shows a significant reduction in precipitation ($-10.97 \text{ mm} \cdot 10\text{a}^{-1}$), whereas SSP245 and SSP585 exhibit increasing trends (1.67 and $1.58 \text{ mm} \cdot 10\text{a}^{-1}$, respectively). This suggests that under future high-emission backgrounds, dust aerosols may partly offset or even reverse the precipitation reduction caused by declining event frequency, likely through enhanced ice-nucleating effects. These results highlight the nonlinear response characteristics of aerosol-cloud-precipitation interactions across different emission path-ways.

e) Section 4 Discussion and Conclusion: the discussion is too many with repeating the discussions in Sect. 3. Please modify this section with 1) concluding the study results, 2) extracting the highlights, 3) discussion on the limitations of this study, and 4) outlook of further study on this issue.

Response: Thank you for your comments. We have revised and restructured Section 4 Discussion and Conclusion in accordance with the provided guidance. The specific revisions are detailed as follows:

This study demonstrates that despite the overall increase in atmospheric moisture

content under global warming, the actual atmospheric humidity in the study region shows a declining trend, making it more difficult for the air to reach saturation. However, dust events can promote a positive precipitation feedback by transporting abundant dust aerosols and coupling with the dynamic-thermodynamic processes that enhance vertical moisture transport. Observational statistics confirm that over the past 50 years, D_EP accounts for 35.52% in frequency and 34.34% in precipitation amount of the total regional EP. Notably, 21% of stations in the southern part contributed over 90% before the year of 2000. Quantitative assessment further indicates that the average net contribution of dust aerosols to EP is 6.6%. Given this overall promotive effect on precipitation, D_EP events are projected to persist at elevated levels throughout the near-term 21st century under high-emission scenarios. The results reveal the amplifying mechanism of dust aerosols on EP through the combined effects of ice nucleation and condensation under favorable moisture conditions, and highlight the particularly significant role of dust in promoting ice-phase particle growth, thus emphasizing its function as an efficient ice nucleus.

However, as this study is primarily based on observations and statistics from a specific region, the generalizability of the dust aerosol-precipitation feedback mechanism to other arid and semi-arid regions remains limited. Future work could extend the CMIP6 models to broader arid and semi-arid areas to thoroughly evaluate the regional commonalities and differences in the dust aerosol-precipitation feedback mechanisms under different climatic backgrounds, thus advancing a more holistic understanding of the interaction mechanisms between the water cycle and climate change in global drylands.

2. Technical comments :

a) It is suggested with the better title: Response of Extreme Precipitation to Dust Aerosols in the Tarim Basin under Climate Warming and Wetting or Response of Extreme Precipitation to Dust Aerosols in the Tarim Basin over past 50 years.

Response: Thank you for your comments. We have carefully considered your

comment and agree that the original title does not fully represent the content of our study. Both alternative titles you proposed indeed better convey the main focus of the paper. To emphasize the long-term temporal dimension of our analysis, we have decided to adopt the title "Response of Extreme Precipitation to Dust Aerosols in the Tarim Basin over the Past 50 Years."

b) Please label the station names with station number in y-coordinate the Figure 3c-d.

Response: Thank you for your comment. We understand that the station abbreviations in the original Figure 3c-d may have caused confusion without their full names specified. To address this, we have now incorporated a textual explanation in Section 2.1 on Ground observations that specifies each station's full name with its corresponding abbreviation. This revision ensures readers can clearly identify all stations. Regarding the suggestion to label the y-coordinate with station numbers, we have tested this version. While it does enhance station identification, we found that the high density of labels compromised the overall readability and clarity of the figure. Therefore, to best serve the reader's understanding, we have retained the figure with abbreviations on the y-axis, supported by the complete mapping provided in the text. The specific revisions are detailed as follows:

With Tazhong Station (TZ) as the boundary, the areas to its south are Yingjisha (YJS), Maigaiti (MGT), Shache (SC), Zepu (ZP), Qiemo (QM), Yecheng (YC), Pishan (PS), Moyu (MY), Hetian (HT), Luopu (LP), Minfeng (MF), Cele (CL), and Yutian (YT); while the areas to its north are Ruoqiang (RQ), Yuepuhu (YPH), Kashi (KS), Jiashi (JS), Atushi (ATS), Keping (KP), Alar (ALE), Tieganlike (TGLK), Awati (AWT), Aksu (AKS), Shaya (SY), Xinhe (XH), and Korla (KEL).

c) Please give the full names of acronyms at the first appearance of acronyms, such as OMR, SSP245 and SSP585.

Response: Thank you for your comments. We have carefully checked the manuscript and confirm that the full name of OMR was already provided upon its first

occurrence in the Introduction: "Then we apply the observational minus reanalysis (OMR) approach to quantitatively reveal the net contribution of dust aerosols to EP at a climatic observational scale." This text has been highlighted in yellow in the revised manuscript for clarity.

Regarding the emission scenarios, we note that the full names of SSP1-2.6, SSP2-4.5, and SSP5-8.5 were not formally provided upon their first mention. This issue has been corrected in Section 2.4 (Climate Projection Data) of the revised manuscript. The specific revisions are detailed as follows:

Projections from five global climate models (UKESM1-0, NorESM2-LM, MPI-ESM1-2-LR, MPI-ESM1-2-HR, AWI-ESM-1-REcoM) from the Coupled Model Intercomparison Project Phase 6 (CMIP6) were analyzed under three Shared Socioeconomic Pathway (SSP) scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5) to assess changes in D_{EP} over the Tarim Basin (O'Neill et al., 2016; Riahi et al., 2017).

d) Please change “3.2.4 Cloud Microphysical Properties” to “3.2.4 Cloud physical Properties”, because of some 3cloud macrophysical Properties.

Response: Thank you for your comments. The heading has been revised to "3.2.4 Cloud Physical Properties" to accurately reflect the scope of cloud properties discussed.

e) Please unify “South Xinjiang” with “Tarim Basin” in the manuscript.

Response: Thank you for your comments. To maintain consistency with the manuscript title and based on the distribution of the selected stations, we have revised the text by replacing all instances of "South Xinjiang" with "Tarim Basin" throughout the manuscript.

Reviewer #2:**Comments:**

Dust aerosols significantly influence cloud evolution and subsequent precipitation processes, primarily through their modulation of cloud microphysical properties via aerosol-radiation and aerosol-cloud interactions. Based on multi-source observational data, this study aims to analyze the impact of dust aerosols on cloud microphysical characteristics over long timescales and quantitatively assess their contribution to extreme precipitation events. The research topic holds considerable scientific value, and the analysis is relatively systematic and comprehensive. Therefore, I recommend acceptance of this manuscript after the authors address the following points.

Response: Thank you so much for your kindness and comments.

General comments:

1. The impact of dust aerosols on extreme precipitation is modeled under various emission scenarios, adding completeness to the paper. Nevertheless, the interpretation of the results is too succinct to convey the significance of these findings. The analysis and discussion of this part (Figures 9b and 9c) should be expanded.

Response: Thank you for your comments. We have revised this section in accordance with the provided guidance. The specific revisions are detailed as follows:

To further understand the impact of dust aerosols on EP, analyses of CMIP6 model projections are conducted for future changes in D_EP events under different emission scenarios. Historical simulations indicate that D_EP events were low probability occurrences prior to 1950, after which their frequency increased continuously and gradually evolved into a regionally common weather phenomenon. This finding is consistent with the results of Zhou et al. (2025) based on ground-based observations, confirming the model capability to reproduce historical climate states. Under future scenarios, the frequency of D_EP events in the Tarim Basin shows a strong dependence on emission scenarios. Under the low-emission scenario (SSP126), the annual frequency exhibits a significant decreasing trend (trend = $-1.2 \text{ d} \cdot 10\text{a}^{-1}$), which is

particularly pronounced in the near term (2021–2040; $-2.76 \text{ d} \cdot 10\text{a}^{-1}$). In contrast, under the medium- and high-emission scenarios (SSP245 and SSP585), the declining trend weakens considerably (-0.85 and $-0.19 \text{ d} \cdot 10\text{a}^{-1}$). Notably, the downward trend under SSP585 is statistically insignificant, and frequency remains high with fluctuations in the near term, reflecting the complex modulation of cloud microphysical processes by high aerosol concentrations. Correspondingly, a decreasing trend with diminishing rates (-4.77 , -4.36 , and $-3.46 \text{ mm} \cdot 10\text{a}^{-1}$) is observed for D_EP precipitation from 2015 to 2100 as the emission scenario intensifies. It is noteworthy that during the near-term period, only SSP126 shows a significant reduction in precipitation ($-10.97 \text{ mm} \cdot 10\text{a}^{-1}$), whereas SSP245 and SSP585 exhibit increasing trends (1.67 and $1.58 \text{ mm} \cdot 10\text{a}^{-1}$, respectively). This suggests that under future high-emission backgrounds, dust aerosols may partly offset or even reverse the precipitation reduction caused by declining event frequency, likely through enhanced ice-nucleating effects. These results highlight the nonlinear response characteristics of aerosol-cloud-precipitation interactions across different emission path-ways.

2. To ensure the robustness of the conclusions regarding threshold selection, it is recommended that the authors include an additional analysis in the main text or supplementary materials. For instance, a brief demonstration of whether key statistical characteristics of D_EP events, such as trends and contribution rates, remain consistent when using the 80th or 85th percentile thresholds compared to the current 75th percentile would be valuable.

Response: Thank you for your comments. To ensure the robustness of the conclusions regarding threshold selection, we have conducted supplementary analyses using different percentile thresholds.

Following the same methodology applied in the main analysis, we recalculated the frequencies of EP and D_EP events by adjusting the threshold to the 80th and 85th percentiles, respectively. Under the 80th percentile threshold, 4,503 EP events and 1,228 D_EP events were identified. When the threshold was raised to the 85th percentile, the corresponding frequencies decreased to 3,359 EP events and 895 D_EP events. This stepwise reduction in event count with increasing percentile aligns with expected

statistical behavior.

The trends of key statistical characteristics for extreme precipitation under the 80th, 85th, and 90th percentile thresholds have been added to Supplementary Figures S1 and S2. The results show that although the magnitude of increase for each metric attenuates as the threshold rises, all core indicators consistently exhibit a statistically significant upward trend across the different percentile thresholds. These indicators include the frequency of extreme precipitation events, the associated precipitation amount, and their respective contribution rates to total precipitation. This consistent pattern robustly demonstrates that the core conclusions of our study are not contingent upon a specific threshold choice, thereby confirming the rationality of our selected threshold and the overall robustness of the research findings. Following the analysis of extreme precipitation characteristics in Figure 2, the following content is supplemented:

When the thresholds for EP are set at the 90th, 85th, and 80th percentiles, the statistical characteristics of EP events exhibit a consistent increasing trend (figure omitted), thereby confirming the rationality of the selected threshold and the overall robustness of the research findings.

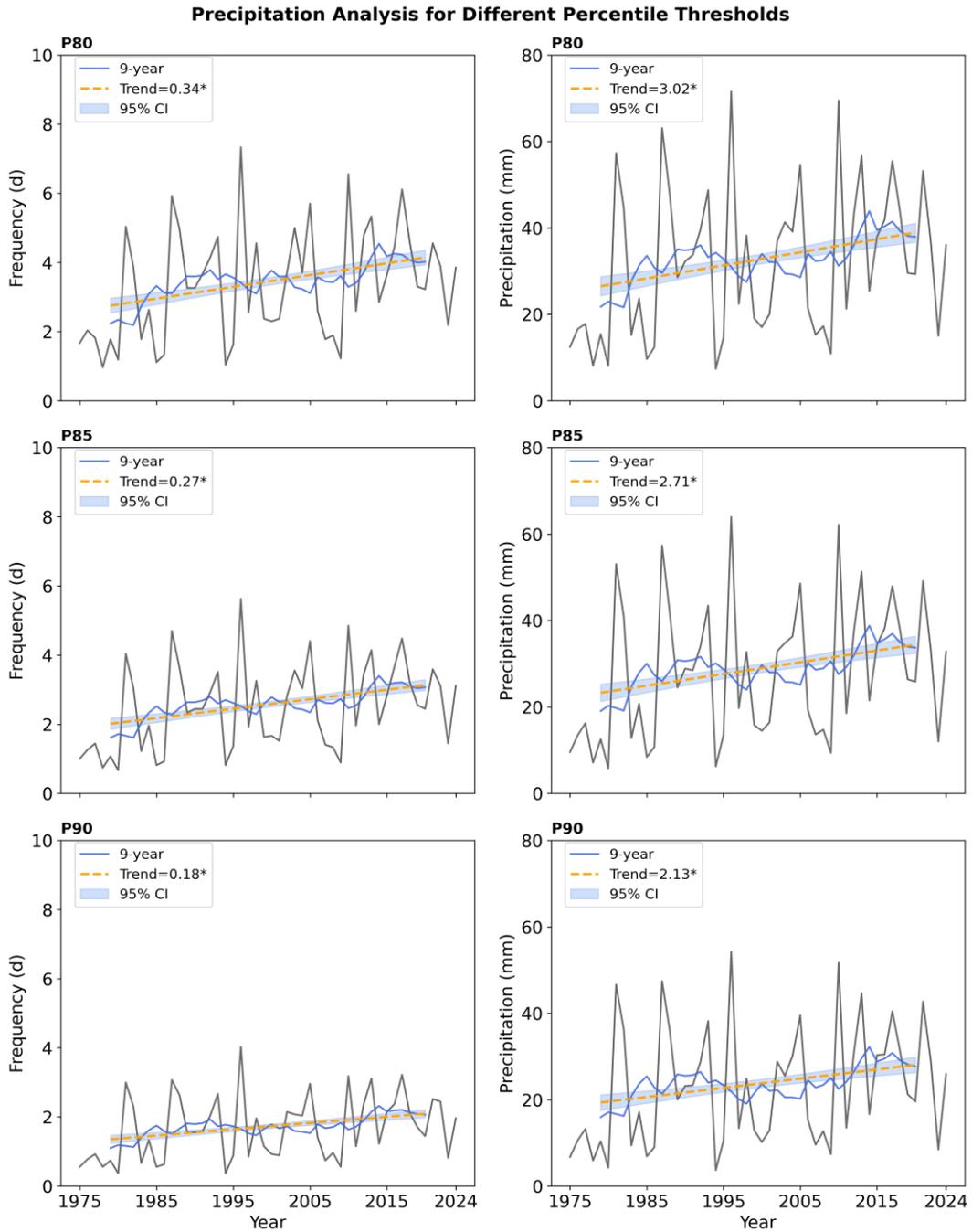


Fig. S1. Statistical characteristics of extreme precipitation events under different thresholds. The left column shows the interannual variation in the frequency of EP (units: d), and the right column presents the interannual variation in the amount of EP (units: mm). From top to bottom, the rows correspond to the thresholds of the 80th, 85th, and 90th percentiles, respectively.

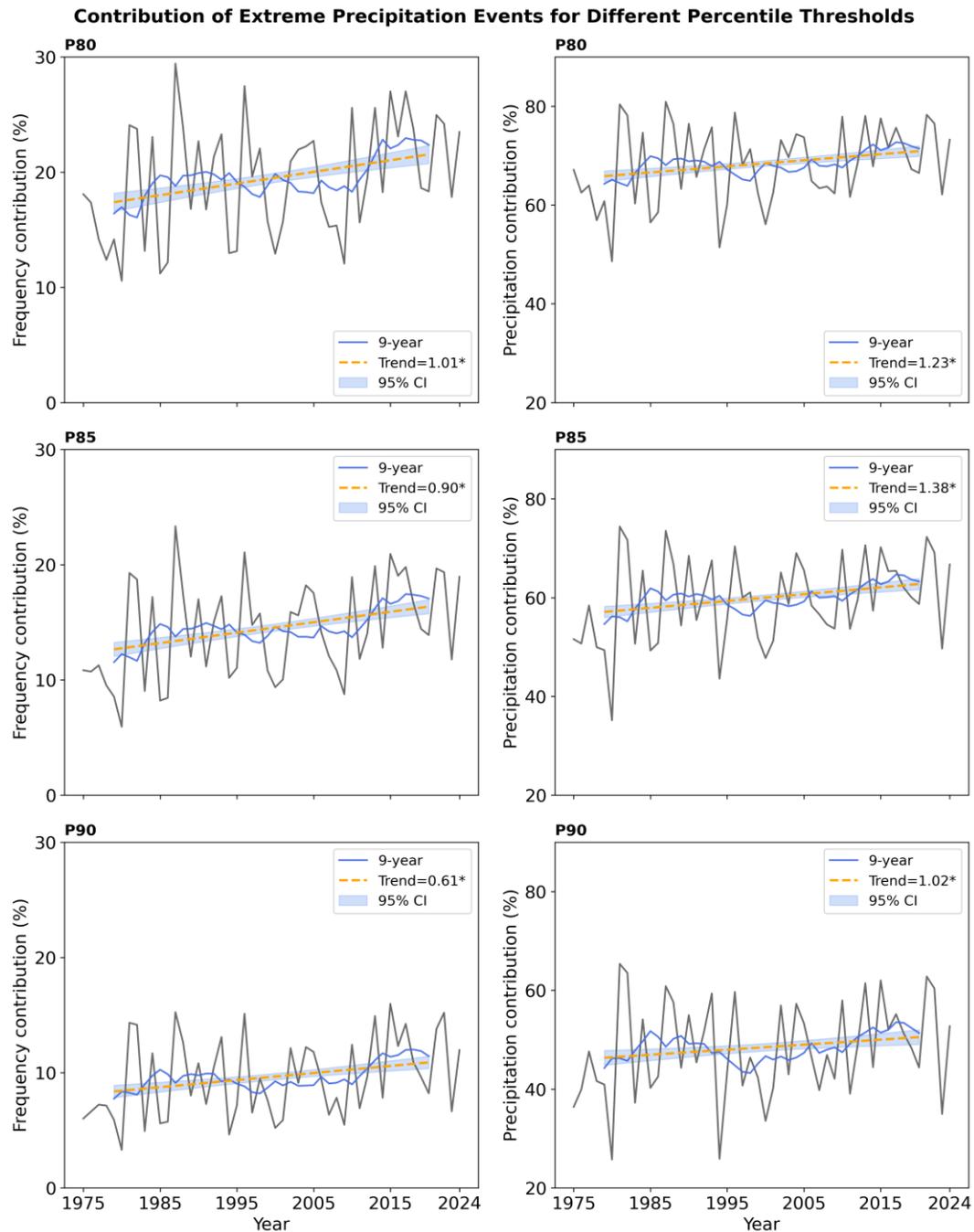


Fig. S2. Statistical contributions of extreme precipitation events under different thresholds. The left column shows the interannual variation in the frequency contribution of EP (units: %), and the right column presents the interannual variation in the amount contribution of EP (units: %). From top to bottom, the rows correspond to the thresholds of the 80th, 85th, and 90th percentiles, respectively.

Specific comments:

1.Line 33: "This findings" contains a grammatical error and should be corrected to "These findings".

Response: Thank you for your correction. The revised content is as follows:

These findings reveal that dust aerosols serve as a key regulator of the water cycle in arid regions, providing a new perspective for understanding the mechanisms driving EP.

2.Line 36: "Dust–cloud-precipitation interactions" should be revised to "Dust-cloud-precipitation interactions".

Response: Thank you for your correction. We have revised the hyphen formatting accordingly. The revised content is as follows:

Keywords: Dust aerosol, Extreme precipitation, Dust-cloud-precipitation interactions, Tarim Basin

3.It is recommended to replace "spring and summer" in Line 39 with "March–August" and maintain this terminology consistently throughout the manuscript.

Response: Thank you for your comments. We acknowledge the point that using the more precise term "March-August" enhances the clarity and consistency of the manuscript. We have revised the text accordingly by replacing all instances of "spring and summer" with "March-August" throughout the manuscript.

4.Lines 117-118 state that 'It is noteworthy that only five to six models satisfy the aforementioned daily scale output specification'. Please specify which output variables (e.g., daily precipitation, dust concentration) were used to screen the models, leading to the exclusion of others.

Response: Thank you for your comments. This screening criterion is crucial because our analysis of D_EP is based on daily scale definitions of precipitation events and dust events (using AOD as the diagnostic variable). Most models provide daily precipitation, but only a limited subset also outputs daily AOD. Models lacking either of these daily outputs were therefore excluded. The revised content is as follows:

"It is noteworthy that only five to six models satisfy the requirement for daily scale output of both precipitation and aerosol optical thickness (AOD)."

5.In Section 2.5, "Definition of EP events", the D_EP event appears to be defined based on station observation data. How is the D_EP event defined when investigating the future projections of extreme precipitation influenced by dust

aerosols?

Response: Thank you for your comments. Specifically, the extreme precipitation threshold was derived by averaging the station-based extreme precipitation thresholds computed over the past five decades across the Tarim Basin, resulting in a unified scalar threshold. This threshold was then applied to identify extreme precipitation events in all gridded precipitation data (both historical and future). For identifying dust events, the 50th percentile of AOD from observational data in the study region, as reported by Zhou et al. (2025), was adopted as the dust event threshold. A future D_EP event is defined when a grid point satisfies both conditions on the same day. In summary, the two thresholds (precipitation and AOD) objectively derived from historical station observations serve as universal criteria for identifying D_EP events in gridded future projections. In the revised version of the manuscript, we have added a clear clarification at the end of Section 2.5 (“Definition of Extreme Precipitation Events”) to elaborate on this key methodological step. The revised content is as follows:

“D_EP events in future climate projections are defined based on the EP and AOD thresholds statistically derived from station observations (Zhou et al., 2025).”

Reference:

Zhou, C., Liu, Y., Li, D., Zhu, Q., Tan, Z., Luo, R., Song, M., Zhu, C., Wang, Y., Mamtimin, A., Yang, X., Yang, F., Huo, W., Gao, J., Ma, M., and Wang, T.: Multisource Observations of Dust Rain in the Tarim Basin: Dust Events Act as a Trigger for Rainfall, ACS EST Air, 2, 2275–2287, <https://doi.org/10.1021/acsestair.5c00217>, 2025.

6.Lines 153-156 mention "removing the associated systematic errors from the reanalysis". What specific method was employed to achieve this?

Response: Thank you for your comments. Specifically, the long-term statistical discrepancies in precipitation event characteristics between the observational dataset and the reanalysis dataset were first calculated. This climatological mean discrepancy, which is considered to represent the persistent, model-derived bias inherent in the reanalysis, was then subtracted from the reanalysis data series during the subsequent composite analysis of D_EP events. This correction aims to isolate the component of the difference between observed and reanalysis-based D_EP events that is attributable

to dust aerosols, rather than to the inherent systematic biases in the reanalysis's representation of precipitation. We appreciate your attention to this methodological detail and hope this explanation clarifies the procedure.

7.The sentence in Line 164, "We analyze the background environmental conditions...", should be revised to "This step involves analyzing the background environmental conditions...".

Response: Thank you for your comments. We acknowledge that beginning the sentence with "This step involves..." would improve the logical flow by explicitly linking the analysis to the methodological framework outlined in the preceding text. Following your recommendation, we have revised accordingly in the manuscript. The revised content is as follows:

“This step involves analyzing the background environmental conditions from the perspectives of dynamic and water vapor conditions, and investigates the internal pathways of influence via cloud microphysical processes. Step 3.”

8.In Lines 176-178, the phrasing "frequency (81%) and amount (74%)" is ambiguous. Do these percentages refer to the proportion of stations showing a significant increasing trend, or do they indicate the magnitude of the trend itself? The authors are advised to clarify this to ensure precise interpretation.

Response: Thank you for your comments. The percentages (81% and 74%) refer to the proportion of stations within the Tarim Basin that exhibit a statistically significant increasing trend in EP event frequency and amount, respectively. They do not represent the magnitude of the trend itself. We have revised the sentence in the manuscript to eliminate this ambiguity. The revised content is as follows:

“Observational data indicate that a majority of stations in the Tarim Basin show significant increasing trends in the frequency and amount of EP events, with 81% and 74% of stations exhibiting such trends, respectively (Figs. 2a, 2b).”

9.It is recommended to delete the word "respectively" in line 194 of the figure caption.

Response: Thank you for your comments. The revised content is as follows:

The plus sign (+) and dot (·) in (a) and (b) denote trends that are statistically

significant and non-significant at the 95% confidence level based on the Student's t-test; the asterisk (*) in (c)–(f) indicates statistical significance.

10.Lines 226-229 describe the study area as "reconstructed using a moving coordinate system centered on the stations experiencing D_EP events". Could you please specify whether this coordinate system moves dynamically with each individual D_EP event, or is it aggregated based on specific time windows?

Response: Thank you for your comments. To clarify, the moving coordinate system was constructed individually for each of the 1,588 D_EP events. Each event was defined based on its respective reporting station, which served as the origin of a local coordinate frame extending 3 degrees in both the east–west and north–south directions, yielding a uniform 6°×6° spatial domain. In this local frame, the x-axis was aligned parallel to latitudinal circles and the y-axis parallel to longitudinal circles, with coordinates representing relative displacements in longitude and latitude from the station origin. Subsequently, all 1,588 individual 6°×6° domains were spatially composited into a single representative 6°×6° field for analysis, without aggregation based on specific time windows. This approach allowed us to examine the average spatial structure around stations during D_EP events while preserving the event-centered perspective. We appreciate your attention to this methodological detail and hope this explanation clarifies the procedure.

11.Line 259: "undersores" is a spelling error and should be corrected to "underscores".

Response: Thank you for your comments. We have corrected it and have also carefully reviewed the entire manuscript to identify and correct any similar issues.

12.Lines 258-259: The clause "However, observations show an increasing trend in EP events within the Tarim Basin" can be replaced with the more concise and impactful phrase "However, the observed increase in EP events within the Tarim Basin".

Response: Thank you for your comments. The revised content is as follows:

However, the observed increase in EP events within the Tarim Basin (Fig 2), which underscores that dust aerosols play a significant role in EP events.

13.Line 279: Please delete the redundant "nuclei".

Response: Thank you for your comments. The revised content is as follows:

Furthermore, when comparing D_EP events and EP events, the former demonstrates a higher level of moisture saturation, providing more favorable conditions for dust aerosols to act as ice nuclei or condensation and thereby promote precipitation.

14.Lines 294-296: The text states "significantly increasing the particle size of hydrometeors such as liquid water radius (LWR) and ice water radius (IWR; Figs. 7d, 7e)". According to classical cloud microphysics, the ice nucleation process inherently consumes supercooled liquid water, converting it to ice phase particles, which should theoretically reduce liquid water content and decrease the liquid water radius. Please clarify the physical mechanism behind the observed increase in LWR.

Response: Thank you for your comments. According to cloud microphysics, the ice nucleation process does indeed consume supercooled liquid water, thereby reducing the in-cloud liquid water content. We have carefully re-examined the original statement and acknowledge that the description regarding a "significant increase in liquid water radius (LWR)" was imprecise. The revised content is as follows:

“The resulting ice crystals then grow through processes such as collision-coalescence, leading to a significant increase in the size of ice-phase particles, as indicated by the ice water radius (IWR; Fig. 7j). Notably, the mean liquid water radius (LWR) is also larger during D_EP events (Fig. 7i), which is likely attributable to strong updrafts supplying abundant moisture that enhances condensation concurrent with ice growth.”

15.Line 304: Please change "g m⁻²" to "g·m⁻²".

Response: Thank you for your comments. We have revised "g m⁻²" to "g·m⁻²" and have carefully reviewed the entire manuscript to identify and correct any similar issues.

16.It is recommended to replace "Therefore" in line 331 with "Consistently".

Response: Thank you for your comments. To better align with the logical flow of the context, "Therefore" has been replaced with "Consistently."

17.Lines 360-364: It is recommended to replace the conjunction pair "On one

hand... On the other hand..." with "Under certain conditions... Under other conditions..." to more accurately reflect that these are potential outcomes under different scenarios, rather than two coexisting aspects of a single process.

Response: Thank you for your comments. Following the comprehensive rewrite of the "Results and Discussion" section in response to another reviewer's comments, the specific sentences mentioned in the original text are no longer directly present. However, we have fully incorporated and applied your suggestions within the overall logical framework of the revised manuscript.

18.It is recommended to correct "persists" to "persist" in line 383.

Response: Thank you for your comments. Following the comprehensive revision of the "Results and Discussion" section in response to the comments from another reviewer, the specific sentences originally referenced in the text have been rewritten as follows:

“Given this overall promotive effect on precipitation, D_EP events are projected to persist at elevated levels throughout the near-term 21st century under high-emission scenarios.”