Please note: Paragraphs in black are reviewer comments. Paragraphs in blue are point-to-point responses.

Anonymous Referee #3

This study analyzes 23 years (2000-2022) of nationwide data in China, revealing a decline in light rain from 2000-2013, followed by an increase from 2013-2022. The shift closely aligns with PM2.5 trends during China's Emission Control Era, with machine learning and causal inference showing that aerosol-cloud microphysical effects explain 59-63% of these decadal changes. This work bridges atmospheric chemistry and hydrology by combining long-term data and advanced analysis to separate human-caused aerosol effects from natural variability, filling a major knowledge gap and providing policy-relevant insights for aligning air pollution mitigation with climate adaptation strategies. Overall, the paper is well-written with logical organizations. However, the paper still has some unclear or incomplete parts need to be improved before the publication.

- Justification for 2013 as a turning point

The study designates 2013 as the dividing year for trend analyses in both precipitation and aerosol concentrations but offers insufficient background or rationale for this choice. Using the same breakpoint for both variables without justifications risks introducing bias, particularly given that the XGBoost model subsequently identifies aerosols as the dominant factor. The authors should provide a robust justification, supported by literature, independent evidence, or an objective determination from precipitation data, explaining why 2013 is also an appropriate breakpoint for light-rain analysis.

Re: We thank the reviewer for this insightful comment. As analyzed and discussed in Section 3.1 of the original text, our research is based on the analysis of the trends in light rain and $PM_{2.5}$ during the study period (2000-2022). Specifically, we found that light rain showed a decreasing trend before 2013, while it exhibited a rapid increasing trend after 2013. In contrast, $PM_{2.5}$ displayed an increasing trend before 2013 and a rapid decreasing trend after 2013. Combined with the scientific understanding of the impact of aerosols on precipitation from previous studies (e.g., Jiang et al., 2014; Qian et al., 2009), we hypothesize that aerosols may have played a crucial role in driving the variation trend of light rain over the past two decades. Therefore, we decided to conduct analysis and research focusing on two phases: 2000-2013 and 2013-2022. To avoid any misunderstanding, we have added a figure (Fig. 1) illustrating the variation trends of nationally averaged light rain and $PM_{2.5}$.

We have also revised the text accordingly, please refer to Line198-228 in the revised manuscript:

"Figure 1 illustrates the spatial distributions and long-term trends of light precipitation frequency and $PM_{2.5}$ mass concentrations across China during the studied periods (2000 – 2022). Statistically significant decreasing trends in light rain days (mean rate: 1.0 days yr^{-1}, $p < 0.05$) were observed nationwide during 2000 – 2013, with the most pronounced decline in southern China (2.3 days yr^{-1}, $p < 0.01$) (Fig. 1). Conversely, a reversal trend emerged during 2013 – 2022, showing continent-wide increases (1.9 days yr^{-1}, $p < 0.01$), particularly in southwestern China and the Yangtze

River Basin (central-eastern regions), where the growth rate reached 2.6 days yr^{-1}. The data analysis also reveals an inverse correlation between light precipitation trends and $PM_{2.5}$ variations: a significant $PM_{2.5}$ increase (0.39 $\mu g\ m^{-3}\ yr^{-1}$, $p < 0.01$) occurred during 2000 – 2013, contrasting with a substantial decline (2.5 $\mu g\ m^{-3}\ yr^{-1}$, $p < 0.01$) post - 2013. Actually, the rapid decrease in $PM_{2.5}$ mass concentration since 2013 have been widely observed due to the implementation of the national "Air Pollution Prevention and Control Action Plan" in China (Zhang et al., 2020; Wei et al., 2021; Bai et al., 2024; Zhang et al., 2024).

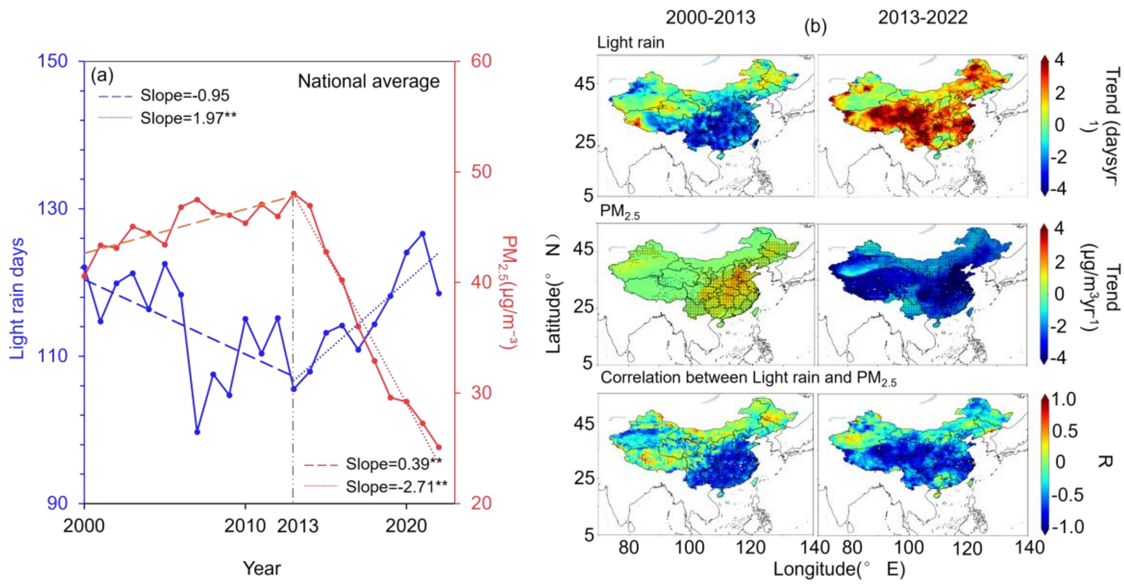

Figure 1. National trend and spatial patterns of light rain and $PM_{2.5}$. (a) Nationally averaged time series of light rain days (blue lines) and $PM_{2.5}$ mass concentration (red lines) from 2000 to 2022. The dashed lines represent the piecewise linear trends for the periods 2000–2013 and 2013–2022, with the slopes indicated. Trends significant at the 95% confidence level are marked with **. (b) Spatial distribution of the trends of light rain, $PM_{2.5}$ and spatial correlation between $PM_{2.5}$ and light rain days in 2000–2013 and 2013–2022. This map of China is created based on same-origin data provided by the Tianditu Platform (www.tianditu.gov.cn). (black dots indicate passing the 95% significance test).

In particular, this inverse relationship is most evident in six anthropogenically influenced regions (Fig. 2): North China (NC), South China (SC), East China (EC), Southwest China (SWC), Central-South China (CSC), and the Fenwei Plain (FW). This regional division is based on established frameworks that consider distinct physiographic (e.g., topographic basins, climate zones) and anthropogenic (e.g., population density, industrial activity) characteristics (Chen et al., 2024). For instance, the Fenwei Plain (FW) is treated separately from North China (NC) due to its unique enclosed topography that fosters pollution accumulation, despite some similarities in overall trends.

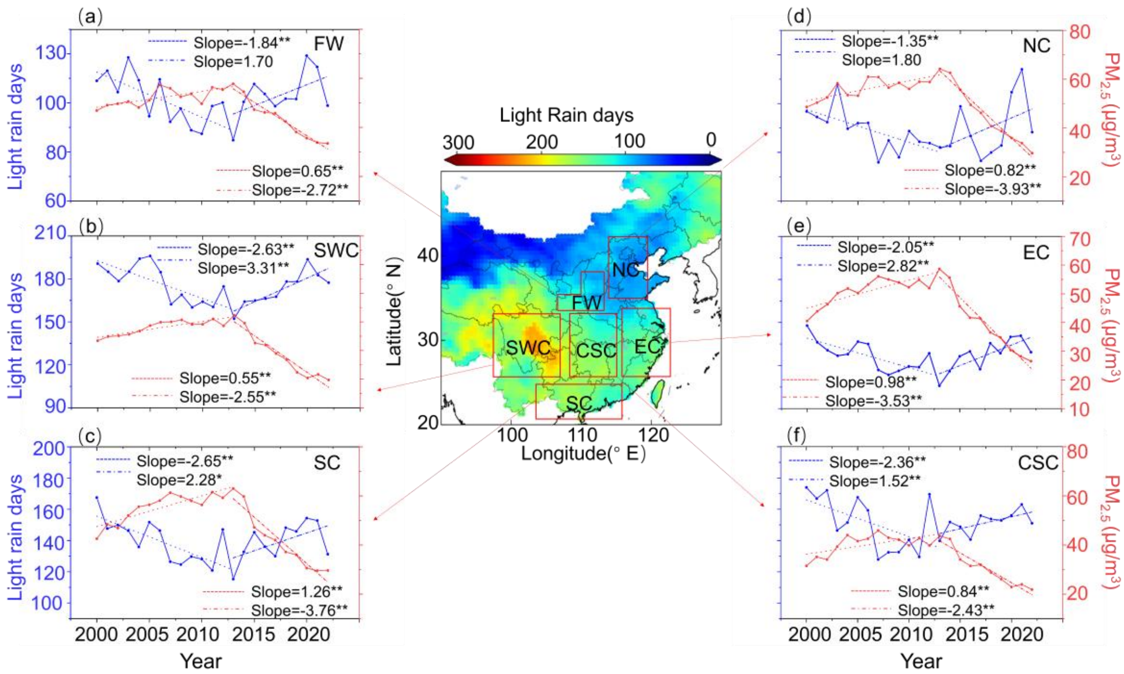

Figure 2. The fitted variation trends of light rain days (blue lines) and the fitted variation trends of $PM_{2.5}$ (red lines) in different six selected regions. The middle map shows the spatial distribution of average light rain days during 2000–2022 and the six selected study regions."

The references mentioned above are:

Bai, Y., Liu, M.: Multi-scale spatiotemporal trends and corresponding disparities of PM2.5 exposure in China. Env. pollution, 340, 122857. https://doi.org/10.1016/j.envpol.2023.122857, 2024.

Qian, Y., Gong, D., Fan, J., Leung, L. R., Bennartz, R., Chen, D., Wang, W.: Heavy pollution suppresses light rain in China: Observations and modeling, J. Geophys. Res., 114, D00K02, https://doi.org/10.1029/2008JD011575, 2009b.

Shao, T., Liu, Y., Wang, R., Zhu, Q., Tan, Z., 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.

Wang, Y., Ma, P., Jiang, J., Su, H., Rasch, P. J.: Toward reconciling the influence of atmospheric aerosols and greenhouse gases on light precipitation changes in Eastern China, J. Geophys. Res. Atmos., 121, 5878–5887, https://doi.org/10.1002/2016JD024845, 2016.

Wei, J., Li, Z., Lyapustin, A., Sun, L., Peng, Y., Xue, W., Su, T., Cribb, M.: Reconstructing 1-km-resolution high-quality PM2.5 data records from 2000 to 2018 in China: spatiotemporal variations and policy implications, Remote Sens. Environ., 252, 112136, https://doi.org/10.1016/j.rse.2020.112136, 2021.

Zhang, F., Wang, Y., Peng, J., Chen, L., Sun, Y., Duan, L., Ge, X., Li, Y., Zhao, J., Liu, C., Zhang, X., Zhang, G., Pan, Y., Wang, Y., Zhang, A. L., Ji, Y., Wang, G., Hu, M., Molina, M. J., Zhang, R.: An unexpected catalyst dominates formation and radiative forcing of regional haze, PNAS, 117(8), 3960-3966, https://doi.org/10.1073/pnas.1919343117, 2020.

Zhang, R., Zhu, S., Zhang, Z., Zhang, H., Tian, C., Wang, S., Wang, P., Zhang, H.: Long-term variations of air pollutants and public exposure in China during 2000–

2020, Sci. Total Environ, 2024, 930. https://doi.org/10.1016/j.scitotenv.2024.172606, 2024.

- Justification for Regional Division

The authors divide the study area into six regions without sufficient justification. For example, it is unclear to me why regions with similar light rain frequencies and trends are treated separately rather than combined (e.g., FW and NC). Clarification on the criteria or rationale behind the regional boundaries is needed.

Re: We thank the reviewer for raising this point. The six regions were defined based on a synthesis of key physiographic (e.g., topographic basin boundaries) and anthropogenic (e.g., population density, industrial activity) criteria, which is a well-established framework for regional climate and air pollution studies in China. This classification allows us to examine the aerosol-light rain relationship across distinct environmental and socio-economic contexts.

To address the reviewer's concern, we have now added a clear justification in the manuscript where these regions are first introduced (Line 211-216 in Section 3.1):

"This regional division is based on established frameworks that consider distinct physiographic (e.g., topographic basins, climate zones) and anthropogenic (e.g., population density, industrial activity) characteristics (Chen et al., 2024). For instance, the Fenwei Plain (FW) is treated separately from North China (NC) due to its unique enclosed topography that fosters pollution accumulation, despite some similarities in overall trends."

We clarify that while some regions may exhibit similar bulk trends (e.g., FW and NC), their underlying geographic and meteorological characteristics (e.g., the enclosed basin of FW vs. the more open NC) and primary emission sources differ significantly, justifying their treatment as separate entities for a more mechanistic analysis.

- Justification of Selected Factors in XGBoost Model

Little explanation is provided for focusing solely on PM2.5, RH, WS, T, E, TCLW, CAPE, and LCC as factors explaining light rain trends. It remains unclear whether other relevant variables were considered or excluded. I recommend the authors provide evidence or rationale supporting the selection of these factors to demonstrate that the analysis covers the most important influences.

Re: We thank the reviewer for this comment. The selection of these specific factors ($PM_{2.5}$, RH, WS, T, E, TCLW, CAPE, LCC) was based on a comprehensive review of the existing literature, which identifies them as the most critical and commonly cited drivers of light rain variability in China. Our Introduction provides the foundational rationale for this selection, which we have now explicitly summarized in the revised manuscript (Line 140-146 in Section 2.2) to enhance clarity:

"The selection of these specific factors is grounded in their well-established physical linkages to light rain processes, as extensively documented in prior studies (Qian et al., 2009a; Huang and Wen, 2013; Li et al., 2017). Briefly, $PM_{2.5}$ is included to quantify aerosol impacts on cloud microphysics, while the meteorological variables collectively represent the thermodynamic, moisture, dynamic, and cloud-related conditions that are fundamental to light rain formation. This approach ensures our model captures the key mechanistic drivers identified in the literature.”

And brief rationale is as follows:

1) $PM_{2.5}$ was selected due to its established role in modulating cloud microphysics and precipitation through aerosol-cloud interactions (ACI) and aerosol-radiation interactions (ARI), as repeatedly demonstrated in studies over China (Qian et al., 2009a; Fan et al., 2015; Li et al., 2017).
2) Meteorological factors (T, RH, WS, E, TCLW) were chosen because prior research has consistently highlighted their importance.
3) Temperature (T) and Relative Humidity (RH) are fundamental to condensation processes and have been directly linked to observed declines in light rain (Qian et al., 2007; Zhou et al., 2020).
4) Water Vapor Pressure (E) and Total Column Liquid Water (TCLW) directly represent the atmospheric moisture content, a primary control on precipitation formation (Wu, 2015).
5) Wind Speed (WS) influences aerosol and moisture transport, as well as atmospheric mixing.
6) Convective and Cloud Factors (CAPE, LCC): Convective Available Potential Energy (CAPE) and Low Cloud Cover (LCC) are key indicators of atmospheric stability and cloud conditions, which multiple studies have shown to be crucial for light rain occurrence (Huang and Wen, 2013; Li et al., 2017).

This set of variables encompasses the primary mechanisms discussed in the literature: aerosol effects, thermodynamic environment, moisture supply, and atmospheric dynamics. While other factors exist, the selected variables represent the most influential and widely recognized drivers based on the current state of knowledge, allowing for a parsimonious yet comprehensive model.

The references mentioned above are:

Qian, Y., Gong, D., Fan, J., Leung, L. R., Bennartz, R., Chen, D., Wang, W.: Heavy pollution suppresses light rain in China: Observations and modeling, J. Geophys. Res., 114, D00K02, https://doi.org/10.1029/2008JD011575, 2009a.

Huang, G., Wen, G.: Spatial and temporal variations of light rain events over China and the mid-high latitudes of the Northern Hemisphere, Chin. Sci. Bull., 58, 1402–1411, https://doi.org/10.1007/s11434-012-5593-1, 2013.

Li, Z., Rosenfeld, D., Fan, J.: Aerosols and Their Impact on Radiation, Clouds, Precipitation, and Severe Weather Events, in: Oxford Research Encyclopedia of Environmental Science, Oxford University Press, https://doi.org/10.1093/acrefore/9780199389414.013.126, 2017.

Following are some specific comments.

Specific comments:

1. Abstract: Some results like +1.97(-2.08) and 59-63% cannot be found in the main text. Please make sure the consistency.

   Re: We sincerely thank the reviewer for their meticulous attention to detail. We apologize for the inconsistencies and are pleased to provide the following clarification and corrections:

   1) Regarding +1.97 (-2.08) days yr^{-1}:

These values represent the national average contribution of $PM_{2.5}$ to the trend in light rain frequency, calculated as the mean of the regional contributions presented in Figure 7. The purpose of providing this overall mean is to offer a concise national-scale summary of the aerosol effect. Figure 7 itself displays the data for the six individual regions to reveal the spatial heterogeneity behind this average. We have now explicitly added this calculation to the main text (Section 3.4, Line 370-372) to ensure clarity.

2) Regarding 59-63%:

The numerical discrepancy between the Abstract and Section 3.4 is a low-level typographical error: the “58-65%” in Section 3.4 was incorrect. We have revised it to “59-63%” (consistent with the Abstract), with the correction visible in Line 354 of the updated manuscript. We apologize for this oversight and appreciate your help in enhancing the manuscript’s accuracy.

2. Line 98-100: no literature or data to support the opposite trends before and after 2013.

Re: We thank the reviewer for this comment. We acknowledge that the statement in the Introduction is a forward-looking summary of our key finding, which is then substantiated in detail in the Results section. We have made the following revisions (or see lines 99-102):

“The study period has been focused on the years of 2000-2022, a period during which $PM_{2.5}$ concentrations show a significant upward trajectory before 2013 followed by a markedly downward decline thereafter (see Section 3.1 and Fig. 1), providing a natural experiment to quantify aerosol effects in precipitation.”

3. Figure 1: It’s good to show the regions have significant trends or correlation, like Figure 3. In addition, please use symmetric color bar for middle panel.

Re: We thank the reviewer for these constructive suggestions. We have now added black dots to the panels to indicate grid cells where the trends are statistically significant at the 95% confidence level ($p < 0.05$). And we have adjusted the color bar for the middle panel to make it symmetric around zero.

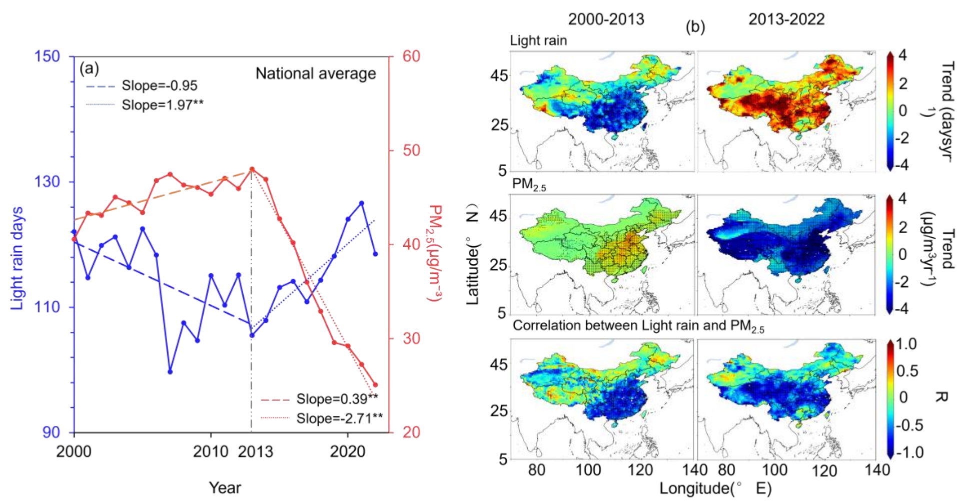

Figure 1. National trend and spatial patterns of light rain and $PM_{2.5}$. (a) Nationally averaged time series of light rain days (blue lines) and $PM_{2.5}$ mass concentration (red lines) from 2000 to 2022. The dashed lines represent the piecewise linear trends for the periods 2000–2013 and 2013–2022, with the slopes indicated. Trends significant at the 95% confidence level are marked with **. (b) Spatial distribution of the trends of light rain, $PM_{2.5}$ and spatial correlation between $PM_{2.5}$ and light rain days in 2000–2013 and 2013–2022. This map of China is created based on same-origin data provided by the Tianditu Platform (www.tianditu.gov.cn). (black dots indicate passing the 95% significance test).

4. Line 197-200: should be Fig S2 since Fig. S1 does not show correlation results.
   Re: Corrected. Please refer to Line 245.

5. Figure 2: 1) no x-axis information, 2) no caption for the plot in the middle.
   Re: We thank the reviewer for pointing out these omissions. We have revised Figure 2 to include the x-axis information and have added a detailed caption for the middle plot.

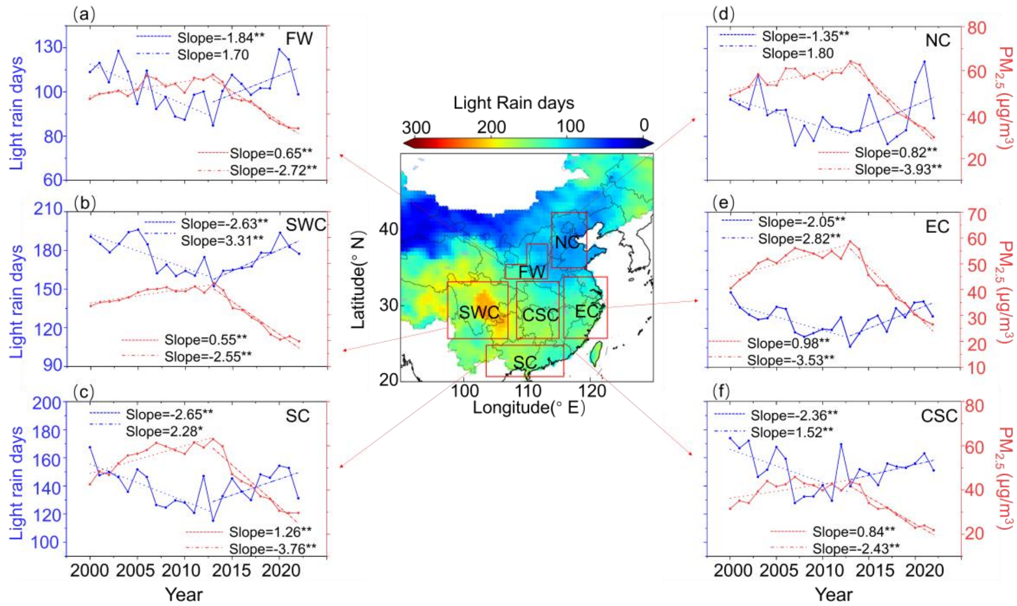

Figure 2. The fitted variation trends of light rain days (blue lines) and the fitted variation trends of $PM_{2.5}$ (red lines) in different six selected regions. The middle map shows the spatial distribution of average light rain days during 2000-2022 and the six selected study regions.

6. The opposite trends of light rain and aerosol before and after 2013 in different regions are shown in Figure 2. How are trends in national wide scale and how do they apply to other meteorological factors?
   Re: Regarding the national-scale trends of light rain and aerosols, these are in fact the primary focus of Figure 1 and are detailed in Section 3.1. According to the reviewer's comments, we have added a pannel plot in Fig 1 to show the

mean changes in the light rain and $PM_{2.5}$. It shows a significant decrease in light rain frequency alongside a significant increase in $PM_{2.5}$ during 2000 - 2013, which reversed to a widespread increase in light rain and a decrease in $PM_{2.5}$ during 2013 - 2022.

Regarding the trends of other meteorological factors, we have now revised the description based on Fig. 3, which just shows the variation trends of other affecting factors of E, T, CAPE, TCLW, WS RH, and LCC of China over 2000 - 2013 and 2013 - 2022 (Lines 239-242), or as follows:

"A key observation is that, in contrast to the strong and statistically significant nationwide trends seen in $PM_{2.5}$, the trends of these meteorological parameters are characterized by pronounced spatial heterogeneity and largely insignificant changes over large portions of China."

The revised text emphasizes that our analysis of Figure 3 reveals a key finding: the meteorological factors (T, RH, CAPE, E, LCC, TCLW, WS) exhibited pronounced spatial heterogeneity and largely statistically insignificant trends over large parts of China during both periods, especially when contrasted with the strong and coherent nationwide trends of $PM_{2.5}$. This observation, which is consistent with other studies, is crucial for interpreting why our subsequent machine learning analysis identifies aerosols as the dominant factor underlying the light rain trends in this natural experiment.

7. Are the details in Figure S1 already plotted in Figure 3? If yes, no need to add Figure S1.

Re: We thank the reviewer for this comment. Figure S1 is not a duplicate but provides the essential statistical significance (p-value) information for the trends shown in Figure 3. To make this relationship clear, we have now explicitly stated in the manuscript text (Line 237-239):

"Figure 3 depicts the long-term trends of meteorological factors (T, RH, CAPE, E, LCC, TCLW, and WS) potentially associated with light rain variability in China during 2000 - 2013 and 2013 - 2022, while the statistical significance ($p < 0.05$) of these trends is shown in Supplementary Fig. S1."

We believe both figures are necessary for a complete interpretation of the trend analysis.

8. Figure 4: contribution before and after 2013? Why not as a whole?

Re: We thank the reviewer for these questions. Figure 4 and the accompanying text in Section 3.2 provide the quantitative contributions. To make this clearer, we have added more statements in the revised manuscript (Lines 274-277; Lines 285-292):

"Considering that the temporal variation trends of these factors are not identical, we presented and analyzed the conditions of the two research periods (2000 - 2013 and 2013 - 2022) (Fig. 4) - this was done to compare and explore whether the relative contribution or importance of each factor to precipitation has changed across different stages."

"Notably, the contribution of $PM_{2.5}$ declined from 15.5% to 12.1% (a 3.4% decrease, $p < 0.05$), coinciding with China's stringent emission controls (Shao et al., 2022; Wang et al., 2016). Conversely, the contributions of TCLW and CAPE increased significantly from 7.2%/9.4% in 2000 – 2013 to 13.6%/10.6% in 2013 – 2022 ($p < 0.01$). LCC and WS remained negligibly minor factors (< 6% contribution). Moreover, spatial heterogeneity (Fig. 3) revealed no substantial differences in factor contributions between the two periods, except for $PM_{2.5}$ and TCLW. Conspicuously, the meteorological factors exhibited statistically insignificant temporal trends, implying stable physical mechanisms underlying their impacts on light rain."

A more detailed justification is provided in our response to Comment 12.

9. Check throughout the manuscript. Some phrases show repeatedly with both the full term and abbreviation together (e.g., SEM).
Re: We have checked the entire manuscript and revised instances where phrases (e.g., SEM) were repeatedly presented with both full terms and abbreviations.

10. Figure 7: Please consider using more distinctive colors for clearer differentiation.
Re: We thank the reviewer for this suggestion. We have revised Figure 7 by using a more distinct and colorblind-friendly palette to improve clarity and differentiation between the factors.

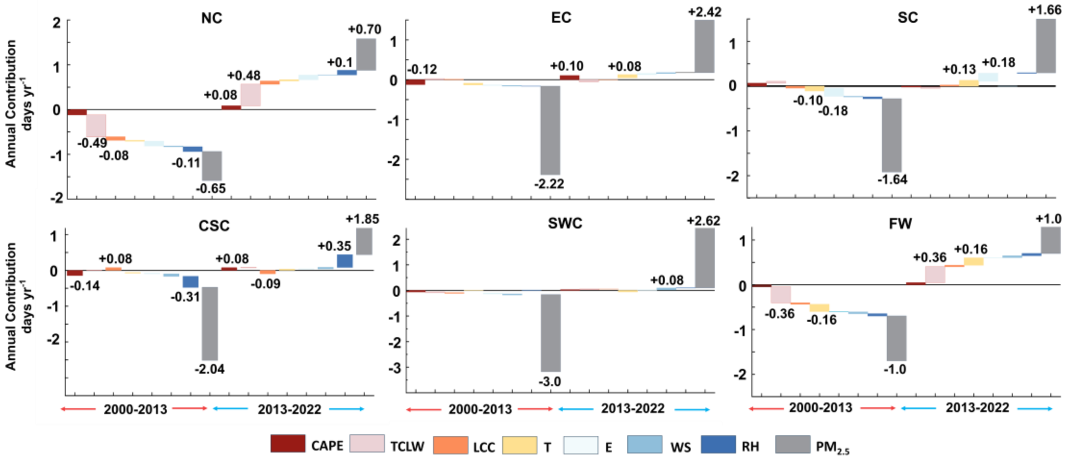

Figure 7. Quantified contribution of each factor to the long-term changes of light rain days in the six selected regions of China over the periods of 2000 - 2013 and 2013 - 2022.

11. Reorganize the section 3: it alternates between discussing nationwide results and those from the six major regions, causing confusion as the narrative and figures jump back and forth.
Re: Considering and combining the previous several comments from the reviewer**#3**, we have carefully revised Section 3 to significantly improve its logical structure and readability. The revised version is as follows (or see lines

198-271 in the revised version),

"Figure 1 illustrates the spatial distributions and long-term trends of light precipitation frequency and $PM_{2.5}$ mass concentrations across China during the studied periods (2000 – 2022). Statistically significant decreasing trends in light rain days (mean rate: 1.0 days yr^{-1}, $p < 0.05$) were observed nationwide during 2000 – 2013, with the most pronounced decline in southern China (2.3 days yr^{-1}, $p < 0.01$) (Fig. 1). Conversely, a reversal trend emerged during 2013 – 2022, showing continent-wide increases (1.9 days yr^{-1}, $p < 0.01$), particularly in southwestern China and the Yangtze River Basin (central-eastern regions), where the growth rate reached 2.6 days yr^{-1}. The data analysis also reveals an inverse correlation between light precipitation trends and $PM_{2.5}$ variations: a significant $PM_{2.5}$ increase (0.39 μg m^{-3} yr^{-1}, $p < 0.01$) occurred during 2000 – 2013, contrasting with a substantial decline (2.5 μg m^{-3} yr^{-1}, $p < 0.01$) post - 2013. Actually, the rapid decrease in $PM_{2.5}$ mass concentration since 2013 have been widely observed due to the implementation of the national "Air Pollution Prevention and Control Action Plan" in China (Zhang et al., 2020; Wei et al., 2021; Bai et al., 2024; Zhang et al., 2024).

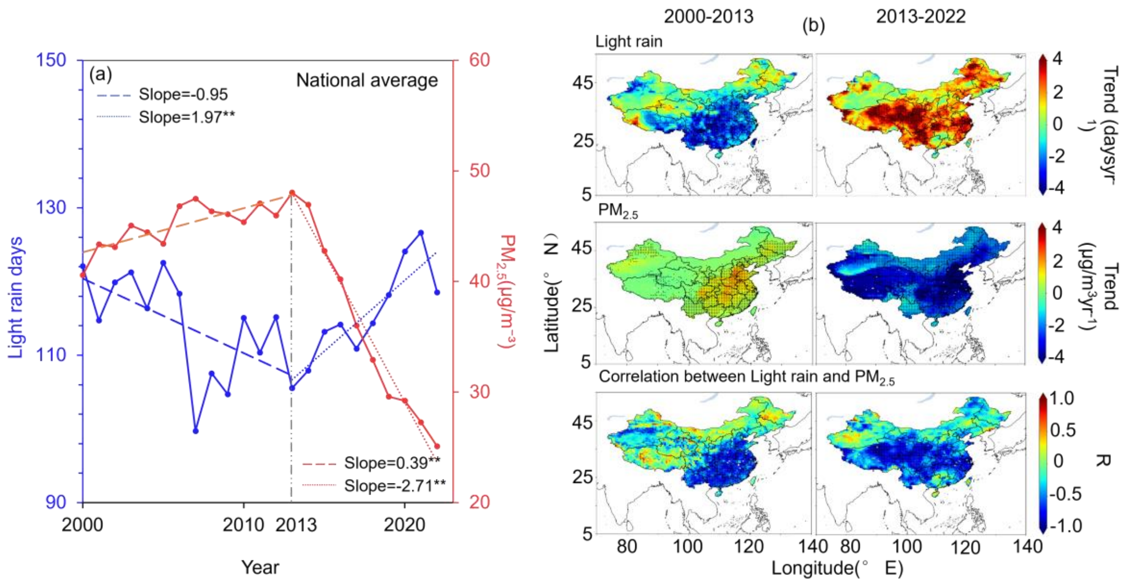

Figure 1. National trend and spatial patterns of light rain and $PM_{2.5}$. (a) Nationally averaged time series of light rain days (blue lines) and $PM_{2.5}$ mass concentration (red lines) from 2000 to 2022. The dashed lines represent the piecewise linear trends for the periods 2000–2013 and 2013–2022, with the slopes indicated. Trends significant at the 95% confidence level are marked with **. (b) Spatial distribution of the trends of light rain, $PM_{2.5}$ and spatial correlation between $PM_{2.5}$ and light rain days in 2000–2013 and 2013–2022. This map of China is created based on same-origin data provided by the Tianditu Platform (www.tianditu.gov.cn). (black dots indicate passing the 95% significance test).

In particular, this inverse relationship is most evident in six anthropogenically influenced regions (Fig. 2): North China (NC), South China

(SC), East China (EC), Southwest China (SWC), Central-South China (CSC), and the Fenwei Plain (FW). This regional division is based on established frameworks that consider distinct physiographic (e.g., topographic basins, climate zones) and anthropogenic (e.g., population density, industrial activity) characteristics (Chen et al., 2024). For instance, the Fenwei Plain (FW) is treated separately from North China (NC) due to its unique enclosed topography that fosters pollution accumulation, despite some similarities in overall trends.

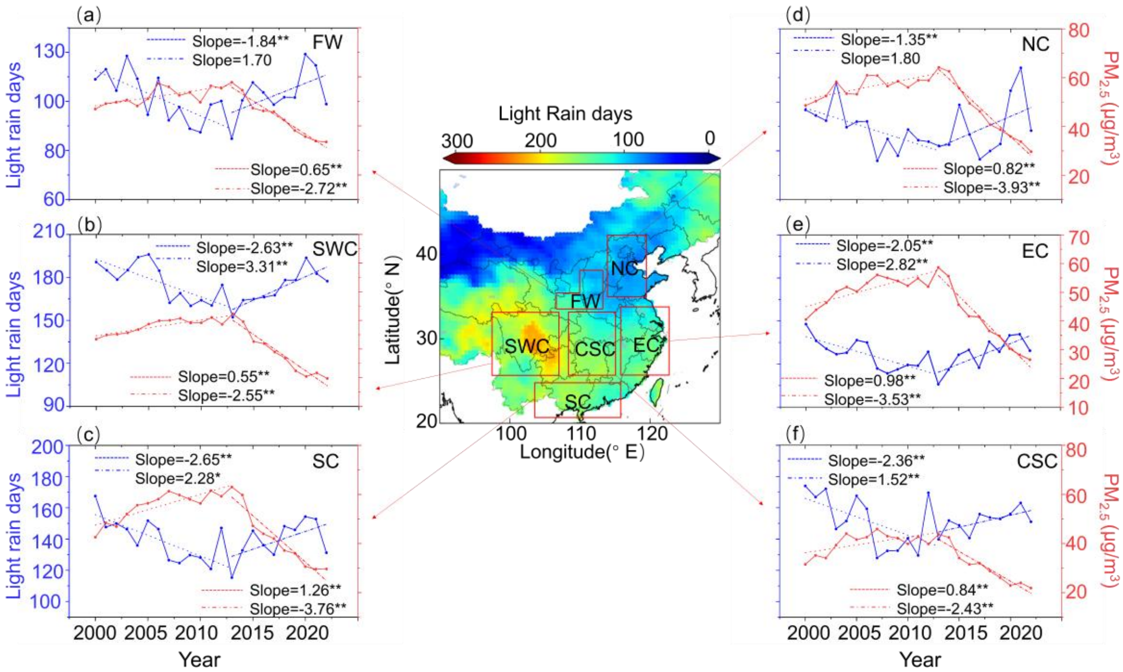

Figure 2. The fitted variation trends of light rain days (blue lines) and the fitted variation trends of $PM_{2.5}$ (red lines) in different six selected regions. The middle map shows the spatial distribution of average light rain days during 2000–2022 and the six selected study regions.

Since previous studies attribute light rain suppression in polluted regions to aerosol-cloud microphysical interactions (Qian et al., 2009b; Wang et al., 2016; Shao et al., 2022), our analysis suggests that the observed decadal shifts in light precipitation (2000 – 2013 decline vs. 2013 – 2022 increase) are likely driven by long-term aerosol concentration variability. Notably, regions with minimal anthropogenic activities (e.g., Inner Mongolia and northwestern China) exhibited no significant $PM_{2.5}$-light rain correlations but with good correlations with meteorological factors (e.g., RH) (Fig. 1, Fig. S2), implying contributions from non-aerosol factors.

Figure 3 depicts the long-term trends of meteorological factors (T, RH, CAPE, E, LCC, TCLW, and WS) potentially associated with light rain variability in China during 2000 – 2013 and 2013 – 2022, while the statistical significance ($p < 0.05$) of these trends is shown in Supplementary Fig. S1. A key observation is that, in contrast to the strong and statistically significant nationwide trends seen in $PM_{2.5}$, the trends of these meteorological parameters are characterized by pronounced spatial heterogeneity and largely insignificant changes over large portions of China. For the E, from 2000 to 2013, approximately 60% of regions exhibited insignificant trends, only with the significant decline ($p < 0.05$) observed in southwestern China and the Qinghai-Tibet Plateau (Fig. S2). During 2013 – 2022, E just decreased significantly in very few areas of northeastern China and northern Xinjiang, areas concurrent with RH increases (Cong et al., 2009). Conversely, large areas of southeastern China experienced nonsignificant E reductions. Notably, E-enhanced regions seems expanded in recent decades, likely attributable to global warming effects (IPCC, 2021). However, the enhanment is not statistically significant (Fig. S2). Analysis reveals that 56% of Chinese regions showed T increases slightly during 2000 – 2013, with accelerated warming rates post - 2013. The CAPE demonstrated weakened trends across southeastern China during 2000 – 2013, while remaining stable in western/northwestern regions. This spatial pattern aligns with anthropogenic aerosol impacts. The aggravated aerosol pollution over 2000 - 2013 likely suppressed convection in densely populated eastern China via microphysical mechanisms (Zhao et al., 2006). However, $PM_{2.5}$ reductions since 2013 moderated CAPE declines, with some regions (e.g., middle-lower Yangtze River) even exhibiting strengthening trends, indicating meteorological sensitivity to aerosol loading changes. The TCLW decreased only in the Yangtze River Basin and Tibetan Plateau during 2000 – 2013, but reversed to increasing trends post - 2013. There are no evident variations (statistically insignificant) in TCLW elsewhere during the two periods (Fig. S2). Nationwide WS reductions (statistically nonsignificant) were observed during both periods, though southeastern China experienced accelerated declines post - 2013, potentially linked to persistent particulate pollution and urbanization processes (Zhang and Wang, 2021). The RH declines affected less than 30% of China during 2000 – 2013, most prominently in the Tibetan Plateau, northeastern/southwestern China. During 2013 – 2022, it is observed with nonsignificant RH variations becoming dominant nationwide. The LCC trends spatially mirrored RH patterns, likely underscoring their coupled responses to anthropogenic and climatic drivers. While these meteorological parameters exhibited spatially variable trends, their magnitudes were generally much smaller than $PM_{2.5}$ variations. Subsequent sections will quantitatively evaluate their combined impacts on light rain frequency.

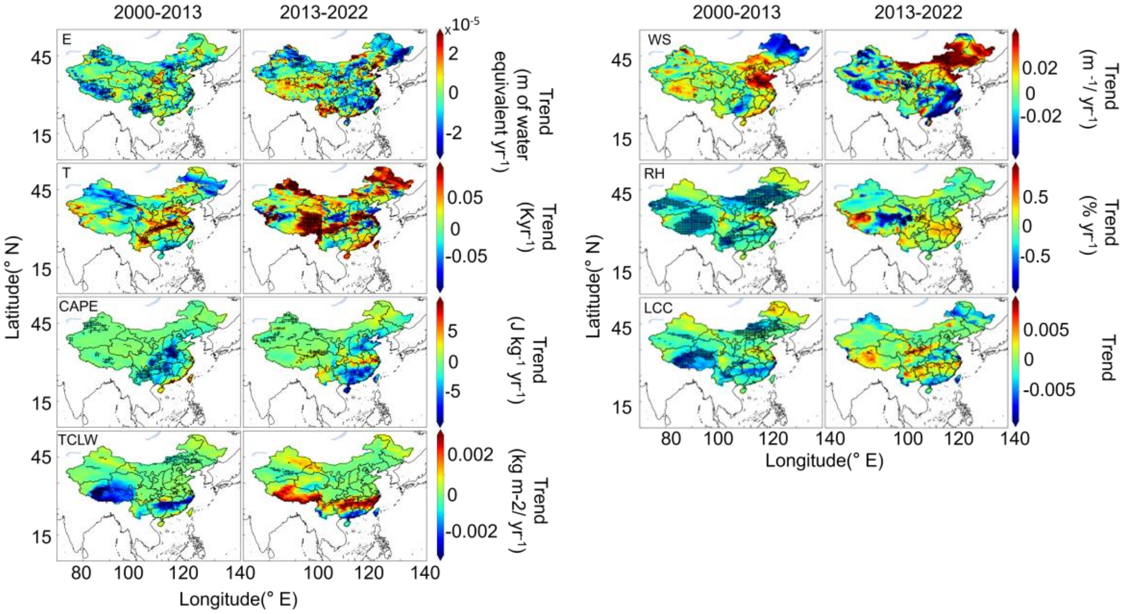

Figure 3. The fitted variation trends of other affecting factors of E, T, CAPE, TCLW, WS RH, and LCC of China over 2000 - 2013 and 2013 - 2022."

12. Why is the quantification of contributions from different factors divided into two separate periods instead of analyzing the entire 23-year period as a whole? Since the key contributors appear similar for both periods, splitting the analysis may reduce the ability to identify the main drivers of the shifted trends. This choice along with the resulting interpretation seems unclear. Further clarification or justification is recommended.

Re: We thank the reviewer for this profound question. We agree that analyzing the entire period could also identify the overall main drivers. However, considering that the temporal variation trends of these factors are not identical, we presented and analysed the conditions of the two research periods (2000–2013 and 2013–2022) – this was done to compare and explore whether the driving factors of influencing the precipitation long-term trends has changed across different stages. In addition, our objective was not only to identify the key factors but, more importantly, to quantify how their specific contributions changed in response to the policy-driven shift in aerosol concentrations around 2013. As we shown in Fig. 7, it is the change in the magnitude and direction of the influence of the same set of factors (most notably $PM_{2.5}$) that mechanistically explains the observed trend shift. A whole-period analysis would only yield a single, static measure of importance, completely miss this dynamic interplay and failing to answer why the trend reversed.

Finally, from a modeling perspective, segmenting the data allows the XGBoost model to more accurately learn the specific, non-linear relationships between predictors and the target variable (light rain) that were operative within each unique physicochemical regime. This approach provides a clearer and more reliable quantification of contributions for each period, which is essential for our mechanistic interpretation.

In conclusion, while a whole-period analysis might identify overarching key factors, it would be inadequate for probing the changing mechanisms that are the focus of our research.

To clarify this, we have added statements in the revised version of the manuscript, see Methods section (Line 132-137), Section 3.4 (lines 339-344):
"The XGBoost model was applied separately to the two periods (2000-2013 and 2013-2022) rather than to the entire dataset. This approach was chosen because the underlying physical relationships between the predictors and light rain are expected to differ significantly between the pollution-accumulating and pollution-abatement regimes. Training separate models prevents the estimation of a misleading 'average' relationship and allows for a more accurate quantification of the distinct drivers operative in each period."

"…As stated previously, considering that the temporal variation trends of these factors are not identical, we presented and analysed the conditions of the two research periods (2000–2013 and 2013–2022) – this was done to compare and explore whether the driving factors of influencing the precipitation long-term trends has changed across different stages. Therefore, this dual-method approach quantifies both observed patterns (e.g., downward trends in 2000–2013 vs. upward trends post - 2013) and underlying causal mechanisms..."