Responses to Referee #2:

The manuscript investigates the role of the recent decline in East Asian anthropogenic aerosols in driving precipitation and temperature changes across Australia. The authors highlight the potential for aerosols to contribute to enhancing the fire risk via widespread drying and warming. The topic is timely and very important, as not many studies have examined the influence of recent changes in aerosols on recent climate variations. However, I find several major weaknesses in the study, including in the simulation design, that prevent the manuscript from being acceptable for ACPD. Unfortunately, I need to recommend a rejection. Happy though to reconsider the manuscript if reviewed accordingly.

Thank you for your feedback. We will carefully consider the points you raised regarding the simulation design and other aspects of the study. We value your insights and will make every effort to improve the quality of our work. We would be grateful for your reconsideration of the manuscript. Please see our point-by-point responses (in blue) to your comments below.

Major comments:

I believe there is a serious overinflation of the recent observed rainfall changes over Australia. Firstly, the authors use observations and plot linear trends from 2010, while model results are shown as 3-year differences from 2013. While the latter accounts for the decline in aerosols, observations show that the years 2010 and 2011 were anomalously wet over Australia, and just a couple of years before rainfall was much less (I have checked by plotting observations since 2000). This can also be inferred by examining Fig 2, where clearly the trend in panel d is affected by the two early years. By eye, using 3-year composites from 2013, the rainfall changes are very modest. Looking at more recent years, it turns out that 2019 was also anomalously dry, and more recent years (excluding those affected by COVID-related reduced emissions) show a recovery. Therefore the results based on observations, which ultimately is the motivation of the study, are strongly affected by the extremely short record and cannot be trusted.

Thank you for pointing out the strong variability in rainfall in Australia. We agree with reviewer that the observed trend of rainfall could be affected by the wet years in 2010/2011 and dry year in 2019, which could be induced by the interval variability (such as ENSO). However, we could not deny the decreasing precipitation during 2010–2019 and rule out the potential influence of changing aerosols on the rainfall variation. Additionally, we are trying to quantify the role of aerosol reduction in China in the Australian climate, rather than fully attribute to changing Australian climate to aerosols in China, considering that aerosol reductions in China are found to contribute to small part of the changing precipitation in Australia. The simulation results are still robust enough to support our conclusions because our model experiments are based on validated climate model, providing strong evidence that aerosol reductions in China have a significant impact on Australia's climate.

In fact, the emission reduction of aerosols and precursors in China starts in 2010 rather than 2013. We chose the year 2013 in simulation was because China implemented the "Air Pollution Prevention and Control Plan" in 2013 and established nationwide $PM_{2.5}$ observation sites in 2013. As the reviewer mentioned, Australia experienced a transient from dry years before 2010 to wet years in 2010/2011 and the rainfall recovery after 2020. It is also in accordance with the increasing aerosols in China before 2010 and the slowdown in aerosol reduction in recent years. But it still requires quantitative analysis.

Related to the point above, it is not surprising that observed circulation trends (e.g., Fig. S18) are extremely weak. Yet, this is the mechanism driving Australian rainfall changes, thus is central to the proposed aerosol influence.

As mentioned earlier, given natural variability and the multiple factors influencing precipitation in Australia, it is quite challenging to capture patterns in the observations that resemble the results of the sensitivity experiment on China's aerosol reductions. We have redrawn the circulation figure (Figure S17 below), displaying all circulations regardless of whether they pass the significance test. Notably, we can observe clear similarities with the model results.

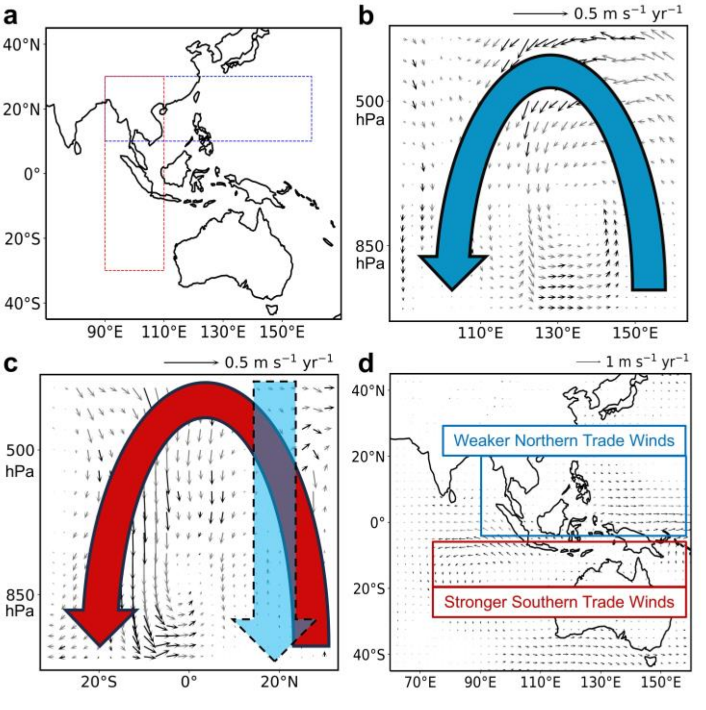

Figure S17. Linear trends in observed vertical circulations and 850 hPa wind fields in Asia-Pacific regions. Panel **b** and **c** shows pressure–longitude and latitude cross-section of linear trends in annual mean atmospheric circulations (unit: m s^{-1}, vectors) over areas marked with the blue and red box in panel **a** during 2010–2019 from ERA5. Panel **d** shows linear trends of wind fields (unit: m s^{-1}, vectors) at 850 hPa in Asia-Pacific regions. Trends of atmospheric circulations and winds which are statistically significant at the 90% confidence level are shown in black, while the insignificant ones are shown in grey.

The model analysis is also weak in the sense that 3-year composites are extremely short to identify forced trends. In addition, observed trends should be first compared to those from a control simulation and the contribution of aerosols should be related to the model world, not observations.

We believe there may be a misunderstanding regarding the 3-year composites mentioned by the reviewer. In our study, we did not use 3-year composites for climate variables (only for $PM_{2.5}$ and AOD in observations since they are more linear than climate variables). Our equilibrium experiment designs have been described in the 2.2 Model Description and Experimental Design section.

Regarding the model comparison, we would like to clarify that due to the nature of our equilibrium experiments, direct comparison with baseline control experiments is not feasible. Even in transient simulations, models may not be able to fully capture the short-term and complex observational signal, as observational data are influenced by numerous factors over short time periods. However, models can provide a quantitative evaluation of how specific factors, such as aerosols, might contribute to climate phenomenon. This approach has been commonly used in previous studies (Bollasina et al., 2011; Heede and Fedorov, 2021; Hwang et al., 2024; Vecchi et al., 2006; Wang et al., 2023; Yang et al., 2022) to isolate the impact of individual forcers. This limitation has been noted in the discussion section: "Another limitation of this study is that we calculated the relative contribution of aerosol changes in China to the changing climate in Australia by combining model simulations and observational data, which could lead to the inconsistency and introduce biases to the quantitative results.".

Another major weakness is the experimental design. The authors examine long-term changes coming from equilibrium runs, which are far from representing the actual transient response over 10 years or so. This is likely far from being in equilibrium. I would have seen large-ensemble transient simulations with time-varying aerosols (2013-2024 for example) as more appropriate and suitable.

We appreciate the reviewer's concern regarding the use of equilibrium runs and the suggestion to use large-ensemble transient simulations. While transient simulations offer a more dynamic representation of temporal changes, the relatively short period from 2013 to the present may not provide enough time for the climate system to fully respond to aerosol changes. This is particularly true when considering the long timescales required for oceanic heat capacity to equilibrium. Furthermore, equilibrium simulations allow for a clearer isolation of the forced response to aerosol changes, minimizing the impact of short-term climate variability.

We do acknowledge, however, that transient simulations would offer a more accurate depiction of the time-varying effects of aerosol reductions, especially as aerosol reductions in China continue. As the climate system responds more robustly over time, transient simulations will likely become a more appropriate tool. Therefore, while equilibrium simulations are potentially more suitable for the present study, we plan to use transient simulations in future research.

We have also mentioned the limitation of not using transient simulations in the discussion section: "While this study relies on equilibrium simulations to isolate the forced response to aerosol changes, we acknowledge that transient simulations, which account for time-varying aerosol reductions, would provide a more accurate depiction of the dynamic climate system response. Given that aerosol reductions in China continue to evolve, transient simulations would be more appropriate for capturing the full temporal effects of these changes. Large-ensemble transient simulations are suggested in future studies to better represent the evolving aerosol-climate interactions over time and to enhance the robustness of the findings.".

Trends or changes should always be plotted with the related statistical significance, such as in Figs. 1 and 2.

Thank you for the suggestion. Now all trends or changes have been plotted with statistical significance.

Fig 3: I think it would be more appropriate to display the divergent wind, rather than the total wind.

We chose to display the total wind in Figure 3 to highlight the strengthening of Southern Trade Winds. For the divergent winds, we also displayed moisture divergence (Figure S18), which is more directly related to the changes in precipitation patterns that we are investigating.

References:

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