Response to Reviewer Comments

Dear Reviewer and Editors:

We are sincerely grateful to the editor and reviewer for their valuable time for reviewing our manuscript. The comments are very helpful and valuable, and we have addressed the issues raised by the reviewer in the revised manuscript. Please find our point-by-point response (in blue text) to the comments (in black text) raised by the reviewer. We have revised the paper according to your comments (highlighted in blue text of the revised manuscript).

Sincerely yours,

Dr. Yuanjian Yang, representing all co-authors

#Reviewer 2#

This present study the potential effects of different types of aerosols on precipitation microphysics. Many previous studies have revealed the potential effect of aerosols on precipitation, while little attention has been paid on the aerosols on precipitation microphysical structures and processes, considering the different aerosol species. This topic is interesting and meaningful. The paper is composed logically, well-written, and the figures are clear. How I have some concerns of the manuscript, therefore a major revision is suggested.

Major suggestions

(1) Why choose specific criteria for defining aerosols and identifying polluted environments? Are there any references to support this choice? Could different criteria

lead to varying conclusions about the results?

Response: In the manuscript, three types of environments are classified, including clean, fine aerosol-polluted, and coarse aerosol-polluted environments. In nature, both fine and coarse particles coexist in the environment, making it difficult to distinguish fine and coarse particle pollution. To ensure the integrity of the coarse and fine particle pollution environments, we have imposed restrictions on the proportions of these two particle types to the total aerosol concentration. On the one hand, we need to ensure that the AOD of coarse particles is relatively high (exceeding 60% quantiles), while also ensuring that their proportion exceeds that of fine particles (i.e., more than 50%). This approach ensures that in a coarse-particle pollution environment, coarse particles are the dominant contributor. The same rationale applies to the classification of fine aerosol-polluted environments.

In addition, to ensure the robustness of the results, we have performed a sensitivity test by changing the PDF thresholds. In the sensitivity test, a clean environment is classified when the total AOD is below 0.235 (the lowest 33%). A fine (or coarse) aerosol-polluted environment must not only fall within the top 67% quantiles across all sampled data, but also have the AOD of fine (or coarse) particles exceeding 50% of the total aerosol AOD. The new thresholds and sample sizes are shown in Table R_1. Similarly, the boxplots of RR, N_w, D_m, and Z_e near-surface at 2.5 km altitude, as well as LWP and STH for shallow precipitation under different aerosol conditions in South China, are shown in Figure R_1. Sensitivity tests show conclusions similar to those of the previous thresholds. For example, compared to clean environments, RR, N_w, D_m, LWP, and Z_e decrease slightly in the fine aerosol-polluted environments, but increase in coarse aerosol-polluted environments.

In the revised manuscript, we have made more clear about the methods of environment classification (lines 211-215), as well as the sensitivity to the AOD thresholds to the results (lines 219-222).

Table R_1 Sensitivity test: Definitions of clean conditions, fine and coarse aerosol-polluted environments in southern China during the summers of 2014-2021.

Environment	Definition	Samples
Clean	Total AOD < 0.235	10090
Polluted_Fine	Fine AOD > 0.355 & Fine AOD ratio>50%	8330
Polluted_Coarse	Coarse AOD > 0.0495 & Coarse AOD ratio>50%	2557

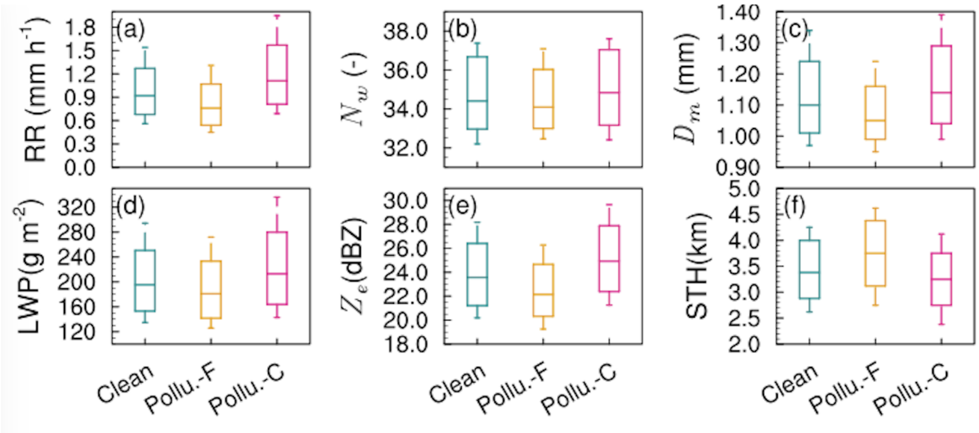

Figure R_1 Similar to Figure 2 in the manuscript, but for new AOD thresholds presented in Table R1.

(2) This study primarily outlines the main observational findings and potential underlying mechanisms of aerosols on precipitation. How do these findings compare with previous studies? Please include more comparisons with past research, highlighting both differences and similarities.

Response: Thank you for the nice suggestions. The main focus of this study is to elucidate the differences in the microphysical processes of precipitation under varying aerosol backgrounds, which is a relatively new scope in the meteorological field. Frankly, the topic of the effects of different aerosol types on shallow precipitation is not new (Pan et al., 2022; Liu et al., 2022; Fan et al., 2018). For example, Liu et al. (2022) found that coarse particles promote rainfall while fine particles suppress it, and these impacts are independent of meteorological conditions. However, their focus was mainly on shallow precipitation over the ocean, with limited attention given to shallow precipitation over land, and they did not analyze the associated microphysical processes. Moreover, we found that the extent of suppression or enhancement by fine and coarse aerosols varies with environmental conditions. These conclusions contribute new insights to the field.

In the revised manuscript, more comparisons with previous studies have been added in "Conclusion and Discussion". Please see lines 611-612, lines 617-619, and lines 637-638.

References:

Liu, F., Mao, F., Rosenfeld, D., Pan, Z., Zang, L., Zhu, Y., Yin, J., and Gong, W.: Opposing comparable large effects of fine aerosols and coarse sea spray on marine warm clouds, Communications Earth & Environment, 3, 232, 10.1038/s43247-022-00562-y, 2022.

Fan, J., Rosenfeld, D., Zhang, Y., Giangrande, S. E., Li, Z., Machado, L. A. T., Martin, S. T., Yang, Y., Wang, J., Artaxo, P., Barbosa, H. M. J., Braga, R. C., Comstock, J. M., Feng, Z., Gao, W., Gomes, H. B., Mei, F., Pöhlker, C., Pöhlker, M. L., Pöschl, U., and de Souza, R. A. F.: Substantial convection and precipitation enhancements by ultrafine aerosol particles, Science, 359, 411-418, 10.1126/science.aan8461, 2018.

Pan, Z., Mao, F., Rosenfeld, D., Zhu, Y., Zang, L., Lu, X., Thornton, J. A., Holzworth, R. H., Yin, J., Efraim, A., and Gong, W.: Coarse sea spray inhibits lightning, Nat Commun, 13, 4289, 10.1038/s41467-022-31714-5, 2022.

Minor suggestions

1. Line 30, radar and radar reflectivity … -> radar reflectivity

   Response: Done (Line 31). Thank you.

2. Line 34-35, where does the "22.2% " come from?

   Response: It comes from the results in Figure 10. **'with an enhancement of 22.2%'** has been added (Lines 582-583).

3. Line 73, Other studies suggest -> Another study suggests

Response: Done (Line 75). Thank you.

4. Line 138, This sentence is missing a period.

   Response: Done (Line 146). Thank you.

5. Line 91, efficiency of coalescence of rain droplets-> coalescence efficiency of rain droplets

   Response: Done (Line 93). Thank you.

6. Lines 96 – 97, for the study on the effect of the effect of aerosols on shallow precipitation -> the study of aerosols effect on shallow precipitation.

   Response: Done (Lines 98-99). Thank you.

7. Lines 173-176, Is there any reference for the definitions for the fine and coarse aerosols?

   Response: A reference by (Gelaro et al., 2017) has been added to the manuscript (Line 186). Thank you.

   Reference:

Gelaro, R., McCarty, W., Suárez, M. J., Todling, R., Molod, A., Takacs, L., Randles, C. A., Darmenov, A., Bosilovich, M. G., Reichle, R., Wargan, K., Coy, L., Cullather, R., Draper, C., Akella, S., Buchard, V., Conaty, A., da Silva, A. M., Gu, W., Kim, G.-K., Koster, R., Lucchesi, R., Merkova, D., Nielsen, J. E., Partyka, G., Pawson, S., Putman, W., Rienecker, M., Schubert, S. D., Sienkiewicz, M., and Zhao, B.: The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2), Journal of Climate, 30, 5419-5454, https://doi.org/10.1175/JCLI-D-16-0758.1, 2017.

8. Line 204, it should be 8967.

   Response: Sorry for the careless error in the previous manuscript. It has been corrected in the manuscript (Line 222).

9. Line 226, how about the ratios of dust and sea salt aerosols to the coarse aerosol? Similar, how about the black carbon, organic carbon and sulfate to the fine aerosols?

Response: Thank you. The average AODs for five different aerosol species across various environmental settings are computed to determine the contributions of each aerosol type (Table R_2). It can be seen that the mean AOD of sulfate (0.481) is the largest for fine aerosol-polluted environments, while it is the sea salt (0.164) for coarse aerosol-polluted environments. In determining the average AODs across five species relative to the overall mean AOD (Table R_3), sulfate aerosols represent 54.8% in clean environments and 80.4% in fine-polluted environments, while sea salt accounts for 63.1% in coarse-aerosol polluted environments..

In the revised manuscript, ' **The mean AODs of five aerosol species under various environmental conditions are calculated to understand the contributions of different aerosol types (not shown). In South China, the primary contributors to aerosol species are sulfate aerosol, sulfate aerosol, and sea salt aerosols in clean, fine, and coarse aerosol-polluted environments, respectively.**' has been added in lines 224-228.

Table R_2 The mean AODs of five aerosol species in different environmental conditions

	Sulfate	Organic carbon	Black carbon	Dust	Sea salt
Clean	0.092	0.017	0.009	0.006	0.044
Fine-polluted	0.481	0.052	0.029	0.014	0.022
Coarse-polluted	0.072	0.013	0.006	0.005	0.164

Table R_3 The mean ratio of five aerosol species (units: %) to the total AODs in different environment conditions

	Sulfate	Organic carbon	Black carbon	Dust	Sea salt
Clean	54.8	10.12	5.35	3.57	26.19
Fine-polluted	80.4	8.70	4.85	2.34	3.68
Coarse-polluted	27.7	5.0	2.3	1.92	63.1

10. Line 227, "Coarse AOD > 0.0425" is duplicated.

Response: Sorry for the careless. Done (Line 253). Thank you.

11. Line 240, "promoting" -> benifical for the

Response: Done (Lines 265-266). This sentence has been modified to '**Nevertheless, the presence of coarse aerosol-polluted conditions appears to inhibit the vertical development…**'

12. Line 245, "mode" - > environments

Response: Done (Lines 268-272). This sentence has been modified to '**Examining the situation from a microphysical standpoint, it is observed that in comparison to a clean environment…**'

13. Line 251, provide some reference to support this statement.

Response: Done. As responded to question 9, sea salt contributes to 63.1% of the total aerosols in the coarse-polluted environment. This has been added in Data and Methods (Lines 226-228).

14. Line 281, not in italics.

Response: Done (Line 304). Thank you.

15. Line 359, fine mode -> fine; similarly in Line 367

Response: Done (Line 382). This has been modified to **'In presence of fine aerosol-mode'.**

16. In section 3.3, since precipitation can be affected by many other effects, please explain more about the reasons of choosing these two factors (CAPE and RH at 850hPa).

Response: Thank you. We totally agree with you that the precipitation can be influenced by numerous factors. In the manuscript, **'However, precipitation itself is a complex process influenced by multiple thermal and dynamic environmental factors, such as instability, humidity, temperature, and wind vectors. Among these, dynamic conditions and moisture levels are particularly important indicators.'** has been added in Lines 400-403. Additionally, a further analysis of the sensitivity of surface air temperature to aerosol's impact on precipitation has been discussed.

Based on the tercile values of the TM values during precipitation events in southern China, the samples are grouped into three groups. TM1 < 299 K, TM2: 299~301 K, and TM3: >301K. The result in Figure R_2 shows that the suppression of RR in fine aerosol-polluted environments and the invigoration of RR in coarse aerosol-polluted environments are independent of the temperature conditions. Similarly to the conclusion of different CAPE and RH at 850hPa conditions (Figure 6 and Figure 7), the amplitude of the invigoration and suppression are related to the meteorological conditions. The invigoration and suppression effects are more significant under low surface air temperature conditions (TM1).

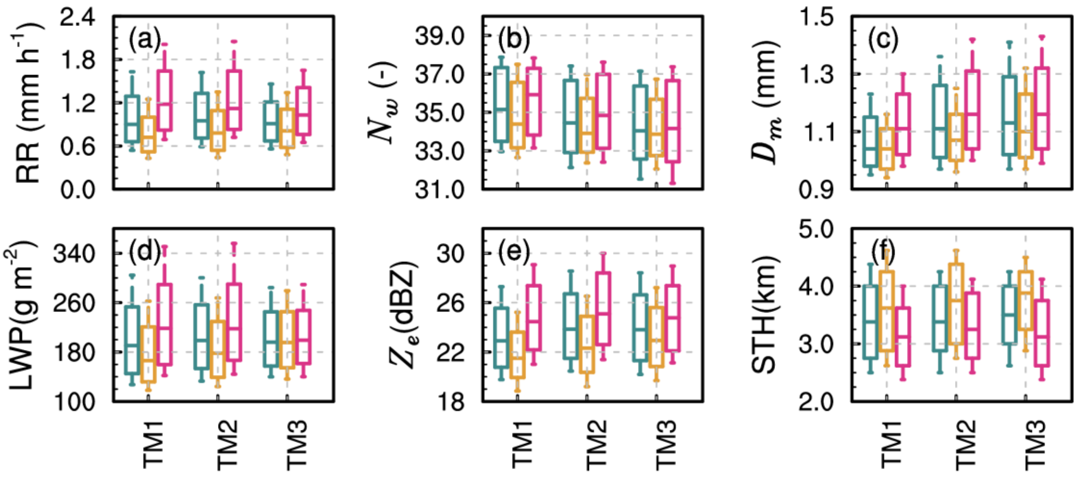

Figure R_2 Box plot of the near-surface rain rate (a), N_w (b), D_m (c), LWP (d), Z_e (e), and STH (f) under different aerosol and surface air temperature conditions for shallow precipitation over southern China during the summers of 2014-2021.

17. Line 502, where the -> the

Response: Done (Line 524). Thank you.

18. Line 550, modify the phrase "the presence of CAPE and RH"

Response: Done (Line 573). Thank you. ' the presence of CAPE and RH ' has been changed to ' **the value of CAPE and RH** '.

19. Line 554, notify the previous findings specifically.

Response: Done (Lines 576-577). We mean that **'These conclusions are consistent with the results in Figure 5.'**

20. Line 639: available on May 2023 -> accessed in May 2023

Response: Done (Line 691). Thank you.