

Comment to “Aerosol-Driven Precipitation Modification: Spatiotemporal Heterogeneity in Precipitation Microphysics and Vertical Structures over China's Megacity Clusters” by Peng et al.

This study investigates aerosol effects on precipitation vertical structures and microphysical characteristics across four Chinese urban clusters, including sensitivities to meteorological factors. Interesting results have been shown with suggested mechanisms. In principle, this study is worthy for publication with necessary modifications.

Major comments:

- (1) Noting the complex interactions between aerosol, cloud, precipitation, and meteorology, many physical explanations or mechanisms proposed here are with uncertainties, so cautions should be paid to the descriptions, particularly those claims regarding mechanisms.
- (2) As mentioned in the previous comment, the discussion of mechanisms appears somewhat limited. The mechanisms discussed in the study, such as the Twomey effect, lifetime effect, and semi-direct effect, are primarily associated with warm clouds. However, the precipitation cases analyzed in this study include both cold-topped and warm-topped systems. Important processes related to mixed-phase clouds, such as the role of ice nuclei and the invigoration effect (Rosenfeld et al., 2008), receive relatively little attention. For example, while the authors emphasize the importance of the semi-direct effect of dust in the BTH region, dust is also a major source of ice nuclei, which could substantially influence cold-topped precipitation formation. This aspect warrants further consideration and discussion.
- (3) If possible, a proofreading service is suggested to improve the English writing of this paper.

Detailed comments:

Line 45-46: IPCC report could be referred for this claim.

Line 48-51: In addition to early study, recent studies regarding their roles in hydrological cycle, extreme weather event, and climate system could be also mentioned as supporting material, such as Zhao et al. (2018, 2020, doi: 10.1029/2018GL079427, doi: 10.1093/nsr/nwz184).

Line 56: what does “these” here denote?

Line 62-65: Note that this effect is for absorptive aerosols within clouds, not for that outside the clouds.

Line 69-71: Regarding the regional variations, recent study by Li et al. (2025, doi: 10.1029/2024JD042649) could be mentioned.

Line 83-84: I am not sure if this claim is fair or not since many recent studies are actually considering the season, precipitation type, along with meteorological effects.

Line 151: remove “the” of “the 85%”

Figure 1: How do the authors consider the elevation effect on ACI? In other words, do the authors consider the spatial variation in elevation height when studying ACI at each region?

Line 172-175: We should also note that hail also often occurs in spring or even summer in north China.

Line 183-188: How reliable is the aerosol classification?

Line 189-190: How many hours are the aerosols used prior to precipitation events?

Line 191-198: similarly, the spatial and temporal resolution for data used here should be provided.

Line 197: A space is needed between the number and the unit: “850 hPa” instead of “850hPa” (also in Line 481).

Line 204: The definition of “valid precipitation systems” requires further clarification. It is unclear whether the threshold of four contiguous precipitation pixels refers to near-surface precipitation or to the existence of a precipitation profile. Some profiles may show precipitation aloft but none reaching the surface.

Line 208: “SO_{4A}” should be “SO_{4A}”.

Line 232: Variable X should be defined.

Line 355-358: Relevant references should be added to support the statements.

Line 360: Fig. 5a mentioned here does not show RR and Ze; please check if this is a typographical error (should likely be “Fig. 4a”).

Lines 361-362: The statement “... Ze increase linearly with aerosol loading in the BTH ...” seems valid only for the lower layers (<5 km) in the BTH according to Fig. 4b.

Line 363-364: “Fig. 4a-e” may be a typographical error and should likely be “Fig. 3a-e”.

Line 365: “Fig. S1a” should be corrected to “Fig. S2a”.

Line 364-367: It seems that the authors did not catch the finding from cited study, what they indicated is: This discrepancy may arise from the predominant influence of DUA on the spring AOD composition of the BTH region, whereby their radiative effect enhances the atmospheric instability and triggers earlier precipitation.

Lines 386–387: It might be helpful to clarify whether the term “particle” refers to aerosol particles or to cloud/raindrop particles, as this term appears in multiple places throughout the manuscript. A clear distinction may improve the overall clarity of the physical interpretation.

Figure 4: Unit for height should be given (also in Fig. 8).

Lines 403-407: The sentence could be simplified to avoid redundancy and improve clarity.

Line 410-413: The statement that prolonged cloud lifetime enhances precipitation should be supported with appropriate references and further discussion.

Lines 435–437: Relevant references should be added to support the statement.

Line 453-455: I doubt if this claim is accurate or not. For example, there are almost no coalescence and break-up processes for non-precipitating clouds.

Line 499: please rephrase the sentence to make it clear.

Section 5.2 and 5.3, please modify the section title to make it more reasonable.