We provide detailed responses to all comments below; the responses are shown in blue, and all revisions in the manuscript are highlighted in red.

Report 1

Summary:

This study examines the impact of sub-cloud aerosol concentrations in different size ranges on cloud particle properties in liquid, mixed-phase, and ice clouds. The introduction and data sections are well-written. The numerical simulations are particular insightful and lend useful context to the process-level hypotheses made by the authors. The inclusion of the adiabatic cloud model on top of analyzing flight data from numerous flights across hydrometeor phases is commendable and a step beyond studies that solely use either observational or modeling datasets.

The authors have done a good job addressing comments to the original manuscript and the revisions have improved the quality of the manuscript considerably. I have minor comments to be addressed before publication is recommended.

We sincerely thank the reviewer for the positive assessment of our manuscript and for the constructive comments. We are glad that the revisions have improved the quality of the manuscript. All minor comments have been carefully addressed, and corresponding revisions have been made in the manuscript.

Detailed, point-by-point responses are provided below.

Minor comments:

Line 17: Define H as the normalized cloud height.

We thank the reviewer for this helpful suggestion. The definition of H as the normalized cloud height has been added in the revised manuscript.

Under high sub-cloud aerosol loading, effective droplet diameters in the lower part (H<0.3, **H is normalized cloud height**) of liquid and mixed-phase clouds are 2.4 and 2.8 μm larger, respectively, than those in the upper part (H>0.7).

Line 82: I would recommend rephrasing this sentence. We do understand how the indirect effects work – as also highlighted by some of the text in the introduction and the cited works. The uncertainty arises in their impact on the radiation budget through the effective radiative forcing, or through the co-variability in aerosol- and environmental-impacts on cloud properties which makes the quantification of aerosol effects alone more challenging.

We thank the reviewer for this insightful comment. The sentence has been rephrased accordingly in the revised manuscript.

Line 117: this paragraph and Figure 1 are welcome additions to the revised manuscript. However, a 2D lat/lon map that shows the city, geographical boundaries, and the surrounding regions (land/ocean) along with the flight tracks may also be nice. This will help readers who are not familiar with this location.

We thank the reviewer for this helpful suggestion. Following this recommendation, a 2D latitude – longitude map has been added to the revised manuscript, showing the city location, geographical boundaries, surrounding land – ocean distribution, and the flight tracks.

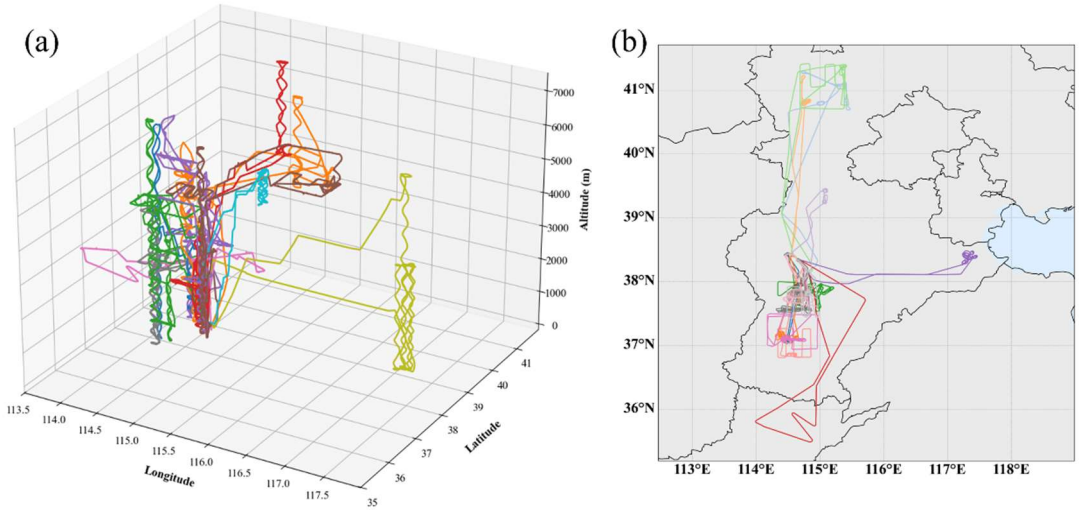


Figure.1. Map of the aircraft flight tracks and observation region over the North China Plain.

Line 195: Introduce “H” here.

We thank the reviewer for this helpful suggestion. The parameter H has now been introduced here and defined as the normalized cloud height in the revised manuscript.

In this study, the vertical positions of clouds from different flights were normalized to a dimensionless height parameter H ranging from 0 to 1. Cclouds were divided into lower (0 – 0.3), middle (0.3 – 0.7), and upper (0.7 – 1) layers based on normalized height(H), and the particle distributions were analyzed within each layer.

Line 205: I recommend the authors split figure 3 into two figures – one for aerosol distributions and one for cloud hydrometeors. I say this because the aerosol spectra needs to be displayed in two forms – the entire spectra as shown in the last column in Fig.3 but also a zoomed in version that shows the difference in small-sized aerosols between the different loading scenarios. In the current version, the latter is very hard to distinguish.

We thank the reviewer for this helpful suggestion. Following this recommendation, Figure 3 has been reorganized and split into two separate figures: one focusing on aerosol size distributions and the other on cloud hydrometeor size distributions. In addition, for the aerosol spectra, we now present both the full size range and a zoomed-in view highlighting the small-sized aerosol differences under different loading conditions.

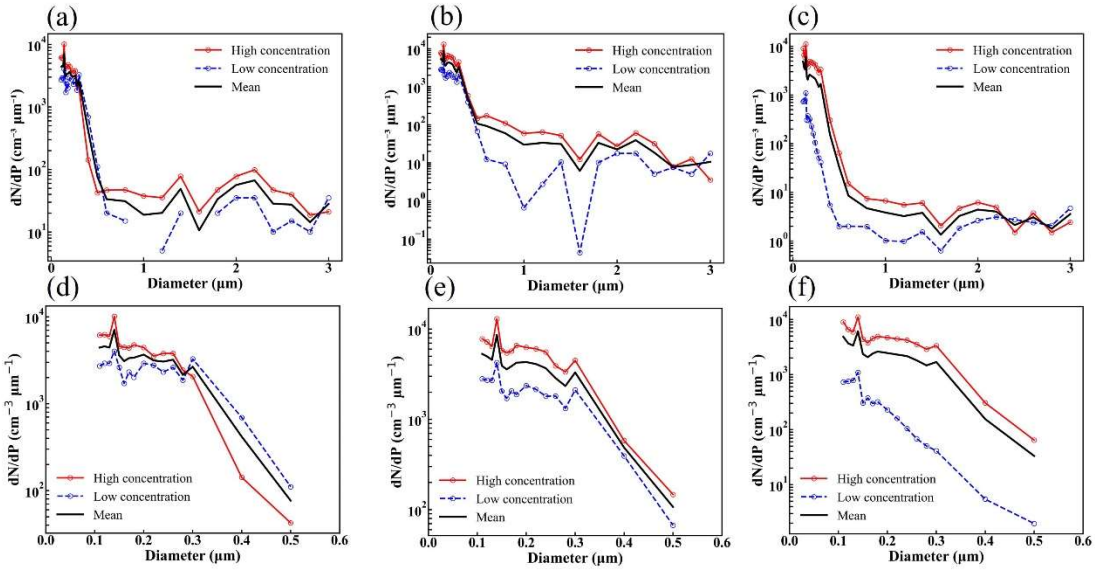


Figure 3. Aerosol number size distributions below the observed clouds under different aerosol loading conditions. Panels (a-c) show the aerosol size distributions below warm, mixed-phase, and ice clouds, respectively, under high and low aerosol loading, along with the mean distribution (black line). Panels (d-f) present a zoomed-in view of the small-size range. The red and blue curves represent high and low aerosol loading, respectively.

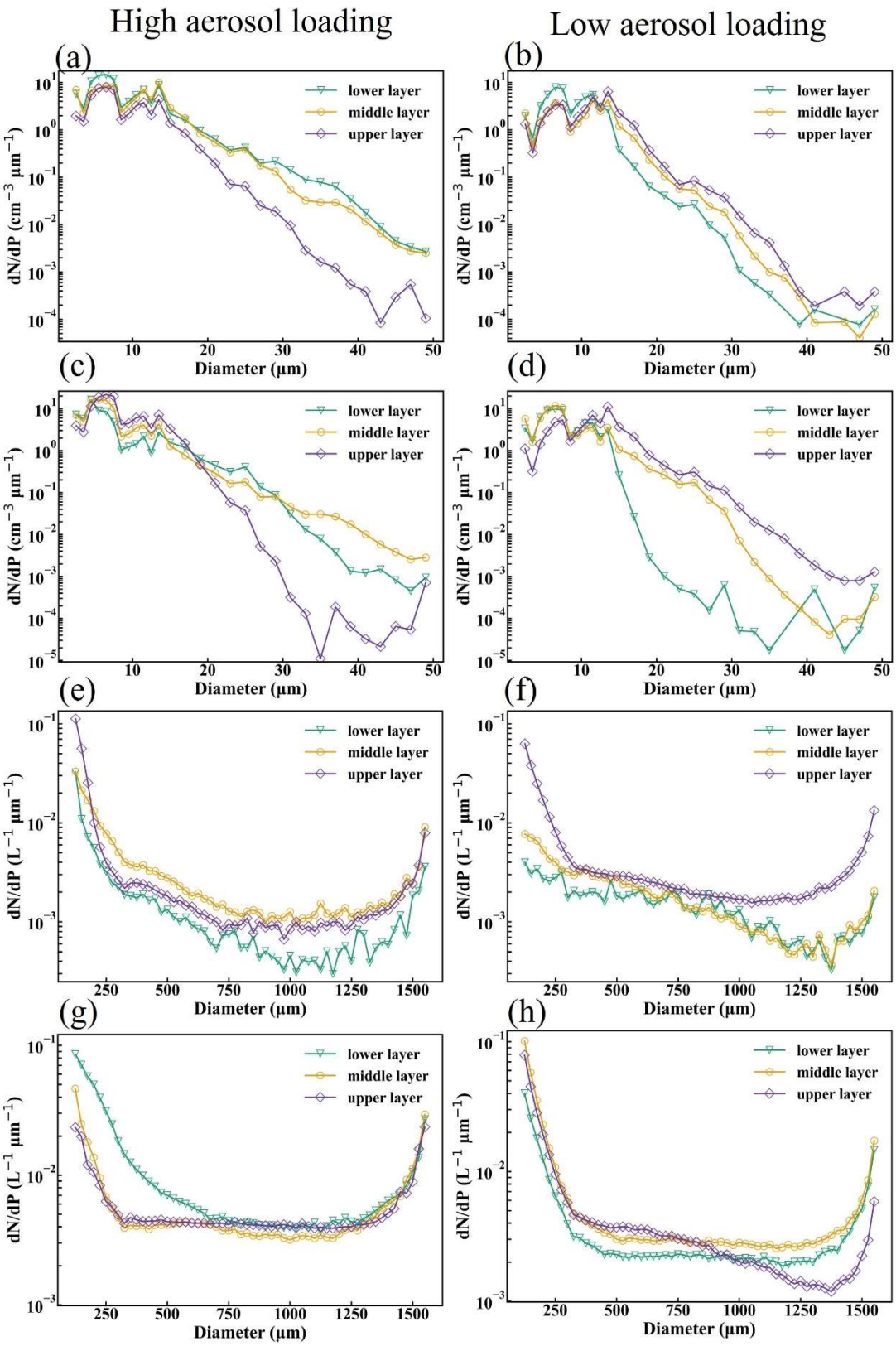


Figure 4. Size distributions of cloud particles in different regions of the observed clouds under high and low aerosol loading conditions. The left column (a, c, e, g) corresponds to high aerosol loading, and the right column (b, d, f, h) corresponds to low aerosol loading. Panels (a-b) show cloud droplet spectra in warm clouds; panels (c-d) show cloud droplet spectra in mixed-phase clouds; panels (e-f) show ice crystal spectra in mixed-phase clouds;

and panels (g-h) show ice crystal spectra in ice clouds. In each panel, the green, yellow, and purple curves represent the lower, middle, and upper layers of the cloud, respectively.

Line 224: The discussion of "H" in this paragraph should be moved to the beginning of the previous section.

We thank the reviewer for this helpful suggestion. Following the recommendation, the definition and explanation of the normalized cloud height "H" have been moved to the beginning of the previous section to improve the logical flow and readability of the manuscript.

Line 232: I highly doubt the differences shown in panels (a) and (e) are statistically significant throughout the cloud column-perhaps only near cloud base. A significance test should be conducted, and the statement be modified to reflect the ranges of H for which the differences are significant. I recommend the authors do such testing for all statements but critically for this statement as it forms the basis of many of their conclusions.

We thank the reviewer for this important comment. We agree that the differences shown in panels (a) and (e) may not be statistically significant throughout the entire cloud column. Following this suggestion, we have revised the statement to focus only on the most prominent and representative differences observed in the lower layer of the cloud.

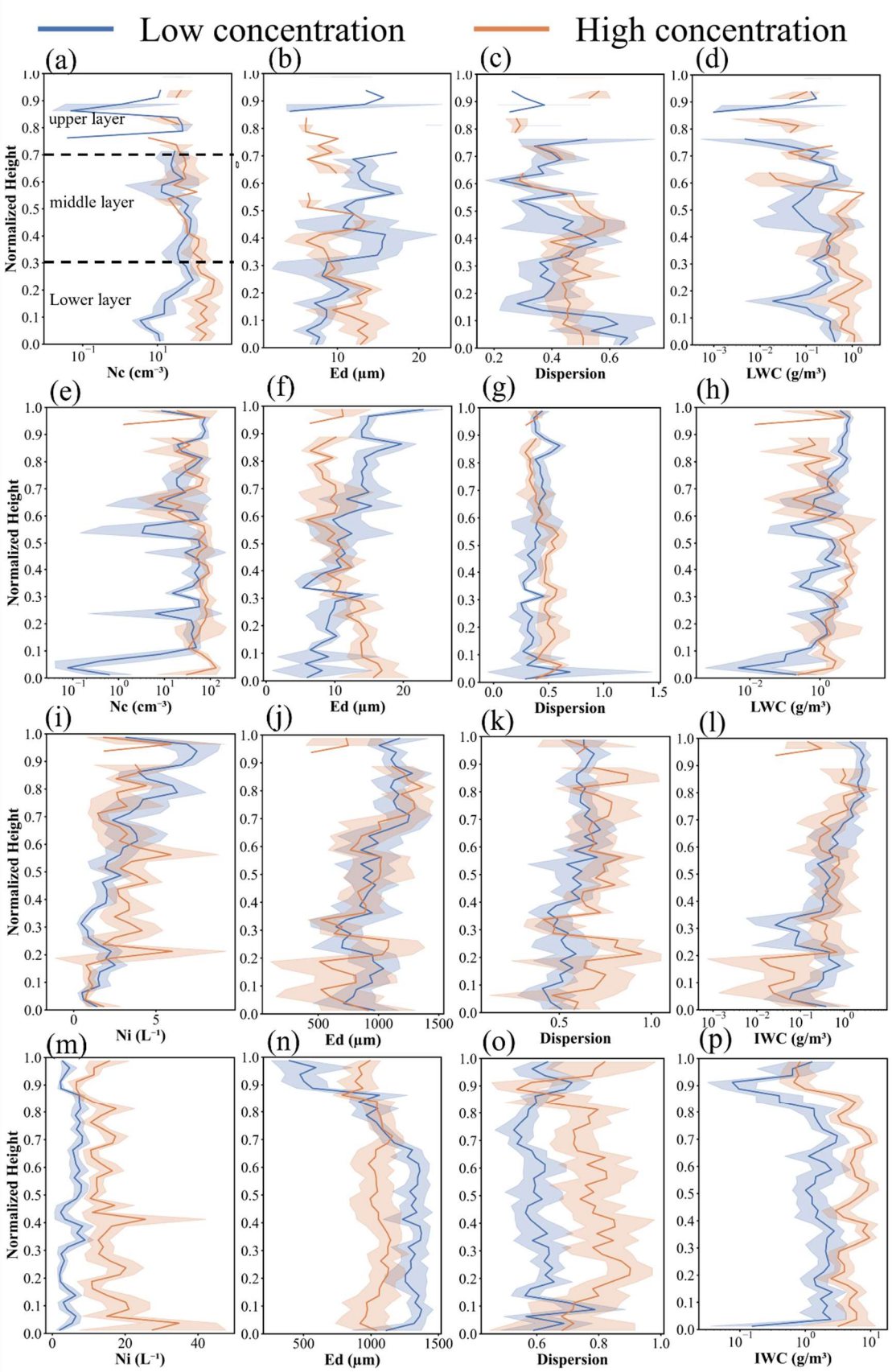
Consequently, the concentrations of both cloud droplets and ice crystals are greater in the lower layer of the cloud under high-aerosol conditions.

Figure 3:
- Please add column titles-high and low aerosol loading - above columns 1 and 2.
- Please make the vertical axis limits consistent between columns 1 and 2.

We thank the reviewer for this helpful suggestion. The original Figure 3 has been separated into two figures (cloud particle distributions and aerosol size distributions). In the revised figures, the column titles indicating high and low aerosol loading have been added, and the vertical axis limits have been made consistent between the corresponding panels.

Figure 4:
- It would be nice to have a marker in one of the panels to define the vertical extent of the lower/mid/upper cloud layer.

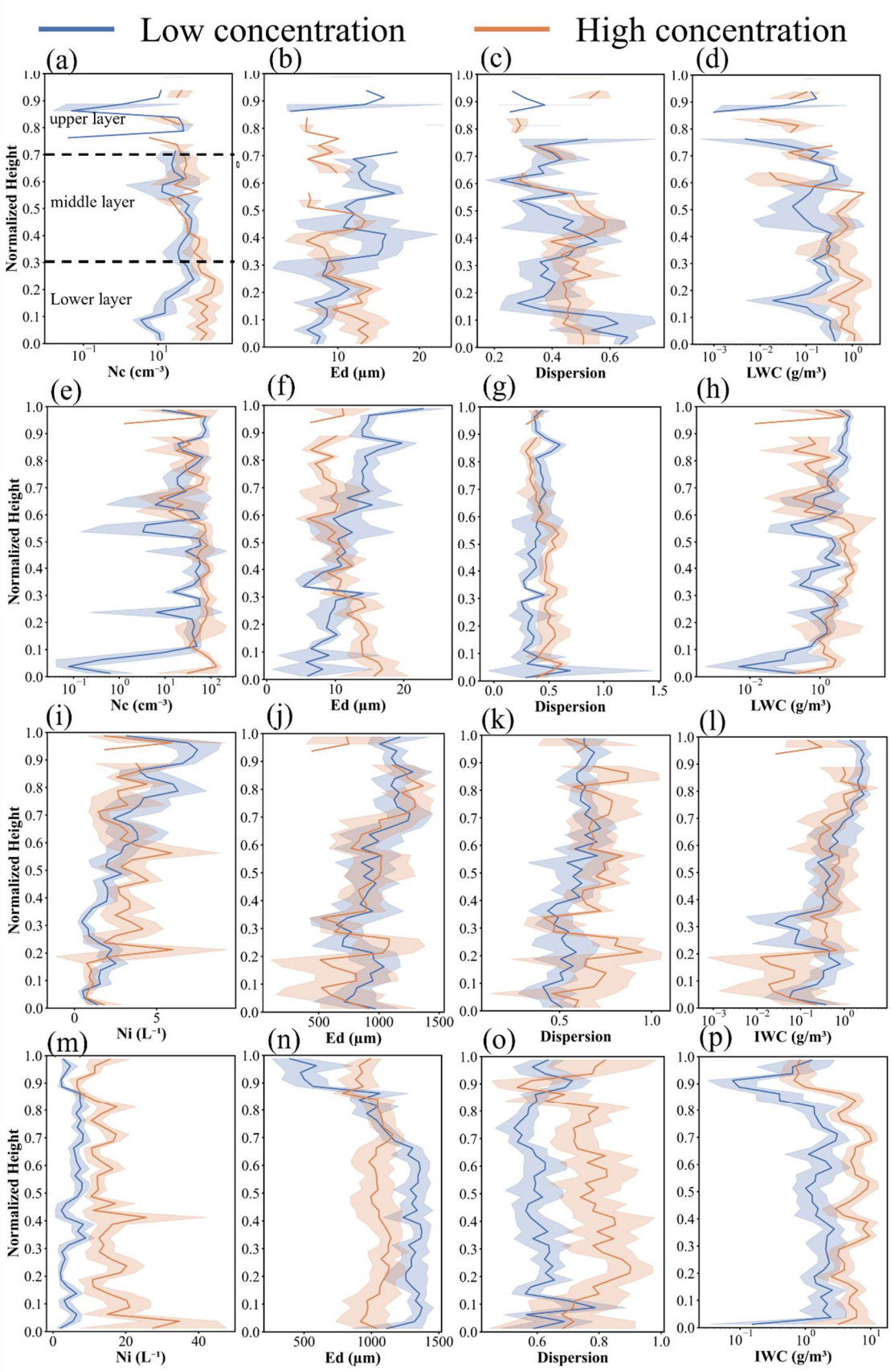
We thank the reviewer for this helpful suggestion. We have revised Figure 4 accordingly by adding markers to indicate the vertical extent of the lower, middle, and upper cloud layers in the panels, as shown in the updated figure.


Low concentration
High concentration
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
upper layer
middle layer
Lower layer
Normalized Height
Nc (cm⁻³)
Ed (μm)
Dispersion
LWC (g/m³)
Ni (L⁻¹)
IWC (g/m³)

Report 2

I think that the new visualization of Figure 4 is much improved from the original scatter plot and thank the authors for making that change. I still find it somewhat noisy, and would suggest using even wider bins for averaging, unless the authors feel strongly that smaller bins such as these are necessary. Since most of the arguments made about this plot are about relative changes with height or magnitude differences between high and low aerosol concentration cases, I would anticipate that these would still be evident if the curves were smoothed out a bit.

We thank the reviewer for this helpful suggestion. Following the reviewer's advice, we have revised Figure 4 by applying wider bins for averaging. The updated visualization is noticeably improved, with reduced noise and clearer vertical trends. Importantly, the key features discussed in the manuscript including the relative variations with height and the differences between high and low aerosol loading.



In terms of the description of these results, I have a few small comments:

- In general, I would suggest qualifying several of these statements to say that the patterns hold *in general.* For example, Lines 243-244 say that "Consequently, the concentrations of both cloud droplets and ice crystals are greater under high-aerosol conditions (Figures 3a, e, i and m)." However, with the current bin size used for averaging, it can be seen that this is not *always* the case. I would suggest that similar statements be clarified to say that these observed patterns are generally/usually/largely the case.

We thank the reviewer for this helpful and constructive comment. We agree that, given the variability and the current binning approach, the observed patterns do not hold in all cases. Following this suggestion, we have revised the relevant statements throughout the manuscript to clarify that these patterns are generally or largely observed, rather than universally applicable.

Consequently, the concentrations of both cloud droplets and ice crystals are greater in the lower layer of the cloud under high-aerosol conditions.

- Line 244: Fig. 3 needs to be updated to Fig. 4.

We thank the reviewer for pointing out this error. The figure reference has been corrected

- Line 270-272: Is this statement supposed to apply to panel (o) for ice crystals in ice clouds? I am not quite seeing this in panel (k) for ice crystals in mixed-phase clouds.

We thank the reviewer for this careful observation. We confirm that the value of H=0.4 in the original manuscript was a typographical error. The correct value is H=0.34, where a local minimum in spectral dispersion is observed.

For the ice crystals in mixed-phase clouds, the spectral dispersion is significantly greater under high-aerosol loading than under low-aerosol loading, with a local minimum at H=0.34.

- Line 273: Should this reference panels c, g, k, and o since it is discussing spectral dispersion?

We thank the reviewer for this helpful suggestion. We agree that the discussion of spectral dispersion should refer to panels (c), (g), (k), and (o). The figure references have been corrected accordingly in the revised manuscript.

In ice clouds, spectral dispersion varies little with height under low-aerosol conditions, whereas under high-aerosol conditions, it increases for H<0.25 and decreases for H>0.75 **(Figure 4c, g, k and o).**

Lastly, I appreciate the authors including a map of the flight tracks in the new Figure 1. Personally, I would suggest making this a 2D image on a map just to give readers a better sense of how much land area these flights cover within the North China Plain. I don't necessarily think that the vertical dimension in this figure communicates as much. But this is arguably more of a personal preference, and I understand if the authors want to keep the figure as is.

We thank the reviewer for this helpful suggestion. Following this recommendation, we have retained the original figure and added a supplementary 2D map view to better illustrate the spatial coverage of the flight tracks over the North China Plain. This addition provides a clearer representation of the horizontal extent of the observations while preserving the vertical information in the original figure.