Response to the Comments of Referees

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Title: Exploring aerosol-cloud interactions in liquid-phase clouds over eastern China and its adjacent ocean using the WRF-Chem-SBM model
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We thank the reviewers and editor for providing helpful comments to improve the manuscript. We have revised the manuscript according to the comments and suggestions of the referees.
The referee's comments are reproduced (black) along with our replies (blue). All the authors have read the revised manuscript and agreed with the submission in its revised form.

Anonymous Referee #2

Review comments of "Exploring aerosol-cloud interactions in liquid-phase clouds over eastern China and its adjacent ocean using the WRF-Chem-SBM Model" by Zhao et al., 2023

General comments

The authors simulate the liquid-phase clouds in eastern China over land and ocean and explorethe different aerosol-cloud processes including aerosol activation, precipitation and entrainment-evaporation in eastern China (EC) and eastern China ocean (ECO). Their simulations use the technical as detailed as possible and evaluation is very valuable. The analysis of aerosol-cloud interactions provides many new insights in this specific region, such as which mechanisms dominant in which region. Overall, I recommend publish it after address some specific comments below. Given that the comments below are mainly at the aspect of presenting and discussion, I guess the reviewer can address them in 2-3 weeks. So I recommend minor revision.

Specific comments

1. The simulation uses SBM, 4d data assimilation and WRF Chem. All those techniques are the current "most" detailed representation of aerosol-cloud interactions. So I believe readers may be curious about the computational cost of this kind of simulations. I think it valuable to describe the computational cost in the method section for other people to decide on their model configurations.

   Thanks for suggestions. Using the model configurations of this study, EC and ECO simulations require around 15,000 and 10,000 CUP core-hours, respectively. We have added this information in section 2.1.

2. “supersaturation pathway”, this terminology is mentioned without a clear definition. Based on the content, I guess the “multiple supersaturation pathway” means the multiple contributing factors to supersaturation, or multiple aerosol-cloud processes that impacts supersaturation, is that right? I suggest a clear definition of it. If this terminology was used in previous literature, I recommend citing the papers. For me, “pathway” is usually used to describe the spatial trajectories.

   We have deleted the use of "supersaturation pathway" in the text and replaced it with a description of specific physical processes or the use of terms such as “contributing factors to supersaturation” and “processes affecting supersaturation”.

3. Abstract: surface longwave radiative forcing cooling is mentioned. Also, the cloud top radiative cooling is also mentioned in the results section. Please specify which cooling you refer to in the item 3 for EC and item 2 for ECO.

   Both the abstract and section 3.3 discuss the effect of meteorological fields on aerosol-cloud, where cooling refers to cooling due to cold northerly winds. We revised the abstract and the text.

4. Line 174-175: add “respectively” at the end of the sentence

   We've added it.

5. Line 185-186: How did you match that? Please clarify it.

   In order to compare the WRF simulation with MODIS, we first interpolated the MODIS data to the WRF grid to make the coordinates match, for each grid and each time the simulated value is available for analysis only when the MODIS data is valid, otherwise the simulated value is set as the missing value and does not participate in the calculation. We have added in Section 2.3 of the modified manuscript.

6. Figure 2: 4d data assimilation has large effects on temperature and humidity. Are those the two major variables assimilated? Does the assimilation take care of wind also?

   Temperature and wind is assimilated directly, and humidity is indirectly affected by assimilating temperature, dew point, wind and air pressure. We provide this clarification at section 2.2 and the beginning of the second paragraph of section 3.1.

7. Figure 4: I don’t mind the figure goes in the current form, but add a legend showing the red, blue and black lines would be better.

   We added a legend to Figure 4a, along with the figure caption indicating what each color line represents.

8. Line 248: “low over land and high over ocean” is only evident for CER, but not Nd. Modify the sentence please.

We have modified this paragraph.

9. Line 258-259: Aerosol and clouds are still not good. Probably it is better to go through those differences and provide a possible explanation for the differences. I know simulating aerosol and clouds are hard (I believe "everybody" knows that), but it is not good to explain Figure 5 in this way, given the fact that model underestimate CTH, overestimate CTP, overestimate CER over ocean, overestimate Nd over land...

   We have modified the description in Section 3.1 to point out in more detail on overestimation and underestimation of the variables.

   In addition, we effectively improved the model's ability to simulate aerosols by providing the model with chemical initial and boundary conditions from Community Atmosphere Model with Chemistry (the WRF defaults were previously used).

10. Line 263 "produced by anthropogenic emission". To reach this explanation, a plots showing the chemical composition may help. Although Figure 7 can be used to infer this, but a pie diagram is better and clearer.

    Thanks for suggestion, we replaced the original Figure 7 with a pie diagram (Figure 8 in the revised manuscript) to show the results more clear.

11. Line 265-266: "ECO aerosols are mainly transported from EC". I can not reach this from Figure 7. Please clarify.

    This is shown in Fig. 8b of the revised version, i.e. ECO's locally emitted chloride and sodium aerosols contribute less than 20% of the total aerosol mass.

12. Line 315: Two methods are mentioned here. So which way did you use for Figure 9 and 10, and why?

    Fig. 9 (Fig. 10 in the revised manuscript) shows the results by sampling from each vertical layer (left two columns) and the sampling of the entire columns (right two columns). In Fig. 10 (Fig. 11 in the modified manuscript), we used the sampling data from each vertical layer in order to reflect the aerosol-cloud-meteorological field relationship in a more detailed and immediate way. We added notes in Fig. 9, the figure captions for Figs. 9 and 10, and in the main text of Section 3.3.

    In addition, we found some problems with our previous statistical method to the sample of figs. 9-13. Previously, we set 200 (aerosol, x-axis) × 100 (Nd, y-axis) bins for the horizontal and vertical coordinate variables of the figure, traversed all samples (each sample contained Naero or AOD, Nd, aerosol volume mean radius, supersaturation, and water vapor content values). When the aerosol and Nd values of a sample satisfy the corresponding aerosol and Nd intervals, the value for that sample is the value for that bin. This approach suffers from traversal order, which prevents the

complete representation of the aerosol-cloud relationship. In the revised manuscript we corrected the statistical method , it is still the same bin as before, but we first put all the samples that match the aerosol and Nd intervals of each bin into the corresponding bin, and then average the samples in each bin to obtain the value of each bin. We added a note on the method in the caption of Fig.10.

13. Line 325: Do you mean Figure 9a and 9e?

    Yes, we corrected it.

14. Figure 9: The subplots are not the same in size, which looks odd. Also, the order is odd too. Add the four figures in the third row to the end of the first and second row for EC and ECO, respectively. I recommend using log for the x-axis for N_aero and Nc.

    We adjusted the order and size of the subplots.

    The figure below shows the result of using N_{aero} and N_d logarithmic coordinates, it causes the figure to overemphasise high values at low N_{aero} and N_d, which is not conducive to showing the overall change. So we still use the original coordinates.

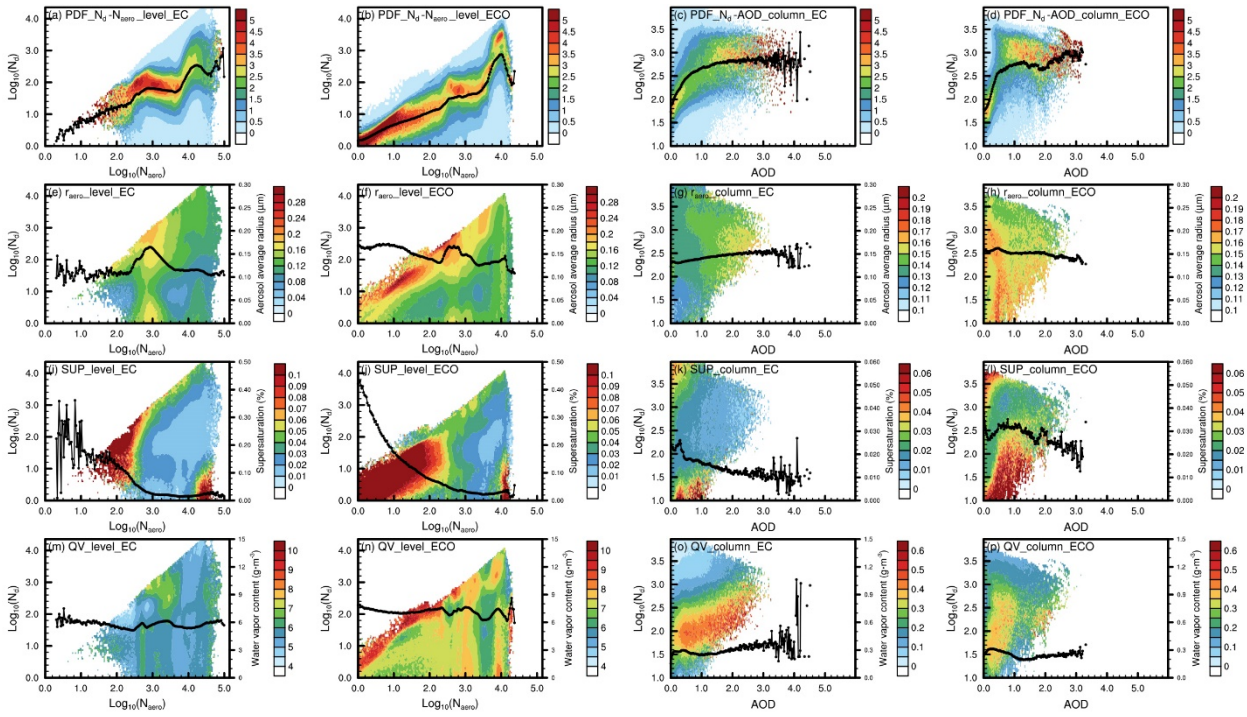

Figure RC2-1. Same as Fig. 10 of the revised manuscript, but using log for the x-axis for N_{aero} and N_d

15. The authors use the differences between Nd and N_aero in Figure 9, and the ratio of Nd to N_aero in Figure 10. Why did you use different metrics? What would the figure be like if you use another metric?

    Using the ratio of N_d and N_{aero} allows us to see the strength of aerosol activation under different meteorological fields and aerosol conditions, whereas the direct use of N_d values as shown in the

figure below, whose high values are overall skewed towards the high N_{aero} coordinates, is not conducive to our understanding of the effect of different aerosol conditions on activation.

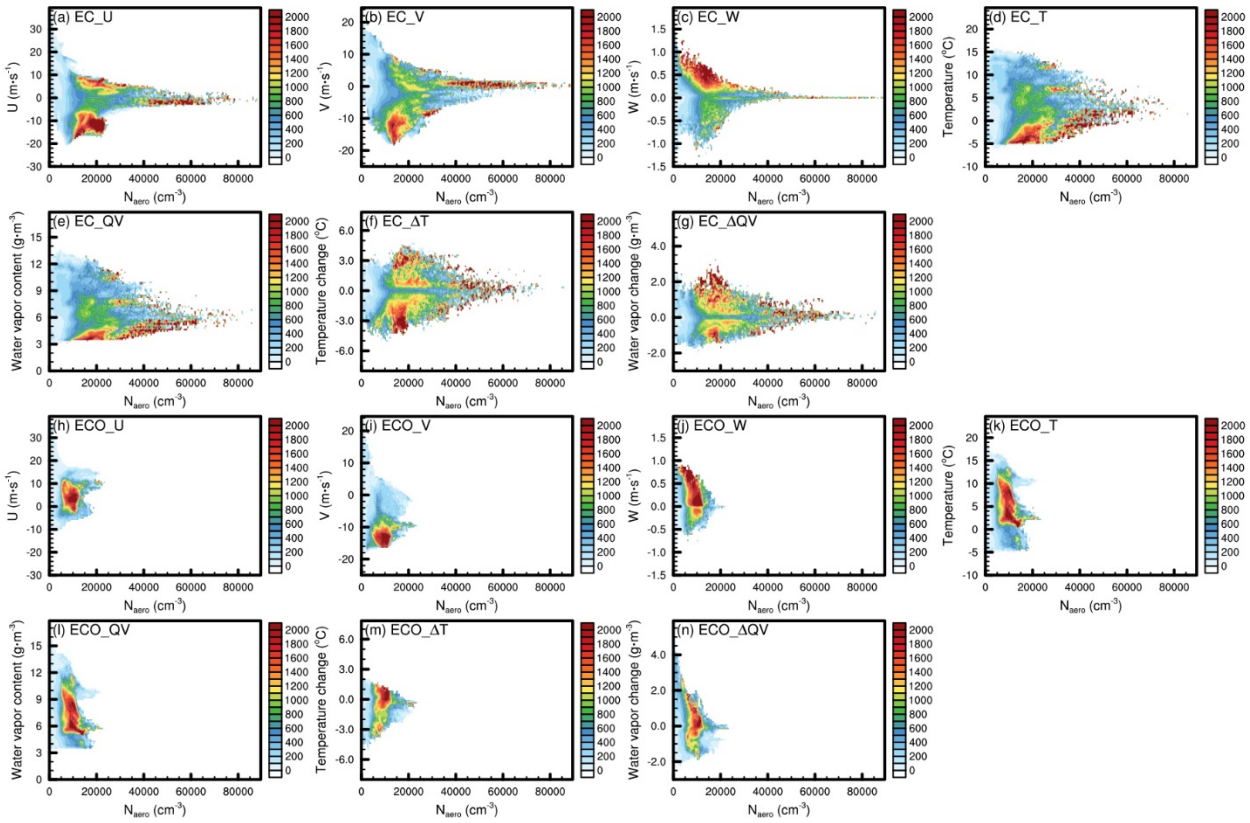

Figure RC2-2. Same as Fig. 11 of the revised manuscript but for N_d

16. Figure 10: use log for x-axis

Shown below, as before, using log for x-axis would make the figure overemphasize information about high values at low N_{aero}, which is not conducive to showing the overall variation, so we used the original coordinates.

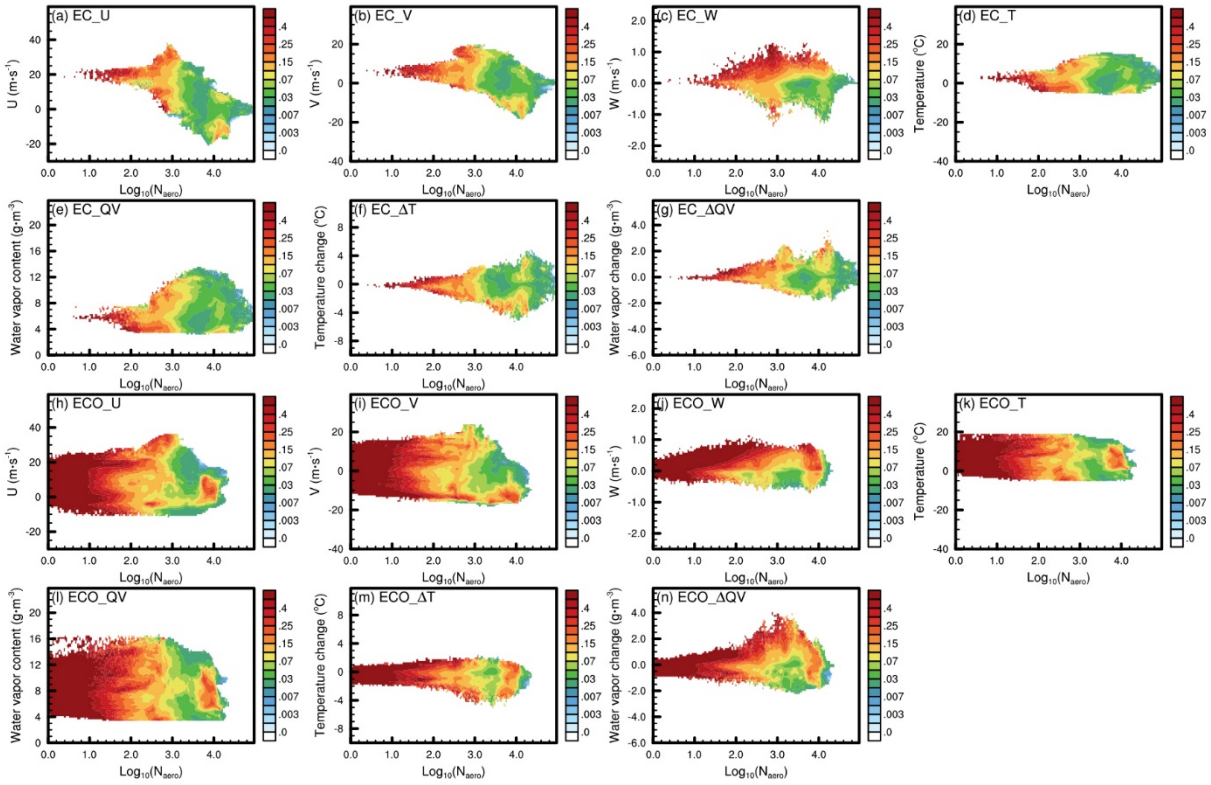

Figure RC2-3. Same as Fig. 11 of the revised manuscript, but using log for x-axis

17. Figure 10 caption use “water vapor variation”, but y-axis use “water vapor changes”. Please use consistent word.

    It should be "change", we revised the figure captions.

18. Line 382: did you use the exact 0? Or a very small threshold values?

    The original was exactly 0, but this led to too few samples of non-precipitating clouds and difficulty in clearly distinguishing the difference between precipitating and non-precipitating clouds, so we used new filtering criteria for precipitating (rainwater content above 1 mg·m-3 for each vertical layer and above 1 g·m-2 for column) and non-precipitating (rainwater content below 0.001 mg·m-3 for each vertical layer and below 0.001 g·m-2 for column) clouds in the revised manuscript.

19. Line 383-384: this phenomenon is not specific to precipitating clouds. The non-precipitating clouds also has similar trends.

    We re-analyzed it using more appropriate sampling and statistical methods (see response to comment 12 for details).

20. Line 384: influence -> net influence

    We've revised it.

21. The major problem with figure 11 and related text: data after a large Nd may have very small sample size. So I don't think it is valid to derive any conclusion using that portion of plots, say when Nd>16000 cm-3 for EC and >12000 cm-3 for ECO.

    We revised these texts by replacing them with statements such as "after N_d reaches its peak" and "the near-surface with high aerosol concentrations"…