Response to Referee #1 in Report #2

Dear Referee,

Thank you for your positive and constructive comments. We have addressed your comments and the corresponding replies are listed below.

With regards,

Naifu Shao, Chunsong Lu*, and co-authors.

1) Validation. I still find it hard to understand how the evaluation was performed. There are now additional explanations of the evaluations measures, like the Heidke skill score. But the crucial information regarding the parameters used for calculating this and other scores does not seem to be present. This is crucial.

Reply: Thank you for your valuable comments. The crucial information regarding the parameters used for calculating Heidke skill score is revised (Page 9, Lines 201-208): "Elements *a*–*d* are determined by the occurrence of fog at observation stations located in domain 03 and the closest model grids to those observations, as shown in Table 3. If fog events are both observed at stations and simulated at the closest model grids, we recognize those as "hits" and *a* in Eq.1 represents the total number of "hits" during the entire fog event. Similarly, *d* represents the number of "correct negatives" for the correct non-event simulations. On the other hand, if fog events are simulated but not observed, we recognize those as "false alarms" and *b* represents the total number of "false alarms" during the entire fog event. Conversely, *c* represents the total number of "misses", which indicates that fog events are observed but not simulated."

In addition to the Heidke skill score, information regarding the parameters used to calculate the other scores is given below.

The equations for root-mean-square error (RMSE) and mean bias (MB) are

$$\text{RMSE} = \sqrt{\sum_{i=1}^{n} \frac{(M_i - O_i)^2}{n}}, \tag{S1}$$

and

$$\text{MB} = \frac{1}{n}\sum_{i=1}^{n}(M_i - O_i), \tag{S2}$$

where M and O represent the results from simulation and observation; n is the total number of observation stations. They are added in the supplement. We also revised the main text (Page 39, Line 865): "The equations for RMSE and MB (Eq. S1-S2) are given in the supplement." The equations for the normalized mean bias (NMB), normalized mean error (NME), mean fractional bias (MFB), and mean fractional error (MFE) have already been given in the supplement (Eq. S3-S6). We have emphasized this information in the main text (Page 8, Line 186): "Eqs. S3–S6 in the supplement".

The paragraph starting at line 181 very vaguely introduces the evaluation, but (a) does not state explicitly which HIMAWARI product(s?) are being used

Reply: The Himawari product is level 2 full-disk cloud property data. We have added this information (Page 7, Line 154).

(b) what ground-based observations and of what parameter are being used

Reply: Ground-based observations refer to observations at meteorological stations. Observed visibility and relative humidity at those stations are used to evaluate fog distribution in Fig. 4. We have added the description (Page 8, Line191-193): "To identify observed fog at ground-based stations (the black circles in Fig. 4), we apply two criteria: visibility less than 1 km and relative humidity greater than 90% (Yan et al., 2020)."

(c) what time frames are covered

Reply: The time frames of Himawari products we used are 08:00 local standard time (LST) on 26 and 27 November 2018, respectively (Page 8, Lines 189-191).

(d) what resolutions are used

Reply: Spatial resolution of Himawari cloud product is 0.05°×0.05°. We have added this information (Page 7, Lines 159-160).

(e)what pre-processing steps, if any, were performed on the datasets

Reply: There are no pre-processing steps in using Himawari products.

(f) what are the references associated with these datasets

(g) what is known about product quality

Reply: We would like to reply to the two comments together. The references associated with these datasets are Bessho et al. (2016), Iwabuchi et al. (2018) and Yang et al. (2020). Himawari cloud products have been evaluated against the Moderate Resolution Imaging Spectroradiometer (MODIS) (Bessho et al., 2016; Letu et al., 2020) and cloud profiles from aircraft measurements (Zhao et al., 2020). Therefore, the quality of the Himawari cloud product is reliable. These information are added (Page 7, Lines 154-159).

The wording in the validation section is extremely vague. What is fog "magnitude"? (184), what is "generally consistent qualitatively"? (184). Please be specific.

Reply: We mean that the word "magnitude" refers to the value of fog optical depth, and the phrase "generally consistent qualitatively" indicates that the fog distribution and the value of fog optical depth show similarities between the simulation and observation. We have revised the sentence (Page 8, Lines 193-195): “Qualitatively, the value of fog optical depth and the fog spatial distribution in the simulation are roughly similar to those observed by the Himawari satellite and at ground-based stations."

2) Representativity. While the state of the art chapter states a problem with a very wide scope, the study itself is focused on one situation in one particular location. In lines 444 onwards the authors present arguments for general applicability of the study, which however I find unconvincing. For a generalization I deem it necessary to state the range of conditions for which you believe your insights to hold. E.g., are the findings of this study transferrable to other fog situations in the same location? Other locations? Where, what conditions? Please specify and substantiate.

Reply: Thank you for your valuable comments. We have revised the sentences (Page 20, Lines 469-473): "This study focuses on a two-day radiation fog event in the Yangtze River Delta, China, which has a large population. The conclusions are expected to be applicable to radiation fog events in this region and other regions with similar human activities. It would be interesting to see if similar conclusions can be found in other fog types (e.g., advection fog) in other regions (e.g., ocean)."

References

Bessho, K., Date, K., Hayashi, M., Ikeda, A., Imai, T., Inoue, H., Kumagai, Y., Miyakawa, T., Murata, H., and Ohno, T.: An introduction to Himawari-8/9—Japan's new-generation geostationary meteorological satellites, Journal of the Meteorological Society of Japan. Ser. II, 94, 151-183, https://doi.org/10.2151/jmsj.2016-009, 2016.

Iwabuchi, H., Putri, N. S., Saito, M., Tokoro, Y., Sekiguchi, M., Yang, P., and Baum, B. A.: Cloud property retrieval from multiband infrared measurements by Himawari-8, Journal of the Meteorological Society of Japan. Ser. II, https://doi.org/10.2151/jmsj.2018-001, 2018.

Letu, H., Yang, K., Nakajima, T. Y., Ishimoto, H., Nagao, T. M., Riedi, J., Baran, A. J., Ma, R., Wang, T., and Shang, H.: High-resolution retrieval of cloud microphysical properties and surface solar radiation using Himawari-8/AHI next-generation geostationary satellite, Remote Sens. Environ., 239, 111583, https://doi.org/10.1016/j.rse.2019.111583, 2020.

Yang, Y., Zhao, C., and Fan, H.: Spatiotemporal distributions of cloud properties over China based on Himawari-8 advanced Himawari imager data, Atmos. Res., 240, 104927, https://doi.org/10.1016/j.atmosres.2020.104927, 2020.

Zhao, L., Zhao, C., Wang, Y., Wang, Y., and Yang, Y.: Evaluation of cloud microphysical properties derived from MODIS and Himawari-8 using in situ aircraft measurements over the Southern Ocean, Earth Space Sci., 7, e2020EA001137, https://doi.org/10.1029/2020EA001137, 2020.

Response to Referee #2 in Report #1

Dear Referee,

Thank you for your positive and constructive comments. We have addressed your comments and the corresponding replies are listed below.

With regards,

Naifu Shao, Chunsong Lu*, and co-authors.

The authors have responded well to my previous comments and those of the other reviewer, and the manuscript is much improved. The third simulation is useful and the new title and the additional clarity around the aerosol-fog interactions are clear improvements. The use of optical depth in Figure 4 is helpful. The suggestion that aerosol-fog interactions in the first fog affect the second for are now more convincing.

Reply: Thank you for your valuable comments.

However, I did not find clear responses of the authors, or changes in the manuscript, to address the comments of the editor, which are also very important. Perhaps the authors did not yet have the opportunity to respond. Therefore I recommend the manuscript be returned for minor revisions in order for the authors to respond to these additional suggestions (mainly around effects of radiative heating and cooling, expanding on lines 430-437, and written English). Specific discussion of the dependence of heating and cooling rates on droplet concentration is still lacking, and generally the written English can still be improved, especially in the new text, in line with the editor's suggestions.

Reply: Yes, we did not yet have the opportunity to respond. We now address the editor's and your comments together. The editor requested a discussion of the results in Petters et al. (2012), Fig. 1, and also suggested referring to a paper by Prabhakaran et al. (2023)

for further discussion. We have analysed the long-wave cooling and short-wave heating in the fog layer (Fig. 9b), referring to Fig. 1 in Petters et al. (2012) and Fig. 3h in Prabhakaran et al. (2023) in the main text. We have added sentences (Page 14, Lines 335-339): "When LWP is less than 20 g m^{-2}, vertically integrated long-wave cooling and short-wave heating are stronger under polluted conditions than those under clean conditions (Fig. 9b). This is similar to results from Petters et al. (2012) and Prabhakaran et al. (2023). Because N_d shows a similar trend with LWP (Fig. S5), the dependence of heating and cooling rates on droplet concentration is consistent with the results based on LWP." We have also expanded the conclusion as you suggested (Page 20, Lines 457-459): "Radiative cooling and heating within the fog layer depend on LWP and N_d. When LWP in fog is less than 20 g m^{-2}, and higher aerosol loading enhances vertically integrated cooling and heating in optically thin fog."

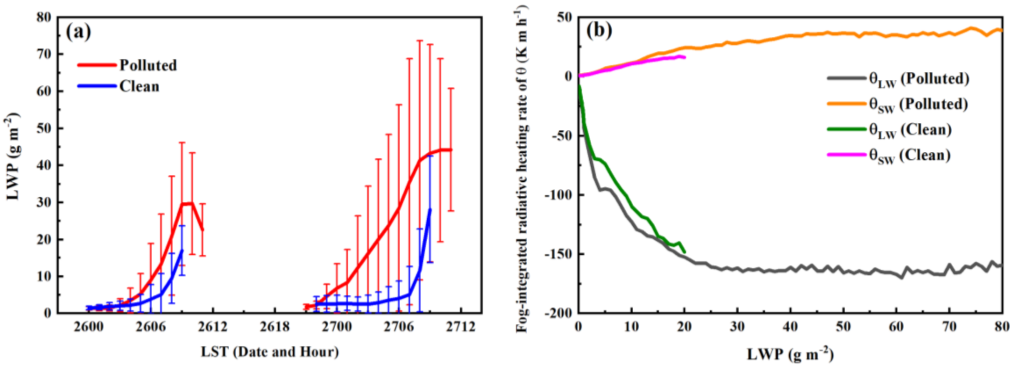

Figure 9. (a) The timeseries of liquid water path (LWP) under polluted and clean conditions. The length of the bar represents standard deviation. (b) Dependence of fog-integrated radiative cooling or heating with LWP under polluted and clean conditions. θ_{LW} and θ_{SW} represent vertically integrated heating rate of potential temperature (θ) within the fog layer due to long-wave radiation and short-wave radiation, respectively. Time '2512' indicates 12:00 local standard time (LST) (LST = Universal Time Coordinated + 8 h) on 25 November 2018. The other time expressions follow the same logic.

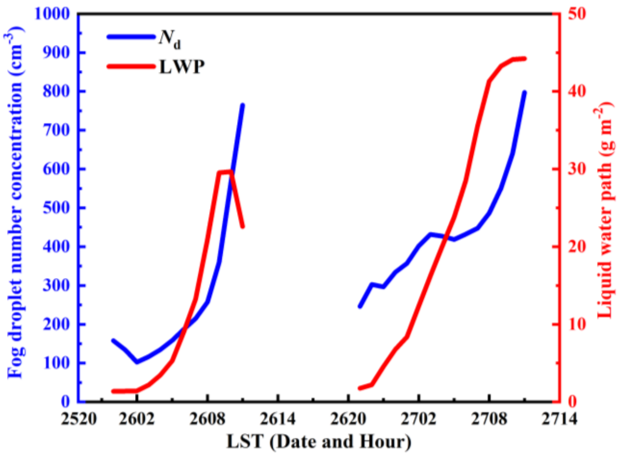

Figure S5. The timeseries of average liquid water path (LWP) in domain 03 under polluted and clean conditions (the red line: polluted conditions, the blue line: clean conditions). Time '2520' indicates 20:00 local standard time (LST) (LST = Universal Time Coordinated + 8 h) on 25 November 2018. The other time expressions follow the same logic.

The written English has been improved. Wiley Editing Services (https://editingse rvices. wiley.cn/) provides thorough English language editing.

More specific editorial comments:

(a) Abstract lines 17-18, 22,37: "PBL"->"the PBL", as is done correctly at line 75

Reply: We have added "the" as you suggested (Page 1-2, Lines 17-18, 22, 38).

(b) Sentence at line 163 needs improving.

Reply: We have revised the sentence (Page 7, Lines 170-171): "According to Fog1 dissipation time, clean conditions change to polluted conditions at 12:00 LST on 26 November 2018."

(c) L305 rendering->"leading to"

Reply: We have revised the phrase as you suggested (Page 14, Lines 320).

(d) The new additions starting at line 444 are repetitive, sound too defensive, and are too vague. I suggest this text be removed.

Reply: We have revised the sentences to show representativity as another referee suggested (Page 20, Lines 469-473): “This study focuses on a two-day radiation fog event in the Yangtze River Delta, China, which has a large population. The conclusions are expected to be applicable to radiation fog events in this region and other regions with similar human activities. It would be interesting to see if similar conclusions can be found in other fog types (e.g., advection fog) in other regions (e.g., ocean).”

References

Petters, J. L., Harrington, J. Y., and Clothiaux, E. E.: Radiative–dynamical feedbacks in low liquid water path stratiform clouds, J. Atmos. Sci., 69, 1498-1512, https://doi.org/10.1175/JAS-D-11-0169.1, 2012.

Prabhakaran, P., Hoffmann, F., and Feingold, G.: Evaluation of Pulse Aerosol Forcing on Marine Stratocumulus Clouds in the Context of Marine Cloud Brightening, J. Atmos. Sci., 80, 1585-1604, https://doi.org/10.1175/JAS-D-22-0207.1, 2023.

Dear Prof. Graham Feingold,

Thank you for your positive and constructive comments. We have addressed all the comments and the corresponding replies are listed below. Furthermore, the Wiley Editing Services (https://editingservices.wiley.cn/) provides thorough English language editing.

With regards,

Naifu Shao, Chunsong Lu*, and co-authors

Response to Comments on July 3:

Regarding Reviewer 1: As noted, the reviewer (and I) would like to see responses to all my (the Editor's) comments in general, and particularly regarding the effect of aerosol on LW and SW in optically thin fog and the quantification of LWP. Here I would like to see discussion of results in Petters et al. (2012), Fig, 1. You will see that for clouds with LWP < 20 g/m2, high aerosol concentration increases radiative cooling for the same LWP. In addition, in the SW, high aerosol concentration increases absorption (at the same LWP). You can also see further discussion in a paper by Prabhakaran et al. (2023) DOI 10.1175/JAS-D-22-0207.1, Pg 1590. Full engagement with ideas in these papers will enhance the impact of your work. My request for quantification of LWP becomes clear when you consider aerosol effects on cooling/heating at low LWP (Petters, Fig. 1).

Reply: We have analysed the quantification of LWP, especially the effect of aerosol on long-wave and short-wave radiation in optically thin fog (Fig. 9 and Fig. S5). We have added related description (Page 14, Lines 332-339): "As shown in Fig. 9a, LWP is larger under polluted conditions than that under clean conditions, particularly for Fog2. The average LWP in Fog1 and Fog2 under polluted conditions are 11.6 and 24.3 g m^{-2}, respectively. When LWP is less than 20 g m^{-2}, vertically integrated long-wave cooling and short-wave heating are stronger under polluted conditions than those under clean conditions (Fig. 9b). This is similar to the results from Petters et al. (2012) and

Prabhakaran et al. (2023). Because N_d shows a similar trend with LWP (Fig. S5), the dependence of heating and cooling rates on droplet concentration is consistent with the results based on LWP.” We have also expanded the conclusion according to reviewer’s suggestion (Page 20, Lines 457-459): “Radiative cooling and heating within the fog layer depend on LWP and N_d. When LWP in fog is less than 20 g m^{-2}, higher aerosol loading enhances vertically integrated cooling and heating in optically thin fog.”

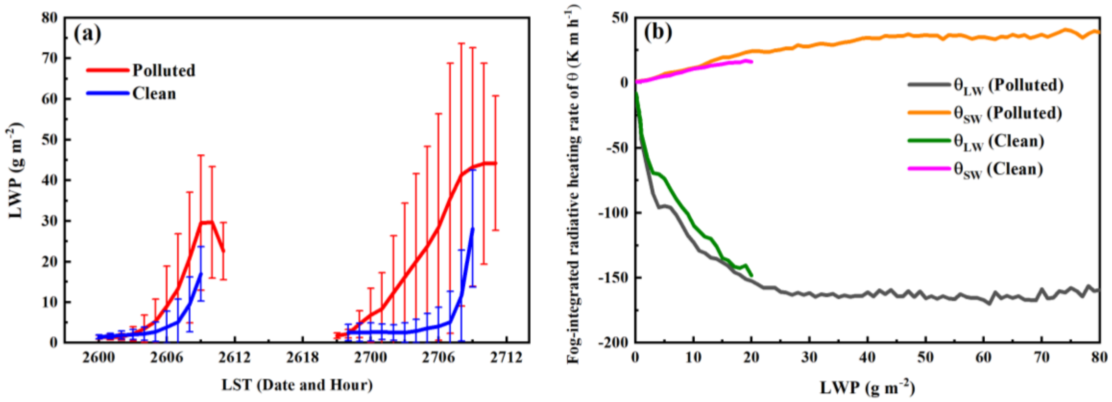

Figure 9. (a) The timeseries of liquid water path (LWP) under polluted and clean conditions. The length of the bar represents standard deviation. (b) Dependence of fog-integrated radiative cooling or heating with LWP under polluted and clean conditions. θ_{LW} and θ_{SW} represent vertically integrated heating rate of potential temperature (θ) within the fog layer due to long-wave radiation and short-wave radiation, respectively. Time ‘2512’ indicates 12:00 local standard time (LST) (LST = Universal Time Coordinated + 8 h) on 25 November 2018. The other time expressions follow the same logic.

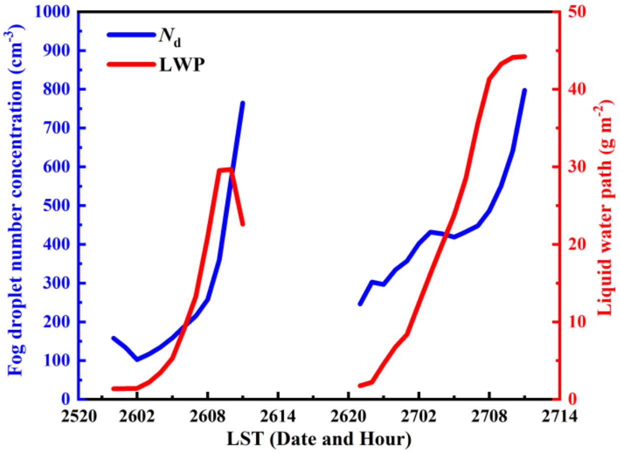

Figure S5. The timeseries of average liquid water path (LWP) in domain 03 under polluted and clean conditions (the red line: polluted conditions, the blue line: clean conditions). Time '2520' indicates 20:00 local standard time (LST) (LST = Universal Time Coordinated + 8 h) on 25 November 2018. The other time expressions follow the same logic.

Regarding Reviewer 2: Please address both points ('Evaluation' and Representativity), although don't use the word 'validation' since one cannot validate a model - one can only test or evaluate a model, which is in fact the spirit of the reviewer's comment.

(1) Evaluation

Reply: We have revised 'validation' to 'evaluation' (Page 7, Line153; Page 8, Line174). We have revised the sentences about fog distribution evaluation (Page 8, Lines 191-195): "To identify observed fog at ground-based stations (the black circles in Fig. 4), we apply two criteria: visibility less than 1 km and relative humidity greater than 90% (Yan et al., 2020). Qualitatively, the value of fog optical depth and the fog spatial distribution in the simulation are roughly similar to those observed by the Himawari satellite and at ground-based stations."

We have also revised the sentences about the calculation of the Heidke skill score (HSS) (Page 9, Lines 201-208): "Elements *a*–*d* are determined by the occurrence of fog at observation stations located in domain 03 and the closest model grids to those observations, as shown in Table 3. If fog events are both observed at stations and simulated at the closest model grids, we recognize those as "hits" and *a* in Eq.1 represents the total number of "hits" during the entire fog event. Similarly, *d* represents the number of "correct negatives" for the correct non-event simulations. On the other hand, if fog events are simulated but not observed, we recognize those as "false alarms" and *b* represents the total number of "false alarms" during the entire fog event. Conversely, *c* represents the total number of "misses", which indicates that fog events are observed but not simulated."

(2) Representativity

We have revised the sentences (Page 20, Lines 469-473): "This study focuses on a two-day radiation fog event in the Yangtze River Delta, China, which has a large population. The conclusions are expected to be applicable to radiation fog events in this region and other regions with similar human activities. It would be interesting to see if similar conclusions can be found in other fog types (e.g., advection fog) in other regions (e.g., ocean)."

References

Petters, J. L., Harrington, J. Y., and Clothiaux, E. E.: Radiative–dynamical feedbacks in low liquid water path stratiform clouds, J. Atmos. Sci., 69, 1498-1512, https://doi.org/10.1175/JAS-D-11-0169.1, 2012.

Prabhakaran, P., Hoffmann, F., and Feingold, G.: Evaluation of Pulse Aerosol Forcing on Marine Stratocumulus Clouds in the Context of Marine Cloud Brightening, J. Atmos. Sci., 80, 1585-1604, https://doi.org/10.1175/JAS-D-22-0207.1, 2023.

Response to Comments on April 29:

Comments:

I note that nowhere in your manuscript do you discuss the role of shortwave radiation and its affect on fog lifetime. This is an important part of the discussion. With increasing liquid water path (LWP) and increasing drop concentration, SW heating increases. There are also longwave aerosol-related effects: at low LWP (< ~ 25 g/m2); an increase in drop concentration will increase radiative cooling. I also note that there is no quantitative information on LWP, only its response (e.g., Table 4). This is really important information if one is to understand the radiation interactions.

Reply: Thank you for your suggestion. The detailed response to this comment is given in the "Response to Comments on July 3". Furthermore, we add the following discussion (Page 12-13, Lines 288-292): "Compared with clean conditions, the larger τ_t (mainly due to larger τ_c) and delayed fog dissipation in polluted conditions reduce short-wave radiation reaching the ground (from −46 W m^{-2} to −121 W m^{-2}) during the Fog1 dissipation time. This leads to a decrease in T_{2m} (from −0.2 °C to −1 °C) and PBLH (from −42 m to −118 m), which further prolongs fog duration (Fig. 7)."

A linguistic revision:

1) What are "conducive PBL conditions"? I think you mean "conducive to fog formation". Please make changes throughout.

Reply: Yes, we mean "conducive to fog formation". We have modified the phrase to be: "PBL conditions conducive to Fog2 formation". We have revised the entire article.

2) change 'scenario' to 'event'

Reply: All 'scenario' in our article have been revised to 'event'.

3) remove all "the" before "EXPn"

Reply: All "the" before "EXPn" has been removed.

4) dissipation time (not dissipate time)

Reply: All “dissipate time” has been revised to “dissipation time”.

5) Fog 1 occurs under clean conditions (not Fog1 161 is under the clean condition)

Reply: We have revised “is under the clean conditions” to “occurs under clean conditions”.

6) “under clean and polluted conditions” (remove ‘the’)

Reply: It has been removed in our article.

7) What is ‘more remarkable AFI’? Do you mean stronger AFI? Please be clear.

Reply: Yes, ‘more remarkable AFI’ means stronger AFI. We have revised it in our article.

8) “can enhance cooling” do you mean “enhances cooling”? Please use clear causal language if that’s what you mean. There are many instances "can affect", "can indicate".

Reply: Yes, we mean that “enhances cooling”. We have revised all the related phrases.

9) You have a tendency to create new acronyms like AFI, FOD, TOD, which makes the manuscript less readable to the broader audience. The use of symbols significantly alleviates this problem (e.g., \tau_f, \tau_t). Even AFI might be unnecessary given the familiar ACI. (You could simply point out that ACI in fog has its own particular questions). Also, why N_f when N_d (drop concentration) or N_c (cloud droplet concetration) are widely used. And \tau_c would be better than \tau_f. As it is you use other standard cloud-related acronyms such as LWP, LWC.

Reply: Thank you for your suggestions to make the manuscript more readable to the broader audience. We have revised the acronyms and symbols accordingly. AFI, FOD, TOD and N_f have been revised to ACI, τ_c, τ_t and N_d, respectively.