Dear Editors and Reviewers:

Thank you very much for your careful review and valuable suggestions with regard to our manuscript "Impacts of synoptic forcing and cloud inhibition on aerosol radiative effect and boundary layer structure during winter pollution in Sichuan Basin, China" (Manuscript Number: EGUSPHERE-2023-1806). Those comments are helpful for revising and improving our paper. We have studied these comments carefully and made modifications in the manuscript according the reviewers' comments. The responses to the reviewers' comments are listed as follows.

This study classified the synoptic patterns influencing the SCB and revealed the impacts of meteorological factors on $PM_{2.5}$ concentrations. Using WRF-CHEM simulations, the authors explored the influence of synoptic conditions and cloud radiation interaction (CRI) on aerosol radiation interaction (ARI) and PBL structures during a high $PM_{2.5}$ event. The findings contribute to the understanding of CRI, ARI, and the PBL interactions in regions with wet and cloudy weather. This paper is rightfully within the scope of ACP. However, certain sections require further clarification to enhance the paper's clarity. Please find my detailed comments below for your consideration.

Response: We are appreciated with your valuable comments, and have carefully considered the issues below to improve this research.

1. Line 90-91: What does the unit 'h' in cloud cover stand for?

Response: We are sorry for the clerical error, and have rephrased this sentence as: The mean annual relative humidity in the SCB is around 75%, with cloud fraction exceeding 80%, and an average of 1200 hours of sunshine per year. Please see Line 98-100 of the revised manuscript.

2. Line 136: Provide the full name of "ECMWF".

Response: Thanks for this careful comment. "ECMWF" is short for "European Centre for Medium-Range Weather Forecasts". We have added the full name when first mentioned it in Line 186 of the revised manuscript.

3. Line 139: What criteria were used to select these four representative cities?

Response: Thank you for this comment. We selected these four representative cities in the western,

southern, northwestern, and eastern regions of the basin, to capture diverse pollution and meteorological conditions within the SCB. These cities are chosen to represent the most polluted regions (Zhao et al., 2018; Lu et al., 2022), as well as typical basin and mountainous cities. Furthermore, there are only four sounding stations in the SCB available: Wenjiang (CD), YB, DZ, and Shapingba (CQ). These stations in the four cities can provide valuable vertical and surface meteorological observations, as well as pollution data, contributing comprehensive dataset used in this study. We have added the reason why we choose these four cities in Line 178-185 of the revised manuscript.

4. Line 169: Are chemical initial and boundary conditions considered in this study?

Response: Thanks for the comment. We used the default chemical initial and boundary conditions. However, we made specific adjustments to the anthropogenic emissions in this study. To address the empirically overestimated $PM_{2.5}$ emissions by the MEIC in the SCB (Zhan et al., 2023), the ensemble square root Kalman filter were implemented on the $PM_{2.5}$ emission during simulation (Wu et al., 2018; Lu et al., 2021). Additionally, the first 48 hours of the simulation were designated as the model spin-up period. As a result, the simulation results for $PM_{2.5}$ concentrations are acceptable in this study. Please see Line 223-226 and Line 245-247 in the revised manuscript for details.

5. Line 173: Change "the impact of CRI inhibition on ARI and ARI" to "the impact of CRI inhibition on ARI".

Response: We are thankful for your kind remind and have followed the suggestion in Line 234 of the revised manuscript.

6. Line 174-176: It is more logical to state that you utilized this MEIC emission inventory because it aligns closely with the study period.

Response: Thanks for the comment. We have rephrased this sentence in Line 236-239 of the revised manuscript to make it more logically.

7. Line 178: Why is the year 2017 the key year about current $PM_{2.5}$ pollution?

Response: We are sorry for not clarify it clearly. The Chinese government announced clean-air

action in the year of 2013, aiming to reduce $PM_{2.5}$ concentrations in the next 5 year. Specifically, the year of 2017 was identified as a key year for assessing $PM_{2.5}$ pollution in China, as significant practical actions were implemented during the period. We have added some more description about this in Line 236-238 of the revised manuscript.

8. Line 181-186: Please provide a clearer explanation of EXP3. Why do EXP2 and EXP3 represent the influences of ARI without CRI inhibition?

Response: We apologize for any confusion. In EXP3, both ARI and CRI were shut down, while in EXP2, only CRI was omitted. By comparing the results of EXP2 and EXP3, we can isolate and assess the specific influence of ARI without the presence of CRI inhibition. In order to clarify the experimental setup, we have added Table 2 in the revised manuscript to provide a clear overview of the four numerical simulation experiments.

9. Line 200-202: Are there any observations supporting this point?

Response: We are appreciated with this rigorous comment. We have added Figure S1 in the revised supplement, and some further analysis and discussion regarding this point are also provided. Please see Line 262-264 of the revised manuscript and Figure S1 in the supplement.

10. Line 207-209: What does "influencing all four cities" refer to?

Response: We feel sorry for the confused description and have rephrased the description as "During this month, two severe $PM_{2.5}$ pollution episodes occurred: one from January 1 to 7 and another from January 24 to 31 in 2017. These pollution episodes had a significant impact on air quality in all four cities. The highest daily $PM_{2.5}$ concentrations recorded during these episodes were 291.17 $\mu g/m^3$ in CD and 276.21 $\mu g/m^3$ in YB.". Please see Line 274-277 of the revised manuscript.

11. Figure 4: It would be better to plot the outline of the SCB in this figure to enhance readability.

Response: We appreciate for your kind suggestion and have added the outline of the SCB in the figures. Please see Figure 3, 7 and 8 in the revised manuscript.

12. Line 245: Ensure all data is presented with the same number of decimal places.

Response: Thanks for this careful comment. We have unified the number of decimal places in Line 317-320 of the revised manuscript.

13. Figure 5c: The unit should be “μg/m3”.

Response: We feel sorry for the mistake and have made modification. Please see Figure 4 of the revised manuscript.

14. Line 267: Clarify which direction of airflow controls the upper-layer of the basin.

Response: Thanks for your kind remind. It should be “when the southerly airflow controlled the upper-layer of the basin”. We have made modification in Line 355 of the revised manuscript.

15. Line 269-279: Support your explanation with relevant figures, data, or existing research results.

Response: Thank you for your comment. The issue can be explained by our previous study (Lu et al., 2022). This study indicated that a “warm lid” appeared when the southerly airflow controlled the SCB around 850 hPa, suppressing the vertical exchange of pollutants within the basin. Forced by the surrounding high mountains, pollutants can fully mixed and chemical reactions conduct through secondary circulation in the basin. When the northerly airflow began to dominate the SCB, the “warm lid” was disrupted, leading to dispersion of pollutants through vertical transport. The evolution of 850 hPa synoptic forcing and vertical meteorological conditions (Figure 2 and 6) aligns with the study of Lu et al (2022). Therefore, there are also similar pollution change mechanisms. Actually, Figure 12 and the relate descriptions also can support the similarities in mechanisms between the two studies. Please see the descriptions in Line 357-370 and Figure 12 of the revised manuscript.

16. Line 376: What do the other two regions represent? You mentioned four cities in your previous results.

Response: We are sorry for the neglect. The southern SCB (YB) and the western SCB (CD) share similarities in terms of topography, but quite different with the eastern SCB (CQ). A strong ARI was primarily observed in CQ, as well as in the western and southern SCB, despite CQ

experiencing lower pollutant concentrations compared to the other two regions (Figs. S4 and 7). Without considering the CRI, the ARI in the western and southern SCB would be much more pronounced than that in CQ. This is due to obviously higher cloud cover under Patterns 2 and 5 in CD and YB compared to CQ (Figure 5). As for the northwestern SCB (DZ), we have added some relate analysis. The ARI in DZ is lower than in the other three regions. When the CRI is not considered, the ARI in DZ is higher than in CQ but lower than in CD and YB. This is because DZ has lower aerosol concentrations compared to CD and YB, but under the influence of weather patterns 2 and 5, DZ exhibits higher cloud cover than CQ. Please see Line 469-482 of the revised manuscript for the modification.

17. Line 406-408: The difference in CRI between Pattern 2 and Pattern 5 may also contribute to varied surface cooling.

Response: Thanks for the valuable comment. We admit that the stronger surface cooling during Pattern 5 may also due to the differences in CRI. To provide a more visual representation of the comparison, we have added Figure 12. The figure shows the $PM_{2.5}$ concentration under Pattern 5 was higher than Pattern 2 throughout the atmospheric column, indicating stronger aerosol radiative forcing and a more significant impact on the boundary layer structure and surface cooling under Pattern 5. Please see Figure 12 and Line 509-511 of the revised manuscript.

Sincerely,

Authors