Dear Reviewer:

Thank you for careful comments. These comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied the comments carefully and have made corrections which we hope meet with approval. The Reviewer's comments are in blue and our responses are in black. Revised portion are marked in red in the marked-up manuscript. The main corrections in the paper and the point-to-point responses are as following:

Response to Reviewer #2:

Main comments:

1). Model Configuration and Experimental Design: The authors claim that the difference between the NO-ACIsub and ACIsub runs represents the impact of subgrid-scale ACI in the first set of experiments. However, the control run (NO-ACIsub) uses the regular KF cumulus parameterization without microphysical processes in convection, while the ACIsub run incorporates both subgrid-scale microphysics and subgrid-scale aerosol-cloud interactions. In the title, abstract, results analysis, and conclusion, the authors attribute the differences between the ACIsub and NO-ACIsub runs solely to subgrid-scale ACI. However, some of the significant differences could be due to the subgrid-scale microphysics. This could mislead readers into attributing all the differences to subgrid-scale aerosol-cloud interactions. The authors should reconsider the experimental design to more clearly distinguish the effects of subgrid-scale ACI.

Response: Accept. We have reworked the description of the first set of experiments design to more clearly distinguish between the model development (coupling subgrid-scale cloud microphysics and radiation feedback) and the subgrid-scale ACI effects throughout the revised manuscript. The detailed modifications are described below:

Throughout the manuscript, the names of the first set of experiments are modified. The NO-ACI_{sub} experiment is renamed the CONTROL experiment to represent the model runs without subgrid-scale cloud microphysics and cloud radiation feedback. The ACI_{sub} experiment is renamed the CU-MP-RA experiment to represent the model runs with subgrid-scale cloud microphysics and cloud radiation feedback.

In the **Abstract**, the original contents have been modified as following:

Aerosol-cloud interaction (ACI) significantly influences global and regional weather and is a critical focus in numerical weather prediction (NWP), but subgrid-scale ACI effects are often overlooked. Here, subgrid-scale ACI mechanism is implemented by explicitly treating cloud microphysics in KFeta convective scheme with real-time size-resolved hygroscopic aerosol activation, and introducing subgrid-scale cloud radiation feedback in an atmospheric chemistry model CMA_Meso5.1/CUACE. Focus on summer over central and eastern China, the performance evaluation shows that this developed model with subgrid-scale cloud microphysics and radiation feedback refines cloud representation even in some grid-scale unsaturated areas and subsequently leads to attenuated surface downward shortwave radiation (~18.5 W m^{-2}) more realistic. The increased cloud radiative forcing results in lower temperature (~0.35°C) and higher relative humidity (~2.5%) at 2 m with regional mean bias (MB) decreasing by ~40% and ~18.1%. Temperature vertical structure and relative humidity below ~900 hPa are improved accordingly due to cooling and humidifying. The underestamated precipitation is enhanced, especially at grid-scale, thus reducing regional MB by ~34.4% (~1.1 mm). The performance differences between various subregions are related to convective conditions and model local errors. Additionally, compared to simulations with anthropogenic emissions turned off, subgrid-scale actual aerosol inhibits cumulative precipitation during a typical heavy rainfall event by ~4.6 mm, aligning it with observations, associated with lower autoconversion at subgrid-scale and less available water vapor for grid-scale condensation, suggesting competitions between subgrid- and grid-scale cloud. This study contributes to the understanding of the impact of subgrid-scale ACI on NWP.

In the **Introduction**, we have redefined the objective and research contents of this study in lines 97-107 in the revised manuscript.

In the **Model configurations and experimental design,** we have rewrote the descriptions of multiple sensitivity experiment in lines and Table 3 in the revised manuscript.

Table 3: Descriptions of multiple sensitivity experiments.

Experiment	Description
CONTROL	Model runs without subgrid-scale cloud microphysics and cloud radiation feedback
CU-MP-RA	Same as CONTROL, but with subgrid-scale cloud microphysics and cloud radiation feedback
ACI_{sub}-DC	Same as CU-MP-RA, but for a deep convective process and fixing the cloud droplets number concentration in the Thompson cloud microphysics scheme as 300 cm^{-3}
$CACI_{sub}$-DC	Same as ACI_{sub}-DC, but turning off MEIC anthropogenic emissions

In the **Results and discussions**, we have reworked the contents about performance evaluation for the first set of experiments, especially in Section 5.2, where we have revised the section title to “Performance evaluation of predicted meteorological factors”, and deleted the description of subgrid-scale ACI in the discussions.

In the **Conclusions**, we have revised the reasons for the changed performance of the model results and added future perspectives for distinguishing the differences between subgrid-scale cloud microphysics and radiation feedback effects on meteorological prediction in lines 651-654 in the revised manuscript.

2). Contradictory Model Configuration: In line 120, the authors mention that sand/dust (SD) is available in the CUACE model. However, in lines 155-156, they state, “The current scheme does not include real-time ice nucleation because dust is not available in the CUACE model.” Following this, the authors apply an empirical formula for constant ice nucleation (IN). This contradictory description of the model configuration could confuse readers and should be clarified.

Response: Revised. Thank you for the reminder. In fact, in the current model, only road dust is available and calculated in real time, while sand dust from natural sources that can act as effective ice nuclei are not available. Therefore, we clarify this in lines 155 in the revised manuscript.

3). The ACIsub run results in more total precipitation and a higher CLWP. There

should be some compensating reduction in vapor at certain levels of the troposphere in the ACIsub run. However, the ACIsub simulation also shows increased vapor moisture at each vertical layer of the troposphere (Fig. 9f). It is concerning that some hydrological processes might be double-counted, or there may also be significant differences in ice-phase hydrometeors. This should be discussed in the manuscript.

Response: Revised. According to your suggestions, we have added a discussion of the more total precipitation and higher CLWP accompanied by increased relative humidity and changed water vapor in the CU_MP_RA experiment, as well as giving ice-phase and liquid-phase hydrometeors changes in lines 513-518 in the revised manuscript, and a description of the calculations of hydrometeors processes for the cumulus convection scheme and the cloud microphysics scheme in lines 199-201 in the revised manuscript. The changes in relative humidity (RH) depend on temperature and water vapor content. As shown in Figure 9 and Figure 8, it can be seen that the RH increases in each vertical layer of the troposphere, which has a clear correspondence with the decrease in temperature. The increase in RH is more related to the decrease in temperature.

For water vapor, Figure S3 shows the comparasion of vertical profiles of vapor moisture mixing ratio between the CONTROL and CU_MP_RA experiment. It can be seen that the water vapor mixing ratio increases slightly below ~400 hPa and decreases a little above ~400 hPa. The increase in water vapor is primarily associated with the redistribution of water vapor due to the incorporation of cloud microphysics processes in the Kfeta convection scheme, as the original scheme tends to convert excessive condensed water into convective precipitation (Song and Zhang, 2011). Similar increases in water vapor accompanied by increases in precipitation can be also found in the study of Song and Zhang (2011).

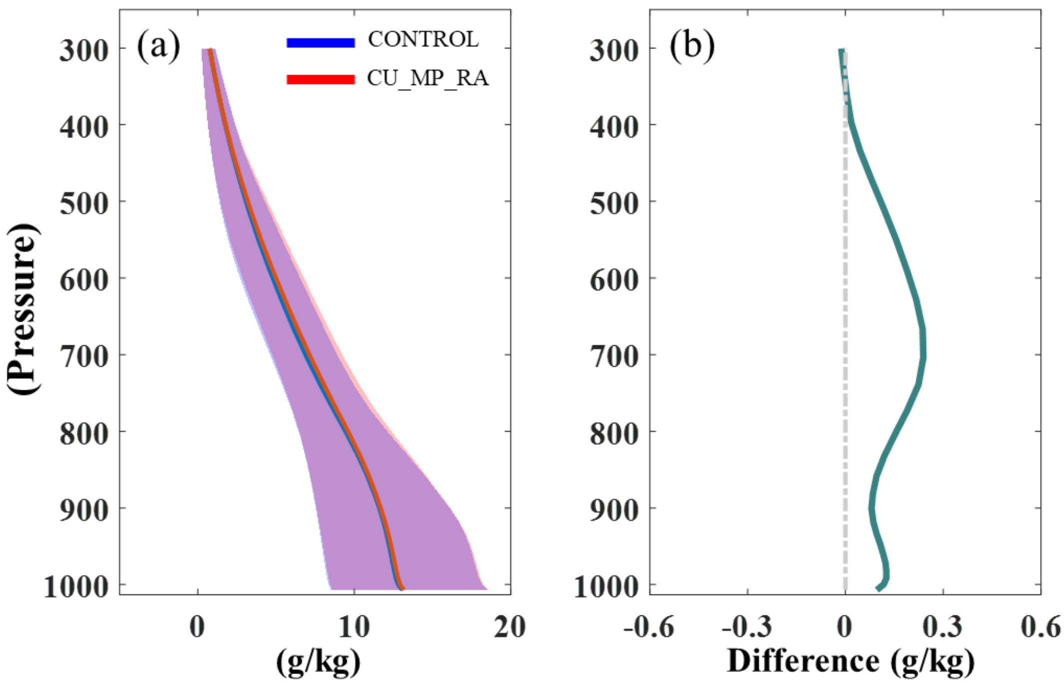

Figure S3: (a) The vertical profiles of vapor moisture mixing ratio in the Control and CU_MP_RA experiment. (b) The diffence of vertical vapor moisture mixing ratio between the Control and CU_MP_RA experiment. In the (a), the shadings are the spread of vapor moisture mixing ratio in six regions, and the solid lines are their average results.

For cloud water and cloud ice content, Figure S4 shows changes in grid-scale cloud water and ice mixing ratio. The increase in total precipitation is primarily attributed to the enhancement of grid-scale precipitation. The grid-scale cloud water mixing ratio increases between ~800 hPa and ~400 hPa, while the cloud ice content also increases above approximately 500 hPa, which may be associated with enhanced convective detrainment. The increase in grid-scale precipitation is linked to the rise in both ice-phase and liquid-phase hydrometeors at grid-scale, and a detailed analysis of precipitation sources and sinks requires further discussions.

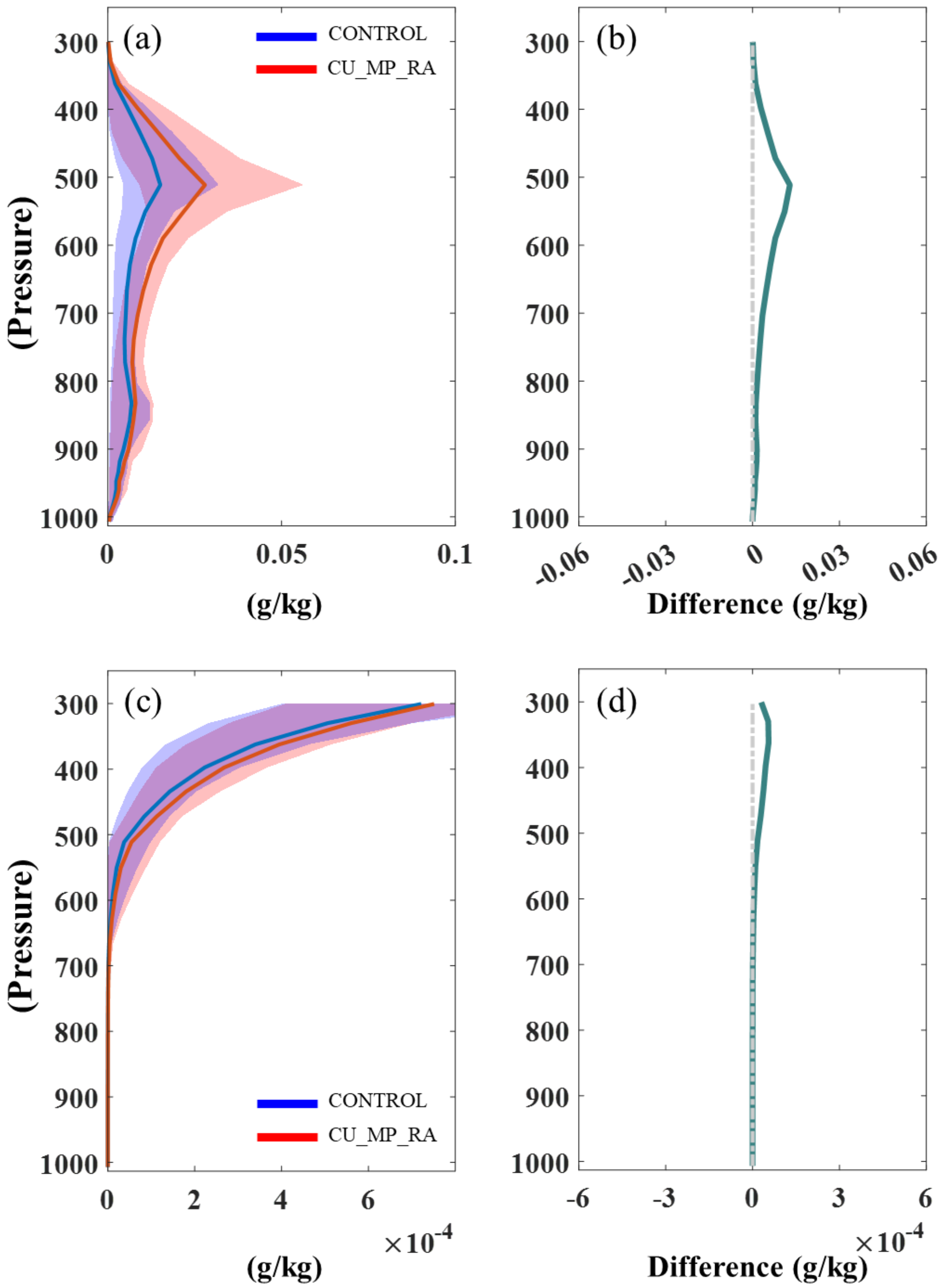

Figure S4: Same with Figure S1, but for cloud water (a and b) and ice (c and d) mixing ratio at grid-scale.

The calculations of hydromorphic processes in the cumulus convection scheme and the cloud microphysics scheme are described more detailed. We have examined in detail the calculations of hydrometeors processes in both schemes, and there is no double-counted. In the cloud microphysics scheme, we do not change the original calculation process and did not include the information of sub-grid scale clouds, and the grid-scale hydrometeors are calculated separately. In the cumulus convection scheme, the SZ2011 scheme is directly coupled into the KFeta scheme through the one-to-one correspondence of the specific values of cloud-water mixing ratio, cloud-ice mixing ratio, precipitation production rate and snow production rate, and the subgrid-scale hydrometeors are only fed back to influence the grid-scale hydrometeors only through the detrainment and entrainment processes.

4). The authors attribute the increased total precipitation in the ACIsub run to "Subgrid-scale ACI further enhances precipitation, especially at grid-scale." However, the results of large-scale and convective precipitation are not shown in section 5.2 of the manuscript. The partition of resolved and unresolved precipitation should be provided, at least in the supplementary material, to help readers better understand the precipitation physics in this study.

Response: Revised. We have added the Figure S2 in the Supplement, which shows the spatial distribution of grid-scale and subgrid-scale precipitation from CONTROL, the CU-MP-RA experiment, and the difference between the CU-MP-RA and CONTROL experiment. The increase in total precipitation is mainly caused by the increase in grid-scale precipitation, which is likely related to convective detrainment of cloud ice (Song and Zhang, 2011).

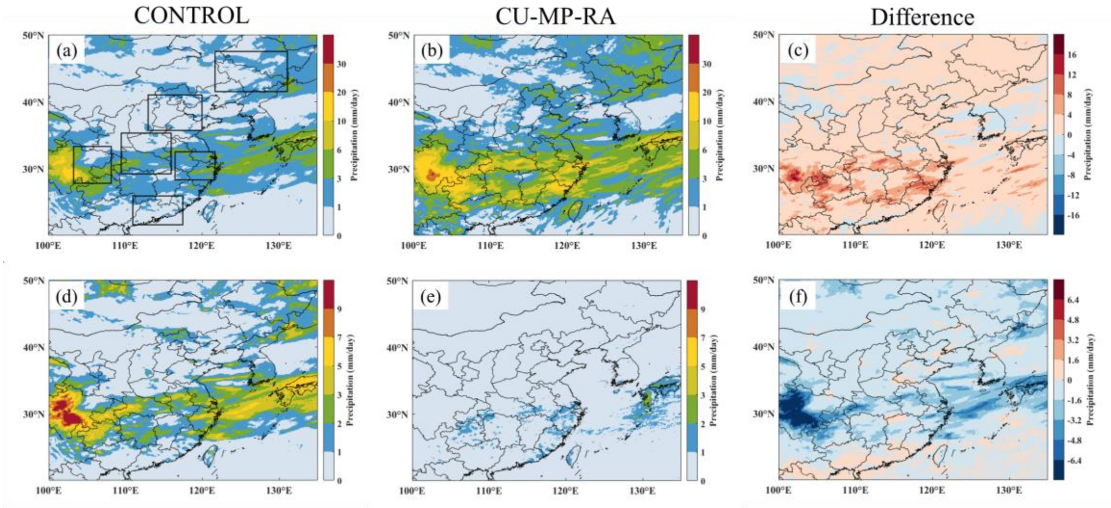

Figure S2. The spatial distribution of grid-scale (a-c) and subgrid-scale (d-f) precipitation from the CONTROL (left column), the CU-MP-RA experiment (middle column), and the difference between the CU-MP-RA and CONTROL experiment (right column).

5). The ACIsub run shows stronger relative humidity throughout the vertical atmosphere compared to the NO-ACIsub run (Fig. 9). Additionally, there is a notable increase in CLWP in the ACIsub run (Fig. 5f) compared to the NO-ACIsub run (Fig. 5e). However, the difference in cloud fraction between the ACIsub and NO-ACIsub runs is not significant. The further analysis of high, middle, and low clouds might help.

Response: Accept. We have added Figure S1 in the Supplement, which shows the spatial distribution of high, middle, and low cloud fraction from the CONTROL and CU-MP-RA experiment, and further analyze the changes in cloud fraction with higher relative humidity and CLWP in lines 345-347 in the revised manuscript.

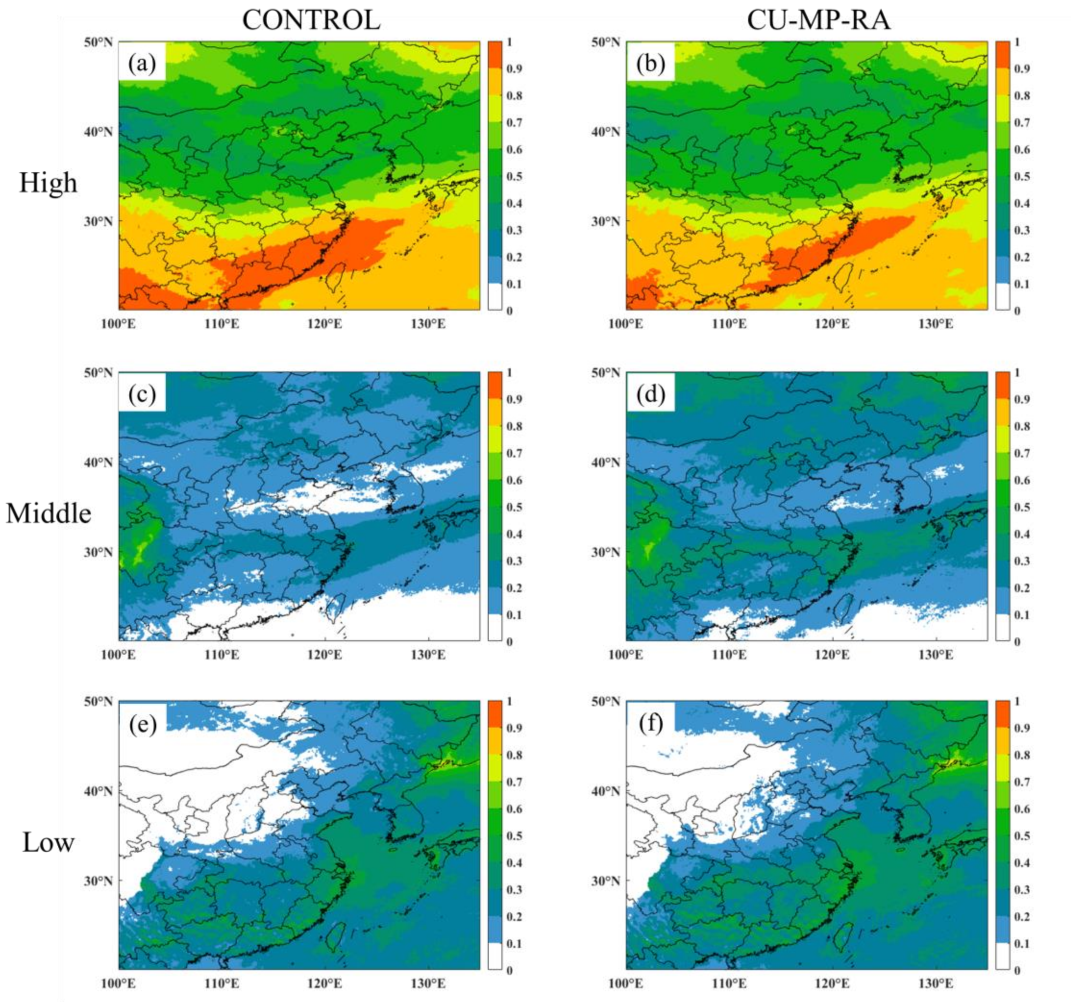

Figure S1. The spatial distribution of high (a-b), middle (c-d), and low (e-f) cloud fraction from the CONTROL (left column) and CU-MP-RA experiment (right column).