Review of "Insights of warm cloud biases in CAM5 and CAM6 from the single-column modeling framework and ACE-ENA observations" by Wang et al.

This manuscript presents a study using the single column configurations of NCAR CAM5 and CAM6 to simulate marine boundary-layer cloud and aerosol properties over the eastern North Atlantic during the ACE-ENA field campaign. The authors further accessed the uncertainty in cloud microphysics parameterization.

The manuscript is clear in addressing scientific questions and well analyzes the results. The figures also strongly support the analysis from model results and observations. However, readers are hard to follow the main points in the current structure of the manuscript, especially for those unfamiliar with CAM5 and CAM6. Some general comments reflect my concern.

We appreciate the reviewer's detailed comments and constructive suggestions. We have carefully revised the manuscript according to these valuable comments. Point-to-point responses are provided below. The reviewers' comments are in black, our responses are in blue, and the quotes from our manuscript are in italics.

General comments:

1. The title of the manuscript highlights the main discussion focusing on the warm cloud biases in CAM5 and CAM6, but the authors did not clearly point out the differences between CAM5 and CAM6. A table could help readers compare the main differences between the two models.

As suggested, we have now created a new Table 1 to summarize the physical parameterizations relevant with warm rain processes.

2. Section 3 is to evaluate SCAM6 using ACE-ENA observations. Again, I do not know whether I should expect that SCAM5 and SCAM6 have similar results. The section title should be changed since the authors added many contents of SCAM5. The same figures as Fig. 1 and Fig. 2 should be present in the manuscript or supplementary for SCAM5.

We have changed the subtitle for Section 3 as "Evaluation of SCAM using ACE-ENA observations". As suggested, we have also provided the SCAM5 evaluation figures similar to Figs. 1 and 2. Since the simulations of the meteorological fields by SCAM5 largely resemble those by SCAM6, we put those two figures into our supplementary materials and discuss them in the main text. The similarity is expected as they are driven by the same large-scale forcing data.

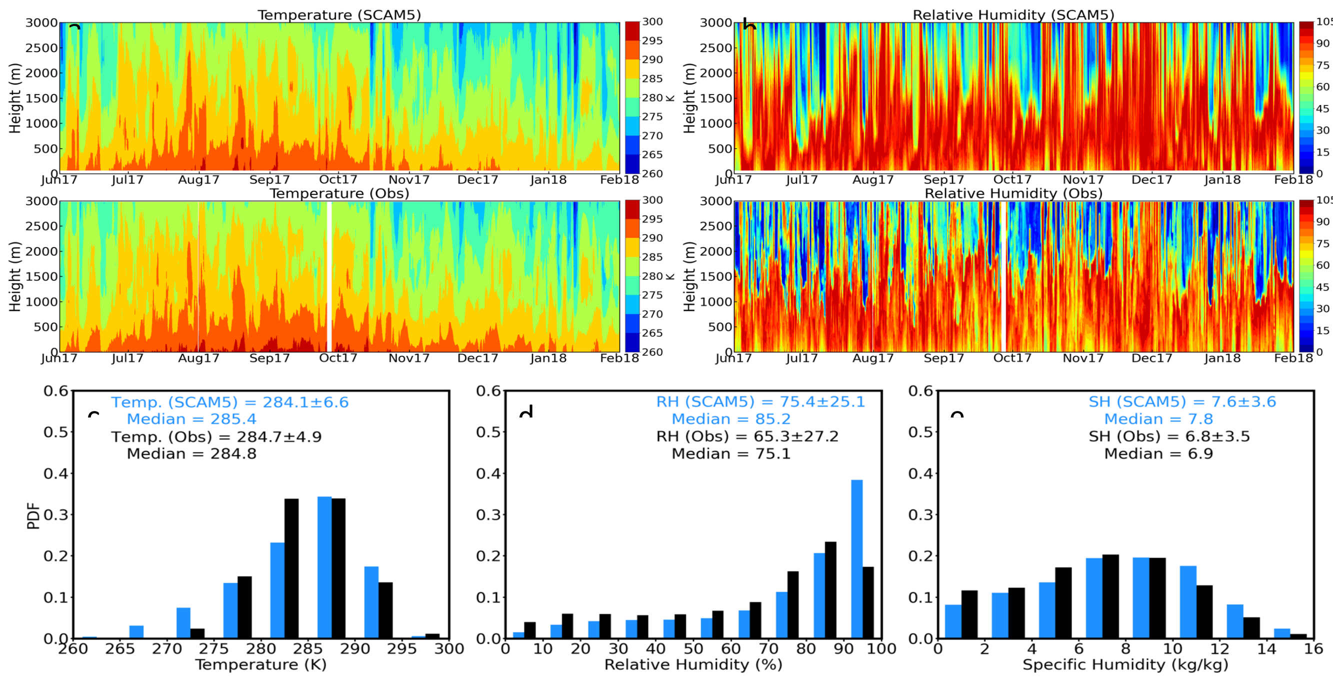

Figure S4. The same with Fig. 1 but for SCAM5.

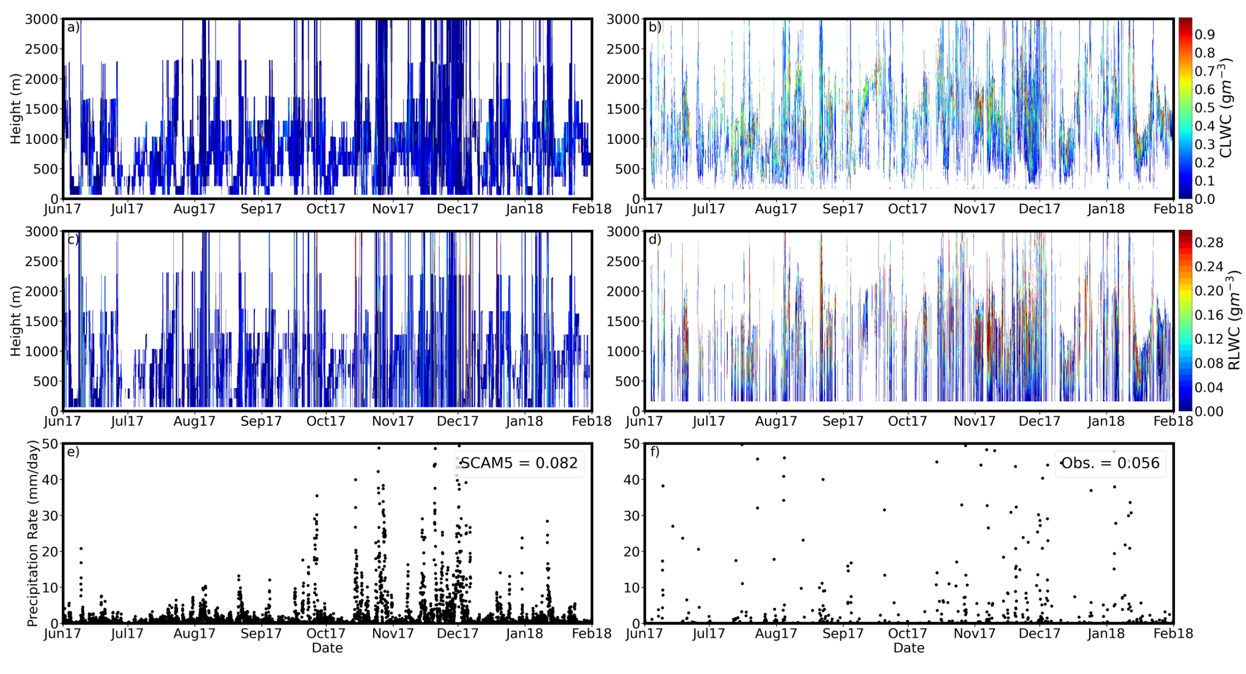

Figure S5. The same with Fig. 2 but for SCAM5.

3. Returned KK scheme (D21-KK) has improved autoconversion and accretion rates with mean cloud droplet radius. However, the turned coefficients are tested in CAM5 by Dong et al., 2021. It seems reasonable if D21-KK did not offer a better result in SCAM6 because those coefficients need to be returned for CAM6. Why did the authors think the results came from introducing sub-grid cloud variations in CAM6?

We are sorry for this confusion stemming from our unclear statements and insufficient description. In fact, our SCAM6 D21 experiment recalibrated autoconversion parameterization using the method to similar Dong et al. (2021), not the identical parameters. The accretion parameterization remains the same, as CAM6 did not retune its parameters. We have now added in the Section 2.2 as: *"CAM6 microphysics aims to reduce the autoconversion dependency on the* N_c*, so* $\alpha 2$ *and A are set as -1.1 and 13.5, respectively, with* $\alpha 2$ *unchanged. We did the same recalibration for CAM6 autoconversion processes, and the corresponding A' is parameterized as:*

$$A'(Z) = 3359 \times exp\left(-0.721\, r_{m,c}(Z)\right) + 8, \quad (7)$$

Hence the updated autoconversion for CAM6 microphysics has the form as below:

$$R'_{auto}(Z) = \frac{RLWC(Z)}{\int \rho_{air} P_r(Z) dt} R_{auto}(Z) = f_e\, A'(Z) q_c^{2.47}(Z) N_c^{-1.1}, \quad (8)$$

Where f_e *represents an enhancement factor which is diagnosed from the CLUBB to account for sub-grid variabilities of cloud and rain."*
Therefore, it was expected that this recalibration on CAM6 would do the same improvement on the warm rain rates. However, the results deny this hypothesis and the likely cause is the newly introduced sub-grid cloud variations in CAM6.

4. The authors provided Table 1 in the manuscript but did not mention it in the text. All experiments, including those experiment names, are hard to follow in the manuscript.

To clarify our experiments, we have now added a new section 2.2 entitled "Numerical experiment design" on page 6 to detail the experiments and echo the Table 1.

Specific comments:

Lines 101-102: The two-moment cloud microphysical scheme is updated to version 2 (MG2; Gettelman and Morrisons, 2015) …

Revised as suggested.

Lines 156-157: Furthermore, the CLWC (RLWC) is scaled by the cloud (rain) fraction within …

Corrected as suggested.

Line 158: in-situ or in situ should be consistent throughout the paper.

We now use "in situ" throughout the paper.

Lines 167-168: Why choose the research flights with a "L" shape?

We have now clarified that to facilitate the model-observation comparisons, we selected only those research flights that followed a horizontal track within one grid size of the CAM models (1.25° longitude and 0.9° latitude), centered on the ARM-ENA site. Also, to meet the criteria for comparison with SCAM6, each aircraft case must include comprehensive vertical sampling of cloud and aerosol within the specified time period. Table S1 lists the dates and time periods of the selected flights.

Lines 251-260: The authors did not mention fig. 4 in the text.

We have now referred to Fig. 4 for those discussions.

Lines 304-307: It is not clear the canceling effect here. For the authors' arguments, the result should be seen in summer and winter.

To clarify our explanation, we have now rephrased the statements as "*Surprisingly, the modeled N_C shows good agreement with observations, despite the overestimated N_{CCN}. One plausible reason is the canceling effect from the too strong N_C sink in the model. The overestimated cloud droplet size by the model (Fig. 3b) fosters the warm rain formation, and in turn, efficiently deplete cloud droplets (Zheng et al., 2022b), keeping the modeled N_C at a comparable level with the observations.*" In the summer, the modeled Nc is also comparable with observations (the red line stay in the shading of the observations), so the hypothesized canceling effect may take place as well.

Line 343: Since the authors defined CLWC in the paper, they should avoid using cloud LWC.

Revised as suggested.

Line 363: increased CLWC?

Corrected as suggested.

Line 398: SCAM5/6

Corrected as suggested.

Line 423: The link does not work.

The link is restored, and the related materials are available to view.

Figure 5: Why using normalized height for Nc?

The reason is that the cloud layer thickness and vertical positions differ for each corresponding time stamp. We need to normalize the height within each cloud layer to ensure that the Nc vertical variation is representative. We have now made it clear in the figure caption.