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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A Model Intercomparison of CCN-Limited Tenuous Clouds in the High Arctic" *by* Robin G. Stevens et al.

Anonymous Referee #2

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General comments:

The authors test the sensitivities of simulated Arctic clouds to aerosol perturbations represented differently by multiple variables, such as prescribed droplet number concentrations, prescribed or variable cloud condensation nuclei (CCN) concentrations, and also prescribed ice crystal number concentrations, using three large-eddy simulation (LES) models and three numerical weather prediction (NWP) models. Microphysical processes in the simulated clouds are investigated in detail. The sets of simulations listed in Table 2 are well designed to test the sensitivity of clouds to different perturbations. Observational data from a field campaign is also presented, which helps the evaluation of the simulation results. They conclude that the clouds (or their water content) are CCN-limited, meaning that the properties of the clouds are heavily de-

pendent on the concentrations/existence of CCN. They also conclude that changes in these Arctic clouds may have impacts on the surface radiative balance since these clouds tend to have a warming effect. Figure 11 and 12 are especially interesting and highlight the findings from this paper. I would like to suggest some minor revisions/questions/comments below;

Specific comments:

Figure 1: Is there any observational data of surface precipitation available?

Page 7 line 1-2: Does this mean that microphysical processes in these clouds are purely liquid-based, not involving ice, due to possibly the lack of ice-nucleating particles (INPs)? Or ice often exists in these clouds (e.g. Figure 1), but just precipitation processes are dominantly through warm-rain?

Page 11 line 6-8: Does the fact that MIMICA is initialized at much earlier than the other two LES models have any impacts on the results?

Figure 2: It may be nice to also show actual temperature so that the temperatures for cloud-base and cloud-top can be roughly estimated.

Page 13 line 16-17: Does this mean that the results are taken from a single column at the center of the simulation domain? According to Figure S1 there seems to be a wide spatial variation in simulated results, but are analyzed results quite similar/different if domain-averaging or other methods are used, instead of extracting data from the center of the domain?

Figure 3 and 5: Since the observed quantity is LWC, how does simulated LWC look like (maybe add it in the third row)? Also, it would be helpful if you add dashed lines to indicate the defined "cloudy" and "nearly-cloud-free" periods in the "Observed LWC" figure.

Figure 4 and 5 captions: Although it says "Rain sedimentation tendencies for COSMO-NWP are not available.", the quantities are still plotted (bottom row, middle column), if

I'm understanding it correctly?

Figure 6: Can you maybe add a column for LWC so that the comparison of observation and simulations is possible?

Figure S2 caption: "CCN80prog_noice" should be modified to "CCN30prog_NOICE"

Page 22 line 30-32: While simulated results may be relatively insensitive to the inclusion of ice, IWC seems not to be negligible in Figure 1 as compared to LWC, though scales are different for LWC and IWC there. Does this mean that simulations are underrepresenting ice mass?

Figure 9: Although I'm aware of the consistent color scale for rain, ice, snow, and graupel, can you change the color scale for snow so that more information can be seen in colors? Or if snow and graupel masses do not play a major role in the whole microphysical processes in those clouds, the bottom two rows could be omitted. Also, I suggest adding observed and simulated IWC to the bottom row if possible.

Page 25 line 30-31: I wonder if some of the differences are due to other reasons, such as ambient conditions (simulated meteorology, especially when LES and NWP simulations are compared) and/or model resolutions, for example?

Figure 10: Maybe some of the columns that are not discussed much in the text can be omitted, so that each plot becomes a little larger?

Figure 11 and 12: If I understand the figure and the timeline in Figure 1 correctly, the boxes in these figures represent the simulated results for the transition period from cloudy to nearly-cloud-free period (1200UTC August 31st – 1200UTC September 1st). However, it does not include the cloudy period itself. That means, if one were to evaluate model performance or compare simulations with observations in this figure, should the boxes lie somewhere between hatched and shaded regions? Maybe the shading and hatching are for reference, but can you also provide the observed average over the same period (1200UTC August 31st – 1200UTC September 1st)? Also, hatching

seems to be a little weak and hard to see, so I suggest thickening it. Additionally, either shading for cloud-free period or hatching for cloudy period can be modified to a different color (currently both of them look grey), so that their differences become clearer (e.g., the row for net LW).

Figure 11 and 12 caption: Modify "indicates" to "indicate" in ". . . the shaded regions indicates . . ."

Page 26 line 4: Remove "be" in "This would be result in. . ."

P.26 line 8-9: Does COSMO-LES have 7 hours for spin-up + 9 hours for analysis? At page 11 line 3, it was stated to be 2 hours of spin-up.

Page 28 line 33: Add "is" in ". . . This primarily due to . . ."

It is better to consistently capitalize the word "_NOICE" throughout the paper, since there are currently places with "_noice" instead.

Figures: Minor suggestion, but it may be a good idea for all figures to have consistent labels. For example, it may be in the form of "1e-01", "0.1", or "10^1" (e.g., Figure 6).

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