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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The importance of Aitken mode aerosol particles for cloud sustenance in the summertime high Arctic: A simulation study supported by observational data" *by* Ines Bulatovic et al.

Anonymous Referee #2

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General comments:

The authors employed two numerical models to perform a series of simulations to study the importance of Aitken mode aerosol particles for cloud sustenance in the summertime high Arctic. The messages in the abstract seem to be clear. After reading through the main text of the paper, I find some interesting results. But I am also confused by arbitrary model and simulation configurations and overwhelmed by poorly interpreted, disorganized, and probably unnecessary results. Throughout the manuscript, the authors used a lot of speculations in their reasoning where solid evidences are expected.

The writing also has huge room for improvement. I listed my major and minor concerns as well as suggestions regarding the technical aspects of the manuscript below.

Specific comments (major):

If I understand correctly, the main idea of this paper is that, for some combinations of model configurations (i.e., Aitken mode and accumulation mode aerosol number concentration, aerosol kappa value, and ice number concentration), the modeled cloud can survive through 12 h, meaning that during this period, the clouds can maintain sufficient liquid water against processes that depletes liquid water (like subsidence, entrainment of warm air, losing moisture due to glaciation and precipitation, so on) and generate enough supersaturation to activate the prescribed Aitken mode aerosol. Was the specified aerosol size distribution for each simulation used from the beginning of the simulation? How important are aerosols during the spin-up? In other words, are the differences among simulations using the same model and between MIMICA and RAMS due to the activation behavior when the turbulent motion is very weak? What if all simulations (in each model) begin with a robust cloud and fully-developed the turbulence, spun-up using same configurations, and then switch to different aerosol number concentrations? I don't think a juicy but non-turbulent cloud is a realistic starting point to test aerosols' impacts on sustaining clouds or produce results that are relevant to the real world. Please justify this choice.

A few other questions related to initialization and spin-up: Is the initial cloud size distribution related to the Aitken mode and accumulation mode aerosol? For each model, are the liquid water content profiles in all simulations identical at the beginning? Are all microphysical processes (e.g., all processes related to precipitations) turned on from the beginning?

It is worthwhile to be more specific about the activation of aerosol particles in MIMICA and RAMS as configured for this study. It seems that the activation scheme in MIMICA is identical to the one used to generate Fig. A10. What about in RAMS? Are the ss in

Fig. 10 and Fig. 11 same as those used in the activation scheme in the models?

It seems that the authors tried to use an observed sounding to set up the baseline simulations, and then perform sensitivity tests on top of that. However, the authors did not provide enough details (for example, dedicated figures) for readers to understand the case. Please consider showing some details. I found the ASCOS sounding available from https://bolin.su.se/data/ascos-radiosoundings. Did the authors use the original 0535 UTC 31 August 2008 sounding from this archive? Or an idealized version of it? The authors used the observed CCN to justify the use of AC20_AK20 as the baseline simulation. However, the cloud layer in the aforementioned sounding seems to be decoupled from the surface. If this is the case, does it still make sense to use surface measurement to determine the base case?

The authors mentioned a few times that Arctic stratocumulus may entrain moist air from above the cloud top, but provided no evidence. (Whether other studies showed entrainment of moisture from above the cloud could happen is irrelevant to this study.) Initial sounding (together with profiles from the middle of the simulations) can be used to show whether there is moist layer above the cloud top.

Choice of model configurations, shared simulation setup, and experiment design are perplexing and arbitrary. Why were the vertical resolutions different, especially as the authors suspected that the different vertical resolutions may be the source of some discrepancies between the simulation results from the two models (e.g., L254). Why were the microphysics in RAMS so much more complicated (even with hail turned on) than in MIMICA? Why was aggregation turned off and only for MIMICA? Why was MIMICA used for ice number concentration sensitivity test while certain ice-related budget terms are not available from it (L289)?

Much of the results regarding rain and ice are only superficially described and discussed, with no obvious connection to the main goal of the paper, and sometimes contain errors. A few examples are provided here.

L277: “The pockets of condensation and evaporation present in the main cloud layer are well-correlated with updrafts and downdrafts and they tend to cancel each other in the mean. This is why the average condensation rate in the main cloud is of the same order of magnitude as the one in the sub-cloud layer.” Totally lost.

L415: “The presence of both positive and negative differences with time is a result of differences in cloud dynamics with different distributions of updrafts and downdrafts with time that govern the rain production in the cloud (cf. Fig. A9).” But there is nothing about “distributions with time” in Fig. A9.

L421: “change in the Aitken mode particle number concentration results in that maximum updrafts are reached at somewhat different times”, what is the significance of this?

L422: “Differences are in general greater in MIMICA than in RAMS since there is a slightly more total ice in MIMICA”. Does “since” mean “because” here? Does greater total ice water content (or path?) have to lead to greater differences?

Other than the “entrainment of moisture aloft”, here are a few additional examples of unacceptable speculation.

L288-289, “Examining the total ice deposition/sublimation rates would most likely lead to similar rates between the two models”. (BTW, “The ice crystal deposition and sublimation rates are higher in RAMS than in MIMICA since the two models partition the total ice deposition differently among ice hydrometeor categories” is also just speculation, isn’t it?)

L411-412: “an increase in the Aitken mode particle concentration may lead to stronger turbulence and more cloud liquid water production”. Turbulence intensity and cloud liquid water budget can be diagnosed. It does not make sense to speculate (“may lead to”).

Minor comments:

Contents in Sections 2.1 and 2.3 are not clearly separately. For example, why are number of model grid points and resolution introduced in Section 2.1 but domain size in Section 2.3?

Please clarify a few model or simulation configurations issues: Is it correct that the time step is 2 s for MIMICA? What about RAMS? The terminal speed is only introduced for MIMICA, what about RAMS? What are the references for the terminal speed formulas used? Is the 0.2 L-1 ice number concentration based on ASCOS observations? Need reference. Why is divergence set to 1.5E-6 s-1? Is the same value used for all model layers?

L130: Is the wet deposition calculated for any tracers in either model?

L346: Since they are simplified LW cooling calculation that only depends on LWC, why not using same formula for both MIMICA and RAMS?

L349: “Stable cloud base”, do you mean “steady”?

L383: “Fig. 5”, should be Fig. 6?

Examples of poor writing:

L265: “total ice”, do you mean “total ice mixing ratio”? There are a few “total ice” throughout the text.

L377: “available water vapor” what is this?

Suggestions on technical issues:

Please consider marking cloud top and base whenever relevant.

Colors are saturated in some figures, e.g., Fig. 3f. Please adjust.

L292: “from the different model descriptions”, should be “configurations”?

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