Review of manuscript **acp-2022-36**: *Arctic mixed-phase clouds sometimes dissipate due to insufficient aerosol: evidence from observations and idealized simulations* by Sterzinger, L. J., Sedlar, J., Guy, H., Neely III, R. R., and Igel, A. L.

Overview

This paper investigates the impact of a sudden decrease of aerosol concentrations on the dissipation of mixed-phase clouds in the Arctic boundary layer. The importance of understanding low-levels clouds in the Arctic has been well established, as well as the fact that lot of this understanding is still lacking. One step in improving scientific knowledge of Arctic mixed-phase clouds can be this paper. It starts by a brief recapitulation of the problem, pick a certain niche (single-layer mixed-phase clouds during Arctic spring and summer), and chooses three representative examples to motivate a novel model study. The model study uses well established software, RAMS, to conduct idealized large-eddy simulations. The results are then examined, and a clear conclusions are drawn. While this paper has a high potential, it has also some significant shortcomings:

1. Not distinguishing between causation and correlation in the observations;
2. Lack of replicability due to incomplete description of the methodology;
3. Omitting discussion of dynamic effects.

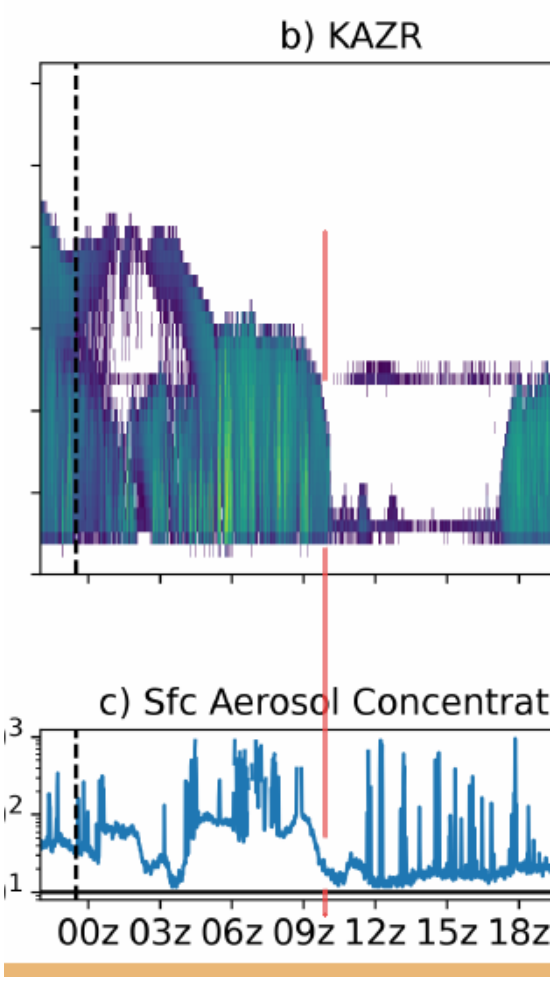
Each of these major issues is described in its own section below. I believe that authors will be easily able to fix them.

Overall recommendation

Publish after major revisions

Major Comment 1

The causational relationship between the decrease in the aerosol concentrations and changes in changes in the properties of the clouds are expected. However, this paper goes an extra steps and claims that observed dissipation of clouds is most likely due to decrease in the aerosol concentrations. However, observations as described in the section 2.1 show only the correlation of these two events. Furthermore, figure 2.b and 2.c show that the cloud started dissipating while the aerosol concentrations were still high (please see the red line in the snapshot below).



Therefore, it is possible that the the causation could work the other way around: increased precipitation could possibly scavenge aerosols from the lower part of the boundary layer. Or it is also possible that both changes are caused by an advection of slightly different air mass. Unfortunately, I do not see this addressed discussed in the paper.

Furthermore, it leads to slightly misleading part of the title: "evidence from observations and idealized simulations". What we currently see in the paper is "evidence from idealized simulations motivated by observations."

Major Comment 2

The section "2.3 Experimental setup" is well written, yet clearly incomplete, which means that the study is in the current form not replicable.

The following properties of the setup of simulations are missing:

- radiation scheme: which radiation scheme is used? Is it coupled to the microphysics?
- surface conditions: considering that most of the simulations are during the day, the surface albedo might play a role. But its setting is not described.
- wind velocity: what is the initial profile of wind velocity, and is it derived from observations, or the reanalysis?

- meso-scale forcing: is the initial wind velocity maintained?
- upper boundary conditions: Do you use the *Gravity wave radiation condition (Klemp and Durran, 1983)*, or something else?

Speaking further about the replicability, I was not able to find the case setups in any of the online repositories linked in the data statement. The case setup files are either missing, or are well hidden in somewhere deep within the directory tree. I would like to ask the authors to fix that as well before the submission of the review manuscript.

Major Comment 3

The paper omits discussing the dynamic effects of the boundary layer, and whether they are represented in the model.

- Dynamic effect in general: the cloud dissipation in OLI and SMT could be affected by wind shear driven entrainment. Unfortunately the data in the online repository do not show the wind velocity data, and the simulation setup is unclear (see last paragraph of Major Comment 2).
- Dynamic effect in general II: How much does the increased precipitation effect the surface fluxes? (see Major Comment 2)
- Dynamic in the model: The *temperature nudging* is usually applied above the boundary layer. However here it is applied withing the boundary layer, which could be a serious issue. The whole cloud dissipation could be caused by the sudden removal of the cloud. Have you performed a sensitivity test for that? Have you also checked how it affects model spin-up?
- Dynamic limitations of the model: When the clouds disappear and some of the model levels remain supersaturated, is the dynamic core of the simulation still working correctly?

Minor Comments

line 99: "ASL"
The abbreviation ASL should be defined. The default meaning of ASL is "Atmospheric Sciences Laboratory" or "American Sign Language".

Figure 2:
The panels b, c, and d are very small. Expanding them the figure on the full width of the page would help.

Figure 2, panel c:

- missing label of the axis y.
- related to the point above, is there a specific meaning for "z" in *00z, 03z, 09z,* or is it just a formatting issue?

Figure 2, panel d:
Adding longitude and latitude to axis would be nice, or at least adding some other geographical

coordinates.

Line 109: "(CPC) (measuring particles 10-3000 µm“
Did the instrument only measure particles larger than 10 micrometer? That would mean that wast majority of aerosols was not recorded. Or do you mean "nm“?

Figure 3:
Same issues as Figure 2

Figure 3.a:
The potential temperature profile is missing, only relative humidity is shown. Please add it to the plot.

Figure 4:
Same issues as Figure 2

Line 153: there is a dry layer at 400 m.
The panel 3.a shows only a very minor decrease in humidity.

Line 177: "... aggregates, snow, hail, and graupel"
Are aggregates a separate category from snow?

Lines 178–179:
The list of the microphysical processes is slightly confusing.

- It seems that *sublimation* is missing

Figure 5:
Considering that three cases are compared with respect how fast the clouds dissipate, it would make more sense to show figures under each other.

Line 237–238: “all further discussion will be discussed“
It would be better to write "all features will be further discussed...“ or "all events will be further discussed“

Figure 7, panel a:
The legend is confusing. The caption of the figure does not explain any of the terms there. Therefore reader can't know

- what is the difference between "Rain" and "Precip“,
- what is the line "Cloud“.

Figure 7, panel b:
The legend is confusing here as well. The caption of the figure does not explain any of the terms. It seems that deposition is not considered in the ice budget and instead "Cond“ is.

Figure 8:
Same as figure 7

Figure 9:
Same as figure 7

Line 276: "about hours after"
How many hours?

Line 276: "in a fog layer near the surface"
This does not make sense. How could there form a fog layer when all aerosols were removed?

Line 281: "b y"
by

Line 293: growth budget in 2D (Fig. 8(d-e))
Does 2D refer to height and time?

Line 293: "different than the other two"
More fitting would be "different from"

Line 293: "...in SMT caused the relatively drier above-cloud air to be mixed and entrained into the cloud,"
This is a good point, but it is not shown in the result part.

Line 376–379: "We believe that, given the evidence from these three simulations, the microphysical balance state of the cloud is more important to determining the response to aerosol removal than boundary layer properties"
This is a very strong statement, and currently not supported by results.
The effect of other boundary layer properties (such as wind shear or surface forcing) is not compared in the results. This seems more like a proposal for a future research.

Line 384: 6.1.22.
Insert a space between 22 and dot, so the link will work.

Lines 400–401:
The title of the paper does not have to been in capitals.

Line 530: Sterzinger, L.: Data for Sterzinger et al. (2022, in Prep)
This should be in the data statement only, not in the References.

Line 532: Sterzinger, L.: Plotting Scripts for Sterzinger et al (2022) (in Prep),
This should be in the data statement only, not in the References.