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Comment on acp-2020-1318

Anonymous Referee #2

Referee comment on "Midlatitude mixed-phase stratocumulus clouds and their interactions with aerosols: how ice processes affect microphysical, dynamic, and thermodynamic development in those clouds and interactions?" by Seoung Soo Lee et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1318-RC2, 2021

The paper reports on the sensitivity analysis of a supercooled stratus cloud to changes in cloud condensation nucleation and ice nucleating particles.

The authors frame the analysis as an investigation of changes to condensation and evaporation rate. Unfortunately I think that misses out what is going on in this cloud. We are also lacking process rates that could help to clarify the situation. The authors claim that the changes in WP are simply due to changes in condensation and evaporation. What it looks like is happening is that dehydration of the layer at which the cloud forms is being controlled by hydrometeor number concentration that ultimately controls the particle mean size and the flux of mass out of the cloud.

While the simulations seem to be fine, the interpretation needs to be revisited and additional plots included.

Main point.

The authors seek to explain the changes in WP by changes in condensation and evaporation rate. This is not the complete water budget for the cloud. There is also sedimentation that needs to be taken into account. My impression from looking at the results is that the WP changes can all be explained by the role of sedimentation dehydrating the cloud layer. The authors discuss increased surface area leading to more efficient condensation, but to first order the amount condensed is governed by how high a parcel ascends (if the timescale for condensation/deposition is shorter than eddy overturning timescale). The particle number concentration then leads to smaller particles for higher concentrations that fall slower and are therefore less efficient at dehydrating the cloud layer.

This can be demonstrated by:

i) showing precipitation rate at cloud base for the different simulations (precip rate will decrease with increasing concentration).

ii) setting the sedimentation speed of ice particles to zero – this would then mean that the control and 100x IN simulations develop similar WP.

iii) for evaporation rate to be important thre would need to be a large change in cloud top evaporation rate (converted to Wm-2) compared to any change in longwave cooling rate between simulations.

I think the authors should carry out these suggestions

Other points.

Line 146 there are several high resolution studies of mixed-phase stratiform cloud that could usefully be reviewed and compared to. Here are some examples.

Possner et al. GRL 2017. https://doi.org/10.1002/2016GL071358

Young et al. ACP 2017. https://acp.copernicus.org/articles/17/4209/2017/

Ovchinnikov et al. JGR 2011. https://doi.org/10.1029/2011JD015888

It would also be worth looking at Ackerman et al.

https://pubs.giss.nasa.gov/docs/2004/2004_Ackerman_ac07000g.pdf

Line 152. Need to slightly rewrite - there have always been aerosols affecting clouds.

Line 221. Some more metrological information would be useful. What temperature is cloud base and cloud top at?

Line 242. Is representing this variability within the domain important? How does it compare to just using averaged values over the domain?

Line 291-298. So the microphysics uses up the aerosol ?

And then the aerosol is nudged back to a background concentration? What is the timescale to do this? Why isn't advection of aerosol from the boundary sufficient?

Reasonably well, seems vague. In what way is it reasonable? And to what level of accuracy?

Line 297-298. so the aerosols are not used by the clouds?

Line 301 the simulations are run such that the microphysics see the aerosol and can activate it to form cloud but does not remove it ?

I think this section (3.2) needs to be rewritten to clarify how the aerosol is being used in the microphysics.

Line 350 section 4, 4.1

I am afraid I disagree with the interpretation presented here. The modelling results need to be reassessed and text rewritten.

Line 408-409. i would assume this is simply because cloud parcels have ascended higher (fig 3d shows the cloud top is ~1km higher for the noice simulation). In the ice simulations the water will be efficiently removed (due to deposition, riming and sedimentation) stopping the parcels reaching saturation as they ascend.

Assuming similar updraft speeds and modest supersaturations if this microphysics supports it,, then the condensation rate just represents how much water has been removed from the parcel.

Its not the condensation rate alone, but the sink of moisture from the ascending cloud parcels that controls the lwp, iwp.

line 433-434. is this just because there is coexisting ice that is competing for water. This will make it harder to activate new droplets.

1 per cc ice particles is extremely high concentrations for these temperatures.

In observations it should be more like 1-10 litre. 100litre if secondary production of ice is occurring

Line 441-444. No. the lower wp is because moisture has been removed from the column by sedimentation

Line 455-470. Deposition is occurring because the vapour pressure over ice is lower than the environmental vapour pressure (in this case at water saturation). This will be a sink of water vapour leading to droplets evaporating and maintaining the vapour pressure at water saturation.

If the cloud parcel is not fully glaciated then the water should be condensed out by the time the top of the parcel ascent is reached with perhaps a few seconds lag if there is substantial supersaturation.

The reason that the wp is larger for higher cinc is that the parcel has not been dehydrated. The total water is unchanged because the particles are much smaller and are not sedimenting out in the timescale of the parcel ascent.

In fact, if an even higher concentration were used the wp should exceed the control noice as the vapour can be brought to ice saturation.

You can assess this by looking at the precipitation rate at cloud base.

Changing the concentration will change the sink rate of moisture to ice, but you can estimate that timescale (e.g. Korolev and Mazin, JAS, 2003). The concentrations used here are high, so the timescales will be short - approaching what you typically see for liquid. For control even though concentrations are 100x less than droplets, the ice particle size is probably 10x the size of the droplets and it is the integrated number x size that controls the phase relaxation timescale. For the 10x and 100x IN concentrations - the phase relaxation will likely be similar to the control noice case.

Line 474. i assume this is a histogram of all of the columns in the domain for the final timestep? Fig 5 does not look like a cumulative frequency plot. It is not constantly increasing or decreasing as wp changes

Line 497. In this section, what has been tested indirectly is the role of sedimentation in dehydrating parcels.

You could demonstrate this by turning off sedimentation for ice and seeing that the control wp was the same as the 100x IN wp.

Line 577 ,For the control noice runs there is also sedimentation. Decreasing aerosol leads to formation of larger droplets that fall faster - more rainout means lower wp. We need to see the cloud base rainrates.