

We thank all reviewers for their time and critical review of the manuscript which we feel provided an important perspective on the material presented. As such, the manuscript is much more focused and streamlined. Our point-to-point responses to the reviewer are given below. For clarity, all responses are provided in blue

Response to report #1

I suggest to shorten the abstract and to focus only on the main conclusions here.
The abstract is modified as suggested

P3 L15: the increased evaporation of the smaller cloud droplet at the cloud periphery under polluted conditions can also increase the mixing between the cloud and the environment.
“Increased evaporation of smaller drops can result in stronger cold pool formation and enhanced secondary convection” is changed as suggested to “Increased evaporation of smaller drops can result in stronger cold pool formation and enhanced secondary convection, and such increased evaporation at the cloud periphery under polluted conditions can also increase the mixing between the cloud and the environment”

P14 L5: is it the same magnitude of forcing you get in the model results?
The maximum difference in the model run is about 40W/m^2

P2L12 (and other places): I suggest to be consistent and use “DCC” for “deep convective clouds” in all places.
All deep convective clouds in the content has been changed into DCC except for when it first appeared.

P6 L19: at this point you still didn’t mention the use of a nested grid with 4 domains so the reader don’t know what does “the entire 4th domain” is referring to.
The “4th domain” has been changed into a “certain domain” to avoid this problem.

P10 L30: what is the scale of the exponential decrease in aerosol concentration with height?
The CCN concentration is calculated as followed:
When height $\leq 2\text{km}$, CCN concentration = a certain number ($300/\text{cm}^3$ in this case)
When height $> 2\text{km}$, CCN concentration = $300 \cdot \exp\left(-\frac{\text{height}-2\text{km}}{2\text{km}}\right) (/ \text{cm}^3)$

P11 L2: you are talking here about wind shear but present values of wind speed.
(P11L20) “Wind shear” is corrected to “wind speed”

P12 L28: “DCC cloud”, you can delete the second “cloud”.
Second “cloud” deleted

P14 L23: correct: “From model hours 20 onwards, The...”
Corrected

P19 L12 and P19 L25: change number to concentration – aggregation is sensitive to

concentration and not to absolute number of partials.
Number at those two places have been changed into concentration as suggested.

P23 L14: suggest to add “(SBM)” after “spectral-bin microphysical”
SBM has been added as suggested.

I noted that you are referring to Fig. 6 only at the last paragraph of the manuscript. Isn't it appropriate to refer to it at the end of P15 or begging of P16?

Yes. The description is for figure 6 but it wrongly quoted figure 5 at the beginning of p16.
(Now figure 14 after changing the order of Results)

Figures: correct cm-3 to cm⁻³, L-1 to L⁻¹ and so on.
All corrections have been made in updated plots, as suggested.

Response to report #2

- The authors explain that (e.g. p23, l27/28) “Latent heat release in the heterogeneous nucleation regime is increased in the dust cases due to [...] smaller, more numerous particles”. I do not think that this really is an effect of particle size but rather a consequence of an increased glaciation of the cloud. I mean to say that the total amount of ice, independent of whether it is distributed to many small or a few larger particles, controls vapor deposition. Yes, the water mass that go through the phase change is what decides the amount of latent heat release, “Latent heat release in the heterogeneous nucleation regime is increased in the dust cases due to diffusional growth and liquid-to-ice phase changes during riming of the smaller, more numerous particles.” was changed into “In the dust cases, stronger diffusional growth and liquid-to-ice phase changes during riming of the smaller, more numerous particles lead to a increase of total ice mass, resulting in an increase of latent heat release in the heterogeneous nucleation regime.” to better describe the process.

- I am struggling to reconcile Figs. 10 and 14 (d) with the authors conclusion on “less efficient graupel formation reducing convective rain rates” (e.g. p1, l24): Fig 14 (d) show that the reduction is dominated by a reduction around 6km height. In Fig. 10, riming seems to be about the same, while autoconversion is decreased and aggregation increased in this region - so for me it seems that a reduction in autoconversion is the cause of decreased precipitation. Could you clarify this, maybe with the help of difference plots in Fig. 10? Similarly, do you provide an explanation for your observation that “precipitation formation is shifted to colder temperatures” (e.g. p24, l2)? Comparing Fig. 14 (d) and Fig. 10 this seems to correspond to a shift from autoconversion to aggregation.

As you pointed out, when extra IN is added to the system, the heterogeneous nucleation is enhanced, the system has less water to form liquid droplets and autoconversion will indeed decrease. However, from figure 10 (now figure 8) we can also see that the aggregation (ice collection) is becoming stronger as we increase the IN number. The reduction at ~6km is duo to both effects. The shift from autoconversion to aggregation results in the shift of precipitation formation to colder temperatures.

- I suggest to move section 4.2 “Radar Reflectivity” to the end of section 4. This would allow

to discuss its findings using results from the foregone analysis. Also, it would reflect the structure of abstract and conclusion.

The order is adjusted as suggested

- The authors find that “reducing dust layer moisture content by 5% “ (e.g. p25, 11) inverts the convective radar reflectivity difference pattern. What does this sensitivity to layer moisture mean for the robustness of the results?

Measurements from AIRS/AMSU/HSB indicate that the relative humidity in the dust layer is about 20% drier than the surrounding air. The sensitivity study with reduced moisture content is to mimic this observed conditions.

Smaller/technical comments:

- p1, l20: Do you mean: Before they are transported into the anvil?

Yes.

- p6, l19: The “4th domain” is mentioned here without having been introduced.

The “4th domain” has been changed into a “certain domain” to avoid this problem.

- p7, l8: The sentence does not make sense as is.

“Currently there is no deposition and condensational nucleation parameterization connecting with aerosol properties and developed based on deep convective clouds” is changed into “Currently there is no deposition and condensational nucleation parameterization that is developed to connect with aerosol properties for DCC.”

- p13, l13: Where is the rain rate increased? Near the equator? Below the core it seems decreased?

The rain rate below 0 °C (at higher altitude than the 0 °C layer) has increased, as well as the reflectivity.

- p13, l21: Could you also comment on the strong increase in snow radius below the freezing level?

Similar to graupel, the snow radius is increased due to immersion freezing of large rain drops

- p17, l1: The black lines in Fig. 7 (a,b) do not look like more than 90% of ice formation occur above the -38 degree line. Could you clarify this?

Because that ice can be transported by air flow, ice found above -38 °C layer is not necessarily produced there. Percentage of homogeneously formed ice at above -38 °C layer is reducing with increasing IN number. The sentence is indeed confusing and is deleted.

- p 21, l16-19: I find this very hard to see - could you show/discuss this more clearly?

The convective PSD is evolving similarly to the stratiform PSD. From hour 6 when the clouds begin to develop to hour 18 when the clouds reach their mature stage, we can see that compared with the clean case, there is a tendency in the D.12 and D1.2 cases that from hour 12, the number of small ice particles is keep decreasing while the number of large particles is increasing, and the radius threshold between large and small is increasing. That is, the number of large particles is increasing and the average size of large particles is becoming larger. However, after hour 24, we can see from figure 7a and figure 9a that the clouds themselves

are becoming weaker, number of particles of all size are decreasing. The large particles fall out first, therefore the reversed pattern after hour 24.

- p24, l2 and l 17/18: These sentences repeat each other.
L2 was deleted.

- Fig 2: Why don't you show difference plots here?

In figure 2, the different effect of extra IN on the pattern and intensity are quite substantial especially above 6km. The difference is clear to see in those plots. Using difference plots may not make them clearer.

- Fig 10: Why don't you use difference plots here? Can aggregate numbers be converted to rates so that their magnitudes can be compared to riming and autoconversion?

Autoconversion rates in the warm region exceed the color scale for all dust levels so that they cannot be compared. Could you add a level to the color scale or use difference plots?

Similar to the previous reply, using difference plots may not make points clearer. We tried to add a level to the color scale, but it did not show significant difference.