Review of Sela et al. "Aerosol perturb mixed-phase microphysics and anvil radiative effects in deep convection"

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Sela et al. investigate aerosol-convective cloud interactions in two cases of convection-permitting numerical simulations with the ICON-Ham-lite model. The model is run with realistic boundary conditions for situations observed in the TRACER field campaign in Houston, TX, USA. The authors find that increasing cloud-condensation-nuclei concentrations suppresses the warm-rain process, reduces riming due to the smaller collision efficiency of small droplets with larger ice crystals, and enhances evaporation, ice nucleation, and depositional growth in the mixed-phase temperature range inside convective clouds. The changes in microphysical processes in the mixed-phase range cause cloud ice to take the form of smaller, slowly falling particles rather than graupel, leading to larger ice water content in the cloud anvil. The microphysical changes enhance the magnitudes of shortwave and longwave cloud radiative effects due to their influence on the cloud anvil.

The topic of aerosol-deep convective cloud interactions is highly relevant and a major knowledge gap highlighted in recent community assessments of climate forcing. For this reason, the paper has the potential to be a valuable contribution to the scientific literature. However, in my opinion, the paper could be improved with more precise discussion of cloud microphysical processes supported by more evidence. Some suggestions to improve the paper are listed below. I believe the paper may be suitable for publication if these issues are addressed.

General Comments

Use of aircraft observations

The ESCAPE aircraft campaign measured convective clouds in the same domain as the simulations presented in this paper. In particular, RF13 from the Convair aircraft and RF11 and RF12 from the SPEC Inc. Learjet collected measurements on June 17, 2022, which is one of the two cases simulated in this paper. I suggest that the authors analyze the aircraft data on this day to compute typical microphysical properties in the convective clouds. For instance, it would be helpful to know if the observed cloud-droplet number concentration and cloud-droplet size distribution agree with those in the default numerical simulation. Given that the proposed physical mechanisms in this work all begin with a change in the cloud-droplet size and number concentration in the liquid part of the cloud, and that microphysical processes are very uncertain in numerical models, it would strengthen the modeling evidence if the authors can demonstrate that the model cloud-droplet properties agree with observations.

More precise discussion of cloud microphysics

In several places the discussion of cloud microphysics is either qualitative or relies on inference rather than direct evidence. Given that the authors are working with a

model that can provide most variables that would be desired, it seems like it would be an improvement to actually show direct evidence rather than make inferences.

One example is the paragraph at line 169, in which the authors infer that polluted cases with small droplets in the mixed-phase range favor ice growth by the Wegener-Bergeron-Findeisen (WBF) process. The WBF process typically does not occur when the updraft speed is larger than 1-2 m s^{-1} because in that situation the air is supersaturated with respect to both ice and liquid (Korolev, 2007). Given that the peak updraft speeds in convective cells in the ESCAPE campaign were measured at 10-30 m s^{-1} (Patil et al., 2026), it seems plausible that the WBF process is not active in most of the convective cores in nature. The author's claim that the WBF process explains differences between the simulations would be much more convincing if the authors could explicitly show that the water vapor pressure in the mixed-phase range of the convective core is often between the saturation vapor pressures for ice and liquid in the simulations.

Another example is the claim that polluted clouds have less riming because the smaller droplets in the polluted clouds have lower collision efficiency with the ice particles. The authors argue that this is a consequence of the smaller droplets having less inertia and therefore being carried around the larger collector ice crystals with the air streamlines. Lamb and Verlinde (2011) show that if the larger collector particle has a radius greater than ~50 μm, then the collection efficiency is nearly constant and close to 1 for all collected droplets with radius larger than ~10 μm (their Fig. 9.12). Thus, the argument made by the authors seems valid only if a substantial fraction of the droplet population shifts from larger than 10 μm to smaller than 10 μm in response to increasing aerosols. I wonder if this is actually true because even in the polluted case it seems possible that droplets forming at the cloud base will have enough time to grow to sizes larger than 10 μm via condensation by the time they reach heights at which riming can be significant in the non-polluted case. Can the authors explicitly show the size distribution of the cloud droplets in the mixed-phase range to support their claim about reduced collision efficiency?

Clearer Description of Calculations

It is not clear to me how the statistics in Fig. 9 are calculated. For instance, does each cloud object contribute one data point to the histogram in 9a-b, or does each time step of each cloud object contribute one data point to the histogram in 9a-b? If it is only one data point per cloud object, then does "anvil area" represent the maximum area attained by the cloud object over its lifecycle? Do the fractions in 9c-d represent the fraction of all grid-cells inside cloud objects at all time steps of the object tracking that exceed the threshold CTP? Or does it represent the fraction of cloud objects that exceed the threshold CTP in at least one grid cell during at least one time step during the cloud lifecycle? How many cloud objects are tracked in total, and how many lat-lon-time gridboxes or cloud objects contribute to the fractions and histograms plotted in Fig. 9? Please clarify.

Specific Comments

- Fig. 7: consider reporting ice nucleation is units of kg kg-1 s-1 to be consistent with the units of other microphysical terms
- Line 316: typo – “CTH pressure thresholds” -> “cloud top pressure thresholds”

References

Korolev, A., 2007: Limitations of the Wegener–Bergeron–Findeisen Mechanism in the Evolution of Mixed-Phase Clouds. *J. Atmos. Sci.*, **64**, 3372–3375, https://doi.org/10.1175/JAS4035.1.

Lamb, D. and Verlinde, J.: Physics and chemistry of clouds, Cambridge University Press, United Kingdom, ISBN 9780521899109, https://doi.org/10.1017/CBO9780511976377, 2011.

Patil, S., McFarquhar, G. M., Huang, Y.,Roberts, G., Wolde, M., Nichman, L., et al. (2026). Quasi-steady state supersaturation: Do high values derived from ESCAPE represent real high supersaturations and the potential for condensational invigoration? Journal of Geophysical Research: Atmospheres, 131, e2025JD045547.https://doi.org/10.1029/2025JD045547