Review of “Mixed-phase Direct Numerical Simulation: Ice Growth in Cloud-Top Generating Cells“ by Chen et al. (egusphere-2022-1142)

The manuscript describes the first direct numerical simulations of mixed-phase cloud microphysics. By conducting a large number of sensitivity studies, the authors analyze how the relative humidity and the liquid water content affect the Wegener-Bergeron-Findeisen process in a turbulent environment. They show that the results do not substantially deviate from idealized parcel simulations. The main differences are in the widths of the droplet and ice crystal size distributions.

While the results are not very exciting, this is an important contribution to the literature, as the interaction of turbulence and mixed-phase cloud microphysics is not very well studied. Thus, I support the manuscript’s publication in Atmospheric Chemistry and Physics, subject to a few major and minor comments detailed below.

Major Comments

Are K’ and D’ the same for ice and liquid particles? The authors consider kinetic effects on the coefficients for thermal conductivity and water vapor diffusivity for ice crystal growth the same way they are used for liquid droplets. I have major concerns if this is acceptable (see, e.g., Zhang and Herrington 2014).

The dry aerosol size seems to be unrealistically large. A droplet growing from a dry aerosol of 1 µm in radius needs to be considered a giant nucleus. Initializing all liquid droplets with such a large dry aerosol is not realistic, as only a minority of cloud droplets are grown on aerosol particles as large as this.

Connect results to theory. There is a lot of theory on the Wegener-Bergeron-Findeisen process in the literature. As this study builds upon that work and extends it by including turbulence, it would be worthwhile to include some of the calculations of, e.g., Korolev and Field (2008).

Minor Comments

L. 13: While I see this is the abstract, please explain briefly what cloud-top generating cells are. I do not consider them common knowledge.

Ll. 23 – 33: Small-scale mixed-phase cloud processes are not only a sub-grid scale problem. The lack of understanding addressed in this study is much more fundamental. Thus, the authors should not understate the physics investigated here.

Ll. 63 – 64: This applies to all mesoscale models, not only WRF-type models. Moreover, WRF is not defined.

Ll. 87 – 88: If the effects of T’ and qv’ have not been considered before, was the spectral broadening shown in previous studies only due to temperature fluctuations caused by fluctuations in the vertical velocity?

Ll. 90 – 91: What is “the early stage of a mixed-phase cloud”?

Ll. 104 – 106: The crystal habit should depend on temperature and humidity.

Eqns. 4 and 5: Are those \delta the same as \sigma?

Tab. 2: I hope this is a typo, but a dissipation rate of 10 m^2 s^-3 is about 10 000 times larger than what one would expect in a cloud with the LWCs used here.

Ll. 195 – 199: This is not a steady state. It only looks like a steady state because the simulation time is too short to detect any changes. Clarify this.

Ll. 200 – 203: How are these statements supported? To which figure are the authors referring to?

Ll. 267 – 268: It is quite interesting that the ice crystal size distribution is only susceptible to turbulence when the environment is almost ice-saturated. This finding should be highlighted in the conclusions/summary, as it might help to constrain the conditions in which those interactions are important.

Fig. 9: Could you speculate on what would happen to the relative dispersions if the supersaturation fluctuations are turned off at, e.g., t = 20 s? Would a non-zero relative dispersion be maintained, or would it decrease to zero?

Ll. 346 – 354: This analysis is entirely qualitative. Is it possible to quantify the correlations between liquid droplets, ice crystals, and the supersaturation?

Technical Comments

General: Please increase the line spacing in the draft version of the manuscript. The draft is very hard to read.

Ll. 18 ff.: State units in upright characters.

Ll. 46 – 48: There is something wrong with the sentence starting with "A majority […]".

Ll. 92 – 93: Double reference to Pruppacher and Klett (2010).

L. 102: Add units to Rv.

Tab. 1: I suggest replacing liters (L) with cubic centimeters (cm^3). Last row: No unit for ice concentrations.

All figures: Add the simulation group name to the title of each panel.

Fig. 3, caption: This should be an LWC of 0.002 g m^-3.

Fig. 4: Increase the quality of the plot. The panels are blurry.

Fig. 5a and b: Ordinate labels are missing.

References

Korolev, A., & Field, P. R. (2008). The effect of dynamics on mixed-phase clouds: Theoretical considerations. *Journal of the Atmospheric Sciences*, *65*(1), 66-86.

Zhang, C., & Harrington, J. Y. (2014). Including surface kinetic effects in simple models of ice vapor diffusion. *Journal of the Atmospheric Sciences*, *71*(1), 372-390.