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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Impact of hygroscopic CCN and turbulence on cloud droplet growth: A parcel-DNS approach" *by* Sisi Chen et al.

Anonymous Referee #2

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The submitted paper describes a set of simulations of evolution of cloud droplet spectrum within non-entraining adiabatic air parcel. The focus of the study is the impact of in-cloud seeding of the cloud with monodisperse droplets on the final cloud and drizzle drop spectra. The simulations include representation of turbulent inhomogeneities using a Direct Numerical Simulation (DNS) approach, with the DNS box representing the adiabatic parcel (with a volume of ca. 4.5 cubic litres). The simulation scenario is a 1500 m parcel ascent with a constant vertical velocity of 2 m/s with:
i) representation of spatial variations in heat and moisture disabled until reaching the level of maximal saturation (i.e., after ca. 350 m of ascent) - this phase assumes homogeneous ambient conditions;
ii) seeding with droplets (of 4 or 8 μm in radius) happening instantaneously at the level

of maximal saturation;
iii) further ascent for next ca. 1150 metres with DNS-resolved effects of turbulent inhomogeneities as well as with simulation of collisional growth.

Technically, point (i) is realised in the presented simulations by using a parcel model with Lagrangian-in-radius size spectrum evolution below the level of maximal saturation, and then initialising the DNS simulation with particle population matching the spectrum obtained with the parcel model. Due to application of this initialisation technique, the simulations are termed "parcel-DNS" approach.

The simulations are run with 12 different model settings that differ by enabling/disabling coalescence, turbulent fluctuations, solute effects and altering properties of the seeded droplets.

The problems addressed in the paper clearly match the scope of ACP. I concur with the first reviewer that Fig. 7 is a major riddle for the reader. Clearly, the piecewise-linear LWC profile needs to be explained and the "jumps in the statistics" need to be eliminated by deriving spectral properties from the droplet population and not from the binned spectrum.

I list below several other relatively major remarks that warrant requesting a major revision to the simulation protocol, result analysis and the manuscript itself.

1. First of all, I would argue that among all possible choices of the moment to switch on representation of turbulent inhomogeneities (i.e., the switch from parcel to DNS model), the level of peak supersaturation is the most unintuitive one. Numerically, it is likely one of the trickiest points for drop growth solver. Since the solute and curvature effects are resolved in the DNS, why not to benefit and resolve activation, especially as its sensitivity to supersaturation fluctuations is continuously being discussed in literature. It is all the more puzzling as the no-fluctuation activation is coupled with further growth in strongly turbulent environment.

2. The courageous assumption of 1.5 km adiabatic ascent with constant speed calls at least for more discussion on limitations of the study due to lack of representation of entrainment.

3. The numerical experiments presented in the paper lack any sensitivity analysis that would confirm the convergence of the results and quantify their sensitivity to spatial, spectral and temporal resolution as well as to the choice of set-up parameters. For instance, the initial aerosol spectrum is discretised onto a grid of only 39 classes for the parcel simulations, which is a crude resolution. While the Lagrangian-in-radius treatment of particle size evolution is indeed free from numerical diffusion (not dispersion - p5/l117), it is highly sensitive to the spectral discretisation (see e.g. discussion of Fig. 8 in Kreidenweis et al. 2003, doi:10.1029/2002JD002697).

4. Since the simulations feature collisional growth, perhaps it would be beneficial to analyse cloud and drizzle water separately (or is it already the case which could be related to the kink in the LWC profile in Fig. 7?), especially as the authors comment on autoconversion parameterisations. On a related note, the recent work by Noh et al. (2018, doi:10.1175/JAS-D-18-0080.1) is perhaps worth citing when discussing autoconversion rate dependence on spectral parameters (e.g., p8/l198,l204).

5. It would be beneficial to switch from reporting particle concentrations per unit volume to concentrations per unit mass of air, so the variation stemming from diminishing density along the 1.5 km ascent would be excluded. This could also help to understand the difference between the total particle concentration in the log-normal distributions $133 + 66.6 + 3.06 = 202.66\,cm^{-3}$ (in standard T,p conditions?) vs. total initial concentration of $112\,cm^{-3}$ (page 5, lines 112-113).

6. Mentioning seeding in the title of the paper would certainly better convey the focus of the study and, in my opinion, "an in-cloud seeding case study" could well

replace the "parcel-DNS approach" subtitle.

7. A table summarising the simulations would be very helpful. Currently, model description is mixed with the set-up description, while some key parameters are hard to find in the text (e.g., domain size is just given in parenthesis in a sentence on particle concentrations). Also, Table 1 would be more helpful with added "collisions" column and with all 12 simulations listed. Same concerns all mentions of "six experiments" - there are 12 DNS runs.

8. Last but not least, please clarify if the study can be independently reproduced by providing information on the versions of the model code used and its availability.

Other remarks:

- p1/l17: "interaction" $\rightsquigarrow$ interactions
- p1/l34: space before parenthesis missing
- p2/l23: framework $\rightsquigarrow$ frameworks
- p2/l26: "certain microphysical processes" – please be more specific
- p2/l38: "solve" $\rightsquigarrow$ "solves"
- p2/l41: isn't the motivation to reduce the computational cost, rather than to reduce uncertainty? (replacing DNS with a parcel model actually increases uncertainty...), I would suggest removing the whole paragraph actually (lines 41–51)
- p2/l45: "aerosol processing" in some contexts is used to refer to modification of ambient aerosol after evaporation of droplets (due to aqueous chemical reactions and collisions) – perhaps worth rephrasing

- p3/l60: “nuclei ... enhances” ⇝ “nuclei ... enhance” (or “representation of ...”)
- p3/l69: “Section 2.1-2.2” ⇝ “Sections 2.1-2.2”
- p3/l73: “droplet chemistry composition” ⇝ “hygroscopicity”
- p4/Fig2: suggest finding alternative wording for “stairs”, please rephrase the last sentence: “fitting the distributions to the DNS” seems awkward, typo in “processers”
- p5/l109: are four significant digits really necessary when specifying initial RH?
- p5/l118: “thermodynamic equilibrium” sounds puzzling, I suggest following Jensen and Nugent and explaining what is meant: “in equilibrium (dr/dt=0)”
- p6/l136: “aerosol processing” – see comment p2/l45 above
- p6/eq2: drop growth equation (2) implies that supersaturation is defined as $S = e/e_s$ (as in Jensen and Nugent 2007), but in Chen et al. 2018b it is defined as $S = qv/q_{vs}$ – of course numerically almost the same, but perhaps worth clarifying
- p7/l167: why not replacing the inline fraction with just $\kappa = 0$?
- p7/l171: k ⇝ κ
- p7/l166: “turbulent advection of the supersaturation fluctuation” suggests S' is among the advected quantities
- p8/184: “extremely slow”: be more specific
- p8/187: “when” ⇝ “When”
- p8/l192: $o()$ ⇝ $\mathcal{O}()$

- p8/l197: space before parenthesis
- p8/l202: avoid word “claim”
- p9/Fig2: mention in the caption that collisions were enabled
- p11/Figs5-6: mention in the caption that collisions were enabled
- p12/Fig7: mention in the caption that collisions were enabled
- p14/l297-298: remove “which is a major facility”?
- p14/l300-301: rephrase “support from Cheyenne ... and from Graham and Cedar”
- References: use journal abbreviations
- References: most entries have doi/url given twice
- References: if there is a doi assigned, do not list url (e.g.: Skamarock et al., Yang et al.)

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