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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Diffusional growth of cloud droplets in homogeneous isotropic turbulence: DNS, scaled-up DNS, and stochastic model" *by* Lois Thomas et al.

Anonymous Referee #3

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General Comments

This study applies the scaled-up DNS method to simulate supersaturation fluctuations and spectral broadening in an idealized framework of forced, isotropic turbulence. The supersaturation fluctuations are produced by the turbulent vertical motions. Scaled-up DNS is what I would consider to be the simplest possible form of large-eddy simulation. In scaled-up DNS, the molecular diffusivities are increased to maintain the same kinetic energy dissipation rate as an otherwise identical simulation with a smaller grid size. In the present application, the range of scales between the domain size and grid size was maintained. Droplet condensational growth was represented using the super-droplet method. The impact of the droplet multiplicity of the super-droplet method on the simulations was studied. The results (i.e., supersaturation standard deviations) of the scaled-up DNS were compared with those from a stochastic model, and exhibited very good agreement.

Specific Comments

1. lines 36-45: What is described here is not the only mechanism by which supersaturation fluctuations can be produced within a cloud, and probably not the msst important. Entrainment and mixing also produce supersaturation fluctuations and are well-known to be an important source of spectral broadening, and should be mentioned here in order to place the focus of this study in proper perspective. As will be mentioned later, the set-up of the simulations actually implies an external forcing, which could be interpreted as a crude representation of entrainment.
2. lines 46-47: It would be appropriate to refer here to the even earlier study by Su et al. (1998) in which diffusional growth of cloud droplets in a turbulent environment was simulated using the Explicit Mixing Parcel Model, which is essentially a 1D kinematic DNS.

   lines 54-56: Droplet sedimentation was included in the EMPM simulations mentioned.

   Su, C.-W., S. K. Krueger, P. A. McMurtry, and P. H. Austin, 1998: Linear eddy modeling of droplet spectral evolution during entrainment and mixing in cumulus clouds. *Atmos. Res.,* **47–48,** 41–58.
3. line 57: Unclear. What has a "small impact on the droplet spectra"?
4. lines 56–64: State what mean supersaturation was used in these studies.

5. line 65: It is possible to do simulations with larger domains with the EMPM. It would appropriate to mention here that the EMPM simulations reported in Su et al. (1998) used a 20-m domain size, and EMPM domains up to 100-m domains were used in Tölle and Krueger (2014).

   Tölle, M. H., and S. K. Krueger, 2014: Effects of entrainment and mixing on the droplet size distributions in warm cumulus clouds. *J. Adv. Model. Earth Syst.,* **6,** 281–299, doi:10.1002/2012MS000209

6. lines 67–69: Be clear about the source of the supersaturation fluctuations that you are referring to, which vertical gradients of potential temperature, not entrainment and mixing. Noting this also makes the explanation of why large eddies produce larger fluctuations more obvious.

7. lines 69–72: It would also be appropriate to mention the EMPM approach here, because it certainly does perform "DNS-like simulations in computational domains comparable to the size of the LES grid box." Furthermore, the recent development of a linear-eddy based SGS model that is combined with the super droplet method by F. Hoffmann should be mentioned.

   Hoffmann, F. and G. Feingold, 2019: Entrainment and Mixing in Stratocumulus: Effects of a New Explicit Subgrid-Scale Scheme for Large-Eddy Simulations with Particle-Based Microphysics. J. Atmos. Sci., 76, 1955-1973, https://doi.org/10.1175/JAS-D-18-0318.1

   Hoffmann, F., T. Yamaguchi, and G. Feingold, 2019: Inhomogeneous Mixing in Lagrangian Cloud Models: Effects on the Production of Precipitation Embryos. J. Atmos. Sci., 76, 113-133, https://doi.org/10.1175/JAS-D-18-0087.1

8. line 100, Eq. (1): In general, this equation should include a term $w' d\bar{T}/dz$. I suspect that this term is missing because $d\bar{T}/dz = 0$ is enforced due to the cyclic b.c. at the top and bottom boundaries. It this is the case, it should be mentioned.

   It should also be mentioned that forcing $d\bar{T}/dz = 0$ is equivalent to forcing a non-zero gradient of potential temperature, which acts as the source of temperature and supersaturation fluctuations.

9. line 111. Eq. (3): State how changes in R^3 are calculated if not by using (2).

10. line 118: Please state the initial conditions, particular the initial temperature profile, as well as the initial supersaturation profile.

11. Figure 2: It would be enlightening to the readers to discuss how the TKE can be made non-dimensional in terms of flow parameters (a velocity scale specifically).

12. Figures 6–8: Please state whether the supersaturation statistics plotted are at the droplets or everywhere in the flow. They are most useful for understanding the DSD properties if they are at the droplets, as those for the stochastic model are.

13. Figure 7; It would be enlightening to the readers to discuss how σ_S can be made non-dimensional in terms of flow parameters.

14. Figure 9: It would be enlightening to the readers to discuss how σ_{R^2} can be made non-dimensional in terms of flow parameters.

15. lines 272-73: Clarify this sentence: "The fluctuating in space supersaturation in the dynamic simulations (i.e., real DNS or scaled-up DNS) is modelled as independent realizations of the fluctuating in time supersaturation." I am not sure what you mean. Modelled by what? The stochastic model? Also clarify that the stochastic model predicts supersaturation fluctuations at the droplets. (See comment 12.)

16. line 283 and Figure 10: Clarify that the stochastic model predicts supersaturation fluctuations at the droplets.

17. line 317: Please explain why small-scale motions would reduce σ_S.
18. Section 6: It would probably be helpful to many readers to make clear how scaled-up DNS differs from LES. In my view, it is really LES but with a constant eddy viscosity, which is not a good SGS model. Explain why you chose this approach rather than using a better SGS model? I would also suggest that you discuss the advantages and the disadvantages of the scaled-up DNS approach. For the problem addressed, it seems that the stochastic model captures the important physics, and that the scaled-up DNS does not add any additional insights.
19. lines 332-33: I agree with this statement. You may want to mention again other possible methods that have been developed (such as those mentioned in comments 2, 5, and 7).
20. lines 365-6: This might be too general of a statement. The large eddies dominate for this mode of supersaturation fluctuation because they span a larger potential temperature difference for the same mean vertical gradient. For other modes of supersaturation fluctuation generation such as entrainment, large eddies also dominate, but for a different reason (their greater mixing time scale).
21. lines 381-82: "Finally, one can also consider applying scaled-up DNS in simulations of the turbulent entrainment and mixing similar to those discussed in Kumar et al. (2018)." There is a significant drawback for this application of scaled-up DNS due to the importance of the small-scale supersaturation fluctuations in determining DSDs. Such near-Kolmogorov-scale variability is not present in scaled-up DNS.
22.

Technical Comments

1. line 139: It would be helpful to define L_1 and L_2.