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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 #2

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This study uses a modified DNS to investigate the effect of turbulence on the diffusional growth of cloud droplets in much larger domains (up to 64*64*64 mˆ3) compared with traditional DNS. The method is the combination of increasing air viscosity to allow DNS in a larger domain and using Lagrangian particle-based microphysics to lower the number of particles needed to be tracked in a larger domain. Results show that the variance of droplet radius increases with the square root of time, which is consistent with previous studies and the result from a stochastic model. Different domain sizes and multiplicities are also tested to check the convergence of the scaled-up DNS. The paper is interesting. However, I have some comments needed to be addressed before this manuscript can be accepted.

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Discussion paper

Major comments:

1. Running DNS in a larger domain is not new, for example, Rotunno and Bryan (2018) recently applied direct numerical simulation to study lee vortices in a larger domain by setting viscosity as 1 m2/s. Although the combination of this technique and Lagrangian cloud model is interesting, it is not clear to me whether it is suitable to do that, or at least what we can learn from it, for the following reasons:

1.1 When air viscosity is changed, it is unclear to me whether thermal diffusivity is also changed accordingly in this study. If not, the Prandtl number will be different compared with air. It means that this is a fluid that does not behave as air. If yes, this will be consistent with R&B (2018).

1.2 Changing air viscosity and thermal diffusivity will also slow down the condensational growth of cloud droplets following physical rules. But I guess this effect is ignored in this study.

Therefore, the scaled-up DNS in this study simulates a turbulent cloud system that is not similar dimensionless to natural clouds. Therefore, it is unclear to me what we can learn from it. I hope the authors can comment on this.

2. For the same energy dissipation rate, if air viscosity increases, Kolmogorov's length scale increases and therefore a coarser resolution can be used. However, Komogrov's velocity scale also increases at the same time. Larger velocity fluctuation in a larger domain leads to larger supersaturation fluctuation (Figure 7), and thus faster broadening of droplet size distribution (Figure 9). The reason that the variances of droplet size distribution from DNS/scaled-up DNS are consistent with the stochastic model (Figure 10) is that they generate/use the same strength (e.g., PDF) of the velocity field. Therefore, their agreement and the consistency with the tˆ(1/2) scaling law is not a big surprise to me. However, in an idealized homogeneous isotropic turbulent cloud, the velocity (supersaturation) fluctuation should be independent of the volume we choose, meaning that in either a volume of 1 mˆ3 or 10 mˆ3, the energy dissipation rate, Ko-

mogrov’s length scale and velocity scale should be the same. Therefore, it is unclear to me how the simulated cloud in a domain size associated with the increase of Komogrov’s velocity scale, is related to the conceptual cloud with the same large domain with the original (smaller) Komogrov’s velocity scale. Please comment on it.

3. Figure 4 shows that results converge for different multiplications. As stated around line 257 “Note that for real DNS (Table 2 and Fig. 4), having a droplet in one of several dozens of grid volumes still results in supersaturation fluctuations in agreement with real droplets.” However super droplet even with the multiplicity equals to 1 (real droplets) is one out of eight grid boxes, meaning that the density of droplet is low in the domain. Is it possible the evolution of the supersaturation fluctuation shown in Figure 4 is just the background even without droplet? I think a more careful test is to track more particles in real DNS, at least 10 per grid box, and then change the multiplicity but maintain the same number of particles in the domain.

Minor comments:

1. Line 17: “mean droplet radius variance”, should it be “droplet radius variance”?

2. Line 50: “however, see the comment on that paper by. . .” This sentence is not clear to me.

3. Line 101: “K is the molecular diffusion coefficient” should be “thermal diffusion coefficient”

4. Equation 2: I think \delta t should be removed to make sure the unit is correct. Please check.

Reference:

Rotunno, Richard, and George H. Bryan. "Numerical simulations of two-layer flow past topography. Part I: The leeside hydraulic jump." Journal of the Atmospheric Sciences 75, no. 4 (2018): 1231-1241.

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