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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Direct Lagrangian tracking simulation of droplet growth in vertically developing cloud" *by* Yuichi Kunishima and Ryo Onishi

Anonymous Referee #1

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The model design and approach described in this paper are highly creative. The focus of the work is on Lagrangian aspects of precipitation formation through CCN activation, cloud droplet condensation growth, and ultimately coalescence growth. The number of published direct numerical simulations and Lagrangian-particle models is rapidly growing, but the key novelty of this work is the configuration of the simulation domain to have an extreme aspect ratio: 1 cm x 1 cm x 3 km for the main set of simulations. CCN, cloud droplets, and precipitation particles are discrete and tracked in three dimensions within the simulation domain, with condensation and coalescence growth directly calculated. The paper provides several insights into the coalescence growth process, which directly result from the adopted Lagrangian approach. I have suggested a few places

where some additional analysis may provide even further insight, although I realize that this is a first effort in that direction. I anticipate that this type of simulation approach will continue to yield insights into the transition from condensation to coalescence growth, statistical aspects of stochastic condensation, etc. I recommend publication, after the following suggestions have been considered.

Page 1, line 1: "all the warm-rain processes" may be a dangerous thing to say. For example, full hydrodynamic interactions are not represented. Perhaps better to state that "key warm-rain processes" are included.

Page 1, line 5: Euler framework should be Eulerian framework.

Abstract: the meaning of "surface raindrops" may not be clear in the abstract. Later in the paper it is explained, but at least in one place in the abstract, better to define as raindrops that reach the surface.

Page 1, line 21: it would be appropriate to include more citations of work taking a direct tracking Lagrangian approach, e.g., Vaillancourt et al., Wang et al., Kumar et al., Chen et al. J Atmos Sci 2018.

Page 2, line 21: transportation should be transport.

Section 2.2.1: specify the maximum height change, e.g., for the top of mixed layer initially at 740 m.

Equation 3: confusing to use notation F for acceleration. Perhaps f would be more consistent with typical notation.

Page 4, line 31: also should cite other DNS papers where hydrodynamic interactions have been shown to be important (e.g., Wang and colleagues).

Equation 7: the purpose of this stochastic initial radius is not clear. Why not simply grow cloud droplets from the activated CCN size?

Table 2: Specify that "Initial number concentration" refers to initial CCN concentration.

Page 8, line 17: should “homogeneously distributed” be “uniformly distributed”? Particles are not clustered, so I assume they are distributed with uniform probability.

Page 8, lines 23-24: here, reference could be made again to Table 1 so that the vertical gap can be properly understood.

Page 9, line 15: where is Table 4.1?

Page 10, lines 13-15: is there a “remarkable difference”? It is not clear to me what “sharp ridge” is referred to, so please explain more clearly.

Page 11, line 6: provide more explanation of what is meant by “Lagrangian statistics”. For example, path history of collision times and sizes, etc.

Page 11, lines12-14: the observation that raindrops that reach the surface consist of CCN initially found below 900 m does not seem surprising, given that the model has no mechanism for entrainment. If I am missing something subtler, please explain.

Page 11, lines 19-20: This finding is intriguing. It could be interesting to see a pdf of droplet size at the time of first collision.

Page 11, line 22: need to define “Top-1” more clearly, e.g., the first droplet to reach the surface.

Figure 6: this is really interesting because it is clear that eventually the “top-1” drop collects other collector drops. It would be enlightening to see the transition from collection of cloud droplets to collection of collector drops (analogous to autoconversion versus accretion, perhaps). Although it would not show the time history, perhaps a pdf of droplet sizes that are collected by the “top-1” drop would be helpful. This is not required, I am just suggesting that there is more in the results that could be learned here. (Similar is true for the above comment on Page 11, lines 19-20.)

Page 14, lines 22-26: the supplementary movie is fantastic, definitely something I will show to students in the future. I recommend that a different term than “look-up view”

be used. Perhaps “upward-looking view” or “upward view”?

Page 15, lines 7 and 10: I think “statistics on” should be “statistics of”.

Section 5: It might be useful to discuss similarities of this nearly-one-dimensional modeling approach to the one-dimensional turbulence models that have been used in cloud physics calculations (e.g., linear eddy modeling, Su et al Atmos. Res. 1998).

Section 5: It also would be useful to discuss how the simulation approach can be used for future studies of stochastic aspects of coalescence, which have been a topic of recent interest (e.g., Kostinski et al BAMS 2005, Bec et al Phys Rev E 2016, Wilkinson Phys Rev Lett 2016)

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