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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluating the effects of microphysical complexity in idealised simulations of trade wind cumulus using the Factorial Method" *by* C. Dearden et al.

Anonymous Referee #3

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In this study, the factorial method is used in order to evaluate and compare the sensitivity of microphysical schemes of different degrees of complexity to a change in environmental and microphysical properties. Three bulk schemes that differ in the complexity of the activation process representation are tested and a bin model is used as a benchmark for comparison and evaluation. Results show that when the vertical velocity is high, a simple activation representation is enough. At lower vertical velocity the relative sensitivity to the aerosol and environmental factors differ. The method used to evaluate and compare the microphysical schemes is very interesting. The study is limited by the use of a highly idealized 1-D case and a short panel of microphysical schemes tested. I think the following major points should be clarified before publication.

Major points.

1 - Using LES simulations, Jiang et al (2010) show that precipitation rate in cumulus clouds depends on the LWP, the cloud droplet number concentration and to a lower extent the cloud lifetime. Similar relationships between precipitation rate, cloud droplet number concentration and liquid water path or cloud depth have been shown to be valid in the case of stratocumulus clouds from observational and LES studies. In a real cloud, LWP, cloud depth, entrainment rate, vertical velocity, cloud lifetime, temperature are not independent. What do motivate the choices of the parameters that are used for the sensitivity study and those that are kept fixed, in view of the simplicity of the case considered? How much does the change in temperature keeping relative humidity to a constant value impact the LWP?

2 - The bin model is used as a benchmark to compare bulk models with activation schemes of different complexity. I think it should be stated in the abstract that bulk models differ only by the activation representation. Simulations show differences between bulk and bin schemes in terms of intensity of the precipitation flux which, as pointed out by the authors, is probably due to differences in collection efficiencies. A more detailed description of the bulk microphysical scheme should be given. What is used for accretion? Is selfcollection taken in account? A conclusion of the paper is that the differences in the sensitivity to the temperature profile and the CCN concentration can be due to the differences in evaporation rate below cloud base. Can it be due to the differences in the collection efficiencies? Extending the study to the precipitation flux at cloud base or to the evaporation rate in the subcloud layer should give information on the role of evaporation rate in the differences obtained between the bulk and the bin schemes. Could the results be different using another parameterization of the autoconversion and accretion rates? Stevens and Seifert (2008) show that precipitation can be very sensitive to the selfcollection process. It should be stated if this process is taken in account or not because it impacts terminal velocities.

3 - The value 20 microns in radius is used to separate the cloud droplet category and

the rain drop category to compare bin and bulk local mixing ratios and rain water path (Fig 4) whereas the KK scheme assumes a separation radius of 25 microns.

4 - Fig 5 is an interesting plot that show the evolution of the μ profile. First, how is μ calculated? Secondly, I think a Log-scale should be used for the color bar. It would give a better idea of the typical μ values encountered. Indeed, the sensitivities of terminal velocities to μ increases when μ decreases (e.g. fig 7 in Stevens and Seifert, 2008). For values of the order of 10 and above, the distribution is close to a monodispersed distribution. Moreover, is the precipitation flux significant everywhere the value of μ is shown? (I think a threshold should be used if it is not the case). What is the reason of the discontinuities in μ values at the beginning of rain formation?

Minor points

5 - I am also wondering why the liquid water content reach its peak value in the lower part of the cloud. The reason of this feature should be pointed out. Moreover, why doesn't the LWP decrease at the end of the simulations in Fig 3 because of evaporation?

6 - P23499, L24; P23503, L17; Table 3: "number" should be replaced by "number concentration".

7 - P23499, L 5, I would change the formulation "warm clouds are particularly sensitive" to "warm clouds physical properties are particularly sensitive". I would change the formulation "liquid water content of trade wind cumulus" because a LWC is a local value. I would change the construction of the sentence because the second part still refer to the Albrecht hypothesis.

8 - P23499, L17, L18, what is "warm convection"?

9 - P23499, L21, "unresolved by the model grid": not well formulated.

10 - P23499, L24, "of the 1st indirect effect": would "of the aerosol indirect effect" or "of the 1st and 2nd aerosol indirect effects" not be better?

11 - P 23500, L 1, "bulk scheme assume a functional form of the hydrometeor size distribution". This is not always true. For instance the KK collection parameterizations are tuned using spectra from bin simulations. There is no assumption of an analytical distribution.

12 - P 23502, L19-26, I would add van Zanten et al (2010) as a reference for the GCSS BLWG RICO intercomparison exercise.

13 - P 23503, L23, I suggest to add a reference for the gamma distribution.

14 - P 23504, L12, "is used to represent the cloud liquid water (the mass mixing ratio), and the droplet number concentration is taken as a constant in the calculation of the intercept parameter in Eq (2)". This is a bit confusing: is there a process that necessitates a distribution hypothesis for cloud water for the 1-m scheme?

15 - P23504, In equation (4) N is the CCN concentration rather than the cloud droplet concentration.

16 - P 23504, L3, I would had Marshall and Palmer (1948) as a reference for the exponential distribution.

17 - P 23503, L10, The KK scheme has been tuned to spectra from LES simulation with a bin microphysical scheme of stratocumulus-topped boundary layers with maximum local values of the liquid water content of the order of 1 g kg-1.

Technical comments

- I would use one typography to write units (e.g. m/s and ms-1, cm-3 and /cc)

- P 23501, L7, spelling: "analsyed"

- P 23502, L1; L7 "Köhler" and not "Kohler"

- P 23512, L27, spelling: "precipiate"

- Table 3: units are missing for CCN.

References

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