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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 #1

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General comments

This article evaluates the sensitivity of microphysical outcomes (predominantly surface precipitation rate and accumulation) to environmental factors for a series of successively more complicated microphysical parameterizations. The authors employ the factorial method (FM) to quantify contributions to the sensitivity of individual factors. The research methodology is sound, and the article is concise and well organized.

The dynamical framework is exceedingly simple and is, as far as I can tell, completely equivalent to the KiD-driven framework used in the GCSS microphysical intercomparison. The simplicity is by design, in order to enable a consistent dynamical forcing across all the microphysical schemes and to isolate differences in simulation outcomes arising purely from different microphysical and environmental responses. Dynamical feedbacks are not considered. So given that the simple methodological framework is consistent and logically constructed, to what extent are the results meaningful for real boundary layer clouds? Specifically, how might dynamical feedbacks amplify or damp the sensitivities exhibited in this study? (The latter is more likely in my opinion.) The authors should speculate, as rigorously as possible, on how dynamical feedbacks will influence the microphysical sensitivities they present. The paper mentions the neglect of entrainment, and that discussion should be expanded and extended more generally to feedbacks between dynamics and precipitation (and microphysical processes in general).

The factor separation analysis focuses entirely on precipitation rate; yet other quantities are just as important, for example cloud and rain drop concentration, liquid water path, cloud optical depth, and effective radius. With the in-depth discussion of the dependence on precipitation rate, a similar analysis applied to N would be interesting. Why does the paper not include any analysis applied to these other quantities? (I do appreciate the paper's concision.)

Specific comments

Page 23499, lines 5–6. "... changes in aerosol concentration could have important consequences for weather and climate, through modification of the liquid water content of trade cumulus." This begs for a citation or two, especially since the two indirect effect papers are cited earlier in the sentence.

Page 23499, line 26. "...has become feasible to include indirect effects on warm convective clouds..." This seems like odd wording that would better apply to GCM cloud parameterizations, where the AIE effects are highly parameterized (almost imposed). In the microphysical schemes like those tested in the paper, the AIEs are actually represented by the interplay of microphysical, dynamical, and radiative processes.

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Page 23500, lines 16–20. Isn't Stein and Alpert (JAS 1993) typically cited when referring to the factorial method? I notice that Dearden (2009) doesn't cite SA93, either. I leave whether to cite SA93 up to the authors' discretion.

Page 23503, lines 11–12. KK scheme tuned to bin microphysical simulations. More specifically, the microphysical process rates in KK are formulated via multiple nonlinear regression of simulated spectra.

Page 23503, lines 20–21. "...2–m rain schemes with an invariant shape parameter can suffer from... excessive size sorting." Yet this study assumes μ=0 from the beginning. Why?

Page 23503, line 22. "...both rain and liquid..." There are a couple instances of cloud water referred to simply as "liquid," rather than cloud water or cloud liquid water. The distinction between the cloud and rain categories should always be clear.

Page 23507, lines 3–13. rationale for $\tau \sim 1/w$. This timescale is sensible for a Lagrangian framework, but why does it apply in an Eulerian sense? I could not track down the Shipway and Hill paper (QJRMS draft).

Page 23508, Sec. 3.2. The authors should emphasize the lead author's nice write-up in Dearden (2009) for a more comprehensive discussion of their factorial method approach.

Page 23510, line 22. T=RICO. This manner of denoting the temperature profile is not consistent with the other two parameters, which are dimensionally consistent.

Page 23511, line 1. A 40 micron diameter threshold for rain drops is quite small for robust cumulus clouds. The RICO intercomparison used 80 microns. Why was 40 microns used?

Page 23511, lines 9–20. I really like this paragraph and Fig. 5.

Page 23513, line 19–20. Calculation of the relative contributions of each factor. This

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will be more clear if the factor separation methodology is more thoroughly explained earlier (or includes the Dearden 2009 reference, as mentioned above).

Page 23514, discussion ending at lines 21–23. The lack of sensitivity at large vertical velocity values boils down to the fact that by some threshold value of w, all the CCN are activated, right? This concept is straightforward, but it needs to be more explicitly stated.

Page 23517, lines 14–18. Balance between complexity and computational cost. These statements are a wonderful “bottom line” of this study, subject to the caveat of no dynamical feedbacks.

Page 23518, lines 5–17. The comparison of bin schemes in this study, and the results from the RICO intercomparison, suggest that a single bin-microphysics solution cannot be thought of as the truth or used as baseline for verification of bulk models.

Page 23618, lines 19–22. Putting ACPIM bin microphysics into 3D LES. I don’t see how this comment applies to the study. Adding this bin microphysics scheme into 3D LES will no doubt be useful, but then it will be no different in principle from any other 3D LES models. And dynamical effects can be included without going to a full 3D LES.

Technical comments

Axis and legend labels on some of the figures, particularly the multi-panel figures, are woefully small. Additionally, the multi-panel figures are not put together very artistically (small labels; no (a), (b), (c), etc.; lots of white space between panels).

The manuscript contains some odd punctuation choices. For example, a comma should follow “However” on line 18 of p. 23499. A thorough final read-through should catch these.

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