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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Microphysical process rates and global aerosol-cloud interactions" *by* A. Gettelman et al.

Anonymous Referee #1

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In this manuscript, the authors examined microphysical process rates in global climate models and investigated how their relative contributions to rain formation (in particular, the relative roles of autoconversion vs. accretion) affect aerosols-clouds-precipitation interactions. A steady-state model is further used to explore how differences in microphysical treatment of rain formation may affect the relative contribution of autoconverion and accretion, and further on precipitation susceptibility to aerosols. Simulated autoconverion rate, accretion rate, and the ratio of autoconversion/accretion are also compared with VOCALS observations. This is a timely study, as the community starts to focus more on process understanding of microphysical processes in determining aerosol indirect effects in both models and in observations. This detailed study of microphysical processes in global climate models provides many useful insights on

how different microphysical processes balance each other and how they further impact aerosol indirect effects in CAM5. This represents a step forward in better representing aerosol indirect effects in global climate models. The manuscript is also well organized, and written. I therefore recommend its publication after some minor clarifications:

Page 11794, Figure 1, microphysical rates: Is "Liq sed" the sedimentation of cloud droplets? It would be a surprise that the sedimentation of cloud droplets is the dominant process over S.E. Pacific. This is also true over W. Pacific below 900mb. Any explanation?

Page 11794, Section 3, steady state model: Please provide the basic input parameters used for the steady state model, like what is cloud height, and replenishment rate. I would think the results shown in Figure 2 are those after the model reaches the steady-state. How about Figure 3? Does Figure 3 show the evolution of cloud water before it reaches the steady-state? What do the individual points represent? Also, in the base case and DiagQr, why do Ac/Au (Figure 3a) and Ac/Rain (Figure 3b) seem decrease with increasing LWP for individual lines?

Page 11796, Eq. (3): The authors used Eq. (3) to "mimic" diagnostic rain scheme typically used in global climate models. Here rain water used for collecting cloud droplets is replaced by "rain water" generated just through the autoconversion process. I feel this may oversimplify how diagnostic rain schemes typically work in GCM. GCMs typically have a time step of 20-30 minutes. In diagnostic rain schemes used in GCMs, the time dependence term is set to zero. Rain water is then diagnosed through the balance between rain generation and rain sedimentation (typically through multiple iterations). So the "rain water" used for collecting cloud droplets is not the same as the rain water directly generated through the autoconversion. Also, as the time step in the steady-state model is much shorter (5-30 seconds) than a typical GCM time step (20-30 mintues), I would think the "diagnostic" assumption (i.e., time dependence term is zero for rain water) in the steady-state model is even more problematic than in GCM. The much smaller Ac/Au ratio in this case (0.001 to 0.01 Figure 3a, DiagQr) than that in CAM5

(10 to 0.5) seems also suggest that Eq. (3) oversimplifies how diagnostic rain schemes works in GCM. I would still think this is an interesting test, but some clarifications on how realistic this can “mimic” diagnostic rain schemes in GCMs will be helpful.

Page 11797, line 5, nearly constant Sp (close to the exponents for Autoconversion), especially in the basic model: For example, at LWP=400 g/m2, the Au/Rain is less than 0.1 for the basic model. As here Autoconverion only contributes less than 10% to surface precipitation rate, I would think Sp will be smaller, but it is still very larger (close to 2.0). Any explanation? Also, how is Sp calculated for the steady state model? Does this base on the steady-state value only, or includes all values during the evolution before it reaches the steady-state?

Page 11799, Figure 5d, e, f: Further sorting data into different LWP bins may provide better insights on the relationship between AOD and autoconverion, accretion, and AU/AC ratio, as LWP is the primary macrophysical controlling factor.

Page 11800, line 21: Spop (the susceptibility of precipitation frequency to aerosols) is argued to be a better metric for cloud lifetime effects of aerosols than Sp (Wang et al., 2012), as Spop is more related to auconverion process (Au/R ratio), while Sp is more relatd to Ac/R ratio.

Page 11806, lines 3-15: the link between Sp shown in Figure 10 and microphysical rates shown in Figure 9 seems not that clear, as the authors also mentioned in the abstract. As Sp is influenced more by accretion, Spop may be a better alternative. Some discussions on this may be helpful.

Page 11894, Figure 9: It will be interesting to see how Au/R looks like in these different experiments, as Au/R ratio includes ice processes as well and therefore may be a better measure of how autoconverion contributes to the sink of cloud water.

Page 11791, line 9: One of the challenges in satellite studies is about establishing causation, as the authors noted later that correlation does not necessarily imply cau-

sation. There are some debates in literatures regarding the approach used in Quaas et al. (2008). Quaas et al. (2008) used the relationship of dlnNd and dlnAOD from satellite observations to establish the functional dependence of Nd on AOD, and then used them to estimate first aerosol indirect effects from satellite observations. However, using a global climate model, Penner et al. (2011) showed that dlnNd/dlnAOD derived from present day simulation often strongly underestimate the true dlnNd/dlnAOD derived from the difference of preindustrial and present-day simulations.

Page 11794, Figure 1: So the red bold solid line is for “MP Liq” (the total microphysical tendency)? But in the legend shown in Figure 1a, “MP Liq” is shown as red thin sold line.

Page 11800, line 26, rain rate unit: it will be more readable if the unit is mm/day. Also, it seems the rain rate threshold is till not large (If I convert it correctly, it is 0.0004 mm/day), so not sure why it is “significant rain rates”.

Page 11806, Sp in Figure 10 (and Figure 7), it this based on warm clouds only, or both warm and cold clouds?

Penner, J. E., L. Xu, and M. Wang (2011), Satellite methods underestimate indirect climate forcing by aerosols, Proceedings of the National Academy of Sciences of the United States of America, 108(33), 13404-13408.

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