Atmos. Chem. Phys. Discuss., 13, C5586–C5592, 2013
www.atmos-chem-phys-discuss.net/13/C5586/2013/

Atmospheric Chemistry and Physics Discussions

ACPD
13, C5586–C5592, 2013

Interactive Comment

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

A. Gettelman et al.

andrew@ucar.edu

Received and published: 7 August 2013

Replies to Anonymous Referee #1

» We thank the reviewer for their time and attention to this manuscript, and for their detailed comments. We have clarified the text in many places as suggested by this and the other reviewers, and redone a few of the figures. Results have been changed by being more consistent with application of pre-microphysics liquid water path, which was not used in the earlier draft for the GCM susceptibility figures 7 and 10. The revised figures are more consistent with previous work. We have eliminated figure 8 from the previous draft, which will help simplify and clarify section 5 as requested by the reviewers: this section will be totally rewritten. We have also added error bars to these susceptibility figures, which will clarify the significance of the results and differences discussed. We have also investigated further the use of the probability of precipitation (POP) as a metric as suggested, and comments on that are contained below.

We think in the revision, with the comments detailed below, we will have satisfied all the major reviewers' concerns. In particular, we have rewritten section 5 and made the changes suggested by Reviewer #3, which we think will address the broad concerns of this reviewer about readability. We have eliminated a figure (figure 8) from the original draft as part of trying to shorten and clarify the manuscript as suggested.

Detailed replies to be implemented in the text are contained below. These are incorporated in a revised draft that per ACP policy will be uploaded separately.

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 dom-

ACPD
13, C5586–C5592, 2013

inant process over S.E. Pacific. This is also true over W. Pacific below 900mb. Any explanation?

» Yes, it is liquid sedimentation. It occurs because large scale condensation creates condensate, and it slowly settles in a few layers while autoconversion and accretion act. It does not continue to the surface (as an alternative precipitation mechanism). This has been clarified in the text.

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.

» Added

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?

» Figure 3 presents steady state solutions. Noted in the text at the end of the first paragraph of section 3.

What do the individual points represent?

» Individual simulation results. Noted in the text at the end of the first paragraph of section 3.

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?

» The 'lines' represent variations in drop number for a given height. As drop number increases for fixed cloud height, autoconversion decreases relative to accretion as expected. Noted in the text.

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

ACPD
13, C5586–C5592, 2013

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.

» We agree that this is a simplification. We have added words to this effect and tried to clarify the text. In particular, we note that while the value of the ratio changes with timestep (which might be expected), it is the change in the slope with LWP and the susceptibility that is fundamentally different (and we show is more like the GCM).

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?

» Sp is calculated once the model reaches steady state. Sp is defined on page 11795, line 21 as the sensitivity of precipitation (rain rate) to drop number = -dln(R)/dln(Nd). Autoconversion seems to fall off faster than Sp does, probably due to the scatter in the simulation results (in Figure 3b. This is clarified now in the text.

ACPD
13, C5586–C5592, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

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.

» This is a good idea. We examined this by adding LWP thresholds fro Figure 5 D-F. For a range of LWP bins, the plots are qualitatively the same, and thus the relationships are robust across a wide range of LWP. This is now noted in the text.

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.

» Spop was investigated as a metric, but the definition is a bit problematic in the GCM because of the need to average over time, and average in non-precipitating cases. This destroys the local relationship between rain and process rates, as different situations need to be averaged together in either space or time to construct points for the regressions. We have made plots of Spop, and they look similar to results in Wang et al 2012, but we do not think Spop is really appropriate for process rates. We do not see closer correspondence between Spop and the process rates (Au/R) than with Sp. We note this now in the text. We have tried to focus on multiple metrics (Au/R, Ac/R) as well that might be related to drop number and aerosols.

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.

» Reduced slope of the Ac/Au ratio for the QrScl Case and the Ac*10 case in Figure 9 seems to correlate with reduced Susceptibility change in Figure 10. This is consistent with effects on accretion. This is clarified now in the discussion (slightly later, pg 11807, line 2). We do not think Spop is better alternative, given the dependence on the

ACPD

13, C5586–C5592, 2013

averaging noted above. We mention (but do not show) the Spop relationship

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.

» We have re-plotted figure 6 for sensitivity cases shown in Figure 9 Accretion/Rain is lower and Autoconversion/Rain is higher for those simulations with boosted accretion and lower sensitivity. Peak in Ac/R is shifted to higher LWP. Au/R increases more with lower susceptibility. We have noted this in the text. The problem with including such a figure, as we also note in the text now, is that altering accretion changes LWP and this affects ratios that are a function of LWP. So this may not be the best metric. Now noted in the text.

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 causation. 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.

» Text added to the introduction.

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.

» Should be thick. Corrected.

Page 11800, line 26, rain rate unit: it will be more readable if the unit is mm/day. Also,

ACPD

13, C5586–C5592, 2013

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”.

» Whoops. The paper stated the wrong unit. The threshold is in m/s, and the analysis code is correct. This corresponds to 0.43 mm/day. Noted the other unit in the text.

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

» Warm. Now noted in the text.

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.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 11789, 2013.