Atmospheric Chemistry and Physics Discussions

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Comment on acp-2021-542

Anonymous Referee #2

Referee comment on "What rainfall rates are most important to wet removal of different aerosol types?" by Yong Wang et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-542-RC2, 2021

Summary:

In this study, the authors investigate the effects of rainfall frequency and intensity on aerosol wet deposition in versions of CAM5 with the default deep convection scheme and a new stochastic scheme. The authors present an approach to identify the rainfall rates are most efficient for the wet removal of aerosol particles, which is different for Aitken, accumulation and coarse modes, and depends on latitude and land vs ocean. Stochastic convection tends to increase the scavenging amount mode. Of particular interest, is that the rain rates associated with the most scavenging are smaller than the rain rates associated with most rainfall, indicating frequency is more important than intensity for aerosol removal. The reduction in precipitation frequency with the stochastic scheme contributes to higher aerosol concentrations.

Overall, the manuscript presents unique research investigating the mechanisms controlling atmospheric scavenging of aerosols by precipitation. It is well motivated and the writing is clear. The methods and results are novel and will be of interest to readers of Atmospheric Chemistry and Physics. This work should be acceptable for publication after revision, which includes additional observational comparison and addressing the major/minor comments below.

Major Comments:

1. The stochastic deep convection scheme should be described in more detail and contrasted with the default ZM scheme. It is introduced on line 122 with no explanation of

how it is works and how the reader would expect the results to differ from ZM. I suggest adding a paragraph describing the scheme and providing insights into how the reader might expect it to influence aerosol removal processes.

2. How does the TRMM definition of convective and large-scale precipitation compare to the CAM5 definition of convective and large-scale? Do they mean the same thing in the observations and model? In other words, if you applied the same criteria used to partition TRMM into convective and large-scale components to the partitioning of PRECT from CAM5, would you recreate the same results as PRECC and PRECL? I'm not sure that you would, but this is something that would be worth trying in order to justify the comparison in Figure 1.

3. Precipitation observations are presented (GPCP and TRMM), but are there any observational constraints on wet deposition that could be used in this analysis? Reference is given to Wang et al. that has shown that suppressing the too frequent occurrence of rainfall in the light intensity range matches AOD observations, but it would be useful to show that here as well. This would help the reader understand if the increase in concentration with STOC shown in Figure 12 is more (or less) realistic when compared to observations. And is there potentially an observational dataset that specifically assesses wet deposition to take this evaluation further?

4. In a longterm climatological average, one would expect the sources (emissions) to be about equal to the sinks (wet and dry deposition) of aerosol. Therefore, a difference in total wet removal between CAM5 and STOC would likely be balanced by differences in dry deposition. The burden and lifetime may differ between versions, but if the climate isn't changing over the course of the simulation, the sources and sinks should be in balance. Since aerosol emissions are the same (at least for POM and BC) in CAM5 and STOC, the sinks should be the same. A large difference in total wet removal would imply there is a corresponding difference in dry deposition. Have dry deposition differences been quantified?

5. In addition to considering the removal of aerosols, more is needed to contextualize the formation of aerosol in the atmosphere. Sulfate is produced interactively in the model through gas-phase and aqueous-phase secondary production, as well as direct emissions. The production of sulfate aerosol is highly dependent on aqueous chemistry in particular, which may be changed with stochastic parameterization and cloud water availability. This can contribute to differences in concentrations and removal as well as the precipitation characteristics. There may be unexplored implications of the intensity and frequency change of precipitation in the stochastic model for aqueous chemistry and resultant removal of sulfate aerosols relative to the production. Are there differences in sulfate production in the two configurations of the model assessed here?

Minor Comments:

Lines 64: Add a comma: “With the sensitivity tests, by artificially…”

Lines 69-70: Suggested: “it is not clear yet what rainfall rates contribute to the most aerosol wet deposition climatologically.”

Lines 79: Suggested: “how much does convective...”

Lines 86: Suggested: “In section 3, precipitation characteristics, especially for amount distributions (defined by daily cumulative rainfall), in two simulations are presented first and evaluated with observations.”

Line 135: Suggest adding the Pendergrass and Hartmann, 2014 reference here as well.

Pendergrass, A. G., and Hartmann, D. L. (2014). Changes in the Distribution of Rain Frequency and Intensity in Response to Global Warming, Journal of Climate, 27(22), 8372-8383.

Line 150: Since "aerosol wet scavenging" is not part of equations 1-3, suggest removing this statement here. It should be associated with equations 4-6.

Line 168: "synergy" is not the right word here.

Line 206: Along the lines of the major comment above. Is the partitioning between convective and large-scale in the observations consistent with the partitioning in the model?

Line 216: Suggest adding the Kooperman et al. 2018 citation here.

Line 239: It might be better to write this as f = P/R to indicate how f is calculated, since no equation is shown for that earlier.

Line 242: This sentence "Over the tropics, ..." is confusing and difficult to follow, suggest revising.

Line 261: Much of the discussion in this section focuses on the tropics, more attention could be paid to extratropical precipitation as it contributes to the regional nature of precipitation changes between CAM5 and STOC (i.e., Figures 5, 6, 8, and 9 could be described further).

Line 362: As this follows the definition of amount median for precipitation used in Kooperman et al. 2018, suggest citing that here.

Line 420: Suggest changing GCM to CAM5 here. Since no other models are assessed here and this issue is somewhat a result of model formulation, it is not clear if it will be the same in other models with different formulations of wet removal.

Line 397: PM2.5 was previously mentioned in the introduction as motivation. What are the implications of this research in regard to surface air pollution? Do the authors have some insight as to the nature of the representation of wet deposition on the size distributions relevant to PM2.5? Discussion of this in the conclusion section would help connect to the motivation/introduction.