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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Uncertainty assessment of current size-resolved parameterizations for below-cloud particle scavenging by rain" *by* X. Wang et al.

Anonymous Referee #1

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General Comment:

This article by Wang et al. provides a review of current parameterizations for below-cloud particle scavenging by rain. This includes an interesting comparison between below-cloud scavenging coefficients predicted from the parameterizations, and field/laboratory measurements. The article also investigates the impacts of various parameterizations on predicted particle bulk concentrations, and size distributions. The results of this investigation are helpful towards improving the representation of below-cloud scavenging in global models. The following points should be addressed before consideration for publication.

Major Points:

Sections 2 and 3 of the article give considerable attention to showing how different formulations for 1) raindrop-particle collection efficiency, 2) raindrop number size distribution, and 3) raindrop terminal velocity, lead to differences in the predicted scavenging coefficients. The main point seems to be that the predicted scavenging coefficients are sensitive to differences in the assumed collection efficiency and raindrop number distribution, which can change the scavenging coefficients by up to one order of magnitude, and a factor of 3-5, respectively. Section 5 seems to be rather discontinuous with this earlier discussion. I would suggest modifications to Section 5 to indicate more clearly how the sensitivity of the scavenging coefficients to the factors discussed in Section 2 and 3 (and the abstract) relates to the predicted changes to the aerosol concentrations and distributions examined in Section 5. These changes to the predicted concentrations and distributions appear to be primarily related to the choice of parameterizations that are an empirical fit to field data, as opposed to theoretical calculations. The introduction should be strengthened to explain more clearly that the study will also consider parameterizations that are empirical fits to field data, in addition to the parameterizations based on theoretical calculations, which are the focus of Sections 2 and 3.

Specific Points:

1) Page 2505, line 25 states that there have been no specific analytical expressions recommended. Section 4 starts with a reference to analytical formulas. Could the authors clarify this sentence in the introduction?

2) Page 2508, line 10, and page 2509, line 6, refer to the Slinn (1983) equation as a “semi-empirical approximation”, and an “analytical expression”. Is this consistent wording?

3) Could Figs. 1, 2, 4, and 6 be presented in Section 2? It might be helpful to see those plots during this earlier part of the discussion.

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4) Sections 2.1 and 3.1 discuss the Slinn parameterization for collection efficiency, and the alternative of a constant efficiency. How do these parameterizations compare to the collection efficiency expression given in Park et al. (2005), based on Jung and Lee (1998), and also the efficiencies used in Croft et al. (2009)?

5) Page 2515, line 6, how do the results change with particle density?

6) Page 2516, line 1, explains that smaller raindrops are more efficient collectors since they fall slower and there is more time for interactions with nearby particles. I thought that the definition of collection efficiency was time-independent – can you clarify this point?

7) Page 2516, line 12, quantify what is meant by 'significantly enhance'. In the abstract I think this is the one order of magnitude uncertainty in the scavenging coefficients attributed to collection efficiency, but I missed this in the Section 3.1 discussion. Also, I am still not sure if I am convinced whether this is truly an uncertainty, or just a difference related to a more complete, versus less complete description of the collection efficiency. Can you explain why you choose to call this an uncertainty?

8) Figure 3, what causes the scavenging coefficients to increase for particles larger than 10 μm?

9) Page 2517, lines 9-12, quantify what is meant by 'many fewer; and 'not as large' and 'wider'.

10) Page 2518, lines 20-21, quantify what is meant by 'different representative drop diameters'. How much change in the representative diameter do you mean, and by how much does the scavenging coefficient change?

11) Figure 5, what causes increased differences between the parameterizations for particles larger than 10 μm?

12) Page 2518, line 23, do you mean 'very close' to each other, or to the other parameterizations?

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13) Page 2519, line 15. A rainfall intensity of 1mm/h was chosen. How do your results differ for more extreme rainfall intensities, such as 0.1 or 50 mm/h?

14) Page 2520, line 25-26, quantify what is meant by ‘very fast’, ‘quite fast’ and ‘slowest’.

15) Page 2522, line 16, suggests that turbulence was also be an important process to consider. How does this relate to the work of Vohl et al. (2000)? I thought that turbulence may not be important for larger collectors such as raindrops.

16) Page 2523, line 12, suggests the need for new measurement data. Can you comment on whether this new data should be focused on laboratory or fieldwork? Since field observations inherently include all physical processes, do we need to be careful in deriving empirical parameterizations from field observations for use in large scale models that already include those additional physical processes separately?

17) At the start of Section 5 there are few details about the model that you used. Could you provide a few additional details about the time-step, number of aerosol bins, and a general model description.

18) Does the treatment of the aerosol size distribution introduce any further uncertainties? If a bin model is used, does the number of bins influence the predicted scavenging?

19) Section 5 gives results for a rainfall intensity of 1 mm/hr. How would your results change for more extreme rainfall intensities, both lighter and heavier?

20) The abstract states that predicted particle concentrations differ by more than a factor of ten, but I did not find this explicitly stated in Section 5. Please check this. Also, the factor of 10, or more, does not seem to be related to the uncertainties in the 3 dominant factors in the theoretical formulations of the scavenging coefficient. Rather, this seems to be related to choosing an empirical fit based on field measurements versus using theoretical formulas. I think that this source of the discrepancy should be

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more clearly pointed out in the abstract.

21) Page 2524, line 27, can you give the primary cause for the largest differences that are found for ultrafine and coarse particles? Also quantify here what you mean by ‘largest differences’.

22) Page 2525, line 4, could you check with your model whether the scavenging for 0.01 – 3 μm was important for long-lasting or very heavy rainfall? The second last sentence of the abstract seems to refer to this point, and also again in the conclusion. I think this should be examined further in this section if the result is in the abstract.

23) How would results using the scavenging parameterization of Bae et al. (2006) compare to the results shown in Figures 9 and 10?

24) Page 2526, line 4-5, I think that the conclusion should point out that this under-prediction related to field data was not seen in comparison with the in-door laboratory data, and should also mention that the additional known physical processes (transport, mixing, cloud and aerosol microphysics) that influence field data are not included in the theoretical calculations. This makes a fair comparison between field and theoretical calculations difficult.

25) Page 2526, line 9-10. I am not sure that the findings can support the conclusion that ‘new collection mechanisms need to be identified’. As you point out, the results in this article, and previous work that you present (Andronache et al. (2006), Sparmacher (1993)) seem to suggest that models need to include additional physical processes to make a fair comparison with field data, as opposed to exposing deficits in the understanding of the below-cloud scavenging process itself.

26) Page 2526, line 10, can you explain why turbulence might be important for collectors as large as raindrops?

27) Page 2526, line 14, what do you mean by ‘overall below-cloud scavenging’? Do you mean the overall change to the aerosol distribution?

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28) Page 2526, line 23, can you explain what you mean by ‘new collection mechanisms’? Is there some aspect of the impaction scavenging process itself that we are missing? Or do we need to better understand how the other various physical processes (transport, mixing, aerosol and cloud microphysics) additionally influence the aerosol concentrations and distributions?

29) Page 2527, last paragraph, this is an interesting point related to time-step. It seems that you have conducted some sensitivity tests. Would it be possible to include any of these results in an earlier section?

30) A more general question, do you think that the term ‘below-cloud scavenging’ or ‘impaction scavenging’ is better suited to this process, since particle scavenging by rain could also occur in clouds?

31) Based on their work, could the authors make any recommendations in regard to a preferred approach for the representation of below-cloud particle scavenging in large scale models?

32) Table 2: explain acronyms MP, DE and FL.

33) Figure 5: explain acronyms listed in legend.

Technical corrections: 1) Page 2524, line 26, ‘precipitations’ → ‘precipitation

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