Atmos. Chem. Phys. Discuss., 6, S441–S444, 2006
www.atmos-chem-phys.org/acpd/6/S441/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "A parameterization of size resolved below cloud scavenging of aerosols by rain" *by* J. S. Henzing et al.

Anonymous Referee #3

Received and published: 4 April 2006

General comments:

The authors present a parameterization for scavenging of aerosols by impaction with falling rain below clouds. The explicit formulation of this problem has already been worked out in the literature. As described by the authors, the scavenging coefficient can be computed with an explicit equation for the volume swept by a falling rain drop. However several aspects of the problem remain intractable (at least for models that cannot resolve aerosol/cloud microphysics), so the authors apply previously published empirical expressions for the rain drop size distribution, the rain drop fall velocity, and the rain/aerosol collection efficiency. Concluding that the resulting integral expression for the scavenging coefficient is still too intensive for a global model, they then fit a parametric equation to the semi-empirical solution in order to further simplify the computation. The parameterization allows for variations in the size of aerosol particles, and also includes as assumed rain drop size distribution. The scheme thus provides some added realism compared to more simplified bulk schemes included in many models, and therefore may be a significant improvement. The authors note some persistent problems with scavenging in global models owing to the inability of such models to resolve rain microphysical processes. This paper is appropriate for publication in ACP following revisions to address some issues raised below.

Specific comments:

1. Because the coefficients for equation #4 are not included, there is insufficient information provided for a reader to implement the scheme. A minimum requirement for publication should be that an interested reader can fully implement the parameterization introduced in the paper.

2. The authors give the impression in their introduction that impaction scavenging below cloud has been mostly ignored (p.1357 lines 6-12). This is not the case. In fact, in the reference list of the paper are examples of studies using schemes ranging from simple bulk parameterizations (Balkanski et al. 1993 - some authors are left out of the reference in the paper) to size-resolved schemes similar to the authors' (Andronache 2003). The authors should be more complete here. Can the authors draw some conclusions about how their scheme may compare with others? A more challenging question: in light of the fact that global models cannot resolve the size distribution of aerosols or rain drops (section 5 of the paper), and cannot resolve the mesoscale distribution of rainfall (see next point below), can the authors mount an argument based on the literature or the performance of their own model that a size-resolved scavenging scheme is more accurate than a bulk scheme?

3. There is a large source of uncertainty in all impaction scavenging computations with global models, which is not mentioned by the authors. Impaction scavenging will

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depend strongly upon the fraction of the model grid column containing precipitation. At present, there is no good theory for determining the raining fraction, except for precipitation from cumulus convection in models with convection parameterizations that predict vertical velocities. For a variety of reasons, it is likely that most models underestimate the precipitating fraction (Wilcox and Ramanathan, 2004). In section 3.2.1 the authors should describe how the TM4 model determines the fractions Vi in equation 5. I think some discussion in section 5 is also warranted that comments on this source of uncertainty.

4. The authors refer to impaction scavenging as ‘below cloud’ scavenging, as many others have, although impaction scavenging can act inside a cloud if there is interstitial aerosol. The authors remove the possibility of impaction scavenging within clouds by assuming, as others have, that all of the aerosol within the cloud is already in the aqueous phase (presumably by nucleation scavenging). For many regimes, particularly continental cases and even polluted marine cases, this assumption may not be accurate. Is it possible that the authors have underestimated the amount of aerosol removed by impaction scavenging because of this?

5. To evaluate their model, the authors compare the amount and residence time of sea salt to quantities from other models (section 4). Are there values from observations that can be compared as well? If so they should be quoted here.

6. P.1366, lines 23-25 states “Ěsix models Ě sea salt lifetime for the whole size range is 2.1 days (varying between 0.8 and 4.55 days).” Is this range the spread of results among the six model, or the spread from large to small particle sizes? If the former is true and 2.1 days is the average of the model estimates, then this should be clearly stated. If indeed the models differ so much, can the authors draw any conclusions about how the differences in model formulation of scavenging may contribute to disagreement between models? Again, some comparison with observed values would substantially improve this section of the paper.

References:

Balkanski, Y. J. et al., J. Geophys. Res. 98, 20,573-20,586, 1993.

Andronache, C., Atmos. Chem. Phys., 3, 131-143, 2003.

Wilcox E. M. and Ramanathan, V., Tellus, 56B, 435-450, 2004.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 1355, 2006.

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