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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Strong sensitivity of aerosol concentrations to convective wet scavenging parameterizations in a global model" *by* B. Croft et al.

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Author Response to Referee 1 (A. Ekman):

The authors thank this referee for the constructive review, which has helped to improve the clarity of our presentation.

RC: Abstract: It is not clear that the 'two limiting cases' deal with the 'explicit aerosol uptake version' of the model and whether one of these 'two limiting cases' is the one compared to the standard ECHAM5-HAM or not. I think that the authors in the abstract should (more clearly) explain that there are actually four different cases that they consider (three explicit versions of the model + the standard). In my opinion, it wouldn't

hurt to introduce the abbreviations (PF_init, CF_init, CF_pipe, CF_ed) already in the abstract.

AC: The abstract is now rewritten. In this revised abstract we clearly state that we will compare between five simulations, including the standard ECHAM5-HAM model. We decided not to introduce the simulation abbreviations in the abstract in order to make the abstract more concise. However, we now introduce these abbreviations earlier in the text (in the introduction, and earlier in the model description) so that the reader becomes more readily familiar with the simulation abbreviations. Note that we have added a fifth simulation (CF_imp), which has a physically detailed size dependent parameterization for impaction scavenging due to collisions between aerosols and both cloud droplets and ice crystals. This allows a more thorough examination of the relative contributions of aerosol activation and collision processes to wet scavenging.

Please note that this manuscript version has undergone major revisions in response to the second referee's comments. The discussion section is completely rewritten to present a more thorough examination of the contribution of aerosols entrained above convective cloud bases to wet scavenging in the ECHAM5-HAM model. Our analysis now goes further to examine the relative contribution of aerosol activation and collision processes to wet scavenging in the simulated convective clouds. We also give consideration to the influence of the wet scavenging on aerosol number, in addition to aerosol mass, and the resultant feedbacks on predicted CDNC. We further examine the feedback of the CDNC changes on both stratiform and convective precipitation. We find that the wet deposition changes between our simulations are dominated by the assumptions for the wet scavenging of aerosols entrained above convective cloud bases, as opposed to the precipitation changes, except for sea salt in the tropics. This extended analysis has led to completely revised abstract, discussion and conclusion section and prompted us to revise the title of the paper to "Impact of entrained aerosols on convective wet scavenging in a global model". We retain the original figures and tables. However, these figures have been revised and re-ordered to better suit the re-

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vised discussion. Also, Figs. 7, 8, and 9 are new figures, and Tables 4 and 6 are new tables.

RC: Introduction: In principle the same comments as for the abstract, the authors should explain already here that they do four different simulations; one reference ECHAM5-HAM (PF_init), one ECHAM5-HAM with 'standard' explicit treatment of aerosol uptake(CF_init) and two limiting cases (CF_pipe and CF_ed). You can always refer to the more detailed explanation that will follow in section 2.2.

AC: The five simulations are now introduced in the introduction section, third paragraph from the last and with a note that a more detailed description will follow in the model description section.

RC: Introduction: Please explain which observations you will compare with and why these observations are selected.

AC: The final paragraph of the introduction now contains this information.

RC: Model description, page 1693, line 6-7: Is the two moment microphysics scheme by Lohmann (2008) used in all simulations? I.e. also the PF_init? This is not clear. It would also be nice to give some more information about the two moment microphysics scheme, e.g. that it concerns both cloud droplets and ice crystals, how well the scheme deals with microphysical processes such as accretion etc.

AC: Yes, the two moment microphysics scheme of Lohmann (2008) is used for all simulations. This is now clearly stated in the first line, second paragraph of Section 2. This same paragraph now includes information about the processes included in the scheme, and details about how autoconversion, accretion and aggregation are parameterized.

RC: Model description: It would be good to state (somewhere) in the model description that the model does not consider in-cloud formation of aerosol. This is only discussed later on in section 3.2. The statement on page 1707, lines 5-9, that below-cloud scav-

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enging is only considered in cloud-free gridboxes, should also be mentioned in the model description.

AC: The third paragraph of Section 2 has been revised to include a statement that in-cloud formation of sulfate is included for stratiform, but not convective clouds in ECHAM5-HAM. We added (to the fourth paragraph of Section 2) a more thorough discussion about the treatment of below-cloud scavenging in the model. We explain that below-cloud scavenging occurs only in the cloud-free grid boxes. We have also added a discussion about the factors that confound the parameterization of the below-cloud scavenging process for convective clouds in GCMs, including the parameterization of the precipitating fraction and the issue of precipitation falling from the side of tilted rain shafts. We now explain that we choose to keep this parameterization fixed for all simulations since we did not want to introduce a haphazard correction to this parameterization for the purposes of this study, but rather wanted to focus on the in-cloud scavenging processes.

RC: Model description: Do the changes apply for both deep and shallow convection?

AC: Yes, the changes in the wet scavenging parameterization are applied for shallow, mid-level and deep convection. We have added this to model description in the first paragraph of Section 2.1.

RC: Results: The authors only describe differences in aerosol mass concentrations, what about aerosol number concentrations? This would be interesting to see, also in relation to the changes in CDNC.

AC: We agree that an examination of the aerosol number should be included. We have added Table 6, which gives the global and annual mean number burdens for the seven lognormal modes for each of the five simulations. The discussion now has a subsection (Section 3.1.2), which considers the changes in aerosol number between our simulations. We find that our model simulations with more vigorous scavenging of the accumulation and coarse mode aerosols entrained above cloud base have greater

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global, annual mean new particle formation and increased global and annual mean Aitken mode number burdens. In our model, aerosol activation is parameterized such that Aitken mode aerosols contribute strongly to the CDNC. Thus, in comparing between our five simulations we find that increased Aitken mode number contributes to the increase of the convective and stratiform CDNC. The final subsection of the revised discussion includes this analysis (Section 3.2). We have added Fig. 7, which shows the geographic distribution of aerosol number burdens and the difference between simulation PF_init and CF_pipe. This figure is also examined in relation to the geographic distribution of precipitation changes (Fig. 8). As well, we have added Table 4, which presents the global and annual mean stratiform CDNC, liquid water and precipitation response and Table 6, which gives the global, annual mean aerosol number burdens for the five simulations.

RC: Results: The authors include statements such as 'CF_ed 'has the closest agreement', 'all simulations are resonable', and 'The agreement between the observations and the model is best and similar for the simulation PF_init and CF_ed', but don't give any quantitative measures to support these statements.

AC: We agree that quantitative measures are needed to support these statements. We now present mean fractional bias and correlation coefficients and slope parameters for our comparisons between the model simulations and observations/retrievals. These quantitative measures are added to the Figures 3, 5, 9, and 10. The related discussion in the text also makes reference to these quantitative measures.

RC: Figure 2: Why do you show CF_ed as a 'reference'? Wouldn't it make more sense to show CF_init - Figure 3: It would be interesting to see the net of the two bottom panels.

AC: These figures have been revised, and are now Figures 4 and 6. Figure 4 now shows the standard model simulation (PF_init) as the reference. The new Fig. 6 now focuses on the comparison of zonal, annual mean CDNC between the simulations

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conducted in our study. We removed the original bottom panels of this figure. We think that this presentation contributes more to our discussion about the feedback of scavenging-induced aerosol number changes on CDNC than the previous version of this figure.

RC: Technical comments: Page 1689, line 25: I suggest changing 'greatly' to 'much'

AC: Done.

RC: Page 1690, line 24 (and in references): The reference 'Fridland (2004)' should be 'Fridlind (2004)'.

AC: Done.

RC: Page 1693, line 19-20: For which years are the climatological SSTs and sea ice?

AC: The climatological SSTs and sea ice are for the year 2000. This is added to the model description section.

RC: Page 1694, lines 8-9: This sentence is unclear. I suggest: "Within each aerosol mode, Ri is the same for ice crystals and for cloud droplets".

AC: This change in now included in the text.

RC: Page 1694, line23: Change "The tracers deposition. . .." to e.g. "The tracer deposition. . ."

AC: Done.

RC: Page 1701, line 1: Change "As well, the . . ." to e.g. "In addition, the. . ."

AC: Done.

RC: Page 1701, line 7: The title of section 3.1.1 does not read very well.

AC: The discussion subsection titles are revised to reflect the major revisions to the text of the discussion.

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RC: Page 1701, lines 8-12: This paragraph is not necessary, it is already explained in the previous section.

AC: This is removed.

RC: Page 1704, lines 2-3: This sentence does not read very well.

AC: This sentence is now rewritten.

RC: Page 1704, line 5: I suggest changing 'greater' to 'higher'.

AC: Done.

RC: Page 1708, lines 19-20: This sentence does not read very well.

AC: This sentence is rewritten.

RC: Page 1709, line 1: Please specify that you mean aerosol mass concentrations.

AC: We specify that we mean aerosol mass concentrations.

RC: Page 1725, Figure text: change 'colorscales' to 'color scales'.

AC: Caption is revised.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 1687, 2012.