Atmos. Chem. Phys. Discuss., 6, S1843–S1849, 2006
www.atmos-chem-phys-discuss.net/6/S1843/2006/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impact of cloud-borne aerosol representation on aerosol direct and indirect effects" *by* S. J. Ghan and R. C. Easter

S. J. Ghan and R. C. Easter

Received and published: 18 July 2006

2 Specific comments

2.1 Abstract:

The abstract is short and overall clear (except page 4342, line 10: "many variables of interest": this is rather vague). The conclusions concerning radiative effects should be included here as well.

AC: We have modified the abstract so that it specifically refers to biases in aerosol, droplet number, and direct and indirect radiative forcing

2.2 Section 1:

The compilation of how other models treat cloud-borne particles is very interesting and the authors should go into more detail here, as the sensitivity experiments are meant to span the range of these currently used treatments. In particular, those models which prescribe the fraction of cloud-borne particles do so in different ways and for different processes. Some of the cited models prescribe the fraction of cloud-borne particles only for wet deposition. This fraction either depends on aerosol size, LWC, and cloud type (warm/cold) (ECHAM/MADE), cloud type (stratiform liquid/ice/mixed or convective) (ECHAM5-HAM), or is set to 100% whenever clouds are present (Barth et al., 2000), and so on. In some of these models (e. g. CAM-Oslo and ECHAM/MADE) changes to the aerosol size distribution during cloud evaporation are taken also into account in a simplified way. It should also be mentioned how scattering of sunlight by cloud-borne particles and by interstitial particles in the cloudy fraction of a grid-box is treated (or whether it is treated separately from the rest of the aerosol at all) in the cited models. Going into more detail here would increase the relevance of this paper, because it would allow the reader to gain a better understanding of other currently used models in addition to MIRAGE.

AC: We have expanded Table 1 to provide more details on the treatment of cloud-borne AP by other models. We have not, however, discussed the different treatments of direct and indirect aerosol effects by these models, or have explored the sensitivity of direct and indirect effects to the different model treatments, as this would be well beyond the scope of this study.

2.3 Section 2:

2.3.1 The treatment of cloud-borne particles in the experiment DIAG does not become very clear. In at least some of the cited models (e.g. Barth et al. (2000), Stier et al. (2005), Lauer et al. (2005)), the cloud-borne fraction is only prescribed when clouds precipitate. For non-precipitating clouds all particles (interstitial and cloud-borne are not differentiated) take part in aerosol microphysical processes like coagulation. Is this the same in DIAG? Please specify. What about radiative properties of interstitial particles in the cloudy fraction of a grid-box? Do they add to the optical depth? This

ACPD
6, S1843–S1849, 2006

should have an impact on figures 11, 12 and 13. I suspect that treatment of cloud-borne particles in some of the models is even cruder than in the experiment DIAG, and this should be underlined. I suggest to add another sensitivity experiment similar to DIAG but with a more rudimentary treatment of cloud-borne particles, e.g. including cloud-borne particles into the normal aerosol microphysical processes and not including (if DIAG does do so) interstitial particles in the cloudy fraction into calculation of the direct radiative forcing.

AC: We have added a sentence that explains how the cloud-borne fraction is used for DIAG, and which processes are affected by the DIAG approximation, and a sentence that summarizes the treatment of aerosol optical properties in MIRAGE. We see no need for a cruder treatment than DIAG, because it already uses the same treatment of scavenging and coagulation as other models.

2.3.2 In the simulation P-NOADV, cloud-borne particles do not undergo large-scale transport. What about cloud droplet number? Is this quantity advected, and if yes, doesn't this lead to inconsistencies?

AC: Advection of condensed water and droplet number was inadvertently turned off in all of these simulations. This is inconsistent with the transport of cloud-borne aerosol (P-FULL), but is consistent when transport of cloud-borne aerosol is neglected (P-NOADV). However, our results consistently show little difference between simulations with and without advection of cloud-borne aerosol. We therefore conclude that, at least for the resolutions considered here, advection of droplet number would make little difference in the results, and the inconsistency between the advection of droplet number and cloud-borne aerosol is of little consequence.

2.3.3 Ice-phase processes are totally neglected in the P-FULL and all other experiments. Although discussion of the exact treatment is not subject of this paper, this should be mentioned.

AC: We have added a sentence about this at the end of the paper.

ACPD

6, S1843–S1849, 2006

Interactive Comment

2.4 Section 4:

2.4.1 All results are discussed for annual mean values. I expect that this reduces the errors considerably. How would results look like for monthly mean values?

AC: We have looked at the climatological means for January and July and have found very similar results. We've indicated so in the text.

2.4.2 Is there a reason why no correlation coefficients are given for the scatter plots?

AC: We have added the spatial correlation coefficient to Table 2, and discussion in the text.

2.4.3 page 4349, line 7: ". . . , where aerosols are resuspended when clouds glaciate": This is not clear to me. Do you mean that aerosols are resuspended in the real atmosphere because of cloud droplet evaporation during the Bergeron-Findeisen process? Is this treated in P-FULL? But then the bias between P-FULL and P-RESUSPEND should be small for these situations. Or do you mean that PRESUSPEND does actually better represent the truth for these situation than the reference simulation? Please clarify.

AC: Actually, this version of MIRAGE does not treat the Bergeron-Findeisen process at all, instead predicting only the total cloud condensate and diagnosing the cloud phase from temperature. So the statement in line 7 is inappropriate. A more likely explanation for the larger differences near the poles and in the middle troposphere is the longevity of precipitation combined with the abundance of aerosol. We have modified the text accordingly.

2.4.4 page 4349, line 17: "stratiform cloud wet removal and adjustment are both significantly greater in the DIAG and P-RESUSP simulations." This is confusing. Shouldn't these processes be smaller in DIAG as less particles are transferred to the cloud phase (no particle-droplet collisions)?

AC: This might be true for Aitken and nuclei mode particles, but for accumulation mode particles most of the transfer from aerosol to cloud phase is accomplished by activation. In MIRAGE2, all of the transfer from aerosol to cloud phase is accomplished by activation, because Brownian diffusion scavenging of interstitial aerosol is neglected. We have added a sentence here indicating that for the DIAG and P-RESUSP treatments the activated aerosol is replenished each time step, which enhances actiavation scavenging.

2.4.5 page 4350, line 15 ff: This sounds like cloud-borne particle concentrations, summed over all modes, do not equal cloud-droplet concentrations not even in P-FULL. How can this be the case? How good is the agreement when all modes are included? I understand that biases can arise when cloud-borne particles are not advected, but this is a serious model inconsistency as well. Please clarify and comment.

AC: Droplet number exceeds cloud-borne aerosol number by up to 50%, even for P-NOADV.. The bias is most acute in regions with deep convection. The bias arises because, although MIRAGE treats the influence of deep convection on activated aerosol number, it neglects the influence on droplet number. Since deep convection entrains more activated aerosol from stratiform clouds than it detrains at cloud top, deep convection is a net sink of cloud-borne aerosol. Although this is an inconsistency, it has little impact on droplet number because most condensed water detrained from deep convective clouds is ice rather than droplets.

2.4.6 page 4350, line 23: "... and the P-TOTM treatment also agrees quite well": From figure 7, it seems like cloud droplet number is systematically underestimated in PTOTM although this is less the case for CCN@2% in figure 8. Could you explain this?

AC: No, we cannot explain why the P-TOTM treatment produces a bias in droplet number but not in CCN concentration. This is even more a mystery for the increased due to anthropogenic sulfur. It is probably somehow due to the inability of the P-TOTM treatment to distinguish between the cloud-born fractions of each specie in the aerosol modes.

ACPD

6, S1843–S1849, 2006

2.4.7 The number of figures could be reduced, as some of the figures 2, 5, 6, 7, 8, 9, 10, 11, 12, 13 give a similar message. I would suggest to omit figure 5 (accumulation mode mass), as it does not give substantially new information. Figure 8 is presented in order to provide the link between cloud droplet number concentration and accumulation mode number concentration. However, the scatter in cloud droplet number concentration is still larger than the scatter in CCN@2%. Therefore, as figure 8 does not provide a satisfactory explanation for the bias in P-RESUSP and DIAG, I would suggest to omit this figure as well.

AC: We have removed figures 5 and 8.

2.4.8 page 4362, figure 2: There seems to be a threshold value at 1.5E12 m-2 in PRESUSP and DIAG. Can you explain this?

AC: The apparent threshold is due to the large bias simulated in the arctic. The threshold is the local minimum in aerosol burden simulated there. We've added a sentence in the test explaining this.

3 Technical corrections

3.1 page 4345, line 18: Ovtchinnikov Ghan (2005) is missing in the reference list.

AC: Citation added.

3.2 page 4346, line 5: Koch et al. (2006) instead of (2005)

AC: Corrected.

3.3 page 4347, line 6/7: "the same representation of aerosol activation": For the reader's convenience, please add which activation parametrization is used. AC: Citation added.

3.4 page 4351, line 26: To help the reader, please add "the negative sign of the bias is consistent with the positive sign of the bias for aerosol optical depth"

ACPD
6, S1843–S1849, 2006

AC: Changed.

3.5 page 4356, line 21: Correct “Kristjansson1” AC: Corrected.

3.6 page 4358, table 1: Barth et al. (2000): This paper describes the NCAR CCM3, not the NCAR CAM. This is confusing. Is there a reference for treatment of cloud-borne particles in the NCAR CAM, or is it equal to the treatment in the CCM3? If so, please add. You also should add CAM (Community Atmosphere Model) in order to differentiate it from the Canadian Aerosol Module.

AC: We’ve added citations to recent papers describing the treatment of aerosols in CAM, and have spelled out Community Atmosphere Model for clarity.

3.7 page 4358, table 1: ECHAM5-HAM instead of ECHAM5 for Stier et al. (2005)

AC: Corrected.

3.8 page 4359, table 2: According to my understanding from the text, these are errors of accumulation mode (and not total) aerosol number, mass, and cloud-borne aerosol number. Please indicate this in this table as well.

AC: Accumulation mode text added to table.

3.9 page 4362 ff, figures 2, 5, 6, 7, 8, 9, 10, 11, 12, 13: The x-axis title is drawn quite close to the tick labels.

AC: Title moved.

3.10 page 4364, figure 4: The fonts are not rendered very well.

AC: The rendering will be improved.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 4341, 2006.