Atmos. Chem. Phys. Discuss., 12, C12327–C12331, 2013
www.atmos-chem-phys-discuss.net/12/C12327/2013/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Black carbon vertical profiles strongly affect its radiative forcing uncertainty" *by* B. H. Samset et al.

B. H. Samset et al.

b.h.samset@cicero.uio.no

Received and published: 6 February 2013

We thank both anonymous reviewers for their kind assessments and constructive comments on our submitted manuscript. Below we answer all non-technical issues raised. All typos noted and technical comments are also taken into account in the revised manuscript. Where both reviewers have addressed the same issue, we refer one of the reviewers to the other response.

From Anonymous Referee #2

Specific points:

Page 28936, lines 17-24. Whilst I am sure that you are right in the calculation of the contributions, I cannot quite understand how the 20% variability due to vertical

distribution comes from. Please make this clearer.

Response: We agree that the section explaining this estimate was too brief. We have expanded it in the revised version, and the full section now reads as follows:

—

4.1 RF variability due to vertical profiles

We first quantify the fraction of the total modeled RF variability attributable to vertical profiles alone. Figure 1a shows the global mean anthropogenic BC burden from models participating in AeroCom Phase 2, in addition to three models from AeroCom Phase 1 included to investigate the magnitude of variability due to model developments. We find a multi-model mean of 0.19 mg/m2, but with a relative standard deviation (RSD) of 32% and a model spread from 0.09 to 0.37 mg/m2. Table 1 lists the numbers for individual models. Under an assumption of equal specific forcing, this alone will cause a large diversity in the total BC forcing predicted by the models. AeroCom Phases 1 and 2 found a similar burden range, as shown by the whisker boxes in Figure 1a. Note that the AeroCom P1 includes BC from all sources, i.e. including biomass burning, while P2 results are for BC from fossil and biofuel burning (BCFF) sources only. This causes the P2 burden and RF means to be lower than for P1 (see Discussion for further comments). Figure 1b shows the RF for each model, recalculated from the concentration profiles using a common EP (Samset and Myhre, 2011). We find a stronger mean RF than from either of the AeroCom phases. This is partly due to the strength of the EP used, which is higher than for most AeroCom models, and partly to the fact that the present study includes BC from biomass burning as mentioned above. See Discussion for further comments.

The recalculated RF values are highly correlated (Pearson corr. coeff. ïĄš=95%) with the burden values, as expected since a common EP is used. However, dividing the recalculated RF by the global mean burdens gives global estimates of BC forcing efficiency (radiative forcing exerted per gram of BC aerosol), that are independent of the burden value simulated by the host model. This is shown in Figure 1c. If the modeled spatial and temporal aerosol distributions, notably the vertical profiles, were also identical or merely related by a simple scaling, this spread would vanish. The remaining diversity therefore carries information on the impact of the 4D BC concentration profiles on the model RF spread, separate from the variability due to burden differences.

In the following paragraph we quantify the contribution of the vertical profile to total model spread. Our method is to calculate the relative standard deviation (RSD) of the residual variability, after normalizing the recalculated RF by the model burdens. We then compare this to RSDs from the native model RF estimates. First, note that there is a residual variability in the forcing efficiency (Figure 1c) that is due to the variations in the 4D (spatial and temporal) aerosol mass distributions, with a relative standard deviation (RSD) of 16%. This number is dominated by the vertical distributions, but will also have components from horizontal and temporal variability in the aerosol fields between models. To isolate the contribution from vertical distributions, we performed the analysis using global mean BC and efficiency profiles per month, averaging out any horizontal differences, and then using global, annual mean profiles, to also remove temporal variability. The resulting RSD from vertical profiles alone is found to be 13%.

Next, we compare this to variability on forcing per burden in AeroCom P1 and P2, which in both cases is around 40%. Our residual RSD from vertical profiles is therefore approximately 30% of the variability values from both these studies. However, three models in P2 have mass extinction coefficients that deviate significantly from recommendations given in the literature (Bond et al., 2006) and thus unduly influence the RSD. Removing contributions from these three models reduces the RSD on the forcing per burden to 32%, subsequently increasing our estimate of the variability due to vertical profiles to 40%. Finally, we need to relate this to the total model RF variability. Assuming that RF variability is in some way a combination of variability in burden and forcing efficiency, we first note that t in P1 and P2 these two factors have approximately equal RSDs.If they were uncorrelated the vertical distribution could therefore be said

to contribute half of the total variability on RF, which from our above calculation is 20%. This is however not the case. We will show below that 20% can instead be considered a lower limit. To investigate the correlation of variability in burden and forcing efficiency, we note that in both AeroCom P1 and P2, the burdens and forcing efficiencies are weakly anticorrelated. This is apparent from the fact that the RSD on the RF (shown in Figure 1) is lower than it would be if the errors on burden and forcing per burden were uncorrelated. Quantifying this effect using numbers from AeroCom P2, we find a weak Pearson correlation coefficient of ïĄš=-0.46 (or -0.40 if we again remove the three outlier models).

In the present analysis, we can estimate the impact of the vertical distributions by the fraction of mass simulated above 500hPa, or approximately 5km, shown in Table 1 as M5k. M5k is calculated by integrating the BC vertical profiles presented in Figure 2a for model layers above or below an average pressure of 500hPa, and then taking the ratio of these values. We observe that M5k is strongly correlated with the recalculated RF (ïĄš=0.70) and forcing per burden (ïĄš=0.97), as expected due to the efficiency profile used for the present analysis. However M5k is also weakly positively correlated with the total burden (ïĄš=0.48). The vertical distribution variability therefore does not contribute to the observed anticorrelation between burden and forcing per burden in AeroComP1 and P2. We can assume that forcing per burden is determined by a combination of the vertical profile (positive correlation with burden) and a set of uncorrelated global variables such as BC optical properties (which must then have a combined negative correlation with burden). The variability on BC RF would be higher if the models had not compensated for high burden with a low forcing efficiency and vice versa. Since the vertical variability rather leads to a high efficiency for a high burden, its impact on the RF variability is likely stronger than the minimum estimate of 20% above. The present analysis does not allow for rigorous quantification, but it is unlikely to be larger than the 50% of the variability on total BC RF caused by forcing per burden. Hence we have a range of 20% to 50% of the variability of modeled BC RF caused by differences in vertical distributions.

—

We hope that this clarifies our reasoning.

Figure 1. I was puzzled as to why the present study which uses AEROCOM 1 and AEROCOM 2 models can produce a mean BC RF greater than that for either Aerocom 1 or Aerocom 2 alone, but I presume this is because only a subset of AEROCOM models have been used in this study? Please add some text to clarify (possibly to caption?)

Response: There are two main reasons for this. Partly it's because the AeroCom phase 2 RF values are for anthropogenic BC from fossil- and biofuel only, while the numbers in the present work include BC from biomass burning. Consequently aerosol burdens are higher. This can be seen in figure 1a, though the reviewer is correct that the usage of a subset of the models also influences the spread. The second part is due to the usage of a single normalized forcing profile across all models, that is stronger than the AeroCom mean value. Hence most model RFs can be expected to be stronger here than in the host model. We've added a clarifying sentence to sec. 4.1, and also somewhat extended the discussion point on this issue. (The sentence is included in the response above.)

Figure 4: Please change the colour scheme as I found it very difïňĄcult to distinguish the different shades or yellow/brown. This was made even more of a challenge by the small size of the legend.

Response: We agree, and will change the color scheme to more complementary colors.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 28929, 2012.