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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Standard climate models radiation codes underestimate black carbon radiative forcing" *by* G. Myhre and B. H. Samset

G. Myhre and B. H. Samset

gunnar.myhre@cicero.uio.no

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O. Boucher (Referee)

The manuscript is short, well written and presents some interesting results. The authors present a convincing explanation for the BC radiative forcing discrepancy they observe between 2-stream and multi-stream RT codes. The manuscript being short, it nevertheless raises a number of questions, which once answered by the authors, should improve the manuscript further and warrant pulication.

The authors use 8-stream and 16-stream configurations of their multi-stream RT code. However I could not find a comparison between these two versions. It seems that the 8-stream configuration is used for Figs. 1 and 2, while the 16-stream configuration

is used for Fig. 3. It would be good to know the minimum number of stream that is required to get a stable solution. In other words, does the BC RF converge and how fast at low surface albedo when the number of streams is increased.

Response: We have replaced the 16-stream simulations by 8-stream simulations in Fig 3. The following text is included in section 3.3: 'The agreement between 8-stream and even higher number of streams such as 16-stream simulations is generally within 1%, except for very small absolute RF values. Simulations with 4-streams are generally close to 8-stream simulations.'

If the authors' explanation for what they observe for BC is correct, then shouldn't that apply also to gaseous absorption in the solar spectrum? Wouldn't gaseous absorption by O3, H2O, CO2, CH4, ... also be underestimated by 2-stream RT codes? A lot of the gaseous absorption occurs in the near-infrared where scattering is less, and O3 absorbs everything where it absorbs in th UV, so the effect should be less. But H2O has many absorption bands below 1 _m. Maybe the authors should look into this or at least mention it. This could have some implications for the water vapour feedback in climate models (e.g. in polar regions, where surface albedo is large, T change is amplified and q change per unit of T change is large). I wonder if the effect found on an absorbing aerosol (i.e. BC) is not associated with a countereffect on scattering aerosols (e.g. sulfate). Does the radiative effect of scattering aerosols depend on the number of streams used?

Response: We have added the following text into the manuscript where additional simulations have been performed for gases absorbing in the solar spectrum in section 3.2: 'For pure scattering aerosols 2-stream simulations varies with solar zenith angle (see Randles et al. (2013)) and albedo compared to 8-stream simulations, but on a global mean 5% stronger negative RF. ' Further the following has been added to section 4: 'The underestimation for BC is largest in the presence of scattering components. This also applies to gases with solar absorption. However, under clear sky condition, underestimation of a similar magnitude to BC will only be caused by gases with solar absorption in UV and visible region where Rayleigh scattering is strong. Thus ozone in the lower troposphere is the only gas that is substantially influenced by the number of streams in the radiative transfer simulations. For a global increase in water vapour by 20% in the lowest 1-2 km of the atmosphere, the difference between 2-stream and 8-stream simulations is found to be less than 1%.'

Finally I wonder how general the results here are. The authors mention that most climate models use two-stream approximations with the delta-M method, but do not substantiate their findings. I would be surprised if all two-stream models use the same approximation to truncate the forward peak of the aerosol phase function. Isn't there some spread in the Stier et al. and Randles et al. papers among the two-stream models?

Response: We have modified the sentence somewhat from 'are around' to 'could be up to 10%' since it is somewhat difficult to quantify how many of the models have used a standard 2-stream setup. With some very few exceptions the 2-stream simulations in Randles et al. shows a consistent pattern with underestimations compared to multi-stream simulations. In Stier et al. other factors overwhelm this 10% factor such as surface albedo, clouds, water vapour. For a better quantification of the underestimation in Randles et al. we have added the following sentence.

'The clear sky results for selected profiles and solar zenith angles in Randles et al. (2013) showed an average model underestimation between 12 and 15% compared to benchmark model simulations.'

How does the two-stream RT code used here compare with the other two-stream RT code used in Stier et al. and Randles et al.? I think the statement on lines 6–10 of page 26179 should be more substantiated or qualified.

Response: As mentioned above the following sentence has been added: 'The clear sky results for selected profiles and solar zenith angles in Randles et al. (2013) showed an average model underestimation between 12 and 15% compared to benchmark model

simulations'

The caption for Figure 1 needs to be revised. It looks like a ratio rather than a relative difference. Same for Figure 2b.

Response: Thanks, corrected.

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