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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "A new method for evaluating the impact of vertical distribution on aerosol radiative forcing in general circulation models" *by* M. R. Vuolo et al.

Anonymous Referee #1

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Review of "A new method for evaluating the impact of vertical distribution on aerosol radiative forcing in general circulation models" by Vuolo et al., submitted to *Atmos. Chem. Phys.*

The manuscript studies and quantifies the coupling between the direct radiative forcing exerted by a given aerosol component and the radiative effects of other aerosols and clouds. Non-linearities in aerosol direct radiative effect and forcing caused by clouds and other aerosol species are often mentioned in the literature, but rarely quantified in a consistent framework, which this study does successfully, with a well-chosen focus on black carbon aerosols.

The description and discussion of results are good and exhaustive, and the figures well chosen. The presentation of the methodology is weaker, and I detail below the aspects of the manuscript that should be improved before publication.

1 Main comments

- I fail to understand why F(B) appears in Equation 1. Shouldn't that be F(clear) in order to define both RF(A|B) and RF(A) with respect to the same reference? Equation 2 looks ok, but it simply says that the radiative forcing exerted by agents A and B is the sum of the radiative forcings exerted by A and B each taken alone, plus a coupling term dRF. This does little to clarify the dRF term. Moreover, the role of those equations in the paper is unclear, since they are never used again.
- Section 3.4.2: It took me a while to understand how the experiments are designed once the lowest and highest cloud levels have been identified. What I understand now is that in the *abv* experiment, aerosols below the highest cloud level are set to zero to keep only those aerosols that are above clouds. For the *in* experiment, aerosols that are below and above clouds are set to zero. For the *blw* experiment, experiments above the lowest cloud level are set to zero. Is that correct? In addition, the text leaves several questions open:
  - What is set to zero, exactly? Mass-mixing ratios or aerosol optical depths?
  - The method used to isolate aerosol layers with respect to clouds will affect the single-scattering albedo and asymmetry parameter of the total aerosol column, so changes in normalised radiative forcing are not only due to the vertical position of the aerosol. Correct?
  - Why did the authors decide to set aerosols to zero in cloud-free columns? Leaving those untouched would have guaranteed that differences between

experiments only originate from the cloudy sky, and removed the complications discussed in Section 4.2.

- The authors derive the aerosol radiative forcing with respect to an atmosphere containing no aerosols. This definition is different to the IPCC definition, which takes pre-industrial aerosols as a reference (see below). That difference is not a problem in itself, but it raises an intriguing question: since pre-industrial aerosol radiative forcing will also suffer from non-linearities due to coupling between the different aerosol species and clouds, how does the pre-industrial coupling term compare to the present-day coupling term?

2 Other comments

- Throughout the paper, clearly indicate that radiative forcings are diagnosed at the top of the atmosphere.
- Page 18811, line 7: "*(190 compared to 179)*". What is the quantity being mentioned here, and its units?
- Page 18811, line 12: The dependency of direct radiative effect in aerosol amount (equivalent to aerosol optical depth, if the aerosol size distribution, chemical composition and environmental factors such as surface albedo remain the same) is indeed non-linear, but not strongly so. See Figure 3 of Boucher *et al.* (1998).
- Page 18812, line 3: The presentation of assumptions in Bellouin *et al.* (2008) and Evan *et al.* (2009) is misleading. The text should note that Bellouin *et al.* (2008) acknowledge the importance of direct aerosol forcing in cloudy-sky, and that Evan *et al.* (2009) calculate the forcing at the surface, where the cloud "masking" assumption is arguably more acceptable than at the top of the atmosphere.

- Page 18812, line 5: I guess the authors mean "single-column model".
- Page 18813, line 16: The definition of radiative forcing is, if indeed taken from the IPCC assessment reports, incomplete. First, the perturbation to the forcing agent is specifically a change since pre-industrial conditions. Second, the tropospheric state remains fixed to unperturbed values. Therefore, the authors do not compute a radiative forcing in the IPCC sense of the term, but a radiative effect with respect to an atmosphere with no aerosols (as stated in Page 18816, lines 24–26).
- Page 18814, lines 1–2: The text refers to agents A and B, but Figure 1 uses B and C. It would be useful to harmonise the notations.
- Page 18814, Figure 1, and Appendix: Note that the method of resolution of the equation of radiative transfer illustrated here is commonly called the "adding-doubling" method.
- Page 18815, line 8: AeroCom 1 or 2?
- Page 18815, line 16: What is meant by "*(rather hygroscopic)*"?
- Page 18816, lines 5–7: Is hygroscopic growth applied separately to each aerosol component, or for the mixture? The text seems to suggest the latter, but is unclear because the words "*our first assumption*" on line 3 imply that a second assumption is made.
- Page 18817, line 2: But those differences in meteorology are removed after a few timesteps when the model is nudged towards the ECMWF re-analysis, correct?
- Pages 18818–18819, sections 3.4.1 and 3.4.2: A Table summarising the configurations and experiments would be helpful.

- Page 18819, line 24: Are cloud levels determined in each model column, that is the aerosol vertical profile in the *abv*, *in*, and *blw* experiments differ from one column to the next?

- Page 18821, line 6: Aerosol direct radiative effects will also cause feedbacks on modelled meteorology (since they modify the radiative budget), so should be listed here.

- Page 18821: It may be clearer to merge the explanation for points 1 and 3 together, since both configurations are in fact double calls to the radiation scheme, with the non-advancing call using aerosols and climatological clouds, and the advancing call using no aerosols and interactive clouds.

- Page 18831, Table 1, and Figure 8: Results suggest that the radiative forcing by total aerosols is stronger (more negative) than the sum of the component radiative forcings. Myhre et al. (2013) find the opposite result (see their Figure 16), which I find easier to understand: when all aerosols are considered together, there is more scattering and absorption in the atmosphere, thus component aerosols experience smaller radiative fluxes than when they are considered independently, thus their radiative forcing is weaker. Can the authors explain their result?

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 18809, 2013.