

Interactive comment on “Black carbon reduction will weaken the aerosol net cooling effect” by Z. L. Wang et al.

Anonymous Referee #2

Received and published: 16 January 2015

General comments

This is an interesting paper which shows single-model results of the net climate effect of reducing black carbon (BC) aerosol emissions, both with and without reducing co-emitted compounds. I recommend publication of the paper, but I do have some concerns which need to be addressed first. In particular, no quantification or discussion of the model uncertainty is given, the co-emission assumption should be further justified, and analysis of surface temperature change is confusing since the model has been run with prescribed sea-surface temperatures. Please see below for details.

Specific comments

Introduction. Semi-direct aerosol effect is not mentioned in the introduction. It is im-
C11251

portant for BC, and should be explained briefly. You could refer to e.g., Koch and Del Genio (2010).

Page 33119, line 20-21. It is good that the uncertainty limits from Bond et al. are mentioned, but I think that this huge uncertainty in climate forcing of BC, and the associated ongoing debate should be emphasized more in the introduction. Other studies, such as Myhre et al. (2013, ACP), have much lower estimate of the direct aerosol effect of BC, which is reflected in the best estimate in the latest IPCC report (Boucher et al., 2013; Myhre et al., 2013). Recent literature also suggests that the climate effect of BC may be overestimated due to overestimation of its lifetime, and this might be worth mentioning (see e.g., Hodnebrog et al., 2014; Samset et al., 2014; Wang et al., 2014).

Page 33120, line 17-21. An overall reference to the model used, and also to the RCP scenarios (van Vuuren et al., 2011) would be appropriate here.

Page 33122, line 12. Please specify which year GHG concentrations are from.

Page 33122, line 15. Year 2000 is already 15 years ago, so I would not call this “present-day conditions”. Alternatively you could call it “recent past”.

Page 33122, line 16-28. No references are given to the RCP scenarios – this is needed. Only a web address is given, and this does not even work.

Page 33122, line 26-27. What about biomass burning emissions? Were they kept constant at year 2000 levels or are they also changed when using RCP scenarios?

Page 33123, line 1-4. Which year(s) are these data representing? Do you have any reference to the data?

Page 33123, line 4-5. I am not convinced that 10 years are enough for the analysis. The paper does not give any information about uncertainties in the results and the year-to-year variability. Usually when running climate models, even with prescribed SSTs, natural variability can be very large and long simulations are needed (at least 30 years, but this depends on the size of the forcing). This is particularly important for the

semi-direct and indirect aerosol effects, which depends on the cloud cover, while the quantification of the direct aerosol effect varies less from year to year. Please justify that 10 years are enough to derive radiative fluxes that are within reasonable accuracy.

Page 33123, line 15. What is the argument for RCP4.5 representing the most likely future situation?

Page 33123, line 17-20. In principle, when running with prescribed SSTs, the sum of the semi-direct and indirect aerosol effects should not deviate too far from the difference between the change in net radiation flux at TOA and the direct aerosol effect. However, results in Table 3 show that this difference is rather large. Is estimation of change in cloud radiative forcing (CRF) an appropriate way of quantifying the semi-direct and indirect aerosol effects? In Ghan et al. this is done differently for the shortwave. As indicated above, I am also curious how large the inter-annual variation is, especially for CRF.

Page 33124, line 8-9. Any reasons for the underestimation? Is this a known problem.

Page 33124, line 20-21. Specify that it is a net cooling effect that is enhanced.

Page 33124, line 18-21. Given the strong emission reduction for BC, the change in direct aerosol effect of 0.07 W m^{-2} is quite small. As far as I can see from the multi-model comparison in Myhre et al. (2013, ACP), the BCC model has much lower normalized radiative forcing for BC than most of the other models. I think this is worth mentioning.

Page 33124, line 22. This implies that the semi-direct aerosol effect for BC in this model is positive and larger than the direct aerosol effect of BC. The IPCC AR5 indicates that the BC semi-direct effect is negative, although this is uncertain, with a best estimate of -0.1 W m^{-2} and a range from -0.3 to $+0.1 \text{ W m}^{-2}$ (Boucher et al., 2013). Some justification of this strong positive semi-direct effect would be useful, e.g., a plot of the change in cloud cover between SIM1 and SIM2?

Page 33124, line 23. BC also changes the stability of the atmosphere, and this could

C11253

also lead to a change in cloud cover, in addition to the changes in cloud evaporation (which is caused by changes in relative humidity) (see e.g., Hansen et al., 1997; Cook and Highwood, 2004; Johnson et al., 2004).

Page 33124, line 24. What is the cause of the decrease in sulphate mass concentration? Emissions of SO_2 are the same in the two simulations.

Page 33125, line 2-4. This is probably mostly due to the fact that prescribed SSTs have been used. Therefore, the global mean surface air temperature would not change much. I do not understand the point of including the surface temperature analysis in Table 3 and the discussion, and suggest removing it from the paper.

Page 33125, line 5-8. Since this is a very important point of the paper, this needs to be further justified and referenced, rather than just stating that “ SO_2 and OC emissions are likely to be reduced proportionally when BC emission is decreased...”. Furthermore, co-emissions of other compounds, such as CO_2 , might be more important than SO_2 and OC, and this should be mentioned/discussed (see e.g., Rogelj et al., 2014).

Page 33125, line 20. Is only the cloud albedo effect included or is the lifetime indirect effect also included? This is not clear from the method section and should be specified.

Page 33126, line 8. In Fig. 2, labels a, b, c, etc. seem to be missing.

Page 33126, line 16. See earlier comment on cloud evaporation and atmospheric stability changes.

Page 33127, line 14. See above. Perhaps better to use semi-direct aerosol effect instead of cloud evaporation?

Table 2. I assume these emission numbers include biomass burning in addition to fossil fuel and biofuel emissions? It would be good to specify this.

Table 3. As mentioned before, it would be useful to show some uncertainty values. E.g., you could include standard deviations representing the inter-annual variation of

C11254

the different radiative effects. Again, I suggest removing the T_{2m} results to avoid confusion.

Technical corrections

Page 33119, line 8. I suggest inserting “absorbed” after “radiation”.

Page 33122, line 3-4. This sentence is a bit strange. I think there are some commas missing. Please fix or rephrase.

Page 33126, line 24. Replace “in most of areas” with “in most areas”.

Table 3. Please insert “(DRT)” after “direct”, “(CRF)” after “semi-direct and indirect”, and “(FNT)” after “net effect at the TOA”.

References

Boucher, O., Randall, D., Artaxo, P., et al.: Clouds and Aerosols, in: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Stocker, T. F., Qin, D., et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 571–658, 10.1017/CBO9781107415324.016, 2013.

Cook, J., and Highwood, E. J.: Climate response to tropospheric absorbing aerosols in an intermediate general-circulation model, *Q. J. R. Meteorol. Soc.*, 130, 596, 175-191, 10.1256/qj.03.64, 2004.

Hansen, J., Sato, M., and Ruedy, R.: Radiative forcing and climate response, *J. Geophys. Res.-Atmos.*, 102, D6, 6831-6864, 1997.

Hodnebrog, Ø., Myhre, G., and Samset, B. H.: How shorter black carbon lifetime alters its climate effect, *Nature Communications*, 5, 5065, 10.1038/ncomm6065, 2014.

Johnson, B. T., Shine, K. P., and Forster, P. M.: The semi-direct aerosol effect: Impact of absorbing aerosols on marine stratocumulus, *Q. J. R. Meteorol. Soc.*, 130, 599,

C11255

1407-1422, 10.1256/qj.03.61, 2004.

Koch, D., and Del Genio, A. D.: Black carbon semi-direct effects on cloud cover: review and synthesis, *Atmos. Chem. Phys.*, 10, 16, 7685-7696, 10.5194/acp-10-7685-2010, 2010.

Myhre, G., Shindell, D., BreiÅon, F.-M., et al.: Anthropogenic and Natural Radiative Forcing, in: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Stocker, T. F., Qin, D., et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 659–740, 10.1017/CBO9781107415324.018, 2013.

Rogelj, J., Schaeffer, M., Meinshausen, M., et al.: Disentangling the effects of CO₂ and short-lived climate forcer mitigation, *Proceedings of the National Academy of Sciences*, 111, 46, 16325-16330, 10.1073/pnas.1415631111, 2014.

Samset, B. H., Myhre, G., Herber, A., et al.: Modelled black carbon radiative forcing and atmospheric lifetime in AeroCom Phase II constrained by aircraft observations, *Atmos. Chem. Phys.*, 14, 22, 12465-12477, 10.5194/acp-14-12465-2014, 2014.

van Vuuren, D. P., Edmonds, J., Kainuma, M., et al.: The representative concentration pathways: an overview, *Climatic Change*, 109, 1-2, 5-31, 10.1007/s10584-011-0148-z, 2011.

Wang, Q. Q., Jacob, D. J., Spackman, J. R., et al.: Global budget and radiative forcing of black carbon aerosol: Constraints from pole-to-pole (HIPPO) observations across the Pacific, *J. Geophys. Res.-Atmos.*, 119, 1, 195-206, 10.1002/2013jd020824, 2014.

Interactive comment on *Atmos. Chem. Phys. Discuss.*, 14, 33117, 2014.

C11256