Atmos. Chem. Phys. Discuss., 12, C12090–C12097, 2013
www.atmos-chem-phys-discuss.net/12/C12090/2013/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluation of preindustrial to present-day black carbon and its albedo forcing from ACCMIP (Atmospheric Chemistry and Climate Model Intercomparison Project)" *by* Y. H. Lee et al.

Y. H. Lee et al.

yunha.lee.00@gmail.com

Received and published: 28 January 2013

We thank Dr Hagler for her constructive comments and suggestions and have made several changes to the paper to address the issues raised. Reviewers' comments are shown in italics with our response shown after each.

General comments

The authors have made a tremendous effort in comparing a large number of different model outputs and addressing key uncertainties regarding BC climate forcing in

snowcovered areas. This paper certainly merits publication and will advance the body of scientific knowledge on this topic, however there are a few issues that need to be addressed regarding how the measurement data are presented and handled. These issues include:

(1) Inadequate description of measurement techniques and uncertainties. Authors need to clearly separate discussion of atmospheric BC measurements versus snow or ice BC measurements and discuss techniques and uncertainties. Major points here include: a. Air: Atmospheric BC measurements have a long history of measurement application and technique evaluation. Authors are primarily using optical filter-based datasets (PSAP, Aethalometer) for atmospheric measurements and discussion should be focused there. A critical uncertainty for those data is the selection of the mass absorption coefficient. Other uncertainties include filter-loading artifacts and misattribution of other light absorbing species as BC (e.g. brown carbon, iron oxide). Authors discuss (page 17) a variety of mass absorption coefficients applied to the data sets and only lightly touch upon the fact that a BC / EC comparison (Sharma papers) established a much higher MAC value that would significantly change the calculated BC values. A high MAC estimate comparing BC from the PSAP versus EC has also been observed at Summit, Greenland (Hagler, G.S.W., Bergin, M.H., Smith, E.A.., and Dibb, J.E., 2007. A summer time series of particulate carbon in the air and snow at Summit, Greenland, Journal of Geophysical Research-Atmospheres, 112, D21309, doi:10.1029/2007JD008993.). Authors are encouraged to take all measurements using the same model instrument (e.g., Aethalometer at 880 nm) and recalculate BC with an identical instrument-specific MAC value as another point of comparison to the model outputs.

Response: We have 7 stations that measure the BC concentrations using Aethalometer (all European and two arctic stations), and 4 out of 7 stations used a constant MAC, which varies from 15.9 m2/g to 19 m2/g by station (but up to 28 m2/g for the

ACPD
12, C12090–C12097, 2013

winter times in Alert). Except for the Alert winter season, this variation does not seem to be significant – BC concentrations would be varied only by -5% to 12% if using 16.9 m2/g as an identical instrument-specific MAC value. The main conclusions from the current evaluation are little affected by using the identical instrument-specific MAC. The following is added in Section 4.2 in the revised manuscript.

"4 out of 7 stations used the constant mass absorption cross-sections, which vary from 15.9 m2 g-1 to 19 m2 g-1 by station (but up to 28 m2 g-1 for the winter times in Alert). Our major conclusions are little affected by some variations in mass absorption cross section - except for the Alert winter season, BC concentrations would differ only by -4% to 14% if using 16.6 m2 g-1 as a default conversion value."

b. Snow/Ice: The paper currently lacks a sufficient description of snow/ice measurements and vaguely implies atmospheric BC measurement evaluations are applicable. This is not the case and the snow/ice measurements need to be discussed separately. For example, the McConnell ice cores use a novel laser-induced incandenscence technique that is an actual BC mass measurement and is not replicated in the atmospheric measurements shown in this paper. This is the same technique applied in the Kaspari et al. ice core, which the authors mentioned as reporting "unusually low" values. While this instrument is used for some atmospheric studies, the extraction of BC particles from meltwater via nebulization is a major difference for snow measurements. Other measurement techniques melt and filter snow or ice, which has potential loss of BC particles, then apply measurement techniques (thermal-optical EC, integrating sphere) that differ from the atmospheric measurements being utilized in this paper. One recent and very relevant paper to consider is: Schwarz et al., in review at AMTD - http://www.atmos-meas-tech-discuss.net/5/3771/2012/amtd-5-3771-2012.html Another basic overview the authors may find helpful is a recent summary in EPA's Report to Congress on Black Carbon,

ACPD

12, C12090–C12097, 2013

section 5.6 - http://www.epa.gov/blackcarbon/2012report/Chapter5.pdf

Response: The following is added in introduction.
"For BC in surface snow or ice cores measurements, several methods have been used for BC analysis: optical methods [e.g., Doherty et al., 2010], thermo-optical methods [e.g., Lavanchy et al., 1999;Ming et al., 2008;Xu et al., 2009a], coulometric titration-based method [e.g., Ming et al., 2008], gas chromatography with thermo-chemical treatments [e.g., Thevenon et al., 2009] and a laser-based incandescence (i.e.. Single Particle Soot Photometer, SP2) [e.g., McConnell et al., 2007;Kaspari et al., 2011;Bisiaux et al., 2012b]. Compared with the atmospheric measurement, the BC in snow or ice generally requires a filtration, which is to collect BC from a melted snow/ice sample before analysis, which can lead the potential BC loss. The novel laser-based method does not need the filtration process because it can be used directly to measure the BC mass concentrations in snowmelt [McConnell et al., 2007]. However, this method uses the nebulization process to aerosolize the BC from snowmelt, and Schwarz et al., [2012] point out that the nebulizer performance may result in an underestimates of the BC concentration."

(2) The authors include a model (GISS-E2-R) with a 40% increase in BB emissions. This confounds the ability to compare other factors that may differentiate this model output against the others. Authors are encouraged to run a variation of the model with identical emissions inputs to improve the intercomparison.

Response: We agree with the Referee's point, but cannot re-run all simulations since it is not feasible. We strongly doubt that the main conclusions/findings would be significantly affected by the 40% increase in BB emissions in the GISS-E2-R model. Nevertheless we felt it is important to show how much BC predictions are affected by the 40% increase in the BB emissions. Hence we ran GISS-E2-R 2000 timeslice

ACPD
12, C12090–C12097, 2013

experiments with/without 40% increase (i.e. 4-years average after 2 year-spinup). With the 40% higher BB emissions, first of all, global annual emission rate (also total deposition rate) is increased by 13%; for the global burden, by 10%. For spatial distributions, except BB source and its downwind regions, the impact is +/- 10% in most areas.

Even though we did not run the preindustrial simulation, the BC burden and deposition in the preindustrial simulations could be affected more than the present-day case because the total BC emission rate is increased by 26% with applying the 40% increase in the BB emissions, which is about 2 times higher than the present-day case. The following is added in Section 2.1 in the revised manuscript – new part is shown in bold.

"All participant models use the same emission rate except the GISS-E2-R, which increases BB emission by 40% to compensate for the underestimated BC predictions over the biomass burning regions of Africa and South America [Koch et al., 2009b]. **While having the same emission is useful for model inter-comparison, the 40% increase in BB emissions results in less than 10% changes in the spatial distributions of the column burden in the 2000 timeslice simulations except near and downwind from BB sources (based on GISS-E2-R 2000 timeslice experiments with/without 40% increase in the BB emissions), and the range in emissions used in GISS-E2-R can be considered realistic.**"

(3) The ability to reproduce BC concentrations in surface snow (and later ice core archives) is anticipated to be heavily impacted by the accuracy of the estimated spatial variation in snowfall. How well do the models estimate snow fall rates spatially and is there variance between models for the snow estimates? How do model estimates of spatial snowfall patterns compare to observations?

ACPD
12, C12090–C12097, 2013

Response: For the ice core cases, we presented the evaluation of models' accumulated precipitation rate against the ice core observations in Figure 12 (Figure 13 in the revised manuscript) and discuss the results in Section 4.4. For the Arctic surface snow data, because the precipitation data were not provided together, we obtained a long-term precipitation measurement to evaluate the precipitation simulated in ACCMIP models, which is available in the revised manuscript (see below). However, we would like to make it clear that the BC snow concentrations are only indirectly affected by the precipitation fields in ACCMIP models because precipitation was prescribed in the offline snow and sea-ice simulations from reanalysis data spanning the same time period over which the BC concentrations in snow were measured. The following paragraph is added in Section 4.3.

"Precipitation rates simulated in the ACCMIP models affect the simulated BC snow concentrations only through their influence on aerosol deposition fluxes. The offline snow and sea-ice simulations prescribe precipitation fields from re-analysis data spanning the same time period over which the BC measurements were conducted, We evaluated the ACCMIP models' precipitation rates using gauge-based precipitation measurements that are available for the period of 1995 to 2004 and cover large areas in the Arctic (http://ine.uaf.edu/werc/people/yang/yang_files/MonthlySum/). We selected the measurement sites only when all monthly mean data from 1995 to 2004 were available. Figure 10 shows the seasonal mean precipitation rates for the multi-model mean and standard deviation compared to the observation over the high NH latitude region. With some exceptions, models overall have good skill in capturing the observed spatial and temporal patterns of the precipitation. This suggests that biases in model precipitation are likely only a second order source of bias in these evaluations of BC concentrations in snow."

Note: Figure 10 is presented on the last page of this response but is appeared as Fig.1 (I can't find the way to show as Fig.10)

ACPD

12, C12090–C12097, 2013

Minor suggestions:
- Table 4 – Add mass absorption coefficient applied to each measurement data set. - Table 5 – Add measurement technique for each data set.

Response: Changed as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 21713, 2012.

ACPD
12, C12090–C12097, 2013

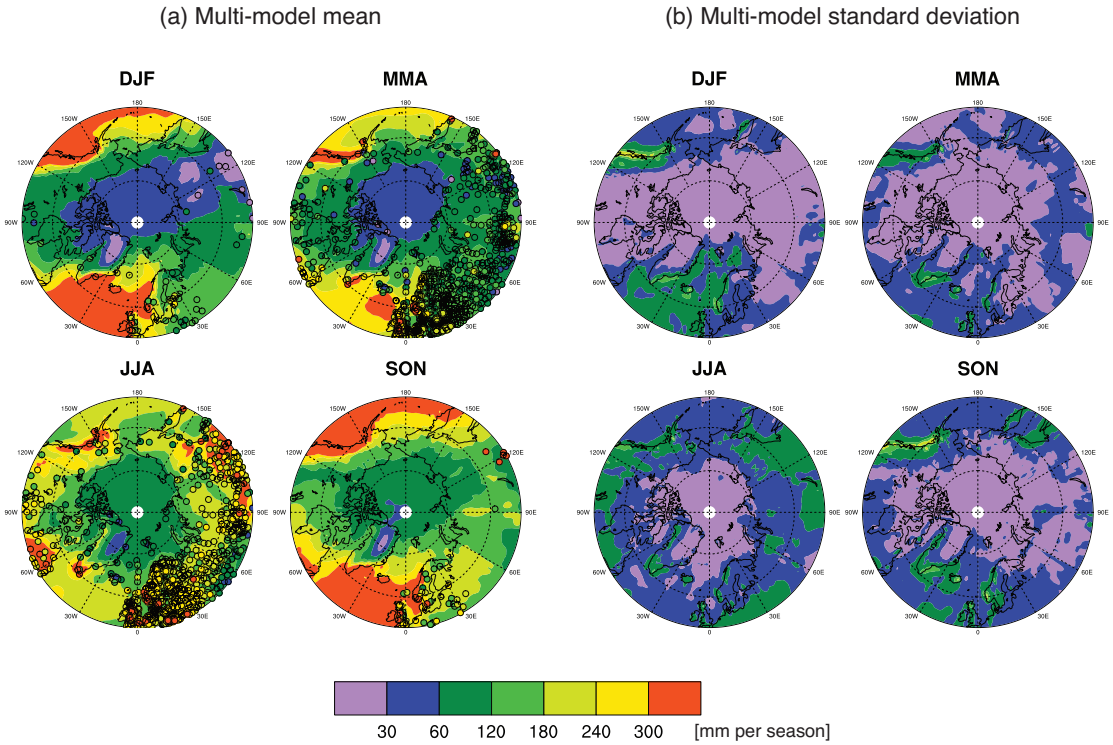

Fig. 1. Comparison of (a) multi-model mean and (b) standard deviation of seasonally accumulated precipitation rates [mm per season] in 2000 to gauge-based precipitation measurements from 1995 to 2004.

ACPD
12, C12090–C12097, 2013

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