

1. The definition of different model types is a little bit confusing and needs to be more consistent. When the CTMs and CCMs are first introduced in the introduction, it would help to clarify the differences between these two model types and their different applications so the motivation of examining the mix of these models is clear. Next in the description of “models”, two other model types: LPDM and ACM, are introduced without any explanation. How does an ACM differ from a CCM? CanAM4.2 is considered as an ACM in Table 1, but a CCM in section 2.3. Also, WRF-Chem is a regional climate model coupled with a chemistry module; technically, it is not a CTM, which refers to chemistry models driven by meteorology fields with no feedback.

Yes we agree, a description of the various model types is missing and the models types have not been assigned fully consistently. We also found that we referred to ACM as atmospheric chemistry model instead of as an aerosol climate model.

We added following two paragraphs to explain the different model types:

In our comparison two types of atmospheric models were used: off-line models and on-line models. Both model types have certain advantages and disadvantages. Off-line models based on meteorological re-analysis data can capture actual meteorological situations, thus facilitating a direct comparison of measured and modelled aerosol quantities. Often, they also have higher resolution than the on-line global models. However, off-line models cannot be used for predictions and the off-line coupling can also cause inaccuracies in the treatment of transport, chemistry and removal processes. The global on-line models in our study are free-running and thus produce their own model climate, which means that they cannot reproduce a given meteorological situation. Nevertheless, their modelled climate should correspond to the current climatic conditions and, thus, seasonally averaged quantities (i.e., averages over many different meteorological situations) should be comparable to measured quantities. The main advantage of the on-line models is that they can also be used for predictions.

We used two different types of off-line models, namely Eulerian chemistry transport models (CTMs) and one Lagrangian particle dispersion model (LPDM). Our on-line models were climate chemistry models (CCMs), where a climate model is coupled with a chemistry and aerosol module. We also use one global climate model coupled with an aerosol module which, however, does not simulate atmospheric chemistry. We refer to this as an aerosol climate model (ACM) to distinguish it from the CCMs. Furthermore, we use one regional weather forecast model coupled on-line with a chemistry model (WRF-Chem). This model is similar to the CCMs, but only used for regional simulations and it is designed for short-term simulations rather than simulations over climate time scales. WRF-Chem is also nudged towards re-analysis data and therefore can capture actual meteorological situations, similarly to the off-line models.

2. Aerosol emissions are important for understanding the simulations of concentrations and seasonal variations. Unfortunately, the two emission papers that this paper refers to, Klimont et al. 2015 a and b, are neither published yet, nor available anywhere. In this case, the authors need to give more detail about the emissions used, such as temporal resolution of other main sectors in addition to domestic heating; are the pan-Arctic BC and SO₂ emissions used in this study comparable to previous studies? Especially if underestimations of biomass burning emissions and missing Russian BC sources are suggested responsible for comparison with obs, how do the biomass burning and anthropogenic BC emissions used compare with other emission data sets in literature?

We agree it is unfortunate that the Klimont et al. (2015a, b) papers are still in preparation. However, detailed statistics of the ECLIPSE emissions at high latitudes (e.g., national emission totals for all Arctic Council nations) are presented in the AMAP (2015) report. This report contains a full chapter discussing the ECLIPSE emissions, including comparisons with several other emission inventories.

With respect to anthropogenic emissions of BC at high latitudes, the biggest difference to other inventories is the inclusion of emissions from gas flaring. While flaring emissions are not very large compared to BC emissions from other sources, some of the emissions are at very high latitude and so are particularly important for the Arctic. The impact of this source on BC in the Arctic is large and has already been quantified by Stohl et al. (2013). Adding flaring emissions also leads to improvements of the simulations with most (or all) of the models used here (unpublished comparisons done with several models). A comparison for India has shown that ECLIPSE emissions are higher than, for instance, RETRO emissions (partly due to the inclusion of emissions from wick lamps), which leads to better agreement between model simulations and measurements in South India (Gadhavi et al., 2015).

We think it would be distracting from the main purpose of the paper to provide too many details about the emissions used, especially since the relevant information will soon be available. However, we have added the following text:

“A detailed description of the high-latitude emissions in the ECLIPSE inventory, including national totals for Arctic Council nations and comparisons with other emission inventories can be found in AMAP (2015). The ECLIPSE emissions were also used and discussed by Stohl et al. (2013) for the Arctic and Gadhavi et al. (2015) for India.”

AMAP: AMAP Assessment 2015: Black Carbon and Ozone as Arctic Climate Forcers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, in press, 2015.

With respect to biomass burning emissions, we use the GFED inventory and this data set has been documented extensively by others, so we do not see a need to provide more information in our paper.

3. The conclusions of the paper could be significantly elevated, if the authors can provide more discussions and insights regarding the model-data and model-model discrepancies. For example, CanAM4.2 performs much better than any of other models especially for sulfate concentrations and surface aerosol. What is so unique about this model? The third conclusion seems to allude that internally mixing leads to similar removal of BC and sulfate, so are those three models that simulate the correlation between BC and sulfate better all assuming internally mixing while others not?

Unfortunately, we don't know why CanAM tends to produce better agreement with near-surface observations than other models. The group running CanAM made a more thorough investigation on what might cause the differences in the simulated BC concentrations. This analysis has been submitted to JGR (Mahmood et al.; 2015 submitted). CanAM produces higher near-surface and lower tropospheric concentrations in winter and spring than NorESM, CESM, or SMHI. Sensitivity tests with CanAM and CESM give evidence for a strong sensitivity of these results to parameterizations of stratiform wet deposition and aging processes. Stratiform wet deposition in CanAM is relatively inefficient in winter and spring compared to the other models, which explains the higher surface concentrations in CanAM. We have not determined the cause of these differences

but it seems likely that these differences are related to parameterizations of wet deposition scavenging efficiencies in the models.

We added to the manuscript:

The reason why CanAM4.2 captures the spring peak better might be that this model has a less efficient removal through wet deposition under stratiform condition compared to the other models (Mahmood et al., 2015 submitted).

Additionally we also added some more information how aerosols are treated in the various models in table 1.

Some minor comments:

1. Page 10428, line 15: “eBC/rBC” reads like the ratio of eBC over rBC. Suggest to change to eBC or rBC

We replaced all eBC/rBC as suggested.

2. Page 10428, line 16: “previous comparisons”

We substituted past by previous

3. Page 10431, line 5: sulfate originates from sea salt over the oceans? Nss-SO4 is a form of sulfate aerosol but not a source.

We reworded to:

Sulfate aerosols are formed by sea spray over the oceans or originate from natural sources such as oxidation of DMS or volcanoes.

4. Page 10436, line 3: Klimont et al., (2015 a and b) not available. Need to give more information. See main comment above.

See our response to the earlier comment.

5. Page 10436, line 22: is the nudging in WRF-Chem applied to all the vertical levels? How frequent?

The nudging was applied every six hours on winds, temperature and humidity to all vertical levels above the PBL. We added the information to table 1.

6. Page 10436, line 27: insert a “including” after “CCMs”

Done.

7. Page 10441, line 24: “data the comparison”?

Thanks, we meant the data comparison.

8. Page 10442, line 6: references needed for “and in most other global emission inventories”

We have replaced this text with the following sentences: Similar problems likely occur with most other global emission inventories. For instance, AMAP (2015) compared the ECLIPSE emission

data set with 10 other inventories and found that the differences between the different inventories grow with latitude and are largest north of 70°N (i.e., high-latitude Eurasian emissions).

9. Page 10443, line 22: “focused”

Thanks, changed.

10. Table 1: what is the simulated model domain for each model?

All models except for three were run on a global model domain. SMHI-MATCH, WRFchem and DEHM were only run for the Northern Hemisphere – we added this information into table 1

11. Table 2 caption : Change to “Median values of observed. . .”; insert “at surface” after “mass concentrations”

Thanks, changed.

12. Figure 5: replace “eBC/EC” with “eBC or EC

We replaced all eBC/EC as suggested.

3. Figure 6. The light red shaded areas are not visible in the figure – at least not in my printed copy

This is strange. We checked again and both on the print outs and on the screen they seem well visible to us.