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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol optical depth over the Arctic: a comparison of ECHAM-HAM and TM5 with ground-based, satellite and reanalysis data" *by* J. von Hardenberg et al.

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The paper is well-written and easy to read. I would therefore recommend its publication while recommending to the authors to add a section with an overview of the models' "climate" (i.e. winds, cloud cover and precipitation) over the period 2001-2006.

We included a new subsection (3.1) at the beginning of the results section, titled "Model precipitation". In this section we present and comment two new figures (now fig 2a and 2b) which show monthly mean climatologies in the period 2003-2006 (common to all

datasets) of zonally averaged precipitation and of zonally averaged total cloud cover, as a function of month and latitude. The text of this new section is as follows:

"3.1 Model precipitation

In the Arctic wet removal processes are the main mechanisms for aerosol removal (gravitational sedimentation plays a minor role because the aerosol is dominated by small particles). For these reasons the ability of a global climate model in reproducing reasonably the atmospheric branch of the water cycle is crucial, in particular cloud and precipitation fields at high latitudes and their seasonality. We compare Arctic precipitation climatologies in ERA-Interim, MACC and in the ECHAM model, reporting in Figure 2a zonally averaged total precipitation fields, as a function of the month, averaged over the period 2003-2006, common to all datasets. Both a nudged and free simulation of ECHAM are shown. While average precipitation is comparable in winter months, ECHAM shows slightly higher precipitation in summer, compared both to MACC and ERA-Interim, mainly south of 70°N, particularly for the non-nudged simulation. Investigation of spatial maps (not shown) reveals that this excess summer precipitation occurs mainly over the areas from eastern Siberia to Alaska. This difference may be particularly relevant for removal of OC, BC and sulfur aerosols emitted by summer fires in these areas. Figure 2b also reports a comparison of total cloud covers (as a fraction) in the different models. While MACC shows the highest cloud fraction in all months at high latitudes, and cloud cover in ECHAM, in particular in the nudged run, is lower compared to ERA-Interim and MACC, the differences remain of the order of 0.1."

Examining in detail atmospheric transport (winds) in the model and in the reanalyses is a more complex issue which would fall outside the scope of this paper. In this work we address potential issues in transport by using runs of the ECHAM model which are nudged to ERA-Interim reanalyses. The resulting model wind fields keep indeed close to the reanalysis ones. Further, the TM5 simulations presented here were obtained using directly ERA-Interim for transport. As we discuss in the paper, there may of course still exist issues such as for example a possible underestimation of the export of aerosols from the PBL to the free troposphere, but the large-scale wind fields are reproduced in the model.

Wind fields are also provided by the MACC reanalysis for the period 2003-2006. It might be worth it to use the winds from MACC rather than ERA-Interim when available as those wind fields would have been produced with the same (and more recent) model version that has produced the aerosol fields.

This would certainly be a possibility. Since both are reanalysis products, and both based on IFS, the instantaneous wind fields produced by the two systems are indeed quite similar. For this reason we expect that our results would not be affected too much by such a change. Looking at instantaneous daily wind fields from both systems confirms this point (we checked for a few random months, for example 01/2003 and 07/2003). When used to nudge the ECHAM model the change in resolution has also to be considered, which would further smoothen out any differences. Finally we also notice that MACC does not cover the entire period considered in this paper (2001-2006), which is instead covered by ERA-Interim.

Why not show the plots of the sea-salt and the organic carbon?

We enclose to this reply the spatial maps for the EGFED simulation, showing total AOD and the contribution to total AOD by OC and SS. We do not include these plots in the paper in order not to burden it with too many (and not too relevant) figures.

This is interesting. Perhaps this is an overestimation of sea-salt in the reanalysis. It would be great to have other (independent) observations. Unfortunately the period under study is precedent to the launch of the CALIPSO satellite (April 2006). Could the authors think of datasets other than the MODIS data for model assessment?

We agree that further validation of the MACC reanalysis over a more recent period, using CALIPSO data, would be useful, but it is beyond the scope of this paper.

Did you use any multiplicative factor for the black carbon and organic matter emissions from wildfires? It appears to be something needed in order for model AODs to match satellite remotely sensed AODs. Please see these publications for further reference: J. W. Kaiser et al., 2012: [. . .] Huijnen, V. et al, 2012 [. . .]

We thank the reviewer for this suggestion. We included the two citations in the paper and we performed a new experiment in which OC and BC of the GFED3 emissions are multiplied by a factor 3.4. The results have been added to figure 7 (now 8) in which we compare the effect on AOD at the station locations of different emission datasets, discussing them as follows:

“Two recent publications (Kaiser 2012 and Huijnen 2012) recommend to enhance particulate emissions from wildfires with a global corrective factor of 3.4 in order to compensate for an observed discrepancy between bottom-up and top-down aerosol emission estimates. We tested this suggestion performing an experiment with the EGFED emissions, in which OC and BC emissions are multiplied by this factor, also reported in Fig. 8. We find a significant increase from June to August for Barrow, where modeled AOD becomes comparable with observations. Indeed in this area summer fires in Siberia, Alaska and Canada can have a significant impact. The differences compared to the other simulations remain extremely small at all other stations. “

We also added a sentence in the conclusions to point out this result.

Could also be due to wrong cloud and precipitation fields in the model. Since the wet removal is so crucial, then it’s important to make sure that the models have a reasonable representation of the atmospheric branch of the water cycle.

We added the following sentence discussing this point in the conclusions:

" . . . In particular, values in autumn and winter appear too high, and a summer minimum appears, while areas with high AOD over northern Russia and America in summer are not reproduced. These differences in seasonality may be linked with the higher summer precipitation in ECHAM compared to MACC and ERA-Interim, reported in section 3.1. While the wet-scavenging parameters are reduced in the modification, summer precipitation at high latitudes can still contribute to significant wet scavenging, leading to low summer aerosol concentrations."

I am not convinced by the explanation given in lines 15-19 that chemical and physical processes are more important than transport because the model showed little sensitivity to being run in climatological mode or nudged using analyzed winds. Lack of the right seasonality and wrong spatial structure for arctic aerosols can only be related to 1) errors in transport or 2) errors in emissions, and the authors exclude both. I may be missing something, but to me it's not possible that it all comes down to the wet scavenging.

We removed the sentence from lines 15-19 and we reorganized the discussion to point out also the importance of correctly reproducing model climate at high latitudes, in particular precipitation. See also our reply below.

I would also recommend reconsidering the conclusions. Given the lack of right seasonality in the model AOD, I am not convinced that only working on more complex parameteriza- tions for wet removal processes is the best solution.

Again, I am not sure that looking at improving scavenging processes alone is a good idea. The fact that the AOD matches better with observations in magnitude when using the Bourgeois and Bey (2011) parameterization but the seasonality is still wrong, means to me that focusing on the wet removal processes is not the way to go. You may just be getting higher AODs for the wrong reasons. A more in-depth look at the model wind, clouds and precipitation fields for the Arctic would be more instructive.

We restructured our conclusions to take into account these comments. In particular

we now use the following formulation (after discussing the wet scavenging modification results):

"The results reported above indicate that changes in wet scavenging, while they do not produce a correct seasonality and spatial aerosol distribution, allow to reach yearly averaged values of AOD in the Arctic which are more realistic. Efforts towards a better representation of aerosols in the Arctic, for ECHAM-HAM and possibly TM5, should aim at improving the representation of features and processes involving aerosol removal and transformation. In particular, two aspects should be considered: On one hand, the atmospheric models have to be capable, at high latitudes, to represent correctly physical features related to wet removal, such as cloud coverage, structure and precipitation. On the other hand current parametrizations for wet removal have to be further developed and tuned, taking into account some of the specifities of the Arctic environment. Several improvements that may be beneficial are being developed and need to be investigated in detail. A recent study (Browse et al., 2012) associates the seasonal cycle of Arctic aerosols with scavenging processes, in particular with the passage from inefficient scavenging of soluble aerosols from ice clouds in winter to more efficient scavenging from low, warm liquid clouds in summer. Croft et al. (2010) compared different in-cloud aerosol scavenging parametrization schemes for ECHAM-HAM, finding large variabilities in aerosol mass and number burdens, and improved agreement with recent diagnostic and prognostic scavenging schemes, particularly at high latitudes. Improved schemes for below-cloud scavenging by snow in ECHAM-HAM are discussed in Croft et al. (2009).

Another source of discrepancy can be related to differences in transport mechanisms between the models and the real atmosphere. While large-scale winds are similar, mesoscale dynamics and transport barriers are poorly represented by the global models considered here. Future developments should thus also consider aerosol dynamics in high resolution regional and global models capable of describing mesoscale processes."

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 8319, 2012.

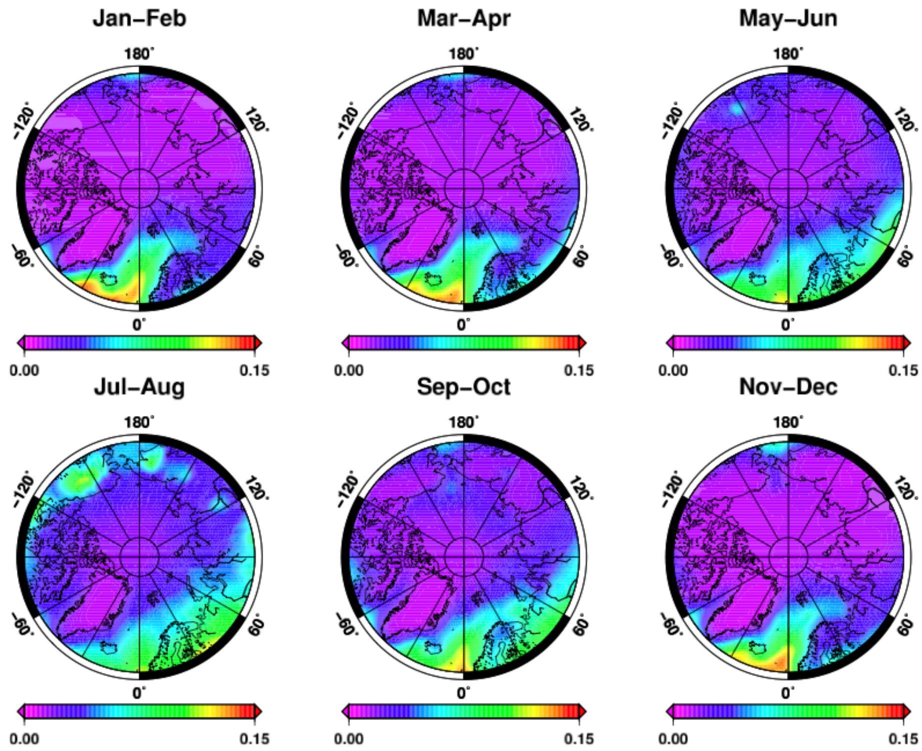

Fig. 1. Map of total AOD for the EGFED simulation.

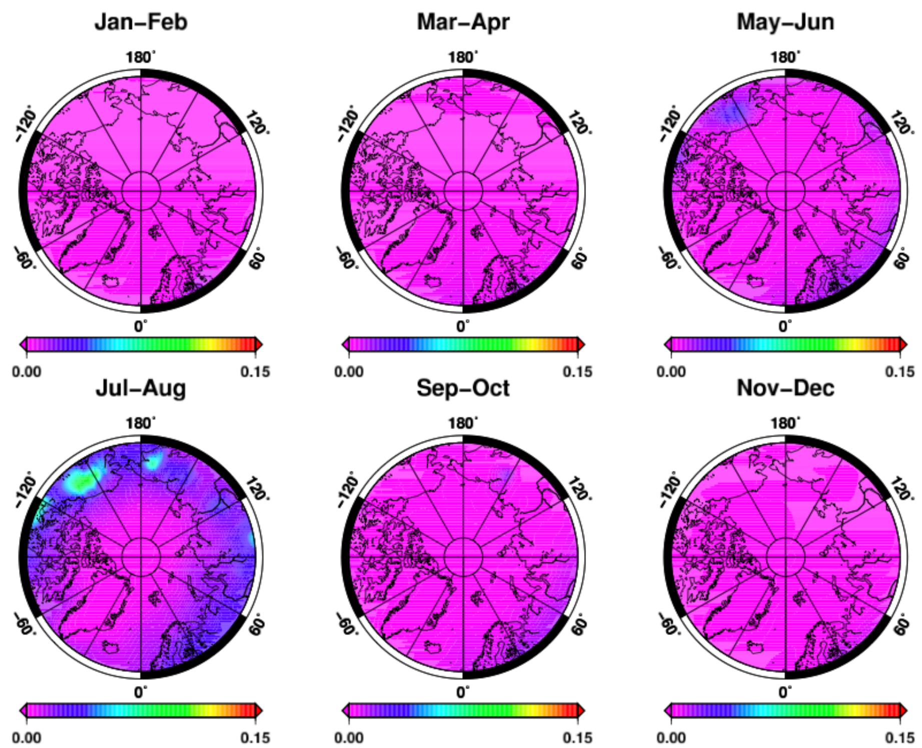

Fig. 2. Map of contribution to total AOD by OC for the EGFED simulation.

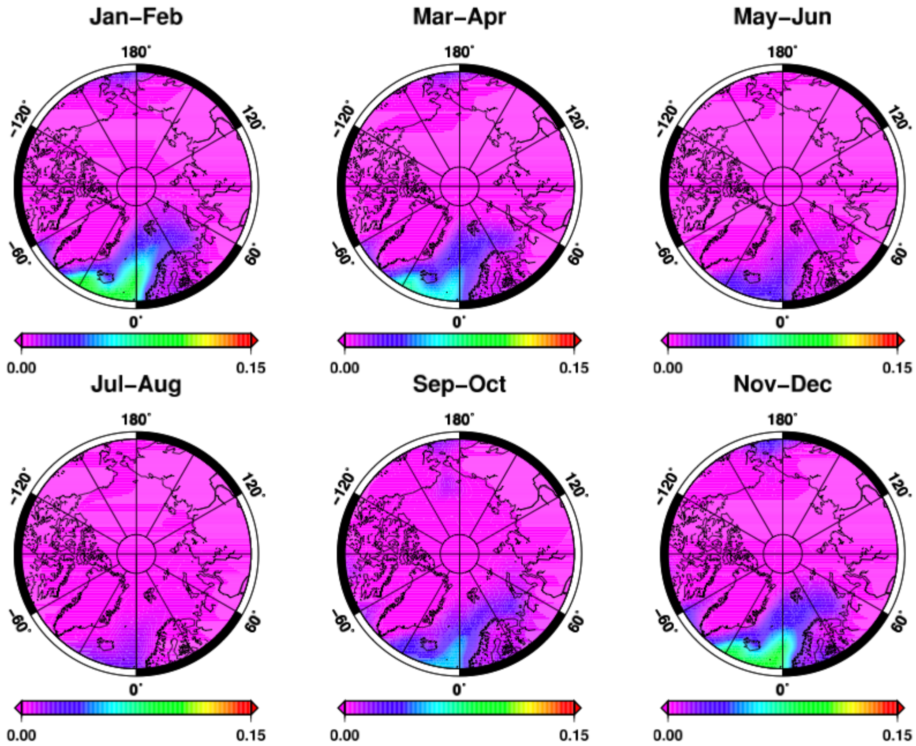

Fig. 3. Map of contribution to total AOD by SS for the EGFED simulation.