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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impacts of climate change on air pollution levels in the Northern Hemisphere with special focus on Europe and the Arctic" *by* G. B. Hedegaard et al.

Anonymous Referee #1

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The manuscript by Hedegaard et al. (2008) describes the analyses and results on air pollution impacts from future climate change for Europe and the Arctic. This research is important especially when there are few studies that look at the climatic impacts in these regions with regards to air quality. The descriptions and discussions are systematic, thorough, and with good details. The manuscript has sections that are repeated and should be removed to shorten the overall length. There are also descriptions that can be added to provide more information on the presented analyzes.

The two objectives of the study are:

(1) To show that the large scale general circulation model (ECHAM4-OPYC3) can be

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used to drive chemical transport model (DEHM) and produce adequate results.

(2) Investigate the future changes in meteorology and chemical conditions with the coupled climate and air quality model framework (ECHAM4-OPYC3 DEHM) assuming no changes in future anthropogenic emissions.

To address (1), model performance statistics for selected species are compared between DEHM driven by ECHAM4-OPYC3 and DEHM driven by observation based weather forecast system (ECMWF MM5) for the 1990-1999 period. To investigate the changes in future air quality (2), the coupled model system (ECHAM4-OPYC3 DEHM) is applied to simulate conditions in 2040-2049 and 2090-2099 periods, and results compared against the base-case 1990-1999.

Specific comment/question:

– Additional descriptions on emissions used in the model system will better aid the interpretation of the results. In Section 2.2 (pg 1766 line 10-22) emissions are compiled from GEIA, EDGAR and EMEP datasets. Since these are annual emissions, do they differ by year/month throughout the decadal runs? It is obvious that SO2 emission varied throughout the 1990-1999 episode, what about the SO2 emission variations in the future decades? How does the emission variation differ from the sulfur model used in the ECHAM4-OPYC3 model? What about emissions of other species?

– "Variable emissions" is mentioned in Section 4.3 (line 15). Is this variability in anthropogenic emissions, or only in biogenic emissions? Similarly, more descriptions on the biogenic emissions are necessary since they vary significantly between the current and future scenarios: what species are being estimated with the BEIS model? How does the emission change with global/regional forcing between scenarios? Does the model account for changes in vegetation/CO2 from the influences of global forcing? – If biogenic isoprene is the only specie that changed between scenarios, this should be mentioned in Sec 2.2 with summary of magnitude changes.

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– Section 3.1 last paragraph: What is the fifth 10-year long simulation?

(1) ECMWF-MM5 DEHM 1990-1999

(2) ECHAM4-OPYC3 DEHM 1990-1999

(3) ECHAM4-OPYC3 DEHM 2040-2049

(4) ECHAM4-OPYC3 DEHM 2090-2099

– In addition to temporal comparisons with spatially averaged data (average across all sites), how does the model system perform spatially? Can the (ECHAM4-OPYC3 DEHM) system capture the urban/rural concentration variability similar to that driven by a forecast system (MM5 DEHM)?

– Pg 1774: What is the likely cause for over predicting SO4/SO4 WD? The over prediction is more obvious in MM5 driven DEHM and there is a clear seasonal trend in the positive bias.

– The unit label for SO4 in Figure 2 and 3 are [mgN/m2] and not [mgS/m2]?

– There are repeated descriptions of the statistical methods. Section 4 and Sections 5.1 and 5.2.

– Table 1 and Table 3 are not "color coded" as mentioned in the manuscript and the table captions.

– Table 2 and Table 3 the entry for "O3"; is repeated. What is the difference between "O3", "O3 H", and "O3 DM"?

– If I understand correctly, in Section 5.2 and 5.3 the t-tests are carried out with annual averaged concentrations (10 samples and 18 degrees of freedom). Since most species have large seasonal concentration variations, how would the conclusions differ with monthly/seasonal averaged concentration comparisons?

– It is not entirely clear how FB in Table 2 and Table 3 are calculated. In Table 2, is

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a positive FB means MM5 driven DEHM is overestimated compared to the ECHAM4-OPYC3 driven DEHM?

– Following the analyses in Section 5.3 Pg 1780, one can see consistent reductions in NH3/NH4 WD and increases of SO2 from 1990 to 2040 and 2090. If the emissions are constant for the three scenarios, what cause these species to vary? Does the DEHM model have inorganic thermodynamic equilibrium algorithm to account for the inorganic chemistry of the sulfate-ammonium-nitrate system?

– Pg 1781 line 1: The conclusion: "Generally the concentration of particles and the wet depositions are predicted very well with respect to their mean values." is slightly overstated. Only results for sulfate PM were presented and discussed in Section 5. The t-test results in Table 2 showed significant differences in the annual mean concentrations for nitrate and ammonium between the two model systems.

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– Section 6.2.2: The changes of SO4 WD (Fig 7) are insignificant everywhere, however in the t-test (Table 3) there are significant reductions in SO4 WD between the current and future decades. What cause the inconsistent results? The reverse is seen for ozone, where Fig 10 showed significant changes in most areas but Table 3 showed no significant changes for O3, O3H and O3 DM between current and future scenarios.

– Section 6.2.4: Besides the Caribbean, portions of Alaska also have higher ozone and NO2. There are evidences of ship emissions causing higher NO2 in the future (compare Fig 7 with Fig 11). If emissions for the scenarios are the same, what caused the increases in SO2/NO2 on these ship routes given the higher OH/O3 in the future?

– Section 6.2.5: "Since the model do not posses any memory of this specie [OH], but is only estimated via a production term and a loss term." - OH is known to form and deplete via many different chemical pathways (eg R1). Does the statement mean that the model does not assume a background concentration of OH? Or does it mean

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that because of the fast reactivity/short lifetime, the model does not account for the transport of OH?

– Section 6.2.5: What are the likely causes of different OH spatial distribution with elevation? Besides Greenland, what caused the large gradient differences between land and ocean?

– Section 6.3 pg 1791: The SO4 reductions in Norilsk surrounding areas correspond better to reductions in SO2 (Fig 2) than to increases in SO4 wet deposition emphasized in the manuscript (Fig 9). The significant increases in SO4 in the northeastern portion of North America also correspond with increases in SO2 than to changes in SO4 wet deposition.

– Section 6.3 pg 1791: The authors argued that increase in sulfate (SO4) over Norilsk is due to increases in OH which caused more oxidation of SO2 - (thus decrease SO2 lifetime and increase SO4 concentrations). This does not seem to be supported by the predicted OH changes for the region. In Fig 12 (bottom right subplot) there is no significant difference in the future OH concentrations for the areas representing Norilsk (the red hotspot in the center of Fig 8 bottom right subplot).

– Please label/identify the locations mentioned in the manuscript in one of the figures (eg Norilsk, Mediterranean, etc.).

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 1757, 2008.