Atmos. Chem. Phys. Discuss., 8, S3878–S3883, 2008
www.atmos-chem-phys-discuss.net/8/S3878/2008/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "A multi-model assessment of pollution transport to the Arctic" *by* et al.

Anonymous Referee #2

Received and published: 18 June 2008

General comments

The manuscript describes a multi-model assessment of the response of arctic gas (CO) and aerosols (SO2 and Black Carbon, BC) concentrations to perturbations in anthropogenic pollutant emissions from several regions. They study in details the relative importance of source regions in the Arctic region, and try to assess the influence of transport, microphysics and chemistry on the CO, BC and sulfate variabilities between the models. The paper is well written and presents significantly new results in terms of intercomparison and participates in assessing what should be the focus of future studies to improve global models accuracy. However, the paper should investigate in more details the discrepencies in terms of transport pattern between the models to really conclude on the influence of transport, microphysics and chemistry on the inter-model

variability. The fact that the discrepencies of transport patterns toward the arctic is not clearly shown in the article makes the conclusion doubtful. So the article needs more evidence to support the conclusions. The paper should be acceptable for publication in ACP after addressing the following comments.

Major points:

In the section 5.2, the authors are trying to isolate the processes governing variations in aerosols by comparing the arctic sensitivity to the different region sources in the models. They found that the intermodel variations of arctic sensitivity are larger for BC than for CO. As the CO is insoluble, they concluded that the wet removal processes of aerosols and BC play a more important role than the dry transport to the arctic. Finally, they concluded that *"dry transport differences play a major role in the intermodel variations of insoluble"* tracer like CO, and *"aerosol physics and wet removal play a more important role"* for aerosol and BC variability, and are the principle source of uncertainty for these species. In the conclusion and discussion section, the authors say that *"Previous work has discussed apparently conflicting results on transport (Law and Stohl, 2007)"*. On Page 8411, the authors compare their BC results with the results from Koch and Hansen (2005). After changing the average emission factors to match up the emission from Koch and Hansen, they conclude that the results on the BC sensitivity in the arctic are in agreement with Koch and Hansen, and thus the results of the global models are robust. They finally suggest that the main differences come from the differences between emission inventories. They conclude by: *"The relative importance of the different regions is robust"* and *"The current results are robust across models in many respects, allowing better understanding of how various types of pollutants arrive in the Arctic and influence climate and air quality"*

With the evidences presented in the article, I am not convinced by the conclusions. If the aerosol and BC arctic sensivities are mainly influenced by the wet removal processes in the model, it's more likely because of differences in transport patterns and not because of differences in microphysics and/or in-cloud processes calculated in these

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models.

The results in Stohl (2006) on the BC sensitivity in the arctic (calculated with the Lagrangian particle dispersion model FLEXPART) look different from those of Koch and Hansen (2005) even though they use both the same surface inventory. One of the novelty in the article is that Stohl (2006) has defined 3 main transport pathways that the airmasses have to take before reaching the arctic: 1) a low level altitude transport+uplift due to the arctic front, 2) a low level altitude transport+ diabatic surface cooling: these 2 kind of transport affect mostly the european emissions. The third transport is a strong uplift (near the source region), with a free tropospheric transport and a diabatic cooling in the arctic. In this case, wet scavenging is expected outside the arctic region. This transport pattern involves emissions from Asia and America. In general, the wet deposition can occur in the arctic for particles from europe, while it exclusively occurs outside the arctic for asian particles. What Stohl (2006) found also is that the BC sensitivity to the source regions is much lower in summer than in winter because of transport pattern differences, and not because of microphysics or wet deposition. In winter, the Asian plumes undergo a strong uplift near the source emission region, and reach the arctic relatively dry. Precipitations occur almost exclusively outside the arctic, in contrast to the fast european trajectories. In summer, the transport is slower, and almost twice as long to reach the arctic. the highest PES is found over ocean. Finally, Stohl explained that the differences with the Koch and Hansen (2005) study are likely due to systematically differences in transport patterns.

First of all, there is no discussion about these 3 different transport patterns in the introduction of the article. As this article discusses in priority the transport toward the arctic and is entitled "A multi-model assessment of pollution transport to the Arctic", these specific transport patterns should be at least cited in the introduction. Then, the fact that the results presented in the article are consistent with those from Koch and Hansen means that they are not consistent with Stohl (2006). So the question is: Even though the average concentrations and relative contribution of the source regions to

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the Arctic is robust, does this mean that the typical transport patterns toward the arctic are robust between the models anyway? This is the key point as this is more likely the main factor of the discrepencies found between Stohl (2006) with a Lagrangian particle dispersion model and Koch and Hansen (2005) with a global model. This is clear when one thinks about the strong uplift in the Asia region. If the asian airmasses take a different transport pattern to enter the arctic and don't undergo a strong uplift, that will affect the humid convection and then the microphysics and the wet removal involved in it.

Furthermore, the robustness of the models found in the arctic is partly due to the fact that the statistics in this paper are calculated over a large region (from 68N to 90N and -180 to 180 in longitude). However, when looking at the model results for some specific stations (figure 7), the results look highly variable, especially for the BC and sulfate. How does the relative contribution of the different regions look like for these stations? are they still robust between the models? As the authors said in the introduction, the pollution that reaches the Arctic *"alters local radiative fluxes, temperature profiles and cloud properties"*. I think that the statistics about the relative contribution of the source regions into the whole arctic region is probably not enough to assess the robustness of the models about the local alteration due to this pollution transport.

So my suggestion is that the analysis should not only be based on the total concentration in the arctic, but also on the transport patterns taken by the different sources, to conclude on the robustness between models.

One suggestion is to calculate the standard deviation of the relative contribution of the source regions to the CO sensitivity for 3 different levels in grid cells of say 15 degrees in longitude and between 63N and 68N to see the discreprencies at the entrance of the arctic region, and between 68N and 90N to see the longitudinal discrepencies within the arctic region, in winter and summer. That will give a better idea on the local robustness of the transport in the models and/or which part of the arctic and the entrance region has the strongest discrepancy between the models. For instance, if

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the strongest discrepencies occur preferentially over the atlantic and pacific oceans, that will mean that the large scale transport (and the wet removal) from warm conveyor belts is not robust between models. If the variability is uniform over the globe, so that will confirm your hypothesis that the global models have consistent transport patterns toward the arctic.

minor points:

page 8388, l 19: "it is crutial to quantify the relative importance of emissions from various source regions in determining local pollutant levels": Stohl (2006) is based on this, and should be cited in this context.

page 8389, l 15: "Northern Asia (Russia) was not included as a source region as its total emissions of most pollutants are comparatively small" This is right for the anthropogenic sources, but probably not for the biogenic sources. The biomass burning emission of BC and CO can increase significantly the BC amount in the Arctic.

page 8390, l 13: "followed by a year of integration with 2001 meteorology": Please, explain why 2001. Is it for being more realistic with the surface inventories?

page 8392, l 11: "Surface values are those in the lowest model layer": Does the lowest layer mean the same thing throughout the models? if they are not consistent, that should be quoted in the text as a source of uncertainties for the surface results in the Arctic.

page 8392, l 9: "... the Arctic DOME at low altitude during the cold ..."

page 8392, l 11: "(Law and Stohl, 2007; Klonecki et al., 2003)" You should cite Stohl, 2006 here too.

page 8392, l 14: "During summer, when the polar front is at its furthest north, emissions from East Asia, Europe and North America have a comparable influence on the Arctic surface (per unit emission), with a slightly larger contribution from Europe." This is different than what Stohl (2006) has found, and should be cited here or in the dis-

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cussion/conclusion section.

page 8395, l 3: "The enhanced winter sensitivity results from both faster transport during winter and slower removal at this time as the Arctic is stable and dry": citation?

page 8403: l 24 and 28: change "SA" to "South Asia".

Table 1: A column with the references of the models would be helpful. Add also in the caption or in the table that the horizontal resolution is in degree.

Figure 7: The grey lines are invisible when this figure is printed. Please make the gray lines darker, or change the colorcode.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 8385, 2008.