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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Source attribution and interannual variability of Arctic pollution in spring constrained by aircraft (ARCTAS, ARCPAC) and satellite (AIRS) observations of carbon monoxide" *by* J. A. Fisher et al.

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We thank the reviewer for the thoughtful and useful comments. Our responses to the comments are provided below, with the reviewer's comments italicized.

1. Uncertainty in the optimized emission estimates. While aircraft-based corrections (Table 2) from ARCTAS and ARCPAC qualitatively agree with each other, quantitatively they differ quite significantly. This implies that the corrections are sensitive to the available measurements and are campaign-dependent. I am particularly baffled by the

ARCPAC panel in fig 4. While the ARCTAS-based optimized results moves the mean vertical profiles of CO closer to the observations below 4 km, the two peaks (∼1km and ∼5km) which are associated with enhanced Russian biomass burning plumes (Figure 7) completely disappeared. This clearly suggests two things: i) the lower-level bias is possibly corrected for the wrong reason, and ii) a 32% downward correction is too much and as a result the Russian biomass burning contribution are too small. In addition to derive correction factors based on ARCTAS only or ARCPAC only, have the authors try the two combined? I would think by increasing the data size, it helps to reduce the uncertainty.

We agree with the reviewer that a single inversion using both datasets is a more robust method to assess the source contributions. We have re-done the inversion using the combined ARCTAS and ARCPAC dataset and have changed the text, tables, and figures accordingly.

2. The validity of using AIRS to understand transport of pollution to the Arctic and the associated interannual variability. I feel the discussion on this is rather weak, possibly incomplete. As pointed out by the authors that the sensitivity of AIRS CO is generally weak in the boundary layer. The 9 April 2008 transport event which occurred below 2 km is a typical example of this inadequacy. Therefore, analysis based on AIRS CO will fail to detect long-range transport of pollution, in particular European pollution and Russian biomass burning, that occur in the lower troposphere, which is of great, if not the greatest, importance in understanding Arctic composition and transport. As a result, it is not surprising to find that AIRS CO column show little correlation with NAO, which was shown to be the driving dynamic forcing of pollution transport to the Arctic (Eckhardt et al., 2003; Duncan and Bey, 2004). Is it possible to extend the model simulation with the regional tagged tracers from a single year to 2003-2008? Whether this manuscript is written as a modeling paper focusing on understanding the interannual variability of pollution transport to the Arctic or a paper trying to test the ability of AIRS CO to observe pollution transport to the Arctic, using additional information provided by

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a multiyear model simulation will certainly help for an in-depth understanding of both the interannual variability and the limitation of AIRS CO. I understand this might be a lot to ask for at this stage of the publication. If this is not possible, I would encouraged the authors to expand section 5 to a more in-depth discussion on the validation and limitation of AIRS CO in the polar region, as pointed out by M. Deeter, and how this will possibly affect the detection of the interannual variability of pollution transport to the Arctic using AIRS CO.

We have added the following text discussing the validation and possible limitations of AIRS CO to the beginning of section 5:
"AIRS version 5 total column retrievals for 2003-2007 have been validated against FTIR data at three high latitude sites and show excellent agreement (Yurganov et al., 2009). At Ny Alesund (80°N), the mean annual bias is near zero. Mean bias is also near zero at Kiruna (68°N) and Harestua (60°N) for DOF for signal greater than 0.7, but negative biases are observed at lower DOF. Overall, northern hemispheric AIRS total column observations in April show an 8% negative bias relative to FTIR data. Validation of AIRS CO retrievals in the northern hemisphere with aircraft in situ profiles indicates AIRS is biased approximately 10% high from 300-900 mb with little quantitative sensitivity to the boundary layer, like all thermal IR sounders (McMillan et al., 2009). In the Arctic, this lack of sensitivity may be compounded by the cold surface. We therefore expect AIRS to be capable of identifying transport to the Arctic in the mid-troposphere but not at low altitude, and test this below with two case studies of pollution plumes observed by ARCTAS."

We have also added text after our discussion of the second case study highlighting the limitations of using AIRS CO for studies of interannual variability:
"The limited ability of AIRS to observe low-altitude CO enhancements prevents us from using AIRS to systematically identify near-surface transport events to the Arctic. As we have shown with the GEOS-Chem simulation, this mainly impacts our interpretation of pollution from European sources, which is primarily (though not exclusively) trans-

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ported at low altitude. AIRS is most useful for identifying mid-tropospheric transport, which as we have seen privileges Asian influence."

In our discussion of the link between AIRS CO and the NAO we have highlighted that our analysis has several "limitations," including (as previously mentioned) "the lack of sensitivity of AIRS to surface concentrations where the correlation is strongest."

Additionally, we have added a sensitivity study to investigate the role of transport using the model. Unfortunately, GEOS-5 meteorological fields are not available for years prior to 2004; therefore to retain consistency in the simulations, our sensitivity simulation used 2005 meteorology with a posteriori 2008 emissions. We have added a paragraph detailing the sensitivity study at the end of section 5 along with a new figure (Figure 16).

Page 19405, line 10-15. I am not clear about how you determine the correction factors. Do you regress the tagged CO tracers onto model total CO first, and onto observed CO second, and the ratio of the two slopes is the correction factor? Please clarify.

We now clarify as follows:
"Emissions from these five sources are assumed to represent the only sources of model error. The regression is performed after first subtracting the modeled contribution from all other sources from the total modeled and observed CO. The resulting fit coefficients represent the source corrections needed to minimize the discrepancy between observations and model."

Page 19043, line 22-26. This sentence probably fits better in the last paragraph of section 2 (page 19043).

We have moved the sentence as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 19035, 2009.