Atmos. Chem. Phys. Discuss., 9, C2674–C2679, 2009
www.atmos-chem-phys-discuss.net/9/C2674/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effect of regional precursor emission controls on long-range ozone transport – Part 1: short-term changes in ozone air quality" *by* J. Jason West et al.

J. West

jasonwest@unc.edu

Received and published: 11 July 2009

Response to Anonymous Referee 2.

We thank Referee 2 for his/her thoughtful comments and attention to this manuscript. We agree that there are large uncertainties in this study, and have changed the presentation of the paper significantly to better communicate those uncertainties. The biggest concerns of Referee 2 deal with the fact that we model only one year of meteorology, not considering meteorological variability in our results, and our use of emissions from the early 1990s while emissions have changed since that time.

My major concern is that the results are based on only ONE YEAR of model output

(using meteorological fields generated from a climate model). Therefore no measure of uncertainty or significance relative to climate model interannual variability has been provided.

1. The results are based on an emissions inventory for the early 1990s, about 15-20 years ago. Emissions of ozone precursors in the present day are likely to be different, especially in the United States and Europe where control policies have been implemented, and East Asia where there has been recent intense economic development. This issue is mentioned on Page 7039 and loosely in the conclusion section but it needs to be qualified with how it will affect the major conclusions of the study.

2. A major weakness in the study is that all the results are based on only one year of model simulation using meteorological fields from the MACCM3 Community Climate Model. Anything can happen in a particular year in the climate model! It could have been a particularly dry, wet, cold, hot etc. year. The ozone simulation is very susceptible to meteorology. The maximum changes in the polluted regions (for NOx reductions within that region) are about 1ppbv. Interannual climate variability could be larger than this signal for some regions. The smaller inter-region differences at the pptv level could even be a different sign year to year. Further model years are needed to be run and averaged to yield viable results that can be used by the scientific and policy communities. Typically, chemistry-climate models are run for 10 years to remove the influence of interannual variability in the climate model. Measures of uncertainty / standard deviation need to be included in Tables 2-9.

We thank the reviewer for his/her suggestions on these uncertainties. The results certainly would be more robust had we simulated multiple meteorological years and used that as a basis for quantitatively estimating uncertainty (although this would not be the only uncertainty). However, to be clear, we are not using a coupled chemistry-climate model. Rather meteorology is prescribed and is identical in the base and perturbation experiments. Whereas coupled chemistry-climate models would need to compare multiple simulations to account for internal variability in the models, modeling an en-

semble is not strictly necessary in our case. Rather, the issue in our case is whether the year of meteorology simulated is representative of typical conditions, and how large inter-annual variability in transport may be.

Because we have conducted simulations for many source regions, simulating multiple years for each source region would have severely taxed our time and computing resources, and is beyond the scope of this paper. Accordingly, we have directed the reader to some of the studies that have modeled inter-annual variability for particular source regions, as a basis for determining uncertainty. Many comparable studies in the literature that use chemical transport models with prescribed meteorology only model a single year of meteorology (e.g., Wild et al., 2004; Berntsen et al., 2005; Derwent et al., 2008). Our contribution is to analyze multiple source regions in a common modeling framework, which has been missing from the literature, while studies of inter-annual variability have mainly focused on particular source-receptor pairs.

Our presentation of the methods and conclusions of the study has changed significantly in response to the above comments, and we have added discussion of the relevance of changes in emissions since the early 1990s. The methods section has been updated to acknowledge these important sources of uncertainty before presenting the results:

"Table 1 presents the anthropogenic NO_x emissions in each region in the base simulation. While our simulations represent emissions from the early 1990s, ozone precursor emissions have likely decreased since that time from NA, EU, and FSU, and are likely to have increased elsewhere (Schultz et al., 2007); increases may be most pronounced in East Asia, where NO_x emissions are likely to have increased by more than 50

Similarly, we have updated the conclusions to better communicate this uncertainty:

"There are several important uncertainties and limitations in this work. Our findings are dependent on the definitions of different world regions used here, and should be evaluated through similar experiments in several different models. The emissions used in this study are uncertain and have changed since the early 1990s, particularly in less

industrialized regions, and these uncertainties are expected to affect our estimates of the changes in ozone for 10

3. The model seems to over-predict surface ozone with large discrepancies in the U.S. No evaluation is provided for 7 of the 9 regions. The model-observation discrepancies are orders of magnitude larger than the changes imposed via the NOx perturbations applied within the regions. How useful are the results for developing regulatory controls when the current ozone simulation does not match observations convincingly?

Horowitz et al. (2003) compare the model results against gas-phase measurements for many species, emphasizing the model performance above the surface. In this paper, we make use of surface measurements from global datasets that are available for the early 1990s. Other surface measurements (including EANET) did not become available until later, and surface measurements of ozone and precursors are sparse elsewhere. The results of this paper are useful for informing policy, but we clearly acknowledge the important uncertainties involved (improved through the response to 1 and 2 above), and do not intend for this study to be used "for developing regulatory controls." Few certainly agree that future research to reduce these uncertainties is important, but this study provides unique contributions to the current literature.

4. Are aerosols and more importantly gas-aerosol interactions (full coupling) included in the model simulations? These effects could impact the results significantly, for example, in the case of nitrate aerosol formation.

Aerosols are not modeled fully in this set of simulations, but the most important influences of heterogeneous reactions on the N-species are included. This version of the model includes heterogeneous reactions of N_2O_5 and NO_3 on sulfate aerosols, using prescribed mixing ratios of sulfate from previous model simulations. Details on the chemistry of the simulations are detailed in Horowitz et al. (2003) and summarized by Naik et al. (2005), and we have added one sentence to the methods section to address this:

"The simulations emphasize gas-phase photochemistry and while aerosols are not modeled explicitly, heterogeneous reactions of N_2O_5 and NO_3 on sulfate aerosols are included."

5. Figure 5 is difficult to see clearly and the y-axes all have different scales, which makes it difficult to compare the panels.

Following the recommendations of Reviewer 1 we have improved this figure by removing the outlines for each panel. The figure prints very small in the discussion paper, and we anticipate that it will be larger in the final ACP manuscript. Here we choose to use different y-axes for each panel as some influences would be lost if we adjust to the larger scales of the receptor regions with the largest influences (FSU and SE). The different scales allow the reader to see the monthly patterns of influences as clearly as possible, while many of the other figures and tables communicate the relative importance of different source-receptor pairs. We have added a note to the figure caption alerting the reader to the different vertical scales.

6. NOx (and CO and NMVOC) emissions reductions applied are homogeneous spatially within a region and across all source types. In reality, emissions controls would address specific source types (e.g power plants or motor vehicles etc.) that operate in distinctly different regions. How does the assumption of homogenous emissions perturbations affect the results?

The reviewer is correct that our idealized emission controls may differ from the results of real actions to control emissions. This is appropriate in this case, as we wish to explore the sensitivity of the model to idealized changes in each precursor. We have added a sentence to the methods section to alert the reader to the fact that real emission controls may have different effects on emissions and long-range transport:

"We model idealized controls on emissions of individual pollutants, whereas real actions to control emissions may affect multiple pollutants simultaneously, and may alter the spatial or temporal distributions of emissions."

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 7033, 2009.