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Atmospheric Chemistry and Physics Discussions

Interactive comment on "An analysis of long-term regional-scale ozone simulations over the Northeastern United States: variability and trends" *by* C. Hogrefe et al.

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We would like to thank Prof. Cohan for his review of our manuscript. We appreciate the supportive comments regarding the work presented in this manuscript and the helpful suggestions for improving the clarity of presentation. Our responses to the points raised by Prof. Cohan are shown below.

Specific Comment 1: There seems to be a tendency in the results and discussion to highlight the advantages of the ECHAM5-MOZART boundary conditions, even as the authors note its shortcomings. Although ECHAM5-MOZART yields greater variability than STATIC, it also experiences worse performance by many measures (e.g., Table 3

vs 5, Fig 12 a, Fig 14), in part due to the substantial high bias of ECHAM5-MOZART. This result is unfortunate, since it would be hoped that the much greater effort involved in generating and downscaling spatially- and temporally-resolved boundary conditions would have yielded better results.

Response: We agree that the use of better resolved boundary conditions had a mixed impact on CMAQ model performance. While the representation of variability was improved through the use of time-varying boundary conditions, systematic biases in the ECHAM5-MOZART simulations did lead to a deterioration of other aspects of CMAQ ozone performance such as mean biases and trends. We will carefully review and edit the final paper to avoid emphasizing the benefits over the drawbacks of using the ECHAM5-MOZART boundary conditions. The results clearly show that deriving boundary conditions from a global model for use in a regional model will not necessarily result in improved model performance. Our overall interpretation of the results from the CMAQ/ECHAM5-MOZART simulations is best stated on page 23064, lines 13-19: "... boundary conditions that are either unrealistic or affected by incompatibilities between global and regional models can affect the modeling system's ability to simulate long-term ozone variability and trends, especially for the lower percentiles of the ozone distribution. Potential future improvements would include longterm hemispheric modeling with a single modeling system employing nested grids from global to urban scales and the use of tropospheric observations in data assimilation (Hollingsworth et al., 2008)"

Specific Comment 2: The comparison of boundary conditions convolves two differences: static vs time-varying boundary conditions, and the use of CMAQ defaults vs MOZART generated BCs (which Table 2 shows to be very different in magnitude). While it is too late to isolate these differences, this limitation should be noted.

Response: We agree that it would be interesting to perform additional CMAQ simulations to separate these effects. One simulation could utilize boundary conditions generated by overlaying normalized temporal fluctuations extracted from the MOZART simulation on the static CMAQ default profile. Another simulation could utilize a constant (time-invariant) vertical profile derived from time-averaging the MOZART concentrations. Performing these additional simulations is outside the scope of the present study, but we will note this an area of future research in the final paper.

Specific Comment 3: The claim that agreement is better for upper than lower percentiles (p. 23057, lines 1-3) is contradicted by Figure 7, which seems to show a steady offset between observed and CMAQ. Figure 7 itself seems inconsistent with Figures 5 and 6, which indeed show CMAQ performing better for the higher percentiles.

Response: We thank Prof. Cohan for pointing out that our use of the word "better" was too vague in this context. When comparing the observed and simulated trends for the different parts of the ozone distribution, both directionality and trends need to be considered. While Figure 7 indeed shows that there is an approximately constant offset of about 0.2 – 0.3 ppb/yr in the absolute magnitude of observed and simulated trends across all percentiles, the impact of that constant offset varies across the percentiles. For the 95th percentile, the median trend across all sites is -0.71 ppb/yr for the observations and -0.89 ppb/yr for CMAQ/STATIC. For the 50th percentile, these numbers are -0.07 ppb/yr observed vs. -0.32 ppb/yr simulated, and for the 5th percentile, they are +0.24 ppb/yr observed vs. -0.03 ppb/yr simulated. Therefore, the approximately constant offset has a relative impact of $\sim$25% at the 95th percentile but a much larger relative impact for the 50th and 5th percentiles in terms of trend magnitude. Moreover, the offset actually reverses the directionality of the trend between observations and model predictions for the 5th percentile. We will include this more quantitative discussion in the final paper.

Technical Corrections:

1. p. 23057, line 19: change "was" to "were", for consistency with next sentence.

Response: We will make this correction in the final paper.

2. p. 23060, line 3: change "evaluation" to "evaluating"

Response: We will make this correction in the final paper.

3. p.23061, line 16: specify what is meant by "recent work"

Response: This refers to recent ECHAM5-MOZART simulations performed by two of the authors (M. Schultz and S. Rast). These simulations were performed as part of the EUROHYDROS project and their analysis is ongoing. A reference to the EUROHYDROS final report will be added to the final paper.

4. p. 23063, line 19: remove the word "simulations"

Response: We will make this correction in the final paper.

5. Table 2: Are the ECHAM5-MOZART results averaged over the 18-year period?

Response: Yes. This will be clarified in the final paper.

6. Tables 3 and 5: Since there's no interesting difference between 1-h and 8-h performance, I'd recommend just showing 8-h and merging Tables 3 & 5 so that STATIC and MOZART results can be compared more readily. The statement on p. 23055, lines 4-5 is sufficient to note the similar 1-h and 8-h performance.

Response: We thank Prof. Cohan for this suggestion and will consider it in the final paper. We agree that dropping the 1-hr results would not lead to any significant loss of information. However, we would like to point out that the CMAQ/STATIC and CMAQ/MOZART model evaluation results are being discussed in different sections of the manuscript, so combining the Tables might disrupt the flow of the paper.

7. Table 4: It is confusing what is meant by the entries for maximum and minimum trends. Do you mean trends at the sites with min/max concentration (and if so, the numbers seem to be reversed), or do you mean minimal and maximal trends (and if so, it may make more sense to base this on maximal magnitude, since the maximal magnitude trends probably line up with the sites with maximal concentration).

Response: The entries in questions represent minimal and maximal trends, i.e. they do not necessarily represent the trends at the stations having the min/max concentrations shown in the first two data columns. We will consider displaying the trends at the maximum/minimum concentration sites instead or base the max/min definition on the absolute unsigned trend magnitude rather than the signed trends. We also noticed that Table 4 was mislabeled as displaying results for only May – September when in fact results were based on year-round data, consistent with Figure 8. We will make the necessary revisions in the final paper.

8. Figures 4b and 7 are subsumed by Figure 10, and thus could be deleted to reduce the heavy figure count of this article.

Response: We thank Prof. Cohan for this suggestion and will consider it in the final paper. However, we would like to note that Figures 4b and 7 serve a different purpose than Figure 10. Figures 4b and 7 are part of Section 3.1 which focuses on introducing methods to compare observed and simulated ozone variability and trends. In contrast, Figure 10 is part of Section 3.3 which focuses on comparing the impact of chemical boundary conditions on the simulated ozone variability and trends using the methods introduced in Section 3.1. Thus, even though the information from Figures 4b and 7 is repeated in Figure 10, it serves a different purpose in the context of Section 3.3.

9. Figure 11: Unclear whether it shows MOZART - STATIC, or absolute value of difference.

Response: The figure shows CMAQ/MOZART-ECHAM minus CMAQ/STATIC, not the absolute value of the differences. However, for all four seasons, the difference is positive for almost all grid cells. The only exception is the northwest corner of the modeling domain during winter which shows negative differences. We will clarify this aspect in the final paper.
