Modeling Atmospheric Mercury Deposition to the Great Lakes: Examination of the Influence of Variations in Model Inputs, Parameters, and Algorithms on Model Results

Executive Summary
from Final Report for work conducted
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Executive Summary

This study examined the influence of variations in inputs, parameters, and algorithms on the estimated 2005 atmospheric mercury deposition to the Great Lakes with the HYSPLIT-Hg model. It represents an extension of the baseline analysis carried out with FY2010 Great Lakes Restoration Initiative (GLRI) funding (Cohen et al., 2011)[1]. The overall objective of this FY2011-funded 2nd phase of the project was to determine how robust the model results are with respect to various uncertainties in the analysis.

As described in the baseline analysis report, the overall modeling methodology is based on a series of unit emissions (1 g/hr) simulations of Hg(0), Hg(II), and Hg(p) from a number of standard source locations (SSL's). Each simulation with the HYSPLIT-Hg model was for 15 months, representing 3 months of "model spin up" before the start of 2005 and the 12 months of 2005. Results from the unit emissions simulations are then used, through spatial and chemical interpolation, to estimate the 2005 impacts on the Great Lakes and other key receptors from each source in the emissions inventory used in the analysis. In the baseline analysis, a total of 408 15-month HYSPLIT-Hg unit-emissions simulations were carried out to provide the basis for the analysis. As described below, a total of 828 additional 15-month HYSPLIT-Hg simulations were carried out in this 2nd phase of the project.

Due to computational resource constraints, only a few different overall variations in the "full" analysis could be undertaken. However, numerous variations were examined for a subset of five "illustrative" standard source locations (SSL's), representing local, regional, national/continental, and global sources. Several different types of variations were investigated for these illustrative source locations, including input meteorological data, and dispersion, deposition, and chemical transformation methodologies. A total of 320 different 15-month HYSPLIT-Hg simulations were carried out. The variations that were generally found to have the biggest influence on the simulations were: (a) the choice of input meteorological data [NARR (North American Regional Reanalysis) vs. EDAS (Eta Data Assimilation System)]; (b) variations in a particular model parameter affecting the wet deposition of atmospheric particles; and (c) variations in the emissions release height, primarily for the "local" impacts examined. Other variations examined, in numerous dispersion and chemical transformation parameters, generally had relatively small impacts on the simulations.

As discussed in the report, the NARR meteorological dataset is believed to be more accurate than then comparable EDAS dataset for 2005, and so the changes resulting from the use of the NARR rather than EDAS dataset to drive the HYSPLIT-Hg model can be viewed more as an "improvement" in the results rather than strictly a representation of the uncertainty associated with the choice of meteorological data.

Similarly, the impacts associated with variations in release height, while significant for near-field deposition impacts, should not be thought of strictly as an uncertainty. This is because the emissions release height used as the default was chosen to be representative of the mercury sources with the

[1] Cohen, M., R. Draxler, R. Artz (2011). *Modeling Atmospheric Mercury Deposition to the Great Lakes. Final Report for work conducted with FY2010 funding from the Great Lakes Restoration Initiative.* NOAA Air Resources Laboratory, Silver Spring, MD. Dec 16, 2011. 160 pages. Available at: http://www.arl.noaa.gov/documents/reports/GLRI_FY2010_Atmospheric_Mercury_Final_Report_2011_Dec_16.pdf

largest impacts. Thus, while a different (e.g., lower) release height was found to influence the results immediately downwind of the source, this would generally affect sources with relatively small impacts. Moreover, most of the emissions impacting the Great Lakes are not immediately upwind of a given lake. Therefore, this issue is not expected to have an overly significant impact on the overall results.

The variation if the particle-wet-deposition parameter (WETR), found to exert significant influence over the modeling results in some cases, does represent more of an uncertainty in the simulation. The "true" value of this parameter is not known accurately. However, variations in this parameter primarily affected emissions of Hg(p), which accounted for only 2% of the total emissions used as input for the analysis. Therefore, the impact on the overall results of this uncertainty is not expected to be significant.

An additional 154 HYSPLIT-Hg 15-month simulations were carried out examining the impact of range of numerical issues on the modeling results. Numerical issues examined included changes in operating systems and compilers, changes in optimization schemes employed by the compiler, and changes in array handling algorithms within the HYSPLIT-Hg model. This analysis, presented in the Appendix, showed that these numerical issues did not generally cause changes in any key results greater than a few percent. In most cases, the numerically-related deviations in results – e.g., the modeled deposition to a given Great Lake -- were smaller than 1%

The variations examined for the full analysis, requiring 354 additional 15-month HYSPLIT-Hg simulations, were: (a) the use of NARR vs. EDAS meteorological data to drive the HYSPLIT-Hg model; (b) the use of additional standard source locations (SSL's) to reduce errors in spatial interpolation; (c) variation in the mercury re-emissions rate; and (d) variations in the spatial interpolation methodology.

Doubling the mercury re-emissions rate increased the model-estimated deposition to the Great Lakes by about ~25%. Additional SSL's and variations in spatial interpolation methodology were not found to influence the model results significantly. The NARR-based analysis had results that were more consistent with mercury wet deposition measurement in the Great Lakes region. However, while improved, the model performance for 12 sites in the eastern Great Lakes region did not improve significantly, and the tendency of the modeling analysis to over-predict the wet deposition flux at these sites remained. The overall results from the NARR-based analysis for Great Lakes deposition were somewhat different than those from the EDAS-based analysis. The most common difference was a decrease in model-estimated deposition from local and regional sources in the NARR-based simulations relative to the EDAS-based simulations.

An overall summary of the modeling results is provided below in Figure 1, which shows the overall source-attribution results for the largest variations in "full-analysis" modeling methodology, i.e., NARR vs. EDAS, and doubling the mercury re-emissions rate. While the overall fractions of the deposition contributed by key source types and regions were impacted somewhat by the simulation variations, the relative source-attribution results were not dramatically affected. This suggests that the results are reasonably robust, at least from the perspective of the relative importance of different source types and source regions to the deposition of mercury to the Great Lakes basin.

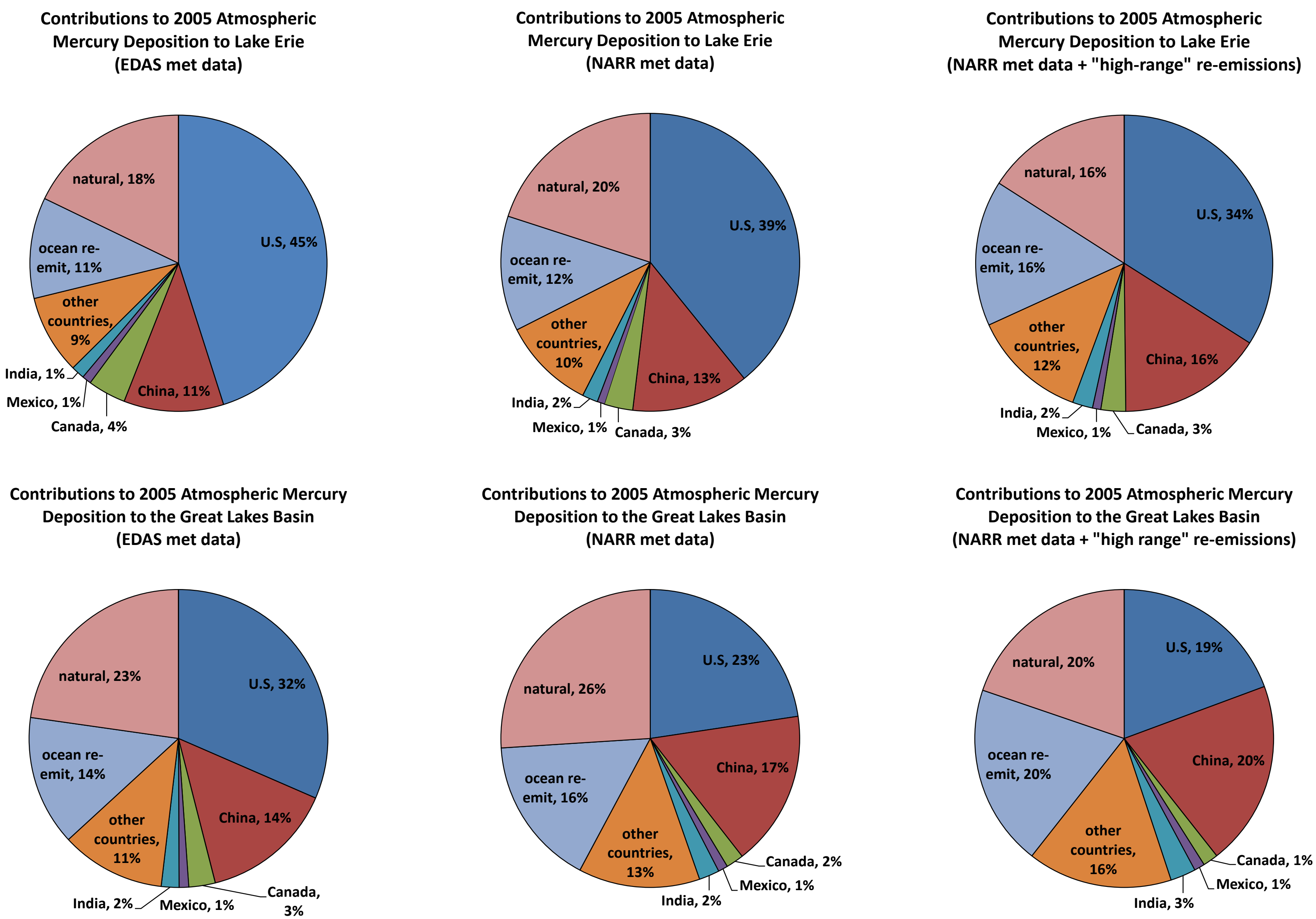

Figure 1. Overall source attribution results for Lake Erie (top row) and the Great Lakes Basin (bottom row) for largest variations in modeling methodology; 2005 baseline (left); key variations showing the largest differences (center & right)