Modeling the Atmospheric Transport and Deposition of Mercury to the Great Lakes

(work funded through the Great Lakes Restoration Initiative)

Dr. Mark Cohen
NOAA Air Resources Laboratory (ARL)
College Park, MD, USA

Briefing Slides for GLRI Monthly Call
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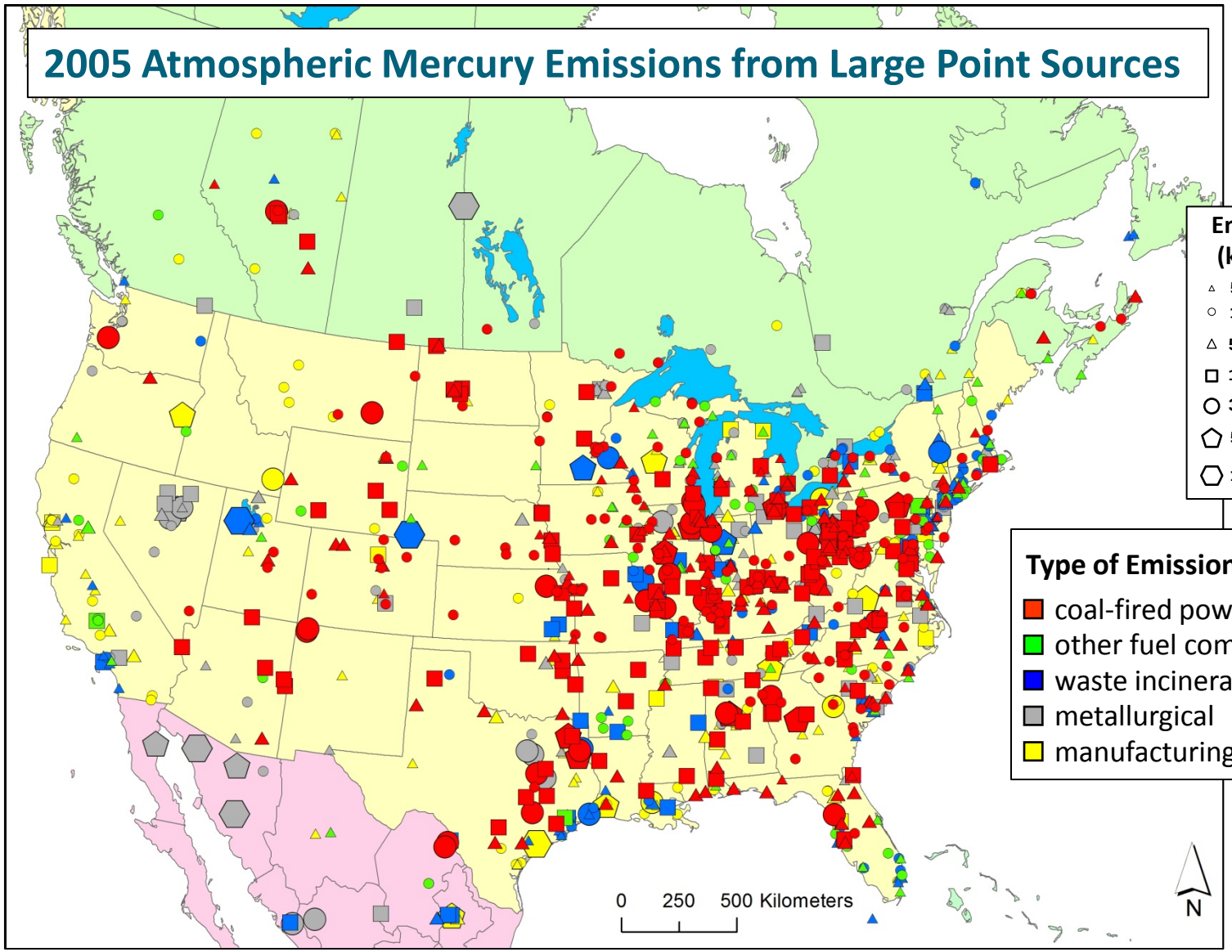
Atmospheric deposition is believed to be the largest current mercury loading pathway to the Great Lakes…

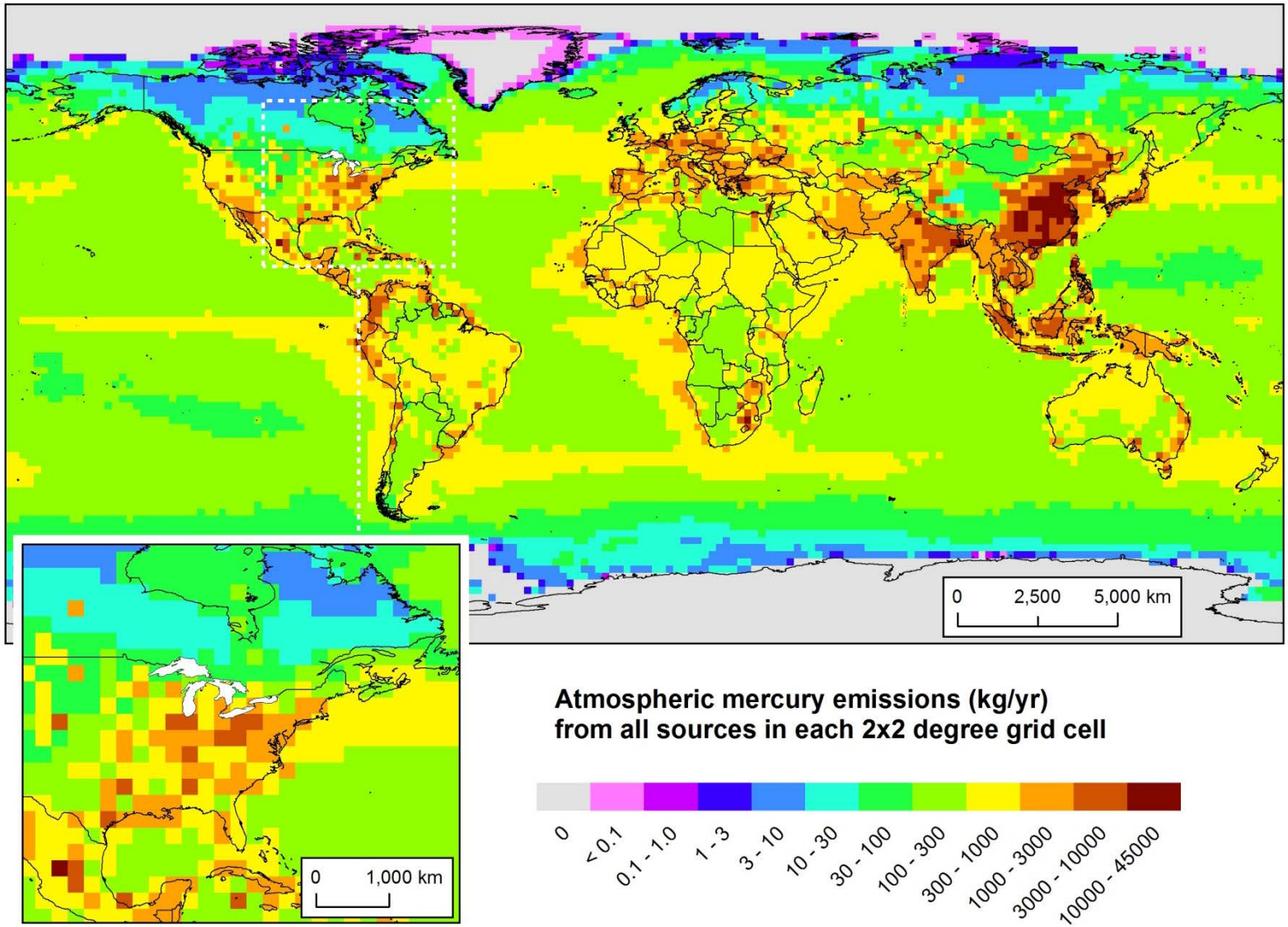
- **How much is deposited and where does it come from?**

(…this information can *only* be obtained via modeling…)

Starting Point: Where is mercury emitted to the air?

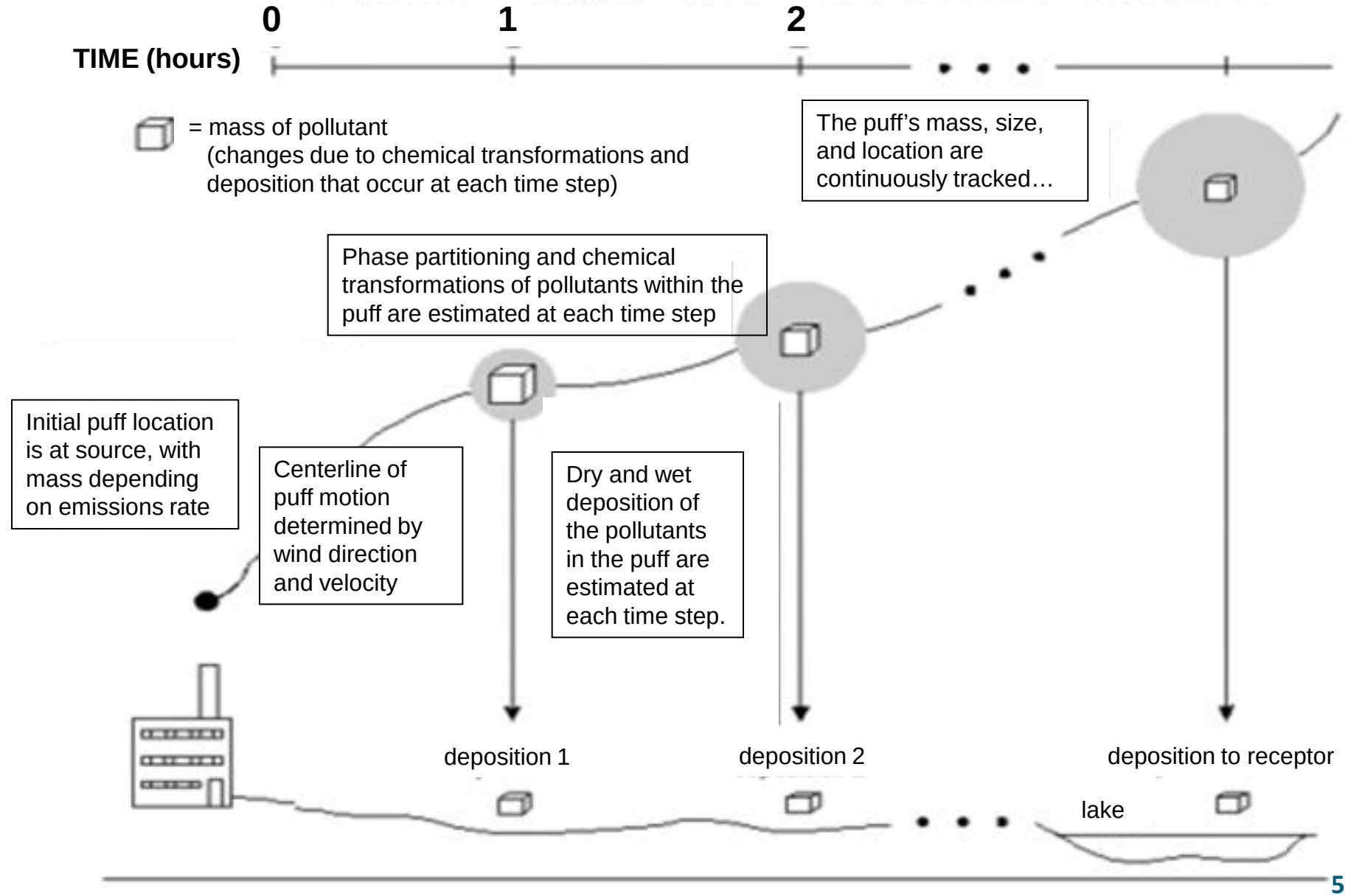


2005 Atmospheric Mercury Emissions (Direct Anthropogenic + Re-emit + Natural)



Next step: What happens to the mercury after it is emitted?

HYSPLIT-Hg Lagrangian Puff Atmospheric Fate and Transport Model



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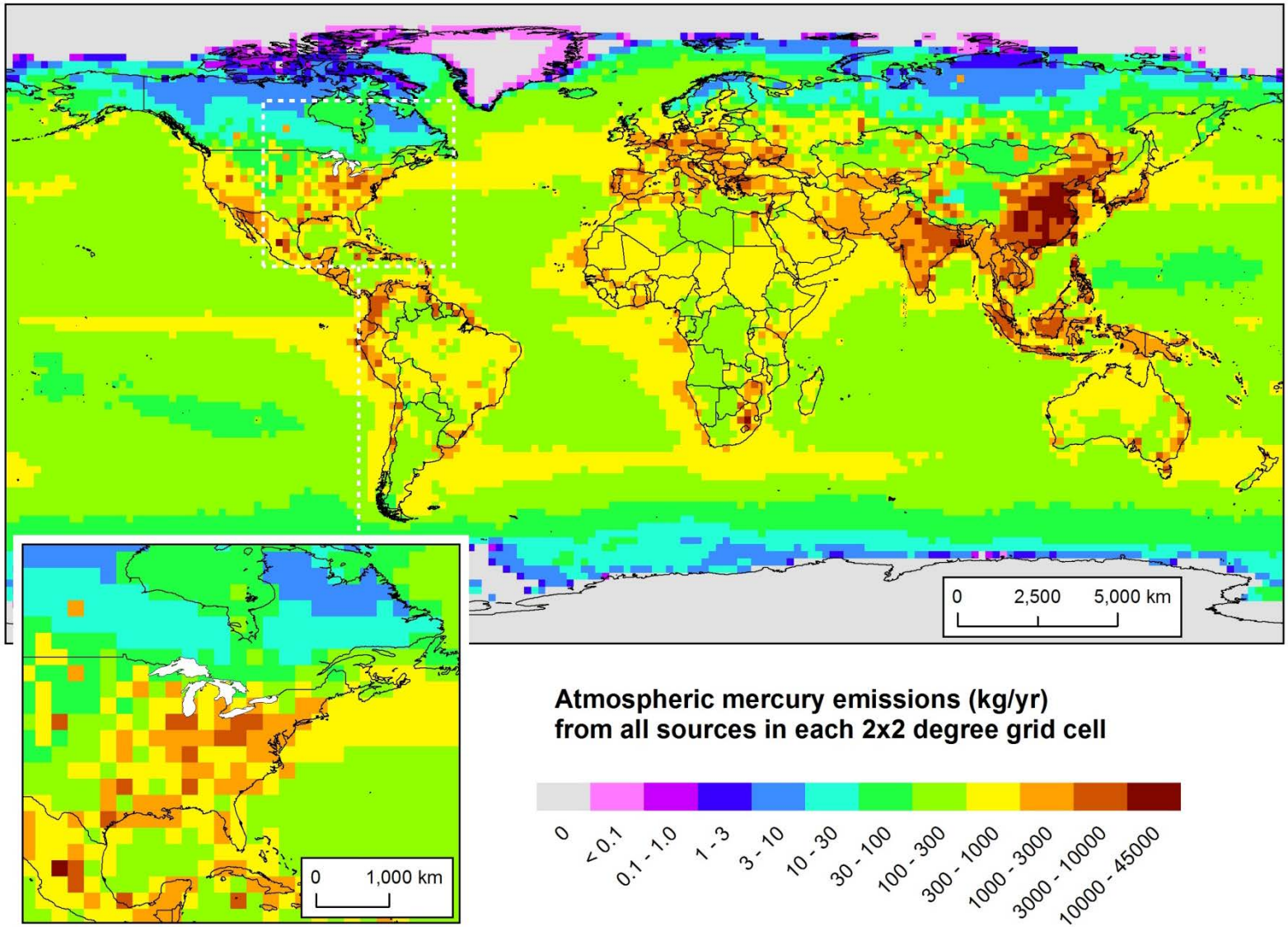
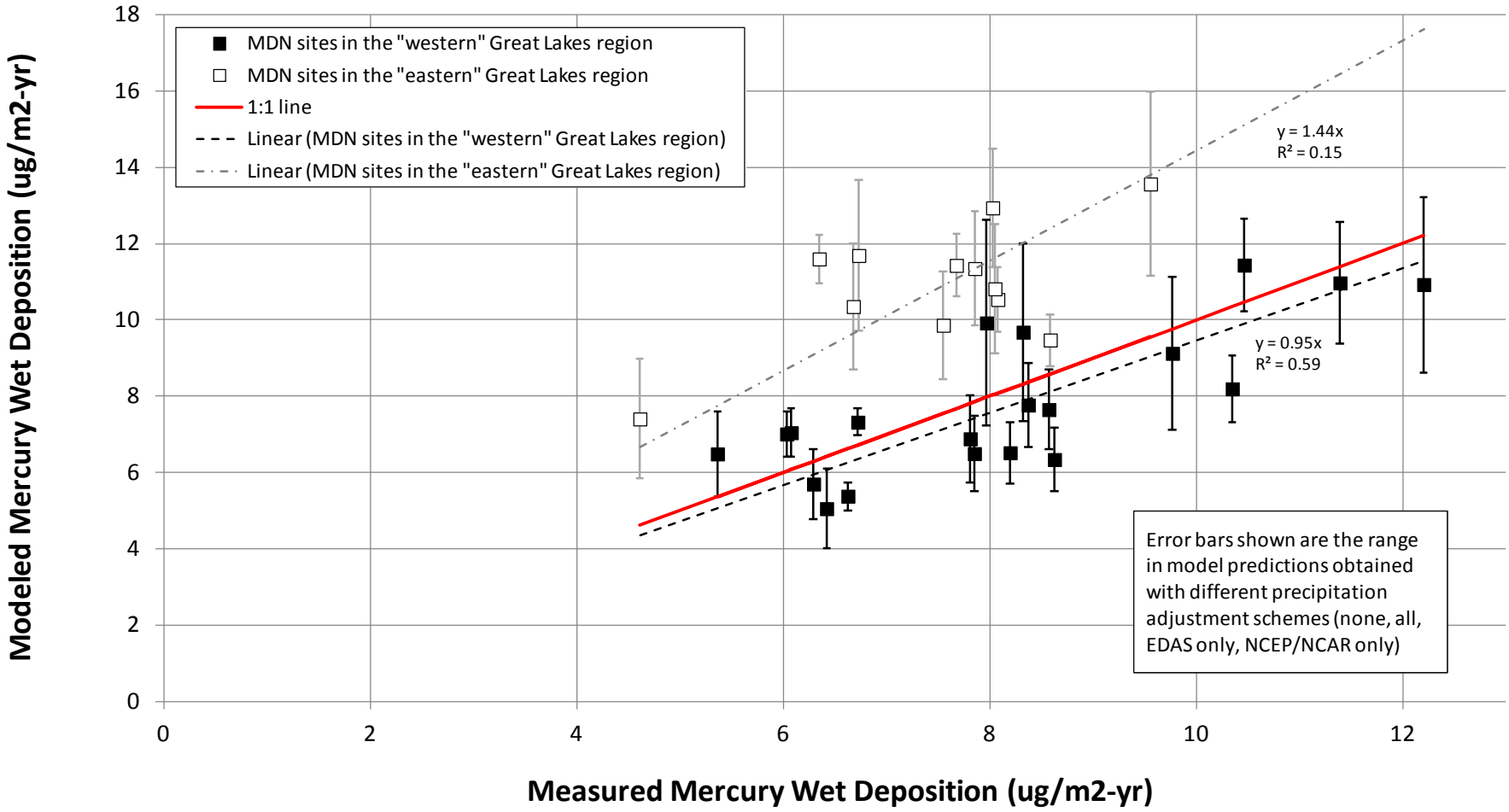
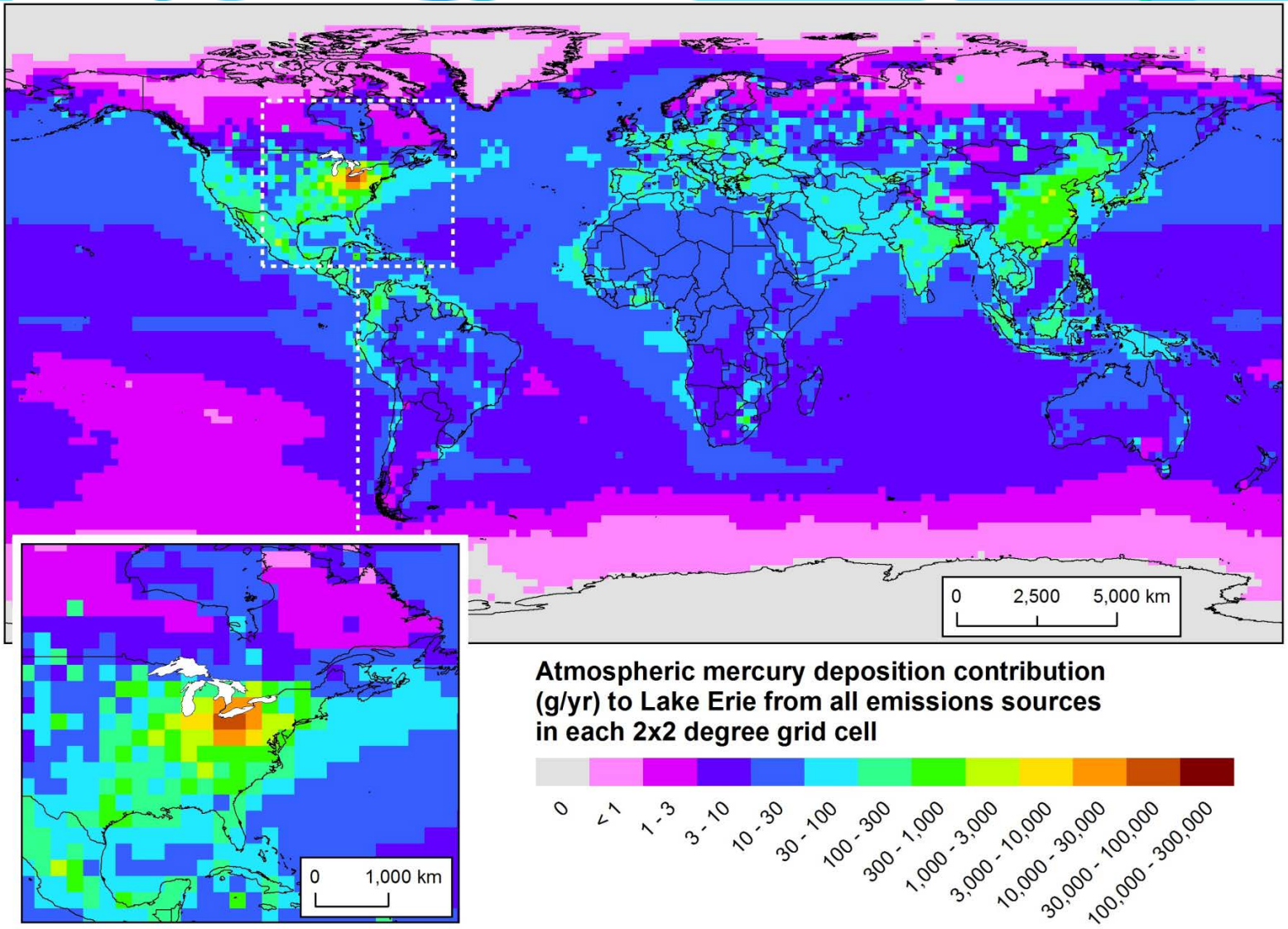


Make sure the model is giving reasonable results

Modeled vs. Measured Wet Deposition of Mercury at Sites in the Great Lakes Region



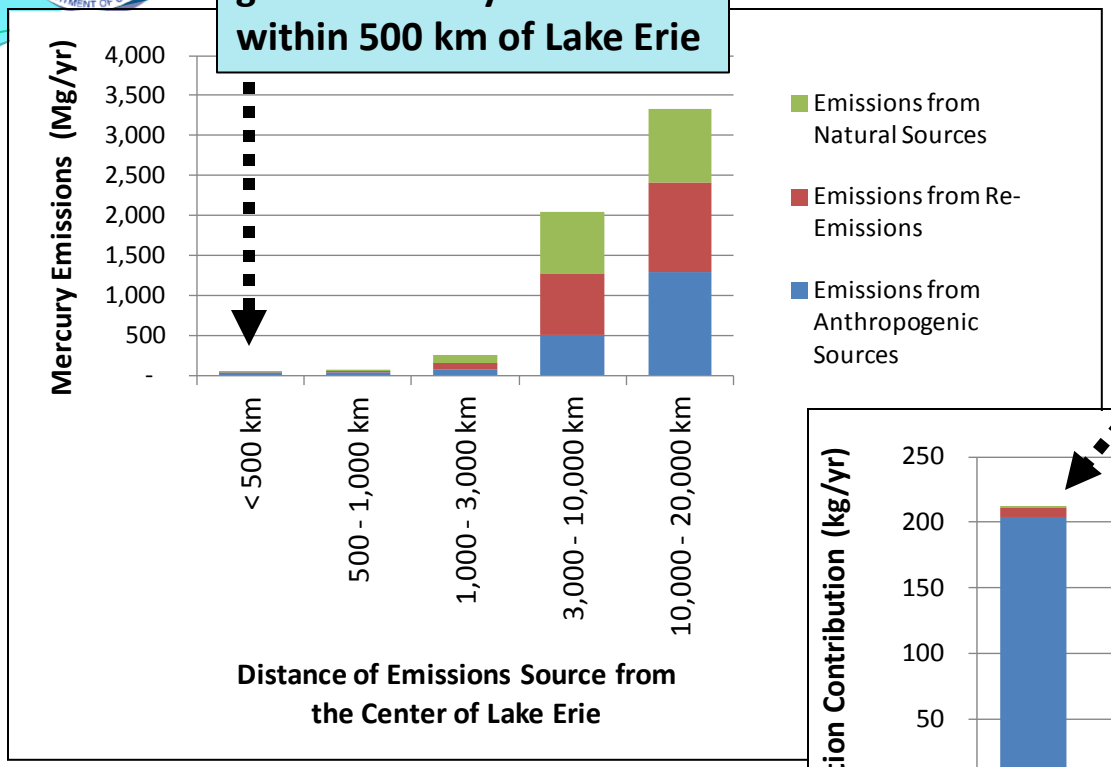
Keep track of the contributions from each source, and add them up



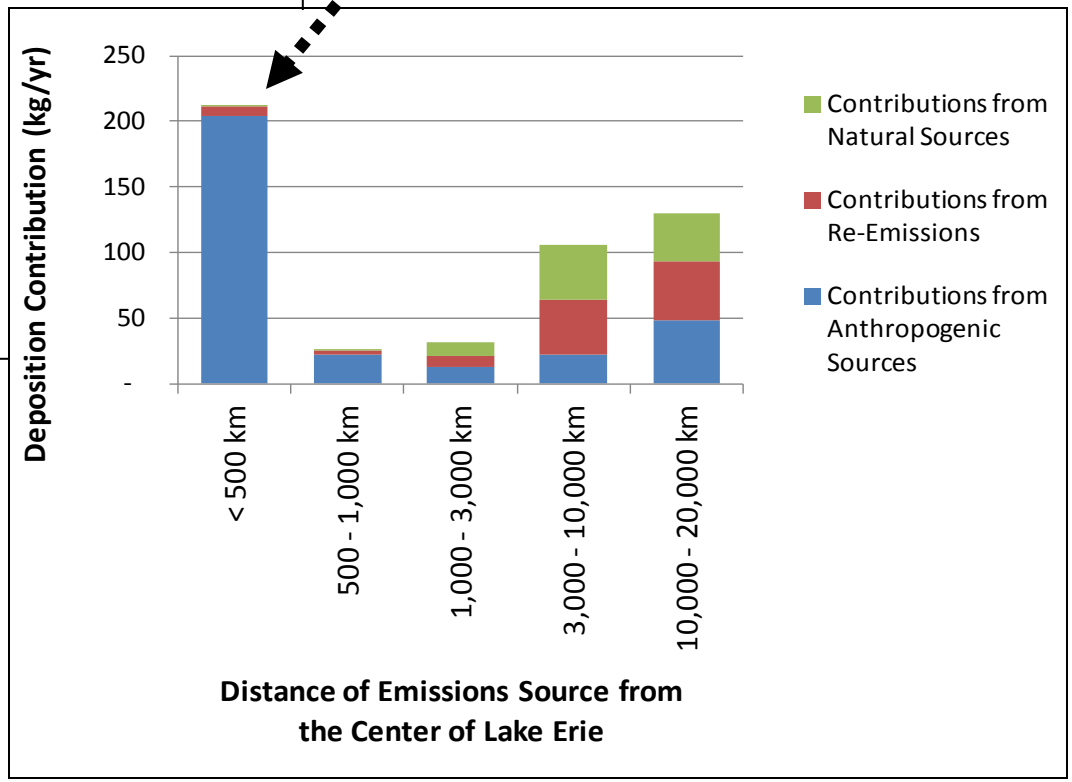
Geographical Distribution of 2005 Atmospheric Mercury Deposition Contributions to Lake Erie

Results can be shown in many ways…

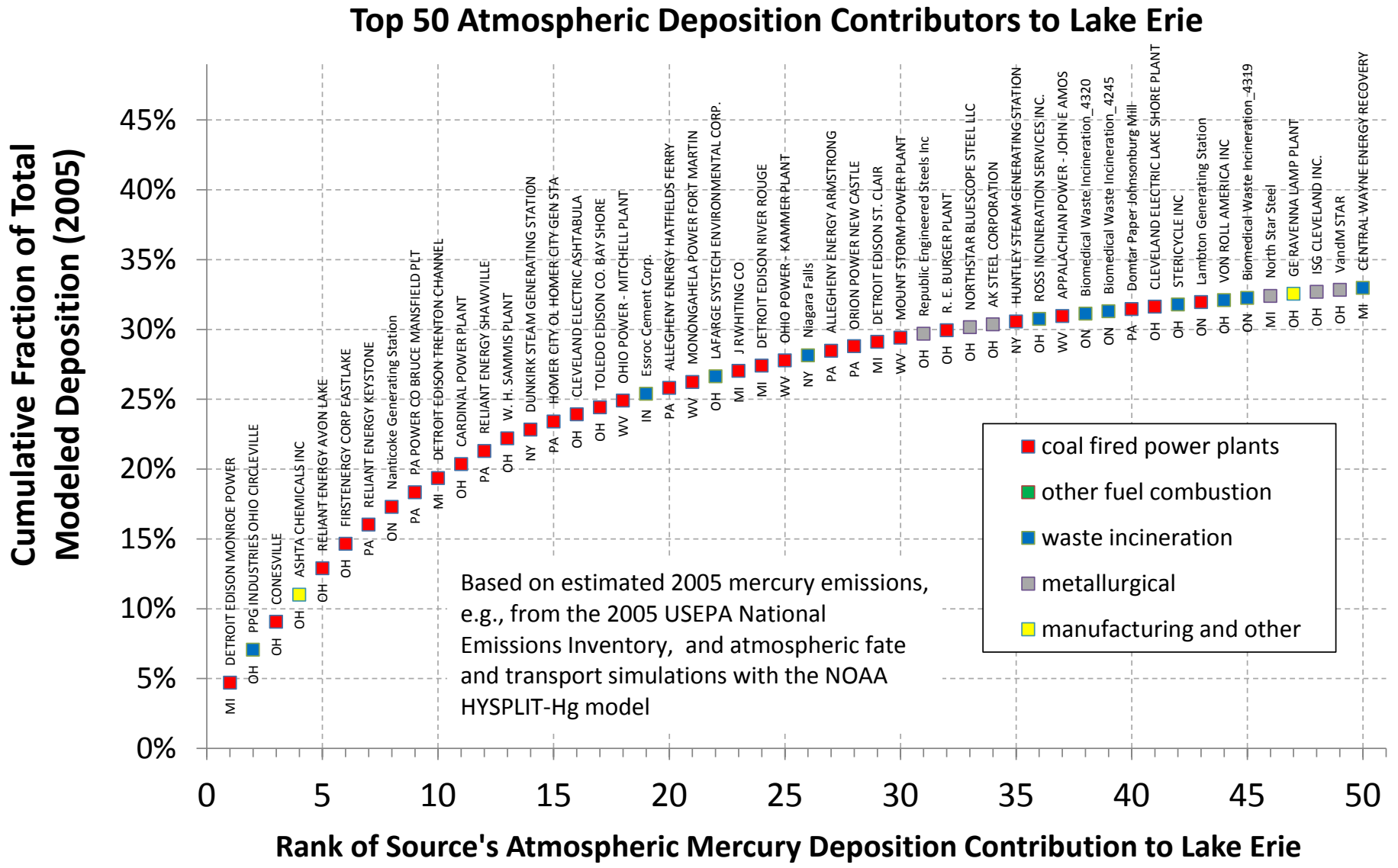
A tiny fraction of 2005 global mercury emissions within 500 km of Lake Erie



Modeling results show that these "regional" emissions are responsible for a large fraction of the modeled 2005 atmospheric deposition

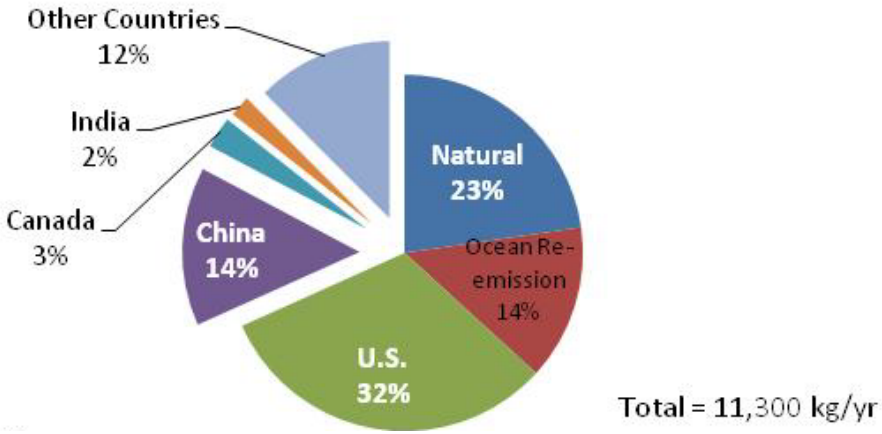


Important policy implications!


Top 50 Atmospheric Deposition Contributors to Lake Erie
Cumulative Fraction of Total Modeled Deposition (2005)
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
5
10
15
20
25
30
35
40
45
50
Rank of Source's Atmospheric Mercury Deposition Contribution to Lake Erie
MI DETROIT EDISON MONROE POWER
OH PPG INDUSTRIES OHIO CIRCLEVILLE
OH CONESVILLE
OH ASHTA CHEMICALS INC
OH RELIANT ENERGY AVON LAKE
OH FIRSTENERGY CORP EASTLAKE
PA RELIANT ENERGY KEYSTONE
ON Nanticoke Generating Station
PA PA POWER CO BRUCE MANSFIELD PLT
MI DETROIT EDISON TRENTON CHANNEL
OH CARDINAL POWER PLANT
PA RELIANT ENERGY SHAWVILLE
OH W. H. SAMMIS PLANT
NY DUNKIRK STEAM GENERATING STATION
PA HOMER CITY OL HOMER CITY GEN STA
OH CLEVELAND ELECTRIC ASHTABULA
OH TOLEDO EDISON CO. BAY SHORE
WV OHIO POWER - MITCHELL PLANT
IN Essroc Cement Corp.
PA ALLEGHENY ENERGY HATFIELDS FERRY
WV MONONGAHELA POWER FORT MARTIN
OH LAFARGE SYSTECH ENVIRONMENTAL CORP.
MI J R WHITING CO
MI DETROIT EDISON RIVER ROUGE
WV OHIO POWER - KAMMER PLANT
NY Niagara Falls
PA ALLEGHENY ENERGY ARMSTRONG
PA ORION POWER NEW CASTLE
MI DETROIT EDISON ST. CLAIR
WV MOUNT STORM POWER PLANT
OH Republic Engineered Steels Inc
OH R. E. BURGER PLANT
OH NORTHSTAR BLUESCOPE STEEL LLC
OH AK STEEL CORPORATION
NY HUNTLEY STEAM GENERATING STATION
OH ROSS INCINERATION SERVICES INC.
WV APPALACHIAN POWER - JOHN E AMOS
ON Biomedical Waste Incineration_4320
ON Biomedical Waste Incineration_4245
PA Domtar Paper Johnsonburg Mill
OH CLEVELAND ELECTRIC LAKE SHORE PLANT
OH STERICYCLE INC
ON Lambton Generating Station
OH VON ROLL AMERICA INC
ON Biomedical Waste Incineration_4319
MI North Star Steel
OH GE RAVENNA LAMP PLANT
OH ISG CLEVELAND INC.
OH VandM STAR
MI CENTRAL WAYNE ENERGY RECOVERY
Based on estimated 2005 mercury emissions, e.g., from the 2005 USEPA National Emissions Inventory, and atmospheric fate and transport simulations with the NOAA HYSPLIT-Hg model
coal fired power plants
other fuel combustion
waste incineration
metallurgical
manufacturing and other

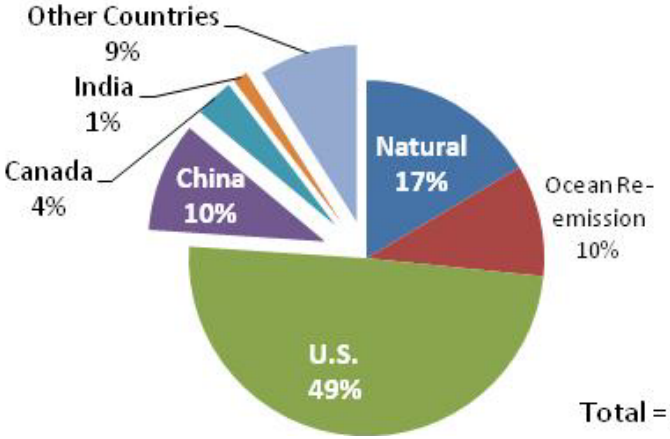
Source-Attribution Results for 2005 from NOAA ARL Atmospheric Mercury Modeling, Ground-Truthed Using Atmospheric Measurements

Sources of Mercury Deposition to the Great Lakes Basin



Total = 11,300 kg/yr

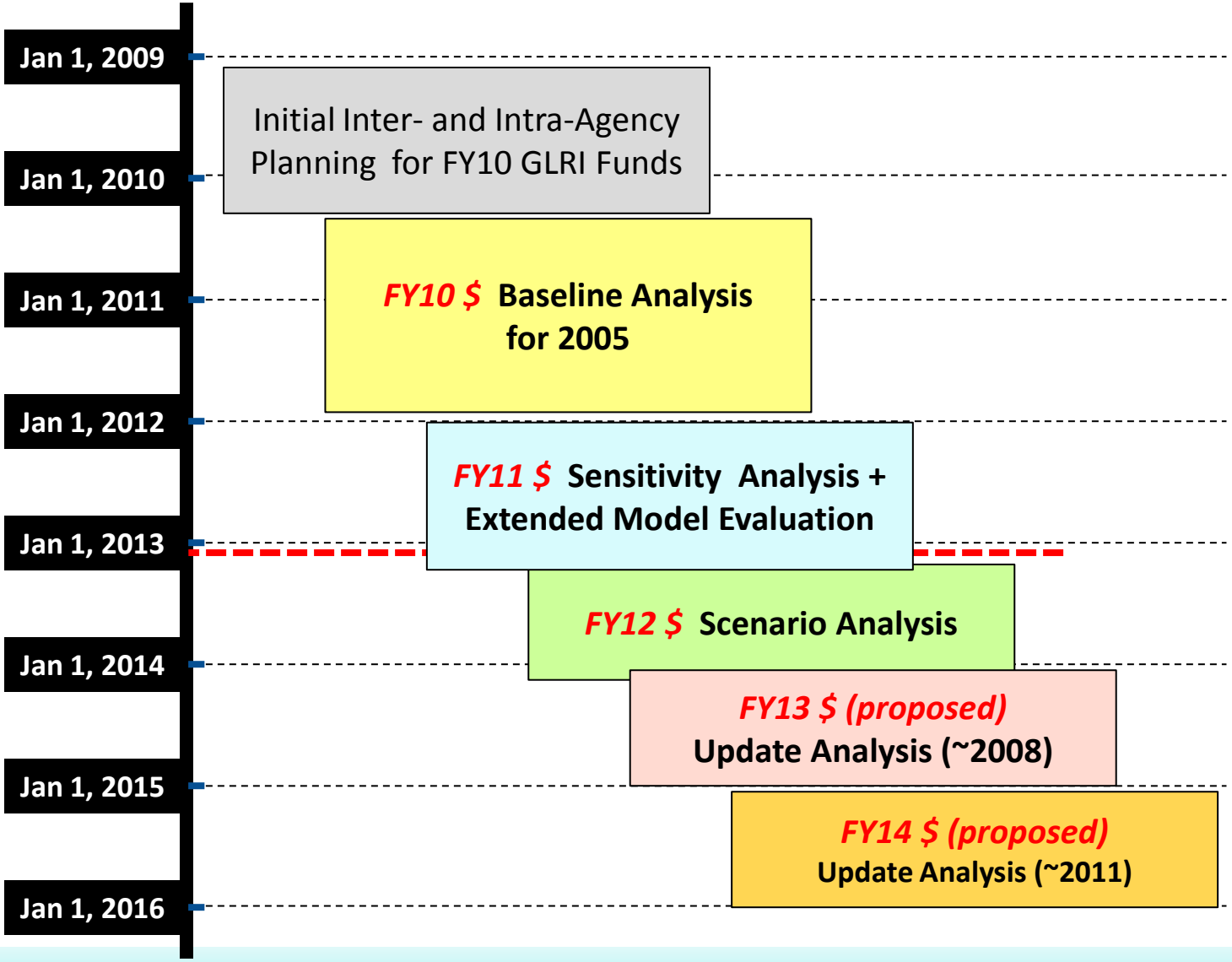
Sources of Mercury Deposition to the Lake Erie Basin



Total = 2,300 kg/yr

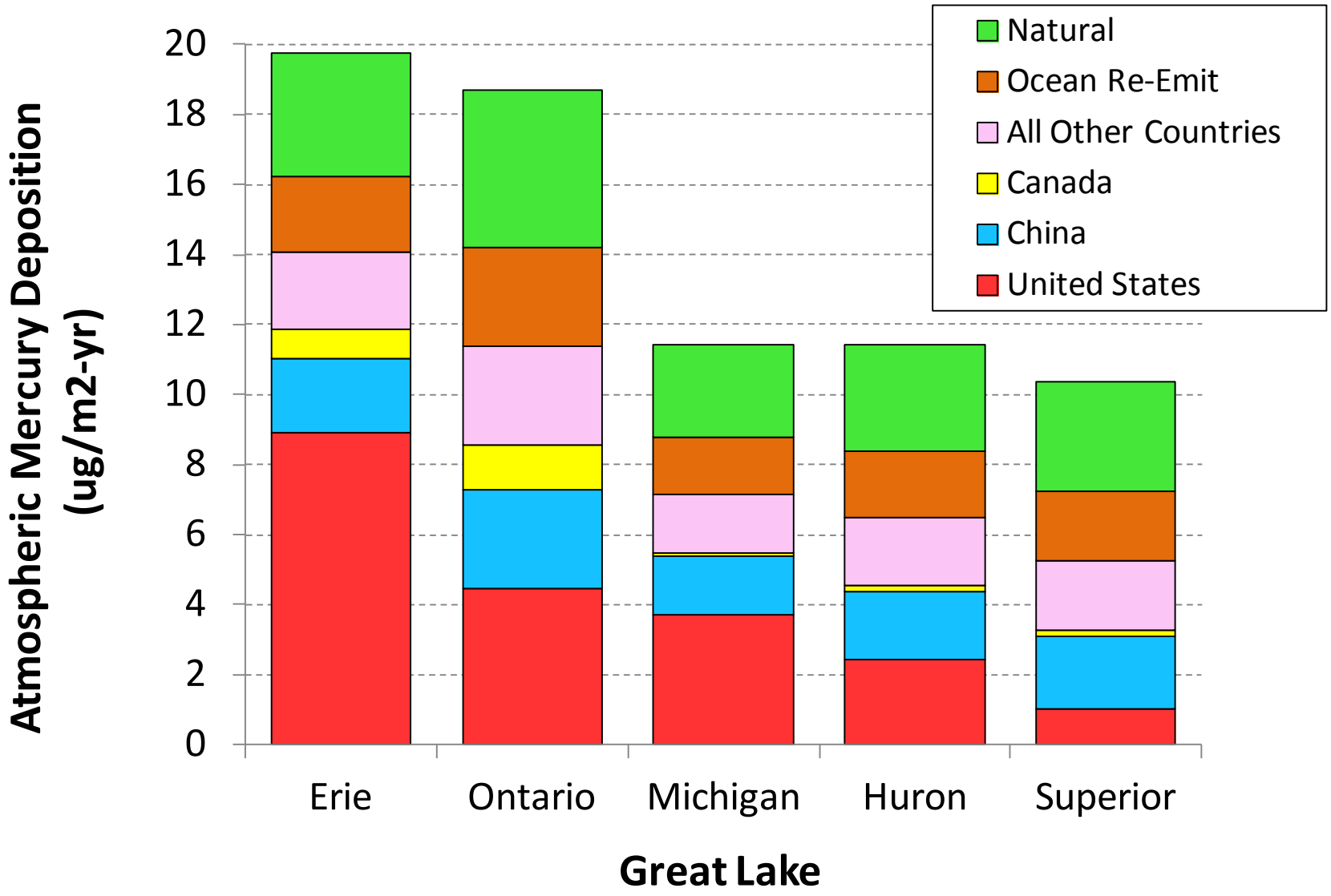
A multi-phase project

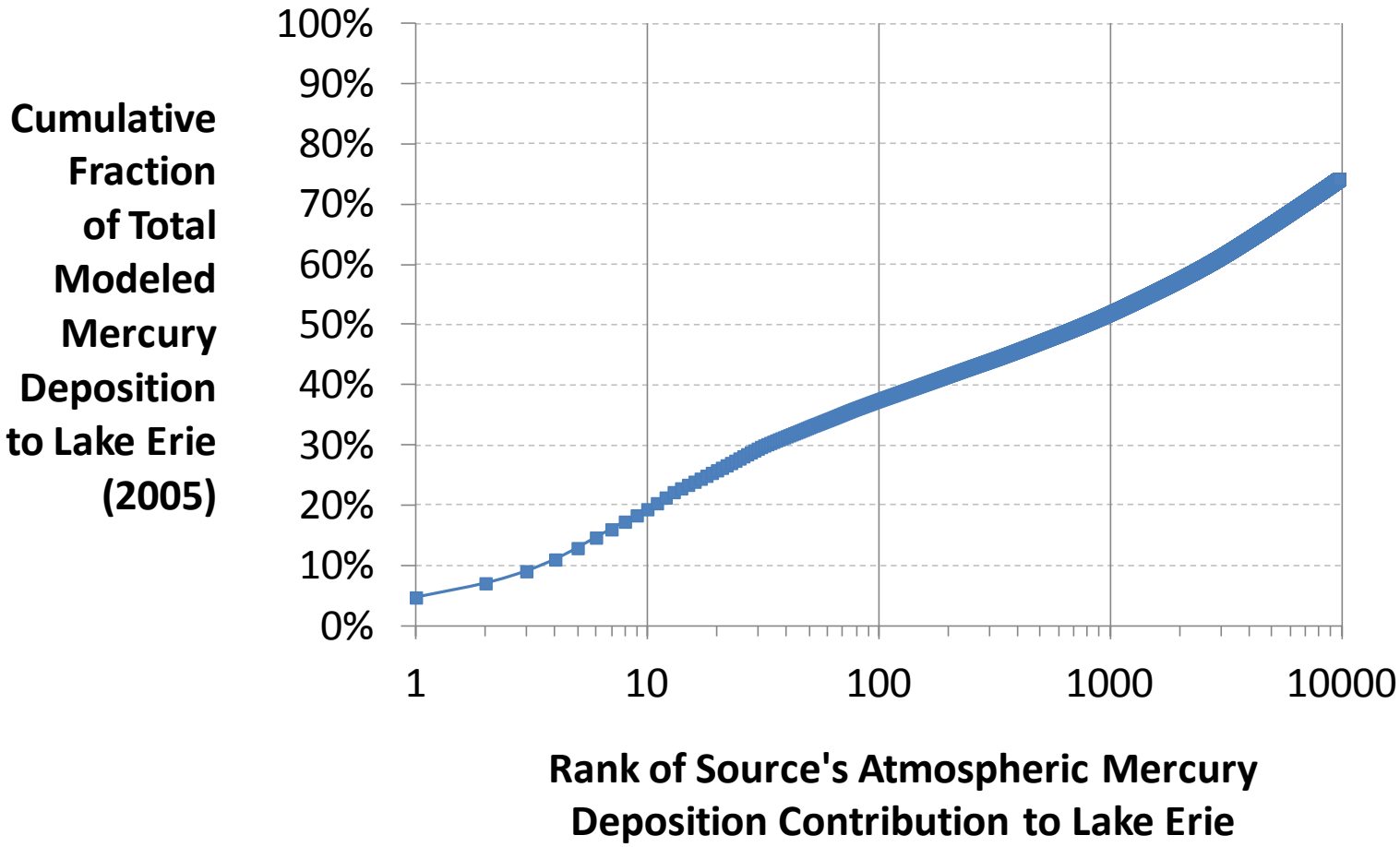
ARL's GLRI Atmospheric Mercury Modeling Project



Thanks!

EXTRA SLIDES


Natural
Ocean Re-Emit
All Other Countries
Canada
China
United States
Atmospheric Mercury Deposition (ug/m2-yr)
0
2
4
6
8
10
12
14
16
18
20
Erie
Ontario
Michigan
Huron
Superior
Great Lake


Cumulative Fraction of Total Modeled Mercury Deposition to Lake Erie (2005)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1000
10000
Rank of Source's Atmospheric Mercury Deposition Contribution to Lake Erie

Phase 1: Baseline Analysis for 2005

(Final Report Completed December 2011)

- 2005 was chosen as the analysis year, because 2005 was the latest year for which comprehensive mercury emissions inventory data were available at the start of this project
- Using 2005 meteorological data and emissions, the deposition and source-attribution for this deposition to each Great Lake and its watershed was estimated
- The model results were ground-truthed against 2005 Mercury Deposition Network data from sites in the Great Lakes region

Modeling Atmospheric Mercury Deposition to the Great Lakes. Final Report for work conducted with FY2010 funding from the Great Lakes Restoration Initiative. December 16, 2011. Mark Cohen, Roland Draxler, Richard Artz. NOAA Air Resources Laboratory, Silver Spring, MD, USA. 160 pages.

http://www.arl.noaa.gov/documents/reports/GLRI_FY2010_Atmospheric_Mercury_Final_Report_2011_Dec_16.pdf

http://www.arl.noaa.gov/documents/reports/Figures_Tables_GLRI_NOAA_Atmos_Mercury_Report_Dec_16_2011.pptx

One-page summary:
http://www.arl.noaa.gov/documents/reports/GLRI_Atmos_Mercury_Summary.pdf

Phase 2: Sensitivity Analysis + Extended Model Evaluation

(current work, with GLRI FY11 funding)

- **Examining the influence of uncertainties on the modeling results, by varying critical model parameters, algorithms, and inputs, and analyzing the resulting differences in results**

- **Ground-truthing the model against additional ambient monitoring data, e.g., ambient mercury air concentration measurements and wet deposition data not included in the Mercury Deposition Network (MDN)**

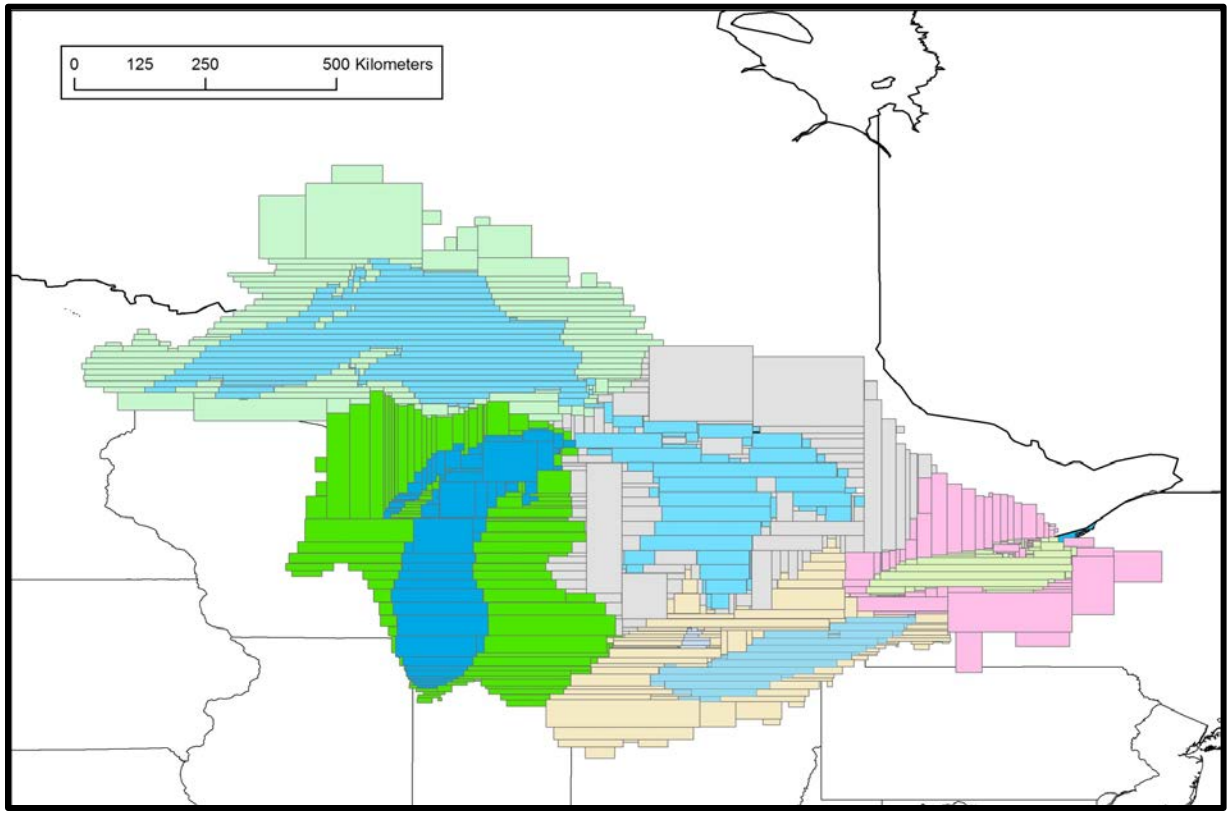
Phase 3: Scenarios

(next year's work, with GLRI FY12 funding)

- A modeling analyses such as this is the *only* way to quantitatively examine the potential consequences of alternative future emissions scenarios
- We will work with EPA and other Great Lakes Stakeholders to identify and specify the most policy relevant scenarios to examine
- For each scenario, we will estimate the amount of atmospheric deposition to each of the Great Lakes and their watersheds, along with the detailed source-attribution for this deposition

Some Key Features of this Analysis

- **Deposition explicitly modeled to actual lake/watershed areas**
  - As opposed to the usual practice of ascribing portions of gridded deposition to these areas in a post-processing step



Some Key Features of this Analysis

- **Deposition explicitly modeled to actual lake/watershed areas**
  - As opposed to the usual practice of ascribing portions of gridded deposition to these areas in a post-processing step

- **Combination of Lagrangian & Eulerian modeling**
  - allows accurate and computationally efficient estimates of the fate and transport of atmospheric mercury over all relevant length scales – from "local" to global.

- **Uniquely detailed source-attribution information is created**
  - deposition contribution to each Great Lakes and watersheds from each source in the emissions inventories used is estimated individually
  - The level of source discrimination is only limited by the detail in the emissions inventories
  - Source-type breakdowns not possible in this 1st phase for global sources, because the global emissions inventory available did not have source-type breakdowns for each grid square

Some Key Findings of this Analysis

- **"Single Source" results illustrate source-receptor relationships**
  - For example, a "typical" coal-fired power plant near Lake Erie may contribute on the order of 100x the mercury – for the same emissions – as a comparable facility in China.

- **Regional, national, & global mercury emissions are all important contributors to mercury deposition in the Great Lakes Basin**
  - For Lakes Erie and Ontario, the U.S. contribution is at its most significant
  - For Lakes Huron and Superior, the U.S. contribution is less significant.
  - Local & regional sources have a much greater atmospheric deposition contributions than their emissions, as a fraction of total global mercury emissions, would suggest.

Some Key Findings of this Analysis (…continued)

- **Reasonable agreement with measurements**
  - Despite numerous uncertainties in model input data and other modeling aspects
  - Comparison at sites where significant computational resources were expended – corresponding to regions that were the most important for estimating deposition to the Great Lakes and their watersheds – showed good consistency between model predictions and measured quantities.
  - For a smaller subset of sites generally downwind of the Great Lakes (in regions not expected to contribute most significantly to Great Lakes atmospheric deposition), less computational resources were expended, and the comparison showed moderate, but understandable, discrepancies.