The Transport and Deposition of Dioxin to Lake Michigan: A Case Study

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Presentation Outline

Ø **Policy Making Context**
and the potential role of models

Ù ***regarding atmospheric deposition*,**
What Do We Need to Know?
and How Well Do We Need to Know It?

Ú **Atmospheric Deposition of Dioxin to Lake Michigan**

Û **Uncertainty Analysis**

Ü **Conclusions and Recommendations**

POLICY MAKING CONTEXT

1.	EFFECTS?	**Harmful effects on wildlife, public health?** ***[what is the exposure? consequences of this exposure?]***
2.	CAUSES ?	**What is the relative contribution of different loadings pathways contributing to the harmful effects?** **And, for any given significant loading pathway, what are the relative contributions of different sources?** **(THIS TALK: ATMOSPHERIC PATHWAY DETAILS)**
3.	COSTS ?	**What are the technical options involved in reducing or eliminating the contributions from major sources?** **What are the costs to implement these options?**

- ***Decision Making: Need Info in All Three Areas***
  Or, it doesn't necessarily do you much good to have precise information in one area, if one or more of the other areas remain very uncertain

- ***How much do we know regarding these questions for dioxin in Lake Michigan?***

THE ROLE AND POTENTIAL VALUE OF MODELS

‘ **MODELS are mathematical/conceptual descriptions of real-world phenomena**

- Necessarily a simplification; the real world is *very* complicated
- Key processes must be sufficiently characterized

‘ **MODELS are POTENTIALLY VALUABLE for:**

- Examining different large-scale scenarios that cannot be easily tested in the real world (e.g., different emissions reduction scenarios).
- Interpreting measurements
- Filling in spatial and temporal gaps between measurements

‘ **MODELS are a TEST of our KNOWLEDGE:**

- Attempts to synthesize everything important about a given system.
- If a model fails, we don’t understand enough about the system.

‘ **MODELS are USED IN developing approximate answers in ALL THREE fundamental policy information areas**

Figure 1: Total Dioxin Emissions for 1996

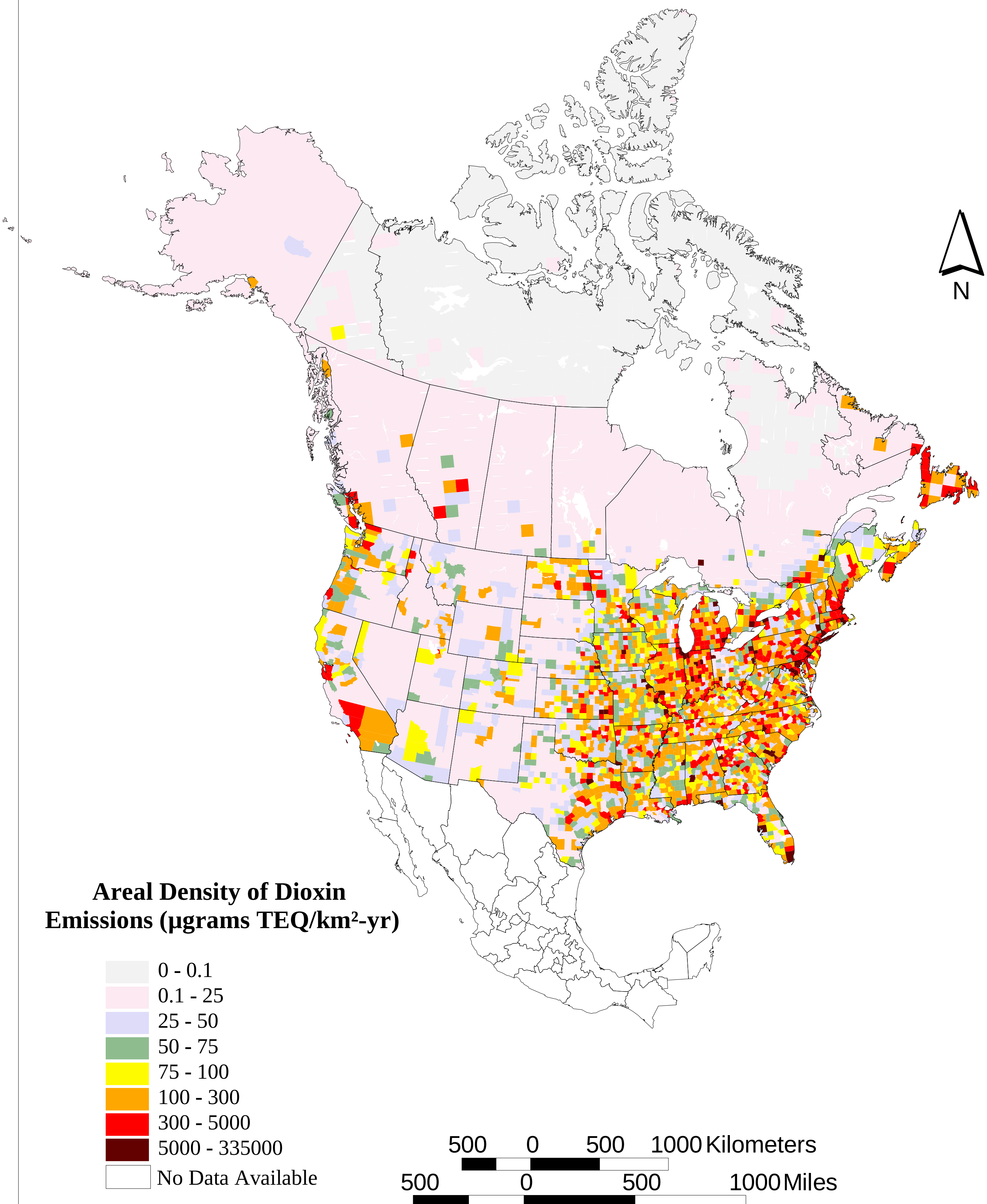


FIGURE 7
Total Dioxin Emissions for 1995/1996
- Medical Waste Incineration -

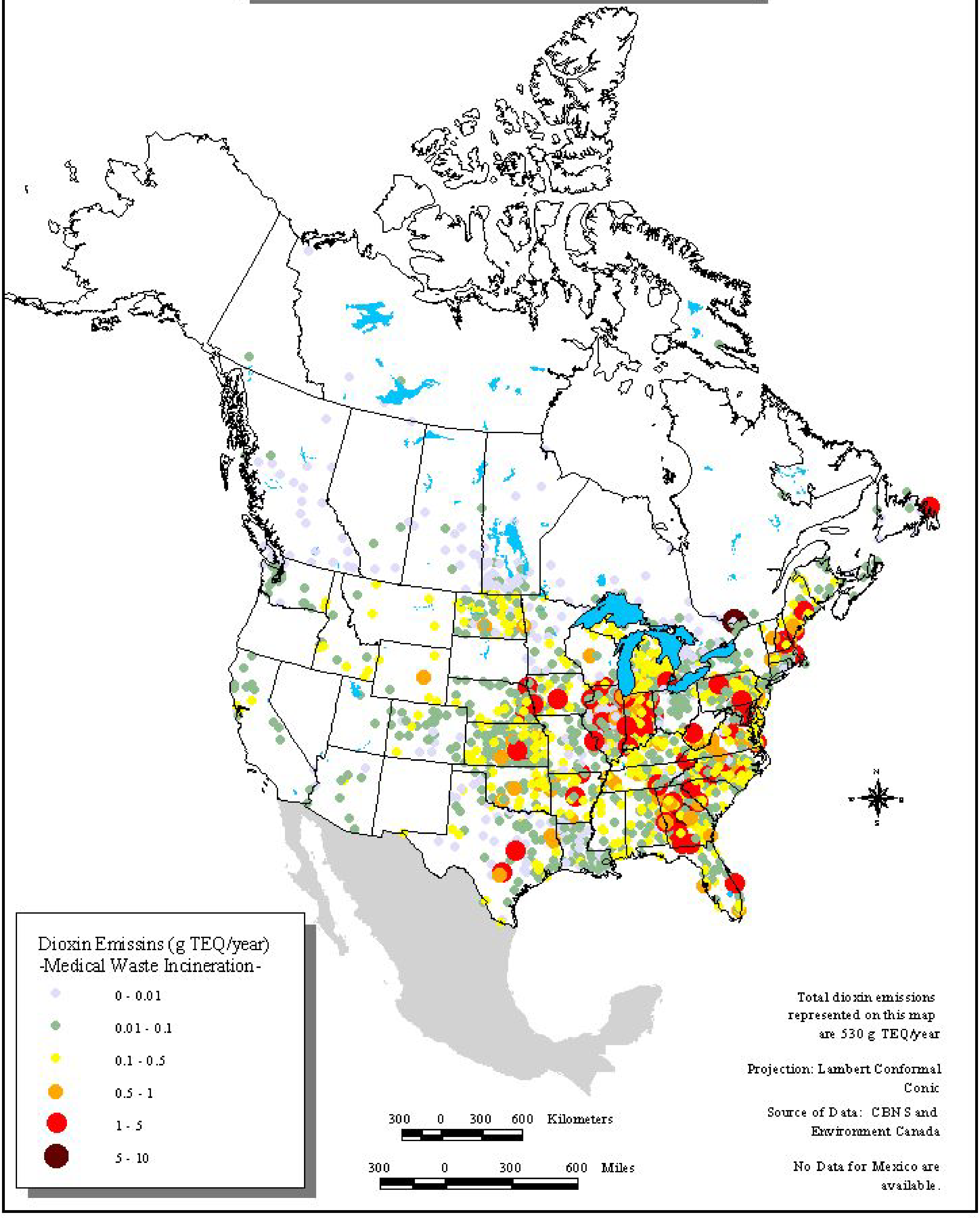
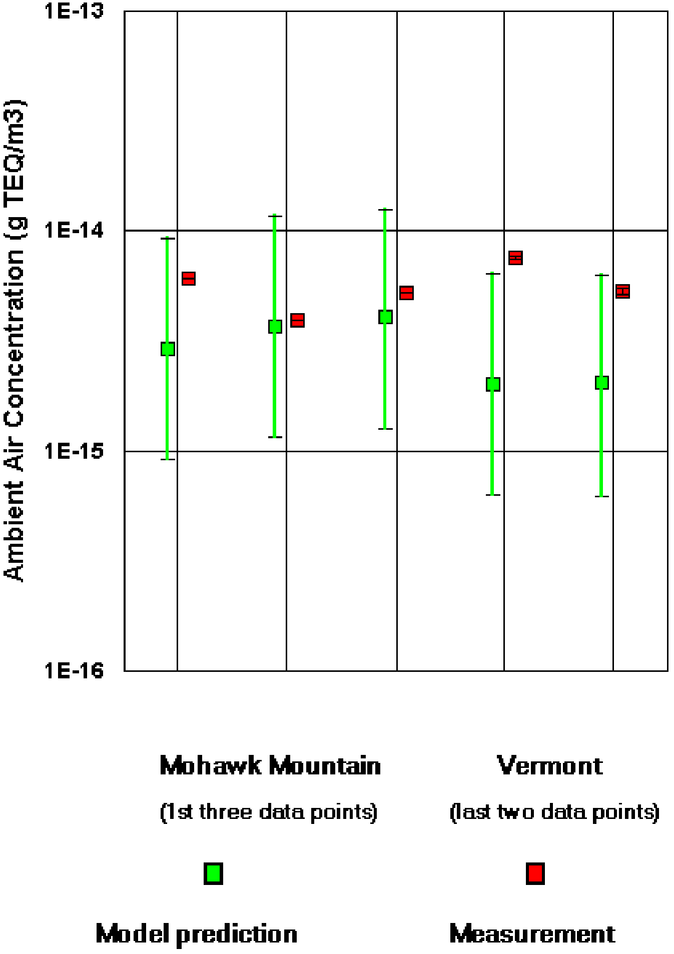
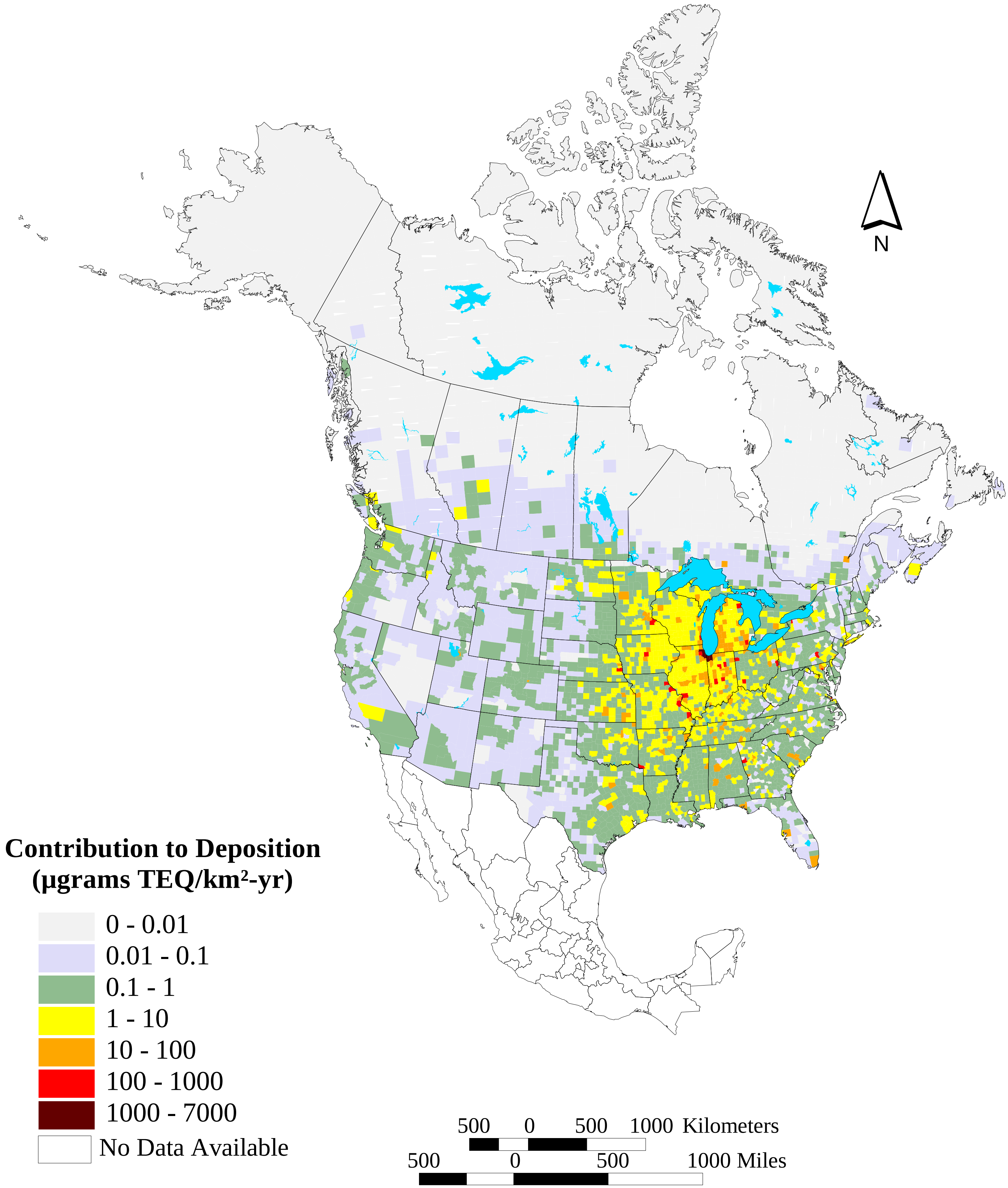


Figure 4. Comparison of Model Predictions with Ambient Measurements at Month-Long Sample Sites [Total PCDD/F (TEQ)]



Mid-Range Estimate of the Contribution to 1996 Atmospheric Deposition of Dioxin to Lake Michigan (μgrams TEQ/km^2-yr)



Estimates of the Percent of Lake Michigan Dioxin Loadings Attributable to the Atmospheric Deposition Pathway	
Study	**Fraction of Current Loadings Contributed Through the Atmospheric Pathway**
Cohen *et al.*	**PCDD/F TEQ: 50-100** **(central estimate ~ 88)**
Pearson *et al.*	**PCDD: 50-100** **PCDF: 5-35**

- Cohen, M., *et al.*, 1995. **Quantitative Estimation of the Entry of Dioxins, Furans, and Hexachlorobenzene into the Great Lakes from Airborne and Waterborne Sources.** Flushing, NY: CBNS, Queens College. Final Report to the Joyce Foundation.

- Pearson, R.F., D.L. Swackhamer, S.J. Eisenreich, and D.T. Long (1998). "Atmospheric Inputs of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans to the Great Lakes: Compositional Comparison of PCDD and PCDF in Sediments." J. Great Lakes Research 24(1): 65-82.

What Do We Need to Know, and.
How Well Do We Need to Know It?

For most policy considerations, the exact contributions of individual sources do *not* need to be known.

It is generally sufficient to know about:

‘ **The geographical extent of the problem**

- C relative impact of local, regional, national, continental, and/or global sources
- C don’t need exact answers, e.g., if 70% or 50% of the contributing air sources arise from within 100 km of the Lake – the policy response will be similar in either case.
- C *Only if the estimates are grossly incorrect will policy deliberations be seriously affected.*

‘ **Which source categories are the most significant contributors?**

- C don’t need exact answers; e.g., it does not matter that much whether municipal solid waste incinerators contribute 20% or 40% to the deposition – the policy response will likely be very similar.
- C *Again, the estimates will be of little or no use only if they are extremely inaccurate.*

Figure 10. Percent of Total Emissions or Total Deposition of Dioxin (1996) Arising from Within Different Distance Ranges From Each of the Great Lakes

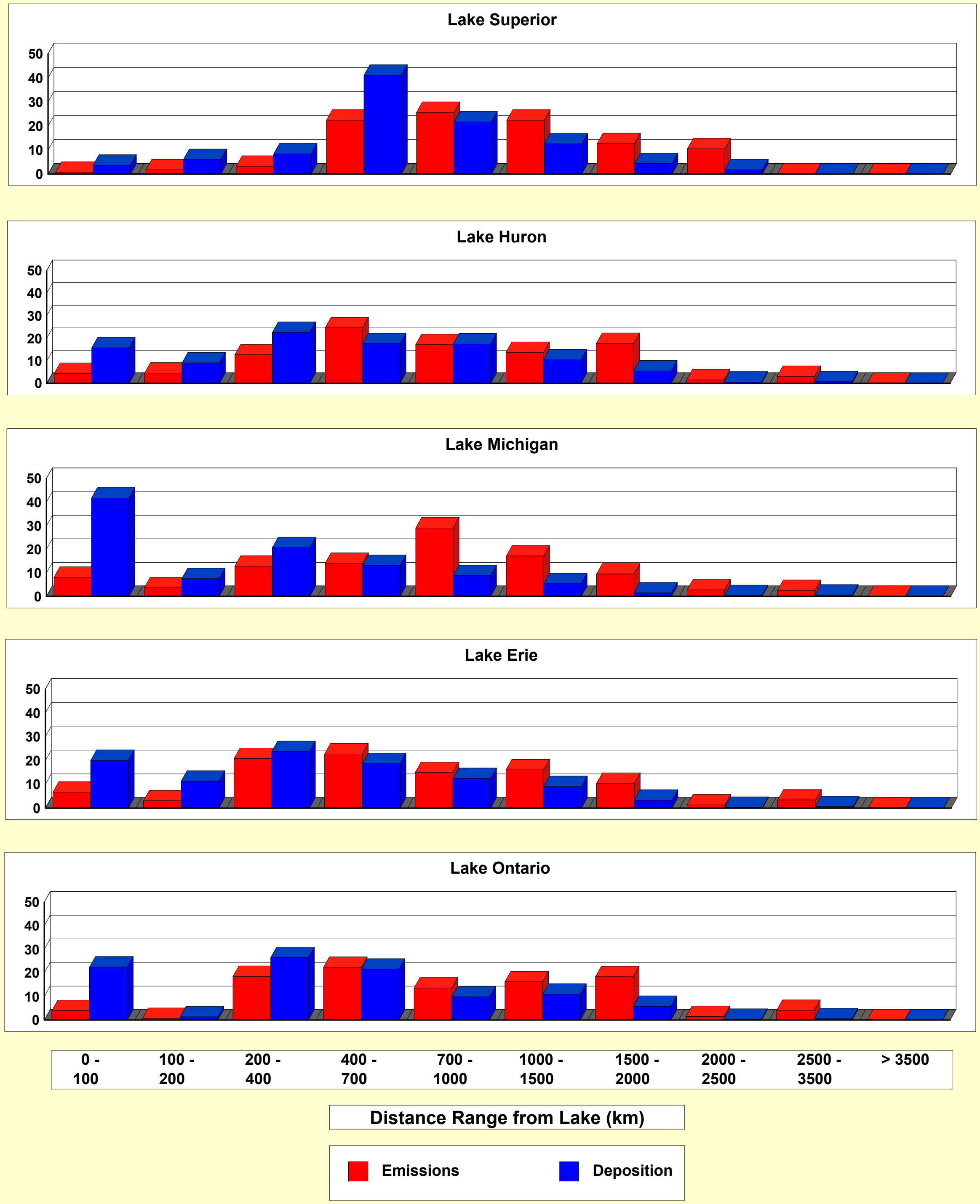
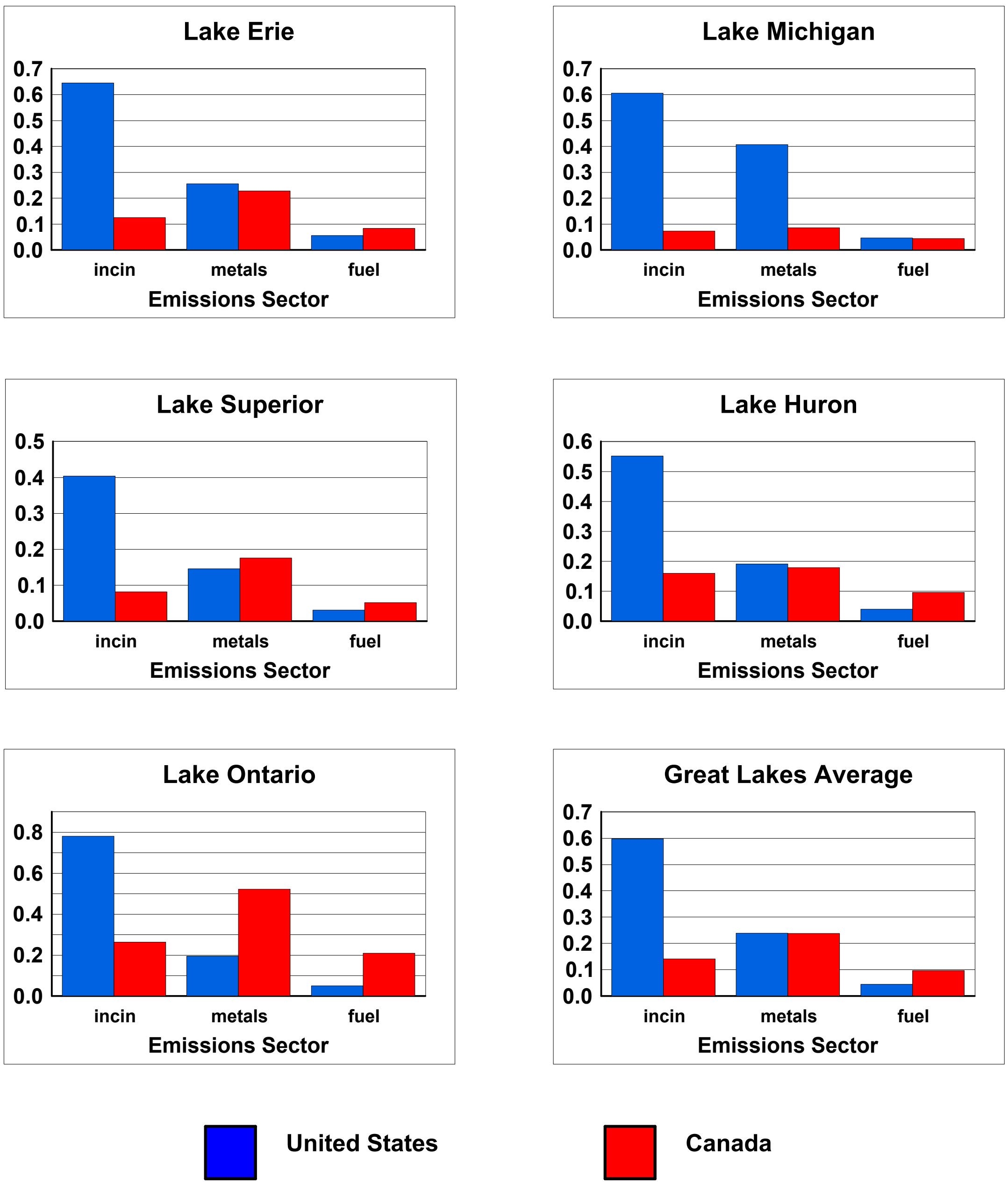


Figure 12. Contriibution of Different Source Sectors to Atmospheric Deposition of Dioxin (pg TEQ deposition / km2) / (person - year)

(Each country's annual deposition flux contribution amount normalized by their total population)

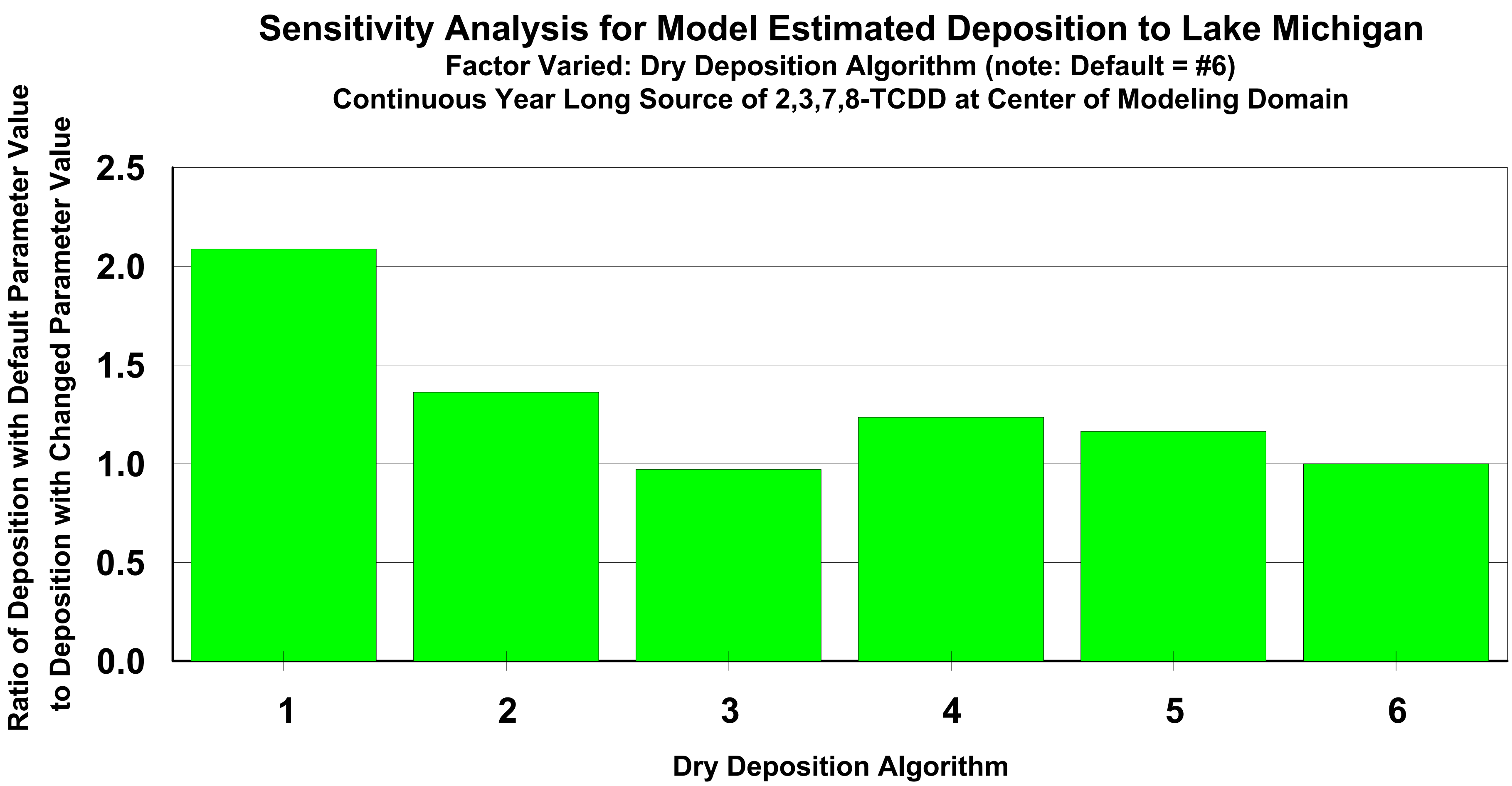


"incin" = waste incineration; "metals" = metallurgical processing; "fuel" = fuel combustion

Major Sources of Uncertainty in Atmospheric Dioxin Modeling

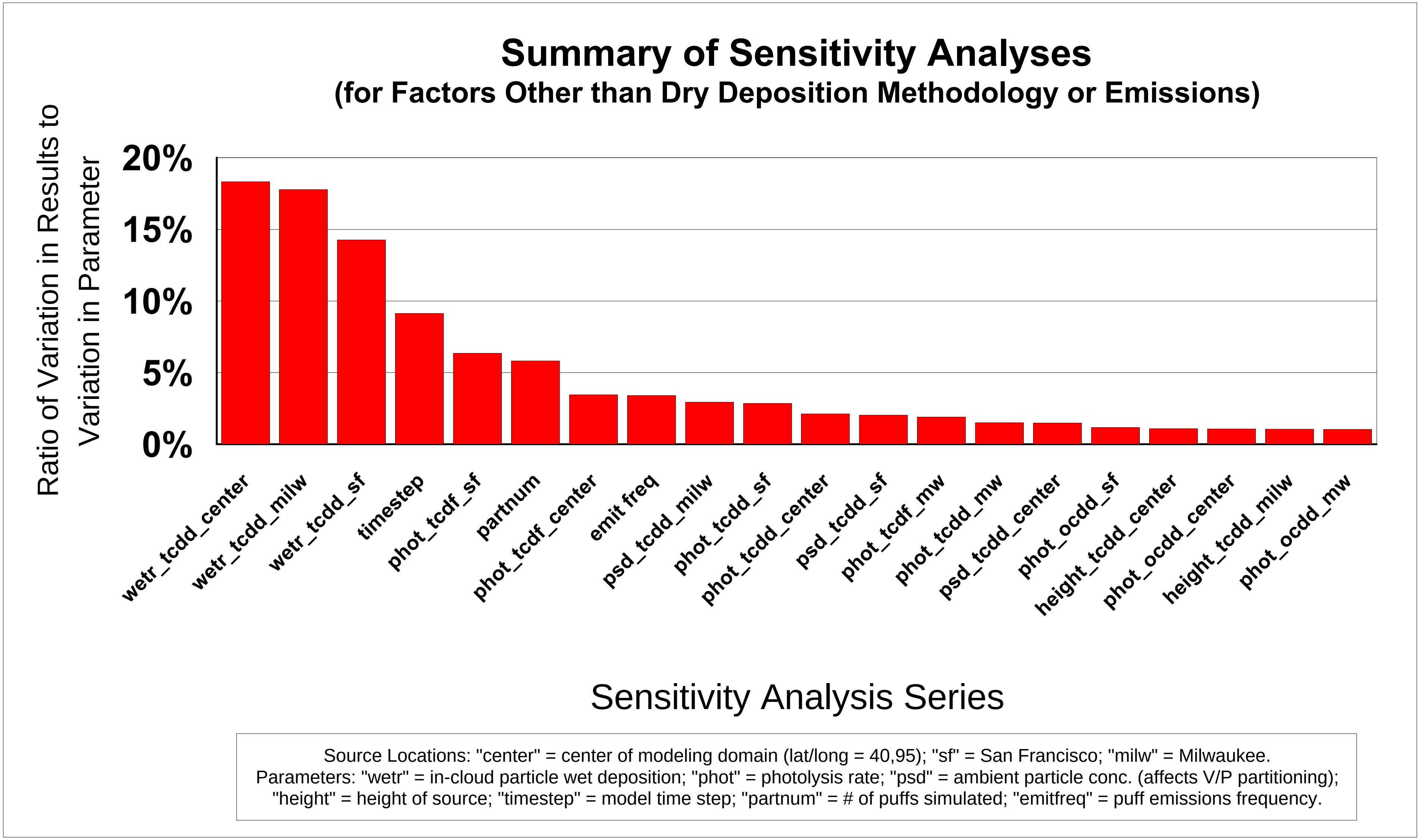
- Emissions Inventory
- Meteorological Data Used as Input to the Model
- Atmospheric Dispersion Simulation
- Atmospheric Fate Processes
  - Vapor/Particle Partitioning
  - Chemical Transformations
  - Wet Deposition
  - Dry Deposition

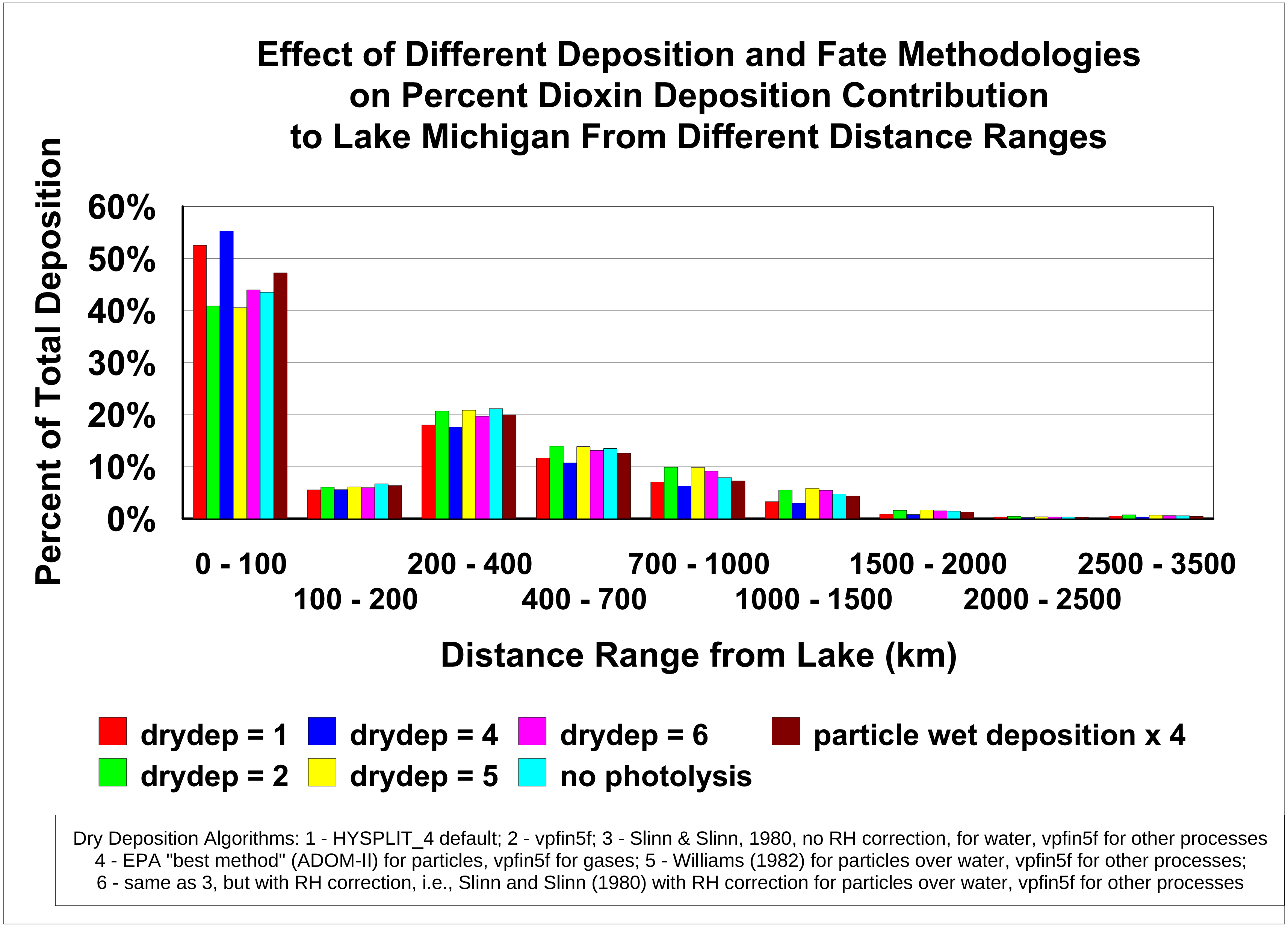
Other than uncertainties in the emissions inventory, the dry deposition modeling methodology is probably the most important factor influencing the results...



Dry Deposition Algorithms: 1 - HYSPLIT_4 default; 2 - vpfin5f; 3 - Slinn & Slinn, 1980, no RH correction, for water, vpfin5f for other processes 4 - EPA "best method" (ADOM-II) for particles, vpfin5f for gases; 5 - Williams (1982) for particles over water, vpfin5f for other processes; 6 - same as 3, but with RH correction, i.e., Slinn and Slinn (1980) with RH correction for particles over water, vpfin5f for other processes

What are the most important factors in the simulation uncertainty (other than the dry deposition methodology and the emissions inventory)?





Effect of Different Deposition and Fate Methodologies
on Percent Dioxin Deposition Contribution
to Lake Michigan From Different Distance Ranges
Percent of Total Deposition
60%
50%
40%
30%
20%
10%
0%
0 - 100
100 - 200
200 - 400
400 - 700
700 - 1000
1000 - 1500
1500 - 2000
2000 - 2500
2500 - 3500
Distance Range from Lake (km)
drydep = 1
drydep = 2
drydep = 4
drydep = 5
drydep = 6
no photolysis
particle wet deposition x 4
Dry Deposition Algorithms: 1 - HYSPLIT_4 default; 2 - vpfin5f; 3 - Slinn & Slinn, 1980, no RH correction, for water, vpfin5f for other processes
4 - EPA "best method" (ADOM-II) for particles, vpfin5f for gases; 5 - Williams (1982) for particles over water, vpfin5f for other processes;
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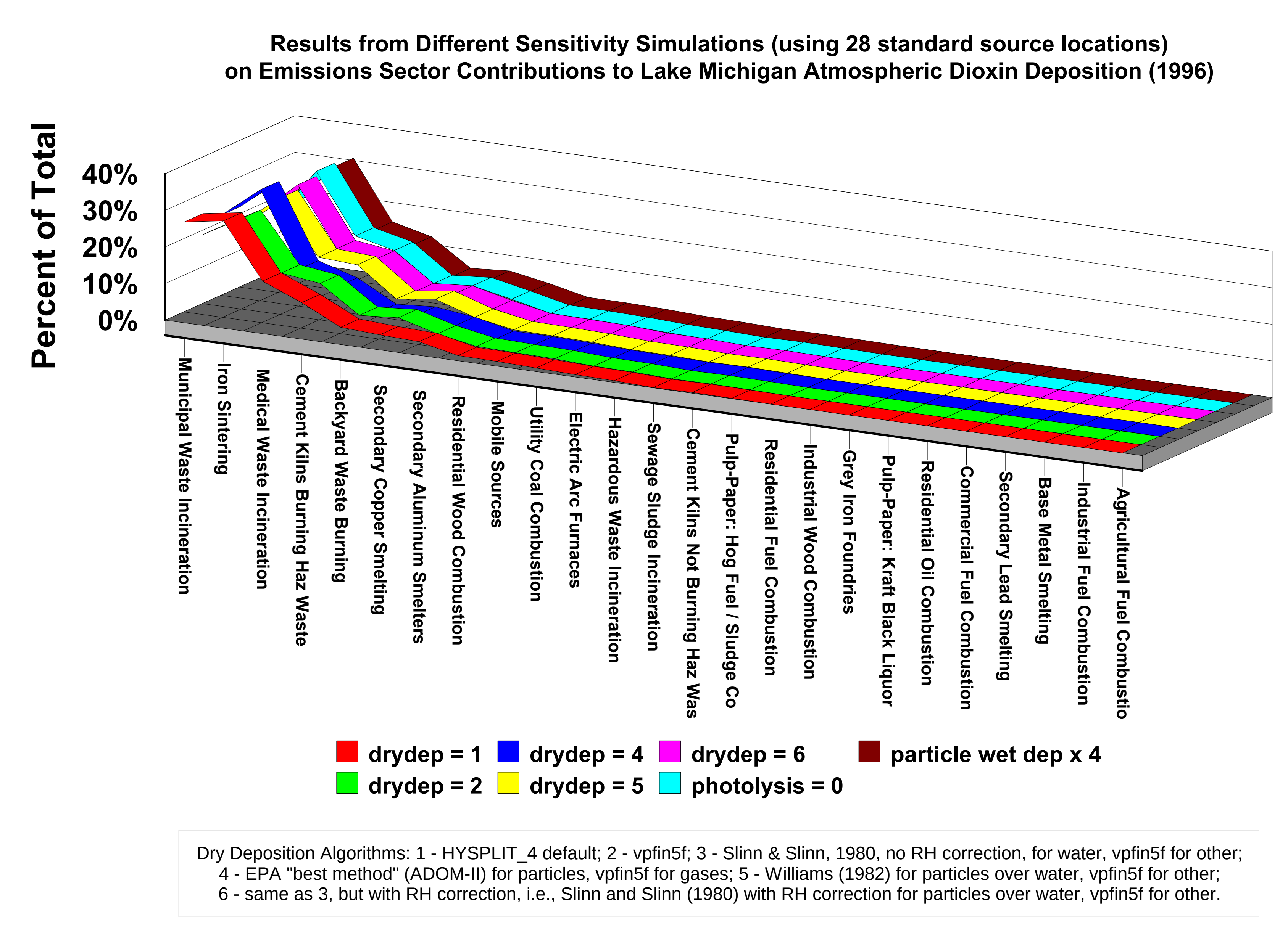

Results from Different Sensitivity Simulations (using 28 standard source locations)
on Emissions Sector Contributions to Lake Michigan Atmospheric Dioxin Deposition (1996)
Percent of Total
40%
30%
20%
10%
0%
Municipal Waste Incineration
Iron Sintering
Medical Waste Incineration
Cement Kilns Burning Haz Waste
Backyard Waste Burning
Secondary Copper Smelting
Secondary Aluminum Smelters
Residential Wood Combustion
Mobile Sources
Utility Coal Combustion
Electric Arc Furnaces
Hazardous Waste Incineration
Sewage Sludge Incineration
Cement Kilns Not Burning Haz Was
Pulp-Paper: Hog Fuel / Sludge Co
Residential Fuel Combustion
Industrial Wood Combustion
Grey Iron Foundries
Pulp-Paper: Kraft Black Liquor
Residential Oil Combustion
Commercial Fuel Combustion
Secondary Lead Smelting
Base Metal Smelting
Industrial Fuel Combustion
Agricultural Fuel Combustio
drydep = 1
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drydep = 6
particle wet dep x 4
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Dry Deposition Algorithms: 1 - HYSPLIT_4 default; 2 - vpfin5f; 3 - Slinn & Slinn, 1980, no RH correction, for water, vpfin5f for other;
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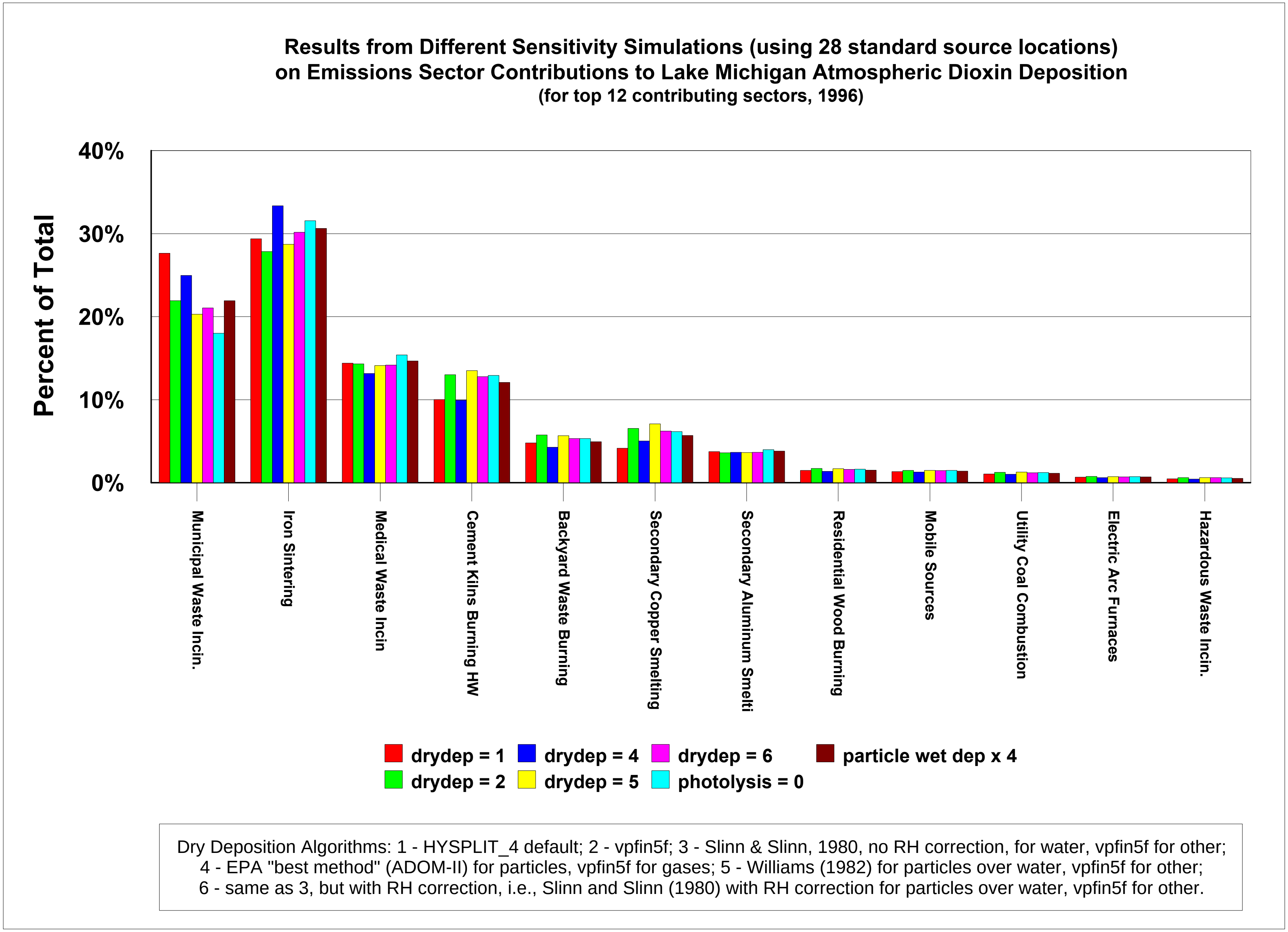

Results from Different Sensitivity Simulations (using 28 standard source locations)
on Emissions Sector Contributions to Lake Michigan Atmospheric Dioxin Deposition
(for top 12 contributing sectors, 1996)
Percent of Total
40%
30%
20%
10%
0%
Municipal Waste Incin.
Iron Sintering
Medical Waste Incin
Cement Kilns Burning HW
Backyard Waste Burning
Secondary Copper Smelting
Secondary Aluminum Smelti
Residential Wood Burning
Mobile Sources
Utility Coal Combustion
Electric Arc Furnaces
Hazardous Waste Incin.
drydep = 1
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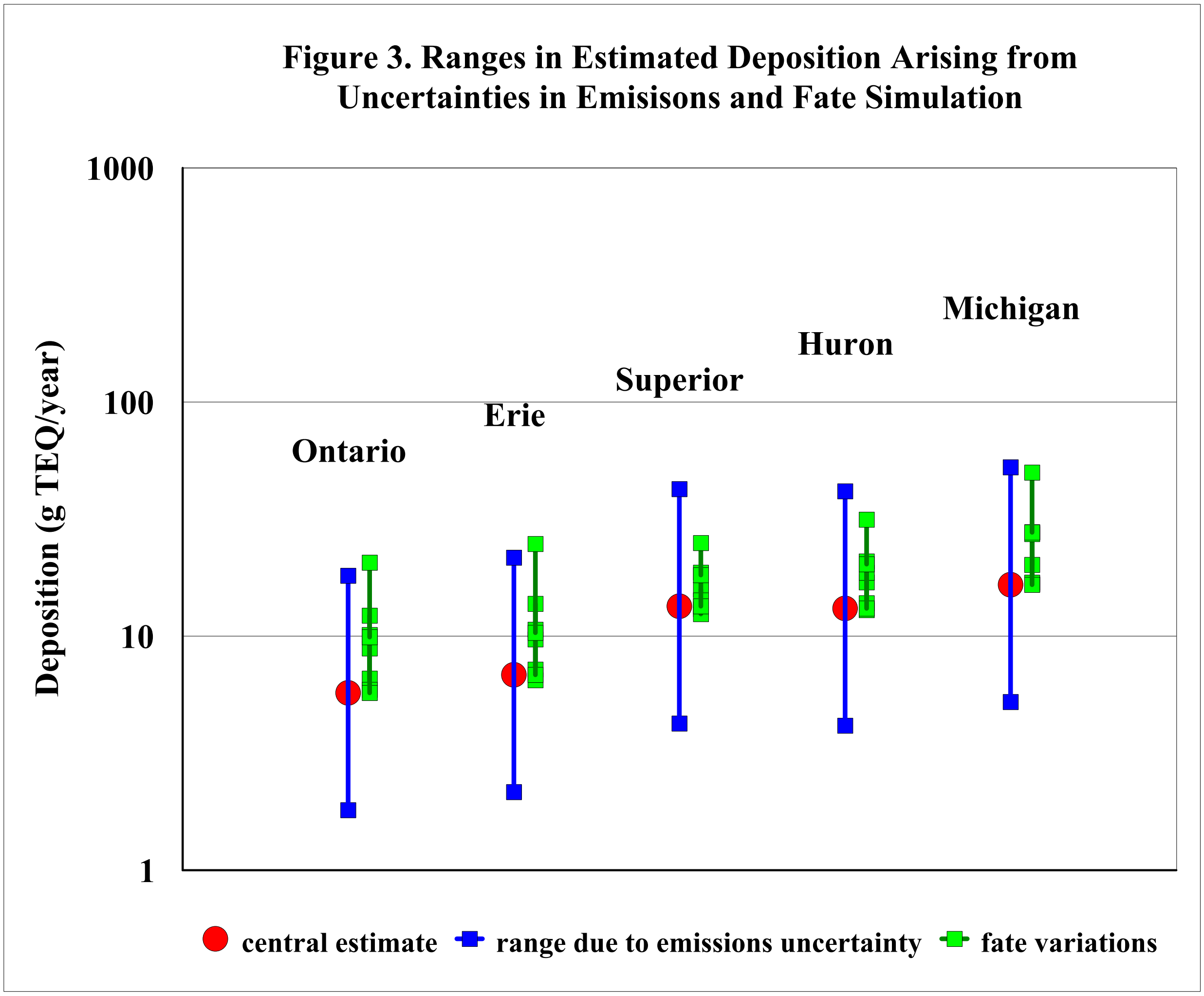
Figure 3. Ranges in Estimated Deposition Arising from
Uncertainties in Emisisons and Fate Simulation
1000
100
10
1
Deposition (g TEQ/year)
Ontario
Erie
Superior
Huron
Michigan
central estimate
range due to emissions uncertainty
fate variations

What could we do to improve the accuracy of atmospheric loading estimates?

‘ **More information on non-atmospheric loading pathways** needs to be collected in order to more accurately place the atmospheric contributions in their proper context.

‘ **Ambient monitoring for dioxin** must be increased in the Great Lakes region. This will allow model evaluation and independent semi-empirical estimates of atmospheric deposition to be made.

‘ **Additional efforts to improve the accuracy of emissions inventories** – including timely updates – must be made. Timely (e.g., annual) updates for at least the largest sources in the inventory would be extremely helpful, because often, these largest sources tend to drive the analysis. If they can be better characterized, the accuracy of the overall analysis can be greatly (and relatively easily) improved.