Receptor Modeling and Wet Deposition Measurements

NADP Annual Meeting and Scientific Symposium

October 15, 2008

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Some Elements of Research Presented were conducted by
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Evolution of Receptor Modeling

- Initially Used for Particulate Matter (PM) Research
- EPA & Others Experimented with Correlation, Factor, and Principal Component Analysis
- Identified Sources of Visibility Degradation and Ambient PM Exposures
- Statistical Methods Quickly Evolved
  - Chemical Mass Balance Model
  - Multivariate Models

Linear Regression and Factor Analysis Models

- These Models Have Been Used By EPA to Determine Fine And Coarse PM Contributions
- Great Smoky Mountains
- Shenandoah Valley and Abastumani Mountains in Georgia, USSR
- Houston, TX And Philadelphia, PA
  - See Publications by Tom Dzubay et al

Example Contemporary Study

- Objective
  - Determine the impact of local/regional coal combustion sources on mercury deposition in the Ohio River Valley
- Time Line
  - Study designed in 1999
  - Work being conducted cooperatively with the University of Michigan
  - Data collection completed end of 2007
    - 2-years of wet deposition data analysis and modeling completed (2003 and 2004)
    - Keeler et al., 2006 ES&T 40, 5874-5881

Mercury Source Apportionment Demonstration Project

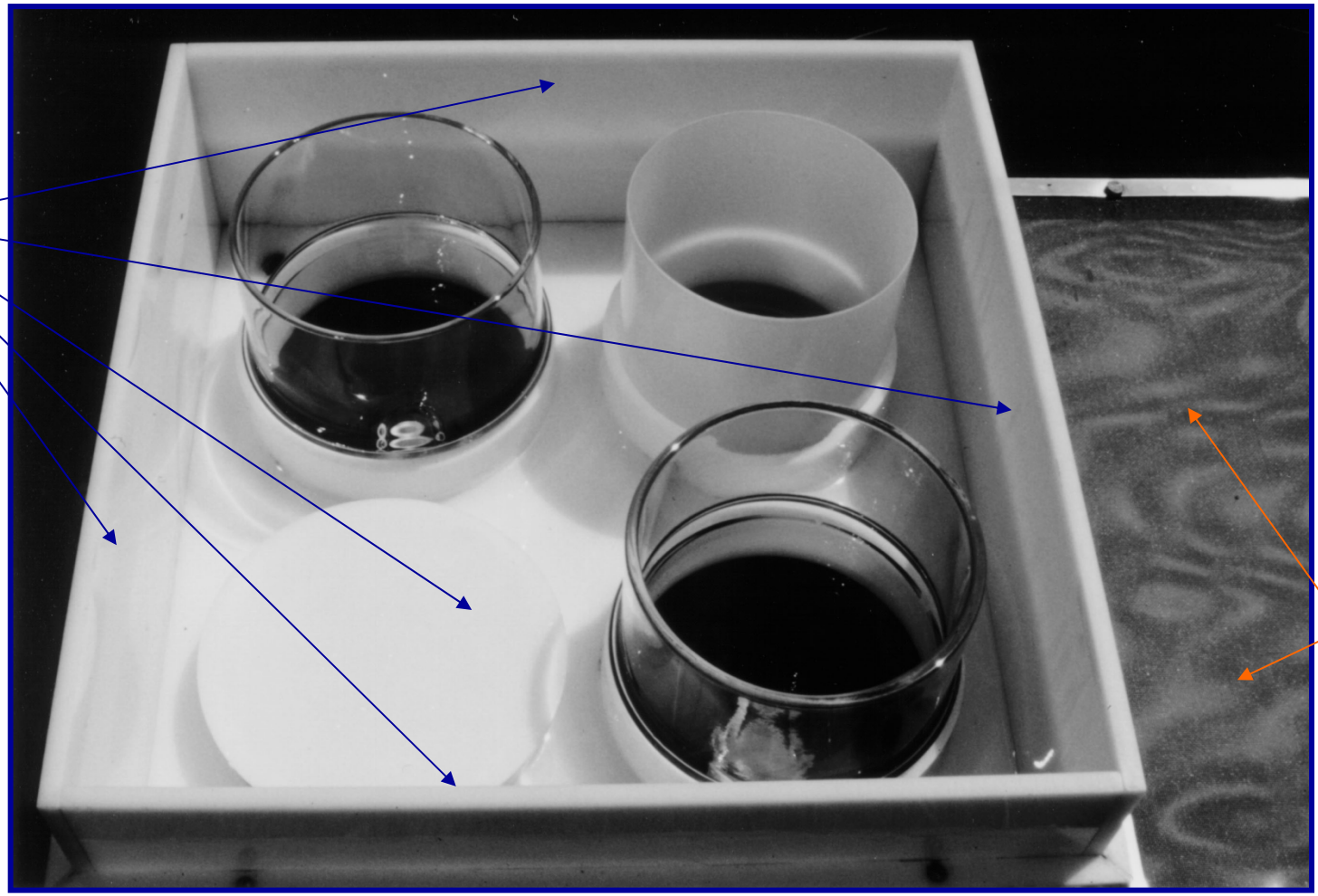
- Comprehensive State-of-the-Art Measurement & Analyses
  - Aerosols - Integrated and Continuous
  - Wet Deposition - Daily Event
  - Gases - Continuous
  - Meteorology - Continuous
- Receptor Modeling
  - EPA Implemented Unmix, and PMF
  - Hybrid Modeling (Regional Transport)

Wet-Only Precipitation Collection

* Landis and Keeler
Environ. Sci. Technol.,
1997, 31, 2610-2615

Insert - Flexible Configurations

- No Significant Splash (in or out) -



High Resolution ICP-MS Analysis

- Low Resolution
  - Li, Be, Rb, Sr, Y, Mo, Ag, Cd, In, Sn, Sb
    Cs, Ba, La, Ce, Nd, Sm, Gd, Dy, W, Tl,
    Pb, Bi, Th, U
- Medium Resolution
  - Na, Mg, Al, P, S, Ca, Sc, Ti, V, Cr
    Mn, Fe, Co, Ni, Cu, Zn
- High Resolution
  - K, Ge, As, Se
- Stable Isotope Ratios
  - Pb

Overview of Source Apportionment

- Source apportionment relates sources and environmental concentrations
- Approaches to source apportionment
  - Deterministic modeling (e.g., CMAQ) – source to receptor
    - Requires emission inventory, chemistry, and meteorology
    - Models emission source impacts on predicted concentrations
  - Receptor modeling – receptor to source
    - Requires comprehensive environmental measurements
    - Statistically identifies sources impacting measured concentrations
- Approaches are independent and complementary

Multivariate Receptor Modeling

- Identify Major “Factors” by Statistical Analysis of an Element Measurement Matrix
- Relate “Factors” to Source Type (e.g., coal combustion) Using Presence and Absence of Tracer Compounds
- Example Tracer Compounds
  - Coal Combustion – S, Se
  - Oil Combustion – Ni, V
- Requires Many Samples (150 or more)
- Steubenville Study
  - Applied both positive matrix factorization (PMF) and Unmix models
  - Estimated source contributors to measured wet Hg deposition

Steubenville PMF Apportionment Results 2003 & 2004

Analyte	Source 1 **Iron/Steel Production**	Source 2 **Oil & Incineration**	Source 3 **Crustal**	Source 4 **Coal Combustion**	Source 5 **Phosphorous**	Source 6 **Molybdenum**
Mg	187	*	558	*	101	*
Al	51	80	355	37	*	52
P	7.8	*	*	*	63.8	*
S	*	*	642	11299	197	*
Cl	267	20480	*	584	*	771
V	2.9	1.1	*	*	*	*
Cr	2.5	*	*	*	*	*
Mn	54.4	*	34.1	*	15.4	*
Fe	344	102	17	37	27	*
Ni	*	3.19	*	*	0.68	*
Cu	1.8	14.0	*	18.4	2.7	7.0
Zn	4.0	44.1	6.1	10.7	5.3	15.6
As	*	0.81	0.10	0.49	0.05	0.27
Se	*	0.97	*	1.73	*	1.30
Rb	*	0.25	0.15	0.20	0.29	0.08
Sr	0.48	3.30	5.64	0.95	1.61	*
Mo	*	*	*	*	*	4.02
Cd	0.09	0.27	*	0.31	0.02	0.23
La	*	0.13	0.63	*	*	0.04
Ce	0.02	*	1.23	*	*	*
Hg	0.01	*	*	0.15	< 0.01	*
Pb	1.10	6.59	0.59	3.62	0.36	1.13
NO_3	*	8639	1501	4532	314	*
% Hg	**6**	*	*	**73**	**2**	*

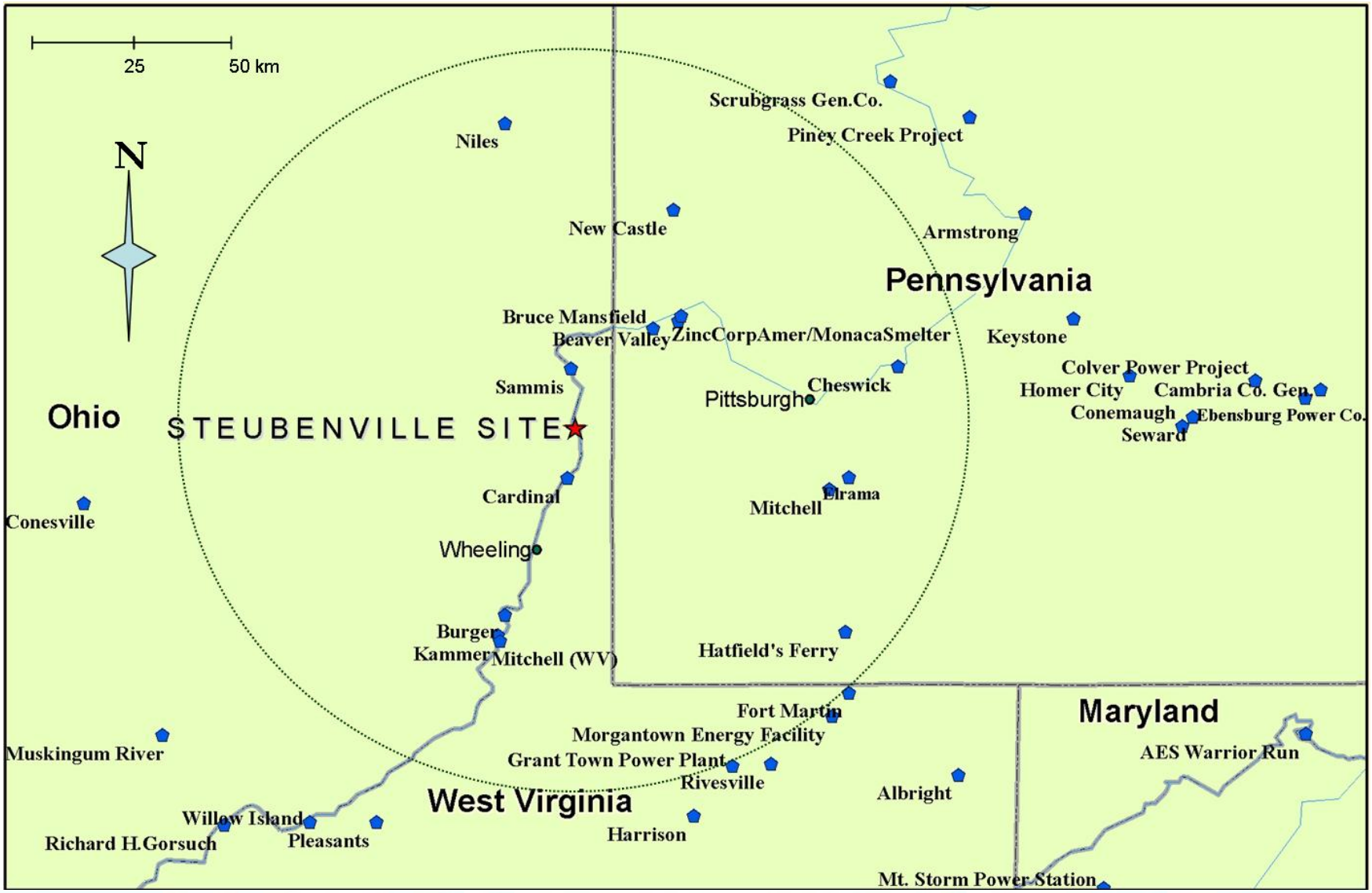
Annualized Steubenville Source Apportioned Mercury Wet Deposition Results ($\mu g\ m^{-2}\ y^{-1}$)

	Measured	PMF Estimated CFUB* Contribution	UNMIX Estimated CFUB* Contribution
2003	13.5	Mean = 9.1 (5-95% CI$^{\Omega}$) = (6.4 – 14.7)	Mean = 9.9 (5-95% CI$^{\Omega}$) = (5.9 – 15.1)
2004	19.7	Mean = 13.1 (5-95% CI$^{\Omega}$) = (9.3 – 21.4)	Mean = 15.5 (5-95% CI$^{\Omega}$) = (9.1 – 23.1)

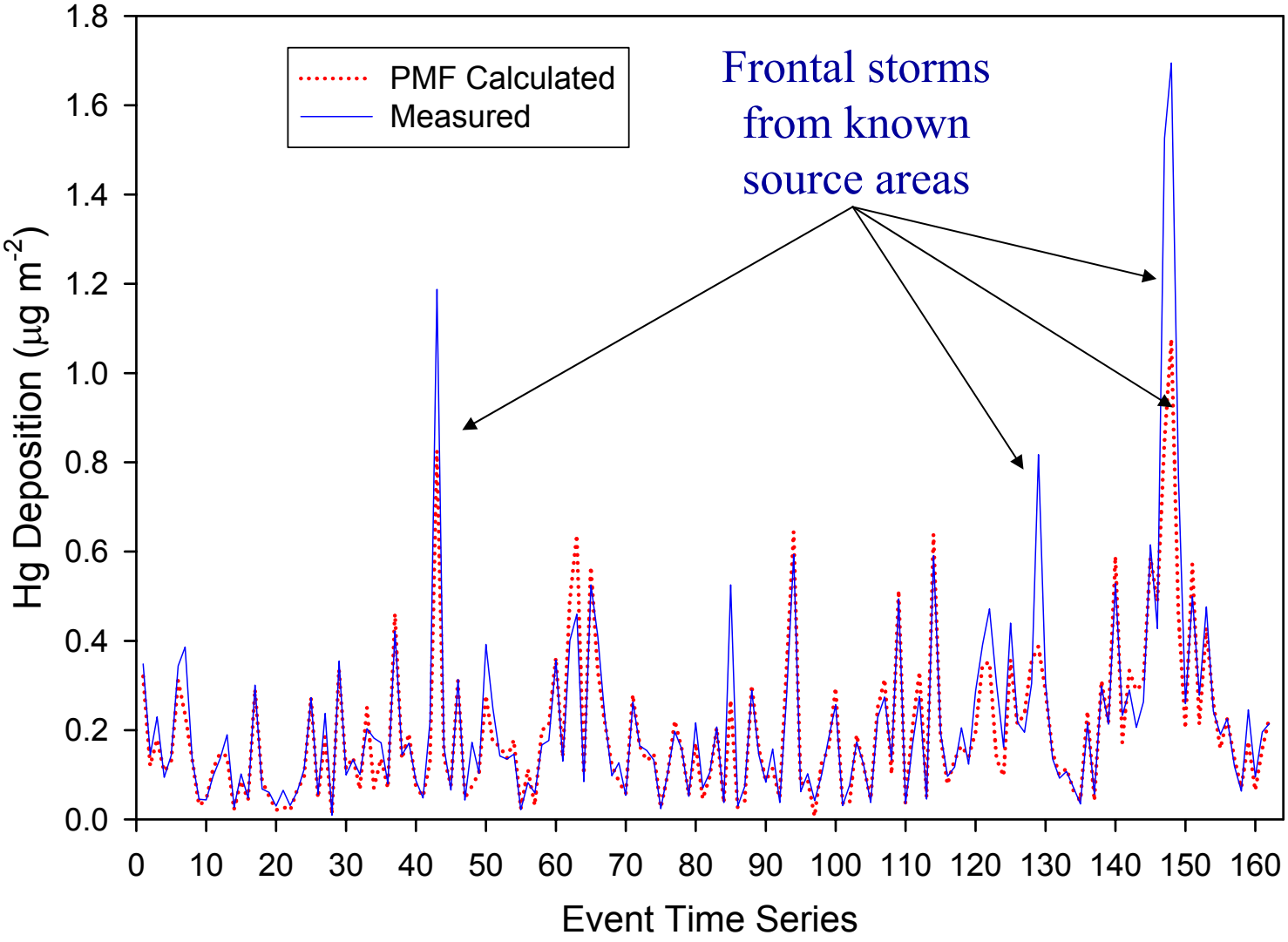
***Coal-fired Utility Boiler**

$^{\Omega}$ Confidence Interval

Location of Surrounding CFUBs



Local Source Impacts?



Summary of Steubenville Receptor Modeling

- Hg wet deposition at Steubenville
  - ~ 80% is attributable to local/regional anthropogenic sources
  - ~ 70% is attributable to coal combustion
  - ~ 20% from reemission/global background
- A significant portion of total Hg wet deposition is driven by a few local coal combustion dominated precipitation events
  - In 2004, >8% of total wet Hg deposition occurred during one event

USEPA Receptor Modeling Web Site

- http:www.epa/heasd/products/unmix.htm
- http:/epa.gov/products/pmf.htm


Questions ?