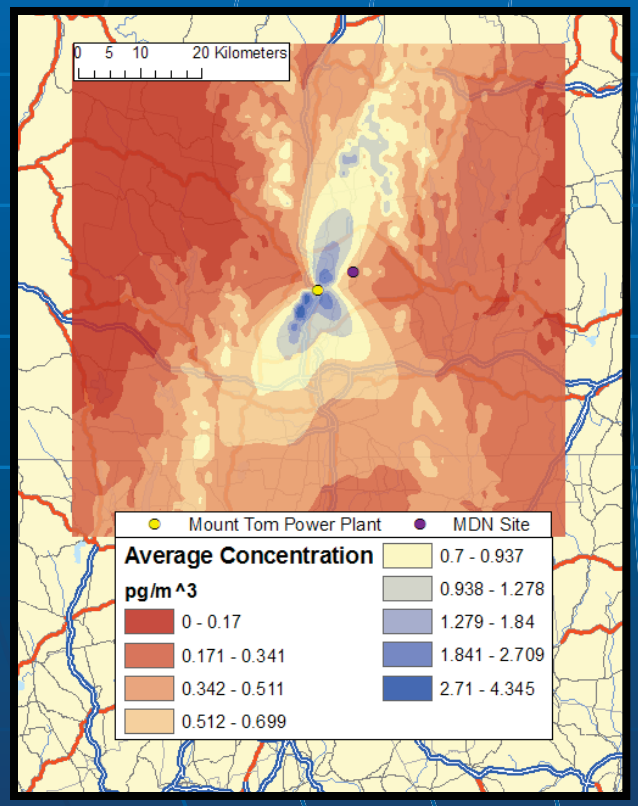
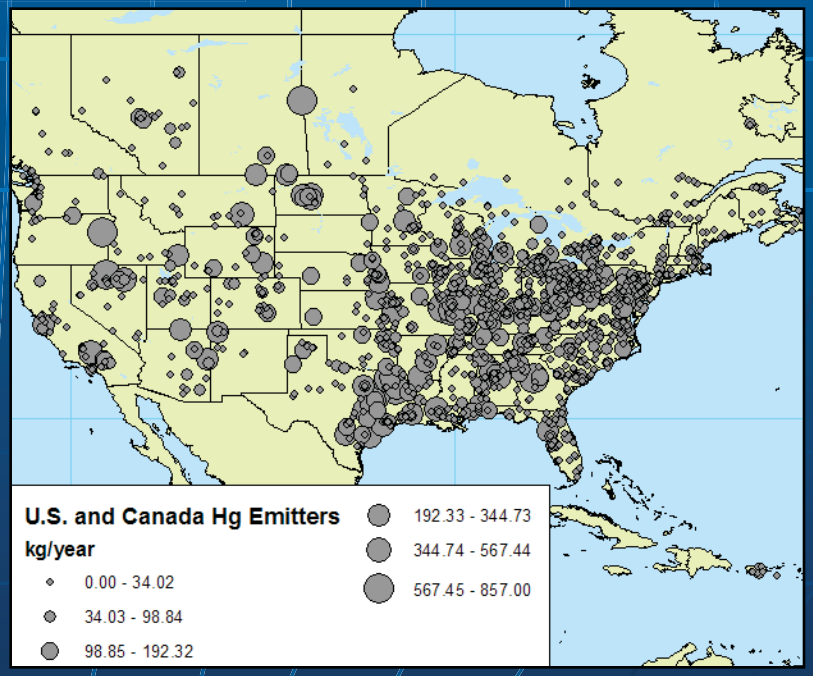
Measuring and Modeling Mercury in the Pioneer Valley



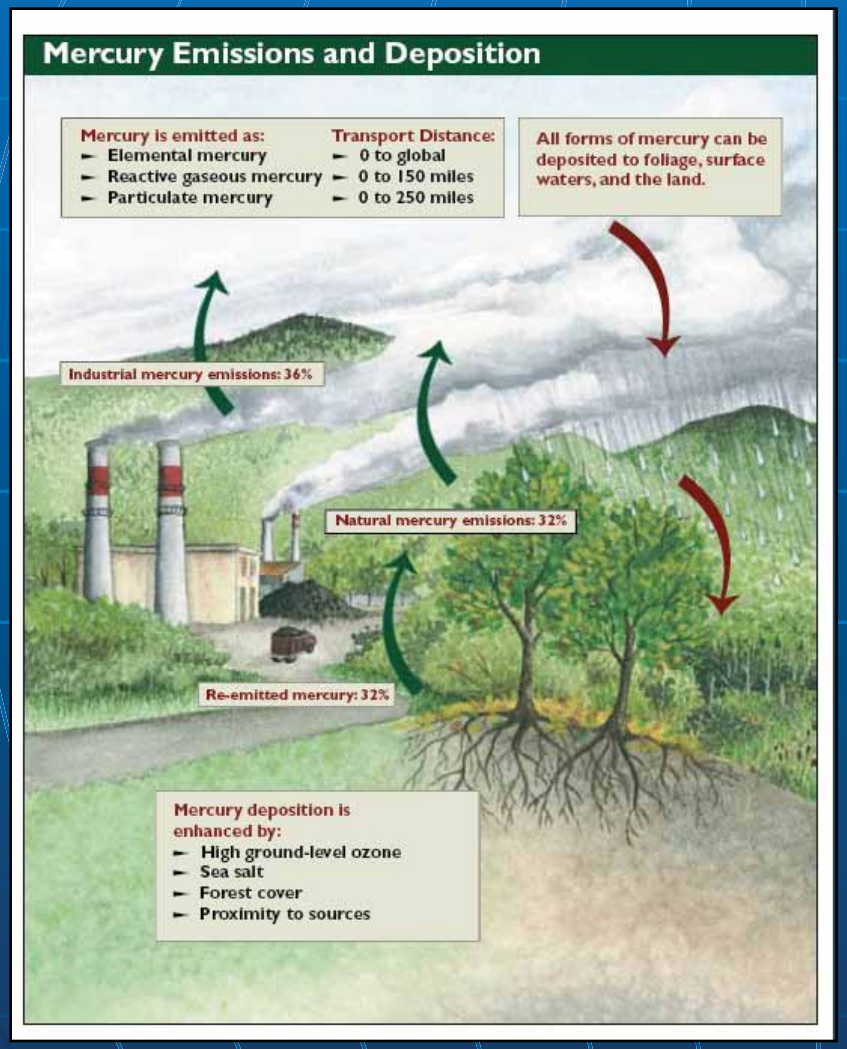
Jonathan Thrope,
With Professor Karena McKinney

Mercury in the Atmosphere

- Natural Sources
  - Volcanoes, rock weathering…
- Anthropogenic Emissions
  - Coal Power Plants, waste incinerators…
- Three Major Species
  - Elemental—Hg^0
  - Reactive—Hg^{2+} (most offten $HgCl_2$)
  - Particulate—Hg(p)



Mercury in the Atmosphere



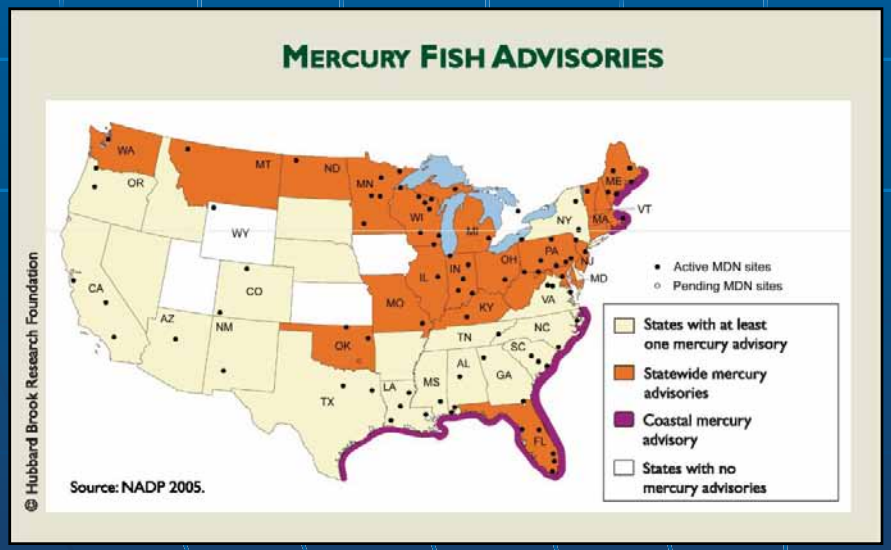
Important Reactions:

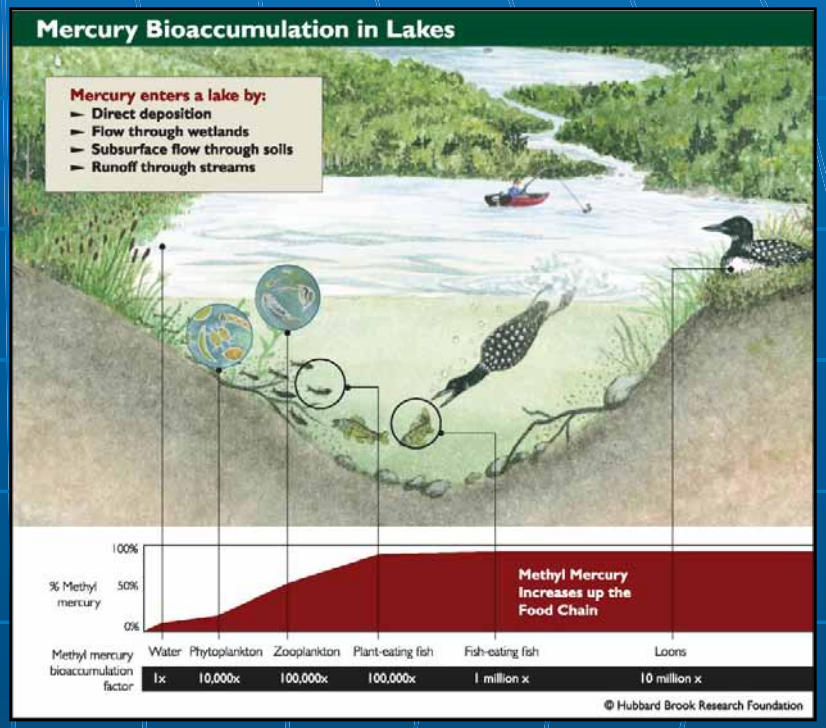
- Gas phase Oxidation of Hg^0 by ozone and $OH^{\cdot}$
- Aqueous reduction of Hg^{2+} by sulfite (SO_3^{2-})
- Aqueous complexation of Hg^{2+} to soot, to form Hg(p)

Driscoll, C.T., D. Evers, K.F. Lambert, N. Kamman, T. Holsen, Y-J. Han, C. Chen, W. Goodale,
T. Butler, T. Clair, and R. Munson. Mercury Matters: Linking Mercury Science with Public Policy in
the Northeastern United States. Hubbard Brook Research Foundation. 2007. Science Links Publication.
Vol. 1, no. 3.

Mercury in the Environment

- Methylation
- Bioaccumulation
- Fish Advisories





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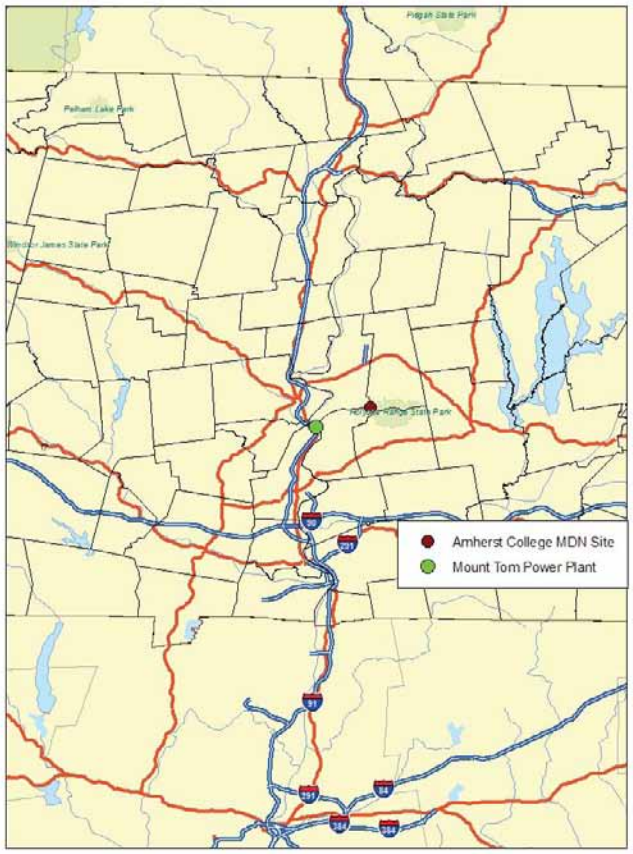
Mercury in the Pioneer Valley



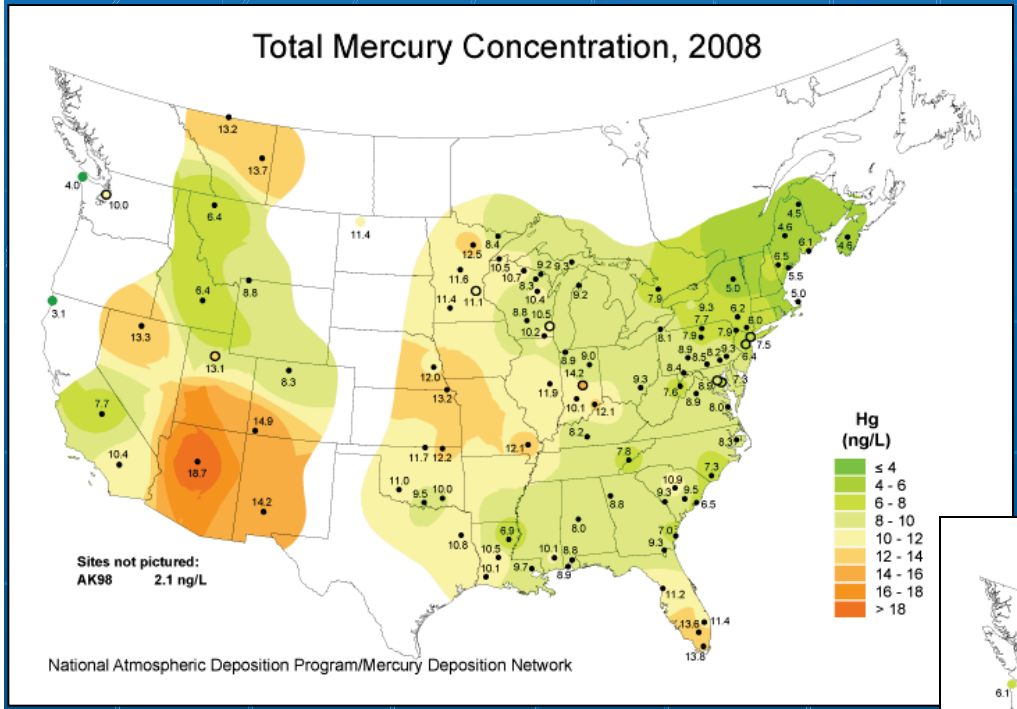
Mercury in the Pioneer Valley

- 146 MW Coal Power Plant
- 1,200 tons of coal/day
- 10.5 kg of Hg in 2008
- 60.1% Hg^0
- 21.6% Hg(p)
- 18.3 Hg^{2+}
- Turbosorp

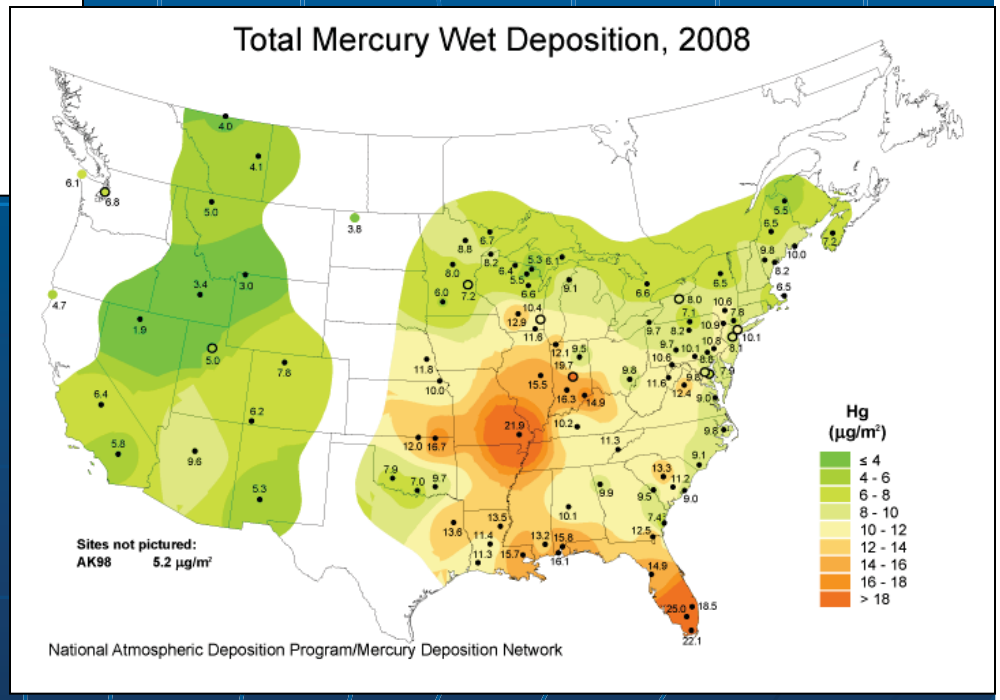
Measuring Mercury

- Rain Deposition Samples
- Air Concentration Measurements

Mercury Deposition Network



Measures Hg concentration in precipitation and total weekly wet deposition



Over 100 Sites

Rain Deposition

- Mercury Deposition Network
- Precipitation Collector

Rain Deposition

- Mercury Deposition Network
- Precipitation Collector
- Rain Gauge

MDN Results

End Date	Total Precipitation (mm)	Capture (%)	Precip. Hg Concentration (ng/L)	Weekly Hg Deposition (ng/m^2)
9/15/2009	11.43	97.5	6	68.4
9/22/2009	Dry Week			
9/29/2009	26.42	90.7	3.6	95
10/6/2009	23.88	97.3	7.1	169.7
10/13/2009	27.94	94	9.6	267.8
10/20/2009	8.13	84.5	1.4	11.3
10/27/2009	52.32	97.3	4.7	245.8
11/3/2009	44.45	98.3	2.8	124.3
11/10/2009	4.064	103.7	3.9	14.8
11/17/2009	33.02	97.6	3.3	111.5
11/24/2009	20.07	96	2.3	46.2
12/1/2009	9.40	95.1	6.1	57.3
12/8/2009	34.04	89.2	3.2	108.8
12/15/2009	49.02	83.4	2.7	132.3
12/21/2009	1.52	24.1	5.2	7.8
12/29/2009	35.31	93	2.8	98.8
1/5/2010	9.14	47.67	3.3	30
1/12/2010	.76	19.69	17.40	13.9
1/20/2010*	30.99	81.70	3.1	96.1
1/26/2010	41.15	93.61	2.4	98.6

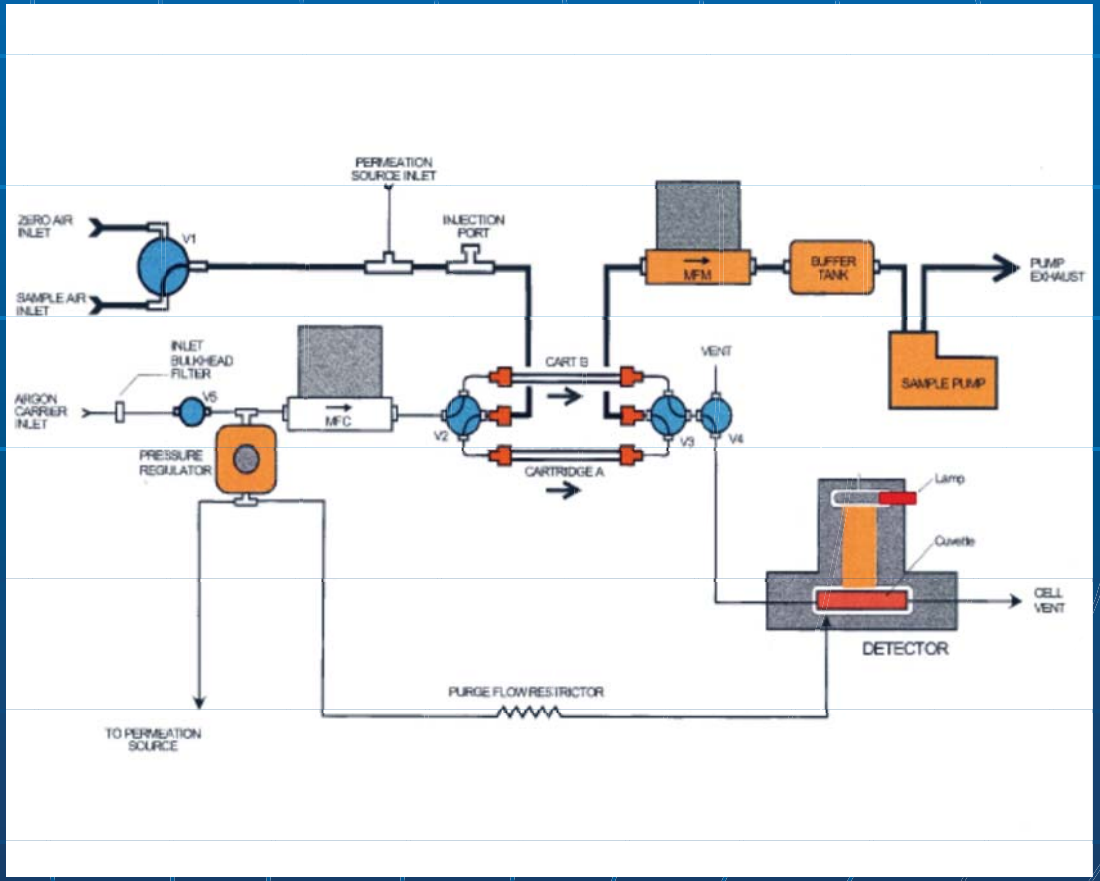
Avg. Concentration: 3.88 ng/L

Total Wet deposition: 1798. ng/m^2

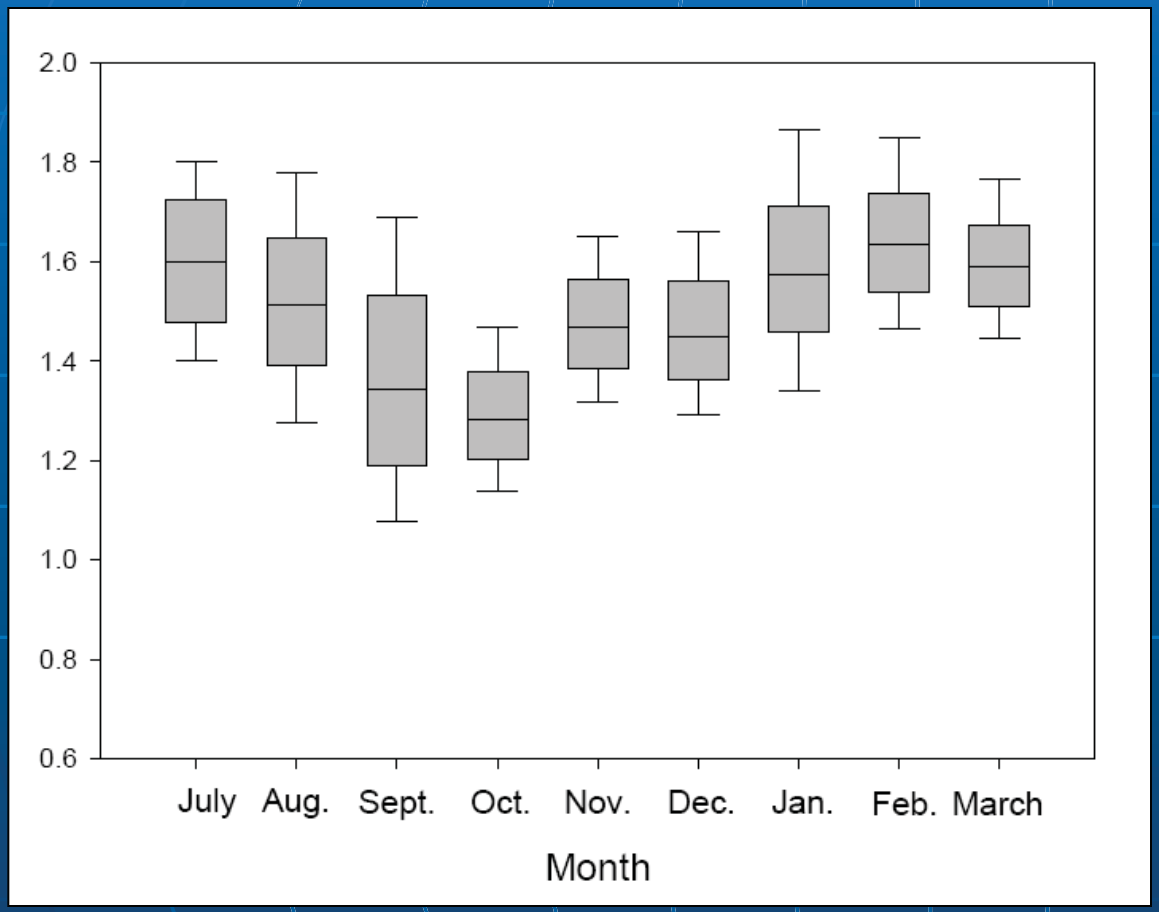
Extrapolated annual deposition: 4721. ng/m^2

Mercury Air Monitoring

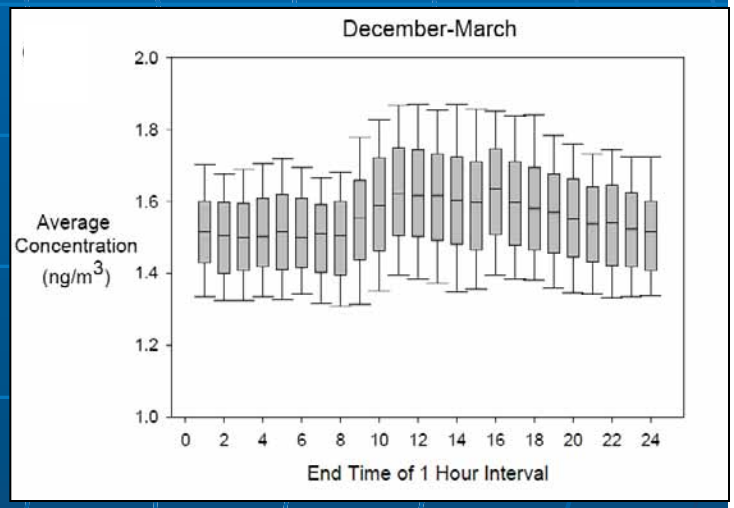
- Mercury Vapour Analyzer



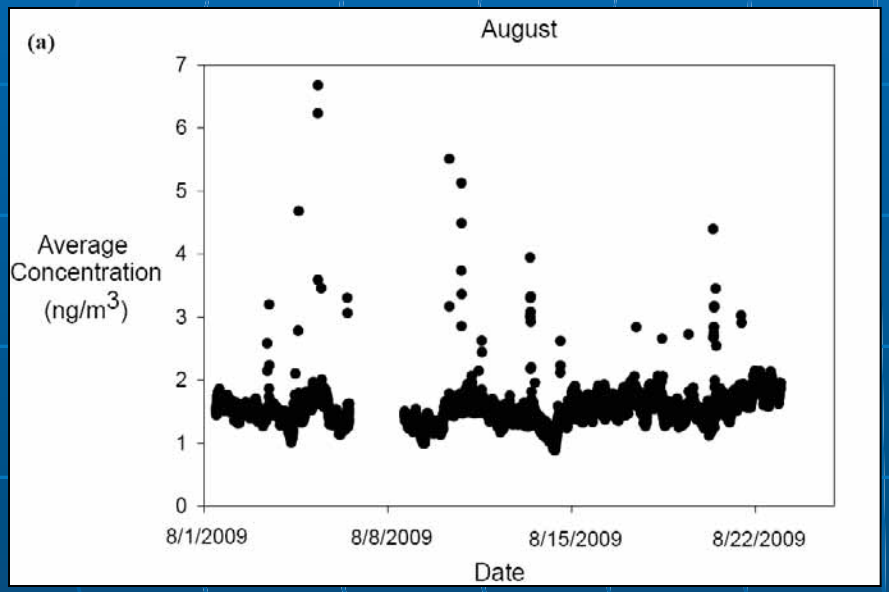
Mercury Air Monitoring

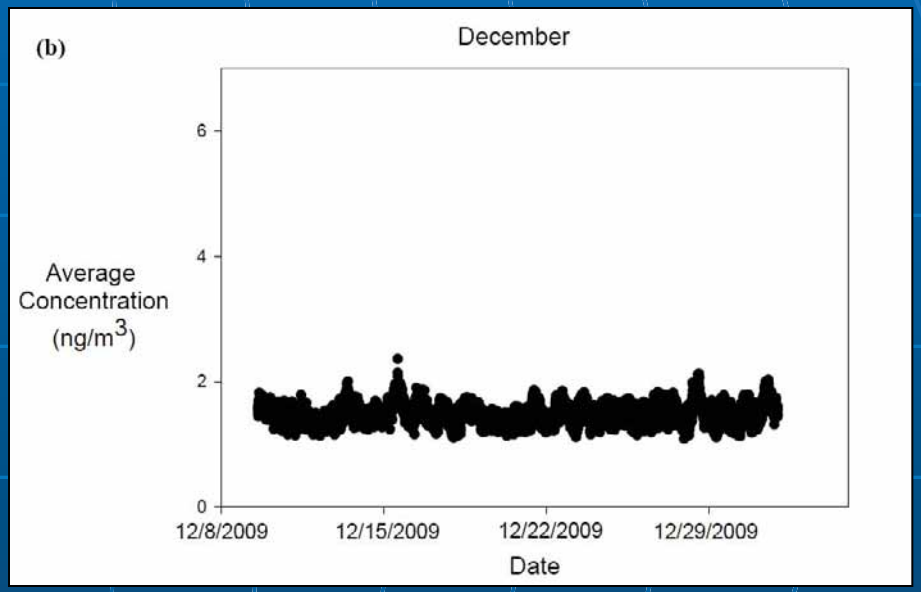


Mean from July 22, 2009 to March 17, 2010: 1.508 ng/m3.



Mercury Air Monitoring





Modeling Mount Tom Mercury

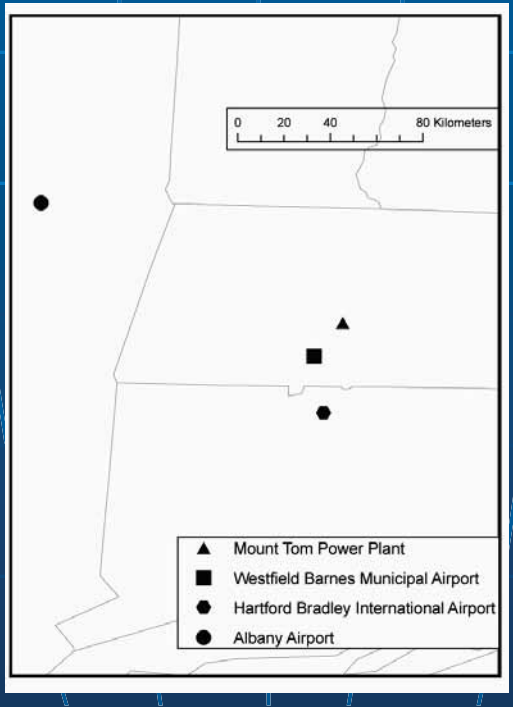
- AERMOD
  - Concentration and Deposition
- AERMET
  - Meteorological Processing
- AERMAP
  - Terrain Processing

Basics of AERMOD

- Steady State Dispersion Model
  - Good within 50 km grid
  - Characterizes the Planetary Boundary Layer (PBL)

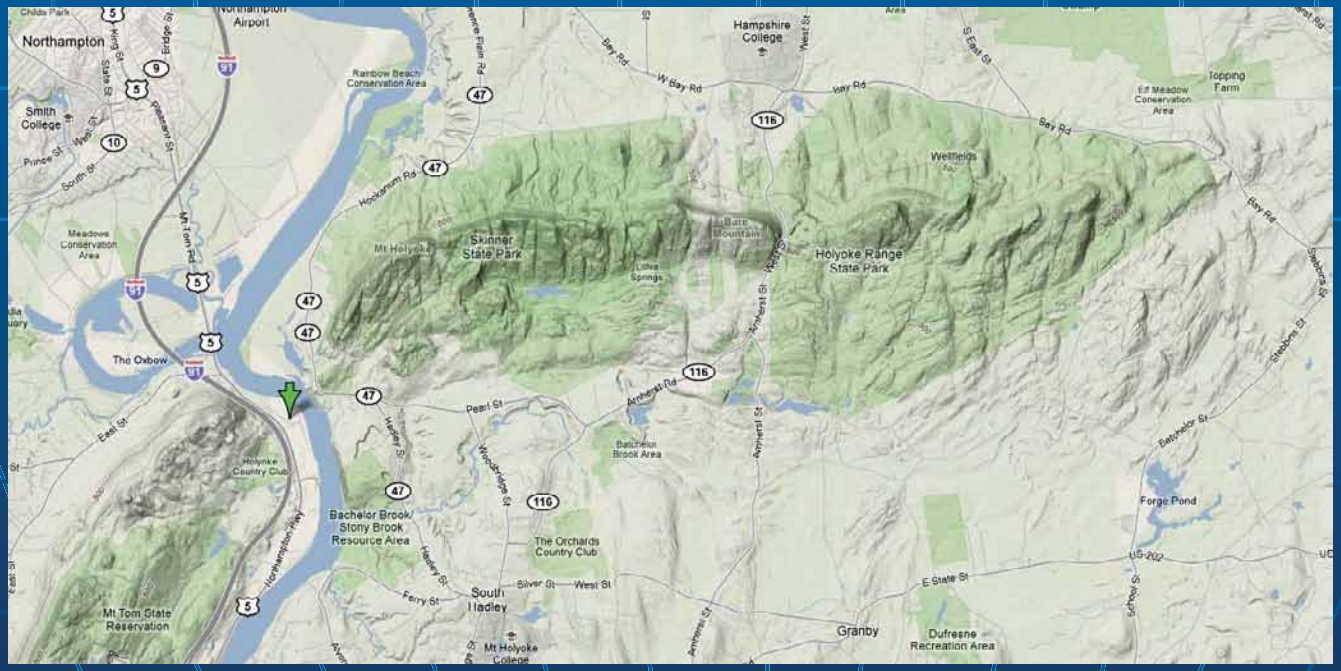
AERMET Inputs

- Surface Data (Barnes Municipal Airport, Westfield)
  - Hourly wind speed/direction, temperature, cloud cover, albedo…
- Upper Air Data (Albany Airport)
  - Upper-Air Temperature Sounding

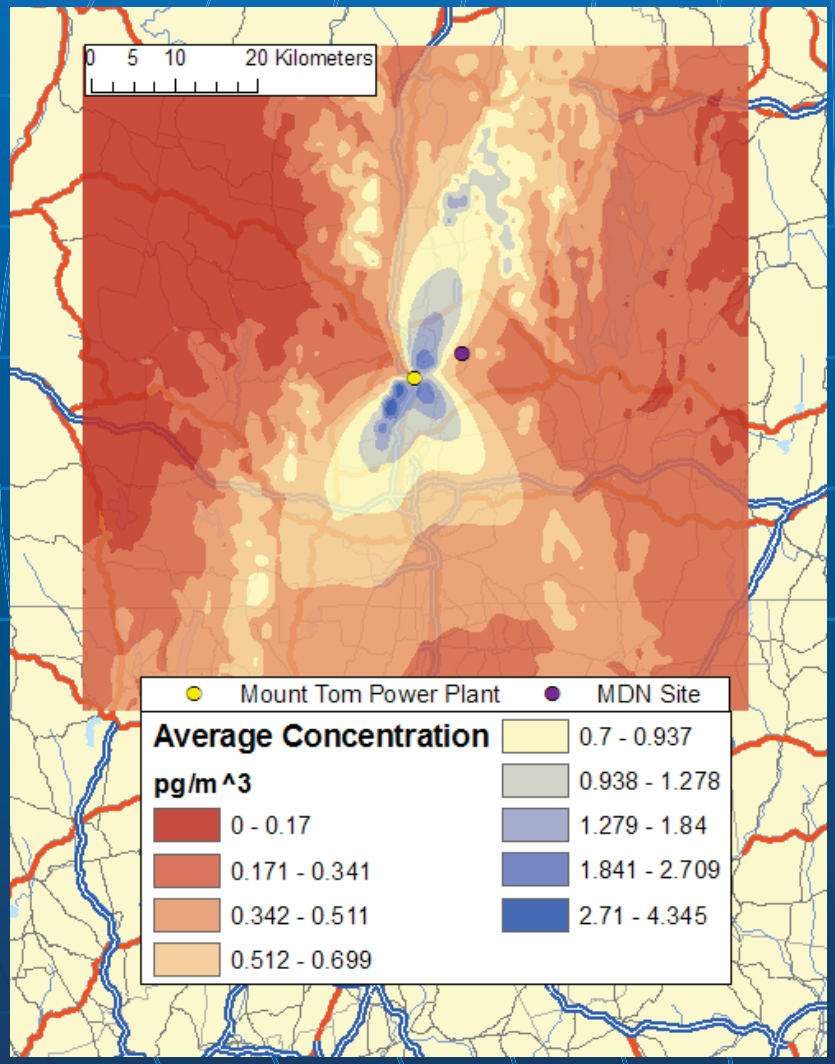


AERMAP Inputs

- Define Receptor Grid
  - Cartesian or Polar
- Each receptor is assigned an elevation and hill height scale

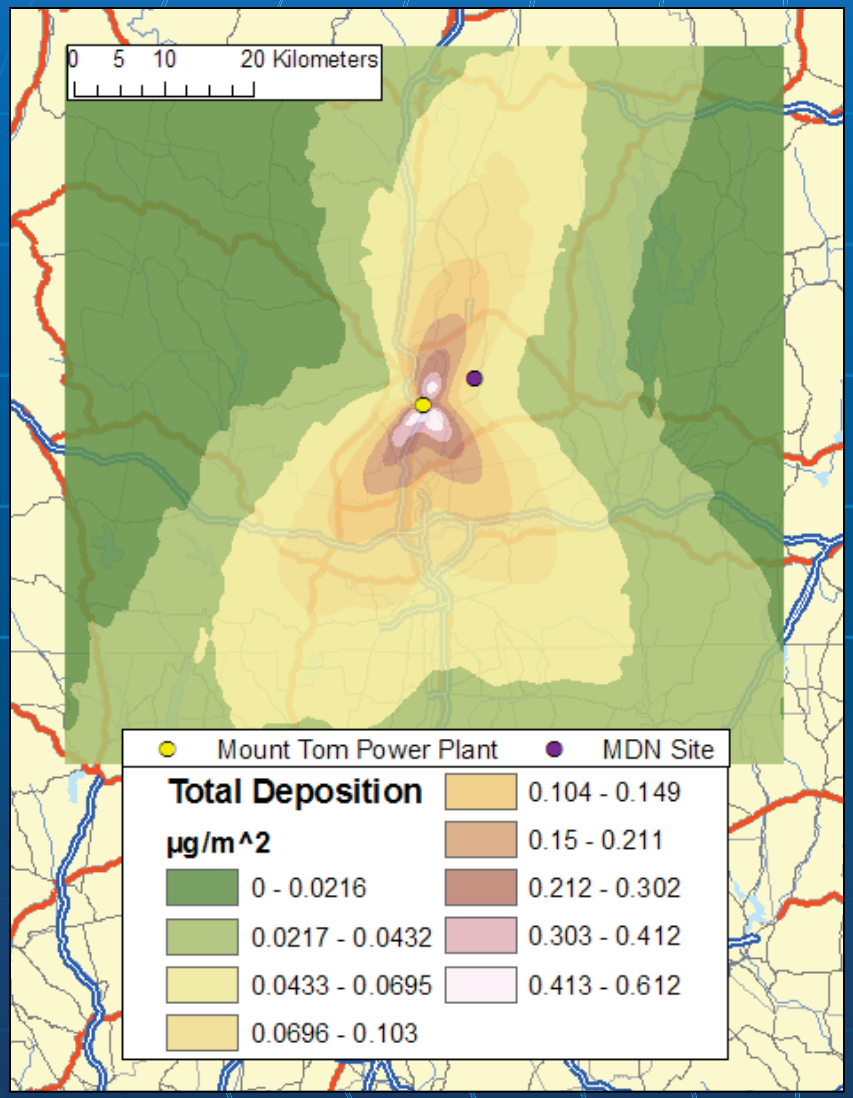


AERMOD Output: Concentration



Average Total Concentration (pg/m^3)	0.360
Average Elem. Concentration (pg/m^3)	0.221
Average RGM Concentration (pg/m^3)	0.059
Average PM Concentration (pg/m^3)	0.079

AERMOD Output: Deposition



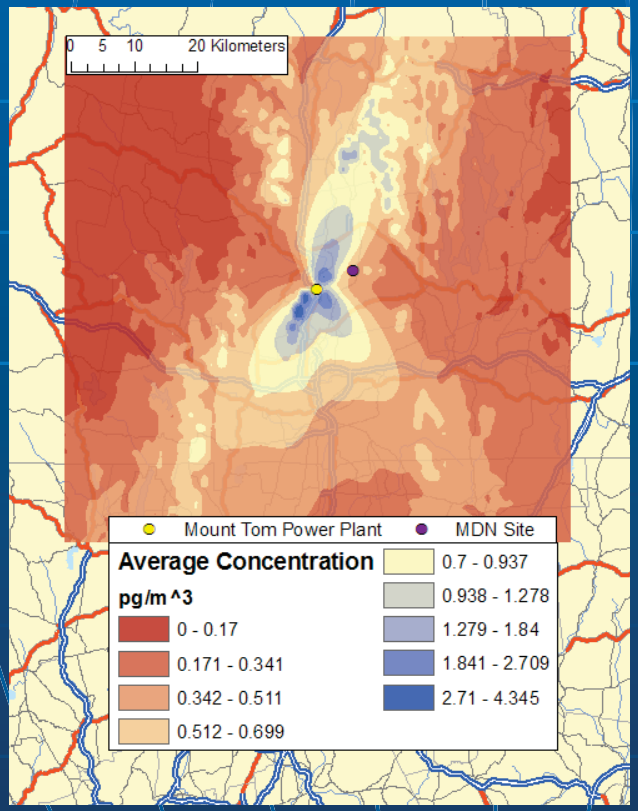
2005-2009	Total Deposition
Deposition at Receptors (µg)	262
Average Deposition/Receptor (µg/receptor)	0.0399
Total Deposition in Grid (g)	256
Percentage Deposited	2.43
	RGM Total Deposition
Deposition at Receptors (µg)	221
Average Deposition/Receptor (µg/receptor)	0.0337
Total Deposition in Grid (g)	216
Percentage Deposited	11.4
	PM Total Deposition
Deposition at Receptors (µg)	40.0
Average Deposition/Receptor (µg/receptor)	0.00609
Total Deposition in Grid (g)	39.0
Percentage Deposited	2.06
	Elem. Total Deposition
Deposition at Receptors (µg)	0.673
Average Deposition/Receptor (µg/receptor)	1.03E-04
Total Deposition in Grid (g)	0.657
Percentage Deposited	0.0346

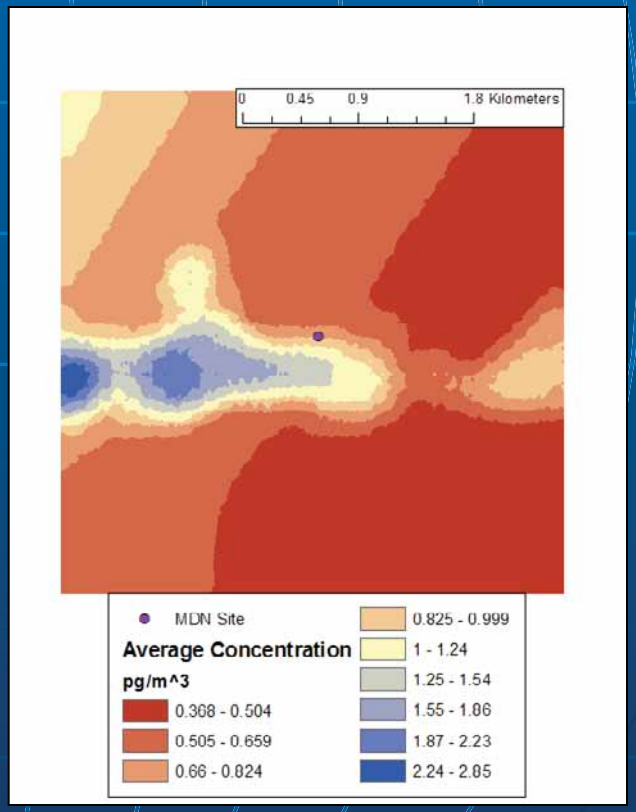
Putting it all Together

- What is Mount Tom Power Plant's Contribution to Local Mercury Levels?
  - Air

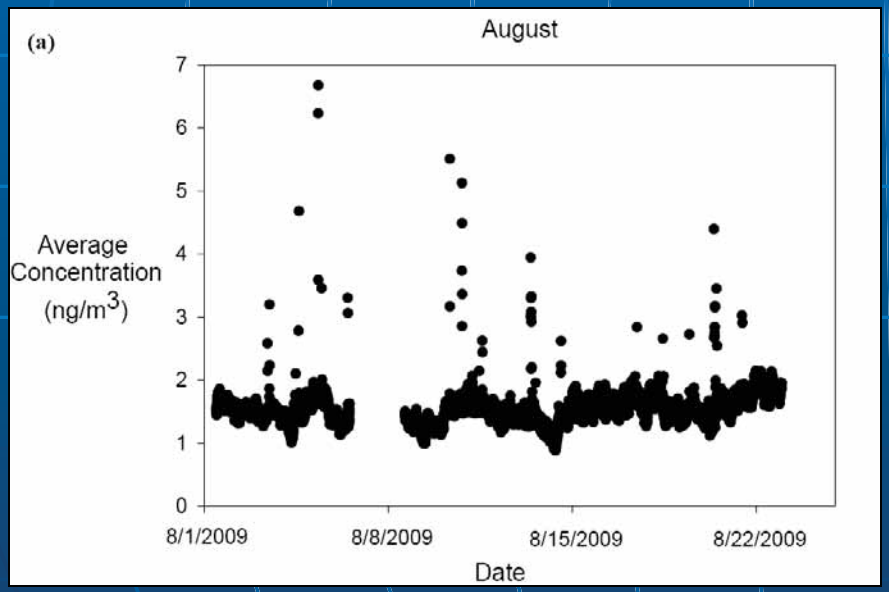
Ambient Readings at Bunker:

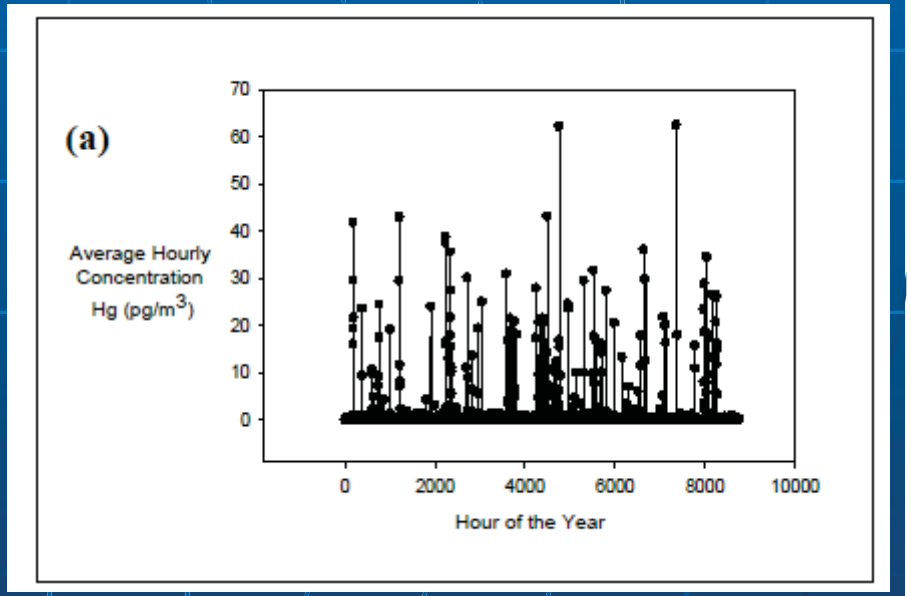
~1.5 ng/m3





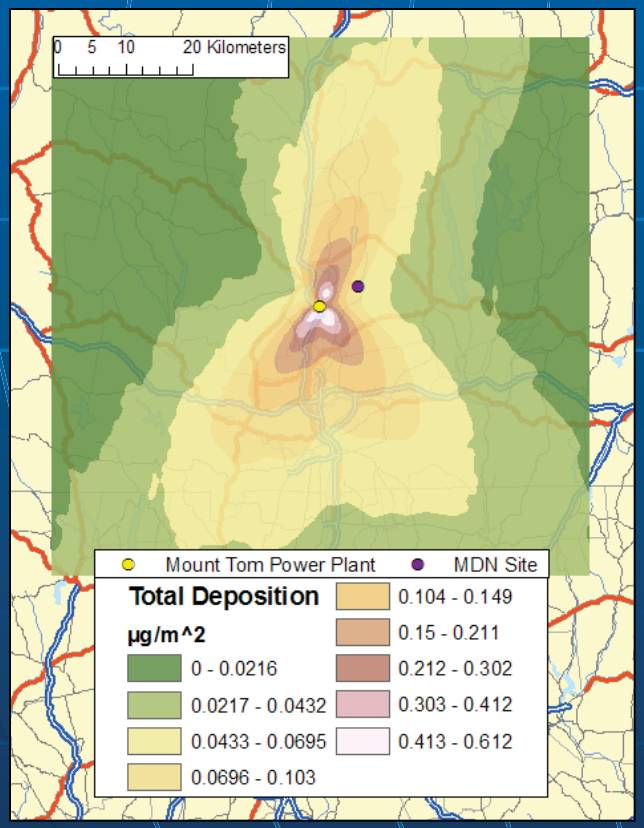
Putting it all Together



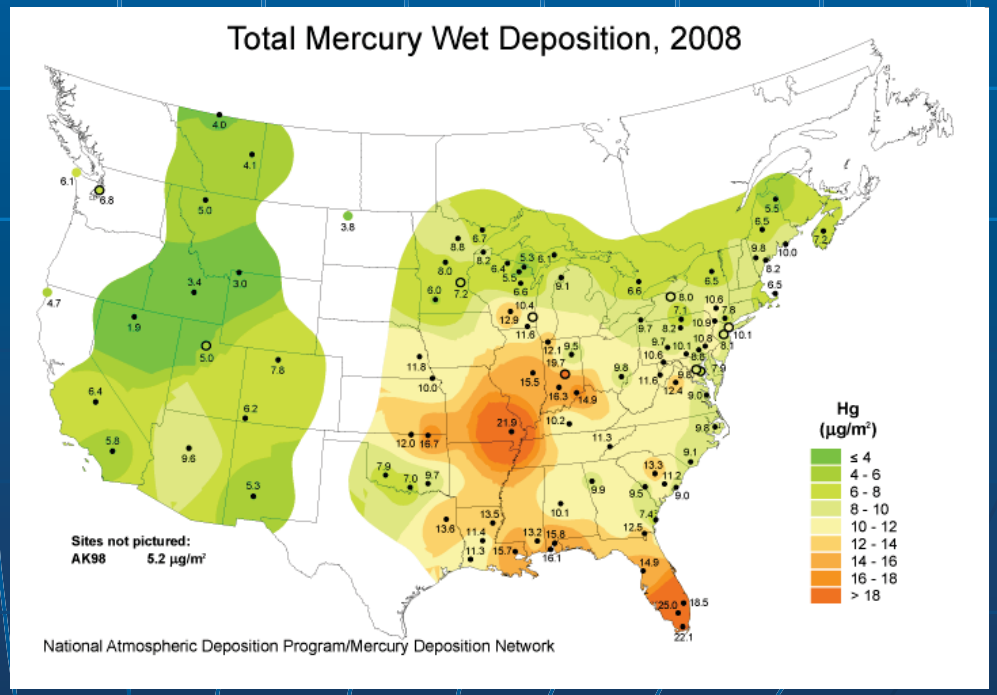


Putting it all Together

- What is Mount Tom Power Plant's Contribution to Local Mercury Levels?
  - Rain



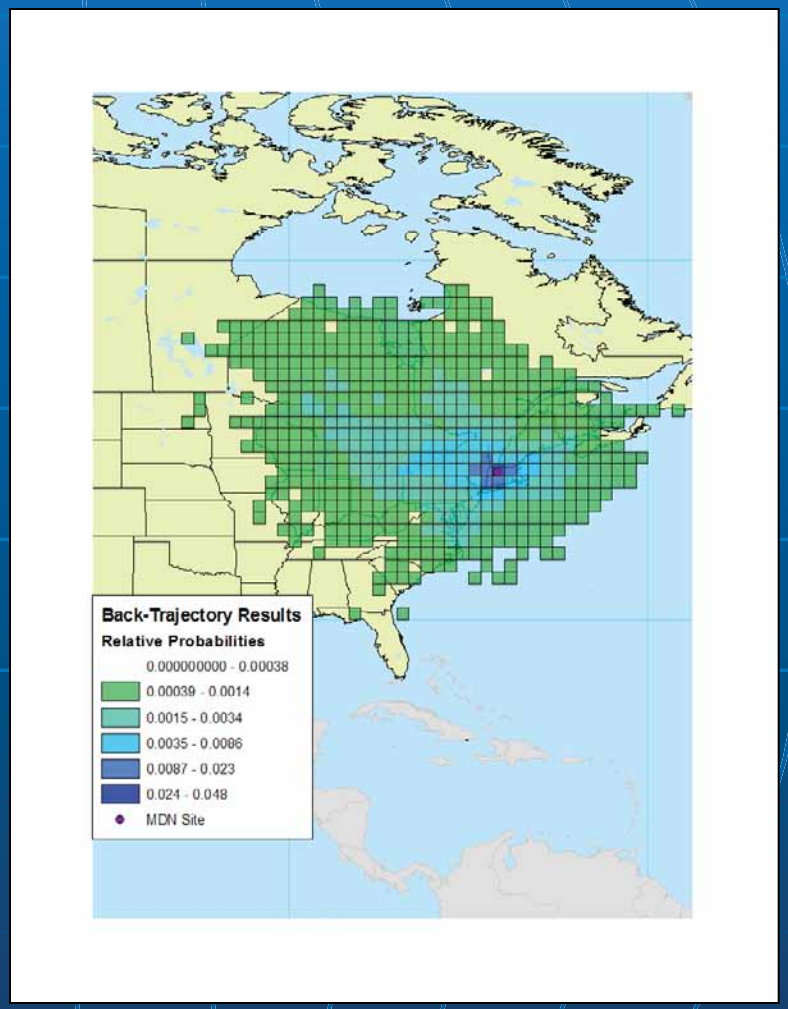
Extrapolated annual deposition at MDN Site: 4721. ng/m^2



Back-Trajectory Regional Modeling

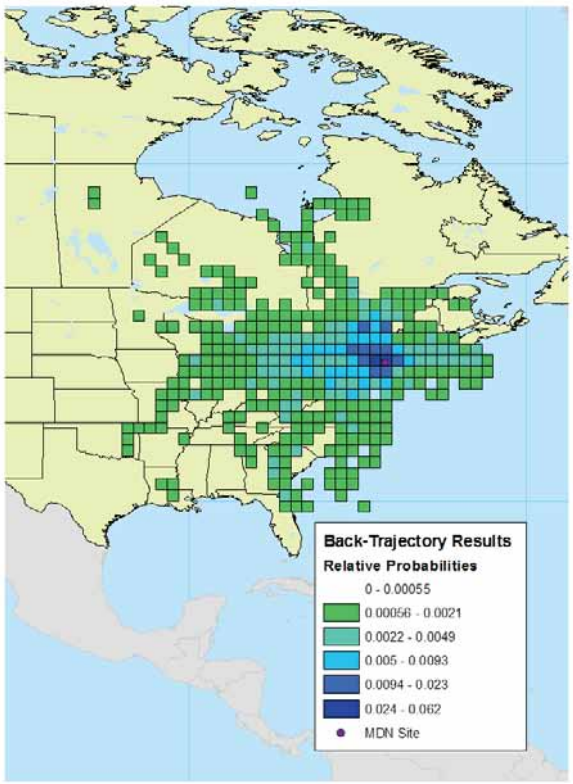
HYSPLIT4

Sample
Back-Trajectory

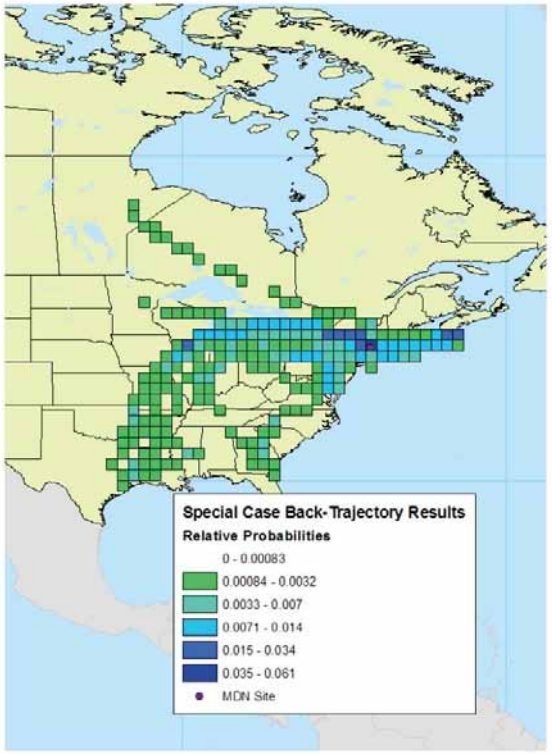


Residence Time
Probability Plot (2009)

Back-Trajectory Regional Modeling

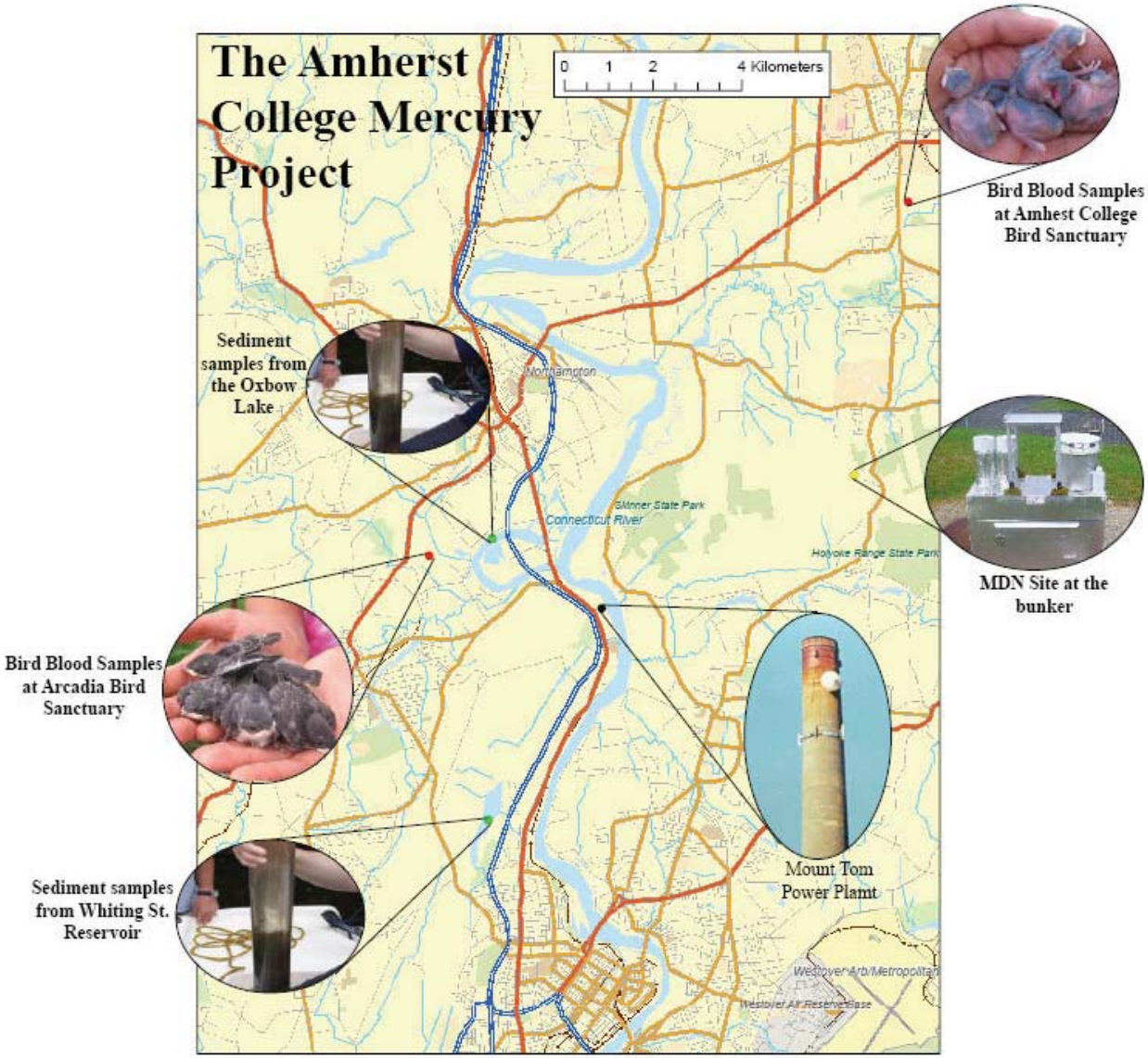


All of August



High Concentration Events

Interdisciplinary Work



Acknowledgements

Thanks to Professor McKinney, Andy Anderson, Chris Walker and Brian Merrigan for guiding me and/or entertaining me throughout this project.

Thanks to the Edward Hitchcock Fund for Student Research in Environmental Science for allowing me to work on the project this past summer.