

# **Mercury Deposition in Pennsylvania: A Status Report**

by

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## Chemical Forms of Mercury

- Gaseous elemental mercury vapor ( $\text{Hg}^0$ )
- Gaseous divalent mercury: mercurous ( $\text{Hg}_2^{2+}$ )  
mercuric ( $\text{Hg}^{2+}$ )
- Particulate bound mercury ( $\text{Hg}_p$ ) both  $\text{Hg}^0$  and  $\text{Hg}^{2+}$
- Organic mercury: mainly methylmercury ( $\text{MeHg}$ )

## **Gaseous elemental mercury ( $\text{Hg}^0$ ):**

- **Less chemically reactive than other forms**
- **A major component of global circulation of atmospheric mercury**

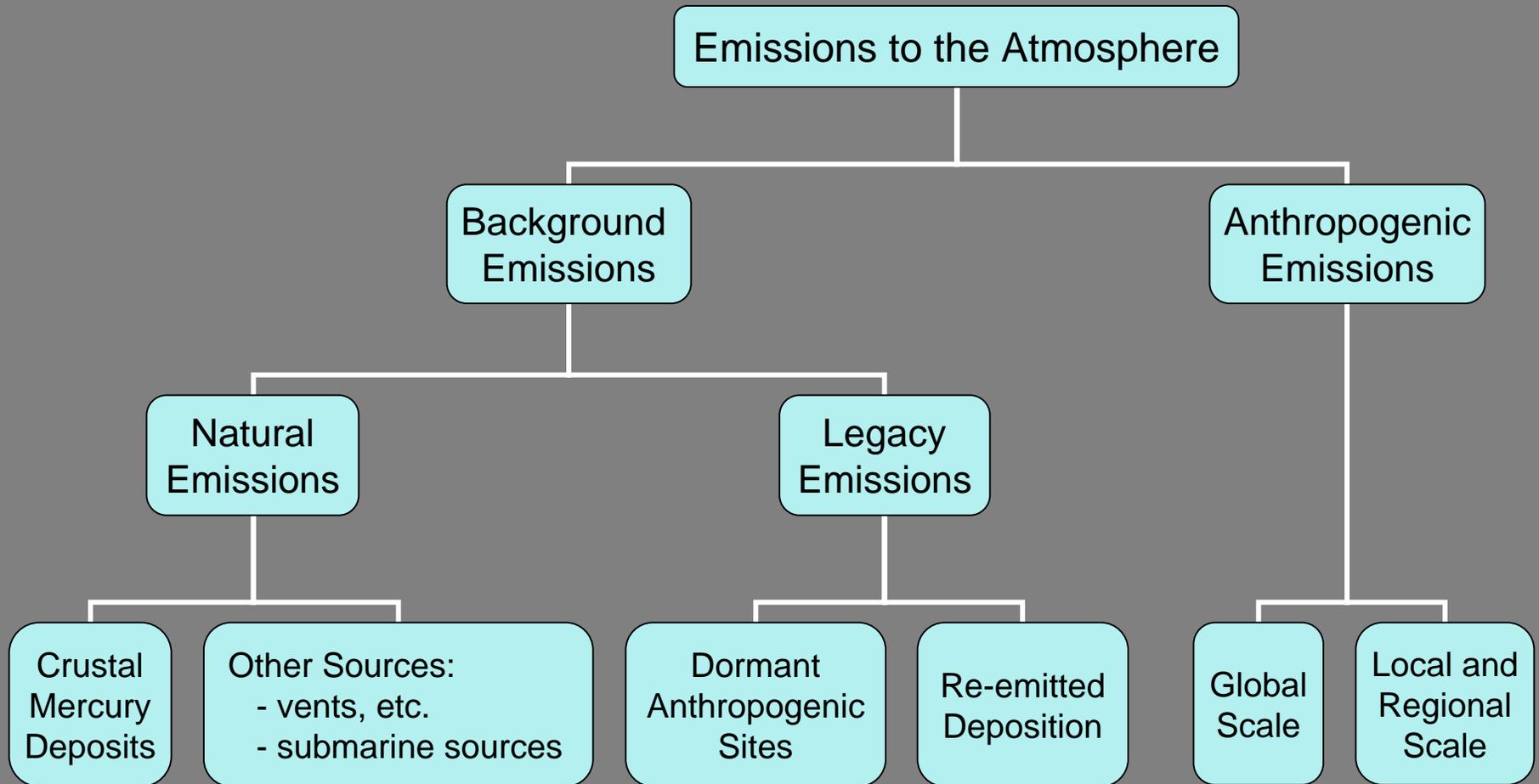
## **Gaseous divalent mercury ( $\text{Hg}_2^{2+}$ and $\text{Hg}^{2+}$ ):**

- **Also called reactive gaseous mercury**
- **Can form many organic and inorganic compounds**
- **$\text{Hg}^{2+}$  is highly soluble and is easily removed from atmosphere, usually within a few tens to a few hundreds of miles from the source.**

## **Methylmercury (MeHg):**

- **Most toxic of the organic mercury species.**
- **Some MeHg in precipitation, but most MeHg in our environment is generated by microbially-mediated transformation of  $\text{Hg}^{2+}$ .**
- **MeHg is a neurotoxin and a teratogen which bioaccumulates up the food chain by a factor of  $10^6$  or more in fish.**
- **MeHg is the major concern from a public health perspective.**

# Mercury Sources



## Summary of Recent Global Mercury Balances

Emissions (mg/yr)	Bergan et al. (1999)	Mason and Sheu (2002)	Lamborg et al. (2002)	Seigneur et al. (2003) (range)
New Anthropogenic	2160	2400	-	2143
Re-emitted Anthropogenic	2000	2090	4800	2134 (1067-2670)
Natural from Land	500	810	1000	1180 (878-1850)
Natural from Oceans	1400	1300	600	954 (720-1396)
Total [re-emitted %]	6060 [50]	6600 [47]	6400 [N.A.]	6411 [50 (33-56)]
Ratio of Current/Pre-industrial	3	3.1	4	3

Seigneur et al., 2004, Environ. Sci. Technol. 38, 555-569

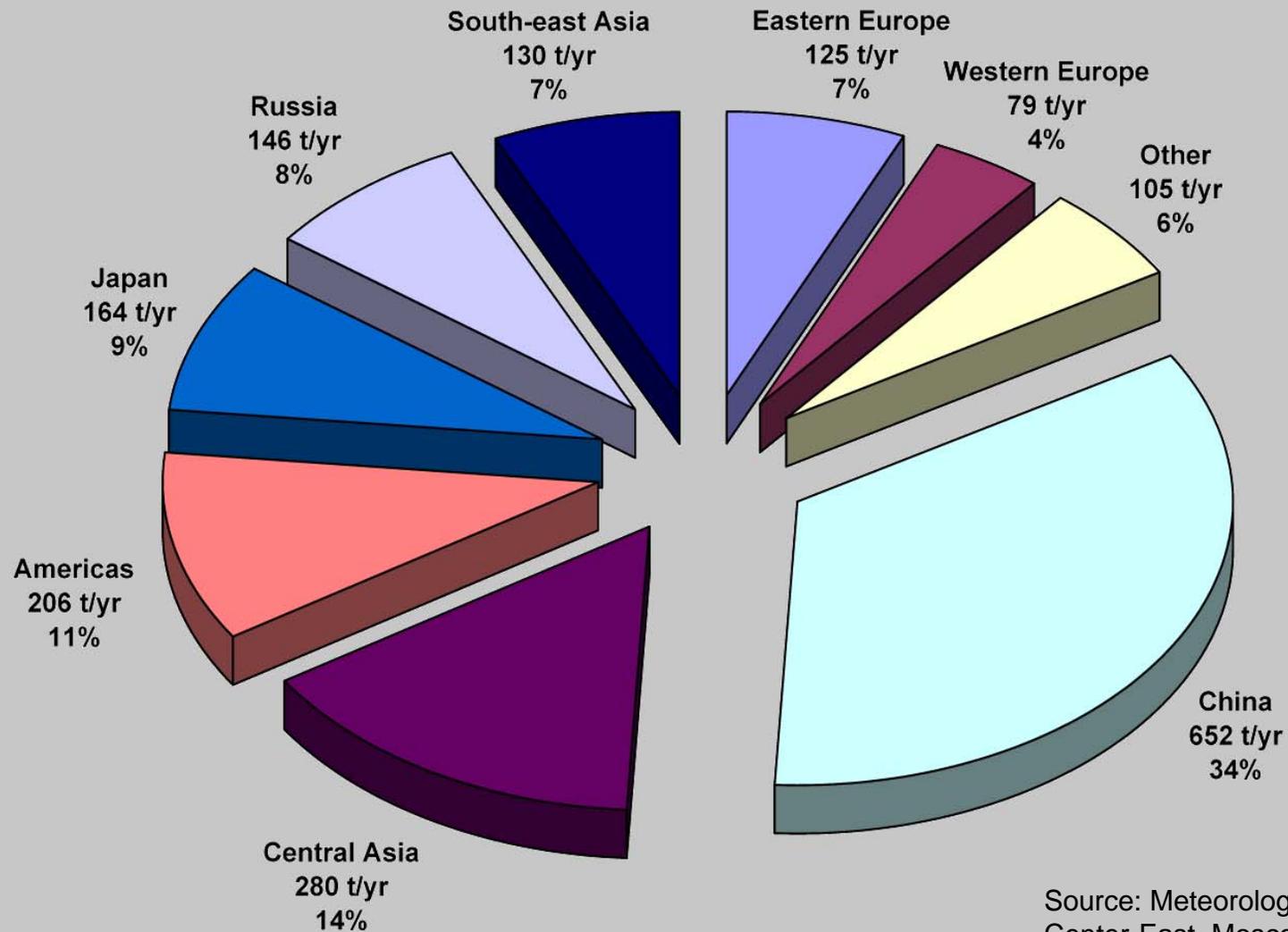
## 2004 North American Industrial Inventory (mg/yr)

Source Category	United States	Southern Canada	Northern Mexico	Total
Electric Utilities	41.5	1.3	9.9	52.7
Waste Incineration	28.8	3.4	(a)	32.2
Non-utility coal burning	12.8	(a)	(a)	12.8
Mining	6.4	0.3	(a)	6.7
Chlor-alkali facilities	6.7	0.05	(a)	6.8
Mobile sources	24.8	b	b	24.8
Other sources	30.9	9.6	23.6	64.1
<b>Total</b>	<b>151.9</b>	<b>14.7</b>	<b>33.5</b>	<b>200.1</b>
Hg(0) / Hg(II) / Hg(p) %	50 / 46 / 4	59 / 26 / 15	52 / 33 / 15	51 / 42 / 7

(a) Included in other sources

Seigneur et al., 2004, Environ. Sci. Technol. 38, 555-569

# Relative Anthropogenic Emissions of Mercury in the Northern Hemisphere



Source: Meteorological Synthesizing Center-East, Moscow

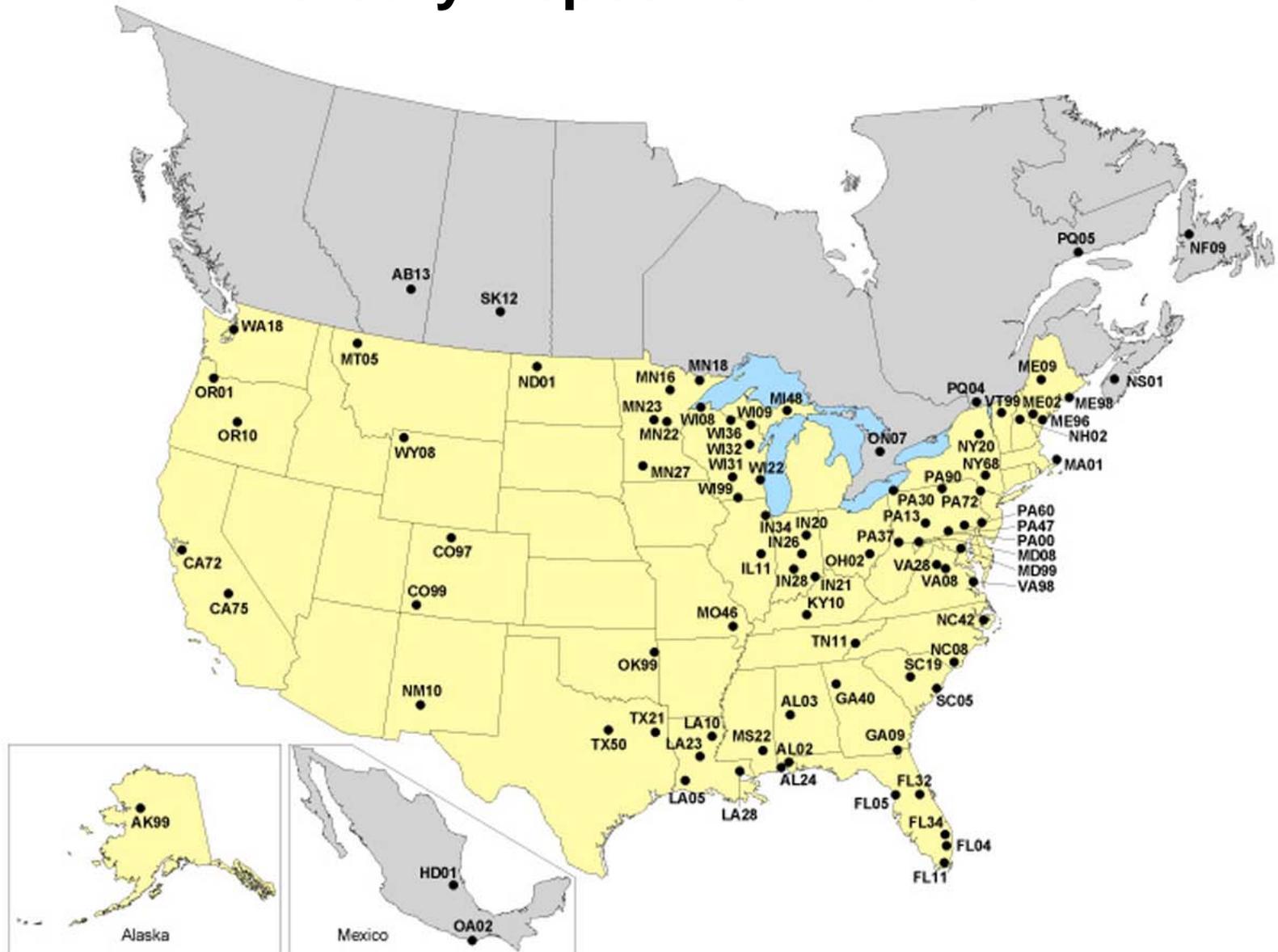
## **What we don't know**

- **Significant uncertainty in flux estimates.**
- **Role of soils and vegetation.**
- **Are we missing important sinks?**
- **Is mercury constantly recycled between terrestrial ecosystems and the atmosphere?  
This could cause the residence time of Hg to appear long when it is actually short.**

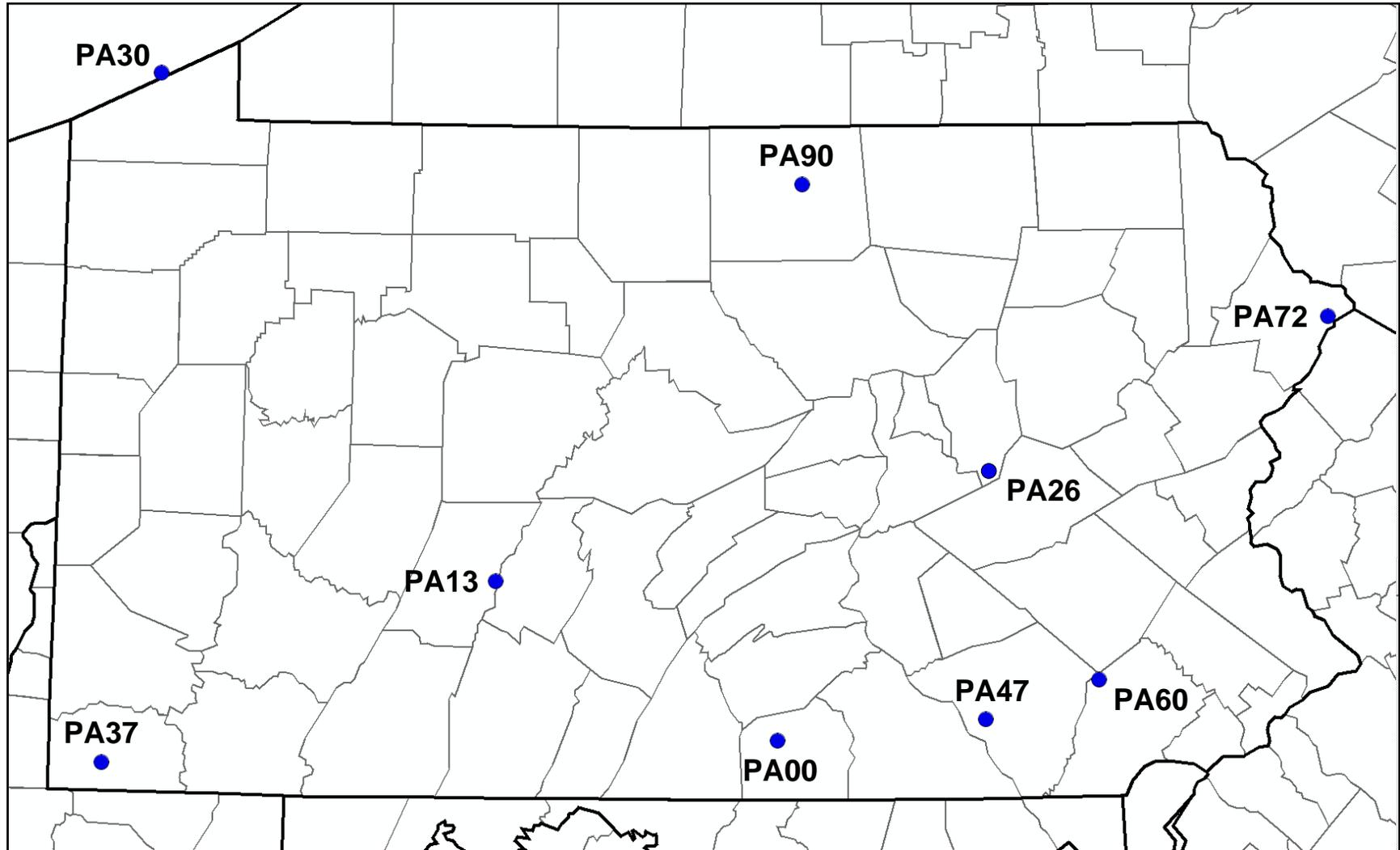
# **National Atmospheric Deposition Program Mercury Deposition Network**

- **Began 1995**
- **Measures total mercury concentration in precipitation during weekly sampling intervals**
- **Designed to quantify spatial and temporal patterns in mercury deposition across USA.**
- **All sites use the same sampling protocol.**
- **All samples are analyzed at Frontier Geosciences in Seattle, WA.**

# National Atmospheric Deposition Program Mercury Deposition Network



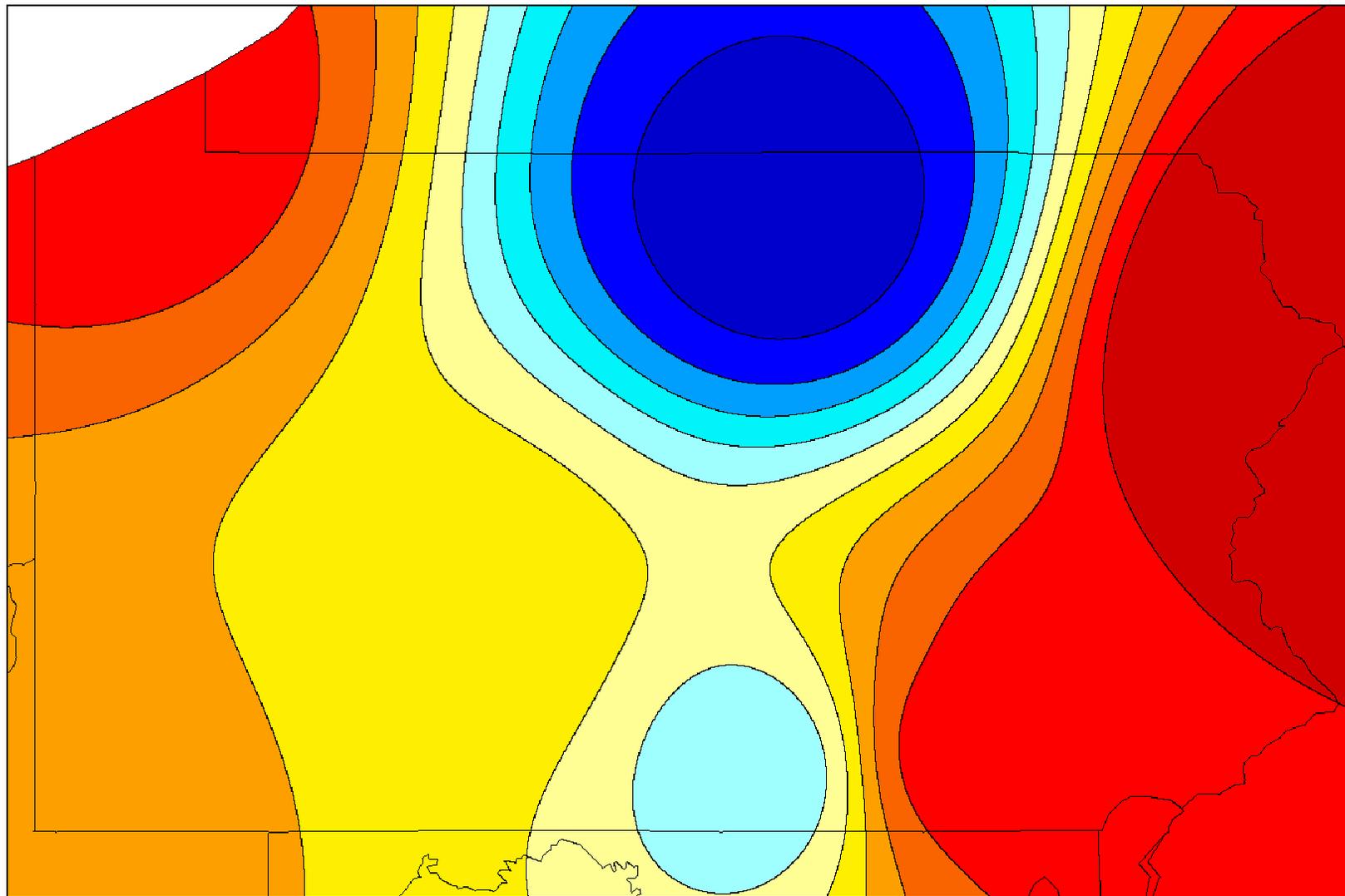
# Mercury Deposition Monitoring Sites in Pennsylvania



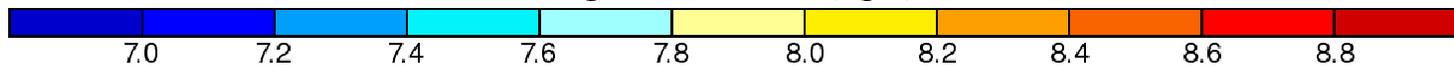
**Mercury  
Deposition  
Network  
precipitation  
sampling  
equipment**



# Annual Volume-Weighted Mean Mercury Concentration: 2004

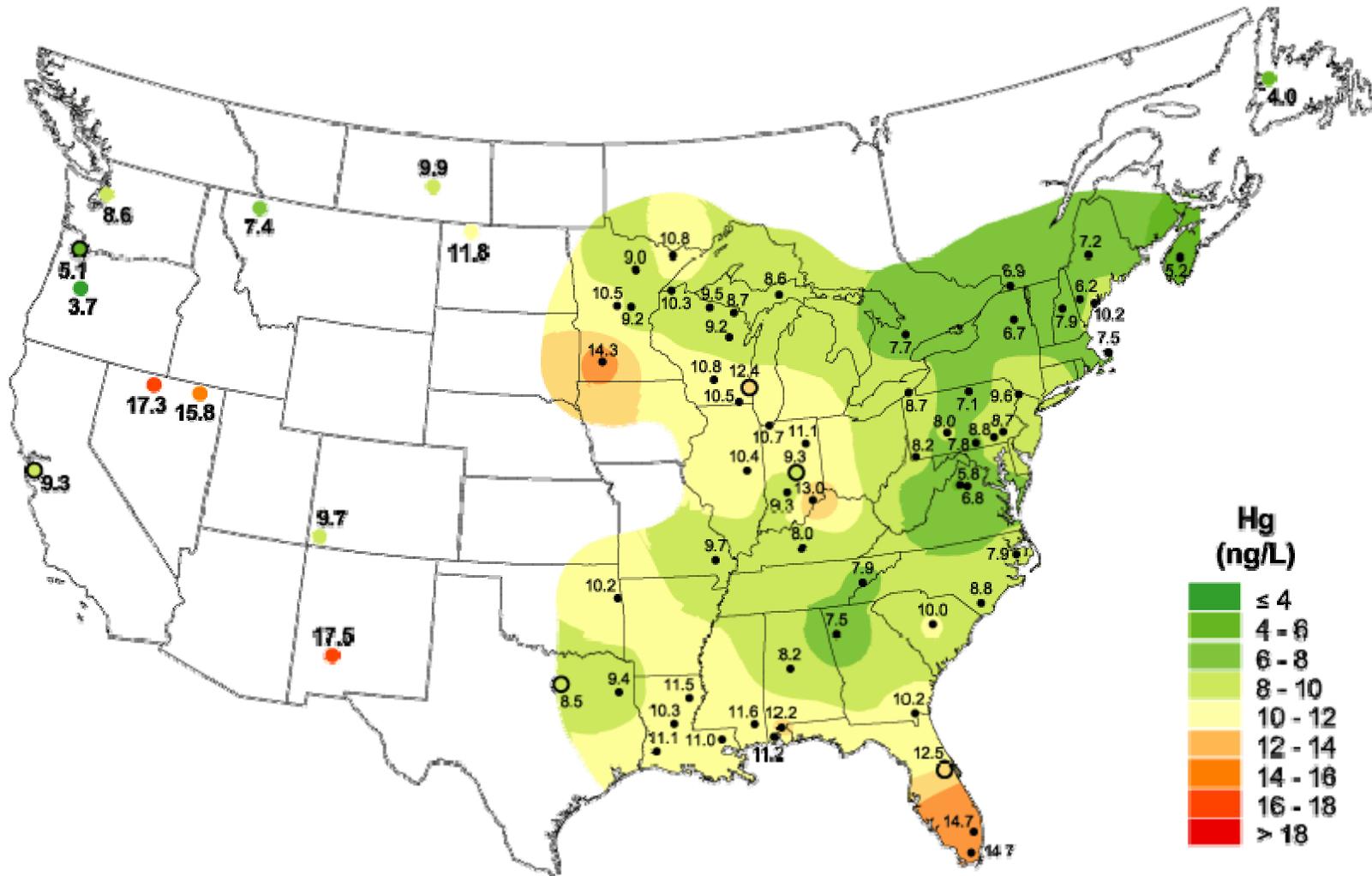


Hg Concentration (ug/L)



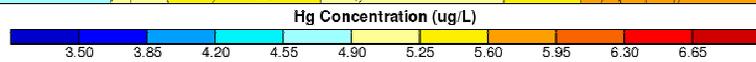
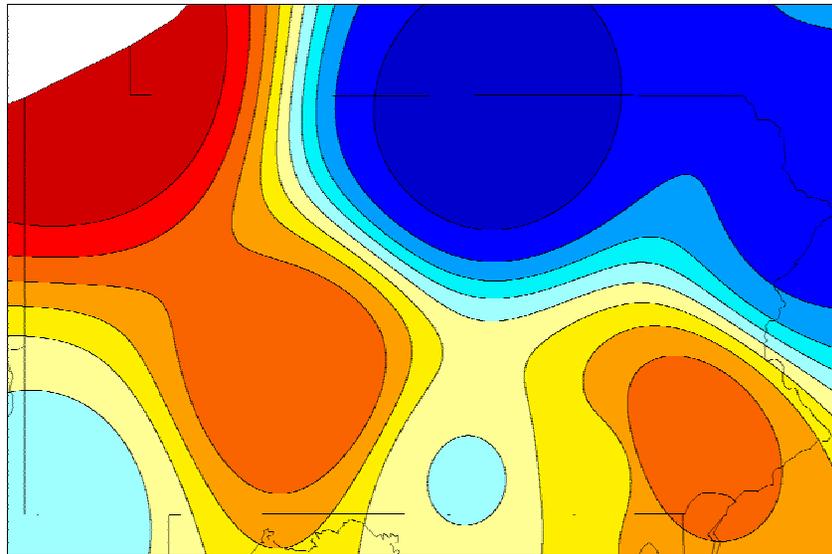
# Annual Volume-Weighted Mean Mercury Concentration: 2004

## National Atmospheric Deposition Program / Mercury Deposition Network

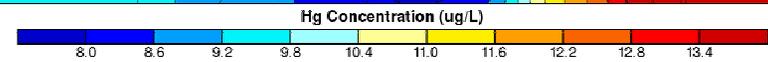
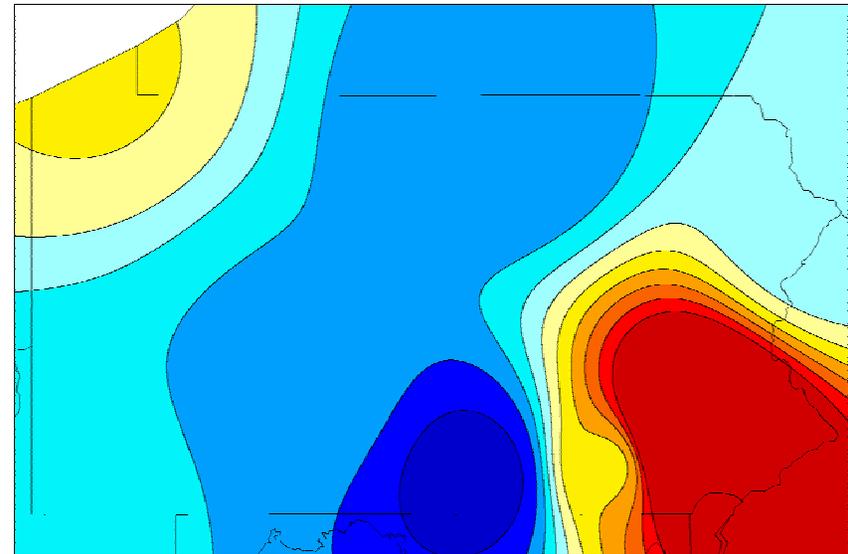


# Quarterly Volume-Weighted Mean Mercury Concentration: 2004

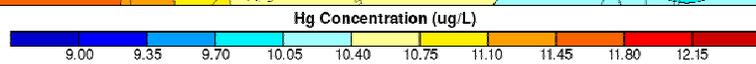
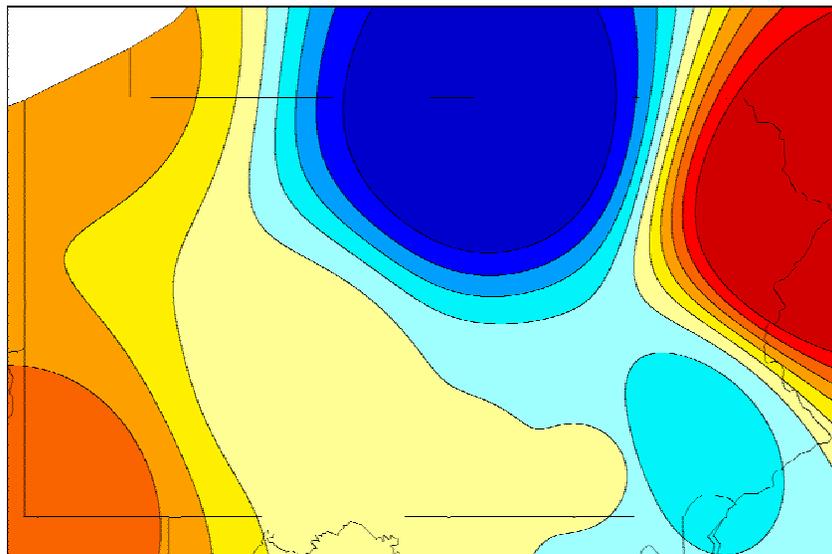
Winter



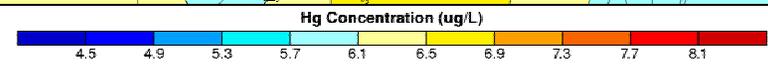
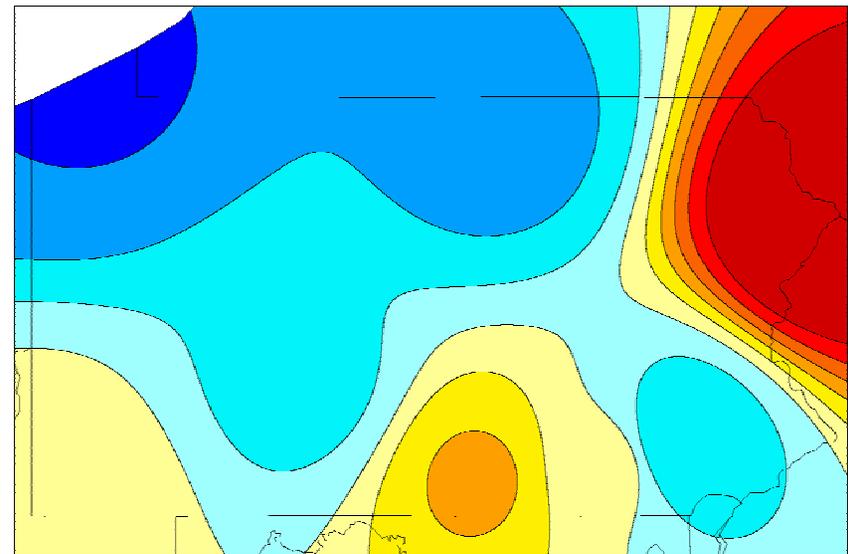
Spring



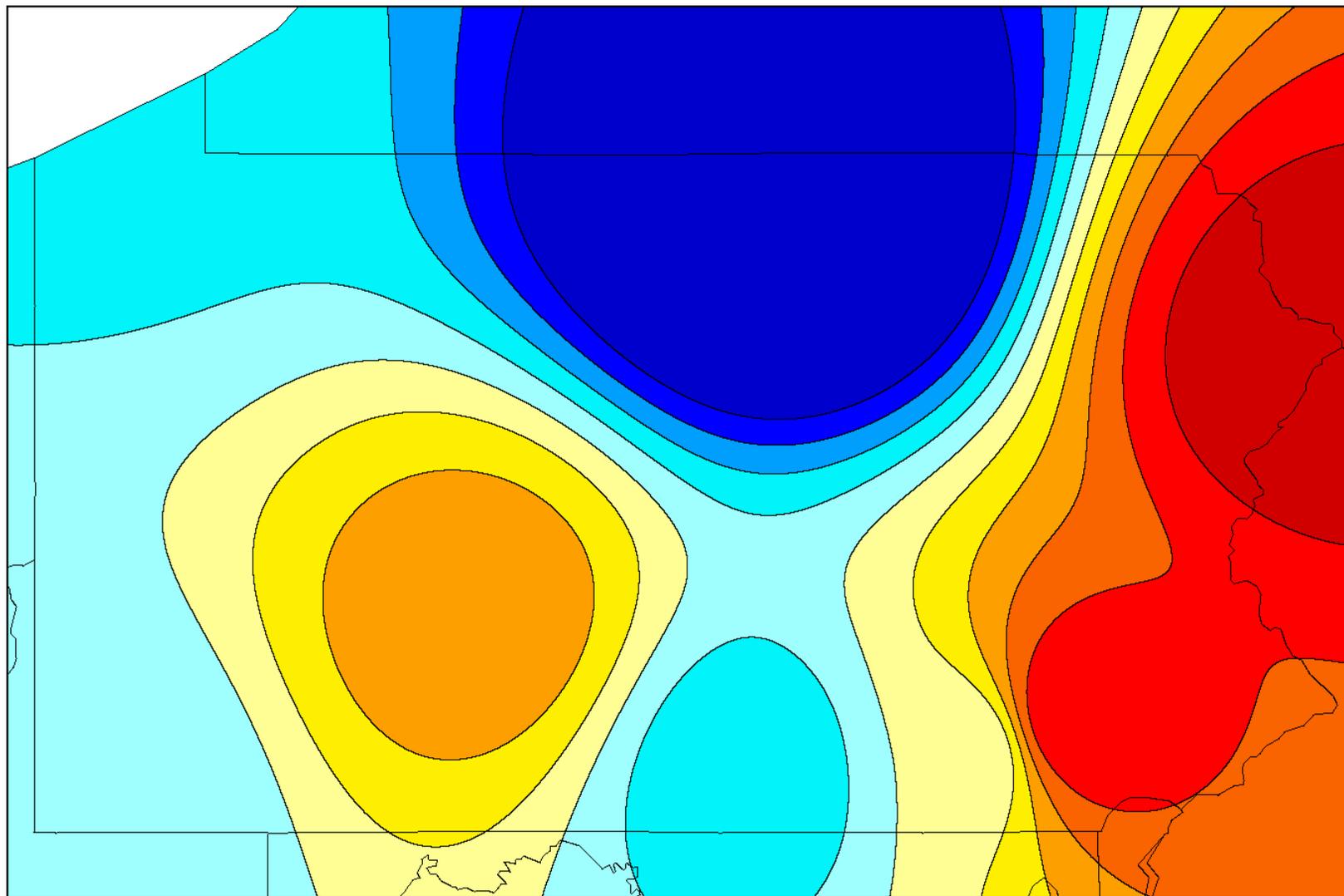
Summer



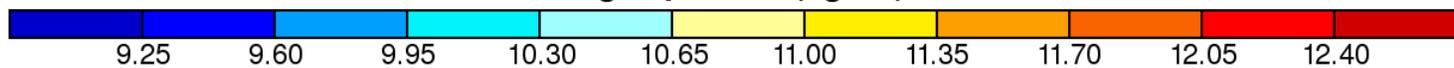
Fall



## Annual Mercury Wet Deposition: 2004



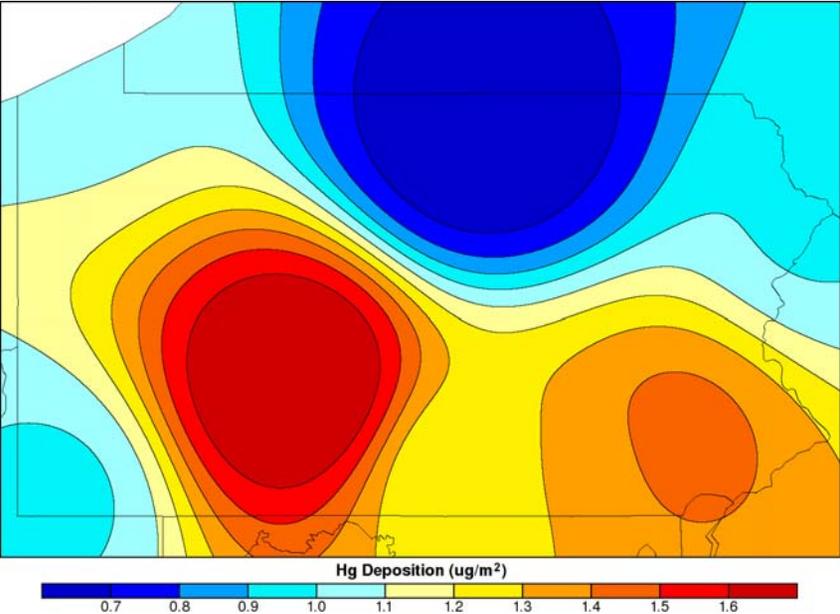
Hg Deposition ( $\mu\text{g}/\text{m}^2$ )



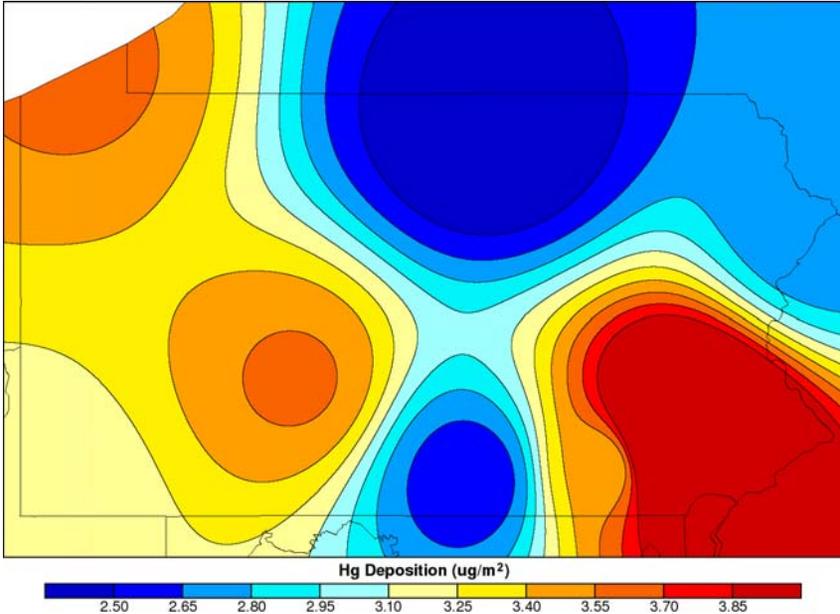


# Quarterly Mercury Wet Deposition: 2004

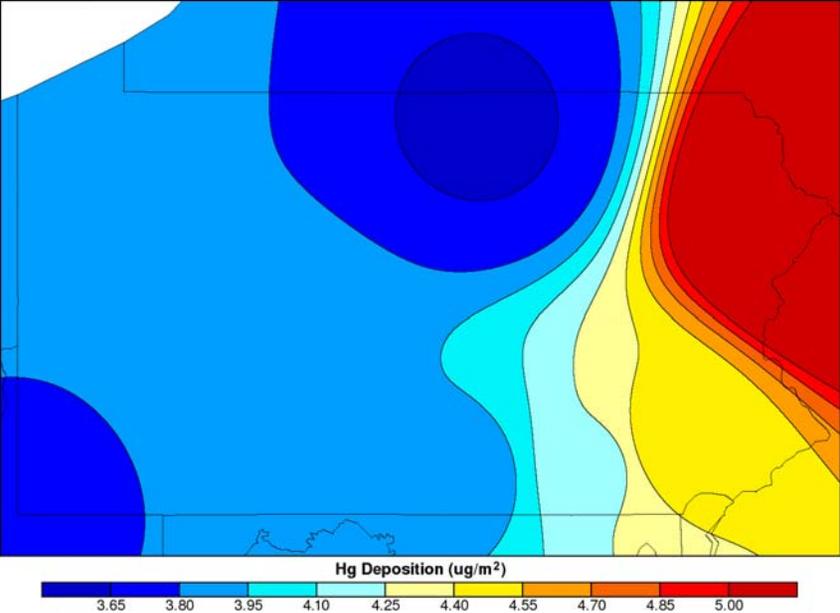
Winter



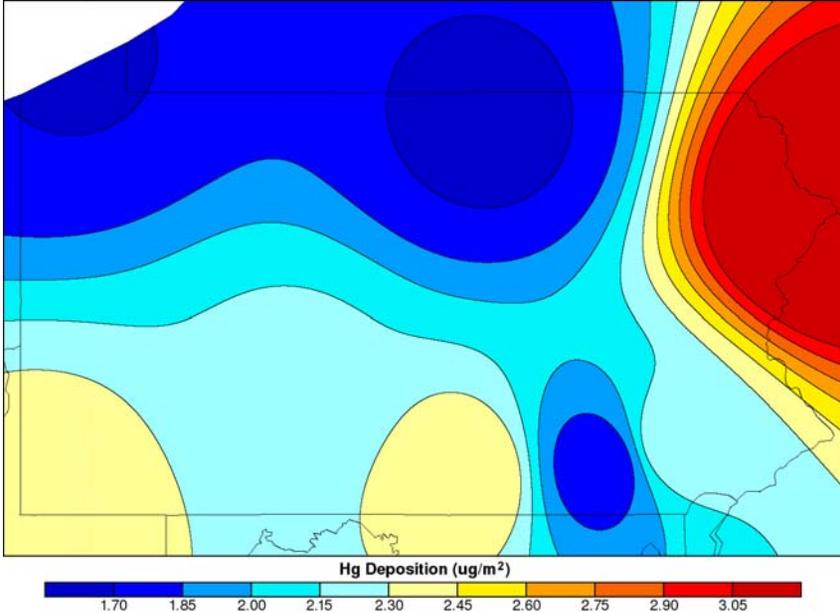
Spring



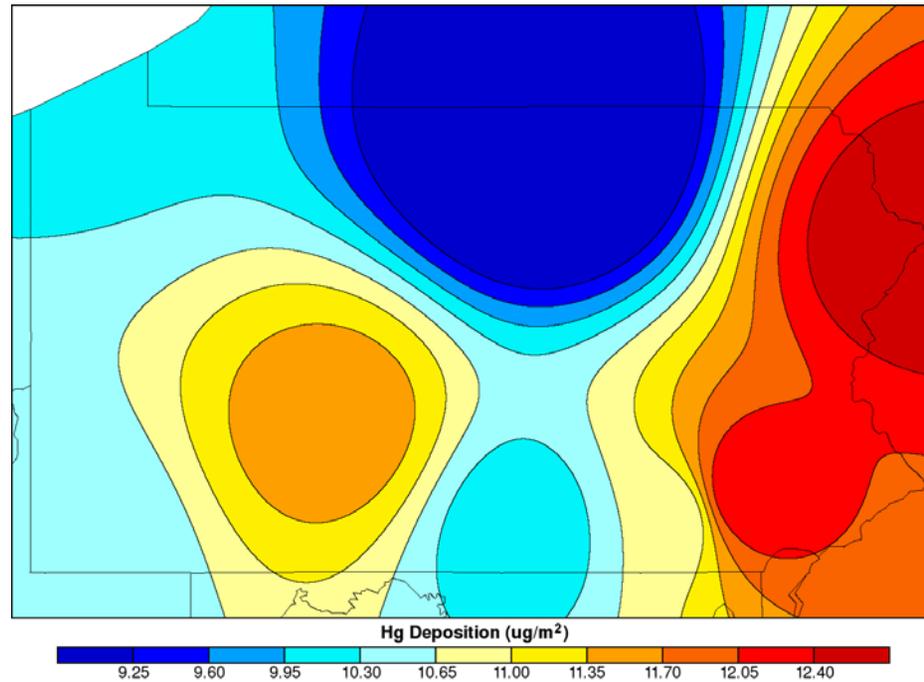
Summer



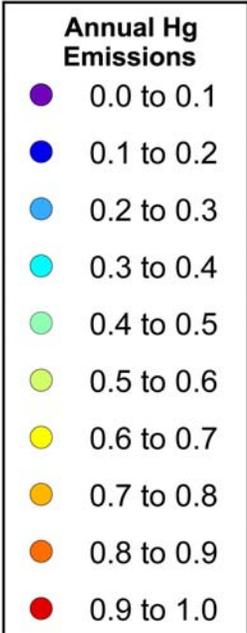
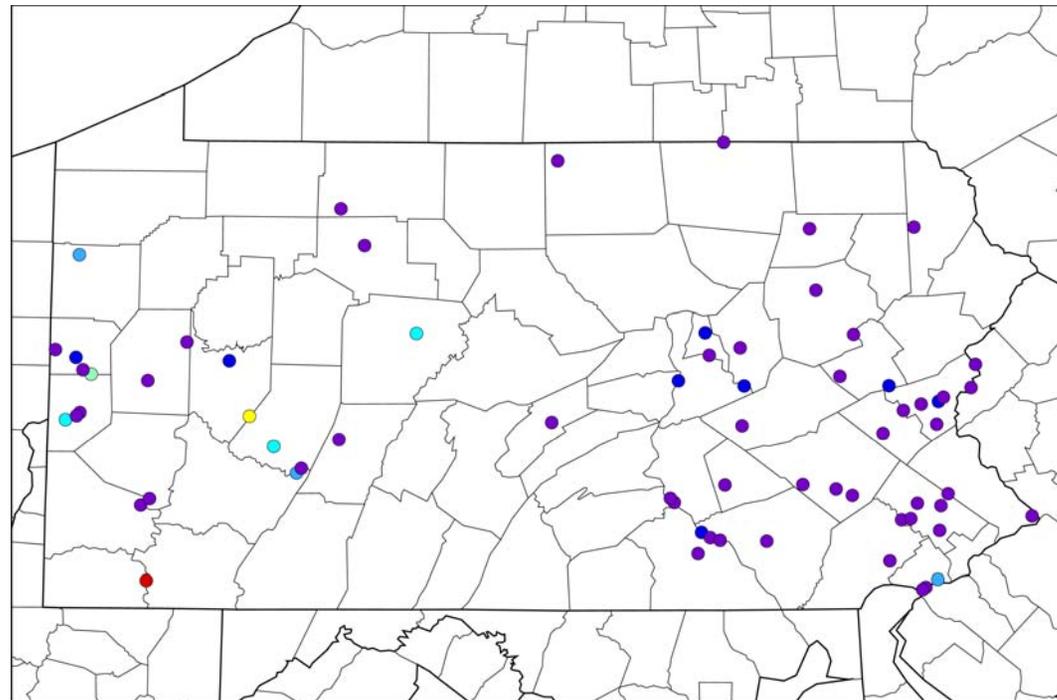
Fall



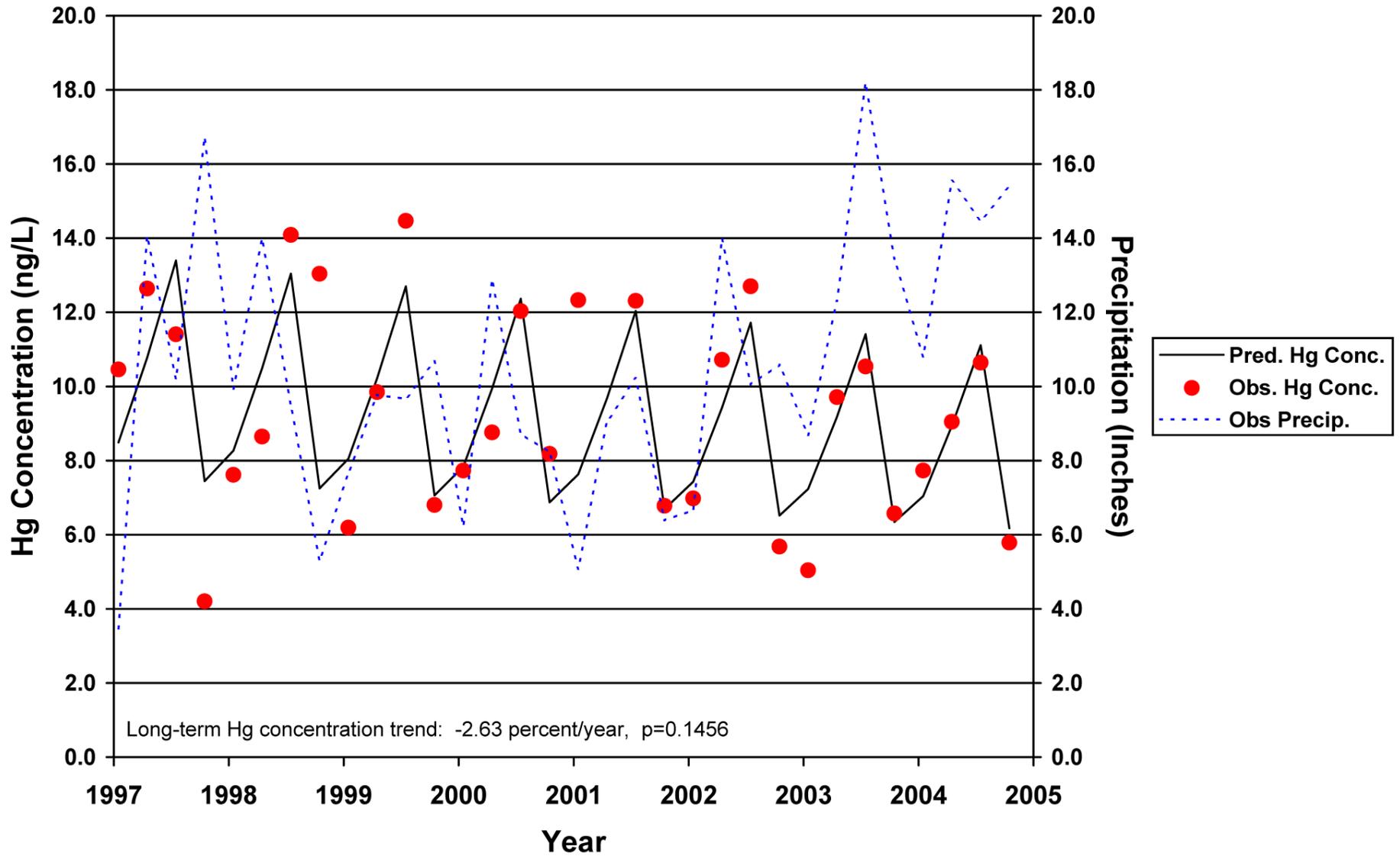
# Annual Mercury Wet Deposition: 2004



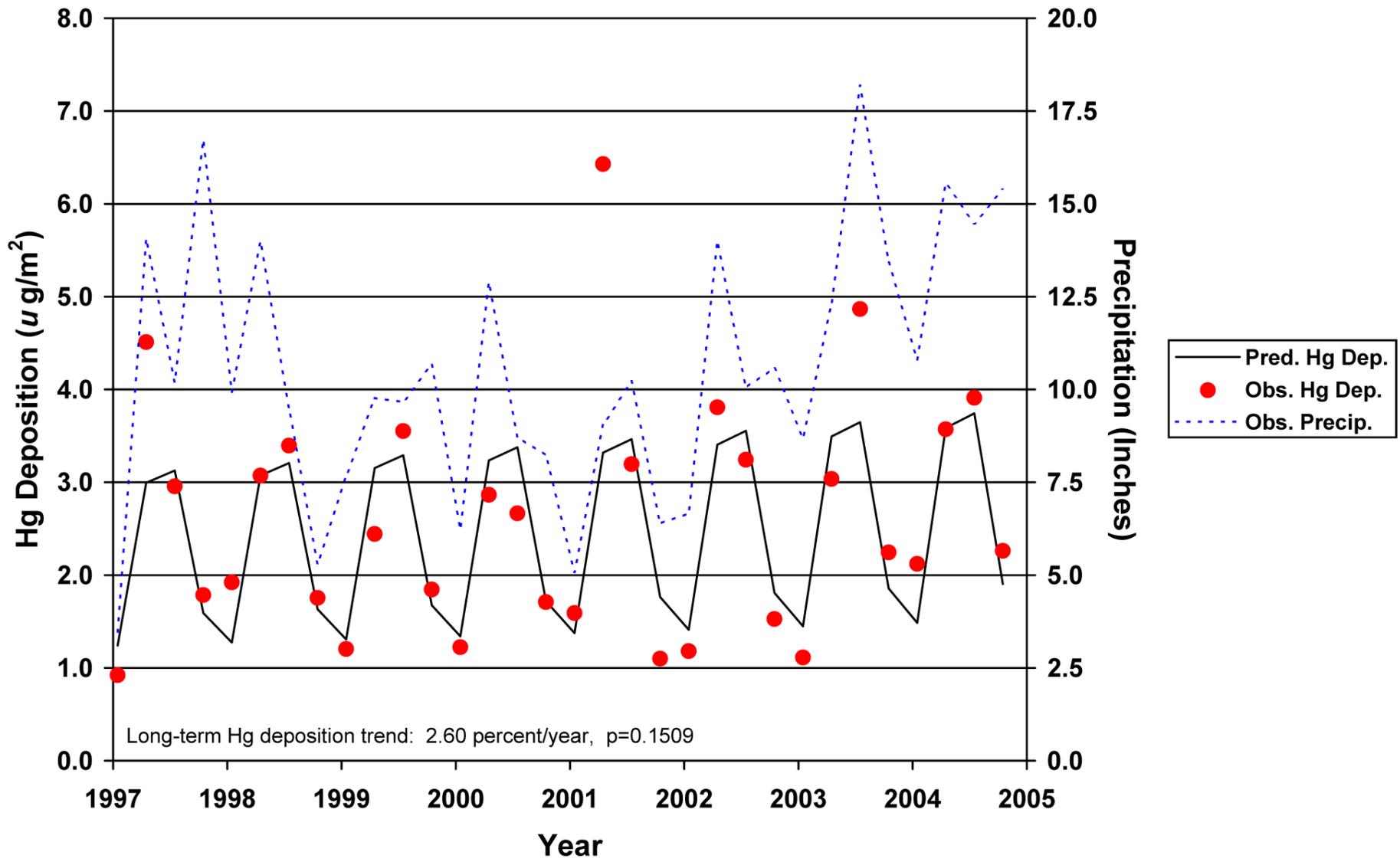
# Annual Mercury Emissions at Major Point Sources during 2004



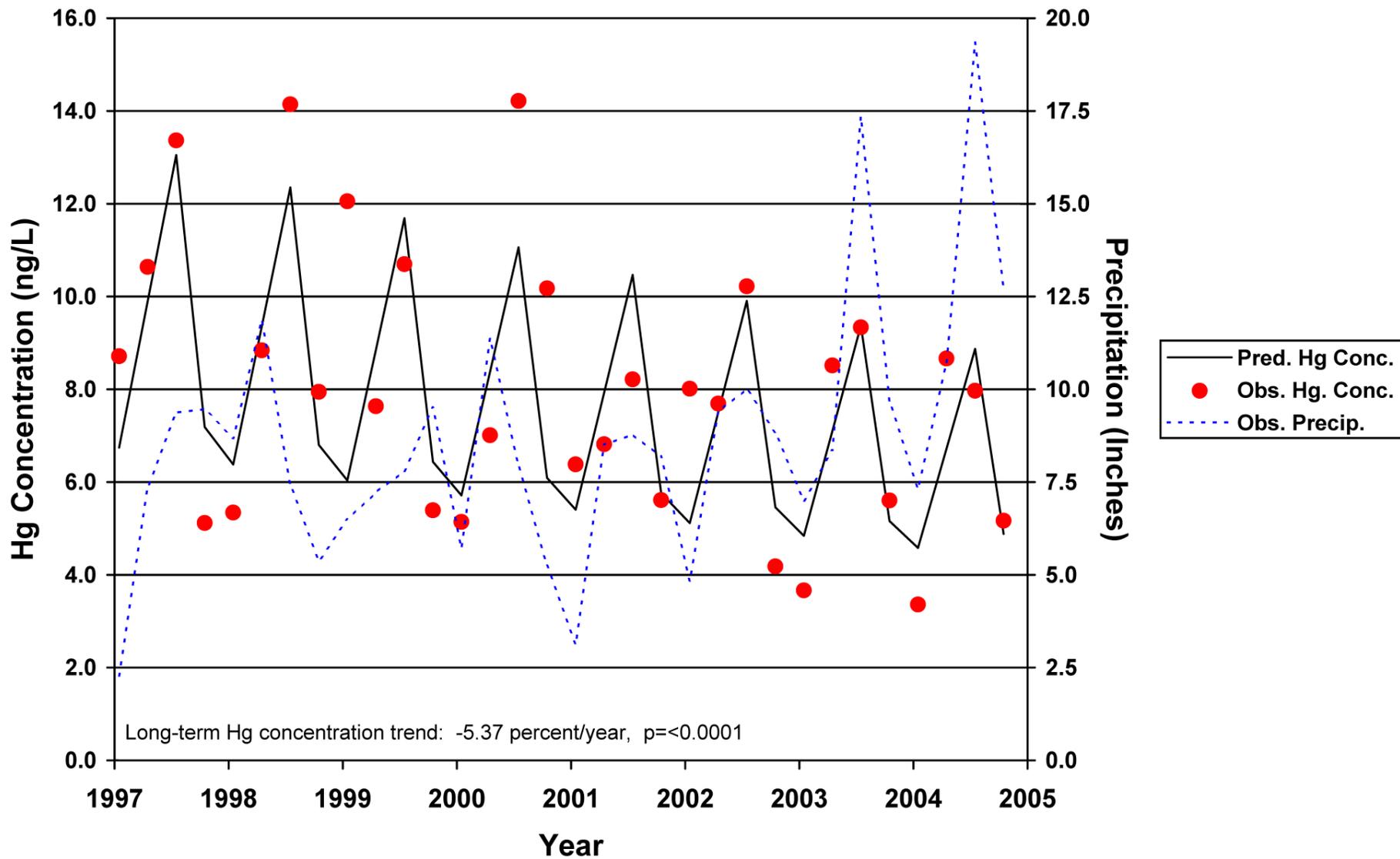
# Seasonal Hg Concentration and Precipitation at Allegheny Portage



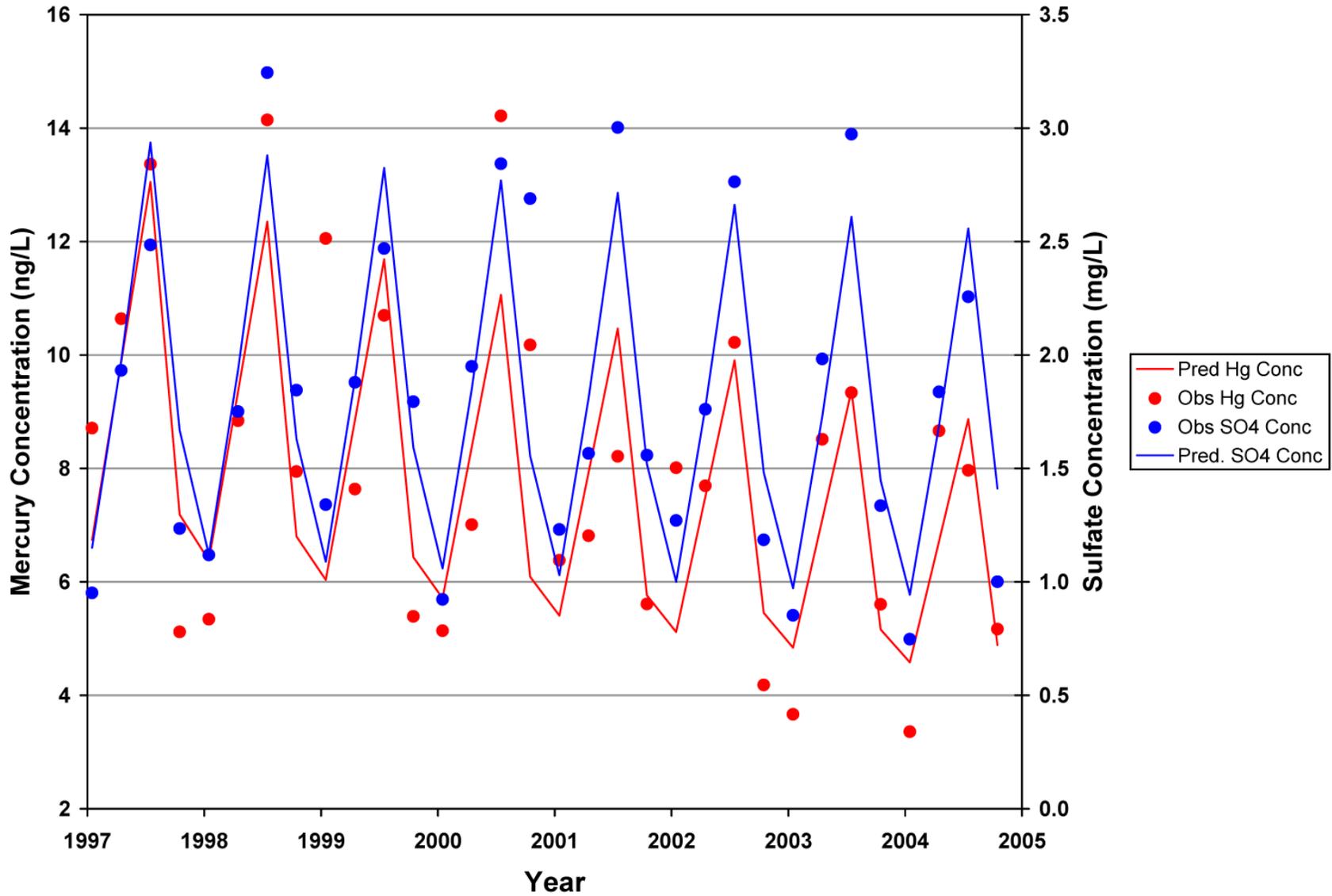
### Seasonal Hg Wet Deposition and Precipitation at Allegheny Portage



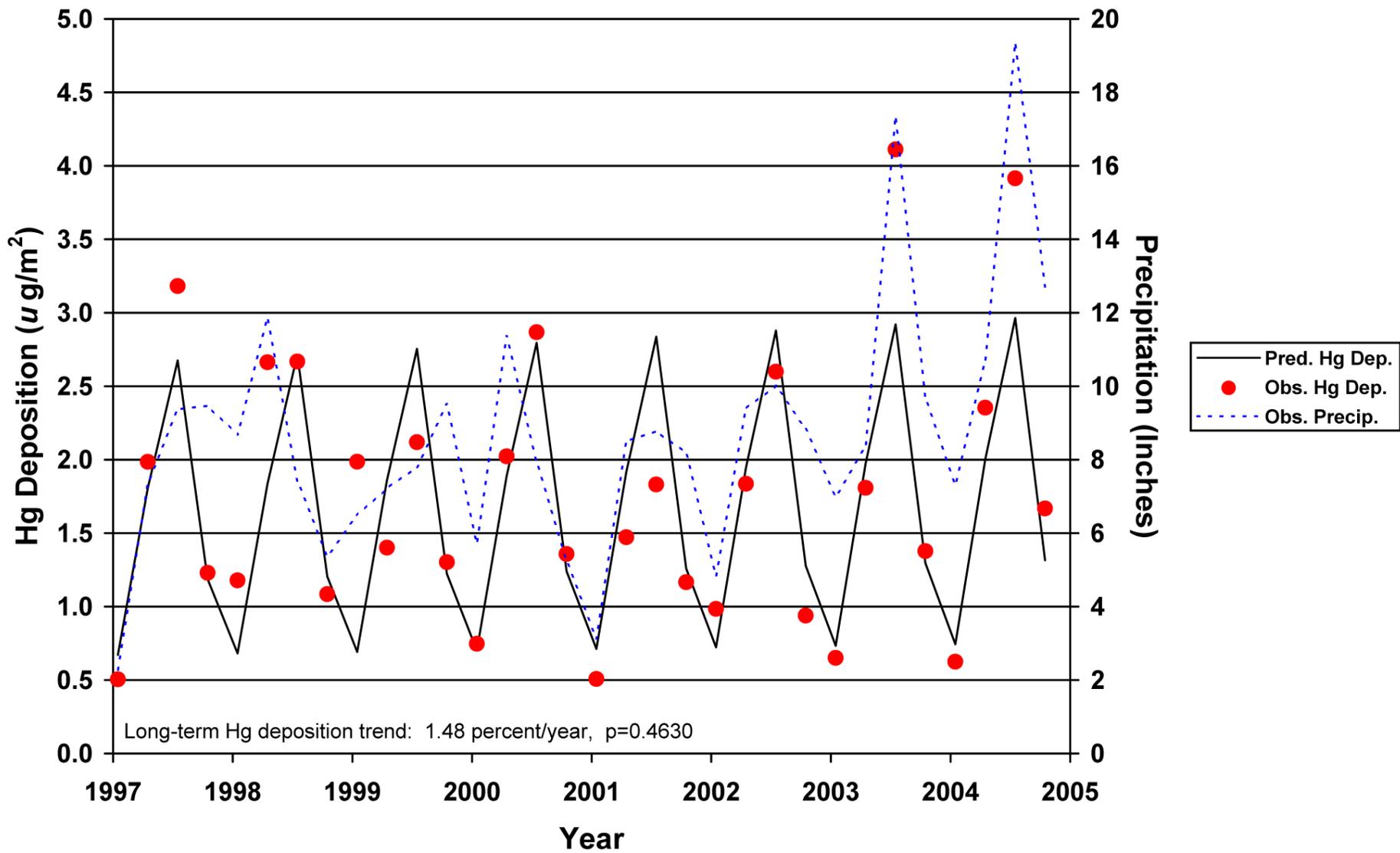
# Seasonal Hg Concentration and Precipitation at Hills Creek State Park



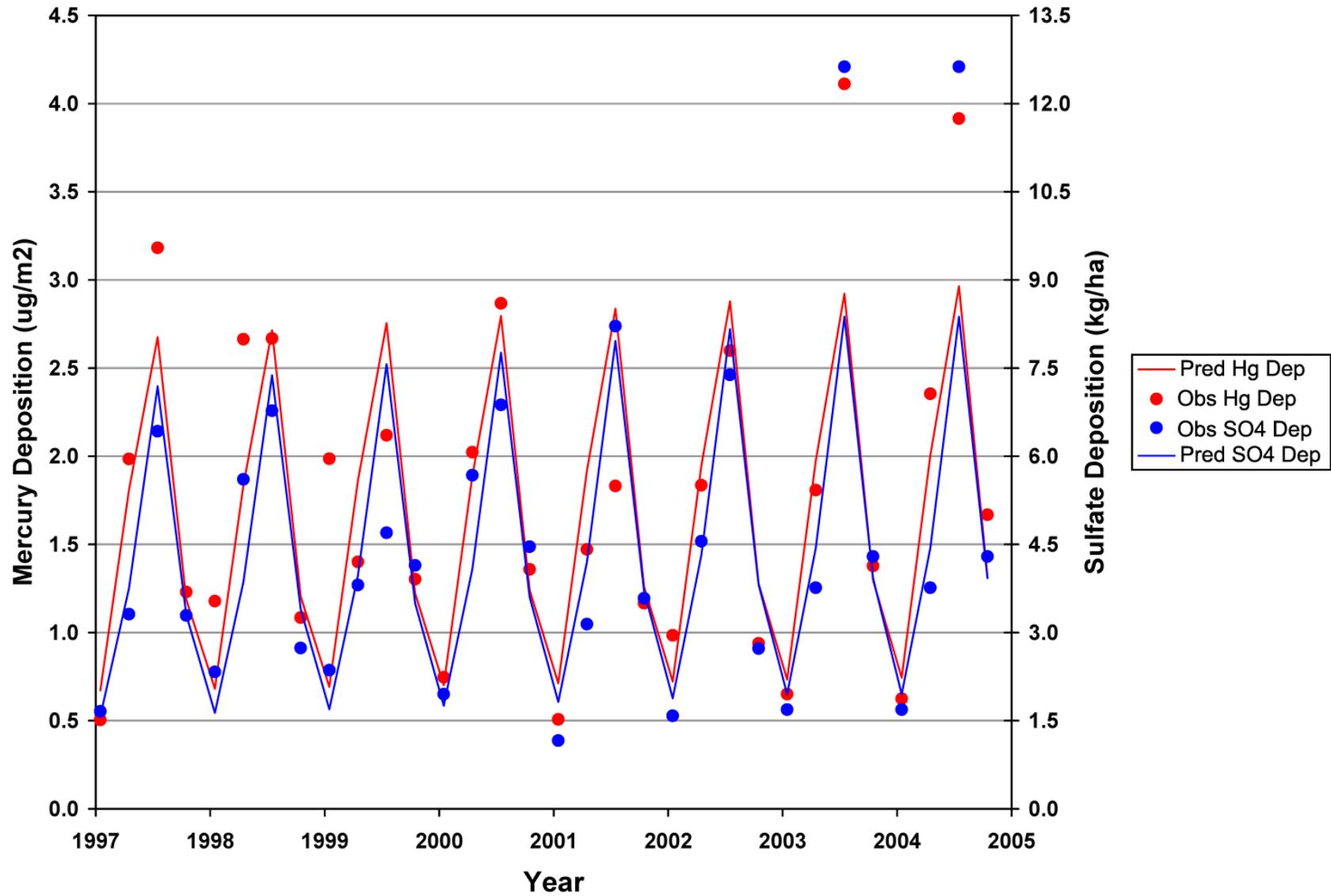
# Trends in Mercury and Sulfate Concentration at Hills Creek State Park



# Seasonal Hg Wet Deposition and Precipitation at Hills Creek State Park



# Trends in Mercury and Sulfate Wet Deposition at Hills Creek State Park

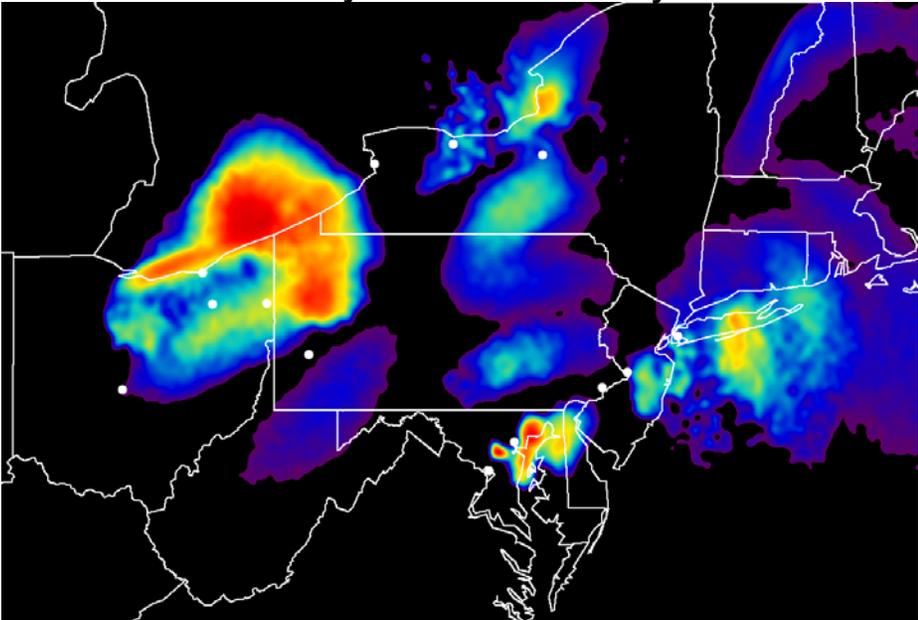


## **What we need to know:**

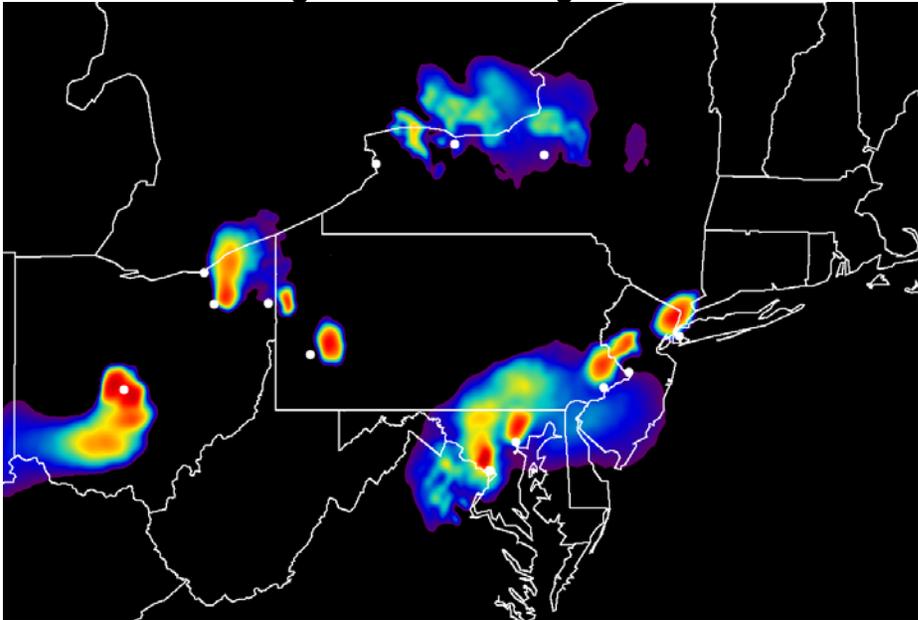
- **Source/receptor relationships and patterns of emissions dispersal from point sources located within Pennsylvania and in surrounding states**
  - **What sources contribute the most to mercury deposition in Pennsylvania?**
  - **What areas are most impacted by emissions from Pennsylvania's local and regional sources?**
  - **Where would emission reduction be most beneficial to Pennsylvania?**
  - **What are the "typical" mercury deposition patterns? Is there really a typical deposition pattern?**

**Atmospheric Dispersal and Deposition of a Hypothetical Particulate Substance Originating from Selected Urban Areas**

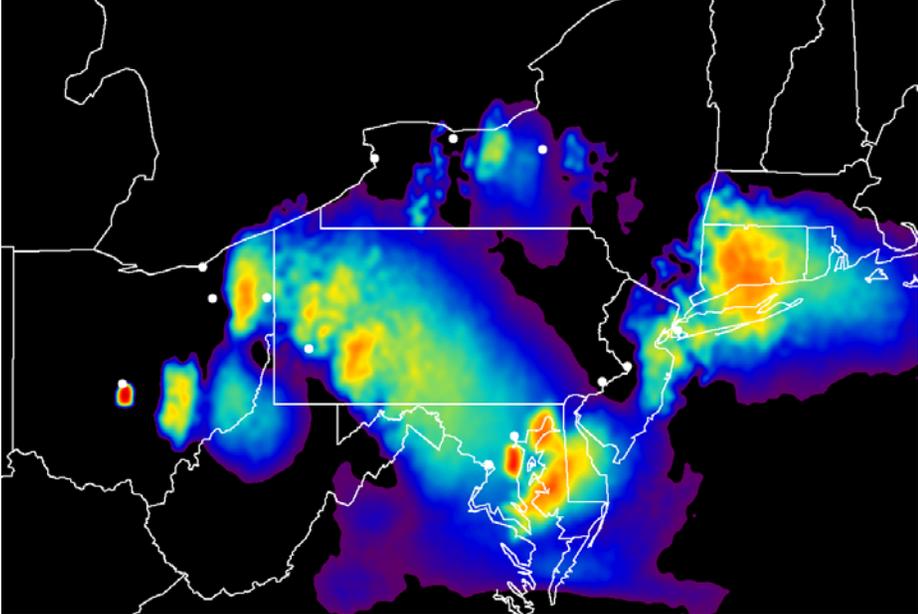
**15 February 2005 → 18 February 2005**



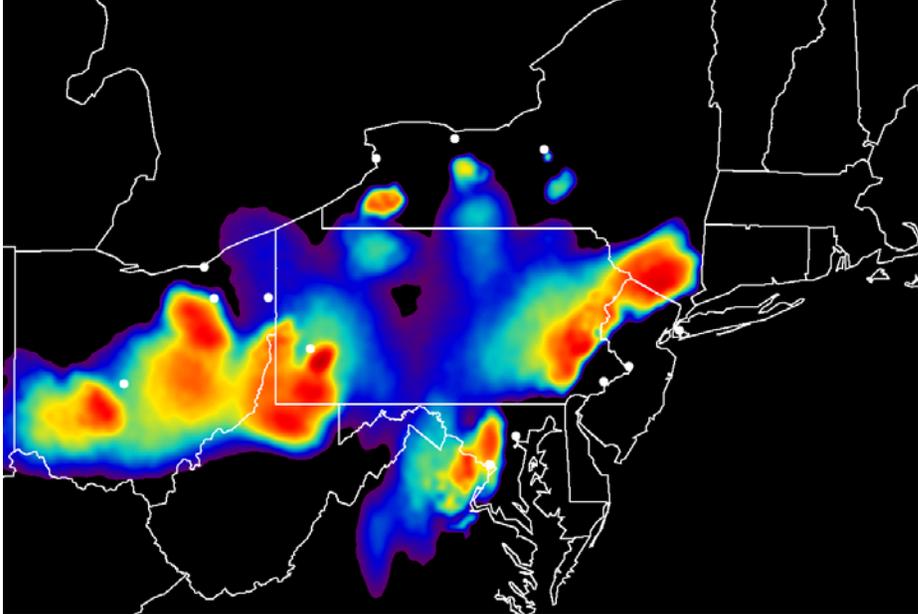
**1 August 2005 → 4 August 2005**



**21 August 2005 → 24 August 2005**

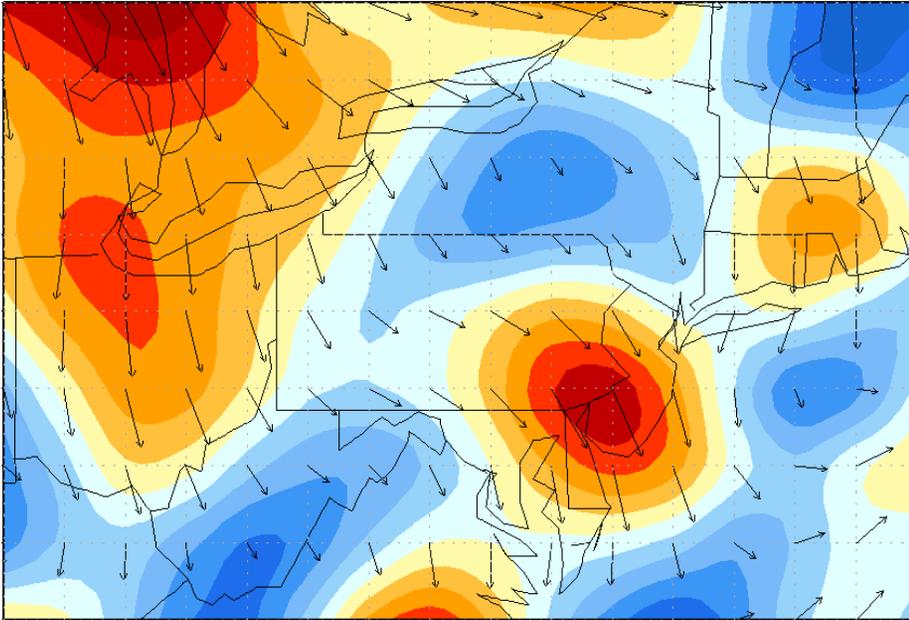


**15 September 2005 → 18 September 2005**

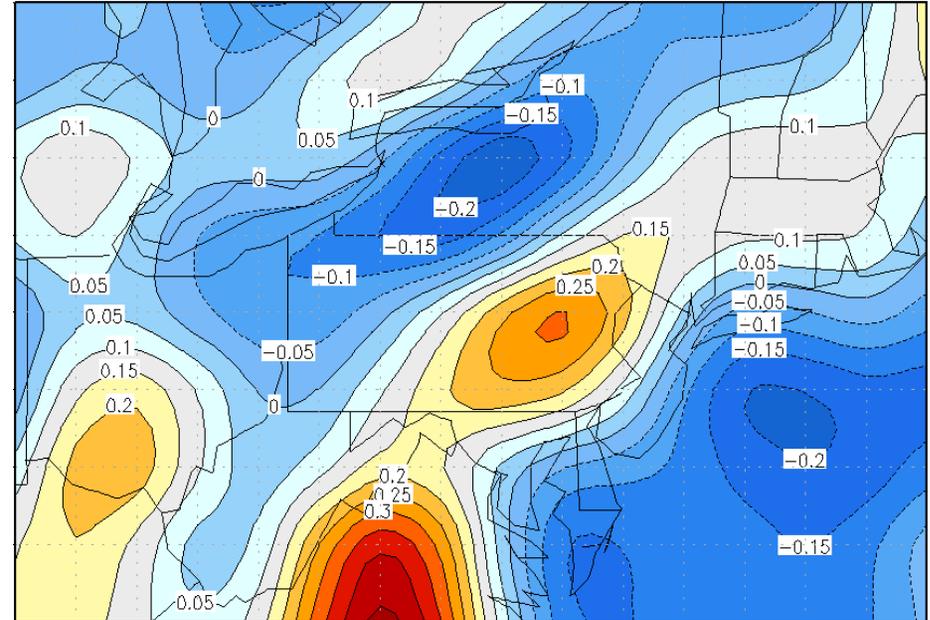


# Meteorology and Patterns of Emissions Dispersal and Deposition: It's really not this simple

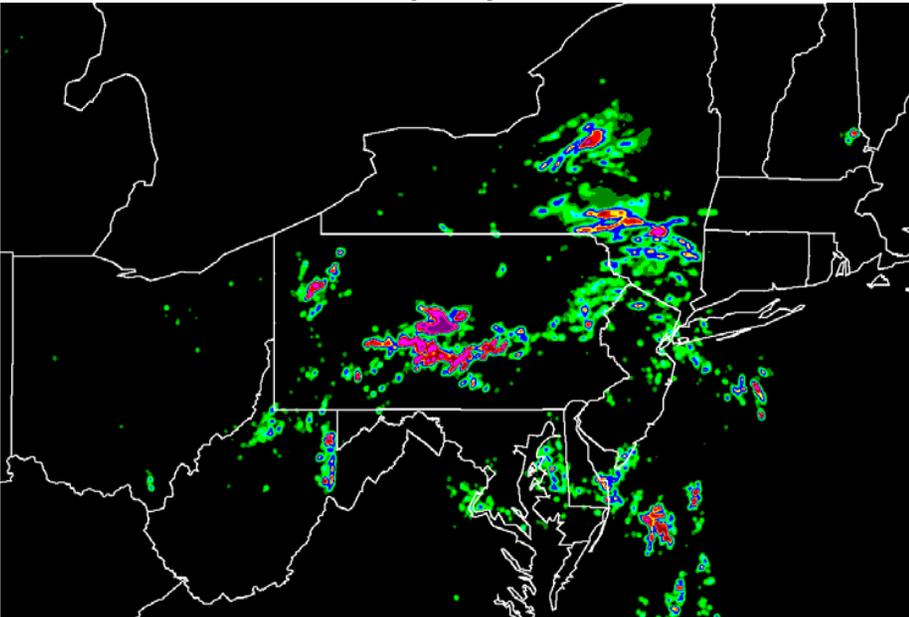
## Multi-level wind data following release



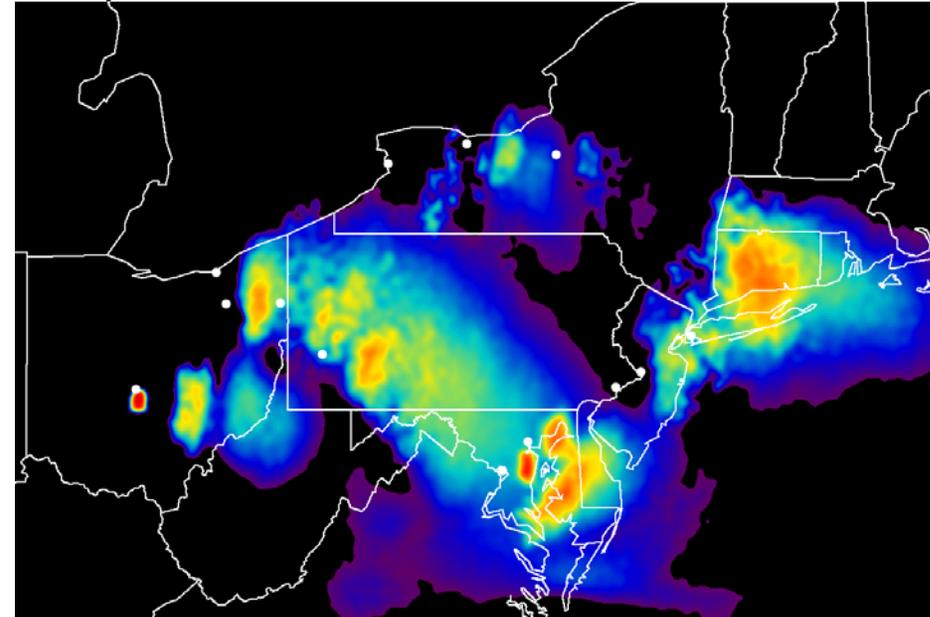
## Vertical velocities of transport layers



## Post-release precipitation events

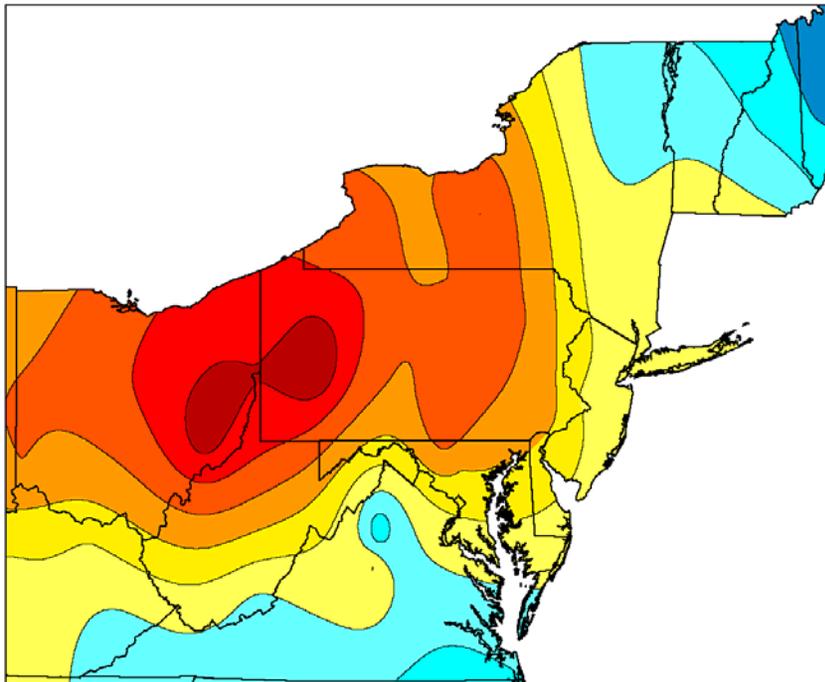


## Deposition of emissions from afternoon of 2005/08/21

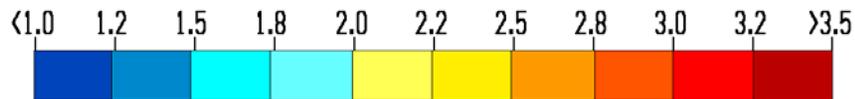


# Sulfate Concentration of Precipitation before and after Implementation of the Clean Air Act Amendments of 1990

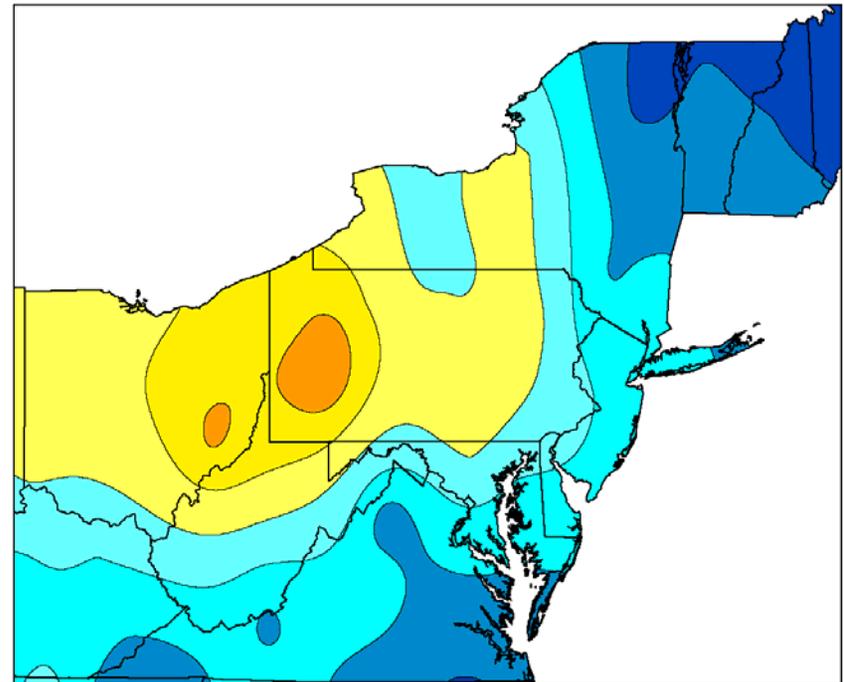
1983-94



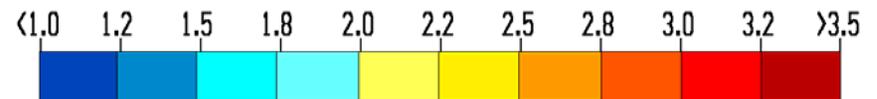
Sulfate Concentration (mg/L)



1995-2003

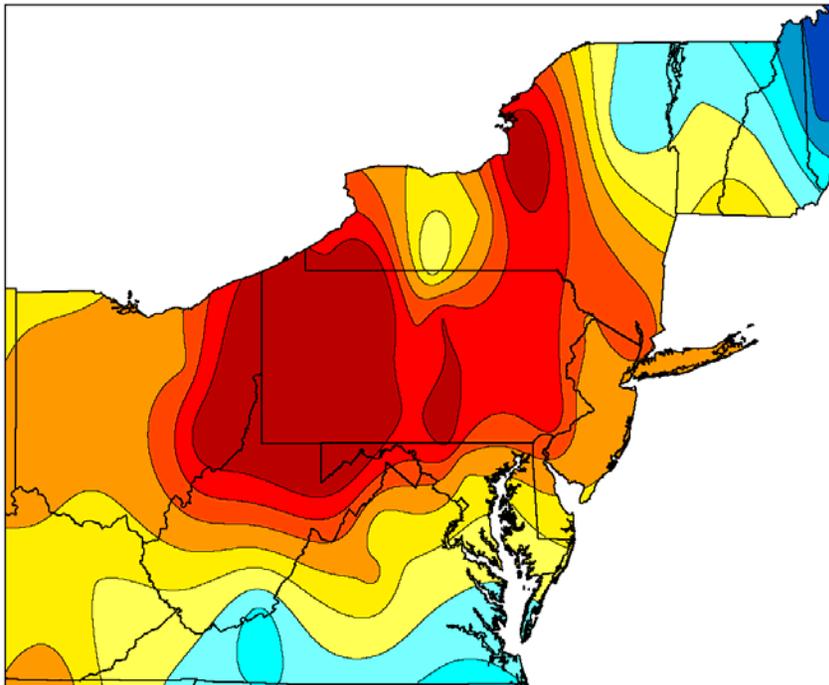


Sulfate Concentration (mg/L)

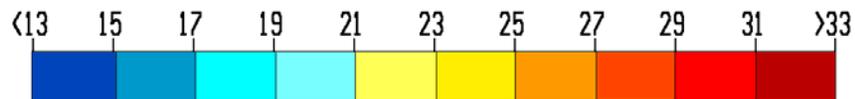


# Sulfate Wet Deposition before and after Implementation of the Clean Air Act Amendments of 1990

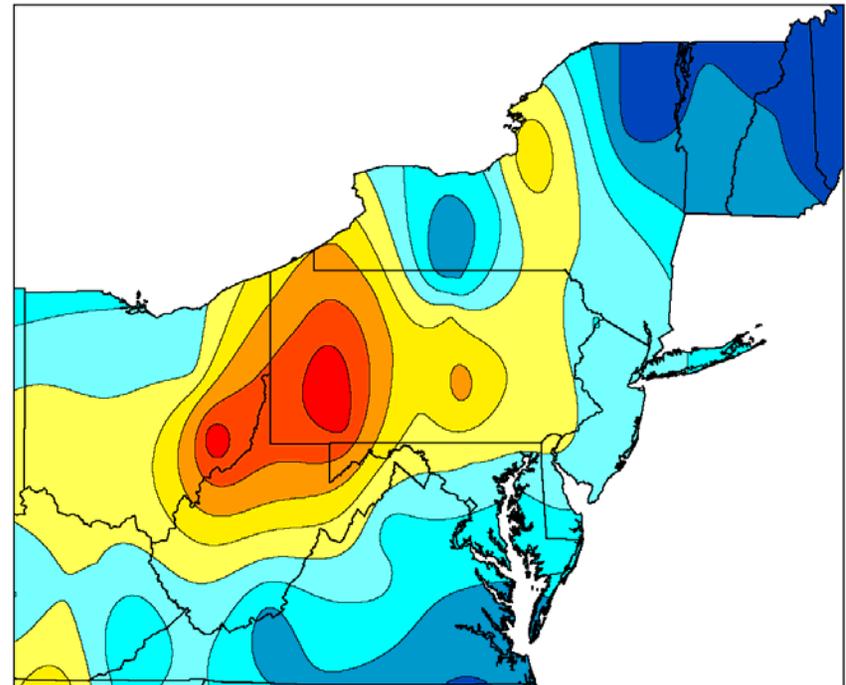
1983-94



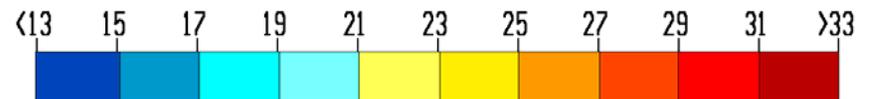
Sulfate Deposition (kg/ha)



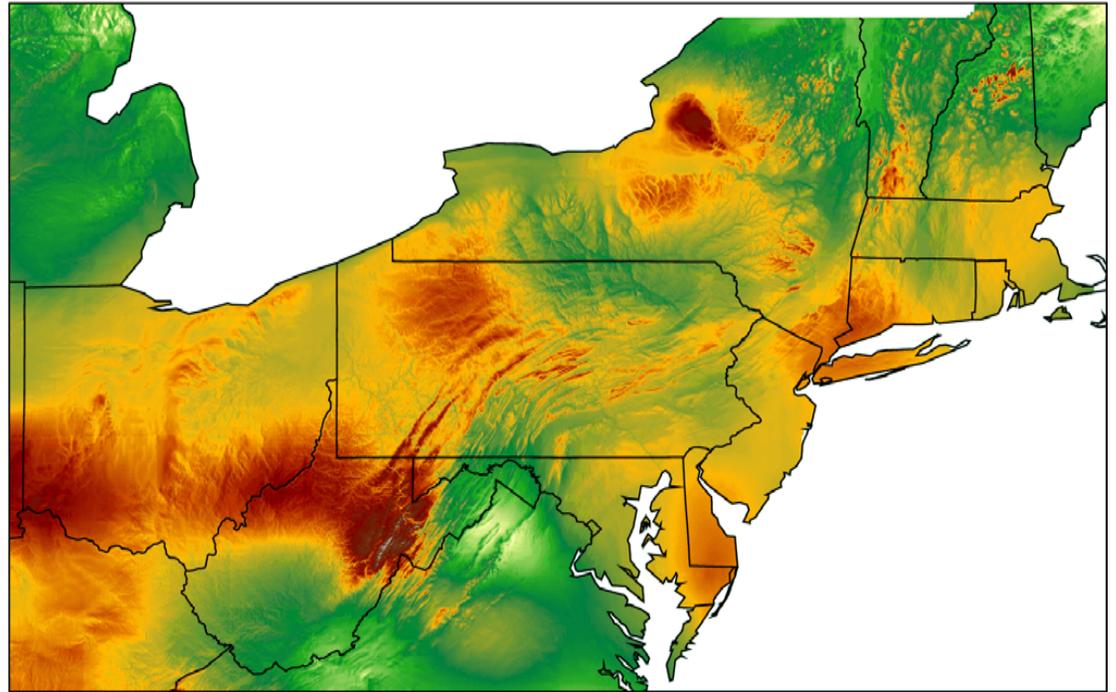
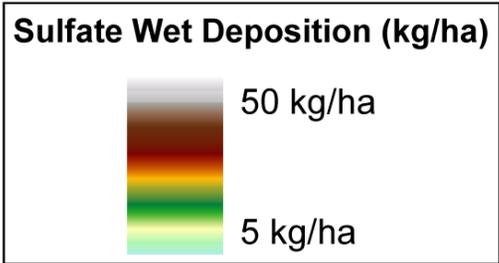
1995-2003



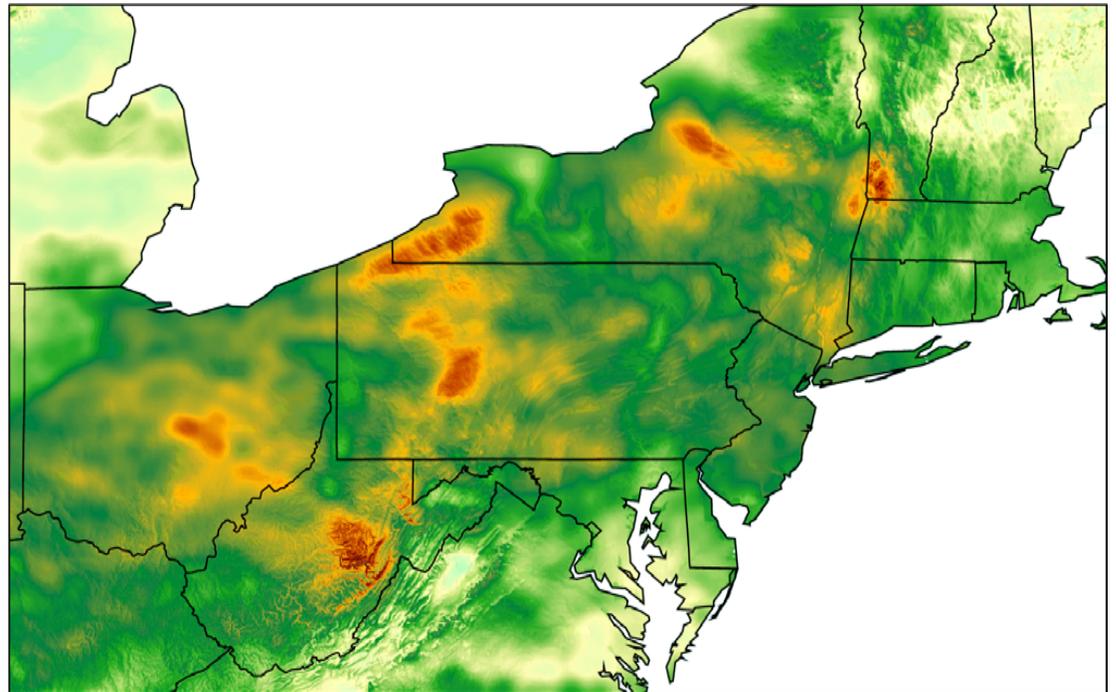
Sulfate Deposition (kg/ha)



**1992 Sulfate Wet Deposition**



**2004 Sulfate Wet Deposition**



# **Environmental Impacts and Responses to Mercury Emissions Trends**

- **Terrestrial ecosystems**
- **Aquatic ecosystems**
  - **Invertebrates**
  - **Fish**
  - **Higher trophic-level consumers of aquatic production (humans, birds of prey)**