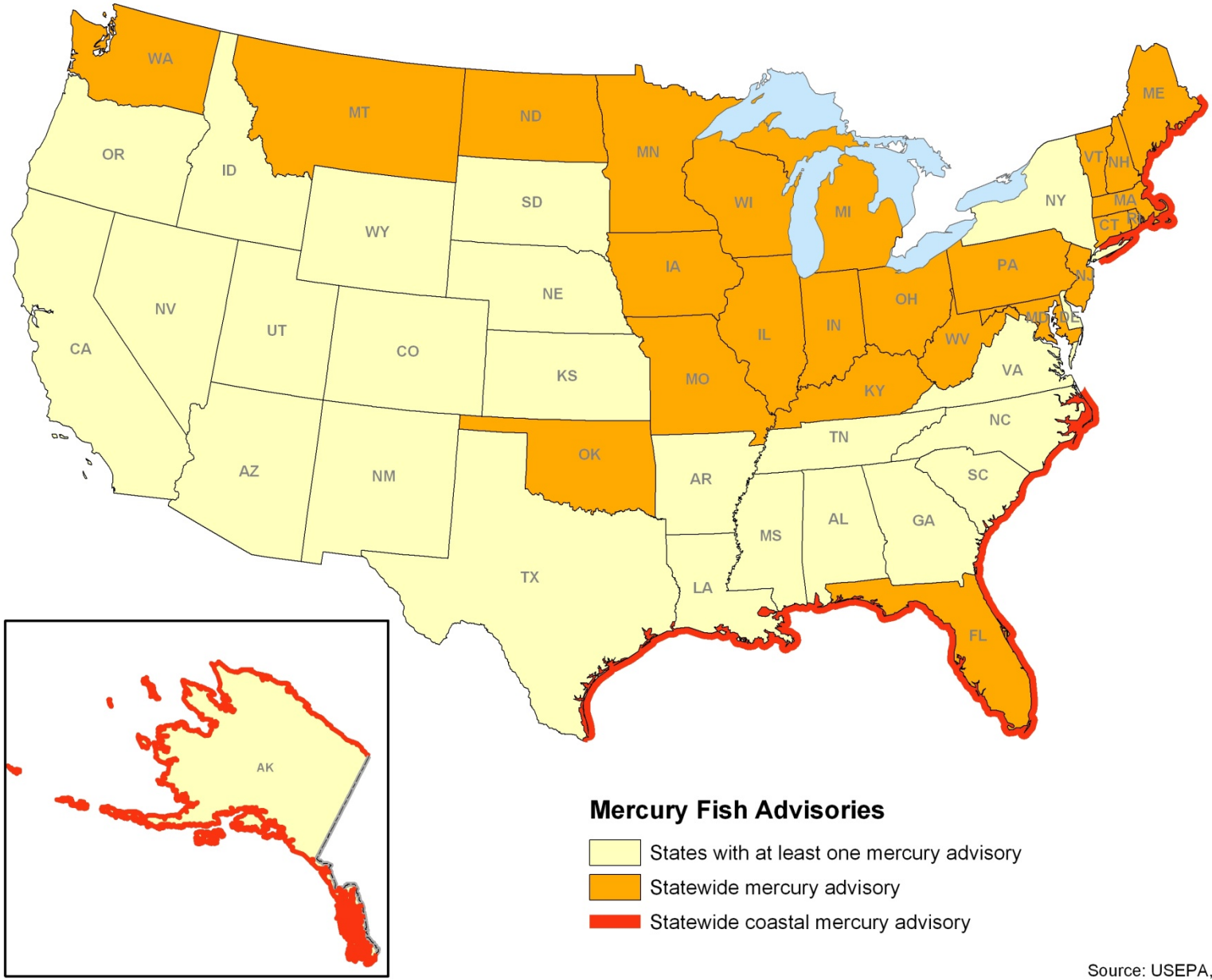
Atmospheric Mercury Monitoring and Modeling Programs of the NOAA Air Resources Laboratory

Mark Cohen, Winston Luke, Paul Kelley,
Steve Brooks, Roland Draxler & Richard Artz

NOAA Air Resources Laboratory
http://www.arl.noaa.gov/mercury.php

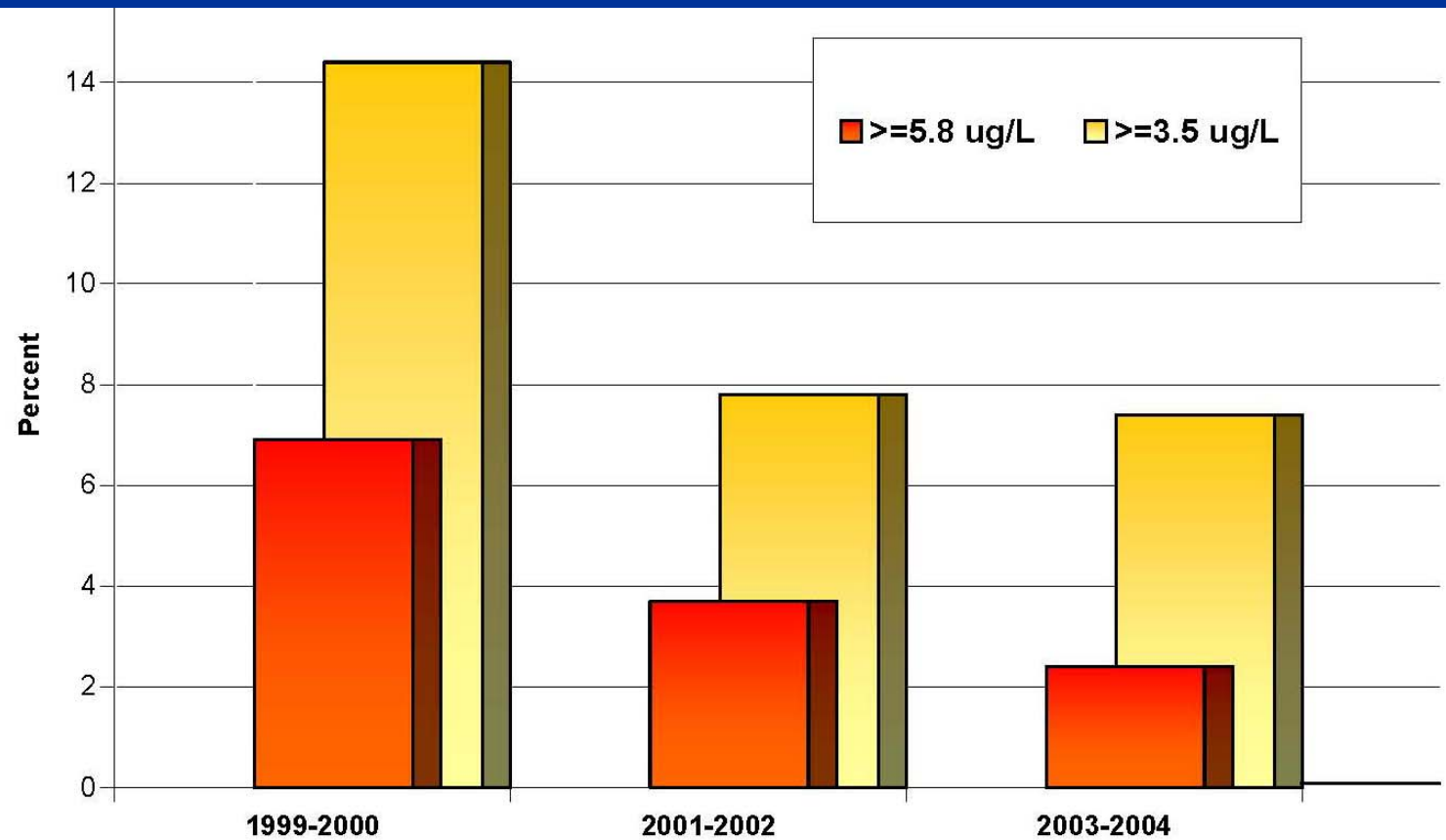
National Water Quality Monitoring Council Meeting
December 9-11, 2008, U.S. Geological Survey
12201 Sunrise Valley Drive, Reston, Virginia

Mercury Fish Consumption Advisories are Ubiquitous



Source: USEPA, 2008

fish consumption advisories seem to be working, but mercury still a problem in the general population… (and probably more so in specific sub-populations)



Percent of women ages 16 through 49 years having blood mercury concentrations greater than those associated with exposures considered higher than EPA's Reference Dose for methylmercury

Adult Women's Blood Mercury Concentrations Vary Regionally in USA: Association with Patterns of Fish Consumption (NHANES 1999-2004).
K. Mahaffey *et al.* (2008). *Environmental Health Perspectives* 2008, in press.

Environmental Mercury Cycling -- Natural vs. Anthropogenic

- Mercury (Hg) is an element... there is the same amount of mercury on Earth today as there always has been
- "natural" Hg cycle – Hg is transported throughout the environment, and chemical transformations interconvert different mercury species
- This has always been going on, and there has always been Hg in fish
- But, we make some Hg unexpectedly "bioavailable"
- Most anthropogenic Hg is "released" as atmospheric emissions:
  - Hg in *coal* is released to the air when coal is burned
  - Hg in *other fuels* is released to the air when they are processed and burned
  - Hg in *ores* is released to the air during metallurgical processes
  - Hg in *products* is released to the air when burned or landfilled after being discarded (e.g., batteries, switches)
- Average, current atmospheric Hg deposition is ~3x pre-industrial levels
- Evidence suggests that newly deposited Hg is more bioavailable

Different "forms" of mercury in the atmosphere

Elemental Mercury -- Hg(0)

- most of total Hg in atmosphere
- *not* very water soluble
- doesn't easily dry or wet deposit
- upward evasion vs. deposition
- atmos. lifetime approx ~ 0.5-1 yr
- globally distributed

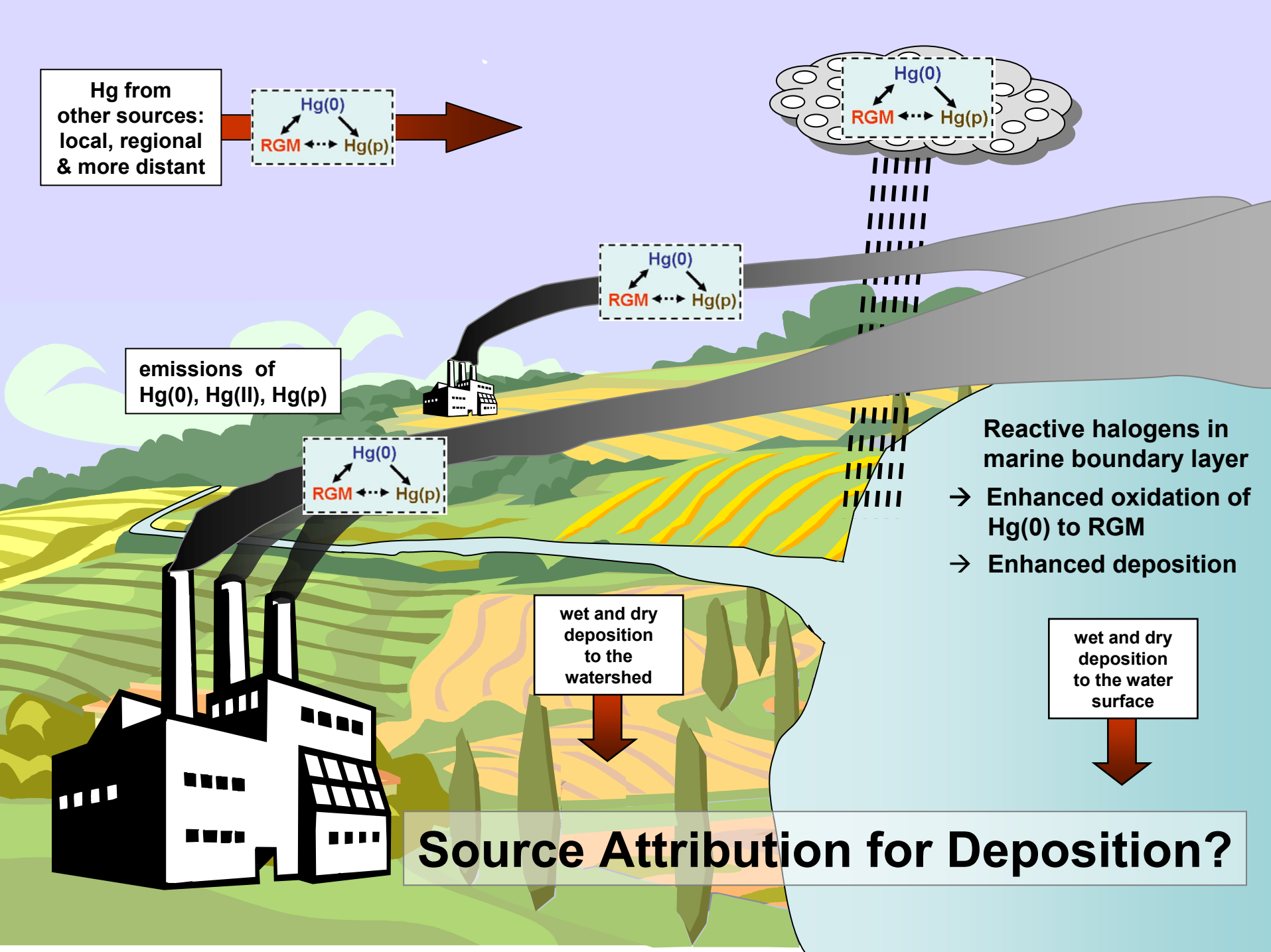
Atmospheric methyl-mercury?

Reactive Gaseous Mercury -- RGM

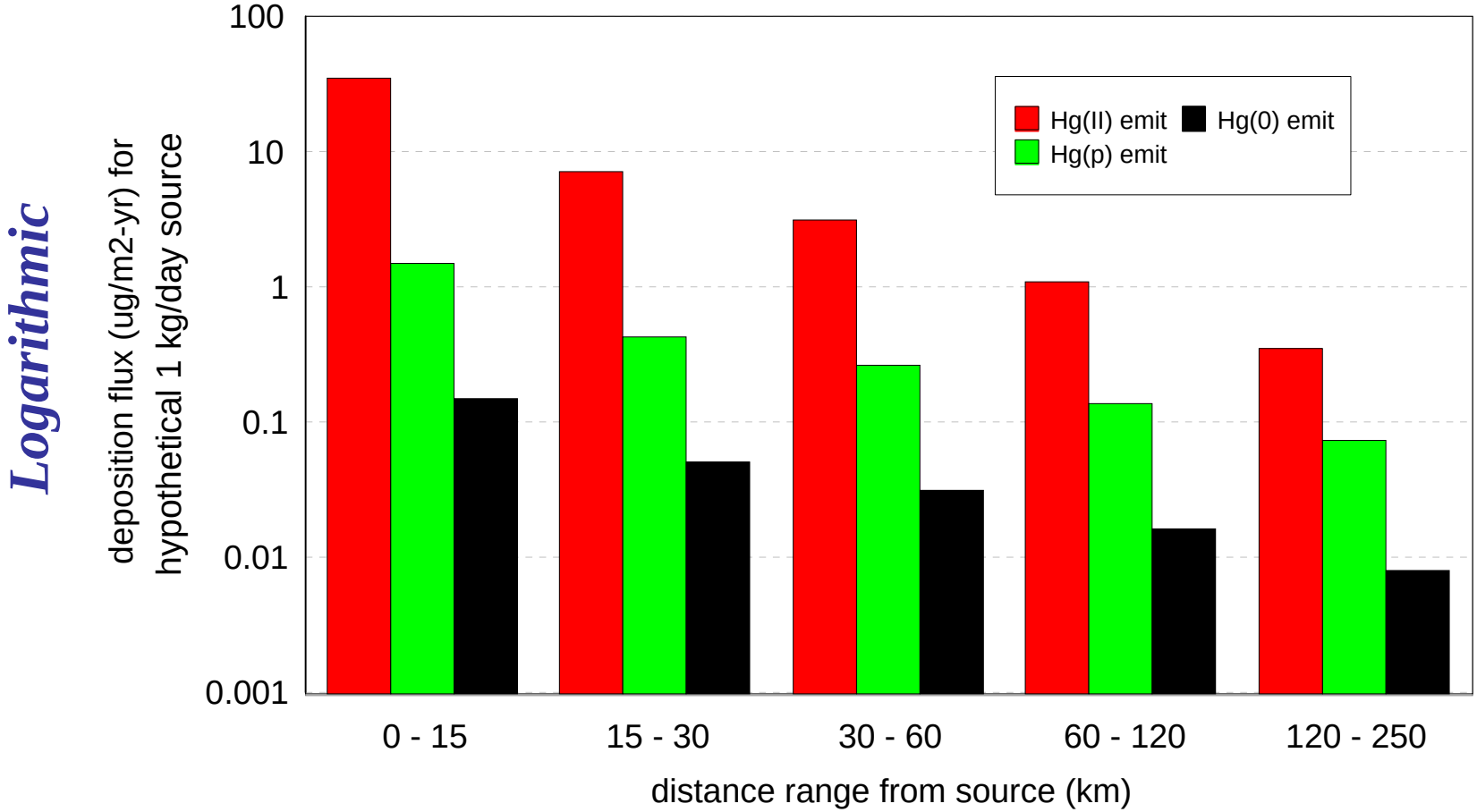
- a few percent of total atmos Hg
- oxidized Hg (HgCl2, others)
- operationally defined
- *very* water soluble and "sticky"
- atmos. lifetime <= 1 week
- local and regional effects
- bioavailable

Particulate Mercury -- Hg(p)

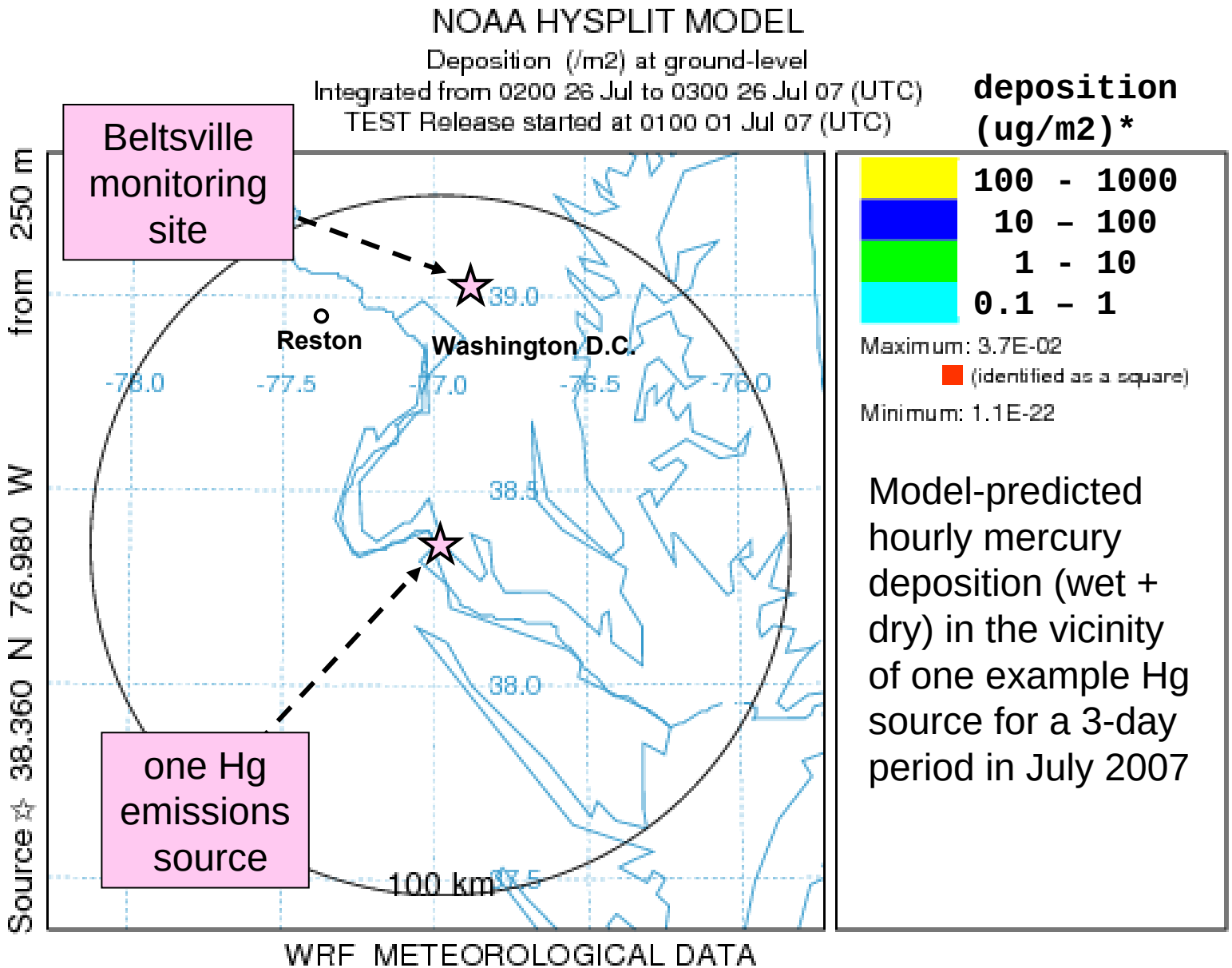
- a few percent of total atmos Hg
- not pure particles of mercury
- Hg compounds in/on atmos particles
- species largely unknown (HgO?)
- atmos. lifetime approx 1~ 2 weeks
- local and regional effects
- bioavailability?


Hg from other sources: local, regional & more distant
Hg(0)
RGM
Hg(p)
Hg(0)
RGM
Hg(p)
Hg(0)
RGM
Hg(p)
Hg(0)
RGM
Hg(p)
emissions of Hg(0), Hg(II), Hg(p)
Reactive halogens in marine boundary layer
→ Enhanced oxidation of Hg(0) to RGM
→ Enhanced deposition
wet and dry deposition to the watershed
wet and dry deposition to the water surface
Source Attribution for Deposition?

Why are emissions speciation data - and potential plume transformations -- critical?

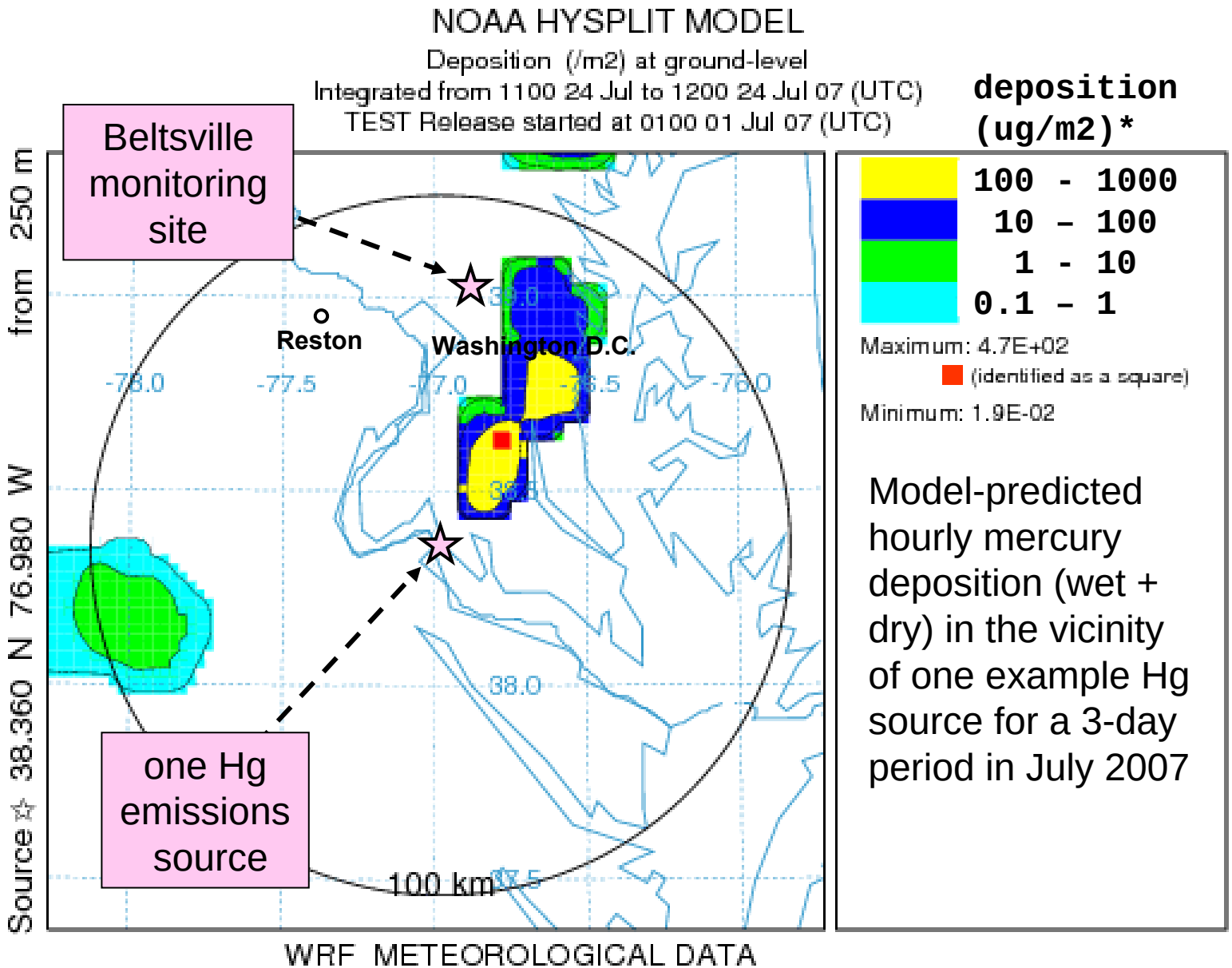


NOTE: distance results averaged over all directions – Some directions will have higher fluxes, some will have lower



Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007

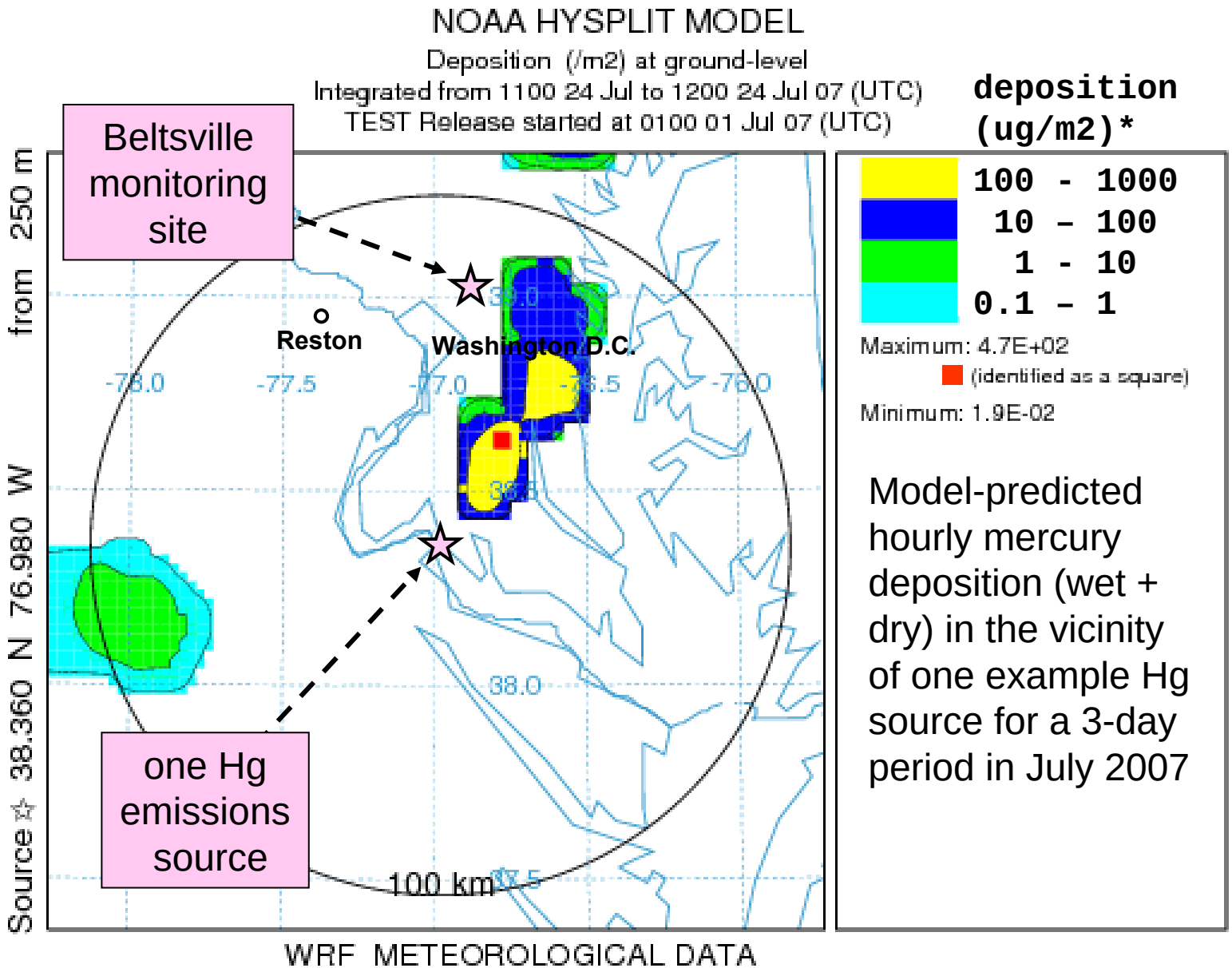
** hourly deposition converted to annual equivalent*



Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007

** hourly deposition converted to annual equivalent*

Large, time-varying spatial gradients in deposition & source-receptor relationships

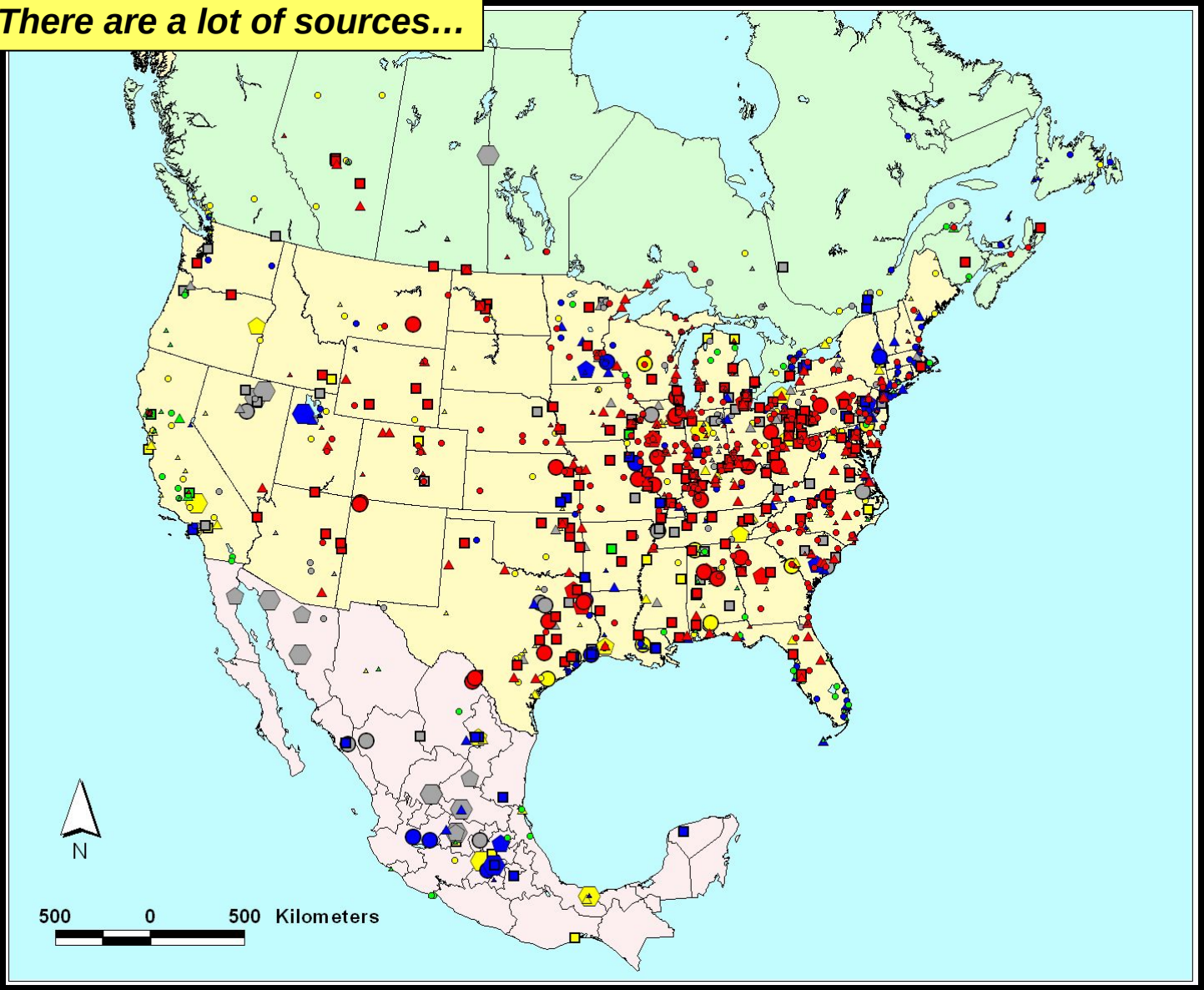


Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007

** hourly deposition converted to annual equivalent*

Large Point Sources of Mercury Air Emissions

There are a lot of sources…



size/shape of symbol denotes amount of mercury emitted (kg/yr)

- 5 - 10
- 10 - 50
- 50 - 100
- 100 – 300
- 300 - 500
- 500 - 1000
- 1000 - 3500

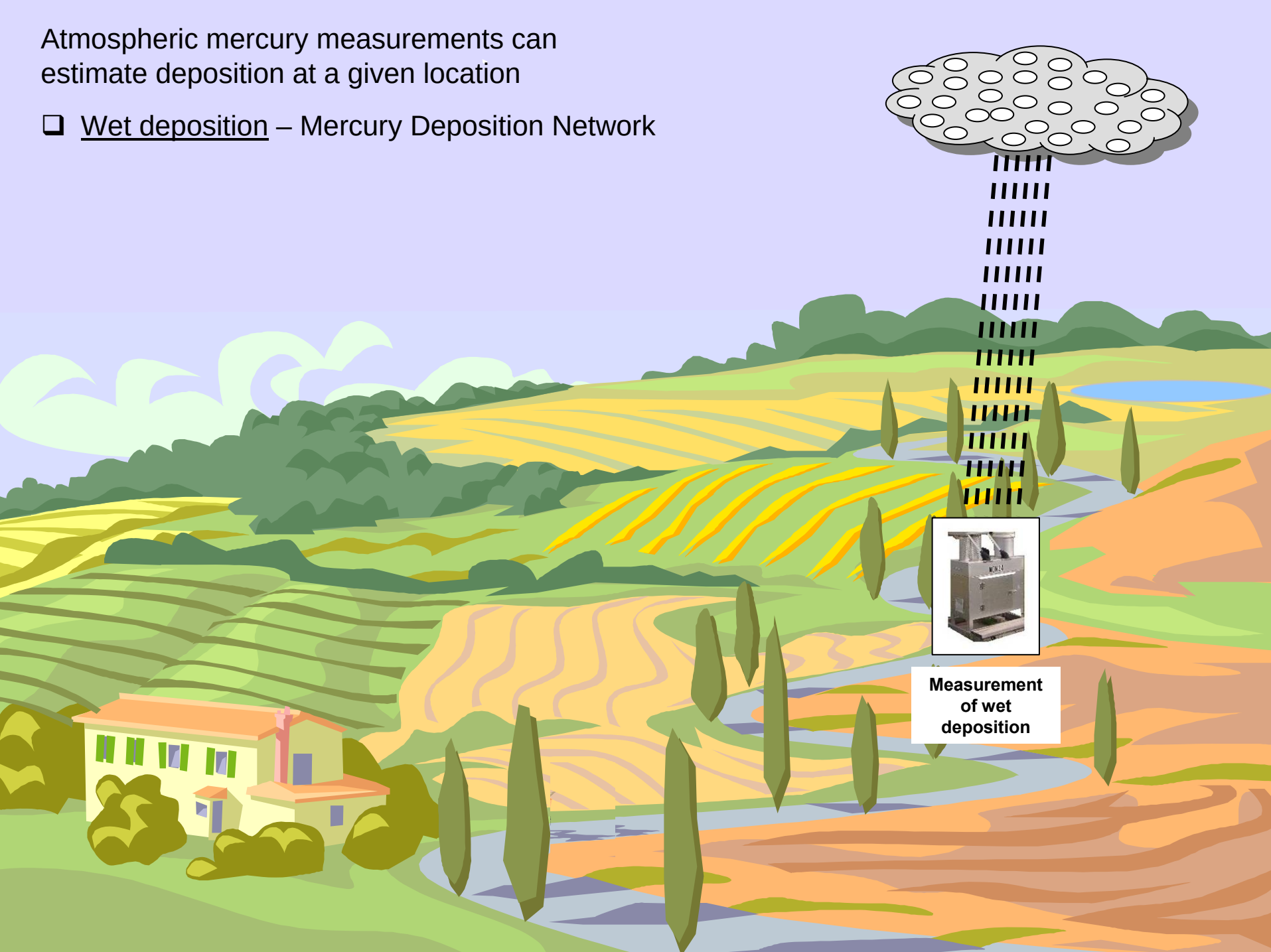
color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

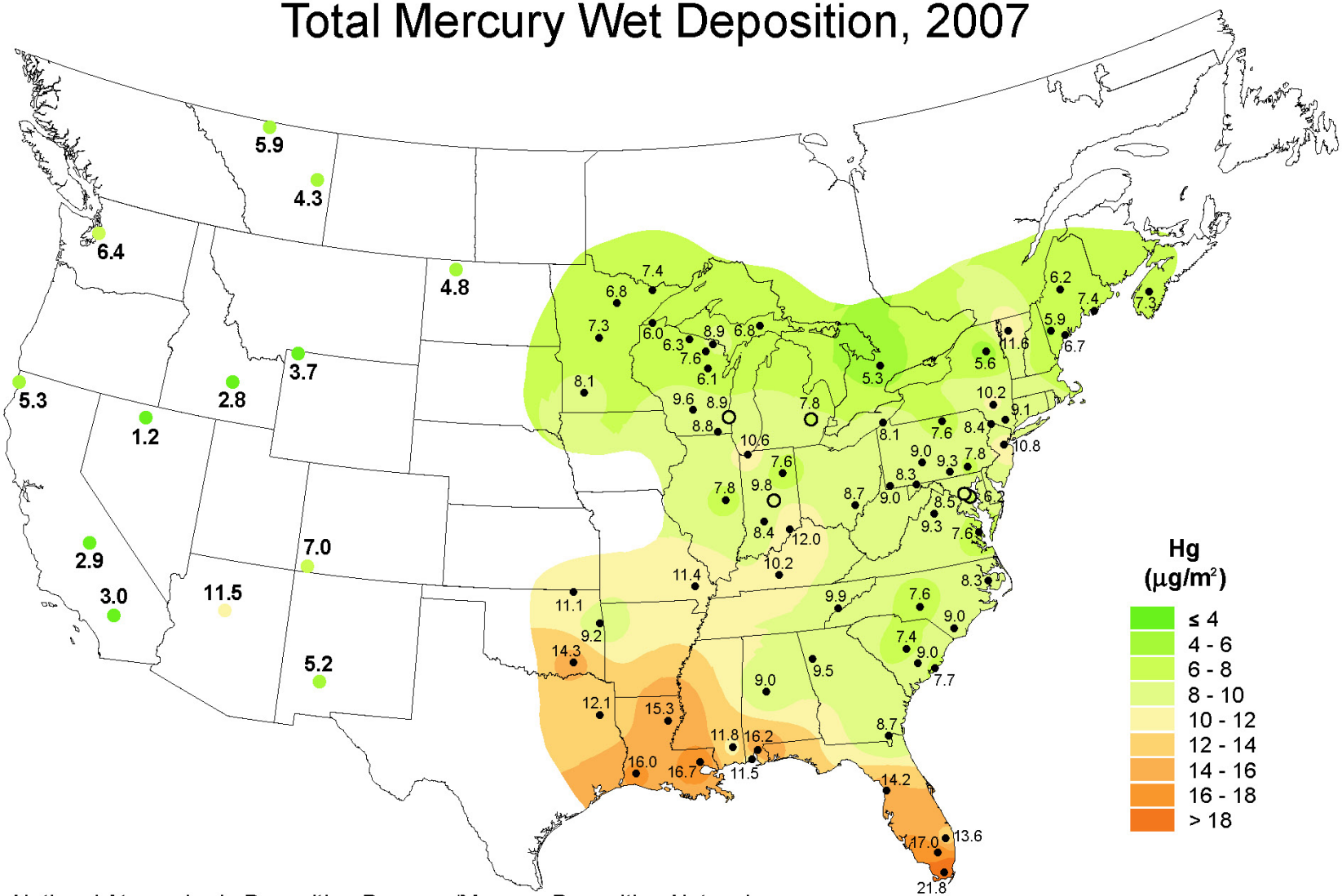
2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation

Atmospheric mercury measurements can estimate deposition at a given location

- ❑ <u>Wet deposition</u> – Mercury Deposition Network



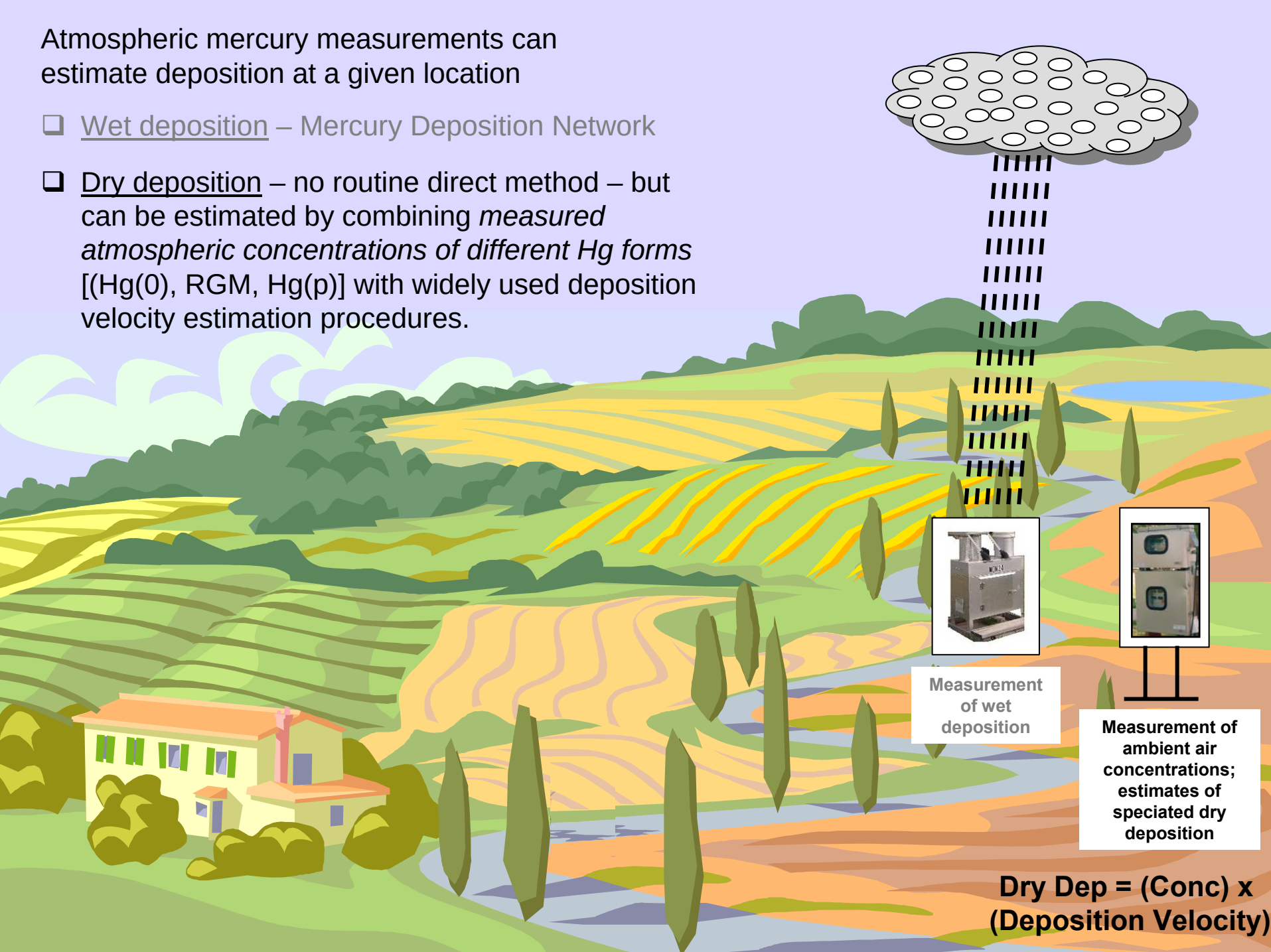
Total Mercury Wet Deposition, 2007



National Atmospheric Deposition Program/Mercury Deposition Network

Atmospheric mercury measurements can estimate deposition at a given location

- Wet deposition – Mercury Deposition Network
- Dry deposition – no routine direct method – but can be estimated by combining *measured atmospheric concentrations of different Hg forms* [(Hg(0), RGM, Hg(p)] with widely used deposition velocity estimation procedures.

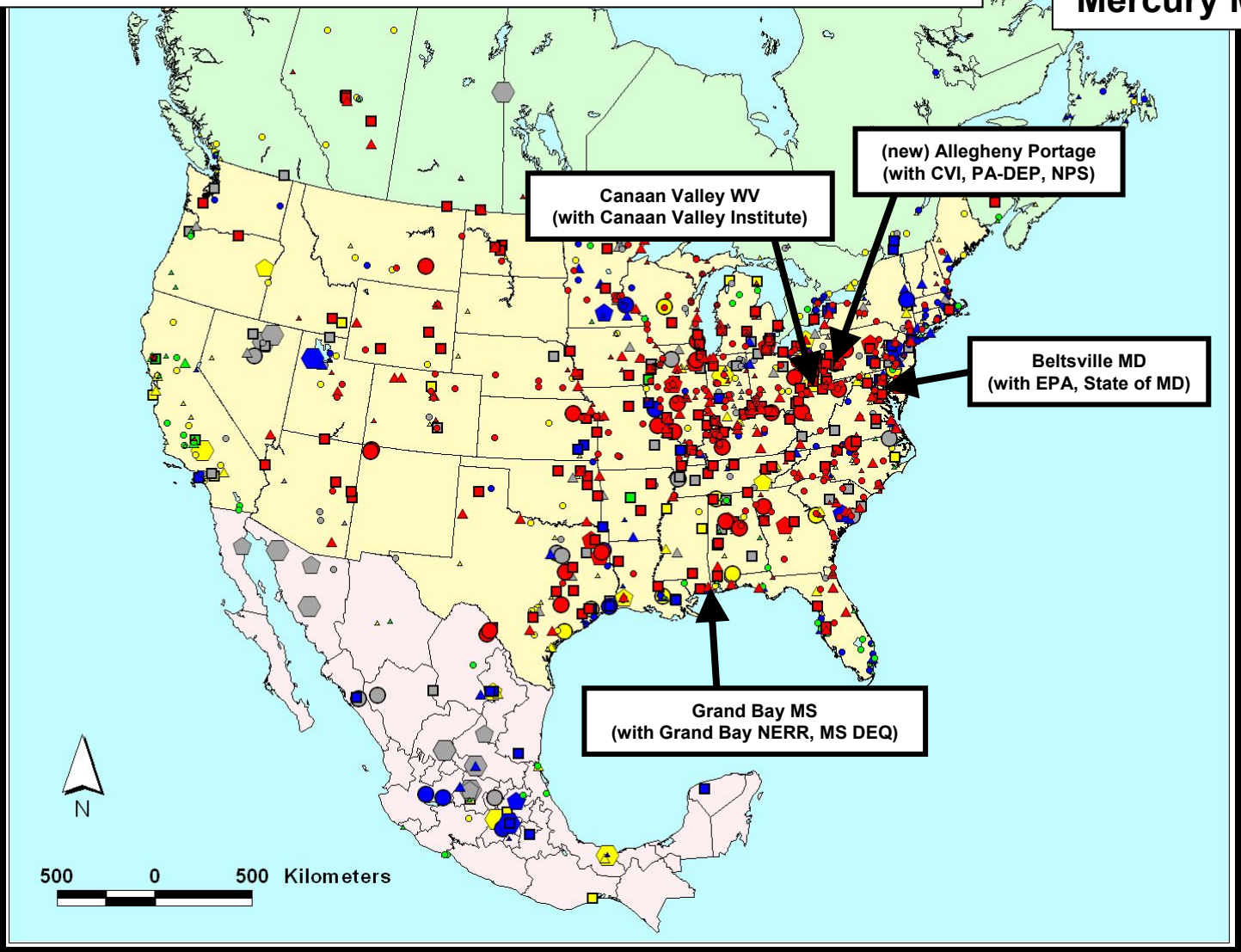


Dry Dep = (Conc) x (Deposition Velocity)

Large Point Sources of Mercury Air Emissions

These sites are part of an emerging national atmospheric mercury monitoring network, being coordinated by NADP

NOAA Air Resources Lab's Collaborative, Long-Term, Speciated Atmospheric Mercury Measurement Sites



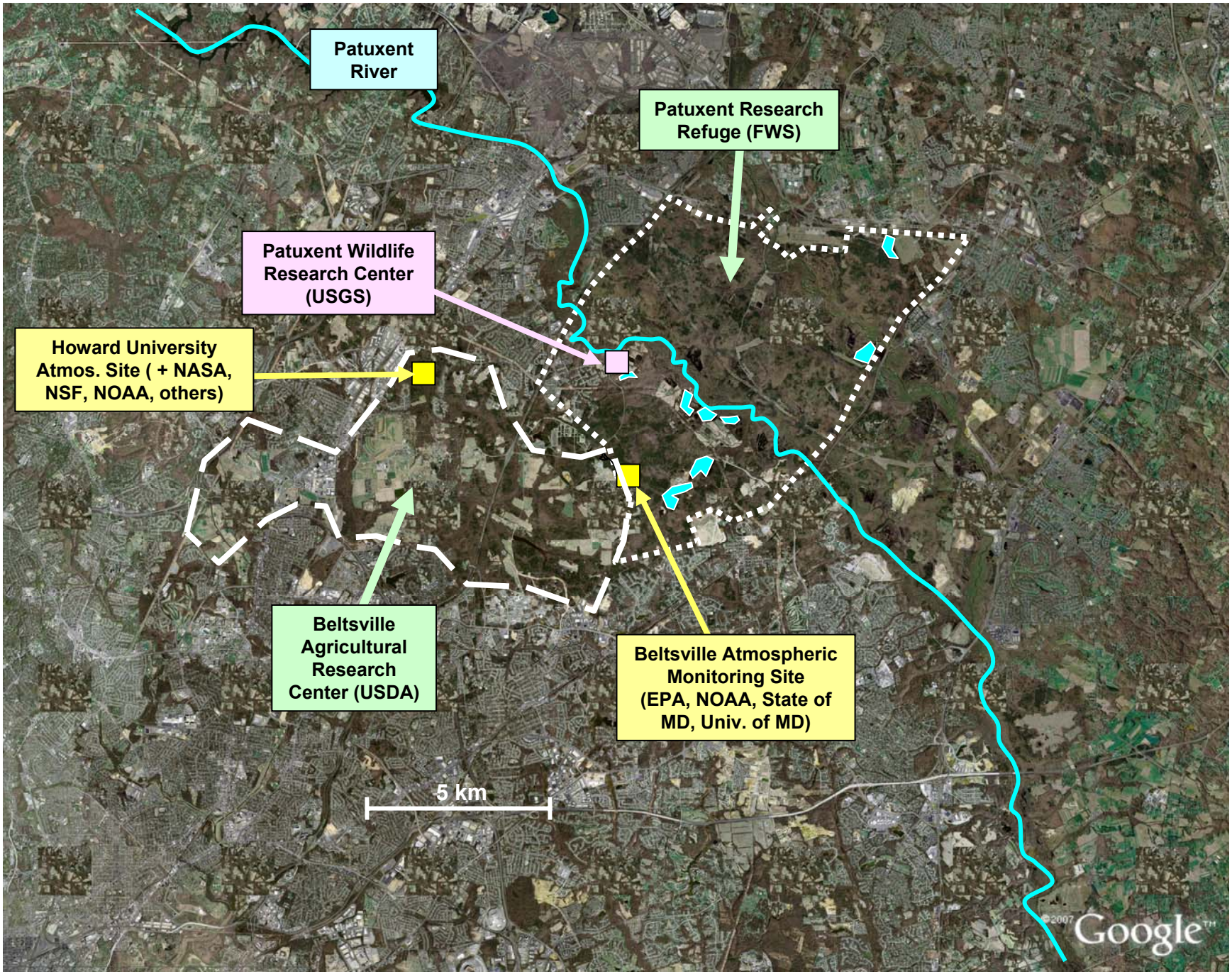
size/shape of symbol denotes amount of mercury emitted (kg/yr)

- 5 - 10
- 10 - 50
- 50 - 100
- 100 – 300
- 300 - 500
- 500 - 1000
- 1000 - 3500

color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation


Patuxent River
Patuxent Research Refuge (FWS)
Patuxent Wildlife Research Center (USGS)
Howard University Atmos. Site (+ NASA, NSF, NOAA, others)
Beltsville Agricultural Research Center (USDA)
Beltsville Atmospheric Monitoring Site (EPA, NOAA, State of MD, Univ. of MD)
5 km
©2007 Google™

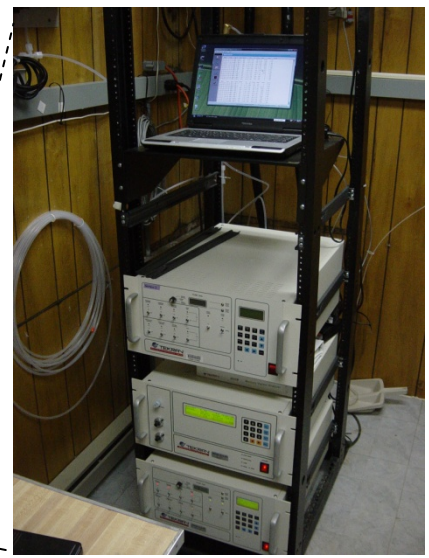
Atmospheric Mercury Measurement Site at Beltsville, MD

ARL's Winston Luke working with RGM and Hg(p) collectors

Precipitation measurements (left to right):
Mercury Deposition Network,
Major Ions (e.g."acid rain"),
Precipitation Amount

mercury and trace gas monitoring tower (10 meters)

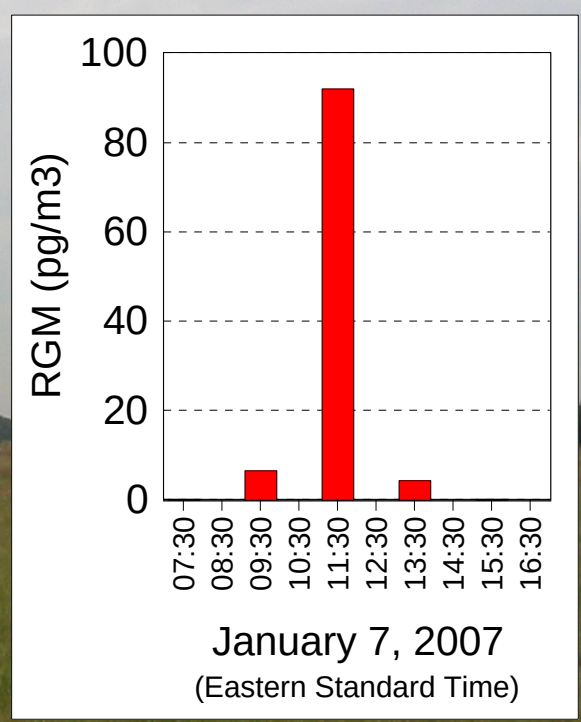
Top of tower (close-up) with two sets of RGM and Hg(p) collectors



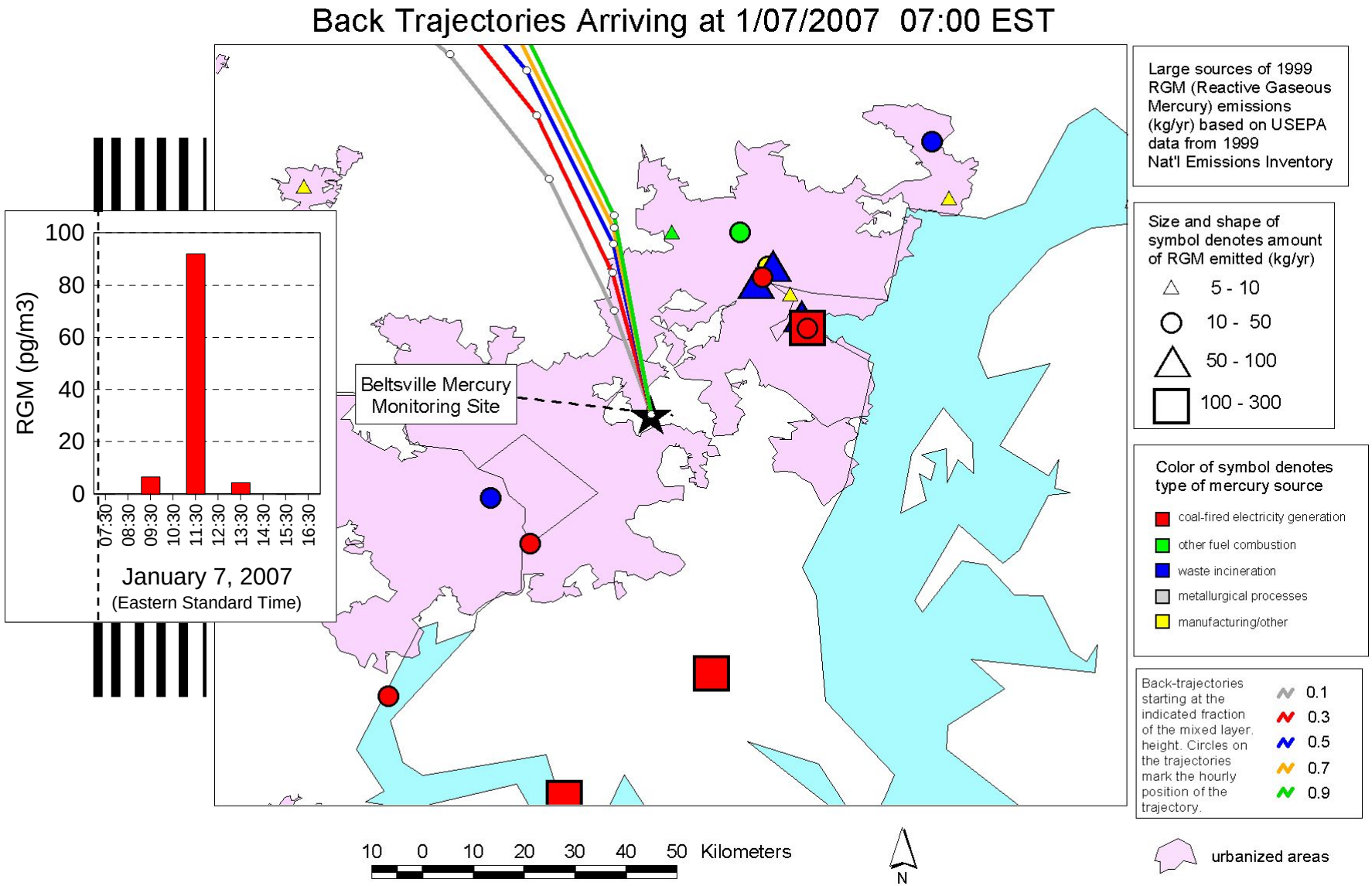
After RGM and Hg(p) is collected, it is desorbed and analyzed inside the trailer, along with Hg(0)

Sometimes, we see evidence of local and regional "plume" impacts

Beltsville Episode January 7, 2007



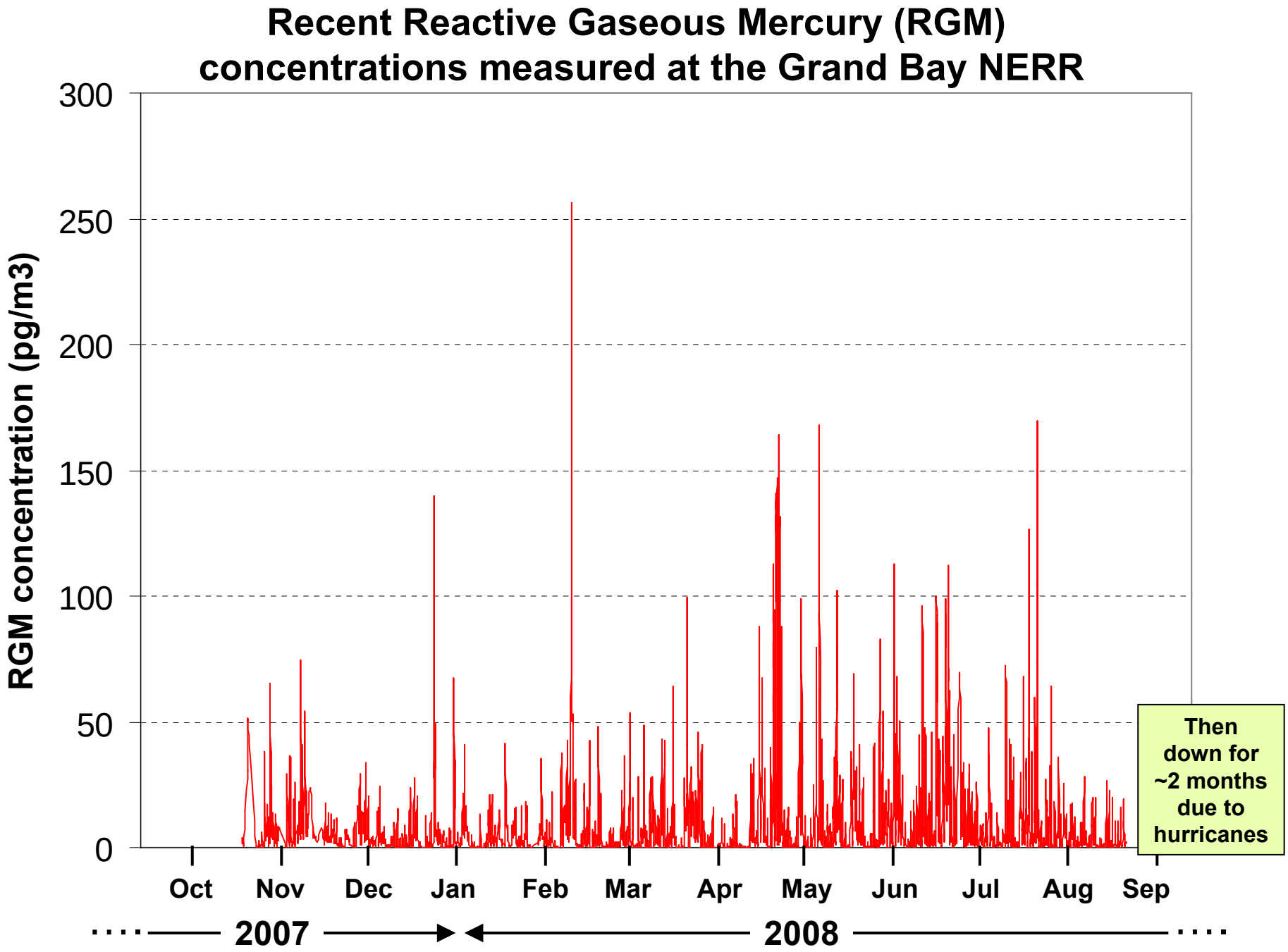
Sometimes, we see evidence of local and regional "plume" impacts



Atmospheric Mercury Measurement Site at the Grand Bay NERR, MS

mercury and trace gas monitoring tower (10 meters)

view from top of the tower


Recent Reactive Gaseous Mercury (RGM) concentrations measured at the Grand Bay NERR
RGM concentration (pg/m3)
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
2007
2008
Then down for ~2 months due to hurricanes

Can we learn what is needed about atmospheric mercury deposition by making atmospheric measurements alone?

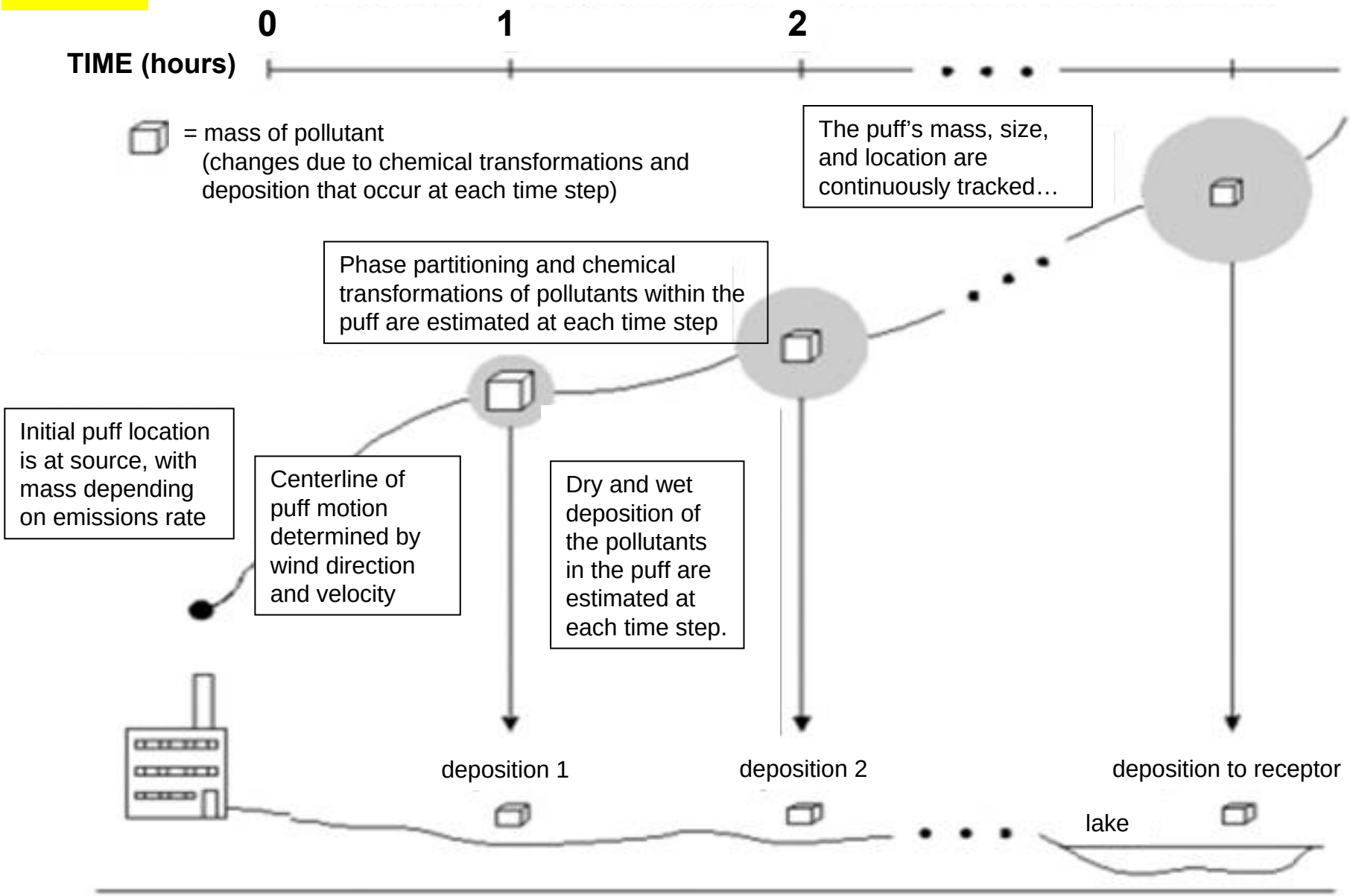
NO…

What Do We Need to Know Regarding Atmospheric Mercury?

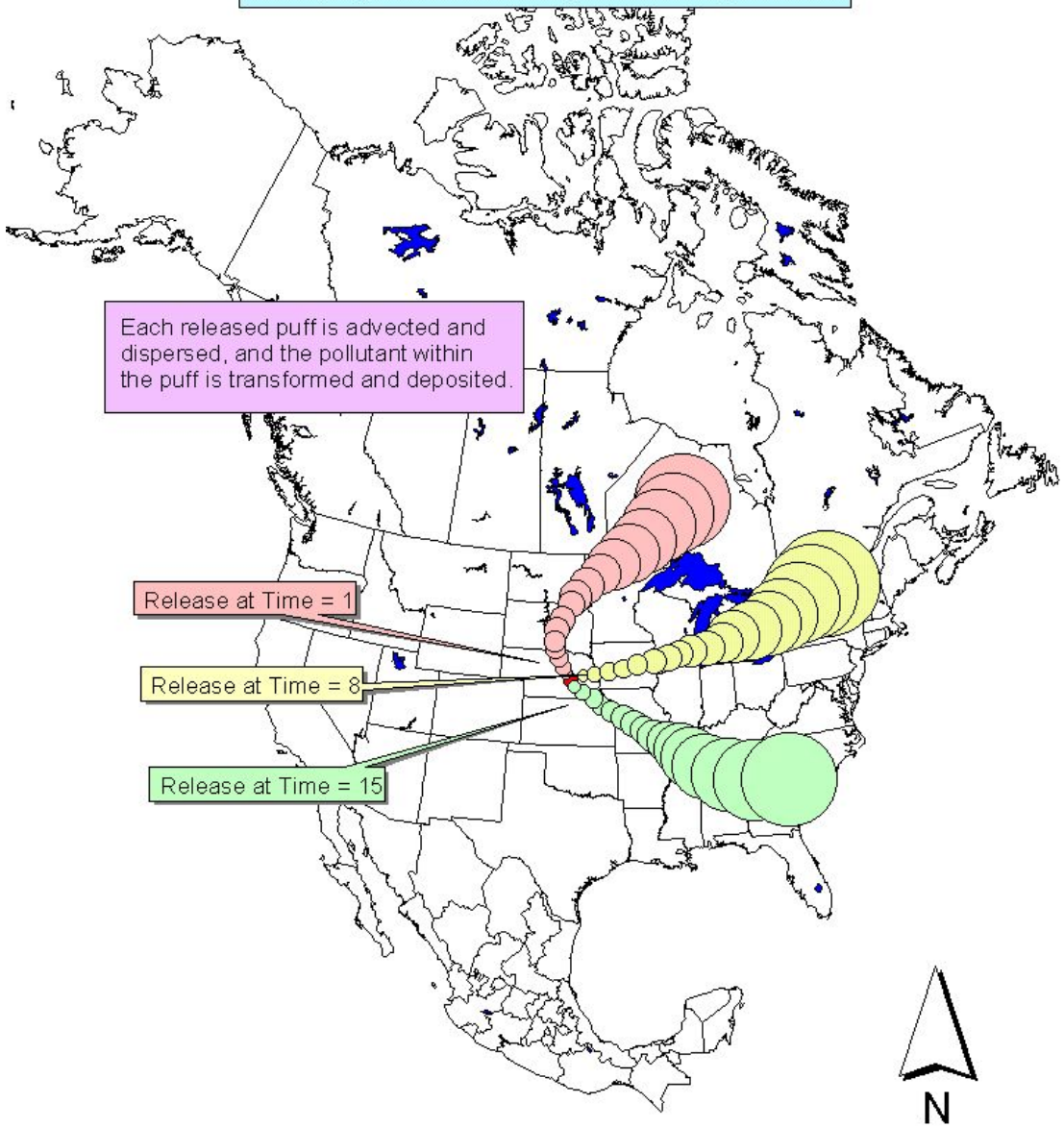
Type of Information
Atmospheric deposition
Source-attribution for deposition
Deposition for historical periods
Deposition for alternative future scenarios

NOAA HYSPLIT MODEL

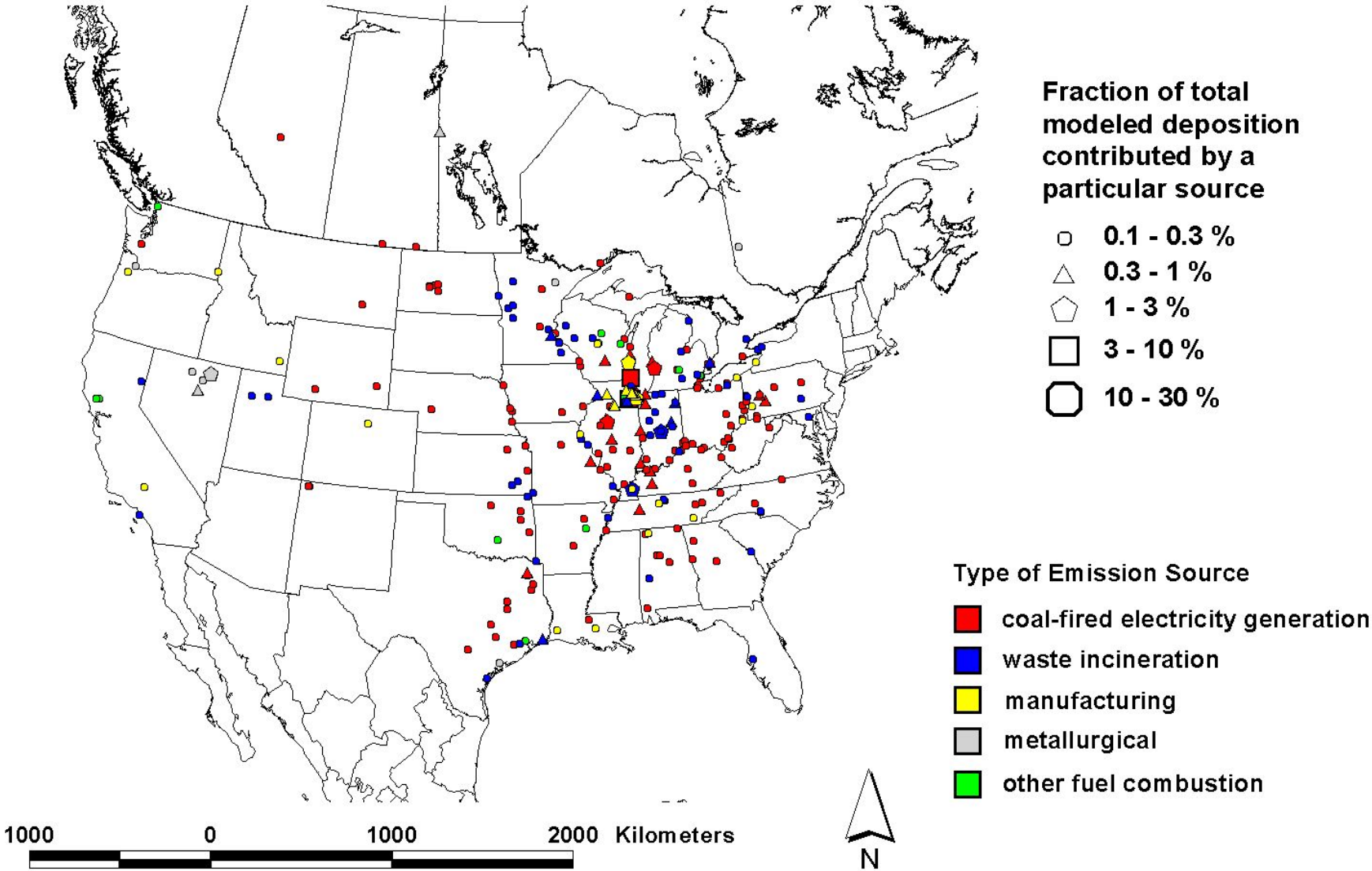
Lagrangian Puff Atmospheric Fate and Transport Model

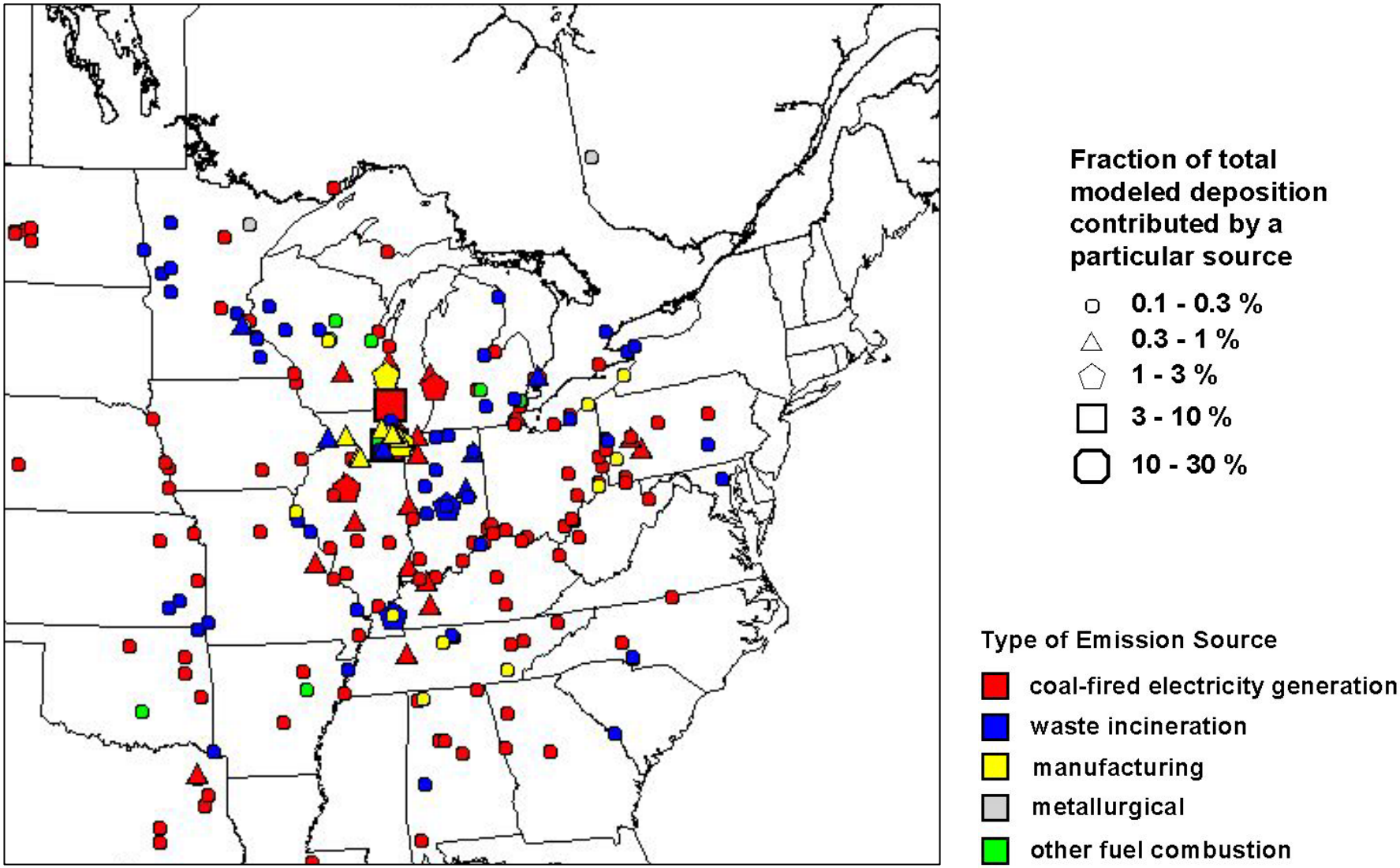


Over the entire modeling period (e.g., one year), puffs are released at periodic intervals (e.g., once every 7 hours).



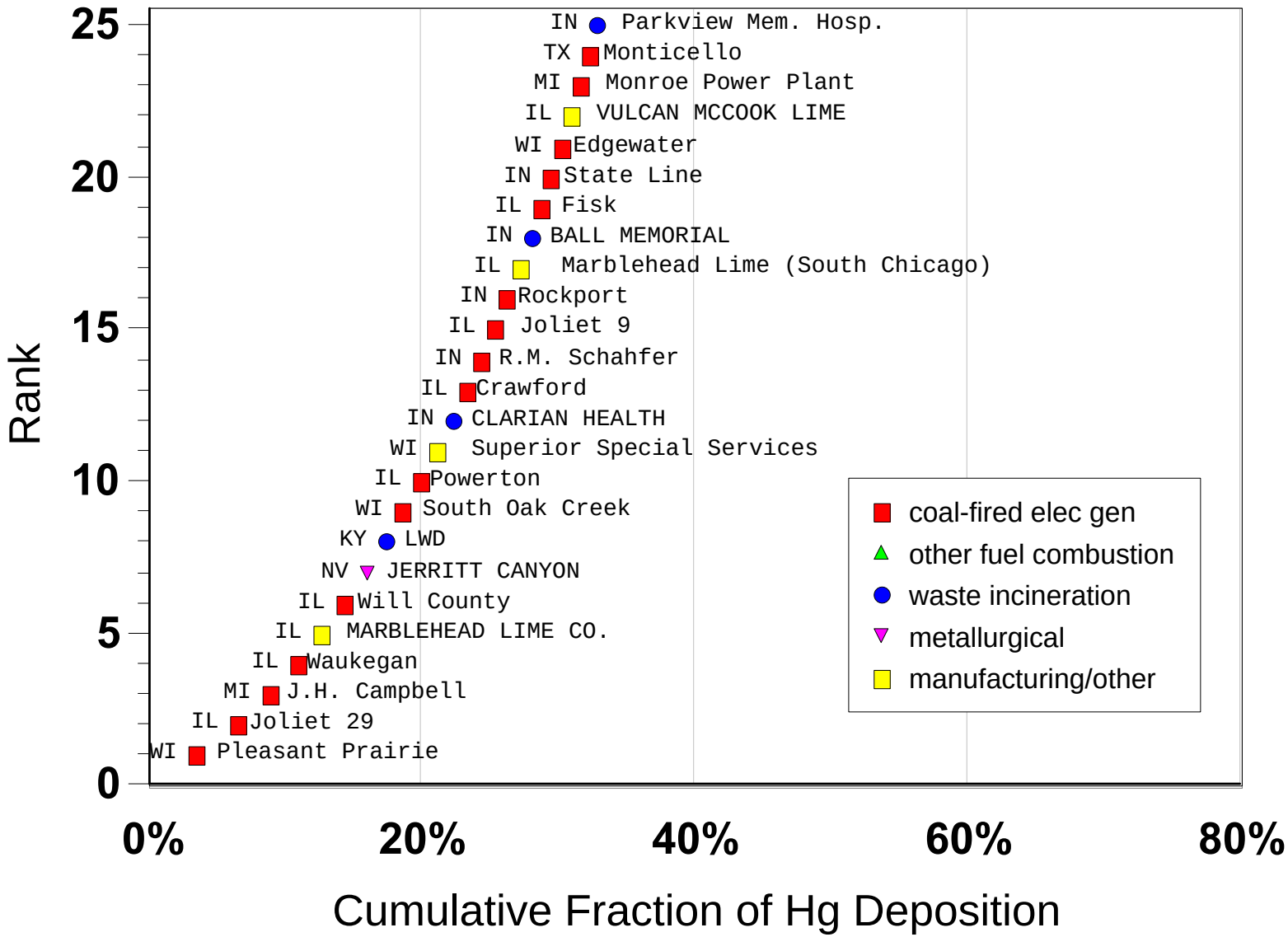
Largest atmospheric deposition contributors to Lake Michigan based on 1999-2000 emissions





Largest modeled contributors to Lake Michigan (close-up).

Top 25 modeled sources of atmospheric mercury to Lake Michigan (based on 1999 anthropogenic emissions in the U.S. and Canada)



Models are not perfect

"…Everyone believes monitoring results except for the person making the measurements… and nobody believes modeling results except for the person doing the modeling…"

How not perfect are they?

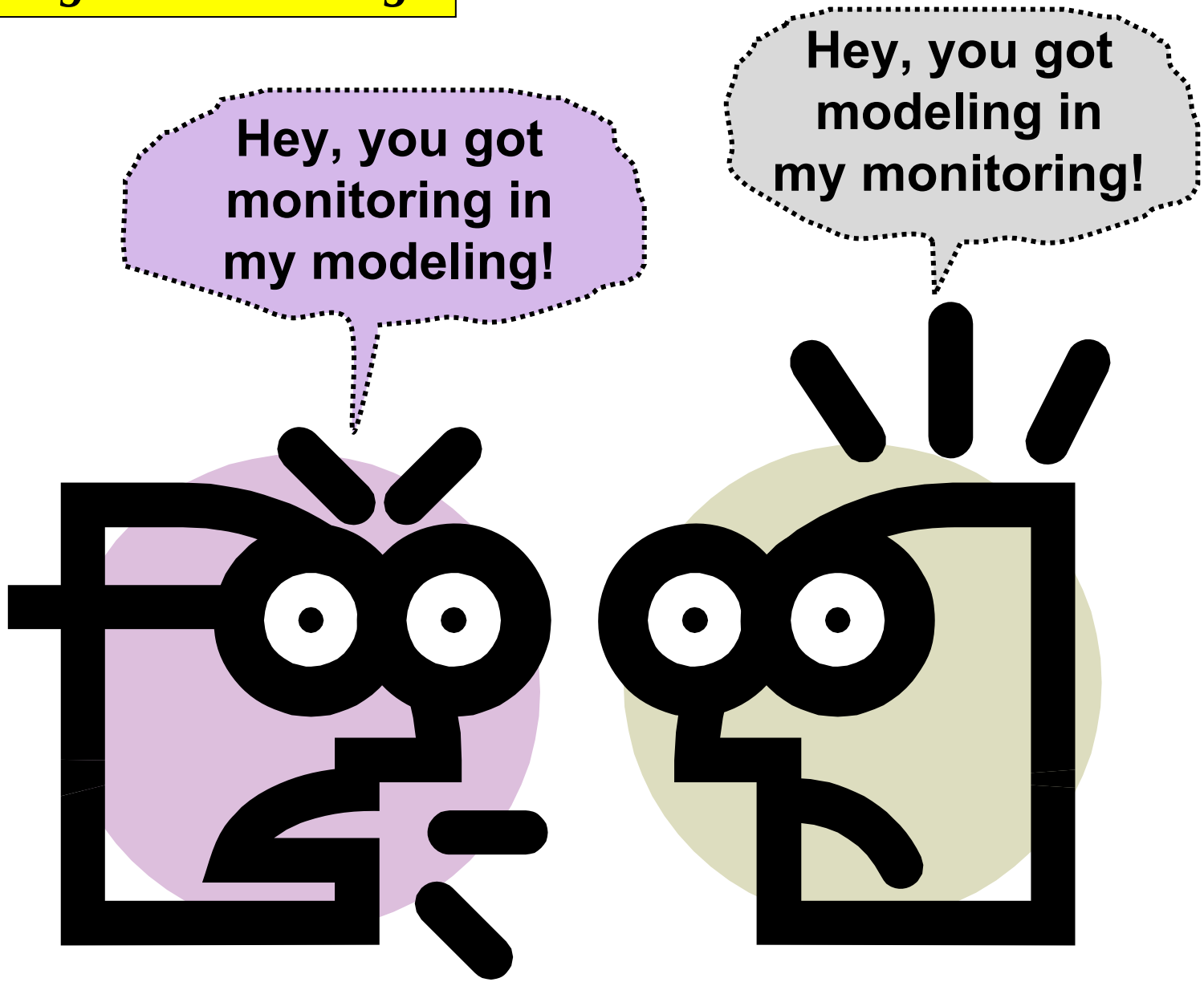
Results are encouraging, but difficult to evaluate models due to lack of contemporaneous monitoring and emissions inventory data

Models are a test of our knowledge…

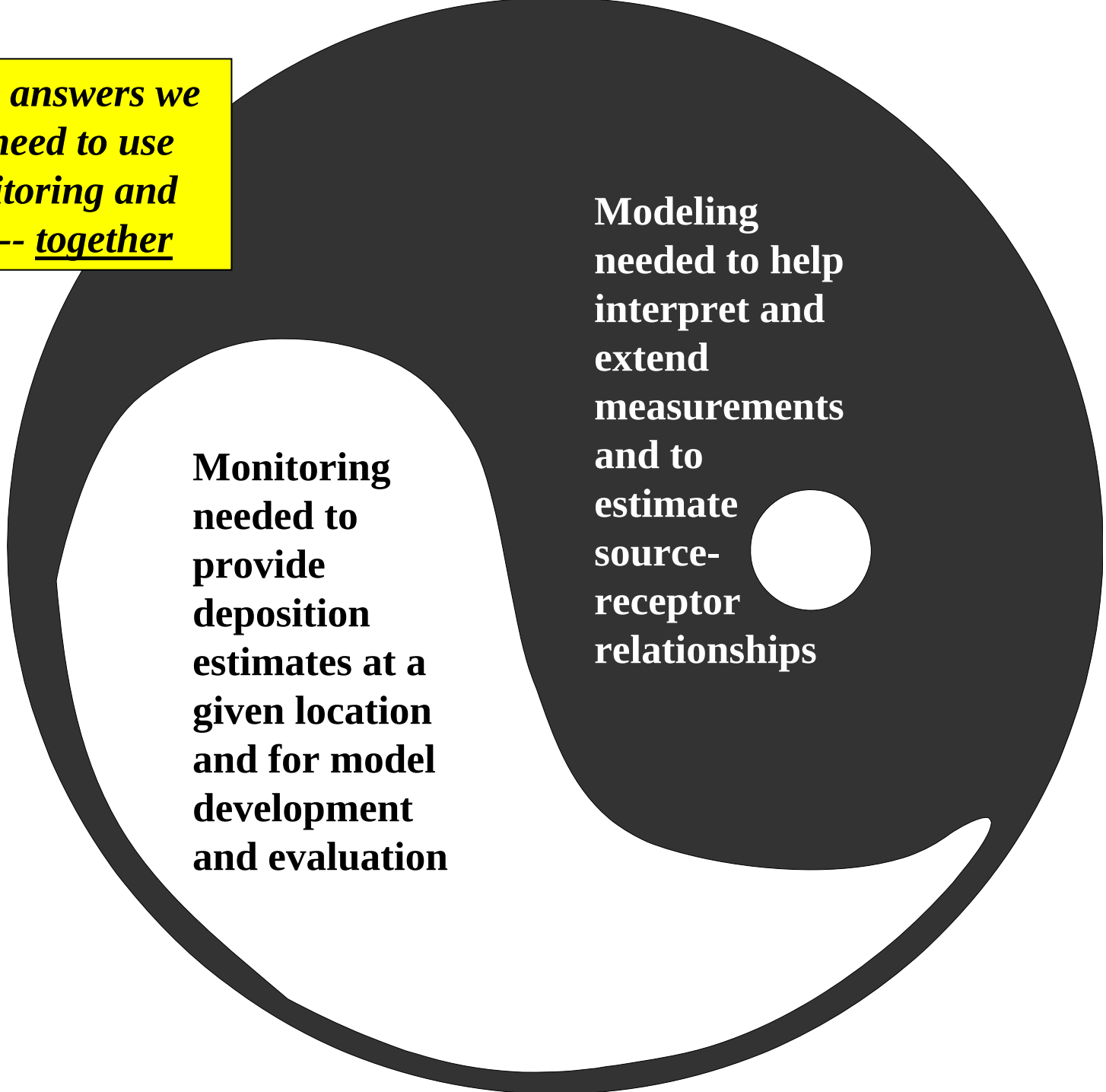
If they don't work, fundamental things about our understanding of atmospheric mercury that are wrong or incomplete…

More certain info at a few locations (monitoring) vs. less certain info region-wide (modeling)

Modeling vs. Monitoring



To get the answers we need, we need to use both monitoring and modeling -- <u>together</u>



Acknowledgements

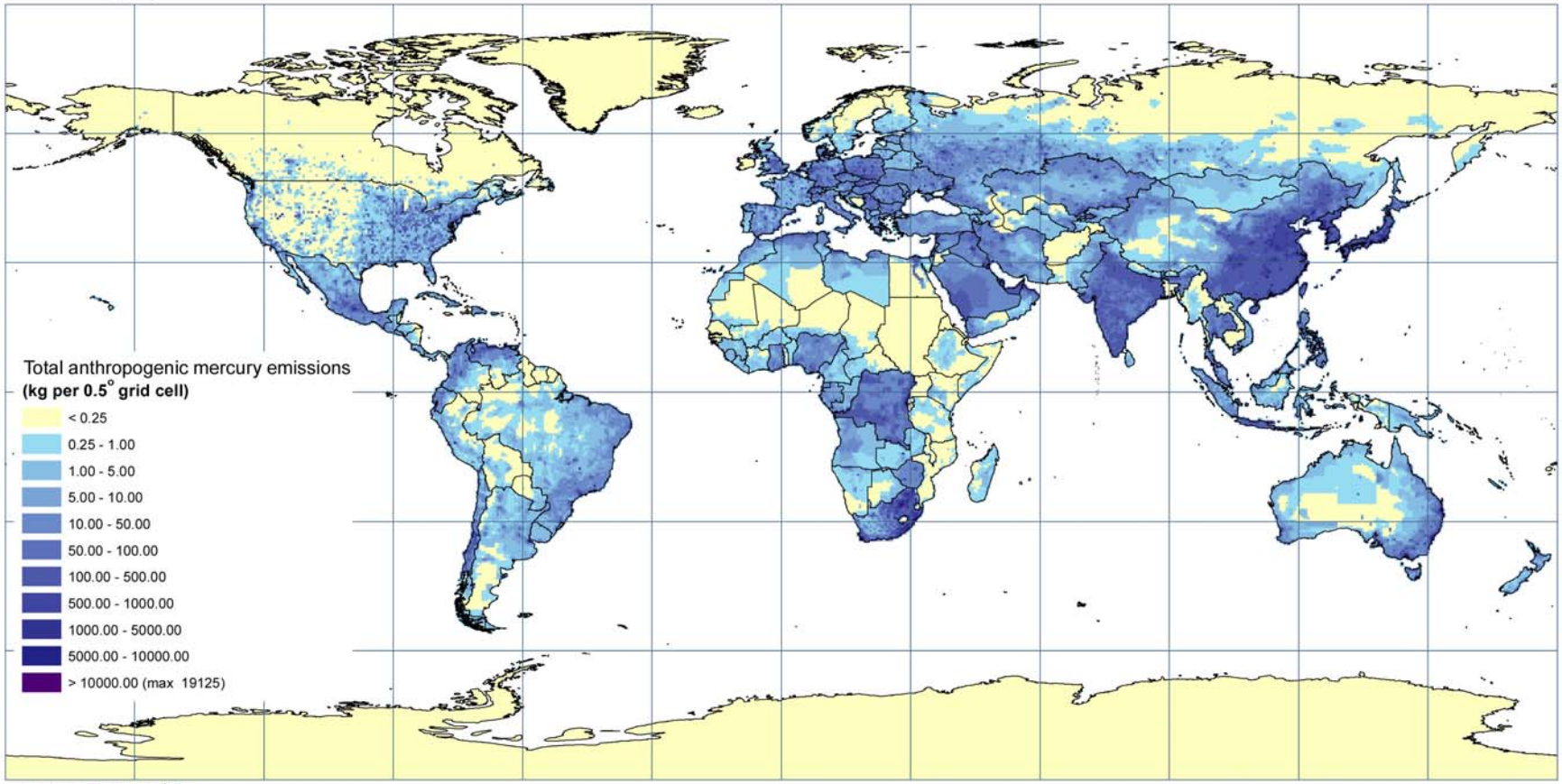
- Gary Matlock, Russell Callender, Jawed Hameedi (*NOAA NOS Nat'l Centers for Coastal Ocean Science*)
- David Schmeltz, Tim Sharac, Rick Haeuber, Sam Napolitano (*US EPA Clean Air Markets Division*)
- Jake Walker, Mark Woodrey, Glen Ruple (*Grand Bay National Estuarine Research Reserve*)
- Durwin Carter (*U.S. Fish and Wildlife Service -- Grand Bay National Wildlife Refuge*)
- Glenn Rolph, Barbara Stunder, Steve Fine (*NOAA Air Resources Laboratory*)
- Prof's Yerramilli Anjaneyulu, Jerzy Lesczcynski, Shelton Swanier & colleagues *(Jackson State Univ.)*

Thanks!

EXTRA SLIDES

Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere, 2000

Total Hg, point sources + distributed sources, 0.5° grid



unprojected (geographic)

citation:
Pacyna, J., S. Wilson and F. Steenhuisen. 2005.
Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere.
(www.amap.no/Resources/HgEmissions/HgInventoryMain.html)

S. Wilson (AMAP), F. Steenhuisen (Arctic Centre, RuG), J. Pacyna (NILU)

Inputs to Model

- meteorology
- emissions

For model evaluation, emissions and meteorology must be for the same time period as ambient measurement data

Atmospheric Mercury Model

- atmospheric chemistry
- wet deposition
- phase partitioning
- surface exchange

Model Evaluation

- Wet deposition data
- Speciated ambient concentration data

Model Outputs

- Wet and dry deposition of different Hg forms to Gulf of Mexico & watershed
- Source attribution information for deposition

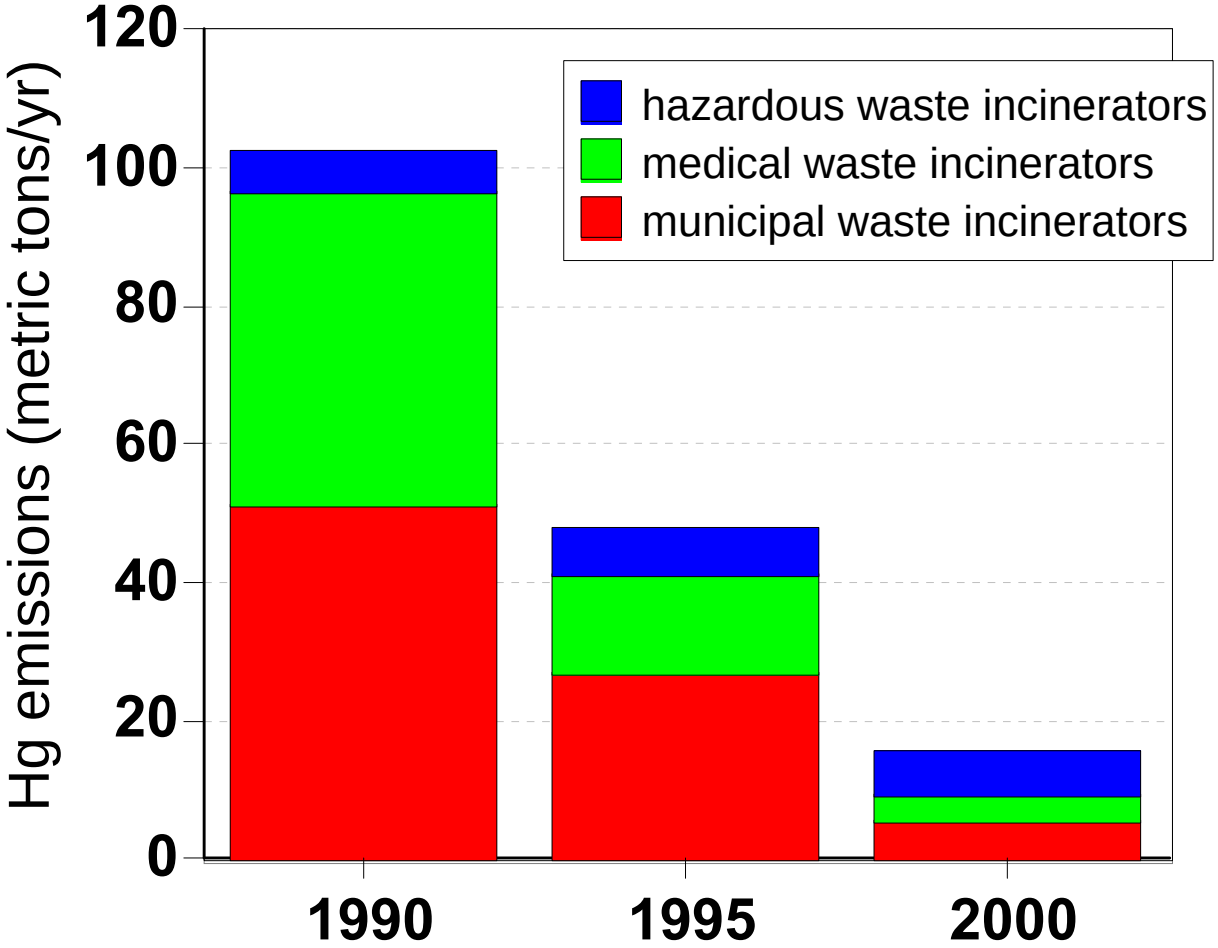
Atmospheric Mercury Modeling for the Gulf of Mexico region

examples of recent, current, and planned work

Model	Group(s)	PI's	Notes
TEAM-CTM	AER (Atmos. & Environ. Research, Inc.); EPRI	Christian Seigneur Leonard Levin	ongoing, global, nested grid
CMAQ-Hg	EPA	Russ Bullock	CAMR, regional + boundary
	Jackson State University	Yerramilli Anjaneyulu	meteorological and Hg modeling effort starting
	Florida DEP; Univ of Mich, others	Jerry Keeler	modeling to be carried out for Florida TMDL
REMSAD	EPA Office of Wetlands, Oceans & Watersheds; ICF	Dwight Atkinson, Ruth Chemerys	recent report; regional + boundary
Geos-Chem	Harvard University	Daniel Jacob	ongoing, global, coarse grid
HYSPLIT-Hg	NOAA Air Resources Laboratory	Mark Cohen Roland Draxler	ongoing, regional; soon global

- **Others?**
- **Collaboration? (e.g., emissions inventories, model intercomparisons)**

Mercury emissions from municipal and medical waste incineration in the United States dropped significantly during the 1990's

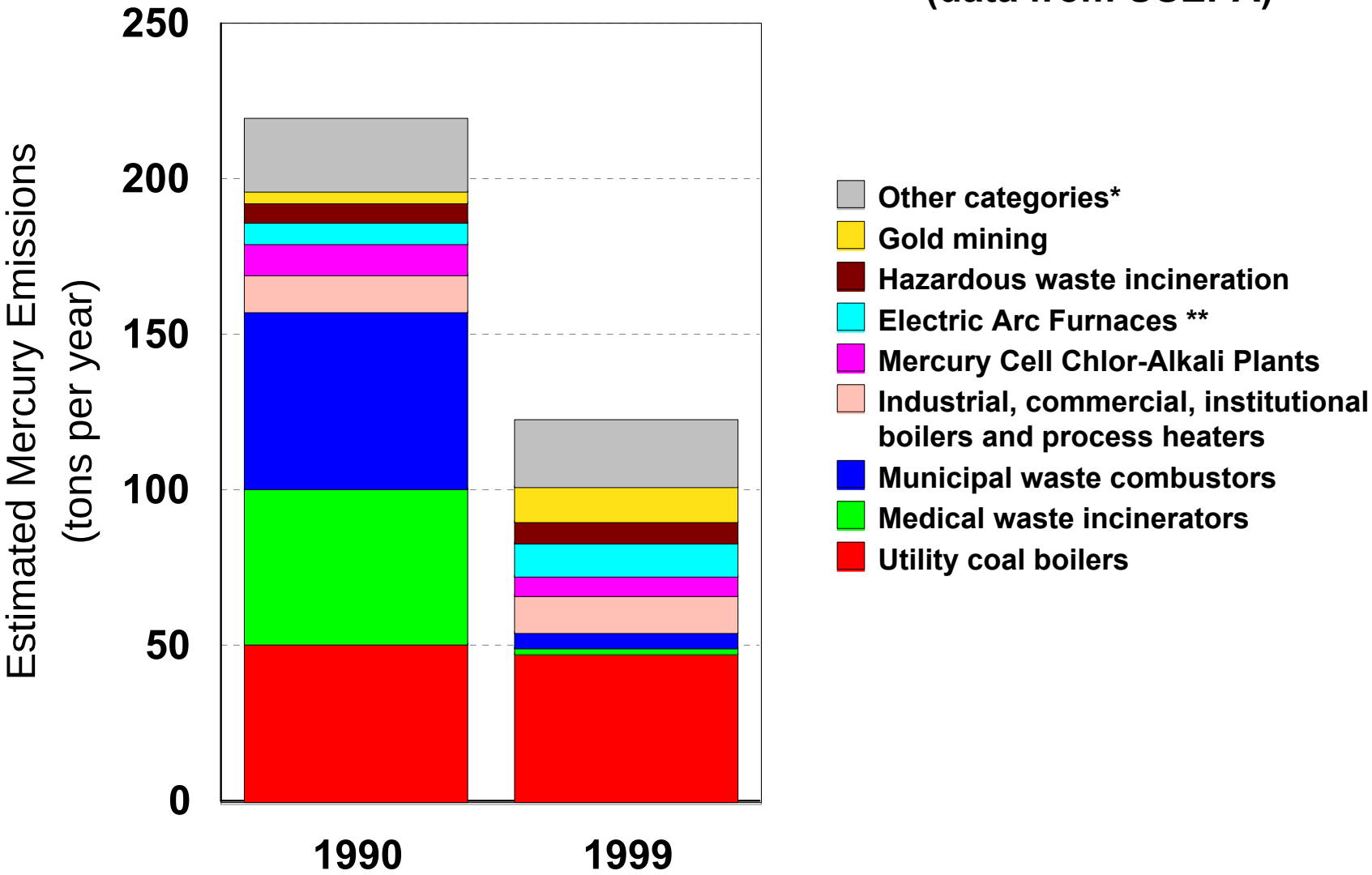


REASONS:

- o closure of some municipal waste incinerators and many medical waste incinerators
- o MACT-related pollution control requirements
- o reduction in mercury content of waste (e.g., battery legislation)

Direct, Anthropogenic Mercury Emissions in the United States

(data from USEPA)



* Data for Lime Manufacturing are not available for 1990.

** Data for Electric Arc Furnaces are not available for 1999. The 2002 estimate (10.5 tons) is shown here.

Some events in the U.S. regulation and prevention of mercury emissions

1965

1970

1975

1980

1985

1990

1995

2000

2005

2010

1970's - 1990's: many mercury-cell chlor-alkali plants converted to alternate processes or closed due to regulatory and other pressures

Clean Air Act Amendments of 1990 – calls for Maximum Achievable Control Technology (MACT) to regulate hazardous air pollutants; *intent is to prohibit emissions trading for these air toxics*

1990's – Hg emissions from municipal and medical waste incinerators fall dramatically due to:

- closure of *some* municipal waste incinerators and *many* medical waste incinerators
- MACT-related pollution control requirements
- reduction in mercury content of waste (e.g., battery legislation)

2002 – Clear Skies Initiative for power plants introduced *(ultimately withdrawn)*

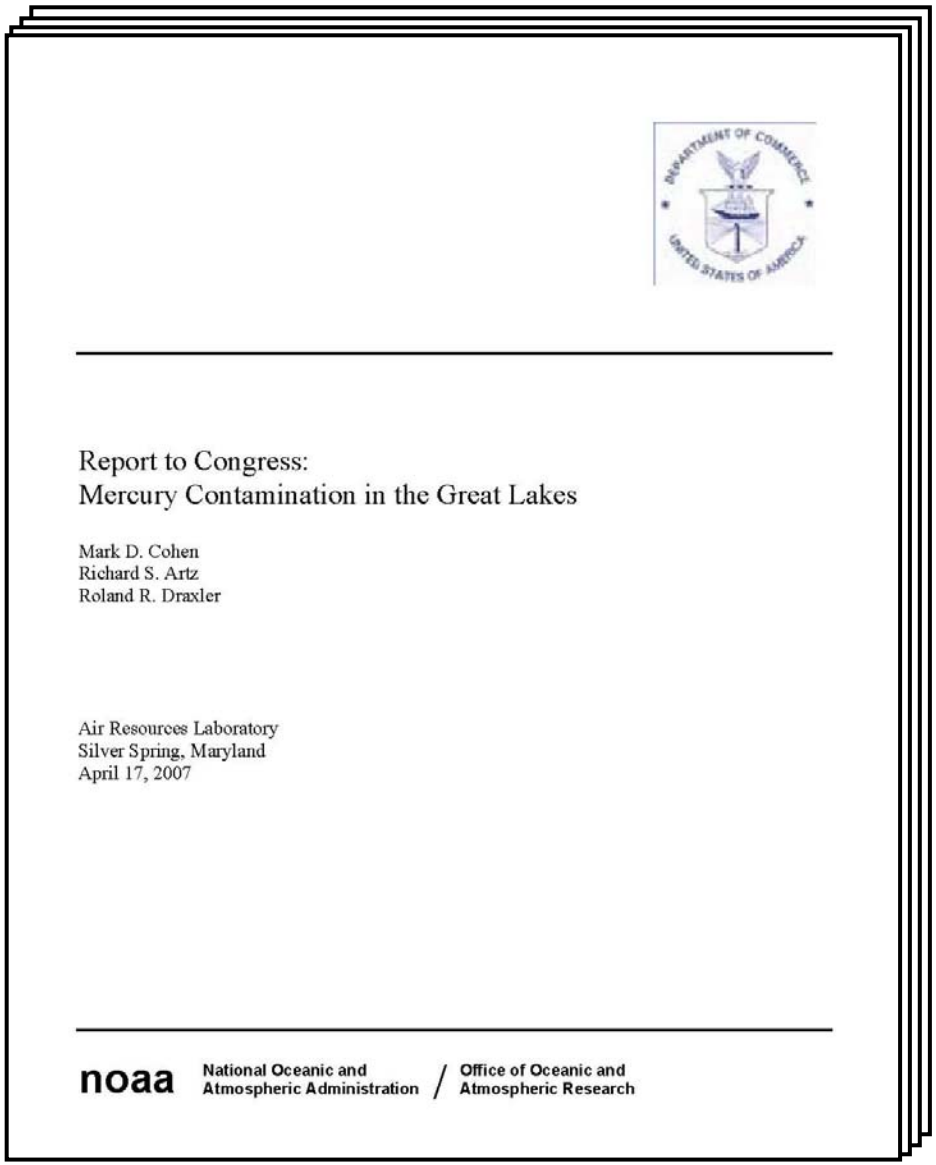
2005 – CAIR (Clean Air Interstate Rule) for power plants (Hg reduced as co-benefit of SO_2 & NO_x controls)

2005 – EPA meets court-ordered deadline and promulgates CAMR (Clean Air Mercury Rule) for power plants – *based on Hg emissions trading*

"Hot Spot" Controversy -- Many States sue EPA & propose / promulgate more strict regulations

NOAA Report to Congress on Mercury Contamination in the Great Lakes

http://www.arl.noaa.gov/data/web/reports/cohen/NOAA_GL_Hg.pdf



Report to Congress:
Mercury Contamination in the Great Lakes

Mark D. Cohen
Richard S. Artz
Roland R. Draxler

Air Resources Laboratory
Silver Spring, Maryland
April 17, 2007

noaa National Oceanic and Atmospheric Administration / Office of Oceanic and Atmospheric Research

- The Conference Report accompanying the consolidated Appropriations Act, 2005 (H. Rpt. 108-792) requested that NOAA, in consultation with the EPA, report to Congress on mercury contamination in the Great Lakes, with trend and source analysis.
- Reviewed by NOAA, EPA, DOC, White House Office of Science and Technology Policy, and Office of Management and Budget (OMB).
- Review process took ~2 years.
- Transmitted to Congress on May 14, 2007

Atmospheric Chemical Reaction Scheme for Mercury

Reaction	Rate	Units	Reference
GAS PHASE REACTIONS			
$Hg^0 + O_3 \rightarrow Hg(p)$	3.0E-20	cm^3/molec-sec	Hall (1995)
$Hg^0 + HCl \rightarrow HgCl_2$	1.0E-19	cm^3/molec-sec	Hall and Bloom (1993)
$Hg^0 + H_2O_2 \rightarrow Hg(p)$	8.5E-19	cm^3/molec-sec	Tokos et al. (1998) (upper limit based on experiments)
$Hg^0 + Cl_2 \rightarrow HgCl_2$	4.0E-18	cm^3/molec-sec	Calhoun and Prestbo (2001)
Hg^0 +OH☝ $\rightarrow$ Hg(p)	8.7E-14	cm^3/molec-sec	Sommar et al. (2001)
AQUEOUS PHASE REACTIONS			
$Hg^0 + O_3 \rightarrow Hg^{+2}$	4.7E+7	$(molar\text{-}sec)^{-1}$	Munthe (1992)
Hg^0 + OH☝ $\rightarrow Hg^{+2}$	2.0E+9	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1997)
$HgSO_3 \rightarrow Hg^0$	$T*e^{((31.971*T)-12595.0)/T)}$ sec^{-1} [T = temperature (K)]		Van Loon et al. (2002)
Hg(II) + HO_2☝ $\rightarrow Hg^0$	~ 0	$(molar\text{-}sec)^{-1}$	Gardfeldt & Jonnson (2003)
$Hg^0 + HOCl \rightarrow Hg^{+2}$	2.1E+6	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1998)
$Hg^0 + OCl^{-1} \rightarrow Hg^{+2}$	2.0E+6	$(molar\text{-}sec)^{-1}$	Lin and Pehkonen(1998)
Hg(II) $\leftrightarrow$ Hg(II)$_{(soot)}$	9.0E+2	liters/gram; t = 1/hour	eqlbrm: Seigneur et al. (1998) rate: Bullock & Brehme (2002).
Hg^{+2} + h🖫 $\rightarrow Hg^0$	6.0E-7	$(sec)^{-1}$ (maximum)	Xiao et al. (1994); Bullock and Brehme (2002)

Total mercury deposition in the Gulf of Mexico region for 2001 estimated by the USEPA-NOAA CMAQ-Hg model (micrograms per square meter, 36 km grid)

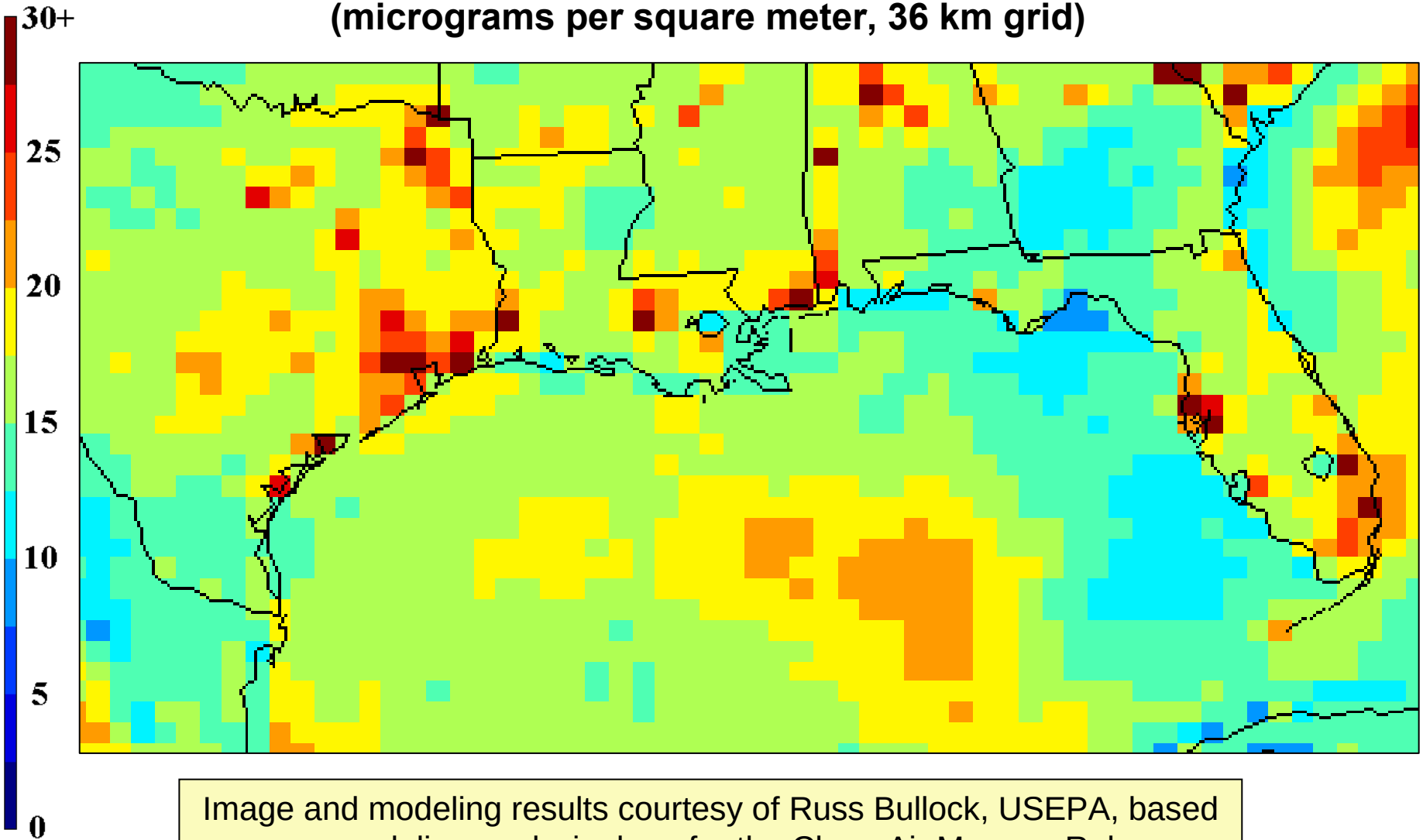
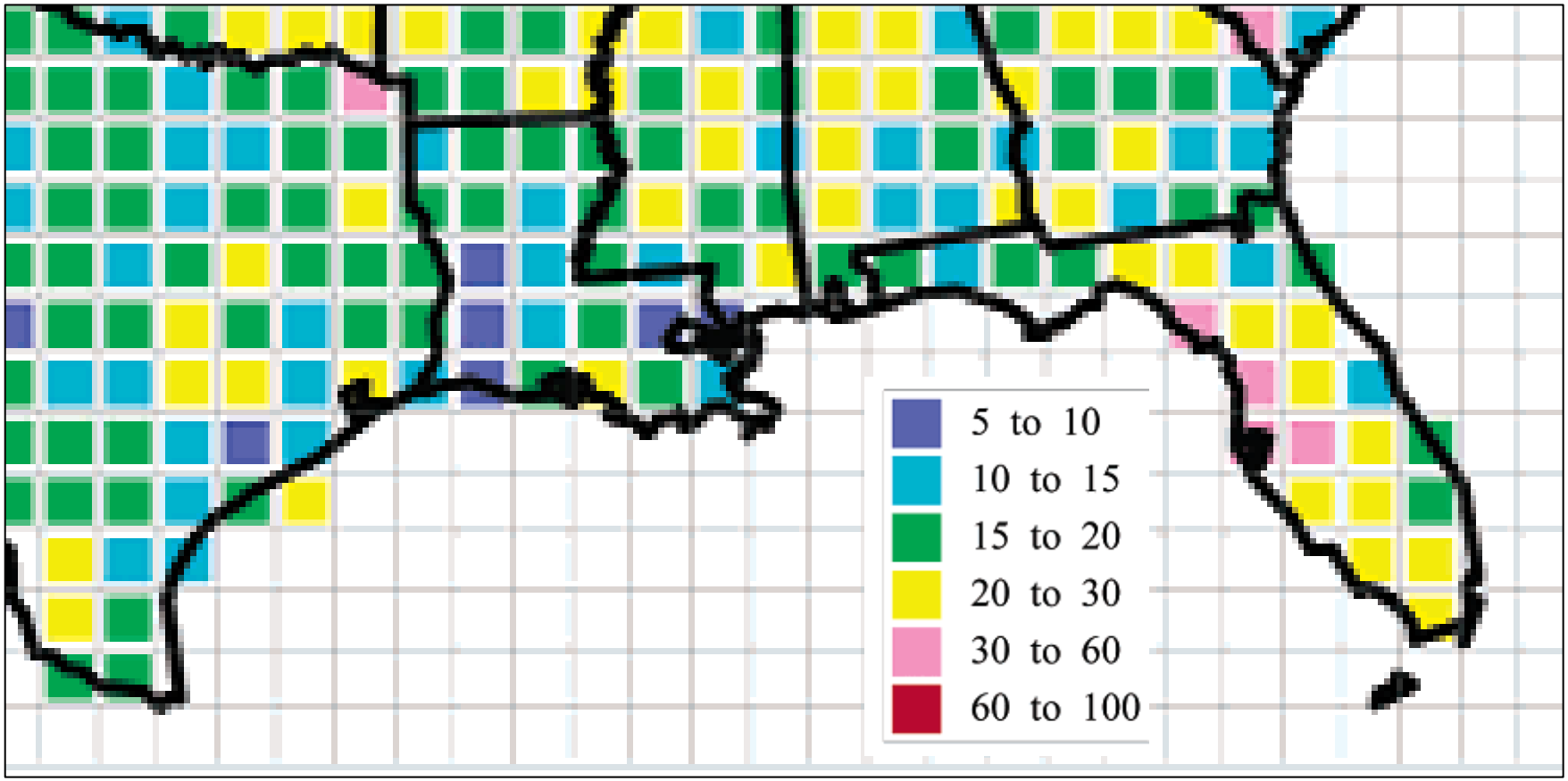


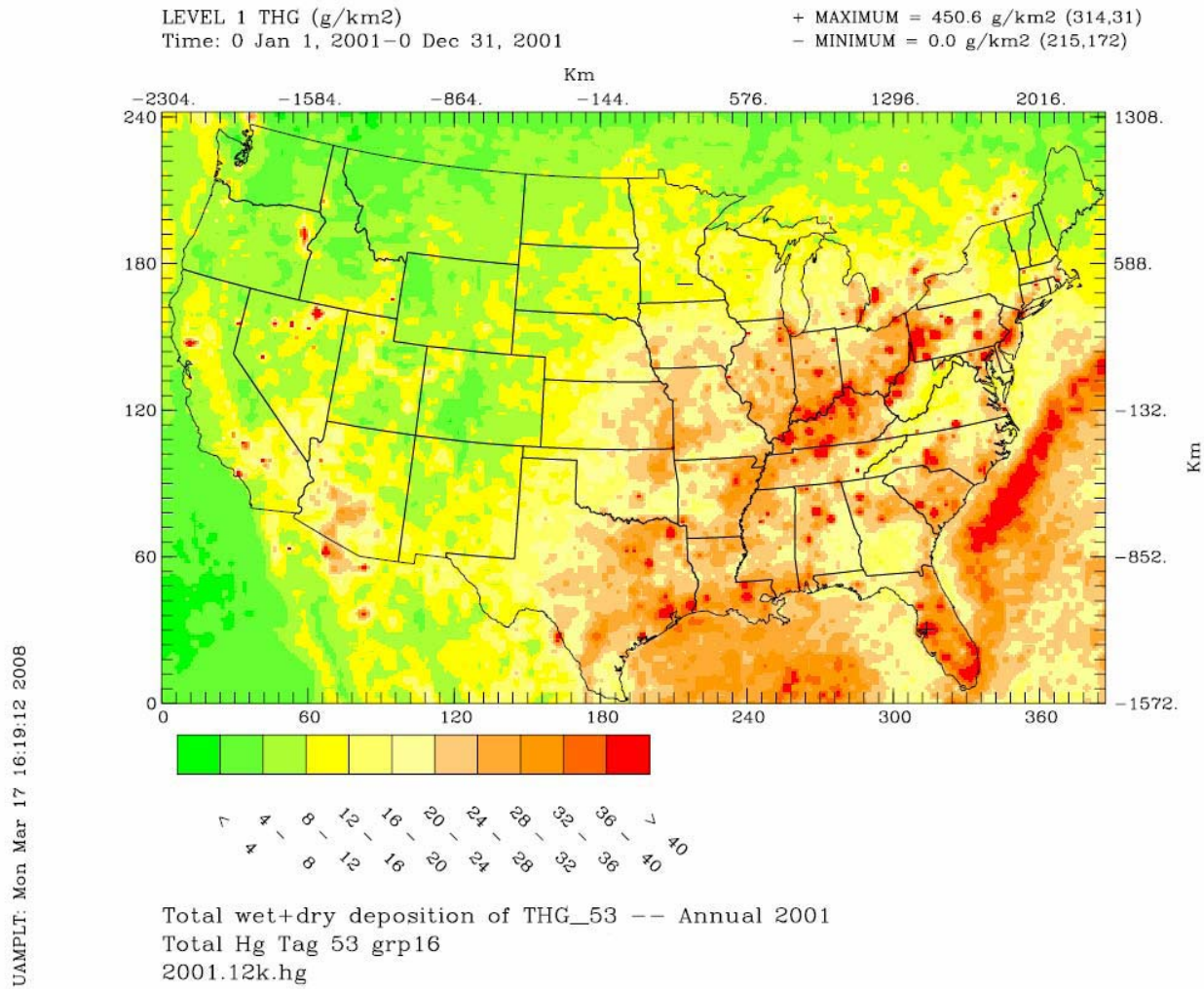
Image and modeling results courtesy of Russ Bullock, USEPA, based on modeling analysis done for the Clean Air Mercury Rule

Total mercury deposition in the Gulf of Mexico region (ca. mid to late 1990's) estimated by the EPRI TEAM-Hg model, coupled with a global chemical transport model (micrograms per square meter, 100 km grid)

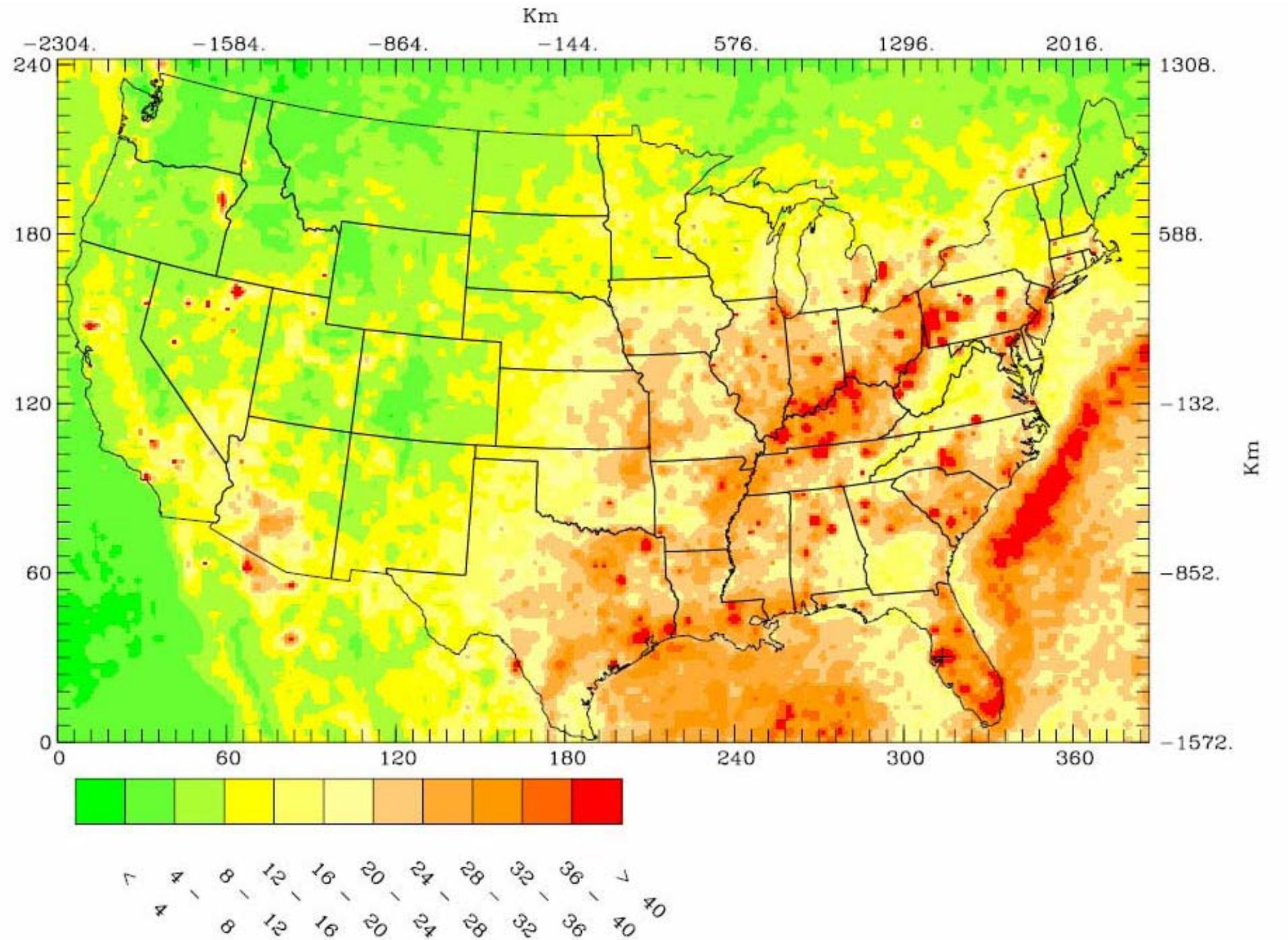


Seigneur, C., *et al.* (2004). Global Source Attribution for Mercury Deposition in the United States. ***Environ. Sci. Technol.* 38**, 555-569

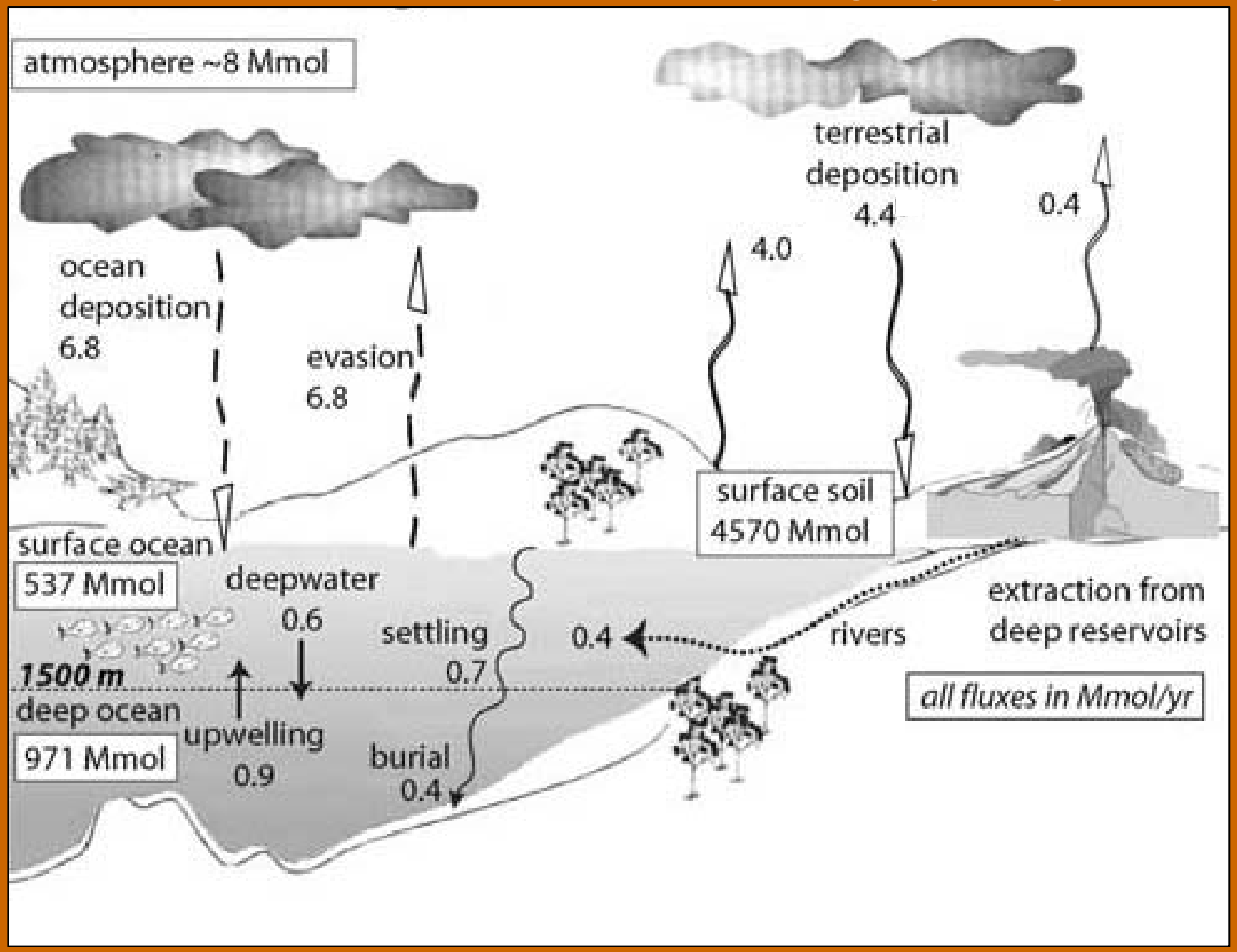
Figure 6-3c. Simulated Annual Mercury Deposition (g km-2) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Total (Dry + Wet) Deposition.



Model-Based Analysis And Tracking Of Airborne Mercury Emissions To Assist in Watershed Planning. August 2008, Watershed Branch (4503-T), Office of Wetlands, Oceans, and Watersheds, U.S. EPA, Washington, DC. *http://www.epa.gov/owow/tmdl/pdf/final300report_10072008.pdf*

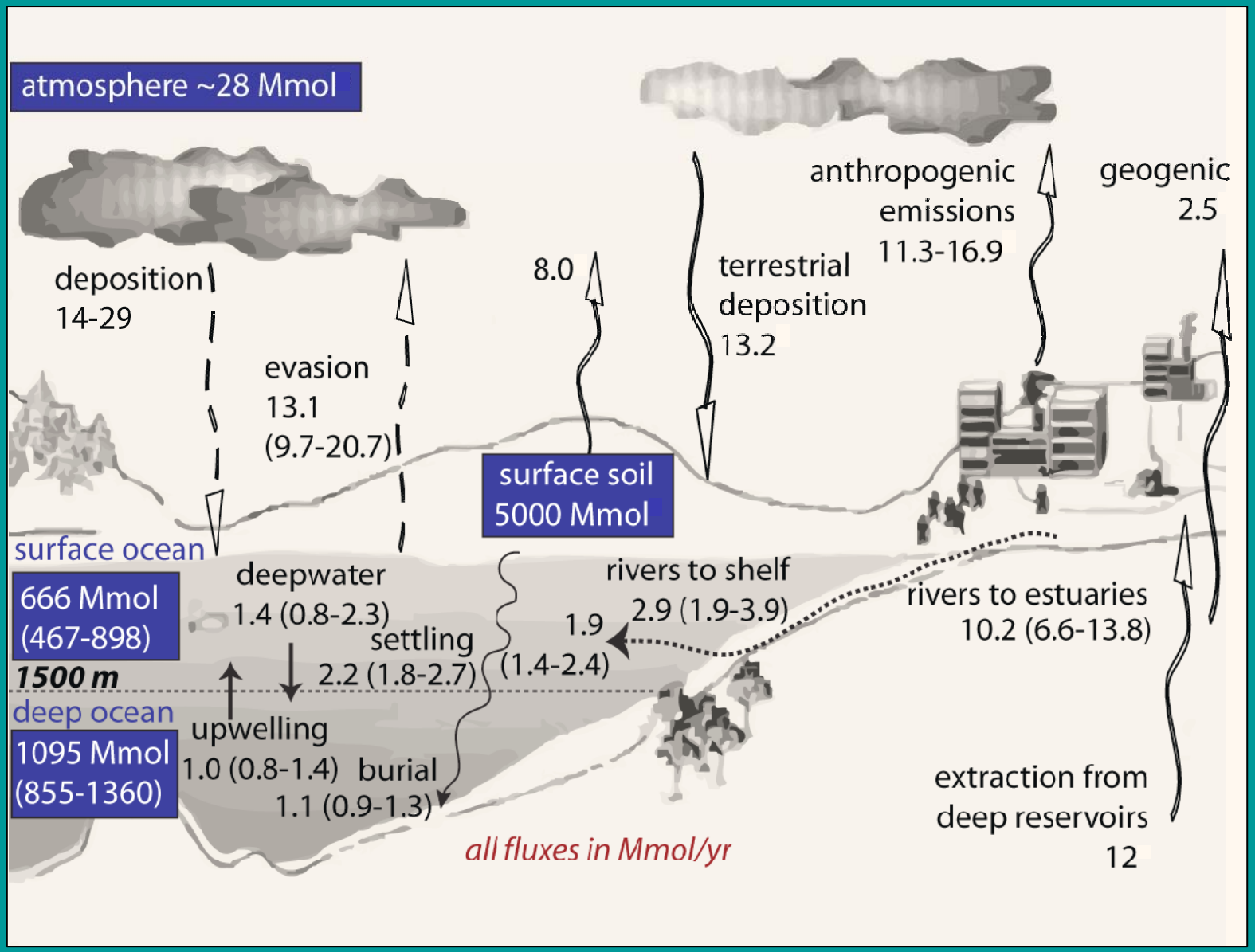

Km
−2304.
−1584.
−864.
−144.
576.
1296.
2016.
240
180
120
60
0
1308.
588.
−132.
−852.
−1572.
Km
0
60
120
180
240
300
360
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
32 - 36
36 - 40
> 40

Pre-Industrial Global Mercury Cycling



Sunderland and Mason (2007). Global Biogeochemical Cycles 21, 4022

Contemporary Global Mercury Cycling



Sunderland and Mason (2007). Global Biogeochemical Cycles 21, 4022

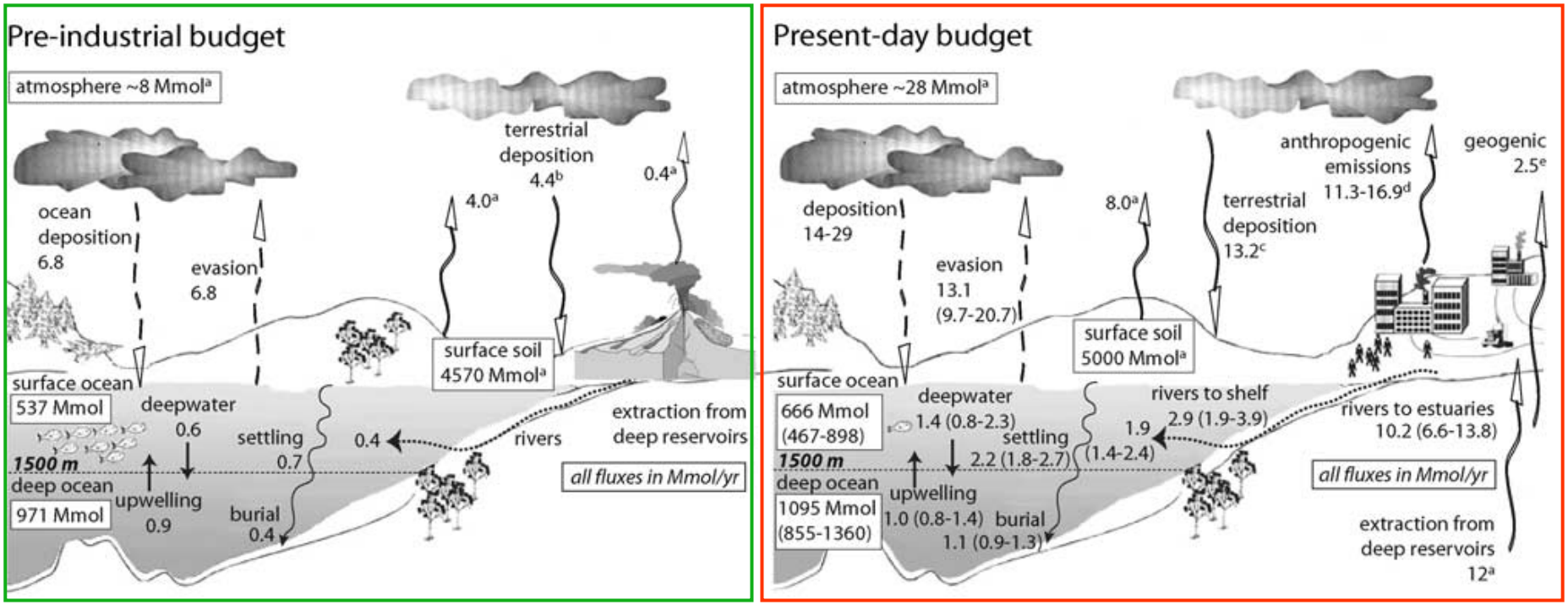
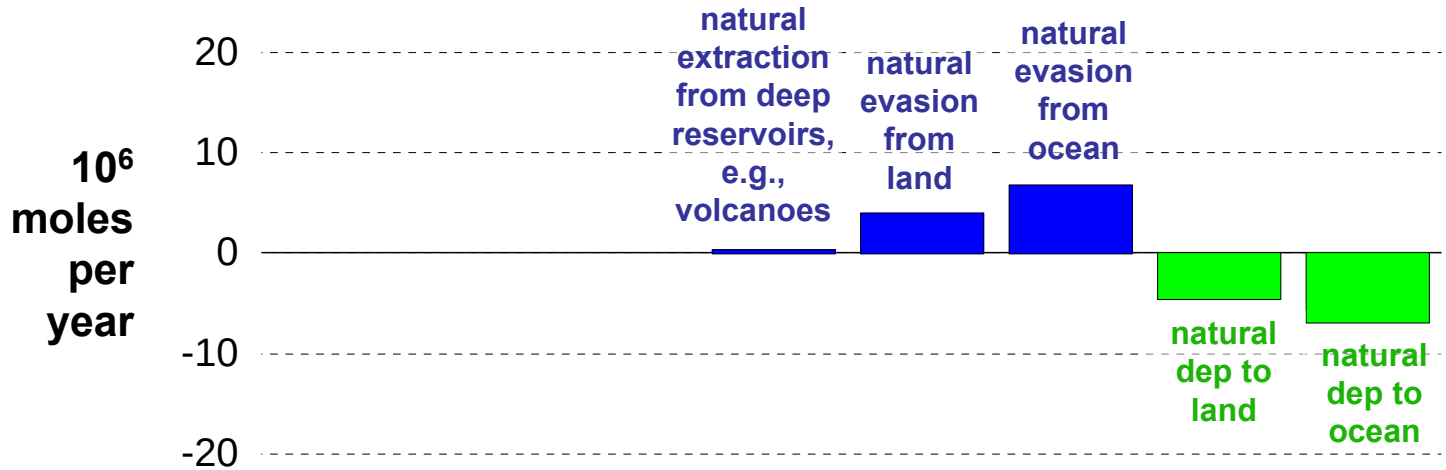


Figure 4. Global budgets for current and preindustrial mercury cycling in oceans. For the present-day ocean, 90% confidence intervals are shown in brackets. Note that for the present-day budget, river fluxes shown refer to the amounts of mercury deposited in each region (estuaries, shelf, open ocean), not the total flux (sum >14 Mmol). (a) From Mason and Sheu [2002]. (b) Calculated by assuming preindustrial atmosphere is at steady state. (c) Estimated from sediment core data showing contemporary atmospheric deposition to terrestrial systems is approximately 3 times greater than preindustrial deposition [Fitzgerald et al., 1998]. (d) Lower end of range is year 2000 global anthropogenic emissions from Pacyna et al. [2006]. Upper limit of anthropogenic emissions were used in GEOS-Chem simulations and include additional sources described by Selin et al. [2007b]. (e) Estimate derived by Selin et al. [2007b].

FROM: Elsie M. Sunderland and Robert P. Mason (2007). Human impacts on open ocean mercury concentrations. GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 21, GB4022.

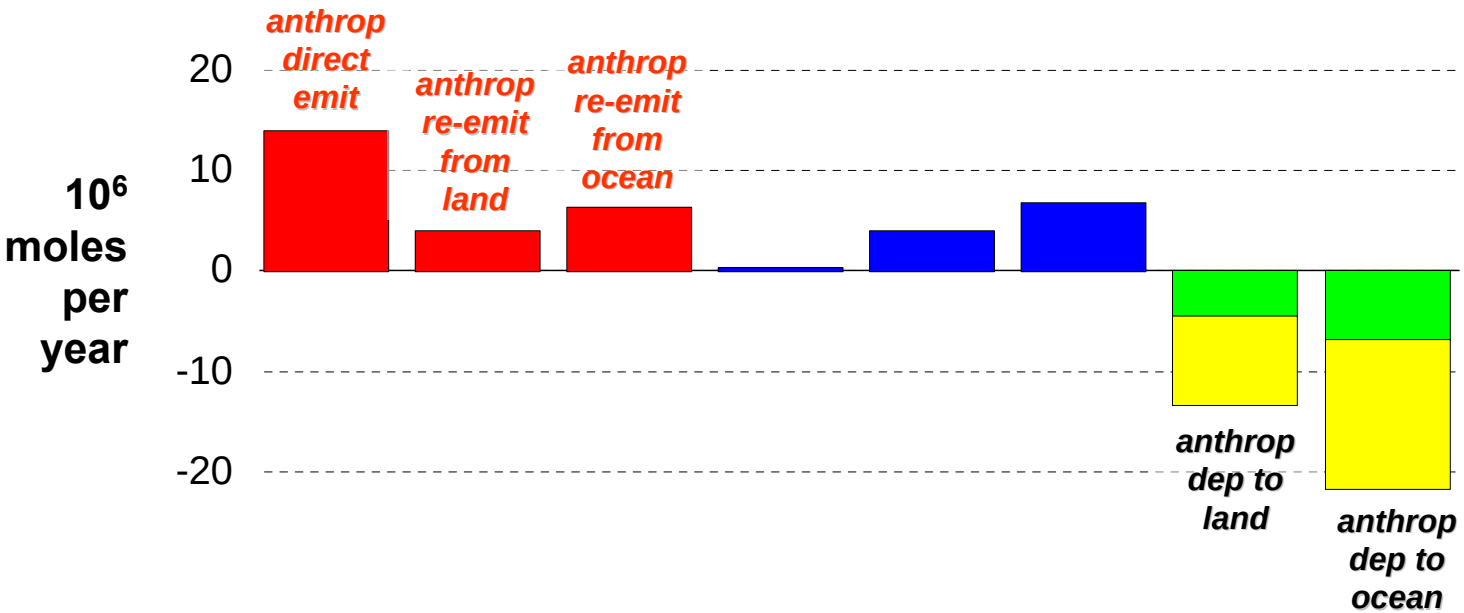
GLOBAL MERCURY CYCLING

(note -10^6 moles ~ 200 metric tons)



pre-industrial: **total mercury in atmosphere ~ 8.0 x 10^6 moles**

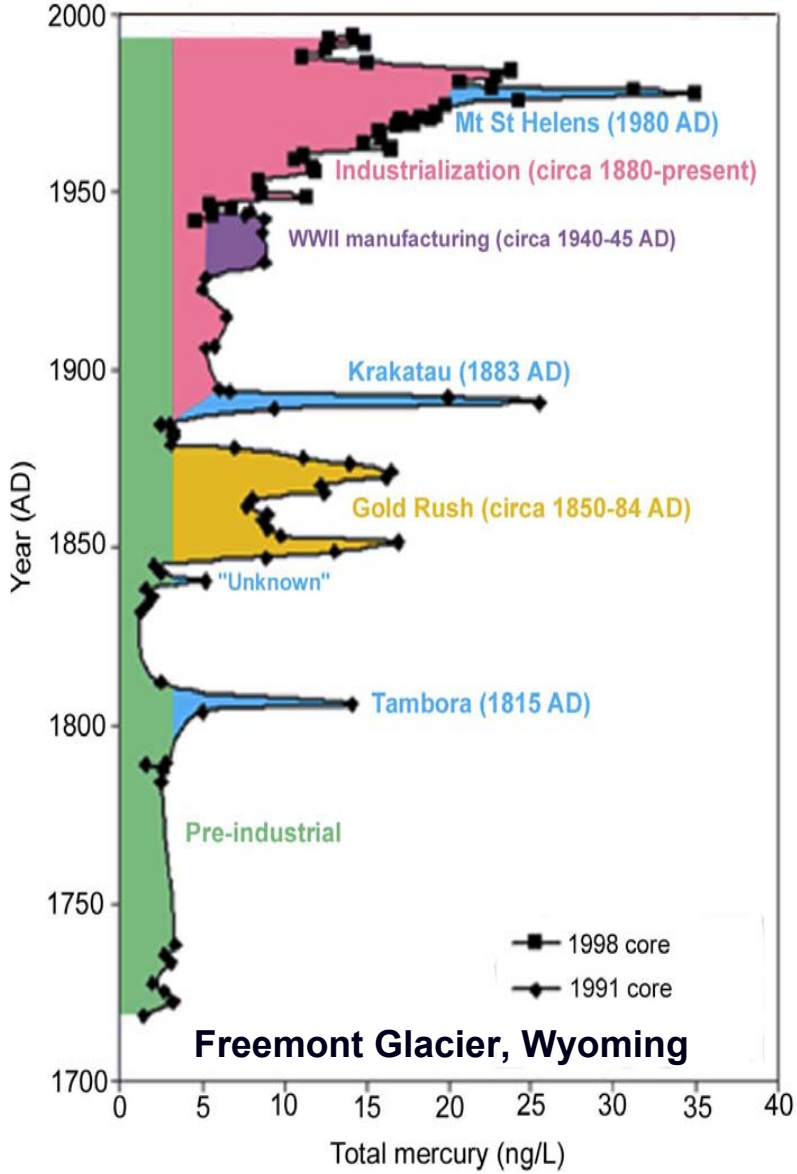
Based on data presented in Sunderland and Mason (2007) *Global Biogeochemical Cycles* **21**: GB4022



contemporary: **total mercury in atmosphere ~ 28.0 x 10^6 moles**

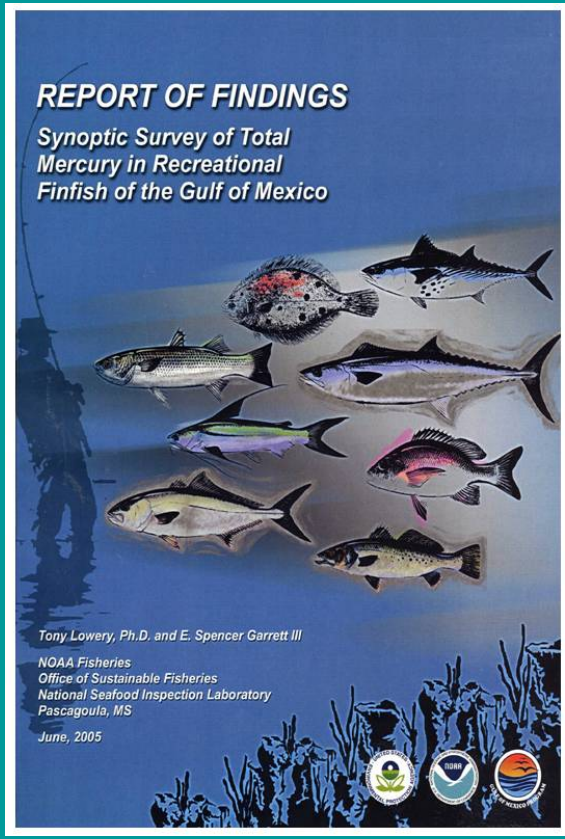
Natural vs. anthropogenic mercury?

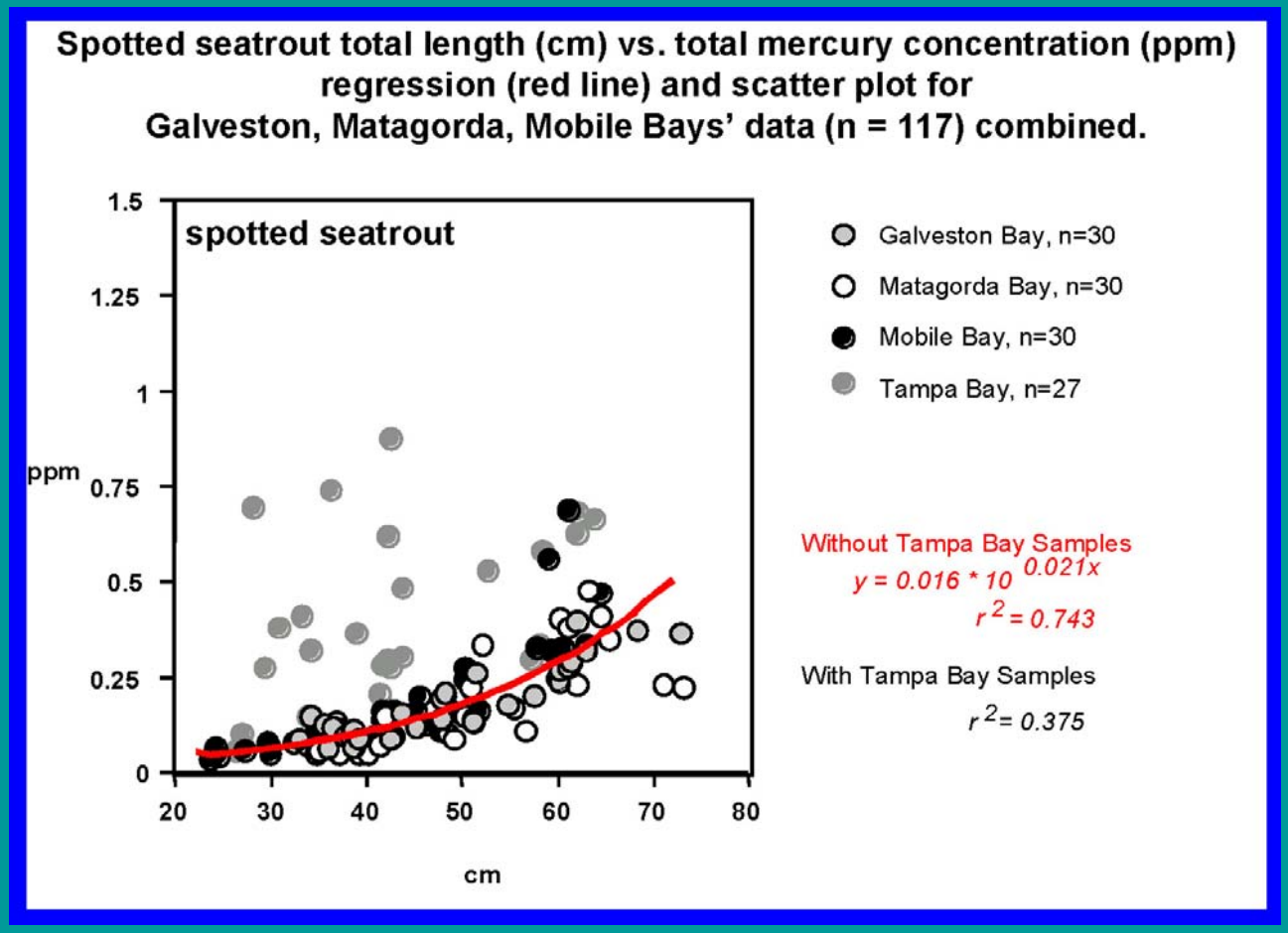
Studies show that anthropogenic activities have typically increased bioavailable Hg concentrations in ecosystems by a factor of 2 – 10



source: USGS, Shuster et al., 2002

NOAA Fisheries, Office of Sustainable Fisheries, National Seafood Inspection Laboratory
Tony Lowery, Spencer Garrett and colleagues





- total mercury in Gulf of Mexico recreational finfish
- reconnaissance survey to provide info for larger surveys
- cookbook for conducting estuarine and marine fish surveys

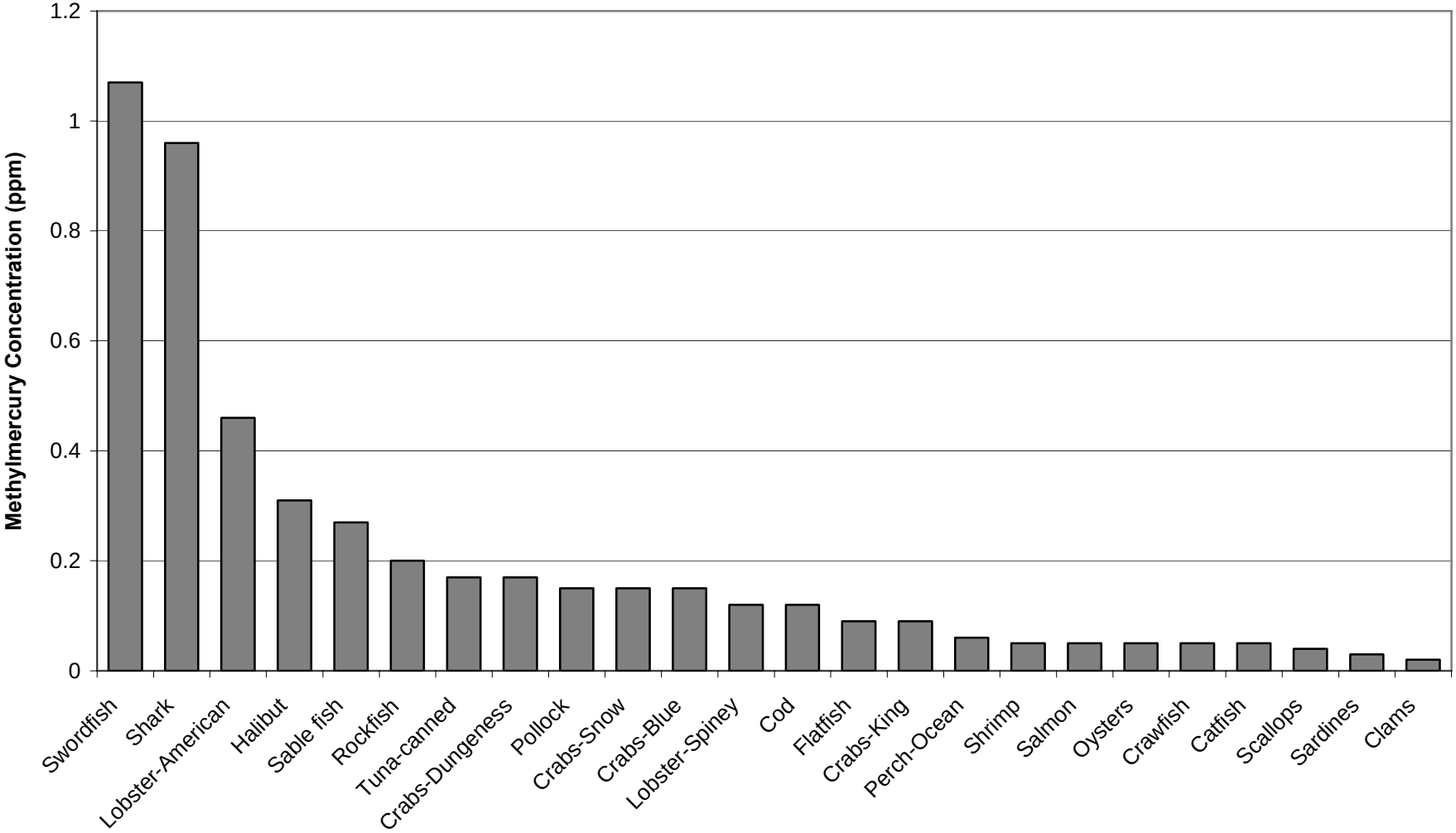
Slide content from Tony Lowery, NOAA

Public Health Context

Public Health Context

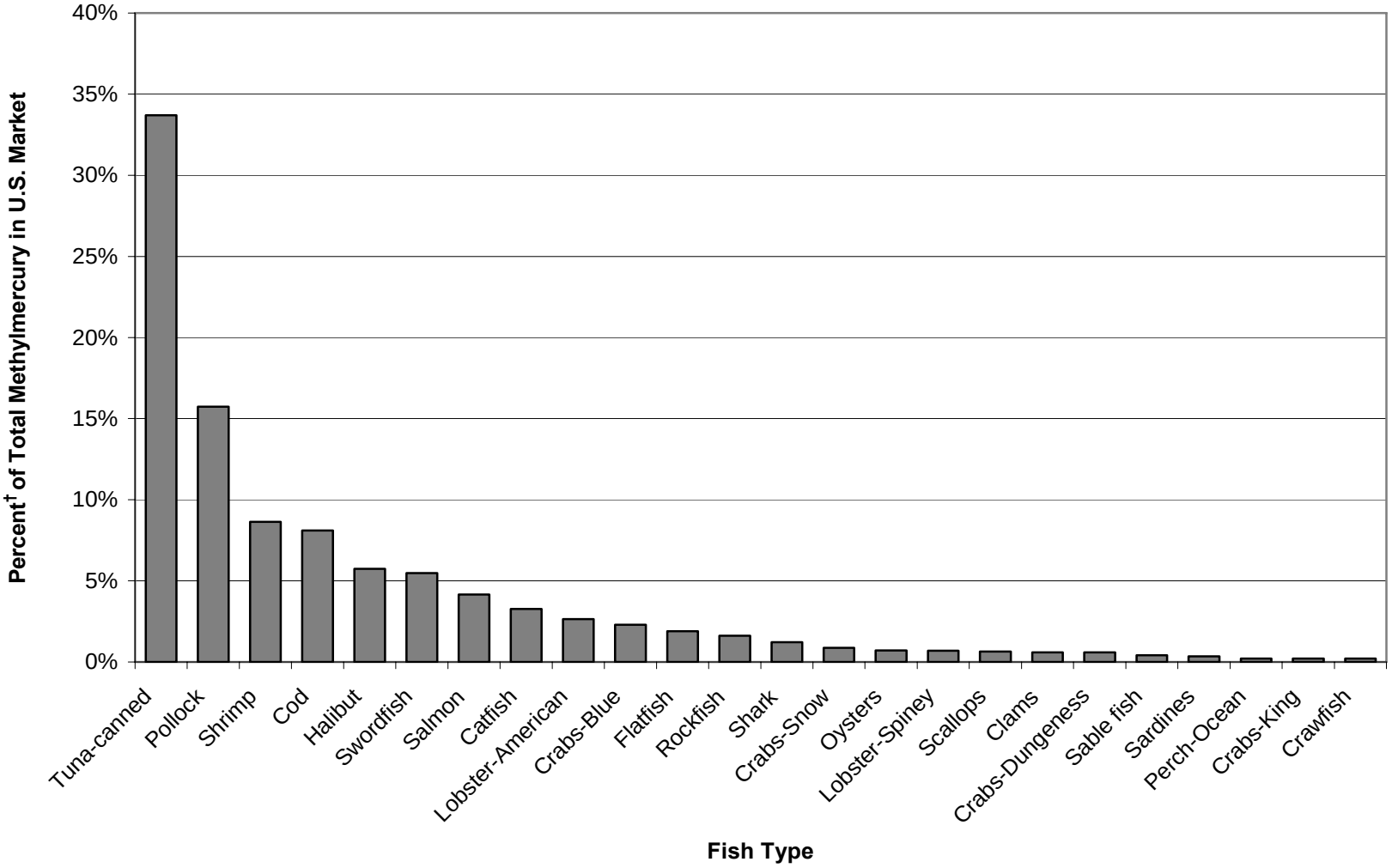
- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity *relatively* well understood
  - well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: *methylmercury* from *fish consumption*

Mean Methylmercury Concentrations for "Top 24" Types of Fish Consumed in U.S. Commercial Seafood Market



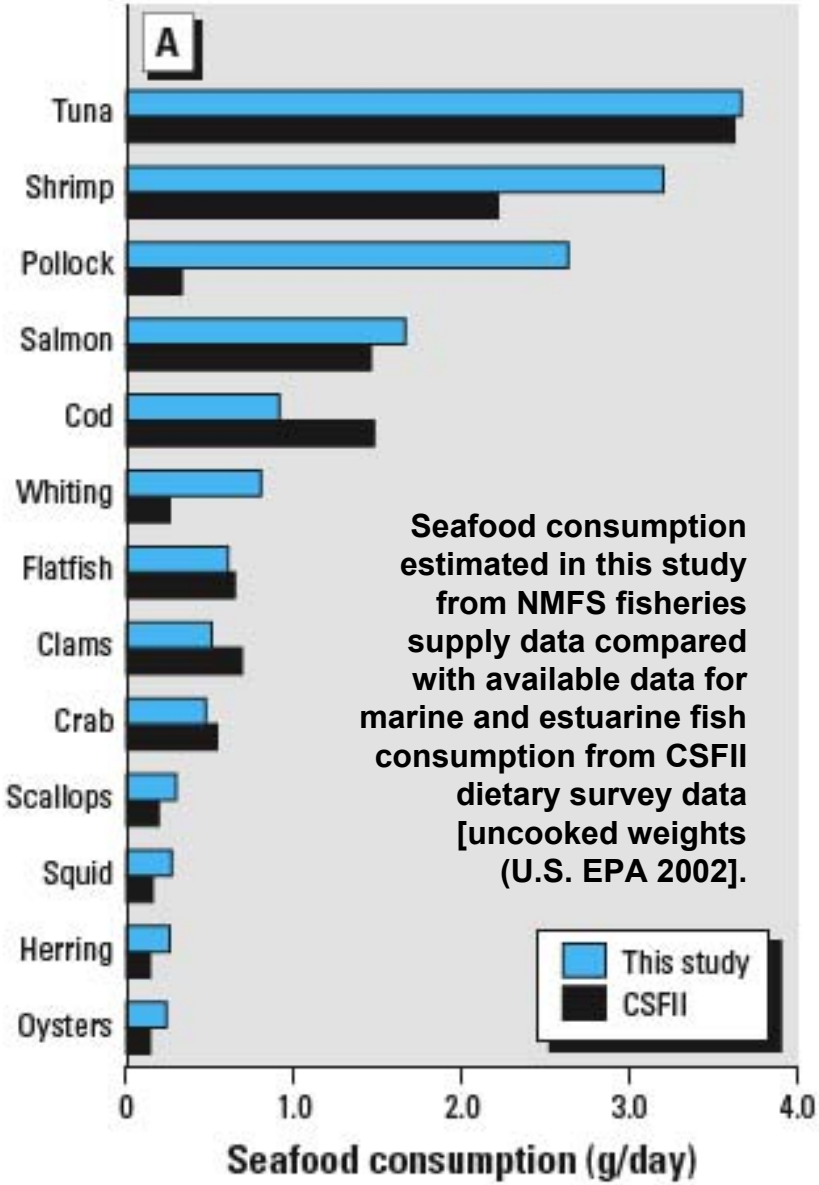
Source of data: Carrington and Bolger, 2002
Based on slide from: Elsie Sunderland, USEPA

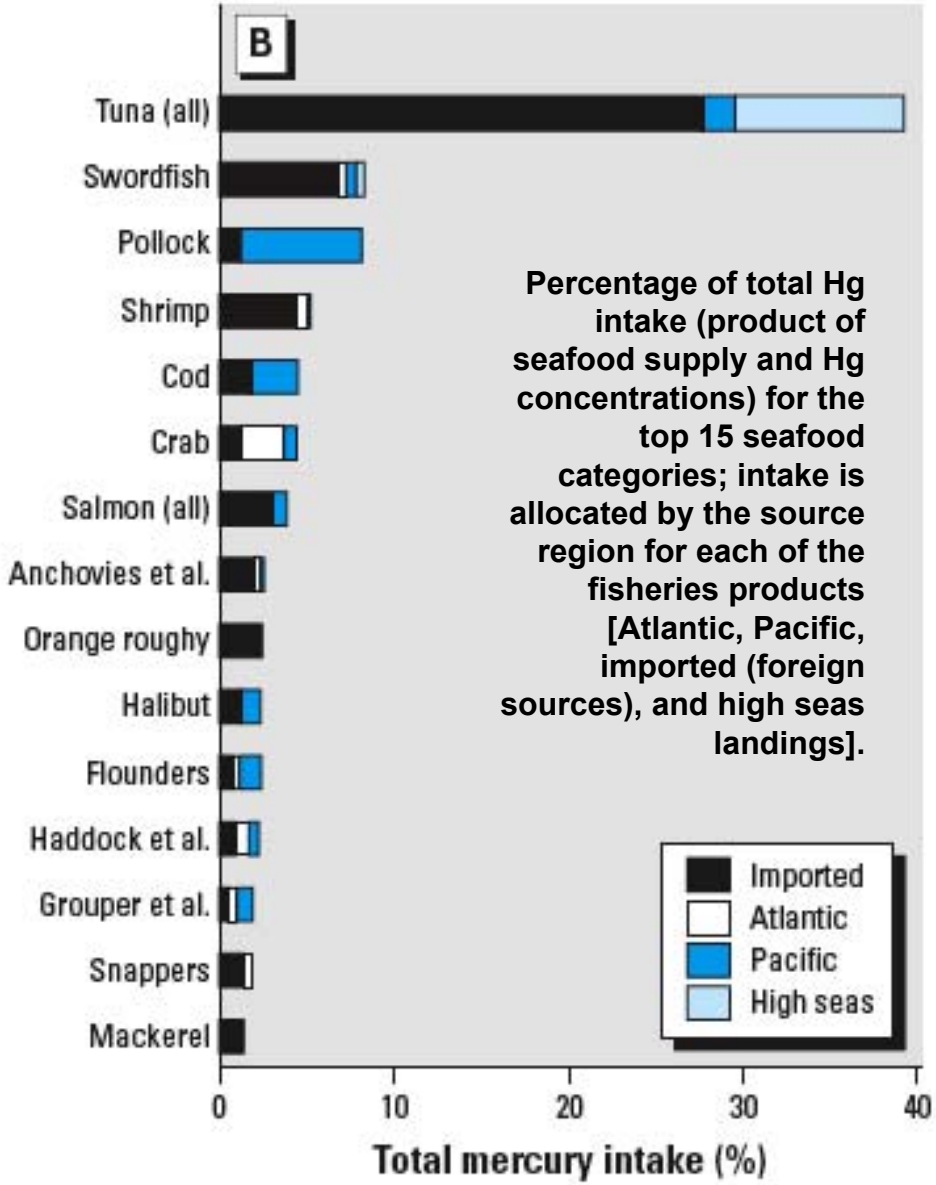
Percent Contribution to per capita Methylmercury Intake by Fish Type for "Top 24" Types of Fish in U.S. Commercial Seafood Market



Source of data: Carrington and Bolger, 2002
Based on slide from: Elsie Sunderland, USEPA

U.S. Population-Wide Consumption & Hg Exposure for Marine and Estuarine Fish





Sunderland, E. (2007). Mercury exposure from domestic and imported estuarine and marine fish in the U.S. seafood market. *Environ Health Perspect* **115**(2):235-42.

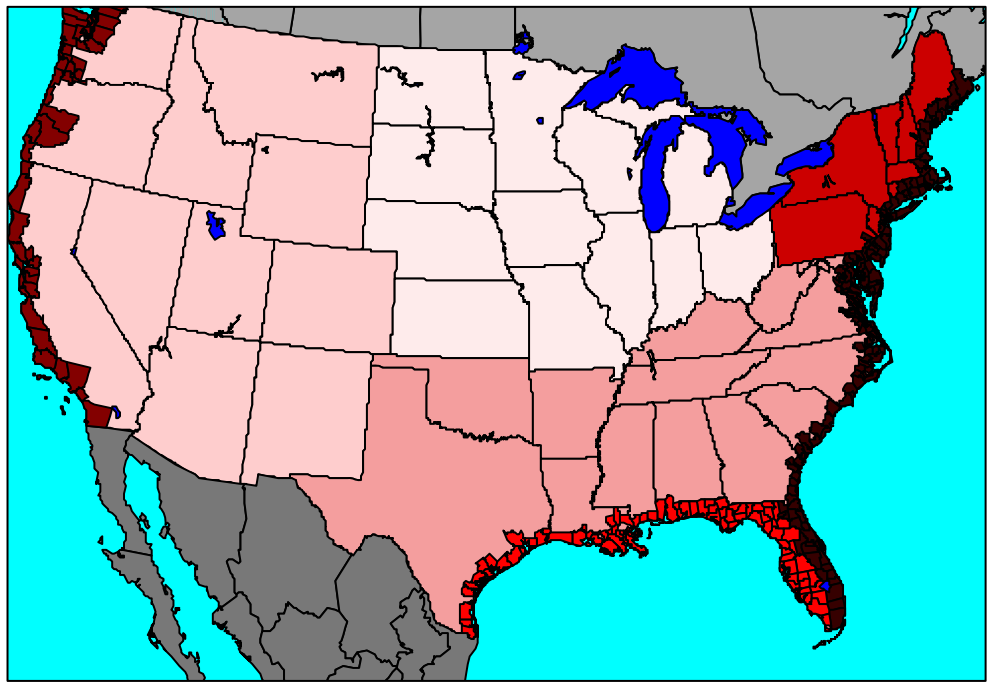
Public Health Context

- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity *relatively* well understood
  - well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: *methylmercury* from *fish consumption*
- **Toxicity believed to be occurring at current exposures**

Blood Hg (ug/L) - U.S. Women ages 6-49 based on NHANES data (1999-2002)

Mean Organic [Hg] µg/L (95% CI)

- **2.7 (2.4-3.1) Atlantic Coast**
- **1.7 (1.5-1.9) Pacific Coast**
- **1.4 (0.7-2.0) Northeast**
- **1.3 (0.6-2.0) Gulf Coast**
- **1.1 (0.7-1.6) South**
- **1.0 (0.7-1.2) West**
- **0.8 (0.6-1.0) Mid West**



Source of data: Mahaffey et al., 2005
Based on slide from: Elsie Sunderland, USEPA

- Based on the NHANES national survey, approximately 6% of women of child-bearing age in the U.S. have blood mercury levels above the EPA's Reference Dose for potential adverse fetal/infant health impacts (~3600 women tested nationwide)

Jones et al. (2004). Blood mercury levels in young children and childbearing-aged women - United States, 1999–2002. *Morbidity and Mortality Weekly Report* (CDC). **53**(43):1018–1020.

- There is controversy over the absolute level of the reference dose and how to interpret it

- ~4,000,000 U.S. live births / yr x ~6% = ~240,000 newborns potentially at risk each year

- NHANES is not designed to capture vulnerable sub-populations with unusually high fish consumption and mercury exposure

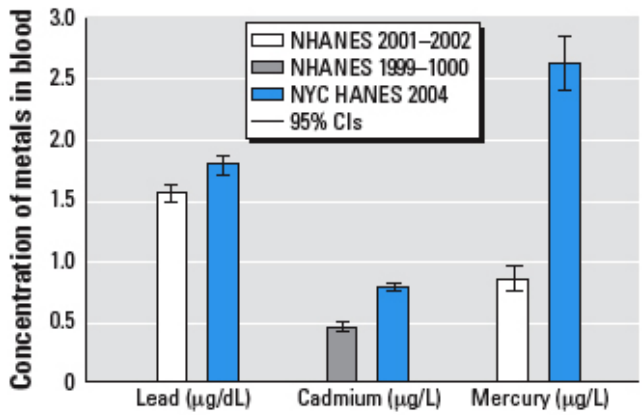


Figure 1. Geometric mean and 95% CI for blood lead, cadmium and mercury concentrations in adults residing in NYC compared with the United States overall, NYC HANES 2004, and NHANES 1999–2002 (CDC 2005a).[a]

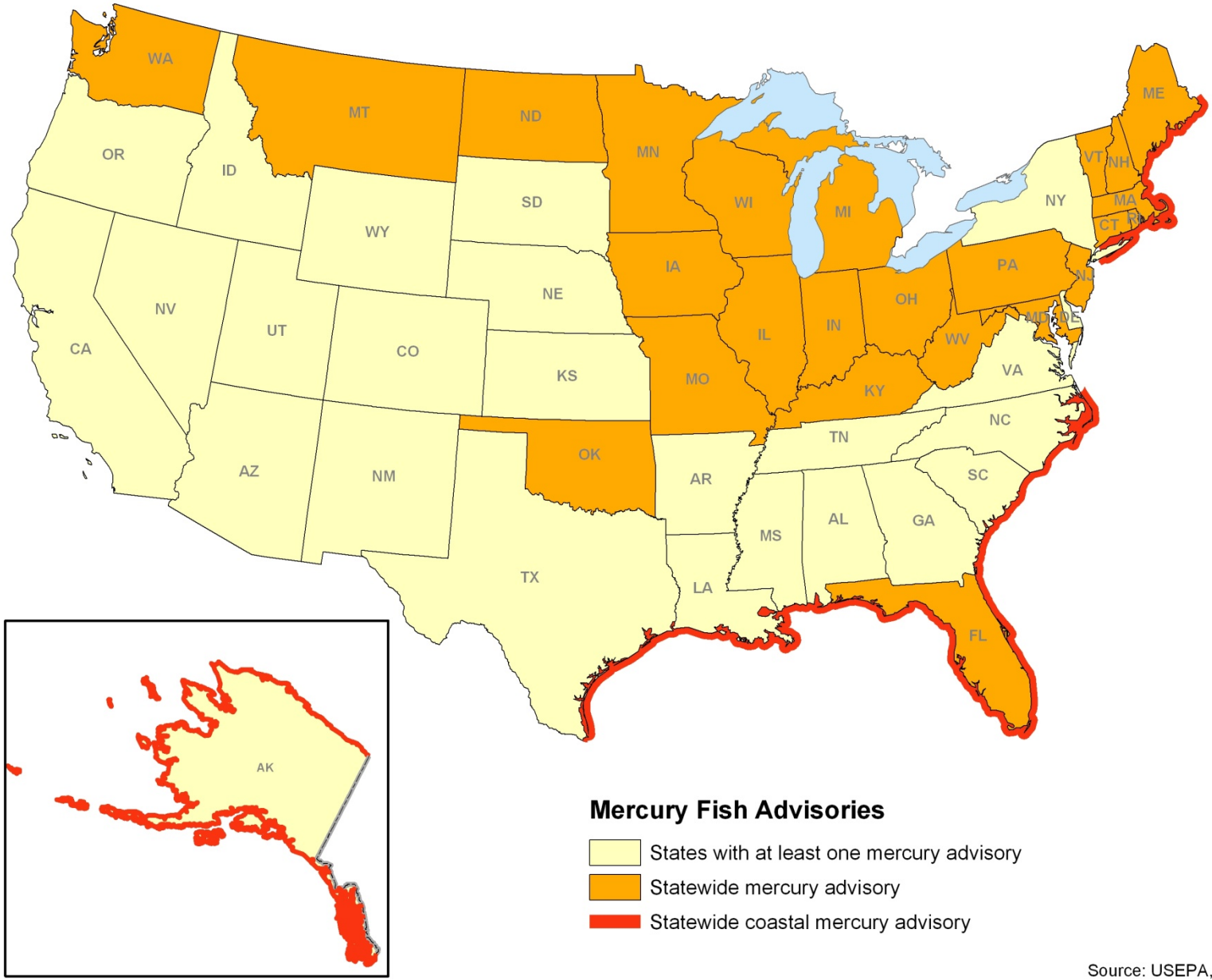
[a]Blood mercury comparison for women age 16–49 years (NHANES) and 20–49 years (NYC HANES).

McKelvey, W., et al. (2007). A Biomonitoring Study of Lead, Cadmium, and Mercury in the Blood of New York City Adults. *Environ Health Perspect* **115**:1435–1441.

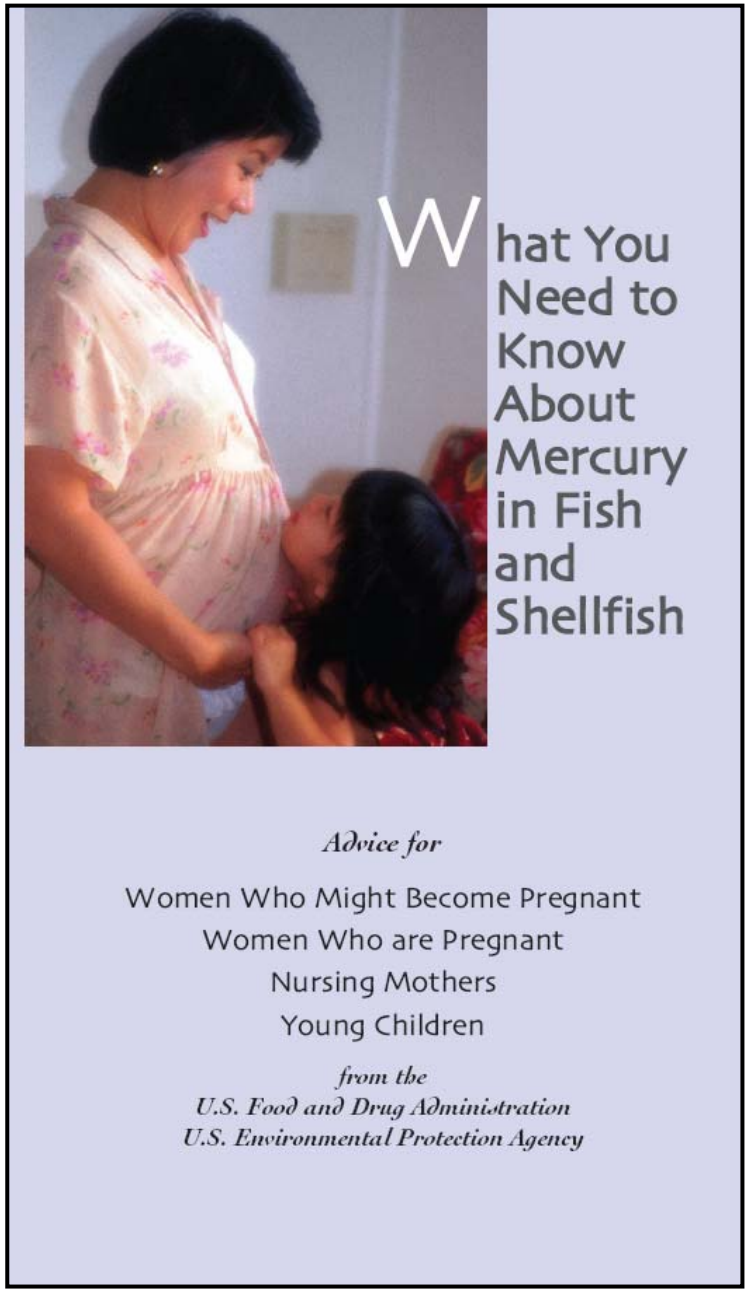
Public Health Context

- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity *relatively* well understood
  - well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: *methylmercury* from *fish consumption*
- Toxicity believed to be occurring at current exposures
- Widespread fish consumption advisories

Mercury Fish Consumption Advisories are Ubiquitous



Source: USEPA, 2008



March 2004

1. **Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.**

2. **Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.**

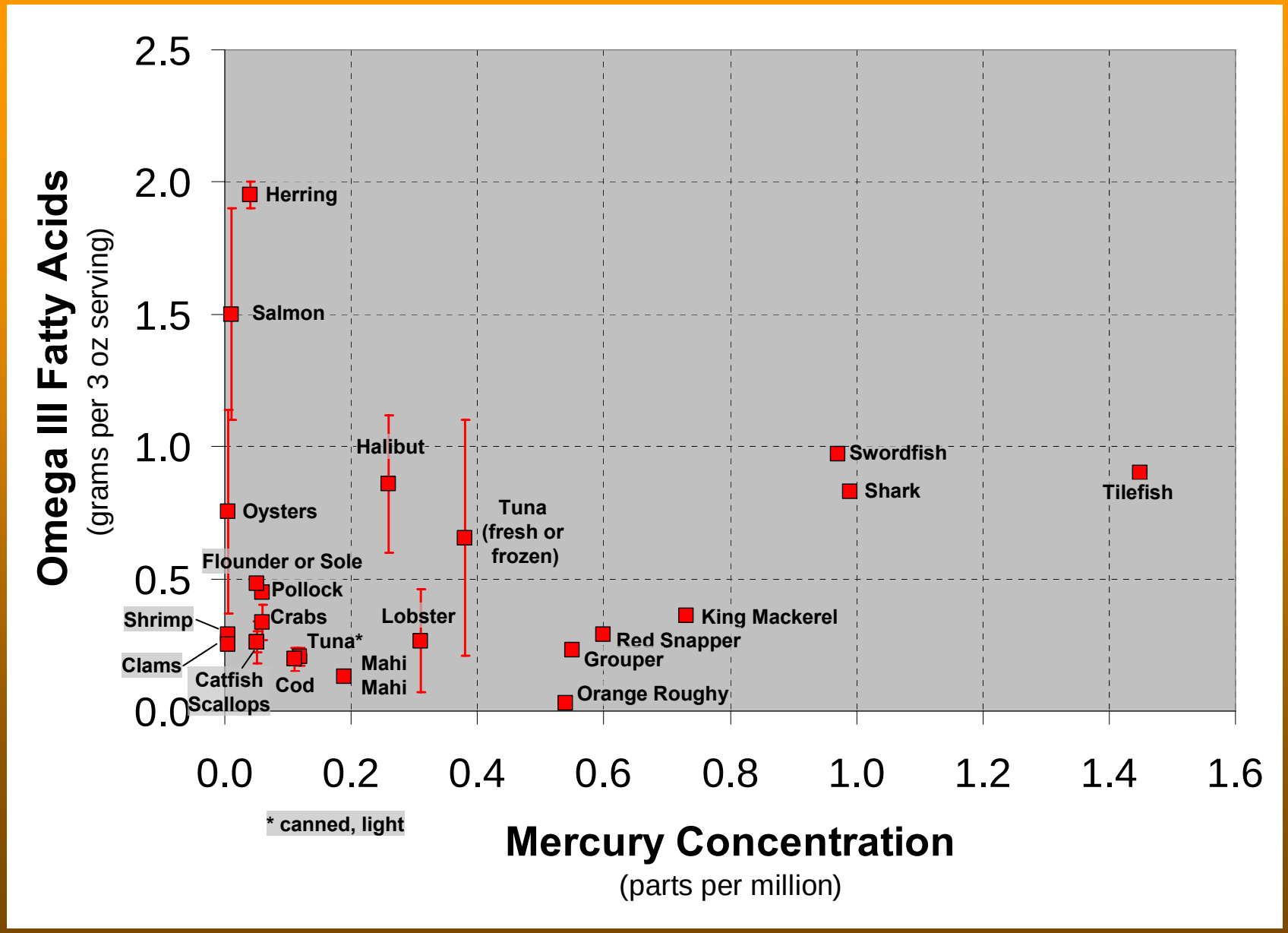
   - Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
   - Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna.
   - So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. **Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas.** If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

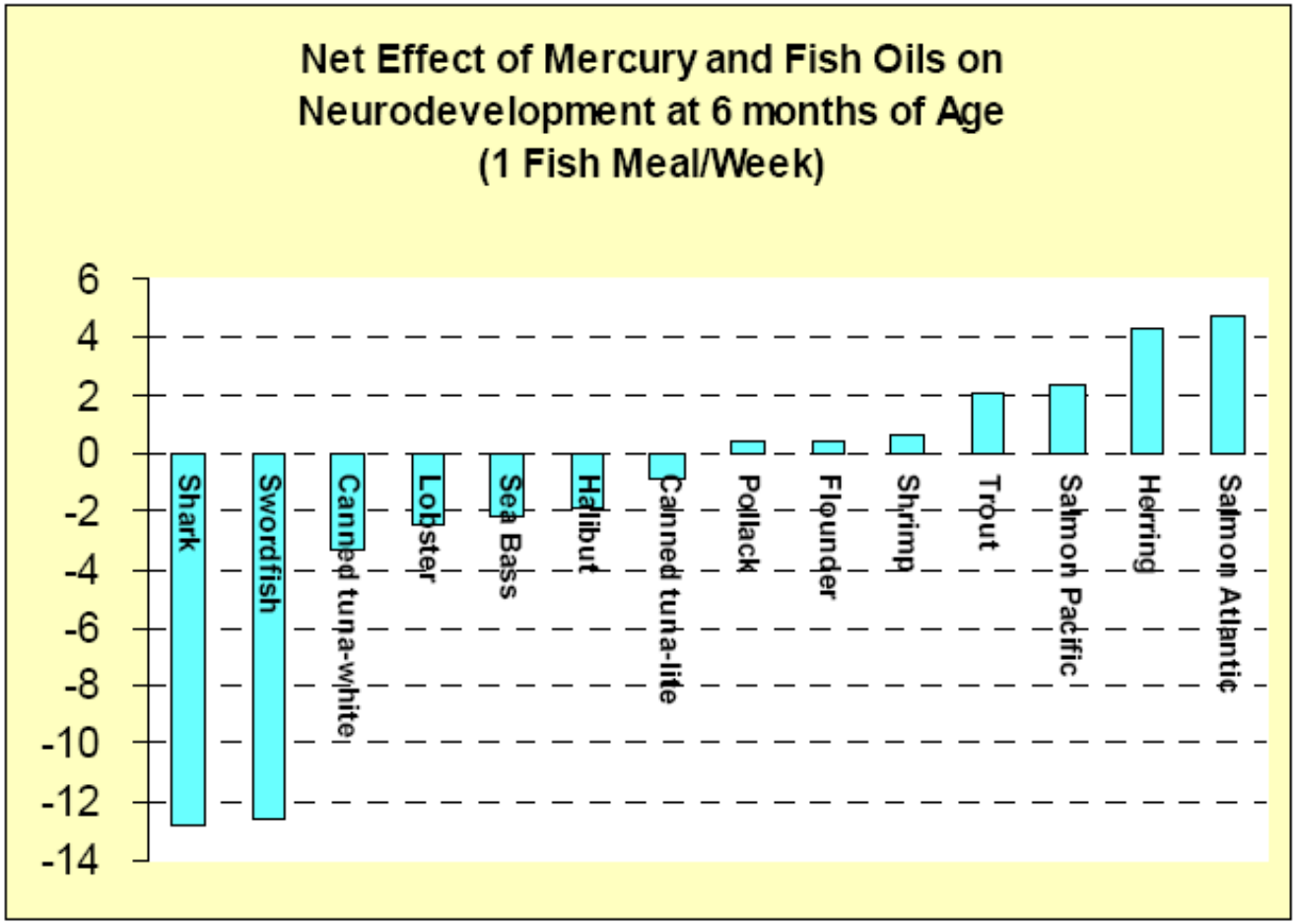
Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

Public Health Context

- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity *relatively* well understood
  - well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: *methylmercury* from *fish consumption*
- Toxicity believed to be occurring at current exposures
- Widespread fish consumption advisories
- Methylmercury vs. Omega-III Fatty Acids



Graph based on data presented by the American Heart Association -- http://www.americanheart.org



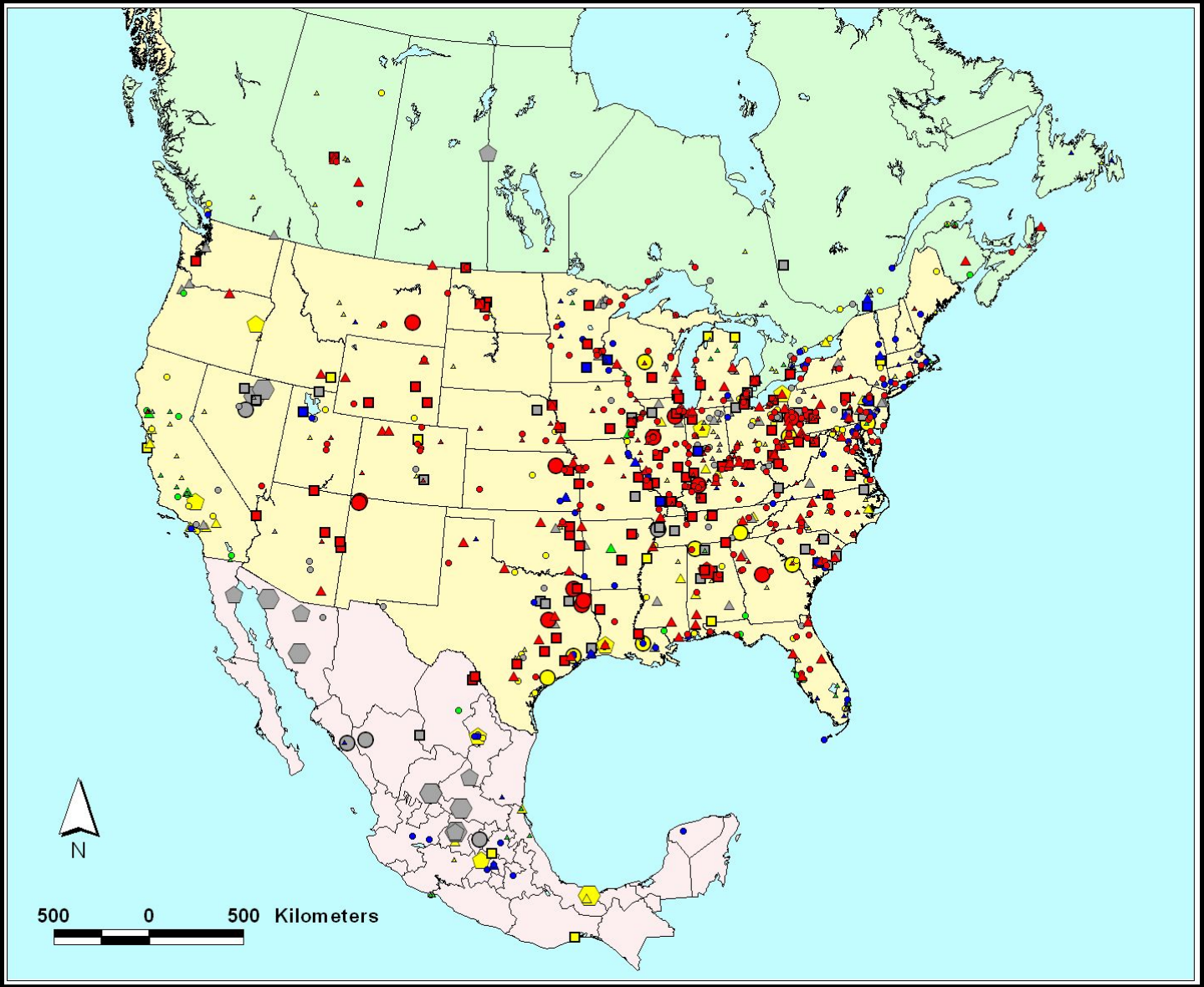
Source: Gary Ginsberg, Connecticut Dept of Public Health (2007). "Risk-Benefit Synthesis for Fish Consumption Advisories," presented at National Forum on Fish Contaminants, Portland, ME. http://www.epa.gov/waterscience/fish/forum/2007/pdf/section2f.pdf

Public Health Context

- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity *relatively* well understood
  - well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: *methylmercury* from *fish consumption*
- Toxicity believed to be occurring at current exposures
- Widespread fish consumption advisories
- Methylmercury vs. Omega-III Fatty Acids
- Selenium – protective role?

+ Wildlife Health Issues
e.g., fish-eating birds

Elemental Mercury -- Hg(0) -- Emissions to the Air



size/shape of symbol denotes amount of mercury emitted (kg/yr)

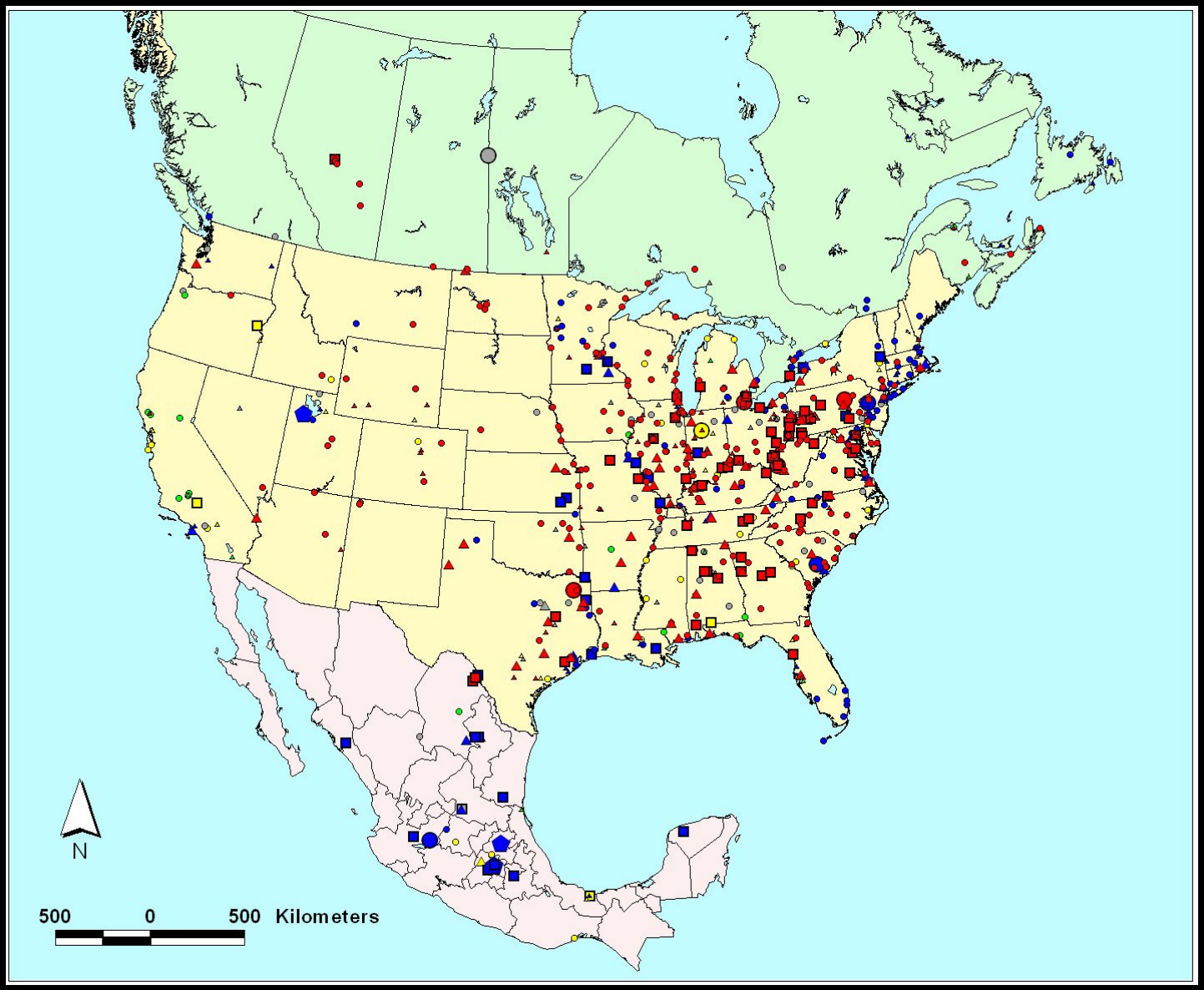
- 5 - 10
- 10 - 50
- 50 - 100
- 100 – 300
- 300 - 500
- 500 - 1000
- 1000 - 3500

color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation

Reactive Gaseous Mercury -- RGM -- Emissions to the Air



size/shape of symbol denotes amount of mercury emitted (kg/yr)

- 5 - 10
- 10 - 50
- 50 - 100
- 100 – 300
- 300 - 500
- 500 - 1000
- 1000 - 3500

color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation

Particulate Mercury – Hg(p) -- Emissions to the Air

size/shape of symbol denotes amount of mercury emitted (kg/yr)

- 5 - 10
- 10 - 50
- 50 - 100
- 100 – 300
- 300 - 500
- 500 - 1000
- 1000 - 3500

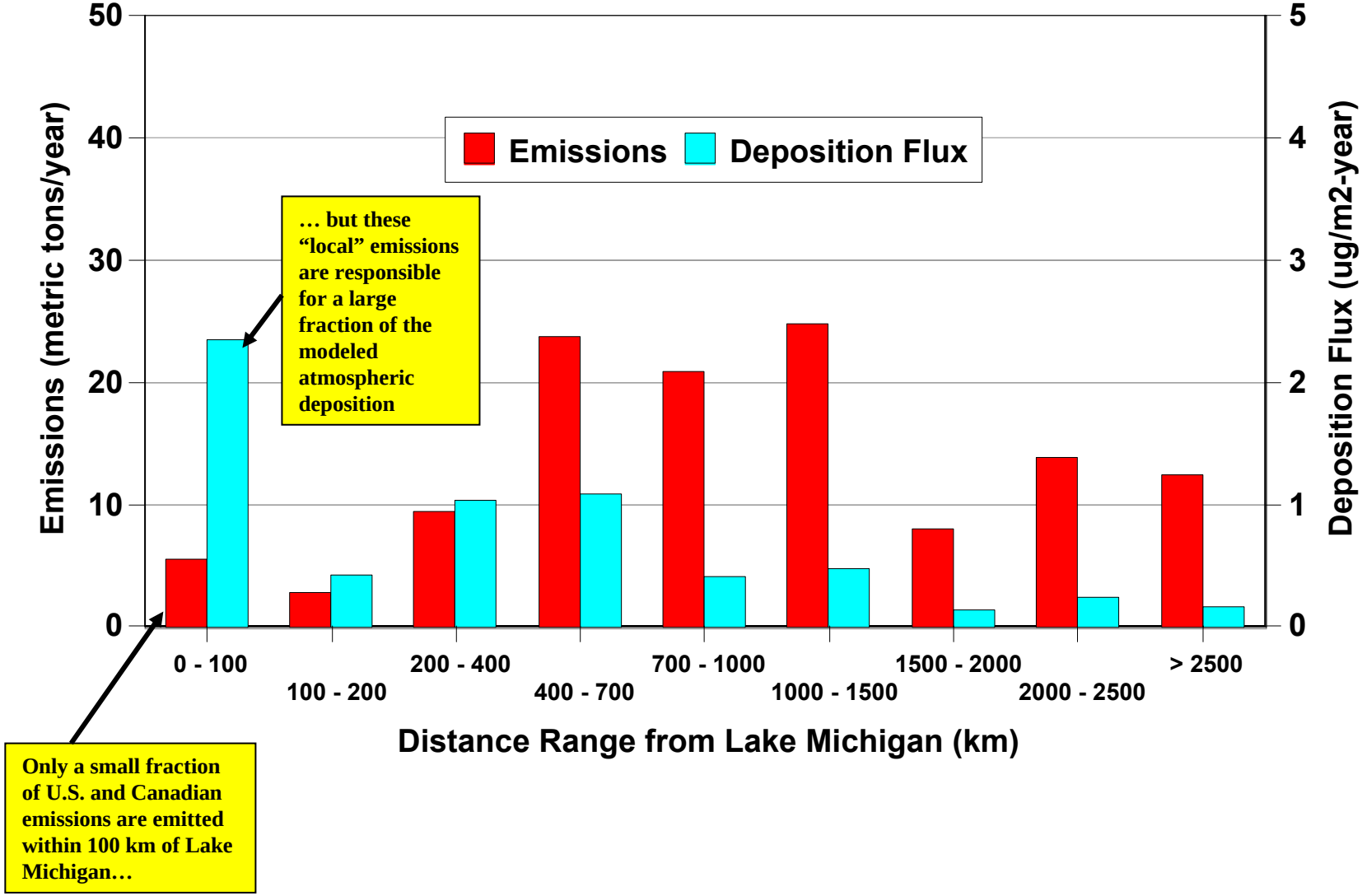
color of symbol denotes type of mercury source

- coal-fired power plants
- other fuel combustion
- waste incineration
- metallurgical
- manufacturing & other

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada;
1999 Mexican data from inventory prepared by *Acosta y Asociados* for the Commission for Environmental Cooperation

Emissions and deposition to Lake Michigan arising from different distance ranges

(based on 1999 anthropogenic emissions in the U.S. and Canada)



Chicago Tribune
—ONLINE EDITION—

http://www.chicagotribune.com/services/site/premium/interceptlogin.register

Nearby coal plants said to harm lake

By Michael Hawthorne
Tribune staff reporter

September 19, 2005

Contradicting a key part of the Bush administration's environmental policy, a new federal study estimates most of the mercury falling into Lake Michigan comes from smokestacks close to the shoreline.

Sixteen of the top 25 sources of mercury dropped into the lake are coal-fired power plants, according to the study by the National Oceanic and Atmospheric Administration (NOAA). Some of the toxic metal comes from as far away as Nevada and Texas, the study found, but most blows toward the lake from coal plants and factories in Illinois, Wisconsin, Michigan and Indiana.

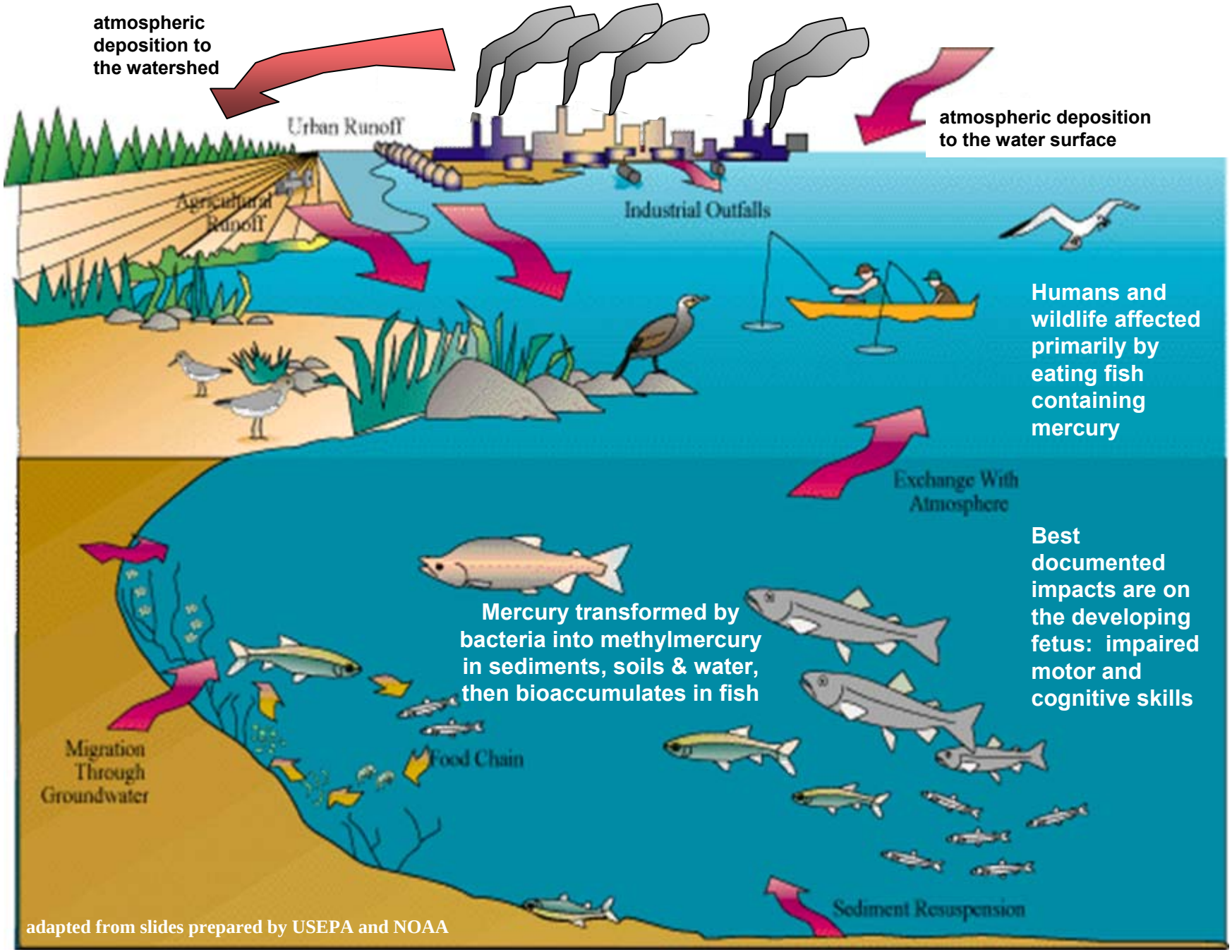
⋮

Atmospheric Mercury Measurement Site at Beltsville, MD

ARL's speciated mercury measurements at Beltsville are co-located with sites from several monitoring networks (CASTNET, MDN, NADP-NTN) and are funded by an Interagency Agreement between the USEPA and NOAA

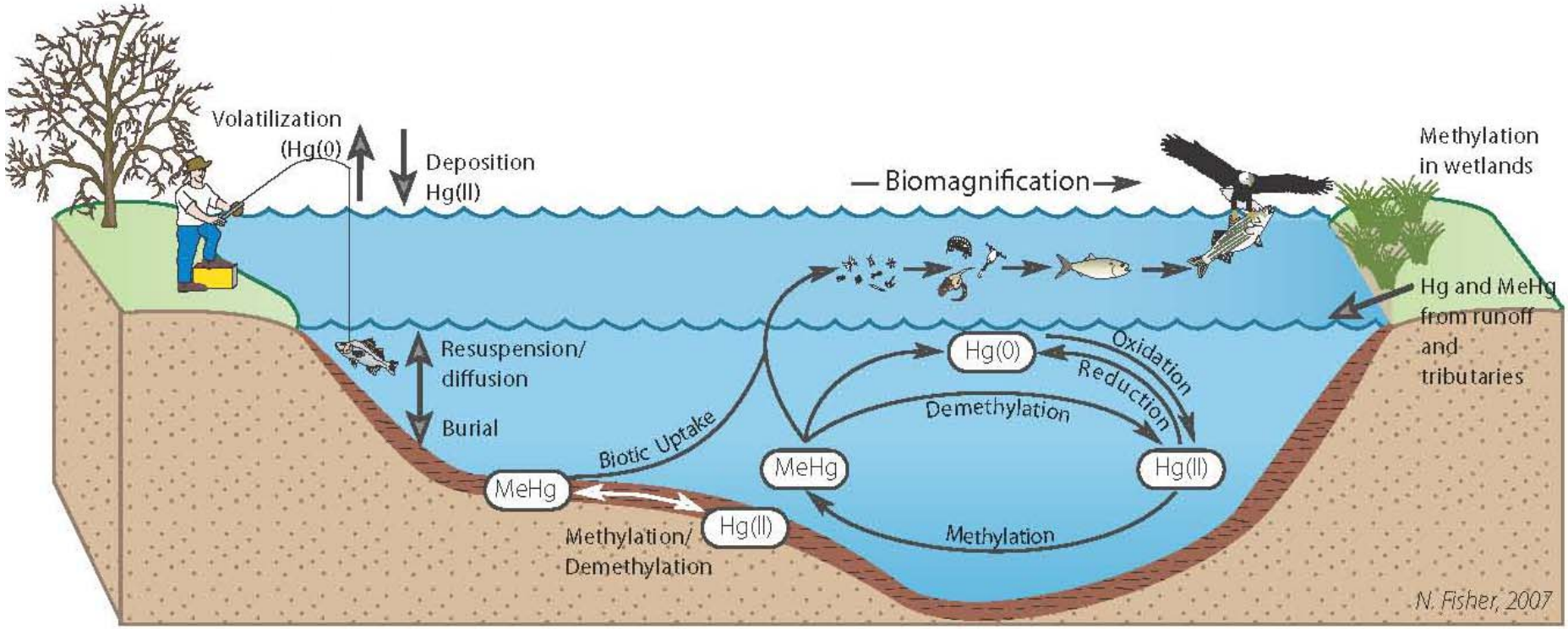
ARL's Winston Luke and Steve Brooks installing ARL's first speciated mercury measurement equipment at Beltsville in 2006

ARL's Steve Brooks, Paul Kelley & Winston Luke after installing first system at Beltsville in 2006



adapted from slides prepared by USEPA and NOAA

The Biogeochemistry of Mercury in an Aquatic Ecosystem



- Oxidized mercury [Hg(II)] required – provided by atmospheric deposition of Hg(II) or *in-situ* oxidation
- Hg(II) transformed to MeHg (methyl-mercury) by sulfate-reducing bacteria under anoxic conditions
- Most commonly occurs in the top layers of the waterbody's sediment
- Methylation can also occur in the water column and in the watershed (e.g., wetlands)
- Me-Hg can bioaccumulate, other environmental forms of mercury do not
- Me-Hg is much more toxic than other environmental forms of mercury

Figure from presentation by Cindy Gilmour,
Smithsonian Environmental Research Center