MercNet – A Vision for Monitoring Spatial and Temporal Changes in Environmental Mercury Loads





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EPA

CLEAN AIR MARKET PROGRAMS

The Mercury Cycle

Mercury is emitted to the atmosphere.

Mercury is deposited in rain and snow and as gases and particles.

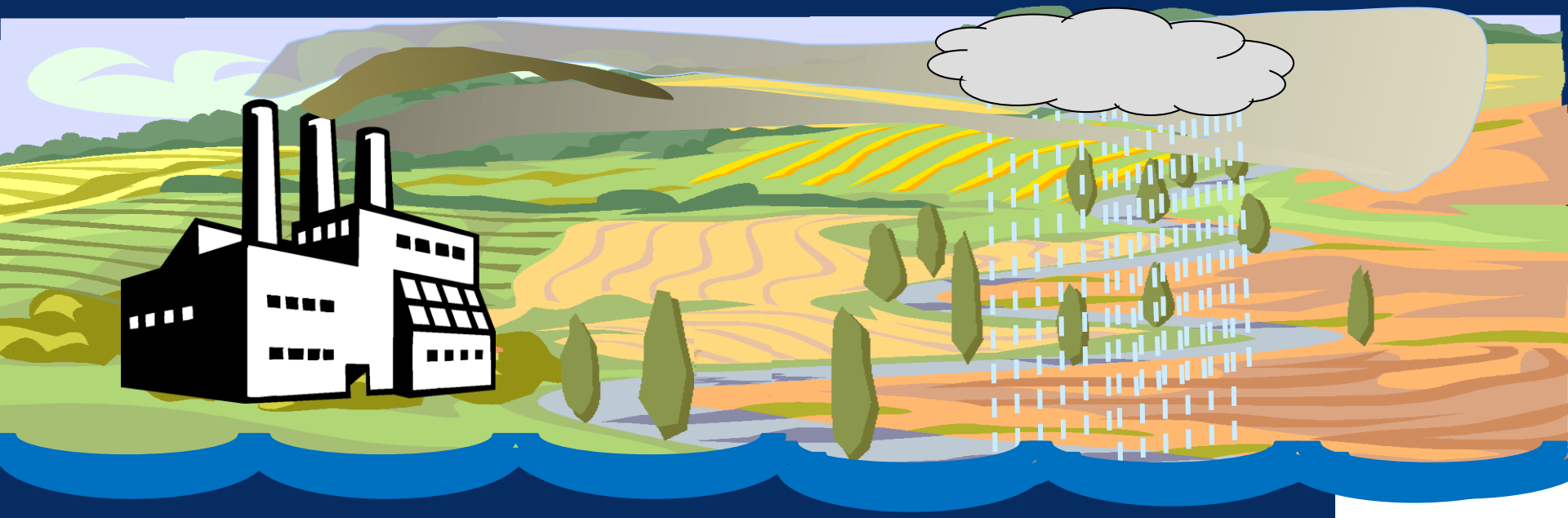
Mercury accumulates in lakes, reservoirs, and forests.

Mercury is transported through watersheds and converted to methylmercury.

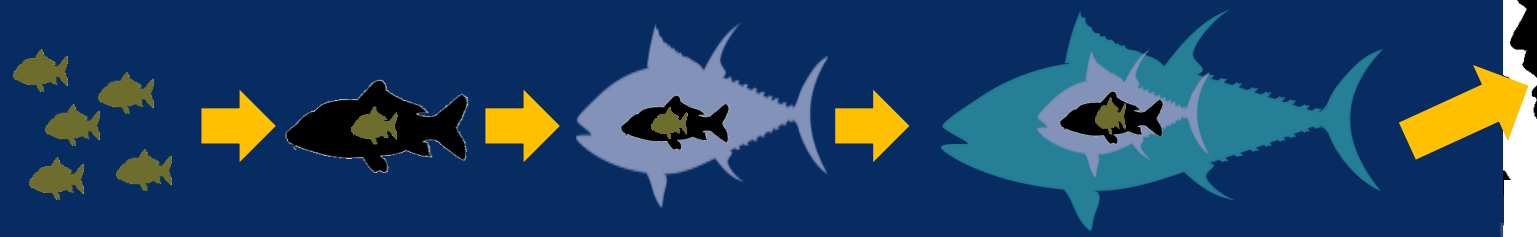
Methylmercury bioaccumulates in food webs.

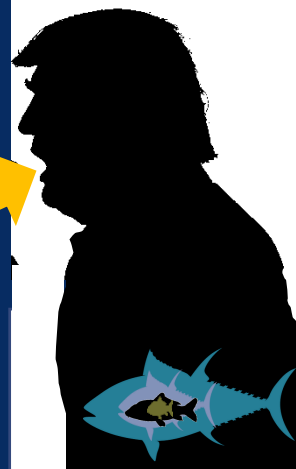
What is the mercury issue?

Accumulation of methylmercury in fish and shellfish



Methylmercury in fish is 100 million times greater than water

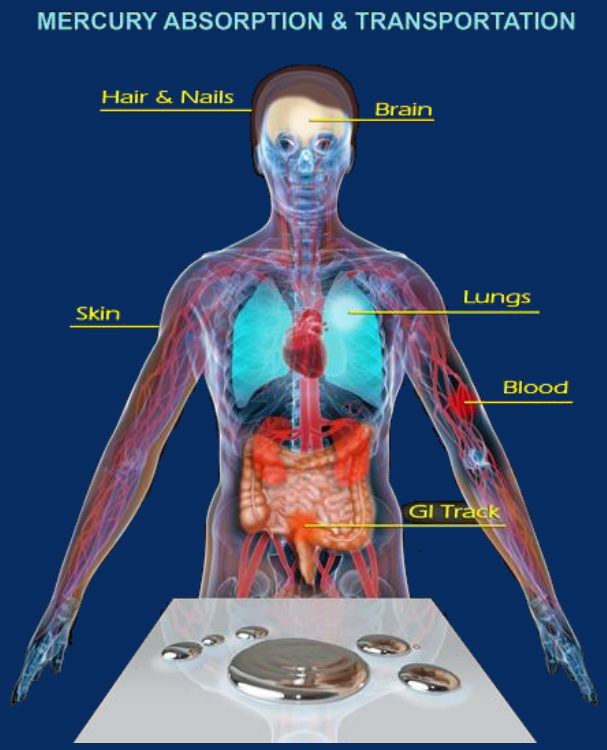




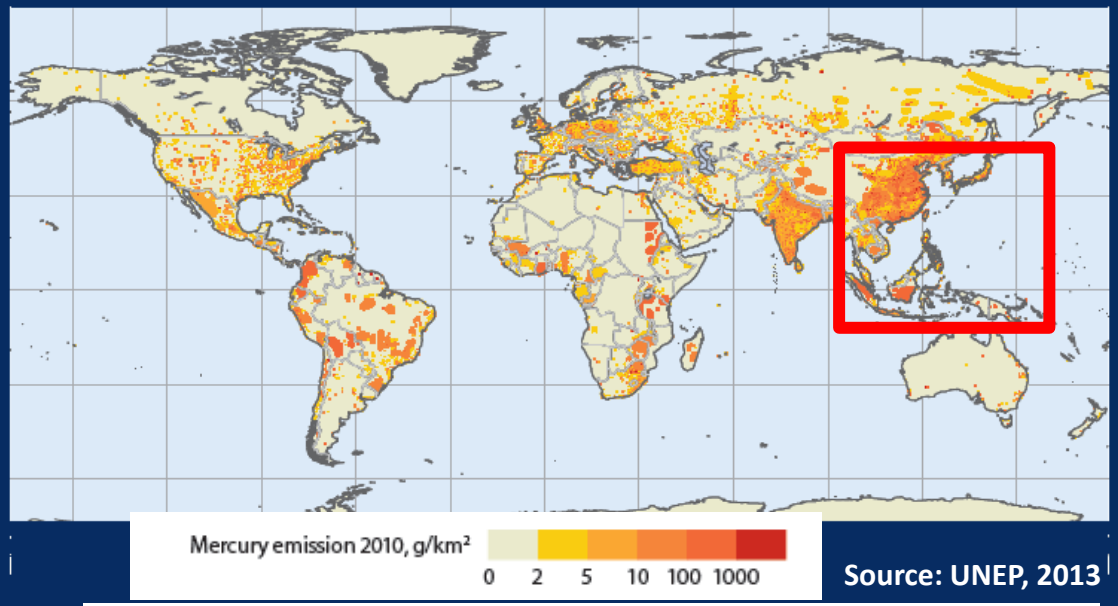
Worldwide, eating fish, shellfish and marine mammals accounts for approximately 75% of the total methylmercury exposure

Leads to health effects in people

- Women of child bearing age
- Children under 14
  - Interferes with brain and nervous system growth and development
  - Impacts cognitive thinking, memory, attention, language, and fine motor and visual spatial skills in children exposed to methylmercury (MeHg) *in utero*
  - Prenatal and infant exposures to high MeHg doses (less frequent) can cause mental retardation, cerebral palsy, deafness and blindness
- Memory and vision loss, tremors and numbness in fingers and toes in adults
- Newer studies showing associations between low-level exposure and sub-clinical changes in cardiovascular and immunological health



Global Anthropogenic Mercury Emissions, 2010



Source: UNEP, 2013

Region*	Emission (range), tonnes**	%
Australia, New Zealand & Oceania	22.3 (5.4 - 52.7)	1.1
Central America and the Caribbean	47.2 (19.7 - 97.4)	2.4
CIS & other European countries	115 (42.6 - 289)	5.9
East and Southeast Asia	777 (395 - 1690)	39.7
European Union (EU27)	87.5 (44.5 - 226)	4.5
Middle Eastern States	37.0 (16.1 - 106)	1.9
North Africa	13.6 (4.8 - 41.2)	0.7
North America	60.7 (34.3 - 139)	3.1
South America	245 (128 - 465)	12.5
South Asia	154 (78.2 - 358)	7.9
Sub-Saharan Africa	316 (168 - 514)	16.1
Undefined (global total for emissions from contaminated sites)	82.5 (70.0 - 95.0)	4.2
Grand Total	**1960 (1010 – 4070)**	**100**

Country	Emissions (tonnes)
Cambodia	3.9
China	575.2
Indonesia	78.2
Japan	17.2
Korea	7.1
Laos	1.3
Malaysia	6.1
Mongolia	6.9
Philippines	33.1
Singapore	0.9
Taiwan	5.5
Thailand	14.9
Vietnam	11.6

Policy Driver: Minamata Convention on Mercury

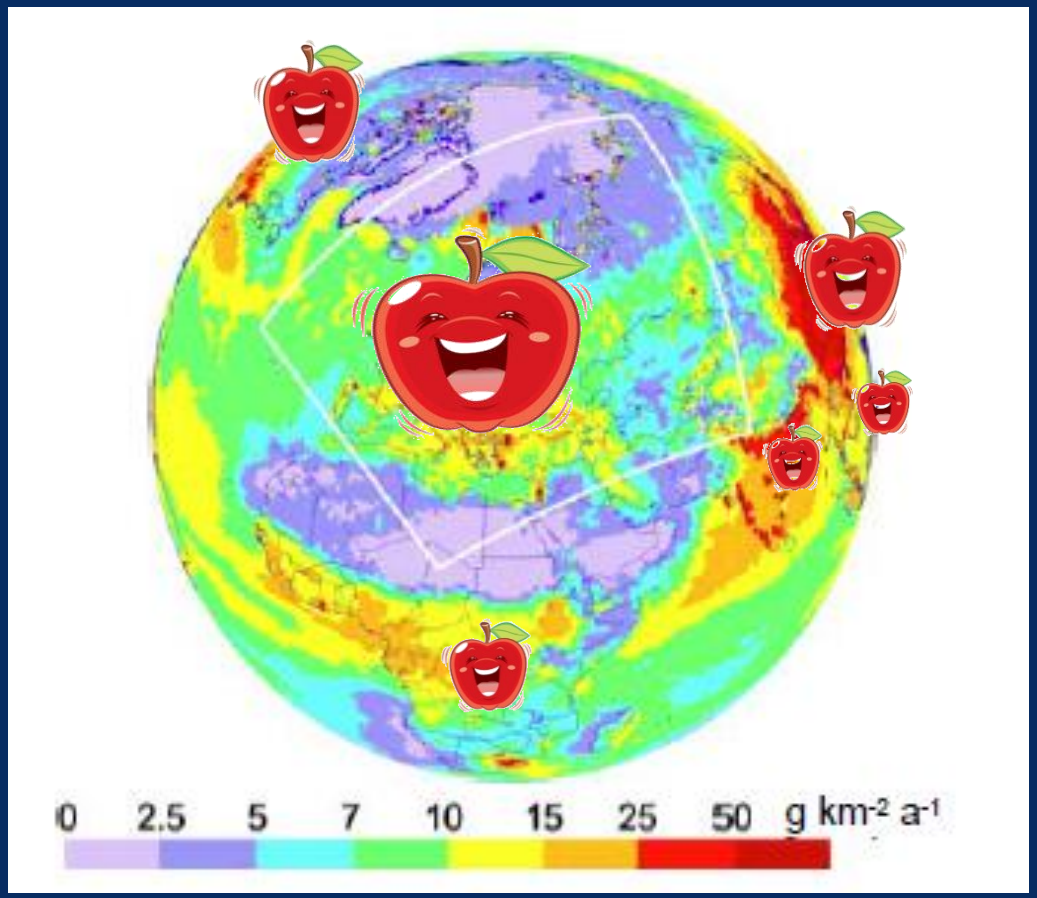
- Global, legally-binding treaty
- 43 countries ratified; 50 required for it to enter into force (90 days after ratification)
- Conference of the Parties (COP1) to the Minamata Convention expected 24-29 September 2017 in Geneva
- Controls mercury from existing and new sources
- Monitor and evaluate the effectiveness of those controls

Our vision for APMMN

- Develop an Asia-Pacific Mercury Monitoring Network
  - A cooperative group of countries, agencies and other organizations
  - Make measurements of
    - mercury wet deposition
    - atmospheric mercury concentrations
  - Use the same instruments and operating procedures
  - Share data to solve the mercury problem

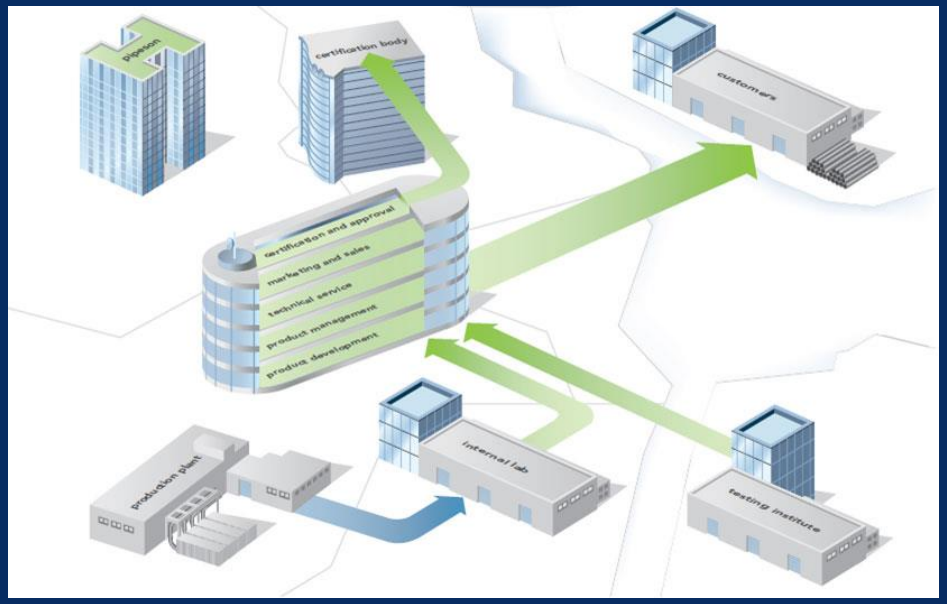
Consistency in measurement is KEY!

- Long-term monitoring is required to see small changes
- Using the same method!!!
  - “apples to apples” comparisons
  - on a global basis



Strive for open access to the data

- Quality assured using a single method
- Stored in one location
- Located on one server for utility by all
- Data used for
  - understanding the mercury science
  - management and policy decisions

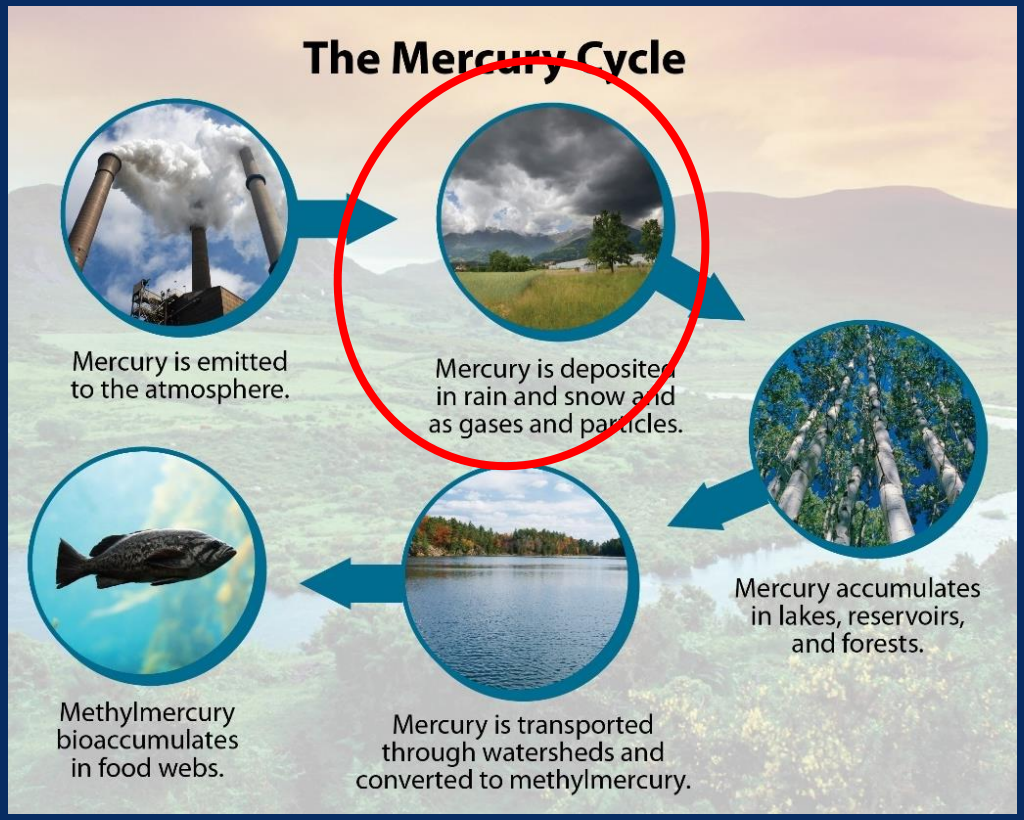


APMMN (wet dep) envisioned across region

- Operating Sites
- Pending Sites
- Affiliated Sites
- Planned Sites
- Laboratory

Focus on monitoring mercury in rainwater and air

- Primary input to ecosystems
- Not very costly (wet)
- Anybody can do it; methods well-developed
- Lots of experience doing it
  - Many experts regionally/globally



But a multi-media mercury monitoring network is needed…

MercNet

Tracking mercury in air, water, land, fish and wildlife

- North American example
- A roadmap for a comprehensive national mercury monitoring network

Established steering committee and participants

- Assembled a group of mercury experts:
  - Atmosphere
  - Sediments
  - Water/Watersheds
  - Fish
  - Wildlife
  - Modeling
  - Policy and Management

- Representing different institutions:
  - Government Agencies (Federal, State, Tribal)
  - Universities
  - Research and monitoring organizations
  - Non-governmental organizations
  - Private companies/Trade groups

Organized a scientific workshop

- Distill recommendations from previous work on measurement parameters for tracking ecological responses to mercury;
- Share information on existing North American sites and programs that monitor ecological endpoints of mercury contamination (e.g., air, water, watershed, sediments, biota);
- Identify mercury monitoring data gaps and establish options for filling those gaps.

The workshop was organized around six questions:

1 – What are the goals and objectives of a national mercury monitoring network?

2 – What are the major elements needed to meet network goals and objectives?

3 – What is already in place?

4 – What are the major gaps?

5 – How can gaps be addressed?

6 – How do the pieces fit together?

Consensus on mercury monitoring network goal & objectives

"Establish an integrated, national network to systematically monitor, assess, and report on policy-relevant indicators of atmospheric mercury concentrations and deposition, and mercury levels in land, water, and biota in terrestrial, freshwater, and coastal ecosystems in response to changing mercury emissions over time"

- Establish baseline mercury concentrations in multiple ecosystem compartments
- Track spatial patterns and long-term trends
- Assess linkages between mercury emissions and methylmercury concentrations in biota
- Document trends in biological indicators of mercury exposure and effects
- Provide mercury and ancillary data to support model development and evaluation
- Assess ecological harm and linkages among mercury emissions, deposition, and wildlife exposure
- Connect national mercury monitoring efforts to other monitoring programs

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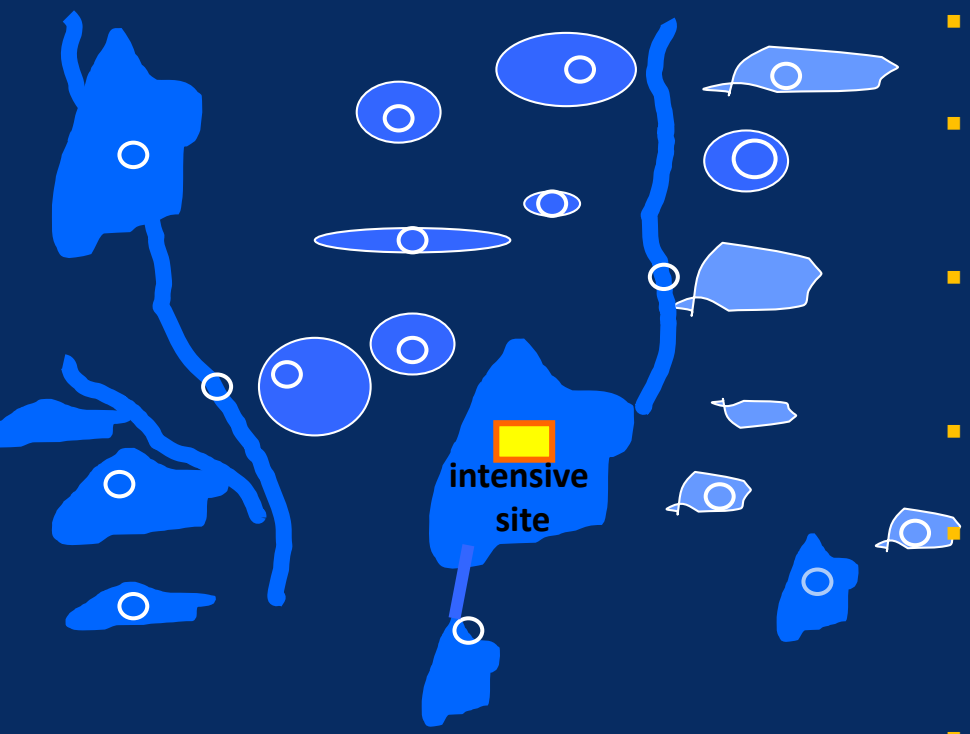
Major design elements

- Propose a combination of "intensive sites" and "cluster sites"
  - Intensive sites are those where detailed studies will be done to track changes and assess the cause of any changes
  - Cluster sites will allow data from the intensive sites to be extrapolated to a broader area, and extrapolate results of the detailed investigations across ecosystems of similar atmospheric input



Slide from Rob Mason, based on Mason et al. (2005)

- Propose 10-20 intensive sites in the U.S
- Each intensive site would have 15-20 cluster sites surrounding it
- Intensive sites would be chosen to represent the different ecoregions of the US
- Sites would be multi-media
- Network must run for an extended period to quantify the range of responses expected in many ecosystem types
- Network should build on existing monitoring efforts, where possible

based on Mason et al. (2005); Harris et al. (2007)

The Indicators

Air & Deposition

- Continuous speciated atmospheric concentrations
- Total wet and dry Hg deposition & flux
- Total Hg weekly wet deposition/flux
- Total and MeHg in throughfall
- Total and MeHg in litterfall
- Total Hg in snowpack
- Mercury evasion/flux
- Watershed inputs/yields

Water & Sediment

- Total and MeHg in soil
- Forest floor surveys
- Total and MeHg, %MeHg in sediments (seasonal)
- Instantaneous sediment methylation/demethylation rate
- Total and MeHg accumulation in cores
- Total and MeHg in surface water (seasonal)
- Water column Hg & MeHg profiles

Indicators in yellow would be monitored at intensive sites only. Black would be monitored at cluster sites, when feasible

The Indicators, cont.

based on Mason et al. (2005); Harris et al. (2007)

Aquatic Biota

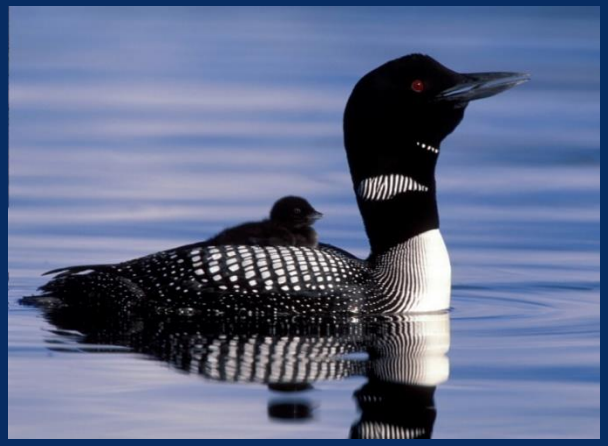
- Total and MeHg in phyto/zooplankton
- Total and MeHg in estuarine benthic invertebrates
- Total and MeHg in whole prey fish (YOY)
- Total Hg in muscle of piscivorous fish

Wildlife

Total Hg in blood, feathers, eggs (as appropriate)

Potential Indicator Species

- Comparison across habitats: Belted kingfisher
- Terrestrial: Racoon, Bicknell's thrush
- Riverine: Mink
- Lake: Common loon
- Lake/coastal: Herring gull, Common tern
- Wetland: Tree swallow
- Estuarine: Sharp-tailed & seaside sparrows
- Marine nearshore: Harbor porpoise
- Marine off-shore: Storm petrel



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Site selection considerations

Baseline data and infrastructure

- Longer-term mercury data
- Existing facilities and infrastructure to support the monitoring program

Will we see and be able to understand a change?

- Sensitive to mercury inputs
- Expected to exhibit large changes due to changes in Hg deposition
- Near emission sources and may receive elevated Hg deposition
- Clearly defined response – few if any confounding factors

Model evaluation

- Useful testbed for evaluation of atmospheric Hg models
- Useful testbed for evaluation of ecosystem Hg models

Want a range of site types

- Overall, want nationwide geographical distribution
- Overall, want range of characteristic response times
- Overall, want some background sites for characterizing global Hg inputs

Other site issues

- Within common loon breeding range
- Endangered, threatened or candidate species at risk to Hg

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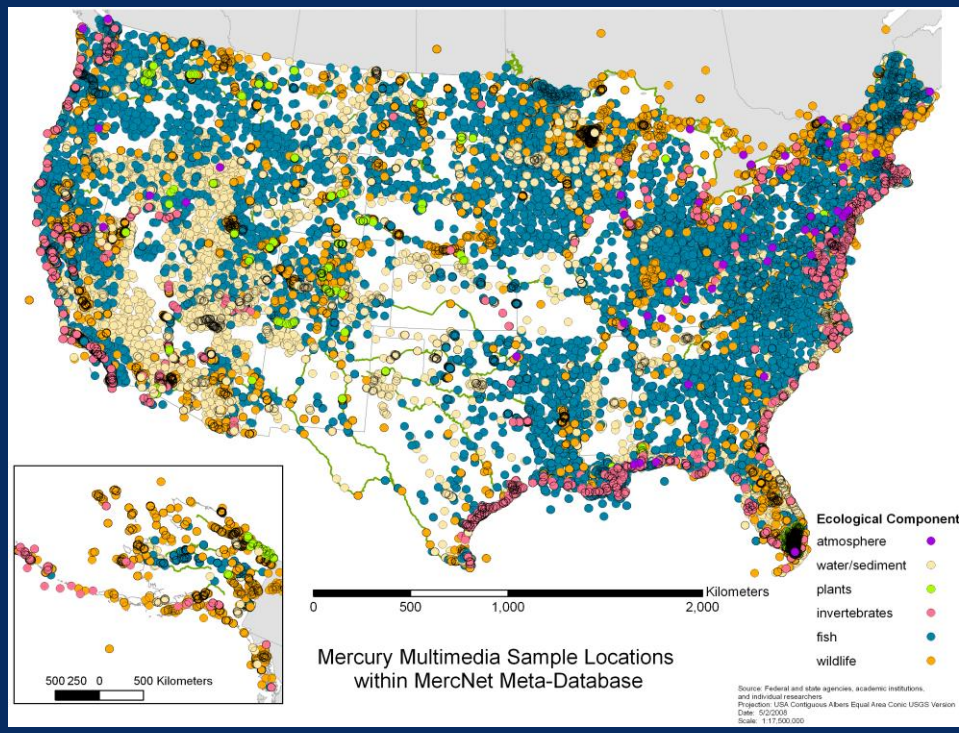
What are the gaps? What's in place?

Developed a MercNet meta-database

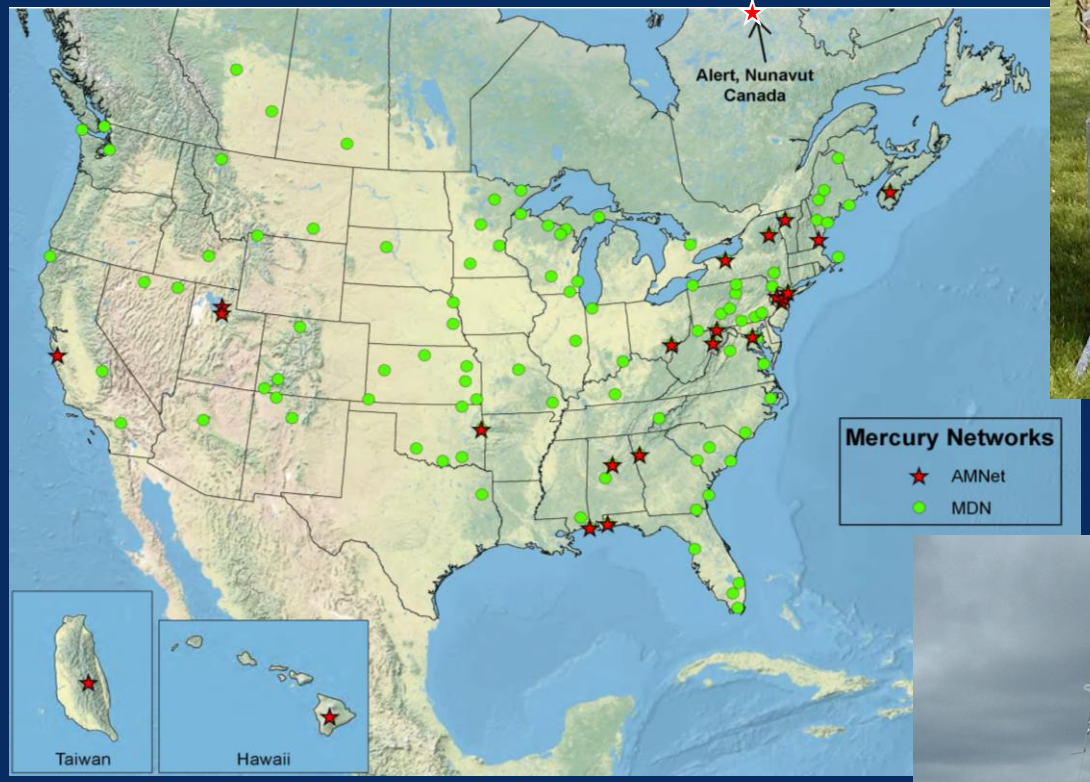
- Based on major environmental monitoring databases, USEPA, USGS, USFWS, NOAA, Biodiversity Research Institute
- More than 200,000 mercury sampling events across the U.S.
- Covers various media: atmosphere, water, sediment, soil, vegetation, invertebrates, fish, birds, reptiles, amphibians, mammals
- Time span of records is from 1896 to 2007



What are the gaps? What's in place?

Example: NADP atmospheric mercury networks: wet deposition & speciated concentrations

Mercury Deposition Network (MDN) & Atmospheric Mercury Network (AMNet)



MDN

- Operating since 1996
- Currently 109 sites
- Weekly total mercury in rain and snow

AMNet

- Launched in 2009
- Currently 21 sites
- Ambient concentrations of elemental (5 minutes), oxidized (2-hour), particle-bound (2-hour)
- Used to estimate dry deposition

- Model for APMMN

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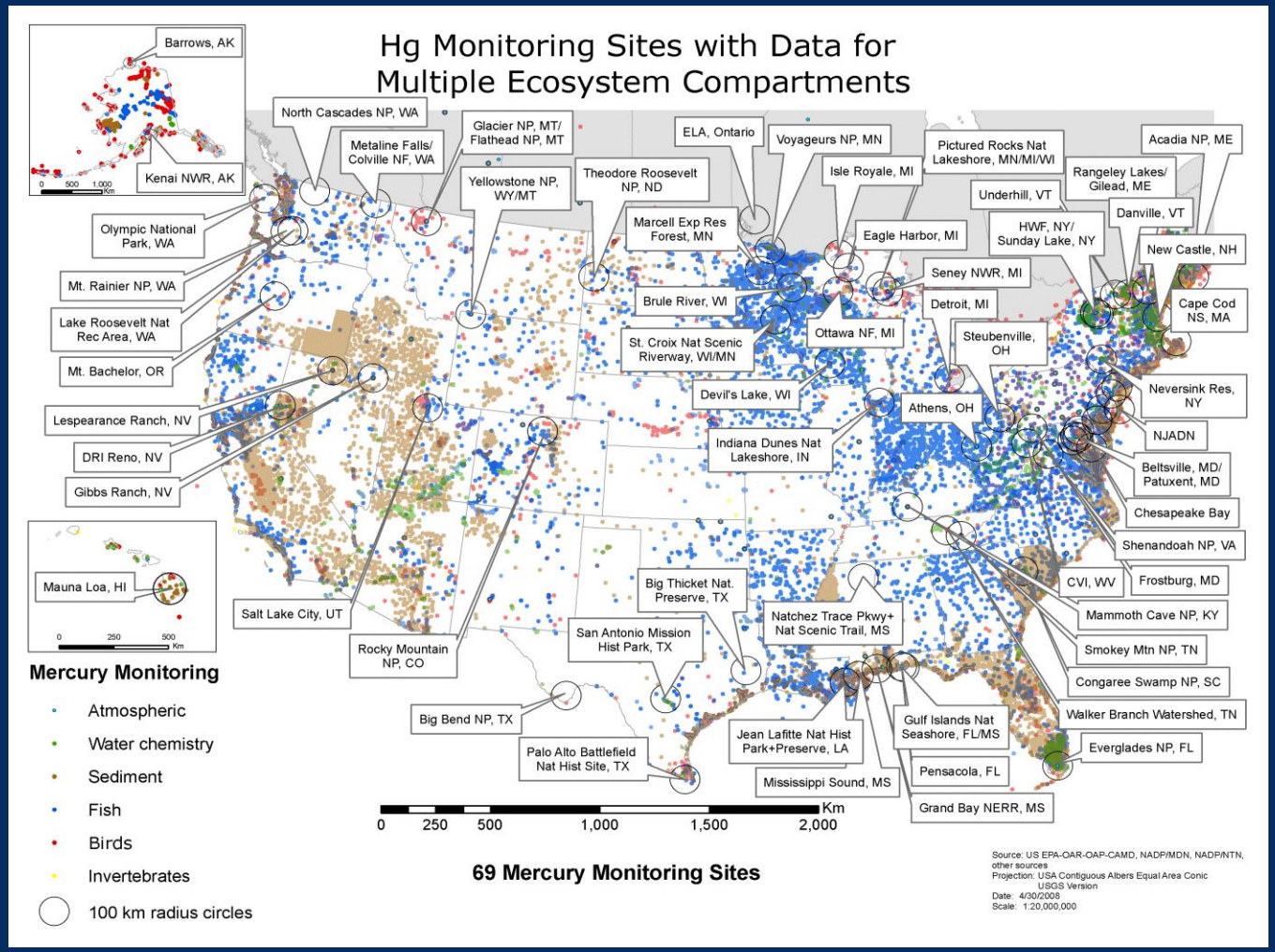
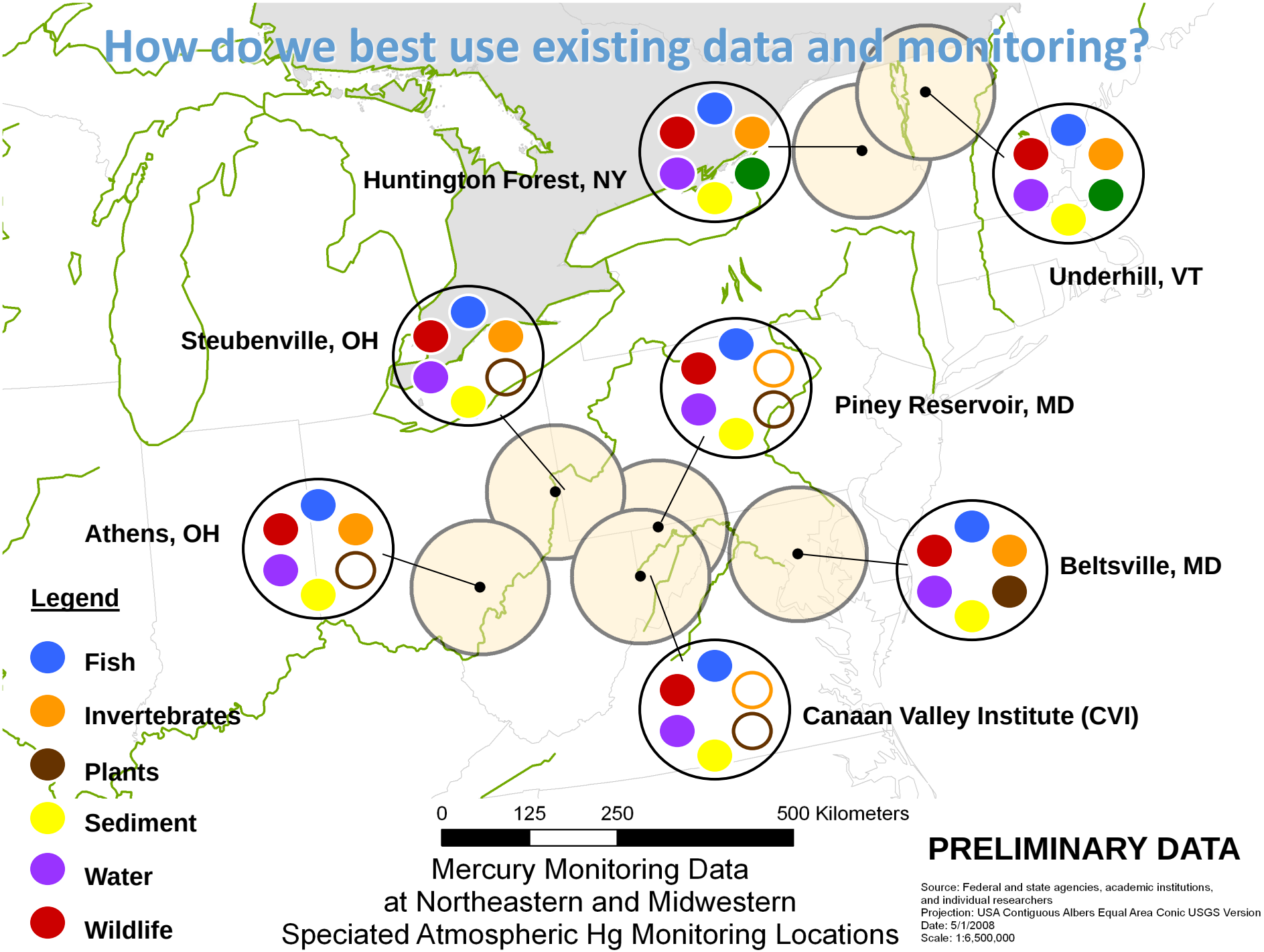
How can gaps be addressed? How do the pieces fit together?

Initial Characterization of Potential "Intensive" Sites

What are the relative advantages and disadvantages of these and other potential intensive sites?



How do we best use existing data and monitoring?

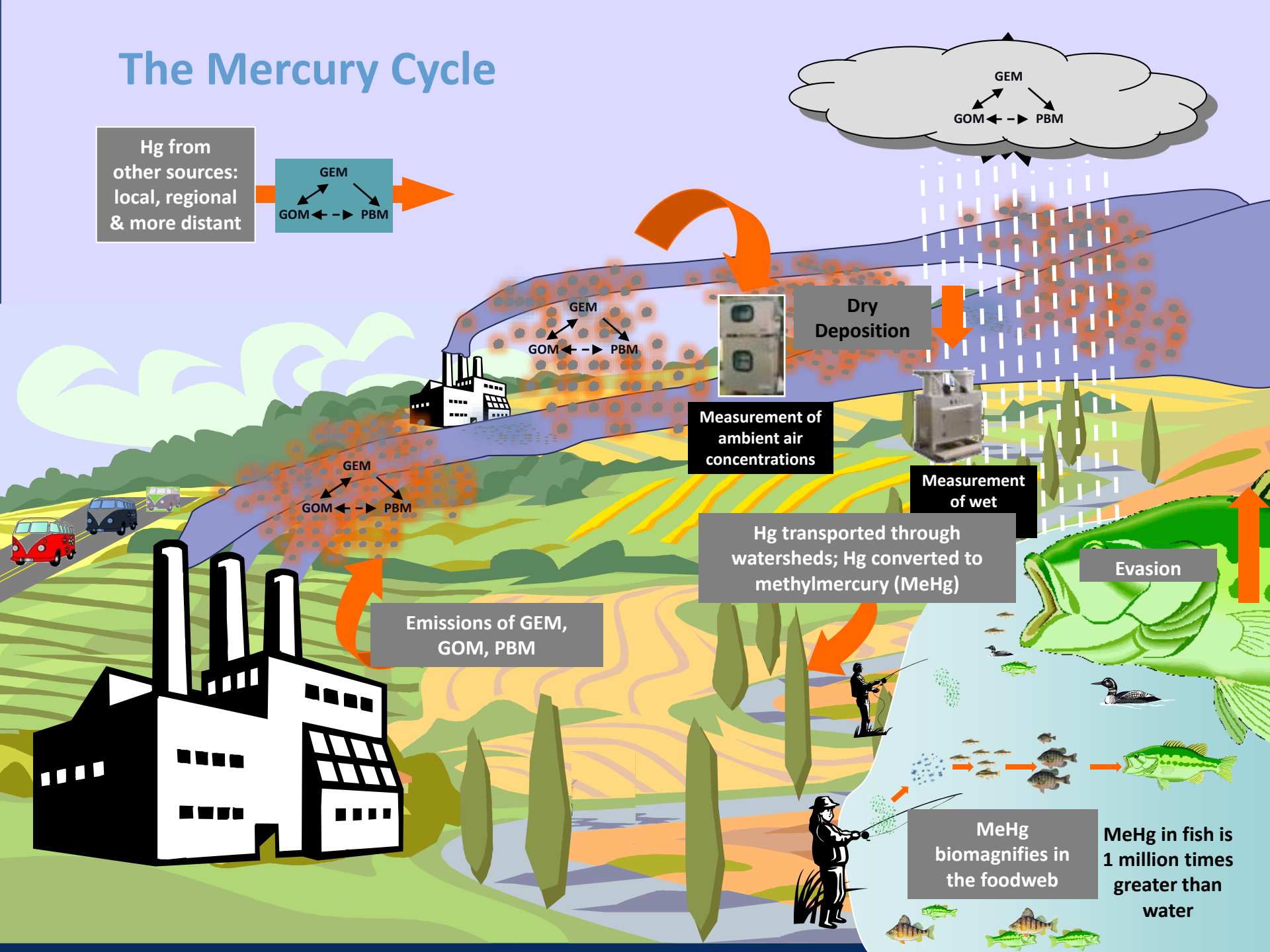


Mercury Monitoring Data
at Northeastern and Midwestern
Speciated Atmospheric Hg Monitoring Locations

Summary - Comprehensive, long-term mercury monitoring information is needed

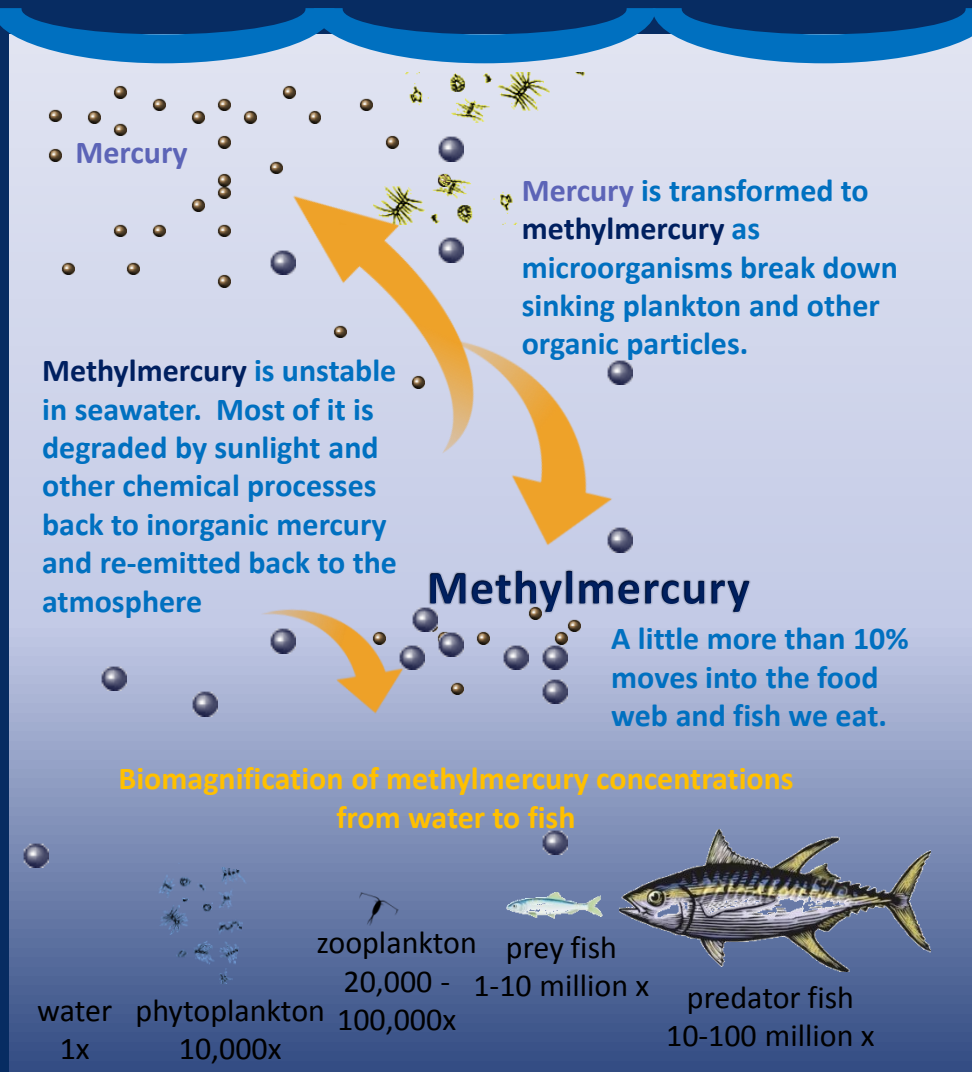
- Assess the linkages between emissions, deposition, fish, wildlife and people; determine spatial and temporal trends
- Current programs monitor portions of the mercury cycle; major data gaps and limited coordination
- Insufficient information for many areas to fully and accurately assess the effectiveness of mercury controls
- In the absence of a national comprehensive mercury monitoring program, we are partnering with other organizations and agencies
  - Organize a community of technical experts
  - Pull together the latest science
  - Build on existing data collection efforts that work

The Mercury Cycle



The problem is methyl mercury (MeHg) exposure through eating contaminated fish/seafood

- Eating fish, shellfish, and marine mammals is the single most important source of human exposure to MeHg globally
- In the US, marine fish and shellfish consumption are estimated to account for over 90% of human mercury exposure; tuna harvested in the Pacific Ocean account for 40% of this total exposure
- In East/Southeast/South Asia fish and seafood are a main protein source
- Depending upon the species of fish consumed, people who rely on subsistence fishing can experience a disproportionally higher risk of MeHg exposure



Some mercury can accumulate in the deep ocean and be buried in sediments

(C-MERC, 2012)

But it isn’t just humans….