Mercury Methylation in the Environment

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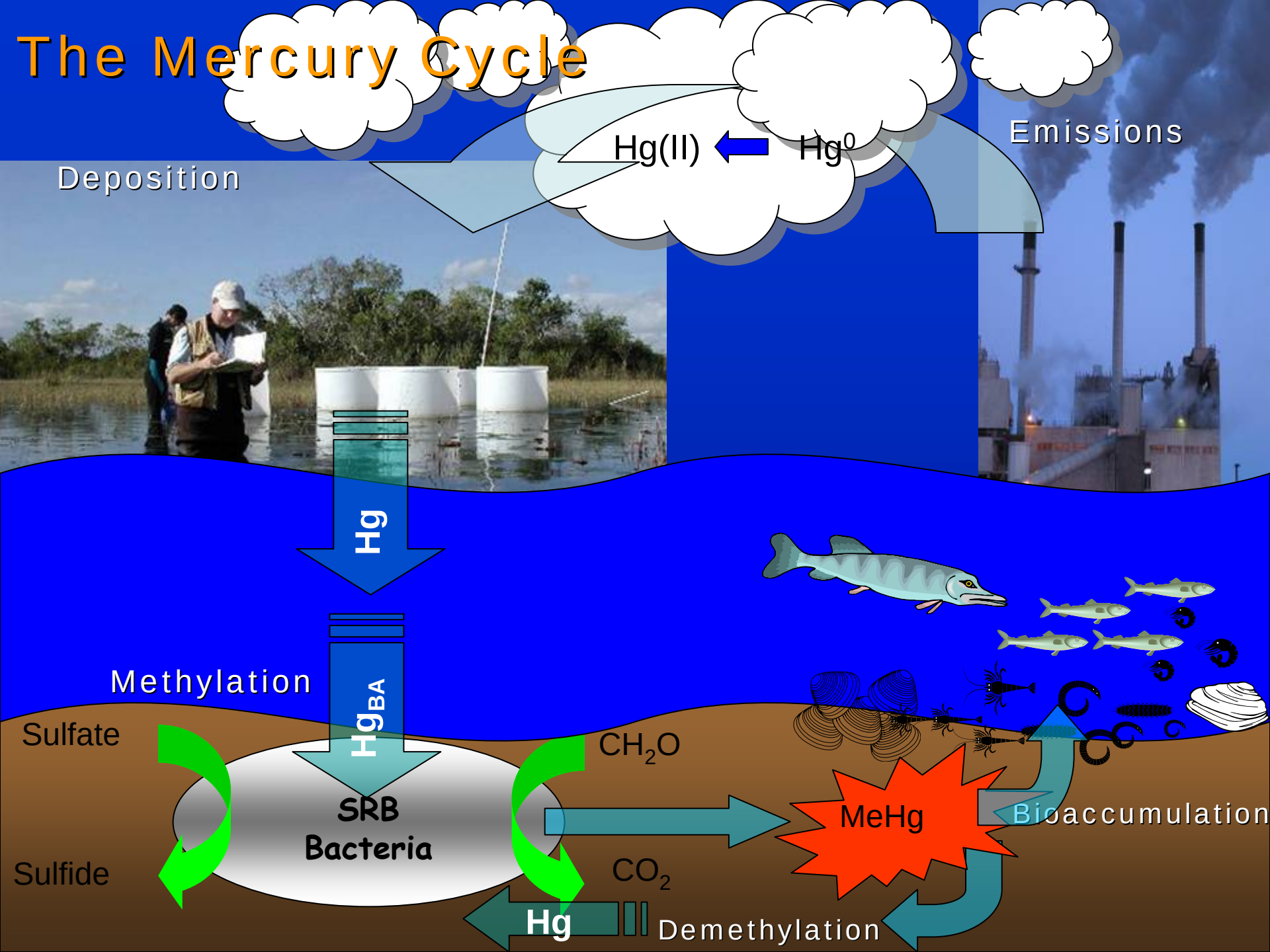
Presentation Outline:

- Overview of the Environmental Mercury Cycle.
- Mercury methylation:
  - Why do we care?
  - Who/what is doing it?
  - Where does it happen?
  - Controlling environmental factors?
- The importance of scale
- New frontiers:
  - Climate change and methylation
  - Engineering methylation inhibition
  - Microbial genetics
  - Instrumentation/methods

Field Locations for the Presentation


The Mercury Cycle
Deposition
Hg(II)
Hg0
Emissions
Hg
Methylation
HgBA
Sulfate
CH2O
SRB
Bacteria
MeHg
Bioaccumulation
Sulfide
CO2
Hg
Demethylation

Envrionmental Controls of MeHg Production

MICROBIAL ACTIVITY

Hg(II)-Methylating Bacteria & MeHg-Degrading Bacteria

- community composition
- electron donors (org-C)
- electron acceptors

  (e.g. SO_4^{2-}, Fe(III))
- pH and redox (Eh)
- temperature

MERCURY AVAILABILITY

Reactive-Hg(II) and MeHg

- amount of total Hg or MeHg*
- chemical form: (HgS, HgS_2^{2-})
- pH and redox (Eh)
- sulfur & carbon chemistry
- binding to particles
- complexation w/ NOM
- quality of the NOM

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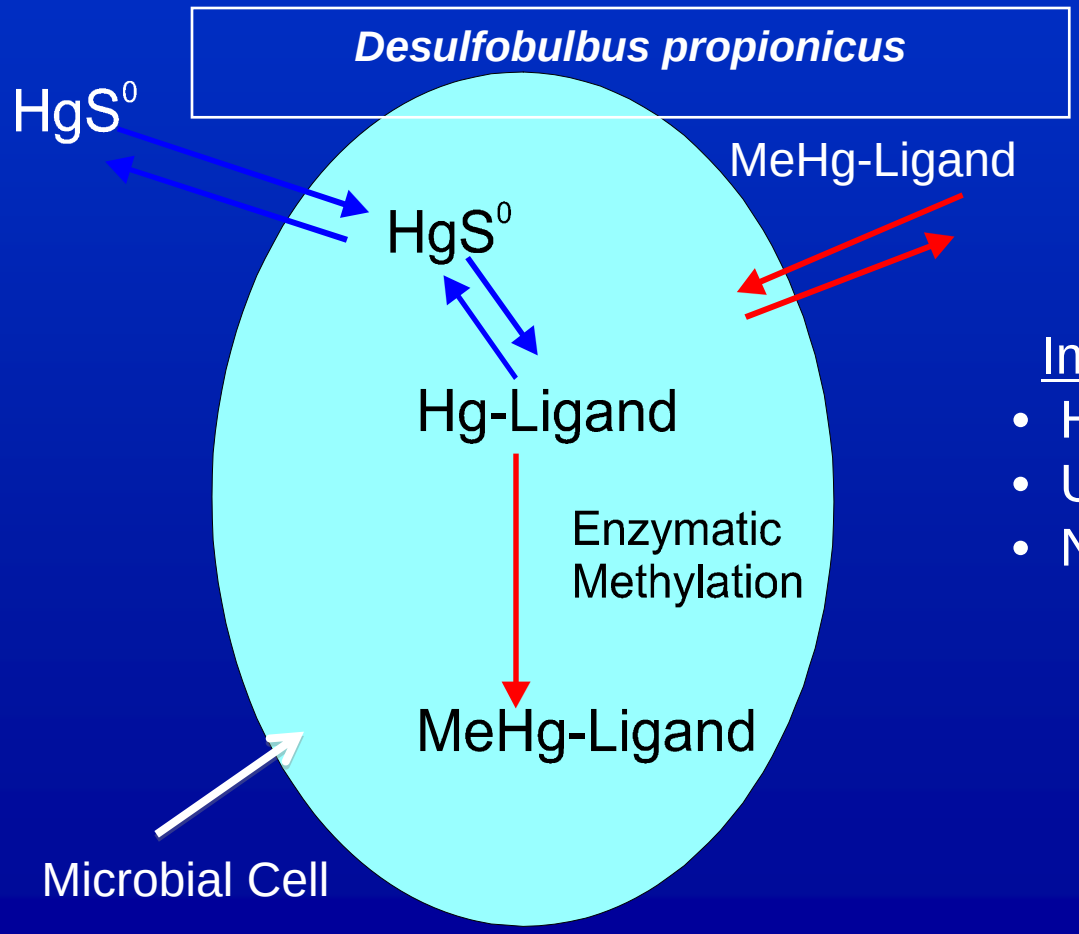
* Much focus on this one, but probably over emphasized

The Benoit-Gilmour-Mason Mercury Methylation Model

- Hg methylation is mediated by sulfate-reducing bacteria
- Methylation occurs inside cells
- B12 is the proximate methylating agent
- Inorganic Hg speciation determines uptake rates by cells

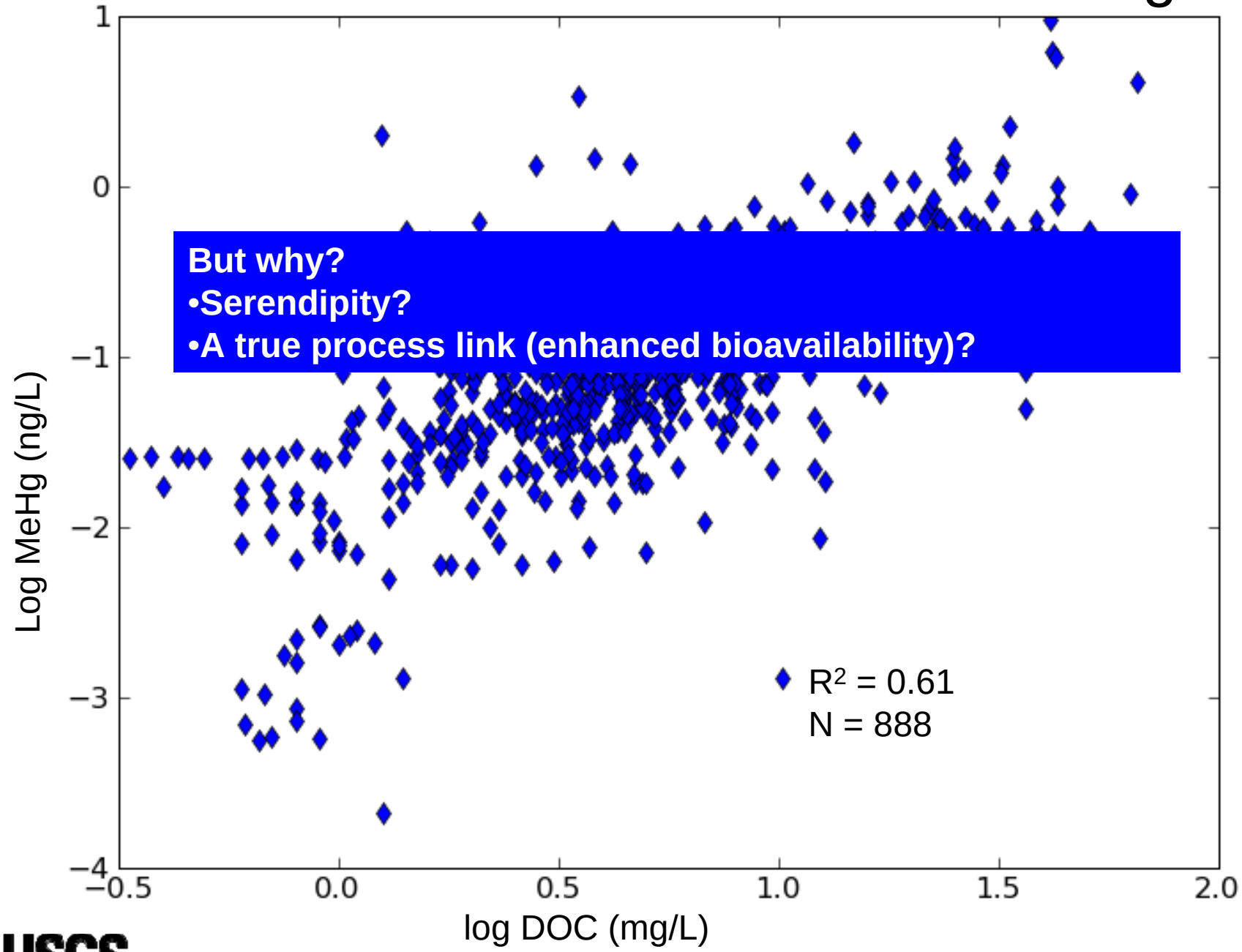


Implications of the Model:

- HgS^0 = bioavailable Hg
- Uptake is passive
- No apparent direct effect of NOM

Benoit, Gilmour and Mason. 2001.Appl. Environ. Microbiol.

National Surface Water DOM vs MeHg



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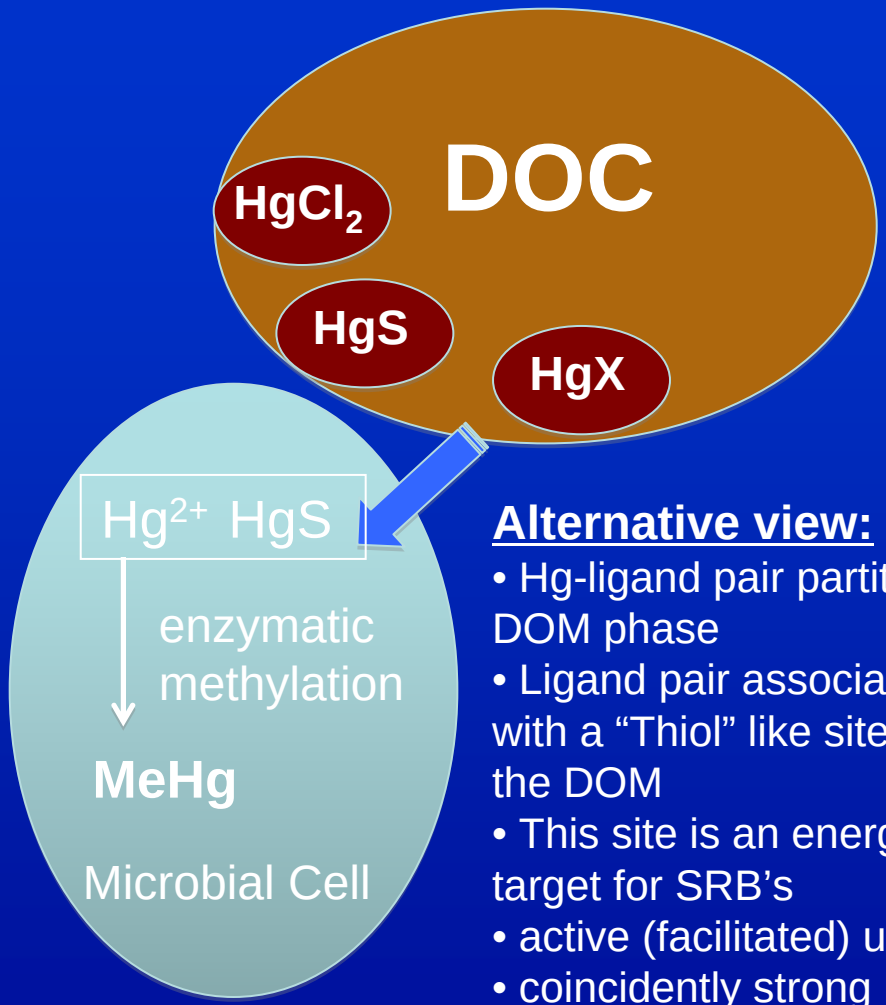
DOC and MeHg Production:



Alternative view:

- Hg-ligand pair partitions to DOM phase
- Ligand pair associates with a “Thiol” like site within the DOM
- This site is an energy target for SRB’s
- active (facilitated) uptake
- coincidently strong binding site for Hg

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DOM Effects on MeHg Production

Results of recent microbial methylation assays in pure culture

- Cultures with added DOM produced significantly greater MeHg than those without.
- Significant variability in response was observed among four different natural DOMs isolated from Minnesota, Georgia, and Florida
- The experimental results support the “new” conceptual model that calls for direct involvement of DOM for enhancing bioavailabilitiy of inorganic Hg for methylation

Mercury Experiment to Assess Atmospheric Loadings In Canada and the United States

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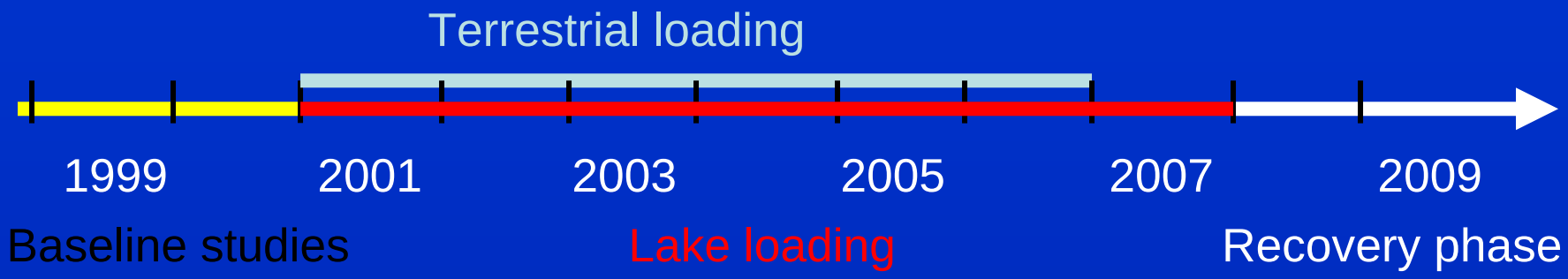
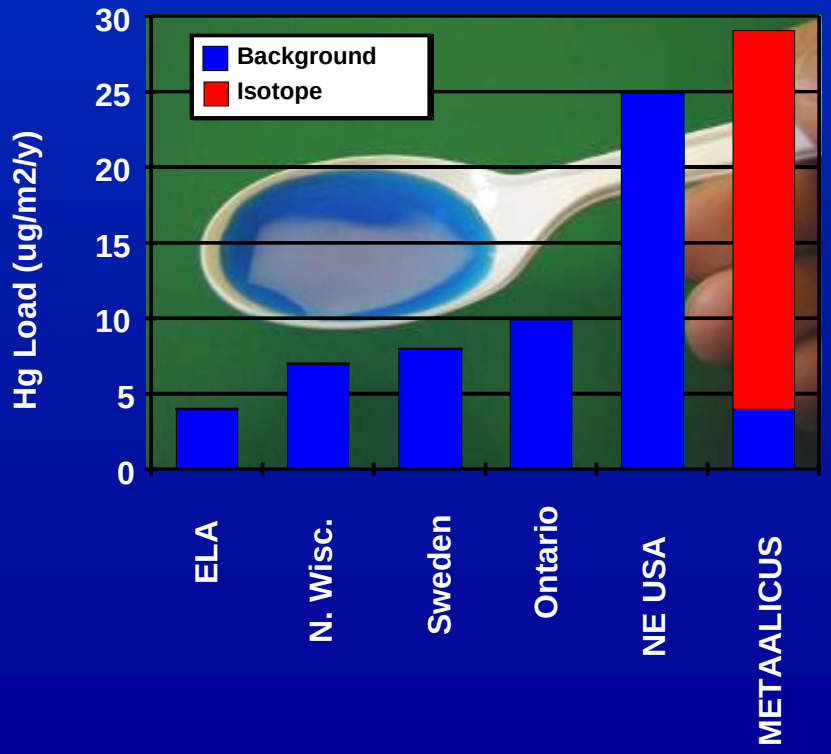
USGS portion funded by the Toxics Program

METAALICUS Approach & Schedule



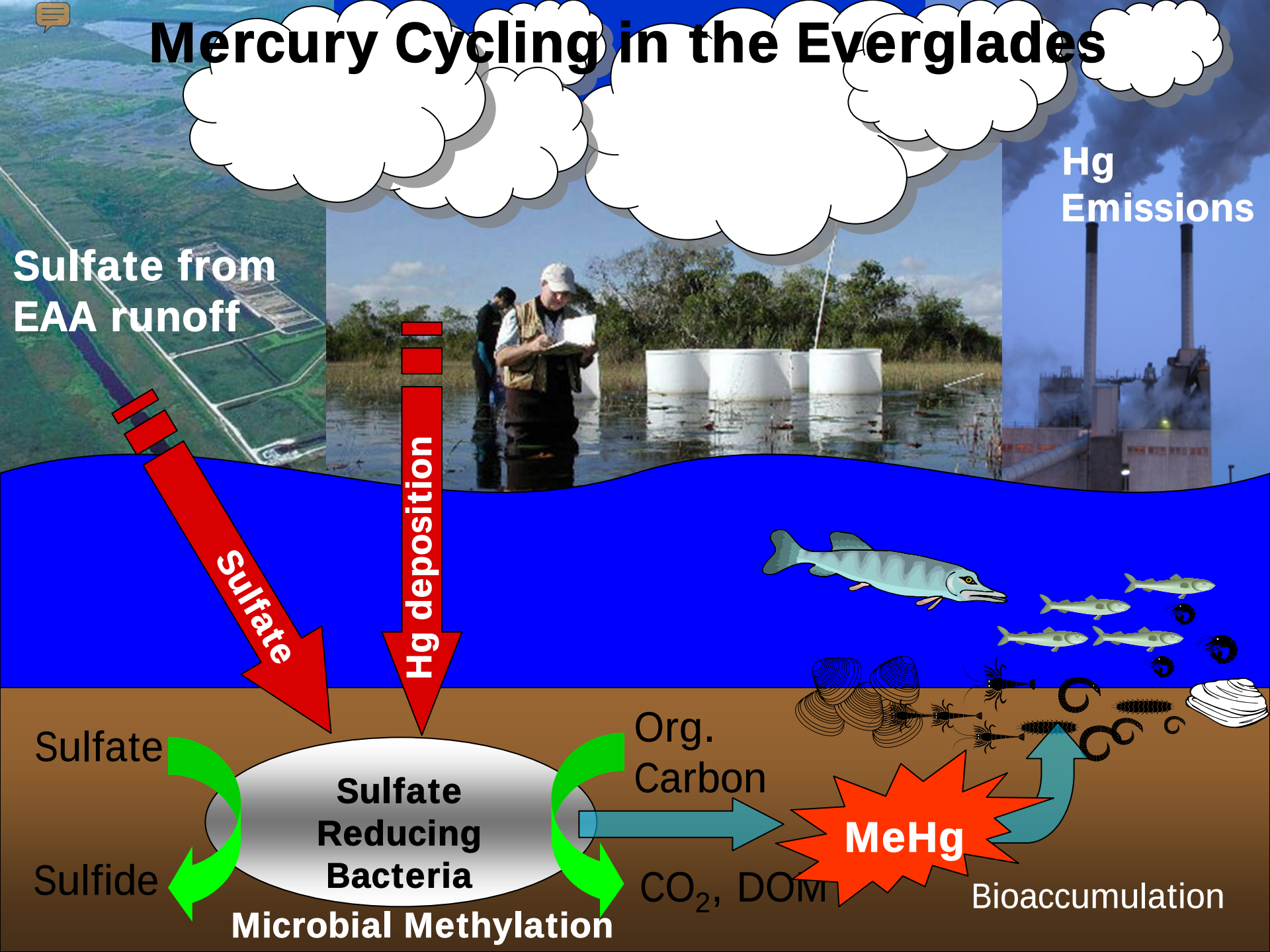
How much mercury are we adding?



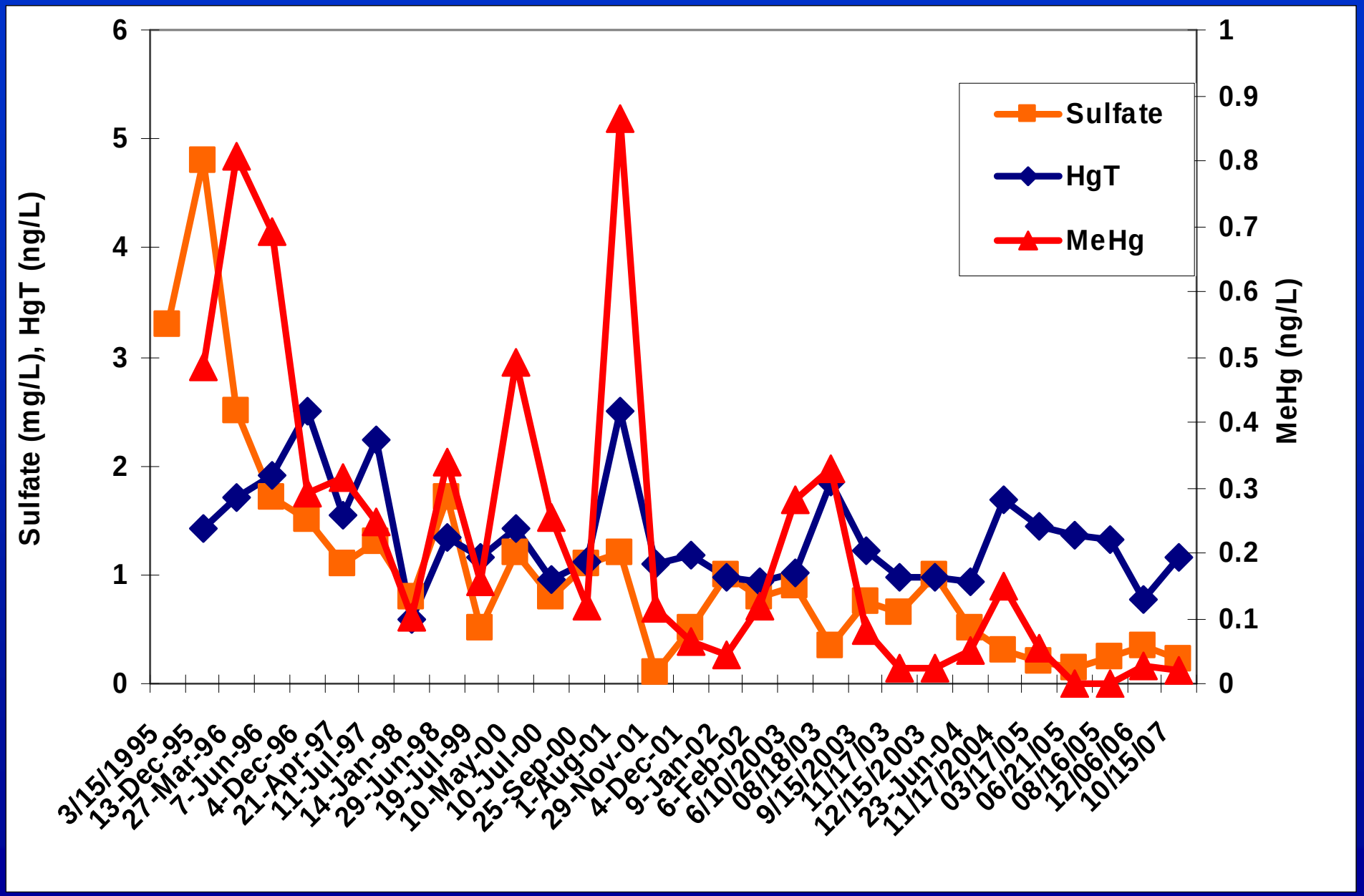
METAALICUS Results Summary

- Overall, the project demonstrated a significant and rapid response to both loading and load reduction.
- The appearance of “old mercury retirement” is evident in the lake sediments where the fraction of the experimentally applied Hg that is methylated becomes less and less with time since addition
- The food web response appears nearly proportional to the change in the net loading rate (accounting for initially rapid loss of the isotope to reduction and volatilization).
- Response of the terrestrial portions of the watershed suggest LONG delays in response to increases and decreases in Hg load.

Mercury Cycling in the Everglades



SO_4, MeHg & HgT Time Series




Mercury Methylation in the World's Oceans
Where's the MeHg Source?
How well does the freshwater conceptupal models hold?
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FLORIDA STATE UNIVERSITY
1851

U.S. Population-Wide Mercury Intake

~200 kg MeHg per year consumed in fish and shellfish

	% MeHg Intake
Fresh & Farmed	14.9%
Nearshore Marine	7.9%
North Atlantic >55N	6.5%
Atlantic	14.7%
North Pacific >30N	29.5%
Pacific/Indian <30N	25.4%
Mediterranean	1.0%
Antarctic	0.1%
Total	100.0%

Data Sources: Sunderland, 2007, NMFS 2000-2006, UNFAO 2000-2006

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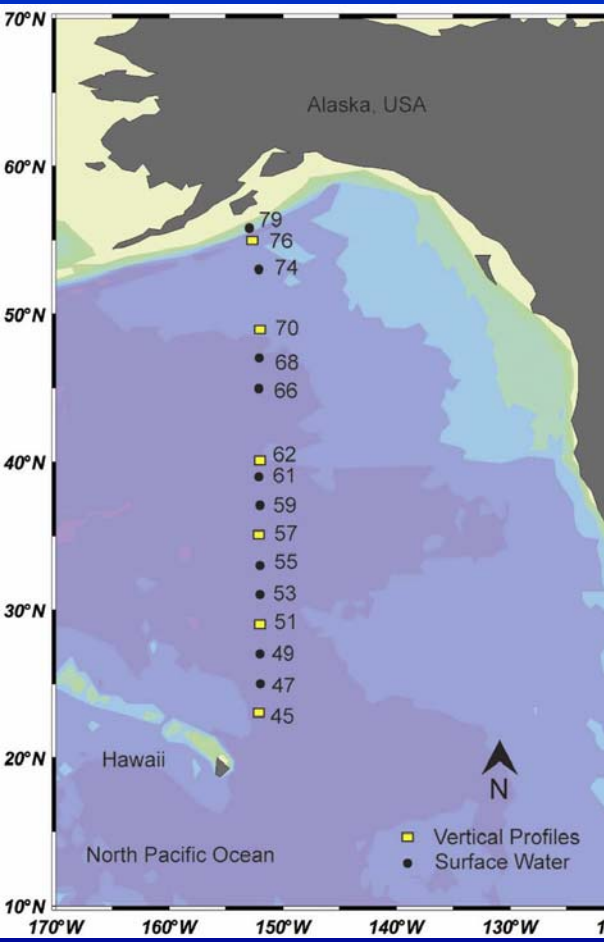
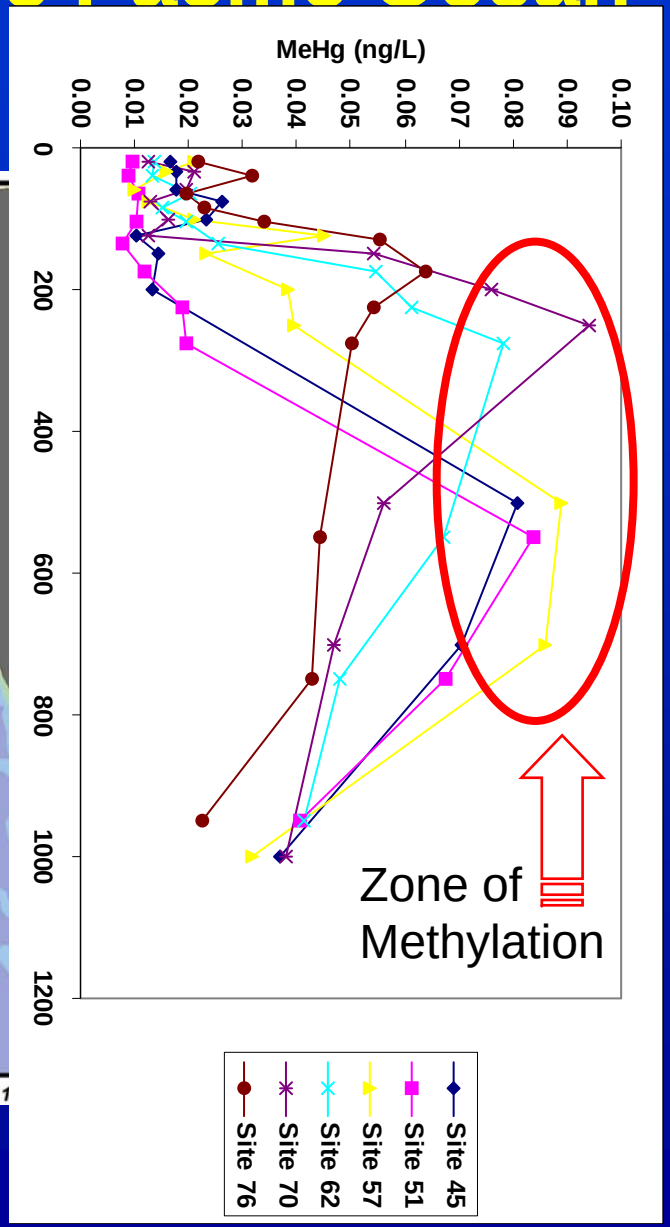
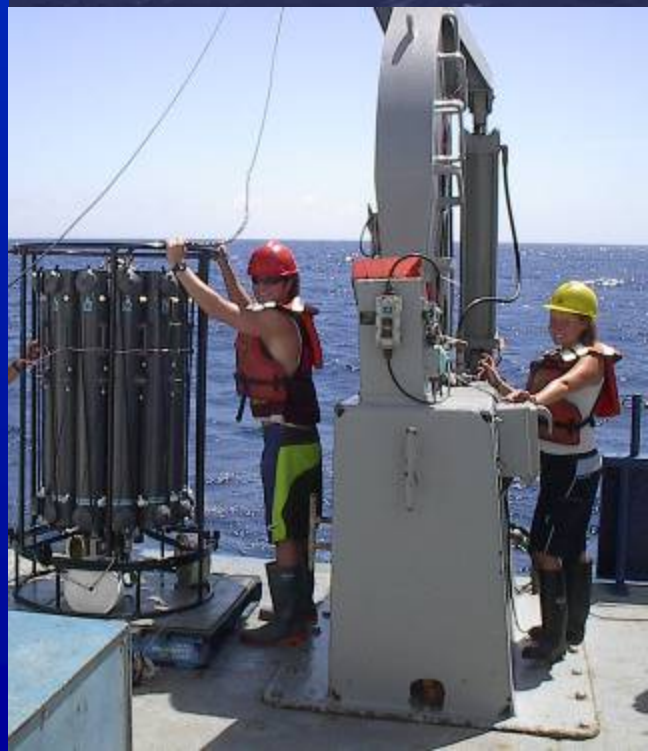
Mercury and Methylmercury Sources to the Pacific Ocean

Study sampling locations







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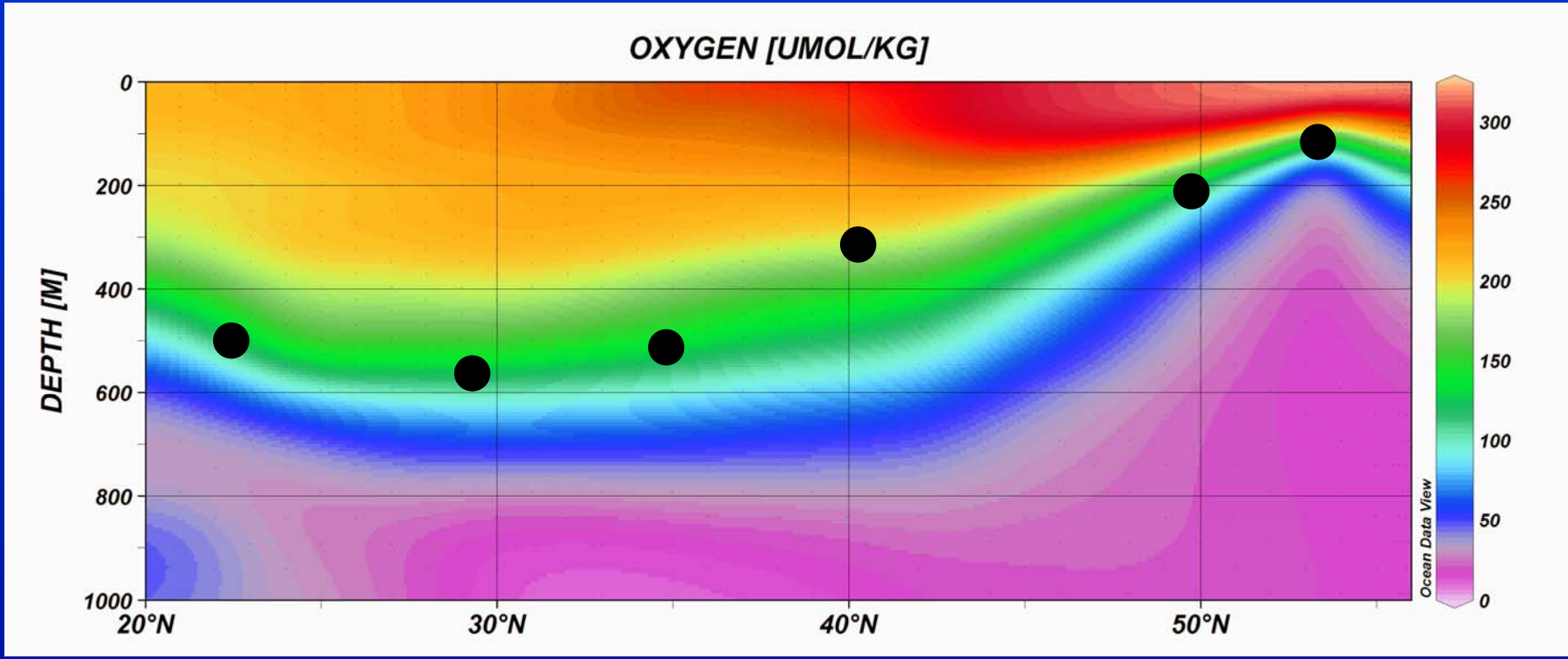
Maximum Observed MeHg Concentration vs Oxycline Position



● Maximum Observed MeHg Concentration

Asian mercury deposition

Conceptual Model for Mercury Sources and Cycling in the Pacific Ocean

Shallow waters

Intermediate waters

Deep waters

surface water subduction

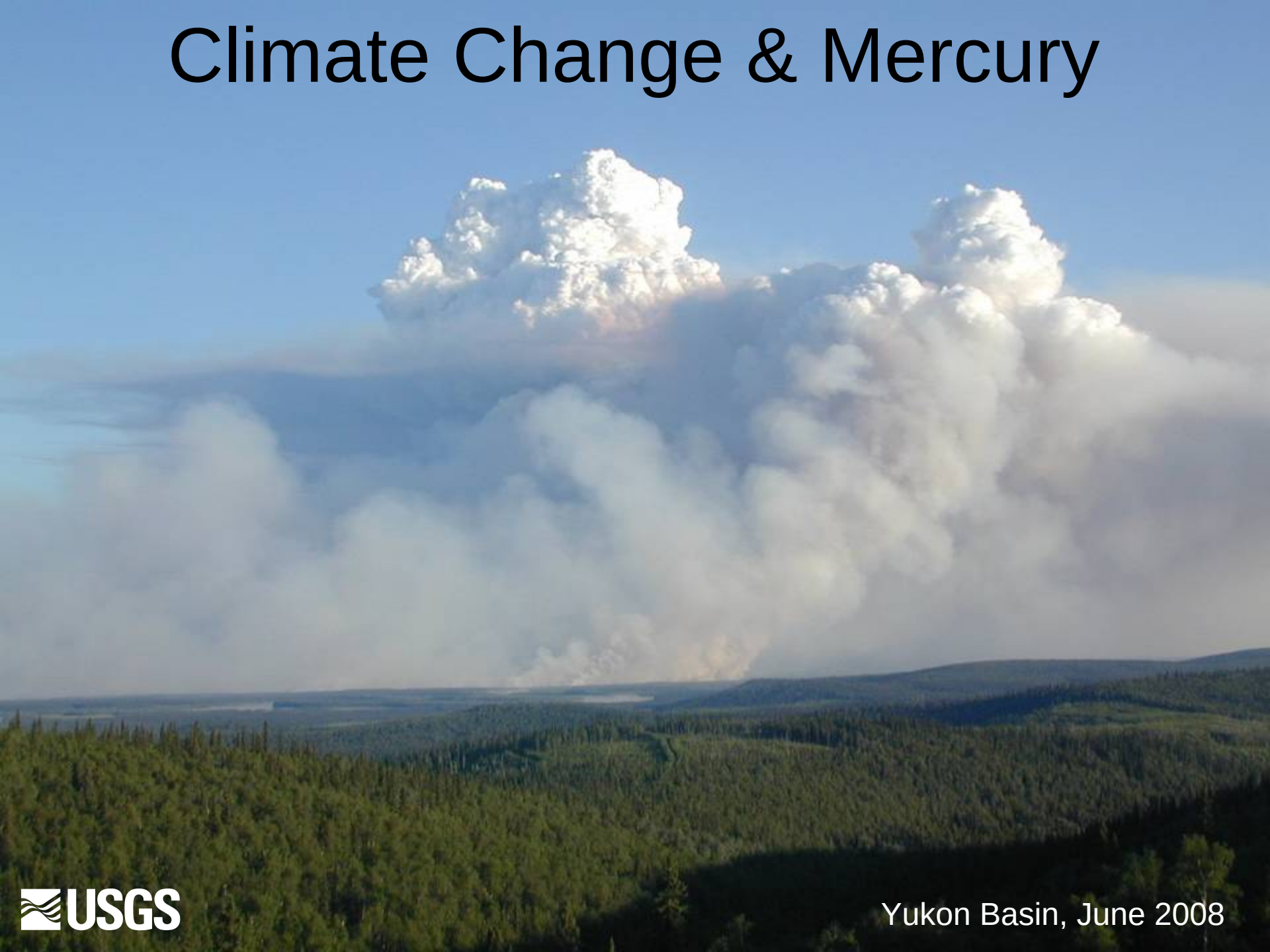
ocean rain

Organic matter breakdown, O2 consumption, and methylation

Western Pacific

Eastern Pacific

Climate Change & Mercury



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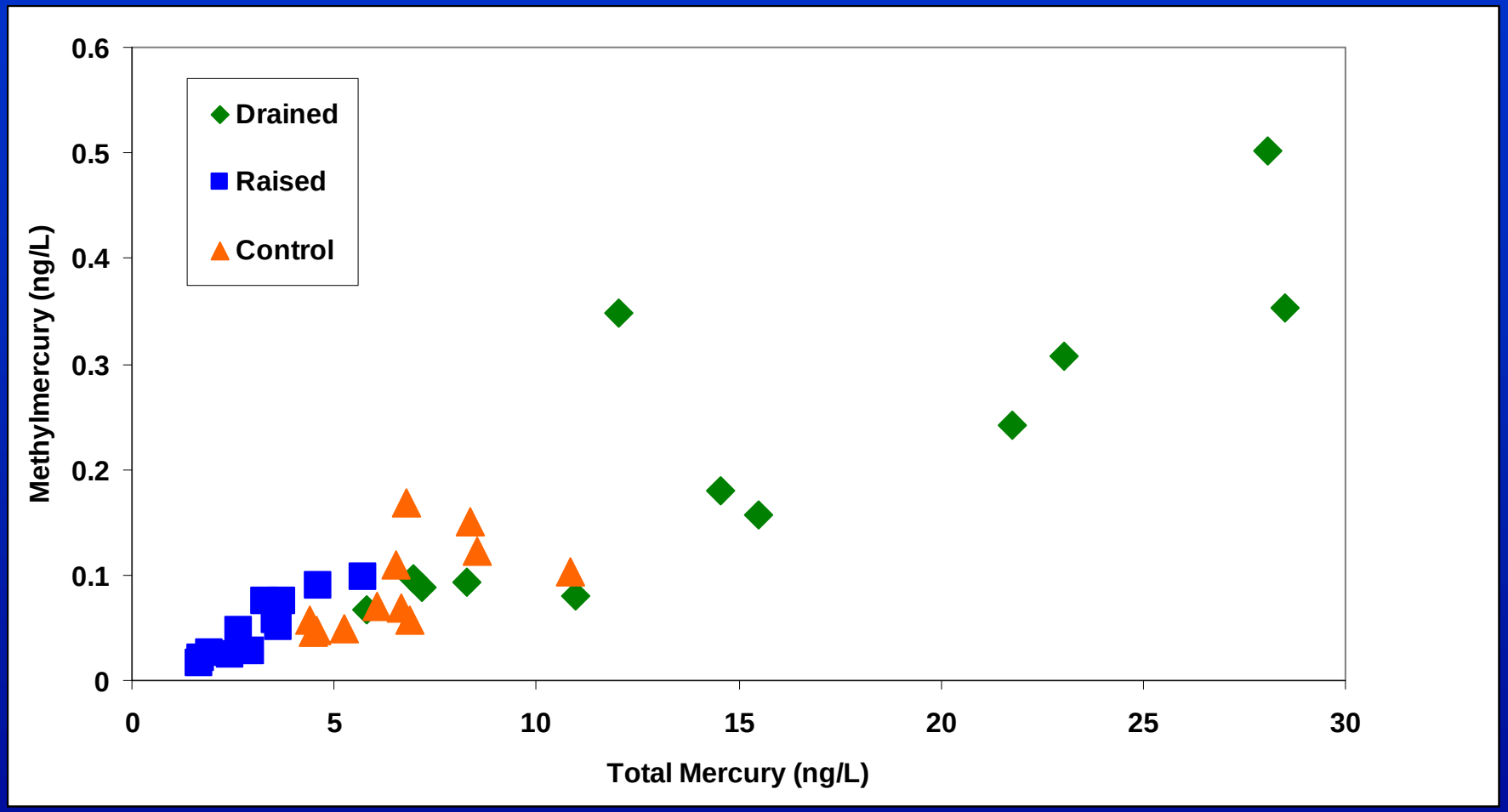
Yukon Basin, June 2008

Effects of Changing Water Levels on Methylmercury Production in Alaskan Wetlands



Results from the Bonanza Creek Wetland water-level manipulation experiment

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Summary:

- Mercury methylation is an enormously complex topic that remains a central piece of the research agenda
- MANY factors affect the net production of MeHg production…including, but not exclusively Hg loading/concentrations
- It is critically important that the details of the controlling factors, locations, etc… of methylation are clearly understood if we are to effectively design corrective actions an understand ALL the alternatives that are possibly available to reduce MeHg production (chemical, physical, biological, hydrological, etc…)
- New technologies are coming on line to add significant improvements to our understanding of methylation
- Attend Mercury2011: Halifax, NS, Canada, July 2011

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Bayou Lacombe, LA