MERCURY IN THE ENVIRONMENT:
Where does it come from and where does it go?

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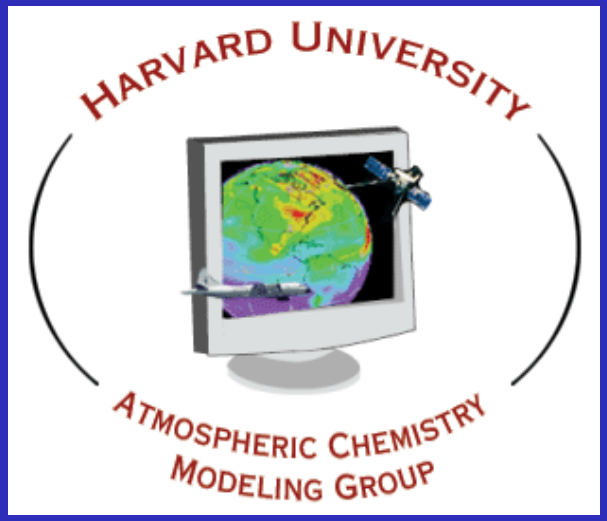
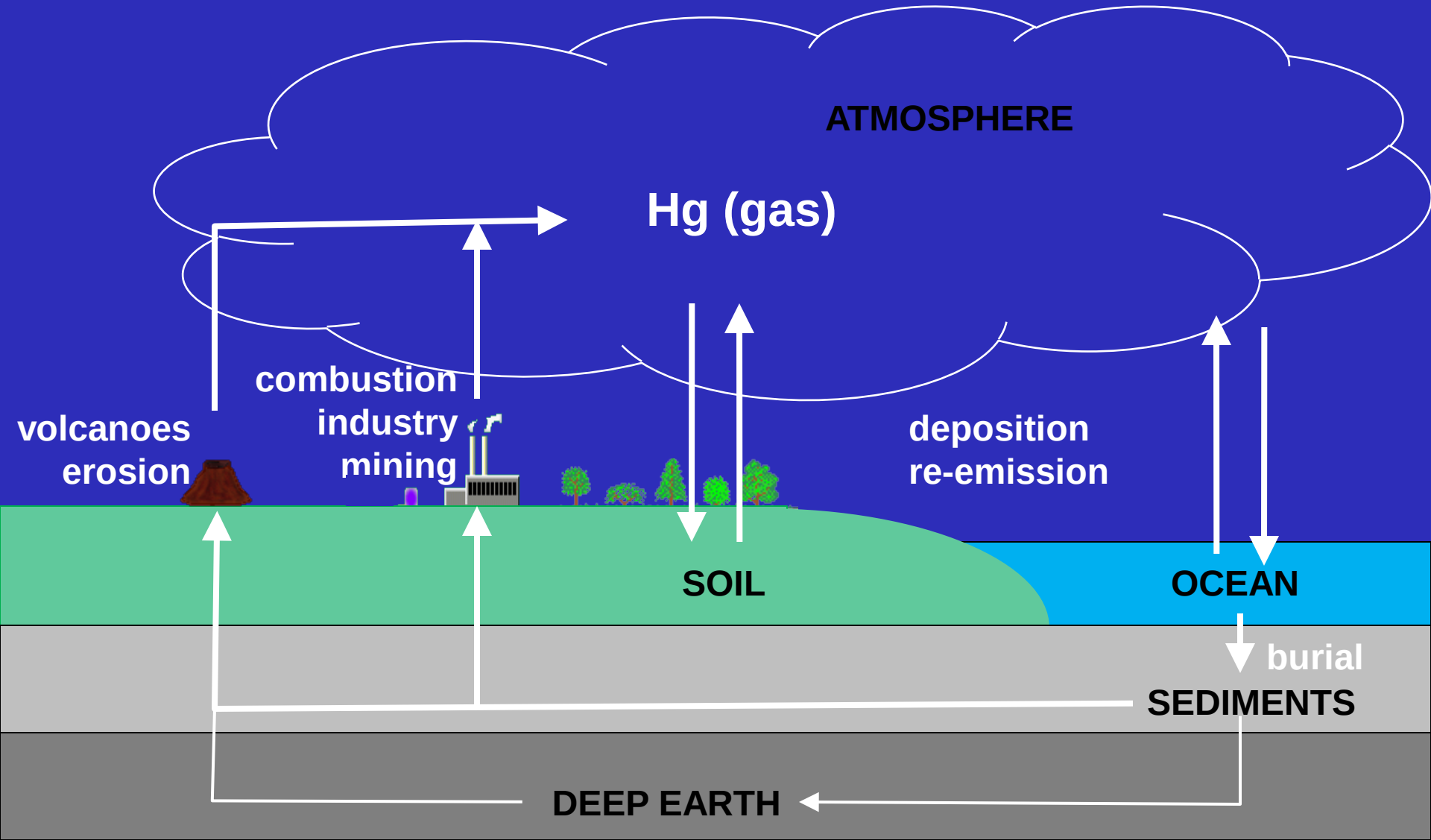
and the Harvard Team-Hg: Helen Amos, Bess Corbitt, Chris Holmes, Hannah Horowitz, Noelle Selin, Nicole Smith-Downey, Anne Soerensen, Elsie Sunderland



and funding from NSF, EPRI

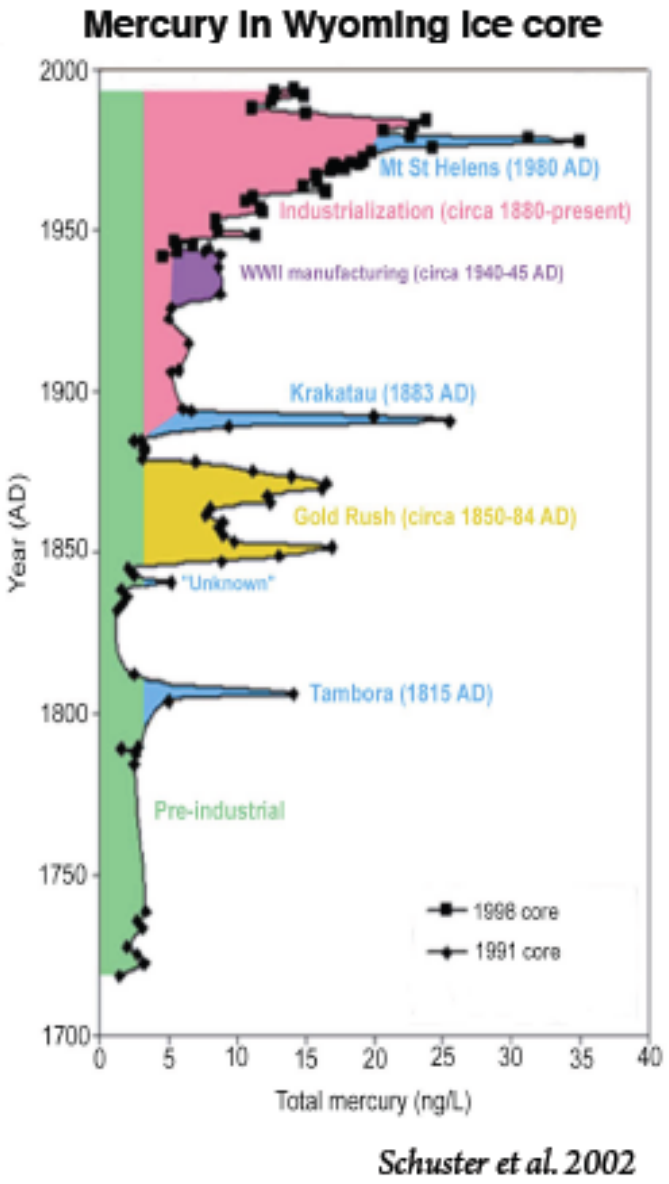
MERCURY (Hg) IS A NATURAL ELEMENT

It cycles continuously between the different reservoirs of the Earth

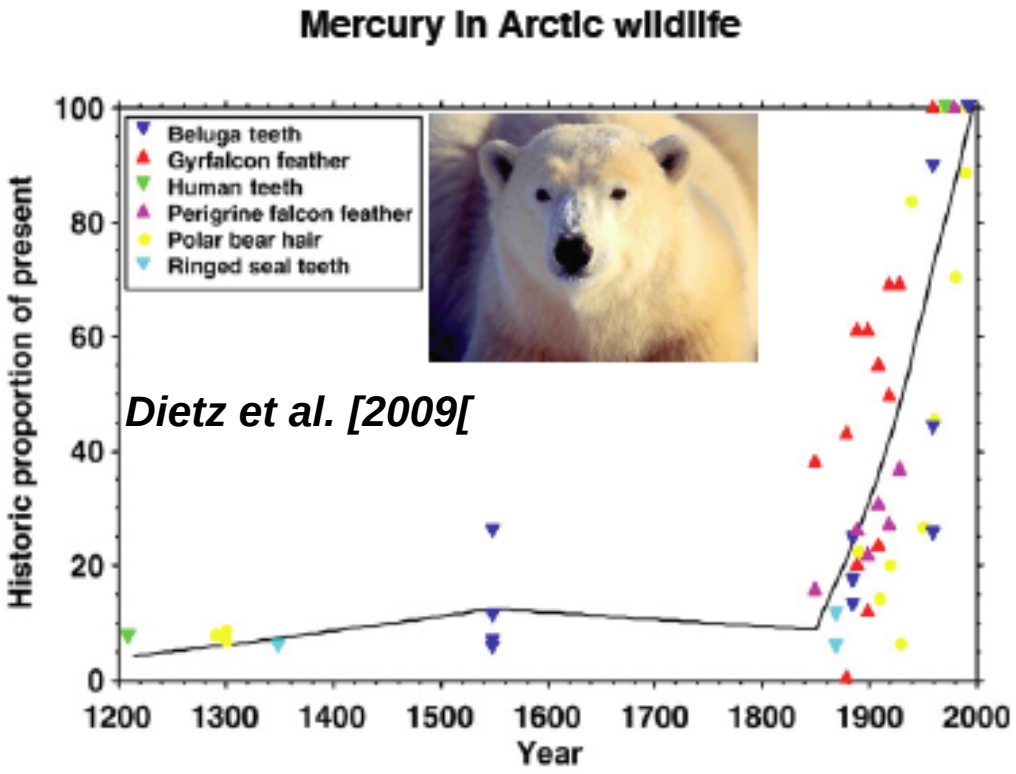


RISING MERCURY IN THE ENVIRONMENT

Global mercury deposition has roughly tripled since preindustrial times



Schuster et al. 2002

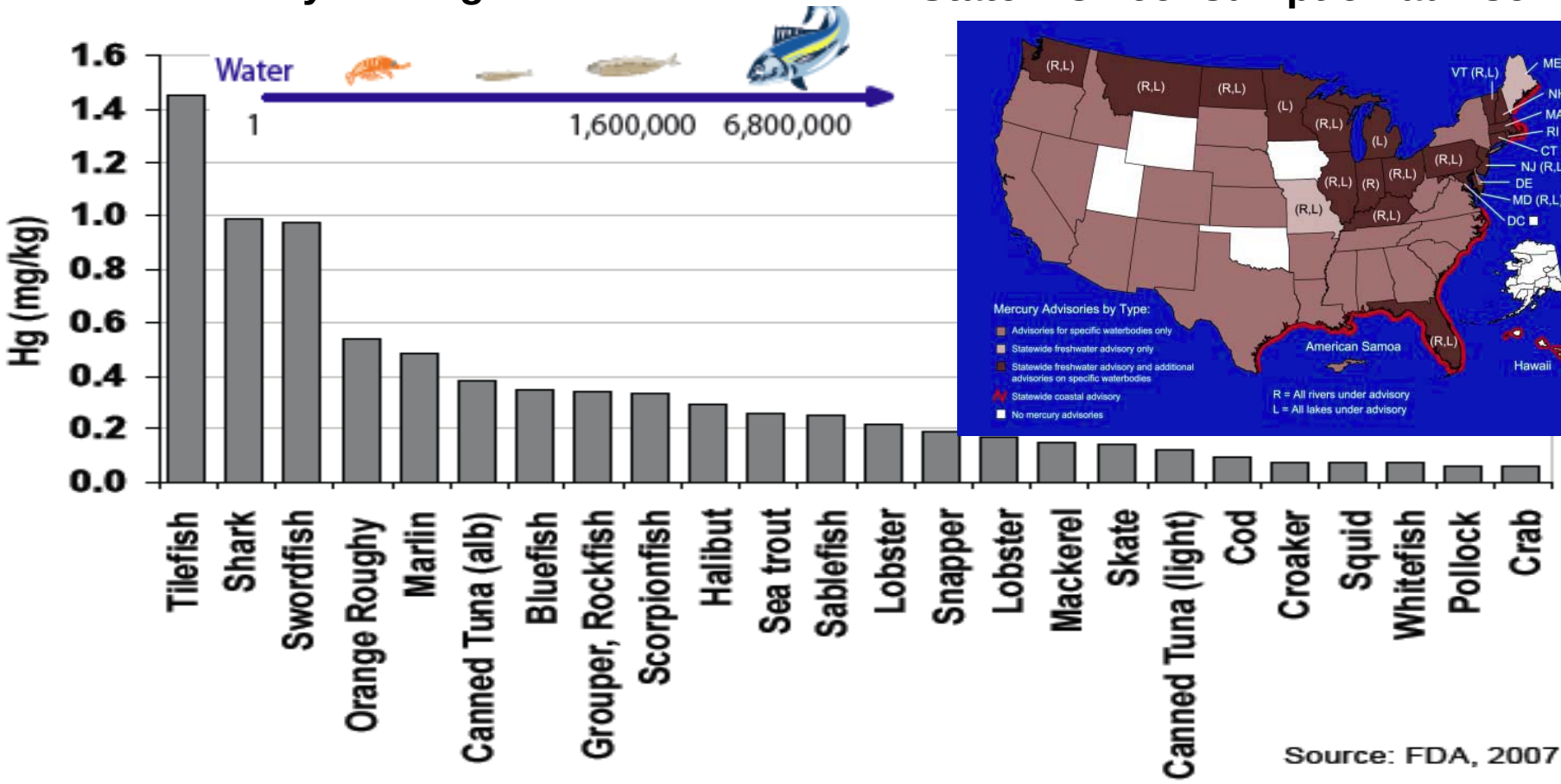


Dietz et al. [2009[

HUMAN EXPOSURE TO MERCURY IS MAINLY FROM FISH CONSUMPTION

Tuna is the #1 contributor

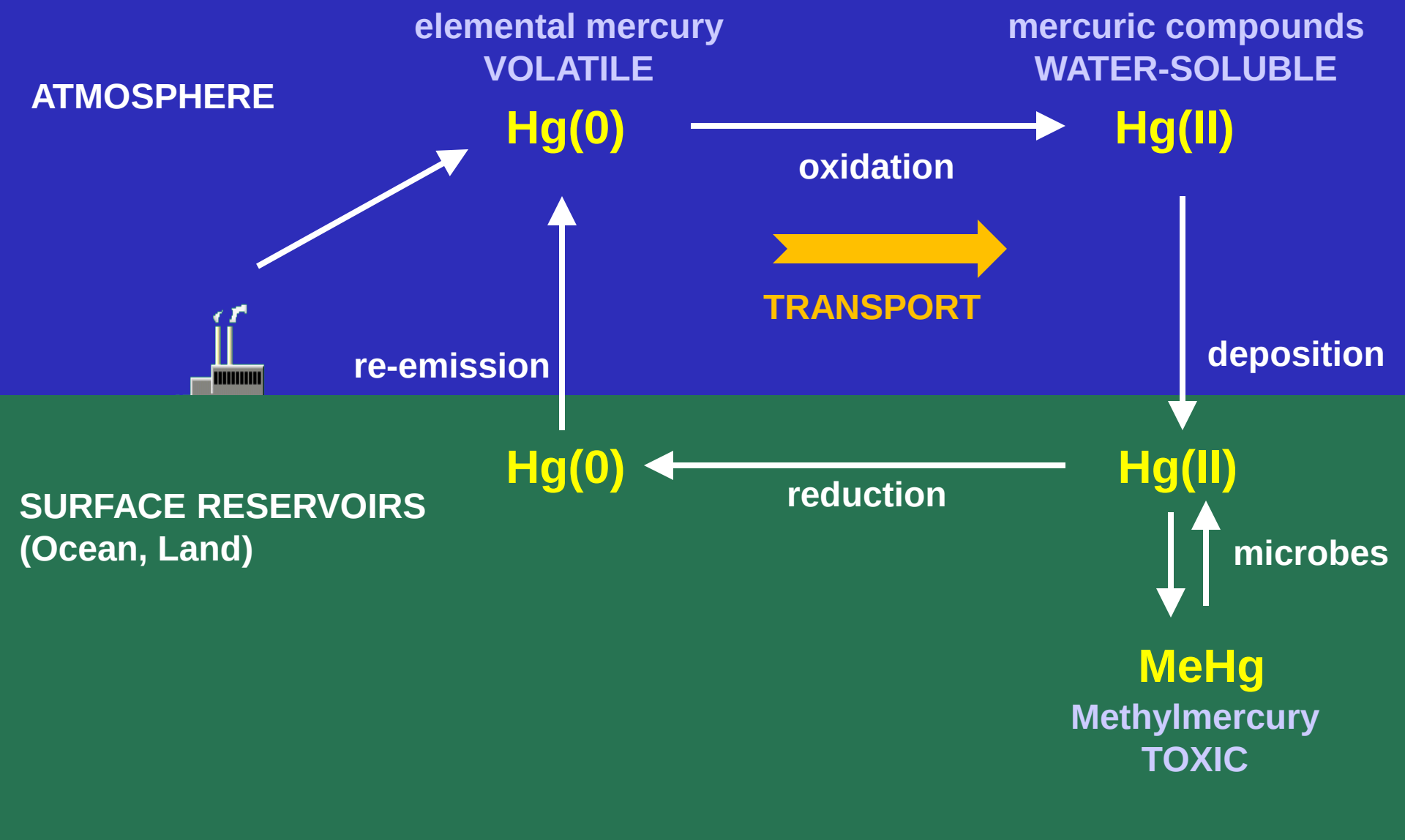
Mercury biomagnification factor



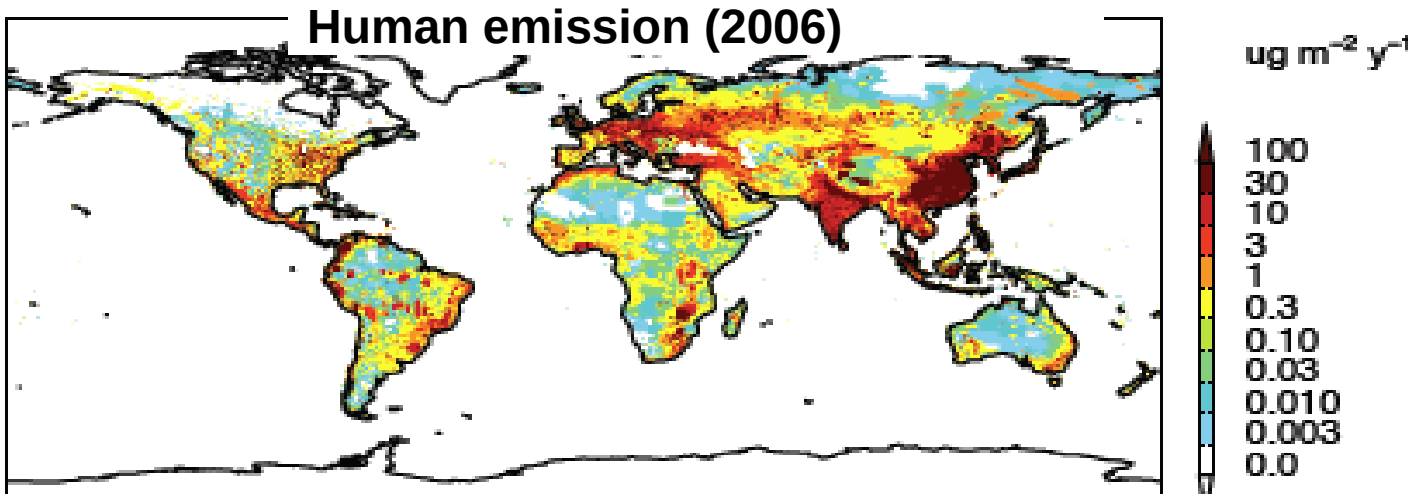
State fish consumption advisories

EPA reference dose (RfD) is 0.1 μg kg^{-1} d^{-1} (about 2 fish meals per week)

MERCURY CYCLING INVOLVES CHEMICAL TRANSFORMATIONS



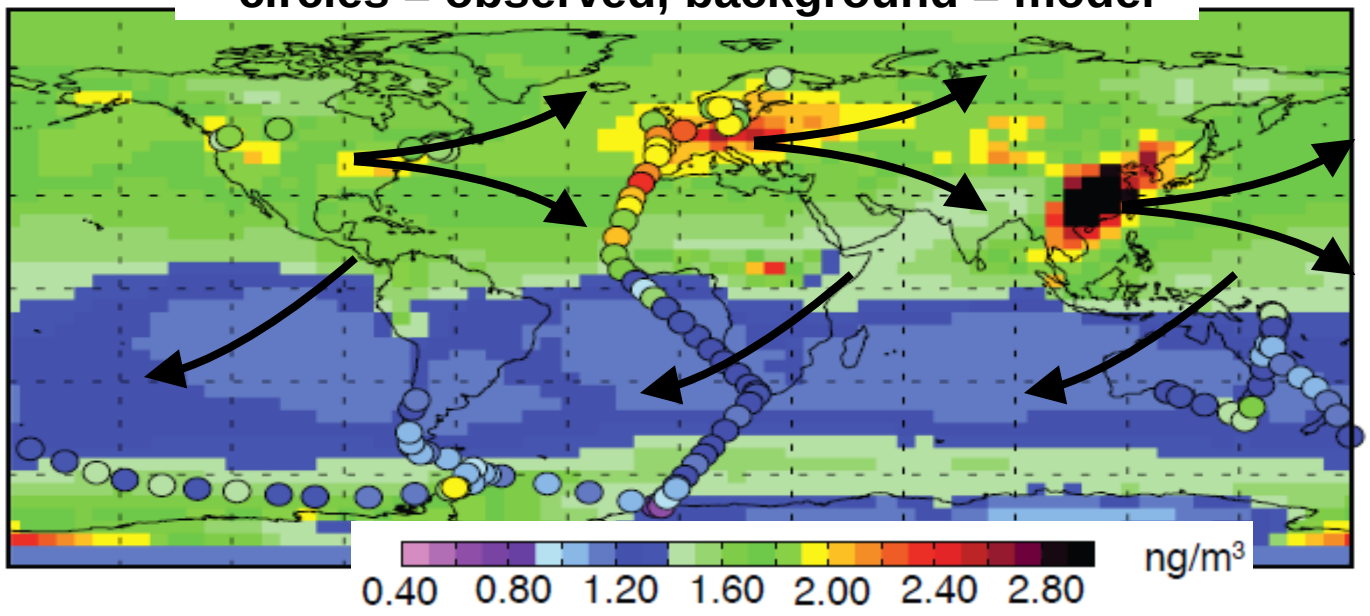
ELEMENTAL MERCURY IS GLOBALLY DISTRIBUTED IN ATMOSPHERE



Mean Hg(0) concentration in surface air: circles = observed, background = model

Transport around northern mid-latitudes: 1 month

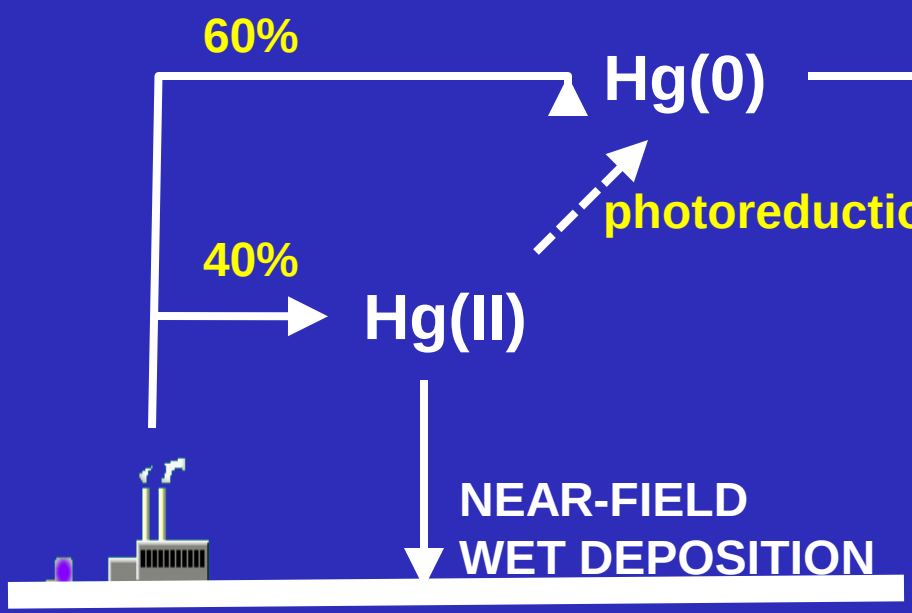
Transport to southern hemisphere: 1 year



Streets et al. [2009]; Soerensen et al. [2010]

LOCAL POLLUTION INFLUENCE FROM EMISSION OF Hg(II)

High-temperature combustion emits both Hg(0) and Hg(II)



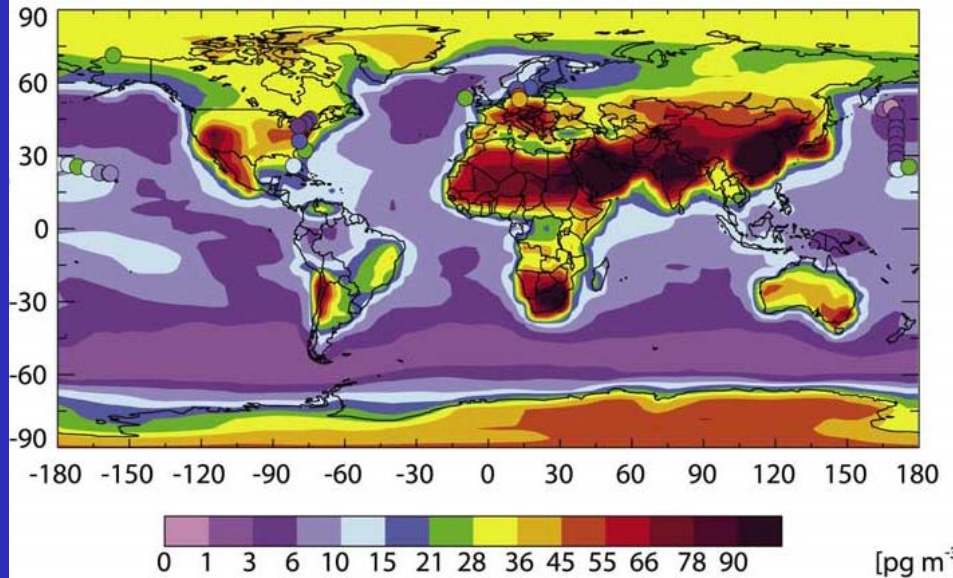
MERCURY DEPOSITION "HOT SPOT"

Large variability of Hg(II) implies atmospheric lifetime of only days against deposition

Thus mercury is BOTH a global and a local pollutant!

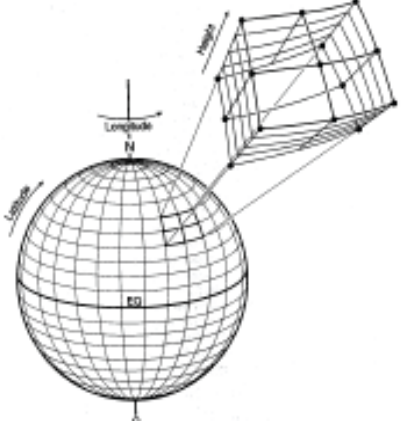
Selin et al. [2007]

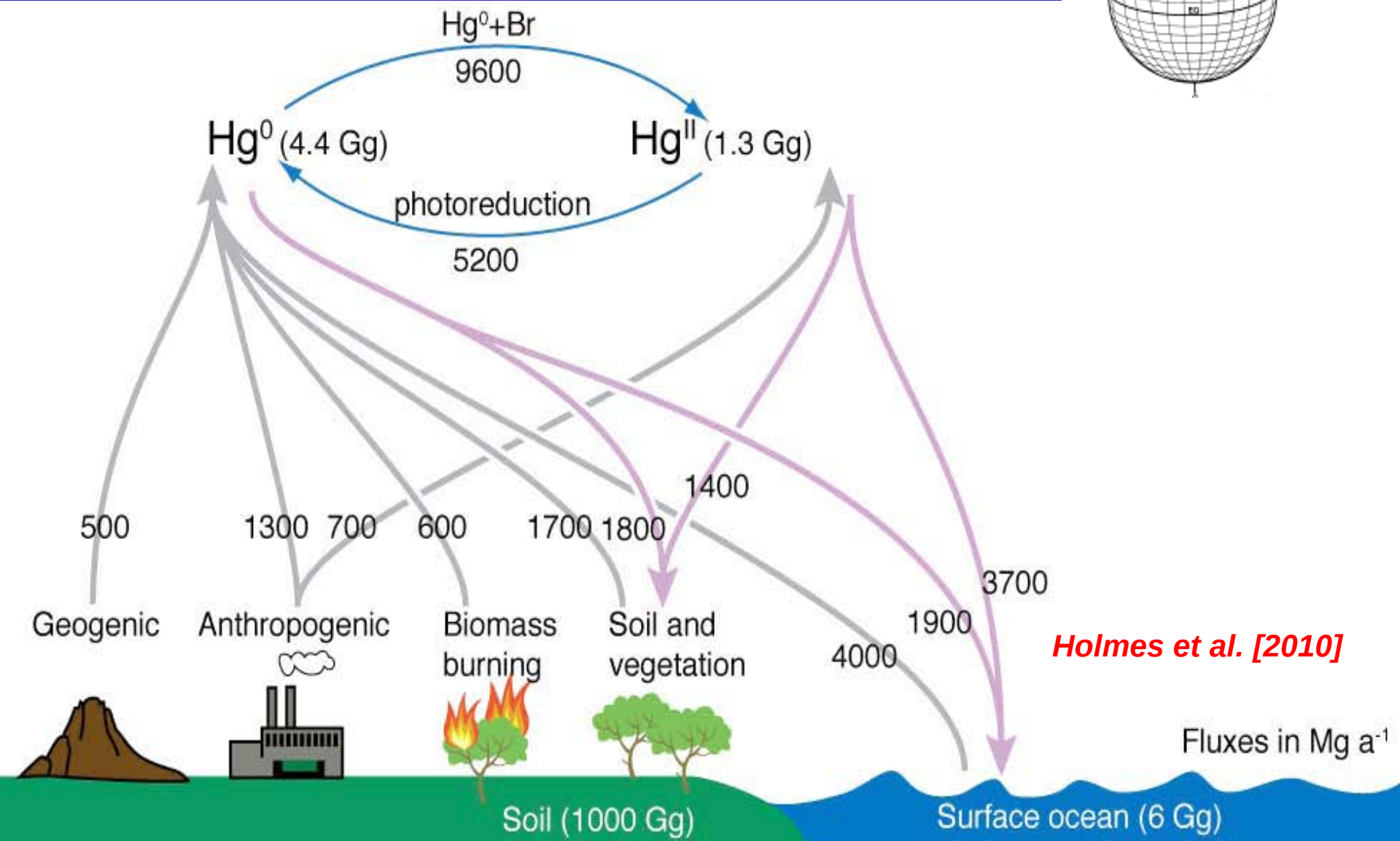
Hg(II) concentrations in surface air: circles = observed, background=model



GEOS-Chem global model of mercury

3-D atmospheric simulation driven by meteorological data and coupled to 2-D surface ocean and land reservoirs





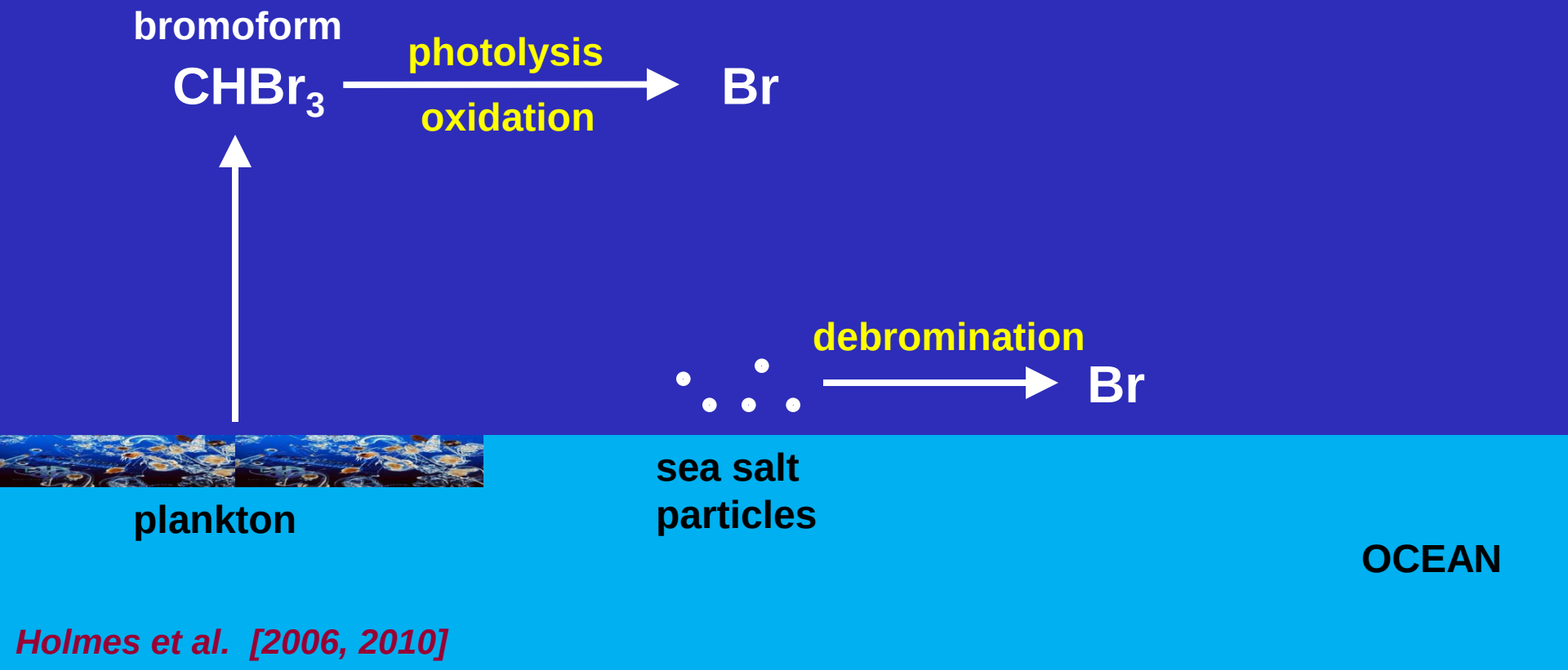
Holmes et al. [2010]

Hg(0) ATMOSPHERIC OXIDATION BY BROMINE ATOMS

$$Hg + Br + M \rightleftarrows HgBr + M$$

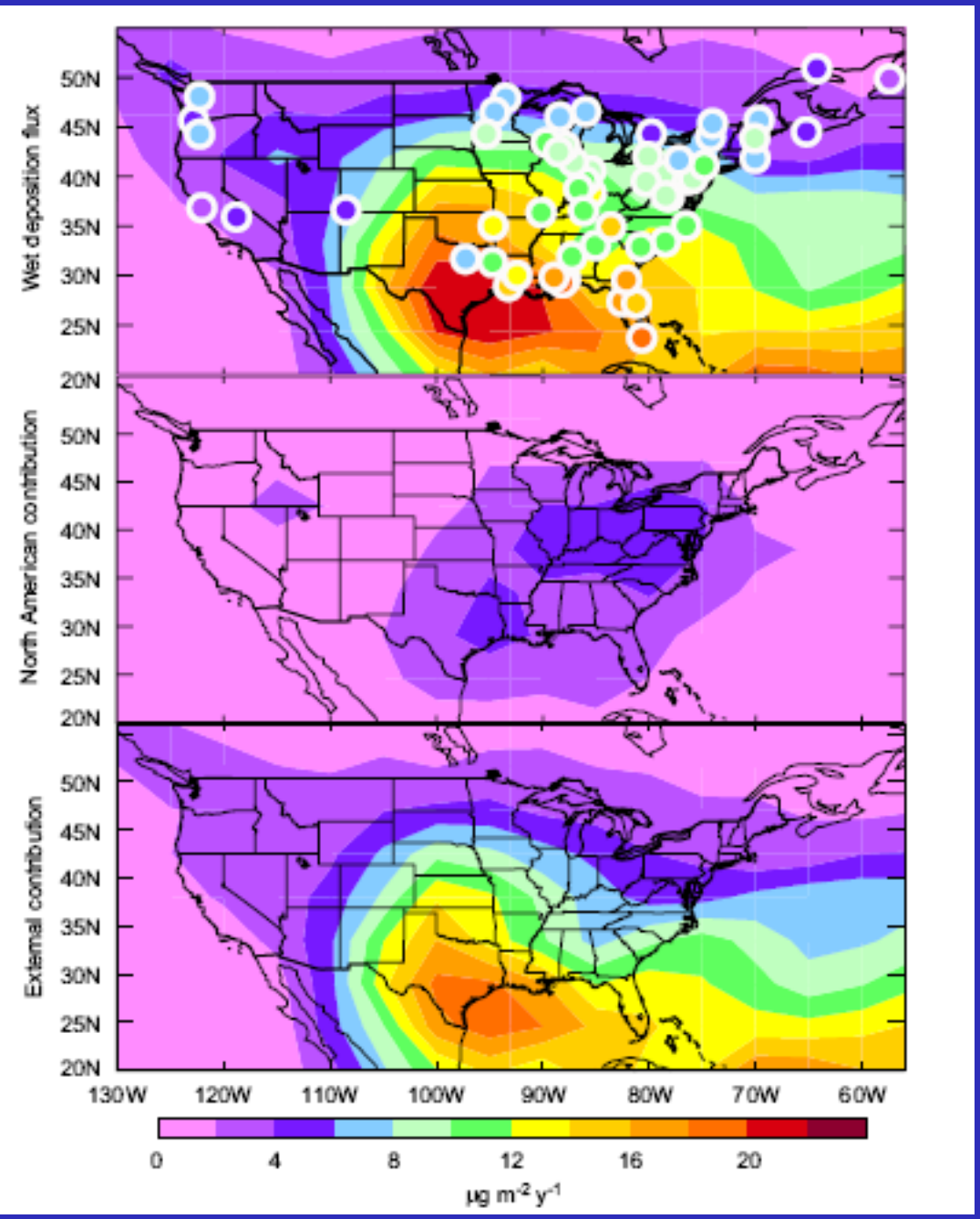
$$HgBr + X + M \rightarrow HgBrX + M \qquad X \equiv OH, Br, Cl$$

promotes deposition of mercury to the oceans



Holmes et al. [2006, 2010]

MERCURY WET DEPOSITION FLUXES, 2004-2005



Circles: observations
Background: GEOS-Chem model

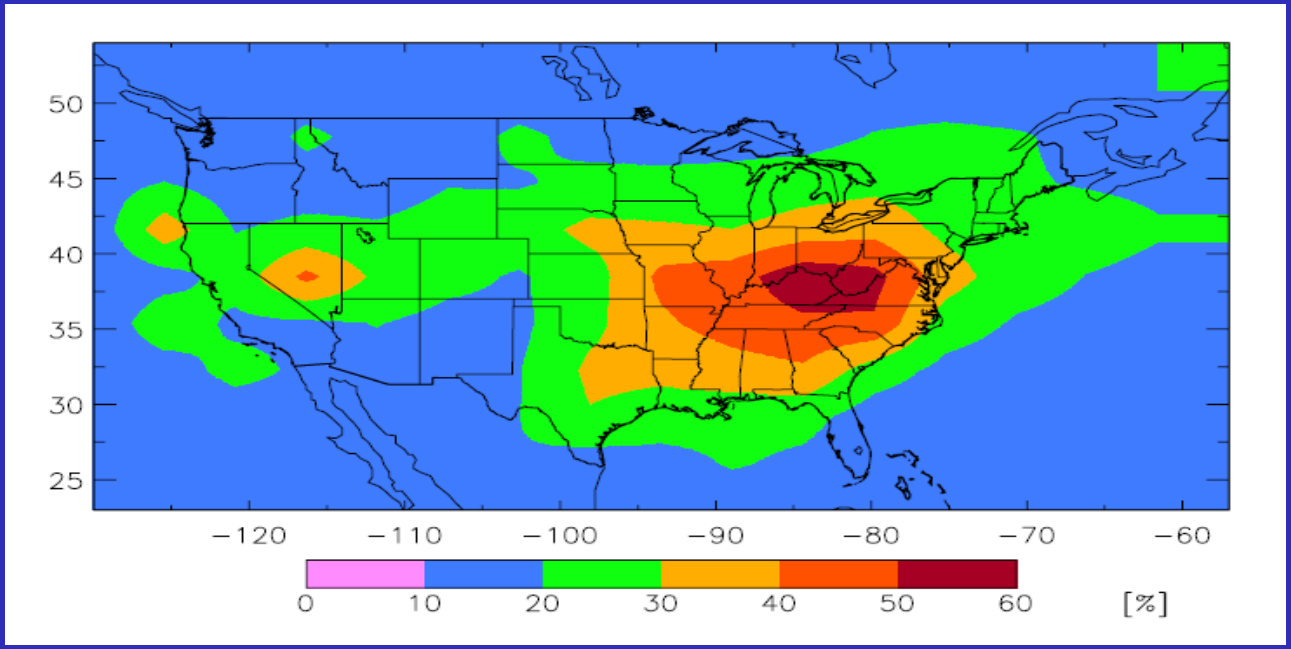
Model contribution from North American anthropogenic sources

Model contribution from external sources

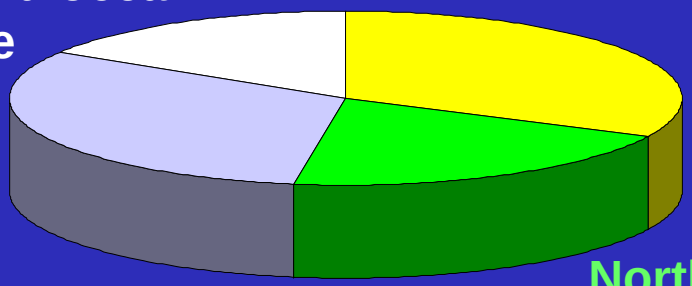
Selin and Jacob [2008]

SOURCE ATTRIBUTION FOR U.S. MERCURY DEPOSITION

% contribution of North American sources to annual total mercury deposition



Legacy anthropogenic re-emitted from soil and ocean on centurial time scale (17%)



Natural (32%)

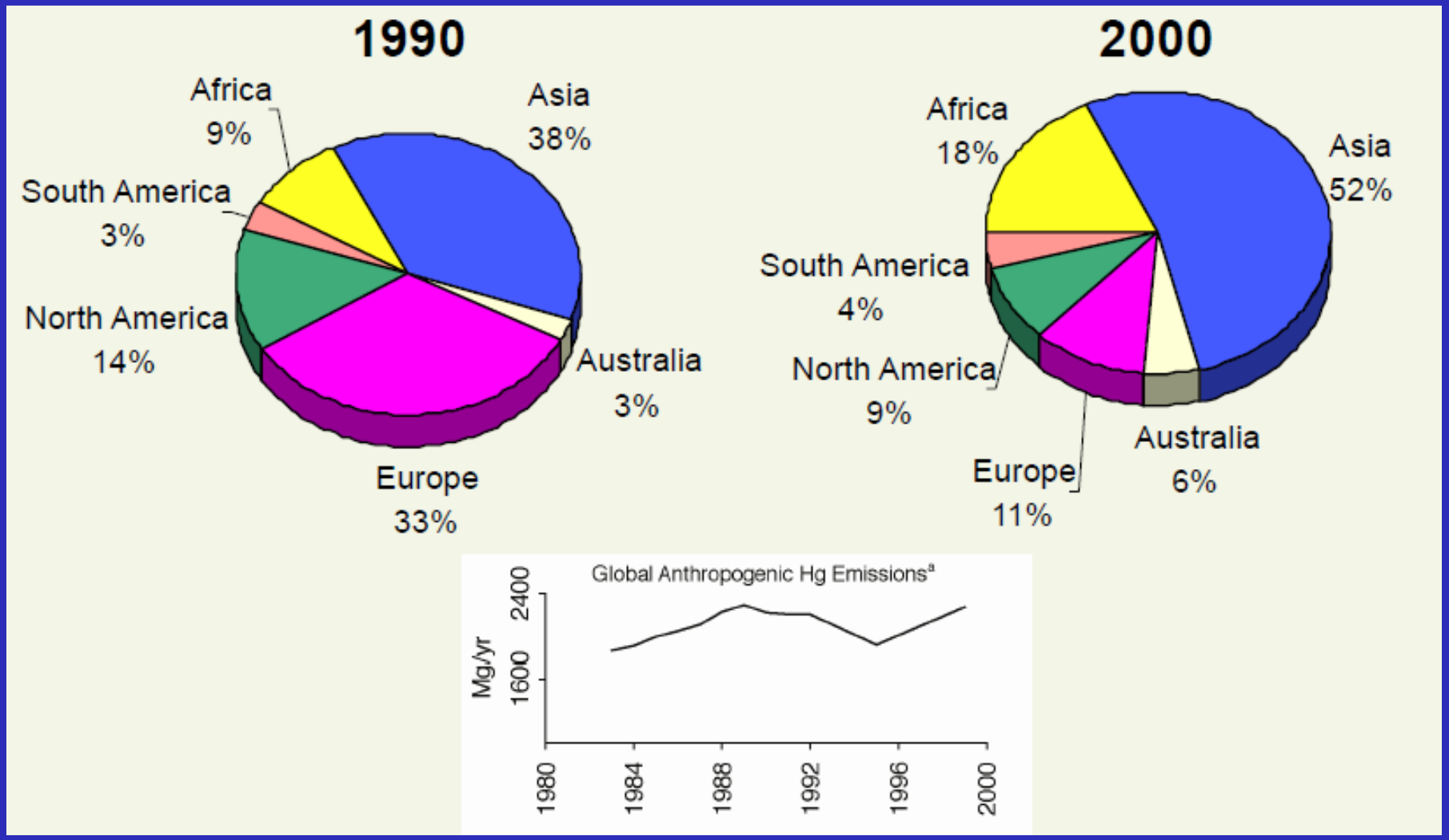
North American anthropogenic (20%)

Rest of world anthropogenic (31%)

Selin and Jacob [2008]

ASIA IS THE LARGEST CONTRIBUTOR TO GLOBAL MERCURY EMISSION

…although this is a recent phenomenon

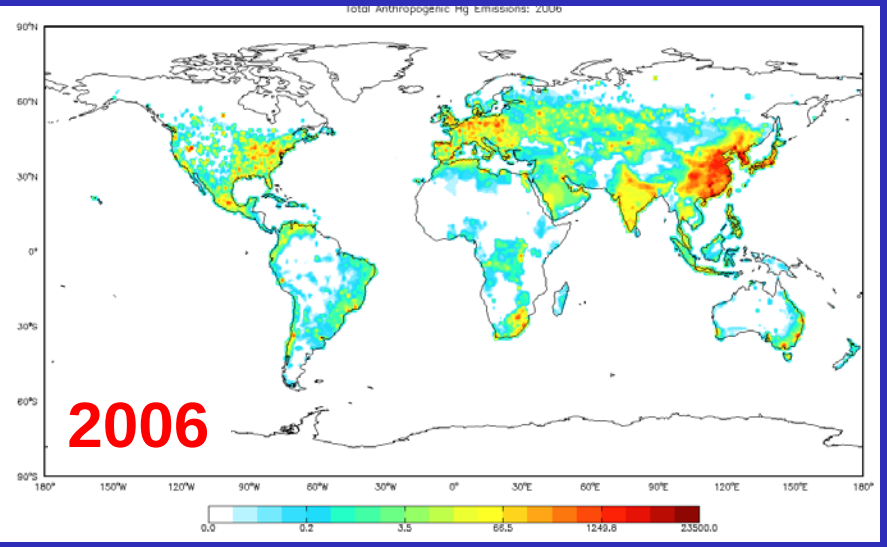


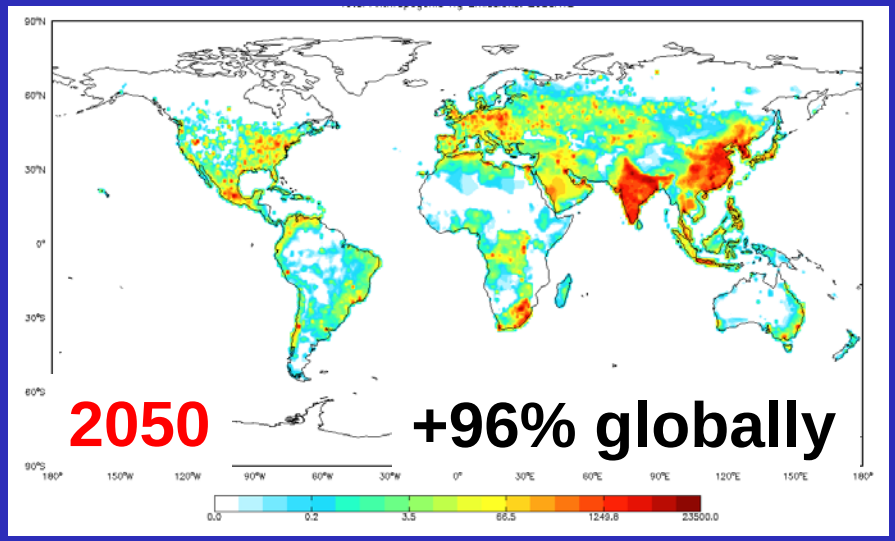
Global human emissions have been flat over past three decades due to compensation between rising Asian and African emissions, decreasing European and North American emissions

Pacyna et al. [2006]

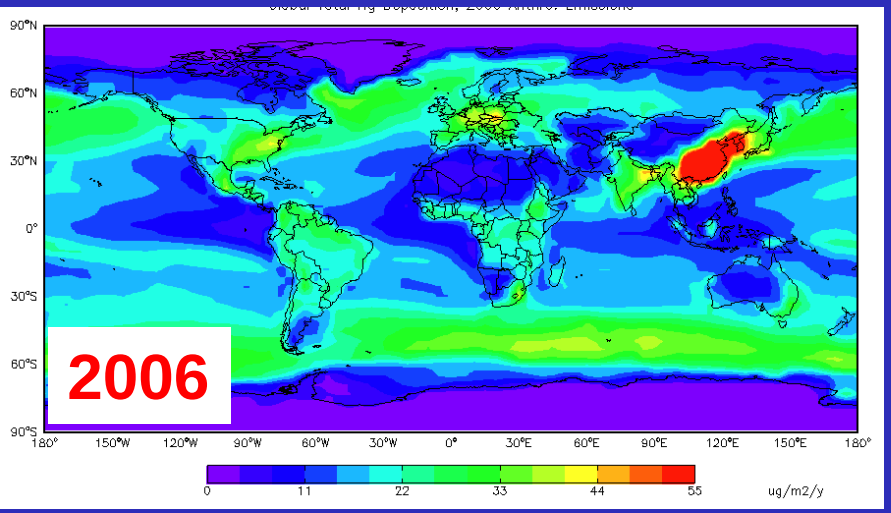
2050 PROJECTIONS FOR IPCC "BUSINESS-AS-USUAL" SCENARIO (A1B)

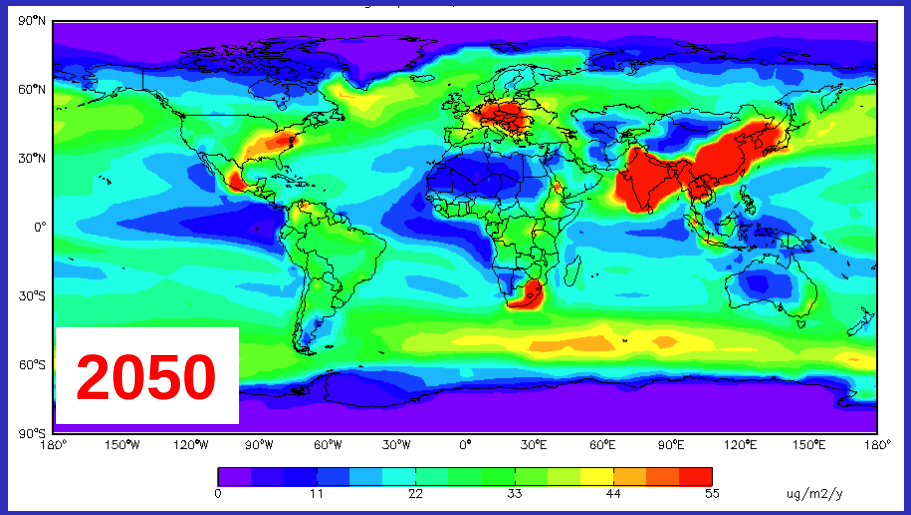
Anthropogenic emissions





Mercury deposition



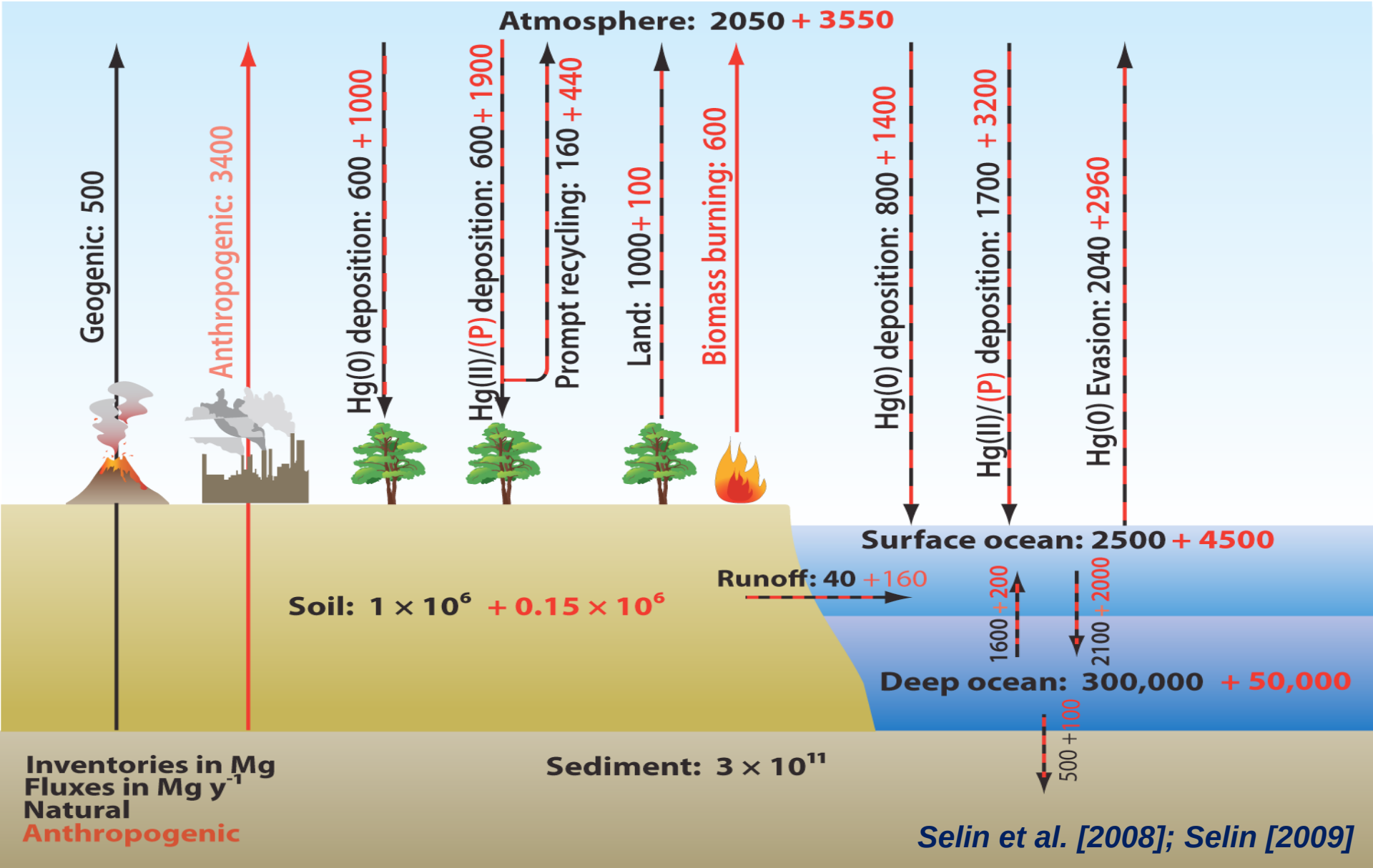


This does not include the increase in legacy emissions from oceans and solis

Streets et al. [2009]; Corbitt et al. [2010]

GLOBAL BIOGEOCHEMICAL CYCLE OF MERCURY

GEOS-Chem natural atmosphere + present-day human enhancement

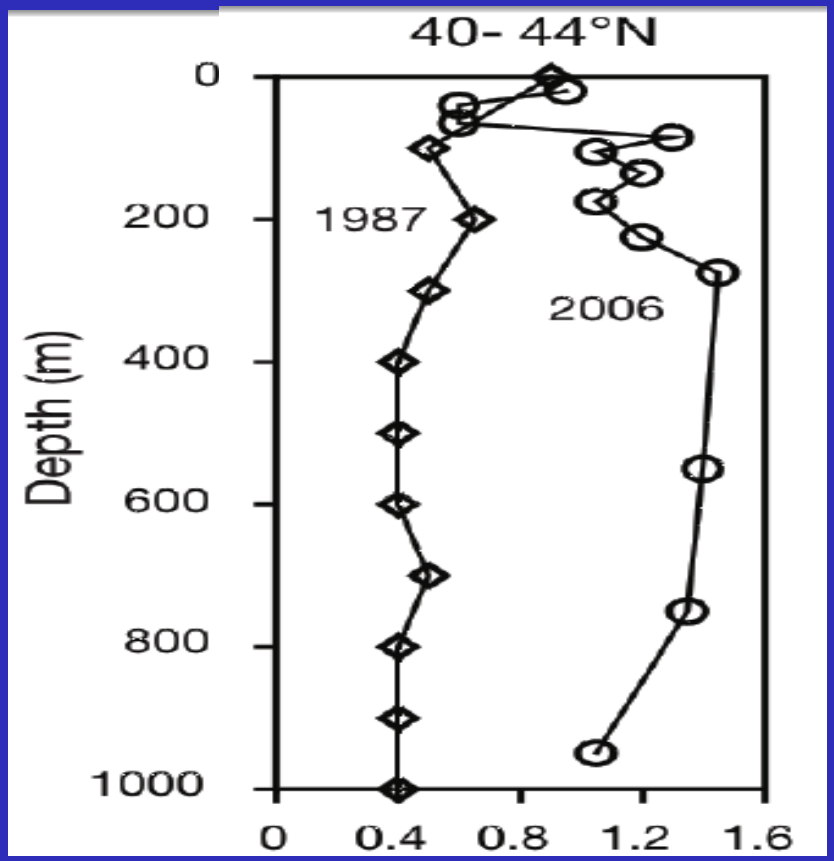


Selin et al. [2008]; Selin [2009]

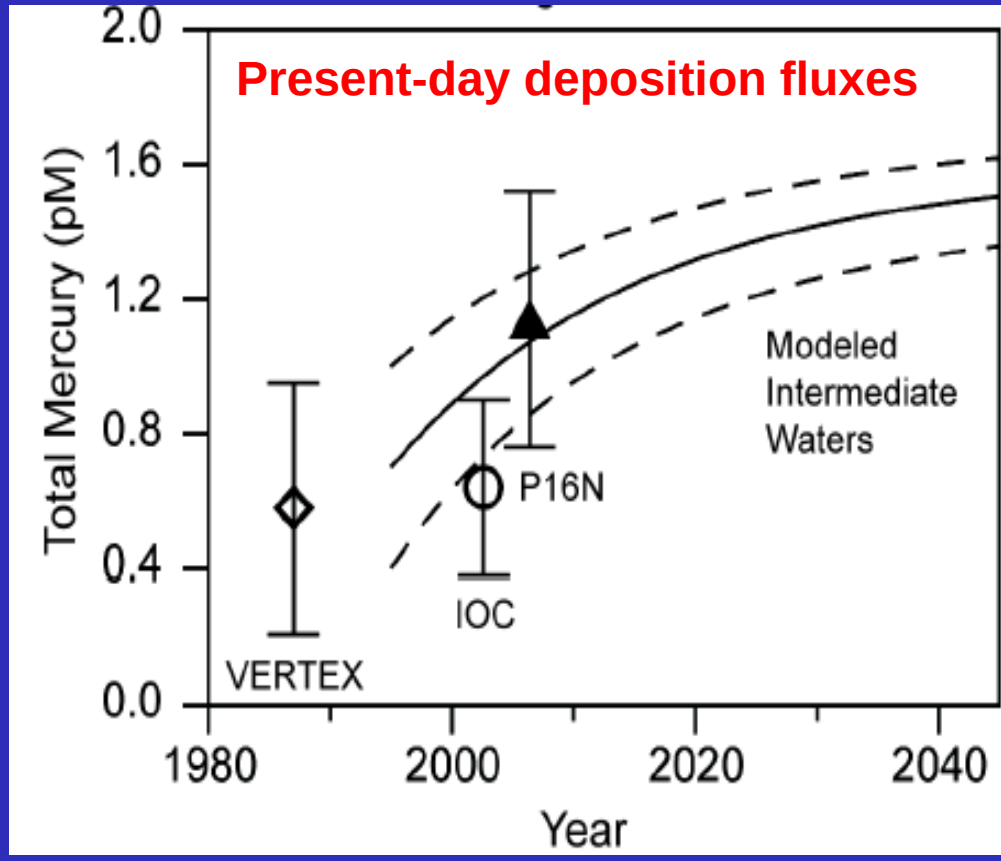
ACCUMULATION OF MERCURY IN THE OCEAN

Future increase in oceanic mercury is expected even if deposition stays constant

Hg observations in N. Pacific



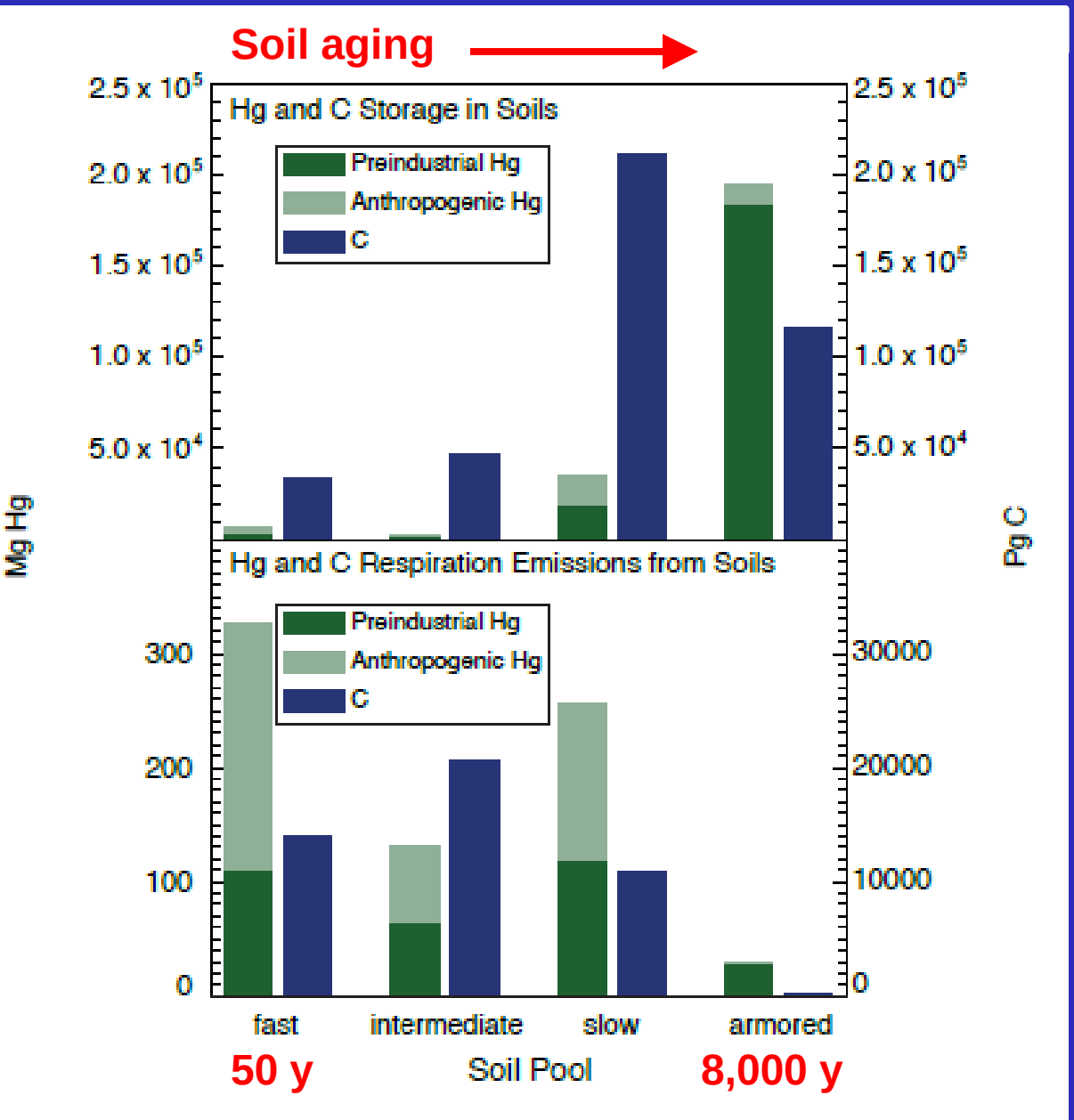
Projected N. Pacific accumulation



Sunderland et al. [2009]

MOBILIZATION OF ANTHROPOGENIC Hg FROM SOILS

New version of GEOS-Chem accounts for soil pools with different lifetimes

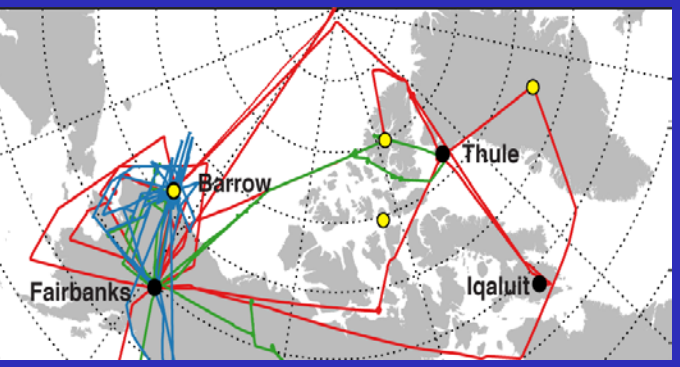


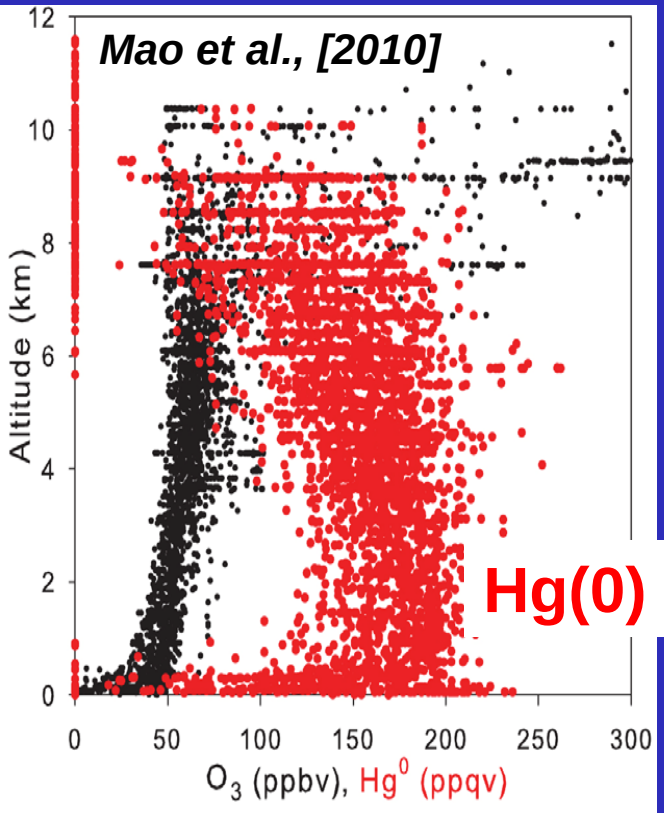
- Mercury accumulates in soil by binding to organic carbon; part is volatilized when organic carbon is respired
- Mercury has a mean lifetime in soil of 630 years, but deposited anthropogenic mercury has a lifetime of only 80 years
- Increased soil respiration in future climate could lead to large soil mercury release

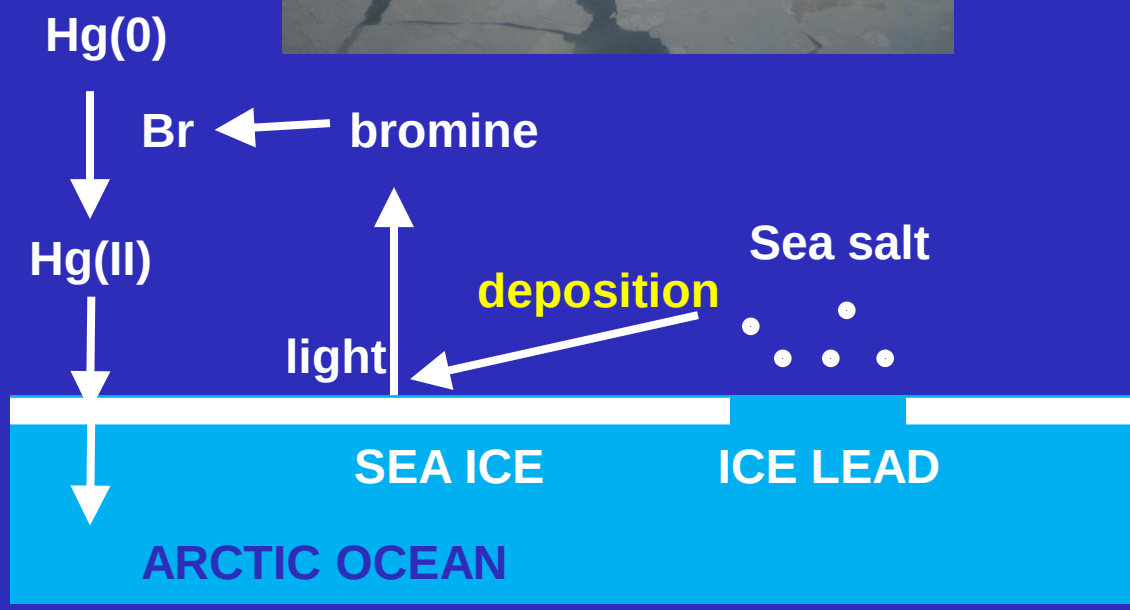
Smith-Downey et al. [2010]

MERCURY DEPOSITION IN ARCTIC SPRING DRIVEN BY SEA ICE LEADS

NASA/ARCTAS aircraft campaign (April 2008)







More ice leads in a warmer Arctic spring will increase mercury deposition to the Arctic Ocean

TOWARDS A GLOBAL MERCURY TREATY:
Focus activity of United Nations Environmental Program (UNEP)

- February 2009: Governing Council of UNEP agrees on need for global legally binding instrument on mercury
- Goal is to complete negotiations by 2013

- In US; Clean Air Mercury Rule (CAMR) to reduce power plant emissions was struck down by courts in 2008; new effort is underway

CHALLENGES:

- How to regulate in the face of considerable uncertainty?
- How to account for legacy mercury from past US and European emissions?
- How to account for possible major effects of climate change?