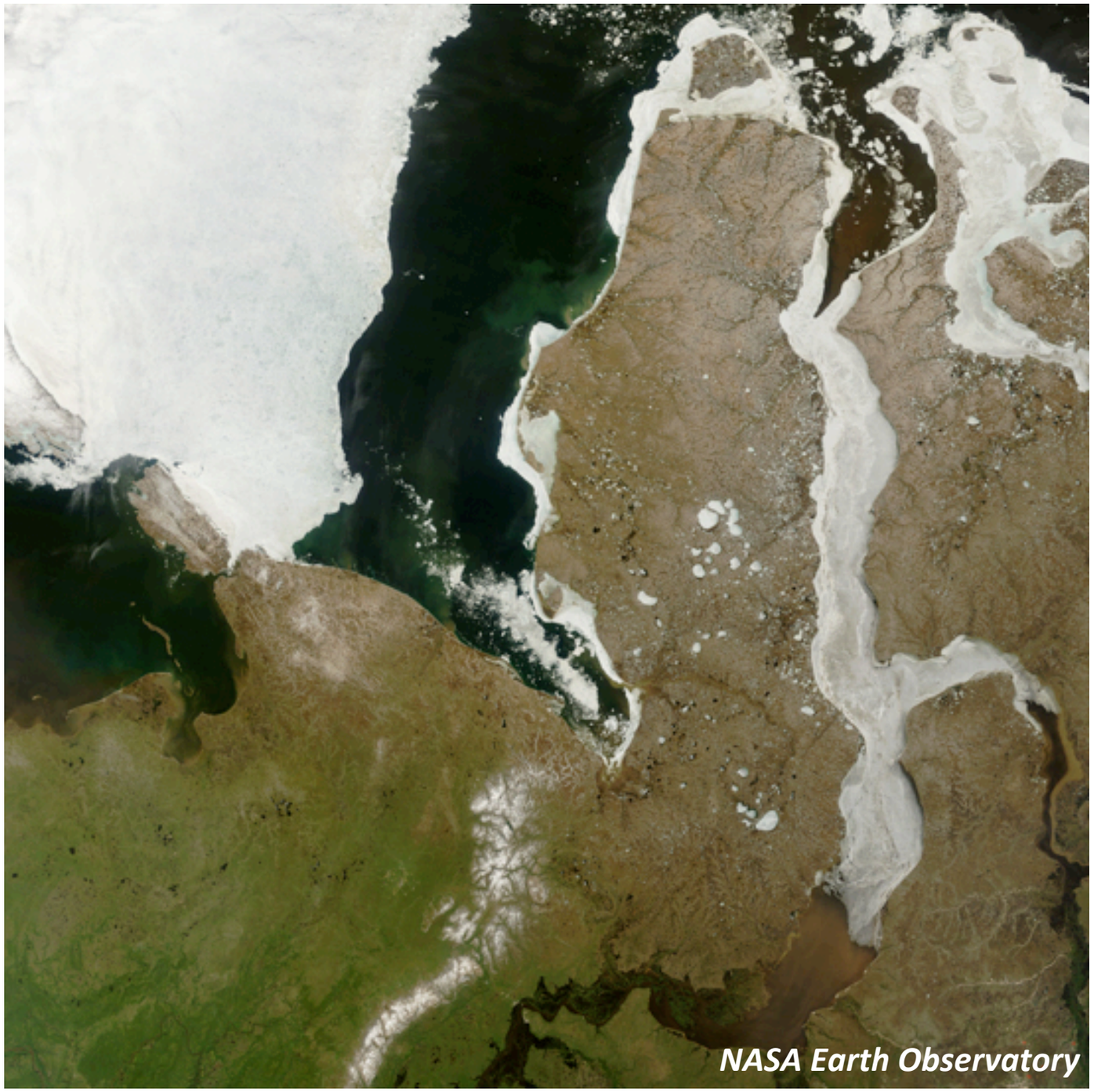
Present-day sources and past variability of mercury in the Arctic atmosphere and ocean



Jenny A. Fisher
University of Wollongong

D. J. Jacob, A. L. Soerensen, H. M. Amos, E. D. Corbitt, D. G. Streets, Q. Wang, R. M. Yantosca, and E. M. Sunderland

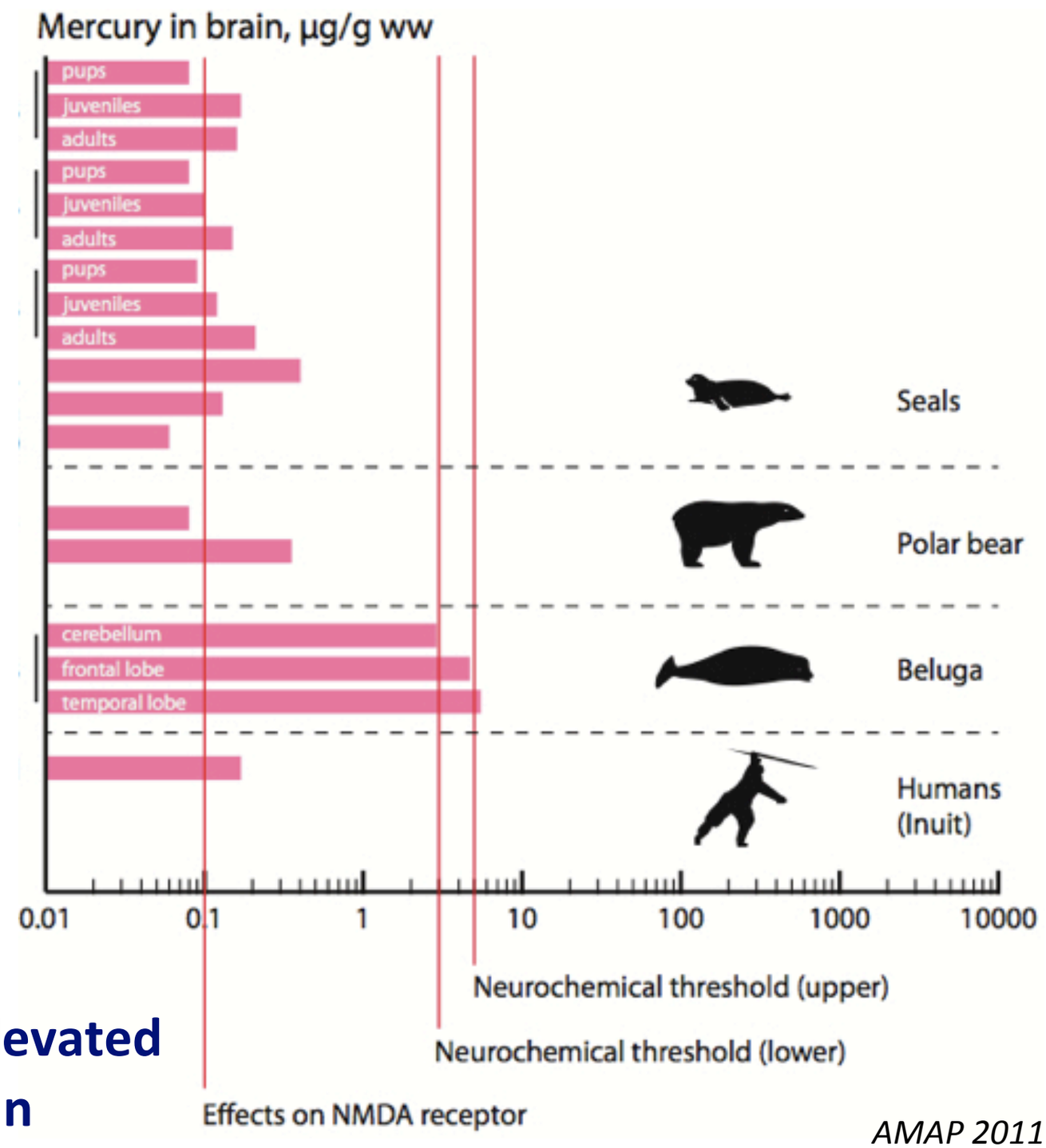
ACCESS XII
25-27 July 2013

Mercury in the Arctic Ocean: an ecological and human health concern

Methylmercury is a potent neurotoxin that bioaccumulates in marine food webs.

High mercury concentrations have been observed in Arctic species that make up traditional northern diets.

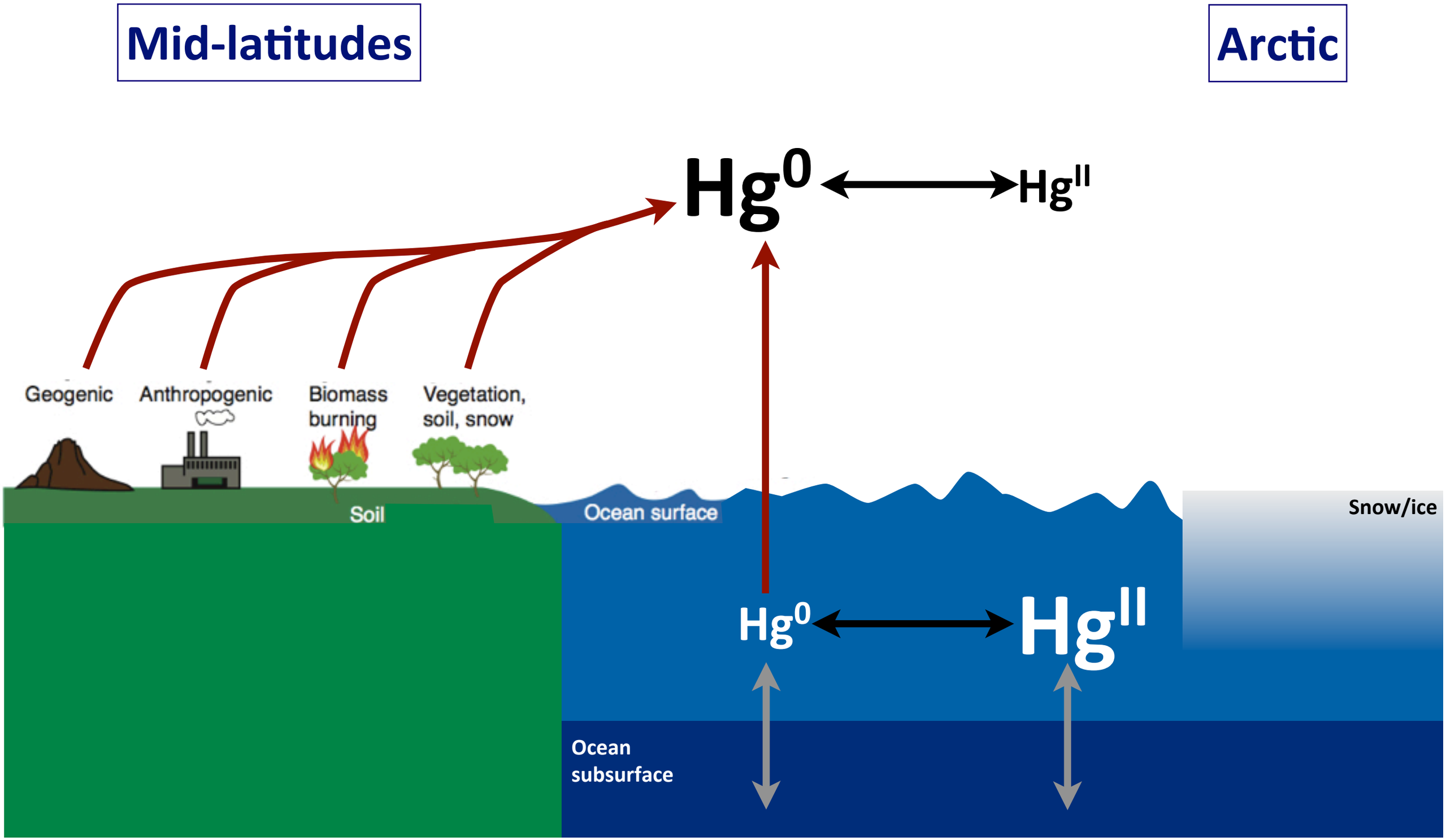
Atmospheric transport brings mercury to the Arctic, but atmosphere-ocean cycling is uncertain.



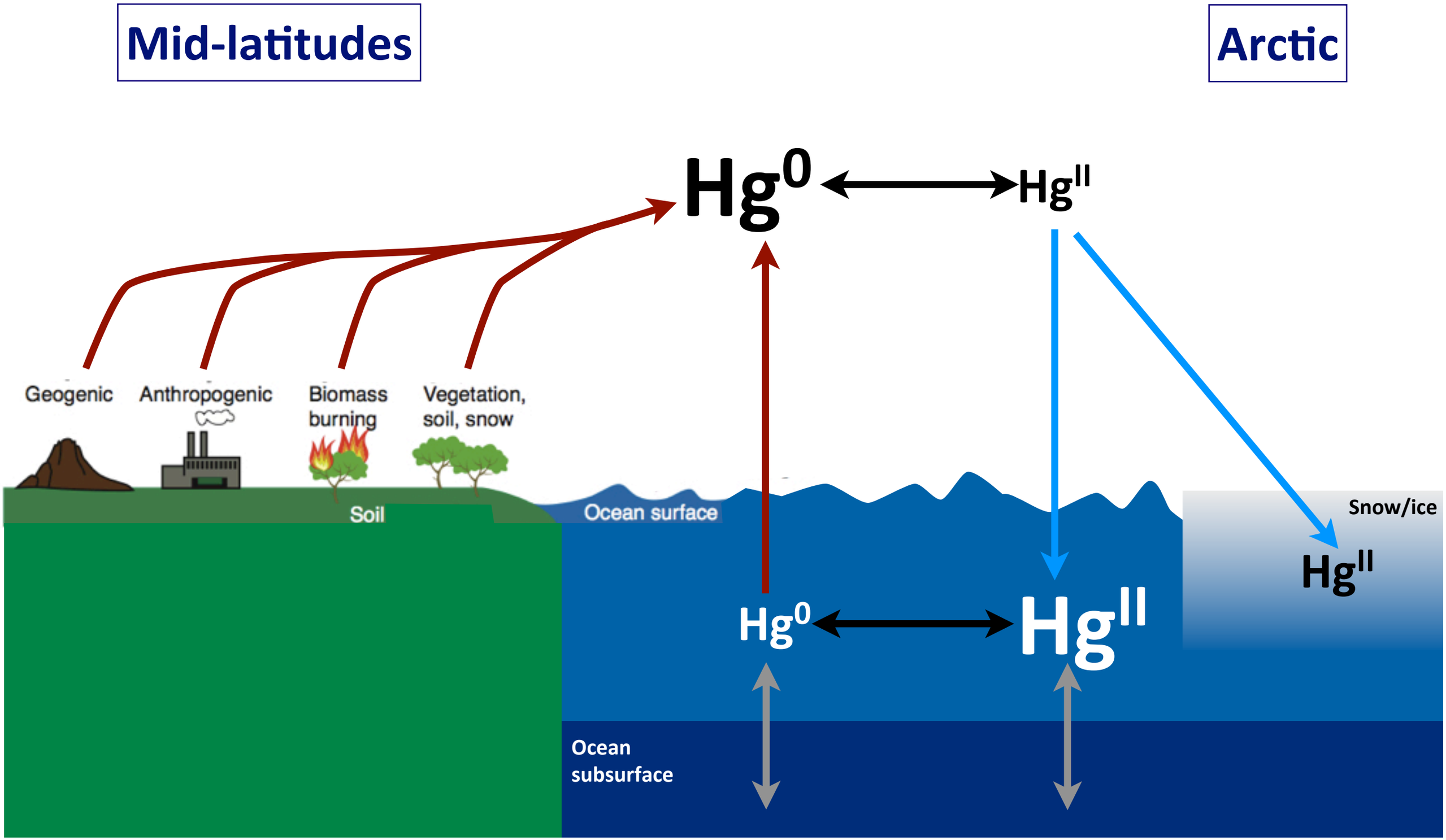
AMAP 2011

<u>Goal</u>:
Understand the factors contributing to elevated mercury in the Arctic atmosphere & ocean

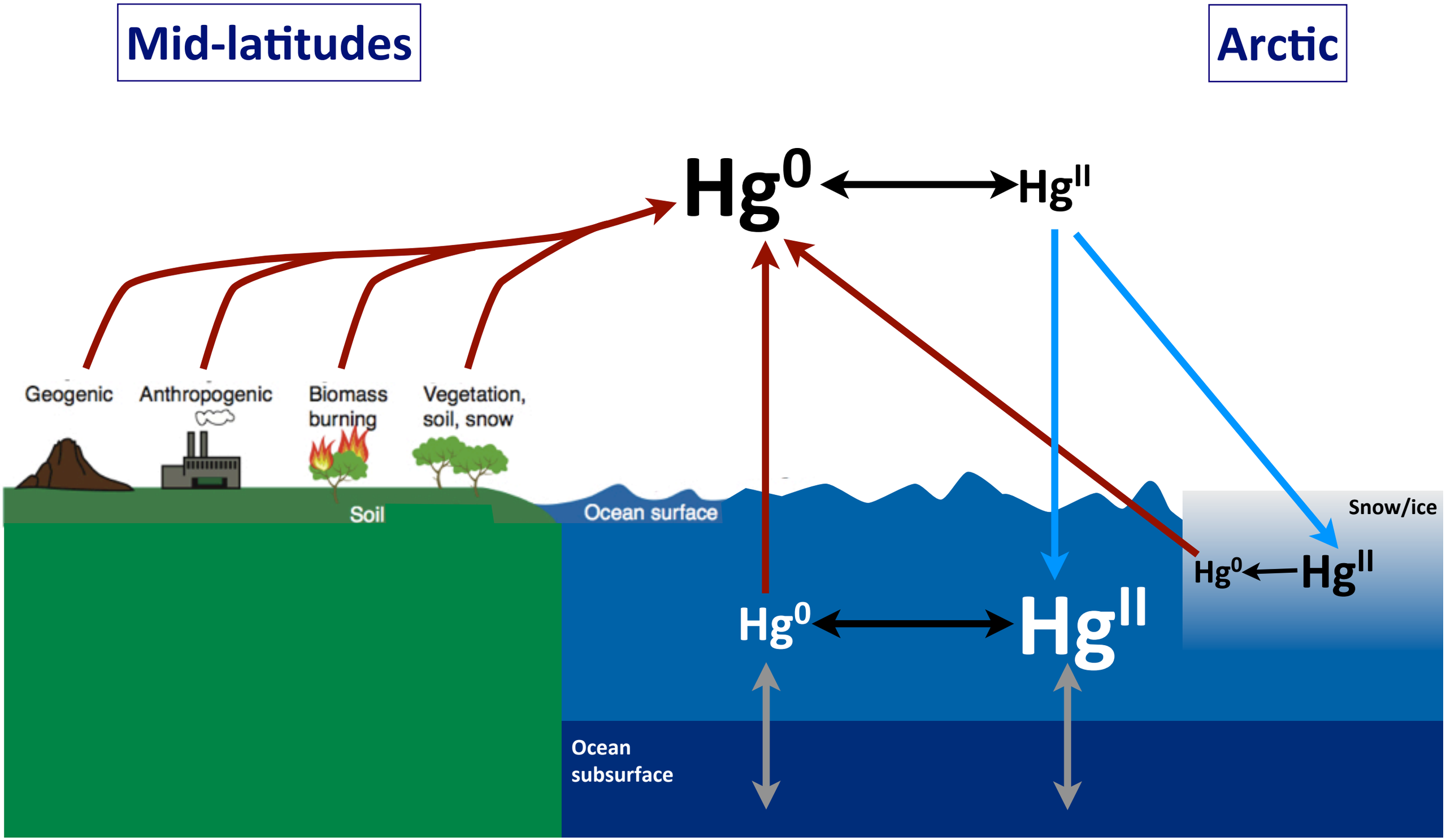
The atmosphere-ocean mercury cycle - an Arctic perspective



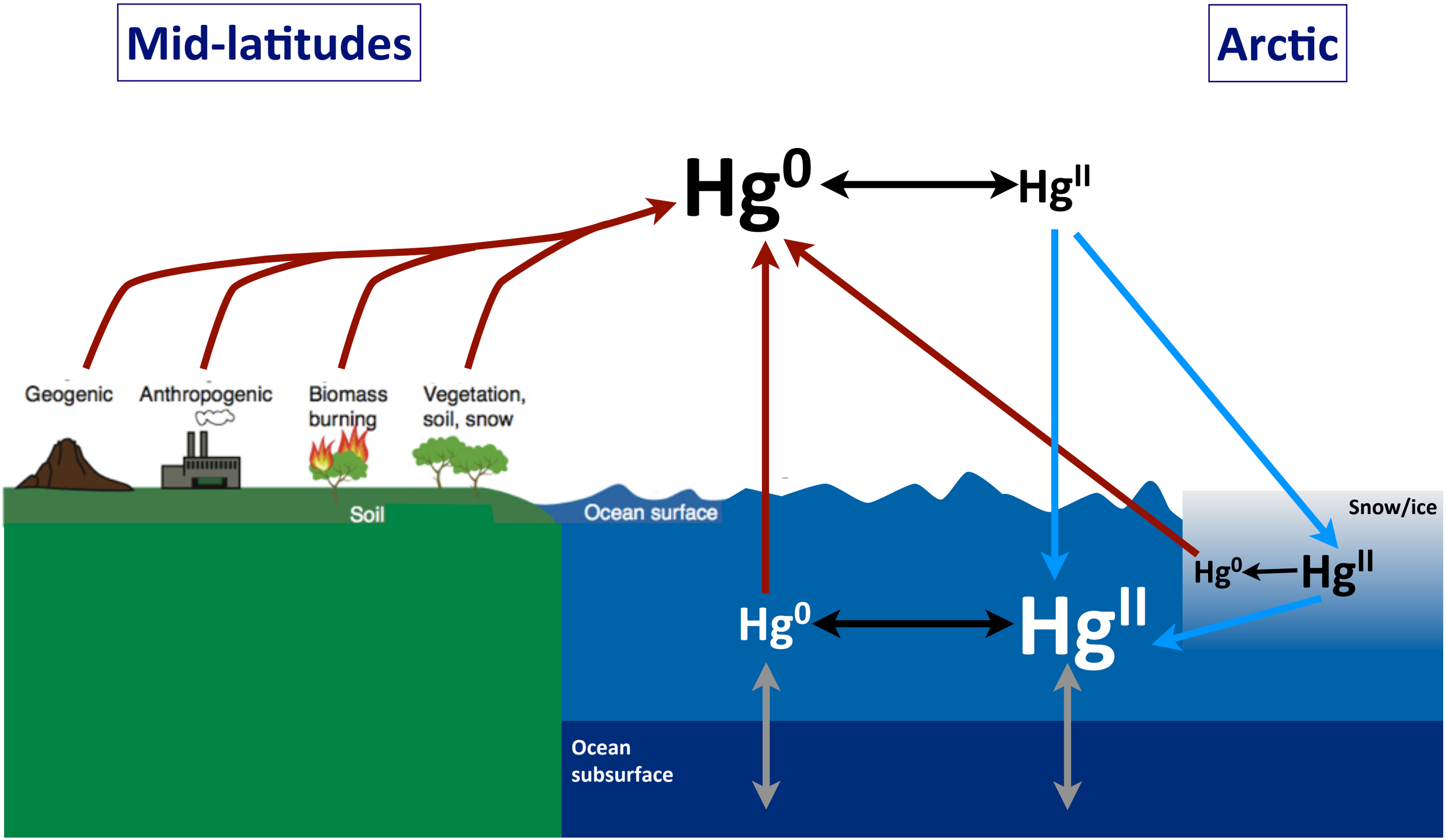
The atmosphere-ocean mercury cycle - an Arctic perspective



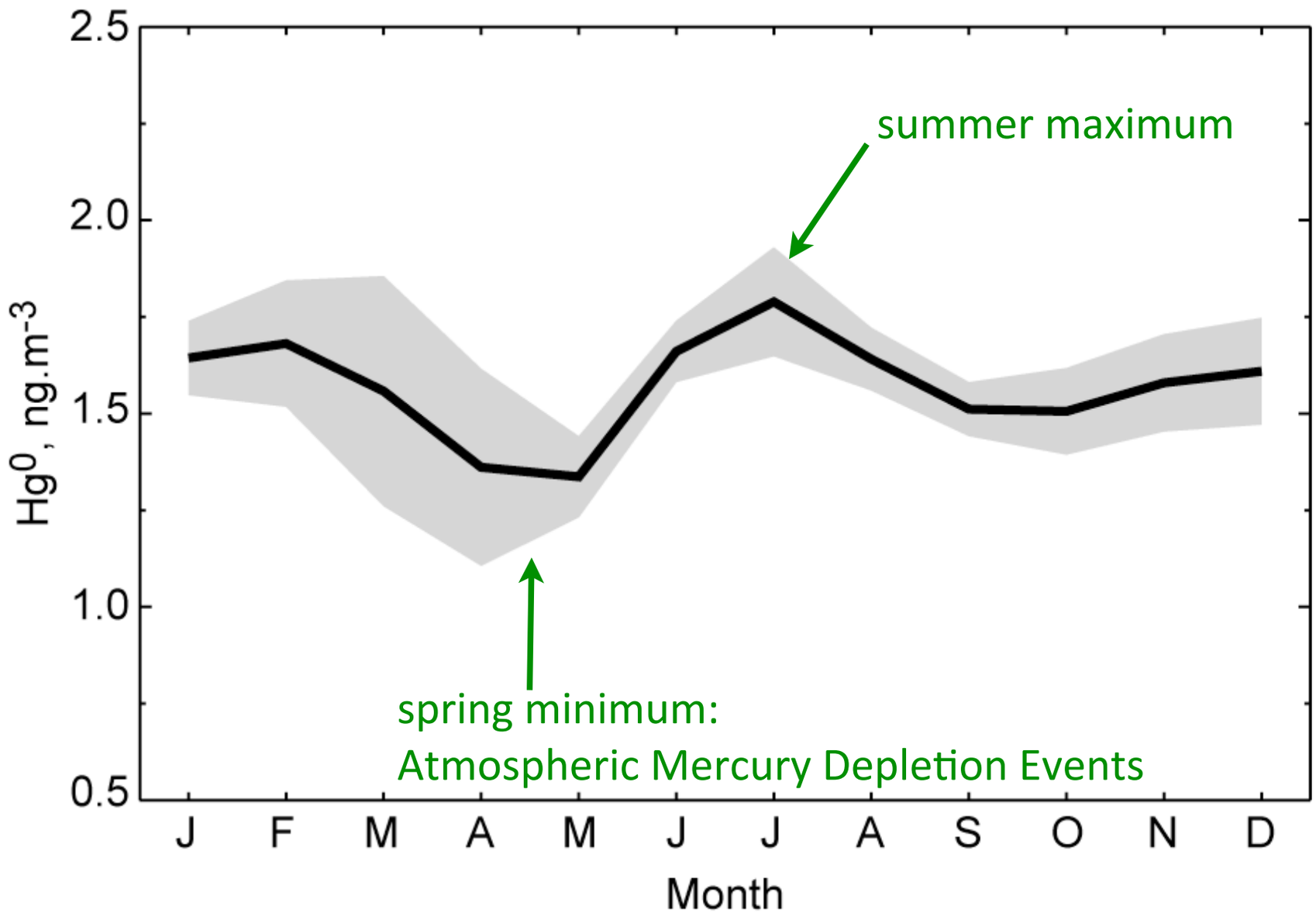
The atmosphere-ocean mercury cycle - an Arctic perspective



The atmosphere-ocean mercury cycle - an Arctic perspective



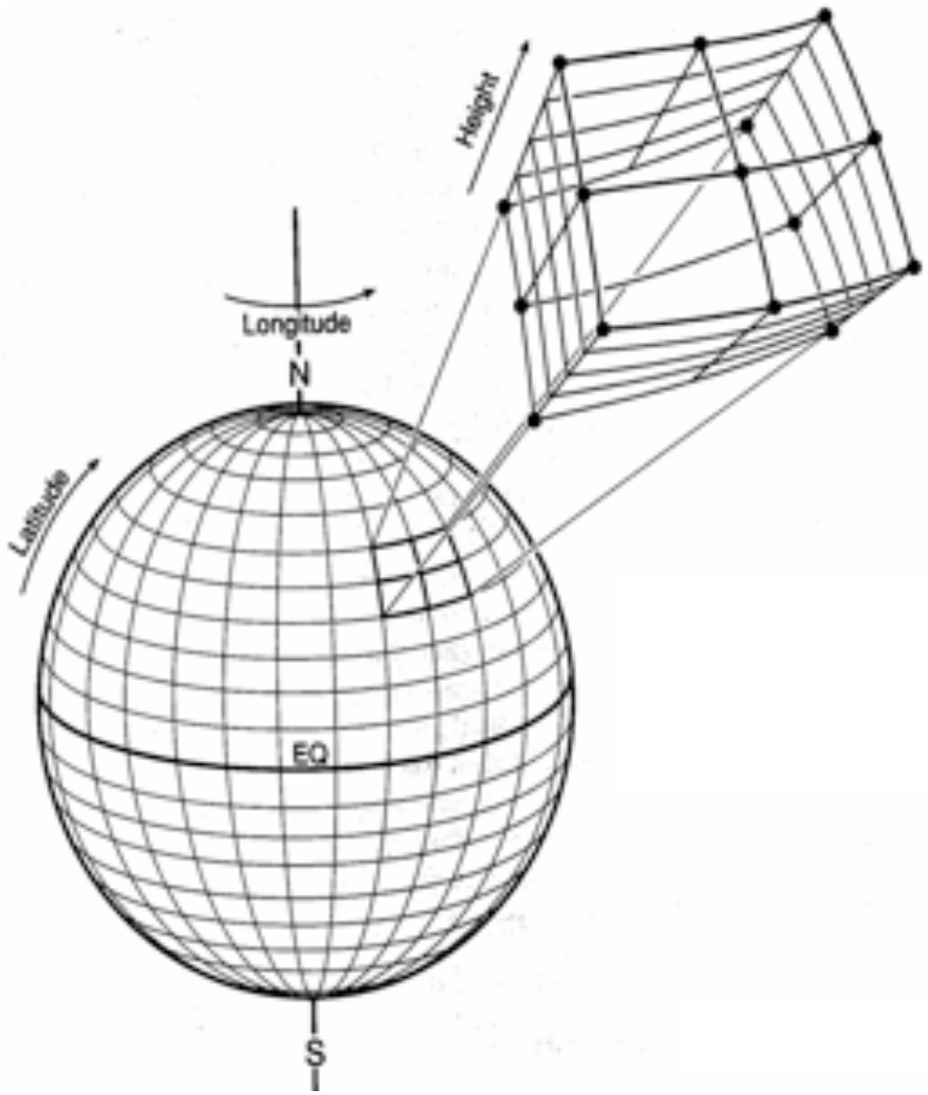
The unique seasonal cycle of Arctic mercury



Observations: multi-year mean over three Arctic sites (Alert, Amderma, Zeppelin)

Can we explain the summer peak using our standard understanding of mercury cycling?

The GEOS-Chem biogeochemical mercury model

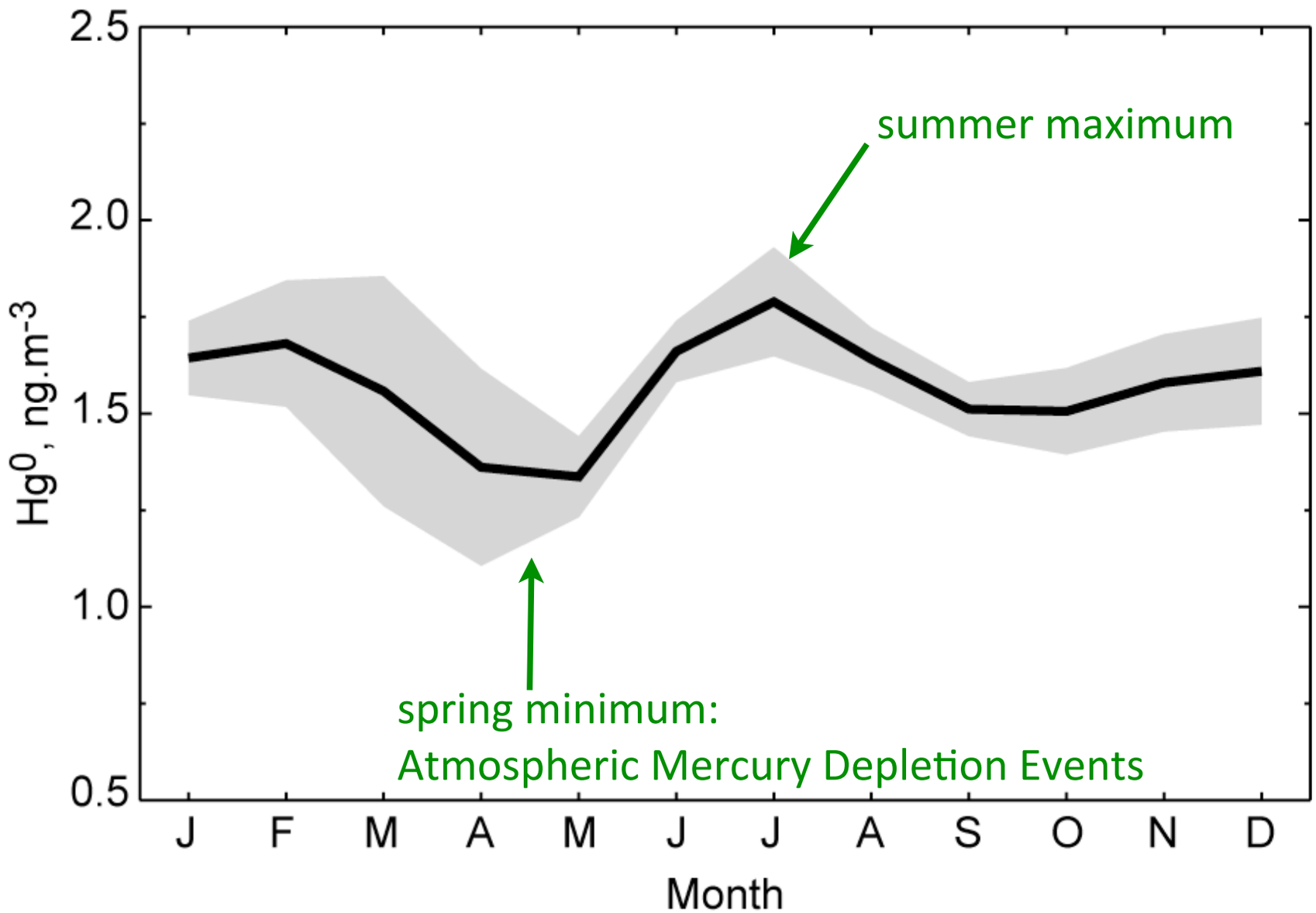


The GEOS-Chem biogeochemical mercury model:

- Global, gridded model
- Driven by input meteorology from an assimilated GCM
- 3-D atmosphere: emissions, chemistry, transport, and deposition
- 2-D slab ocean mixed layer: chemistry, evasion, subsurface mixing and export
- Cryospheric processes: AMDEs, snowpack re-emission, snowmelt delivery to ocean

Represents our best *a priori* understanding of mercury sources & processes

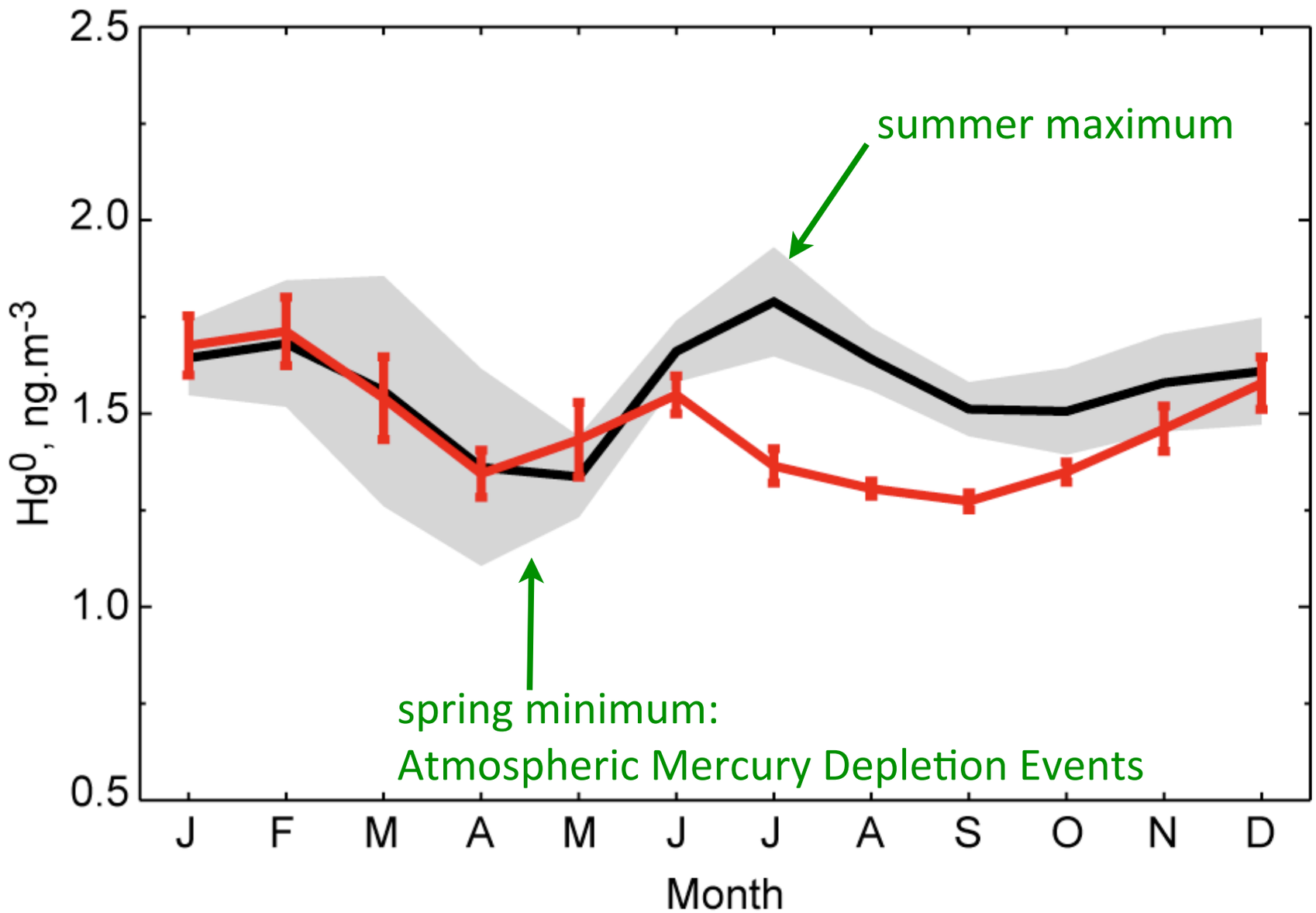
Testing our current understanding: model comparison to atmospheric observations



Observations: multi-year mean over three Arctic sites

Can we explain the summer peak using our standard understanding of mercury cycling?

Testing our current understanding: model comparison to atmospheric observations

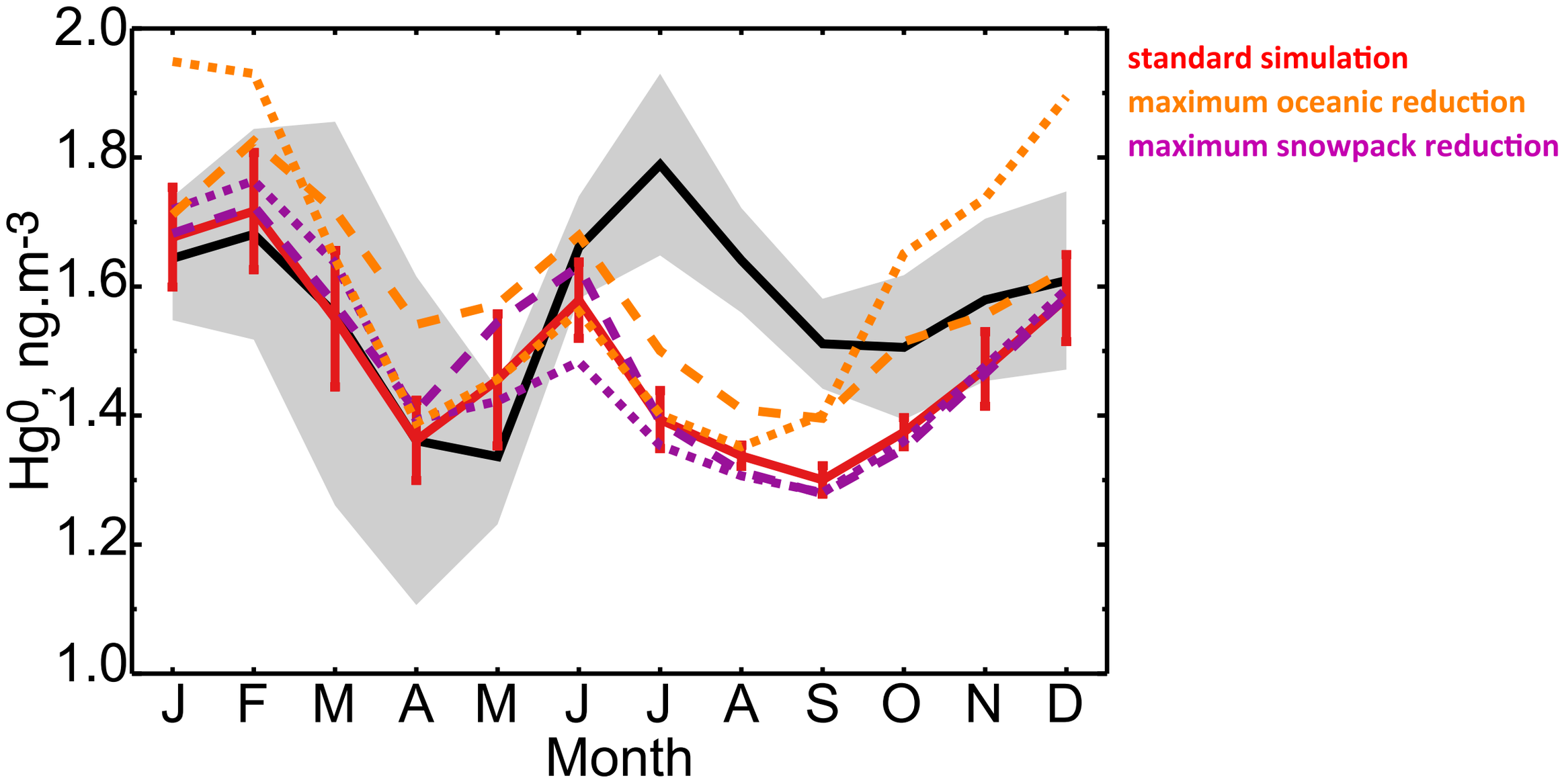


Observations: multi-year mean over three Arctic sites

Model: GEOS-Chem at these sites in 2008

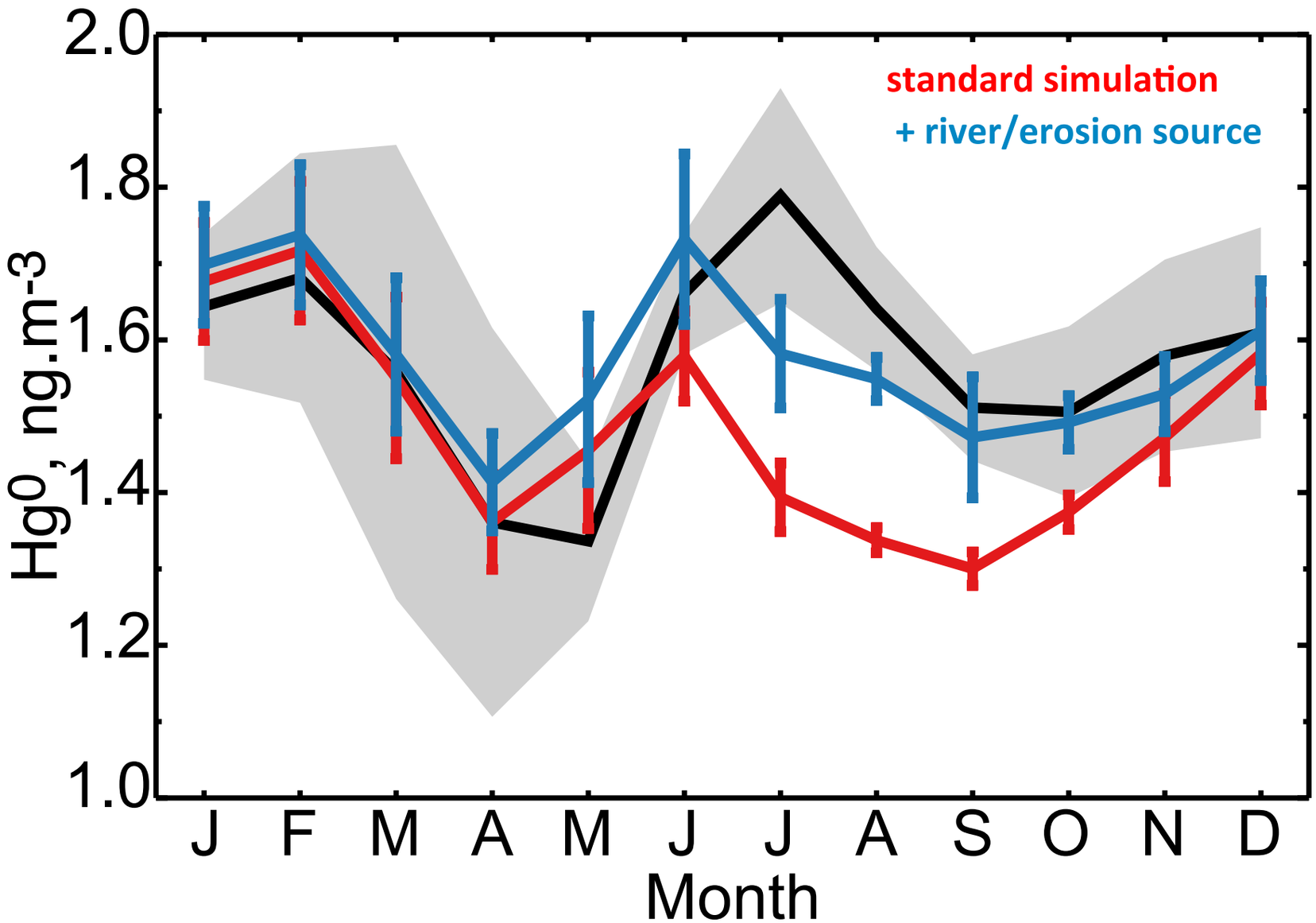
Can we explain the summer peak using our standard understanding of mercury cycling?

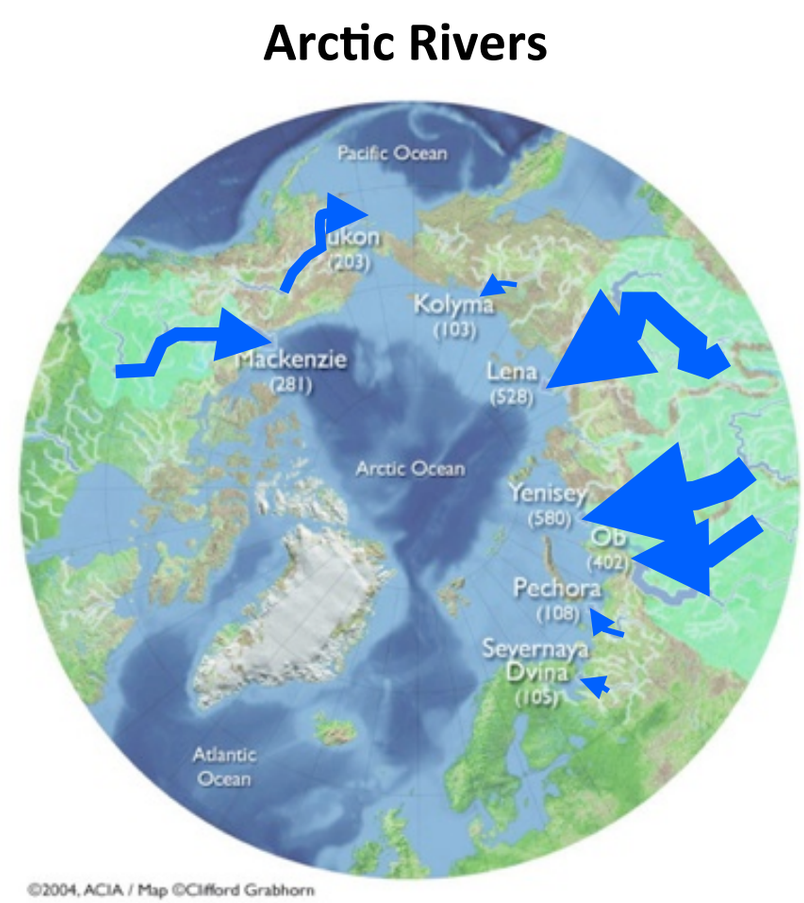
We test hypotheses using model sensitivity simulations



Atmospheric transport, snowpack processing, ocean chemistry cannot explain peak.

We test hypotheses using model sensitivity simulations

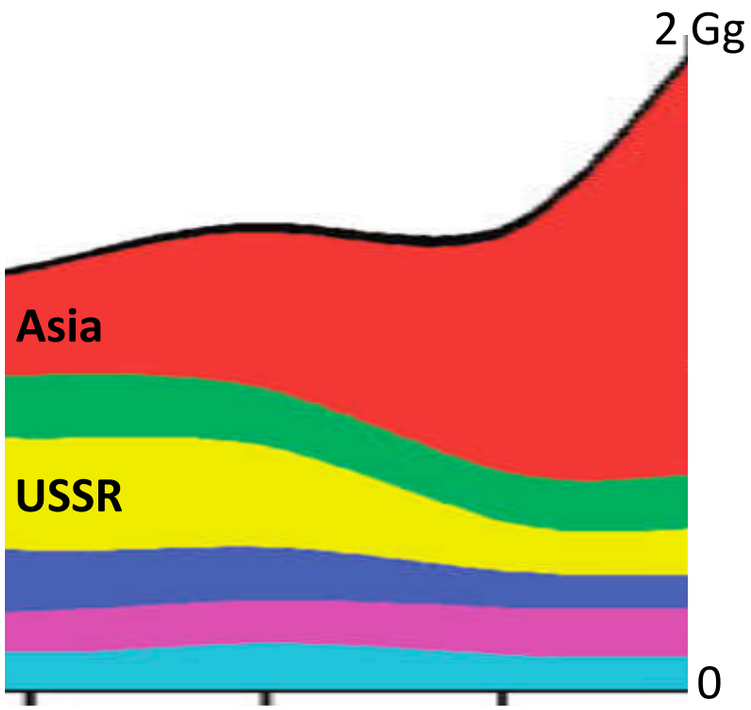




With a large river / coastal erosion source included, GEOS-Chem can reproduce the observed summer peak — a promising hypothesis, but more data are needed!

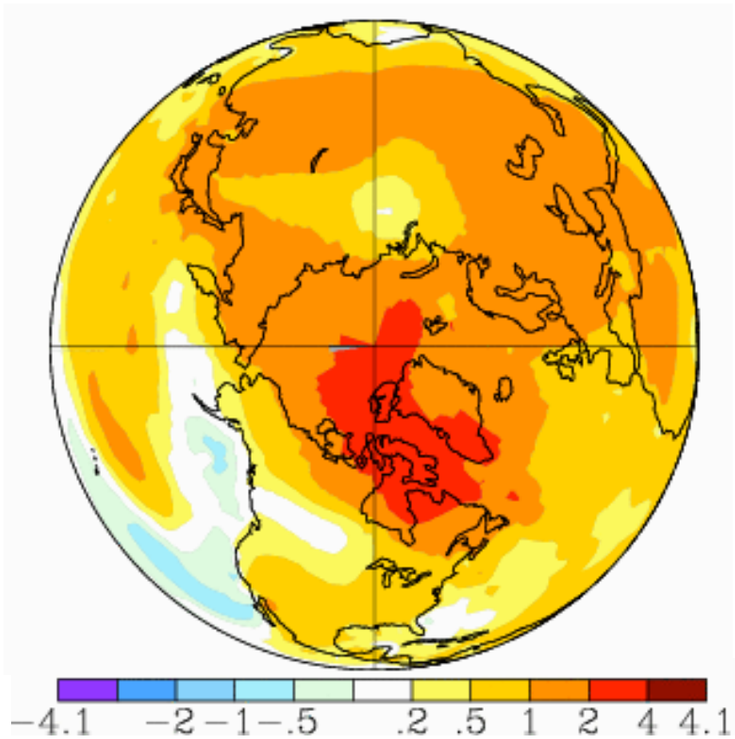
Factors affecting Arctic mercury have changed dramatically

Hg emissions growth: 1979-2010



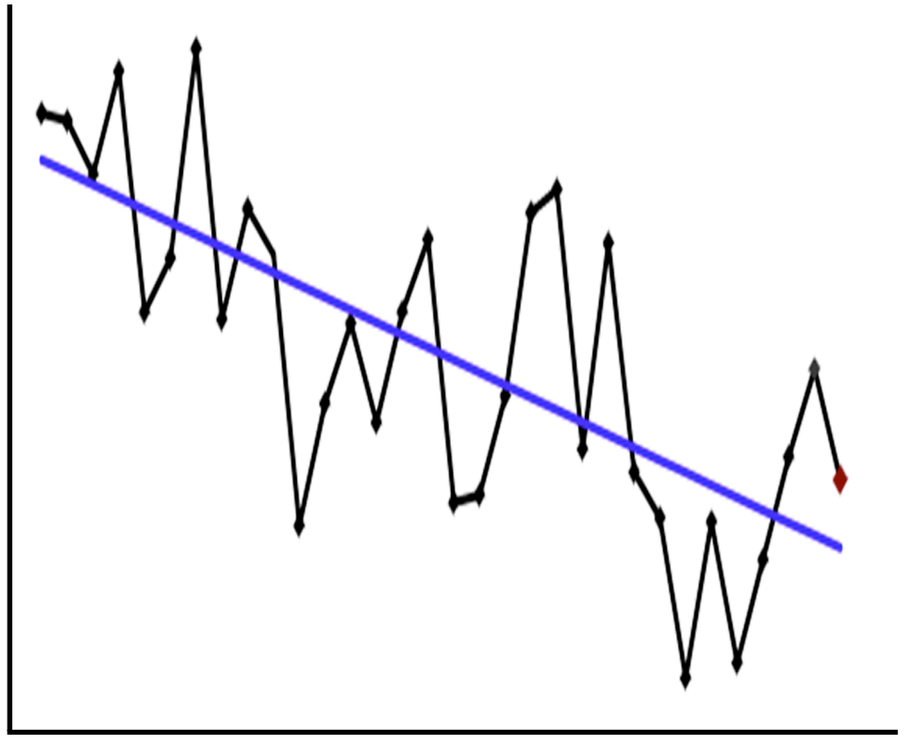
Streets et al. (2011)

Air temperature change: 1979-2010



GISS

May sea ice extent trend: 1979-2010



NSIDC

What are the implications for past — and future — variability in Arctic Hg?

Combined model-observation analysis lends insight

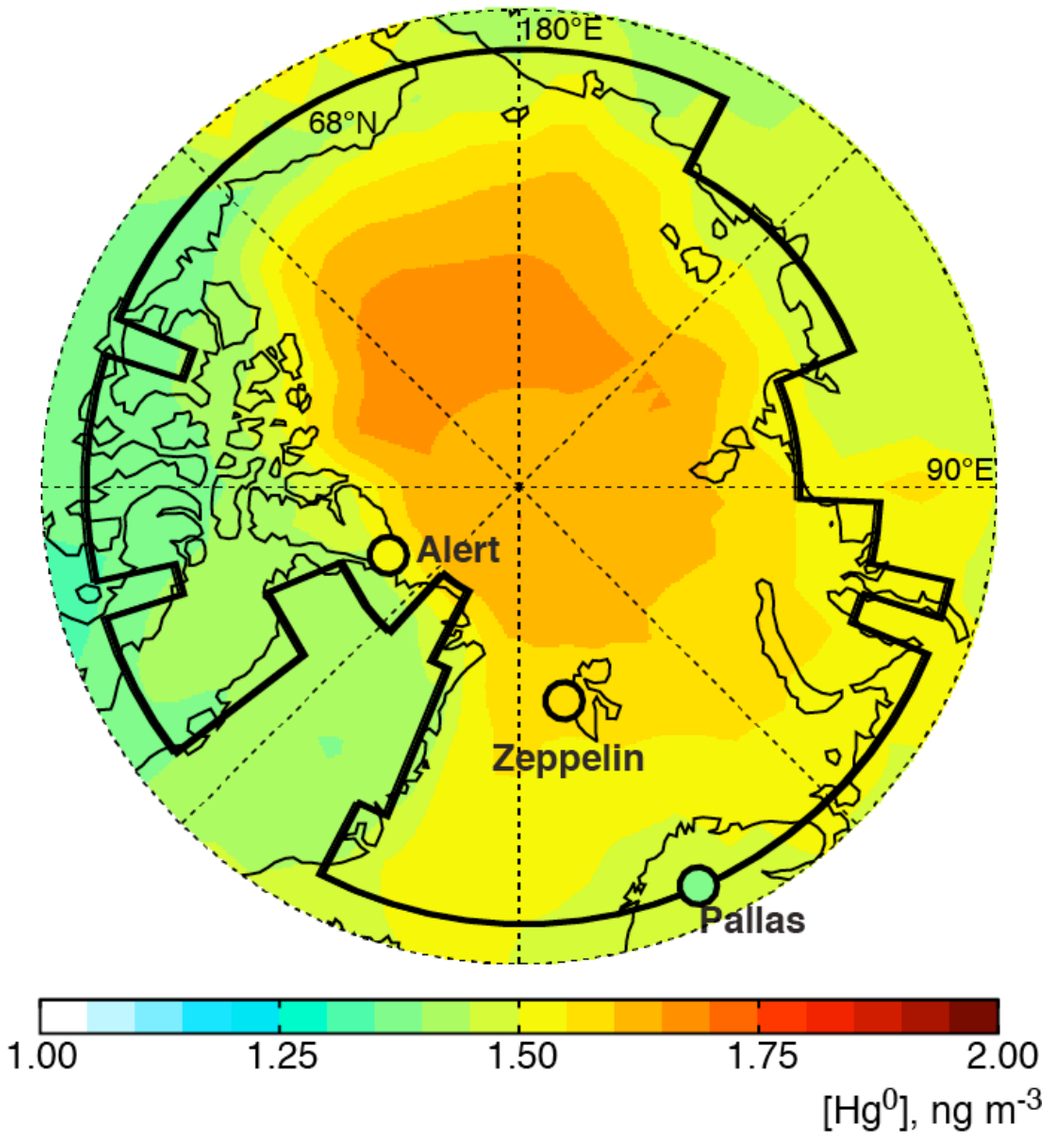
1. 30-year GEOS-Chem simulation of Arctic Hg (1979-2008)

2. Evaluated by long-term atmospheric observations

Alert, Canada (1995-2008)
Zeppelin, Ny Ålesund (2000-2008)
Pallas, Finland (1996-2008)

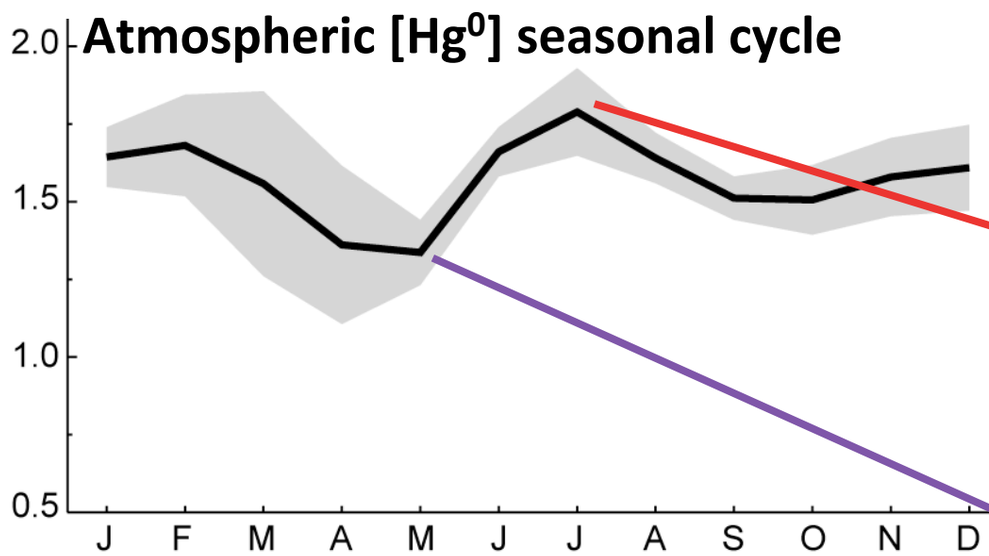
3. Extended to simulation of surface ocean, where long-term records unavailable

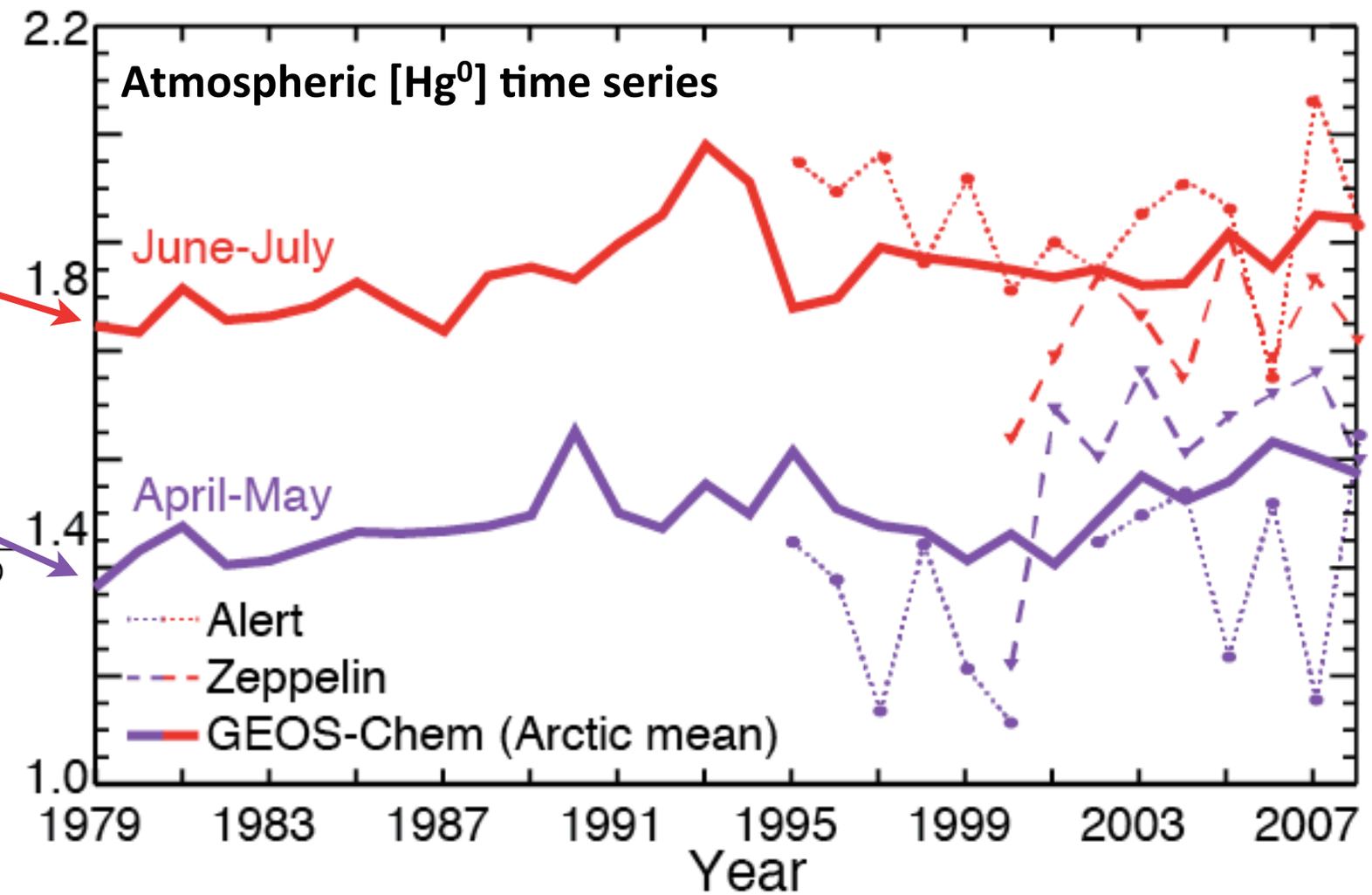
Atmospheric [Hg^0], 1995-2008



We use interannual variability to identify drivers of change

Focus on unique Arctic signatures in spring and summer

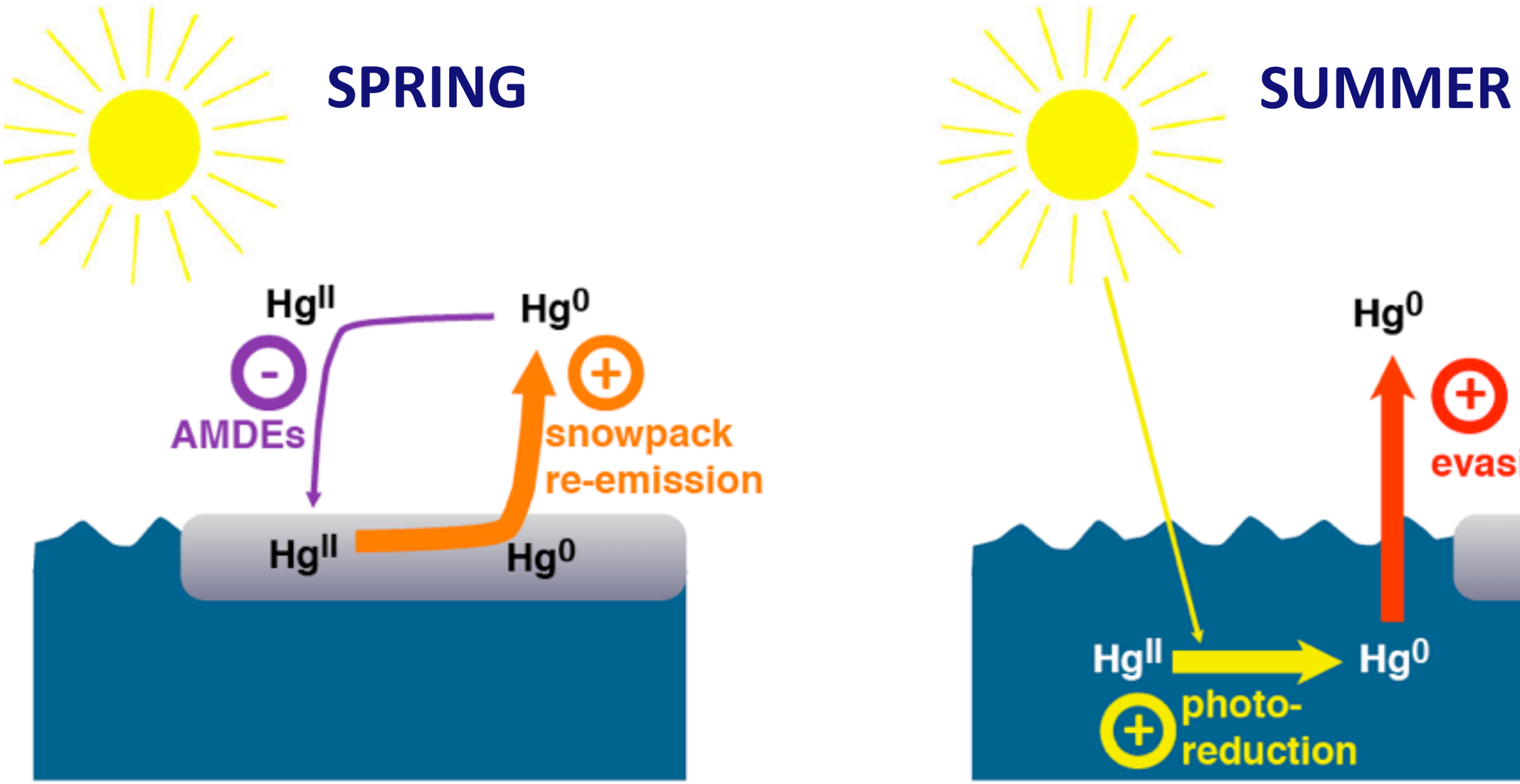




Spring-summer trends are negligible, but IAV is large in observations & model

Atmospheric Hg variability governed by a combination of meteorological drivers

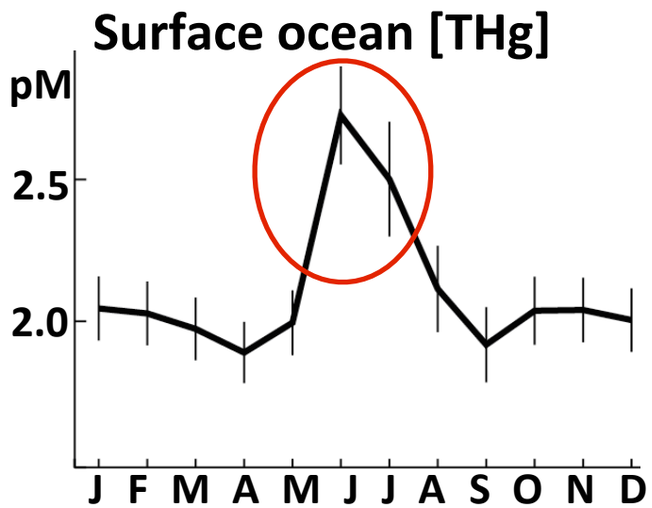
Impacts of high T + low sea ice + high radiation + shallow PBL



Environmental drivers of IAV identified using a principal component analysis (PCA).

Dominant mode explains 80% IAV in spring, 43% in summer.

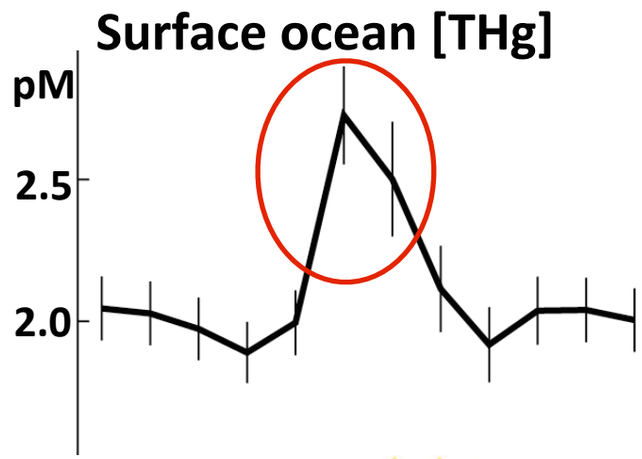
Surface ocean mercury driven by snowmelt & rivers



Arctic ocean mercury and IAV **peak in summer**

No trends in surface ocean mercury

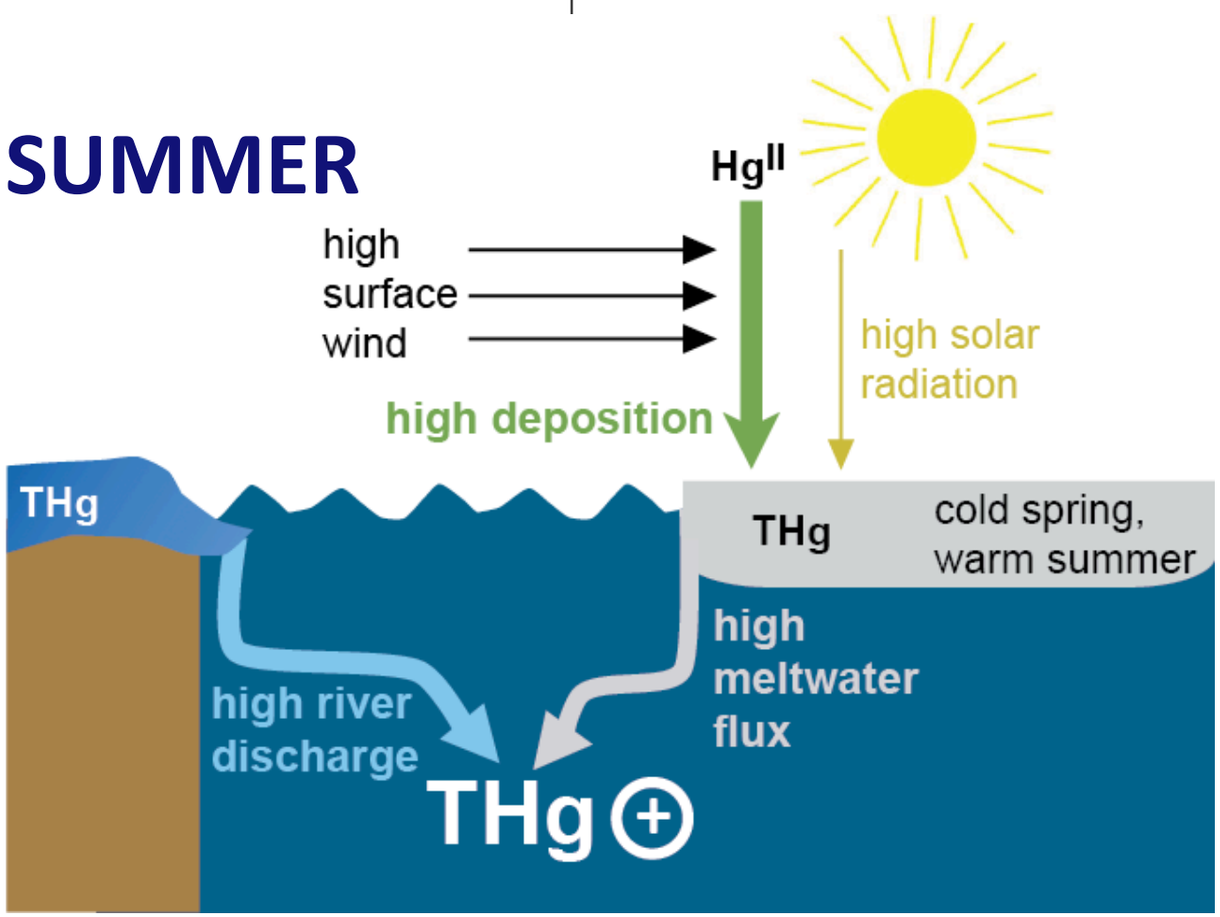
Surface ocean mercury driven by snowmelt & rivers



Arctic ocean mercury and IAV **peak in summer**

No trends in surface ocean mercury

SUMMER



Surface ocean inputs increase with:

Meltwater

- ↑ summer solar radiation (↓ cloudiness)
- ↑ spring-summer T difference = **ΔT**

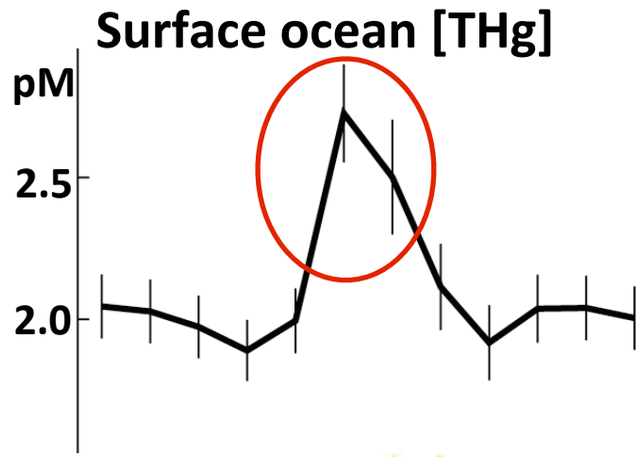
Rivers

- ↑ May river flow

Deposition

- ↑ summer wind speed

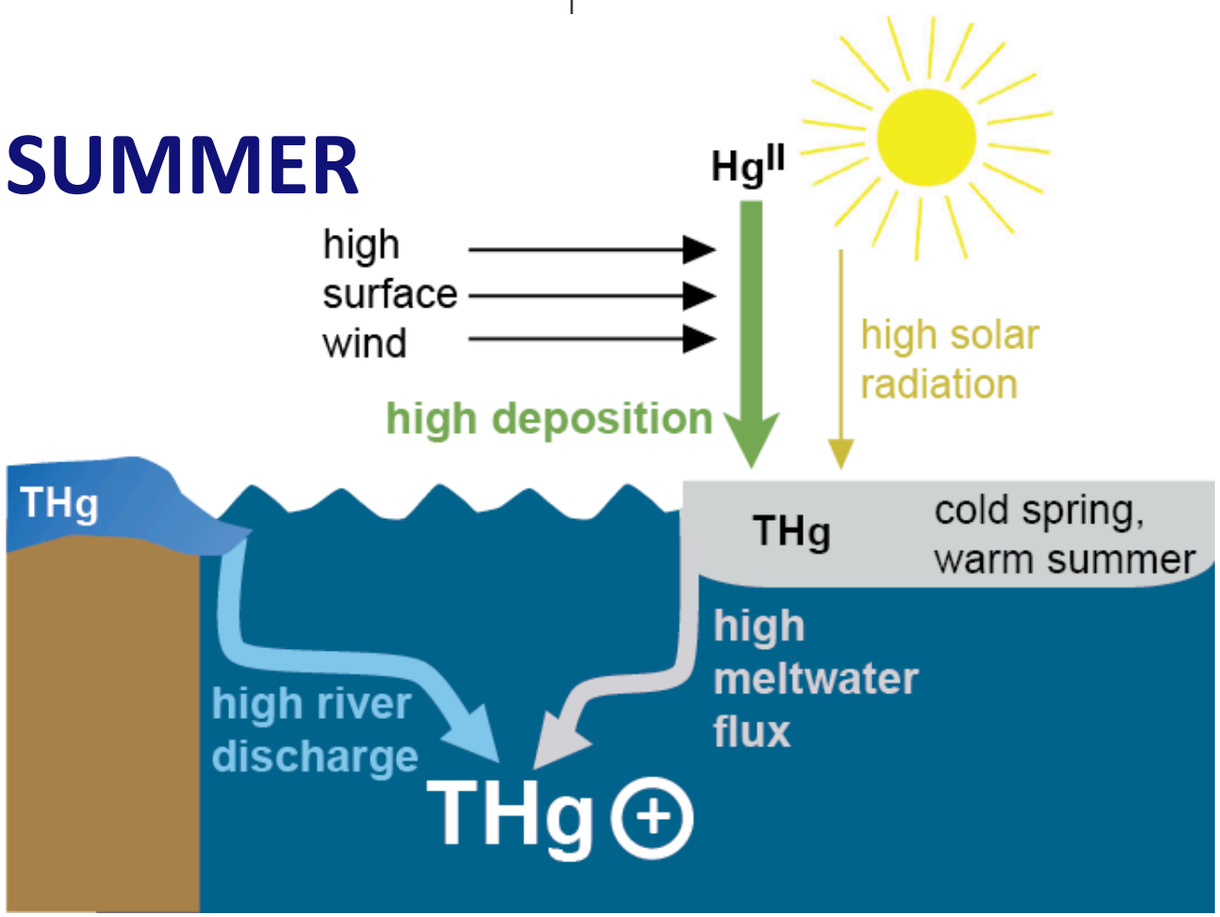
Surface ocean mercury driven by snowmelt & rivers



Arctic ocean mercury and IAV **peak in summer**

No trends in surface ocean mercury

SUMMER



Surface ocean inputs increase with:

Meltwater

- ↑ summer solar radiation (↓ cloudiness)
- ↑ spring-summer T difference = **ΔT**

Rivers

- ↑ May river flow

Deposition

- ↑ summer wind speed

GCMs predict future ↑ cloudiness & ↓ ΔT → less Hg may be added to the Arctic Ocean in future!