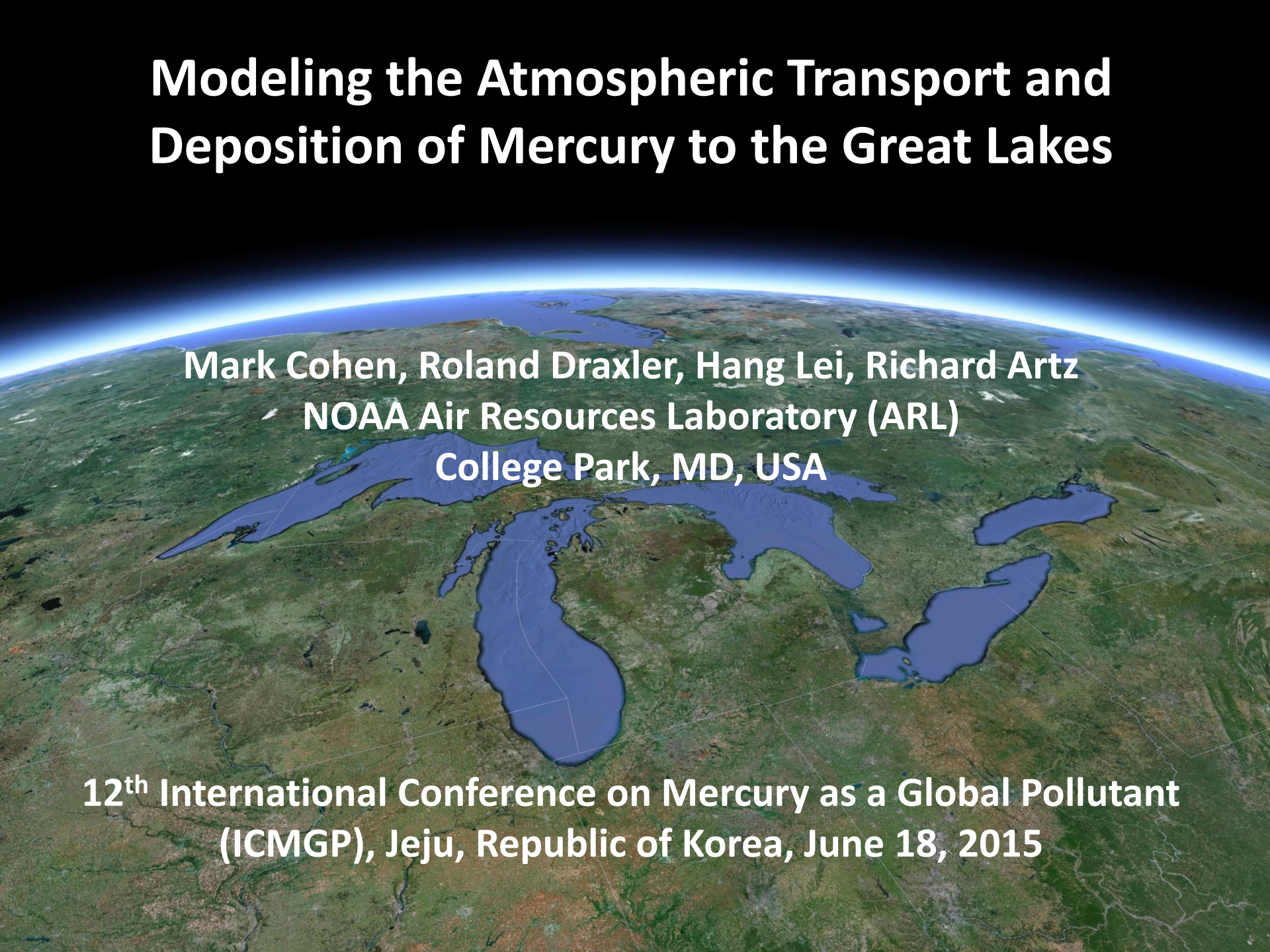
Modeling the Atmospheric Transport and Deposition of Mercury to the Great Lakes



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Emissions

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- Arctic Monitoring and Assessment Program (AMAP)

Measurement Data for Model Evaluation

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- Eric Miller (Underhill Vermont)
- Tom Holsen, Young-Ji Han (New York State sites)
- Mae Gustin, Seth Lyman, et al. (Nevada sites)
- Dan Jaffe, Seth Lyman, et al. (Mt Bachelor site)
- Laurier Poissant and Martin Pilote (St. Anicet)
- Frank Froude (Burnt Island, Egbert, and Point Petre)
- Rob Tordon (Kejimkujik)
- Alexandra Steffen and Cathy Banic (Alert)
- Brian Wiens (Bratt's Lake)

Met Data, IT →

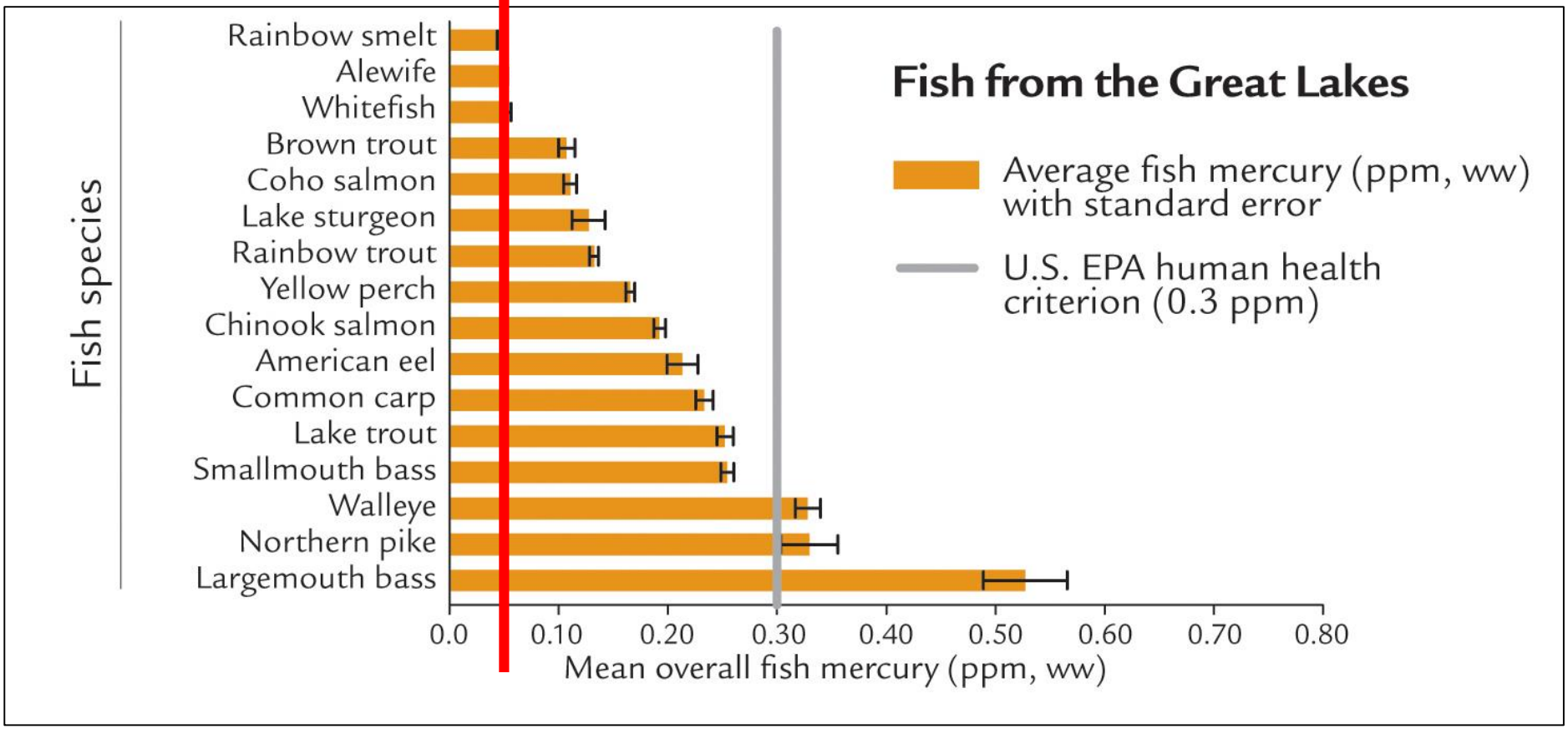
- HYSPLIT Modeling Team at NOAA ARL, Rick Jiang

Funding →

- Great Lakes Restoration Initiative

Mercury in Great Lakes Fish

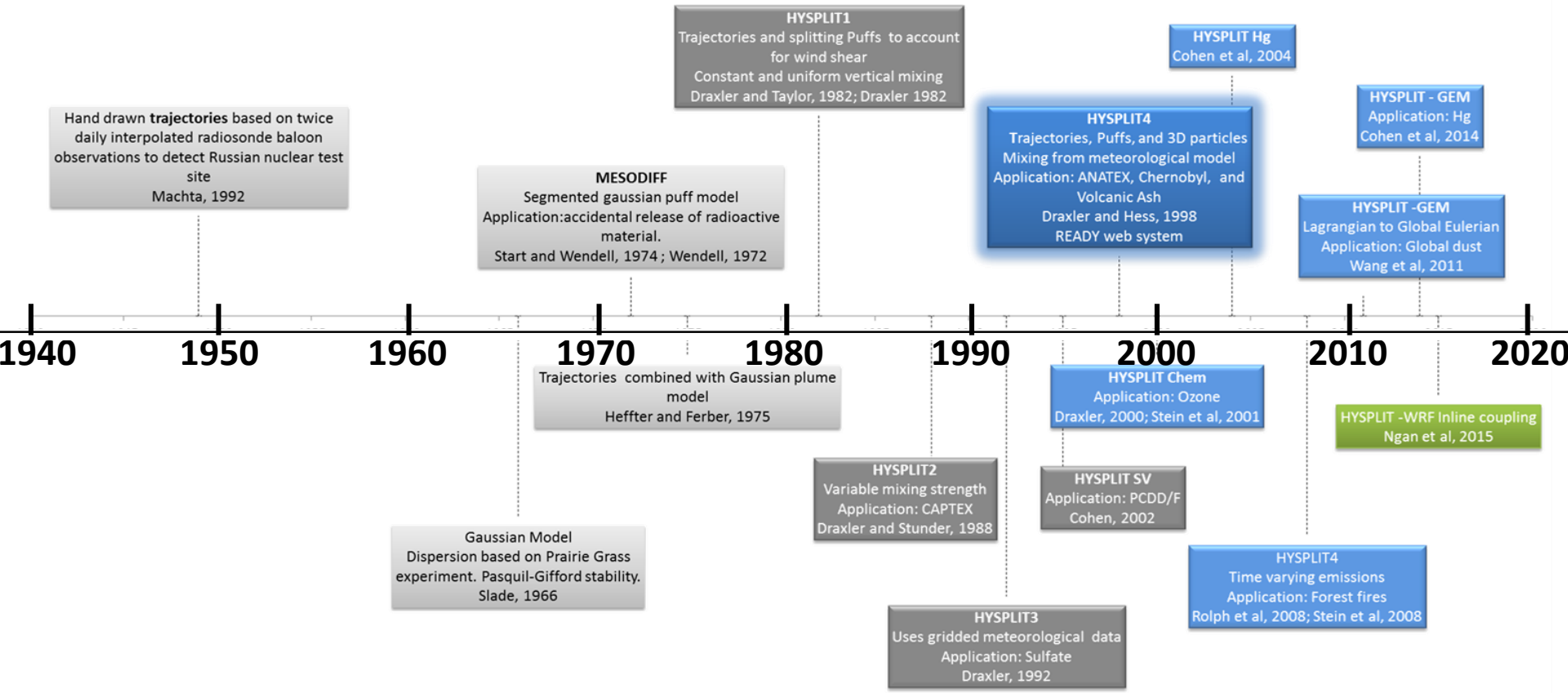
0.05 ppm level recommended by the Great Lakes Fish Advisory Workgroup (2007)



Evers, D.C., et al. (2011). *Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region*. Biodiversity Research Institute. Gorham, Maine. Report BRI 2011-18. 44 pages.

NOAA's HYSPLIT atmospheric transport and dispersion modeling system

Stein, A.F., Draxler, R.R., Rolph, G.D, Stunder, B.J.B., Cohen, M.D., and Ngan, F.
Bulletin of the American Meteorological Society, 2015, in press.
http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-14-00110.1



HYSPLIT can do more than just back-trajectories

Transport and dispersion based on local or rawinsonde data

Transport and dispersion based on gridded meteorological data

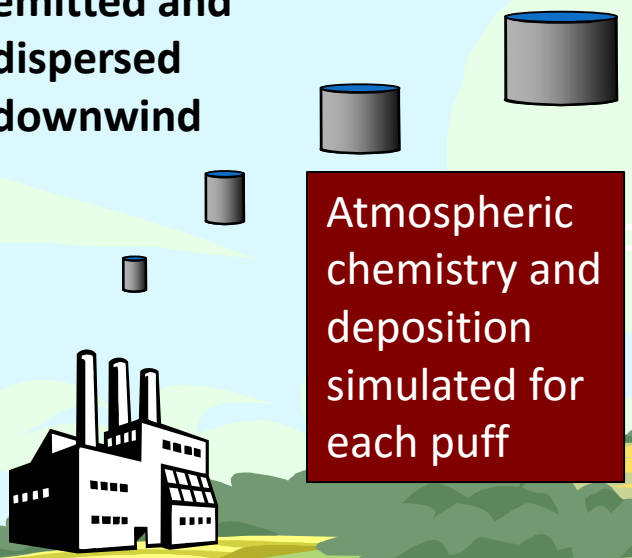
When puffs grow to sizes large relative to the meteorological data grid, they split, horizontally and/or vertically

To simulate the <u>global</u> transport of mercury, puffs are transferred Eulerian grid after a specified time downw (~3 weeks), and the mercury is simulated that grid from then o

This is how we model the local & *regional* impacts.

But for *global* modeling, puff splitting overwhelms computational resources

Puffs of pollutant are emitted and dispersed downwind



Atmospheric chemistry and deposition simulated for each puff

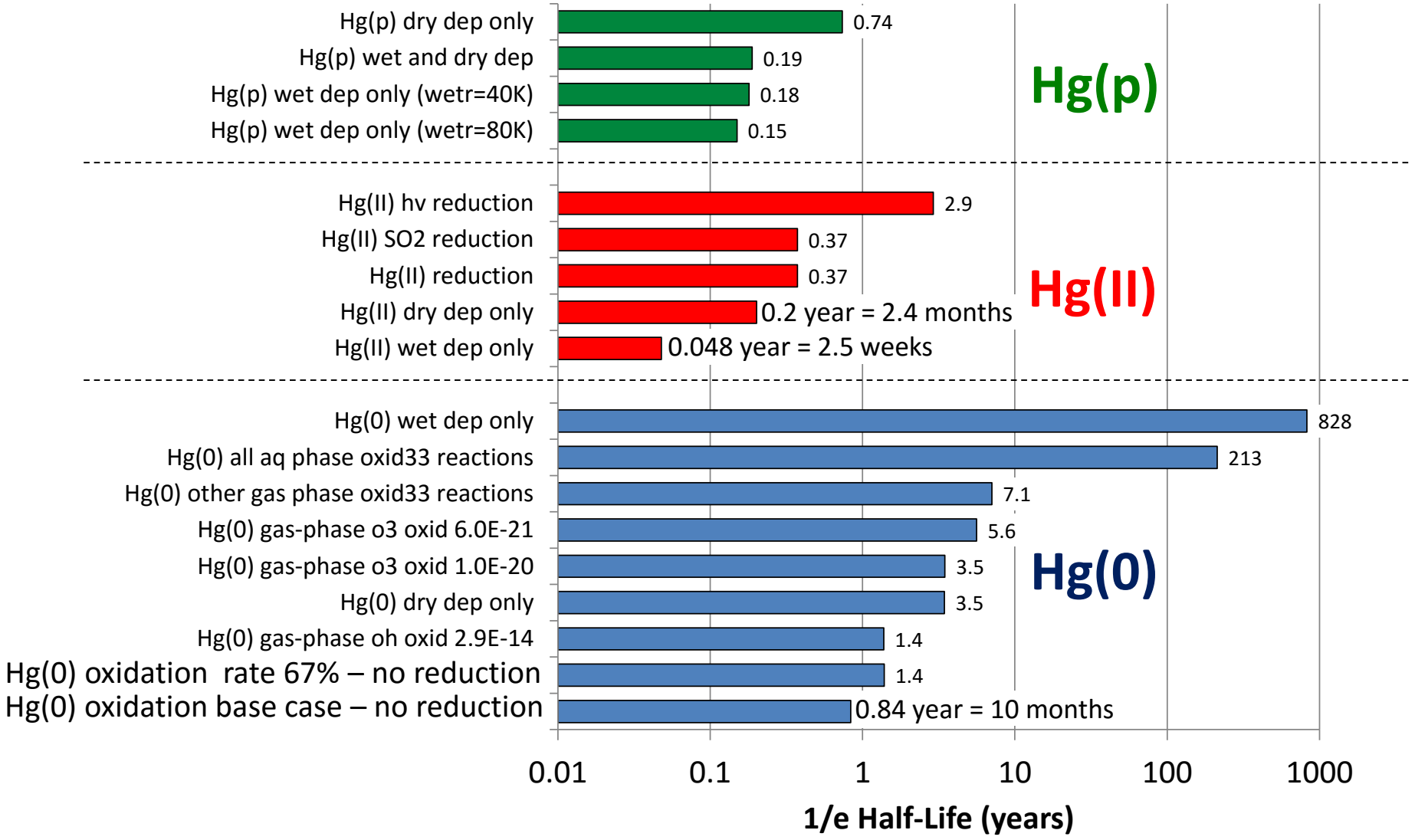
Today's talk will just present Eulerian-only results, for 2005

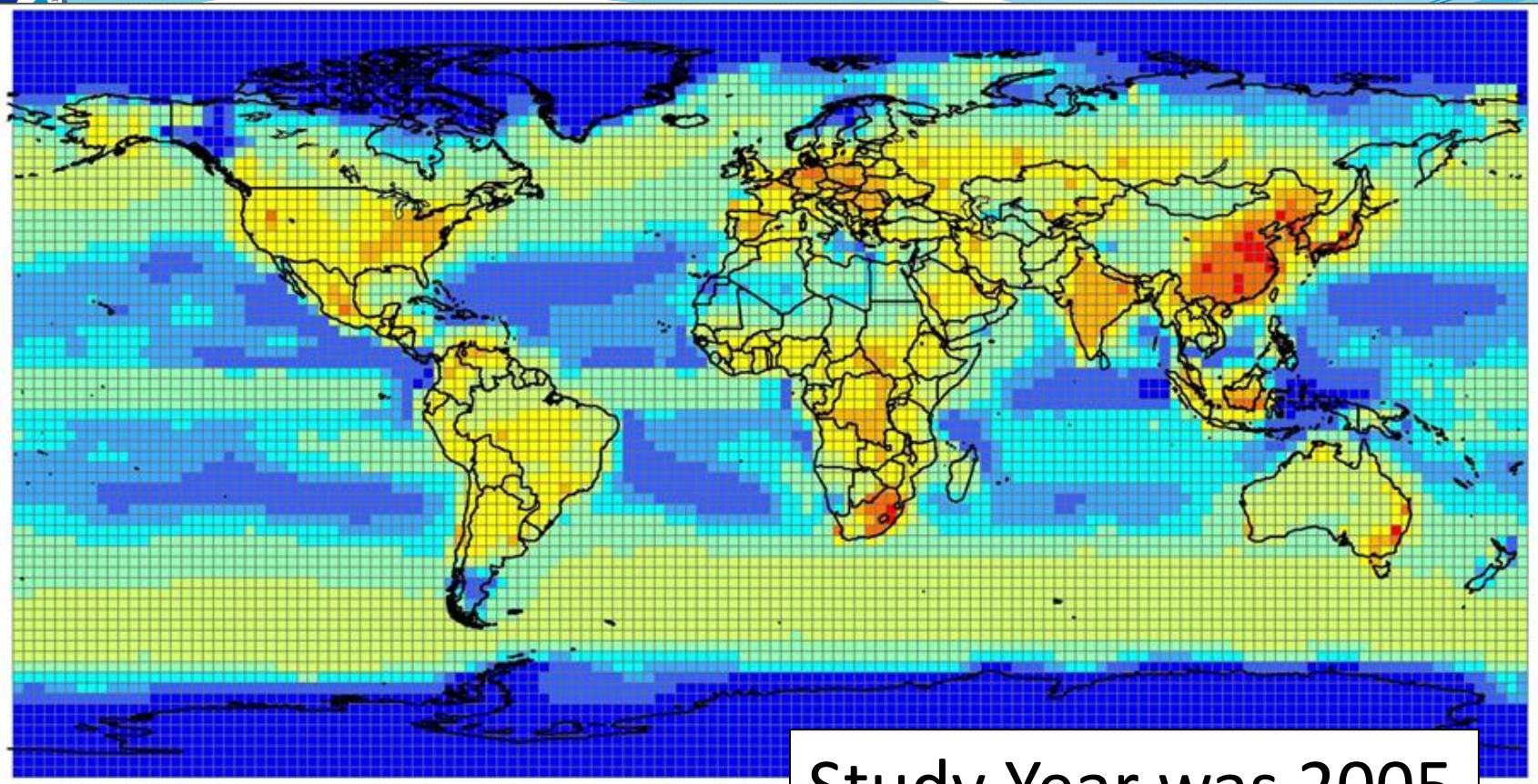
These Eulerian-only simulations were *much faster (a few weeks)* than Lagrangian-only and hybrid Lagrangian-Eulerian simulations *(3-6 months)*

It's important to fail fast!

1/e Half-Lives for Fate Processes within HYSPLIT-Hg

Starting with Uniform Mixing Ratio Throughout the Atmosphere





Study Year was 2005

Emissions Flux (ng/m2-day)

2000.gbl2p5_emit_joined_to_grid

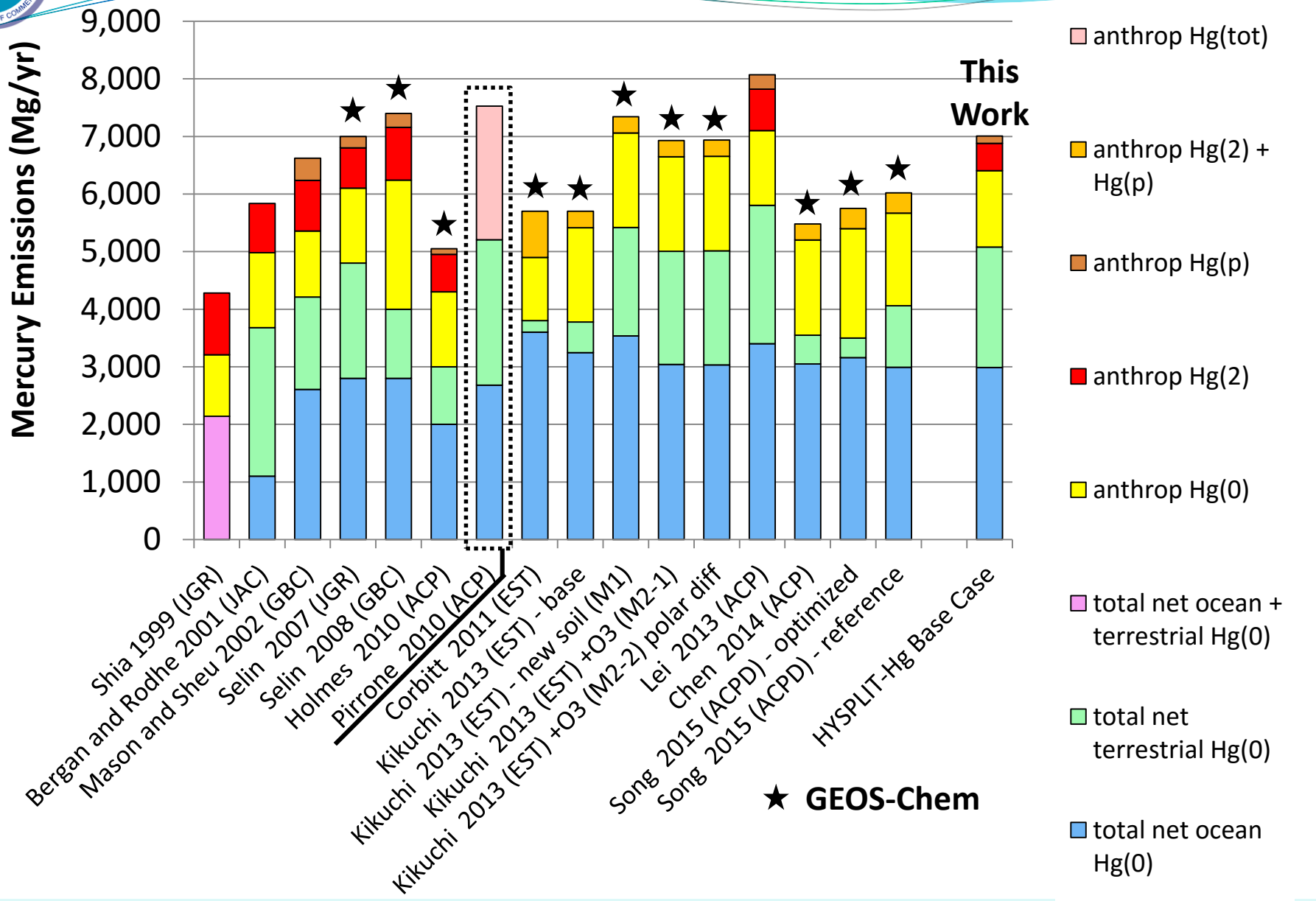
Hgtot_ngm2

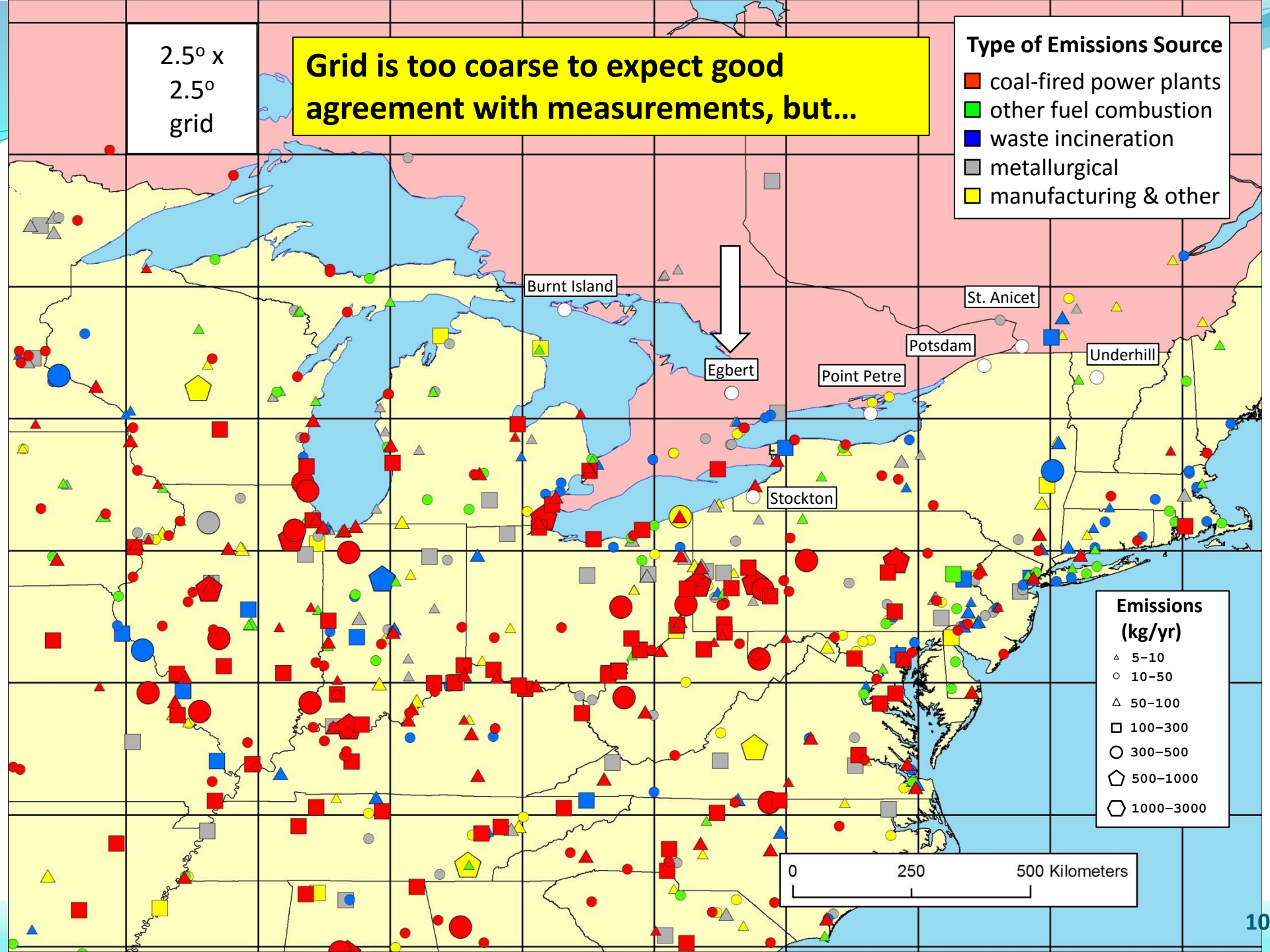
<15 | 15-21 | 21-24 | 24-29 | 29-44 | 44-80 | 80-170 | 170-380 | 380-900 | 900-2400

N

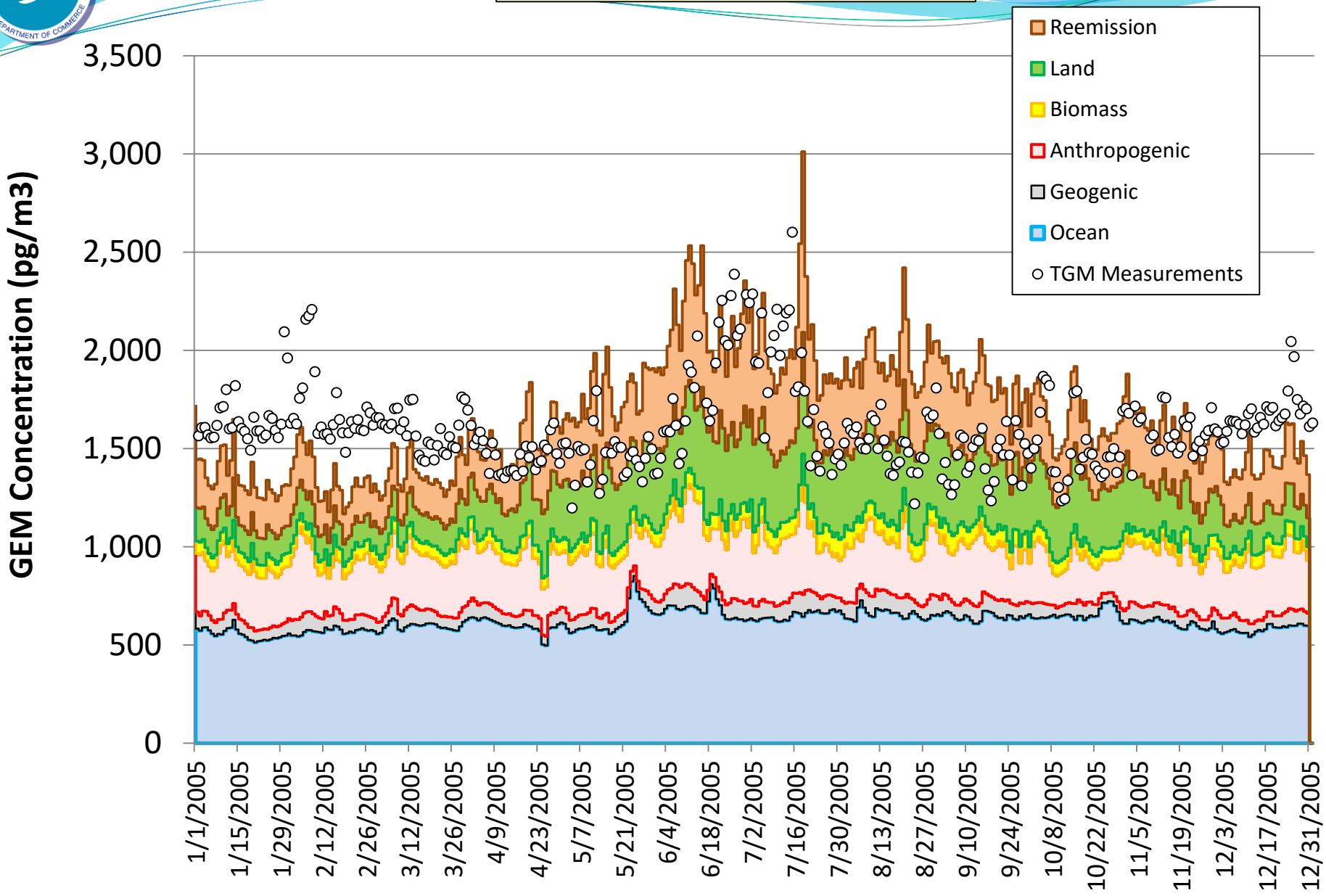
0 5,000 10,000 Kilometers

Emissions Inventories with *Net* Ocean and Terrestrial Hg(0) Fluxes

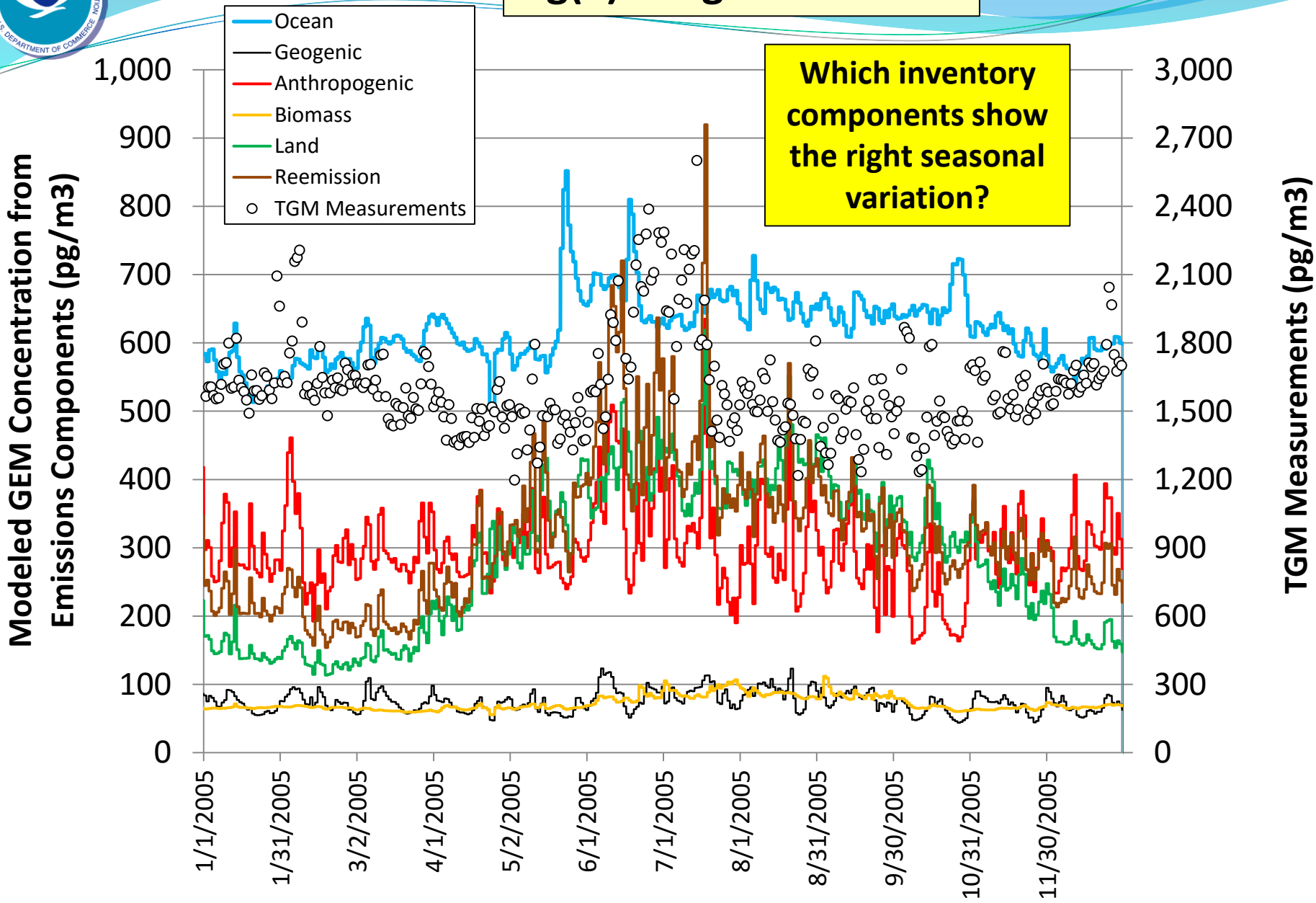



2.5° x 2.5° grid
Grid is too coarse to expect good agreement with measurements, but…
Type of Emissions Source
coal-fired power plants
other fuel combustion
waste incineration
metallurgical
manufacturing & other
Burnt Island
Egbert
Point Petre
Stockton
Potsdam
St. Anicet
Underhill
Emissions (kg/yr)
5–10
10–50
50–100
100–300
300–500
500–1000
1000–3000
0
250
500 Kilometers

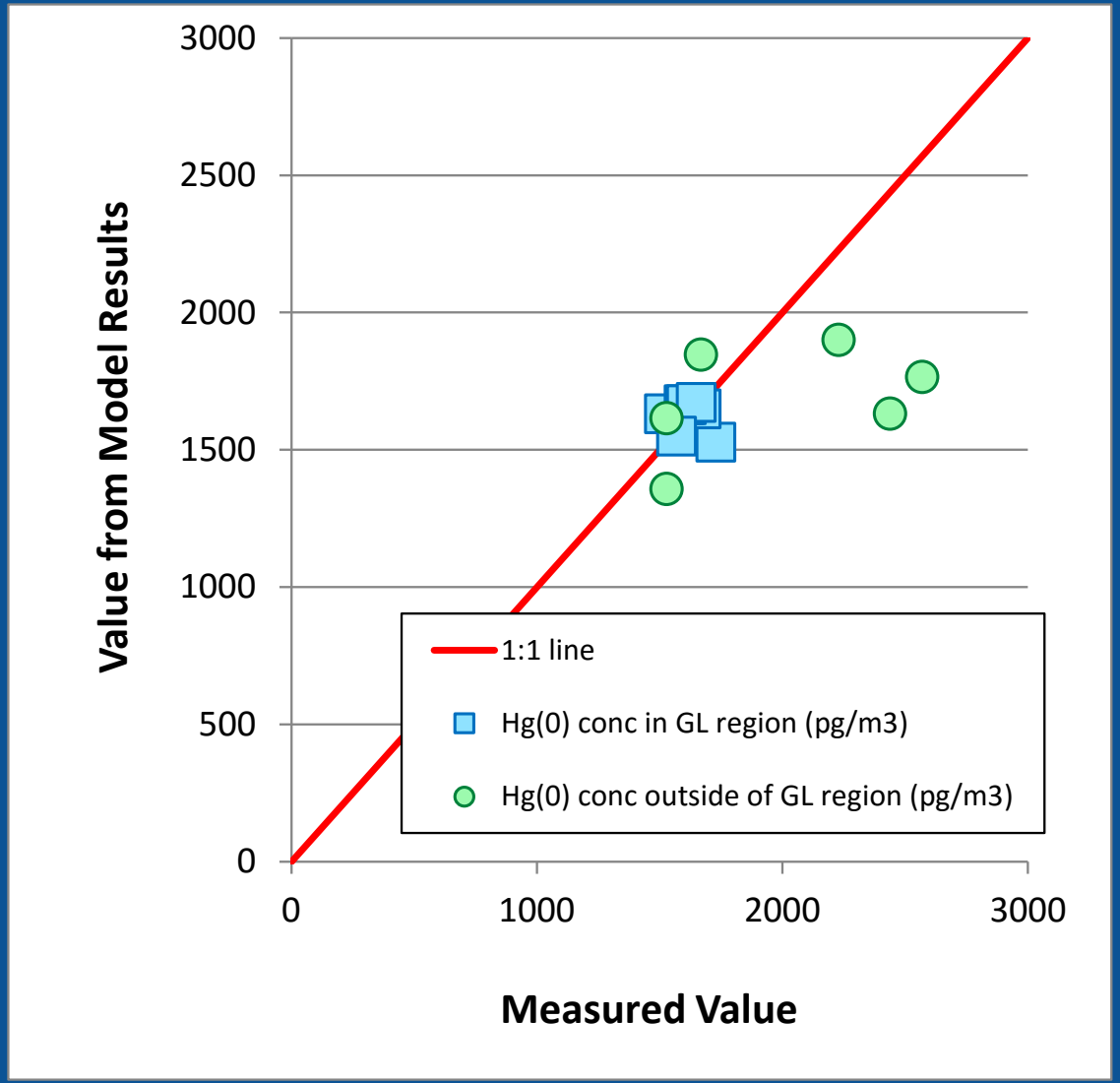
Hg(0) at Egbert Ontario

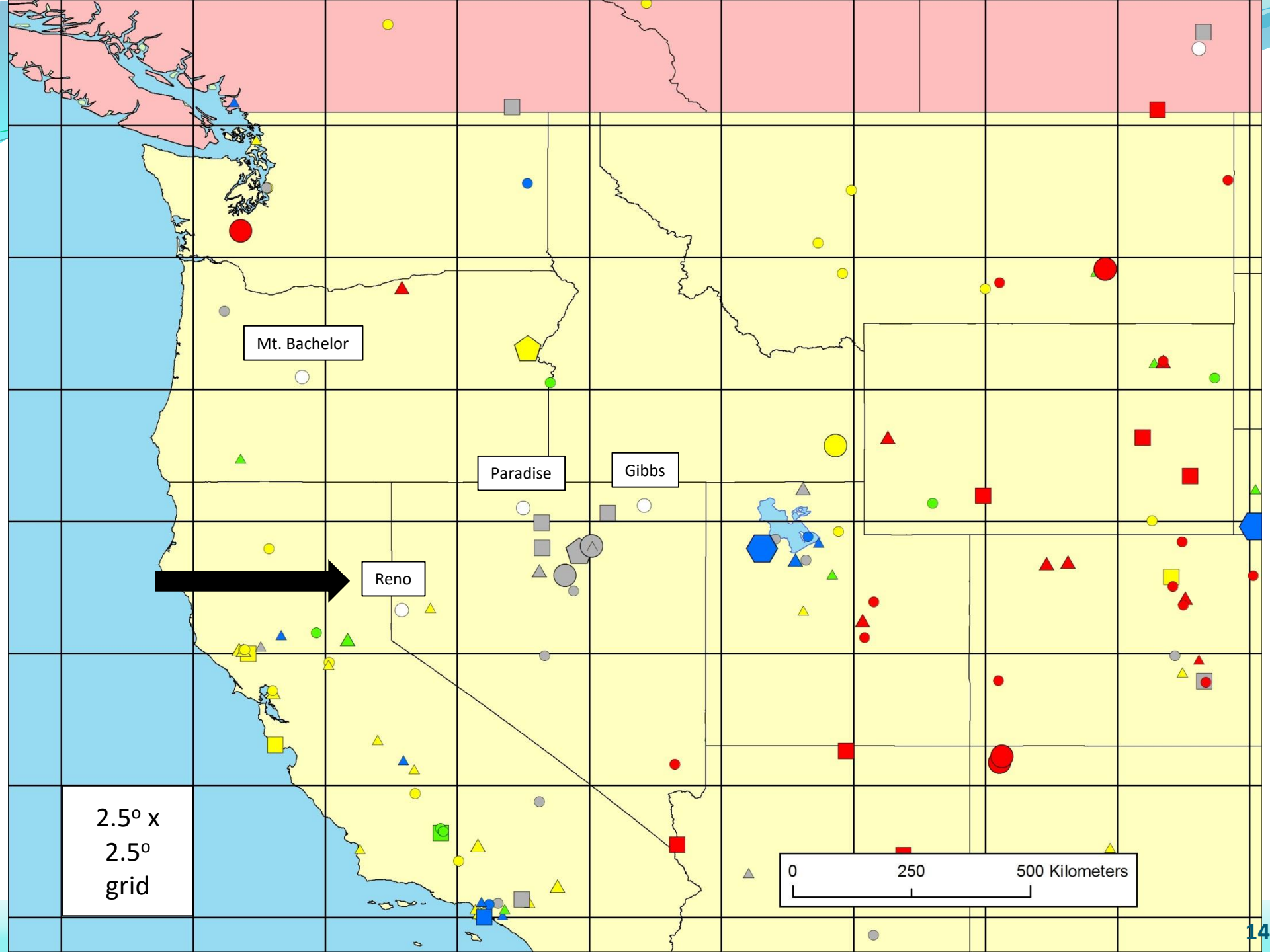


Hg(0) at Egbert Ontario

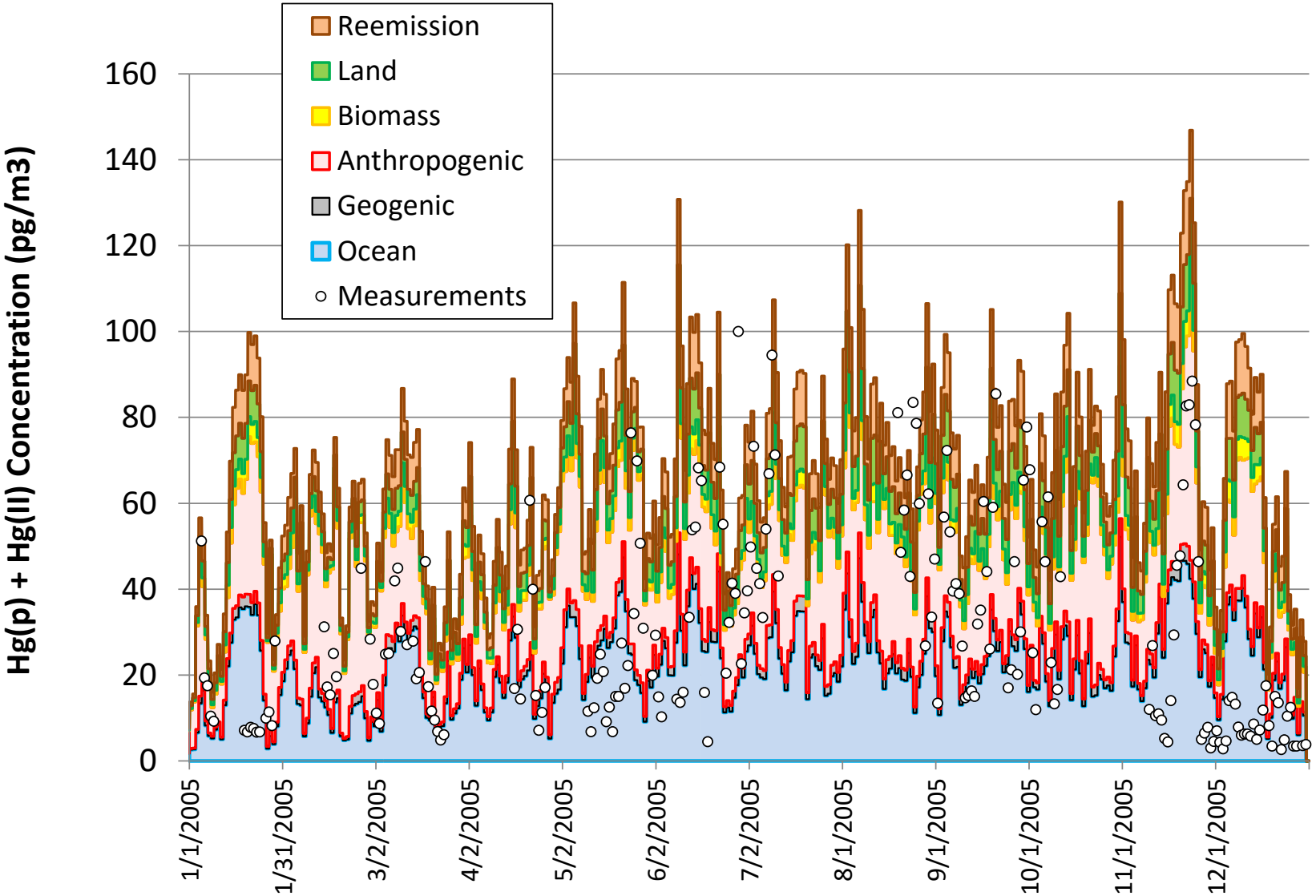


modeled vs. measured Hg(0) concentrations during 2005, for measurement sites in the Great Lakes region and sites outside the region




Mt. Bachelor
Paradise
Gibbs
Reno
2.5° x 2.5° grid
0
250
500 Kilometers

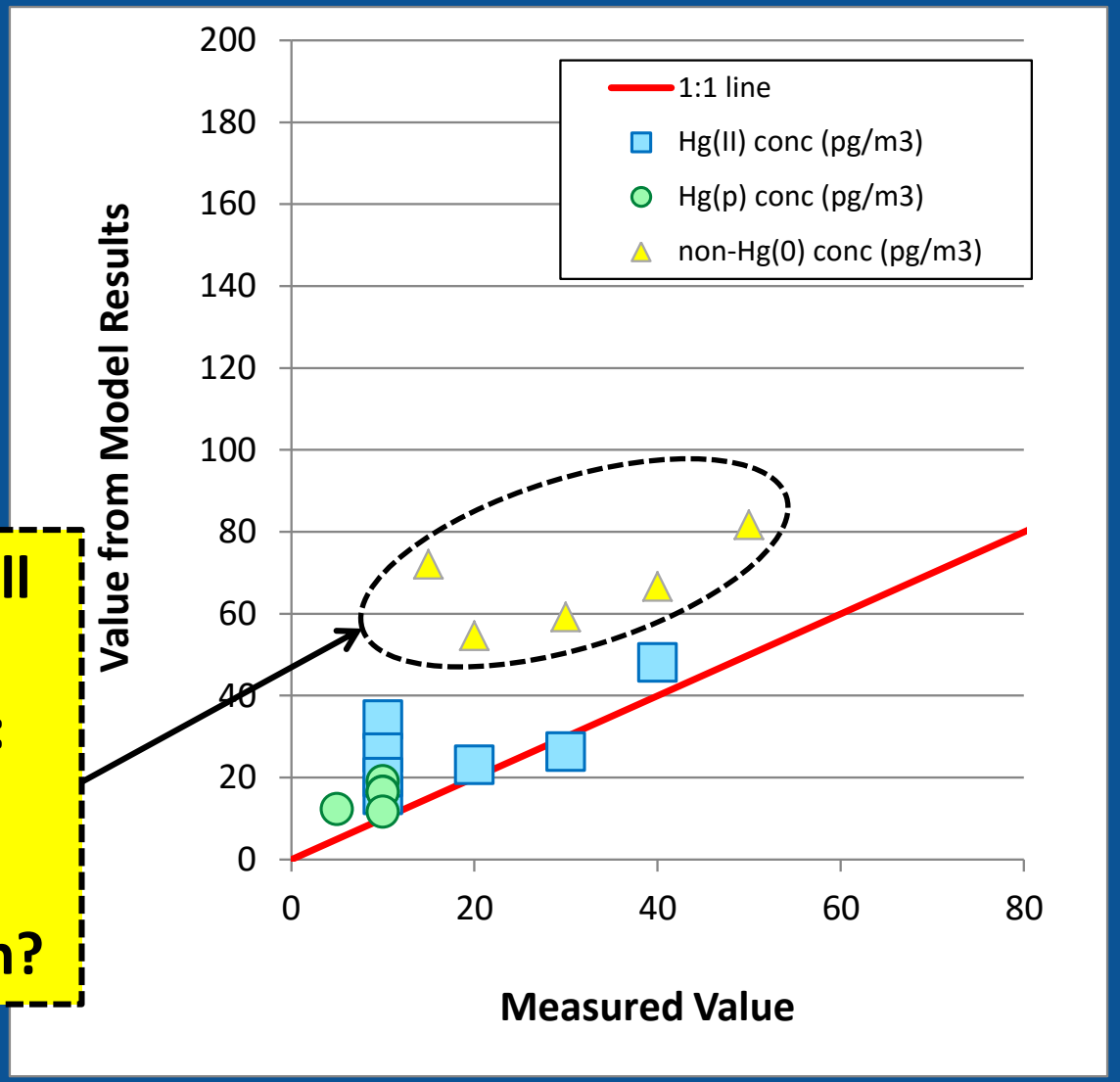
Hg(II) + Hg(p) at Reno (Desert Research Inst.)



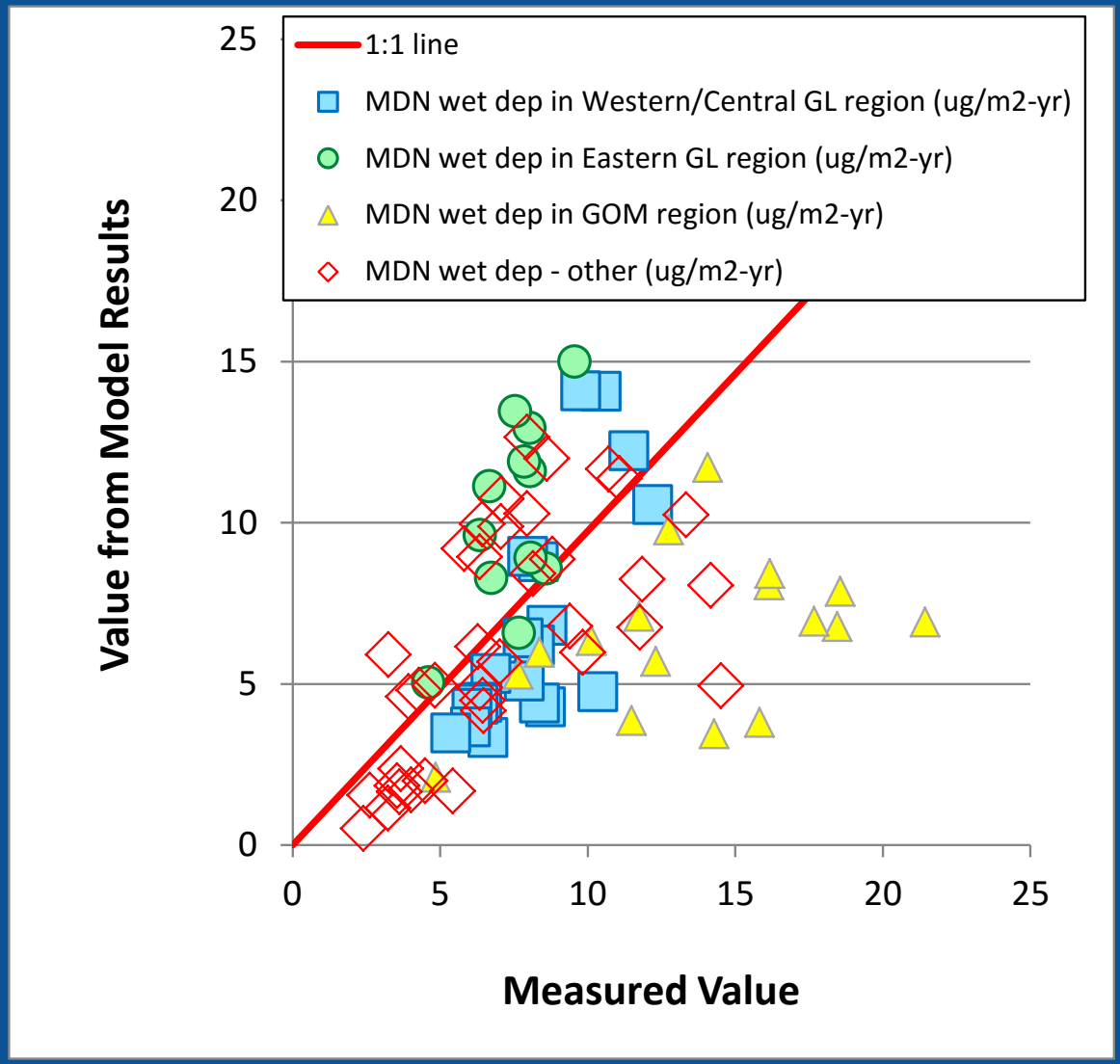
modeled vs. measured Hg(II) and Hg(p) concentrations during 2005

Model estimated total for all non-elemental mercury is higher than measurements:

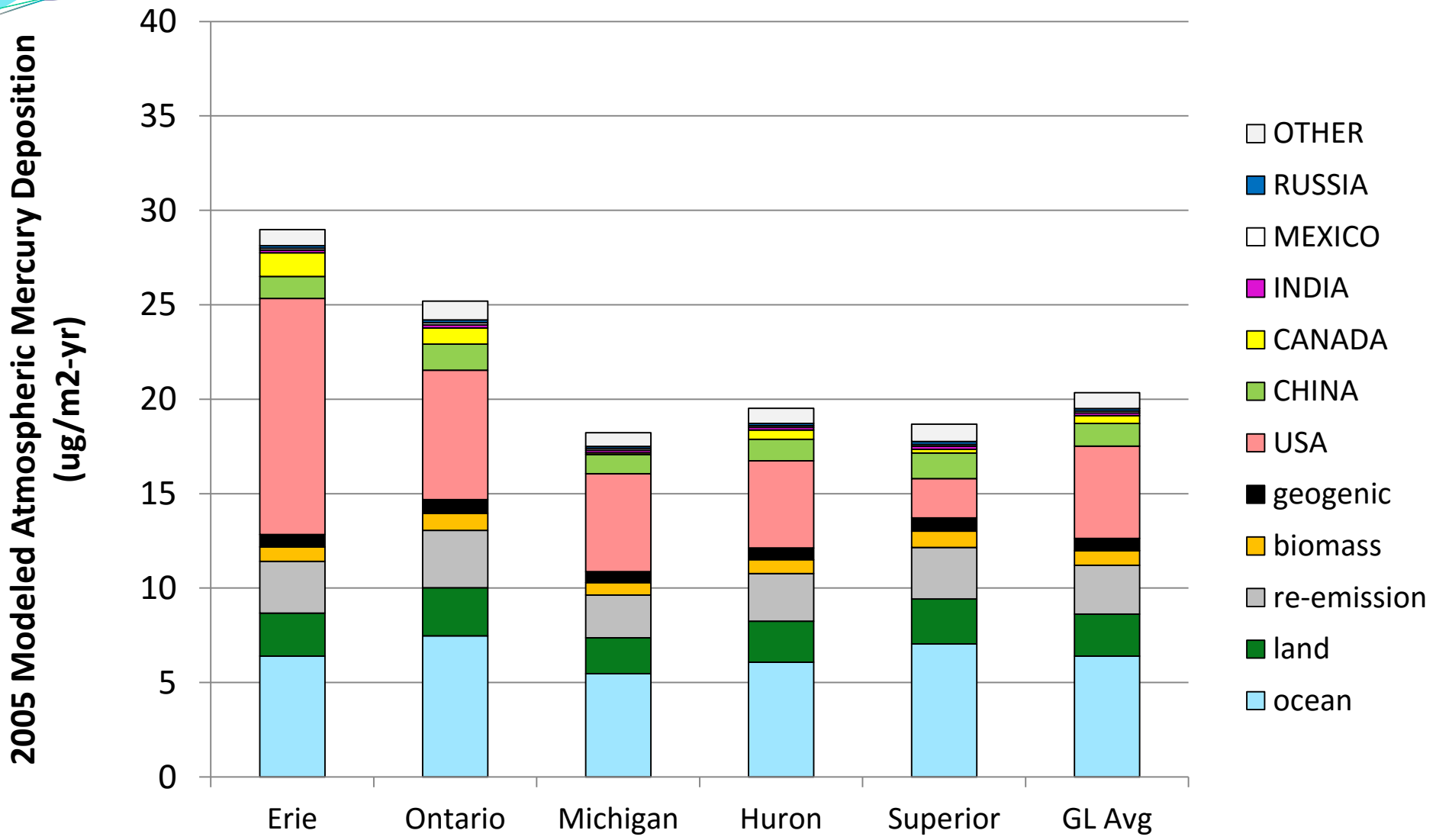
Are the measurements too low or is the model too high?



modeled vs. measured 2005 Hg wet deposition for Mercury Deposition Network (MDN) sites in different regions

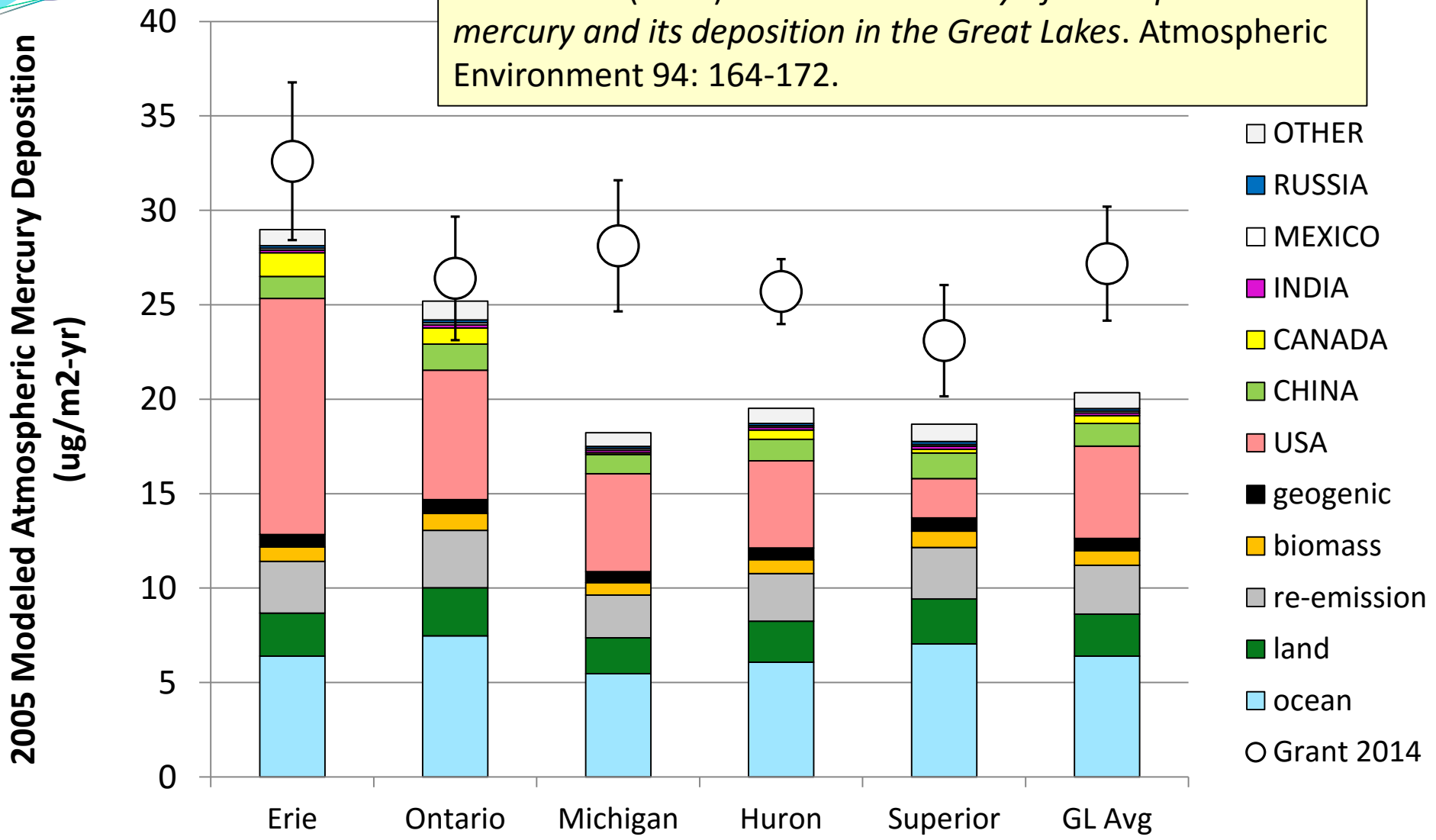


Base Case Source Attribution Results

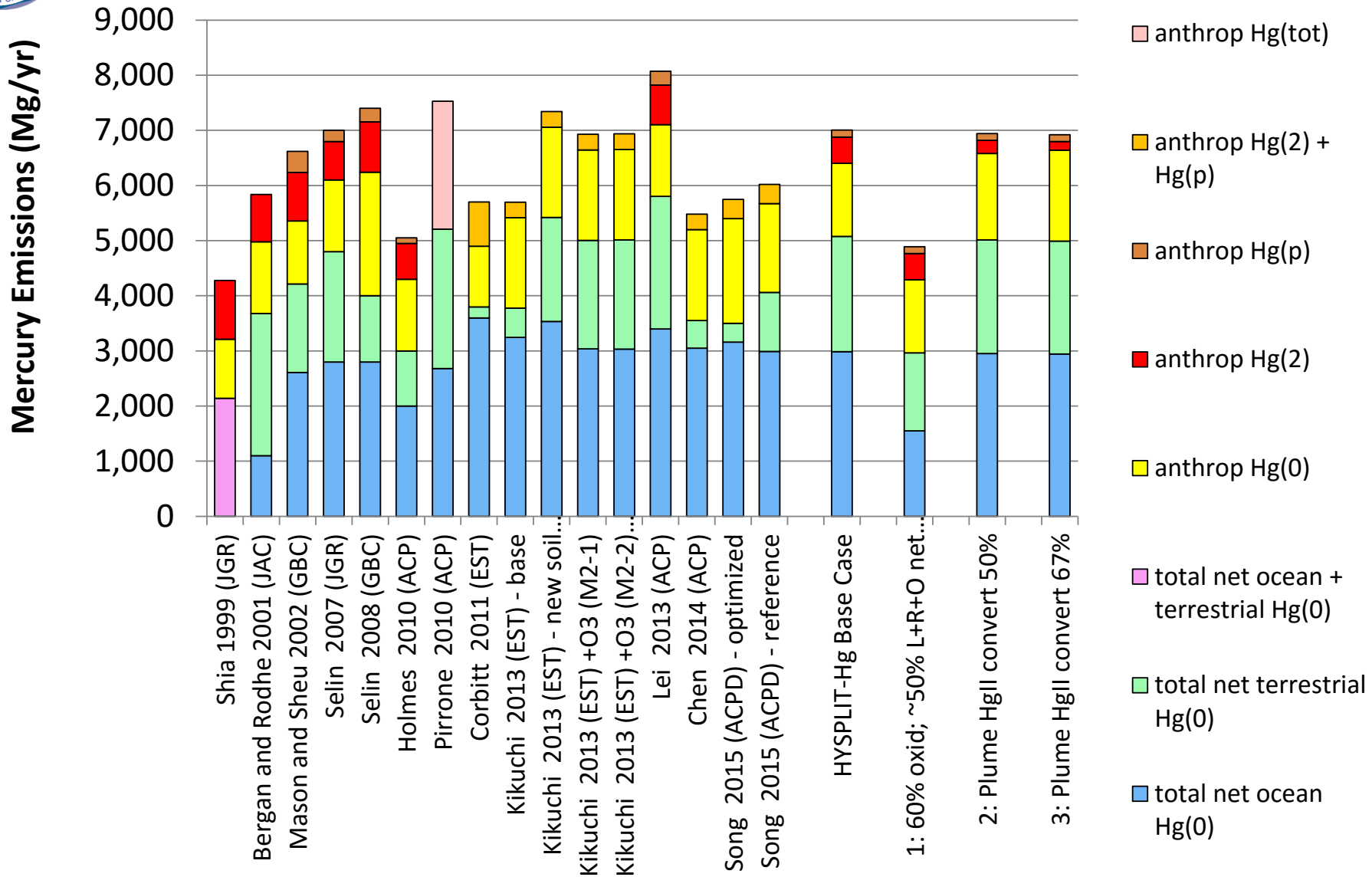


Base-case results compared with recent CMAQ modeling: Grant, S. L., M. Kim, P. Lin, K. C. Crist, S. Ghosh and V. R. Kotamarthi (2014). *A simulation study of atmospheric mercury and its deposition in the Great Lakes*. Atmospheric Environment 94: 164-172.

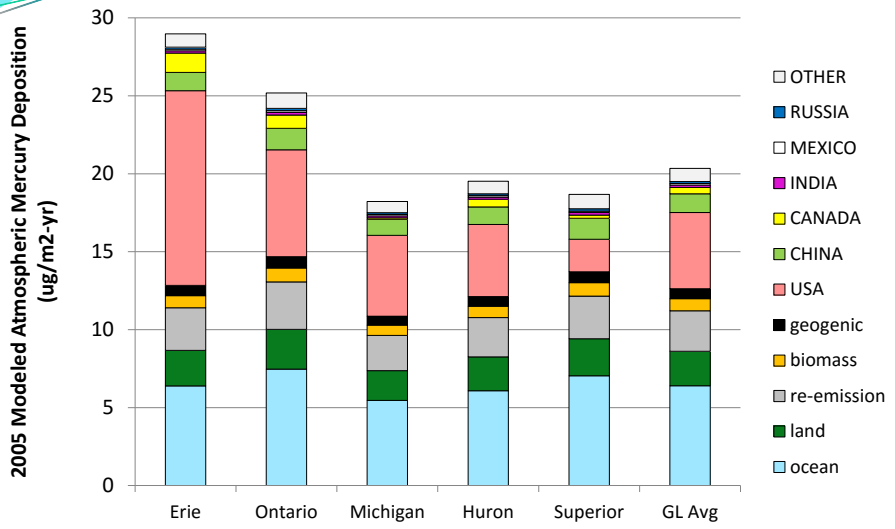
Base



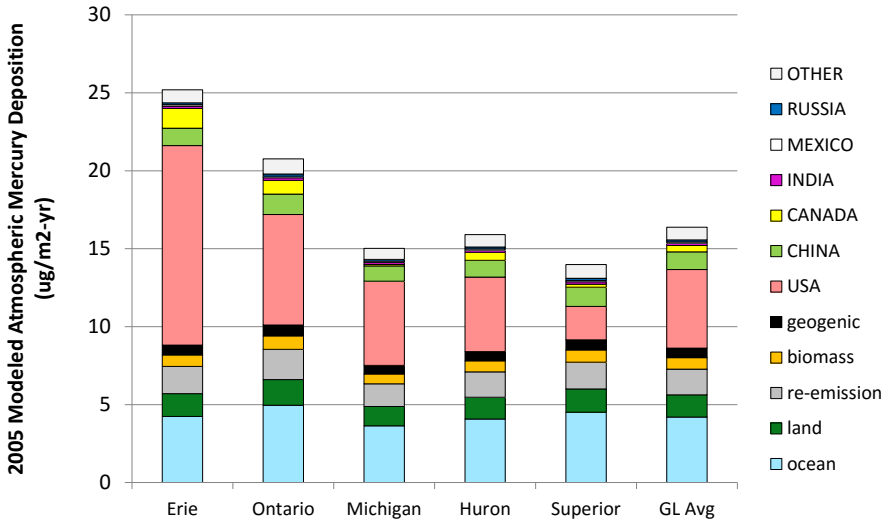
	Base Case	Variation 1 4-D-iii	Variation 2 5-O-i	Variation 3 6-V-i
Oxidation Reaction rates	default	60% less	default	default
Prompt Hg(II) Conversion	0%	0%	50%	67%
Anthropogenic Emit (Mg/yr)	1930	1930	1930	1930
Land + Reemissions + Ocean {Net Hg(0) emissions} (Mg/yr)	4350	2300	4350	4350
Particle Fraction of Hg(0) oxidation	10%	25%	10%	10%
WETR (wet deposition parameter)	40,000	80,000	40,000	40,000
Great Lakes Hg(0) bias	0%	0%	0%	0%
Great Lakes Hg wet dep bias	+2%	-8%	-10%	-14%


Mercury Emissions (Mg/yr)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Shia 1999 (JGR)
Bergan and Rodhe 2001 (JAC)
Mason and Sheu 2002 (GBC)
Selin 2007 (JGR)
Selin 2008 (GBC)
Holmes 2010 (ACP)
Pirrone 2010 (ACP)
Corbitt 2011 (EST)
Kikuchi 2013 (EST) - base
Kikuchi 2013 (EST) - new soil...
Kikuchi 2013 (EST) +O3 (M2-1)
Kikuchi 2013 (EST) +O3 (M2-2)...
Lei 2013 (ACP)
Chen 2014 (ACP)
Song 2015 (ACPD) - optimized
Song 2015 (ACPD) - reference
HYSPLIT-Hg Base Case
1: 60% oxid; ~50% L+R+O net...
2: Plume HgII convert 50%
3: Plume HgII convert 67%
anthrop Hg(tot)
anthrop Hg(2) + Hg(p)
anthrop Hg(p)
anthrop Hg(2)
anthrop Hg(0)
total net ocean + terrestrial Hg(0)
total net terrestrial Hg(0)
total net ocean Hg(0)

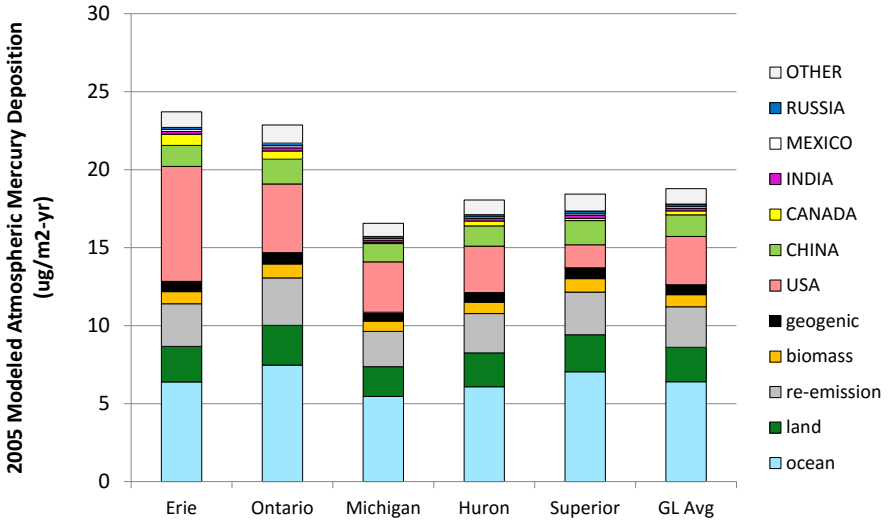
Base Case



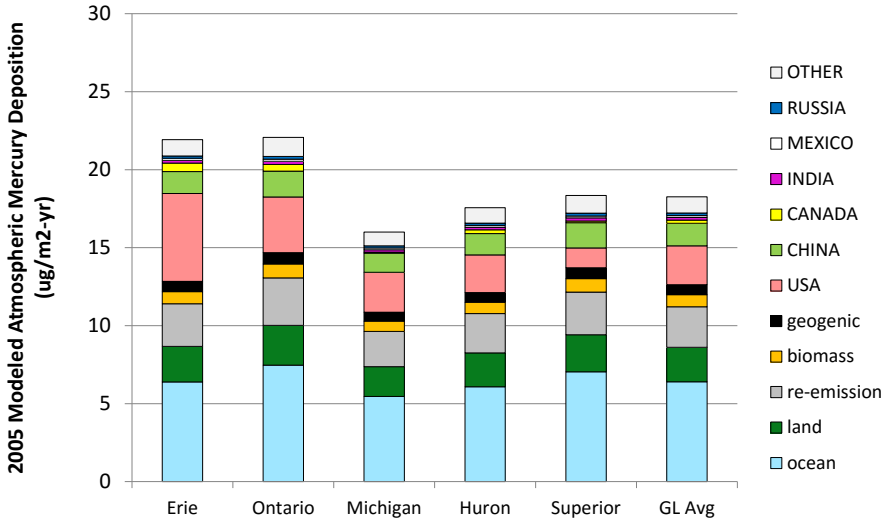
1: 60% oxid; ~50% L+R+O net Hg0



2: Plume HgII convert 50%



3: Plume HgII convert 67%



- **HYSPLIT-Hg Base Case gives reasonable results for 2005**
  - ***Several variations also considered, which can also give reasonable results for 2005***
- **Source Attribution results for the different cases are understandably somewhat different**
  - ***However, policy implications of the different modeling results may not be that different***
- **Next steps:**
  - **Modeling for more recent years, including *detailed* model evaluation at three NOAA/EPA monitoring sites (within AMNet):**
    Beltsville MD; Grand Bay MS; and Mauna Loa HI
  - **+ Nested grid + explicit sub-surface terrestrial & ocean layers**

Thanks!

This work was partially funded through the Great Lakes Restoration Initiative

Great Lakes RESTORATION