Modeling mercury in the ocean and its effect on the marine boundary layer

Focus on the air-sea exchange in the North Atlantic

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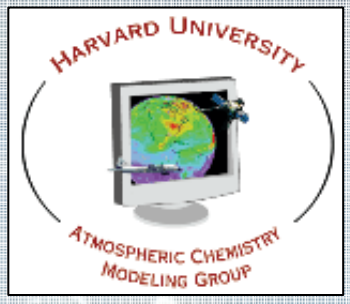
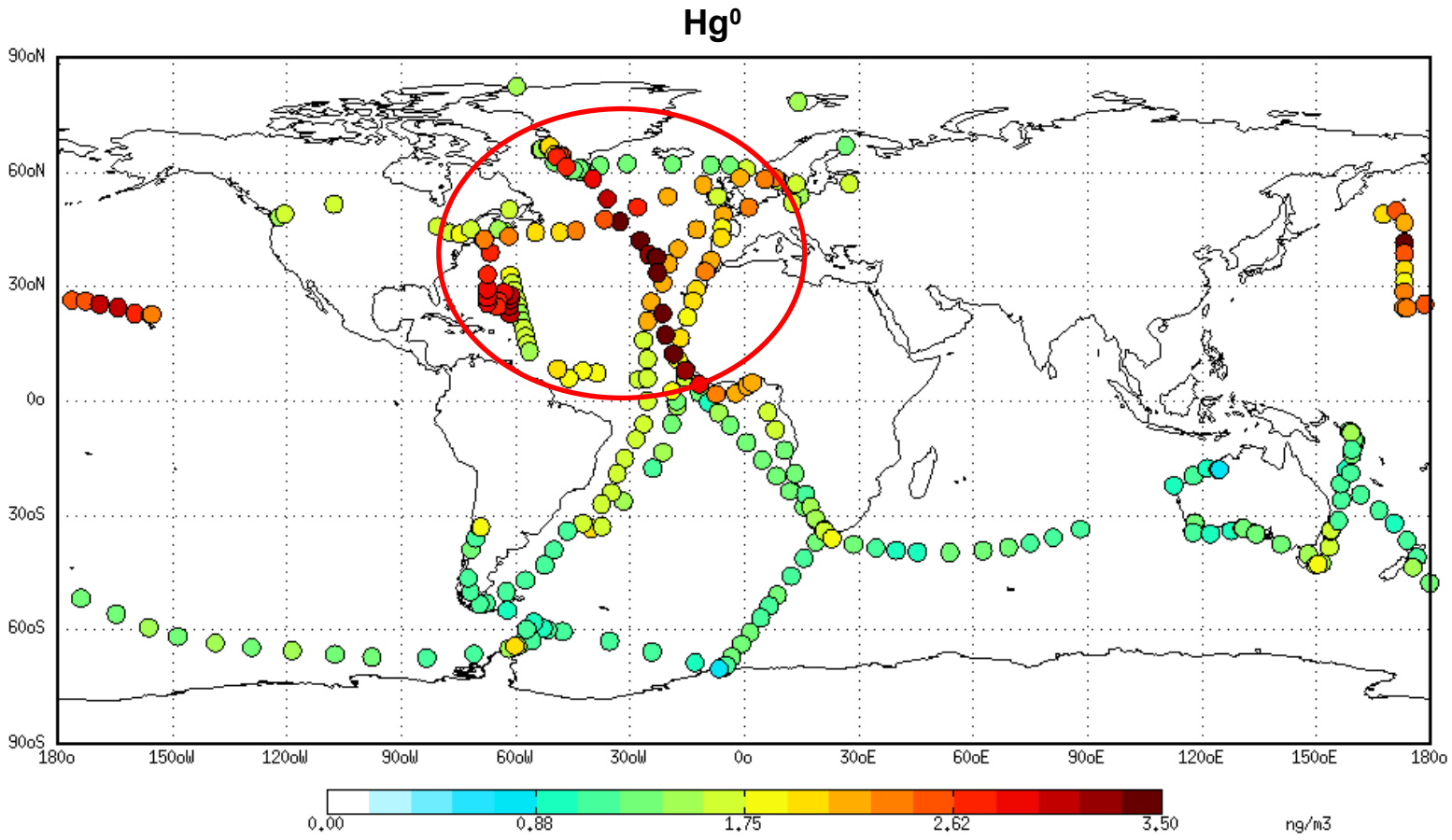


Motivation

What causes high concentrations in the Atlantic boundary layer?

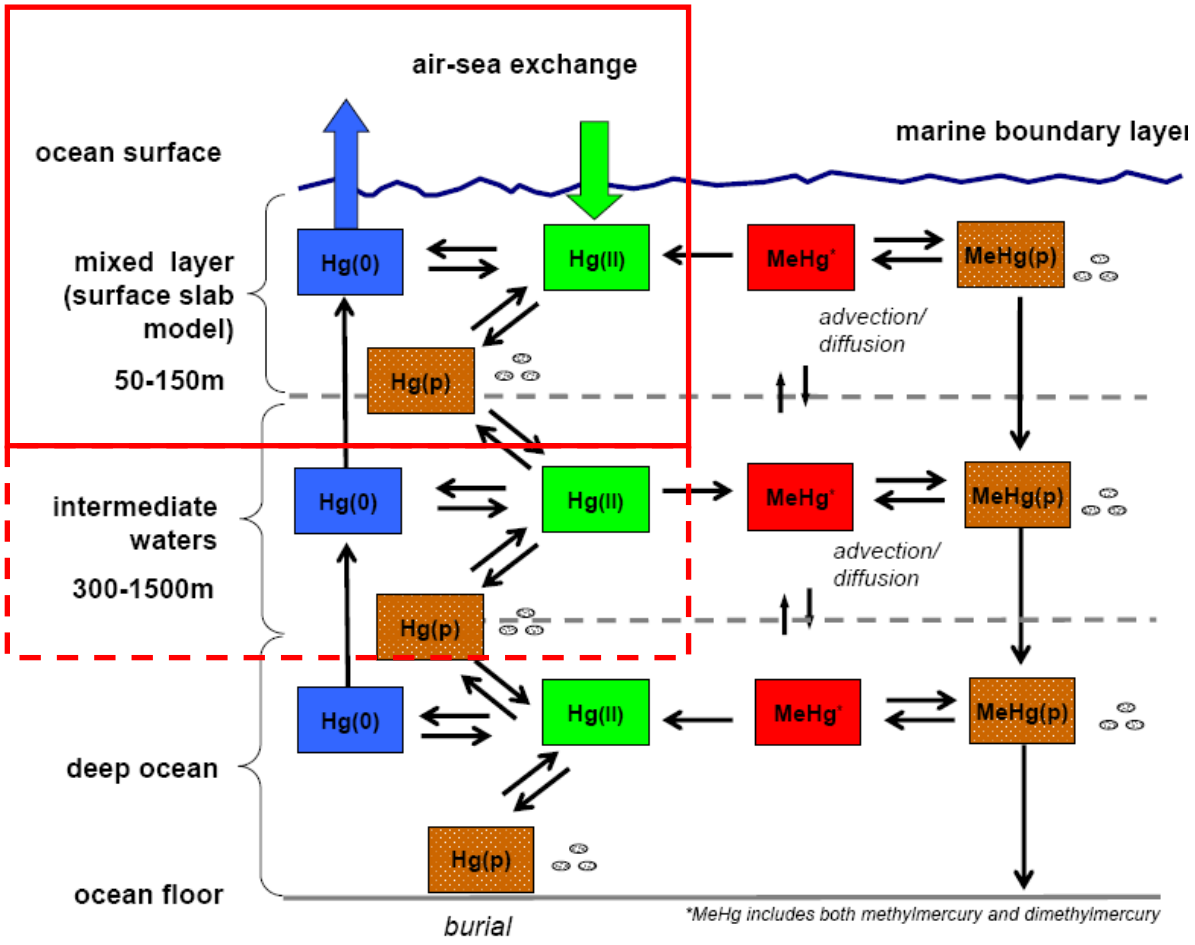


Refs: Galathea expedition
Temme et al. 2003, Laurier et al. 2003 , Laurier et al. 2007, Lamborg et al. 1999

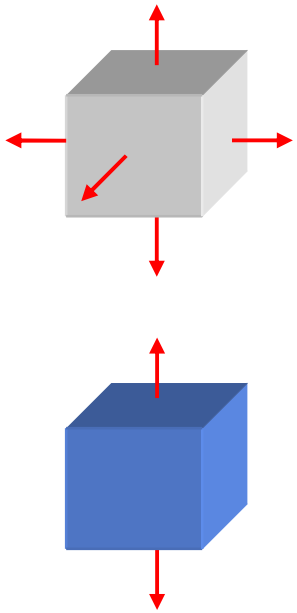
Method

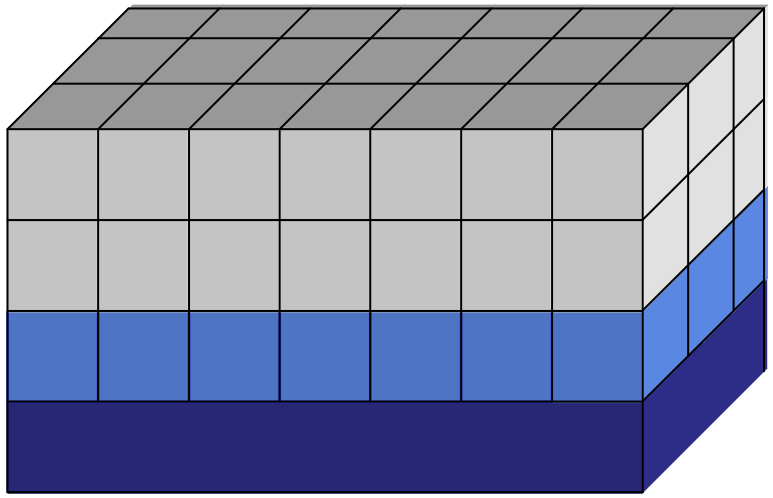
GEOS-Chem mercury model

- Atmospheric global mercury model with Br as primary oxidant
- Includes a mixed layer surface slab model



Method



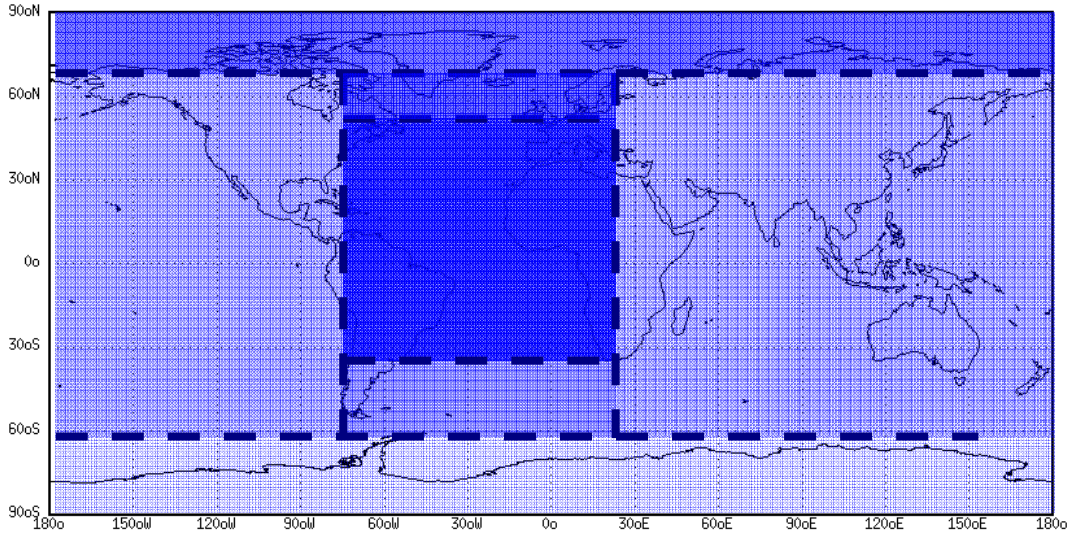


Atmosphere

Mixed layer

Deep ocean

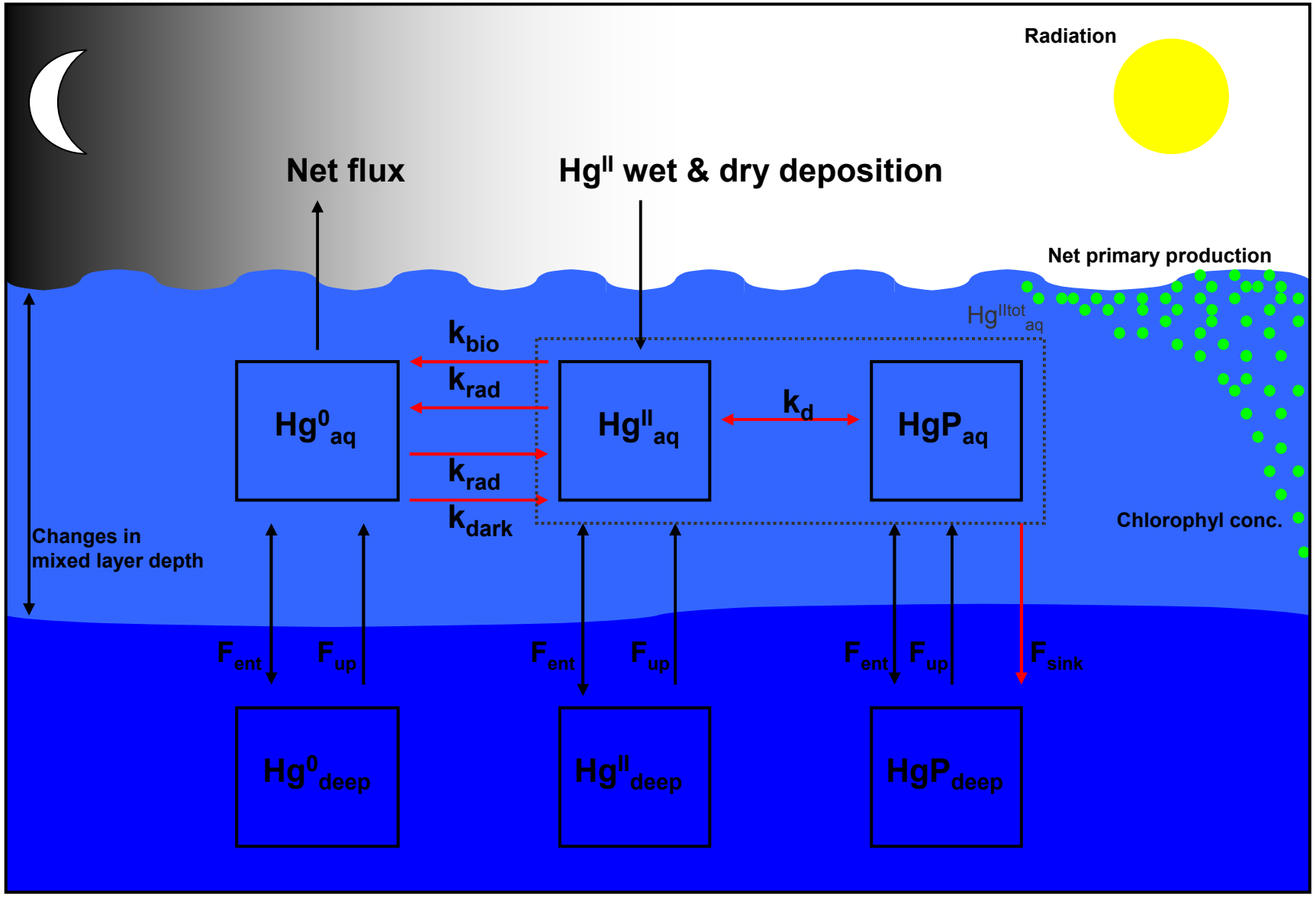
Deep ocean concentration



Hg^{tot} (pM)	
Atlantic	1.82
North Atlantic	1.74
Arctic	1.33
South Atlantic	1.05
Pacific/Indian Oc	0.88
Antarctic	0.71

Sunderland & Mason 2008
Sunderland et al. 2009

Method

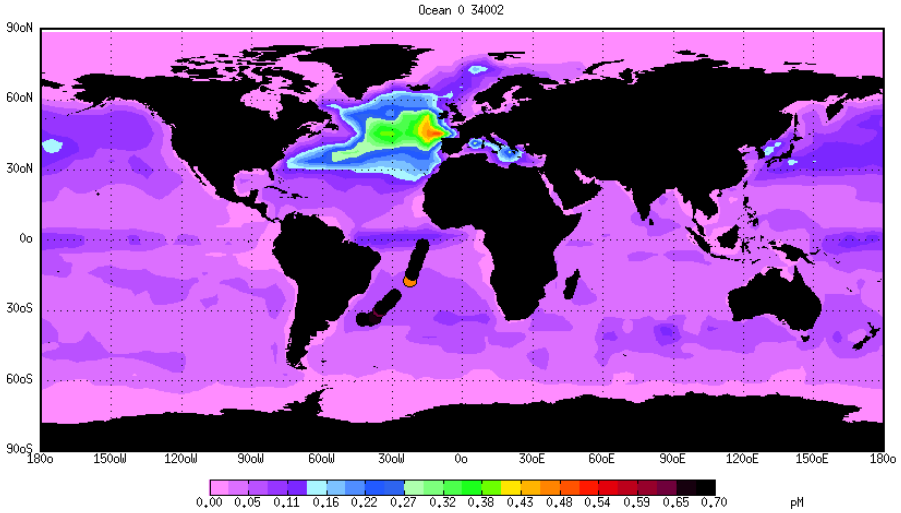

Radiation
Net flux
Hg^{II} wet & dry deposition
Net primary production
Hg$^{IItot}_{aq}$
k_{bio}
k_{rad}
k_{rad}
k_{dark}
k_d
Hg$^0_{aq}$
Hg$^{II}_{aq}$
HgP$_{aq}$
Changes in mixed layer depth
Chlorophyl conc.
F_{ent}
F_{up}
F_{ent}
F_{up}
F_{ent}
F_{up}
F_{sink}
Hg$^0_{deep}$
Hg$^{II}_{deep}$
HgP$_{deep}$

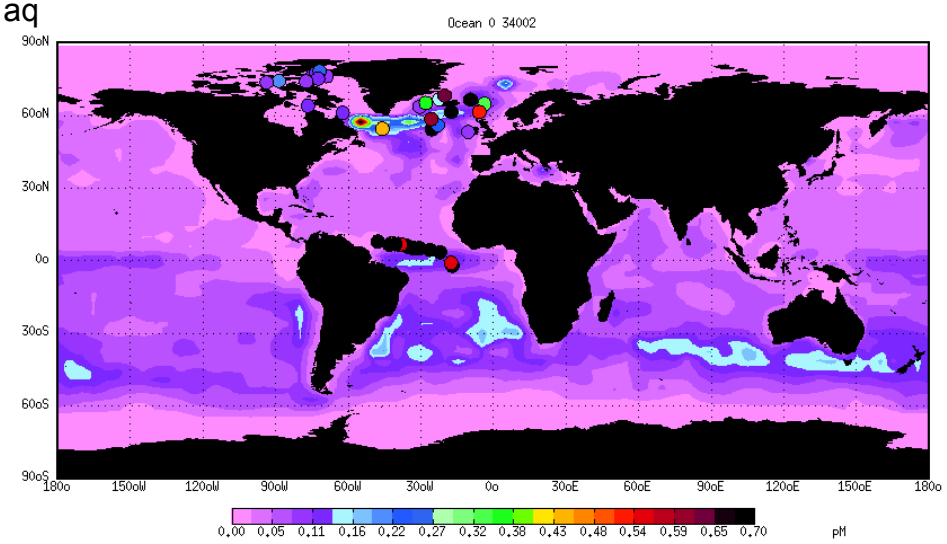
Results

March-May 2006

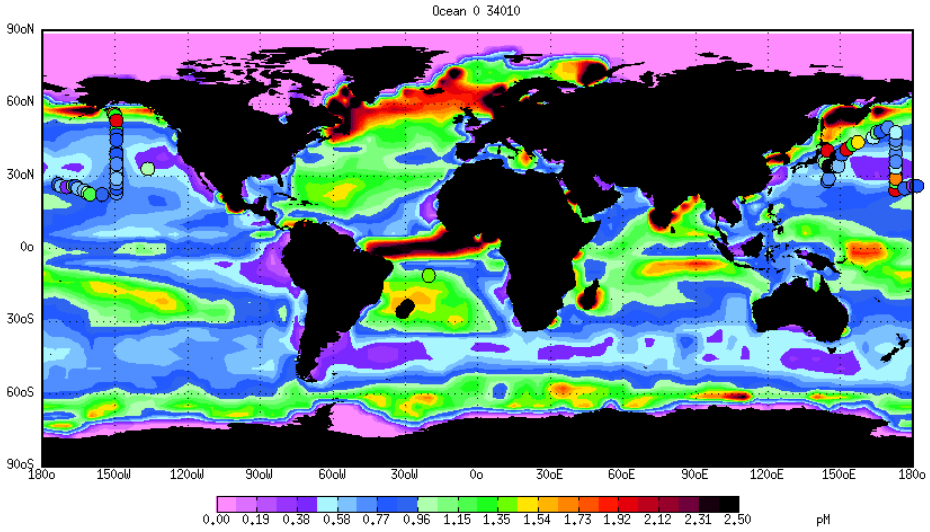
Hg^0_{aq}

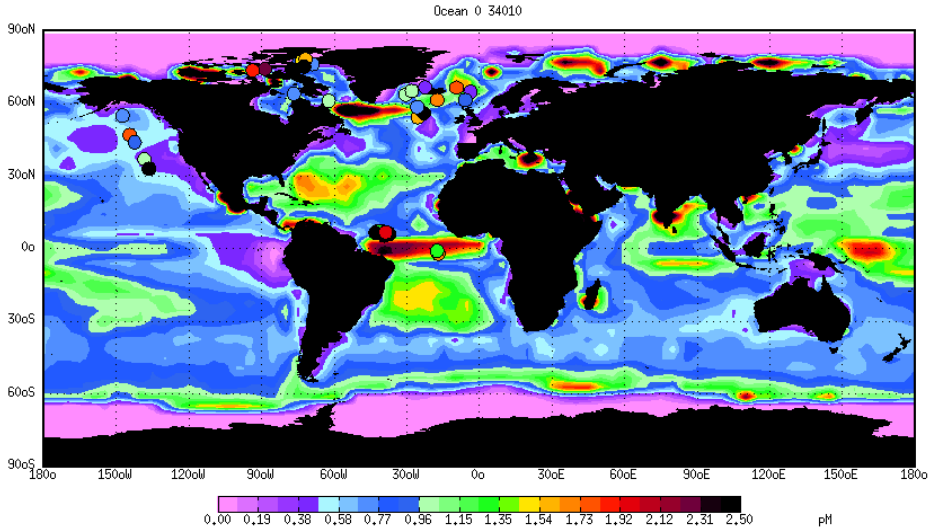
June-October 2006





Hg^{tot}_{aq}



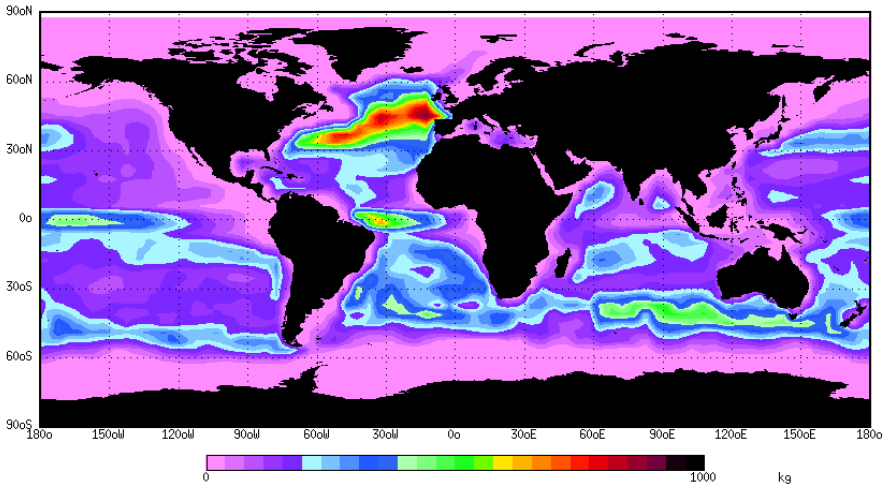


Refs: Mason & Sullivan 1999, Kirk et al. 2008, Laurier et al. 2004, Sunderland et al. 2009

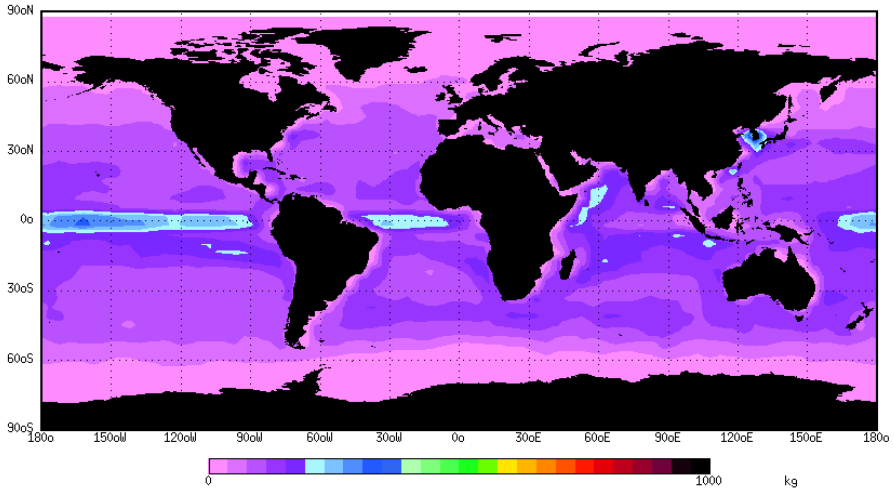
Results

Mean monthly evasion (kg/grid)

New Ocean simulation



Old Ocean simulation



Global yearly evasion

New Ocean simulation
3455 Mg y^{-1}

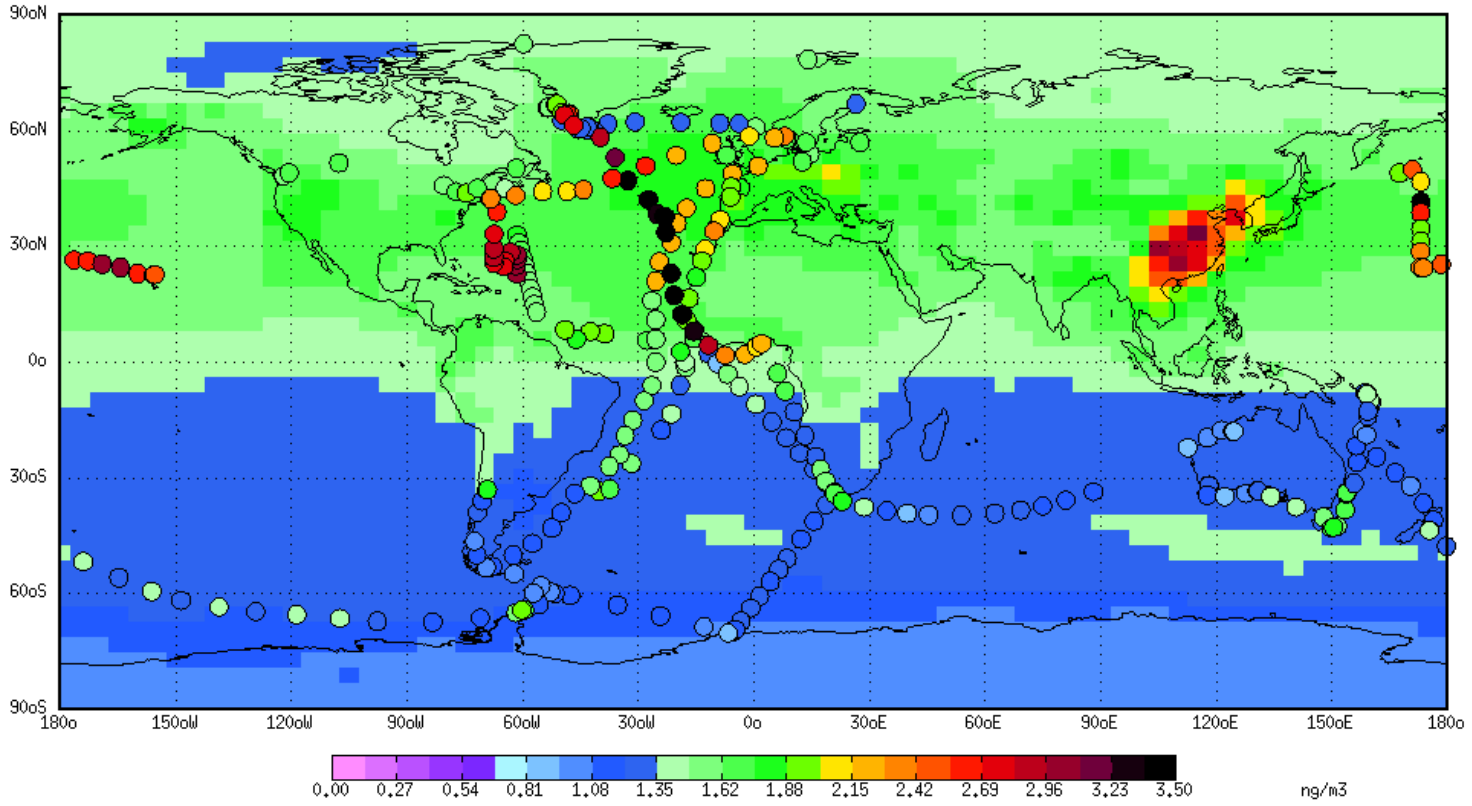
Old Ocean simulation
2234 Mg y^{-1}

Sunderland & Mason, 2007
2600 (1945-4150) Mg y^{-1}

Selin et al. 2008
2800 Mg y^{-1}

Results

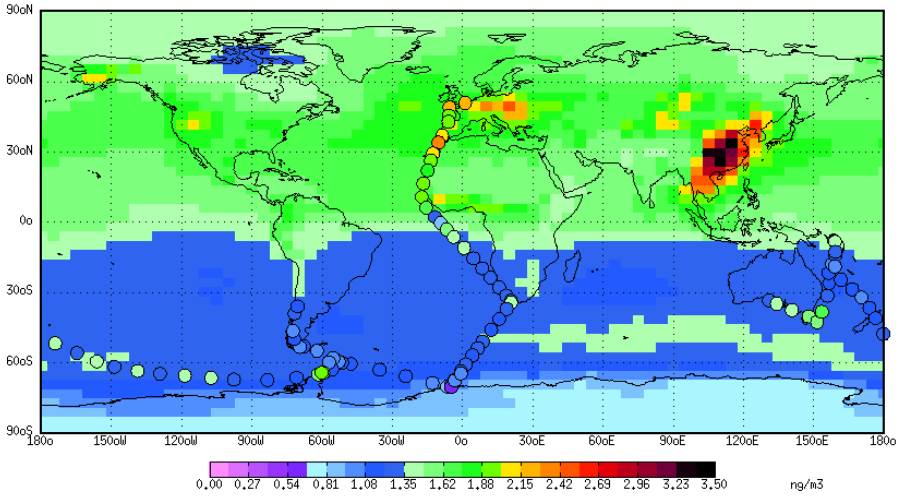
Marine boundary layer yearly average (2006) of Hg^0



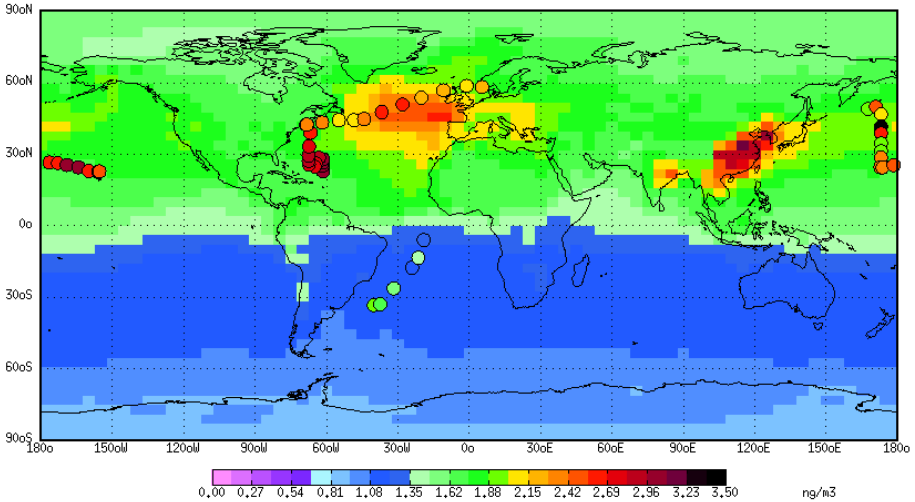
Refs: Galathea expedition, Temme et al. 2003, Laurier et al. 2003 , Laurier et al. 2007, Lamborg et al. 1999, Environmental Canada 2003, EMEP 2005, Ebinghaus et al. 2002, Kellerhals et al. 2003, Weiss-Penzias et al. 2003, Poissant et al 2005, Baker et al. 2002

Results

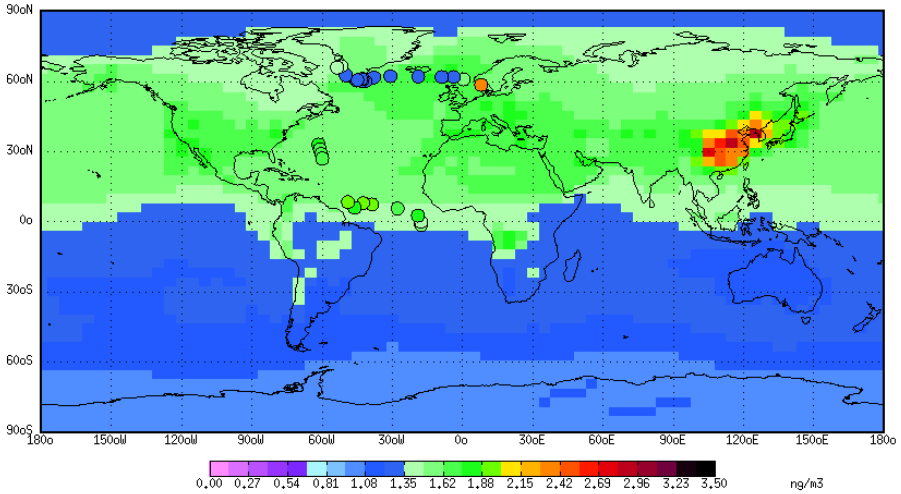
December, January, February



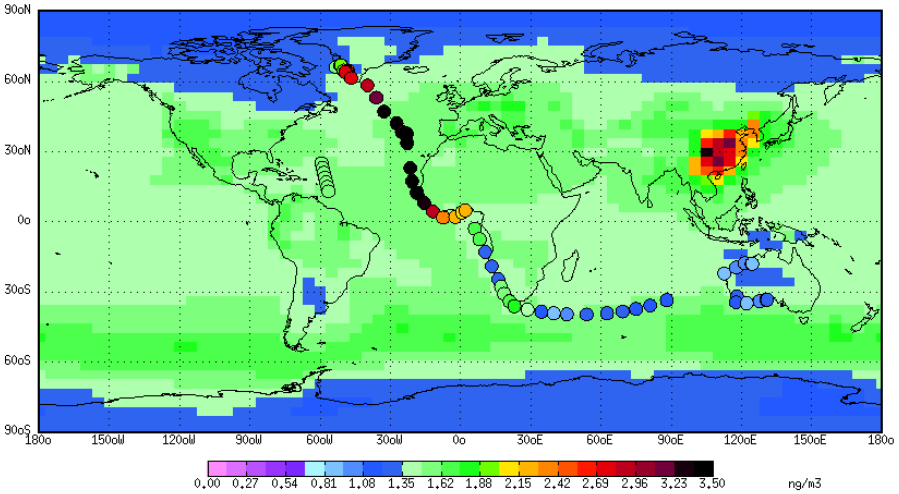
March, April, May



June, July, August

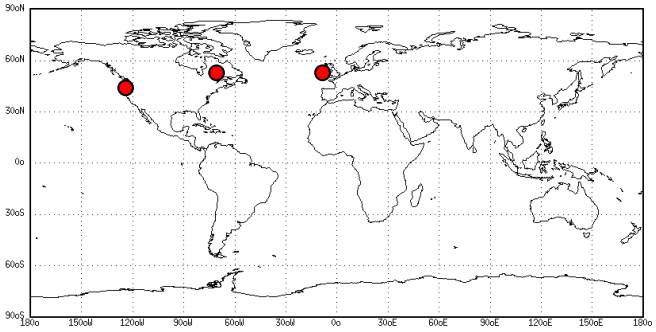


September, October, November



Results

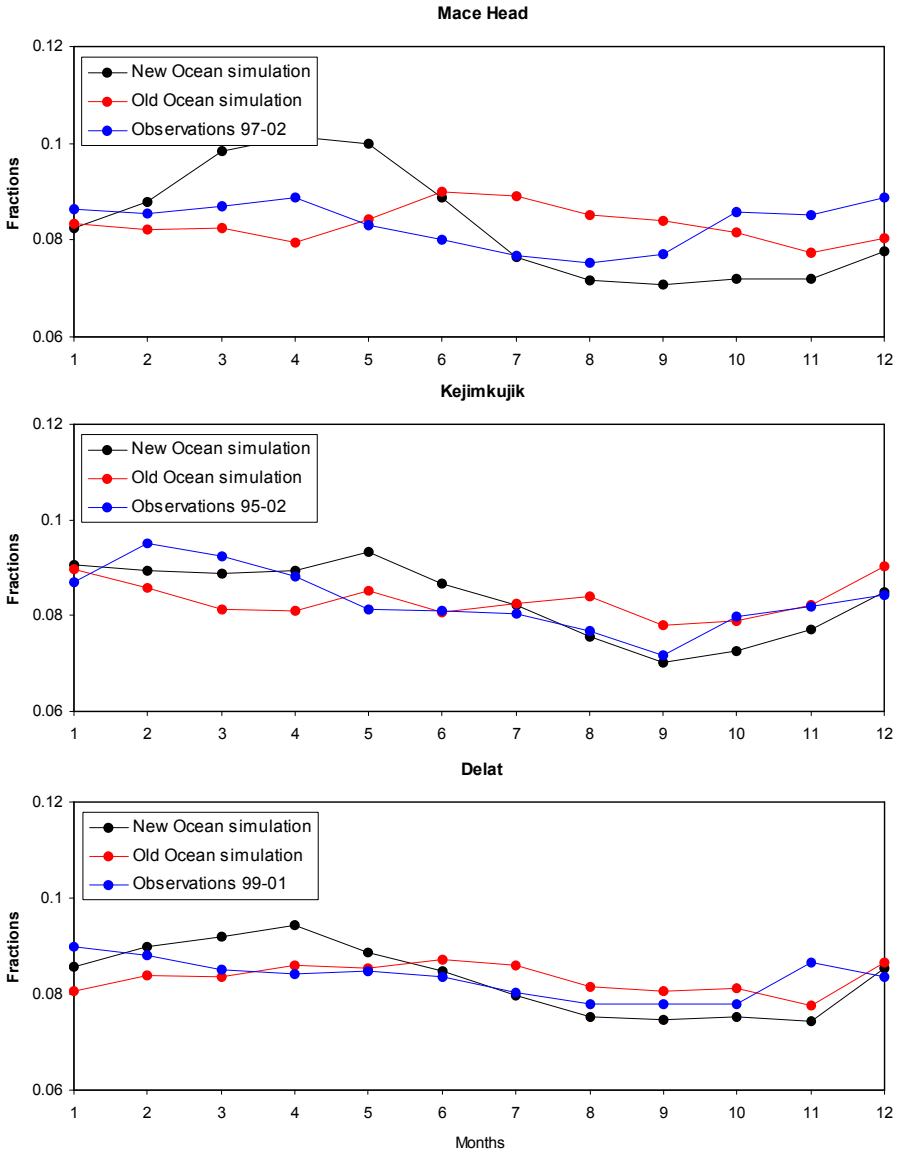
Improvement of the normalized yearly cycle



Mace Head
New Ocean R = 0.53*
Old Ocean R = -0.73**

Kejimkujik
New Ocean R = 0.74**
Old Ocean R = 0.45

Delta
New Ocean R = 0.52
Old Ocean R = -0.15



Refs: Environmental Canada 2003, Ebinghaus et al. 2002, Baker et al. 2002

Conclusion

- Large improvement to the ocean slab model by:
  - Introduction of improved terms
  - Differentiation of deep ocean concentrations

- Introduces a higher yearly variability in the boundary layer of the model
  - This enhance the correlation with observed seasonal cycles
  - The introduction of lateral flow most likely will smooth the cycle

- Ocean flux's can possibly explain variability in measured cruise data

But…

Our netflux of Hg^0 from the ocean is at the upper limits of earlier estimates

With current flux models it is not possible to explain the high concentrations of Hg^0_{aq} in the mixed layers.

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