Mercury sources and budgets in the upper ocean: Results from the global multimedia model FATE-Hg

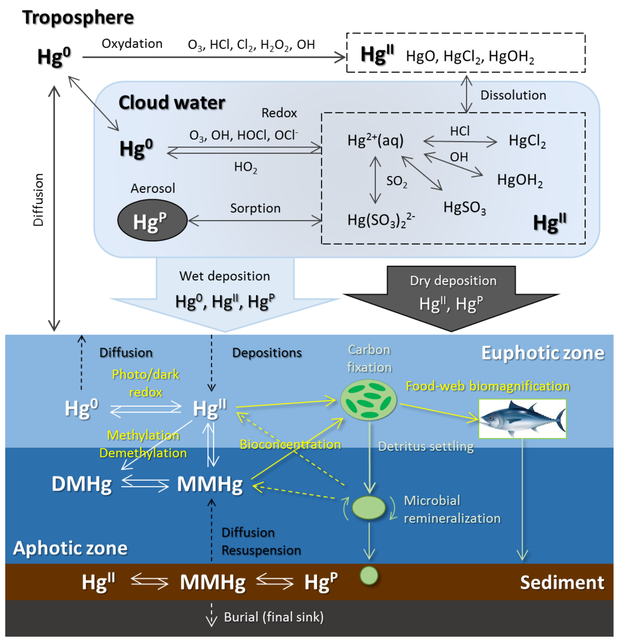
Toru KAWAI, Takeo SAKURAI, Noriyuki SUZUKI
Center for Health and Environmental Risk Research, National Institute for Environmental Studies, Japan

Summary. To evaluate the effectiveness of international efforts to reduce anthropogenic emissions, it is important to understand the changes in mercury concentrations in a region that result from emission reductions in a foreign source region. A new global multimedia model, the Finely-Advanced Transboundary Environmental model for mercury (FATE-Hg), was developed and applied to estimate mercury sources and budgets in the global oceans. The principal characteristic of this model is that it is based on a coupled atmosphere-ocean transport model, and calculates 3D non-steady physical transport in both the atmosphere and the ocean. Additionally, it considers methylated mercury production in the water column followed by biotransfer from lower to higher order marine consumers. We estimated the source-receptor (S-R) relationships using the emission sensitivity method. From the results of S-R analyses, East Asia was the dominant source region in the Northern Hemisphere with a maximum contribution of 58% in the Northwest Pacific. Conversely, in the Southern Hemisphere, contributions from Australia and Oceania, South America, and Africa generally dominated. Sources of mercury in higher order marine consumers (tuna, bonito, and billfish) caught in several different regions were estimated using the results of S-R analyses and global fishery statistical data. The results provide useful information on how to reduce mercury exposure in people in the regions analyzed.

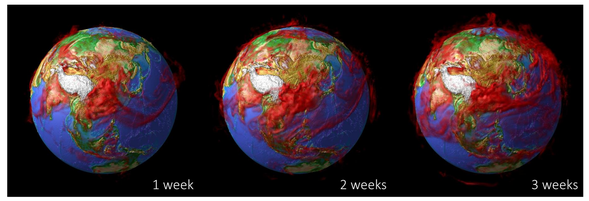
Global Multimedia Model (FATE-Hg)

- FATE-Hg simulates Hg global biogeochemical cycles using emission (EDGARv4.tox1), climate (ECMWF ERA interim, GFDL ODA), reactants (MACC), and satellite (NASA SeaWiFS/MODIS) data.

Modeled Hg processes in FATE-Hg

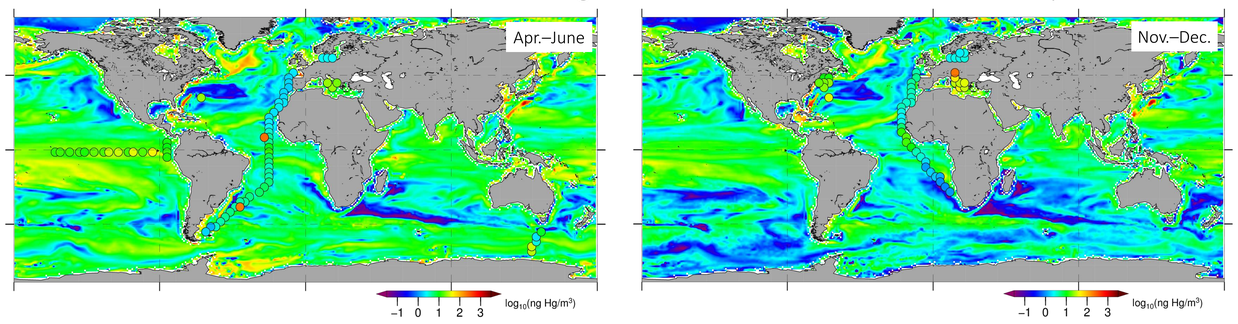


- Coupled atmosphere-ocean transport model



- Satellite-based ecosystem models capable of estimating abundances and trophic structures of marine organisms and vertical carbon cycles through biological pumps
- Transformations in air, cloud water, seawater and sediment with productions of methylated mercuries in the water-column
- Dry and wet depositions, and bidirectional diffusive transports of elemental mercury
- Empirical bioconcentration (BCF) and trophic biomagnification (TMF) models

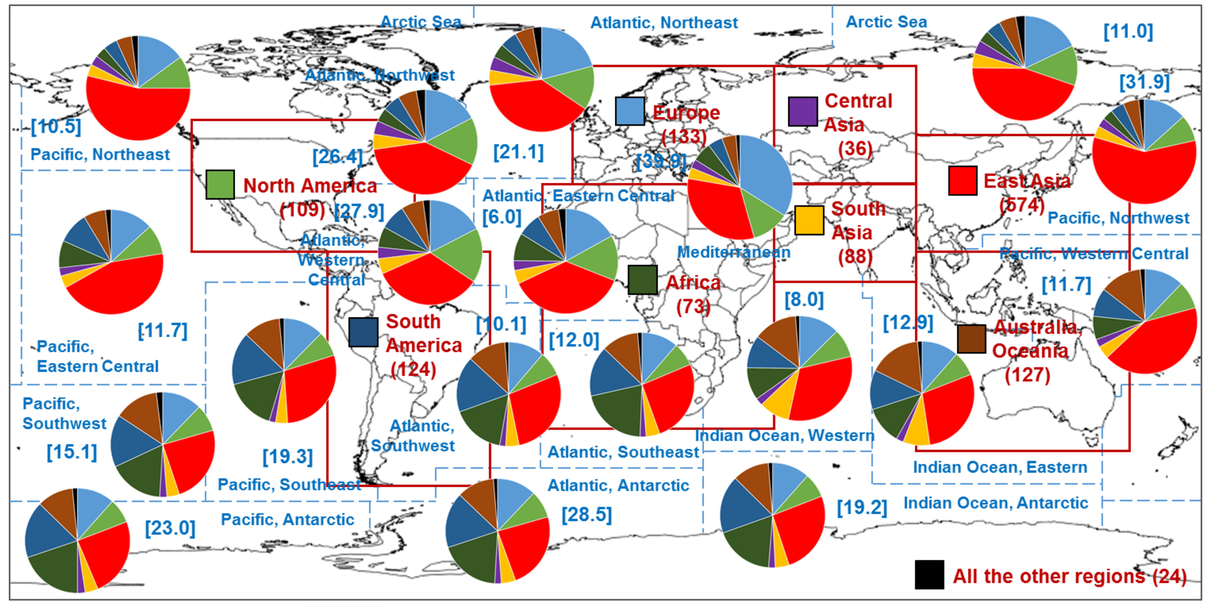
Results of validation for dissolved Hg^0 concentrations in the ocean mixed layer



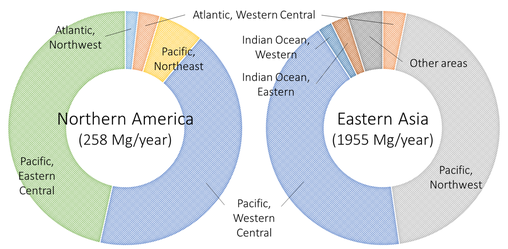
Results

- Sources of mercury in higher order marine consumers caught in several different regions* were estimated using the results of S-R analyses and global fishery statistical data**.

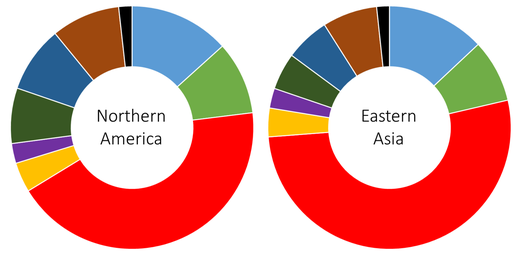
Sources of total mercury (Hg^T) in the ocean mixed layer (FAO major fishing areas)



Annual capture productions
(tuna, bonito, and billfish)



Sources of Hg^T in fishery resources
(tuna, bonito, and billfish)



* Defined by United Nations Statistics Division (UNSD); ** FAO FishStatJ – software for fishery statistical time series (http://www.fao.org/fishery/statistics/software/fishstatj/en)

Acknowledgment: This research was supported by the Environment Research and Technology Development Fund (5-1405, 5-1702) of the Ministry of the Environment, Japan; and JSPS KAKENHI Grant Number 16K00524.