Multi-model mercury simulation and analysis initiative to inform the Minamata and Long-Range Transboundary Air Pollution Conventions

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International Conference on Mercury as a Global Pollutant 2024

The Multi-Compartment Hg Modeling and Analysis Project (MCHgMAP)

- **MCHgMAP** is an international collaborative **"Mechanistic Modeling"** initiative to support the effectiveness evaluations of the Minamata Convention and the Heavy Metals protocol of the Long-Range Transboundary Air Pollution Convention (LRTAP)

- **Broad objectives:**
  - Simulate spatiotemporal environmental (abiotic) Hg trends in air, land and ocean on global scale
  - Determine/constrain modern-day environmental Hg cycling
  - Analyze and attribute observed Hg levels and trends in air, land and ocean
  - Project future changes in environmental Hg levels
  - Determine/prioritize key knowledge gaps and uncertainties

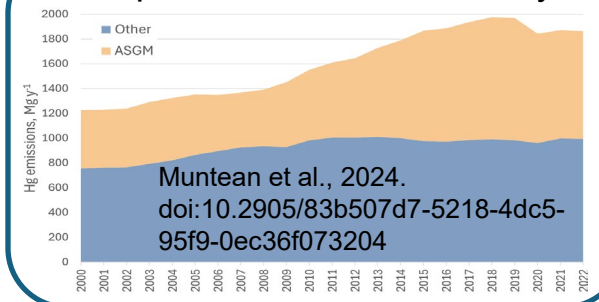
- The MCHgMAP approach is detailed in *Dastoor et al. 2024, The Multi Compartment Hg Modeling and Analysis Project (MCHgMAP): Mercury modeling to support international environmental policy Geosci. Model Dev. Discuss. https://doi.org/10.5194/gmd-2024-65 , 2024*

- Some related talks/posters at ICMGP 2024: Johannes Bieser (Session 18, Wednesday); Marilena Muntean (Thursday); Aryeh Feinberg (Session 31, Friday; Poster #55); Anne Soerensen (Poster # 215)

Modeling focus for the Minamata Convention Effectiveness Evaluation Cycle 1

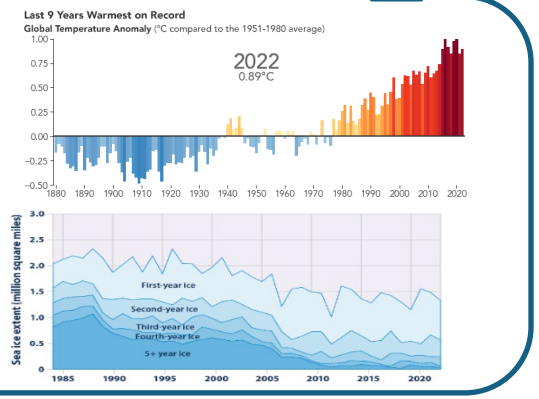
Anthropogenic Hg emissions and releases trends

Updated EDGAR inventory



Other Global changes

Examples



https://earthobservatory.nasa.gov/world-of-change/global-temperatures
https://nsidc.org/data/nsidc-0611

Input

Process-based (mechanistic) Global Multi-Model Ensemble

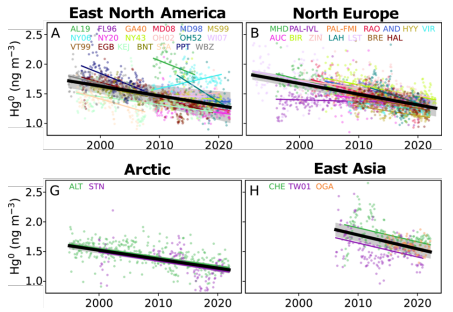
Trend & attribution simulations

Output

Analysis of current environmental Hg levels and trends

Simulate/evaluate current Hg levels and trends

Air



Observed trends: Feinberg et al., 2024; doi:10.31223/X5B38K

Land

Ocean

- **Are trends in emissions consistent with trends in observed levels?**
- **How representative are the observations (levels and trends) on global scale?**

Output

Output

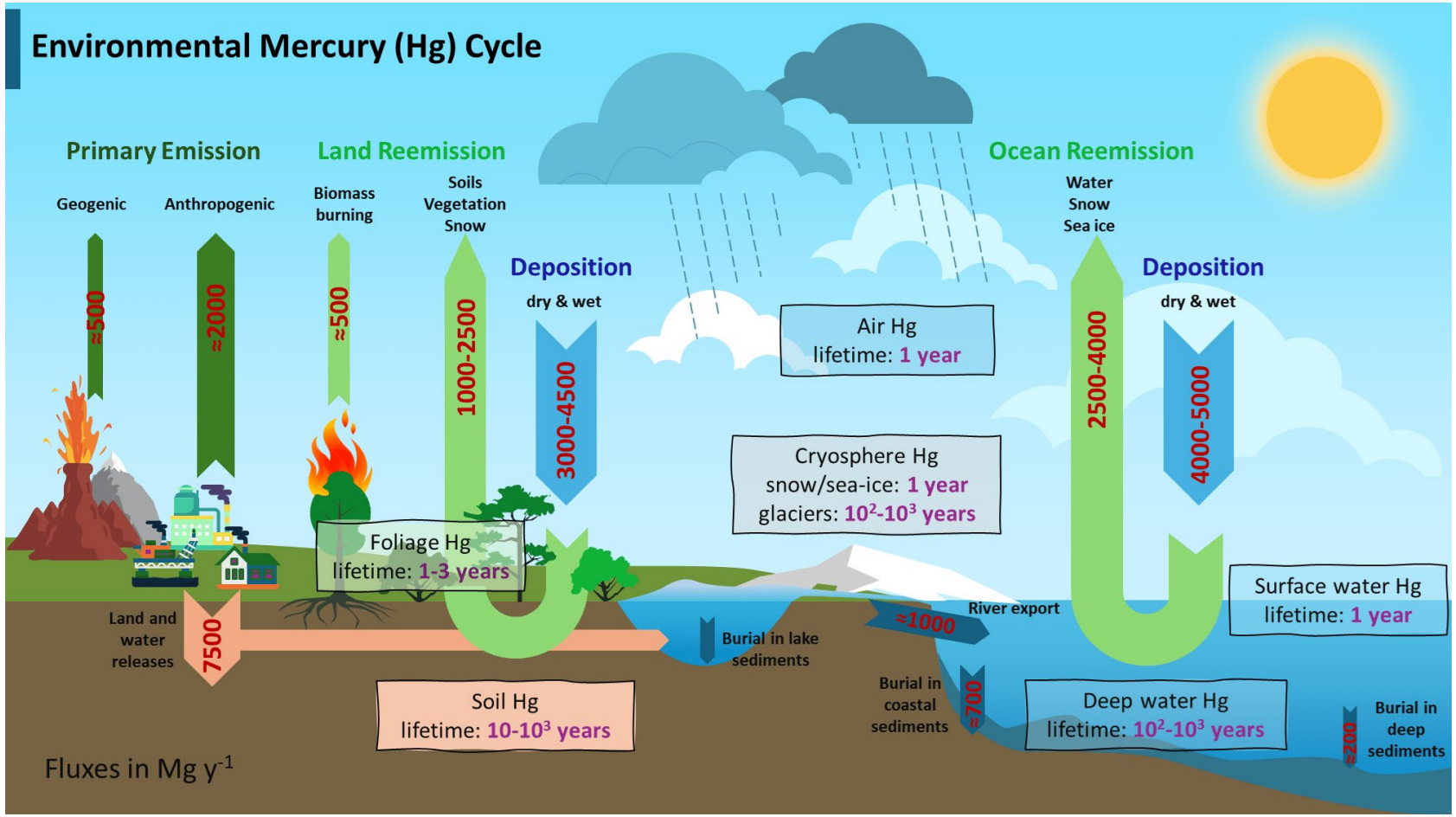
Attribute observed environmental Hg trends

- **How have contemporary anthropogenic emissions and releases contributed to the observed trends?**
- **How have other drivers contributed to the observed trends?**

Environmental (air-land-ocean) Hg modeling and analysis considerations

Analysis of observed environmental Hg trends needs to address:

- Effects of Hg recycling between air, land and ocean on timescales of hours to centuries
- Magnitudes and trends of secondary Hg emissions and releases, about 60-75% of all Hg emissions
- Sensitivity to global changes
- Distinguish effects of recent (small) changes in anthropogenic inputs from global change effects



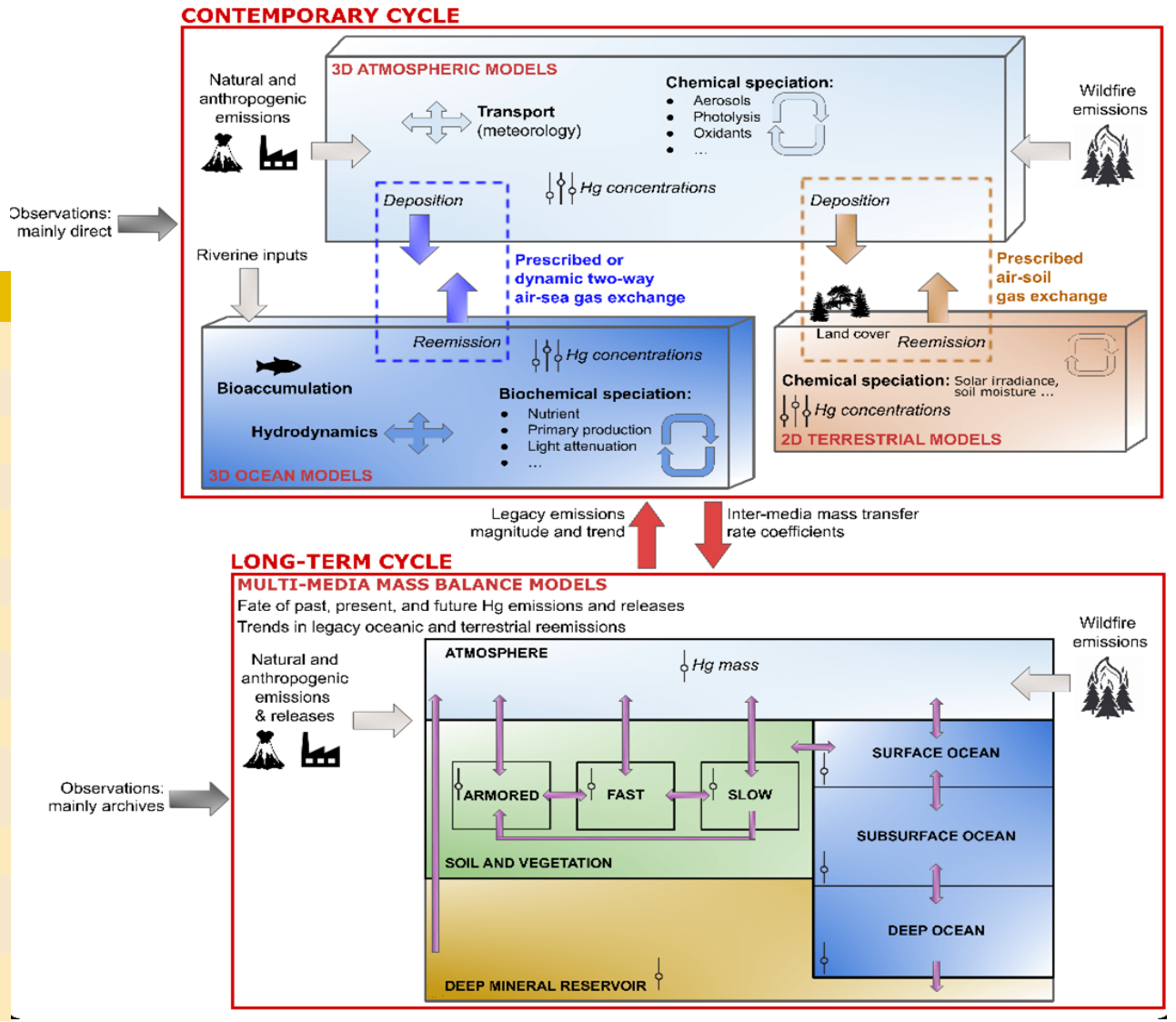
Modern-day Hg flux ranges are from recent modeling studies

MCHgMAP environmental (air-land-ocean) Hg modeling approach

- Ideally, 3D earth system modeling is required - limited availability and computational challenge
- Previous assessment efforts focused on atmospheric models only
- The OESG/MCHgMAP approach: couple **detailed** single-medium (**atmosphere, land, ocean**) and **efficient multi-media mass balance models** to account for slow and fast changes in global mercury cycling and levels

Participating Models	Institution
3D Atmospheric models	
GEM-MACH-Hg	Environment and Climate Change Canada (Canada)
GEOS-Chem	Massachusetts Institute of Technology (USA)
GLEMOS	Jožef Stefan Institute (Slovenia)
WACCM	Institute of Physical Chemistry Blas Cabrera (Spain)
3D Ocean models	
MERCY	Helmholtz-Zentrum Hereon (Germany)
MITgcm	Nanjing University (China)
2D Terrestrial models	
Air-land Hg exchange model	Institute of Geochemistry, Chinese Academy of Sciences (China) and Lamar University (USA)
Multi-media mass balance models	
Global Biogeochemical Box Model (GBC)	Harvard University (USA) University Grenoble Alpes, CNRS (France)
WorM^3	Indian Institute of Technology Hyderabad (India)

Coordination of air, land, ocean and multimedia mass balance models

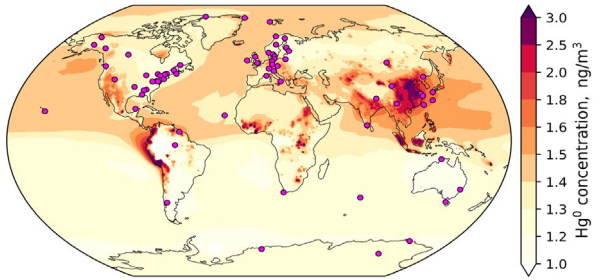


Observation data challenges for model evaluation and development

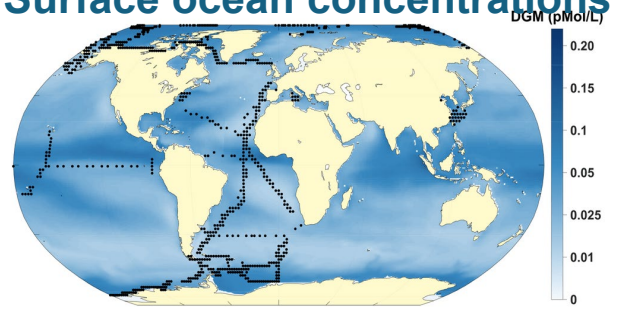
Preliminary model-simulated spatial maps for environmental Hg levels and fluxes with locations of observation sites shown

Contemporary Hg levels

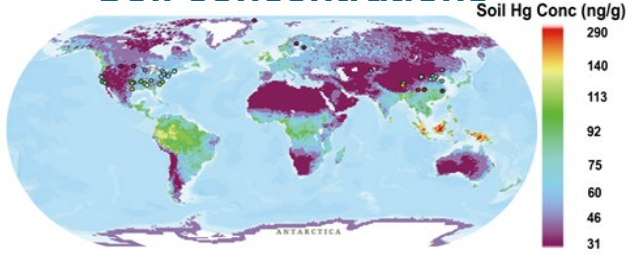
Surface air concentrations



Surface ocean concentrations



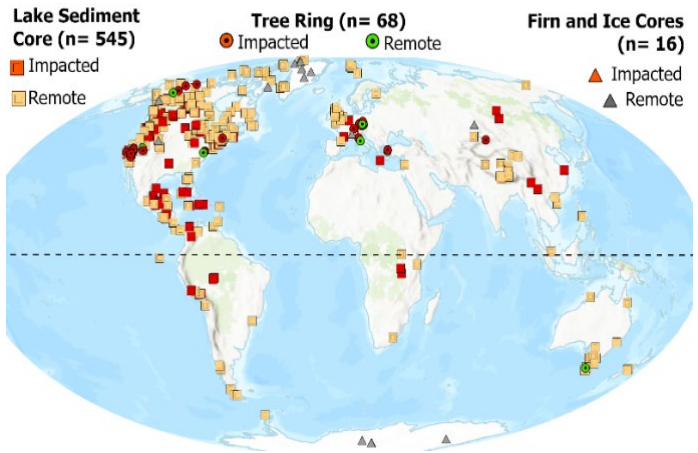
Soil concentrations



Vegetation, snow, fresh water….

- Limited media and spatial coverage
- Lack of inter-media fluxes to constrain global Hg cycling (few direct observations), critical to Hg trend simulation and analysis
- Lack of temporal trends in “other media”
- Natural archives inform all-time changes in environmental Hg levels (legacy Hg effects) but have higher uncertainties and low temporal resolution
- Multi-model approach is helpful, but data gaps need to be addressed!

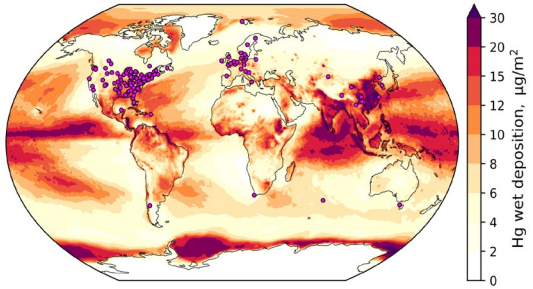
Long-term environmental Hg trends



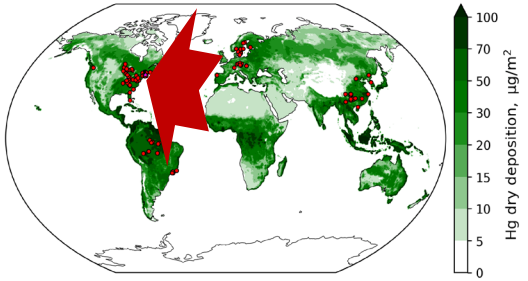
OESG “Other media” observations database in progress

Contemporary inter-media Hg fluxes

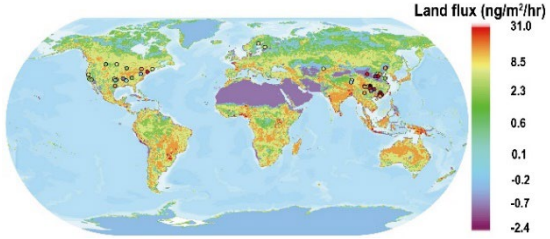
Precipitation uptake



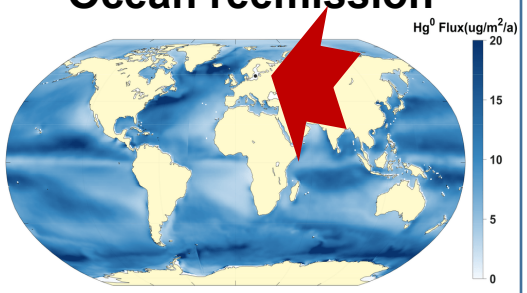
Land/vegetation uptake



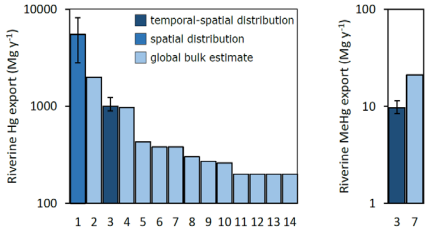
Land reemission



Ocean reemission



Global river export



Different literature values (Dastoor et al. 2024)

<u>Observations</u>:
OESG “air” and “Other media” database in progress

<u>Modeling examples</u>:
Air - GEM-MACH-Hg (ECCC, Canada)
Ocean - MITgcm (Nanjing U., China)
Land – Air-Soil model (Institute of Geochemistry, China; Lamar U., USA)

MC Effectiveness Evaluation: Trend attribution and data

Inconsistency between rising anthropogenic emissions estimates and declining observed levels in recent decades?

- **Issues:**
  - Emissions estimates (magnitude, speciation, distribution)
  - observation representativeness
  - global change (physical and biogeochemical processes)?
- **Suggestions:**
  - Modeling maps useful for network design
  - Passive sampling networks
  - Measure all ecozones
  - Standard and open global database
  - Mass balance perspective to collocate observations
  - More focus on inter-media fluxes – direct and indirect