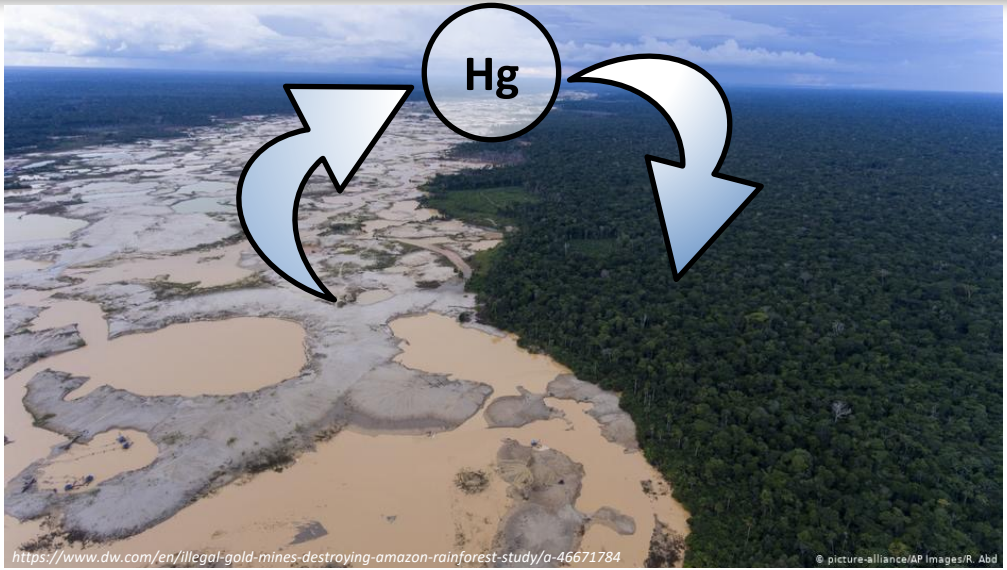
Modelling the Impact of Amazon Land Use Changes on the Vegetation Sink of Atmospheric Mercury



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MIT INSTITUTE FOR DATA, SYSTEMS, AND SOCIETY

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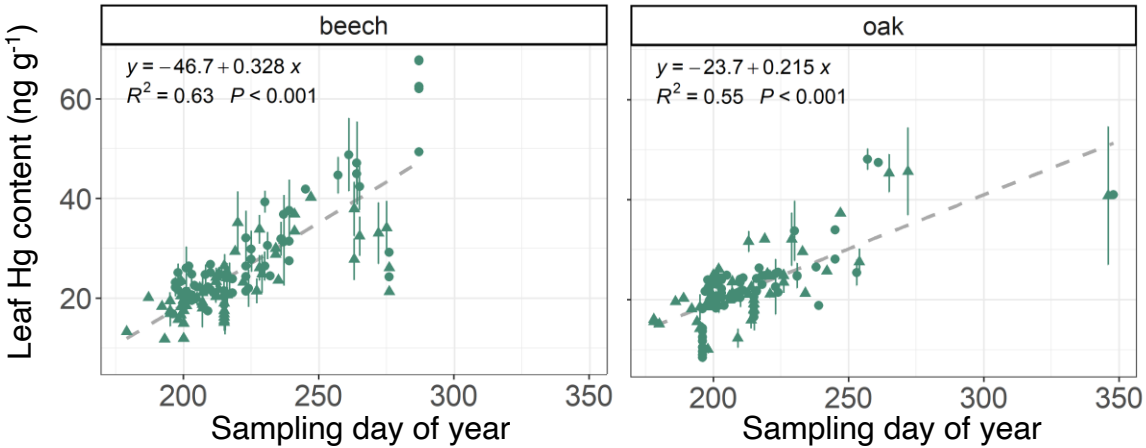
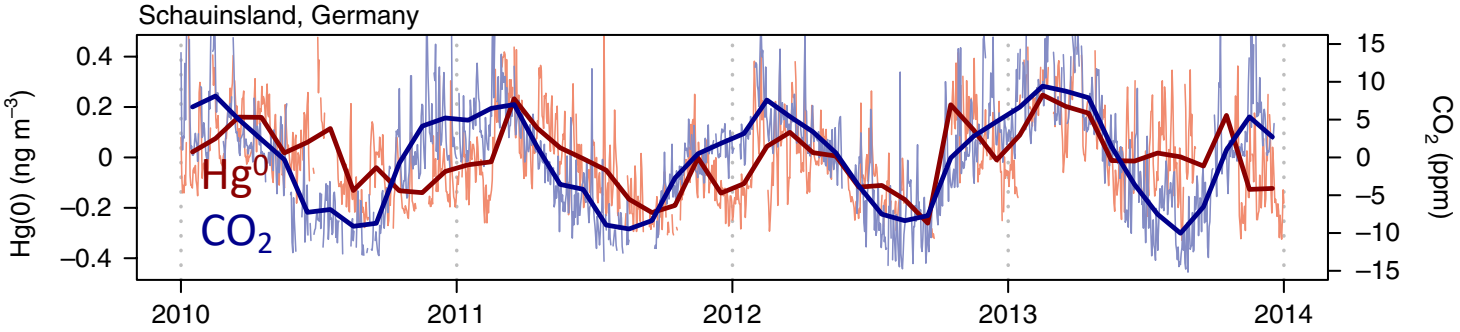
Lots of new evidence for significant Hg vegetation uptake

Tree foliage takes up Hg over the growing season



Wohlgemuth et al., *Biogeosciences* (2022)

Atmospheric Hg^0 seasonality follows CO_2 vegetation pump



Jiskra et al., *Nat. Geosci.* (2018)

Human activities and climate change perturb the vegetation sink

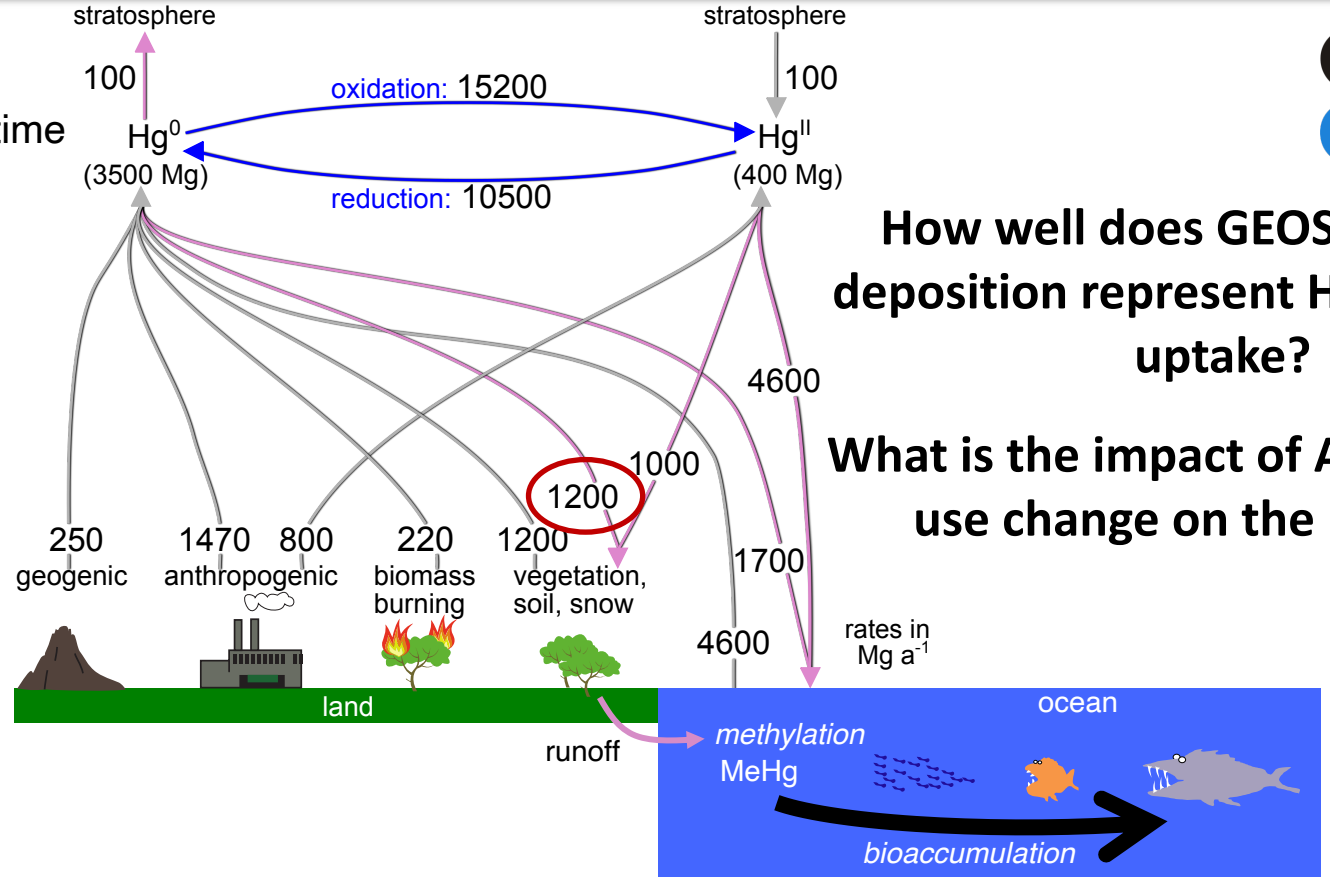
Amazon near tipping point of switching from rainforest to savannah - study

Climate crisis and logging is leading to shift from canopy rainforest to open grassland

INPE: ~80% of the Brazilian Amazon rainforest remaining from 1970s extent

Mercury (Hg), a neurotoxic contaminant, spreads globally in atmosphere

Overall Hg lifetime
~ 5 month



How well does GEOS-Chem dry deposition represent Hg vegetation uptake?

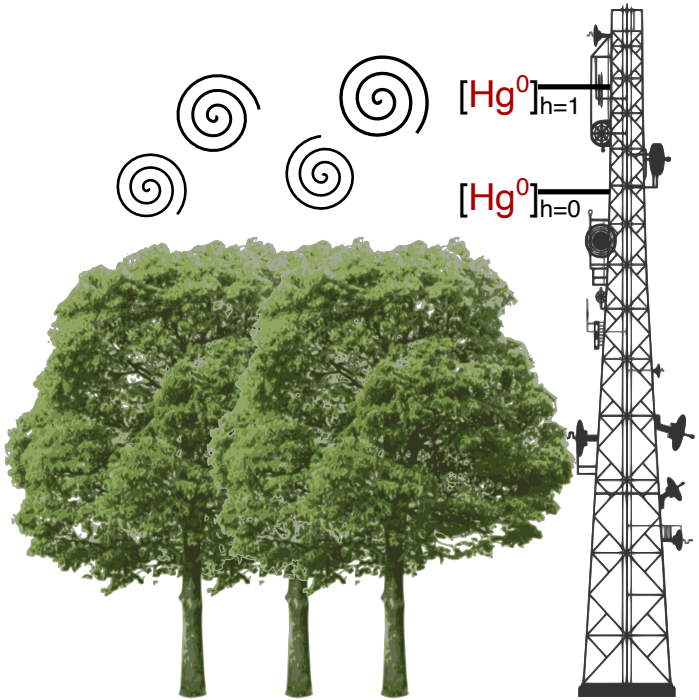
What is the impact of Amazon land-use change on the Hg cycle?

Horowitz et al., *Atmos. Chem. Phys* (2017)

Direct measurements of Hg^0 uptake by forests

Micrometeorological approach

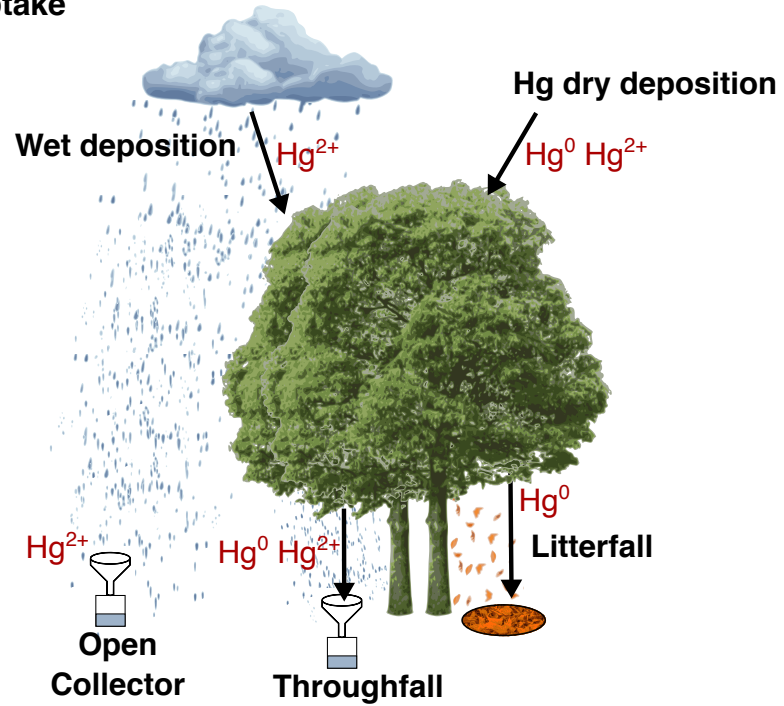
Dry dep ≈ Net Ecosystem Exchange



Common for O_3 but only 1 study for Hg^0 over forests (Obrist et al., 2021)

Biomass balance approach

Total foliar uptake **≈ Litterfall + Throughfall - Open wet dep**

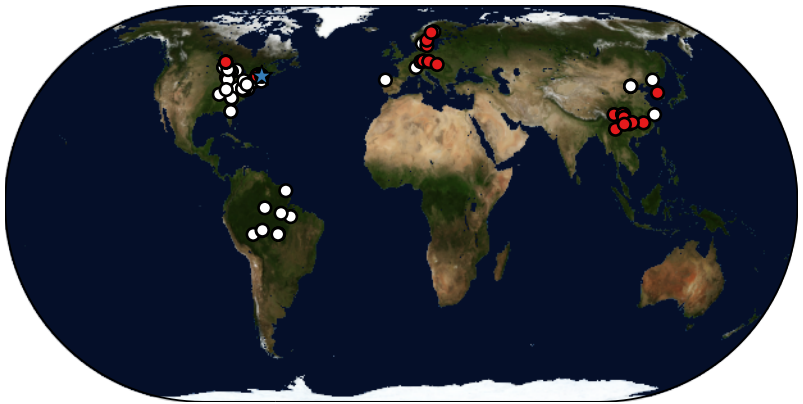


More studies for Hg, but less accurate

Comparing modelled and measured dry deposition velocities

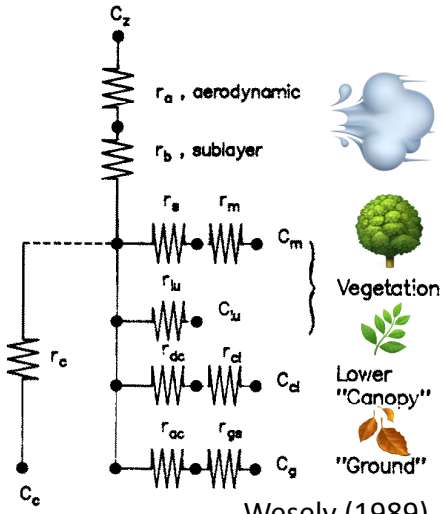
Compiled measurements (93 forest sites)

- Litterfall
- Total foliar uptake
- Flux tower (Obrist et al., 2021)



Extended from previous reviews: Wright et al., (2016); Zhou et al. (2020); Fostier et al. (2015)

Resistance-based scheme in GEOS-Chem

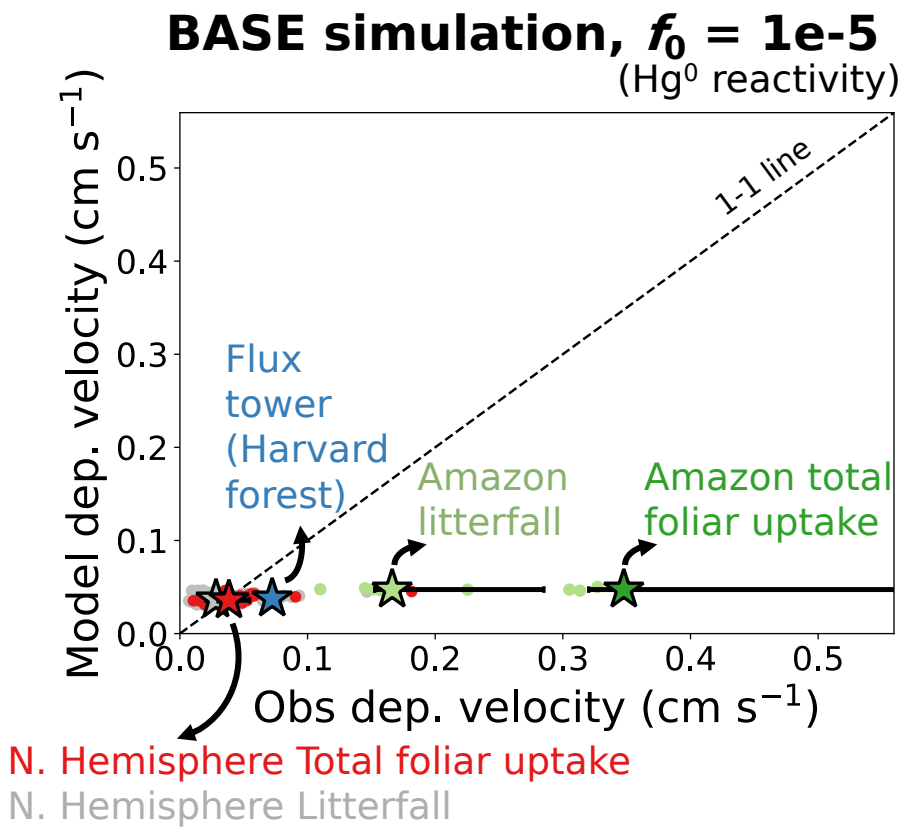


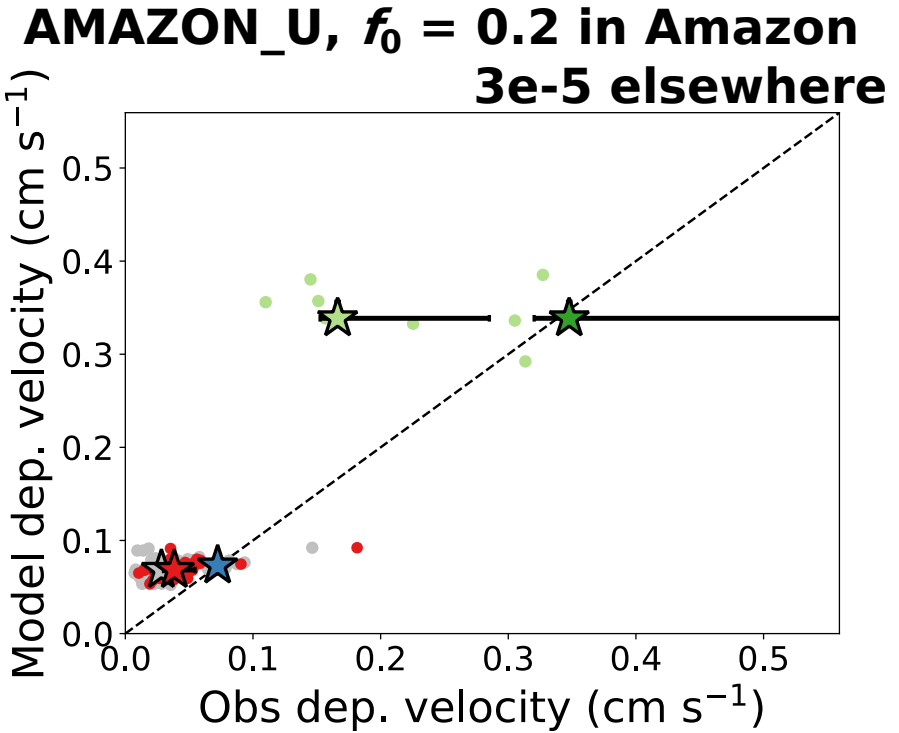
Wesely (1989)

Factors: T, wind, leaf area (LAI), land type
Species: reactivity (f_0) and solubility
Simulation year 2015, MERRA2 meteo

Published: Feinberg et al. *Environ. Sci. Process. Impacts* (2022), Evaluating atmospheric Hg uptake by vegetation in a chemistry-transport model

GEOS-Chem underestimates Hg, especially in Amazon

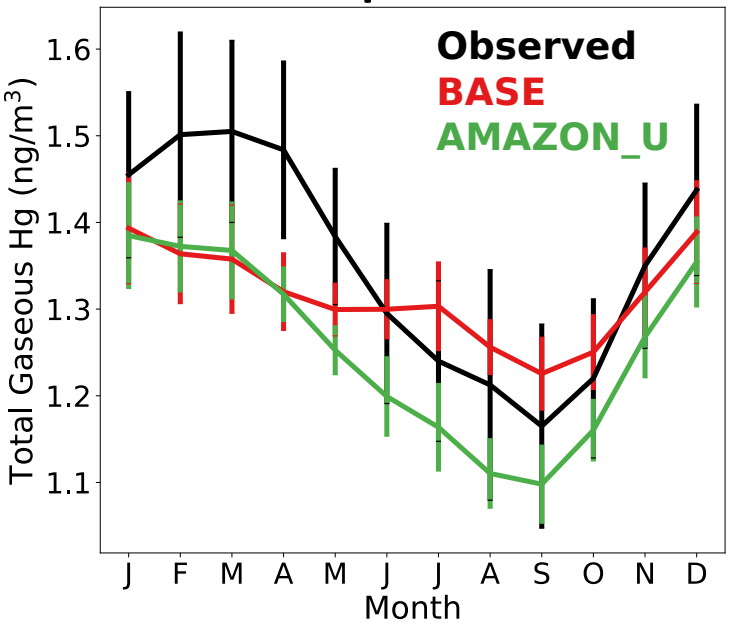




Feinberg et al. *Environ. Sci. Process. Impacts* (2022)

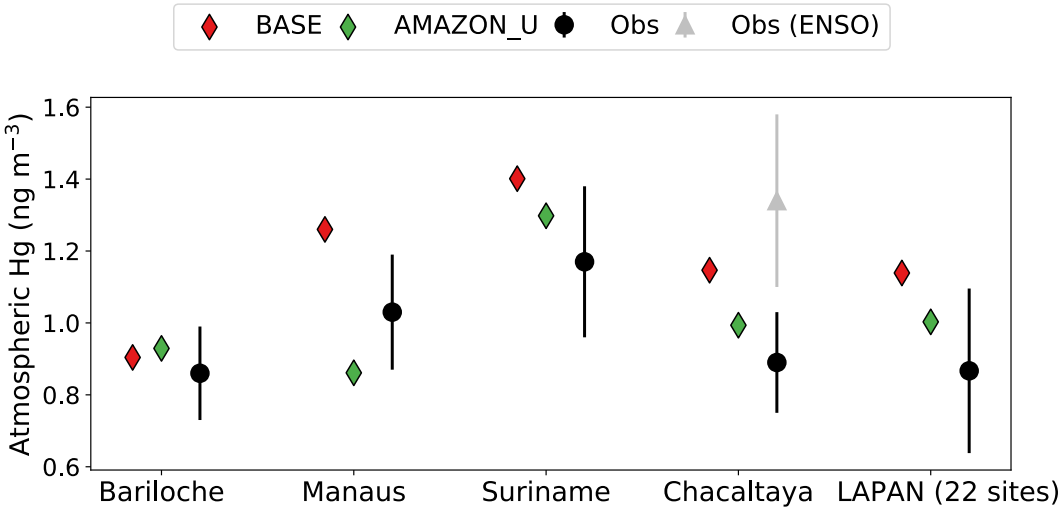
Revised model better agrees with atmospheric Hg observations

Northern Hemisphere midlatitudes



Seasonal amplitude improved when include stronger veg. uptake

South American [Hg] observations



Bias reduced from +0.21 ng m^{-3} to +0.05 ng m^{-3}

Atmospheric measurements from CAPMoN, EMEP, AMNet, GMOS, and LAPAN networks
Sourced in: Travnikov et al. (2017), AMAP/UNEP (2018), Sprovieri et al. (2016), Koenig et al. (2021), Quant (2021)

How does Amazon deforestation impact Hg cycle?

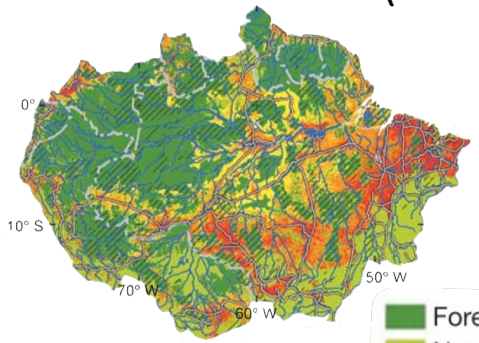
	Reduced uptake	**Biomass burning**	**Increased soil emissions**	**Increased erosion**
				
Previous studies	Fostier et al. (2015)	Melendez-Perez et al. (2014)	Carpi et al. (2014)	Borrelli et al. (2020)

Now with 3-D models, can analyze combined effect and Hg fate

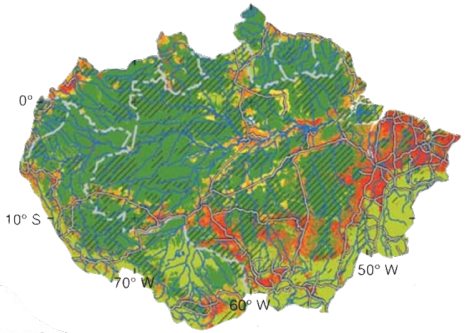
How does Amazon deforestation impact Hg cycle?

Deforestation scenarios → **Models**

Business as Usual (BAU)



Governance (GOV)



Soares-Filho et al., *Nature* (2006)

Extreme upper-end scenario:
Complete deforestation (ALL-DF)

GEOS-Chem

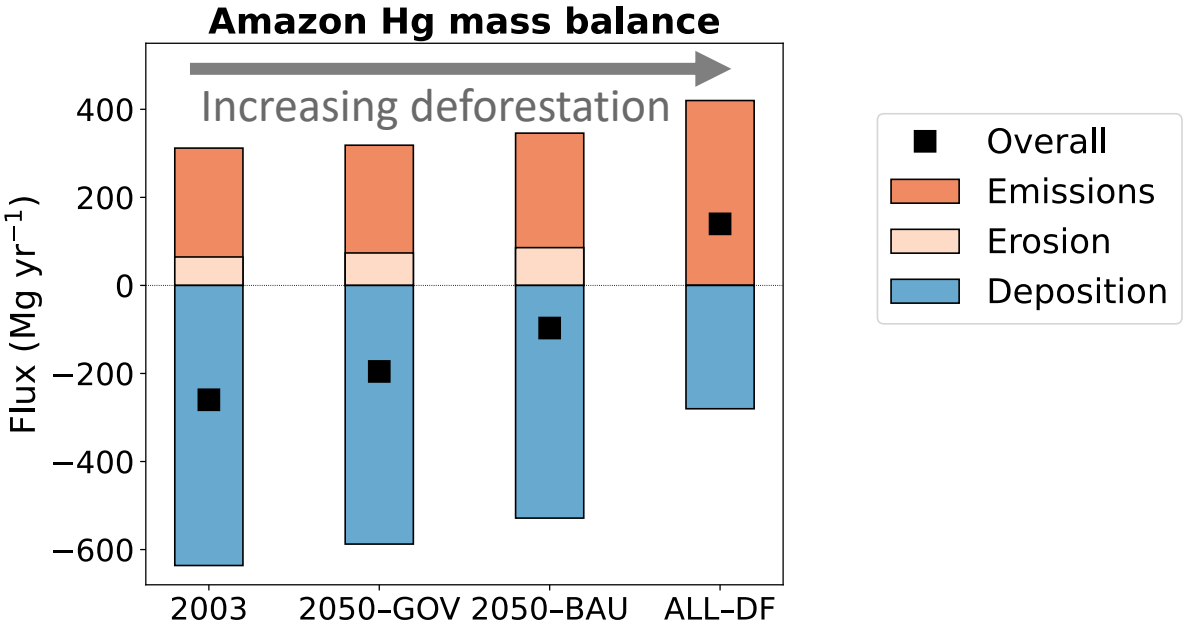
- deposition
- biomass burning
- soil emissions

GloSEM

- soil erosion

Tracking changes to Amazon Hg mass balance

Land use policies determine strength of Amazon Hg sink



Sink becomes 172 Mg yr^{-1} smaller in 2050-BAU scenario compared to 2003

Feinberg, Jiskra et al., in prep. Preliminary results…

Global-scale importance: transfer of Hg to ocean

Atmospheric deposition increases over ocean (ALL-DF)

<u>ALL-DF case:</u>

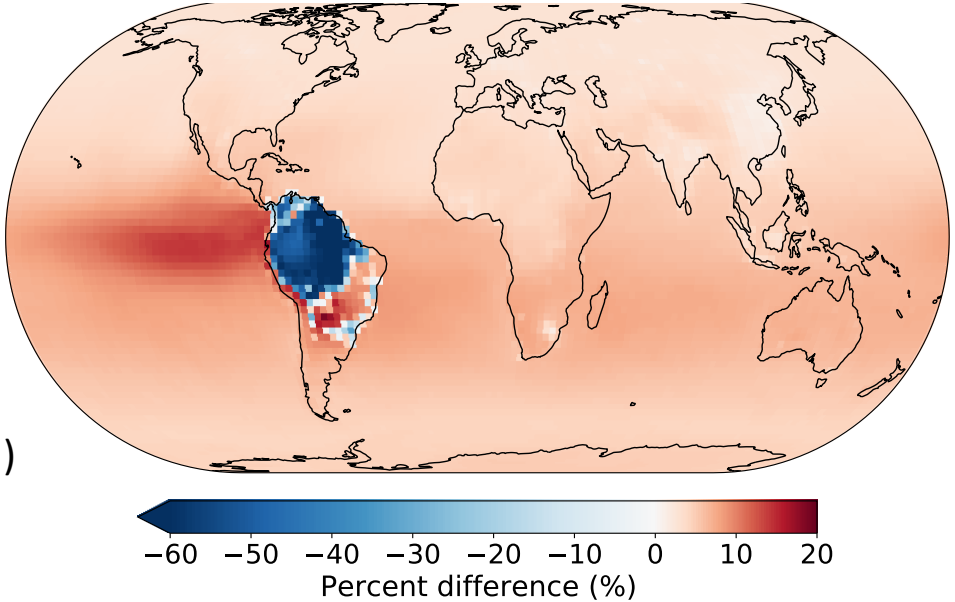
+337 Mg yr^{-1} additional Hg deposited to ocean

(340 Mg yr^{-1} gold mining emissions in S. America)

<u>BAU vs. GOV land use policies:</u>

+61 Mg yr^{-1} additional Hg deposited to ocean

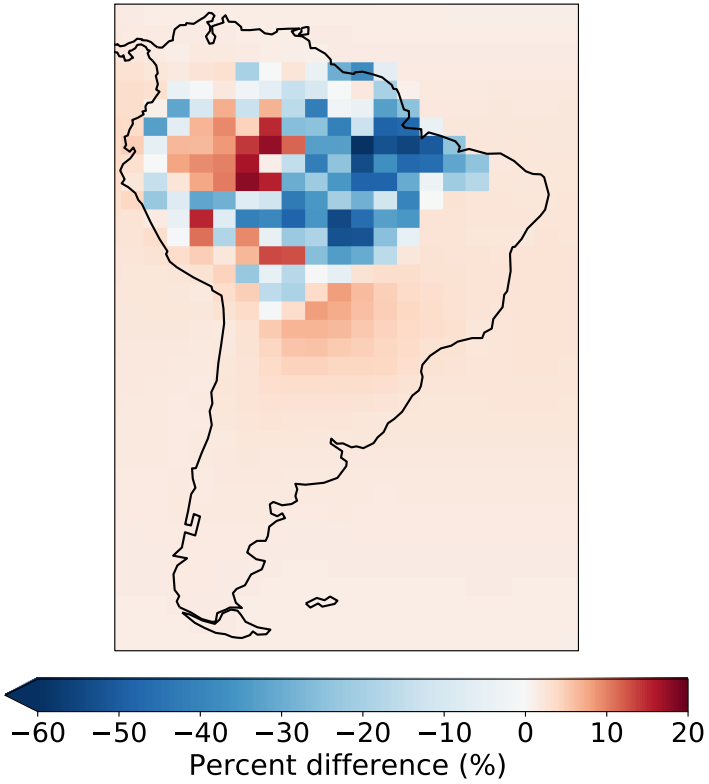
(> GMA18 Hg emissions: Russia, USA, Colombia, …)



Feinberg, Jiskra et al., in prep. Preliminary results…

Regional importance: impact on remaining forests

Hg deposition change (BAU)



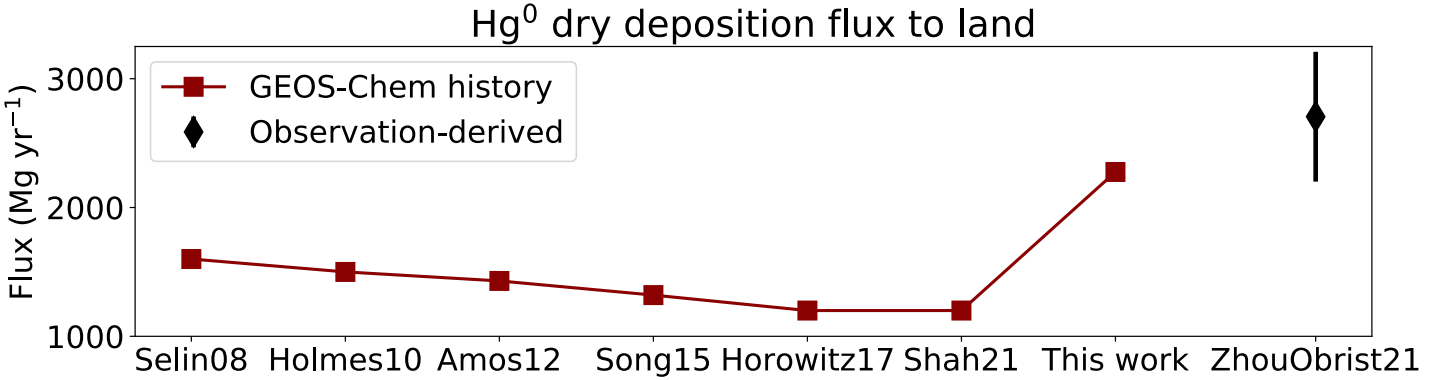
Regional Hg^0 increases by up to 0.3 ng m^{-3}

Hg inputs to remaining Amazon forest increase by up to 20%

Gerson et al. (2022) highlighted Hg impacts on Amazon terrestrial ecosystems

Feinberg, Jiskra et al., in prep. Preliminary results…

Conclusions and Outlook



Takeaway #1

Modelled Hg^0 dry dep now agrees better with observed importance

Takeaway #2

Amazon deforestation leads to substantial Hg mobilization

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Acknowledgements

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- Thanks to all researchers involved in collection, analysis, and publication of public atmospheric Hg measurement datasets (AMNet, EMEP, CAPMoN, GMOS) and vegetation uptake fluxes

Swiss National Science Foundation

Additional presentations at ICMGP:

A. Feinberg: Detecting Recent Atmospheric Mercury Trends at Observation Sites Under Climate Variability

On Demand Talk

N. E. Selin: Quantifying ASGM Mercury Emissions Using Regional Total Gaseous Mercury Measurements

Wed. 27 July 06:30 UTC