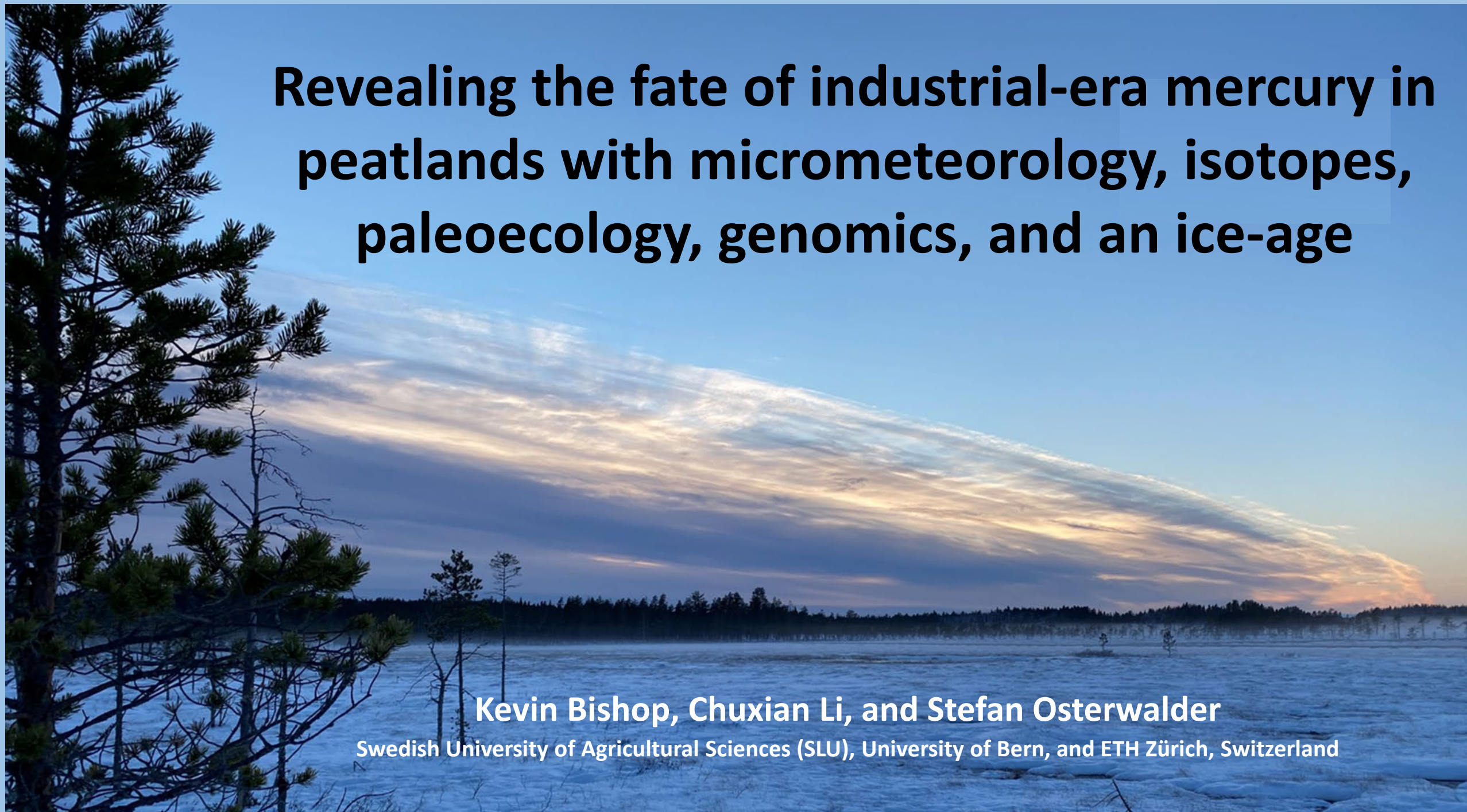
Revealing the fate of industrial-era mercury in peatlands with micrometeorology, isotopes, paleoecology, genomics, and an ice-age



Kevin Bishop, Chuxian Li, and Stefan Osterwalder

Swedish University of Agricultural Sciences (SLU), University of Bern, and ETH Zürich, Switzerland

Reducing Hg emissions central to Minamata treaty

But when will we see the benefits?

Recent advances in understanding and measurement of Hg in the environment: Terrestrial Hg cycling

Kevin Bishop, Heleen A. de Wit, Karin Eklöf, Bo Meng, Carl Mitchell, Stefan Osterwalder, Ami Riscassi, Paul Schuster, Jackson Webster, Wei Zhu, James Shanley

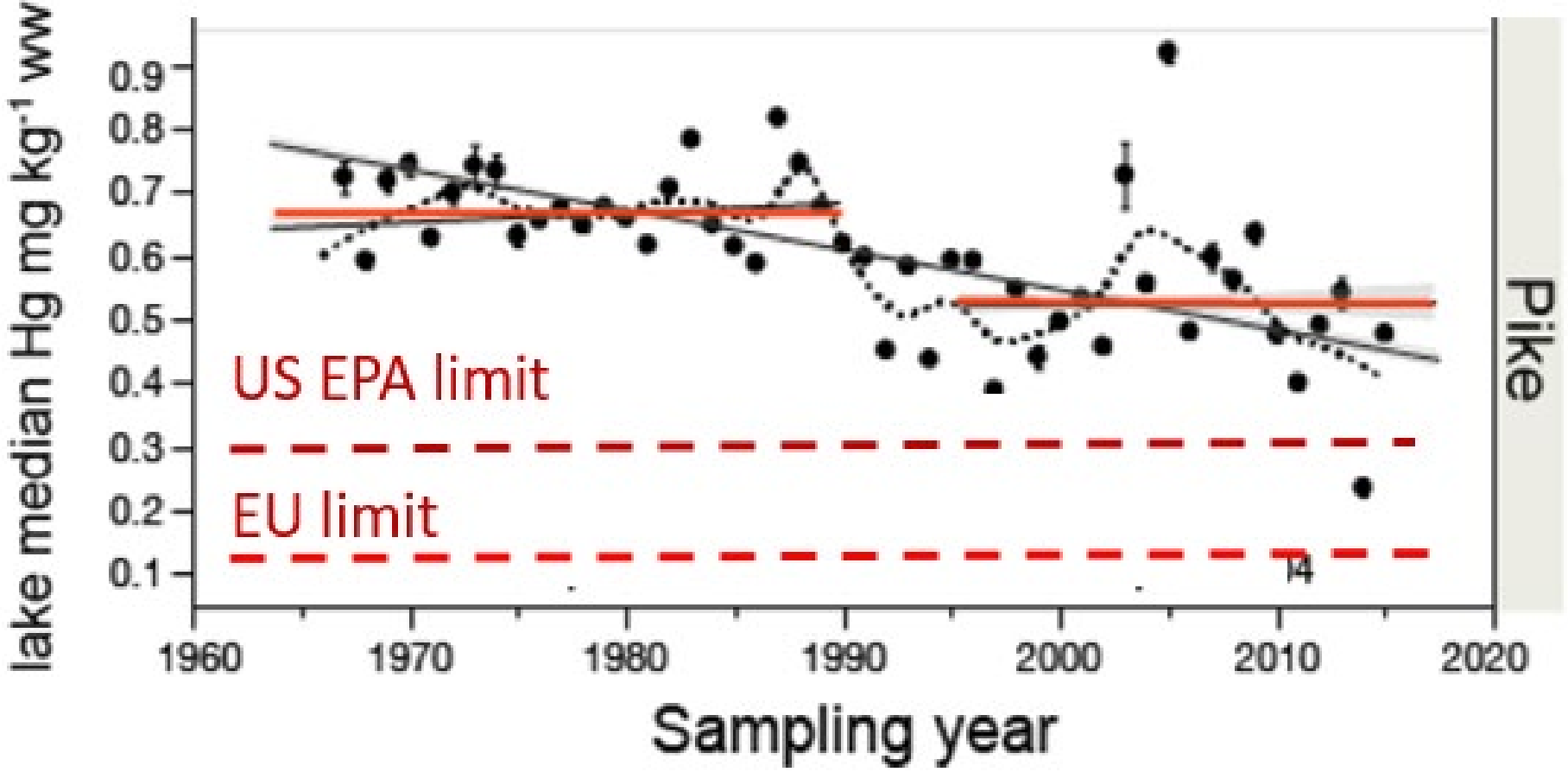
STOTEN 2020

Influence on Surface Waters	Regional impact assessment			
	Global	Tropical	Mid-Lat	High-Lat
Forestry				
Mining				
S-Deposition				
Climate				

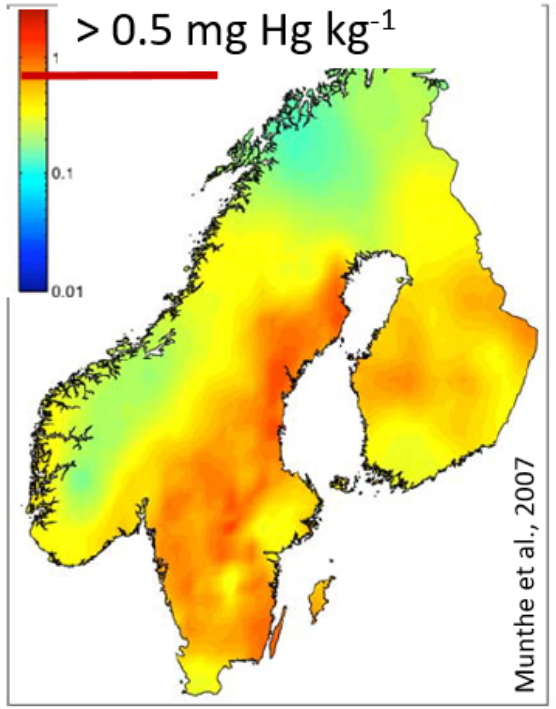
Impact / Certainty		
	High	Low
Small		
Medium		
High		

Climate Change
Co-Pollution -sulfur
Land use – forestry
Artisanal gold mining

Nordic fish Hg still way too high for safe eating, but at least a downward concentration trend…

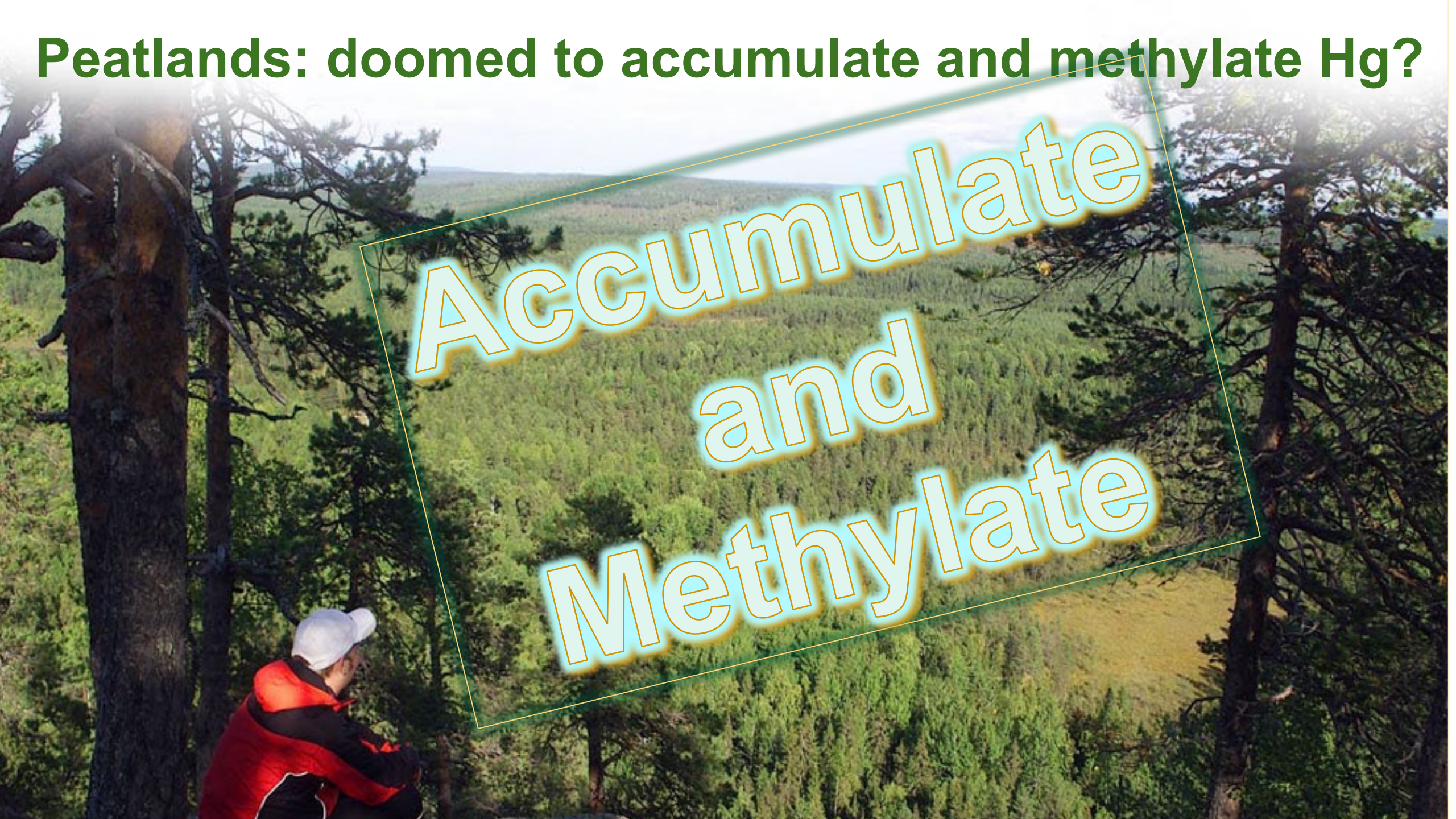


Fish Hg (0.5 mg kg^{-1})
> 50 % of all lakes.



Braaten, et al., ES&T 2019

Peatlands: doomed to accumulate and methylate Hg?

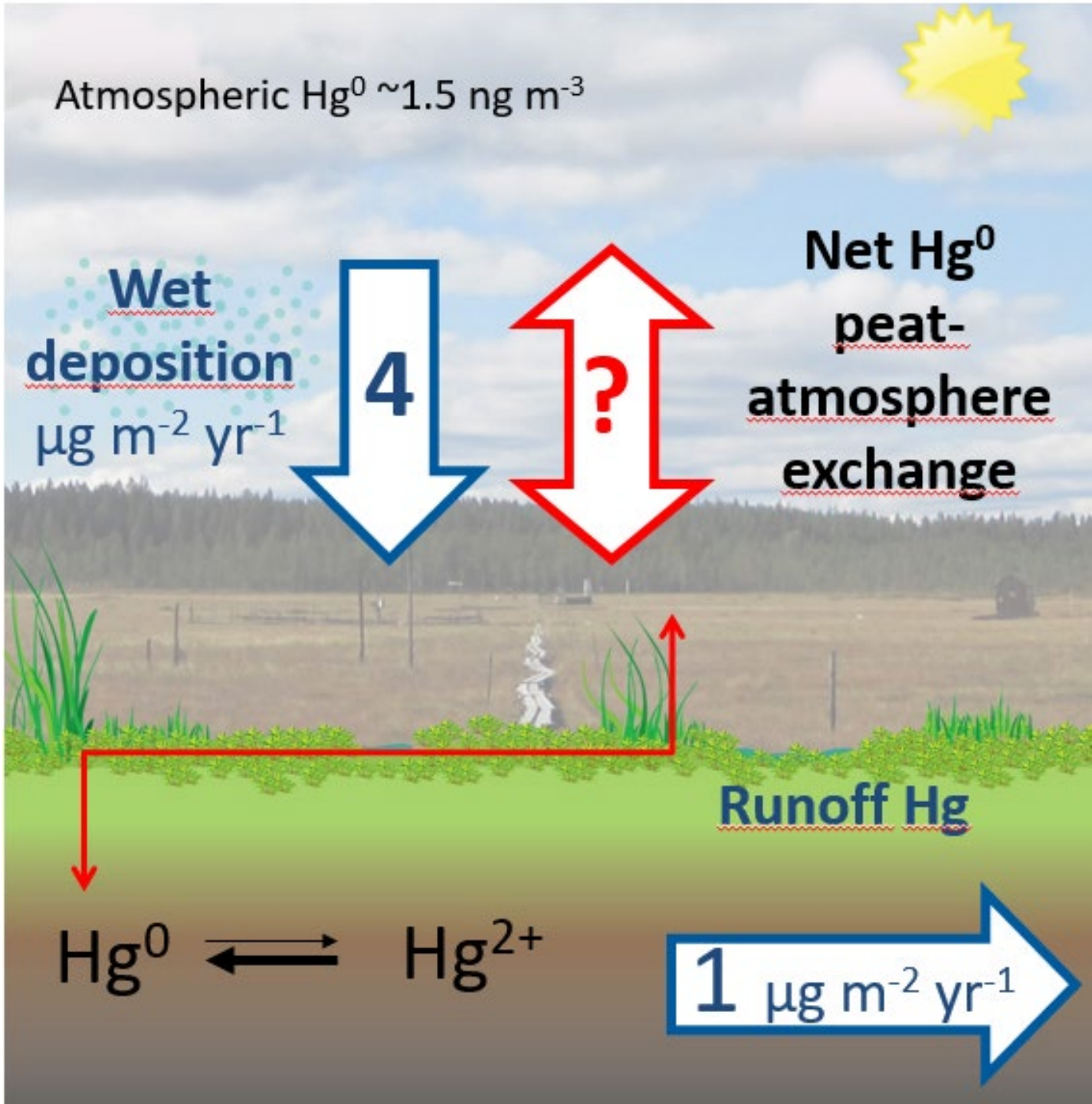


Wet deposition >3x Hg in runoff

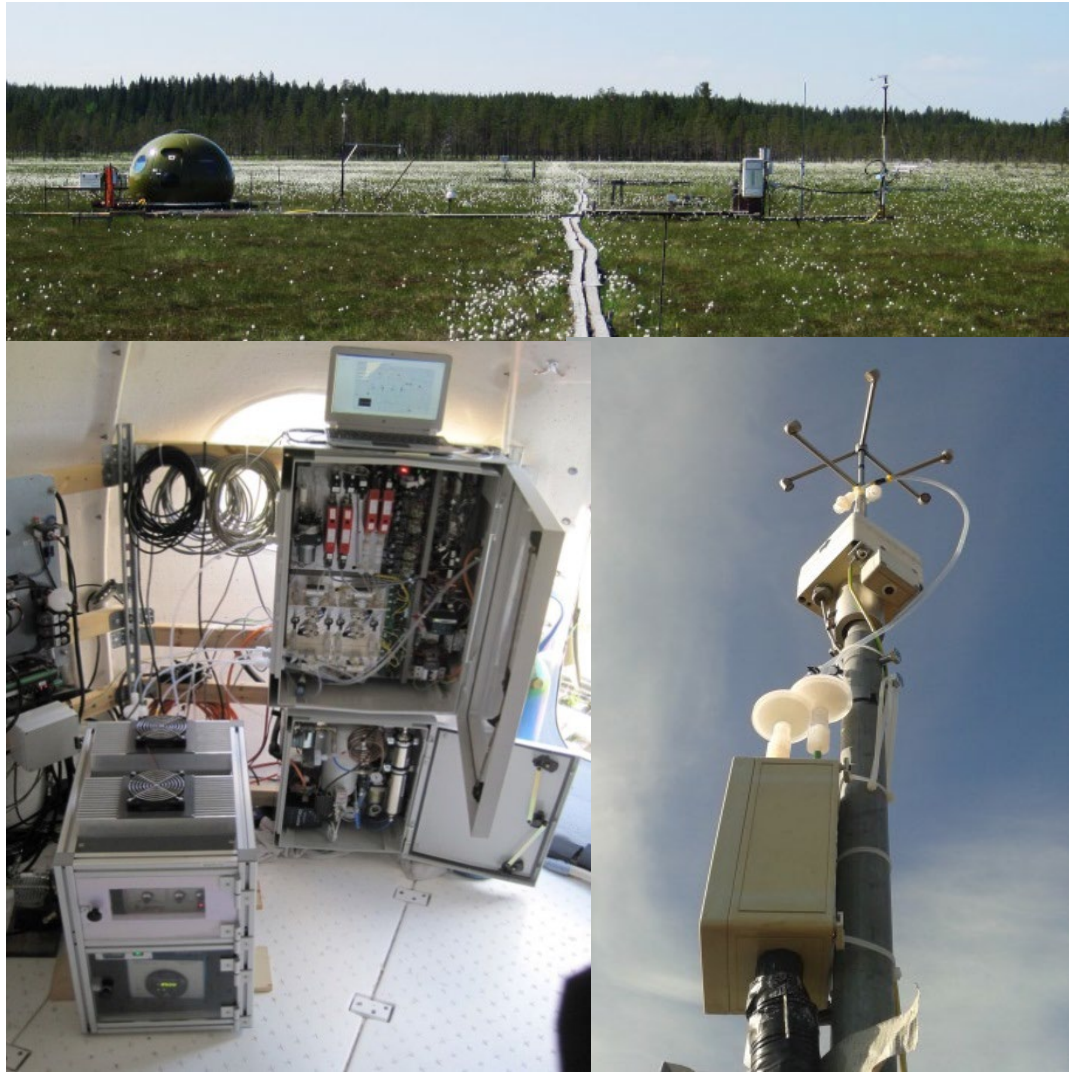
So peatlands are accumulating Hg, and recovery is very distant…

–

unless Hg evading…



Relaxed Eddy Accumulation System (REA)



Dr. Stefan Osterwalder
ETH Zurich

→ Long-term Hg^0 flux

Atmos. Meas. Tech. Discuss., 8, 1–45, 2015
www.atmos-meas-tech-discuss.net/8/1/2015/
doi:10.5194/amtd-8-1-2015

Atmospheric Measurement Techniques Discussions

A dual-inlet, single detector relaxed eddy accumulation system for continuous quantification of mercury land–atmosphere gas exchange

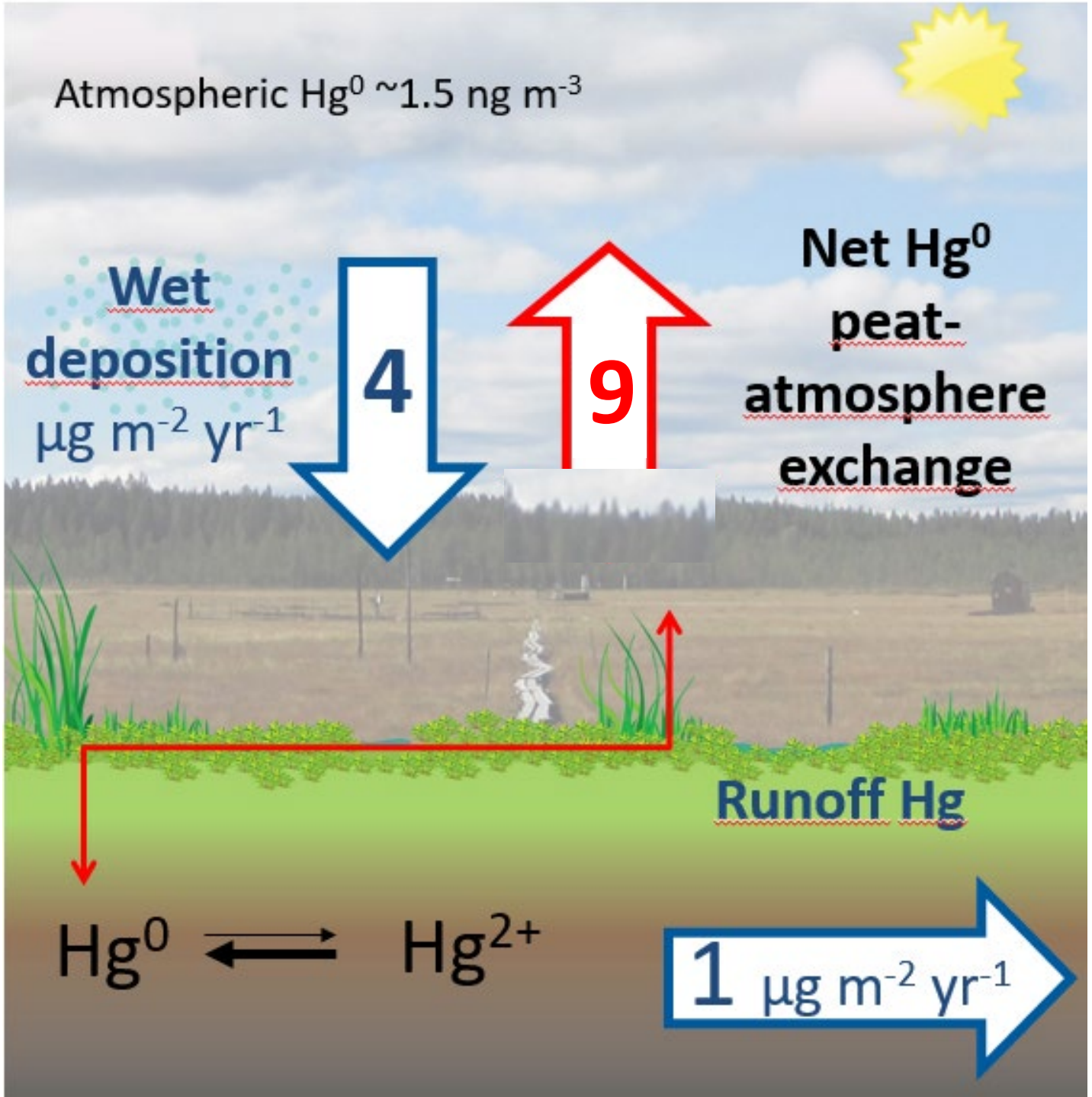
S. Osterwalder[1], J. Fritsche[1], M. B. Nilsson[2], C. Alewell[1], J. Sommar[3], G. Jocher[2], M. Schmutz[4], J. Rinne[5,6], and K. Bishop[7,8]

Degerö, Sweden

120 (!) years of peatlnad research

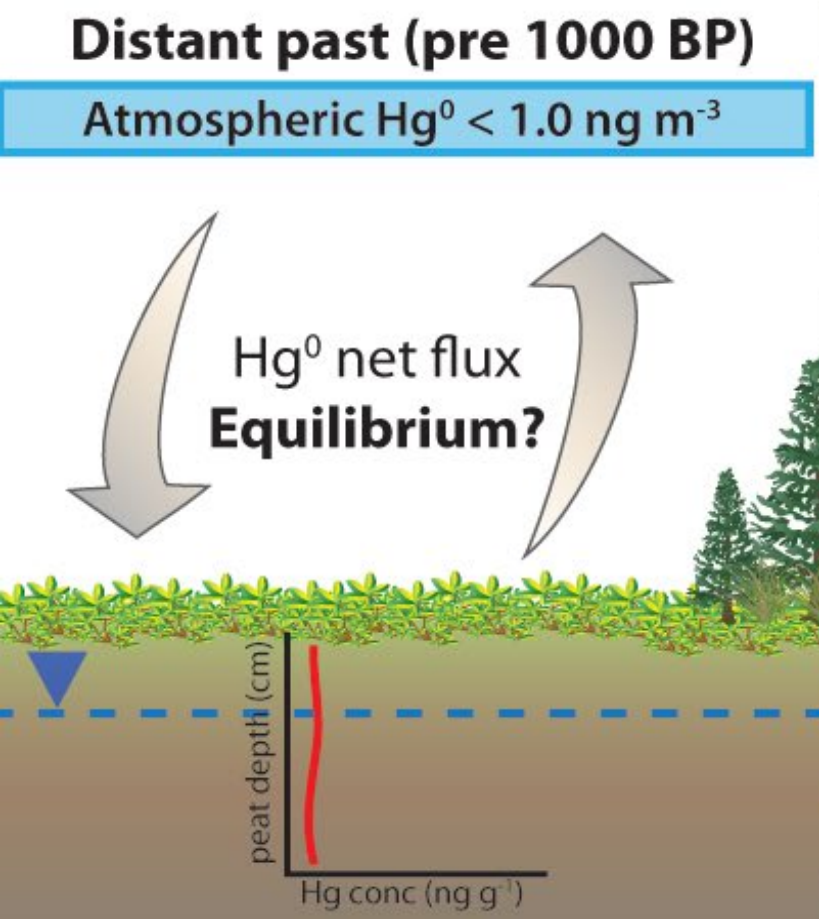
Hg evading!

But how?



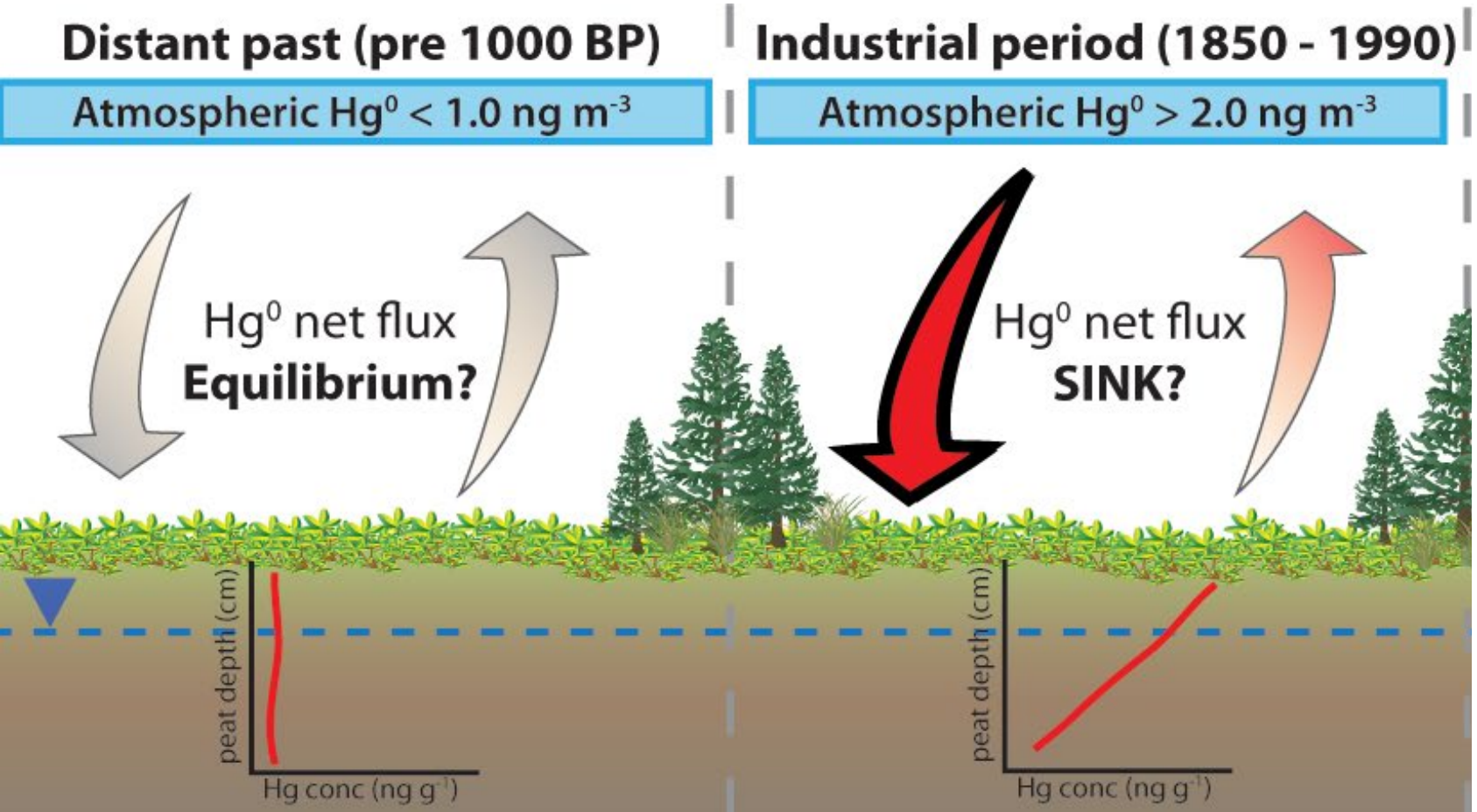
Hypothesis: In the beginning was equilibrium

peatlands were small, stable sinks for Hg^0



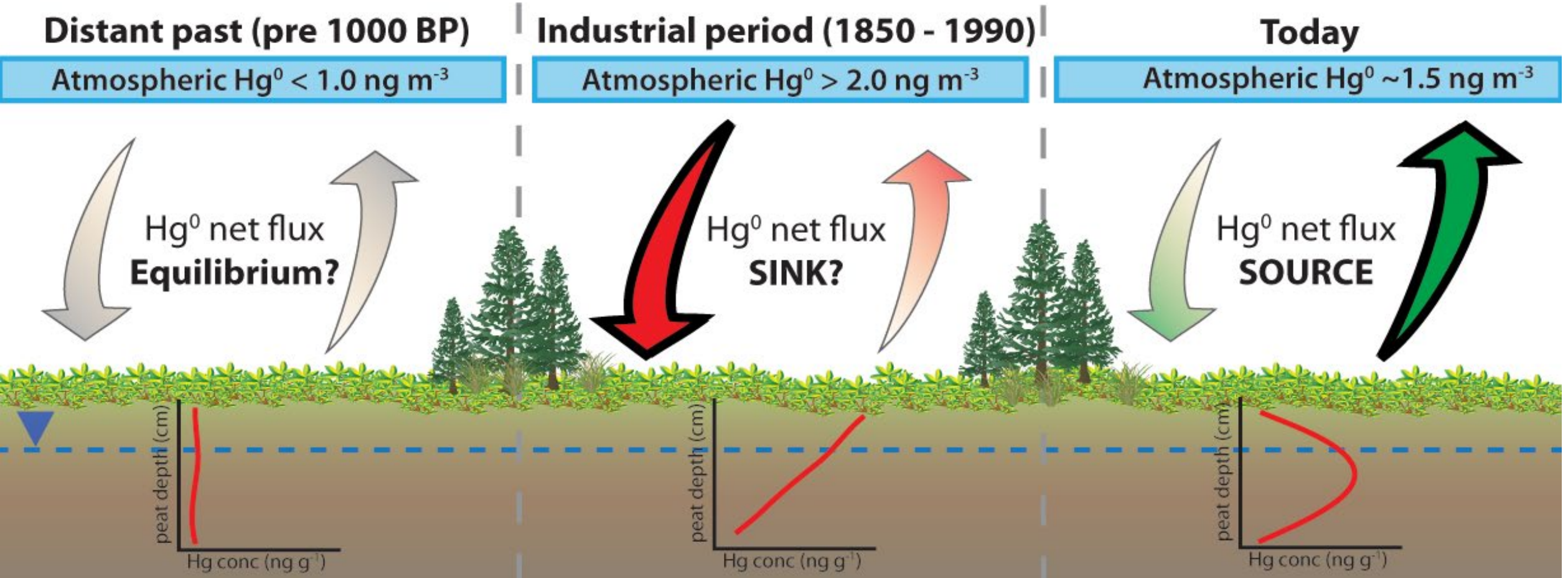
In the distant past,

Hypothesis: As pollution increased atmospheric Hg Pool of legacy Hg in superficial peat grew

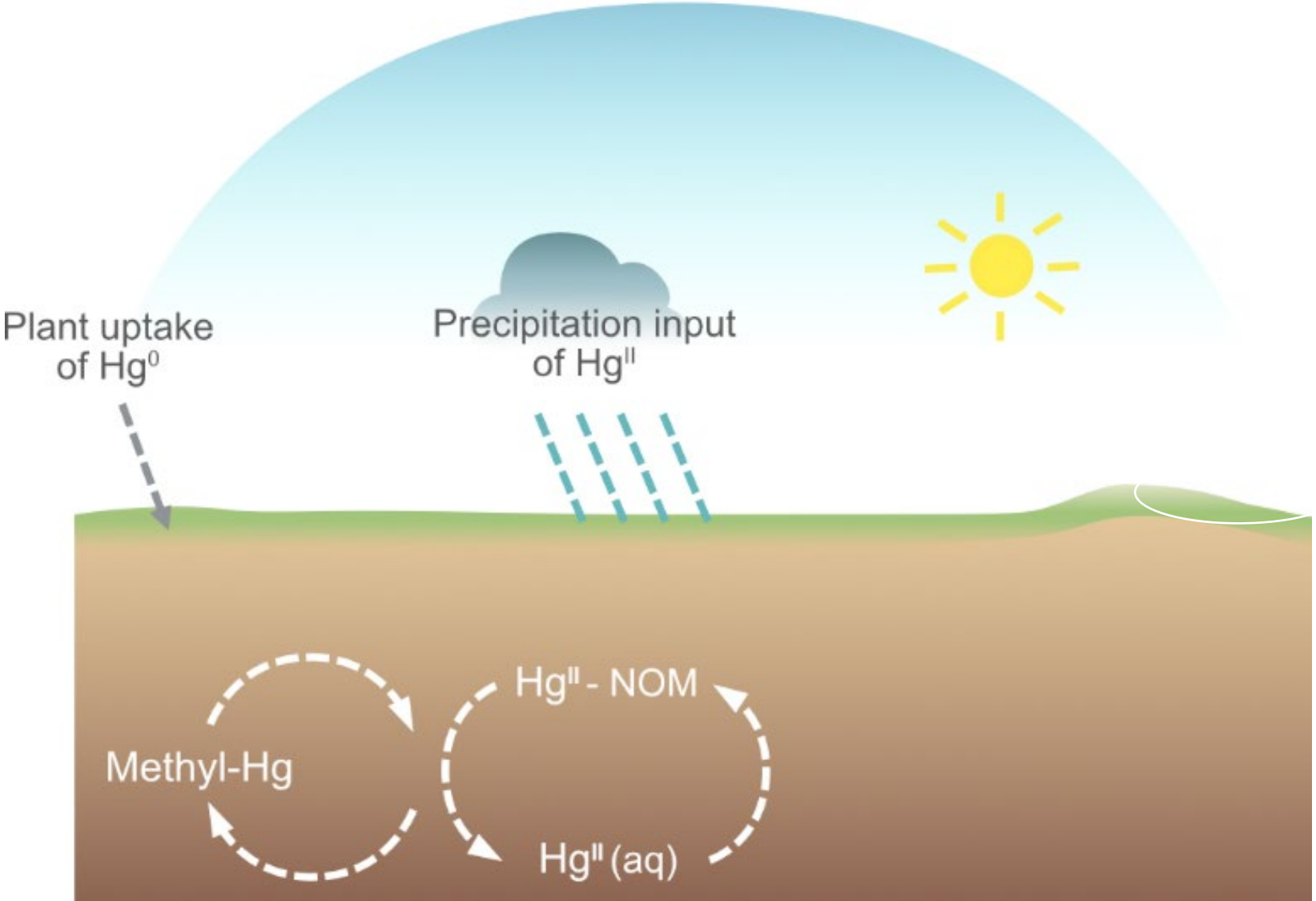


Hypothesis:

After atmospheric Hg declined legacy Hg started evading ca 1990



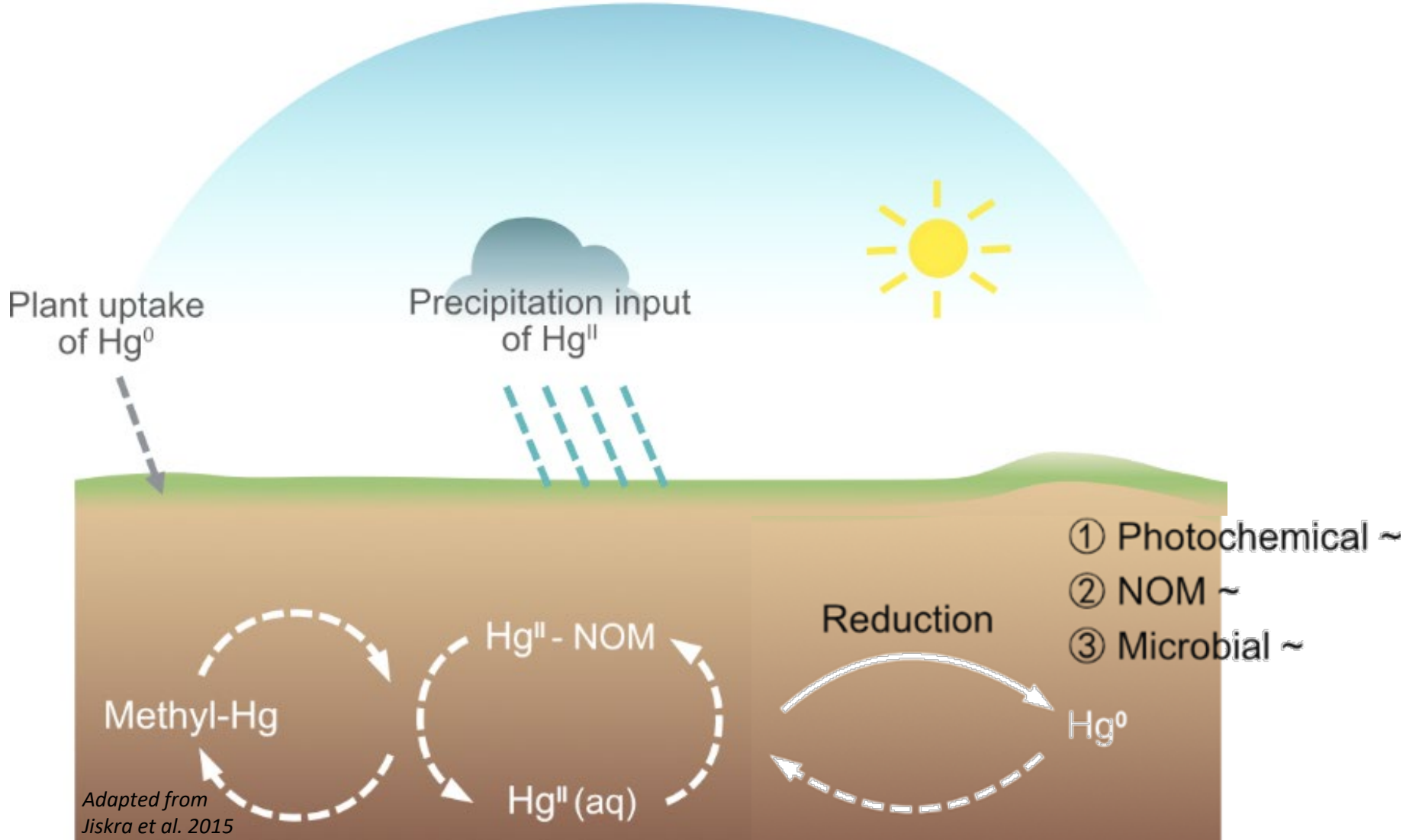
Problem: How to get legacy mercury out of a mire?



Adapted from
Jiskra et al. 2015 _ES&T

Problem: How to get legacy mercury out of a mire?

Answer: Reduction to Gaseous Elemental Hg?

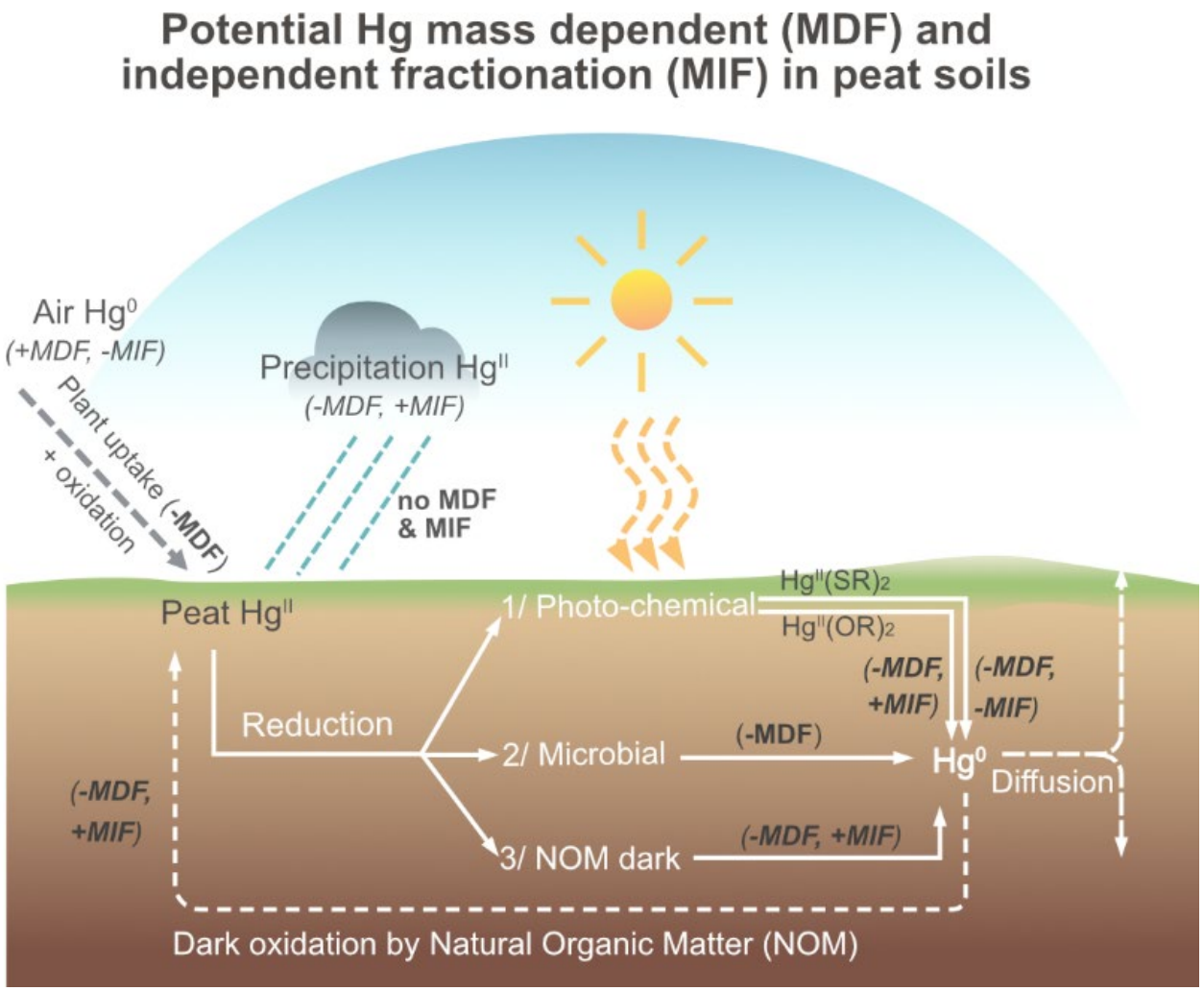


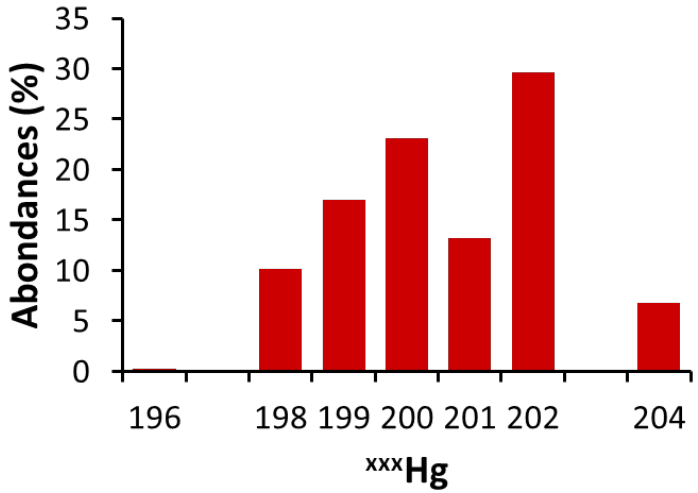
Adapted from Jiskra et al. 2015

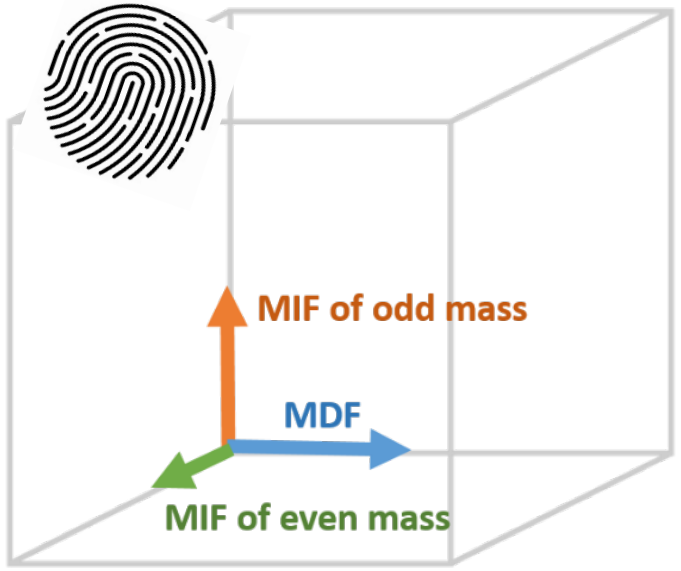
Dr. Chuxian Li
now at Univ. of Bern

Hg isotopes: Fractionation a multi-dimensional fingerprint!

UNIVERSITÄT BERN
OESCHGER CENTRE CLIMATE CHANGE RESEARCH



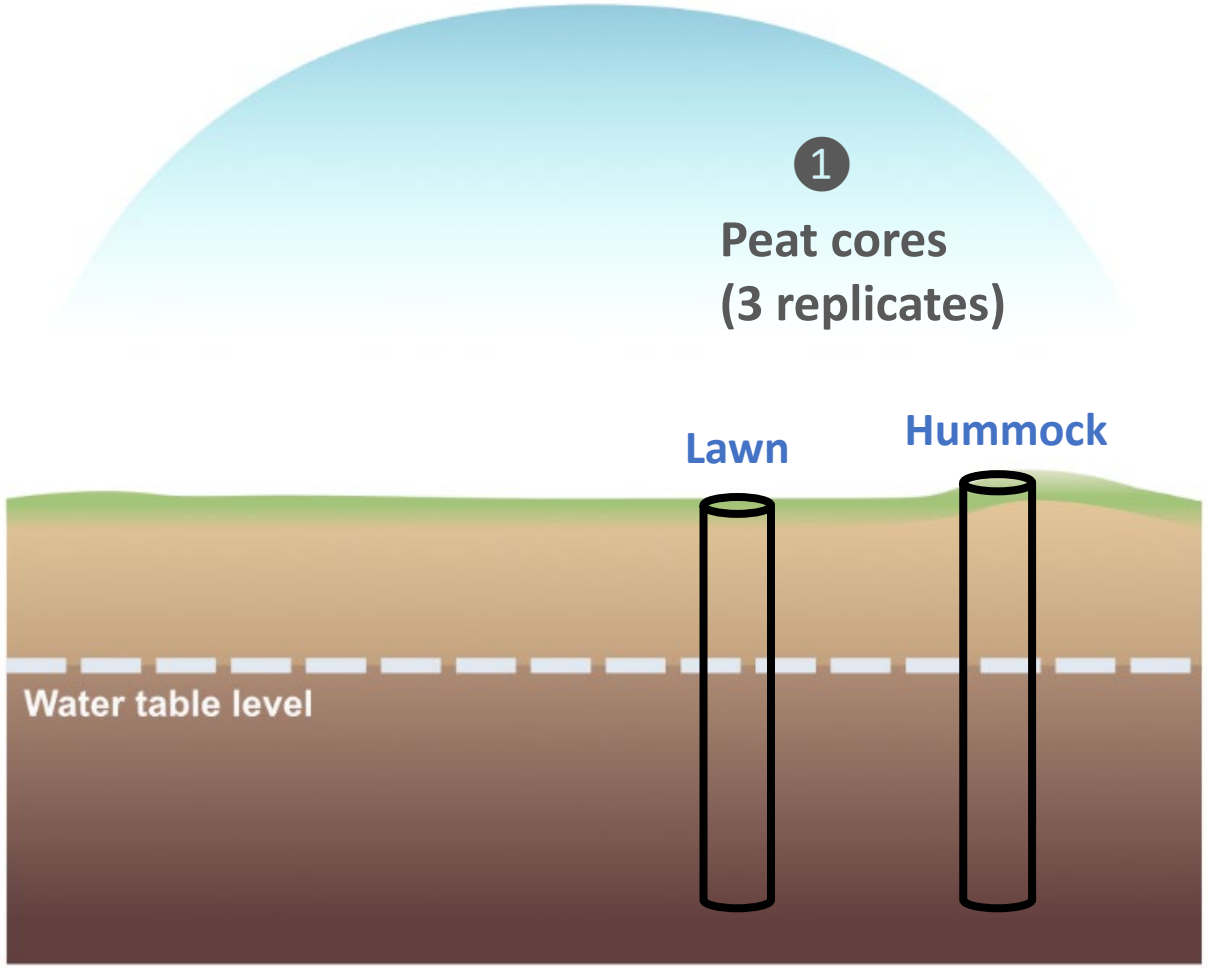


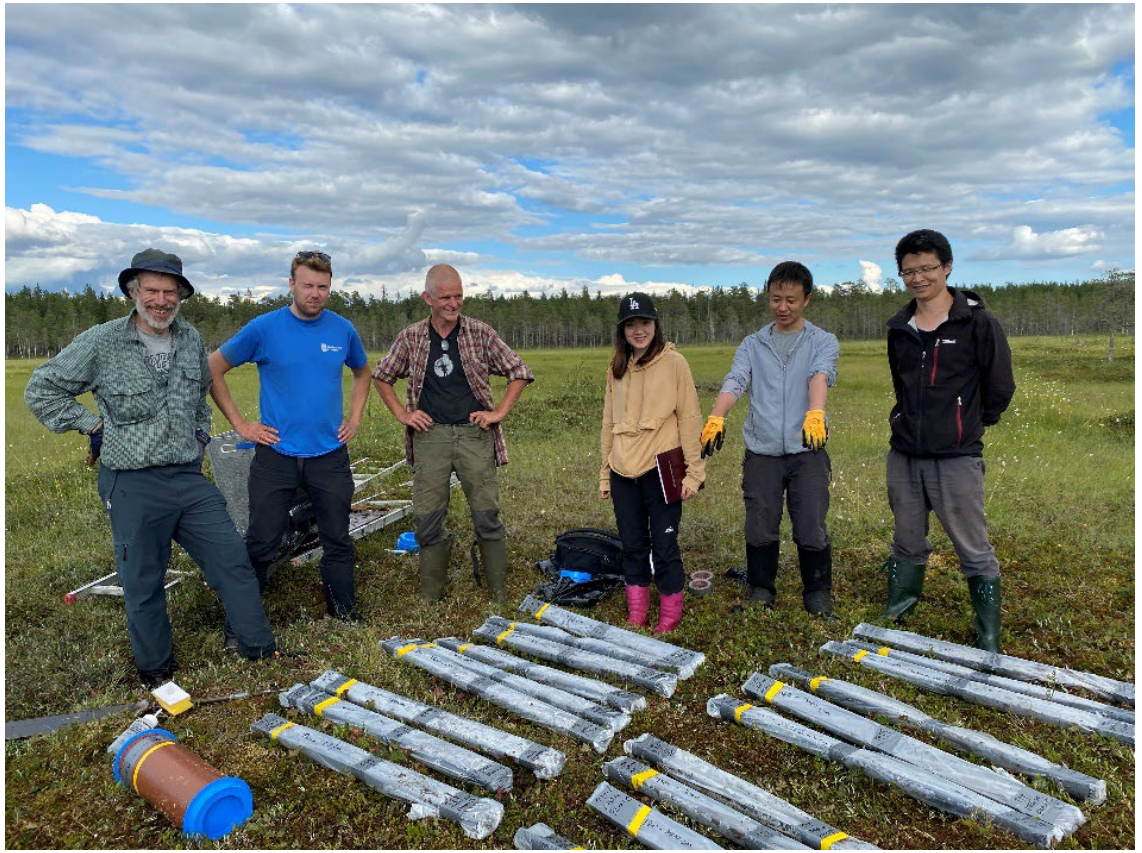


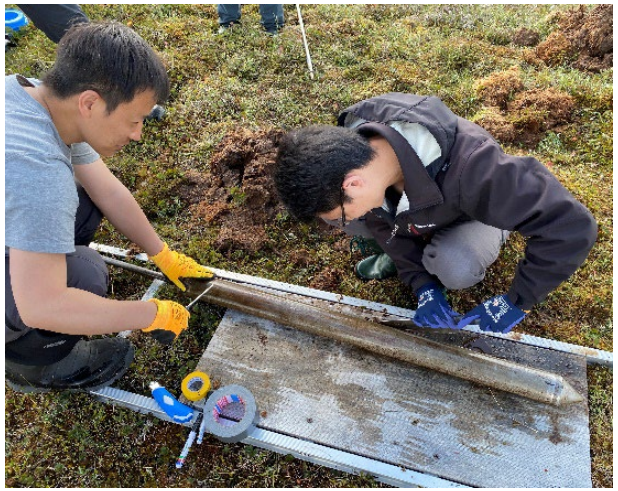
A multi-dimensional Fingerprint!

Li et al., 2023_Geochim. Cosmochim. Acta;
Li et al.,2023_Nature Communications

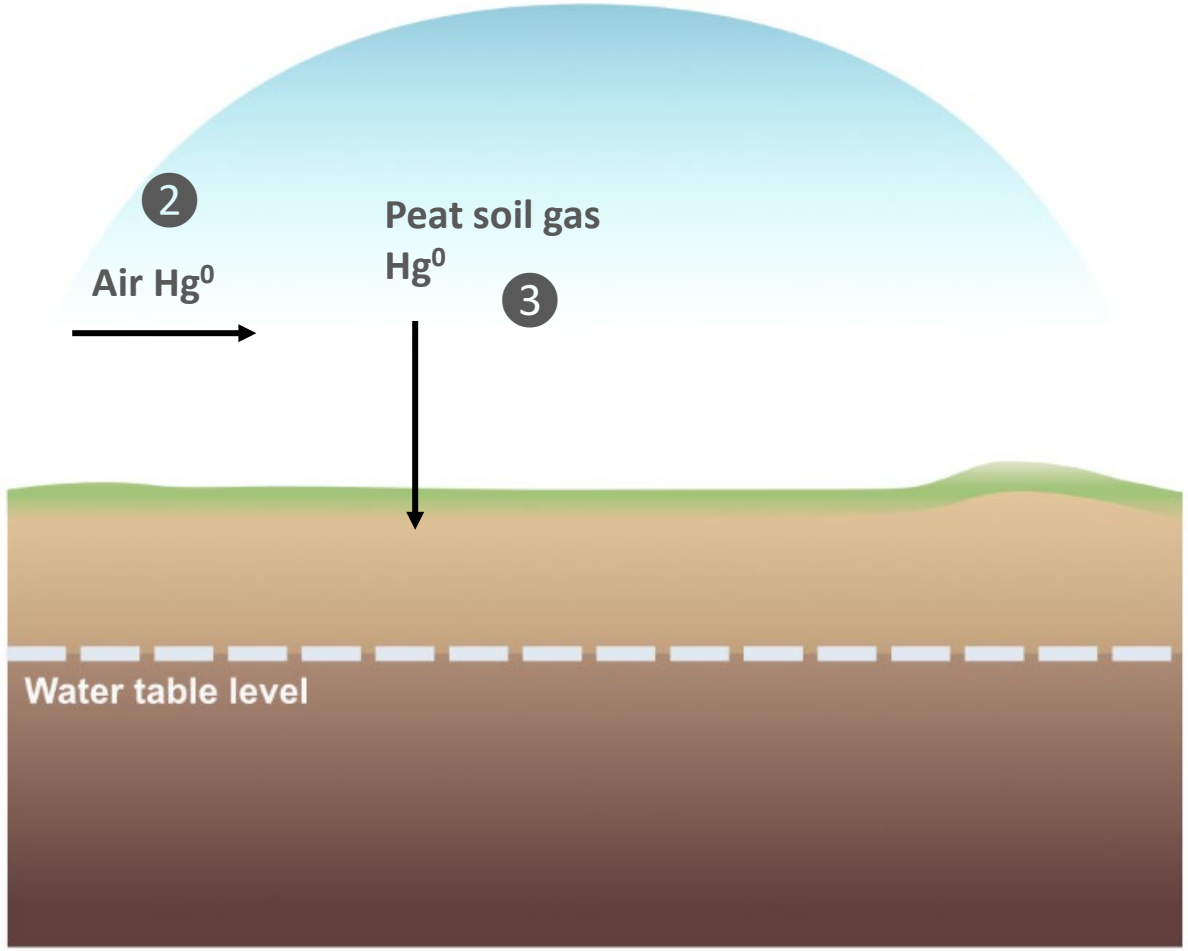
Methods - Peat Cores

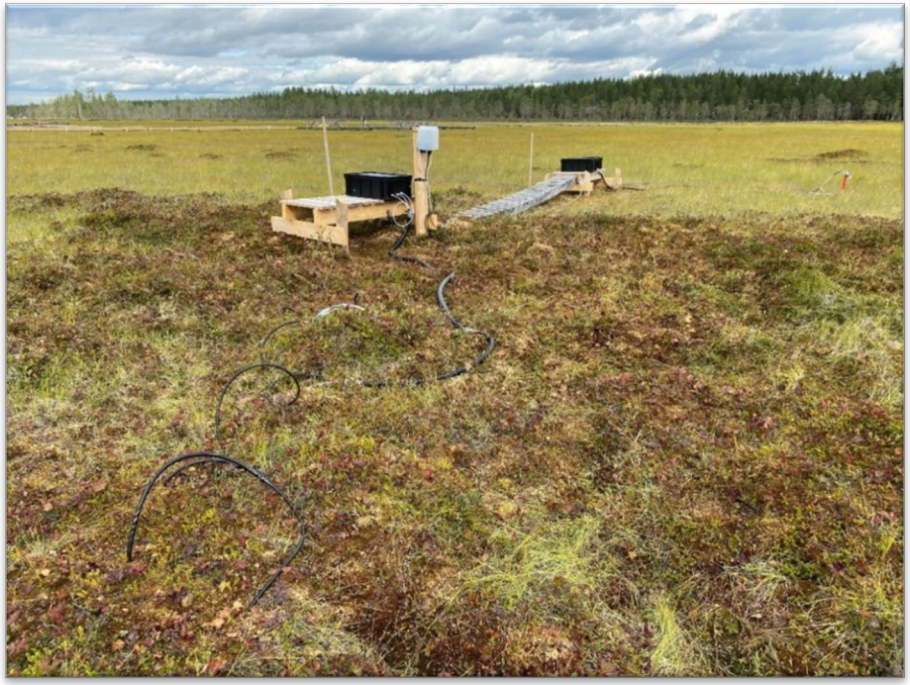




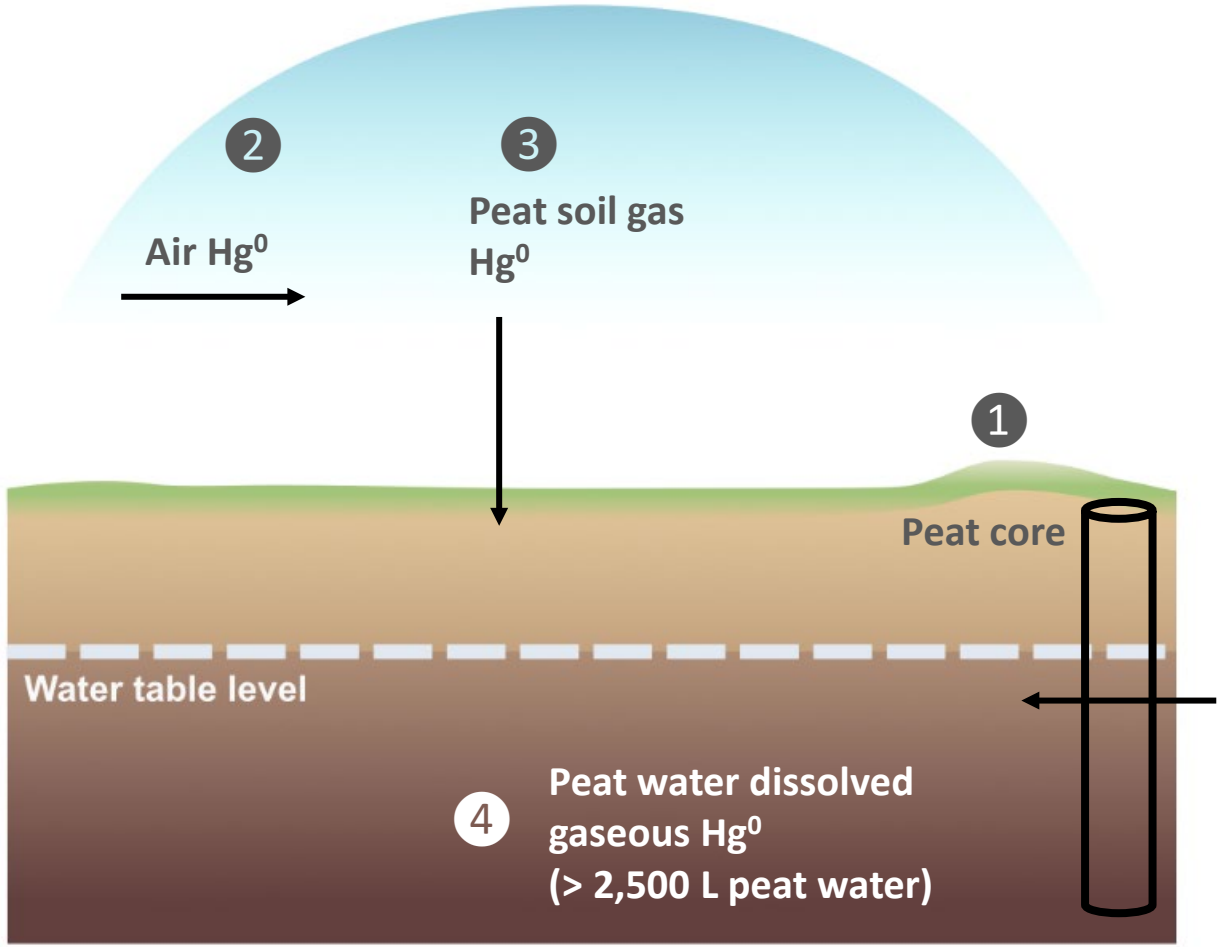


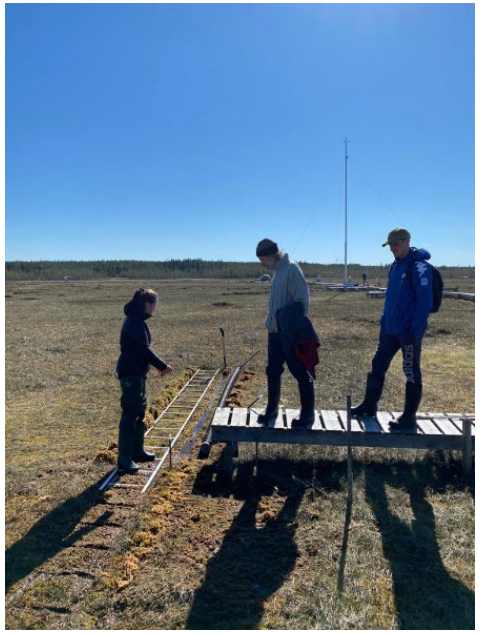
Methods -
Gas concentration gradient from groundwater to atmosphere

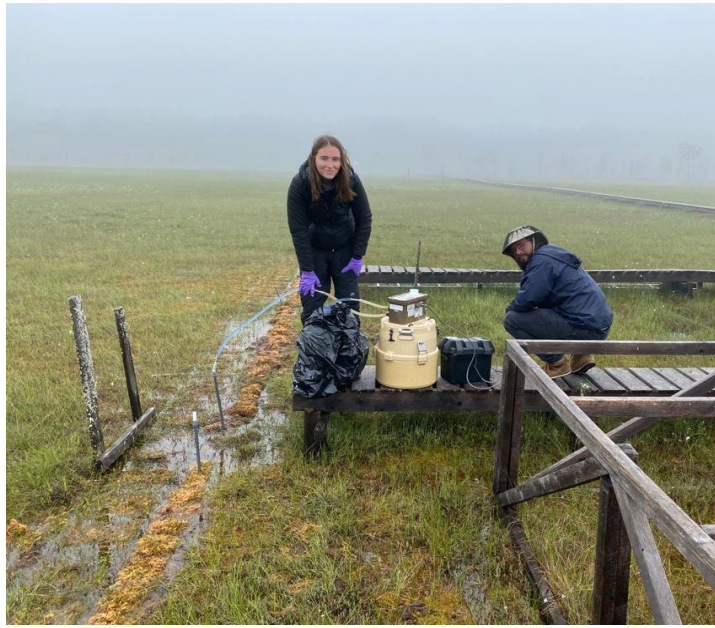




Methods - Dissolved Gaseous Mercury in peat groundwater

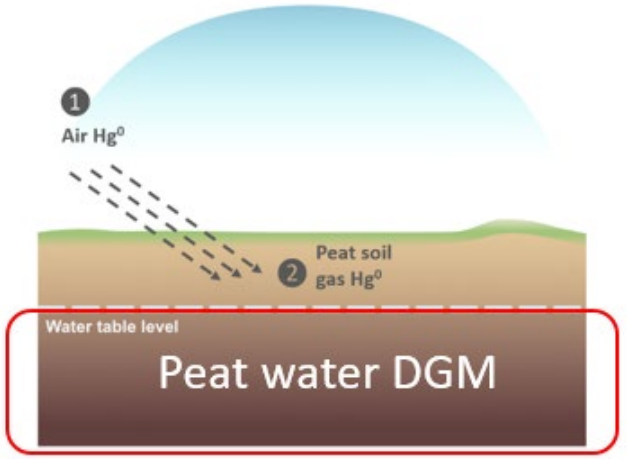


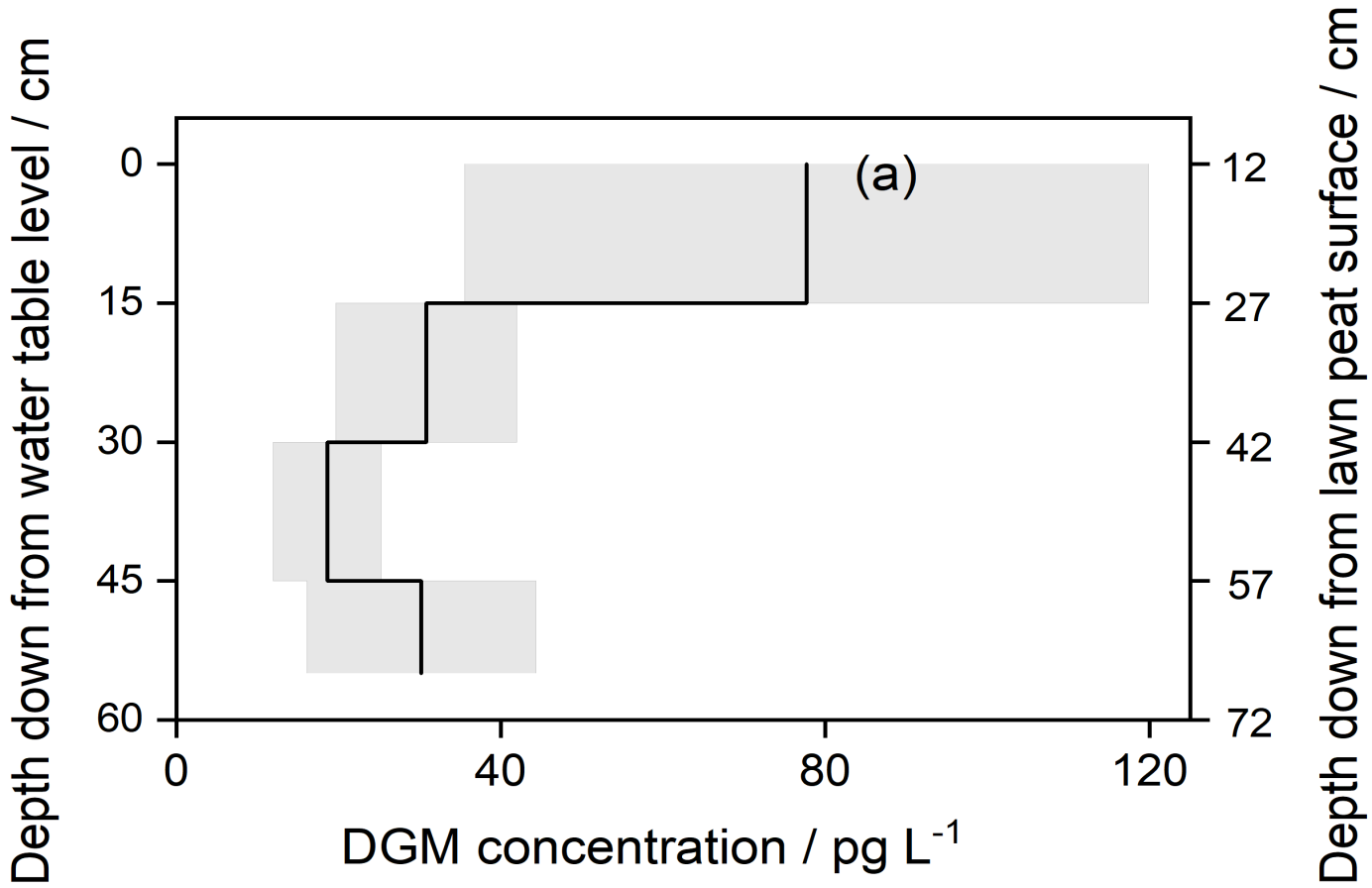




Origin and fate of dissolved gaseous mercury (DGM`

DGM supersaturation of peat groundwater
(peaks 35 cm below the water table)





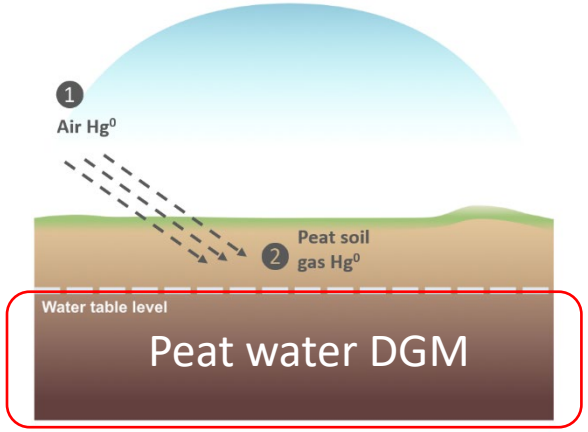
Source of DGM?:

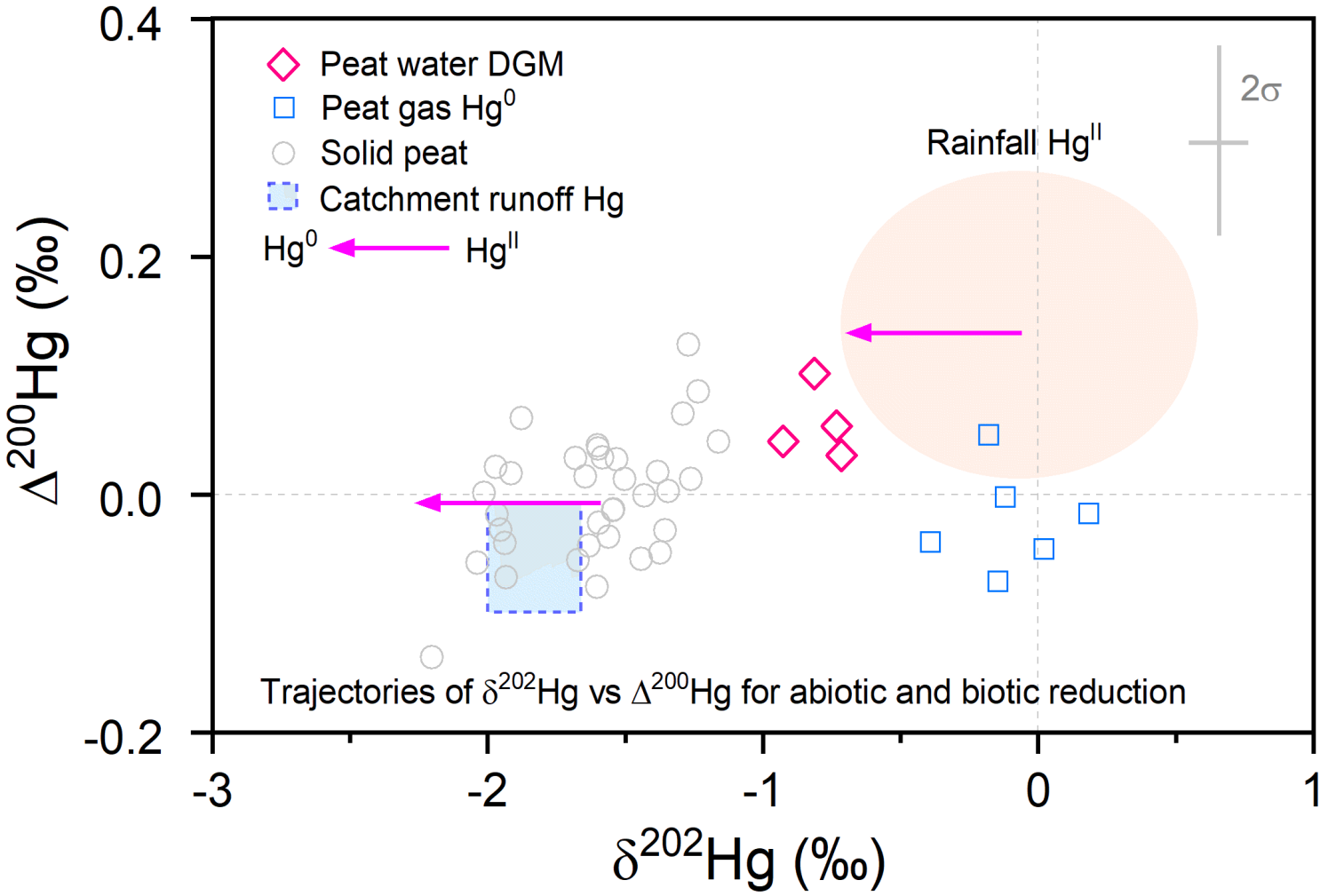
Reduction of peat Hg^{II}?

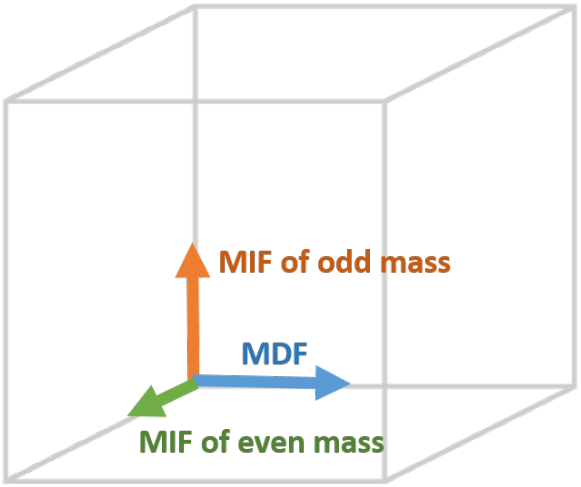
Reduction of rainfall Hg^{II}?

Origin and fate of dissolved gaseous mercury (DGM):

Rainfall the main source of peat water DGM

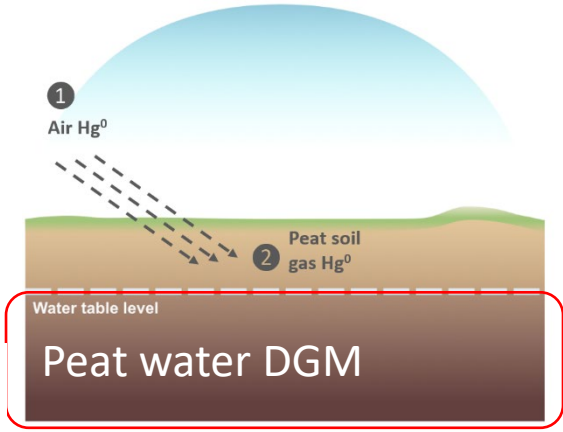


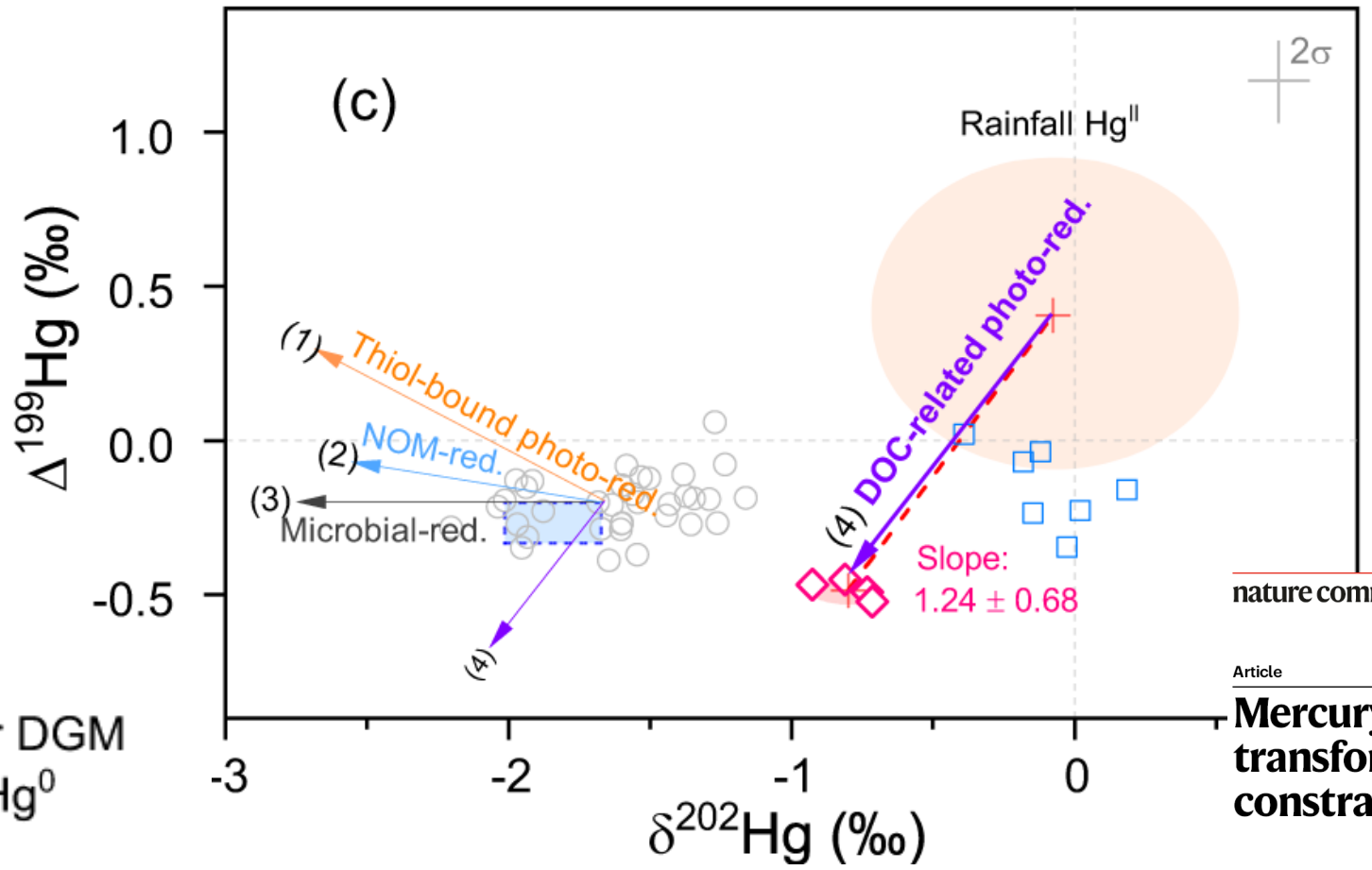




Origin and fate of dissolved gaseous mercury (DGM):

Photo-reductive Hg emission dominates Hg mobility
Dark reduction does NOT release legacy Hg from peat





- Peat water DGM
- Peat gas Hg^0
- Solid peat
- Catchment runoff Hg

Dr. Chuxian Li
now at
Univ. of Bern

nature communications

Article

https://doi.org/10.1038/s41467-023-43164-8

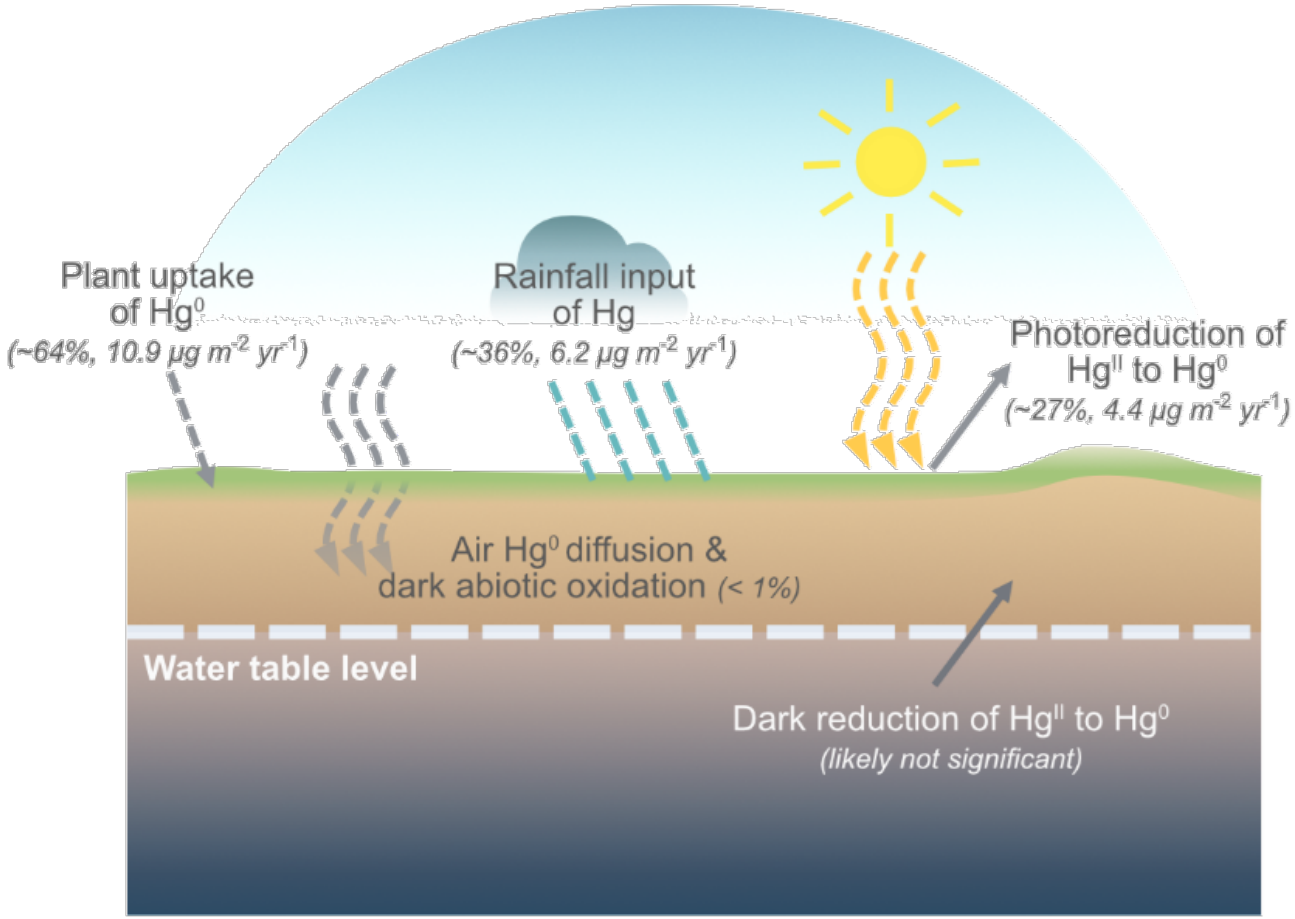
Mercury deposition and redox transformation processes in peatland constrained by mercury stable isotopes

Received: 28 December 2022

Accepted: 2 November 2023

Chuxian Li[1] ✉, Martin Jiskra[2], Mats B. Nilsson[1], Stefan Osterwalder[3], Wei Zhu[1], Dmitri Mauquoy[4], Ulf Skyllberg[1], Maxime Enrico[5], Haijun Peng[1], Yu Song[1], Erik Björn[6] & Kevin Bishop[7]

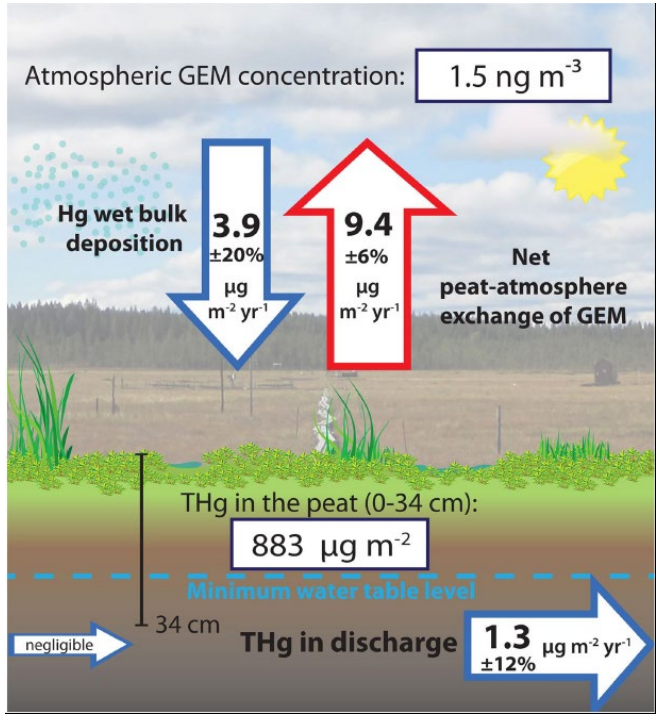
Can Net Hg Evasion be explained without dark Hg reduction to mobilize the pollution legacy?



Li et al., in review

vs

2013-2014



Osterwalder et al., 2017_Sci. Rep.

News & views

nature food

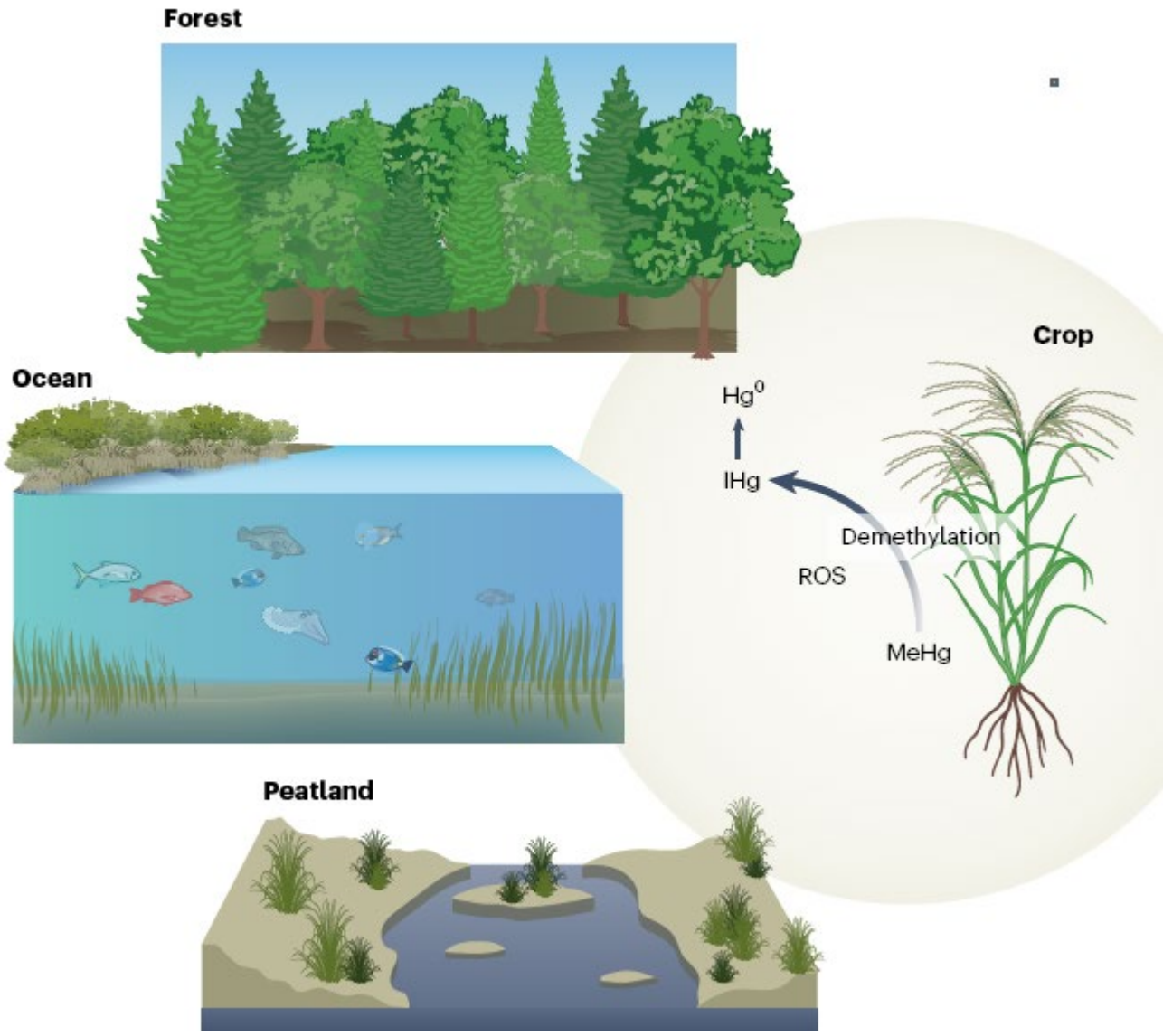
Environmental science

https://doi.org/10.1038/s43016-023-00909-4

Plant demethylation in global mercury cycling

Kevin Bishop, Chuxian Li & Stefan Osterwalder

In vivo pathway for mercury demethylation in plants … reveals a new way in which plants may influence the global cycling of mercury…



A hidden demethylation pathway removes mercury from rice plants and mitigates mercury flux to food chains

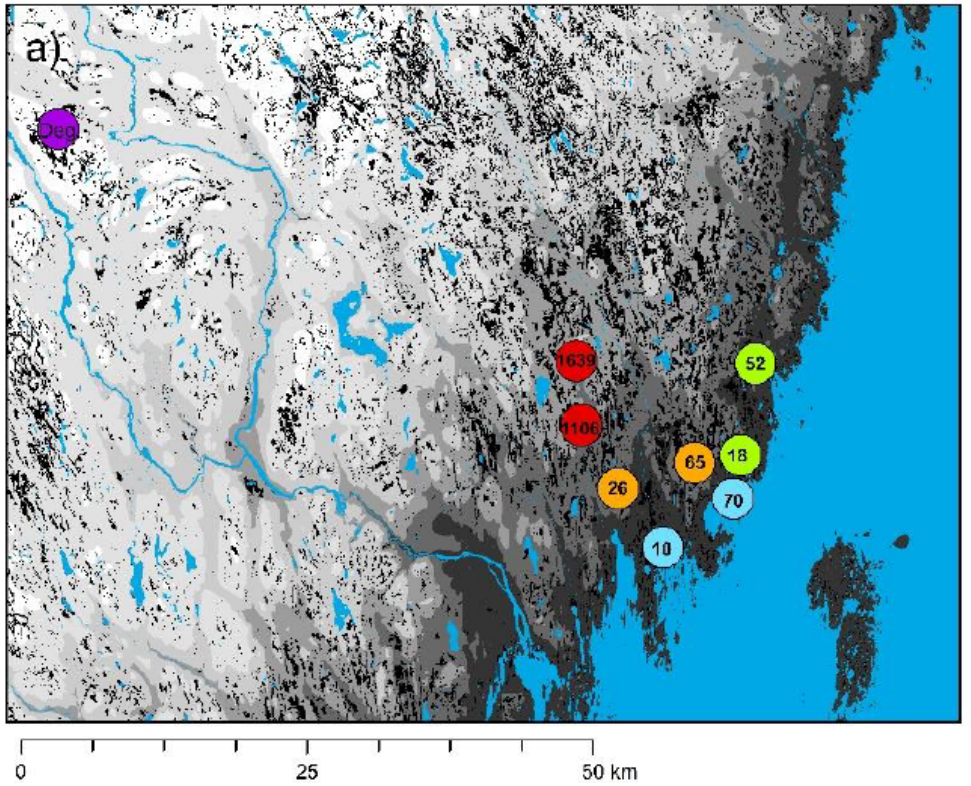
Wenli Tang, Xu Bai, Yang Zhou, Christian Sonne, Mengjie Wu, Su Shiung Lam, Holger Hintelmann, Carl P. J. Mitchell, Alexander Johs, Baohua Gu, Luís Nunes, Cun Liu, Naixian Feng,

Peatland Chronosequence: Nutrient Gradient

(the “ice age” in the title of this talk)

Mire age groups

- Young (<500 years BP)
- Young-Intermediate (500 - 1500 years BP)
- Intermediate-Old (1500 - 3000 years BP)
- Old (3000 - 5000 years BP)
- Degerö (8300 years BP)

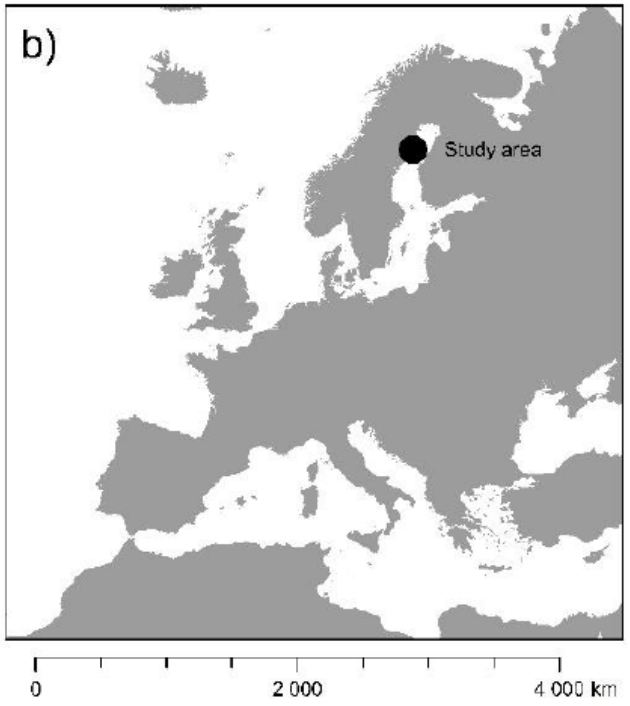


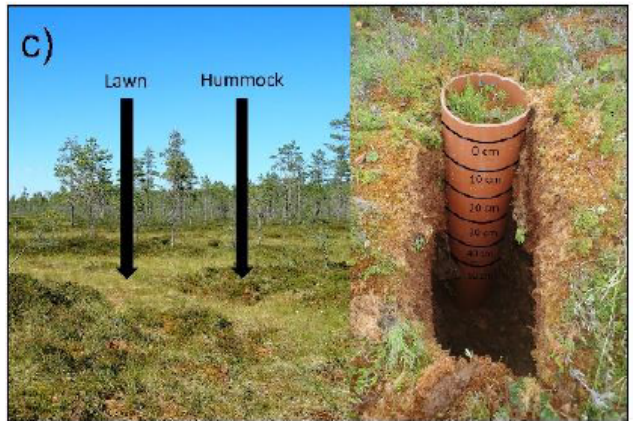
Land surface age

- 0 - 2 000 years BP
- 2 - 4 000 years BP
- 4 000 - 6 000 years BP
- 6 000 - 8 000 years BP
- 8 000-10 000 years BP

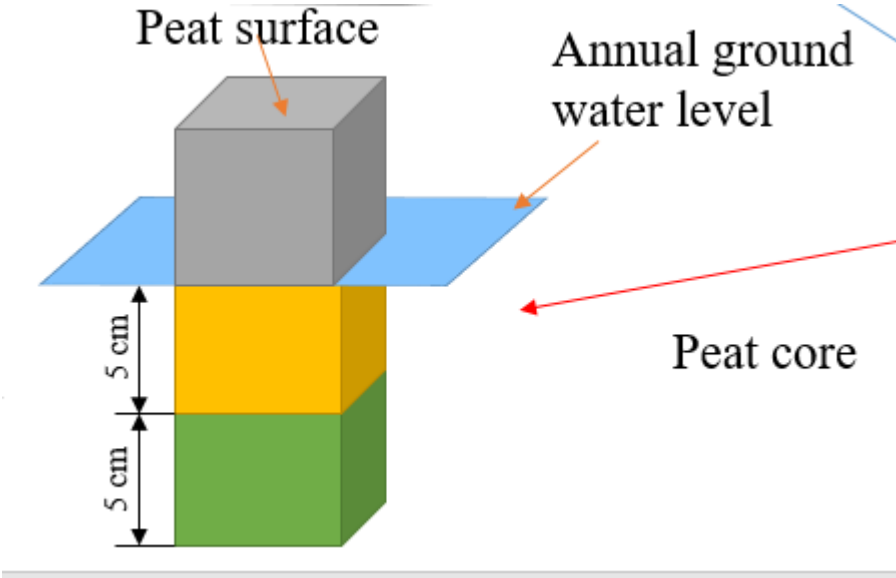
Land cover

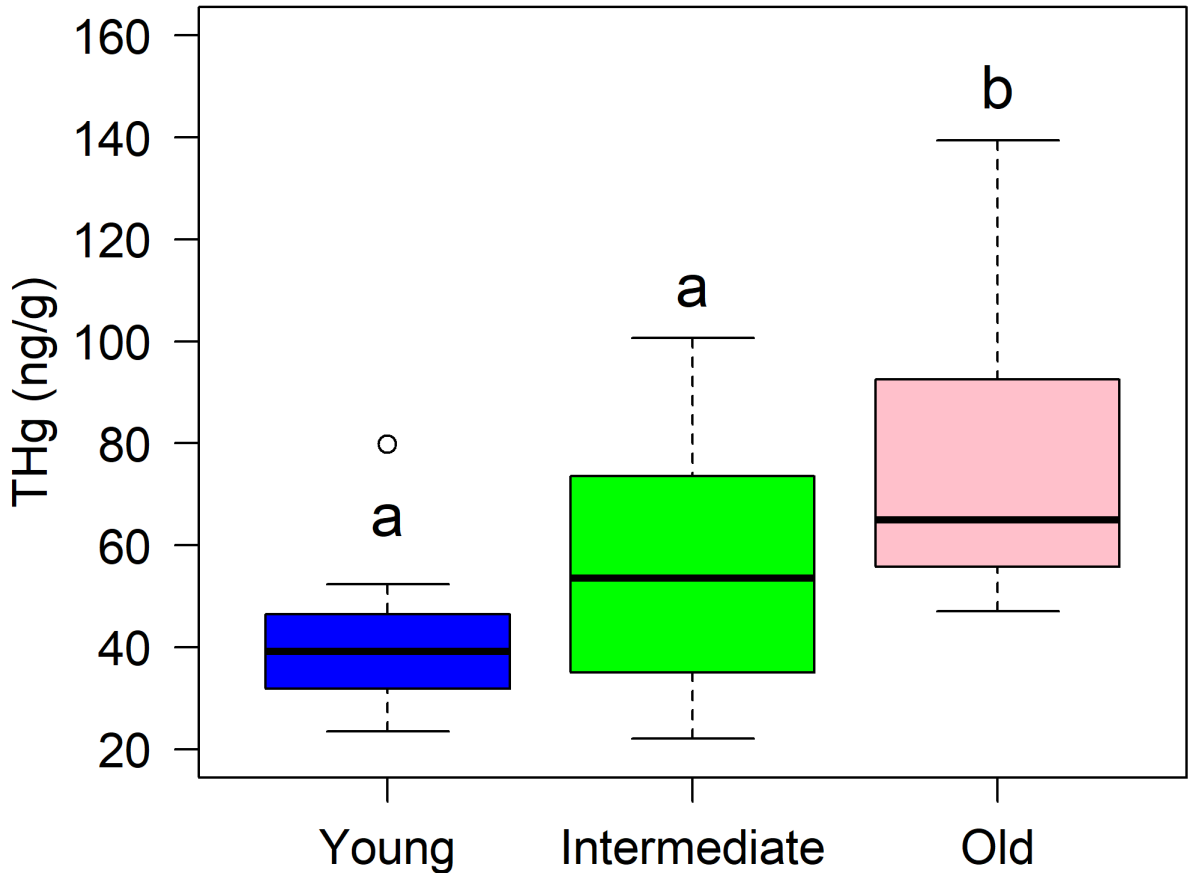
- Mire
- Water





Puzzle: Less Hg in superficial peat of “younger” peatlands



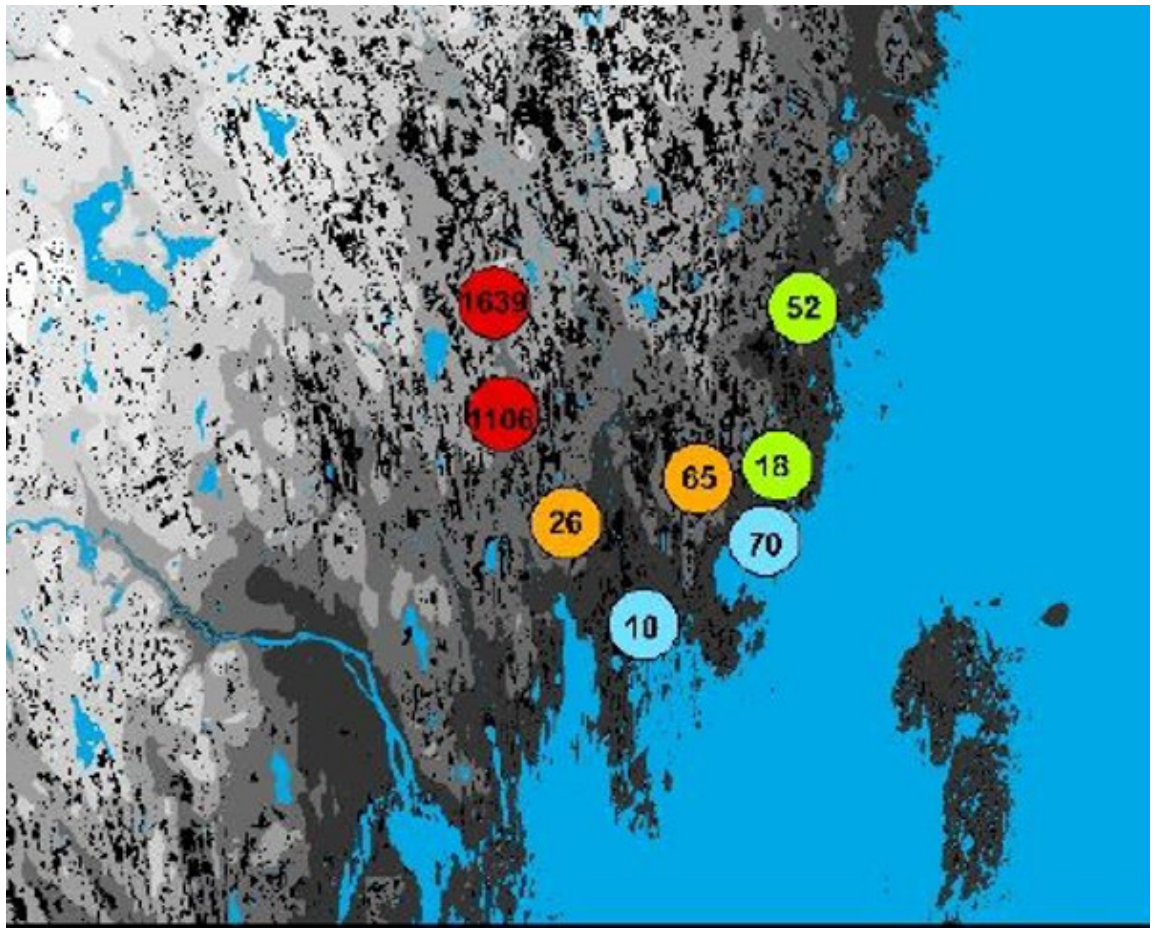


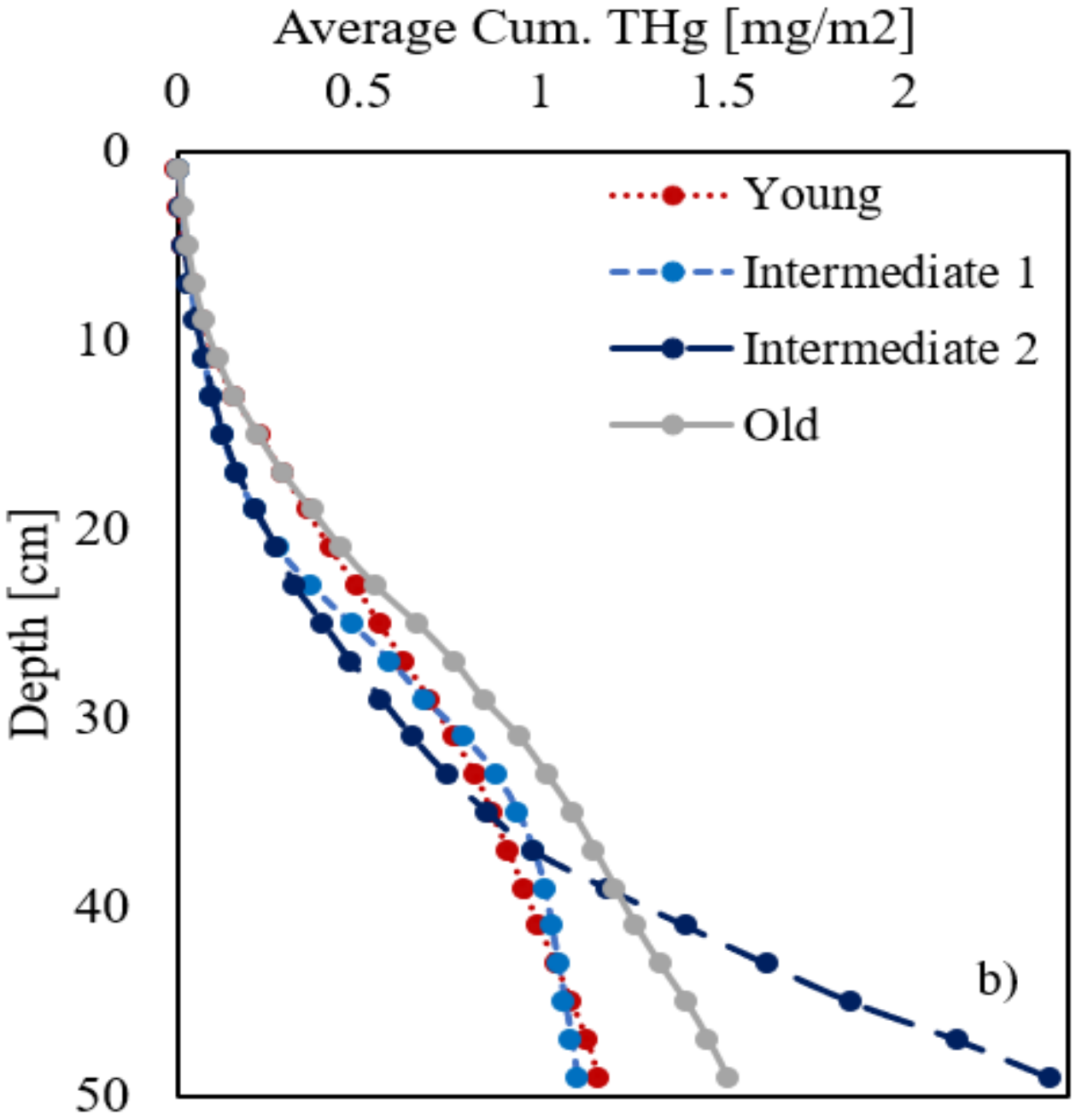
Possible Answer:
5 µg/m^2/year more evasion since 1990 in younger than older mires.

This is added to 6 µg m^{-2} net loss from an ”old” mire

From 10 cm layer to 50 cm core
Cumulative THg and peat mass

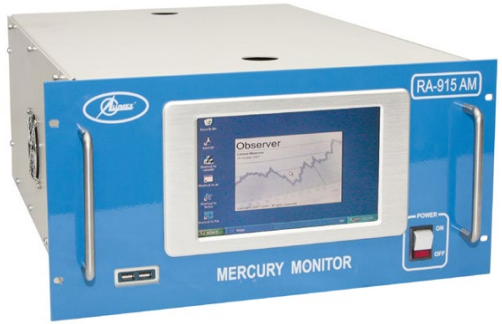
Dating in progress (ca 200yrs)
^{210}Pb, ^{14}C, SCPs





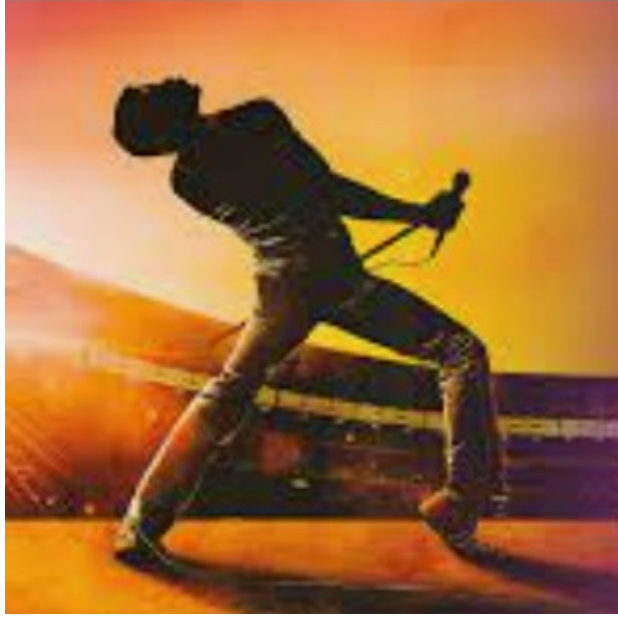
From 20 minutes to 20 Hz for Hg measurements

Introducing *Eddy Mercury*



RA-915AM
Lumex Mercury Monitor

Dr. Stefan Osterwalder
ETH Zurich



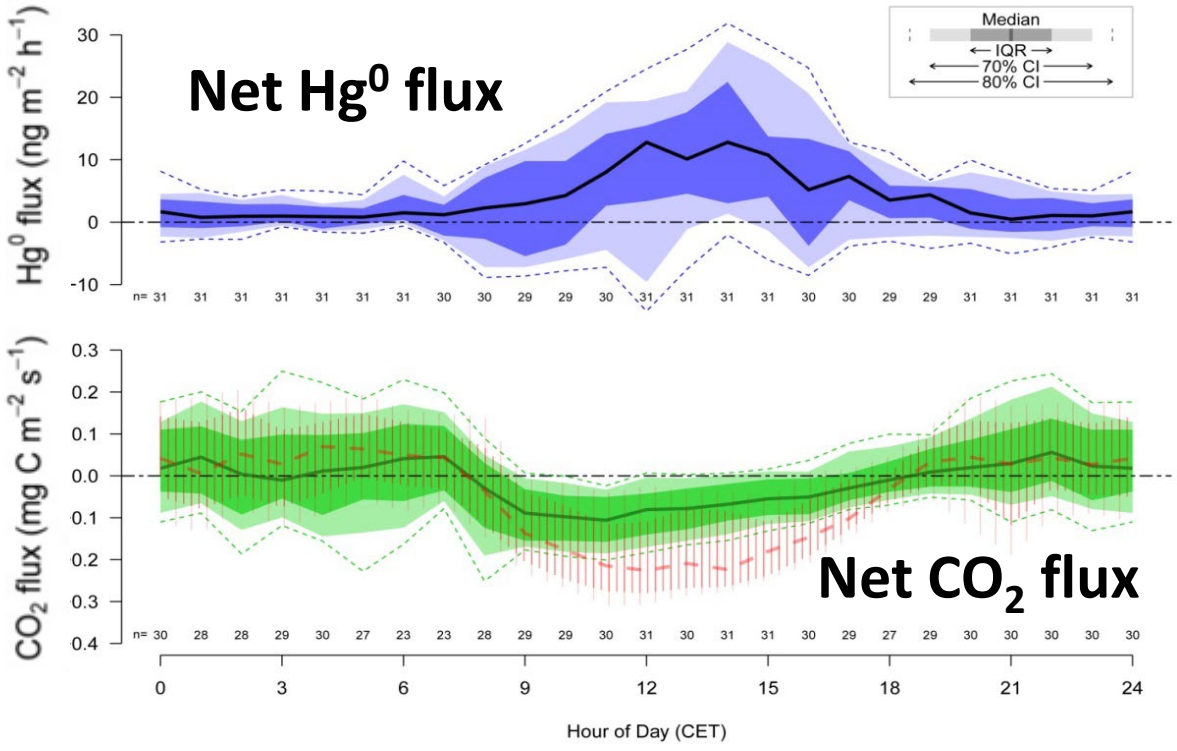
Atmos. Meas. Tech., 13, 2057–2074, 2020
https://doi.org/10.5194/amt-13-2057-2020

Atmospheric Measurement Techniques
Open Access
EGU

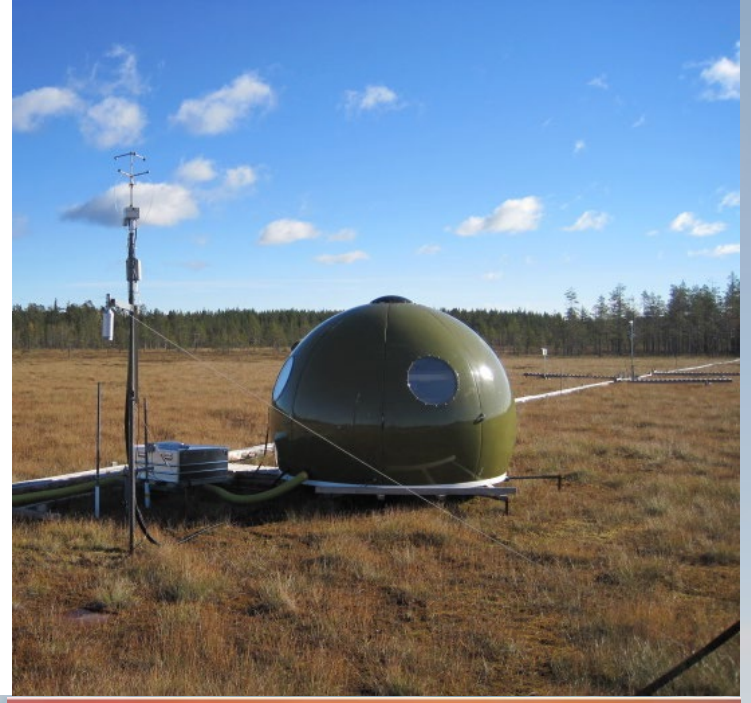
Eddy covariance flux measurements of gaseous elemental mercury over a grassland

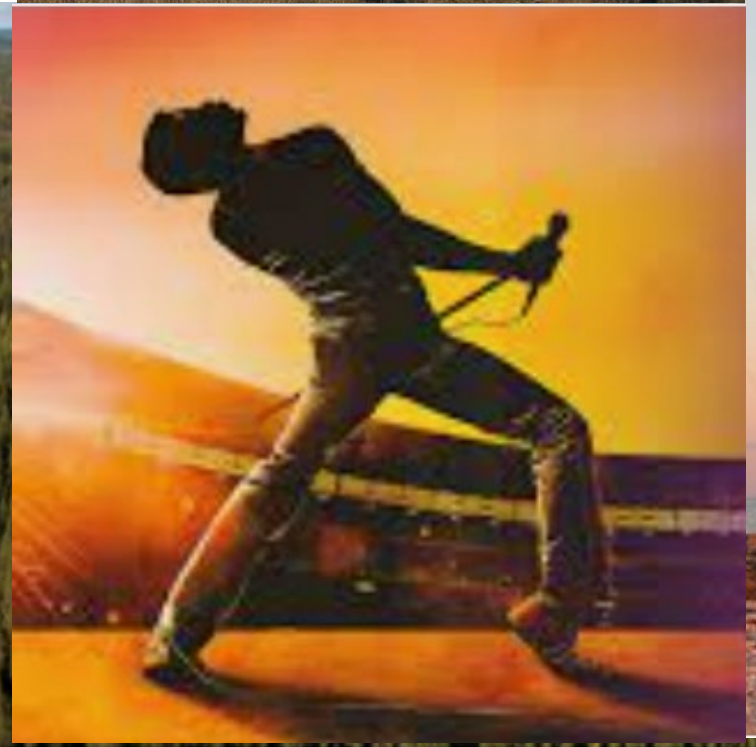
Stefan Osterwalder[1,2], Werner Eugster[3], Iris Feigenwinter[3], and Martin Jiskra[1]

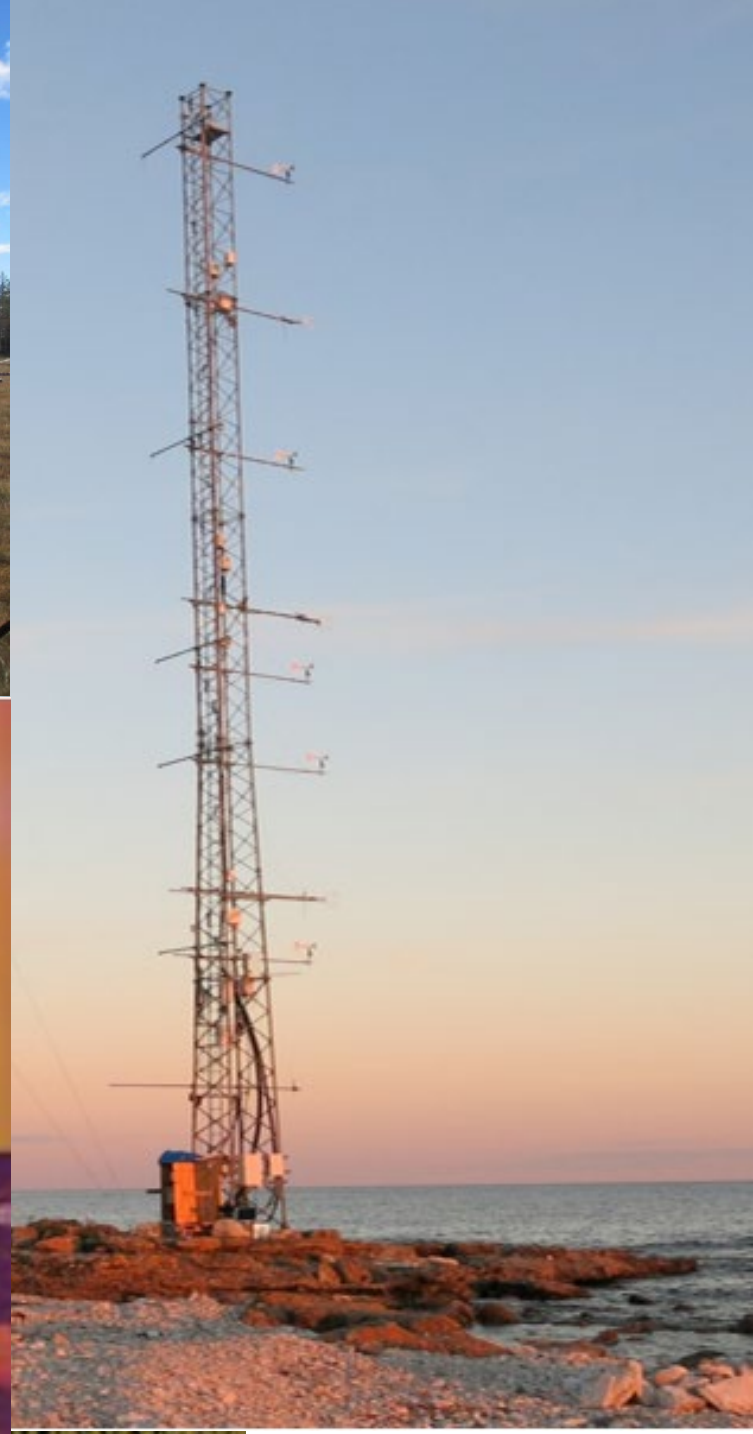
[1]Environmental Geosciences, University of Basel, 4056 Basel, Switzerland
[2]Institut des Géosciences de l'Environnement, Université Grenoble Alpes, CNRS, IRD, Grenoble INP, 38000 Grenoble, France
[3]Institute of Agricultural Sciences, ETH Zurich, 8092 Zurich, Switzerland



Eddy Mercury's new gigs







Thanks for your attention

See you at BioGeomon 12!

Umeå Sweden, June 8-12, 2026

kevin.bishop@slu.se *biogeomon@slu.se*

SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE