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Mercury stocks in discontinuous permafrost and their mobilization by river erosion and sedimentation in the Yukon River Basin

Isabel Smith

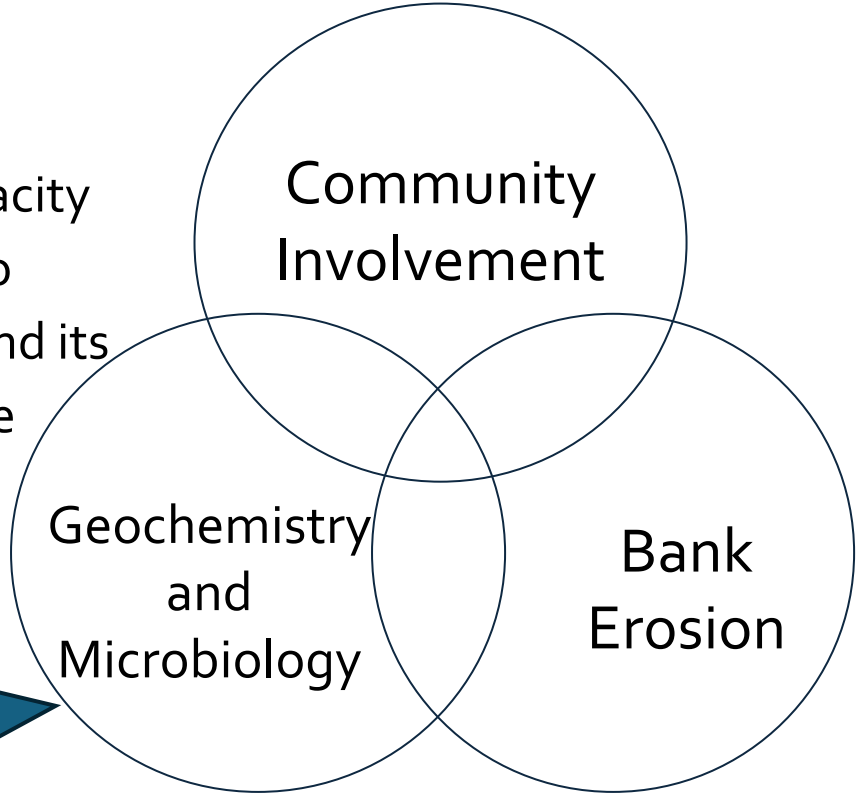
Yutian Ke, Emily C. Geyman, Jocelyn N. Reahl, Madison M. Douglas, Emily A. Seelen, John S. Magyar, Kieran B.J. Dunne, Edda A. Mutter, Woodward W. Fischer, Michael P. Lamb, A. Joshua West

Yukon Riverbank Erosion Navigating the New Arctic (NNA) Project

Objective:

To develop the capacity to plan and adapt to riverbank erosion and its consequences in the Yukon River Basin

Specifically focused on Mercury!



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USC University of Southern California

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Global Mercury Cycle with Major Reservoirs

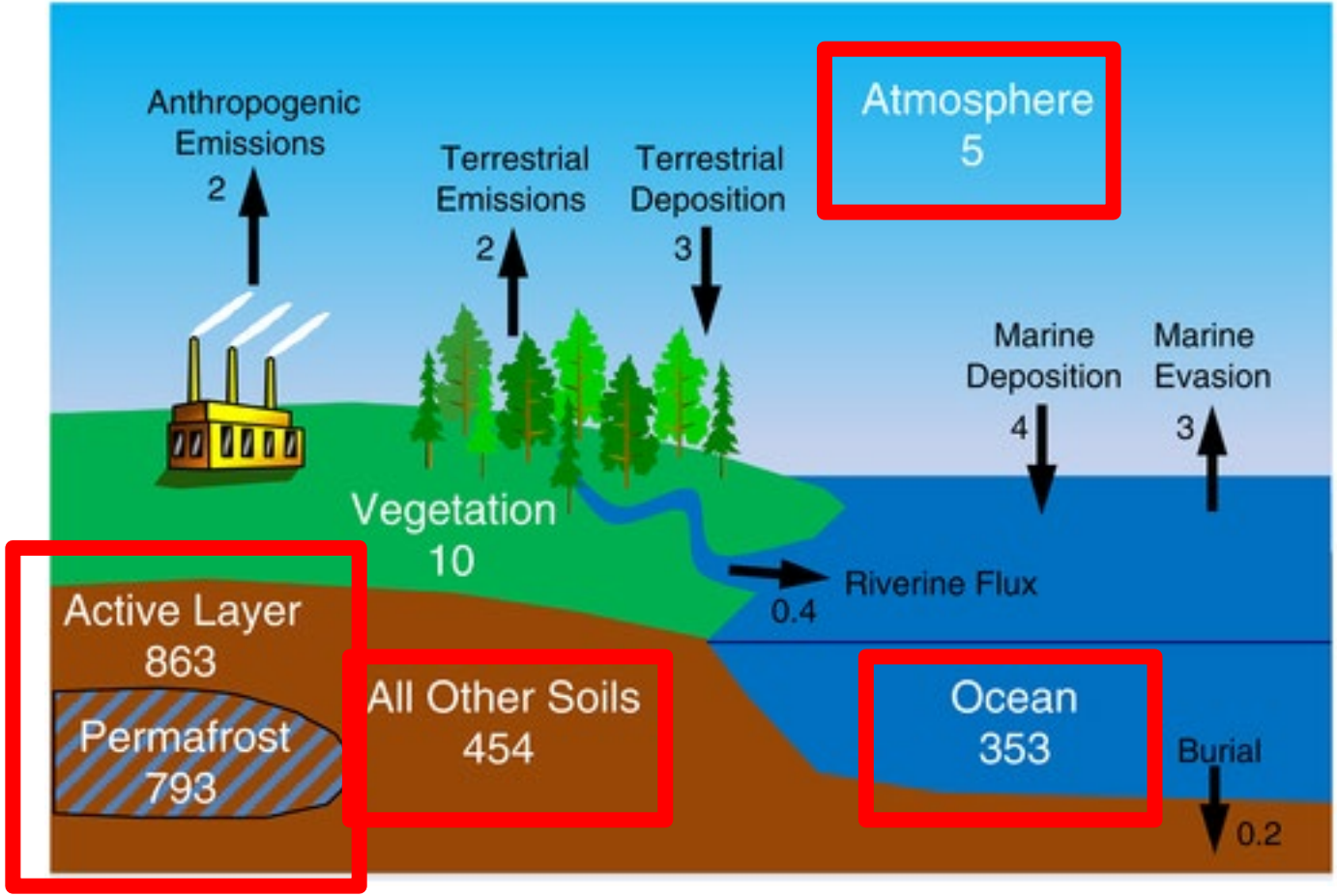


Figure: Schuster et al 2018

Global Mercury Cycle with Major Reservoirs

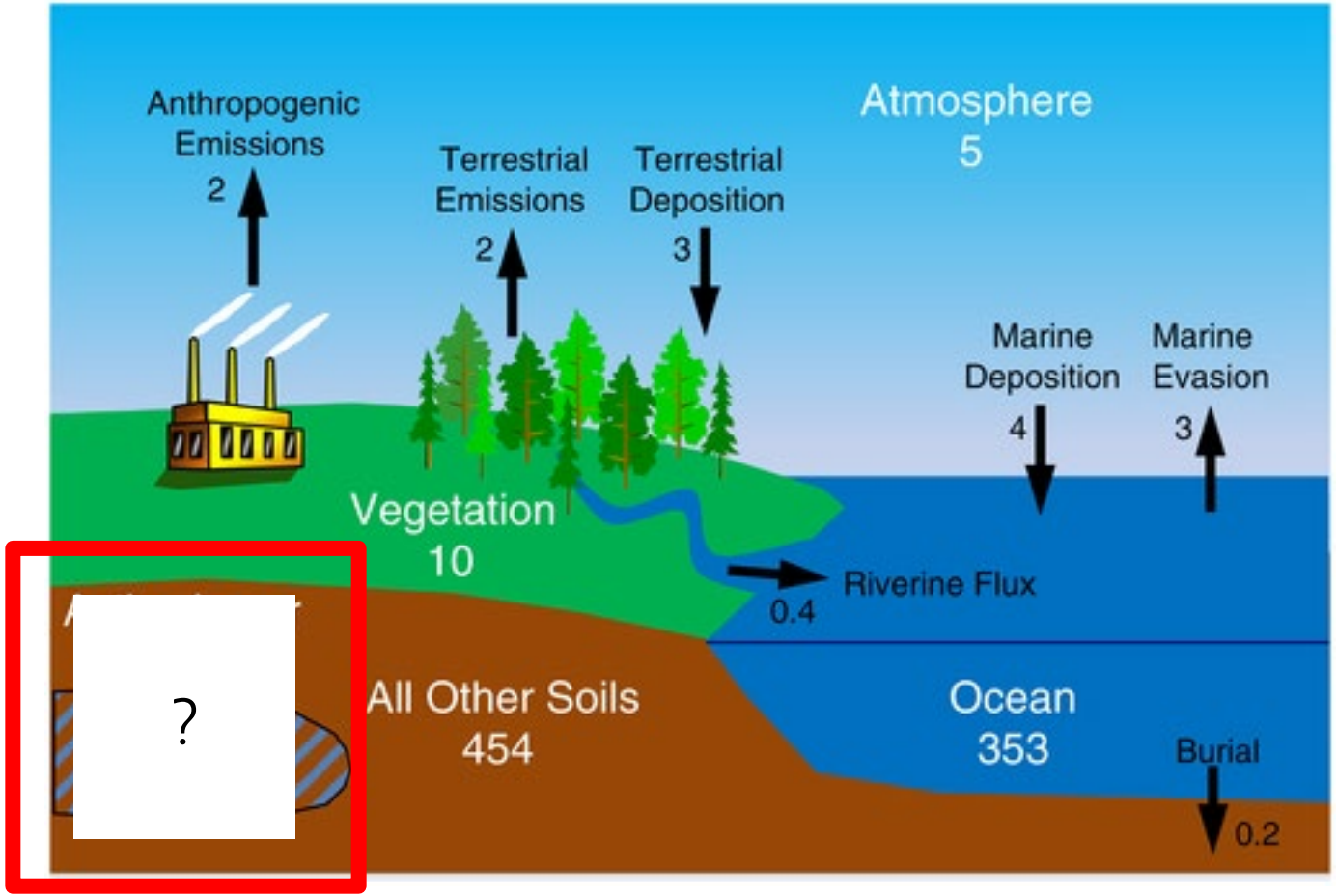


Figure: Schuster et al 2018

Estimates of Mercury in Arctic Permafrost

Permafrost Stores a Globally Significant Amount of Mercury

Paul F. Schuster, Kevin M. Schaefer, George R. Aiken, Ronald C. Antweiler, John F. Dewild, Joshua D. Gryziec, Alessio Gusmeroli, Gustaf Hugelius, Elchin Jafarov ... See all authors

First published: 05 February 2018 | https://doi.org/10.1002/2017GL075571 | Citations: 194

This article was corrected on 20 JUN 2018. See the end of the full text for details.

2018

→ 755 Gg Hg in top 1 m

Mercury in Active-Layer Tundra Soils of Alaska: Concentrations, Pools, Origins, and Spatial Distribution

2018

C. Olson, M. Jiskra, H. Biester, J. Chow, D. Obrist

First published: 19 June 2018 | https://doi.org/10.1029/2017GB005840 | Citations: 41

→ 184 Gg Hg in top 1 m

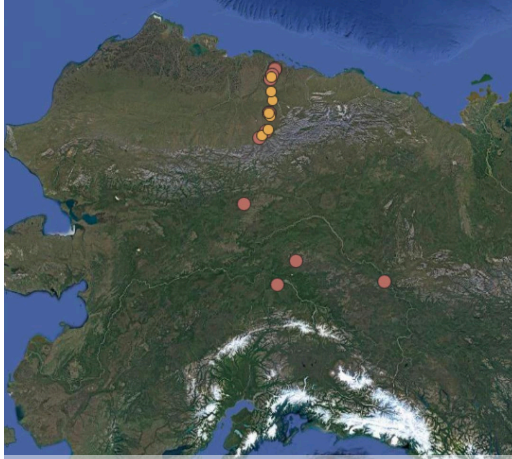
Research article | CC BY

A revised pan-Arctic permafrost soil Hg pool based on Western Siberian peat Hg and carbon observations

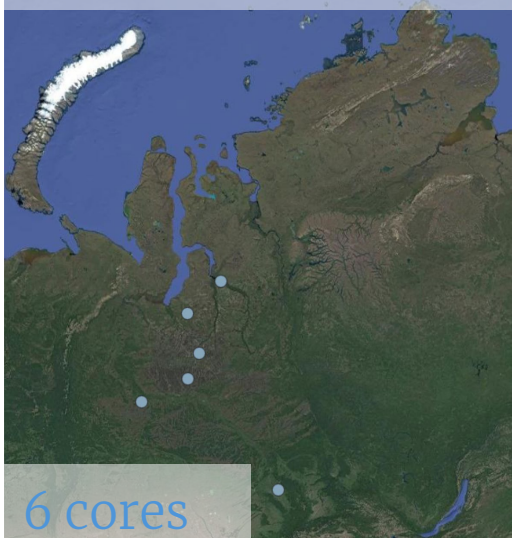
2020

Artem G. Lim, Martin Jiskra, Jeroen E. Sonke, Sergey V. Loiko, Natalia Kosykh, and Oleg S. Pokrovsky

→ 240 Gg Hg in top 1 m

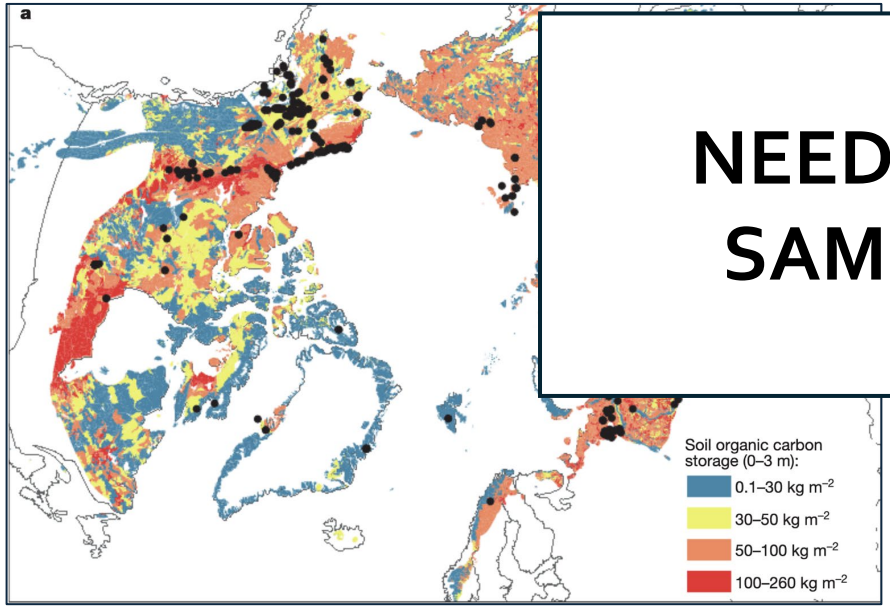


13 cores and 7 sites



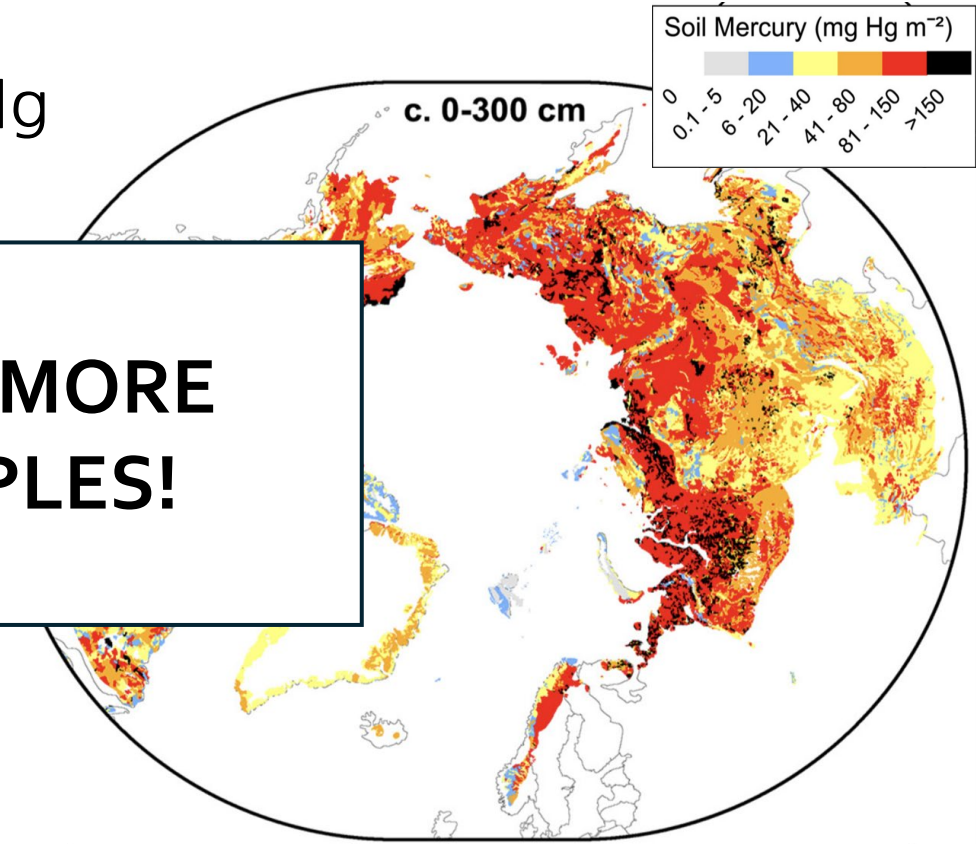
6 cores

Existing studies maps of Arctic soil OC (see below) + use Hg/OC data → maps of soil Hg across entire Arctic!

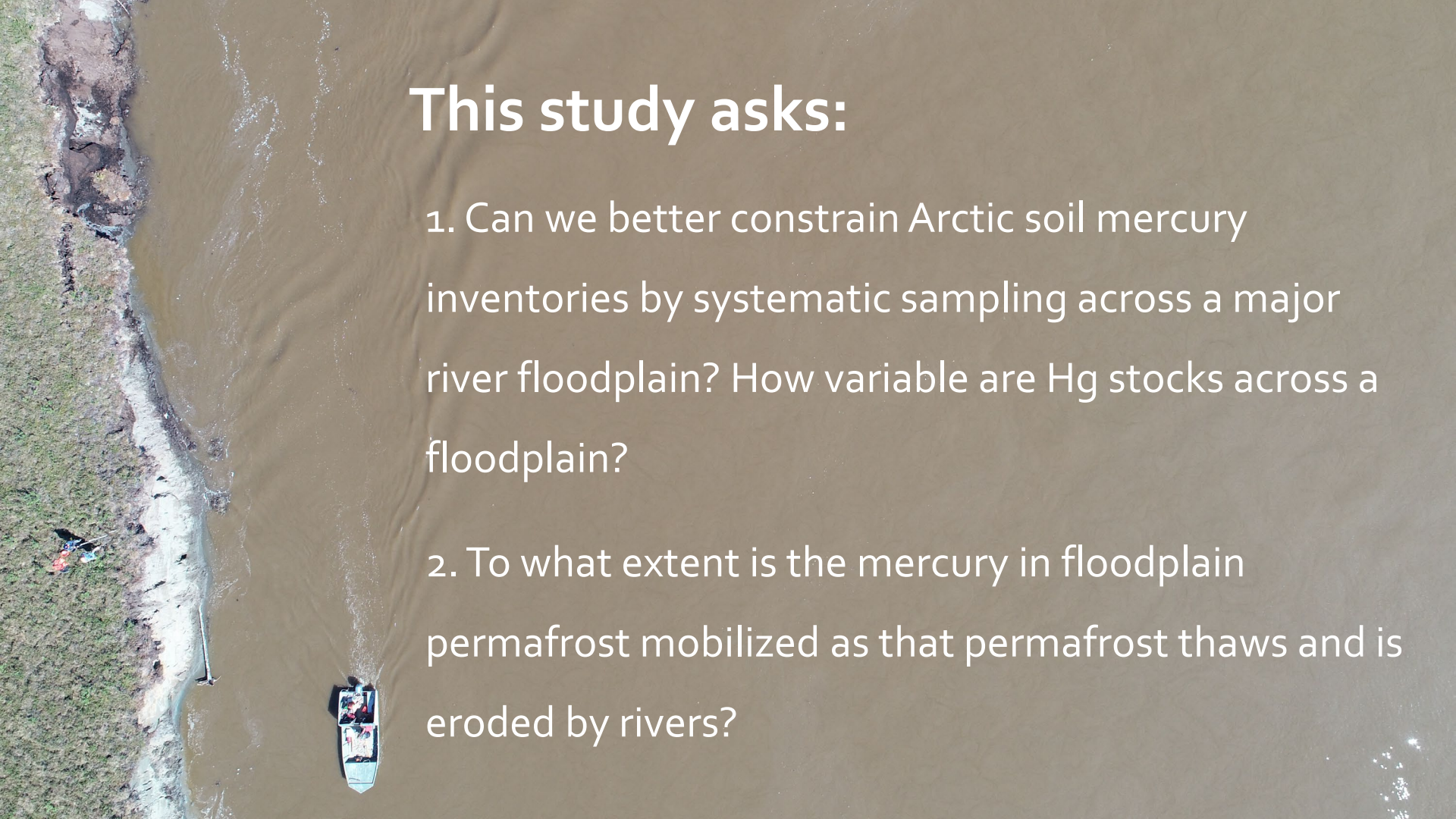


Organic Carbon Stock Map (Schuur et al. 2015)

NEED MORE SAMPLES!



Mercury Stock Map (Schuster et al 2018)



This study asks:

1. Can we better constrain Arctic soil mercury inventories by systematic sampling across a major river floodplain? How variable are Hg stocks across a floodplain?

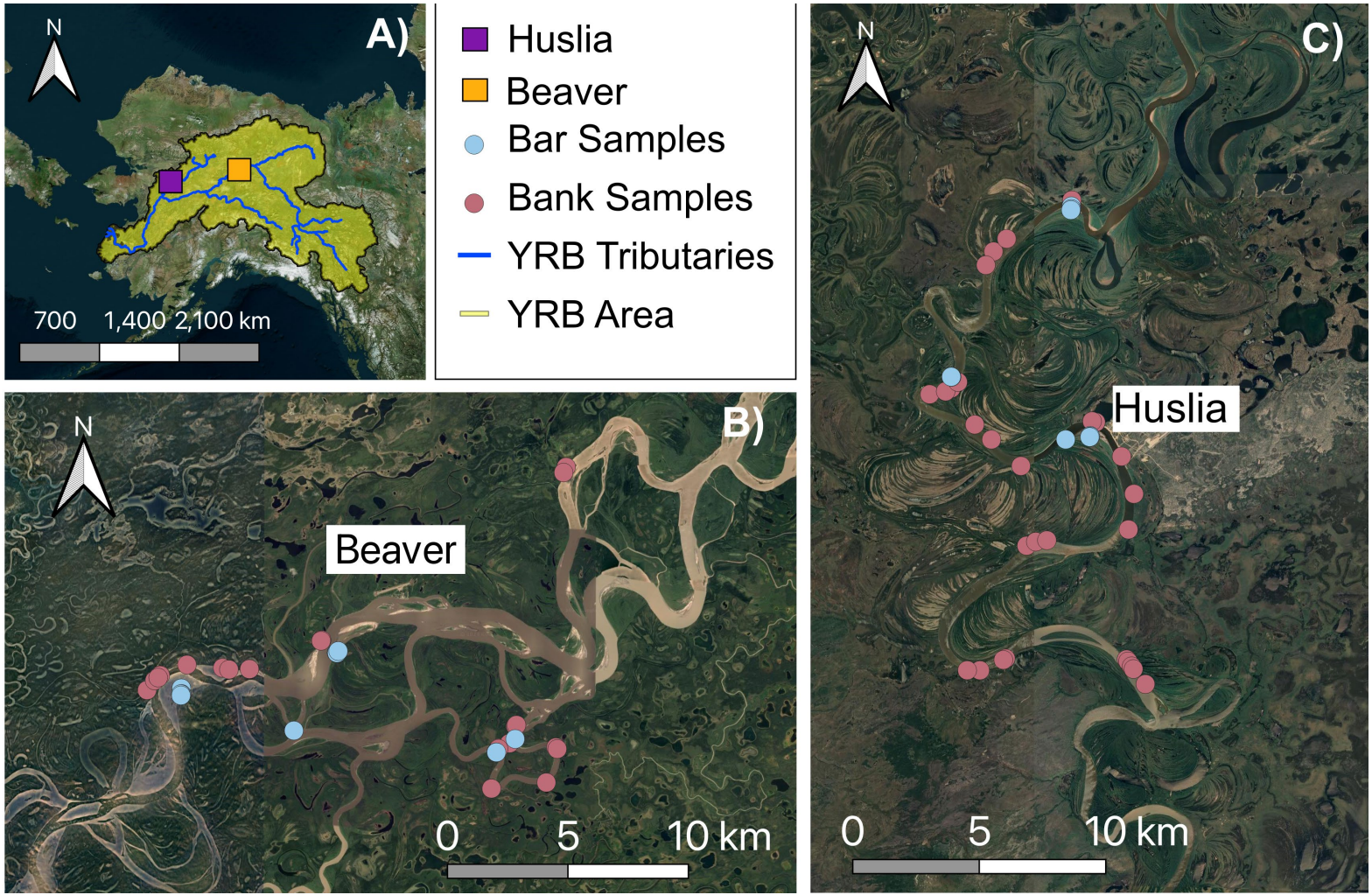
2. To what extent is the mercury in floodplain permafrost mobilized as that permafrost thaws and is eroded by rivers?

Field Sites: Yukon River Basin

- Discontinuous permafrost
- Distinct sediment properties
  - Huslia - coarse sand
  - Beaver - gravel
- Varying levels of:
  - Flooding
  - Erosion
  - Permafrost thawing

2022 Sediment Samples

n = 413
Bars n = 29
Banks n = 56



Smith et al. *Environ. Res. Lett.* (2024)

Collecting Sediment Samples

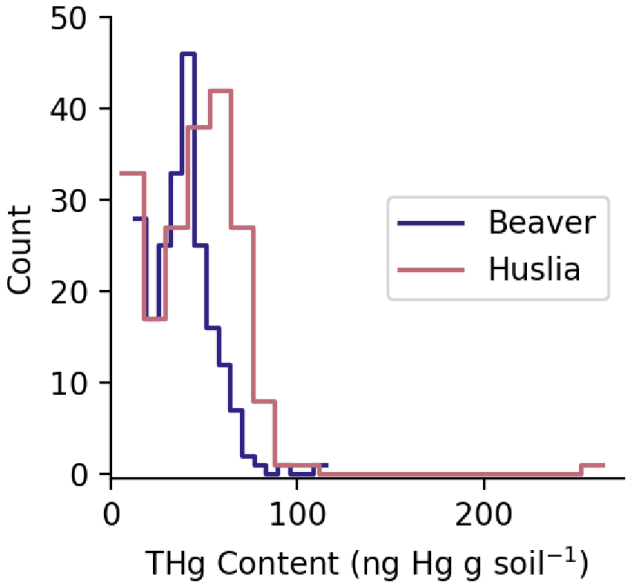
Photo Credits: Madison Douglas

Taking sedimentological and geomorphological measurements

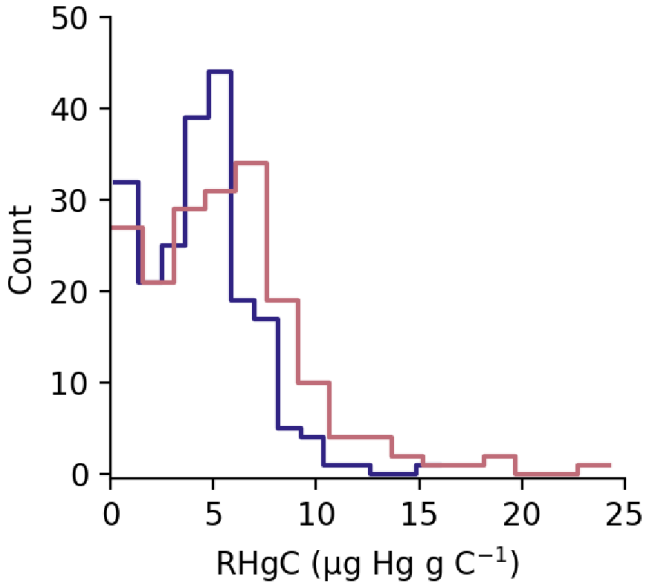
Photo Credits: Isabel Smith and Emily Seelen

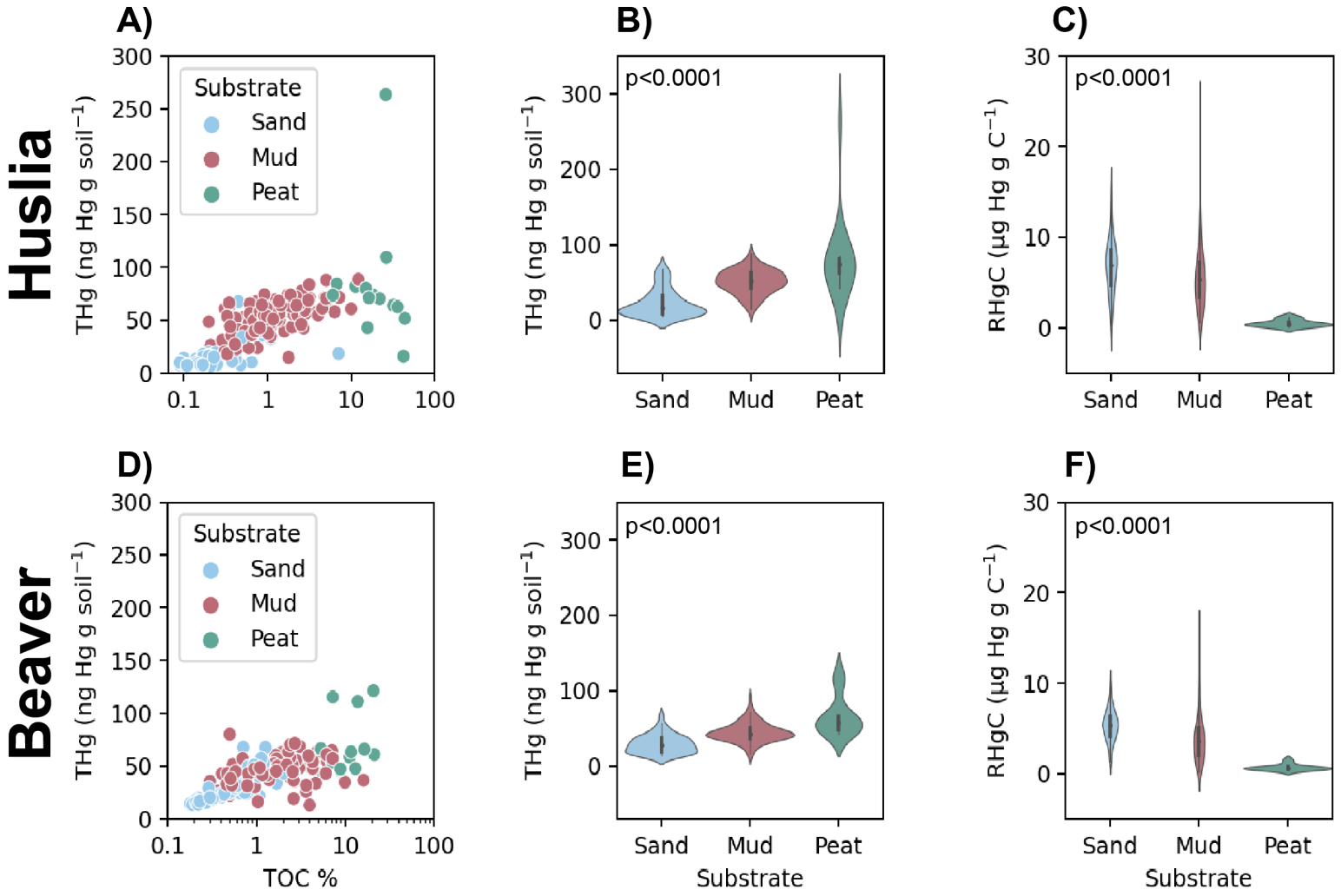
Sediment Analysis Results

A)



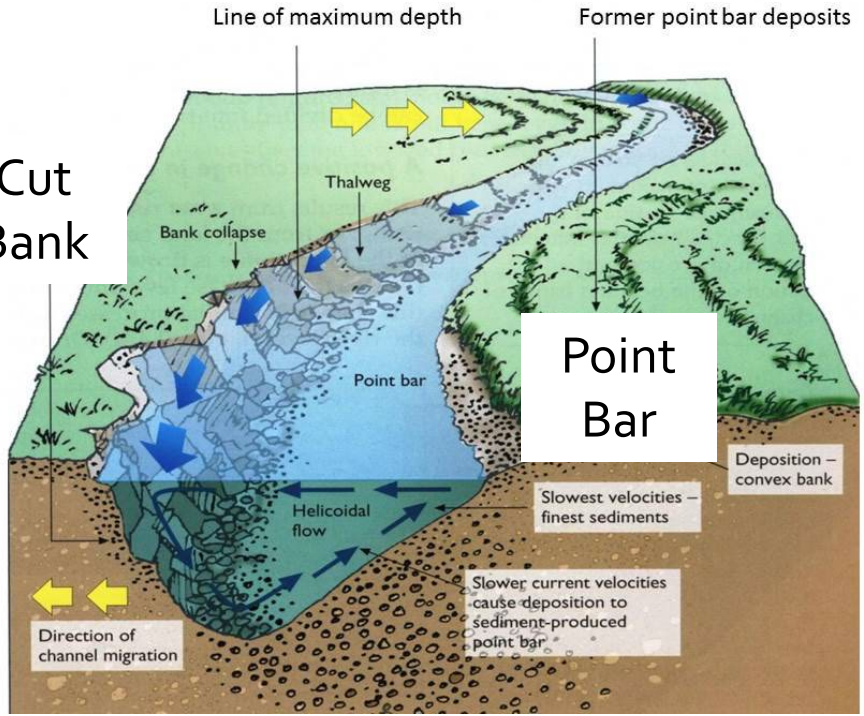
B)




Huslia
Beaver
A)
B)
C)
D)
E)
F)
Substrate
Sand
Mud
Peat
THg (ng Hg g soil^{-1})
RHgC (µg Hg g C^{-1})
p<0.0001
TOC %
Substrate

1. ~~Can we better constrain pan-Arctic soil mercury inventories by systematic sampling across a major river floodplain?~~ **And how variable are Hg stocks across a floodplain?**

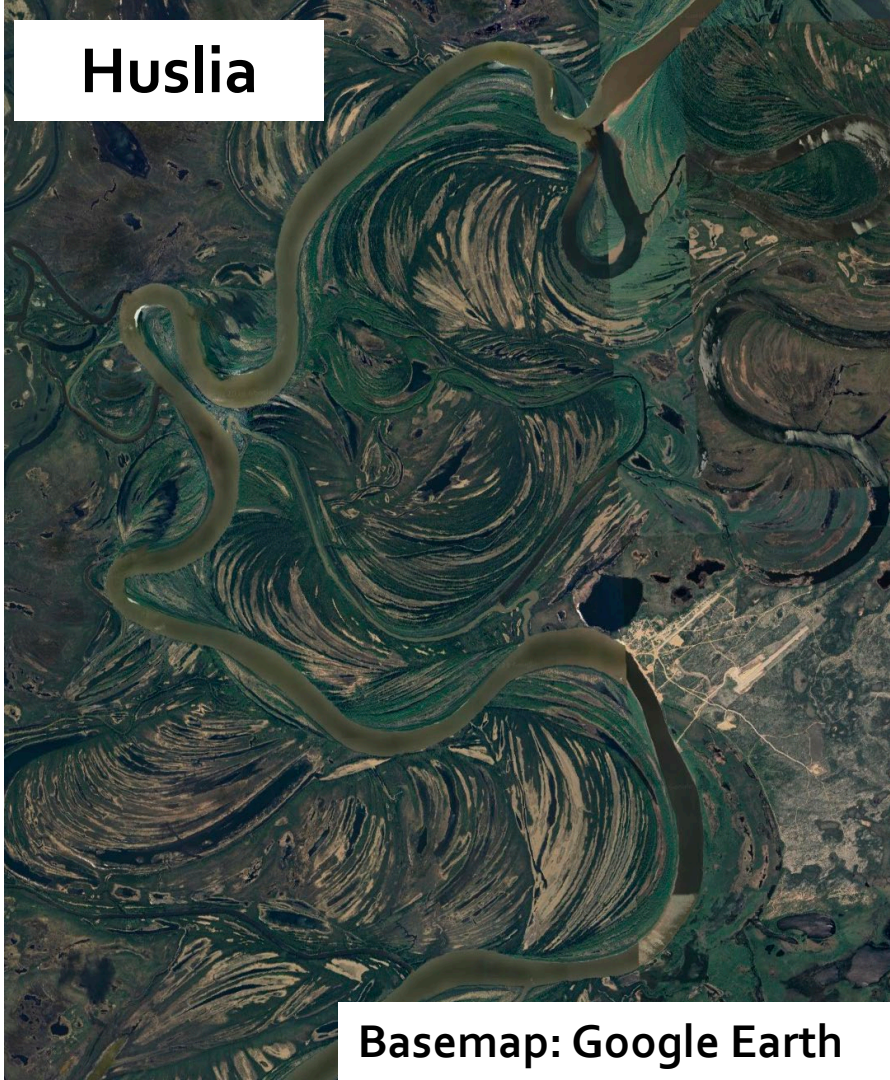
River Morphology

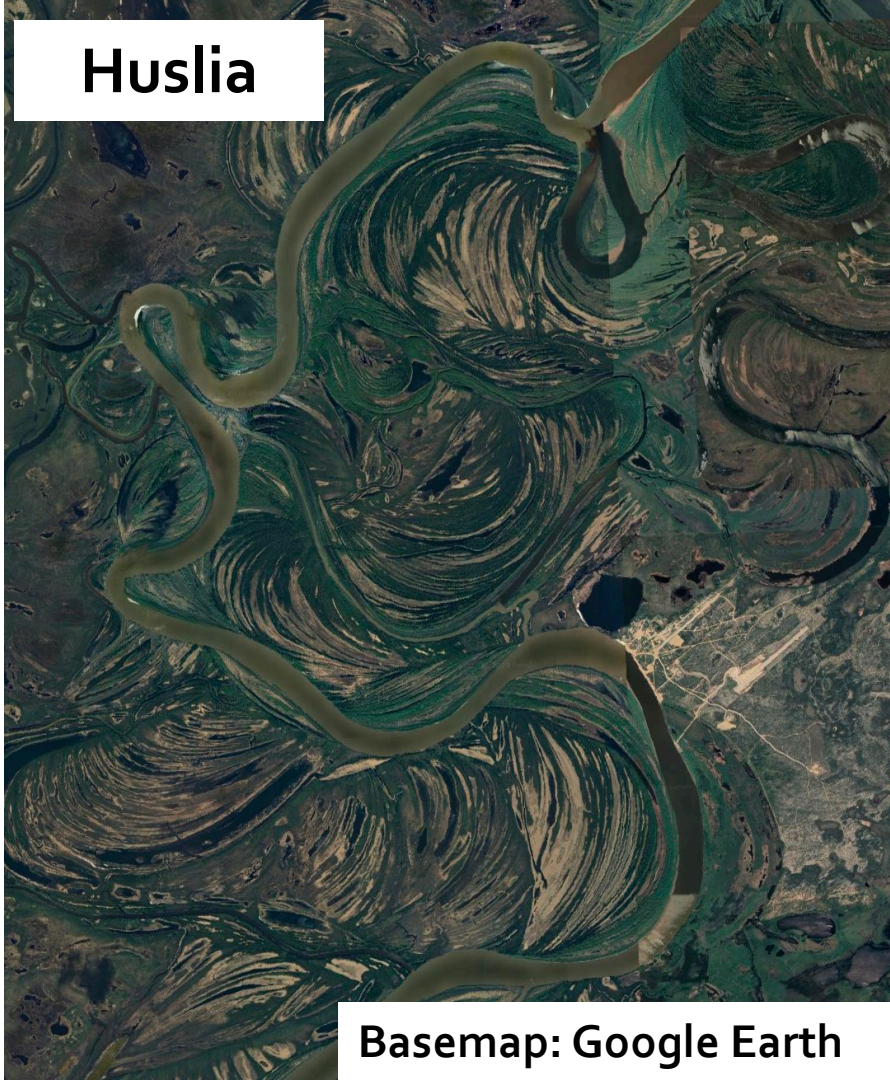


Cut Bank

Point Bar

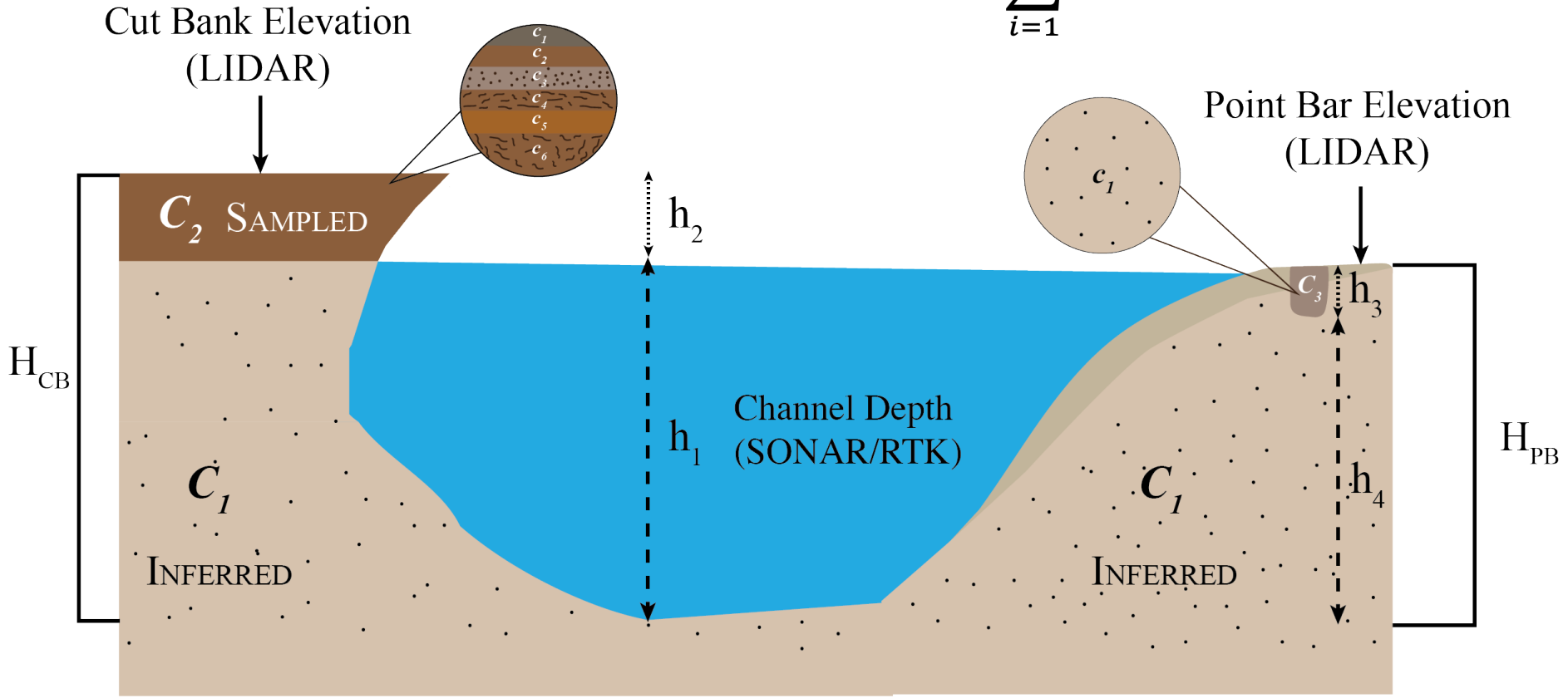
Figure Credit: Patricia Kokkinos

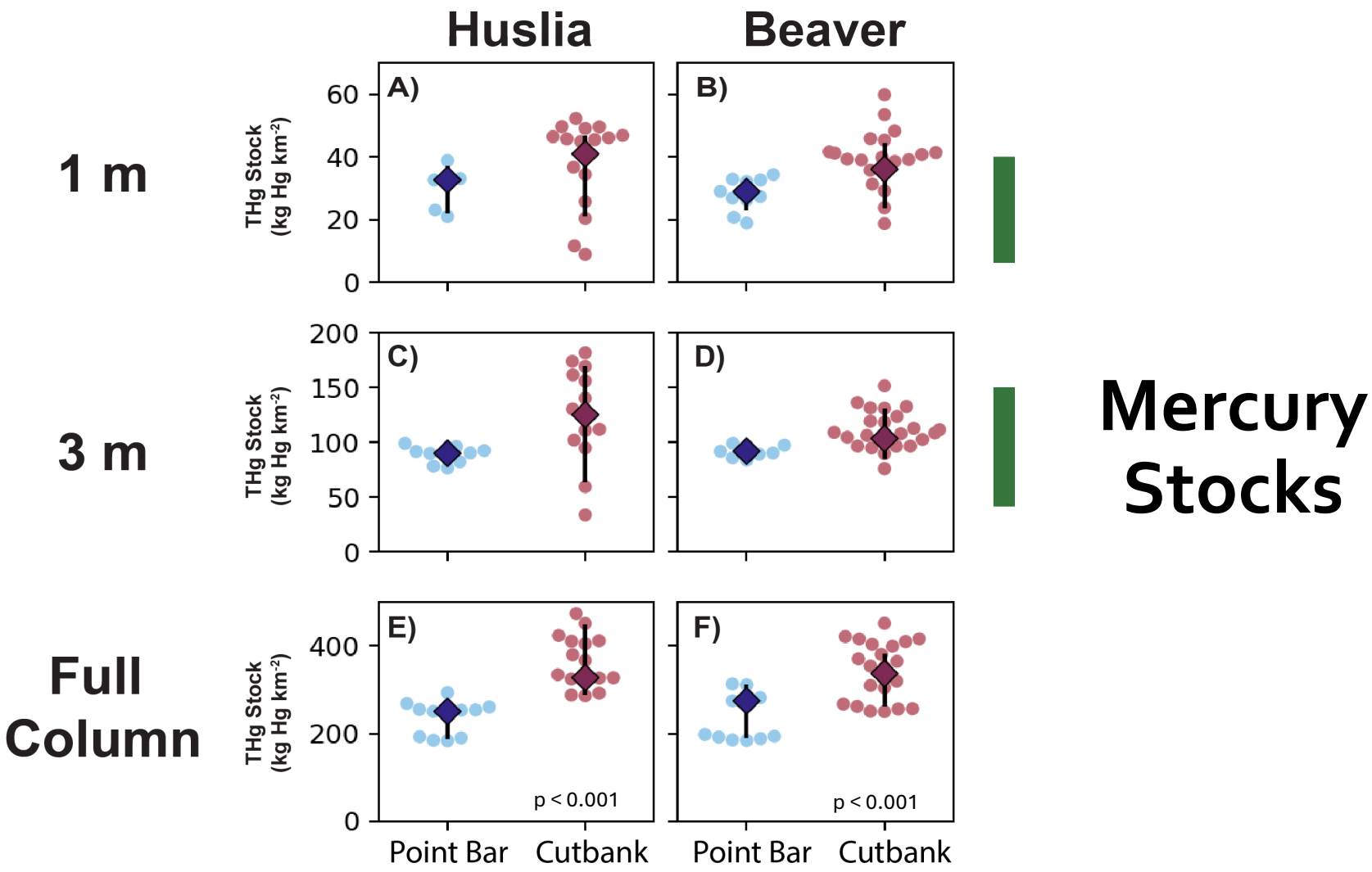



Huslia
Basemap: Google Earth

Bank Stock Reconstruction

$$C = \sum_{i=1}^{n} p_i * H_i * c_i(1 - M_{H_2O,i})$$




Huslia
Beaver
1 m
3 m
Full Column
THg Stock (kg Hg km-2)
A)
B)
C)
D)
E)
F)
0
20
40
60
50
100
150
200
400
p < 0.001
p < 0.001
Point Bar
Cutbank
Point Bar
Cutbank
Mercury Stocks

This study asks:

✅Can we better constrain Arctic soil mercury inventories by systematic sampling across a major river floodplain? How variable are Hg stocks across a floodplain?

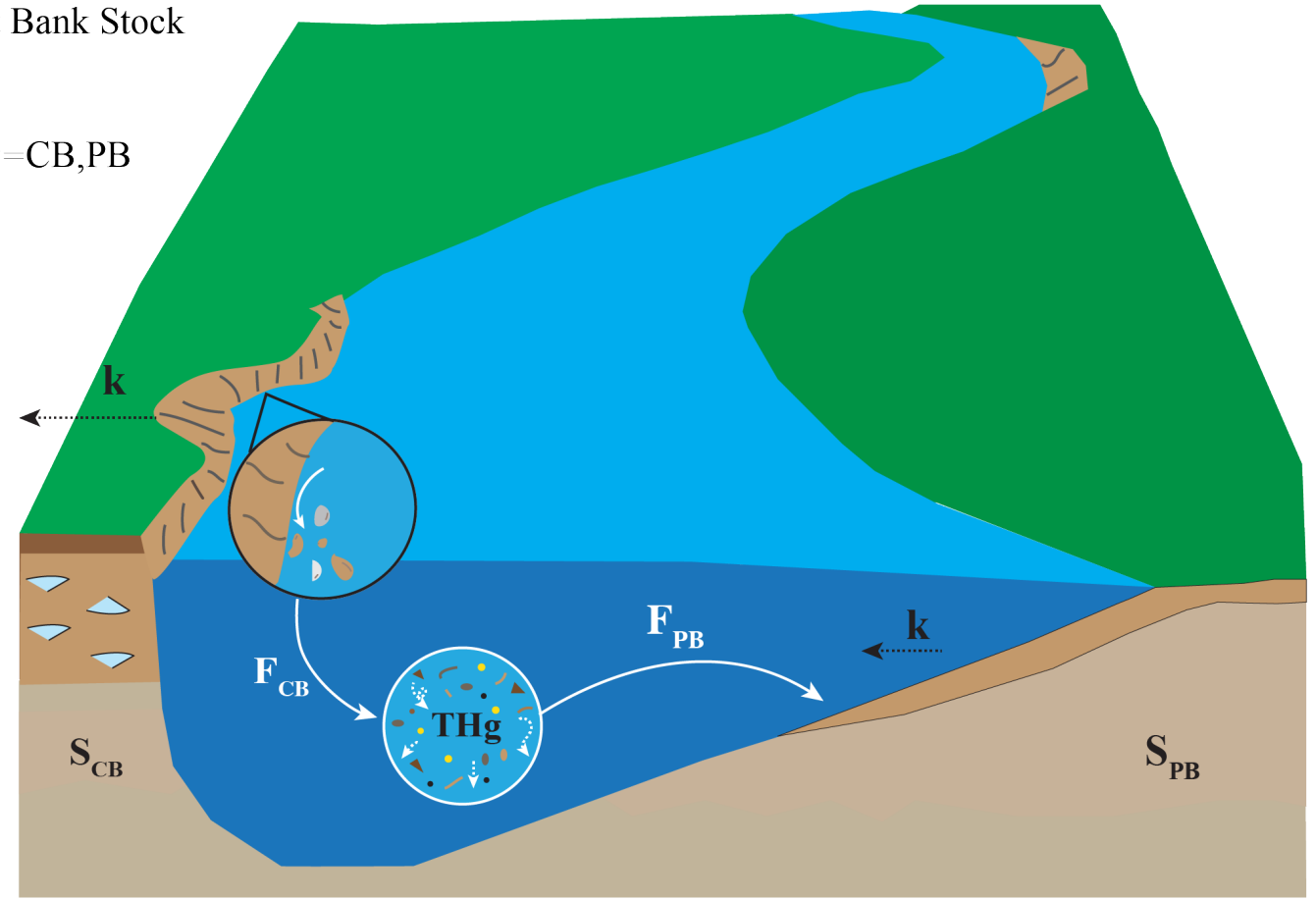
2. To what extent is the mercury in floodplain permafrost mobilized as that permafrost thaws and is eroded by rivers?

Particulate Hg Flux Model

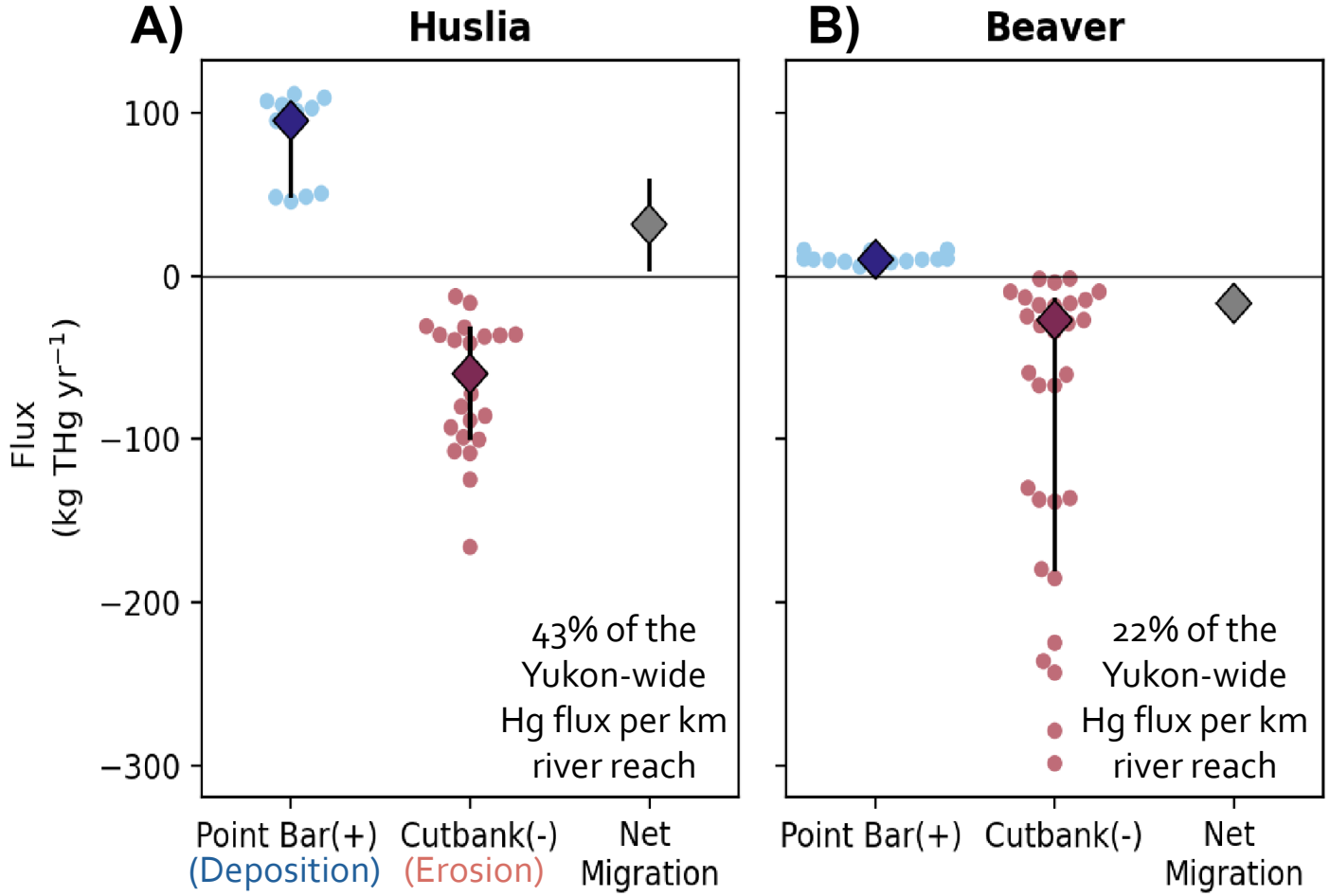
F- Flux
L - River Reach Length
S - Point Bar or Cut Bank Stock
k - Migration rates

$F = L*k*S_x$ where x=CB,PB

$F_{Net} = -F_{CB} + F_{PB}$



Mercury Fluxes



Conclusions

- THg and RHgC show trends with substrate composition.
- Environmental factors, like substrate composition, should be incorporated into future Hg models
- Understanding sediment erosion and deposition is critical for assessing changes in Hg transport at least on short time scales.

Acknowledgements & Questions