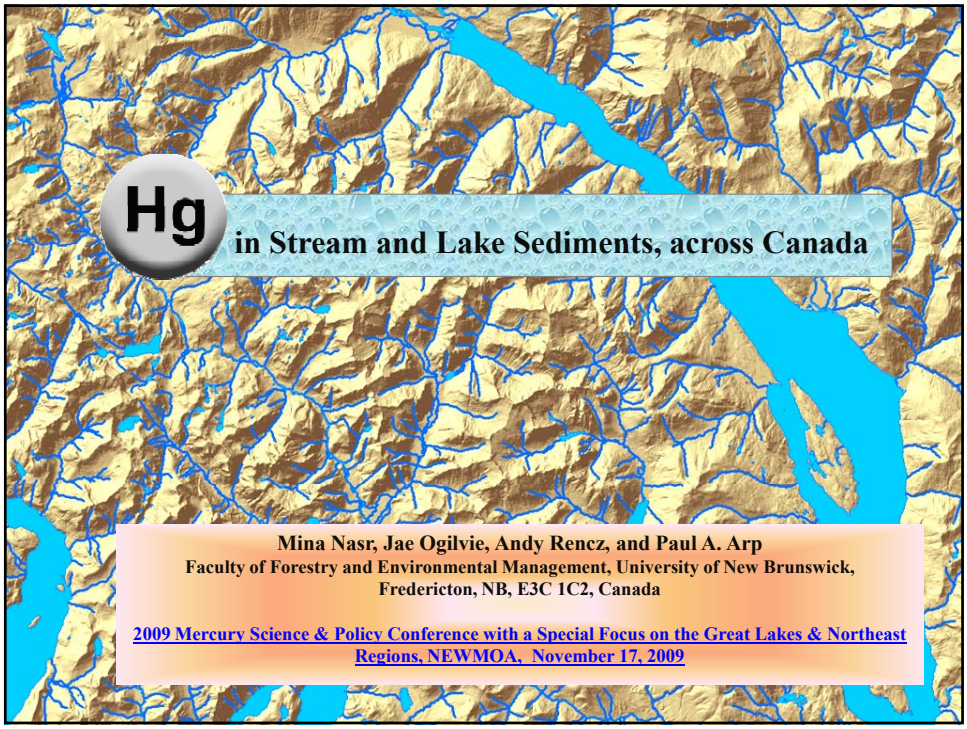

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Introduction

This study represents the analyses of Geological Survey of Canada open-file data for mercury (Hg) concentrations in lake and stream sediments at about **142,000** sampling locations.

The extent of stream or lake Hg transfer via sediments depends on:

- upland soil and stream bank erosion rates (Bagnato et al., 2009; Friske et al., 1995; Miller et al., 1998; Smith et al., 1999; Tenhulscher et al., 1992),
- geological processes that release Hg containing minerals (Bagnato et al., 2009; Coker et al., 1995; Gustin, 2003; Jebrak et al., 2002; Smith et al., 2008),
- geochemical correlations between Hg and mineral composition, and physical and chemical properties of water (pH, temperature, color, etc...) (Vaidya et al., 2000),
- transformation, mobilization and transportation of Hg from sediments to water and from water to sediments (Chadwick et al., 2006; Skyllberg 2006; Vaidya et al., 2000), and
- atmospheric deposition (Hermanson et al., 1998).

Purpose

The main objective of this study is to discern the hydro-geospatial context of Hg variations in lake and stream sediments by

- upland/lowland sampling spots,
- percentage of wet-area coverage per basin above the sampling locations, and
- geological substrates

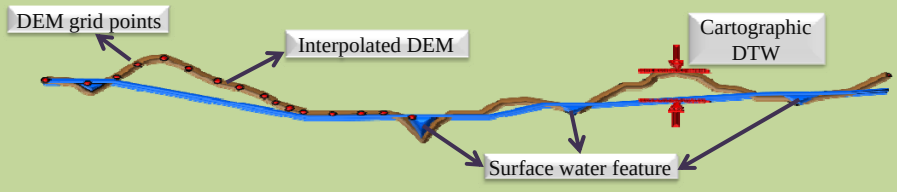
Techniques

Digital elevation models (DEMs) were used to delineate:

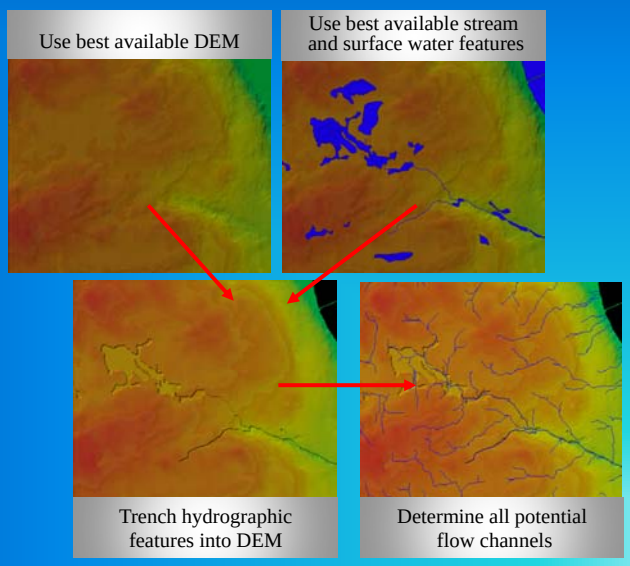
- local flow channels, directions and accumulation, stream orders, and catchment areas by lake and stream sampling location
- uplands from lowlands, based on a cartographic depth-to-water index (DTW)
  - across Canada at 300 m resolution
  - across specific sampling regions, at 10 m resolution

Techniques

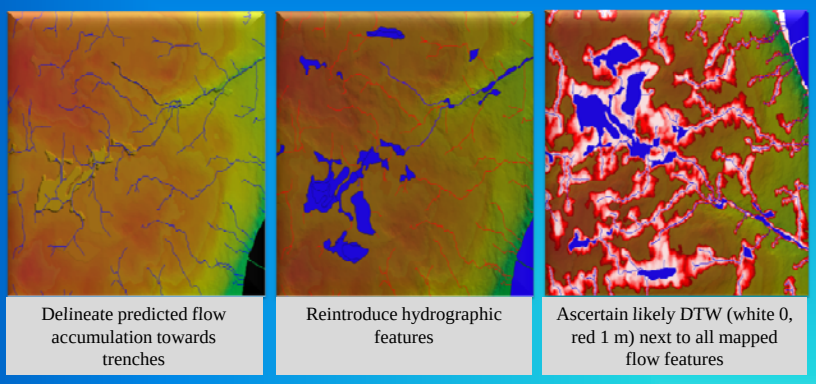
Deriving the cartographic depth-to-water index (DTW) based on digital elevation modeling

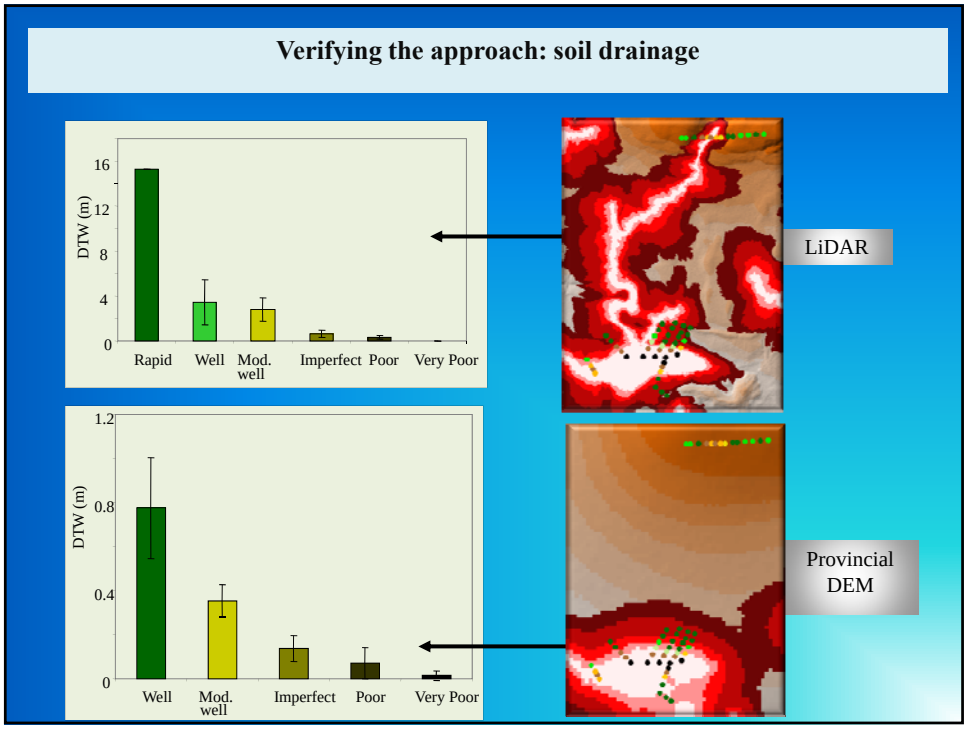


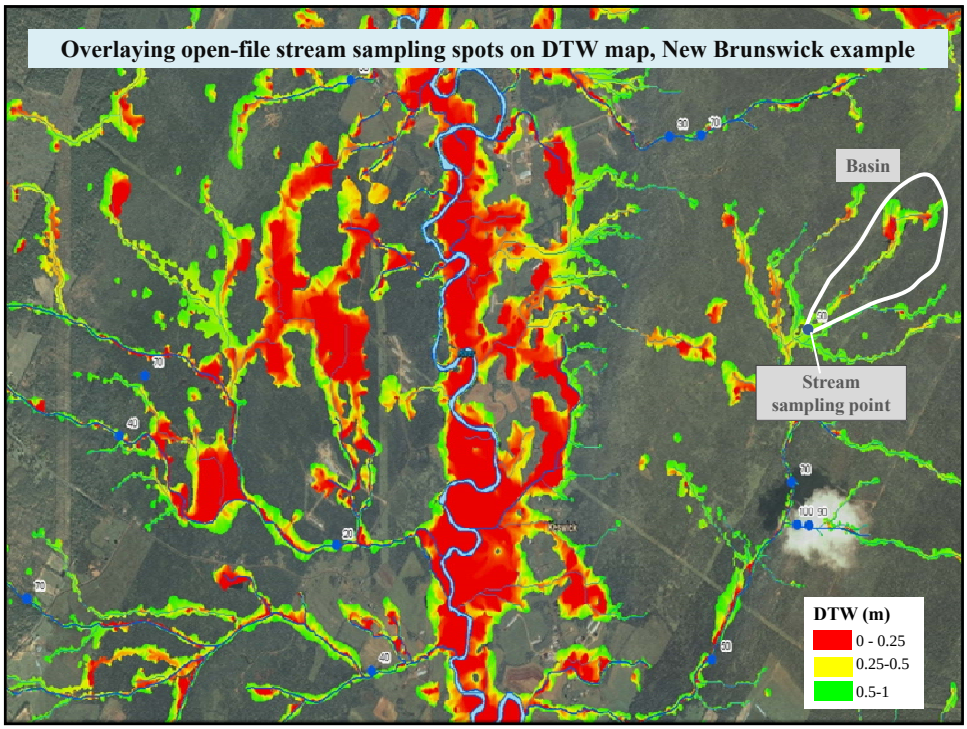
Automated flow-channel derivation from DEMs

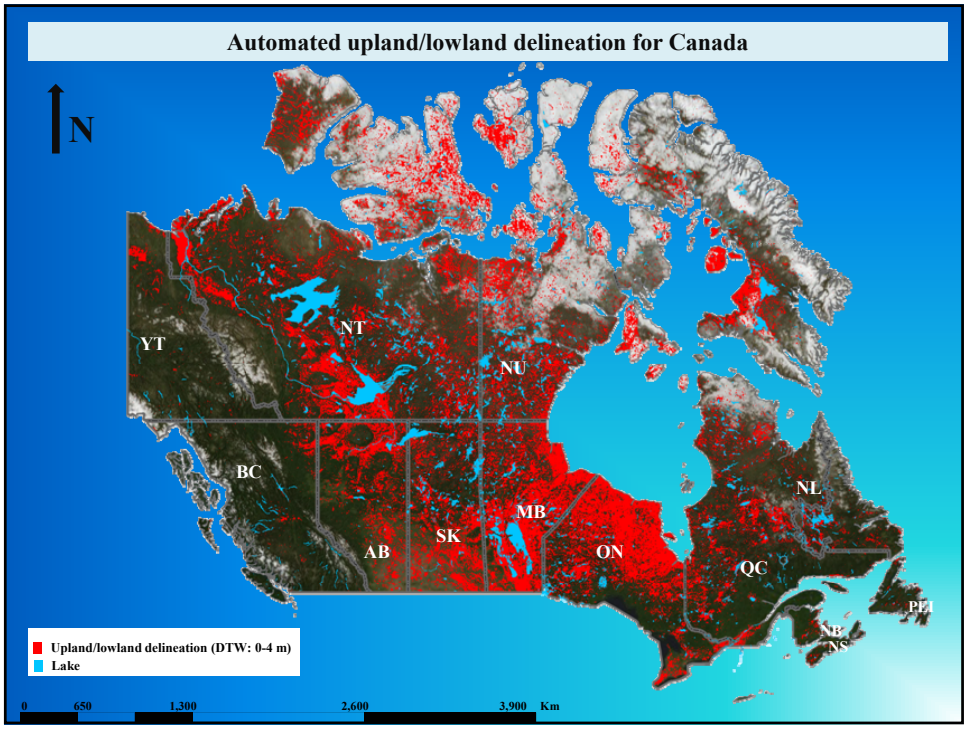


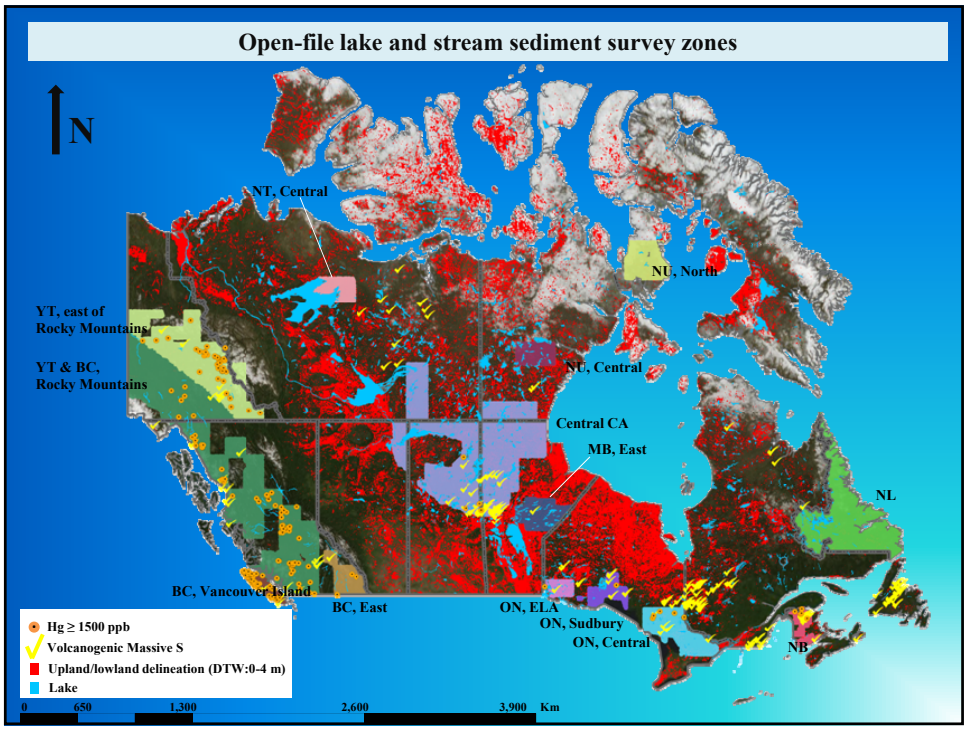
Automated upland/lowland delineation based on DTW




Verifying the approach: soil drainage
DTW (m)
16
12
8
4
0
Rapid
Well
Mod. well
Imperfect
Poor
Very Poor
LiDAR
DTW (m)
1.2
0.8
0.4
0
Well
Mod. well
Imperfect
Poor
Very Poor
Provincial DEM


Overlaying open-file stream sampling spots on DTW map, New Brunswick example
Basin
Stream sampling point
DTW (m)
0 - 0.25
0.25-0.5
0.5-1


Automated upland/lowland delineation for Canada
N
YT
NT
NU
BC
AB
SK
MB
ON
QC
NL
PEI
NB
NS
Upland/lowland delineation (DTW: 0-4 m)
Lake
0
650
1,300
2,600
3,900
Km

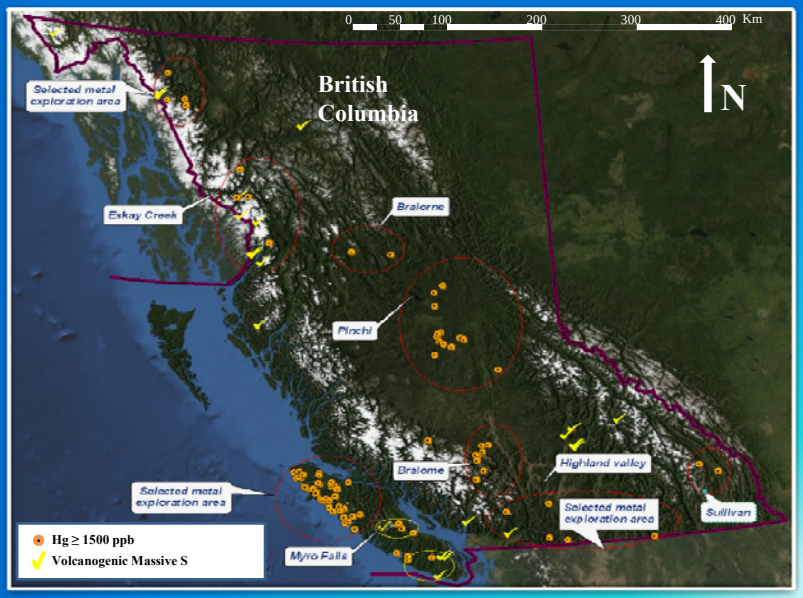

Open-file lake and stream sediment survey zones
N
NT, Central
NU, North
YT, east of Rocky Mountains
YT & BC, Rocky Mountains
NU, Central
Central CA
MB, East
NL
BC, Vancouver Island
BC, East
ON, ELA
ON, Sudbury
ON, Central
NB
Hg ≥ 1500 ppb
Volcanogenic Massive S
Upland/lowland delineation (DTW:0-4 m)
Lake
0
650
1,300
2,600
3,900
Km

Results: Hg concentrations (ppb) in lake & stream sediments, by survey zones and upland/lowland delineation

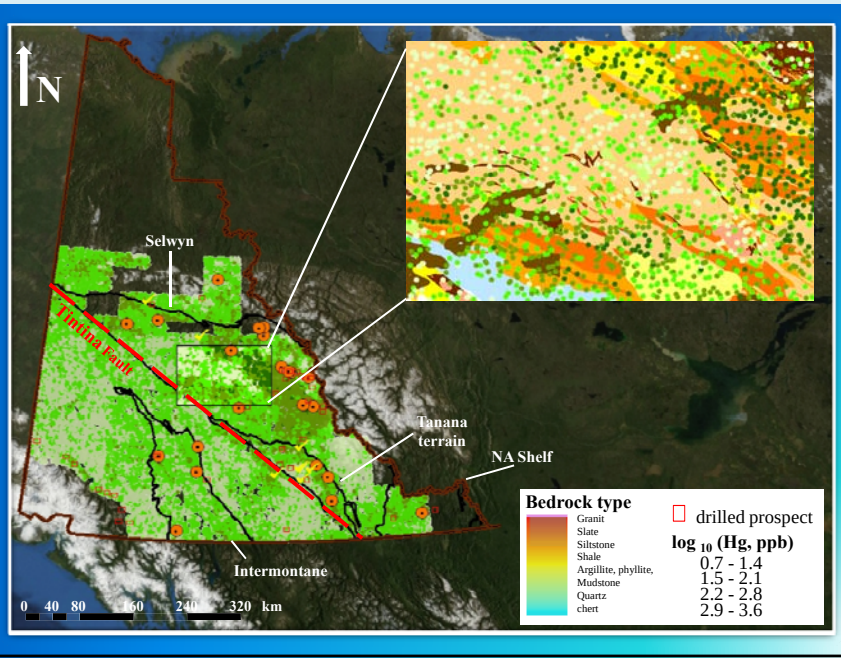
	Hg (ppb)						Hg (ppb) Lake			Hg (ppb) Stream		
Survay zone (number)	n	Mean	Min	Max	StdD	Std. Error	Upland	Lowland	Ratio*	Upland	Lowland	Ratio*
Nunavut, Central	1,232	29	10	110	18	0.52	33	26	1.27			
British Columbia, East	3,972	35	10	2,380	65	1.03				36	35	1.02
Nunavut, North	2,118	44	10	150	20	0.44	45	43	1.04			
Manitoba, East	5,111	45	10	801	21	0.29	49	44	1.10			
Central Canada	31,523	55	5	1,560	33	0.19	58	51	1.15			
North West Territories, Central	1,298	57	10	295	36	0.99	60	50	1.20			
Yukon and BC, West of Anomaly	39,847	59	5	9,200	128	0.64	104	81	1.27	59	56	1.05
Ontario, ELA	1,954	80	11	1,047	46	1.05	87	74	1.18			
Labrador	20,549	82	8	900	57	0.40	87	80	1.09	33	27	1.21
New Brunswick	7,771	84	10	6,830	97	1.10	129	129	1.00	84	73	1.15
Yukon and Surrounding (Anomaly)	11,372	110	8	5,950	149	1.40	123	106	1.16	113	96	1.18
Ontario, Central	3,242	115	10	1,020	63	1.11	123	97	1.27			
Ontario, Sudbury	9,157	126	10	5,000	101	1.05	133	119	1.12	42	42	1.00
British Columbia, Vancouver Island	2,882	165	10	9,400	492	9.17				170	138	1.24
Total	**142,028**	**73**	**5**	**9,400**	**119**	**0.32**	**81**	**64**	**1.27**	**74**	**64**	**1.15**

* upland / lowland ratio

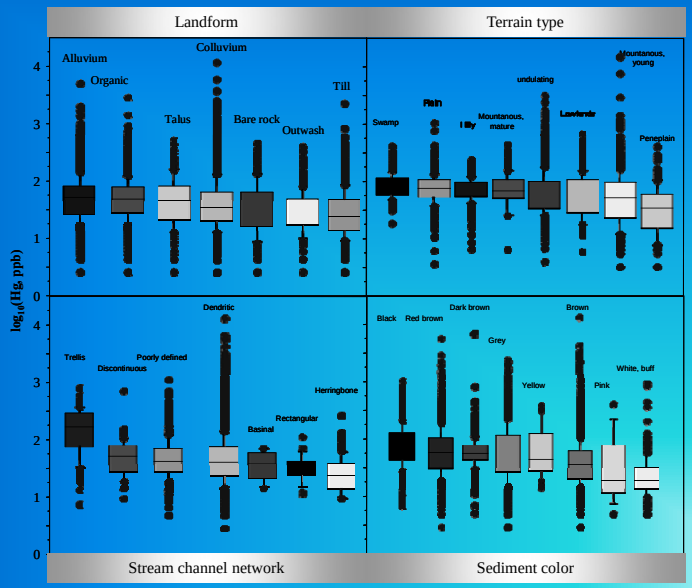
Results: Hg concentration (ppb) hotspots in stream sediments, British Columbia



Results: Distribution of Hg concentrations (ppb) in stream sediments, Yukon open-file data

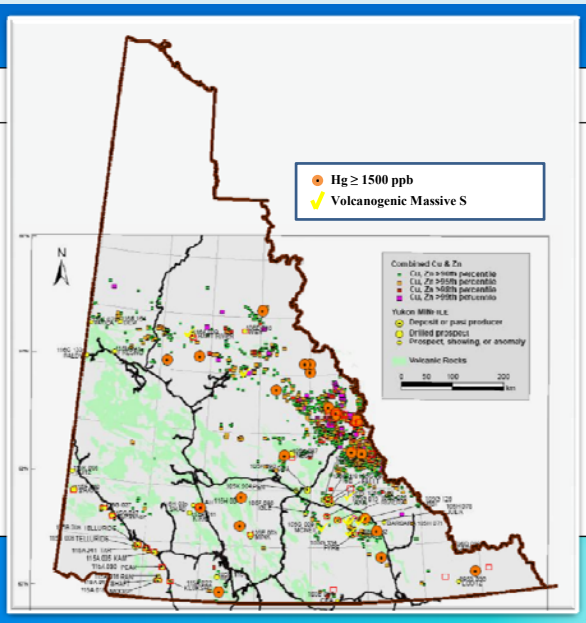


Results: log $_{10}$(Hg, ppb) concentrations by sediment and location attributes, Yukon



Results: Regression analysis for $\log_{10}$(Hg concentrations (ppb)) in stream sediment, Yukon

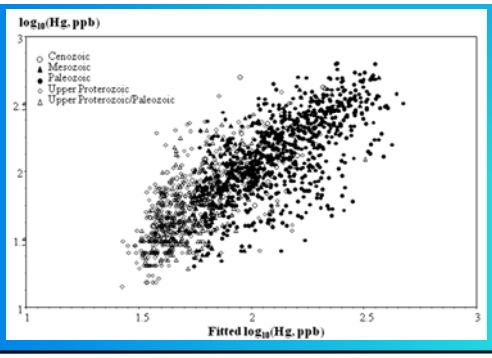
Variables	R^2
Intercept	
log10(Cu,ppb)	0.227
log10(Cd,ppb)	0.396
log10(Zn, ppb)	0.403
log10(LOI,%)	0.477
Stream width (m)	0.480
Stream depth (m)	0.484
Stream order	0.488
Flow rate	0.490
Bedrock age (10^6 yrs)	**0.491**



Results: Regression analysis for $\log_{10}$(Hg concentrations (ppb)) in stream sediment, Yukon

Variables	Coeff.	Std. Error	Std. Coeff.	t-Value	P-Value	R^2
Intercept	2.124	0.042	2.120	50.800	<0.0001	
log10(Cu,ppb)	0.228	0.013	0.382	17.500	<0.0001	0.480
log10(Ag,ppb)	0.254	0.019	0.264	13.500	<0.0001	0.543
log10(LOI,%)	0.172	0.020	0.144	8.570	<0.0001	0.561
Rock type: era[a]	**0.145**	**0.013**	**0.211**	**11.100**	**<0.0001**	**0.594**
(Aw/AB)$^{0.5}$	**-0.405**	**0.091**	**-0.074**	**-4.430**	**<0.0001**	**0.604**

[a] Rock type coding: Mezozoic 1, Paleozoic 1, Cenozoic 0, upper Proterozoic 0, Plaeozoic/Upper Proterozoic 0
Aw: wet area; AB: basin area

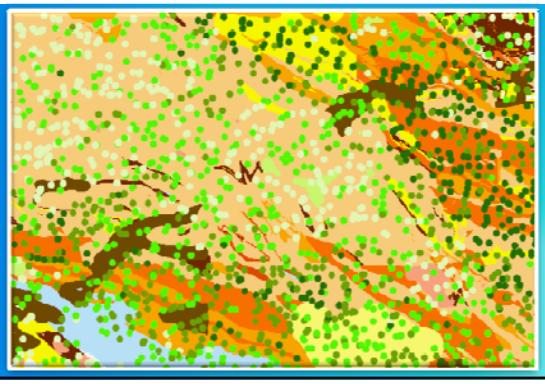


Results: Hg concentrations (ppb) in stream sediment, Yukon

Hg concentrations decrease with increasing wet-area coverage per basin.

log_{10} (Hg, ppb)	Mean AB (m^2)	Mean Aw (m^2)	Aw/AB (%)
0.7 -1.4	14,091,364	2,340,856	**16.6%**
1.5 - 2.1	19,225,483	2,773,182	**14.4%**
2.2 - 2.8	18,024,657	2,504,088	**13.9%**
2.9 - 3.6	5,465,382	596,753	**10.9%**

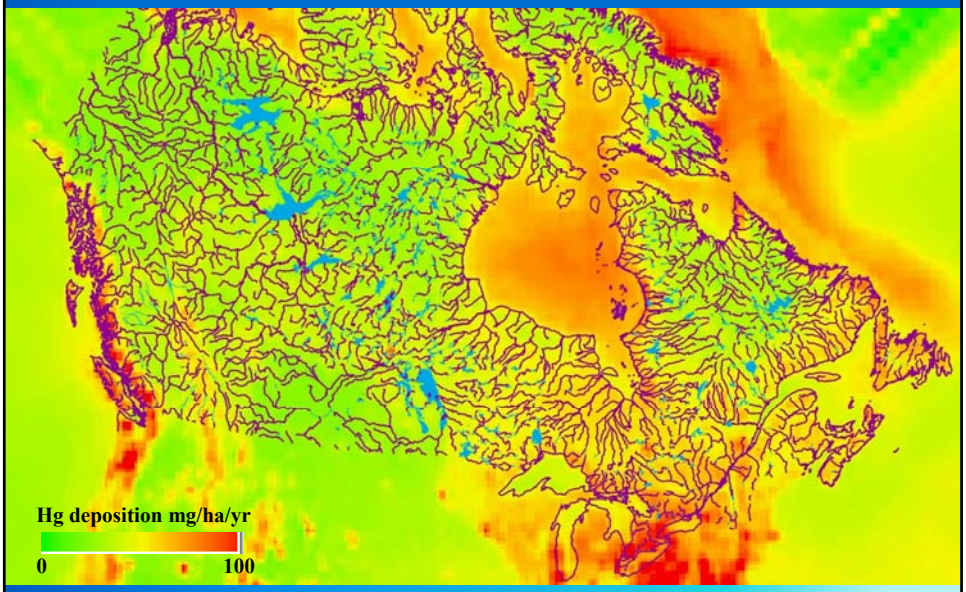
Aw: wet area; AB: basin area



Summary

- Hg concentrations are, on average, slightly higher in lake than in stream sediments, but the latter are more variable than the former.
- High Hg concentration clusters occur near the central north-eastern border of Yukon, on Vancouver Island, in south-eastern of Ontario, and north-central New Brunswick.
- The Canada-wide upland/lowland delineation pattern reveals, on average, a consistent reduction in Hg concentrations from upland to lowland sediment sampling locations.
- Hg concentrations in Yukon stream sediments increase
  - with increasing Cd, Cu, and Zn (ppm), loss on ignition (LOI,%), stream depth, and
  - with decreasing stream order (from primary to quaternary), stream width and flow rate ($R^2 = 0.491$).
- The best-fitted regression results are further improved to 60% by adding wet-area percentage per basin and geological era as additional Hg-concentration predictor variables.

Next step: placing all of the above within the atmospheric Hg deposition context, across Canada



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Acknowledgements

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