SWOT measurements of northern hydrology

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(In terms of surface area)

The vast majority of the world's lakes and wetlands are in the high northern latitudes.
IMPORTANCE:
1. Greenhouse gas exchange
2. Global thermohaline circulation
3. Migratory birds and ecosystems
4. Water supply, hydropower & navigation
5. ...

UNKNOWNNS:
1. Current storage distribution, fluxes and variability
2. Water balances
3. Precipitation
4. ....
GLWD yields ~203,000 lakes (sized 0.1 – 50 km²) northwards of 45N

Best currently available dataset (GLWD, 2004)

(NOTE: Yongwei Sheng talk tomorrow a.m.)

(Walter et al., 2007)
SWOT will measure: $A_t$ and $dH/dt; dH/dx$

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(storage anomaly, m$^3$)
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**Lakes:** $(A_t)(dH/dt) = dS/dt$
*(storage anomaly, m$^3$)*

**Rivers:** $(A_t/L)(dH/dt)(v_{est}) = dQ/dt$
*(discharge anomaly, m$^3$/s)*

(estimate from $dH/dx$; OR calibrate from ground $Q$ or $v$ data)
SWOT will measure: $A_t$ and $\frac{dH}{dt}$; $\frac{dH}{dx}$

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Simulating SWOT: 9 lakes of Peace-Athabasca Delta

A_t: MODIS
dH/dt: ground

(Note: Tamlin Pavelsky talk tomorrow a.m.)
\((A_t)(dH/dt) = dS/dt\)

\((\sim 200 - 500,000 \, \text{m}^3)\)
HYDRAULIC GEOMETRY

dH/dt vs. A_t
("Area-stage relationship")
dH/dt vs. A_t ("Area-stage relationship")

**LINEAR and variable**
Lake bathymetry:
Lake size:

![Graph showing the relationship between area stage and regression slope, with an R² value of 0.68.](image)
For a circle:

\[ A \text{ (km}^2) \]
For nature: (200,000 lakes, GLWD)
\[ \Delta S = (A)(\Delta H) \]

\[ \varepsilon_{\Delta S} = (\Delta H^2 \varepsilon_A^2 + A^2 \varepsilon_{\Delta H}^2)^{1/2} \]

\[ \varepsilon_{\Delta H} = \left[ \left( \varepsilon_{\Delta S}^2 - \Delta H^2 \varepsilon_{\Delta A}^2 \right) / A^2 \right]^{1/2} \]
\[ \Delta S = (A)(\Delta H) \]

\[ \varepsilon_{\Delta S} = (\Delta H^2 \varepsilon_A^2 + A^2 \varepsilon_{\Delta H}^2)^{1/2} \]

\[ \varepsilon_{\Delta H} = \left(\frac{(\varepsilon_{\Delta S}^2 - \Delta H^2 \varepsilon_{\Delta A}^2)}{A^2}\right)^{1/2} \]

\[ \varepsilon_{\Delta S} = 10,000 \text{ m}^3; \quad \varepsilon_{\Delta A} = 8000 \text{ m}^2 \]
SWOT and rivers: Lena River, Siberia

At: MODIS

dQ/dt: ground
SWOT and rivers: Lena River, Siberia

HYDRAULIC GEOMETRY

("Area-discharge relationship": power law)

(Time lag = +8 days)
(dQ/dt vs. A: POWER LAW and variable)
(dQ/dt vs. A: POWER LAW and variable)
HYDRAULIC GEOMETRY

\[ W = aQ^b \]
\[ D = cQ^d \]
\[ V = eQ^c \]

\[ b + d + c = 1 \]
CONCLUSIONS:

1. Northern high latitudes are wet, unknown, and important.

2. Precision of SWOT retrievals (dS/dt; dQ/dt) will vary with hydraulic geometry from lake to lake and even along the same river-course. This issue has not been addressed by VM-type simulation studies.

→ “It’s not just the specs of the satellite that matter - it’s the specs of the SITE”

3. Potential solutions: First-order area correction (lakes); building empirical rating functions over the mission lifetime for each & every SWOT target (i.e. a map of A/dH, A/dQ regression slopes); and scaling amount of multi-looking accordingly.

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BACKUP SLIDES
HYDRAULIC GEOMETRY

1.5 km²

dH/dt vs. Aₜ
("Area-stage relationship")

LINEAR and variable

1300 km²
Smith et al., “Disappearing Arctic Lakes,” Science, 2005
Even the current northern lake/wetland extent is poorly known (let alone storage!):

West Siberia
(Frey and Smith, Glob. Biogeochem. Cycles, 2008)
The solution: Semi-regular estimates of $dQ/dt$ for all high-latitude rivers.

~weekly sampling is generally sufficient to resolve the timing and magnitude of the annual hydrograph for most large Arctic rivers.

Only a few hundred high-latitude rivers are currently measured.

(Smith et al., Water Resources Research, 1996)