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EGU26-16084: Abstract

Soil Moisture Correlation with Small Water Body Extents in Canadian Wetlands:

Application to SMAP Soil Moisture Improvement

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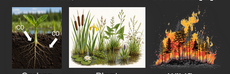
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1- Motivation & Background

Why It Matters

Wetlands are hydrologically dynamic, but poorly monitored at a global scale

In wetlands, soil moisture controls [1]:



Wet & Healthy



Drying wetlands increases fire risk and releases stored carbon [2]

Dry & Vulnerable



Soil moisture determines whether they store or release carbon [3]

The Challenge

Sparse In Situ Measurements

Point-based observations cannot capture spatial variability across wetlands



Passive microwave remote sensing is widely used for global soil moisture [4]

SMAP

- Launched in 2015
- At L-band (~1.4 GHz)



SMAP shows lower accuracy in wetlands

Why? Water contaminates the radiometer signal [5]

Limitations

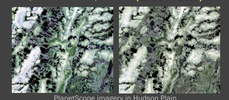
of the Current Approach

SMAP water correction is based on a static water mask (MOD44W, [6]), but it is ...

Coarse:
250 m resolution often misses small water bodies

Not dynamic:
Cannot capture the high seasonal changes in wetlands

Spring (More Water) | Late Summer (Less Water)



PlanetScope imagery in Hudson Plain

Surface water in wetlands varies seasonally; static maps fail to capture this variability

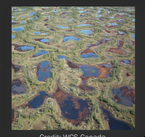
Research Gap

We still do not fully understand:

- How do dynamic small water bodies in wetlands influence SMAP signals
- Whether they can be used to estimate soil moisture in wetland regions

Key Question

Can seasonal expansion and contraction of small surface water bodies serve as a proxy for soil moisture conditions within SMAP footprint in wetlands?



Credit: WCS Canada

Objectives

Quantify the Relationship

Between soil moisture & seasonal water extent

Evaluate the Potential

Assess whether Sentinel-1-derived dynamic water maps can serve as a potential soil moisture proxy for improving SMAP retrieval performance

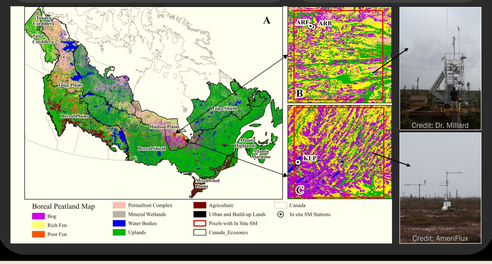
2- Study Area

Canadian Wetland Distribution [7]

Selected Sites:

- Attawapiskat River, ON, CA (CA-ARB & CA-ARF)
- Kinosheo Lakes, ON, CA (CA-KLP)

Chosen for:
1- High wetland fraction within the SMAP footprint
2- Reliable long-term measurements



Credit: Dr. Millard

Credit: AmeriFlux

Global Applicability

- Canada was chosen because of its high wetland density
- Given the global distribution of wetlands and limited in situ data, this framework is transferable across wetland systems worldwide.



The total extent of the world's wetlands (Credit: Global Lakes and Wetlands Database

3- Data Processing Workflow

1- Input Data

- SMAP Brightness Temperature
- In Situ Soil Moisture
- Sentinel-1 GRD
- Topography



2- Upscaling

- Upscale in situ soil moisture to 36-km pixel

Area-weighted average based on the proportional extent of each land cover type (Bog, Fen, Hummock, or Hollow)

3- Pre-processing

- Speckle reduction using Lee filter

4- Features

$1- \ NDPI = \frac{\sigma^0_{VV} - \sigma^0_{VH}}{\sigma^0_{VV} + \sigma^0_{VH}}$

$2- \ NVVI = \frac{\sigma^0_{VV}}{\sigma^0_{VV} + \sigma^0_{VH}}$

$3- \ NVHI = \frac{\sigma^0_{VH}}{\sigma^0_{VV} + \sigma^0_{VH}}$

$4- \ \frac{\sigma^0_{VV}}{\sigma^0_{VH}}, \frac{\sigma^0_{VH}}{\sigma^0_{VV}}$

5- Training Data

- 1300 random points per study area
- Visual labeling using high-resolution PlanetScope imagery

6- Classification

- Extract values for each point
- Random Forest Classifier [8]

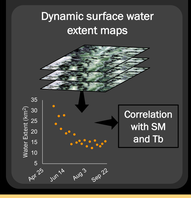


Water/Land Classification

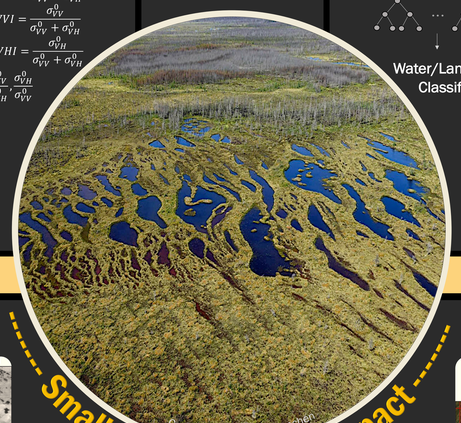
7- Post Processing

- Majority Filter (3*3 m)
- Sum surface water within each 36-km SMAP pixel
- Assess correlation between:
  - In situ SM,
  - SMAP Tb,
  - Water extents

Dynamic surface water extent maps

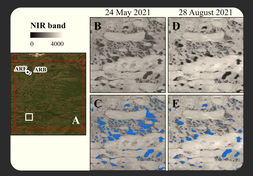


4- Results

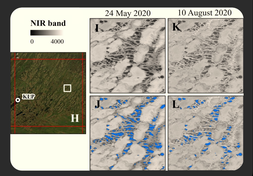


1- Surface Water Classification

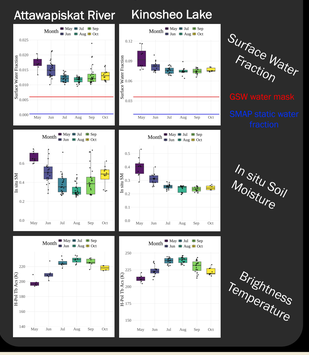
Attawapiskat River



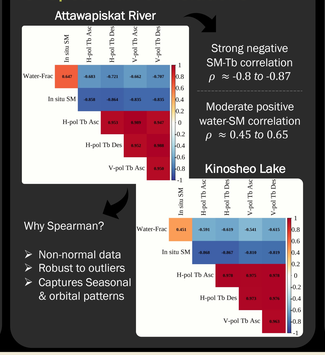
Kinosheo Lake



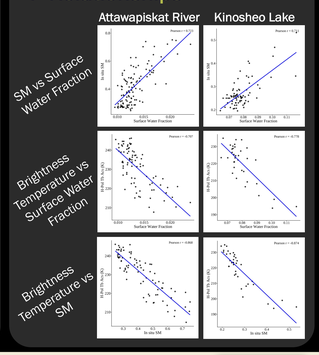
2- Temporal Dynamics



3- Spearman Correlations



4- Relationships



5- Implication and Discussion

Physical Basis for SMAP Water Correction

- SMAP water correction for Brightness Temperature

$$Tb^{Corrected} = \frac{Tb^{SMAP} - \alpha Tb^{Water}}{1 - \alpha}$$

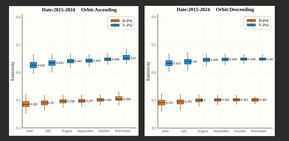
α: Fractional water derived from surface water classification maps

Brightness temperature of water can be estimated using Temperature (T) and emissivity (ε) of water

$$Tb^{Water} = \varepsilon^{Water} \times T$$

From 2014-2024 SMAP data over pure inland water bodies in Canada: ε^{Water}

H-Pol ~ 0.30 | V-Pol ~ 0.44

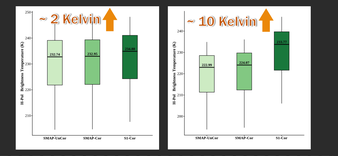


Impact of Dynamic Water Fraction on SMAP Brightness Temperature (Tb)

Tb Distributions (ascending orbit)

- SMAP_UnCor (Uncorrected Tb)
- SMAP_Cor (SMAP Tb Water Corrected Using MODIS)
- S1_Cor (Tb Dynamic Water Corrected Using Sentinel-1)

Attawapiskat River (1-2% water) | Kinosheo Lake (6-10% water)



Dynamic water correction removes water contributions more accurately → Results in drier and warmer land signals (Tb increases)

Take Home Message

Wetland surface water extent is not just noise for the SMAP soil moisture retrieval algorithm; it is a proxy for regional wetness that can be used in SMAP calibration in wetland-dominated regions

6- Future Direction

Alternative Calibration Metric for SMAP in Wetlands

Wetlands lack in situ data (remote, costly)

Current calibration is based on the agricultural network

Under-sampled wetlands limit the SMAP algorithm for accurate soil moisture estimation

Proposed Solution:

Use dynamic surface water extent (Sentinel-1) as a calibration proxy in the SMAP tau-omega model

- Scalable
- Remote
- Applicable to unmonitored wetlands

Next Steps

- Recalibrate the SMAP radiative transfer model parameters using updated Tb and the dynamic surface water extent in wetlands as proxy for soil moisture.
- Apply improved soil moisture estimates for wetlands wildfire risk and vulnerability prediction.



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References

[1] Vitt, D. H. (2006). Functional characteristics and indicators of boreal peatlands. In Boreal peatland ecosystems (pp. 9-24). Berlin, Heidelberg: Springer Berlin Heidelberg.
[2] Turetsky, M. R., Benscoter, B., Page, S., Rein, G., Van Der Werf, G. R., & Watts, A. (2015). Global vulnerability of peatlands to fire and carbon loss. Nature Geoscience, 8(1), 11-14.
[3] Price, J. S., Branfireun, B. A., Michael Waddington, J., & Devito, K. J. (2005). Advances in Canadian wetland hydrology, 1999–2003. Hydrological Processes: An International Journal
[4] Njoku, E. G., & Entekhabi, D. (1996). Passive microwave remote sensing of soil moisture. Journal of hydrology, 184(1-2), 101-129.
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Link to the References

Contact

Our Lab info

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