# Project 3.2: Real-time Spatial Information Evaluation and Processing

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# Outline

- Soil Moisture
  - Activities at the Kensaton soil moisture SMAP calibration/validation site
  - SMAP product validation over an Arctic tundra site
  - Cal/val field campaign in 2016
- Soil Freeze/Thaw
  - Ground-based networks
  - A soil freeze/haw validation campaign for SMAP



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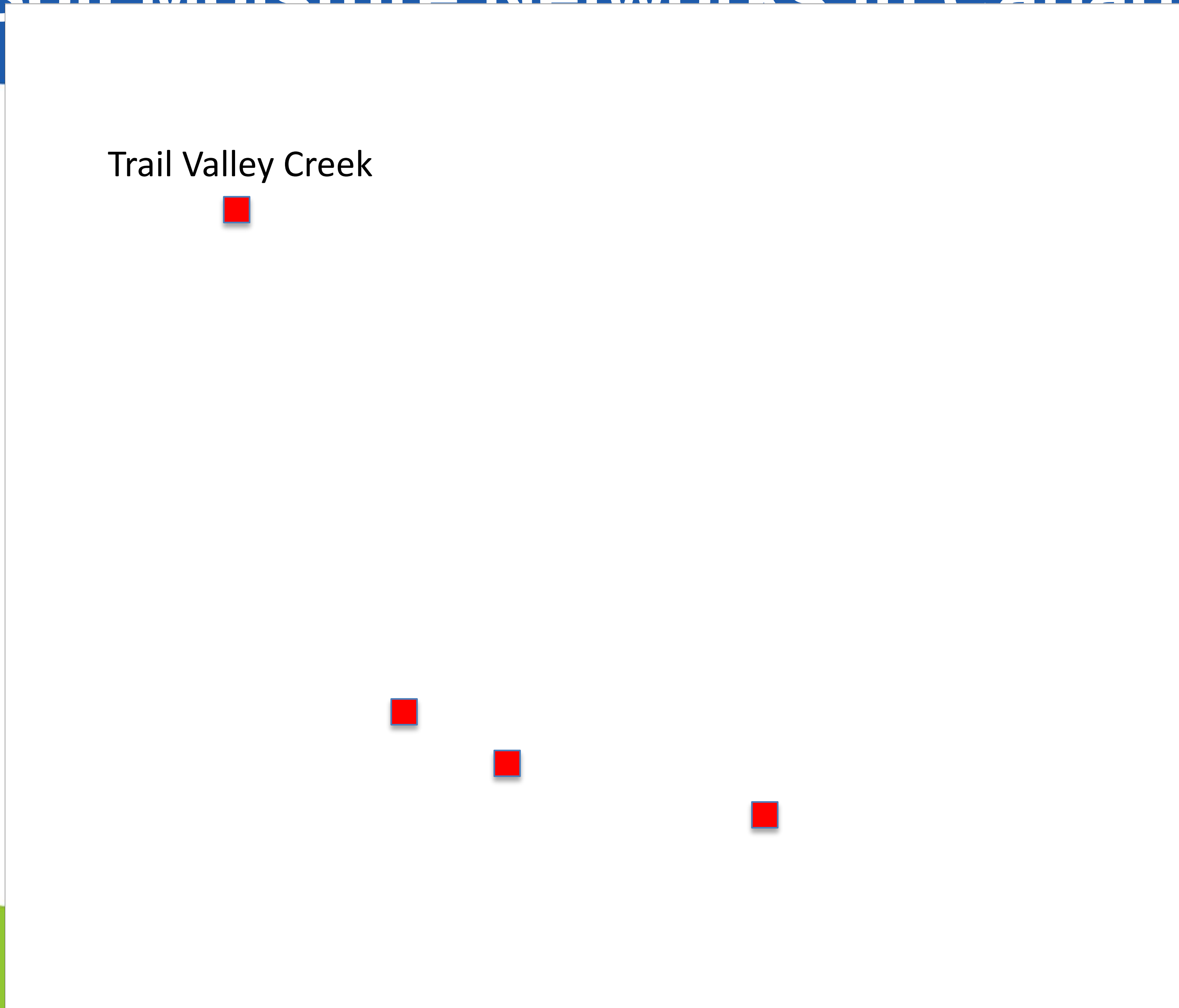
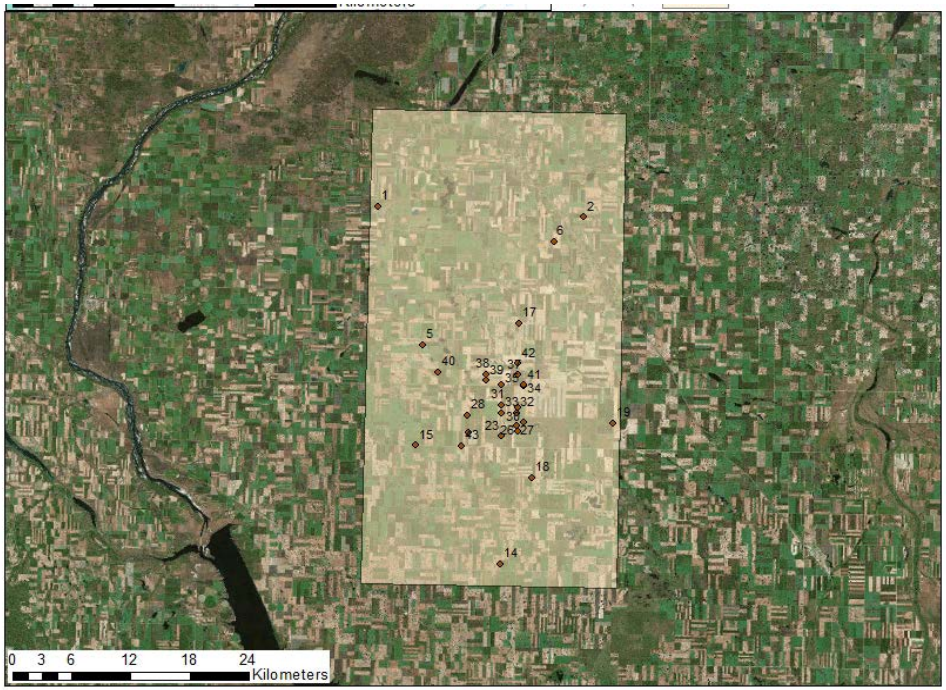
# Soil Moisture Networks in Canada



# Kenaston Network

- SMAP consistently demonstrating a dry bias
- Strong performance at Kenaston network site: ubRMSE = 0.027, r = 0.79
- Global average ubRMSE is 0.038; r = 0.78 (meeting mission targets)
- SMAP 9km enhance product now available
- Entering senior review

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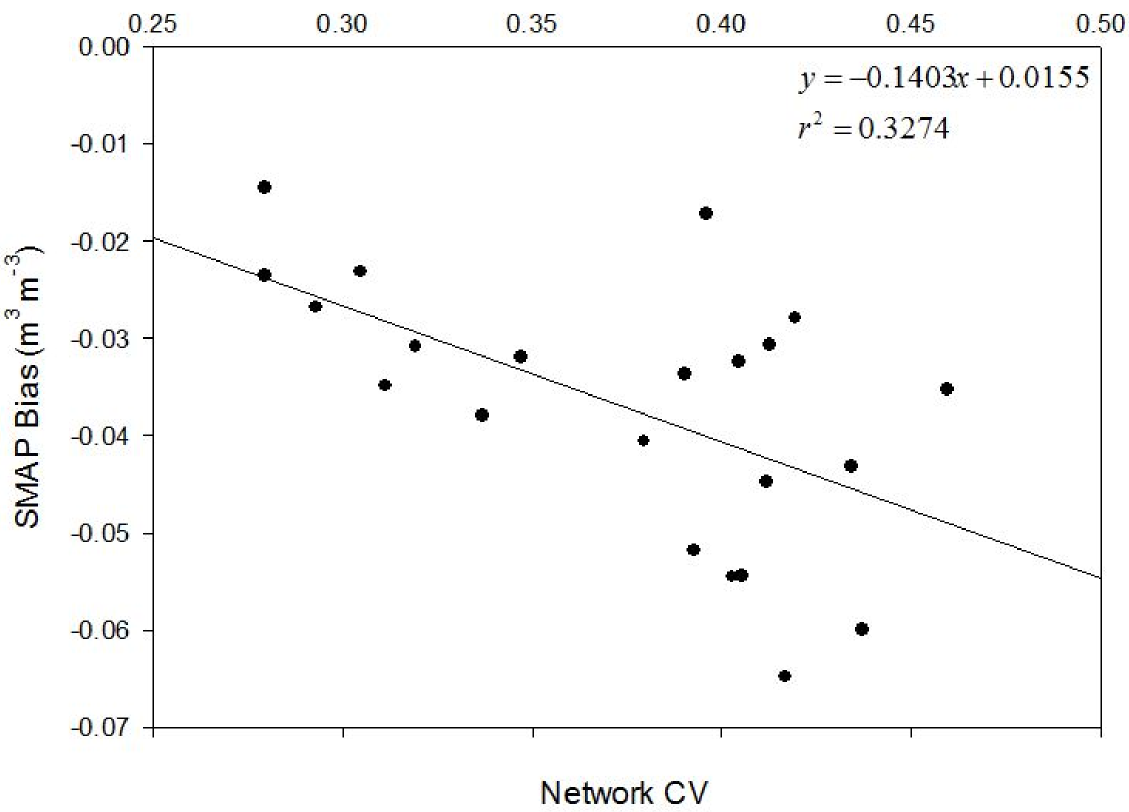
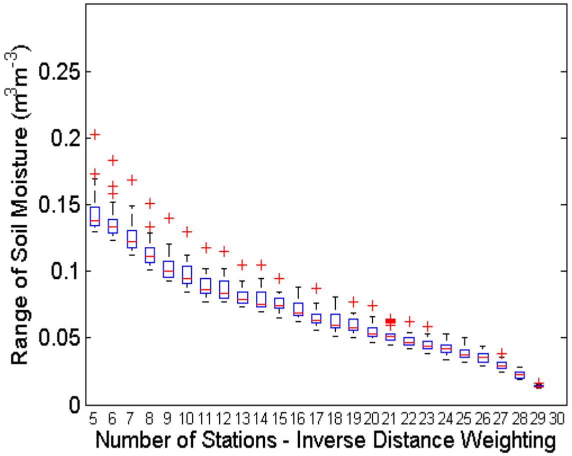
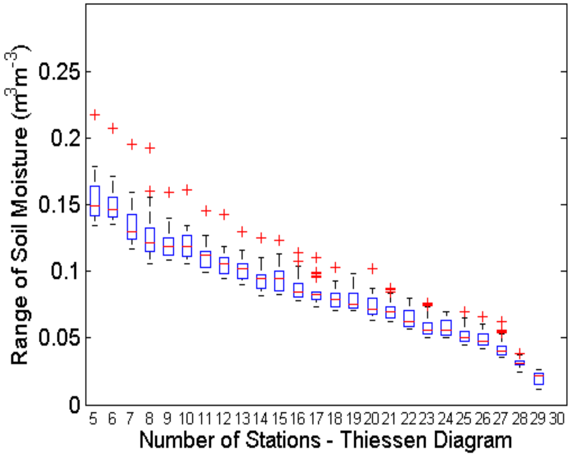
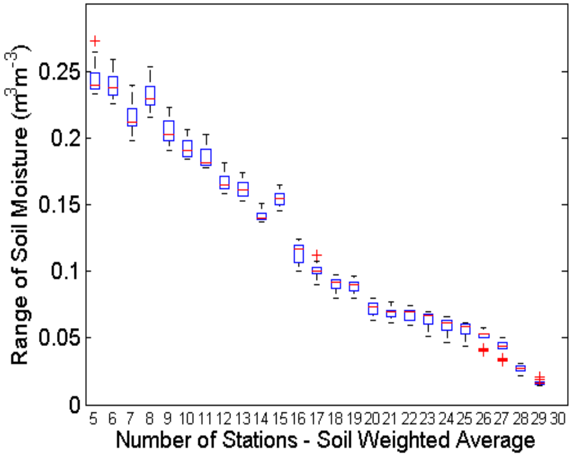
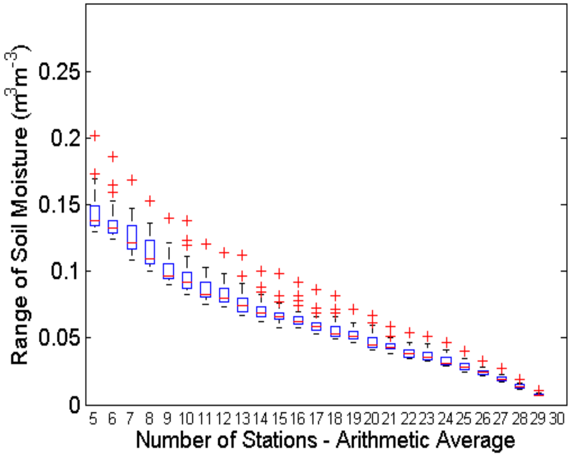



Knowledge of the network CV could provide insight into time periods when the network should be used with caution for cal/val activities




The range in upscaled soil moisture across all possible random combinations of stations from 5 to 30. Soil weighting shows the least stability .

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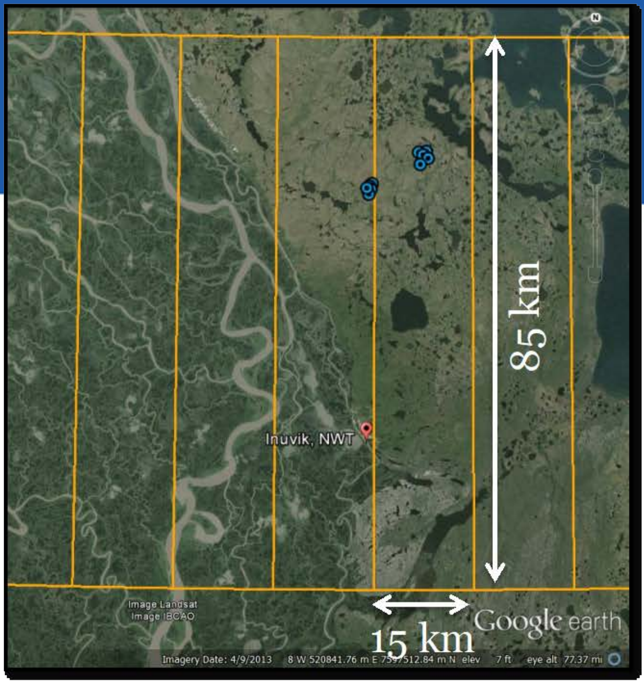



**Table 1.** The Pearson *r* for the Tb Provided on the Two Global Grid Pixels (G-1 and G-2) Associated With the TUP and TMM Sites, Respectively, and the North Polar Grid, Relative to the CMEM Modeled Tb

| | Product | 2015 | 2016 |
|---|---|---|---|
| SMAP L1C Tb (TUP) versus CMEM | H-pol fore | 0.02 | 0.10 |
| | V-pol fore | −0.01 | 0.11 |
| SMAP L1C Tb (TMM) versus CMEM | H-pol fore | 0.26 | 0.11 |
| | V-pol fore | 0.18* | 0.11 |
| SMAP L1C Tb (North Polar grid) versus CMEM | H-pol fore | 0.39* | 0.51* |
| | V-pol fore | 0.44* | 0.55* |

*Significance at $\alpha = 0.05$.

Wrona et al., 2017 GRL

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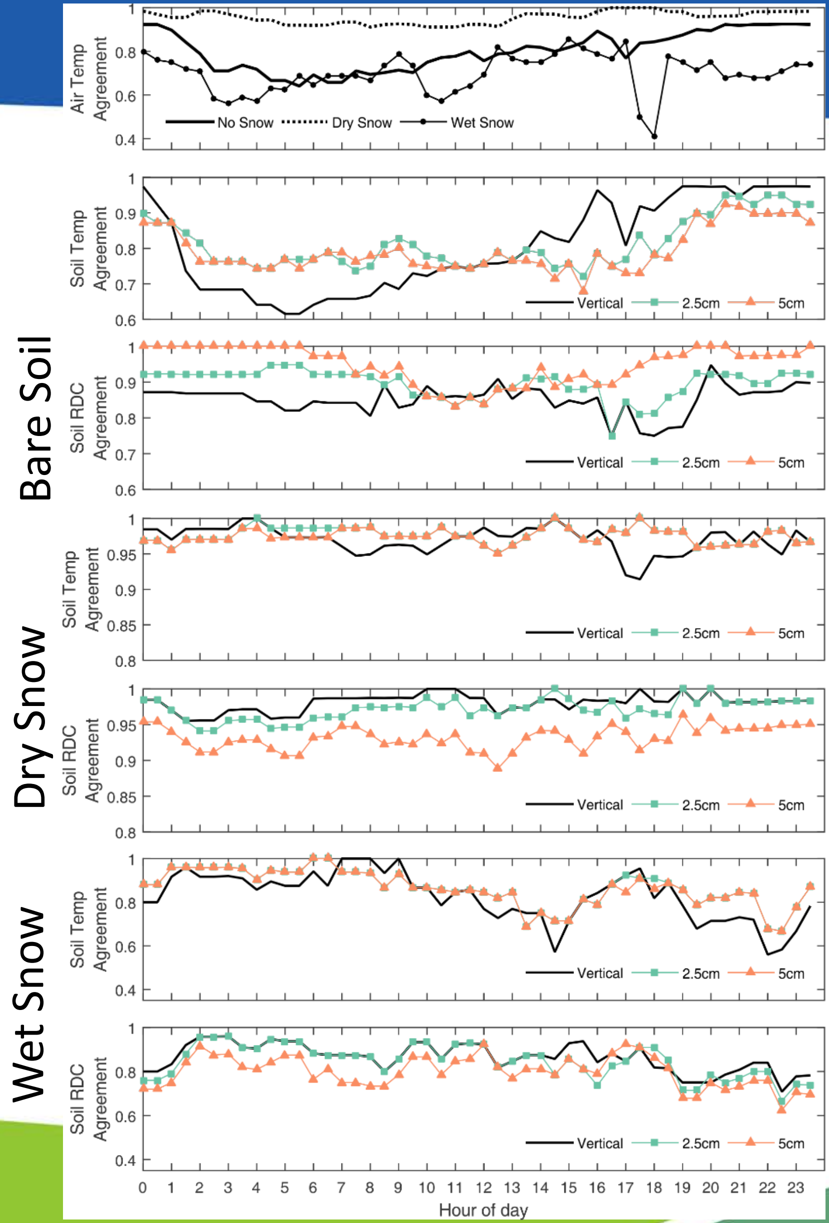
# Validation of the Soil Freeze Thaw State: Results




Air Temperature (top panel) good proxy under dry snow conditions, however very poor under wet or bare soil.

Under Bare soil conditions, soil dielectric measurements (near but not at surface) correspond most closely

Under dry snow conditions, soil temperature measurements near surface correspond most closely

Under wet snow both soil temperature and soil dielectric are similar, both greatly exceed air temperature proxy

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# Soil Freeze Thaw SMAP Experiment

- October 28-November 13, 2015 we conducted a freeze thaw SMAP experiment near Carmen, Manitoba
- Morning and afternoon flights of NASA's King-Air aircraft carrying their Scanning L-band active passive sensor (SLAP)
- Ground crews observing freeze/thaw state (temperature), soil freezing state and soil moisture


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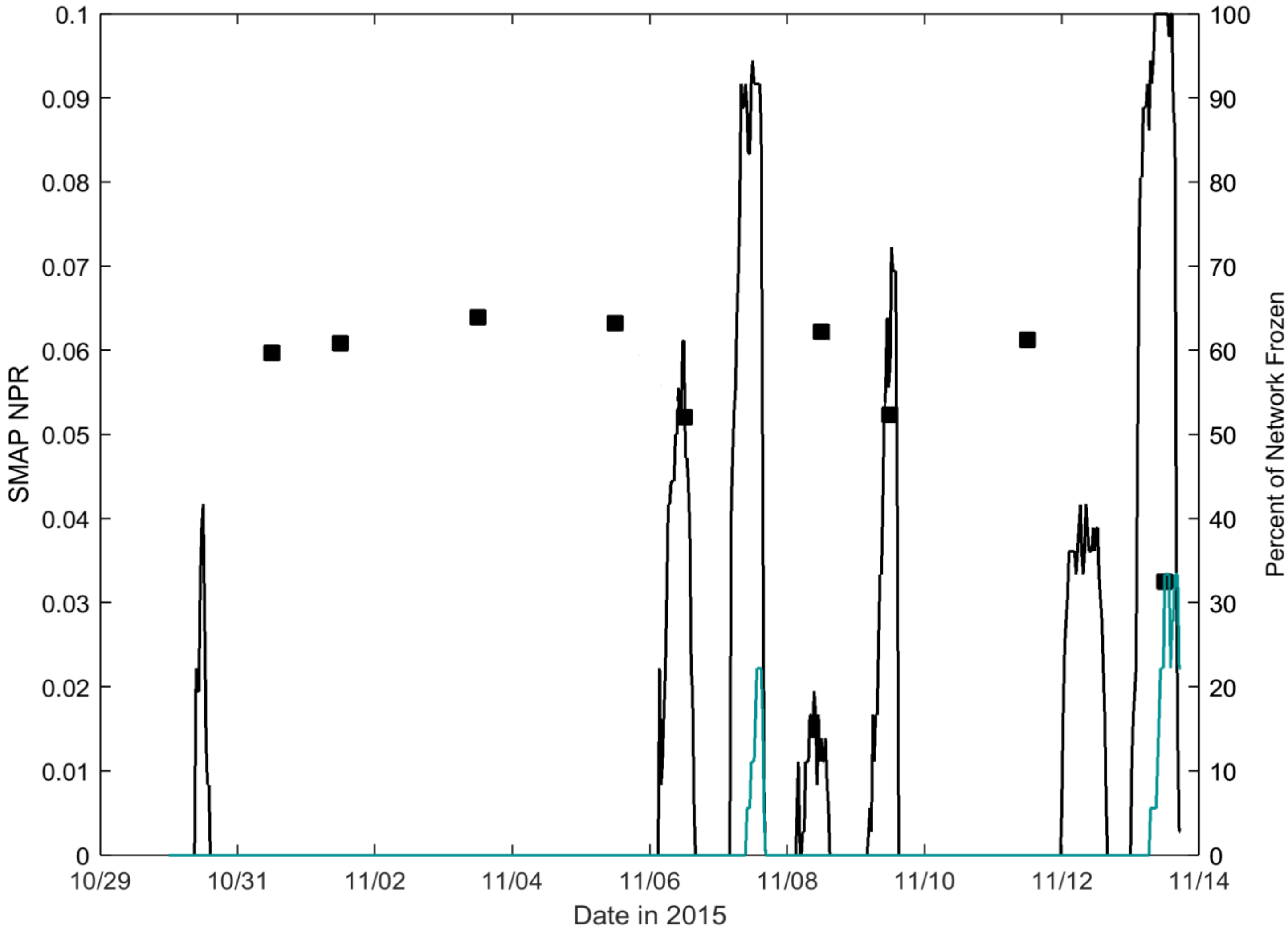


to diurnal F/T events for near surface freezing

# Acknowledgments

Andreas Colliander and NASA SMAP Science Team
Alexandre Roy, Alain Royer, Chris Derksen, Peter Toose
SLAPEX2015 team: Jarrett Powers and AAFC team, Paul Houser, Ed Kim, Kyle Macdonald

## Funding Support

- Canadian Space Agency
- Environment Canada
- Canadian Foundation for Innovation
- Ontario Innovation Trust
- National Science and Engineering Council of Canada (Discovery and Changing Cold Regions Network)

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# Characterizing Runoff Ratios over Canadian Watersheds using Satellite Derived Soil Moisture

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# Soil Moisture-Runoff Linkages

- Soil moisture is widely recognized as one of the critical controls on surface runoff processes
- Influences the flashiness of streams within a catchment area
- Traditionally measured in situ (e.g. impedance probes)
- Soil-moisture assimilation into rainfall-runoff models have shown the value of incorporating soil moisture into hydrological flood-forecast models

- Canada has a lack of real-time and historic observational runoff data over catchments
- Very sparse gauging network with complete records


Average Annual Unit Runoff dam$^3$/km$^2$. Probability of exceedence - 1994

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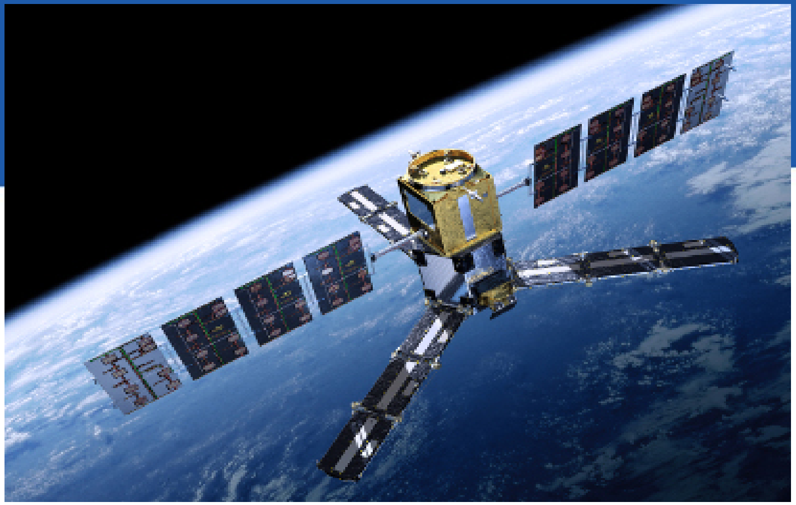
# SMOS Soil Moisture



Launched by the ESA in 2009

L-band radiometer operating at 1.4 GHz (21 cm wavelength)

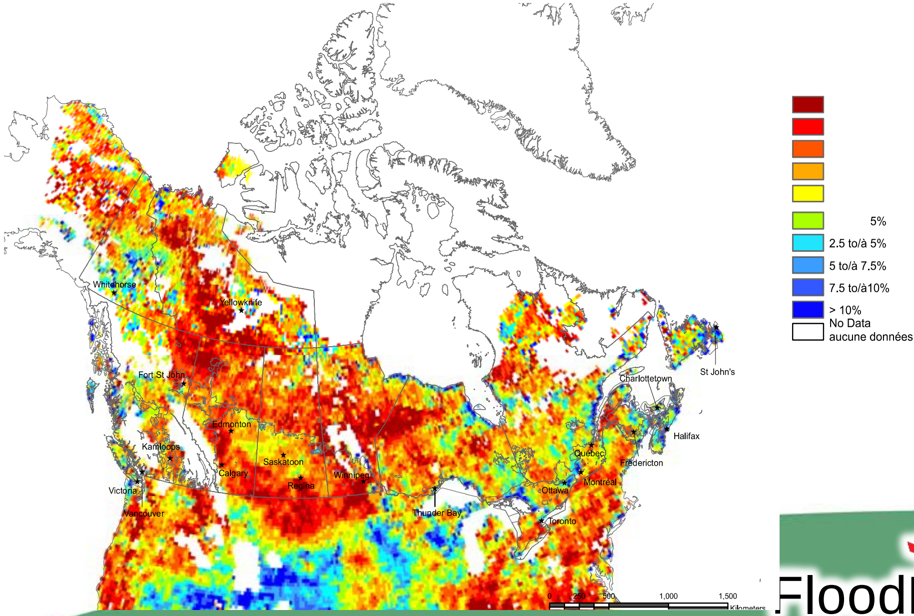
Sun-synchronous, quasi-circular orbit, dusk-dawn, 23-day repeat cycle, **3-day sub-cycle**

Average spatial resolution of **40km**

Soil Moisture retrieval accuracy of **4%**

Retrieves surface soil moisture content (top ~5cm of the soil)

Soil moisture signal impacted by snow, ice and frozen soils, vegetation cover.

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Agriculture and Agri-food Canada, 2016; Kerr et al., 2012

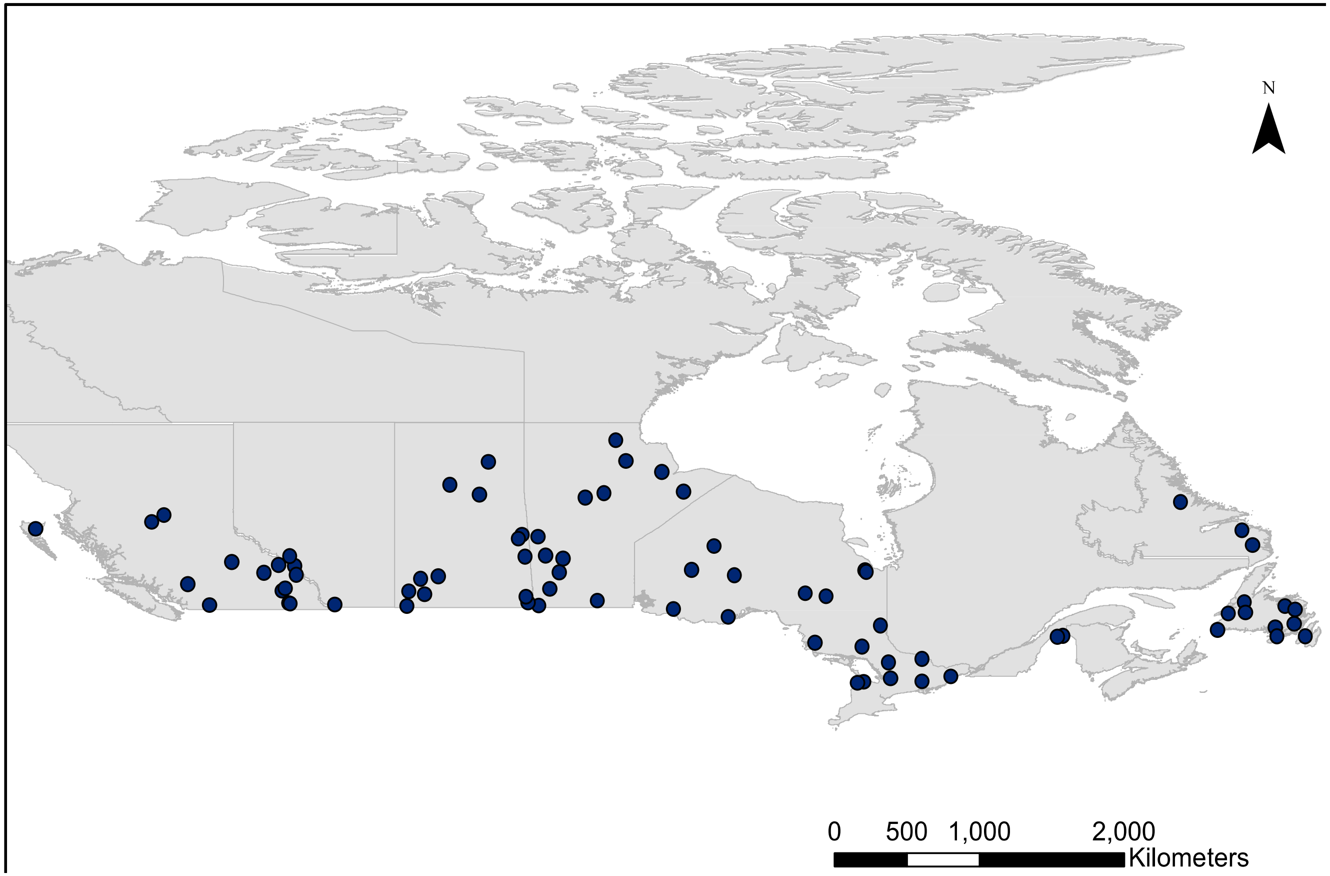
# Research Gaps

- Soil moisture-runoff studies predominantly focused on a single instrumented basin
- Lack of data over large and remote regions of Canada

# Research Aims

- Analyze the importance of SMOS antecedent soil moisture data in relation to runoff generation in a large scale Canadian context
- Characterize the dominant hydrologic and topographic controls on this relationship

# Basin Selection




**76** gauging stations from the Canadian Reference Hydrologic Basin Network (RHBN) and their contributing watersheds, distributed throughout the West Coast, Prairie, Central and Atlantic regions of Canada south of the 60$^{th}$ parallel. Watershed boundaries were determined from the HydroBASINS dataset (www.hydrosheds.org/)

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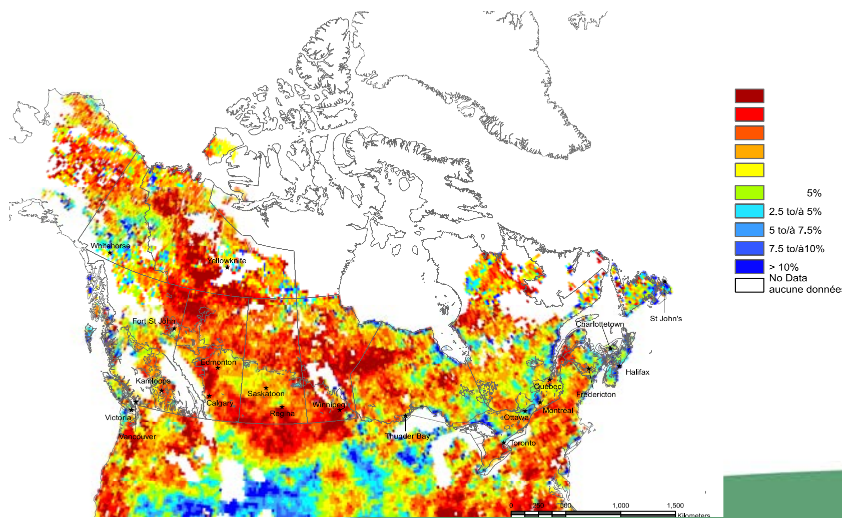
# Data Sources

- Precipitation Data
  - Daily gridded precipitation from nearest precipitation gauge
  - CAPA dataset
- Discharge Data
  - Water Survey of Canada (2016)
  - Environment Canada gauging station
- Soil Moisture Data
  - Weekly soil moisture anomaly data (Agriculture and Agri-food Canada)

Complete SMOS and gauging station data series were only available for 2010-2014.

Only warm season data (May-November) were included.

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# Data Processing

$$S_n = \frac{\sum_g S_g A_{bg}}{\sum_g S_g}$$

**SMOS and CAPA Interpolation Methodology**

Mean Soil Moisture (S) in catchment b is computed where Abg is fractional area of catchment b within grid cell g (Koster et al. 2000)

**Semi-automated modified Chapman Baseflow separation algorithm**

$$Q_b(i) = \frac{k}{2-k} Q_b(i-1) + \frac{1-k}{2-k} Q(i) \qquad k = \left(\frac{Q}{Q_5}\right)^{1/t}$$

Chapman, 1999

$Q_b(i)$ is baseflow at time *I*
$Q$ is the total stream flow

$k$ is the baseflow recession parameter
(a function of the slope of the correlation line [$Q/Qo$])

**Calculating the Runoff Ratio for each watershed**

- Runoff Ratio = $\dfrac{\text{Quickflow Discharge } (m^3/\text{week})}{\text{Precipitation}(m/\text{week}) * \text{Area } (m^2)}$

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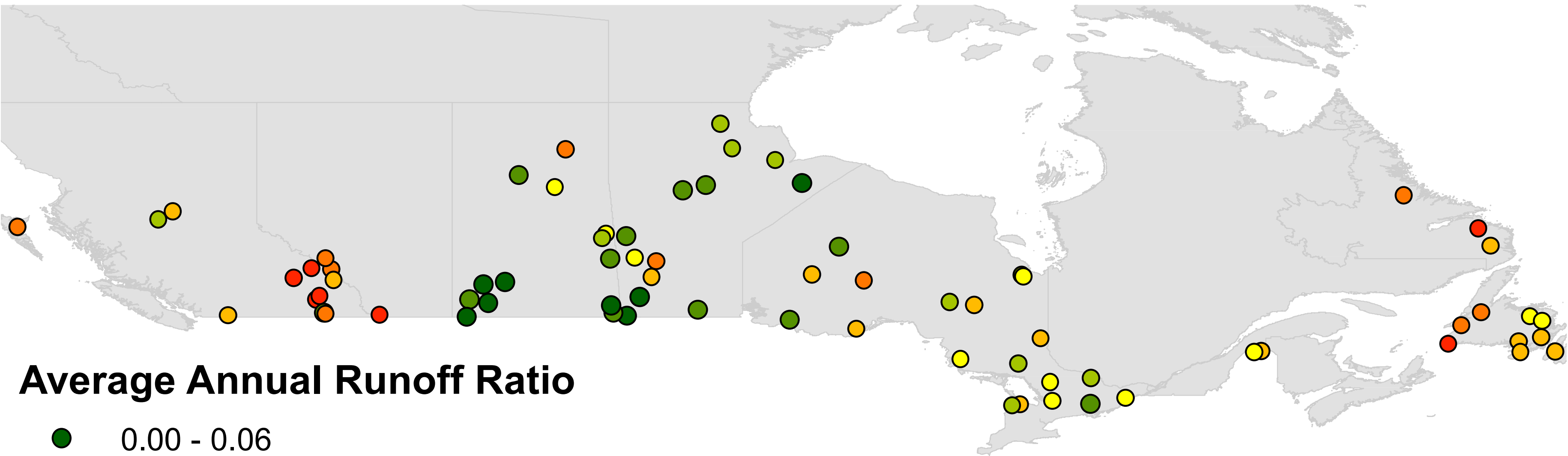
# Runoff Ratio Over Catchments




**Average Annual Runoff Ratio**

- 0.00 - 0.06
- 0.06 - 0.17
- 0.17 - 0.26
- 0.26 - 0.35
- 0.35 - 0.54
- 0.54 - 0.83
- 0.83 - 0.99

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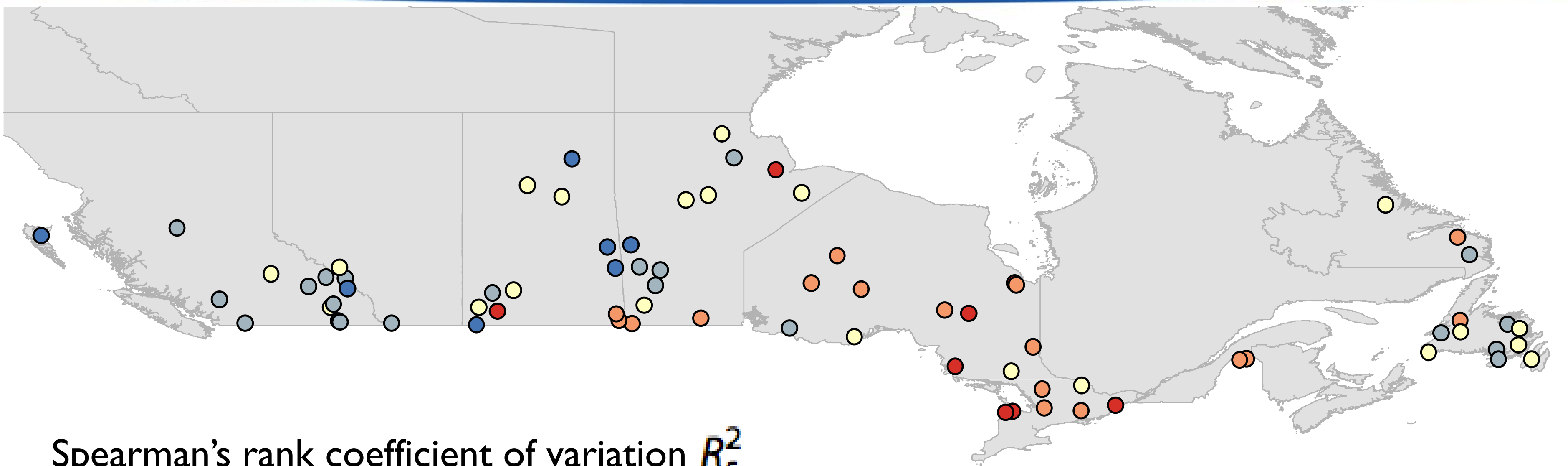
# Strength of Antecedent SMOS Soil Moisture-Runoff Relationship



Spearman's rank coefficient of variation $R_s^2$

- -0.53 - -0.20
- -0.20 - 0.01
- 0.01 - 0.18
- 0.18 - 0.38
- 0.38 - 0.59

0 500 1,000 2,000 Kilometers

43% of basins showed a statistically significant Rs value between the 1-week antecedent soil moisture anomaly and the weekly runoff ratio

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# Basin Characteristics

Correlations calculated using 43 hydroclimatic, topographic, soil and landcover basin characteristics

$R_s^2$ Values for basin characteristics, runoff ratio and soil moisture-runoff correlations (N=76)

| | Average Annual Runoff Ratio | Soil Moisture-Runoff Correlation |
|---|---|---|
| Latitude | -0.09 | -0.30 |
| Longitude | 0.05 | 0.43 |
| Gross Drainage Area Km2 | -0.06 | 0.21 |
| Pfafstetter level | 0.03 | -0.16 |
| Silt % | -0.45 | 0.12 |
| Sand % | 0.20 | 0.19 |
| Clay % | -0.46 | 0.18 |
| Gravel % | -0.07 | -0.09 |
| Organic Carbon % | -0.07 | 0.28 |
| Drainage Density | -0.11 | 0.19 |
| Average Annual Days of Precip | 0.70 | -0.01 |
| Average Warm Season Precip (mm) | 0.52 | 0.22 |
| Precipitation Seasonality Index | -0.38 | 0.07 |
| Minimum Slope | 0.38 | -0.36 |
| Maximum Slope | 0.62 | -0.41 |
| Mean Slope | 0.62 | -0.42 |
| Compactness Ratio | 0.17 | -0.35 |
| Min Elevation (m) | -0.10 | -0.29 |
| Max Elevation (m) | 0.21 | -0.41 |
| Mean Elevation (m) | 0.11 | -0.34 |
| %Settlement | -0.12 | 0.11 |
| %Roads | -0.18 | 0.13 |
| %Water | 0.00 | 0.14 |
| %Forest | 0.43 | -0.11 |
| %Trees | 0.14 | 0.02 |
| %Treed Wetland | 0.03 | 0.13 |
| %Cropland | -0.26 | 0.05 |
| %Grassland | -0.36 | 0.04 |
| %Natural Grassland | 0.49 | -0.05 |
| %Wetland | 0.02 | 0.20 |
| %Wetland Shrub | 0.08 | 0.05 |
| %Wetland Grass | 0.02 | -0.43 |
| %Other (Rock, Ice, Barren) | 0.45 | -0.20 |
| April Snowcover % | 0.37 | -0.20 |
| May Snowcover % | 0.48 | -0.17 |
| June Snowcover % | 0.26 | -0.16 |

Significant at the 95% level

Significant at the 90% level

# Key Findings

- ~40% of basins showed a significant correlation between the SMOS soil moisture anomaly and the basin runoff ratio
- Considerable variety in strength of relationship over individual basins
- Strong spatial patterns; relationship weakens in northern latitudes, mountainous and coastal regions
- Basin topography (slope, elevation) show the strongest controls on the relationship
- Landcover does not seem be have a dominant factor
- Method shows some promise as large scale tool to characterize controls on runoff across remote Canadian watersheds

Further analysis:

- Developing a predictive model for areas of high SMOS SM correlation
- Validation with supplemental basins

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# Thank You

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