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Up-Scaling of SMAPVEX16 Soil Moisture Field Data - SMAP Cal/Val Workshop Fairfax VA

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Canada

SMAPVEX16-MB Field Campaign

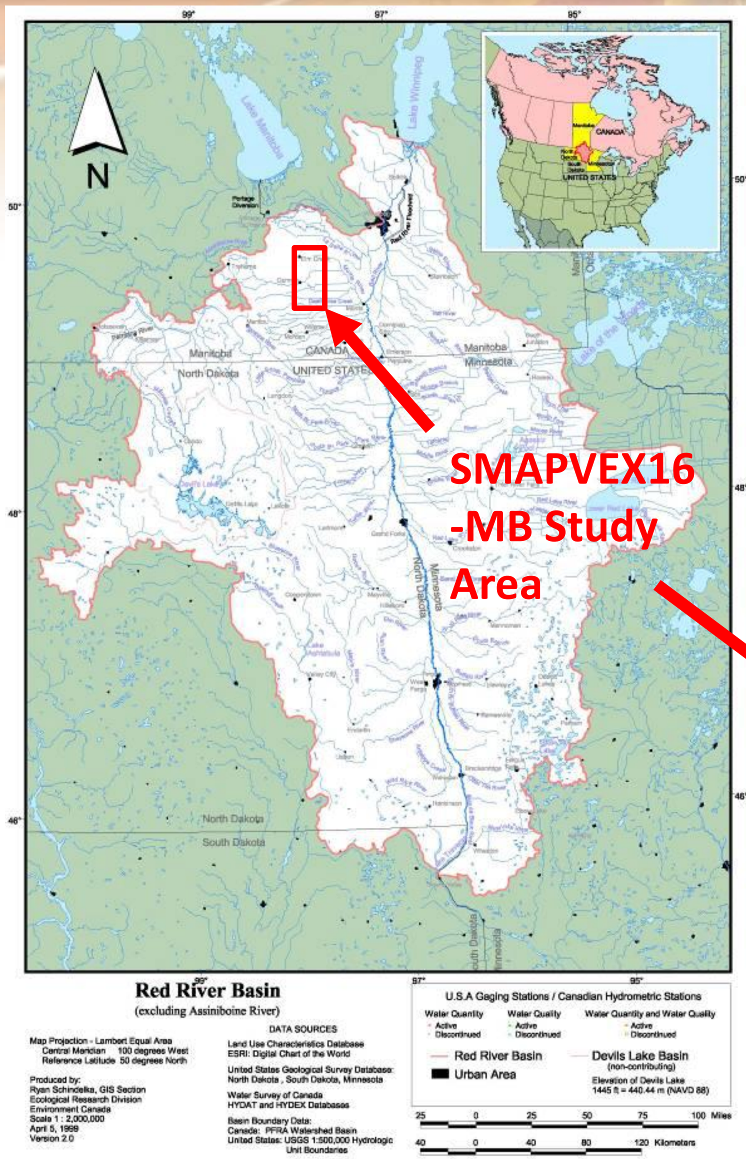
- Canada conducted a 2016 field study with NASA (SMAPVEX16-MB) to improve soil moisture retrievals from the satellite and examine new approaches to compensate for the loss of the SMAP radar.

- The campaign follows the highly successful pre-launch field campaign (SMAPVEX12) conducted in MB in 2012 and an earlier campaign (CANEX10) in SK in 2010. A smaller freeze-thaw campaign was conducted in MB in 2015.

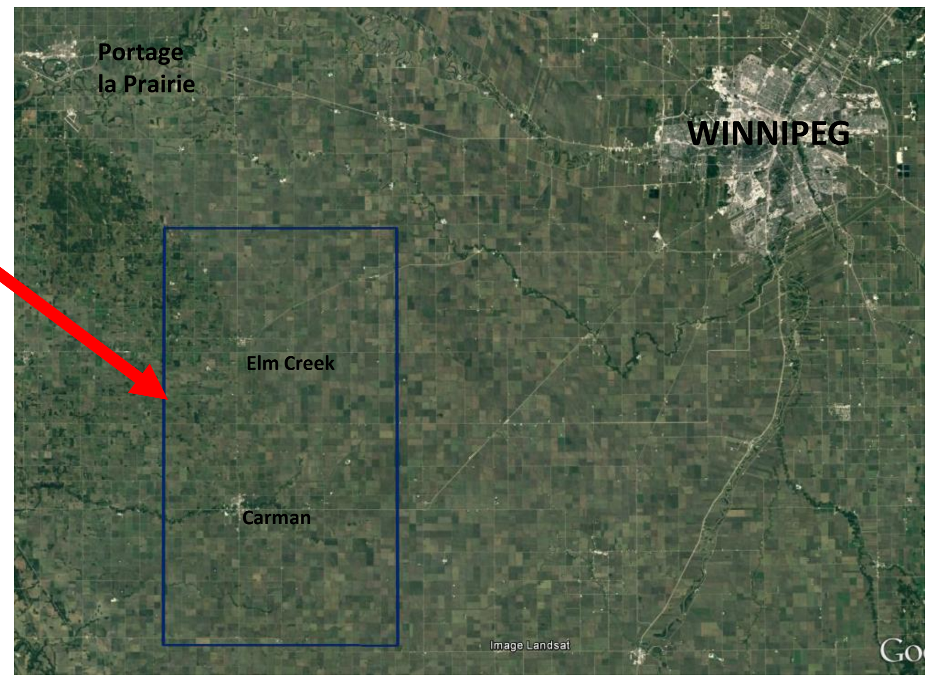
- The 2016 study was located in the same area as AAFC’s soil moisture network. The network is a core validation site for NASA for the duration of the SMAP mission.

- AAFC, Environment Canada, University of MB/Guelph/Sherbrooke/MB Ag conducted the field component of the 2016 campaign. NASA contributed airborne sensors.

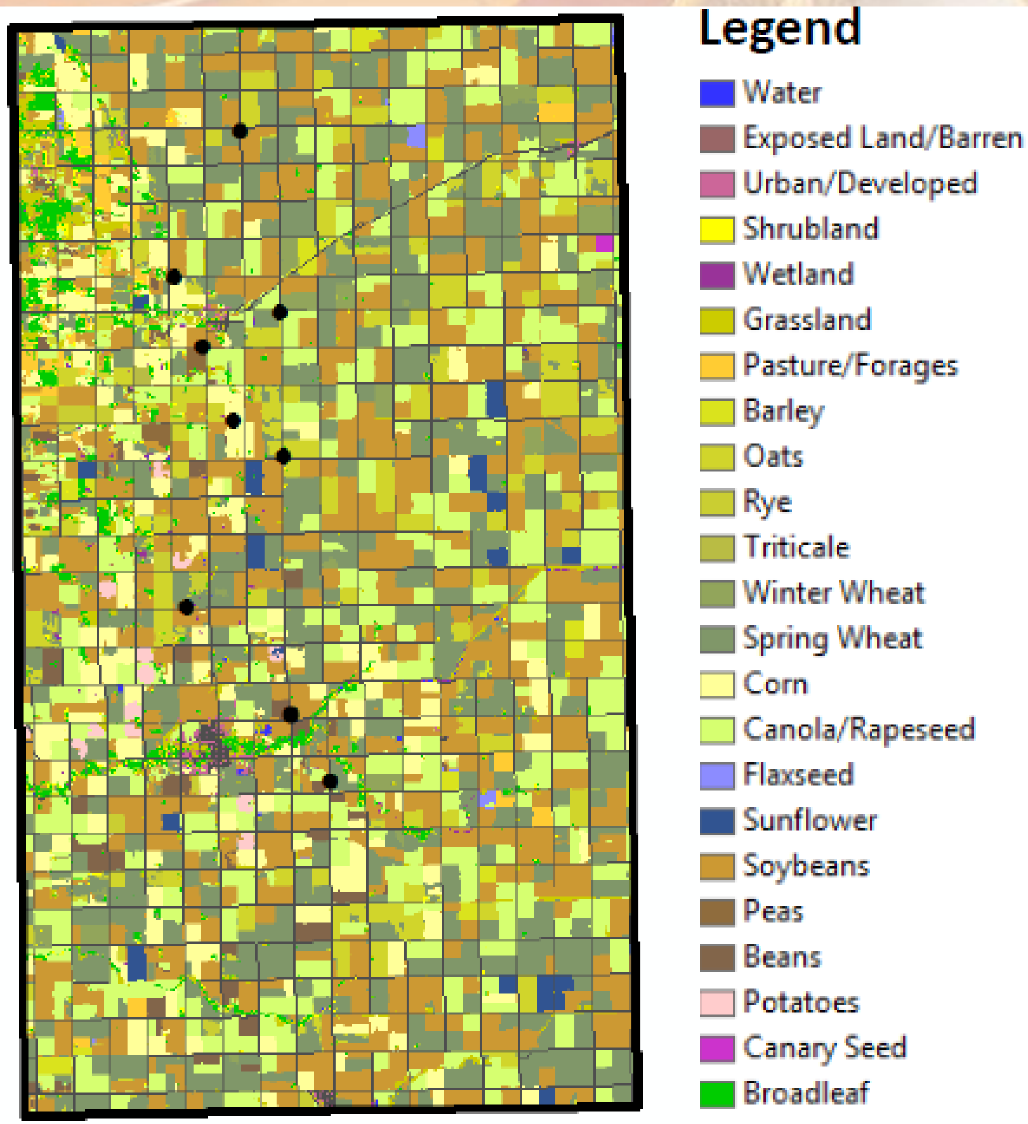
SMAPVEX16-MB Location



A SMAP pixel (L1B TB) is used as the study area (36 x 47km). The site is located Southwest of Winnipeg in the Carman-Elm Creek area.



SMAPVEX16-MB Annual Crops



A total of 50 fields were selected for sampling. 21 fields from the SMAPVEX12 were used for the 2016 campaign.

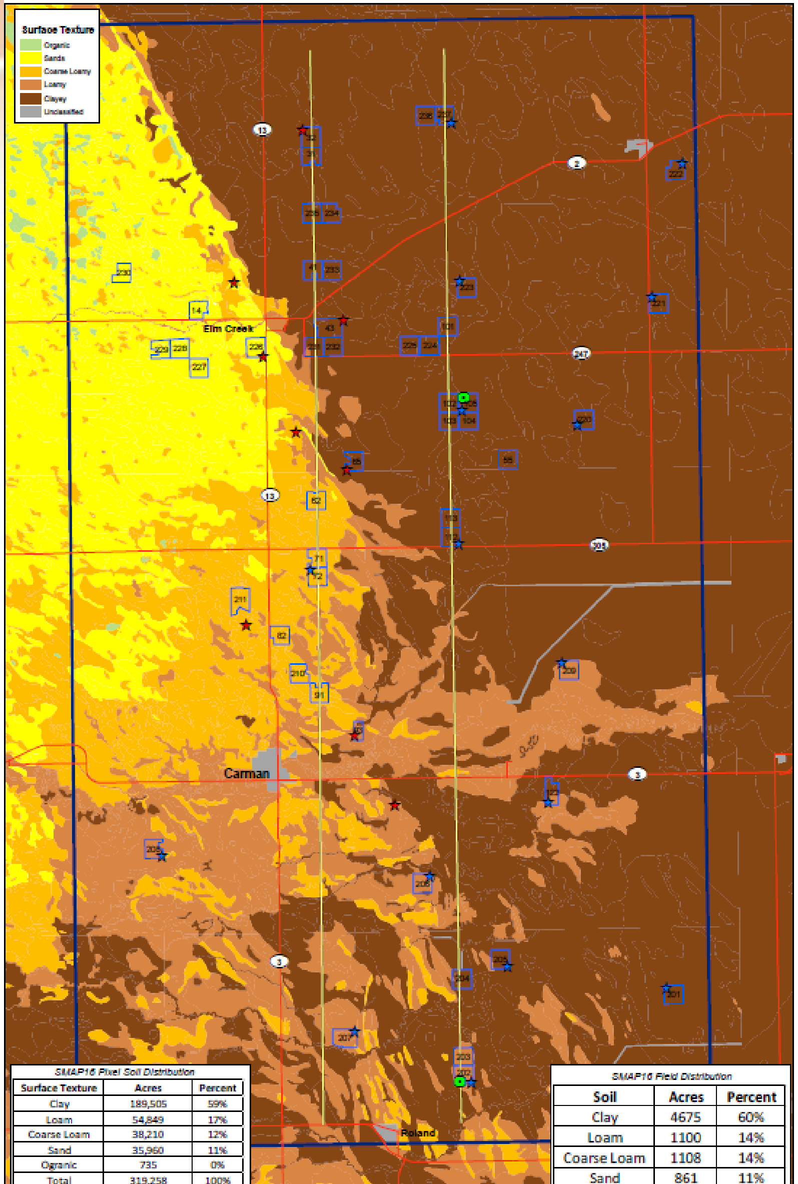
MB Crop Insurance and AAFC Annual Crop Inventory (derived from satellite imagery) was analyzed to look at cropping trends in the study area.

Soybeans, wheat and canola accounted approximately 70% of crops grown in the study area (2 and 5 year average). Other crops include corn, oats, field beans and forages.

Fields were selected based on the dominant crops represented within the study area.

SMAPVEX16-MB Soils

SMAPVEX16 Soils: Surface Texture



SMAP16 Pixel Soil Distribution

Surface Texture	Acres	Percent
Clay	189,505	59%
Loam	54,849	17%
Coarse Loam	38,210	12%
Sand	35,960	11%
Ogranic	735	0%
Total	319,258	100%

SMAP16 Field Distribution

Soil	Acres	Percent
Clay	4675	60%
Loam	1100	14%
Coarse Loam	1108	14%
Sand	861	11%

Soil surface textures within the SMAP study area. Data is from the 1:20k Canada-Manitoba Soil Survey Report D60.

Clay and Fine Loamy soils account for approximately 76.5% of the study area.

Coarse Loamy and Sand soils account for 23.5% of the study area.

Fields were selected based on soil surface texture representation within the study area.

SMAPVEX16-MB Objectives

1. Investigate anomalous retrievals (under-estimation of soil moisture values/rapid dry-downs following a precipitation event) from the SMAP satellite. This is a common occurrence on agricultural core-validation sites with annual crop production.
2. **Improve up-scaling processes for core-validation sites. Data collected from the campaign will be useful in determining if the methods AAFC has developed to up-scale soil moisture data for SMAP are valid.**
3. Develop and evaluate down-scaling approaches that utilize SMAP radiometer data given the loss of the radar. These include the use of other active radar sensors.
4. Deploy ground-based instruments (radiometer and scatterometer) to better understand soil moisture and vegetative contribution to microwave responses.

Up-Scaling Analysis

1) Use field data collected during soil moisture sampling days (handheld sensor data) to validate temporary station data.

2) Utilize temporary station surface soil moisture data that was collected from SMAPVEX16 study fields and compare to data collected from the AAFC permanent stations (RISMA) network.

3) Adjust weighting scheme from 76.5/23.5 to 65/35 clay-fine loamy/sand-coarse loamy, respectively, based on enhanced L2 SM P E pixel shift.

4) Investigate different up-scaling methods (arithmetic average, soil-weighted, Voronoi pixel, soil weighted Voronoi and NOAH LSM modeled 5cm).

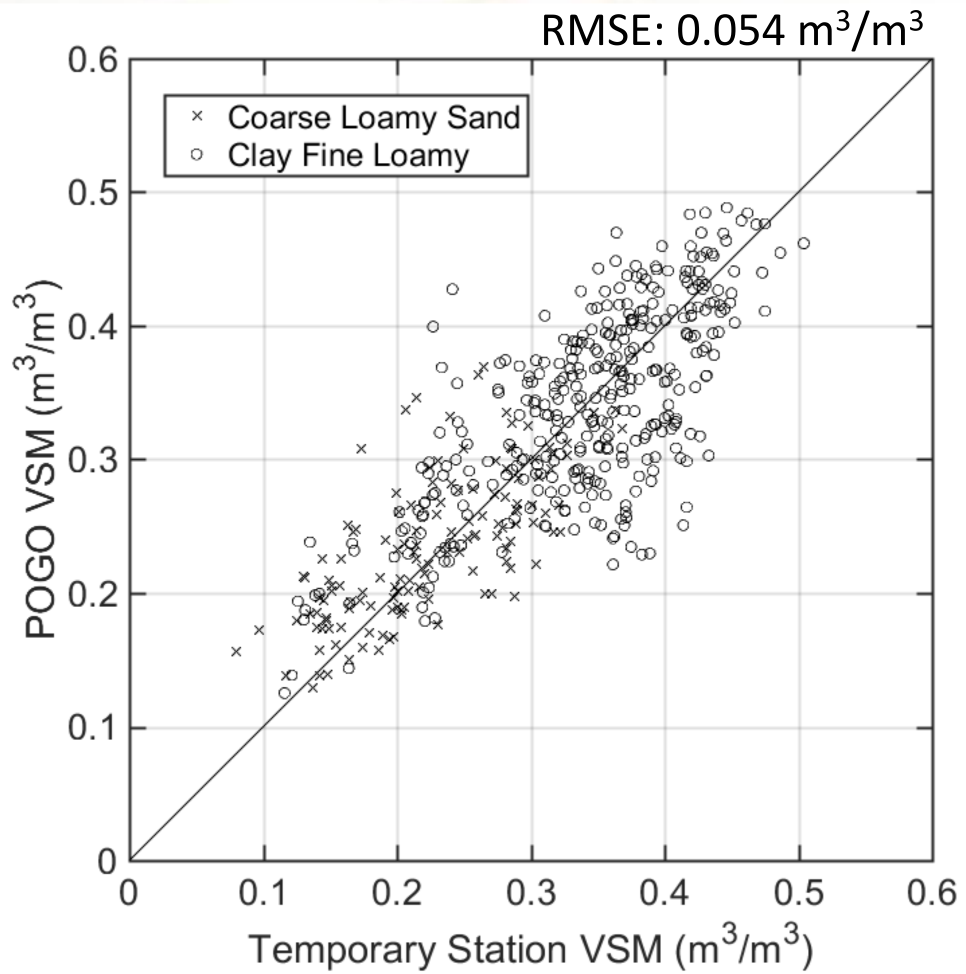
5) Compare results from SMAP (L2 SM P E) to upscaling methods that use SMAPVEX16 in-situ data.

POGO Field Data and Temporary Station

Handheld (POGO) soil moisture data that was collected at the 16 field sites was compared to soil moisture data collected from the vertical 5cm hydraprobe that was installed at Site 1.

POGO data from 45 of the 50 SMAPVEX16 study fields that fell within the new L2_SM_P_E pixel were used for the comparison. A mean soil moisture value was calculated from the 16 field sites (3 readings per site—48 readings in total).

Vertical 0-6cm hydraprobe values that were recorded at 8 and 9am (CDT) were extracted and averaged. This was done to coincide with the SMAP and PALS overpass.



POGO Field Data and Temporary Station

- Given that fields were selected to contain uniform surface soil textures/crops and sampling sites avoided depressions/field drains and other non-representable locations, there are still significant differences in surface soil moisture values across the field. Micro-topography caused by tillage/seeding will also influence soil moisture values with drier values at the top of a furrow and wetter values at the bottom. POGO measurements on all fields have revealed these differences. Analysis of POGO readings at each field site revealed a 0.031 m^3/m^3 average variation in soil moisture values for clay-fine loamy soils and 0.049 m^3/m^3 average variation in soil moisture for sand-coarse loamy soils.

- There was no protocol for the placement of the temporary station 0-6cm hydraprobe (top-middle-bottom of the furrow). Placement of all hydraprobes at one position may have improved error.

- RMSE value of 0.054 m^3/m^3 is reasonable given field spatial variability and micro-topography and there is good agreement between the POGO and temp station data during the campaign.

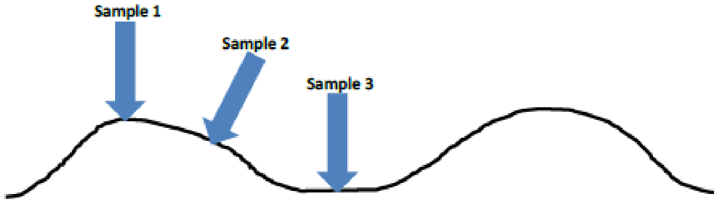


Figure 16. Location of replicate soil moisture measurements at each site

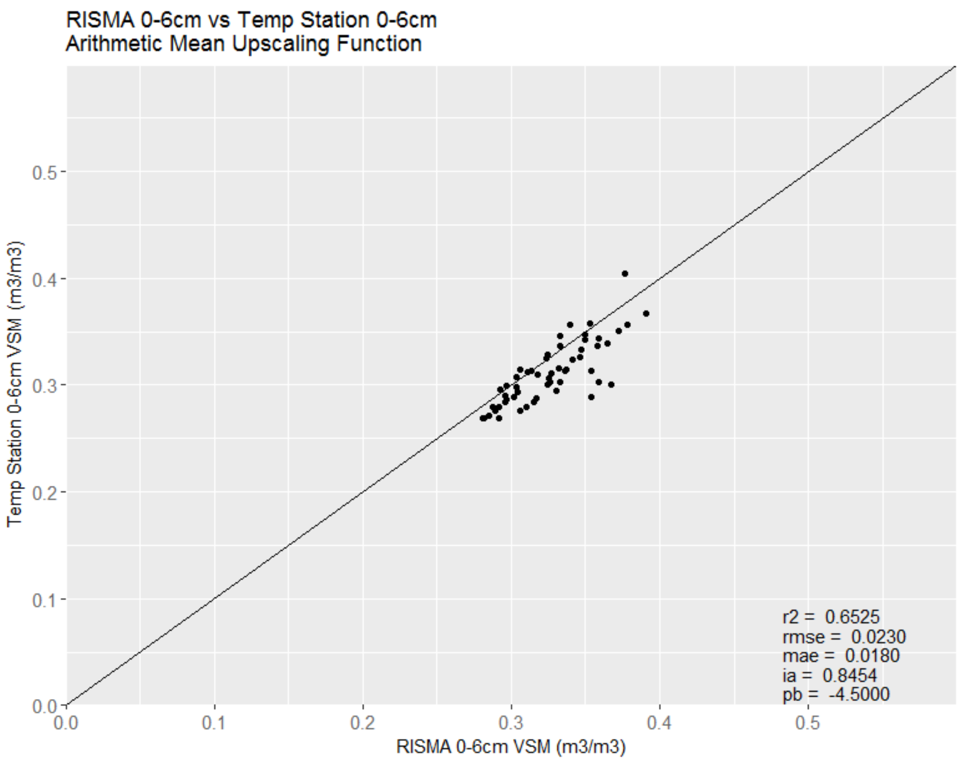
RISMA – Temp Station Comparison

- RISMA station data was downloaded for the same period (June-July) and the 0-6cm hydraprobe data was extracted.
- Only 7 of the 9 RISMA stations were used. Station 4 was shutdown in May due to multiple probe failures at various depths. Station 7 had incomplete data June-July due to power issues.
- 5 stations have Clay-Fine Loamy surface texture (Stations 2, 3, 5, 6, 8).
- 2 stations have Coarse Loamy-Sand surface texture (Stations 1, 9).
- Both RISMA and temporary station data were processed using different upscaling approaches and results were compared.
- Data was collected from both RISMA and temporary stations during the 56 day window of June 1st to July 26th 2016.
- Quality controlled data from the temporary stations was used to interpolate data gaps caused by power issues or probe failure.

Arithmetic Average

- A simple average of the RISMA and Temp station 0-6cm probes was calculated.

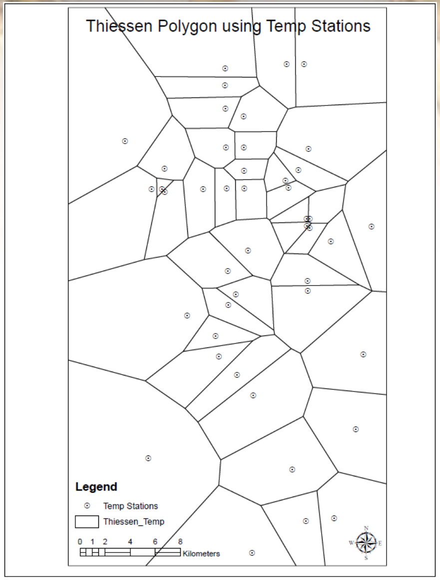
- RMSE value is low (0.023 m^3/m^3). This is likely the result of the number of fields selected for the campaign to be proportional to the occurrence of sand-coarse textured (23.5%) and clay-fine loamy surface textured soils within the study area (76.5%).

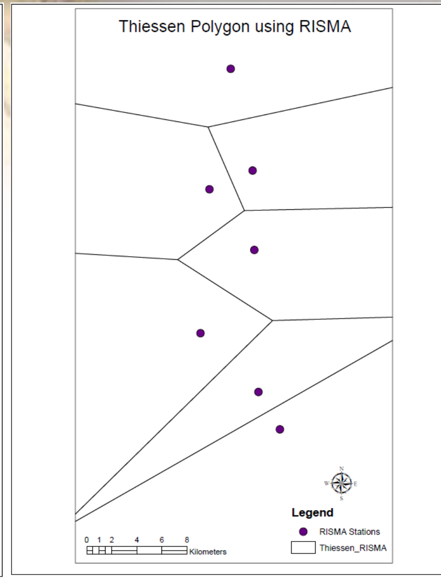


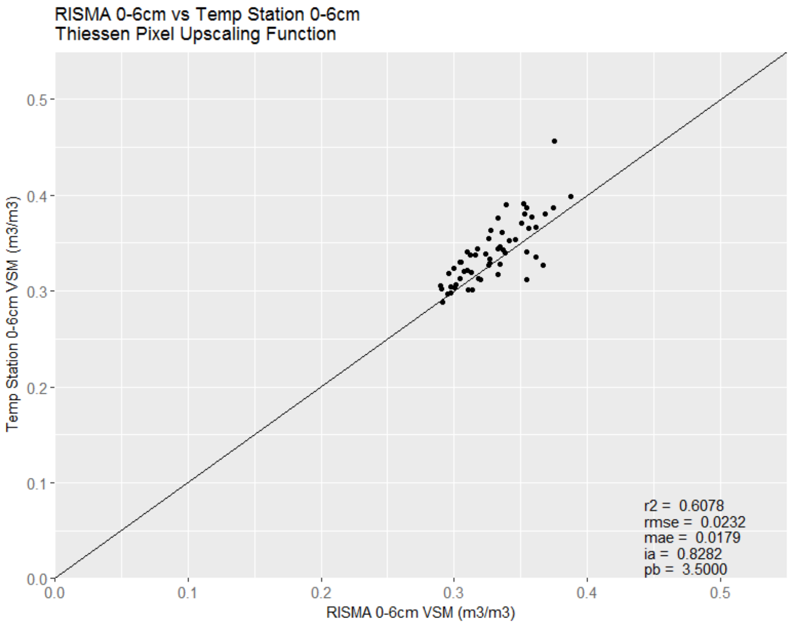
Voronoi Pixel

- A Voronoi diagram was created from the locations of the RISMA and Temp stations. Area-weighted values were used to calculate a soil moisture value for the 0-6cm probes.

- RMSE value is low (0.023 m^3/m^3).



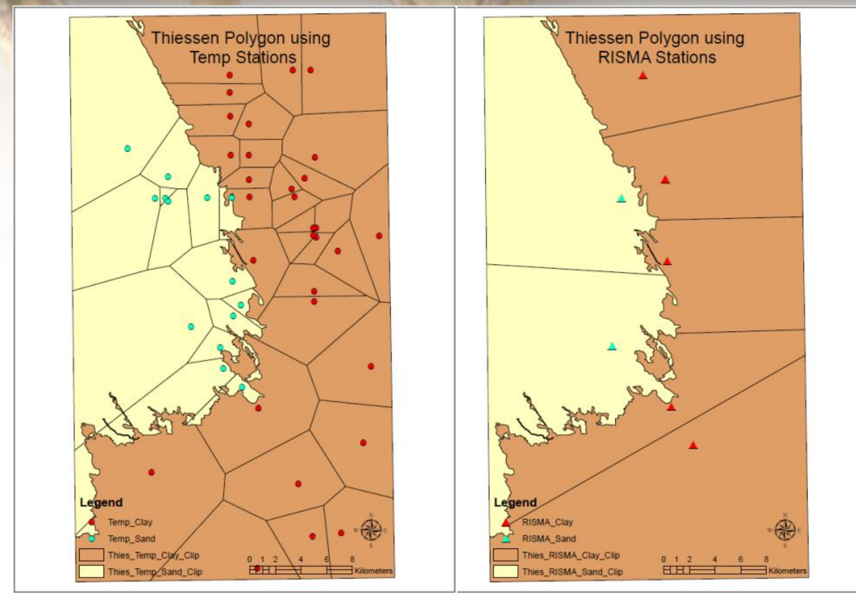


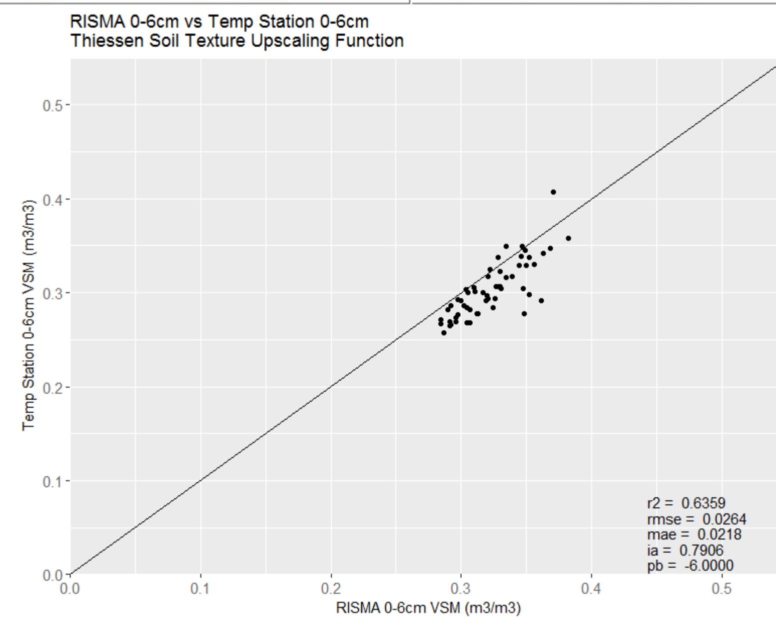


Soil-Weighted Voronoi

- A Voronoi diagram was created from the locations of the RISMA and Temp stations. The polygons were further partitioned by the soil texture map separating clay-fine loamy soils and sand-coarse loamy soils. Area-weighted values were used to calculate a soil moisture value for the 0-6cm probes.

- RMSE value is (0.026 m^3/m^3), slightly higher than using the Voronoi pixel approach.

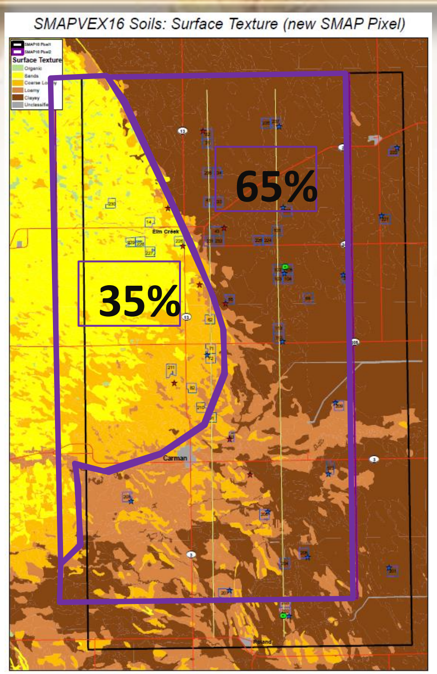


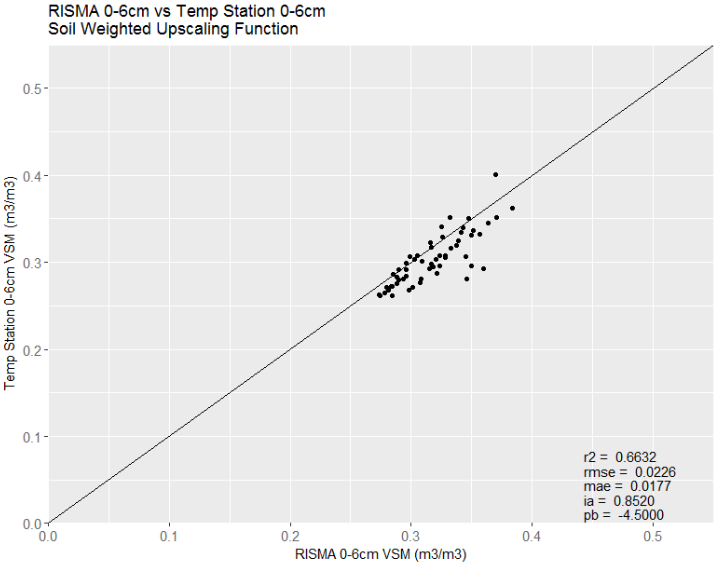


Soil-Weighted

- Using the soil texture map, a 65% weighting was applied to soil moisture measurements from sites on clay-fine loamy soils and a 35% weighting was applied to sites on sand-coarse loamy soils. The weightings were used to calculate a soil moisture value for the 0-6cm probes. This is the approach that is currently used for validation of SMAP data from the Carman CVS.

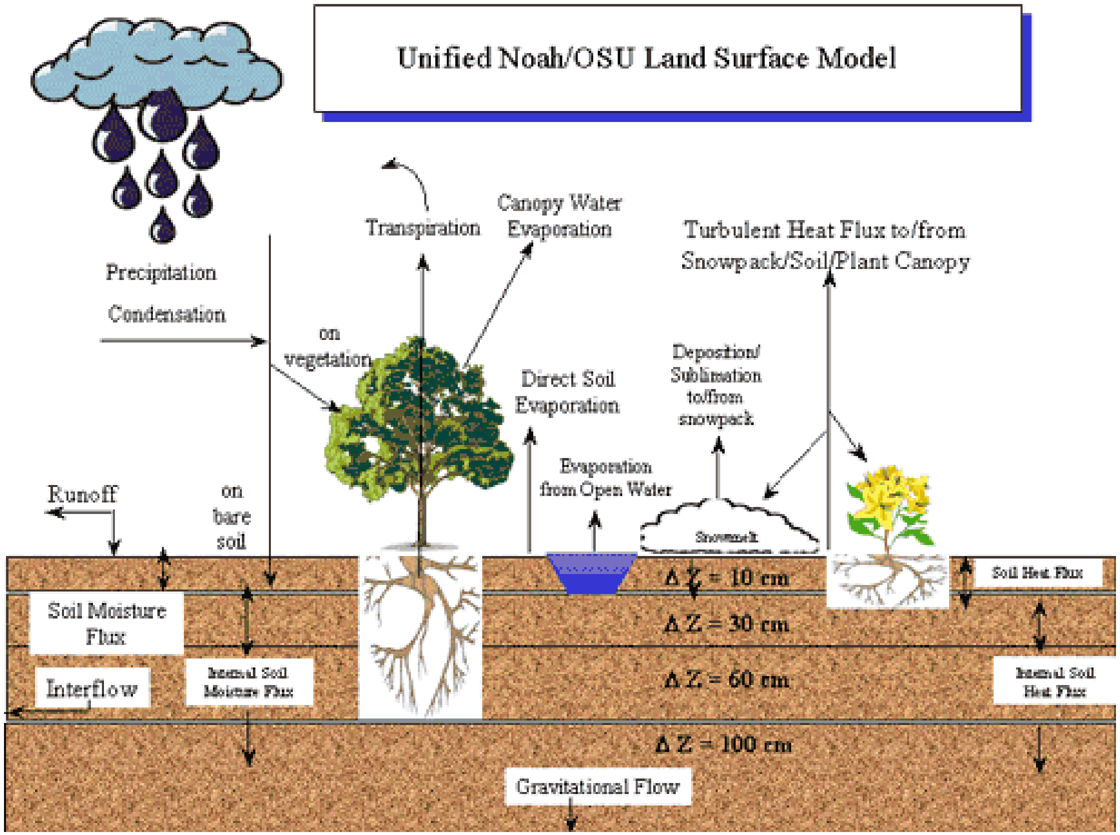
- RMSE value is (0.023 m^3/m^3).





Unified NOAH LSM

The NOAH model is a unified version of the Oregon State University land surface scheme. Model input and parameters include air temperature at 3m, RH at 3m, surface pressure, incoming solar radiation, total rainfall for half hour, average wind vector at 6m and down-welling longwave from sky. NDVI values were collected from MODIS and greenness calculations were derived from NDVI using a linear relationship.

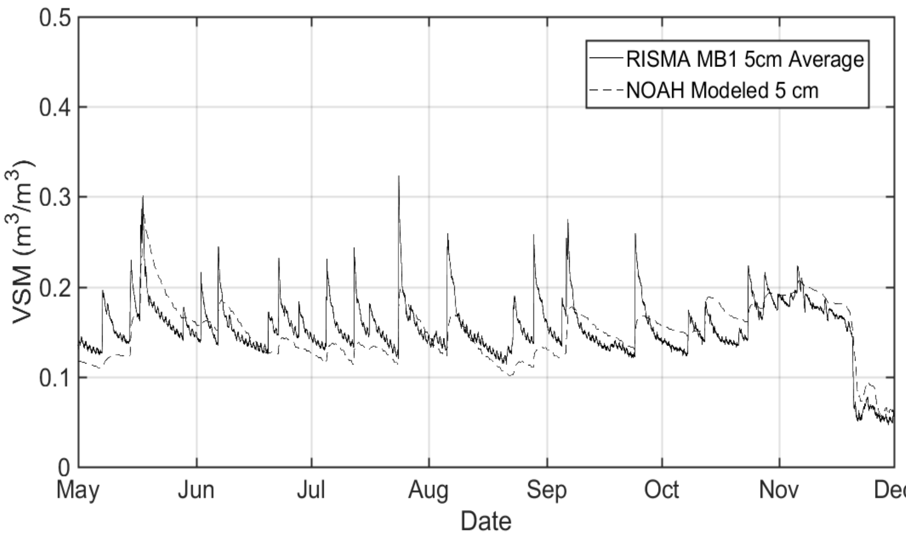


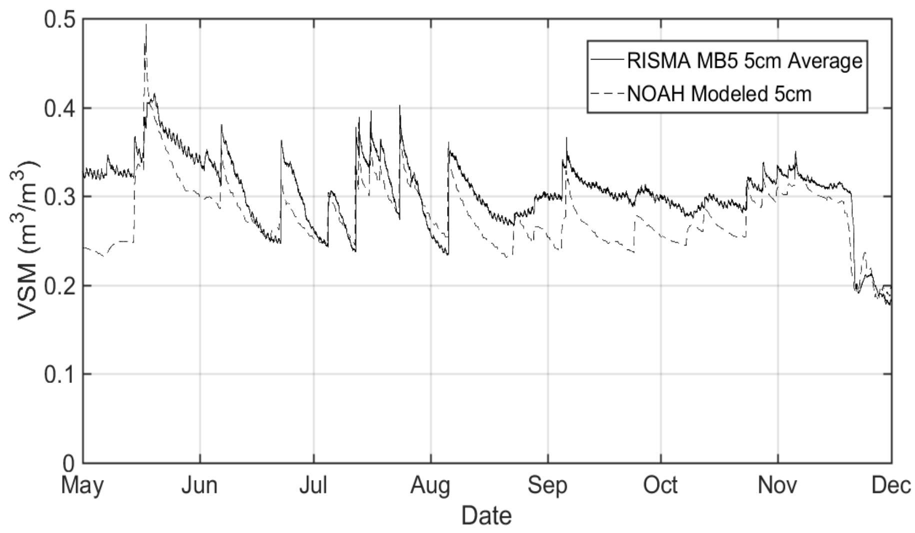
NOAH LSM Spin Up

The NOAH LSM was used to generate soil moisture values for the SMAP pixel. The model spin up was run for 2015 in a 1-D mode and the modeled point data was compared to the 5cm values recorded by RISMA stations MB1 and MB5 (May to November).

Hydrological state variables were generated at 30 minute time steps and compared to soil moisture stations representative of the surface soil textural properties of the SMAP pixel.

Stations	R	RMSE (m^3/m^3)	MAE (m^3/m^3)
MB1	0.502	0.028	0.022
MB5	0.719	0.065	0.060





NOAH LSM 2016

The NOAH model was then run in 2-D for 2016. A 1 km fishnet was created over the SMAP L2 SM P E pixel and the model was run over each grid cell using 2016 met data from 7 of 9 RISMA stations.

Soil moisture values generated over the gridded SMAP pixel were then validated against RISMA stations MB1, MB3 and MB8. SYMAP was used to interpolate the data over the entire 1 km fishnet grid.

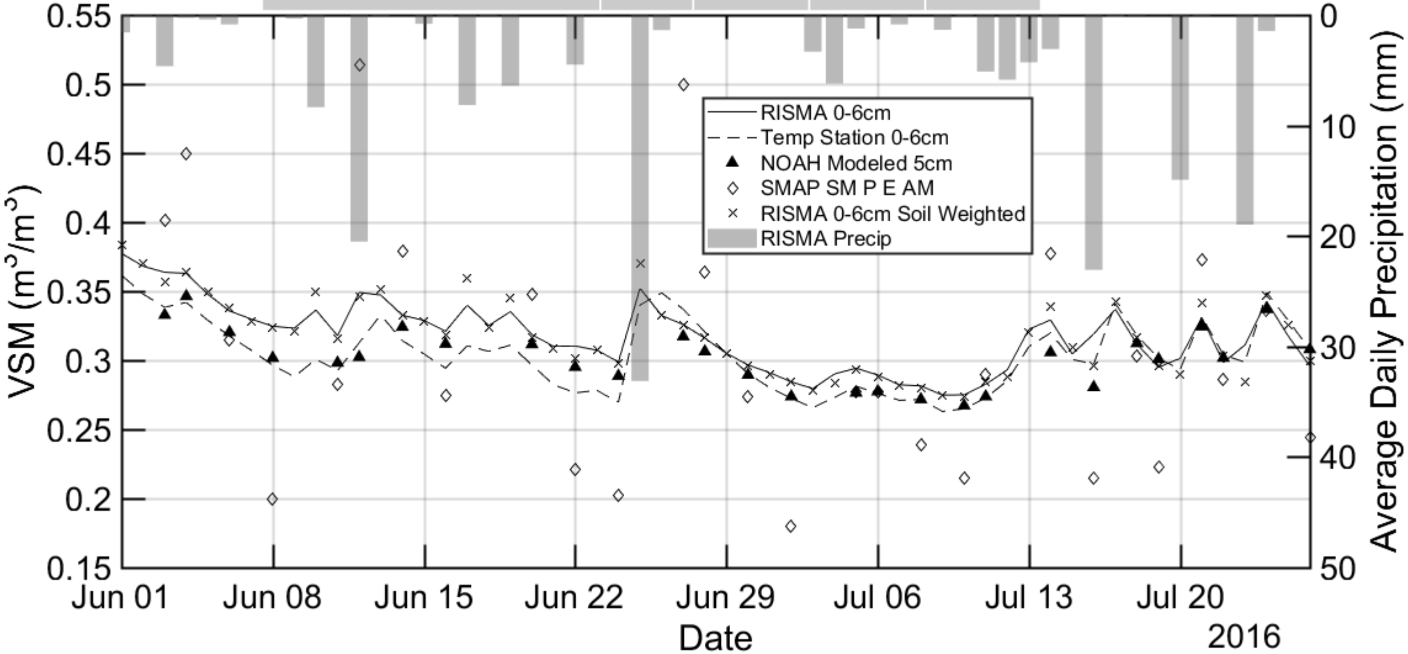
Stations	R	RMSE (m^3/m^3)	MAE (m^3/m^3)
MB1	0.536	0.033	0.024
MB3	0.855	0.035	0.026
MB8	0.881	0.042	0.028

SMAP L2 Comparison

Daily averaged soil moisture values from RISMA and the Temp stations were plotted against values from SMAP L2_SM_P_E (des v3).

Errors for SMAP are over 0.070 m^3/m^3 but not as high as previously noted. Temp and RISMA stations are in good agreement for the duration of the campaign.

Upscaling Approach	R	RMSE (m^3 / m^3)	MAE (m^3 / m^3)	PBias
Soil-weighted	0.751	0.072	0.056	-2.60
Arithmetic mean	0.750	0.073	0.059	-5.00
Voronoi diagram	0.748	0.075	0.062	-6.00
Soil-weighted Voronoi diagram	0.759	0.074	0.060	-4.20
NOAH Modeled 5cm	0.637	0.076	0.057	1.20



Discussion

- There were no differences when comparing the RISMA stations to the 45 temporary stations using the 4 upscaling approaches.

- All of the 4 upscaling methods agreed strongly with RMSE values between 0.023 – 0.026 m^3/m^3. Also the NOAH LSM did a good job of modelling surface soil moisture data when comparing them to RISMA values.

- When the 4 upscaling approaches and NOAH model were compared to SMAP data, RMSE values were very similar 0.072 – 0.076 m^3/m^3.

- The analysis indicates that the current RISMA network and soil-weighted upscaling are doing a good job in representing soil moisture values for the SMAP validation purposes.

- Lack of dynamic range during the campaign may have led to better agreement between SMAP retrievals and upscaled values.

- Results are pending publication in Vadose zone.

SMAPVEX16-MB Participating Organizations

Canada
Agriculture & Agri-Food Canada
Environment & Climate Change Canada
University of Manitoba
University of Guelph
University of Guelph
University of Sherbrooke
University of Montreal
ETE-INRS
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