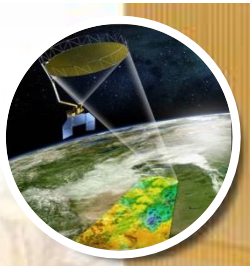
Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada



Up-Scaling of SMAPVEX16 Soil Moisture Field Data - SMAP Canada Workshop Guelph, ON

Jarrett Powers, Matthew Friesen, Hassan Bhuiyan
AAFC Science & Technology Branch
Winnipeg, MB

May 16, 2017

Canada

SMAPVEX16-MB Field Campaign

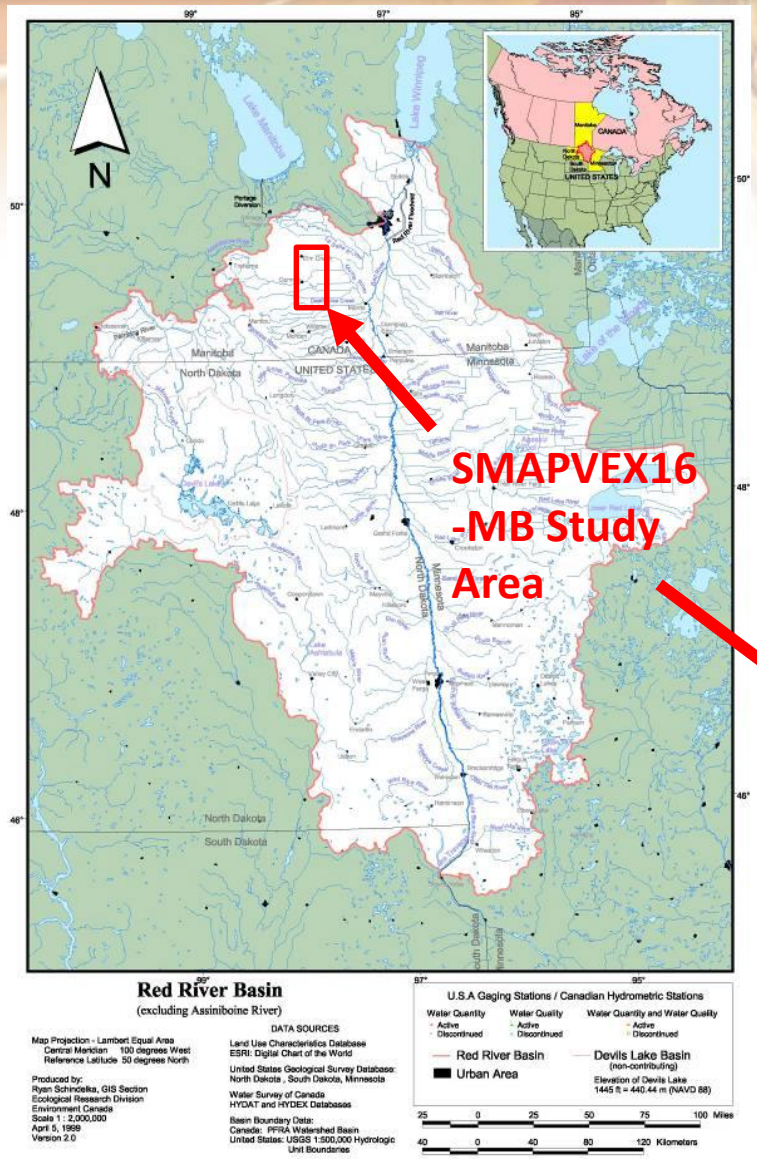
- Canada conducted a 2016 field study with NASA (SMAPVEX16-MB) to improve soil moisture retrievals from the satellite and examine new approaches to compensate for the loss of the SMAP radar.

- 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.

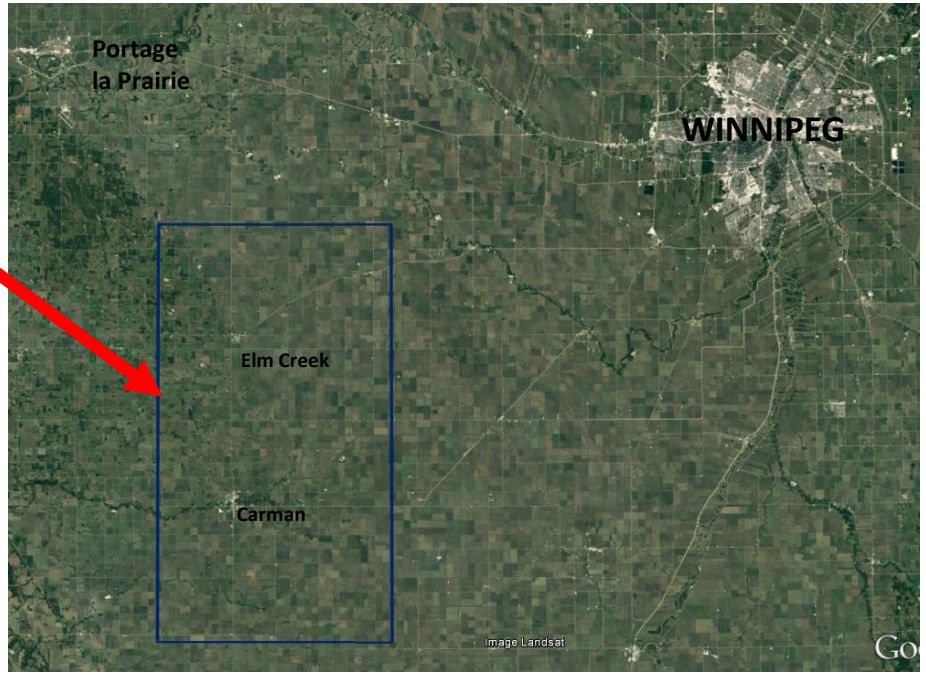
- The 2016 study was located in the same area as AAFC's soil moisture network. The network is a core validation site for NASA for the duration of the SMAP mission.

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

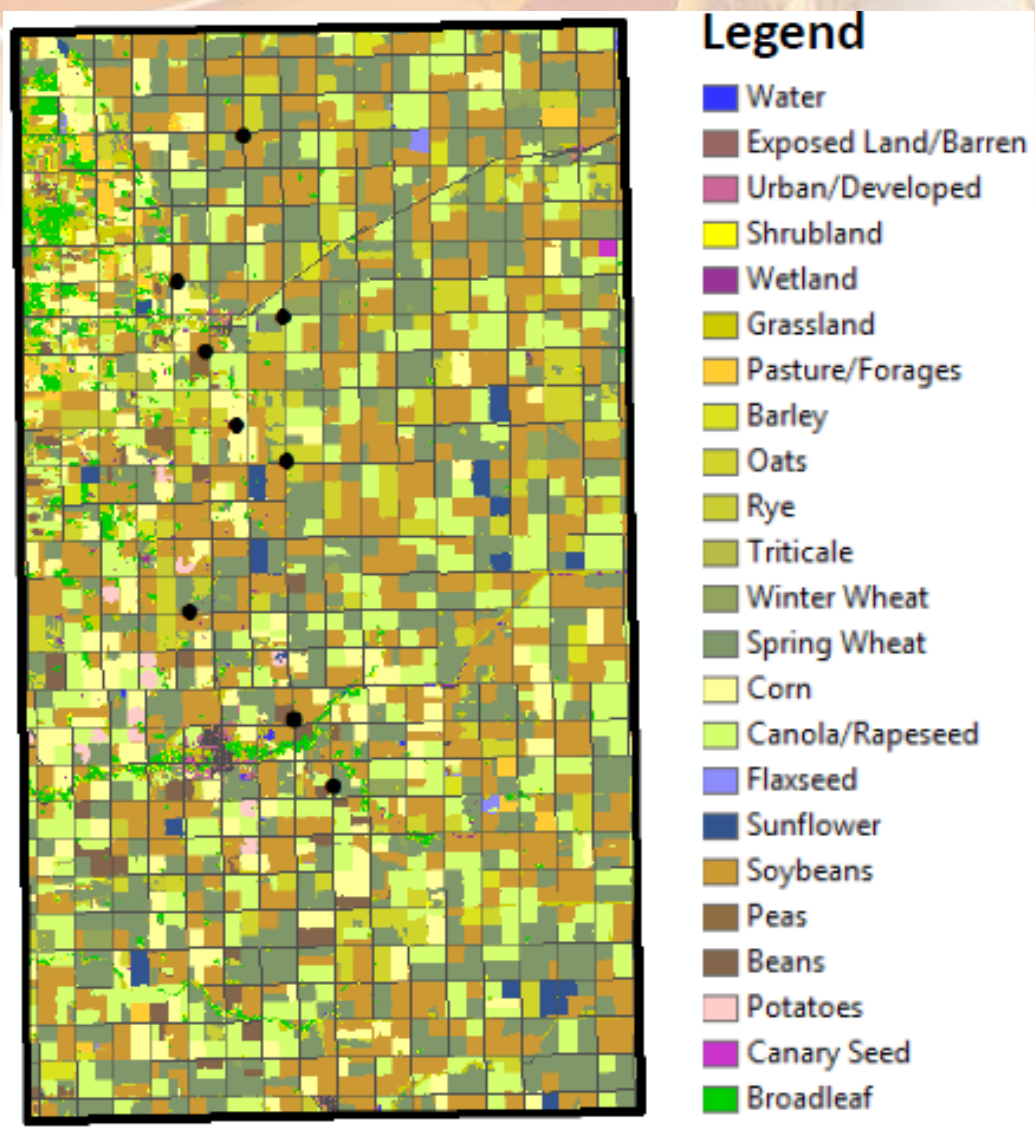
SMAPVEX16-MB Location



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



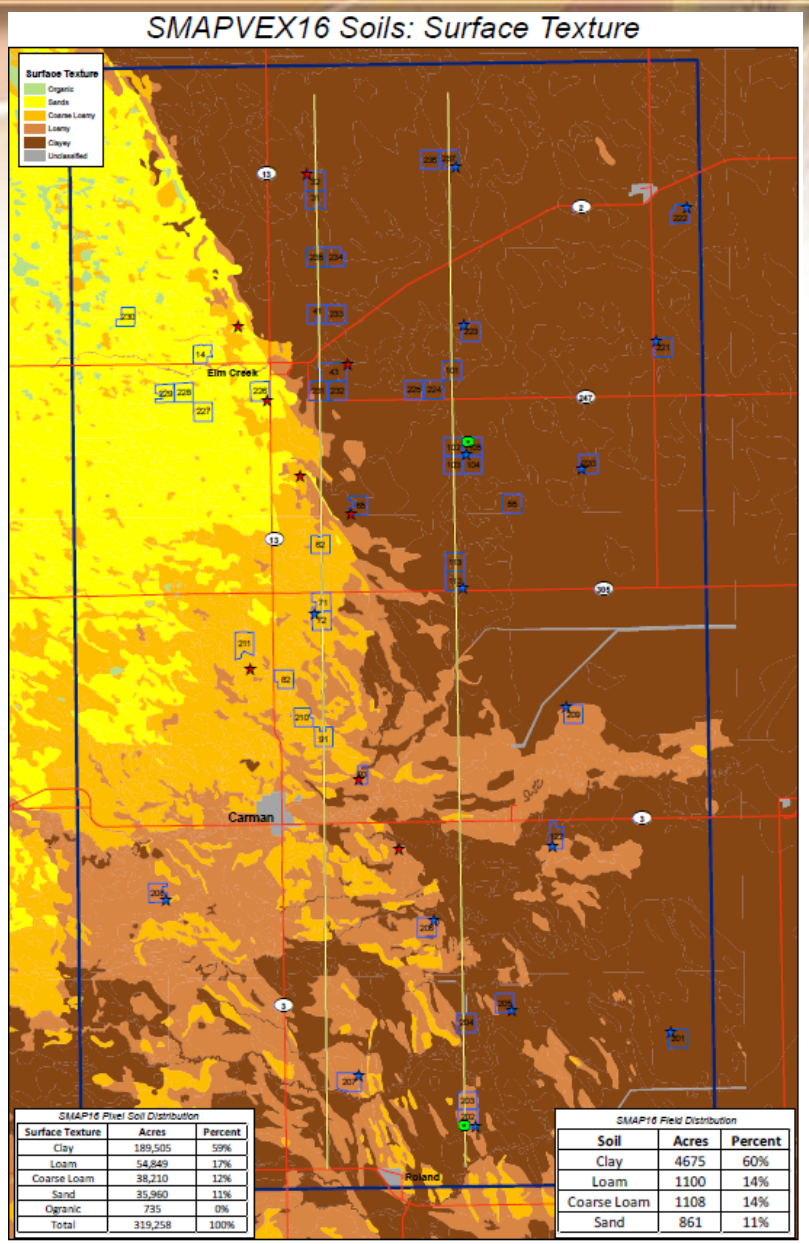
A total of 50 fields were selected for sampling. 21 fields from the SMAPVEX12 were used for the 2016 campaign.

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



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 sensor active radar sensors.
4. Deploy ground-based instruments (radiometer and scatterometer) to better understand soil moisture and vegetative contribution to microwave responses.

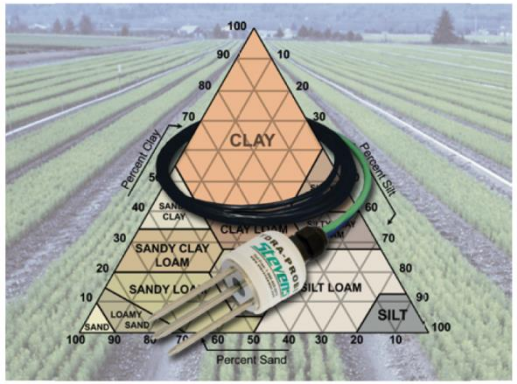
AAFC RISMA Instrumentation

RISMA 7 south of Elm Creek, MB

The MB Real-time In-situ Soil Monitoring for Agriculture (RISMA)network has 9 permanent soil moisture stations located in the Carman-Elm Ck. The stations support AAFC remote sensing, soil sensor research and are a core validation site for the SMAP mission.

- 3 Soil moisture probes at surface (vertical)
- 3 Probes at 5 cm, 20cm, 50cm and 100 cm
- Probes are 50-100 feet from field edge
- Tipping bucket rain gauge, air temp, relative humidity, solar radiation (2014)
- Data is transmitted hourly via cell modem
- Site-specific calibrations were developed to convert RDCs to volumetric soil moisture values

Hydra Probe II Soil Sensor



Soil profile prior to install

SMAPVEX16-MB Temporary Stations

USDA temporary station at Site 1 (canola)

USDA and AAFC temporary soil moisture stations were installed at Site 1 on all 50 fields.

Stations were installed in May and removed in July-Aug.

Each station has a Stevens Hydraprobe at 5cm vertical and 5cm horizontal. Data was logged hourly over 2 months. Over 90,000 measurements were collected.

40 stations also had a CS655 TDR probe at 5cm.

16 stations were equipped with tipping buckets to provide better coverage of rainfall throughout the study area.

SMAPVEX16-MB Sampling Sites

SMAPVEX16 sampling grid

16 sample points were selected for each field.

The sampling grid was located 100m from the edge of the field. Points were 75m between each other and 200m between the rows.

Rows were in the direction of crop seeding.

Use of aerial photography to avoid field drains.

SMAPVEX16-MB Soil Moisture Sampling

POGO calibration sampling in corn

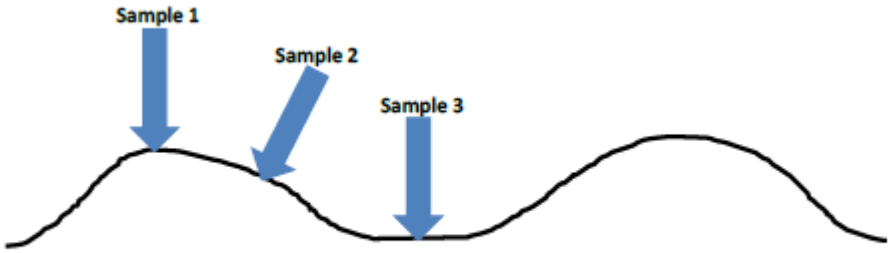


Figure 16. Location of replicate soil moisture measurements at each site

Stevens POGOs were used to measure Real Dielectric Values (RDC) at all 16 locations in each of the fields.

3 measurements/site (48 readings per field) were made each sampling day. Approximately 30,000 measurements over the campaign

Core samples and 3 readings were taken at Site 1 and at one other rotating site. Core samples were used to develop site-specific calibrations for the POGO and temp station data.

SMAPVEX16-MB Soil Moisture Sampling

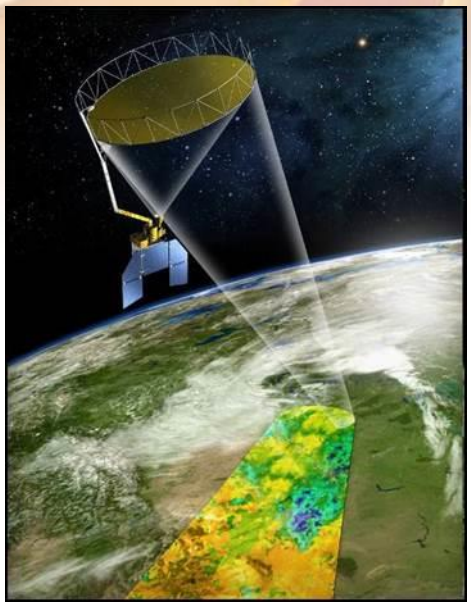


Figure 13. The PALS instrument mounted on the DC-3

Soil Moisture sampling days coincided with SMAP overpass (8-8:30am CST) and DC-3 PALS overflights.

PALS flew 5 transects at 10,000ft to map the SMAP pixel and 2 low altitude flight lines at 4,000ft to provide better resolution data.

A total of 12 soil moisture sampling days (6 in Phase 1 – June8-20 and 6 in Phase 2 – Jul10-22) were completed during the campaign. 1 additional sampling day was undertaken with no PALS flight in Phase 1.

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) Investigate different up-scaling methods (arithmetic average, soil-weighted, Thiessen polygon).

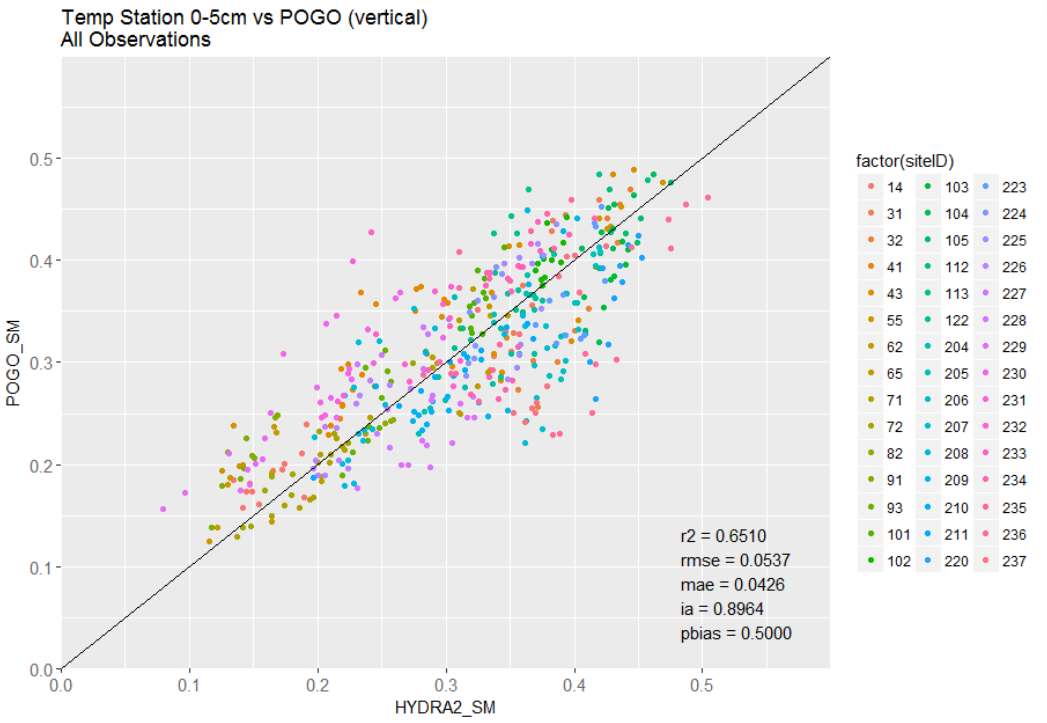
4) Compare results to SMOS and SMAP (L3_SM_P_E) to upscaling methods that use SMAPVEX16 study fields and RISMA data.

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 fall within the new L3_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 0-5cm 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 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 3.1% average variation in soil moisture values for clay-fine loamy soils and 4.9% average variation in soil moisture for sand-coarse loamy soils.

- There was no protocol for the placement of the temporary station 0.5cm hydraprobe (top-middle-bottom of the furrow). Placement of all hydraprobes at one position may have improved error.

- RMSE value of 5.4% is reasonable given field spatial variability and micro-topography and there is good agreement between the POGO and temp station data during the campaign.

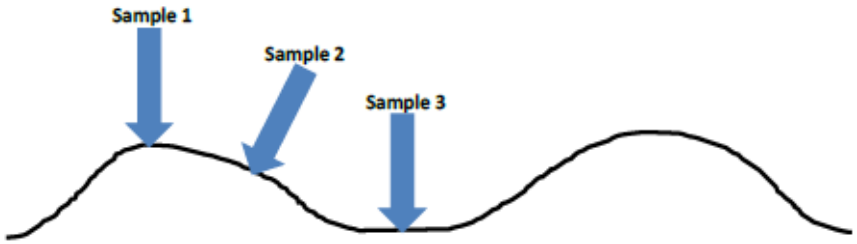


Figure 16. Location of replicate soil moisture measurements at each site

RISMA – Temp Station Comparison

RISMA station data was downloaded for the same period (June-July) and the 0-5cm 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.

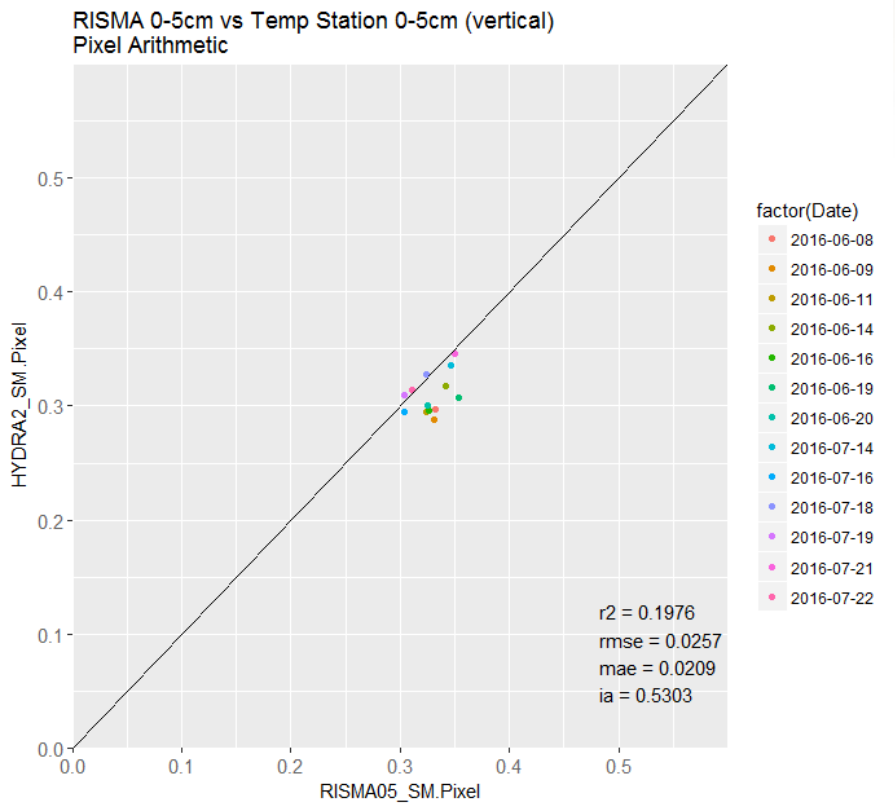
5 stations have Clay-Fine Loamy surface texture (Stations 2, 3, 5, 6, 8).

2 stations have Coarse Loamy-Sand surface texture (Stations 1, 9).

Both RISMA and Temp station data were processed using different upscaling approaches and results were compared.

Arithmetic Average

- A simple average of the RISMA and Temp station 0-5cm probes was calculated for the 13 soil moisture sampling dates.
- Some Temp stations experienced issues (power, wiring, etc) during the campaign. These stations were not included in the Temp station calculation.
- RMSE value is low (2.6%). This is likely the result of the number of fields selected for the campaign to be proportional to the occurrence of sand-coarse textured (25%) and clay-fine loamy surface textured soils within the study area (75%).

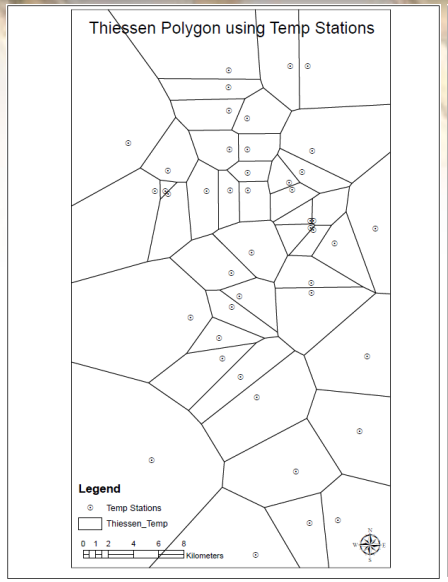


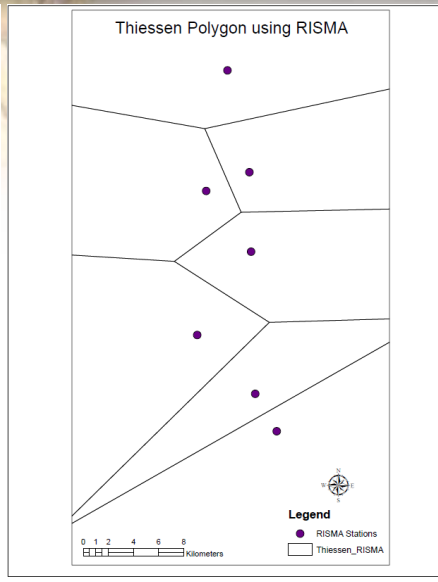
Thiessen Polygon

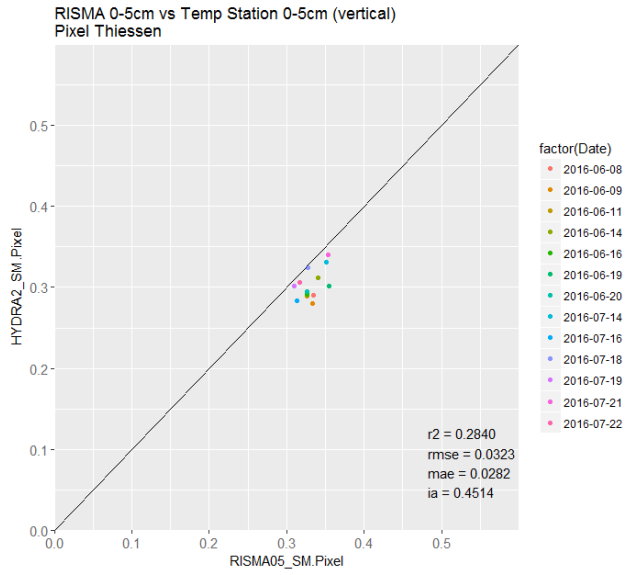
- Thiessen polygons were created from the locations of the RISMA and Temp stations. Area-weighted values were used to calculate a soil moisture value for the 0-5cm probes was calculated for the 13 soil moisture sampling dates.

- Some Temp stations experienced issues (power, wiring, etc) during the campaign. These values were replaced with POGO data that was collected from Site 1.

- RMSE value is low (3.2%) but slightly higher than the arithmetic average.





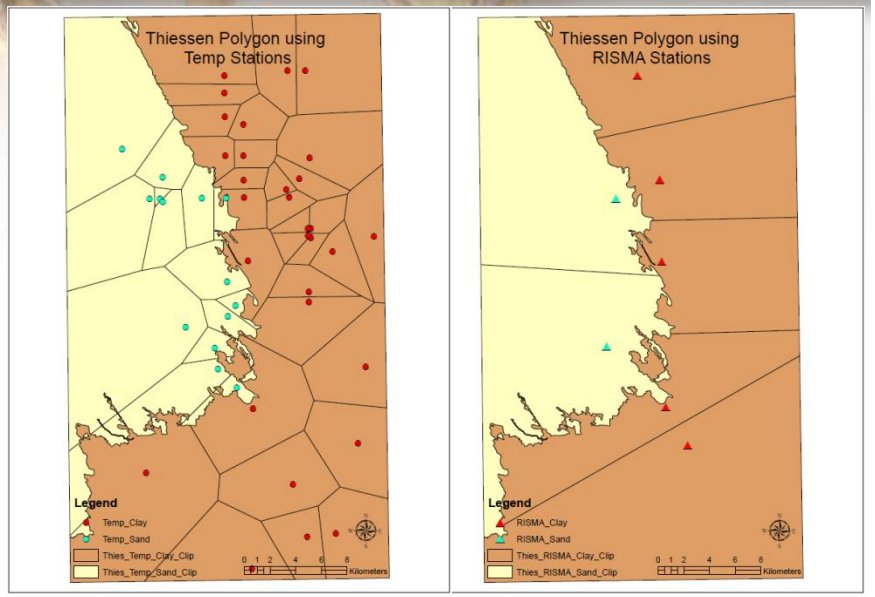


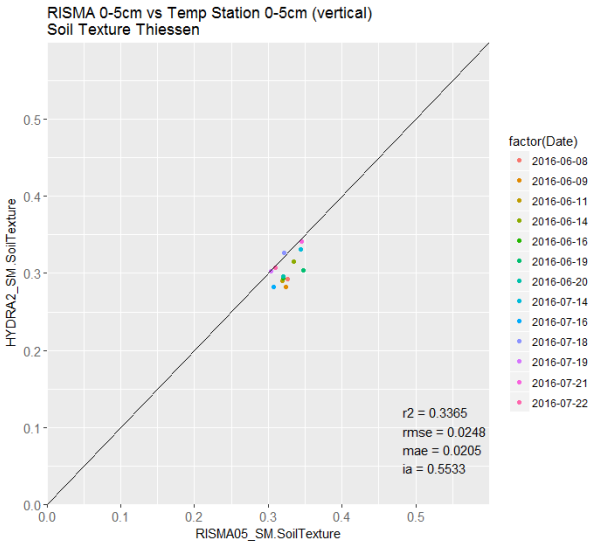
Soil-Weighted Thiessen Polygon

- Thiessen polygons were 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 0-5cm probes was calculated for the 13 soil moisture sampling dates.

- Some Temp stations experienced issues (power, wiring, etc) during the campaign. These values were replaced with POGO data that was collected from Site 1.

- RMSE value is (2.5%), slightly lower than using the Thiessen polygon approach.



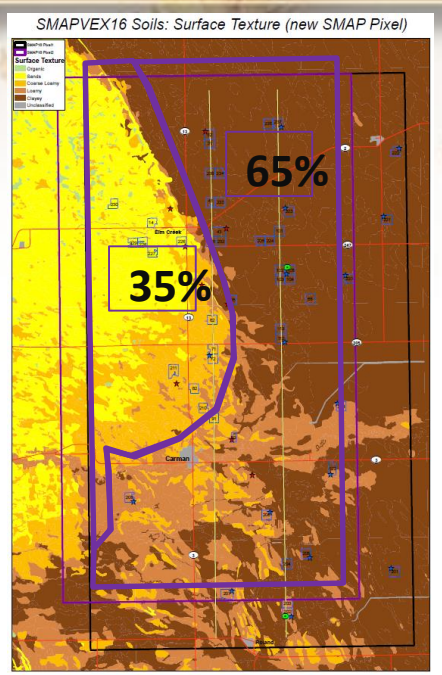


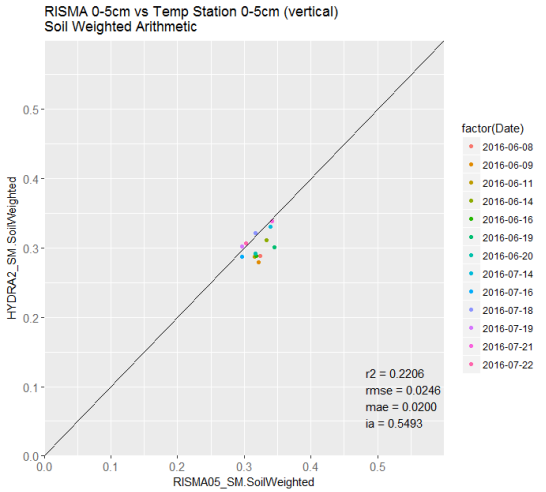
Soil-Weighted

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 0-5cm probes. This is the approach that is currently used for validation of SMAP data from the Carman CVS (5cm probes only).

Some Temp stations experienced issues (power, wiring, etc) during the campaign. These stations were not included in the Temp station calculation.

RMSE value is (2.5%), identical to the Soil Weighted Thiessen polygon approach.

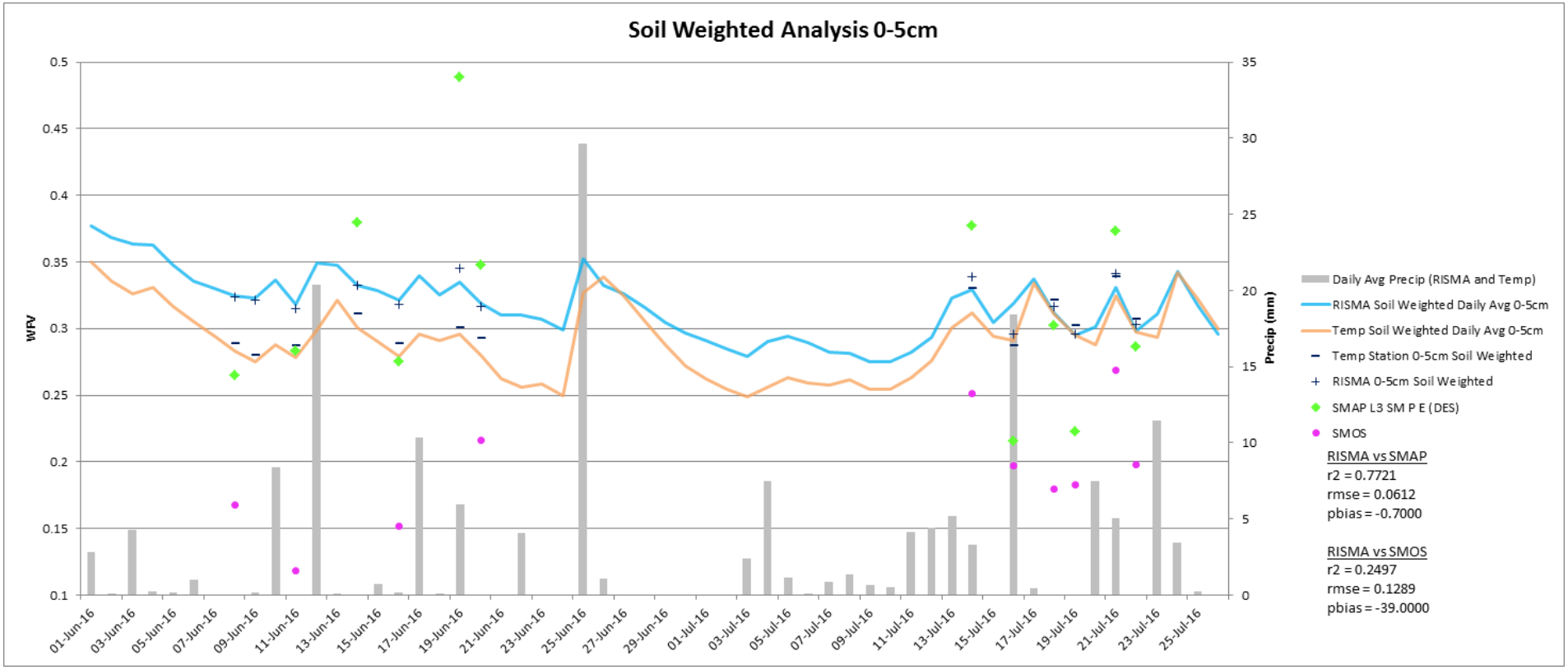




SMAP-SMOS Comparison

Daily averaged soil moisture values from RISMA and the Temp stations were plotted against values from SMOS (des) and SMAP L3_SM_P_E (des) for the 13 sampling dates.

Errors for SMAP are over 6% but not as high as previously noted. SMOS values are high and there is a strong bias. Temp and RISMA stations are in good agreement for the duration of the campaign.



Discussion

- Analysis of the different upscaling approaches using data from AAFC's RISMA stations no significant differences in comparison to the SMAPVEX16 temp stations. There was a small reduction in error when a soil-weighted approach was used for up-scaling.

- Overall, the 7 RISMA stations were in good agreement when compared to soil moisture values from the 45 temp stations…….2.5-3.2% RMSE depending on up-scaling method.

- SMAP L3_SM_P_E retrievals (6% RMSE) with the RISMA network (rapid drydowns and underestimated soil moisture values). Errors are less than what we have previously seen(10%).

- SMOS errors are higher and all underestimated. SMOS footprint may be shifted further west into the coarser-textured soils?

- Lack of dynamic range (soils were mostly wet for both phases of the campaign) in soil moisture. Expect better agreement between with in-situ measurements and satellite retrievals.

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
Manitoba Agriculture

United States

NASA - GSFC
NASA - JPL
USDA - ARS Hydrology & Remote Sensing Laboratory

Italy

ISSIA CNR