Agriculture and Agri-Food Canada
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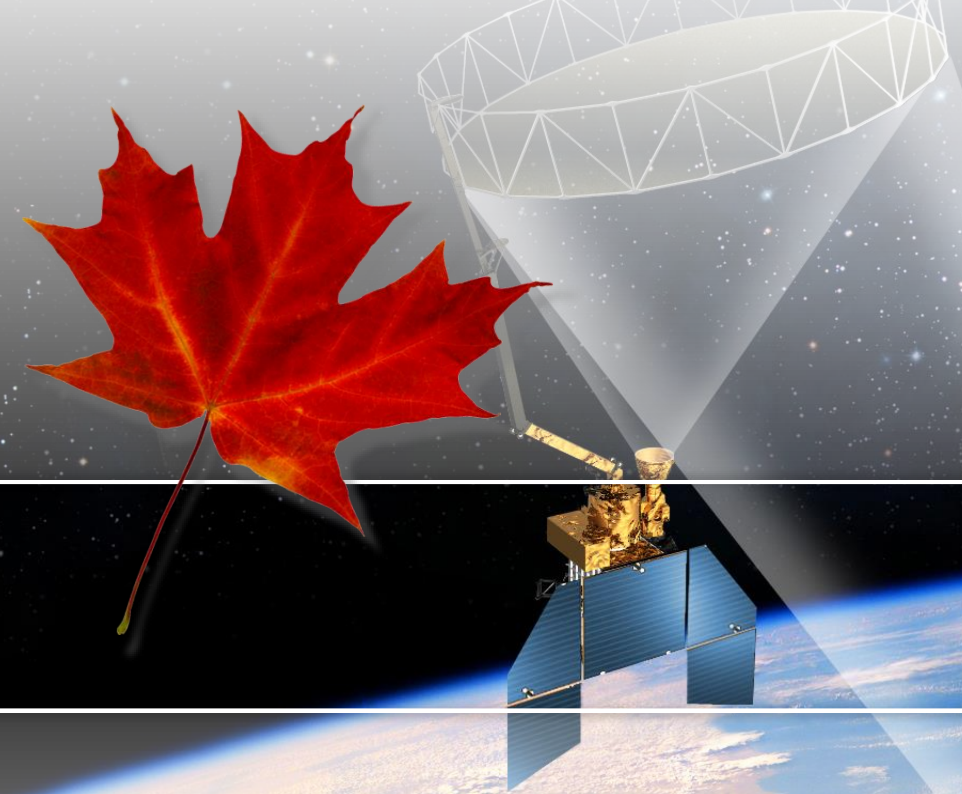
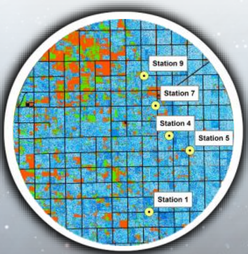
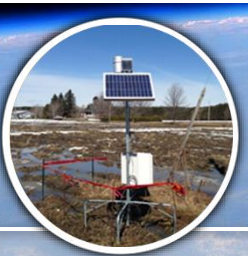






SMAPVEX16-MB
Data Collection Summary
Analysis of Vegetation Water Content

SMAPVEX16 MB: Research Objectives

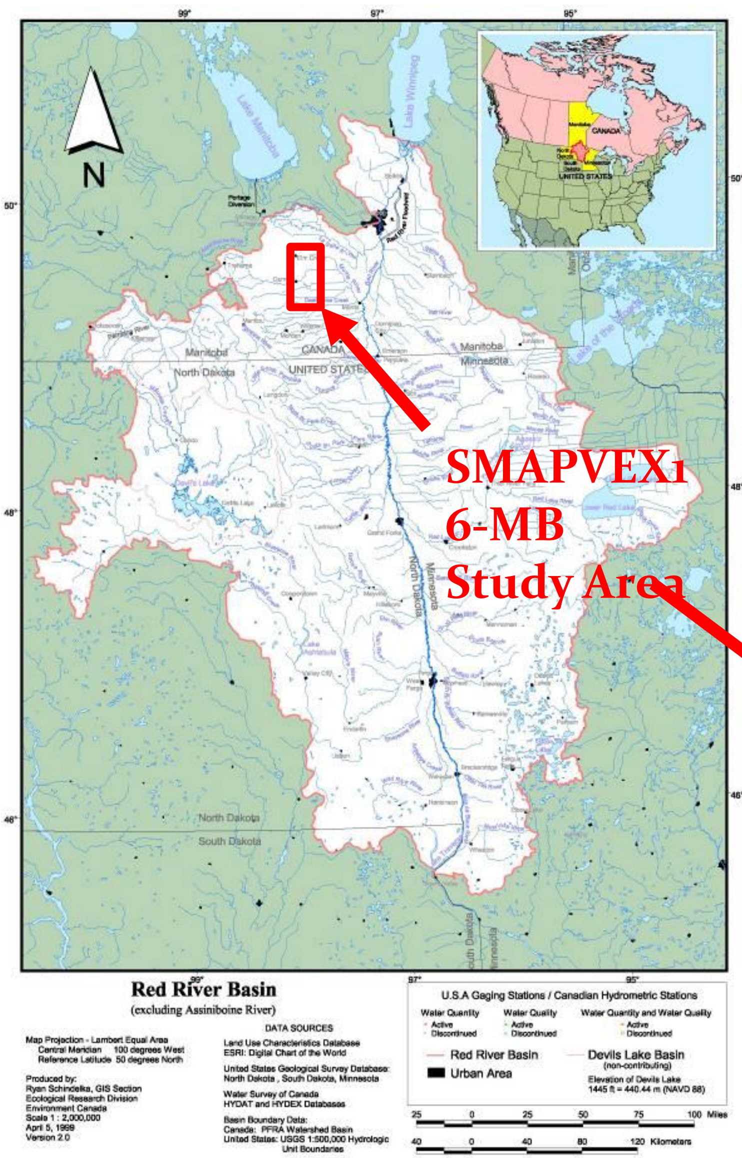
- Investigate anomalous retrievals (under-estimation of soil moisture values/rapid drydowns following a precipitation event) from the SMAP satellite. This is a common occurrence on agricultural core-validation sites with annual crop production.

- 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.

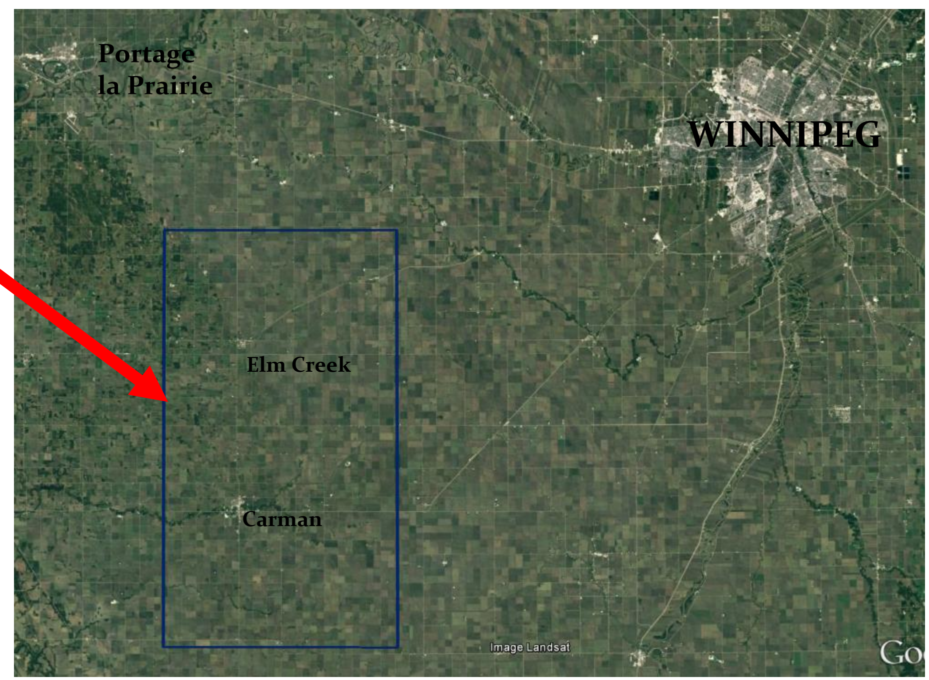
- Develop and evaluate down-scaling approaches that utilize SMAP radiometer data given the loss of the radar. These include the use of other sensor active radar sensors.

- Deploy ground-based instruments to better understand soil moisture and vegetative contribution to microwave responses.

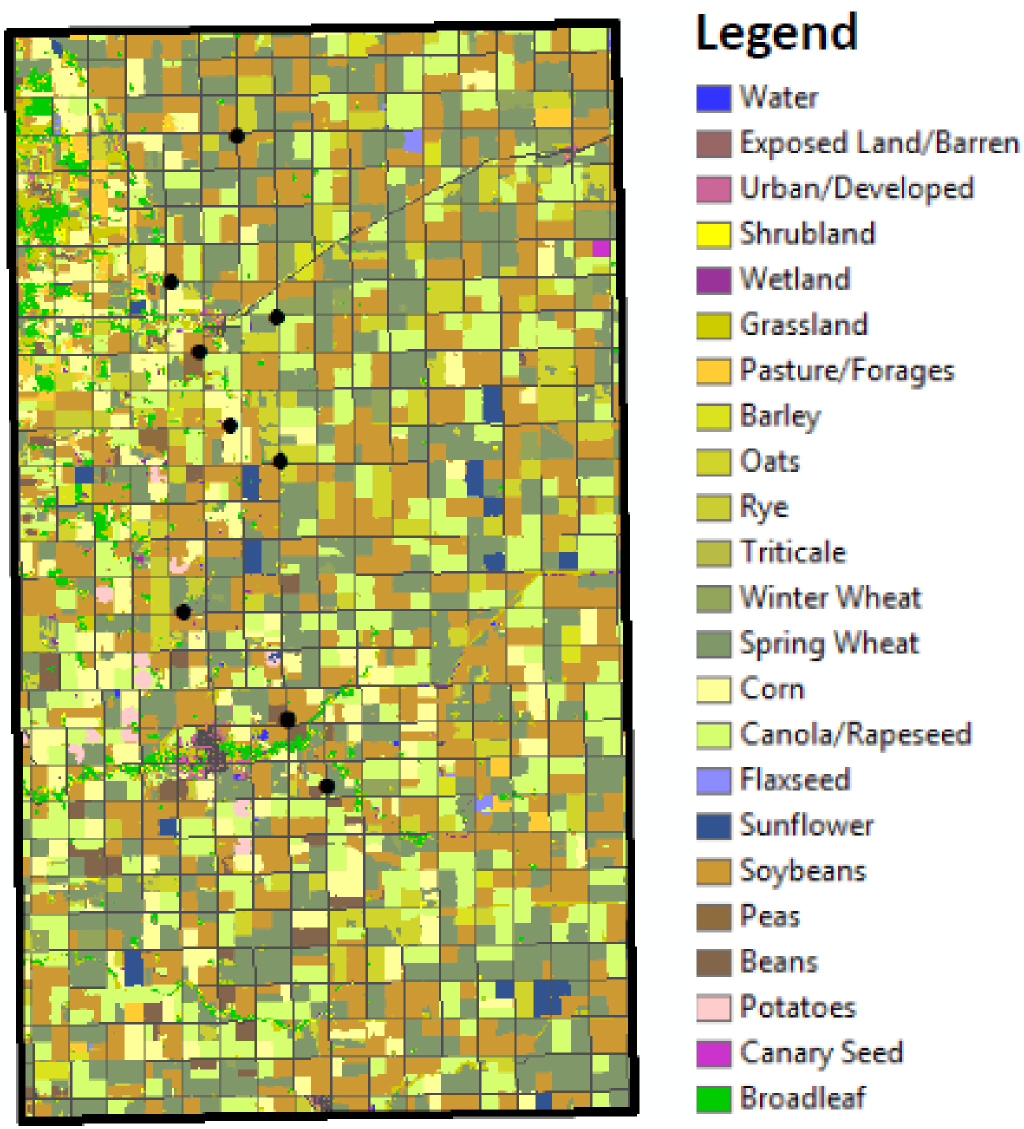
SMAPVEX16-MB Location



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.

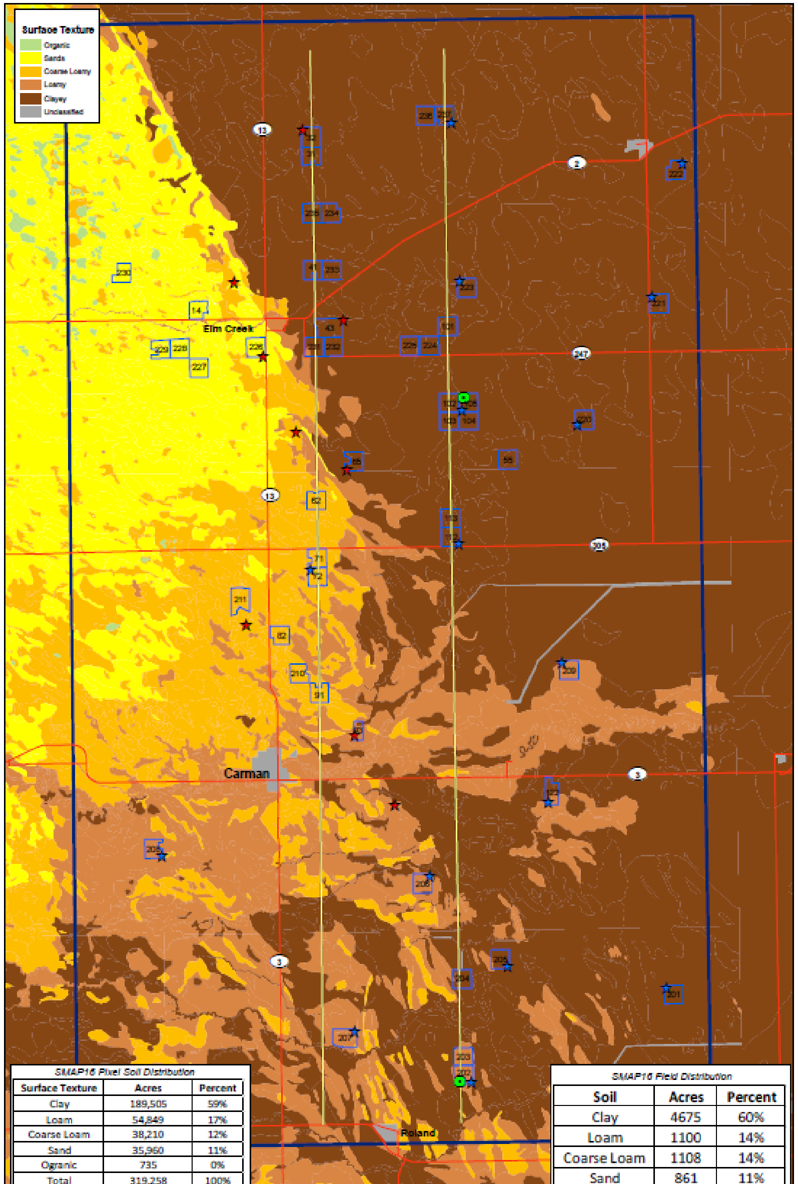
MB Crop Insurance and AAFC Annual Crop Inventory (derived from satellite imagery) was analyzed to look at cropping trends in the study area.

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 Sampling Strategy

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.

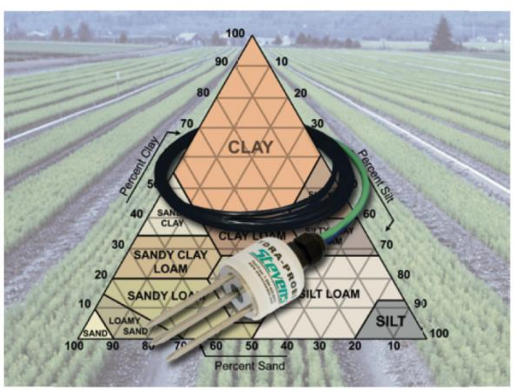
Rows were in the direction of crop seeding.

Use of aerial photography to avoid field drains.

AAFC Permanent Network - RISMA

RISMA 7 south of Elm Creek, MB

Hydra Probe II Soil Sensor



Soil profile prior to install

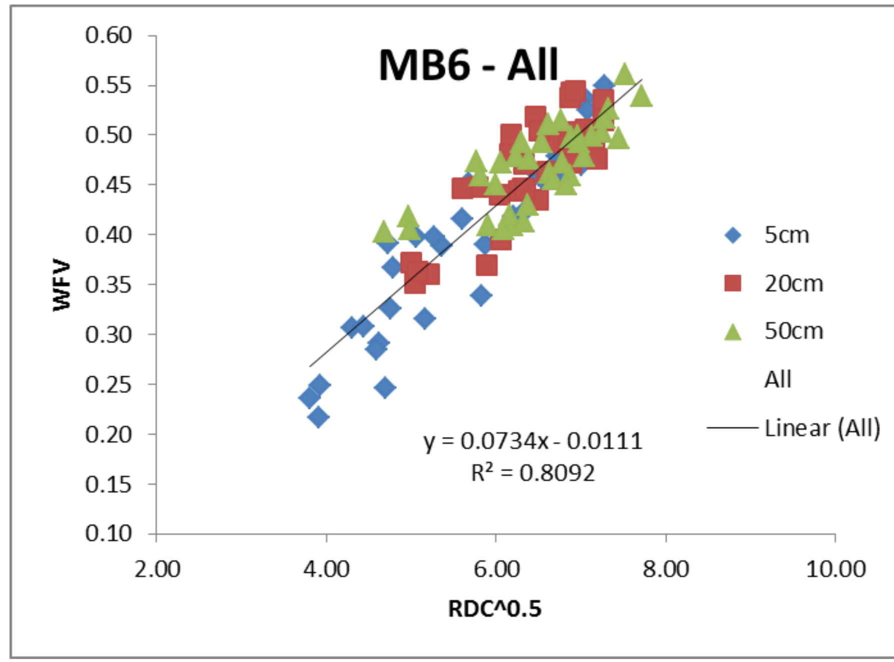
The MB Real-time In-situ Soil Monitoring for Agriculture (RISMA)network has 9 permanent soil moisture stations located in the Carman-Elm Ck, 3 in Sturgeon Ck and 3 in Carberry. The stations support AAFC remote sensing, soil sensor, irrigation and hydrology research.

The Carman-Elm Ck network is 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

Calibration of RISMA

The soil moisture calibration equations (conversion of RDC to VWC) are based on a regional in-situ calibration developed by RoTimi Ojo (UofManitoba). The regional calibration equations were applied to the sandy and loam soils, while the site specific equations were applied to the more variable clay soils.



$$y = 0.0797\sqrt{RDC} - 0.053$$

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 Soil Moisture Sampling

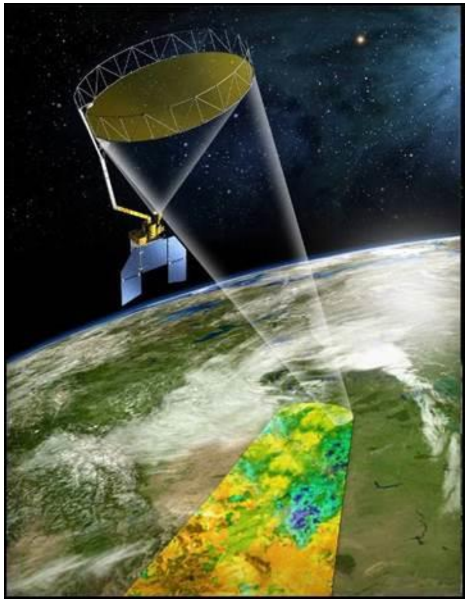


Figure 13. The PALS instrument mounted on the DC-3

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.

SMAPVEX16-MB Soil Moisture Sampling

POGO calibration sampling in corn

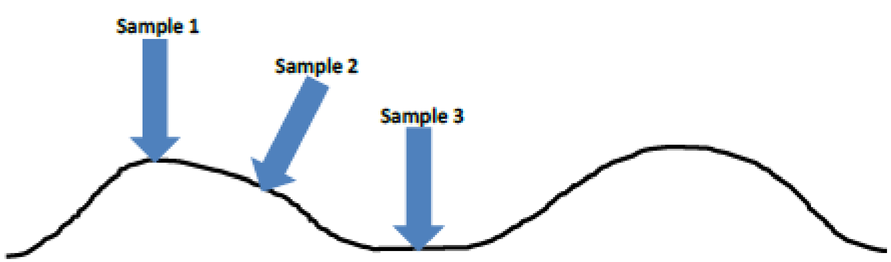


Figure 16. Location of replicate soil moisture measurements at each site

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.

Soil temp (5 & 10cm) and skin temps (soil and veg) recorded at Site 1, 8, 9, 16.

Surface roughness measurements were collected once at the start of the campaign for each field.

SMAPVEX16-MB Vegetation Sampling

Soybean LAI photo

Wheat at infloresence emergence

The objective of the vegetation sampling component was to measure biomass and plant water content to assess the effectiveness of vegetation parameterization associated with soil moisture retrieval models for both passive and active microwave sensors.

50 fields were sampled twice during Phase 1 and twice during Phase 2 (weekly basis). Also, fields were sampled once between Phase 1 and 2 (June22-July10) for a total of 5 sampling times over the campaign.

Plant count, row direction and row spacing were collected before the start of the campaign.

Plant height and Leaf Area Index (LAI) photos were collected at various crop growth stages to characterize ground cover. Plants were harvested to determine wet/dry biomass. Plants were partitioned to determine plant water content from stems, leaves, flowers and seeds.

SMAPVEX16-MB Ground Based Radiometers

EC Radiometer at Field 202 (canola)

UofSherbrooke at Field 105 (wheat)

2 ground-based radiometers (ECCC and UofSherbrooke) were deployed for the duration of the campaign (June 9-July 22). Plans to deploy a scatterometer were abandoned due to equipment failure at the start of the campaign.

Sensors were installed at the edge of yardsites adjacent to a canola crop (Field 202) and wheat crop (Field 105).

Daily multi-angular observations of TBH and TBV from 30° to 70° with an increment of 5° were collected on the canola and wheat fields. The instruments were otherwise left to measure at 40°.

Soil moisture/temp was collected from a temp station installed inside the footprint. Additional hand-held measurements during SMAP soil moisture sampling days and during RADARSAT-2 and SMOS PM acquisitions were also taken. Soil roughness and vegetation was also collected around the footprint.

SMAPVEX16-MB Data Availability

- Similar to 2012, field data and ancillary datasets have been loaded into an ESRI geodatabase. For non-GIS users, the data is available as text (csv) files.

- Full metadata is available with both spatial and non-spatial data.

- Version 1 was released Dec 22, 2016

- Version 2 was released April 4, 2017
  Additional data: EC continuous radiometer; soil properties (lab);
  Stevens POGO data with calibrated vol soil moisture measurements;
  LAI and crop scan; crop height.

- Data can be downloaded to project partners from the University of Sherbrooke ftp server. Contact Ramata Magagi ramata.magagi@usherbrooke.ca for access.

- After July, 2017 data will be transferred to the National Snow & Ice Data Centre (NSIDC) https://nsidc.org/ and made publically available.

SMAPVEX16-MB Team

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Maria Abrahamowicz, Environment Canada
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Matt Gervais, University of Manitoba
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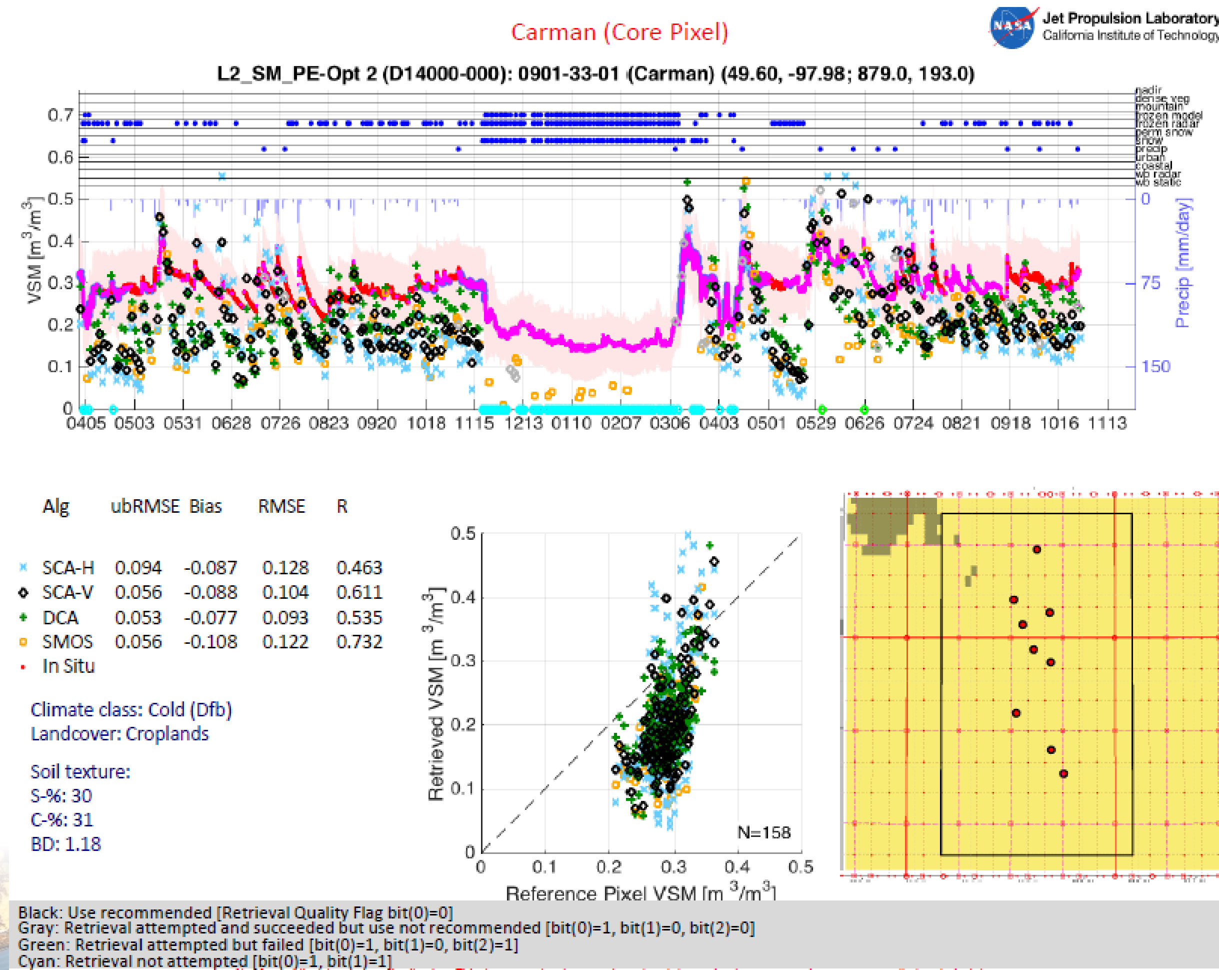
Vineet Kumar, Agriculture and Agri-Food Canada
Xiaoyuan Geng, Agriculture and Agri-Food Canada

SMAP vs In-Situ Soil Moisture in Carman

- Comparison results between the SMAP soil moisture retrievals and the RISMA soil moisture demonstrate that:
  - SMAP retrievals responds to precipitation events
  - SMAP retrievals experience a rapid dry down
  - SMAP retrievals underestimate soil moisture values



Credit: Jet Propulsion Laboratory, California Institute of Technology, NASA

Carman Soil Moisture - Potential Sources of Errors

- AAFC is investigating potential sources of error that could explain SMAP's underestimation of soil moisture over the Carman site

- The following sources of error have been identified:
    - RISMA's soil moisture values
    - RISMA's upscaling technique which is based on a soil area weighting technique
    - SMAP's soil texture fractions
    - SMAP's vegetation water content

- This presentation will address the issue of the VWC estimated from SMAP

Comparing VWC from SMAP vs SMAPVEX16-MB

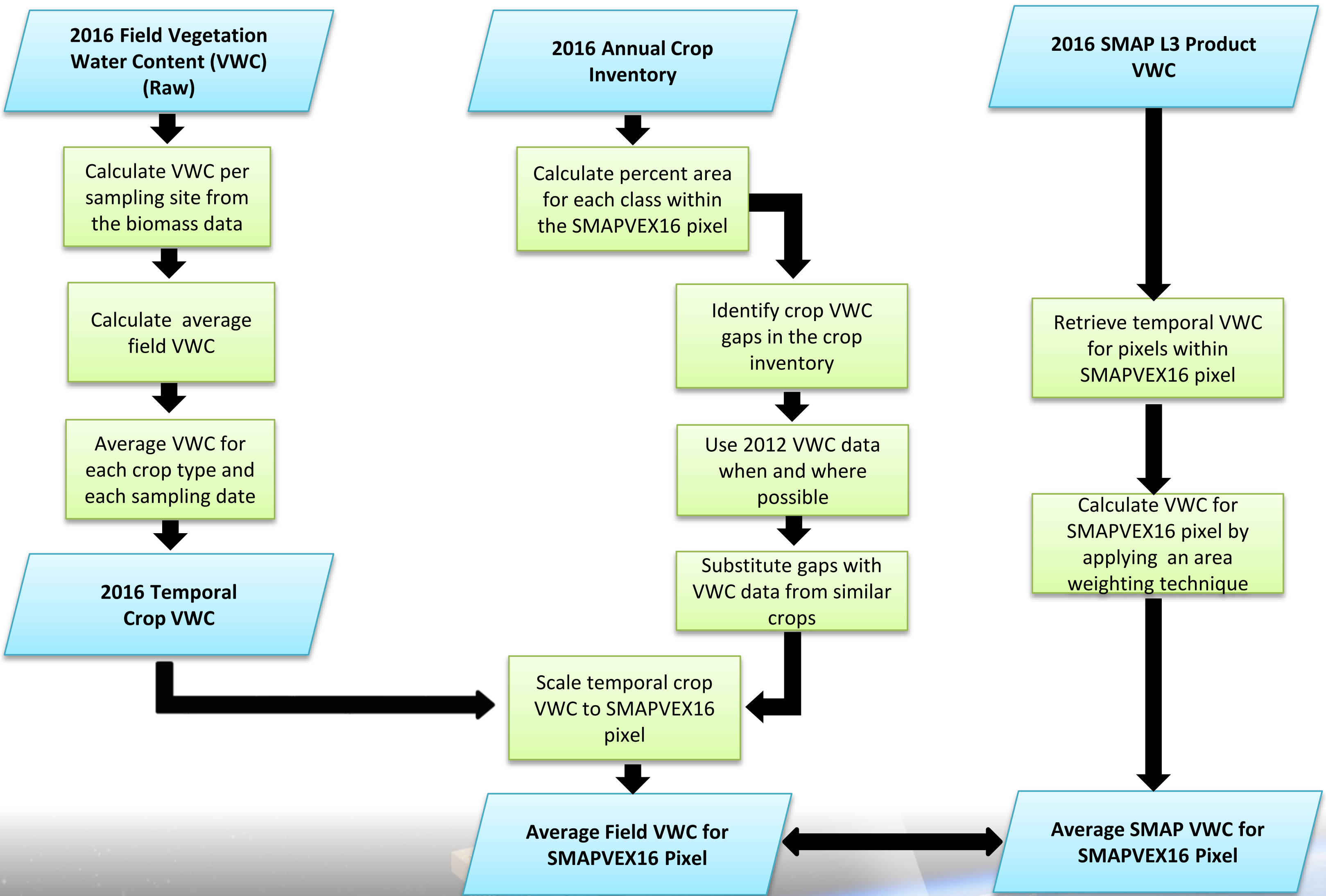
- The main objective of this study is to compare the vegetation water content retrievals from SMAP and those calculated from the field data during the SMAPVEX16-MB field campaign.

- SMAP accounts for its vegetation contribution by computing the vegetation optical thickness (τ), which is derived from the vegetation water content (VWC). The VWC is estimated from NDVI climatology, which is created from a 10-year average of normalized difference vegetation index values from MODIS.

- To compare the SMAP VWC with the field VWC, this study will use the crop biomass data collected during SMAPVEX16-MB.

- The general methodology includes:
    - Deriving temporal crop VWC from the SMAPVEX16-MB ground data
    - Estimating average VWC for the SMAPVEX16-MB pixel by using AAFC's 2016 annual crop inventory and filling data gaps with SMAPVEX12-MB data
    - Extracting 2016 temporal VWC from the SMAP L3 product and scaling to the SMAPVEX16-MB pixel
    - Comparing the 2016 temporal VWC from the SMAPVEX16-MB with the SMAP L3 VWC

Comparing SMAP and Field VWC - Methodology

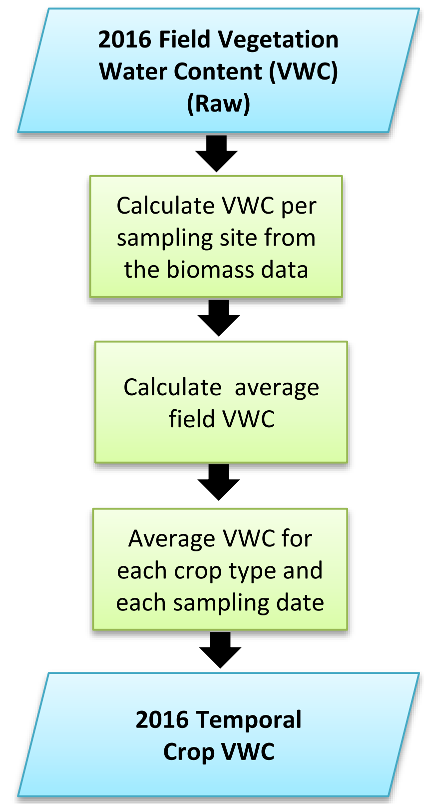


Deriving Crop VWC from SMAPVEX16-MB

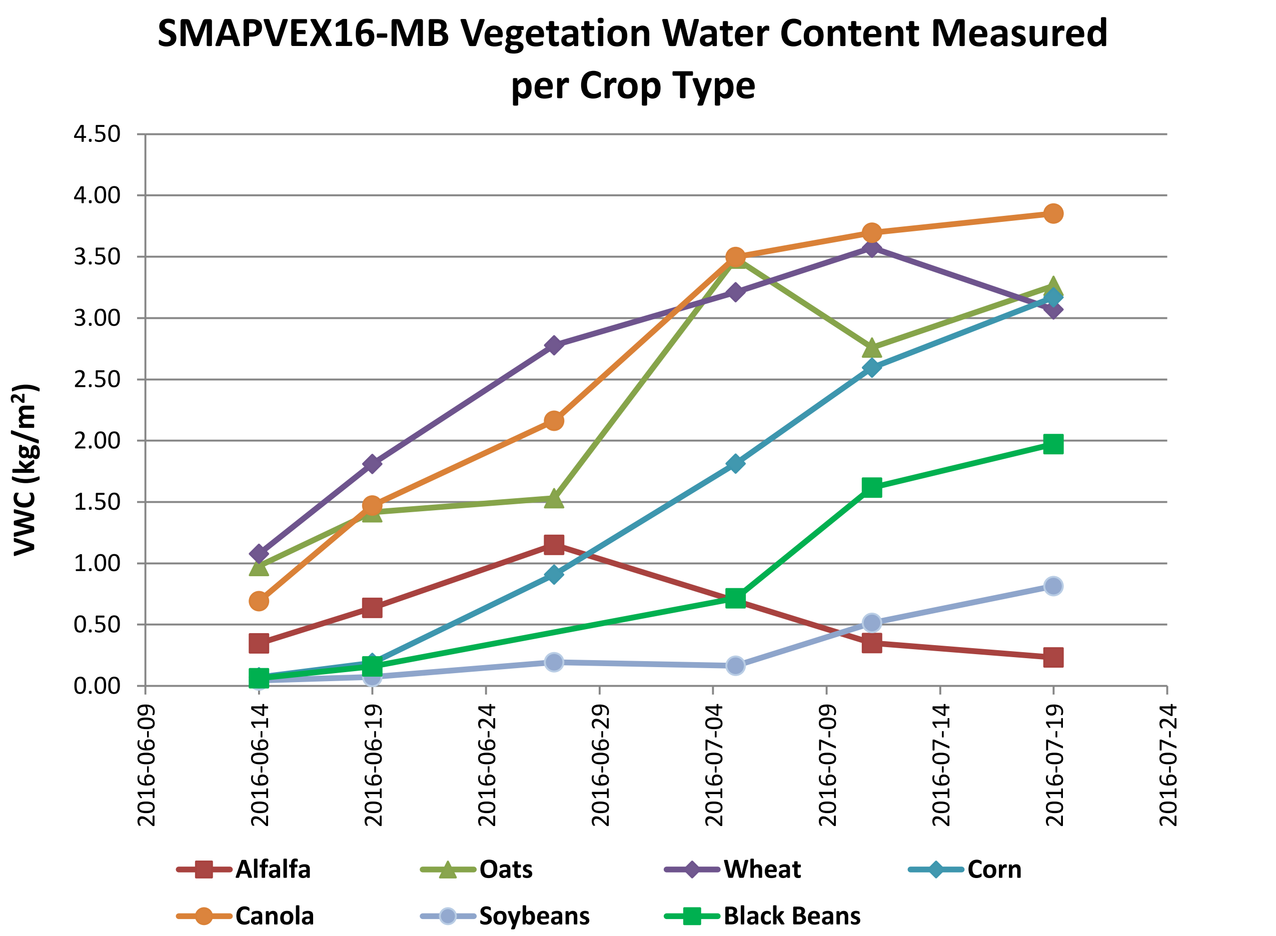
- Destructive crop biomass samples were collected throughout the SMAPVEX16-MB field campaign. For wide-spaced row crops such as corn, soybeans or black beans, five plants per row in two consecutive rows (10 in total) were collected for each sampling site. For narrow-spaced row crops such as wheat, oats, or canola, plants were collected using a 0.5 m x 0.5 m quadrate.

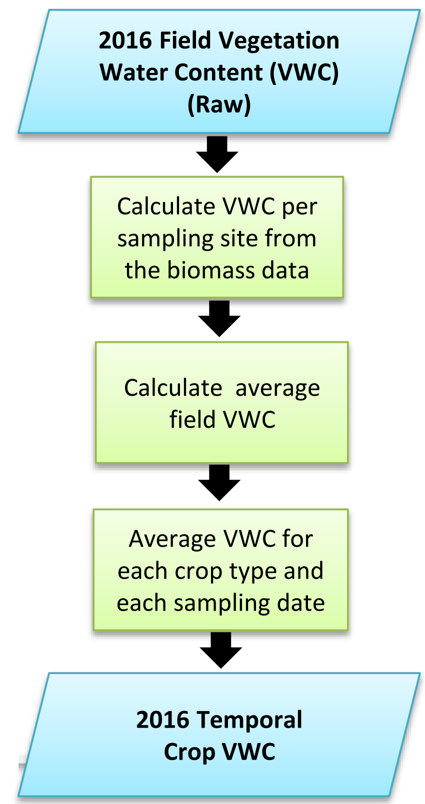
- Wet crop biomass was weighted in the lab, oven dried and then re-weighed. VWC was calculated by subtracting the dried from the wet weights, and scaled if required to kg/m^2 units.

- VWC was then averaged for each sample site and then for each field. An average crop VWC was calculated by averaging VWC for each crop type.

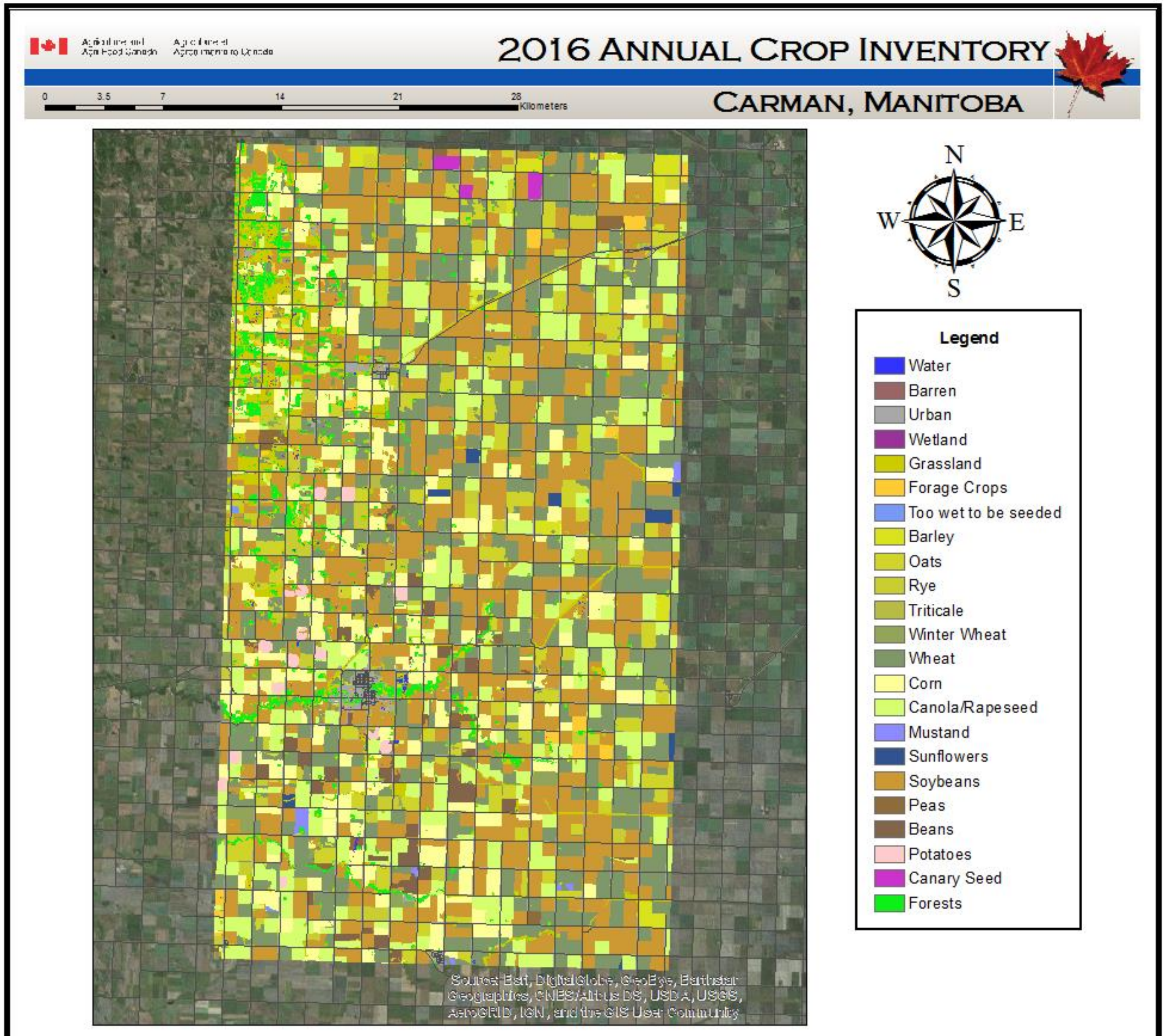


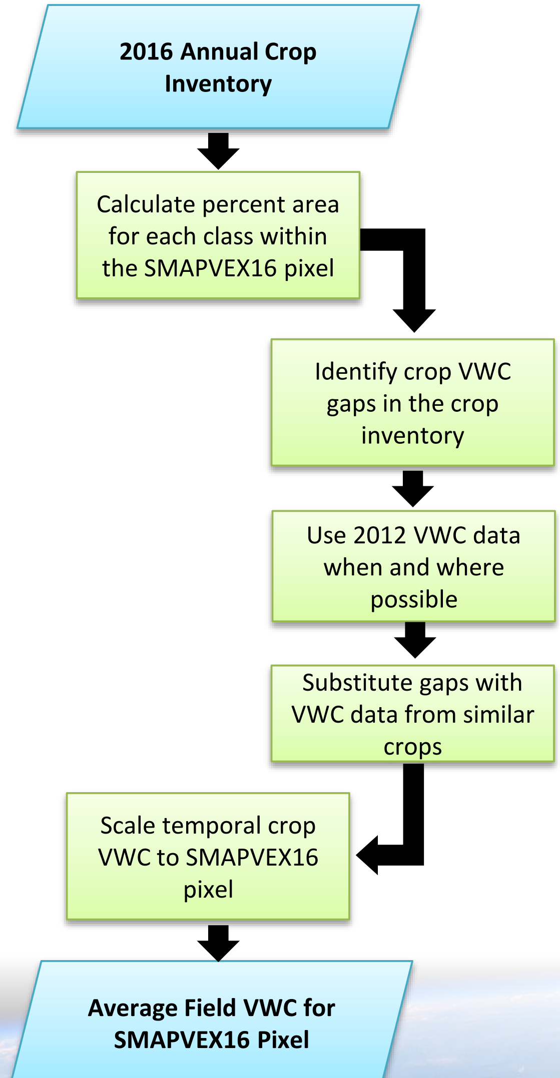
Results - SMAPVEX16-MB Crop VWC





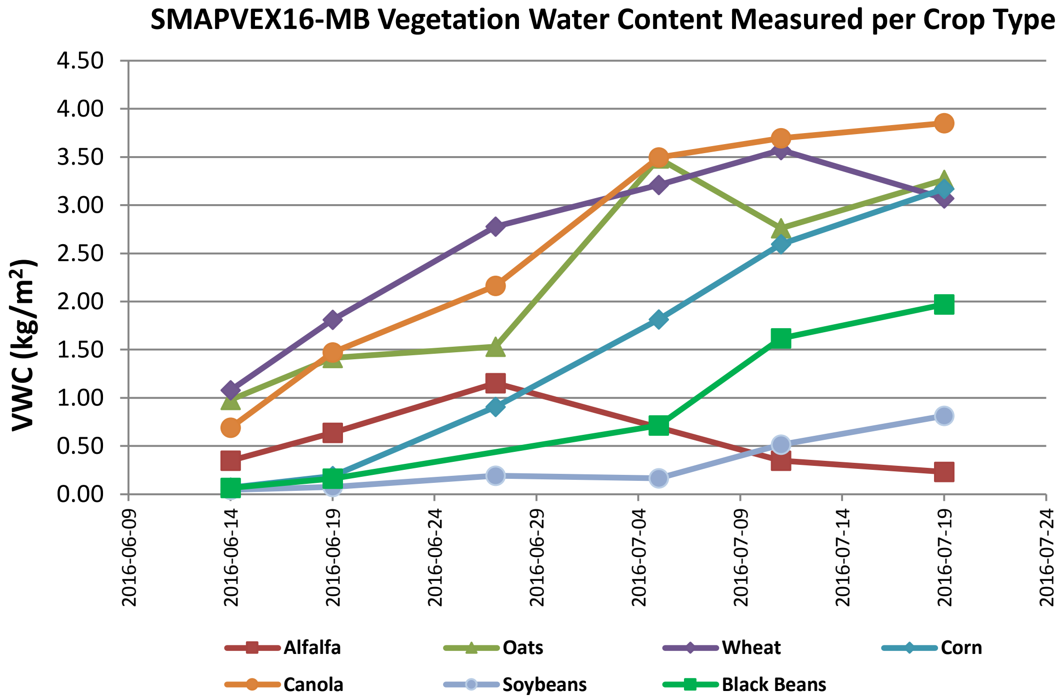
Estimating VWC for the SMAPVEX16-MB Pixel





Results – SMAPVEX16-MB Average Crop VWC

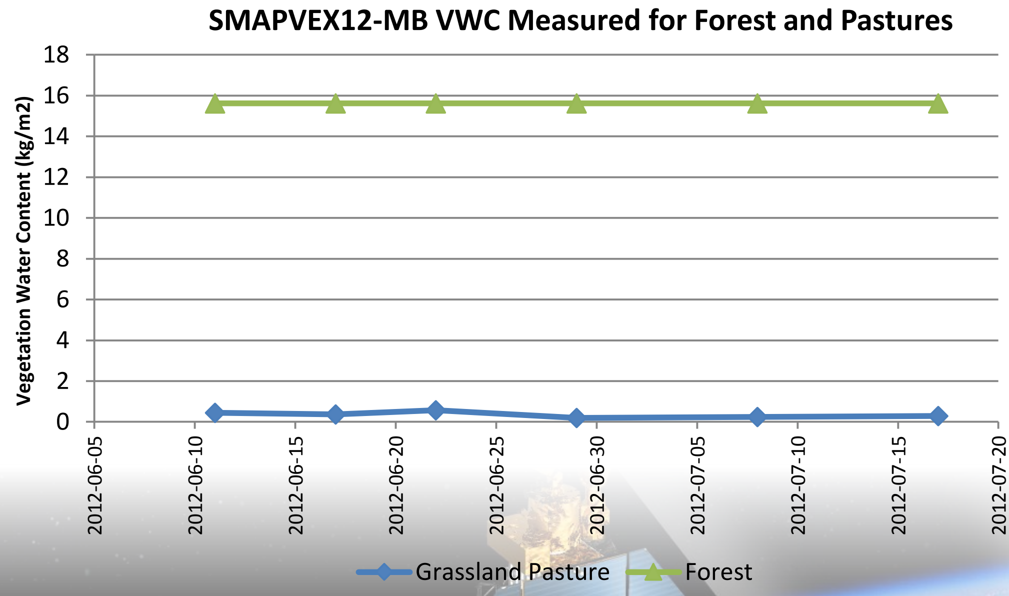
- All land classes within the SMAP ROI are listed on the table. VWC data in 2016 were collected for the classes in green shade (see graph below) whereas surrogate classes from the 2016 dataset will be used for crops with similar plant structures. The other classes will be simply ignored, but these only represent 4.26% of the SMAP ROI.



CROP	TOTAL AREA (%)	SURROGATE CLASS
Water	0.07	N/A
Barren	0.05	N/A
Urban	3.95	N/A
Wetland	0.16	N/A
Grassland	5.03	Pasture (2012)
Forage Crops	0.76	✓
Too wet to be seeded	0.03	N/A
Barley	1.04	Wheat
Oats	5.91	✓
Rye	1.53	Wheat
Triticale	0.04	Wheat
Winter Wheat	0.71	Wheat
Other Wheat	20.47	✓
Corn	9.69	✓
Canola/Rapeseed	13.49	✓
Flaxseed	0.17	Wheat
Sunflower	0.36	Canola
Soybeans	30.64	✓
Peas	0.49	Soybeans
Beans	1.49	✓
Potatoes	0.53	Soybeans
Canary Seed	0.24	Canola
Forest	3.14	Forest (2012)
TOTAL	100	

Results – SMAPVEX12-MB Forest/Pasture VWC

- Given the percent area represented by the forested and grassland (pasture) classes, better approximation of the VWC was required. Hence, data from the SMAPVEX12-MB campaign was used and integrated into the 2016 VWC data calculations.
- It is thus assumed that the forested and pasture VWC in 2016 did not vary much from the 2012 dataset.



CROP	TOTAL AREA (%)	SURROGATE CLASS
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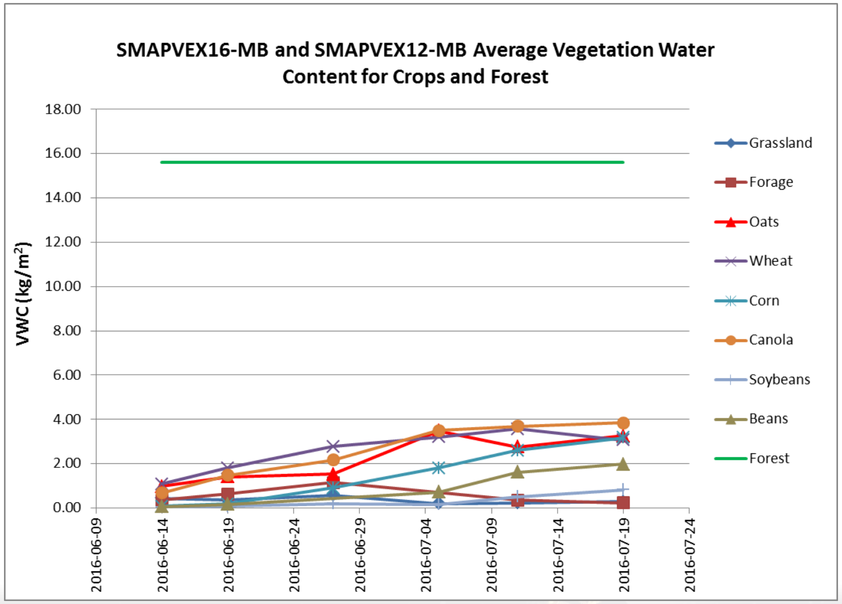
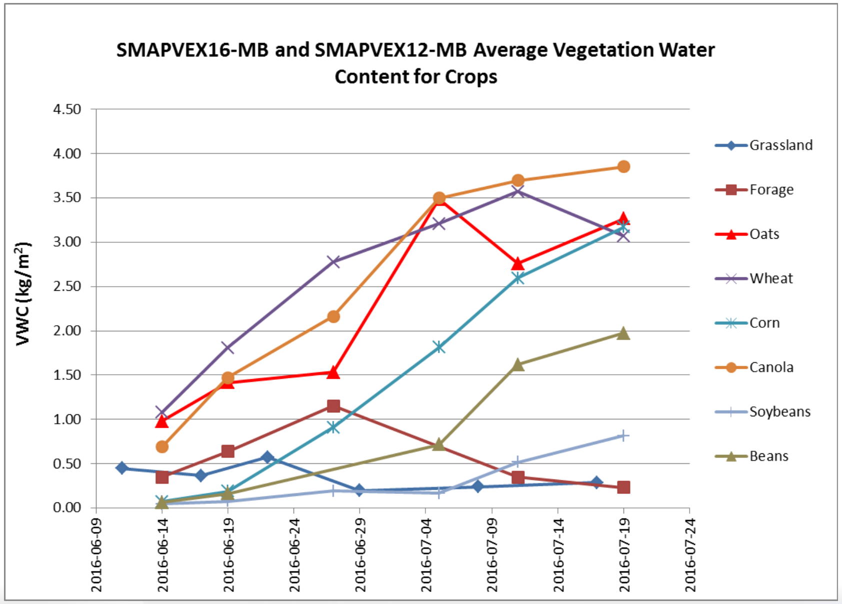
Barren	0.05	N/A
Urban	3.95	N/A
Wetland	0.16	N/A
Grassland	5.03	Pasture (2012)
Forage Crops	0.76	✓
Too wet to be seeded	0.03	N/A
Barley	1.04	Wheat
Oats	5.91	✓
Rye	1.53	Wheat
Triticale	0.04	Wheat
Winter Wheat	0.71	Wheat
Other Wheat	20.47	✓
Corn	9.69	✓
Canola/Rapeseed	13.49	✓
Flaxseed	0.17	Wheat
Sunflower	0.36	Canola
Soybeans	30.64	✓
Peas	0.49	Soybeans
Beans	1.49	Black Beans
Potatoes	0.53	Soybeans
Canary Seed	0.24	Canola
Forest	3.14	Forest (2012)
TOTAL	100	

Results – Combining Field VWC from SMAPVEX16-MB and SMAPVEX12-MB

- The field VWC collected for grassland and forest during SMAPVEX12-MB was combined with the one collected for SMAPVEX16-MB
- The graph on the left shows VWC for all classes including the forest, whereas the graph on the right only shows the VWC for agricultural crops.
- Forest VWC was calculated by Mahta (2012)[1].

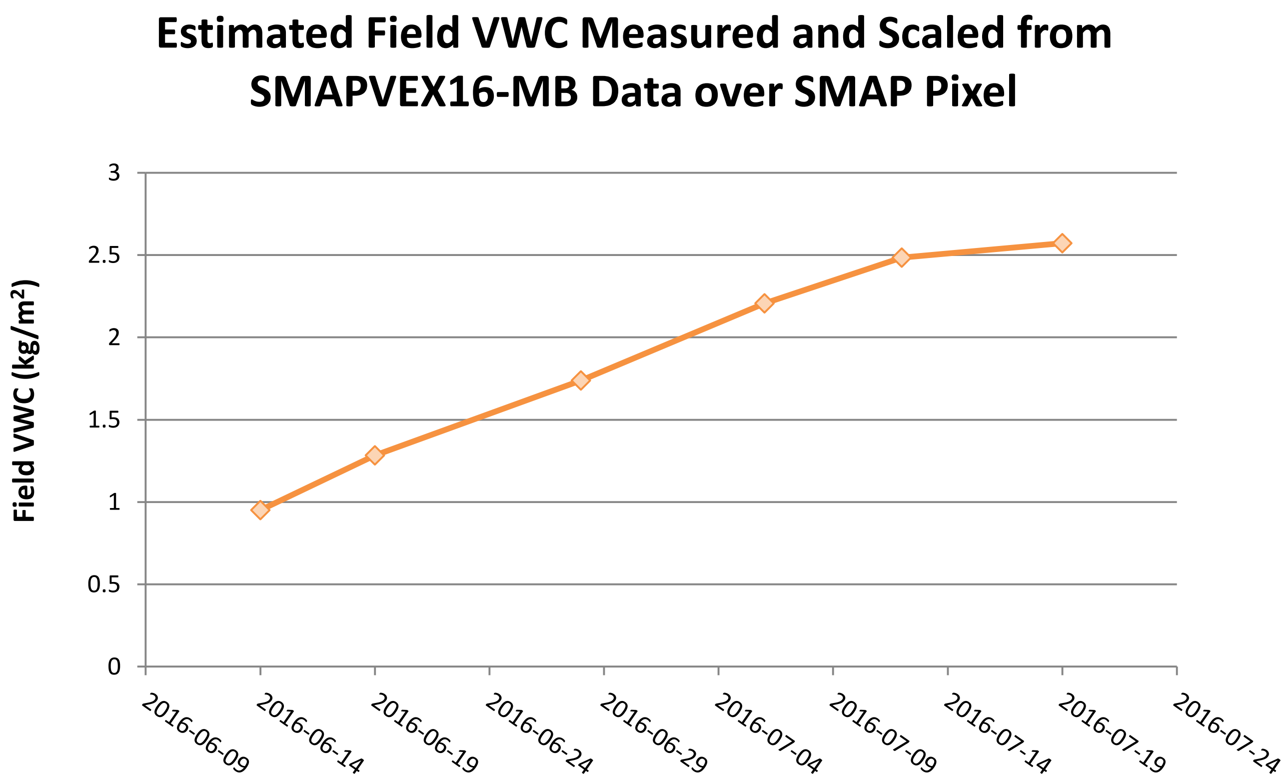




[1] Moghaddam, Mahta (2012). *Vegetation Water Content of Forest Sites* from SMAPVEX12 SMAP Validation Experiment 2012 at https://smapvex12.espaceweb.usherbrooke.ca/intranet.php.

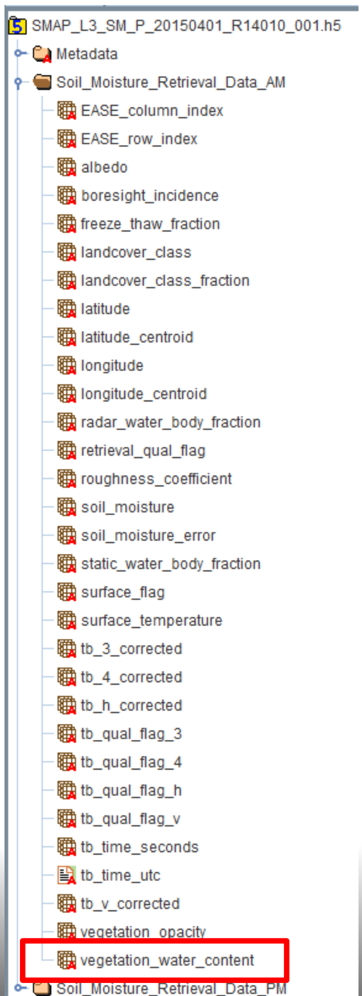
Results – Estimated VWC for the SMAPVEX16-MB Pixel

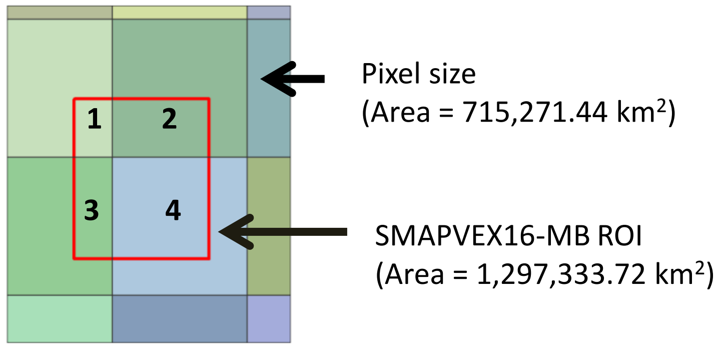
Estimated Field VWC Measured and Scaled from SMAPVEX16-MB Data over SMAP Pixel						
Dates	2016-06-14	2016-06-19	2016-06-28	2016-07-06	2016-07-12	2016-07-19
SMAPVEX16-MB VWC	0.95	1.28	1.74	2.21	2.48	2.57



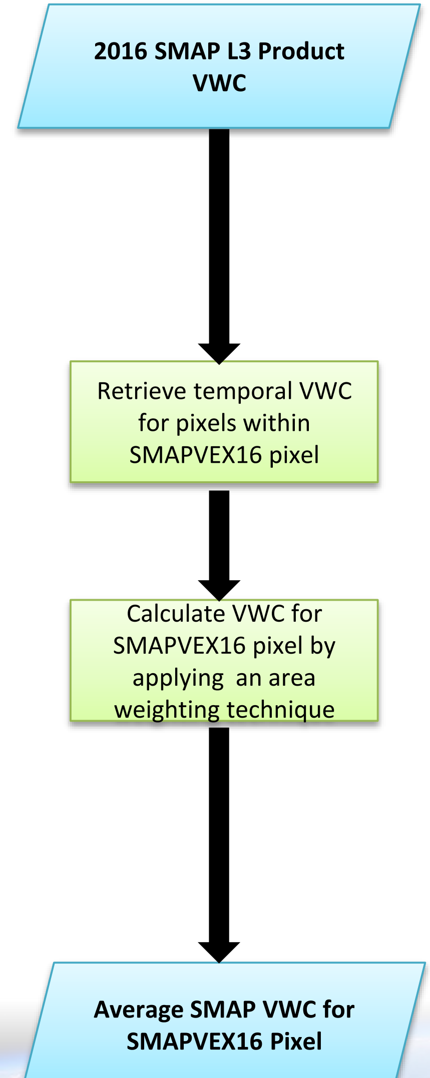
Extracting SMAP Vegetation Water Content

- SMAP VWC was retrieved from the SMAP L3 Radiometer Global Daily 36 km EASE-Grid Soil Moisture, Version 4 product for both AM and PM passes



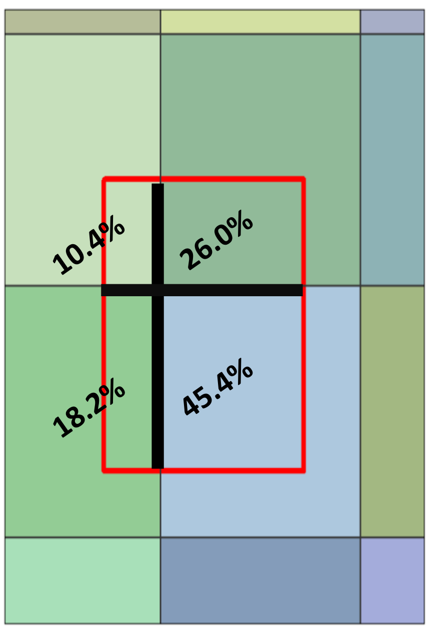


SMAP Vegetation Water Content								
Date	**VWC - AM Pass**				**VWC - PM Pass**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
2016-06-13					2.777	2.747	2.378	2.322
2016-06-15					2.874	2.856	2.460	2.422
2016-06-18					3.008	3.002	2.654	2.653
2016-06-20	3.077	3.077	2.753	2.772	3.043	3.040	2.704	2.713
2016-06-27	3.244	3.233	3.030	3.029				
2016-06-28	3.253	3.234	3.056	3.034	3.244	3.233	3.030	3.029
2016-07-05	3.324	3.259	3.227	3.094				
2016-07-06	3.335	3.274	3.243	3.123	3.324	3.259	3.227	3.094
2016-07-11	3.393	3.350	3.326	3.270				
2016-07-12					3.405	3.365	3.342	3.300
2016-07-17					3.423	3.349	3.372	3.325
2016-07-20					3.412	3.255	3.364	3.258
2016-07-21	3.409	3.232	3.363	3.242				



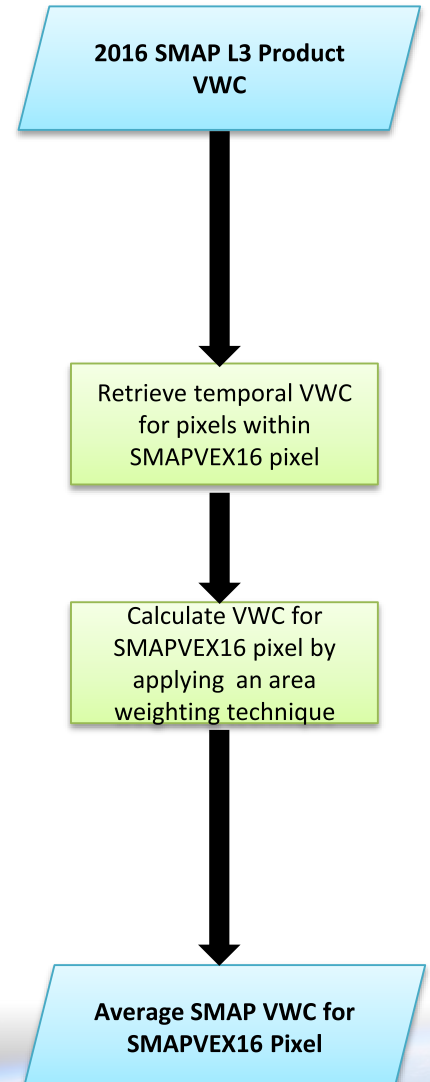
Extracting SMAP Vegetation Water Content (Cont')

- Given that the original SMAPVEX16-MB pixel does not fall exactly over the SMAP L3 EASE-Grid 2.0, an area weighted technique was applied to the overlapping pixels to calculate average VWC over the SMAPVEX16-MB.

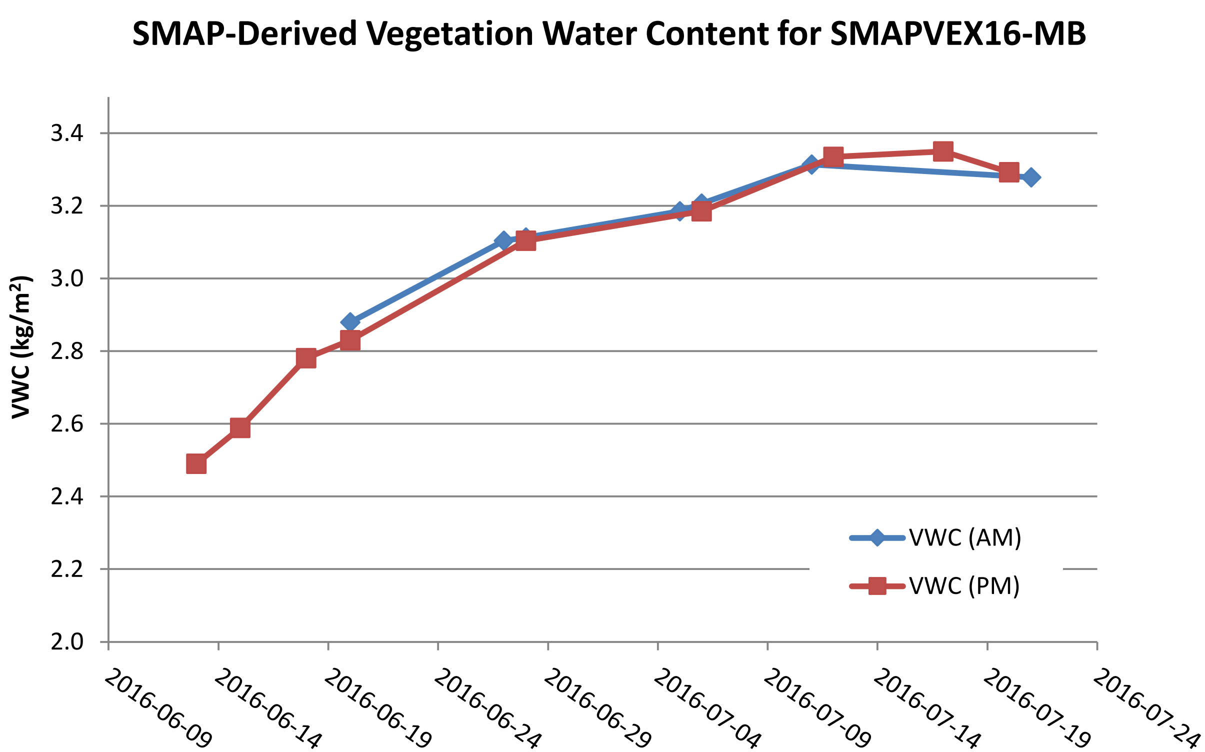


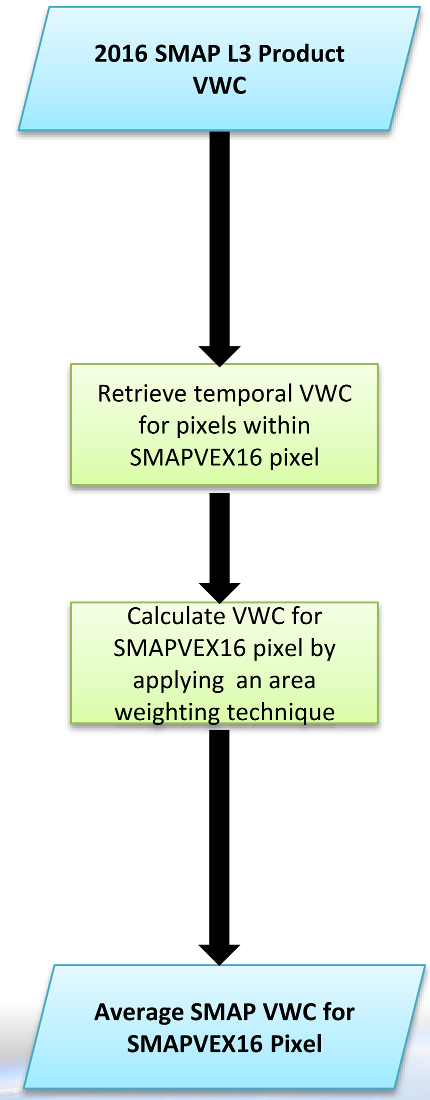
The figure above shows the original SMAPVEX16-MB ROI over the VWC pixels of the SMAP L3 EASE-Grid 2.0 product.

SMAP Weighted Vegetation Water Content		
Date	VWC (AM)	VWC (PM)
2016-06-13		2.490
2016-06-15		2.589
2016-06-18		2.781
2016-06-20	2.879	2.830
2016-06-27	3.105	
2016-06-28	3.113	3.105
2016-07-05	3.185	
2016-07-06	3.206	3.185
2016-07-11	3.314	
2016-07-12		3.336
2016-07-17		3.350
2016-07-20		3.299
2016-07-21	3.279	



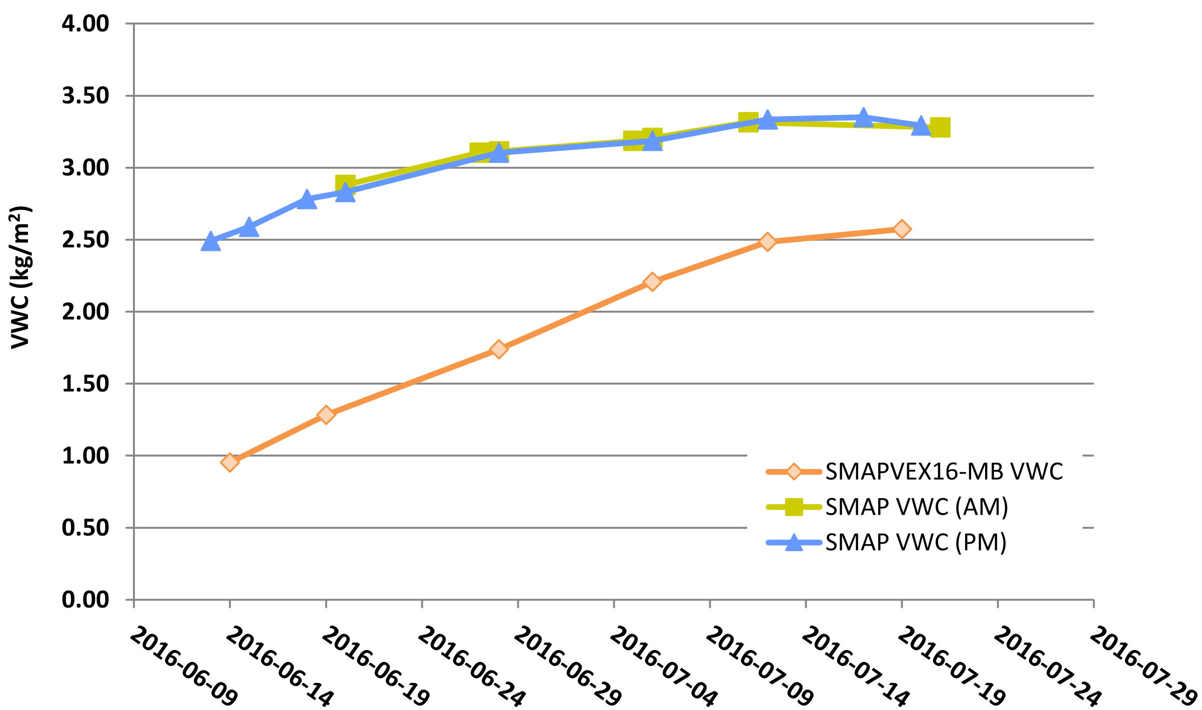
Results - SMAP Vegetation Water Content





Results – Comparing SMAP vs SMAPVEX16-MB VWC

Date	2016-06-13	2016-06-14	2016-06-15	2016-06-18	2016-06-19	2016-06-20	2016-06-27	2016-06-28	2016-07-05	2016-07-06	2016-07-11	2016-07-12	2016-07-17	2016-07-19	2016-07-20	2016-07-21
SMAPVEX16-MB VWC		0.95			1.28			1.74		2.21		2.48		2.57		
SMAP VWC (AM)						2.88	3.10	3.11	3.18	3.21	3.31					3.28
SMAP VWC (PM)	2.49		2.59	2.78		2.83		3.10		3.18		3.34	3.35		3.29	



Conclusions and Recommendations

- AAFC is investigating potential sources of error that could explain SMAP's underestimation of soil moisture over the Carman site. A study has been conducted to compare SMAP's 2016 estimated vegetation water content (VWC) versus SMAPVEX16-MB's measured VWC.

- AAFC has determined from the analysis of SMAPVEX16-MB's data and a scaling method (based on an area weighted technique) that the VWC ingested into the SMAP soil moisture retrieval algorithm is overestimated throughout the growing season for the SMAP pixel over Carman, Manitoba.

- The VWC overestimation is quite significant in the early stages of crop growth (approximately 1.5 kg/m^2), i.e. June. At the peak of biomass, the overestimation is reduced but still important (close to 0.75 kg/m^2).

- AAFC recommends that NASA ingests the SMAPVEX16-MB measured VWC into the SMAP soil moisture retrieval algorithm over the 2016 growing season. Re-processing the 2016 SMAP soil moisture data with the measured VWC will aid in better understanding the impact of the VWC overestimation on the soil moisture retrievals over the Carman SMAP pixel.