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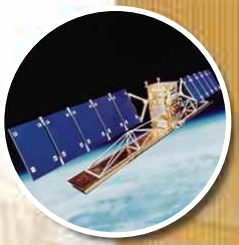


Heather McNairn

SMAPVEX12

SMAP Validation Experiment 2012

Canada

SMAPVEX 2012

Objectives (refer to experimental plan):

•To support calibration and validation of SMAP data and products

•To familiarize operational program and policy users with passive and active soil moisture products, to prepare these users for exploitation and assimilation of SMAP products, once available

Location:

•Southern Manitoba (Canada)

•Southwest of capital of Manitoba - Winnipeg

Timing:

•6 weeks to capture variable soil and vegetation conditions

•Data collection from June 7 – July 19, 2012

SMAPVEX Participating Agencies

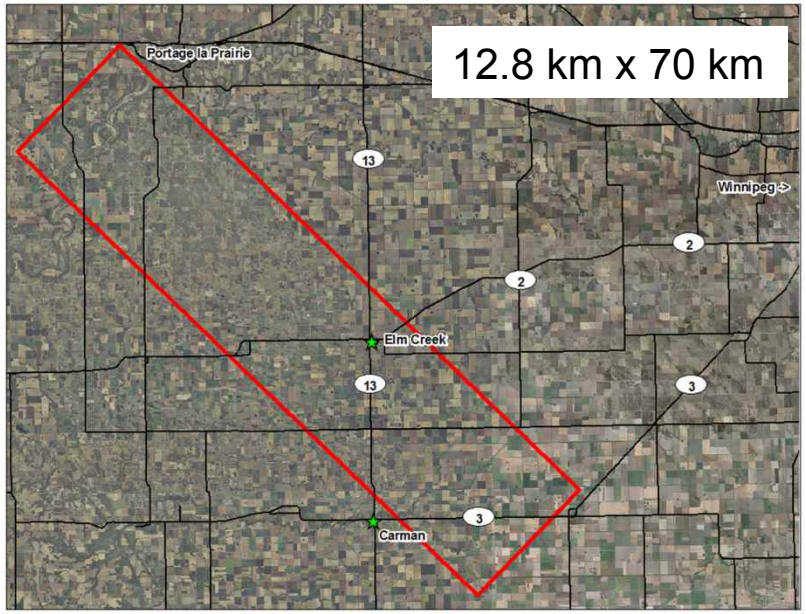
Canada

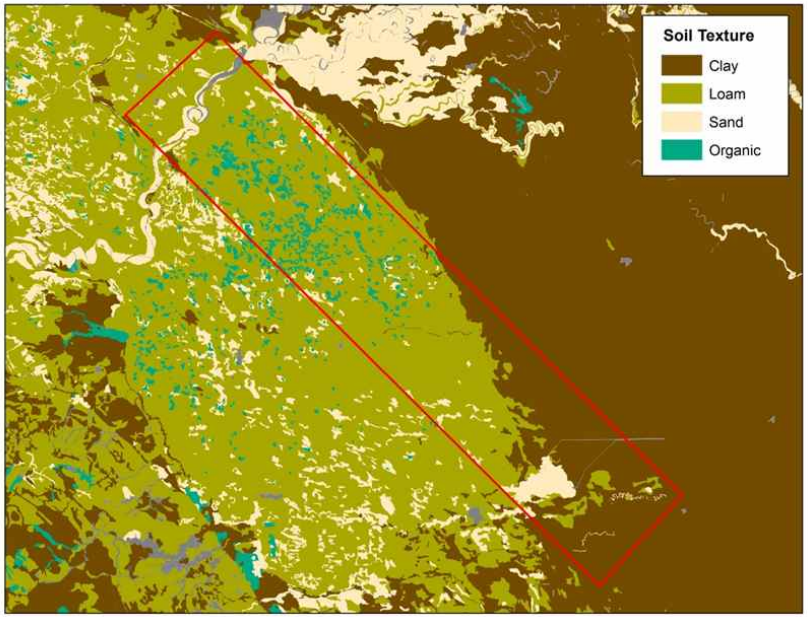
- Agriculture and Agri-Food Canada
- Environment Canada
- University of Guelph
- University of Sherbrooke
- University of Manitoba
- Manitoba Agriculture, Food and Rural Initiatives (MAFRI)
- Canadian Space Agency

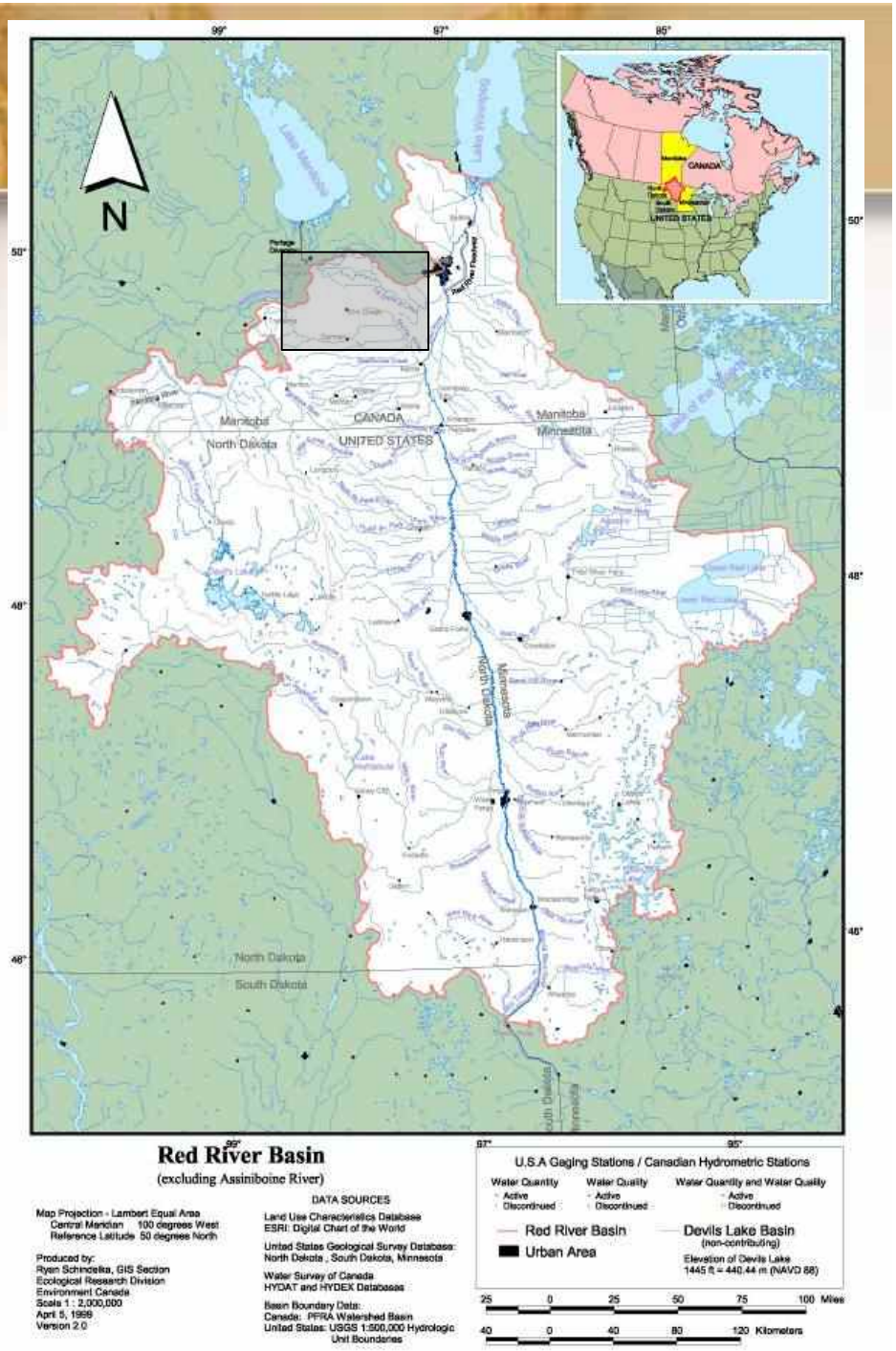
U.S.A.

- NASA and JPL
- U.S. Department of Agriculture
- Massachusetts Institute of Technology
- University of Southern California
- University of South Carolina
- Texas A&M University
- University of Washington
- Ohio State University
- University of Florida
- Florida International University
- University of Montana
- University of Colorado

Site Location





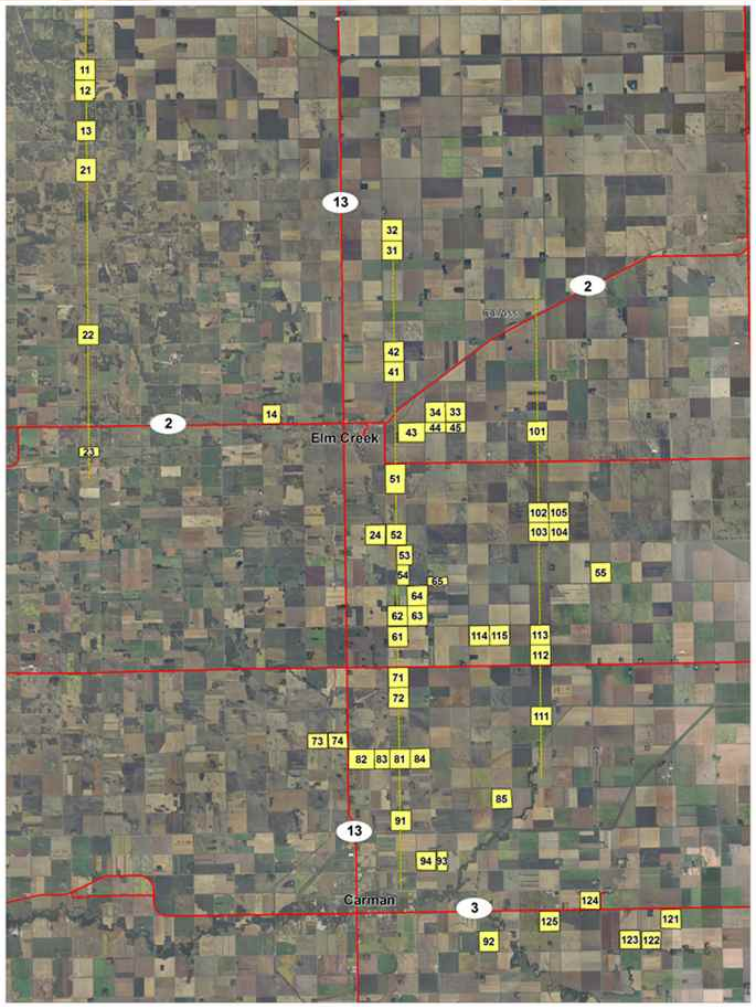


AAFC SAGES soil moisture network

- 9 permanent soil moisture stations installed in 2011
- 6 Stevens hydra probes at surface (vertical and at 5 cm horizontal)
- 3 probes at each depth (20 cm, 50 cm and 100 cm)
- probes are 50-100 feet from field edge
- tipping bucket rain gauge
- data is transmitted hourly via cell phone to Ottawa
- nearly 400,000 soil moisture\temperature readings during campaign

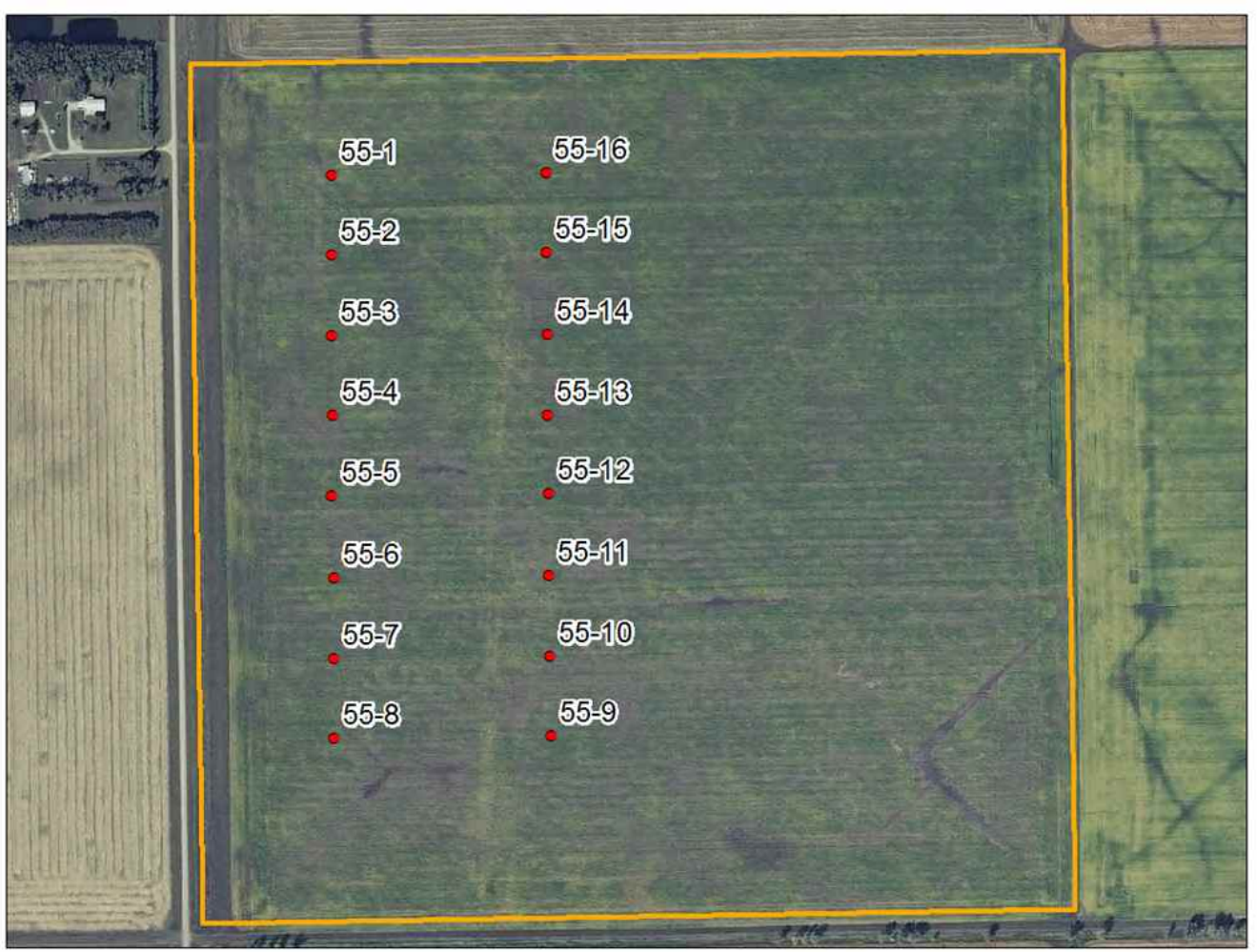
SMAPVEX Site Characteristics

- 2011 dominant annual crops included cereals (32.2% of area), canola (13.2%), corn (7.0%) & soybean (6.7%)
- approximately 16.4% of the site is occupied by perennial cover (grassland and pasture)
- 55 SMAPVEX agriculture fields
  - beans 1, soybeans 15, canola 6, corn 10, spring wheat 14, winter wheat 2, forage 1 & pasture 6
- 4 forested sites, varying degrees of tree cover



Cropland Site Characteristics

- 16 sample points arranged in two transects running parallel to crop row direction
- in total, 880 cropland sample points
- sample points pre-loaded into GPS units for easy navigation to sites



Temporary Stations

- temporary soil moisture stations were installed: USDA 40, MAFRI 4
- USDA probes at a depth of 5 cm, MAFRI probes at 5, 20, 50, 100 cm
- soil moisture and temperature recorded hourly on data loggers
- installed after seeding, removed before harvest
- over 525,000 readings during SMAPVEX

Field Organization

- 2 days of crew training prior to campaign
- flight days (soil moisture sampling)
  - go/no-go call at 5:45 AM
  - crews arrived at fields around 7:30 AM and completed sampling around noon
  - each crew of 2 sampled 4-5 cropland fields
  - soil moisture data downloaded and QC'ed daily
  - 17 soil moisture days
  - some dropped fields due to road access or crop dusting
- non-flight days (vegetation sampling)
  - goal was to measure vegetation on each field once per week
  - cropland crew measured height, stem diameter, LAI, crop reflectance and took biomass samples
  - forest crews took spatial or destructive samples
  - 12 vegetation days
- crop structure team (2) worked independent of fly/no fly days

Hand Held Moisture Probes

- hand held Stevens Hydra probes were used to collect data coincident in time with flight overpasses, at each of 16 sites (in 55 fields) and 4 forest sites
- cropland sites: 3 replicate readings at each site (total of 48 measurements per field)
- over 44,000 moisture readings during SMAPVEX

Soil Moisture Cores

- one 5 cm soil core collected at one of 16 sites (in 55 fields) during each flight overpass
- cores were oven dried to provide volumetric soil moisture to calibrate Hydra probe readings, and for particle size distribution determination
- over 850 soil cores collected

Soil and Vegetation Temperature

- subsurface soil temperature (at 5 cm & 10 cm) and surface soil and vegetation temperature (shaded and sunlit) recorded for 4 sites per field during every flight overpass (points 1, 8, 9 and 16)
- over 5000 soil and crop temperature readings collected

Crop Biomass and Reflectance

- 3 vegetation sample sites per field (points 2, 11 and 14)
- each field visited about once per week (900 samples in total collected)
- CropScan (440-1700 nm) reflectance collected at one site per field (14 measurements per site)

- destructive biomass samples collected to provide wet/ dry biomass and volumetric water content
- wheat/pasture/forage using 0.5 x 0.5m quadrat; all other crops by collecting 10 plants over 2 rows
- measured crop height and stem diameter (10 plants)
- lab crew determined plant phenology (BBCH scale)

- site 2 samples separated for plant organs before weighing and drying
- samples placed in drying room
- sub-sample placed in drying oven to determine drying correction factor

Leaf Area Index

Soybeans: Field #34 – June 16

- LAI is very good indicator of crop productivity and directly related to crop yield
- measured using hemispherical digital photos
- same 3 sites as biomass samples (2, 11 and 14)
- 7 photos will be taken along two transects (14 in total)
- approximately 12,000 photos or 0.5 TB

Soil and Vegetation Structure

Wheat: Field #71 – June 11

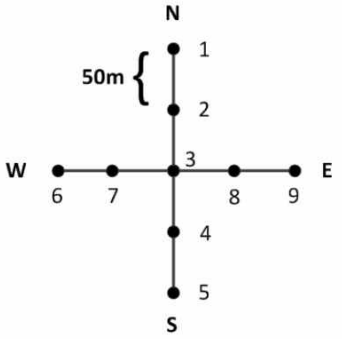
Canola: Field #124 – June 16

- surface roughness measured parallel to look direction for aircraft and satellites using pin board
- once after seeding with 2 measurements per field (3 metre profile)
- photos post-processed for rms and correlation length

- 17 fields visited 5-6 times to measure crop structure attributes (2 sites per field)
- plant height, stem width, stalk height, stalk angle, number of leaves, leaf length, leaf width, leaf thickness, leaf angle, number of plants per square meter, row orientation and row width

Forest Sampling

- observation area within each site consisted of two orthogonal transects within a circle of 100 m radius
- temporary soil moisture station at F1 and F2
- nine soil moisture sampling points within each observation area
- parameters measured during flight days:
  - soil moisture and dielectric constant (Steven's Hydra probes)
  - soil organic depth
  - soil temperature at 0 cm, 5 cm and 10 cm depths.
  - soil bulk density samples for soil texture



Forest Vegetation Measurements

Vegetation sampling (non-flight days)

(1) spatial sampling

(2) destructive sampling & dielectric measurements

Spatial sampling (June 7 to June 28)

- measured every tree within +/- 1 meter of the transect line for DBH, height and species
- at every 10 meters along the transect:
  - trunk height (hypsometer or a yard stick)
  - number of primary branches (visual)
  - angle of primary branches (visual)
  - fractional ground cover in percent (quadrat and visual estimate)
  - understory height (yard stick)

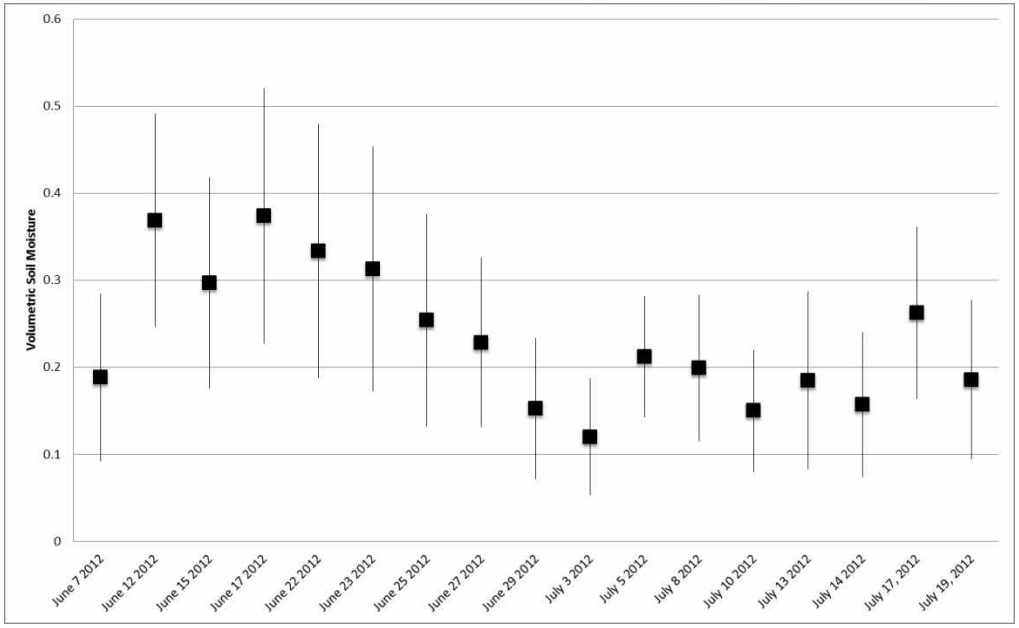
Forest Vegetation Measurements

Destructive measurements (June 29 to July 17) consisted of harvesting/felling an “average” tree

- trunk diameter at each 30 cm interval
- wafer of ~ 3 cm thickness for gravimetric measurements at each 30 cm interval
- primary branch angles
- number of branches (primary, secondary) and leaf count
- all branch lengths, diameters, and when possible, dielectric constant
- 3-4 samples of branches for gravimetric measurements
- note on leaf clumping

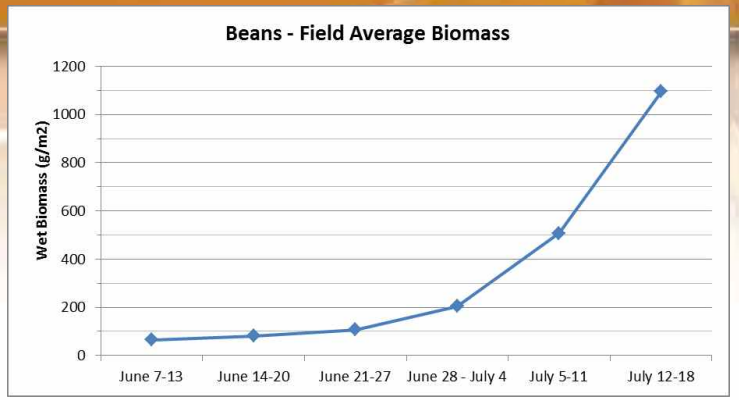
Dielectric measurement using an Agilent field portable network analyzer (FieldFox N9923A)

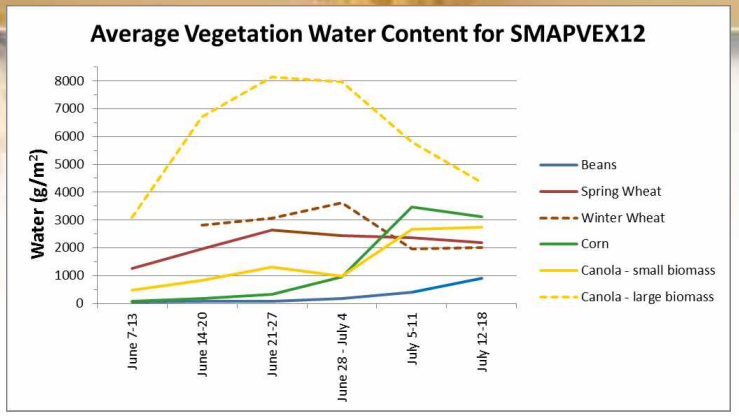
Soil Moisture Conditions During SMAPVEX

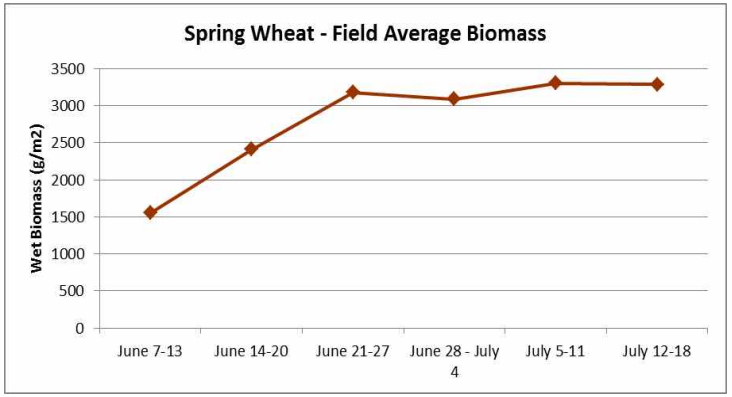


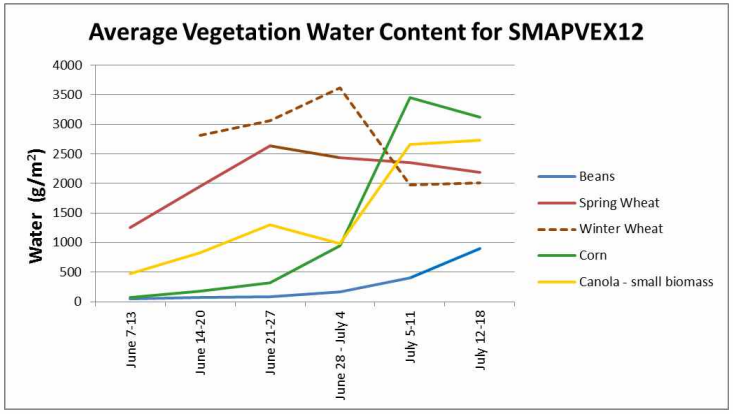
- large variation in soil moisture conditions (> 50% VWC to <10%)
- temporally, wetter conditions early in SMAPVEX followed by dry down and generally drier conditions in latter half with smaller wetting and drying events
- spatially, very large variations in any given day due differences in soil textures among 55 fields

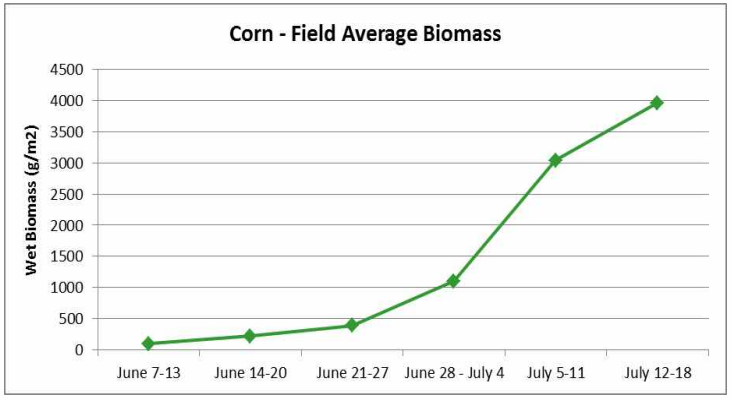
Variation in Biomass and Canopy Water Content

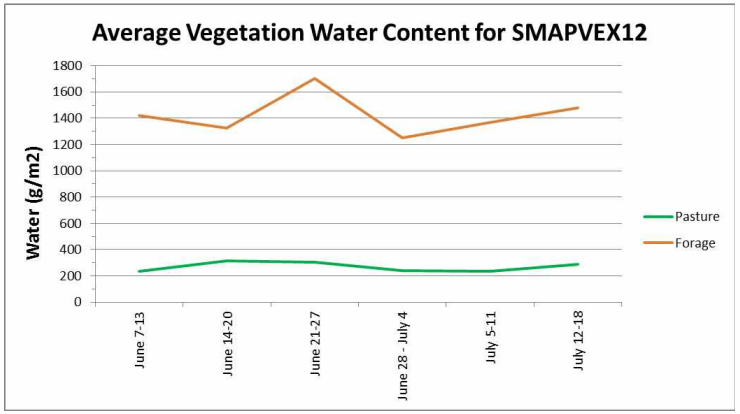












Satellite Acquisitions

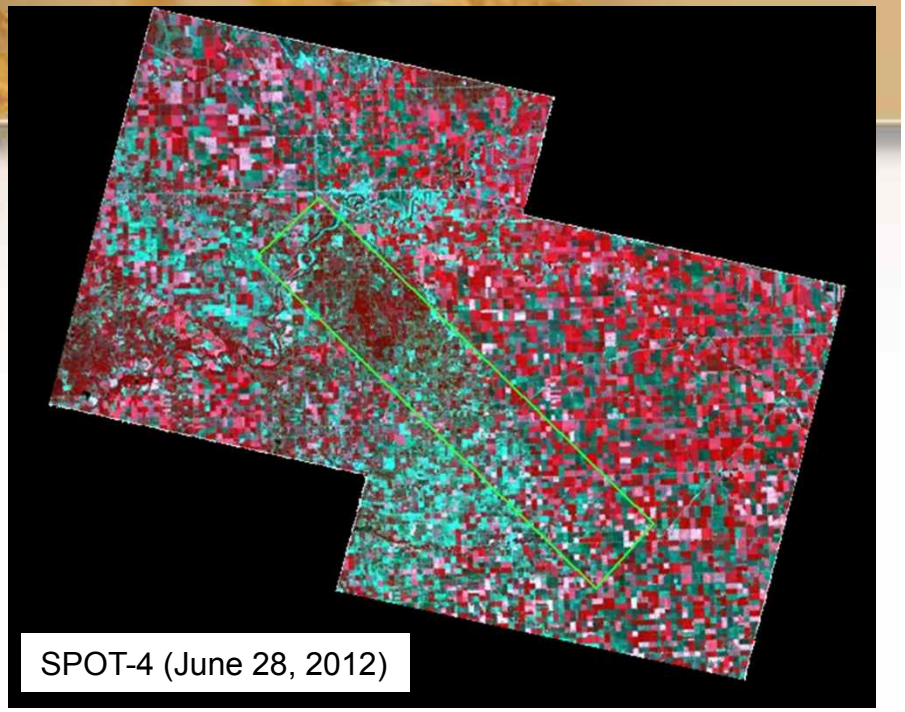
- Optical and SAR satellites programmed

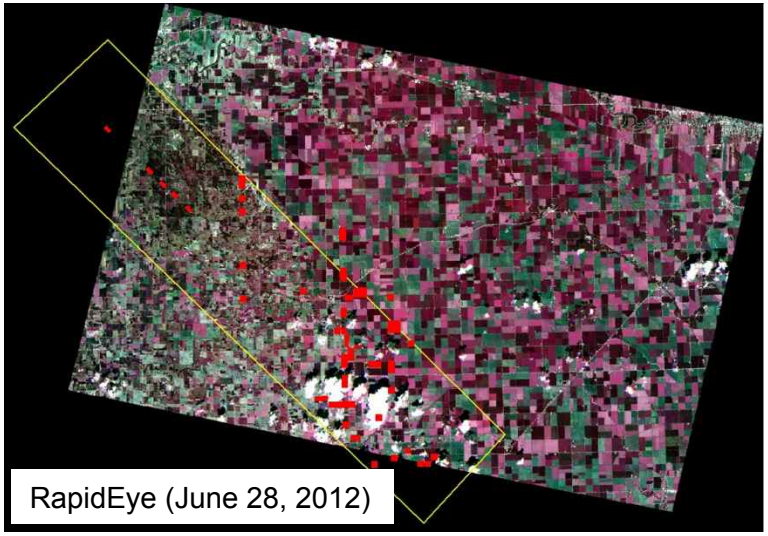
- RapidEye
  - 20 dates from May 14th to September 26th
  - 5 m resolution (B,G,R,RE,NIR)

- SPOT-4/5 images
  - 4 dates (3 complete coverages)
  - Re-sampled to 20 m (B,G,R,NIR)

- SAR Satellites (May to September)
  - 58 Fine Wide Quad-Pol RADARSAT-2 (2-3 frames per date) (partial coverage)
  - 7 Standard Mode RADARAST-2 (dual polarization) (complete coverage)
  - 13 Dsc and 9 Asc TerraSAR-X StripMap (VV, VH) (partial coverage)

- Restrictions on access due to data licensing


SPOT-4 (June 28, 2012)


RapidEye (June 28, 2012)

Lessons Learned

SMAPVEX12 field crew during training at the AAFC Regional Operations Centre in Winnipeg June 6th, 2012

•Biomass became “gigantic” near end of campaign stretching lab crew and facilities to limit. Need to revisit drying procedures and facilities.
•Forest sampling needed to be scaled back due to available resources. Forest cover at sites typical of Canadian Prairies, but did it meet needs of SMAP forest team?
•By end of campaign, crew was exhausted. Should consider redistribution of crew to provide more hands later in campaign, and to have more spares to give crew more rest.
•Revisit training to give crews more hands on experience with equipment.
•Hydra probes with PDAs were not field robust. Are there other options?

•But it’s always a trade-off between scope of campaign and costs/resources.

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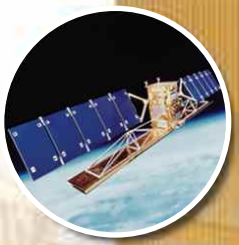

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SMAPVEX12

SMAP Validation Experiment 2012

Canada

Data Preparation and Access

- University of Sherbrooke is hosting SMAPVEX web site http://pages.usherbrooke.ca/smapvex12/
- all ground data will be available via the Sherbrooke intranet web site to SMAPVEX participants. Wider distribution next summer.
- all cropland ground data will be housed in an ESRI Geodatabase and Access database created by AAFC, with accompanying meta data. Database is expected to be available on web site by end of November. Exception would be VWC for corn.
- collation of forestry data being led by USC (Mahta Moghaddam)
- collation of crop structure data being led by Sab Kim
- reports: experimental plan (completed), data collection report (in review), soil moisture calibration and VWC correction (available soon)
- level of effort by University of Guelph, Manitoba, AAFC and USDA to calibrate soil and vegetation data has been extensive; must release well calibrated data (to best of our ability)

Data Preparation and Access

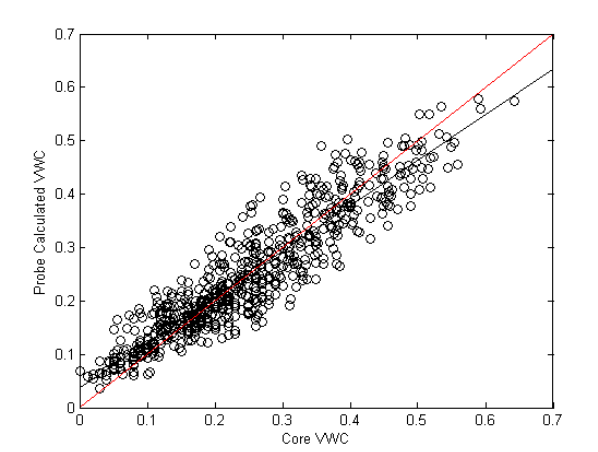
Cropland Data	Status	In Geodatabase
Download & QC data from field instruments	Completed	
Enter in data from lab and field sheets	Completed *corn yet to be corrected	biomass*, VWC*, height, stem diameter, phenology, soil temperature (5 and 10 cm), surface crop and soil temperature, row direction, plant spacing, row spacing, plant density, volumetric soil moisture from bulk density samples, soil texture
Post processing of photos for roughness	Completed	rms, correlation length, look direction
Post processing of crop scan reflectance	Completed	reflectance at each wavelength
Weather data	Completed	air and soil temperature, precipitation
Calibration of hand held probes	Completed	probe type (hydra/theta), real dielectric constant, calibrated soil moisture, calibration model (field/ general)
Calibration of AAFC permanent in situ probes and USDA temporary stations	Nearing Completion	
Post processing of photos for LAI	Nearing Completion	
Calibration of VWC	In Progress (corn)	

Hydra Probe Calibration

General model

- use soil core data with average of associated 3 Hydra Probe readings
- 702 data points, identified and removed 31 outliers (> 2x standard deviation)
- linear model relating the volumetric water content determined from the core samples and the corresponding average square root of the real dielectric constant from probe measurements

$$\theta v = 0.0862(\epsilon_r)^{0.5} - 0.0962 \quad (r^2 \text{ of } 0.8523, \text{ RMSE of } 0.0475 m^3\ m^{-3})$$

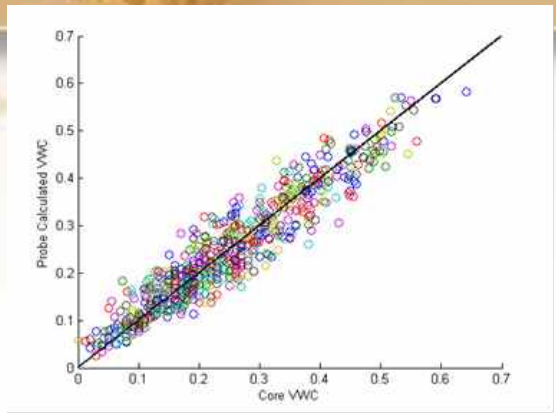


Core measured volumetric water content and the probe calculated volumetric water content using linear model. The black line is the fitted regression, and the red line is the 1:1 line

Hydra Probe Calibration

Field specific model

- investigated calibration of each field individually, using only the data from that field
- resulted in 55 linear models, one for each field (equation relating the core volumetric water content and the square root of the real dielectric constant)
- lower residual errors (on average 0.0386m^3 m^{-3}) for all but 5 fields
- For 50 fields: applied field specific model
- For 5 fields (11, 12, 13, 73 and 122): applied general model



Core volumetric water content, and the calculated volumetric water content using the individual field equations. The black line is the 1:1 line.

USDA temporary stations: same models will be used to calibrate

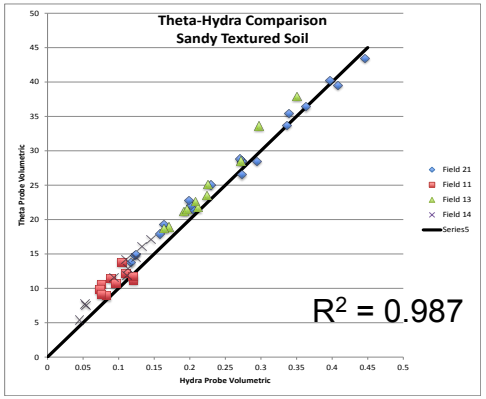
AAFC SAGES stations

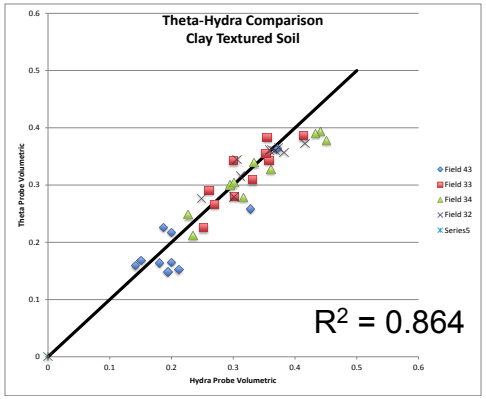
- soil bulk density samples were collected at time of station installation, at each probe depth (down to 1 metre)
- samples sent to lab for particle size analysis, and for dry down experiment to determine calibration model
- Currently evaluating results of dry down

Theta Probe Calibration

- Theta to Hydra probe comparison: a series of surface measurements were acquired at the same location with both sensors on several different fields

- agreement between probes is very good and thus the “equivalent Hydra probe volumetric moisture” for a Theta probe measurement can be estimated using simple regression equations





- then convert “equivalent Hydra probe moisture” to a real dielectric constant using the loam calibration equation for the Hydra probe

RDC = ((Hydra probe equivalent θv + 0.179) / 0.109)^2

- The RDC then used with the Hydra probe field calibration equations to derive field-calibrated values of volumetric soil moisture for those field measured with the Theta probe

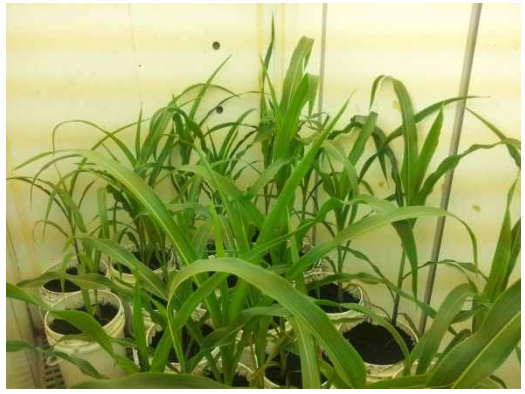
Calibration of Vegetation Water Content

- volume of biomass did not permit drying of vegetation samples in ovens. Biomass was dried either in drying trailer or University of Manitoba drying room. Lab crew cut vegetation samples to speed up drying.

- concern that not all water was removed by this process

- subsamples of air-dry vegetation for all crops were used to determine an oven-dry calibration. Sub-sample of air-dry vegetation was placed in oven at 60^{o}C for 48 hours.

- air-dry to oven-dry conversion was remarkably consistent for wheat, beans, canola and forage. Almost all water (~95%) had been removed by air-drying. Based on oven-dry results a conversion factor of 94.57% was applied to dry biomass and VWC calculations for these crops.



- corn was less consistent depending on phenology. University of Manitoba is growing 76 corn plants in a growth chamber. Seeding on September 14; plants are being harvested over 10 week period, weighed and oven dried. Results so far have been quite consistent (water content of 90.8%). Experiment will be completed by December 10.