Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Architecture, implementation and application of soil moisture in-situ sensor network across Canadian agricultural landscapes

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Canada

Agenda

- Business requirements
- In-situ sensor network design and implementation
- Sensor calibration and QA/QC
- Data management and access
- Application and use cases

Business requirements

- Departmental needs

  Cost-effectively validate SAR derived soil moisture map

  Provide representative soil moisture data to modellers

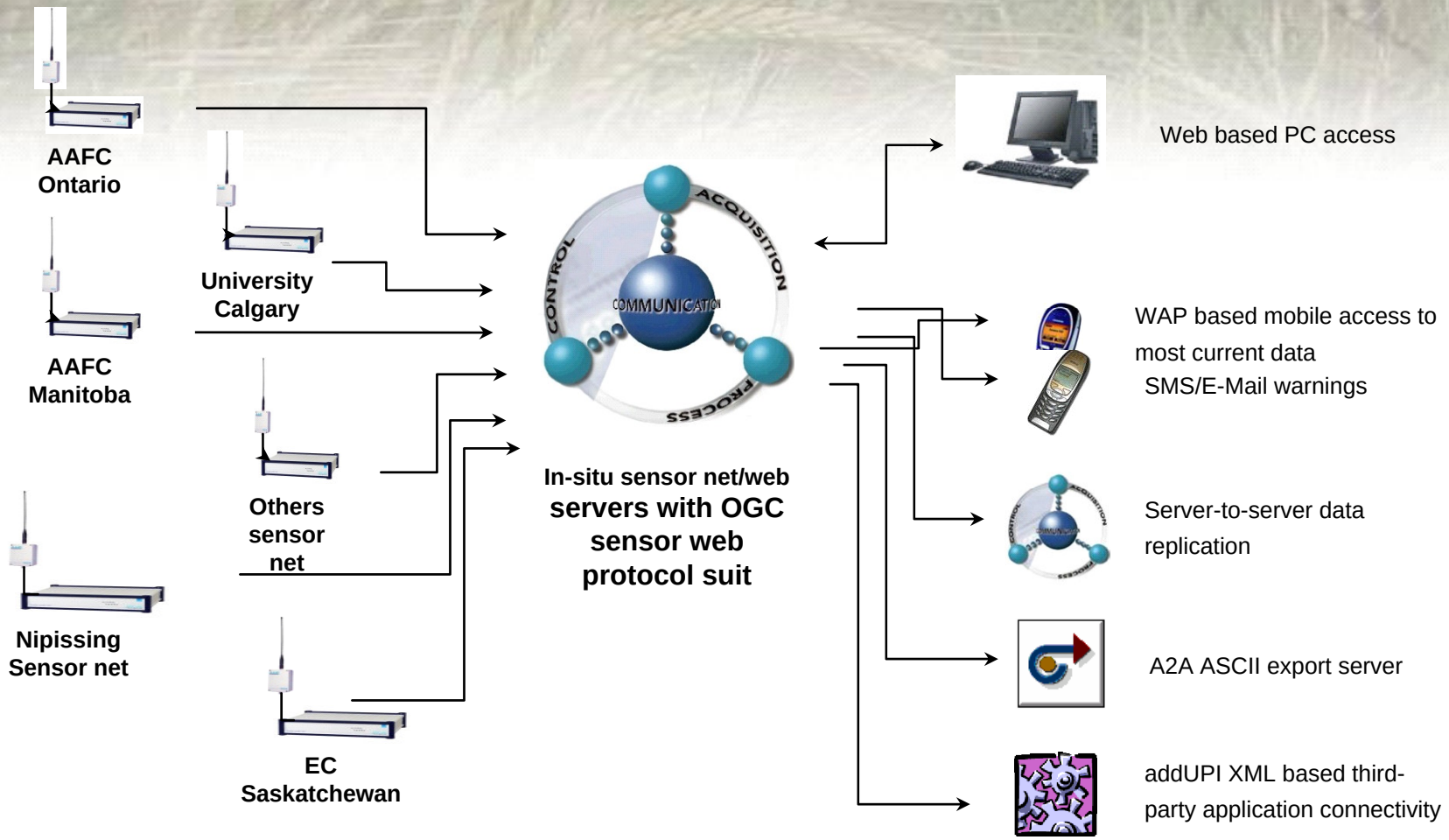
- Added business case for NASA field campaign for SMAP cal/val

- Producers would like to access the data collected from their farms via Internet or smart phone.

- To meet departmental priorities in the area of Science and Innovation

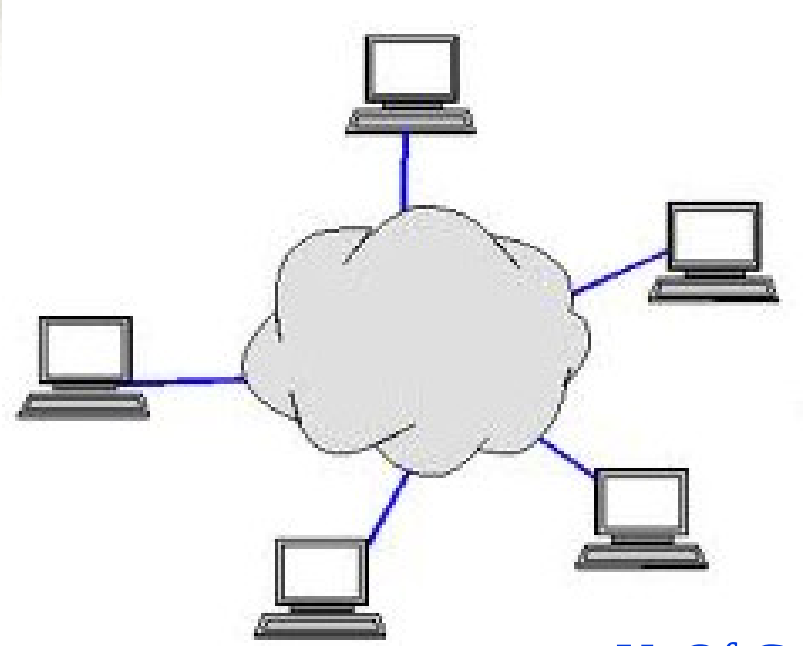
In-situ sensor network design and implementation

Sensor Web architecture



Architecture of our use case

Public users



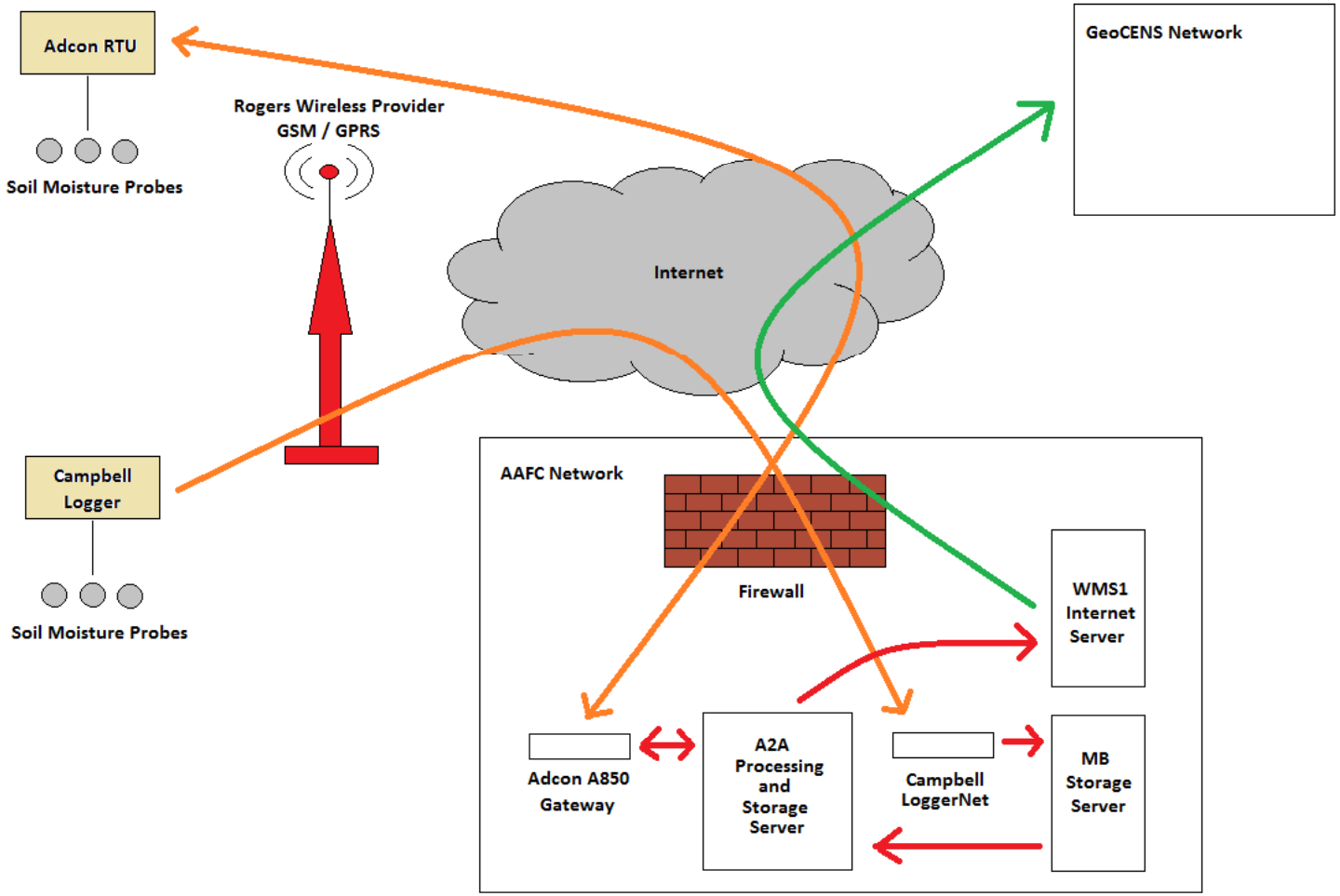
AAFC sensor web server

Other
sensor web servers

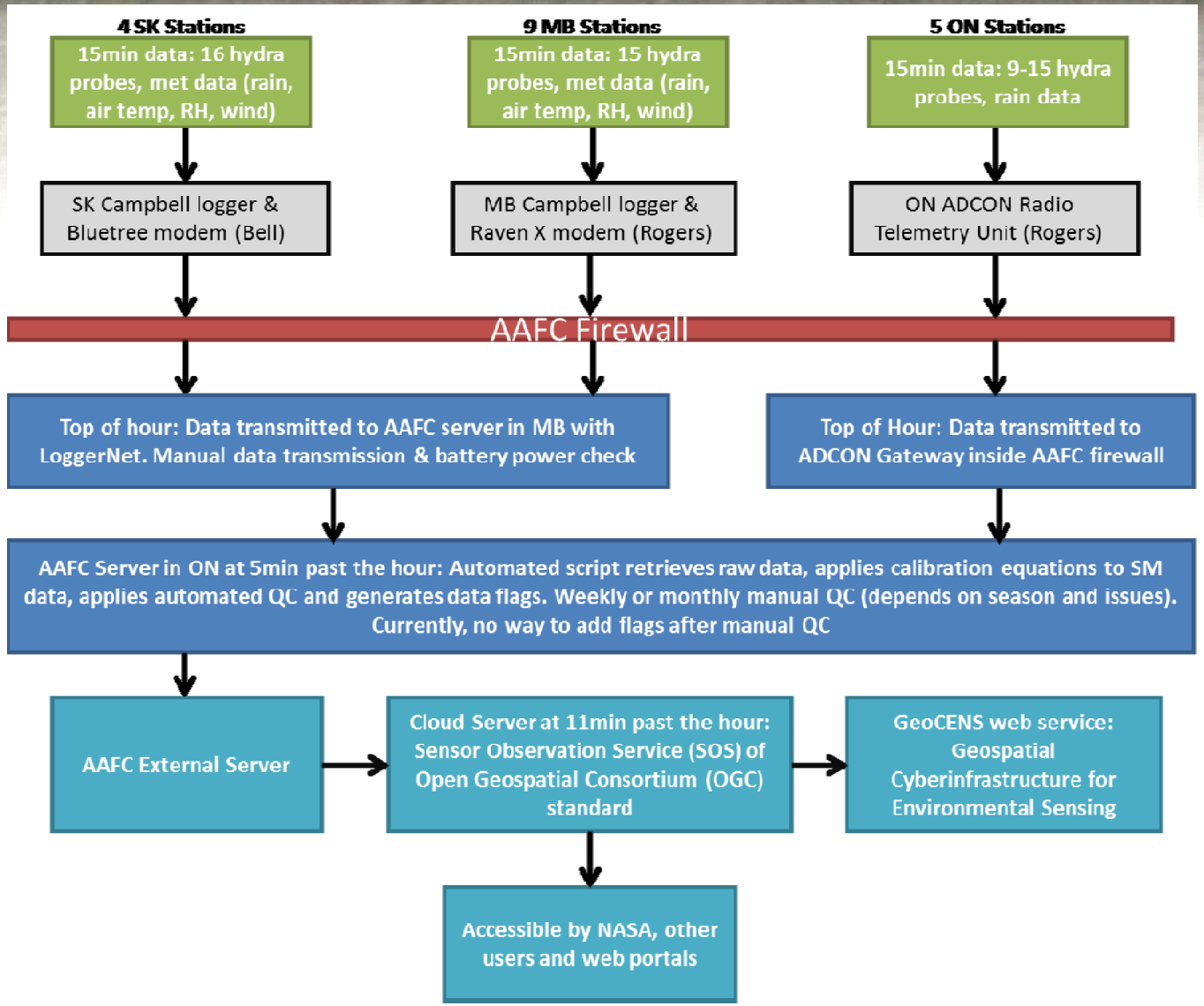
Nipissing University
sensor web server

U. Of Calgary
GeoSENS server

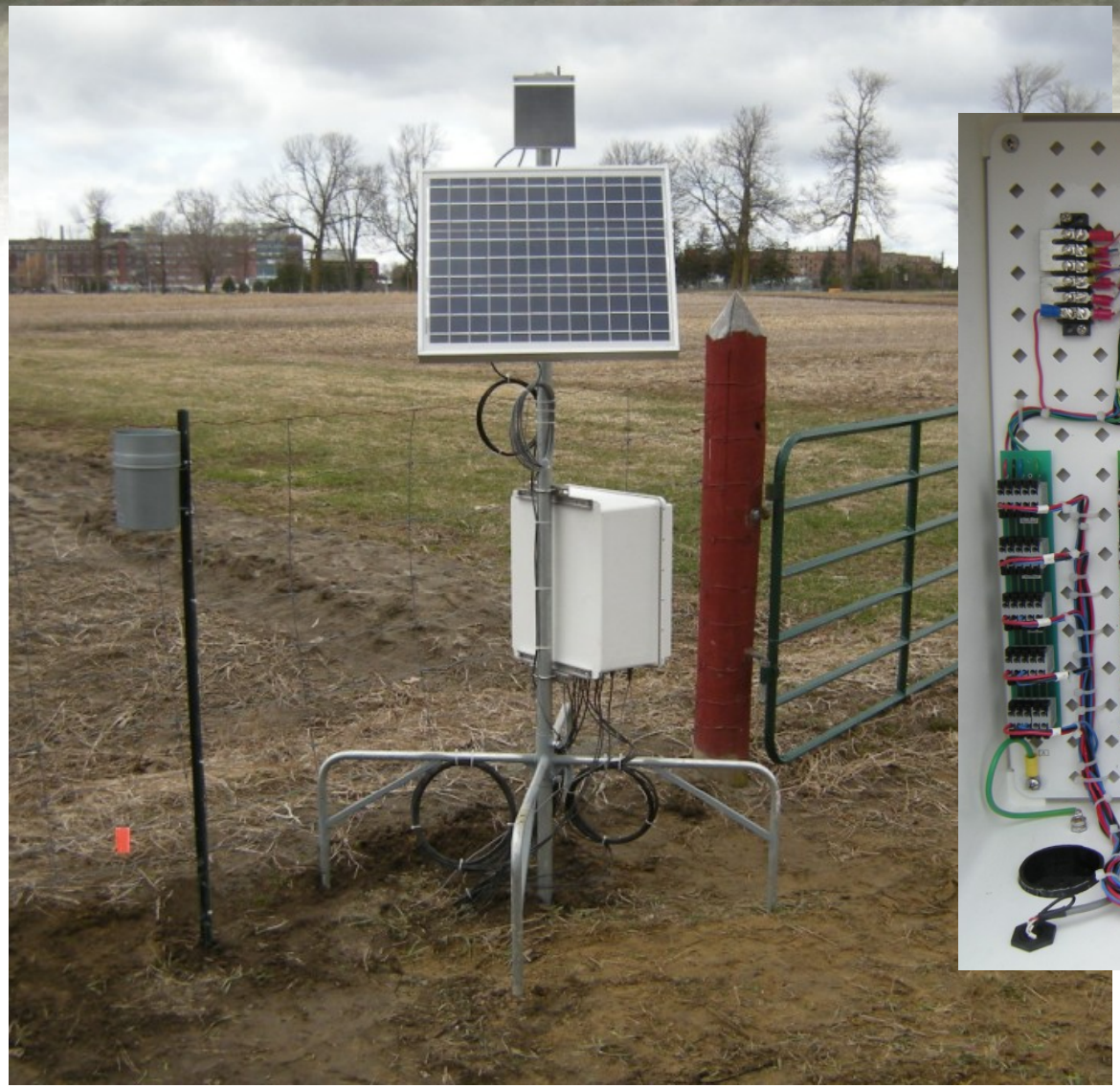
Star-network based insitu-senor web

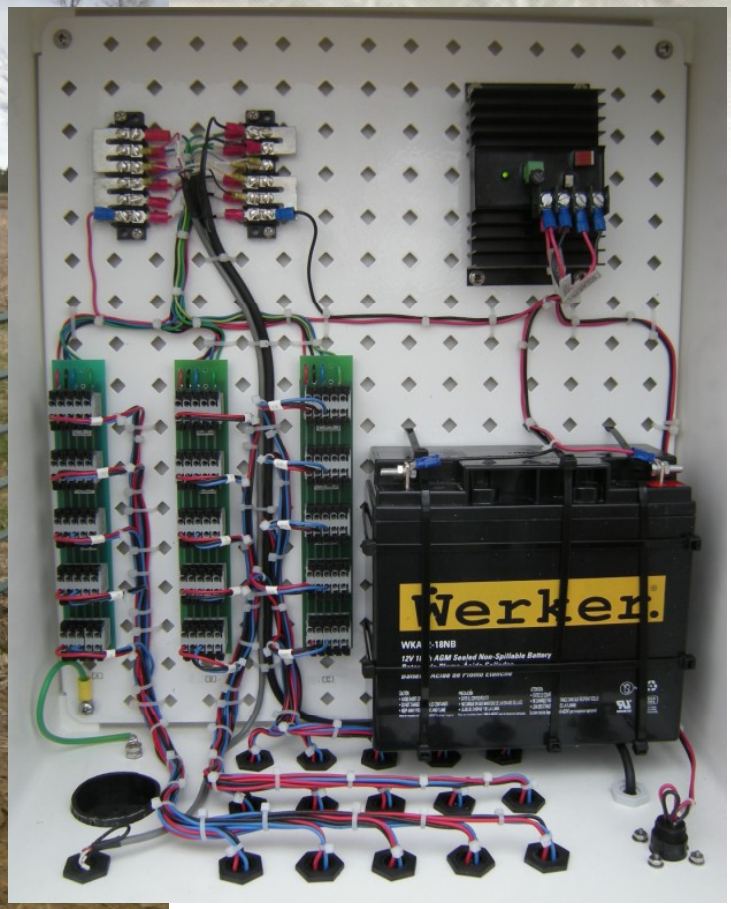


Descriptive view of the system

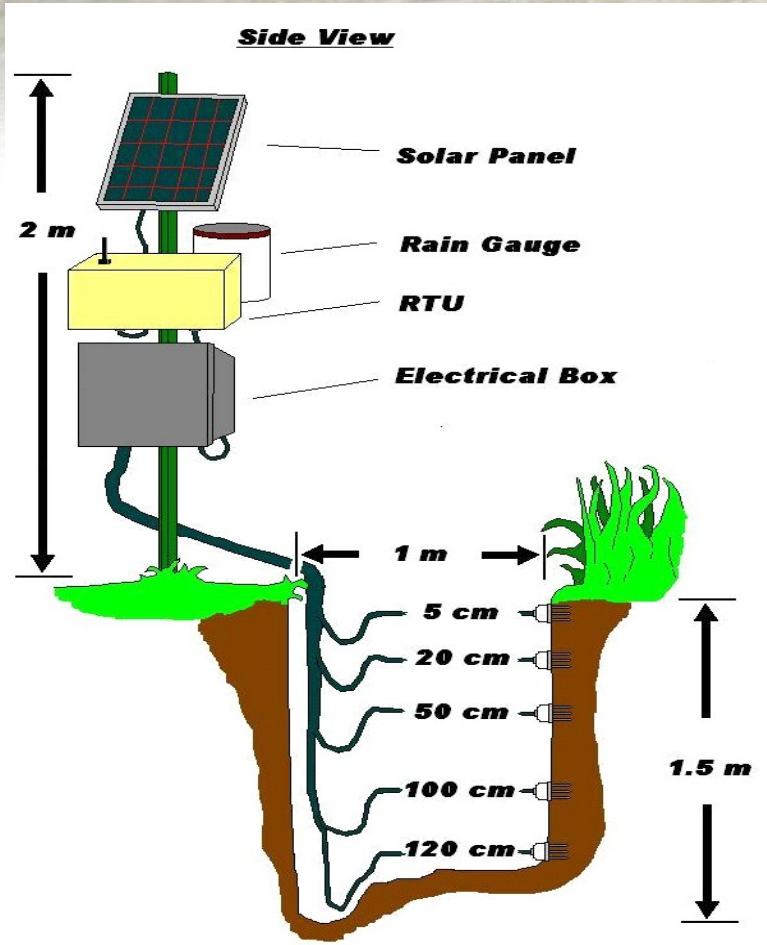


In-situ station design





In-situ sensor station installation



Installing Soil Probes

Notes on installation and site configuration

Sensor calibration and QA/QC

Notes on calibration

Four calibration methods have been studied in Casselman site

Hydroa probe default loam setting

uses a calibration equation and the coefficients for the equation are averages of the coefficients from 20 soils.

Site specific calibration

a regression for each soil (Kennedy et al. 2003), to transform the real dielectric constant values to more closely match the gravimetrically determined volumetric moisture content value.

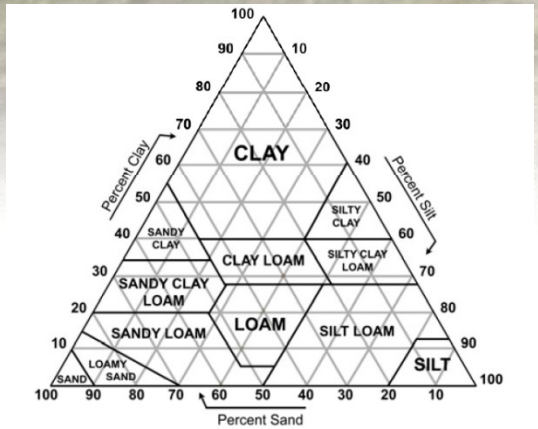
Soil texture and pedology based empirical method

uses calibration curve for each soil class on the soil texture triangle (Bellingham, 2007), was used to obtain the volumetric soil moisture from real dielectric constant

Using model developed by Peplinski et al., 1995

A semi-empirical dielectric mixture model

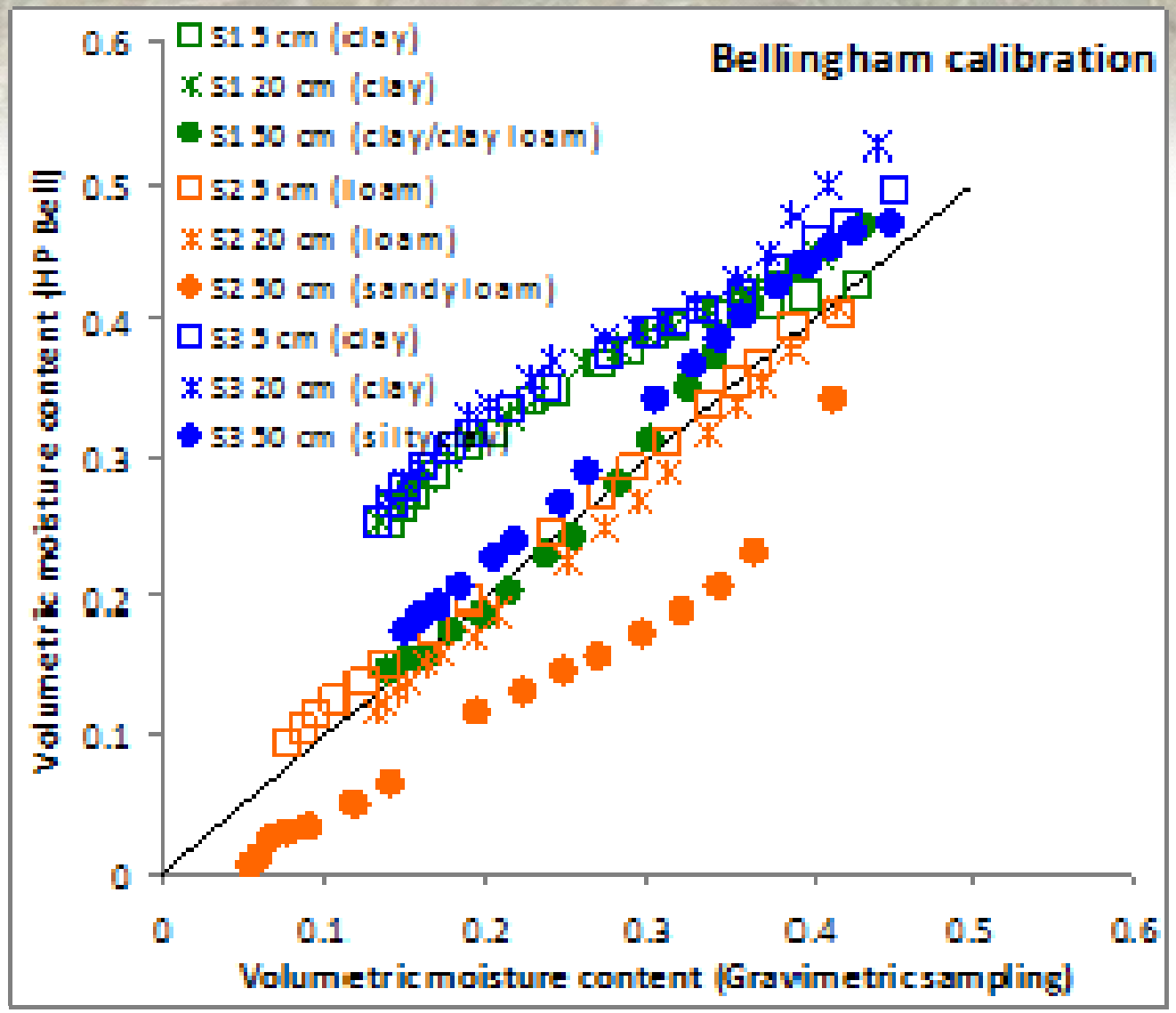
Notes on calibration



Based on our calibration test, the performance of Bellingham method is comparatively better than other methods and the Bellingham method can be used to convert soil moisture station real dielectric readings to volumetric moisture content.

Location	Sand %	Clay %	Silt %	Stevens's texture class	Calibration equations
S1 - 5cm	8.26	53.06	38.67	Clay	VMC = (0.0032414 RDC^3 - 0.2464 RDC^2 + 6.553 RDC - 20.93) / 100
S1 - 20cm	8.64	52.23	39.13	Clay	VMC = (0.0032414 RDC^3 - 0.2464 RDC^2 + 6.553 RDC - 20.93) / 100
S1 - 50cm	28.42	41.67	29.91	Clay/Clay loam	=0.1033 SQRT(RDC) - 0.1768
S2 - 5cm	34.70	19.87	45.43	Loam	=0.109 SQRT(RDC) - 0.179
S2 - 20cm	36.48	17.60	45.92	Loam	=0.117 SQRT(RDC) - 0.1847
S2 - 50cm	68.23	6.11	25.66	Sandy loam	=0.1017 SQRT(RDC) - 0.1786
S3 - 5cm	23.83	43.79	32.38	Clay	VMC = (0.0032414 RDC^3 - 0.2464 RDC^2 + 6.553 RDC - 20.93) / 100
S3 - 20cm	24.38	46.11	29.51	Clay	VMC = (0.0032414 RDC^3 - 0.2464 RDC^2 + 6.553 RDC - 20.93) / 100
S3 - 50cm	2.42	52.23	45.34	Silty clay	=0.1088 SQRT(RDC) - 0.1738

Notes on calibration



Data management and access

Data access via Sensor Web

- World Wide Web provides enormous distributed computing resources.
- Sensor Web leveraging Internet protocols connects distributed and networked heterogeneous in-situ and remote sensors.
- An effective Sensor Web should be constructed using interoperable protocols and application interfaces.
- A Sensor Web is achieved by connecting the to information centers/servers/nodes that store, disseminate, exchange, display, and manage the sensed information.

Data access with interoperable API

- The **Sensor Observation Service** (SOS) is a web service to query real-time sensor data and sensor data time series and is part of the Sensor Web.

- The offered sensor data comprises descriptions of sensors themselves, which are encoded in the Sensor Model Language (SensorML), and the measured values in the Observations and Measurements (O & M) encoding format.

- The web service as well as both file formats are open standards and specifications of the same name defined by the Open Geospatial Consortium (OGC).

Source: Wikipedia

Data access: SOS xml stream

Firefox | http://54.243.250.10/ | http://54.243.250.10/SOS/sos

54.243.250.10/SOS/sos

This XML file does not appear to have any style information associated with it. The document tree is shown below.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        Agriculture and Agri-Foods Canada In-Situ Soil Sensor Observation Service (SOS)
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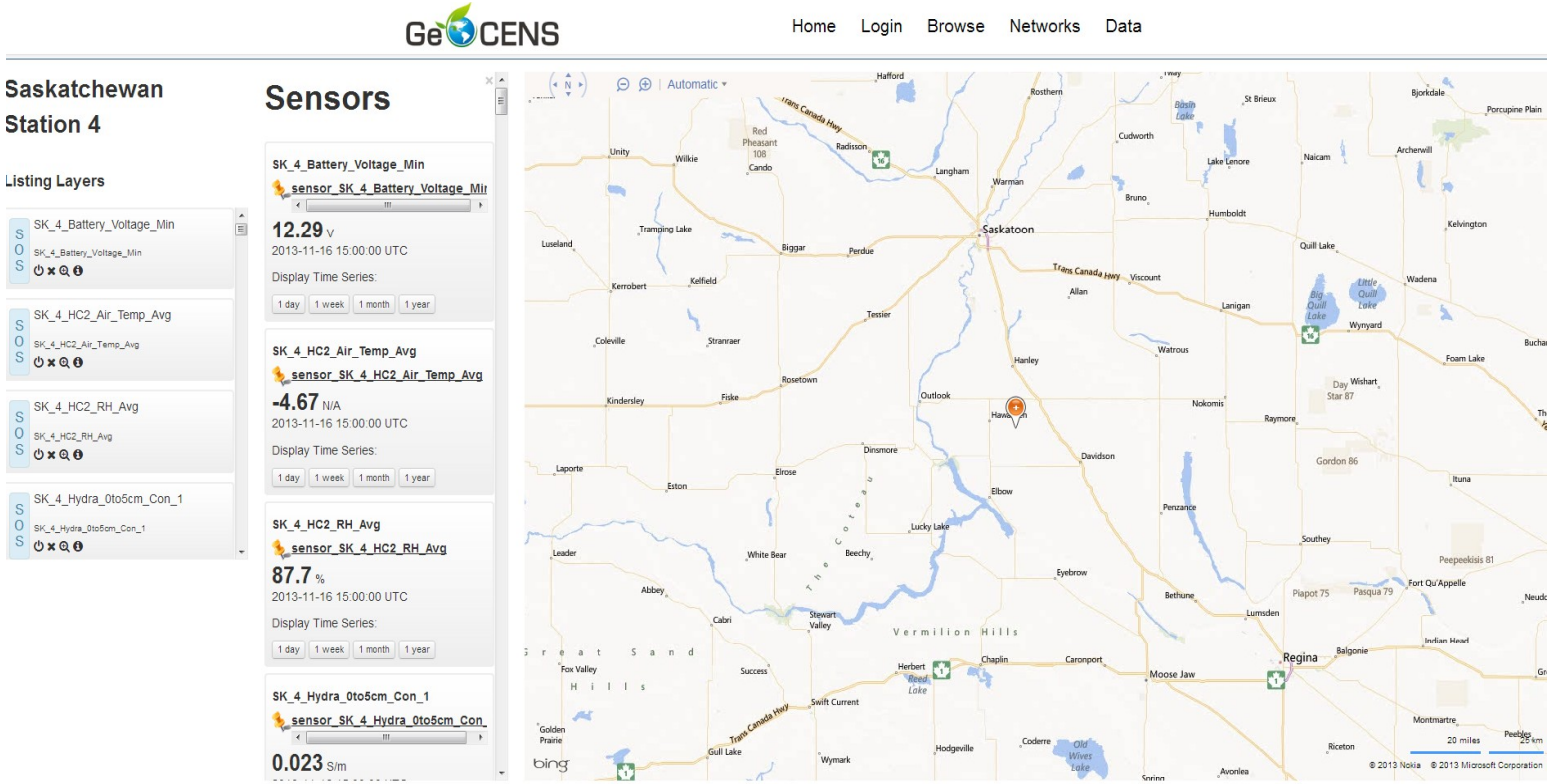
10:01 AM
01/12/2012

GeoCENS Portal—a SOS use case

- Created and maintained by ServerUp
- http://aafc.geocens.ca/
- Current contract with ServerUp includes improving data downloading capability and generating a data summary window when viewing latest data from a station



Data summary and visualization

- The data summary table will be achievable and downloadable and will contain something like the following data:

  Date/time of last reading: June 14, 2013 14:00 CST or EST

  Current Conditions (past hour):

  –Air Temp: 25.3 °C

  –Relative Humidity: 50 %

  –Wind Direction: WSW / 241 °

  –Wind Speed: 19 km/h

  –Max Wind Speed: 30 km/h

  –Min Wind Speed: 12 km/h

  –Precip, past hour (or 15 min): 0 mm

  –Precip, since midnight: 2.1 mm

  Conditions Previous 24 Hours or previous day (June 13, 2013)

  –Total Precip: 1.4 mm

  –Min Air Temp: 13.1 °C

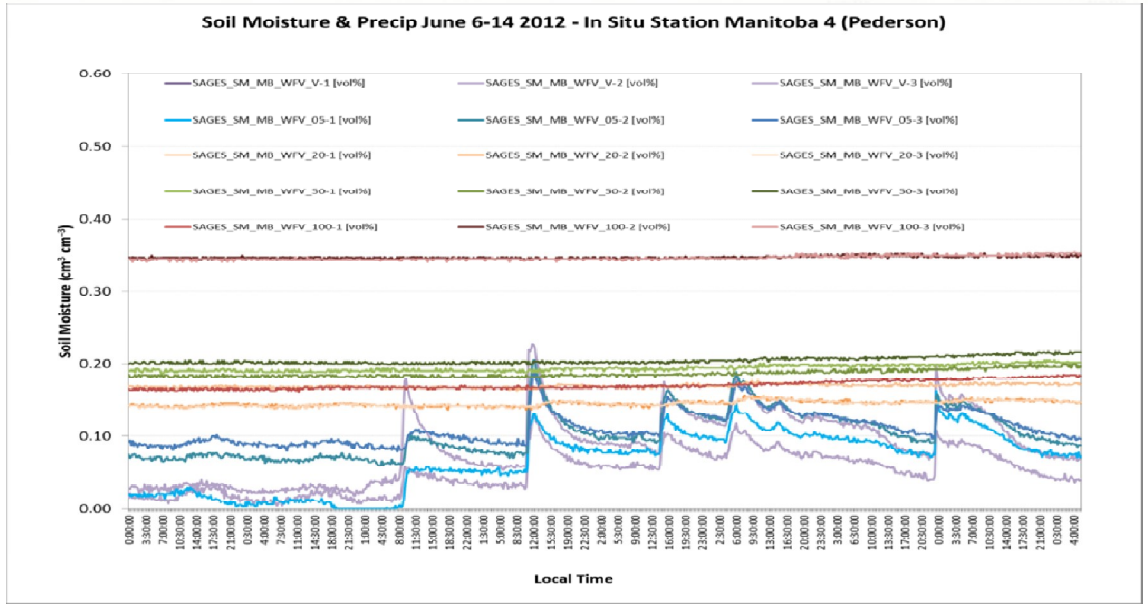
  –Max Air Temp: 27.3 °C

  –Ave Air Temp: 20.2 °C

  –Ave RH: 60.3 %

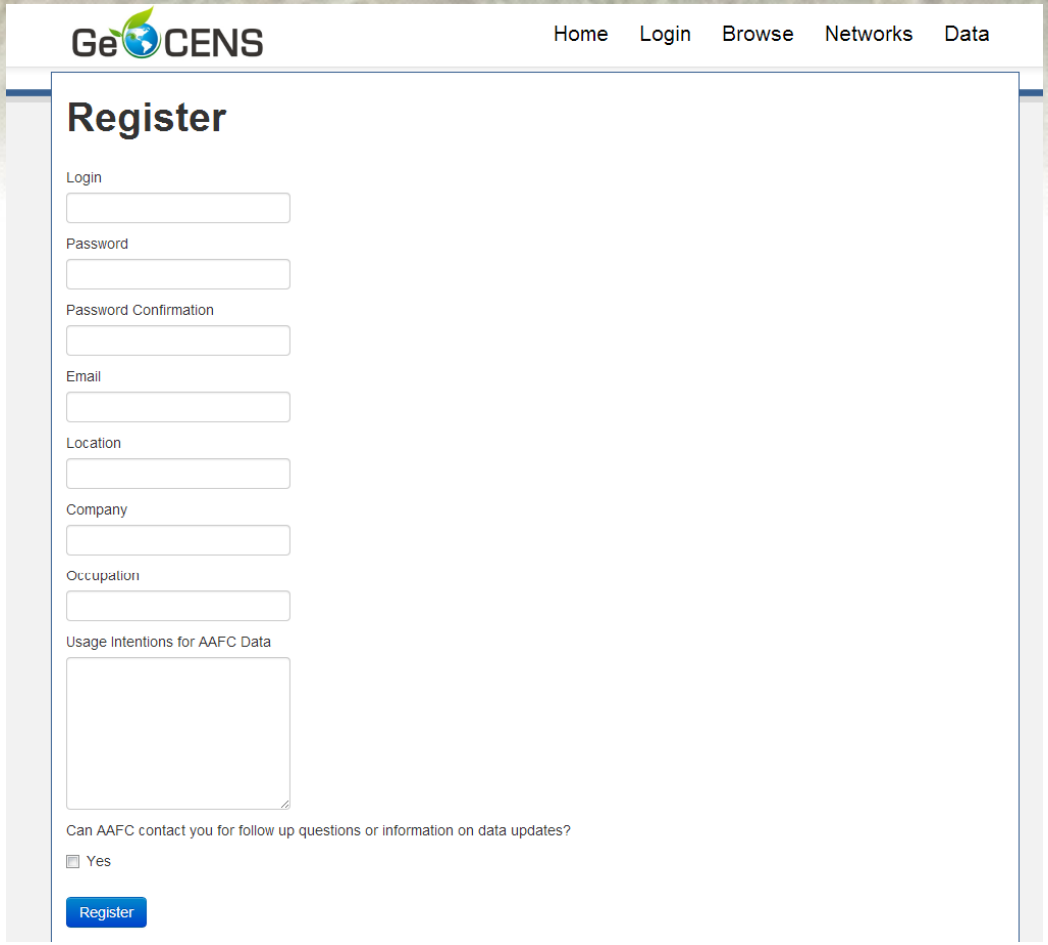
  –Ave Wind Direction: SW / 240 °

  –Ave Wind Speed: 20.1 km/h



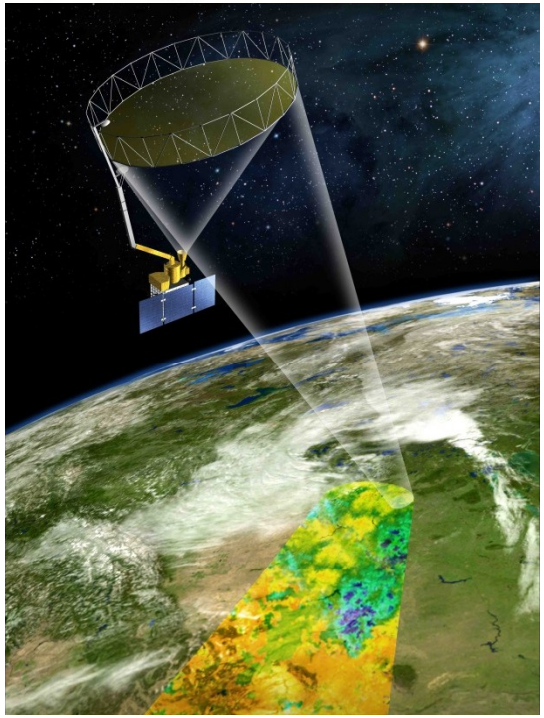
Data access: download

- The archived summary data can be downloaded by the general public
- The complete data set can currently be downloaded by the public as long as they register and log in.



Application and use cases

In-situ data for SMAP sensor cal/val



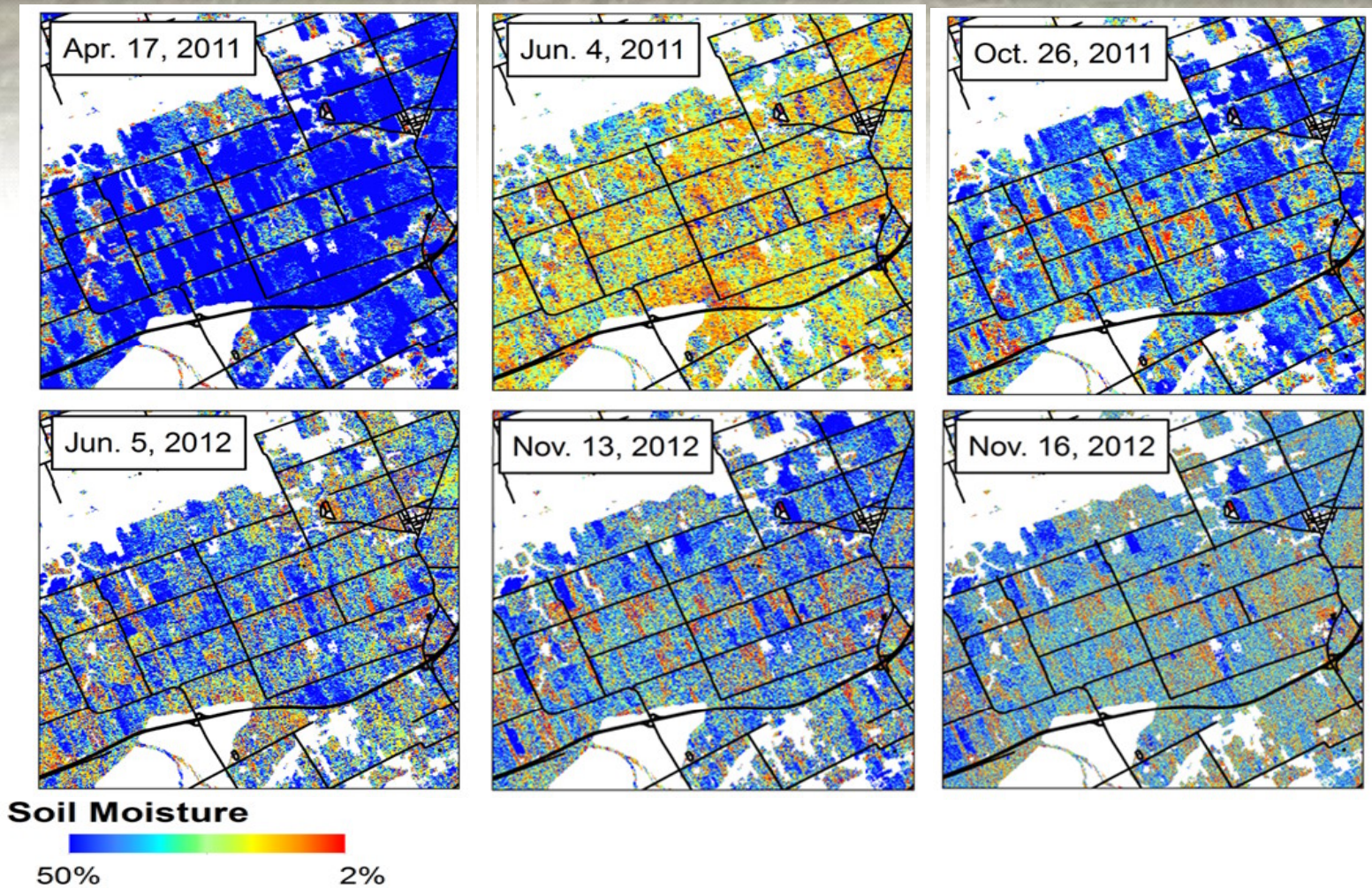
Objectives: SMAP will provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance understanding of processes that link the water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also be used to quantify net carbon flux in boreal landscapes and to develop improved flood prediction and drought monitoring capabilities.

Observatory: The SMAP observatory employs a dedicated spacecraft with an instrument suite that will be launched on an expendable launch vehicle into a 680-km near-polar, sun-synchronous orbit, with equator crossings at 6 am and 6 pm local time.

Instrument: The SMAP instrument includes a radiometer and a synthetic aperture radar operating at L-band (1.20-1.41 GHz). The instrument is designed to make coincident measurements of surface emission and backscatter, with the ability to sense the soil conditions through moderate vegetation cover. The instrument measurements will be analyzed to yield estimates of soil moisture and freeze/thaw state. The measurement swath width is 1000 km, providing global coverage within 3 days at the equator and 2 days at boreal latitudes (>45 degrees N).

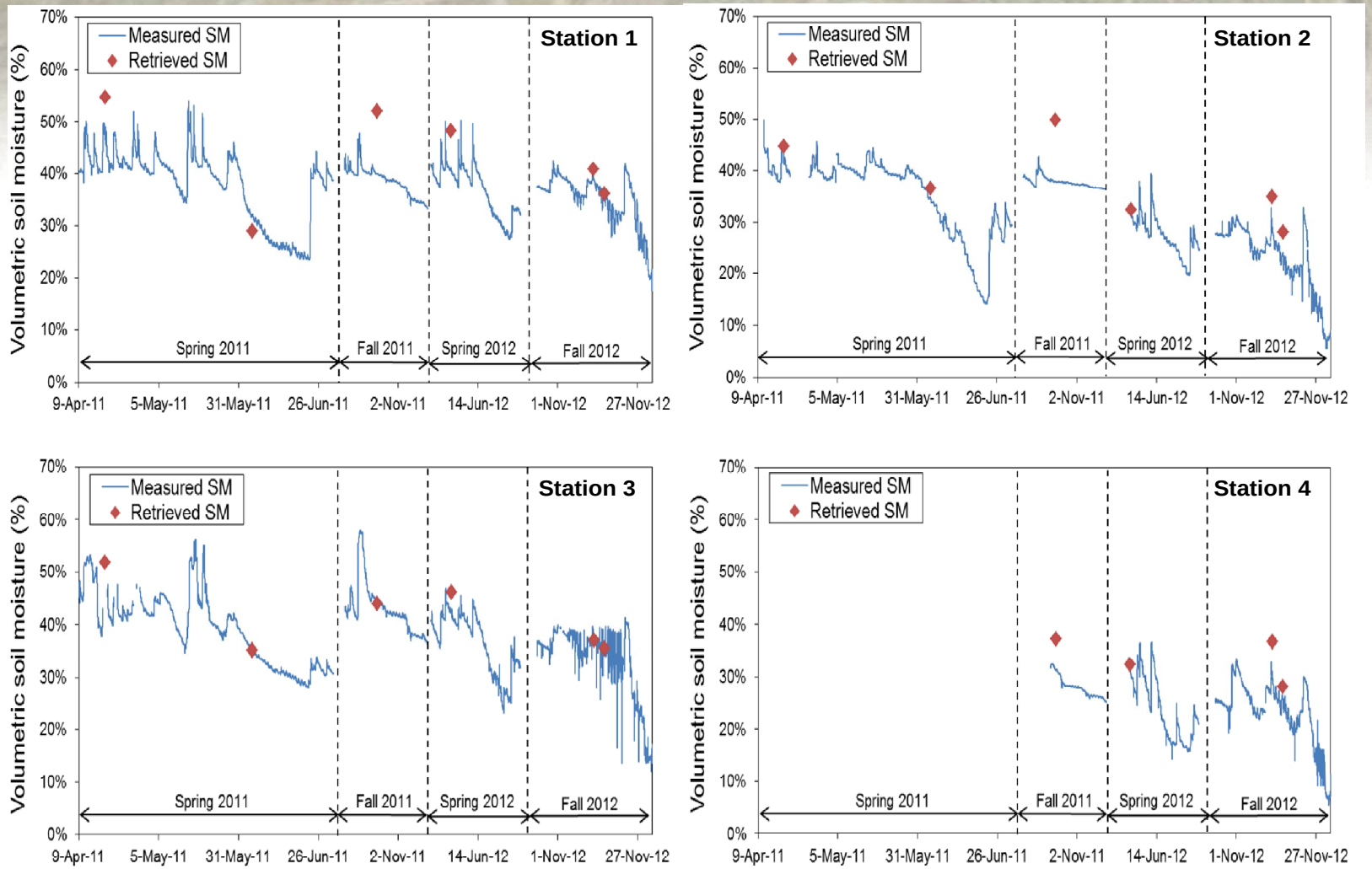
Operations: SMAP science measurements will be acquired for a period of three years. A comprehensive validation program will be carried out after launch to assess the accuracies of the soil moisture and freeze/thaw estimates. Data products from the SMAP mission will be made available through a NASA-designated data center.

SAR derived soil moisture validation



Soil moisture maps retrieved from RADARSAT-2 image pairs using the hybrid inversion method.

SAR derived soil moisture validation



Temporal evolution of soil moisture data sets for each *in situ* station.

Extended in-situ sensor for pivot monitoring

Thank you!

Contact: xiaoyuan.geng@agr.gc.ca
Tel. 613-759-1895