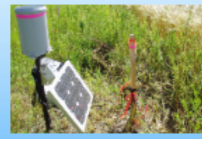
CanEx-SM10

Canadian Experiment for Soil Moisture in 2010





Experimental plan

Version 28/05/2010

Université de Sherbrooke · Cartel · University of Guelph · Université du Québec École de technologie supérieure · Environment Canada · CSA ASC · Agriculture and Agri-Food Canada · USDA

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1. Introduction

The Canadian Experiment for Soil Moisture in 2010 (CanEx-SM10) originated as an initiative of Canadian researchers to support the Soil Moisture and Ocean Salinity (SMOS) validation activities over land and to develop soil moisture retrieval algorithms. The experiment was extended to include pre-launch validation and algorithm development for the Soil Moisture Active and Passive (SMAP) mission through a collaboration with US researchers. CanEx-SM10 field phase will take place from May 31 to June 17, 2010 over agricultural and forested sites located in Saskatchewan, Canada.

1. 1. Project description

In many regions, soil moisture is one of the most important factors influencing meteorological conditions such as near-surface air temperature and humidity, boundary-layer mixing, clouds, and precipitation. It is a main controlling element for the distribution of vegetation, drought, and flood risk. At large scale, soil moisture is an essential part of the global water and energy cycles.

Due to the heterogeneity of several environmental factors, the spatio-temporal distribution of soil moisture is difficult to estimate based on current routinely available data. With the recent launch of ESA's Soil Moisture and Ocean Salinity (SMOS) satellite in November 2009 and the future launch of the National Aeronautics and Space Administration (NASA)'s Soil Moisture Active and Passive (SMAP) satellite in 2014, both operating at L-band, significant improvements are expected in global soil moisture estimation. In this context, researchers from academic and governmental organisations in Canada and USA developed CanEx-SM10 with the aim of improving soil moisture estimation over large areas based on microwave remote sensing data.

As part of CanEx-SM10, microwave measurements from satellites (SMOS, AMSR-E, RADARSAT-2, and ALOS-PALSAR), will be collected along with data from airborne passive and active instruments(L-band radiometer aboard Environment Canada (EC)'s Twin Otter aircraft and NASA's L-band Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) flown in a Gulfstream III piloted aircraft). One important aspect of CanEx-SM10 is to collect field measurements of soil moisture, surface temperature, and surface characteristics (roughness, vegetation, LAI, bulk density, etc.) at a time close to the satellite and airborne acquisitions to support the validation of SMOS and pre-launch validation activities of SMAP. Two domains, each covering 33 km x 71 km (about two independent SMOS pixels) were selected in agricultural and forested areas of Saskatchewan, Canada. Measurements from these two sites should provide diverse and robust soil moisture for very different types of soil and vegetation.

Over the agricultural area, about 60 fields will be sampled for soil moisture, surface temperature, and surface characteristics measurements from June 2-14, 2010. Two soil moisture sampling strategies will be performed. One strategy is related to the validation issue of SMOS products and the development of soil moisture inverse modeling based on both active and passive microwave measurements. The second strategy is a more intensive sampling to provide a sampling regime that would enable to relate the time series (networks) measurements to field averages and to develop scaling method of SMOS data.

The other domain is the Boreal Ecosystem Research and Monitoring Sites (BERMS) that are essentially composed of 4 forest types (old Aspen, old Jack Pine, Fen, and old Black Spruce). Over this area, the sampling of soil moisture will be conducted one day on or about June 16 at measurement points selected on the basis of road access facilities and at distance close to SMOS grid centres. Vegetation characteristics will be measured later in two campaigns on June 14-16 and on July 13-20, 2010.

The field campaign soil moisture data collected during CanEx-SM10 will be complemented by the observations from the permanent existing soil moisture measurement networks managed by EC and the University of Guelph (U of G). A temporary network of about twenty stations will be installed by the United States Department of Agriculture (USDA) to collect hourly soil moisture data over the BERMS site. Over 50 people will participate in the ground and aircraft components of CanEx-SM10.

1. 2. Objectives

The general objective of CanEx-SM10 is to contribute to the validation of SMOS soil moisture estimation and brightness temperature products, and the pre-launch validation activities of the future SMAP mission. Specifically, through the field data measurements over agricultural and forested sites, the following scientific points will be addressed:

- Qualitative and quantitative analysis of L-Band microwave data
- Development of soil moisture retrieval algorithms from passive and active microwave data (SMOS, RADARSAT-2, ALOS-PalSAR, L-Band airborne data from EC's radiometer and NASA's UAVSAR)
- Scaling methodologies for SMOS coarse resolution data
- Assimilation of SMOS data in land surface systems to improve land surface initial conditions provided to environmental forecast models.

2. Study Sites

2. 1. Kenaston

2.1.1 General Description

The field site is located south of Saskatoon near Kenaston, Saskatchewan. Figure 1 illustrates the location of the Kenaston mesonet within Saskatchewan, relative to both the US border and to Saskatoon. Figure 2 illustrates the relative scales of the two nested study sites for EC and U of G. The study area was designed to avoid the irrigated fields along Diefenbaker Lake and South Saskatchewan River to the west and south, by hummocky uplands to the northeast and by Diefenbaker Lake and forested areas to the south.

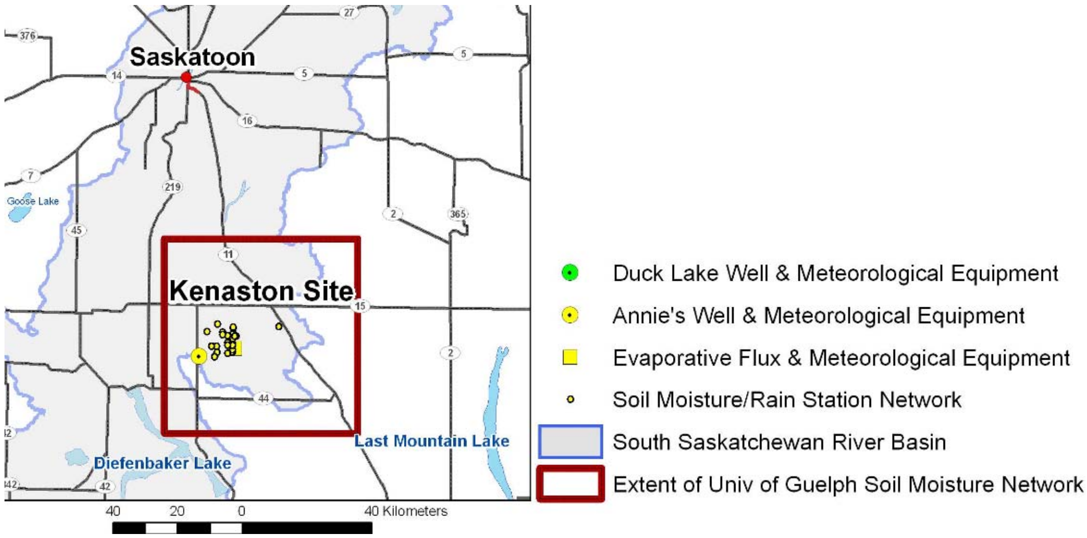


Figure 1. The Kenaston soil moisture mesonet (EC and U of G) near Saskatoon, Saskatchewan Canada is one of the study sites for the CanEx-SM10.

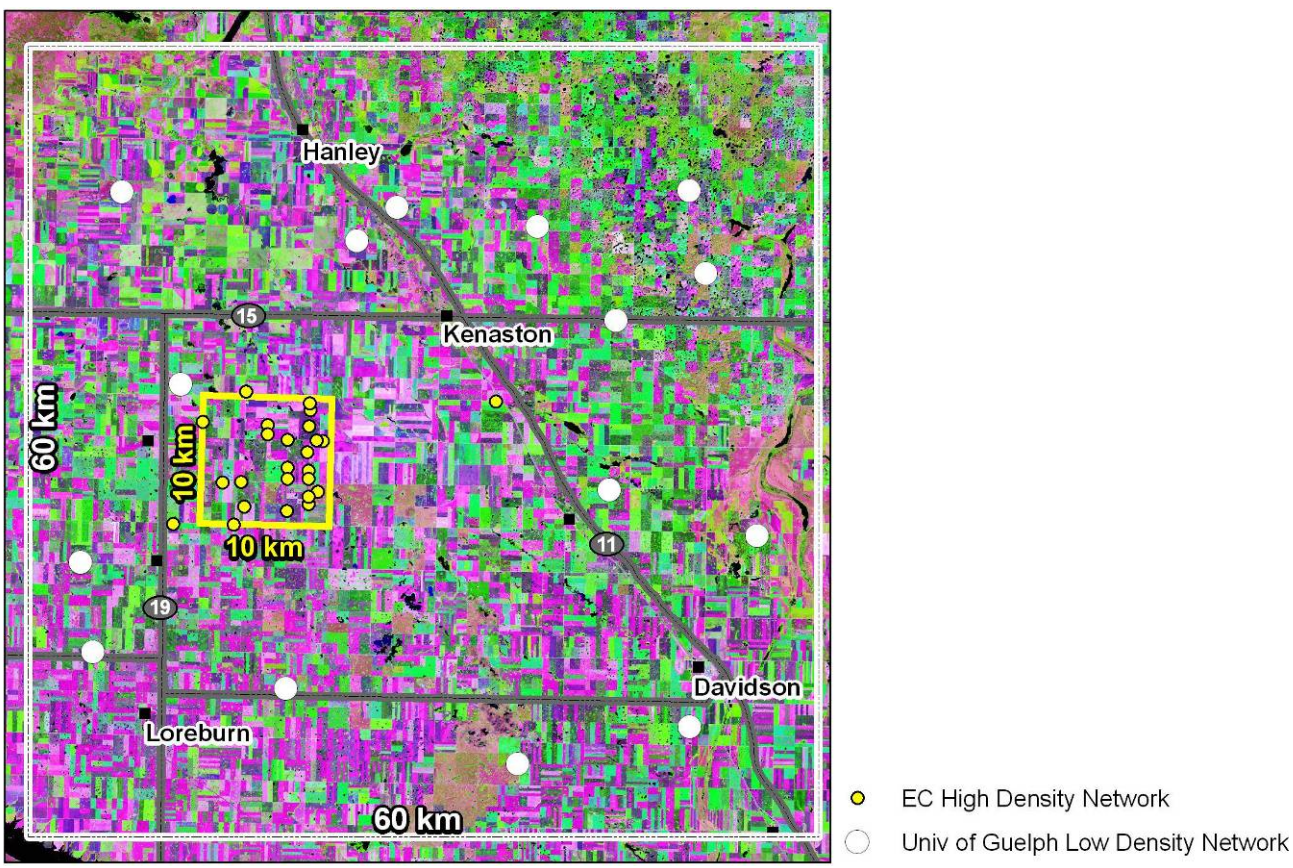


Figure 2. The nested study area (yellow box, EC and white box, U of G) superimposed on a false colour Landsat image from 1999 (mid IR, near IR, red). The green red response represents differing brightness images from varying landcover as seen by the Landsat image.

2.1.2 Available soil moisture networks.

2.1.2.1. EC's soil moisture stations set-up (high density network)

The high density network shown in Figure 2 consists of 24 soil moisture stations. The lower right portion of the area includes a pasture and the flux tower site. A deep well lysimeter installation is located just to the south west of the yellow box in Figure 2. These sensors were installed in the fall of 2006 and during the spring of 2007.

Figure 3 illustrates the distribution of the EC's soil moisture stations within the high-density area. The area is divided into 0.8 km x 0.8 km grid cells (0.5 mile by 0.5 mile, or one quarter section). It is logical to work in a 1/2-mile grid size compared to a 1-km grid size in an agriculture area. The intent was to cover the main crop types (cereal crops, pulse crops, oil seeds, grass/alfalfa and pasture), soil textures (clay, clay/loam and loam in this area) and tillage practices. Ultimately, the selection of crop rotation is dictated by the landowners.

In addition to installing soil moisture stations within the selected quarter sections, manual surface soil moisture sampling (using handheld Steven's Water Hydra Probes) will be conducted along transects across these fields. This is to get a better picture of the distribution of soil moisture over the field and to be able to relate the (station) point value to an average field value.

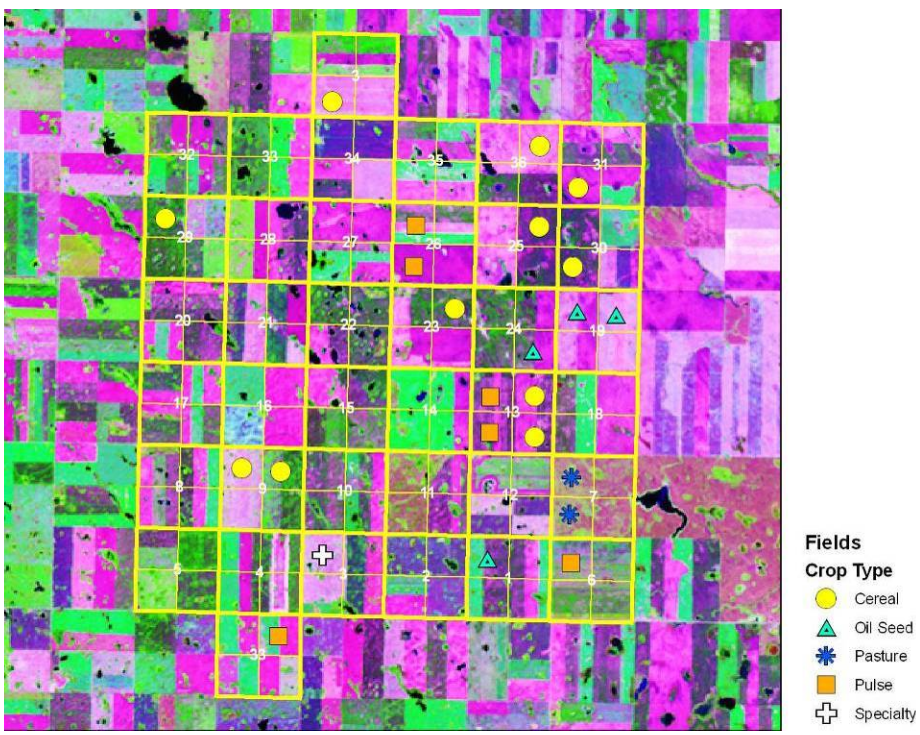


Figure 3. The high-density network in yellow. Each grid cell is 1/2 mile by 1/2 mile. Each of the soil moisture stations are shown with the 2007 crop type. The location for the flux tower is the north; pasture station (NW07) and the deep well lysimeter is located just south and west of the larger area outlined in yellow.

Seven TB3 tipping buckets and a number of older (and less accurate) TE tipping buckets are installed together with the soil moisture stations. Preferably, every soil moisture station would have a tipping bucket, but this is not possible due to high costs. Additionally we have two Geonor weighing precipitation gauges, one located at the flux tower and one at the geologic weighing lysimeter.

Figure 4 illustrates the station set-up. Each soil moisture station consists of three Steven's Water Hydra Probe 2 soil moisture sensors (one data logger, one battery, one solar panel and optionally one tipping bucket (precipitation rates) or precipitation weighing gauge (accumulated precipitation). The soil moisture sensors record soil moisture and temperature at 5 cm, 25 cm and 50 cm depths.

For this network, soil moisture is measured within the field in order to be representative of field conditions; however, the practicalities of agricultural field management make this difficult. As a result, each surface sensor is installed vertically into the top soil approximately 6.5 meters from the field edge and is then moved back to the edge of the field just prior to harvesting. There is maintenance at each site to ensure that the vegetation growth within the plot mimics the rest of the field (hand weeding, seeding and cutting). The two deeper sensors (25 cm and 50 cm) are installed permanently within the field, approximately 6.5 m from the edge (the cable length is 7.6 m). These two sensors and cable lengths are buried deep enough in the ground to allow the landowner to work the ground without disturbing the sensors. The data logger, power supply and a potential precipitation gauge will be left outside the edge of the field. All sensors are installed approximately 10 cm apart (horizontally). A separate hole was cored for each depth and the probes were inserted into the "undisturbed" soil. At the time of installation, a sample was be taken and used for calibration of the sensor.

For the field campaign in 2010, a second surface sensor was installed in a permanent location, just outside the field, at the 5 cm depth to provide a comparison with the University of Guelph's horizontally installed sensors.

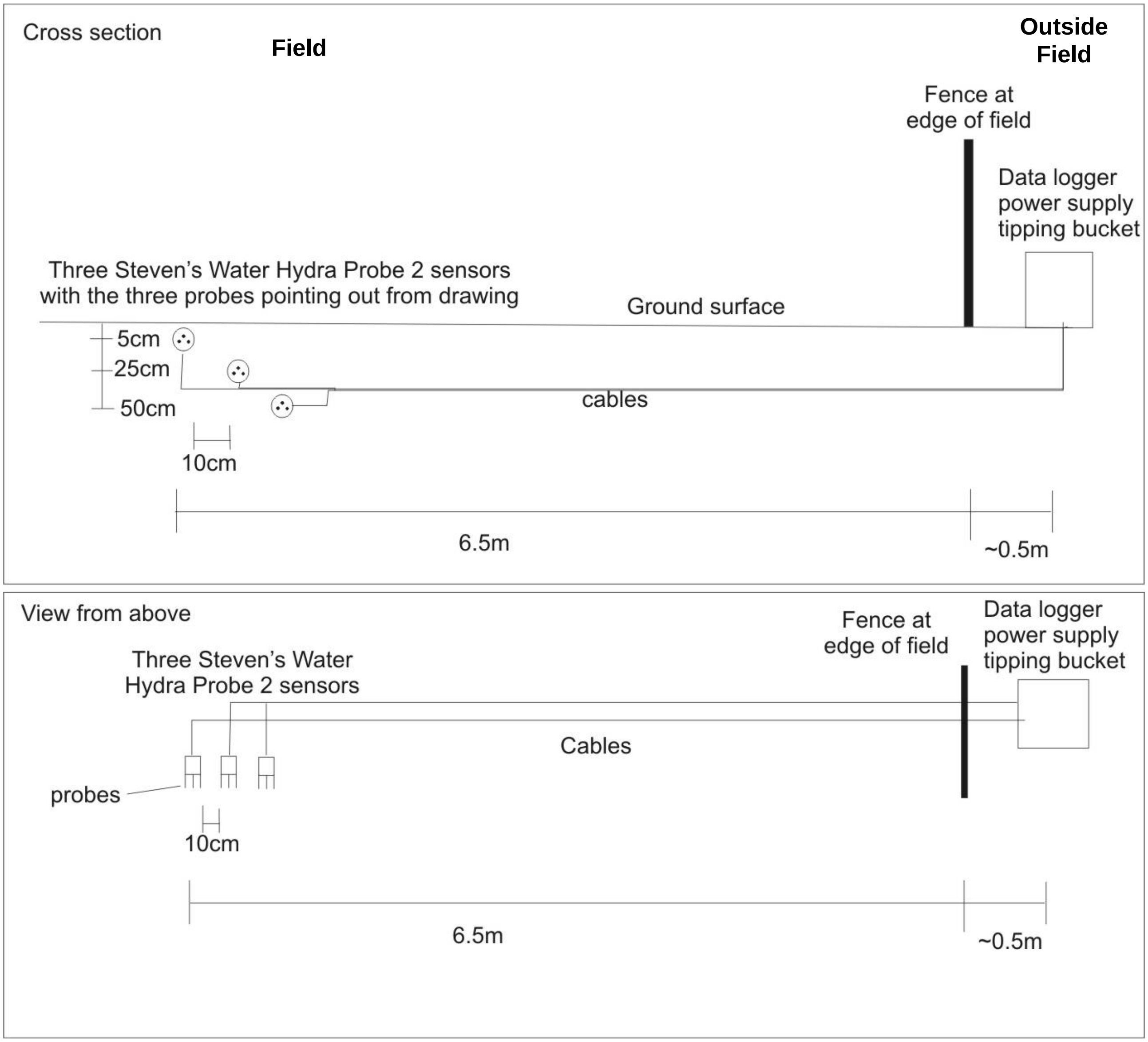


Figure 4. Schematic drawings of EC's soil moisture station set-up. *Note*: drawings are not to scale.

2.1.2.2.University of Guelph Soil Moisture Station Set-up (low density network)

The University of Guelph (U of G) has 16 stations distributed in an area that surrounds the high density EC network, as shown in Figure 5.

Figure 5. U of G 16 site locations surrounding EC's high density network.

The individual site setup is the same as for the EC network, with the only difference being that the soil moisture station is installed outside of the field and there is a single surface probe installed horizontally.

The Hydra soil moisture probe determines soil moisture and salinity by making a high frequency (50 MHz) complex dielectric constant measurement. A complex dielectric constant measurement simultaneously resolves the capacitive and conductive parts of a soil's electrical response. The capacitive part of the response is most indicative of soil moisture while the conductive part reflects predominantly soil salinity. Temperature is determined from a calibrated thermistor incorporated into the probe head.

Sensors at the EC and U of G sites have been calibrated using a lab derived calibration equation that relates a known soil moisture to the measured dielectric constant measurement. Typically, without any knowledge of the soil type, the accuracy of the Stevens probe is +/- 0.03 volumetric water fraction (wfv). For example a measured value of 0.20 wfv could correspond to an actual wfv of 0.17 to 0.23 depending on soil type. With a crude knowledge of soil type (sand, silt, clay classification), the uncertainty drops to typically +/- 0.015-0.020 wfv to give a range of soil moisture for our example of 0.18-0.22 wfv. If a soil-specific calibration for the particular soil is performed, the uncertainty drops to less than +/- 0.005 wfv, and for our example, the range is down to 0.195-

0.205 wfv. The remaining uncertainty is predominantly due to inaccuracies in the calibration process and the basic electrical properties measurement.

2.1.3 Other supporting data

The following overall regional characteristics influenced the selection of the in situ soil moisture mesonet sites and the approach to validation of associated remote sensing:

- *Topography*: The area is not perfectly flat as it has a valley going through the centre of the area. The northeast corner of the area is hummocky. Figures 6 and 7 illustrate the digital elevation model (DEM) of the area, while Figure 8 shows a slope histogram.
- *Watersheds*: This area mainly covers the headwaters of the Brightwater Creek, which has been gauged since 1960 (05HG002 gauging station). Figure 9 illustrates the sub watersheds within the Outlook/Davidson area. The flow in Brightwater Creek is very low most of the year with spikes in the spring and/or fall.
- *Irrigation*: Minimal. Only one irrigated field could be located within the study area
- *Area of open water*: Based on a classification of the 1999 Landsat data illustrated in Figure 2, the percentage of open water within the study area is 1.5%. It should be noted that although the percentage of open water probably was underestimated (due to mixed pixel issues, presence of small ponds, wetlands covered by vegetation), the value obtained is well under the 5% cut-off for SMOS validation. Another point to consider is that there will be more water present in a very wet year and less in a dry year.
- *Land cover*: The land cover is dominated by cultivated fields (93% of total area), but there are also large areas of grass/pasture land (6% of total area). Figure 10 shows the general land cover of the area and Table 1 shows the fractions as classified by the Prairie Farm Rehabilitation Administration (PFRA) based on Landsat data.
- *Soil texture*: Most of the area is covered by loam, but there are also areas with clay loam and small pockets of clay (http://sis.agr.gc.ca/cansis/publications/sk/index.html).
- *Urban/Rural centres*: Five very small rural centres are within the study area. These towns have a population of less than 500.
- *Distance from Saskatoon*: Approximately 80 km to Kenaston at the north edge of the study area (4-lane highway).

Table 1. Percentage of land use based on Landsat data

Crop Type	Percentage of Area
Pasture-Forage	34.5%
Cereals	30.7%
Canola	12.3%
Field Peas	9.2%
Uncultivated Grassland	7.6%
Lentils	4.3%
Fallow	1.4%
Flaxseed	0.1%
	100.0%

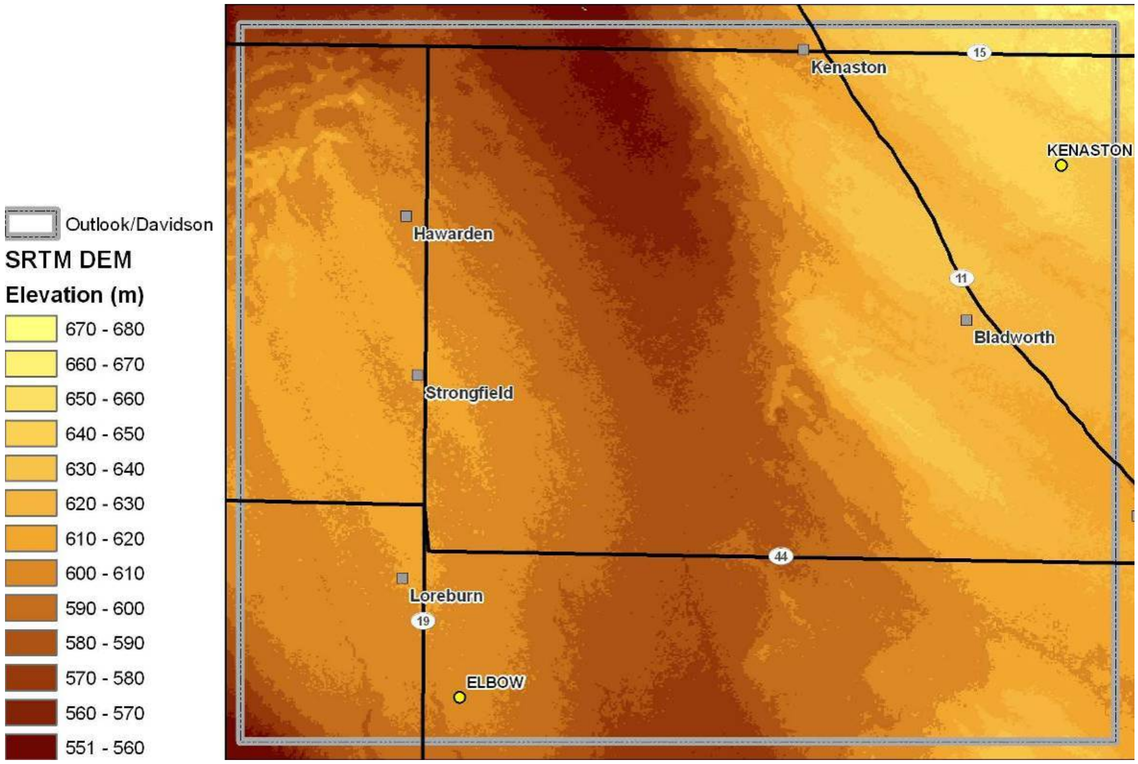


Figure 6. Digital Elevation Model (DEM) based on Shuttle Radar Topography Mission (SRTM).

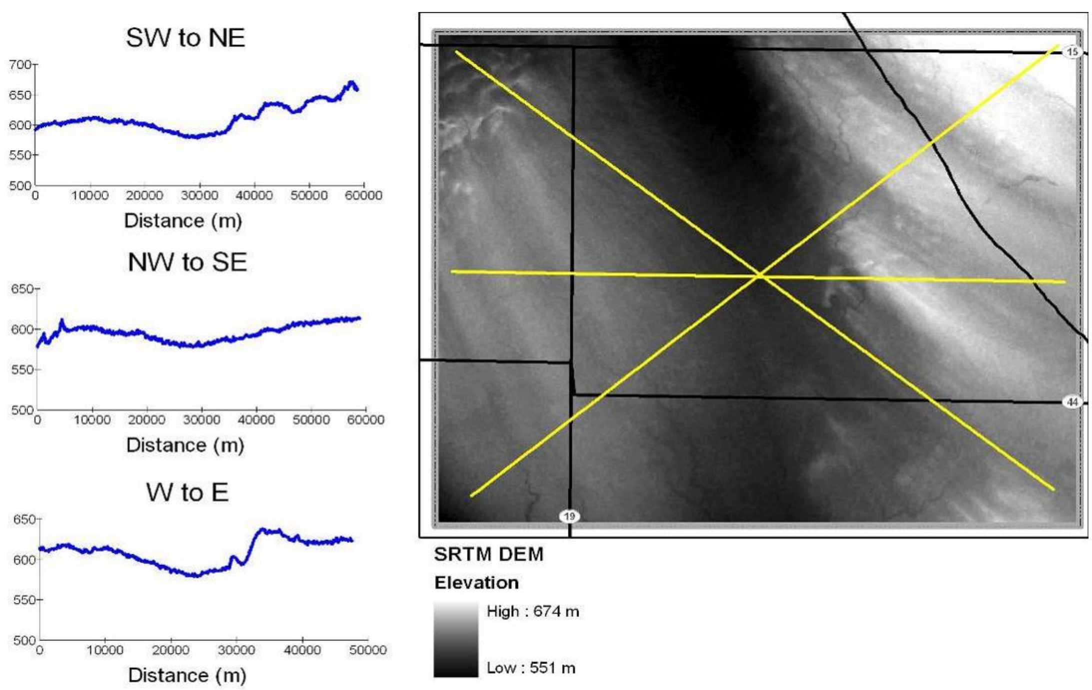


Figure 7. Gray scale DEM based on SRTM. Three elevation profiles along the yellow lines are also shown. Note that the scale is different for the first profile.

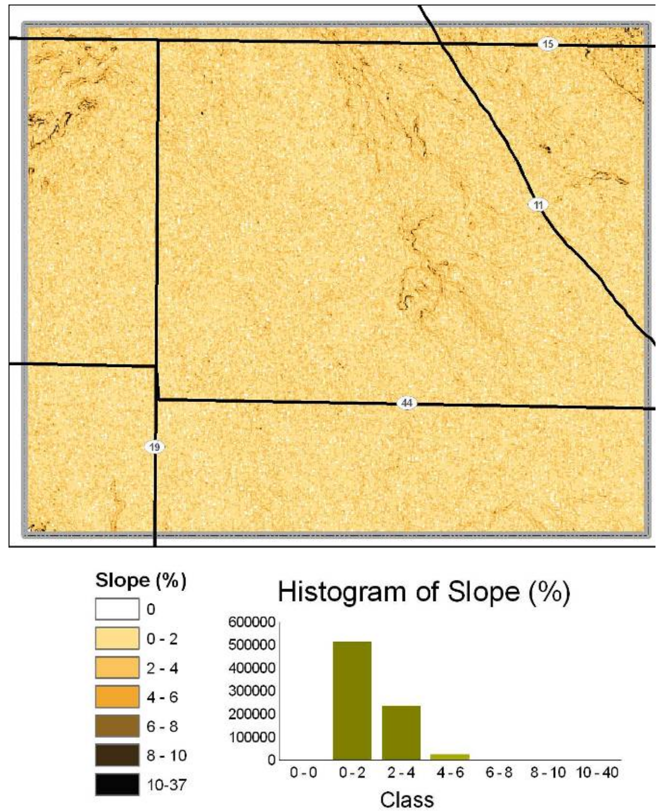


Figure 8. Slope of the area calculated based on the SRTM DEM. The histogram shows that most of the area is characterized by a slope between zero and four percent.

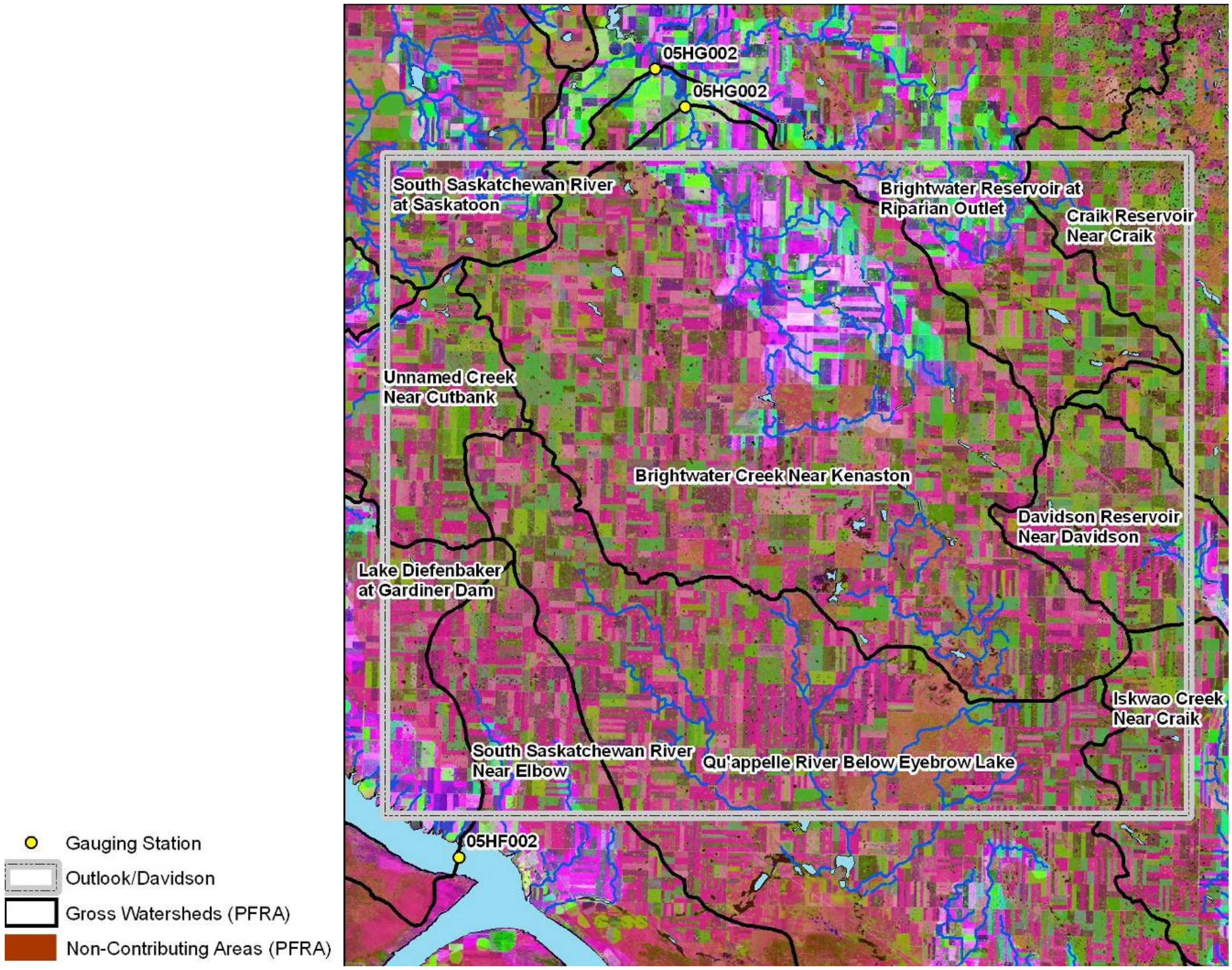


Figure 9. PFRA gross watersheds and gauging stations (PFRA database v4) within and near the Outlook/Davidson study area. The non-contributing areas as modeled by PFRA are also shown. These are the areas which do not contribute to downstream accumulations of stream flow for a median (1:2) annual runoff. The green red response represents differing brightness images from varying landcover as seen by a Landsat image.

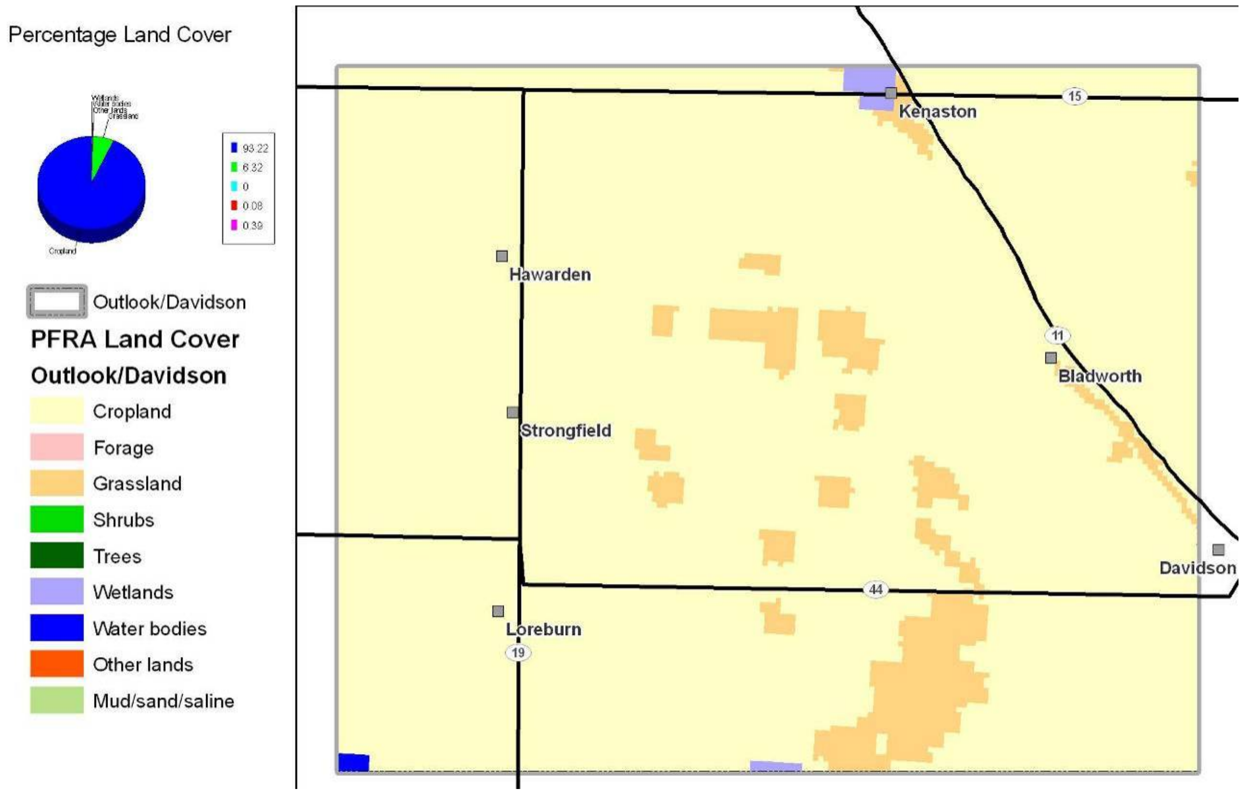


Figure 10. General land cover as classified by PFRA based on Landsat data. The pie chart illustrates that cropland (blue in chart) covers 93% of the area, while grassland (green in chart) covers 6%.

2.1.4 Sampling Fields

In addition to the 24 EC and 16 U of G permanent soil moisture monitoring fields, approximatly 20 additional manual survey (MS) fields were selected for the sampling. Table 2 and Figure 11 give the geographic location, expected cover type and spatial location). Agriculture and Agri-Food Canada (AAFC) used a 2008 crop classification of the region around Kenaston to determine the typical land use. The approximate proportions are provided in Table 1. These do not include minor crops. Forage-pasture and grassland make up a significant proportion of the agricultural fields.

Table 2. Coordinates of the sampling fields at Kenaston site- 24 EC fields, 16 U of G fields, and 20 manual survey (MS) fields.

Field type	Field #	Land Description	Latitude	Longitude	Easting	Northing	Coordinate location	Map
EC	Flux_NW07	NW07-28-3	51.38166	-106.41595	401463	5693220	datalogger	254
	NE07	NE07-28-3	51.38686	-106.41382	401622	5693795	NW	283
	NW01	NW01-28-4	51.36794	-106.44924	399116	5691739	datalogger	254
	NW03	NW03-28-4	51.37055	-106.49602	395866	5692095	datalogger	254
	SW03	SW03-29-4	51.44878	-106.49597	396047	5700794	datalogger	283
	NW06	NW06-28-3	51.37273	-106.42528	400794	5692239	datalogger	283
	SW07	SW07-28-3	51.37805	-106.42558	400785	5692831	datalogger	283

	NE09	NE09-28-4	51.38724	-106.49938	395670	5693956	datalogger	254
	NW09	NW09-28-4	51.38647	-106.51955	394265	5693899	datalogger	254
	NE13	NE13-28-4	51.39579	-106.42625	400777	5694805	datalogger	254
	NW13	NW13-28-4	51.39739	-106.44930	399177	5695014	datalogger	254
	SE13	SE13-28-4	51.39036	-106.42624	400766	5694201	datalogger	254
	SW13	SW13-28-4	51.39003	-106.44916	399170	5694196	datalogger	254
	NW19	NW19-28-3	51.41635	-106.41844	401364	5697081	datalogger	283
	NE23	NE23-28-4	51.41640	-106.45007	399165	5697129	datalogger	254
	SE24	SE24-28-4	51.40838	-106.42772	400702	5696207	datalogger	254
	NE25	NE25-28-4	51.42619	-106.42624	400843	5698186	datalogger	254
	NW26	NW26-28-4	51.42649	-106.47176	397679	5698282	datalogger	254
	SW26	SW26-28-4	51.42024	-106.47181	397662	5697586	datalogger	254
	NW29	NW29-28-4	51.42767	-106.54278	392745	5698514	datalogger	254
	SW30	SW30-28-3	51.41661	-106.41844	401365	5697110	datalogger	283
	SW31	SW31-28-3	51.43702	-106.42579	400898	5699389	datalogger	283
	NE33	NE33-27-4	51.35817	-106.50642	395114	5690733	datalogger	254
	NE36	NE36-28-4	51.44159	-106.42625	400876	5699898	datalogger	254
UofG	3	SE 14-30-02	51.56509	-106.17990	418217	5713327	datalogger	McCraney
	4	SW 25-30-01	51.59142	-106.01464	429712	5716084	datalogger	McCraney
	5	NE 01-29-05	51.45292	-106.56715	391110	5701358	datalogger	Rosedale
	6	SW 09-30-03	51.55342	-106.37762	404491	5712268	datalogger	Rosedale
	7	NW21-29-01	51.50214	-106.09270	424157	5706233	datalogger	McCraney
	8	SE 03-30-29	51.53508	-105.99498	430989	5709799	datalogger	McCraney
	9	SE 29-27-05	51.32998	-106.67242	383484	5687848	datalogger	Loreburn
	11	NW09-28-01	51.38636	-106.09708	423660	5693362	datalogger	McCraney
	12	NW31-27-28	51.35641	-105.93509	434889	5689875	datalogger	Arm River
	13	NW03-27-05	51.26900	-106.65679	384420	5681043	datalogger	Loreburn
	14	SW 36-26-04	51.24677	-106.44599	399076	5678260	datalogger	Loreburn
	15B	NE 36-27-05	51.21272	-106.34972	390730	5690751	datalogger	Loreburn
	16	SE17-28-2	51.40163	-106.23852	413847	5695217	NE	282
	17 temp	SE10-28-5	51.38013	-106.61340	387719	5693333	NE	254
	18 temp	NW20-27-3	51.32917	-106.39096	403091	5687349	NE	253
	19 temp	NW04-31-1	51.62708	-106.09853	423961	5720134	SW	313
MS	MS01	SW16-27-5	51.30003	-106.66001	384274	5684499	SW	254
	MS02	SE05-27-3	51.27090	-106.38592	403320	5680863	SW	253
	MS03	SW18-28-2	51.38740	-106.28523	410571	5693691	SW	282
	MS04	NW21-27-3	51.32918	-106.36419	404956	5687315	NE	253
	MS05	SE12-28-3	51.37286	-106.28552	410522	5692074	SE	283
	MS06	SW19-28-27	51.40776	-105.86117	440104	5695523	NW	281
	MS07	SE17-30-2	51.56211	-106.23884	414127	5713064	SE	282
	MS08	NW06-29-1	51.53650	-106.14689	420456	5710112	NW	282
	MS09	SW02-27-5	51.27892	-106.61330	387479	5682079	NW	254
	MS10	SW15-28-6	51.39463	-106.77727	376355	5695210	NW	284
	MS11&MS12	N05-27-5	51.28524	-106.68370	382585	5682892	NW	254
	MS13	NW28-28-2	51.43066	-106.23792	413944	5698445	NW	282
	MS14	NW35-28-3	51.43691	-106.33208	407411	5699254	SE	283
	MS15	NW21-28-28	51.41630	-105.89742	437594	5696503	NW	282
	MS16	SW30-28-28	51.41656	-105.94365	434380	5696572	SW	282
	MS17	NE24-28-29	51.41656	-105.94365	434380	5696572	NE	282
	MS18	SE 07-28-3	51.37998	-106.41299	401665	5693029	NW	254
	MS19	SE28-28-28	51.42341	-105.87415	439222	5697274	NE	282
	MS20	NW34-28-5	51.35825	-106.62522	386843	5690919	NE	254
	MS01	SW16-27-5	51.30003	-106.66001	384274	5684499	SW	254

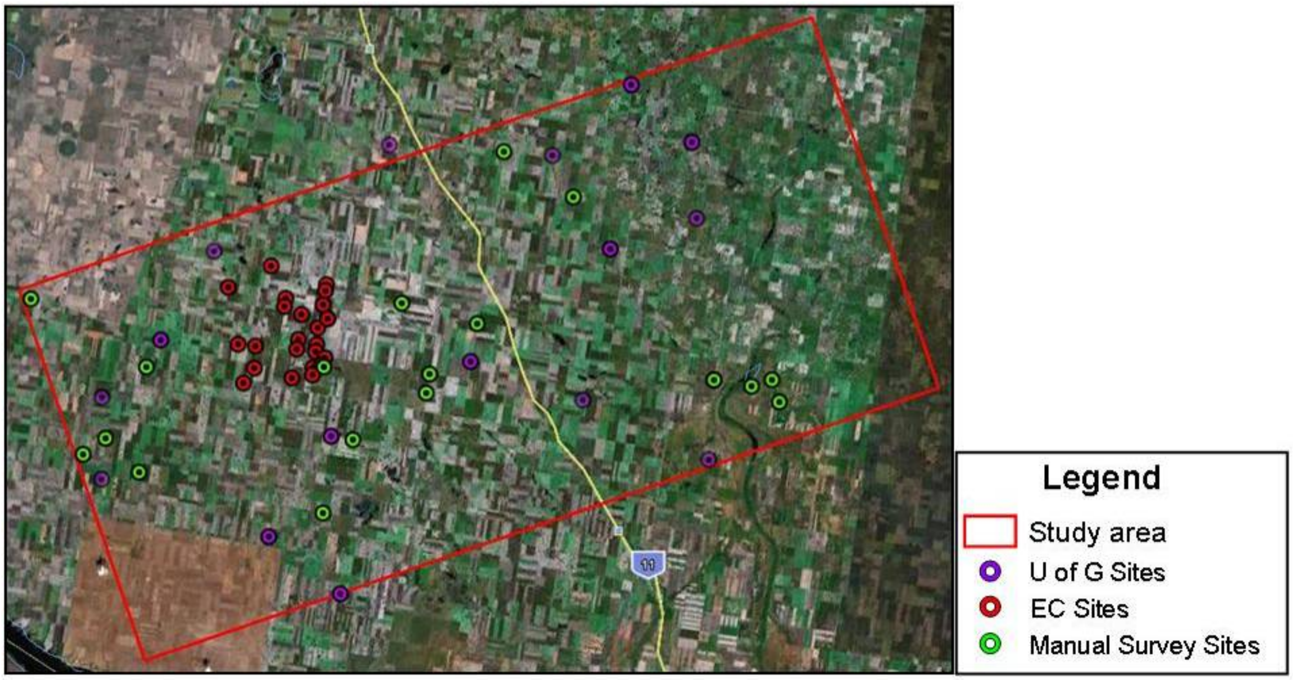


Figure 11. Geographic location of the 60 sampling fields at Kenaston site

2.2. BERMS

2.2.1. General Description

BERMS is located in the southern boreal forest in north central Saskatchewan. The BERMS research effort is a collaborative project with EC and other government agencies and universities (http://berms.ccrp.ec.gc.ca/Overview/e-overview-brochure.htm). The project began in 1996 following the end of the BOReal Ecosystem and Atmosphere Study (BOREAS). While BOREAS was an episodic research project that took place in 1994 and 1996, the BERMS project is continuous.

BERMS Mission Statement

Much of the Canadian landscape is covered with boreal forest and this landscape plays an important role in the global climate, including a significant impact on global carbon and water cycles. However, many of these processes and interactions in the boreal forest are poorly understood, especially with respect to climatic variability and change. BERMS is determining the role of the boreal forest in the global carbon balance, assessing how this role may change under future climate scenarios, and examining how forest management effects carbon sequestration. This is being done by comparing carbon budgets of three adjacent mature boreal forest ecosystems and several disturbed (burned or harvested) ecosystems and characterizing the influence of seasonal and interannual climatic variability on these ecosystems.

BERMS Study Region

The BERMS region is located north of Prince Albert in Saskatchewan near the southern extent of the boreal forest (Figure 12, 13). The topography is generally rolling and the dominant vegetation type depends on soil type, drainage conditions and disturbance. The dominant species in well drained and sandy soils are jack pine with black spruce more prominent in wetter, less well drained areas. Aspen, which is typically a disturbance species, can be found in areas that have been burned or harvested. Other species, such as white spruce, birch, and tamarack can also be found.

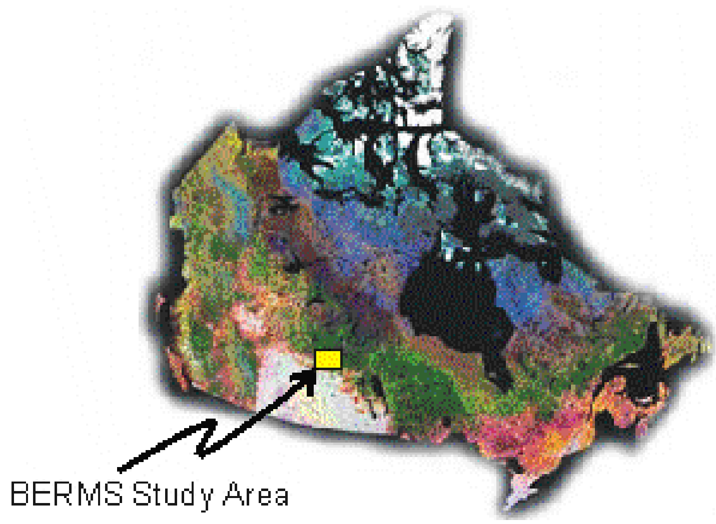
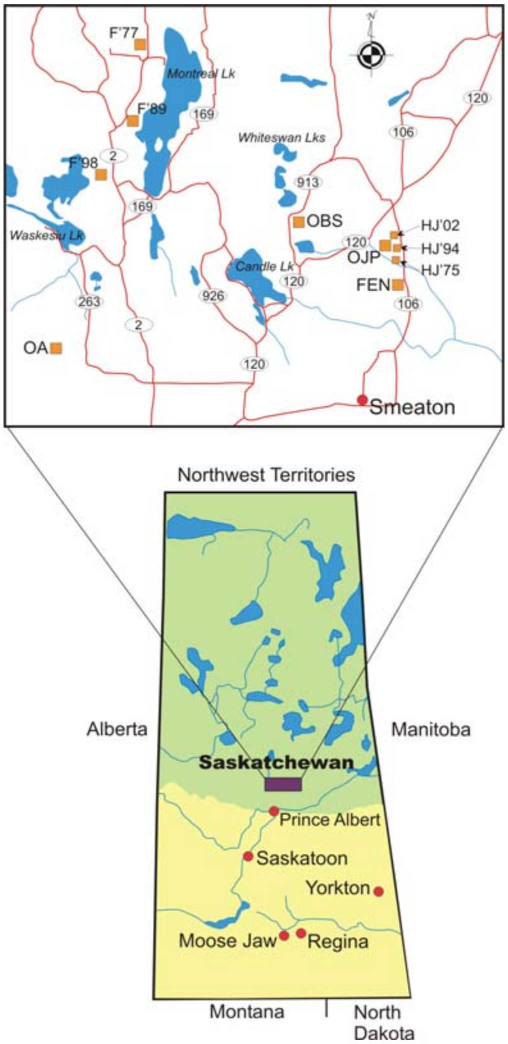


Figure 12. Location of the BERMS study area in the southern Canadian boreal forest.



Research Sites:
OA: Old Aspen
OBS: Old Black Spruce
OJP: Old Jack Pine
HJ'75: Jack Pine harvested in 1975
HJ'94 Jack Pine harvested in 1994
HJ'02: Jack Pine harvested in 2002
FEN: Patterned Fen
F'77: Fire site burned in 1977
F'89 Fire site burned in 1977
F'98 Fire site burned in 1977

Figure 13. Location of the BERMS study sites in central Saskatchewan

The CanEx-SM10 project does not use the entire BERMS study area but rather is confined to a domain in the most eastern portion of the study area. This allows the CanEx-SM10 project to focus on a smaller validation area and reduce the contribution of lakes into the microwave measurements. The study areas, defined by the National Research Council (NRC) Twin Otter radiometer flight box [53.59 N-54.27; 104.32-104.99 W] and the UAVSAR flight box [53.59 N-54.29; 104.32-105.22 W], are presented on Figure 14.

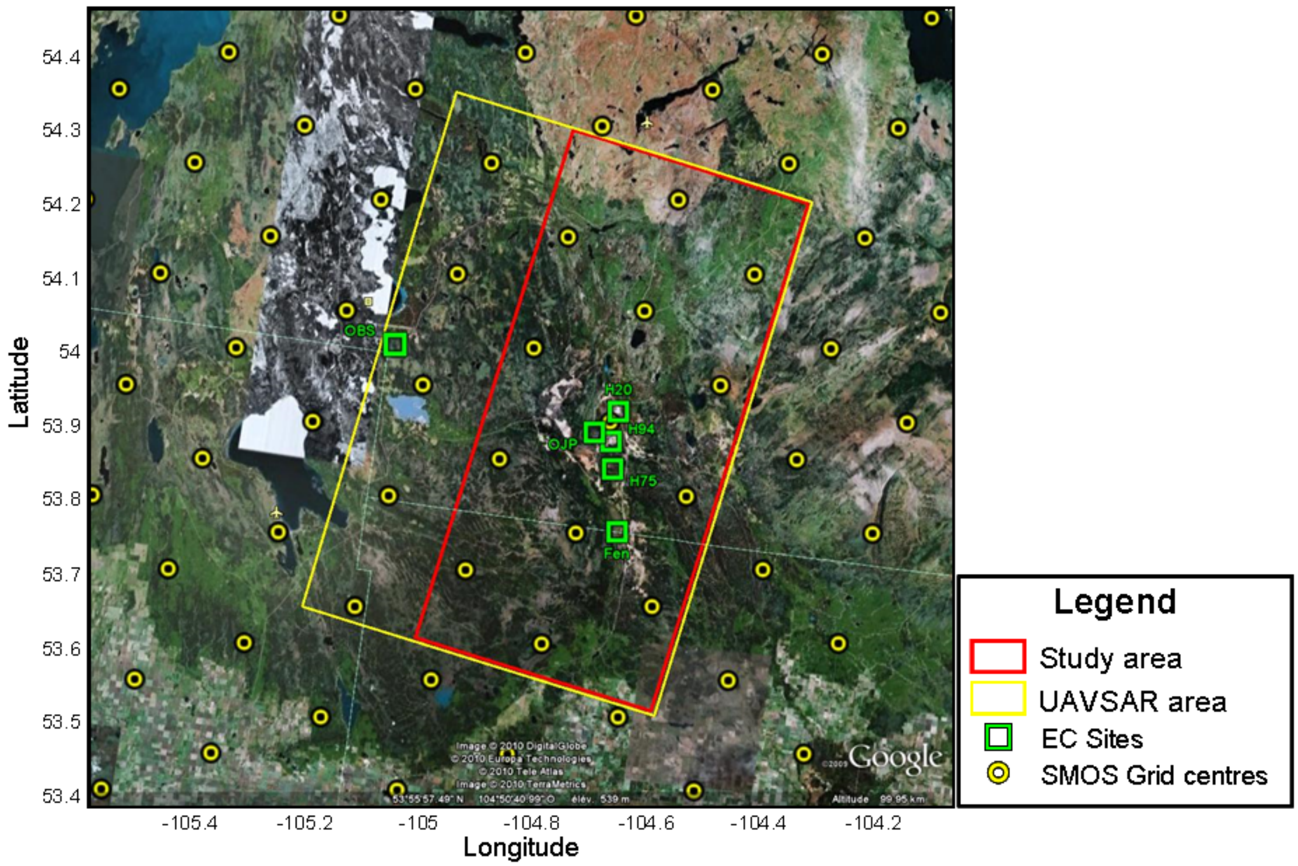
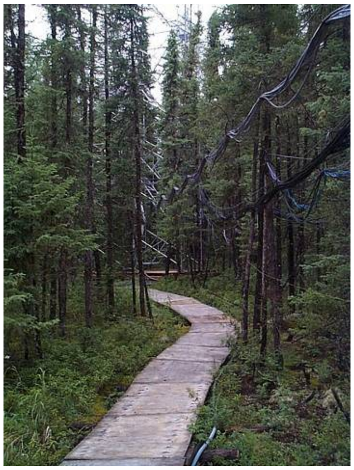


Figure 14. CanEx-SM10 study area over BERMS

BERMS research sites

As shown on Figure 13, BERMS consists of a series of instrumented research sites located in various vegetation types and age structures throughout the region. Within the study domain indicated above are OBS, OJP, FEN, H75, H94 and H02. Figure 15 and Table 3 provide a brief description of each site as well as the measurement program occurring there. More information can be found at http://berms.ccrp.ec.gc.ca/Sites/e-sites.htm


OBS


OJP


FEN


H75


H94


H02

Figure 15. Photos of BERMS research sites

Table 3. BERMS research sites information and measurement programs.

Acronym	Description	Location	Date established
OBS	Old Black Spruce Mature wet coniferous black spruce forest Moss and Labrador tea understory Stand age ~ 114 years Canopy height 11 m	100 km NE of Prince Albert, SK, near White Swan Lake lat: 53.987 deg N long: -105.117 W, elevation: 628.94m	BOREAS: 1994, 1996 BERMS climate program: Dec 1996-present BERMS flux program: Aug 1999-present
OJP	Old jack Pine Mature dry coniferous jack pine forest Lichen understory	100 km NE of Prince Albert, SK, near Narrow Hills Provincial Park lat: 53.916 deg N	BOREAS: 1994, 1996 BERMS climate program: Mar 1997-present BERMS flux program:

	Stand age ~ 94 years Canopy height 14 m	long: -104.69 deg W, elevation: 579.27m	Aug 1999-present
H94	Harvested Jack Pine 1994 Young jack pine stand logged in 1994 Stand age ~ 20 years Canopy height ~ 2-3 m	100 km NE of Prince Albert, SK, near Narrow Hills Provincial Park lat: 53.908 deg N long: -104.656 deg W	BERMS climate program: Mar 2001-present BERMS flux program: Mar 2001-present
H75	Harvested Jack Pine 1975 Young jack pine stand logged in 1975 (originally part of BOREAS experiment) Stand age: ~ 30 years Canopy height ~ 5 m	100 km NE of Prince Albert, SK, near Narrow Hills Provincial Park lat: 53.875 deg N long: -104.65 deg W	BERMS climate program: Oct 2003-present BERMS flux program: May 2004-present
H02	Harvested Jack Pine 2002 Site was logged in 2000 with the surface scarified in 2002 Ground cover consisting of sparse grass, shrubs and immature jack pine seedlings	100 km NE of Prince Albert, SK, near Narrow Hills Provincial Park lat: 53.945 deg N long: -104.649 deg W	BERMS climate program: Mar 2003-present BERMS flux program: Mar 2003-present
Fen	Patterned fen surrounded by black spruce, tamarack and jack pine forest (originally part of BOREAS experiment)	100 km NE of Prince Albert, SK, near Narrow Hills Provincial Park lat: 53.78 deg N long: -104.616 deg W	BOREAS: 1994, 1996 BERMS climate program: Jul 2002-present BERMS flux program: Dec 2002-present

2.2.2. Available long term soil and meteorological data networks

Soil Moisture

Each of the BERMS research stations listed in Table 3 operates at least one soil moisture profile as part of the climate monitoring program. The depth of these observations varies somewhat by site. These are as follows: OBS, 2 profiles at 2.5, 7.5, 22.5, 45, 60-90 and 90-120 cm; Fen, 2 profiles at 0-15 and 15-30 cm; OJP, two profiles at 0-15, 15-30, 30-60, 60-90, and 90-120 cm; HJP94, two profiles same as OJP with two additional measurements at 0-15 cm; HJP75, two profiles same as OJP; HJP02, two profiles same as OJP with two additional measurements at 0-15 cm. At OBS, one profile has the top volumetric water content (VWC) sensor installed horizontally at 2.5 cm below the moss-peat interface at a total depth of 5 cm from the top of the moss layer. The second profile has the top VWC sensor also installed at 2.5 cm below the moss-peat interface but 9 cm below the top of the moss layer. The other depths are referenced to the bottom of the moss. Where the depths are specified as a range, the instrument has either been installed vertically (e.g. 30-60 cm) or at a 45 degree angle (e.g. 15-30 cm) to represent an average value for the depth range. Generally, instruments nearer to the surface are installed at 45 degrees while deeper instruments are installed vertically and referenced to the top of the mineral soil (with the exception of OBS as noted above). All measurements are made at 4 hour intervals with the exception of the Fen which is made every 30-minutes. Data are archived daily by CRD in Saskatoon and time stamped using UTC.

Soil temperature

Each of the BERMS research stations listed in Table 3 operates at least one soil temperature profile as part of the climate monitoring program. These are as follows: OBS: 2 profiles at 2, 5, 10, 20, 50, and 100 cm and moss temperature at 1.5 cm below the moss layer; Fen, OJP, HJP75: 2 profiles at 2, 5, 10, 20, 50 and 100 cm; HJP94: 2 profiles at 2, 5, 10, 20, 50, and 100 cm and 3 profiles at 2, 5, and 10 cm; HJP02: 2 profiles at 2, 5, 10, 20, 50, and 100 cm, 2 profiles at 1, 3, and 5 cm, 3 profiles at 2 and 5 cm. All temperature measurements are made every 30-minutes.

Supporting meteorological data

The BERMS sites listed in Table 3 operate a full suite of meteorological instruments as part of the climate monitoring program. These include precipitation (with only summer precipitation at H75 and H94), temperature and humidity (at several levels through the canopy), radiation (4 way and net), above and below canopy wind speeds and direction, surface pressure, tree bole temperatures (varies by site), and the exchange of carbon, energy, and water between the canopy and the atmosphere via eddy covariance instrumentation.

Supporting ecological data

They are available over each of the BERMS research stations except the Fen. They consist of forest characteristics (type, tree height, age, DBh, density, LAI, biomass, etc.), soil bulk density, and soil chemical properties.

2.2.3. Other supporting data - BERMS Temporary Soil Moisture Network (BTN)

General description

The BTN will consist of up to 20 Stevens Hydra Probes installed at 5 cm (providing a range of 3-7 cm) depth within the focus SMOS pixel located in the centre of the BERMS primary network (Figure 16). The coordinates of the BTN stations are given in Table 4. A BTN station will be co-located at each of the BERMS research sites, including OBS which is outside of the primary study area.

Measurement objectives

The BTN will provide a validation dataset which can verify and extend the long term in situ BERMS soil moisture network to a SMOS/SMAP satellite scale. Using this temporary data record along with some additional gravimetric soil moisture collection for verification, the long term in situ network can be ‘scaled’ to a large scale soil moisture estimate which can be directly compared to satellite estimates. The statistical technique used is a simple temporal stability analysis, developed during previous field experimentation.

Installation and operating period

The BTN will be installed prior to the Kenaston campaign (late May) and operate unsupervised until site removal in August. Note that at least one BTN site (SW corner) is not currently marked on Figure 16 as it has not yet been accessed.

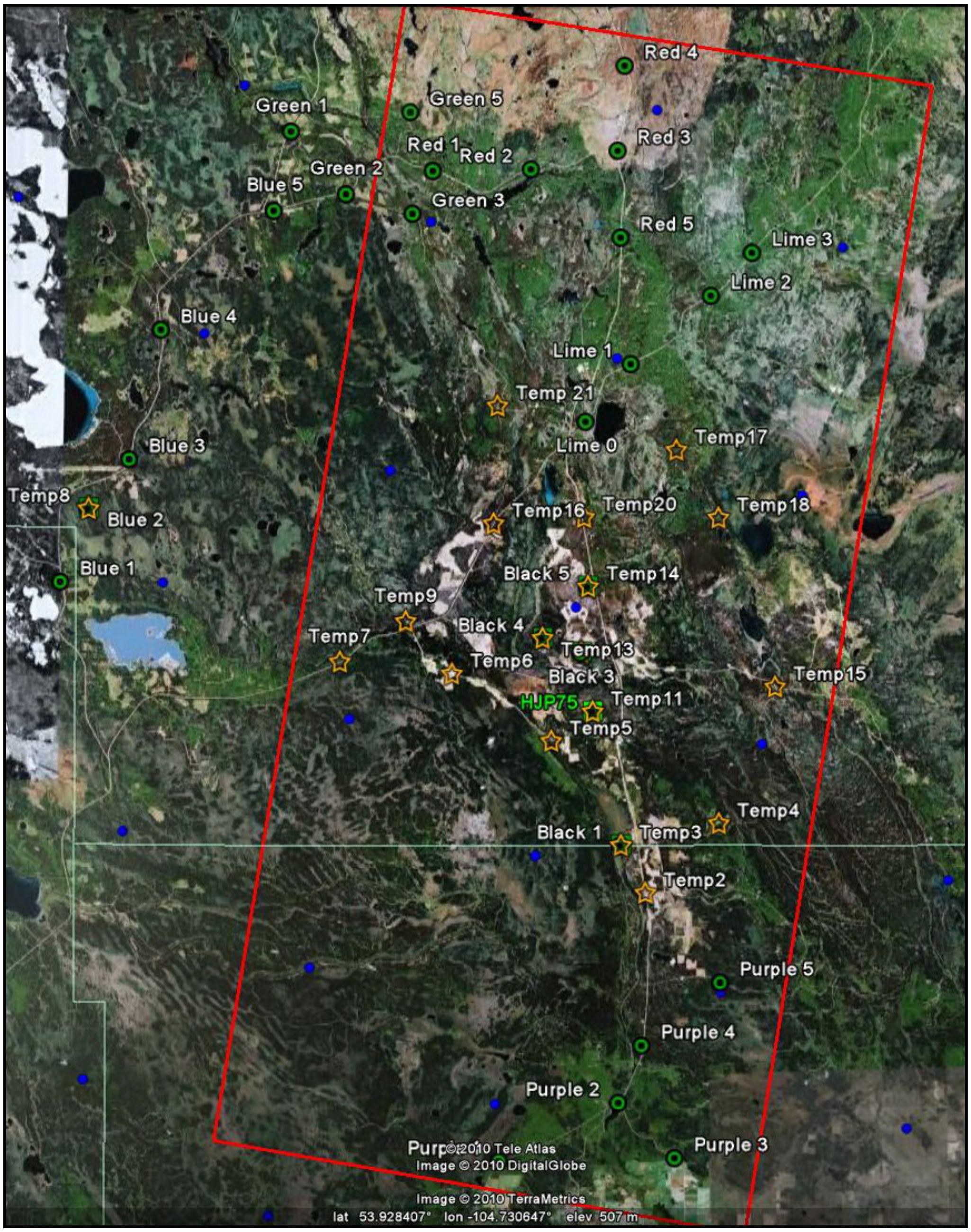


Figure 16. Map of the BERMS Temporary Network (orange stars labelled Temp#) and the Ground Team Sampling locations (green circles labelled Colour#) within the BERMS primary study area (red box). The blue dots are SMOS grid centres.

Table 4. BTN site locations.

Site_ID	Latitude	Longitude	Altitude (m)	Photograph #
Temp 2	3°46'33.50"N	104°35'46.30"W	481	194 - 199
Temp 3	53°48'7.95"N	104°37'8.10"W	488	200 - 203
Temp 4	3°48'50.84"N	104°31'38.15"W	465	204 - 208
Temp 5	3°51'34.88"N	104°41'2.29"W	498	209 - 212
Temp 6	3°53'48.20"N	104°46'36.80"W	526	213 - 220
Temp 7	3°54'11.70"N	104°52'54.58"W	552	230 - 234
Temp 8	3°59'13.81"N	105° 7'4.04"W	588	N/A
Temp 9	3°55'31.99"N	104°49'12.87"W	535	221 - 225
Temp 11	3°52'32.99"N	104°38'42.72"W	497	N/A
Temp 12	3°54'30.27"N	104°39'21.19"W	506	N/A
Temp 13	3°54'58.82"N	104°41'31.31"W	505	322-325
Temp 14	3°56'41.05"N	104°38'57.62"W	517	326-333
Temp 15	3°53'21.53"N	104°28'27.09"W	463	318 - 321
Temp 16	3°58'45.89"N	104°44'16.51"W	533	226 - 229
Temp 17	54° 1'11.35"N	104°33'58.41"W	508	304 - 308
Temp 18	3°58'56.88"N	104°31'36.47"W	500	309 - 313
Temp 20	3°58'58.37"N	104°39'10.76"W	526	334 - 336
Temp 21	54° 2'39.11"N	104°44'3.23"W	551	337 - 339

2.2.4. Sampling fields

Figure 16 shows the locations of the BERMS Ground Team Sampling (BGTS). Each team (names based on colors) will sample up to 5 locations. The locations (Table 5) are all along accessible roads and trails in the study area. BGTS will occur on a single day (anticipated to be June 16, 2010) coordinated with satellite overpasses and aircraft flights.

Measurement objectives

The objective of the GTS is to achieve an adequate geographical distribution of soil moisture samples in the BERMS study area given the constraints of road access and time. While the BTN will be concentrated in the centre of the BERMS area, the GTS teams will be distributed throughout the area. The objective is to provide a 1-day spatially distributed dataset to validate satellite and aircraft retrievals of soil moisture.

Sampling locations

Sampling locations are shown on Figure 16. These locations (Table 5) were identified, located, and documented for future reference but they can be modified on the day of sampling if required by sampling teams. Also, GTS teams may add sites during the campaign if time allows.

Table 5. GTS site names and locations.

Site_ID	Latitude	Longitude	Altitude (m)	Photograph #s
Purple 1	3°37'41.42"N	104°43'56.21"W	479	173 - 176
Purple 2	3°39'37.45"N	104°37'15.76"W	455	177 - 179
Purple 3	3°37'47.38"N	104°34'7.04"W	453	180 - 183
Purple 4	3°41'31.27"N	104°35'57.30"W	467	184 - 188
Purple 5	3°43'35.93"N	104°31'32.50"W	472	189 - 193
Blue 1	3°56'49.12"N	105° 8'35.70"W	599	235 - 238
Blue 2	3°59'13.81"N	105° 7'4.04"W	588	N/A
Blue 3	54° 0'52.50"N	105° 4'44.99"W	595	239 - 240
Blue 4	54° 5'9.28"N	105° 2'59.74"W	610	241 - 244
Blue 5	54° 9'5.58"N	104°56'38.79"W	602	245 - 248
Green 1	4°11'43.23"N	104°55'41.48"W	594	257 - 262
Green 2	54° 9'39.16"N	104°52'34.41"W	582	249 - 252
Green 3	54° 9'0.67"N	104°48'48.59"W	564	253 - 256
Green 5	54°12'21.96"N	104°48'56.33"W	581	101 -263 - 267
Red 1	4°10'25.80"N	104°47'39.85"W	577	268 - 270
Red 2	4°10'28.61"N	104°42'7.03"W	591	271 - 274
Red 3	54°11'5.38"N	104°37'12.67"W	603	275 - 281
Red 4	4°13'53.41"N	104°36'48.59"W	646	282 - 285
Red 5	54° 8'12.91"N	104°37'3.51"W	617	286 - 290
Lime 0	54° 2'8.73"N	104°39'2.75"W	498	N/A
Lime 1	54° 4'2.55"N	104°36'29.88"W	570	291 - 294
Lime 2	54° 6'17.77"N	104°31'57.69"W	554	295 - 297
Lime 3	54° 7'42.72"N	104°29'37.81"W	552	298 - 303
Black 1	53°48'7.95"N	104°37'8.10"W	488	200 - 203
Black 2	3°52'32.99"N	104°38'42.72"W	497	N/A
Black 3	3°54'30.27"N	104°39'21.19"W	506	N/A
Black 4	3°54'58.82"N	104°41'31.31"W	505	322-325
Black 5	3°56'41.05"N	104°38'57.62"W	517	326-333

3. Description of ground-based instrumentation

3. 1. Ground instruments specifications

3. 1. 1. Hydra Probe II, profilometer

Hydraprobe

The Steven's HydraProbe II, analog was used for the CanEx-SM 10 experiment. The output of the Hydra Probe's on-board data conversion program is water fraction by volume (wfv). For example, a water content of 0.20 wfv means that a one liter soil sample contains 200 ml of water. Full saturation (all the soil pore spaces filled with water) occurs typically between 0.3-0.45 wfv and is quite soil-dependent. There are a number of other units used to measure soil moisture. They include % water by weight, % field capacity, % available (to a crop), and tension (or pressure). They are all inter-related in the sense that for a particular soil, knowledge of the soil moisture in any one of these units allows the soil moisture level in any of the other unit systems to be determined. It is important to remember that the conversion between units can be highly soil-dependent. The unit of water fraction by volume (wfv) was chosen for the Hydra Probe for a number of important reasons. First, the physics behind the soil moisture measurement dictates a response that is most closely tied with the wfv content of the soil. Second, without specific knowledge of the soil, one can not convert from wfv to the other unit systems. Third, the unit wfv allows for direct comparison between readings in different soils. A 0.20 wfv clay contains the same amount of water as a 0.20 wfv sand.

While the design of the Hydra Probe and the data reduction algorithms were carefully chosen to minimize the effects of variations in soil type on measurement accuracy, there are some important things to keep in mind. The response of the Hydra probe to soils with identical wfv values will vary slightly from soil to soil. Typically, without any knowledge of the soil type, the accuracy is +/- 0.03 wfv. For example a measured value of 0.20 wfv could correspond to an actual wfv of 0.17 to 0.23 depending on soil type. With a crude knowledge of soil type (sand, silt, clay classification), the uncertainty drops to typically +/- 0.015-0.020 wfv to give a range of soil moisture for our example of 0.18-0.22 wfv. If a soil-specific calibration for the particular soil is performed, the uncertainty drops to less than +/- 0.005 wfv, and for our example, the range is down to 0.195-0.205 wfv. The remaining uncertainty is predominantly due to inaccuracies in the calibration process and the basic soil electrical properties measurement. It is important to note that because the reproducibility of the Hydra probe is typically +/- 0.003 wfv, or better, the ability to measures changes and characterize a particular soil is very good. For example, if we have no knowledge of soil type and we have a soil moisture reading of 0.20 wfv, then we have a range of actual soil moisture values that this reading may reflect as discussed in the previous example. However, suppose that after a one month period accompanied by periods of rainfall and drying we again have a Hydra Probe reading of 0.20 wfv. We can be assured that the soil moisture content of the soil is identical to that obtained one month prior to within the reproducibility of the measurement, i.e. 0.003 wfv. Simply stated, the relative accuracy is higher (by about an order of magnitude) than the absolute accuracy.

Soil Temperature

Taylor® Switchable Digital Pocket Thermometer

Featuring a switchable display, this economical digital thermometer provides a fast response and easy, accurate readings in either Fahrenheit or Celsius.

- Display reads to 0.1°F/°C and updates every one second.
- 4.75″(12 cm) stainless steel stem and flattened profile to prevent rolling
- Power: one 1.5V watch battery (two included)
- Temperature range: -58°F to +500°F/-50°C to +260°C

Figure 17. Taylor® Switchable Digital Pocket Thermometer

TIR
Metris TN400L Professional Grade Infrared Thermometer

- NSF approved
- Infrared Temperature Range -76 to 932F (-60 to 500C)
- Infrared Accuracy ±2% of reading or ±2°C
- 0.1° resolution for accurate readings
- Selectable temperature units F/C
- 12:1 Distance to spot size ratio
- Emissivity preset to 0.95
- Bright large amber back-lit LCD display
- 2 AAA batteries (included) provide nominal 180 hours continuous operation

Figure 18. Metris TN400L Professional Grade Infrared Thermometer

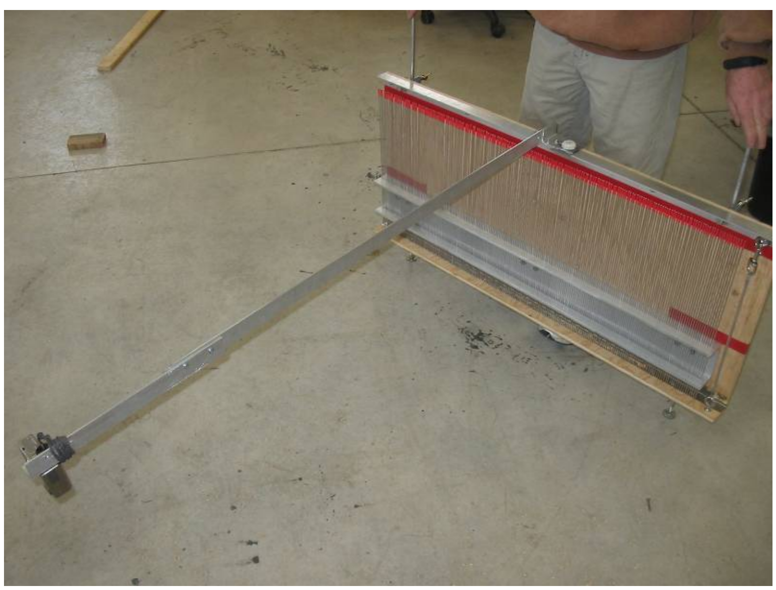
Pin Profiler

The profilometer used during CanEx_SM10 consists of:

- 1-m long profiler which supports 200 pins spaced by .5 cm. The top of pins are colored in red to match technical requirements (linked to the software that will be subsequently used for the retrieval of roughness parameters).
- A digital camera to take the photographs of the variation of surface height resulting from the displacement of the tops red pins,
- A metallic bar of 127-cm long to fix the camera at the top of the profiler and perpendicularly to it,
- Bubble level installed at the top of the profiler to get the profiler as level as possible,
- Two metallic bars of 61-cm long to identify the position of the profiler on the soil surface during the measurements. These bars will allow to mark each side of the profiler on the soil surface,
- A wire having a hook installed on the right side of the profiler to maintain the pins immobile against the profiler,
- Two legs on the back of the profiler to level the profiler.

In addition:

- A compass is necessary to install the profiler in the look direction of the sensor,
- A software to compute the roughness parameters s and l, corresponding to the standard height and the correlation length of the surface, respectively,
- Two people are required to handle the profilometer during the measurements.



a) Front of the profiler used during CanEX_SM10

b) Back of the profiler used during CanEX_SM10
Figure 19. Profilometer used during CanEx_SM10

Bulk Density

Bulk density (p_b) is the ratio of the dry weight of the soil particles (*M*) to the bulk volume (L^3) of the soil calculated as $p_b = M / L^3$. Field measurement is conducted by removing a known volume of soil and obtaining the wet and dry mass of the soil sample. Necessary equipment includes (figure 20)
1) Sampling container or core
2) Hand shovel
3) Putty knife or scraper
4) Hammer
5) Zip Lock bag

Figure 20. Bulk Density Sampling Equipment

3.1.2. Inventory of ground instruments

Table 6. Equipment needs according to teams

Soil Moisture teams (12)	**need**	**have**
Hydroprobes (anticipated 25% breakage)	12 units + 3 units	10 with reader (EC) 4 with PDA (Guelph) 1 with PDA (Sherbrooke)
Long field probe holders	12	3 (EC) 9 ordered
Soil Thermometers (anticipated 50% breakage)	12 +6	**18 ordered**
Thermal Infrared , TIR (anticipated 25% breakage)	12 +3	**15 ordered**
GPS	12	12 (AAFC)
Cameras	12	2 – 12.1 megapixel (EC – Saskatoon) 1 – 4 megapixel (EC – Saskatoon) 1 – 1.2 megapixel (EC – Saskatoon) 3 – 4 megapixel (EC – Edmonton) 1 – 8 megapixel (EC – Anne Walker) 1 – 12 megapixel (EC – Anne Walker) 1 – unknown resolution (U of Sherbrooke) **2 to be purchased**
Compass	12	**12 to be purchased**
Trucks	12	3 EC Saskatoon 3 U of Sherbrooke 3 EC Anne Walker **3 to be rented**
Bulk density samplers	70	**70 to be made**
Ziploc bags and plastic wrap	360 + 360 ft	**To be purchased**
Soil roughnes/veg Teams (2)		
Pin profiler with camera mount	2	2 – U of Sherbrooke
GPS	4 (each team member needs)	3 – EC, Anne Walker (2 Garmin 60Csx, 1 Garmin V) 1 – EC Saskatoon (Garmin 5)
Compass	2	**2 to be purchased**
Gridded white board	2	**2 to be purchased**
Trucks	2	**2 to be rented**
Multispectral and LAI team (1)		
Truck	1	**1 to be rented**
GPS	1	1 – EC Saskatoon (Garmin IV)

- Assorted other supplies, spray paint
- OSH support – 15 cell phones (KEN) 8 sat phones (BERMS), weather radios (have 5), lightning detectors (1), first aid kits (have 15), bug spray, sunscreen, flats of water

3.1.3. Time series data support

EC network (24 sites)

- **Location of permanent sites (EC)**

Table 7. Location of permanent sites (EC)

EC 24 permanent sites				
Site	**Latitude**	**Longitude**	**Easting**	**Northing**
Flux_NW07	51.38166	-106.41595	401463	5693220
NE07	51.38686	-106.41382	401622	5693795
NW01	51.36794	-106.44924	399116	5691739
NW03	51.37055	-106.49602	395866	5692095
SW03	51.44878	-106.49597	396047	5700794
NW06	51.37273	-106.42528	400794	5692239
SW07	51.37805	-106.42558	400785	5692831
NE09	51.38724	-106.49938	395670	5693956
NW09	51.38647	-106.51955	394265	5693899
NE13	51.39579	-106.42625	400777	5694805
NW13	51.39739	-106.44930	399177	5695014
SE13	51.39036	-106.42624	400766	5694201
SW13	51.39003	-106.44916	399170	5694196
NW19	51.41635	-106.41844	401364	5697081
NE23	51.41640	-106.45007	399165	5697129
SE24	51.40838	-106.42772	400702	5696207
NE25	51.42619	-106.42624	400843	5698186
NW26	51.42649	-106.47176	397679	5698282
SW26	51.42024	-106.47181	397662	5697586
NW29	51.42767	-106.54278	392745	5698514
SW30	51.41661	-106.41844	401365	5697110
SW31	51.43702	-106.42579	400898	5699389
NE33	51.35817	-106.50642	395114	5690733
NE36	51.44159	-106.42625	400876	5699898

- **Calibration of sensors**

Environment Canada undertook a calibration procedure to calibrate the HydraProbe sensors for their respective in-situ applications. There were 24 sites, 3 depths each (with some exceptions) that need calibration. The general procedure was to take a 72 hr oven dried (60ºC) soil core, measure the increase in weight as we drip water on a constant rate while simultaneously monitoring the parameters measured by the sensor. The wet-up procedure took about 5 hours. A scale was interfaced with a computer that generated a weights file (weights.txt). At the same time the sensor was hooked up to a datalogger that, once downloaded, will give us a *.dat file.

The incremental increase in weight gives us the incremental increase in mass (or volume) of water, from which we calculate the range of soil moistures. At the end of the experiment we removed the sensor, dried the soil core for 72 hours in the oven and reweigh to get the dry mass and bulk density of the cores.

- **Calibration equations**

The above process generated 72 distinct calibration equations for each of the 3 soil depths at each of the 24 sites. The form of the equation is a 3rd order polynomial with soil moisture dependant on the temperature corrected real dielectric constant. A technical note or paper is in progress.

- **Data website**

Environment Canada maintains a website and 2007-2009 data for each of the active sites (not all 24 sites were active every year) is posted and available for download with permission.

U of G network (16 sites)

- **Location of permanent sites (to be inserted)**

Table 8. Location of permanent sites (U of G)

U of G 16 permanent sites				
Site	**Latitude**	**Longitude**	**Easting**	**Northing**
3	51.56509	-106.17990	418217	5713327
4	51.59142	-106.01464	429712	5716084
5	51.45292	-106.56715	391110	5701358
6	51.55342	-106.37762	404491	5712268
7	51.50214	-106.09270	424157	5706233
8	51.53508	-105.99498	430989	5709799
9	51.32998	-106.67242	383484	5687848
11	51.38636	-106.09708	423660	5693362
12	51.35641	-105.93509	434889	5689875
13	51.26900	-106.65679	384420	5681043
14	51.24677	-106.44599	399076	5678260
15B	51.21272	-106.34972	390730	5690751
16	51.40163	-106.23852	413847	5695217
17 temp	51.38013	-106.61340	387719	5693333
18 temp	51.32917	-106.39096	403091	5687349
19 temp	51.62708	-106.09853	423961	5720134

- **Calibration of sensors**

A network of *in-situ* sensors was established over a 60 by 60 km area in Central Saskatchewan to capture the expected variability of soil moisture profiles in the regions of study, at the scale of passive microwave derived soil moisture data sets. The network consists of 16 sites with soil moisture monitoring probes installed horizontally at depths of 5, 20 and 50 cm. The probes are centred on the measurement depth, therefore a probe centred at 5 cm provides an integrated measurement of soil moisture from 3.5-6.5 cm. A geographic information system-based model was implemented to determine optimal location of the 16 sites on the basis of representatively capturing the variability in soil type and topography. Crop type was not considered in the model, as it varies from year to year. Final site selection was limited to those areas where land access was granted by landowners.

Stevens Vitel Hydra Probe II soil water monitoring sensors are installed at each location. Each sensor has a manufacturer's reported accuracy of +/- 3% soil moisture prior to soil-specific calibration. Voltages from the sensors were converted to soil moisture values based on generic sand, silt or clay algorithms provided by the manufacturer. In order to refine these estimates, a soil-specific calibration technique based on soil type was employed. A known volume of soil was extracted adjacent to each probe, oven dried at 85ºC for 48 hours, and gradually wetted to saturation over a period of 6 hours. During the wetting period, a sensor recorded soil water content and real and imaginary dielectric constants, while a digital scale recorded the change in mass. A third order polynomial was used to relate observed and probe soil water content with the real dielectric constant to calibrate probe estimates. A unique calibration curve was established for each sensor and the original soil moisture values were input into the equation to obtain soil moisture measurements to within an accuracy of +/- 1.5 to 2 %.

- **Calibration equations**

The above process generated 72 distinct calibration equations for each of the 3 soil depths at each of the 24 sites. The form of the equation is a 3^{rd} order polynomial with soil moisture dependant on the temperature corrected real dielectric constant. A technical note or paper is in progress.

3.2. Aircraft instruments

During CanEx-SM10, L-band passive and active airborne measurements will be collected. Environment Canada's radiometers operating at 1.4, 6.9, and 19-37-89 GHz will be onboard NRC's Twin Otter aircraft, whereas NASA's UAVSAR will be flown in a Gulfstream III piloted aircraft. UAVSAR is a 1.2575 GHz polarimetric synthetic aperture radar designed by the Jet Propulsion Laboratory (JPL), one of NASA's centers.

3. 2.1. Twin Otter and EC Radiometers

EC's passive microwave radiometers will be mounted port-side of the Twin Otter aircraft (Figure 21), which will be flying at an altitude of 2341 m (7680 ft) at 110 NM/h (i.e., 203.7 km/h or 56.6 m/s). Details on these radiometers are listed in Table 9. Table 10 and Figure 22 present the change in the dimensions of the microwave radiometers' instantaneous field of view (IFOV) as a function of frequency and flight characteristics. The spatial resolution is about 2.25 km for the L-band radiometer flying at 2341 m altitude.

In addition to the passive microwave radiometers, the Twin Otter will carry visible and infra red radiometers (Table 9). They will provide useful data to enhance the analysis of the satellites and airborne microwave data sets. The visible data will provide information for land cover and vegetation. The TIR data will be used for the modeling of microwave data.

Table 9. Technical characteristics of Twin Otter radiometers in CanEX-SM10. The flying altitude is 2.34 km

Radiometer	Frequency/Wavelength	Field of view (degrees)	Comments
Radiometrics AC1900	19.0 (18.5-19.5) GHz	6°	Linear dual polarization, 53° incidence angle
Radiometrics AC3700	37.0 (36-38) GHz	6°	Linear dual polarization, 53° incidence angle
Radiometrics AC8900	89.0 (87-91) GHz	6°	Linear dual polarization, 53° incidence angle
Attex 6.9	6.9 (6.4-7.4) GHz	9°	Linear dual polarization, 53° incidence angle
Radiometrics AC1400	1.413-1.510 GHz central selectable, 25 KHz bandwidth	30°	Linear dual polarization, 40° incidence angle
	or 1.475 (1.425-1.550) GHz	30°	Linear dual polarization, 40° incidence angle
Kipp and Zonen pyranometers	302-2800 nm	Hemispherical	Separate nadir and zenith
Kipp and Zonen CNR1 net radiometer	Pyronometer: 305-2800 nm Pyrgeometer: 5000-50000 nm	Hemispherical	4 radiometers, nadir and zenith, harware-subtracted to directly provide net radiation
Exotech Model 100BX radiometer: (0.5-0.6, 0.6-0.7, 0.7-0.8, 0.8-1.1 um)	chA: 456-522 nm chB: 524-595 nm chC: 629-687 nm chD: 762-898 nm	15°	nadir, operated in 'TM' mode
Heitronics KT-19 IR thermometer (2)	9.6-11.5 um	2.5°	nadir and 53° incidence angle

Table 10. IFOV of the EC's microwave radiometer.

Nautical Mile Offset: Flight Path from Swath Centreline	NRC Aircraft Flying Heights (ft):	NRC Aircraft Flying Heights (m):	1.4GHz			6.9GHz			19-37-89GHz		
			Approx. IFOV: (m) width x length	Distance (m): Flight Path to Footprint Edge	Distance (m): Flight Path to Footprint Centre	Approx. IFOV: (m) width x length	Distance (m): Flight Path to Footprint Edge	Distance (m): Flight Path to Footprint Centre	Approx. IFOV: (m) width x length	Distance (m): Flight Path to Footprint Edge	Distance (m): Flight Path to Footprint Centre
0.1	640	195	115-182 x 188	91	185	46-57 x 86	221	264	32-37 x 57	233	262
0.2	1280	390	231-365 x 375	182	370	93-114 x 171	441	527	64-73 x 113	465	522
0.3	1920	585	346-547 x 563	273	555	139-171 x 257	662	791	95-110 x 170	698	783
0.4	2560	780	461-729 x 751	364	740	185-229 x 343	882	1054	127-146 x 227	930	1044
0.5	3200	976	577-911 x 938	455	924	232-286 x 429	1103	1318	159-183 x 284	1163	1305
0.6	3840	1171	692-1094 x 1126	546	1109	278-343 x 514	1323	1580	191-219 x 340	1395	1565
0.7	4480	1366	808-1276 x 1314	637	1294	324-400 x 600	1544	1844	223-256 x 397	1628	1827
0.8	5120	1561	923-1458 x 1501	728	1479	371-457 x 686	1764	2107	255-293 x 454	1860	2087
0.9	5760	1756	1038-1641 x 1689	819	1664	417-514 x 772	1985	2371	286-329 x 511	2093	2349
1	6400	1951	1154-1823 x 1877	910	1849	463-572 x 857	2205	2634	318-366 x 567	2325	2609
1.1	7040	2146	1269-2005 x 2064	1001	2033	510-629 x 943	2426	2898	350-402 x 624	2558	2870
1.2	**7680**	**2341**	**1384-2187 x 2252**	**1092**	**2218**	**556-686 x 1029**	**2646**	**3161**	**382-439 x 681**	**2790**	**3131**
1.3	8320	2536	1500-2370 x 2440	1183	2403	602-743 x 1114	2867	3424	414-475 x 738	3023	3392
1.4	8960	2731	1615-2552 x 2627	1274	2588	649-800 x 1200	3087	3687	445-512 x 794	3255	3652
1.5	9600	2927	1730-2734 x 2815	1365	2773	695-857 x 1286	3308	3951	477-549 x 851	3488	3914
1.6	10240	3122	1846-2917 x 3002	1456	2957	742-914 x 1372	3528	4214	509-585 x 908	3720	4174
1.7	10880	3317	1961-3099 x 3190	1547	3142	788-972 x 1457	3749	4478	541-622 x 965	3953	4436
1.8	11520	3512	2077-3281 x 3378	1638	3327	834-1029 x 1543	3969	4741	573-658 x 1021	4185	4696
1.9	12160	3707	2192-3463 x 3565	1729	3512	881-1086 x 1629	4190	5005	604-695 x 1078	4418	4957
2	12800	3902	2307-3646 x 3753	1820	3697	927-1143 x 1714	4410	5267	636-731 x 1135	4650	5218
2.1	13440	4097	2423-3828 x 3941	1911	3882	973-1200 x 1800	4631	5531	668-768 x 1191	4883	5479

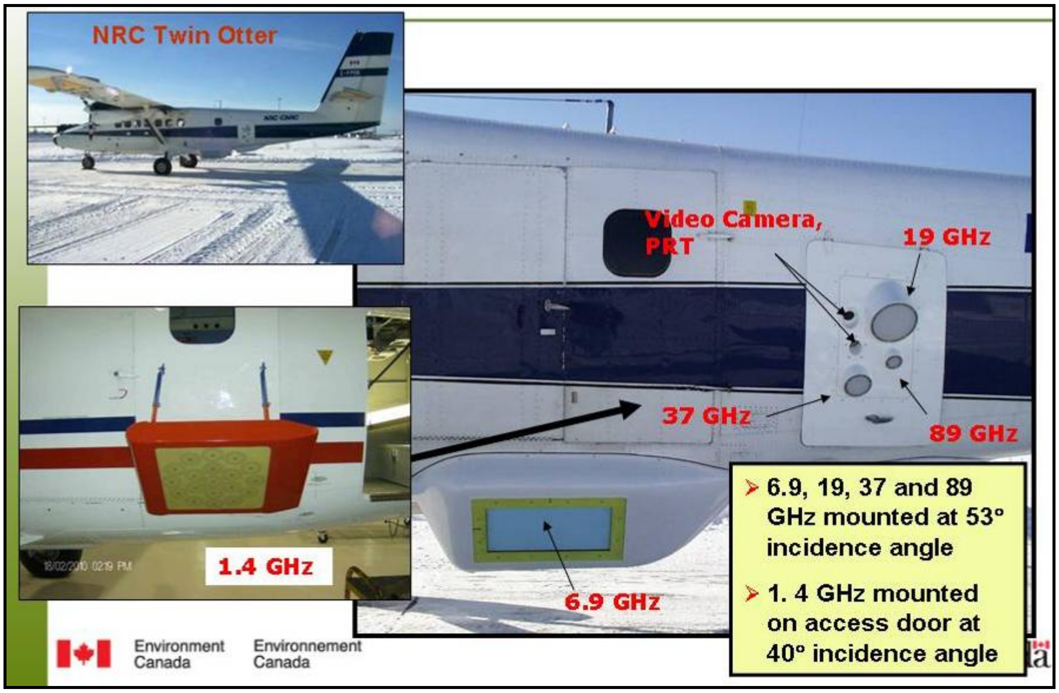


Figure 21. Installation of EC's microwave radiometers on the NRC Twin Otter

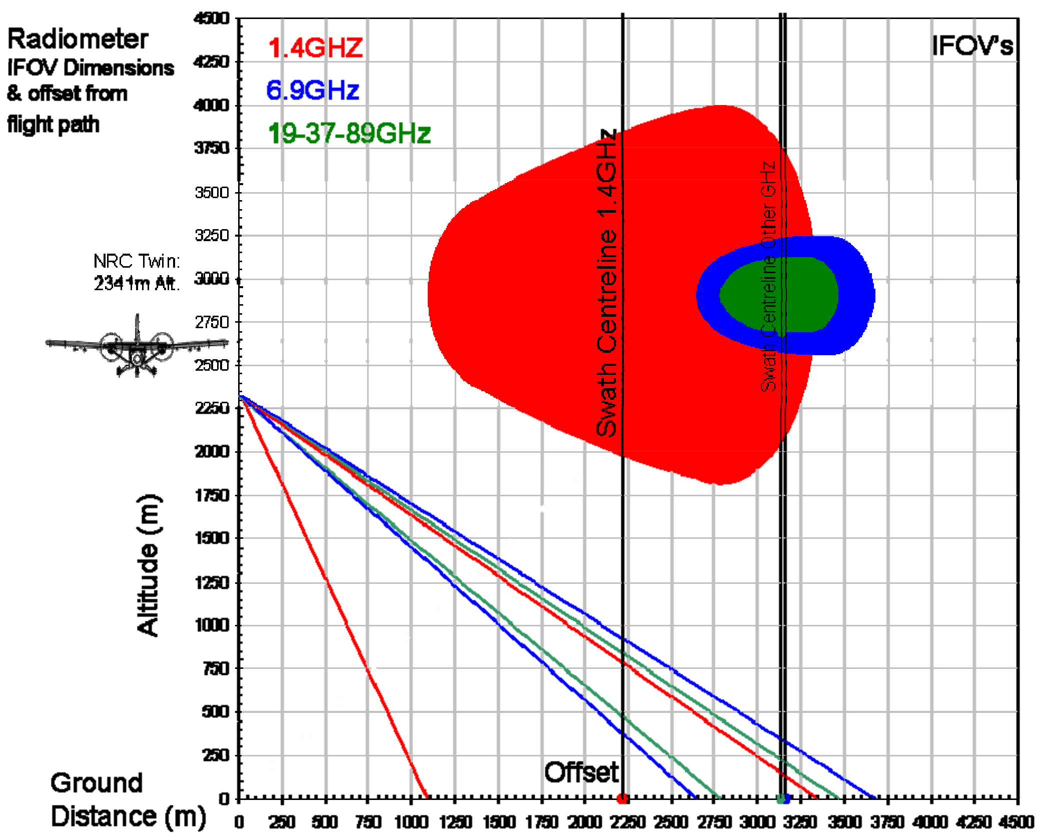


Figure 22. EC's microwave radiometers IFOV dimensions

3.2.2. NASA G-II and UAVSAR

The Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) is an aircraft based fully polarimetric L-band radar that is also capable of interferometry. It is currently implemented on a NASA Gulfstream-III aircraft (http://uavsar.jpl.nasa.gov/). Details on the UAVSAR are listed in Table 11.

Table 11. UAVSAR description

Instrument	Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)
Owner	NASA/JPL/Dryden (USA)
Platform	Gulfstream III; operating altitude up to 13 km
Frequencies	L-band (1.26 GHz)
Polarizations	HH, HV, VH, VV
Spatial Resolution	80 MHz Bandwidth, 1.66 m range x .8 m azimuth SLC 3 m multi-looked (6 looks)
Scan Type	SAR with Electronically scanned active array, range swath ~20 km looking left of track between 25 and 65 degrees.
Antenna Type	Phased Array

For CanEx, the nominal flight altitude is 13 km and the aircraft speed is 220 m/s. UAVSAR looks to the left of flight direction and collects data over a swath between 25 and 65 degrees, which is a nominal swath of 21 km. The most relevant portion of the data swath for SMAP, which has an incidence angle of 40 degrees, will be data collected between ~35 and 45 degrees, which is a narrower swath of ~3.8 km.

3.3. Satellite instruments

The technical characteristics of satellite instruments used during CanEx-SM10 are summarised in Table 12 For detailed descriptions, the reader is referred to SMOS, AMSR-E, RADARSAT-2, and ALOS-PALSAR web sites.

Table 12. Technical characteristics of satellite instruments

System	Satellites	Frequency (GHZ)	Polarization	Incidence angle (°)	Resolution
Passive	SMOS	1.4	Single: H or V Pol: H and V	0 -55	30-50 km
	AMSR-E	6.9, 10.7, 18.7, 23.8, 36.5, and 89	H and V	55	25 km

Active	RADARSAT-2	5.4	Single: HH Dual: HH, HV Quad Pol: HH, HV, VH, HV	20-49	3-100 m
	ASAR-Envisat		Single: HH Dual: HH, HV Wide: HH or VV	15-45	30-150 m
	ALOS-PALSAR	1.4	Single: HH Fine Dual: HH, HV Quad Pol: HH, HV, VH, HV ScanSAR: HH	34.3 34.4 21.5;23.1 20.1-36..5	10-100 m
Multi-spectral	SPOT-4		-		20 m
	LANDSAT				30 m
	AWiFS				56 m (at nadir)

4. Data acquisition over Kenaston

4. 1. Experiments

4.1.1. Calendar of data acquisition

The data acquisition matches the calendar of SMOS overpasses over the Kenaston site from June 1-15, 2010 (Table 13). For the dates corresponding to SMOS overpasses, satellite microwave measurements (AMSR-E, RADARSAT-2, ASAR-Envisat and ALOS-PALSAR) will be collected quasi simultaneously to SMOS and to the airborne passive and active microwave acquisitions. The latter include measurements from EC's L-band radiometer NASA's UAVSAR. It is important to note that these dates are all nominal pending weather and aircraft related issues.

On June 2, 3, 5, 8, 10, and 13, field measurements of soil moisture, surface temperature, and surface characteristics (roughness, vegetation, LAI, bulk density, etc.) at a time close to satellite and airborne acquisitions will be collected, over well distributed fields, for the validation and the pre-launch validation of SMOS and SMAP data, respectively.

Intensive soil moisture measurements will be conducted on June 7 and on June 11 to provide a sampling regime that would enable to relate the time series (networks) measurements to field averages. They will be also used to develop scaling method that would allow radar soil moisture retrievals to be related to SMOS data.

Table 13. Calendar of data acquisition over the Kenaston site

Date	Ground	Aircraft	Satellites	Local time	Flight direction	Beam mode	Resolution	Incidence angle (°)	Polarization
June 1st			RADARSAT2	7:34 AM	D	Quad-pol	6 m×9 m	20-21.8	HH, VV, HV, VH
			AMSR-E	3:47 AM	D	Pol	48 km	55	H and V
			RADARSAT2	6:58 PM	A	Quad-pol	6 m×9 m	40.2-41.6	HH, VV, HV, VH
			SMOS	7:21 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:21 PM	A	Pol	48 km	55	H and V
June 2nd	Soil moisture Soil roughness Soil density Vegetation	EC NASA	SMOS	6:40 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	2:52 AM	D	Pol	48 km	55	H and V
			RADARSAT2	7:05 AM	D	Standard	25 m	44.4-49.3	HH+HV
			AMSR-E	2:03 PM	A	Pol	48 km	55	H and V
June 3rd	Soil moisture Soil roughness Soil density Vegetation	EC NASA	SMOS	6:21 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	3:35 AM	D	Pol	48 km	55	H and V
			SMOS	7:43 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:30 PM	A	Pol	48 km	55	H and V
June 4th			AMSR-E	1:51 PM	A	Pol	48 km	55	H and V
June 5th		EC	SMOS	6:23 AM	A	Pol	30-50 km	0-55	H and V

	Soil moisture Soil roughness Soil density Vegetation	NASA	AMSR-E	3:23 AM	D	Pol	48 km	55	H and V
			RADARSAT2	7:17 AM	D	Standard	25 m	33.5-39.7	HH, HV
			RADARSAT2	6:41 PM	A	Standard	25 m	20-27.2	HH, HV
			SMOS	8:04 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	2:34 PM	A	Pol	48 km	55	H and V
June 6th			AMSR-E	4:05 AM	D	Pol	48 km	55	H and V
			SMOS	7:26 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:39 PM	A	Pol	48 km	55	H and V
June 7th	Intensive soil moisture		SMOS	6:45 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	3:11 AM	D	Pol	48 km	55	H and V
			ASAR	11:13 AM	D	AP (I6)	30 m	39.1-42.8	HH, HV
			AMSR-E	2:22 PM	A	Pol	48 km	55	H and V
			ALOS	11:43 PM	A	Fine Dual	20 m	34.4	HH, HV
June 8th	Soil moisture Soil roughness Soil density Vegetation	EC NASA	SMOS	6:06 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	3:53 AM	D	Pol	48 km	55	H and V
			RADARSAT2	7:30 AM	D	Quad-pol	6 m×9 m	24.6-26.4	HH, VV, HV, VH
			RADARSAT2	6:53 PM	A	Quad-pol	6 m×9 m	36.4-38	HH, VV, HV, VH
			SMOS	7:48 PM	D	Pol	30-50 km	0-55	H and V

			AMSR-E	*1:27 PM*	*A*	*Pol*	*48 km*	*55*	*H and V*
June 9th			AMSR-E	2:58 AM	D	Pol	48 km	55	H and V
			ALOS-W	12:16 PM	D	Wide	100 m	27.1	HH
			AMSR-E	2:09 PM	A	Pol	48 km	55	H and V
June 10th	Soil moisture Soil roughness Soil density Vegetation	EC NASA	SMOS	6:28 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	3:41 AM	D	Pol	48 km	55	H and V
			ASAR	11:18 AM	D	Wide	150 m	16-44	HH or VV
			LANDSAT	11:06 AM	-				
			SMOS	8:10 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	*1:30 PM*	*A*	*Pol*	*48 km*	*55*	*H and V*
			ASAR	10:41 PM	A	Wide	150 m	16-44	HH or VV
June 11th	Intensive soil moisture		*AMSR-E*	*2:46 AM*	*D*	*Pol*	*48 km*	*55*	*H and V*
			RADARSAT2	7:06 PM	A	Standard	30 m	44.4-49.3	HH, HV
			SMOS	7:31 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:57 PM	A	Pol	48 km	55	H and V
June 12th			*SMOS*	*6:50 AM*	*A*	*Pol*	*30-50 km*	*0-55*	*H and V*
			AMSR-E	3:29 AM	D	Pol	48 km	55	H and V
			RADARSAT2	7:13 AM	D	Wide	25 m	38.7-45.3	HH, HV

			AMSR-E	*2:40 PM*	*A*	*Pol*	*48 km*	*55*	*H and V*
June 13th	Soil moisture Soil roughness Soil density Vegetation	EC NASA	SMOS	6:12 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	*1:30 AM*	*D*	*Pol*	*48 km*	*55*	*H and V*
			ASAR	11:24 AM	D	AP (I3)	30 m	16-44	HH, HV
			SMOS	7:53 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:45 PM	A	Pol	48 km	55	H and V
			ASAR	10:47 PM	A	Wide	150 m	16-44	HH or VV
June 14th			AMSR-E	3:17 AM	D	Pol	48 km	55	H and V
			ALOS-W	12:23 PM	D	Wide	100 m	27.1	HH
			AMSR-E	2:28 PM	A	Pol	48 km	55	H and V

In addition to LANDSAT acquisition on June 10th, other auxiliary data will be acquired over the Kenaston site. The SPOT-4 (20 m) satellite has been programmed for the Kenaston site, through the SPOT Canadian distributor Iunctus. All cloud-free (< 20% cloud cover) SPOT images will be procured. In addition, AAFC has requested that EOTech, the North American distributor for ResourceSAT-1's AWiFS satellite, acquire all AWiFS data over Canada's Prairie agricultural extent, beginning April 15th, 2010. This will include the Kenaston site which falls within the Canadian agricultural region.

4.1.2. Ground-based experiments (measurement strategies) over Kenaston (KEN)

Ground measurement strategies were drafted to accomplish the objectives of the project. The science question posed by the project necessitated the sampling of soil moisture, soil roughness, bulk soil density, and vegetative characteristics including leaf area index and multispectral characteristics.

Given our resources, the following teams were formed

- 12 – 2 person soil moisture teams (also measuring soil temperature and TIR)
- 2 – 2 person vegetation and soil roughness teams
- and 3 persons for multispectral and LAI.
- One person dedicated to data entry.
- **Total 32 persons**

In each case, an objective for the sampling was stated. In some cases, our resources placed limitations on the amount of sampling that could reasonably be accomplished and a strategy for prioritizing was instituted.

This section of the document deals with each type of sampling team and their measurement strategies. Each sampling strategy has a stated objective, provides a rational by which the measurement objective is prioritized, outlines the measurement strategies, and lists the protocol and training documents found in Appendix 6.

4.1.2.1. Soil moisture, soil temperature, TIR and bulk density

Soil Moisture

Objective:

To measure the soil moisture at the SMOS scale of 30 km and to assess field-scale variability in soil moisture to assist in scaling issues. There are also secondary scaling objectives to a) relate the time series data at a point to field averages and to b) scale from the 14 point sample to a scale that would allow radar soil moisture retrievals to be related to SMOS data, and to c) examine within RADARSAT2 resolution (30m) variability of soil moisture.

Prioritization Scheme:

The objective was to measure the average soil moisture of a large number of fields to get a representative value for soil moisture at the SMOS scale of 30 km. Therefore on overpass days, given our 12-2 person teams, we obtained the measurement of the average soil moisture for 48-60 fields over an area of approximately 45 x 70 km. Scaling issues by selecting a subset of fields will be monitored with intensive soil moisture measurements on two days of the campaign, June 7 and 11.

General overpass sampling regimes:
The sampling will take place over two transects, 400 m apart with 7 points along the transect at 100 m spacing (see Table 14. General Overpass sampling regime over entire field for soil moisture, temperature, TIR, bulk density and flights for June 2, 3, 5, 8, 10 and 13, 2010.
and Figure 23).

- Each point will be have a pre-programmed GPS coordinate and on the first sampling day each point will be marked with biodegradable spray paint, so each successive measurement will be taken at the same point.
- Soil moisture measurements will be stored in the PDA or Hydraprobe reader, and also transcribed on data sheets to be collected at the end of the day. Soil temp and TIR to be recorded on data sheets. Coverage photos to be taken at each soil moisture site/date/field. Older 3-4 megapixel cameras are adequate for this task. Each team is responsible for labeling the photographs of each field with ID, date taken, and direction of photo if feasible.
- We will have 12 soil moisture teams. The coverage of 48-60 fields means that each team will perform soil sampling for 4-5 fields with each overpass.
- Assuming each field will take 40 minutes (0.7 + 0.4 + 0.7 +0.4 km = 2.2 km walking) with 30 minutes of travel time between each site is 320 (5.33 hours) plus the travel to and from Kenaston. This will mean 11 km of walking in a little over 8 hour days while in the field plus the associated staging, photocopying of notes, debriefing time. Field days will be long days.
- While we have estimated that we will have 24 soil moisture people in the field, we may suffer attrition. For each 2 person reduction in numbers, we will reduce the number of sampled fields by 4- 5.

Table 14. General Overpass sampling regime over entire field for soil moisture, temperature, TIR, bulk density and flights for June 2, 3, 5, 8, 10 and 13, 2010.

Sampling points per field:	14, GPS points to be supplied
Transects per field:	2, 400 m apart
Points per transect:	7
Spacing between points:	100 m with a start 50 m into the field
Number of readings per point	3 (top, bottom and side of furrow)
Soil moisture measurement depth	Probe inserted vertically, soil moisture is integrated over 6 cm
Soil temperature	4 points each of two depths (5 cm and 10 cm)
TIR	4 measurements in each field. Exposed Vegetation, Shaded Vegetation, Exposed Ground, and Shaded Ground.
Bulk Density	1 core sample, 3 probe readings within 15 cm and consistent with respect to the furrow

Site Photos	One taken in the direction of the crop row, preceded by photo of field ID, date, time, direction of crop row notes (diagram in field notes)

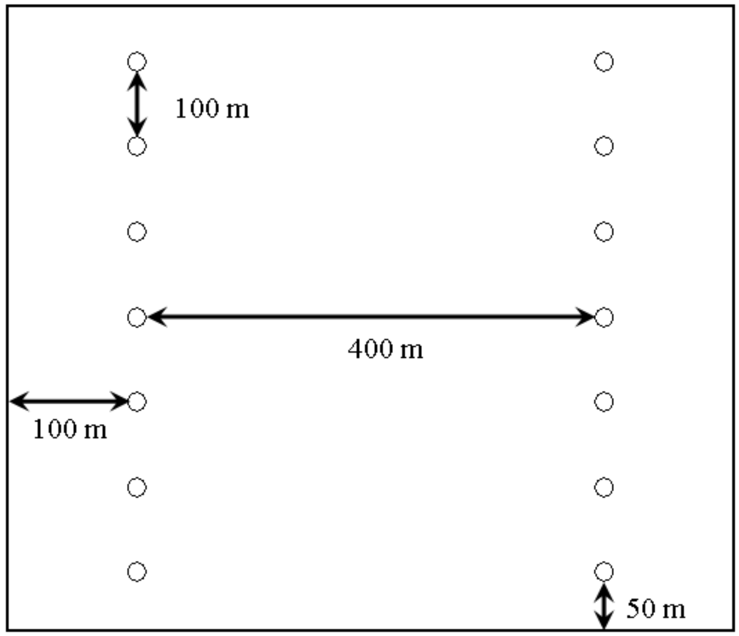


Figure 23. Diagram of sampling strategy, 14 points over 800 m x 800 m, 2 transects 400 m spacing with 7 points at 100 m intervals (not to scale). Note these two transects coincide with two of the transects that will be measured on the intensive sampling days.

Intensive sampling, non-flight days:
The aim is three-fold

1. To provide a sampling regime that would enable us to incorporate measurements derived from other sampling regimes undertaken in 2007 and the current sampling regime in 2010 to relate the time series measurements to field averages.
2. To scale from the 14 point sample to a scale that would allow radar soil moisture retrievals to be related to SMOS data, and
3. To examine the soil moisture variability within RADARSAT2 standard mode resolution (30 m)

The two intensive sampling days are targeted as June 7th, morning sampling and June 11th, afternoon sampling to answer the objectives above.

On June 7th, we will address the scaling objective (objective 1 above) related directly to the time series data, the sampling strategy will concentrate on the permanent, time series soil moisture sites. The current survey will have a start point 100 m from the east and 50 m from the south into the field, 4 transects spaced 200 m apart with survey points at 50 m increments (see Table 15 and Figure 24). Three replicates (top, bottom and side of furrow) were taken at each measurement point. It is anticipated that it will take about 1.5 hours per field for a team of two

On June 11th, we will examine the second objective (to relate radar soil moisture retrievals with soil moisture estimation from SMOS data) and sampling will entail 5 transects distanced by 50 m. For each transect, there are 13 measurement points distanced by 25 m (see Table **16.** Intensive sampling regime, 200 x 200 m, June 11 (p.m.)

16 and Figure 25). Also on June 11th we will look at the third objective with a sampling regime, with 6 transects, 10 apart. Each transect will have 6 measurement points, at 5 m intervals (Table 17. **Intensive sampling regime, 50 x 50m, June 11 (p.m.)**

17 and Figure 26). These two sampling schemes will take a team of two about 1.5 hours to complete in one field.

The number of fields undertaken on each day will depend on how many teams are sent out. The selection of fields will concentrate on those fields with time series data and will be chosen to reflect the variability within the crop mix that is representative of the area.

Table 15. Intensive sampling regime, entire field, June 7 (a.m.)

Sampling points per field:	52, GPS points to be supplied
Transects per field:	4, 200 m apart
Points per transect:	13
Spacing between points:	50 m with a start 100 m from east and 50 m from south into the field
Number of readings per point	3 (top, bottom and side of furrow)
Soil moisture measurement depth	Probe inserted vertically, soil moisture is integrated over 6 cm
Soil temperature, (if we can get equipment)	Unknown
TIR (if we can get equipment)	unknown

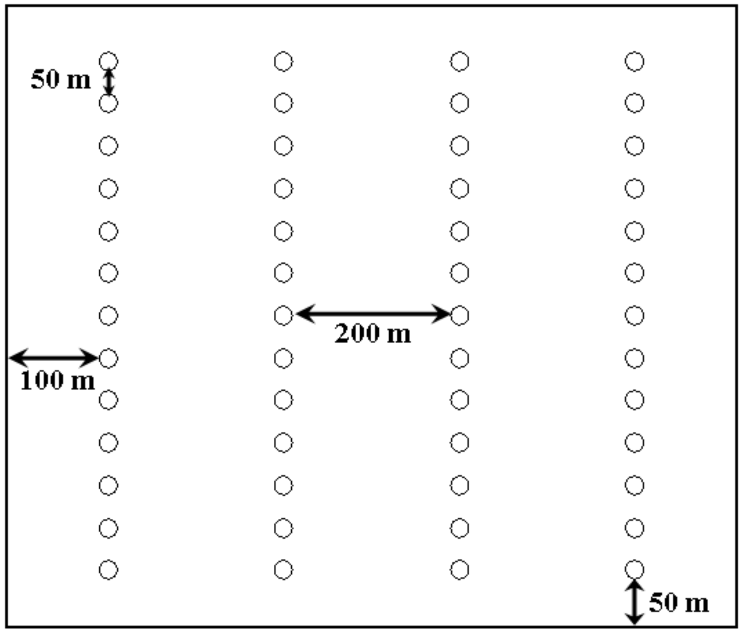


Figure 24. Diagram of intensive sampling strategy, 52 points over 800 m x 800 m, 4 transects 200 m spacing with 13 points at 50 m intervals (not to scale). Note two of these transects coincide with the transects that will be measured on general overpass days.

Table 16. Intensive sampling regime, 200 x 200 m, June 11 (p.m.)

Sampling points per field:	65, GPS points to be supplied
Transects per field:	5, 50 m apart
Points per transect:	13
Spacing between points:	25 m with a start 100 m from east and 50 m from south into the field – same start point as above
Number of readings per point	3 (top, bottom and side of furrow)
Soil moisture measurement depth	Probe inserted vertically, soil moisture is integrated over 6 cm
Soil temperature, (if we can get equipment)	Unknown
TIR (if we can get equipment)	unknown

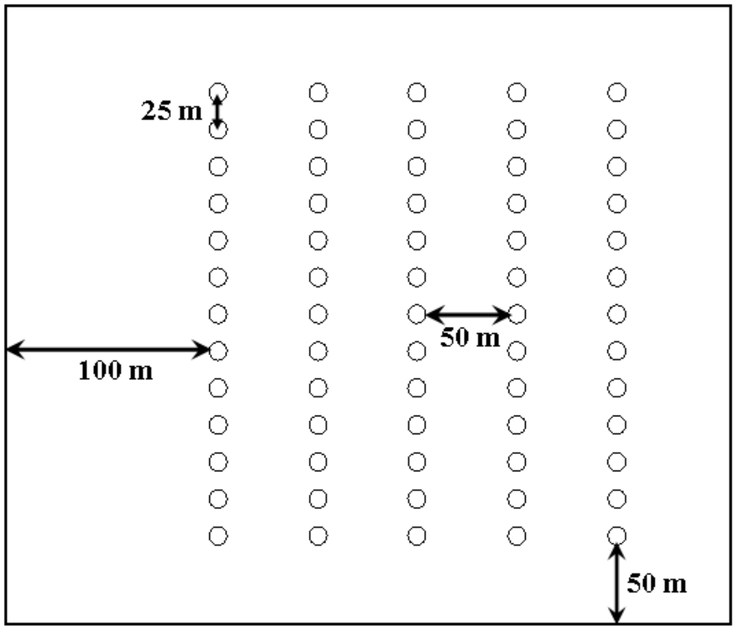


Figure 25. Diagram of intensive sampling strategy, 65 points over 200 m x 200 m, 5 transects 50 m spacing with 13 points at 25 m intervals (not to scale). Note two of these transects coincide with the transects that will be measured on the 800 m x 800 m intensive monitoring scheme.

Table 17. Intensive sampling regime, 50 x 50m, June 11 (p.m.)

Sampling points per field:	36, GPS points to be supplied
Transects per field:	6, 10 m apart
Points per transect:	6
Spacing between points:	25 m with a start 100 m from east and 50 m from south into the field – same start point as above
Number of readings per point	3 (top, bottom and side of furrow)
Soil moisture measurement depth	Probe inserted vertically, soil moisture is integrated over 6 cm
Soil temperature, (if we can get equipment)	Unknown
TIR (if we can get equipment)	unknown

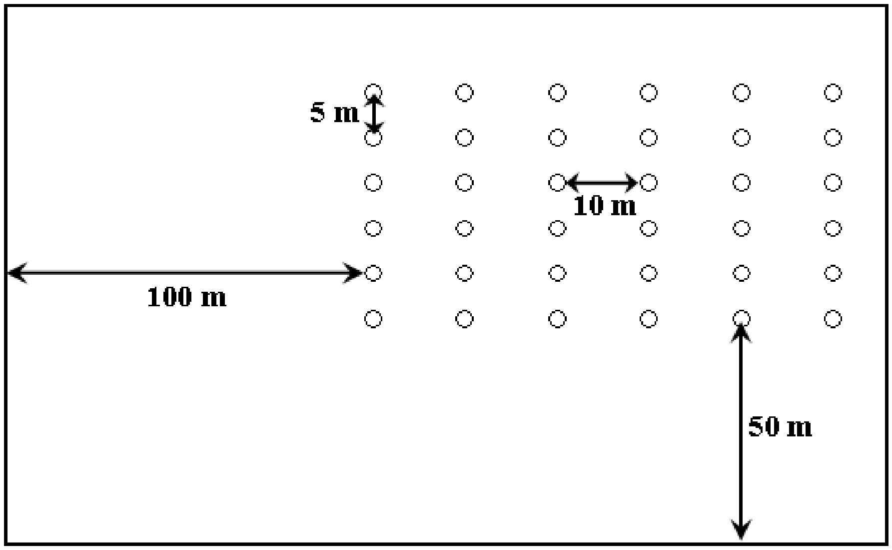


Figure 26. Diagram of intensive sampling strategy, 36 points over 30 m x 50 m, 6 transects 10 m spacing with 6 points at 5 m intervals (not to scale). Note two of these transects coincide with the transects that will be measured on the 200 m x 200 m intensive monitoring scheme.

Bulk Density

Objective: To provide data to calibrate the manual soil moisture probes over a range of soil moisture conditions for all fields. Gravimetric sampling with bulk density will allow a calculation of the field volumetric moisture content to be compared to the data that comes from the probes.

Prioritization:
As extensive work has been done to calibrate the probes at the EC or U of G field sites, the first priority is to obtain gravimetric and bulk density samples from the manual survey sites. However, there is still a need to scale the EC or U of G point measurements to the field scale.

Measurement Strategy:
On each flight overpass/ground sampling day, one 0-5 cm gravimetric sample with bulk density sample (core) will be taken for each field (60 fields x 6 sample days = 360 samples). This sample is to be taken at one of the 14 sample points, a different point will be chosen each sample day (i.e. do not revisit the same sample point each day).

During this experiment, 3 HydraProbe measurements will be taken nearby the sample core. Each sample should be taken in similar physical setting (i.e. along similar position in a furrow and within 15 cm from the sample). The Hydraprobe readings must be written down on the sampling sheet.

The soil moisture and bulk density teams will be responsible for photocopying and filing their data sheets, data entry of soil moisture values, the weigh and recording of wet weights for the bulk density samples. At the laboratory, the sample must be removed from the zip lock bag and immediately weighed. The wet weight is recorded and the sample is placed on to a labelled container for oven drying. The sample is then oven dried for 24 hrs. at 105°C and re-weighed.

4.1.2.2. Soil roughness and vegetation

Four people were assigned for the soil roughness, and vegetation sampling. The vegetation sampling and roughness should be performed at the same time to minimize disturbance.

A survey of those previously involved in soil roughness measurement and vegetations sampling thought a soil roughness and vegetation sampling team could spend 45-60 minutes on roughness and then 15-30 minutes on vegetation. There is about 30 minutes of drive time between each field. In one day we will aim to sample 3-4 fields per day per team in addition to the time to commute to Saskatoon.

Daily time estimates to cover the 3-4 fields per day:
(1.5 hours + 0.5 hour)*3 fields = 6 hours and (1.5 hours + 0.5 hour)*4 fields = 8 hours +3 hours commute. = 9 -11 hours per day.

We have two – two person soil roughness/vegetation teams. Therefore if each team covers 3-4 fields per day, 5 days per week we will cover 20 fields per team per week. With two teams we could sample 40 fields each week. We anticipate that each field will only have to be sampled once for roughness and the two teams will revisit most of the fields (actively growing, no fallow) for a second sampling of vegetation only during the two week campaign. If we find that soil roughness and vegetative roughness sampling takes longer, we will visit each field only once during the campaign with the exception of re-measuring fallow fields that are tilled during the campaign and any field that experiences significant vegetation growth during the experiment.

Soil roughness

Objective:
To measure the representative soil roughness and soil roughness correlation lengths to quantify the impact on SAR response in measuring soil moisture at the SMOS scale.

Measurement of Soil Roughness
Photos and roughness data from July 2008 underwent a variability analysis and it was determined that there was not much field to field variability. Within field variability was assumed to be even less than field to field variability. Therefore a 3 m roughness profile (1 m profiler end to end) with 3 replicates at one site would be sufficient to represent surface roughness.

- 1-m long profilometers will be used to estimate the surface roughness, the profiler is placed end to end 3 times to give a 3 m long profile measurement per replicate
- One replicate consists of a 3-m profile parallel to the look direction of the UAVSAR and another 3-m profile parallel to the look direction of the RADARSAT2, descending angle.
- 3 replicates, approximately 5 m apart.
- Vegetation is removed (or flattened by using a long cardboard) along this transect so that it doesn't interfere with the soil roughness measurement and so that a photo (10 megapixel camera) can be taken of the pins.
- It is desirable that the vegetation that is removed shall be used in the vegetation sampling to minimize disturbance.

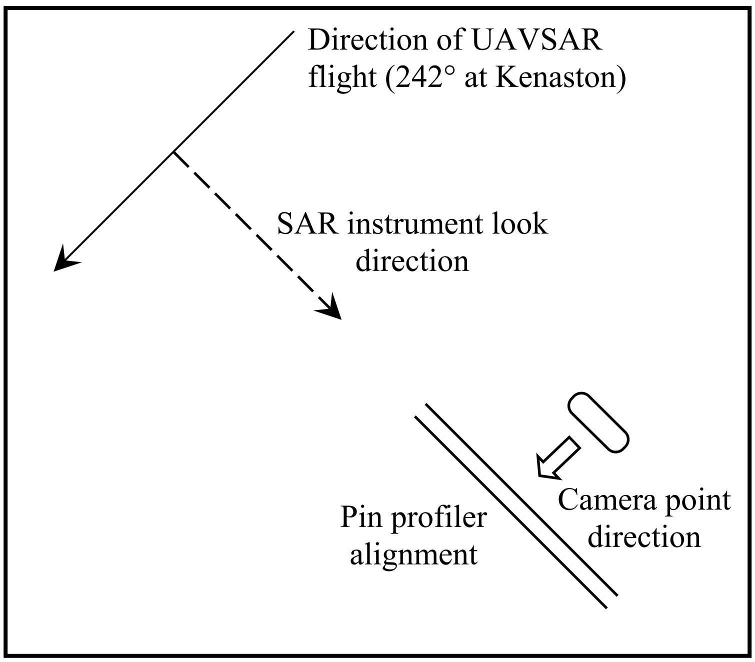


Figure 27. An example of the first metre pin placement for one replicate of the pin profiler placed for the UAVSAR flight path at 242º for the KEN campaign.

Table 18. Soil roughness measurements

Characteristics to be determined	• Pin profile measurement of the soil surface
Measurements, minimize destruction	• 3 – 1 m profiles, end to end with vegetation flattened to allow photograph to be taken. • 3 replicates parallel to the look direction of • UAVSAR, • RADARSAT2, descending

Vegetation

Objective:
To assess the water content of the biomass present to quantify the impact on microwave response in measuring soil moisture at the SMOS / SMAP scale.

Vegetation Sampling
Vegetation is more variable than surface roughness and it was agreed that 3 sites would be selected across a field. The selection of site location would be determined from an analysis of SPOT and soils (if available) data by Heather McNairn of AAFC and these coordinates will be supplied to the measurement teams. One replicate of biomass and several replicates of physical characteristics (TBD by Mahta – probably 3-10, averaged for one reading per site) would be performed at each site.

Biomass

- At each site, a gridded board should be placed behind the vegetation and a photo should be taken
- Biomass measurements, 1 m sampling in a row (if row is defined and row spacing data/plant density data is collected), otherwise in 50 cm grids (1 replicate each) – grid frame or meter stick to be supplied
- Wet mass must be determined very quickly, within 2 hours ideally. If samples are contained in a paper bag and then placed in a sealed plastic bag, the degradation can be slowed enough to do wet weights at the end of the day. If we do not have an extra person to do lab work, we will have to make this the responsibility of the veg sampling team.
- Condensation or dew collected on the vegetation at the time of sampling (common in the early morning hours) should be very gently shaken from the sample prior to bagging. Please note if there is excess condensation that has collected in the bag at the end of the day during the wet weight process.

Physical field and plant characteristics

- Number of replicates dependent on field variability
- Plant height and stem diameter.

Table 19. Vegetation sampling, biomass and physical characteristics

Characteristics to be determined	• vegetation height, stem diameter, plant density or coverage and vegetation water content • last item will require measurement of mass in lab and oven drying
Measurements, destructive	• 50 cm x 50 cm grid per site, 3 sites OR • 100 cm row per site, with row spacing and plant density data to be collected,
Site photos	• 1 gridded photograph photo per site, 3 sites

Vegetation height and stem diameter	• 3 – 10 each height and diameter, averaged, at each site, 3 sites

Roughness Vegetation Team

The site visits for the roughness/vegetation team need to be performed in about 40-50 minutes and the recommended procedure would be:

- team of two arrives at 1st roughness/veg site which will be close to road access. The team takes the 3 roughness replicates as well as one gridded vegetation photo, one biomass sample and measures the height and stems.
- The team splits up with each person going to the second and third site to take only the gridded vegetation photo, biomass sample, height and stem measurements, OR
- If it is more time efficient (i.e. the given site locations are progressive) to work as a team, the team of two would visit each successive site.
- Return to vehicle and move to next field.

The roughness vegetation team will need to report on progress about 5 days in to access if we are meeting targets. Additionally the roughness vegetation team will be responsible for archiving of data sheets, photographs and performing lab weights at the end of each day.

4.1.2.3 LAI and multispectral

LAI and multispectral data will be collected by a 3 person team, 2 persons on LAI (Jiali and a student from AAFC) and 1 person from the University of Guelph.

Leaf Area Index

Objective:
Quantification of the microwave response (brightness temperature or backscatter) due to vegetative growth or LAI at the SMOS scale. Research has demonstrated that this response, in terms of both backscatter and polarimetric variables, can be well characterized by surface soil moisture and LAI.

Prioritization scheme:
The LAI team can cover about 4-5 fields in a working day. Working 6 days per week, they can cover 24-30 fields each week – about ½ the number of total fields sampled. A priorization scheme (perhaps similar to the priority scheme for vegetation sampling) needs to be developed.

Table 20. LAI measurement Strategy (AAFC)

SPOT images	2 – 10m or 20m SPOT in July 2008, June 2009 to aid in site selection
Sites per field	Relatively homogeneous, one or two depending on field variability

LAI sites	3 replicates within 10 m • LAI • Overhead hemispherical photo (i.e. 6 over 3 crop rows) • Overhead vertical photo at 1.5-2m
GPS points	Pre-programmed from SPOT analysis – marked with flag or paint?

- It is estimated that LAI measurements and overhead photos would take approximately 30 minutes per sample site (30 minutes per field if only one sample site is visited).
- Crop growth can be significant under favourable meteorological conditions. Given resource constraints, however, LAI measurements have typically been assumed to be representative of the crop canopy for up to a week before or after the LAI data collection.
- Thus, the LAI team proposes to collect LAI at each site twice – once immediate at the start of the field campaign on June 1, with a second set of measurements acquired in the last week of the field campaign.

Multispectral

Objective:
Surface reflectance data is valuable in developing methods to estimate the vegetation water content and other canopy variables. Observations made concurrent with biomass sampling provide the essential information needed for larger scale mapping with satellite observations. In addition, reflectance measurements made concurrent with satellite overpasses allow the validation of reflectance estimates based upon correction algorithms.

Prioritize:
Will be working with the LAI team and can cover about 4-5 fields in a working day. Working 6 days per week, they can cover 24-30 fields each week – about ½ the number of total fields sampled. A priorization scheme (perhaps similar to the priority scheme for vegetation sampling) needs to be developed.

Measurement Strategy:
Vegetation Water Content Sampling Location:

Reflectance data will be collected for each vegetation sampling location (Figure 28) just prior to removal using the following sampling scheme.

Making sure that the radiometer is well above the plant canopy; take a reading every meter for 5 meters. Repeat, for a total of 5 replications located 1 meter or 1 row apart.

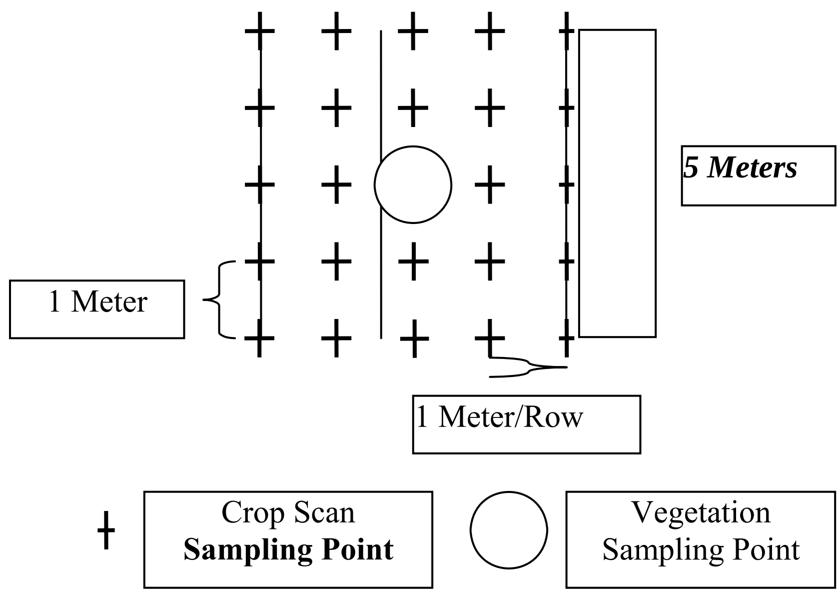


Figure 28. Vegetation sampling scheme

Field Transect:

Each different land use type (Winter Wheat, corn, pasture, etc...) will be characterized by transect sampling. Reflectance will be collected at representative sites (Figures 29 and 30). Reflectance will also be collected over water for calibration purposes. This should be done at least twice, to coincide with the Landsat overpasses. The following sampling scheme will be used for transect sampling.

Making sure that the radiometer is well above the plant canopy, take a reading every 5 meters for 25 meters, walk 75 meters, continue until you have gone 400 meters. Walk over 100 meters. Do another 400 meter transect going in the opposite direction.

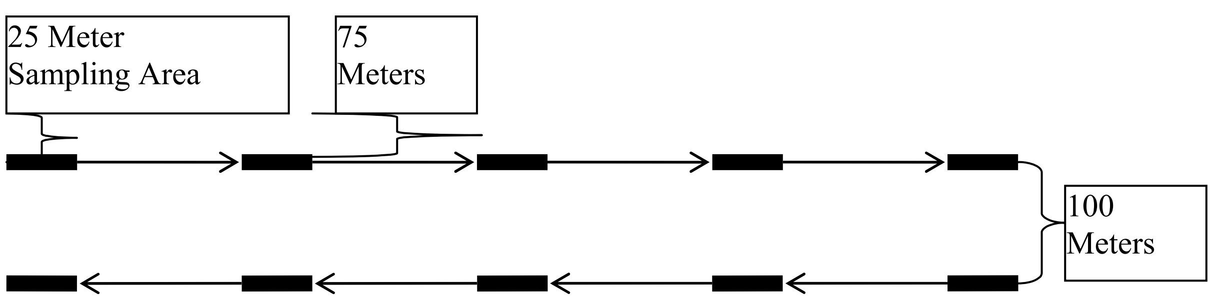


Figure 29. Transect sampling scheme

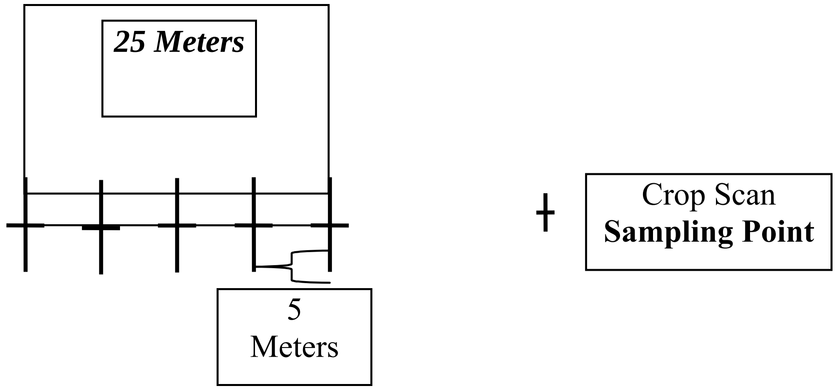


Figure 30. Enlarged transect sampling area

4.1.3. Aircraft campaigns (flight lines)

Objectives

Airborne microwave measurements will support the validation of SMOS products (L1, L2) and the pre-launch validation of SMAP data as well as the soil moisture retrievals from these two spatial missions. In addition to validation issues over agricultural areas, aircraft measurements will be used to investigate the scaling effect on remote sensing data and to understand the transferability of ground measurements to satellite observations. Furthermore, UAVSAR acquisitions aim to develop and validate backscattering forward model over Kenaston agricultural area.

4.1.3.1. Twin Otter acquisitions over Kenaston

Simultaneously to ground measurements and SMOS overpasses, aircraft campaigns will be conducted over Kenaston site following the calendar presented in Section 4.1.1. Figure 31 shows the coverage of the aircraft operations conducted with the Twin Otter flying specifications given in Table 21. The dashed line between waypoints represents the centreline of the 1.4 GHz radiometer swath as it flies along.

Table 21. EC's Twin Otter aircraft flying specifications at L-Band (1.4 GHz) over Kenaston and BERMS sites

Twin Otter flying specifications at L-Band for CanEx-SM10	
Altitude (km)	2.34
Incidence angle (°)	40
Number of parallel flightlines	16
Flightline length (km)	70.5
Spatial resolution at L-band (km)	~ 2.25

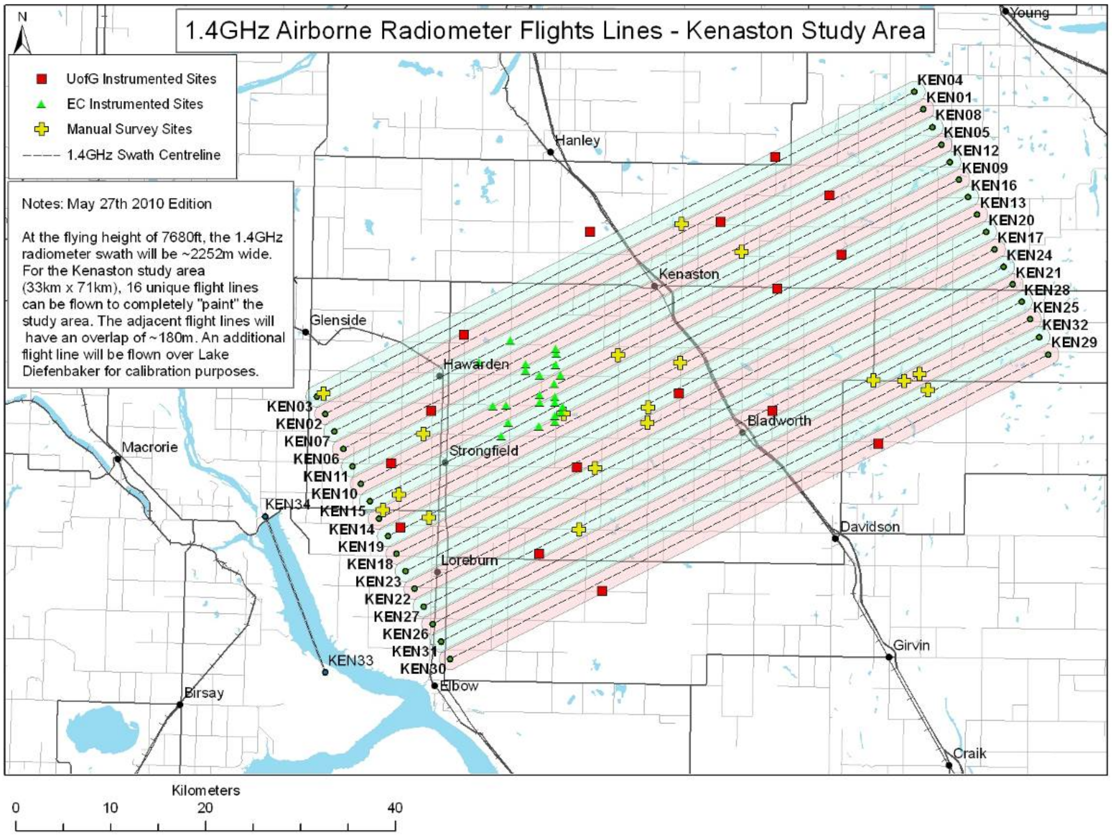


Figure 31. Flight-lines over Kenaston study area. U of G, EC and the manual survey sites are represented respectively by the red, green and yellow marked symbols.

4.1.3.2. UAVSAR acquisitions over Kenaston

UAVSAR will provide coverage of the Kenaston (KEN) domain that has been defined for the EC L-band radiometer with incidence angles of 35-45 degrees. This will require multiple lines. The entire domain will be flown with the same heading in order to reduce confounding effects associated with geometric features. For KEN this will be a heading of 242 degrees. In addition to these lines, an additional 3 lines over KEN will be flown with the opposite heading. Finally, one additional line will be flown on June 8 to match a portion of the anticipated coverage by ALOS PALSAR the previous night. The coverage box is described in Table 22. The heading will be 350 degrees.

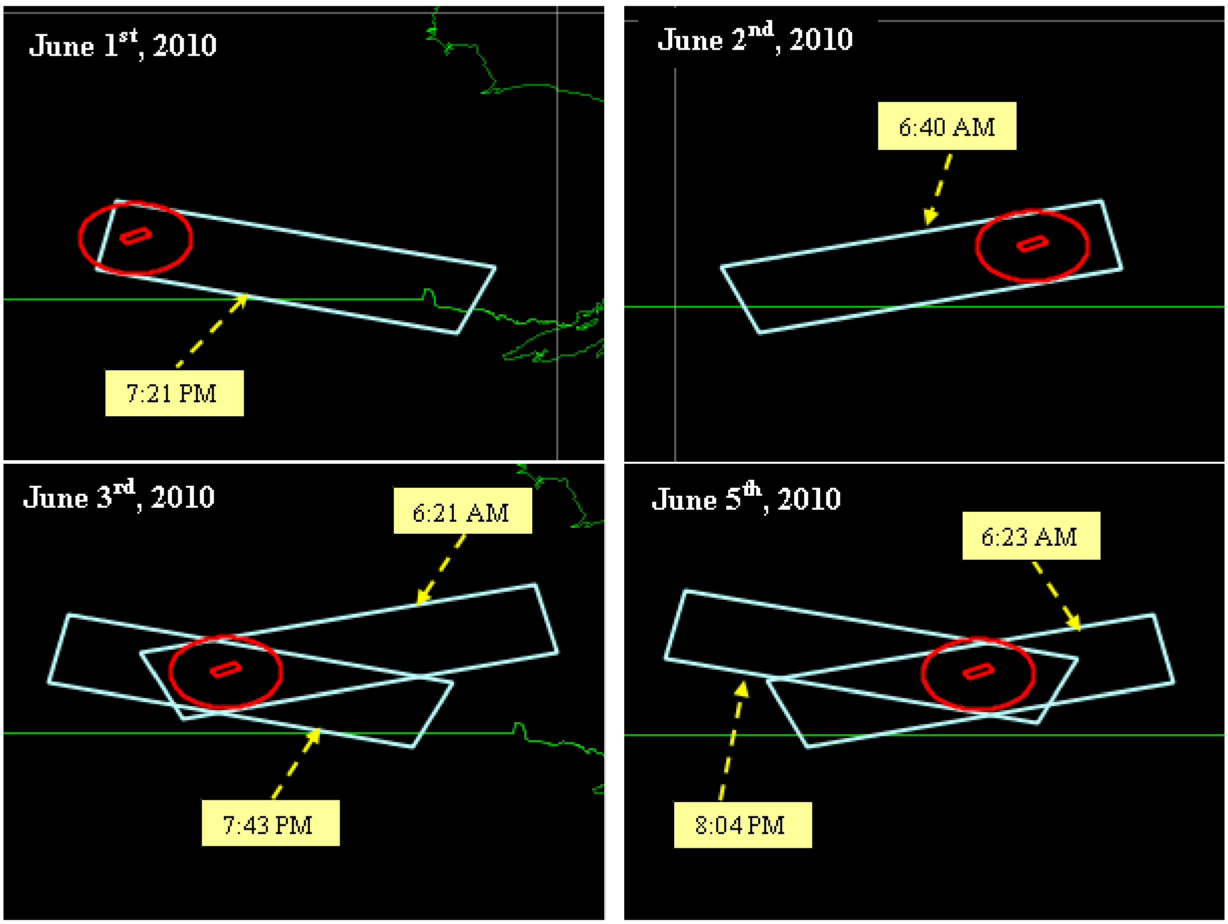
Table 22. Corner coordinates of UAVSAR coverage for ALOS PALSAR

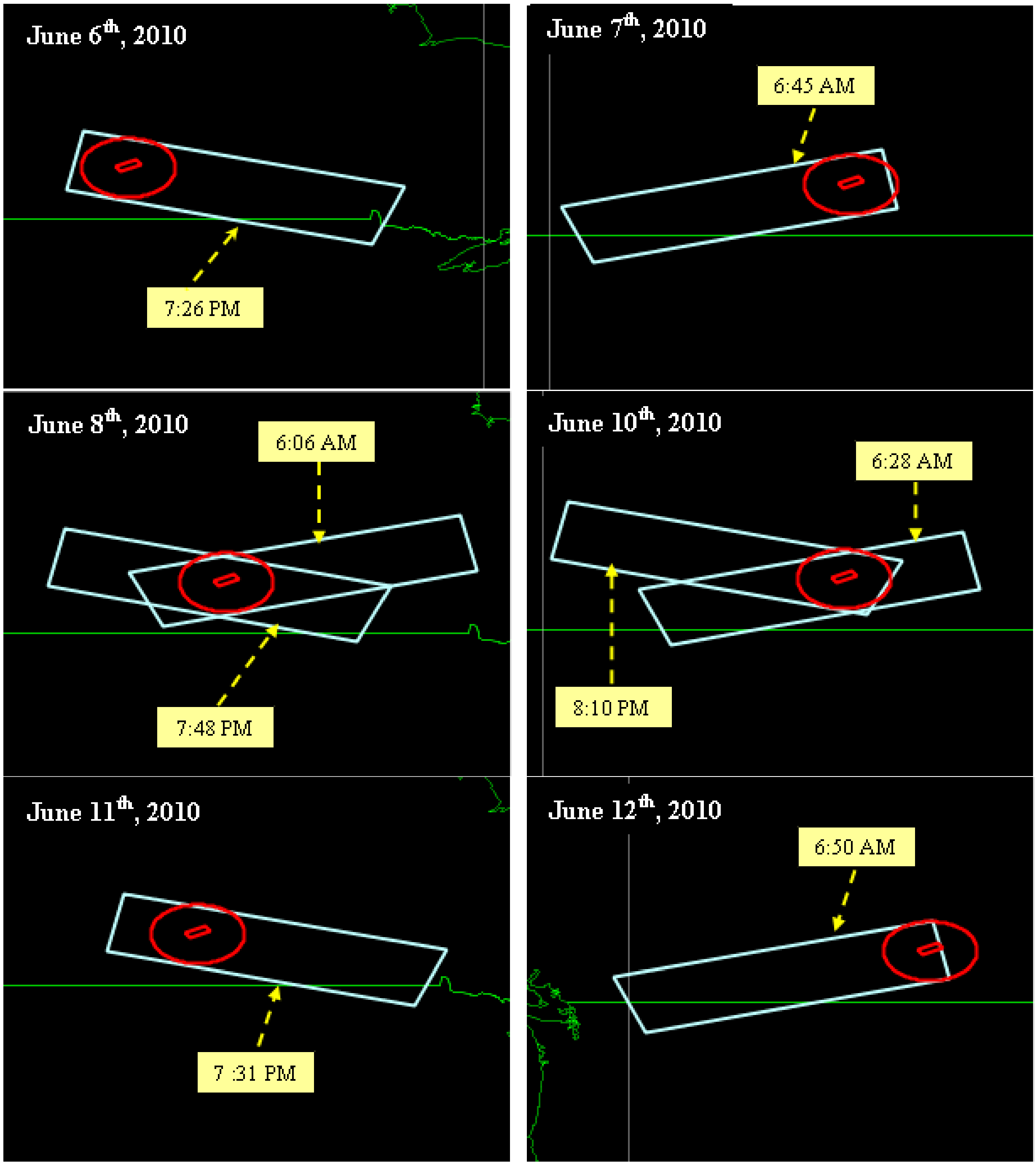
Longitude (Degrees)	Latitude (Degrees)
-106.848	51.969
-106.530	52.005
-106.524	50.831
-106.212	50.865

4.2. Satellite data coverages

Satellite acquisitions covering completely (or almost) the study site were selected to meet the objectives of CanEx-SM10 (Section 1.2). SMOS, RADARSAT-2, ASAR-Envisat, and ALOS-PALSAR spatial coverages are presented below.

SMOS




June 6th, 2010
7:26 PM
June 7th, 2010
6:45 AM
June 8th, 2010
6:06 AM
7:48 PM
June 10th, 2010
6:28 AM
8:10 PM
June 11th, 2010
7 :31 PM
June 12th, 2010
6:50 AM

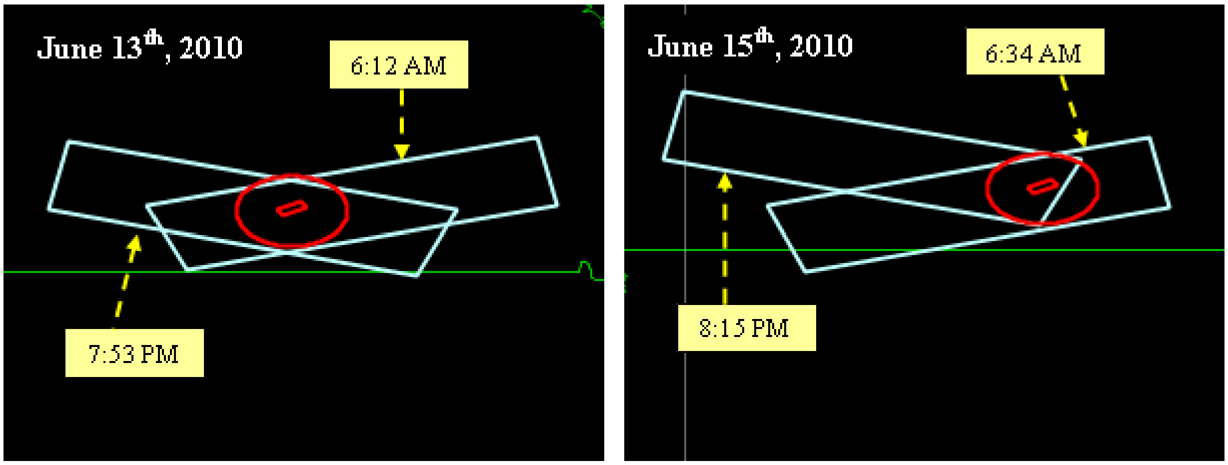
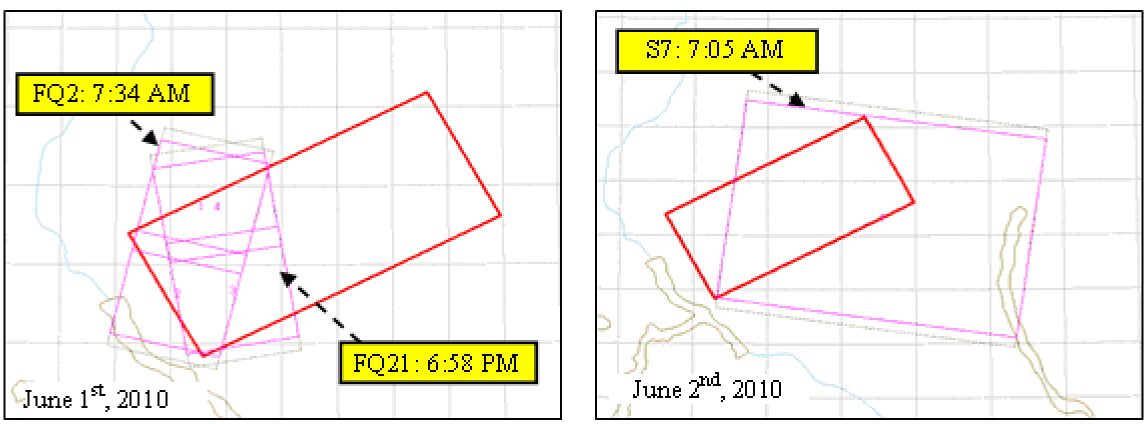


Figure 32. SMOS coverages (blue boxes) over Kenaston site (red box) from June 1-15, 2010 (the red circle is an area of 150 km radius around the study site)

RADARSAT-2

For RADARSAT-2, a combination of Fine Quad (FQ), Standard and Wide Swath modes have been programmed (Table 13). RADARSAT-2's FQ mode provides fully polarimetric data, but at significantly reduced swath widths (25 km), which provide only partial coverage over the Kenaston site. FQ acquisitions were thus focused over the EC in situ site, and two frames of FQ were requested to provide 25 km (in range) by 50 km (in azimuth) coverage. Where FQ coverage was minimal for any portion of the Kenaston site, Standard and Wide Swath modes were programmed. Whenever possible, both ascending and descending acquisitions were programmed, at divergent incidence angles.



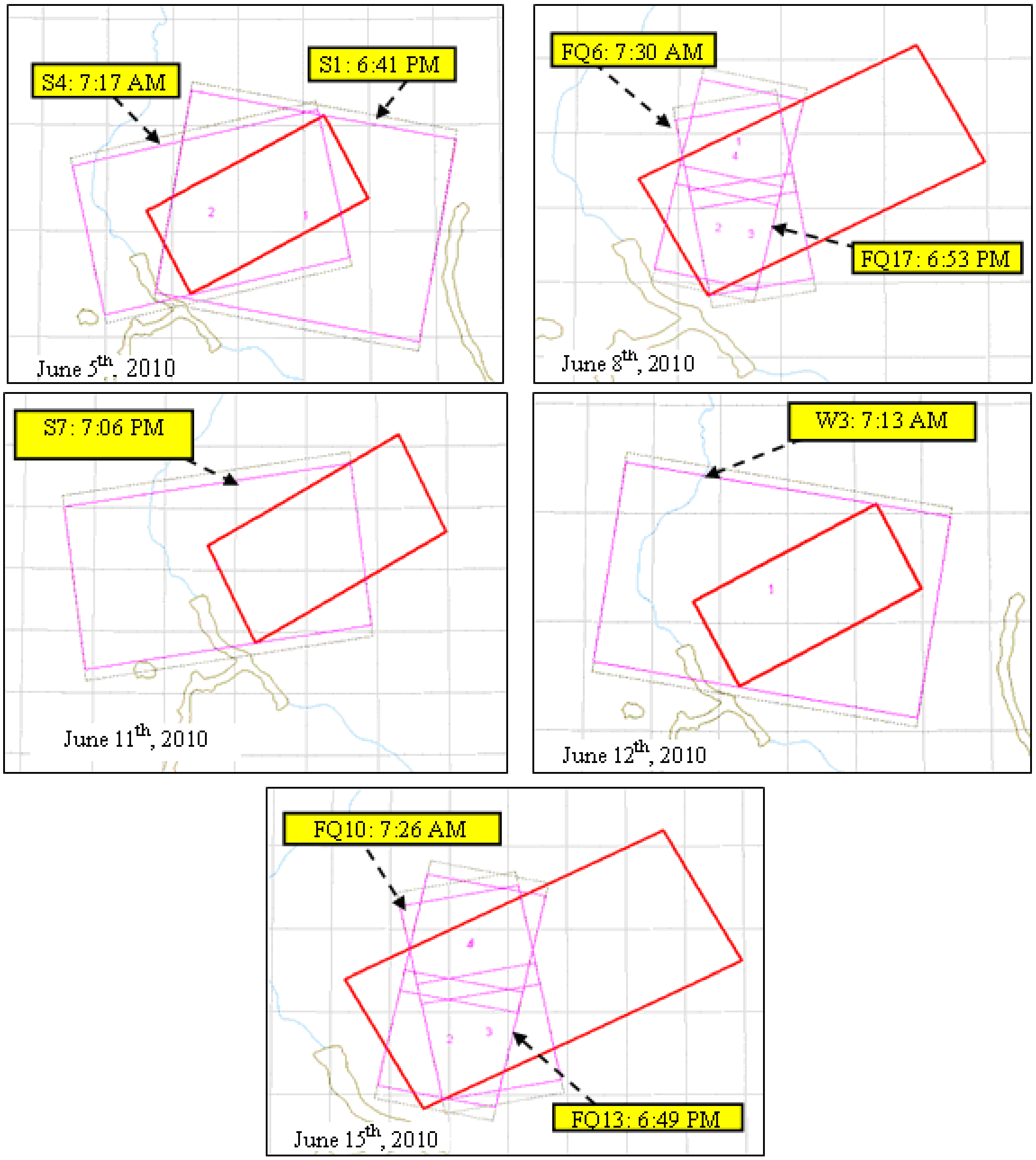


Figure 33. RADARSAT-2 coverages (magenta boxes) over Kenaston site (red box) on June 1, June 2, June 5, June 8, June 11, June 12, and June 15, 2010.

<u>ASAR-Envisat</u>

Where RADARSAT-2 data is not available, ASAR-Envisat acquisitions were programmed in Alternating Polarisation (AP) mode on June 7th and in Wide mode on June 10th and June 13th. They will be provided free of charges by ESA in the framework of SMOS cal/val activities.

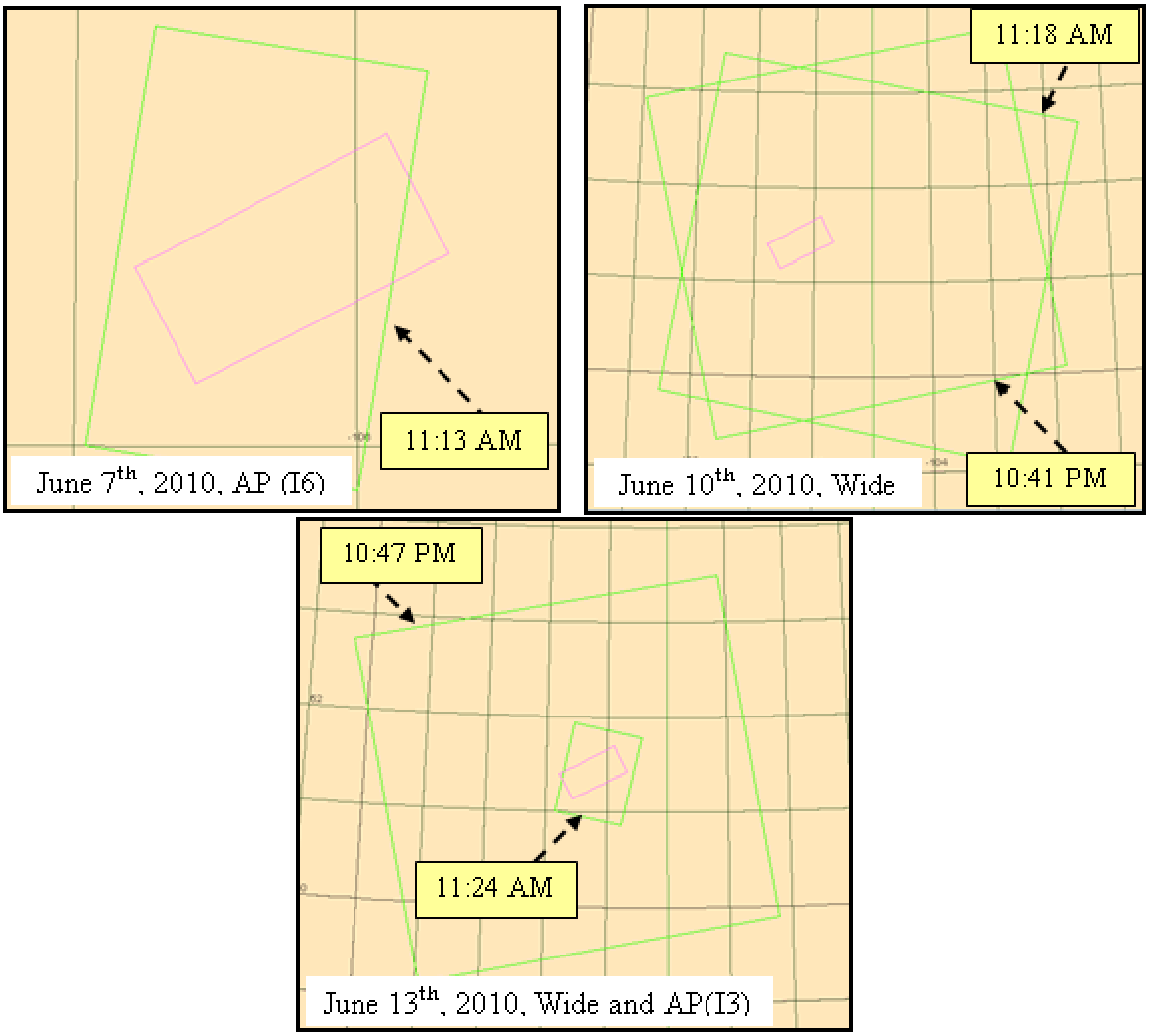


Figure 34. ASAR-Envisat coverages (green boxes) over Kenaston site (magenta box) on June 7, June 10, and June 13, 2010

ALOS-PALSAR

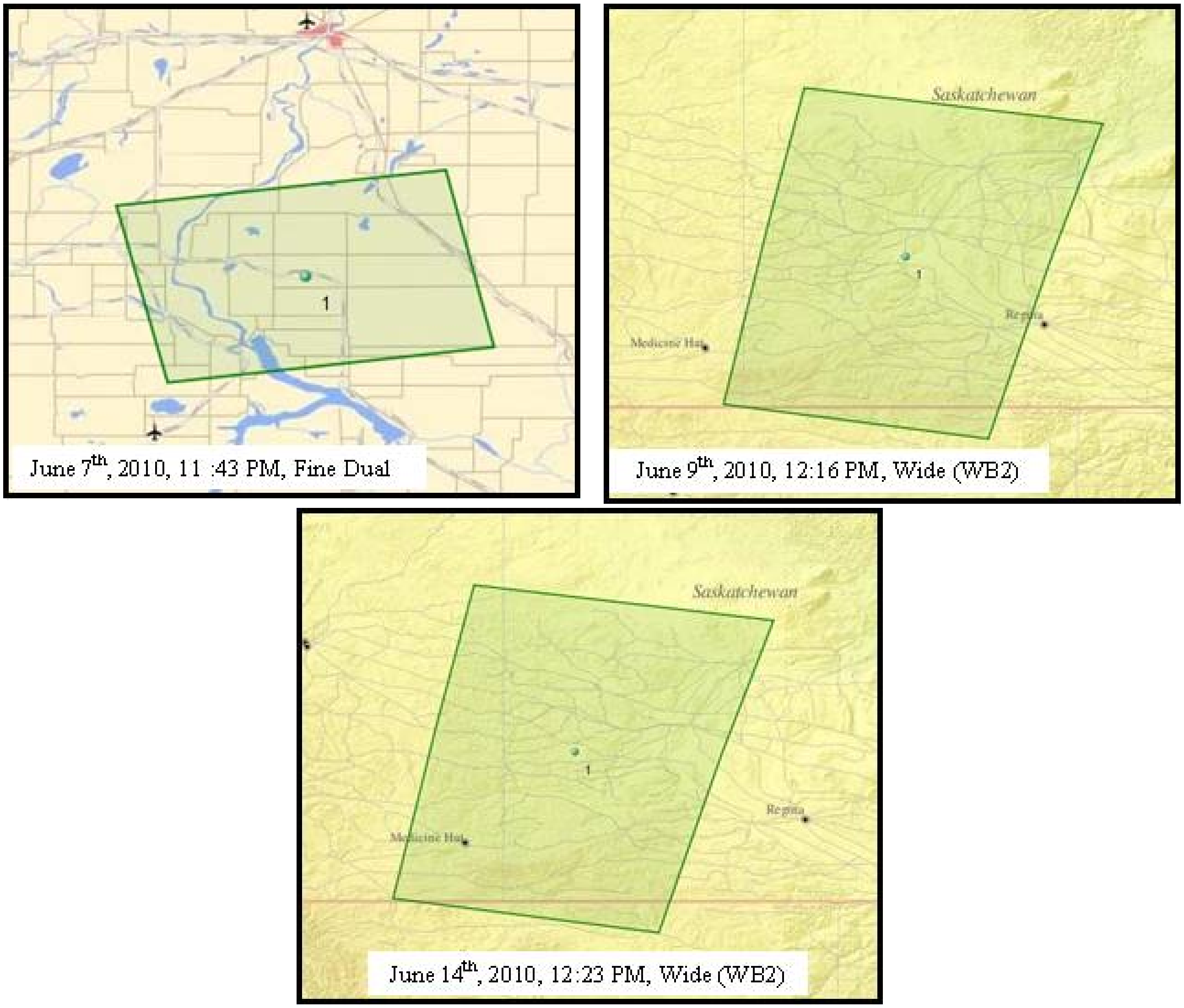


Figure 35. ALOS-PALSAR coverage (green box) over Kenaston site on June 7, June 9, and June 14, 2010

5. Data acquisition over BERMS site

5.1. Experiments

5.1.1. Calendar of data acquisition

On June 15th and 16th, active and passive satellite microwave data (AMSR-E, RADARSAT-2, ASAR-Envisat, ALOS-PALSAR) corresponding to SMOS overpasses will be acquired over BERMS.

On June 16th, field measurements of soil moisture and surface temperature will be collected at a time close to satellite and airborne acquisitions for the validation and the pre-launch validation of SMOS and SMAP data, respectively. In addition, standard vegetation characteristics (height, dBh, etc.) will be measured.

On June 14-16 and on July 13-20, 2010 detailed measurements of vegetation characteristics (size, dielectric constant, orientations, etc.) will be performed.

Table 23. Calendar of data acquisition over BERMS site

Day	Ground	Aircraft	Satellites	Local time	Flight direction	Beam mode	Resolution	Incidence angle (°)	Polarization
June 15th	Soil moisture measurements		RADARSAT2	7:25 AM	D	Quad-pol	9 m×6 m	24.7-26.3	HH, VV, HV, VH
			SMOS	6:33 AM	A	Pol	30-50 km	0-55	H and V
			AMSR-E	3:59 AM	D	Pol	48 km	55	H and V
			RADARSAT2	6:50 PM	A	Standard	25 m	41.7-46.2	HH, HV
			SMOS	8:13 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	1:33 PM	A	Pol	48 km	55	H and V
June 16th	Soil moisture measurements	EC NASA	SMOS	5:55 AM	A	Pol	30-50 km	0-55	H and V
			ASAR	11:29 AM	D	Wide	150 m	15-50	HH or VV
			ALOS	10:52 PM	D	Fine Dual	20 m	34.3	HH, HV
			AMSR-E	3:04 AM	D	Pol	48 km	55	H and V
			SMOS	7:35 PM	D	Pol	30-50 km	0-55	H and V
			AMSR-E	2:16 PM	A	Pol	48 km	55	H and V
June 14-16 and July 13-20	Detailed measurements of forest characteristics								

5.1.2. Ground-based experiments over BERMS (measurement strategies)

In addition to agricultural areas, the BERMS forested area was selected to conduct the validation of SMOS soil moisture estimation and brightness temperature products, and the pre-launch validation for the future SMAP mission. This will rely on ground measurements of soil moisture, temperature, and forest characteristics. In addition, L-band passive and active microwave aircraft data (sections 4.1.3 and 5.1.3) will support the validation and pre-launch validation of SMOS and SMAP, respectively. A one-day field experiment is planned on 16 June 2010 to collect both soil moisture and aircraft measurements over BERMS, subject to weather and aircraft constraints. Detailed vegetation information will be provided by a combination of remotely sensed imagery and field sampling conducted on June 14-16 and on July 13-20, 2010. The following sections describe the sampling strategies that will be used for soil moisture and vegetation characteristics at the BERMS site.

5.1.2.1 Ground-based experiments - Soil moisture, soil temperature, and bulk density

Resources

The BERMS domain benefits from a permanent in situ network (BERMS Permanent Network-BPN) described in Section 2.2. This will be complemented by two additional types of soil moisture measurements: the BERMS temporary in situ network (BTN), and the ground team sampling (GTS).

Objective

The above resources for soil moisture measurements will be used to accomplish the following objectives:

- soil moisture validation at the SMOS scale;
- development and validation of both forward and inverse modeling using passive and active microwave data;
- establish the transferability and compatibility of BPN and BTN data sets using gravimetric soil moisture collection;
- establish the scaling characteristics of the permanent network (BPN) for long-term validation of soil moisture products including SMOS and SMAP.

Volumetric soil moisture and soil temperature

Prioritization scheme:

BERMS Permanent Network (BPN)

As described in Section 2.2, over the study domain, 6 BPN stations collect soil moisture at different depths (Figure 16). The measurements are made at 4-hour intervals with the exception of the Fen which is made every 30-minutes.

BERMS Temporary Network (BTN)

These stations will be installed over the BERMS domain. The specific area that will be instrumented incorporates that encompassing a SMOS footprint (~40 km diameter) and the BPN sites. These will be installed in late May 2010 and left in place through August

2010. The network (Figure 16) is composed of about 20 Stevens Hydra Probes measuring and recording the 5-cm depth soil moisture. Some BTN stations will be co-located at the BPN for validation/verification purposes. Gravimetric soil moisture samples will be collected at each BTN site three times; at installation, during the June 16 flight, and during site removal.

Ground team sampling Network (GTS)
This sampling strategy (Figure 16) was developed to satisfy the spatial distribution of soil moisture measurements for the validation of soil moisture retrievals from SMOS and aircraft acquisitions. It will be a 1-day (anticipated to be 16 June 2010) sampling conducted by 7 or 8 GTS teams, simultaneously with the aircraft and SMOS acquisitions. Considering that each GTS team will sample 5 locations, soil moisture will be collected with the Hydra probes for about 30-35 locations spatially distributed over BERMS study area (see Figure 16) in consideration of the BTN and road accessibility. Road access will limit sampling in the southwestern and northeastern parts of the domain (Figure 36).

The GTS locations (Table 5) are all along accessible roads and trails. At each site, sampling will be conducted at 3 measurement points. These will be located within the surrounding canopy at a nominal distance of 20, 25, and 30 m from the indicated GTS site (Figure 36). For each of the three measurement points at a site, 3 Hydra probe readings will be collected. This leads to 9 readings per GTS location and a total of 270-315 readings. For each GTS location, photos looking up, down, and horizontally will be taken to assist in describing the site vegetation and understory. To the degree it is possible, the GPS location of each point should be recorded.

Table 24. Sampling regime over BERMS study area for soil moisture and temperature

Sampling points per GTS:	3, GPS points to be supplied
Spacing between points:	5 m (20 m, 25 m and 30 m from the GTS)
Number of readings per point	3 (top, left and right side of measurement point)
Soil moisture measurement depth	Probe inserted vertically, soil moisture is integrated over 6 cm
Soil temperature	Simultaneously to soil moisture
Gravimetric soil moisture	3 samples per GTS
Site Photos	Photos looking up, down, and horizontally

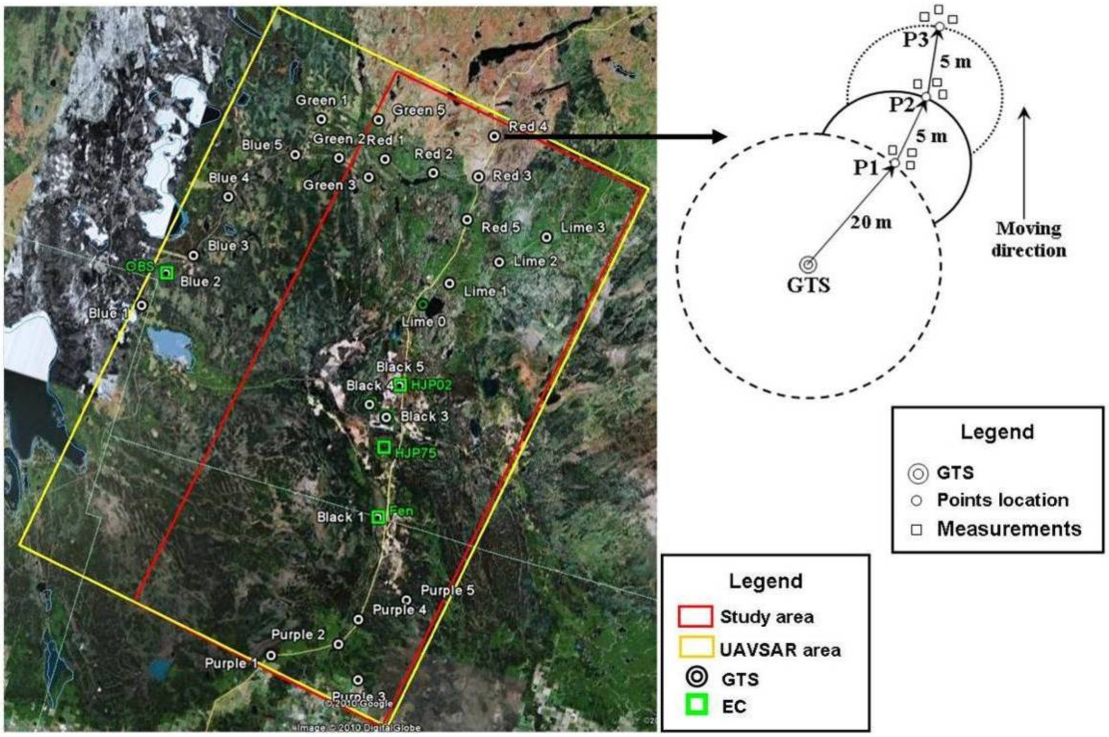


Figure 36. GTS sampling strategy. For each GTS location, soil moisture measurements will be conducted within the surrounding canopy at 3 points (P1, P2, and P3) located at a nominal distance of 20, 25, and 30 m from the indicated GTS site. For each point, 3 Hydra probe readings will be collected at the squares locations.

Gravimetric soil moisture

For each GTS location, 3 gravimetric soil moisture samples will be collected;one at each measurement point and simultaneously to the 2nd Hydra probe reading. Also, gravimetric samples will be collected at each BTN installation and removal for BPN verification and its use for large scale soil moisture estimation.

The procedure for these volumetric and gravimetric soil moisture measurements is as follows:

- Use GPS to record GTS coordinates, if possible.
- Volumetric soil moisture measurements will be stored in the PDA or Hydraprobe reader, and also transcribed on data sheets to be collected at the end of the day. Soil temperature to be recorded on data sheets.
- Collect 3 gravimetric samples for each GTS (one at each measurement point and simultaneously to the 2nd Hydra probe reading)
- Coverage photos to be taken at each GTS. Each team is responsible for labeling the photographs of each GTS with ID, date taken, and direction of photo if feasible.

- There will be 7 or 8 soil moisture sampling teams, 5 GTS locations each. With 9 readings per GTS, about 315-360 readings will be collected over the entire area.

Soil bulk density

Soil bulk density at different depths is available from BERMS ecological datasets for the research sites OBS, OJP, H75, H94 and H02 (all except the FEN research sites).
During the 1-day sampling, measurements of soil bulk density will be conducted over BERMS study area. Bulk density samples over BERMS may be complicated by the presence of an organic layer of variable thickness. Collection of the bulk density sample will be similar to the method described over the Kenaston site after the organic layer is measured and removed.

5.1.2.2. Vegetation

Background

The SMAP team seeks to investigate the retrieval of soil moisture in boreal landscapes using L-band active/passive microwave remote sensing and to asses freeze/thaw processes as related to land-atmosphere carbon exchange in boreal ecosystems. During the June 2010 CanEx-SM10 field campaign, active/passive microwave aircraft and satellite data will be collected over of a sub-region of the BOREAS/BERMS study area in Saskatchewan, Canada (Section 5.1.1). A series of physically-based backscatter and emissivity models will be employed to a) support analysis of the relationships between soil moisture, land cover, and remote sensing signatures and b) to assess the performance of the SMAP algorithms as applied in a boreal landscape. The forward modeling analysis will enable examination of soil moisture retrieval error based on land cover characteristics. The purpose of this Vegetation Measurement Protocol is *to quantify the vegetation structure and moisture properties to support analysis of the links between the land cover and remote sensing data sets, as related to assessment of the SMAP algorithm performance, and to provide a sound combination of datasets and respective systematic land cover information*. This protocol focuses on characterization of the vegetation cover.

Summary of forward model vegetation input parameters

- Fraction of vegetation cover
- Trees per unit area
- Height from ground to canopy bottom (trunk layer)
- Height of canopy/crown
- Trunk size (diameter)
- Tree height
- Branch, leaves/needles diameter
- Branch, leaves/needles length
- Branch, leaves/needles density
- Branch, leaves/needles orientation
- Branch, leaves/needles, trunk volumetric water content
- Dielectric properties for trunk, branches, leaves/needles

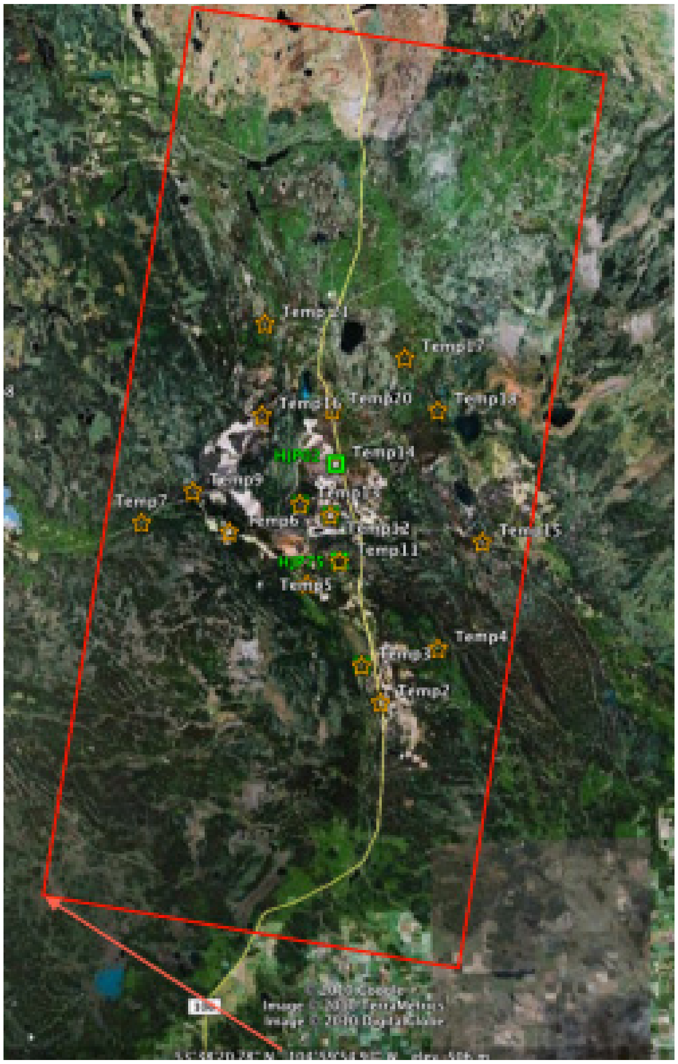


Figure 38. BERMS site with "temporary" soil moisture sampling sites (Temp #).

Approach

The number of samples of each input parameter is determined based on a combination of: A) model sensitivity to the parameter (non-additive, non-linear, dynamic interactions); B) heterogeneity of each parameter in the field; C) time and resource limitations.

Our approach is to conduct these measurements at the 20 "temporary" soil moisture sites (BTN sites where ~3 months of soil moisture sampling will be

a)
b)
c)

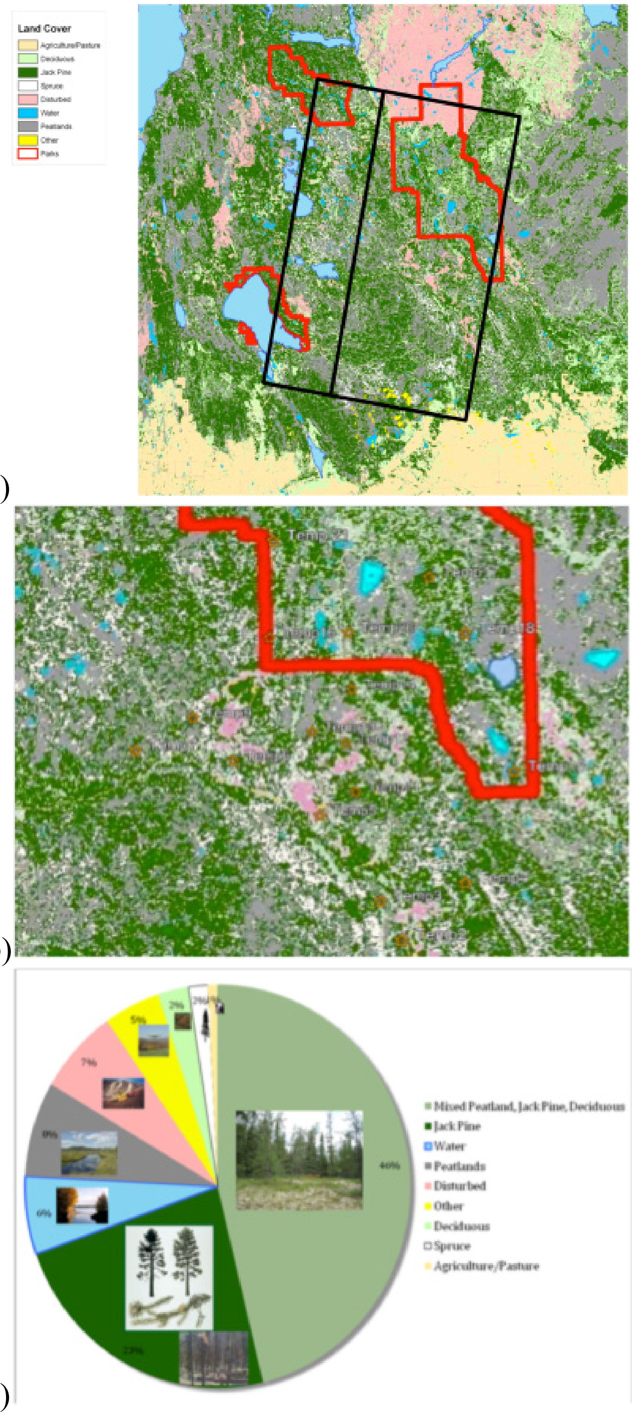


Figure 37. a) Land cover classification; b) zoom to sites; c) frequency distribution. The sites (b) are situated on 56% mixed (9/16), 25% Jack Pine (4/16), 13% Deciduous (2/16), and 6% disturbed (1/16).

on-going during 2010; Figure 38). However, given the time and resource limitations, we will concentrate our efforts at 12 of these sites with primary consideration to representation of land cover distribution, as determined from remotely sensed land cover and tree height maps[1] (Figure 37abc and 39abc), and accessibility.

According to the maps, the temporary sites are adequately representative of the land cover distribution (should be ground verified). An additional site will be needed to include peatland areas. Otherwise, the majority of the sites are in mixed areas, of which six (of the current nine) sites will be selected for vegetation measurement: sites 2, 3, 6, 7, 15, and 21.Three (of the current four) Jack Pine dominated sites will be used: sites 4, 14, and 17. One (of the current two) deciduous sites will be used: site 13. Finally, the one (of one) disturbed site will be used: site 5. This totals to 12 sites. A preliminary selection of sites is shown in Figure 40 and Table 25.

Josh Fisher will make an initial assessment of the sites on June 14-16, 2010 while conducting dielectric constant measurements during the overpass flights. The exact sites will be decided upon after the initial assessment. During this June period Mahta Moghaddam and 2 of her students will conduct the vegetation sampling at as many sites as time allows. Josh Fisher, Kyle McDonald, Erika Podest and Mahta Moghaddam (and/or one of her students) will return to the sites on July 13-20, 2010 to complete the vegetation sampling.

The first 4 days (July 14, 15, 16, 17) will be dedicated to broad sweeping, transect-based measurements of forest properties: DBH (m, at 1.3 m), tree height (m), height to crown (m), LAI (m^2 m^{-2}), branch area index (m^2 m^{-2}), stem density (# $area^{-1}$), species identification (species, genus, family),fractional overstory cover (m^2 m^{-2}), fractional understory vegetation cover (m^2 m^{-2}),

a) b) c)

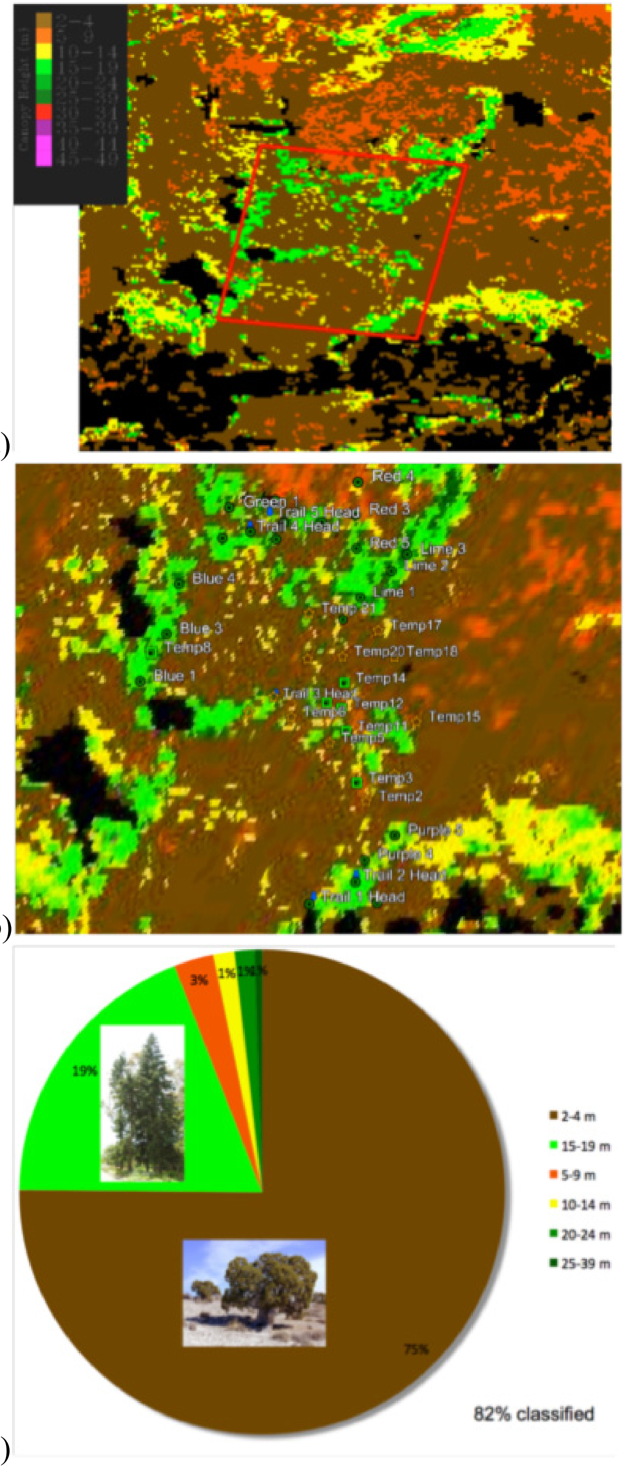


Figure 39. a) Tree height classification; b) zoom to sites; c) frequency distribution. The sites (b) are situated on 76% 2-4 m (13/17) and 24% 15-19 m (4/17).

[1] The land cover map is a combination of Landsat 5 TM and Landsat 7 ETM+ provided by the Saskatchewan Research Council. The tree height map is provided by Marc Simard, JPL.

understory depth (m), fractional necromass cover (m^2 m^{-2}), and litter depth (m). We will conduct three 100 m transects per site, equi-angled from the centroid of the site, taking measurements within 1.5 m (~5 ft) of the transect line on either side. Trees considered more than half within that buffer will be included, and vice versa. The values per 300 m^2 will be scaled up to the whole site linearly.

The final 2 days (18, 19) will be dedicated to detailed measurements of canopy characteristics at a sub-set of the sites: needle/leaf area (m^2), wet and dry mass (kg), angle/orientation (deg), shape (descrip); branch diameter (m), length (m), wet and dry mass (kg), angle/orientation (deg), primary and secondary density (# $area^{-1}$). The trees chosen will be 3 trees per site (i.e., of the 12 sites) representing the range of species, physiological and environmental characteristics present.

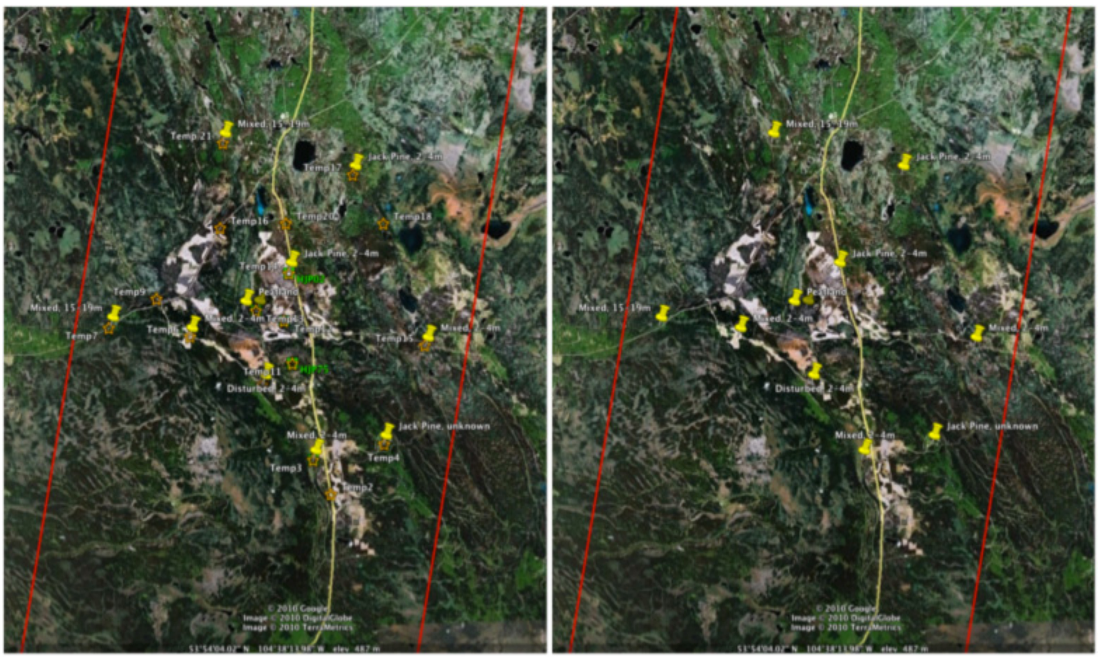


Figure 40. Proposed vegetation sampling sites (yellow pins) superimposed on soil moisture sites (left, orange stars) and alone (right).

The data will be processed by Josh Fisher and made available to members of the CanEx – SM10 team. Specifically, the data will be used by Sab Kim to ingest into the L2_SM_A algorithm development and radar backscatter forward model.

Table 25. Site selection representation relative to images analysis.

Land Cover	Image	Sites
Mixed	46%	50%
Jack Pine	23%	25%
Peatland	8%	8%
Disturbed	7%	8%
Deciduous	2%	8%
Tree Height		
2 - 4 m	75%	78%
15 - 19 m	19%	22%

Table 26. Vegetation measurement instruments over BERMS

Measurement	Units	Measurement Method, Equipment Required	Equipment Needed (Required Minus Owned)	Expected measurement error
Needle/leaf		Telescoping scissors; pruning shears	NEED	
Density	# m^{-3}	Visual count/estimate	n/a	10%
Dry mass	kg	Oven dried, balance weighed	Have 1 (McDonald)	7%
Length	m	Measuring tape	Have 1 (McDonald)	10%
Mean angle (orientation)	Deg	Compass, inclinometer/altimeter	Have compass (McDonald)	15%
Shape	descrip	Visual identification	(http://en.wikipedia.org/wiki/Leaf_shape)	5%
Wet mass	kg	Field balance	NEED	8%
Branch		Ladder; tree climber; scaffold; saw	NEED	
Branch diameter	m	Measuring tape (steel)	Have 1 (McDonald)	15%
Branch length	m	Measuring tape (steel)	Have 1 (McDonald)	8%
Dry mass	kg	Oven dried, balance weighed	Have (McDonald)	7%
Mean angle (orientation)	Deg	Compass; inclinometer/altimeter	Have 1 (McDonald)	15%
Primary branch density	# m^{-3}	Count	n/a	10%
Secondary branch density	# m^{-3}	Count/visual estimate	n/a	20%
Wet mass	kg	Clippers, field balance	NEED	8%
Tree				
Diameter at breast height (1.3 m, DBH)	m	DBH tape	Have 1 (McDonald)	4%
Dielectric constant (trunk, branches, needles/leaves)	kg m-2	Dielectric constant meter	Have 1 (McDonald)	?
Ground-to-canopy height	m	Laser altimeter/hypsometer	NEED	7%
Species identification	Name	Visual identification	Field guide*	2%
Stem dry wood density	kg m-3	Stem corer/increment borer, oven dried, balance weighed	Have (McDonald)	5%
Tree height	m	Laser altimeter	NEED	10%
Understory (shrubs, herbs, mosses, lichens)				
Dry mass (non-partitioned)	kg	Clippers/pruning shears, oven dried, balance weighed	NEED clippers	15%
Wet mass (non-partitioned)	kg	Clippers, field balance	NEED clippers, field balance	7%
Fractional understory vegetation cover	%	Quadrat, count/estimate	NEED	10%
Species identification	Name	Visual identification	Field guide**	5%
Litter depth	m	Spade, measuring tape & pole	Have (McDonald)	
Forest				
Branch area index	m2 m-2	LAI-2000	NEED [Brenda]	15%
Fractional necromass cover	%	Quadrat, densiometer	NEED	10%
Fractional vegetation cover	%	Quadrat, densiometer, balance, scope, visual ID	NEED	8%
Leaf area index (LAI)	m2 m-2	LAI-2000	NEED [Brenda]	12%
Stem density	# m-2	Measuring tape, wedge prism	Have 1 (McDonald)	7%

* Field guide: “Trees of the Northern United States and Canada” by John Laird Farrar.
**Field guide: XXXXX

Additional equipment required:

- Satellite phone [Brenda]
- GPS units [Brenda]
- Walkie-talkies [Brenda]
- Calculator
- Camera
- Helmet
- Gloves

Hypsometer options:

- Haga altimeter
- Blume – Leiss altimeter
- Suunto clinometer
- Abney level
- Merrit hypsometer

Densiometer options:

- Right-angle prism densiometer
- Spherical drown densiometer

Tools specifications:

- Wheeler pentaprism tree caliper
- Barr + Stroud optical dendrometer
- Relaskop
- Telerelaskop

5.1.3. Aircraft campaigns (flight lines)

Objectives

Airborne microwave measurements over the BERMS forested area will support the validation of SMOS products (L1, L2) and the pre-launch validation of SMAP data as well as the soil moisture retrievals from these two spatial missions. Furthermore, UAVSAR acquisitions aim to develop and validate backscattering forward model over BERMS forested area.

5.1.3.1. Twin Otter acquisitions at BERMS

Simultaneously to the ground measurements and to SMOS overpasses, aircraft campaigns will be conducted over BERMS site following the calendar presented in Section 5.1.1. Figure 41 shows the coverage of the aircraft operations conducted with the Twin Otter flying specifications given in Table 21. The dashed line between waypoints represents the centreline of the 1.4GHz radiometer swath as it flies along.

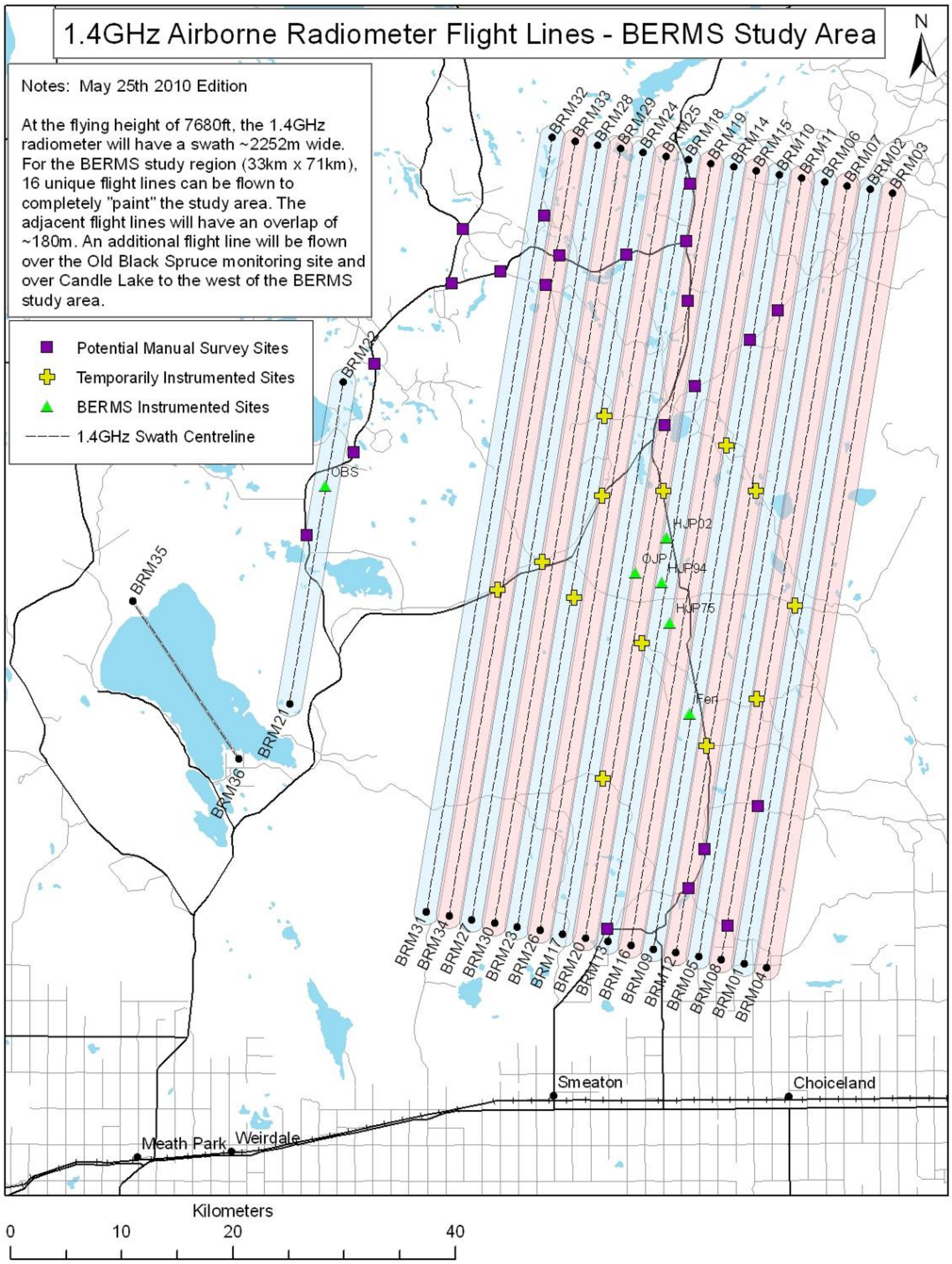


Figure 41. Fight-lines over BERMS study area. EC, BTN and the manual survey sites are represented respectively by the green, yellow and purple marked symbols.

5.1.3.2. UAVSAR acquisitions over BERMS

UAVSAR will provide coverage of BERMS domain with incidence angles of 35-45 degrees. The domain that will be flown by the UAVSAR at BERMS is larger than that of the Twin Otter. The corner coordinates are listed in Table 27.The entire domain will be flown with the same heading in order to reduce confounding effects associated with geometric features. For BERMS this will be a heading of 9.3 degrees. In addition to these lines, one additional line will be flown over BERMS with the reverse heading.

Table 27. Corner coordinates of UAVSAR coverage of BERMS

Longitude (Degrees)	Latitude (Degrees)
-105.066	54.294
-105.223	53.664
-104.321	54.222
-104.502	53.595

5.2. Satellite data coverages

Satellite acquisitions covering completely (or almost) the study site were selected to meet the objectives of CanEx-SM10 (Section 1.2). SMOS, RADARSAT-2, ASAR-Envisat, and ALOS-PalSAR spatial coverages are presented below.

SMOS

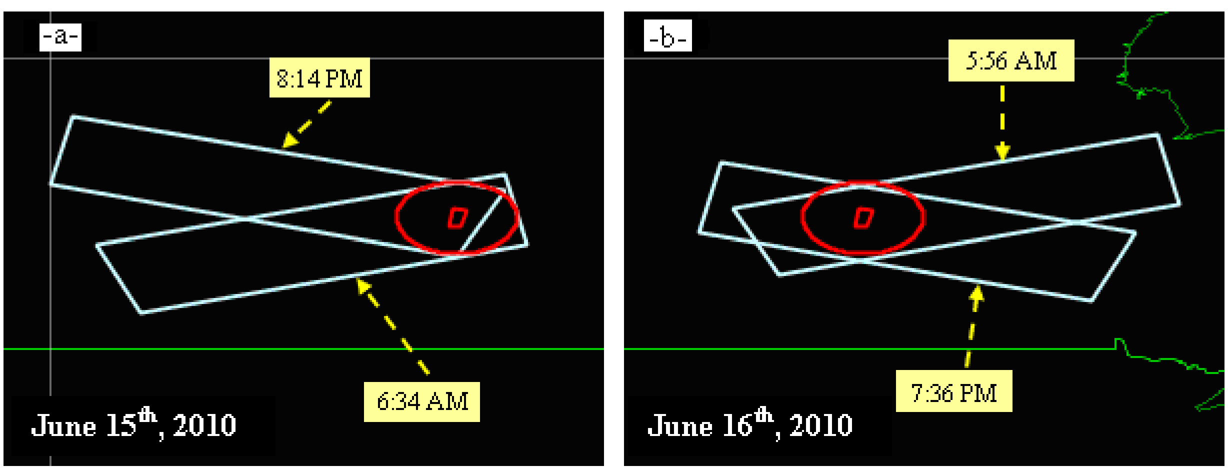


Figure 42. SMOS coverages (blue boxes) over BERMS site (red box) on June 15-16, 2010 (the red circle is an area of 150 km radius around the study site)

RADARSAT-2

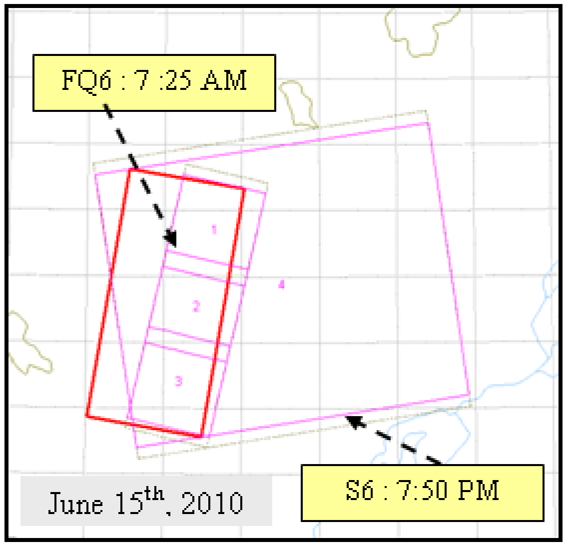


Figure 43. RADARSAT-2 coverages (magenta boxes) over BERMS site (red box) on June 15th 2010

ASAR-Envisat

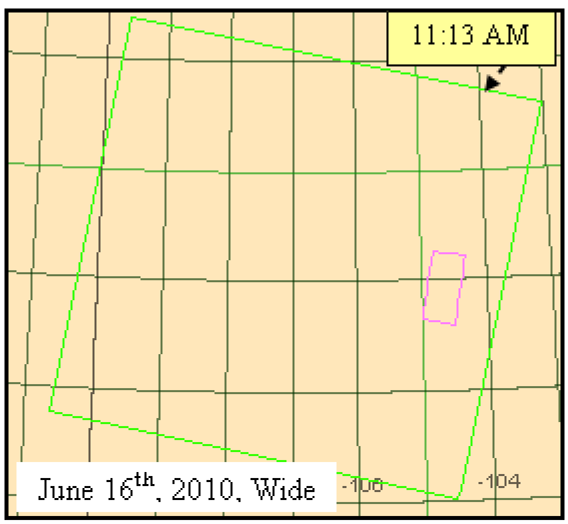


Figure 44. ASAR-Envisat coverage (green box) over BERMS site (magenta box) on June 16th, 2010

ALOS-PALSAR

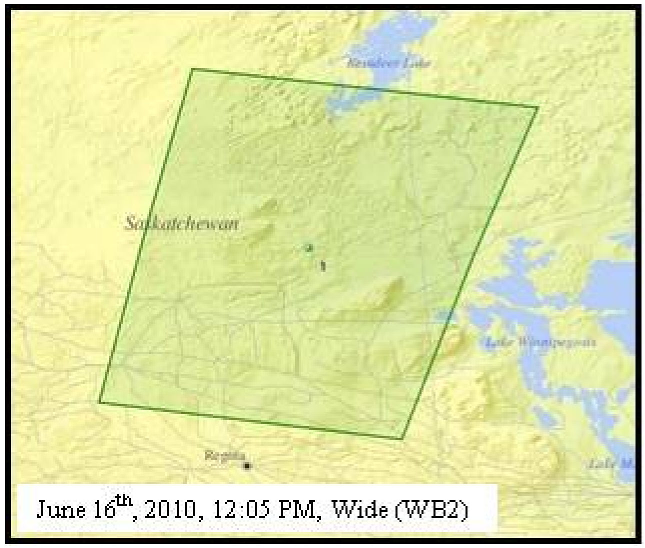


Figure 45. ALOS-PALSAR coverage (green box) over BERMS site on June 16, 2010.

6. Appendix 1

Ground Measurement Protocols

6.1 Field Protocols, general overview on daily activities – Kenaston (KEN)

KEN: June 2, 3 (AMSR), 5 (AMSR), 8, 10 (AMSR), 13,

Departure from base to field	5:30 a.m.
Arrival at site and start sampling o **5 fields per team per overpass** o **Estimate is 40 minutes sampling per field with 30 minutes travel time**	7:00 a.m.
Overpass time	6:00 a.m.
End of sampling and start to base	12:30 p.m.
End of day time and activities	2:00 p.m. o Truck cleanup and organization for next day o Data sheets photocopied and filed o Wet weights on daily soil cores and into oven o Dried soil cores removed from oven, weighed o Data entry (field and lab) and archiving
Debriefing meeting	4:00 p.m. Three centre: airport crew, NHRC, Winnipeg
Data inspection for data review meetings	On down days we should be looking at our data and interfacing with the roughness/veg team. Any fields with new tillage should be reported to Brenda.

Intensive field sampling days	
June 7th (a.m. overpass)	5:30 a.m. departure 6:00 a.m. arrival at field 12:30 p.m. finish in field and start return
June 11th (p.m. overpass)	departure from NHRC 2:00 p.m., 3:30 p.m. arrival at field, 9:00 p.m. finish.

Data review meetings	June 4th 2:00 p.m.
	June 9th 2:00 p.m.

Designated down days (estimated)	June 6th
	June 12

Typical day in the life of roughness/veg team, goal is to sample 3-4 fields per day (5-6 days per week). All fields sampled once or possibly twice

Departure from base to field	5:30 a.m.
Arrival at site and start sampling	7:00 a.m.
End of sampling and start to base	12:30 p.m.
End of day time and activities	2:00 p.m. o Truck cleanup and organization for next day o Data sheets photocopied and filed o Wet weights on daily vegetation samples and into oven o Dried vegetation removed from oven, weighed o Data entry (field and lab) and archiving
Debriefing meeting	4:00 p.m.
Data inspection	The soil roughness teams should provide daily updates on progress to Brenda. If fields are tilled during the campaign, the soil moisture team be reporting which fields need reassessment

Typical day in the aircraft teams, operations out of Saskatoon
Sonde data from Hanley base will be available to flight team
Links to appropriate forecast products will be made available on the CanEx-sm10 google site

Departure from base to field	5:30 a.m. flight departure
Arrival at site and start sampling	6:30
End of sampling and start to base	2:00 p.m. to 3:00 p.m.
End of day time and activities	3:00 p.m. to 4:00 p.m.
Debriefing meeting (operational weather, enhanced 5 day forecasts available)	4:00 p.m.

Daily Briefing – 4:00 p.m. daily with backup teleconference line
Phone number: 1-877-413-4788
Access code: 4324277
Aircraft (both EC and UAVSAR will have go/no go by 5:00 p.m. each day)

Component	**Person**
Past 24 hr radar precip products	Dave Patrick, EC Winnipeg
1 – 2 day forecasts, including severe weather, interpreted forecasts for aviation, enhanced 5 day forecasts.	Brian Wiens, Neil Taylor, Larry Flysak, Brian Bukowsky, Wpg severe weather office. • Bruce Cole - laptop and telus air card for real time radar data in field. • Internet site with forecast links for easy access • Sonde data from Hanley base operations • Weather radios (5) and lightning detector (1) in field
Aircraft	Anne Walker (EC) Tom Jackson (UAVSAR) Take off time is: 5:30 a.m.
Soil moisture	Brenda Toth
Soil roughness/vegetation teams	Ramata Magigi

Adverse weather and emergency contact numbers/protocols

Local RCMP	
Person (s) responsible for campaign day cancelled	Aaron Berg, Brenda Toth, Ramata Magagi, Tom Jackson, Anne Walker
Adverse weather – campaign day cancelled	**Calling tree – based on 4 person teams established in training** Team member 1 – Team member 2 – Team member 3 – Team member 4 –
Person(s) responsible for in field stand downs o **Any person in the field may report to one of these for adverse weather (hard rain, hail, thunder/lightning)** o **Bruce Cole will be centred in Hanley and is the designated field safety officer.**	Bruce Cole: Ramata Magagi: 819-580-1446 Aaron Berg: 519-830-3953 Craig Smith Danette Bilodeau Brad Williams Erica Keet Brenda Toth: 306-222-1119
Adverse weather – stand down	**Calling tree – based on 4 person teams established in training** Team member 1 – Team member 2 – Team member 3 – Team member 4 –

6.2. Soil Moisture measurements, Kenaston (KEN)

Soil moisture is measured with a Steven's HydraProbe and reader (or PDA). All soil moisture readings should be noted on field worksheets. Section 6.2.2 illustrates the field worksheet for the 14 point survey that is conducted on the overpass/flight days. There is another set of worksheets that will be used for the intensive soil moisture monitoring days of June 7 and 11th in section 6.2.3

6.2.1. Soil moisture probe instructions

<u>Reader Operation Manual</u>

1. Turn on reader; *ON/OFF*.
   - Will display: 'Stevens Water Reader'
     '(Soil type) Ready to Read'

2. To select type of soil use <, >, for Sand, Silt or Clay

3. If you press *READ*, the soil measurement will be displayed but it will not be saved.

4. To save data, press *FUNCTION FUNCTION*. Logging will be turned on. Then to take measurements press *READ* for Temperature and Soil Moisture and *READ* again for Soil Salinity and Soil Conductivity. To return to logging mode use *READ* or *FUNCTION*. (Note: after the temperature and soil moisture measurements are logged and displays the only button that works is *READ*)
   - *FUNCTION FUNCTION* will display: 'Logged # Ready to log'
   - *READ* will display: 'Wait Reading Probe…'
     'TC, TF, WaterWFC'
   - *READ* again will display: 'NaCl, SoilC'
   - *READ/FUNCTION* will display: 'Ready to read and log'
   - Note: if it is displaying voltages, it is not saving the data. You need to press *FUNCTION* one more time in ready mode.

5. Continue pressing *READ* to log more samples.

6. When you change location, use the ^,˅ to change the location.
   - This will display the site number.
   - Any measurements saved after changing the site number will be logged with that site number.

7. To cancel logging mode press *ON/OFF*. This will return to Reading mode.

8. To turn reader off, press *ON/OFF*, once in reading mode.

9. If you are in Reading mode and you only press *FUNCTION* once, this will still be in reading mode but when you press *READ* it displays the Voltages instead of the Temperature, Soil Moisture, Soil Salinity and Soil Conductivity.

Soil Moisture Protocols (including bulk density)

1. Please be sure to indicate your reader or unit number, field ID, crop type and start date/time on your sheet. Set your reader or PDA to the loam setting.

2. Using your pre-supplied GPS coordinate, walk to the first point in the field (paint marker). Use the field diagram to indicate the relative position of the datalogger (if available), the road, a north arrow, start and end points (1 and 14) and other identifying or significant features on the field diagram.

3. At each point (1, 2 …7) in each transect, take three measurements. Ensure that you step squarely on the foot rest of the probe holder and that you have good contact with the soil. You may need to brush aside or scrape away any surface debris to get good contact.

4. Take a soil moisture reading (store and mark on data sheet) three times, top, bottom and side of furrow. Also take a GPS reading

5. At points 1, 7, 8 and 14, record a soil temperature reading (make good contact and allow the device to equilibrate for 1 minute).

6. At points in the field that represent exposed vegetation, shaded vegetation, exposed ground and shaded ground, please take a TIR measurement and record.

7. At one point in the field take a bulk density soil core

    a. spray core with Pam, and sharp edge down push core squarely into the soil (you can use your foot, hammer as shown, 2 x 4, or sledge).

b. If the core is not square or there is significant compaction (inside of core soil level is lower than field), please start again
c. Excavate around the soil core using trowel, you will need to dig past the bottom of the core

d. Twist the soil core to break the bottom
e. Insert the trowel at an angle below the bottom of the soil core and remove the entire core with excess soil at the bottom.
f. If the soil core comes away with missing soil at the top or bottom, start again.
g. Very carefully trim soil in the core level with the bottom of the core.

h. Remove the soil from the coring device and place in a Ziploc bag, ensure that all of the soil is retained. If soil is dropped and cannot be accurately retrieved, start again.

i. Ensure the Zip-lock bag is identified (field ID, date and initials).

8. Please record any pertinent details such as if the field is wet with dew and when it dried, if there were any small showers, if there was evidence of recent tillage or spray, (there will be widely spaced tracks in the field).

9. Record your end time on your data sheet.

10. At one point in the field, take a photo of the completed field diagram from the soils data sheet and then take a photo of the field in the direction of the crop row or tillage direction.

6.2.2. Data Sheets for Soil Moisture – KEN general overpass

See next page

KEN Soil Moisture Worksheet - General Overpass and Flight Days
Soil Moisture Observation Team and Reader# ________________________________

Field Identifier and crop type	Start Date/Time:	End Date/Time:

Note: Transects are 400 m apart, measurements are in increments of 100 m. Start of transect is 50 m into field from top or bottom and 100 m in from 'left' of diagram on next page
Use the GPS to find approximate point location, with exact point marked by paint.
All readings to be stored in the HydraReader (set to loam) or PDA as well as readings noted below

Transect 1		**Transect 2**	
Soil moisture	GPS/Soil Temperature	Soil moisture	GPS/Soil Temperature
1a	E	8a	E
1b	N	8b	N
1c	**Temp ºC at 5 cm** **Temp ºC at 10 cm**	8c	**Temp ºC at 5 cm** **Temp ºC at 10 cm**
2a	E	9a	E
2b	N	9b	N
2c		9c	
3a	E	10a	E
3b	N	10b	N
3c		10c	
4a	E	11a	E
4b	N	11b	N
4c		11c	
5a	E	12a	E
5b	N	12b	N
5c		12c	
6a	E	13a	E
6b	N	13b	N
6c		13c	
7a	E	14a	E
7b	N	14b	N
7c	**Temp ºC at 5 cm** **Temp ºC at 10 cm**	14c	**Temp ºC at 5 cm** **Temp ºC at 10 cm**

TIR (all temps in ºC)

Exposed veg	Shaded veg	Exposed Ground	Shaded Ground

General Observations

Dew Start	Dew End	Tillage or Spray?		

Bulk Density sample (note field ID, date taken, survey point and initials on bagged sample

Survey Point	Probe reading 1	Probe Reading 2	Probe reading 3

Please mark on diagram

______ Field ID, date, initials

______ start point (point 1)

______ end point (point 14)

______ location of road

______ datalogger (if applicable)

______ direction of tillage or crop growth

______ north arrow

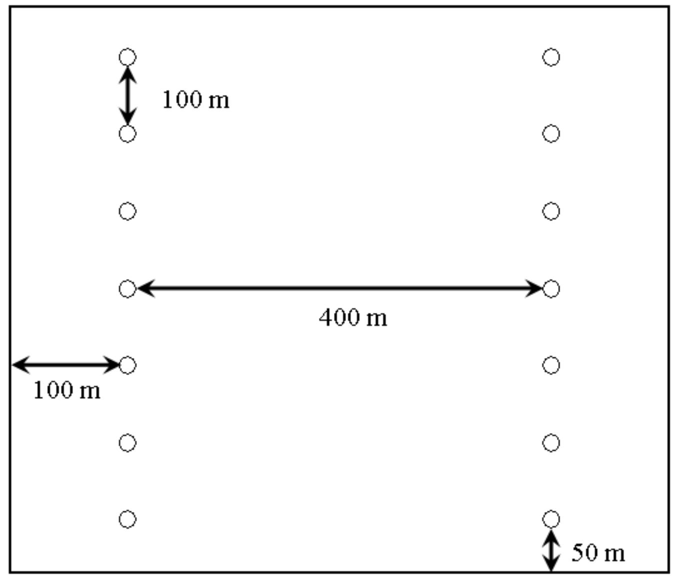
______ location of bulk density sample

______direction and location of photo

______ general observations

And also please note if there has been tillage or roughness changes since the last visit. YES/NO (circle one)

Photograph this diagram to ID field photos



Field ID:______________________

Date: ______________________

Initials: ______________________

At the end of every day the observation team is responsible for photocopying the field notes and filing in the observations binder. Remove dried soil from the oven and record dry+tare weights. Tare and record tare weight and ID of a drying tin, place wet soil in drying tin, wet weigh your soil cores, and record wet weight+tare on the data sheet in lab. Place container+soil in the oven. Download all soil moisture data, download all photos, and copy to the central data drive.

Adverse weather and emergency contact numbers/protocols

Local RCMP	
Person (s) responsible for campaign day cancelled	**Stephane Belair, Tom Jackson, Ramata Magigi, Brenda Toth Anne Walker,**
Adverse weather – campaign day cancelled	**Calling tree – based on 4 person teams established in training**
Person(s) responsible for in field stand downs o **Any person in the field may report to one of these for adverse weather (hard rain, hail, thunder/lightning)**	Aaron Berg: 519-830-3953 Ramata Magagi: Brenda Toth: 306-222-1119 Danette Bilodeau Brad Williams Craig Smith Co-op Student Bruce Cole Erin Thompson (even days) Dell Bayne (odd days)
Adverse weather – stand down	**Calling tree – based on 4 person teams established in training**

6.2.3. Data Sheets for intensive KEN soil moisture survey days, June 7 (a.m.) and June 11 (p.m.)

See next page

June 7, 2010

KEN Soil Moisture Worksheet - Intensive Monitoring
Soil Moisture Observation Team and Reader#

____

Field Identifier and crop type	Start Date/Time:	End Date/Time:

Please mark on diagram

_______ Field ID, date, initials

_______ start point (point 1)

_______ points 14, 27

_______ end point (point 52)

_______ location of road

_______ datalogger (if applicable)

_______ direction of tillage or crop growth

_______ north arrow

_______ location of bulk density sample

_______direction and location of photo

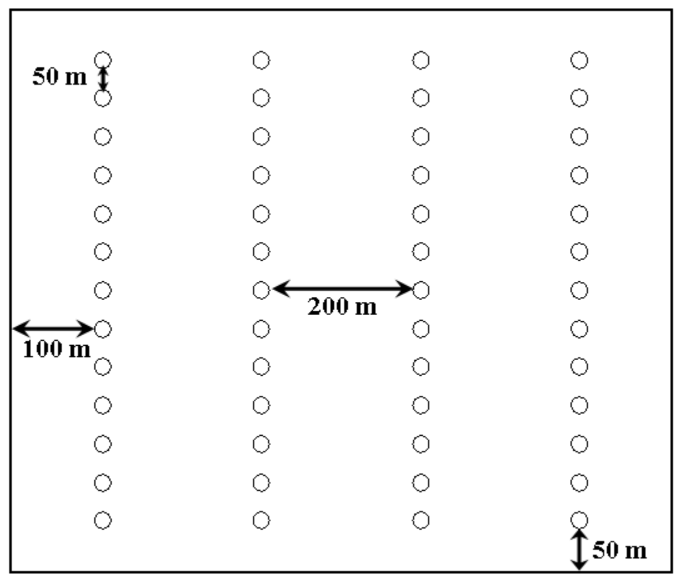
_______ general observations

Photograph this diagram to ID field photos

Field ID:________________________

Date: ________________________

Initials: ________________________



General Observations

Dew Start	Dew End	Tillage or Spray?		

Use the GPS to find a point location,
All readings to be stored in the HydraReader (set to loam) or PDA as well as readings noted below:

Transect 1		Transect 2	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
1 top	E	14 top	E
1 bottom	N	14 bottom	N
1 side		14 side	
2 top	E	15 top	E
2 bottom	N	15 bottom	N
2 side		15 side	
3 top	E	16 top	E
3 bottom	N	16 bottom	N
3 side		16 side	
4 top	E	17 top	E
4 bottom	N	17 bottom	N
4 side		17 side	
5 top	E	18 top	E
5 bottom	N	18 bottom	N
5 side		18 side	
6 top	E	19 top	E
6 bottom	N	19 bottom	N
6 side		19 side	
7 top	E	20 top	E
7 bottom	N	20 bottom	N
7 side		20 side	
8 top	E	21 top	E
8 bottom	N	21 bottom	N
8 side		21 side	
9 top	E	22 top	E
9 bottom	N	22 bottom	N
9 side		22 side	
10 top	E	23 top	E
10 bottom	N	23 bottom	N
10 side		23 side	
11 top	E	24 top	E
11 bottom	N	24 bottom	N
11 side		24 side	
12 top	E	25 top	E
12 bottom	N	25 bottom	N
12 side		25 side	
13 top	E	26 top	E
13 bottom	N	26 bottom	N
13 side		26 side	

Transect 3		Transect 4	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
27 top	E	40 top	E
27 bottom	N	40 bottom	N
27 side		40 side	
28 top	E	41 top	E
28 bottom	N	41 bottom	N
28 side		41 side	
29 top	E	42 top	E
29 bottom	N	42 bottom	N
29 side		42 side	
30 top	E	43 top	E
30 bottom	N	43 bottom	N
30 side		43 side	
31 top	E	44 top	E
31 bottom	N	44 bottom	N
31 side		44 side	
32 top	E	45 top	E
32 bottom	N	45 bottom	N
32 side		45 side	
33 top	E	46 top	E
33 bottom	N	46 bottom	N
33 side		46 side	
34 top	E	47 top	E
34 bottom	N	47 bottom	N
34 side		47 side	
35 top	E	48 top	E
35 bottom	N	48 bottom	N
35 side		48 side	
36 top	E	49 top	E
36 bottom	N	49 bottom	N
36 side		49 side	
37 top	E	50 top	E
37 bottom	N	50 bottom	N
37 side		50 side	
38 top	E	51 top	E
38 bottom	N	51 bottom	N
38 side		51 side	
39 top	E	52 top	E
39 bottom	N	52 bottom	N
39 side		52 side	

June 11, 2010 - coarse

KEN Soil Moisture Worksheet - Intensive Monitoring
Soil Moisture Observation Team and Reader#

____

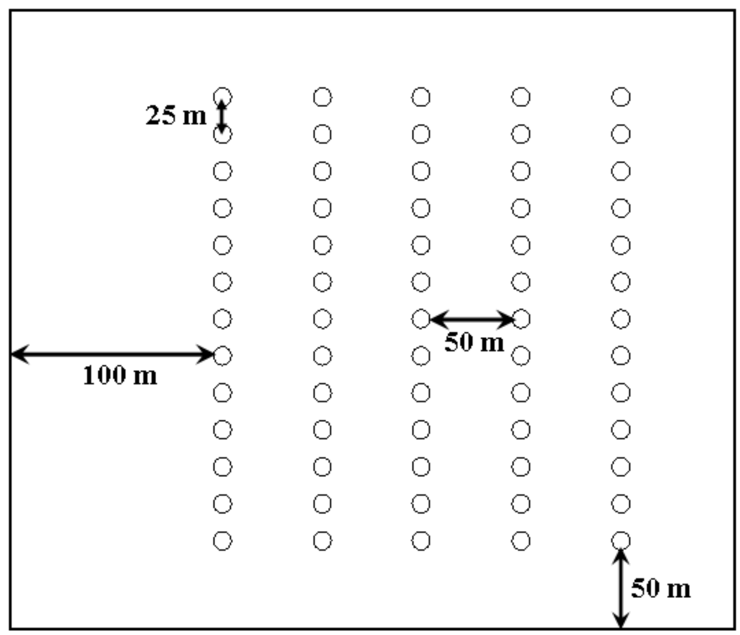
Field Identifier and crop type	Start Date/Time:	End Date/Time:

Photograph this diagram to ID field photos

Field ID:________________________

Date: ________________________

Initials: ________________________



Please mark on diagram

_______ Field ID, date, initials

_______ start point (point 1)

_______ points 14, 27, 52

_______ end point (point 65)

_______ location of road

_______ datalogger (if applicable)

_______ direction of tillage or crop growth

_______ north arrow

_______ location of bulk density sample

_______direction and location of photo

_______ general observations

General Observations

Dew Start	Dew End	Tillage or Spray?		

Use the GPS to find a point location,
All readings to be stored in the HydraReader (set to loam) or PDA as well as readings noted below:

Transect 1		Transect 2	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
1 top	E	14 top	E
1 bottom	N	14 bottom	N
1 side		14 side	
2 top	E	15 top	E
2 bottom	N	15 bottom	N
2 side		15 side	
3 top	E	16 top	E
3 bottom	N	16 bottom	N
3 side		16 side	
4 top	E	17 top	E
4 bottom	N	17 bottom	N
4 side		17 side	
5 top	E	18 top	E
5 bottom	N	18 bottom	N
5 side		18 side	
6 top	E	19 top	E
6 bottom	N	19 bottom	N
6 side		19 side	
7 top	E	20 top	E
7 bottom	N	20 bottom	N
7 side		20 side	
8 top	E	21 top	E
8 bottom	N	21 bottom	N
8 side		21 side	
9 top	E	22 top	E
9 bottom	N	22 bottom	N
9 side		22 side	
10 top	E	23 top	E
10 bottom	N	23 bottom	N
10 side		23 side	
11 top	E	24 top	E
11 bottom	N	24 bottom	N
11 side		24 side	
12 top	E	25 top	E
12 bottom	N	25 bottom	N
12 side		25 side	
13 top	E	26 top	E
13 bottom	N	26 bottom	N
13 side		26 side	

Transect 3		Transect 4	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
27 top	E	40 top	E
27 bottom	N	40 bottom	N
27 side		40 side	
28 top	E	41 top	E
28 bottom	N	41 bottom	N
28 side		41 side	
29 top	E	42 top	E
29 bottom	N	42 bottom	N
29 side		42 side	
30 top	E	43 top	E
30 bottom	N	43 bottom	N
30 side		43 side	
31 top	E	44 top	E
31 bottom	N	44 bottom	N
31 side		44 side	
32 top	E	45 top	E
32 bottom	N	45 bottom	N
32 side		45 side	
33 top	E	46 top	E
33 bottom	N	46 bottom	N
33 side		46 side	
34 top	E	47 top	E
34 bottom	N	47 bottom	N
34 side		47 side	
35 top	E	48 top	E
35 bottom	N	48 bottom	N
35 side		48 side	
36 top	E	49 top	E
36 bottom	N	49 bottom	N
36 side		49 side	
37 top	E	50 top	E
37 bottom	N	50 bottom	N
37 side		50 side	
38 top	E	51 top	E
38 bottom	N	51 bottom	N
38 side		51 side	
39 top	E	52 top	E
39 bottom	N	52 bottom	N
39 side		52 side	

Transect 5	
Soil moisture	**GPS**
53 top	E
53 bottom	N
53 side	
54 top	E
54 bottom	N
53 side	
55 top	E
55 bottom	N
55 side	
56 top	E
56 bottom	N
56 side	
57 top	E
57 bottom	N
57 side	
58 top	E
58 bottom	N
58 side	
59 top	E
59 bottom	N
59 side	
60 top	E
60 bottom	N
60 side	
61 top	E
61 bottom	N
61 side	
62 top	E
62 bottom	N
62 side	
63 top	E
63 bottom	N
63 side	
64 top	E
64 bottom	N
64 side	
65 top	E
65 bottom	N
65 side	

June 11, 2010 - fine

KEN Soil Moisture Worksheet - Intensive Monitoring
Soil Moisture Observation Team and Reader#

____

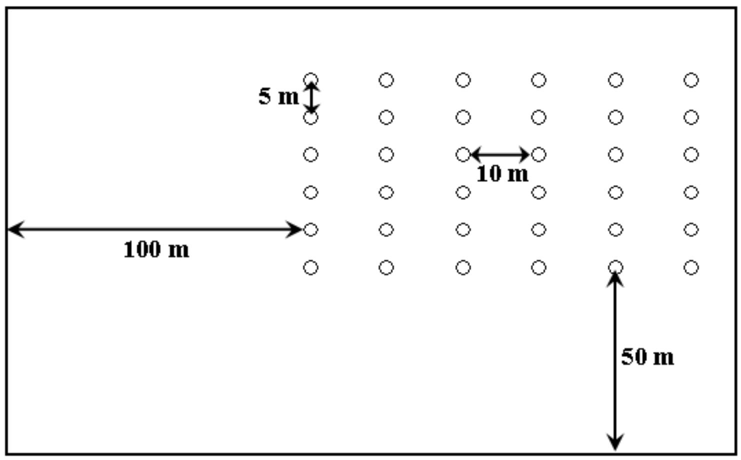
Field Identifier and crop type	Start Date/Time:	End Date/Time:

Photograph this diagram to ID field photos

Field ID:________________________

Date: ________________________

Initials: ________________________



Please mark on diagram

_______ Field ID, date, initials

_______ start point (point 1)

_______ points 7, 13, 19, 25, 31

_______ end point (point 36)

_______ location of road

_______ datalogger (if applicable)

_______ direction of tillage or crop growth

_______ north arrow

_______ location of bulk density sample

_______direction and location of photo

_______ general observations

Use the GPS to find a point location,
All readings to be stored in the HydraReader (set to loam) or PDA as well as readings noted below:

Transect 1		Transect 2	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
1 top	E	7 top	E
1 bottom	N	7 bottom	N
1 side		7 side	
2 top	E	8 top	E
2 bottom	N	8 bottom	N
2 side		8 side	
3 top	E	9 top	E
3 bottom	N	9 bottom	N
3 side		9 side	
4 top	E	10 top	E
4 bottom	N	10 bottom	N
4 side		10 side	
5 top	E	11 top	E
5 bottom	N	11 bottom	N
5 side		11 side	
6 top	E	12 top	E
6 bottom	N	12 bottom	N
6 side		12 side	

Transect 3		Transect 4	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
13 top	E	19 top	E
13 bottom	N	19 bottom	N
13 side		19 side	
14 top	E	20 top	E
14 bottom	N	20 bottom	N
14 side		20 side	
15 top	E	21 top	E
15 bottom	N	21 bottom	N
15 side		21 side	
16 top	E	22 top	E
16 bottom	N	22 bottom	N
16 side		22 side	
17 top	E	23 top	E
17 bottom	N	23 bottom	N
17 side		23 side	
18 top	E	24 top	E
18 bottom	N	24 bottom	N
18 side		24 side	

Transect 5		Transect 6	
Soil moisture	**GPS**	**Soil moisture**	**GPS**
25 top	E	31 top	E
25 bottom	N	31 bottom	N
25 side		31 side	
26 top	E	32 top	E
26 bottom	N	32 bottom	N
26 side		32 side	
27 top	E	33 top	E
27 bottom	N	33 bottom	N
27 side		33 side	
28 top	E	34 top	E
28 bottom	N	34 bottom	N
28 side		34 side	
29 top	E	35 top	E
29 bottom	N	35 bottom	N
29 side		35 side	
30 top	E	36 top	E
30 bottom	N	36 bottom	N
30 side		36 side	

6.3. Soil Roughness, KEN

The surface roughness is measured using a pin profiler and digital camera. Use of a compass is necessary to place the pin profiler in the same direction as the look direction of the following sensors:

RADARSAT2, descending
UAVSAR

NOTE: The look direction is the direction perpendicular to the orbital track or flight line as the SAR is side looking.

RADARSAT 2 perpendicular to descending orbital track:
UAVSAR perpendicular to flight track:

6.3.1 Soil Roughness Instruction

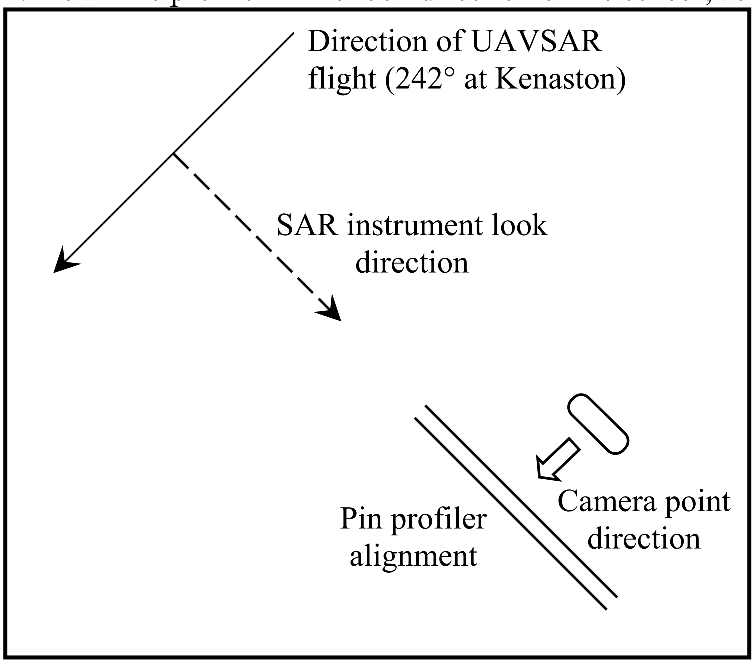
For each field, three replicates will be performed at one site in each field. One replicate is represented as a surface roughness measurement of 3-m length. The 3-m profile is created by taking three 1-metre profile photos immediately adjacent to each other (ie. take one photo, move pin profiler so that the end of profile photo 1 is the beginning of profile photo 2, and so on). Thus for each field, one site is selected and a total of 9 photos (3 adjacent photos x 3 replicates) are collected. A complete set of these 9 measurements will be taken at this one site, per field, in the look direction of each SAR sensor (RADARSAT2 (descending angle), and UAVSAR). Each SAR sensor has a different look direction, thus 18 photos (3 adjacent photos x 3 replicates x 2 look directions) at this one site. If the surface roughness is considered very smooth with no row structure, the roughness team can opt to take one set of measurements (i.e. 9 measurements) to represent the roughness viewed by the two SAR sensors. The pin meter traces the variation of surface height and the information is recorded in a photograph taken with a digital camera (see the figure below). Over each field, the 3 replicates will be made at one site. The photographs of each 3-m profile measurement will be processed with software to derive the values of the roughness parameters s and l, corresponding to the standard height and the correlation length of the site as observed in the look direction of the satellite and of the UAVSAR. Then, the mean and the standard deviation values of the parameters s, l are computed to determine the field roughness.

- 1-m long profilometer will be used to estimate the surface roughness. The profiler is placed end to end 3 times to give a 3-m long profile measurement
- One replicate consists of a 3-m profile parallel to the look direction of each of the SAR sensors; RADARSAT2 (descending) and the UAVSAR sensor.
- 3 replicates, over one site, each replicate approximately 5 m from each other.
- Before taken the photo (10 megapixel camera) of the pins, vegetation is removed (or flattened by using a long cardboard) along this transect so that this vegetation doesn't interfere with the soil roughness measurement,

- It is desirable that the vegetation that is removed shall be used in the vegetation sampling to minimize disturbance.

Pin Profiler and Camera Protocols:

1. With the compass find the look direction of the sensor (account for the magnetic inclination of the study area),
2. Install the profiler in the look direction of the sensor, as shown:



3. Place the metallic bars of 61-cm long at left and right sides of the profiler to identify its location,
4. Place the digital camera on the metallic bar of 127-cm long fixed at the top of the profiler and perpendicularly to it; the distance between the camera and the profiler is ~ 118 cm,
5. Remove the vegetation along the profiler (or flatten it by using a long cardboard) to avoid interference with roughness along the profiler,
6. Use the legs fixed on the back of the profiler to level the profiler (check with the bubble level).
7. Use the hook to slide down the pins,
8. Take the photograph of the tops red pins (see Figure below),
9. Record the photograph number on the worksheets,
10. Turn off the camera and remove it from the 127-cm long metallic bar,
11. Handle horizontally the profiler, one people at each side, and use the hook to replace the pins as they were before they slid down,
12. Use the previous location of the profiler (marked with the 61-cm long metallic bars) to place it end to end, for the next measurement,
13. Repeat the process 3 times to obtain a 3-m long profile measurement.

Notes

The above mentioned dimensions referred to the profilometer used during CanEx-SM10,
Do not install the profiler on a soil surface that is trampled
To avoid damages, handle the device carefully,
Withdraw the damaged pins and replaced them,
Keep a space on both sides of the profiler. This is very important for the photographs processing,
If need, help the pins to slid down,
To avoid interference between the red tops pins and the clothes color during the photographs processing, do not wear red clothes.

6.3.2 Soil Roughness Datasheet, KEN

There will be one set of measurements for each field, three, 3m replicates in the look direction of each of the satellites (RADARSAT2 (descending) and UAVSAR flights) for a total of 18 photos.

A second set of measurements may be necessary during the campaign; the soil moisture team will advise if there appears to be a need to revisit sites because of tillage or change in roughness.

See the next page for the datasheet.

KEN Soil Roughness Observation Team: ______________________________

Field Identifier and crop type	Start Date/Time:	End Date/Time:

RADARSAT2 descending satellite overpass direction: _______ º
The following measurements are perpendicular to this direction.
Row direction is not considered.

Site 1	**Replicate 1** **E________________** **N________________**			**Replicate 2** **E________________** **N________________**			**Replicate 3** **E________________** **N________________**		
Measurement photos (3 m end to end)	**a 0-1m**	**b 1-2m**	**c 2-3m**	**a 0-1m**	**b 1-2m**	**c 2-3m**	**a 0-1m**	**b 1-2m**	**c 2-3m**
Pictures (please note photo numbers)									
Standard height (cm)									
Corrélation length (cm)									
Mean values and std (cm)									

Shaded values are calculated and are not completed in the field

UAVSAR Flight Overpass direction: º
The following measurements are made perpendicular to this direction.
Row direction is not considered.

Site 1	**Replicate 1** **E________________** **N________________**			**Replicate 2** **E________________** **N________________**			**Replicate 3** **E________________** **N________________**		
Measurement photos (3 m end to end)	**a 0-1m**	**b 1-2m**	**c 2-3m**	**a 0-1m**	**b 1-2m**	**c 2-3m**	**a 0-1m**	**b 1-2m**	**c 2-3m**
Pictures (please note photo numbers)									
Standard height (cm)									
Corrélation length (cm)									
Mean values and std (cm)									

Shaded values are calculated and are not completed in the field

At the end of every day the observation team is responsible for photocopying the field notes and filing in the observations binder. Download all photos, and copy to the central data drive.

6.4. Vegetation sampling, KEN

Vegetation sampling takes place along with surface roughness to minimize crop disturbance. Please be as conservative as possible as a measure of respect to the landowner. Remember that these crops represent income to the producers.
The site visits for the roughness/vegetation team need to be performed at the GPS locations given, in 1-2 hours, and the recommended procedure would be:

- team of two arrives at 1st roughness/veg site which will be close to road access. The team takes the 3 roughness replicates (each of 4 sensor directions) as well as biomass sample and measures height and stems at Site one.
- team splits up with one person going to Site 2 and one person to Site 3 to take only the biomass, height and stem measurements
- meet back at vehicle and move to next field.

6.4.1. Biomass sampling and physical plant characteristic measurement instructions

Biomass

- At each site, a gridded board should be placed behind the vegetation and a photo should be taken
- Biomass measurements, 1 m sampling in a row (if row is defined and row spacing data collected), otherwise in 50 cm grids (1 replicate each)
- Wet mass must be determined very quickly, within 2 hours ideally. If samples are contained in a paper bag and then bagged in plastic, the degradation can be slowed enough to do wet weights at the end of the day. If we do not have an extra person to do lab work, we will have to make this the responsibility of the veg sampling team.
- Condensation or dew collected on the vegetation at the time of sampling (common in the early morning hours) should be very gently shaken from the sample prior to bagging. Please note if there is excess condensation that has collected in the bag at the end of the day during the wet weight process.

Physical field and plant characteristics

- Number of replicates dependant on field variability
- Plant height and stem diameter.

Vegetation Protocols

1. Stand Height (cm)

Height will be measured by placing a measuring rod on the soil surface and determining the height of the foliage visually.

2. Stem Diameter (mm)

Use the callipers to measure the diameter of a typical plant taken in the biomass sampling.

3. Row Direction (º)

Use the compass to measure the direction of the rows

4. Row Spacing (cm)

Determine the row spacing by placing a meter stick perpendicular to the crop row and measure the distance between the center of one row and the center of the adjacent row.

5. The number of plants in a 1 m row

Place a meter stick along the row. The meter stick will be placed at the center of a plant stem and that stem counted as the first plant. All plants within the one-meter length are to be counted. Counts are recorded on the sampling sheet.

6. Stand Density

Calculated value using row spacing and the number of plants per row.

7. Green and Dry Biomass

Row Crops: To measure biomass, plants will be cut at the ground surface. All plants for the sampling location (1 m row) will be placed into a paper bag with a label for the sampling site. If the plants are large, it may be necessary to place each plant in to a separate paper bag with a label for the sampling site and row. If the plants are wet with dew, gently shake the vegetation prior to bagging. All samples from a location are then placed a plastic bag (s) for transport to the lab.

Other Types of Vegetation: All vegetation within the specified area (0.5 m x 0.5 m will be cut at ground level. If it is determined that there is a significant thatch layer in grass sites it may be necessary to characterize this as a separate canopy component. Vegetation for the sampling location will be placed into a paper bag with a label for the sampling site. If the plants are wet with dew, gently shake the vegetation prior to bagging. All samples from a location are then placed in a plastic bag(s) for transport to the lab.

Green biomass will be measured by weighing the samples immediately upon return to the lab. Note if there was pooled water in the bag. Dry biomass will be determined after drying the vegetation in ovens at 60C for 48 hours (longer if necessary).

8. Photographs of crop against the gridded white board

Photographs will be taken of the plot area at the time of sampling. These will be collected with a digital camera. A gridded marker board will be used. The field ID, date, time, crop type and sampler initials will be marked on the board for each sample site.

6.4.2. Biomass sampling and physical plant measurement data sheets

See next page

KEN Vegetation Observation Team: ______________________________

Field Identifier and crop type	Start Date/Time:	End Date/Time:

Sample ID	Stand Height (cm)	Plant Diameter (cm)	Row Direction	Row Spacing (cm)	Number of Plants in 1 m row OR plants in 50 cm grid	Stand Density	Green Biomass (g)	Dry Biomass (g)	Vegetation water content (%)

Shaded values are calculated or determined by oven drying.

At the end of every day the observation team is responsible for photocopying the field notes and filing in the observations binder. Remove dried vegetation from the oven and record dry+tare weights. Tare and record tare weight and ID of a drying tin or bag, place wet soil in drying tin or bag, wet weigh your vegetation, and record wet weight+tare on the data sheet in lab. Place container+veg in the oven. Record all vegetation data, download all photos, and copy to the central data drive.

6.4.3. Multispectral sampling instructions and protocol

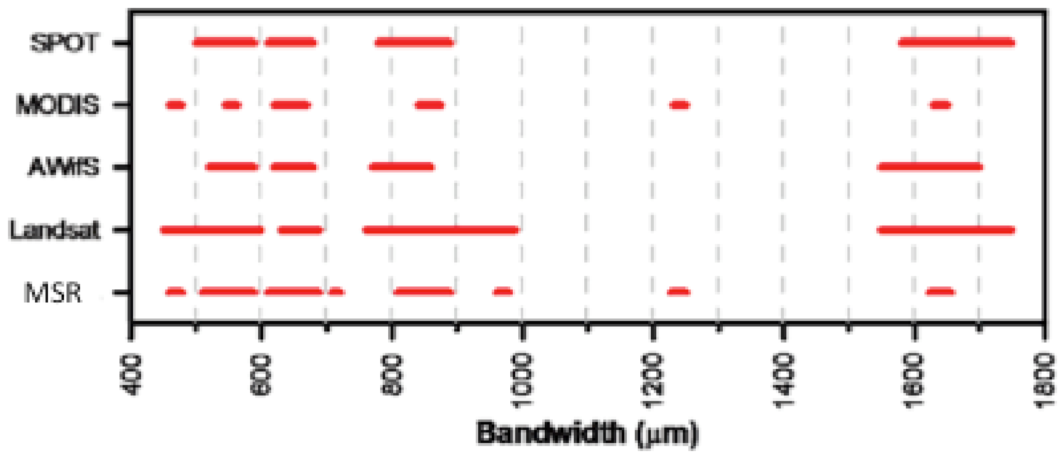
Surface reflectance data is useful for the development of models for estimation of vegetation water content and other vegetation parameters. Observations of surface reflectance made concurrently with the biomass samples will be useful for the development of these models and for upscaling this information to larger scales. Furthermore, if the reflectance measurements are concurrent with satellite overpasses the data can be used for the validation of satellite based reflectance estimates and development of correction algorithms.

For CanEx-SM10, we are using an instrument developed by CROPSCAN (http://www.cropscan.com). The CROPSCAN dual-detector instrument simultaneously measures sunlight and the amount of reflected light thus reducing the number of calibrations. The CROPSCAN Multispectral Radiometer (MSR) has both up-and-down-looking detectors for measurement of sunlight at different wavelengths. The CROPSCAN multispectral radiometer systems consist of a radiometer, data logger controller (DLC) or A/D converter, terminal, telescoping support pole, connecting cables and operating software. The radiometer uses silicon or germanium photodiodes as light transducers. Matched sets of the transducers with filters to select wavelength bands are oriented in the radiometer housing to measure incident and reflected irradiation.

For CanEx-SM10 we will be using a MSR16R unit configured with the following bands:

ID	Centre Wavelength and Bandwidth
MSR16R-470U	470 nm up sensor (10nm BW)
MSR16R-470D	470 nm down sensor (10nm BW)
MSR16R-550U2	550 nm up sensor (40 nm BW)
MSR16R-550D2	550 nm down sensor (40 nm BW)
MSR16R-650U2	650 nm up sensor (40 nm BW)
MSR16R-650D2	650 nm down sensor (40 nm BW)
MSR16R-710U	710 nm up sensor (12 nm BW)
MSR16R-710D	710 nm down sensor (12 nm BW)
MSR16R-850U2	850 nm up sensor (40 nm BW)
MSR16R-850D2	850 nm down sensor (40 nm BW)
MSR16R-970U	970 nm up sensor (10 nm BW
MSR16R-970D	970 nm down sensor (10 nm BW)
MSR16R-1240U	1240 nm up sensor (12 nm BW)
MSR16R-1240D	1240 nm down sensor (12 nm BW)
MSR16R-1640U	1640 nm up sensor (16 nm BW)
MSR16R-1640D	1640 nm down sensor (16 nm BW)

The correspondence of these bands with available optical satellites is shown in the following Figure.

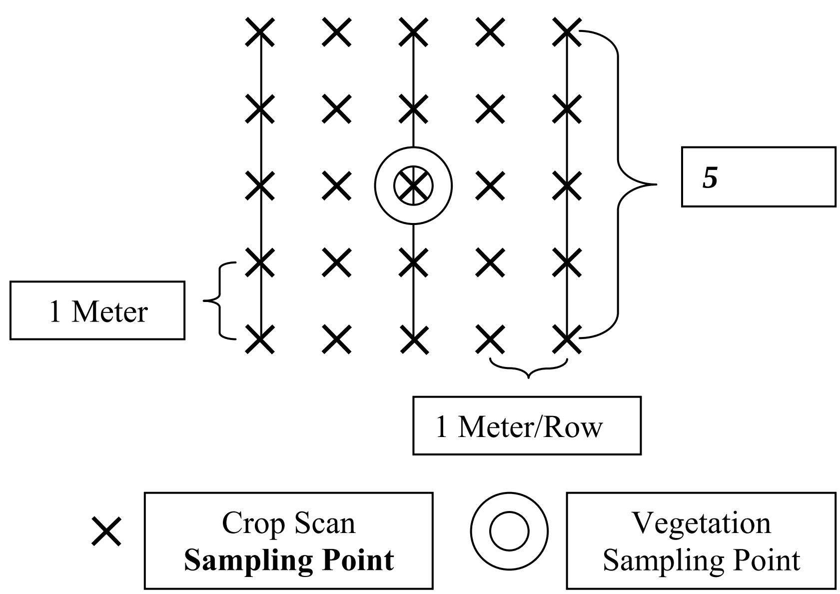


Sampling protocols.

1) Reflectance over Biomass Sample Site

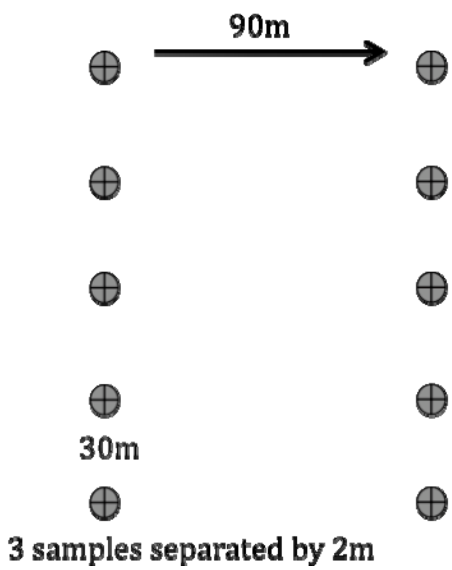
Reflectance data will be collected for each vegetation sampling location (see the Figure below) just prior to removal using the following sampling scheme.

Making sure that the radiometer is well above the plant canopy; take a reading every meter for 5 meters. Repeat, for a total of 5 replications located 1 meter or 1 row apart.



2) Field Transect

Each different land use type (Winter Wheat, pasture, etc.) will be characterized by transect sampling. Reflectance will be collected at representative sites. Reflectance will also be collected over water for calibration purposes. This should be done to coincide with the satellite overpasses. The following sampling scheme will be used for transect sampling:



6.4.4. Multispectral sampling dataSheets

See next page

KEN Multispectral Worksheet
Multispectral Observation Team and Reader#

____

Field Identifier and crop type	Start Date/Time:	End Date/Time:

MSR Field Data Sheet

Date and Time of Day:

Observer:

Data File Name:

General Field and Weather Conditions:

6.4.5. LAI measurement instructions

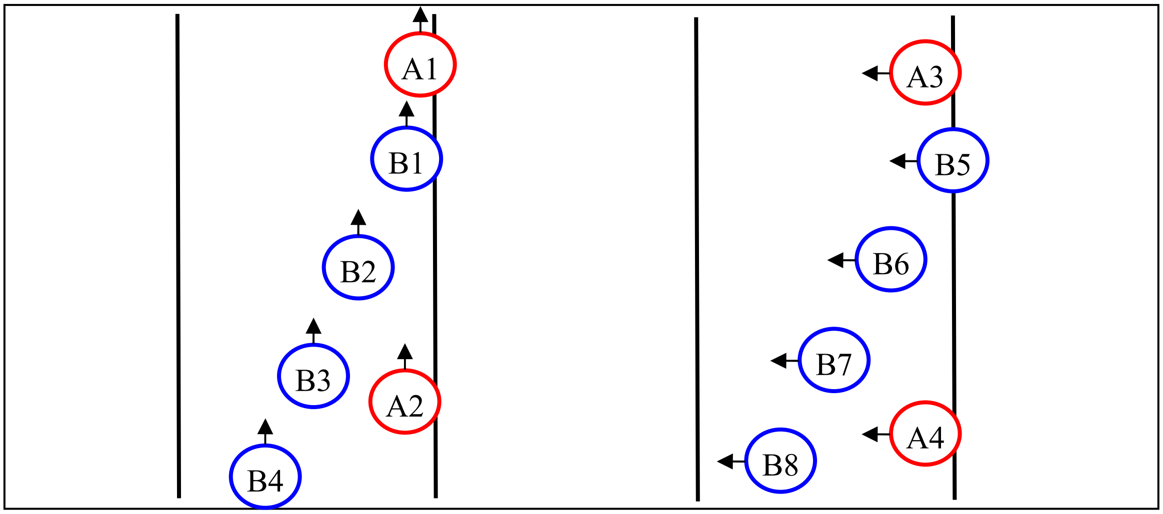
The LAI measurements will be taken using two types of instruments. For every sample site, hemispherical photos will be taken using a Nikon D300S fisheye camera. For sites where crops are sufficiently tall, LAI measurements will also be taken using LAI-2000. This means the height of the canopy is at least five times the width of the plant leaf. In addition, for each sample site, supporting crop architecture photos will also be taken using a regular digital camera. Step by step instructions for the associated measurements are documented bellow.

6.4.5.1 LAI measurement using LAI-2000

LAI-2000 data will need to be acquired during diffuse light conditions or low sun angles. Therefore measurements should be taken early in the morning or later in the evening (not between 10 am and 4 pm).

LAI-2000 Procedures

1). Locate each sample site using GPS
2). Power on
3). LOG: record the plot type (at the WHAT prompt) and the site (at the WHERE prompt). Indicate a suffix for each measurement (PA=parallel; PE=Perpendicular) and number the files 1-6 for each site.
4). Using the 90° optic cover on the lens and ensuring the instrument is level, collect an above canopy reading. Take four below-canopy readings making sure to keep facing parallel to the rows; one inside the row, one ¼ across the row, one ½ way across the row, and one ¾ across the row (B1, B2, B3, B4). Walk along the row a few steps in between measurements (see Figure below). Complete this file with a second above-canopy reading.
5). Start a new log file for the same site, and take another above canopy measurement facing perpendicular to the rows. Still facing perpendicular to the rows, take four below-canopy readings just as in Step 4 (B5, B6, B7, B8). Complete the log file with a second above-canopy reading.
6). Walk approximately 5 m (5-7 steps) along the row and repeat this sequence. Collect a total of 6 sets of measurements along a row transect (3 parallel to the row and 3 perpendicular to the row).
7). Power off (FCT 09)



Parallel and perpendicular sample design for each measurement set for LAI-2000

When making measurements using LAI-2000, please keep the following in consideration:

- Use your shadow to shade the sensor and as much of the plant canopy as possible when measuring both above and below readings. Make all readings with your back to the sun, and the view cap blocking the sensor's view of you and the sun.
- Make sure the sensor points to an open area when you take above readings.
- Do not take the sensor directly under a leaf when you take below readings.
- Use levelling bubble when taking measure on flat area
- Setup LAI-2000 instrument for an input sequence of ↑↓↓↓↓↑ (Up-Down-Down-Down-Down-Up).

<u>*Downloading data from LAI-2000*</u>

1). Connect the LAI-2000 to you computer using the USB cable.
2). Start the FV2000 program on your computer.
3). File-Acquire.
4). Set the COM port on the upper-right corner to 4 (AAFC laptop USB)
5). Set the destination file for the LAI data. Call your file ***.txt.
6). FCT33: format: Standard; Print Obs: Yes
7). (on pc) click the download button
8). FCT 32: from 1; Thru:99 (select a big number to make sure you download all the files)
9). When the download is finished, click Done.

6.4.5.2 LAI measurement using Nikon D300S fisheye camera

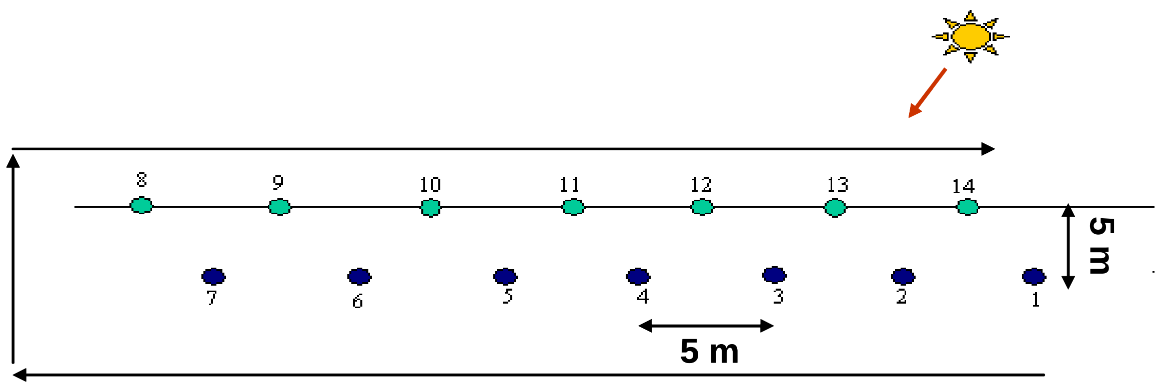
<u>*Camera setup:*</u>

1). Exposure Mode set to P (programmed).
2). Frame Release Mode (top left dial of body) set to Single.
3). Auto Focus Mode (front of body) set to Manual.
4). Metering (top right) set to Matrix.
5). AF Area Mode set to Matrix.

6). Image format (using menu) set to NEW RAW HIGH + JPEG fine.
7). Image quality (using menu) set to 14 bit.
8). White balance (using menu) set to sun or shadow.
9). Active D Lighting (using menu) set to Auto.
10). Hand held (using menu) set.
11). Noise reduction (using menu) set to hand held.
12). Image display (using menu) set to histogram + details.
13). Set local time (using menu)

<u>*Sampling scheme*</u>

A 70 m long parallel transets will be walked at 5 m spacing. For rwo crops, samples will be taken in gaps between rows. When walking back, make sure to shift position as shown in the Figure below. When taking the photo, the operator should always face the sun. At each site, a total of 14 photos will be taken and recorded on the data sheet. Please make sure mark the sun direction at the time of photo.



Sampling transect for hemispherical photos.

6.4.5.3 Crop architecture photos

Crop characterization photos will be collected using a regular digital camera at each site coincident with the LAI measurement and accompanying each set of hemispherical photo collection.

1). Locate each sample site within each field using GPS
2). For a developed canopy, take one landscape photo from edge of field
3). At the sample site, take one photo parallel to the planted crop rows, one perpendicular to the crop rows, and one looking downward at the canopy at the height of 1.5 m.
4). Record the photo numbers on the data sheet.

6.4.6. LAI datasheets

See next page

KEN LAI Worksheet
LAI Observation Team and Reader#

Field Identifier and crop type	Start Date/Time:	End Date/Time:

LAI-2000 Data Sheet

Campaign		Field notes & observations:
Date		
Time		
Sky condition		
Site #		
Latitude		
Longitude		
Crop type		
Collected by		

Hemispherical Photo Data Sheet

Campaign		Crop type	
Date		Transect orientation	
Time		Camera facing Up or Down	
Sky condition		Camera height	
Site #		Starting photo #	
Latitude		Ending photo #	
Longitude		Collected by	
Field notes			

Crop Architecture Photo Data Sheet

Campaign		Notes:
Date		
Time		
Site #		
Photo # (overview)		
Photo # (paralelle to the row)		
Photo # (perpendicular to the rows)		
Photo # (looking down)		

6.5. BERMS soil moisture sampling

6.5.1. Soil moisture measurement, instructions and protocols

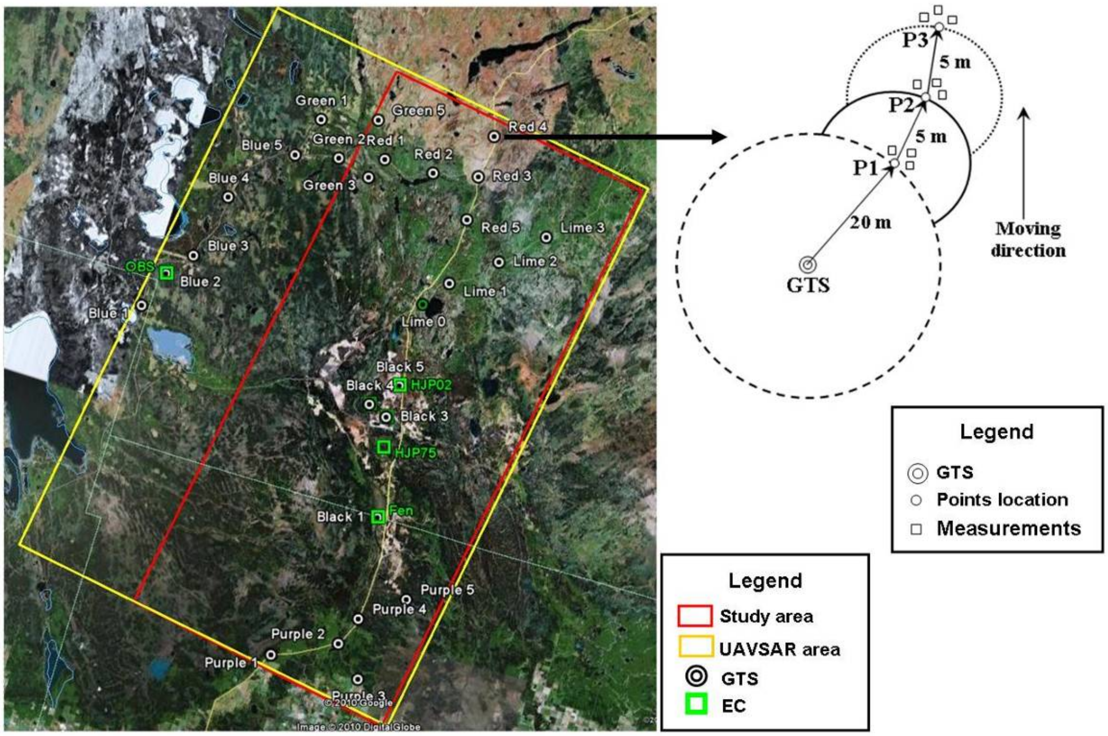
Since the GTS (GroundTeam Sampling) locations are all along accessible roads and trails, the sampling will be conducted at 3 measurement points (P1, P2, and P3) located into the canopy around a radius of 20, 25, and 30 m from each GTS location (see diagram next page).

For each GTS, use the GPS to find (if possible) approximate location of measurement points P1, P2, and P3.
For each measurement point, 3 Hydra probe readings will be collected for volumetric soil moisture and soil temperature.
For each measurement point gravimetric samples will be collected simultaneously to the 2nd Hydra probe reading.

All readings to be stored in the HydraReader (set to loam) or PDA as well as readings noted below.

GTS	1					
Measurement points	P1		P2		P3	
Distance from GTS (m)	20		25		30	
Vol. soil moisture measurements and Ts	sm	Ts	sm	Ts	sm	Ts
	sm11a	Ts11a	sm21a	Ts21a	sm31a	Ts31a
	sm12a*	Ts12a	sm22a*	Ts22a	sm32a*	Ts32a
	sm13a	Ts13a	sm23a	Ts23a	sm33a	Ts33a
Mean values	sm1a	Ts1a	sm2a	Ts2a	sm3a	Ts3a
STD	std_sm1a	std_Ts1a	std_sm2a	std_Ts2a	std_sm3a	std_Ts3a
Mean values and std	sma, std_sma Tsa, std_Tsa					
Gravimetric samples	g12a		g22a		g32a	

Fill this table for each GTS
Shaded values are calculated and are not completed in the field
* indicated the collection of gravimetric samples in addition to Hydra probe readings



GTS sampling strategy. For each GTS location, soil moisture measurements will be conducted at 3 points (P1, P2, and P3) around a radius of 20 m, 25 m and 30 m from the GTS. For each point, three reading points represented by the squares

6.5.2. Data Sheets for GTS soil moisture measurements over BERMS

See next page

BERMS Soil Moisture Worksheet
Soil Moisture Observation Team and Reader#

____

GTS Identifier and forest type	Start Date/Time:	End Date/Time:

GTS	#					
Measurement points	P1		P2		P3	
Distance from GTS (m)	20		25		30	
Vol. soil moisture measurements and Ts	sm	Ts	sm	Ts	sm	Ts
+Gravimetric samples →						
Mean values						
STD						
Mean values and std						
Gravimetric samples	g12a		g22a		g32a	

At the end of every day the observation team is responsible for photocopying the field notes and filing in the observations binder. Remove dried soil from the oven and record dry+tare weights. Tare and record tare weight and ID of a drying tin, place wet soil in drying tin, wet weigh your soil cores, and record wet weight+tare on the data sheet in lab. Place container+soil in the oven. Download all soil moisture data, download all photos, and copy to the central data drive.

6.5.3. BERMS bulk density measurements

Bulk density samples over BERMS may be complicated by the presence of an organic layer of variable thickness. Collection of the bulk density sample will be similar to the method described over the Kennaston site after the organic layer is measured and removed. The following steps outline the sampling procedure for bulk density estimates at the BERMS site.

1) Record the presence of organic layer. Measure the depth of the layer.
2) Using a knife remove a 15x15cm area of organic matter which overlays the mineral soil (if present). Place this sample into a labeled bag for oven drying.
3) In the underlying mineral soil, drive sampling ring into the soil to obtain a bulk density sample.
4) Excavate region surrounding core to remove sample container. Remove excess sample from bottom and sides of sample container.
5) Place the sample in a sampling bag for oven drying.

Of note the Hydra-Probe samples should be taken from the region where the organic layer has been removed. Do not take samples of the organic layer with the Hydra-probe sensor.

6.5.4. Data Sheets for GTS soil moisture measurements over BERMS

See next page

BERMS Bulk Density Worksheet
Bulk Density Observation Team and Reader#

____

GTS Identifier and forest type	Start Date/Time:	End Date/Time:

Location

ID	LAT	LONG

SITE DESCRIPTION:

Time of day and site overview

SITE PHOTOS:

Photo #	Description – direction, overview

Organic Layer: Sampling bag number____

Mineral Layer: Sample bag number

____

Hydra Probe Measurements:

1
2
3

6.6. BERMS vegetation measurements

BERMS Vegetation Worksheet
Vegetation Observation Team and Reader#

InitialsQQ							
Date (MM-DD-YYYY)							
Time (X am/pm)							
Site (GPS coord; 5 decimals)							
RAPID SAMPLING	**UNITS**	**# DECIMALS**					
(100 m transect; within 1.5 m of transect line)							
Tree location	GPS coord	5					
Tree species identification	Name	or Photo					
DBH	cm	2					
Ground-to-canopy height	m	2					
Tree height	m	2					
LAI	m2 m-2	2					
Branch area index	m2 m-2	2					
Primary branch density	# m-3						
Secondary branch density	# m-3						
Dielectric constant: trunk	kg m-2	2					
EVERY 10 m							
Fractional vegetation cover	%	1					

Fractional necromass cover	%	1					
Fractional understory vegetation cover	%	1					
Understory species identification	Name	or Photo					
Litter depth	m	2					
INTENSIVE SAMPLING							
(Remember to record all information above for each tree)							
Needle/leaf							
ID (label bag)	GPS coord _ #	5					
Shape	Name						
Density	# m-3	0					
Mean angle/orientation	Deg	2					
Wet mass	g	2					
Branch							
ID (label bag)	GPS coord _ #	5					
Mean angle/origentation	Deg	2					
Diameter	cm	2					
Length	cm	2					
Wet mass	g	2					
Understory							
ID (label bag)	GPS coord _ #	5					
Wet mass	g	2					

7. Appendix 2

Training and Team Assignments

7.1. CanEx-sm10 Training and Gear Lists

7.1.1. Sub group leads responsible for

- **Critical review of their section of the experimental plan, instructions, protocols, datasheets.**
- **Assisting in training or leading the training**
- **Daily briefings**
- **Supervising the lab work, analysis and producing the output data**

KENASTON (KEN)

Overall coordination	**Brenda Toth (Ramata Magagi)**
Soil Moisture	**Brenda Toth (Aaron Berg)**
Vegetation	**Peggy O'Neill**
Surface Roughness	**Ramata Magagi**
Bulk Density	**Aaron Berg**
LAI	
MSR	

BERMS

Overall coordination	**Ramata Magagi**
Soil Moisture	
Vegetation	
Surface Roughness	
Bulk Density	
LAI and MSR	

7.1.2. Training Days

CanEx-SM10 Training Day 1
Date/Time: Monday May 30, 2010, 9:00 a.m. to 4:30 p.m.
Location: 11 Innovation Blvd, Saskatoon Saskatchewan
Syllabus:

- Building protocols, security issues
- OSH**,** Task Hazard Analysis
- Practical training compass, gps,
- Data storage protocols, hardcopies, digital storage

Soil Moisture teams

- Theory for soil moisture teams

- Practical training HydraProbe and downloading, soil moisture teams
- Bulk density samples, oven drying and data sheets

Soil Roughness/vegetation teams

- Theory for soil roughness, vegetation
- Practical training, profiler, vegetation
- Oven drying and datasheets

LAI, multispectral teams

- Theory for LAI and multispectral teams
- Practical training LAI, MSR teams

lunch not provided, but there is a cafeteria on site

CanEx-SM10 Training Day 2
Tuesday June 1, 2010
Date/Time: Tuesday, Jun3 1, 2010, 7:00 a.m. to 3:00 p.m.
Staging location: 11 Innovation Blvd, 7:00 a.m. sharp meet time
Syllabus:
please be prepared to go into the field and to bring lunch and snacks (see field supplies list)

A BBQ will be planned offsite (Forestry Farm, or at NHRC if weather is inclement) either Monday or Tuesday.

7.1.3. Field supplies for surveys, CanEx-SM10 June 2010

<u>Personal:</u>
Hat, water, layers, sunglasses, good sturdy walking shoes or boots, gloves if desired,
Sense of humor
Food and snacks that pack well
Water for the entire day

<u>Will be supplied in truck:</u>
Additional water
Bug spray
Sun screen
First Aid kit
Home safe sheets and emergency procedure manual
Contact information for in field safety person, weather advisories, calling tree

7.2 Ground Measurement Teams

7.2.1 Kenaston (KEN) teams

- **Each KEN training team will tackle two sets of field sites on June 1.**
- **The drivers for the second are arbitrary and can be switched, as long as documentation of licensing and insurance are provided.**

- **Yellow highlighted persons have First Aid, there should be one in every two person team if possible.**
- **Underlined persons have supplied their driver's licences and certificate of insurance**

June 1st Training Driver (for a team of 4)	Team	Driver for field campaign days	Participants	Field sites	Field sites
Danette Bilodea	**Soil Moisture A**	Danette Bilodeau	Sarah Impera	A1. A2. A3. A4. A5.	
	Soil Moisture B	Mariko Burgin	Jess Rogers		B1. B2. B3. B4. B5.
Brad Williams	**Soil Moisture C**	Brad Williams	Andreas Colliander	C1. C2. C3. C4. C5.	
	Soil Moisture D	Erica Keet	Ramata Magagi		D1. D2. D3. D4. D5.
Craig Smith	**Soil Moisture E**	Craig Smith	Muluneh Admass (starts	E1. E2. E3. E4. E5.	
	Soil Moisture F	Anna Pacheco	Kalifa Goita		F1. F2. F3. F4. F5.
Stacey Dumanski	**Soil Moisture G**	Stacey Dumanski	Ruzgeh Akbar	G1. G2. G3. G4. G5.	
	Soil Moisture H	Jennifer Melatini	Brian Wiens (to June 9) Heather McNairn (after June 8)		H1. H2. H3. H4. H5.
Aaron Berg	**Soil Moisture I**	Aaron Berg	Krystal Chin	I1. I2.	

				I3. I4. I5.	
	Soil Moisture J	Garry Toth (TBC)	Kim Gauthier Schampert		J1. J2. J3. J4. J5.
Jon Belanger	**Soil Moisture K**	Jon Belanger	Tara Holland	K1. K2. K3. K4. K5.	
	Soil Moisture L	Emily Huxter	Imen Gherboudj		L1. L2. L3. L4. L5
	Soil roughness/veg Week	Dell Bayne (week 1) Erin Thompson (week 2)	Amine Merzouki Najib Djamai	Fields A-F	for roughness/veg
	Soil roughness/veg	Peggy O'Neill	Louis-Philippe Rousseau Alicia Joseph	Fields G-L	for roughness/veg
	MSR and LAI	Thomas Barabash (LAI)	(Jiali Shang LAI) Amie Melnychuck (MSR)	All fields	
	Back up as needed		Heather McNarin (June 8 – 15) Charles Maule (all dates)		

7.2.2 BERM teams

BERMS Soil Moisture Sampling Ground Teams June 15th

	Team	Driver	Sampler	Accomodations	# rooms booked	Vehicle
1	Greeen	Craig Smith	Amie Melnychuk	East Trout	2	CRD
2	Orange	Dell Bayne	Danette Bilodeau	Prince Albert	2	NHRC
3	Black	Erin Thompson	Ramata Magagi	Smeaton	2	CRD
4	Purple	Bruce Cole*	Imen Gherboudj	Smeaton	2	CRD
5	Red	Jon Belanger	Tara Holland	Caribou Creek	1	Rental
6	Lime	Aaron Berg	Erica Keet	Caribou Creek	2	Rental
7	Blue	Louis-Philippe Rousseau	Jess Rogers	Whiteswan Lake	1	Rental
8	TBD**	Brad Williams	Andreas Colliander	Smeaton	2	NHRC

*Safety Officer
** a suggestion would be to sample along the Harding road that runs East-West through the centre of the box and then if time allows, north on Hwy 120 towards Caribou Creek.

7.3. Building Access

Any visitor to the National Hydrology Research Centre (11 Innovation Blvd) can sign in anytime during business hours as a visitor for Brenda Toth.

If your name is on the CanEx-sm10 participants list you will be able to sign in and out of the National Hydrology Research Centre during all campaign hours, including after normal working hours as well as Saturdays and Sundays. If there are any questions, you or the building commissionaire can reach Brenda Toth at (306) 222-1119 (cell), 9975-5724 (office) or find her in suite 2220.]

You will be cleared for access in the following areas (there is a building map at the front desk, main floor foyer):

- Seminar room (used for daily briefings and data entry)
- Staging area
- Soil moisture/bulk density lab
- Vegetation lab

Please be careful when walking by the eyewash areas, if the chains are pulled there will be a flood!

Use of personal laptops is permitted in the building, but they cannot be connected to the internal network or establish Internet connections. The only exception to this is hard wired Internet connections in the Seminar room on the main floor and room 2268 on the second floor and only through wall connections marked as ‘non-EC internet’.

8. Appendix 3

Emergency and Health and Safety Protocols

Saskatoon 911 - Fire Department, Ambulance or Police

RCMP:

Outlook RCMP, 867-5440
Craik (Davidson) RCMP, (306) 734-5200
Saskatoon RCMP, (306) 975-5173 or (306) 975-1610

Ambulance:

Saskatoon St John Ambulance, (306) 343-0041
Davidson Sk. 708 Government Rd., (306) 567-2115 or (306) 567-2309
Davidson Fire and Rescue, (306) 567-7957
Outlook & District, (306) 867-9111

Hospital locations (severe injuries including allergic reactions)

Davidson is approximately 20 minutes south of Kenaston and 107 km southeast of Saskatoon

- Davidson Health Centre, (306) 567-2801 (See map below)

Outlook is approximately 30 minutes west and south of Kenaston

- Outlook Union Hospital, (306) 867-8676 (See map below)

Saskatoon is approximately 45 minutes north west of Kenaston and 107 km northwest of Davidson

- Royal University Hospital: College Drive
  - Head north into Saskatoon on Highway 11 until the College Drive West exit (this is past Safeway, Jysk)
  - Take College Drive West onto College Drive
  - Royal University Hospital is about 3 km and on the north side of College Drive

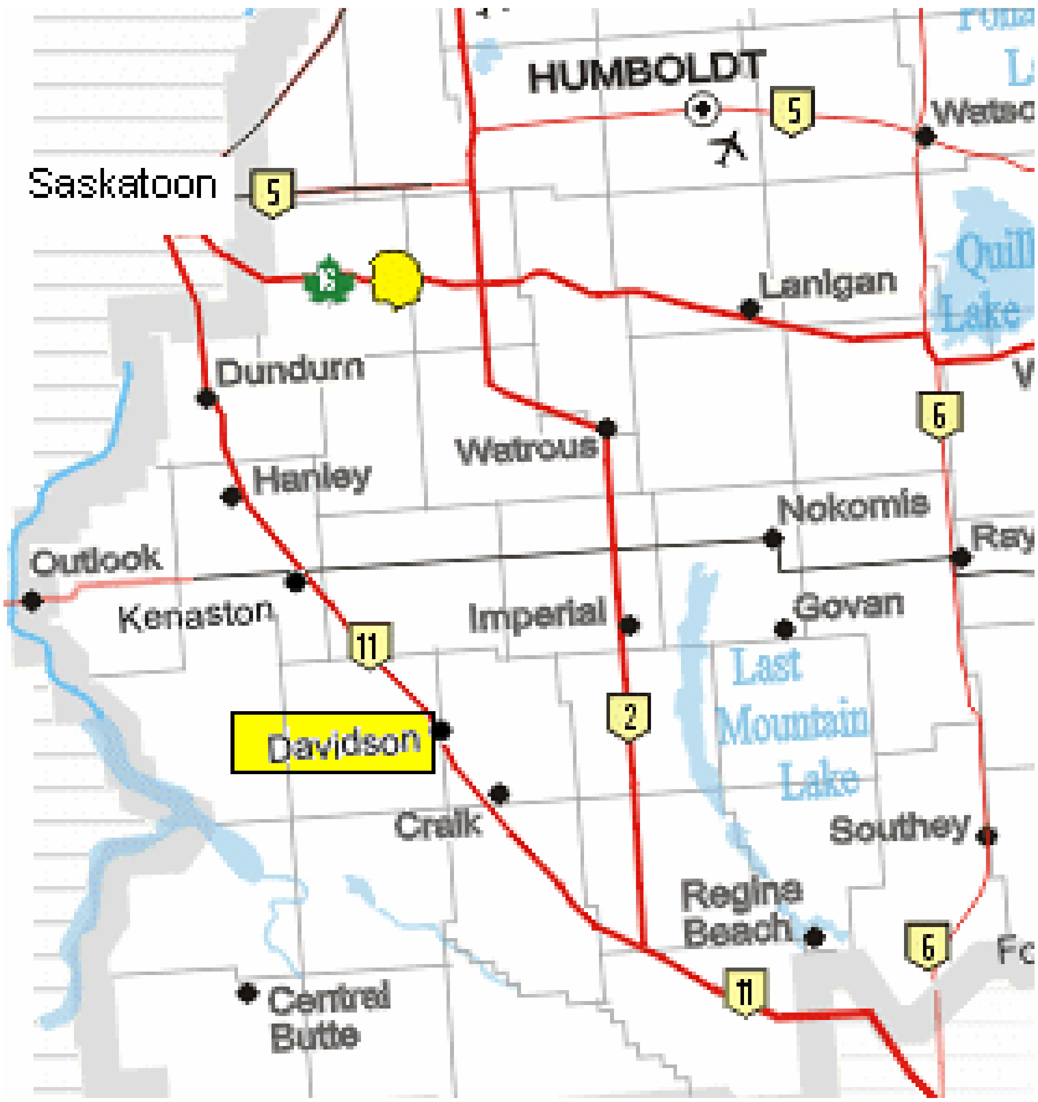
Medi-Clinic locations (minor injuries, sprains, sunburn etc)

Name: Outlook Medical Clinic Physicians & Surgeons (See map below)
Address: 313 Saskatchewan Avenue West
Outlook, SK S0L2N0
Phone: (306) 867-8626

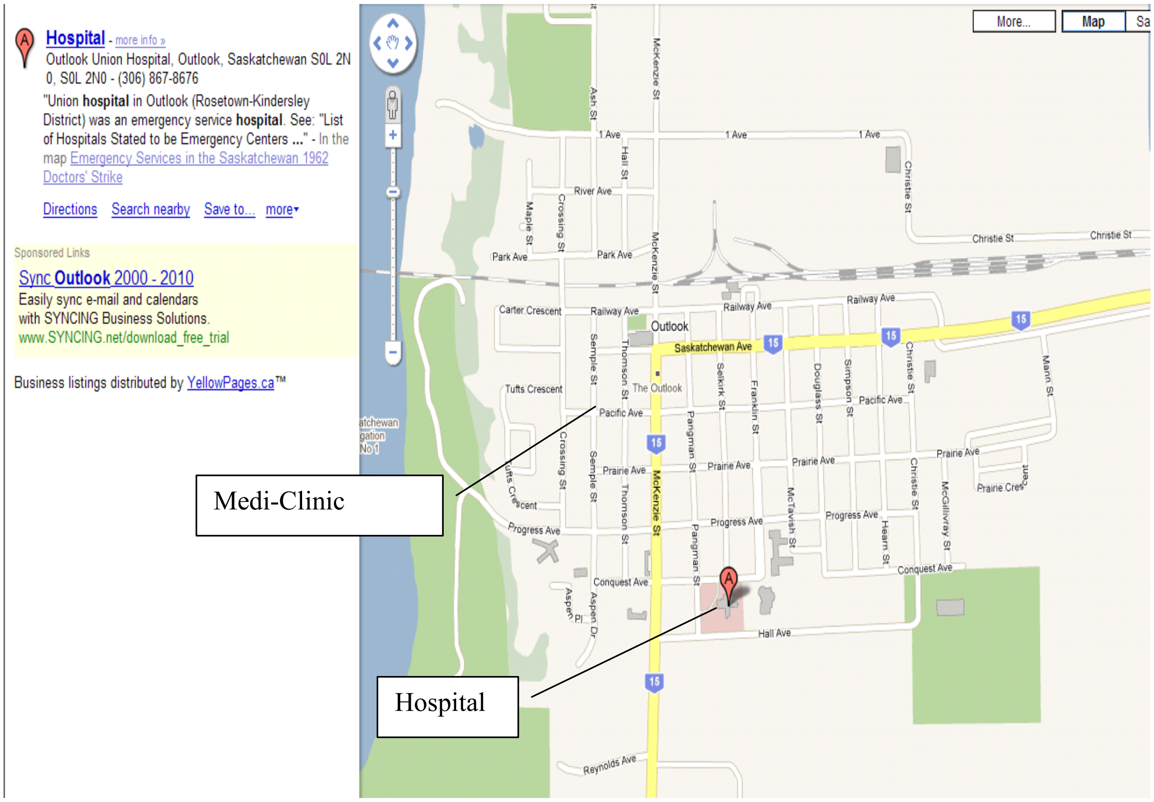
Name: Family Medicine and Urgent Care
Address: 101 - 3301 8th Street East (access via the 8th Street East off ramp from

Highway 11)
Circle Centre Mall
Saskatoon, Sask, S7H 5K5
Phone: (306) 955-1530

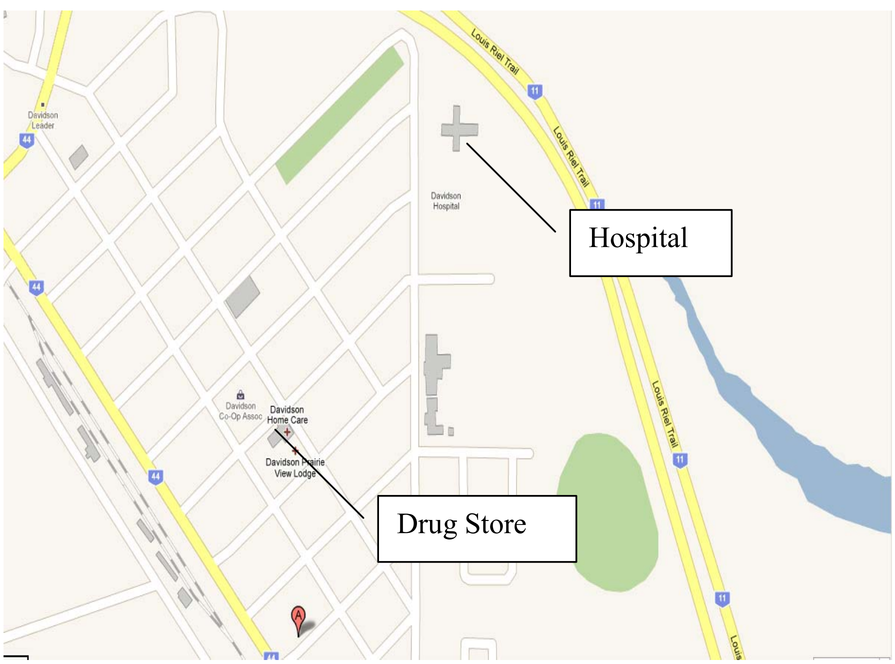
General Map:
Saskatoon, Davidson, Outlook
Kenaston, Highway 11



Outlook Map, Hospital and Medi-Clinic



Davidson, Hospital and Drugstore



Stand-down procedure (lightning, heavy rainfall)

If you see lightening in the area, please ensure your safety be getting into the vehicle first; take the probe and probe holder with you if the lightening is not imminent. If the lightening is very near, drop the probe and leave it behind. After you are safe, please call the in field safety person. Field stand downs will be communicated using the calling tree established during training.

Field Precautions

How to protect yourself from lightening
Watch the skies and be aware of lightening. Lightning kills about 80 people in the U.S. each year and injures hundreds. In most places, lightning hits most often in late afternoon in spring and summer. But lightning can hit anyone in the wrong place at the wrong time. Lightning can hit the same place many times too. Lightning can stop your heart and kill you. But you can also get burns, nervous system damage, and other health problems. Some of these you may not notice until months after a lightning strike.

If you hear thunder and see lightning, act right away – especially if you count 30 seconds or less between the thunder and lightning. If the thunder gets louder or you see the lightning more often, the storm is getting closer. (Sometimes lightning will strike out of a sunny sky 10 miles or more from a storm.) Lightning hits tall things, metal, and water – or a person standing on open ground or a roof.

If a storm is near

Do NOT:
• Be the tallest object in an area.
• Stand out in the open.
• Stand under a tree. (If the tree is hit, you can be too.)
• Stand in a gazebo or open shelter, like a baseball dugout or bus shelter.
• Stand next to metal objects – pipes or light poles or door frames or metal fences or communication towers – indoors or out.
• Stay next to water – ponds or running water – indoors or out.
• Use plug-in power tools or machines – indoors or out.
• Use a plug-in telephone (or a computer with a modem) – indoors or out.

Do:

- **Get into an enclosed building – like a house or shopping center or school or office building.**
- **Get into a car, van, truck, or bus with the windows closed all the way. Do not touch the doors or other metal inside. (Open cabs on heavy equipment will not protect you. A convertible with the top up will not protect you. Rubber tires will not protect you.)**
- **If you are out in the open and have nowhere to go, squat down with your feet together and only let your feet touch the ground. Put your hands over your ears (to protect against noise). That way, you are so low the lightning may hit something else. And by not touching much of the ground, you have less**

chance that the lightning will move across the ground toyou. Do not lie flat on the ground.

- **Do not go back to work outdoors until a half-hour after the lightning and thunder stop.**

If someone is hit:

- **Call emergency services (911).**
- **A victim does not stay electrified. You can touch him/her right away. If the victim has no pulse, try CPR (cardio-pulmonary resuscitation). If there's a portable defibrillator, follow the instructions. But be careful about staying in the open in a storm to take**

How to protect yourself from the sun

When working outdoors in the sun, protect yourself by:

- ✓ Wearing suitable clothing (hats, long-sleeve shirts, long pants or skirts) made of a tightly-woven fabric that blocks the sun's rays yet allows perspiration to evaporate;
- ✓ Wearing departmentally-approved sunscreen for skin and lip on all exposed skin; employees should ensure to apply the sunscreen as indicated by the product's instructions and to re-apply the sunscreen in the event that it is washed off;
- ✓ Wearing departmentally-approved sunglasses (or clip-ons), as provided by your supervisor; (in the event that these items are lost or broken, inform your supervisor as soon as possible).
- ✓ Scheduling work in the shade as much as possible.
- ✓ Ensuring that you have potable water and drink every 20 minutes even if you do not feel thirsty, to guard against dehydration and heat-related illnesses.

How can West Nile (WN) Virus be prevented?

West Nile (WN) virus is a mosquito-borne virus. Mosquitoes transmit the virus after becoming infected by feeding on the blood of birds which carry the virus.

A. People working outdoors where mosquitoes occur

People who work outdoors, particularly in swampy or wooded areas where there is high risk of being bitten by mosquitoes, should consider taking the following precautions:

- ✓ Wear long-sleeved shirts and full-length trousers. Two layers of clothing make biting less likely, but this may be hazardous in warm weather or while doing heavy work. In hot conditions with the potential for heat stress, mesh suits with elasticized cuffs and attached hoods should be considered.

- ✓ Wear high boots and tape or seal ends of trousers to prevent mosquito bites. If practical, wear a mosquito net over your hat to protect head, face and neck. Wear light-coloured clothing which is less attractive to mosquitoes.

- ✓ Use DEET-based (N,N-diethyl meta-toluamide) insect repellents on exposed skin, following package directions carefully. The concentration of DEET varies among repellents. Higher concentrations do not provide better protection, but may extend the length of protected time from about 3 to 8 hours. Adults should not use products containing more than 30% DEET. Keep repellent away from eyes and mouth, and do not apply to the palms of your hands and fingers. Wash your hands after applying repellent.

- ✓ Certain products containing DEET can be applied to clothing. Follow instructions carefully when applying these products.

- ✓ If practical, work outdoors when it is cooler, when there is brisk air movement or when there is strong sunlight, as mosquitoes are less active in these weather conditions. If practical, stay indoors at dawn and dusk and in the early evening hours when mosquitoes are most active.

- ✓ Use proper screens in good condition on windows and doors of work buildings or lodgings.

B. People involved in handling live birds or collecting dead birds

People handling live or dead birds should consider the following precautions:

- ✓ Avoid bare-handed contact with live birds. People who handle live wild birds which may be infected should minimize potential exposure to excretions by wearing vinyl, PVC, latex (if not allergic) or rubber gloves. Care should be taken to avoid tearing or puncturing gloves or skin by the birds' beaks, talons or claws. Remove gloves by turning them inside-out, dispose of them in a sealed plastic bag, and wash hands immediately. These precautions are to prevent contact of any blood or body fluids from potentially infected animals with a break in your skin, with your eyes or mucous membranes.

- ✓ Bare-handed contact with dead birds should also be avoided, and dead birds should be handled with protective gloves in ways that minimize potential exposure to excretions. The Canadian Cooperative Wildlife Health Centre recommends that the public should not pick up dead birds, but contact the local Natural Resources office. Other risks from dead birds include infection from *salmonella* or *chlamydia*.

- ✓ Dead bird specimens should be double-bagged in thick plastic bags that resist puncture by beaks, talons, claws, nails, etc. Birds should be picked up by inverting a plastic bag over the carcass, to ensure there is no direct contact with the bird or its excretions. Keep the bag closed at all times thereafter, place it in a second sealed bag, and wash your hands immediately afterward.

- ✓ Always wash your hands well, with soap and warm running water, after handling live or dead birds.

C. People involved in collecting blood or other tissues from birds (including hunters)

WNV may be transmitted to humans from body fluids of infected animals. You should therefore prevent blood or body fluids of potentially infected birds from contacting any break in your skin, or your eyes or mucous membranes. People exposed to these fluids should consider the following precautions:

- ✓ Use vinyl, PVC, latex (if not allergic) or rubber gloves when collecting blood or tissue samples, cutting open dead birds, or when cleaning wild game, to prevent blood-to-blood contact.

- ✓ Do not collect, harvest or handle birds which appear to be sick, or whose behaviour is abnormal.

- ✓ Handle tissue samples or meat from gamebirds as if they may be infected, using protective gloves and containers, and cook meat from game birds until well done.

- ✓ Wash utensils used to collect tissue samples from birds, to operate on birds, or to prepare game birds, then soak them in a solution of one part household bleach and ten parts water for 20 minutes.

How can Hantavirus be prevented?

People can contract the Hantavirus infection through inhalation of respirable droplets of saliva or urine, or through the dust of feces from infected wild rodents, especially the deer mouse. Transmission can also occur when contaminated material gets into broken skin, or possibly, ingested in contaminated food or water.

People involved in the clean-up of rodent contaminated areas should wear rubber gloves, rubber boots and respiratory protective equipment that is equipped with a high-efficiency particulate air (HEPA) filter. (if heavy accumulations of droppings it is necessary to use powered air-purifying (PARP) or air-supplied respirators)

How can Lyme disease be prevented?

The bacteria that cause Lyme disease come from small, insect-like creatures called ticks. Ticks range in size from 1 to 4 millimeters (not much larger than a small ant). However, unlike insects, ticks have eight legs instead of six. In areas where ticks are found, outdoor workers should know about the risk of Lyme disease and should take precautions to protect themselves.

- ✓ Find out from your local public health office if there are ticks in your area, especially Ixodes ticks.

- ✓ Wear protective clothing to prevent ticks from getting access to your skin. This includes long sleeve shirts that fit tightly around the wrist, and long-legged pants tucked into stockings or boots.

- ✓ Use insect repellants that effectively repel ticks (such as those containing DEET). Apply the repellent to pant legs, socks, shoes, and the skin.

- ✓ Check for ticks on and under clothing after working in tick-infested areas. A daily total-body skin inspection greatly reduces the risk of infection since ticks may take several hours to two days to attach to the skin and feed.

- ✓ Carefully remove ticks found attached to the skin. Gently use tweezers to grasp head and mouth parts of the tick close to the skin as possible. Pull slowly to remove the whole tick. Try not to squash or crush them since this can help bacteria to get into the body.

- ✓ Wash affected area with soap and water or disinfect (with alcohol or household disinfectant) after removing ticks.

- ✓ Contact a doctor immediately if you have an illness that resembles Lyme disease, especially when you have been in an area where there are ticks.

Summer driving

We are often cautioned regarding safe driving habits before the winter. That does not mean that summer driving is without risks. In addition to heavier traffic volumes, there are some technical driving challenges as well. Perhaps you have received an e-mail that recounts a story about a woman who, while driving with cruise control on during a light rainfall, suddenly saw her car take-off like an airplane and lost control of the vehicle. Is it true? Yes and No. Cars cannot take flight as an airplane does, that would require that they also have wings. However, according to the Canada Safety Council, when driving with cruise control on any slippery surface it is possible to aquaplane and therefore lose control of the vehicle due to the efforts of the computer to accelerate the motor under such conditions. Some models of cars automatically shut-off the cruise control under such circumstances, others do not. To be sure, check the owner's manual or cancel cruise control whenever conditions are slippery. Moreover, ensure that your tires are not worn or under-inflated.

The biggest concern you will face during the KEN campaign is that the highway between Saskatoon and the field sites have a heavy population of deer and moose. In particular, the times around dawn and dusk is when the risk is highest. The driver of the vehicle should watch the sides of the roads and ditches and can request that the passenger of the vehicle should assist in detecting roadside animals.

Deer and moose may also be a risk during the BERMS campaign.

Be aware of marijuana operations

It is conceivable that you may encounter illegal marijuana growing operations while working in the field. The chances are low, but not unlikely, as it is impossible to know the precise location of these plantations. If you encounter such a situation, be cautious, as many grow-ops may be booby-trapped or guarded. Do not touch anything, and exit the area using the same route used to get in. If confronted, do not offer resistance or take the law into your own hands. Leave the scene immediately and contact local authorities, preferably the RCMP, once in a secure area.

Keep the Wild in Wildlife

If You Encounter A Bear

Bears are very intelligent and complex animals. Each bear and each encounter is unique; there is no single strategy that will work in all situations. Some guidelines:

Stay calm. Most bears don't want to attack you; they usually want to avoid you and ensure you're not a threat. Bears may bluff their way out of an encounter by charging and then turning away at the last second. Bears may also react defensively by woofing, growling, snapping their jaws, and laying their ears back.

Immediately pick up small children and stay in a group.

Don't drop your pack. It can provide protection.

Back away slowly, never run! Bears can run as fast as a race- horse, both uphill and downhill.

Talk calmly and firmly. If a bear rears on its hind legs and waves its nose about, it is trying to identify you. Remain still and talk calmly so it knows you are a human and not a prey animal. A scream or sudden movement may trigger an attack.

Leave the area or take a detour. If this is impossible, wait until the bear moves away. Always leave the bear an escape route.

Bear Spray?

Effectiveness is not guaranteed!

Recent research indicates that bear spray can be effective against some bears when used properly. If you plan to carry it, be aware that wind, spray distance, rain and product shelf life can all influence how well it works. Carefully read directions on the can prior to your trip. The best way to live safely with bears is to avoid contact with them.

Bear Attacks

Bears do not like surprises. Try to avoid such encounters by being alert and making noise.

If you surprise a bear and it defends itself:

If you have bear spray, use it. If contact has occurred or is imminent, ***PLAY DEAD!*** Lie on your stomach with legs apart. Protect your face, the back of your head and neck with your arms. Remain still until the bear leaves the area. These attacks seldom last more than a few minutes. While fighting back usually increases the intensity of such an attack, in some cases it has caused the bear to leave. If the attack continues for more than several minutes, consider fighting back.

If a bear stalks you and then attacks, or attacks at night:

DON'T PLAY DEAD - FIGHT BACK!

First – try to escape, preferably to a building, car or up a tree. If you can't escape, or if the bear follows, use bear spray, or shout and try to intimidate the bear with a branch or rock. Do whatever it takes to let the bear know you are not easy prey. This kind of attack is very rare but can be very serious because it often means the bear is looking for food and preying on you.

Elk Alert!

Elk are dangerous - no matter when or where you see them. Give Elk the right of way and stay at least three bus lengths away (30 m/100 ft).

Cow elk are particularly dangerous during calving season (mid-May to the end of June).

Bull elk are especially dangerous during mating season (mid- September to the end of October).

Report all conflicts with elk to park staff

In park townsites, you may see elk peacefully mowing someone's front lawn or pruning the back yard shrubbery. They look pretty tame, but they're not. They are wild animals that have learned to survive in a place that's full of people. 'Urban' elk have the same needs as other wild animals: they need to feed, rest, mate, and bear young – undisturbed. If these needs are not met, survival is threatened. And whenever a wild animal perceives a threat – say someone approaching too closely – it is likely to attack. The only other option is to run away, but in populated areas there just aren't many places for an animal to run. Instead we're the ones who must "back off".

This Is Also Cougar Country

Cougars are not often seen because they are solitary, elusive and active mainly at night. may be more active in areas that have habituated deer, like towns and campgrounds. Avoid meeting a cougar by travelling in groups and making lots of noise.

Keep children close to you. ee- roaming pets may attract and be attacked by cougars.

If you encounter a cougar:

Immediately pick up small children.

Face the animal, and retreat slowly – do NOT run or play dead.

Try to appear bigger by holding your arms or an object above your head.

Actions such as shouting, waving a stick and throwing rocks may deter an attack.

Be aggressive.

Give Them the Space They Need

Please do your part to limit the impact that so many people have on park wildlife. Give all the animals you see the respect they deserve and the space they need. Enjoy a safe visit and ensure that future generations have the chance to see wildlife that is truly wild.

How Close is Too Close?

We recommend you keep at least three bus lengths (30 metres/100 ft) away from large animals and about three times that distance (100 metres/325 ft) away from bears. Here are some more tips for wildlife watchers and photographers:

Don't entice wildlife by feeding, reaching out or simulating calls (eg. elk bugling).

Keep the animal's line of travel or escape route clear. If it approaches you, move away.

Retreat immediately if you notice signs of aggression or any behaviour change.

Avoid direct eye contact. Animals feel threatened by this.

Leave nesting birds, denning animals and newborn or young animals alone.

Task Hazard Analysis

See next pages

Task Hazard Analysis #088

Ball Hitch Trailers

Revised 20070214

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
Using a vehicle to tow a trailer involves: • Pre-trip planning • Hooking up a trailer • Towing a trailer • Parking and unhooking a trailer	1. Accidents (personal injury or property damage) due to improper towing procedures. 2. Injury to driver or assistant while hooking up the trailer. 3. Trailer breaking free of the tow vehicle. 4. Trailer rolling and injuring personnel or doing damage to equipment.	1. Document safe work procedures and ensure employees are familiar with them.	1. Provide PPE and clothing appropriate for conditions and task.	1. Ensure employees receive mandatory training and are observed for competence: • Trailer towing • Defensive Driving

Other Related Documents / Resources

- http://infolane.ec.gc.ca/%7Ehr/OSH/hazards_e.html
- http://infolane.ec.gc.ca/%7Ehr/OSH/arp_e.html

Manager's name & signature / Date

Employee's name & signature / Date

Task Hazard Analysis #086

Carrying Equipment

Revised 20061207

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
Carrying equipment involves: • Loading/unloading equipment from vehicle • Carrying equipment to/from vehicle	1. Poor weather 2. Awkward and/or heavy equipment 3. Wearing restrictive gear 4. Slippery conditions 5. Rough terrain 6. Uphill/ downhill *7.* Unstable ground could result in*:* • Back injury from improper lifting • Lost or broken equipment • Damage to environment • Injury from falling	1. Document safe work procedures for carrying equipment and ensure employees are familiar with them.	1. Provide PPE and clothing appropriate for conditions and task: • Gloves appropriate for weather conditions • CSA approved work boots appropriate for field and weather conditions • Appropriate clothing for weather conditions • Sunglasses	1. Ensure employees receive mandatory training and are observed for competence: • Standard First Aid • Wilderness First Aid and/or Wilderness survival, if activity is conducted in a remote area as defined in department

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
			• Insect repellent • Sun screen	al Working Alone Policy. • Safe Lifting Techniques

Other Related Documents / Resources

- http://infolane.ec.gc.ca/%7Ehr/OSH/hazards_e.html
- http://infolane.ec.gc.ca/%7Ehr/OSH/arp_e.html

Task Hazard Analysis #078

Loading/unloading Vehicles

Revised 20061213

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
Loading/unloading vehicle	1. Slipping and falling 2. Wet surface 3. Tripping 4. Falling ice (head injury) 5. Non latching sliding doors and tailgates (hand and/or head injuries) 6. Strains (back injuries)	1. Document safe work procedures for loading/unloading vehicles and ensure employees are familiar with them.	1. Provide PPE and clothing appropriate for conditions and task: • Safety footwear • CSA approved hard hat	1. Ensure employees receive mandatory training and are observed for competence: • Safe Lifting

Other Related Document / Resources

- http://infolane.ec.gc.ca/%7Ehr/OSH/hazards_e.html
- http://infolane.ec.gc.ca/%7Ehr/OSH/arp_e.html

Manager's name & signature / Date

Employee's name & signature / Date

Task Hazard Analysis #077

Launching or unloading small trailers

Revised 2007-07-24

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
1. Prepare to launch	1. Poorly conditioned ramp, 2. Slippery ramp 3. Damage to the trailer and vehicle, 4. Damage to the boat, 5. Injury to the person unhooking the tie-down 6. straps	1. Document safe work procedures and ensure employees are familiar with them.	1. Provide PPE and clothing appropriate for conditions and task: • ??	1. Ensure employees receive mandatory training and are observed for competence: • ??
2. Launching	7. Poor weather conditions, 8. Assistant could be backed into, 9. Injury to assistant, 10. Boat could tip, 11. Trailer could get stuck			
3. Loading	12. Poorly conditioned ramp, 13. Slippery ramp 14. Damage to the trailer and vehicle, 15. Damage to the boat,			

	16. Injury to person hooking boat to trailer, 17. Trailer could get stuck, 18. Assistant could get crushed			
4. Inspect boat/trailer				

Other Related Document / Resources

- http://intranet.ec.gc.ca/hr-rh/default.asp?lang=En&n=2DD142B3-1
- http://intranet.ec.gc.ca/hr-rh/default.asp?lang=En&n=1AB758D2-1

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Task Hazard Analysis #075

Using Non-Power Hand Tools

Revised 20070612

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
1. Ensure tool is safe to use. 2. Ensure the proper tool, attachments and assists are used for the job.	1. Missing damaged or improperly adjusted parts 2. Cuts, abrasions, contusions 3. Stab wounds 4. Eye injury 5. Pinched fingers/hands 6. Muscle strains 7. Flying debris	1. Document safe work procedures for using hand tools and ensure employees are familiar with them.	1. Provide PPE and clothing appropriate for conditions and task: • CSA approved eye protection • Work gloves • Safety boots, when using digging tools.	1. Ensure employees receive mandatory training and are observed for competence: • First Aid

Other Related Documents / Resources

- http://infolane.ec.gc.ca/%7Ehr/OSH/hazards_e.html
- http://infolane.ec.gc.ca/%7Ehr/OSH/arp_e.html

Manager's name & signature / Date

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Task Hazard Analysis #011

All Terrain Vehicles (ATVs)

Revised 20061219

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
1. Driving an ATV	1. Sudden movement of ATV when starting. 2. Falls or accidents due to: • Narrow trails along ridges • Drop-offs of unknown depth • Limited visibility over drop-offs • Sudden light changes • Off-cambered trails • Oncoming or cross traffic • Dust and debris • Obstacles e.g. tree branches • Steep hills 3. Drowning and hypothermia due to: • Unsafe ice conditions • Unknown water depth • Wet brakes	1. Ensure that ATV drivers hold a valid license where required by provincial or territorial laws. 2. Document safe work procedures for driving an ATV and ensure employees are familiar with them: • trip planning • pre-use vehicle inspection • vehicle operations • terrain familiarization • working alone restrictions 3. Equip all ATVs with an approved first-aid kit. 4. Require all ATVs to undergo a mechanical	1. Provide PPE and clothing appropriate for conditions and task.	1. Ensure employees receive mandatory training and are observed for competence: • An ATV driver training course. • Appropriate level of first-aid training. • Approved field survival course.

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
	• Slippery slopes • Changing weather conditions 4. Becoming stranded due to: • Accident • Mechanical breakdown • Illness • Inclement weather	fitness inspection by qualified person in accordance with the maintenance schedule defined in the Manufacturer's Operators Manual. 5. Carry phone and follow call in procedures.		
2. Carry out emergency field repairs.	5. Accidents due to: • Cuts from sharp objects or tools • Burns from hot mechanical components • Battery acid burns • Vehicle falling off jack • Blows or crushing injuries from moving mechanical components or tools	1. Equip all ATVs with a field repair kit including tools and spare parts. 2. Document safe work procedures for ATV field maintenance, including: • Approved maintenance level and limitations. • Cautions		2. Require all ATV users to successfully complete a course in ATV field repair
3. Transporting an ATV.	6. Accidents, damage to government or private property due to improper loading, unloading, and transporting procedures.	3. Specify standards for any device used to transport an ATV. 4. Require annual inspection of transport device, including hitch and lighting, by a		

BASIC STEPS	HAZARDS (Known or foreseeable)	CONTROL MEASURES	PERSONAL PROTECTIVE EQUIPMENT	TRAINING
		qualified person. Inspection reports should be retained on file until the vehicle is no longer in service. 5. Document safe work procedures for transporting ATVs, including: • Loading and unloading procedures • Cautions • Working alone restrictions		
4. Hauling items on an ATV.	1. Accidents due to unbalanced or unsecured load or exceeding load capacity.	6. Follow manufacturer's Operators Manual with respect to maximum capacity and loading procedures.		

Other Related Documents / Resources

- http://infolane.ec.gc.ca/%7Ehr/OSH/hazards_e.html
- Human Resources Site – Occupational Health and Safety – Reference Documents

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Employee's name & signature / Date