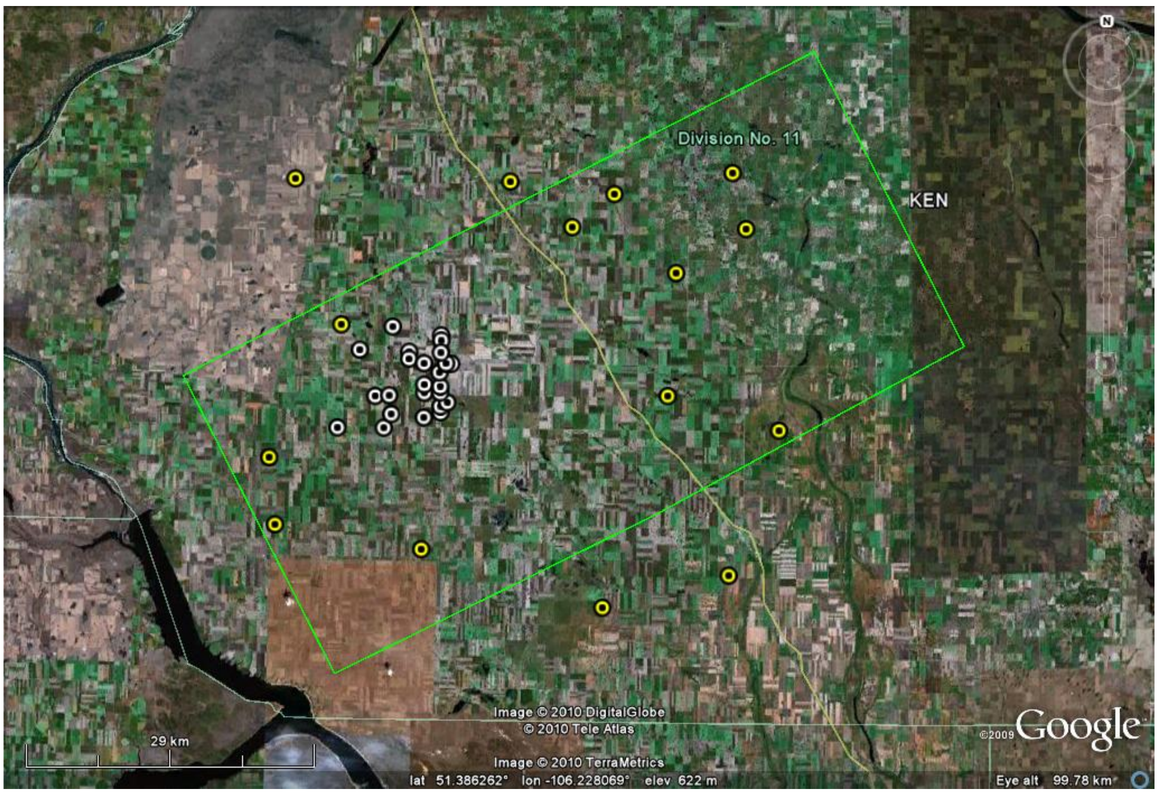
CanEx Field Campaign
(UAVSAR and SMAP)

May 31-June 17, 2010



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1. Background

The Canadian Experiment (CanEx) will be conducted to support development and validation of soil moisture algorithms and products from two new satellite platforms; the ESA Soil Moisture Ocean Salinity (SMOS) and the NASA Soil Moisture Active Passive (SMAP missions. Each mission utilizes a different technology, which are described in a following section. In addition, each mission is at a different point in its implementation. SMOS, which was launched in late 2009, is in its post-launch calibration/validation (cal/val) phase. CanEx will provide aircraft and ground-based validation of the brightness temperature and soil moisture products. SMAP is due for launch in 2014. CanEx will contribute to SMAP's pre-launch cal/val activities that include algorithm development and validation and establishing post-launch validation infrastructure.

The key resources for CanEx are the existing in situ soil moisture networks, the Canadian aircraft-based L-band radiometer, and the NASA aircraft-based L-Band radar (UAVSAR). These are described in following sections. Complementing the in situ resources will be intensive sampling of a large number of fields concurrent with aircraft and satellite data acquisition.

CanEx evolved from a radiometer only SMOS validation campaign that was planned by several Canadian groups. This was to provide mapping of L-band brightness temperature over large domains (several SMOS pixels) supported by ground-based observations. CSA and NASA agreed to collaborate and modify the campaign to support SMAP needs. This resulted in the UAVSAR being added and the ground sampling and radiometer flights being expanded.

2. SMOS and SMAP Satellites

2.1. *SMOS*

SMOS was designed to make observations of soil moisture over Earth's landmasses and salinity over the oceans for a period of at least three years. (http://www.esa.int/esaLP/LPsmos.html) Data from SMOS will result in global soil moisture maps at least every three days. The optimal frequency for soil moisture sensing is 1.427 GHz/wavelength of 21 cm (L-band), which requires a large aperture (or antenna size) in order to achieve a spatial resolution that is useful for applications (generally considered to be 50 km). To solve this problem; SMOS uses the first polar-orbiting spaceborne 2D interferometric radiometer.

The interferometric method employs a number of small receivers that measure the phase difference of incident radiation. The technique is based on the cross-correlation of observations from all possible combinations of receiver pairs. A two dimensional 'measurement image' is taken every 1.2 seconds that has a nominal spatial resolution of 40 km. From an altitude of about 758 km, the antenna will view an area almost 3000 km in diameter. A benefit to the science algorithms is that as the satellite moves along its orbital path, each measurement area on the ground is observed under a range of viewing angles by each antenna receiver. This provides additional degrees of freedom in constructing retrieval algorithms.

SMOS data are provided in several different formats. The level 1C and 2 products are resampled to a fixed Earth grid. This grid s known and has been incorporated into the CanEx design. The SMOS grid centers are at a higher spatial density than the actual spatial resolution of the data at that point. Each grid point represents a nominal 40 km diameter domain.

2.2. *SMAP*

SMAP is one of four first-tier missions recommended by the U.S. National Research Council's Committee on Earth Science and Applications from Space (Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Space Studies Board, National Academies Press, 2007). It will provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance understanding of processes that link the water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also be used to quantify net carbon flux in boreal landscapes and to develop improved flood prediction and drought monitoring capabilities. It is currently scheduled for a 2014 launch. (http://smap.jpl.nasa.gov)

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

SMAP will utilize a large (6 m) deployable mesh antenna that will provide brightness temperatures with a nominal 40 km resolution, similar to SMOS. Besides the difference in antenna technology, the radar on SMAP will support two higher resolution soil moisture products and freeze-thaw state. There will be a radar only 3 km product and a combined radiometer-radar product with a 9 km resolution.

3. Instruments and Aircraft

The two aircraft instruments involved in this campaign are the Environment Canada (EC) L-band radiometer and the NASA JPL UAVSAR. Each will be flown on a different aircraft with different operating and measurement characteristics described below.

3.1. *EC Radiometer*

EC has acquired an L-band radiometer that will be installed on their Twin Otter aircraft.(web site or reference?) This will be configured for a 40 degree incidence angle looking left of the aircraft heading. As shown in Table 1, the instantaneous field of view is 30 degrees. A decision was made in developing CanEx that the Twin Otter would fly at its maximum altitude that did not require oxygen for the crew, which is 3000 m. This results in an instantaneous footprint of 1600 m along track and 2800 cross track. The aircraft speed will be ~ 60 m/s and the integration time will be 1 second.

In addition to the L-band radiometer, the Twin Otter includes a suite of additional microwave radiometers described in Table 1. Video and thermal infrared information is also collected.

Table 1. EC Twin Otter Microwave Radiometers					
Frequency (GHz)	1.4	6.9	19.35	37	89
IFOV (Deg.)	30	9	6	6	6
Incidence Angle (Deg.)	40	53	53	53	53
Polarizations	Dual	Dual	Dual	Dual	Dual

3.2. *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 2.

UAVSAR looks to the left of flight direction. 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. At an altitude of 13 km this would be a 4 km wide section of the swath offset 9 km from the flightline.

Table 2. 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

4. Flight Mission Schedule

The mission will be divided into two time periods/sites Kenaston (KEN), agriculture, and BERMS, forest. Figure 1 shows the general locations of these two areas. The first priority for the aircraft component of CanEx is to collect radiometer and radar observations over the same domain on the same day. The choice of days will be dictated by the weather (not good to fly with ongoing or imminent rainfall) and the priorities that follow:

- SMOS-A (am), SMOS-P (pm), and ALOS-F (FBD) passes that day
- SMOS-A (am) and SMOS-P (pm) passes that day
- SMOS-A pass only
- Observing a range of soil moisture conditions
- Maximizing the number of UAVSAR/EC flights over the longest period (the point here is that although we would prefer to spread the flights out in time, if this is not possible it is still desirable to fly the maximum number of days budgeted)

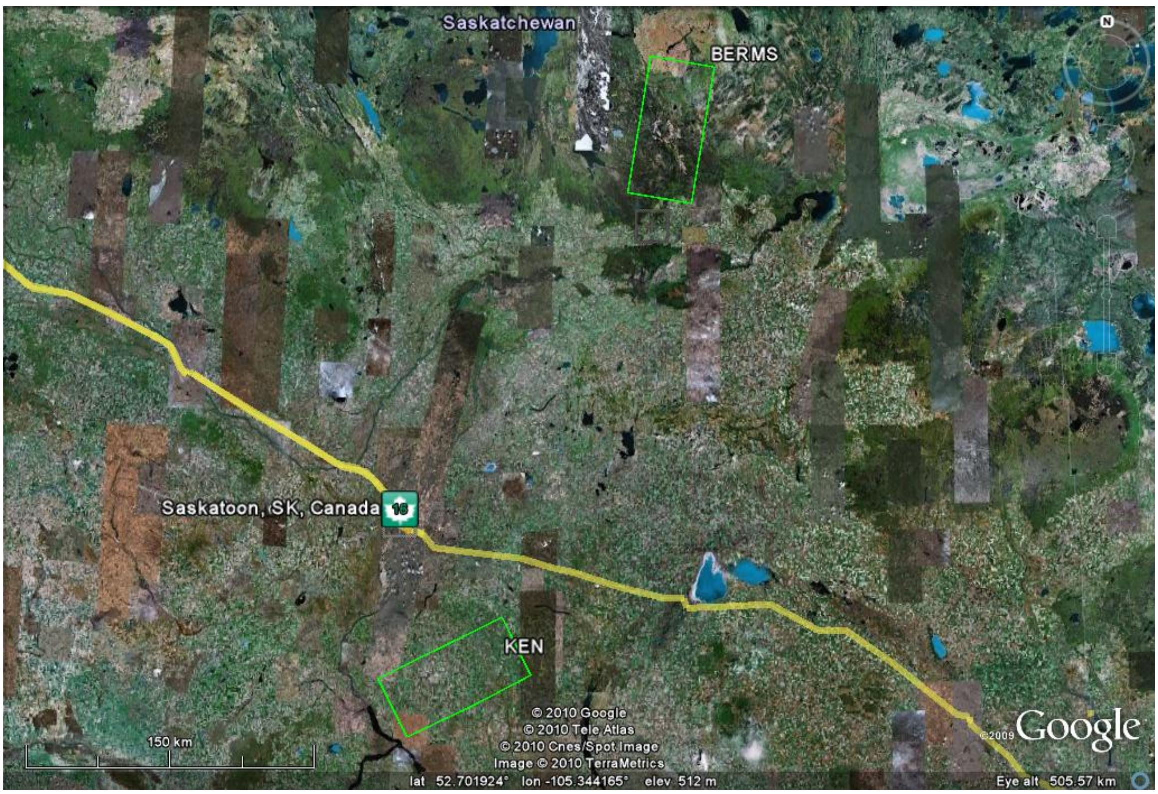

Figure 1. The CanEx domain showing the two aircraft mapping and ground sampling areas (KEN, BERMS).

Table 3 summarizes relevant satellite coverage information and the dates scheduled for KEN and BERMS. Based upon the priorities listed above, the budgeted flight hours, logistics, and additional SMAP concerns discussed later; a set of flight dates is identified. This schedule assumes no cancellations due to weather, aircraft, or instrument down days.

Table 3. Satellite and Aircraft Calendar June 2010

First choice flight dates are hatched. Possible dates are solid. Green=KEN and blue=BERMS	**COVERAGE for KEN**	1 SMOS-P*, AMSR-A, RSAT-P Aircraft arrive	2 SMOS-A, AMSR-P	3 SMOS-A, SMOS-P, AMSR-A	4 ALOS-W, AMSR-P	5 SMOS-A, SMOS-P, AMSR-A, RSAT-A, RSAT-P
6 SMOS-P, AMSR-P	7 SMOS-A, AMSR-A, AMSR-P, ASAR-A	8 SMOS-A, SMOS-P RSAT-A, RSAT-P ALOS-F (previous night)	9 ALOS-W, AMSR-A, AMSR-P	10 SMOS-A, SMOS-P, AMSR-A, ASAR-A, LandSat5-A	11 SMOS-P, AMSR-P, RSAT-P	12 SMOS-A*, AMSR-A, RSAT-A
13 SMOS-A, SMOS-P, AMSR-P, ASAR-A, ASAR-P	14 ALOS-W, AMSR-A, AMSR-P **COVERAGE for BERMS**	15 SMOS-A, SMOS-P*, AMSR-P	16 SMOS-A, SMOS-P, ALOS-W, AMSR-A, AMSR-P	17 AMSR-A, AMSR-P Aircraft depart	18 SMOS-A, SMOS-P, AMSR-A, AMSR-P	15 SMOS-A, SMOS-P*, AMSR-P

Note that the June 17th flight is expected to be UAVSAR only and will take place only if there are remaining flight hours. This is discussed further in the flight line section. Also, there are logistical issues with moving ground teams between the KEN and BERMS site that need to be considered.

5. Study Areas and Test Fields

Site selection and study areas were driven by the existence of in situ networks, representation of the mapping domains, and logistics. Two areas with existing in situ soil moisture networks were selected Kenaston (KEN), which is primarily agriculture, and BERMS, which is Boreal forest.

Within the KEN area there are two nested networks; the higher density/small domain Kenaston and the lower density/larger domain Saskatoon network (Figure 2). These permanent sites will provide long term observations for both SMOS and SMAP. Conducting additional sampling in these fields and at higher density in the area will contribute to calibration and verification of this valuable validation resource. Access to the adjacent fields is also expected to be possible due to pre-existing cooperation with the land owners/operators. Each site includes soil moisture at a depth of 5 cm.

The network site locations will be augmented with additional sites to provide information in areas of KEN that have no sites or underrepresented vegetation/soil conditions.

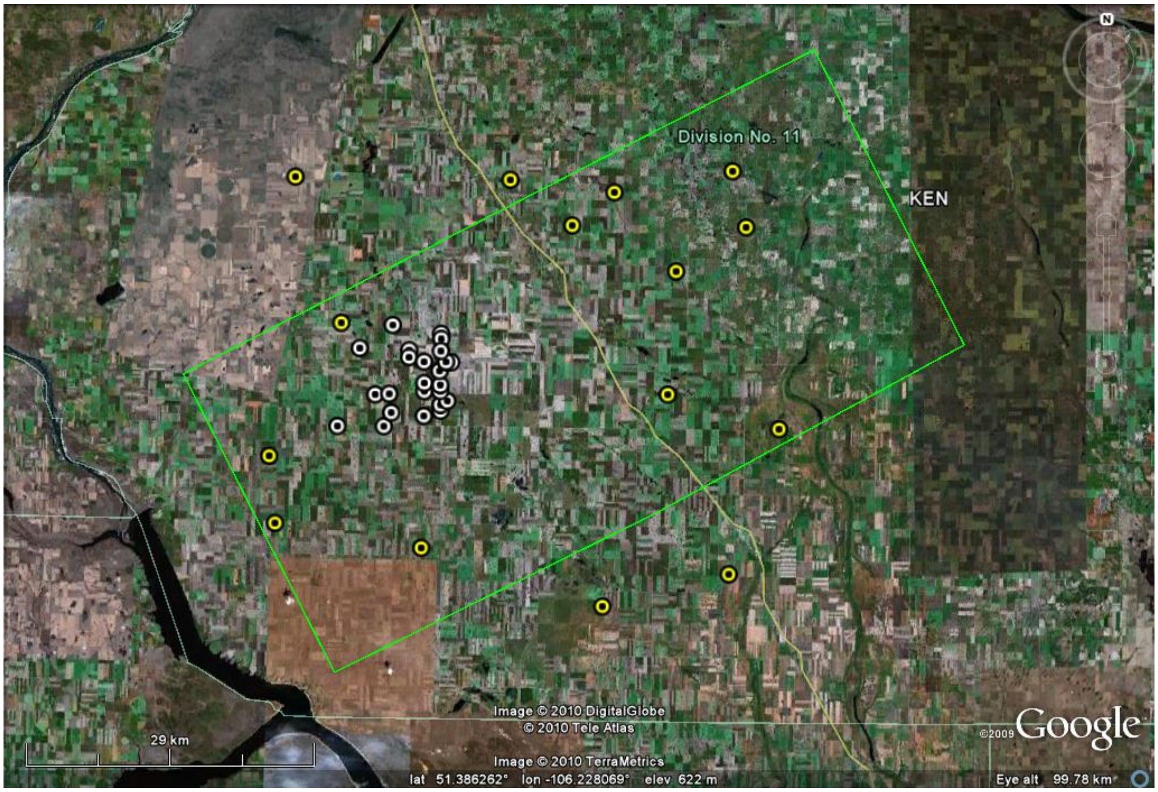

Figure 2. The Kenaston (KEN) area shoeing the aircraft mapping domain and the locations of the in situ sites (White-Kenaston network and Yellow=Saskatoon network).

In the BERMS area there are six in situ soil moisture sites (Figure 3). As with the KEN area, it would be beneficial if as part of CanEx we can contribute to the calibration and scaling of these sites for satellite validation. Capturing a range of conditions (with only one day) and sampling under the logistical challenges of this area will require an innovative experiment design if we are to do more than a one tome characterization. Therefore, we are planning to conduct two types of sampling here. The first will be by ground teams and the second using a temporary network. The temporary network will be focused on the center of the domain near the five in situ sites. It will be installed prior to the flight and will remain in place for approximately two-months.

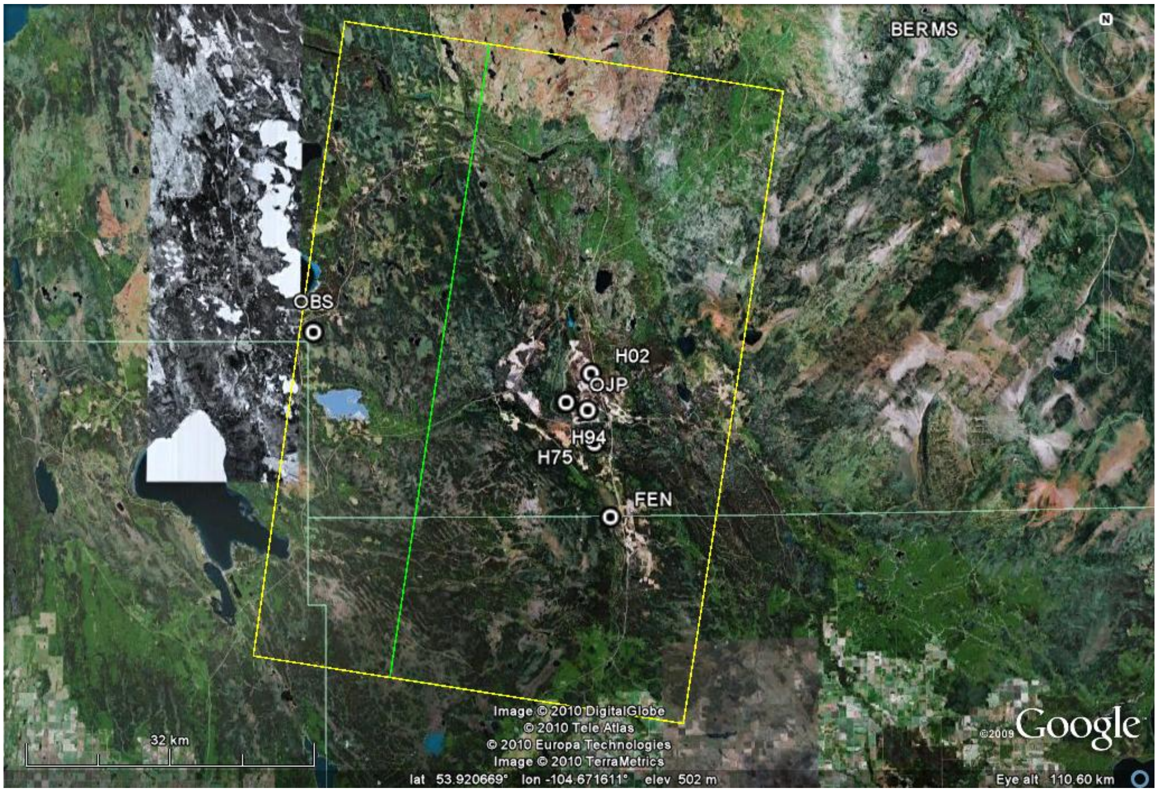

Figure 3. The BERMS area showing the aircraft mapping domains (EC green and UAVSAR yellow) and the locations of the in situ sites (White circles).

6. UAVSAR Flight Lines and Plan

The primary objective of the UAVSAR flights is to provide data to support the SMAP radar only and combined radar-radiometer soil moisture retrieval algorithm development and validation. To achieve this objective, the campaign should cover as long a period as possible with a flight interval similar to SMAP coverage, every 2-3 days. Diverse conditions and changes in soil moisture are desirable over the period. Ground-based observations must be available. In order to address the combined algorithm issues, EC Twin Otter flights should be the same day. If flights are made on days with SMOS coverage it will be possible to analyze scaling aspects of integrating active and passive observations.

Taking into account these factors, the schedule shown in Table 1 was developed. All UAVSAR flights will be planned to coincide with the beginning of ground sampling (~7:30 am local time). The last day of flights may be de-scoped depending up flight-hour resources available. An additional (and possibly de-scoped) flight over BERMS may be conducted if there are remaining resources (only over lines with in situ sites).

Coverage is requested for the entire KEN box and the BERMS-UAVSAR box at incidence angles between 35 and 45 degrees (to best match the SMAP incidence angle) and for the same azimuth angle or heading (to facilitate scaling and simulating satellite coverage). The corner coordinates of these two boxes are listed in Tables 4 and 5.

In addition to this coverage, in the KEN area we are requesting coverage a smaller area (Table 6) with flights in the opposite direction. One of these additional lines will be flown twice. This additional data will be used to evaluate the additional value of fore and aft data acquisition for SMAP as well as data rate.

Finally, on the night of June 7th there will be an ALOS Palsar Fine Beam Dual Polarization acquisition over the KEN area. In order to establish the utility of Palsar data in SMAP algorithm development (it has a different configuration), we are requesting that one additional UAVSAR line is flown on June 8th that has the same azimuth angle as Palsar. The coordinates listed in Table 7 are the line we would like UAVSAR to cover at a 40 degree incidence angle headed South to North.

Table 4. Corner Coordinates of the CanEx KEN Area

Longitude (Deg.)	Latitude (Deg.)
-106.79454	51.39918
-105.89380	51.69817
-106.57078	51.13839
-105.67367	51.43567

Table 5. Corner Coordinates of the CanEx BERMS-UAVSAR Area

Longitude (Deg.)	Latitude (Deg.)
-105.06578	54.29447
-104.32063	54.22194
-104.50212	53.59501
-105.22300	53.66455

Table 6. Corner Coordinates of the CanEx KEN Area Reverse Heading Coverage (35-45 Degrees)

Longitude (Deg.)	Latitude (Deg.)
-106.76104	51.35604
-105.85838	51.65272
-105.79659	51.58021
-106.69793	51.28594

Table 7. Coordinates of the CanEx KEN UAVSAR coverage at 40 degrees on June 8th..		
	Longitude (Deg.)	Latitude (Deg.)
South End	-106.30500	50.89375
North End	-106.58400	51.91175

7. Ground Based Soil Moisture Sampling Plan

Under development

8. Key Points of Contact for UAVSAR Operations and Soil Moisture

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