



Soil Moisture Active Passive Validation Experiment 2008 (SMAPVEX08) Experiment Plan



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1. Background

The Soil Moisture Active Passive Mission (SMAP) is currently in Phase A and addressing numerous issues related to the L3 soil moisture retrieval algorithms. During discussions at the SMAP Workshop in June 2007, at pre-Phase A Science Transition Team meetings, and previously during Soil Moisture Mission Working Group meetings, a number of specific questions have been identified. Many of these questions need to be answered in the near-term:

- How well do new alternative RFI suppression techniques under consideration for SMAP work over RFI contaminated land areas? (RFI)
- There is a lack of robust sets of concurrent passive and active L-band observational data including temporal change for algorithm development and validation. Concurrent active-passive is what is new with SMAP and we have very few data sets to date for algorithm development and evaluation. (TAP)
- How do high resolution SAR relate to lower resolution radar data of SMAP? There are potentially valuable SAR resources (PALSAR and UAVSAR) that can contribute to SMAP validation. (RS)
- What effect does azimuthal orientation have on radar backscatter for different land covers and topographic conditions at the spatial resolution of SMAP? This is a significant question in using temporal change algorithms. (AZ)
- Does topography have to be accounted for in retrievals? (TOPO)
- Can soil moisture be retrieved over urbanized areas? (URBAN)
- Under what conditions can we expect to retrieve soil moisture under forest canopies? (FOREST)

Addressing these issues as soon as possible would contribute to mission definition and algorithms design and selection. To the necessary information, a series of aircraft-based flights will be conducted on the Eastern Shore of Maryland and Delaware in the fall of 2008 (~two weeks in early October). The primary sensor for this campaign will be the Passive Active L-Band System (PALS); however, several other new instruments will be part of the experiment. This will be the first SMAP Validation Experiment (SMAPVEX08).

2. Study Site

The region selected for SMAPVEX08 is a mixed agriculture and forest site located about 1 hour east of Washington, DC on the Eastern Shore (of the Chesapeake Bay). Flight lines will cover portions of Maryland and Delaware. The corner coordinates of the primary study area are listed in Table 1. The general location is shown in Figure 1.

This region is located on the Delmarva Peninsula and land cover is mixed agriculture (58%) and forest (33%). Summer crops are primarily corn and soybeans. The field sizes, shapes and alignments are highly variable. Some of the forested areas are wetlands. Figure 2 is a Landsat image from Sept. 23, 1999. In this false color image, deep red is forest, medium red is likely to be soybeans, and white/gray is harvested and senescent corn. Forests are primarily deciduous; however, there are coniferous/evergreen areas.

ARS HRSL is conducting studies of agricultural water quality, conservation practices, and forest wetlands within the region and has some established sampling sites.

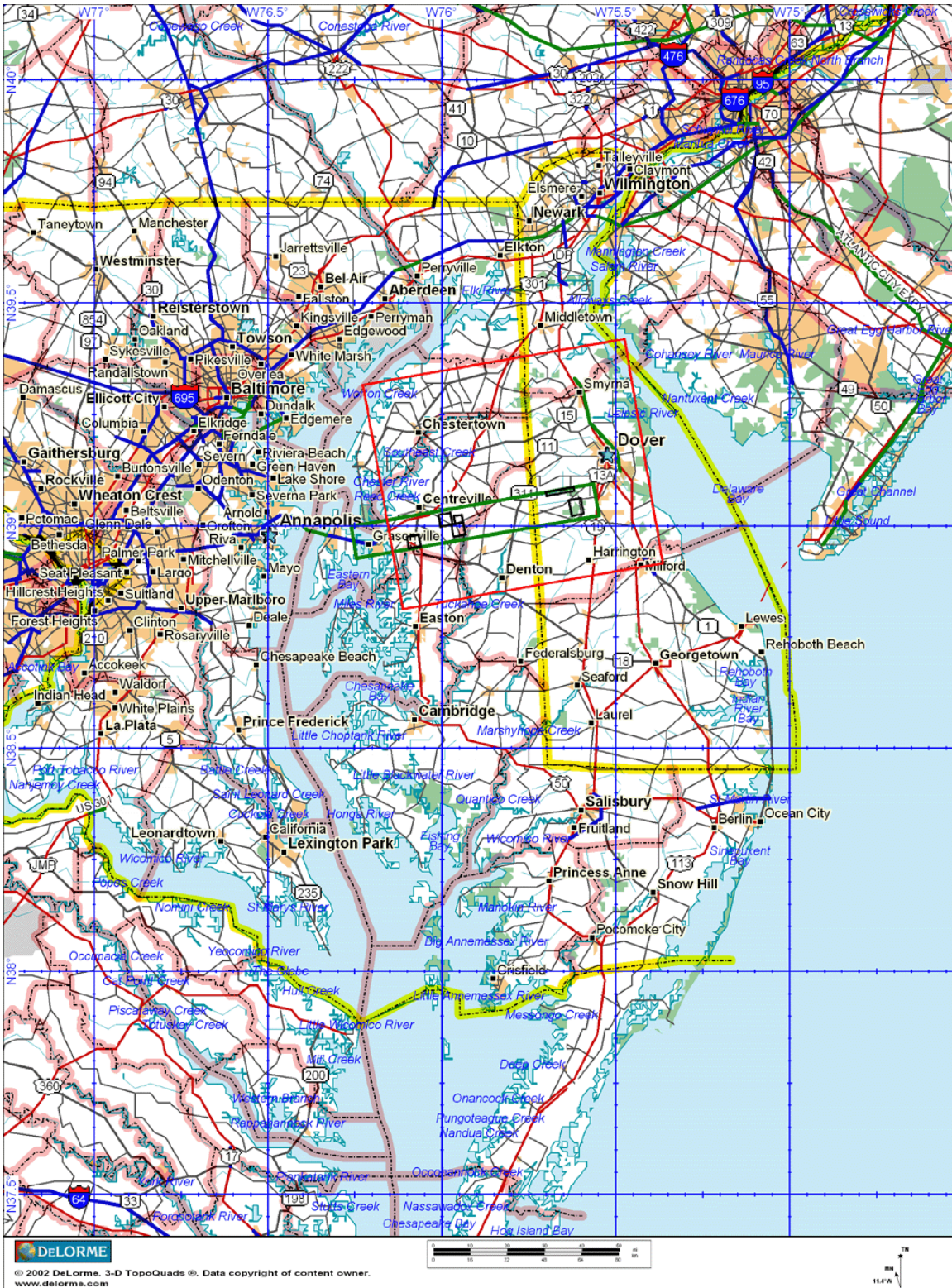


Figure 1. SMAPVEX08 Study Region.

Table 1. Choptank Study Area		
Corner	Latitude (Deg.)	Longitude (Deg.)
Upper Left	38.99888	-76.2611
Upper Right	39.09452	-75.5647
Lower Left	38.92763	-76.2449
Lower Right	39.02327	-75.5485

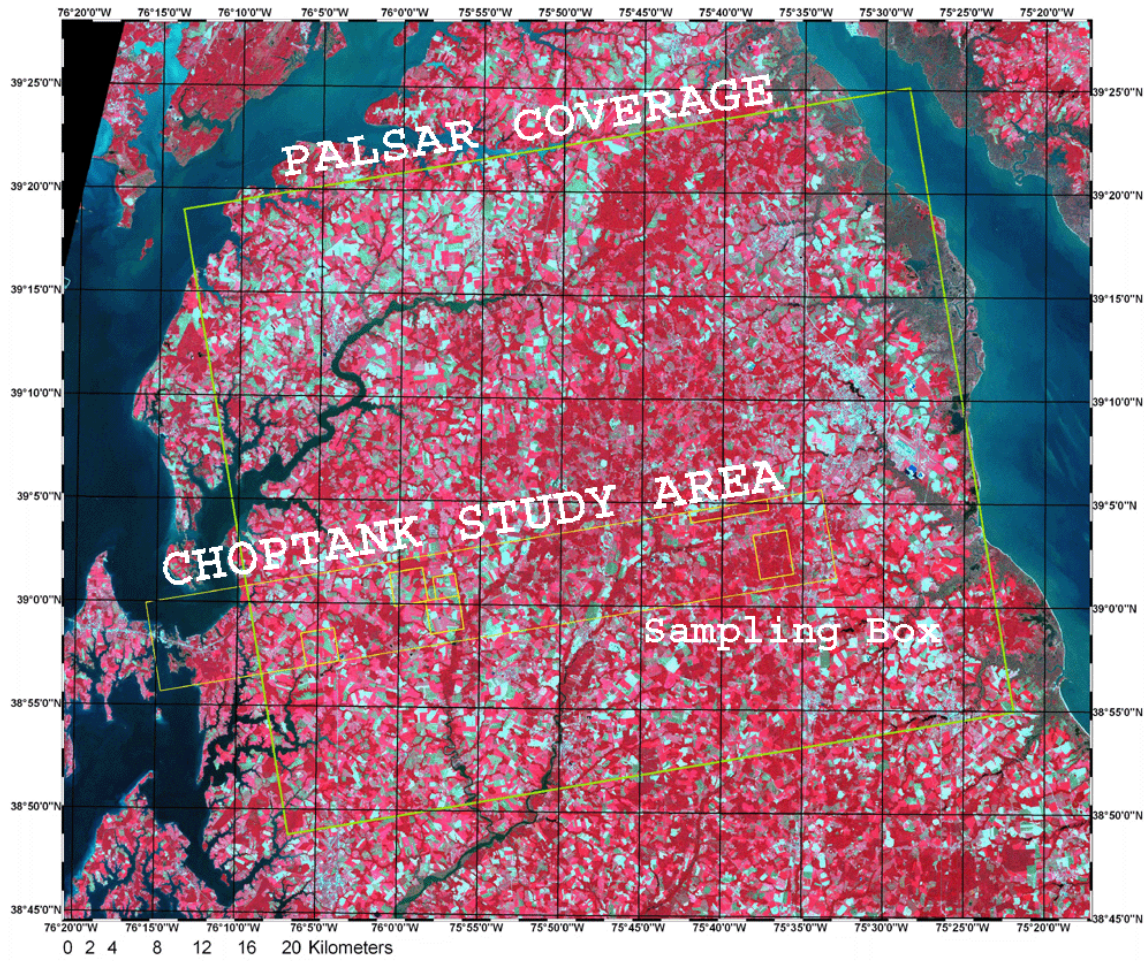


Figure 2. Landsat TM False Color Composite of the Choptank Site (Sept. 23, 1999).

Figures 3-5 illustrate ground conditions on July 22, 2008. Figure 3 shows typical soybeans planted in no-till wheat stubble and corn. Figure 4 includes soybeans planted with conventional tillage and corn. Figure 5 illustrates forest canopy and understory conditions.

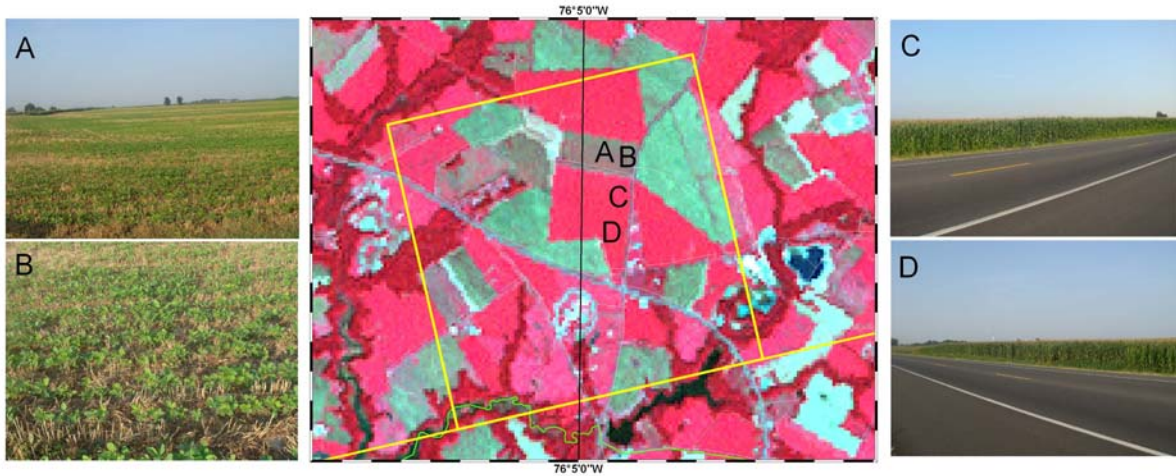


Figure 3. Ground conditions on July 22, 2008. Locations A and B are soybeans planted in no-till wheat stubble and locations C and D are conventional till corn.

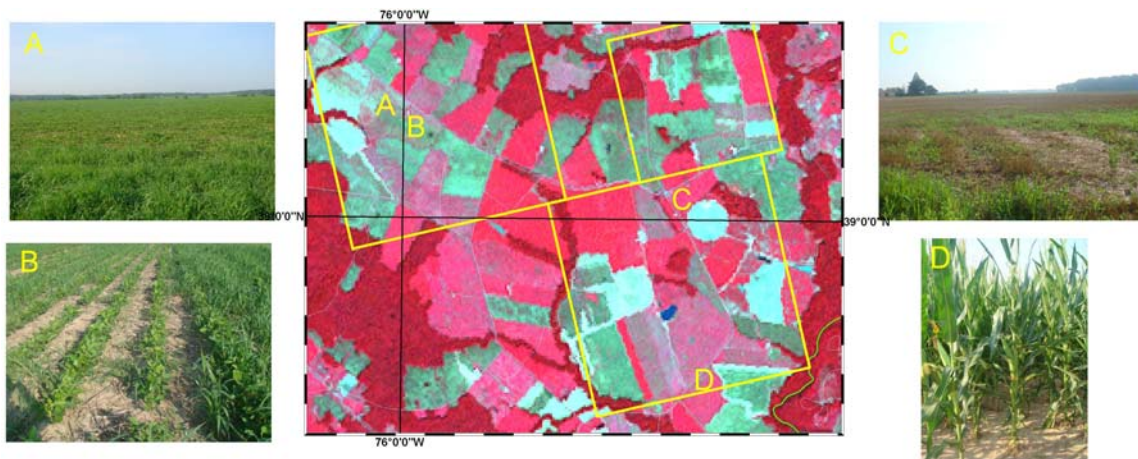


Figure 4. Ground conditions on July 22, 2008. Locations A and B are conventional till soybeans, location C is no till soybeans, and locations D is conventional till corn.

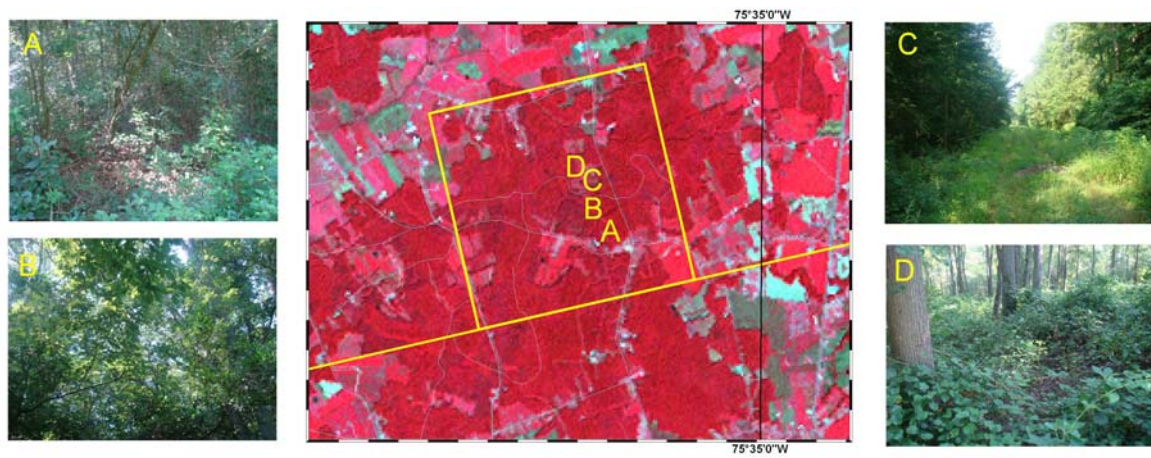


Figure 5. Ground conditions on July 22, 2008. All locations illustrate forest sites.

3. Aircraft Instruments

Four aircraft L-band instruments (PALS, MAPIR, LIS, and GSPR) and one satellite sensor will contribute to SMAPVEX08. These will be flown on two aircraft that will be described in a following section (PALS-Twin Otter, MAPIR/LIS/GPSR-P3B). At this time it is uncertain whether the UAVSAR will be available. Some preliminary information on the UAVSAR is included in Appendix I.

3.1. PALS

The Passive/Active L-band Sensor (PALS) provides radiometer products, vertically and horizontally polarized brightness temperatures, and radar products, normalized radar backscatter cross-section for V-transmit/V-receive, V-transmit/H-receive, H-transmit/H-receive, and H-transmit/V-receive. In addition, it can also provide the polarimetric third Stokes parameter measurement for the radiometer and the complex correlation between any two of the polarized radar echoes (VV, HH, HV and VH). Table 2 provides the key characteristics of PALS.

Instrument		Passive/Active L-band Sensor (PALS)
Owner		Jet Propulsion Laboratory (USA)
Platform		Twin Otter, C-130, P-3, DC-8
Passive	Frequencies	1.413 GHz
	Polarizations	V, H, +45, -45 polarizations
	Spatial Resolution	20 degrees (3dB beamwidth in Deg.)
Active	Frequencies	1.26 GHz
	Polarizations	VV, HH, VH, HV
	Spatial Resolution	20 degrees
Scan Type		Fixed
Antenna Type		Microstrip planar antenna with >30 dB polarization isolation
POC/Website		Simon.Yueh@jpl.nasa.gov
Current Status		Operational, flight tested on Twin Otter and C-130.

PALS has flown in three major soil moisture experiments (SGP99 [Njoku et al., 2002, Wilson et al., 2001], SMEX02 [Narayan et al., 2004], and CLASIC [Bindlish et al., 2008]). Beginning with CLASIC, a new flat-panel antenna array was substituted for the large horns. The planar antenna consists of 16 stacked-patch microstrip elements arranged in a four by- four array configurations. Each stacked-patch element uses a honeycomb structure with extremely low dielectric loss at L-band to support the ground plane and radiating patches. The measured antenna pattern shows better than 33 dB polarization isolation, far exceeding the need for the polarimetric measurement capability. This compact, lightweight antenna has enabled PALS to transition to operating on small aircraft, such as the Twin Otter (Figure 6).

Since CLASIC, the PALS has been augmented with additional components designed to detect and mitigate Radio Frequency Interference (RFI). The demonstration and

evaluation of these elements are an important consideration in the SMAPVEX08 design and will be very important to SMAP.

PALS will be mounted at a 40 degree incidence angle looking to the rear of the aircraft. The 3dB spatial resolutions of the instruments at two potential altitudes are 350 m (1000 m altitude, minimum for the radar operation) and 1100 m (3000 m, maximum). It is important to note that PALS provides a single beam of data along a flight track and that any mapping must rely upon multiple flightlines at a spacing of the footprint width.

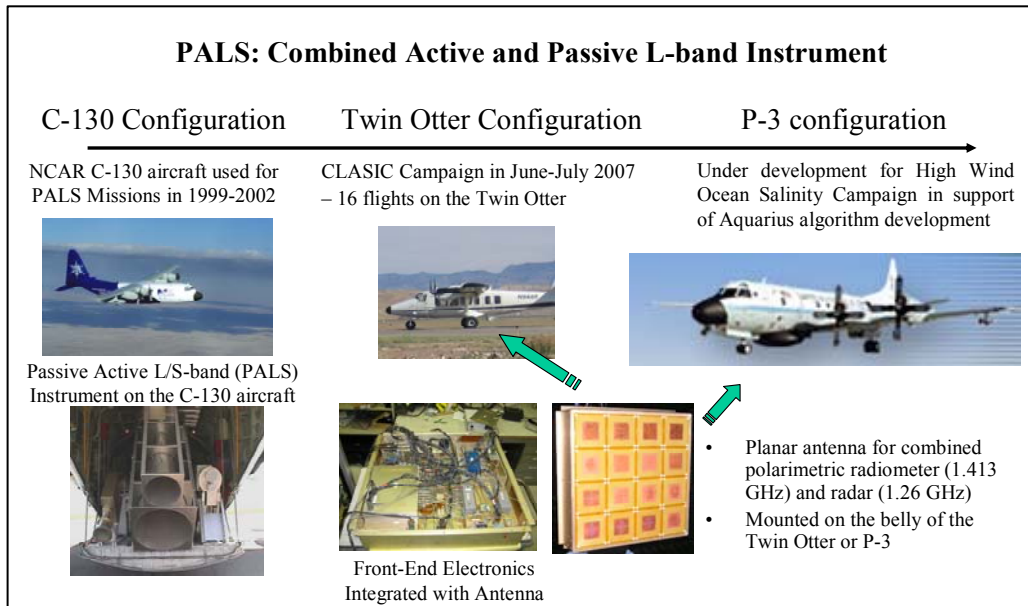


Figure 6. The PALS installations on aircraft.

3.2. MAPIR


The Marshall Airborne Polarimetric Imaging Radiometer (MAPIR) is a new aircraft based L band radiometer that observes emissions in the 1401-1425 MHz passband. As described in Table 4 and illustrated in Figure 7, it can operate in several modes that facilitate mapping larger regions and can effectively simulate the SMAP radiometer configuration while doing this.

The MAPIR antenna is a planar phased array that can electronically steer two independent beams that feed four ultra stable radiometers. The radiating element of the antenna subsystem is a dual-polarized, probe-fed patch antenna comprised of 80 individual “smart” patches. The antenna has a main lobe beamwidth of $\sim 15^\circ$ at boresight and first sidelobe level of less than -30 dB achieved by a Taylor Amplitude Taper. Each antenna element has a phase shifting network associated with each polarization to point the beam at a given scan angle up to $\pm 45^\circ$ from boresight. Each RF pathway results from any combination of four independent beam steering angles. Thus, the system is capable of simultaneous measurements of horizontal and vertical polarizations or a single polarization at two different look angles.

The MAPIR system architecture utilizes two two-channel narrow band receivers associated with the 1401-1425 MHz passbands, one for each polarization or for different look angles. These receivers also serve as the RF front end for two four-channel wideband (1350-1450 MHz) receivers. Both the narrowband and wideband receiver subsystems will send analogue signals to a common digital backend subsystem that will process signals in the Agile Digital Detector system to detect radio frequency interference (RFI) for post-flight elimination. MAPIR also includes a high-speed spectrum analyzer that will be used to acquire high spectral resolution RFI for characterization.


MAPIR will be integrated on the NASA P-3B aircraft based at Wallops Flight Facility (WFF). The P-3B has a cruising speed of 600 km/hr and maximum altitude of 8,000 m. Table 5 shows the average footprint resolution and swath width at ± 40 degree incidence angle for several altitudes to be flown during SMAPVEX08.

Table 4. MAPIR Description	
Instrument	Marshall Airborne Polarimetric Imaging Radiometer (MAPIR)
Owner	NASA/MSFC (USA)
Platform	Local aircraft, NASA P-3, Lear 25
Frequencies	1.413 GHz
Polarizations	H, V for two simultaneous beams
Spatial Resolution	15° (3dB beamwidth in deg.)
Scan Type	In-flight programmable electronic beam steering modes for two independent beams: Staring, Push-broom, Conical
Antenna Type	80 element planar patch phased array
POC/Website	Chip Laymon, NASA/MSFC, charles.laymon@nasa.gov
Current Status	System level testing, aircraft integration



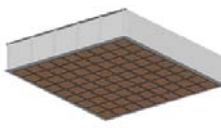
MAPIR: Marshall Airborne Polarimetric Imaging Radiometer

[C. Laymon, NASA/MSFC, charles.laymon@nasa.gov]

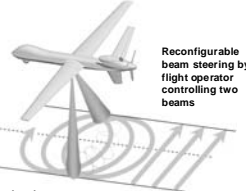


Features


- Real aperture, L-band phased array antenna
- 81 elements
- Dimensions: 102 x 102 x 18 cm
- Beamwidth: 15° boresight
- Polarization: vertical and horizontal
- In-flight reprogrammable, electronic beam steering with electronic phase shifters
- No scanning (staring) or reconfigurable scanning modes (line or conical)
- Look angle: 0°-45°, 360° azimuth, 1° resolution
- Simultaneously observe emissions at two locations, or one location and two polarizations
- Two radiometers: 1400-1426 MHz for science; 1350-1450 MHz for RFI detection
- Digital back end detects and eliminates L-band RFI
- Integrated spectrum analyzer to characterize RFI
- 5 microchip temperature sensors on each patch; data stored in on-board external EEPROMs
- cross polarization isolation at least -30 dB
- ~100 lbs.




L-band phased array radiometer with 15° beamwidth uses Programmable Integrated Circuits (PIC) to steer two beams to acquire data simultaneously at two polarizations or two locations.




Reconfigurable beam steering by flight operator controlling two beams




Multilayer boards developed at MSFC used to control antenna beam steering are embedded behind each patch




Small in-house developed and third party receivers are used to sample different bandwidths—one for science, one for RFI detection






Spectrum analyzer to characterize RFI & digital back end detects and eliminates L-band RFI



BenADC-V4 with on-board Xilinx FPGA



Partners

C. Laymon, PI J. McCracken, PM NASA Marshall Space Flight Center, Earth Science Office

Figure 7. MAPIR details and aircraft integration.

Table 5. MAPIR Average Footprint Resolution and Swath Width with a ± 40 Degree Incidence Angle

Altitude (m)	Spatial Resolution (m)	Swath (m) in Conical Mode
8000	4200	18900
4000	2100	9500
2000	1000	4700

This is the first flight mission for MAPIR and several operational objectives will be addressed. Minimum science objectives are to acquire brightness temperature data at 40° in staring mode at different resolutions over varied land cover types at varied soil moisture conditions. In order to acquire concurrent 40 degree data with the LIS, the staring position will be to the left or right of the flight direction (which creates an issue in matching data to the PALS flight lines). An important secondary objective is to detect, acquire & archive spectral characteristics of RFI. MAPIR will be flying with the DBSAR instrument (see below); therefore, mission design will attempt to acquire integrated passive/active data sets. In addition, to the degree possible the missions will be designed to cover the PALS lines for intercomparison.

3.3. L Band Imaging Scatterometer (LIS)

The L-Band Imaging Scatterometer (LIS) is a 1.26 GHz airborne phased array radar developed at NASA Goddard Space Flight Center for flight operation onboard the P-3 aircraft. LIS combines electronic beam steering and digital beam forming allowing the implementation of different scanning techniques. The LIS efforts are part of the RadSTAR (DBSAR) initiative intended to develop the technology that enables combined radar/radiometer systems that jointly uses a single, dual frequency antenna with cross-track scanning capabilities. The LIS hardware and data processor system have recently been upgraded to perform higher resolution (SAR) measurements. Table 6 includes details of the LIS instrument. LIS looks below the aircraft and in scatterometer mode views multiple beam positions across track (± 45 degrees).

Instrument	L-Band Imaging Scatterometer
Owner	Rafael Rincon , NASA GSFC (USA)
Platform	NASA P-3
Frequencies	L-band (1.26 GHz)
Polarizations	H or V; presently using H
Spatial Resolution	Scatterometer mode: 150 m in range, 12 degree beamwidth. SAR mode: 10 m in range, 10 in azimuth
Scan Type	Across track (± 45 degrees for radar-32 equally spaced footprints, 2.9 deg.); conical scan being developed
Antenna Type	Microstrip Patch array with beam synthesis (both active and passive); ESTAR = dipole array.
POC/Website	Rafael.F.Rincon@nasa.gov; 301-614-5725
Current Status	Some hardware upgrades required; Additional radar modes require testing (conical scan mode being developed; SAR mode ready for test).

The LIS beam positions relevant to SMAP will be located to the right and left of the flight track, as installed on the P-3. Footprint widths and locations of the +/-40 degrees beam positions in relationship to a flight line at potential flight altitudes are listed in Table 7. Note that integration time has not been selected yet. Total swath will equal 2*altitude. The spatial resolution at 4000 m altitude is approximately the same as PALS and the value at 8000 m is close to the SMAP radar product.

Table 7. LIS Average Footprint Resolution and Offset from Flightline for a ±40 Degree Incidence

Altitude (m)	Angle	
	Spatial Resolution (m)	Offset (m)
8000	2800	6712
4000	1400	3356
2000	700	1678

Efficient spatial coverage of the Choptank study area would require flying EW looking north and south. However, this coverage would have a 90 degree azimuthal viewing angle offset from PALS (and PALSAR). The flight lines described in a later section address this issue.

3.4. GPSR

Global Positioning System (GPS) radio-navigation signals strongly reflect from [liquid] water and, to a lesser extent, from land surfaces. The strength of the land-reflected signal is a function of both surface roughness and dielectric constant. As shown in Figure 8, the airborne GPS Reflectometer is used to simultaneously acquire both the direct-from-satellite and surface-reflected signals. Surface-reflected signals emanate from elliptically shaped areas of constant transmission path delay which yields a power vs. delay map of the surface. Note that this configuration of transmitter (satellites) and physically separate receiver (Reflectometer) form a type of bi-static radar system. The ratio of reflected-to-direct signal power is proportional to surface reflectivity and, allowing for roughness and utilizing appropriate surface models, to surface dielectric constant. The Global Positioning System Reflectometer (GPSR) will fly on the NASA P3-B aircraft. Some features of the GPSR are listed in Table 8.

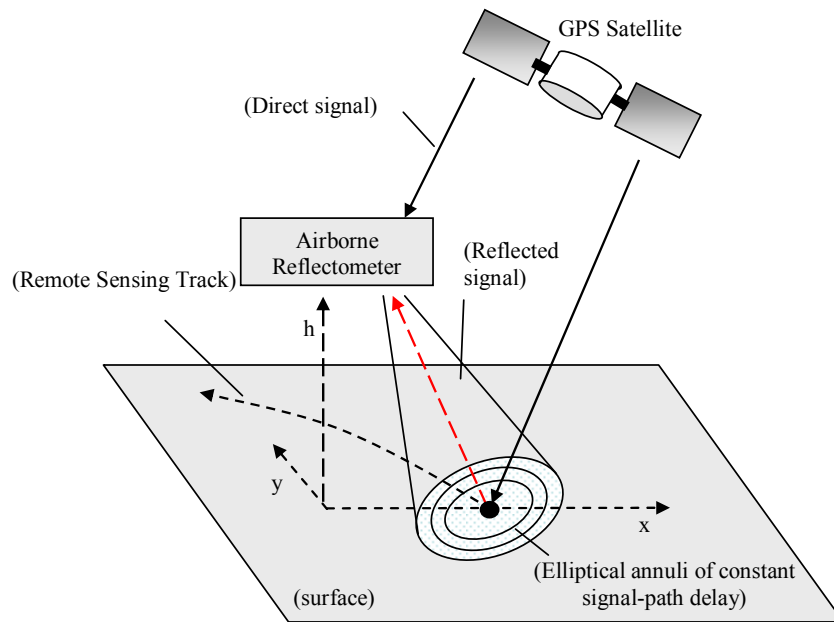


Figure 8. GPSR remote sensing geometry.

Table 8. GPSR Description	
Instrument	Global Positioning System Reflectometer (GPSR) (Delay Mapping Receiver)
Owner	NASA-Langley (USA)
Platform	Light aircraft or tower-based
Frequencies	1.575 GHz (GPS C/A Code, L1 Frequency)
Polarizations	RHCP (direct signal), LHCP (surface-reflected signal)
Spatial Resolution:	1 st Fresnel zone extent varies with aircraft (instrument) altitude and GPS satellite elevation angle. Examples for satellites between 65° - 90° in elevation: - 20 m resolution at 300 m altitude, - 34 m resolution at 1100 m altitude. ~1 st Fresnel zone for generally smooth terrain (e.g. agricultural areas)
Scan Type	(n/a)
Antenna Type	L-band 1.57542 GHz, 3.5" hemispherical antennae (direct/zenith and reflected/nadir)
POC's/Website	Michael Grant (NASA-LaRC), Michael.S.Grant@nasa.gov or Stephen Katzberg (S. C. State Univ./LaRC), Stephen.J.Katzberg@nasa.gov
Current Status	Operational

4. Land Surface Satellite Remote Sensing Data

4.1. PALSAR

The Phased Array type L-band Synthetic Aperture Radar (PALSAR) is on the JAXA ALOS platform. Table 9 and Figure 9 present the various features of the system. The repeat cycle is 46 days and the local equatorial crossing time 10:30 am for the descending pass. The data are available to currently selected investigators. This radar sensor can operate in several modes. Each of these has different constraints and in general they operate in a predetermined mode for different periods of the year. Requests are more likely to be granted if they conform to these configurations. The four default configurations that are summarized in Table 10.

Instrument	Phased-array type L-band SAR (PALSAR)	
Owner	JAXA	
Platform	Satellite (ALOS)	
Frequencies	1.27 GHz	
Polarizations	HH, HV, VH, VV	
Spatial Resolution	10-100 m	
Scan Type	SAR	
Antenna Type	SAR	
POC/Website	Earth Observation Research Center (EORC), JAXA http://www.eorc.jaxa.jp/ALOS/index.htm	
Current Status	Operational	

Mode	Polarizations	Angles (Deg.)	Resolution (m)	Swath (km)	Pass
Fine Beam	HH	34.3	12.5	70	A
Fine Beam	HH, HV	34.3	12.5	70	A
Polarimetric	HH, VV, HV, VH	21.5	12.5	60	A
ScanSAR	HH	20.1-36.5	100	360	D

In order to contribute to SMAP, we must attempt to obtain data that is similar in configuration and verify consistency to the SMAP design. For SMAP we would prefer fully polarimetric at 40°. This cannot be provided by PALSAR. Considering the default modes we have two choices; either an angle close to 40° with two polarizations or fully polarimetric at a significantly lower incidence angle. Of the two options, the first is likely to provide us with the most information for SMAP and should be selected.

A request was made to JAXA for all possible coverage during this period and the list of scenes in Table 11 was provided. It includes a mixture of the default modes. *Based upon the current schedule of SMAPVEX08, only the 10/08/2008 pass falls in the campaign time frame.* Depending on the circumstances, it is possible JAXA may acquire additional scenes over the study area. FBD mode observations are made on ascending passes looking to the *right* of the satellite track. Figure 2 includes the extent and orientation of

the swath over the Choptank site. Corner coordinates for the PALSAR FBD data over the Choptank study area are listed in Table 12. The May and July 2008 acquisitions are available.

Observation Date	Mode	A/D
05/06/2008	WB1	A
05/23/2008	FBD34.3	A
06/04/2008	WB1	A
07/08/2008	FBD34.3	A
08/23/2008	FBD34.3	A
09/07/2008	WB1	D
09/16/2008	PLR21.5	A
10/08/2008	FBD34.3	A

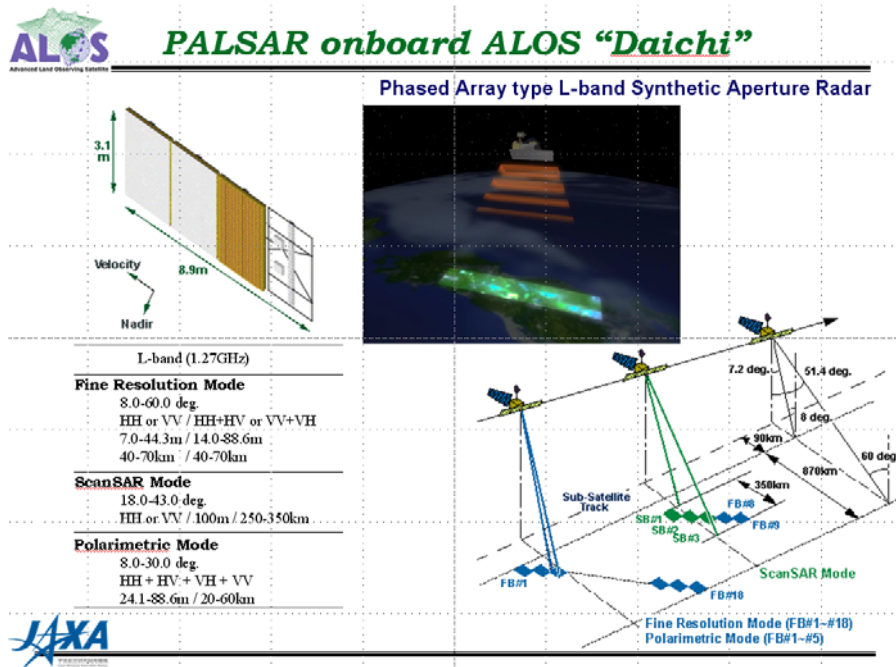


Figure 9. Schematic of PALSAR Observing Modes.

The overpass will occur at approximately 10:30 pm local time on October 8. Since the logistics of ground and aircraft operations at night are too difficult to safely manage, data acquisitions on both October 8 and October 9 should be planned in order to minimize the possibility of a rainfall event occurring between the satellite and aircraft coverage times. If conditions and forecasts are favorable, only one of the two flights may be required.

Table 12. PALSAR FBD Image Coordinates		
Corner	Latitude (Deg.)	Longitude (Deg.)
Upper Left	39.316	-76.227
Upper Right	39.419	-75.475
Lower Left	38.813	-76.112
Lower Right	38.916	-75.365

PALSAR data from the May 23 and July 8, 2008 FBD acquisitions were successfully acquired. A portion of the data over the Choptank study area are shown in Figure 10.

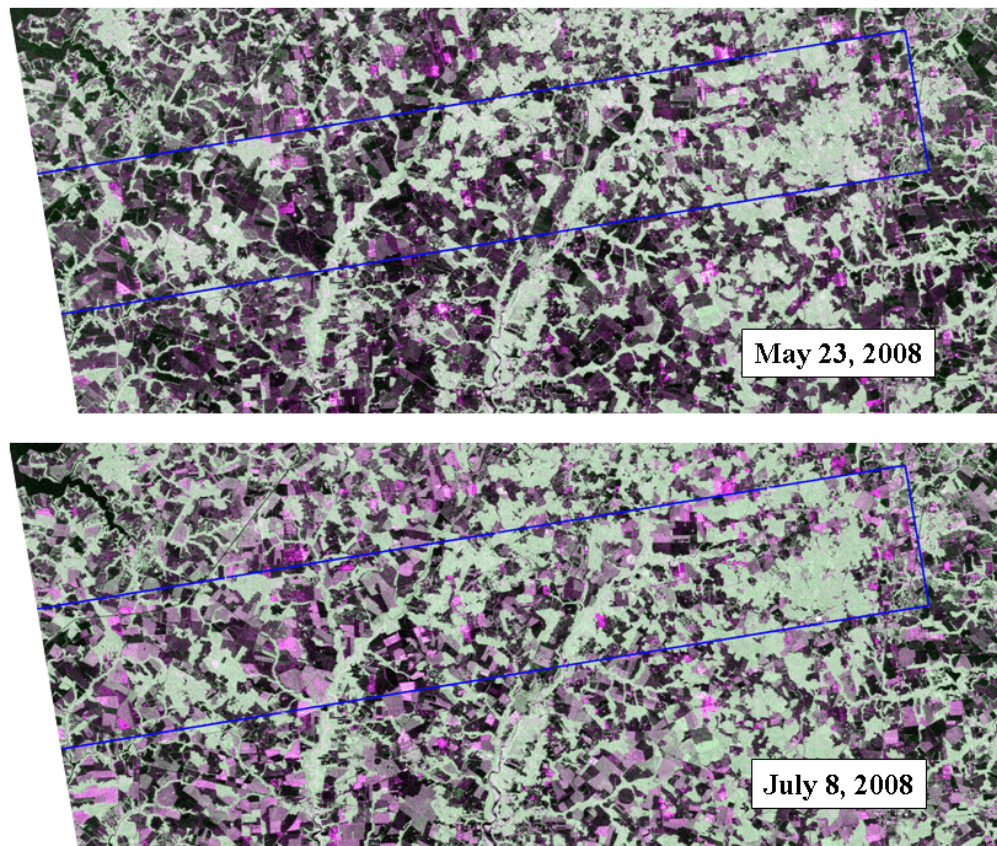


Figure 10. PALSAR composite images of the Choptank study area (R=HH, B=HV, and G=HH).

4.1. Advanced Microwave Scanning Radiometer (AMSR-E)

AMSR-E on Aqua (<http://wwwghcc.msfc.nasa.gov/AMSR/>) was launched in May 2002. Algorithm development and validations of AMSR-E soil moisture products are very important components of the SMEX program (Njoku et al., 2003).

As shown in Table 13, the lowest frequency of AMSR-E is 6.9 GHz (C band). However, studies indicate that there is widespread radio frequency interference (RFI) in the C band channels (Li et al., 2004). Therefore, it is likely that the most useful channels for soil moisture will be those operating at the slightly higher X band. The viewing angle of AMSR is a constant 55°. Details on AMSR-E can be found at <http://wwwghcc.msfc.nasa.gov/AMSR/>. Aqua afternoon overpasses are summarized in Table 14.

Frequency (GHz)	Polarization	Horizontal Resolution (km)	Swath (km)
6.925	V, H	75	1445
10.65	V, H	48	1445
18.7	V, H	27	1445
23.8	V, H	31	1445
36.5	V, H	14	1445
89.0	V, H	6	1445

Month	Day
9	29
9	30
10	2
10	4
10	6
10	9
10	11
10	13

4.2. WindSat

WindSat is a satellite-based multi-frequency polarimetric microwave radiometer developed by the Naval Research Laboratory for the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO) (Gaiser et al., 2004). It is one of the two primary instruments on the Coriolis satellite. The Coriolis satellite was successfully launched on January 6, 2003 with an expected life cycle of three years.

The WindSat radiometer operates at nominal frequencies of 6.8, 10.7, 18.7, 23.8, and 37 GHz. Using a conically-scanned 1.83 m offset parabolic reflector with multiple feeds, the WindSat covers a 1025 km active swath (based on an altitude of 830 km) and provides two looks at both fore (1025 km) and aft (350 km) views of the swath. The nominal earth incidence angle (EIA) is in the range of 50 – 55 degrees. The inclination of the WindSat orbit is 98.7 degrees. It has a sun synchronous polar orbit with an ascending node at 6:00 PM and a descending node at 6:00 AM.

The WindSat has similar frequencies to the Advanced Microwave Scanning Radiometers on the Earth Observing System (AMSR-E), with the addition of full polarization for 10.7, 18.7 and 37.0 GHz and the lack of an 89.0 GHz channel. The characteristics of the WindSat radiometer are listed in Table 15. Initially, the methods developed for algorithm development and validations for AMSR-E may be applied to WindSat with minimal modifications. The coverage dates are summarized in Table 16.

Frequency (GHz)	Polarization	Incidence Angle (Degrees)	Footprint (Km)	Fore/Aft Swath (Km)
6.8	V, H	53.5	40 x 60	1025/350
10.7	V, H, U 4	49.9	25 x 38	1025/350
18.7	V, H, U, 4	55.3	16 x 27	1025/350
23.8	V, H	53.0	12 x 20	1025/350
37.0	V, H, U, 4	53.0	8 x 13	1025/350

Month	Day
10	1
10	2
10	3
10	7
10	8
10	13
10	14

4.3. MODIS and ASTER

The NASA Terra and Aqua spacecraft (<http://terra.nasa.gov/About/>, <http://aqua.nasa.gov/about/>) include several instruments of value to the investigations of soil moisture and vegetation dynamics proposed here. Of particular interest are the Moderate-resolution Imaging Spectroradiometer (MODIS) and on board both the Terra and Aqua satellites (<http://modis.gsfc.nasa.gov/>) and the Advanced Spaceborne Thermal

Emission and Reflection Radiometer (ASTER) on board Terra (<http://asterweb.jpl.nasa.gov/>).

The Terra satellite has a descending orbit that crosses the equator about 10:30 AM local time (SGP overpasses ~11:30 am CDT) and the Aqua satellite has an ascending equatorial crossing time of 1:30 PM local time (SGP overpasses ~2:50 CDT). Coverage of a single location varies with the orbital path, so coverage can be either daily or every other day. The angle of incidence varies depending on the orbital path from -55° to 55° for a swath of 2330 km. The bands of MODIS are listed in Table 17.

Table 17. MODIS Bands			
Primary Use	Band(s)	Wavelength	Pixel Size
Vegetation Index	1	620-670 nm	250 m
Vegetation Index	2	841-876 nm	250 m
	3	459-479 nm	500 m
	4	545-565 nm	500 m
Vegetation H ₂ O	5	1230-1250 nm	500 m
Vegetation H ₂ O	6	1628-1652 nm	500 m
	7	2105-2155 nm	500 m
Ocean Color	8-16	405-877 nm	1000 m
Atmospheric H ₂ O	17-19	890-965 nm	1000 m
Thermal	20-36	3.660-14.385 nm	1000 m

Most of the imagery from MODIS is provided by the NASA GSFC and LP DAAC as 250m, 500m or 1km gridded data products. Surface reflectance for bands 1-7 are provided as product MOD09, which has: (1) an atmospheric transmittance correction; and (2) a cloud mask. These data are not explicitly corrected for topography. A view-angle corrected surface reflectance is supplied every 8-days by product MCD43 in MODIS bands 1-7.

Other MODIS products of interest are land cover type and phenology (MOD12), vegetation indices (MOD13), leaf area index (MOD15), evapotranspiration (MOD16), net primary production (MOD17), and land surface temperature (MOD11), which are produced at daily, 8-day or 16-day intervals.

ASTER, another Terra sensor, provides high resolution visible (VIR (15m), shortwave infrared (SWIR - 30m)), and thermal infrared (TIR - 90m)) data (see Table 18). Coverage is only obtained on request and these are prioritized. ASTER scenes have been requested (Table 19). The local overpass time will be 10:58 am.

System	Channel	Spectral Range (μm)	Spatial Resolution (m)
VIR	1	0.52-0.60	15
	2	0.63-0.69	
	3N	0.78-0.86	
	3B	0.78-0.86	
SWIR	4	1.60-1.70	30
	5	2.145-2.185	
	6	2.185-2.225	
	7	2.235-2.285	
	8	2.295-2.365	
	9	2.360-2.430	
TIR	10	8.125-8.475	90
	11	8.475-8.825	
	12	8.925-9.275	
	13	10.25-10.95	
	14	10.95-11.65	

Month	Day
8	30
10	1

4.4. Landsat Thematic Mapper

The Landsat Thematic Mapper (TM) satellites collect data in the visible and infrared regions of the electromagnetic spectrum. Data are high resolution (30 m) and are very valuable in land cover and vegetation parameter mapping. Additional details on the Landsat program and data can be found at <http://landsat7.usgs.gov/programdesc.html>. At the present time Landsat 5 is still in operation and coverage dates are listed in Table 20.

Month	Day
9	25
10	10

4.5. Advanced Wide Field Sensor (AWiFS)

AWiFS is a moderate-spatial resolution sensor on board the Resourcesat-1 satellite from the Indian Remote Sensing Program (launched October 17, 2003). Data are available from Space Imaging (Thornton, Colorado). AWiFS has a swath of 740 km, which gives it a higher temporal repeat frequency than Landsat or Aster, but less than MODIS on Terra

and Aqua. The pixel size for AWiFS data is 56 m. If available these data will be acquired. Characteristics of AWiFS are presented in Table 21.

Equatorial crossing	10:30 AM
Orbit height	817 km
Swath width (km)	740 km
Orbit Inclination	98.7°
Number of orbits per day	14
Spatial Resolution (m)	56
Spectral Bands (micron)	0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70

4.6. SPOT

SPOT (Satellite Pour l'Observation de la Terre) is a high-resolution, optical imaging earth observation satellite system operating from space and is operated by the Spot Image Corporation in Toulouse, France. It has been designed to improve the knowledge and management of the earth by exploring the earth's resources, detecting and forecasting phenomena involving climatology and oceanography, and monitoring human activities and natural phenomena. The SPOT system includes a series of satellites and ground control resources for satellite control and programming, image production, and distribution. For SMAPVEX08, a SPOT scene will be collected for vegetation and geolocation purposes after Sept. 29 2008 that will be cloud-free for the study region at a resolution of 10m with Level 2A processing and nearest neighbor reprocessing at +/- 31 degrees. The channels are; 500-590 nm, 610-680 nm, and 780-890 nm. Other complementary activities in the region will provide SPOT imagery during August and December of 2008 as well.

5. Mission Designs

5.1. RFI Detection and Mitigation

The sources of L-band RFI as well as mitigation strategies are critical issues for SMAP. The detection and mitigation strategies have very good theoretical models. However, the RFI environment is less certain. These flights could improve our understanding of the environment and demonstrate the effectiveness of the design in an airborne system.

The PALS and related detection and mitigation components on the Twin Otter (TO) will be the primary source of data. However, the P-3B with MAPIR and LIS will also conduct RFI flights as part of their basic mission design. The following discussion relates primarily to the TO/PALS.

The objectives related to RFI for SMAPVEX08 are:

- Validate theoretical models of the RFI environment
- Demonstrate performance of SMAP design to be presented at SRR
- Collect data for additional characterization of the RFI environment

The requested flights are, in order of priority:

- 1) *Known radar sources nearby the Choptank study area.*

There are at least two potential radar targets that should be observed (Table 22). These can be incorporated into missions designed for other purposes but might require additional lines that orient PALS in a particular direction relative to the target. A single coverage is adequate. In addition to the radars, a known RFI site (ESTAR flights) will be flown if possible. The location is included in Table 22.

Site	Latitude (Deg.)	Longitude (Deg.)
Gibbsboro, NJ	39.8250	-74.9553
Oceana NAS	36.8020	-76.0395
ESTAR RFI Site	37.5750	-75.8200

- 2) *Collect data during transit flights*

Characterizing RFI and evaluating mitigation over a wide range of environments is very important and can be accomplished during the TO transit flights that will consist of three legs; (1) Grand Junction-Des Moines, (2) Des Moines-Delaware, and (3) Delaware-Grand Junction. Leg 1 would include the Denver area, Nebraska, and western Iowa that would provide a mix of urban, rangeland and agriculture. Leg 2 (without deviations) would pass by south of Chicago and cross northern Indiana, Illinois, and Ohio before crossing southern Pennsylvania (Pittsburgh and Philadelphia). It is suggested that on the return leg that the track from Delaware first head to Oklahoma City. This would cover West Virginia, Kentucky, Missouri and eastern Oklahoma. If possible, a few passes over the

Little Washita Watershed are suggested for comparison with CLASIC RFI observations. The last portion of this transit leg would include western Oklahoma and Colorado, which is rangeland and agriculture (irrigated and dryland).

3) *Fly over urban areas to collect RFI data and demonstrate detection and mitigation*

Basing out of Delaware offers easy access to many major urban/suburban areas. Observing these features is also of interest to the SMAP algorithm team. Selecting the flight lines for these purposes may be refined after the PALS has had a chance to observe the general RFI environment.

A possible mission is described in Table 23. This includes a line to New York City, a transit from there to northern New Jersey and a return over Philadelphia. Based upon a nominal aircraft speed of 200 kph this mission as described would be about one hour.

Line	Start		Stop		Length (km)
	Latitude (Deg.)	Longitude (Deg.)	Latitude (Deg.)	Longitude (Deg.)	
R01	39.6788	-75.6063	40.8005	-73.6320	210
R02	40.8005	-73.6320	40.8005	-74.2528	50
R03	40.8005	-74.2528	39.6788	-75.6063	170

5.2. Multitemporal Soil Moisture

There is a lack of adequate data sets for the development and evaluation of potential SMAP soil moisture algorithms. In particular, datasets with concurrent active passive observations. The largest data gap is in time series of radar data at the nominal spatial resolution of the SMAP products. This information is urgently needed for mission design. Therefore, for SMAPVEX08 we have identified the following objectives:

- Enhancement of concurrent passive and active L-band data sets
- Temporal change radar algorithms at coarse scale

To accomplish these objectives we will fly a series of flightlines with the TO in a consistent manner over the Choptank Watershed area of Maryland and Delaware (Figure 11). Figure 12 and Table 24 describe the TO/PALS flightlines. Lines prefixed with D are transit lines to and from the aircraft base in Delaware. Flights will be conducted about every other day, depending upon weather conditions and history. The TO/PALS lines will be flown at high altitude (3 km) in order to obtain low resolution radar data (1.1 km) over a mixed landscape where the nominal field size will be 300 m. Some design considerations are:

- Lines will be parallel with a small amount of overlap that will facilitate producing map products
- Lines will be flown in alternating directions to minimize flight time required
- The orientation was selected to match that of PALSAR ascending passes. This results in nominally EW and WE lines

- The general location covers most of the PALSAR swath and includes fields with ongoing cooperation

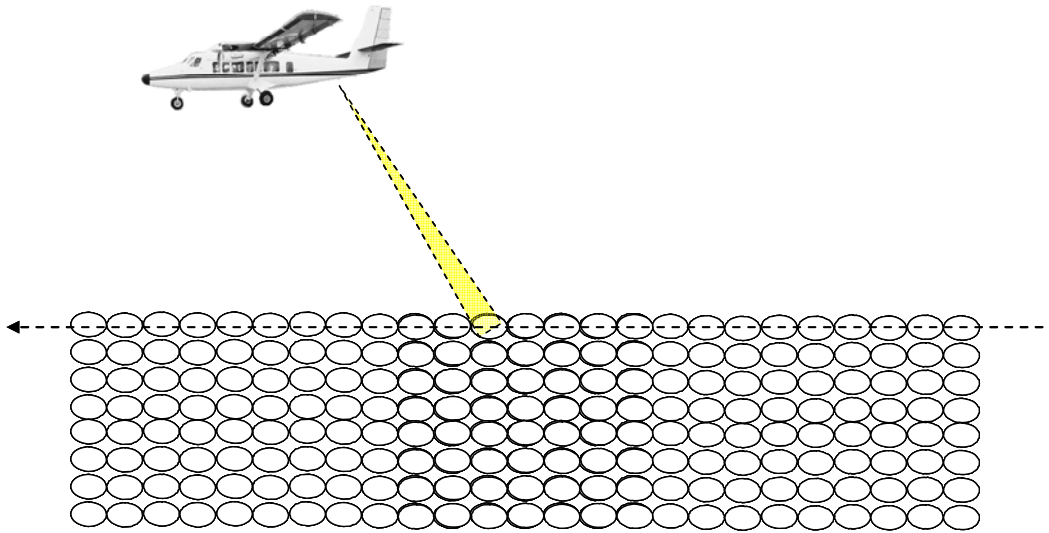


Figure 11. Temporal Active Passive (TAP) Flightline Schematic.

Line	Start		Stop		Length (km)
	Latitude (Deg.)	Longitude (Deg.)	Latitude (Deg.)	Longitude (Deg.)	
D01	39.6788	-75.6063	38.9944	-76.2601	60
T01	38.9944	-76.2601	39.0901	-75.5637	60
T02	39.0812	-75.5617	38.9855	-76.2581	60
T03	38.9766	-76.2561	39.0723	-75.5596	60
T04	39.0633	-75.5576	38.9677	-76.2540	60
T05	38.9588	-76.2520	39.0544	-75.5556	60
T06	39.0455	-75.5536	38.9499	-76.2500	60
T07	38.9410	-76.2480	39.0366	-75.5515	60
T08	39.0277	-75.5495	38.9321	-76.2459	60
D02	38.9321	-76.2459	39.6788	-75.6063	70

Based upon a nominal speed of 200 kph, these lines would require approximately four hours to complete. In addition, a water calibration line over the Delaware Bay will be flown each day.

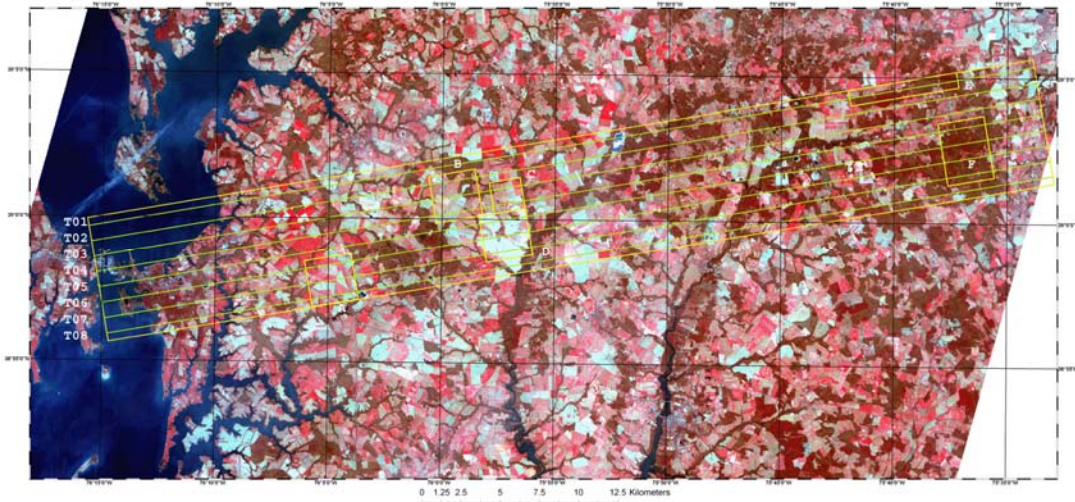


Figure 12. Landsat TM False Color Composite of the Choptank Site (Sept. 23, 1999) showing the TO/PALS flightlines (T01-T08) and the sampling boxes (A-F).

5.3. Radar Scaling

It is well known that high resolution SAR is highly responsive to surface structural features, in addition to soil moisture. The variations of these parameters in most landscapes have made it difficult to develop robust soil moisture retrieval methods. On the other hand, lower resolution radar data exhibits more synoptic patterns. Existing and future aircraft and satellite radar resources will be of value in pre-launch SMAP research and post launch validation. Understanding how to scale these to SMAP is critical to exploiting these resources.

The objectives of the Radar Scaling (RS) flights are:

- Establish the scaling of PALSAR to SMAP radar resolution via high altitude PALS
- Establish the scaling of PALSAR to SMAP radar resolution via multiple altitude LIS

To accomplish these objectives we will fly a series of TO/PALS flightlines over the Choptank Watershed area of Maryland and Delaware within twelve hours of a satellite PALSAR overpass on October 8 and/or October 9. As noted previously, on an ascending pass the PALSAR instrument will look to the right of track. The TAP flightlines were aligned to be perpendicular to this track (Table 24). However, as designed for TAP, only half the lines look in the same direction as PALSAR. *On this one day, several of the lines that are not correctly oriented will be flown in both directions.*

Figure 13 illustrates the coverage of PALS, PALSAR, and LIS. Assuming that the P-3 flies at an altitude of 8 km, the LIS swath will be 16 km. In order to match the PALSAR orientation the P-3 flightlines must be oriented roughly N-S. Of the 32 LIS beam positions, only those in the 35-45 degree range looking east are relevant for this comparison.

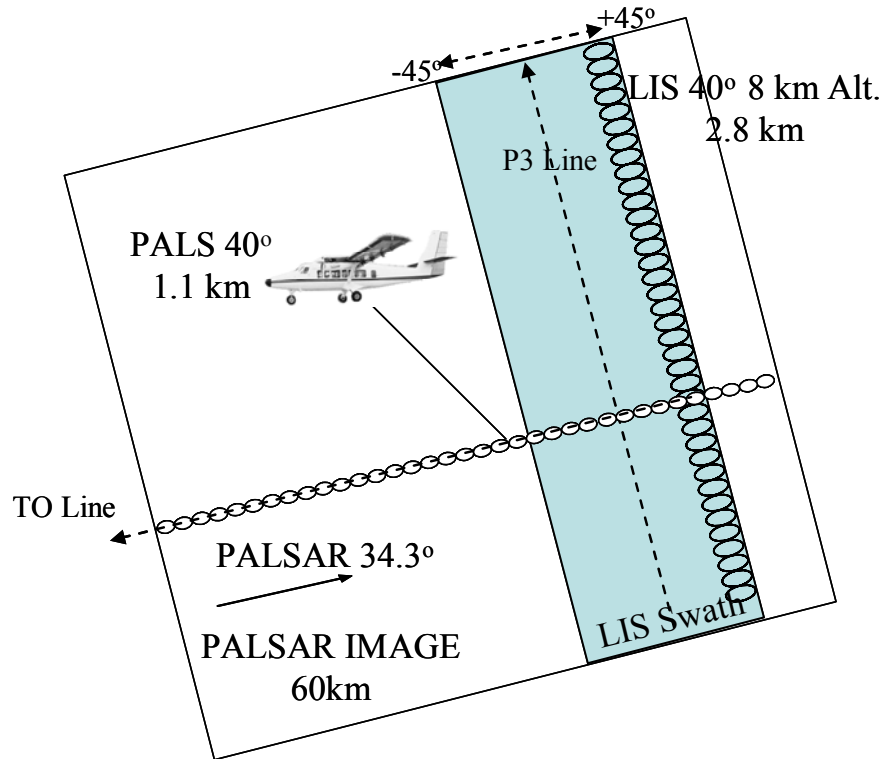


Figure 13. Schematic of the Radar Scaling Flights.

It is not feasible to cover the entire PALSAR image, or the Choptank study area with LIS footprints that match the incidence and azimuth angle of the other instruments. It is suggested that four lines be used. These would be located to cover the sampling boxes with the required geometry and would be the full length (NS) of the PALSAR image.

5.4. Azimuthal Orientation

Based upon the SMAP design, for a specific site the footprint will have a different azimuthal orientation each day. There have been some analyses of azimuthal effects with the ERS scatterometer at coarse scales (50 km) that suggests that it is not an issue at that scale. However, at higher resolutions the azimuth angle does impact the measurement. Within most agricultural domains row orientation is usually apparent in SAR data. There is also the question of changes in mixtures within footprints on different passes. How significant these changes are on our ability to use temporal change based retrievals is unknown. The research question is; will SMAP radar data be more like high resolution SAR or coarse resolution scatterometer data?

The following objectives were identified for AZ investigations:

- Resolve the effects of azimuthal orientation on radar backscatter at low resolution
- Effects of different land covers and topographic conditions
- Multiple-scale analyses

We will address these issues using several sets of TO/PALS flightlines over the Choptank site on a single day. Wetter conditions would enhance variability. First a long flightline over the study area will be flown at low (1000 m) and high (3000 m) altitude both E-W and W-E. Then a single point will be flown at high altitude in 4 directions oriented N-S, E-W, NE-SW, and SE-NW. This will be repeated at low altitude. Table 25 lists the flightlines. The focal point may be changed depending upon field conditions closer to the mission date.

It should also be noted that data collected as part of the TO/PALS and P-3/LIS RS flights can also address this issue.

Line	Start		Stop		Length (km)
	Latitude (Deg.)	Longitude (Deg.)	Latitude (Deg.)	Longitude (Deg.)	
D03	39.6788	-75.6063	39.0568	-75.5596	70
A01	39.0568	-75.5596	38.9300	-76.2330	60
A02	38.9300	-76.2330	39.0568	-75.5596	60
A03	38.9834	-75.9643	39.0331	-75.9643	8
A04	39.0076	-75.9976	39.0076	-75.9320	8
A05	39.0331	-75.9320	38.9834	-75.9976	8
A06	38.9834	-75.9320	39.0331	-75.9976	8
D04	39.0331	-75.9976	39.6788	-75.6063	70

5.5. Additional P-3 Flights

The P-3 will base out of the Wallops Flight Facility (WFF). The general mission profile is to fly from there and collect data at 2000, 4000, and 8000 m over the Choptank site. After science data collection one of two routes will be flown to return to WFC that will cover areas where RFI is expected (New Jersey and Virginia). The P-3B ground speed will be ~500 kph. A preliminary set of flightlines is presented in Table 26.

Name	Altitude	Latitude	Longitude	Latitude	Longitude
N2	2000 m	39.1260	-75.3631	38.9425	-76.3749
S2	2000 m	38.9093	-76.3749	39.1017	-75.3544
C4	4000 m	39.1149	-75.3660	38.9247	-76.3834
C8	8000 m	39.1149	-75.3660	38.9247	-76.3834

6. Ground Support and Ancillary Data Plans

Ground observations will be collected concurrent with aircraft flights. These will include soil moisture, soil temperature, surface temperature, and vegetation parameters. Another important element of the campaign is the acquisition of satellite imagery for mapping vegetation and land cover.

Soil moisture sampling will include concurrent observations of agricultural fields using Theta probes. Forest sites will be monitored with small temporary networks of in situ sensors that will be installed prior to the first flight and removed after the last. In addition, teams will visit the sites on flight days to collect limited verification data and to update land cover information, including ground photography. Protocols for sampling are included in Section 8.

One change from our traditional approach to sampling will be made for SMAPVEX08. Since our objectives require that we try to understand the phenomena at resolutions similar to SMAP footprints, we will be acquiring data at relatively coarse resolutions. At these scales it is unlikely that any satellite footprint would be homogeneous, therefore, we will not attempt to correlate individual fields to footprints (at low altitudes). Instead we will attempt to characterize soil moisture for all fields within an area (block) large enough to include several aircraft footprint. Within each block there may be 10 or more fields. Each of these fields will be sampled to provide statistically meaningful field average soil moisture. These collections of fields can then be integrated up to various footprint scales and locations.

Figure 12 shows the Watershed Blocks that were selected based upon diversity of conditions and logistics. The process of getting permissions for access is underway. Following this, field identifications will be developed.

6.1. Ground Soil Moisture Measurement Campaign

The goal of soil moisture sampling in the Watershed Block sites is to provide a reliable estimate of the mean and variance of the volumetric soil moisture within the aircraft sensor sampling footprint. The aircraft based microwave investigations, which will be conducted between 8:30am and 12:30pm EDT. This determines the time window for the Watershed Block sampling.

The primary measurement made will be the 0-6 cm dielectric constant (voltage) at eight locations in each field using the Theta Probe (TP). These locations will be co-located with any flux tower/instrument installed in the field, when present. Additional details will be provided in the Protocols section of the experiment plan. Dielectric constant is converted to volumetric soil moisture using a calibration equation. There are built in calibration equations and, as the result of SMEX02 and SMEX03 studies (Cosh et al., 2005), site specific calibrations have proven more reliable. Therefore, at two standard locations within each field the 0-6 cm gravimetric soil moisture (GSM) will be sampled on each day of sampling using a scoop tool. GSM is converted to volumetric soil moisture (VSM) by multiplying gravimetric soil moisture by the bulk density of the soil. Bulk density will be

sampled one time at each of these four locations using an extraction technique. These coincident gravimetric samples will provide a ground truth for Theta Probe calibration activities. It is anticipated that individual investigators may conduct more detailed supplemental studies in specific sites.

TPs consist of a waterproof housing which contains the electronics, and, attached to it at one end, four sharpened stainless steel rods that are inserted into the soil. The probe generates a 100 MHz sinusoidal signal, which is applied to a specially designed internal transmission line that extends into the soil by means of the array of four rods. The impedance of this array varies with the impedance of the soil, which has two components - the apparent dielectric constant and the ionic conductivity. Because the dielectric of water (~81) is very much higher than soil (typically 3 to 5) and air (1), the dielectric constant of soil is determined primarily by its water content. The output signal is 0 to 1V DC for a range of soil dielectric constant, ϵ , between 1 and 32, which corresponds to approximately 0.5 m³ m⁻³ volumetric soil moisture content for mineral soils. More details on the probe are provided in the sampling protocol section of the plan.

Watershed block sampling will only be performed on days with aircraft coverage of the watershed. However, due to timing of activities it may happen that ground sampling will be ongoing before the scheduled aircraft mission is cancelled.

6.2. Mini-Station Based Soil Moisture Measurements

Small scale stations will be deployed in several regions to assist in the calibration of aircraft datasets as well as monitor the localized soil moisture conditions for local surface flux work. These networks will vary in size and distribution, but will be composed of similar mini-stations.

Each station will consist of a soil moisture/soil temperature sensor recording at 30 minute intervals. The Stevens Water Hydra Probe (I) will be the sensor of choice, as it has proven reliable and robust in previous experiments as well as long term networks such as the USDA-NRCS SCAN. The datalogger is a Campbell Scientific CR206 datalogger with integrated 915MHz Radio. This will allow for small scale networking of sensors in some locations. Power will be provided by small solar panels designed specifically for the CR206 datalogger.

Forest Flux Study Region – A mini-net will be established in the forested regions in Delaware near Dover, DE. Covering a region approximately 3 km by 3 km in scale, a network of 10 Mini-stations will be deployed with a predominance in the local wind direction for measurements within the fetch of the local flux stations, beneath the forest canopy.

The exact locations of these sensor packages will not be determined until just before the SMAPVEX IOP. There is no regular ground sampling schedule for soil moisture in the forested sites; however, at least once during the experiment, some soil moisture sampling will be conducted in coordination with the mini-station deployment to verify the accuracy and representativeness of the installations.

6.3. Vegetation and Land Cover Classification

Vegetation biomass and soil moisture sampling will be performed for all watershed sites. The primary measurements during CLASIC from the Vegetation Sampling Team are: 1) plant density, 2) Leaf Area Index (LAI), 3) stem water content per plant, 4) foliage water content per plant, and 5) leaf Equivalent Water Thickness (leaf EWT). Vegetated fields will be sampled during week 1 (June 9-16) and resampled during week 3 (June 22-June 29) of CLASIC. The Vegetation Sampling Team will also make other important measurements at cropped sites such as 6) plant height, 7) plant cover, 8) digital photographs, and 9) number of leaves per plant (for determination of plant growth stage). In addition, multispectral observations will be made with a Cropscan instrument, described in the protocol sections.

Sampling will take place in two segments each day. In the morning, a group of three people will go to one to three sites and make measurements, return and process the samples at the work area. In the afternoon, one or two more sites will be visited by the team with an additional team deployed to characterize the surface roughness of each of the watershed sites. Some of the Vegetation Sampling Team will need to make leaf reflectance measurements in the afternoon. Each site will have 3 plots, two coincident with the GSM sampling points and the other a VSM sampling point.

Land cover maps of the watershed and region will be developed using procedures described in Doriaswamy et al. (2004). This will require the acquisition of several satellite images. In addition, a detailed survey of the low altitude mapping will be performed that includes the crop row direction where applicable.

The objectives of the soil and surface temperature are nearly identical to those of soil moisture. There are a few differences related to the spatial and temporal variability of temperature versus soil moisture. Typically the soil temperature exhibits lower spatial variability, especially at depth. On the other hand surface temperature can change rapidly with changes in radiation associated with clouds. In addition, it can be difficult to correctly characterize surface temperature at satellite footprint scales (30 m – 1 km) using high resolution ground instruments. This is especially true when there is partial canopy cover.

6.4. Surface Roughness

Each Watershed Block site field will be characterized one time during the time frame. The grid board photography method employed in previous experiments will be used. A total of three locations will be selected in a field, including two gravimetric sampling points. Between two and four pictures will be taken at each location to insure data capture and one pair of images will be processed for xy directions.

7. Logistics

7.1. Security/Access to Fields

Do not enter any field that you do not have permission to enter. If questioned, politely identify yourself and explain that you are with the USDA/NASA experiment. Flyers will be available that provide a general overview of the experiment. In case of any trouble, leave the field and contact your SMAPVEX supervisor. At the time of sampling, if the farmer is working in the field, DO NOT sample and contact your SMAPVEX supervisor. Prior to the experiment all requests for field access are to be directed to Mike Cosh (Micahel.Cosh@ars.usda.gov). Do not assume that you can use a field without permission. Requests for installations and unplanned sampling made during the experiment will not be easy to satisfy. Tracking down a landowner and getting permission can take up to a half-day of time by our most valuable people. These people will be extremely busy during the experiment. Therefore, if you think you will have specific needs that have not been addressed, you did not spend enough time planning...so learn for the next time.

7.2. Safety

General Field Safety

There are a number of potential hazards in doing field work. The following page has some good suggestions. Common sense can avoid most problems. Remember to:

- When possible, work in teams of two
- Carry a phone
- Know where you are. All roads have street signs. Make a note of your closest intersection.
- Do not touch or approach any unidentified objects in the field. Notify your SMAPVEX supervisor after returning to the field headquarters
- Dress correctly; long pants, long sleeves, boots, hat
- Contact with corn leaves can cause a skin irritation
- Use sunscreen.
- Protective eyewear is strongly encouraged because corn leaves can be very sharp on their edges and can be hazardous to your eyes.
- Carry plenty of water for hydration.
- Notify your teammate and supervisors of any preexisting conditions or allergies before going into the field.

Mike Cosh, SMAPVEX Safety Officer, 410-707-2478

Beltsville Area SAFETY NEWS RELEASE

WE WANT YOU TO KNOW



Release 00-01

SUMMERTIME SAFETY FOR OUTSIDE WORKERS

PREVENTING HEAT-RELATED ILLNESS

When your body is unable to keep itself cool, illnesses such as "heat exhaustion" and "heatstroke" can occur. As the air temperature rises, your body stays cool when your sweat evaporates. When sweating is not enough to cool your body, your body temperature rises, that is when you may become ill with a heat-related illness.

Tips to stay cool:

1. Supervisors should encourage workers to drink plenty of water (approximately one cup of cool water every 15-20 minutes). Avoid caffeinated drinks such as coffee and tea which can contribute to dehydration.
2. Supervisors should encourage workers to wear light-colored, lightweight, loose-fitting clothing. Workers should change if their clothing becomes completely saturated.
3. Supervisors should have employees alternate work and rest periods, with longer rest periods in a cooler area. Shorter, but frequent, work-rest cycles are best. Schedule heavy work for cooler parts of the day and use appropriate protective clothing.
4. Supervisors should consider an employee's physical condition when determining fitness to work in a hot environment. Obesity, lack of conditioning, pregnancy and inadequate rest can increase susceptibility to heat stress illnesses.
5. Supervisors and employees should learn to spot the symptoms of heat illnesses and what should be done to help:

HEAT EXHAUSTION: The person will be sweating profusely, lightheaded, and suffer dizziness. Have the victim rest in a cool place and drink some fluids. The condition should clear in a few minutes.

HEAT STROKE: This is a medical emergency. A Person may faint and become unconscious. Their skin will be dry and hot, possibly red in color. A person exhibiting these symptoms should be moved to a cool place, do **not** give the victim anything to drink, wet the persons skin with cool wet cloths, and CALL 911.

PREVENTING SUN-RELATED ILLNESSES

Exposure to ultraviolet radiation may lead to skin cancer. One million new cases of skin cancer are diagnosed each year. Cumulative sun exposure is a major factor in the development of skin cancer. The back of the neck, ears, face and eyes are sensitive to sun exposure. Luckily these and other body parts can be easily protected by wearing proper clothing, sunscreen, or sunglasses. By taking precautions and avoiding the sun's most damaging rays, you may be able to reduce your risk.

Tips to prevent sun exposure:

1. Avoid the sun at midday, between the hours of 10:00 a.m. and 3:00 p.m., when the ultraviolet rays are the strongest. If possible, schedule outside work for early in the morning.
2. Protective apparel should be worn.
HATS provide protection for the face and other parts of the head. When selecting a hat consider how much of your face, ears and neck will be shaded.
SUNGLASSES protect your eyes from serious problems. Ultraviolet rays from the sun can lead to eye problems, such as cataracts. Make sure your sunglasses provide 100% UV protection. This rating should be on the label when purchasing new ones.
CLOTHING will protect against the sun and minimize heat stress. For maximum benefit, lightweight, light-colored, long-sleeves, and long pants that are 100% cotton fiber is preferred to provide both comfort and protection.
3. Use Sunscreen: Any skin that may possibly be exposed should be protected by sunscreen. One million new cases of skin cancer are diagnosed each year. The American Academy of Dermatology recommends wearing sunscreen with an SPF of at least 15 every day, year-round. As an added benefit, Some sunscreens now come formulated with insect deterrents in them to prevent bites from insects such as mosquitoes, deer ticks, etc.

Released July 3, 2000

SAFETY NEWS RELEASE is published by the Beltsville Area Safety, Occupational Health and Environmental Staff. Comments or questions, please contact M. Winkler at winMerm@ba.ars.usda.gov.

Ticks

Ticks are flat, gray or brownish and about an eighth of an inch long. When they are filled with their victim's blood they can grow to be about a quarter of an inch around. If a tick bites you, you won't feel any pain. In fact you probably won't even know it until you find the tick clamped on tightly to your body. There may be some redness around the area, and in the case of a deer tick bite, the kind that carries Lyme Disease, a red "bull's-eye" may develop around the area. This pattern could spread over several inches of your body.

When you find a tick on you body, soak a cotton ball with alcohol and swab the tick. This will make it loosen its grip and fall off. Be patient, and don't try to pull the tick off. If you pull it off and it leaves its mouth-parts in you, you might develop an irritation around these remaining pieces of tick. You can also kill ticks on you by swabbing them with a drop of hot wax (ouch!) or fingernail polish. After you've removed the tick, wash the area with soap and water and swab it with an antiseptic such as iodine.

Ticks are very common outdoors during warm weather. When you are outdoors in fields and in the woods, wear long pants and boots. Also spray yourself before you go out with insect repellent containing DEET.

(Source: www.kidshealth.org/cgi-bin/print_hit_bold.pl/kid/games/tick.html?ticks#first_hit)

Drying Ovens

The temperature used for the soil drying ovens is 105°C. Touching the metal sample cans or the inside of the oven may result in burns. Use the safety gloves provided when placing cans in or removing cans from a hot oven. Vegetation drying is conducted at lower temperatures that pose no hazard.

Driving

- Observe speed limits and try to keep the dust minimal (slow down) around houses.
- Watch for loose gravel, sand, and farm animals
- Do not leave car unlocked (theft)
- Do not leave all windows sealed when car is unattended (heat buildup can break a window)

Lightning

- Lightning can be a deadly force, watch the skies for sudden cloud development.
- Do not leave your vehicle in a thunderstorm.

Medical

For medical emergencies call 911 or go to:

Hospitals

In Maryland

Memorial Hospital at Easton, MD
219 S Washington St
Easton, MD 21601
(410) 822-1000

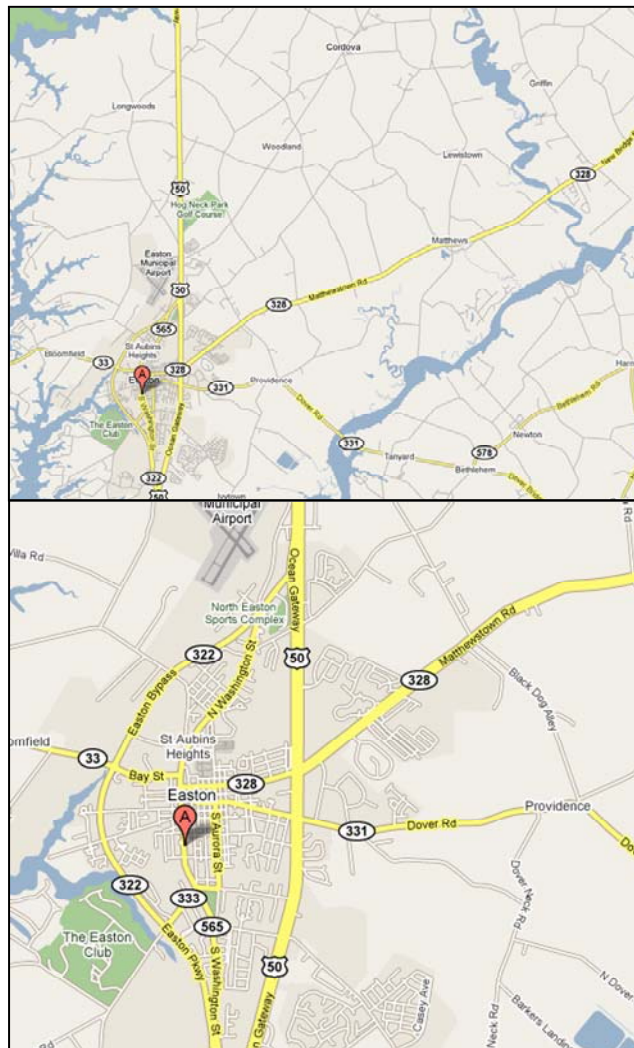


Figure 14. Easton's Memorial Hospital

Also in Maryland:
Chester River Hospital
100 Brown St
Chestertown, MD 21620
(410) 778-3300

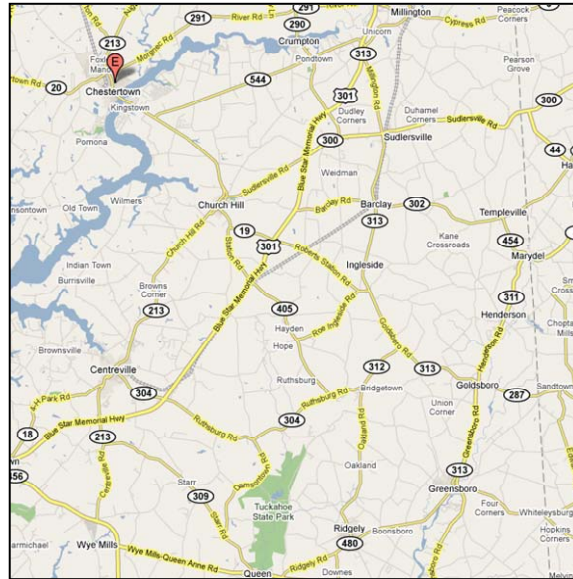


Figure 15. Chester River Hospital

In and near Dover, Delaware
Kent General Hospital
640 S State St
Dover, DE 19901
(302) 674-4700

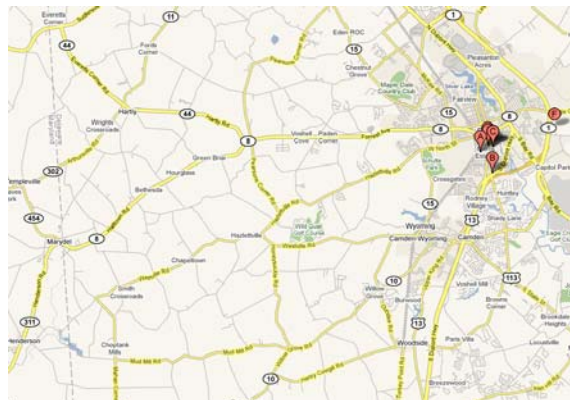


Figure 16: Kent General Hospital in Dover, DE

7.3. Local Contacts and Shipping

Michael Cosh
USDA-ARS-Hydrology and Remote Sensing Lab
Rm 104 Bldg 007 BARC-West
Beltsville, MD 20705
301-504-6461
Fax: 301-504-8931
Michael.Cosh@ars.usda.gov

8. Sampling Protocols

8.1. General Guidance on Field Sampling

- Sampling is conducted **every day**. It is canceled by the group leader if it is raining, there are severe weather warnings or a logistic issue arises.
- **Know your pace.** This helps greatly in locating sample points and gives you something to do while walking.
- If anyone questions your presence, politely answer identifying yourself as a scientist working on a NASA/USDA soil moisture study with satellites. If you encounter any difficulties **just leave** and report the problem to the group leader.
- Although gravimetric and vegetation sampling are destructive, try to **minimize your impact** by filling holes. Leave nothing behind.
- Always sample or move through a field along the **row direction** to minimize impact on the canopy.
- Please be considerate of the landowners and our hosts. **Don't** block roads, gates, and driveways. Keep sites, labs and work areas clean of trash and dirt.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust.
- Avoid parking in tall grass, catalytic converters can be a **fire hazard**.
- **Close any gate** you open as soon as you pass.
- Work in **teams of two. Carry a cell phone.**
- Be aware that increased security at government facilities may limit your access. **Do not assume that YOU are exempt.**

8.2. Watershed Site Surface Soil Moisture and Temperature

Soil moisture and temperature sampling of the watershed area sites is intended to estimate the site average and standard deviation. Watershed site sampling will take place between 8:30 am and 12:30 pm. It is assumed here that most of these sites will be on the order of several hundred meters, however, there will be a number of variations that may require adaptation of the protocol. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-6 cm gravimetric soil moistures using the scoop tool
- 0-6 cm soil bulk density (separate team)
- Surface temperature of exposed and in-shadow ground using a hand held infrared thermometer
- Surface temperature of exposed and in-shadow vegetation using a hand held infrared thermometer
- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations

Preparation

- Arrive at the coordination point at assigned time. Check in with group leader and get any special instructions for that days sampling.
- Assemble sampling kit
 - Bucket
 - Theta Probe and data logger (use the same probe each day, it will have an ID)
 - Scoop tool
 - 8 cm spatula
 - 4 cm spatula
 - Notebook
 - Pens
 - Box of cans (see note below)
 - Soil thermometer
 - Handheld infrared thermometer
 - Extra batteries (9v, AA, AAA)
 - Screwdriver
 - First aid kit (per car)
 - Phone (if you have one)
- Each team should take one box of 20 cans for selective calibration sampling.
- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- Check weather
- The first time you sample, it will help to use marking tape/spray paint to mark your transect rows and sample point locations. Use only marking tape/spray paint to mark your sites
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site “A”, Field,##, and Point “##”, such as A0101.
- Use a new **notebook** page each day. Take the time to draw a good map and be legible. These notebooks belong to the experiment; if you want your own copy make a photocopy.

SMAPVEX08 SAMPLING CHECKLIST

At each Gravimetric site (2 & 6), the following data are taken:

- (3) 0-6 cm Theta Probe soil moisture measurements
- (1) 0-6 cm Soil Sample at the B TP site
- (3) Soil Temperature readings at 1 cm, 5 cm, and 10 cm at B position
- (4) Infrared temperature readings
- GPS location for the sampling site
- Notes on Vegetation cover type and Weather Conditions

At every site, the following data are taken:

- (3) 0-6 cm Theta Probe soil moisture measurements
- GPS location for the sampling site

Three sampling points for Theta Probe are: A in Row, B ¼ Row, C ½ Row; If no row structure, 3 points within 1m of each other.

Four IRT points are taken as follows: (you can leave spaces blank)

EG: Exposed Ground (in sun)

SG: Shadowed Ground

EV: Exposed Vegetation (in sun)

SV: Shadowed Vegetation

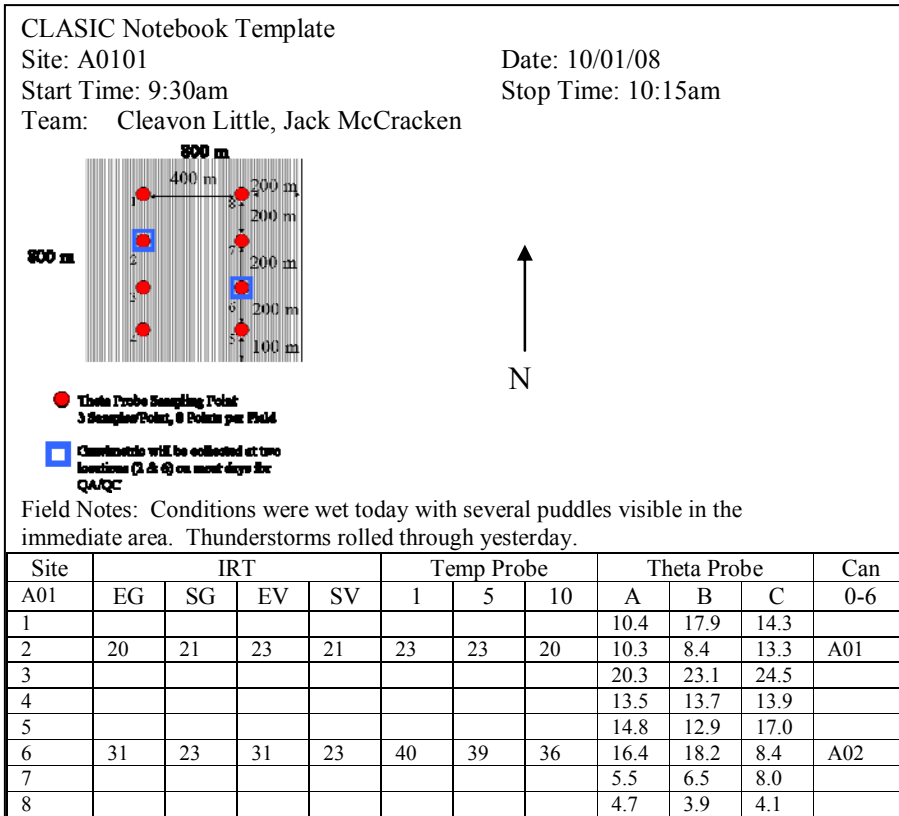
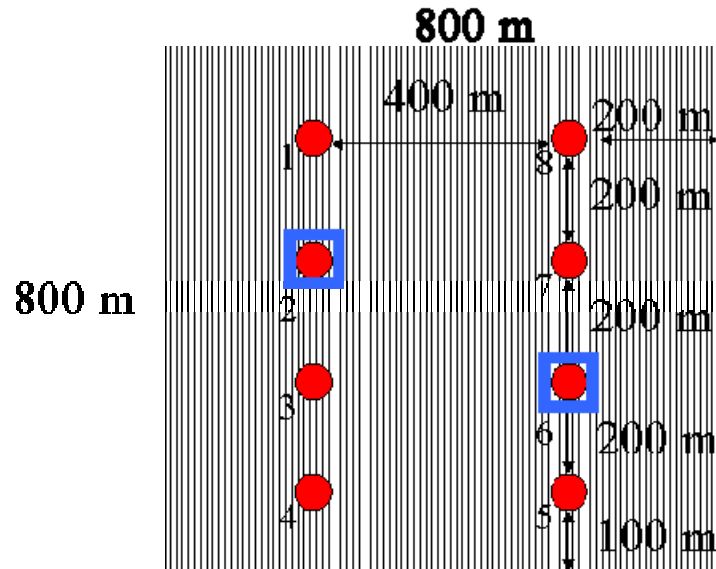


Figure 17. Notebook Sample template for SMAPVEX ARS Notebook

Procedure

- Upon arrival at a site, note site id (A01##), your name(s) and time in notebook. Draw a schematic of the field (It might be a good idea to do this before you go out for the day). Indicate the TP ID you are using.
- **We will be sampling gravimetrically at points of opportunity, so you will need to use sampling cans when you deem it necessary. Use cans sequentially.**
- From this location initiate a sampling transect across the site. Plan your sampling to be completed over 8 points within the field, along two transects of 4 points each.
 - In a row crop, sample in the row adjacent to the row you are walking in, it is suggested that this be the row to your right.
 - At all points collect three TP samples across the row as suggested in Figure 19. **See the Theta Probe protocol for how to use the instrument and data logger.**
 - At points labeled gravimetric in Figure 19 (two per site) collect
 - One gravimetric soil moisture sample for 0-6 cm following the procedures described using the scoop, enter can numbers on diagram in book **(See Gravimetric Sampling with the Scoop Tool protocol)**
 - One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe, enter values in book **(See Temperature Sampling protocol)**
 - Four surface thermal infrared temperatures (Degrees C) using infrared thermometer, enter value in book **(See Temperature Sampling protocol)**



● **Theta Probe Sampling Point**
3 Samples/Point, 8 Points per Field

□ **Gravimetric will be collected at two locations (2 & 6) on most days for QA/QC**

Figure 18. Schematic of layout of samples in a watershed site.

- After completing this transect move perpendicular into the site and initiate a new transect and work back toward your start point sampling along the way. This will result in a total of 8 sampling points.
 - Exit the field before attempting to move to the second transect.
- As you move along the transect note any anomalous conditions on the schematic in your notebook, i.e. standing water.
- Record your stop time and place cans in box.

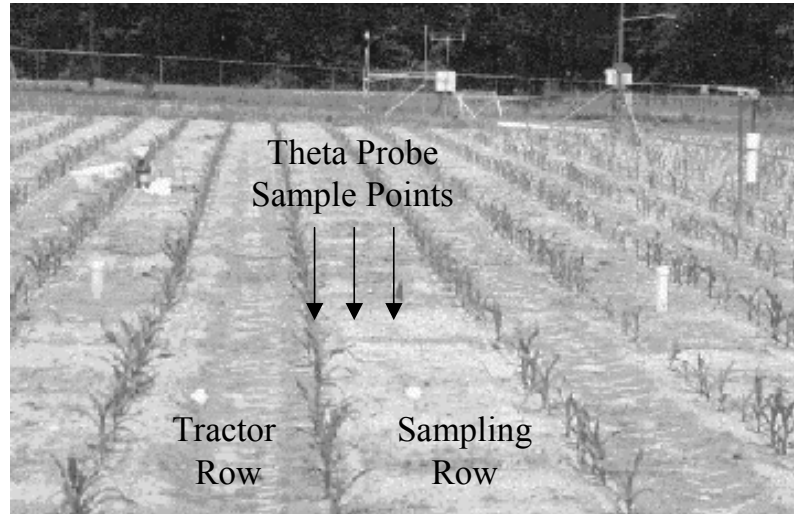


Figure 19. Schematic of layout of Theta Probe sample points.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling. Do not leave something until the next day.
- For each site, weigh the gravimetric samples and record on the data sheets (Figure 20) that will be provided. Use a single data sheet for all your samples for that day and record cans sequentially.
- Transfer temperature and other requested data to data sheets (same sheet used for GSM).
- Place cans in (in box) “TO OVENS” area and data sheet in collection box.
- Turn in your TP and data logger to the person in charge. They will be responsible for downloading data.
- Clean your other equipment.

SMAPVEX08
Gravimetric Soil Moisture Sampling

Dates: _____ Team: _____
Time: _____ Observers: _____

Site ID	Local Sample Time	IRT in C				Soil Temp in C			Theta Probe (%)			0-6 cm		
		A	B	C	D	1 cm	5 cm	10 cm	A	B (GSM Site)	C	Can ID	Wet Wgt	Dry Wgt

Figure 20. Example of Lab Data Sheet

8.3. Theta Probe Soil Moisture Sampling and Processing

There are two types of TP configurations; Type 1 (Rod) (Figure 21) and Type 2 (Handheld) (Figure 22). They are identical except that Type 1 is permanently attached to the extension rod.



Figure 21. Theta Probe Type 1 (with extension rod).



Figure 22. Theta Probe Type 2.

Tps consist of a waterproof housing which contains the electronics, and, attached to it at one end, four sharpened stainless steel rods that are inserted into the soil. The probe generates a 100 MHz sinusoidal signal, which is applied to a specially designed internal transmission line that extends into the soil by means of the array of four rods. The impedance of this array varies with the impedance of the soil, which has two components - the apparent dielectric constant and the ionic conductivity. Because the dielectric of water (~81) is very much higher than soil (typically 3 to 5) and air (1), the dielectric constant of soil is determined primarily by its water content. The output signal is 0 to 1V DC for a range of soil dielectric constant, ϵ , between 1 and 32, which corresponds to approximately 0.5 m³ m⁻³ volumetric soil moisture content for mineral soils. More details on the probe are provided in the sampling protocol section of the plan.

Each unit consists of the probe (ML2x) and the data logger or moisture meter (HH2). The HH2 reads and stores measurements taken with the ThetaProbe (TP) ML2x soil moisture sensors. It can provide millivolt readings (mV), soil water (m³.m⁻³), and other measurements. Readings are saved with the time and date of the reading for later collection from a PC.

The HH2 is shown in Figure 23. It applies power to the TP and measures the output signal voltage returned. This can be displayed directly, in mV, or converted into other units. It can convert the mV reading into soil moisture units using conversion tables and soil-specific parameters. Tables are installed for Organic and Mineral soils, however, greater accuracy is possible by developing site-specific parameters. For SMAPVEX, all observations will be recorded as % and processed later to mV for calibration.

Use of the TP is very simple - you just push the probe into the soil until the rods are fully covered, then using the HH2 obtain a reading. Some general items on using the probe are:

- One person will be the TP coordinator. If you have problems see that person.
- A copy of the manual for the TP and the HH2 will be available at the field HQ. They are also available online as pdf files at <http://www.dynamax.com/#6>, <http://www.delta-t.co.uk> and <http://www.mluri.sari.ac.uk/thetaprobe/tprobe.pdf>.
- Each TP will have an ID, use the same TP in the same sites each day.
- The measurement is made in the region of the four rods.
- Rods should be straight.
- Rods can be replaced.
- Rods should be clean.
- Be careful of stones or objects that may bend the rods.
- Some types of soils can get very hard as they dry. If you encounter a great deal of resistance, stop using the TP in these fields. Supplemental GSM sampling will be used.
- Check that the date and time are correct and that Plot and Sample numbers have been reset from the previous day.
- Disconnect sensor if you see the low battery warning message.
- Protect the HH2 from heavy rain or immersion.
- The TP is sensitive to the water content of the soil sample held within its array of 4 stainless steel rods, but this sensitivity is biased towards the central rod and falls off towards the outside of this cylindrical sampling volume. The presence of air pockets around the rods, particularly around the central rod, will reduce the value of soil moisture content measured.
- Do not remove the TP from soil by pulling on the cable.
- Do not attempt to straighten the measurement rods while they are still attached to the probe body. Even a small degree of bending in the rods (>1mm out of parallel), although not enough to affect the inherent TP accuracy, will increase the likelihood of air pockets around the rods during insertion, and so should be avoided. See the TP coordinator for replacement.



Figure 23. HH2 display.

Occasionally, the soil is too hard to successfully insert a TP; therefore, a jig (Soil Moisture Insertion Tool – SMITY) has been constructed, shown in Figure 24. This is a tool used to make holes in hard or difficult soils to ease the stress on the TP. To use, place the slider plate (Figure 25) on the surface to be probed. Using pressure or a hammer, drive the SMITY into the ground. Avoid any side-to-side movement, to avoid faulty measurements. Once the SMITY is completely in the ground, hold the slider plate on the surface and pull straight up on the SMITY. Holding the slider plate to the ground should maintain the surface for proper TP insertion. Clean the SMITY and proceed with the TP measurement. Insert the TP probe exactly into the holes created by the SMITY. The TP tines are slightly larger than the holes, but will be much easier to insert than without the SMITY.



Figure 24: SMITY, Soil Moisture Insertion Tool, with slider extended and retracted.

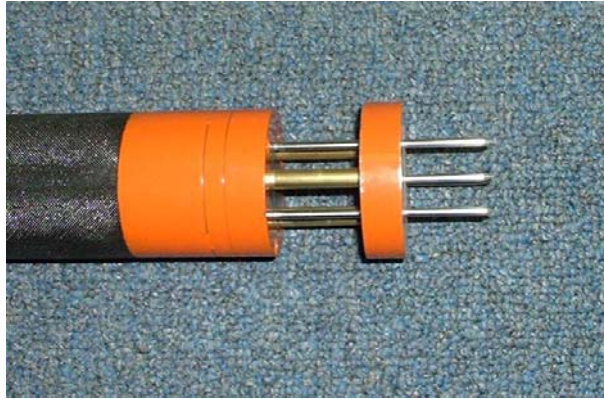


Figure 25: Close-up of the SMITY slider.

Before Taking Readings for the Day Check and Configure the HH2 Settings

1. Press **Esc** to wake the *HH2*.

Check Battery Status

2. Press **Set** to display the **Options** menu
3. Scroll down to **Status** using the **up** and **down** keys and press **Set**.
4. The display will show the following
Mem % Batt %
Readings #.
 - If Mem is not 0% see the TP coordinator.
 - If Battery is less than 50% see TP coordinator for replacement. *The HH2 can take approximately: 6500 TP readings before needing to replace the battery.*
 - If Readings is not 0 see the TP coordinator
5. Press **Esc** to return to the start-up screen.

Check Date and Time

6. Press **Set** to display the **Options** menu
7. Scroll down to **Date and Time** using the **up** and **down** keys and press **Set**.
8. Scroll down to **Date** using the up and down keys and press **Set** to view. It should be in MM/DD/YY format. If incorrect see the TP coordinator or manual.
9. Press **Esc** to return to the start-up screen.
10. Press **Set** to display the **Options** menu
11. Scroll down to **Date and Time** using the **up** and **down** keys and press **Set**.
12. Scroll down to **Time** using the up and down keys and press **Set** to view. It should be local (24 hour) time. If incorrect see the TP coordinator or manual.
13. Press **Esc** to return to the start-up screen.

Set First Plot and Sample ID

14. Press **Set** at the start up screen to display the **Options** Menu.
15. Scroll down to **Data** using the **up** and **down** keys and press **Set**.

16. Select **Plot ID** and press **Set** to display the **Plot ID** options.
17. The default ID should be A. If incorrect scroll through the options, from A to Z, using the **up** and **down** keys, and press **Set** to select one.
18. Press **Esc** to return to the main Options menu.
19. Scroll down to **Data** using the **up** and **down** keys and press **Set**
20. Scroll down to **Sample** and press **Set** to display available options. A sample number is automatically assigned to each reading. It automatically increments by one for each readings stored. You may change the sample number. This can be any number between 1 and 2000.
21. The default ID should be 1. If incorrect scroll through the options, using the **up** and **down** keys, and press **Set** to select one.
22. Press **Esc** to return to the main Options menu.

Select Device ID

23. Each HH2 will have a unique ID between 0 and 255. Press **Set** at the start up or readings screen to display the main **Options** menu.
24. Scroll down to **Data** using the **up** and **down** keys and press **Set**.
25. Select **Device ID** and press **Set** to display the **Device ID** dialog.
26. Your ID will be on the HH2 battery cover.
27. Scroll through the options, from 0 to 255, and press **Set** to select one.
28. Press **Esc** to return to the main menu.

To take Readings

1. Press **Esc** to wake the *HH2*.
2. Press **Read**
If successful the meter displays the reading, e.g.-
ML2 Store?
32.2%vol
3. Press **Store** to save the reading.
The display still shows the measured value as follows:
ML2
32.2%vol
Press **Esc** if you do not want to save the reading. It will still show on the display but has not been saved.
ML2
32.2%vol
4. Press **Read** to take the next reading or change the optional meter settings first, such as the Plot ID. Version 1 of the Moisture Meter can store up to 863 if two sets of units are selected.

Troubleshooting

Changing the Battery

- The HH2 unit works from a single **9 V PP3** type battery. When the battery reaches 6.6V, (~25%) the HH2 displays :
***Please Change
Battery**

- On receiving the above warning have your data uploaded to the PC next, or replace the battery. Observe the following warnings:
 - **WARNING 1: Disconnect the TP, immediately on receiving this low battery warning. Failure to heed this warning could result in loss of data.**
 - **WARNING 2: Allow HH2 to sleep before changing battery.**
 - **WARNING 3: Once the battery is disconnected you have 30 seconds to replace it before all stored readings are lost.** If you do not like this prospect, be reassured that your readings are safe indefinitely, (provided that you do disconnect your sensor and you do not disconnect your battery). The meter will, when starting up after a battery change always check the state of its memory and will attempt to recover any readings held. So even if the meter has been without power for more than 30 seconds, the meter may still be able to retain any readings stored.

Display is Blank

The meter will sleep when not used for more than 30 seconds. This means the display will go blank.

- *First check that the meter is not sleeping by pressing the Esc key. The display should become visible instantly.*
- If the display remains blank, then try all the keys in case one key is faulty.
- Try replacing the battery.
- If you are in bright light, then the display may be obscured by the light shining on the display. Try to move to a darker area or shade the display.

Incorrect Readings being obtained

- Check the device is connected to the meter correctly.
- Has the meter been set up with the correct device.

Zero Readings being obtained

- If the soil moisture value is always reading zero, then an additional test to those in the previous section is to check the battery.

Settings Corrupt Error Message

- The configurations such as sensor type, soil parameters, etc. have been found to be corrupt and are lost. This could be caused by electrical interference, ionizing radiation, a low battery or a software error.

Memory Failure Error Message

- The unit has failed a self-test when powering itself on. The Unit's memory has failed a self test, and is faulty. Stop using and return to HQ.

Some Readings Corrupt Error Message

- Some of the stored readings in memory have been found to be corrupt and are lost. Stop using and return to HQ.

Known Problems

- When setting the date and time, an error occurs if the user fails to respond to the time and date dialog within the period the unit takes to return to itself off. (The solution is to always respond before the unit times out and returns to sleep).
- The Unit takes a reading but fails to allow the user to store it. (This can be caused if due to electrical noise, or if calibrations or configurations have become corrupted. An error message will have been displayed at the point this occurred).

8.4. Gravimetric Soil Moisture Sampling with the Scoop Tool

- Remove vegetation and litter.
- Use the large spatula (6 cm) to cut a vertical face at least 6 cm deep (Figure 26a).
- Push the GSM tool into this vertical face. The top of the scoop should be parallel with the soil surface. (Figure 26b).
- Use the large spatula to cut a vertical face on the front edge of the scoop (Figure 26c).
- Use the small spatula to cut the sample into a 0-1 cm depth..
- Place the sample the top 0-1 cm in the odd numbered can. The small spatula and a funnel aid extraction of the sample in the can (Figure 26d).
- Take a second sample of 0-6 cm depth and place it in the even numbered can.
- Remember to use cans sequentially and odd numbers for the 0-1 and even for 0-6 cm samples.
- Record these can numbers in the field notebooks at the point location on the map.
- A video clip showing the gravimetric sampling technique can be downloaded from an anonymous ftp site hydrolab.arsusda.gov/pub/sgp99/gsmsamp.avi.
- At the specific sampling points where it is required, measure the soil temperature at 1, 5 and 10 cm depths using the digital thermometer provided. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.
- At the specific sampling points where it is required, measure the surface temperatures of A) exposed vegetation, B) in-shade vegetation (half the canopy height), C) exposed ground, and D) in-shade ground. If it is not possible to take a measure of any of these four observations at a site, make a note of that in the notebook. This would represent either 0% or 100% vegetation cover. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.

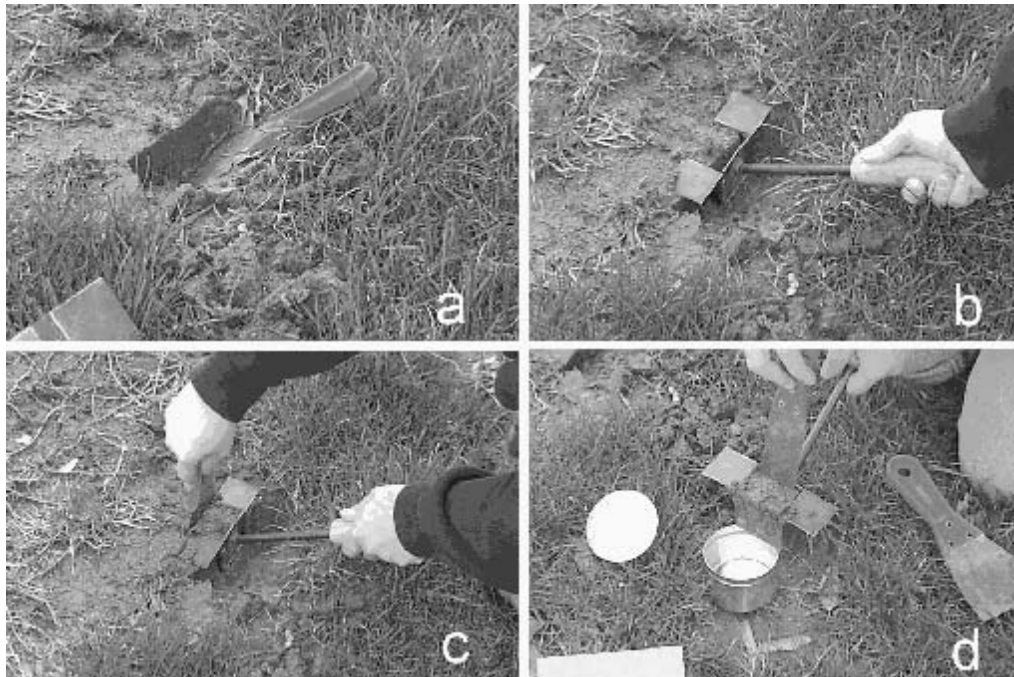


Figure 26. How to take a gravimetric soil moisture sample.

8.5. Gravimetric Soil Moisture Sample Processing

All GSM samples are processed to obtain a wet and dry weight. It is the sampling teams responsibility to deliver the cans, fill out a sample set sheet, and record a wet weight at the field headquarters. A lab team will transport the samples and place them in the drying ovens. They will perform the removal of samples from the oven, dry weighing, and can cleaning.

All gravimetric soil moisture (GSM) samples taken on one day will be collected from the field headquarters each afternoon. These samples will remain in the ovens until the following afternoon (approximately 24 hours).

Wet Weight Procedure

1. Turn on balance.
2. Tare.
3. Obtain wet weight to two decimal places and record on sheet.
4. Process your samples in sample numeric order.
5. Place the CLOSED cans back in the box. Arrange them sequentially.
6. Place box and sheet in assigned locations.

Dry Weight Procedure

1. Each day obtain a balance reference weight on the wet weight balance and the dry weight balance.
2. Pick up all samples from field headquarters.
3. Turn off oven and remove samples for a single data sheet and place on tray.
4. These samples will be hot. Wear the gloves provided
5. Turn on balance.
6. Tare.
7. Obtain dry weight to two decimal places and record on sheet.
8. Process your samples in sample numeric order.
9. All samples should remain in the oven for approximately 20-22 hours at 105°C.
10. Try to remove samples in the order they were put in.
11. Load new samples into oven.
12. Turn oven on.
13. Clean all cans that were removed from the ovens and place empty cans in boxes. Check that can numbers are readable and replace any damaged or lost cans with spares.
14. Return the clean cans to the field HQ.

Data Processing

1. Enter all data from the sheets into an Excel spreadsheet. One file per day, one worksheet per site.

2. There will be a summary file for each day that will contain the means and standard deviations.
3. All files are backed up with a floppy disk copy.
4. The summary file will be transmitted to a central collection point on a daily basis.
5. You may keep copies of raw data for any site that you actually sample at this stage. You may not take any other data until quality control has been conducted

8.6. Soil Bulk Density and Surface Roughness

All sites involved in gravimetric soil moisture sampling will be characterized for soil bulk density and surface roughness. The bulk density method being used is a volume extraction technique that has been employed in most of the previous experiments and is especially appropriate for the surface layer. Three replications will be made at each field.

The Bulk Density Apparatus -

The Bulk Density Apparatus itself consists of a 12" diameter plexiglass ring with a 5" diameter hole in the center and three 3/4" holes around the perimeter. Foam is attached to the bottom of the plexiglass. The foam is 2 inches high and 1 1/2 inches thick. The foam is attached so that it follows the circle of the plexiglass.

Other Materials Required for Operation:

- Three 12" (or longer) threaded dowel rods and nuts are used to secure the apparatus to the ground.
- A hammer or mallet is used to drive the securing rods into the ground.
- A bubble level is used to insure the surface of the apparatus is horizontal to the ground.
- A trowel is used to break up the soil.
- An ice cream scoop is used to remove the soil from the hole.
- Oven-safe bags are used to hold the soil as it is removed from the ground. The soil is left in the bag when it is dried in the oven.
- Water is used to determine the volume of the hole.
- A plastic jug is used to carry the water to the site.
- One-gallon plastic storage bags are used as liners for the hole and to hold the water.
- A 1000 ml graduated cylinder is used to determine the volume of the water. Plastic is best because glass can be easily broken in the field.
- A turkey baster is used to transfer small amounts of water.
- A hook-gauge is used to insure water fills the apparatus to the same level each time.

Selecting and Preparing an Appropriate Site -

1. Select a site. An ideal site to conduct a bulk density experiment is: relatively flat, does not include any large (>2 cm) rocks or roots in the actual area that will be tested and has soil that has not been disturbed.
2. Ready the site for the test. Remove all vegetation, large (>2 cm) rocks and other debris from the surface prior to beginning the test. Remove little or no soil when removing the debris.

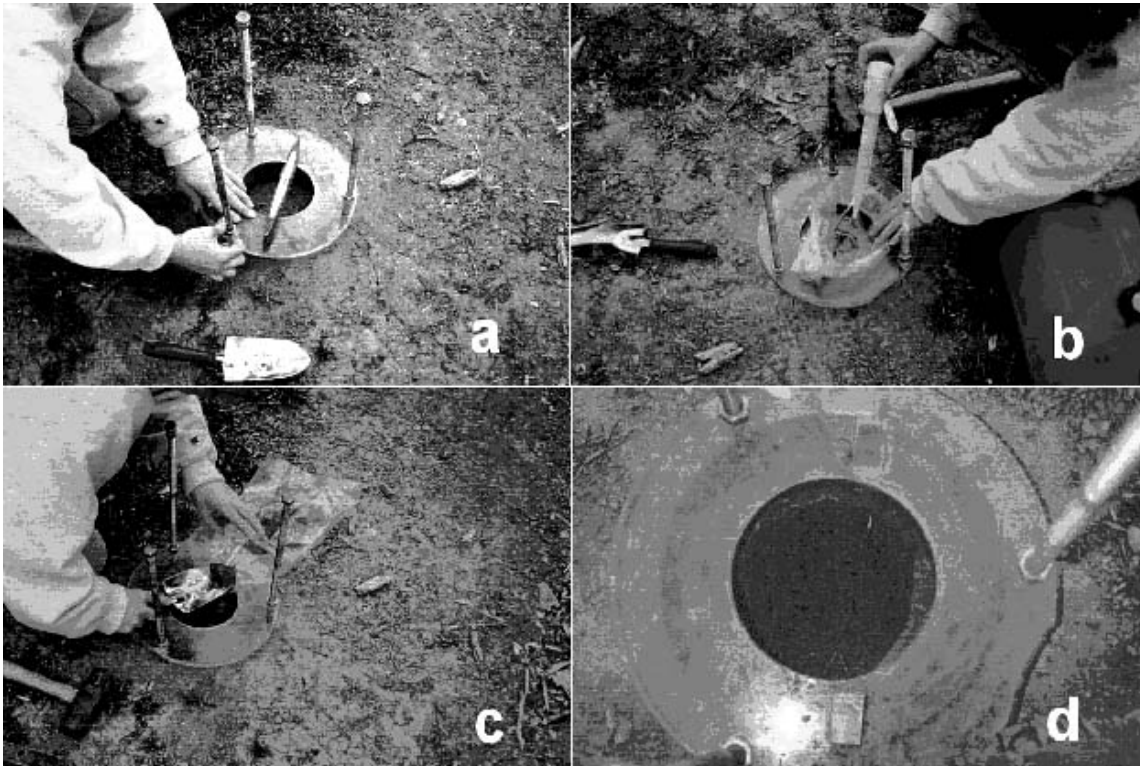


Figure 27. How to take a bulk density sample

Bulk Density Procedure -

Securing the Apparatus to the Ground

1. Place the apparatus foam-side-down on the ground.
2. Place the three securing rods in the 3/4" holes of the apparatus.
3. Drive each dowel into the ground until they do not move easily vertically or horizontally. (Figure 27a)

Leveling the Apparatus Horizontally to the Ground

1. Tighten each of the bolts until the apparatus appears level and the foam is compressed to a height of 1" to 1 1/2".

2. Place the bubble level on the surface of the apparatus and tighten or loosen the bolts in order to make the surface level. Place the level in at least three directions and on three different areas of the surface of the apparatus.

Determining the Volume from the Ground to the Hook Gauge

1. Pour exactly one liter of water into the graduated cylinder.
2. Pour some of the water into a plastic storage bag.
3. Hold the plastic bag so that the water goes to one of the lower corners of the bag.
4. Place the corner of the bag into the hole. Slowly lower the bag into the hole allowing the bag and the water to snugly fill all of the crevasses.
5. Slightly raise and lower the bag in order to eliminate as many air pockets as possible.
6. Lay the remainder of the bag around the hole.
7. Place the hook-gauge on the notches on the surface of the apparatus.
8. Add water to the bag until the surface of the water is just touching the bottom of the hook on the hook-gauge. A turkey-baster works very well to add and subtract small volumes of water. Be sure not to leave any water remaining in the turkey-baster. (Figure 27b)
9. Place the graduated cylinder on a flat surface. Read the cylinder from eye-level. The proper volume is at the bottom of the meniscus. Read the volume of the water remaining in the graduated cylinder. Record this volume. Subtract the remaining volume from the original 1000 ml to find the volume from the ground surface to the hook-gauge.
10. Carefully transfer the water from the bag to the graduated cylinder. Hold the top of the bag shut, except for two inches at either end. Then use the open end as a spout. (It is best to reuse water, especially when doing multiple tests in the field.)

Loosening the Soil and Digging the Hole

1. Label the oven-safe bag with the date and test number and other pertinent information using a permanent marker.
2. Loosen the soil. The hole should be approximately six cm deep and should have vertical sides and a flat bottom. An ice cream scoop is helpful to scrape the bottom of the hole so that it is flat. (The hole should be a cylinder: with surface area the size of the hole of the apparatus and depth of six cm.)
3. Remove the soil from the ground and very carefully place it in the oven-safe bag. (Be careful to lose as little soil as possible.) (Figure 27c and d)
4. Continue to remove the soil until the hole fits the qualifications.
5. Loosely tie the bag so that no soil is lost in transportation.

Finding the Volume of the Hole

1. Determine the volume from the bottom of the hole to the hook-gauge as described in **Determining the Volume from the Ground to the Hook-Gauge**. Record this volume. Reusing the water from the prior measurement presents no potential problems and is necessary when performing numerous experiments in the field.
2. Subtract the volume of the first measurement from the second volume measurement. The answer is the volume of the hole.

Calculating the Bulk Density of the Sample

1. Weigh the sample, and subtract the tare weight of the bag. Record the weight.
2. Dry the soil in an oven at 100°C for at least 24 hours.
3. Reweigh the sample, and subtract the tare weight of the bag. Record the weight.
4. Divide the dry weight of the sample by the volume of the hole. The result is the bulk density of the sample.

Potential Problems and Solutions

After I started digging I hit a large (>2 cm) rock. What should I do?

The best solution is to start over in another location. Also, you can remove the rock from the soil and subtract the volume of the rock from the total volume of the water. You should never include a rock in the density of the soil. Rocks have significantly higher densities than soil and will invalidate the results. Roots, corn cobs, ants and even mole holes will also invalidate the results. If you find any of these things the best thing to do is start the test again at another site.

After I began digging the hole I noticed one of the dowels wasn't the apparatus firmly in place. Do I have to start over?

Unfortunately, if you have already started digging you do have to start the experiment again. Replacing the dirt to find the volume between the ground surface and the hook-gauge will give an inaccurate volume and thus an inaccurate soil density.

I noticed that the bag holding the water has a small leak. Is there anything I can do?

If the leak began after you had already found the volume, it is not necessary to start again. The volume is being measured in the graduated cylinder. If you have already removed the appropriate volume of water leaks in the bag, it will not affect the results of the test. However, if you noticed the leak before finding the volume, you will have to start again.

Surface Roughness

Surface roughness photographs will be obtained using the grid board approach. For grasses this should be performed after canopy and thatch removal. Four replications will be made at each site. Two photos are taken at each location, one with the board going

North/South, the other with the board going East/West. For row crops, photos will be taken across (c) and along (a) the rows. The soil surface must be visible; therefore it may be necessary to remove plants, but do not damage more plants than you have to. Push the board into the soil surface so that there is no space between the board and the soil surface. Place a card with the site ID on the board and take a photo of the board and the soil surface in front of the board. (see figure 29) Surface roughness photos will be taken once during the experiment unless there is a change in the field conditions (plowing, planting, harvesting ...).



Figure 28. Surface Roughness Photo

8.7. Soil Temperature Probes

Several different types of temperature probes may be used to measure soil temperature. These all have a metal rod, plastic top and digital readout. The version used will be the Max/Min Waterproof Digital Thermometer (Figure 29).

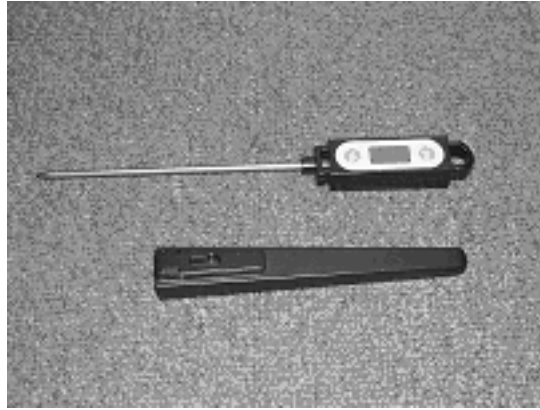


Figure 29. Temperature Probe with Handle/Cover

To Operate:

1. Press On/Off to switch on
2. Verify that the measurement is in Celsius and that the probe is not set to Max or Min
3. Probed into 1 cm of soil at the desired location.
4. Wait for reading to stabilize, and then record the number in the field book.
5. Push the probe to a depth of 5 cm, let it stabilize and record data.
6. Push Probe to a depth of 10 cm, let it stabilize and record data.
7. Turn off probe and cover.

If necessary the cover can be placed on the top of the probe and used as a handle, but do not force the probe into the ground with undue force, as the probe may break.

Normal operation of the probe is simple, but please make sure that neither Max nor Min appear on the LCD. This is a different mode of operation and will not be used for this experiment.

8.8. *Infrared Surface Temperature*

The infrared surface temperature probe uses 4 AAA batteries that last for a long time.

Operating instructions:

1. Press the Red On/Off button
2. Verify that the measurement is in Celsius and that the probe is not set to Max or Min. If the probe is set to Max/Min, the LCD display will read Max/Min on the bottom right corner.
3. The infrared probe takes an instantaneous measurement (1-2 sec), when you press the red button. The reading will remain on the display after you release the button, till you turn off the device.
4. Point the probe on the exposed canopy (making sure your shadow does not fall on the location where you are pointing the probe). Try to take a measurement at the top of the canopy. This may not be possible for sites that have tall corn canopy and for the forest sites. If possible, take a measurement of the exposed vegetation surface as high as possible at these locations. This is surface temperature measurement A.
5. Point the probe on the shaded canopy. Try to make a measurement at roughly half the canopy height. This is surface temperature measurement B.
6. Point the probe on the exposed ground surface (making sure your shadow does not fall on the location where you are pointing the probe). This may not be possible in dense canopy where the vegetation cover is 100% (make a note in the notebook). This is surface temperature measurement C.
7. Point the probe on the shaded ground surface. This may not be possible for sites which have very little vegetation (typically soybean sites at the beginning of the experiment). This is surface temperature measurement D.
8. These four observations are done at the points marked 'ALL' and at the tower sites.
9. Turn the probe off by holding on the Red button till the LCD display turns off.

8.9. Hydra Probe Soil Moisture Installations

Figure 30 shows a close up of the Hydra probe. As with the installation of any soil moisture measuring instrument, there are two prime considerations: the location the probe is to be installed at, and the installation technique. A copy of the instruction manual for the HP will be available at the field HQ and can also be found at <http://hydrolab.arsusda.gov>.



Figure 30. The Hydra probe used at the tower locations.

Selecting a Location for the HP

- The probe installation site should be chosen carefully so that the measured soil parameters are "characteristic" of the site.
- Care should be taken that the instrument settles into position before any measurements are considered quality controlled.
- Make sure that the site will be out of foot traffic and is carefully marked and flagged.

Installation of the HP

- The installation technique aims to minimize disruption to the site as much as possible so that the probe measurement reflects the "undisturbed site" as much as possible.
 - Dig an access hole. This should be as small as possible.
 - After digging the access hole, a section of the hole wall should be made relatively flat. A spatula works well for this.
 - The probe should then be carefully inserted into the prepared hole section. The probe should be placed into the soil without any side to side motion which will result in soil compression and air gaps between the tines and subsequent measurement inaccuracies. The center of the probe head

should be at a depth of 5 cm. This will give a sensing depth of 3-7 cm which will assure a stable signal, less sensitive to surface activity.

- After placing the probe in the soil, the access hole should be refilled.
- For a near soil surface installation, one should avoid routing the cable from the probe head directly to the surface. A horizontal cable run of 20 cm between the probe head and the beginning of a vertical cable orientation in near soil surface installations is recommended. Furthermore, sinking the wire deeper than the installation depth is a good method of insuring that the wire will not act as a surface water pathway.

Other general comments are below.

- Avoid putting undue mechanical stress on the probe.
- Do not allow the tines to be bent as this will distort the probe data
- Pulling on the cable to remove the probe from soil is not recommended.
- Moderate scratches or nicks to the stainless steel tines or the PVC probe head housing will not affect the probe's performance.

8.10. Vegetation Sampling

The protocols used in past experiments have been adapted for SMAPVEX.

Parameters

- Photographs
- Plant height
- Leaf count
- Stand density
- Leaf density
- Green and dry biomass
- Surface reflectance
- Leaf area (LAI)

Sampling Locations

Vegetation sampling will be conducted on all of the soil moisture sampling fields. Three representative locations within each field will be sampled during the course of the study to quantify the full range of vegetative cover. An effort will be made to co-locate these sampling locations with the soil moisture sampling points. GPS coordinates of each location within a field will be recorded. Vegetative sampling is intended to estimate the average site conditions, and data are not intended for footprint averaging.

Sampling Frequency

Each field will be sampled once or twice during the field campaign. If rapid growth is expected in particular fields, the frequency can be increased.

Site Identification

Sites will be identified with their SMAPVEX field names, followed by a letter to denote the sampling location.

Sampling Scheme

Sampling locations will be selected to provide a representative sample from that area of the field. For row crops (corn and soybeans), 1 plant per row, for 5 rows (a total of 5 plants) will be sampled for green and dry biomass. If the plants are very small, 10 plants may be sampled. These same rows will be sampled for height, stand density, and row cover.

For grasses, weeds, winter wheat and other non-row crops, all vegetation within a 0.44 m by 0.44 m area at a location will be removed. A folding wooden yardstick will be used to define the area. (see Figure 31)

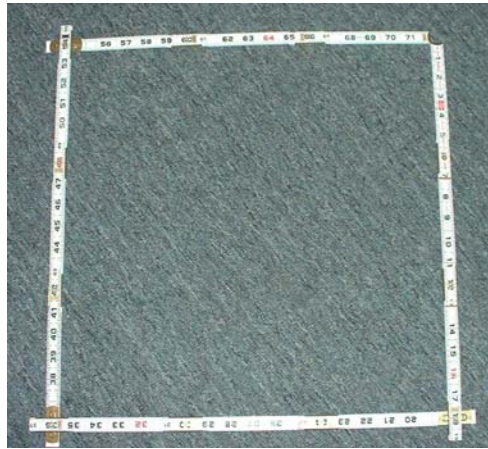


Figure 31. Vegetation Sampling Frame

Data Recording

Data will be recorded onto the sampling sheet illustrated in Figure 32. Data sheets will be maintained as part of the permanent experimental record to verify the data once it is entered into the computer.

Vegetative Sampling

Date: 06/05/2007 Time: 13:47 Observers: Lynn, Iva,

Crop: Pasture

Sample ID	Stand Height (cm)	Row Direction	Row Spacing (cm)	Stand Density	Green Biomass (g)	Dry Biomass (g)
A04-A	75	na	na	na	112.8	63.3
A04-B	66	na	na	na	96.2	

Figure 32. Example of the vegetation sampling data sheet

8.10.1 Digital Photographs of Vegetation

Photographs will be taken of plot area at the time of sampling. These will be collected with a digital camera. A marker board will be used to mark the plot, field location, and date. Photographs will be collected at an oblique angle (30-45° from horizontal) and at nadir at a height of a minimum of 1 m above the canopy. Cameras will be fixed to a telescoping pole to allow positioning above the canopy and a remote trigger to collect data. Three photos will be taken in each plot in this order; marker board, oblique, and nadir.

8.10.2 Plant Height

Height will be measured by placing a measuring tape on the soil surface and determining the height of the foliage visually. One person will hold the measuring tape and the other will make the measurement.

8.10.3 Leaf Count

For the first plant that is sampled at each sampling site and plant location, a leaf count will be conducted. Starting from the bottom, each leaf longer than 10 cm (corn) or 3 cm (soy) will be counted and recorded in the data sheet.

8.10.4 Stand Density

First 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. Stand density will be determined by placing a meter stick along the row sampled.

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. If a plant is at the end of the meter stick and more than half of the stalk extends beyond the end of the meter stick it is not counted. Counts are recorded on the sampling sheet.

8.10.5 Leaf Density

A mature corn plant will develop a total of 20-21 leaves. These are the primary surface to which moisture adheres, therefore, their count and surface area are important to the estimation of total surface wetness.

8.10.6 Green and Dry Biomass

To measure biomass a plant will be cut at the ground surface from each sampling row. The five plants for the sampling site will be placed into a plastic bag with a label for the sampling site. A separate tag with the sampling site id will be placed into the bag as additional insurance against damaged labels. These plants will be transported to the field facility for separation of the plant material into stalks and leaves for corn and stems and leaves for soybean. Corn plants can be separated into leaves and stalks in the field for easier transport to the laboratory. These plant parts will be placed into a bag for drying and marked with sample site id.

Green biomass will be measured for both components (stalks or stems and leaves) by weighing the sample immediately after separation of the components. If the biomass has excess of moisture on the leaves and stalks this will be removed by blotting with a paper towel prior to weighing. Dry biomass will be determined after drying the plant components in ovens at 75C for 48 hours.

8.10.7 Ground Surface Reflectance

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.

For SMAPVEX, we are using instruments developed by CROPSCAN (<http://www.cropscan.com>). Other instruments may be also be used if available. Most hand-held radiometers, which are used to measure soil and plant reflectance in the field, have one detector that must be calibrated frequently for changing amounts of sunlight. Dual-detector instrument designs measure the amount of sunlight and the reflected light simultaneously; thus, fewer calibrations are required and data may be acquired rapidly. The CROPSCAN Multispectral Radiometer (MSR) is an inexpensive instrument that has up-and-down-looking detectors and the ability to measure sunlight at different wavelengths. The basic instrument is shown in Figure 33.



Figure 33. CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm)

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. Filters of wavelengths from 450 up to 1720 nm are available.

For SMAPVEX08 we will be using a MSR16R unit with the following set of bands:

<u>Satellite</u>	<u>ID</u>	<u>Center Wavelength (Bandwidth)</u>
Thematic Mapper	MSR16R-485TMU	485 nm up sensor (90 nm BW)
	MSR16R-485TMD	485 nm down sensor (90 nm BW)
	MSR16R-560TMU	560 nm up sensor (80 nm BW)
	MSR16R-560TMD	560 nm down sensor (80 nm BW)
	MSR16R-660TMU	660 nm up sensor (60 nm BW)
	MSR16R-660TMD	660 nm down sensor (60 nm BW)
	MSR16R-830TMU	830 nm up sensor (140nm BW)
	MSR16R-830TMD	830 nm down sensor (140nm BW)
	MSR16R-1650TMU	1650 nm up sensor (200nm BW)
	MSR16R-1650TMD	1650 nm down sensor (200nm BW)
MODIS	MSR16R-650U2	650 nm up sensor (40 nm BW)
	MSR16R-650D2	650 nm down sensor (40 nm BW)
	MSR16R-850U2	850 nm up sensor (60 nm BW)
	MSR16R-850D2	850 nm down sensor (60 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)

These bands provide data for selected channels of the Landsat Thematic Mapper and MODIS instruments. Channels were chosen to provide NDVI as well as a variety of vegetation water content indices under consideration.

In the field the radiometer is held level by the support pole above the crop canopy. The diameter of the field of view is one half of the height of the radiometer above the canopy. It is assumed that the irradiance flux density incident on the top of the radiometer (upward facing side) is identical to the flux density incident on the target surface. The data acquisition program included with the system facilitates digitizing the voltages and recording percent reflectance for each of the selected wavelengths. The program also allows for averaging multiple samples. Ancillary data such as plot number, time, level of incident radiation and temperature within the radiometer may be recorded with each scan.

Each scan, triggered by a manual switch or by pressing the space key on a terminal or PC, takes about 2 to 4 seconds. An audible beep indicates the beginning of a scan, two beeps indicate the end of scan and 3 beeps indicate the data is recorded in RAM. Data recorded in the RAM file are identified by location, experiment number and date.

The design of the radiometer allows for near simultaneous inputs of voltages representing incident as well as reflected irradiation. This feature permits accurate measurement of reflectance from crop canopies when sun angles or light conditions are less than ideal. Useful measurements of percent reflectance may even be obtained during cloudy conditions. This is a very useful feature, especially when traveling to a remote research site only to find the sun obscured by clouds.

Three methods of calibration are supported for the MSR16R systems:

2-point Up/Down - Uses a diffusing opal glass (included), alternately held over the up and down sensors facing the same incident irradiation to calibrate the up and down sensors relative to each other (<http://www.cropscan.com/2ptupdn.html>).

Advantages:

- Quick and easy.
- Less equipment required.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.
- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Up & Down - Uses a white card with known spectral reflectance to calibrate the up and down sensors relative to each other.

Advantages:

- Provides a more Lambertian reflective surface for calibrating the longer wavelength (above about 1200 nm) down sensors than does the opal glass diffuser of the 2-point method.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.

- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Down Only - Uses a white card with known spectral reflectance with which to compare down sensor readings.

Advantages:

- Only down sensors required, saving cost of purchasing up sensors.
- Best method for radiometer use in greenhouse, under forest canopy or whenever irradiance flux density is different between that striking the top of the radiometer and that striking the target area.

Disadvantages:

- White card must be carried in field and recalibration readings must be taken periodically to compensate for sun angle changes.
- Less convenient and takes time away from field readings.

Readings cannot be made in cloudy or less than ideal sunlight conditions, because of likely irradiance change from time of white card reading to time of sample area reading.

There are six major items you need in the field -

- MSR16 (radiometer itself)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Figure 34)
- CT100 (hand terminal, connected to the DLC with a serial cable) (Figure 35)
- Calibration stand and opal glass plate
- Memory cards
- Extension pole (with spirit level adjusted so that the top surface of the radiometer and the spirit level are par level)



Figure 34. data logger controller & cable adapter box



Figure 35 CT100 hand terminal

Set Up –

- Mount the radiometer pole bracket on the pole and attach the radiometer.
- Mount the spirit level attachment to the pole at a convenient viewing position.
- Lean the pole against a support and adjust the radiometer so that the top surface of it is level
- Adjust the spirit level to center the bubble (this will insure that the top surface of the radiometer and the spirit level are par level)
- Attach the 9ft cable MSR87C-9 to the radiometer and to the rear of the MSR Cable Adapter Box (CAB)
- Connect ribbon cables IOARC-6 and IODRC-6 from the front of the CAB to the front of the Data Logger Controller (DLC)
- Plug the cable CT9M9M-5 into the RS232 connectors of the CT100 and the DLC (the DLC and CAB may now be placed in the shoulder pack for easy carrying)
- Mount the CT100 on the pole at a convenient position
- Adjust the radiometer to a suitable height over the target (the diameter of the field of view is one half the height of the radiometer over the target)

Configure MSR –

- Perform once at the beginning of the experiment, or if the system completely loses power
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **1** then **ENTER**, input the correct date, Press **ENTER**
- At Command * Press **2** then **ENTER**, input the correct time, Press **ENTER**
- At Command * Press **3** then **ENTER**, input the number of sub samples/plot (5), Press **ENTER**

- At Command * Press **6** then **ENTER**, input a 2 or 3 character name for your sampling location (ex OS for Oklahoma South), Press **ENTER**; input the latitude for your location, Press **ENTER**; input the longitude for your location, Press **ENTER**
- At Command * Press **9** then **ENTER**, input the GMT difference, Press **ENTER**
- At Command * Press **M** then **ENTER** until you return to the main menu

Calibration –

- *We are using the 2-point up/down calibration method*
- Calibrate everyday before you begin to take readings
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **11** then **ENTER** to get to the Calibration menu
- At Command * Press **3** then **ENTER** to get to the Recalibration menu
- At Command * Press **2** then **ENTER** for the 2-point up/down calibration
- Remove the radiometer from the pole bracket and place on the black side of the calibration stand, point the top surface about 45° away from the sun, press **SPACE** to initiate the scan (1 beep indicates the start of the scan, 2 beeps indicate the end of the scan, and 3 beeps indicate the data was stored)
- Place the separate opal glass plate on top of the upper surface and press **SPACE** to initiate scan
- Turn the radiometer over and place it back in the calibration stand, cover it with the separate opal glass plate and press **SPACE** to initiate scan
- CT100 will acknowledge that the recalibration was stored
- At Command * Press **M** then **ENTER** until you return to the main menu
- Return the radiometer to the pole bracket
- Store configuration onto the memory card

Memory Card Usage –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **7** then **ENTER** to get to the Memory Card Operations menu
- Memory Card Operations menu is:
 1. Display directory
 2. Store data to memory card (use to save data in the field)
 3. Load data from memory card (use first to download data from memory card)
 4. Save program/configuration to card (use to save after calibrating)
 5. Load program/configuration from card (use when DLC loses power)
 6. Battery check
- M Main menu
- There are 2 memory cards, 64K for storing the program/configuration and 256 for storing data in the field

Taking Readings in the Field –

- Switch the CT100 power to on

- Press **ENTER** 3 times to get to MSR menu
- Press **ENTER** to continue or **M** to return to the main menu
- Enter beginning plot number, **ENTER**
- Enter the ending plot number, **ENTER**, record plot numbers and field ID in field notebook
- Adjust the radiometer to a suitable height (about 2 meters) over the target, point the radiometer towards the sun, center the bubble in the center of the spirit level and make sure that there are no shadows in the sampling area
- **Do not** take measurements if $IRR < 300$
- Initiate a scan by pushing **SPACE**, the message ‘scanning’ will appear on the screen and a beep will be heard
- When the scan is complete (about 2 seconds) ‘**’ will be displayed and 2 beeps will be heard
- Now, you can move to the next area
- 3 Beeps will be heard when the data has been stored
- Press **SPACE** to start next scan, **R** to repeat scan, **P** to repeat plot, **S** to suspend/sleep, **M** to return to the MSR main menu, **W** to scan white standard, and **D** to scan Dark reading
- When you are done scanning at that field location, press **M** to return to the MSR main menu, then press **10** to put the DLC to sleep
- Switch the CT100 power off

Downloading Data –

- Plug the cable RS9M9F-5 into the RS232 connectors on the front DLC and the serial port of your PC
- Start the CROPSCAN software on the PC
- Choose RETRIEVE from the menu and press **ENTER**
- Select your PC COM port and press **ENTER**
- Enter your file name (MMDDFL.MV, where MM is month, DD is day, FL is first and last initials of user and MV for raw millivolt data files)
- After the data is downloaded, press **Y** then **ENTER** to clear the data from the DLC

Two types of sampling will be performed as part of SMAPVEX:

Vegetation Water Content Sampling Location:

Reflectance data will be collected for each vegetation sampling location (Figure 36) 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.

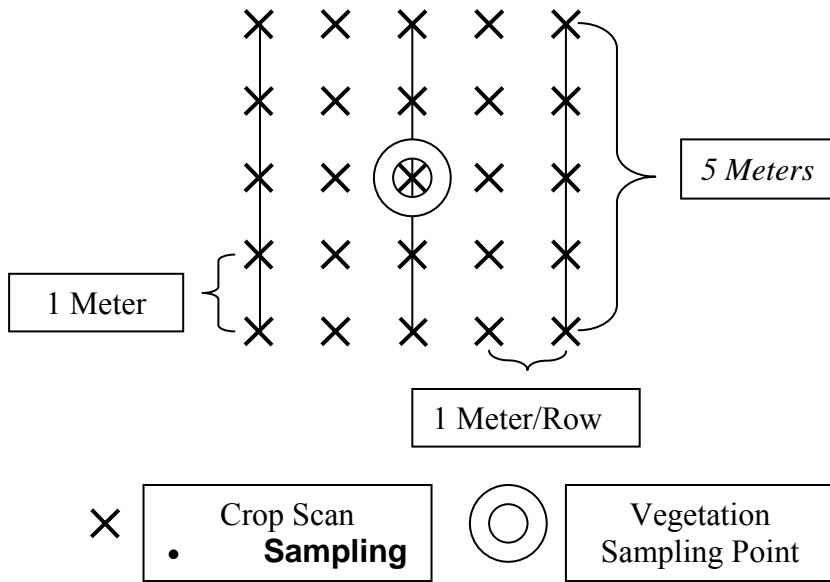


Figure 36 Vegetation sampling scheme

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 37 and 38). 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.

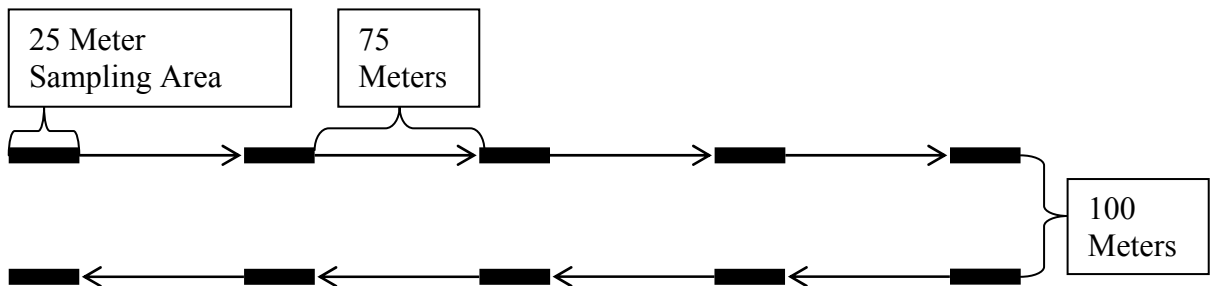


Figure 37. Transect sampling scheme

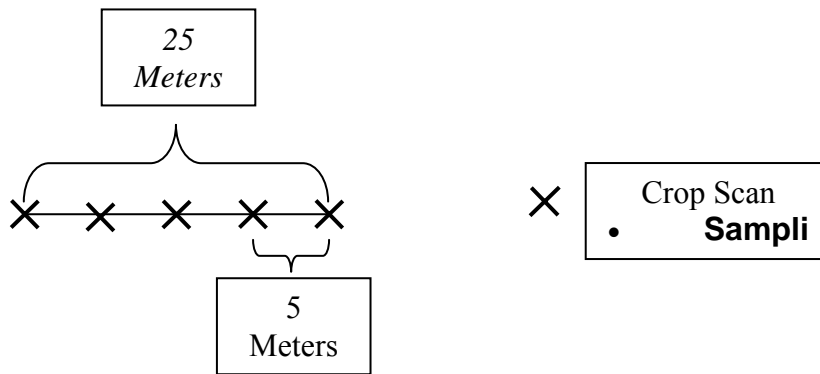


Figure 38. Enlarged transect sampling area

8.10.8 Leaf Area

Leaf area will be measured with a LAI-2000 (Figure 39). The LAI-2000 will be set to average 5 points into a single value so one observation is taken above the canopy and 4 below the canopy. For *grasses and weeds and non-row crops*, five sets of measurements (each set consisting of 1 above the canopy and 4 beneath the canopy) will be made. Measurements will be taken every meter on 5 meter transects. For *row crops*, the 4 beneath canopy measurements will be taken across a plant row (in row, $\frac{1}{4}$ row, $\frac{1}{2}$ row and $\frac{3}{4}$ row).

If the sun is shining, the observer needs to stand with their back to the sun and put a black lens cap that blocks $\frac{1}{4}$ of the sensor view in place and positioned so the **sun and the observer are never in the view of the sensor**. The observer should always note if the sun was obscured during the measurement, whether the sky is overcast or partly cloudy with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked “shaded”, if shadows could be seen during the measurement then the measurement is marked “sunny”. Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements.



Figure 39. The LAI-2000 Instrument

Operating the LAI-2000 -

Plug the sensor cord into the port labeled “X” and tighten the two screws.

Place a black view-cap over the lens that blocks 1/4 of the sensor view; that 1/4 that contains the operator. Place a piece of tape on the view cap and body of the sensor so if the cap comes loose it will not be lost.

Turn on the logger with the “ON” key (The unit is turned off by pressing “FCT”, “0”, “9”).

Clear the memory of the logger -

Press “FILE”

Use “↑” to place “Clear Ram” on the top line of display

Press “ENTER”

Press “↑” to change “NO” to “YES”

Press “ENTER”

General items –

When changing something on the display, get desired menu item on the top line of display and then it can be edited.

Use the “↑” and “↓” to move items through the menu and the “ENTER” key usually causes the item to be entered into the logger.

When entering letters, look for the desired letter on the keys and if they are on the lower part of the key just press the key for the letter; if the desired letter is on the upper part of the key then press the “↑” and then the key to get that letter.

Press “BREAK” anytime to return to the monitor display that contains time, file number or sensor readings on one of the five rings that are sensed by the LAI-2000.

Do not take data with the LAI-2000 if the sensor outputs are less than 1.0 for readings above the canopy.

To Begin -

Press **“SETUP”**

Use “↑” to get “XCAL” on the top line of the display and press **“ENTER”**

Following XS/N is the serial number of the sensor unit, enter appropriate number

Check or put appropriate cal numbers from LICOR cal sheet into the 5 entries.

Final press of **“ENTER”** returns you to “XCAL”

Use “↑” to get to “RESOLUTION”

Set it to “HIGH”

Use “↑” to get to “CLOCK”

Update the clock (set to local time using 24 hr format)

Press **“OPER”**

Use “↑” to get “SET OP MODE” on top line of display

Choose “MODE=1 SENSOR X”

Enter “↑”, “↓”, “↓”, “↓”, “↓” in “SEQ”

Enter "1" in “REPS”

Use “↑” to get to “SET PROMPTS”

Put “SITE” in first prompt

Put “LOC” in second prompt

Use “↑” to get to “BAD READING”

Choose "A/B=1"

Press **“BREAK”**

Display will contain the two monitor lines

Use “↑” and “↓” to control what is displayed on the top line in the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If FI is selected, then the file number is displayed)

Use the “→” and “←” to control what is displayed on the bottom line of the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If X2 is selected, then ring #2 output is displayed)

Press **“LOG”** to begin collecting data

Type in the response to the first prompt (if **“ENTER”** is pressed the same entry is kept in response to the prompt).

Type in the response to the second prompt (if **“ENTER”** is pressed the same entry is kept in response to the prompt).

Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

For Row crops –

1. Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
 2. Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.
 3. Place the sensor one-quarter (1/4) of the way across the row and record data again.
 4. Place the sensor one-half (1/2) of the way across the row and record data again.
 5. Place the sensor three-quarters (3/4) of the way across the row and record data again.
- Repeat steps 1-5 so that you have a total of 5 sets of measurements.

For Other Types of Vegetation –

1. At your starting spot, place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
2. Place the sensor below the plant canopy in the same place level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Repeat step 2 every meter, for a total of 1 up and 4 down measurements.
4. Repeat for a total of 5 transects.

The logger will compute LAI and other values automatically. Using the “↑” you can view the value of the LAI.

NOTE: You will record the “SITE” and “LOC” along with the LAI value on a data sheet.

The LAI-2000 is now ready for measuring the LAI at another location. Begin by pressing “LOG” twice. The file number will automatically increment.

When data collection is complete, turn off the logger by pressing “FCT”, "0", "9".

The data will be dumped onto a laptop back at the Field Headquarters.

Downloading LAI-2000 files to a PC Using HyperTerminal -

Before beginning use functions 21 (memory status) and 27 (view) to determine which files you want to download. Make a note of their numbers.

- 1) Connect wire from LAI-2000 (25pin) to PC port (9 pin).

- 2) Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | LAI2000.ht)
- 3) On the LAI-2000, go to function 31 (config i/o) and configure I/O options.
Baud=4800, data bits=8, parity=none, xon/xoff=no.
- 4) On the LAI-2000, go to function 33 (set format) and setup format options. First we use Spdsheet and take the default for FMT.
- 5) In HyperTerminal go to Transfer | Capture text. Choose a path and filename (LAIMMDDFL.SPR, where MM is month, DD is day, FL is first and last initials of user and SPR for spreadsheet data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.
- 6) On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from: 1 thru: 25 will print all files numbered 1-25. Others will not be downloaded.
- 7) Once you hit enter in function 32, lines of text data will be sent to HyperTerminal. The LAI-2000 readout will say 'Printing file 1, 2, etc'. Check the window in HyperTerminal to ensure the data is flowing to the PC. This may take a few minutes, wait until all the desired files have been sent.
- 8) In HyperTerminal go to Transfer | Capture text | Stop.
- 9) On the LAI-2000, go to function 33 (set format) and setup format options. Now set to Standard, Print Obs = yes
- 10) In HyperTerminal go to Transfer | Capture text Choose a path and filename (LAIMMDDFL.STD, where MM is month, DD is day, FL is first and last initials of user and STD for standard data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.
- 11) On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from: 1 thru: 25 will print all files numbered 1-25. Others will not be downloaded.
- 12) In HyperTerminal go to Transfer | Capture text | Stop.
- 13) Using a text editor (like notepad) on the PC, open and check that all the LAI data has been stored in the text file specified in step 3. Make a back up of this file. Once you're sure the LAI values look reasonable and are stored in a text file on the PC, use function 22 on the LAI-2000 to delete files on the LAI-2000 and free up its storage space.

Note: The above instructions assume that HyperTerminal has been configured to interface with the LAI-2000, i.e. the file LAI2k.ht exists. If not, follow these instructions to set it up.

- 1) Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | Hypertrm
- 2) Pick a name for the connection and choose the icon you want. Whatever you pick will appear as a choice in the HyperTerminal folder in the start menu later. Hit OK.
- 3) Connect using com1 or com2. Choose your com port, hit OK. Setup Port settings as follows: Bits per second = 4800, Data Bits = 8, Parity = none, Stop bits = 1, Flow control = Hardware. Say OK.
- 4) Make sure the wire is connected to the LAI-2000 and the PC and proceed with step 3 in the download instructions above. When finished and leaving HyperTerminal you will be prompted to save this connection.

8.11. Global Positioning System (GPS) Coordinates

The acquisition of geographic coordinates at all sample point locations (e.g., WC and IA points, vegetation sites, and flux towers) is necessary for mapping of data in a Geographic Information System (GIS). A Garmin eTrex “sportsman” GPS will be used to collect location data (Figure 40). This unit has the capacity to store up to 500 geographic coordinates or waypoints and it is designed so that all key entries can be performed with the left hand alone. Accurate GPS data can be acquired 24 hours a day under all weather conditions. The only restraint is that the eTrex antenna--location determination is made at the site of the internal antenna--must have a clear view of the sky in all directions. Once accurate location data at a particular sample site has been acquired and confirmed, no additional measurements at that site will be needed.

- All sampling points will be located using a handheld GPS.
 - WC points
 - IA points
 - Vegetation samples
 - Flux towers

General Information

Record eTrex ID number (etched on back cover), site and point ID, and latitude and longitude coordinates in field notebook.

Watershed and regional sites should be labeled as follows:

Watershed: Site WC## and point ## (e.g., WC05-02)

Regional: Site IA##

Carry at least two (2) extra AA alkaline batteries. The eTrex is configured to run in Battery Save mode which automatically turns the GPS receiver on and off to conserve power. In this mode, the eTrex should operate for approximately 22 hours. A “Battery Low” message will appear at the bottom of the screen when the unit has ten (10) minutes of battery life remaining.

eTrex GPS Features (see Figure 40)

UP/DOWN ARROW buttons: used to select options.

ENTER button: used to confirm selections or data entry.

PAGE button: switches between display screens (or “pages”) and functions as escape key.

POWER button: turns eTrex GPS as well as display backlight on and off.

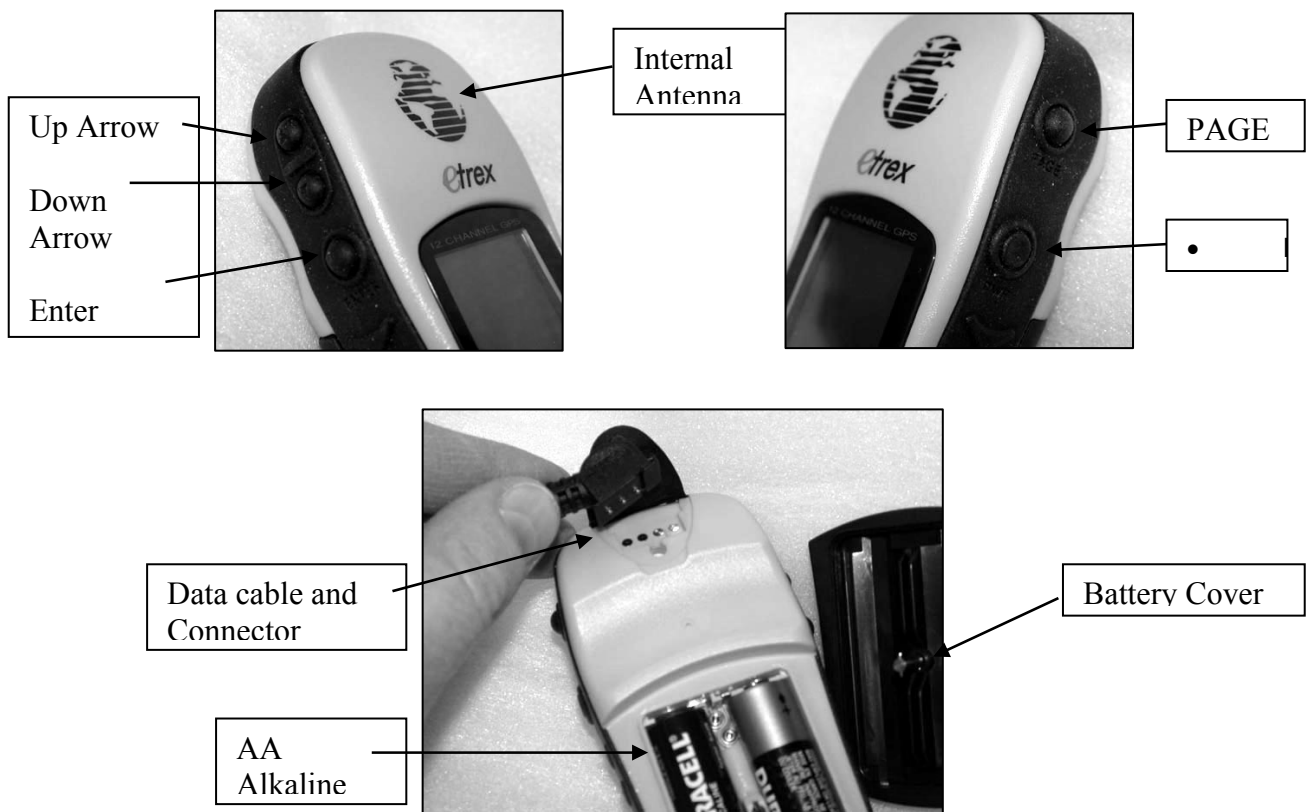


Figure 40. GPS features

All eTrex operations are carried out from the four (4) “pages” (or display screens) shown in Figure 41. The PAGE key is used to switch between pages. (The Map and Pointer Pages are used for navigation and will not be discussed further.)

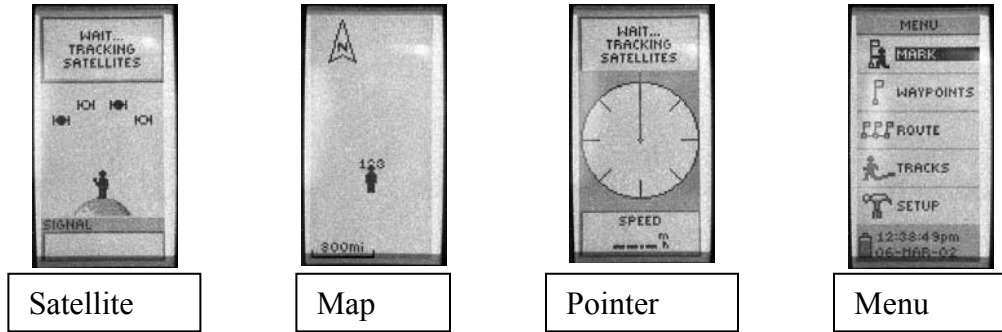


Figure 41. GPS display screens or “pages”

Setup at Headquarters Prior to Data Collection

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed.
2. Confirm configuration parameters:
 - PAGE to Menu screen; ARROW to Setup; press ENTER (Figure 42)
 - Use the following key sequence to check configuration parameters:
 - ARROW to first parameter; press ENTER;
 - confirm values (see configuration values below);
 - press PAGE to return to Setup menu;
 - ARROW to next parameter, etc.
 - The following are the parameters and required settings;
 - Time = Format: **24 Hour**; Zone: **US-Central**; (UTC Offset: -**6:00**); Daylight Saving: **Auto**
 - Display = Timeout: **15 sec.**
 - Units = Position Format: **hddd.ddddd°**; Map Datum: **WGS 84**;
Units: **Metric**; North Reference: **True**
 - Interface = I/O Format: **Garmin**
 - System = Mode: **Battery Save**

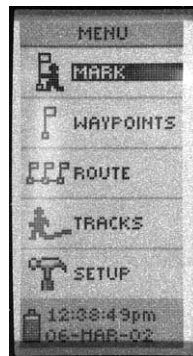


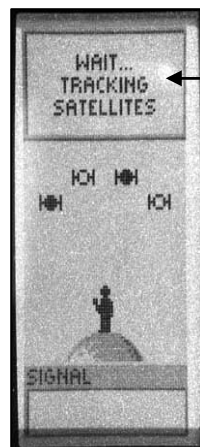
Figure 42. GPS Menu Page

3. Turn eTrex off after GPS data collection by depressing and holding POWER button until screen blanks.

Important Note: Geodetic datums mathematically describe the size and shape of the earth and provide the origin and orientation of coordinate systems used in mapping. Hundreds of datums are currently in use and particular attention must be paid to what datum is used during GPS data collection. The Global Positioning System is based on the World Geodetic System of 1984 (WGS84). However, popular map products such as USGS 1:24,000 topo sheets originally used the North American Datum of 1927 (NAD27). Most of the maps in this series have been updated to the North American Datum of 1983 (NAD83). Fortunately, there is virtually no practical difference between WGS84 and NAD83. Yet significant differences exist between NAD27 and NAD83. (In Iowa, a north-south displacement of approximately 215 m occurs between NAD27 and NAD83.) *All geographic coordinates collected with the eTrex GPS should be acquired using the following parameters: latitude/longitude (decimal degrees), WGS84 datum, meters, true north.* Various coordinate conversion software packages such as the Geographic Calculator (\$500) or NOAA's Corpscon (free) exist which allow the conversion of geodetic (latitude and longitude) coordinates into planar (UTM or State Plane) coordinates for GIS mapping.

GPS Field Data Collection

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed (Figure 43). Wait until text box at top of screen reads "READY TO NAVIGATE" before continuing.



Wait until "READY TO NAVIGATE" is displayed AND
Accuracy is ≤ 10 m
(Up to 5 minutes at a new location;
15-45 seconds on subsequent visits.)

Figure 43. GPS Satellite Page

2. Adjust screen backlight and contrast, if necessary.
 - Turn backlighting on by quickly pressing and releasing POWER button from any screen. (To save power, the backlight remains on for only 30 seconds.); AND/OR,
 - Adjust screen contrast by pressing UP (darker) and DOWN (lighter) buttons from Satellite Page.

3. Initiate GPS point data collection:
 - PAGE to Menu screen (Figure 42); Arrow to Mark; press ENTER. (Shortcut: press and hold ENTER button from any screen to get to Mark Waypoint page below.)
 - ARROW to alphanumeric ID field (Figure 44); press ENTER. Use ENTER and UP/DOWN buttons to edit ID, if necessary. (Waypoint ID increments by one (1) automatically.)
 - Record latitude (North) and longitude (West) coordinates displayed at bottom of screen into field notebook. *Do not rely on electronic data download to save data points!*
 - ARROW to OK prompt; press ENTER to save point coordinates electronically.

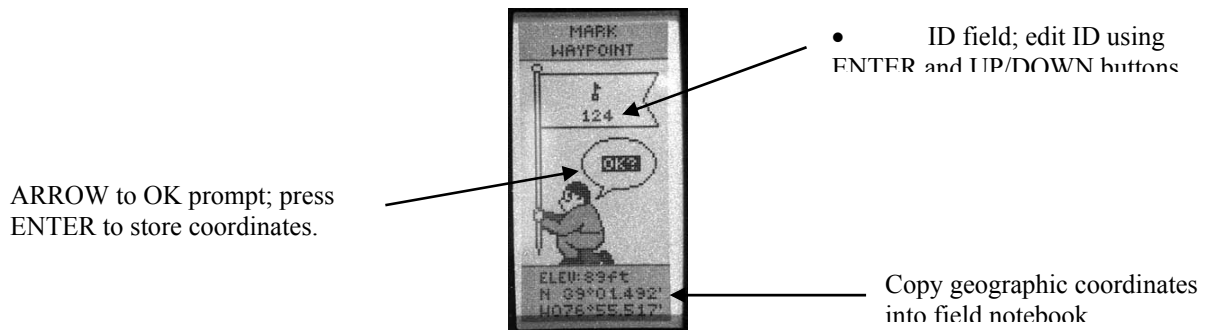


Figure 44. GPS Mark Waypoint Page

4. Turn eTrex off after GPS data collection by depressing and holding POWER button until screen blanks.

Electronic Data Downloading

Electronic data downloading will be performed at field headquarters by assigned person.

Connect PC data cable by sliding keyed connector into shoe at top rear of eTrex (under flap); power eTrex on.

Launch Waypoint.exe

GPS => Port => Com?

Waypoints => Download

File => Save => Waypoint

Select Save as type: Comma Delimited Text File

9. References

Bindlish, R., T.J. Jackson, S. Yueh, S. Dinardo, M.H. Cosh, M.H., and R. Sun, 2008, Combined Passive Active Soil Moisture Observations During CLASIC. Proc. International Geoscience and Remote Sensing Symposium, Boston, MA. In press.

Cosh, M.H., T.J. Jackson, R. Bindlish, J. Famiglietti, and D. Ryu, 2005, A comparison of an impedance probe for estimation of surface soil water content over large region. *Journal of Hydrology*, 311:49-58.

Doraiswamy, P. C., J. L. Hatfield, T.J. Jackson, B. Akhmedov, J. Prueger, and A. Stern, 2004. Crop condition and yield simulations using Landsat and MODIS, *Remote Sensing of Environment*, 92: 548-559.

Gaiser, P. W., K. M. St. Germaine, E. M. Twarog, G. A. Poe, W. Purdy, D. Richardson, W. Grossman, W. L. Jones, D. Spencer, G. Golba, J. Cleveland, L. Choy, R. M. Bevilacqua, and P. S. Chang, 2004, The WindSat spaceborne polarimetric microwave radiometer: Sensor description and early orbit performance, *IEEE Trans. Geosci. Remote Sens.*, 42:2347–2361.

Jackson, T.J., D.M. Le Vine, A.Y. Hsu, A. Oldak, P. Starks, C.T. Swift, J. Isham, and M. Haken, 1999, Soil moisture mapping at regional scales using microwave radiometry: the Southern Great Plains hydrology experiment. *IEEE Trans. Geosci. Rem. Sens.*, 37:2136-2151.

Li, L., E. G. Njoku, E. Im, P. S. Chang, and K. S. Germain, 2004, A preliminary survey of radio-frequency interference over the U.S. in Aqua AMSR-E Data, *IEEE Trans. Geosci. Rem. Sens.*, 42:380-390.

Narayan, U., V. Lakshmi, and E. Njoku, 2004, Retrieval of soil moisture from passive and active L/S band sensor (PALS) observations during the soil moisture experiment in 2002 (SMEX02). *Rem. Sens. Environ.*, 92:483-496.

Njoku, E., W. Wilson, S. Yueh, S. Dinardo, F. Li, T. Jackson, V. Lakshmi, and J. Bolten, 2002, Observations of soil moisture using a passive and active low frequency microwave airborne sensor during SGP99. *IEEE Trans. Geosci. Rem. Sens.*, 40:2659-2673

Njoku, E., T. Jackson, V. Lakshmi, T. Chan, T., and S. Nghiem, 2003, Soil moisture retrieval from AMSR-E. *IEEE Trans. Geoscience and Remote Sensing*, 41:215-229.

Wilson, W. J., S. H. Yueh, S. J. Dinardo, S. Chazanoff, F. Li, and Y. Rahmat-Samii, 2001, Passive Active L- and S-band (PALS) microwave sensor for ocean salinity and soil moisture measurements. *IEEE Trans. Geosci. Rem. Sens.*, 39:1039-1048.

Appendix I: UAVSAR

The UAVSAR is a new aircraft based fully polarimetric L-band radar that is also capable of interferometry. Table I-1 provides a basic description of the instrument. It is currently implemented on a Gulfstream-III aircraft. Flying at high altitude it can provide data over a 15 km swath at a nominal 2 m spatial resolution. It could be a valuable tool in the SMAP program for algorithm development and validation. The disparity in scales of UAVSAR, PALSAR, and PALS are very large. Much like with PALSAR-PALS, understanding the scaling of the high resolution to the satellite footprint will be critical to SMAP.

Table I-1. Description of the UAVSAR.		
Instrument		Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)
Owner		NASA/JPL/Dryden (USA)
Platform		Gulfstream III
Passive	Frequencies	
	Polarizations	
	Spatial Resolution	(3dB beamwidth in Deg.)
Active	Frequencies	L-band
	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
Antenna Type		Phased Array
POC/Website		Scott Hensley Scott.Hensley@jpl.nasa.gov www.uavsar.jpl.nasa.gov
Current Status		Operational after Summer of 2008

Figure I-1 illustrates the coverage of the different sensors. The UAVSAR collects data over a 20 km swath; however, much of this is at angles that are not relevant to SMAP. We will request that the lines be oriented with the PALSAR track. Eight (or more) lines will be flown to provide coverage of the intensive sampling blocks centered on 40 degrees. Each will be flown in a N-S and S-N direction. The lines will be approximately 60 km long. In addition, an E-W oriented pass will be requested.

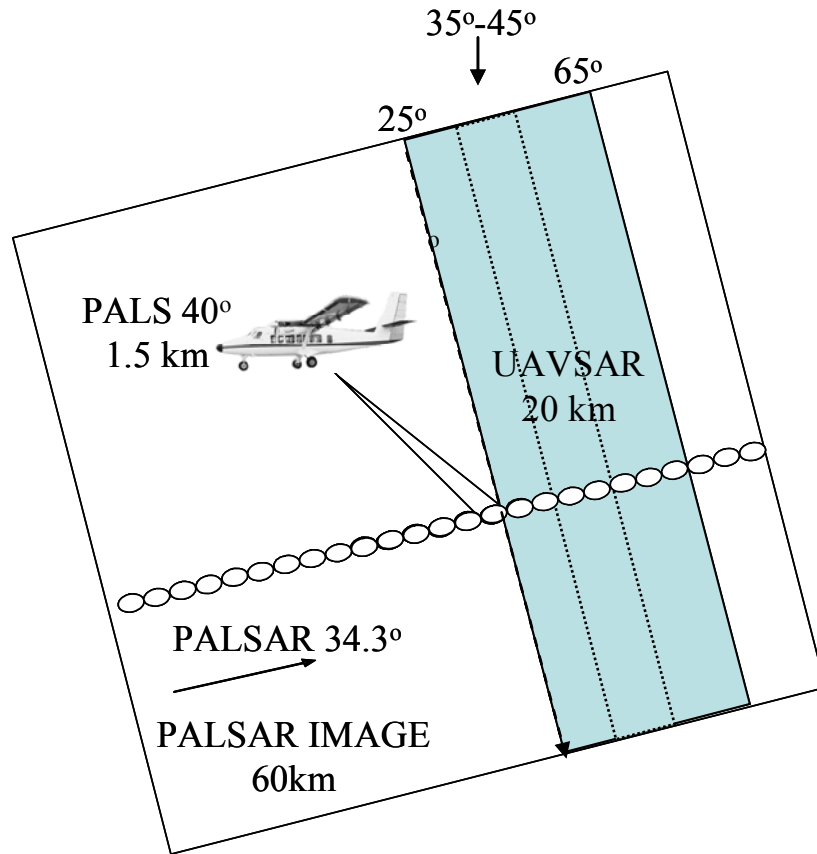


Figure I-1. Schematic of the Radar Scaling Flights for UAVSAR.