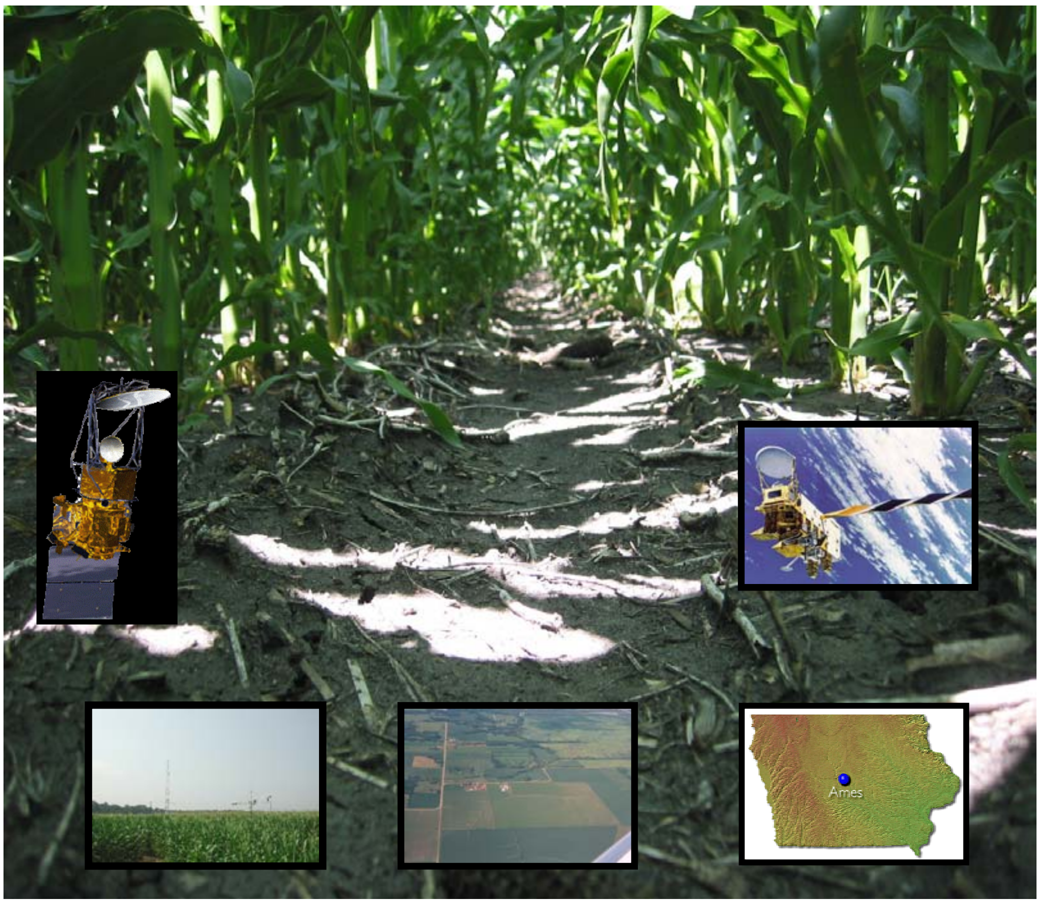
Soil Moisture Experiment 2005

and Polarimetry Land Experiment (SMEX05/POLEX)



Experiment Plan

June 2005

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1 OVERVIEW AND SCIENTIFIC OBJECTIVES

1.1 Introduction

Major activities are underway throughout the world to develop operational soil moisture remote sensing, integrate such measurements with conventional methods and models, and to understand the role of this variable in land atmosphere interaction, global circulation, and carbon cycling, as well as global security. Although we know that microwave remote sensing provides a direct measurement of soil moisture there have been many challenges in algorithm science and technology that we have faced on the path to providing global measurements. At the present there are two distinct opportunities that could significantly move the community further along the roadmap to satellite based soil moisture products; operational moderately low frequency instruments such as the Advanced Microwave Scanning Radiometer (AMSR), WindSat radiometer and Conical Scanning Microwave Imager/Sounder (CMIS) and exploratory L band missions (SMOS and Hydros).

Research is needed to fully exploit the operational satellite instruments, recognizing limitations of these sensors in terms of Radio-Frequency Interference (RFI) mitigation, spatial resolution and vegetation attenuation. Robust algorithms and extensive validation are still needed. Now and for the near future, low frequency passive microwave remote sensing will involve coarse spatial resolutions that are difficult to characterize from theory and are challenging even using conventional techniques. Surface soil moisture exhibits exceptionally high spatial variation at scales ranging from a point (~ 5 cm) through landscape features and climatic regimes. Field experiments, especially those involving both ground and aircraft measurements, provide the linkage between spatial scales necessary for both algorithm development and validation.

Soil Moisture Experiments 2005 and Polarimetry Land Experiment (SMEX05/POLEX) will address algorithm development and validation related to all of the current and scheduled soil moisture satellite systems. Specific objectives include:

- Exploration of unique polarimetric information from satellites such as Windsat and CMIS for soil moisture with supporting aircraft instrumentation
- Diurnal effects associated with soil, vegetation and atmosphere at the 6 am/6 pm observing times of Hydros, SMOS, CMIS, and Windsat
- Enhancement of Aqua AMSR-E soil moisture validation
- Statistics and mitigation of RFI for CMIS risk reduction

Of these objectives, polarimetric microwave studies will be the primary driver for experiment design. SMEX05/POLEX will be the first campaign designed to study the unique and unexplored information that can be extracted for land applications using fully polarimetric observations. The Airborne Polarimetric Microwave Imaging Radiometer (APMIR), an aircraft simulator of WindSat and CMIS, will be available for SMEX05/POLEX that will facilitate replicate observations of a range of landscape features. In addition, with APMIR sub-band and emitter database, we will collect regional RFI statistics and evaluate the sensor capability in terms of RFI mitigation and its benefit in improving soil moisture retrieval performance. Many satellites (WindSat, CMIS, SMOS and Hydros) will share the same diurnal observation characteristics (6 am/ 6 pm). Efforts in SMEX05 to focus on this time frame will offer the opportunity to understand phenomena that may be specific to these observing times. Of particular interest is the effect of dew on the microwave brightness temperature (Jackson and Moy 1999). If the presence of dew has a significant impact on the brightness temperature it will be necessary to develop methods to identify this condition and possible correct for the dew effects.

All ground based and aircraft observations will also support the soil moisture algorithm validation of Aqua AMSR-E. WindSat will transition to CMIS on the NPOESS operational platforms and AMSR to the Japanese GCOM satellites. All efforts in SMEX05/POLEX will contribute to these programs.

1.2 Relevance to NRL and NPOESS Programs

NRL conducts an integrated science and technology program to observe, understand and predict the phenomena, processes and dynamics of the Navy/Marine Corp/DoD operational environment. SMEX05/POLEX addresses retrieval of soil moisture, a key state variable, and characterization of polarimetric signatures of vegetation and soil. Therefore SMEX05/POLEX contributes directly to two thrust areas:

- Environmental Model Development: Encompasses empirical and numerical model development techniques and associated efforts designed to diagnose problems and increase the efficiency and accuracy of those models and model systems in a variety of computational environments.
- Sensor and Data: Encompasses efforts to develop new or enhance existing shipboard, in-situ, airborne, and spaceborne sensors and appropriate inversion and other techniques to obtain environmental data.

Soil moisture is a lynchpin environmental variable in environment assessment and prediction. It has great impacts on a broad range of global security operations, including landings, cross country mobility prediction, mine detection and rapid airfield construction. Timely and effective knowledge of soil moisture at regional spatial scales is critical for gaining the awareness and minimizing or eliminating the weather impact on operations. Primarily designed to exploit the vast potential of passive microwave polarimetry, SMEX05/POLEX is charged with improving remote sensing of soils and vegetation at both global and regional spatial scales, by investigating the complete and unexplored microwave polarimetric properties of these targets.

NPOESS is striving to seek risk reduction and mitigation for its CMIS mission to ensure sound and proven theoretical basis and underlying assumptions for its Environmental Data Records (EDR) algorithms. As one of the six launch-critical EDRs, soil moisture represents an elevated risk factor for CMIS mission due to its relative weak knowledge base extractable from the heritage soil moisture algorithms in terms of precise modeling of radiative transfer process and its parameterization, mitigation of Radio Frequency Interference (RFI), heterogeneity modeling of land targets, scaling and physical validation of soil moisture retrieval. The WindSat radiometer is an immediate relevant predecessor to CMIS, but its polarimetric signature over land remains largely unexplored due to its primary ocean mission. Therefore it is pivotal for NPOESS to leverage most recent development in soil moisture retrieval as well as engage modeling issues that are unique for CMIS instruments and its orbit configurations, which will be implemented through field experiments specifically designed to address physical bases for soil moisture sensing and through algorithm simulation and validation using opportunities provided by WindSat sensor systems and/or the aircraft simulator of these satellite instruments.

1.3 Relevance to NASA Hydrology Programs

SMEX05/POLEX will address science priorities of at least three NASA programs related to hydrology; the Terrestrial Hydrology Program (THP), the Aqua AMSR-E, and the Hydros misssion. The soil moisture research priorities of the THP Soil Moisture Mission Working Group were recently updated to reflect program results and the success of the Hydros mission (Entekhabi et al. 2004). Those that include science objectives that are complementary to the SMEX05/POLEX are

- Participate in field experiment opportunities that address key mission issues through cooperative efforts with other programs and agencies
- Develop more robust radar soil moisture retrieval algorithms
- Improve multiple resolution retrieval algorithms that integrate active/passive measurements

The NASA Aqua AMSR-E program is attempting to develop a robust soil moisture algorithm and reliable products. Problems with radio frequency interference (RFI) at 6.925 GHz have created problems because pre-launch efforts had focused on the use of this frequency. New efforts have been initiated that use higher frequencies but require more research and validation. SMEX05/POLEX will contribute through both the ground and aircraft components to AMSR-E soil moisture validation. AMSR-E is also serving a valuable role in terms of lessons learned in attempting to generate a soil moisture product that will benefit Hydros and CMIS.

1.4 Elements of Soil Moisture Experiments in 2005 (SMEX05/POLEX)

Field experiments in support of remote sensing, hydrology and climate have included catchments throughout North America (Little Washita, Oklahoma: SGP97, SGP99, SMEX03; Little River, Georgia: SMEX03; Walnut River, Iowa: SMEX02; Walnut Gulch, Arizona: SMEX04). These experiments have been intensive efforts ranging from one to six weeks in duration. The basic approach used in these experiments has been to collect ground-based samples of soil moisture in conjunction with aircraft flights at the same time as satellite overpasses. The aims of these experiments have been:

- Validation of remotely sensed data from aircraft and/or space-borne microwave sensors, including validation of the retrieval algorithm and/or calibration of certain non-physical parameters in these algorithms
- The mapping of spatial and temporal variability of soil moisture, specifically, the spatial and temporal patterns after a dry-down.
- The relationship of soil moisture to vegetation and the near-surface atmospheric characteristics, as well as land-atmosphere interaction variables such as evapotranspiration and latent heat fluxes.

- The collection of in-situ gravimetric data for soil moisture for validation of the land surface hydrological models used to simulate the watershed at pre-specified spatial and temporal resolutions.

SMEX05/POLEX will involve four complementary elements:

- In-situ soil moisture networks
- Aircraft mapping of soil moisture
- Intensive sampling concurrent with the aircraft mission
- Satellite products

Ground based observations will include a combination of in-situ and mobile soil moisture data collection. A network of continuous point observations of surface soil moisture will be established within the Walnut Creek watershed as well as over a larger regional domain for the duration of SMEX05.

The sparse network in the Walnut Creek watershed area south of Ames, IA would be supplemented with more intensive observations by mobile teams during the intensive observing period on specific days with either aircraft and/or satellite observations. These will include intensive sampling of representative fields to support the aircraft activities as well as characterizing a regional domain for satellite validation and scaling. The general sampling scheme is shown in Figure 1.

Aircraft observations provide the critical bridge for scaling and integrating the point observations to the coarse satellite footprints. In addition, the higher resolution aircraft soil moisture products are of value in more intensive hydrologic investigations. A NRL aircraft (P-3B) will support the Advanced Polarimetric Microwave Imaging Radiometer (APMIR) that includes C, X, and higher frequencies. Missions will be flown approximately every other day and timed (if possible) to coincide with current satellite coverage and the observing times of planned missions. The experiment is currently planned for June 15 through July 5, 2005. This set of flights would provide diverse vegetation conditions, which are critical to the success of the experiment. Vegetation conditions will also be extensively studied as part of the field campaign.

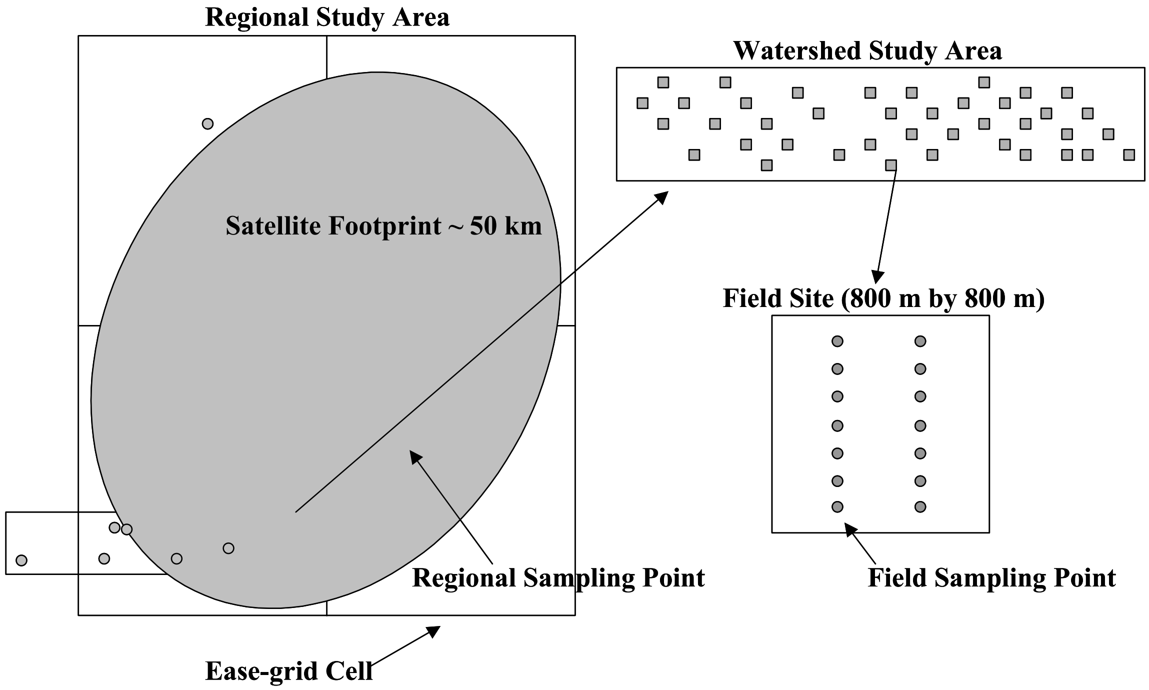


Figure 1. Schematic diagram showing the soil moisture ground sampling plan for SMEX05/POLEX.

2 SATELLITE OBSERVING SYSTEMS

2.1 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 1. Initially, the methods developed for algorithm development and validations for AMSR-E may be applied to WindSat with minimal modifications. The coverage dates and times of WindSat during SMEX05/POLEX are summarized in Table 2. Note that the average morning overpass time is 7:36 am local time. Figure 2 is a WindSat brightness temperature image of the SMEX05/POLEX region obtained in July 2003.

Table 1. Characteristics of WindSat.

Frequency (GHz)	Polarization	Incidence Angle (Deg.)	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

Table 2. SMEX05/POLEX WindSat Coverage Dates and Times			
Month	Day	Hour (Local)	Minute
6	13	7	52
6	14	7	35
6	15	7	17
6	15	18	42
6	16	18	24
6	19	7	48
6	20	7	31
6	20	18	55
6	21	7	13
6	21	18	37
6	22	18	20
6	25	7	44
6	26	7	26
6	26	18	50
6	27	18	33
6	28	18	15
6	30	7	57
7	1	7	39
7	2	7	22
7	2	18	46
7	3	18	28
7	4	18	11
7	6	7	52
7	7	7	35
7	8	7	17
7	8	18	41

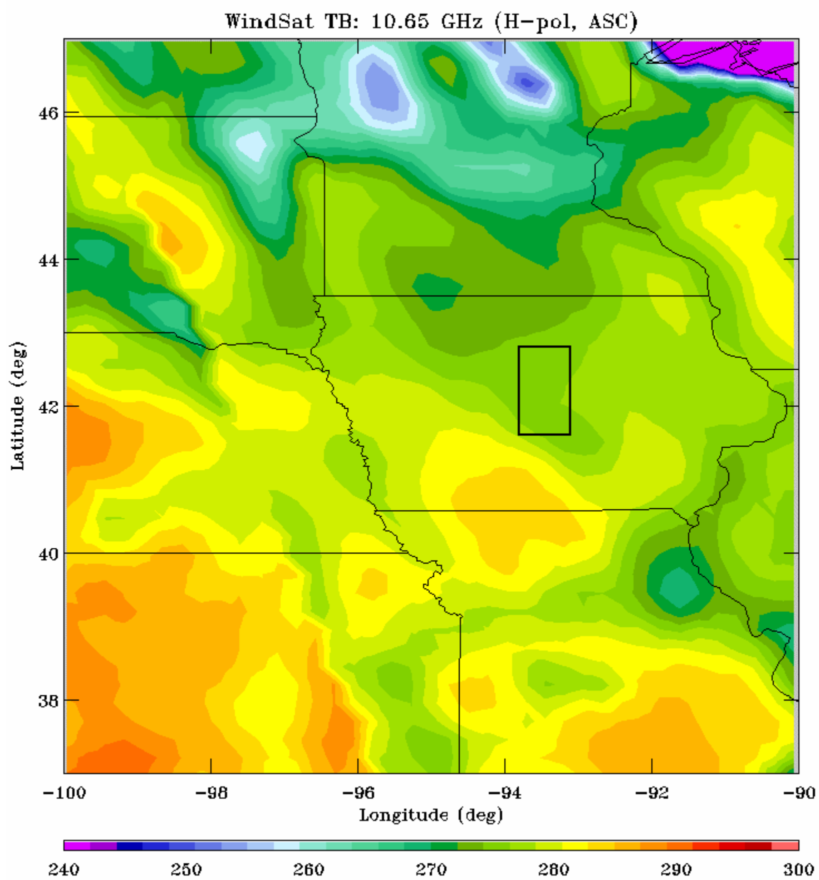


Figure 2. WindSat brightness temperature image obtained between July 1-5 2003. The small box indicates SMEX05/POLEX region.

2.2 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 3, 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^{o}. Details on AMSR-E can be found at http://wwwghcc.msfc.nasa.gov/AMSR/. Figure 3 illustrates the type of coverage provided by AMSR-E. The average local overpass times in the SMEX05/POLEX region at this time of the year are 3:10 and 14:10. Aqua overpasses for the SMEX05/POLEX region are summarized in Table 4.

Table 3. AMSR-E Characteristics			
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

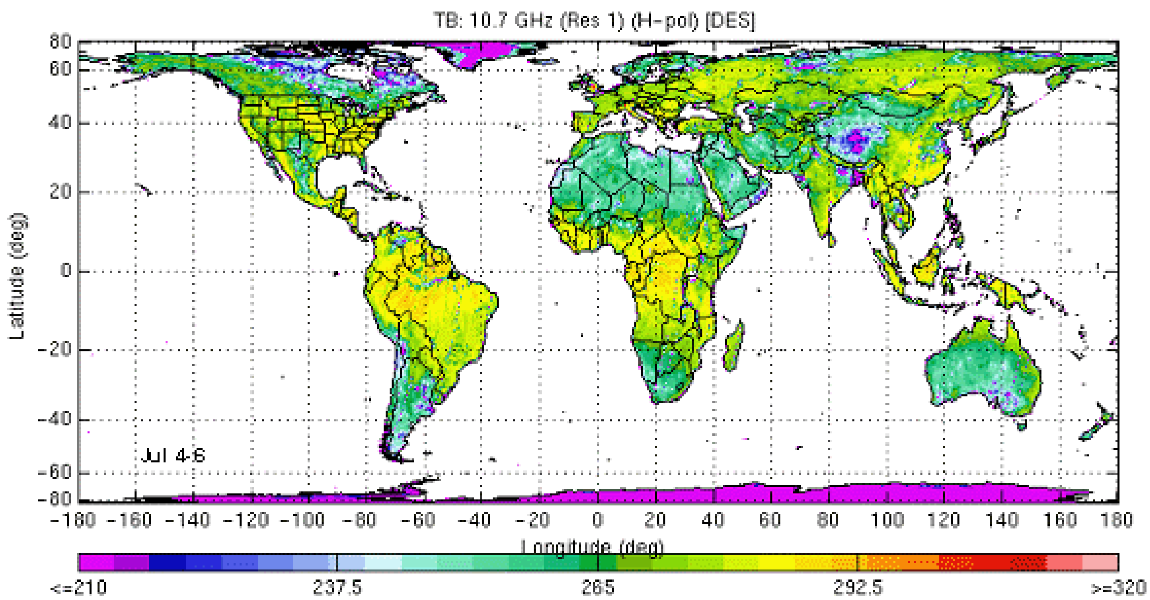


Figure 3. Example of AMSR-E brightness temperature image, three-day global composite.

Aqua includes several other instruments of potential value to investigators in the 2005 experiment:

- The Atmospheric Infrared Sounder (AIRS) is a high-resolution instrument, which measures upwelling infrared (IR) radiances at 2378 frequencies ranging from 3.74 and 15.4 micrometers.
- The Advanced Microwave Sounding Unit (AMSU) is a passive scanning microwave radiometer consisting of two sensor units, A1 and A2, with a total of 15 discrete channels operating over the frequency range of 50 to 89 GHZ. The AMSU operates in conjunction with the AIRS and HSB instruments to provide atmospheric temperature and water vapor data both in cloudy and cloud-free areas.
- Clouds and the Earth's Radiant Energy System (CERES) is a broadband scanning radiometer, with three detector channels, 0.3 to 5.0 micrometers, 8.0 to 12.0 micrometers and 0.3 to 50 micrometers.

- Moderate Resolution Imaging Spectroradiometer (MODIS) is a passive imaging spectroradiometer. The instrument scans a cross-track swath of 2330 km using 36 discrete spectral bands between 0.41 and 14.2 micrometers.

Table 4. SMEX05/POLEX Aqua AMSR-E Coverage Dates and Times

Month	Day	Hour (Local)	Minute
6	12	2	59
6	12	14	05
6	14	13	52
6	15	3	29
6	15	14	35
6	17	3	17
6	17	14	23
6	19	3	04
6	19	14	10
6	21	2	52
6	21	13	50
6	22	3	35
6	24	3	22
6	24	14	28
6	26	3	10
6	26	14	16
6	28	2	58
6	28	14	04
6	30	13	51
7	1	3	28
7	1	14	34
7	3	3	16
7	3	14	22
7	5	3	03
7	5	14	09
7	7	2	51
7	7	13	57
7	8	3	34

2.3 Special Sensor Microwave Imager (SSM/I)

SSM/I satellites have been collecting global observations since 1987. The SSM/I satellite data can only provide soil moisture under very restricted conditions because the frequencies (see Table 5) were not selected for land applications (Jackson 1997, Jackson et al. 2002, Teng et al. 1993). The viewing angle of the SSM/I is 53.1^{o}.

Table 5. SSM/I Characteristics			
Frequency (GHz)	Polarization	Spatial Resolution (km)	Swath (km)
19.4	H and V	69 x 43	1200
22.2	V	60 x 40	1200
37.0	H and V	37 x 28	1200
85.5	H and V	15 x 13	1200

There may be as many as four satellites with the SSM/I on board in operation during SMEX05/POLEX. The local ascending equatorial crossing times of the three currently available satellites are F13 (17:54), F14 (20:46), and F15 (21:20). F16 (07:54) was launched in October 2003. SSM/I data are useful in some aspects of algorithm development and provide a cross reference to equivalent channels on the WindSat and AMSR-E instruments. SSM/I data are freely available to users through http://www.saa.noaa.gov/. As in past experiments, the data will be subset and repackaged for this experiment.

2.4 Envisat Advanced Synthetic Aperture Radar (ASAR)

The Envisat satellite was launched by the European Space Agency in March 2002 (http://envisat.esa.int/). It is designed to provide Earth observations using a suite of remote sensing instruments. Of particular interest to soil moisture and hydrology is the inclusion of the Advanced Synthetic Aperture Radar (ASAR) that will provide both continuity to the ERS-1 and ERS-2 mission SARs and next generation capabilities. Envisat also has a visible and near infrared imaging system called MERIS. Envisat has a sun synchronous polar orbit. The exact repeat cycle for a specific scene and sensor configuration is 35 days.

The ASAR is a C band instrument, which is the same frequency as the ERS instrument. Unlike the ERS satellites that had a fixed angle of incidence (23^o) ASAR has a wider range of choices that can provide more frequent coverage and a variety of incidence angles. ASAR Image Mode will provide data acquisition in the seven different swath positions listed in Table 6, giving incidence angles ranging from 15° to 45°. IS1 is closest to the track of the satellite and IS7 is furthest away. When acquired simultaneously, each IS views a different area across track. In order to get all IS positions for the same ground location a series of days is required.

The other new feature of ASAR of interest for soil moisture is the alternating polarization (AP) mode. In this mode two polarization combinations (ERS had only VV) can be obtained (VV and HH, HH and HV, or VV and VH). It is anticipated that this additional information will enhance soil moisture retrieval. Swath width is nominally 100 km and the product pixel size is 30 m.

There are a limited number of data products available in dual polarization mode. Those of interest include: Alternating Polarization Mode Precision Image (APP) and Alternating Polarization Ellipsoid Geocoded Image (APG). Each will be a nominal 100 x 100 km scene with a pixel spacing of 12.5 x 12.5 m and a pixel size of 30 x 30 m. The APG is resampled to a North orientation and georectified.

Table 6. Specifications for ASAR Image Mode Swaths.			
Image Swath	Swath Width (km)	Ground, position from nadir (km)	Incidence Angle Range
IS1	105	187 - 292	15.0 - 22.9
IS2	105	242 - 347	19.2 - 26.7
IS3	82	337 - 419	26.0 - 31.4
IS4	88	412 - 500	31.0 - 36.3
IS5	64	490 - 555	35.8 - 39.4
IS6	70	550 - 620	39.1 - 42.8
IS7	56	615 - 671	42.5 - 45.2

In general the VV-VH combination is preferred for soil moisture. IS2 provides continuity of the ERS observations. IS1-IS3 may be better for minimizing roughness effects while IS4-IS6 may provide more vegetation information. Data takes must be scheduled and are limited to approved investigations. Coverage of the SMEX05/POLEX sites concurrent with ground data collection will be requested. Potential IS2 data sets ordered are listed in Table 7. There are a number of other coverages available.

Table 7. Envisat ASAR AP Data Ordered for SMEX05/POLEX				
Month	Day	Hour (Local)	Minutes	IS Mode
5	1	16	33	1
5	4	16	27	3
5	17	16	24	4
5	20	16	30	2
5	30	16	15	6
6	5	16	27	3
6	8	16	32	1
6	21	16	24	4
6	24	16	30	2
7	4	16	15	6
7	10	16	27	3
7	13	16	32	1
7	29	16	30	2

Another instrument on Envisat that may be of value in SMEX05/POLEX is the MEdium Resolution Imaging Spectrometer Instrument (MERIS). This is a 68.5^{o} field-of-view pushbroom imaging spectrometer that measures the solar radiation reflected by the Earth, at a ground spatial resolution of 300 m, in 15 spectral bands (412.5, 442.5, 490, 510, 560, 620, 665, 681.25, 705, 753.75, 760, 775, 865, 890, and 900 nm), programmable in width and position, in the visible and near infra-red. The instrument has a very wide swath, which results in frequent coverage. MERIS allows global coverage of the Earth in 3 days. MERIS data cannot be obtained at the same time as ASAR image products.

2.5 Terra Sensors

The NASA Terra spacecraft (http://terra.nasa.gov/About/) includes several instruments of value to the soil moisture investigations proposed here. Of particular interest are the Moderate-resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

MODIS is on both the Terra and Aqua satellites (http://modis.gsfc.nasa.gov). The Terra satellite has a descending orbit that crosses the equator about 10:30 AM local time and the Aqua satellite has an ascending equatorial crossing time of 1:30 PM local time. 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 8.

Most of the imagery from MODIS is provided by the NASA GSFC DAAC as data products. Surface reflectance for bands 1-7 are provided as product MOD 09, which has: (1) an atmospheric transmittance correction; (2) a view angle correction for BRDF; and (3) a cloud mask. The data are not corrected for topography.

Table 8. 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_2O	5	1230-1250 nm	500 m
Vegetation H_2O	6	1628-1652 nm	500 m
	7	2105-2155 nm	500 m
Ocean Color	8-16	405-877 nm	1000 m
Atmospheric H_2O	17-19	890-965 nm	1000 m
Thermal	20-36	3.660-14.385 :m	1000 m

Other MODIS data products of interest are land cover type (MOD 12), vegetation indices (MOD 13), leaf area index (MOD 15), evapotranspiration (MOD 16), net primary production (MOD 17), and land surface temperature (MOD 11), which are composited to produce a cloud-free image at 1000 m pixel resolution every 10 days.

ASTER provides high resolution visible (VIR, short wave infrared (SWIR), and thermal infrared (TIR) data on request (see Table 9). Coverage is only obtained on request and these are prioritized. In general, the data coverage occurs on the same day as Landsat 7 for a 60 km swath.

MODIS (Terra) and ASTER coverage dates during SMEX05 are shown in Table 10.

Table 9. Characteristics of the ASTER Sensor Systems			
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	

Table 10. SMEX05 Terra MODIS and ASTER Coverage Dates						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
June 12 Terra	13 SMEX05 start	14 Terra	15	16 Terra	17	18 Terra
19 Terra	20	21 Terra	22	23 Terra ASTER	24	25 Terra
26	27	28 Terra	29	30 Terra	July 1	2 Terra
3	4 Terra	5 Terra	6	7 Terra	8	9 Terra ASTER

2.6 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, following a problem, Landsat 7 is now providing modified products. An instrument malfunction occurred onboard Landsat 7 on May 31, 2003. The problem was caused by failure of the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite. The problem is permanent and results in an up to 25 % data loss per scene. The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) is still capable of acquiring useful image data with the SLC turned off, particularly within the central portion of any given scene (about 22 km). These data are still acquired and are referred to as "SLC-off" mode. SLC Enhanced products are also now available that use interpolation schemes to fill missing data gaps. These can be based on pre-loss of SLC scenes or other dates.

The Iowa site is located on row 31 of both path 26 and 27. For path 27 the northern portion is not well covered, however, the Walnut Creek area is included. It may be necessary to acquire row 30 for complete coverage if these dates are important. Falling in the overlap of the two paths results in relatively frequent coverage. Coverage dates for Landsat 5 and 7 are listed in Table 11. Figure 4 illustrates the scene coverage.

Table 11. Landsat TM Coverage for SMEX05/POLEX

Landsat 5		Landsat 7	
Date	Path	Date	Path
May 30	26	May 29	27
June 6	27	June 7	26
June 15	26	June 14	27
June 22	27	June 23	26
July 1	26	June 30	27
July 8	27	July 9	26
July 17	26	July 16	27
July 24	27	July 25	26
August 2	26	August 1	27
August 9	27	August 10	26
August 18	26	August 17	27
August 25	27	August 26	26

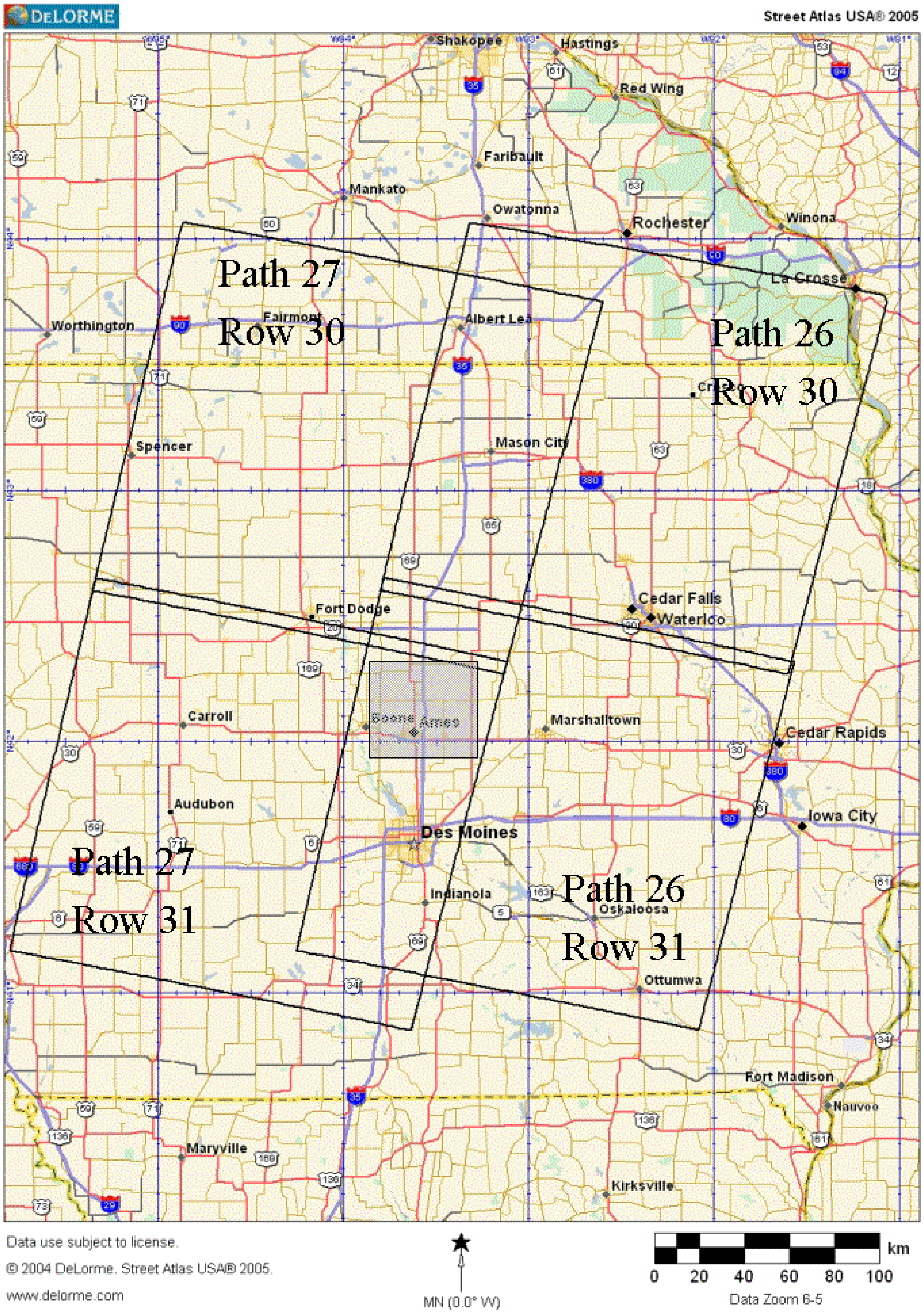


Figure 4. SMEX05/POLEX Landsat TM coverage areas.

2.7 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. Quarter scenes (or quads, 370 km by 370 km) have been ordered for SMEX05, which are within 55 ° zenith angle of the study area center point, to provide the potential for weekly coverage. Characteristics of AWiFS are presented in Table 12.

Table 12 Characteristics of the AWiFS system

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

3 AIRCRAFT REMOTE SENSING CAMPAIGN

The aircraft campaign consists of several sets of flightlines designed to address the multiple objectives of SMEX05/POLEX. The primary instrument involved will be the Airborne Polarimetric Microwave Imaging Radiometer (APMIR).

APMIR was designed and built by the Naval Research Laboratory as a tool for calibration and validation (cal/val) of the Coriolis WindSat and Defense Meteorological Satellite Program SSMIS satellite microwave radiometer sensors. Additional goals in developing APMIR were to provide data for improving retrieval algorithms and to serve as a cal/val tool for the NPOESS CMIS instrument.

APMIR has multiple frequencies and polarizations to match the relevant satellite channels. (Table 13). The 37.0, 19.35 or 18.7, and 10.7 radiometers are fully polarimetric by way of polarization combining, while the other channels measure vertical and horizontal polarizations.

APMIR can be operated in a non-scanning or conically-scanning mode. Footprint and swath characteristics for high and low altitude operations are listed in Table 13 for each frequency. These are similar to those of the Polarimetric Scanning Radiometer (PSR) employed in the previous SMEX. At altitudes below approximately 3000 m the scanning will not be contiguous. For low level flights a fixed beam position will be used. The position can be adjusted for either forward or backward looking in flight. This will allow for consistent azimuth direction.

Table 13. APMIR Frequencies and Coverage (based on a 53 degree incidence angle)

Channel (GHz)	Beam width (Deg)	Altitude = 7.6 km		Altitude = 0.9 km
		Footprint (km)	Swath (km)	Footprint (km)
6.6, 6.8, 7.2	9.4	2.1 x 3.5	20	0.24 x 0.42
10.7	5.9	1.3 x 2.2	20	0.15 x 0.27
18.7 / 19.35	6.8	1.5 x 2.5	20	0.18 x 0.30
22.235 / 23.8	5.3	1.2 x 1.9	20	0.15 x 0.24
37	6	1.3 x 2.2	20	0.15 x 0.27

APMIR will be installed on an NRL P-3 aircraft based at Naval Air Station Patuxent River in Maryland. NRL P-3 tailnumber 674 will be used with APMIR for the first time. Deployment dates are expected to be June 13 to July 5. The aircraft will be deployed to Des Moines International Airport for SMEX05/POLEX. The primary mission of the P-3 is to collect low altitude data over intensively sampled fields with the APMIR instrument. Other very important objectives involve mapping a larger region at high altitude for scaling studies and risk mitigation for future missions. Figure 5 shows APMIR mapping results from a previous flight.

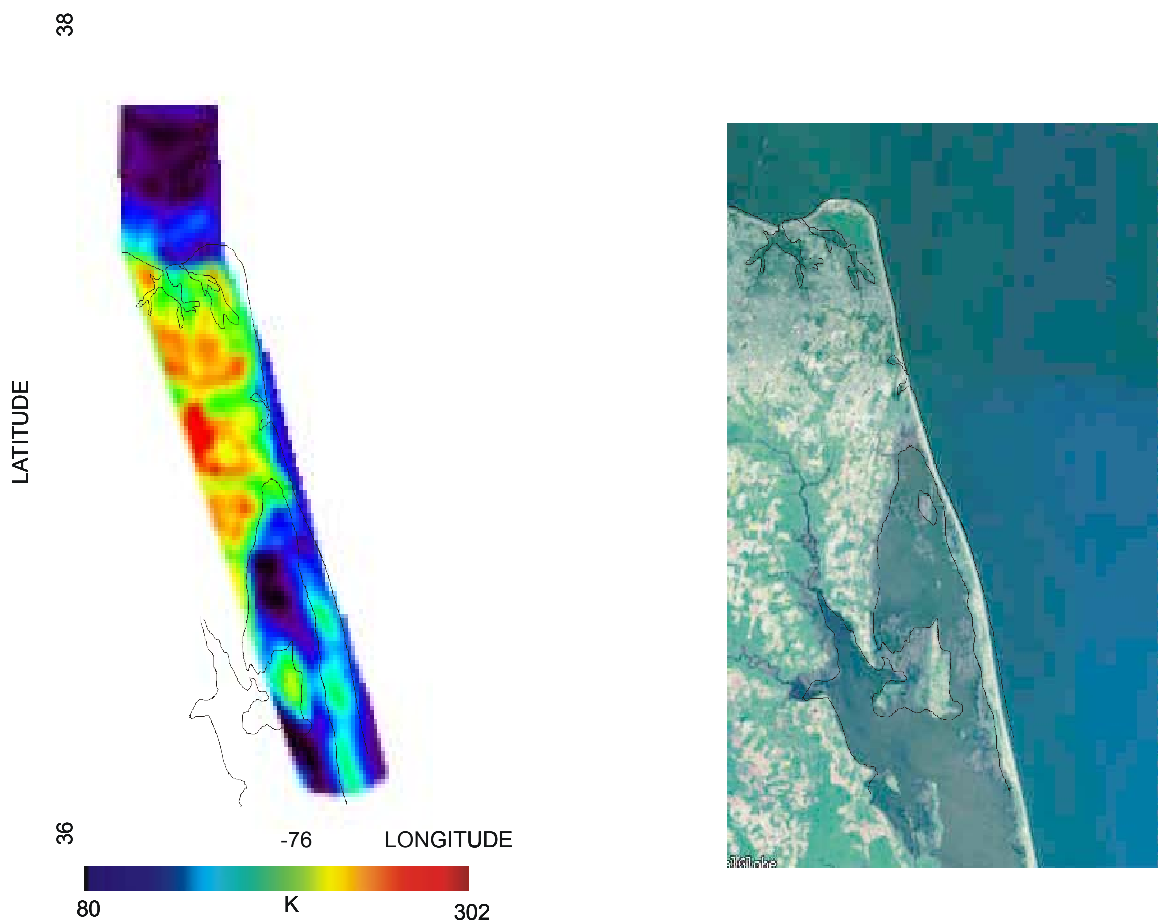


Figure 5. APMIR 6 GHz horizontal polarization data collected over the east coast of Virginia

As mentioned, low altitude coverage is essential. We are assuming this will be about 1000 m, however, this may be decreased pending specific conditions at the site. APMIR was not designed to fly at low altitudes, and thermal stability may be an issue. During check flights on 674 currently planned for May, low altitude performance will be evaluated. If problems develop, the priority of data sets will be reconsidered. At this point the low altitude lines and low altitude azimuthal patterns are the highest priority. In this situation some compromise on a higher altitude will be necessary, as well as the mapping extent.

Coverage will include flights at the same nominal morning overpass time of WindSat (as well as Hydros). Based upon a local average overpass time of 0736, a 0600 takeoff will be requested with as much coverage as possible between approximately 0630 and 0830. Local sunrise is at approximately 0545. Daily mission duration will be limited to three to four hours per day.

It is anticipated that there may be as many as four mission profiles. These are described in the following section.

Low altitude mapping

This is one of the primary missions. It will focus on the Walnut Creek watershed area just south of Ames, IA. A total of eight different lines will be flown; seven of these are east-west oriented flightlines and designed to provide nearly contiguous coverage of the watershed area. The nominal length of these lines will be 45 km. Lines will be flown east-west with alternating headings, although the instrument will be swung 180 degrees in azimuth (with respect to the aircraft) so as to always point in the same compass direction. One of these lines, most likely A, may be flown in looking in both directions. The two passes over this line should be sequential in order to separate directional effects from temporal effects. Previous experience with aircraft instruments and work in this region indicated that measurement differences can occur for different pointing directions. These can be related to peculiarities of the installation, RFI, or sun angle. Flying each line in both directions would be ideal, however, it would also be costly. Therefore, a decision was made to alternate directions and to use a single pointing direction. Flightlines are listed in Table 14 and shown in Figure 6.

Table 14. SMEX05/POLEX Low Altitude Mapping Flightlines

Line No.	Altitude (km)	Length (km)	Start Latitude (Deg.)	Start Longitude (Deg)	Stop Latitude (Deg.)	Stop Longitude (Deg)
A	1	45	41.9572	-93.48	41.9572	-94.03
B	1	45	41.9684	-94.03	41.9684	-93.48
C	1	45	41.9612	-93.48	41.9612	-94.03
D	1	45	41.9542	-94.03	41.9542	-93.48
E	1	45	41.9466	-93.48	41.9466	-94.03
F	1	45	41.9396	-94.03	41.9396	-93.48
G	1	45	41.9320	-93.48	41.9320	-94.03
H	1	19	41.9942	-93.7885	42.0047	-94.0147
E*	3	45	41.9466	-93.48	41.9466	-94.03

One of the least studied land cover types is forest. The logistics of sampling and obtaining a range of conditions are both contributing problems. In order to add in more forest sites in SMEX05/POLEX we have extended all mapping flightless further west than those used in SMEX02 and we have added an additional flightline (H).

At an aircraft speed of 200 knots (370 km/hr) with turn time, coverage of a line would require approximately 10 min. As an example, eight lines with double coverage of one would require approximately 2 hours on site. This is only an estimate and further review of the flight plan will likely result in improvement.

The nominal field size that will be used for sampling is 800 m by 800 m, although there is variability in the exact dimensions. In general the region has a uniform road network spaced 1.6 km apart that partially defines the field boundaries. For each ground site it is desired that the aircraft observations fall entirely within the field boundaries. Using information provided in Table 13, at an altitude of 900 m the across track dimension of the C band channel of APMIR will be 240 m. Therefore, if a flightline is centered on a field, this allows for a 280 m cross track deviation from the specified flightline while still retaining within field coverage. Note that errors in following the flightline or failing to account for beam pointing due to aircraft roll or yaw cannot be corrected in post processing. The along track footprint for the same configuration is 420 m. This means for an 800 m field that until the beam center is 210 m into the field it will include coverage of the previous field. The same issue occurs at the end of the field. Therefore, only when the beam center is between 210 m and 590 m can the data be considered within the field observations. At an aircraft speed of 200 knots (100 m/s) this results in about 3.8 seconds of integration time, which should be adequate for estimating the field average brightness temperature.

Low altitude mapping is intended to provide the critical data base for soil moisture algorithm and polarization effects studies. Efforts will be made to collect as many data sets as possible during SMEX05/POLEX. To complement the lines described above, Line E will be repeated at a higher altitude with APMIR operating in scanning mode.

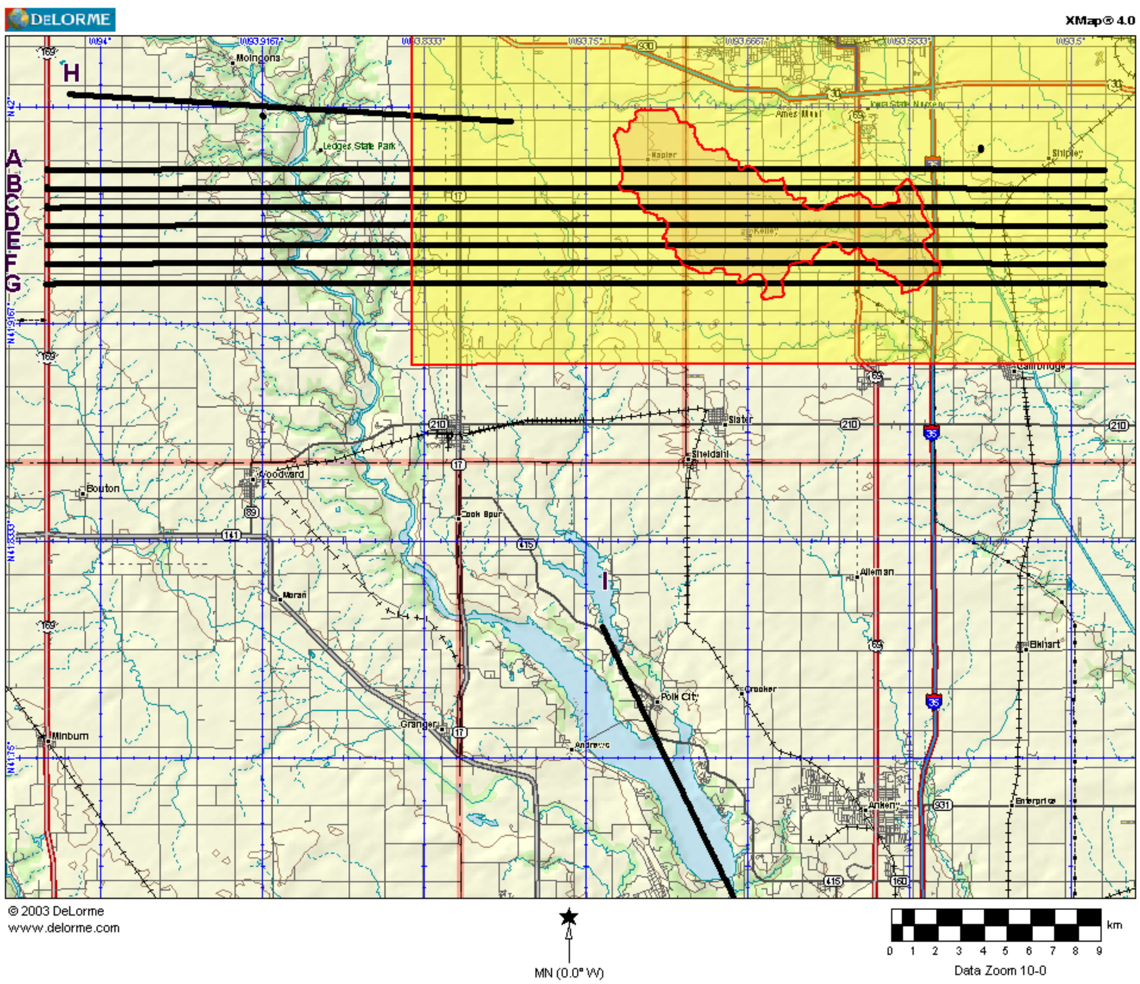


Figure 6. SMEX05/POLEX low altitude mapping flightiness over the Walnut Creek watershed area. Black lines are the low altitude microwave flightlines.

Low altitude temporal

One of the science questions that will be addressed in SMEX05/POLEX concerns the diurnal nature of microwave brightness temperature and its relationship to the characteristics of the atmosphere, vegetation, and soil. Linking the morning and afternoon observations of WindSat and those of AMSR-E requires the study of the changes that occur over the day. Of particular concern, especially for WindSat, is the presence of dew and low-level atmospheric moisture on the brightness temperature. This issue will carry over to CMIS, SMOS and Hydros. Very little research has been conducted to address these issues. One way to approach this is using multi-temporal coverage of one or more flightlines with supporting ground sampling that characterizes the physical variables. As in any study, a range of conditions would be extremely valuable, i.e., wet soil with and without dew and dry soil with and without dew. Coverage every half hour from 0600 LT until 1000 LT would be ideal. For multiple satellite observations, coverage every two hours from 0600 LT until 1800 LT would be one approach. It is anticipated that the temporal studies might be conducted on two to four dates.

One or more of the low altitude flightlines in Table 14 will be used. A constant pointing direction is required. The choice of flightline would be based upon maximizing the ground sampling and instrumentation, especially the coverage of the flux tower sites. It is anticipated that these flights will be scheduled on the same day as the regional/high altitude mapping.

High altitude mapping

These flights provide the linkage to WindSat and AMSR. It is desired to cover at least a 50 by 50 km domain that includes the low altitude study area. Coverage of such a large domain will require multiple flightlines. The instrument will operate in scanning mode for these flights. In order to produce a useful map product a temporal correction of the data is necessary. This requires flightline overlap. In previous experiments this coverage has been achieved with four north-south oriented flightlines at a flight altitude of 7.6 km. If flying at this altitude is an issue, tradeoffs in overlap, spatial domain, and contiguous coverage will have to be made. At the nominal aircraft speed, each flightline (with extension and turns) would require 20 minutes, or a total of about 1.33 hours. These flights would only take place on days with concurrent WindSat or AMSR coverage. Table 15 and Figure 7 are the high altitude mapping lines proposed for SMEX05/POLEX. The flightline direction is not critical, however, they should be flown sequentially to facilitate temporal correction. The time of day for these missions (as well as the choice of days) will depend upon the status of WindSat during SMEX05. If it is not operating, the missions will be planned based upon the AMSR-E schedule.

Table 15. SMEX05/POLEX High Altitude Mapping Flightlines

Line No.	Altitude AGL (km)	Length (km)	Start Latitude (Deg.)	Start Longitude (Deg)	Stop Latitude (Deg.)	Stop Longitude (Deg)
J	7.6	83	41.76	-93.7729	42.50	-93.7729
K	7.6	83	42.50	-93.6398	41.76	-93.6398
L	7.6	83	41.76	-93.5073	42.50	-93.5073
M	7.6	83	42.50	-93.3755	41.76	-93.3755

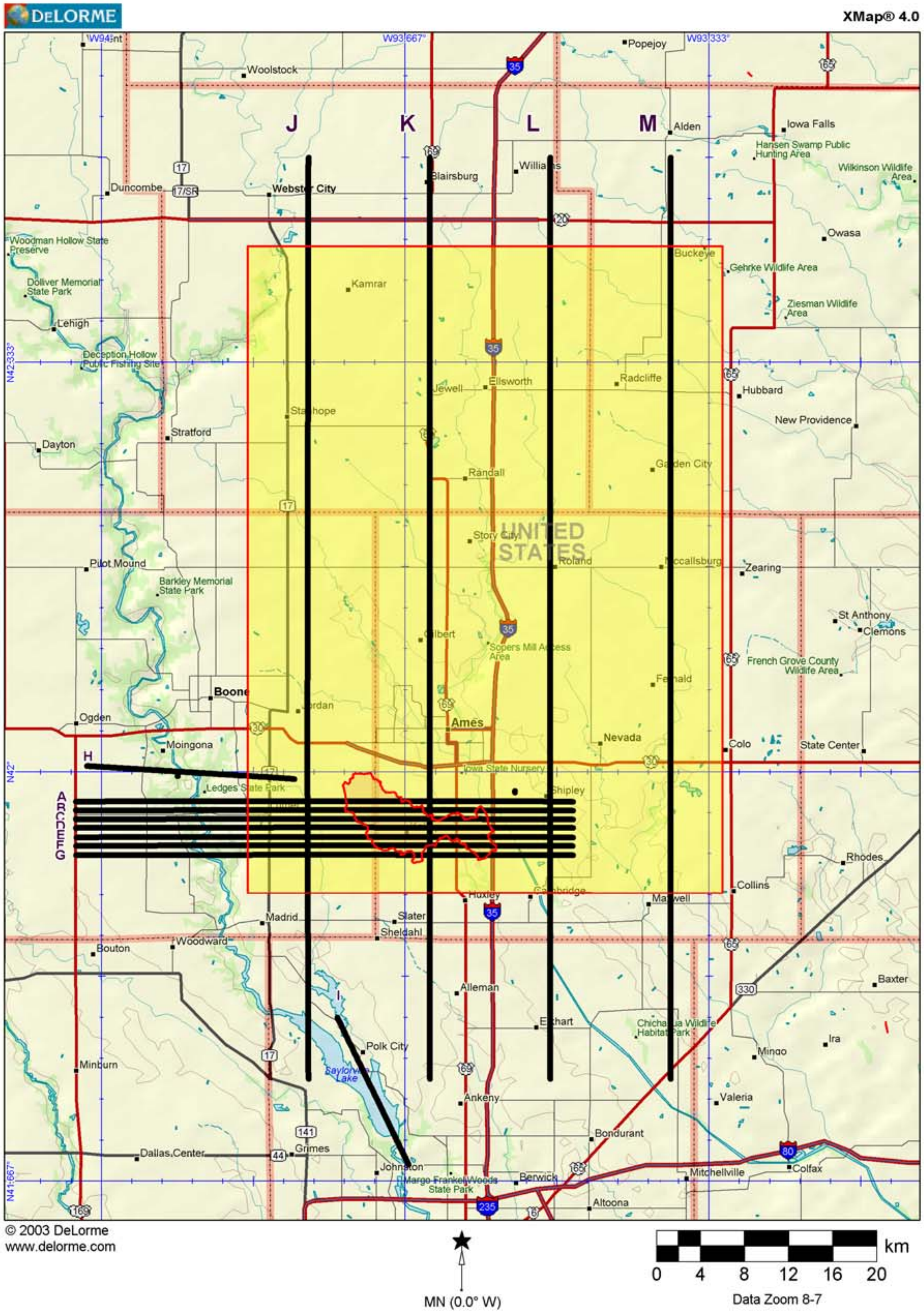


Figure 7. SMEX05/POLEX high altitude mapping flightlines (vertically-oriented).

Water Calibration

Saylorville Lake on the west side of Des Moines can be used as a water calibration site. This same line was flown in SMEX02. The lake is over 10 km long. The lower portion, which is suggested as the primary target, is 5 km long and 2 km wide. Arrangements will be made to obtain daily water temperatures. Table 16 includes the coordinates of the water calibration line. The water calibration will be flown on every flight date, if possible.

Table 16. SMEX05/POLEX Water Calibration Flightlines

Line No.	Altitude (km)	Length (km)	Start Latitude (Deg.)	Start Longitude (Deg.)	Stop Latitude (Deg.)	Stop Longitude (Deg.)
I	0.5	15	41.6800	-93.6600	41.8000	-93.7413

Low altitude azimuthal

This is another primary mission. It will examine the azimuthal dependence of brightness temperature for a number of fields by flying over a single point from eight or more different directions at low altitude in an asterisk pattern. Windsat data analysis indicates that such an azimuthal dependence is significant and related to measurement geometries, and thus must be quantified and separated from effects resulting from geophysical variations. Figure 8 illustrates the general design of this mission. At an aircraft altitude of 1000 ft and speed of 210 knots, each flightline would require about 12 minutes including turn and alignment adjustment. As an example, an eight-line pattern would require about one and a half hours on site. This mission would be integrated with low altitude mapping or temporal mapping and would not be dependent on the time of day. The site would be in the domain of the low altitude mapping. A few sites have been pre-selected based on their size, homogeneity and vegetation type. But such selections will be updated according to most recent in-situ information and near real-time results from the low altitude mapping.

RFI Identification, mitigation and validation

RFI identification and mitigation are necessary steps in preserving the integrity of the natural radiation and their applications in land remote sensing. Several techniques have been developed to detect and correct RFI signals using spectral difference or sub-band techniques (Li et al., 2003; Bindlish et al. 2005, Jackson et al. 2005). Sub-band technique has also been selected by NPOESS for CMIS RFI mitigation. However these RFI techniques have not yet been validated using any ground truth data in terms RFI characteristics. We plan to construct an RF emitter database for the experiment region prior to the science flights. With the sub-band design of APMIR, we can then examine the sensor capability in terms of RFI detection/mitigation and the benefit of RFI techniques in terms of soil moisture retrieval performance, which can be carried out in two tasks:

(1) The RFI signals extracted from APMIR can be compared with RFI source characteristics in terms of position, intensity, polarization and spatial pattern.

(2) The RFI suppressed C-band brightness temperatures can be examined using multichannel data analysis and in-situ soil moisture data to quantify the benefit of these RFI techniques.

In addition to validation of RFI techniques, we will also conduct a C-band RFI survey in and around Iowa region during the science and transit flights. RFI statistics collected by SMEX05/POLEX will be used to address CMIS design issues.

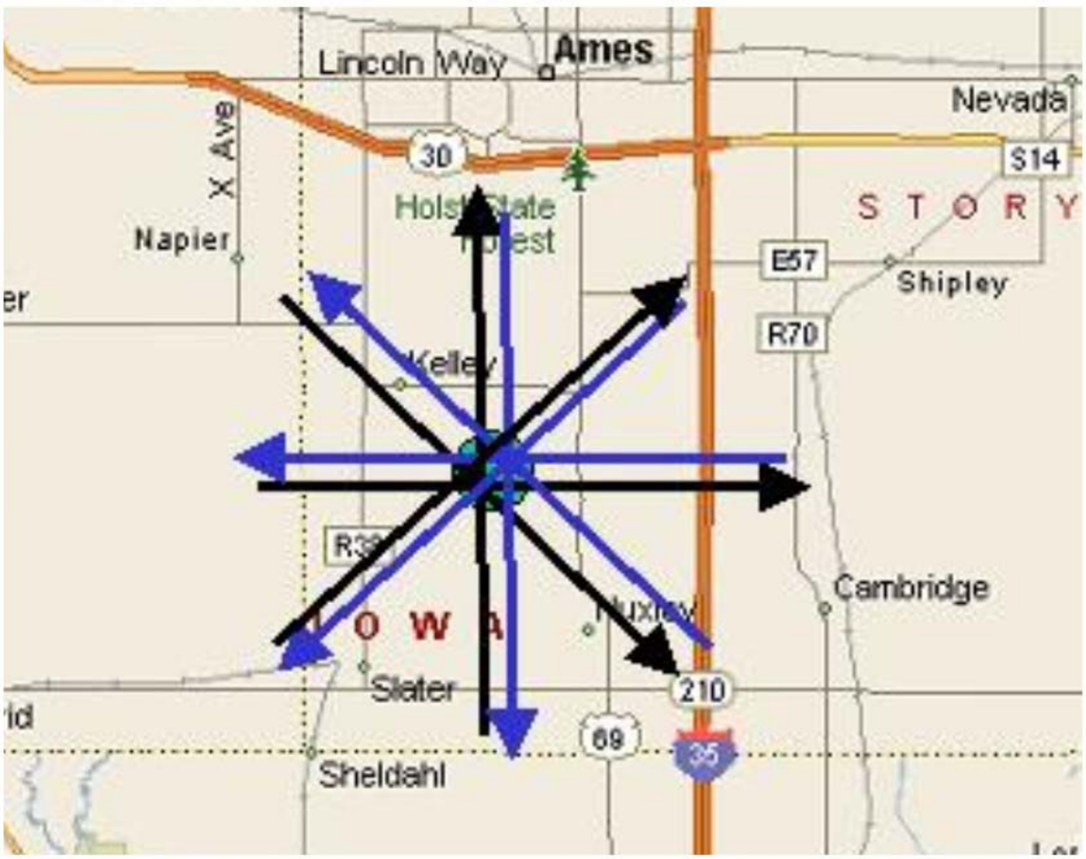


Figure 8. Flightlines to study azimuthal effects.

Satellite and Aircraft Schedules

Table 17 below summarizes the satellite overpasses during SMEX05/POLEX. This information and aircraft logistics and priorities were then used to generate a tentative aircraft flight schedule (Table 18). This should only be considered an example. Weather conditions and aircraft operation will have significant impacts on this schedule.

Table 17. SMEX05/POLEX Summary of Satellite Coverage (Daytime Passes of W=Windsat, A=AMSR, L5=Landsat 5).

June 12 A	13 W	14 W A	15 W A L5	16	17 A	18
19 W A	20 W	21 W A ASAR	22 L5	23	24 A ASAR	25 W
26 W A	27	28 A	29	30 W A	July 1 W A L5	2 W
3 A	4 ASAR	5 A	6 W	7 W A	8 W L5	9

Table 18. SMEX05/POLEX Example of Aircraft Schedule (LM=Low altitude mapping, LT=Low altitude temporal, HM=High altitude mapping, A=Asterisk).

June 12	13 P-3 Transit	14 **Briefings**	15 LM	16 LM, A	17 LT, HM	18
19 LM, A	20	21 LT, HM	22	23	24 LM, A	25 LT, HM
26 LM, A	27 **BBQ**	28 LT, HM	29	30 LM. A	July 1 LM, A	2
3 LT, HM	4	5 P-3 Transit	6	7	8	9

4 FIELD CAMPAIGN DESIGN

4.1 General Site Description

In order to satisfy the requirements of the multiple objectives of SMEX05 it was necessary to include a test site that would provide a data set for the analysis of polarimetric observations for a range of vegetation structures and water contents. In addition, a relatively short planning period could be compensated for by using a previously established study site. As a result, a study site in Iowa was selected. Within this region is a small watershed, Walnut Creek just south of Ames, IA This watershed has been the focus of research by the USDA ARS National Soil Tilth Lab (NSTL) http://www.nstl.gov/. It was also the region used in SMEX02 (Kustas et al. 2003).

Nearly 95% of the region and watershed is used for row crop agriculture. Corn and soybean are grown on approximately 80% of the row crop acreage, with greater than 50% in corn, 40-45% in soybean and the remaining 5-10% in forage and grains (Doriaswamy et al. 2004).

The watershed is representative of the Des Moines Lobe, which covers approximately 1/4 of the state of Iowa. The climate is humid; with an average annual rainfall of 835 mm. SMEX05 is currently planned from mid June to early July. At the outset corn will be in early stages of growth and most soybean fields will be essentially bare soil. The expected vegetation water contents for corn and soybeans over the growing season are shown in Figure 9 (Jackson et al. 2004).

The area around central Iowa is considered the pothole region of Iowa because of the undulating terrain. This area on the Des Moines lobe represents the youngest of soils in the United States. Two features standout in this terrain. First, the lack of a surface stream channel except for the areas near streams and rivers. Second, the large variation of soil types within a field. Surface organic matter contents often range from 1-2 % to over 8% in a transect from the pothole areas to the eroded knolls within the same field. This is also coupled with a variation in rooting depth. These features create a potential condition in the spring and extremely wet summers of a soil surface covered with random water-filled potholes. Typically, however, these potholes are dry by early spring due to subsurface drainage and farmers are able to plant without any problems. This variation, however, presents a challenge when field sampling to ensure that the surface conditions within the field are adequately sampled. Additional regional information can be found at the following sites http://mcc.sws.uiuc.edu/Introduction/micis.html and http://www.exnet.iastate.edu/Information/weather.html

The heaviest precipitation months are May and June (about 1/3 of the annual total) Rainfall events in the spring and summer are often thunderstorms, providing brief and intense showers. The topography is characterized by low relief and poor surface drainage. As described above, “prairie potholes” are a common feature of the region. The soils are loams and silty clay loams, with generally low permeability. Anthropogenic forces have significantly modified the hydrologic character of the basin. Over the past 100 years most of the potholes have been drained, much of the land cultivated and many of the agricultural fields have been tile drained to assist in subsurface drainage (tile flow). Conventional tillage is most widely used, however no tillage and ridge tillage have been recently introduced.

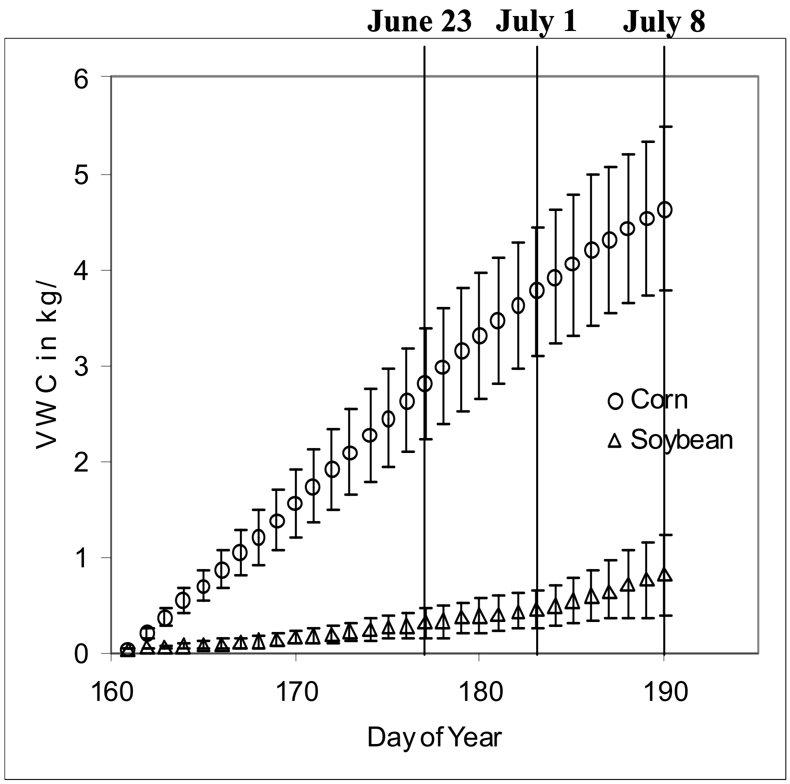


Figure 9. Vegetation water content of corn and soybeans over the growing season near Ames, IA from SMEX02 (Jackson et al. 2004).

Within the Walnut Creek watershed area there are 20 recording rain gauges separated by 1-mile (1.6 km) intervals or sections. Air temperature is also recorded at these sites. There are two meteorological stations located in the watershed measuring air temperature, relative humidity, wind speed and direction, soil temperature and solar radiation. Five stream gauging locations in the watershed designed to isolate water flow and water quality for three sub-watersheds and the entire basin.

Figure 10 shows the regional study area. Figure 10 is a false color Landsat TM image of the regional study area obtained on July 1, 2002. Figure 11 is a sequence of higher resolution Landsat TM images of the watershed area from SMEX02. Nearly all fields rotate between corn and soybeans each year. Both row and drilled soybeans planting practices are in use. Figure 12 shows row soybean and corn conditions on June 27th 2000.

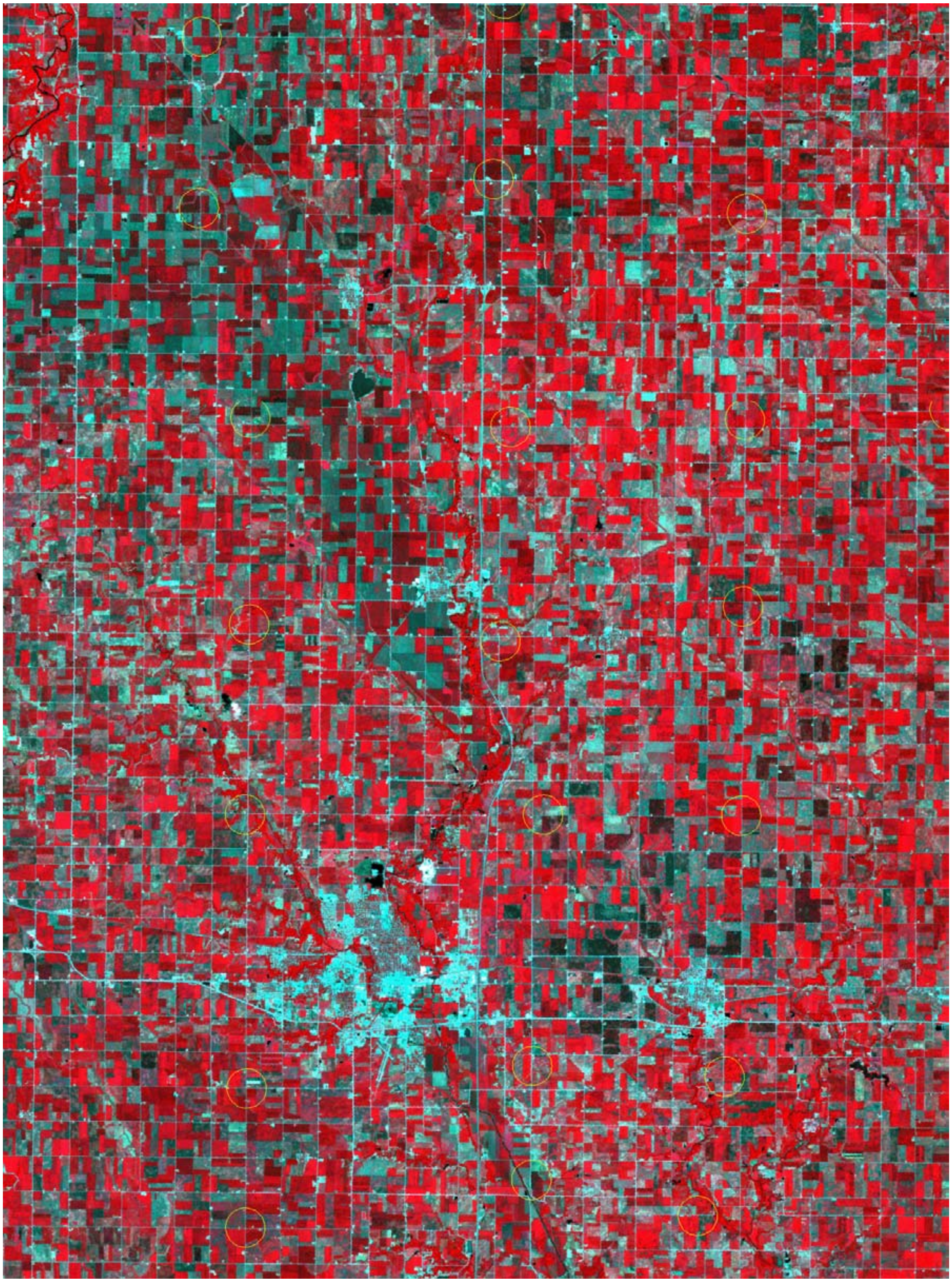


Figure 10. SMEX05 portion of a Landsat 7 July 1, 2002 false color composite.

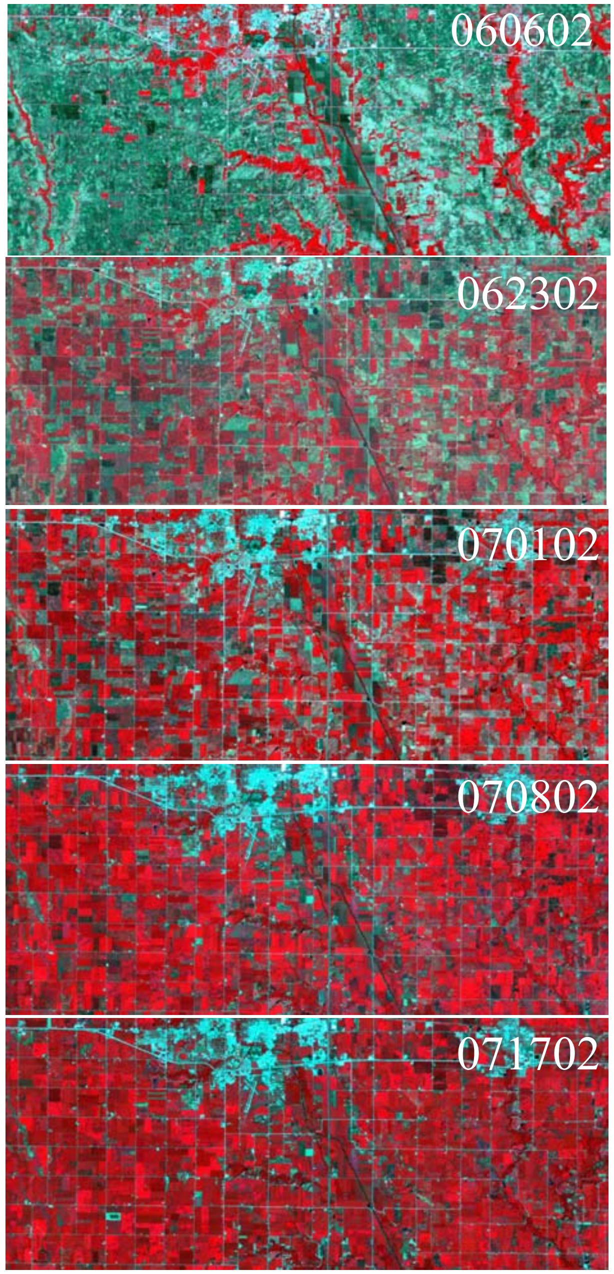


Figure 11. Walnut Creek watershed portion of Landsat images obtained during SMEX02 (false color composite).

a)

b)

Figure 12. Walnut Creek, Iowa a) typical corn canopy and b) typical row soybeans on June 28, 2000.

4.2 Watershed Sites

Sites were identified within the Walnut Creek watershed (code=WC) to satisfy the data requirement of the APMIR. To the extent possible the sites selected had the following characteristics:

- At least 800 m in the NS direction
- At least 800 m in the EW direction
- Centered on one of the low altitude flight lines
- Single cover condition
- Single management unit
- Balance of corn, soybeans and forest
- Balance of row direction
- Dominant soil types
- Permission to use

Table 19 summarizes these sites. Crop type and row direction will be provided just prior to the field campaign.

Table 19. Walnut Creek Watershed Sites					
Site	Special Observations	Crop	Row Direction	Reference Coordinates	
				Latitude (Deg.)	Longitude (Deg.)
WC01		Corn	E-W	41.968976	-93.761498
WC04	Flux Tower	Corn	E-W	41.975860	-93.741785
WC05		Corn	N-S	41.961452	-93.741376
WC06		SB	N-S	41.932645	-93.753104
WC10	Flux Tower	Corn	N-S	41.976182	-93.690128
WC11	Flux Tower	SB	N-S	41.973094	-93.694440
WC12		Corn	N-S	41.960987	-93.685741
WC13		Corn	E-W/N-S	41.953950	-93.687370
WC15	Flux Tower	SB	E-W	41.939482	-93.667054
WC18		SB	N-S	41.946855	-93.653498
WC19		Corn	E-W	41.932496	-93.443050
WC21		Corn	E-W	41.968307	-93.634528
WC22		Corn	N-S	41.946816	-93.628282
WC33		SB	E-W	41.971737	-93.649407
WC34	Flux Tower	Grass	-	41.965333	-93.583933
WC35	Flux Tower	Corn	E-W	41.932659	-93.923780
WC36		Corn	E-W	41.932486	-93.911595
WC37		Timber	-	41.975729	-93.910280
WC38		SB	E-W	41.975974	-93.817827
WC39		Corn	N-S	41.975917	-93.732974
WC40		Corn	E-W	41.968596	-93.663013
WC41		Forest	-	41.962891	-93.881860
WC42		Forest	Check In	41.954482	-93.897671
WC43		Corn	N-S	41.954212	-93.800174
WC44		SB	N-S	41.953889	-93.712572
WC45		Corn	N-S	41.946957	-93.926641
WC46		Timber	-	41.932508	-93.850080
WC47		Corn	N-S	41.932704	-93.744059
WC48		SB	E-W	41.932032	-93.693150
WC49		SB	E-W	41.931906	-93.683982
WC50		Timber	-	42.000582	-93.933335
WC51		Timber	-	41.997248	-93.876418

4.3 Regional Sites

Regional sites were selected to provide representative coverage over an area large enough to include several WindSat/AMSR sized footprints. The Tower sites described later will also be used for regional studies. In SMEX02 a large number of sites were sampled using conventional methods. For SMEX05 we used this information and temporal stability analysis as described in Cosh et al. (2004) to reduce this to a representative subset. In addition, in order to provide coverage of all satellite passes and an extended time domain we decided to use insitu instrumentation supported by limited conventional sampling. Table 20 summarizes the tentative locations.

Table 20. Iowa Regional Sites

Site	Reference Coordinates	
	Latitude (Deg.)	Longitude (Deg.)
IA06	42.2555	-93.6991
IA16	42.4288	-93.5597
IA29	42.3410	-93.4243
IA32	42.0929	-93.4258
IA40	42.4418	-93.2930
WC31	41.9681	-93.4099

5 GROUND BASED OBSERVATIONS

5.1 Tower-based Flux Measurements

Through this project and collaborative relationships we will deploy a number of eddy covariance systems (total of 6) through the study area, with each system consisting primarily of Campbell Scientific CSAT3 3-D sonic anemometer and KH20 krypton hygrometer, measuring momentum flux and sensible and latent heat fluxes between the land and the atmosphere across the watershed. Figure 13 illustrates a typical tower installation. These observations will be representative at the "patch" or local scale (i.e., length scales ~ 10^2 m). These systems will also provide a picture of the complete energy balance by including net radiation, soil heat flux, and radiometric surface temperature measurements. In addition, there will be several systems, which will also be measuring net carbon exchange by eddy covariance with the 3D sonic and LiCor LI-7500 open path CO_2/H_20 sensors. This will permit a very detailed assessment of water-energy-carbon fluxes and controls as a function of crop type and amount of cover and tillage practices. For selected sites with a significant fractional bare soil component, there are also plans to make measurements of soil respiration using LiCor LI-6200 sensors. The locations of the flux measurement sites include two long term sites operated by NSTL (WC10 and WC11). The remaining sites were distributed over the watershed area based upon the extent of the watershed and representative crop conditions. The sites including flux observations are: WC04, WC10, WC11, WC15, WC34, and WC35.

Figure 13. Flux tower in WC16 during SMEX02.

5.2 Sun Photometer

The NASA Aeronet, which is led by Brent Holben, will provide SMEX05 with an eight channel (Cimel) sun photometer. The sun photometer is designed to view the sun and sky at preprogrammed intervals for the retrieval of aerosol optical thickness and water vapor amounts, particle size distribution, aerosol scattering, phase function, and single scattering albedo. It measures the intensity of sunlight arriving directly from the Sun. Although some Sun photometers respond to a wide range of colors or wavelengths of sunlight, most include special filters that admit only a very narrow band of wavelengths. These measurements are used to radiometrically correct satellite imagery in the visible and infrared bands. By radiometrically correcting these images it is then possible to quantitatively extract physical parameters and compare multiple dates. The instrument will be installed at a central location to provide data appropriate for the intensive site and for the regional area studies.

5.3 Vegetation and Land Cover

Vegetation biomass and soil moisture sampling will be performed for all watershed sites. The primary measurements during SMEX05 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). Corn and soybean sites in the Walnut Creek Watershed will be sampled during week 1 (June 13-17) and resampled during week 3 (June 27-July 1) of SMEX05. The Vegetation Sampling Team will also make other important measurements at the corn and soybean 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.

Sampling will take place in two segments each day. In the morning, groups of two 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 each team. Some of the Vegetation Sampling Team will need to make leaf reflectance measurements in the afternoon. Each site will have 5 plots about 60 m apart in the field; the 60 m accounts for any spatial correlation among plots.

During week 2 (June 20-24) of SMEX05, foliage and stem water contents will be determined for woodland sites. The site selection is yet to be determined, primarily because the steep gullies and tall trees (> 12 m). Several plots of 25 m by 25 m will be laid out with measuring tapes at each site. Each tree over 1.3 m tall will be counted (density), species recorded, height (inclinometer) and diameter at 1.3 m measured. LAI will be measured using hemispherical photographs. Species, height, and diameter are used to calculate the total dry biomass of the plot using regression equations from the USDA Forest Service.

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 are will be performed that includes the crop row direction.

5.4 Soil Moisture

Ground based soil moisture measurements will be made for a variety of investigations. The three primary objectives are:

- Provide field (~800 m) average surface volumetric soil moisture for the development and validation of microwave remote sensing soil moisture retrieval algorithms at a range of frequencies primarily from aircraft platforms. This will be called Watershed sampling.
- Provide footprint scale (~ 50 km) average surface volumetric soil moisture for the development and validation of satellite microwave remote sensing soil moisture retrieval algorithms at a range of frequencies. This will be called Regional sampling.
- Provide calibrated continuous soil moisture for water and energy balance investigations. This will be called Tower sampling.

5.4.1 Watershed Sampling

The goal of soil moisture sampling in the Watershed sites is to provide a reliable estimate of the mean and variance of the volumetric soil moisture for fields that are approximately 800 m by 800 m. These measurements are used primarily to support the aircraft based microwave investigations, which will be conducted between 0630 and 0830 local time. This determines the time window for the Watershed site sampling.

The primary measurement made will be the 0-6 cm dielectric constant (voltage) at fourteen locations in each field using the Theta Probe (TP). 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 studies (Cosh et al. 2005), site specific calibrations are available. In addition, at four standard locations within each field the 0-1 and 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. 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 to1V DC for a range of soil dielectric constant, ε, between 1 and 32, which corresponds to approximately 0.5 m^3 m^{-3} volumetric soil moisture content for mineral soils. More details on the probe are provided in the sampling protocol section of the plan.

Unlike previous SMEX, the Watershed 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.

5.4.2 Regional Sampling

The goal of soil moisture sampling over the Iowa region is to provide a reliable estimate of the VSM mean within a single satellite passive microwave footprint (~50 km) at the nominal time of the WindSat and AMSR-E overpasses (possibly four in a day). In order to satisfy this requirement we will be using insitu sensors (Vitel Hydra Probes) with data loggers. These sensors will be installed at a depth of 5 cm and provide the soil moisture and temperature. A single location in each of sites will be sampled every half hour. The locations of these sites will be a subset of the SMEX02 regional sites. The sampling team will download the soil moisture and soil temperature data from the dataloggers. The regional sites will be sampled couple of times every week (on satellite overpass days). Soil moisture samples and soil temperature observations will be made to calibrate the in-situ observations. The tower sampling sites described in the next section will be part of this sampling network.

5.4.3 Tower Sampling

Tower sampling is intended to provide continuous measurements of the surface soil moisture at the locations of the surface flux towers. A single Vitel Hydra Probe capacitance sensor will be installed at a depth of 5 cm. To insure accurate calibration of these devices, the TP and GSM measurements will be made near these locations on each sampling date.

Soil moisture and temperature for the surface layer will be measured using Vitel Type A Hydra Probes. This version is compatible with Campbell CR-10 data loggers, the temperature output voltage never exceeds 2.5 volts.

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

As a soil is wetted, the low dielectric constant component, air, is replaced by water with its much higher dielectric constant. Thus as a soil is wetted, the capacitive response (which depends upon the real dielectric constant) increases steadily. Through the use of appropriate calibration curves, the dielectric constant measurement can be directly related to soil moisture.

The dielectric constant of moist soil has a small, but significant, dependence on soil temperature. The soil temperature measurement that the Hydra probe makes can be used to remove most of the temperature effects.

The Hydra Probe has three main structural components, a multiconductor cable, a probe head, and probe sensing tines. The probes will be installed horizontally in the soil with the center tine at a depth of 5 cm. Additional details on the Hydra Probe are provided in the sampling protocol section of this plan.

The measured raw electrical parameters determined by the HP are the real and imaginary dielectric constants. These two parameters serve to fully characterize the electrical response of the soil (at the frequency of operation, 50 MHz). These are both dimensionless quantities.

Because both the real and imaginary dielectric constants will vary somewhat with temperature, a temperature correction using the measured soil temperature is applied to produce temperature corrected values for the real and imaginary dielectric constant. The temperature correction amounts to calculating what the dielectric constants should be at 25^{o}C.

The dielectric constants are used to calculate soil moisture with conversion equations. The manufacturer provides these, however, through the ground sampling component it should be possible to refine these for each site.

5.5 Soil and Surface Temperature

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.

5.5.1 Watershed Sampling

Temperature sampling will be conducted at the four locations selected for GSM sampling. These will be distributed over the each site. The soil temperatures will be obtained using a temperature probe inserted to depths of 1 cm, 5 cm, and 10 cm depths. The surface temperature will be sampled using handheld infrared thermometers (IRT) at the four locations. At each of these locations surface temperature of exposed and shadow ground and vegetation will be measured. Details about the location of these measurements are provided in the protocol section of the plan.

5.5.2 Regional Sampling

The Vitel Hydra Probe provides soil temperature at 5 cm. In addition to the in-situ observations, soil temperature observations will be made couple of times during the week to calibrate the in-situ sensors. The soil temperatures will be obtained using a temperature probe inserted to depths of 1 cm, 5 cm, and 10 cm depths. The surface temperature will be sampled using handheld infrared thermometers (IRT) at the four locations. At each of these locations surface temperature of exposed and shadow ground and vegetation will be measured. Details about the location of these measurements are provided in the protocol section of the plan.

5.5.3 Tower Sampling

The Vitel Hydra Probe provides soil temperature at 5 cm. An Apogee infrared sensor will be installed on each tower and will provide surface observations. This device provides the measured surface temperature and the sensor housing temperature. This second observation can be used to adjust for diurnal effects. These will be installed at a height of 2 m on the tower at an angle of 30 degrees. More information can be found in the protocols section of the plan.

5.6 Surface Roughness

Each Watershed site will be characterized one time during the time frame. The grid board photography method employed in previous experiments will be used.

5.7 Vegetation Surface Wetness

Vegetation surface wetness, which includes dew condensation, fog, and rainfall present on the surface of a plant, may play a significant role in the attenuation/scattering of the microwave signature of the surface. To investigate this role, a number of observations must be made during the experiment to provide a clear picture of the surface wetness conditions during the aircraft and satellite flights. Combining these observations with meteorological data and other land surface parameters, it is hypothesized that the effect of vegetation surface wetness on microwave emissions can be quantified.

The parameters to be recorded during the morning hours of each day are:

- Plant Height
- Plant Density
- Leaf Count
- Leaf Surface Area
- Leaf Area Index
- Leaf Wetness per Leaf square meter
- Leaf Wetness per square meter
- Dew Onset and Duration (Intensity if feasible)
- Meteorological Data including air Temperature, surface temperature, dew point temperature, and precipitation

Non-destructive sampling of LAI using LiCor LAI-2000 instruments will be conducted in coordination with destructive sampling and leaf wetness collection. Since the experimental period will span the active growing stages for both corn and soybeans, repeated sampling efforts will be made to capture the many stages of plant surface area and LAI.

In addition to physical sampling, several meteorological flux towers and electronic leaf wetness sensors (Campbell Scientific 237-L) will be stationed throughout the watershed to help track indicator variables. Current leaf wetness sensors are limited in their ability to index the degree of wetness, but with more comprehensive meteorological parameters, there is hope of modeling the formation and quantity of dew. The planned locations of these sensors are listed in Table 21.

Table 21. Leaf Wetness Sensor Locations.

Raingage or Field Id	# of Sensors	Long	Lat
WC04	4	-93.7417	41.9758
WC10	4	-93.6901	41.9761
WC11	4	-93.6944	41.9730
WC15	4	-93.6670	41.9394
WC34	4	-93.5839	41.9653
WC35	4	-93.9237	41.9326
WC13	4	-93.6873	41.9539
WC22	4	-93.6282	41.9468
WC43	4	-93.8001	41.9542
WC48	4	-93.6931	41.9320
701	1	-93.6846	41.9643
704	1	-93.6527	41.9650
705	1	-93.6591	41.9368
706	1	-93.6583	41.9505
707	1	-93.6788	41.9505
708	1	-93.6977	41.9505
710	1	-93.7171	41.9644
713	1	-93.7174	41.9940
714	1	-93.6981	41.9677
719	1	-93.5946	41.9577
720	2	-93.6114	41.9633
721	2	-93.5856	41.9356
722	2	-93.5796	41.9628
WC06	2	-93.7531	41.9326
WC43	2	-93.8001	41.9542

6 REGIONAL NETWORKS AND GENERAL SITE CONDITIONS

6.1 USDA Soil Climate Analysis Network (SCAN)

The USDA NRCS has initiated nationwide soil moisture and soil temperature (SMST) analysis network called SCAN. Details and data can be obtained at the following web site http://www.wcc.nrcs.usda.gov/smst/smst.html. Hourly observations are provided to the public on the Internet in real time. Each system provides hourly observations of:

Air temperature
Barometric pressure
Wind speed
Precipitation
Relative humidity
Solar radiation
Soil temperature at 5, 10, 20, 50 and 100 cm
Soil moisture at 5, 10, 20, 50 and 100 cm

A SCAN site was installed near Ames, IA at Latitude: 42.00^o, Longitude: 93.74^o and Elevation: 1073 Feet on 09/23/2001. Figure 14 shows the site conditions at the Ames site.

Figure 14. SCAN site at Story County, IA

6.2 NSTL Meteorological Stations

NSTL operates rain gages, stream gages, and meteorological stations within the Walnut Creek watershed. All are on data loggers, which are downloaded on a weekly basis. The locations of the raingages are shown in Figure 15. Data for the SMEX05/POLEX time period will be provided following the experiment. Other periods of record may be obtained by contacting NSTL.

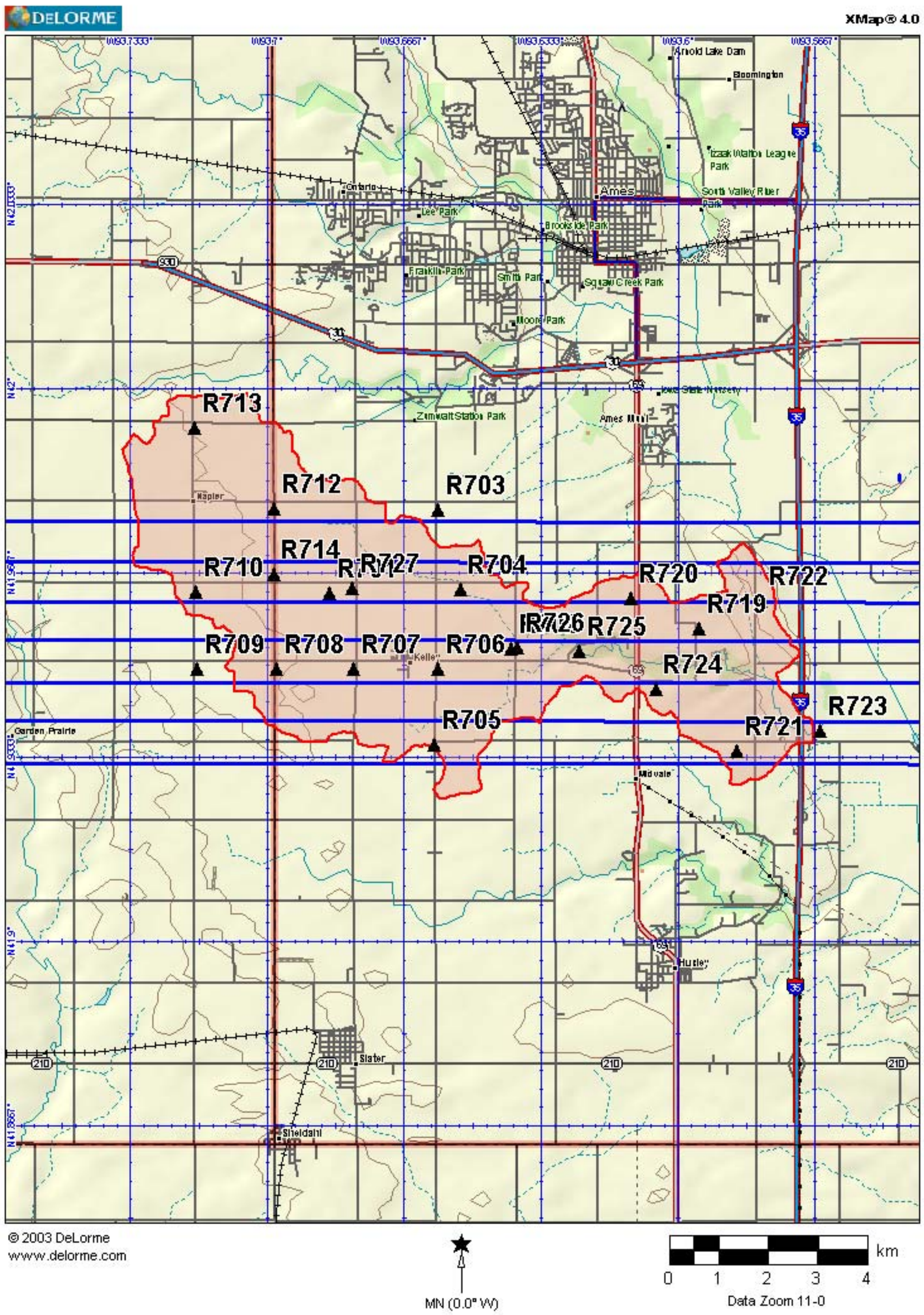


Figure 15. Rain rages within the Walnut Creek watershed.

Two of the rain gage sites include additional meteorological observations (701 and 702). Measurements are made every minute and recorded every hour. End of day max-min air temp and daily total rainfall and max wind speed are recorded. Observations made are:

- solar radiation (kJ/m^2)
- air temperature (C)
- saturated vapor pressure (kPa)
- actual vapor pressure (kPa)
- 4 cm soil temperature (C)
- 20 cm soil temperature (C)
- wind speed (m/s)
- wind direction (degrees)
- hourly total rainfall (mm)

6.3 Iowa Environmental Mesonet

The Iowa Environmental Mesonet (IEM) collects environmental data from cooperating members with observing networks. The data is stored and available on the following website. http://mesonet.agron.iastate.edu/. Contributors are Iowa State University, the National Weather Service, the Iowa Department of Transportation and local sponsored school networks. Nearby station locations in the Iowa State Agroclimate portion of the network are shown in Figure 16.

Iowa State AgClimate stations provide measurements of

Precipitation	Inches
Solar Radiation	Kilo calories per meter squared
Air Temperature	Fahrenheit
Soil Temperature (10 cm)	Fahrenheit
Wind speed	MPH
Wind Direction	Degrees
Relative Humidity	%
Time	local time, either CST or CDT

These data are available as real time plots or can be extracted from archives.

The NWS operates three networks of interest. Automated Surface Observing System (ASOS). Stations are located at airports and measurements are made every minute of temperature, dew point, wind, altimeter setting, visibility, sky condition, and precipitation. They also operate the Automated Weather Observing System (AWOS), which provides wind speed and direction, temperature and dew point, visibility, cloud heights and types, precipitation, and barometric pressure. Finally, limited observations of precipitation and temperature are available through the NWS Cooperative Observer Program [COOP] in which daily observations are reported by volunteer observers.

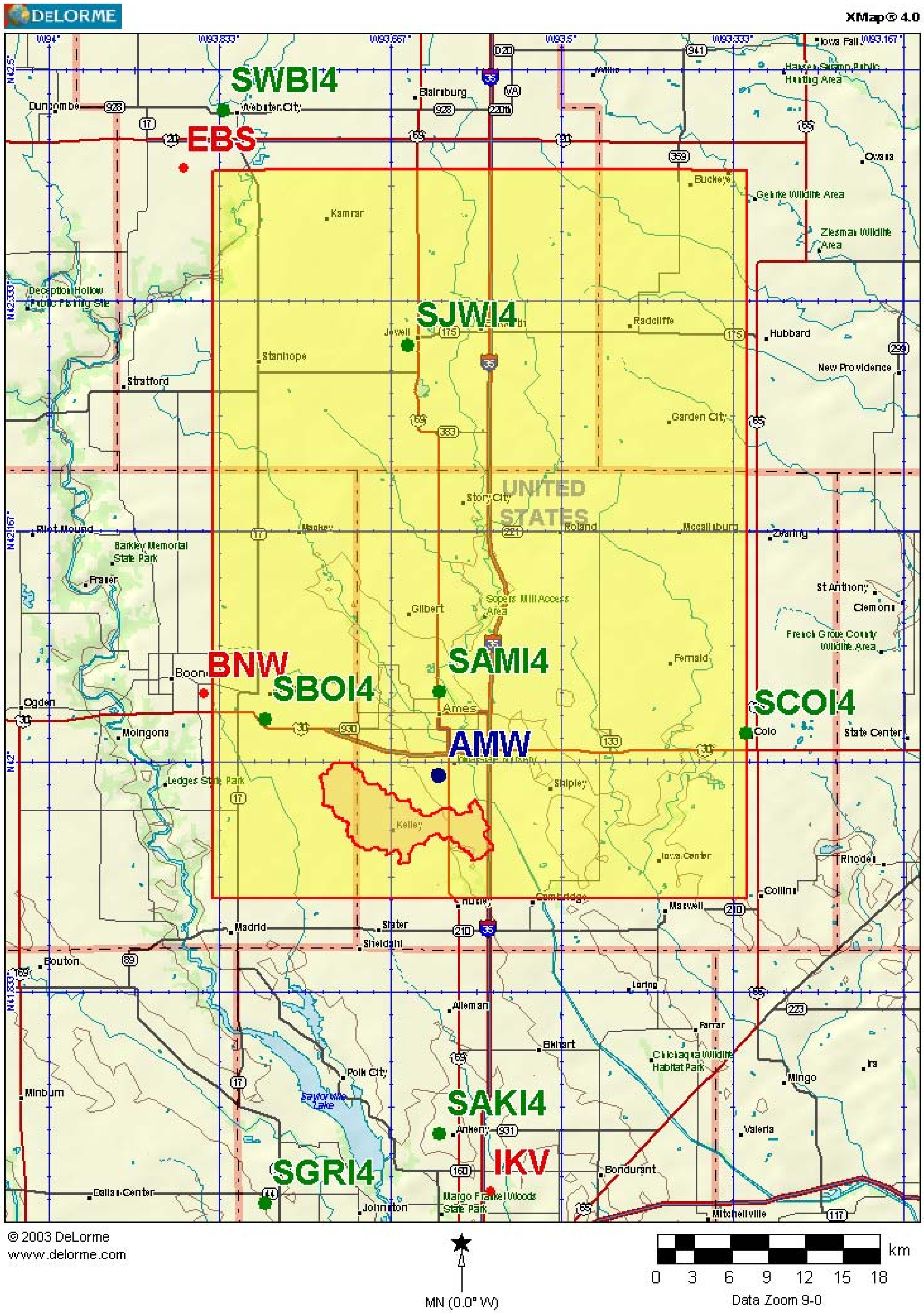


Figure 16. Meteorological stations in the SMEX05/POLEX region.

7 SAMPLING PROTOCOLS

7.1 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.**

7.2 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 6:30 am and 8:30 am. It is assumed here that most of these sites will be quarter sections (800 m by 800 m), 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
- 0-1 and 0-6 cm gravimetric soil moistures using the scoop tool
- 0-6 cm soil bulk density (separate team)
- Is there dew present at the location and how much? A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure.
- 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 (one time)

Preparation

- Arrive at the field headquarters at assigned time. Check in with group leader and review notice board.
- 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)
- For the WC sites, each team should take one box of 18 cans.
- 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 "WC##" and Point "##".
- 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.

Procedure

- Upon arrival at a site, note site id (WC##), 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.
- Assess the amount of dew at the location your sampling. A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure.
- Assemble 8 sequential cans and indicate on schematic where they will be used. ***Odd numbered cans are used for the 0 – 1 cm sample and even numbered cans are used for the 0 – 6 cm sample.*** See Figure 17 as an example of such a diagram.
- **Use cans sequentially**.
- From a reference point for the site (usually a corner), measure 200 m along one side to locate the first transect.
    - Transects should be parallel with the row direction.
    - If possible, select a row that is a tractor row to walk in.

- From this location initiate a sampling transect across the site. Take the first sample at 100 m and repeat every 100 m until you are 100 m from the edge of the site. For a standard quarter section site this will result in 7 samples along the transect.
    - Sample in the row adjacent to the row you are working 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 18. **See the Theta Probe protocol for how to use the instrument and data logger.**
    - At all points make a qualitative assessment of the amount of dew present by recording a 0 (no dew), 1 (a little dew), or 2 (a lot of dew) in the field notebook.
    - At points labeled ALL in Figure 17 (four per site) collect
        - One gravimetric soil moisture sample for 0-1 cm and 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)**

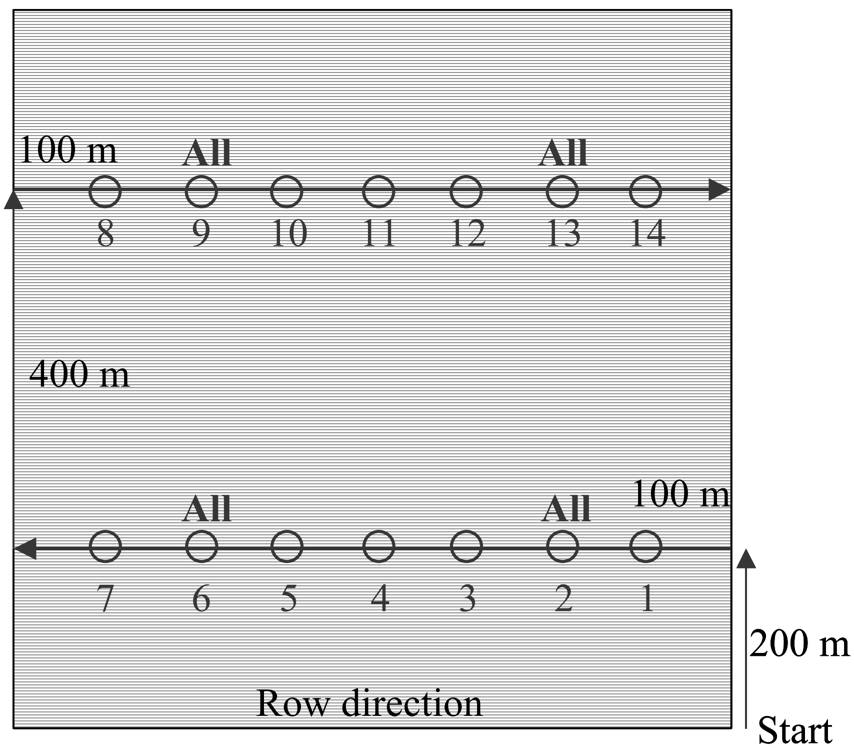


Figure 17. Schematic of layout of samples in a watershed site.

- After completing this transect move 400 m perpendicular into the site and initiate a new transect. This will result in a total of 14 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.

- If there is a tower/leaf wetness sensor in the field, take a fifth set of ALL readings
  - One gravimetric soil moisture sample for 0-1 cm and 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)**
- Record your stop time and place cans in box. Try to keep them cool.

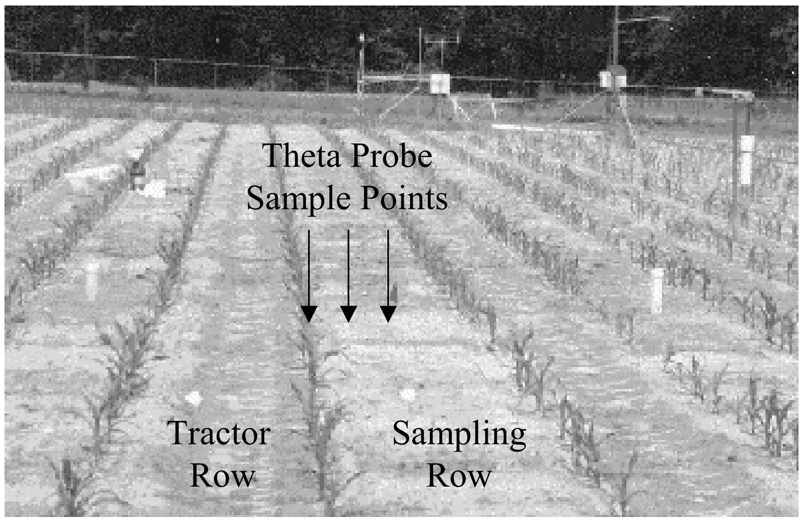


Figure 18. Schematic of layout of Theta Probe sample points.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- For each site, weigh the gravimetric samples and record on the data sheets (Figure 19) 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.

7.3 Regional Site Surface Soil Moisture and Temperature

Soil moisture and temperature sampling of the region near Ames Iowa is intended to estimate the site average and standard deviation at the scale of passive microwave satellite footprints and grid cells. In order to satisfy this requirement we will be using insitu sensors (Vitel Hydra Probes) with data loggers. These sensors will be installed at a depth of 5 cm and provide the soil moisture and temperature. A single location in each of sites will be sampled every half hour. The locations of these sites will be a subset of the SMEX02 regional sites. These sites will be manually sampled only a couple of times for calibrations purpose during the field campaign.

Gravimetric Soil Moisture Sampling Date ________________ Observers ___________________
Time ________________
Sites ____________________

Site ID	Sample ID	Wet Weight	Dry Weight	Surface Temperature				Soil Temperature		
				A	B	C	D	1 cm	5 cm	10 cm
WC01	AB01	210.15		25	24	23	22	22	20	18
WC01	AB02									
WC01	AB03									
WC01	AB04									
WC01	AB05									
WC01	AB06									
WC01	AB07									
WC01	AB08									
WC02	AB09									
.	.									
WC02	AB16									

Figure 19. Example of the gravimetric soil moisture sampling data sheet.

The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-1 and 0-6 cm gravimetric soil moistures and bulk density using the coring tool
- Four surface temperatures using a hand held infrared thermometer (See Temperature Sampling protocol)
- 1 cm soil temperature
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations (one time)

7.4 Theta Probe Soil Moisture Sampling and Processing

There are two types of TP configurations; Type 1 (Rod) (Figure 20) and Type 2 (Handheld) (Figure 21). They are identical except that Type 1 is permanently attached to the extension rod.

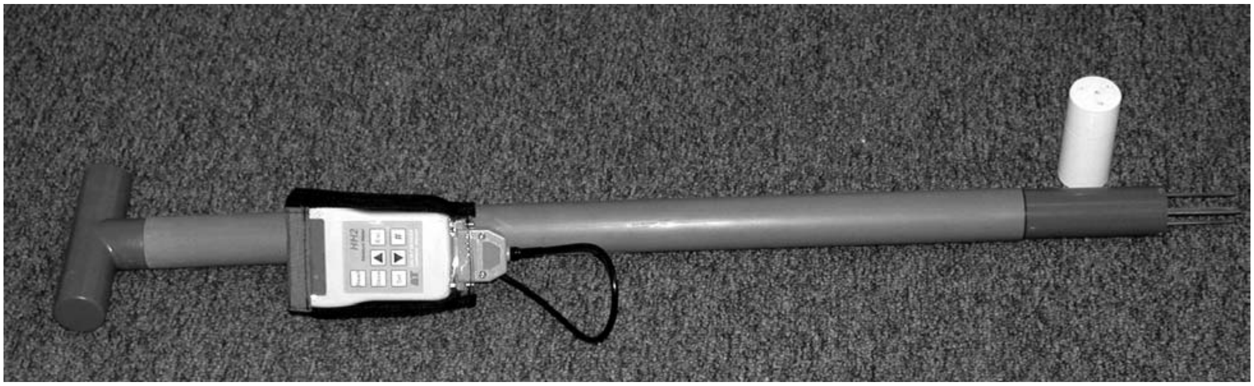


Figure 20. Theta Probe Type 1 (with extension rod).

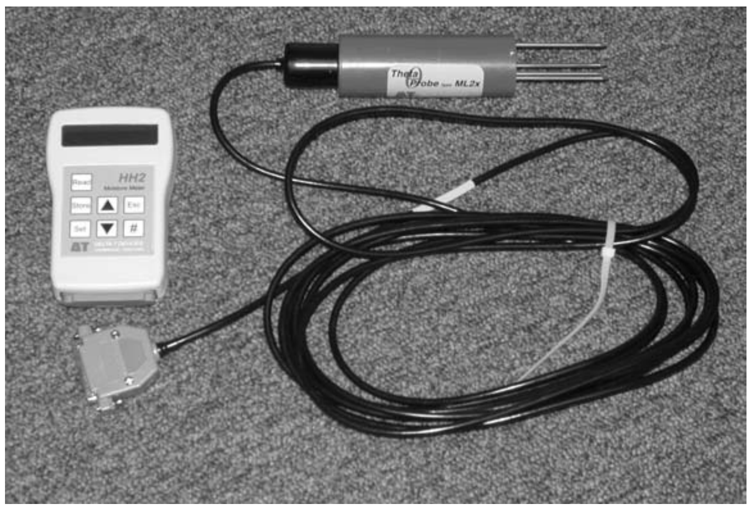


Figure 21. Theta Probe Type 2.

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 22. 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 SMEX05, all observations will be recorded as mV and processed later to soil moisture.

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 22. HH2 display.

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.

Taking 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.

7.5 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 23a).
- Push the GSM tool into this vertical face. The top of the scoop should be parallel with the soil surface. (Figure 23b).
- Use the large spatula to cut a vertical face on the front edge of the scoop (Figure 23c).
- Use the small spatula to cut the sample into a 0-1cm 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 23d).
- 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.

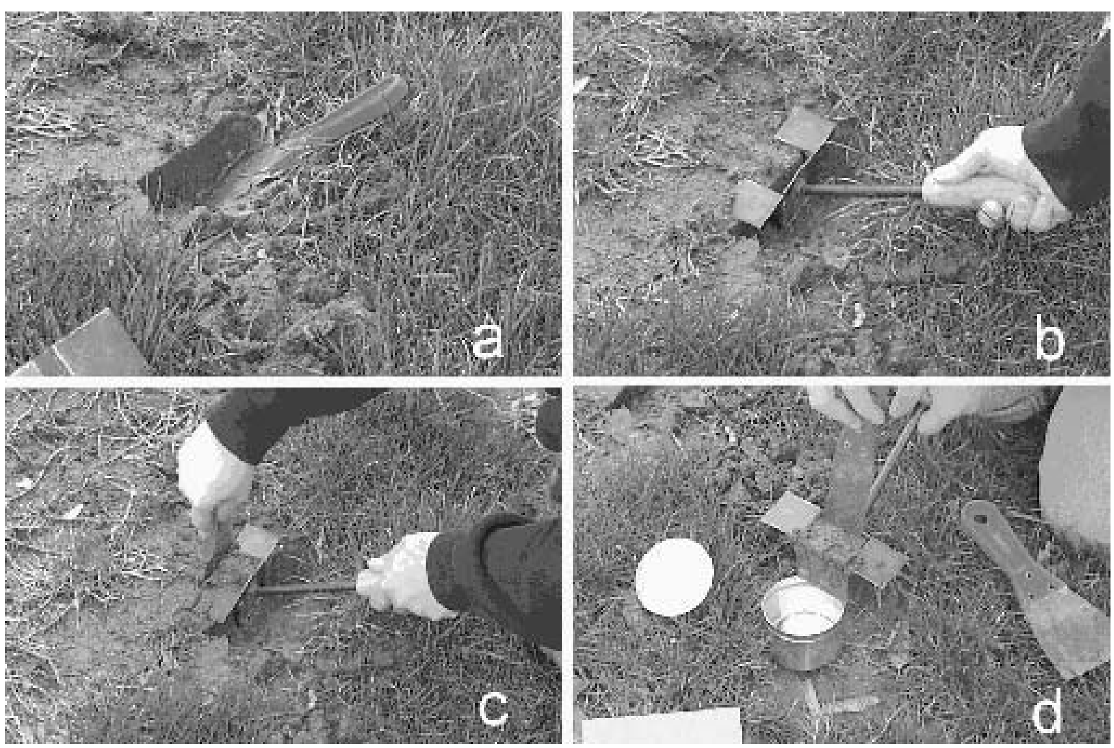


Figure 23. How to take a gravimetric soil moisture sample.

7.6 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^{o}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

7.7 Watershed Site 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. Four replications will be made at each site.

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.

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 24a)

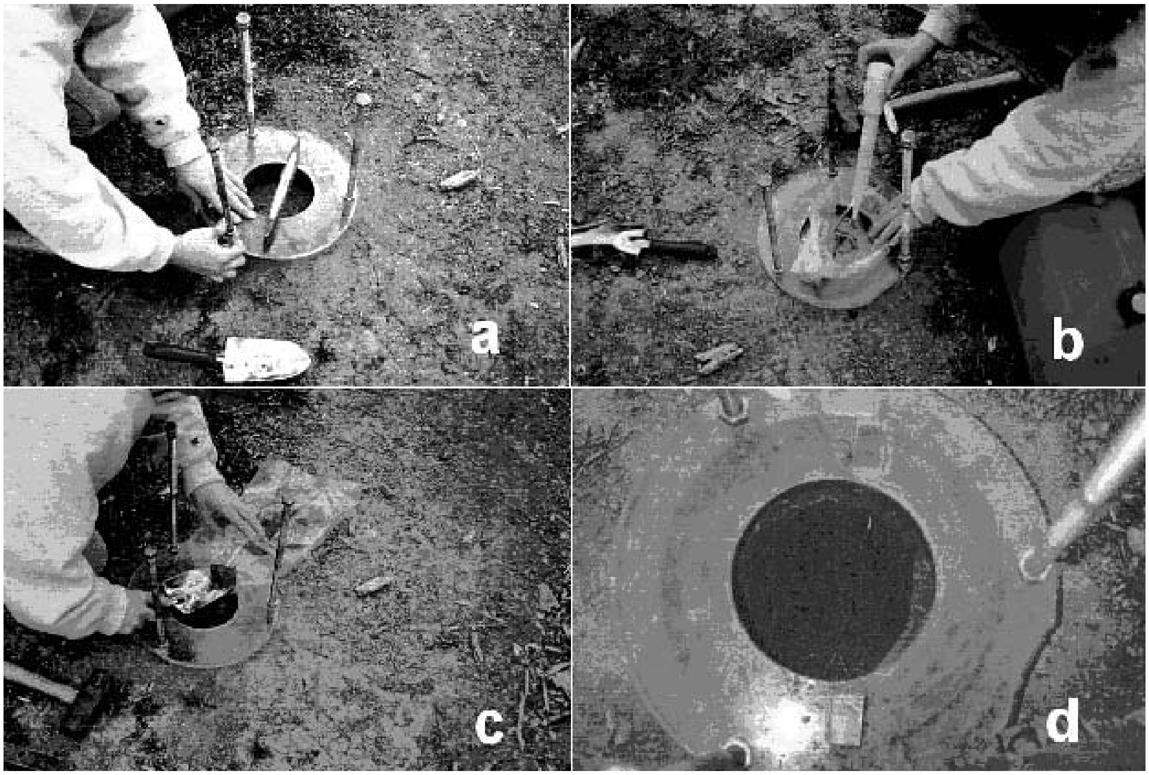


Figure 24. How to take a bulk density sample

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 24b)
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 24c 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.

<u>Potential Problems and Solutions</u>

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, corncobs, 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. For row crops, photos will be taken both 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 25) In addition, nadir photos will be taken of the same area. For these photos, place the card with the site ID and a ruler on the surface of the soil and take a photo straight down taking care not to get your shadow in the photo. Surface roughness photos will be taken once during the experiment unless there is a change in the field conditions (plowing, planting, harvesting …).

Figure 25. Surface roughness photo.

7.8 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 26).

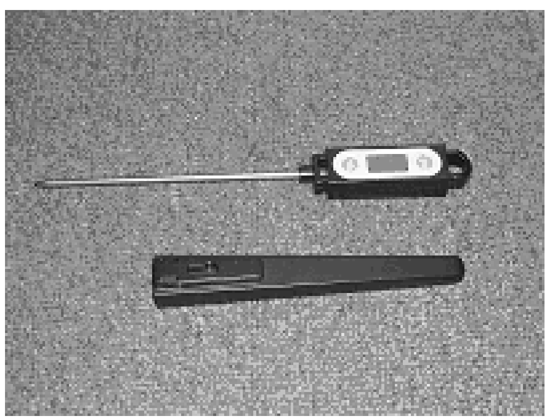


Figure 26. Temperature Probe with Handle/Cover

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.

7.9 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 site 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.

7.10 Hydra Probe Soil Moisture and Apogee Temperature Sensor Installations

Figure 27 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 27. 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 be 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.

Installation of the Apogee Surface Temperature Sensor

A copy of the instruction manual for the Apogee sensor (Figure 28) will be available at the field HQ and can also be found at http://hydrolab.arsusda.gov.

- Height
- Target
- Angle

Figure 28. Apogee thermal infrared sensor.

7.11 Vegetation Sampling

Purpose of Sampling

The purpose of vegetative sampling is to provide an estimate of the variation in the vegetative components in the corn and soybean fields across the SMEX05 study sites, in particular the vegetation water content per area (VWC-area, kg/m2). In addition, SMEX05 will include the characterization of several woodland sites.

VWC is the vegetation water content per plant (VWC-plant, kg/plant) times the plant density (number plants/m2). VWC-plant is the sum of the stem water content (kg/plant) and the foliage water content (kg/plant); these are considered separately because microwave sensors are sensitive to the total water content whereas optical sensors are sensitive to the foliage water content. Stem water content (stalks for corn) is determined from the difference between stem fresh weight and stem dry weight.

Similarly, foliage water content (kg/m2) of a plant is calculated from the difference of fresh weight and dry weight, and the vegetation water content of the foliage (VWC-foliage, kg/m2) is the product of the foliage water content and the plant density. However, foliar water relationships in the remote sensing literature are based on Leaf Area Index (LAI, m2 leaves/m2 ground) and leaf Equivalent Water Thickness (leaf EWT, millimeters where 1 mm = 1 kg/m2). Leaf EWT is determined from the difference of fresh weight and dry weight of the sample divided by the leaf area of the sample. Therefore, VWC-foliage is also the product of LAI and leaf EWT.

Parameters

1. Phenology (number of leaves per plant)
2. Plant height
3. Plant cover
4. Plant density
5. Leaf densityLeaf Area Index (LAI)
6. Multispectral measurements
7. Stem water content per plant
8. Foliage water content per plant
9. Equivalent Water Thickness (leaf EWT)
10. Digital photographs

Sampling Locations

An attempt will be made to sample all watershed sites. Agricultural sites will be sampled twice, once in week one and again in week three. Woodland sites will be sampled in week two. In the morning, groups of two people will go to one to three sites and make measurements, return and process the samples at the work area. In the afternoon each team will visit one or two more sites. Some of the Vegetation Sampling Team will need to make leaf reflectance measurements in the afternoon. Each site will have 5 plots about 60 m apart in the field; the 60 m accounts for any spatial correlation among plots.

Site Identification

Sites will be identified with a unique site id made of the field number TBD.

Sampling Layout

Each location in a field site will be identified with a flag in the right hand corner and a pole that extends above the crop height to aid in location. Sampling plot will be located with GPS units and coordinates recorded for the corners of the site prior to the first sample collection. .

Sampling Scheme

Be aware that we are sampling in fields that are privately owned. Minimizing damage to the plants and fields is essential. DO NOT CUT OR DAMAGE A PLANT UNLESS YOU ARE REMOVING IT AS A SAMPLE. Also, review the general sampling guidelines in an earlier section.

- When arriving at the site, locate the first plot by walking in the row direction 60 m from the entrance (moving well past any border rows) and mark the GPS location as a waypoint.
- Place a flag at this location.
- Note crop type, row direction and row spacing.
- Count plants for density, measure plant height with a meter stick, estimate plant cover, and determine LAI with an LAI-2000 for a 15 m transect along the row (do both sides).
- Select a plant of average height in the transect, cut it at ground level, and place it into a large paper bag. You may cut the stalk/stem but try to fold the leaves. Mark on the bag with the date, team, site number and plot number. Place the paper bag into a trash bag and tie it to prevent moisture loss.
- If there is time, an extra plant can be collected at one of the plots for spectral measurements with the ASD spectroradiometer; put these plants into a separate paper bag and enclose them into a trash bag.
- Plots 2-5 will be located as follows from the first plot by moving into the center of the field from the road. Corn rows are generally 30 inches apart, and soybean rows are either 15 or 30 inches apart. If the row direction runs parallel with the road. Move about 60 m into the field by counting 79 rows (for 30 inch rows) for plot 2. Mark the GPS location as a waypoint and collect the measurements and plant sample as above for a 15 m transect along the row. Then move another 60 m (79 rows) into the field for plots 3, 4, and 5. If the row direction runs perpendicular to the road, move left or right 6 rows and continue 60 m along the rows towards the center of field for plot 2. Continue moving across 6 rows to the left or right and 60 m along the rows for plots 3-5. When moving across rows, try not to break the plants.

Leaf area index, as measured by the LAI-2000, usually requires diffuse light only. In SMEX02, Anderson found there is a constant offset of about 0.5 m2/m2 in LAI measured in direct sunlight and diffuse light. Therefore note the sunlight conditions by looking for shadows on the ground. If there are no shadows, the light is diffuse; if the shadows are visible, the sunlight is direct. The wand of the LAI-2000 must be facing away from the sun (with your back to the sun), so depending on row direction you may not be standing in between rows you are sampling. Sampling is done at four locations from within the center of the row to directly between the rows. You will need to reposition yourself for each reading to avoid getting direct sunlight into the sensor of the LAI-2000.

Plant growth stage (the V and R system) is hard to determine in the field because small leaves are usually sloughed off. In corn, count the number of green and senescent leaves that have a visible leaf collar at the base of the leaf. There will be one or two leaves at the top of the corn plant that will not have the leaf collar exposed, these should not be counted. Later, a correction factor will be applied to get the V-stage. In soybean, count the number of nodes (enlarged portion of the stem). At the nodes you will either find a branching stem or a leaf. Sometimes it is hard to follow the main stem from the branching stems, but the main stem will have the largest number of nodes.

Plant cover is the amount of space between the rows overtopped by the plants. So if the row spacing is 30 inches, and the plants overtop 10 inches on either side, the plant cover is 67% [(10 + 10)/30]. Determine the height to the topmost fully exposed leaf collar. Place a meter stick straight up along side a plant and take a digital photograph of the space between the two rows.

During week 2 (June 20-24) of SMEX05, foliage and stem water contents will be determined. The site selection is yet to be determined, primarily because the steep gullies and tall trees (> 12 m). Several plots of 25 m by 25 m will be laid out with measuring tapes at each site. Each tree over 1.3 m tall will be counted (density), species recorded, height (inclinometer) and diameter at 1.3 m measured. LAI will be measured using hemispherical photographs. Species, height, and diameter are used to calculate the total dry biomass of the plot using regression equations from the USDA Forest Service.

Samples of wood and leaves of dominant species will be obtained for leaf EWT and stem water content measured as above, but the selection of these samples will be based on opportunity at each site. Tree leaves have two morphological types, sun leaves (top of the canopy) and shade leaves (bottom of the canopy). Sun leaves of a given species generally have smaller leaf area and are thicker (ie higher leaf EWT) compared to shade leaves.

Sample Processing

The work measuring fresh and dry weights will be done in the dryer building at the Iowa State Agronomy and Agricultural Engineering Research Center (west of Ames) at the Intersection of US-30 and U Avenue, about three miles northwest from SMEX05 Headquarters. To get there from US-30, turn south on U Avenue, take the second left and go past the quonset huts on the left; the dryer building is directly in front. Park on the south side of the building. The work room is in the east wing to the right. **We are guests here, you do not have permission to use equipment or enter any other facilities at this location.**

After completing a morning or afternoon sampling session, return to the work area, and open the trash bags one at a time. Cut the leaves off at the stalk/stem and measure the total leaf area by placing the leaves on the conveyor belt of the LI-3100C leaf area meter. Be sure to check the calibration on the LI-3100C and to initialize the meter between plants. Then place the leaves into another paper bag, mark the bag with team, date, site and plot, and measure the fresh weight. Leave the stalks/stems in the original paper bag (which may be wet from the cut plant), and measure the fresh weight. Fold the paper bags and place them in a cart in the dryer room being used.

In the evening at the hotel, arrange to download the GPS data, LAI-2000 data, and digital photographs.

After about a week, the dry weights of each bag will be measured. First the total bag weight will be determined, then the plant material will be emptied and the bag weight alone will be measured. The plant materials will be placed into a used trash bag and placed by the building entrance for disposal.

Landcover Validation

During the weekends, land cover data will be collected for the region. Drive along the roads in the area assigned. At a large field (> 400 m, about 1/4 of a mile, a quarter-section field will be about ½ of a mile or 800 m), drive on the road to the approximate center of the field's side. Determine your GPS location in UTM. Add 100 m to the northing if the field is to the north of the road or add 100 m to the easting if the field is to east of the road, or subtract 100 m from northing or easting if the field is to the south or west of the road, respectively. Record crop type, estimate crop height, and try to determine row direction. Be aware that border rows may hide the true row direction. It is especially important to get fields other than corn and soybeans.

Data Recording

Data will be recorded onto a sampling sheet similar to that shown in Figure 29. Each field will have a separate notebook and data sheets for each sampling plot within the field. Each blank on the sheet will be filled in during the observation period. Data sheets will be maintained as part of the permanent experimental record to verify the data once it is entered into the computer.

Vegetation Surface Wetness Sampling Sheet

Date: Samplers: Field:

Crop Type: Row Direction:

Sampling Site	Sample	Lat	Lon	Phen	Height	Leaf Count	Row Spacing	Row Density	Leaf	Time	Leaf Surfac e Area	Total Wet Wgt	Total Dry Wgt	LAI
1	1								1					
									2					
									3					
	2								1					
									2					
									3					
	3								1					
									2					
									3					
2	1								1					
									2					
									3					
	2								1					
									2					
									3					
	3								1					
									2					
									3					
3	1								1					
									2					
									3					
	2								1					
									2					
									3					
	3								1					
									2					
									3					

Figure 29. Example of the vegetation surface wetness sampling data sheet.

7.12 Vegetation Surface Wetness

A variety of techniques will be used to determine canopy wetness amount in the field. The parameters required are:

1. Phenology
2. Digital Photo, GPS
3. Plant Height
4. Stand Density
5. Leaf Density
6. Physical Sampling of Leaf Wetness
7. Leaf Surface Area
8. Leaf Area Index (LAI-2000)

Sampling Scheme

Canopy surface wetness sampling will be done in some subset of the watershed and regional sampling fields. The protocol for sampling in a given field is as follows:

1. Begin sampling no later than 6am in order to capture moisture during the time of interest.
2. There will be 3 sampling locations within the each field of study (see Figures 30 and 31). If there is a leaf wetness sensor within the field, the first of these studies areas will be within 10m of this site. Sampling sites will be spaced 100 m apart and can be located on the path toward the dew sensor. Samplers will use their own discretion to determine sampling location. It is recommended to sample 5 rows to either side of the soil moisture sampling locations within the field to provide soil moisture at the surface.
3. Record GPS coordinates for each of the three sampling location.
4. At each sampling location, 3 plants will be measured at 5 meter intervals.
5. The phenology of the plant will be assessed and recorded in the vegetation sampling sheet (see Figure 29). Also, take several digital photos of the area for the record, including some up close pictures of the leaves containing 'dew'.
6. The height of the plant will be measured with a measuring tape and recorded.
7. Stand density and leaf count will be recorded for the plant(s) of interest.
8. Sample one leaf each for corn or three leaves each for soy from the lower, middle and upper canopy for the plant of interest using the protocol described below. If the plant is too disturbed from the initial sampling, capture the next leaf from an adjacent undisturbed plant. Repeat.
9. Capture the sampled leaves in plastic bags, label and seal.
10. Repeat 5 meter down the row.
11. LAI-2000 measurements will be taken at each of the sampling locations at three levels (0 m, 1/3 canopy height, and 2/3 canopy height), which means there will be 3x3x3 readings per field. Sample in the adjacent row so that you aren't sampling where you have cut leaf samples.

12. Once sampling at the first sampling location (3 repetitions) is complete, proceed onto the second sampling location and repeat, then move on to the third sampling location.

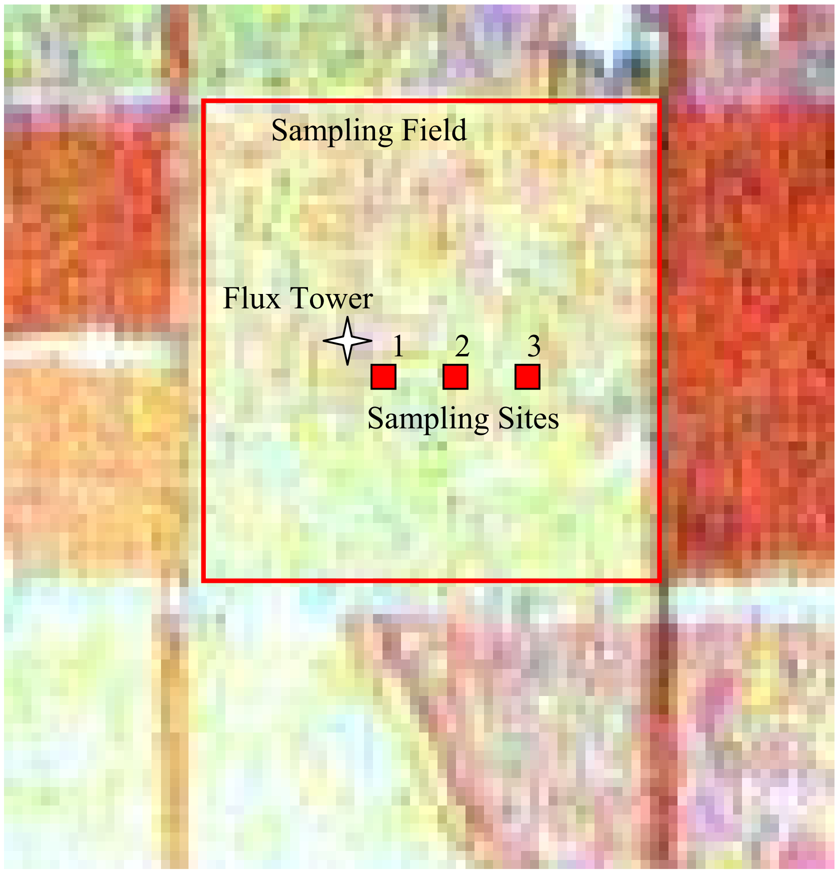


Figure 30. Theoretical sampling design for a ¼ section field in SMEX05.

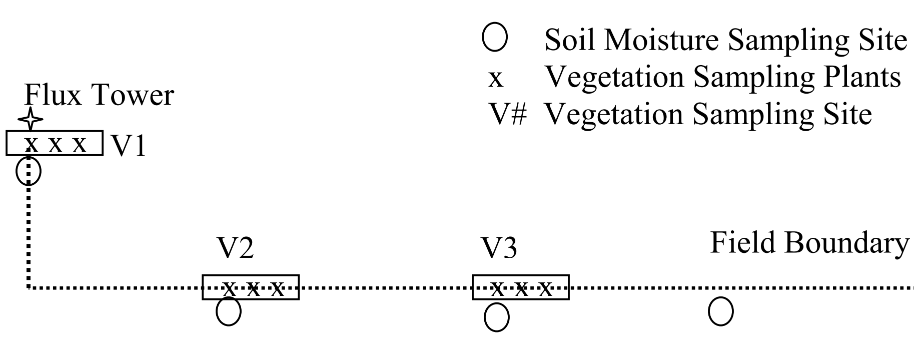


Figure 31: Close up of sampling design

7.13 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 (30-45º 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.

7.14 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.

7.15 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.

7.16 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.

7.17 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.

7.18 Phenology

Phenological stage for crops will be determined using standard phenological guides.
Corn: http://maize.agron.iastate.edu/corngrows.html#vegetative
Soybean: http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/a1174/a1174w.htm

There are two main stages of interest for corn and soybeans during this study, the vegetative and reproductive stages. These are defined below in Table 22.

Table 22: The approximate growth stages for corn and soybeans.

Corn:

Vegetative Stages	Name	Description
VE	emergence	Plant first breaks through the ground surface.
V1	first leaf	The first leaf is formed.
V2	second leaf	Two leaves have formed.
V3	third leaf	Three leaves are apparent
V(n)	nth leaf	Total of (n) leaves
VT	tasseling	From the top of the corn plant, a tassel has emerged.
Reproductive Stages		
R1	silking	Silk has formed at the tips of the ears.
R2	blister	The kernels of the ears have emerged and resemble blisters.
R3	milk	The cob has grown to near full size and the silk begins to discolor due to environmental conditions.
R4	dough	The kernels of the plant begin to firm up and the ears are full size.
R5	dent	The kernels have solidified and the tops of have a noticeable dent in them.
R6	physiological maturity	Ears are completely formed and hard and the outer husk is discolored, though the stalk may still be green.

Soybeans:

Vegetative Stages		
VE	Emergence	Emerges from the soil.
VC	Cotyledon Stage	Single leaves are fully expanded.
V1	First Trifoliate	First triple leaf is fully emerged.
V2	Second Node	Second triple leaf is fully emerged.
V3	Third Node	Third triple leaf is fully emerged.
V(n)	nth Node	(n)th triple leaf is fully emerged.
V6	6^{th} Node	Flowering will soon start
Reproductive Stages		
R1	Beginning Bloom	First flower
R2	Full Bloom	Flower in top 2 nodes
R3	Beginning Pod	3/16" pod in top 4 nodes
R4	Full Pod	3/4" pod in top 4 nodes
R5	Beginning Seed	1/8" seed in top 4 nodes
R6	Full Seed	full size seed in top 4 nodes
R7	Beginning Maturity	one mature pod
R8	Full Maturity	95% of pods on the plant are mature

7.19 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.

7.20 Physical Sampling of Canopy/Leaf Wetness

Corn: Select three leaves from the plant to sample. Leaf #1 should be from the lower third of the plant height. Leaf #2 should be from the middle third and Leaf #3 should be from the upper 3rd. Place a filter paper in the node or base of the leaf to be sampled to collect the Placing a filter paper on the top and bottom of the leaf at the base of the leaf, gently run the papers up to the end of the leaf, making sure not to lose any moisture off the side. If the filter paper saturates, use more than one and record the number in the record sheet. Set the filter paper firmly into the base of the leaf to capture the moisture at the base, referred to as the node capture. Wipe up the leaf until all visible surface wetness is absorbed and be sure to check the underside of the leaf as well. Make all attempts to capture all of the moisture from the leaf. Place all filter papers for the three types of leaf wetness (node, top, and bottom) in separate plastic bags, and label with field, sampling location, plant #, and leaf #. If the plant was significantly disturbed in the sampling, move to an adjacent plant to sample the next leaf. After dew has been removed, excise the leaf and place it in a plastic bag and label it by field, location, plant # and leaf #.

Soybean: Two types of soybean moisture will be measured: top and bottom moisture. Treating three leaves as one, sandwich the leaves between two filter papers and retrieve all the moisture and put into two plastic bags. Clip the leaves at the base of the leaf and store in another bag for later area calculation.

Grassland: Sampling the leaf wetness in grassland will require some trial and error in the field. Select a small area of grass to sample. Starting from the bottom of the clump of grass slide a ring of filter paper (wadded together) up the grass to collect the moisture. A partner will maintain the clump of grass at the base and once all the moisture is collected, bag the wet paper and clip the grass leaves for area calculations later.

Once you return to the lab, weigh the plastic bag, which contains the filter paper and record the weight on the data sheet. Note the number of filter papers used and subtract the equivalent dry filter paper weight from the total wet weight. Also subtract the plastic bag weight. This will equal the weight of the water on that leaf. * Average weights for dry filter paper and plastic bags will be determined at the start of the experiment.

7.21 Leaf Surface Area

The surface area of the sampled leaves will be determined by placing the leaves on a digital scanner and scanning the image. The free software NIH Image will be used to compute the leaf surface area and perimeter to quantify the amount of leaf surface area. This will be done at the end of the day in the lab. Select three leaves from the plant to sample. Leaf #1 should be from the lower third of the plant height. Leaf #2 should be from the middle third and Leaf #3 should be from the upper 3rd. Placing a filter paper on the top and bottom of the leaf at the base of the leaf, gently run the papers up to the end of the leaf, making sure not to lose any moisture off the side. If the filter paper saturates, use more than one and record the number in the record sheet. Set the filter paper firmly into the base of the leaf to capture the moisture at the base, referred to as the stem capture. Wipe up the leaf until all visible surface wetness is absorbed and be sure to check the underside of the leaf as well. Make all attempts to capture all of the moisture from the leaf. Place all filter papers in one plastic bag, and label with field, sampling location, plant #, and leaf #. If the plant was significantly disturbed in the sampling, move to an adjacent plant to sample the next leaf. After dew has been removed, excise the leaf and place it in a plastic bag and label it by field, location, plant # and leaf #.

Once you return to the lab, weigh the plastic bag, which contains the filter paper and record the weight on the data sheet. Note the number of filter papers used and subtract the equivalent dry filter paper weight from the total wet weight. Also subtract the plastic bag weight. This will equal the weight of the water on that leaf. * Average weights for dry filter paper and plastic bags will be determined at the start of the experiment.

7.22 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 SMEX05, 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 32.

Figure 32. 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 SMEX05 we will be using a MSR16R unit with the following set of bands:

Satellite	***ID***	***CenterWavelength (Bandwidth)***
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) (Figure 32)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Figure 33)
- CT100 (hand terminal, connected to the DLC with a serial cable) (Figure 34)
- 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 33. Data logger controller & cable adapter box.

Figure 34. CT100 hand terminal.

***<u>Set Up</u>* –**

- 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 into main menu

- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **5** then **ENTER,** input your plot ID (numbers 1-999 only), Press **ENTER**
- Press **M** to return to the MSR main menu
- At Command * Press **8** then **ENTER** to get to the MSR program
- Press **ENTER** to continue or **M** to return to the MSR 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 SMEX05:

Vegetation Water Content Sampling Location:

Reflectance data will be collected for each vegetation sampling location (Figure 35) 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.

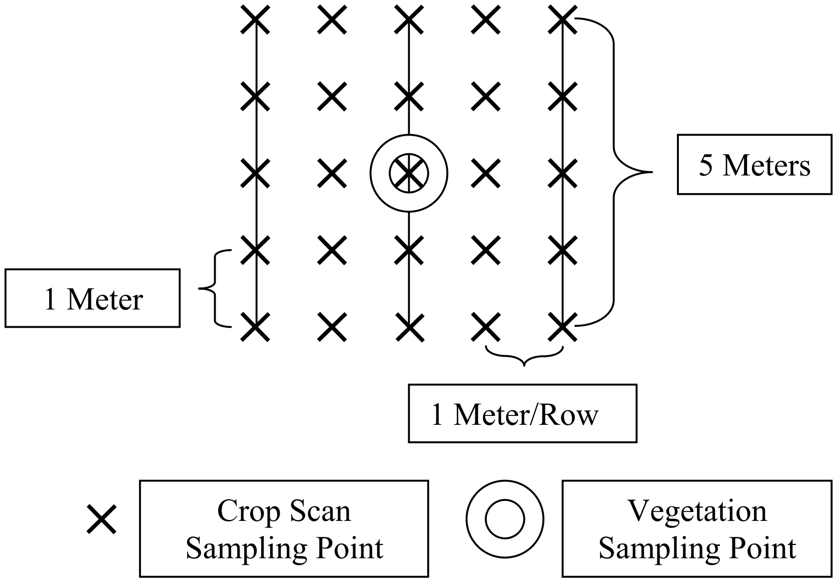


Figure 35. Vegetation sampling scheme.

Field Transect:
Each different land use type (soybeans, corn, grasslands, etc...) will be characterized by transect sampling. Reflectance will be collected at representative sites (Figures 36 and 37). Reflectance will also be collected over water for calibration purposes. This will be done weekly, 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.

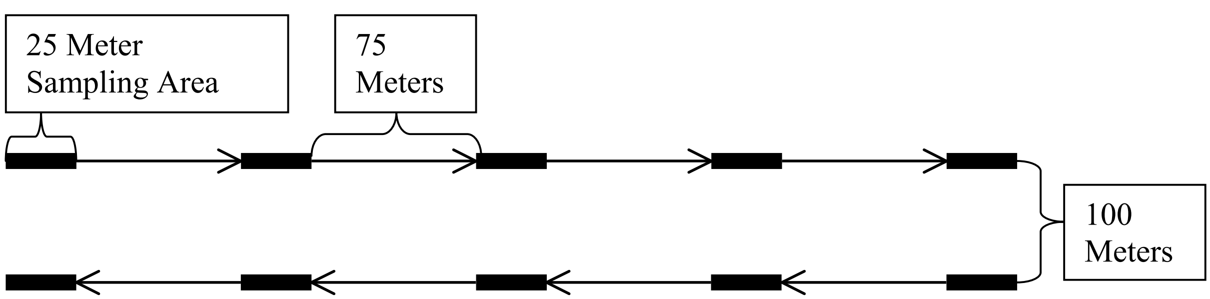


Figure 36. Transect sampling scheme.

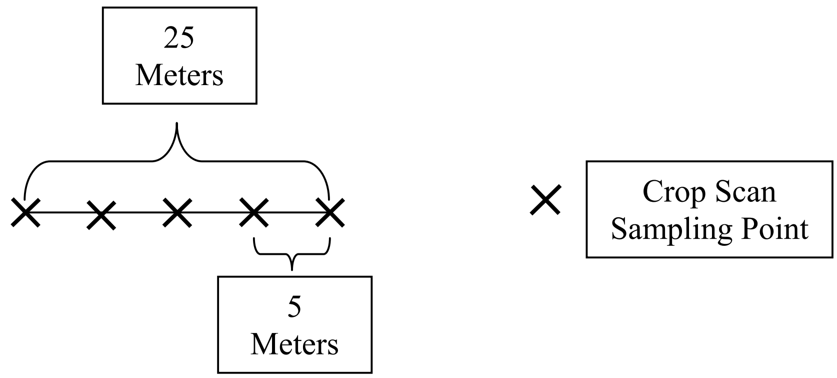


Figure 37. Enlarged transect sampling area.

7.23 Leaf Area Index

Leaf area will be measured with a LAI-2000 (Figure 38). For *row crops* in the inter-row region at least one meter away from where the biomass sample was taken, but still in a region of similar canopy amount. [Need to state that LAI is taken >1m away from biomass sampling area, should still be taken in a part of canopy that has similar characteristics. LAI can drop precipitously over a couple meters down the row, and you need the LAI to be consistent with where the dew was sampled. This gets back to question of how the sampling areas are going to be selected. Ideally, you make a measurement in the center of a large uniform area. Dew at the edge of a discontinuity will be different from dew in a homogeneous part of the canop. The LAI-2000 will be set to average 4 points into a single value so one observation is taken above the canopy and 4 beneath the canopy; in the row, ¼ of the way across the row, ½ of the way across the row and ¾ of the way across the row. This gives a good spatial average for row crops of partial cover. 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. If possible these should be made just before clipping. Protocols for *shrubs and trees* will be developed if necessary.

If the sun is shining, the observer needs to stand with their back to the sun and put a black lens cap that blocks ¼ 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. Also, it is important to check the LAI-2000 internal clock each day to verify they are recording in CDT.

Figure 38. 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 grasslands and shrubs:

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 plant canopy in one corner of your sampling area level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Repeat for the other 3 corners

Repeat steps 1-3 so that you have a total of 5 sets of measurements.

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.

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
8. desired files have been sent.

9. In HyperTerminal go to Transfer | Capture text | Stop.

10. On the LAI-2000, go to function 33 (set format) and setup format options. Now set to Standard, Print Obs = yes

11. 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.

12. 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.

13. In HyperTerminal go to Transfer | Capture text | Stop.

14. 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 it's 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 which is 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.

7.24 Electronic Leaf Wetness Sensor

The 237 Leaf Wetness Sensor (Figure 39) is designed to simulate the surface area of a leaf. It is primarily used to determine the percentage of time that a surface (i.e., leaf surface) is wet versus dry. The electrical resistance of the surface is measured. As moisture forms on the surface, the resistance of the sensor decreases because the water closes the circuit. The sensors have been painted with a base coat of black latex and then two coats of off-white latex paint dried overnight at 70 C between each coat. The wet/dry transition point is also determined. Studies on the ability of the sensor to measure amount of dew will also be investigated, though preliminary analysis indicates this unlikely.

Installation of the sensor will vary by site, but there will be some consist elements. The sensor should be installed within the plant canopy to experience the same microclimate as the plants. Instruments will be installed in the crop row. Two heights will be used, 1/3 of canopy height and 2/3 of canopy height for corn and 2/3 of canopy height for soybean and other crops. These heights will be readjusted weekly to accommodate plant growth. All sensors will be installed at a 45 degree angle with the horizon and they will be installed facing north for consistency. Two data quantities will be recorded every 15 minutes, resistance and % of time wet. These are common variables retrieved from the sensors.

Ten sites will have a total of four sensors. In corn fields, they will be installed at two locations at two heights, 1/3 and 2/3 canopy height. Their locations will be at least 10 meters apart and are intended to study in field variability. In soybean fields, these four sites will be installed at four locations at a height of 2/3 of canopy height in four locations, separated by at least 10m. Five sites will have two sensors installed at two different locations, preferably in different topographic regions to provide a point of contrast. These will be installed at a height of 2/3 plant height. Ten other sites will have one sensor installed at 2/3 of plant height.

Figure 39. The 237 Leaf Wetness Sensor

7.25 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 **e**Trex "sportsman" GPS will be used to collect location data. 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 **e**Trex 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 **e**Trex 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 **e**Trex is configured to run in Battery Save mode which automatically turns the GPS receiver on and off to conserve power. In this mode, the **e**Trex 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.

***e*Trex 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 **e**Trex GPS as well as display backlight on and off.

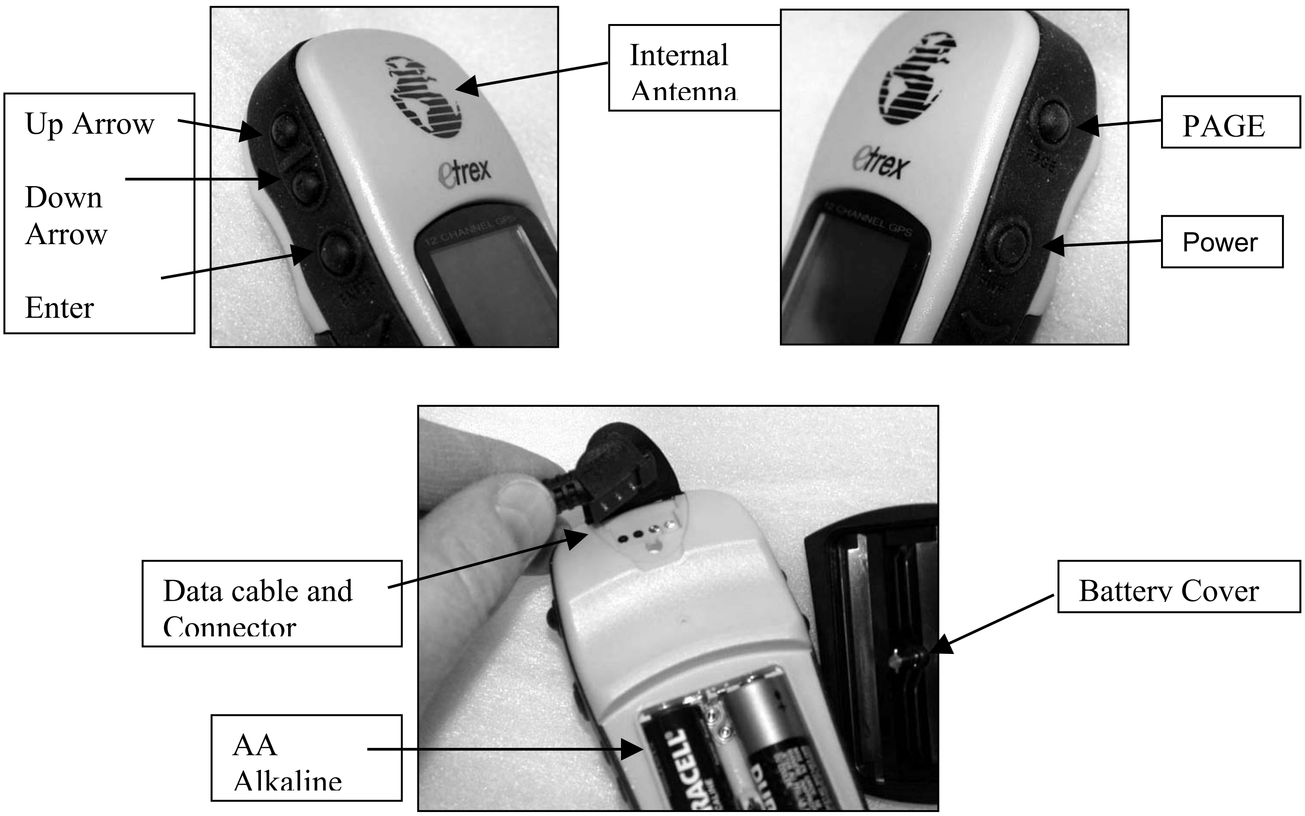
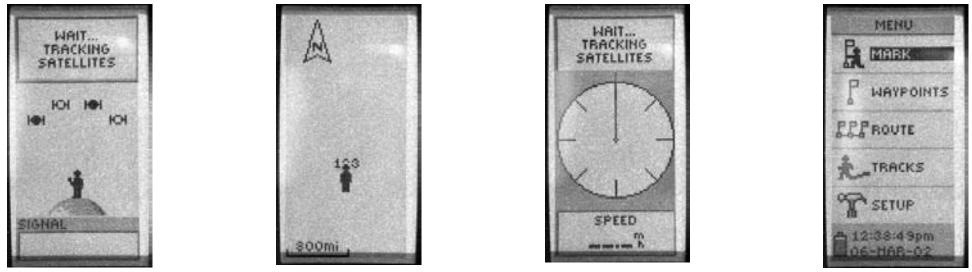


Figure 40. GPS features.

All **e**Trex 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.)



Satellite | Map | Pointer | Menu

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**

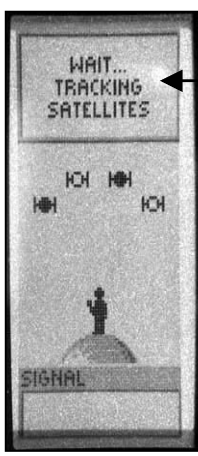
Figure 42. GPS Menu page.

3. Turn **e**Trex 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 exists between NAD27 and NAD83. (In Iowa, a north-south displacement of approximately 215m occurs between NAD27 and NAD83.) *All geographic coordinates collected with the **e**Trex 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.

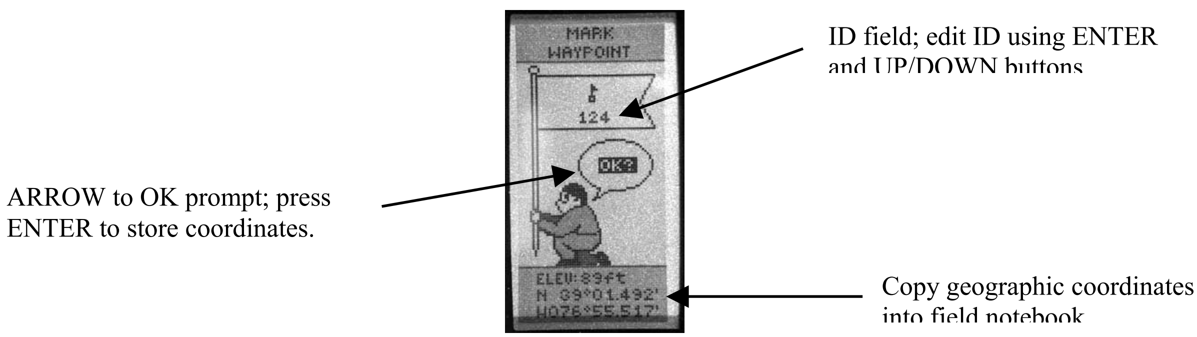


Figure 44. GPS Mark Waypoint Page.

4. Turn **e**Trex 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

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10 LOGISTICS

10.1 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 SMEX supervisor. At the time of sampling, if the farmer is working in the field, DO NOT sample and contact your SMEX supervisor. Prior to the experiment all requests for field access are to be directed to Mike Cosh (mcosh@hydrolab.arsusda.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.

- Access to field headquarters: Open 6 am until 4pm everyday. For periods of time during the day the lab may be unattended and locked. In this circumstance contact a SMEX supervisor for entry.
- Access to the NSTL: Restricted to USDA employees and others by prior arrangements

10.2 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 SMEX 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.

Lynn McKee, SMEX Safety Officer, 202-679-3654
Mike Cosh, Asst. Safety Officer, 410-707-2478
Rajat Bindlish, Asst. Safety Officer, 301-529-4708

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 winklerm@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 "bulls-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
- Road intersections are often unsigned, use caution, and watch for cross traffic.
- 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.

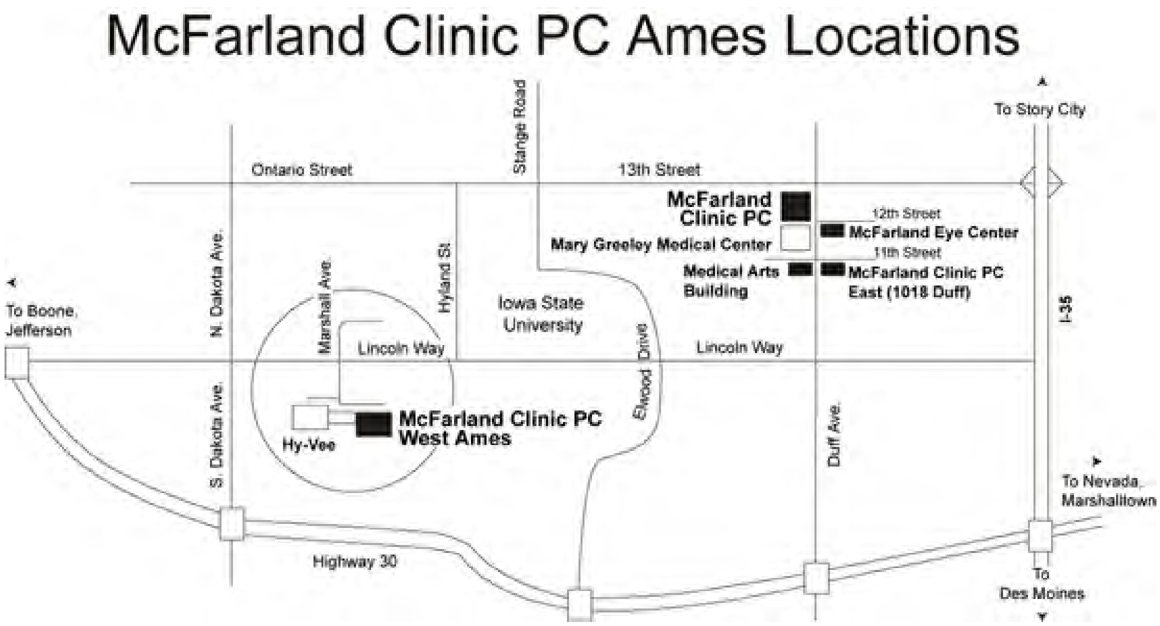
Tornados

- Be aware of the weather at all times, have a plan where to seek shelter in case of a tornado
- If a tornado approaches, do not get into the car but find the lowest spot on the ground and lay flat.

Medical

For medical emergencies call 911 or go to:
Mary Greeley Medical Center
1111 Duff Avenue, Ames, IA 50010
Phone: 515-239-2011

For non-emergency medical problems:
Adult Medicine in the McFarland Clinic
1215 Duff Avenue, Ames IA, 50010
Phone: 515-239-4431



10.3 Hotels

Ames, IA (Location for ground sampling teams)

Baymont Inn & Suites Ames
2500 Elwood Drive
Ames, IA 50010
Phone: (515)-296-2500
Fax: (515)-296-2874
http://www.baymontinns.com/lq/properties/propertyProfile.do?ident=LQ4539&propId=4539
There is a block of rooms under the code "6012USDA" at the rate of $55/night. You need to call the hotel directly and make your reservation. If you have problems talk to Emily Halverton.

Heartland Inn
US 30 and Interstate 35, Ames, IA 50010
Phone: (515)-233-6060 / 800-334-3277
Fax: (515)-233-1911
www.heartlandinns.com/locations/ames.html

More information can be obtained at http://www.amescvb.com/visitors/lodging.asp

Des Moines, IA (Location for aircraft team)

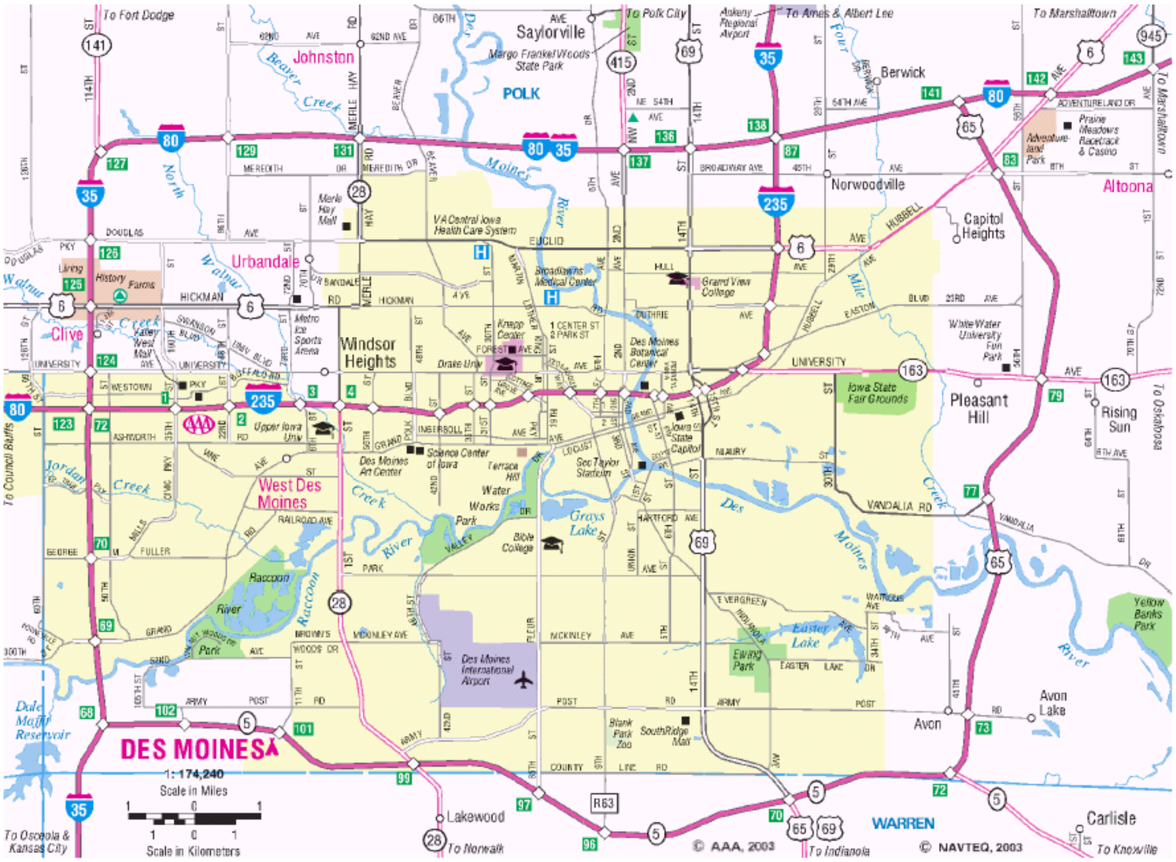
Embassy Suites Hotel Des Moines-On The River
101 East Locust Street
Des Moines, IA 50309
Phone: (515)-244-1700
Fax: (515)-244-2537
http://www.embassysuites.com/en/es/hotels/index.jhtml?ctyhocn=DSMDNES

10.4 Directions and Maps

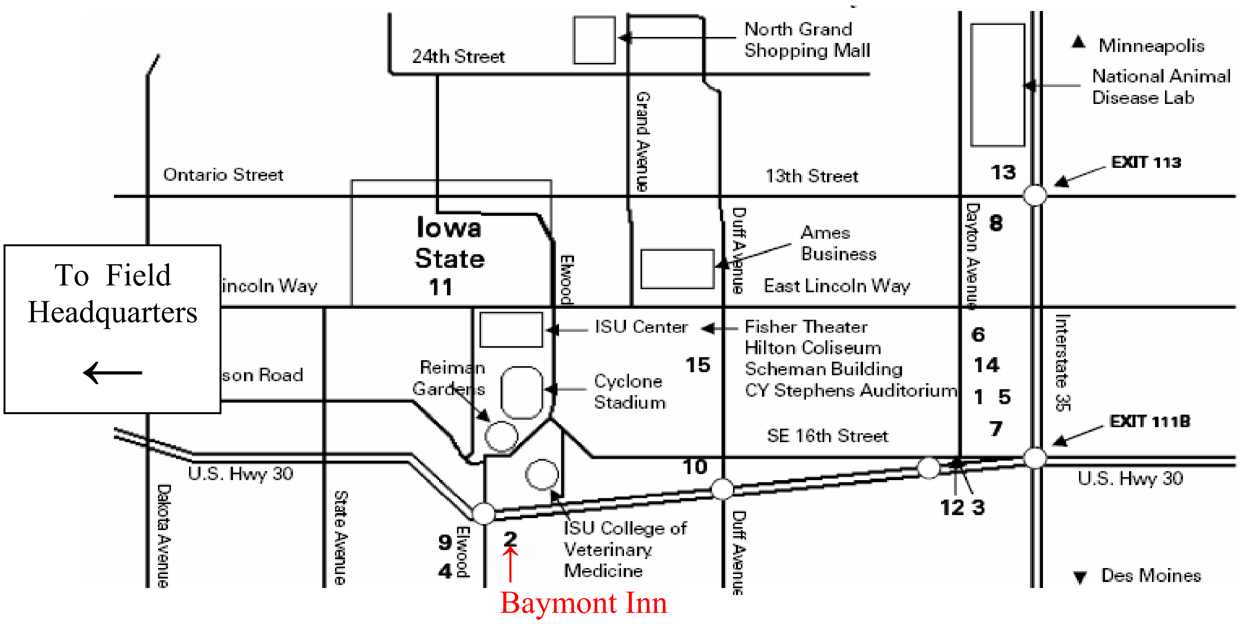
Directions from the Des Moines Airport to Embassy Suites Hotel Des Moines:
- Exiting the airport parking lot, turn left onto Fleur Drive
- Turn right onto Locust Street, cross river bridge, hotel is on the right.

Directions from the Des Moines Airport to Ames:
- As you leave the Des Moines Airport, turn Left onto Fleur Drive and take Fleur to I-235 East
- At the northeast edge of Des Moines, take the I-35 North Minneapolis exit
- Take I-35 North, approx. 28 miles to Ames.
- Get off I-35 at Exit 111B, Highway 30 West

The following is a general map of the Des Moines area.



The following map shows general features of the City of Ames. When coming from Des Moines, get off I-35 at Exit 111B, Highway 30 West. For the Baymont Inn, continue West on Hwy 30, go South on Elwood Drive. For the Heartland Inn, Hwy 30 West to SE 16th St. turn North.



The location of the Field Headquarters for SMEX05 is an ARS building located on 240th St near W Ave. To get there from Ames Hotels, take Highway 30 West, exit at X Ave going South, take the first right onto 240th Street and follow to Field Headquarters on the right. A photo is also shown. The All Hands meeting on June 14th will be held here.

SMEX05 Field Headquarters

10.5 Local Contacts and Shipping

USDA/ARS National Soil Tilth Laboratory
2150 Pammel Drive
Ames, IA 50011-4420

Jerry Hatfield
(515) 294-5723
hatfield@nstl.gov

John Prueger
(515) 294-7694
prueger@nstl.gov

Tim Hart/SMEX05
USDA-ARS
National Soil Tilth Laboratory
2150 Pammel Drive
Ames, IA 50011