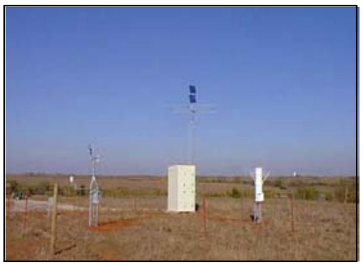
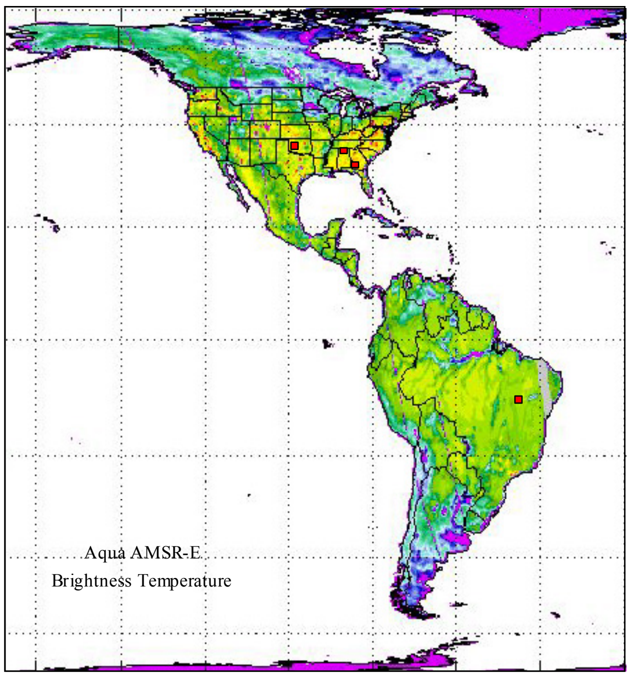
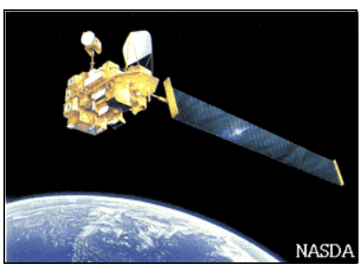
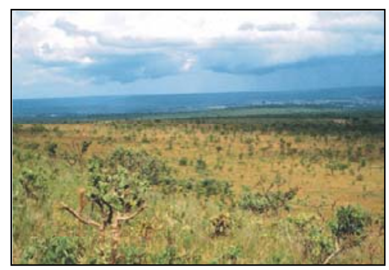
SOIL MOISTURE EXPERIMENTS IN 2003 (SMEX03)









Experiment Plan
June 2003

NASA Terrestrial Hydrology Program

AMSR-E

Aqua

USDA ARS Embrapa

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0 EXECUTIVE SUMMARY

Soil moisture field experiments have been very successful at addressing a broad range of science questions, focusing technology development and demonstration, and providing educational experiences for undergraduate and graduate students. The data have been used in studies that went well beyond the algorithm research, primarily due to an emphasis on developing map-based products.

For 2003, a soil moisture field experiment (SMEX03) is proposed that would support the NASA Terrestrial Hydrology Program Soil Moisture Mission science objectives, the NASA Global Water and Energy Cycle Research Program, the EOS Aqua Advanced Microwave Scanning Radiometer (AMSR) Project, and NOAA-DOD prototype land parameter algorithms utilizing data from the Special Sensor Microwave Imager (SSM/I) and Coriolis/Windsat. The objectives of SMEX03 are to understand land-atmosphere interactions, extend instrument observations and algorithms to a broader range of vegetation conditions, validate land surface parameters retrieved from AMSR data, and evaluate new instrument technologies for soil moisture remote sensing. We have chosen to address the combined objectives with ground/aircraft/spacecraft observations over sites in Oklahoma, Georgia, Alabama, and Brazil during the summer of 2003.

This report describes the elements of SMEX03 in detail. Coverage includes the aircraft and satellite soil moisture sensors, the land atmosphere experiments, aircraft missions, ground data collection, regional networks and test sites. A set of abstracts describing the research goals of the individual investigators is also included.

1 OVERVIEW AND SCIENTIFIC OBJECTIVES

The significance of a hydrologic state variable is expressed well in the recent description of NASA's Global Water and Energy Cycle research program. *Water is at the heart of both the causes and the effects of climate change. Ascertaining the rate of cycling of water in the Earth system, and detecting possible changes, is a first-order problem with regard to the renewal of water resources and hydrologic hazards. A more complete understanding of water fluxes, storage, and transformations in the land, atmosphere, and oceans will be the central challenge to the hydrological sciences in the 21st century. Improved knowledge and prediction of the water cycle can yield large benefits for resource management and regional economies if variability and uncertainties can be understood, quantified and communicated effectively to decision-makers and to the public. The overarching objective is to improve the understanding of the global water cycle to the point where useful predictions of regional hydrologic regimes can be made. This predictive capability is essential for practical applications to water resource management and for validating scientific advances through the test of real-life prediction.*

Soil moisture is the key state variable in hydrology: it is the switch that controls the proportion of rainfall that percolates, runs off, or evaporates from the land. It is the life-giving substance for vegetation. Soil moisture integrates precipitation and evaporation over periods of days to weeks and introduces a significant element of memory in the atmosphere/land system. There is strong climatological and modeling evidence that the fast recycling of water through evapotranspiration and precipitation is the primary factor in the persistence of dry or wet anomalies over large continental regions during summer. As a result, soil moisture is the most significant boundary condition that controls summer precipitation over the central U.S. and other large mid-latitude continental regions, and essential initial information for seasonal predictions.

A common goal of a wide range of agencies and scientists is the development of a global soil moisture observing system (Leese et al. 2001). Providing a global soil moisture product for research and application remains a significant challenge. Precise *insitu* measurements of soil moisture are sparse and each value is only representative of a small area. Remote sensing, if achievable with sufficient accuracy and reliability, would provide truly meaningful wide-area soil wetness or soil moisture data for hydrological studies over large continental regions.

Development and implementation of the remote sensing component of a global soil moisture observing system will require advancements in science and technology. Many aspects of the research require validation and demonstration, which can only be accomplished through controlled large-scale field experimentation. Large-scale field experimentation requires significant resources to be successful that are usually contributed from several programs.

Through a series of workshops and research announcements science and technology priorities for soil moisture remote sensing have been identified. Elements requiring field experimentation were identified and, to the extent possible, combined into Soil Moisture Experiments for 2002 (SMEX02) and 2003 (SMEX03). SMEX02 focused on microwave remote sensing of soil moisture in an agricultural setting. SMEX03 addresses validation and a range of natural vegetation types.

At the present time there are three programs that significantly influence the direction of research and the requirements of a soil moisture field experiment. These are the Soil Moisture Mission (HYDROS), Global Water & Energy Cycle (GWEC) Research and Analysis, the Advanced Microwave Scanning Radiometers (AMSR) on Aqua and ADEOS-II. The relevant science needs of each program are described in the following sections. These were merged into the SMEX03 experiment plan.

1.1 Soil Moisture Missions and HYDROS

Soil moisture was recognized by the NASA Post 2002 program as a critical measurement. As a result, several scientific reviews were conducted to define a Soil Moisture Mission (EX-4a). The final report can be found at http://maximus.ce.washington.edu/~tempcm/Post2002/smm3.html. This mission is based on a scientific consensus that an L band microwave remote sensing with high spatial resolution (<10 km) is needed for soil moisture. Alternative technology paths toward achieving this include combining large filled aperture antennas and radar and synthetic aperture radiometers. In a series of workshops the following science issues were identified hat needed to be addressed in field experiments:

- *Conduct a field experiment to collect passive microwave data to extend the calibration and validation to agricultural crops at peak biomass.*
- *Conduct a field experiment to collect passive microwave data to validate algorithm performance in regions with diverse topography.*
- *Conduct field experiments to collect passive microwave data to explore their usefulness in different types of forest canopies.*
- *Soil moisture retrieval algorithms that rely on ancillary data or multichannel data need to be compared*
- *Evaluations of soil moisture retrieval techniques with C band data can be performed using near future satellite missions such as Aqua and ADEOS-II. Conduct field experiments to collect aircraft and ground passive microwave data concurrent with AMSR over passes that will allow the validation of algorithms and definition of the scaling behavior of the measurements.*
- *Establish a series of validation sites where high quality ground data will be collected consistently.*
- *Airborne simulators for each proposed space instrument need to be built for pre-mission studies and mission-current validation flights.*

In response to the most recent ESSP AO, a soil moisture mission called HYDROS was developed and proposed as the first NASA EX-4a mission (website). HYDROS as shown in Figure 1 utilizes a filled aperture L band radiometer to provide a 40 km soil moisture product. This is combined with higher resolution radar data to produce a 10 km soil moisture product. HYDROS has been selected by NASA as an alternate mission and is currently in a risk reduction phase. As part of the risk reduction several tasks were identified, one of which specifically addresses demonstration of soil moisture algorithm performance using data from field experimentation.

As noted above, an alternative path for higher spatial resolution soil moisture products is synthetic aperture radiometry. ESA is currently developing a moderate resolution (50 km) L band two dimensional synthetic aperture radiometer. This is called the Soil Moisture Ocean Salinity (SMOS) mission. Although it will not have the desired EX-4a spatial resolution, such a mission would provide a first experience and a valuable science data product. At the present time, the launch is anticipated in 2007 http://www.esa.int/export/esaLP/smos.html. SMOS will utilize two dimensional synthetic aperture radiometry and will employ a variation on soil moisture algorithms that has not been rigorously calibrated and validated. The aircraft instruments utilized and field experiments conducted in SMEX03 are highly relevant to the SMOS project.

H Y D R O S

The Hydrosphere State Mission - A NASA Earth System Science Pathfinder | HYDROS will provide the first global views of Earth's changing soil moisture and land surface freeze/thaw conditions, leading to breakthroughs in weather and climate prediction and in the understanding of processes linking water, energy, and carbon cycles.

MEASUREMENT REQUIREMENTS:
- **Spatial Resolution:**
  - **Hydroclimatology soil moisture at 40km**
  - **Hydrometerology soil moisture at 10km**
  - **Freeze/thaw condition at 3km**
- **Temporal Sampling: Global in 2-3 days (2 days Above 50N)**
- **Mission Duration: 2 years**

INSTRUMENT:
- **L-band active/passive system**
- **Wide swath (1000 km) with constant look angle (39°)**

STATUS:
- **In risk reduction to address algorithm and partnership questions**

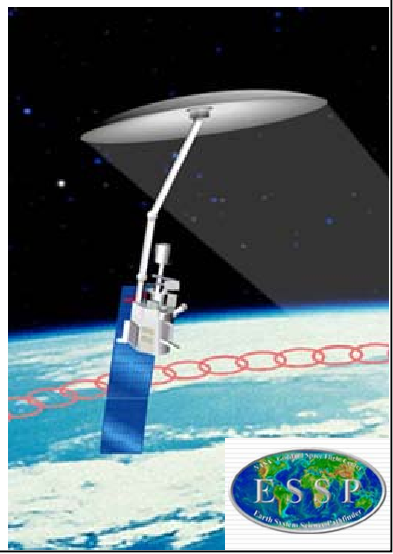

Figure 1. Features of the HYDROS mission.

1.2 Global Water & Energy Cycle (GWEC)

The most recent NASA initiative relevant to soil moisture research is the Global Water & Energy Cycle (GWEC) program. A current focus of this program is to explore the connection between weather-related fast dynamical/physical processes that govern energy and water fluxes, and climate responses and feedbacks. The objective of this research is to address the water and atmospheric energy cycles as a single integrated problem. This approach includes exploring the response of regional hydrologic regimes (precipitation, evaporation, and surface run-off) to changes in atmospheric general circulation and climate, and the influence of surface hydrology (soil moisture, snow accumulation and soil freezing/thawing) on climate.

Key scientific questions of this program are listed below along with specific issues that can be addressed by SMEX02 and SMEX03.

Is the global cycling of water through the atmosphere accelerating?

- Assessment of large-scale variability patterns and/or global trends in the occurrence of extreme hydrologic events (e.g., floods and droughts), based on the analysis of global remote

sensing and *insitu* observational data.
- Estimation of evaporation fluxes over the land and oceans, based on the assimilation of relevant observational data, and advanced parameterizations of model sub-grid scale processes (e. g. planetary boundary layer dynamics).
- Diagnostics of spatial and temporal changes in the distribution of surface energy and water storage; diagnostics of atmospheric responses to changes in ocean and land boundary conditions.

What are the effects of clouds and surface hydrologic processes on climate change?
- Use satellite remote sensing to improve land surface process modeling and the understanding of soil-vegetation-atmosphere interactions at regional or greater scales.
- Establish the interrelationships and feedbacks among clouds, precipitation, boundary layer, and land surface processes using improved coupled land-atmosphere models and assimilated data.
- Determine how land-atmosphere interactions, as affected by orography, vegetation, and soil, affect the predictability of large-scale terrestrial hydrology and atmospheric systems, including precipitation and runoff.

How are variations in local weather, precipitation, and water resources related to global climate change?

- Analysis of the effect of spring and early summer hydrologic anomalies (snow accumulation, soil moisture, soil freezing and thawing) on subsequent weather and precipitation patterns, and hydrologic phenomena (impacts on runoff, water storage, and inland water bodies), and how climate change might affect such anomalies in the future.
- Establish the scientific justification for future space-based observations of soil moisture, snow, surface water, or other hydrologic variables, through scientific analysis and field investigations, including the improvement in our understanding of the global water and energy cycle, floods and droughts, and climate change.
- Determine techniques for transferring regional (e.g. GAPP) hydrologic process understanding and prediction tools to other areas of the world, using remotely sensed and emerging Coordinated Enhanced Observing Period (CEOP) observations scheduled for 2001 to 2003.

1.3 Advanced Microwave Scanning Radiometer (AMSR)

While it will be years before a spaceborne L band instrument will be available, a major opportunity exists to maximize the AMSR instruments that are part of the recently launched Aqua and ADEOS-II satellites. A critical element of the AMSR program is validation of the soil moisture products. In addition, there are gaps in the knowledge base available for algorithm development, especially over vegetation. The EOS Aqua AMSR-E science team is highly involved in the SMEX03 program.

AMSR includes C and X band channels that offer improved capabilities for soil moisture sensing over current satellite options (even though it is less optimal than the proposed L band radiometers proposed for SMOS and HYDROS). The spatial resolution will be significantly better than its predecessor SMMR. Figure 2 is an example of composite coverage using the descending orbits for the month of July 2002.

AMSR research will contribute to efforts to understand and validate soil moisture retrievals from HYDROS and SMOS. Validating large footprint observations is a difficult task and in the past it has been neglected. We have to commit to collecting real soil moisture data, not surrogate variables, and these should correspond to the sensor measurement depth. What we learn in attempting this for AMSR will be of great benefit to current and future soil moisture missions.

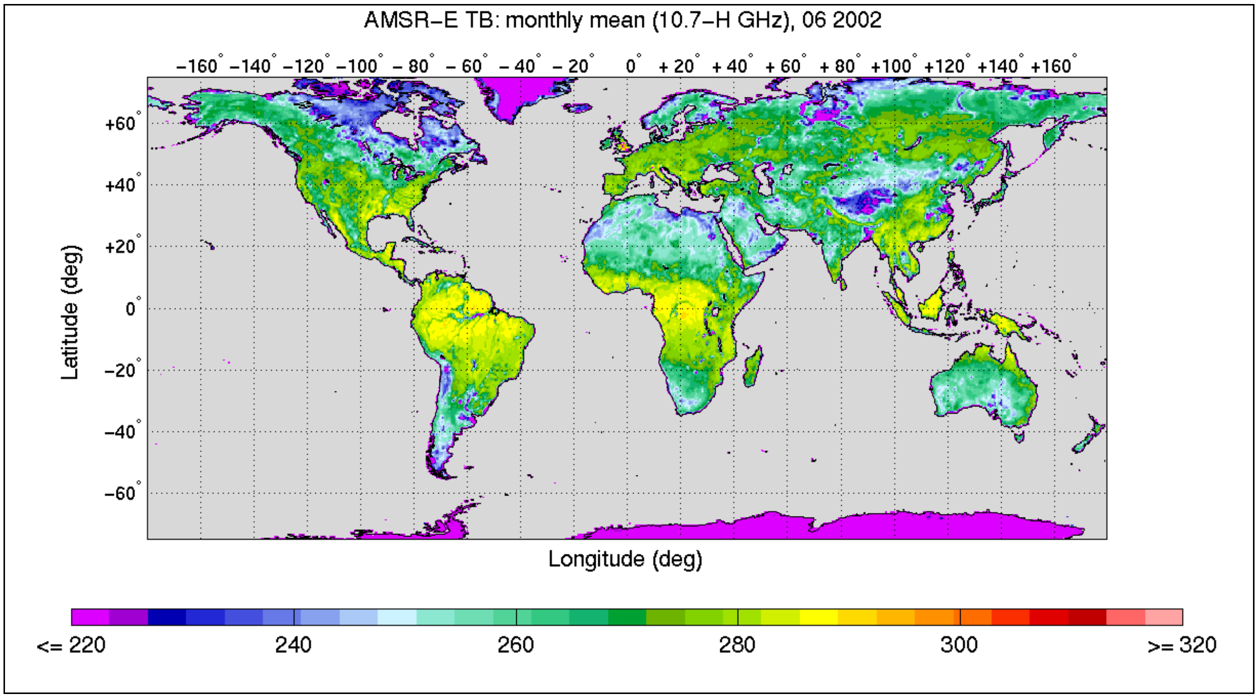

Figure 2. Average AMSR-E brightness temperatures over the U.S. for July 2002.

All AMSR research will contribute to efforts to understand and validate soil moisture retrievals from HYDROS and SMOS. Validating large footprint observations is a difficult task and in the past it has been neglected. We have to commit to collecting real soil moisture data, not surrogate variables, and these should correspond to the sensor measurement depth. What we learn in attempting this for AMSR will be of great benefit to HYDROS and future soil moisture missions.

1.4 Soil Moisture Field Experiment for 2003 (SMEX03)

Field experiments, in particular the series that has been conducted at the Southern Great Plains (SGP) site, have been very successful at addressing a broad range of science and instrument questions. The data have been used in studies that went well beyond the algorithm research, primarily due to an emphasis on developing map-based products.

For 2003, a field experiment is proposed that would support the science needs of Soil Moisture Missions (HYDROS and future), GWEC, and AMSR. Main elements of the experiment are to understand land-atmosphere interactions, validation of AMSR brightness temperature and soil moisture retrievals, extension of instrument observations and algorithms to more challenging vegetation conditions, and the evaluation of new instrument technologies for soil moisture remote sensing. We have chosen to address the combined objectives with ground/aircraft/spacecraft observations over sites in Oklahoma, Georgia, Alabama, and Brazil during the summer of 2003.

This report describes the elements of SMEX03 in detail. Coverage includes the aircraft and satellite soil moisture sensors, the boundary layer experiments, aircraft missions, ground data collection, regional networks and test sites. A set of abstracts describing the research goals of the individual investigators is also included.

2 SATELLITE OBSERVING SYSTEMS

2.1 Advanced Microwave Scanning Radiometers (AMSR and AMSR-E)

Two versions of the AMSR instrument were launched in 2002, AMSR-E on Aqua (http://wwwghcc.msfc.nasa.gov/AMSR/) in May and AMSR on ADEOS-II (http://adeos2.hq.nasda.go.jp/default_e.htm) in December. If the AMSR and AMSR-E projects continue as expected it is likely that data from both platforms will be available for SMEX03. SMEX03 is Algorithm development and validations are very important components of SMEX03.

As shown in Table 1, the lowest frequency is 6.9 GHz (C band). However, preliminary studies indicate that there is widespread radio frequency interference (RFI) in the C band channels. 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/ and AMSR at http://adeos2.hq.nasda.go.jp/shosai_amsr_e.htm. Figure 2 illustrates the type of coverage provided by AMSR-E. There are some small differences in the spatial resolution of AMSR and AMSR-E. The most important difference between the two satellites is the time of day of the overpasses. Aqua is 1:30 am and pm local time and ADEOS-II is 10:30 am and 10:30 pm. AMSR has a slightly larger antenna and higher altitude than AMSR-E resulting in slightly better spatial resolution and a swath of 1600 km.

Based on the results of SMMR and supporting theory (Wang, 1985, Ahmed, 1995, and Njoku and Li, 1999), we anticipate that this instrument will be able to provide soil moisture information in regions of low vegetation cover, less than 1 kg/m^2 vegetation water content. There are very few data sets that have been obtained that include the low frequencies of the AMSR instruments, especially dual polarization at off nadir viewing angles. Early research efforts did examine these frequencies in limited ground and aircraft experiments (Wang et al. 1983 and Jackson et al. 1984). Several of these data sets can be found at the following web site http://hydrolab.arsusda.gov/. Recent experiments have incorporated X and C band observations (Jackson and Hsu 2001, Jackson et al. 2002).

Table 1. 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

Aqua includes several other instruments of potential value to investigators in the 2003 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.
- Humidity Sounder for Brazil (HSB) is a passive scanning microwave radiometer with a total of 5 discrete channels operating in the range of 150 to 183 GHz.
- 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.

ADEOS-II also has several other sensors that are relevant to SMEX03; GLI, SeaWinds (described in a later section), and Polder. The Global Imager (GLI) is an optical sensor with 23 channels in the visible and near-infrared region (VNIR), 6 channels in the short wavelength infrared region (SWIR), and 7 channels in the middle and thermal infrared region (MTIR). The ground resolution is 1 km at the nadir. Channels in VNIR and SWIR have a resolution of 250 m at the nadir. Swath width is 1600 km. Some important channels that had not been utilized in the past include the near ultraviolet 0.38 micrometer, oxygen absorption at 0.76 micrometer, and water vapor absorption at 1.4 micrometer. It has 1.6, 2.2, 3.7, 8.6, 10.8, 12.0 micrometer channels, which correspond to atmospheric windows, and 6.7, 7.3 and 7.5 micrometer channels for acquiring vertical profile of water vapor field. More information can be found at http://adeos2.hq.nasda.go.jp/shosai_gli_e.htm.

The Polarization and Directionality of the Earth's Reflectance (POLDER) is a French CNES sensor that measures the polarization, and directionality and spectral characteristics of the solar light reflected by aerosols, clouds, oceans and land surfaces. Multi angle viewing is achieved by the along track migration at the spacecraft velocity of a quasi-square footprint intercepted by the total instantaneous ±43° × ±51° wide field of view. This footprint is partitioned into 242 × 274 elements of quasi-constant 7 km × 6 km resolution, imaged by a CCD matrix in the focal plane. Simultaneously, a filter and polarizer wheel rotates and scans eight narrow spectral bands in the visible and near infrared (443, 490, 564, 670, 763, 765, 865, 910 nm), and three polarization angles at 443, 670 and 865 nm. For more information see http://ceos.cnes.fr:8100/cdrom-00b/ceos1/satellit/polder/grndseg.htm.

2.2 Tropical Rainfall Mapping Mission (TRMM) Microwave Imager (TMI)

All of the study areas in SMEX03 fall within the coverage domain of the Tropical Rainfall Mapping Mission (TRMM) Microwave Imager (TMI). It is a five-channel, dual-polarized, passive microwave radiometer with a viewing angle of 52.75^{o} (see Table 2). Coverage is available between + and - 38 degrees latitude. The lowest frequency of the TMI is about half that of the SSM/I. Other interesting features of the TMI are its significantly higher spatial resolution (at 19 GHz the TMI is 18 km as opposed to the SSM/I 60 km). For most of the southern U.S. it is possible to obtain coverage every day. Details on this satellite can be found by starting at the following web site http://trmm.gsfc.nasa.gov/data/. There are several sources for these data and products. TMI data have been used in previous soil moisture mapping applications (Jackson and Hsu 2001).

Table 2. TMI Characteristics			
Frequency (GHz)	Polarization	Horizontal Resolution (km)	Swath (km)
10.7	V, H	38	790
19.4	V, H	18	790
21.3	H	16	790
37.0	V, H	10	790
85.5	V, H	4	790

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 3) 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°.

There may be as many as four satellites with the SSM/I on board in operation during SMEX03. The ascending equatorial crossing times (UTC) of the three currently available satellites are F13 (17:54), F14 (20:46), and F15 (21:20). F16 is scheduled for launch in summer 2003. SSM/I data are useful in some aspects of algorithm development and provide a cross reference to equivalent channels on the TMI and AMSR instruments. As part of SMEX03 an attempt will be made to provide validation of exploratory soil wetness and temperature products. 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.

Table 3. 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

2.4 Coriolis WindSat

WindSat is a multi-frequency polarimetric microwave radiometer developed by the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO) (http://www.pxi.com/windsat). It is one of the two primary instruments on the DoD Space Test Program's Coriolis Mission. The Coriolis satellite was successfully launched on January 6, 2003, with an expected life cycle of three years. The WindSat data may be available for SMEX03 on all sites spanning from June 24, 2003 to September 26, 3003, or possibly just the part of the experiment on the site of Brazil in the later date of September 2003 if there are delays in calibration.

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 89.0 GHz. The characteristics of the WindSat radiometer are listed in Table 4. The methods developed for algorithm development and validations for AMSR-E during SMEX03 may be applied to WindSat with minimal modifications.

Table 4. 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

2.5 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 that is of interest in SMEX03. Envisat has a sun synchronous polar orbit. Local overpass times in Oklahoma are close to those of the Aqua satellite (descending in early afternoon). The exact repeat cycle for a specific scene and sensor configuration is 35 days. 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.

The ASAR is a C band instrument with a wide variety of observing modes. It is the alternating polarization (AP) mode that is of greatest interest to soil moisture. In this mode two polarization combinations 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.

In contrast to the ERS SARs, which had a fixed swath position (23° mid-swath incidence angle), ASAR Image Mode will provide data acquisition in the seven different swath positions listed in Table 5, 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 is viewing a different area across track. In order to get all IS positions for the same ground location a series of days is required.

Table 5. 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

There are a limited number of data products available in dual polarization mode. Those of interest include:

- Alternating Polarization Mode Precision Image (APP)
- 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.

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 all U.S. sites concurrent with ground data collection will be requested. A more comprehensive data set will be acquired over the Little Washita Watershed. Data set selection is currently being reviewed. Table 6 shows requestedl coverage during the primary ground sampling for U.S. sites during SMEX03.

The MEdium Resolution Imaging Specrometer Instrument (MERIS) 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 (Table 7), 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. MERIS data have been requested for daytime passes on June 29, July 2, 5, 8, 12, 15,18, 21, and 24 at a nominal time of 11:00 am CDT.

Table 6. Dates of Requested ASAR Coverage During SMEX03						
Site/Study	Polarizations	Ascending (night) Descending (midday)	Incidence Range	Track	Frame	Date
Little Washita Long Term Soil Moisture Network	VV-VH	A	IS2	2019	693	326
	VV-VH	A	IS2	2019	693	430
	VV-VH	A	IS2	2019	693	604
	VV-VH	A	IS2	2019	693	709
	VV-VH	A	IS2	2019	693	813
	VV-VH	A	IS2	2019	693	917
	VV-VH	A	IS2	2019	693	1022
OK-SMEX03	VV-VH	D	IS1	1112	2907	715
	VV-VH	A	IS1	1019	693	709
	VV-VH	D	IS3	3069	2907	712
	VV-VH	A	IS3	3062	693	712
	VV-VH	D	IS4	4026	2907	709
	VV-VH	A	IS5	5105	693	715
	VV-VH	D	IS6	6484	2907	706
GA-SMEX03	VV-VH	D	IS2	2369	2979	628
	VV-VH	A	IS2	2362	621	628
	VV-VH	A	IS3	3405	621	701
	VV-VH	D	IS4	4326	2979	625
AL-SMEX03	VV-VH	A	IS1	1405	693	701
	VV-VH	A	IS2	2405	693	701
	VV-VH	D	IS4	4412	2907	701
	VV-VH	D	IS5	5412	2907	701

Table 7. MERIS Bands	
Band.	Band Center nm)
1	412.5
2	442.5
3	490
4	510
5	560
6	620
7	665
8	681.25
9	705
10	753.75
11	760
12	775
13	865
14	890
15	900

2.6 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 can view the entire surface of the Earth every 1-2 days. MODIS is a whisk broom scanning imaging radiometer consisting of across-track scan mirror, collecting optics, and a set of linear arrays with spectral interference filters located in four focal planes. MODIS has a viewing swath width of 2330 km (the field of view sweeps ± 55° cross-track) and will provide high-radiometric resolution images of daylight-reflected solar radiation and day/night thermal emissions over all regions of the globe. Its spatial resolution ranges from 250 m to 1 km at nadir, and the broad spectral coverage of the instrument (0.4 - 14.4 μm) is divided into 36 bands of various bandwidths optimized for imaging specific surface and atmospheric features. The observational requirements also lead to a need for very high radiometric sensitivity, precise spectral band and geometric registration, and high calibration accuracy and precision. Coverage time is about 16:15 UTC. MODIS data for SMEX03 regions of interest will be acquired by CODIAC.

ASTER coverage will be requested for the Oklahoma region for several dates during the planned study period (minimum of July 2 and 18).

2.7 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. Band 8 (panchromatic) for Landsat 7 has a 10 m resolution. Additional details on the Landsat program and data can be found at http://geo.arc.nasa.gov/sge/landsat/landsat.html. The Landsat paths and row reference numbers for the SMEX03 study regions are listed in Table 8. The projected dates of coverage for each site are listed in Table 9.

Table 8. SMEX03 Landsat TM Path and Row Numbers

Region	Path/Row
OK South (OS) -Little Washita (LW) Oklahoma	28/36
OK North (ON) Oklahoma	28/35
Little River (GA) Georgia	18/38
Huntsville (AL) Alabama	20/36 and 21/36
Cerrado Region (BZ) Brazil	220/68 and 220/69

Table 9. SMEX03 Landsat TM Days of Observation

OS-ON (28/35-36)		GA (18/38)		AL				BZ (220/68)
				(20/36)	(21/36)	(20/36)	(21/36)	
TM 7	TM 5	TM 7	TM 5	TM 7		TM 5		TM 7
April 13	April 21	April 23	April 15	April 2	April 12	April 13	April 20	Sept. 5
April 29	May 7	May 9	May 1	April 21	April 28	April 29	May 6	**Sept. 21**
May 15	May 23	May 25	May 17	May 7	May 14	May 15	May 22	Oct. 7
May 31	June 8	June 10	June 2	May 23	May 30	May 31	June 7	
June 16	June 24	**June 26**	*June 18*	June 8	June 15	June 16	*June 23*	
July 2	*July 10*	July 12	*July 4*	**June 24**	**July 1**	*July 2*	July 9	
July 18	*July 26*	July 28	July 20	July 10	July 17	July 18	July 25	

2.8 Advanced Very High Resolution Radiometer (AVHRR)

This is a TIROS-N series satellite designed to operate in a near-polar, sun-synchronous orbit. During SMEX03 it is anticipated that 2 satellites may be providing AVHRR data Currently these NOAA 15 (morning coverage) and NOAA 16 (afternoon coverage). The AVHRR sensor collects data in the visible and infrared regions of the electromagnetic spectrum and has a spatial resolution of approximately 1 km. Additional information on these data can be found at http://www.saa.noaa.gov/.

Data can be acquired in three formats from the satellite. High Resolution Picture Transmission (HRPT) data are full resolution image data transmitted to a ground station, as they are collected. The average instantaneous field-of-view of 1.4 milliradians yields a HRPT ground resolution of approximately 1.1 km at the satellite nadir from the nominal orbit altitude of 833 km (517 mi). Local Area Coverage (LAC) is full resolution data that are recorded on an onboard tape recorder for subsequent transmission during a station overpass. Resolution is the same as HRPT. Global Area Coverage (GAC) data are derived from a sample averaging of the full resolution AVHRR data. Four out of every five samples along the scan line are used to compute one average value and the data from only every third scan line are processed, which results in a 1.1 km by 4 km resolution. AVHRR data for SMEX03 regions of interest will be acquired by CODIAC.

2.9 Geostationary Operational Environmental Satellites (GOES)

GOES satellites provide continuous monitoring in selected visible and infrared electromagnetic channels. Coverage of Iowa is currently provided by GOES-8. Of particular interest to this project is the imager. This is a multichannel instrument (0.65, 3.9, 6.7, 11, and 12 micrometers) that senses radiant energy and reflected solar energy from the Earth's surface and atmosphere. The resolution is 1 km for the visible and 4 km for the infrared channels. Additional information can be found at http://www.saa.noaa.gov/. GOES data for SMEX03 regions of interest will be acquired by CODIAC.

2.10 SeaWinds QuikSCAT

SeaWinds is a radar scatterometer on QuikSCAT. It was launched in 1999 and was designed to measure near-surface wind speed over the Earth's oceans. A second instrument was launched on ADEOS-2 in December of 2002, and is expected to be operational by mid-2003. SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna spins at a rate of 18 rpm, scanning two pencil-beam footprint paths at incidence angles of 46^{o} (H-pol) and 54^{o} (V-pol). The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on Earth's surface with an 1800 km swath. QuikSCAT sampling at the latitude of Iowa is approximately two times daily; and ADEOS-2 is anticipated to have similar coverage.

QuikSCAT is in a sun-synchronous, 803-kilometer, circular orbit with a local equator crossing time at the ascending node of 6:00 A.M. +/- 30 minutes. The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction. There is considerably overlap of these footprints, with approximately 8-20 of these ellipses with centers in a 25x25 km box on the surface. Signal processing provides commandable variable range resolution of approximately 2- to 10-km. The nominal resolution is approximately 6 km—an effective range gate of 0.5 msec. Additional information is available at http://podaac.jpl.nasa.gov/quikscat/qscat_doc.html.

Gridded (0.2x0.2 degree) daily observations are available through BYU. Documentation is available at http://podaac.jpl.nasa.gov:2031/DATASET_DOCS/dLongSigBrw.html, and data orders can be placed through linked pages. Non-binned data are available, on tapes and through FTP, from the PO.DAAC (http://podaac.jpl.nasa.gov/quikscat/qscat_data.html). For the ADEOS-II sensor NOAA will process data the data and then forward them to meteorological agencies around the world and to the general public. In addition, data will be processed by the SeaWinds Project at JPL and then sent to NASA's Physical Oceanography Distributed Active Archive Center for archiving and distribution. JPL will present the science data on a web page at http://winds.jpl.nasa.gov..

3 AIRCRAFT REMOTE SENSING INSTRUMENTS

3.1 Polarimetric Scanning Radiometer (PSR)

The PSR is an airborne microwave imaging radiometer operated by the NOAA Environmental Technology Laboratory (Piepmeier and Gasiewski 2001) for the purpose of obtaining polarimetric microwave emission. It has been successfully used in several major experiments including SGP99 and SMEX02 (Jackson et al. 2002).

A typical PSR aircraft installation is comprised of four primary components: 1) scanhead, 2) positioner, 3) data acquisition system, and 4) software for instrument control and operation. The scanhead houses the PSR radiometers, antennas, video and IR sensors, A/D sampling system, and associated supporting electronics. The scanhead can be rotated in azimuth and elevation to any arbitrary angle. It can be programmed to scan in one of several modes, including conical, cross-track, along-track, and spotlight. The positioner supports the scanhead and provides mechanical actuation, including views of ambient and hot calibration targets. The PSR data acquisition system consists of a network of four computers that record several asynchronously-sampled data streams, including navigation data, aircraft attitude, scanhead position, radiometric voltage, and calibration target temperatures. These streams are available in-flight for quick-look processing.

During SMEX03, the PSR/CX scanhead will be integrated onto the NASA WFF P-3B aircraft in the aft portion of the bomb bay. The PSR/CX scanhead is an upgraded version of the previously successful PSR/C scanhead used during SGP99 and was used in SMEX02 (Figure 3 and Table 10). The installation will utilize the NOAA P-3 bomb bay fairing, and will locate the PSR immediately aft of the NASA GSFC 2DSTAR L-band radiometer.

The PSR/CX scanhead will have the polarimetric channels listed in Table 10 for SMEX03. The system will be operated in two imaging modes, both using conical scanning. Mapping characteristics are described in Table 11. Figure 4 shows the results of one day of mapping brightness temperature using the PSR in SGP99.

At the end of a each set of flight lines a steep (~60 degree) port roll will be requested for the purpose of calibrating the PSR radiometers using cold sky looks. Additional details on the PSR not presented here can be found at http://www1.etl.noaa.gov/radiom/psr/.

Figure 3. PSR/C scanhead installed on the NASA P3-B aircraft during the SGP99 experiment.

Table 10. PSR/CX Channels for SMEX03

Frequency (GHz)	Polarizations	Beamwidth
5.82-6.15	V,h	10°
6.32-6.65	V,h	10°
6.75-7.10 *	v,h,U,V	10°
7.15-7.50	V,h	10°
10.6-10.8 *	v,h,U,V	7°
10.68-10.70 *	V,h	7°
9.6-11.5 um IR	V+h	7°

* Indicates close to an AMSR-E channel.

Table 11. PSR Flightline and Mapping Specifications for SMEX03

	Wide Area Imaging	High-Resolution Imaging
Location	Regional	Watershed
Altitude (AGL) in m	7300	1800
Number of parallel flight lines	4	4
Flight line length (km)	150	50
Flight line spacing (km)	19	4.75
Scan period (seconds)	8	3
Incidence angle (deg)	55	55
3-dB footprint resolution	3.0 km at 6 GHz 2.0 km at 10 GHz	750 m at 6 GHz 500 m at 10 GHz
Sampling	Oversampling above Nyquist	Nyquist

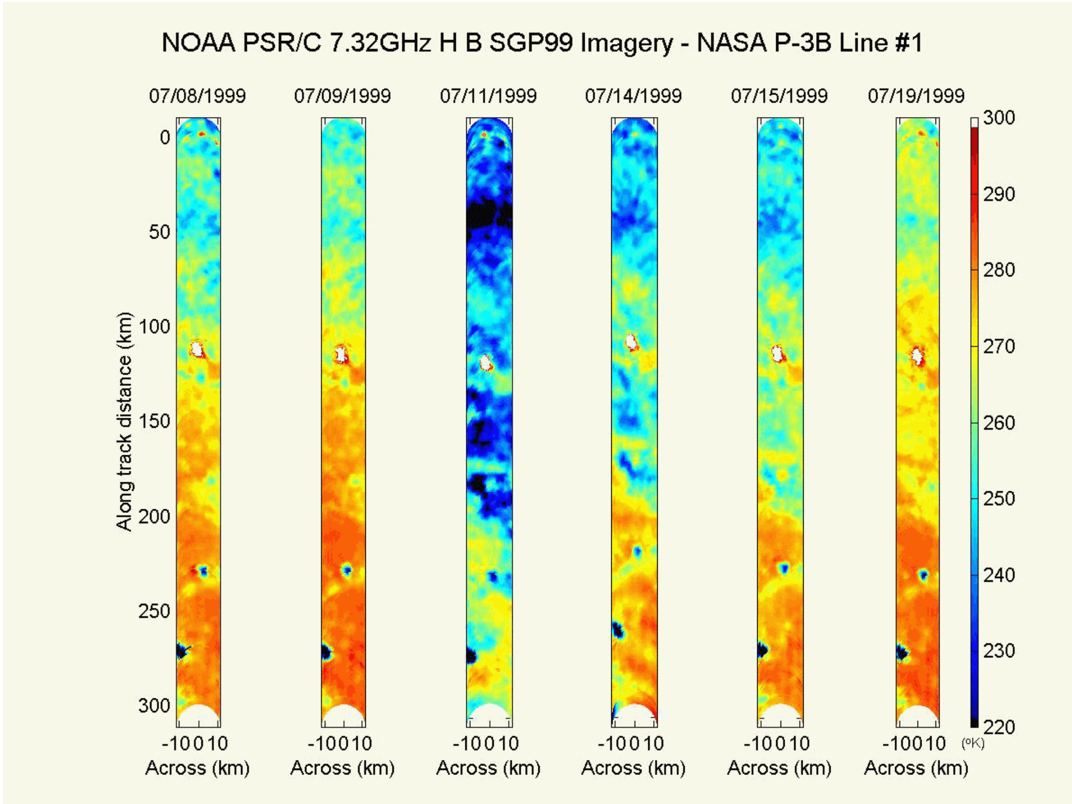

Figure 4. SGP99 PSR/C conically-scanned brightness temperature imagery 7.325 GHz channel, H-polarization, North looking.

3.2 Two Dimensional Synthetic Aperture Radiometer (2DSTAR)

Aperture synthesis is an interferometric technique that has the potential to break through the barrier on resolution set by antenna size on future passive microwave instruments in space. The technique has been applied successfully to earth remote sensing using synthesis in one dimension (the L-band radiometer, ESTAR) (Le Vine et al. 1990 and 1994). New research is being conducted at the Goddard Space Flight Center and University of Massachusetts to go the next step and demonstrate the potential of aperture synthesis in both dimensions for meeting future remote sensing goals. An aircraft prototype instrument operating at L-band is being built by this team with ProSensing Inc. This prototype uses digital correlation and employs a configurable antenna that can be arranged into several thinned array configurations.

2DSTAR consists of three major subsystems, the antenna array, the RF receiver and the digital processor. The antenna array consists of a rectangular array of dual polarized, patch antennas tuned to L-band (1.413 GHz). In the 2DSTAR instrument, the digital processor averages for a minimum time (on the order of 0.1 second, but adjustable) and then hands the products over to the data system, which stores them and does further averaging as desired. Figure 5 shows the detail of the antenna array. A fully populated, rectangular array of patches is being built. However, only some of the patches will be connected to a receiver. For example, the instrument could operate as a thinned array in the shape of a cross, "+", as shown in Figure 5. A fully populated array is being built so that different configurations can be tried and to minimize effects of mutual coupling by providing a common environment for each patch.

The 2DSTAR instrument has been designed to operate from an aircraft (the NASA P-3) in a nadir looking orientation as shown in Figure 6. Using aperture synthesis, one obtains a map of the entire field-of-view of each individual antenna in each integration cycle. This allows for a number of processing options. For example, it allows one to arrange the pixels in the equivalent of a conical scan as illustrated in Figure 6 or to use the multiple looks that one obtains with each pixel as it moves through the field-of-view to reduce noise by averaging or to retrieve additional data. In the later case, because a given pixel is viewed at different incidence angles as it moves through the field of view, it may be possible to retrieve parameters such as attenuation in the canopy in the case of a soil covered with a layer of vegetation.

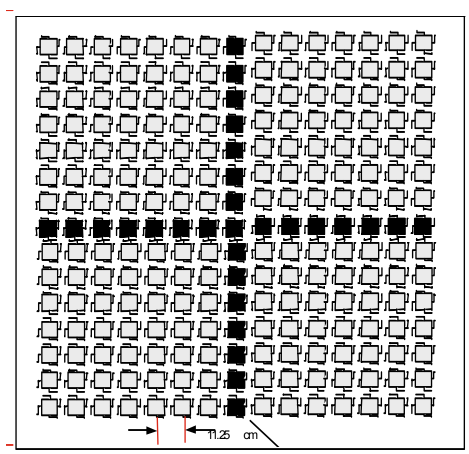

Figure 5. Antenna patch array shown configured for measuring using a cross "+" configuration.

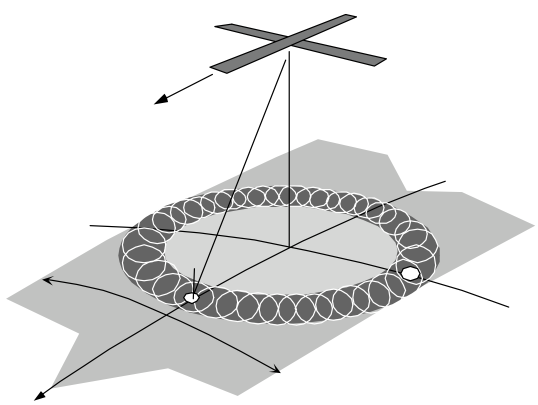

Figure 6. A thinned array in a nadir-pointing mode illustrating the potential for conical scanning.

3.3 Global Positioning System (GPS) Bistatic Radar

Use of Global Positioning System (GPS) signals reflecting off of land and ocean surfaces is under research as a new, potentially inexpensive remote sensing tool [Armatys et al., 2000, Masters et al., 2000, 2001]. The GPS Bistatic Radar instrument measures L-band GPS satellite signals reflecting from the land surface to estimate soil moisture. Simultaneous measurement of both direct and surface-reflected GPS signals constitutes a bistatic radar system, with transmitters located at GPS satellites and a separate receiver located on an aircraft platform. Land surface bistatic radar cross sections are estimated using relative measurements of the reflected signal power and measurements of the direct, line-of-sight signal power. Surface soil moisture can subsequently be inferred from the bistatic cross section estimates along with information on the surface roughness characteristics and soil properties. A general illustration of how this is used for remote sensing is shown in Figure 7.

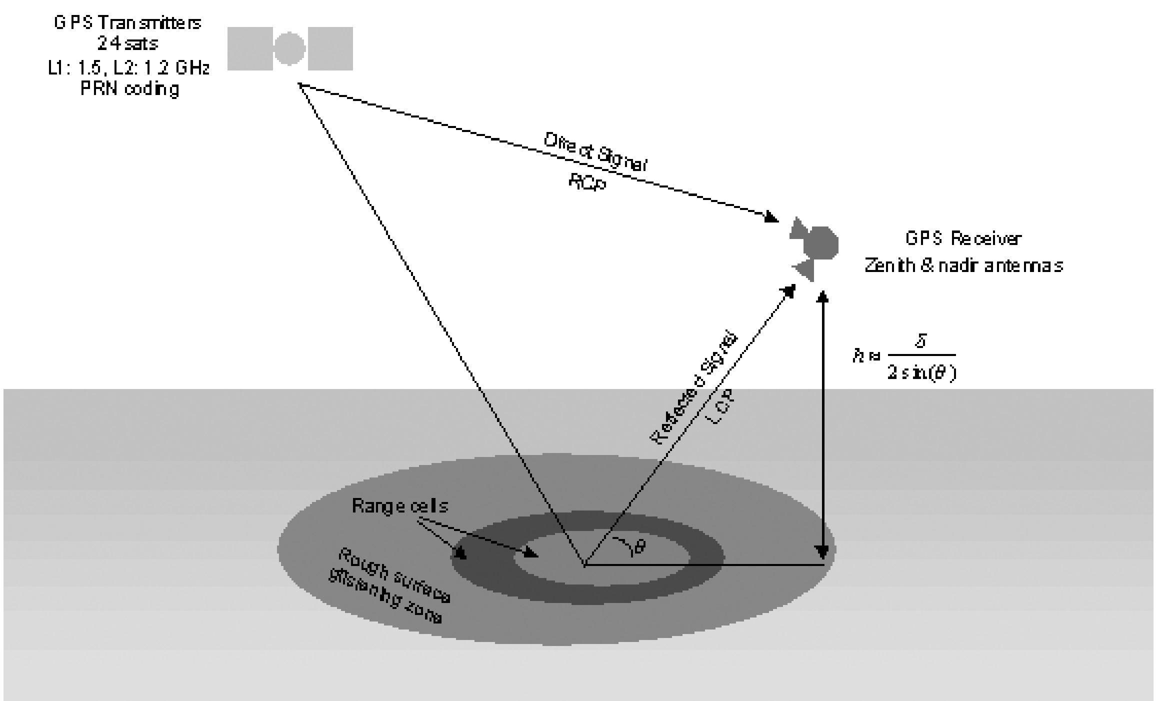

Figure 8. Bistatic radar configuration of reflected GPS signals.

GPS Bistatic Radar Concept

The GPS satellite constellation currently broadcasts a civilian-use carrier signal at 1.57542 GHz, which is bi-phase modulated by satellite-specific pseudorandom noise codes. The signals are encoded with timing and navigation information so that the receiver can calculate the positions of the transmitting satellites and solve for its own position and time by measurement of pseudoranges from at least four satellites. These direct signals are normally received by a low-gain, hemispherical, zenith antenna. These same GPS signal transmissions also reflect off of the Earth's surface and can be measured with a nadir-viewing antenna at longer delays than the direct signal. The reflected signal is modified by the roughness and dielectric properties of the scattering surface. If the roughness is known *a priori* or is assumed constant over time, the ratio of reflected signal power to the direct signal power is an indicator of the dielectric constant of the surface. Therefore, this ratio can be used to temporally sense changes in soil moisture in the top 5 cm of the surface. Additionally, the polarization of the RCP direct signal is predominantly LCP upon surface reflection for most incidence angles. Because the geometry is variable depending upon the slowly changing transmitter and receiver positions, a hemispherical nadir antenna is used.

The received signals are cross-correlated with a replica signal (1 ms code length) to produce a narrower, approximate 1 μs correlation pulse. This procedure is similar in design to pulse compression radar receivers. Previous efforts have been focused on the distribution or spreading of the reflected signal power over time delay, which is an indicator of the roughness of the reflecting surface. For soil moisture sensing, the observable is the ratio of the magnitudes of the reflected and direct signal powers.

In bistatic radar systems, scattering is mainly forward, and the radar cross section is expressed as a normalized bistatic cross section. For the specific case of an aircraft receiving direct and land-reflected GPS signals, we use an analytical scattering model [Zavorotny and Voronovich, 2000]. The model is based upon physical optics and will employ a rough surface estimated from the SMEX03 terrain.

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Delay Mapping Receiver

The current GPS Bistatic Radar receiver is based upon a modified Plessey 12-channel C/A code receiver built by NASA Langley Research Center. New receivers, such as the APL sampling receiver, are currently being developed for GPS bistatic radar applications, and their use in SMEX03 is possible. The Plessey receiver is comprised of a single board containing two RF front-ends and a correlator, which is connected to a PC/104 computer in a small, lightweight chassis (20x15x15 cm). The RF front-ends perform automatic gain control, down conversion, and IF sampling. The PC/104 computer serves as the controller and data logger for both GPS navigation functions and recording the reflected and direct signal powers.

In the Delay Mapping Receiver (DMR) mode of operation, five channels track direct signals in a conventional, closed-loop fashion. The pseudorange and Doppler measurements made by these channels are used to form navigation solutions. The other 14 correlators (two for each of seven channels) are controlled in an open-loop mode to measure reflected signal power at specific delays relative to one or more of the direct signal channels. For each of the slaved reflection correlators, one hundred 1 ms correlator samples are averaged to produce an estimate of reflected signal power at a rate of 10 Hz. The reflected signal power is sampled in discrete bins around the time delay corresponding to the arrival of the signal from the specular reflection point. The direct and reflected signal power measurements are stored on internal disk for later analysis. In the DMR mode of operation, the bistatic radar receiver can operate for long periods without user intervention.

In SMEX03, the GPS Bistatic Radar will fly on the NASA P-3. The GPS Bistatic Radar instrument is currently installed on the NASA P-3 and collecting data during the CLPX03 and AMSRICE03 missions. It will remain on the NASA P-3 for all of the SMEX03 campaigns. For SMEX03, software changes will be introduced to collect bistatic radar measurements from up to five simultaneous satellite reflection geometries. This will provide five separate measurements of surface bistatic cross sections at varying incidence angles. The radar footprint is nominally 20 m diameter at 1 km altitude and varies as a function of the surface roughness and aircraft altitude.

MGRS Sampling Receiver

A sampling GPS receiver instrument will also fly on the NASA P-3. The Multiple GPS Reflections Recording System (MGRS) was originally developed at the Johns Hopkins University/Applied Physics Laboratory. It is based on a concept proposed to APL and supported by S. Katzberg (NASA/LaRC). This system was successfully tested in 2002 during flights above the Atlantic Ocean. The system records all possible in-phase and quadrature GPS signals (from all available satellites, both direct and reflected from Earth's surface) with a Nyquist frequency.

These raw data are stored in removable hard disks. The data are processed after the flight using special software in order to produce power waveforms containing information about surface roughness and soil moisture. The MGRS instrument provides more flexibility in processing GPS bistatic radar data than the DMR but requires post-processing using a software receiver. The two instruments will be synergistic in understanding GPS bistatic radar applied to soil moisture remote sensing. Simultaneous measurements of soil moisture done by both the DMR and the MGRS will also be a very important test of the new MGRS recording system. During SMEX03, the MGRS instrument will be taken on a loan by NOAA/ETL and installed onto the NASA WFF P-3B aircraft. The NOAA/ETL participant V. Zavorotny will operate the MGRS during the SMEX03 and work with processed data in order to retrieve the soil moisture and compare it to available airborne and surface truth measurements.

Data Analysis

The GPS-based measurements will be evaluated in conjunction with the observations made by the NOAA PSR and NASA ESTAR instruments and the ground sampling of soil moisture. The GPS Bistatic Radar measurement parameters are presented in Table 12. These tests will guide future development of optimized receivers and processing algorithms to retrieve soil moisture and surface roughness information from GPS Bistatic Radar measurements.

The University of Colorado at Boulder and NOAA/ETL will operate the GPS Bistatic Radar instruments. For more information on GPS Bistatic Radar remote sensing, visit http://ccar.colorado.edu/~dmr.

Table 12. GPS Bistatic Radar Parameters	
Frequency	1.575 GHz
Polarization	LCP
Incidence Angle	0-60 deg (predicted by satellite geometry)
Spatial Resolution	Variable w/ height & angle (20 m @ 1 km alt.)
Footprints	Up to 12 simultaneous footprint zones

3.4 Airborne Synthetic Aperture Radar (AIRSAR)

AIRSAR is a side-looking radar instrument developed by the Jet Propulsion Lab http://airsar.jpl.nasa.gov/. It has several operating modes. In SMEX03 the polarimetric (POLSAR) will be used. In POLSAR mode, fully polarimetric data are acquired at all three frequencies C-, L-, and P-band. Fully polarimetric means that radar waves are alternatively transmitted in horizontal (H) and vertical (V) polarization, while every pulse is received in both H and V polarizations. Therefore, there are four combinations; HH, VV, HV and VH. Basic parameters of the AIRSAR are listed in Table 13. It is anticipated that the 20 MHz bandwidth data will be requested. Data will be collected only in Oklahoma.

Table 13. AIRSAR Parameters			
Channel	C	L	P
Frequency GHz	5.29875	1.2375	0.4275
Pixel Spacing 20 MHz Bandwidth (m)	10 x 10		
Swath Width 20 MHz Bandwidth m	15		

4 GENERAL EXPERIMENT DESIGN

4.1 Regional Soil Moisture Ground Sampling

Ground based soil moisture measurements will be made for a variety of investigations. How these will be integrated for each of the study regions will vary but should be based upon the general model shown in Figure 8. The three primary objectives are:

- 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 is called Regional sampling.
- Provide calibrated continuous soil moisture for water balance investigations. This is called Tower sampling.
- 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 is called Field sampling.

The goal of Regional soil moisture sampling is to provide a reliable estimate of the VSM mean and variance within a single satellite passive microwave footprint (~50 km) and multiple EASE-grid 25 km cells at the nominal time of the Aqua or ADEOS-II AMSR overpass (1330 or 1030 local standard time). The exact center location and orientation of the satellite footprint will vary with each overpass. A grid of sites will be sampled each day that covers a domain of approximately 50 km by 100. The exact size and layout will vary at each of the five Regional study areas. Spacing will be nominally 8-10 km between sites. The layout should attempt to provide a minimum of six sites within each 25 km square EASE-grid cell. A single location within each of these sites will be sampled. As noted, these measurements are used primarily to support the AMSR based microwave investigations; therefore, the Regional sampling will be conducted within one to two hour time window of the satellite overpass.

The primary measurement made will be the 0-6 cm dielectric constant at a single location in each site using the Theta Probes (TP). Dielectric constant is converted to volumetric soil moisture using a calibration equation. There are built in calibration equations, however, we will develop field and site specific relationships using supplemental either volumetric soil moisture or gravimetric soil moisture and bulk density sampling. Each sampling day, a coring tool will be used to extract a single VSM sample of the 0-3 cm and 3-6 cm soil layers. The composite set of VSM samples and TP dielectric constants will be used to calibrate the TP for each site. Figure 9 illustrates how regional sampling was performed in SMEX02.

An integral part of the Regional sampling will be the existing continuous soil moisture sampling sites (Towers). Each of these will be sampled to contribute to the calibration of the insitu sensors.

Do not enter any field that you do not have permission to enter. 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.

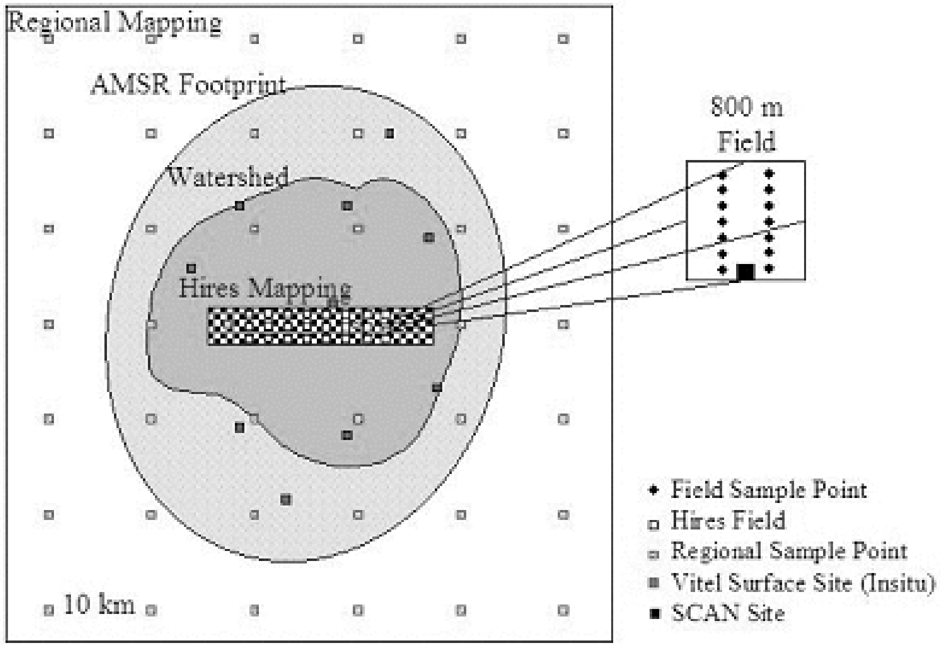

Figure 8. The general approach used in SMEX03 soil moisture sampling.

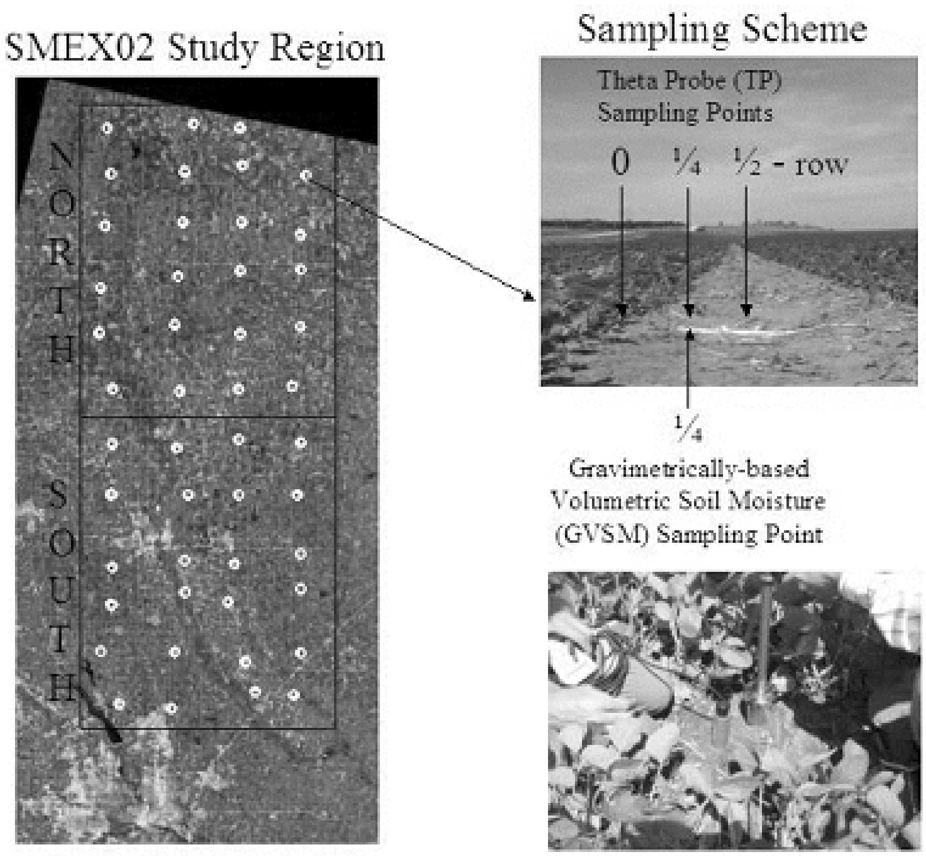

Figure 9. Regional soil moisture sampling in SMEX02.

4.2 Field Soil Moisture Ground Sampling

The goal of soil moisture sampling in the Field sites is to provide a reliable estimate of the mean and variance of the surface 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.

The primary measurement made will be the 0-6 cm dielectric constant (voltage) at fourteen locations in each field using the Theta Probe (TP). Dielectric constant is converted to volumetric soil moisture using a calibration equation. There are built in calibration equations, however, we will develop field specific relationships using supplemental volumetric soil moisture and bulk density sampling. At four specified locations within each site the volumetric soil moisture (GSM) will be sampled on each day of sampling. A coring tool will be used to extract a single VSM sample of the 0-3 cm and 3-6 cm soil layers. The composite set of VSM samples and TP dielectric constants will be used to calibrate the TP for each site. 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 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.

4.3 Soil and Surface Temperature

The objectives of the soil and surface temperature are nearly identical to those of soil moisture. However, 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 as depth increases. On the other hand surface temperature can change rapidly with varying 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.

The surface temperature will be sampled using handheld infrared thermometers (IRT) only at all locations with insitu thermal infrared sensors. The primary purpose of this sampling is to provide verification of the insitu measurements. Some investigators may collect surface temperature for specific investigations.

The soil temperatures will be obtained using a temperature probe inserted to depths of 1 cm, 5 cm, and 10 cm depths. Regional temperature sampling will be conducted at the specific single location selected for sampling in the site. Field temperature sampling will be conducted at the four locations selected for gravimetric sampling.

4.4 Vegetation, Land Cover and Surface Roughness

Vegetation biomass and soil moisture sampling will be performed on a selected number of representative sites within each Region. The measurements that will be made are:

- Plant height
- Ground cover
- Stand density
- Phenology
- Leaf area (LAI)
- Green and dry biomass
- Surface roughness
- Surface reflectance (Oklahoma South Only)

Non-destructive sampling of LAI using LiCor LAI-2000 instruments will be conducted. The diversity of vegetation types among the locations will require slightly different approaches. Surface roughness measurements will be made in conjunction with vegetation sampling. Surface reflectance measurements will be made at as many sites as possible using CROPSCAN instruments.

Land cover will be mapped using satellite imagery. To support this activity a number of sites will be surveyed in each region for algorithm training. We will rely upon Landsat imagery for this effort.

4.5 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

SCAN sites are located in the OS and GA and several are distributed over AL. These sites are summarized in Table 14.

Table 14. SCAN Sites in the SMEX03 Regions				
Site ID	Name	Latitude (Deg.)	Longitude (Deg.)	Elevation (m)
2022	El Reno, OK	35.550	-98.017	427
2023	Little Washita, OK	34.950	-97.983	358
2027	Little River, GA	31.500	-83.550	107
2053	WTARS, AL	34.900	-86.533	191
2054	Hytop, AL	34.867	-86.100	544
2055	Hodges, AL	34.450	-86.150	194
2056	Stanley Farm, AL	34.433	-86.683	194
2057	AAMU, AL	34.783	-86.550	262
2058	Hartselle USDA, AL	34.433	-87.000	193
2059	Newby Farm, AL	34.850	-86.883	193

4.6 Aircraft Operations and Flightlines

The PSR, 2DSTAR and GPS instruments will be installed on the NASA WFC P3-B aircraft. AIRSAR will fly on the NASA DC-8. An aircraft briefing will be conducted each day. As in previous missions, the goals of the experiment design are to collect data for both algorithm development/verification and soil moisture mapping. The extent and scale of the mapping must satisfy the range of objectives of the land-atmosphere and AMSR components of SMEX03. The following section describes the general aspects of the flight missions.

The P-3B operates from the NASA Wallops Flight Facility in Wallops Island, VA. Details on the aircraft can be found at http://www.wff.nasa.gov/. It will have the PSR, 2DSTAR, and GPS sensor systems on boardl. The primary mission of the P3-B is to collect both low and high altitude data over the study regions with the PSR instrument. High altitude lines are more important than the low altitude lines. Another very important objective is to collect data with the 2DSTAR over the regions. Mission design and operations are dependent on the PSR and not the 2DSTAR.

Flights will be conducted during the day in order to match either the nominal Aqua overpass time of 1330 or ADEOS-II at 10:30 am. Each flight will be approximately 4 hours in duration. Since there are multiple deployment sites (GA/AL, OK, and BZ) the details will be presented in each regional section of the plan. Table 15 summarizes the key features.

Table 15. Summary of Aircraft Mission Features.				
Region	Dates	Aircraft Base	Distance to Start (km)	No. Lines
GA	June 23-July 2	Huntsville Int. Airport (HSV)	460	5
AL	June 23-July 2		0	5
OS	July 2-July 18	Will Rodgers (OKC)	100	9
ON	July 2-July 18		100	4
BZ	Sept. 16-Sept. 26	Brasilia	400	5

The AIRSAR instrument will be flown on NASA's Douglas DC-8. This is a four jet engine aircraft operated out of the Dryden Flight Center in California http://www.dfrc.nasa.gov/airsci/dc-8/dc8page.html. AIRSAR flights for SMEX03 will be flown at an altitude of 8 km.

The primary mission of the DC-8 is to collect AIRSAR data close in time with passive microwave measurements made by instruments on the P-3B aircraft. The objectives of including AIRSAR in SMEX03 are:

- Collect AIRSAR and passive microwave observations (2DSTAR and PSR) at different spatial resolutions that will allow the validation of passive and active data fusion concepts.
- Collect AIRSAR observations concurrent with high quality ground observations over a range of soil moisture and vegetation conditions that will allow the extension and validation of the current radar soil moisture algorithms to vegetated surfaces with higher biomass levels.
- Obtain AIRSAR observations concurrent with Envisat ASAR measurements to evaluate the quality and value of these sensors in soil moisture applications

5 OKLAHOMA STUDY REGION AND EXPERIMENT DESIGN

Two different regional areas will be sampled in Oklahoma, an area incorporating the Little Washita (LW) in the South (OS) and an area dominated by winter wheat in the North (ON). Each mission will include both regions and the watershed. The aircraft base of operations will be Oklahoma City (Will Rogers Airport). Field operations will be based out of Chickasha (OS) and Stillwater (ON).

5.1 Regional Description

The region in Oklahoma selected for investigation is exceptionally well instrumented for surface soil moisture, hydrology and meteorology research. USDA ARS, the Oklahoma Mesonet, and the DOE operate observing networks.

The overall character of the Oklahoma region is reflected in the false color composite image created from a Landsat TM data set collected on July 25, 1997 and is shown in Figure 10. This image is a combination of bands 2, 3, and 4 as the blue, green, and red channels. Red areas in the image indicate vegetation. Whites and blues indicated bare soil and dormant or senescent vegetation. As in past experiments in this region, all winter wheat is expected to be senescent and likely harvested. Two Regional study sites will be sampled; OS in the South that is dominated by grasslands and ON in the North that is dominated by winter wheat. Figure 11 shows typical grassland and winter wheat field conditions during July.

The climate of the two Regions is classified as sub-humid with an average annual rainfall of 75 cm. The topography of the region is moderately rolling with a maximum relief less than 200 m. Soils include a wide range of textures with large regions of both coarse and fine textures.

The Little Washita Watershed

The Little Washita Experimental Watershed (LWREW) is the focus of the OS Region. It is located in southwest Oklahoma in the Southern Great Plains region of the United States and covers an area of 611 sq. km. (Figure 12). The USDA ARS GRL (http://grl.ars.usda.gov) operates meteorological and hydrological observing systems throughout the watershed (described below).

A tributary of the Washita River in southwest Oklahoma, the LWREW is unique in that over a period of several years it has been the target of extensive research. In 1936 the eastern portion of the watershed was chosen as part of a national demonstration project for soil erosion control. In the late 1930's the Civilian Conservation Corps (CCC) did extensive erosion control work, such as terracing, drop structure building, gully plugging, and tree planting. Since establishing county offices in the 1940's, the USDA Soil Conservation Service (SCS) has applied extensive soil and water conservation Structures and measures, including terraces, diversions, farm ponds, floodwater-retarding reservoirs, gully plugging and smoothing, scrub timber removal, and land use planning.

In 1961 the USDA's Agricultural Research Service (ARS), in compliance with U.S. Senate Document 59 (1959), began collecting hydrologic data an the Little Washita Watershed and other watersheds in the vicinity to determine the downstream hydrologic impacts of the SCS floodwater-retarding reservoirs. This data collection process involved an intensive rain gauge network and a stream gauging station near the watershed outlet that provided data on continuous flow, suspended sediment transport, and to a limited extent, water quality. Data on groundwater levels and channel geometry were also collected to determine possible effects of the treatment program.

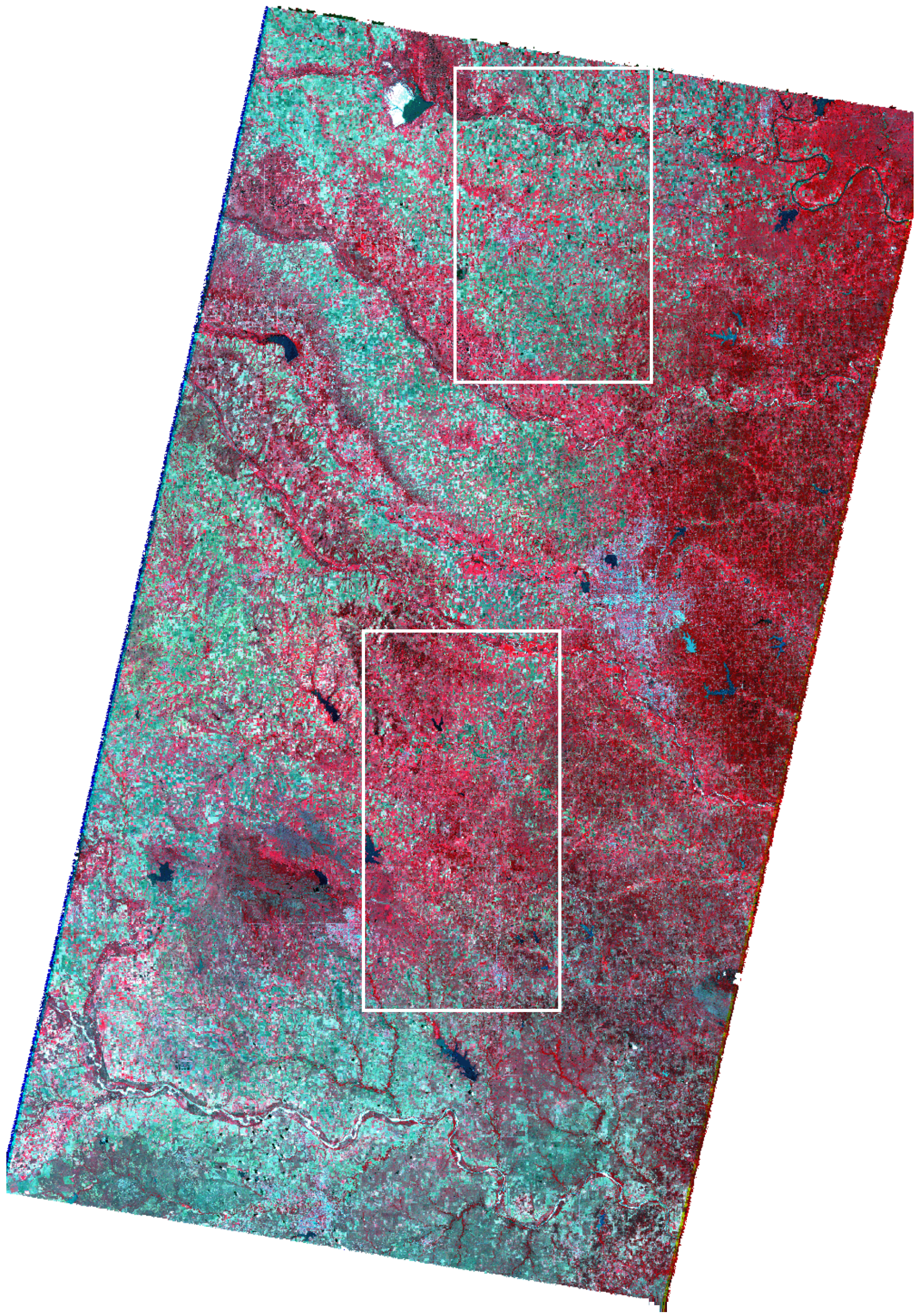

Figure 10. Landsat TM image from July 1997 showing the typical cover conditions and the general locations of the two study regions OS and ON.

Figure 11. Typical vegetation conditions in the OS and ON regions during July. The top photo is an example of grazingland and the bottom photo shows the condition of a winter wheat field.

In 1978 this watershed was one of seven watersheds chosen across the Nation for the Model Implementation Project (MIP), which was jointly sponsored and administrated by the USDA and the U.S. Environmental Protection Agency (EPA). The main objective of the MIP was to demonstrate the effects of intensive land conservation treatments on water quality in watersheds that are larger than about 25 square miles.

Within the LWREW, summers are typically long, hot, and relatively dry. The average daily high temperature for July is 34°C, and the average accumulative rainfall for July is 5.6 cm. Winters are typically short, temperate, and dry but are usually very cold for a few weeks. The average daily low temperature for January is –4°C, and the average accumulative precipitation for

January is 2.7 cm. Much of the annual precipitation and most of the large floods occur in the spring and fall.

The topography of the LWREW is moderately rolling with a maximum relief less than 200 m. Except for a few rocky, steep hills near Cement, OK; the upland topography is gently to moderately rolling. The flatter upland soils are those developed from the finer textured Dog Creek Shale and Blaine Formations near the eastern end of the watershed and those developed from the Cloud Chief Formation in the western portion of the watershed. The alluvial areas have the flattest slopes, usually 1 percent or less. The channel system is well developed throughout the watershed and extends practically to the drainage divide in most areas, so the watershed is well drained except for a few alluvial areas. Drainage ways in the western third of the watershed have eroded through the Cloud Chief Formation into the less erosion resistant, underlying Rush Springs Sandstone. Incised channels in the Rush Springs Sandstone are up to 18 to 21 m deep.

Soils include a wide range of textures with large regions of both coarse and fine textures. Surveys of the soils in the watershed have been made by the SCS and published (Bogard et al. 1978, Moffatt 1973, Mobley et al. 1967). In these surveys 64 different soil series were defined for the watershed, and 162 soil phases were mapped within these soil series to reflect differences in surface soil textures, slopes, stoniness, degree of erosion, and other characteristics that affect land use. Generally, silt and loam textured soils occur in the western and eastern portions of the watershed, with about the center 1/3 of the watershed in sandy textured soils.

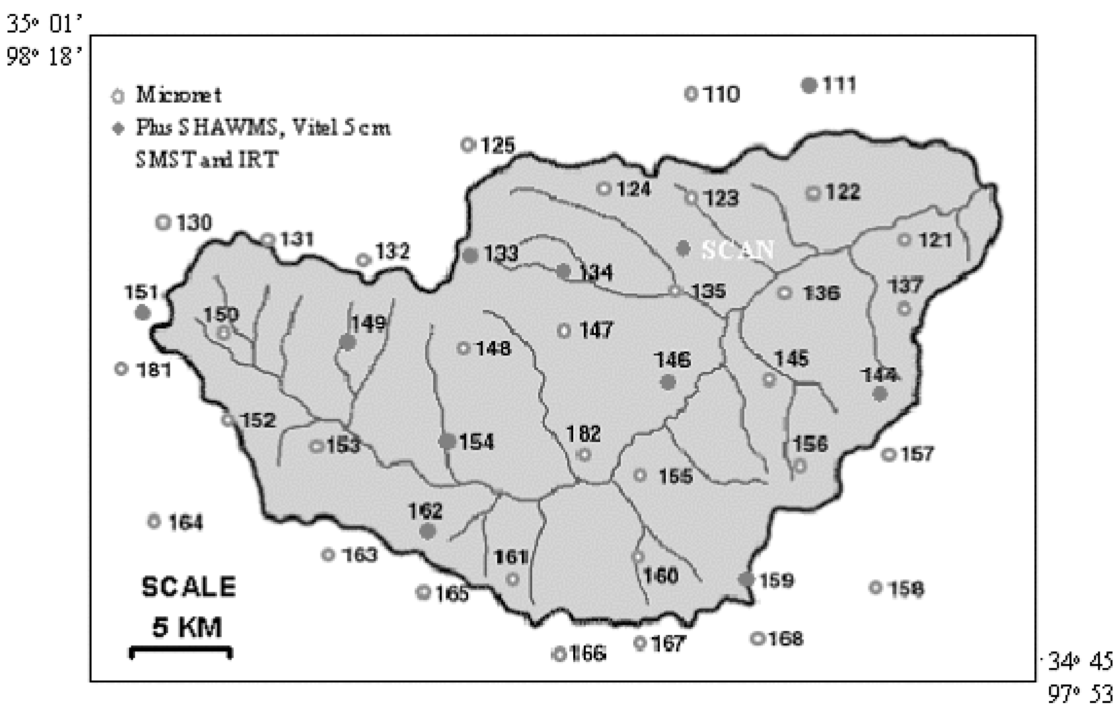

Figure 12. Little Washita Watershed map showing insitu instrumentation.

Land use in the watershed is dominated by rangeland and pasture (63%) with significant areas of winter wheat and other crops concentrated in the floodplain and western portions of the watershed area (Allen and Naney 1964). Figure 11 shows typical grassland and winter wheat field conditions during July. The LW area has been the focus of related remote sensing experiments in 1992 (Jackson et al. 1995), 1994, and both the ON and OS Regions were studied in experiments conducted in 1997 (Jackson et al. 1999, Starks and Jackson 2002) and 1999 (Jackson et al. 2002). Additional details can be found at the following web sites,

http://hydrolab.arsusda.gov/washita92/wash92.htm
http://hydrolab.arsusda.gov/washita92/wash94.htm
http://hydrolab.arsusda.gov/sgp97/
http://hydrolab.arsusda.gov/sgp99/

5.2 Insitu Soil Moisture and Meteorological Networks

LWREW Measurement Networks

The USDA Agricultural Research Service, Grazinglands Research Laboratory at El Reno, OK operates a meteorological network within the Little Washita watershed (LWREW). There are 42 ARS Micronet stations that measure accumulated rainfall, relative humidity and air temperature at 1.5 m, incoming solar radiation, and soil temperature at 5, 10, 15 and 30 cm below ground surface. The meteorological data are provided in 5-minute increments and the soil temperature data are provided in 15-minute increments. The data are telemetered by radio every 15 minutes to a central archiving facility located at the Oklahoma Climate Survey, University of Oklahoma, Norman, OK. There the data are quality controlled, and a data quality indicator is provided for each data entry. Micronet data for June, July and August 2003 will be archived and linked for direct access by SMEX03 investigators.

In addition, the GRL operates an experimental network of Soil Heat and Water Measurement Stations (SHAWMS). Eleven of the 14 SHAWMS (Table 16) stations are co-located with a Micronet, one SHAWMS is located near the NRCS SCAN site in the northeastern part of the LWREW, one is located near the GRL Chickasha Field Office, and one is located at the GRL in El Reno, OK. Each SHAWMS includes a profile of heat dissipation sensors which measures soil water matric potential at 5, 10, 15, 20, 25, and 60 cm below ground surface, at 1-hour increments (Starks 1999). SHAWMS data for June, July and August 2003 will be archived and linked for direct access by SMEX03 investigators.

For the AMSR calibration/validation project, each SHAWMS has also been equipped with an Apogee infrared thermometer (IRT) and a Vitel Hydraprobe. The Apogees measure soil surface/canopy temperatures every 30 minutes (instantaneous value). A nominal (i.e., factory-supplied) calibration equation is used to provide “corrected surface temperatures.” The Vitel Hydraprobes were installed with the center tine at 5 cm below the soil surface and provide a 30-minute (instantaneous) value of volumetric soil water content and soil temperature.

Because of the large pixel size produced by AMSR, the spatial measurement domain was expanded around the LWREW. This expansion was achieved by co-locating an instrument package (one Apogee and four Hydraprobes) with the Minco, Ft. Cobb, Washington, and

Ketchum Ranch Oklahoma Mesonet sites (described in a following section). A similar setup is co-located with the existing DOE ARM/CART facility in the northcentral part of the LWREW. This site is referred to as Capshew. The Hydraprobes at each of these sites are situated at 5, 20, 40, and 60 cm below the soil surface. These 5 sites are called VitelPro sites, shorthand for Vitel Profiling sites. Data from the SHAWMS and VitelPro sites are automatically downloaded daily to the GRL via cellular CDPD modems, where the data are quality controlled and archived on an FTP site to support project objectives. Data from this network will be archived and linked for direct access by AMSR and SMEX03 investigators.

Calibrated profiling Time Domain Reflectometer (TDR) rods have been installed at all SHAWMS sites and selected Micronet sites (Table 17). The type of TDR deployed on the LWREW and the calibration of the TDR rods is described in Heathman et al. (2003).

Locations of the Micronet, SHAWMS, VitelPros, and TDR sites are shown in Figure 12 and coordinates are listed in Table 16.

Table 16. Little Washita Watershed Area Micronet and Soil Moisture Sites

Micronet Site ID	Latitude (Deg.)	Longitude (Deg.)	Elevation (m)	Vitel	TIR	SHAWMS	Mesonet	TDR Profile
110	35.0143	-98.0056	378					x
111	35.0159	-97.9518	360	x	x	x		x
121	34.9587	-97.8985	343					
122	34.9728	-97.9528	368					
123	34.9711	-98.0056	381					
124	34.9728	-98.0580	387					
125	34.9857	-98.1280	419					x
130	34.9565	-98.2847	437					x
131	34.9503	-98.2336	458					
132	34.9417	-98.1783	427					
133	34.9491	-98.1281	430	x	x	x		x
134	34.9366	-98.0753	383	x	x	x		x
135	34.9273	-98.0198	365					
136	34.9277	-97.9656	343	x	x	x		x
137	34.9451	-97.9229	347					x
144	34.8790	-97.9171	387	x	x	x		x
145	34.8842	-97.9714	368					
146	34.8854	-98.0231	358	x	x	x		x
147	34.9069	-98.0757	417					
148	34.8992	-98.1281	430					
149	34.8984	-98.1809	420	x	x	x		x
150	34.9061	-98.2511	430					
151	34.9132	-98.2928	446	x	x	x	x	x
152	34.8612	-98.2511	415					
153	34.8552	-98.2001	414					
154	34.8552	-98.1370	393	x	x	x		x

155	34.8409	-98.0202	390					x
156	34.8430	-97.9584	397					x
157	34.8248	-97.9123	408					
158	34.7836	-97.9327	408					
159	34.7966	-97.9932	439	x	x	x		x
160	34.8003	-98.0370	411					
161	34.7973	-98.0905	407					
162	34.8133	-98.1417	399	x	x	x		x
163	34.8175	-98.1950	408	x	x	x		x
164	34.8216	-98.2789	408					x
165	34.7828	-98.1455	400					
166	34.7538	-98.0895	390					x
167	34.7545	-98.0367	397					
168	34.7542	-97.9774	418					x
181	34.8697	-98.3014	402					
182	34.8449	-98.0732	369					
LW-SCAN	35.2604	-97.9789	358	x	x			
Chicklab	35.0456	-97.9167	331	x	x	x		
ER-SCAN	35.5500	-98.0170	427	x	x			
El Reno	35.5500	-98.0167	427	x	x	x	x	
Washington	34.9817	-97.5206	340	x	x		x	
Minco	35.2719	-97.9556	431	x	x		x	
Ft. Cobb	35.1492	-98.4667	420	x	x		x	
Ket. Ranch	34.5289	-97.7644	341	x	x		x	
Capshew	34.9569	-98.0761	400	x	x			

Oklahoma Mesonet

The Oklahoma Mesonet is an automated network of 115 remote, meteorological stations across Oklahoma (Brock et al. 1995; Shafer et al. 2000). Each station measures nine core parameters: air temperature and relative humidity at 1.5 m, wind speed and direction at 10 m, atmospheric pressure, incoming solar radiation, rainfall, and bare and vegetated soil temperatures at 10 cm below ground level. Nearly half of the sites provide supplemental instruments: temperature sensors at 5 cm under bare and vegetated soil, and at 30 cm under vegetated soil. The Mesonet was installed during 1993 and became operational on 1 January 1994. Since that time, over 100 million observations have been archived at an archiving frequency that exceeds 98% of the possible observations. Data are collected and transmitted to a central point every 15 minutes where they are quality controlled, distributed and archived (Shafer et al. 2000). For additional information about the Oklahoma Mesonet, see http://www.ocs.ou.edu/programs/mesonet.html.

During 1996 matric potential sensors (the Campbell Scientific 229-L) were installed at 60 sites in the Oklahoma Mesonet. The sensors were installed at depths of 5, 25, 60, and 75 cm. Based upon the initial success in using data from this initial deployment of soil moisture sensors, 229-L sensors were installed at an additional 43 Mesonet sites during 1998 and 1999. The network of 229-L sensors is unique in that they provide an estimate of both soil-water potential *and* water content every 30 minutes (Reece 1996; Basara 1998; Starks 1999; Basara and Crawford 2000).

As a result, the soil moisture sensors installed at more than 101 Mesonet sites are now providing a continuous record of soil moisture conditions (two sites were decommissioned during 2001).

In 1998, the National Science Foundation provided funds to upgrade Oklahoma Mesonet with a suite of instruments capable of measuring latent and sensible heat fluxes. Thus, sensors were installed at 89 Mesonet sites during 1999 as part of the Oklahoma Atmospheric Surface-layer Instrumentation System Project (Brotzge et al. 1999, Basara and Crawford 2002). Currently 10 site locations measure surface energy fluxes using the eddy correlation method. These sites are referred to as OASIS Super Sites. The sensors at OASIS Super Sites allow these stations to measure net radiation, sensible, latent, and ground heat fluxes. Also surface skin temperature is measured at Super Sites using an infrared temperature sensor (IRT) manufactured by Apogee and mounted at 2 m. In addition, surface skin temperature is measured at an additional 79 sites designated as OASIS Standard sites. A detailed diagram of the Oklahoma Mesonet is shown in Figure 13. Instrumentation features at each site are summarized in Table 17. It should also be noted that soil moisture is measured at all OASIS site locations.

Data files from the Mesonet are copyrighted. However, SMEX Investigators will be able to access the data through the CODIAC web site.

A subset of Mesonet sites has been identified for enhanced maintenance and study during SMEX03. All Mesonet sites are visited quarterly by field technicians to clean and calibrate sensors as well as to provide site maintenance. However, to ensure that the highest quality data is collected from sensors in and around the SMEX03 domain, enhanced maintenance will be performed. Thus, all sites in Figure 14 will be visited at two-week intervals beginning the week of June 8 to clean sensitive instruments such as the IRT, net radiometer, and Krypton hygrometer.

During the SMEX03 operational period, Mesonet sites within the flight lines will be visited to collect field observations that can be used to quantify the spatial and temporal variability of soil moisture and skin temperature. Thus, IRT measurements will be collected at prescribed locations within the site as well as the surrounding landscape using handheld sensors. In addition, soil cores to a depth of 80 cm will be collected in and around designated sites. These site visits will occur every 2-4 days and will last through the operational period.

Oklahoma Mesonet data will be archived as part of the SMEX03 data set. There will be a lag in delivery to allow quality control. SMEX03 investigators can use the following site to obtain a variety of products http://www.mesonet.org/public/current.html.

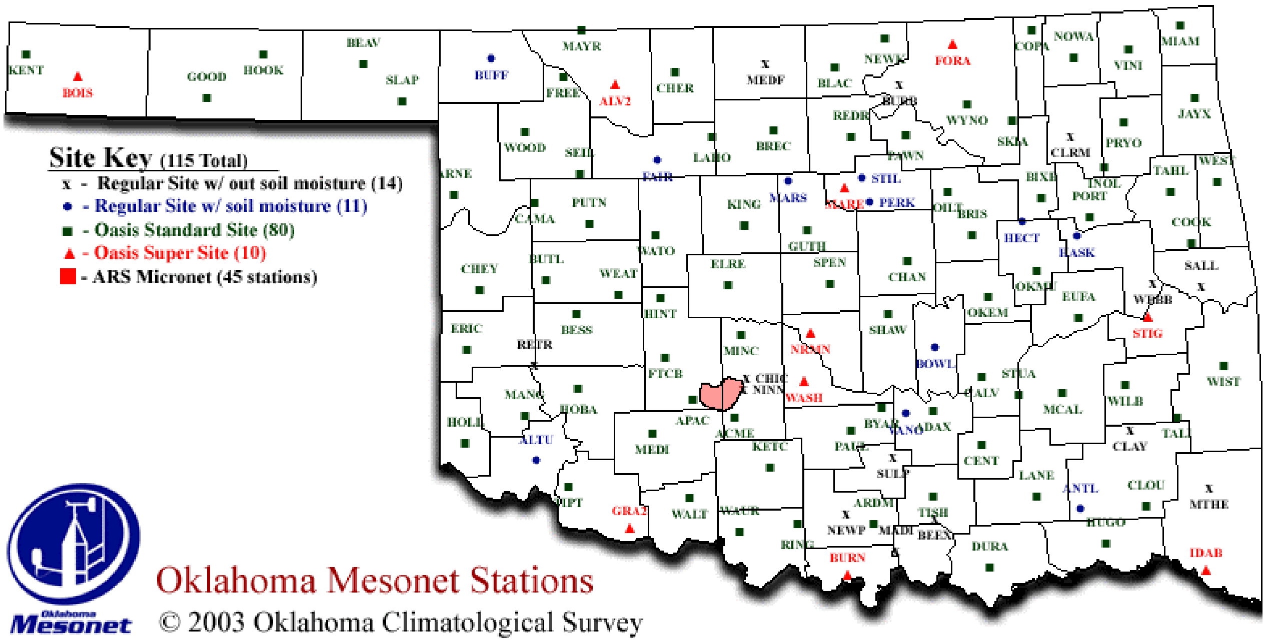

Figure 13. Locations of the Oklahoma Mesonet sites.

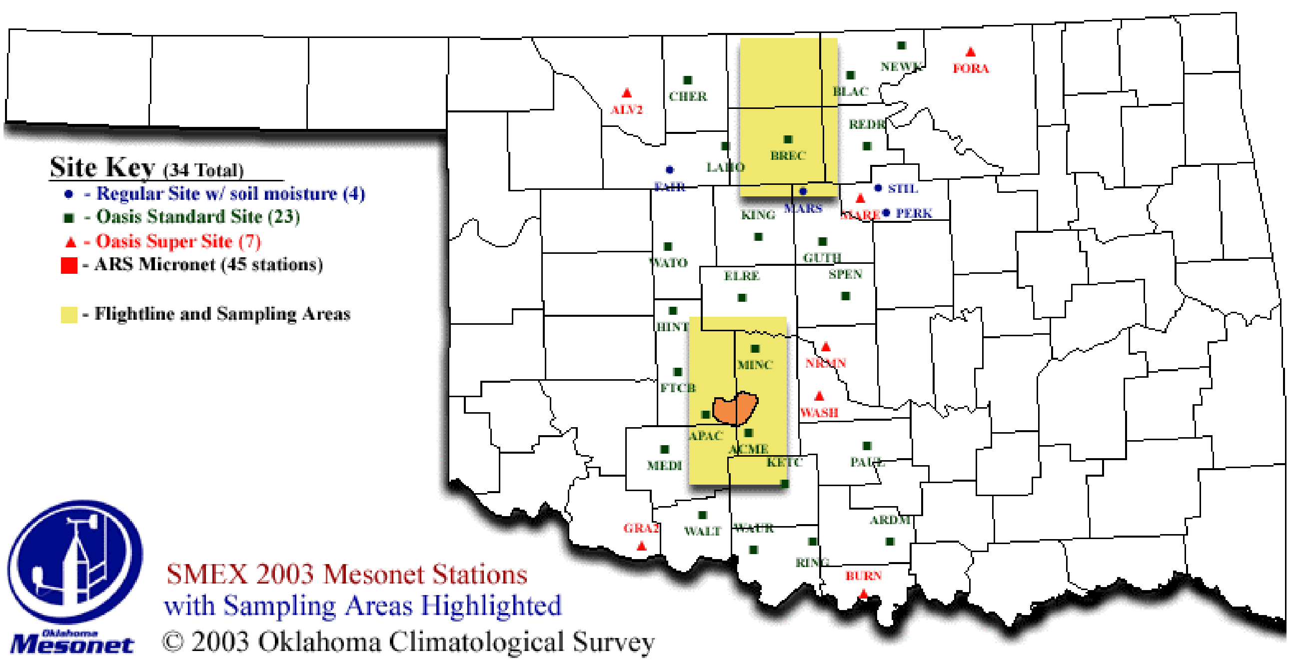

Figure 14. The Oklahoma Mesonet sites identified for enhanced maintenance and study during SMEX03.

Table 17. Oklahoma Mesonet Sites and Characteristics							
Site Identifier	Latitude (Deg.)	Longitude (Deg.)	Elevation (m)	OASIS Standard Site	OASIS Super Site	Soil Moisture	Skin Temperature
ADAX	34.799	-96.669	295	X		X	X
ALTU	34.587	-99.338	416			X	
ANTL	34.224	-95.701	179			X	
ARDM	34.192	-97.085	266	X		X	X
ARNE	36.073	-99.901	719	X		X	X
BEAV	36.802	-100.530	758	X		X	X
BESS	35.402	-99.059	511	X		X	X
BIXB	35.963	-95.866	184	X		X	X
BLAC	36.754	-97.254	304	X		X	X
BOIS	36.693	-102.497	1267		X	X	X
BOWL	35.172	-96.631	281			X	
BREC	36.412	-97.694	352	X		X	X
BRIS	35.781	-96.354	239	X		X	X
BUFF	36.831	-99.641	559			X	
BURB	36.634	-96.811	301				
BURN	33.894	-97.269	228		X	X	X
BUTL	35.591	-99.271	520	X		X	X
BYAR	34.850	-97.003	345	X		X	X
CALV	34.993	-96.334	234	X		X	X
CAMA	36.028	-99.346	589	X		X	X
CENT	34.609	-96.333	208	X		X	X
CHAN	35.653	-96.804	291	X		X	X
CHER	36.748	-98.363	362	X		X	X
CHEY	35.546	-99.728	694	X		X	X
CHIC	35.032	-97.914	328				
CLAY	34.656	-95.326	186				
CLOU	34.223	-95.249	221	X		X	X
COOK	35.679	-94.849	299	X		X	X
COPA	36.910	-95.885	250	X		X	X
DURA	33.921	-96.320	197	X		X	X
ELRE	35.548	-98.036	419	X		X	X
ERIC	35.205	-99.803	603	X		X	X
EUFA	35.300	-95.658	200	X		X	X
FAIR	36.264	-98.498	405			X	
FORA	36.840	-96.428	330		X	X	X
FREE	36.726	-99.142	530	X		X	X
FTCB	35.149	-98.467	422	X		X	X
GOOD	36.602	-101.601	997	X		X	X
GUTH	35.849	-97.480	330	X		X	X
HASK	35.748	-95.640	183			X	

HINT	35.484	-98.482	493	X		X	X
HOBA	34.990	-99.053	478	X		X	X
HOLL	34.686	-99.834	497	X		X	X
HOOK	36.855	-101.225	912	X		X	X
HUGO	34.031	-95.540	175	X		X	X
IDAB	33.830	-94.881	110		X	X	X
JAYX	36.482	-94.783	304	X		X	X
KENT	36.830	-102.878	1322	X		X	X
KETC	34.529	-97.765	341	X		X	X
KING	35.881	-97.911	319	X		X	X
LAHO	36.384	-98.111	396	X		X	X
LANE	34.309	-95.998	181	X		X	X
MADI	34.036	-96.943	232				
MANG	34.836	-99.424	460	X		X	X
MARE	36.064	-97.213	327		X	X	X
MARS	36.119	-97.601	315			X	
MAYR	36.987	-99.011	555	X		X	X
MCAL	34.882	-95.781	230	X		X	X
MEDF	36.792	-97.746	332				
MEDI	34.729	-98.567	487	X		X	X
MIAM	36.889	-94.845	247	X		X	X
MINC	35.272	-97.956	430	X		X	X
MTHE	34.311	-94.823	285				
NEWK	36.898	-96.911	366	X		X	X
NOWA	36.744	-95.608	206	X		X	X
OILT	36.031	-96.497	255	X		X	X
OKEM	35.432	-96.263	263	X		X	X
OKMU	35.581	-95.915	205	X		X	X
PAUL	34.716	-97.229	291	X		X	X
PAWN	36.361	-96.770	283	X		X	X
PERK	35.998	-97.048	292			X	
PRYO	36.369	-95.272	201	X		X	X
PUTN	35.899	-98.960	589	X		X	X
REDR	36.356	-97.153	293	X		X	X
RETR	35.123	-99.360	538				
RING	34.194	-97.588	283	X		X	X
SALL	35.438	-94.798	157				
SEIL	36.190	-99.041	545	X		X	X
SHAW	35.365	-96.948	328	X		X	X
SKIA	36.415	-96.037	282	X		X	X
SLAP	36.597	-100.262	774	X		X	X
SPEN	35.542	-97.341	373	X		X	X
STIG	35.265	-95.181	173		X	X	X
STIL	36.121	-97.095	272			X	

STUA	34.876	-96.070	256	X		X	X
SULP	34.566	-96.951	320				
TAHL	35.973	-94.987	290	X		X	X
TALI	34.711	-95.012	204	X		X	X
TIPT	34.439	-99.138	387	X		X	X
TISH	34.333	-96.679	268	X		X	X
VINI	36.775	-95.221	236	X		X	X
WALT	34.365	-98.321	308	X		X	X
WASH	34.982	-97.521	345		X	X	X
WATO	35.842	-98.526	517	X		X	X
WAUR	34.168	-97.988	283	X		X	X
WEAT	35.508	-98.775	538	X		X	X
WEBB	35.473	-95.132	145				
WEST	36.011	-94.645	348	X		X	X
WILB	34.901	-95.348	199	X		X	X
WIST	34.985	-94.688	143	X		X	X
WOOD	36.423	-99.417	625	X		X	X
WYNO	36.517	-96.342	269	X		X	X
NINN	34.968	-97.951	356				
ACME	34.806	-98.006	397	X		X	X
APAC	34.914	-98.292	440	X		X	X
HECT	35.844	-96.006	243			X	
VANO	34.789	-96.843	320			X	
ALV2	36.708	-98.708	439		X	X	X
GRA2	34.239	-98.744	341		X	X	X
PORT	35.826	-95.560	193	X		X	X
BEEX	34.191	-96.644	196				
INOL	36.142	-95.451	190	X		X	X
NRMN	35.236	-97.465	357		X	X	X
CLRM	36.321	-95.646	207				
NEWP	34.228	-97.201	283				

DOE ARM CART

The Department of Energy's ARM CART SGP Site is centered near Lamont, OK, and covers an area roughly 325 by 275 km, extending from the Little Washita watershed in Oklahoma north into central Kansas. The SGP Extended Facilities (EF) include 22 installations providing observations of air temperature, wind speed and direction, humidity, rainfall, and snow depth; several measures of upwelling and downwelling visible and near-infrared radiation; and estimates of sensible and latent heat fluxes in the atmospheric surface layer. http://www.arm.gov/docs/sites/sgp/sgp.html

DOE ARM CART refers to its soil moisture systems as Soil Water and Temperature System, or SWATS. These utilize the same heat dissipation sensors employed in the SHAWMS and Mesonet. The SWATS take observations once every hour, with data transmitted automatically via phone line every 8 hours. Data is also stored locally, and manually downloaded during biweekly maintenance checks. The final design consists of electronics in a surface-mounted enclosure (data logger, multiplexor, constant-current source, power supply, storage module, and telecommunications equipment) supporting 16 CSI 229-L sensors, deployed in two profiles of 8 sensors each. Sensors are located at depths of 5, 15, 25, 35, 60, 85, 125, and 175 cm, rock permitting. SWATS have been added to each of these Extended Facilities (EF). Locations of all sites in Oklahoma are listed in Table 18. More information can be found at the following web site http://www.arm.gov/docs/sites/sgp/sgp.html.

Table 18. DOE ARM CART Extended Facility Sites in Oklahoma

ID	Name	Latitude (Deg.)	Long. (Deg.)	Eleva-tion (m)	Land Cover	Surface Flux	SWATS	SIROS	SIRS and MFRSR	SMOS
EF-11	Byron	36.881	98.285	360	Alfalfa	ECOR	Yes	Yes	Yes	Yes
EF-12	Pawhuska	36.841	96.427	331	Native Prairie	ECOR	Yes	No	Yes	No
EF-13	Lamont	36.605	97.485	318	Pasture & Wheat	EBBR	Yes	Yes	Yes	Yes
EF-14	Lamont	36.607	97.488	315	Pasture & Wheat	ECOR	Yes	Yes	Yes	Yes
EF-15	Ringwood	36.431	98.284	418	Pasture	EBBR	Yes	Yes	Yes	Yes
EF-16	Vici	36.061	99.134	602	Wheat	ECOR	Yes	No	Yes	No
EF-18	Morris	35.687	95.856	217	Pasture	EBBR	Yes	No	Yes	No
EF-19	El Reno	35.557	98.017	421	Pasture	EBBR	Yes	No	Yes	No
EF-20	Meeker	35.564	96.988	309	Pasture	EBBR	Yes	Yes	Yes	Yes
EF-21	Okmulgee	35.615	96.065	240	Forest	ECOR	Yes	No	Yes	Yes
EF-22	Cordell	35.354	98.977	465	Rangeland	EBBR	Yes	No	Yes	No
EF-24	Cyril	34.883	98.205	409	Wheat	ECOR	Yes	Yes	Yes	Yes
EF-26	Cement	34.957	98.076	400	Pasture	EBBR	No	No	No	No

ECOR=Eddy Correlation surface flux station
EBBR=Energy Balance Bowen Ratio surface flux station
SWATS= Soil Water and Temperature Station
SIROS= Solar and Infrared Radiation Observation Station
SIRS= Solar Infrared Radiation Station
MFRSR= Multi-Filter Rotating Shadowband Radiometer
SMOS= Surface Meteorological Observation System

In addition to the EF sites there is the highly instrumented Central Facility (CF) near Lamont, 4 boundary facilities (BF), and 3 intermediate facilities (IF). Radiosondes are launched from the CF on a regular schedule (only on weekdays). These are (in UTC): 0530, 1130, 2030, and 2330.

Do not enter a site being used by this program without obtaining permission. If any site characterization of sampling is performed this should be done at least 100 m from the permanent instrumentation.

5.3 Flightlines

P-3B

Flightlines in Oklahoma are designed to provide high altitude mapping of two Regional areas (OS and ON), lower altitude mapping of the Little Washita Watershed (LW), and low altitude water calibration. Flightline coordinates for the P-3B are provided in Table 19. A map of the Regional lines is shown in Figure 15 and a map of the LW Watershed lines in Figure 16. The standard mission will be as follows, however, there may be changes based on satellite overpass times and weather conditions:

- Takeoff OKC 10:45 am CDT
- Water Cal 11:00 am CDT
- LW Lines 11:15 am - 12:00 pm CDT
- Ferry to ON
- ON Lines 12:30 pm – 1:15 pm CDT
- OS Lines 1:30 pm – 2:15 pm CDT
- Land OKC 3:00 pm CDT

All times are preliminary estimates and will depend upon specific features that will be encountered and refinement by the aircraft mission manager. Mission duration is expected to be 4.5 hours.

Approximate ON Box (Greater than 2x3 EASE Grid Box)
Upper Left: 36.88, -98.044
Lower Right: 36.08, -97.424

Approximate OS Box (Greater than 2x4 EASE Grid Box)
Upper Left: 35.42, -98.336
Lower Right: 34.42, -97.716

A total of 9 regional and seven watershed missions are anticipated with the P-3B between (and including) July 2nd and July 18th.

Table 19. Oklahoma P-3B Flightlines					
Line	Altitude (m above sea level)	Length (km)	Type	Latitude (Degrees)	Longitude (Degrees)
OK01	7300	110	OS Regional Mapping	35.420	-98.236
				34.420	-98.236
OK02	7300	110	OS Regional Mapping	34.420	-98.096
				35.420	-98.096
OK03	7300	110	OS Regional Mapping	35.420	-97.956
				34.420	-97.956
OK04	7300	110	OS Regional Mapping	34.420	-97.816
				35.420	-97.816
OK05	7300	88	ON Regional Mapping	36.080	-97.944
				36.880	-97.944
OK06	7300	88	ON Regional Mapping	36.880	-97.804
				36.080	-97.804
OK07	7300	88	ON Regional Mapping	36.080	-97.664
				36.880	-97.664
OK08	7300	88	ON Regional Mapping	36.880	-97.524
				36.080	-97.524
OK09	1500	64	LW Mapping	34.952	-98.400
				34.952	-97.700
OK10	1500	64	LW Mapping	34.927	-97.700
				34.927	-98.400
OK11	1500	64	LW Mapping	34.899	-98.400
				34.899	-97.700
OK12	1500	64	LW Mapping	34.870	-97.700
				34.870	-98.400
OK13	500	10	Water Cal	34.775	-98.350
				34.860	-98.363

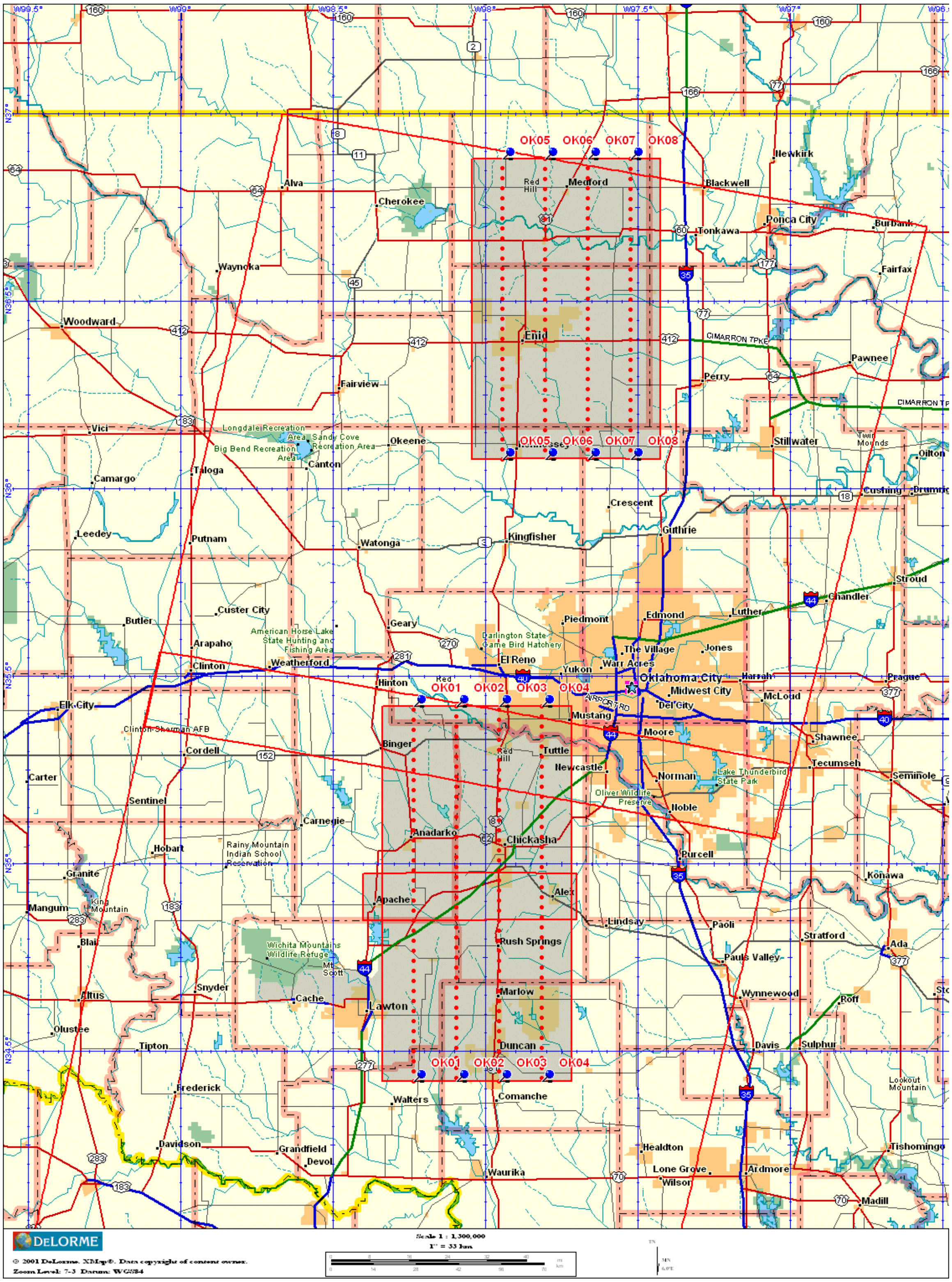

Figure 15. Oklahoma P-3B regional flightlines.

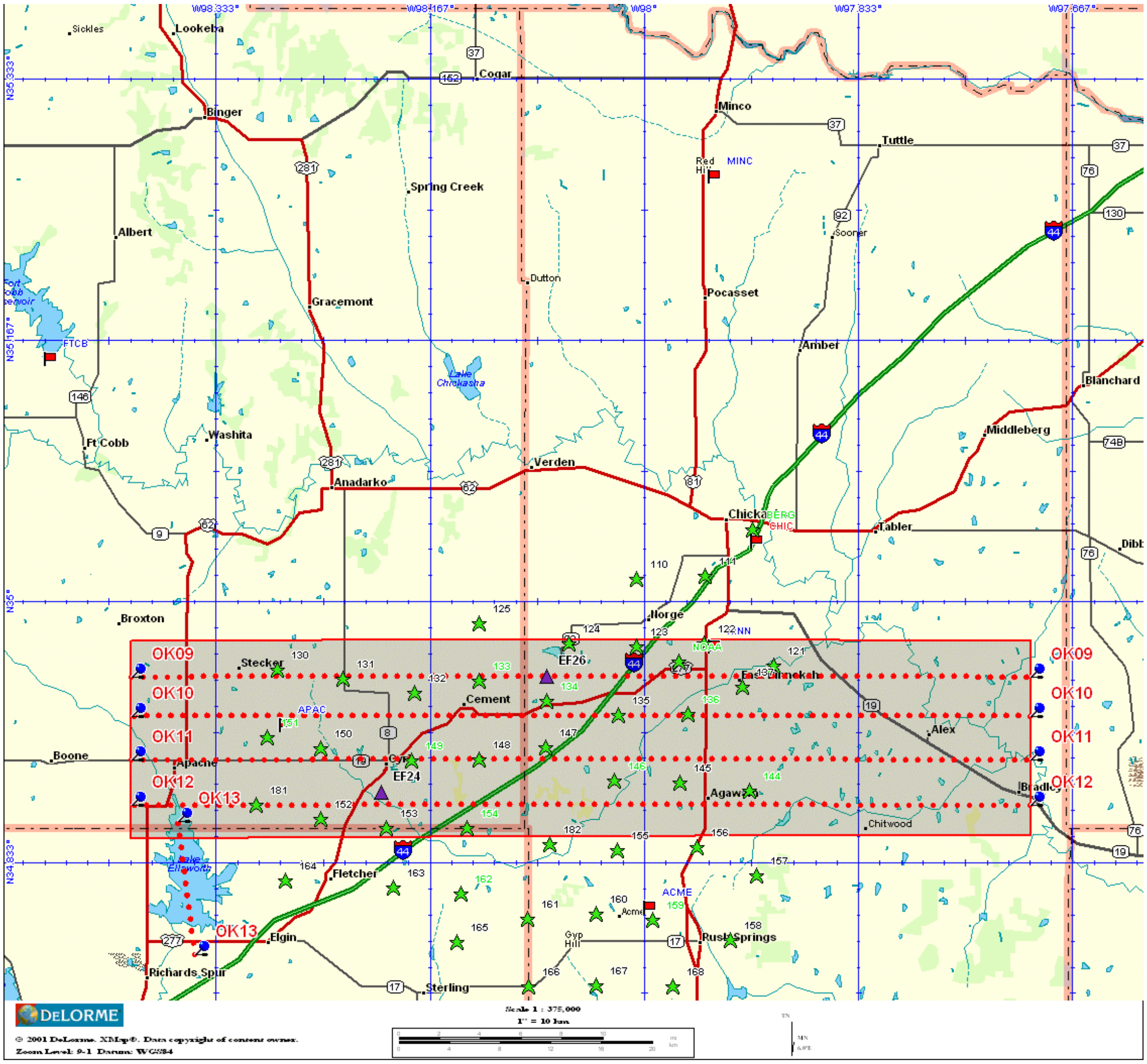

Figure 16. LW Watershed P-3B flightlines. Star symbols represent ARS Micronet sites.

DC-8

In order to accomplish the primary objectives for AIRSAR in SMEX03, the DC-8 mission was developed based on the following features:

- Flights will be conducted only in Oklahoma to minimize transits and complement other activities
- Flights between July 2 and July 12, 2003. It is anticipated that there will be five flight dates. The arrival and departure dates can also be science data collection dates.
- Flights will be concentrated over the Little Washita Watershed, an area 10 km North-South and 40 km East-West where intensive ground sampling will be conducted. Swath coverage areas are summarized in Table 20. Multiple flightlines are desired in order to produce a composite image of the watershed with a nominal incidence angle range close to 40 degrees (the proposed HYDROS incidence angle). This will facilitate the disaggregation studies. In addition, this design will result in multiple incidence angle observations over the test sites, which will allow the exploration of new algorithm concepts. Note that the flightline coverage areas are defined by corner coordinates.
- Regional coverage data sets will be collected for extrapolation of the watershed results to larger scales typical of satellite radiometer footprints. Swath coverage areas are summarized in Table 20.
- Concurrent flights will be made to acquire Envisat ASAR data during SMEX03.
- Flight plan ((2.5 hours)
  - Takeoff OKC 10:00 am CDT
  - LW Lines 10:15 am – 11:00 am CDT
  - OS and ON Lines 11:15 am – 12:15 pm CDT
  - Land OKC 12:30 pm CDT

Table 20. NASA DC-8 AIRSAR Flightline Parameters

Description	Box	Latitude (Deg.)	Longitude (Deg.)	Altitude (Km)	Length (Km)
Watershed					
Four lines will be flown in an East-West racetrack to provide coverage of the area at angles between 35 and 45 degrees.	LW Box	34.9705	-98.4	8	50
		34.9705	-97.7		
		34.8847	-97.7		
		34.8847	-98.4		
Regional					
Coverage of two boxes using a single North-South line for each.	Regional Box 1	35.42	-98	8	100
		35.42	-97.764		
		34.42	-97.764		
		34.42	-98		
	Regional Box 2	35.42	-97.805	8	100
		35.42	-97.56		
		34.42	-97.56		
		34.42	-97.805		

5.4 Ground Sampling

Regional site ground sampling in Oklahoma South (OS) and Oklahoma North (ON) will follow the general protocols described earlier. The sites selected are listed in Tables 21 and 22. Within OS there will be a slightly higher density of sites in the vicinity of the LW because a secondary objective to sampling is the verification of the measurements provided by the various Insitu instrumentation.

In order to support the 2DSTAR and AIRSAR requirements, a number of field sites will be sampled within the LW. Most of these have been used as test sites in previous experiments and to the degree possible these are arranged in clusters. Watershed sites are listed in Table 23 and shown in Figure 17. The numbering of these sites is not sequential. We attempted to retain site ids used in the previous SGP97 and SGP99 experiment. However, not all sites were retained and some new sites were added.

Regional and Watershed teams will operate independently. The Field sampling will follow the protocol described in a later section. All ground sampling is conducted **every day**. Do not assume cancellations, unless specifically informed by the group leader. The group leader may cancel sampling if it is raining, there are severe weather warnings or a logistic issue arises.

Table 21. OS Regional Sites

Site	Network Site ID	Crop	Reference Coordinates	
			Latitude (Deg.)	Longitude (Deg.)
OS01		Pasture	35.37438	98.23543
OS02		Pasture	35.29907	98.26022
OS03		Pasture	35.23831	98.27113
OS04		WW	35.17652	98.25400
OS05		Pasture	35.11597	98.23364
OS06		Pasture	35.01948	98.23611
OS07	151, APAC	Pasture	34.91324	98.29260
OS08	149	Pasture	34.89847	98.18076
OS09	164	Pasture	34.82172	98.27895
OS10		Pasture	34.73054	98.23256
OS11		WW	34.66512	98.19780
OS12		Pasture	34.59947	98.21086
OS13		WW	34.51481	98.21395
OS14		Pasture	35.36880	98.13013
OS15		Pasture	35.27254	98.13255
OS16		Pasture	35.22438	98.09706
OS17		WW	35.11532	98.09037
OS18	125	Pasture	34.98570	98.12800
OS19	133	Pasture	34.94923	98.12802
OS20	134	Pasture	34.93693	98.07493

OS21	146	Pasture	34.88594	98.02265
OS22	154	Pasture	34.85542	98.13688
OS23	162	Pasture	34.81353	98.14159
OS24	166	Pasture	34.75389	98.08944
OS25		Pasture	34.63645	98.10825
OS26		Pasture	34.53192	98.10493
OS27		WW	35.33333	97.94253
OS28	MINC	Pasture	35.27247	97.95569
OS29		WW	35.21081	97.95615
OS30		Pasture	35.14403	97.96062
OS31	CHIC	Pasture	35.04625	97.91549
OS32	111	Pasture	35.01601	97.95205
OS33	SCAN	Pasture	34.96181	97.97213
OS34	136	Pasture	34.92794	97.96533
OS35	144	Pasture	34.87909	97.91703
OS36	159	Pasture	34.79670	97.99321
OS37		Pasture	34.67766	97.96026
OS38		Pasture	34.59628	97.96488
OS39		WW	34.52382	98.00271
OS40		WW	35.39282	97.87285
OS41		Pasture	35.31077	97.8496
OS42		Pasture	35.21968	97.83177
OS43		Pasture	35.14339	97.83121
OS44		Pasture	35.06770	97.81290
OS45		Pasture	34.98445	97.76084
OS46		Pasture	34.97206	97.82018
OS47		Pasture	34.81138	97.79295
OS48		Pasture	34.73059	97.86178
OS49		Pasture	34.65648	97.81067
OS50		Pasture	34.58209	97.81141
OS51	KETC	Pasture	34.52895	97.76501
OS52		Pasture	34.48990	97.85127

Table 23. ON Regional Sites

Site	Network Site ID	Crop	Reference Coordinates	
			Latitude (Deg.)	Longitude (Deg.)
ON01		WW	36.80039	97.96424
ON02		Pasture	36.7409	97.96403
ON03		WW	36.66223	97.96777
ON04		WW	36.59533	97.89555
ON05		Pasture	36.51976	97.91237
ON06		WW	36.46183	97.90581

ON07		WW	36.32508	97.88768
ON08		WW	36.24954	97.88841
ON09		WW	36.18639	97.89331
ON10	MEDF	Pasture	36.79207	97.74579
ON11		WW	36.73674	97.78197
ON12		WW	36.66735	97.81966
ON13		WW	36.57713	97.80360
ON14		Pasture	36.50852	97.78455
ON15		WW	36.43546	97.78101
ON16		WW	36.34920	97.78135
ON17		WW	36.26509	97.78099
ON18		WW	36.19639	97.78106
ON19		WW	36.80786	97.68097
ON20		WW	36.74972	97.68095
ON21		WW	36.67683	97.66776
ON22		WW	36.58395	97.65628
ON23		WW	36.50741	97.65627
ON24	BREC	WW/Pasture	36.41210	97.69438
ON25		WW	36.31789	97.71033
ON26		WW	36.25896	97.71296
ON27	MARS	WW/Pasture	36.11870	97.60159
ON28		WW	36.83133	97.53726
ON29		WW	36.75136	97.5427
ON30		WW	36.69658	97.53041
ON31		WW	36.61033	97.57633
ON32		WW	36.50703	97.57655
ON33		WW	36.43239	97.55382
ON34		WW	36.33145	97.57072
ON35		WW	36.25909	97.55835
ON36		Pasture	36.17242	97.57028

Table 24. LW Watershed Sites

Site	Network Site ID	Crop	Reference Coordinates	
			Latitude (Deg.)	Longitude (Deg.)
LW02	SCAN	Grass	34.957222	-97.981796
			34.960445	-97.979127
LW03	EF-26	Grass	34.956683	-98.083986
	Capshew		34.963383	-98.075696
LW04		Grass	34.956749	-98.092856
			34.963383	-98.083986
LW11	136	Grass	34.920332	-97.970097
			34.927566	-97.961799

LW12		Grass	34.920332	-97.961972
			34.927493	-97.953260
LW13		Grass	34.913771	-97.961972
			34.920332	-97.953353
LW20		WW	34.913402	-98.286102
			34.920658	-98.277829
LW21		WW	34.906087	-98.284195
			34.913083	-98.277895
LW22		WW	34.906318	-98.277626
			34.913030	-98.269029
LW25		WW	34.934802	-98.338803
			34.940978	-98.330541
LW26		WW	34.935025	-98.330261
			34.942011	-98.321662
LW27		WW	34.936140	-98.303652
			34.942134	-98.295709
LW28		WW	34.935097	-98.295112
			34.942082	-98.286839
LW31		Crop	34.931484	-97.977187
			34.934677	-97.970906
LW32		Crop	34.931423	-97.969962
			34.938659	-97.961987
LW33		Crop	34.935402	-97.960714
			34.942107	-97.954060

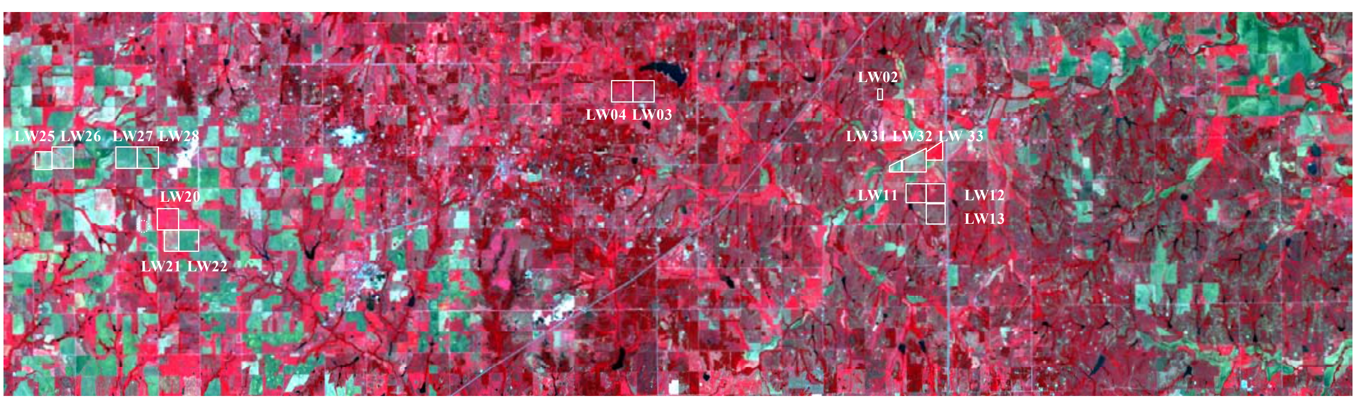

Figure 16. LW Field sampling sites.

5.5 Logistics

Security

Access to the ARS facility in Chickasha will only be permitted when there is an ARS federal employee present.

Field and Lab Safety

See Appendix A

Hotels

Oklahoma City

Embassy Suites Hotel (Aircraft Briefing Hotel)
1815 South Meridian
Oklahoma City, OK 73108
(405) 682-6000

A block of rooms has been secured at the Embassy Suites at $65 (plus tax). We will also have the use of a separate room for briefings. It is strongly suggested that you take advantage of this rate. The affiliation name is USDA. This rate will only available to those staying an extended period. Otherwise, the Hampton Inn usually has a government rate. A Wingate Inn and Hampton Inn are next door. Refer to the following web site http://www.okccvb.org/hotel/hotel.php for phone numbers etc.

Chickasha, OK

For ground sampling in OS it is recommended that you stay in Chickasha, which is where the field HQ will be.

Days Inn
2701 S 4th Street
Chickasha, OK 73018
(405) 222-5800
Group Rate under USDA $36/night single or $41/night double

Best Western Inn (alternate $40/night)
2101 S 4th Street
Chickasha, OK 73018
(405) 224-4890

There are other places listed at the following web site http://www.chickasha-cc.com/Tourism/Motel%20Listing.htm.

Stillwater, OK

For ground sampling in ON it is recommended that you stay in Stillwater, which is where the field HQ will be. The following hotel is suggested.

Holiday Inn
2515 W. 6th Ave.
Stillwater, OK 74074
*(*405) 372-0800
*Fax: (*405) 377-8212
http://www.ichotelsgroup.com/h/d/hi/hd/swook
Rates: $56 for singles (under 2USD)

Shipping Information

Chickasha, OK

Prior to June 16

USDA ARS Offices El Reno, OK (405) 262-5291 fax (405) 262-0133
Pat Starks USDA ARS
USDA ARS Grazinglands Res. Lab
7207 W. Cheyenne St.
El Reno, OK 73036

After June 16

USDA ARS Offices Chickasha, OK (405) 224-7393 fax (405) 224-7396
Gary Heathman USDA ARS
USDA ARS
Route 3 Cotton Research Rd.
Chickasha, OK 73018

Stillwater, OK

Ronald Elliott
Biosystems and Agricultural Engineering Lab
Oklahoma State University
323 North Cleveland St.
Stillwater, OK 74078
Wayne Kiner (Laboratory Manager) - (405) 744-5428

Directions

Chickasha, OK

Maps showing the locations of the Embassy Suites Hotel, ARS Chickasha Lab, the Chickasha Motels, and the OSU lab are included in Appendix B. A 1995 aerial photo showing the ARS facility is shown in Figure 17. The main building is a tan metal structure. Enter on the east side.

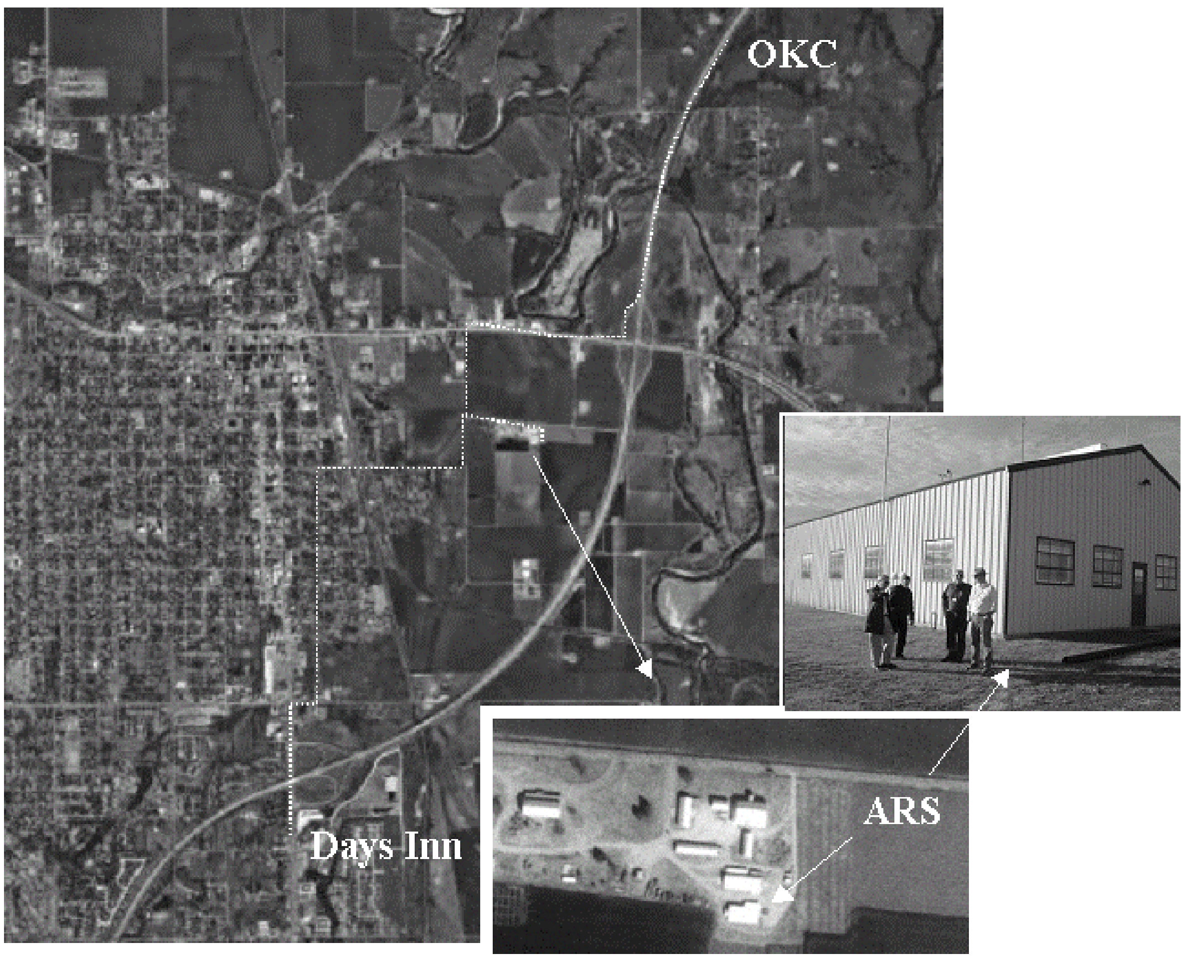

Figure 17. Aerial and ground photos showing the ARS Chickasha Lab location and general directions from the hotel and Oklahoma City.

Stillwater, OK

From the OKC airport terminal the access road will be taking you North.
Drive about 1.5 miles and turn right (East) onto Airport Drive, a divided highway.
Drive about 1.2 miles to I-44. Take the I-44 East to Tulsa, a lefthand exit.
Follow I-44 East about 18 miles to I-35 North to Wichita.
(Note, at about 6.5 miles from the Airport Drive I-44 exits to the right. Be sure to follow it.

At 13.5 miles I-35 and I-44 combine for 4.5 miles before I-35 heads north. Do not take the

Turner Turnpike, I-44 Toll.)

Follow I-35 North about 36 miles to Exit 174. Exit right on Highway 51 East to Stillwater.
Drive east on 51 about 17 miles To Stillwater.
Turn left (north) on Monroe, the second traffic light.
Ag Hall is on the SW corner of Monroe and Farm Rd.
***Biosystems Lab**: Southeast corner of Cleveland and Hall of Fame*
Total Distance: 74 miles
Estimated Time: 1 hour, 15 minutes

Local Contacts

USDA ARS Offices Chickasha, OK (405) 224-7393 Gary Heathman
USDA ARS Offices El Reno, OK (405) 262-5291 Pat Starks
OSU Biosystems & Agricultural Engineering Laboratory (405) 744-5428 Ron Elliott

6 LITTLE RIVER WATERSHED, GEORGIA (GA)

The first deployment will cover the GA and AL sites. The aircraft base of operations will be the Huntsville International Airport during this deployment. On a given day it would be possible to choose the best target and if required both sites could be flown. The general locations of the two sites are shown in Figure 18.

Figure 18. General locations of the AL and GA regional areas.

6.1 Regional Description

Figure 19 illustrates the general vegetation conditions that can be expected in the Little River Georgia (GA) region during SMEX03. There is considerable forest, primarily pines in the uplands and field edges, and some hardwoods in the stream bottoms. The dominant crop types are peanuts and cotton. Other types of crops grown include tobacco, corn, soybeans, melons, and some vegetable crops, these are in minor acreage. Corn and melons are planted early in the year (March), cotton will be planted throughout the end of April and early May, and peanuts will be planted in May. Corn will develop a full canopy by May-June, peanuts and melons will cover the soil surface by the end of June, and Cotton will fill out some time in July. The photo shown in Figure 20 is of cotton and was taken on June 21 of 1999 following an early May planting. Figure 20 also shows peanuts in early July. Most of the soils are well drained and have a sandy surface layer and a loamy subsoil that is mostly mottled. Nearly level to gently sloping soils are extensive on uplands. Most of these soils are well drained and have smooth, convex slopes. In places, poorly drained soils are in depressions and along drainageways. These soils have a sandy surface layer and a loamy subsoil. Nearly level flood plain soils are common near the rivers and creeks. These soils are poorly drained and mainly loamy throughout.

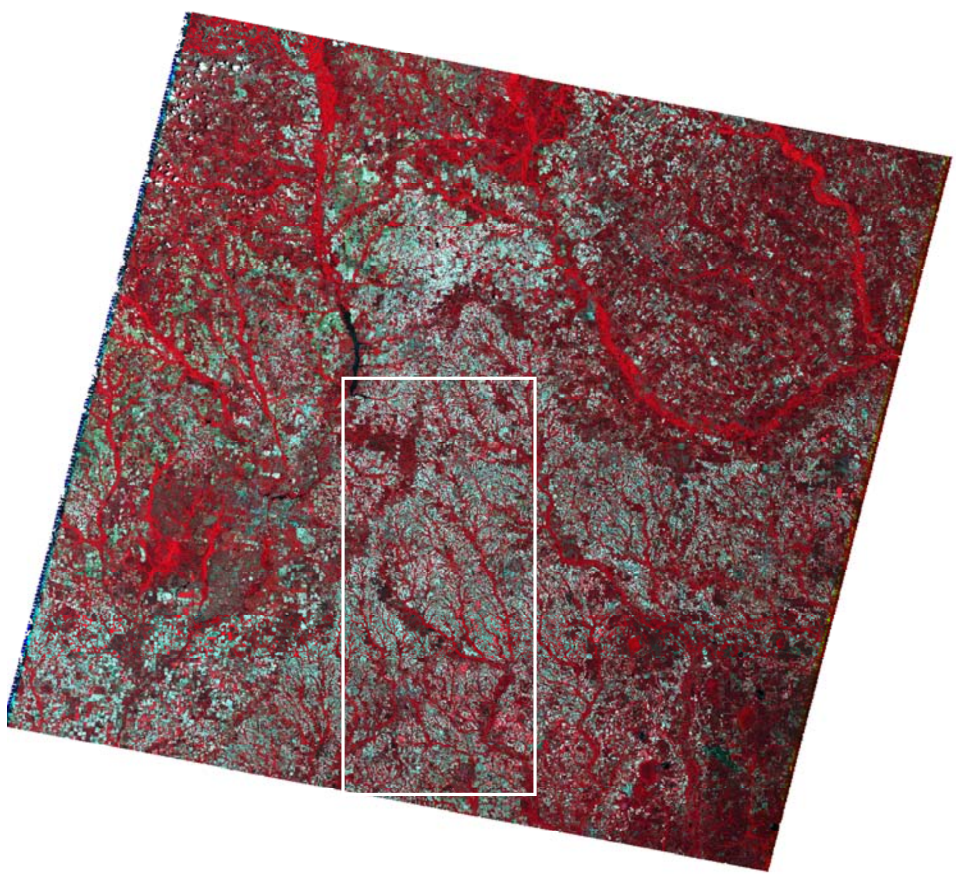

Figure 19. Landsat TM Image from June 2000 for the Little River Georgia Region.

Figure 20. Vegetation conditions in the GA Regional area expected in late June. Top photo shows peanuts and the bottom photo shows cotton.

6.2 Insitu Soil Moisture and Meteorological Networks

The USDA-ARS Southeast Watershed Research Lab has collected hydrologic and climatic data on the 334 km^2 Little River (LR) Experimental Watershed near Tifton, Georgia since 1968. Its hydrologic network consists of raingages and streamgages within nested watersheds as shown in Figure 21.

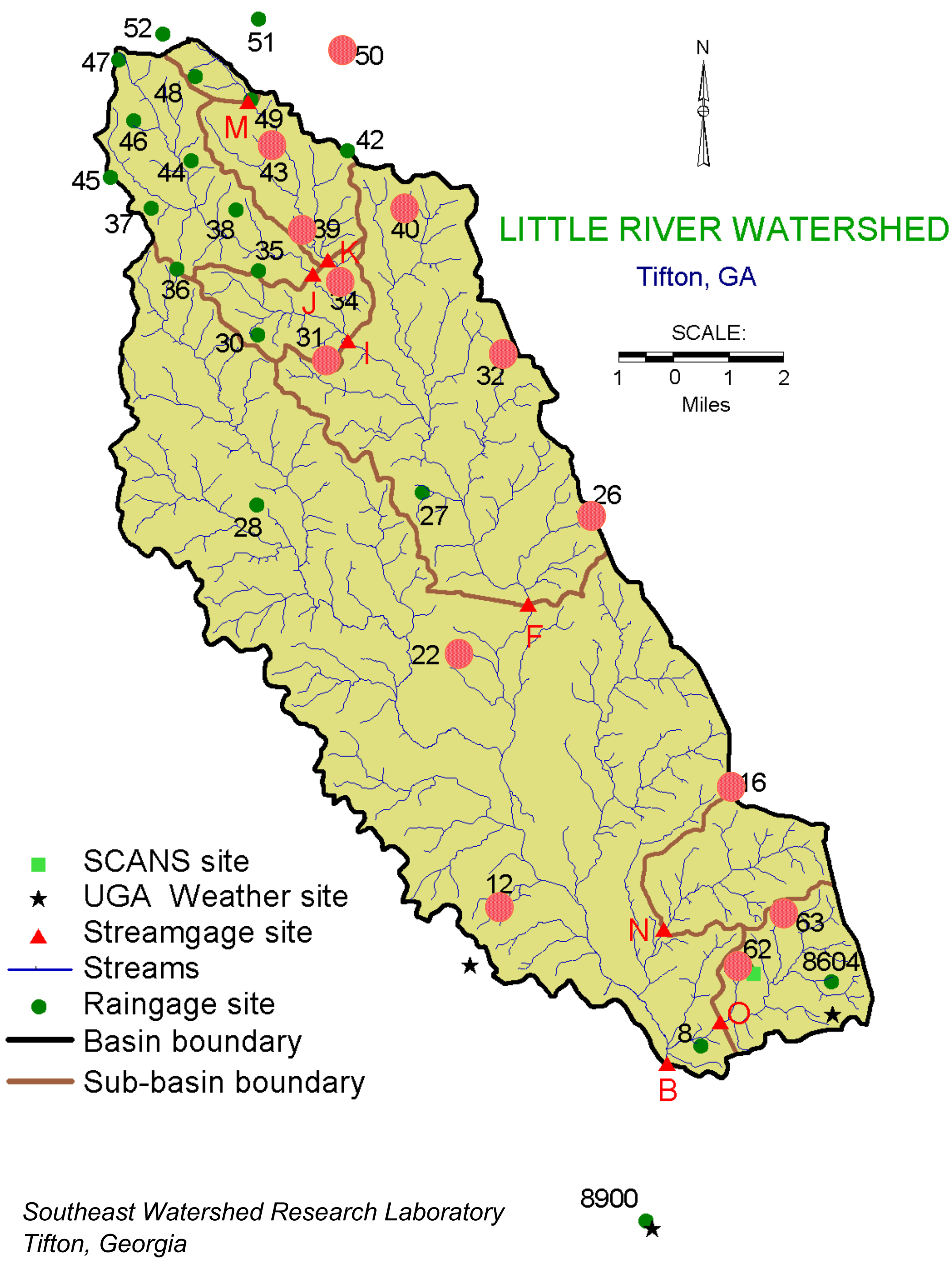

Figure 21. The Little River Watershed raingages and streamgages. Precipitation stations with soil moisture probes are highlighted.

The Little River Watershed is in the headwaters of the Suwannee River Basin, a major interstate basin that begins in Georgia and empties into the Gulf of Mexico in the Big Bend region of Florida. The Suwannee River Basin is completely contained in the Coastal Plain Physiographic Region and is the largest free-flowing river in the Southeastern U.S. Coastal Plain. The Little River is a tributary of the Withlacoochee River which, along with the Alapaha River, is one of two main tributaries of the Suwannee River.

The experimental watersheds are located in a paired and nested arrangement that facilitates testing of analytical formulas and modeling concepts. Instrumentation was installed in the late 1960's and early 1970's and has been in continuous operation since that time. Continued operation of this hydrologic network supports hydrologic research as well as the environmental quality and riparian research programs of the SEWRL and cooperators.

Extensive land use information (Williams 1982, Perry et al. 1999) and physical characterization data (Sheridan and Ferreira 1992) exist for the LREW. The watershed land use is a mixture of row-crop agriculture, pasture and forage production, upland forest, and riparian forest. Sub-watersheds range from about 25% to about 65% agricultural land. A detailed data management system exists to provide processing, editing, and summarization of LREW data (Sheridan et al. 1995). Rainfall in the region is poorly distributed and often occurs as short-duration, high-intensity convective thunderstorms (Bosch et al. 1999). Hydrologic and water quality measurements collected on the watershed include stream flow, precipitation, and nutrient, pathogenic bacteria, and pesticide content. The hydrologic measurement network consists of eight horizontal broad-crested weirs with v-notch center sections. Five minute continuous upstream and downstream stage data are recorded. Within the watershed a network of 35 tipping bucket precipitation gages record five minute cumulative rainfall (Figure 21). The spacing between the precipitation gages varies from three to eight km.

As part of the project sponsored by the NASA Aqua Calibration/Validation Program, surface soil moisture sensors have been installed at a number of locations in the LR and surrounding region (Figure 21). Thirty-nine Stevens-Vitel (http://www.stevenswater.com/) soil moisture probes have been installed at thirteen locations within or near the watershed. Each of the thirteen locations contains three soil moisture probes and a digital-recording raingage. The soil moisture sensors are installed at 5, 20, and 30 cm. Precipitation totals are recorded every minute during rainfall events and half-hour soil moisture averages are calculated from five minute readings. All data are transferred daily and available on a near real-time basis from the SEWRL web site at: http://www.tifton.uga.edu/sewrl/.

The sites are approximately 9 km apart. The selected subset of LR raingage sites provides watershed-area coverage (Figure 21) and cover a range of soil types (Table 23). There is one NRCS SCAN site within the watershed (http://www.wcc.nrcs.usda.gov/scan/index2.html), a Bowen ratio station, and three University of Georgia meteorological stations where rainfall, air temperature, relative humidity, incoming solar radiation, and wind speed and direction are measured. An additional seven soil moisture sites will be established in 2003. These sites will be distributed outside of the watershed and at existing raingage sites.

Additional Information on the Little River watershed can be found at http://www.tifton.uga.edu/sewrl/. In addition, the state of Georgia has an extensive meteorological network and provides both real time and historic data products. The Georgia Automated Environmental Monitoring Network was established in 1991 by the College of Agriculture and Environmental Sciences of the University of Georgia. Each station monitors air temperature, relative humidity, rainfall, solar radiation, wind speed, wind direction, and soil temperature at 2, 4, and 8 inch depths every 1 second. Data are summarized at 15 minute intervals and at midnight a daily summary is calculated. There are 40 stations distributed over the state. This information can be found at http://www.griffin.peachnet.edu/bae/. One of these sites is about 3 km off the lower SE boundary of the watershed.

Table 23. Locations of GA Little River Watershed Insitu Soil Moisture Sites.

Site Name	Latitude (WGS84)	Longitude (WGS84)	Elevation (m)	Soil Type
RG12	31.523	-83.639	101.21	Fuquay loamy sand 0-5% slope
RG16	31.557	-83.567	123.13	Tifton loamy sand 2-5% slope
RG22	31.591	-83.655	105.20	Tifton loamy sand 2-5% slope
RG26	31.629	-83.612	115.77	Tifton loamy sand 2-5% slope
RG31	31.671	-83.698	121.80	Tifton loamy sand 2-5% slope
RG32	31.673	-83.642	123.04	Tifton loamy sand 2-5% slope
RG34	31.692	-83.693	112.14	Fuquay loamy sand 0-5% slope
RG39	31.705	-83.705	112.53	Fuquay loamy sand 0-5% slope
RG40	31.711	-83.674	134.27	Tifton loamy sand 2-5% slope
RG43	31.726	-83.716	132.24	Tifton loamy sand 2-5% slope
RG50	31.752	-83.693	113.08	Sunsweet gravelly sandy loam 5-12% slope
RG62	31.508	-83.560	107.62	Dothan loamy sand 2-5% slope
RG63	31.521	-83.548	110.85	Fuquay loamy sand 0-5% slope
LR SCAN	31.506	-83.565	106.68	Dothan loamy sand 2-5% slope
LR Bowen	31.506	-83.565	106.68	Dothan loamy sand 2-5% slope
UGA Tifton	31.500	-83.533	116.00	Tifton loamy sand 0-2% slope

6.3 Flightlines

It is anticipated that there will be three missions between and including July 23th and July 2nd. Flightlines are listed in Table 24 and shown in Figure 22.

Table 26. SMEX03 Georgia (GA) Flightlines

Line	Waypoint	Altitude (m above ground level)	Length (km)	Type	Latitude (Degrees)	Longitude (Degrees)
GA01	A	7300	125	Regional Mapping	31.9600	-83.8812
	B				30.9000	-83. 8812
GA02	A	7300	125	Regional Mapping	30.9000	-83.7499
	B				31.9600	-83.7499
GA03	A	7300	125	Regional Mapping	31.9600	-83.6184
	B				30.9000	-83. 6184
GA04	A	7300	125	Regional Mapping	30.9000	-83.4887
	B				31.9600	-83.4887

There are several possible daily mission plans that may be used because we will be conducting experiments in both AL and GA while deployed at HSV.

HSV Plan A: Fly both the GA and AL on the same day (5 hours)

Takeoff HSV 9:30 am CDT
Ferry to GA
GA Lines 11:45 am – 12:45 pm EDT
Ferry to AL
AL Lines 1:00 - 2:00 pm CDT
Water Cal 2:15 pm CDT
Land HSV 2:30 pm CDT

HSV Plan B: Only AL (2 hours)

Takeoff HSV 11:30 am CDT
AL Lines 12:00 - 1:00 pm CDT
Water Cal 1:15 pm CDT
Land HSV 1:30 pm CDT

HSV Plan C: Only GA (3:45 hours)

Takeoff HSV 9:45 am CDT
Ferry to GA
GA Lines 12:00 – 1:00 pm EDT
Ferry to AL
Water Cal 1:15 pm CDT
Land HSV 1:30 pm CDT

HSV Plan D: Only AL July 2 (3:45 hours)

Takeoff HSV 9:45 am CDT
Water Cal 10:00 am CDT
AL Lines 11:00 am - 12:00 pm CDT
Ferry to OK
Land OKC 1:30 pm CDT (POTENTIAL OK MISSION)

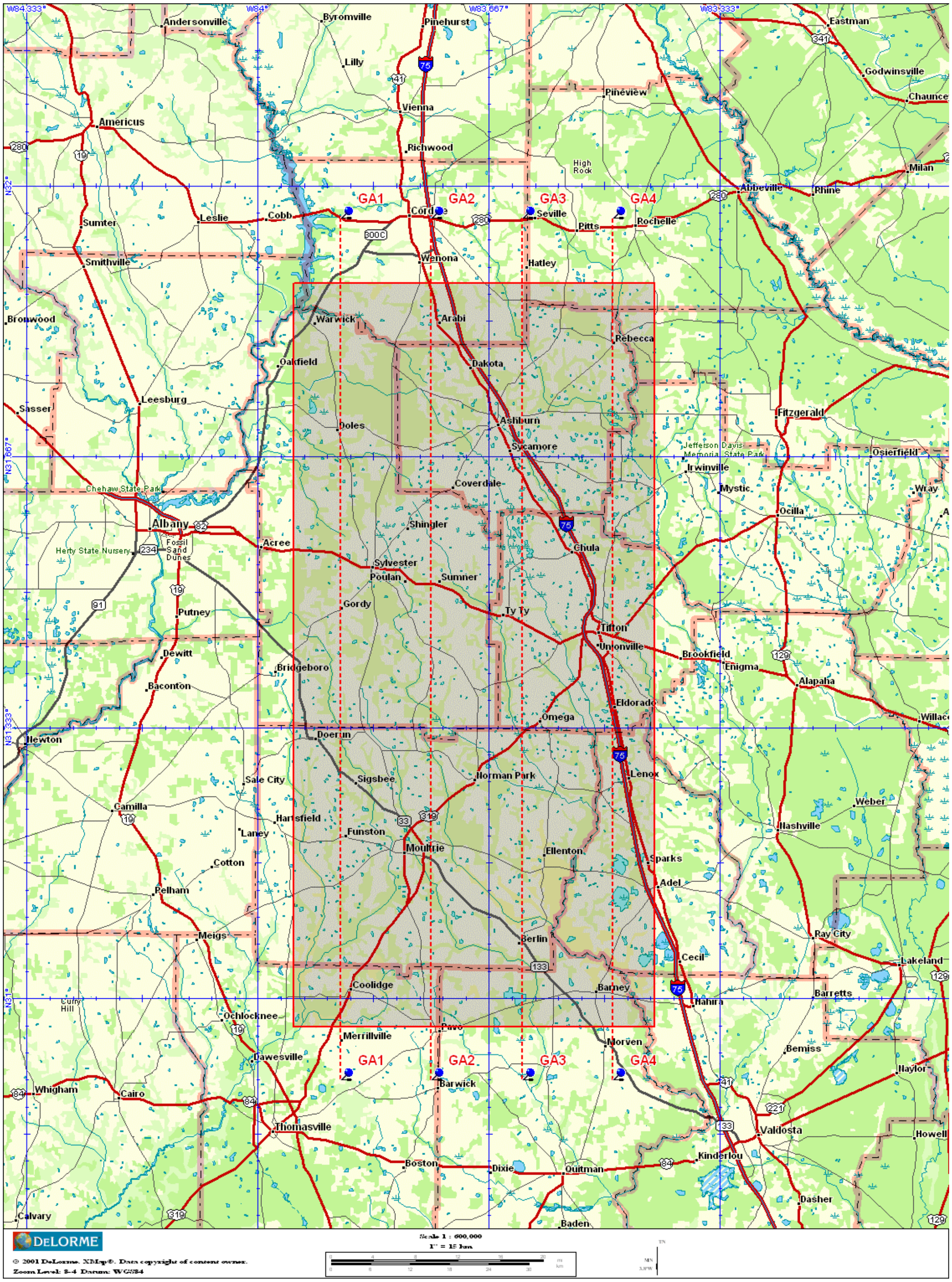

Figure 22. GA Regional flightlines.

6.4 Ground Sampling

Regional site ground sampling in GA will follow the general protocols described earlier. The sites selected are listed in Tables 25. Within GA there will be a slightly higher density of sites in the vicinity of the LR because a secondary objective to sampling is the verification of the measurements provided by the various Insitu instrumentation.

Ground sampling will be conducted on days with either aircraft missions or a satellite overpass.

Table 25. GA Regional Sites.

Site	Network Site ID	Crop	Irrigation	Reference Coordinates	
				Latitude (Deg.)	Longitude (Deg.)
GA01	RS 18	cotton	N	31.7319	-83.7049
GA02	RS 17	forest	N	31.7269	-83.7155
GA03	RS 19	cotton	N	31.7394	-83.7227
GA04	RS 20	forest	N	31.7328	-83.7602
GA05	Hardin 4	strip-till cotton	N	31.8041	-83.8232
GA06	Tison 1	pasture	N	31.7011	-83.8876
GA07	Tison 2	peanuts	N	31.7269	-83.9372
GA08	Tison 3	forest	N	31.7354	-83.9310
GA09	RS 21	young pines	N	31.6758	-83.7193
GA10	Greene 5	pasture	N	31.8199	-83.6834
GA11	Greene 4	corn	Y	31.8074	-83.6518
GA12	Greene 3	strip-till cotton	N	31.7957	-83.6390
GA13	Greene 2	pasture	N	31.7636	-83.6099
GA14	Wilson	forest	N	31.7862	-83.5114
GA15	Story	strip-till cotton	Y	31.7214	-83.4662
GA16	Jones	forest	N	31.7208	-83.5916
GA17	Apperson 1	cotton	N	31.4648	-83.9164
GA18	Apperson 2	cotton	N	31.4794	-83.8797
GA19	Jeffords	forest	N	31.4968	-83.8263
GA20	Young 4	strip-till cotton	Y	31.6105	-83.7596
GA21	RS 22	cotton	N	31.6308	-83.7099
GA22	Young 5	forest	N	31.5963	-83.7110
GA23	RS 15	double row peanuts	Y	31.5678	-83.6943
GA24	Land	pasture	N	31.5282	-83.7009
GA25	Gibbs	forest	N	31.4355	-83.5847
GA26	RS 1	row crops	Y	31.4416	-83.5869
GA27	RS 2	pasture	N	31.4907	-83.5928
GA28	RS 3B	peanuts	Y	31.5101	-83.6458
GA29	RS 4	forest	N	31.5314	-83.6339
GA30	RS 11	pasture	N	31.5603	-83.6180
GA31	RS 13	row crops	Y	31.5568	-83.6279

GA32	Register 1	forest	Y	31.6049	-83.4720
GA33	Register 2	cotton	Y	31.6033	-83.4874
GA34	RS 16	row crops	Y	31.6345	-83.6305
GA35	RS 10	row crops	N	31.5513	-83.5788
GA36	RS 9	row crops	Y	31.5432	-83.5532
GA37	RS 5B	cotton	Y	31.5086	-83.5573
GA38	Lasseter 1	cotton	Y	31.2240	-83.7496
GA39	Evarts	forest	N	31.2594	-83.8434
GA40	Lasseter 2	pasture	Y	31.2923	-83.8176
GA41	Lasseter 3	cotton	Y	31.3339	-83.8174
GA42	McCorvey	row crops	Y	31.3699	-83.8364
GA43	Oak Ridge	forest	N	31.3686	-83.7482
GA44	Dodson B	pasture	Y	31.4140	-83.6112
GA45	Dodson C	cotton	Y	31.4036	-83.6265
GA46	Dodson F	forest	N	31.3840	-83.6774
GA47	Baker 2	cotton	Y	31.2232	-83.6099
GA48	Baker 3	cucumbers	Y	31.2627	-83.5575
GA49	Janelle	forest	N	31.3337	-83.4848

6.5 Logistics

Security

Access to the ARS facility in Tifton will only be permitted when there is an ARS federal employee present.

Field and Lab Safety

See Appendix A

Hotel

Microtel Inn
196 S Virginia St.
Tifton, GA
229-387-0112
Quoted a group weekly rate of $343 for a double suite ($49/night)
Should be under Experiment Station/Dave Bosch

Shipping Information

Attn: David Bosch
USDA-ARS, SEWRL
PO Box 946

2375 Rainwater Road
Tifton, GA 31794

Directions

To reach the SEWRL laboratory from Interstate take exit # 64, the Rural Development Center and ABAC exit, proceed south on Hwy 41 to 20th St. Proceed west over railroad track to Moore Hwy. Go right on Moore Highway traveling north. Just after going under I-75 take a left onto Rainwater Road. Continue west on Rainwater to the blue office building at 2375 Rainwater.

Maps showing the locations of the, ARS Tifton Lab and local hotels are included in Appendix B.

Local Contacts

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Tstrickland@tifton.usda.gov
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7 ALABAMA MESONET (AL), ALABAMA

7.1 Regional Description

The northern Alabama study area spans the Alabama-Tennessee border in the Tennessee River Valley (Figure 23). The eastern third of the study area is comprised of remnants of the Cumberland Plateau and is characterized by significant relief (Figure 24). The remaining part of the study area is a smooth or gently rolling plain that is part of the Highland Rim of the Interior Low Plateau.

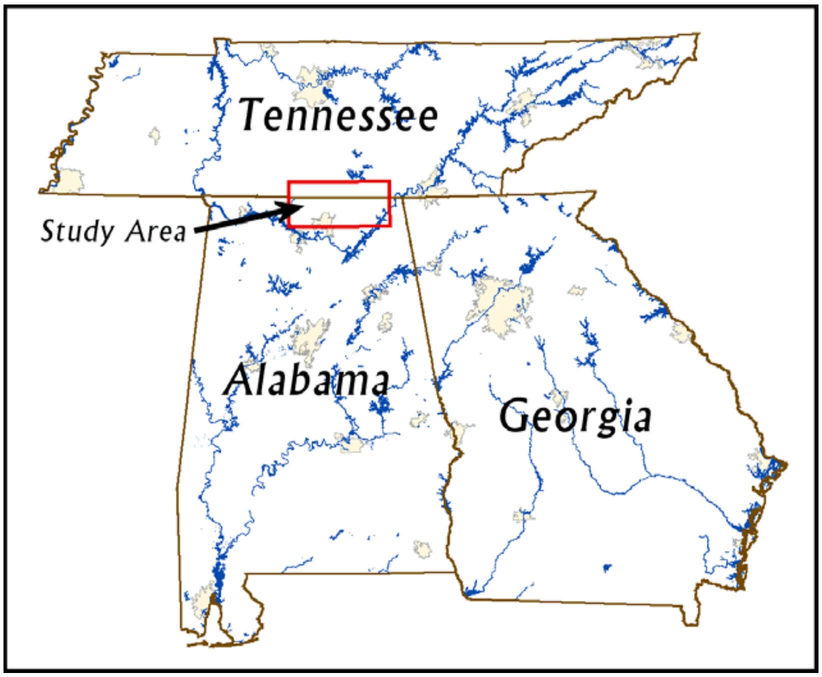


Figure 23. Map showing the location of the study area in the Tennessee Valley spanning the Alabama-Tennessee state line.

About 60 percent of the study area is covered by soils with moderate infiltration rates. These soils overlie primarily Paleozoic carbonate rocks that are predominant in the eastern part of the study area. These soils are very deep, clayey soils on gently sloping uplands. Typically, they have dark-reddish brown silt loam topsoil and a dark red silty clay loam and clay subsoil. Soils with slow infiltration rates cover about 38 percent of the study area. These soils primarily overlie the sandstone and unconsolidated sand, but also overlie carbonate rocks. These soils are moderately deep, loam soils on gently sloping uplands. Typically, they have dark-grayish brown fine sandy loam surface layer and brownish sandy clay loam sub-soils overlying hard sandstone bedrock at a depth of 20 to 40 inches. Other locations of the study region have a mixture of soils with moderate to slow infiltration rates, and in some places very slow infiltration rates, which cover about 2 percent of the area. Soils with high infiltration rates are present in less than 1 percent of the area and are located at the northern and eastern parts of the area.

Figure 24. Photographs that depict the “typical” setting characteristic of the Alabama study area. The hills in the upper photograph are remnants of the Cumberland Plateau and comprised predominantly of limestone bedrock. A cotton crop is shown in the lower photograph.

Most of this area consists of small and medium-sized farms. Agricultural land (pasture and cultivated land) accounts for about 40 percent of land use. Pasture accounts for about 72 percent of all agricultural land throughout the study area. Cultivated land generally is located in the central and southwestern part of the study area, where relief is lowest (Figure 24 and 25). The western region contains the largest percentage of cultivated land (16 percent). Corn, soybeans, cotton, and wheat are the predominant crops grown in this area. Corn acreage was the largest of the crop areas in 1992 and accounted for about 34 percent of the total harvested acreage of these crops (U.S. Department of Commerce, 1994). Soybean acreage accounted for about 32 percent, cotton about 23 percent, and wheat about 11 percent of the total harvested acreage of all four crops in 1992. The amount of forested land ranges from about 27 percent in the western part to 68 percent in the eastern part of the study region where topographic relief is greatest. The plateau and remnant “mountains” support a mixed oak-pine forest. Shortleaf pine, loblolly pine, sweetgum, yellow-poplar, red oaks, and white oaks are the major overstory species. Dogwood and redbud are major midstory species. Japanese honeysuckle, greenbrier, low panicums, bluestems and native lespedezas are understory species.

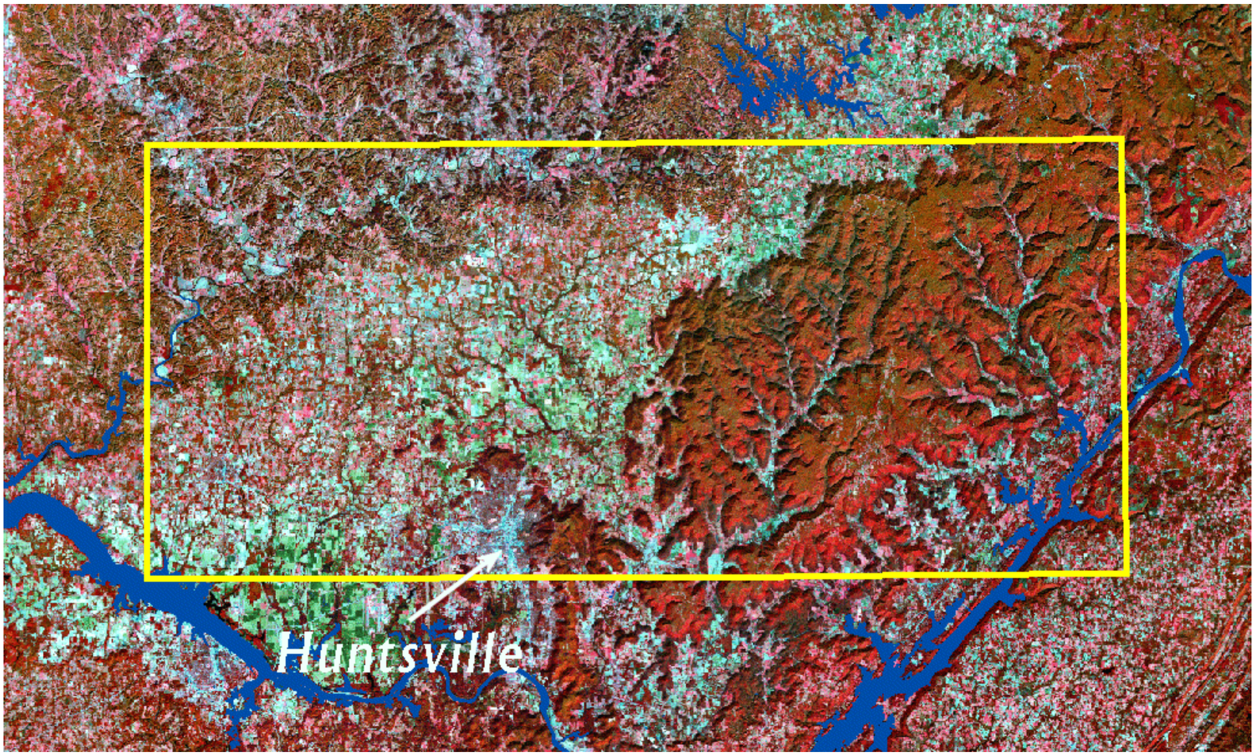


Figure 25. False-color image of the northern Alabama study area (yellow boundary). The arrow points to downtown Huntsville, Alabama. The southern end of the Cumberland Plateau is the red feature in the eastern portion of the study area. Cultivated land is green or white, pasture is pink.

The study region has a temperate and warm, humid climate. Average temperature across the region ranges from 56 to 61ºF with an average annual temperature of about 59ºF. The warmest months are July and August and the coolest month is January. Average annual precipitation is about 56 inches. The average amount of precipitation for individual sites in the study area ranges from about 50 inches in the western part of the study area to about 60 inches in the eastern part of the study area. The increase in precipitation from west to east generally corresponds to the increase in elevation. Average rainfall amounts are highest during November through May, with March generally being the wettest month. Average rainfall amounts are lowest from June through October. August through October are usually the driest months of the year.

7.2 Meteorological and Soil Moisture Networks

Alabama Mesonet

The Center for Hydrology, Soil Climatology, and Remote Sensing (HSCaRS) developed an outdoor research and teaching laboratory equipped with permanent sensors that continuously record environmental and meteorological data. The HSCaRS Mesonet is located in north central Alabama covering an area of approximately 6300 km^2 (Figure 26). The network covers Madison county and portions of Jackson, Limestone, Marshall, and Morgan Counties.

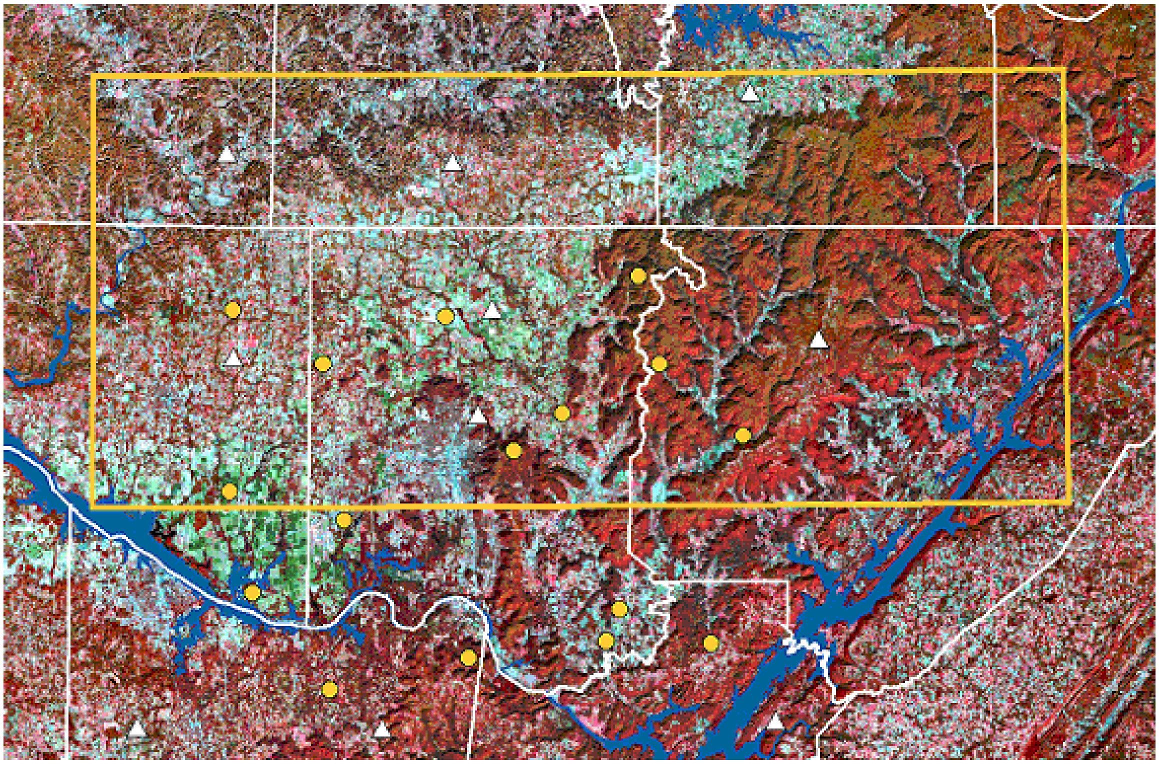


Figure 26. Map showing the location of meteorological (triangles) and soil profile (circles) monitoring stations in northern Alabama.

The Mesonet includes seven meteorological stations and 16 soil profile stations (Figure 26 and Tables 27 and 28). The meteorological stations and associated soil profile systems are part of the USDA NRCS NWCC Soil Climate Analysis Network (SCAN). They are fully automated and provide near real-time observations at five-minute intervals that are averaged over 60 minutes and transmitted to the NWCC and HSCaRS laboratories every hour through the USDA SCAN system for quality control and dissemination. The data collected at each weather station include: soil moisture and temperature, air temperature and relative humidity, wind speed and direction, solar radiation, rainfall (Figure 27) (Table 29).

Soil profile systems are collocated with each of the seven meteorological stations. There are 16 additional soil profile stations located throughout the Mesonet area (Figure 27) (Table 29). The soil profile stations are equipped with soil moisture and temperature sensors, soil heat flux plates, and a tipping bucket rain gauge. The soil moisture sensors records soil moisture fluxes at five depths between 5 and 102 cm. Soil temperature is measured at 5, 10 and 20 cm and soil heat flux is measured between 5 and 10 cm. These data are recorded at 15-minute intervals and stored on data loggers, which are downloaded every two weeks for quality control and dissemination. Additionally, laboratory measurements of the thermal conductivity, diffusivity and specific heat capacity of the soil at each soil profile station are available.

Table 27. Location of SCAN stations and associated land cover.				
Site #	Latitude (Deg.)	Longitude (Deg.)	Elev. (m)	Land cover
WS 1	34.8488	-86.8848	203	Pasture near ditch
WS 2	34.4403	-87.0141	193	Wetland edge
WS 3	34.4449	-86.1652	209	Grassland on knoll
WS 4	34.4393	-86.6874	175	Pasture
WS 5	34.7854	-86.5591		Grassland on campus
WS 6	34.9016	-86.5385	191	Grassland on A&M farm
WS 7	34.8659	-86.1026	512	Edge of pine forest on hillside
WS 8	35.0747	-86.8942	221	Grassland on hilltop
WS 9	35.0643	-86.5914	300	Pasture near paved road
WS 10	35.1392	-86.1911	305	Grassland

Table 28: Location of Alabama Mesonet soil profile stations and associated land cover.				
Site #	Latitude (Deg.)	Longitude (Deg.)	Elev. (m)	Land cover
PS 1	34.9012	-86.8866	204	Cotton field beside hardwood forest
PS 2	34.7000	-86.8910		Cotton field
PS 3	34.5890	-86.8607		Cotton field
PS 4	34.5408	-86.7534	193	Clearing in pine forest
PS 5	34.8411	-86.7666		Pasture on hillside near paved road
PS 6	34.8937	-86.6024		Cotton field
PS 7	34.6687	-86.7383	200	Pasture at edge of gravel lot
PS 8	34.5335	-86.3900	179	Pasture near paved road
PS 9	34.7451	-86.5124	495	Hilltop clearing in hardwood forest
PS 10	34.7858	-86.4473		Cotton field
PS 11	34.5690	-86.3715		Grassland near ditch
PS 12	34.8984	-86.1706		Clearing in hardwood forest; sloped
PS 13	34.9369	-86.3443	251	Cotton field on hilltop
PS 14	34.7596	-86.2051	212	Grassland near paved road
PS 15	34.5311	-86.2511	348	Grassland on hilltop near paved road
PS 16	34.5804	-86.5614		River bottom

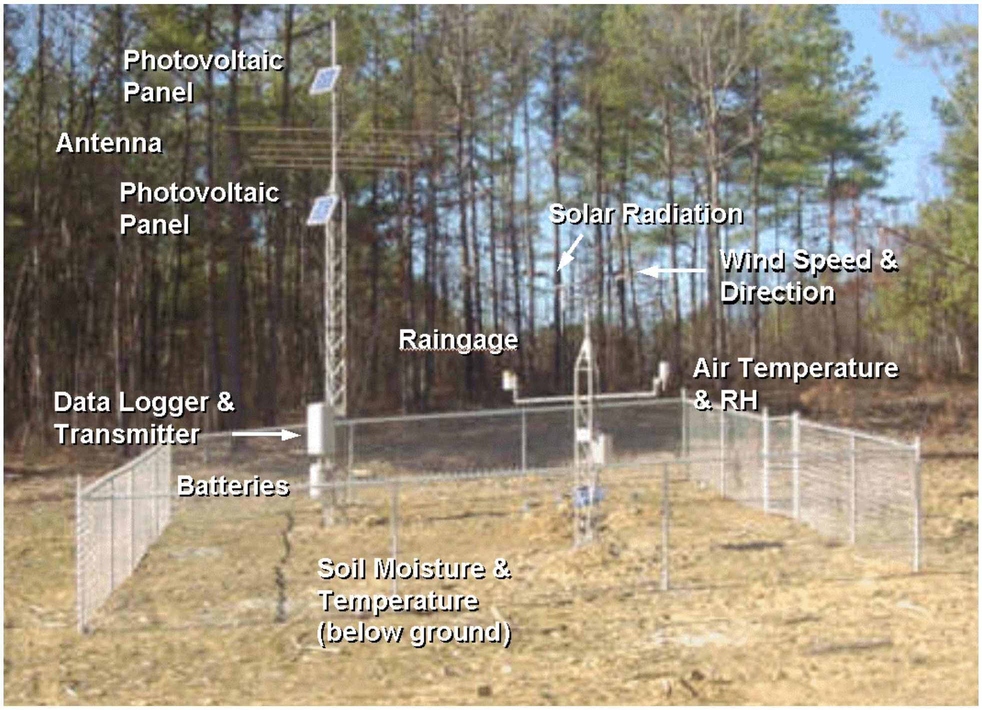


Figure 27**.** Photograph of a SCAN station that integrates meteorological and soil profile instrumentation into a single automated system.

Table 29. Instrumentation used in the Alabama Mesonet systems				
Variable	Sensor/Equipment	Vendor	Model	Height/Depth
Solar radiation	Pyranometer	Licor	LI-200SZ	15 or 30 ft.
Wind speed & dir.	Anemometer, vane	R. M. Young	03001-5	15 or 30 ft.
Air temp. & RH	Thermometer, probe	CSI/Vaisala	CS500	9 or 10 ft.
Rainfall	Tipping bucket	Campbell Sci.	TE525	5 or 9 ft.
Soil moisture	Probe	Vitel	Steven’s	2, 4, 8, 20, and 40 in.
Soil moisture	Probe	Delta-T	PR1/6w-L10	2, 4, 8, 20, and 40 in.
Soil moisture	Probe	Delta-T	ML2x	4 and 8 in.
Soil temperature	Probe	Vitel	Steven’s	2, 4, 8, 20, and 40 in.
Soil temperature	Probe	Dynamax	TM-L35	2, 4, 8, (20) in.
Soil heat flux	Plate	Campbell Sci.	HFT	2 and 4 in.
	Data logger	Campbell Sci.	CR10X	
	Transmitter	Meteor	545B	

Data may be viewed on the Internet at:
http://www.wcc.nrcs.usda.gov/scan/Alabama/alabama.html
Some graphical results are available at:
http://wx.aamu.edu/ALMNET.html

For further information, contact:
Dr. Tommy L. Coleman, Director, HSCaRS (256) 372-4192 tcoleman@aamu.edu
Dr. Teferi Tsegaye, Assistant Director, HSCaRS (256) 372-4219 ttsegaye@aamu.edu
Mr. Robert Metzl Research Associate, HSCaRS (256) 372-4226 rmetzl@aamu.edu

CHARM Raingage Network

NASA has established a volunteer-based precipitation network in the Huntsville and Madison County area in support of local weather and climate research at the Global Hydrology and Climate Center (GHCC). The Cooperative Huntsville-Area Rainfall Measurement (CHARM) network has been operating continuously since January 1, 2001. The network is comprised of approximately 100 volunteers who take daily rainfall measurements. The network also incorporates 20 automated rain gauge data from the National Weather Service (NWS), NASA, and the United States Geological Survey (USGS) that report data at 1-5 minute intervals on a 24h basis. The network covers about a 3600km^2 region, including all of Huntsville and portions of Madison, Jackson, Limestone, and Morgan Counties in northern Alabama (Figure 28). The CHARM measurements are used to validate weather radar and lightning data, monitor spatial distributions of precipitation for soil moisture studies or modeling activities, and to support various satellite remote sensing studies (Figure 29). Observers submit data daily by 0900 local time. An automated procedure screens the data for outliers and produces maps of rainfall amount. Data from this network may prove invaluable during SMEX03 to assess the spatial variability of rainfall that occurs during the experiment.

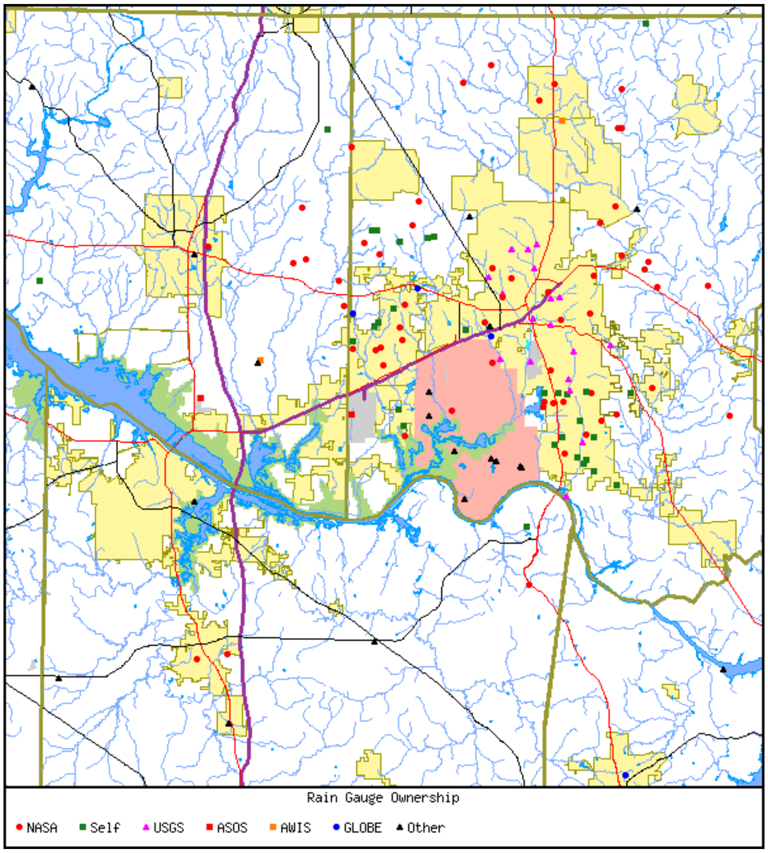


Figure 28. The CHARM Network in northern Alabama. The network covers a region of about 60 x 80 km.

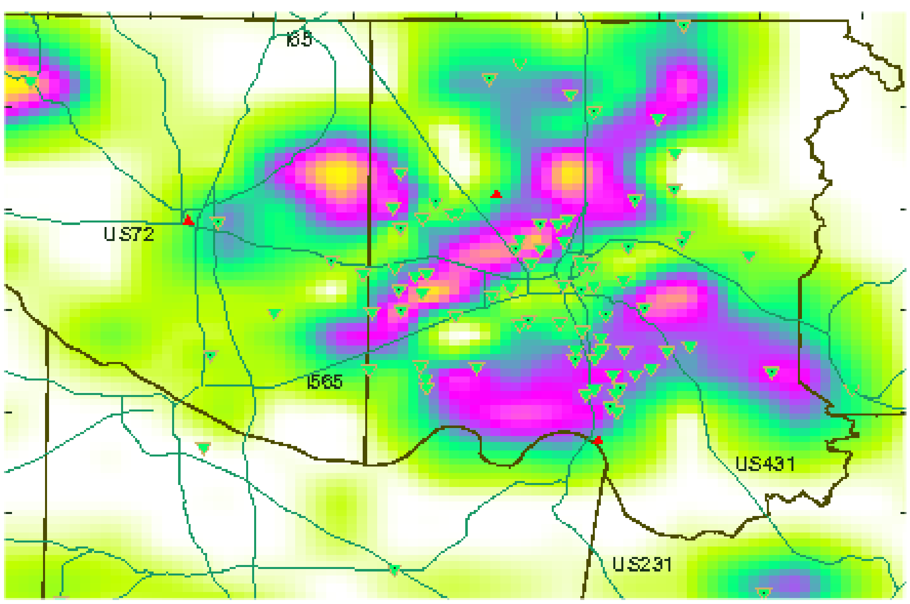


Figure 29. An example of the spatial variability of rainfall over Northern Alabama typical of summertime thunderstorms.

7.3 Flightlines

It is anticipated that there will be three missions between and including July 23th and July 2nd. Flightlines are listed in Table 30 and shown in Figure 30.

Table 30. SMEX03 Alabama Flightlines						
Line	Waypoint	Altitude (m above ground level)	Length (km)	Type	Latitude (Degrees)	Longitude (Degrees)
AL1	A	7300	140	Regional Mapping	35.0900	-85.7298
	B				35.0900	-87.1257
AL2	A	7300	140	Regional Mapping	34.9800	-87.1257
	B				34.9800	-85.7298
AL3	A	7300	140	Regional Mapping	34.8700	-85.7298
	B				34.8700	-87.1257
AL4	A	7300	140	Regional Mapping	34.7600	-87.1257
	B				34.7600	-85.7298
AL5	A	500	10	Water Calibration	34.4183	-86.2467
	B				34.5600	-86.1100

There are several possible daily mission plans that may be used because we will be conducting experiments in both AL and GA while deployed at HSV.

HSV Plan A: Fly both the GA and AL on the same day (5 hours)

Takeoff HSV 9:30 am CDT
Ferry to GA
GA Lines 11:45 am – 12:45 pm EDT
Ferry to AL
AL Lines 1:00 - 2:00 pm CDT
Water Cal 2:15 pm CDT
Land HSV 2:30 pm CDT

HSV Plan B: Only AL (2 hours)

Takeoff HSV 11:30 am CDT
AL Lines 12:00 - 1:00 pm CDT
Water Cal 1:15 pm CDT
Land HSV 1:30 pm CDT

HSV Plan C: Only GA (3:45 hours)

Takeoff HSV 9:45 am CDT
Ferry to GA
GA Lines 12:00 – 1:00 pm EDT
Ferry to AL

Water Cal	1:15 pm CDT
Land HSV	1:30 pm CDT

HSV Plan D: Only AL July 2 (3:45 hours)

Takeoff HSV	9:45 am CDT
Water Cal	10:00 am CDT
AL Lines	11:00 am - 12:00 pm CDT
Ferry to OK	
Land OKC	1:30 pm CDT (POTENTIAL OK MISSION)

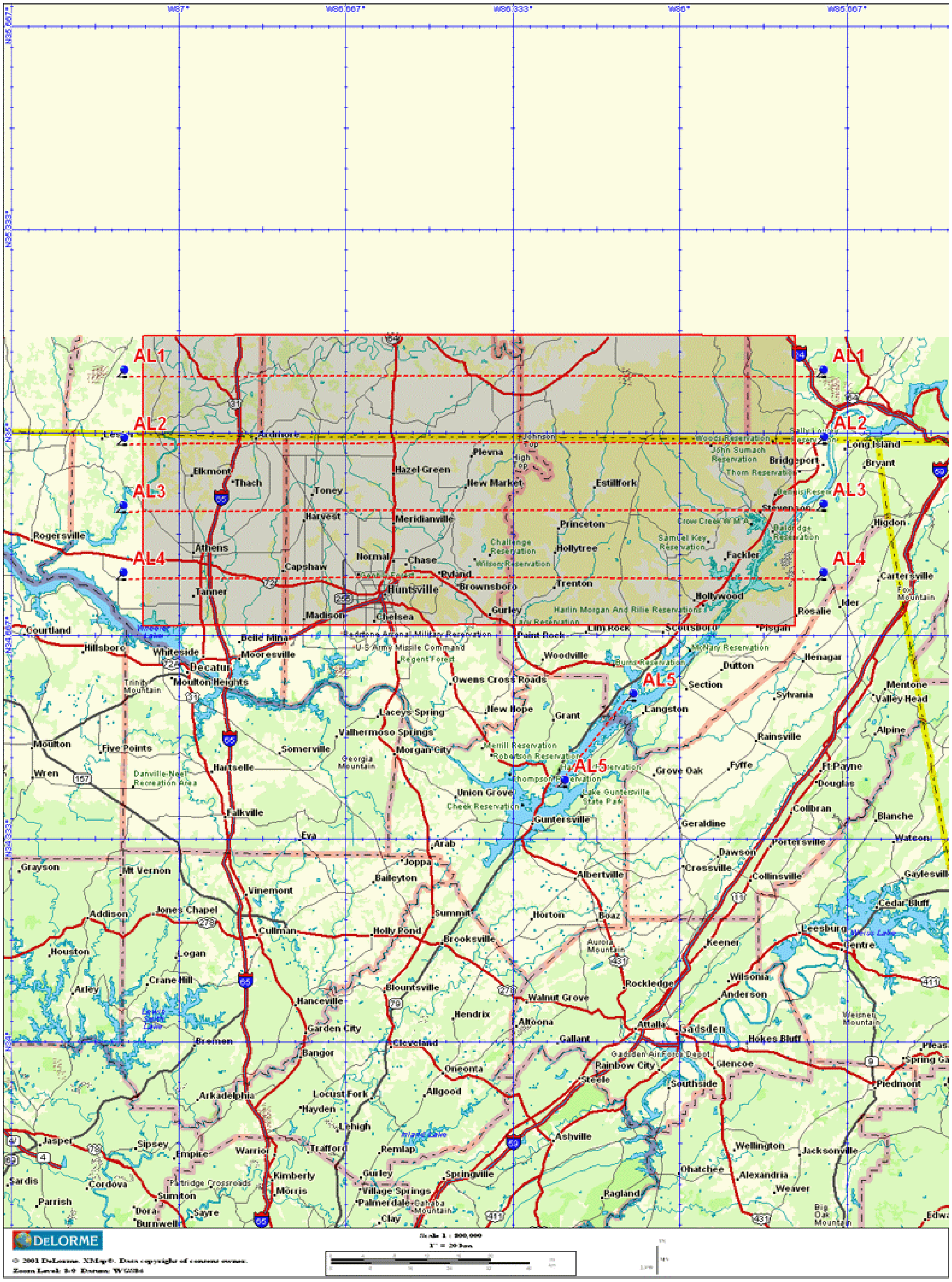


Figure 30. Alabama (AL) regional study area and flightlines.

7.4 Ground Sampling

Regional site ground sampling in AL will follow the general Regional protocols described earlier. The sites selected are listed in Tables 31.

Ground sampling will be conducted on days with either aircraft missions or a satellite overpass.

Table 31. Alabama AL Regional Sites

Site	Network ID	Land Cover	Reference Coordinates	
			Latitude (Deg.)	Longitude (Deg.)
AL01	Giles 1	Crop land	35.1105	-87.0015
AL02	Giles 2	Crop land	35.1283	-86.8750
AL03	Giles 3	Crop land	35.0503	-86.9989
AL04	Giles 4	Crop land	35.0458	-86.8654
AL05	Lincoln 1	Pasture	35.1144	-86.7562
AL06	Lincoln 2	Pasture	35.1192	-86.6176
AL07	Lincoln 3	Hardwood	35.1150	-86.4809
AL08	Lincoln 4	Pasture	35.1177	-86.3599
AL09	Lincoln 5	Pasture	35.0541	-86.7582
AL10	Lincoln 6	Cropland	35.5458	-86.6226
AL11	Lincoln 7	Cropland	35.0548	-86.5013
AL12	Lincoln 8	Cropland	35.0592	-86.3711
AL13	Franklin 1	Cropland	35.1150	-86.2495
AL14	Franklin 2	Cropland	35.1200	-86.1059
AL15	Franklin 3	Hardwood	35.1116	-85.9688
AL16	Franklin 4	Cropland	35.0588	-86.2450
AL17	Franklin 5	Hardwood	35.0542	-86.1208
AL18	Franklin 6	Hardwood	35.0587	-86.9876
AL19	Marion 1	Upland Hardwood	35.1183	-85.8482
AL20	Marion 2	Upland Hardwood	35.0659	-85.8495
AL21	Limestone 1	Not Planted	34.9271	-87.0528
AL22	Limestone 2	Cotton	34.9414	-86.8917
AL23	Limestone 3	Corn	34.8803	-87.0234
AL24	Limestone 4	Hay Field	34.8830	-86.8707
AL25	Limestone 5	Wheat	34.7853	-87.0190
AL26	Limestone 6	Cotton	34.7830	-86.8640
AL27	Limestone 7	Not Planted	34.7329	-87.0418
AL28	Limestone 8	Not Planted	34.7297	-86.8562
AL29	Madison 1	Pasture	34.9799	-86.7722
AL30	Madison 2	Crop land	34.9588	-86.6029
AL31	Madison 3	Pasture	34.9799	-864534
AL32	Madison 4	Crop land	34.9364	-86.4146

AL33	Madison 5	Crop land	34.8847	-86.7434
AL34	Madison 6	Crop land	34.8782	-86.6116
AL35	Madison 7	Cotton	34.7978	-86.4716
AL36	Madison 8	Cotton	34.8700	-86.4531
AL37	Madison 9	Crop land	34.7652	-86.7127
AL38	Madison 10	Bottom Land Hardwood	34.7782	-86.6481
AL39	Madison 11	Crop land	34.8164	-86.4931
AL40	Madison 12	Cotton	34.7858	-86.4473
AL41	Madison 13	Cotton	34.7610	-86.7366
AL42	Madison 14	Urban/pasture	34.7199	-86.6414
AL43	Madison 15	Upland Land Hardwood	34.7453	-86.5123
AL44	Madison 16	Crop land	34.7540	-86.4011
AL45	Jackson 1	Hardwood	34.9670	-86.2003
AL46	Jackson 2	Hardwood	34.9423	-86.0674
AL47	Jackson 3	Hardwood	34.9329	-85.9672
AL48	Jackson 4	Hay Field	34.9350	-85.8396
AL49	Jackson 5	Grass Pasture	34.8734	-86.2159
AL50	Jackson 6	Pine	34.8910	-86.1014
AL51	Jackson 7	Hay Field	34.8859	-85.9448
AL52	Jackson 8	Hay Field	34.8782	-85.8219
AL53	Jackson 9	Soybean	34.8028	-86.2410
AL54	Jackson 10	Fescue	34.7753	-86.1303
AL55	Jackson 11	Corn	34.7685	-86.0049
AL56	Jackson 12	Bottom Land Hardwood	34.7647	-85.8292
AL57	Jackson 13	Soybean	34.7336	-86.2484
AL58	Jackson 14	Soybean	34.7276	-86.1255
AL59	Jackson 15	Hay Field	34.7191	-86.0080
AL60	Jackson 16	Hay Field	34.7186	-85.8434

7.5 Logistics

Security

The Alabama A&M University Winfred Thomas Agricultural Research Station is gated and locked at night after normal work hours. The research lab building and each of the laboratories are also accessible by key. Keys will be issued to personnel on a limited basis for access to these facilities. During the day, however, you can expect all labs and buildings to be unlocked.

All field samples will be processed in the laboratories at the Winfred Thomas Agricultural Research Station of Alabama A&M University (Figures 31 and 32). The Research Station is located about 8 miles north of Huntsville near the town of Hazel Green (372 Walker Lane, Hazel Green, AL 35750). The laboratory consists of approximately 3700 ft^2 of floor space with a drying room for slow-drying vegetation, grinding/sieving room for soil samples, and cold storage. The laboratory has restroom facilities including showers. Access to the Research Station, the building, and to the individual labs will require a key.

Figure 31. Photograph of the Winfred Thomas Agricultural Research Station at Alabama A&M University.

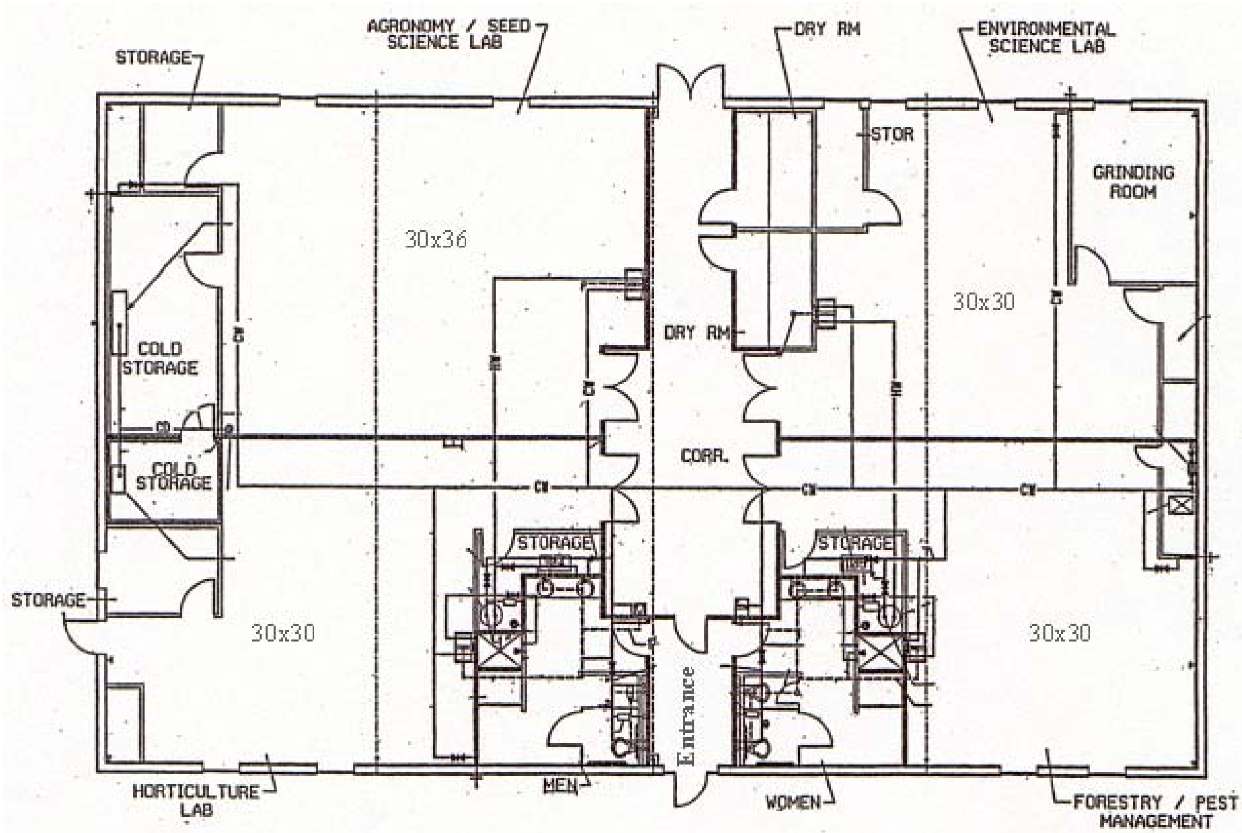


Figure 32. Floor plan of the laboratories at the Winfred Thomas Agricultural Research Station at Alabama A&M University.

Field and Lab Safety

See Appendix A

Hotels & Motels

Radisson Inn Huntsville Airport
8721 Madison Blvd.
Madison, AL 35758
256-772-8855
FAX: 256-464-0783
Web site: http://www.radisson.com/madisonal
Group Rate $67/night+tax under USDA

Additional lodging can be found at: http://wwwghcc.msfc.nasa.gov/LocalHotels.html

Shipping Information

Equipment and supplies that are needed for the experiment should be shipped directly to Winfred Thomas Agricultural Research Station at Alabama A&M University. Please provide notification of any shipments you plan to send so that we can notify you of their arrival. Packages should be shipped to:

Dr. Tommy Coleman
c/o SMEX03
372 Walker Lane
Hazel Green, AL 35750

Directions

From the North, West, and South to Alabama A&M Univ. Research Station:

From I-65, approach Huntsville on I-565 to Memorial Parkway (Rt. 231/431) and exit going north on Memorial Parkway. You will pass Alabama A&M University on the right. Continue north 8.2 miles from the football stadium to Walker Lane. Turn Right on Walker La. and go 0.6 miles to the entrance to the Research Station on the right. Enter the station (gravel road) and turn right at the first intersection. Proceed west about ¼ mi. to the gold building on the right, which is the laboratory that will serve as the central staging area.

From Huntsville International Airport to local lodging in nearby Madison:

If your lodging is in Madison, AL, you will exit the airport following signs to Madison and Rt. 20, which are just outside the airport.

Local Contacts

Dr. Tommy L. Coleman
Director, Center for Hydrology, Soil Climatology and Remote Sensing
Alabama A&M University
Normal, Alabama
(256) 851-5075; tcoleman@aamu.edu

Dr. Charles Laymon
Global Hydrology and Climate Center
Huntsville, Alabama
(256) 961-7885; charles.laymon@msfc.nasa.gov

Research Station Manager: Mr. Hosea Nalls (256) 828-2114; Fax: (256) 828-2109

8 BRAZIL (BZ)

8.1 Regional Description

The quality of the soil moisture product derived from AMSR-E will in part depend upon the specific regional validation efforts. There are obvious gaps in the geographic and climatic conditions that are currently planned for study. The inclusion of sites in Brazil will greatly improve the robustness of the validation effort.

The Brazilian ecological region known as the Cerrado (Figure 33) was selected as the focus of the SMEX03 experiment. This region consists of over 200 million hectares dominated by grasslands. Typical vegetation conditions within the study region are illustrated in Figure 34. Figure 35 shows general vegetation conditions as reflected in a Landsat image obtained in February 2000. A validation site in this domain would be compatible with AMSR capabilities and would also be representative of a large geographic region. For SMEX03 a site that includes the Cerrado and the bordering semi-arid region called the Cattinga was selected for mapping.

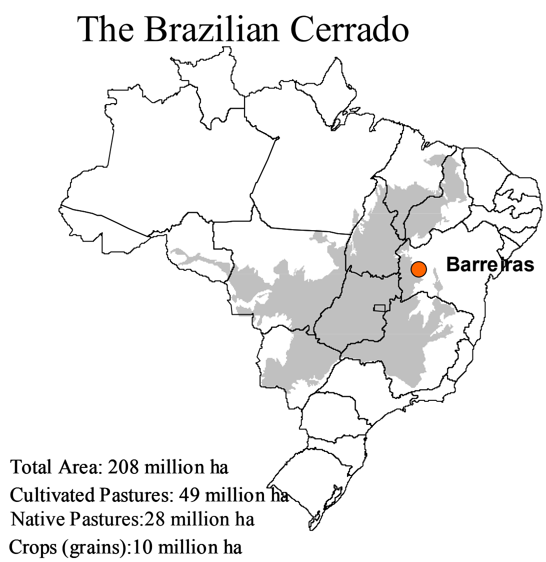


Figure 33. The Cerrado Region of Brazil.

An additional objective of SMEX03 in Brazil is to increase our understanding of the passive microwave response of the diverse vegetation types found in this region of the world. We are particularly interested in the rainforest. There is evidence that there is no below canopy contribution to the passive microwave emission at the AMSR frequencies and that the brightness temperature is nearly constant over extended periods. This allows the rainforest to be used as a calibration (hot) target for the satellite sensors. Considering the current uncertainties that exist with AMSR calibration this may be a significant contribution of SMEX03. To address this objective we will study a transect from Brasilia to Santareum on the last day of the mission.

Vegetation Near Barreiras
S 12.100° W 44.977°

MN-1 Abandoned Pasture
S 12.000° W 44.941°

MN-4 Cultivated Pasture
S 11.750° W 44.748°

LE-2 Rice
S 11.917° W 45.289°

Figure 34. Potential sampling sites illustrating vegetation cover conditions in the BZ Region. Photos were obtained in March 2003.

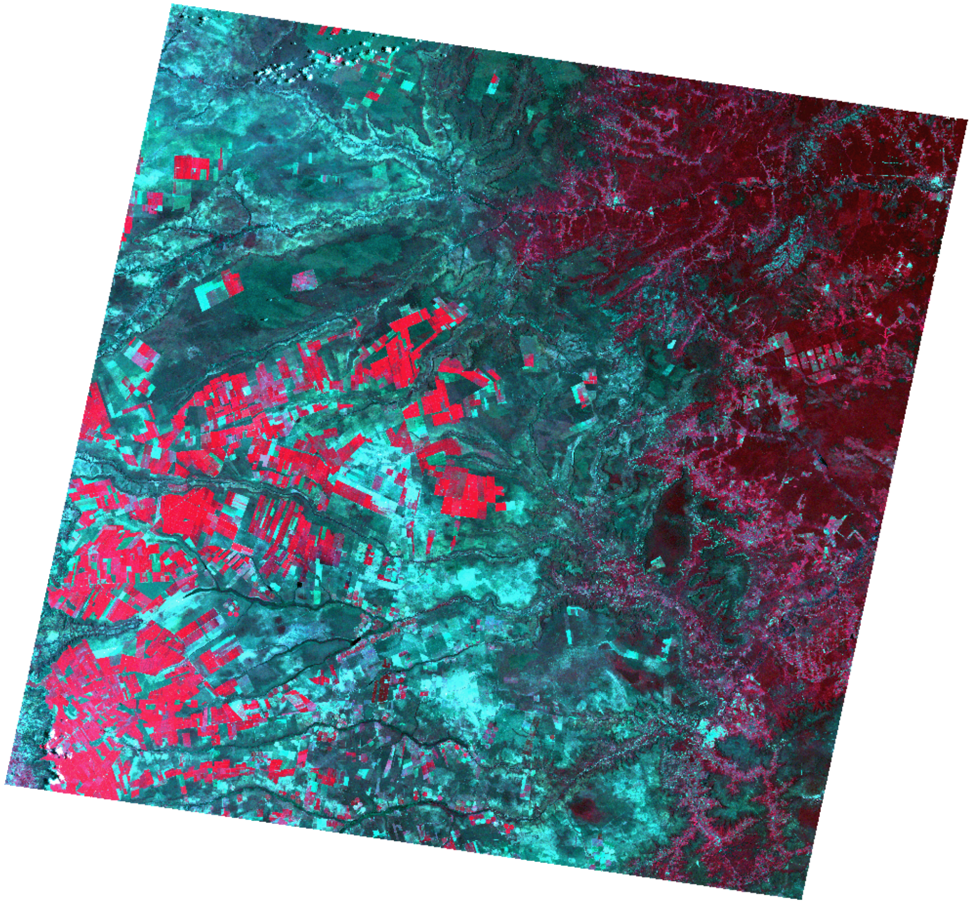


Figure 35. Landsat 7 TM image obtained February 22, 2000 (220/68) of the Cerrado Region near Barreiras, Brazil.

8.2 Insitu Soil Moisture and Meteorological Networks

Meteorological stations are sparsely distributed in the region. In addition to these, the Brazilian Embrapa team will install meteorological and insitu soil moisture stations in the study region prior to the aircraft experiment. Some of these may be left in place for continued validation of the satellite data. These stations will include the Vitel Hydra Probe at a depth of 5 cm.

8.3 Flightlines

The NASA P-3B aircraft will be traveling to and from Punta Arenas, Chile for a sea ice mission in Antarctica. It will have a high-resolution simulator of the AMSR satellite instrument on board called the PSR/A and PSR/C-X. Following the sea ice portion we will exchange the PSR/A for an L band radiometer (ESTAR). ESTAR is the predecessor to 2DSTAR and is described in Jackson et al. (1999).

The time frame for SMEX03 Brazil is September 16 to 26, 2003. This could shift a few days either way depending upon conditions encountered during the sea ice mission and problems encountered during the switch from PSR/A to ESTAR. It is anticipated that the aircraft would be available for flights on four to five days. Each flight might be three to four hours long. The aircraft base of operations would be the Brasilia Airport.

The flightlines in Brazil (BZ) (Figure 36 and 37 and Table 32) were designed to provide regional mapping several times during the deployment and coverage of an extended transect one time when returning to the U.S. Mapping lines will provide coverage of two ecological domains, Cerrados and Semi-arid.

The transect (Figure 36) line will provide coverage of a diverse set of vegetation conditions and will be supported by ground observations at important locations.

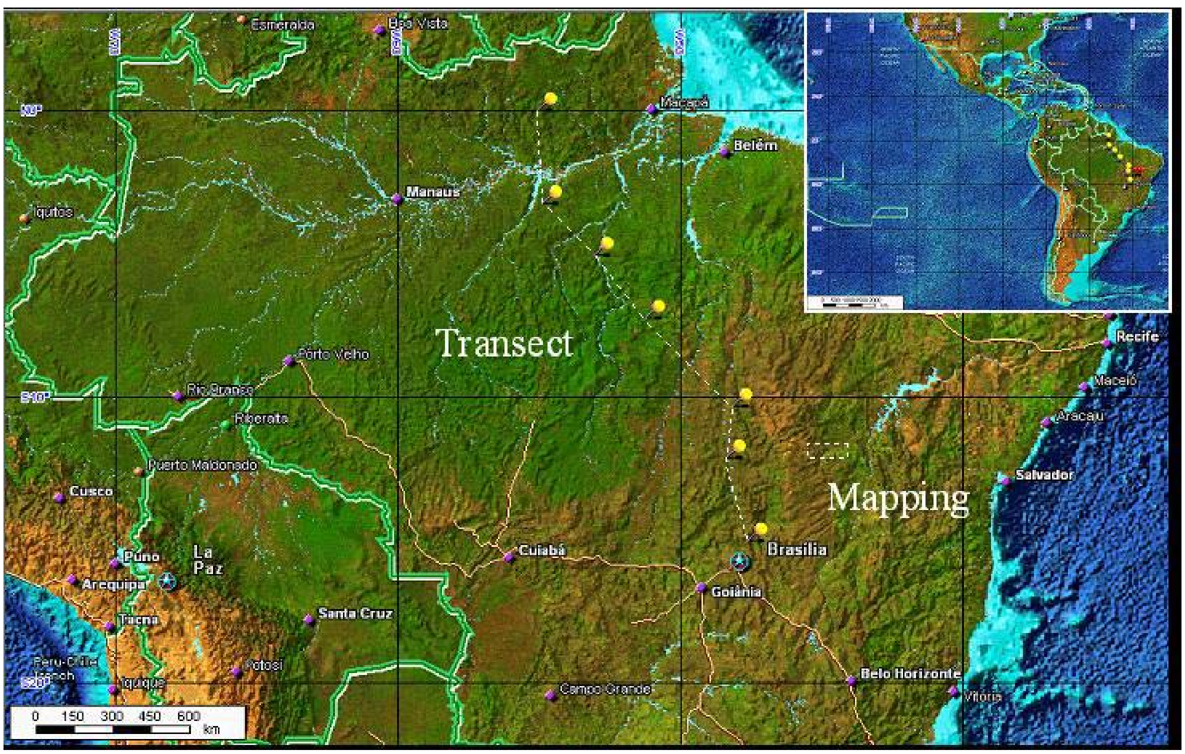


Figure 36. Location of Brazil regional study area and transect flightline

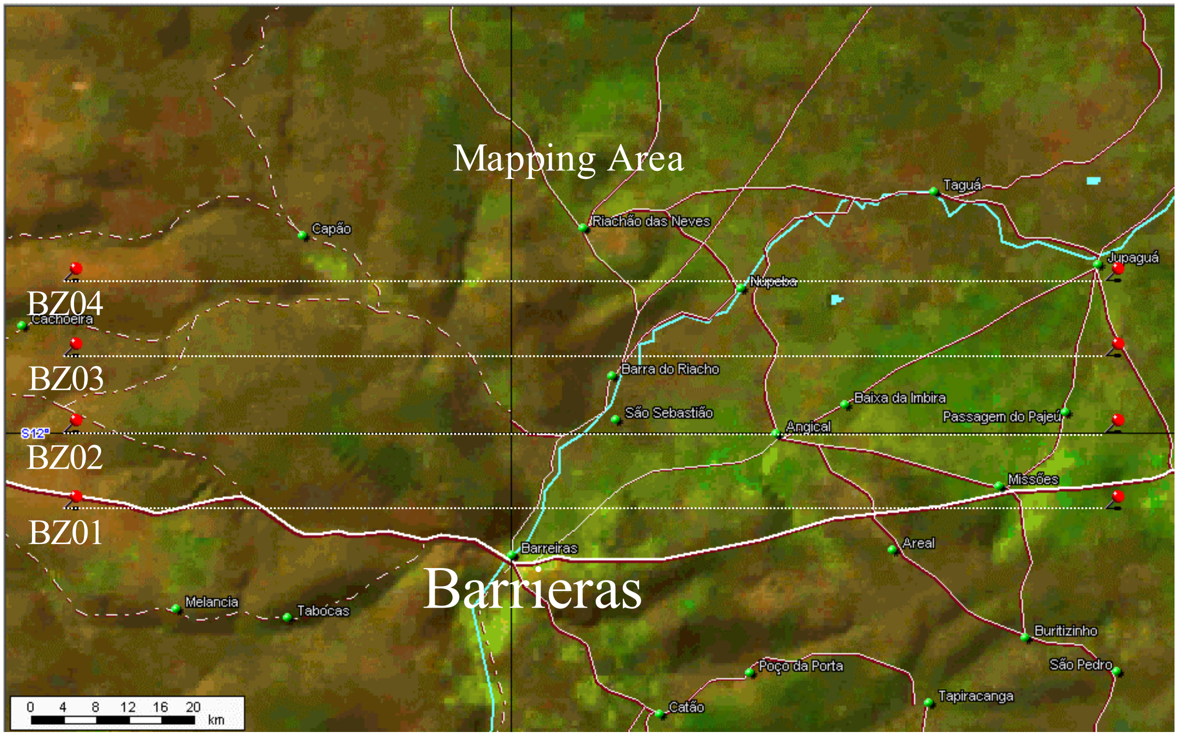


Figure 37. Brazil (BZ) regional study area and flightlines.

Table 32. SMEX03 Brazil (BZ) Flightlines

Line	Waypoint	Altitude (m above ground level)	Length (km)	Type	Latitude (Degrees)	Longitude (Degrees)
BZ01	A	7300	120	Regional Mapping	-12.083	-45.500
	B				-12.083	-44.333
BZ02	A	7300	120	Regional Mapping	-12.000	-44.333
	B				-12.000	-45.500
BZ03	A	7300	120	Regional Mapping	-11.916	-45.500
	B				-11.916	-44.333
BZ04	A	7300	120	Regional Mapping	-11.833	-44.333
	B				-11.833	-45.500
BZ05	A	7300	2130	Transect	-47.597	-15.830
	B				-48.339	-12.177
	C				-48.142	-10.351
	D				-51.223	-7.383
	E				-53.021	-5.099
	F				-54.893	-3.286
	G				-55.000	0.000

8.4 Ground Sampling

The Brazilian team will have complete responsibility for the ground component of the experiment and will provide ground sampling of soil moisture, soil temperature and vegetation. To the degree possible they will follow the protocols provided in this plan.

Sampling will be primarily the Regional type. Sites will be selected to represent typical conditions and distributed over the mapping domain, subject to road access. Those listed in Table 33 are a preliminary subset.

Table 33. Preliminary ground sampling sites for Brazil

Site	ID	Land Cover	Reference Coordinates	
			Latitude (Deg.)	Longitude (Deg.)
BZ01	MN-1	MN = Mansidao; abandoned pasture	-12.0000	-44.9411
	MN-2	MN = Mansidao; regeneration	-11.9167	-44.8847
	MN-3	MN = Mansidao; natural vegetation	-11.8333	-44.8322
	MN-4	MN = Mansidao; cultivated pasture	-11.7500	-44.7481
	RN-3	RN = Riachao das Neves; local farmer's backyard	-11.8333	-44.8542
	RN-4	RN = Riachao das Neves; urban area	-11.7500	-44.9028
	SF-1	SF = Sao Francisco farm; natural vegetation	-12.0000	-45.4411
	AE-1	AE = aeroporto; remaining natural vegetation	-12.0000	-45.1089
	LE-1	LE = Luis Eduardo Magalhaes city; natural vegetation	-12.0000	-45.2767
	LE-2	LE = Luis Eduardo Magalhaes city; rice crop	-11.9167	-45.2892
	AN-1	AN = Angical city; urban area of Angical	-12.0000	-44.6867

8.5 Logistics

Field and Lab Safety

See Appendix A

Hotels

Brasilia

The aircraft team will use the following hotel.
Metropolitan Flat Hotel
SHN, QUADRA 2 - BLOCO H
BRASILIA, BR 70710300
Brasília - DF 70702-905
T: (5561) 424-3500
F: (5561) 327-3938
General Manager: Wlisses F. Santos
E-mail: wsantos@atlantica-hotels.com

Barreiras

Ground sampling team may use these hotels in Barreiras
Solar das Mangueiras Hotel
Coordinates: 12° 07′ 57” S and 45° 00′ 53” W
Address: Av. Ahylon Macedo, 2000
47806-180 Barreiras, BA
Phone: 55 77 612-9200

Solar das Mangueiras Hotel

Chale dos Buritis
Address:Rodovia BR-020 Km 06 Lotes 14 e 15 Chácara Candeias
Phone: 55 77 611-3852
near Police Station (200 meters before the Police Station, from Brasilia to Barreiras)

Car Rentals

Solar Rent a Car (phone: 77 611-4480 or 61 342-4480)
Good Way Rent a Car (phone: 77 612-2880)
Average price: R$ 200,00 / day (one real = 3,50 dollars)

Directions

See Appendix B

Local Contacts

Edson E. Sano
Embrapa Cerrados
BR-020 Km 18 Cx. Postal 08.223
73.301-970 Planaltina, DF BRAZIL
55(61)388-9904
Fax 55(61)388-9879
sano@cpac.embrapa.br

Eduardo Delgado Assad
Embrapa Informática Agropecuária
Av. Dr. André Tosello n. 209
Campus da UNICAMP
CEP 13083-886
Campinas S.P. Brazil
(19) 37895805
assad@cnptia.embrapa.br

9 SCHEDULES (U.S.)

22 **AIRCRAFT Availability**	23 P-3 HSV		25		27	28
29	30	1	2 P-3 OKC DC-8 OKC		4	5
	7	8	9	10	11	12 DC-8 Departs
13	14	15	16	17	18	19 P-3 Departs

Brazil: September 16-26, 2003

22 **Satellite** **AQUA** ***Landsat*** ***Envisat***	23 AL GA *AL(5)*	24 *AL(7)*	25	26 *GA(7)*	27 AL GA	28 *GA*
29	30 AL GA	1	2 AL GA *OK(7) AL(5)*		4 *GA(5)*	5 OK
OK		8 OK	*OK*	10 OK	11	12 OK *OK*
	14	OK *OK*	16	17 OK	18 *OK(7)*	19 OK

10 SAMPLING PROTOCOLS

10.1 General Guidance on All Types of Sampling

- Sampling is conducted **every day**. It may be 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.
- Some of the sampling sites may have livestock. Please be considerate towards the cattle and **do not try to scare them** away.
- 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.**

10.2 Field Site Surface Soil Moisture and Temperature

Field site sampling will take place within approximately one hour of aircraft overflights.

Field sampling refers to intensive sampling of specific fields. At this time we anticipate that this will only be conducted within the Little Washita Watershed (LW) in SMEX03. Soil moisture and temperature sampling of the watershed area sites is intended to estimate the site average and standard deviation. 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
- 0-3 and 3-6 cm gravimetric soil moistures using the coring tool
- Surface temperature using a hand held infrared thermometer at Apogee Sites
- 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)
  - Coring tool and coring tool hammer
  - Soil Moisture Insertion Tool (SMITY)
  - 10 cm spatula
  - 4 cm spatula
  - Funnel
  - Bottle brush
  - Notebook
  - Pens
  - Box of cans (see note below)
  - Soil thermometer
  - Handheld infrared thermometer
  - Extra batteries (9v, AA, AAA)
  - Screwdriver
  - Camera
  - First aid kit (per car)
  - Phone (if you have one)
- For the LW sites, each team should take one box with the appropriate number of cans. The cans will be numbered XX01-XX18. Use only boxes labeled AA through BZ.
- 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 flags to mark your transect rows and sample point locations. Use only plastic flags and mark with the site ID and point ID (i.e. LW05-02). **Do not use flags in field that may be grazed or tilled**. Mark the transect start positions on the sides of the road and fences. Use non-toxic paint provided to mark points.
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site “LW##” 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 (LW##), 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.
- Assemble 8 sequential cans and indicate on schematic where they will be used. ***Odd numbered cans are used for the 0 – 3 cm sample and even numbered cans are used for the 3 – 6 cm sample.*** See Figure 38 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 there is an active crop.
    - 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.
    - For row crop fields, sample in the row adjacent to the row you are working in, it is suggested that this be the row to your right.
    - If the field is pasture or grass, try to maintain a straight line so that you can keep track of your location. For sampling locations, avoid cow paths and other anomalies in the field.
    - At all points collect three TP samples across the row as suggested in Figure 39. If the field is non-row crop, locate an area approximately 1 m^2 and sample three random points separated by at least 15 cm apart. **See the Theta Probe protocol for how to use the instrument and data logger.**
    - At points labeled ALL in Figure 38 (four per site) collect
        - One gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the procedures described using the coring tool, enter can numbers on diagram in book **(See Gravimetric Sampling with the Coring Tool protocol).** The Coring Tool should be used at the location of the second TP reading. This is to maintain consistency between row crop and non-row crop fields.**If the coring tool cannot be used, use the scoop tool.**
        - One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe, enter values in book **(See Temperature Sampling protocol).**
        - One averaged surface thermal infrared temperature (Degrees C) (if the sampling site is instrumented with a permanent Apogee sensor) using infrared thermometer, enter value in book **(See Temperature Sampling protocol)**
- 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.
    - For row crops it is better to 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.
- In case of a permanent instrumentation (Micronet, Mesonet, SHAWMS) take a full set (ALL) readings near the instrumentation.
- Record your stop time and place cans in box. Try to keep them cool.

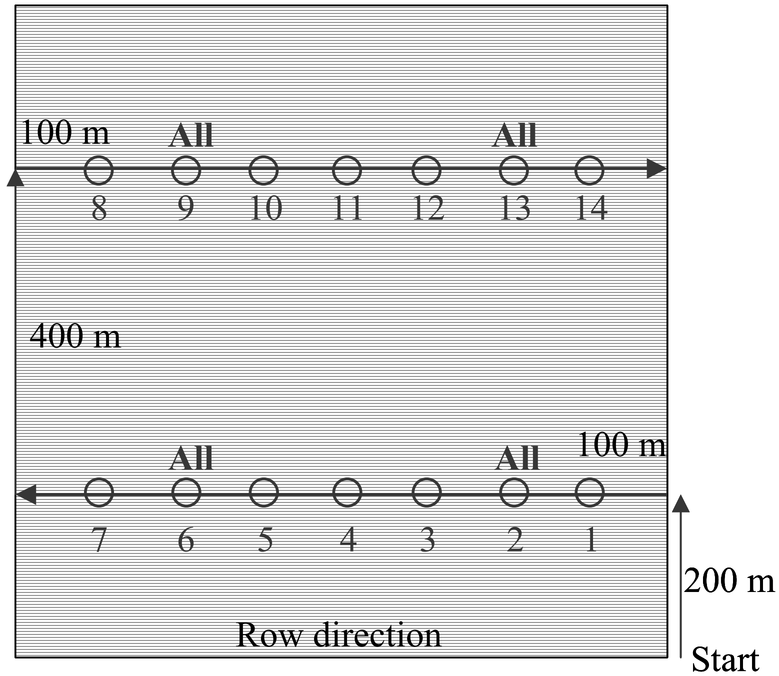


Figure 38. Schematic of layout of samples in a watershed site.

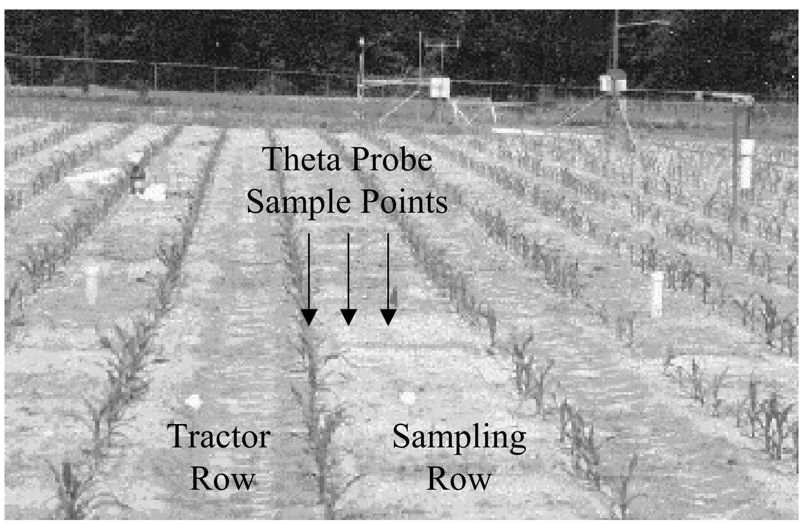


Figure 39. Schematic of layout of Theta Probe sample points.

Sample Data Processing

- Return to the field headquarters immediately upon finishing all sampling.
- For each site, weigh the gravimetric samples and record on the data sheets (Figure 44) 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.

10.3 Regional Site Surface Soil Moisture and Temperature

Regional sampling will take place within approximately 90 minutes of a satellite overpass. The first sample will be taken around 11:30 am. The sampling will be done between 11:30 am and 2:30pm.

Soil moisture and temperature sampling of the selected regions is intended to estimate the site average and standard deviation at the scale of passive microwave satellite footprints and grid cells. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-3 and 3-6 cm gravimetric soil moistures and bulk density using the coring tool
- Surface temperature using a hand held infrared thermometer **(IF ASSIGNED)**
- 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)
    - Coring tool and coring tool hammer
    - Scoop tool
    - Soil Moisture Insertion Tool (SMITY)
    - 10 cm spatula
    - 4 cm spatula
    - Funnel
    - Bottle brush
    - Notebook
    - Pens
    - Box of cans (see note below)
    - Soil thermometer
    - Handheld infrared thermometer (IF ASSIGNED)
    - Extra batteries
    - Screwdriver
    - Camera
    - First aid kit (per car)
    - Phone

- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- For the regional sites, each team should take one box of 18 cans. The cans will be numbered XX01-XX18. Use only boxes labeled CA through CZ.
- The first time you sample, it will help to use flags or paint to mark the field entry point and sample point location. Use only plastic flags and mark with the site ID (i.e. OS05). Do not place flags in a field with grazing or potential tillage. For these conditions use paint.
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site (i.e. OS##).
- Check weather

Procedure

- Upon arrival at a site, note site id (OS##), your name(s), TP ID, 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).
- Assemble 2 sequential cans. ***Odd numbered cans are used for the 0 – 3 cm sample and even numbered cans are used for the 3 – 6 cm sample.***
- Go to the pre-established sampling location.
    - The sampling sites should be at least 100 m inside the field boundaries.
    - Sample in the row adjacent to the row you are working in, it is suggested that this be the row to your right (If no rows choose a random location within 1 meter of the selected location).
    - At the location collect three TP samples across the row as suggested in Figure 39. Always start with the sample directly in the plant row and move out.
    - Using the coring tool collect one gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the Coring Tool Sampling protocol, enter can numbers in book. This sample should be done coincident with the second TP sample, in either row crop or non-row crop fields.
    - One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe, enter values in book
    - At all Apogee sites, one averaged surface thermal infrared temperature (Degrees C) using infrared thermometer, enter value in book This may not be collected by all teams.
    - Record your stop time and place cans in box. Try to keep them cool.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- Weigh the gravimetric samples and record on the data sheets that will be provided. Use a separate sheet for each date and record cans sequentially. (see Figure 40)
- Transfer temperature and other requested data to data sheets (same sheet used for GSM).
- Place cans in oven 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.

SMEX03 Regional
Gravimetric Soil Moisture Sampling

Dates: ____________________ Team: ____

Time: ____________________ Observers: ____

Site ID	Local Sample Time	IRT in C	Soil Temp in C			Theta Probe (%)			Can ID	Depth in cm	Wet Weight (grams)	Dry Weight (grams)
			1 cm	5 cm	10 cm	A	B	C				

Figure 40. Example of the gravimetric soil moisture sampling data sheet.

10.4 Theta Probe Soil Moisture Sampling and Processing

There are two types of TP configurations; Type 1 (Rod) (Figure 41) and Type 2 (Handheld) (Figure 42). They are identical except that Type 1 is permanently attached to the extension rod.

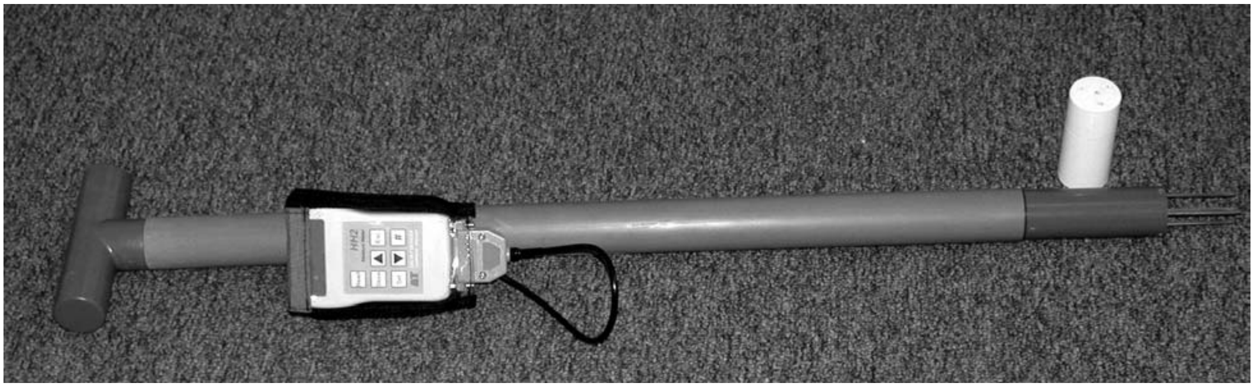


Figure 41. Theta Probe Type 1 (with extension rod).

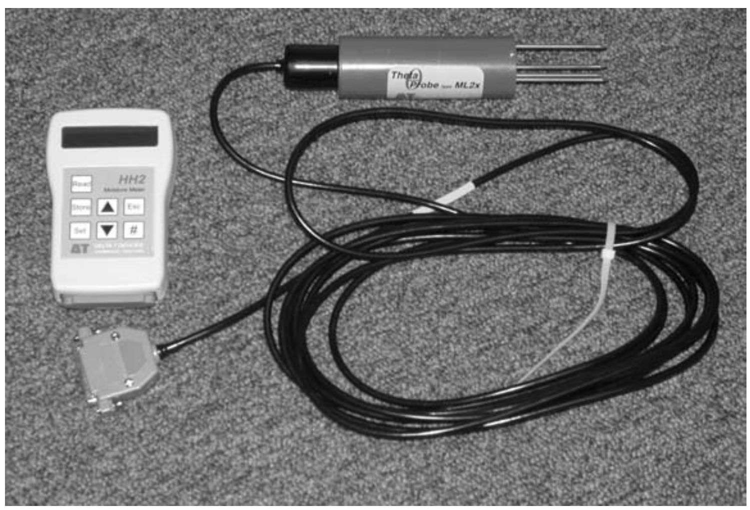


Figure 42. Theta Probe Type 2.

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 43. 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 SMEX02, all observations will be recorded as mV and processed later to soil moisture.

Figure 43. HH2 display.

Occasionally, the soil is too hard to successfully insert a TP, therefore, a jig (Soil Moisture Insertion Tool – SMITY) has been constructed, shown in Figure 44. This is a tool used to make holes in hard or difficult soils to ease the stress on the TP. To use, place the slider plate (Figure 45) on the surface to be probed. Using pressure or a hammer, drive the SMITY into the ground. Avoid any side-to-side movement, to avoid faulty measurements. Once the SMITY is completely in the ground, hold the slider plate on the surface and pull straight up on the SMITY. Holding the slider plate to the ground should maintain the surface for proper TP insertion. Clean the SMITY and proceed with the TP measurement. Insert the TP probe exactly into the holes created by the SMITY. The TP tines are slightly larger than the holes, but will be much easier to insert than without the SMITY.

Figure 44: SMITY, Soil Moisture Insertion Tool, with slider extended and retracted.

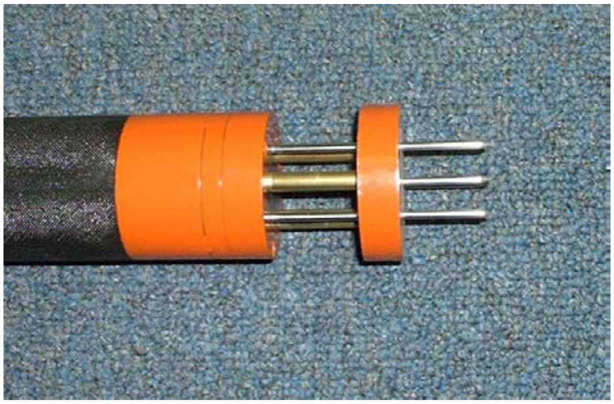


Figure 45: Close-up of the SMITY slider.

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.

Before Taking Readings for the Day Check and configure the HH2 settings

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

Check Battery Status

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

Check Date and Time

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

Set First Plot and Sample ID

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

Select Device ID

23. Each HH2 will have a unique ID between 0 and 255. Press **Set** at the start up or readings screen to display the main **Options** menu**.**
24. Scroll down to **Data** using the **up** and **down** keys and press **Set.**
25. Select **Device ID** and press **Set** to display the **Device ID** dialog.

26. Your ID will be on the HH2 battery cover.
27. Scroll through the options, from 0 to 255, and press **Set** to select one.
28. Press **Esc** to return to the main menu.

To take Readings

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

Troubleshooting

Changing the Battery

- The HH2 unit works from a single **9 V PP3** type battery. When the battery reaches 6.6V, (~25%) the HH2 displays :
  ***Please Change**
  Battery
- On receiving the above warning have your data uploaded to the PC next, or replace the battery. Observe the following warnings:
  - ***WARNING 1: Disconnect the TP, immediately on receiving this low battery warning. Failure to heed this warning could result in loss of data.***
  - ***WARNING 2: Allow HH2 to sleep before changing battery.***
  - ***WARNING 3: Once the battery is disconnected you have 30 seconds to replace it before all stored readings are lost.*** If you do not like this prospect, be reassured that your readings are safe indefinitely, (provided that you do disconnect your sensor and you do not disconnect your battery). The meter will, when starting up after a battery change always check the state of its memory and will attempt to recover any readings held. So even if the meter has been without power for more than 30 seconds, the meter may still be able to retain any readings stored.

Display is Blank

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

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

Incorrect Readings being obtained

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

Zero Readings being obtained

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

Settings Corrupt Error Message

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

Memory Failure Error Message

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

Some Readings Corrupt Error Message

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

Known Problems

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

10.5 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 46a).
- Push the GSM tool into this vertical face. The top of the scoop should be parallel with the soil surface. (Figure 46b).
- Use the large spatula to cut a vertical face on the front edge of the scoop (Figure 46c).
- Use the small spatula to cut the sample into a 0-3 and a 3-6 cm depth sample.
- Place each sample depth in a separate can, the small spatula aids extraction (Figure 46d). Remember that the odd numbered cans are for the top layer and the even are for the deeper layer (remember to use cans sequentially and odd numbers for the 0-3 and even for 3-6 cm samples).
- Record these can numbers in the field notebooks at the point location on the map.
- 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 temperature. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.

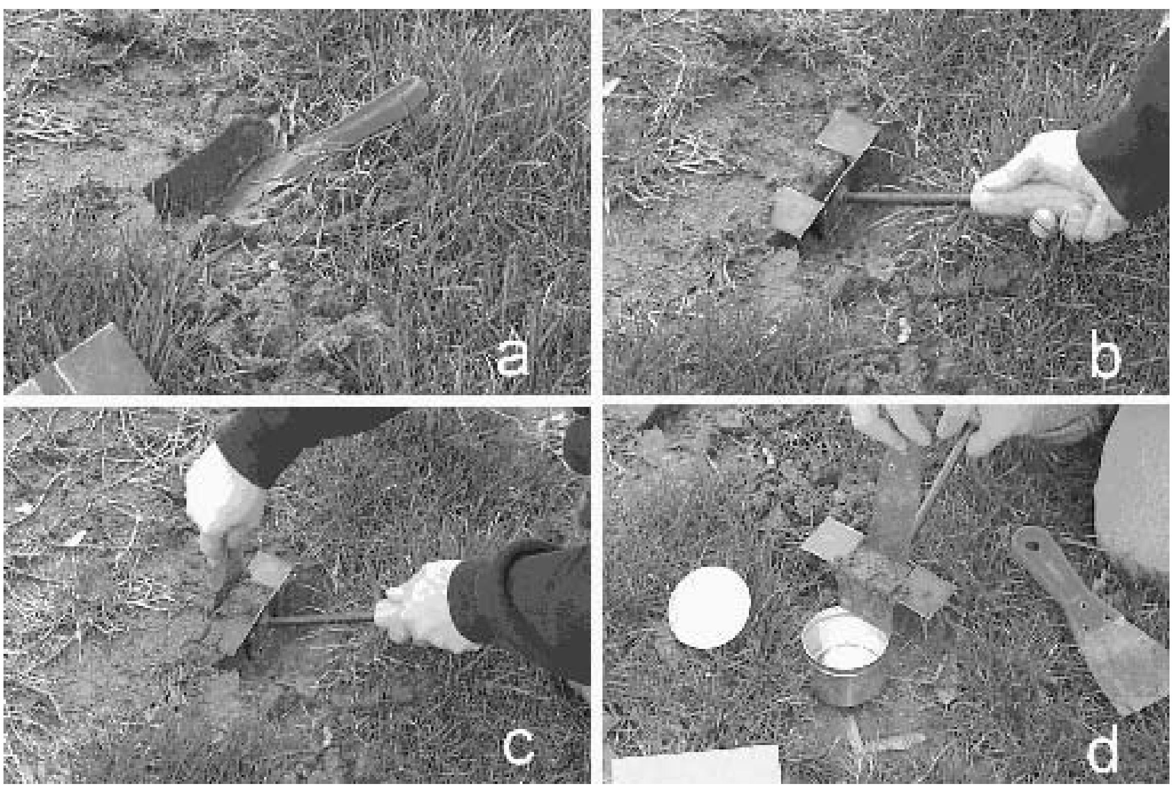


Figure 46. How to take a gravimetric soil moisture sample.

10.6 Gravimetric Soil Moisture and Bulk Density Sampling with the Coring Tool

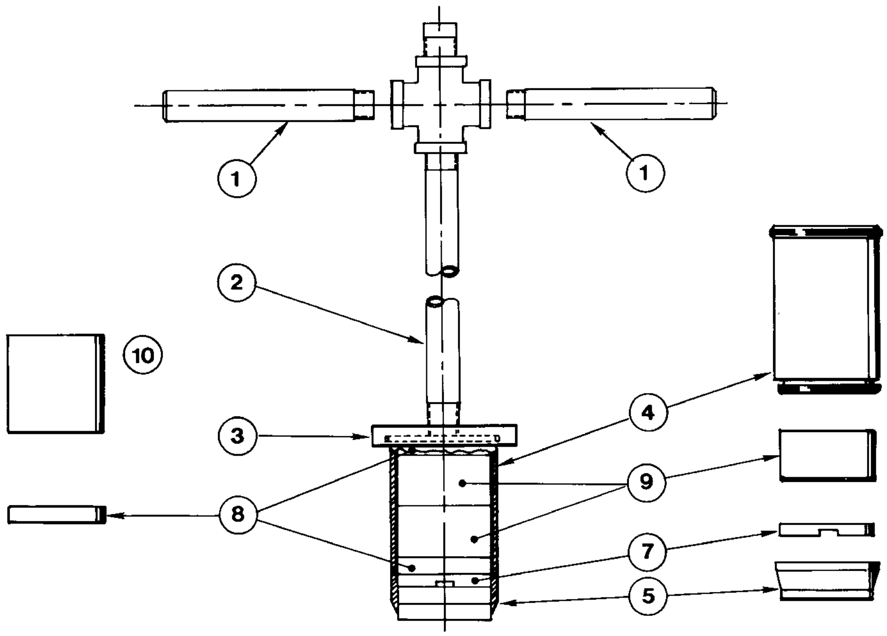
- The tool is called a 200-A soil core sampler.
- Figure 47 shows the parts of the apparatus.
- The thin cutting tip will be used in SMEX03 because we anticipate that the soils will be uniform and rock-free. This can be replaced using a spanner tool to unscrew it from the barrel.
- The cap is unscrewed to insert or remove rings.
- The ring volumes are 3 cm=>68.7 cm^3. (diameter of the ring is 5.4 cm)

Procedure for Taking a Sample

- Insert five sample rings and the extractor ring in the following order starting from the cutting end
  - Extractor
  - 1 cm
  - 1 cm
  - 3 cm
  - 3 cm
- Replace cap with handle
- Insert the coring tool into the soil. If necessary, the hammer tool can be used. The hammer rod is inserted into the handle.
- Stop when the lip of the cap reaches the surface, try not to compact the sample.
- Remove the core and inspect the tip to make sure the notches on the extractor ring are clear. Use the extractor tool (Figure 47) to assist in cleaning these notches. Also inspect for separation within the coring tool by looking for protruding soil at the bottom of the tool. If there is separation, dispose of this sample and start again.
- Remove the cap.
- Use the extractor tool (from the bottom or cutting edge) to push the rings out the top or cap end.
- Using a wide spatula, cut the rings apart into the soil moisture cans using the soil funnel to insure capture of the entire sample..
- Place the 0-3 cm and 3-6 cm samples in cans (Remember odd-0-3 cm and even-3-6 cm).
- It can be difficult to extract a perfect surface 3 cm sample for bulk density. However, it s still useful as a GSM sample. Please make a note on the sample quality in your notebook.
- Clean all rings.

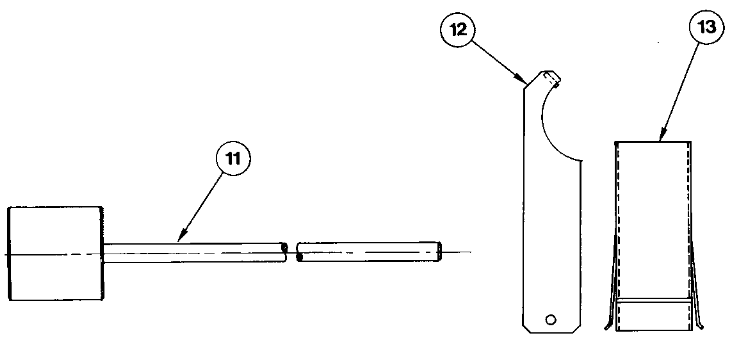
Computing the Volumetric Soil Moisture and Bulk Density

- Compute the sample GSM and dry mass
- Divide the mass of the soil by the volume of the cylinder (3 cm) hole to obtain the sample bulk density
- Compute VSM=GSM*BD



PARTS BREAKDOWN

ITEM NO.	PART NO.	DESCRIPTION	ITEM NO.	PART NO.	DESCRIPTION
1	201-6	HANDLE			
2	201-100	STEM ASSEMBLY	7	201-9	NOTCHED EXTRACTOR RING
3	201-4	CAP	8	208	CYLINDER 1 CM. LONG
4	201-3	BARREL	9	207	CYLINDER 3 CM. LONG
5	201-1	BLADE CORING TIP	10	206	CYLINDER 6 CM. LONG



PARTS BREAKDOWN (CONTINUED)

ITEM NO.	PART NO.	DESCRIPTION
11	202	DRIVE HAMMER
12	203	SPANNER WRENCH
13	204	SLOTTED CORE EXTRACTOR

Figure 47. Coring tool parts.

10.7 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 can, fill out a sample set sheet, and record a wet weight at the field headquarters. A lab team will place the samples 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 in late afternoon or early the following morning. These samples will remain in the ovens until the morning of the second day (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 before 8:00 am the following day.

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

10.8 Watershed Site Soil Bulk Density and Surface Roughness

All sites involved in gravimetric soil moisture sampling will be characterized for soil bulk density. The method 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 are made for each site.

The Bulk Density Apparatus

The Bulk Density Apparatus itself consists of a 12" diameter plexiglass piece with a 6" 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 three inches high and two inches thick. The foam is attached so that it follows the circle of the plexiglass. Figure 48 shows the basic components.

Other Materials Required for Operation:

- Three 12" 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 and 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 gas can 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 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 rocks or roots in the actual area which will be tested and has soil which has not been disturbed.
2. Ready the site for the test. Remove all vegetation, rocks and other debris from the surface prior to beginning the test. Remove little or no soil when removing the debris.

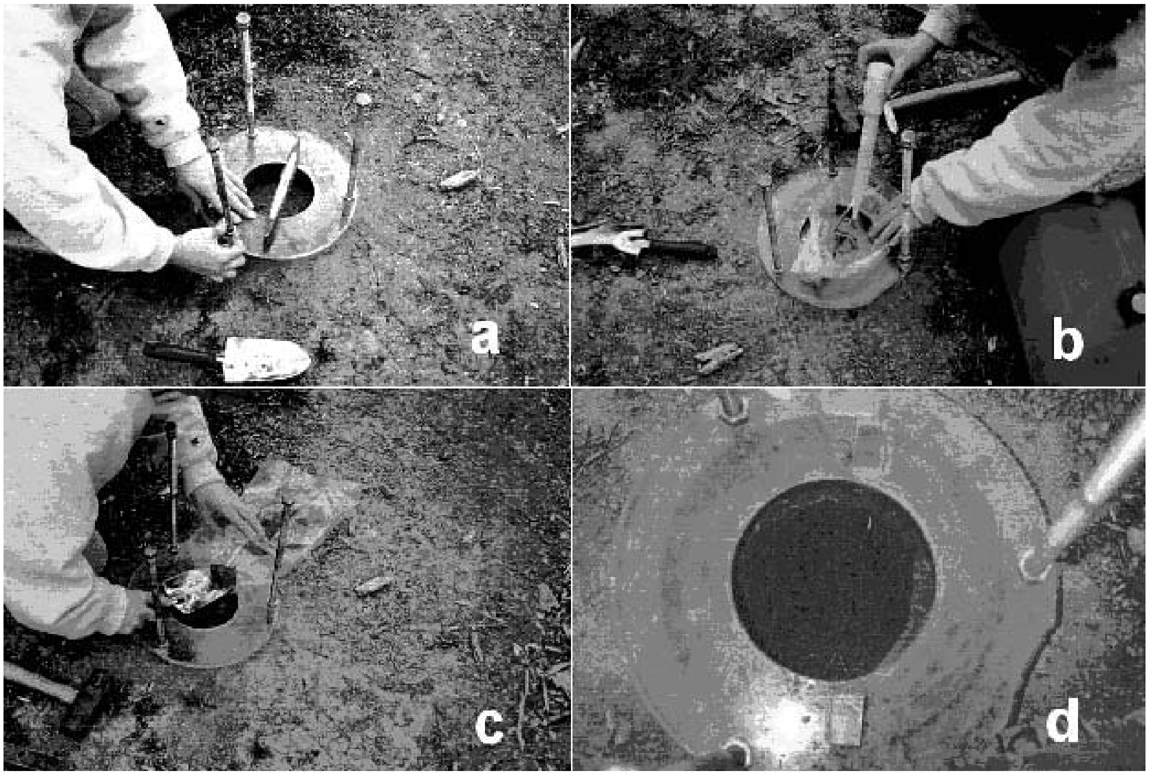


Figure 48. How to take a bulk density sample.

Bulk Density Procedure

Securing the Apparatus to the Ground

1. Place the apparatus foam-side-down on the ground.
2. Place the three securing rods in the 3/4" holes of the apparatus.
3. Drive each dowel into the ground until they do not move easily vertically or horizontally. (Figure 50a)

Leveling the Apparatus Horizontally to the Ground

1. Tighten each of the bolts until the apparatus appears level and the foam is compressed to 1-1/2" to 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 50b)
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. 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. (The hole should be a cylinder: with surface area the size of the hole of the apparatus and height of six inches.)
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 50c and d)
4. Continue to remove the soil until the hole fits the qualifications.

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**. 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 Density of the Soil

1. Dry the soil in an oven for at least 24 hours.
2. Determine the mass the soil.
3. Divide the mass of the soil by the volume of the hole. The answer is the density of the soil.

Potential Problems and Solutions

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

After I began digging the hole I noticed one of the dowels wasn't the apparatus firmly in place. Do I have to start over?
Unfortunately, if you have already started digging you do have to start the experiment again. Replacing the dirt to find the volume between the ground surface and the hook-gauge will give an inaccurate volume and thus an inaccurate soil density.

I noticed that the bag holding the water has a small leak. Is there anything I can do? If the leak began after you had already found the volume, it is not necessary to start again. The volume is being measured in the graduated cylinder. If you have already removed the appropriate volume of water leaks in the bag, it will not affect the results of the test. However, if you noticed the leak before finding the volume, you will have to start again.

Surface Roughness

- Take a photo along and across the rows at each BD location with the grid board.
- The site and sample ID should be indicated in the photo.

10.9 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 in Oklahoma will be the Max/Min Waterproof Digital Thermometer (Figure 49).

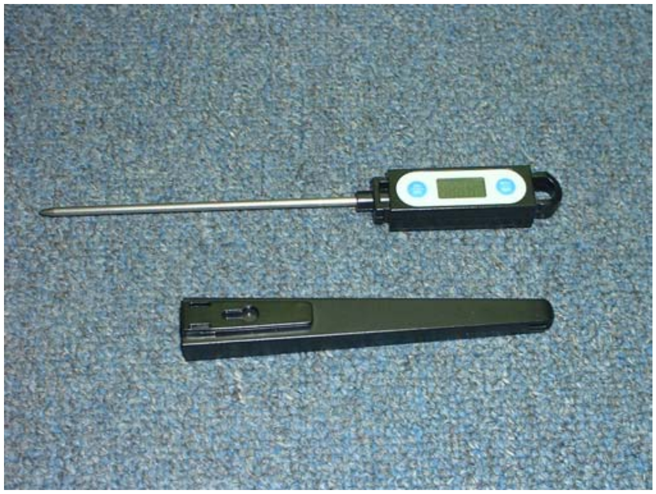


Figure 49. Temperature Probe with Handle/Cover

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.

10.10 Hydra Probe Soil Moisture and Apogee Temperature Sensor Installations

Figure 50 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 he field HQ and can also be found at http://hydrolab.arsusda.gov.

Figure 50. 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.
- 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 probe should be inserted far enough that the plane formed where the tines join the probe head is flush with the soil surface.
    - 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.
- 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 51) will be available at he field HQ and can also be found at http://hydrolab.arsusda.gov.

- Height
- Target
- Angle

Figure 51. Apogee thermal infrared sensor.

10.11 Vegetation Sampling

The protocols used in SMEX02 have been adapted for SMEX03. There are different vegetation types in each region that will require protocol modification. Please see the plans for each region on specific procedures.

Parameters

1. Plant height
2. Ground cover
3. Stand density
4. Phenology
5. Green and dry biomass
6. Leaf area (LAI)
7. Surface reflectance

Sampling Locations

Vegetation sampling will be conducted on a subset of the soil moisture sites and will vary by region. Three representative locations within each selected field will be sampled during the course of the study to quantify the full range of vegetative cover. It is important to note that for all sites, even regional, the vegetative sampling is intended to estimate the average site conditions, and data are not intended for footprint averaging. Preliminary site selection will be performed using aerial and satellite imagery. Final selection will be based upon field surveys conducted just prior to the field campaign.

Sampling Frequency

The number of rounds of sampling will be at least once for Alabama, Georgia, and Brazil and twice for Oklahoma. If rapid growth is expected in particular fields, the frequency can be increased.

Site Identification

Sites will be identified with a unique site id made up of the region id, V for vegetation, site number, and within field location (1-3). For row crops, add an additional final character designating sampling row (sampling rows will be label A-E). For example, Oklahoma South (OS) vegetation (V) site 20 location 1 row A would be OSV201A. The ‘V’ will denote a vegetative sampling site to avoid any potential confusion with other measurement sites within the same field.

Sampling Layout

Each location will be identified with a flag (or paint if flagging is not allowed) in each corner to aid in locating the site. Sites should be located at least 100 m from roads, farmhouses, etc. For row crops, each sampling location will consist of a 10 row area, 6 m in length. For other types of vegetation (grasses, weeds, etc.) an area 2 m by 2 m will be used. This will provide adequate area for all sampling dates (see Figure 52).

GPS coordinates of each location within a site will be recorded for the corners of the location. The actual sampling will not require the use of GPS. Sampling location will be marked at the edge of the field for assistance. These marks and locations will be compiled in the field notebook. In the case of row crops, the sampling location will be flagged at the end row of the field so the sampling crews can travel down the rows. Flags should include the id, and approximate number of paces to the location.

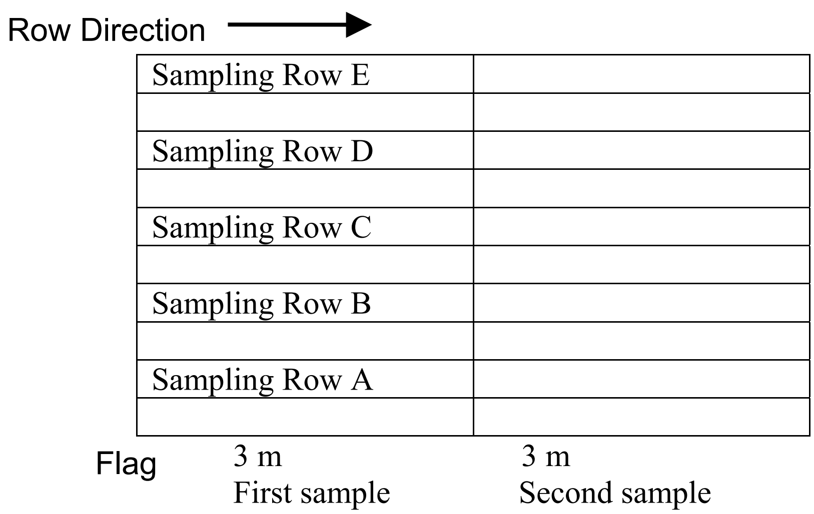


Figure 52. Vegetation sampling layout.

Sampling Scheme

Sampling locations will be selected to provide a representative sample from that area of the field. For row crops, one plant will be sampled from every other row for phenological stage and green and dry biomass (5 plants total). These same rows will be sampled for height, stand density, and row cover. Leaf area will be measured at four locations (in-row, ¼ across row, ½ across row, ¾ across row) using a LAI-2000. The first sampling position will be between the first row (flag location) and the row to the left. The first time sampling, begin on the end next to the flag, the second sampling will begin 3 m down the row from the flag.

For grasses, weeds, winter wheat and other non-row crops, all vegetation within a 0.44 m by 0.44 m area at a location will be removed. A folding wooden yardstick will be used to define the area. (see Figure 53)

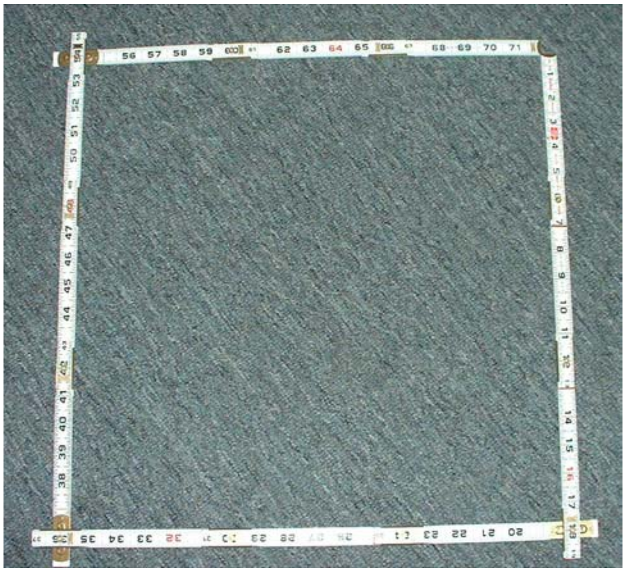


Figure 53. Vegetation sampling frame.

Protocols

1) Stand density (row crops only)

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 in each of the 5 rows 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.

2) Height

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

3) Phenology

Phenological stage for crops will be determined using standard phenological guides. Guides for specific crops/covers are listed below:

Corn:	http://maize.agron.iastate.edu/corngrows.html
Soybeans:	http://www.agron.iastate.edu/soybean/beangrows.html
Cotton:	http://www.aces.edu/department/ipm/cip3.htm
	http://muextension.missouri.edu/explore/agguides/crops/g04268.htm

	http://cipm.ncsu.edu/cottonpickin/disorders/introduction.htm
Peanuts:	http://www.peanutfarmer.com/special/bayer.pdf
Grasses:	http://www.ag.ndsu.nodak.edu/dickinso/grassland/1022.htm
	http://www.caf.wvu.edu/~forage/growth.htm

4) Green and Dry Biomass

Row Crops: To measure biomass a plant will be cut at the ground surface from each of the 5 sampling rows. The five plants for the sampling location will be placed into a paper bag with a label for the sampling site. If the plants are large, it may be necessary to place each plant in to a separate paper bag with a label for the sampling site and row. All samples from a location are then placed in a single plastic bag for transport to the lab. A separate tag with the sampling location id will be placed into the bag as additional insurance against damaged labels. If desired, the plants can be separated into leaves and stems/stalks before obtaining the green biomass measurement.

Other Types of Vegetation: All vegetation within the specified area will be cut at ground level. If it is determined that there is a significant thatch layer in grass sites it may be necessary to characterize this as a separate canopy component. Vegetation for the sampling location will be placed into a paper bag with a label for the sampling site. All samples from a location are then placed in a single plastic bag for transport to the lab. A separate tag with the sampling location id will be placed into the bag as additional insurance against damaged labels

Shrubs and Trees: It would be highly desirable to characterize these conditions. However, at this time we do not have a protocol for dealing with these cover conditions.

Green biomass will be measured by weighing the samples immediately. If the biomass has excessive moisture, it 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 (longer if necessary).

5) Photographs

Photographs will be taken of the 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. Four photos will be taken in each plot in this order: marker board, oblique, and nadir (or as close as possible), and a synoptic field photo.

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 54) Surface roughness photos will be taken once during the experiment unless there is a change in the field conditions (plowing, planting, harvesting …).

Figure 54. Surface roughness photo.

6) Leaf Area

Leaf area will be measured with a LAI-2000 (Figure 55). For *row crops* in the inter-row region at least one meter away from where the biomass sample was taken (5 sets of 4 across-row measurements). 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.

Figure 55. The LAI-2000 instrument.

Operating the LAI-2000 -

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

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

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

Clear the memory of the logger -

Press “**FILE**”
Use “↑” to place “Clear Ram” on the top line of display
Press “**ENTER**”
Press “↑” to change “NO” to “YES”
Press “**ENTER**”

General items –

When changing something on the display, get desired menu item on the top line of display and then it can be edited.
Use the “↑” and “↓” to move items through the menu and the “**ENTER**” key usually causes the item to be entered into the logger.
When entering letters, look for the desired letter on the keys and if they are on the lower part of the key just press the key for the letter; if the desired letter is on the upper part of the key then press the “↑” and then the key to get that letter.
Press “**BREAK**” anytime to return to the monitor display that contains time, file number or sensor readings on one of the five rings that are sensed by the LAI-2000.
Do not take data with the LAI-2000 if the sensor outputs are less than 1.0 for readings above the canopy.

To Begin -

Press “**SETUP**”

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

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

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

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

Use “↑” to get to “RESOLUTION”

Set it to “HIGH”

Use “↑” to get to “CLOCK”

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

Press “**OPER**”

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

Choose “MODE=1 SENSOR X”

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

Enter "1" in “REPS”

Use “↑” to get to “SET PROMPTS”

Put “SITE” in first prompt

Put “LOC” in second prompt

Use “↑” to get to “BAD READING”

Choose "A/B=1"

Press “**BREAK**”

Display will contain the two monitor lines

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

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

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

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

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

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

For Row crops –

1. Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will

be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

2. Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Place the sensor one-quarter (1/4) of the way across the row and record data again.
4. Place the sensor one-half (1/2) of the way across the row and record data again.
5. Place the sensor three-quarters (3/4) of the way across the row and record data again.

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

For Other Types of Vegetation –

1. 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.

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.

15) 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.

Several different multispectral radiometers will be used in the various regions. Alabama will employ a GER 1500 (http://www.ger.com/1500.html). Oklahoma and Georgia will use instruments developed by CROPSCAN (http://www.cropscan.com). 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 basis instrument is shown in Figure 56.

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.

Figure 56. CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm).

For Oklahoma there will be two MSR16R units available 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.

During field data collection 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 56)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Figure 57)
- CT100 (hand terminal, connected to the DLC with a serial cable) (Figure 58)
- 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 57. Data logger controller and cable adapter box.

Figure 58. CT100 hand terminal.

Set Up –

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

Configure MSR –

- Perform once at the beginning of the experiment, or if the system completely loses power
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **1** then **ENTER**, input the correct date, Press **ENTER**
- At Command * Press **2** then **ENTER**, input the correct time, Press **ENTER**
- At Command * Press **3** then **ENTER**, input the number of sub samples/plot (5), Press **ENTER**
- At Command * Press **6** then **ENTER**, input a 2 or 3 character name for your sampling location (ex OS for Oklahoma South), Press **ENTER;** input the latitude for your location, Press **ENTER;** input the longitude for your location, Press **ENTER**
- At Command * Press **9** then **ENTER**, input the GMT difference, Press **ENTER**
- At Command * Press **M** then **ENTER,** to return to the MSR 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, 5 different areas within 10 m will be scanned at each field location
- 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 SMEX03:

Vegetation Water Content Sampling Location: Reflectance and LAI data will be collected for each vegetation sampling location just prior to removal.

Field Transect: Each Little Washita watershed site will be characterized by transect sampling. Reflectance and LAI measurement will be collected at each of the soil moisture sampling locations (14 total). This should be done at least twice, once to coincide with the first Landsat overpass and the second near the end of the field campaign.

Data Recording

Data will be recorded onto the sampling sheet illustrated in Figure 59. 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.

Vegetative Sampling

Date ______________Time _________________ Observers ____________________
Row Spacing_______________
Row Direction _____________________
Crop _____________________________
Photographs Taken __________
MSR Done _____________

Sample id	Stand density (plants/m)	Height (m)	Phenology	Green Biomass (g)	Dry Biomass (g)	Leaf Area Index	Sun/shade
OSV101A							
OSV101B							
OSV101C							
OSV101D							
OSV101E							

Figure 59. Example of the vegetation sampling data sheet.

10.12 Global Positioning System (GPS) Coordinates

The geographic coordinates of all soil, vegetation, and micrometeorological sample sites need to be collected in order to map their locations in a geographic information system (GIS). A Garmin **e**Trex "sportsman" GPS will be used to collect the position data. This unit has the capacity to store up to 500 geographic coordinates or waypoints and 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 GPS measurements at that site will be needed.

- All sampling points will be located using a handheld GPS including
  - Soil samples
  - Vegetation samples
  - Flux towers
  - Met stations

- To the extent possible, a single individual should make all of the readings. This person can be assigned to different teams on different days or use field markings provided by the teams.

General Information

Record site ID, and latitude and longitude coordinates in field notebook. 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 eTrex should operate for approximately 22 hours. A "Battery Low" message will appear at the bottom of the screen when the unit has ten (10) minutes of battery life remaining.

eTrex GPS Features (see Figure 60)

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 also functions as escape key.
POWER button: turns **e**Trex GPS as well as display backlight on and off.

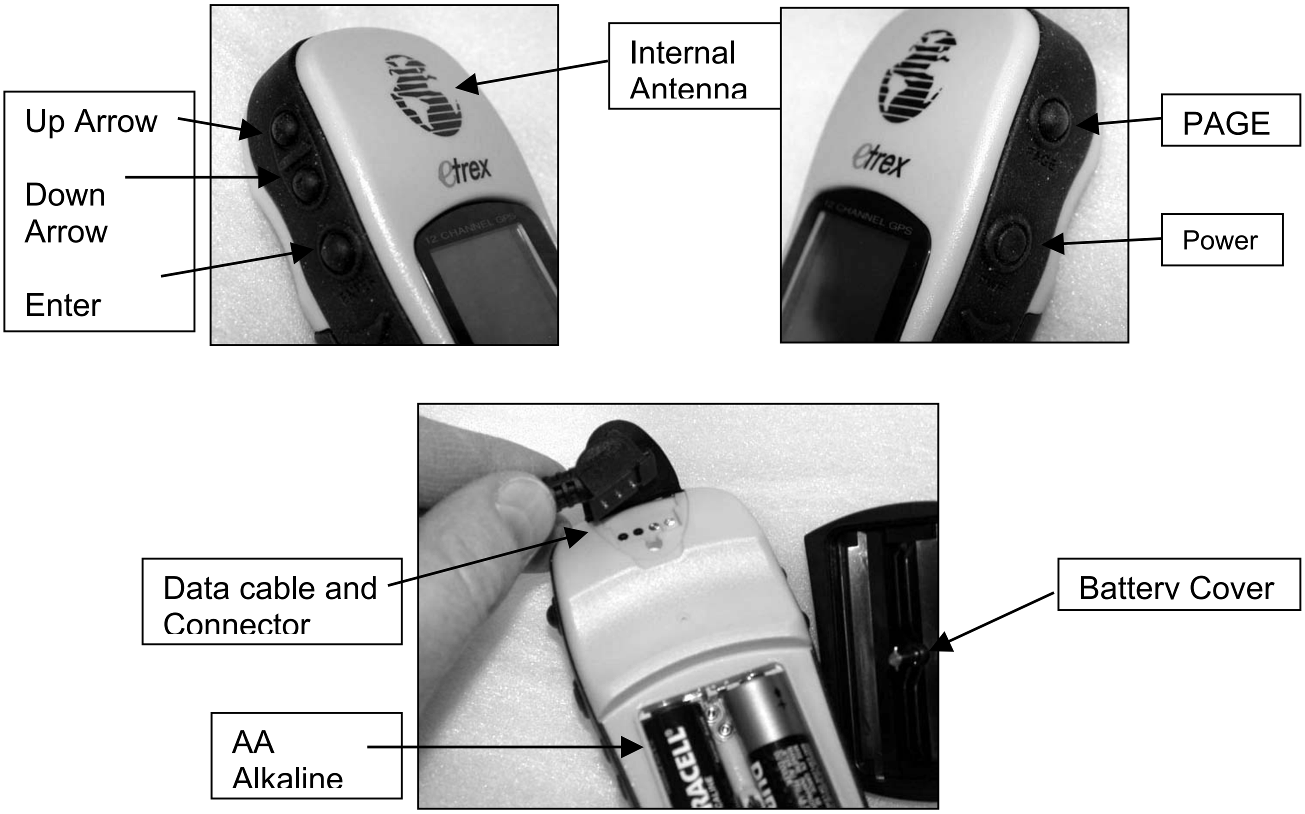


Figure 60. GPS features.

All **e**Trex operations are carried out from the four (4) "pages" (or display screens) shown in Figure 61. The PAGE key is used to switch between pages. (The Map and Pointer Pages are used for navigation and will not be discussed further.)

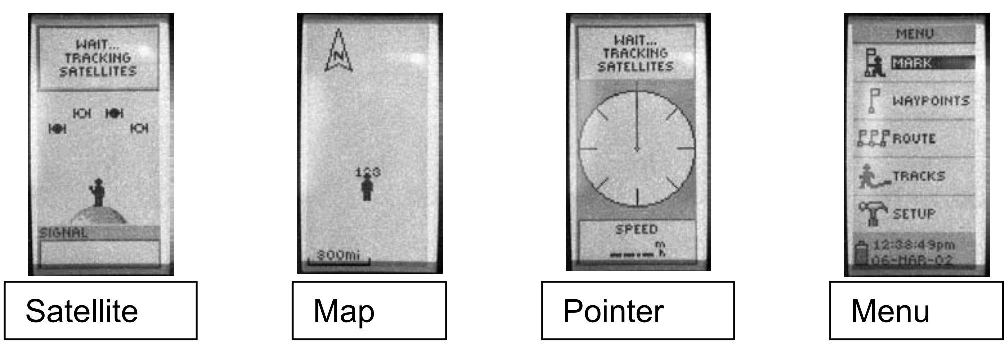


Figure 61. GPS display screens or "pages".

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 62)
   - 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; press enter, repeat above steps for all parameters.
   - The following are the parameters and required settings;
     - Time = Format: **24 Hour**;
     - Zone: If Oklahoma, **US-Central**, (UTC Offset: **-6:00**);
If Georgia, **US-Eastern**, (UTC Offset: **-5:00**);
If Alabama, **US Central**, (UTC Offset: **-6:00**);
If Brazil, **Brasilia**, (UTC Offset: **-3:00**)
     - 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 61. 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 the orientation of coordinate systems used in mapping. Hundreds of datums are currently in use and particular attention must be paid to what datum is used during GPS data collection. The Global Positioning System is based on the World Geodetic System of 1984 (WGS84). However, popular map products such as USGS 1:24,000 topo sheets originally used the North American Datum of 1927 (NAD27). Most of the maps in this series have been updated to the North American Datum of 1983 (NAD83). Fortunately, there is virtually no practical difference between WGS84 and NAD83. Yet significant differences exist on the order of hundreds of meters 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****.* Coordinate conversion software packages such as NOAA's free Corpscon (http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml) exist which allow for 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 62). Wait until text box at top of screen reads "READY TO NAVIGATE" before continuing.

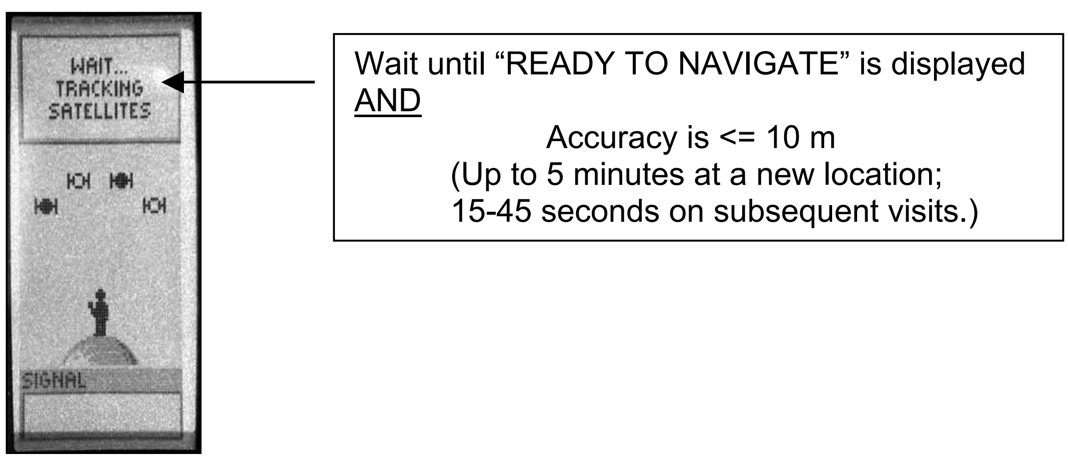


Figure 62. GPS satellite page.

2. Adjust screen backlight and contrast, <u>if necessary</u>.
   - 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 the Satellite Page.

3. Initiate GPS data collection:
    - PAGE to Menu screen (Figure 61); 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 63); press ENTER. Use ENTER and UP/DOWN buttons to edit ID, <u>if necessary</u>. (Waypoint ID increments by one (1) automatically.)
    - Record latitude and longitude coordinates displayed at bottom of screen into field notebook. *Do not rely solely on electronic data download to save data points!*
    - ARROW to OK prompt; press ENTER to save point coordinates electronically.

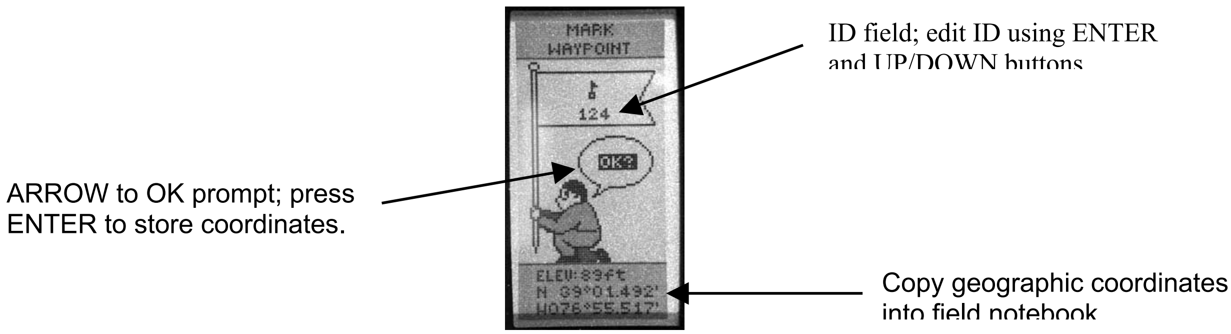


Figure 63. GPS Mark waypoint page.

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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12 INVESTIGATOR ABSTRACTS

Spatial variability of soil water over different soil and vegetation combinations within the Coastal Plain

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Rationale:

Soil water within the upper soil horizon has a dramatic impact upon runoff, erosion, plant growth, and land-atmosphere interactions. Great advances have been made in remote sensing techniques used to estimate soil water. However, in order to further advance this research it is necessary to properly characterize the impact of soil type and vegetation on soil water conditions and remotely sensed estimates. Errors in soil water estimates obtained through remote sensing that are caused by vegetation effects must be properly characterized and minimized to advance the science.

Hypothesis:

Within physiographic regions, soil water content is consistent and predictable across unique combinations of topography, soil type, and vegetation cover and responds consistently to similar precipitation inputs.

Data Collection:

We will examine the spatial variability of soil water as measured at the soil surface under several different soil / vegetation combinations during the study. Gravimetric (0-1, 0-3, and 3-6 cm) and theta probe (0-6 cm) measurements of soil water will be collected across a distribution of soil type / land cover combinations within a 50 km by 75 km region. Topography, soil type, vegetation, and precipitation and irrigation inputs at each sample site will be characterized. These data will be used to compare soil water conditions across the region in terms of topography, soil type, vegetation, and water inputs.

Contribution to SMEX 03:

The soil water measurements across the 50 km by 75 km region will be used to evaluate the remotely sensed measurements for the Coastal Plain Region. These data are critical for interpretation of the remotely sensed data from the satellite and aircraft instruments.

Comparison between continuous soil water measurements and soil water data collected through field sampling

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Rationale:

Continuous measurements of soil water are being collected at several sites throughout the Little River Watershed. Soil water measurements are being taken every 30 minutes at 5, 20, and 30 cm at 20 locations in and around the watershed. While the sites represent a variety of soil types and geographic positions, they are installed within a single vegetation type, that being grass. To apply the data it will be necessary to relate these measurements to soil water conditions in additional vegetation types, particularly row crops and forested sites. Once these relationships are properly understood the continuous soil water measurements can be used to estimate soil water conditions throughout the region.

Hypothesis:

Soil water conditions within the sod based continuous measurements sites are representative of the soil water conditions in other vegetation types throughout the region.

Data Collection:

Continuous soil water measurements will be collected and recorded by the Southeast Watershed Research Laboratory. Gravimetric and theta probe measurements of soil water will be collected through regional sampling at sites within and outside of the Little River Watershed. Precipitation data will be collected using the Little River Watershed rain gage network and supplemented with NEXRAD data.

Contribution to SMEX 03:

The continuous soil water measurements will supplement the regional sampling data to provide a denser representation of soil water conditions throughout the region. These data will then be used to test the satellite and aircraft estimates of soil water.

Relationship between 0-1 cm soil water and 0-6 cm soil water contents

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Rationale:

Depending upon the wavelength, remotely sensed estimates of soil water are representative of a very shallow soil water content. This depth is often less than 1 cm. Difficulties related to measuring soil water in this narrow layer with instrumentation normally prevents measurement at this depth. More often, instruments collect data from the 1-3 cm or deeper depths. To extend the utility of the shallow (0-1 cm) soil water estimates it is necessary to relate these observations to deeper soil water contents.

Hypothesis:

Soil water content at 0-1 cm below the soil surface and 0-6 cm below the soil surface respond differently to precipitation inputs but can be related through proper understanding of precipitation inputs and water flux.

Data Collection:

Soil water contents from 0-1, 0-3, and 3-6 cm will be collected gravimetrically throughout the study period. Soils and precipitation inputs at the collection sites will also be characterized.

Contribution to SMEX 03:

If relationships can be derived to relate the shallow 0-1 cm soil water content to soil water contents deeper in the profile, then the utility of the remotely sensed data can be greatly expanded.

Modeling soil water conditions under different soil and vegetation combinations within the Coastal Plain

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Rationale:

Physically based models are currently used to examine many different natural conditions. The accuracy of these models often hinges upon their ability to accurately simulate the hydrologic conditions within the soil and at the soil surface. A model which can accurately represent soil water conditions existing under different soil and vegetation types as a function of climatic inputs would be extremely valuable for the Coastal Plain and many other regions of the world.

Hypothesis:

Through proper characterization of the topography, the physical properties of the soil, the vegetation, and the climatic inputs, the soil water conditions existing within different soil / vegetation combinations can be accurately simulated.

Data Collection:

Climatic inputs will be characterized during the study period. Soil water data at multiple sites will be collected both through the regional sampling and the continuous soil water measurement network. Soil types at each sample site will be characterized and hydrologic parameters evaluated from existing data bases.

Contribution to SMEX 03:

A properly configured model which accurately simulates soil water conditions across several soil / vegetation combinations would provide a resource for examining the variability of soil water across the study region. These data could then be used to evaluate the accuracy of the remotely sensed estimates of soil water.

Assessing the Role of Hydrologic Modeling for Validation of AMSR-E Soil Moisture Products

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The coarse spatial resolution of spacebornce microwave radiometers (> 30 km) poses a severe challenge for efforts to validate soil moisture products derived from such observations. Validation based on point-scale observations requires an upscaling strategy (e.g. block kriging, interpolation, or weighted averaging) capable of converting local observations into meaningful predictions of soil moisture at the footprint-scale. The success of any given strategy hinges largely on obtaining an adequate description of soil moisture spatial autocorrelation and the manner in which soil moisture variability is cross-correlated with observable land surface attributes (i.e. topography, soil and vegetation cover).

Given the practical difficulties in obtaining in situ soil moisture data sets of sufficient length and extent to provide such descriptions, recent interest has focused on the use of distributed hydrologic models to bridge the scale gap between in situ observations and footprint-scale retrievals. The assumption underlying such approaches is that hydrologic models are capable of realistically capturing landscape-scale soil moisture heterogeneity. Regional soil moisture observations during SMEX03 provide an excellent opportunity to test such an assumption and clarify the potential role of distribution hydrologic modeling for validation of spaceborne retrievals and/or the design of optimal in situ observation networks.

Specific goals include:

- Intercomparison of statistical and explicit representations of surface soil moisture heterogeneity obtained from field observations, aircraft retrievals, and hydrologic models during SMEX03.

- Development and testing of model-based strategies for upscaling a subset of regional soil moisture observations up to the AMSR footprint scale.

Field Observations of Soil Moisture Variability Within Satellite Footprints During SMEX03 in Oklahoma and Brazil

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Previous work has explored the scaling behavior of soil moisture variability from the point to the footprint scale. This work has been conducted during the SGP97, SGP99 and SMEX02 experiments. Consistent behavior has been identified across scales. Our field studies during SMEX03 will focus on the regional scale, and will determine whether the behavior of soil moisture variability observed in the land cover and climatic conditions of SMEX02 in Iowa is exhibited in the differing conditions of Oklahoma in SMEX03. Our work in Brazil will focus on establishing a footprint-scale validation site, and will provide a third footprint-scale data set in different land cover/climate conditions for comparison with the Iowa and Oklahoma data.

Dual C- and X-band High-Resolution Imagery of Soil Moisture

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The Polarimetric Scanning Radiometer was originally developed at the Georgia Institute of Technology starting with a concept proposal in 1995, and first operated on the NASA P-3B aircraft in 1997 for the Labrador Sea Ocean Winds Imaging (OWI) experiment (Piepmeier and Gasiewski 1996) [1]. Since this initial deployment it has been upgraded and successfully operated by the NOAA Environmental Technology Laboratory (ETL) during several many campaigns, including the Third Convection and Moisture Experiment (CAMEX-3) in August and September 1998, Southern Great Plains Experiment (SGP99) during July 1999, Meltpond 2000 during June-July 2000, Soil Moisture Experiments in 2002 (SMEX02), Wakasa Bay 2003, Cold Land Processes Experiments (CLPX) in 2002 and 2003. As a result of these campaigns the PSR has provided the first airborne passive microwave imagery of ocean surface wind vector fields, the first multiband conical-scanned imagery of hurricanes, intense convection, and stratiform precipitation, the first high-resolution dual C- and X-band imagery of soil moisture, and the first high-reslution multiband polarimetric imagery of snowpack and sea ice emission.

During the 2003 Soil Moisture Experiment (SMEX03), the PSR/CX scanhead will be integrated onto the NASA WFF P-3B aircraft in the aft portion of the bomb bay. The PSR/CX scanhead was successfully used during SMEX02 and is an upgraded version of the PSR/C scanhead used during SGP99. The installation will utilize the NOAA P-3 bomb bay fairing, and will locate the PSR immediately aft of the NASA GSFC ESTAR L-band radiometer on the NASA P-3. The upload will commence at NASA WFF around June 12, 2003. Flights over ground truth sites in Georgia, Alabama, and Oklahoma will occur starting during the period from June 24 through July 17, with transit back to WFF around July 18. A total of approximately nine 3-4 hour data flights are planned in Georgia-Alabama, and three in Oklahoma. Flights will be coordinated with soil moisture ground sampling efforts.

The primary hypotheses to be studied using the PSR/CX data during SMEX02 are:

- Can C-band imagery be used to reliably measure surface soil moisture in the presence of agricultural biomass?
- Can coincident C- and X-band imagery be used to improve single-band measurements by compensating for vegetation-induced brightness perturbations?

The first of these hypotheses was answered in the affirmative for grassland and agricultural regions cultivated with low-canopied crops during the PSR SGP99 campaign, wherein good correlation was obtained between PSR-estimated soil moisture and surface truth over Oklahoma during mid-summer conditions. During SMEX02 it was observed that useful soil moisture signatures can be observed over cropland, although algorithms for soil moisture retrieval have not yet been developed. During SMEX03 we will study the estimation of soil moisture using C-band for both cropland and denser biomass, included forested regions, to learn the extent to which C- and X-band imagery can be used for soil moisture retrieval.

In addition to the above hypotheses, the following issues will be studied:

- Applications of sub-watershed soil moisture mapping, both in water management, flash-flood and wildfire potential estimation, and surface emission modeling.
- Algorithm development for C- and combined C- and X-band soil moisture retrieval.
- Statistics of the anthropogenic interference spectrum to better determine the requirements for interference mitigation on future spaceborne and airborne C- band radiometric systems.
- The potential for using GPS reflectometry to measure soil moisture.

The successful development of dual C- and X- band radiometry for airborne soil moisture mapping is expected to help improve the ability to manage the distribution of water as well as the prediction of hazardous conditions.

Ancillary data required for the above investigations include *in-situ* soil moisture samples, crop type maps, watershed terrain maps, and canopy height and biomass samples. GPS soil moisture reflection measurements by V. Zavorotny of NOAA/ETL and colleagues will be made and compared to available airborne and surface truth measurements.

[1] See http://www.etl.noaa.gov/technology/psr/ ,

Large Scale Soil Moisture Estimation Using In Situ Point Sources for Satellite Validation

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Preliminary studies have been conducted in the area of large scale soil moisture observation, including Washita '92, SGP97, and SMEX02. These experiments included intensive ground sampling coupled with an aircraft campaign, which began the development of soil moisture retrieval algorithms for passive microwave remote sensing. These experiments led to the development of satellite instruments designed to retrieve estimates of surface soil moisture from space. The validation of satellite soil moisture products, such as those provided by the AMSR and AMSR-E instruments, requires accurate estimates of large scale surface soil moisture across a variety of land forms and climates. For the validation of these satellite instruments, short term experiments are important, but long term monitoring of surface soil moisture is an unavoidable necessity. It is not possible to gravimetrically monitor the surface at scales sufficient for validation, but an innovative statistical analysis may allow a small number of points to replace the large scale mapping needed. This concept is called temporal stability and it holds the key to the future of effective satellite validation.

The first step in this analysis is to construct large scale soil moisture sensor networks which monitor the top 5 cm of soil, the penetration depth of the AMSR (-E) instruments. Two such networks have been established in the Little River Watershed near Tifton, GA and the Little Washita River Watershed, near Chickasha, OK. SMEX03 provides an excellent opportunity to study these two regions. During SMEX03, teams will intensively sample the region surrounding the probe network allowing it to be calibrated to predict satellite footprint scale soil moisture. This calibration is based on establishing temporal stability. By establishing a watershed has a consistent or stable soil moisture pattern for long periods of time, a sensor network can be calibrated to estimate that moisture average on a continuous basis at a fraction of the expense of large scale sampling. This work is expected to be exported to other sensor networks in different regions to further the validation of AMSR (-E) products.

Hypotheses
* Are the regions of study in SMEX03 temporally stable with respect to surface soil moisture and at what scales?
* Can a small number of in-situ soil moisture probes accurately predict large scale soil moisture for the purposes of satellite validation?

Contributions to SMEX03
The dense network of soil moisture probes which have been installed in the watersheds since 2002 will provide a generous history of meteorological and hydrological data. Also, the

equipment will remain on site after the experiment is over and will be able to temporally extend the soil moisture information

Validation of the AMSR-E Brightness Temperature and Soil Moisture Products

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Project Description:

We plan to utilize a coupled hydrologic/radiobrightness model (H/RM) to provide "best estimates" of footprint-scale mean volumetric soil moisture and C and X band T_B with associated variance and confidence limits. This information will provide quantitative validation of AMSR-derived soil moisture. The high spatial and temporal resolution of the model output relative to AMSR observations will permit us to evaluate a.) the errors associated with using a limited number of point-scale measurements to estimate footprint-scale mean soil moisture, b.) the errors associated with asynchronous sampling times, and c.) the relationship between surface moisture (~1 cm) and profile moisture. These analyses are necessary to characterize the accuracy of the AMSR data products at footprint scale. Our interest in SMEX03 is to obtain data necessary to conduct these AMSR validation studies. For the most part, the data necessary for hydrologic modeling will be collected as part of the overall SMEX03 sampling/measurement strategy that is presented in the experiment plan. To this extent, we plan to support the gravimetric soil moisture and vegetation sampling programs. The T_B derived from our model will be used to validate the aircraft-derived T_B. Conversely, the aircraft data can be assimilated into the model periodically to improve model performance.

In addition, we wish to address upscaling of vegetation properties from point to footprint scale using remote sensing. Passive microwave remote sensing measurements are highly sensitive to surface roughness and vegetation water content. Previous experiments have used regression of the spectral properties of land cover to scale point measurements of vegetation water content up to aircraft pixel scales. Unlike the agricultural areas of the central US, the agricultural region of north Alabama is comprised of greater overall heterogeneity with smaller fields separated by wider woodland riparian zones and, for the most part, vegetation density in excess of what we have studied thus far in Oklahoma and Iowa. Alabama also has significant relief, which we have not had to contend with in the past. In addition, the spatial distribution of precipitation during the experiment period is typically of very limited extent, yet often substantial volume.

The Iowa study site offered us an opportunity to explore some potentially viable direct remote sensing measurements of the spatial variability of vegetation biomass and surface roughness. We will continue to pursue the use of various multispectral data sets, such as MODIS, ASTER, Quickbird and Radarsat data for the study area. The use of multi- and/or hyperspectral data fused with radar data as a proxy for vegetation biomass will also be investigated. These remote sensing products will be used to investigate upscaling from field measurements of biomass to scales consistent with an AMSR footprint. This scale transformation is an important piece of the puzzle leading to the exclusive use of satellite-based sensors such as Landsat, MODIS, ASTER, Hyperion, Radarsat, etc. for parameter retrieval in conjunction with AMSR soil moisture retrieval algorithms.

Data requirements for hydrologic modeling:

Time-dependent input: wind speed, air temperature, relative humidity, rainfall, atmospheric pressure, downwelling solar radiation, downwelling longwave radiation.

Static variables: slope, saturated hydraulic conductivity, saturated matric potential, soil wilting point, rooting depth, soil porosity, canopy height, fractional vegetation cover, minimum stomatal resistance, leaf area index, reflectance properties.

Contributions:

1.) support for surface GSM and vegetation sampling

2.) modeled, spatially-distributed soil moisture and temperature profiles over regional domain (resolution TBD).

3.) modeled, spatially-distributed T_B over regional domain.

4.) vegetation classification for the study area

5.) remotely sensed proxies for vegetation biomass over regional domain

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Soil Moisture Measurements Using Synthetic Aperture Radiometry

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One possible approach to obtaining global maps of soil moisture from space with resolution of 10 km or better, is the use of aperture synthesis. Aperture synthesis is an interferometric technology for passive microwave sensing, that has been successfully demonstrated in one dimension with the L-band instrument, ESTAR. Research to extend synthesis to both dimensions is underway. SMOS will utilize this concept. An aircraft instrument, called 2DSTAR, is has been developed under NASA's Instrument Incubator Program. GWEC is supporting the field demonstration of this approach for soil moisture.

The specific goals of the measurements with the 2DSTAR instrument are:

- Provide the first demonstration of this technology for large scale soil moisture mapping.
- Develop a multi-temporal soil moisture map series for the Little Washita Watershed similar to those generated in Washita92 and SGP97 using ESTAR.
- Collect concurrent 2DSTAR-AIRSAR data sets to develop and test HYDROS soil moisture retrieval concepts
- The instrument will be used to map large areas for soil moisture to provide data to the SMEX03 research community for studies of land-atmosphere interactions.

GPS Bistatic Radar Soil Moisture Measurements in SMEX03

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The GPS Bistatic Radar instrument measures L-band GPS satellite signals reflecting from the land surface to estimate soil moisture. Simultaneous measurement of both direct and surface-reflected GPS signals constitutes a bistatic radar system, with transmitters located at GPS satellites and a separate receiver located on an aircraft platform. Land surface bistatic radar cross sections are estimated using relative measurements of the reflected signal power and measurements of the direct, line-of-sight signal power. Surface soil moisture can subsequently be inferred from the bistatic cross section estimates along with information on the surface roughness characteristics and soil properties.

The GPS Bistatic Radar instrument successfully participated in SMEX02 on board the NCAR C-130 aircraft, with results showing strong correlation between the L-band bistatic cross section measurements and the spatial and temporal change in soil moisture during the study period. The SMEX03 campaign will provide another opportunity to gather and investigate a controlled data set of land-based GPS reflections in the company of other instruments attempting to remotely sense soil moisture.

In SMEX03, the Delay Mapping Receiver (DMR) instrument that flew in SMEX02 will fly on the NASA P-3. The DMR instrument is currently installed on the NASA P-3 and collecting data during the CLPX03 and AMSRICE03 missions. It will remain on the NASA P-3 for all of the SMEX03 campaigns. For SMEX03, software changes will be introduced to collect bistatic radar measurements from up to five simultaneous satellite reflection geometries. This will provide five separate measurements of surface bistatic cross sections at varying incidence angles. The radar footprint is nominally 20 m diameter at 1 km altitude and varies as a function of the surface roughness and aircraft altitude.

A sampling GPS receiver instrument will also fly on the NASA P-3. The Johns Hopkins University/Applied Physics Laboratory Multiple GPS Reflections Recording System (MGRS) will sample the entire GPS spectrum of direct and reflected signals and save the raw samples to a disk array. Simultaneous measurements of soil moisture by both the DMR and the MGRS will be very important in understanding GPS bistatic radar. During the 2003 Soil Moisture Experiment (SMEX03) the MGRS will be taken on a loan by Valery Zavorotny of NOAA/ETL and installed onto the P-3 aircraft.

Goals in SMEX03:

1. Collect another set of DMR ground reflection measurements in tandem with *in situ* soil moisture measurements and in conjunction with other remote sensing instruments (PSR, ESTAR, etc.).
2. Simultaneously collect raw GPS direct and reflected signal samples using the APL MGRS instrument for in-depth post-processing and comparison with DMR results.
3. Produce surface bistatic cross section and soil moisture estimates and compare with *in situ* soil moisture measurements and co-located remote sensor footprints.
4. Correlate temporal and spatial soil moisture changes with GPS Bistatic Radar estimates.
5. Test new receiver mode that collects measurements from up to five simultaneous satellite reflections.
6. Investigate multi-reflection measurements to increase measurement accuracy and spatial sampling.
7. The GPS Bistatic Radar data sets collected in SMEX03 will be processed by the University of Colorado and NOAA/ETL and made available for use to the SMEX community.

The GPS Bistatic Radar is a proof-of-concept instrument that has the potential for becoming a simple, inexpensive remote sensing tool for land surface characterization. Participation in SMEX03 will provide valuable information in further development of the instrument and its applications to soil moisture remote sensing.

Soil Moisture Variability Studies Under Two Different Hydro-Climatic Regions for SMEX03

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Soil moisture content at the *land surface* and *subsurface* is important for global water balance calculations and land-atmosphere interaction in terms of partitioning upward and downward water and energy fluxes at the land surface. Soil moisture is controlled by factors such as soil type, topography, vegetation, and climate. The planned global-scale land surface mission of the AMSR-E - AQUA (PM) satellite platform, and other insitu-, point-, field-, and aircraft-based soil moisture measurement campaigns present a unique opportunity to study the evolution of multi-scale soil hydrologic processes and controls across the conterminous USA at a range of spatial and temporal scales. We propose collecting and analyzing spatio-temporal soil moisture data using exploratory data analyses, geostatistical analyses, time-stability analyses, scaling, and subsurface flow modeling for two different hydro-climatic regions (i.e., Oklahoma and Georgia).

Hypothesis:
Soil, topography, vegetation, and climate interactively control space-time distribution of soil moisture at different space and time scales. We propose to gain quantitative understanding of their individual and interactive contributions.

SMEX03 Data Needs and Contributions
We will collect surface and subsurface soil moisture data at multiple scales cutting across various soil, land cover, and topographic features in Oklahoma and Georgia during SMEX03 (June-July, 2003) campaign. Our specific research contributions during the SMEX03 will include:

1. Characterization of spatial distribution and process controls (i.e., soil, topography, vegetation) on land-surface and subsurface soil moisture within space-borne remote sensor footprints for two hydro-climatic regions.
2. Developing a framework for comparing methods for estimating space-borne remote sensor footprint-scale mean soil moisture content from point, field-averaged, and air-borne remote sensor data collected during SMEX03 experiment.
3. Identify areas for establishing strategic soil moisture monitoring network based on significant process controls.
4. Testing a newly developed suite of PTVTF upscaling techniques from point, ground, or air-borne remote sensor footprint (e.g., ESTAR or 2D-STAR, 800 m X 800 m) to space-borne AMSR-E footprint (56 km X 56 km) scale.

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Evaluation of AMSR Soil Moisture Algorithms and Products (Aqua and ADEOS-II) and Synergy with SeaWinds Scatterometer Data Over SMEX03 Sites in the U. S. and Brazil

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The AMSR instruments on the Aqua and ADEOS-II satellites were launched in May and December 2002, respectively. Algorithms to derive soil moisture and other land parameters from these instruments have been developed and implemented by the NASA and NASDA AMSR instrument teams. Validation of the soil moisture sensitivity and derived products from AMSR will focus on calibration assessments, field experiments including SMEX02, SMEX03 and follow-ons, and long-term comparisons with data from operational networks. Specific tasks to be addressed utilizing AMSR data in SMEX03 include assessments of the effects of vegetation water content and spatial heterogeneity on the derived soil moisture.

For SMEX03 we plan to extract and analyze time-series fields of AMSR-derived gridded brightness temperatures, soil moisture, vegetation, and quality control parameters over the sites in Oklahoma, Georgia, Alabama, and Brazil based on refinements of the NASA and NASDA AMSR algorithms. We will also generate time-series imagery of scatterometer data from the SeaWinds instrument over the same domains as the AMSR data. The time-series will be compared against aggregated fields derived from precipitation, and meteorological data, NDVI data, model output data, and airborne and in-situ soil moisture data acquired in collaboration with other investigators in SMEX03. The enhanced information content of the combined passive and active microwave satellite data at 25-60 km resolution, in the presence of varied vegetation cover and soil conditions, will be studied.

Use of Regional Microwave-Derived Soil Moisture in Land Data Assimilation and Atmospheric Boundary Layer Studies

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The Hydrological Sciences Branch at NASA / GSFC has a long-standing and comprehensive interest in the application of microwave remote sensing to land surface hydrology. Research within the Branch ranges from investigation of more accurate soil moisture retrieval algorithms to technology development of 2D STAR techniques to application of remote sensing variables in data assimilation and atmospheric boundary layer studies. It is anticipated that Branch members will participate in all of these areas as part of the SMEX03 experiment, especially in support of ground vegetation and soil moisture sampling.

Soil Moisture Retrieval Algorithms

SMEX03 will offer the opportunity to compare the accuracy of soil moisture retrieved using the standard single-channel algorithm to soil moisture retrieved using a multiple-channel approach in a well-characterized low vegetation environment (Oklahoma). This work has direct bearing on future soil moisture mission planning. The performance of the 2D ESTAR is also of much interest given the ongoing STAR technology development activities within GSFC.

Land Data Assimilation

The overall goal of our AMSR calibration/validation effort is (1) to quantify the accuracy and provide validation for soil moisture retrieved from AMSR-E on a variety of time scales, (2) to quantify the geographical, seasonal, and environmental sensitivities of the accuracy characteristics, and (3) to analyze the effects of these uncertainties on the predictability of the global surface water and energy balance using land surface data assimilation techniques in near real-time. The use of data assimilation methods for satellite validation is the next logical step in NASA's ongoing efforts to understand the Earth's land-surface and to extend NASA's emerging observations for application to a vast array of socially-relevant land-surface issues. A nearly real-time operational land data assimilation system will be developed that will monitor the spatial-temporal AMSR soil moisture quality, so as to provide feedback to mission operators of observational problems. This system will also extend AMSR-E products in time and space to produce consistent data assimilation land surface fields that will be valuable for use in subsequent analysis and application. The *in situ* and airborne land surface observations from SMEX03 will be used initially as a surrogate for AMSR data in model runs of the Oklahoma region, and will also be compared to actual AMSR data. For the determination of land surface biophysical parameters such as NDVI, leaf area index, land cover/use type, etc., optical remote sensing data from satellites like MODIS, ASTER, Ikonos, ETM+ and/or AVHRR will also be needed and ingested into the modeling approach.

Validation Work for SSM/IS Land Surface Temperature and Soil Moisture EDRs During SMEX03

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The Defense Meteorological Satellite Program's Special Sensor Microwave Imager (SSM/I) satellites have been collecting global measurements from space for the last 16 years. With the impending launch of the latest F16 SSM/IS satellite now planned for May 2003, it is anticipated that SSM/IS will be undergoing its initial on-orbit checkout phase at the time of the SMEX03 experiment, and that some leveraging of SMEX03 activities for validation of SSM/IS soil moisture and land surface temperature Environmental Data Records (EDRs) will be possible.

Past research studies have demonstrated the capabilities of low frequency microwave sensors for estimation of land surface soil moisture and temperature. While papers in the refereed literature have indicated the potential of SSM/I frequencies in retrieving temperature, accurate estimates of soil moisture generally require the use of lower frequency microwave channels (preferably L band at 1.4 GHz). Because the lowest frequency on SSM/IS is at the much higher frequency of 19 GHz (1.55 cm wavelength), theoretical limitations will restrict the ability of SSM/IS to retrieve soil moisture/soil wetness to bare or lightly vegetated surfaces. The challenge for validation of the SSM/IS soil moisture EDR will be to document (in a quantified repeatable way) the accuracy of the soil moisture retrievals under specific conditions of surface vegetation and roughness.

Validation Activities The main thrust of the SSM/IS validation approach will be to leverage off of NASA/USDA AMSR cal/val activities to the maximum extent possible. These activities consist of two major programs: the extensive SMEX03 soil moisture field campaign and the continuous collection of relevant data from instrument networks in four USDA watersheds across the U.S. for year-long validation.

The main SMEX03 soil moisture field campaign is currently scheduled for June/July, 2003, and will include aircraft overflights with microwave radiometers at lower frequencies than the SSM/IS channels (if the AESMIR instrument is deployed as part of the SMEX03 campaign either in the U.S. or Brazil, then data will be acquired at the higher SSMIS frequencies). Since the AMSR-E frequencies of 6.9 and 10 GHz will respond to soil moisture in a deeper surface layer (~1-2 cm) than 19 GHz, most of the ground validation data will be collected at 2-3 and 5-6 cm depths. The relationship between soil moisture at these depths and the shallower SSM/IS sampling depth (0.3-0.5 cm) will be examined. It is possible that planned gravimetric soil moisture sampling will be augmented in limited areas to collect a 1 cm sample to supplement the SSM/IS validation. Spatial scaling between point samples and the area response, which will be a part of the AMSR analysis, is directly relevant to SSM/IS because of the similar spatial extent of the SSM/IS 19 GHz and AMSR 6.9 GHz footprints.

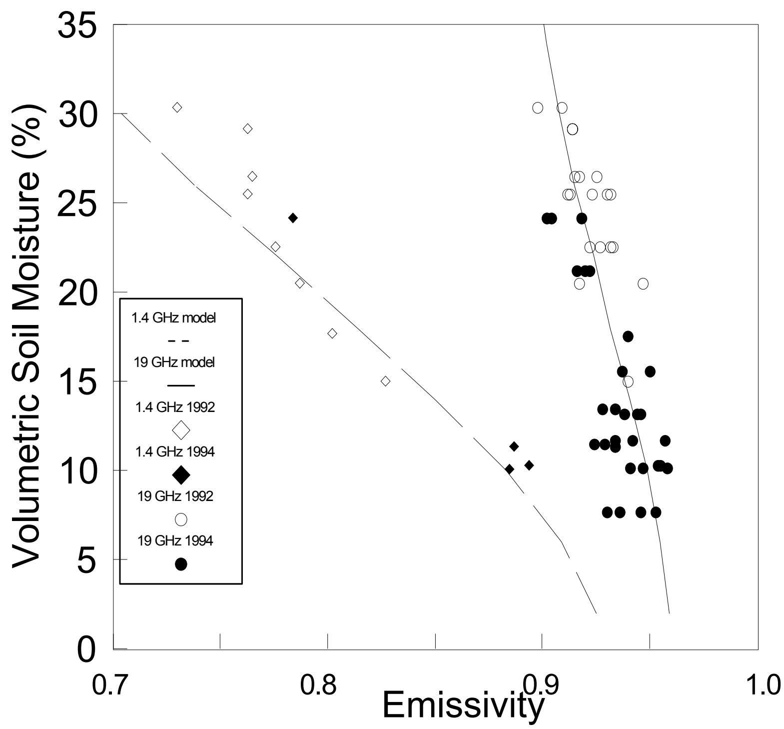

FIGURE 1 Soil moisture-microwave relationship for Oklahoma grasslands in 1992-1994, showing the large difference in sensitivity in the microwave-soil moisture relationship between the 19 GHz SSM/I sensor and equivalent data collected at 1.4 GHz using an aircraft sensor.

Long-term observations in diverse environments are needed to understand possible variations in the soil moisture – microwave relationships that arise from seasonal variations in vegetation cover and temperature. This will be accomplished by utilizing the upgrades under the AMSR cal/val program to *in situ* observations in four USDA instrumented watersheds across the U.S. (Georgia, Oklahoma, Arizona, and Idaho) to better characterize moisture and temperature conditions in the shallow surface layers. In addition, the instrument network in the Oklahoma watershed has been augmented for SSM/IS temperature EDR validation work by adding fixed-mount thermal infrared thermometers to the 17 AMSR-upgraded stations in the 610 km^2 Oklahoma watershed. The Oklahoma watershed currently includes 42 Micronet meteorological stations, 14 ARS SHAWMS stations (which collect 2.5 and 5 cm soil moisture and soil temperature data as part of their soil profile measurements), 2 ARM/CART stations, and 1 NRCS SCAN station. Data are recorded at 30- and 60-minute timesteps continuously year-round to provide information to assess diurnal and seasonal relationships with the satellite microwave measurements. All of the new soil moisture and soil temperature sensors have undergone initial laboratory calibration and will be periodically rechecked to insure data quality.

Combining Data of Aircraft and Spacecraft Microwave Radiometry with in situ Measurements to Determine the Information about Soil-Vegetation System.

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Project Description:

The work plan proposed for SMEX'03 is to participate in on-ground measurements, to collect data on selected soil and vegetation parameters, such as, soil moisture, bulk density, vegetation biomass, and soil temperature. In addition to typical 0-3 and 3-6 cm measurements of soil parameters, measurements in selected areas will be taken down to 50 cm to generate soil moisture profiles for use in hydrologic models. Photographic pictures will be taken in the areas where other parameters are sampled for visual determination of site conditions.

Attempts will be made to obtain ground-based microwave radiometric measurements synchronously with the aircraft and spacecraft microwave observations. If delivered to Huntsville area, these radiometers will be installed at the territory closely located to one of the weather stations and/or installed on a mobile platform to provide opportunity for us to conduct radiometer data sampling in different locations.

The primary objectives of this research are: 1) to study the inter-comparison of the spectral radiation data with soil moisture data at different depths with regard for the vegetation coverage and soil type; 2) to examine the impact of spatial resolution (footprint size) on the range of radiometric data changes and on the correlation distance of these changes in the absence and presence of vegetation; 3) to conduct radiation data modeling with regard for the *in situ* measurements and to compare this data with the results of measurements and 4) to combine the remotely sensed data with *in situ* measurements to estimate the increase in information about soil-vegetation system thus to contribute in database to be used in the hydrological modeling.

Hypothesis

There exists a strong dependence of brightness temperature data at microwaves on land surface parameters, first of all on soil moisture data and biomass of vegetation. The inter-relation between this data is wavelength dependent. Spectral data processing is increasing the information content of measurements. In addition to traditional comparison between the remotely sensed data and the data of *in situ* measurements, a combination of this data will be undertaken to assess an increase in description of soil-vegetation condition.

SMEX'03 Data Needs

Data will be needed of *in situ* measurements, of microwave observations from ground platform, from airplane and satellite. Prior knowledge-based information will be needed about such soil and plant parameters as wilting point, field capacity, plant type and relative vegetation coverage. Some finances will be needed to rent the ground-based radiometers, to invite specialists on radiometer hardware and software to calibrate them in laboratory and field conditions, to adapt the data acquisition system, to operate the radiometers and to process the data collected during experiment (2 to 3 people for 2 to 3 weeks).

Contribution to the SMEX'03 Field Experiment

Research conducted in this work will extend the resulting database. This information will be used in the hydrologic modeling work.

Acknowledgment

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Characterization of Vegetation Parameters Within a Footprint Area of SMEX03

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Rationale:

Leaf area index (LAI) defined as the one-sided leaf area per unit ground area, normalized differences of the vegetation index (NDVI), and fraction of photosynthetically active radiation (fPAR) are key vegetation parameters that describe a canopy structure. Soil moisture estimation models use these parameters. Despite large developments over the past years, the main problem is still the acquisition of these vegetation parameters that are needed to input in the models. These parameters vary on a field scale and undergo rapid changes with time. In the last decade, NDVI derived from NOAA-AVHRR and Landsat Thematic Mapper (TM) has been some of the widely used sources of satellite data available to monitor the activity of vegetation from space. New sensors such as MODIS, having increased spatial resolution as well as spectral and directional properties, will provide improved land cover estimates and vegetation properties, including fPAR. Estimation of these variables from satellite and aircraft based remote sensing data require ground data for validation and testing for bias. Therefore, the objectives of this study are: (1) to measure the LAI and fPAR of soybean and corn at field scale using the AccuPAR Model PAR-80 (Decagon Devices, Inc. Pullman, WA), (2) to validate the Landsat TM, AVHRR, and MODIS derived LAI, NDVI, and fPAR parameters using field scale measurement.

Hypothesis:

Surface biophysical parameters (LAI, fPAR, and biomass) can be accurately estimated from satellite and aircraft remotely sensed data.

Data Collection:

The protocol used to measure vegetation parameters during the SMEX02 field experiment in Iowa, with some modification to fit the type of crops (soybean, corn, cotton and others) at SMEX03 study area, will be utilized. Sampling locations will be coordinated with ground based flux stations and sites that will be used by Alabama A&M University (HSCaRS) scientists. The LAI and fPAR measurement will be taken on a grid from the corn, soybean, and cotton fields using the AccuPAR Model PAR-80 (Decagon Devices, Inc. Pullman, WA) device. Spectral reflectance measurement will also be collected using a hand held radiometer that will measure the incident and reflected light. NDVI will be calculated using the surface spectral measurement and satellite data. The sampling locations on the field will be recorded using a differential GPS unit. The biophysical parameters measured on grid scale will be interpolated across the footprint using a geostatistical kriging method. The normalized difference vegetation index (NDVI) will be derived from Landsat TM, AVHRR, and MODIS sensors and relationships will be established with the measured surface biophysical parameters (LAI, fPAR, and biomass).

Contribution to SMEX03:

Biophysical parameters (LAI, fPAR, and NDVI) measurements obtained from the field scale will be used for watershed, and regional scale soil moisture estimation.

Microwave brightness signatures of cotton during SMEX03

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The microwave brightness at low frequencies is sensitive to near-surface soil moisture in most vegetated surfaces. During SMEX03 we will investigate microwave brightness signature varies with soil moisture and evapotranspiration for a dominant row crop in the Southeastern U.S., namely cotton. The proposed research aims to monitor microwave brightness at 6.7 GHz (C-band) with a tower-based dual-polarized C-band radiometer, matching one of the frequencies of the Advanced Microwave Scanning Radiometer sensor aboard NASA's EOS satellite and the newly launched WindSat by the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NOPESS) Integrated Program Office (IPO).

The microwave observations will be augmented by Eddy Covariance System to measure latent and sensible heat fluxes. Additional micrometeorological and canopy and soil parameters will be observed such as precipitation, relative humidity, and wind speed and direction, air temperature, shortwave and longwave radiation, soil moisture and temperature, and soil and canopy surface temperatures. Periodic vegetation sampling will also be conducted during the SMEX03 to determine phenological stage, plant height and density, LAI, green and dry biomass, row density in cotton.

The dataset collected during the SMEX03 in cotton will give us a unique opportunity to compare field-scale measurement with airborne C-band sensors such as PSR/CX and satellite sensors such as AMSR, AMSR-E, and Windsat. It will be used to examine the feasibility of using the data collected by a tower-based radiometer operating at 6.7 GHz to retrieve soil moisture under the presence of significant vegetation such as cotton.

Near surface soil moisture distribution under different land use practices within the ALMNet study area.

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Soil moisture is a critical component of many regional and global climate studies. It's spatial and temporal distribution within a field and watershed is affected by sources of the hydrological conditions and variability mostly associated with management-related factors. Furthermore, the relative significance of spatial, temporal, and management-induced sources of variation are not well known, nor are they typically accounted for in the soil moisture modeling and mapping efforts. Knowledge of their significance is nevertheless important for the development of both efficient sampling protocols and proper parameterization scenarios. The objectives of this research are: 1) evaluate the variance structure associated with soil moisture within a corn and soybean field; and 2) determine the emitting depth by correlating the near-surface soil moisture data with ground based flux and remotely sensed measurements.

Hypothesis: Evaluating the relative significance of the variance structure of near-surface soil moisture improves the validation process of remotely sensed data.

Sample collection: During the SMEX03 field experiment, repeated soil moisture measurements will be collected from cotton and soybean fields. Soil moisture measurements will be done twice a day within-row and side-row of the row crops. The data collection will be done at least from five soil depths including 2, 3, 4, 5, and 6 cm and in four fields (two cotton and two soybean). A site-specific calibration will be performed before and after the field experiment to compare the soil moisture data collected from each field.

Contribution to SMEX03 field experiment: The availability of such data will improve our understanding about the spatial and temporal variability of soil moisture under cotton and soybean fields. Data collected from this study can be used to couple remotely sensed data with hydrology models and will also assist to validate remotely collected active and passive data.

Evaluation of Regression Tree Algorithm (RTA) and Artificial Neural Networks (ANNs) for Developing Pedotransfer Functions of Soil Hydraulic Parameters

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Knowledge of the spatial and temporal variability of hydraulic properties at different scaling levels is essential to effectively apply many research and management tools. In addition, this will improve our ability to estimate and quantify the spatial distribution of soil moisture. Most hydrologic models that simulate soil hydrologic processes and their impacts on crop growth depend on accurate characterization of such properties. The lack of such information is often considered to be a major obstacle to effectively utilize these tools. It is generally recognized that soil hydraulic properties are affected by numerous sources of variability mostly associated with spatial, temporal, and management related factors. Soil type is considered the dominant source of variability, and parameterization is typically based on soil survey databases. We are trying to identify a set of potential algorithms to predict water retention characteristics from more readily available soil data such as texture, structure, bulk density, organic matter, and Cation Exchange Capacity (CEC). Therefore, the purpose of this study is to evaluate the relationships between soil types and their hydraulic properties at the field scale and to develop a relationship between easily measured soil properties, vegetation characteristics, and hydrologic processes for up scaling, as well as improve the performance of the hydrologic modeling.

The objective of this research is to: 1) develop hierarchical pedotransfer functions (PTFs) using soil, topography, and plant properties; 2) compare two types of PTF models (Artificial Neural Network, Regression Tree Algorithm and estimate soil hydraulic properties at different spatial scales (point and field); and 3) develop a soil database that can be used as an input for watershed or regional scale hydrology models.

Hypothesis: Successful prediction of near surface hydraulic parameters and incorporation of such parameters with existing hydrologic models will improve the model performance at the watershed and regional scales.

Sample collection and analysis: Disturbed and undisturbed soil samples will be collected from the 0-10 cm depth on a grid from two or more corn and soybean fields. The soil samples will be crushed and passed through a 2-mm sieve. The disturbed soil samples will be analyzed for particle size (texture), organic matter, Cation Exchange Capacity (CEC), and pH. Undisturbed soil cores, 7.6 cm long by 7.6 cm diameter will be collected using Uhland core sampler. The samples will be trimmed, wrapped in plastic bags, and stored in a refrigerator at 4°C prior to analysis. They will then be used for the determination of soil physical properties including saturated hydraulic conductivity, water retention, bulk density, and porosity.

Contribution to the SMEX03 Field Experiment: Research outcomes and the resulting database from this work will be used in the watershed and regional hydrologic modeling work.

GLOBE Student Contributions of Gravimetric Soil Moisture Measurements to the SMEX03 Campaign

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GLOBE (http://www.globe.gov/) is an NSF-funded effort that supports a worldwide hands-on, primary and secondary school-based science and education program. The GLOBE Soil Moisture Project (GSMP) is a subset of the overall Program (see http://www.hwr.arizona.edu/globe/sci/SM/SMC/), and aims to mobilize GLOBE-participating students worldwide to collect near-surface (i.e. 0-5 cm and 8-12 cm below ground surface) gravimetric soil moisture data twice per year. The selected annual target dates are during World Space Week/U.S Earth Science Week (early October) and Earth Day Week (mid-April). Additionally, the GSMP aims to motivate schools to collect gravimetric soil moisture data at other times of the year, as a part of various regional soil moisture experiments, such as SMEX03.

In the vicinity of the SMEX03 activities in Georgia and Alabama, students from local GLOBE schools will collect as many gravimetric soil moisture samples as feasible within a 1-hr drive from their school or home. We are encouraging the students to collect measurements using GLOBE-specified protocols for gravimetric soil moisture (GLOBE protocols are found at http://www.globe.gov/).

GLOBE data become public domain once they are submitted using the Internet to the GLOBE database. All SMEX03 participants are welcome to view and use GLOBE soil moisture data. We hope that GLOBE students and their teachers can gain a perspective of the larger SMEX03 experiment by shadowing a ground team or getting a tour of the operation. To further enhance their learning experience, we would also appreciate allowing the students to compare their soil moisture data with data collected by other SMEX03 scientists.

APPENDIX A: SAFETY

Field Hazards

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:

- Work in teams of two
- Carry a phone
- Know where you are. All roads have street signs. Make a note of your closest intersection.
- Dress correctly; long pants, long sleeves, boots, hat
- Contact with corn leaves can cause a skin irritation
- Use sunscreen and bring fluids

For medical emergencies call 911 or go to:

For non-emergency medical problems:

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.

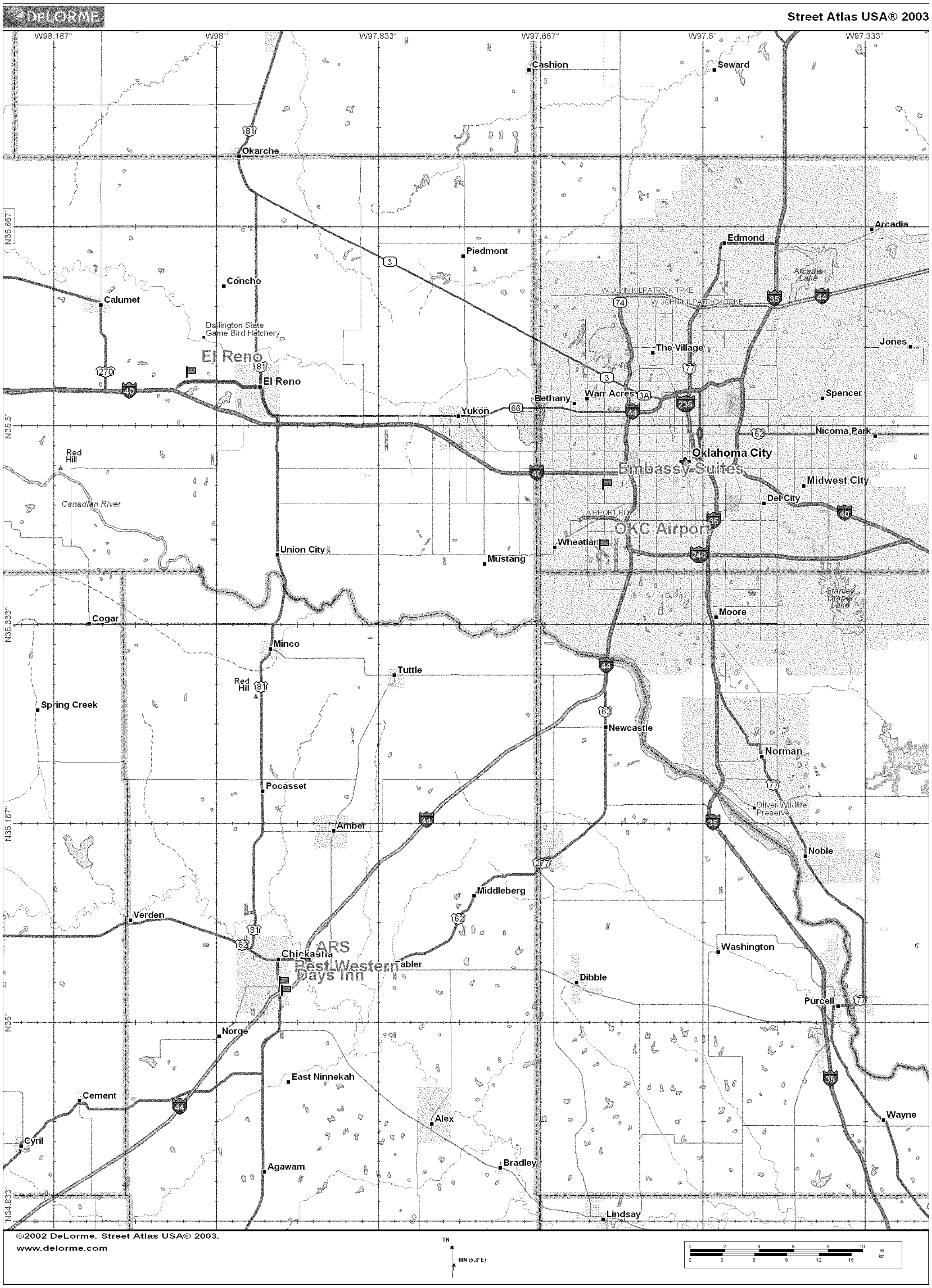
Ticks are very common outdoors during warm weather. When you are outdoors in fields and in the woods, wear long pants and boots. Also spray yourself before you go out with insect repellent containing DEET.

(Source:<http://kidshealth.org/cgi-bin/print_hit_bold.pl/kid/games/tick.html?ticks#first _hit>)

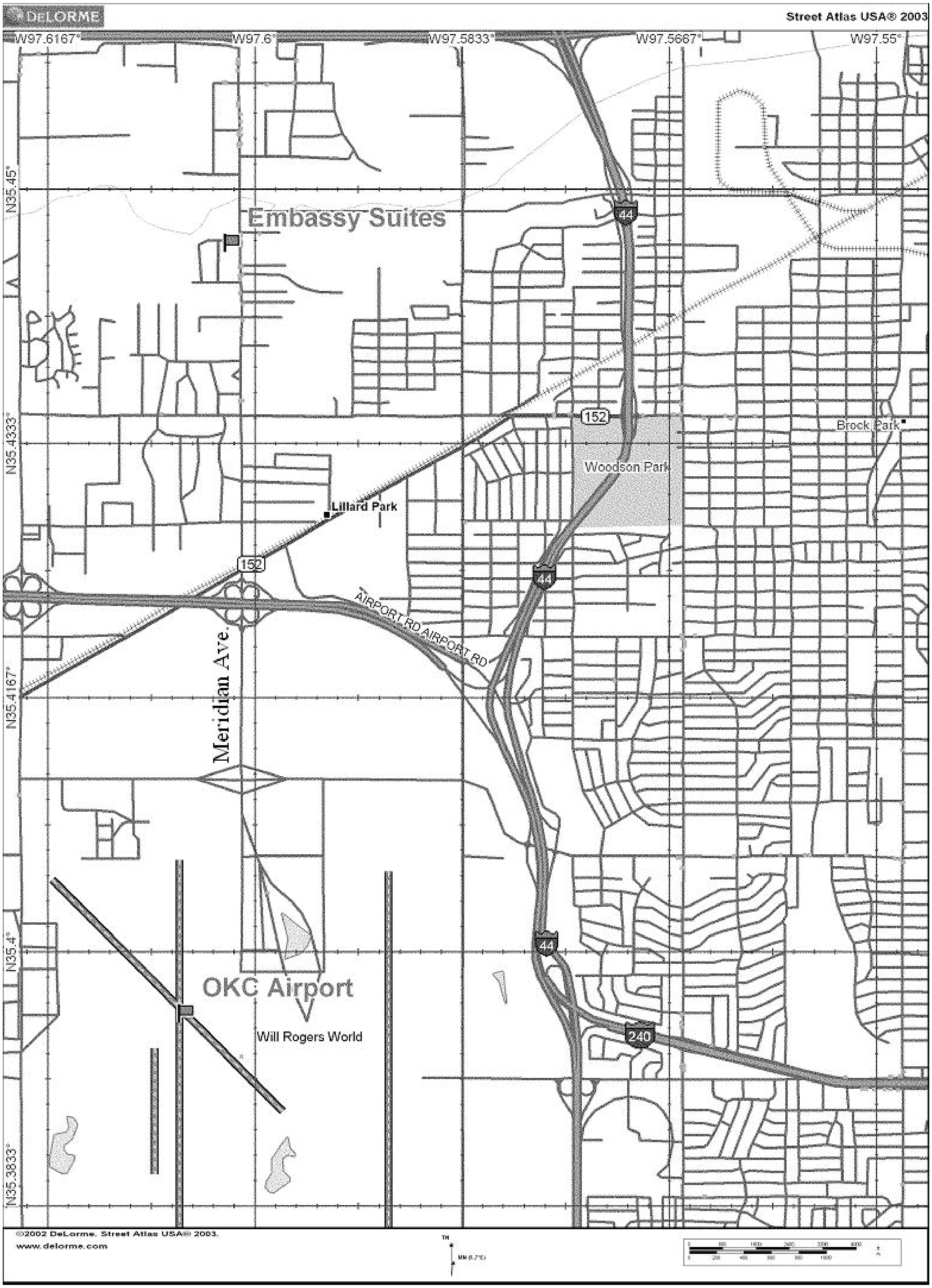
Drying Ovens

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.

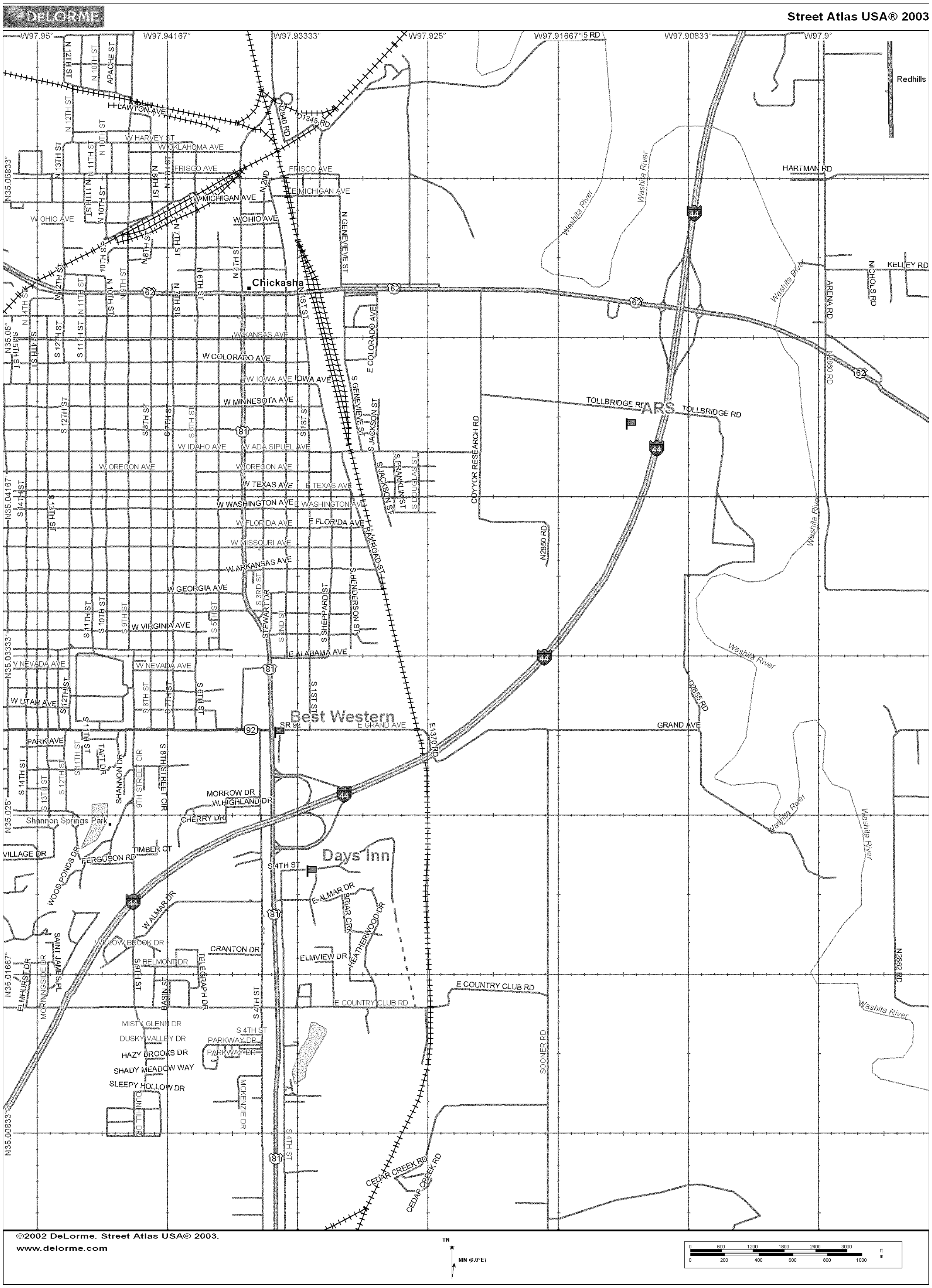
APPENDIX B: MAPS AND LOCATIONS



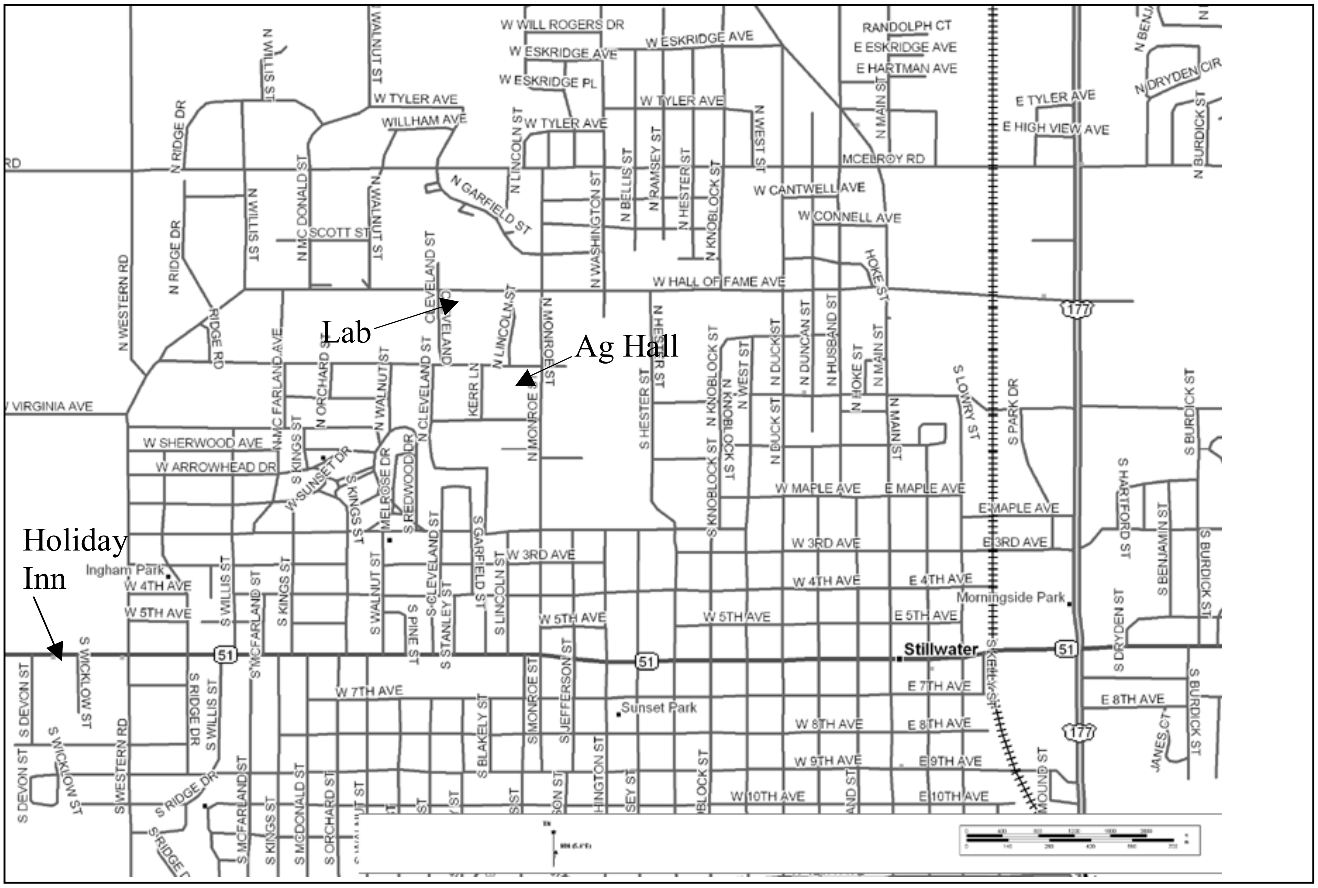
Map 1. Oklahoma City and Chickasha



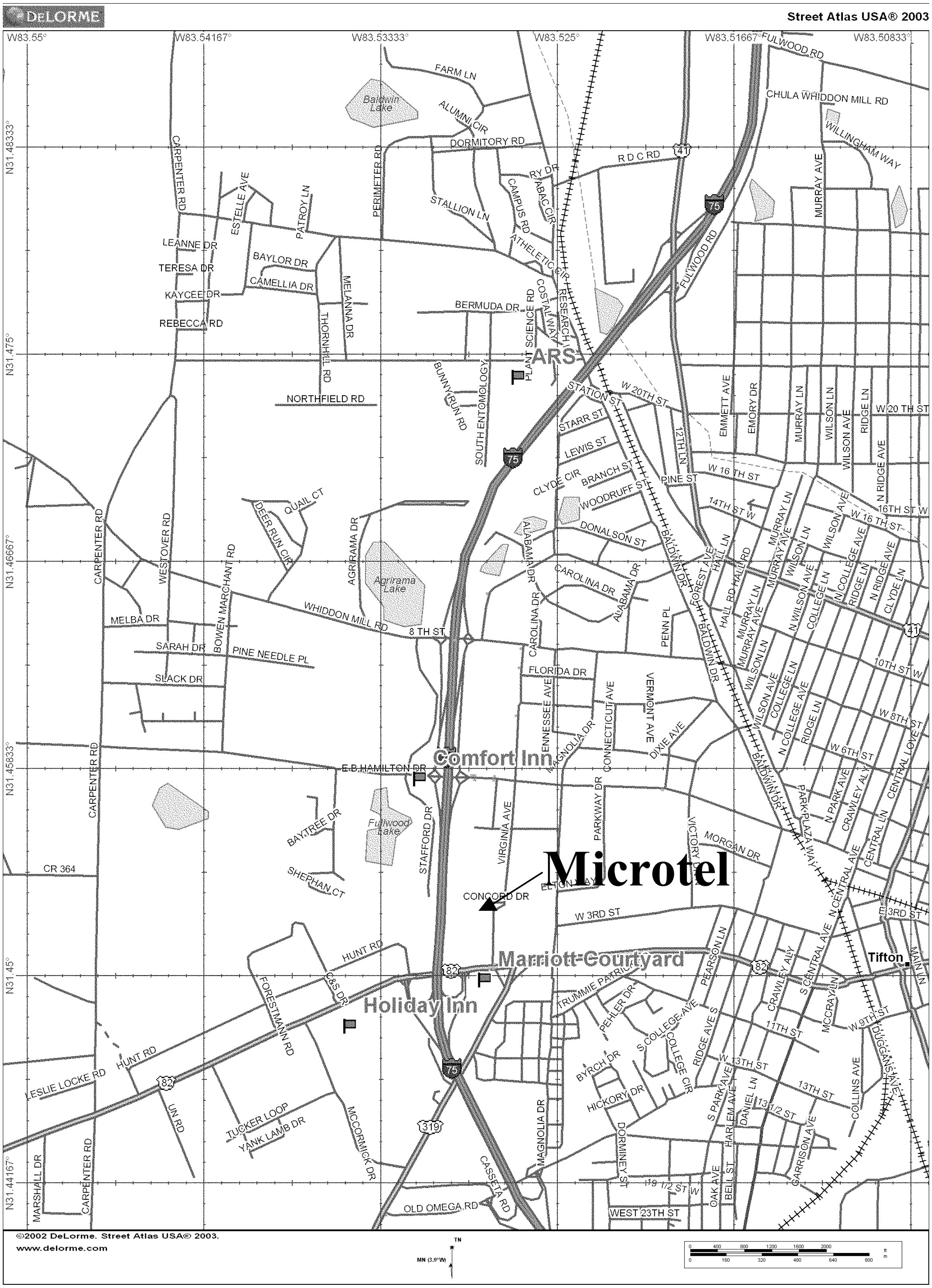
Map 2. Oklahoma City Airport Area



Map 3. Chickasha, OK.



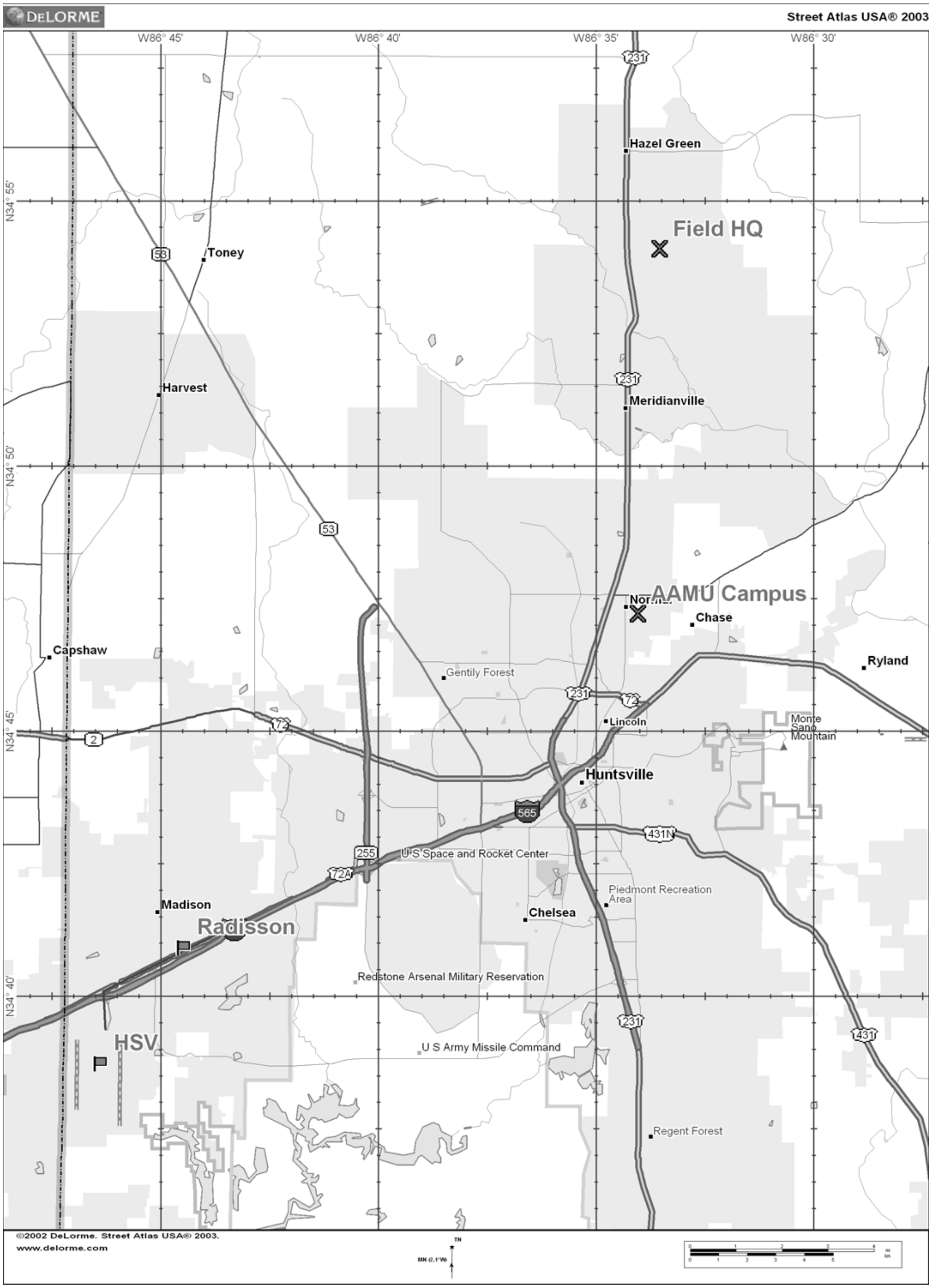
Map 4. Stillwater, OK.



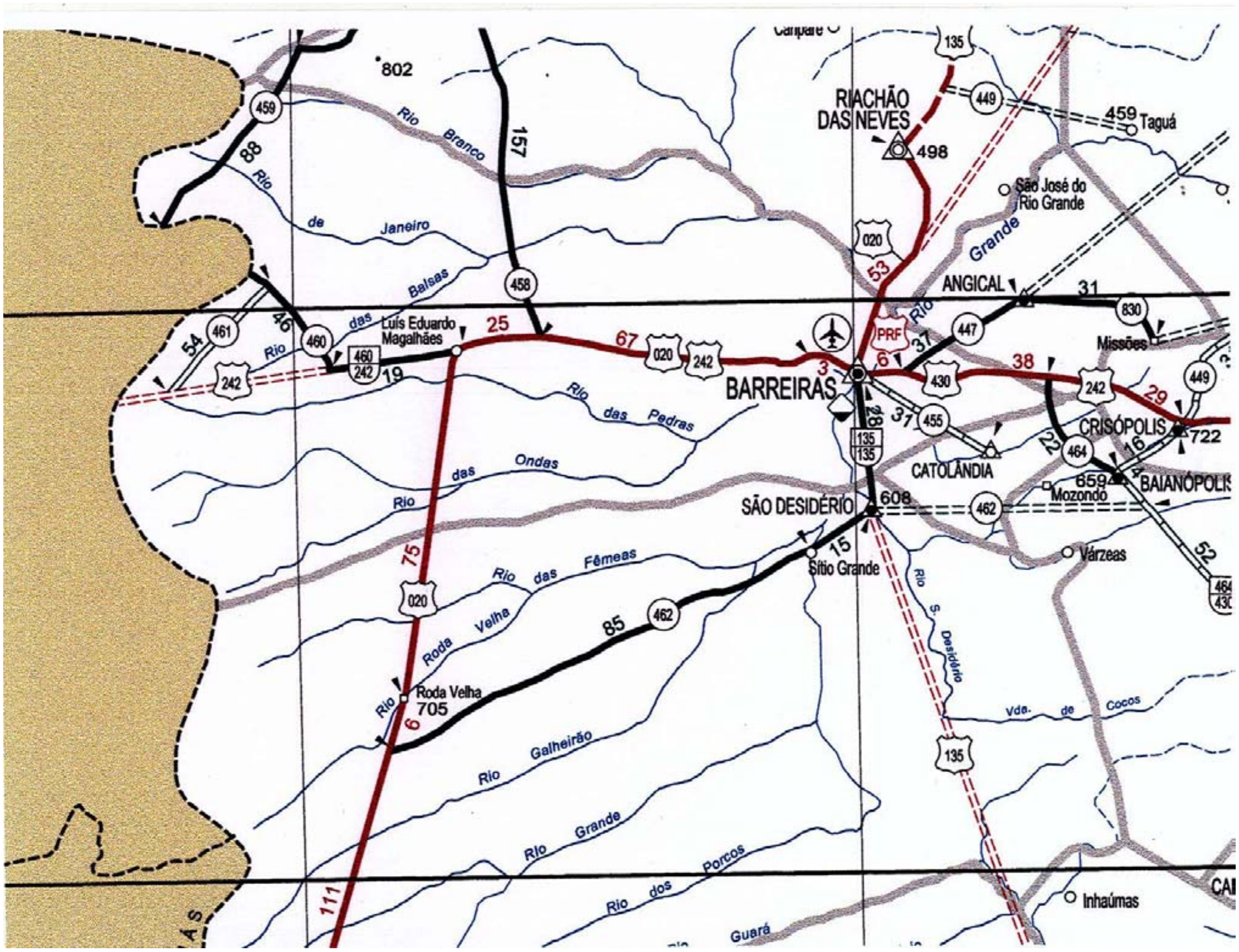
Map 5. Tifton, GA Area.

Map 6. Tifton, GA ARS Office.

Map 7. Huntsville, AL Airport Area



Map 8. Locations in the Huntsville, AL Area



Map 9. Barreiras, Brazil Map