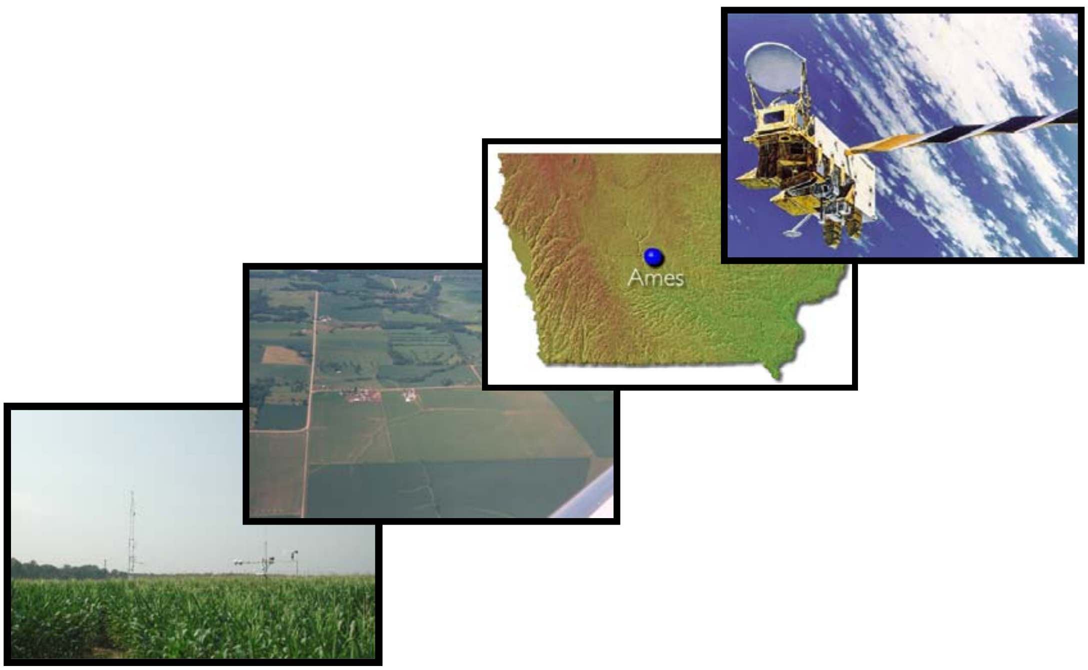
SOIL MOISTURE EXPERIMENTS IN 2002 (SMEX02)



Summary of Experiment Plan

Version April 22, 2002

1 OVERVIEW AND SCIENTIFIC OBJECTIVES

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.

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 (EX-4a), 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 SMEX02 experiment plan.

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 2002, a field experiment is proposed that would support the science needs of EX-4a, 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 Iowa during the summer of 2002.

This report is a summary of the full SMEX02 experiment plan.

2 SMACEX-Soil Moisture Atmosphere Coupling EXperiment

A number of field experiments in the past, including SGP97 and SGP99, have been designed to investigate land surface-atmosphere coupling and the role of remote sensing in Land Atmosphere Transfer Schemes (LATS). However, in these studies, methodologies for upscaling and aggregation have not been adequately developed, implemented and tested because the necessary measurements, models and other tools to perform these tasks either have not existed and/or have not merged in the necessary way. Moreover data quality depends to a degree on the conditions encountered in a particular experiment. Hence building a diverse knowledge base needed to understand the complex interaction of the land surface and atmosphere requires a continued effort in collecting the necessary field observations over different land cover types and climatic conditions. An integral part of SMEX02 is an experiment designed to address these concerns. The SMACEX project is designed to collect atmospheric and remote sensing data over a range of spatial and temporal scales necessary to investigate local and regional scale impacts of landscape heterogeneity on water and energy exchanges.

SMACEX will address several timely research foci in the area of water and energy cycling across the land-atmosphere interface (see below). With additional support for flying time and data processing, the Twin-Otter can collect surface-layer and atmospheric boundary-layer (ABL) flux data. Support for two other remote sensing activities, namely aircraft-based high resolution optical remote sensing data and ground-based Lidar observations of wind and water vapor concentrations in the ABL, will provide simultaneous landscape and atmospheric properties covering a wide range of temporal and spatial scales. Combining these observations together with a network of 15-20 tower-based flux observations will result in a complete set of distributed surface and atmospheric data, allowing for LATS and Large Eddy Simulation (LES) model validation and development and testing of methodologies to bridge the scales from local to regional. A schematic diagram summarizing the measurement and modeling activities (experimental logistics) proposed for the project and the overall framework addressing up-scaling issues is given in Figure 1. This figure also illustrates the interdependency of the proposed activities and that all components of the project are required in order to achieve proposal goals and objectives.

The expected advances with the coupled measurement and modeling program will address one of NASA's core missions of seeking to rigorously bridge between remotely sensed data and operational forecast models, including advances in operational data assimilation schemes.

The overall objective of this work is to use a direct-measurement/remote sensing/modeling approach to understand how horizontal heterogeneities in vegetation cover, soil moisture and other land-surface variables influence the exchange of moisture and heat with the atmosphere.

The field observations will support the analysis of heterogeneities ranging from within field or patch to the regional scales that are commensurate with prediction models of weather and climate. The unique in-situ and aircraft measurements of atmospheric and soil variables and fluxes to be provided in the SMACEX data set are of primary importance. They will be used both to validate fluxes *diagnosed* using remote sensing methods at various scales, and in evaluating results from the LES-remote sensing model that will be used to develop horizontal scaling relationships. The experimental approach is thus also an "up-scaling" endeavor, investigating how remote sensing data at different horizontal and temporal scales may be utilized for both diagnosis and prediction of the surface energy exchanges from patch to regional scales. In particular, we focus on the effects of observation and model scale on the importance and effectiveness of assimilation techniques.

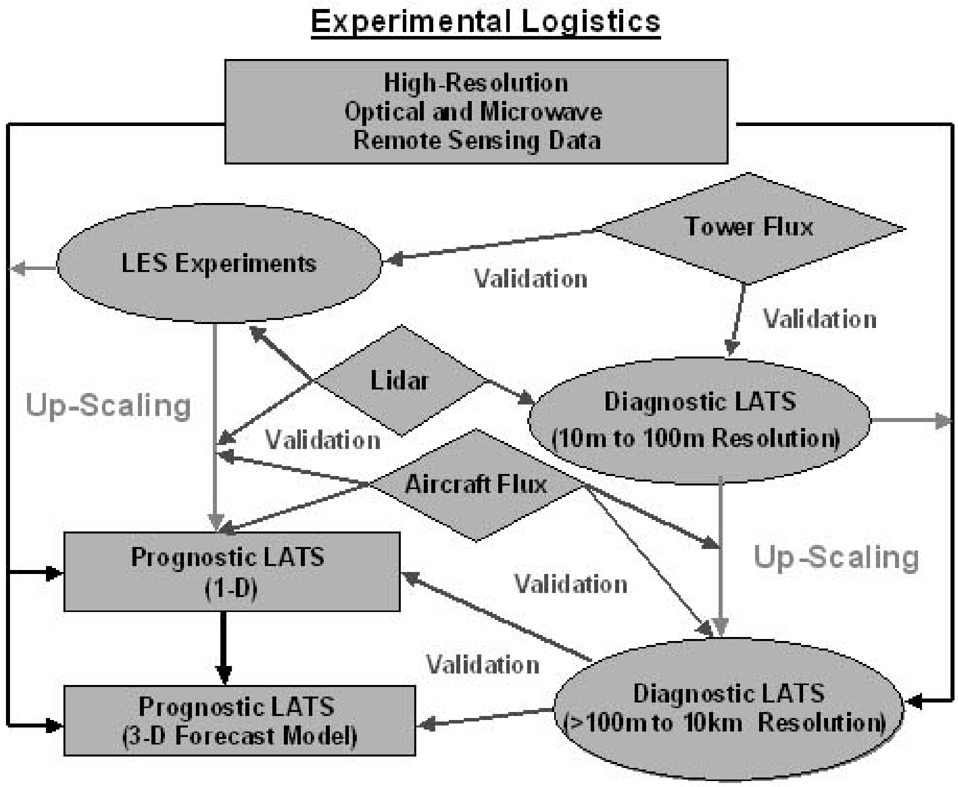


Figure 1. Schematic summarizing measurement and modeling activities and their interrelationships. Validation (blue arrows) of both the high resolution (10 to 100 m) output from LATS and LES remote sensing models is performed with the flux towers and Lidar data, while up-scaling techniques (red arrows) to the coarser resolutions (> 100 m to 10 km) validated with Lidar and aircraft fluxes. Validation of the prognostic LATS is achieved through validated up-scaled diagnostic LATS remote sensing models.

3 SATELLITE OBSERVING SYSTEMS

A key element of SMEX02 is the development and validation of soil moisture products from the Aqua Advanced Microwave Scanning Radiometer (AMSR). Other satellite data will also be important in the investigations. These include passive microwave observations from the SSM/I, microwave radar from Radarsat, ERS-2, Quikscat, and Envisat, and visible and infrared observations from Landsat, NOAA AVHRR, Terra ASTER and MODIS, and GOES. Some details on AMSR are provided below. Landsat data are of particular importance in developing the vegetation and land cover information for a variety of SMEX02 studies. Therefore, a summary of the potential data is also presented.

3.1 Aqua Advanced Microwave Scanning Radiometer (AMSR-E)

Two versions of the AMSR instrument will be launched in 2002/2003 on the Aqua (AMSR-E) (http://wwwghcc.msfc.nasa.gov/AMSR/) and ADEOS-II platforms (http://adeos2.hq.nasda.go.jp/default_e.htm). The NASA EOS Aqua platform (http://eos-pm.gsfc.nasa.gov/) is scheduled for launch in May 2002. A picture of Aqua is shown on the cover of this plan. If the launches of these satellites proceed as scheduled, it is likely that AMSR data will be available for SMEX02. SMEX02 is designed to support AMSR related algorithm development and validation; however, the experiment has a broad set of objectives.

Low frequencies provide the best information for soil moisture retrieval. As shown in Table 1, the lowest frequency of AMSR is 6.9 GHz (C band). The viewing angle will be 55^o. Details on AMSR can be found at http://wwwghcc.msfc.nasa.gov/AMSR/. 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. Based on the results of SMMR and supporting theory 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.

Table 1. AMSR-E Characteristics (Aqua)

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

3.2 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 Iowa site is located in an overlapping area of scenes on paths 26 and 27. It id mostly in row 31. For path 27 the northern portion is not well covered, however, the Walnut Creek area is included. It may be necessary to acquire row 30 for complete coverage. At the present time coverage by both the Landsat 5 and 7 satellites results in frequent temporal coverage. Coverage dates are listed in Table 2 and shown in Figure 2.

Table 2. SMEX02 Potential Landsat Coverage

Date	Landsat No.	Path
June 14	5	27
June 15	7	26
June 22	7	27
June 23	5	26
June 30	5	27
July 1	7	26
July 8	7	27
July 9	5	26
July 16	5	27
July 17	7	26

4 AIRCRAFT REMOTE SENSING INSTRUMENTS

Aircraft remote sensing will include visible, infrared, and microwave instruments. Visible and infrared measurements will be provided by the Utah State University aircraft over the watershed area. A total of four different aircraft microwave instruments may contribute to SMEX02. Two of these instruments are very important to the broad objectives of the experiment: PALS and PSR, which are described below. It is also anticipated that a new L band two dimensional synthetic aperture radiometer (2DSTAR) will participate in SMEX02. A GPS reflectometer will also be part of the instrument. The potential of this approach to soil moisture sensing will also be explored.

4.1 Polarimetric Scanning Radiometer (PSR)

The PSR is an airborne microwave imaging radiometer operated by the NOAA Environmental Technology Laboratory for the purpose of obtaining polarimetric microwave emission. It has been successfully used in several major experiments including SGP99. During SMEX02, 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. The PSR/CX scanhead will have the polarimetric channels listed in Table 3 for SMEX02. The system will be operated in two imaging modes, both using conical scanning. Mapping characteristics are described in Table 4. Additional details on the PSR not presented here can be found at http://www1.etl.noaa.gov/radiom/psr/.

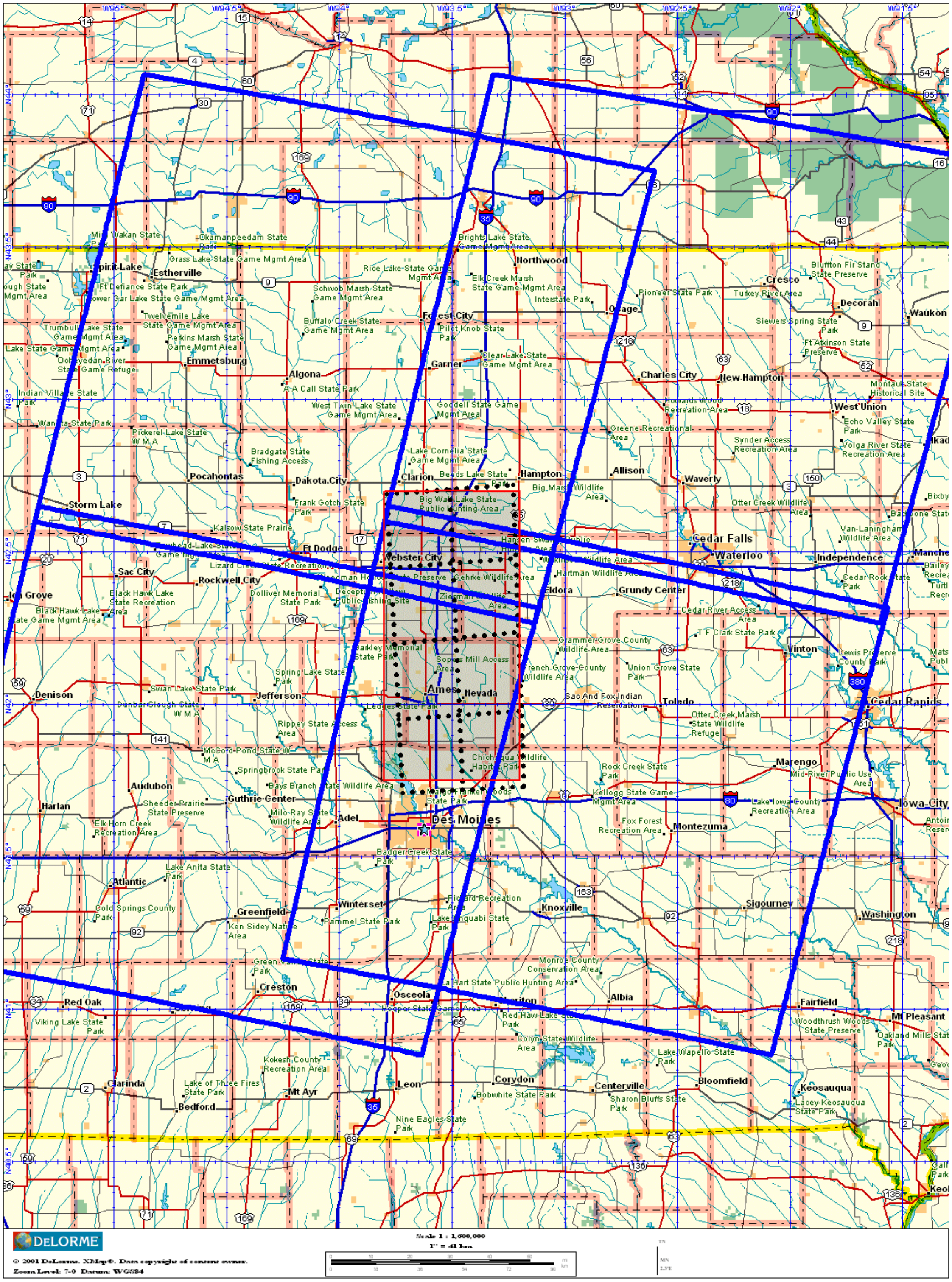


Figure 2. Map showing the SMEX02 region and Landsat TM frame coverage. Blue lines are Landsat scenes, gray area is the SMEX02 region and green lines are Ease Grids.

Table 3. PSR/CX Channels for SMEX02		
Frequency (GHz)	Polarizations	Beamwidth
5.82-6.15	V,h	10o
6.32-6.65	V,h	10o
6.75-7.10 *	v,h,U,V	10o
7.15-7.50	V,h	10o
10.6-10.8 *	v,h,U,V	7o
10.68-10.70 *	V,h	7o
9.6-11.5 um IR	V+h	7o

* Similar to AMSR-E channel.

Table 4. PSR Flightline and Mapping Specifications for SMEX02		
	Wide Area Imaging	High-Resolution Imaging
Location	Iowa Region	Walnut Creek Watershed Site
Altitude (AGL) in m	7300	1800
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

4.2 Passive and Active L and S Band Microwave Instrument (PALS)

In order to evaluate the potential of alternative approaches to soil moisture retrieval, a new L and S band integrated passive/active instrument has been developed (http://eis.jpl.nasa.gov/msh/mission+exp/pals.html). PALS provides single beam observations at L and S bands, dual polarized, passive and active simultaneously. Additional details are described in Table 5. This instrument offers many interesting opportunities for algorithm development and evaluation that have not been available; dual polarization, off nadir viewing typical of conical scanning systems, multifrequency, and both active and passive observations. From these observations we hope to obtain a better understanding of the frequency and polarization characteristics of land surfaces in the L to C-band range, leading to potential improvements in future spaceborne system designs and retrieval algorithms. The PALS instrument was flown successfully in SGP99. PALS will be flown at low altitudes over the Walnut Creek watershed flightlines.

Table 5. Description of the JPL PALS Instrument		
Parameter	Radiometer	Radar
Frequencies	1.41 and 2.69 GHz	1.26 and 3.15 GHz
Polarization	V and H	VV, VH, HH
Spatial resolution (@ 1000 m alt)	400 m	400 m

4.3 Two Dimensional Synthetic Aperture Instrument (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). 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. The 2DSTAR instrument has been designed to operate from an aircraft (the NASA P-3) in a nadir looking orientation. 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.

2DSTAR is still under development. It is anticipated that it will be ready for SMEX02, in fact SMEX02 will be its first deployment. There is an option of flying the ESTAR if 2DSTAR is not considered to be ready for the mission. ESTAR has been very successful in previous missions and will be performance checked this Spring.

5 REMOTE SENSING AIRCRAFT MISSION DESIGN

The PSR and 2DSTAR instruments will be installed on the NASA WFC P3-B aircraft. PALS will be installed on a C-130 aircraft operated by NCAR (http://raf.atd.ucar.edu/). A GPS instrument will be part of the C-130 instrumentation and there may also be one on the P3-B. 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 SMEX02. Unlike recent experiments, low altitude flightlines will be emphasized. The following sections summarize some elements of the flight missions of aircraft that will take part in SMEX02.

5.1 NCAR C-130

The primary mission of the C-130 is to fly low altitude flightlines over the Walnut Creek Watershed area with the PALS instrument. The mission design is similar to SGP99. It will utilize a series of basically East-West lines. These are 800 m apart and offset from the road network by 400 m. Roads are approximately on a square 1600 m grid. With a nominal field size of 800 m and sensor footprint size of 400 m, this procedure provides a reliable sample for the study sites and allows interpolation for mapping.

The flightlines are shown in Figure 3. In past experiments, these types of lines have been flown sequentially in alternating East-West directions. Flights will be conducted in the morning. Each flight will be approximately 2.5 hours in duration. It is anticipated that nine flights will be conducted. The aircraft is expected to arrive in Des Moines on Fri. June 21 and be based out of DMS airport. It is scheduled to depart on July 7.

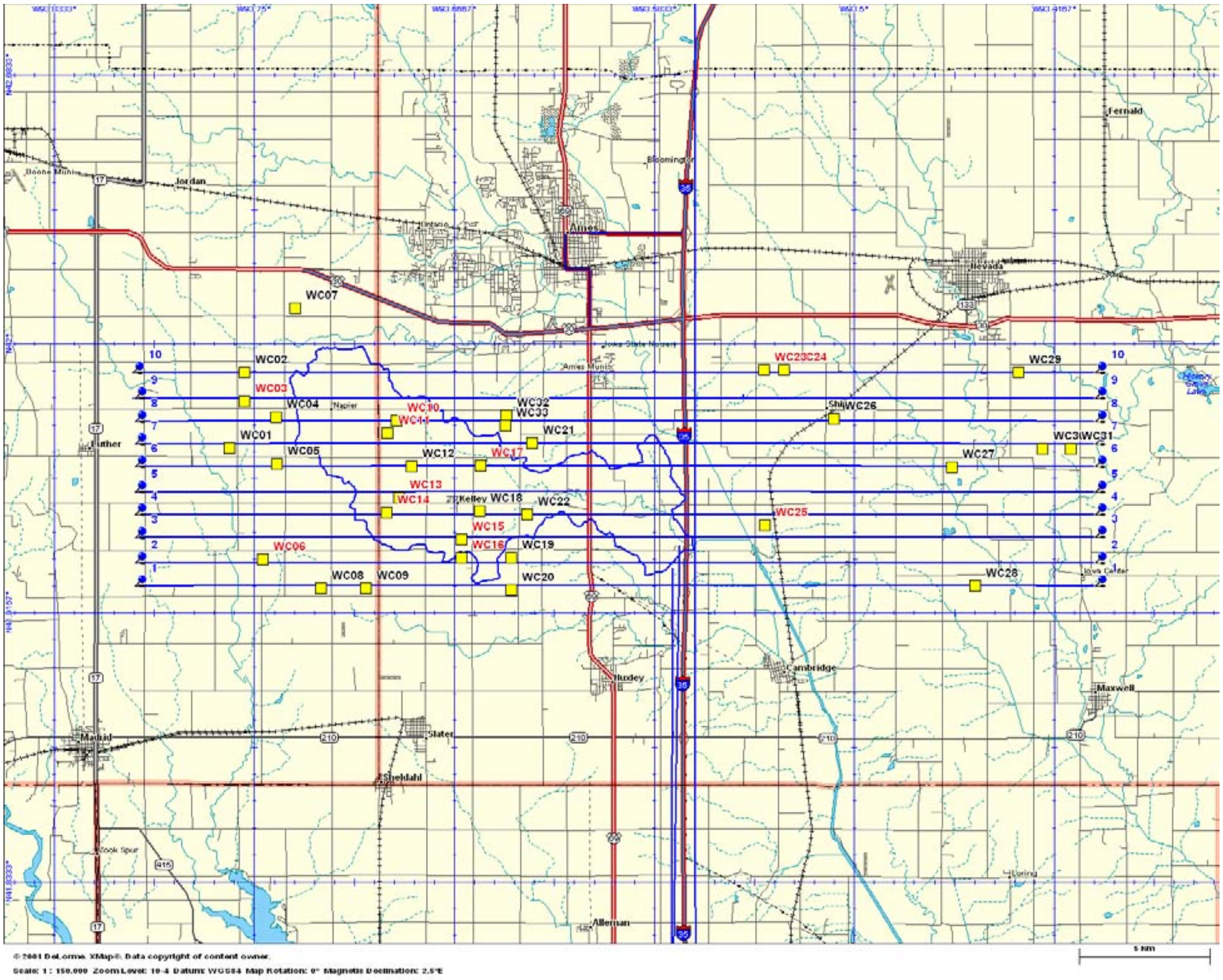


Figure 3. SMEX02 Walnut Creek watershed area and microwave aircraft flightlines. Blue lines are the low altitude microwave flightlines; yellow squares indicate intensive soil moisture sampling sites (those with red text are also flux tower sites).

5.2 NASA P-3B

The primary mission of the P3-B is to collect both low and high altitude data over the Iowa study region with the PSR instrument. Another very important objective is to collect data with the 2DSTAR over the region.

High altitude mapping flightlines are plotted in Figure 4. High altitude lines will provide coverage of an area that is approximately 40 km wide (East-West) and 95 km long (North-South). The low altitude and water calibration lines will be a subset of the C-130 lines. The PSR and 2DSAR are mapping instruments and require fewer flightlines for covering the watershed area.

Flights will be conducted during the mid day in order to match the nominal Aqua overpass time of 1330. Each flight will be approximately 2.5 hours in duration. It is anticipated that eleven high altitude flights will be conducted. The aircraft is expected to arrive in Des Moines on Mon. June 24 and be based out of DMS airport. It is scheduled to depart on July 12.

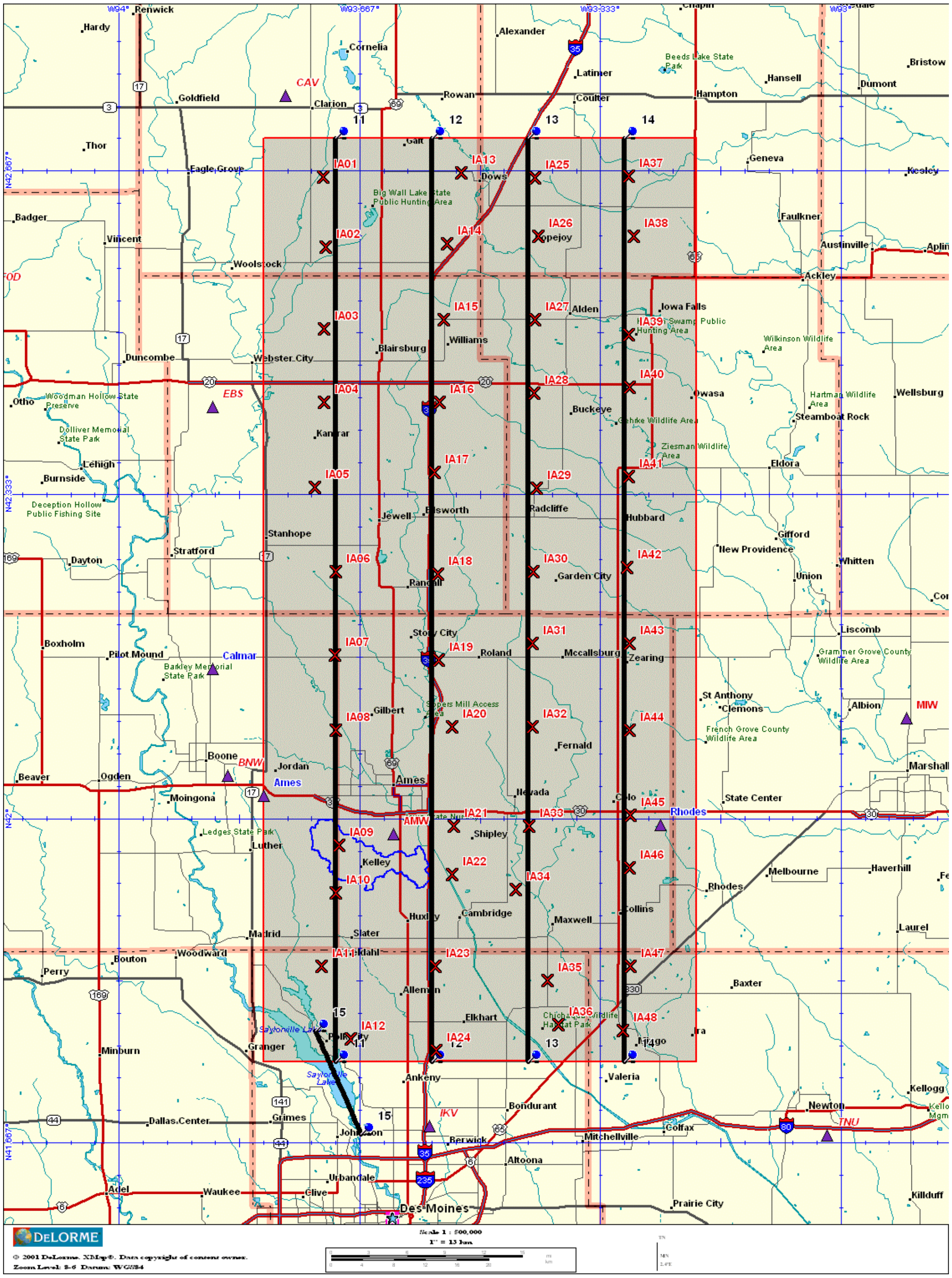


Figure 4. SMEX02 regional flightlines and mapping area. Regional mapping flightlines are indicated in black, regional soil moisture sites are shown as a red X. Triangles indicate various meteorological stations in the area.

5.3 Canadian Twin Otter

The Twin-Otter aircraft operated by personnel from the National Research Council of Canada will be available for making aircraft-based flux observations over several transects surrounding the watershed. Surface layer flux measurements (~30 m agl) will be conducted using an east-west transect starting west of the watershed and ending west of the interstate (Figure 5). The frequency and timing of the flux-aircraft observations will be subject to the flying schedule for the microwave observations. Ideally, flights in the mid-morning (~1030 local time), around the time of EOS Terra and Landsat 7 overpasses, would be the most useful. Mid-morning is also the typical time for the ALEXI output and when the frequency of clouds via boundary layer convective activity is minor. With length of the flight transects ~ 20 km and flying at ~30 m agl, transect-average fluxes represent aggregated values of length scales ~ 10 km. However, sub-sampling transects for comparisons with tower-based observations has also been successful.

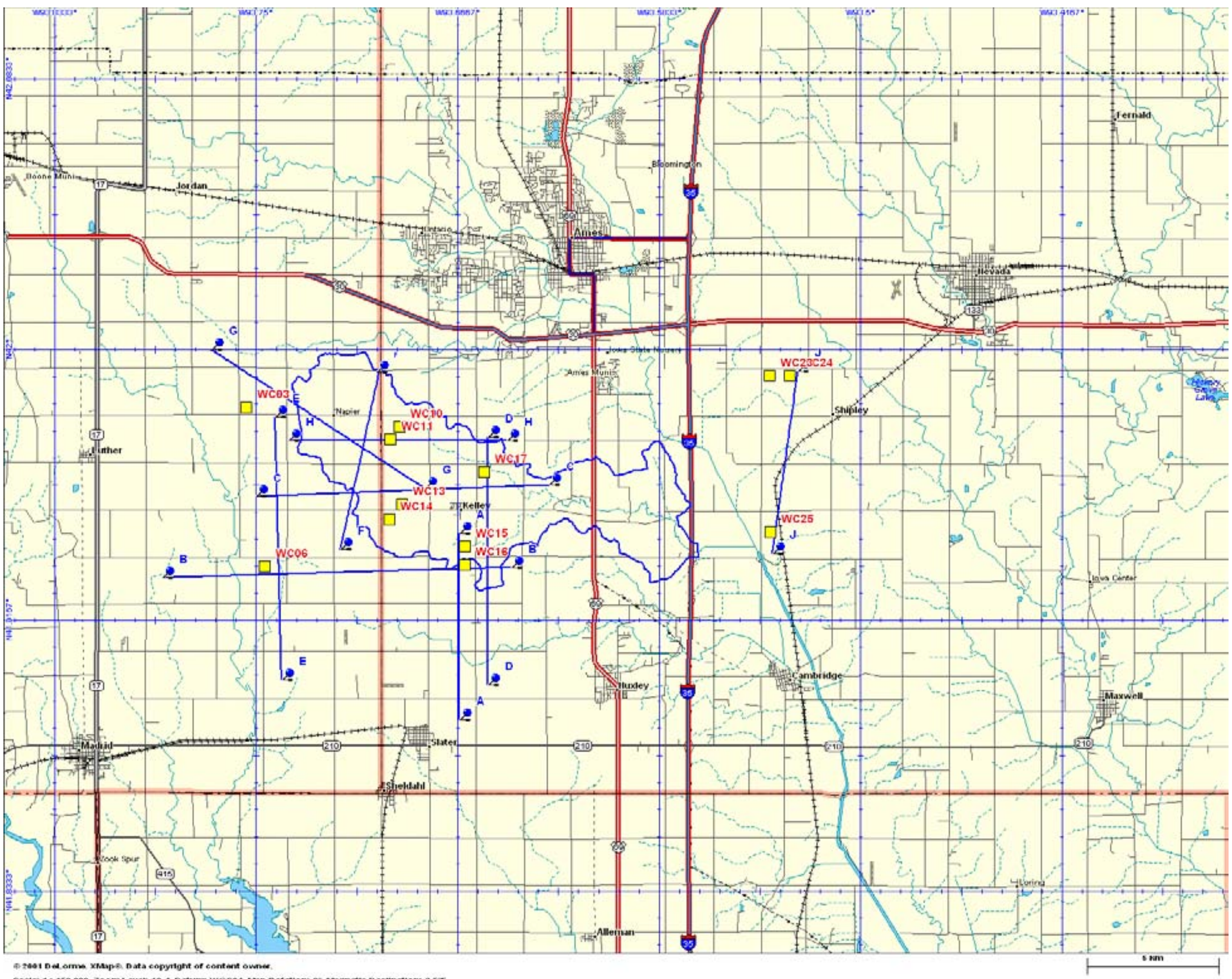


Figure 5. Twin Otter flightlines for SMEX02. Aircraft flux lines are in blue with letter codes. The yellow squares indicate sites with flux towers.

5.4 Utah State University Piper Seneca

Christopher Neale from Utah State University will design flight tracks for his airborne digital system and coordinate missions with NCAR C-130 NASA WFC P3-B and Twin Otter teams. Mapping of the watershed and the area covered by the PALS sensor will be planned. Short-wave imagery will be acquired over the study area from 3200 meters above ground level, using Nikon 20 mm lenses, resulting in a pixel size of approximately 1.5 meters. Each image consists of approximately 2000 x 2000 pixels, so the resulting swath will be 3.0 km. The flightlines will be pre-planned to cover the entire study area, with a side overlap of 30% between imagery. Along each flightline, the images will be acquired with a 60% overlap to facilitate the mosaicing of the imagery during post-processing. The pixel resolution of the optical data will be significantly higher (~ 1.5 m pixel size) than the microwave data from the PALS (~500 m pixel size).

6 IOWA STUDY REGION

In order to satisfy the requirements of the diverse research projects making up SMEX02 it was necessary to include a test site that would provide a data set for the development and verification of alternative soil moisture retrieval algorithms under significant biomass levels associated with agricultural crops and satisfy the land atmosphere investigations described in other sections. It is essential that multi-parameter microwave observations be obtained over a range of soil moisture conditions with moderate to high vegetation biomass conditions. A study site in Iowa was selected. Within this region, is a small watershed, Walnut Creek just south of Ames, IA This watershed has been the focus of research by the USDA ARS National Soil Tilth Lab (NSTL) http://www.nstl.gov/.

Nearly 95% of the region and watershed is used for row crop agriculture. Corn and soybean are grown on approximately 80% of the row crop acreage, with greater than 50% in corn, 40-45% in soybean and the remaining 5-10% in forage and grains. The watershed is representative of the Des Moines Lobe, which covers approximately 1/4 of the state of Iowa. The climate is humid; with an average annual rainfall of 835 mm. SMEX02 is tentatively planned from mid June through mid-July. At the outset corn will be in early stages of growth and most soybean fields will be essentially bare soil. By the end of June in a typical growing season, corn biomass is expected to range between 3 and 4 kg m^{-2}, while soybean will have a biomass of less than 1 kg m^{-2}. This translates to leaf-area index (LAI) values on the order of 2 and 0.5 and fractional canopy cover about 0.75 and 0.5 respectively, for corn and soybean.

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

Two different sets of sampling sites will be used in SMEX02, Walnut Creek watershed (WC) and Iowa regional (IA). The WC sites shown in Figures 3 and 5 were selected to satisfy the data requirement of the PALS and surface/aircraft flux components of the experiment. Regional IA sites were selected to provide representative coverage over an area large enough to include several AMSR sized footprints. These are shown in Figure 4.

7 GROUND BASED OBSERVATIONS

- Tower-based Flux Measurements
- Lidar/Sodar/Radisonde Measurements
- Sun Photometer
- Vegetation and Land Cover
- Soil Moisture
- Soil and Surface Temperature
- Surface Roughness
- Ground Based Microwave Radiometer

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

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

8 GROUND BASED OBSERVATIONS

8.1 Tower-based Flux Measurements

Through this project and collaborative relationships a number of eddy covariance systems will be deployed through the study area, with each system consisting primarily of Campbell Scientific CSAT3 3-D sonic anemometer and KH20 krypton hygrometer, measuring momentum flux and sensible and latent heat fluxes between the land and the atmosphere across the watershed. These observations will be representative at the “patch” or local scale (i.e., length scales ~ 10^2 m). Investigators from USDA-ARS, Utah State University, University of Virginia, University of Iowa, and Texas A&M will be involved. These systems will also have a picture of the complete energy balance by including net radiation, soil heat flux, and radiometric surface temperature measurements. There is also an effort planned by NSTL and Iowa State University scientists to make detailed soil heat flux measurements at several locations within the watershed at varying landscape positions to assess within canopy scale variability. In addition, there will be several systems, which will also be measuring net carbon exchange by eddy covariance with the 3D sonic and LiCor LI-7500 open path CO_2/H_20 sensors. This will permit a very detailed assessment of water-energy-carbon fluxes and controls as a function of crop type and amount of cover and tillage practices. For selected sites with a significant fractional bare soil component, there are also plans to make measurements of soil respiration using LiCor LI-6200 sensors. The sites selected for the towers are shown in Figure 5. Details on the flux tower measurements are provided in the full experiment plan..

8.2 Lidar/Sodar/Radisonde Measurements

Several ground-based atmospheric sensing systems are proposed for deployment for investigating the role of land surface heterogeneity on atmospheric properties and processes. The Raman scanning Lidar from Los Alamos National Lab (LANL) will provide water vapor concentration fields in the lower boundary layer, and a scanning wind Lidar from the University of Iowa (UI) will provide horizontal winds throughout the boundary layer. A scanning elastic Lidar also from UI will map winds in the area, boundary layer height, entrainment zone properties and cloud information. A sodar and radar/RASS system from LANL will be used to measure meso-synoptic scale atmospheric conditions. The Lidar measurements will be coordinated with tower-based flux measurements conducted over several fields having significant differences in roughness and and/or fractional vegetative cover due to differences in planting dates and/or planting method (i.e., drilled versus row planting). The Lidar data provide distributed water vapor and wind fields over the mapped surface temperature, moisture, and cover data. This would be the first time that such detailed data are collected simultaneously, and will provide the basis for assessing the injection of spatial heterogeneity form the land surface and into the lower atmosphere.

Radiosondes are a key element in upper air observation systems. Balloon-borne radiosondes measure upper air temperature, humidity and pressure during their ascent to the upper atmosphere. Radiosonde signals are received and processed by ground equipment, which automatically computes wind speed and direction using global navigation networks.

8.3 Sun Photometer

The NASA Aeronet, which is led by Brent Holben, will provide SMEX02 with an eight channel (Cimel) sun photometer. The sun photometer is designed to view the sun and sky at preprogrammed intervals for the retrieval of aerosol optical thickness and water vapor amounts, particle size distribution, aerosol scattering, phase function, and single scattering albedo. It measures the intensity of sunlight arriving directly from the Sun. Although some Sun photometers respond to a wide range of colors or wavelengths of sunlight, most include special filters that admit only a very narrow band of wavelengths. These measurements are used to radiometrically correct satellite imagery in the visible and infrared bands. By radiometrically correcting these images it is then possible to quantitatively extract physical parameters and compare multiple dates. The instrument will be installed at a central location to provide data appropriate for the intensive site and for the regional area studies.

8.4 Vegetation and Land Cover

Vegetation biomass and soil moisture sampling will be performed for all watershed (WC) sites. The measurements that will be made are:

- Plant height
- Ground cover
- Stand density
- Phenology
- Leaf area (LAI)
- Green and dry biomass

Non-destructive sampling of LAI using LiCor LAI-2000 instruments will be conducted. Since the experimental period is likely to be during the active growing stages for both corn and soybeans, efforts will be made to make LAI measurements several times during the study period, including at the beginning and end of the study.

8.5 Soil Moisture

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

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

8.5.1 Watershed Sampling

The goal of soil moisture sampling in the Watershed sites is to provide a reliable estimate of the mean and variance of the volumetric soil moisture of the surface soil moisture for fields that are approximately 800 m by 800 m. These measurements are used primarily to support the aircraft based microwave investigations, which will be conducted between 0900 and 1200 local time. This determines the time window for the Watershed site sampling.

The primary measurement made will be the 0-6 cm dielectric constant (voltage) at fourteen locations in each field using the Theta Probe (TP). 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 gravimetric soil moisture and bulk density sampling. At four standard locations in each site the gravimetric soil moisture (GSM) will be sampled on each day of sampling. A 0-6 cm scoop tool will be used. This GSM sample be split into

0-1 cm and 1-6 cm samples providing a rough estimate of the site average 0-1 cm GSM. GSM is converted to volumetric soil moisture (VSM) by multiplying gravimetric soil moisture and bulk density of the soil. Bulk density will be sampled one time at each of these four locations using an extraction technique. 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.

8.5.2 Regional Sampling

The goal of soil moisture sampling in the Regional sites is to provide a reliable estimate of the VSM mean and variance within a single satellite passive microwave footprint (~50 km) at the nominal time of the Aqua AMSR overpass (1330 local time). The exact center location and orientation of the satellite footprint will vary with each overpass. A grid of 48 individual sites will be sampled each day that covers a domain of approximately 50 km by 100 km (4 by 12 sites). A single location in each of these 48 sites will be sampled. As noted, these measurements are used primarily to support the Aqua AMSR based microwave investigations, therefore, the Regional sampling will be conducted between 1200 and 1500 local time.

The primary measurement made will be the 0-6 cm dielectric constant at a single location in each site using the Theta Probes described above. There are built in calibration equations, however, we will develop field specific relationships using supplemental gravimetric soil moisture and bulk density sampling. A different approach will be used for the Regional sites than the Watershed sites. Each sampling day, a coring tool will be used to extract a single VSM sample of the 0-1 cm and 1-6 cm soil layers. The composite set of VSM samples and TP dielectric constants will be used to calibrate the TP for each site.

8.5.3 *Tower Sampling*

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

Each surface flux tower will include instruments to measure the surface layer soil moisture and temperature and the surface temperature. This will be a continuous record at a single point within the field site. Cross referencing to the watershed site sampling will be done by collecting Theta Probe soil moisture, gravimetric soil moisture, soil temperature and surface temperature at a location in the vicinity of the tower each time sampling is conducted.

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

8.6 Soil and Surface Temperature

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

The surface temperature will be sampled using handheld infrared thermometers (IRT). The soil temperatures will be obtained using a temperature probe inserted to depths of 1 cm, 5 cm, and 10 cm depths.

8.6.1 Watershed Sampling

Temperature sampling will be conducted at the four locations selected for GSM sampling. These will be distributed over the each site.

8.6.2 Regional Sampling

Temperature sampling will be conducted at the specific single location selected for sampling in the site.

8.6.3 Tower Sampling

Tower sampling is intended to provide continuous measurements of the surface temperature and 2.5 cm soil temperature at the locations of the surface flux towers. The Vitel HP sensor also provides temperature at 5 cm. An Apogee infrared sensor will be installed on each tower and will provide surface observations. This device provides the measured surface temperature and the sensor housing temperature. This second observation can be used to adjust for diurnal effects. These will be installed at a height of 2 m on the tower at an angle of 30 degrees. More information can be found in the protocols section of the plan. When GSM is sampled at the towers the surface and soil temperatures will also be sampled. This effort will include the SCAN site. The temperature measurement provided by the Hydra probe is in degrees Celsius.

8.7 Surface Roughness

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

8.8 Ground Based Microwave Radiometer

The University of Tokyo in cooperation with the Japanese ADEOS-II AMSR program will deploy a ground based microwave radiometer (GBMR) at a site in the Iowa study area. This will most likely be in the watershed. A version of this instrument was part of SGP99.

The observation strategy is to leave the GBMR at a single location for the duration of SMEX02 and collect diurnal data over several adjacent fields (or plots). This location will likely be at the border of sites WC32 and WC33.

9 REGIONAL NETWORKS

9.1 USDA Soil Climate Analysis Network (SCAN) Site

A SCAN site was installed near Ames, IA at Latitude: 42.00°, Longitude: 93.74° and Elevation: 1073 Feet on 09/23/2001. This is also site WC07. 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

9.2 NSTL Meteorological Stations

NSTL operates rain gages, stream gages, and meteorological stations within the Walnut Creek watershed. All are on data loggers, which are downloaded on a weekly basis. Data for the SMEX02 time period will be provided following the experiment. Other periods of record may be obtained by contacting NSTL. Two of the rain gage sites include additional meteorological observations.

9.3 Iowa Environmental Mesonet

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

10 SCHEDULE

The proposed schedule is shown in Table 6. Note that the indicated days for flights are only a scenario and will vary with antecedent and current weather conditions.

Table 6. SMEX02 Schedule

	9-Jun	10	11	12	13	14	15
Surface Flux/Lidar		AH 8:00 am	Setup	Setup	Setup		
Ground Soil Moisture							
C-130							
P3-B		Return		Installation	Installation	Installation	Installation
Twin Otter							
USU				Arrive	Test Flights		
Satellite Data Sets						L5	L7, A
Vegetation							Set 1
	16	**17**	**18**	**19**	**20**	**21**	**22**
Surface Flux/Lidar							
Ground Soil Moisture							
C-130					**Arrive DMS**		
P3-B	Installation	Installation	Installation	Check Flight	Installation	Check Flight	Installation
Twin Otter				Arrive	Test Flights		
USU							
Satellite Data Sets							L7, A
Vegetation	Set 1	Set 1	Set 1	Set 1	Set 1	Set 1	Set 2
	23	**24**	**25**	**26**	**27**	**28**	**29**
Surface Flux/Lidar							
Ground Soil Moisture		AH 8:00 am					
C-130		AH 4:00 pm					
P3-B		AH 4:00 pm					
Twin Otter		AH 4:00 pm					
USU		AH 4:00 pm					
Satellite Data Sets	L5						ES
Vegetation	Set 2	Set 2	Set 2	Set 2	Set 2	Set 2	Set 3
	30	**1-Jul**	**2**	**3**	**4**	**5**	**6**
Surface Flux/Lidar							
Ground Soil Moisture							
C-130							
P3-B							
Twin Otter							
USU							
Satellite Data Sets	L5	L7, A	ES	ES		E2	ES
Vegetation	Set 3	Set 3	Set 3	Set 3	Set 3	Set 3	Set 4
	7	**8**	**9**	**10**	**11**	**12**	**13**
Surface Flux/Lidar							
Ground Soil Moisture							
C-130		Depart					
P3-B						Depart	
Twin Otter							
USU							
Satellite Data Sets		L7, A, ES	L5, ES				
Vegetation	Set 4	Set 4	Set 4	Set 4	Set 4	Set 4	

Key L7=Landsat 7, L5=Landsat 5, A=ASTER, E2=ERS-2 radar, ES=Envisat radar
Hatched = activity on that day

11 INVESTIGATOR PROJECTS

As noted in the introduction, SMEX02 is a combined effort of many individual investigations supported by a number of programs. Each investigator provided an abstract describing their project. The titles and investigators are summarized below; abstracts are included in the full experiment plan.

Flux Measurement and Large Eddy Simulation of Land-Atmosphere Exchange

John D. Albertson and William P. Kustas. Civil and Environmental Engineering, Duke University and USDA ARS HRSL

Operational Use of Scatterometer Data over Land to Improve Hydro-Meteorological Forecasts

Mark A. Bourassa, James J. O'Brien, David E. Weissman, Jeffrey Tongue, Tom Adams. Florida State University, Hofstra University, National Weather Service

Scaling Characteristics of Remotely Sensed Vegetation, Surface Radiometric Temperature, and Derived Surface Energy Fluxes

N. A. Brunsell and R. R. Gillies. Utah State University

Optimizing Land-Atmosphere Interaction Models For Use With Data Assimilation

Anthony Cahill. TAMU

Energy Balance and Crop Yield Studies at Walnut Creek Watershed

Paul Doraiswamy, William Kustas, Jerry Hatfield and John Prueger. USDA ARS HRSL and NSTL

Field Observations of Soil Moisture Variability from the Point to Remote Sensing Footprint Scale

Jay Famiglietti. UC Irvine

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

Albin J. Gasiewski, Aleksandre Yevgrafov, Marian Klein, and Thomas J. Jackson. NOAA Environmental Technology Laboratory, USDA-ARS HRSL

Spatial Variation of Surface Soil Water and Crop Growth across Production Scale Fields

J.L. Hatfield, J.H. Prueger, and C. Walthall. USDA ARS NSTL and HRSL

Determination of Surface Fluxes and Coupling to the ABL

Lawrence Hipps. Utah State University

Improving Hydrologic Models Performance by Better Prediction of Soil Moisture Temporal Variability

Wael Khairy, Teferi Tsegaye, Wubishet Tadesse, Tommy Coleman, Ali Sadeghi, and Gregory McCarty. AAMU and USDA ARS EQL

Calibration Of SVAT-Microwave Models And Soil Moisture Signature Scaling Behavior Under Higher Vegetation Biomass Conditions

Edward J. Kim. NASA/GSFC

Ground Based Microwave Radiometer Experiments in SMEX02

Toshio Koike) and Mahadevan Pathmathevan. The University of Tokyo

Soil Moisture-Atmosphere Coupling Experiment (SMACEX)

William P. Kustas, John D. Albertson, Nate Brunsell , Anthony T. Cahill, Daniel J. Cooper, George R. Diak, William Eichinger, Jerry L. Hatfield, Lawrence E. Hipps, J. Ian MacPherson, Christopher Neale, John M. Norman, John H. Prueger. USDA ARS HRSL

Soil Moisture Retrieval Using the PALS Sensor

Venkat Lakshmi. University of South Carolina

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

Chip Laymon, Bill Crosson, Ashutosh Limaye, Frank Archer, Global Hydrology and Climate Center

Soil Moisture Measurements Using Synthetic Aperture Radiometry

D. M. Le Vine and T. J. Jackson. NASA GSFC and USDA ARS HRSL

Relation of Soil Dielectric Properties to Soil Water Content

Sally Logsdon. USDA ARS NSTL

Aircraft Flux Program as Part of SMACEX (Soil Moisture Atmosphere Coupling EXperiment)

Ian MacPherson and Bill Kustas. National Research Council of Canada and USDA ARS HRSL

GPS Bistatic Radar in SMEX02

D. Masters, P. Axelrad, V. Zavorotny. University of Colorado, Boulder and NOAA Environmental Technology Laboratory

Evolution of Multi-Scale Soil Hydrologic Processes and its Impact on Land-Atmosphere Interaction

Binayak P. Mohanty, Douglas A. Miller, and Todd H. Skaggs. Texas A&M University, Penn USDA ARS SL

Aircraft Remote Sensing and Energy Balance Based Flux Fields

Christopher Neale. Utah State Univ

Soil Moisture Measurements Over Agricultural Fields in SMEX02 Using the Airborne Passive and Active L- and S-band Sensor (PALS)

E. Njoku, S. Dinardo, W.Wilson, S. Yueh T. Jackson, V. Lakshmi. JPL, USDA ARS HRSL, University of South Carolina

Diagnosing Surface Fluxes from Scales of Meters to Megameters Using Remote Thermal/Optical Observations

John Norman, Martha Anderson, John Mecikalski, George Diak and William Kustas. University of Wisconsin-Madison and USDA ARS HRSL

Validation Work for SSM/IS Land Surface Temperature and Soil Moisture EDRs During SMEX02

Peggy O'Neill, Manfred Owe, Tom Jackson. NASA GSFC and USDA ARS HRSL

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

Peggy O'Neill, Paul Houser, Christa Peters-Lidard, Xiwu Zhan. NASA GSFC

An Agroecosystem Water Management Model Prediction and Calibration during SMEX02

Z. Pan, R. Horton, J.H. Prueger, D.P. Todey, M. Segal, and E.S. Takle. Iowa State University, and USDA ARS NSTL

Spatial and Temporal Controls of Soil CO_2 Flux

T.B. Parkin and Z. Senwo, USDA ARS NSTL and Alabama A&M University

Turbulence Mechanisms for Heat, Water and CO_2 Exchange over Midwest Corn Soybean Fields.

J.H. Prueger, J.L. Hatfield, W.P. Kustas, and L.E. Hipps. USDA ARS NSTL and HRSL

Coupled Heat and Water Flow in Surface Soil Layers

T. J. Sauer, T. E. Ochsner, and R. Horton. USDA ARS NSTL and ISU

Characterization of Vegetation Parameters Within a Footprint Area of SMEX02

W. Tadesse, T. Coleman, T. Tsegaye, W. Khairy, and Bridget Sanghadasa. Alabama, A&M University

Integration of Depth Dependent Soil Moisture, Flux, and ESTAR Data to Better Characterize Soil Moisture Distribution under Corn and Soybean Fields

Teferi D. Tsegaye, Wael Khairy, Wubishet Tadesse, and Karnita Golson. . Alabama, A&M University

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

Teferi D. Tsegaye, Wael Khairy, Wubishet Tadesse, Karnita Golson, Yakov Pachepsky, and Binayak Mohanty. Alabama, A&M University and USDA ARS

12 LOCAL LOGISTICS

12.1 Hotels

Ames, IA

Comfort Suites
2609 Elwood Drive
Ames, IA 50010
(515) 268-8808

Ramada Inn Ames
1206 South Duff
Ames IA
515-232-3410

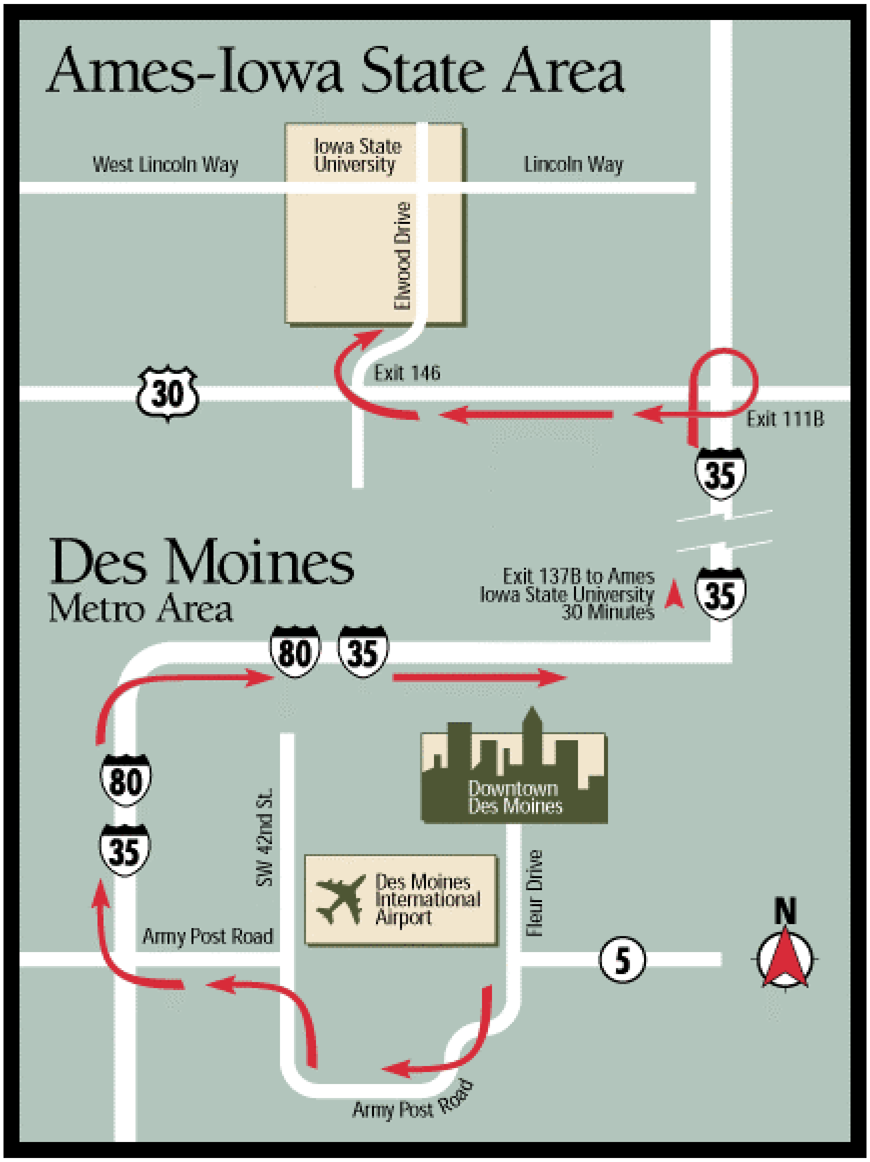
Des Moines, IA

Embassy Suites Hotel Des Moines-On The River
101 East Locust Street
Des Moines, IA 50309
515-244-1700

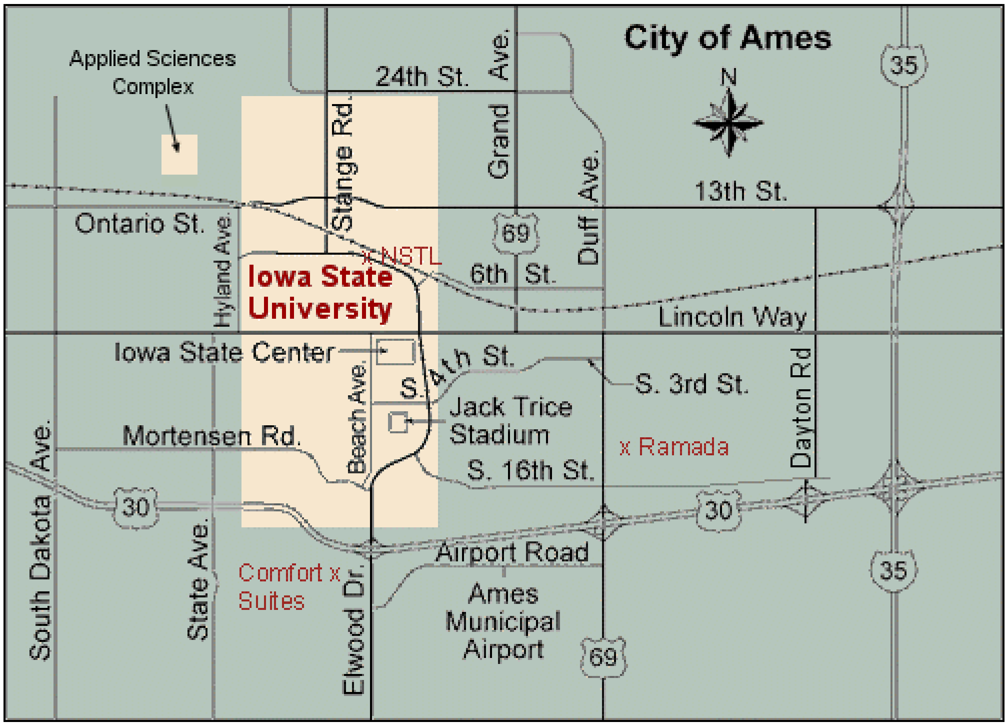
Four Points by Sheraton Des Moines Airport
1810 Army Post Road
Des Moines, Iowa 50325
(515) 287-6464

12.2 Directions

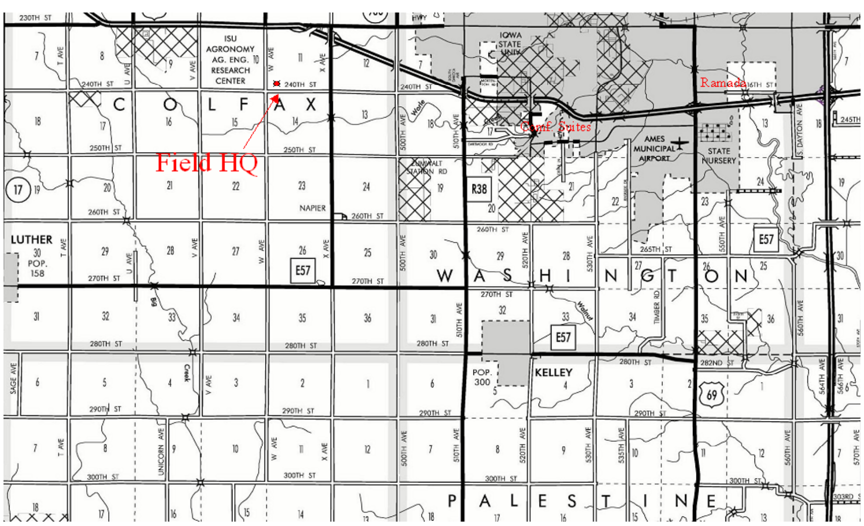
The following map indicates one way to get to Ames from Des Moines. If coming from the airport it is more efficient to head east on Army Post Rd. to Rt. 69 North. This intersects I-235 (East) and becomes I-35 N. Maps are available at the airport near baggage claim.


Ames-Iowa State Area
West Lincoln Way
Iowa State University
Lincoln Way
Elwood Drive
30
Exit 146
Exit 111B
35
Des Moines
Metro Area
Exit 137B to Ames
Iowa State University
30 Minutes
35
80
35
Downtown
Des Moines
80
35
SW 42nd St.
Des Moines
International
Airport
Fleur Drive
N
Army Post Road
5
Army Post Road

This map shows general features of the City of Ames. All hotels have an excellent street map of Ames available for free. When coming fro Des Moines, get off I-35 at Rt. 30 West and then either head North on Duff for the Ramada or South on Elwood for the Comfort Suites.



The location of the Field Headquarters for SMEX02 is an ARS building located on 240th St near W Ave.



12.3 Local Contacts

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

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(515) 294-5723	(515) 294-7694
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