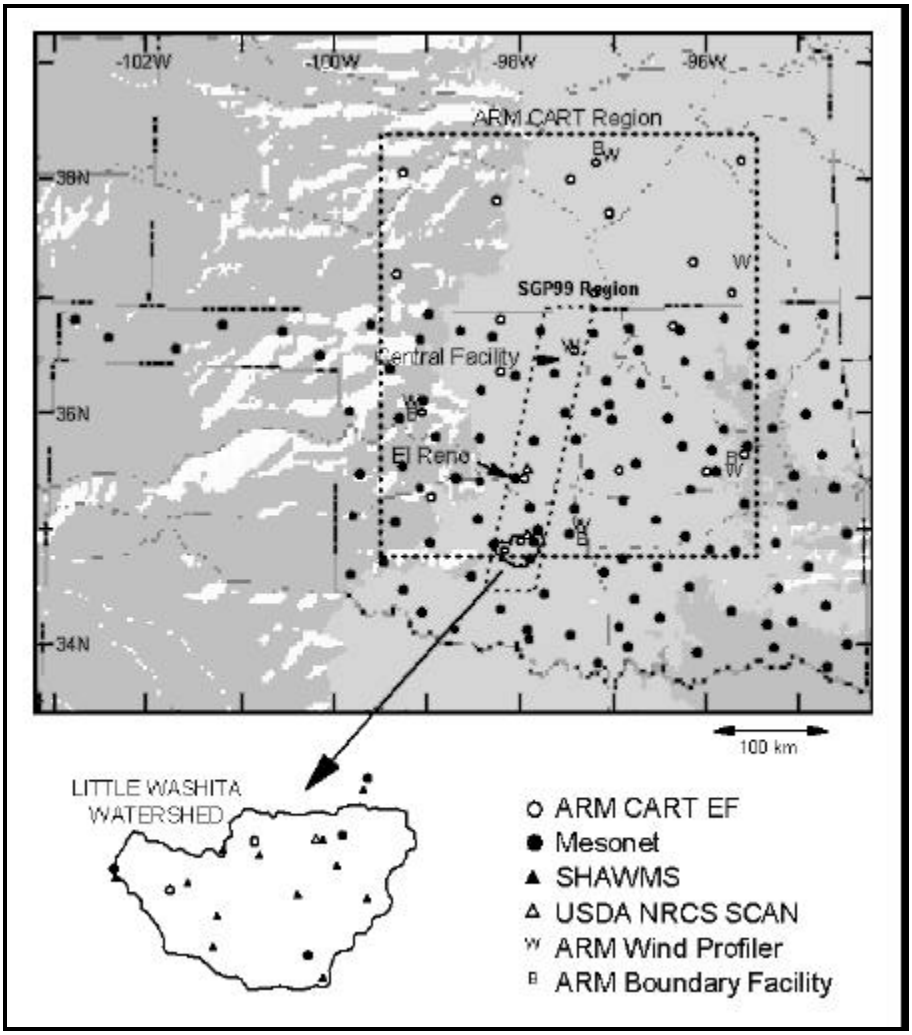
SOUTHERN GREAT PLAINS 1999 (SGP99) EXPERIMENT PLAN

July 8 –21, 1999



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SGP99 EXPERIMENT PLAN EXPERIMENT PLAN Ver. June 1, 1999

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0. EXECUTIVE SUMMARY

There are current and near future satellite observing systems that, while not ideal for soil moisture measurement, can provide information for some conditions. These systems include the Special Sensor Microwave/Imager (SSM/I), the Tropical Rainfall Monitoring Mission (TRMM) Microwave Imager (TMI), and the Advanced Microwave Scanning Radiometer (AMSR).

Of these instruments, AMSR holds the greatest promise for soil moisture. Soil moisture retrieval algorithms for AMSR have been proposed but have not been rigorously evaluated. There are few data sets available for this purpose. Considering the fact that these instruments will be launched in late 2000, this is a critical issue that needs to be addressed for both algorithm development and validation. The Southern Great Plains 1999 Experiment was developed to address this significant gap in our knowledge base. The goals of this effort are to understand how to effectively interpret and utilize satellite microwave data that are available now or will be in the near future and to explore new approaches that may enhance the ability to measure soil moisture from space.

SGP99 will involve a series of aircraft flights with a variety of C, S and L band microwave instruments. This experiment will be the first time that several of the instruments will have flown. The geographic region selected is the Southern Great Plains of the United States. This has been the focus of several previous investigations and provides an excellent test bed for evaluating new sensor systems and algorithms. Land cover conditions in the region, especially at this time of the year are favorable for C band soil moisture retrieval. Aircraft will be deployed between July 7th and July 22nd.

The experiment focuses on soil moisture and remote sensing. Extensive ground truth on soil moisture and the parameters necessary for remote sensing retrieval will be collected. In addition, surface temperature and evaporative fluxes will also be studied. In addition to the goals listed above it will also be possible to study scaling issues and hydrologic processes using the study results.

1. OVERVIEW AND SCIENTIFIC OBJECTIVES

The Southern Great Plains 1997 Hydrology Experiment (SGP97) successfully demonstrated the ability to map and monitor soil moisture using low frequency microwave radiometers (L band, 1.4 GHz). Soil moisture retrieval algorithms developed using higher resolution data were proven to be extendible to coarser resolution (Jackson et al., 1999). Figure 1 shows one sequence of soil moisture observations obtained in SGP97. The resulting data set will be the focus of a wide variety of value added scientific research in hydrology, meteorology, and climate. SGP97 also developed a substantial knowledge of the study site. Details can be found at the NASA GSFC DAAC web site http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/SGP97/sgp97.html.

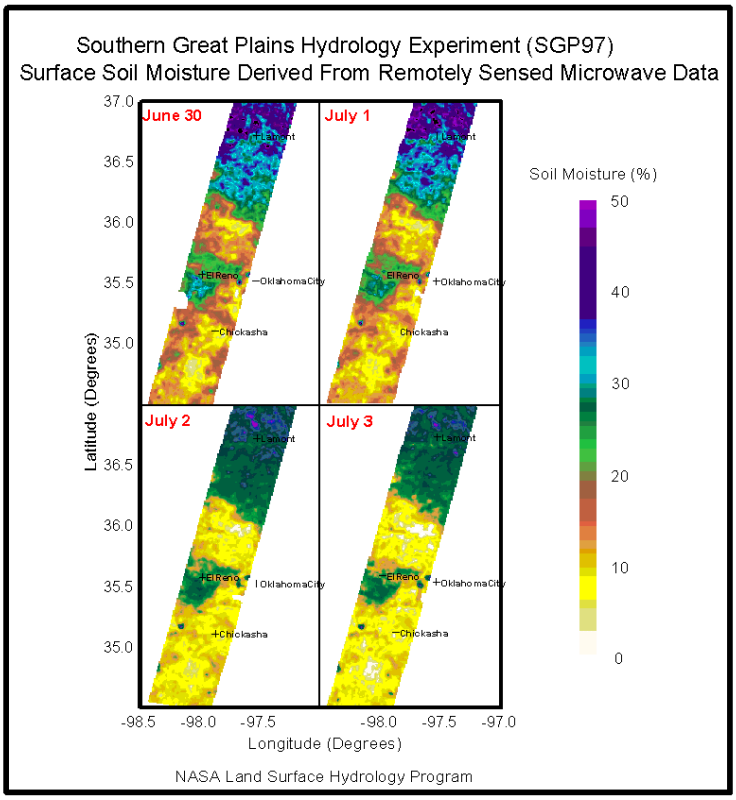

Figure 1. Soil Moisture Images from SGP97

It is well established that an L band sensor is optimal for soil moisture sensing (Jackson, 1993). There are new technologies being developed that make spaceborne systems

feasible. However, even if missions currently under consideration were selected for satellite implementation it would be several years before launch. There are current and near future satellite observing systems that, while not ideal for soil moisture measurement, can provide information for some conditions. These systems include the Special Sensor Microwave/Imager (SSM/I), the Tropical Rainfall Monitoring Mission (TRMM) Microwave Imager (TMI), and the Advanced Microwave Scanning Radiometer (AMSR).

Of these instruments, AMSR holds the greatest promise for soil moisture in regions of low levels of vegetation. Soil moisture retrieval algorithms for AMSR have been proposed but they have not been rigorously evaluated. There are few data sets available for this purpose. With the approaching launch dates of both the EOS-PM and ADEOS-II platforms in late 2000, this is a critical issue that needs to be addressed for both algorithm development and validation as soon as possible. This is the major reason for the Southern Great Plains 1999 Experiment (SGP99) described here. The goals of this effort are to:

- understand how to effectively interpret and utilize satellite microwave data that are available now or will be in the near future
- explore new approaches that may enhance the ability to measure soil moisture from space
- provide an understanding of surface temperature variability in this region for interpreting GOES, AVHRR, and TM thermal sensor observations

The first goal focuses on AMSR and the second on future L band missions. This research will involve collecting ground observations of soil moisture and related variables in conjunction with aircraft and satellite microwave sensor measurements. The geographic region selected is the Southern Great Plains of the United States. The extensive insitu observing networks shown in Figure 2 and the history and experience in this region make it ideal for the investigation. The experiment will also serve as a first step in establishing a post launch calibration/validation effort for the AMSR instruments. In addition to the goals listed above it will also be possible to study scaling issues and hydrologic processes using the study results.

Specific objectives of SGP99 are:

- verify the instrument capabilities and calibrations
- collect concurrent ground soil moisture and aircraft brightness temperature data sets
- acquire concurrent TMI and SSM/I satellite brightness temperature data
- perform regional mapping to support hydrologic and atmospheric research
- test soil moisture retrieval algorithms and identify critical issues
- conduct multi-frequency, multi-polarization, active and passive microwave data collection to support research on the optimal design of future, dedicated, satellite soil moisture sensing systems

SGP99 will form a critical component of the EOS AMSR Validation Plan, both for algorithm development pre-launch and for validation of data products post-launch.

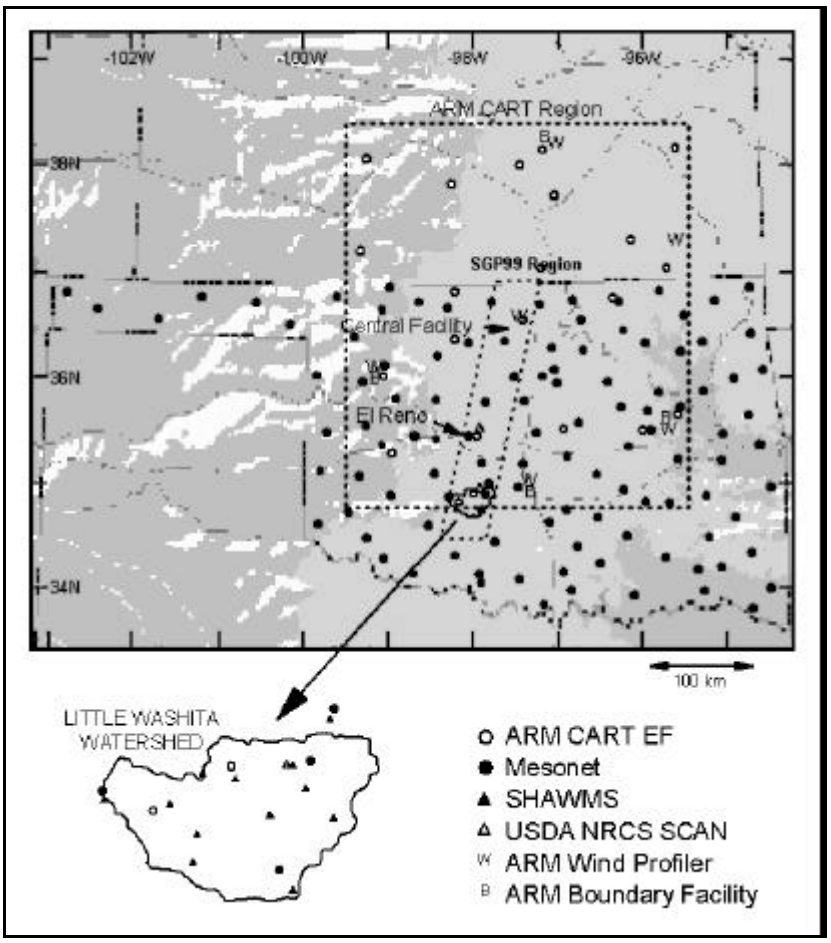

Figure 2. The SGP99 Study Region

2. SATELLITE OBSERVING SYSTEMS

2.1 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 1) were not selected for land applications (Jackson, 1997, Teng et al. 1993). The data can be used to detect flooding because of the extreme dielectric contrast of soil/vegetation and standing water (Basist et al., 1998). SSM/I data are useful in some aspects of algorithm development, serving as a prototype of the data stream that AMSR will provide. The viewing angle of the SSM/I is 53.1^{o}.

Table 1. 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

At the present time, there are three satellites with the SSM/I on board. The ascending equatorial crossing times and estimates of the local over pass times for the SGP99 region are summarized in Table 2.

Table 2. SSM/I Time of Overpasses. SSM/I Time of Overpasses			
	F11	F13	F14
Ascending Equatorial Crossing Time (UTC)	19:25	17:54	20:46
SGP Ascending Local (CDT)	14:40	13:19	15:01
SGP Descending Local (CDT)	02:10	00:39	02:31

There are several sources for SSM/I data processed in a variety of products and formats. These include the NOAA Satellite Active Archive http://www.saa.noaa.gov/ and the Global Hydrology and Climate Center http://ghrc.msfc.nasa.gov/. Data for the experiment period will be subset by the NASA GSFC DAAC.

2.2 TMI

The other current option is the TMI on the TRMM satellite. Evaluating the potential of the TMI in soil moisture estimation is a logical extension of research to date. It is a five-channel, dual-polarized, passive microwave radiometer with a viewing angle of 35° (see Table 3). It is possible that the TMI may improve our ability to estimate soil moisture data and provide us with a bridge between SSM/I and AMSR. 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). TRMM only provides coverage of the tropics. Fortunately, the SGP region falls in its domain and at the latitude of the SGP region it is possible to obtain coverage every day. The anticipated coverage during the SGP99 experiment is summarized in Table 4. 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. A subset of the TMI data will be included in the SGP99 NASA GSFC DAAC site.

Table 3. TMI Characteristics			
Frequency (GHz)	Polarization	Horizontal Resolution(km)	Swath (km)
10.7	V, H	38.3	790
19.4	V, H	18.4	790
21.3	H	16.5	790
37	V, H	9.7	790
85.5	V, H	4.4	790

2.3 AMSR

Two versions of the AMSR instrument will be launched in the 2000-2001 time frame on the EOS-PM (AMSR-E) and ADEOS-II platforms. AMSR is not the optimal solution to mapping soil moisture but it is the best possibility in the near term. As shown in Table 5, the lowest frequency is 6.9 GHz (C band). The viewing angle will be 55°. Based on the results of SMMR and supporting theory (Wang, 1985, Choudhury et al., 1988, Owe et al., 1992, 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/m2 vegetation water content. This is the typical condition for most of the year in the SGP region.

There are very few data sets that have been obtained that include the low frequencies of the TMI and 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/. However, when it was clear that L band was superior these higher frequencies were de-emphasized.

2.4 Landsat TM

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. Georegistered images are used georegister data from other satellites. Additional details on the Landsat program and data can be found at http://geo.arc.nasa.gov/sge/landsat/landsat.html. At the present time the Landsat 5 satellite is available and will collect data over the SGP99 region on June 30th, July 15th, and July 31st. The path and row scene 28/35 covers the northern portion of the region and 28/36 the south. It is also possible that the recently launched Landsat 7 may be in operation by the time of SGP99. Note that data from these satellites must be obtained by individual research groups.

Table 4. TMI Coverage During SGP99			
Orbit	Direction	Date	Time (UTC)
9270	Northbound	7/8/99	17:49
9271	Southbound	7/8/99	19:25
9285	Northbound	7/9/99	16:36
9286	Southbound	7/9/99	18:13
9301	Northbound	7/10/99	17:00
9302	Southbound	7/10/99	18:37
9316	Northbound	7/11/99	15:48
9317	Southbound	7/11/99	17:24
9332	Northbound	7/12/99	16:12
9333	Southbound	7/12/99	17:48
9347	Northbound	7/13/99	14:59
9348	Southbound	7/13/99	16:36
9363	Northbound	7/14/99	15:23
9378	Northbound	7/15/99	14:11
9379	Southbound	7/15/99	15:47
9394	Southbound	7/16/99	14:35
9409	Northbound	7/17/99	13:23
9410	Southbound	7/17/99	14:59
9424	Northbound	7/18/99	12:10
9425	Southbound	7/18/99	13:47
9440	Northbound	7/19/99	12:34
9441	Southbound	7/19/99	14:11
9455	Northbound	7/20/99	11:22
9456	Southbound	7/20/99	12:58
9471	Northbound	7/21/99	11:46
Data selection based upon path center within 200 km of 35N and -97.5W			

Table 5. AMSR Characteristics (EOS-PM)			
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

2.5 Advanced Very High Resolution Radiometer (AVHRR)

This is a TIROS-N series satellite designed to operate in a near-polar, sun-synchronous orbit. There may be two satellites in this series that are in orbit during the experiments. The NOAA-14 satellite in the ascending node (northbound Equator crossing) has a daytime pass of approximately 1340 hours local solar time. The NOAA-12 satellite in the descending node (southbound Equator crossing) has a daytime pass of approximately 0730 hours. 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/help/summary/avhrr1b.html. Data for the month of July, 1999 will be acquired by the UCAR Joint Office of Science Support through CODIAC http://www.joss.ucar.edu/cgi-bin//codiac/projs?SGP99.

2.6 Geostationary Operational Environmental Satellites (GOES)

GOES satellite provide continuous monitoring in selected visible and infrared electromagnetric channels. Of particular interest to this project is the imager. This is a multichannel instrument 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://osdacces.nesdis.noaa.gov/nesdis.htm. The NASA GSFC DAAC will provide an archive for the SGP99 time frame. Data for the month of July, 1999 will be acquired by the UCAR Joint Office of Science Support through CODIAC http://www.joss.ucar.edu/cgi-bin//codiac/projs?SGP99. Full resolution of all channels will be acquired every half hour.

2.7 European Remote Sensing Satellite (ERS-2)

ERS-2 includes a C-band synthetic aperture radar (SAR) operating at VV polarization. The instrument has a fixed incidence angle of 23°. The satellite also has another radar instrument called the scatterometer. Additional information on ERS-2 can be found at http://earth1.esrin.esa.it/ERS/. It is anticipated that ERS-2 data will be acquired during the experiment, however, these data must be obtained by individual research groups. Possible overpass dates and times are listed in Table 6.

Table 6. ERS-2 Coverage of the SGP99 Region		
Area	Date	Time
LW	7/11/99	15:48
LW	7/15/99	04:08
LW	7/27/99	15:45
ER	7/11/99	15:48
ER	7/15/99	04:08
ER	7/27/99	15:45
CF	7/11/99	15:48
CF	7/27/99	15:45

3. AIRCRAFT INSTRUMENTS

A total of five different aircraft microwave instruments are planned for use in SGP99. Because of the focus on L band, there have been few aircraft C band instruments available for research. Recent efforts have resulted in the development of three new airborne C band instruments which are described in Table 7. These new instruments will be important to the AMSR cal/val program. Of particular interest is the PSR-C which will provide a dual polarized image product. Primary objectives in this project are to evaluate and cross calibrate these new instruments, develop a data set for algorithm development and testing (prelaunch), and provide validation of AMSR soil moisture retrievals (post launch). In addition, the L band ESTAR and a new L and S band passive/active dual polarization instrument will be flown.

Table 7. Aircraft C Band Instruments			
Sensor	Developer	Mode of Operation	Other Features
Polarimetric Scanning Radiometer (PSR/C)	NOAA ETL (A. Gasiewski)	Scanner	Option 1: C band V and H (polarimetric) Option 2: 10.7, 18.7, 37.0, and 89.0 GHz V and H (polarimetric)
Step Frequency Microwave Radiometer (Step-C)	Univ. of Massachusetts (C. Swift)	Single beam	V&H, multiple C band frequencies
Airborne C band Microwave Radiometer (ACMR)	NASA GSFC (E. Kim)	Single beam	V&H

3.1 Polarimetric Scanning Radiometer (PSR)

The PSR is an airborne microwave imaging radiometer developed by the Georgia Institute of Technology and the NOAA Environmental Technology Laboratory for the purpose of obtaining polarimetric microwave emission. The PSR consists of a set of polarimetric radiometers housed within a gimbal-mounted scanhead drum. The scanhead drum is rotatable by the gimbal positioner so that the radiometers can view any angle within 70o elevation of nadir at any azimuthal angle. The configuration thus supports conical, cross-track, along-track, fixed-angle stare, and spotlight scan modes which are selectable in flight. Figure 3 shows the PSR installed on the NASA Wallops Flight Center P3-B aircraft.

Figure 3. The PSR-A Installed on the P3-B

The original PSR (PSR/A) consisted of four polarimetric radiometers operating at 10.7, 18.7, 37.0, and 89.0 GHz (see Piepmeier and Gasiewski, 1996). Since then this was modified to include a 21.3 GHz channel. All antennas are of the lens/corrugated feedhorn type with beamwidths of 8° (for both X- and K-bands) and 2.3^o (for both Ka- and W-bands).

Radiometric data is processed using a 80486-based computer within the scanhead, then transmitted to an archival computer in the aircraft cabin via a 10-base 2 LAN link through the sliprings. Thus, all radiometric detection is accomplished inside the scanhead drum.

The scanhead package includes a monochrome CCD telephoto video camera boresighted along the antenna main beams. A network of IRIG-B clocks within the scanhead and controlling computers provides position/sample synchronization to better than one millisecond. A two-axis gyroscope is mounted on the positioner to provide roll and pitch information at ~10 msec intervals. These data are later used to correct the observed imagery for minor aircraft attitudinal variations. Calibration of all radiometers is performed in-flight using standard (unpolarized) hot and cold blackbody targets.

The modularity of the PSR system allows for a straightforward interchange with other scanheads. For SGP99 a new scanhead with a fully polarimetric C-band radiometer has

been developed. The C-band system (PSR/C) will provide simultaneous four-Stokes' vector measurements within four bands adjacent at 5.80-6.20, 6.30-6.70, 6.75-7.10, and 7.15-7.50 GHz. Additional details on the PSR can be found at http://www1.etl.noaa.gov/radiom/psr.html.

PSR/C in a conical scan mode will be the primary mode of data collection in SGP99. It is anticipated that the PSR/A will be flown on one or more days. However, this change of scanheads might result in the loss of a day of aircraft coverage.

3.2 Airborne C-band Microwave Radiometer (ACMR)

ACMR was developed by the NASA Goddard Space Flight Center. It is a single beam dual-polarized C band (6.9 GHz) radiometer. For SGP99, the instrument incidence angle will be fixed at 54 degrees up from nadir, looking rearward from the P-3. The field of view is 12 degrees. The instantaneous footprint at an altitude of 7.5 km is 2.7 x 4.6 km (cross x along track) and at 0.5 km it would be 0.2 x 0.3 km. The ACMR package will include a color video camera and a thermal infrared sensor both aimed parallel to the C-band sensor.

In-flight calibrations will be continuously performed using switched internal calibration loads (hot, ambient, cold). External calibrations (ambient, LN2) will be performed on the ground before and after each flight. The ACMR external calibration targets will be used for cross-calibration with the PSR/C.

3.3 Step-C

The Step-C is operated by the University of Massachusettts. It is a redesign of an existing step frequency C band radiometer in order to provide dual polarization data. The field of view is 15 degrees. It provides 6 frequencies between 4 and 8 GHz.

3.4 Passive and Active L and S Band System (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/aircraft/pals.html) and will be flown in SGP99. This instrument was developed by JPL. It provides single beam observations at L and S band, dual polarized (polarimetric), passive and active simultaneously. Figure 4 shows one of the horn antennas. The incidence angle is selectable between 30 and 50 degrees. Additional details are described in Table 8. This instrument will offer 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. By including it in the C band mission it also creates additional opportunities for research on algorithm development as well as hydrologic processes. From this 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.

Table 8. Description of JPL Instruments		
Parameter	Radiometer	Radar
Frequencies (GHz)	1.41 and 2.69	1.26 and 3.15
Bandwidths (MHz)	20 or 60	1
Polarization (polarimetric)	V and H	VV, VH, HH
Incidence angle (deg.)	30 to 50	30 to 50 (preselected)
Spatial resolution (km) (@ 6,000 ft alt)	1	1

Figure 4. PALS L Band Horn Antenna

3.5 Electronically Scanned Thinned Array Radiometer (ESTAR)

ESTAR is a synthetic aperture, passive microwave radiometer operating at a center frequency of 1.413 GHz and a bandwidth of 20 MHz. As installed in the SGP99 mission it is horizontally polarized.

Aperture synthesis is an interferometric technique in which the product (complex correlation) of the output voltage from pairs of antennas is measured at many different baselines. Each baseline produces a sample point in the Fourier transform of the scene, and a map of the scene is obtained after all measurements have been made by inverting

the transform. ESTAR is a hybrid real and synthetic aperture radiometer which uses real antennas (stick antennas) to obtain resolution along-track and aperture synthesis (between pairs of sticks) to obtain resolution across-track (Le Vine et al., 1994). This hybrid configuration could be implemented on a spaceborne platform.

The effective swath created in the ESTAR image reconstruction (essentially an inverse Fourier transformation) is about 45° wide at the half power points. The field of view is restricted to 45° to avoid distortion of the beam but could be extended to wider angles if necessary. The image reconstruction algorithm in effect scans this beam across the field of view in 2° steps. The beam width of each step varies depending on look angle from 8 to 10°, therefore, the individual original data are not independent, since each data point overlaps its neighbors. Contiguous beam positions can be achieved by averaging the response of several of these data points. This results in approximately nine independent beam positions. For this experiment the swath will be restricted to approximately 35°. Another approach to using the data, especially in a mapping mode, is to interpret each of the original nonindependent observations as a sample point and then use a grid overlay to average the data. The final product of the ESTAR is a time referenced series of data consisting of the set of beam position brightness temperatures at 0.25 second intervals.

Calibration of the ESTAR is achieved by viewing two scenes of known brightness temperature. By plotting the measured response against the theoretical response, a linear regression is developed that corrects for gain and bias. Scenes used for calibration include black body, sky, and water. During aircraft missions, a black body is measured before and after the flight and a water target during the flight. Water temperature is determined using a thermal infrared sensor. The match in level and pattern is quite good and in general the ESTAR calibration should be considered accurate and reliable. For interpretation purposes it should be noted that the sensitivity of soil moisture to brightness temperature is 1% for 3^oK.

ESTAR has demonstrated the potential of L band radiometry and STAR technology (Jackson et al., 1995). Details on ESTAR and soil moisture products can be found at the following web site http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/SGP97/estar.html. Including ESTAR in SGP99 will provide continuity in observations and enhance the analyses using the PSR-C and JPL instrument packages.

4. AIRCRAFT MISSION DESIGN

The PSR-C, ACMR, and ESTAR instruments will be installed on the NASA WFC P3-B aircraft. The Passive/Active L/S-band (PALS) instrument and the Step-C will be installed on a C-130 aircraft operated by NCAR (http://raf.atd.ucar.edu/).

As in previous missions, the goals of the experiment design are to collect data for both algorithm development/verification and soil moisture mapping. Mapping will utilize high

altitude flightlines and will depend heavily on the PSR-C and ESTAR (http://www1.etl.noaa.gov/radiom/psr.html). Covering a large area will be important if comparisons to the TMI are to be made. For algorithm development we will also include several low altitude lines. These will provide more homogenous targets and will be the primary basis for comparisons between instruments.

The area that will be studied in 1999 is basically the same region of Oklahoma that was used in the SGP97 Hydrology Experiment (http://hydrolab.arsusda.gov/sgp97/). Figure 2 shows the general region and observing networks. The Southern Great Plains is an excellent site for calibration and validation activities for soil moisture algorithms. Consistent results using L band instruments have demonstrated that heterogeneous land targets can be used for this purpose (Jackson et al., 1995 and 1999). This is complemented by extensive ongoing soil moisture observing programs throughout the region. These include the Oklahoma Mesonet, the DOE ARM CART, and USDA ARS and NRCS.

The proposed primary aircraft mission consists of seven high altitude lines and five low altitude lines as shown in Figure 5 and described in Table 9. This mission was designed to minimize costs yet achieve the basic goals of the project. The nominal time window for aircraft coverage will be 8:30-11:30 am CDT.

Table 9. SGP99 Remote Sensing Aircraft Flightlines

Line No.	Altitude (km)	Length (km)	Description	Start Lat.	Start Lon.	Stop Lat.	Stop Lon.
1	7.5	280	Mapping	37.0000	-97.6275	34.5000	-98.3400
2	7.5	280	Mapping	34.5000	-98.2225	37.0000	-97.5100
3	7.5	280	Mapping	37.0000	-97.3925	34.5000	-98.1050
4	7.5	100	Mapping	34.5000	-97.9875	35.4183	-97.7417
5	7.5	50	Mapping	35.4183	-97.7417	35.4183	-98.1517
6	7.5	50	Mapping	35.5400	-98.1517	35.5400	-97.6950
7	7.5	150	Mapping	35.5400	-97.6950	37.0000	-97.2750
8	0.5	5	Water	34.7828	-98.3532	34.8565	-98.3592
9	0.5	8	Winter Wheat	34.9107	-98.3065	34.9107	-98.2300
10	0.5	10	Range	34.9597	-98.1155	34.9597	-97.9300
11	0.5	8	Range	34.9568	-97.9570	34.8837	-97.9570
12	0.5	8	Corn	34.9600	-97.8670	35.0500	-97.8670
13	0.5	15	Backup Wheat	35.5435	-98.1100	35.5435	-97.9500
14	0.5	15	Backup Wheat	36.6170	-97.5833	36.6170	-97.3500
15	7.5	120	CASES	37.0000	-97.2750	38.1400	-96.9133
16	7.5	120	CASES	38.1400	-97.0258	37.0000	-97.3925
15	7.5	280	Mapping Alternate	34.5000	-97.9875	37.0000	-97.2750

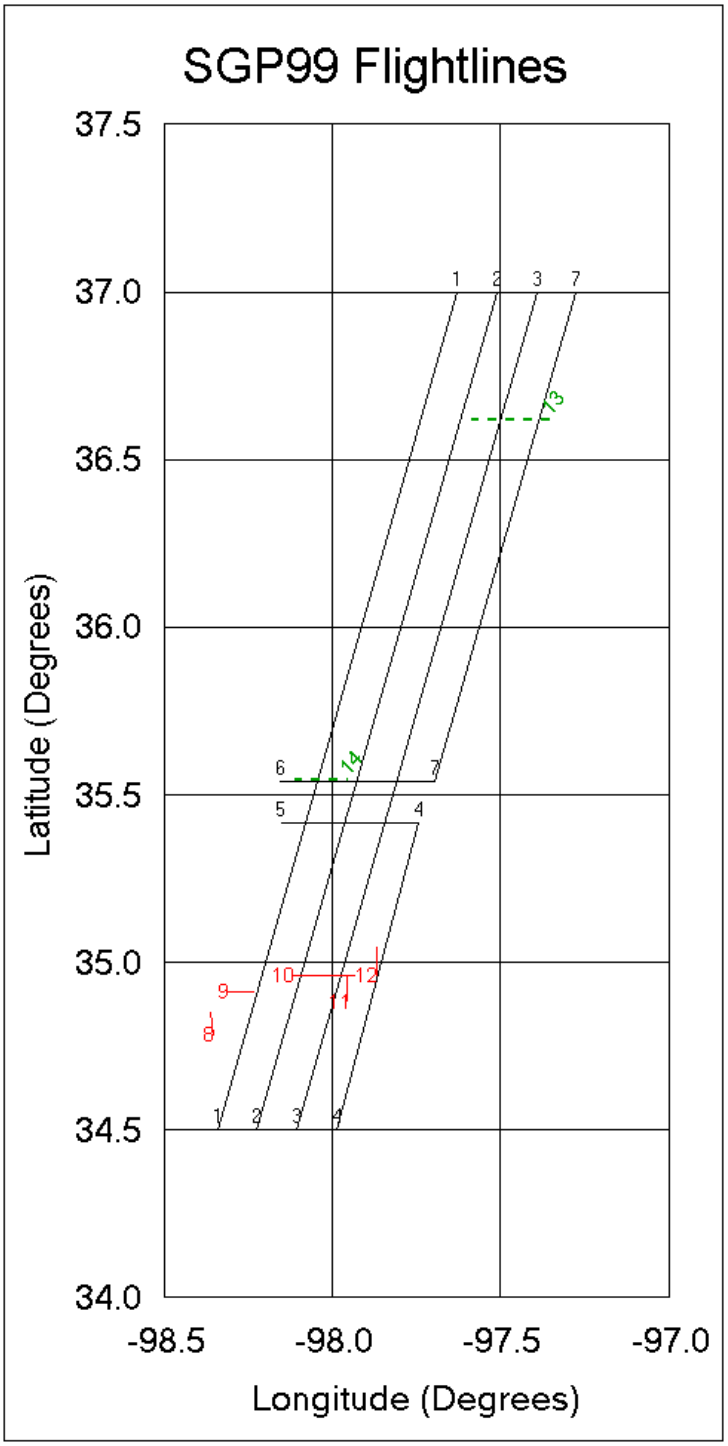

Figure 5. SGP99 Flightlines

The mapping component of the project will involve the P-3 aircraft. Lines 1 through 7 were selected to give the same regional coverage as SGP97. Keeping a large spatial extent will also increase the probability of observing interesting vegetation, soil, and meteorological conditions. The particular design (flying the sequence of lines 4 through 7 instead of a single line) is based upon experience in SGP97. During that mission radio frequency interference (RFI) was found on the north south lines using the ESTAR all across the area. When the flight orientation was changed to east west (lines 5 and 6) the RFI was eliminated. Therefore, we will start will this configuration. If no RFI is present, we can switch to a single line to replace lines 4-7. This replacement is included in Table 9 as line 15.

Two additional high altitude lines are listed in Table 9 that cover the CASES study area (lines 15 and 16). These may be included on selected dates if adequate ground support and interest is noted. They are flown immediately after line 7. The P-3 will also fly a water target at lower altitude, line 8. An alternative water target may be used once on site. It is also desirable to fly lines 9 through 12 each day, however, we are specifying a maximum daily mission of 3.5 hours. Based upon previous experience, it may be possible to the basic mission (1-8) and some of the other lines in this amount of time, however, some adjustments may be necessary when more details are available.

The C-130 flights will be based upon 2 hour missions (approximate time of flights will be 9:00-11:00 am CDT) that collect data on lines 8 through 12. Due to the rear door on the C-130 being open during flight, it is not very efficient to attempt to fly lines 1 through 7. However, this may be attempted at a lower altitude on selected dates. The low altitude lines are primarily in the LW area. The lines over El Reno and the Central Facility (lines 13 and 14) are included as backup. The intention is to use these backup lines only if meteorological conditions in the southern portion of the region do not provide diverse conditions.

A 14 day deployment with 10 days of flights is anticipated. Total flight hours on site will be approximately 35 for the P-3 and 20 for the C-130. The current projection is to conduct the experiment during the middle two weeks of July 1999. A tentative schedule is shown in Table 10. Aircraft operations will be based out of Oklahoma City.

An ideal scenario for the mission would be to observe a drying sequence beginning from saturated soil conditions. A flight will be conducted as soon as possible upon arrival in the SGP region. However, additional flights will be delayed if conditions are exceptionally dry. It is critical that once a drying sequence has started that flights be conducted each day. The only permutation being considered at the present is the possibility of switching the scanhead of the PSR instrument between C band and the higher frequency package. (10.7, 18.7, 37.0, and 89.0 GHz). This would mean the loss of a day of C band data and would require some down time.

Table 10. SGP99 Remote Sensing Aircraft Schedule		
Day	Day	Item
June 22	Tu	Begin instrument installation on P-3 at WFC
June 28	M	First engineering flight tests
July 5	M	Full engineering test flight
July 7	W	Transit to OKC
July 8	Th	First mission
July 21	W	Last mission
July 22	Th	Transit to WFC and download

Data will also be collected during the P-3 transit to OKC from WFC and on the return. A nominal flight track will be suggested that includes diverse conditions and possibly some level of ground support. The purpose of this activity is to collect data over additional vegetation conditions.

5. GROUND DATA COLLECTION

5.1 Sites

Maps of the sites selected are shown in Figures 6, 7, and 8 for the three areas. The sites are also tabulated in Table 11. Figure 9 shows a false color composite image of the LW area derived from TM data collected on July 25, 1997. Site locations are indicated as points or boundaries depending on the sampling method that will be used. Typical ground conditions expected are shown in Figure 10 for rangeland (LW03) and Figure 11 for winter wheat (LW21).

Line 12 and sites (LW24-26) will be used for obtaining a broader range of cropland conditions. Figure 12 shows a false color composite image of the LW area southeast of Chickasha where this line is located. The sites suggested for corn were used in the Washita92 experiment (http://hydrolab.arsusda.gov/washita92/wash92.htm). Corn biomass will be quite high in mid July.

A total of six fields will be sampled in the El Reno area. Figure 13 shows a false color composite image of the ER area.

Four fields and two point sites will be sampled near the ARM Central Facility. Figure 14 shows a false color composite image of the CF area.

5.2 Soil Moisture

Ground support will be focused on the LW area with a modest level at ER and CF and a

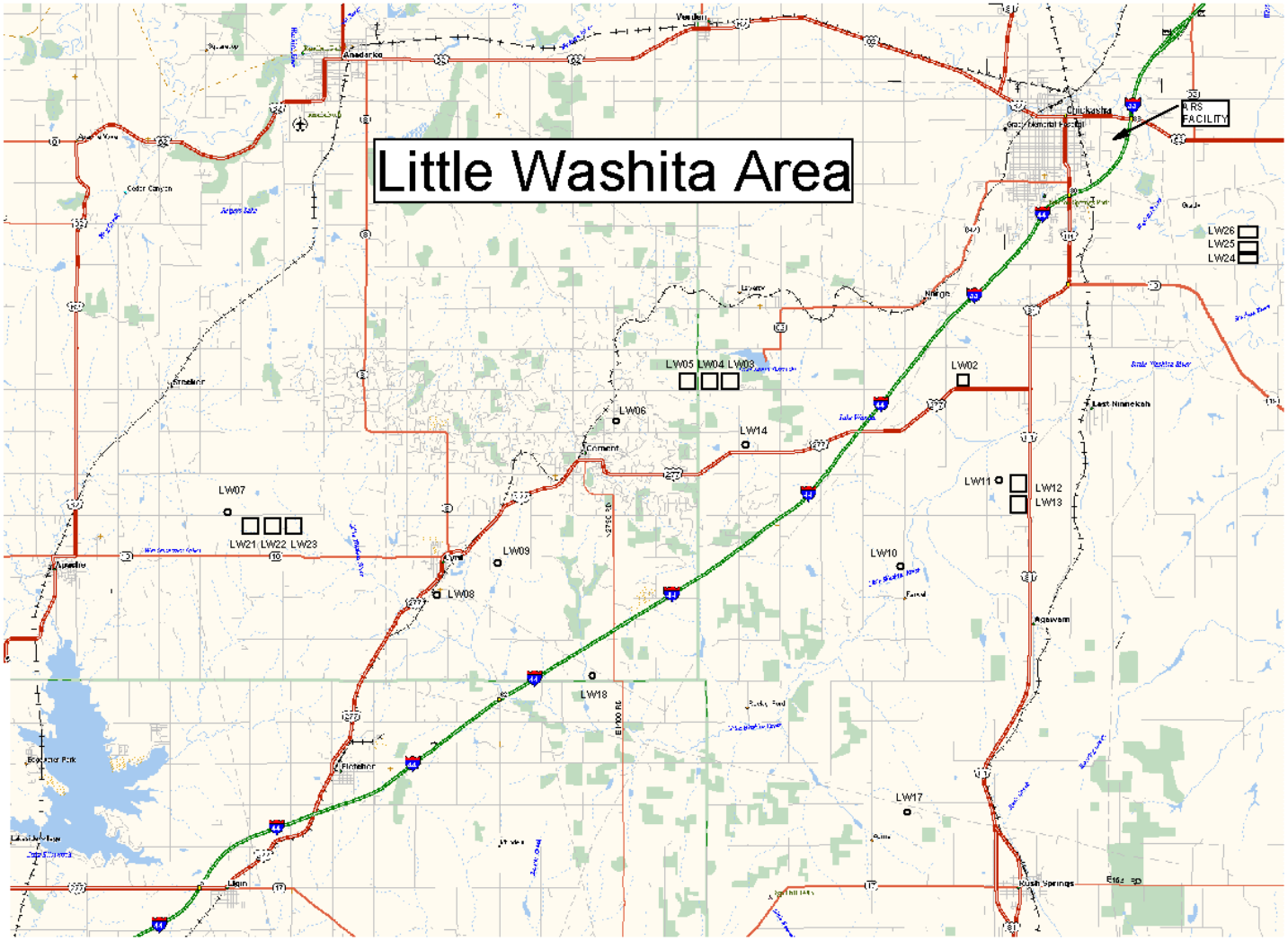

Figure 6. SGP99 Sites in the LW Area

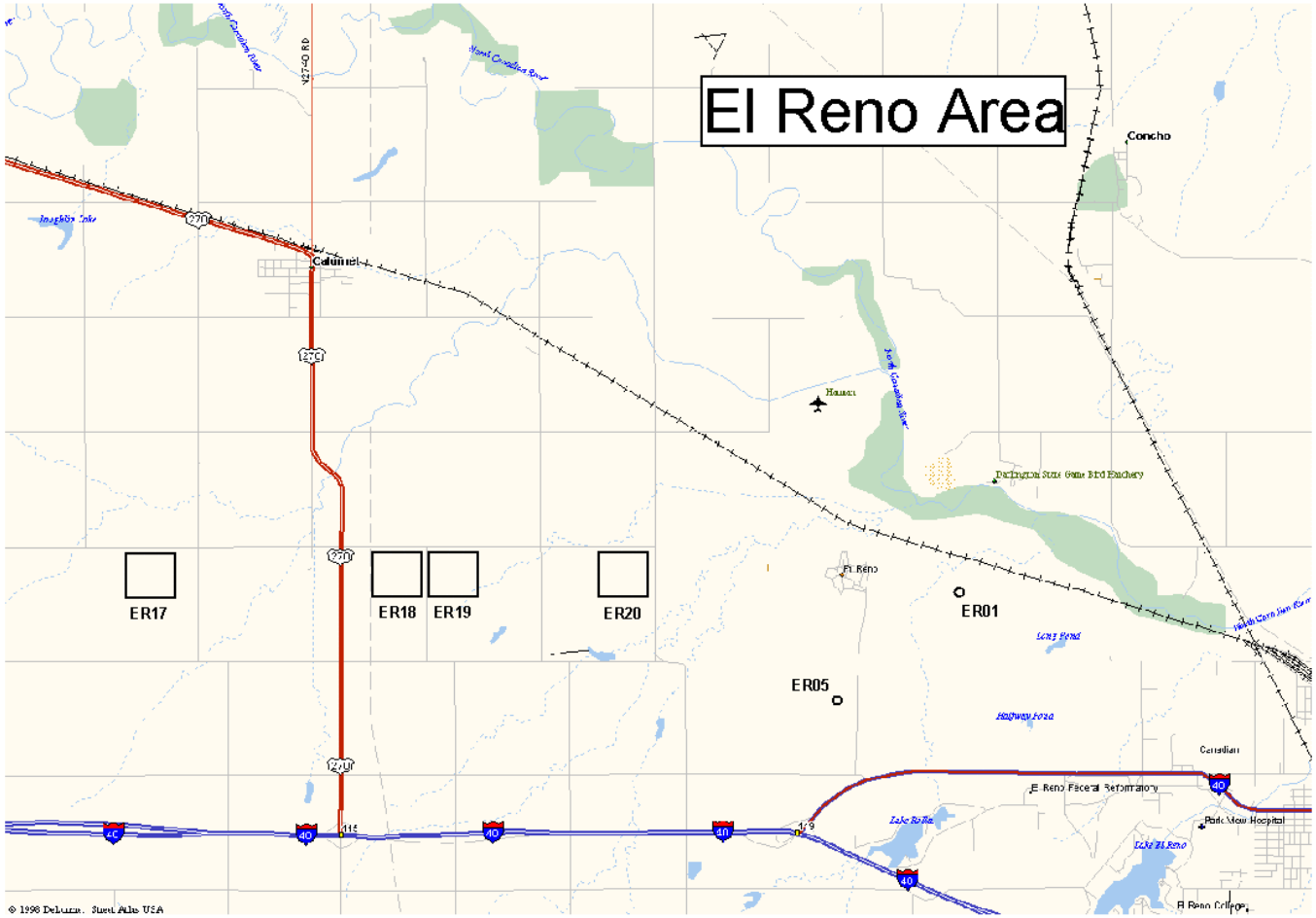

Figure 7. SGP99 Sites in the ER Area

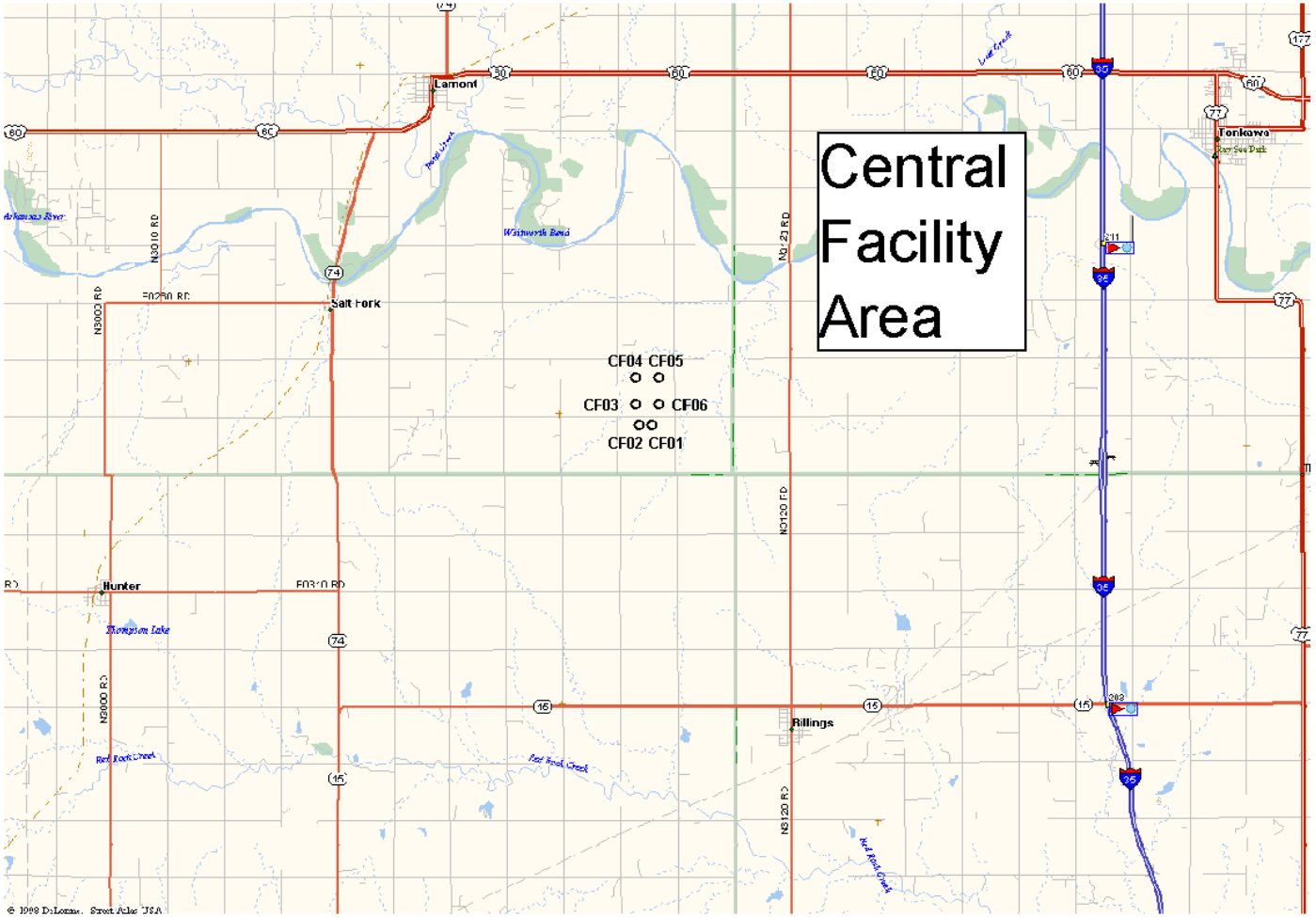

Figure 8. SGP99 Sites in the CF Area

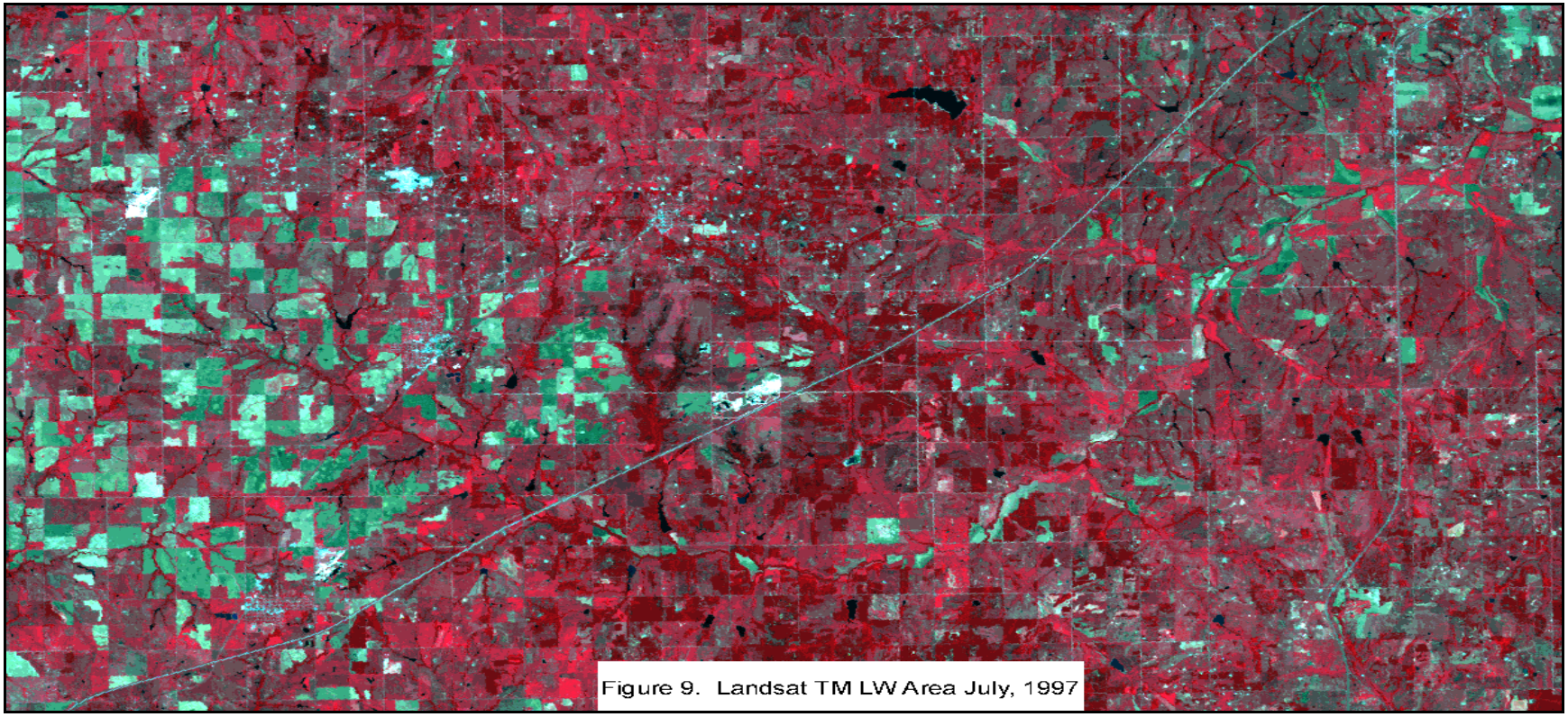

Figure 9. Landsat TM LW Area July, 1997

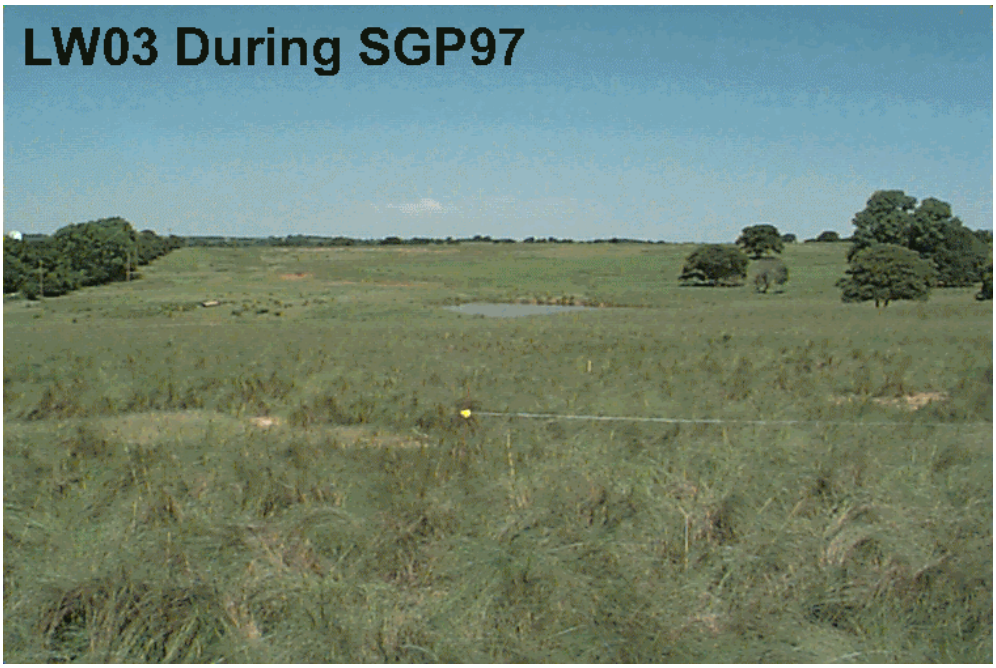

Figure 10. Typical Conditions in a Grass Site

Figure 11. Typical Conditions in a Winter Wheat Site

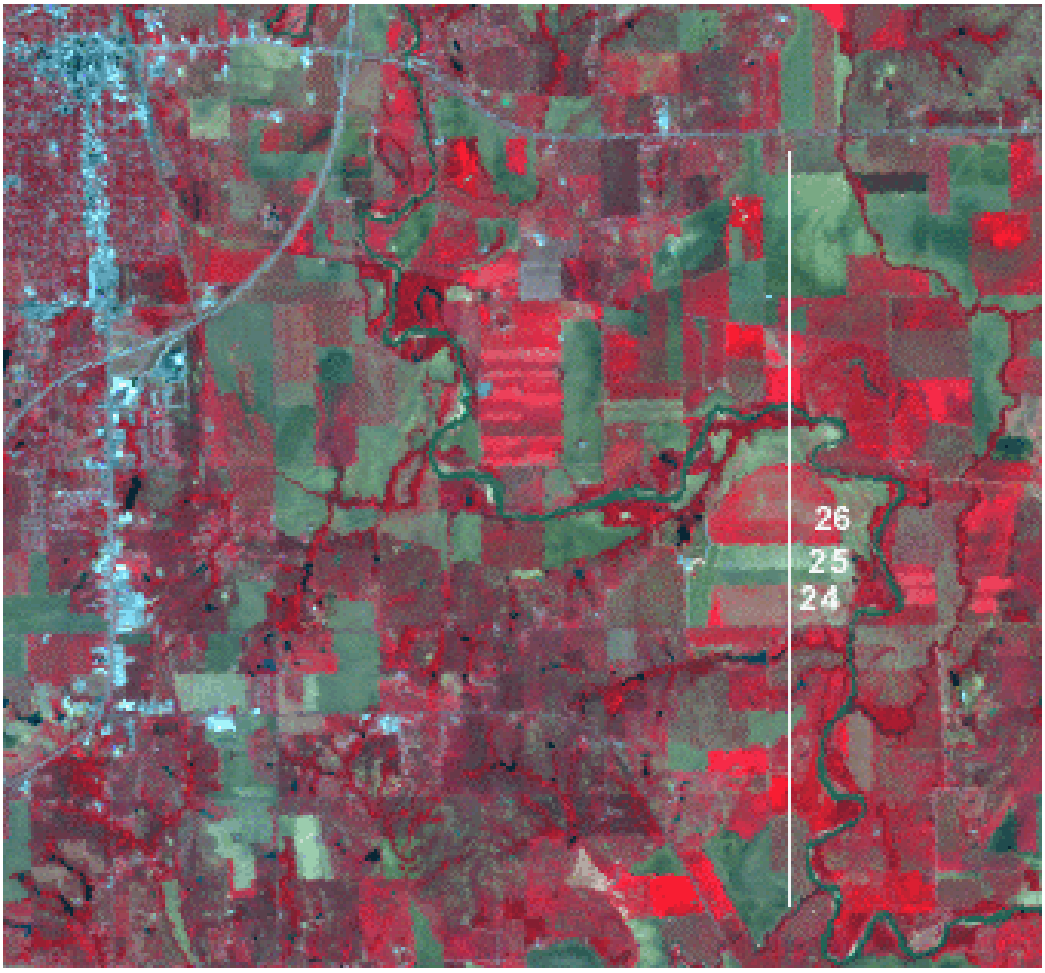

Figure 12. Landsat TM East of Chickasha, OK Showing Flightline that Includes Agricultural Sites July, 1999

few Mesonet locations. Soil moisture sampling will utilize primarily the gravimetric technique and will employ both field and point sampling designs. It is essential that we utilize the same basic techniques and sites that have been used in the past.

One major difference for SGP99 is that an additional soil layer will have to be sampled in order to provide a representative value for comparison with the C band sensors. This will involve splitting the 5 cm depth sample into two layers. One major impact of this will be that the number of samples per field would be increased which will impact the sample processing and drying.

Facilities are available in the LW and ER areas to support gravimetric soil moisture sampling. At the CF area this will be arranged with Oklahoma State University.

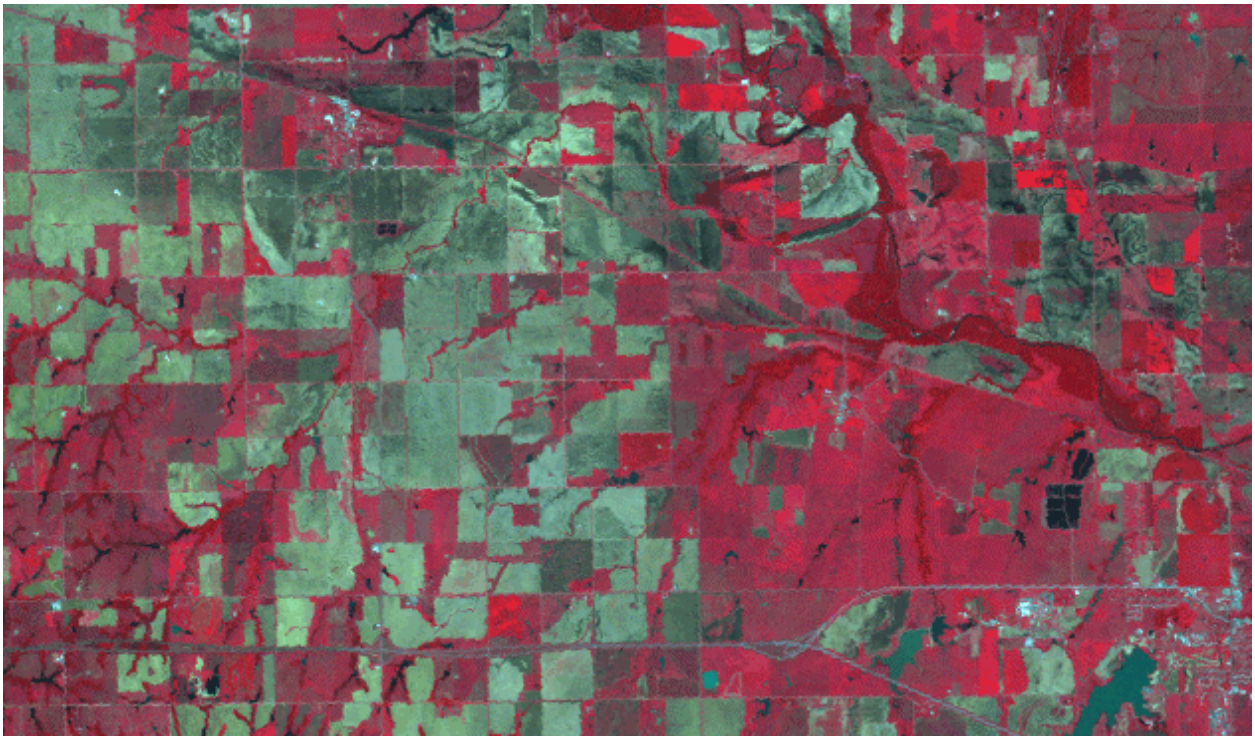

Figure 13. Landsat TM ER Area July, 1997

In SGP97 an alternative method for sampling surface soil moisture using dielectric probes was evaluated. The results indicated that these could be used if careful calibrations are performed. It is anticipated that this method may be used in spatial variability studies.

5.3 Soil and Surface Temperature

Although there are point data available from the ARM and Mesonet, additional surface and soil temperature will be collected. The surface temperature will be sampled using handheld infraRed thermometers (IRT). The soil temperatures will be obtained using the temperature probes at 1 cm, 5 cm, and 10 cm depths. These data will be of value to the algorithm development and will also be used in the analysis of other satellite observations such as validation of the satellite retrieval algorithms (i.e. GOES, TOVS, AVHRR and LANDSAT-7). In addition the data will be used for hydrological model validation as surface temperature is computed by the hydrological models. Soil temperature probes and IRTs (in some cases) will be supplied to the gravimetric sampling teams to collect data for characterization, scaling and variability studies. In addition, spatial and temporal variability studies will be conducted. A limited number of handheld thermal infrared sensors will be available to collect this data at key sites.

Sites will also be selected for monitoring near surface soil temperature continuously using small data loggers.

Figure 14. Landsat TM CF Area July, 1997

5.4 Vegetation and Land Cover Mapping

A scaled down version of the vegetation sampling and mapping conducted in SGP97 will be conducted. A sampling team will characterize the vegetation in each ground site (type,

biomass, water content, height, and LAI). Samples will be georeferenced. During the SGP99 period, a team will collect data georeferencing and land cover for other sites distributed around the region. These data will be used to georegister and classify a Landsat TM and/or NOAA AVHRR image.

5.5 Soil Bulk Density

Each site will be characterized one time during the SGP99 time frame. At this time we plan to use the same sampling techniques and procedures as in SGP97

5.6 Surface Roughness

Each site will be characterized one time during the SGP99 time frame. A ombination of two methods will be employed. The first method uses grid board photography as in SGP97. The second uses a portable laser scanner, which provides more intensive surface roughness characterizations. The laser scanner measures soil microtopography at fine grid spacings. The laser system will scan a continuous area of 1 by 3 m, with positional and elevational resolution on the order of 0.1 to 0.3 mm.

5.7 Ground Penetrating Radar (GPR)

GPR can be used to rapidly measure three dimensional surface soil moisture distributions at the field scale. It can provide a valuable link between point measurements and microwave sensor footprints. Boston College will provide a team to perform GPR surveys of selected sites, probably in the LW area, on a daily basis. The method is time intensive and the number of sites will be limited by logistics.

5.8 Surface Flux Towers

Four fields in the Little Washita area will be instrumented with eddy correlation flux towers by a group from the University of Virginia, Texas A&M, and the USDA Hydrology lab. These towers will measure fluxes of latent heat, sensible heat, and momentum using Krypton hygrometers and 3D sonic anemometers. They will also measure 30-minute averages of: radiometric surface temperature, short and long wave radiation, air temperature, relative humidity, wind speed and direction, soil heat flux, precipitation, and profiles of soil moisture and temperature. Measurements will be taken of leaf area index surrounding the flux towers. An attempt will be made to select fields representing rangeland, standing winter wheat, and cut winter wheat, if possible. The particular site selection will be made at the start of the experiment. Instrument height will be selected for each tower to limit the flux footprints to the underlying field.

5.9 Ground Based Microwave Radiometers

A ground based set of passive microwave instruments will be provided and operated by a team from Nagaoka University of Technology in Japan. This will include 6.926 GHz V/H, 10.65 GHz V/H, and 18.7 GHz V/H. These radiometers will be deployed over ground sites to provide well controlled observations to enhance algorithm development and aircraft and satellite data validation.

Table 11. SGP99 Ground Sampling Sites				
Area	Site	Cross Reference	Cover	Sampling
LW	02	NOAA, NRCS, S	Range	F
	03	A	Range	F
	04		Range	F
	05		Range	F
	06	S	Range	P
	07	M, S	Range	P
	08	A	Wheat	P
	10	S	Range	P
	11	S	Range	P
	12		Range	F
	13		Range	F
	14	S	Range	P
	17	M	Range	P
	18	S	Range	P
	21		Wheat	F
	22		Wheat	F
	23		Wheat	F
	24		Corn	F
	25		Corn	F
	26		Corn	F
ER	01	A, S, NRCS	Range	P
	05	M	Range	P
	17		Wheat	F
	18		Wheat	F
	19		Wheat	F
	20		Wheat	F
CF	01	A	Range	P
	02	A	Wheat	P
	03		Wheat	F
	04		Wheat	F
	05		Wheat	F
	06		Wheat	F

6. REGIONAL NETWORKS

6.1 DOE ARM CART

The Department of Energy (DOE) Atmospheric Radiation Measurement Program (ARM) operates a large number and types of instruments within the SGP99 region. The Southern Great Plains is one of the Cloud and Radiation Testbeds (CART). Here a simplification of the extensive materials prepared by the ARM CART (**<http://www.arm.gov/docs/sites/sgp/sgp.html>**). The site layout is based upon a heavily instrumented central facility (CF) surrounded by 22 extended facilities (fewer instruments) (EF), 4 boundary facilities (BF), and 3 intermediate facilities (IF).

Instrumentation at the CF is listed in Table 12. EF sites include the SIROS, SMOS, EBBR or ECOR, and SWATS. IF facilities include BBSS, MWR, and a 404 MHz Wind Profilers. Each IF has a 915 MHz Wind Profiler.

The schedule for BBSS launches at the CF is (in UTC)

- 0530
- 1130
- 2030
- 2330

Routine operations do not include weekends. As part of SGP99, it has been arranged to include the 1130, 2030, and 2330 launches on Saturday and Sunday.

The Central facility includes two EF sites, one range and the other winter wheat. Therefore, many of the instruments are replicated for each cover type (radiometric observations, wind, temperature and humidity sounding systems, energy balance, surface meteorology, and soil moisture and temperature profile). There are currently 22 EF sites designed to primarily to monitor surface and moisture (energy balance, surface meteorology, and soil moisture and temperature profile).

Table 12. ARM CART Central Facility Observations		
Radiometric Observations	Atmospherically Emitted Radiance Interferometer **(AERI)**	
	Solar Radiance Transmission Interferometer **(SORTI)**	
	Broad Band Solar Radiation Network **(BSRN)**	Pyranometers
		Pyrgeometer
		Pyrheliometer
		Multifilter Rotating Shadow Band Radiometer (MFRSR)
	Solar and Infrared Radiation Observing System (**SIROS**)	Pyranometers up and downwelling
		Pyrgeometer up and downwelling
		Pyrheliometer
		Multifilter Rotating Shadow Band Radiometer (MFRSR)
	UV-B PAR, Multifilter Radiometer **(MFR)**	
Wind, Temperature and Humidity Sounding Systems	Balloon Borne Sounding System (**BBSS**)	Pressure
		Temperature
		Relative Humidity
		Wind Speed
		Wind Direction
	915MHz Profiler with RASS	
	50 MHZ Profiler with RASS	
	Microwave Radiometer	
	Raman Lidar	
	Infrared Thermometer	
Cloud Observations	Whole Sky Imager	
	Belfort Laser Ceilometer	
	Micropulse Lidar	
	Millimeter Cloud Radar	

Table 12. ARM CART Central Facility Observations		
Other	Temp and Humidity at 25 and 60 m tower	
	Energy Balance Bowen Ratio (**EBBR**)	Air Temperature at Two Heights
		Relative Humidity at Two Heights
		Net Radiation at 2 m
		Near Surface Soil Moisture (2.5 cm)
		Near Surface Soil Temperature (0-5 cm)
		Near Surface Soil Heat Flux (5 cm)
		Atmospheric Barometric Pressure
		Wind Direction at 2.5 m
		Wind Speed at 2.5 m
	Eddy Correlation (**ECOR**)	Air Temperature
		Relative Humidity
		Wind Direction
		Wind Speed
	Surface Meteorological Observation Station (**SMOS**)	Air Temperature at 2 m
		Relative Humidity at 2 m
		Atmospheric Barometric Pressure
		Wind Direction at 10 m
		Wind Speed at 10 m
		Precipitation
		Snow Depth
	Soil Water and Temperature System (**SWATS**	Soil Moisture (5, 15, 25, 35, 45, 85, 125, and 175 cm depths)
		Soil Temperature (5, 15, 25, 35, 45, 85, 125, and 175 cm depths)

6.2 Oklahoma Mesonet

The Oklahoma Mesonet is an automated environmental observing system distributed over the state of Oklahoma. There are 114 stations providing observations every 5 minutes. Data are collected and transmitted to a central point every 15 minutes where they are quality controlled, distributed and archived.

Each station consists of a 10 m tower providing measurements of air temperature (1.5 m), relative humidity (1.5 m), wind speed and direction (10 m), barometric pressure, rainfall, solar radiation, and soil temperature (10 cm for both sod and bare soil).

About half the stations provide supplemental measurements of air temperature (9 m), wind speed and direction (2 m), leaf wetness, soil moisture (5, 25, 60 and 75 cm under sod), and soil temperature (5 and 30 cm under sod and 5 cm under bare soil).

Data files from the Mesonet are copyrighted. SGP99 investigators will have access to all data for 1999 through an authorized site. However, these data may not be redistributed. Additional information on the Mesonet can be found on a web page at http://geowww.gcn.uoknor.edu/WWW/Mesonet/mesonet.htm.

6.3 USDA Soil Climate Analysis Network (SCAN)

The USDA NRCS has initiated nationwide soil moisture and soil temperature (SMST) analysis network called SCAN. Details and data can be obtained at the following web site http://www.wcc.nrcs.usda.gov/smst/smst.html. In 1998 two sites were installed in the SGP99 region at the ER and LW areas. Data 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

6.4 USDA ARS Micronet

The USDA Agricultural Research Service, Grazinglands Research Laboratory at El Reno, OK operates a meteorological network within the Little Washita watershed. There are 42 ARS Micronet stations. The data consists of accumulated rainfall, relative humidity, air temperature at 1.5 m, solar radiation, and soil temperature at 5, 10, 15 and 30 cm below ground surface. A data quality indicator is provided for each data entry. Climate data are provided in 5-minute increments and the soil temperature data are provided in 15-minute increments.

In addition, ARS also operates an experimental Soil Heat and Water Measurement System. This includes heat dissipation sensors at selected Micronet sites. These

sensors provide soil water matric potential data. The data consists of matric potential values at 5, 10, 15, 20, 25, and 60 cm below ground surface, at 1-hour increments.

7. OPERATIONS

7.1. Experiment Management

Ground Operations. For each of the three areas there will be one individual designated as area leader. All ground sampling in that area will be coordinated and approved by the area leader. The area leader will be responsible for liaison with the facility contact. Only approved sampling can be conducted in approved sites.

Do not enter any field that you do not have permission to enter. Do not assume that you can use a field without permission. In addition, for access to the CF area sites you will have to satisfy ARM requirements. The SGP CART Site is managed by Argonne National Laboratory (ANL), which means that all ANL safety requirements along with the Department of Energy's safety requirements need to be met. When visiting the Site you must attend a safety orientation. Anyone wishing to visit the CF must contact the facility manager Jim Teske at least a day in advance and obtain the necessary for

There will be an all hands meeting for those involved in ground sampling at the USDA ARS facility in Chickasha at 9:00 am CDT on July 7, 1999. It is critical that all participants attend.

Table 13. SGP99 Ground Operations

Area	Leader	Facility Contact
LW	Jay Famiglietti	Gary Heathman
ER	Peggy O'Neill	Pat Starks
CF	Ron Elliott	Jim Teske

Aircraft Operations. Decisions on whether to conduct flights will be made by Tom Jackson. Once a decision is made, the individual aircraft mission managers and pilots are responsible for changes related to weather, safety, and aircraft operations. For each aircraft, one instrument scientist will be designated to coordinate any changes related to instrument performance.

There will be an all hands meeting for those involved in aircraft operations and measurements at the Embassy Suites in Oklahoma City at 4:00 pm CDT on July 7, 1999. It is critical that all participants attend

7.2 Safety

Field Hazards

There are a number of potential hazards in doing field work. Common sense can avoid some of these:

- Work in teams of two
- Carry a phone
- Know where you are
- Dress correctly; long pants, long sleeves, boots, hat
- Use sunscreen and bring fluids

There are other hazards that require a proactive approach to minimize. The following information is provided for general purposes and was extracted from materials at cited web sites. In all cases, if you have an emergency get to a hospital. For minor problems contact the area operations manager.

Chiggers. Chiggers are the larvae of mites (about 2 mm in size). Chiggers are most often found in low, damp areas where vegetation is heavy, although some species prefer dry areas. Chiggers can cause intense itching and small reddish welts on the skin. The intense irritation and subsequent scratching may result in secondary infection.

Chiggers attach themselves to the skin, hair follicles or pores by inserting their piercing mouthparts. When chiggers attach to humans, they are not usually noticed for some time. During feeding, they inject a fluid into the skin which dissolves tissue. Chiggers feed by sucking up the liquefied tissues.

Itching from chigger bites is usually noticed 4-8 hours after chiggers have attached or have been accidentally removed. The fluid injection causes welts to appear which may last for two weeks. They will also cause a tiny red spot to develop on your skin. As time goes by, the itch will get worse and the red spot will get larger. Some people exhibit an allergic reaction to the injected fluid which results in severe swelling, itching, and fever. People mistakenly believe that chiggers embed themselves in the skin or that the welts contain chiggers. Often scratching at the welt results in secondary infection.

Chiggers prefer to attach on parts of the body where clothing fits tightly or where the flesh is thin, tender, or wrinkled. For this reason, chiggers locate in such areas as the ankles, waistline, knees, or armpits.

Chiggers are easily removed from the skin by taking a hot bath or shower and lathering with soap several times. The bath will kill attached chiggers and others which are not

attached. Since symptoms of contact may not appear for several hours, it is not always possible to completely prevent welts caused by chigger bites. Antiseptic should be applied to all welts which do appear. It is important, but hard to remember not to scratch chigger bites. Temporary relief of itching may be achieved with nonprescription local anesthetics available at most drug stores. Studies have shown that meat tenderizer, rubbed into the welt, will alleviate itching, as will calamine lotion. So will antihistamines such as Benadryl.

If you are going into areas suspected of being infested with chiggers, wear protective clothing and use repellents. Repellents should be applied to legs, ankles, cuffs, waist, and sleeves by clothing application or directly to the body as directed by the label. Wear an insect repellent that contains DEET.

Ticks. Ticks are flat, grey 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.

Snakes. The following are some emergency procedures

WHAT TO DO IF BITTEN BY A VENOMOUS SNAKE

- Allow bite to bleed freely 30 secs.
- Use Sawyer Extractor (see below) for 15secs to 1 minute over both fang tracks
- Cleanse and/or disinfect bite area throughly if possible
- Apply hard direct pressure over bite using a 4 x 4 gauze pad folded in half x 2
- Soak gauze pad in Betadine(tm) solution if available if not allergic
- Strap gauze pad tightly in place with adhesive tape
- Overwrap dressing above and below bite area with ACE bandage
- Wrap ACE (elastic) bandage as tight as one would for a sprain. Not too tight.

- Check for pulses above and below elastic wrap; if absent it is too tight
- Immobilize bitten extremity, use splinting if available.
- Try and keep bitten extremity below heart level or in a gravity dependent position
- Go to nearest hospital or medical facility as soon as possible
- Try and identify, kill and bring (ONLY if safe to do so) offending snake.

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.

7.3 Communications

It is strongly suggested that all groups have a cellular phone that will operate within the SGP region. This will aid logistics as well as safety.

7.4 Briefings

The default decision for the aircraft and the soil moisture sampling is to assume it is on everyday. An aircraft briefing will be held in OKC at the Embassy Suites at 5:00 pm CDT.

8.0 DATA MANAGEMENT AND AVAILABILITY

All experiment participants will be required to contribute a final data product to the experiment data base. Those who do not contribute and those who have not participated in the execution of the experiment will still have access to the data after it has been quality controlled and published as a data report.

- July 1999 Experiment
- August 1999 - Feb. 2000 Processing and Analysis
- June 2000 Workshop/AGU Meeting
- Sept. 2000 Publication and distribution of data (Version 1)

The data management service will be provided by the NASA GSFC Distributed Active Archive Center (DAAC). The general format will be similar to the SGP97 web site http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/SGP97/sgp97.html.

9. SAMPLING PROTOCOLS

9.1 Gravimetric Surface Soil Moisture and Soil Temperature

The gravimetric soil moisture (GSM) sampling is intended to estimate the site average and standard deviation. Precise location within the site is not important, however, the samples should be spatially distributed to obtain meaningful statistics. For this reason a grid is used. In sites that are the subject of spatial variability studies and are marked at sampling points, it is correct to use these markings for locating GSM points. Two types of sampling designs will be employed, Full and Profile. The actual soil moisture sampling is the same but the distribution and number of samples is different.

A few important general items:

- Sampling is conducted **every day**. It is canceled by the area 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 area manager.
- Although GSM sampling is destructive, try to **minimize your impact** by filling holes. Leave nothing behind.
- Please be considerate of the landowners and our hosts. **Don't** block roads, gates, and driveways. Keep sites, labs and work areas clean of trash and dirt.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust.
- Avoid parking in tall grass, catalytic converters can be a **fire hazard**.
- **Close any gate** you open as soon as you pass.
- Work in **teams of two**, within visual contact.
- 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 zerox.
- **Use cans sequentially**. It is OK to use a box for more than one site but don't split a box between two sites.

GSM Sampling Procedure

Preparation

- Arrive at your area operations base at assigned time. Check in with area leader

and review notice board.

- Assemble GSM kit
  - Bucket
  - GSM tool
  - 6 cm spatula
  - 3 cm spatula
  - Notebook
  - Pens
  - Boxes of cans
  - Soil thermometer
  - Handheld infrared thermometer (if assigned)
  - First aid kit (per car)
  - Phone (if assigned)
- Check weather

Full sampling Site

The goal of this sampling is to characterize the mean of what we hope is a "homogeneous" field. A total of 14 points in each site will be sampled. Some sites are not square and the procedure will have to be adapted.

- Upon arrival at site, note site id, 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).
- Assemble 28 sequential cans and indicate on schematic where they will be used. ***Odd numbered cans will be used for the 0 – 2.5 cm sample and even numbered cans will be used for the 2.5 – 5 cm sample.*** See ***Figure 15*****.**
- From a reference point for the site (usually a corner), measure 200 m along one side to locate the first transect.
- 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 on the transect. At selected points you will also collect soil temperature and surface thermal infrared temperature (TIR-if assigned). These are indicated in Figure 15.
- 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.
- As you move along the transect note any anomalous conditions on the schematic in your notebook, i.e. standing water.
- Record your stop time and place cans in box. Try to keep them cool.

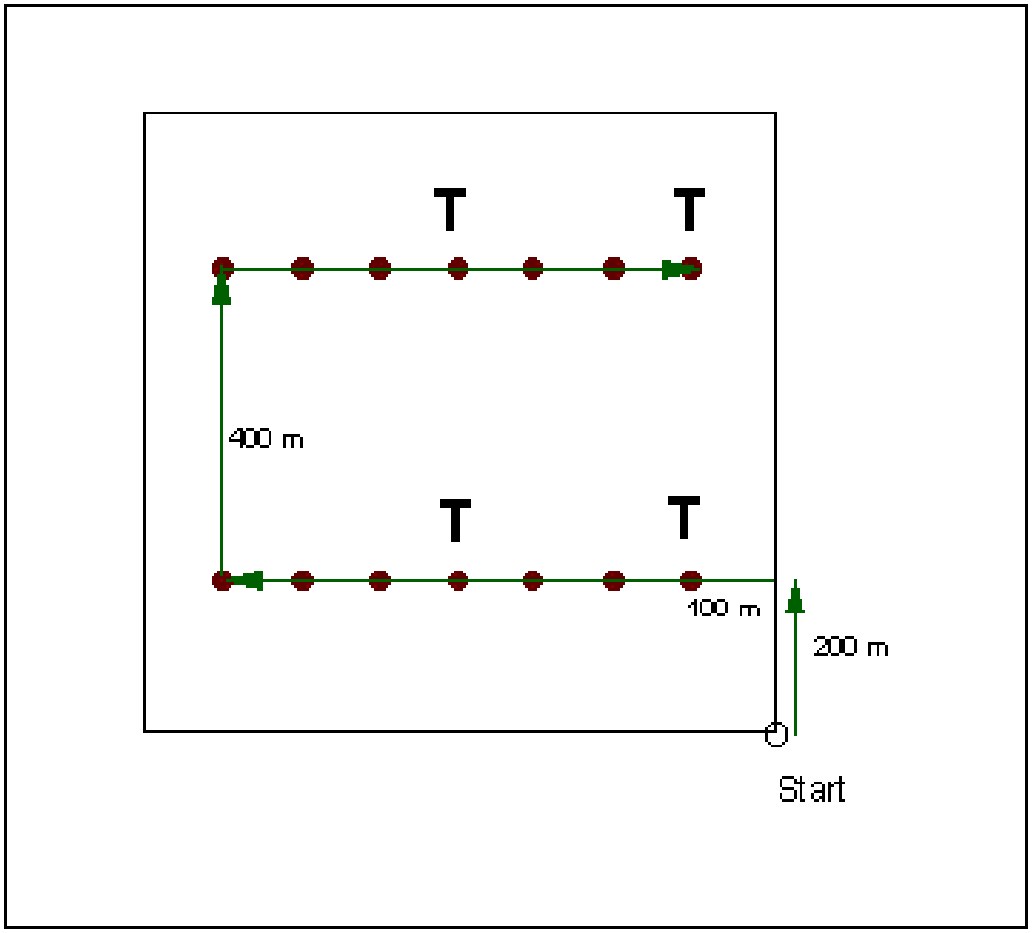

Figure 15. Schematic of Layout of Samples in a Site (T=Temperature)

Profile Sampling Site

These are locations at which the objective is solely to correlate gravimetric surface soil moisture to the data collected by the insitu heat dissipation 5 cm sensors. Nine samples are collected on a nominal grid 10 m apart (total of 20 m by 20 m area) immediately adjacent to the sensor enclosure.

Taking a GSM Sample

1. Remove vegetation and litter.
2. Use the large spatula (6 cm) to cut a vertical face at least 5 cm deep ***(Figure 16 a).***
3. Push the GSM tool into this vertical face. The wings of the scoop should

rest on the soil surface.***(Figure 16 b)***.

4. Use the large spatula to cut a vertical face on the front edge of the scoop ***(Figure 16 c)***.
5. Use the small spatula to cut the sample into a 0-2.5 and a 2.5-5 cm depth sample.
6. Place each sample depth in a separate can, small spatula aids extraction ***(Figure 16 d)***. Remember that the odd numbered cans are for the top layer and the even are for the second layer.
7. A video clip showing the gravimetric sampling technique can be downloaded from an anonymous ftp site hydrolab.arsusda.gov/pub/sgp99/gsmsamp.avi.
8. 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.
9. If you are assigned a TIR, 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.

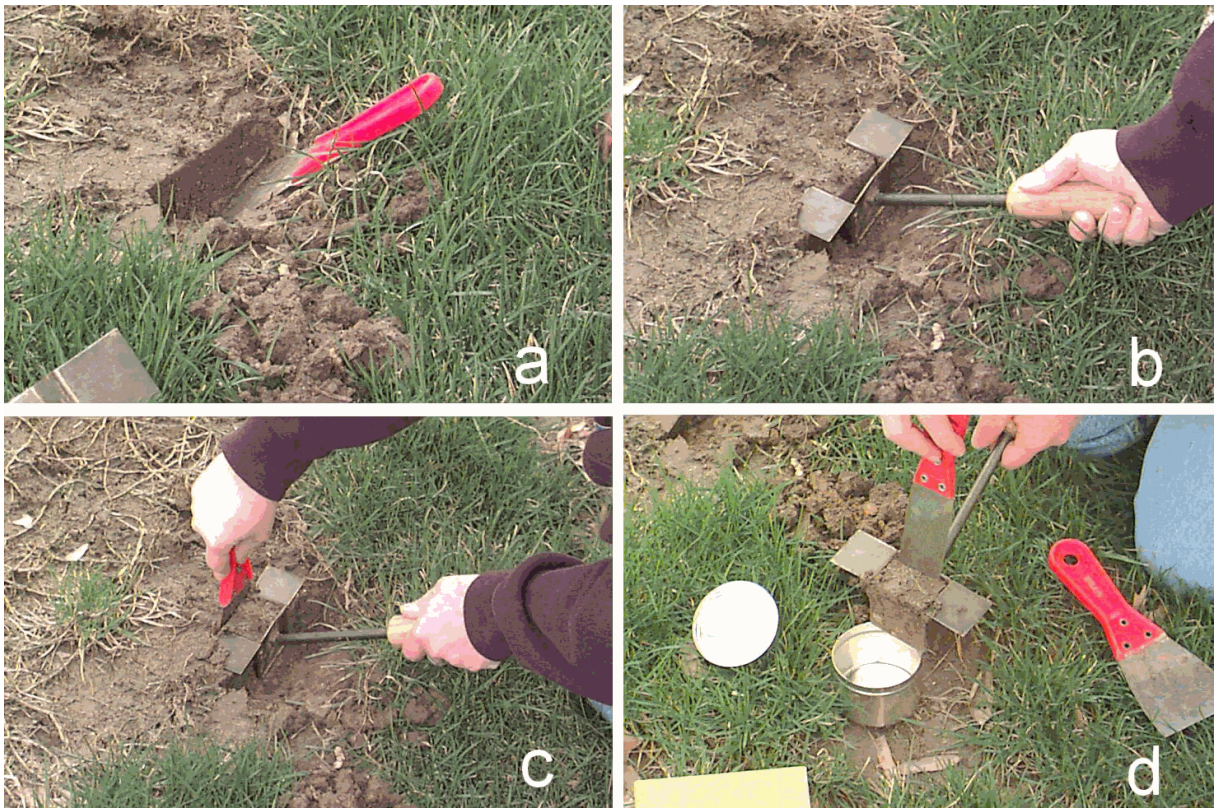

Figure 16. How to Take a Gravimetric Soil Moisture Sample

GSM Sample Processing

All GSM samples are processed to obtain a wet and dry weight. It is the sampling teams responsibility to perform the wet weighing and placement of the samples in the drying ovens. A lab team will perform the removal of samples from the oven, dry weighing, and can cleaning.

The Gravimetric Soil Moisture (GSM) samples will be collected from all sites on a daily basis. After the retrieval of all samples they will be weighed in their wet state and put in the oven. The next day, approximately 22 hours later, the now oven-dry samples will be weighed again. To speed up weighing and to reduce the data processing, the process has partially been automated by connecting the balances with PC's.

Wet Weight Procedure

1. The balance will be connected to a computer that will record the weight.
2. Turn on computer and get the program running. There will be an instruction sheet available on site and instruction will be provided.
3. Process your samples on a site basis and in sample numeric order.
4. Place the open cans (the lid goes on the bottom of the can) in the drying oven. Arrange them sequentially.
5. There will be sheets available for manually recording the weights if you encounter unresolvable problems with the computer operation.

Dry Weight Procedure

1. All samples should remain in the oven for approximately 20-22 hours at 105°C.
2. Try to remove samples in the order they were put in. This should result in sequential groups for sites. Only remove a few sites at a time and keep oven running.
3. These samples will be hot. Wear the gloves provided.
4. Follow the instructions provided for the software to enter the dry weight of can (with its lid).
5. Dump the soil after verifying data and clean the can with the brush provided.
6. Repack the can boxes, check that can numbers are readable and replace any damaged or lost cans with spares.

Data Processing

1. There will be a raw data file for each site on each day.
2. There will be a summary file for each day for each area 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

Equipment

For the automated weighing the following equipment is required:

- 1 IBM compatible PC. 386 or better.
- Mettler Toledo BD series portable balance (BD601)
- RS-232-c/cl Interface
- IBM PC/AT 15-pin 9 socket Interface cable
- Mettler Toledo Balance link software
- The WEIGHING program developed by the USDA-ARS-Hydrology Lab

Note: The interface with interface cable will be connected all balances prior to the SGP >97 experiment.

Installation of Equipment:

It is intended that the PC with the balance and the required software are set up and installed before the SGP >97 experiment begins. If not so, and the coordinator is not present or if the coordinator gave authorization follow the following procedure to set up the equipment. Install the PC in the laboratory. Then connect the Mettler Toldeo interface cable to serial port COM1.

Optionally the mouse can be connected to COM2. Start the computer and turn on the balance by pressing the ON button.

Insert the disk labeled "Data acquisition program, Mettler Toledo BalanceLink ME410023 Ver. 2.20" into the PC. Type A:\installe C:\balink at the prompt. If the 3.5" floppy drive is the B:\ drive type B:\ instead of A:\). Go to C:\BALINK and type LICENCSE, and follow the directions until the program quits.

Take the floppy from the 3.5" disk drive, and insert the 3.5" floppy labeled "BALINK automated soil sample weighing program" into the computer.

Go to the floppy drive and type install. The program WEIGHING is now being installed

into the directory BALINK.

The WEIGHING program

Start the program by typing WEIGHING at the C:\BALINK> prompt. The program will guide you through the weighing procedure until all samples have been weighed.

All data is saved in DOS TAB delimited format, which can be imported in all major spreadsheets. Like MS-Excel, Quattro-Pro, Lotus etc. For a full description how to operate the program read the manual sheet.

Weighing procedure

1. Turn on the balance, the computer and the printer.
2. Make sure the paper in the printer is in the right position.
3. Insert the floppy labeled BACKUP into the 3.5" floppy drive.
4. Start the program WEIGHING.
5. Follow the steps as described on the WEIGHING balance program manual page.
6. Weigh the samples in ascending order.
7. When you are finished weighing you samples store the prints in the right binder (WET or DRY Binder).
8. Always finish your work cleaning up you workspace!

Example of Using the WEIGHING balance program

1. Turn the balance ON.

2. RUN the program by typing WEIGHING at the c:\prompt

Questions from the program	*Comments*
Area you are working in (er/lw/cf)	er = El Reno lw = Little Washita cf = Central Facility
Site this set of cans was collected from	Enter Site number
Wet or Dry samples to be weighed	w = wet d = dry
Option WET	Option DRY

If you enter (W)ET the program will ask you for the Letter of the Box where the samples belong

If you enter (D)RY the program will ask you for the date of the wet samples. Enter date as MM/DD
**The WET data are loaded and appear on the screen SKIP until DRY section

First can in box to be weighed

Enter the number of the first can to be weighed. Always start with the can with the lowest number! (usually can 1).

Last can in box to be weighed

Enter the number of the highest numbered can of the series to be weighed. Normally you have 14 cans per site.

Is this information correct? Ready to proceed? (y/n)

The input sheet appears on the screen, and you are now ready to weigh the samples.

Example of the input sheet as displayed on the screen

```
Gravimetric Soil Moisture Weight Recording
            +-------------------+------------------+
            |    Area: er       |     Site:  1     |
            +-------------------+------------------+

                        |     Sampling      |
 Sample |  Date          DOY   |   Depth  I Wet (g)  I  Dry(g) |  Difference
+----------+-----------------------+-----------+------------+----------+-------------+
  A01      07-08-1999    189        0-2.5    0.00
 A01      05-07-1997    189      2.5-5       0.00
etc.
```

Make sure that the top cell is highlighted and put sample No. 1 on the balance!

Put the first can on the balance

Press the enter button on the balance (most right button).
Note that the balance value is exported to the screen, and that the cursor has moved one line down.

Put the next sample on the balance and repeat that procedure until you get the message:

Done collecting data. Hit any key to see results.

Hit a key. The program automatically saves your data sheet now, shows your data on the screen and prints out a paper copy. At the top of every print you will find the name of the file were the data was saved to.

At the bottom of that page you can see the message:

Done. Hit any key to continue, 'q' to quit.

Press any key to weigh the next set of sample cans, press Q to leave the program.

9.2 Soil Bulk Density

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

Thee Bulk Density Apparatus itself consists of two parts. 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 17*** 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 kitchen 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 gasoline 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.

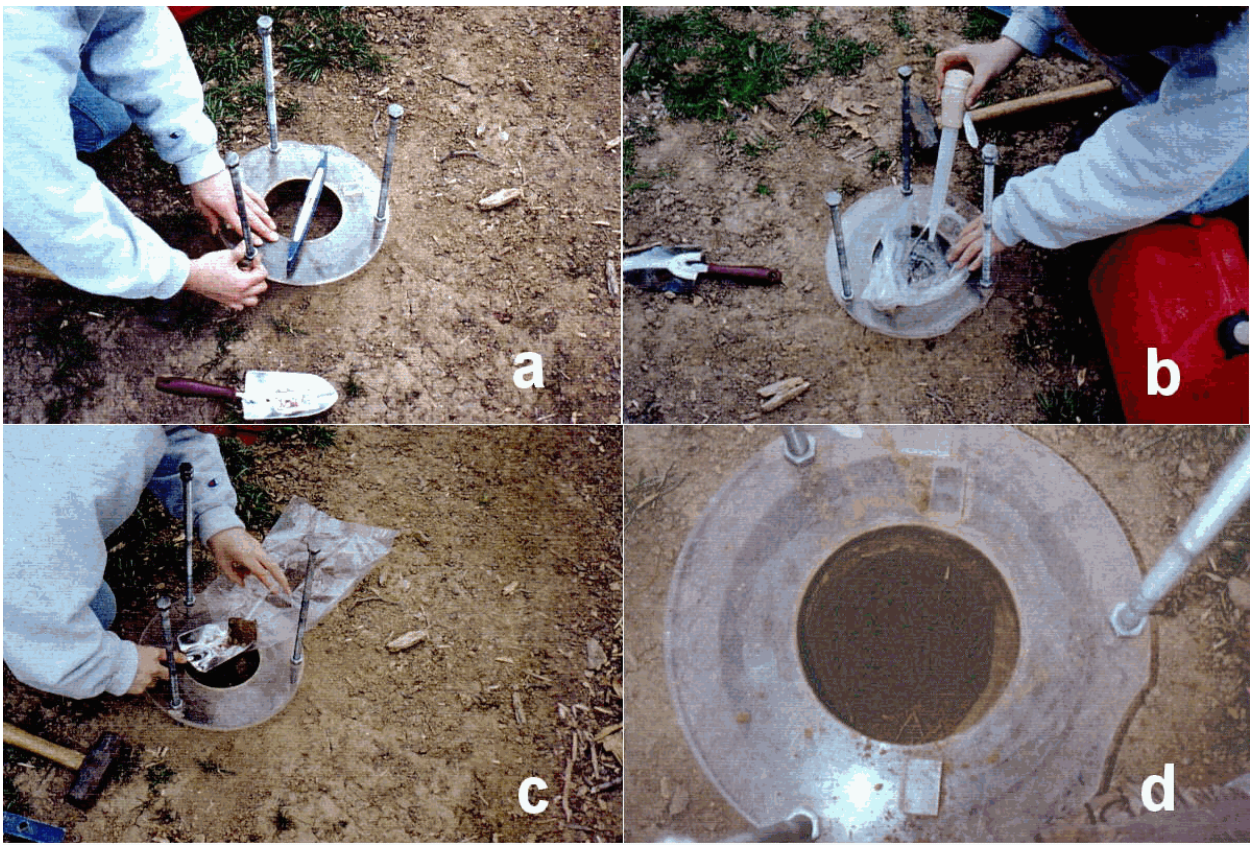

Figure 17. How to Take a Bulk Density Sample

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 rock 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.

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 17 a)***

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 and loosen the bolts in order to make the surface level. (If the bubble is too far to the right, the right side is too high. Tighten the bolt(s) on the right, or loosen those on the left, until it is horizontal.)
3. 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 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 hold 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 surface of the apparatus, so that it is secure between the notches on the opposite sides of the hole.
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 17 b)***
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 inches 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 loose as little soil as possible.) ***(Figure 17 c 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. 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.

9.3 Vegetation Sampling

Activities at Each Site

1. Park on the shoulder of public roads or stay on field roads. **Do not** drive through the field.

2. Enter the field through a normal entry point such as a gate. Avoid climbing fences, if possible. If you open a gate to enter a field, close it immediately.

3. If there is a meteorological station in the field, use the GPS receiver and record its location.

4. Walk ~100 meters (120 paces) to a representative area in the field. The area must be 100 m from field edges. Check the area carefully for snakes and other critters before proceeding. Insert the sampling frame horizontally at the soil surface, starting near your left foot.

5. Use GPS receiver and record location of the sampling frame (Sample #1 only) on the data form.

6. Record vegetation type and growth stage on the data form.

7. Record sky, vegetation, and soil conditions on the data form. Comment on any unusual conditions.

8. Take an oblique and vertical photograph of the vegetation in the sample frame. For the vertical photo, stand outside of the sample frame, hold the camera out over the sample frame at shoulder height with the lens facing down toward the

surface and take a picture.

9. For the oblique picture, stand 3-5 m from the sampling frame and focus on the sampling area. Be sure that the entire sample area is included in the picture. Record the film roll and frame numbers on the Vegetation Data Sheet.

10. Measure leaf area index (LAI) in the sample frame with the plant canopy analyzer (LAI-2000). Use Plant Canopy Analyzer protocol.

11. Measure LAI at 4 additional locations within 3 m of the frame.

12. Clip all of the standing vegetation at the soil surface. Use a meter stick to form the fourth side of the sampling frame. Cut all vegetation within the volume defined by the sampling frame.

13. Place all clipped vegetation in a paper bag (s). Label each bag with :
- Site # e.g., LW01, ER05, CF01, etc.
- Plot # A, B (for the 2 locations within each field or site)
- Sample # 1, …. n (if more than one bag must be used for sample from that plot)

14. Place all bags for a plot in a plastic bag. DON'T FORGET TO GET THE TARE WEIGHTS FOR THE PAPER AND PLASTIC BAGS.

14. Walk a few meters to a new representative area. Repeat steps #5 to 14. This will be plot B.

15. Keep samples as cool as possible.

16. Upon return to a lab facility do the following for each plastic bag:
- Remove paper bags from plastic bag
- Weigh and record weight of the plastic bag
- Weigh and record weight of paper bag

17. Place the bags in the dryer. Allow to dry for 4 days and weigh.

18. When the samples are dry, weigh and record each paper bag on the appropriate data forms.

Plant Canopy Analyzer Protocol

1. Connect sensor to X-connector (on left as viewed from keypad). Clean the lens carefully with a lens brush.

2. *Setup List:*

   Verify X Cal data for X port. Serial No. should match sensor on X-connector. (FCT 01; 02)
   Set Resolution = HIGH.
   Make sure time and date are correct (FCT 05)

3. *Operating Mode:*

   Set Op Mode= 1 sensor X (FCT 11)
   Sequence= 1 above and 5 below (FCT 12)
   Reps= 1
   Bad Reading= BEEP AND IGNORE (FCT 16)

4. Verify that each ring (X1 thru X5) is responding to light. (BREAK)

5. View cap = 90 degrees.

   Sky conditions:
   Diffuse illumination is ideal, but measurements can be made on sunny days with the following precautions:
   Make all Above and Below readings with your back to the sun and with the view cap blocking the sensor's view of you and the sun.
   Shade the sensor with your body to prevent reflections of the sun from influencing the readings.
   Shade the part of the canopy which is visible to the sensor with the umbrella. Sunlit leaves cause the sensor to underestimate LAI.

Sampling

6. Press **LOG**. Enter site number for SITE= prompt, e.g., LW01 or ER08. Enter plot+sample for the SAMPLE= prompt, e.g., A10, A20, or C20. Add a zero to the sample number to indicate measurement is within the sampling frame.

7. Level the sensor **above the canopy**, shade the sensor from direct sun, and press the button on the sensor handle.

Note: Two beeps will be heard: one when the button is pressed and the other when the reading has been completed. Between the two beeps, keep the sensor level.

8. Put the sensor **beneath the vegetation** and level it. The sensor should view the same direction as the Above canopy reading. Press the button on the sensor handle.

9. Move the sensor about 15 cm diagonally (relative to the field of view of the

sensor) and take another beneath the canopy reading. Repeat for 5 beneath the canopy readings. After the last reading the display will show **COMPUTING...**.

Note: The first set of LAI measurements should be within the sampling frame. The subsequent measurements should be within 3 m of the frame.

10. Move to a new area outside the sampling frame and repeat steps #6-9 four times. SITE = stays the same (press enter to retain the value). SAMPLE= the last digit increments by one, e.g, A11, A12, A13, A21, A22, etc.

Downloading LAI-2000 files to a PC (see chapters 6 and 9 of Instruction Manual)

11. Use FCT 31 to set

BAUD =	4800
DATA BITS =	7
PARITY =	None
Xon/Xoff =	No

12. Run communications program, PROCOMM, on personal computer. Configure the computer's RS-232 port to match the LAI-2000. Connect the computer and LAI-2000 with the appropriate cable. Specify the destination for the incoming data. **c:\SGP97\LAI\yymmddn.ext**
    where yymmddn = year, month, day, name of team leader (c=Curry, r=Russ, w=Ward).
    .ext = format of output (.std = standard, .spr = spreadsheet format)

13. Output the LAI-2000 data files in the standard (.STD) and Spreadsheet (.SPR). formats. Backup files to a floppy disk.

14. Print the spreadsheet format files.

15. Clear the files after verifying that all files have been transferred successfully.

10. LOGISTICS

Maps for getting to the various study areas are included as Figures 18 (Oklahoma City Airport Area), Figure 19 (Chickasha), Figure 20 (El Reno), and Figure 21 (Central Facility).

Contacts

USDA ARS Offices Chickasha, OK **(405) 224-7393 fax (405) 224-7396**
Gary Heathman USDA ARS

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Chickasha, OK 73018

Mail Address
USDA ARS
P.O. Box 400
Chickasha, OK 73018

USDA ARS Offices El Reno, OK **(405) 262-5291 fax (405) 262-0133**
Pat Starks USDA ARS

Street Address (FedEx Deliveries)
USDA ARS Grazinglands Res. Lab
7207 W. Cheyenne St.
El Reno, OK 73036

Mail Address
USDA ARS Graz.Res. Lab
P.O. Box 1199
El Reno, OK 73036

ARM Central Facility Lamont, OK **(405) 388-4053 fax (405) 388-4052**
Jim Teske ARM Program Site Manager

Street Address (FedEx Deliveries)
A Shipment Notification Form must be completed and submitted to the site when shipping items there. You can request this form from the SGP CART Site Office at 405/388-4053.

Mail Address
ARM
SGP CART Site Office
R.R. 1, Box 70
Billings, OK 74630

Aircraft Coordination, OKC, OK
Embassy Suites Hotel (**405**) 682-6000

Motels

Oklahoma City, OK

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 $60 (plus tax). We will also have the use of a separate room for operations and meetings. It is strongly suggested that you take advantage of this rate. A special affiliation name will be needed to get this rate. This will be distributed by email. This is only available to those staying the full two weeks. Otherwise, the Hampton Inn usually has a government rate. There is also a Wingate Inn close by. Refer to the following web site http://www.okccvb.org/hotels/hotels98.html for phone numbers etc.

Although it is about 2 miles from the Embassy Suites, a good cheap place (~$210/week) is

Extended Stay America
4820 W. Reno
Oklahoma City, OK 73127
(405) 948-4443; 800-398-7829; fax 948-4434

Chickasha, OK

Days Inn (looks like the best deal in Chickasha-ask for upstairs on extended stay)
2701 S 4th Street
Chickasha, OK 73018
(405) 222-5800

Best Western Inn (the only place I've ever stayed, easy walking to stores and rest.)
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.

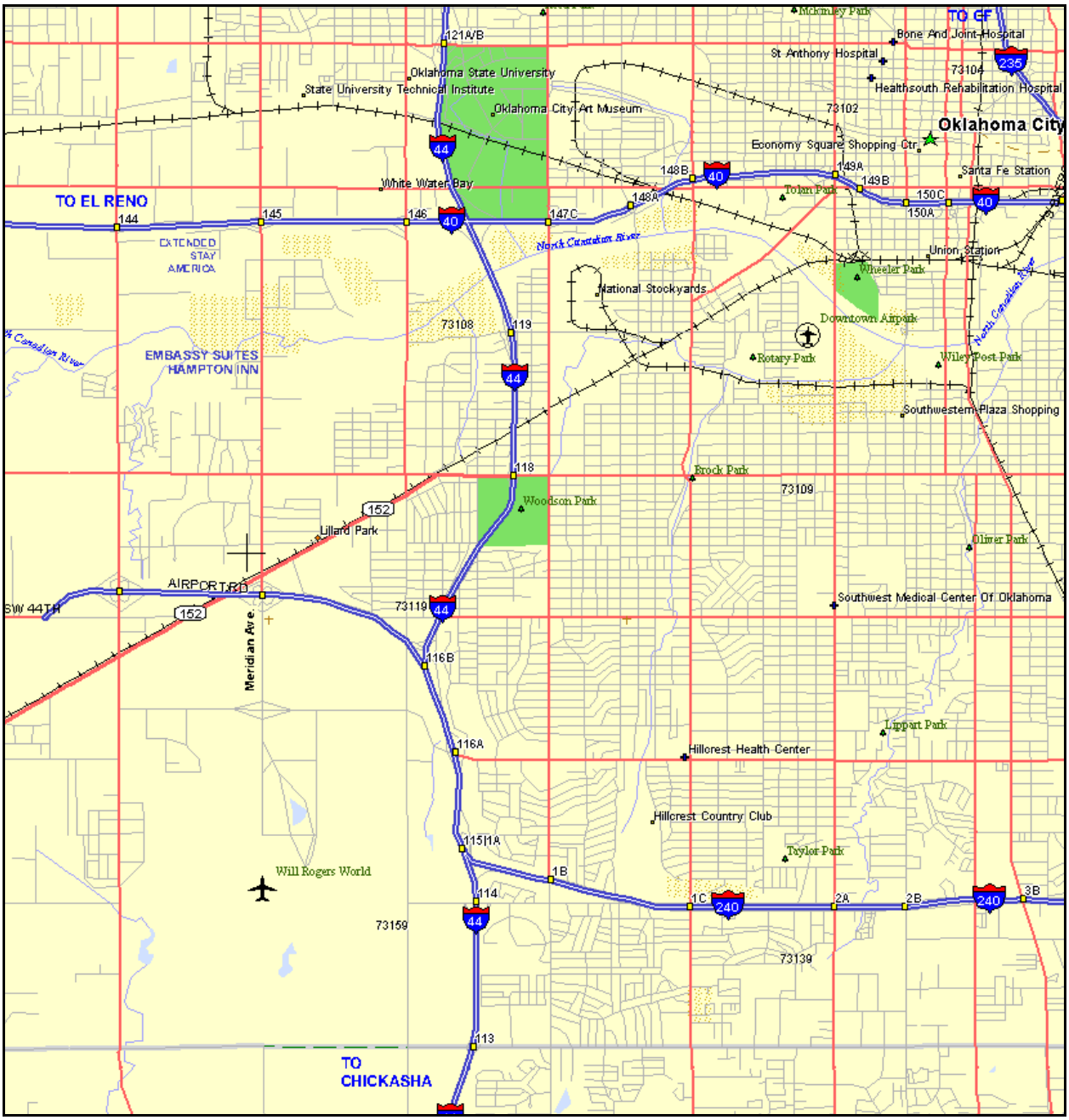

Figure 18. Map of the Oklahoma City Area

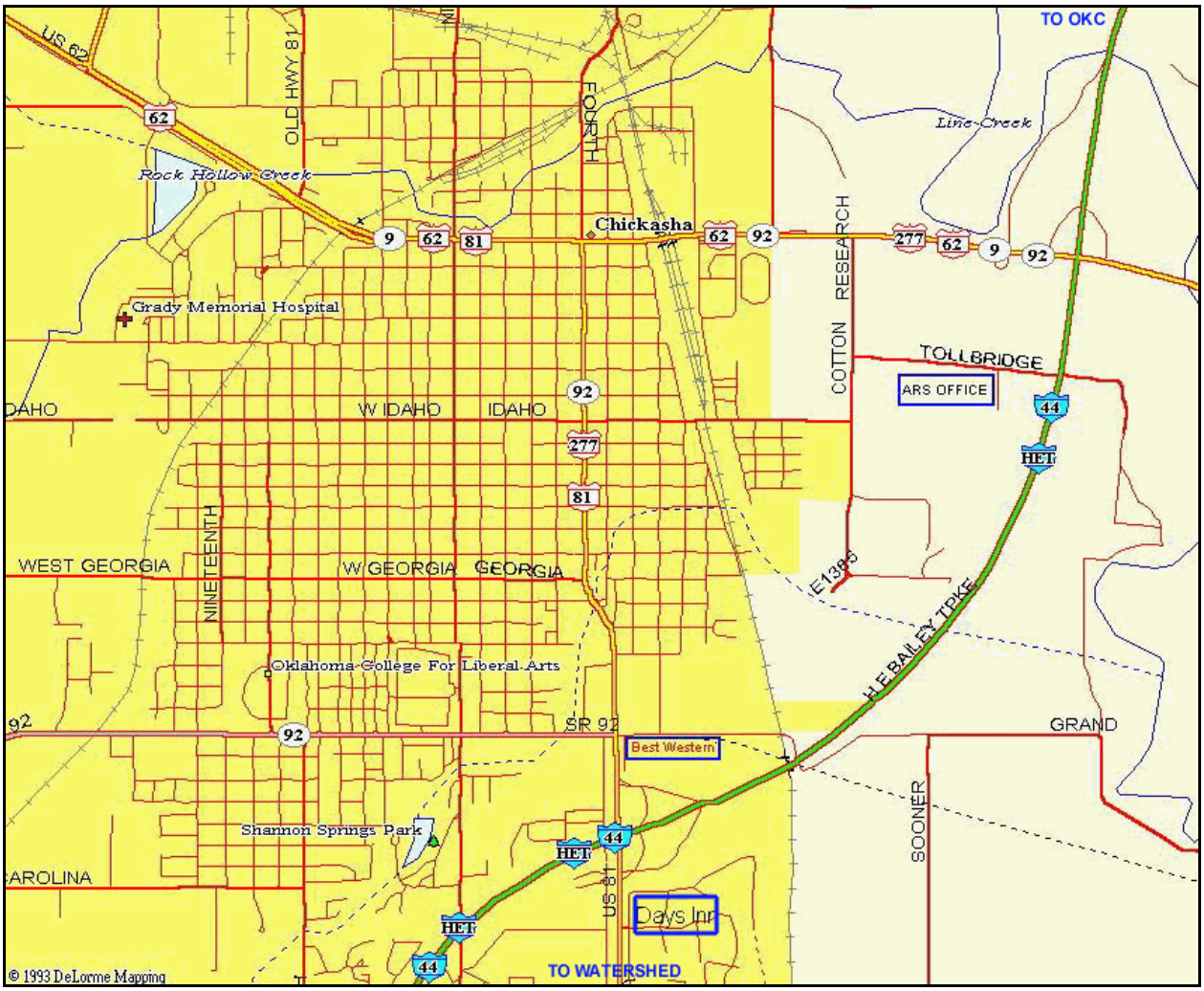

Figure 19. Map of the Chickasha Area

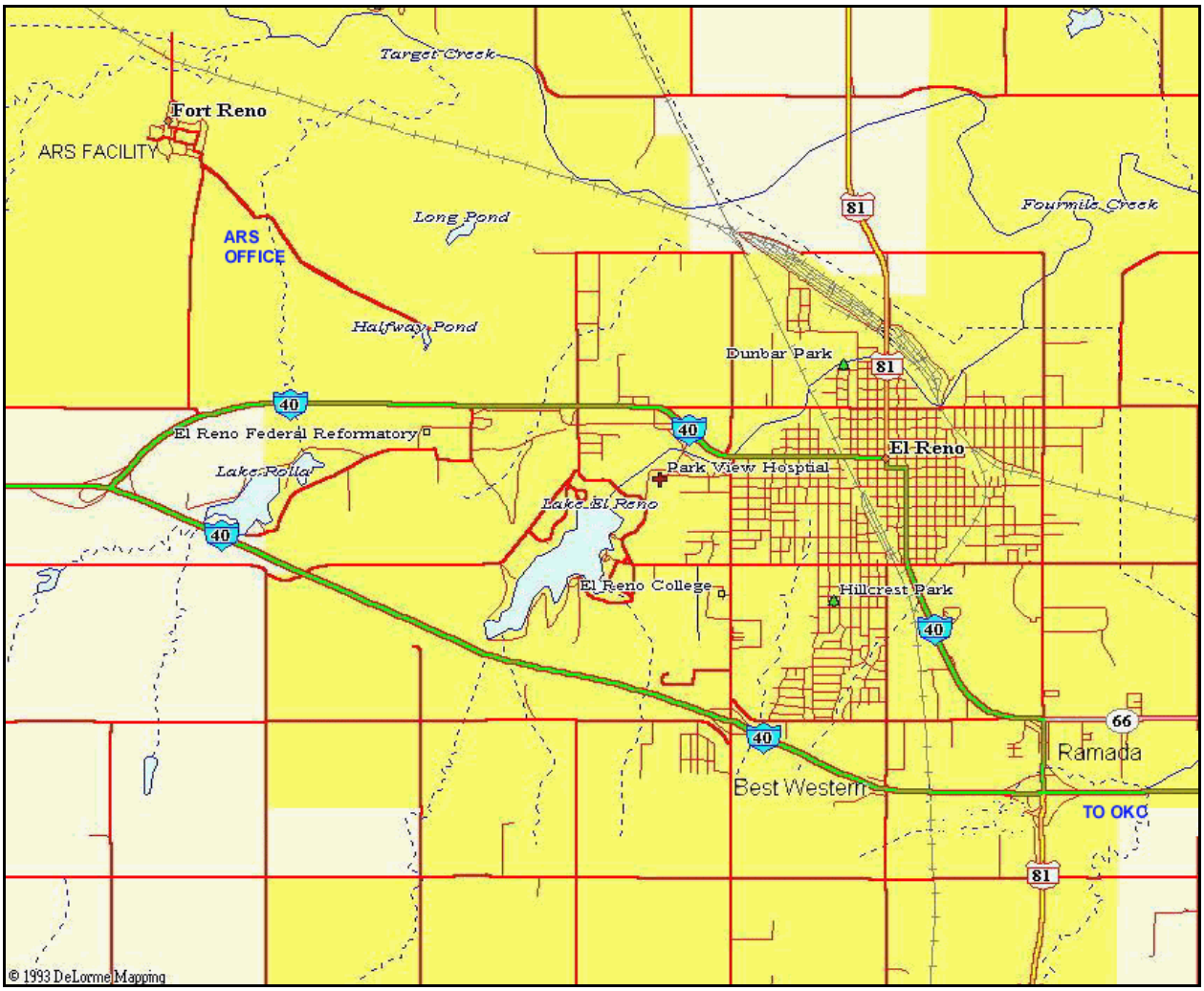

Figure 20. Map of the El Reno Area

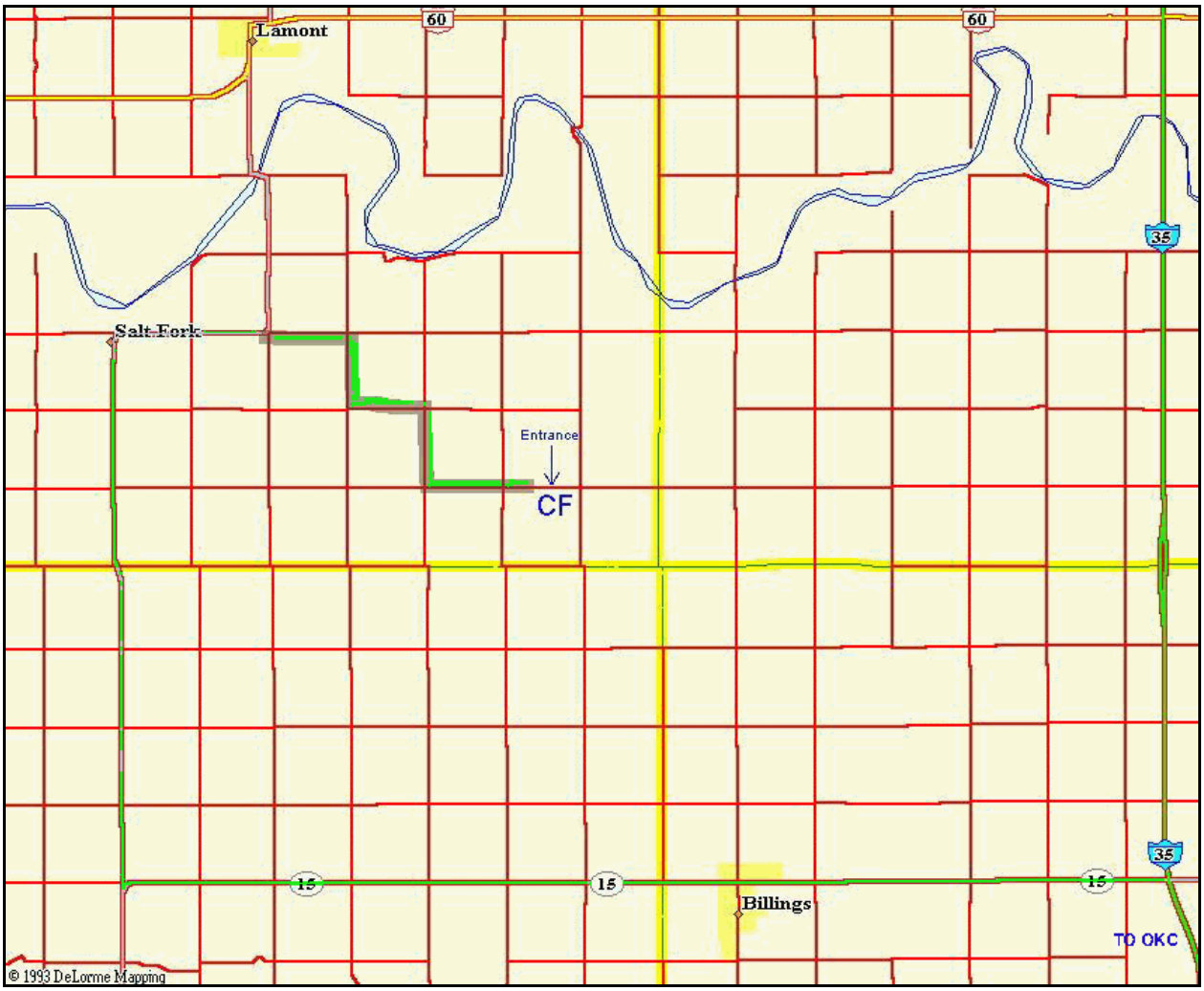

Figure 21. Map of the Central Facility Area

11. PARTICIPANTS

Table 14. SGP99 List of Participants						
	Name	Affiliation	Phone	Email	Location	Activity
Jackson	Tom	USDA HL	301-504-8511	Tjackson@hydrolab.arsusda.gov	ES	P3-B, C-130
Njoku	Eni	JPL	818-354-3693	eni.g.njoku@jpl.nasa.gov	ES	C-130
Wilson	Bill	JPL	818-354-5699	william.j.wilson @jpl.nasa.gov	ES	C-130
Yueh	Simon	JPL	818-354-3012	simon.h.yueh@jpl.nasa.gov	ES	C-130
Dinardo	Steve	JPL	818-354-4212	steven.j.dinardo@jpl.nasa.gov	ES	C-130
Saatchi	Sasan	JPL	818-354-1051	sasan.s.saatchi@jpl.nasa.gov	ES	C-130
Latham	Barron	JPL	818-354-4722	barron.v.latham@jpl.nasa.gov	ES	C-130
NCAR	TBD	NCAR			ES	C-130
NCAR	TBD	NCAR			ES	C-130
NCAR	TBD	NCAR			ES	C-130
NCAR	TBD	NCAR			ES	C-130
NCAR	TBD	NCAR			ES	C-130
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