



Soil Moisture Active Passive Validation Experiment 2016- Iowa (SMAPVEX16-IA) Experiment Plan



Iowa Landscape July 2014

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Table of Contents

1. Introduction	8
1.1. Role of Field Campaigns in SMAP Cal/Val.....	8
1.2. Science Objectives for a Post-Launch SMAP Aircraft-Based Field Campaign.....	9
1.2.1. <i>Investigate and resolve anomalous observations and products</i>	9
1.2.2. <i>Improving up-scaling functions for CVS</i>	10
1.2.3. <i>Contribution to a broader scientific/application objective</i>	10
1.2.4. <i>Validate the L2SMAP algorithm process: pending new directions</i>	13
2. SMAPVEX16 Aircraft Experiment Concept	13
3. South Fork (SF), Iowa Study Area	13
3.1. General Description	13
3.2. Land Cover/Vegetation	14
3.3. Soils.....	15
3.4. Climate	16
3.5. Soil Moisture Network.....	16
4. Flux Towers in Central Iowa.....	20
5. SMAP Validation Grids	21
6. Aircraft Experiment Design	22
6.1. PALS Instrument and Aircraft Description.....	22
6.2. Flight Lines and Flight Plans.....	22
7. Ground-based Sampling	25
7.1. Soil Moisture	25
7.1.1. <i>Temporary Network</i>	25
7.1.2. <i>Soil Moisture Rover</i>	26
7.1.3. <i>High Density Gravimetric Sampling</i>	27
7.3. Vegetation.....	28
7.3.1. <i>Vegetation Communities and Sites</i>	29
7.3.2. <i>Overall Protocol For Each Site</i>	29
8. Precipitation Characterization	30
9. Ground-based Microwave Observations	33
9.1. Field Setup.....	33
9.2. Sensors	34
9.2.1. <i>University of Florida L-band Microwave Radiometer (UFLMR)</i>	34
9.2.2. <i>University of Michigan L-band Microwave Radiometer (UMLMR)</i>	36
9.2.3. <i>University of Florida Radar System</i>	39
9.2.4. <i>Thermal Infrared Sensor</i>	41
9.2.5. <i>Soil Temperature Probes</i>	41
9.2.6. <i>Soil Moisture Probes</i>	42
9.2.7. <i>Precipitation</i>	43
9.2.8. <i>Air Temperature and Relative Humidity</i>	43
9.2.9. <i>Net Radiometer</i>	43
9.3. Vegetation Sampling.....	44
9.3.1. <i>Vegetation Sampling at the Corn Site</i>	44
9.3.2. <i>Vegetation Sampling at the Soybean Site</i>	44
10. Satellites and Overpass Schedules	46
10.1. SMAP and Other Passive Microwave Satellites.....	46

10.2. Radar Satellites	47
10.2.1. RADARSAT2	47
10.2.2. Sentinel 1.....	50
11. CFIS	54
12. Security.....	56
13. Safety.....	56
13.1. General Field Safety.....	56
13.2. Ticks.....	58
13.3. Drying Ovens.....	58
13.4. Driving	58
13.5. Lightning	58
13.6. Medical.....	58
14. Logistics	60
14.1. Hotels	60
14.2. Directions from the Des Moines Airport to Ames.....	60
14.3. Local Contacts	62
14.4. Shipping Address	63
15. Protocols.....	64
15.1. Watershed Site Surface Soil Moisture and Temperature	64
15.2. Regional Site Surface Soil Moisture and Temperature.....	67
15.3. Theta Probe Soil Moisture Sampling and Processing.....	69
15.4. Gravimetric Soil Moisture Sampling with the Scoop Tool.....	75
15.5. Gravimetric Soil Moisture Sample Processing.....	77
15.5.1. Wet Weight Procedure.....	77
15.5.2. Dry Weight Procedure.....	77
15.5.3. Data Processing	77
15.6. Watershed Site Soil Bulk Density and Surface Roughness	78
15.6.1. Securing the Apparatus to the Ground.....	78
15.6.2. Leveling the Apparatus Horizontally to the Ground.....	79
15.6.3. Determining the Volume from the Ground to the Hook Gauge	79
15.6.4. Finding the Volume of the Hole	80
15.6.5. Calculating the Bulk Density of the Sample	80
15.7. Soil Temperature Probes	82
15.8. Infrared Surface Temperature.....	83
15.9. Hydra Probe Soil Moisture and Apogee Temperature Sensor Installations.....	83
15.9.1. Selecting a Location for the HP.....	84
15.9.2. Installation of the HP	84
15.10. Vegetation Sampling.....	85
15.11. Digital Photographs of Vegetation.....	89
15.12. Plant Height	89
15.13. Plant Count	89
15.14. Stand Density.....	89
15.15. Leaf Density	89
15.16. Phenology	89
15.17. Green and Dry Biomass	91
15.18. Physical Sampling of Canopy/Leaf Wetness	91

15.19. Ground Surface Reflectance	92
15.20. Leaf Surface Area	98
15.21. Leaf Area Index	99
15.22. Global Positioning System (GPS) Coordinates	104
16. SMAPVEX16 Bibliography/References	109

List of Figures

Figure 1: L2SMP results for the Sout Fork (Iowa) Core Validation Site	10
Figure 2: OCO-2 overpasses during SMAPVEX16-IA	11
Figure 3: Location of South Fork Experimental Watershed	14
Figure 4: Vegetation water content of corn and soybeans over the growing season near Ames, IA from SMEX02 (Jackson et al. 2004).	15
Figure 5: SMAP Core Validation Sites and Validation Grids in the SMAPVEX15 Domain.....	21
Figure 6. The PALS instrument mounted on the DC-3	22
Figure 7. SMAPVEX16 PALS Flightlines on Google Earth (the high altitude mapping lines are marked with orange and the low altitude high resolution lines are marked with light blue). Also shown is the 36-km validation grid (yellow) and permanent in situ soil moisture stations.	24
Figure 8: Examples of temporary stations installed with a solar panel and CR206 logger. A Stevens Hydra Probe is installed at a depth of 5 cm to mimic the long term in situ station.	26
Figure 9: Soil Moisture Rover from the University Nebraska-Lincoln (UNL).....	26
Figure 10: Map of proposed rainfall instrumentation deployment. Blue and green symbols indicate existing precipitation and soil moisture gauges in the SFEW. Red radar icons show tentative locations of the X-band radars with the corresponding range of 40 kilometers. The large arc is 100 km range from the Des Moines KDMX radar.....	32
Figure 11: Sensor layout at the corn and soybean field sits at the D. Sweeney Farm	34
Figure 12 (a) The UFLMR system, (b) the side view of the UFLMR showing the rotary system, and (c) the front view of the UFLMR showing the receiver antenna. Credits: J. Casanova, University of Florida	35
Figure 13: Block diagram of UFLMR	37
Figure 14: Block diagram of the University of Florida L-band Microwave Radiometer Credits: Roger De Roo, University of Michigan.....	38
Figure 15: UF-LARS mounted on the 25 m Genie platform. (Inset) Trihedral calibration target made of aluminum with an aperture length of 1.28 m. Credits: Karthik Nagarajan, University of Florida	40
Figure 16: Sub-systems within the UF-LARS.....	41
Figure 17: Sentinel-1 Product Modes	51
Figure 18: Data image comparison between OCO-2 pass near Des Moines IA and the path flown by CFIS on August 16.	55
Figure 19: OCO-2/CFIS comparisons.....	55
Figure 20: McFarland Clinic PC Ames Locations.....	59
Figure 21: Des Moines area map.	60
Figure 22: Iowa State Campus map in Ames, IA.	61
Figure 23: Ames IA map.	62
Figure 24: SMAPVEX16 Field Headquarters	62
Figure 25: Sampling in a row crop field.....	66
Figure 26: sampling in a row crop.	67
Figure 27: Example of the gravimetric soil moisture sampling data sheet.	69
Figure 28: Theta Probe Type 1 (with extension rod).....	70
Figure 29: Theta Probe Type 2.	70

Figure 30: HH2 display	71
Figure 31: How to take a gravimetric soil moisture sample.....	76
Figure 32: How to take a bulk density sample	79
Figure 33: Surface roughness photo.....	81
Figure 34: Pin board to be used for surface roughness measurements.	82
Figure 35: Temperature Probe	82
Figure 36: The Hydra probe used at the tower locations.	84
Figure 37: Theoretical sampling design for a ¼ section field in SMEX05.....	88
Figure 38: CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm).....	93
Figure 39: Cropscan data logger controller & cable adapter box.	95
Figure 40: CT100 hand terminal.....	96
Figure 41: The LAI-2000 instrument.....	99

List of Tables

Table 1: SMAP Cal/Val methodologies for L2-L4 Products	8
Table 2: Soil moisture permanent network locations.....	18
Table 3: Locations of temporary soil moisture stations during SMAPVEX16.....	19
Table 4: Eddy covariance sites to be utilized in the experimental campaign.....	20
Table 5: PALS description	22
Table 6. Geometric features of PALS data acquisitions.	23
Table 7: PALS flight line locations for the entire domain	24
Table 8: Technical specifications of a typical unit in the Iowa XPOL radar system.....	31
Table 9: UFLMR Specifications.....	35
Table 10: UMLMR Specifications.....	38
Table 11: Specifications of the thermal infrared sensor (IRR-PN).....	42
Table 12: Specifications of the CNR-1 net radiometer.....	44
Table 13: Passive Microwave Coverage of the Study Domain	46
Table 14: Radarsat2 Standard Mode Parameters.....	48
Table 15: Radarsat 2 Wide Fine QuadPol mode parameters.....	48
Table 16: Radarsat2 Coverage of the Iowa Study Domain	49
Table 17: Sentinel-1a Coverage of the Iowa Study Domain	53

1. Introduction

Field campaigns are a very important component of the process of validating satellite-based geophysical products. They can also strengthen collaboration within and across disciplines that can answer broader science questions. The primary driver for SMAPVEX16 is to address specific issues identified during the first year of SMAP post-launch validation. The top priority will be to contribute to improving the soil moisture algorithms. In addition, it will also include a combined SMAP-OCO2 component.

This introductory section includes the background on the science objectives that led to the experiment design. Data collection details and sampling protocols are described in latter sections.

1.1. Role of Field Campaigns in SMAP Cal/Val

The Soil Moisture Active Passive (SMAP) mission currently provides Level 2 to 4 soil moisture products derived from its L-band passive microwave radiometer. Due to aggressive efforts to mitigate radio frequency interference, the accuracy and temporal and spatial coverage of the passive-based soil moisture products have been very good (Chan et al. 2016). Following the loss of its radar that was to provide a higher resolution soil moisture product, SMAP is currently exploring a suite of approaches to enhance the spatial resolution of the soil moisture products. These include combining active observations from the European Space Agency (ESA) Sentinel 1 radars with the SMAP passive radiometer.

The SMAP post-launch Cal/Val activities are intended both to assess the quality of the mission products and to support analyses that lead to their improvement. A suite of complementary methodologies is being employed (**Error! Reference source not found.**) that will result in a robust global assessment. Beyond the in-orbit checkout (IOC) (launch + 3 months), the first year of operations focused on assessing the products. However, Cal/Val is an activity that continues throughout the mission life, and some anomalies and poor performance issues were identified that would require intensive efforts to resolve.

As noted in **Error! Reference source not found.**, field campaigns are intended to provide detailed information about targeted Cal/Val sites. It is recognized that only a limited number of field campaigns can be conducted due to their cost and the extensive logistics and human resources required (especially if airborne instruments are involved). It should also be noted that data latency is expected in these campaigns because they are typically one-of-a-kind efforts. In planning post-launch Cal/Val activities it is important that airborne instruments in field campaigns are linked with objectives that can only be addressed using airborne systems.

Table 1: SMAP Cal/Val methodologies for L2-L4 Products

Methodology	Role
Core Validation Sites	Accurate estimates of products at matching scales for a limited set of conditions
Sparse Networks	One point in the grid cell for a wide range of conditions
Satellite Products	Estimates over a very wide range of conditions at matching scales
Model Products	Estimates over a very wide range of conditions at matching scales
Field Campaigns	Detailed estimates for a very limited set of conditions

1.2. Science Objectives for a Post-Launch SMAP Aircraft-Based Field Campaign

Summarizing from above, post-launch Cal/Val of SMAP involves the assessment of products and improving the performance of the algorithms. The SMAP Project Science Team (ST) and the Cal/Val Working Group provide guidance to the Cal/Val activities of SMAP. Over the course of several meetings and workshops a consensus on priorities has been developed on what field campaigns can and should address. The following is a list of science issues that can only be addressed using an aircraft-based campaign

- Investigate and resolve anomalous observations and products
- Improve the up-scaling functions for CVS
- Contribute to a broader science/application objective
- Validate the L2_SM_AP algorithm process: pending new directions
- Understand the effects and contribution of heterogeneity on coarser resolution retrievals
- Evaluate the impact of known RFI sources on retrieval
- Analyze heterogeneity effects on L1 product calibration

For SMAPVEX16 the focus will be on item a. It is also expected that it will contribute to items b-d. Further details on the specific contributions follow.

1.2.1. Investigate and resolve anomalous observations and products

The beta-release assessment of the L2SMP (Chan et al. 2016) revealed that while the overall performance was quite good, there were some CVS with very large errors. These were the agricultural sites; South Fork (Iowa) and Carman (Manitoba). In addition, comparison of SMAP and SMOS global products indicated very different results over dense forest regions. Although SMAP produces a flagged retrieval for forest land cover, it is currently not a mission requirement. Therefore, for 2016 the priority will be to improve the retrieval at these agricultural sites. Efforts (and experiment plans) are being provided separately for the two sites. Approaches and protocols will be coordinated to the degree it is possible. This experiment plan is for South Fork, Iowa (SMAPVEX16-IA). The Carman, Manitoba component is designated SMAPVEX16-MB.

For the South Fork site the comparison of the up-scaled in situ data and the SMAP retrievals shows large error and an underestimation bias (**Error! Reference source not found.**). This includes a period in April-May when there are nominal bare soil conditions, suggesting that surface roughness may be responsible. Anomalous behavior is also noted in late August-early September where the SMAP retrievals do not change in response to precipitation as do the in situ measurements.

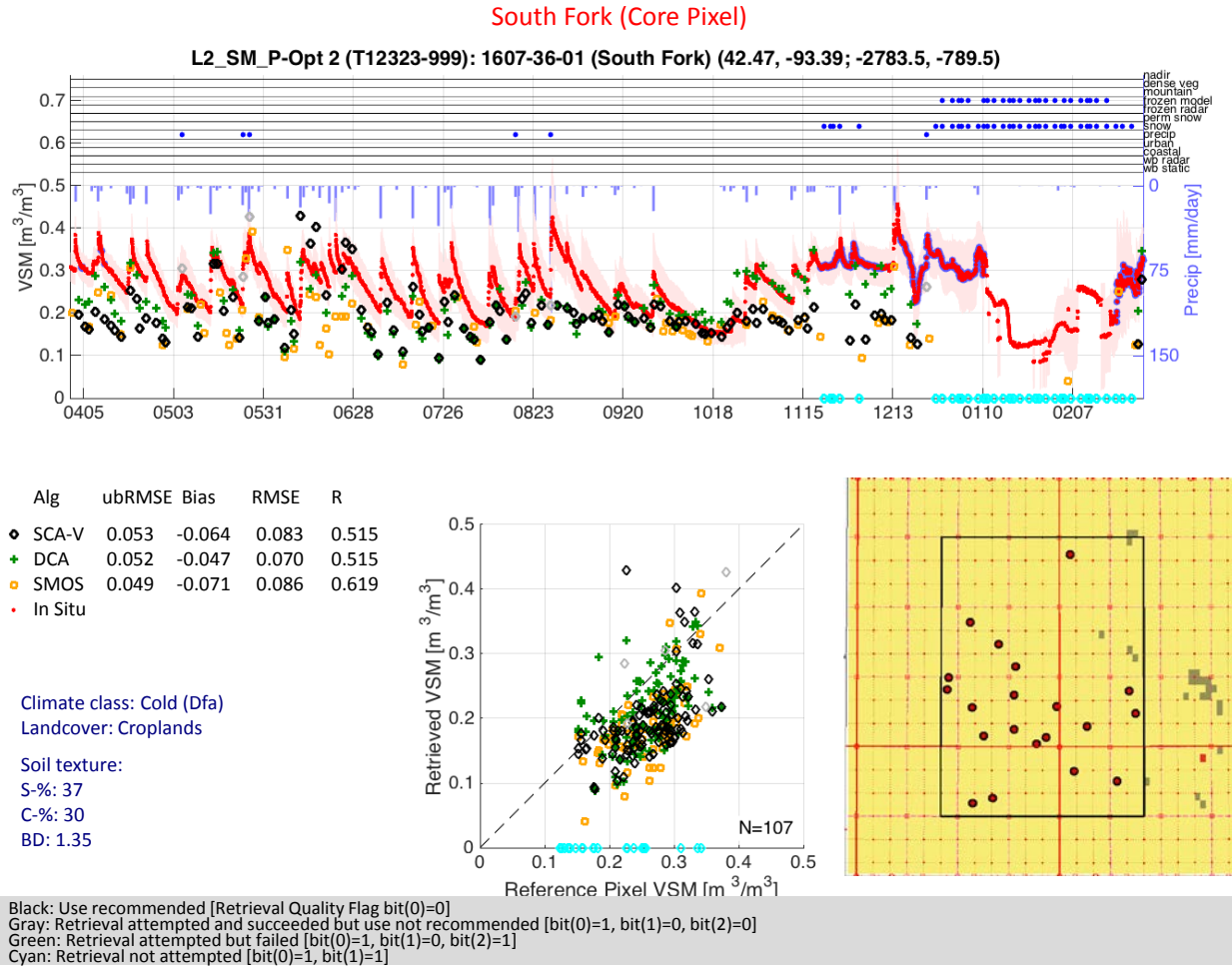


Figure 1: L2SMP results for the Sout Fork (Iowa) Core Validation Site

For SMAPVEX16-IA satellite, aircraft and ground sampling will be conducted during two intensive observing periods (IOPs). These will be bridged with temporary stations and tower-based radiometer/radar observations.

1.2.2. Improving up-scaling functions for CVS

SMAP utilizes a standard procedure for up-scaling the distributed in situ observations to the gridded product. This is based on Thiessen Polygons. There are several approaches that can be used to improve this process that include field campaigns involving more sampling points. SMAPVEX16 will incorporate this approach.

1.2.3. Contribution to a broader scientific/application objective

For SMAPVEX16-IA, the field campaign will be coordinated with validation activities of two other NASA missions; the Orbital Carbon Observatory-2 (OCO-2) and the Global Precipitation Mission (GPM).

1.2.3.1. OCO-2

The Chlorophyll Fluorescence Imaging Spectrometer (CFIS), built for OCO-2 validation and Solar Induced Chlorophyll Fluorescence (SIF) regional studies, will be flying on the Twin Otter during the SMAPVEX16 campaign. The flight campaign (Figure 2) will cover the wider South Fork area, as well as dedicated flight lines covering as many of the flux towers as possible. Targeting the quantification of the impact of water stress on plant productivity, we will repeat flight patterns multiple times per day and generate maps of Solar Induced Chlorophyll Fluorescence at the 10-40m resolution. Most flight will be performed at 10,000 feet elevation, with a swath width of about 600m. Depending on the exact dates of flight (weather permitting) and we adhere to the planned schedule, there will be two (2) OCO-2 overpasses (one in Nadir and one in Glint) during the near 2 week window.

Satellites Overpasses at South Fork, IA 2016

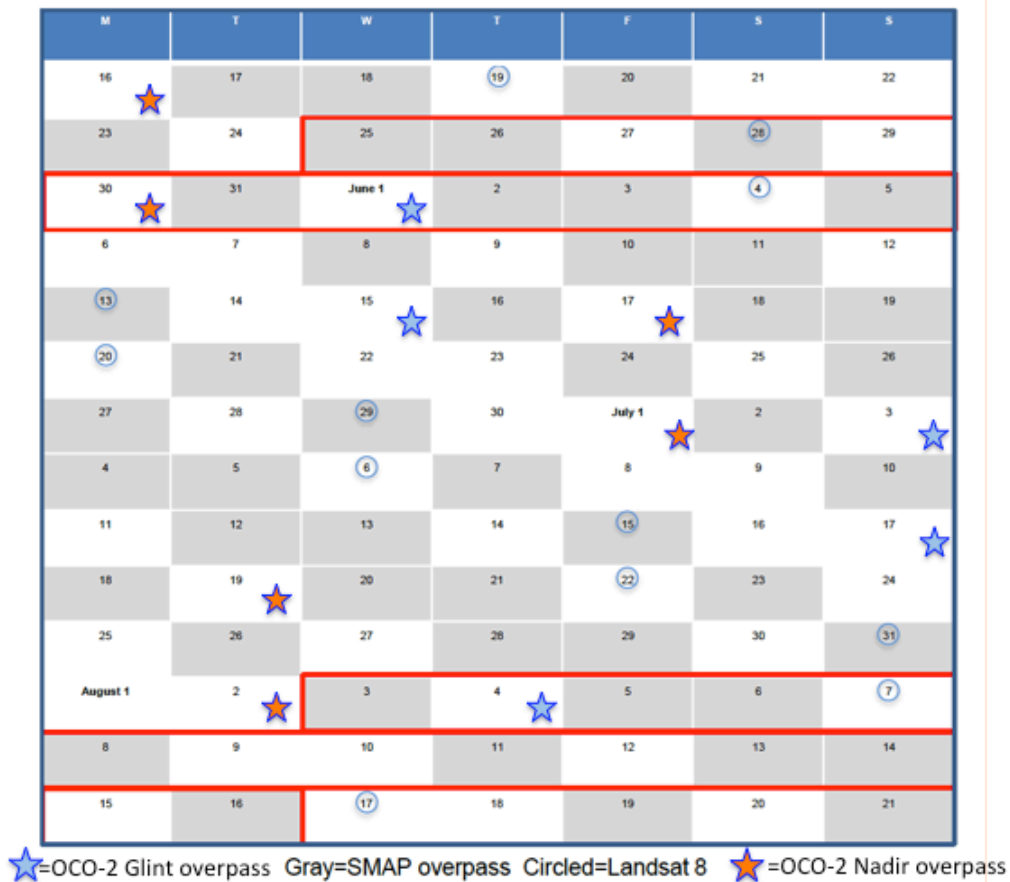


Figure 2: OCO-2 overpasses during SMAPVEX16-IA

CFIS is a high resolution imaging spectrometer, covering the 731-780nm spectral range at <0.1nm resolution. In addition, we will attached a Headwall VIS imager, enabling reflectance measurements in the 300-1000nm spectral range, which will allow retrievals of vegetation properties such as Chlorophyll Content, Leaf Area Index (LAI) and well as Photochemical Reflectance Index (PRI), an additional useful tool to evaluate stress conditions during different overpass times. The combination of Flux towers, soil moisture measurements and SIF will

provide an unprecedented dataset with which we can test synergies between SMAP and OCO-2 and help quantify drought-related reductions in plant productivity.

1.2.3.2. Validation of Global Precipitation Mission (GPM) Products

The GPM Ground Validation (GV) Program includes post-launch evaluation of the accuracy and utility of GPM data products for hydrologic applications. Targeted questions that have been identified will address both the enhancement of GPM retrieval accuracy in semi-arid environments and the utility of GPM observations for water resource applications. These activities will benefit greatly from the simultaneous acquisition of ground-, airborne- and satellite-based soil moisture data products during SMAPVEX16. Applications of satellite-based rainfall to hydrologic applications require rainfall-runoff models. The models need to be constrained and remote sensing soil moisture products provide this function.

From the point of view of GPM Ground Validation objectives, the SMAP campaign will provide:

1. High quality, high-resolution, spatially-distributed maps of rainfall rate over the South Fork basin and the surrounding region and collected in conjunction with GPM overpasses. The rain maps will serve as a direct validation dataset for GPM level II and level III products, a means to assess the spatial variability of rainfall and its impact on GPM measurement uncertainties, and as independent validation/verification of Multi-Radar Multi-Sensor Level II/III GV products.
2. Complementary and coupled high quality ground, airborne and satellite measurements of soil moisture and land surface parameters over the South Fork Basin. This multi-scale dataset combined with stream flow data will provide a robust dataset for integrated hydrologic validation of GPM (and potentially, SMAP) products to include testing of water and energy budget closure, GPM product utility in flood modeling, and evaluation of land-surface emission models used in GPM algorithms.
3. Highly resolved vertical structure information on precipitation rates and types during horizon-to-horizon RHI radar scans collected along/during GPM overpasses.

1.2.3.3. Validation of Calibration-Free Hydrologic Models

SMAPVEX16-IA presents unique opportunity to evaluate ability of the distributed hydrologic models to provide skillful prediction of streamflow without relying on model calibration. The Iowa Flood Center (IFC) operates state-wide distributed model that provides streamflow prediction everywhere in the state in real time and updated every 15 minutes. The model is data intensive and highly distributed. Its conceptual basis is in landscape decomposition into hillslopes and channel links. Rainfall conversion to runoff takes place at the hillslopes and water transport takes places in the stream and river network. The model uses hillslope attributes in terms of geometry, land use, and soil type. Model states include water storage on and below the surface. As the model is not calibrated, it is of scientific interest to evaluate its ability to estimate soil moisture by comparison with ground reference products provided during the campaign as well as with air-borne and space-borne remote sensing products.

1.2.4. Validate the L2SMAP algorithm process: pending new directions

As noted above, SMAP is exploring new approaches to disaggregating the passive-based products to provide higher resolution soil moisture. SMAPVEX16 will be a testbed for these ideas. The SMAP project is currently implementing two products that utilize Sentinel 1a (and potentially 1b) C-band radar data. These will be 3 km and 9 km gridded products.

The SMAP Cal/Val program provides in situ, satellite, and model products that can be used to validate the soil moisture products. However, none of these resources can validate the entire L2SMAP retrieval process (disaggregation and retrieval) on a L2SMP basis. Using an aircraft-based radiometer to provide coverage of SMAP 3 and 9 km data cells is the only way to validate this critical component of the mission. Validating the disaggregation approach and the SM at 9 km will provide increased confidence in the product and/or insights that can be implemented to improve the algorithm.

The validation data sets generated in SMAPVEX16, in particular the maps of soil moisture provided by the aircraft can also be used to evaluate other approaches that can be used for disaggregation, such as those based on thermal and optical data.

2. SMAPVEX16 Aircraft Experiment Concept

The basic design calls for flights over the L2SMP validation grid cell at the CVS. A key requirement of the experiment is higher spatial resolution L-band brightness temperature (TB) coverage of the entire site that can be used to generate TB values for the L2SMAP (9 km and 3 km). The SMAP L2SMP algorithm(s) would be used with this data to generate SM products at both spatial resolutions using the ground sampling to validate the higher spatial resolution retrievals. A variety of soil moisture and vegetation conditions are needed for a robust analysis. Therefore, flights will be conducted over two IOPs at each of the two domains (IA and MB). One IOP will be early in the growing season and the other during Maximum biomass. Aircraft flights will be focused on the SMAP morning overpasses.

Based upon the justification provided, an aircraft-based passive instrument is an essential requirement since it is the only means by which the process of brightness temperature disaggregation can be assessed.

The aircraft based radiometer must be capable of providing coverage of an entire SMAP L2SMP grid cell within ~3 hours in order to minimize diurnal temperature and soil profile variability effects. Spatial resolution of 3 km or better is desirable if all objectives are to be satisfied. The instrument must be stable during flights and well calibrated.

The incidence angle should be centered at 40 degrees and the beam width should be as small as possible considering all other constraints. The antenna pattern should be well known.

For SMAPVEX16 the well-established Passive Active L-band System (PALS) will be utilized (Colliander et al., 2015). It was converted to a scanner that will be capable of meeting the experiment requirement. Details are provided in later sections.

3. South Fork (SF), Iowa Study Area

3.1. General Description

The core of the study area is the USDA-ARS South Fork Experimental Watershed (SF), which encompasses the 350 square kilometers in northern central Iowa, U.S.A. (degrees) that

surrounds the town of Iowa Falls. The watershed is contained within the Red River Basin, which encompasses 7600 square kilometers in the northern plains of the U.S. (Figure 3). The watershed is representative of approximately 60 million hectares of agricultural cropland in central and northern U.S. Elevation of the watershed ranges from 1250 m to 1585 m MSL. Corn and soybeans are the primary crops, with some new development of canola and pasture/grassland for the increasing prominence of hog farming.

South fork was included in the Soil Moisture Experiments in 2002 (SMEX02) and 2005 (SMEX05) (Bindlish, et al. 2006); (Jackson, 2005)). These were primarily focused on the Walnut Creek watershed south of Ames, IA, but included regional flights, which covered portions of the South Fork region. In 2013, a network of soil moisture/soil temperature/precipitation sensors were deployed in a semi-permanent status as part of the IFLOODS study (Coopersmith, et al. 2015). In addition, a campaign of network calibration was conducted in the summer of 2014 with teams of students sampling soil moisture bi-weekly through the growing season to provide an estimate of the representativeness of the permanent network.

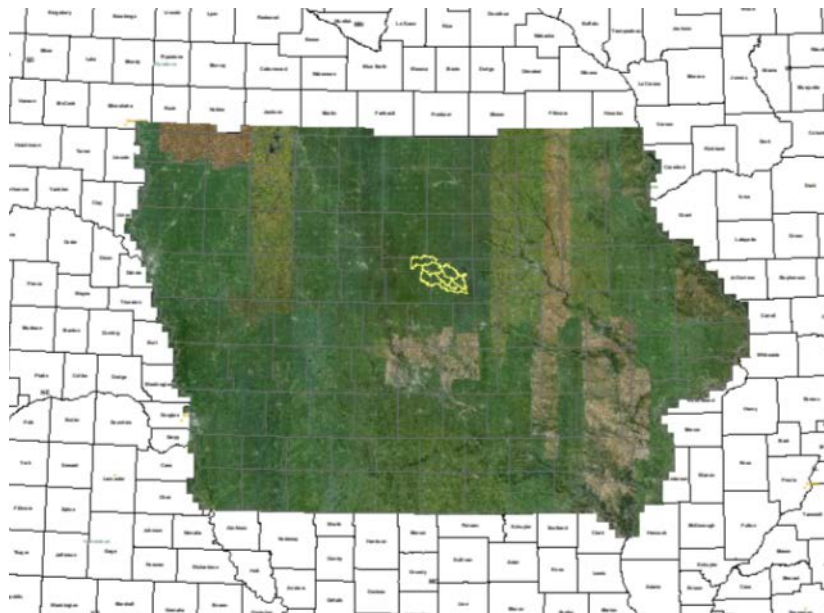


Figure 3: Location of South Fork Experimental Watershed

3.2. *Land Cover/Vegetation*

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 (Doraiswamy et al., 2004). Vegetation water content of corn and soybeans over the growing season near Ames, IA from SMEX02 (Jackson et al. 2004). shows a temporal series of vegetation water content from SMEX02.

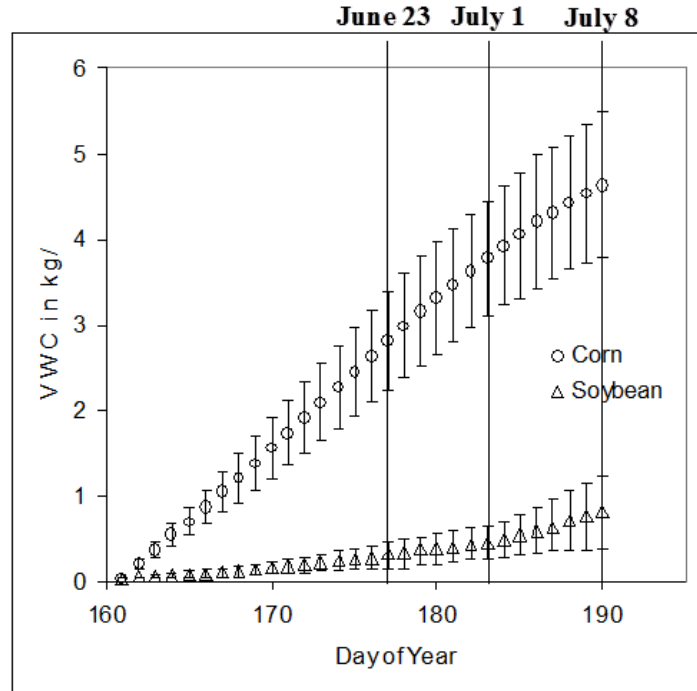


Figure 4: Vegetation water content of corn and soybeans over the growing season near Ames, IA from SMEX02 (Jackson et al. 2004).

3.3. Soils

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

The area around central Iowa is considered the pothole region of Iowa because of the undulating terrain. This area on the Des Moines lobe represents the youngest of soils in the United States. Two features stand out 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>.

3.4. *Climate*

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

3.5. *Soil Moisture Network*

The South Fork Experimental Watershed consists of 20 soil moisture/precipitation systems with some additional measurements at various sites (Table 2 and Figure 5). Fifteen sites operated by USDA have Stevens Water Hydra Probes installed at 5, 10, 20, and 50 cm recording hourly soil moisture and soil temperature information and have two precipitation gages (TE525 and MetOne380). Five additional sites are operated by NASA/University of Iowa with soil moisture and temperature recorded by Campbell Scientific 655 sensors at 5, 10, 20, and 50 cm. An additional 40 temporary soil moisture stations will be deployed within the agricultural fields near the permanent stations and other less monitored regions to provide greater coverage (Table 3). These will consist of singular hydra probes at 5 cm, recording hourly soil moisture and soil temperature.

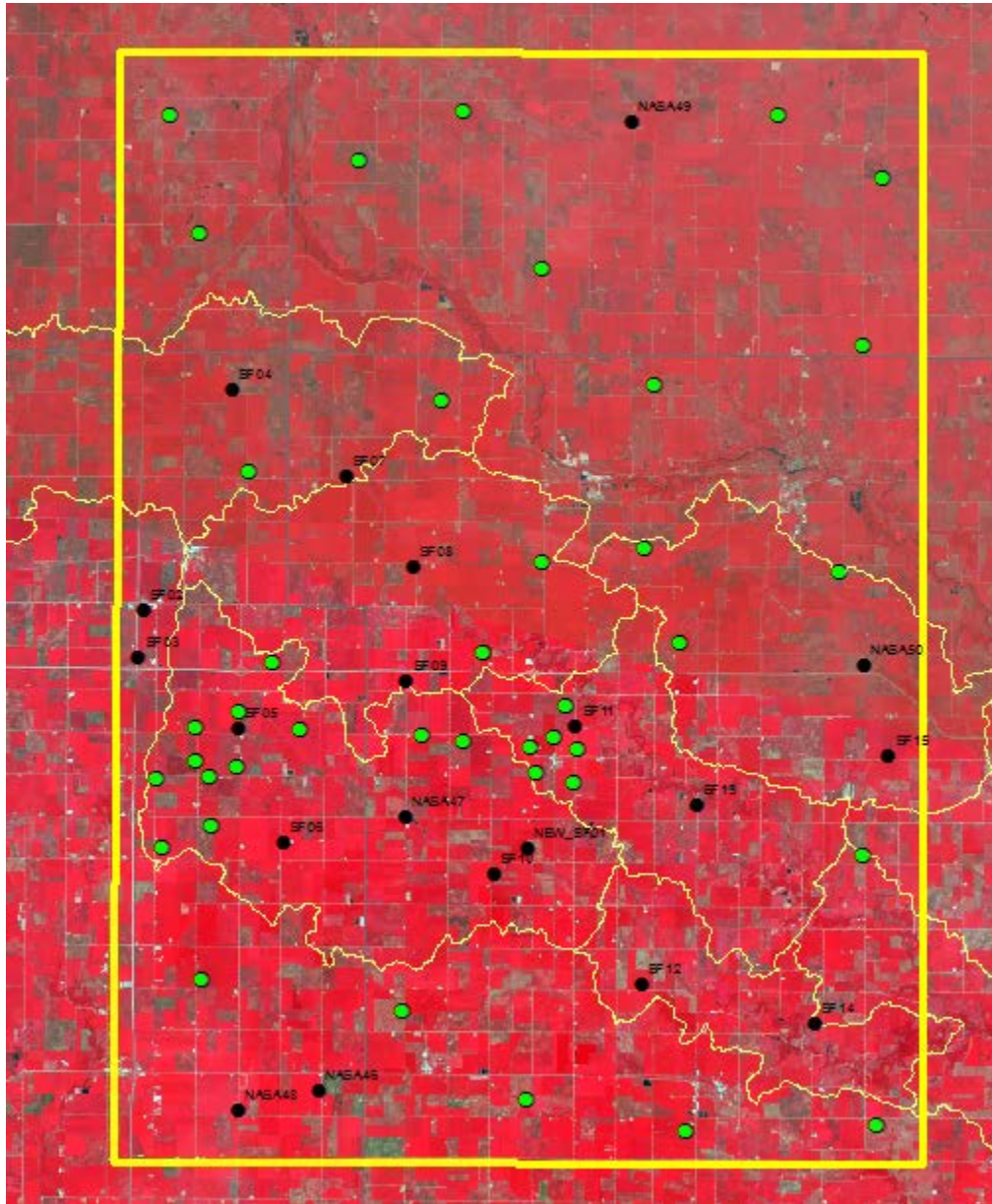


Figure 5: Distribution of Soil Moisture Stations in the SMAPVEX16-IA Validation Grid Domain.

Table 2: Soil moisture permanent network locations

Site ID	Latitude	Longitude
SF01	42.388	-93.386
SF02	42.4693	-93.5655
SF03	42.45296	-93.568
SF04	42.54459	-93.5253
SF05	42.42857	-93.5216
SF06	42.3896	-93.5001
SF07	42.51501	-93.4727
SF08	42.48463	-93.4415
SF09	42.44556	-93.4441
SF10	42.37937	-93.4029
SF11	42.42975	-93.366
SF12	42.3414	-93.3342
SF13	42.40318	-93.3097
SF14	42.32831	-93.2549
SF15	42.42034	-93.2208
NA02	42.30485	-93.4836
NA03	42.398868	-93.4443
NA01	42.297846	-93.5206
NA04	42.637269	-93.3412
NA05	42.45126	-93.2324

Table 3: Locations of temporary soil moisture stations during SMAPVEX16

Site ID	Latitude	Longitude
S01	42.29115	-93.3144
S02	42.29342	-93.2266
S03	42.30188	-93.3882
S04	42.33187	-93.4458
S05	42.34245	-93.5385
S06	42.38609	-93.2325
S07	42.38714	-93.5567
S08	42.39512	-93.5339
S09	42.41032	-93.3669
S10	42.41129	-93.56
S11	42.41174	-93.5349
S12	42.41407	-93.3846
S13	42.41524	-93.5223
S14	42.4174	-93.5417
S15	42.42221	-93.365
S16	42.42251	-93.3865
S17	42.42451	-93.4176
S18	42.42583	-93.3764
S19	42.42669	-93.4373
S20	42.42813	-93.4933
S21	42.42861	-93.542
S22	42.43391	-93.5216
S23	42.43651	-93.3705
S24	42.45123	-93.5061
S25	42.45473	-93.4088
S26	42.45877	-93.3181
S27	42.48318	-93.2438
S28	42.48612	-93.3819
S29	42.4906	-93.3346
S30	42.51665	-93.5175
S31	42.5413	-93.4291
S32	42.54676	-93.3301
S33	42.56052	-93.2333
S34	42.5868	-93.3822
S35	42.59787	-93.5419
S36	42.61801	-93.2243
S37	42.6233	-93.4677
S38	42.63805	-93.5553
S39	42.63939	-93.2736
S40	42.64027	-93.4193

4. Flux Towers in Central Iowa

SMAP will use data from flux towers from agricultural fields to validate its L4 Carbon Product and the OCO2 observation system. The surface energy balance, which includes measurements of net radiation, soil heat flux, sensible and latent heat flux will be made at multiple tower locations in agricultural fields with one native prairie site in central Iowa. In addition, net carbon exchange and total season evapotranspiration is calculated from the energy balance and carbon flux data.

The flux tower sites have 4-component net radiometers, and multiple soil heat flux plates with soil temperature/moisture sensors for estimating the available energy at the land surface. Carbon, sensible and latent heat fluxes are measured using the eddy covariance (EC) technique (consisting of a sonic anemometer and a fast response open path water vapor/CO₂ sensor). Measurements are made at around 5 m above the local terrain. All data are quality controlled and gap-filled before processing to the final stage.

The surface flux tower names, locations, and descriptions are listed in Table 4. These sites are located in production fields in central Iowa with a flux tower in each crop to provide a comparison between crops within a year. In addition at each site there is a network of soil profile temperature and moisture measurement systems and precipitation observations and a Cosmos station (at the Coles Farm). These sites are all referenced to the central Iowa climate normals for the observation period.

Table 4: Eddy covariance sites to be utilized in the experimental campaign

Site names	Brooks Field (NLAE)	Coles Farm (NLAE)	Sweeney (Beltsville)	Ellingson (JPL System)	Neal Smith Wildlife Preserve
Year eddy covariance measurements started	2000	2016	2008 (growing season only)	2016 (growing season only)	2004
Latitude, longitude	41.967°N, 93.695°W,			42.61 N 93.317 W	41.558°N, 93.290°W
Elevation (m)	315				
Mean air temperature (period of study, °C)	9.02	9.02	9.02	9.02	9.02
Annual precipitation (period of study, mm)	971	971	971	971	971
Ecosystem type	Corn/soybean	Corn/soybean	Corn/soybean	Corn/soybean	Native Prairie

5. SMAP Validation Grids

The scanning radiometer on SMAP provides elliptical footprint observations across the scan. The orientation of this ellipse varies across the swath and on successive passes a point on the ground might be observed with very different azimuth angles. A standard assumption in using radiometer observations is that the signal is dominated by the energy originating within the 3 dB (half-power) footprint (ellipse). The validity of this contributing area assumption will depend upon the heterogeneity of landscape.

A major decision was made for SMAP to resample the radiometer data to an Earth-fixed grid at a resolution of 36 km. This facilitates temporal analyses and the disaggregation algorithm that was to be used for the AP product. It ignores azimuth orientation and some contribution beyond the 3 dB footprints mentioned above, although the SMAP L1B_TB data do include a sidelobe correction. An important point is that TBs on the Earth-fixed 36 km grid are used in the retrieval of soil moisture, and it is the soil moisture for these 36 km grid cells that must be validated and improved.

SMAP provides L2 surface (0-5 cm) soil moisture using the radiometer (passive) data only posted on a 36 km EASE2 Grid.. The standard SMAP were established without any acknowledgement of where the CVS might be located. In addition, the CVS were established in most cases to satisfy other objectives of the Cal/Val Partners. One of the criteria for categorizing a site as a CVS is that the number of individual in situ stations (N) within the site is large (target is $N \geq 9$). It was observed when examining the distribution of points at a site that in many cases only a few points fell in any specific standard grid cell. Therefore, it was decided that special SMAP validation grids (VGs) would be established that would be tied to the existing SMAP 36 km standard Grid but would allow the shifting of the 36 km grids at a site to fully exploit N being as large as possible (i.e, the validation grid would be centered over the collection of in situ points at a given CVS to the extent possible).

Computationally the L2 and L3 VG products are the same as the standard product. The selection of the VGs for each site was done by members of the SMAP Algorithm Development Team and Science Team. As noted, the 36 km grid does not change. The selection of the VGs also considered avoiding or minimizing the effects of land features that were not representative of the sampled domain or were known problems in retrieval (.e.g., nonrepresentative terrain, water bodies, etc.).

Figure 5 shows the validation grid used for the SF CVS.

6. Aircraft Experiment Design

6.1. PALS Instrument and Aircraft Description

The Passive/Active L-band Sensor (PALS) provides radiometer products, vertically and horizontally polarized brightness temperatures, and radar products, normalized radar backscatter cross-section for V- transmit/V-receive, V-transmit/H-receive, H-transmit/H-receive, and H-transmit/V-receive. In addition, it can also provide the polarimetric third Stokes parameter measurement for the radiometer and the complex correlation between any two of the polarized radar echoes (VV, HH, HV and VH). Table 5 provides the key characteristics of PALS. For SMAPVEX16 PALS will be installed on a DC-3 (Figure 6). The PALS will be augmented with additional components designed to detect and mitigate Radio Frequency Interference (RFI).

Table 5: PALS description

Passive/Active L-band System (PALS)		
Platform	DC-3	
Passive	Frequency	1.413 GHz
	Polarizations	V, H, +45, -45 polarizations
	Spatial Resolution	21 degrees (3 dB beamwidth) 1.5 km from 3 km altitude
Active	Frequency	1.26 GHz
	Polarizations	VV, HH, VH, HV
	Spatial Resolution	23 degrees (3 dB beamwidth)
Scan Rate	0-16.7 rpm	
Antenna Type	Microstrip planar antenna with >30 dB polarization isolation	



Figure 6. The PALS instrument mounted on the DC-3

6.2. Flight Lines and Flight Plans

PALS will be mounted at a 40° incidence angle for a 360° conical scanning operation (see Figure 6). The 3dB spatial resolution of the instrument will be $\sim 0.35 \cdot \text{altitude}$ above ground along-scan. As will be discussed below, PALS will acquire data at two elevations during

SMAPVEX16 (Low and High). The lowest elevation that PALS can operate at is determined by the minimum distance for radar data acquisition, which is 1067 m (3500 feet) AGL. The nominal elevation in this region is 305 m (1000 feet) ASL. Flight altitude for the low altitude flights was chosen to be 1200 m (about 4000 feet) AGL i.e. 1505 (about 5000 feet) ASL. The highest flight altitude for SMAPVEX was determined by the maximum where the instrument has operated without any issues (and for not requiring oxygen use by the flight crew); 3350 m (11000 feet) ASL, i.e., 3050 m (10000 feet) AGL. The spatial resolutions at these two flight altitudes are summarized in Table 6.

Table 6. Geometric features of PALS data acquisitions.

Target Altitude (AGL) [m]	Nominal Ground Elevation [m]	ASL [m]	Along Scan Resolution [m]	Across Scan Resolution [m]	Effective Resolution [m]
1200	305	1505	581	777	595
3050	305	3355	1476	1974	1513

The PALS flight lines were designed to satisfy the major objectives of SMAPVEX16. The high altitude lines will map the SMAP grid pixel for investigating SMAP radiometer sub-pixel features. A total of six lines will cover a domain ~31 by 42 km. Lines are spaced ~ 5.3 km apart. The coordinates of the end points are given in Table 7. Low altitude lines will be used to provide high spatial resolution data for fields/sites with homogeneous vegetation conditions. Sampling sites will be located directly within the swath of these lines, to the degree possible. Since the nominal field size in the region is 800 m by 800 m, flying these at the low altitude (Table 6) should provide the data necessary for algorithm development and validation. Three lines were designed and locations are listed in Table 7; they cover a range of agricultural conditions. Figure 7 shows a map of the flight lines with the SMAP 36-km validation grid over the South Fork validation site.

Please note that this plan may change once on site due to local aircraft traffic control, radio frequency interference sources, and refined flight planning to reduce total mission duration.

Table 7: PALS flight line locations for the entire domain

	Altitude AGL	START		STOP	
		Latitude (Deg.)	Longitude (Deg.)	Latitude (Deg.)	Longitude (Deg.)
Take off Dubuque					
SF01	10,000 ft.	42.2803	-93.5492	42.6596	-93.5492
SF02	10,000 ft.	42.6596	-93.4866	42.2803	-93.4866
SF03	10,000 ft.	42.2803	-93.4240	42.6596	-93.4240
SF04	10,000 ft.	42.6596	-93.3614	42.2803	-93.3614
SF05	10,000 ft.	42.2803	-93.2987	42.6596	-93.2987
SF06	10,000 ft.	42.6596	-93.2361	42.2803	-93.2361
SFL01	4,000 ft.	42.4282	-93.5783	42.4282	-93.2055
SFL02	4,000 ft.	42.4067	-93.2055	42.4067	-93.5783
SFL03	4,000 ft.	42.3851	-93.5783	42.3851	-93.2055
Return to Dubuque					

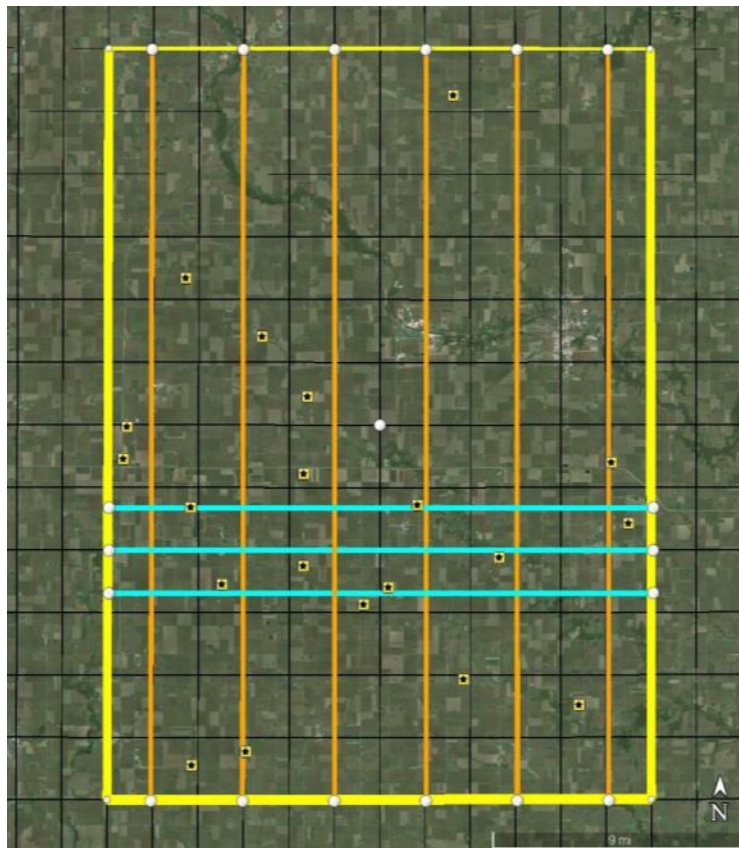


Figure 7. SMAPVEX16 PALS Flightlines on Google Earth (the high altitude mapping lines are marked with orange and the low altitude high resolution lines are marked with light blue). Also shown is the 36-km validation grid (yellow) and permanent in situ soil moisture stations.

7. Ground-based Sampling

7.1. Soil Moisture

Ground-based soil moisture sampling is a key element to a validation campaign. The three approaches that will be exploited will be temporary in situ stations, remote rover technology, and high density gravimetric sampling. Design and efficient use of resources should consider what the data will be used for (objectives). Those identified for SMAPVEX16 are:

- Improve the scaling functions for the CVS by adding more sampling points within these.
 - Not limited to the aircraft component.
 - Can be addressed using temporary stations
- Improve the quality of the calibration and local scaling of in situ sensor estimates
 - Co-located gravimetric sampling
 - If concurrent with SMAP/aircraft it increases the number of samples; however, all comparisons are of value.
 - Range of conditions is of value.
- Provide validation of the higher resolution soil moisture products over the study domain
 - Additional support for the precip/modeling approach

7.1.1. Temporary Network

Previous work has demonstrated the utility of installing short term networks to temporarily increase the spatial resolution of a network. This provides a scaling period which will enable a network manager to provide a more accurate error statistic for the network and scaling functions for improving the representative character of the in situ network. Small soil moisture stations (see Figure 8) will be deployed at coincident precipitation gage sites throughout the domain in the early summer and record hourly soil moisture and soil temperature data. These stations will be low profile and solar power operated. Approximately 40 stations will be deployed in the region (Table 30). These will provide a convenient alternative to field sampling which can introduce additional errors.

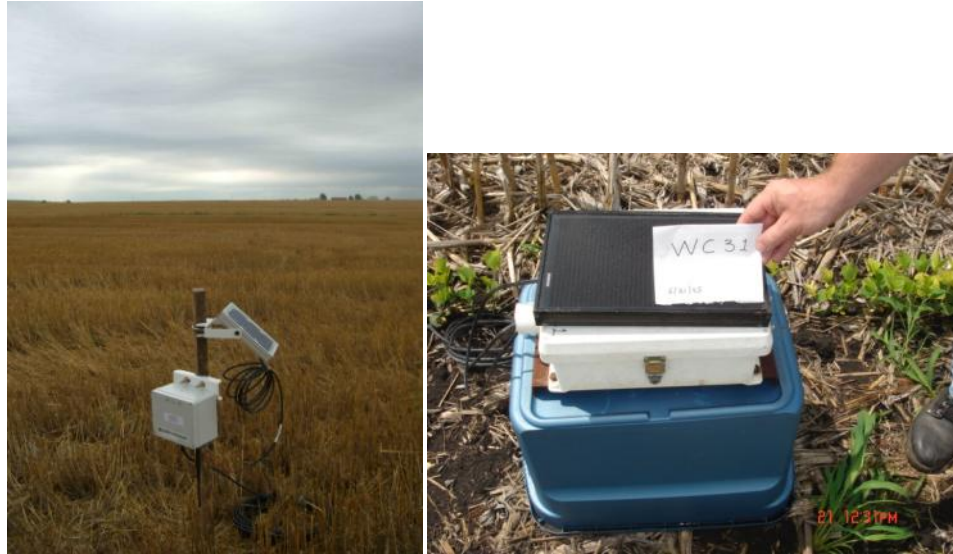


Figure 8: Examples of temporary stations installed with a solar panel and CR206 logger. A Stevens Hydra Probe is installed at a depth of 5 cm to mimic the long term in situ station.

7.1.2. Soil Moisture Rover

The soil moisture rover utilizes the cosmic-ray method to provide a non-contact determination of water content from a mobile, ground-based sensing platform. The rover sample volume covers a diameter of approximately 600 m, and a depth integrated over the top 30 cm of soil. Details on the theory and implementation can be found in Desilets and Zreda (2013) and Zreda et al. (2012). The sensor is mounted in an all-terrain pickup truck for mobility, and collects data on the move (Figure 9). The resulting spatial data consist of a web of linear transects, whose paths follow the road network, with data averaged over segments and interpolated between roads using ordinary kriging. Full details on the processing of rover data are found in Franz et al. (2015).



Figure 9: Soil Moisture Rover from the University Nebraska-Lincoln (UNL).

The planning for SMAPVEX16 is based on a pilot study conducted by UNL from 2014 and summarized fully by Franz et al. (2015). The study successfully mapped a 12 by 12 km domain twenty-two times between May and September 2014. The rover data was converted into spatial products at 1, 3, and 12 km. Each 12 by 12 km survey took 4 hours to complete at a driving

speed of 0.8 km/minute and neutron recording interval of 1 minute. For a 1 minute counting interval the UNL rover has a 3-4% uncertainty which can be propagated through the calibration function and resulting soil water content error.

With respect to SMAPVEX16, a second rover from United States Army Corp of Engineering (USACE) will be used to reduce the drive time in half. Each survey will consist of driving the 1.6 km section roads over the 36x36 km at a maximum speed of 1.6 km per minute taking approximately 6 hours to complete. The rovers will be cross-calibrated for 10 minutes before and after each survey date by parking within 3 m of each other. Following Franz et al. (2015) the raw neutron counts will be converted into 1, 3, 9, and 36 km resolution SWC maps. On off survey days the rovers will be parked in fields where gravimetric and vegetation sampling are being collected for calibration and validation of SWC. Chemistry samples will be collected from each calibration location. The calibration and validation surveys will be split in half in order to perform an error analysis of the rovers. Finally, each rover unit will be cross-calibrated with fixed cosmic-ray probes (at least 2) that are collocated with eddy covariance towers.

The expected deliverables from the cosmic-ray rovers include:

1. Ten rover surveys of SWC at 1, 3, 9, and 36 km inside the SMAP L2SMP grid corresponding to SMAP and PALScan fly overs.
2. Calibration and validation datasets to assess the accuracy of the calibration function and SWC estimates from the CRNP rover.
3. Evaluation of the CRNP calibration function for a 0-5 cm SWC and a 0-30 cm SWC.
4. Site specific estimates of vegetation correction factors for the CRNP rover.

7.1.3. High Density Gravimetric Sampling

Gravimetric sampling will provide an absolute truth measurement for the soil moisture campaign. This sampling will also provide points to calibrate both the rover system and the in situ sensors which provide long term, but potentially non-representative time series. Access to a number of fields has been secured to allow this sampling concurrent with the over passes. These fields will also be used for vegetation and roughness sampling. The current list is shown in Table 7a and may be expanded slightly prior to the campaign.

7.2. Roughness

Each site will be characterized one time during each IOP for surface roughness, with multiple techniques to determine effects of sampling method on the surface roughness estimate. One technique is the grid board photography method employed in previous experiments. Three photos will be taken with a 1 meter board in sequence and another three perpendicular to each other in sequence, and then repeated in 2-3 parts of the field. These will be analyzed for the pertinent surface roughness parameters following the experiment. Additional measurements will be made with a pinboard in a manner similar to the gridboard method. A Lidar system will be deployed in select fields to capture a three dimensional map of the surface in an attempt to capture multiple direction roughness estimates. Lastly, a 3-D camera will be used to collect 3 m lengths of surface roughness in each principle direction (N-S, E-W).

Table 7a. SMAPVEX16 Intensive Sampling Sites

	latitude	longitude
NASA04	42.63727	-93.3412
NASA46	42.30485	-93.4836
S02	42.29342	-93.2266
S03	42.30188	-93.3882
S04	42.33187	-93.4458
S09	42.41032	-93.3669
S10	42.41129	-93.56
S11	42.41174	-93.5349
S13	42.41524	-93.5223
S14	42.4174	-93.5417
S16	42.42251	-93.3865
S17	42.42451	-93.4176
S18	42.42583	-93.3764
S19	42.42669	-93.4373
S21	42.42861	-93.542
S36	42.61801	-93.2243
S39	42.63939	-93.2736
SF01	42.388	-93.388
SF02	42.4693	-93.5655
SF03	42.45296	-93.568
SF04	42.54459	-93.5253
SF07	42.51501	-93.4727
SF10	42.37937	-93.4029
SF14	42.32831	-93.2549
SF15	42.42034	-93.2208
Flux 5	42.60381	-93.3154
Flux 6	42.608	-93.3289
Flux 3	42.48216	-93.5237
Flux 4	42.48867	-93.5223

7.3. Vegetation

Vegetation water content (VWC, kg H₂O/m²) or Equivalent Water Thickness (EWT, mm) can be estimated using wavelengths in the shortwave infrared (SWIR), such as on the MODerate resolution Imaging Spectroradiometer (MODIS) band 5 (1230-1250 nm) and band 6 (1628-1652 nm) or Landsat 8. We will be sampling VWC and EWT for different plant communities for up to 40 for 28 sites in, covering a wide range of plant communities. We will measure stem and leaf water contents, leaf area index, plant cover, and leaf, soil and plot spectral reflectances.

Vegetation water content (VWC) is the mass of liquid water per ground area (ie, kg/m²). For optical remote sensing, VWC is divided by the density of water for equivalent water thickness (EWT), which is the depth of liquid water for a given area. VWC of 1 kg/m² is equal to an EWT of 1 mm.

Leaf EWT is the volume (mass/density) of liquid water divided by the one-sided leaf area. Most leaves have an EWT between 0.1 and 0.2 mm. EWT is convenient for scaling between leaf

and canopy reflectances, because the EWT of the canopy is equal to the average leaf EWT of a leaf times the leaf area index (LAI).

7.3.1. Vegetation Communities and Sites

In Iowa at least 40 sites will be sampled, most will be near soil moisture sampling locations. The number of plots for each plant community is as follows.

7.3.2. Overall Protocol For Each Site

- In Iowa, the plots will be located with GPS coordinates around the date of a Landsat overpass. In each field, three locations will be selected across the field, and samples will be collected. The following data will be collected:
- Crop type, row spacing, plant density,
- plant stalk diameters and height
- plant biomass and plant water content
- plot spectral measurements.

8. Precipitation Characterization

During the spring and summer season, small-scale convective rainfall plays an important role in the generation of soil moisture heterogeneity within the Midwest and Iowa in particular. Accurate estimation of high-resolution (~250-m/5-minutes) rainfall accumulation patterns is therefore required to meet SMAPVEX16-IA soil moisture validation goals associated with the impact of sub-grid-scale soil moisture spatial variability on SMAP retrieval accuracy. While the South Fork experimental watershed contains a high-quality permanent rain gauge network, it can benefit from high resolution radar-based rainfall observations.

During SMAPVEX16-IA four types of supplemental ground-based rainfall instrumentation will be deployed to enhance the existing observing network: 1) two mobile X-band polarimetric scanning radars (see Table 8: Technical specifications of a typical unit in the Iowa XPOL radar system for technical specifications), 2) two laser disdrometers; 3) one vertically-profiling K-band FMCW radar, and 4) high-resolution rainfall products generated operationally by the Iowa Flood Center from the local NEXRAD WSR-88D. The X-band radars will be deployed and maintained by the University of Iowa. The disdrometers and vertically-profiling K-band radar will be provided by the GPM ground validation program and the University of Iowa will be responsible for their deployment and data collection.

Figure 10 illustrates the tentative deployment strategy for the X-band radars and the disdrometers. The two University of Iowa X-band mobile radars will be placed in the vicinity of the SFEW and provide coverage for the (approximately) northern one-third of the SMAPVEX16-IA domain. The radars will overlap over most of the watershed and this will help mitigating possible effect of signal attenuation by rainfall. The disdrometers will be placed by the radars thus helping with radar calibration and tuning of the rainfall estimation algorithms (e.g. Mishra et al. 2016). The vertically-profiling radar will be situated between the two mobile radars acquiring information on the vertical structure of precipitation systems. The entire SMAPVEX16-IA domain will be under the coverage of the KDMX, a WSR-88D NEXRAD radar.

The X-band radars will scan an approximately 180 degree sector over SFEW at two low elevation angles. The exact elevation will be determined once the radars are deployed on sites. The goal is to avoid local ground clutter but keep the elevation as close to the ground as possible. The sector scan will be repeated every 2 minutes; every 10 minutes the radars will perform a vertically pointing scan that will help with channel to channel calibration. During the GPM core satellite overpass the radars will perform horizon-to-horizon along the track scan that will be useful for the GPM-based space radar data analyses. The radars will operate when there is any precipitation in the Iowa domain (this will be determined automatically by analyzing NEXRAD-based rainfall by the Iowa Flood Center.)

Rainfall products for the entire SMAPVEX16-IA domain will be based on a spatial merger of NEXRAD observations with X-band radars retrievals adjusted using rain gauge and disdrometer observations. The processing will be based on a time/space resolution grid of ~250-m/5-minutes. All rainfall instrumentation is expected to be deployed approximately few days prior to the start of SMAPVEX16-IA airborne soil moisture over-flights (on or about May 25, 2016) and will be maintained until at least the final over-flight (on or about June 5, 2016).

Table 8: Technical specifications of a typical unit in the Iowa XPOL radar system.

Technical Characteristic	Description
System	
Nominal R_{max}	40 km
Range resolution	Selectable 15-150 m
Sensitivity	-5 dBZ at 10 km at range resolution of 75 m
Mounting platform	8 x 10 ft customized trailer
Power supply	On-site and trailer-mounted UPS
Time-location sync source	On-site GPS
Radar and antenna controller	Remote operated web-interface
Antenna	
Shape	Parabolic
Polarization	Dual-polarized
Diameter	6 ft
Gain	42 dBi
3-dB beam width	1.3-1.5°
Cross-polarization isolation	~30 dB
Maximum Voltage Standing Wave Ratio (VSWR)	~1.25
Scanning	Az: 0-360°, El: 0-90°
Transmitter	
Operating frequency	9.41 GHz
Transmitter	Magnetron, peak power $P_t = 25$ kW
Pulsing schemes	Staggered PRT and dual-PRF
Receiver	
RF Receiver Gain	~33 dB
Cross-channel receiver isolation	>50 dB
Noise Figure	~3 dB
Dynamic range	80 dB
Digital noise floor	-84 dBm (at 2 MHz receiver bandwidth)
Signal and data processor	
Digital receiver bandwidth	Selectable 2-20 MHz
Range oversampling	Programmable 7.5-75 m
Processing modes	Standard pulse pair, dual pulse pair, FFT
Data Products	
Data archiving	On-site on-demand for raw timeseries and processed products

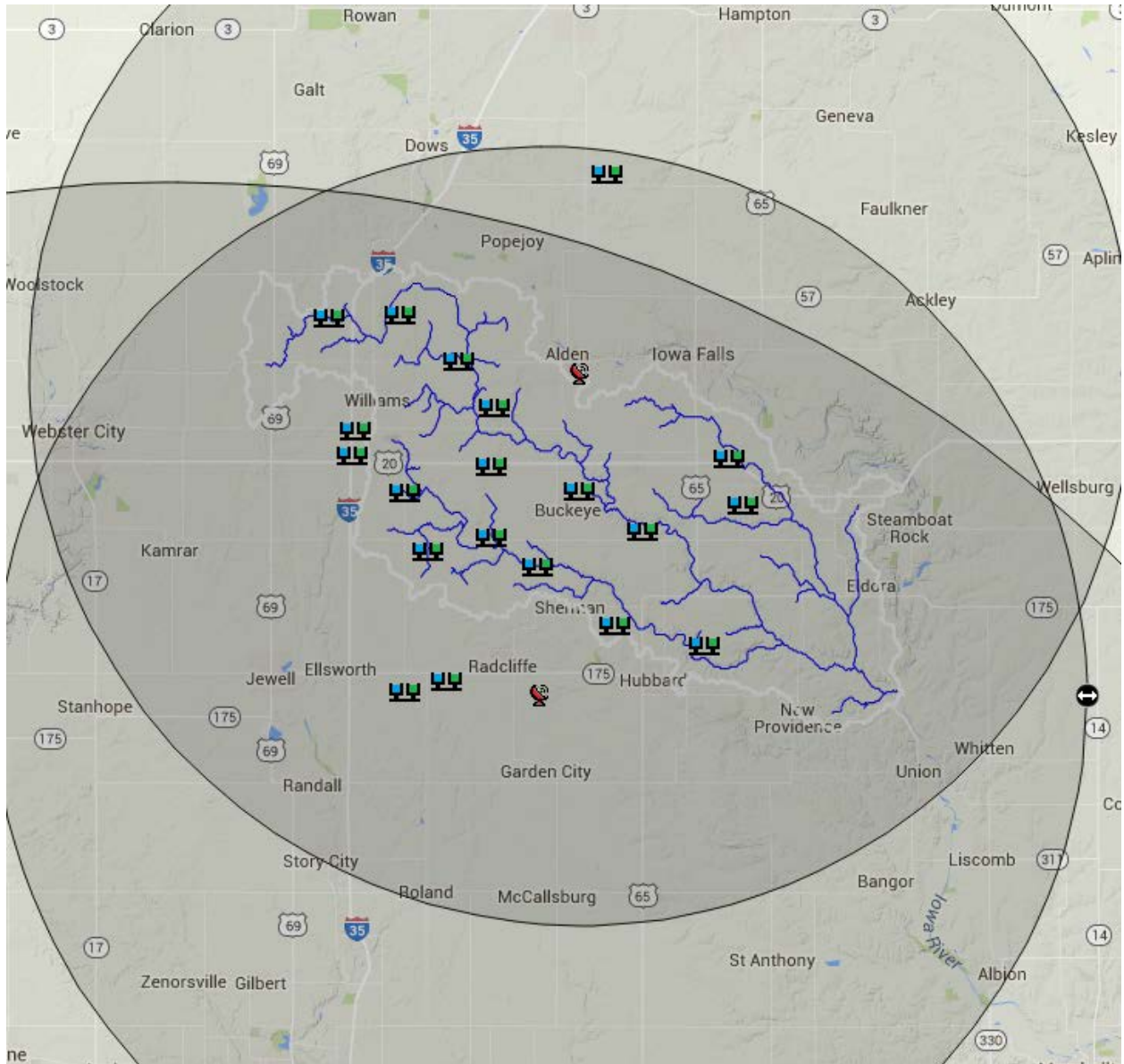


Figure 10: Map of proposed rainfall instrumentation deployment. Blue and green symbols indicate existing precipitation and soil moisture gauges in the SFEW. Red radar icons show tentative locations of the X-band radars with the corresponding range of 40 kilometers. The large arc is 100 km range from the Des Moines KDMX radar.

9. Ground-based Microwave Observations

The goal of this study is to conduct a season-long experiment, which incorporates active and passive microwave observations for a growing season of field corn and soybean. These observations will allow calibration and validation of the observations from the These observations match that of the satellite-based passive microwave radiometers, the Soil Moisture and Ocean Salinity (SMOS) mission, and the recently launched NASA SMAP mission, along with algorithm development and scaling studies in conjunction with the aircraft measurements from PALS (see section XX).

9.1. *Field Setup*

This experiment will be conducted at two study sites at the D. Sweeney Farms near Alden, Iowa (42.43291880N, -93.38607160W). The farm is located within the SMAPVEX16-IA experimental region in South Fork, Iowa. The sites are located at the north and west sides of the farm buildings, respectively, as shown in Figure 11.

The instruments will consist of two ground-based microwave radiometer systems, a ground-based microwave radar system, and micrometeorological stations. The ground-based microwave radiometer systems will be installed at the location shown in Figure 11. The ground-based microwave radar system will be installed adjacent to the radiometer with a portion of the radar footprint overlapping the radiometer footprint, facing in the same direction as the radiometer system. The radar system will move between the two sites to observe critical growth stages of field corn and soybean.

The dimensions of the corn study site are 75 m \times 65m. The plant spacing and row spacing will be measured at the first sampling. The ground-based microwave radiometer and radar systems installation will begin on May 16 (DoY 137) with micrometeorological stations on May 17 (DoY 138). Two rain gauges will be installed inside the field with one rain gauge outside of the field as shown in Figure 11. Four micrometeorological stations with soil moisture and soil temperature sensors will be installed at the locations shown in Figure 11. A relative humidity (RH) and temperature sensor will be installed at the 23x station and a thermal infrared and 4-component net radiometer will be installed south of the 23x station.

The dimensions of the soybean study site are 75 m \times 65 m. The plant spacing and row spacing will be measured at the first sampling. The ground-based microwave radiometer and radar systems installation will begin on May 16 (DoY 137) with micrometeorological stations on May 17 (DoY 138). Two rain gauges will be installed inside the field with one rain gauge outside of the field as shown in Figure 11. Two micrometeorological stations with soil moisture and soil temperature sensors will be installed at the locations shown in Figure 11. Relative humidity (RH) and temperature sensor will be installed at the 23x station and a thermal infrared and 4-component net radiometer will be installed south of the 23x station.

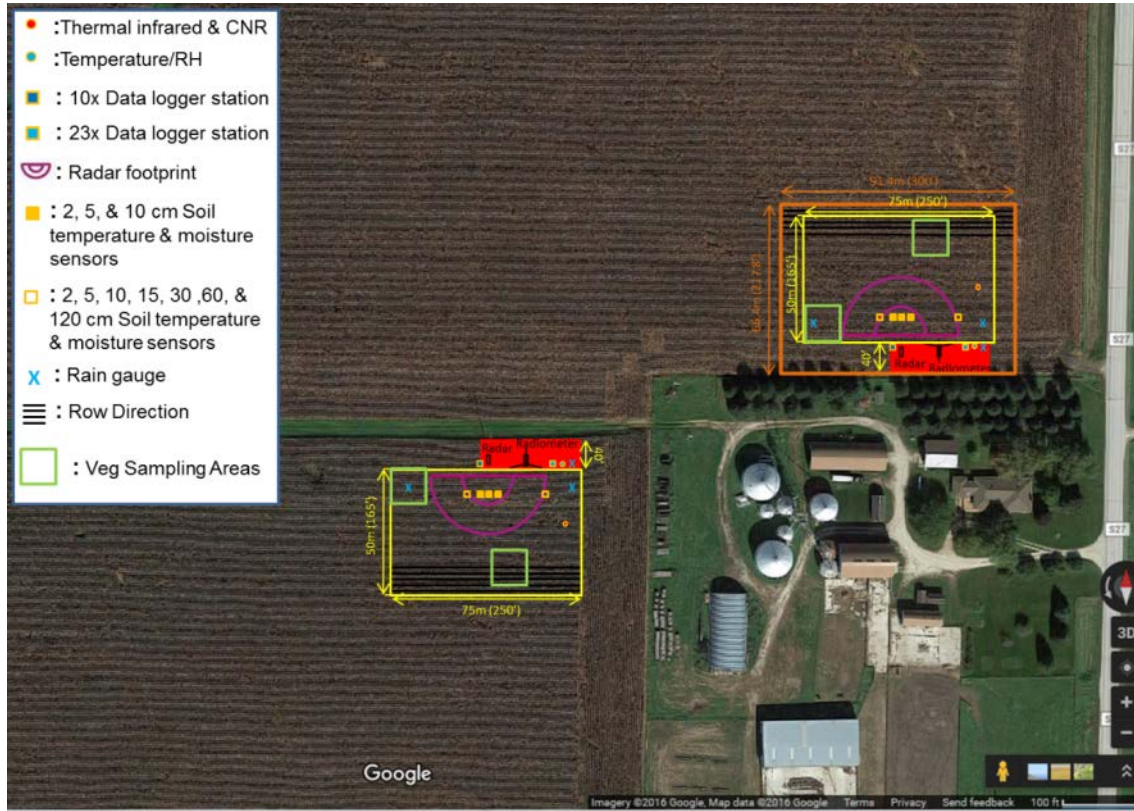


Figure 11: Sensor layout at the corn and soybean field sits at the D. Sweeney Farm

9.2. Sensors

9.2.1. University of Florida L-band Microwave Radiometer (UFLMR)

Microwave brightness temperatures at 1.4 GHz ($\lambda = 21.0$ cm) will be measured every 15 minutes using the University of Florida's L-band Microwave Radiometer system (UFLMR) (Figure 12[a]). The radiometer system consists of a horizontally polarized total power radiometer operating at the center frequency of 1.4 GHz housed atop a 9.14 m tower installed on a 16' trailer bed. The UFLMR was designed and built by the Microwave Geophysics Group at the University of Michigan. It operates at the center frequency at 1.4 GHz, which is identical to the center frequency of the SMAP radiometer. The UFLMR will observe the 5.6 m \times 5.1 m footprint from a height of 8 m. The brightness temperatures will be observed at an incidence angle of 40°. A rotary system will be used to rotate the look-angle of the UFLMR for both field observations and sky measurements. The radiometer will be calibrated at least every week using an Internal Calibration (IC) scheme with an internal match load as a warm reference load and a measurement of sky as cold load. Figure 12(b) shows a close up of the rotary system and Figure 12(c) shows the antenna of the UFLMR. Table 9 lists the UFLMR specifications.

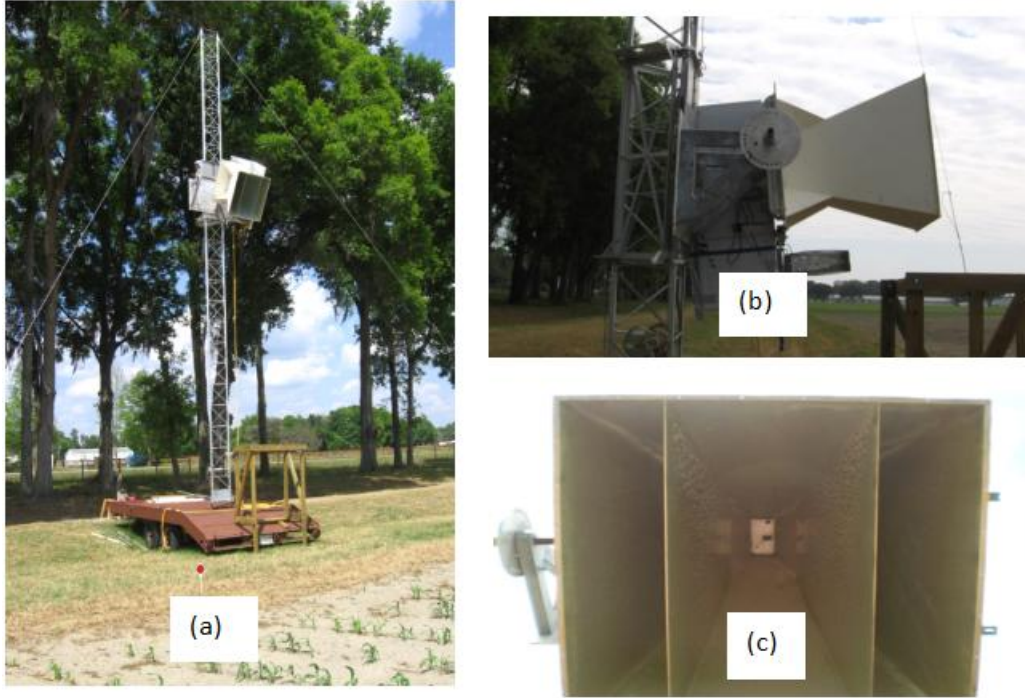


Figure 12 (a) The UFLMR system, (b) the side view of the UFLMR showing the rotary system, and (c) the front view of the UFLMR showing the receiver antenna. Credits: J. Casanova, University of Florida

Table 9: UFLMR Specifications

Parameter	Qualifier	Value
Frequency	Center	1.4 GHz
Bandwidth	3 dB	20 MHz
Beamwidth	3 dB H-pol elevation ^a	22.5°
	3 dB H-pol azimuth ^b	20.0°
Polarizations	Single	H
Receiver temp (T_{rec})		179 K
Noise Figure	From T_{rec}	2.1 dB
RF gain		79 dB
NE Δ T		0.5 K
^a sidelobes < -20 dB		
^b sidelobes < -30 dB		

9.2.1.1. Theory of Operation – UFLMR

The UFLMR uses a thermoelectric cooler (TEC) for thermal control of the Radio Frequency (RF) stages. This is accomplished by the Oven Industries “McShane” thermal controller. McShane is used to cool or heat by Proportional-Integral-Derivative (PID) algorithm with a high

degree of precision at 0.01°C. The RF components are all attached to an aluminum plate that must have sufficient thermal mass to eliminate short-term thermal drifts. All components attached to this thermal plate, including the TEC, use thermal paste to minimize thermal gradients across junctions. The majority of the gain in the system is provided by a gain and filtering block designed by the University of Michigan for the STAR-Light instrument (De Roo 2003). The main advantage of this gain block is the close proximity of all the amplifiers, simplifying the task of thermal control.

The RF block is designed for V- and H-pol switching. However, only the H-pol signal is guided from antenna to coax to the RF block, and the V-pol input to the RF block is a cold load (ColdFet). In the RF block, the first switch alternates between V- and H-pol and the second alternates between the reference load and the signal from the first switch. An isolator prevents reflections of the input signal. After the isolator, the signal goes through a bandpass filter and then an LNA, followed by a series of bandpass filters and power amplifiers before the square law detector and the PDA. The microcontroller logs voltage and physical temperature measurements. Figure 13 shows the block diagram of the UFLMR.

The electrical penetrations use commercially available weatherproof bulkhead connections (Deutsch connectors or equivalent). The heat sinks have been carefully located employing RTV (silicone sealant) to seal the bolt holes. The radiometer uses 15 mil polycarbonate for radiometric signal penetration. It is sealed to the case using a rubber gasket held down by a square retainer.

The UFLMR is equipped with a microcontroller that is responsible for taking measurements, monitoring the thermal environment, and storing data until a download is requested. A laptop computer is used for running the user interface named FluxMon to communicate with the radiometer through Radiometer Control Language (RadiCL). The radiometer is configured to maintain a particular thermal set point, and make periodic measurements of the brightness at both polarizations sequentially and the reference load. The data collected by the radiometer are not calibrated within the instrument, since calibration errors could corrupt an otherwise useful dataset. Figure 13 shows the block diagram of the UFLMR.

9.2.2. *University of Michigan L-band Microwave Radiometer (UMLMR)*

The University of Michigan L-band Microwave Radiometer (UMLMR) is a dual-polarized, radiometer system from the University of Michigan that measures microwave brightness temperatures. The radiometer system consists of a dual polarization total power radiometer and will be housed atop a 9.14 m tower installed on a 16' trailer bed, same as UFLMR during the experiment. The UMLMR operating at a center frequency of 1.4 GHz ($\lambda = 21.0$ cm), will be used to measure every-15-minute data. The UMLMR was designed and built by the Microwave Geophysics Group at the University of Michigan. The height, incident angle, and footprint will be identical to the UFLMR. A rotary system is used to rotate the look angle of the UMLMR both for field observations and sky measurements. The radiometer will be calibrated at least every week with a measurement of sky as cold load. Table 10 lists the specifications of the UMLMR.

9.2.2.1. Theory of Operation – UMLMR

The UMLMR is similar to the UFLMR in many respects, using a thermoelectric cooler (TEC) for thermal control, a similar electromechanical switching mechanism and a Z-World controller; the PDA is the same, and the software is an older version of RadiCL. The RF block is designed for V- and H-pol switching. In the RF block, the first switch alternates between V- and

H-pol and the second alternates between the reference load and the signal from the first switch. An isolator prevents reflections of the input signal. After the isolator, the signal goes through a bandpass filter and then an LNA, followed by a series of bandpass filters and power amplifiers before the square law detector and the PDA. The microcontroller logs voltage and physical temperature measurements.

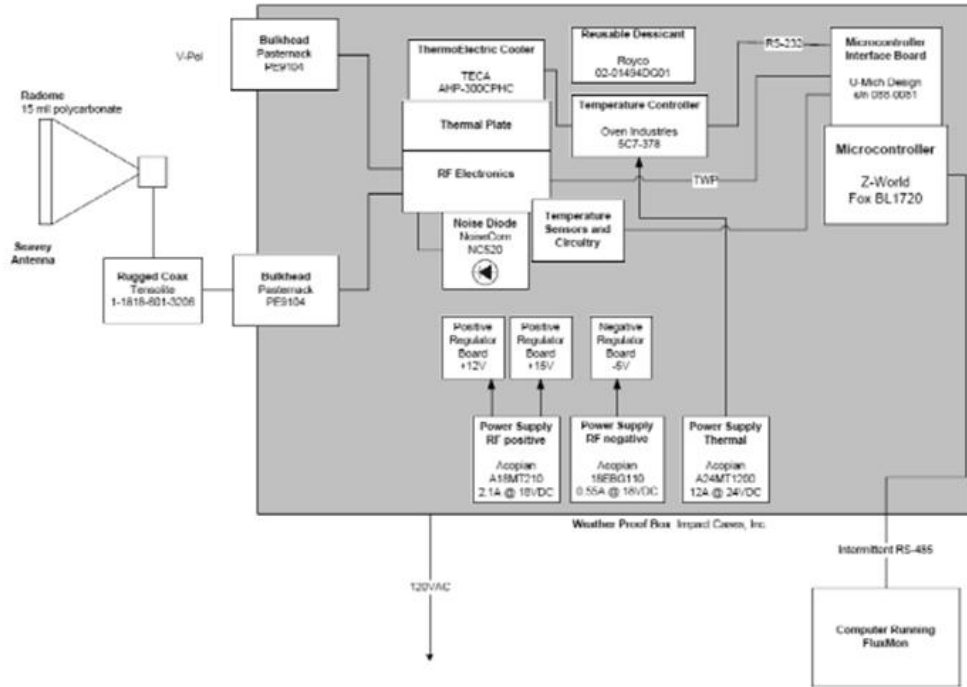


Figure 13: Block diagram of UFLMR

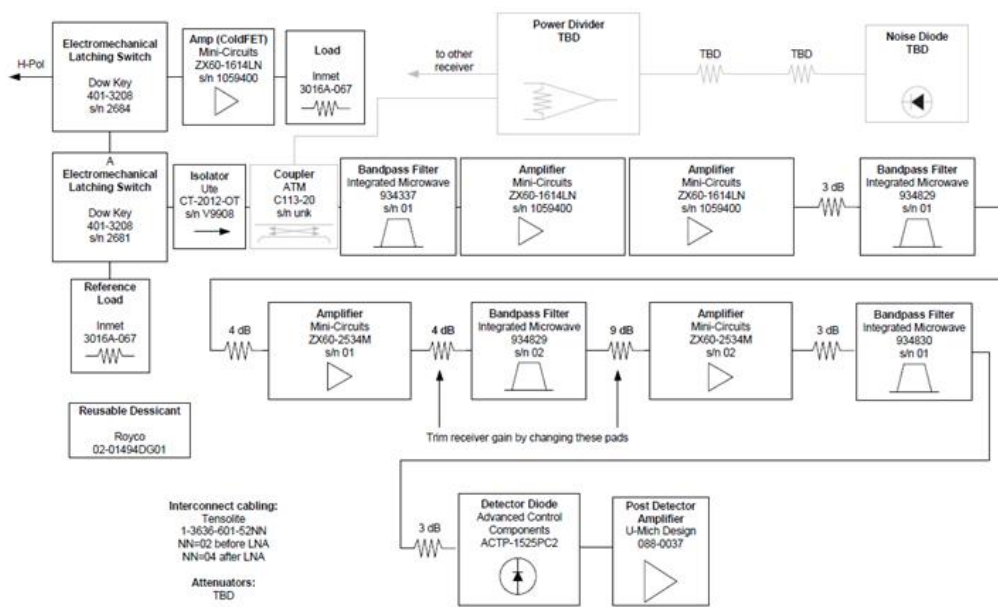


Figure 14: Block diagram of the University of Florida L-band Microwave Radiometer Credits: Roger De Roo, University of Michigan

Table 10: UMLMR Specifications

Parameter	Qualifier	Value
Frequency	Center	1.4 GHz
Bandwidth	3 dB	20 MHz
Beamwidth	3 dB H-pol elevation ^a	22.5°
	3 dB H-pol azimuth ^b	20.0°
	3 dB V-pol elevation ^c	20.0°
	3 dB V-pol azimuth ^d	22.5°
Polarizations	Sequential	V/H
Receiver temp (T_{rec})		179 K
Noise Figure	From T_{rec}	2.1 dB
RF gain		79 dB
$NE\Delta T$		0.5 K
		^a sidelobes < -20 dB
		^b sidelobes < -30 dB
		^c sidelobes < -30 dB
		^d sidelobes < -20 dB

9.2.3. *University of Florida Radar System*

9.2.3.1. University of Florida L-band Automated Radar System (UF-LARS)

Observations of radar backscatter (σ_0) at four polarization combinations, (HH, VV, HV, and VH) and an azimuth range of 0° to 180° with an azimuthal resolution of 9° every 15 minutes resulting in 21 spatial samples will be collected using the University of Florida L-band Automated Radar System (UF-LARS) (Figure 15). The UF-LARS is mounted on a 25 m Genie manlift and is comprised of three major sub-systems: (1) the antenna and the RF (ARF) sub-system, (2) the electro-mechanical positioning (EMP) sub-system, and (3) the software control and data acquisition (SDA) sub-system. Figure 16 shows a simplified block diagram of the UF-LARS. The RF subsystem was based upon the established designs for ground-based scatterometers employing a vector network analyzer with simultaneous acquisition of V- and H-polarized returns. These components operate at a center frequency of 1.25 GHz, with a bandwidth of 300 MHz and the one-way 3 dB beamwidth of 14.7° in the E-plane and 19.7° in the H-plane. The polarization isolation at the center frequency was > 37 dB for all principal planes and decreases to about 23 dB at the band edge of 1400 MHz. The EMP sub-system employs an embedded computer and is composed of three digital inclinometers, an elevation-over-azimuth controller, linear actuators, and a laser range finder. The elevation-over-azimuth controller is used to rotate the look-angle of the UF-LARS for both field observations and sky measurements. The antenna incidence angle will be set to 40° , while the height will be at 16.2m giving a footprint of an arc which has a footprint size of 1033.77 m², based upon the 6 dB beamwidth. The SDA enabled system integration and automated data acquisition using a software control system designed in the C++ and HTML5 environments. Radar calibration included sky measurements and a trihedral corner-reflector (Figure 15) will be done throughout the season. Table 11 summarizes the system specifications.



Figure 15: UF-LARS mounted on the 25 m Genie platform. (Inset) Trihedral calibration target made of aluminum with an aperture length of 1.28 m. Credits: Karthik Nagarajan, University of Florida

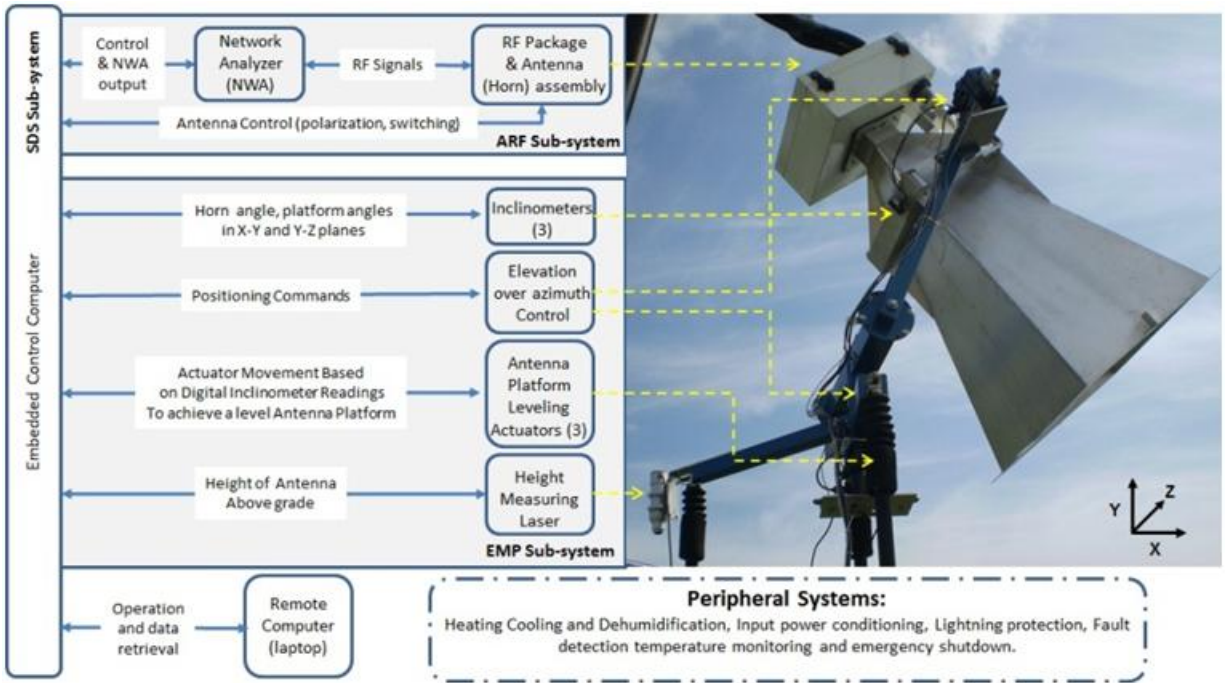


Figure 16: Sub-systems within the UF-LARS
Credits: Karthik Nagarajan, University of Florida

9.2.4. Thermal Infrared Sensor

Two Apogee instruments IRR-PN thermal infrared sensors will be installed; one in the corn and the other in the soybean field site. Table 11 shows the list of specifications of the thermal infrared sensors.

9.2.4.1. Thermal Sensor for Soybean

The sensor will be installed north of the 23x station (as shown in Figure 11) at a height of 2m above the canopy to observe skin temperature at nadir.

9.2.4.2. Thermal Sensor for Corn

The sensor will be installed south of the 23x station (as shown in Figure 11) at a height of 2 m above the canopy to observe skin temperature at nadir.

9.2.5. Soil Temperature Probes

Lab made temperature probes, based on Campbell Scientific 107-1 temperature sensor, will be used to measure soil temperature.

9.2.5.1. Soil Temperature Probes for Soybean

Twenty-three temperature probes will be placed at depths of 2, 5, 10, 16, 32, 64, and 120 cm measuring every fifteen minutes. At the 10x station, the depths will include two replicate at 2, 5, and 10 cm.

Table 11: Specifications of the thermal infrared sensor (IRR-PN).

Description		Value
Field of view		18° half angle
Output	Target temp.	40 μ V per °C difference from sensor body
	Sensor body temp.	0–2500 mV
Accuracy	–10°C to 65°C	\pm 0.2°C absolute accuracy \pm 0.1°C uniformity \pm 0.05°C repeatability
	–40°C to 70°C	\pm 0.5°C absolute accuracy \pm 0.3°C uniformity \pm 0.1°C repeatability and uniformity
Optics		Germanium lens
Wavelength range		8–14 μ m (corresponds to atmospheric window)
Response time		< 1 second to changes in target temperature
Input power		2.5 V excitation
Operating environment		–55–80°C; 0–100% RH (non-condensing) Water resistant, designed for continuous outdoor use
Cable		4.5 meters twisted, shielded 4 conductor wire with Santoprene casing.
Dimensions		6 cm long by 2.3 cm diameter
Mass		190 g
<i>Source: Apogee Instruments Inc. (2007)</i>		

9.2.5.2. Soil Temperature Probes for Corn

Twenty-three temperature probes will be placed at depths of 2, 5, 10, 16, 32, 64, and 120 cm measuring every fifteen minutes. At the 10x station, the depths will include two replicate at 2, 5, and 10 cm.

9.2.6. Soil Moisture Probes

Campbell Scientific time-domain water content reflectometers (CS616) will be used to measure soil volumetric water content. The calibration coefficients will be obtained from calibration and during the experiment.

9.2.6.1. Soil Moisture Probes for Soybean

Twenty-three reflectometers will be placed at depths of 2, 5, 10, 16, 32, 64, and 120 cm measuring every fifteen minutes. At the 10x station, the depths will include two replicate at 2, 5, and 10 cm.

9.2.6.2. Soil Moisture Probes for Corn

Twenty-three reflectometers will be placed at depths of 2, 5, 10, 16, 32, 64, and 150 cm measuring every fifteen minutes. At the 10x station, the depths will include two replicate at 2, 5, and 10 cm.

9.2.7. *Precipitation*

Precipitation will be determined using six tipping-bucket rain gauges with locations shown in Figure 11.

9.2.7.1. Precipitation for Soybean

Two tipping-bucket rain gauges, on the east and west side of the UF-LARS footprint will be installed inside the field at a height of 20 cm above the ground to catch any through fall precipitation. One rain gauge will be installed outside of the field.

9.2.7.2. Precipitation for Corn

Two tipping-bucket rain gauges, on the east and west side of the UF-LARS footprint at a height of 20 cm above the ground and one outside the field will be installed.

9.2.8. *Air Temperature and Relative Humidity*

Air temperature and relative humidity will be measured every fifteen minutes at the 23x stations at a height of 2m just outside of the soybean and corn fields using two Campbell Scientific HMP45C Temperature and Relative Humidity.

9.2.9. *Net Radiometer*

Up- and down-welling shortwave and longwave infrared radiation will be measured every fifteen minutes using two Kipp and Zonen CNR-1 four-component net radiometer, which will be located south of the 23x station in corn and north of the 23x station in soybean as shown in Figure 11. The sensor consists of two pyranometers (CM-3) and two pyrgeometers (CG-3). The sensor will be installed 2m above the canopy facing south. Table 12 shows the list of specifications of the CNR-1 net radiometer.

Table 12: Specifications of the CNR-1 net radiometer

Description	Value
Measurement spectrum: CM-3	305–2800 nm
Measurement spectrum: CG-3	5000–50000 nm
Response time	18 sec
Sensitivity	10–35 $\mu\text{V}/(\text{W}/\text{m}^2)$
Pt-100 sensor temperature measurement	DIN class A
Accuracy of the Pt-100 measurement	$\pm 2 \text{ K}$
Heating	Resistor 24 ohms, 6 VA at 12 volt
Maximum error due to heating: CM-3	10 W/m^2
Operating temperature	-40° – 70°C
Daily total radiation accuracy	$\pm 10\%$
Cable length	10 m
Weight	4 kg
<i>Source: Campbell Scientific (2006a)</i>	

9.3. Vegetation Sampling

9.3.1. Vegetation Sampling at the Corn Site

Vegetation properties in two sampling locations as shown in Figure 11 will be measured weekly during the field experiment. A vegetation sampling will consist of measurements of height, width, biomass, LAI, geometric description of the plant, and vertical distribution of moisture in the canopy. The crop density will be derived from the stand density and row spacing (30") measured at the first sampling. The height, width, wet and dry biomass, vertical distribution of the moisture in the canopy and geometric description of the crop including maximum length, width of each leaf, stem circumference, ear length, and maximum ear circumference of sample plants will be measured. Destructive LAI will also be measured.

During the IOP, vegetation sampling to characterize the diurnal vegetation water content will be done at 6am and 6pm during days with a SMAP overpass. For these samplings, plant density, growth stage, height, node height, and wet and dry biomass of individual leaves, 10cm section of stem, and ears will be measured. For the 6am measurements, dew sampling will also be done.

9.3.2. Vegetation Sampling at the Soybean Site

Vegetation properties in two sampling locations as shown in Figure 11 will be measured weekly during the field experiment. A vegetation sampling will consist of measurements of height, width, biomass, LAI, geometric description of the plant, and vertical distribution of moisture in the canopy. The crop density will be derived from the stand density and row spacing measured at the first sampling. The height, width, wet and dry biomass, vertical distribution of the moisture in the canopy and geometric description of the crop including maximum length,

width of each leaf, stem circumference, pod length, width and thickness of sample plants will be measured. Destructive LAI will also be measured.

During the IOP, vegetation sampling to characterize the diurnal vegetation water content will be done at 6am and 6pm during days with a SMAP overpass. For these samplings, plant density, growth stage, height, node height, and wet and dry biomass of leaves and pods at each node, and 10cm section of stem will be measured. For the 6am measurements, dew sampling will also be done.

10. Satellites and Overpass Schedules

10.1. SMAP and Other Passive Microwave Satellites

Details on SMAP are available on the website and in the SMAP Handbook (<http://smap.jpl.nasa.gov/mission/description/>). SMAP is in an eight-day exact repeat orbit. The satellite provides data over a swath of approximately 1000 km. Using the science orbit predictor tool for SMAP (http://smap_op.apps.nsidc.org/), the coverage during the two IOPs was obtained. Note that these are predictions. Results are summarized in Table 13 for the morning overpass with a nominal time local DST of 8:00 am. Results are expected to be fairly accurate but can vary slightly.

Table 13: Passive Microwave Coverage of the Study Domain

Date	SMAP		SMOS		AMSR2			
	Local Time	Distance (km)	Local Time	Distance (km)	Local Time	Distance (km)	Local Time	Distance (km)
5/23/2016	7:51	-90	6:57	282	3:14	20	14:20	103
5/24/2016								
5/25/2016	7:26	386			3:02	268	14:08	143
5/26/2016	8:03	-327	6:41	54	3:44	593		
5/27/2016					2:49	517	13:55	388
5/28/2016	7:39	148	7:02	392	3:32	351	14:38	480
5/29/2016			6:23	386			13:43	629
5/30/2016					3:20	107	14:26	230
5/31/2016	7:51	-90	6:46	54				
6/1/2016					3:08	140	14:14	18
6/2/2016	7:26	386						
6/3/2016	8:03	-327	6:29	279	2:55	389	14:02	263
6/4/2016					3:38	475	14:44	608
6/5/2016	7:39	148	6:51	163	2:42	640	13:49	506
6/6/2016					3:26	232	14:32	358
6/7/2016								
6/8/2016	7:51	-90	6:34	172	3:14	14	14:20	109
6/9/2016								
6/10/2016	7:26	386	6:56	272	3:01	262	14:08	138
6/11/2016	8:03	-327			3:43	599		
6/12/2016					2:49	511	13:55	382
6/13/2016	7:39	148	6:40	65	3:32	357	14:38	485
6/14/2016							13:42	624
6/15/2016			7:01	381	3:20	112	14:26	236
6/16/2016	7:51	-90	6:22	397				
6/17/2016					3:08	135	14:14	12
6/18/2016	7:26	386	6:45	43				
6/19/2016	8:03	-327			2:55	384	14:01	258
6/20/2016					3:38	480	14:43	613
6/21/2016	7:39	148	6:28	290	2:42	635	13:49	501
6/22/2016					3:26	237	14:32	362
7/24/2016			6:43	17	3:25	240	14:31	366
7/25/2016								
7/26/2016	7:51	-90			3:13	6	14:19	117
7/27/2016			6:26	317				
7/28/2016	7:26	386			3:00	254	14:07	131
7/29/2016	8:03	-327	6:48	125	3:42	605		
7/30/2016					2:48	505	13:54	376
7/31/2016	7:39	148			3:31	363	14:37	492

8/1/2016			6:31	211			13:41	618
8/2/2016					3:19	117	14:25	241
8/3/2016	7:51	-90	6:53	232				
8/4/2016					3:06	130	14:13	7
8/5/2016	7:26	386						
8/6/2016	8:03	-327	6:36	104	2:54	380	14:00	254
8/7/2016					3:36	484	14:42	617
8/8/2016	7:39	148	6:58	340	2:41	631	13:47	498
8/9/2016			6:19	437	3:24	240	14:30	366
8/10/2016								
8/11/2016	7:51	-90	6:41	4	3:12	7	14:18	116
8/12/2016								
8/13/2016	7:26	386	7:02	448	3:00	255	14:06	131
8/14/2016	8:03	-327	6:24	332	3:42	604		
8/15/2016					2:47	506	13:54	377
8/16/2016	7:39	148	6:46	109	3:30	361	14:36	490
8/17/2016							13:41	619
8/18/2016					3:18	116	14:24	240
8/19/2016	7:51	-90	6:30	226				
8/20/2016					3:06	132	14:12	9
8/21/2016	7:26	386	6:52	216				
8/22/2016	8:03	-327			2:53	382	14:00	256
8/23/2016					3:36	482	14:42	615

Another consideration in choosing flight days is the availability of data from other satellites providing brightness temperature, backscatter, or soil moisture estimates. These include SMOS, and AMSR2 (GCOM-W), Sentinel 1a/1b, Radarsat2, and PALSAR-2. The coverage for SMOS and AMSR2 can be reliably predicted and is summarized in Table 13.

10.2. Radar Satellites

Coverage by the radar satellites is by request and there is no guarantee that it will be obtained far in advance of the acquisition date. The following sections summarize the requests or expected acquisitions by Radarsat2 and Sentinel 1A and 1B. PALSAR2 data will be evaluated if it is acquired over the study domain.

10.2.1. RADARSAT2

RADARSAT2 is a C-Band SAR satellite operating at a frequency of 5.405 GHz. The satellite has a repeat cycle of 24 days. RADARSAT2 has a variety of different modes included within the payload. The modes of interest as they pertain to the SMAPVEX16 campaign include the Standard Mode (S) and Wide Fine Quad-Pol Mode (FQW). Details on these configurations are given below in Tables 14 and 15. The requested/scheduled acquisitions are summarized in Table 16.

Standard Mode:

Polarization: Dual-Pol (As programmed for SMAPVEX16 over South Fork, Iowa: Tx: V
Rx: H+V)

Beam Modes: S1-S8

Incidence Angle Range: 20 degrees to 52 degrees

Nominal Ground Swath: 100km

Table 14: Radarsat2 Standard Mode Parameters

Beam Mode	Near Range Incidence Angle (degs)	Far Range Incidence Angle (degs)	Nominal Near Range Resolution (m)	Nominal Far Range Resolution (m)
S1	20.0	27.2	26.8	20.0
S2	24.0	31.3	22.6	17.6
S3	30.4	37.0	27.0	22.7
S4	33.5	39.7	24.8	21.4
S5	36.3	42.2	23.1	20.3
S6	41.2	46.5	20.7	18.8
S7	44.4	49.3	19.5	18.0
S8	48.5	52.1	18.2	17.3

Wide Fine Quad-Pol:

Polarization: Quad-Pol

Beam Modes: FQW1-FQW21

Incidence Angle Range: 18 degrees to 42 degrees

Nominal Ground Swath: 50km

Table 15: Radarsat 2 Wide Fine QuadPol mode parameters

Beam Mode	Near Range Incidence Angle (degs)	Far Range Incidence Angle (degs)	Nominal Near Range Resolution (m)	Nominal Far Range Resolution (m)
FQ1W	17.5	21.2	17.3	14.4
FQ2W	19.0	22.7	16.0	13.5
FQ3W	20.0	23.6	15.2	13.0
FQ4W	21.3	24.8	14.3	12.4
FQ5W	22.5	26.0	13.6	11.9
FQ6W	23.7	27.2	12.9	11.4
FQ7W	24.9	28.3	12.3	11.0
FQ8W	26.1	29.4	11.8	10.6
FQ9W	27.2	30.5	11.4	10.2
FQ10W	28.4	31.6	10.9	9.9
FQ11W	29.5	32.6	10.6	9.6
FQ12W	30.6	33.7	10.2	9.4
FQ13W	31.7	34.7	9.9	9.1
FQ14W	32.7	35.7	9.6	8.9
FQ15W	33.7	36.7	9.4	8.7
FQ16W	34.8	37.6	9.1	8.5

FQ17W	35.7	38.6	8.9	8.3
FQ18W	36.7	39.5	8.7	8.2
FQ19W	37.7	40.4	8.5	8.0
FQ20W	38.6	41.3	8.3	7.9
FQ21W	39.5	42.1	8.2	7.8

Table 16: Radarsat2 Coverage of the Iowa Study Domain

Date Local	Time UTC	Time Local	Pass	Beam
5/22/2016	00:13:29.686	19:13:30	ASC	S (S6)
5/26/2016	23:56:51.879	18:56:52	ASC	S (S1)
5/27/2016	12:09:02.980	7:09:03	DES	S (S7)
5/29/2016	00:09:20.038	19:09:20	ASC	S (S4)
5/30/2016	12:21:32.215	7:21:32	DES	S (S4)
6/1/2016	00:21:49.568	19:21:50	ASC	S (S8)
6/1/2016	00:05:10.482	19:05:10	ASC	S (S3)
6/6/2016	12:17:22.257	7:17:22	DES	S (S5)
6/8/2016	00:17:39.614	19:17:40	ASC	S (S7)
6/9/2016	12:29:50.555	7:29:51	DES	S (S1)
6/12/2016	00:01:01.217	19:01:01	ASC	S (S2)
6/13/2016	12:13:12.520	7:13:13	DES	S (S6)
6/15/2016	00:13:29.733	19:13:30	ASC	S (S6)
6/19/2016	23:56:51.815	18:56:52	ASC	S (S1)
6/20/2016	12:09:02.635	7:09:03	DES	S (S7)
6/22/2016	00:09:19.977	19:09:20	ASC	S (S4)
6/23/2016	12:21:31.780	7:21:32	DES	S (S4)
6/25/2016	00:21:49.522	19:21:50	ASC	S (S8)
6/29/2016	00:05:10.504	19:05:11	ASC	S (S3)
6/30/2016	12:17:22.193	7:17:22	DES	S (S5)
7/2/2016	00:17:39.483	19:17:39	ASC	S (S7)
7/3/2016	12:29:50.731	7:29:51	DES	S (S1)
7/6/2016	00:01:01.099	19:01:01	ASC	S (S2)
7/7/2016	12:13:12.608	7:13:13	DES	S (S6)
7/9/2016	00:13:29.642	19:13:30	ASC	S (S6)
7/13/2016	23:56:51.773	18:56:52	ASC	S (S1)
7/14/2016	12:09:02.742	7:09:03	DES	S (S7)
7/16/2016	00:09:19.954	19:09:20	ASC	S (S4)
7/17/2016	12:21:31.936	7:21:32	DES	S (S4)
7/19/2016	00:21:49.463	19:21:49	ASC	S (S8)
7/23/2016	00:05:10.371	19:05:10	ASC	S (S3)
7/24/2016	12:17:22.354	7:17:22	DES	S (S5)
7/26/2016	00:17:39.501	19:17:40	ASC	S (S7)
7/27/2016	12:29:50.677	7:29:51	DES	S (S1)
7/30/2016	00:01:01.000	19:01:01	ASC	S (S2)
7/31/2016	12:13:12.602	7:13:13	DES	S (S6)
8/2/2016	00:13:29.648	19:13:30	ASC	S (S6)
8/6/2016	23:56:51.622	18:56:52	ASC	S (S1)
8/7/2016	12:09:02.955	7:09:03	DES	S (S7)
8/9/2016	00:09:19.912	19:09:20	ASC	S (S4)
8/10/2016	12:21:32.201	7:21:32	DES	S (S4)

8/12/2016	00:21:49.315	19:21:49	ASC	S (S8)
8/16/2016	00:05:10.354	19:05:10	ASC	S (S3)
8/17/2016	12:17:22.615	7:17:23	DES	S (S5)
All Right Looking, Transmit=V, Receive=H+V, Single frame				

10.2.2. Sentinel 1

The material provided here is extracted from <https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar>.

The Sentinel-1 mission is designed to provide enhanced revisit frequency, coverage, timeliness and reliability for operational services and applications requiring long time series. The mission will provide an operational interferometry capability through stringent requirements placed on attitude accuracy, attitude and orbit knowledge, and data-take timing accuracy. The constellation will cover the entire world's land masses on a bi-weekly basis, sea-ice zones, Europe's coastal zones and shipping routes on a daily basis and open ocean continuously by wave imageries.

Sentinel-1 carries a single C-band synthetic aperture radar instrument operating at a center frequency of 5.405 GHz. It includes a right-looking active phased array antenna providing fast scanning in elevation and azimuth, data storage capacity of 1 410 Gb and 520 Mbit/s X-band downlink capacity. The C-SAR instrument supports operation in dual polarization (HH+HV, VV+VH) implemented through one transmit chain (switchable to H or V) and two parallel receive chains for H and V polarization. Dual polarization data is useful for land cover classification and sea-ice applications.

Sentinel-1 operates in four exclusive acquisition modes illustrated in Figure 17. All SMAPVEX16 acquisitions are IW:

- Stripmap Mode: Stripmap imaging mode is provided for continuity with ERS and Envisat missions. Stripmap provides coverage with a 5 m by 5 m resolution over a narrow swath width of 80 km. One of six imaging swaths can be selected by changing the beam incidence angle and the elevation beamwidth.
- Interferometric Wide Swath Mode: The Interferometric Wide swath (IW) mode allows combining a large swath width (250 km) with a moderate geometric resolution (5 m by 20 m). The IW mode images three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). With the TOPSAR technique, in addition to steering the beam in range as in SCANSAR, the beam is also electronically steered from backward to forward in the azimuth direction for each burst, avoiding scalloping and resulting in a higher quality image. Interferometry is ensured by sufficient overlap of the Doppler spectrum (in the azimuth domain) and the wave number spectrum (in the elevation domain). The TOPSAR technique ensures homogeneous image quality throughout the swath. The IW mode is the default acquisition mode over land.
- Extra Wide Swath Mode: The Extra Wide swath imaging mode is intended for maritime, ice and polar zone operational services where wide coverage and short revisit times are demanded. The EW mode works similarly to the IW mode employing a TOPSAR technique using five sub-swaths instead of three, resulting in a lower resolution (20 m by 40 m). The EW mode can also be used for interferometry as with the IW mode.

- Wave Mode: Sentinel-1 Wave mode, in conjunction with global ocean wave models, can help determine the direction, wavelength and heights of waves on the open oceans. Wave mode acquisitions are composed of stripmap imagerettes of 20 km by 20 km, acquired alternately on two different incidence angles. Wave imagerettes are acquired every 100 km, with imagerettes on the same incidence angle separated by 200 km.

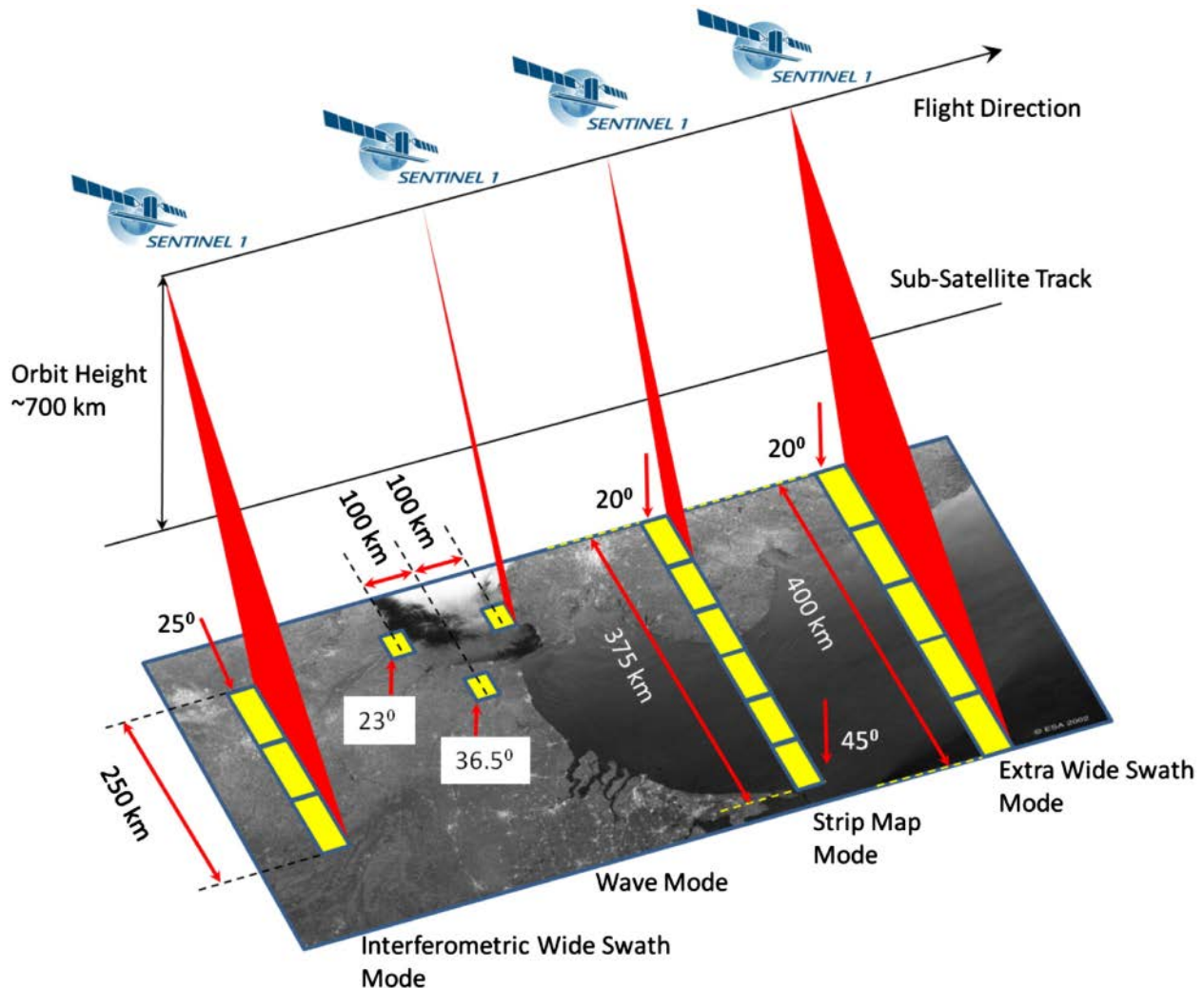


Figure 17: Sentinel-1 Product Modes

There will be two operational satellites. 1A was launched in 2014 and is operational. 1B was launched April 25th 2016 and although it will be in its evaluation stage, data will be acquired. Each Sentinel-1 satellite will be in a near-polar, sun-synchronous orbit, with a 12-day repeat cycle and 175 orbits per cycle. Both Sentinel-1A and Sentinel-1B share the same orbit plane with a 180° orbital phasing difference.

A single Sentinel-1 satellite is potentially able to map the global landmasses in the Interferometric Wide swath mode once every 12 days, in a single pass (ascending or descending). The two-satellite constellation offers a 6 day exact repeat cycle at the equator. Since

the orbit track spacing varies with latitude, the revisit rate is significantly greater at higher latitudes than at the equator.

This scenario aims at fulfilling, during the routine exploitation phase, the observation requirements of the Copernicus services and of ESA/EU member states. In addition, on a best effort basis and with lower priority, a secondary objective is to satisfy other SAR user communities, ensuring continuity of ERS/Envisat, considering requirements from the scientific community, as well as from international partners and cooperation activities.

A high level definition of the Sentinel-1A observation plan, on a repeat cycle basis, is provided below.

- European coverage: A full two pass (ascending and descending passes, providing at least two acquisitions for each area within 12 days) coverage in IWS mode, VV-VH polarization is provided for Europe in the extent of EEA-38 member states every 12 days repeat cycle to provide data for a variety of services and applications. In addition, for European marginal seas high coverage frequency following distinct clustered requirements in IWS mode, VV-VH polarization is provided within each 12 days. An exception is for the Baltic Sea, observed partially in EWS during northern winter, on descending passes, to support sea-ice monitoring activities.
- Polar environments monitoring: Major global sea-ice zones will be observed to satisfy in particular the needs from the Copernicus Marine Environment Monitoring Service i.e.: EWS mode, HH or HH-HV polarization with some gradual increasing revisit frequency as triggered by the requirements and limited by technical constraints. Major global ice-caps are covered at least once a year according to local winter conditions, employing IWS mode, HH polarization, and achieving at least three to four consecutive full coverage.
- Worldwide coverage: All global landmasses are regularly covered following a zonal concept in a stable one pass IWS mode, VV-VH polarization. Zones delineation basically follows climatic-geographical considerations. Zones boundaries are extrapolated to follow administrative boundaries to provide consistent countrywide wall-to-wall coverage. During initial operations, the acquisition of distinct zones is triggered by the approach to derive a background reference dataset, among others suitable for flood monitoring during locally dry conditions which also provide the most stable radiometric conditions. The revisit frequency for all zones increased in line with the gradual mission capacity increase.
- Tectonic and volcanic active areas: Global tectonic and volcanic active areas (following an area extent definition provided by key scientists of the domain) are observed in a stable full two pass IWS mode, VV polarization coverage with a revisit frequency of 24 days per pass (alternating ascending and descending passes, i.e. a particular area is observed every 12 days, interferometric pairs are available every 24 days). Global tectonic and volcanic active areas located within Europe are revisited within 12 days per pass in IWS mode, VV-VH polarization.
- Forestry, Agriculture, Soil moisture retrieval and other specific environmental monitoring: Key project sites all around the globe focusing on specific topics are supported from the first repeat cycles on in IWS mode, with a default polarization in VV-VH, and revisit frequency individually tailored to the specific needs as far as possible.
- Calibration and validation activities: Aiming at the best achievable data quality of Sentinel-1A products, calibration and validation activities are routinely performed during the routine operations phase. These priority activities may locally and temporarily interfere with the

delivery of coverage in consistent mode-polarization combination. Major regions affected by these activities are Northern Alpine Lowlands (Germany, Austria and Switzerland) and the narrow surroundings of Sao Paulo (Brazil), Houston and Chicago (USA). Limiting the consistency of static mode-polarization coverage and causing small observation gaps due to instrument switches, these activities bring the opportunity to explore the variety of the Sentinel-1A image modes to data users of the affected areas.

Both Sentinel 1A and 1B acquisitions will be made for the summer growing season in Iowa and Manitoba. These will all be obtained in IW mode VV-VH polarization. Two ascending tracks will be obtained at a nominal overpass time of 0015 UTC. As noted previously, observations from either satellite are on a 12-day repeat offset by 6-days. The acquisitions planned are as follows:

Iowa

Sentinel 1A	Track 63	June 1, 13, 25; July 7, 19, 31; August 12, 24
Sentinel 1A	Track 165	May 27; June 20; July 2, 14, 26; August 7, 19
Sentinel 1B	Track 63	July 13, 25; August 6
Sentinel 1B	Track 165	July 20; August 1, 13
Sentinel 1B	Track 143*	July 18, 30; August 11

Manitoba

Sentinel 1A	Track 63	June 1, 13, 25; July 7, 19, 31; August 12, 24
Sentinel 1A	Track 136	May 25; June 6, 18, 30; July 12, 24; August 5
Sentinel 1B	Track 63	July 13, 25; August 6
Sentinel 1B	Track 136	July 18, 30; August 11
Sentinel 1B	Track 12*	July 9, 21; August 2

Note that the first repeat of track 165 on 08 June is currently not part of the 1A observation scenario due to a conflict in the observation scenario. In addition, 1B data will become available after the completion of various post-launch procedures and will not begin until July. Tracks 143 (Iowa) and 12 (Manitoba) are descending with nominal over pass times of 1200-1300 UTC.

11. CFIS

CFIS participation in the SMAPVEX campaign, planned for the South Forks, IA region in the summer of 2016, would provide coincident airborne solar-induced chlorophyll fluorescence (SIF) retrievals to characterize landscape-scale photosynthetic activity across target areas of the SMAPVEX domain. Solar Induced Chlorophyll Fluorescence is a direct by-product of photosynthesis and provides a unique dynamic proxy for Gross Primary Production (GPP). Moreover, these SIF retrievals provide information on the biochemical response of vegetation to the physical forcing and environment, particularly soil moisture availability, as will be characterized by the SMAPVEX activities.

With its 10-20m resolution, CFIS should be able to observe not only individual crops within the SMAPVEX observational domain, but within-field variability that exists as a function of resource gradients such as moisture availability. This is of interest to the SMAP project as it will provide an airborne imaging capability to characterize within-pixel heterogeneity for soil moisture retrievals, and will improve SMAP LUE and GPP products. The team had expressed interest in looking at PALS data with CFIS. The CFIS swath-width is significantly narrower than that of PALS or UAVSAR, and flight planning will require the identification of zones within the SMAPVEX domain that are both (a) well monitored by ground stations; and (b) are expected to be characterized by gradients in vegetation type, phenological state, and / or nutrient or water availability so as to produce variation in remotely sensed fluorescence and soil moisture.

The fields in the domain are rather large at 800x800m, providing significant fetch for eddy covariance observations. Assuming that resources are available, the CFIS team may be able to deploy one or more eddy covariance systems within the SMAPVEX domain, to characterize continuous fluxes of carbon dioxide, water vapor (evapotranspiration) and sensible heat between the land surface and atmospheric boundary layer. It is also anticipated that members of the CFIS team will deploy to the SMAPVEX domain to conduct local (leaf and canopy-scale) gas exchange and spectral observations.

The one CFIS flight campaign for FY 2016 will be the SMAPVEX-IA campaign conducted in early August. This campaign should ideally include/start on or before August 2 to take advantage of the OCO-2 Nadir Pass on that day at approximately 1:30pm local time. The SMAPVEX campaign is anticipated to be conducted from August 3-16 and will include 8 SMAP overpasses. OCO-2 will have one additional overpass in glint mode in the region on August 4.

Initial analysis from 2015 campaign has shown good agreement between CFIS radiance and SIF observations and acquisitions over flux towers have shown realistic diurnal variations and agreement. The SMAPVEX-IA campaign will be good opportunity to examine broader range of terrestrial land cover types and environmental conditions, as well as examine leaf level gas exchange and canopy spectrometer observations. Below are two (2) figures from the Drewry et al. presentation at Fall 2015 AGU. Figure 18 shows a data image comparison between OCO-2 pass near Des Moines, Iowa and the path flown by CFIS on August 16. Note the correlation showing the photosynthetic activity in red and less activity in the cooler tones. Figure 19 shows the OCO-2/CFIS comparison and the good agreement between the space borne and air borne platforms.

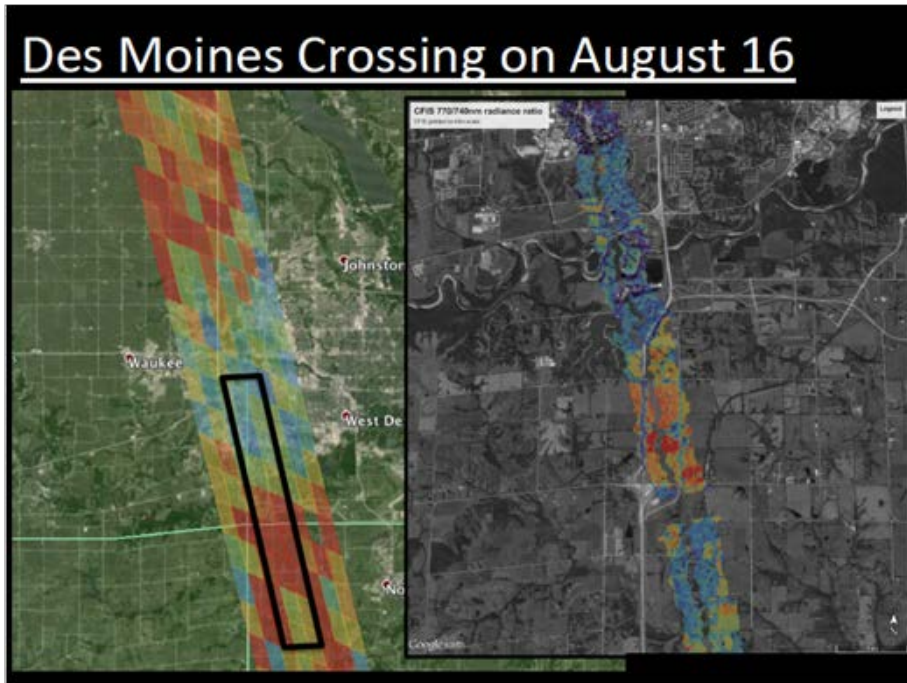


Figure 18: Data image comparison between OCO-2 pass near Des Moines IA and the path flown by CFIS on August 16.

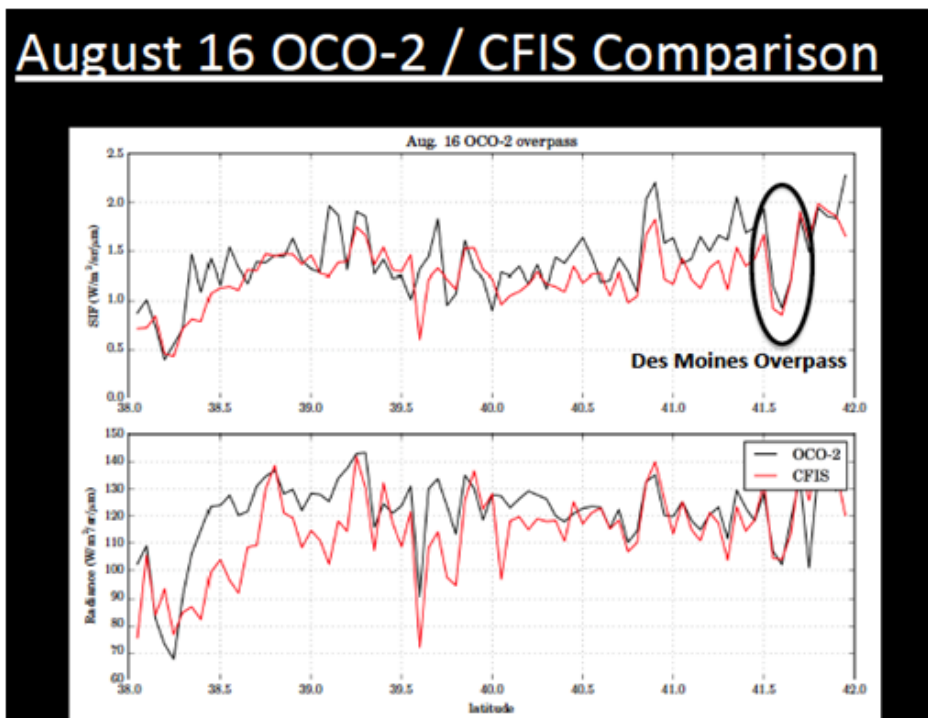


Figure 19: OCO-2/CFIS comparisons.

12. Security

Field Access: Do not enter any field that you do not have permission to enter. If questioned, politely identify yourself and explain that you are with the USDA/NASA experiment. Flyers will be available that provide a general overview of the experiment. In case of any trouble, leave the field and contact your SMAPVEX16 supervisor. At the time of sampling, if the farmer is working in the field, DO NOT sample and contact your SMAPVEX16 supervisor. Prior to the experiment all requests for field access are to be directed to Mike Cosh (Michael.cosh@ars.usda.gov). Do not assume that you can use a field without permission. Requests for installations and unplanned sampling made during the experiment will not be easy to satisfy. Tracking down a landowner and getting permission can take up to a half-day of time by our most valuable people. These people will be extremely busy during the experiment. Therefore, if you think you will have specific needs that have not been addressed, you did not spend enough time planning...*so learn for the next time.*

Access to field headquarters: Open 6 am until 4pm everyday. For periods of time during the day the lab may be unattended and locked. In this circumstance contact a SMAPVEX16 supervisor for entry.

Access to the NLAE: Restricted to USDA employees and others by prior arrangements

13. Safety

13.1. General Field Safety

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

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

Beltsville Area
SAFETY NEWS RELEASE

WE WANT YOU TO KNOW



Release 00-01

SUMMERTIME SAFETY FOR OUTSIDE WORKERS

PREVENTING HEAT-RELATED ILLNESS

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

Tips to stay cool:

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

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

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

PREVENTING SUN-RELATED ILLNESSES

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

Tips to prevent sun exposure:

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

Released July 3, 2000

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

Lynn McKee, SMAPVEX16 Safety Officer, 202-679-3654
Mike Cosh, Asst. Safety Officer, 410-707-2478
Alex White, Asst. Safety Officer, 410-279-2637

13.2. Ticks

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

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

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

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

13.3. 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.

13.4. Driving

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

13.5. Lightning

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

13.6. Medical

For medical emergencies call 911 or go to:

Mary Greeley Medical Center
1111 Duff Avenue, Ames, IA 50010
Phone: 515-239-2011

For non-emergency medical problems:
McFarland Express Care (Inside HyVee)
3800 Lincoln Way, Ames IA 50014
Phone: 515-956-4100
M-F 9-7, Sa & Su 9-5

McFarland Clinic
1215 Duff Avenue, Ames IA, 50010
Phone: 515-239-4400
M-F 8-5, Sa 8-12

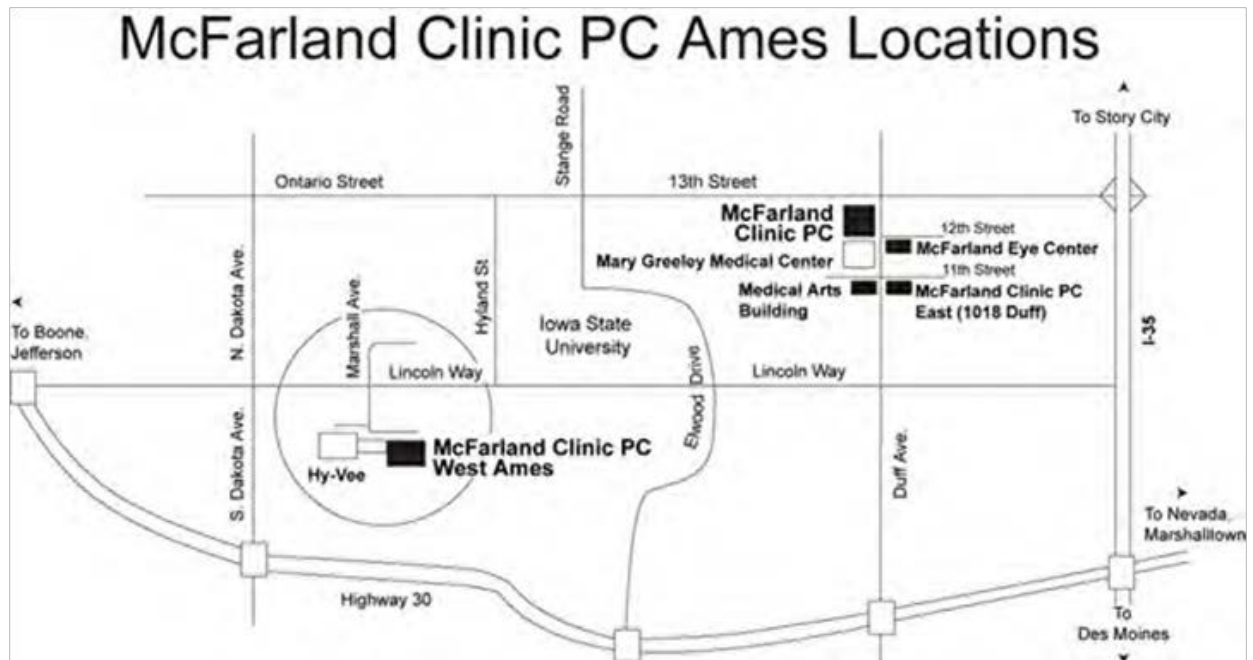


Figure 20: McFarland Clinic PC Ames Locations

14. Logistics

14.1. Hotels

TBD

14.2. Directions from the Des Moines Airport to Ames

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

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

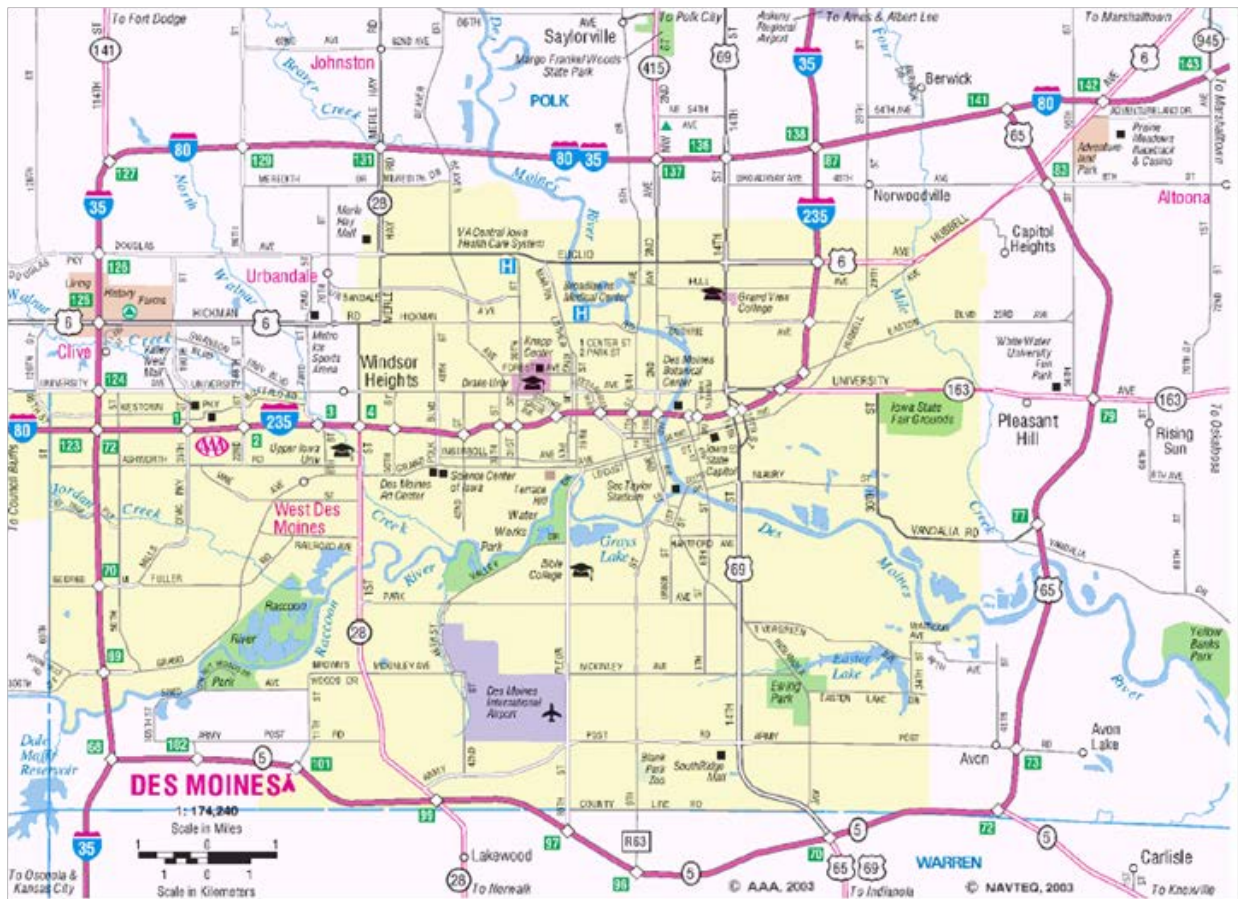


Figure 21: Des Moines area map.

The following map shows general features of the City of Ames. When coming from Des Moines, get off I-35 at Exit 111B, Highway 30 West.



Figure 22: Iowa State Campus map in Ames, IA.

The location of the Field Headquarters for SMAPVEX16 is an ARS building located on 240th St near W Ave. To get there from Ames Hotels, take Highway 30 West, exit at X Ave going South, take the first right onto 240th Street and follow to Field Headquarters on the right. A photo is also shown. The All Hands meeting on May24th will be held here.

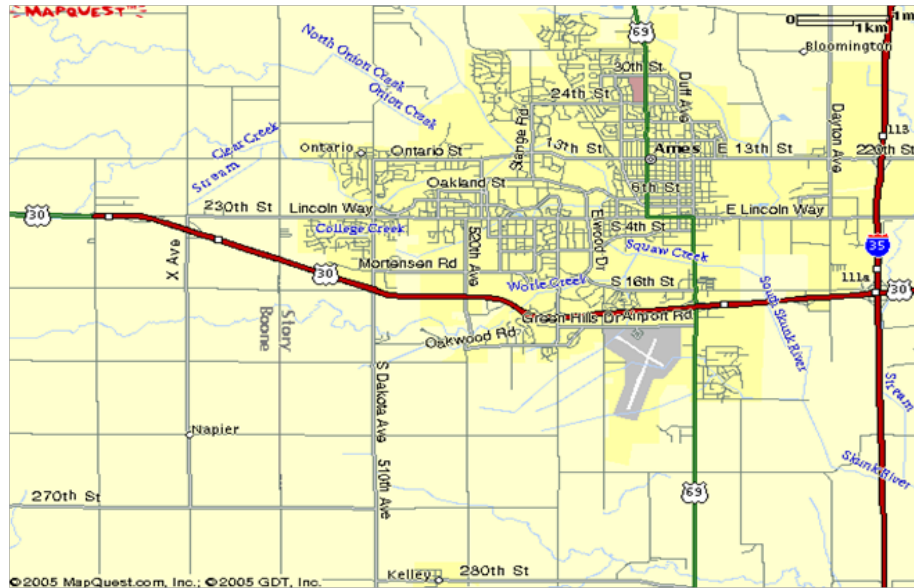


Figure 23: Ames IA map.



Figure 24: SMAPVEX16 Field Headquarters

14.3. Local Contacts

USDA, ARS National Laboratory for Agriculture & Environment (NLAE)
 1015 N University Blvd
 Ames, IA 50011

Jerry Hatfield
 (515) 294-5723
Jerry.harfield@ars.usda.gov

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

14.4. Shipping Address

Forrest Goodman/SMAPVEX16
USDA, ARS, NLAE
1015 N University Blvd
Ames, IA 50011
(515) 294-5723

15. Protocols

General Guidance on Field Sampling

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

15.1. Watershed Site Surface Soil Moisture and Temperature

Soil moisture and temperature sampling of the watershed sites is intended to estimate the site average and standard deviation. Watershed site sampling will take place between 5:30 am and 8:30 am. It is assumed here that most of these sites will be quarter sections (800 m by 800 m), however, there will be a number of variations that may require adaptation of the protocol. The variables that will be measured or characterized are:

- 0-6 cm soil moisture using the Theta Probe (TP) instrument
- 0-3 and 3-6 cm gravimetric soil moistures using the scoop tool
- 0-6 cm soil bulk density (separate team)
- Is there dew present at the location and how much? A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure.
- Surface temperature of exposed and in-shadow ground using a hand held infrared thermometer
- Surface temperature of exposed and in-shadow vegetation using a hand held infrared thermometer
- 5 cm soil temperature
- 10 cm soil temperature
- GPS locations of all sample point locations (one time)

Preparation

- We will likely deploy from the hotel, so arrangements will be made so that people can leave at the appropriate time to take their first sample between 5:30-6:00 AM. Group texts will be used to coordinate any changes.
- At the end of each, make sure you have a complete sampling kit for the next sampling day.
 - Bucket
 - Theta Probe and data logger (use the same probe each day, it will have an ID)
 - Coring Tool kit
 - Soil Auger (0-30 cm)
 - 8 cm spatula
 - 4 cm spatula
 - Notebook
 - Pencils and Sharpies
 - Sealable bags (see note below)
 - Soil thermometer
 - Handheld infrared thermometer
 - Extra batteries (9v, AA, AAA)
 - Screwdriver
 - First aid kit (per car)
 - Phone (if you have one)
- Verify that your TP, data logger, infrared instrument, and soil thermometer are working.
- Check weather
- The first time you sample, it will help to use marking tape/spray paint to mark your transect rows and sample point locations. Use only marking tape/spray paint to mark your sites
- All sample points should be located with a GPS once during the experiment. Points will be referenced by Site “SF##” and Point “##”.
- Use a new **notebook** page each day. Take the time to draw a good map and be legible. These notebooks belong to the experiment; if you want your own copy make a photocopy.
- These notebooks are waterproof and must be used with a pencil. Sampling information will be transferred to a data sheet each day.

Procedure

- Upon arrival at a site, note site id (SF##), your name(s) and time in notebook. Draw a schematic of the field (It might be a good idea to do this before you go out for the day). Indicate the TP ID you are using.
- Assess the amount of dew at the location your sampling. A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure.
- Assemble sealable soil bags and indicate on schematic where they will be used.
- From a reference point for the site (usually a corner), measure 200 m along one side to locate the first transect.
 - Transects should be parallel with the row direction.
 - If possible, select a row that is a tractor row to walk in.
- From this location initiate a sampling transect across the site. Take the first sample at 100 m and repeat every 100 m until you are 100 m from the edge of the site. For a standard quarter section site this will result in 7 samples along the transect.

- Sample in the row adjacent to the row you are working in, it is suggested that this be the row to your right.
- At all points collect three TP samples across the row as suggested in Figure 18. **See the Theta Probe protocol for how to use the instrument and data logger.**
- **At all points make a qualitative assessment of the amount of dew present by recording a 0 (no dew), 1 (a little dew), or 2 (a lot of dew) in the field notebook.**
- At points labeled ALL in Figure 17 (four per site) collect
 - One gravimetric soil moisture sample for 0-1 cm and 0-6 cm following the procedures described using the scoop, enter can numbers on diagram in book (**See Gravimetric Sampling with the Scoop Tool protocol**)
 - One soil temperature (Degrees C) for 1 cm, 5 cm and 10 cm using the probe, enter values in book (**See Temperature Sampling protocol**)

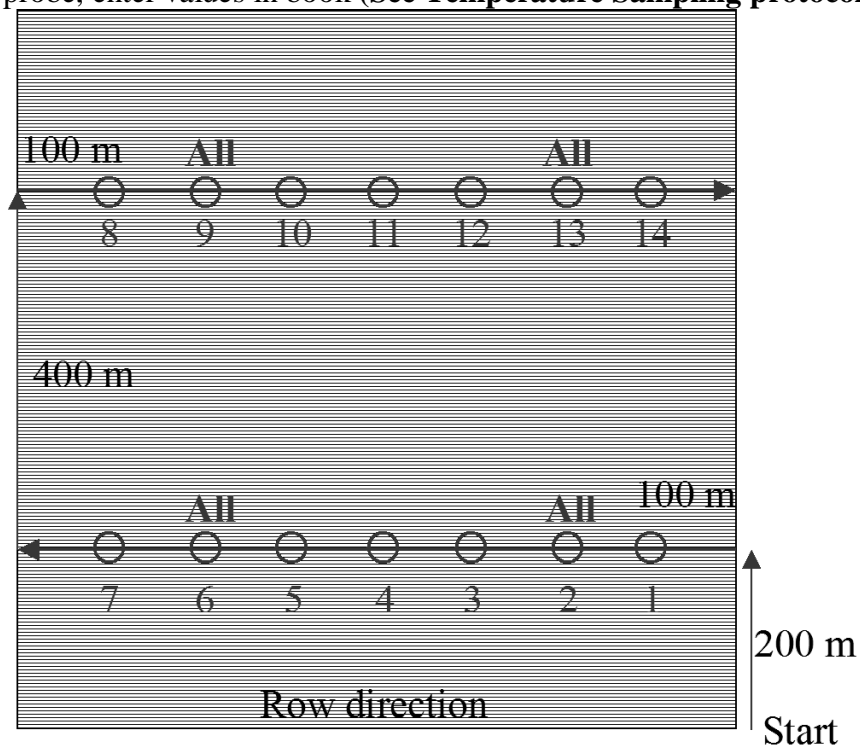


Figure 25: Sampling in a row crop field.

Four surface thermal infrared temperatures (Degrees C) using infrared thermometer, enter value in book (**See Temperature Sampling protocol**)

- After completing this transect move 400 m perpendicular into the site and initiate a new transect. This will result in a total of 14 sampling points.
 - *Exit the field before attempting to move to the second transect.*
- As you move along the transect note any anomalous conditions on the schematic in your notebook, i.e. standing water.

- If there is a tower/leaf wetness sensor in the field, take a fifth set of ALL readings
 - One gravimetric soil moisture sample for 0-3 cm and 3-6 cm following the procedures described using the scoop, enter can numbers on diagram in book (**See Gravimetric Sampling with the Scoop Tool protocol**)
 - One soil temperature (Degrees C) for 5 cm and 10 cm using the probe, enter values in book (**See Temperature Sampling protocol**)
 - Four surface thermal infrared temperatures (Degrees C) using infrared thermometer, enter value in book (**See Temperature Sampling protocol**)
- Record your stop time and place cans in box. Try to keep them cool.

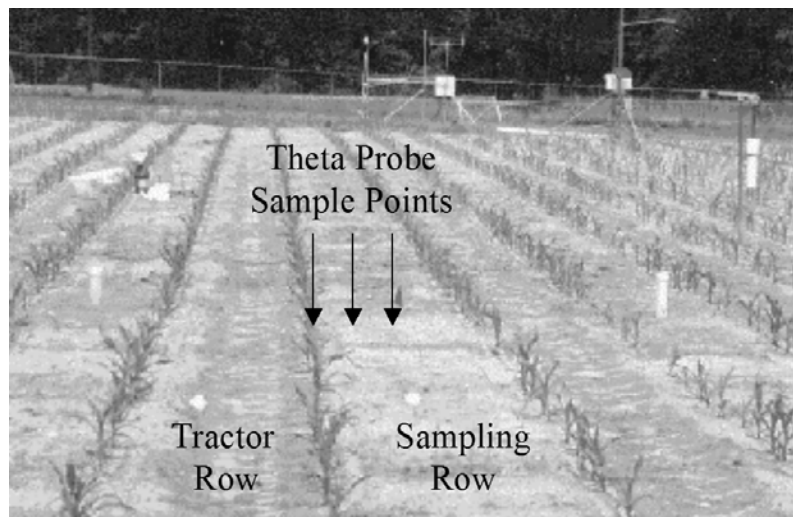


Figure 26: sampling in a row crop.

Sample Data Processing

- Return to the field headquarters immediately upon finishing sampling.
- For each site, weigh the gravimetric samples and record on the data sheets (Figure 19) that will be provided. Use a single data sheet for all your samples for that day and record cans sequentially.
- Transfer temperature and other requested data to data sheets (same sheet used for GSM).
- Place cans in (in box) “TO OVENS” area and data sheet in collection box.
- Turn in your TP and data logger to the person in charge. They will be responsible for downloading data.
- Clean your other equipment.

15.2. Regional Site Surface Soil Moisture and Temperature

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

The locations of these sites will be a subset of the SMEX02 regional sites. These sites will be manually sampled only a couple of times for calibrations purpose during the field campaign.

Gravimetric Soil Moisture Sampling Date _____ Observers _____

Time _____

Sites _____

Site ID	Sample ID	Wet Weight	Dry Weight	Surface Temperature				Soil Temperature	
				A	B	C	D	5 cm	10 cm
SF01	01	210.15		25	24	23	22	20	18
SF01	02								
SF01	03								
SF01	04								
SF01	05								
SF01	06								
SF01	07								
SF01	08								
SF02	09								
SF02	16								

Gravimetric Soil Moisture Sampling

Date _____ Observers _____

Time _____

Sites _____

Site ID	Sample ID	Wet Weight	Dry Weight	Surface Temperature				Soil Temperature	
				A	B	C	D	5 cm	10 cm
SF01	01	210.15		25	24	23	22	20	18
SF01	02								
SF01	03								
SF01	04								
SF01	05								
SF01	06								
SF01	07								
SF01	08								
SF02	09								
SF02	16								

Figure 27: Example of the gravimetric soil moisture sampling data sheet.

The variables that will be measured or characterized are:

- *0-6 cm soil moisture using the Theta Probe (TP) instrument*
- *0-3 and 3-6 cm gravimetric soil moistures and bulk density using the coring tool*
- *0-7.5, 7.5-15, 15-30 soil cores using the soil auger.*
- *Four surface temperatures using a hand held infrared thermometer (See Temperature Sampling protocol)*
- *5 cm soil temperature*
- *10 cm soil temperature*
- *GPS locations of all sample point locations (one time)*

15.3. Theta Probe Soil Moisture Sampling and Processing

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

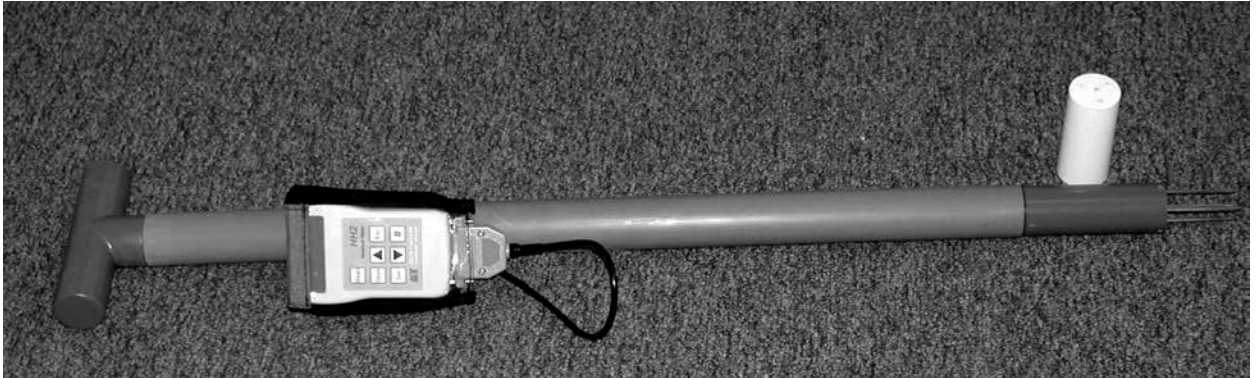


Figure 28: Theta Probe Type 1 (with extension rod).



Figure 29: Theta Probe Type 2.

Each unit consists of the probe (ML2x or ML3) and the data logger or moisture meter (HH2). The HH2 reads and stores measurements taken with the ThetaProbe (TP) ML2x/3 soil moisture sensors. It can provide milliVolt readings (mV), soil water ($m^3.m^{-3}$), and other measurements. Readings are saved with the time and date of the reading for later collection from a PC.

The HH2 is shown in Figure 22. It applies power to the TP and measures the output signal voltage returned. This can be displayed directly, in mV, or converted into other units. It can convert the mV reading into soil moisture units using conversion tables and soil-specific parameters. Tables are installed for Organic and Mineral soils, however, greater accuracy is possible by developing site-specific parameters. For SMAPVEX16, all observations will be recorded as mV and processed later to soil moisture.

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

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



Figure 30: HH2 display.

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

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

Check Battery Status

1. Press **Set** to display the **Options** menu
2. Scroll down to **Status** using the **up** and **down** keys and press **Set**.
3. The display will show the following

Mem % Batt %

Readings #.

- If Mem is not 0% see the TP coordinator.
 - If Battery is less than 50% see TP coordinator for replacement. *The HH2 can take approximately: 6500 TP readings before needing to replace the battery.*
 - If Readings is not 0 see the TP coordinator
4. Press **Esc** to return to the start-up screen.

Check Date and Time

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

Set First Plot and Sample ID

1. Press **Set** at the start up screen to display the **Options** Menu.
2. Scroll down to **Data** using the **up** and **down** keys and press **Set**.
3. Select **Plot ID** and press **Set** to display the **Plot ID** options.
4. The default ID should be A. If incorrect scroll through the options, from A to Z, using the **up** and **down** keys, and press **Set** to select one.
5. Press **Esc** to return to the main Options menu.
6. Scroll down to **Data** using the **up** and **down** keys and press **Set**
7. Scroll down to **Sample** and press **Set** to display available options. A sample number is automatically assigned to each reading. It automatically increments by one for each readings stored. You may change the sample number. This can be any number between 1 and 2000.
8. The default ID should be 1. If incorrect scroll through the options, using the **up** and **down** keys, and press **Set** to select one.
9. Press **Esc** to return to the main Options menu.

Select Device ID

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

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

To take Readings

1. Press **Esc** to wake the *HH2*.
2. Press **Read**
If successful the meter displays the reading, e.g.-

ML2 Store?

32.2%vol

3. Press **Store** to save the reading.
The display still shows the measured value as follows:

ML2

32.2%vol

Press **Esc** if you do not want to save the reading. It will still show on the display but has not been saved.

ML2

32.2%vol

4. Press **Read** to take the next reading or change the optional meter settings first. such as the Plot ID. Version 1 of the Moisture Meter can store up to 863 if two sets of units are selected.

Troubleshooting

Changing the Battery

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

Display is Blank

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

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

Incorrect Readings being obtained

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

Zero Readings being obtained

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

Settings Corrupt Error Message

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

Memory Failure Error Message

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

Some Readings Corrupt Error Message

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

Known Problems

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

15.4. Gravimetric Soil Moisture Sampling with the Scoop Tool

- Remove vegetation and litter.
- Use the large spatula (6 cm) to cut a vertical face at least 6 cm deep (Figure 23a).
- Push the GSM tool into this vertical face. The top of the scoop should be parallel with the soil surface. (Figure 23b).
- Use the large spatula to cut a vertical face on the front edge of the scoop (Figure 23c).
- Use the small spatula to cut the sample into a 0-1cm depth..
- Place the sample the top 0-1 cm in the odd numbered can. The small spatula and a funnel aid extraction of the sample in the can (Figure 23d).
- Take a second sample of 0-6 cm depth and place it in the even numbered can.
- Remember to use cans sequentially and odd numbers for the 0-1 and even for 0-6 cm samples.
- Record these can numbers in the field notebooks at the point location on the map.
- A video clip showing the gravimetric sampling technique can be downloaded from an anonymous ftp site hydrolab.arsusda.gov/pub/sgp99/gsmsamp.avi.
- At the specific sampling points where it is required, measure the soil temperature at 1, 5 and 10 cm depths using the digital thermometer provided. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.
- At the specific sampling points where it is required, measure the surface temperatures of A) exposed vegetation, B) in-shade vegetation (half the canopy height), C) exposed ground, and D) in-shade ground. If it is not possible to take a measure of any of these four observations at a site, make a note of that in the notebook. This would represent either 0% or 100% vegetation cover. Record these values in degrees C to one decimal point in the field notebooks at the point location on the map.

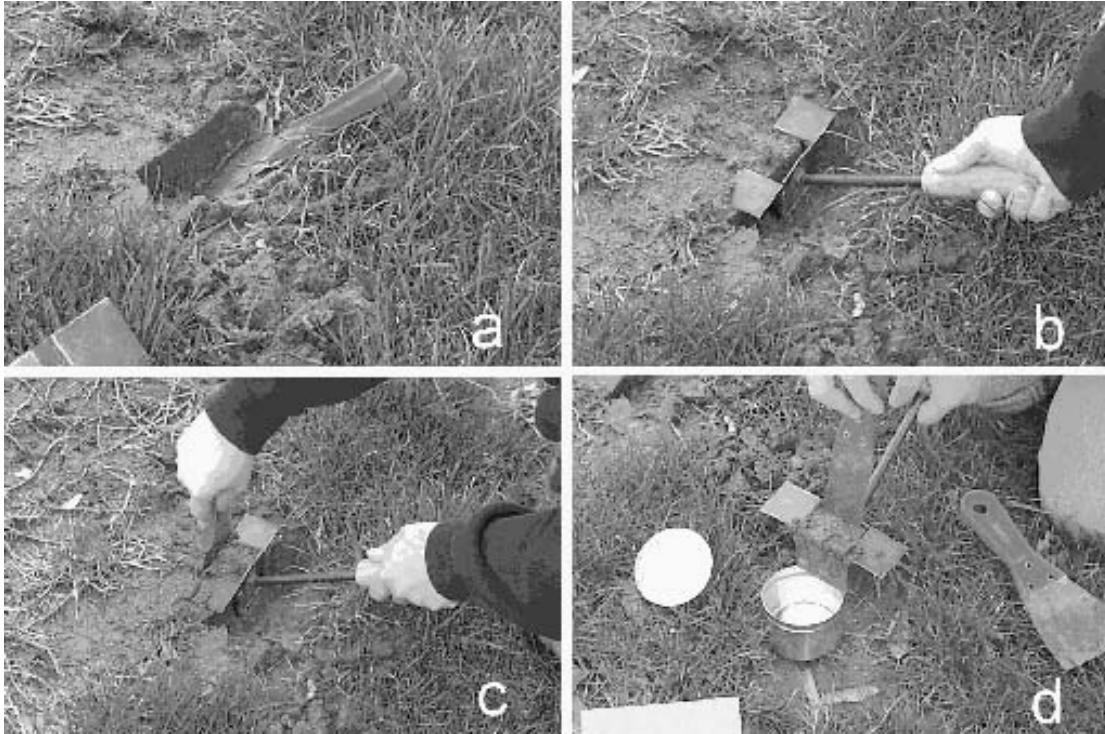


Figure 31: How to take a gravimetric soil moisture sample.

15.5. Gravimetric Soil Moisture Sample Processing

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

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

15.5.1. Wet Weight Procedure

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

15.5.2. Dry Weight Procedure

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

15.5.3. Data Processing

1. Enter all data from the sheets into an Excel spreadsheet. One file per day, one worksheet per site.
2. There will be a summary file for each day that will contain the means and standard deviations.
3. All files are backed up with a floppy disk copy.
4. The summary file will be transmitted to a central collection point on a daily basis.

5. You may keep copies of raw data for any site that you actually sample at this stage. You may not take any other data until quality control has been conducted

15.6. Watershed Site Soil Bulk Density and Surface Roughness

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

The Bulk Density Apparatus

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

Other Materials Required for Operation:

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

Selecting and Preparing an Appropriate Site -

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

Bulk Density Procedure -

15.6.1. Securing the Apparatus to the Ground

1. Place the apparatus foam-side-down on the ground.
2. Place the three securing rods in the 3/4" holes of the apparatus.
3. Drive each dowel into the ground until they do not move easily vertically or horizontally. (Figure 24a)

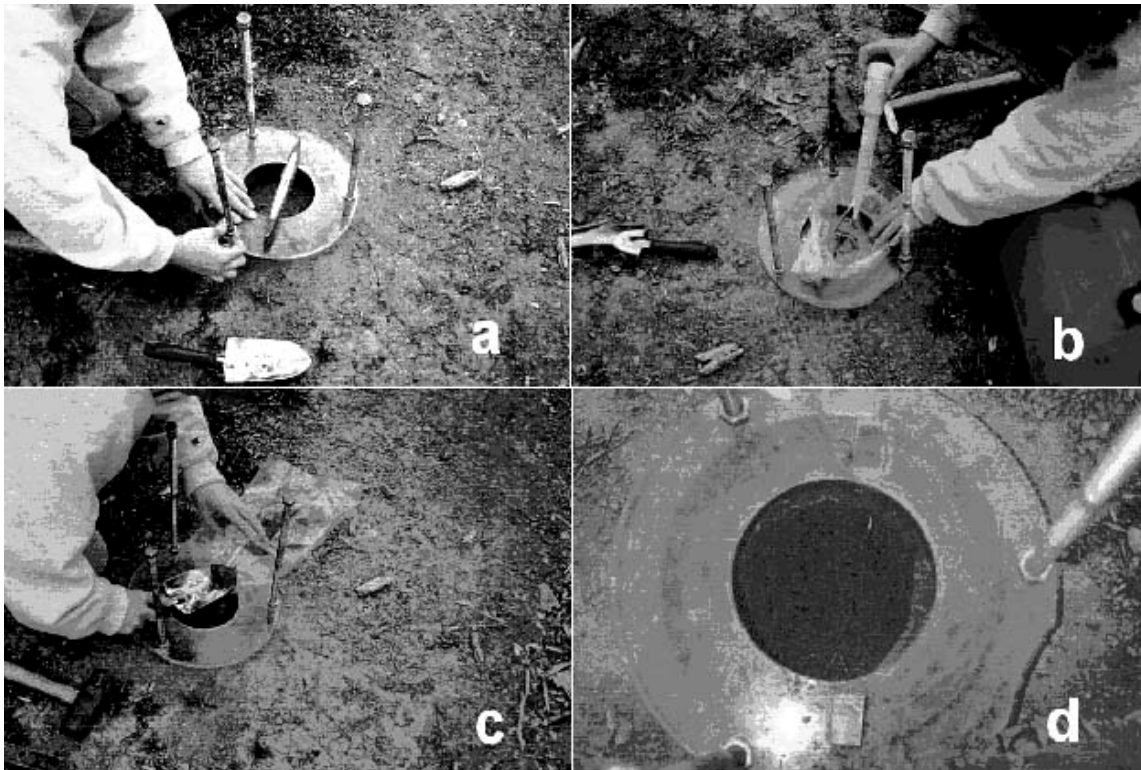


Figure 32: How to take a bulk density sample

15.6.2. Leveling the Apparatus Horizontally to the Ground

1. Tighten each of the bolts until the apparatus appears level and the foam is compressed to a height of 1" to 1 1/2".
2. Place the bubble level on the surface of the apparatus and tighten or loosen the bolts in order to make the surface level. Place the level in at least three directions and on three different areas of the surface of the apparatus.

15.6.3. Determining the Volume from the Ground to the Hook Gauge

1. Pour exactly one liter of water into the graduated cylinder.
2. Pour some of the water into a plastic storage bag.
3. Hold the plastic bag so that the water goes to one of the lower corners of the bag.
4. Place the corner of the bag into the hole. Slowly lower the bag into the hole allowing the bag and the water to snugly fill all of the crevasses.
5. Slightly raise and lower the bag in order to eliminate as many air pockets as possible.
6. Lay the remainder of the bag around the hole.
7. Place the hook-gauge on the notches on the surface of the apparatus.
8. Add water to the bag until the surface of the water is just touching the bottom of the hook on the hook-gauge. A turkey-baster works very well to add and subtract

small volumes of water. Be sure not to leave any water remaining in the turkey-baster. (Figure 24b)

9. Place the graduated cylinder on a flat surface. Read the cylinder from eye-level. The proper volume is at the bottom of the meniscus. Read the volume of the water remaining in the graduated cylinder. Record this volume. Subtract the remaining volume from the original 1000 ml to find the volume from the ground surface to the hook-gauge.
10. Carefully transfer the water from the bag to the graduated cylinder. Hold the top of the bag shut, except for two inches at either end. Then use the open end as a spout. (It is best to reuse water, especially when doing multiple tests in the field.)

Loosening the Soil and Digging the Hole

1. Label the oven-safe bag with the date and test number and other pertinent information using a permanent marker.
2. Loosen the soil. The hole should be approximately six cm deep and should have vertical sides and a flat bottom. An ice cream scoop is helpful to scrape the bottom of the hole so that it is flat. (The hole should be a cylinder: with surface area the size of the hole of the apparatus and depth of six cm.)
3. Remove the soil from the ground and very carefully place it in the oven-safe bag. (Be careful to lose as little soil as possible.) (Figure 24c and d)
4. Continue to remove the soil until the hole fits the qualifications.
5. Loosely tie the bag so that no soil is lost in transportation.

15.6.4. Finding the Volume of the Hole

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

15.6.5. Calculating the Bulk Density of the Sample

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

Potential Problems and Solutions

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

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

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

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

Surface Roughness

Surface roughness photographs will be obtained using the grid board approach. For grasses this should be performed after canopy and thatch removal. For row crops, photos will be taken both across (c) and along (a) the rows, the soil surface must be visible, therefore it may be necessary to remove plants, but do not damage more plants than you have to. Push the board into the soil surface so that there is no space between the board and the soil surface. Place a card with the site ID on the board and take a photo of the board and the soil surface in front of the board. (see Figure 25) Surface roughness photos will be taken once during the experiment unless there is a change in the field conditions (plowing, planting, harvesting ...).



Figure 33: Surface roughness photo.

A surface roughness pin board will also be used to record soil roughness in much the same way as the grid board. The board will be placed at across three consecutive meters in both primary directions. These profiles will be merged together to produce a full soil topography.



Figure 34: Pin board to be used for surface roughness measurements.

15.7. Soil Temperature Probes

Several different types of temperature probes may be used to measure soil temperature. These all have a metal rod, plastic top and digital readout. The version used will be the Max/Min Waterproof Digital Thermometer (**Error! Reference source not found.**).

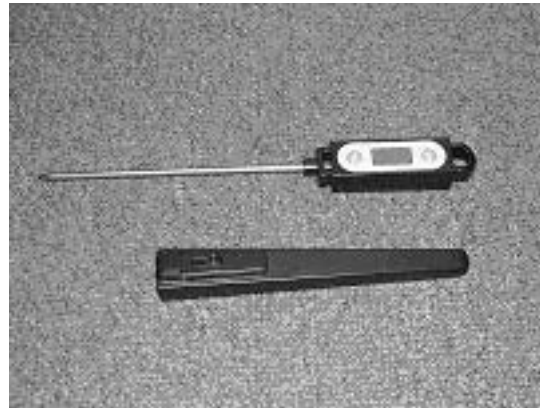


Figure 35: Temperature Probe

To Operate:

1. Press On/Off to switch on
2. Verify that the measurement is in Celsius and that the probe is not set to Max or Min
3. Push the probe to a depth of 5 cm, let it stabilize and record data.
4. Push Probe to a depth of 10 cm, let it stabilize and record data.
5. Turn off probe and cover.

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

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

15.8. Infrared Surface Temperature

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

Operating instructions:

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

15.9. Hydra Probe Soil Moisture and Apogee Temperature Sensor Installations

Figure 27 shows a close up of the Hydra probe. As with the installation of any soil moisture measuring instrument, there are two prime considerations: the location the probe is to be installed at, and the installation technique. A copy of the instruction manual for the HP will be available at the field HQ and can also be found at <http://hydrolab.arsusda.gov>.



Figure 36: The Hydra probe used at the tower locations.

15.9.1. Selecting a Location for the HP

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

15.9.2. Installation of the HP

- The installation technique aims to minimize disruption to the site as much as possible so that the probe measurement reflects the "undisturbed site" as much as possible.
 - Dig an access hole. This should be as small as possible.
 - After digging the access hole, a section of the hole wall should be made relatively flat. A spatula works well for this.
 - The probe should then be carefully inserted into the prepared hole section. The probe should be placed into the soil without any side to side motion which will result in soil compression and air gaps between the tines and subsequent measurement inaccuracies. The center of the probe head should be at a depth of 5 cm. This will give a sensing depth of 3-7 cm which will assure a stable signal, less sensitive to surface activity.
 - After placing the probe in the soil, the access hole should be refilled.
 - For a near soil surface installation, one should avoid routing the cable from the probe head directly to the surface. A horizontal cable run of 20 cm between the probe head and the beginning of a vertical cable orientation in near soil surface installations is recommended. Furthermore, sinking the wire deeper than the

installation depth is a good method of insuring that the wire will not act as a surface water pathway.

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

15.10. Vegetation Sampling

Purpose of Sampling

The purpose of vegetative sampling is to provide an estimate of the variation in the vegetative components in the corn and soybean fields across the SMAPVEX16 study sites.

Parameters

1. Phenology
2. Plant height
3. Ground cover
4. Stand density
5. Leaf density
6. Leaf Area Index
7. Multispectral measurements
8. Green and dry biomass
9. Digital photos

Sampling Locations

Three sites within each field will be sampled during the course of the study to quantify the full range of vegetative cover. A minimum of three sampling times will be considered for SMEX05, a week before the study during the first week, and during the last week. Sites will be determined through field surveys and previously acquired aerial photos.

Site Identification

Sites will be identified with a unique site id made of the field number, within field site and row number, e.g., field number = V09 plus site 1 plus row 2 yields an id of V0912. The V will denote a vegetative sampling site to avoid any potential confusion with other measurement sites within the same field.

Sampling Layout

Each site will be identified with a flag in the right hand corner and a pole that extends above the crop height to aid in locating the site. Each sampling site will consist of a 10 row area by 10 m. This will provide adequate area for all sampling dates (see Figure 29).

Sites will be located with GPS units and coordinates recorded for the corners of the site prior to the first sample collection. Sampling will not require the use of GPS but the right hand row of the sampling site will be flagged at the end row of the field so the sampling crews can travel down the rows.

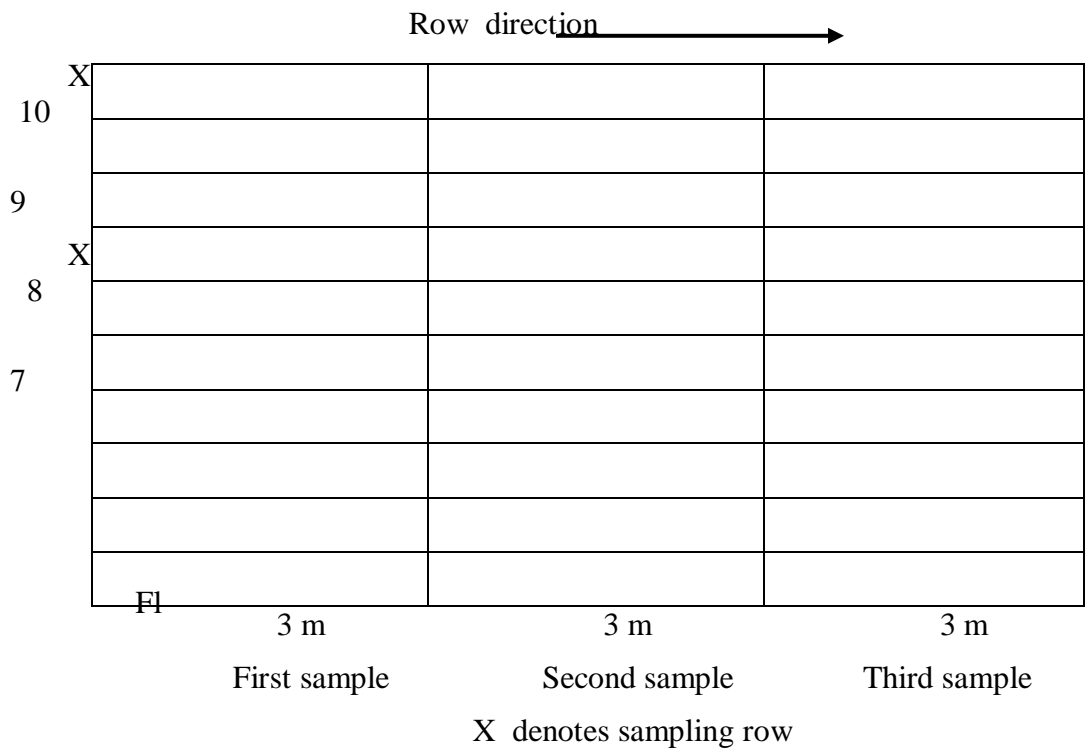


Figure 29. Vegetation sampling layout.

Sampling Scheme

Sampling sites are designed to provide a representative sample from the area of the field. One plant will be sampled from every other row for phenological stage and green and dry biomass (5 plants total). These same rows will be sampled for height, stand density, and row cover. Leaf area will be measured at four locations (in-row, 1/4 across row, 1/2 across row, 3/4 across row) with LI-2000. The first sampling position will be between the first row (flag location and the row to the left.

The first sampling time will begin on the end next to the flag, the second sampling time will begin 3 m down the row from the flag, and the third 6 m from the flag.

Data Recording

Data will be recorded onto the sampling sheet illustrated in Figure 30. Each field will have a separate notebook and data sheets for each sampling plot within the field. Each blank on the sheet will be filled in during the observation period. Data sheets will be maintained as part of the permanent experimental record to verify the data once it is entered into the computer.

Vegetation Surface Wetness Sampling Sheet

Field: _____ Date: _____ Samplers: _____

Crop Type: _____ Row Direction: _____

Site	Sample	Lat	Lon	Phen	Hgt	Leaf Count	Row Spacing	Row Density	Leaf	Time	Leaf Surface Area	Top Wet Wgt	Bot Wet Wgt	Node Wet Wgt	Top Dry Wgt	Bot Dry Wgt	Node Dry Wgt	LAI
1	1								1									
									2									
									3									
	2								1									
									2									
									3									
	3								1									
									2									
									3									
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	2								1									
									2									
									3									
	3								1									
									2									
									3									

Figure 33: Example of the vegetation sampling data sheet

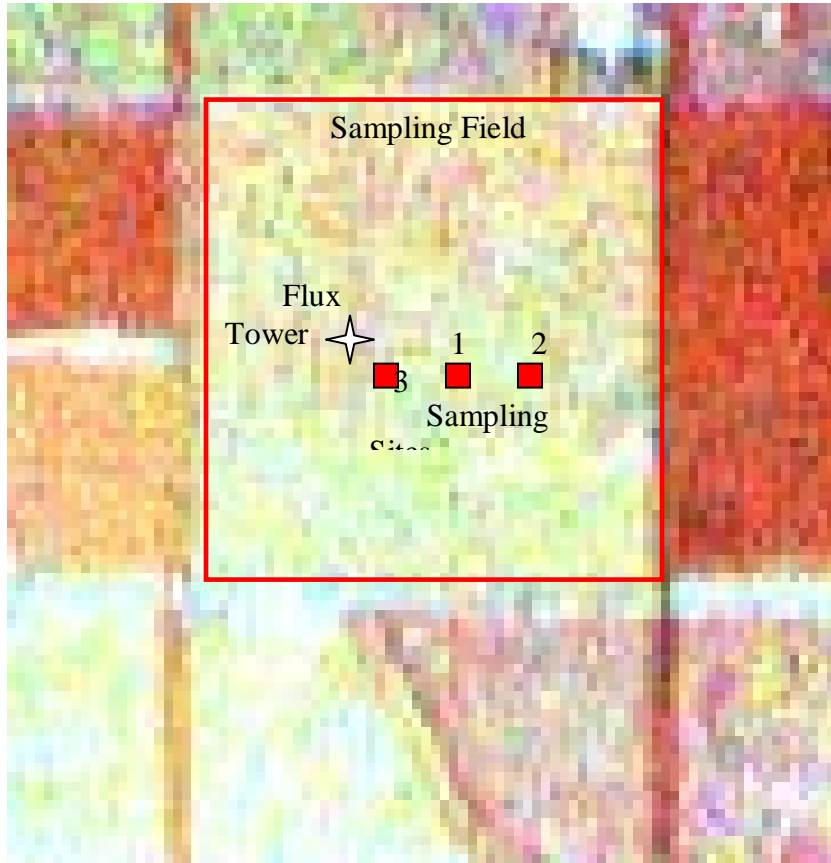


Figure 37: Theoretical sampling design for a 1/4 section field in SMEX05.

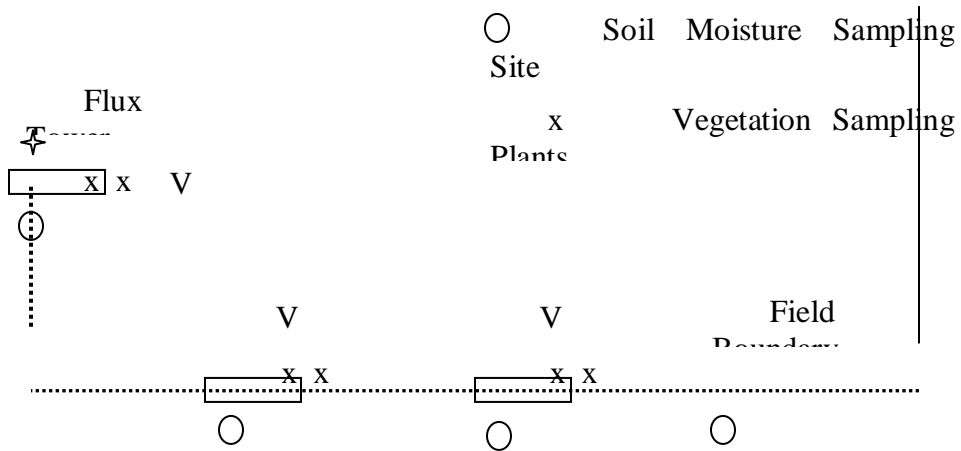


Figure 32: Close up of sampling design

15.11. Digital Photographs of Vegetation

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

15.12. Plant Height

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

15.13. Plant Count

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

15.14. Stand Density

First determine the row spacing by placing a meter stick perpendicular to the crop row and measure the distance between the center of one row and the center of the adjacent row. Stand density will be determined by placing a meter stick along the row sampled. The meter stick will be placed at the center of a plant stem and that stem counted as the first plant. All plants within the one-meter length are to be counted. If a plant is at the end of the meter stick and more than half of the stalk extends beyond the end of the meter stick it is not counted. Counts are recorded on the sampling sheet.

15.15. Leaf Density

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

15.16. Phenology

Phenological stage for crops will be determined using standard phenological guides.

Corn: <http://maize.agron.iastate.edu/corngrows.html#vegetative>

Soybean: <http://www.ext.nodak.edu/extpubs/plantsci/rowcrops/a1174/a1174w.htm>

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

Corn:

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

Soybeans:

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

When collecting data, record the approximate growth stage on the data sheet.

15.17. Green and Dry Biomass

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

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

15.18. Physical Sampling of Canopy/Leaf Wetness

Corn:

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

Soybean:

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

Grassland:

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

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

15.19. Ground Surface Reflectance

Surface reflectance data is valuable in developing methods to estimate the vegetation water content and other canopy variables. Observations made concurrent with biomass sampling provide the essential information needed for larger scale mapping with satellite observations. In addition, reflectance measurements made concurrent with satellite overpasses allow the validation of reflectance estimates based upon correction algorithms.

For SMAPVEX16, we are using instruments developed by CROPSCAN (<http://www.cropscan.com>). Other instruments may be also be used if available. Most hand-held radiometers, which are used to measure soil and plant reflectance in the field, have one detector that must be calibrated frequently for changing amounts of sunlight. Dual-detector instrument designs measure the amount of sunlight and the reflected light simultaneously; thus, fewer calibrations are required and data may be acquired rapidly. The CROPSCAN Multispectral

Radiometer (MSR) is an inexpensive instrument that has up-and-down-looking detectors and the ability to measure sunlight at different wavelengths. The basic instrument is shown in Figure 33.



Figure 38: CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm).

The CROPSCAN multispectral radiometer systems consist of a radiometer, data logger controller (DLC) or A/D converter, terminal, telescoping support pole, connecting cables and operating software. The radiometer uses silicon or germanium photodiodes as light transducers. Matched sets of the transducers with filters to select wavelength bands are oriented in the radiometer housing to measure incident and reflected irradiation. Filters of wavelengths from 450 up to 1720 nm are available.

For SMAPVEX16 we will be using a MSR16R unit with the following set of bands:

<i>Satellite</i>	<i>ID</i>	<i>CenterWavelength (Bandwidth)</i>
Thematic Mapper	MSR16R-485TMU	485 nm up sensor (90 nm BW)
	MSR16R-485TMD	485 nm down sensor (90 nm BW)
	MSR16R-560TMU	560 nm up sensor (80 nm BW)
	MSR16R-560TMD	560 nm down sensor (80 nm BW)
	MSR16R-660TMU	660 nm up sensor (60 nm BW)
	MSR16R-660TMD	660 nm down sensor (60 nm BW)
	MSR16R-830TMU	830 nm up sensor (140nm BW)
	MSR16R-830TMD	830 nm down sensor (140nm BW)
MODIS	MSR16R-1650TMU	1650 nm up sensor (200nm BW)
	MSR16R-1650TMD	1650 nm down sensor (200nm BW)
	MSR16R-650U2	650 nm up sensor (40 nm BW)
	MSR16R-650D2	650 nm down sensor (40 nm BW)
	MSR16R-850U2	850 nm up sensor (60 nm BW)
	MSR16R-850D2	850 nm down sensor (60 nm BW)
	MSR16R-1240U	1240 nm up sensor (12 nm BW)
	MSR16R-1240D	1240 nm down sensor (12 nm BW)

MSR16R-1640U	1640 nm up sensor (16 nm BW)
MSR16R-1640D	1640 nm down sensor (16 nm BW)

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

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

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

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

Three methods of calibration are supported for the MSR16R systems.

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

Advantages:

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

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

Advantages:

- Provides a more lambertian reflective surface for calibrating the longer wavelength (above about 1200 nm) down sensors than does the opal glass diffuser of the 2-point method.

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

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

Advantages:

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

Disadvantages:

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

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

There are six major items you need in the field -

- MSR16 (radiometer itself) (Figure 33)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Figure 34)
- CT100 (hand terminal, connected to the DLC with a serial cable) (Figure 35)
- Calibration stand and opal glass plate
- Memory cards
- Extension pole (with spirit level adjusted so that the top surface of the radiometer and the spirit level are par level)



Figure 39: Cropsan data logger controller & cable adapter box.



Figure 40: CT100 hand terminal.

Set Up –

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

Configure MSR –

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

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

Calibration –

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

Memory Card Usage –

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

Taking Readings in the Field –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu

- At Command * Press **2** then **ENTER** to get to the Reconfigure MSR menu
- At Command * Press **5** then **ENTER**, input your plot ID (numbers 1-999 only), Press **ENTER**
- Press **M** to return to the MSR main menu
- At Command * Press **8** then **ENTER** to get to the MSR program
- Press **ENTER** to continue or **M** to return to the MSR main menu
- Enter beginning plot number, **ENTER**
- Enter the ending plot number, **ENTER**, record plot numbers and field ID in field notebook
- Adjust the radiometer to a suitable height (about 2 meters) over the target, point the radiometer towards the sun, center the bubble in the center of the spirit level and make sure that there are no shadows in the sampling area
- **Do not** take measurements if $IRR < 300$
- Initiate a scan by pushing **SPACE**, the message ‘scanning’ will appear on the screen and a beep will be heard
- When the scan is complete (about 2 seconds) ‘**’ will be displayed and 2 beeps will be heard
- Now, you can move to the next area
- 3 Beeps will be heard when the data has been stored
- Press **SPACE** to start next scan, **R** to repeat scan, **P** to repeat plot, **S** to suspend/sleep, **M** to return to the MSR main menu, **W** to scan white standard, and **D** to scan Dark reading
- When you are done scanning at that field location, press **M** to return to the MSR main menu, then press **10** to put the DLC to sleep
- Switch the CT100 power off

Downloading Data –

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

The basic approach to sampling that will be used is to sample at vegetation water content sampling locations. Reflectance and LAI data will be collected for each vegetation sampling location just prior to removal using the following sampling scheme.

15.20. Leaf Surface Area

Clip the leaf at the base of the leaf, near the stalk. Record the field, location, and sample on the leaf with a marker. For soybean, it might be necessary to write the leaf number on the bag. Store the leaf in a bag. When the leaves are returned to the lab, place each leaf on a grid board and take a digital photograph. This photograph will be digitized in the future and a surface area determined. Taking *the wet weight of each leaf filter paper sample and subtract the plastic bag*

and filter paper weights. Then divide this total surface wetness by the Leaf Surface Area to determine the Surface Wetness per Leaf Area.

15.21. Leaf Area Index

Leaf area will be measured with a LAI-2000 (Figure 36). For *row crops* in the inter-row region at least one meter away from where the biomass sample was taken, but still in a region of similar canopy amount. [Need to state that LAI is taken >1m away from biomass sampling area, should still be taken in a part of canopy that has similar characteristics. LAI can drop precipitously over a couple meters down the row, and you need the LAI to be consistent with where the dew was sampled. This gets back to question of how the sampling areas are going to be selected. Ideally, you make a measurement in the center of a large uniform area. Dew at the edge of a discontinuity will be different from dew in a homogeneous part of the canopy....]. The LAI-2000 will be set to average 4 points into a single value so one observation is taken above the canopy and 4 beneath the canopy; in the row, $\frac{1}{4}$ of the way across the row, $\frac{1}{2}$ of the way across the row and $\frac{3}{4}$ of the way across the row. This gives a good spatial average for row crops of partial cover. For *grasses and weeds and non-row crops*, five sets of measurements (each set consisting of 1 above the canopy and 4 beneath the canopy) will be made. If possible these should be made just before clipping. Protocols for *shrubs and trees* will be developed if necessary.

If the sun is shining, the observer needs to stand with their back to the sun and put a black lens cap that blocks $\frac{1}{4}$ of the sensor view in place and positioned so the **sun and the observer are never in the view of the sensor**. The observer should always note if the sun was obscured during the measurement, whether the sky is overcast or partly cloudy with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked “shaded”, if shadows could be seen during the measurement then the measurement is marked “sunny”. Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements. Also, it is important to check the LAI-2000 internal clock each day to verify they are recording in CDT.



Figure 41: The LAI-2000 instrument.

Operating the LAI-2000 -

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

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

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

Clear the memory of the logger -

Press “**FILE**”

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

Press “**ENTER**”

Press “↑” to change “NO” to “YES”

Press “**ENTER**”

General items –

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

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

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

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

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

To Begin -

Press “**SETUP**”

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

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

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

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

Use “↑” to get to “RESOLUTION”

Set it to “HIGH”

Use “↑” to get to “CLOCK”

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

Press **“OPER”**

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

Choose “MODE=1 SENSOR X”

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

Enter "1" in “REPS”

Use “↑” to get to “SET PROMPTS”

Put “SITE” in first prompt

Put “LOC” in second prompt

Use “↑” to get to “BAD READING”

Choose "A/B=1"

Press **“BREAK”**

Display will contain the two monitor lines

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

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

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

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

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

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

For grasslands and shrubs:

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

2. Place the sensor below the plant canopy in one corner of your sampling area level the sensor and press the black log button on the sensor handle and keep level until the second beep.

3. Repeat for the other 3 corners

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

For Row crops –

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

2. Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.

3. Place the sensor one-quarter (1/4) of the way across the row and record data again.

4. Place the sensor one-half (1/2) of the way across the row and record data again.

5. Place the sensor three-quarters (3/4) of the way across the row and record data again.

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

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

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

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

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

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

Downloading LAI-2000 files to a PC Using HyperTerminal -

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

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

2. Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | LAI2000.ht)

3. On the LAI-2000, go to function 31 (config i/o) and configure I/O options. Baud=4800, data bits=8, parity=none, xon/xoff=no.

4. On the LAI-2000, go to function 33 (set format) and setup format options. First we use Spdsheet and take the default for FMT.
5. In HyperTerminal go to Transfer | Capture text. Choose a path and filename (LAIMMDDFL.SPR, where MM is month, DD is day, FL is first and last initials of user and SPR for spreadsheet data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.
6. On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.
7. Once you hit enter in function 32, lines of text data will be sent to HyperTerminal. The LAI-2000 readout will say 'Printing file 1, 2, etc'. Check the window in HyperTerminal to ensure the data is flowing to the PC. This may take a few minutes, wait until all the desired files have been sent.
8. In HyperTerminal go to Transfer | Capture text | Stop.
9. On the LAI-2000, go to function 33 (set format) and setup format options. Now set to Standard, Print Obs = yes
10. In HyperTerminal go to Transfer | Capture text Choose a path and filename (LAIMMDDFL.STD, where MM is month, DD is day, FL is first and last initials of user and STD for standard data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.
11. On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.
12. In HyperTerminal go to Transfer | Capture text | Stop.
13. Using a text editor (like notepad) on the PC, open and check that all the LAI data has been stored in the text file specified in step 3. Make a back up of this file. Once you're sure the LAI values look reasonable and are stored in a text file on the PC, use function 22 on the LAI-2000 to delete files on the LAI-2000 and free up it's storage space.

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

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

15.22. Global Positioning System (GPS) Coordinates

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

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

General Information

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

Watershed and regional sites should be labeled as follows:

Watershed: Site SF## and point ## (e.g., SF05-02)

Carry at least two (2) extra AA alkaline batteries. The eTrex is configured to run in Battery Save mode which automatically turns the GPS receiver on and off to conserve power. In this

mode, the eTrex should operate for approximately 22 hours. A “Battery Low” message will appear at the bottom of the screen when the unit has ten (10) minutes of battery life remaining.

eTrex GPS Features (see Figure 38)

UP/DOWN ARROW buttons: used to select options.

ENTER button: used to confirm selections or data entry.

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

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

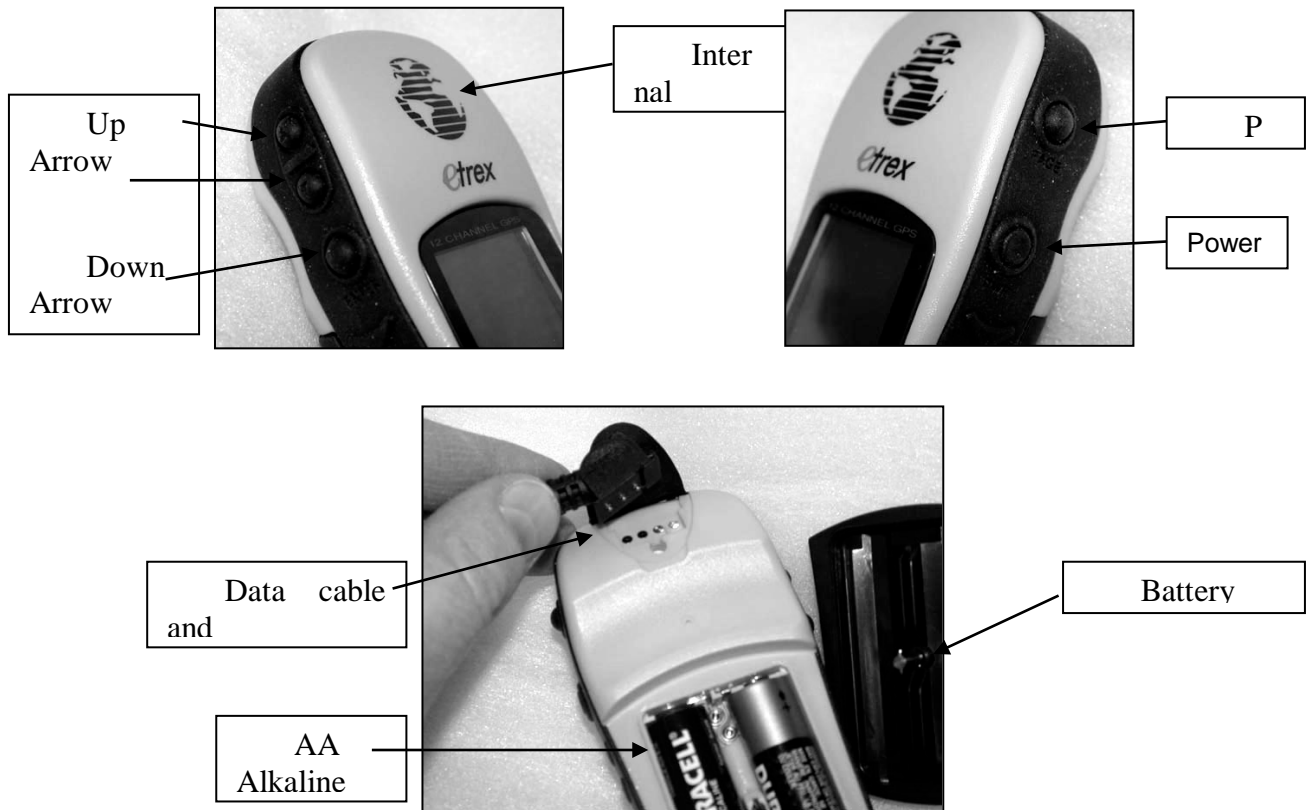


Figure 38. GPS features.

All eTrex operations are carried out from the four (4) “pages” (or display screens) Shown in Figure 39. The PAGE key is used to switch between pages. (The Map and Pointer Pages are used for navigation and will not be discussed further.)

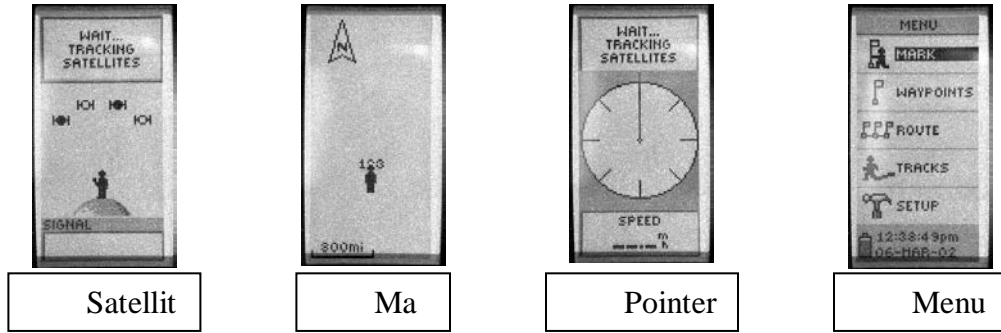


Figure 39. GPS display screens or “pages”.

Setup at Headquarters Prior to Data Collection

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed.
2. Confirm configuration parameters:
 - PAGE to Menu screen; ARROW to Setup; press ENTER (Figure 40)
 - Use the following key sequence to check configuration parameters:
 - ARROW to first parameter; press ENTER;
 - confirm values (see configuration values below);
 - press PAGE to return to Setup menu;
 - ARROW to next parameter, etc.
 - The following are the parameters and required settings;
 - Time = Format: **24 Hour**; Zone: **US-Central**; (UTC Offset: **-6:00**); Daylight Saving: **Auto**
 - Display = Timeout: **15 sec.**
 - Units = Position Format: **hddd.ddddd°**; Map Datum: **WGS 84**; Units: **Metric**; North Reference: **True**
 - Interface = I/O Format: **Garmin**
 - System = Mode: **Battery Save**

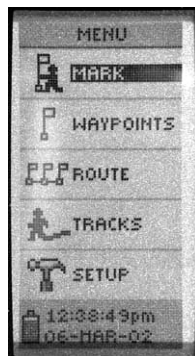


Figure 40. GPS Menu page.

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

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

GPS Field Data Collection

1. Power unit on: Depress and hold power button until eTrex welcome screen appears and Satellite Page is displayed (Figure 41). Wait until text box at top of screen reads "READY TO NAVIGATE" before continuing.

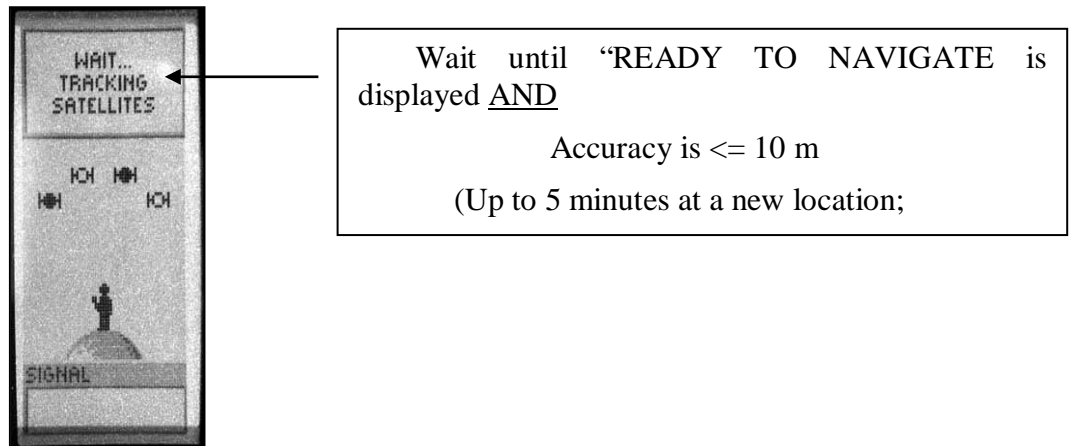


Figure 41. GPS Satellite Page.

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

3. Initiate GPS point data collection:

- PAGE to Menu screen (Figure 39); Arrow to Mark; press ENTER. (Shortcut: press and hold ENTER button from any screen to get to Mark Waypoint page below.)
- ARROW to alphanumeric ID field (Figure 42); press ENTER. Use ENTER and UP/DOWN buttons to edit ID, if necessary. (Waypoint ID increments by one (1) automatically.)
- Record latitude (North) and longitude (West) coordinates displayed at bottom of screen into field notebook. *Do not rely on electronic data download to save data points!*
- ARROW to OK prompt; press ENTER to save point coordinates electronically.

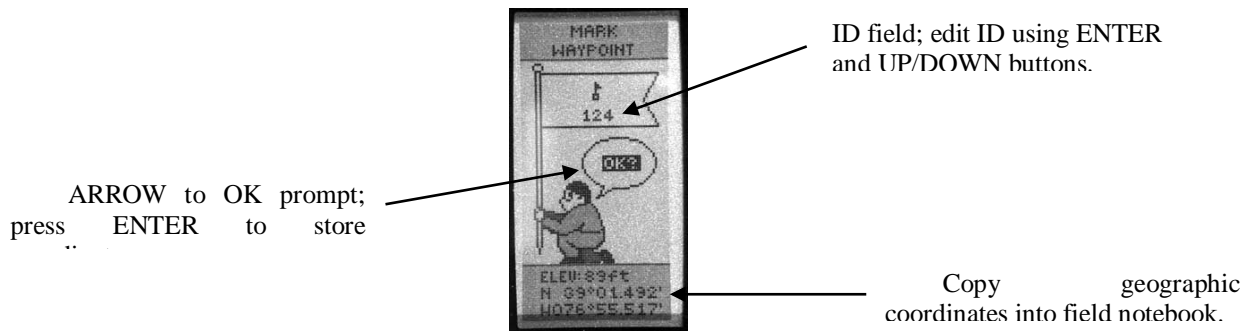


Figure 42. GPS Mark Waypoint Page.

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

Electronic Data Downloading

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

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

Launch Waypoint.exe

GPS => Port => Com?

Waypoints => Download

File => Save => Waypoint

Select Save as type: Comma Delimited Text File

16. SMAPVEX16 Bibliography/References



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