United States Department of Agriculture

NRCS Natural Resources Conservation Service

FINAL REPORT

SOIL MOISTURE/SOIL TEMPERATURE PILOT PROJECT

Geneva, New York SM/ST Station

National Soil Survey Center
Lincoln, Nebraska

National Water and Climate Center
Portland, Oregon

January 29, 2004

PREFACE

The Soil Moisture/Soil Temperature Pilot Project was initiated in 1991 as a ten-year project to determine the feasibility of establishing a national climatic network. This is the final report for the project. The report details the beginning of the project, its history, discoveries, observations, successes and failures, results, improvements, and recommendations for the future.

Garry Schaefer, USDA Natural Resources Conservation Service (NRCS) National Water and Climate Center (NWCC), served as the project leader. Members of the Soil Temperature and Moisture (STM) Team (see Appendix A for a list of team members) aided in the management of the project and provided advice, recommendations, technical expertise, direction, and occasionally a source of labor. Others, including NRCS soil scientists and NRCS NWCC electronics technicians, contributed to the success of the project. Tom Calhoun, USDA NRCS National Headquarters (NHQ), served as the project sponsor. Funding for the project was from the Global Climate Change Initiative. This report was prepared by Garry L. Schaefer, Ron F. Paetzold, Donald J. Huffman, and Ronald D. Yeck.

The Executive Summary section presents a concise overview of the project. The Instrumentation, Data Collection, and Data Management sections of this report each contain the original concept, history, and the final implementation. Everything learned from the project is available in the Results section. An Appendix section is included to provide detailed information that is superfluous to the report. The appendix includes previous project reports in their entirety and other reference materials not considered necessary sections of the basic report.

ACKNOWLEDGEMENTS

The NRCS concept of demonstrating application of the highly successful meteor burst technology of the NRCS Snow Telemetry System (SNOTEL) for automated gathering of soil moisture and soil temperature information was envisioned in the fall of 1990. Tommy A. George, Director, Resource Inventory Division, Tommy Calhoun, Soil Scientist, Soil Survey Division, Dennis Lytle, Soil Scientist, National Soil Survey Center (NSSC), David E. Johnson Director and Garry Schaefer, Data Collection Leader of the Snow Survey and Water Supply Forecasting, West National Technical Center and Jon Werner, Snow Survey Data Collection Officer, Utah laid out the initial plan for a pilot project of a national SM/ST monitoring network.

The SM/ST Pilot Project was funded through the NRCS Global Climate Change Initiative. John Kimble, Soil Scientist, NRCS NSSC, and Tommy Calhoun, Soil Scientist, NRCS, National Headquarters (NHQ), were primarily responsible for the distribution of these funds to the Pilot Project and provided a lot of encouragement throughout the life of the project.

NRCS National Water and Climate Center (NWCC) Electronic Technicians, Ron Bush and Bill Woolcock, have contributed greatly to the success of the project. They are responsible for designing the wiring schemes and played a major role in troubleshooting and solving the problems that cropped up from time to time. Don Huffman, NRCS NWCC, and Bill Woolcock provided the bulk of the required annual station maintenance. Don Huffman was largely responsible for the initial station installation and wise counsel.

Richard Pullman, Don Huffman, and Otto Baumer sampled soils for characterization at the project sites.

Deb Harms, Soil Scientist, NSSC, Denice Schilling, Statistical Assistant, NWCC, and Rose Loehr, Computer Assistant, NWCC, contributed greatly to the project. Deb provided much needed soils information after Otto retired. Denice provided all quality control editing throughout the 10-year pilot project and Rose ensured that the data from the SM/ST pilot project stations were databased and made available on the NWCC web page.

The NRCS Soil Survey Lab in Lincoln, Nebraska, processed the soil samples and performed the characterization analysis for the soils at each SM/ST Pilot Project site.

A special acknowledgement goes out to all of the NRCS personnel and local cooperators for maintenance support during the pilot project. With their help and through their hard work, the pilot project was a great success and helped to bring it to the next phase of development, the Soil Climate Analysis Network (SCAN).

The NRCS Soil Moisture and Temperature (SMT) Team, chaired by Ron Yeck, was a source of technical expertise and provided both advice for the management of the project and frequently a source of labor for project installation, upgrades, maintenance, and troubleshooting.

EXECUTIVE SUMMARY

Soil water status and soil temperature are critical parameters for many applications, including continental-scale climate models, soil classification, and drought assessment. The Soil Moisture/Soil Temperature (SM/ST) Pilot Project was proposed in 1990 to test the feasibility of establishing a national soil-climate monitoring program that meets the growing demands of the global climate change community, modelers, resource managers, soil scientists, ecologists, and others. The project, a cooperative effort by the Resource Inventory Division and the Soil Survey Division of the Natural Resources Conservation Service, was to examine network communications, sensors, data collection electronics, station maintenance, data management, system interfaces, and management of a large national program.

Installation of 21 stations (in 19 states) began in 1991 and was completed the following year. Air temperature, relative humidity, precipitation, solar radiation, windspeed, soil temperature, and soil moisture were measured at 6-hour intervals initially, then hourly toward the end of the project. Soil temperature and soil moisture were measured at depths of 2, 4, 8, 20, 40, and 80 inches. Later the 80-inch soil moisture measurement was discontinued. Many changes were made to the original design, in response to lessons learned during the course of the project. The original soil-moisture sensors were replaced with sensors of a completely different design. A more robust and versatile datalogger was selected to replace the initial data-collection electronics. Every aspect of the measurement system was evaluated critically and improved when necessary.

Data from each site were transferred to master stations by the meteor-burst communications technology proven in the existing NRCS SNOTEL program. From the master stations, data were transmitted via telephone to the central computer facility at the National Water and Climate Center (NWCC) in Portland, Oregon. After data processing converted raw sensor output to useful units, the data were evaluated using quality-control procedures to ensure that station sensors and electronics were functioning within reasonable limits. Algorithms to process and evaluate the data were designed, and computer coding was developed to accommodate the algorithms. Much of the quality control is still performed by hand, although progress continues to be made on development of software to accomplish this tedious task.

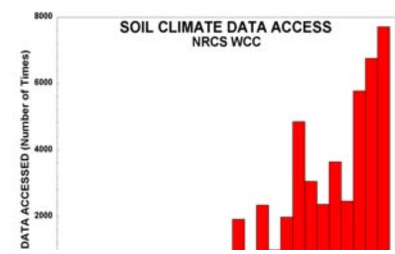
Much of the effort during the 10-year project revolved around evaluating and modifying instrumentation and field methods. Initially, the focus was on developing an operational plan, site selection, and instrument (sensors, communications, data collection systems, etc.) selection. The next tasks were site and soil characterization and station installation. During the early and middle years of the project, emphasis was on system performance. Many difficulties involving operational aspects of individual stations were addressed. Problems with soil moisture sensors were observed at all stations. What initially was considered a sensor calibration problem turned out to be an interface problem involving compatibility between the soil moisture sensors and the data collection electronics. At one time or another, all stations experienced failure of the precipitation sensors. The problem was a culmination of many small effects and thus was difficult to solve.

As problems with field hardware performance and efficiencies were identified, requests were made to instrument manufacturers to make major product changes. Campbell Scientific, Inc., and Meteor Communications Corporation worked together to make their dataloggers and meteor-burst telemetry compatible. Vitel, Inc., introduced a new model soil-moisture sensor designed to our specifications. They also changed their data processing software in response to our needs. The Soil Temperature and Moisture (STM) Team continues to work with manufacturers on ways to improve their products so that they meet our needs.

The mid and later stages of the Pilot Project saw increasing emphasis on data management. Processing of incoming data is needed to convert the raw sensor outputs to relevant climatic information. This conversion required the development calibration curves and associated computer algorithms for each sensor. Data-processing programs had to be written. Initially, user requests required the NWCC staff to send data directly to individuals. Beginning in 1998, data were made available via the Internet through the NRCS NWCC public access web server.

Demand for Pilot Project data has been strong from the beginning. Users were told repeatedly that this was a pilot project designed to explore the feasibility of establishing a large-scale climate monitoring program, not a data collection effort per se and that the data collected were primarily for evaluation of the project, not for general use, and should be considered unreliable. Still, users DEMANDED that the data be released, even though we considered it to be of questionable quality. This project was one of very few sources of this type of data and the only national-scale monitoring effort in place. Toward the end of the project, this became the most extensive long-term data set available. Data downloads from the Internet have steadily and dramatically increased from the first. News of the availability has spread only by word of mouth and through internet searches by users. Uses of the data are many and varied, ranging from continental-scale climate models to snake hibernation studies, from satellite-platform remote-sensor calibration to soil classification. The list goes on and on. Users include research scientists, NRCS field personnel, private industry, and consultants. One request for data came from personnel at an energy (oil) company. They indicated that they thought the next crucial commodity would be clean water and they intended to prepare for the demand. It is anticipated that when enough data become available (adequate spatial coverage and sufficient length of record) to define "normal" years, the data will be extremely valuable for defining drought and monitoring the extent and severity of drought events. We constantly receive requests for more data, data from additional locations, and additional soil properties.

Table 1



In response to this demand, NRCS launched a new effort that is a natural extension of the SM/ST Pilot Project. Called the Soil Climate Analysis Network or SCAN, it is a fully operational and standardized network for soil and meteorological monitoring. We have received money from other government agencies and universities to install additional soil climate stations as part of the SCAN. The enormous worldwide demand for soil-climate data of the type produced by the project suggests a definite and immediate need for a national network of monitoring stations. The STM Team now manages more than 100 cooperative soil-climate projects. More than 50 have been installed in direct response to NRCS requests. The project resulted in the accumulation of a great deal of experience in instrumentation, large-scale project management, and data management. Consequently, there has been a strong demand for this expertise from others interested in establishing monitoring programs of all sizes.

Probably the most important lesson learned from the SM/ST Pilot Project is that any long-term, large-scale program must have support from the agency. A program to provide consistent, high-quality data requires adequate funding for equipment, including funds for scheduled sensor replacement, and adequate personnel to cover the operational aspects of the project, including station selection, site installation, site maintenance, data management, and troubleshooting. A long-term program cannot be run effectively on a year-to-year basis. Budget cuts require choosing between a partial shutdown of the program (closing stations) or reduced maintenance. Reduced maintenance increases quality-control costs, decreases data quality, and generally degrades the entire program. Station closure results in data gaps and increased costs associated with station reopening in times of higher budgets. No long-term, large-scale program should be undertaken without a long-term commitment on the part of agency management.

The Pilot Project successfully demonstrated the feasibility of a national NRCS data-collection program for gathering needed soil-climate data. Technical challenges associated with sensors, interfaces, data transmission, and data management have been solved. The knowledge gained through the SM/ST Pilot Project has been used in the development of the SCAN, which is currently operating with about 90 monitoring stations. The SCAN program should be fully supported. The remaining Pilot Project stations should be upgraded and converted to SCAN stations. Fully implementing the SCAN would provide a highly visible program that would provide needed natural resource data for conservationists, scientists, and land managers worldwide.

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INTRODUCTION

In 1989, NRCS Chief Bill Richards wanted to increase the agency's participation in the USDA Global Climate Change (GCC) Research program. The Soil Survey Division in response offered to have $1.5 million redirected out of CO-02 funding to support GCC activities as long as the research conducted would provide information helpful to better understand soils. The proposal to try to measure real time soil moisture and temperature on a long-term basis in soils that would be sensitive to slight changes in climate was one of several projects initiated with these funds. Coincident with this, the Resource Inventory and Geographical Information System Division wanted to expand its data collection capability to better predict drought by contracting for an additional master station to provide for meteor burst data transmission in the eastern (and central) U.S.

These two divisions joined to sponsor the Soil Moisture/Soil Temperature (SM/ST) Global Climate Change Pilot Project.

According to the cover letter, signed by Richard W. Arnold, Director, Soil Survey Division, for the Global Change Pilot Project (USDA SCS Staff, 1991) the intent was "to eventually have 2,000 sites collecting data across the United States." The landowner agreement form shown in the Global Change Pilot Project (USDA SCS Staff, 1991) allowed the SCS to install, maintain, and operate the data collection for a minimum of 30 years.

OBJECTIVES

As detailed in USDA NRCS 1991 Global Change Pilot Project plan (Appendix D), the project objectives are "to demonstrate the feasibility of a national SCS remote data collection system for gathering the needed global research data." The Pilot Project was designed to "resolve some existing technical challenges associated with sensor design, sensor interfaces for remote data transmission and data management." It was recognized that much data, potentially useful to the global change research effort, was (and is) being collected in small and uncoordinated manual or automated systems across the country. Another major goal of the project was to draw useful data into a centralized database to provide access to agency and non-agency users via telecommunications.

Objectives:

- Demonstrate the feasibility of a NRCS, national, remote, automated, data-collection system for gathering data needed for global climate change research.
- Resolve existing technical challenges associated with site installation, sensor design, sensor interfaces, and data management concerns.
- Assess existing networks to determine what types of soil-climate information are available and if it is accessible.
- Make the data available to a variety of users.

The SM/ST Project was a pilot project to last no more than 10 years and to prove that the following objectives could be met:

1. To establish an eastern SNOTEL meteor burst master station and ten remote stations for the remote collection of eastern climatic information.
2. To test the sensor and remote data collection systems.
3. To provide data for a more complete and more accurate representation of the Soil Moisture and Temperature Regimes of the U.S.
4. To monitor soils in areas under soil moisture or temperature stress that could over time show changes in crop yields or plant community composition due to shifts in climate.
5. To establish benchmark data for soil moisture and temperature conditions in important soils to serve as references with which changes in climates, both past and future, can be compared.
6. Once it was clear the objectives could be met, a larger, comprehensive data collection network could be established if the funding was available and the agency determined it was a priority concern.

The Global Change Pilot Project Plan (USDA SCS Staff, 1991) states “It is the goal in this part of the pilot project to pull together into one database all useable data in addition to the new Global Change data that will be collected. Outside user access to the data base will be very important.”

BACKGROUND

In 1989, NRCS Chief Bill Richards wanted to increase the agency's participation in the USDA Global Climate Change (GCC) Research program. The Soil Survey Division in response offered to have $1.5 million redirected out of CO-02 funding to support GCC activities as long as the research conducted would provide information helpful to better understand soils. The proposal to try to measure real time soil moisture and temperature on a long-term basis in soils that would be sensitive to slight changes in climate was one of several projects initiated with these funds. Coincident with this, the Resource Inventory and Geographical Information System Division wanted to expand its data collection capability to better predict drought by contracting for an additional master station to provide for meteor burst data transmission in the eastern U.S.

These two projects were joined together to become the Soil Moisture/Soil Temperature (SM/ST) Global Climate Change Pilot Project.

The SM/ST Project was a pilot project to last no more than 10 years and to prove that the following objectives could be met:

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6. Once it was clear the objectives could be met, a larger, comprehensive data collection network could be established if the funding was available and the agency determined it was a priority concern.

The selection of monitoring sites varied from place to place depending on the importance of the objectives to that particular region of the country. For example, in the east the emphasis was on establishing the coverage for the meteor burst master station so ten sites were selected to ensure coverage was adequate. In the west sites were selected where additional information was needed to more accurately characterize soil moisture and temperature regimes for Soil Taxonomy, and to characterize sites most sensitive to variations in soil moisture and temperature. In addition, the following criteria were established for the location of all sites:

1. First priority was given to federally managed land, second priority to state managed land, third priority to private land.
2. Sites must be approved by a qualified cultural resources specialist.
3. Vehicle access must be assured
4. Fencing must be allowed
5. Sites needed to be located away from public view.
6. Consideration was given to co-location with Long Term Ecological Research Sites or other long term monitoring projects such as Forest Service Remote Automated Weather Station sites, or ARS and Agricultural Experiment Stations.
7. Benchmark soils were given priority and should be in mapping units of large extent.
8. Soils were to be very deep (>60”), well drained, and preferably medium textured.
9. Landscape position was to be typical of the soil map unit.
10. Management status was to be stable in a grass vegetation.

OVERVIEW

This project was proposed in 1990 to address the lack of consistent soil-climate data to meet growing demands for assessment of global climate change, drought, risk assessment, and to make better resource management decisions (USDA-SCS, 1991). The Resources Inventory Division (RID) and the Soils Division of the NRCS (then SCS) worked together to form a partnership to address this need.

Installation of Soil Moisture/Soil Temperature Pilot Project (SM/ST PP) sites began in 1991 and was completed the following year. Meteor burst communication telemetry provides near real-time data from 21 sites, in 19 states (Figure 1).

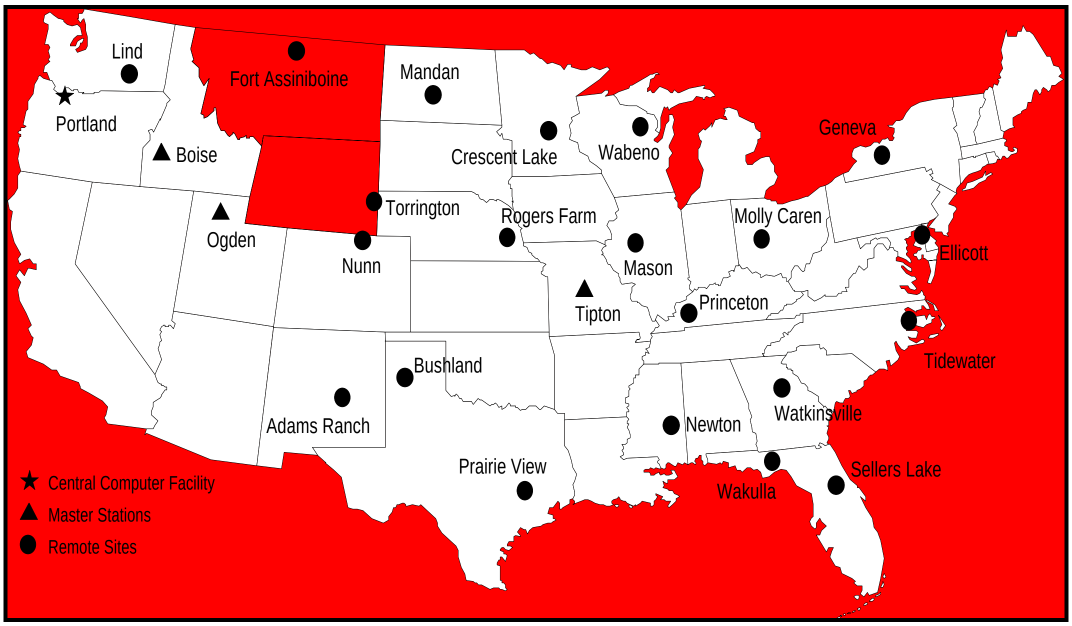

Figure 1. Map of the Original SM/ST Pilot Project locations.

Data from the remote stations are transmitted to one of three master stations hourly. Master stations forward that data via telephone links to the Central Computer Facility at the NRCS, National Water and Climate Center (NWCC) in Portland, Oregon. At the NWCC, the information is processed, stored, and made available to users via the web, direct computer access, or by hardcopy.

The SM/ST remote stations are designed to provide near real-time data from a variety of sensors. The aboveground sensors provide the information required for climate analysis and evapotranspiration (ET) calculations. The below ground sensors from 1991-1994 provided soil temperature and soil moisture at six depths to 80 inches. Replacements for these initial soil moisture and temperature sensors were completed in 1995 with a more reliable sensor. At this time, it was decided that the 80-inch depth was not needed and was no longer necessary for the Pilot Project and need no longer be maintained or installed. Table 1 identifies the various parameters measured at the SM/ST remote stations.

Table 1. Station measurements.

PARAMETER MEASURED	SENSOR TYPE	UNITS	DURATION
Precipitation	Weighing Device	Inches (Annual Accumulation)	1991-Present
Air Temperature	Shielded Thermister	Degrees Centigrade	1991-Present
Solar Radiation	Pyranometer	Watts/Square Meter	1991-Present
Relative Humidity	Capacitance	Percent	1991-Present
Wind Run	Cup Anemometer	Miles/Day	1991-Present
Soil Temperature 2, 4, 8, 20, 40, 80 Inch Depths	Thermister	Degrees Centigrade	1991-1994
Soil Moisture 2, 4, 8, 20, 40, 80 Inch Depths	Electrical Resistance, Granular Matrix & Fiberglass	Moisture Tension, 0.01-2 Bars Moisture Tension, 0.1-15 Bars	1991-1994
Soil Moisture and Temperature 2, 4, 8, 20, 40 Inch Depths	Frequency Domain Complex Dielectric Constant Determination	Water Volume Fraction Temperature-Degrees Centigrade	1994-Present

SCHEDULE

The SM/ST Pilot Project was designed to be completed in ten years. Tom Calhoun, Soil Survey Division Program Manager and STM Team sponsor, reaffirmed that time frame at the first meeting of the Soil Moisture Team held in Lincoln, Nebraska June 23-24, 1994 (USDA-SCS, Aug., 1994).

Ten stations were installed in 1991. The soils at these sites were described and sampled for characterization. In 1992, an additional 11 stations were installed. Again, the soils were described and sampled.

PEOPLE HISTORY

David Johnson from the West National Technical Center (WNTC) represented the NRCS Resource Inventory Division and Tom Calhoun represented the NRCS Soils Division for the initial project proposal and development phases. Jon Werner was overall site installation coordinator for the first year (1991). Don Huffman was the installation team leader. Otto Baumer, National Soil Survey Laboratory (NSSL), was coordinator for the soils instrumentation, design, and scheduling. Richard Pullman, NSSL, traveled to the first eleven sites (1991) to sample the project soils for laboratory characterization and to assist Don Huffman with installation of the soil moisture and temperature sensors. Otto Baumer installed the soil moisture and temperature sensors at the remaining ten sites in 1992 and Don Huffman's crew completed the site installation. The 1991 and 1992 installations were primarily in the eastern and western U.S., respectively. Site characterization, soil descriptions, and laboratory characterization data were completed for the representative soil pedons at each of the twenty-one sites.

During the second project year (1992) Dennis Lytle represented the Soils Division and Garry Schaefer became involved from the NRCS WNTC. Otto Baumer retired in 1994 and was not involved with the pilot project after that year. John Kimble, Soils Division Global Change Projects

Manager, became involved because the project was funded through global change monies. Initial installation costs are shown in Appendix D.

In 1994 a Soil Moisture & Temperature (SMT) Team was formed to serve as an umbrella management group to coordinate the Global Change Pilot Project and related soil moisture and temperature projects. The team also functions to share experiences from various projects. The Global Change Pilot Project was re-designated as the Soil Moisture/Soil Temperature Pilot Project (SM/ST PP) and came under the management of the team along with the Wisconsin Dense Till Project and the Virgin Islands project. Tom Calhoun was designated as team sponsor, Ron Yeck, team leader, and Jon Werner, Garry Schaefer, Ron Paetzold, Tom Gable, Henry Mount, and Ellis Knox as other team members. Garry Schaefer remained the project leader for the SM/ST Pilot Project. In 1995, Ellis Knox retired and Tom Gable left NRCS. Team members added were Don Huffman, and Denice Schilling. In 1996 Deb Harms joined the team (Appendix A shows the current team membership).

SITE SELECTION AND CHARACTERIZATION

Soils and Site Characterization

The selection of monitoring sites varied from place to place depending on the importance of the objectives to that particular region of the country. For example, in the east the emphasis was on establishing the coverage for the meteor burst master station so ten sites were selected to ensure coverage was adequate. In the west sites were selected where additional information was needed to more accurately characterize soil moisture and temperature regimes for Soil Taxonomy, and to characterize sites most sensitive to variations in soil moisture and temperature. In addition, the following criteria were established for the location of all sites:

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9. Landscape position was to be typical of the soil map unit.
10. Management status was to be stable in a grass vegetation.

The soil at each site was fully characterized by documenting site properties, including vegetation, slope, aspect, and other important properties. Large excavations were made with backhoes from which standard, comprehensive, soil pedon descriptions were made, and from which samples were taken for complete laboratory characterization analysis. Local NRCS soil scientists described the soils and assisted with the sampling. Three soil moisture retention measurements (0.1, 0.33, and 15 bar) were made for each soil horizon. Very little change is needed to this practice with the exception of ensuring that equipment is available to facilitate obtaining bulk density samples from very friable horizons (thin or soft horizons in forests or cultivated fields or organic horizons). Also, at least two more soil moisture tension measurements (0.06 and 2.0 bar) should be added to the laboratory analysis suite to more fully define the soil moisture curve.

The following table shows the distribution of sites. There are sites in sixteen of the twenty Land Resource Regions of the continental United States, with most sites in region M.

Table 2: Site Locations by Land Resource Regions

Designation	Region Name	Sites
B	Northwest Wheat and Range	1
F	Northen Great Plains Spring Wheat	2
G	Western Great Plains Range and Irrigated	3
H	Central Great Plains Winter Wheat and Range	1
I	Southwest Plateaus and Plains Range and Cotton	1
J	Southwest Prairies, Cotton, and Forage	1
K	Northern lake States Forest and Forage	1
L	Lake States Fruit, Truck, and Dairy	1
M	Central Feed Grains and Livestock	4
N	East and Central Farming and Forest	1
P	South Atlantic and Gulf Slope Cash Crops, Forest, and Livestock	2
S	Northern Atlantic Slope Diversified Farming	1
T	Atlantic Gulf Coast Lowland Forest and Crop	1
U	Florida Subtropical Fruit, Truck Crop, and Range	1

The following table shows the soil orders represented at the project sites. Six of the eleven soil orders are represented. The soils are dominantly Alfisols and Mollisols.

Table 3. Soil Orders and Suborders represented at the sites

Order	Number	Order	Number
Alfisols	6	**Aridisols**	1
Ustalfs	1	Argids	1
Udalfs	4	**Entisols**	1
Aqualfs	1	Psamments	1
Mollisols	6	**Spodosols**	1
Udolls	2	Orthods	1
Borolls	3	**Ultisols**	1
Xerolls	1	Udults	1
		Unclassified	6

INSTRUMENTATION

DATA TRANSMISSION (METEOR BURST)

Meteor Communication Corporation (MCC) model MCC 550C was used for both meteor burst telemetry and sensor polling. Originally, NovaLynx instrumentation was used to provide an interface between the MCC 550C and the soil moisture sensors and the solar radiation sensor. The NovaLynx electronics amplified the solar radiation sensor output and provided an excitation signal for the soil moisture sensors. Beginning in 1998, Campbell Scientific, Inc CR10X dataloggers were tested as replacements for the sensor-polling function of the MCC instrumentation.

Performance specifications for the master stations are in Appendix D.

The SM/ST Pilot Project uses meteor burst telemetry for obtaining remote site information. This type of communication system does not rely on satellites to transmit the data, rather it bounces radio signals off cosmic dust. The earth is constantly being bombarded by particles that are at least one gram or larger in weight and leaves a sufficient ionized gas trail behind it to enable meteor burst communication to reflect or re-radiate a signal back to the earth. If a remote site detects this signal, it will transmit the data back to the master station. A master station is a ground-based facility designed to transmit and receive a radio signal. Once the master station has the remote site data, it uses standard telephone connections to transfer the data to the Central Computer Facility in Portland, OR.

The SM/ST Pilot Project leases one master station from Meteor Communication Corporation (MCC) which is headquartered in Kent, Washington. The master station that serves the Midwest and East is at Tipton, Missouri. Fourteen SM/ST remote stations report through this facility. The remaining seven stations report through the existing NRCS owned and operated SNOTEL master stations. The SNOTEL system currently operates about 570 active remote sites that use these two master stations. They are located near Boise, Idaho and Ogden, Utah. Figure __ identifies the location of the 21 SM/ST Pilot Project sites, the three master stations, and the Central Computer Facility.

The remote station meteor burst telecommunications equipment is Meteor Communication Corporation model MCC 550C

Data from the master stations are sent via normal telephone communications to the Central Computer Facility (CCF) in Portland, Oregon. It is at this center, that the data are processed, subjected to quality control procedures, stored, analyzed, and made available to the users.

Meteor burst communications have been extremely reliable throughout the 10-year project.

DATALOGGER

No separate datalogger was used in the pilot project initially. The remote station meteor burst telecommunications transceiver served as the datalogger. Meteor Communication Corporation (MCC) model MCC 550C was used for both meteor burst telemetry and sensor polling. Originally, NovaLynx instrumentation was used to provide an interface between the MCC 550C and the soil moisture sensors and the solar radiation sensor. The NovaLynx electronics amplified the solar radiation sensor output and provided an excitation signal for the soil moisture sensors. The transceiver controls all data acquisition functions and does all the calculation of maximum, minimum, and average values. The MCC-550C transceiver allows for the connection of all analog and pulse counting sensors that are used in the SM/ST project. The lack of flexibility in the programming and timing of certain events resulted in the need to replace this integrated device with separate datalogger equipment and meteor burst communication devices for the Soil Climate Analysis Network (SCAN) system. Beginning in 1998, Campbell Scientific, Inc. CR10X dataloggers were tested as replacements for the sensor-polling function of the MCC instrumentation. The SCAN system is the implementation phase of the SM/ST project.

AIR TEMPERATURE

The measurement of air temperature used a YSI thermistor device with a range of +60 to –30 degrees centigrade. Each air temperature sensor used a 6 vane Gill shield to minimize the affect of direct sunlight on the thermistor. This sensor worked well throughout the pilot project and provided good air temperature information.

PRECIPITATION

The measurement of all types of precipitation is difficult. The project selected an "all season" weighing gage for the job. The SM/ST project uses an ETI Instrument Systems NOAH II total precipitation gauge that contains a non-freezing fluid for winter operation. It is designed to measure precipitation for a year before requiring servicing. One reservoir holds the full-strength, non-freezing solution while a second reservoir holds the "spent" fluid. A small 12-volt pump is used to transfer non-freezing solution from the reservoir to the gauge cylinder. Problems with the gauges resulted from pump failure attributed to small amounts of oil present in some antifreeze, and high fluid viscosity during the cold winter months. The gage is also extremely sensitive to electrical static discharge. Several improvements have been made to increase overall reliability, including installation of heavy-duty pumps and an improved grounding, but the overall reliability of this gage is poor.

RELATIVE HUMIDITY

Relative humidity is measured using capacitance sensor (Vaisala model HMP35C). The sensor has performed well over the years, but does require annual maintenance.

SOLAR RADIATION

Solar radiation was measured using a pyranometer (Matrix Sol-a-meter model Mk 1-G). The sensor performed well over the years and was annually checked using a calibrated pyranometer. Output was compared at the site.

WIND SPEED

Wind speed was measured using a cup anemometer (R. M. Young Model 03101). Over the years, some of the cups broke and had to be replaced. Some bearings also had to be replaced. The sensor was reliable and wind speed was checked annually using a hand held anemometer.

SOIL TEMPERATURE

Thermistors, initially installed at each of the six soil-moisture measurement depths, were fabricated at the NWCC. Those were later replaced by commercially available units that were more effectively sealed to prevented water leakage and corrosion. In addition, they were more cost-effective than the ones fabricated in-house. Thermistors were used in conjunction with Coleman and Watermark sensors (Table 1) but soil temperature was obtained from the thermistor in the Vitel soil moisture sensor when the were installed beginning in 1994. Properly functioning

80-inch thermistors continued to be monitored after the switch to Vitel sensors since moisture sensors were then not placed at the 80-inch depth.

SOIL WATER

Soil Moisture and Temperature Sensors

Ceramic matrix (Watermark) and fiberglass (Coleman) electrical resistance type soil moisture sensors used initially.

In 1991, each soil temperature and moisture sensor, at each of six depths, was affixed to the end of proper length PVC tube which was installed in a bore hole. The design of the sensor units and the pattern of installation are shown by diagrams on pages 16 and 15, respectively, of Appendix D. This system had the advantage of easy replacement of sensors.

In 1992, the sensors at the remaining sites were installed at the appropriate depths, separated by tamped soil, in a single bore hole. The initial configuration was abandoned because of concerns that moisture and temperature would be affected by channeling along the sides of the PVC tubes.

Vitel HYDRA soil water sensors used frequency-domain dielectric measurements to determine volumetric soil water content.

The type of soil moisture sensor in the project was changed beginning in 1994 from resistance type sensors that related to soil moisture tension to ones measuring dielectric constant that related to soil moisture volume after they were successfully tested. Table 1 summarizes changes in types of sensors and elimination of 80-inch depth installation. The replacement soil-moisture sensors also measure soil temperature and salinity.

Soil moisture sensors must be calibrated prior to installation. A tool for installing the Vitel sensors needs to be developed to make the installation more efficient and insure proper soil contact. Where sites are placed to represent soil and climate parameters related to growing crops, procedures need to be developed to have sensors in the upper 10 cm of the soil throughout the year except during the times when field operations would disturb the sensors.

The practice of testing new sensors, as new technology becomes available, should be continued.

STATION INSTALLATION

A concrete base was poured for the pre-fabricated electronics shed. Concrete pads were also was poured for the towers and the precipitation gage. The electronics shed is four feet square and eight foot high, with a two-section (upper and lower halves) door. The electronics enclosure and batteries are located within the shed. The shed also serves as storage for precipitation gage antifreeze, a ladder, and various spare supplies.

A NEMA box is used to provide connections for the below-ground sensors to cables running to the electronics enclosure. This makes sensor replacement easier. All wires to the underground sensors are buried. All wires between the NEMA box and the electronics shed are run through buried two-inch PVC pipe. These wires are in the form of three separate runs of 16 gage 12 conductor cable.

The air-temperature, relative humidity, solar radiation, and wind sensors are located on the 10 foot instrument tower. A separate 20 foot tower is used to support the communications antenna. Air temperature and relative humidity are measured at four feet above the ground. Solar radiation and wind speed are measured at approximately ten feet.

Soil moisture and temperature sensors were installed in a “spider” configuration at the first ten stations. Each sensor was affixed to the end of a ¾-inch PVC tube with the lead wire from the sensor inside the tube. Six separate holes were augured in the soil and a PVC tube with the attached sensor inserted into each hole. The leads were fed into a NEMA box where they were connected to a terminal strip. Three runs of 12 conductor wire from the terminal strip were run through two-inch PVC tube to the instrument enclosure and attached to the NovaLynx data collection instrument.

The soil moisture and temperature sensors were installed in a single hole at the remaining eleven stations.

DATA COLLECTION

The climate parameters monitored by the project were chosen specifically to be useful to modelers. Soil moisture and soil temperature information is often requested by continental scale modelers, among others. Solar radiation, air temperature, wind speed, and relative humidity are needed by many models to estimate evaporative demand. And precipitation is necessary for water balance equations.

Initially, a NovaLynx data collection-transmission instrument was chosen to poll the sensors and relay the data to the master station via meteor-burst telemetry. The instrument was capable of accepting a 0-5 V input and providing certain excitation voltage signals, such as continuous, pulse, and step functions.

The sensors were polled and the data stored in groups or tables. The first group consisted of station and diagnostic information such as battery voltage, transceiver diagnostics, etc. The second group consisted of the aboveground or atmospheric climatic variables such as wind and precipitation. The third information group contained soil moisture and soil temperature.

The NovaLynx and later the MCC data collection instrumentation were incapable of providing the proper excitation voltage signal to the resistance-type soil moisture sensors initially used in the project. In order to prevent electrode polarization, the sensors require an alternating current signal. The NovaLynx and MCC provided step voltage signals of 0 and +5 volts, or essentially an on-off signal. This signal could not prevent electrode polarization and caused erratic sensor output. The poor performance of the soil moisture sensors was attributed to the failure to calibrate the sensors before installation. An attempt was made to calibrate the sensors in the field. The results of this attempt demonstrated that the problem of erratic readings lay elsewhere. An examination of the overall system, from the sensor to the data processing, storage, and retrieval was conducted and the source of the problem was identified as electrode polarization. Since the data collection instrumentation required for the meteor-burst system was incapable of providing the required excitation signal, it was necessary to replace the soil moisture sensors with a compatible type. A frequency-domain dielectric-type instrument, manufactured by Vitel, Inc., used in some other Soil Moisture and Temperature Team projects, was selected. The Vitel sensors were installed beginning in 1996 and by 1997 they were in place at all Pilot Project sites. No Vitel sensors were installed at the 80-inch depth. The SMT Team discussed this and decided that the objectives of the Pilot Project could be met without a soil moisture sensor at that depth. The utility of the data from the 80-inch depth also was considered to be less than that of the shallower depths. The depths used in an operational program should be selected carefully to provide the maximum utility. The Vitel sensors posses a thermistor, so soil temperature may also be obtained from a single instrument. These sensors have performed well since their installation.

Precipitation is a difficult variable to measure. A weighing-type sensor with an anti-freeze solution was selected as the precipitation sensor. A windscreen around the mouth of the gage is used to lessen the effects of windy conditions. This windscreen has been replaced and the configuration modified during the course of the project. Precipitation data is given as a cumulative value over the course of the “water year” which runs from October 1 to September 30. There has been some debate over the form that the user should get the data — cumulative over a water year, or calendar year, or hourly values like the rest of the data.

Solar radiation, air temperature, relative humidity, and wind speed are sampled every 10 seconds and averaged over each hour. The data are presented as hourly data. Maximum and minimum values of some parameters such as air temperature are also provided on an hourly basis.

OUTSIDE DATA

The WSFS, WNTC Climatic Data Access Facility was tasked to investigate the availability of existing data and databases/systems that meet the needs of Global Change monitoring and research.

The Global Change Pilot Project (USDA SCS Staff, 1991) states "It is the goal in this part of the pilot project to pull together into one database all useable data in addition to the new Global Change data that will be collected. Outside user access to the data base will be very important."

Existing data include those collected as part of other SMT Team managed projects. Data for 21 stations in Wisconsin are on the NWCC computer and available through the Internet. Plans are to include data from all projects.

METADATA

Metadata refers to information about the data and how it was collected. Included in the metadata are descriptions of the location, sensors, soils, landscape, vegetation, instrumentation, sensor locations, etc. This is important information for serious users who may wish to compare the data from one particular program with that from another. A very important component of the metadata is the station history. It is critical to document any changes in operation, sensor type, etc.

Metadata for the SM/ST Pilot Project stations is available through the Internet in files associated with each station's data. The soil characterization data for each project site is available via a "hot link" between the WCC home page, where the project data is located, and the NSSC home page, where all NRCS soil characterization is located. The soil characterization data for the Pilot Project may also be found in Appendix C of this document. It is reproduced here because of problems accessing the data in the NSSC home page. Other metadata, such as instrumentation and station location, may be found in Appendix C also.

DATA MANAGEMENT

Data were downloaded daily from each station via meteor burst telemetry to a master station then forwarded to the NWCC central computer facility in Portland, Oregon. The data were processed to convert the raw sensor output to useful measurement units. UNIX OPERATING SYSTEM

Denise Shilling, NRCS computer assistant in Great Falls, Montana, examined data to provide quality control.

To understand data management, it is important to understand the flow of information from the remote sites and how the data gets into the Central Computer Facility (CCF). The remote sites transmit their data hourly, via meteor burst communication to one of three master stations. The data that is transmitted is a voltage value that represents the sensor reading. The master stations are located in Boise, Idaho, Ogden, Utah, and Tipton, Missouri and use conventional telephone communications to send the data to the CCF in Portland, Oregon. The master stations do not do any sensor conversions. The Natural Resources Conservation Service, National Water and Climate Center (NWCC) manage the CCF. Once the data arrives at the CCF, the voltage values are converted to engineering units. Each site and each sensor is identified in the database with a sensor label. Each label contains the conversion equation necessary to convert the voltage values to engineering units. From here, the data values are placed into the database and hourly reports are generated and placed on the ftp server for users.

An NRCS statistical assistant looks at each sites data approximately every two weeks and edits accumulated precipitation values that are bad. Other site data are examined at the same time to see if they fall within acceptable ranges. Graphs are produced and values are compared to help to identify problems. All values that look suspicious are noted and sent to the NWCC for more careful examination. Because of extremely limited staff resources, these suspicious values may not be looked at for over a month. If the NWCC person confirms that the data values are bad, it will be noted and a closer examination of the sensor label that is used to convert the data to engineering units is checked to ensure that it is being converted properly. If the label is found to be correct and no other reason can be identified a maintenance trip is planned.

If a maintenance trip is needed, careful examination of travel dollars and staff resources had to be analyzed. In most cases, a single site would not be visited, due to insufficient funding and not enough staff resources. Maintenance at most of the SM/ST sites is done annually. If more than one site has problems, a site visit is scheduled to handle the multiple sites.

Additional automated data screening could have been implemented for the SM/ST project. Some limited CCF software screening tools are available, but because of a lack of staff resources that could be dedicated to the creation of site specific and sensor specific profiles this was not accomplished during the pilot project phase. As a result of running the pilot project it is noted that sufficient staff resources must be dedicated to data quality control in SCAN to ensure good information and products can be provided to the users.

Beginning in May 1998 the data were placed on the NWCC Internet homepage. The web address is http://www.wcc.nrcs.usda.gov. The web site contains the current and historic data for each of the sites. In addition to the data, each site contains all of the soil pedon information, site picture, and a “hot link” to the National Soil Survey Center Laboratory database which all of the site characterization (chemical, physical, and mineralogical) information. The two URL are:

http://vmhost.cdp.state.ne.us:96/ or
http://vmhost.cdp.state.ne.us/~nslsoil/soil.html.

Throughout the first 6 years of operating the pilot project numerous changes in configuring sensors at the remote sites were done. Sensors were mapped into specific channels at the remote site for transmission to the CCF. With each change in channel position, a subsequent change was needed in the database to properly decode the sensor voltage reading and determine the correct engineering unit conversion. The change to convert the new position of the sensor was done; no attempt was made to ensure that the output reports properly tracked this change. Therefore; the historical data, while available, is difficult to use and the users need to look at the historical data in conjunction with the sensor label file that tracks all of the changes. Insufficient staff resources prevented the uniform positioning of each sensor. Ideally, this remains to be accomplished in order to make the data more useful to the users.

Table 4. NWCC Soil Climate site "hot links" to other sites.

ADDRESS	DESCRIPTION
http://vmhost.cdp.state.ne.us:96/	NRCS NSCC laboratory soil pedon database
http://vmhost.cdp.state.ne.us/~nslsoil/soil.html	NRCS NSCC laboratory soil pedon database
http://www.hprcc.unl.edu/index.html	High Plains Regional Climate Center database
http://evans.amedd.army.mil/eo/observances/nhhm.htm	Rutgers soil moisture databank

OUTSIDE DATA

The WSFS, WNTC Climatic Data Access Facility was tasked to investigate the availability of existing data and databases/systems that meet the needs of Global Change monitoring and research. This report identified 1,652 stations across the United States that had some type of soil moisture/soil temperature measurements associated with a climate station.

"It is the goal in this part of the pilot project to pull together into one database all useable data in addition to the new Global Change data that will be collected. Outside user access to the data base will be very important."

RESULTS

SITE SELECTION

Physical site selection is often governed only by the parameters to be measured. This project has demonstrated that station security should also be a factor when selecting a final location for an installation. Urban growth patterns in an area may dictate where a site should be located or how long it can safely remain in an area. The Ellicott City SM/ST site was in place for eight years on a University of Maryland rural research and education center. It was irreparably vandalized a short time after a housing subdivision was built within sight of the installation.

Site selection resulted in fairly good geographic distribution except for the lack of sites in the southwestern states. The distribution represents a wide range of climatic conditions necessary to test sensors in areas of extreme cold and hot, although no sites were located in deserts. The cold climates did cause failure of precipitation gauges, showing the need to modify or replace the gauges with ones that would function in extreme temperature. Likewise, in the southeastern states, the high incidence of lightening strikes and resulting equipment damage or malfunction bare the need for different grounding techniques.

The placement of sites on publicly owned land was a priority because of continuity of ownership and access. That was a good plan and we recommend that it be continued to the extent possible for site selection of similar future projects.

INSTRUMENT SELECTION

For each parameter to be measured there are numerous sensors on the market, each with some claim to superiority, and each with a unique technique for representing that parameter. It is imperative that sensors be selected carefully to ensure the following:

1. Sensor is designed to withstand the weather conditions to which it will be subjected.
2. Sensor calibration can easily be accomplished in the field or laboratory.
3. Sensor is compatible with the device used to log the data.
4. Sensor output accurately represents the parameter being measured.
5. Specific output is in units compatible with user needs.

The Coleman and Watermark soil moisture sensors installed early in the pilot project were a good example of not following these guidelines. These sensors were not calibrated prior to installation. An attempt was made to do the calibrations in the field, during the first three years of the project. This was a difficult and expensive undertaking which concluded with varying degrees of success. The result was a confidence level such that bars of tension were translated into soils being categorized as merely dry, damp, or wet.

INSTRUMENT CALIBRATION

Factory supplied calibration curves were often used for sensors. The calibration of some sensors, such as the relative humidity sensors, was performed in the field after installation.

SITE MAINTENANCE

Each state was given $2,000.00 per year for each station to provide for site maintenance.

It became evident very quickly that the sites would need to be managed similarly to the surrounding areas. Although the area inside the soils enclosure is only 256 square feet, it was found to respond differently to precipitation from the areas adjacent to the site. Where sites are located on range or pastureland, an attempt was made to plant similar species inside the enclosure. The landholder was asked to maintain the ground as if the enclosure did not exist. The only exception was for grazing. We obtained varying degrees of success in this activity. Those sites that were located on or near active research facility grounds have been kept up more consistently than those sites located further from human activity.

STATION MAINTENANCE

Routine annual maintenance was performed at each station. Wiring was checked for damage due to animals, vandals, or weather. Solar radiation panels were cleaned if necessary and checked for damage or misalignment. Batteries were checked for charge and capacity. Insect and rodent nests were removed from the enclosures, if necessary. Fresh desiccant was added to the enclosures.

INSTRUMENT MAINTENANCE

Routine annual maintenance was performed at each station. In addition, if the quality control procedures identified a problem with a sensor or group of sensors, a maintenance trip was scheduled as soon as possible to correct the problem.

The precipitation gage required disposal of the used fluids and recharge. Each gage also had to be reset annually.

Calibration of the wind, relative humidity, and solar radiation sensors was checked during the annual maintenance visits.

DATA COLLECTION

NovaLynx, MCC, or Campbell instruments were used to poll the various sensors at pre-determined intervals. Some instruments, such as the solar radiation sensor, provide a simple voltage output, which can be measured directly by the polling instrument. Other instruments, such as the soil moisture sensors, require excitation by the polling instrument. This signal may be in the form of a DC low voltage input or the sensor may require a complex signal. For instance, the resistance-type soil-moisture sensors initially used in the project require an alternating current signal to prevent electrode polarization.

The raw data were sent via meteor burst telemetry to a master station. The master station time was added to the data packet, which in turn, was relayed via telephone lines to the central computer facility of the WCC in Portland, OR.

DATA MANAGEMENT

Raw sensor data must be processed to provide useful information. Algorithms for data conversions had to be devised and entered into the computer. The data storage format had to be designed. A procedure for receiving the raw data, processing it, and storing it had to be devised and implemented. Often during the course of the project, changes were made or discovered processing errors corrected. Such actions usually required changes in the data storage format and/or changes in the processing algorithms. Procedures had to be developed to handle missing data.

Quality control helps spot problems with bad or drifting sensors, incorrect processing algorithms, data transfer problems, etc. Quality control procedures had to be devised and implemented. Many of these were automated, so that the computer could check to see if values were reasonable. Much of the quality control relied on a person examining the data in graphical form.

Initially, the emphasis of the project was on station performance and maintenance. Although, data collection and processing were initiated early during the project, not much attention was given to improving the process, efficiency, quality control, data access, or products for users until late into the project. It would have been advantageous for the project to continue for another two or three years so that quality control procedures could have been refined and so that possible information products could have been examined. Some possibilities include maps of soil moisture supply, normal soil moisture and deviations from normal, precipitation or irrigation required to bring the soil moisture up to normal, normal soil temperatures, etc.

DATA DEMAND

The demand for the type of data produced by this project is much greater than was anticipated. Users besieged those involved in the Project, literally demanding access to the data. The collection of the data into an accessible form via the Internet has to be regarded as a major accomplishment of the Project.

Data were made available via the Internet starting in November of 1997 (May 1998?). Downloads of data, as presented in Figure 2, have increased steadily and dramatically. Users have learned of this web site, primarily through word-of-mouth and “surfing the net” for climatic data. An examination at the users who download data revels a diverse group representing many countries. Many of the users represent the various U.S. government agencies. Large amounts of data are downloaded by university researchers. In addition, perhaps surprisingly, private industry is well represented.

Discussions with users indicate a surprising diversity in the utility of the data. Many are looking at frost depth for soil interpretations. Some users are interested in GIS applications. NRCS Soil Scientists want the data to populate the NASIS database, for soil classification purposes, and to test and improve Soil Taxonomy. Researchers use the soil climate information to model soil microbe populations and for snake hibernation studies. Private industry is anticipating that clean water will be an important commodity in the future. The data are used in many models, ranging from field-size irrigation scheduling models to continental-scale climate circulation models. Many of the large-scale models find use in Global Climate Change studies.

It is anticipated, that when enough data become available (adequate spatial coverage and sufficient length of record) to define “normal” years, the data will be extremely valuable for defining drought and monitoring the extent and severity of drought events. As more potential users become aware of the existence of the data, it will find many more and diverse applications. The Agency will really miss a tremendous opportunity, if it does not fund and support SCAN. SCAN will provide high-quality data of great value to a large and diverse user population, while providing high visibility to the Agency and enhancing its reputation.

The demand for soil climate data is so great that other U.S. Government Agencies, State Agencies, Universities, and private land owners are providing funding to the Soil Moisture and Temperature Team to install additional SCAN stations. Several universities are providing funds and other kinds of support in return for additional stations. The Team has installed more than 50 stations in direct response to NRCS requests. There are now more than 100 cooperative soil-climate projects managed by the SMT Team. The expertise gained from the SM/ST Pilot Project by the SMT Team is in high demand.

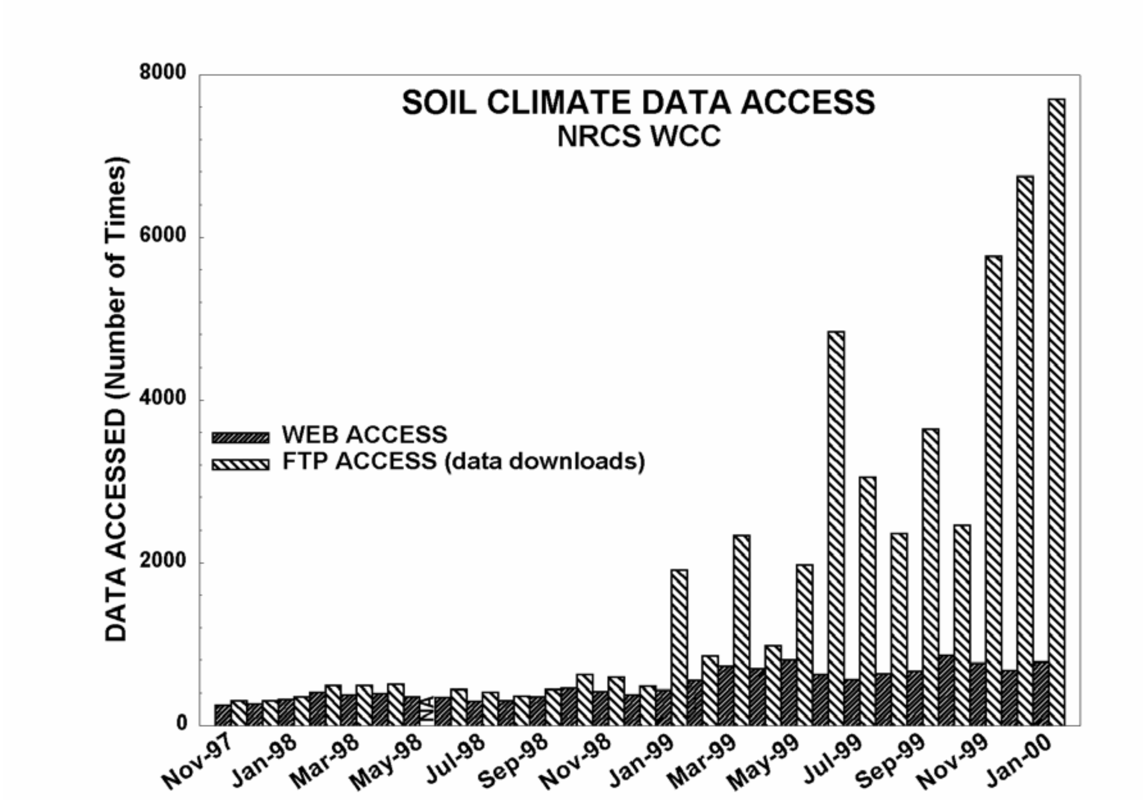

Figure 2. Data access and downloads by users.

ACCOMPLISHMENTS

The demand for the type of data produced by this project is much greater than was anticipated. Users besieged those involved in the Project, literally demanding access to the data. The collection of the data into an accessible form via the Internet has to be regarded as a major accomplishment of the Project.

It would have been advantageous for the project to continue for another two or three years so that information products could have been examined and developed. Some possibilities include maps of soil moisture supply, normal soil moisture and deviations from normal, precipitation or irrigation required to bring the soil moisture up to normal, normal soil temperatures, etc.

Even though this was a Pilot Project rather than a monitoring program, the success rate of the data collection effort was quite good. True, there were problems with sensor failure and sensor-system interfaces; however, the overall data population as a percentage of possible collected data was very good. The chief problems were with the precipitation sensors and soil moisture sensors. The success rate improved after the resistance-type soil moisture sensors were replaced with frequency-domain dielectric type sensors. The precipitation sensor performance improved throughout the Project as the sources of the various problems were discovered and solved.

A quality control system was initiated, and although it would be inadequate for a comprehensive monitoring program, it provided up-to-date information on sensor and communications performance. It was especially helpful in pinpointing problems early and allowing corrections to minimize data loss.

As in any good scientific study, the project resulted in the creation of an abundance of many new questions. The most significant of these appears to be how best to present the information. Discussions stimulated by the project show support for defining “normal” years (or months) of soil temperature and water content of the root zone (or other standard soil thickness) after enough years of data are collected to make these assessments. The departure from normal could be a good indicator or drought, excess water, unusual temperatures, etc. This would also provide a useful tool for forecasting probabilities of successful crop production and yield estimates. It would also be valuable to define the extent and severity of droughts.

LESSONS LEARNED

Data management is a much larger task than initially assumed. It takes more people and time than original estimates. Along these lines, quality control is a major task that was also underestimated.

The importance of keeping station histories up-to-date is emphasized. A complete record of installation, site characterization, instrumentation, and maintenance history, including sensor replacement, is vital to the success of any comprehensive program.

Continuity must be maintained in the data when components of the system are replaced or upgraded.

For each parameter to be measured there are numerous sensors on the market, each with some claim to superiority, and each with a unique technique for representing that parameter. It is imperative that sensors be selected carefully to ensure the following:

1. Sensor is designed to withstand the weather conditions to which it will be subjected.
2. Sensor calibration can easily be accomplished in the field or laboratory.
3. Sensor is compatible with the device used to log the data.
4. Sensor output accurately represents the parameter being measured.
5. Specific output is in units compatible with user needs.

The Coleman and Watermark soil moisture sensors installed early in the pilot project were a good example of not following these guidelines. These sensors were not calibrated prior to installation. An attempt was made to do the calibrations in the field, during the first three years of the project. This was a difficult and expensive undertaking which concluded with varying degrees of success. The result was a confidence level such that bars of tension were translated into soils being categorized as merely dry, damp, or wet.

Soil moisture sensors must be calibrated prior to installation. A tool for installing the Vitel sensors needs to be developed to make the installation more efficient and insure proper soil contact. Where sites are placed to represent soil and climate parameters related to growing crops, procedures need to be developed to have sensors in the upper 10 cm of the soil throughout the year except during the times when field operations would disturb the sensors.

Coarse fragments cause installation problems when trying to augur holes into the soil. The best solution in these instances is to dig as small of a hole (pit) as possible and install the sensor into the side of the hole and back-fill carefully in an attempt to restore the soil to a condition as near natural as possible.

The practice of testing new sensors, as new technology becomes available, should be continued.

Several soil moisture sensor installation configurations were tried during the course of the project. The objective was to minimize the chances of moisture migrating from the soil surface, along the wires, causing erroneous readings by the sensors. The most foolproof method involved keeping the sensor wires below ground until near the NEMA enclosure, then bringing them up into the bottom of the enclosure through a piece of two inch PVC conduit.

Use of two inch PVC conduit for all underground wiring raceways proved to be a mixed blessing. It made it extremely easy to pull new wire when necessary, and was an effective deterrent to rodents. On the other hand, when moisture got in the conduit, it tended to remain there, soaking the wiring insulation. Several sites sustained major damage to sensor wiring when field mice gained access to the raceways, precipitation gage, and NEMA enclosure. Screens clamped over the raceway openings in the instrument shelters kept the mice out but still allowed for airflow.

The precipitation gage selected for the project was the ETI Instrument Systems NOAH II total precipitation gage. It was picked because of its ability to automatically drain and recharge itself when a preset catch was reached. Under ideal conditions it worked very well. When subjected to the kinds of conditions typical of the winter environment of most of the mid to northern US, its operation was less than satisfactory. The gage used a small 12-volt automotive windshield washer pump to recharge the catch basin. When the reservoir was filled with the environmentally friendly PGE recharge solution currently used by NRCS, and the air temperature would drop, the fluid became more viscous, causing the pump to stall. It has been extremely difficult to keep these gages operating in an unattended mode.

Lightning is a phenomenon common to all remote monitoring sites. The microprocessors and electronic circuitry present in sensors, data loggers, and data transmission devices require that great attention be paid to voltage attenuation and the proper grounding of all equipment. Much of the wiring that was used during the early phases of the project was unshielded. The interface and multiplexer boards built by the NRCS-NWCC Electronics Maintenance Facility were not protected against over-voltage. After enduring several site failures with their associated loss of data, new shielded cables were run, transorbs were added to vulnerable circuits, grounding was enhanced, and lightning attenuators were installed at each site.

Physical site selection is often governed only by the parameters to be measured. This project has demonstrated that site security should also be a factor when selecting a final location for an installation. Urban growth patterns in an area may dictate where a site should be located or how long it can safely remain in an area. The Ellicott City SM/ST site was in place for eight years on a University of Maryland rural research and education center. It was irreparably vandalized a short time after a housing subdivision was built within sight of the SM/ST installation.

As cooperators and partners began to see the value in the data being collected by SM/ST sites, requests for more and different sensors became common. Prior to agreeing to bring a sensor up on any system, issues such as power budget and voltage compatibility need to be resolved. In the SM/ST Pilot Project, it took three maintenance seasons before the proper combination of solar panels, voltage regulators, and batteries was determined. Power needs vary with latitude and known local climatological characteristics at a site.

Data management has been a larger portion of the project than originally anticipated. Constant quality control and editing of data is necessary to detect sensor problems, spot data anomalies, and assess overall remote site health. Better understanding of the actual data being collected and how NRCS partners intend to use it has resulted in significant changes in the collection of some data parameters.

The ability to provide as many as 62 channels (limited by data transmission system) of hourly data has attracted a great deal of attention to the SM/ST Pilot Project. NRCS partners see this as an opportunity to obtain a more diverse picture of what their sensors are monitoring. SM/ST team members see it as an opportunity to provide a broader spectrum of data and products for a diverse group of users. Our field technicians need channels to provide diagnostic tools to help in remotely troubleshooting potential problems at a site. The overhead this creates at each remote site is negligible, but the load it puts on the entire system, and the computer systems that collect, monitor, and archive the data is tremendous. Manually editing this volume of data is a virtual impossibility. A number of editing tools have had to be developed and employed just to be able to keep up. The best solution is to collect only the data needed, and only as often as is absolutely necessary.

RECOMMENDATIONS

Budget (including people), schedule, performance are the three parameters involved in a program or project that define the total effort. If budget decreases, than schedule must increase or performance must decrease. If the schedule is shortened, than the budget must increase or the performance must decrease. If the performance must increase, than either the budget must increase or the schedule must decrease. All three parameters are connected and anything that affects one necessarily affects one or both of the others.

- Need sufficient resources (MONEY & STAFF) to do the job properly.
- Need to know budget.
- Need a sensor replacement schedule.
- Need a sensor re-calibration schedule.
- Need full-time dedicated technicians to trouble-shoot problems at sites to keep them running between annual maintenance visits.
- Reports should include:
- Normal soil moisture in root zone
- Departure from normal
- Precipitation required to bring root zone to normal state.
- Data must be available through the Internet.
- Need to pay careful attention to units — metric or SI vs. U.S. customary.
- Need to consider data presentation — tabular vs. graphic, cumulative vs. hourly or daily, max, min, etc.
- Need to pay attention to time — local standard time, local solar time, GMT, etc.
- Need commitment on part of management to support long term program — can't survive on year-to-year basis.
- Adequate staff, funding, and time, must be provided for operation of a long-term program or data quality and continuity will suffer, and as a result, will get a reputation for poor quality.
- Need long-term data in order to define "normal" conditions. Cycles exist, such as the 22-year sunspot cycle and the approximately 20-year drought cycle, in addition to major weather influencing events such as "el nino", etc. Data for a single year or even a few years is insufficient to characterize climate.

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APPENDICES

APPENDIX A

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APPENDIX B

SOIL MOISTURE/SOIL TEMPERATURE PILOT PROJECT PUBLICATIONS AND PRESENTATIONS

Paetzold, R. F. 1995. NRCS soil climate projects. GCIP Meeting. Oct. 16-18, Minneapolis, MN.

Paetzold, R. F., D. Harms, K. Hubbard, D. J. Huffman, R. Loehr, B. Miller, H. Mount, G. L. Schaefer, D. V. Schilling, J. Werner, and R. D. Yeck. 1999. USDA NRCS Soil Moisture and Temperature Team. Poster presentation for the Second Approximation International Conference on Soil Resources: Their Inventory, Analysis, and Interpretation of Use in the 21st Century, June 10-12, Minneapolis, MN.

Schaefer, G. L. and R. F. Paetzold. 1999. Real time soil and climate monitoring. Poster presentation for the Second Approximation International Conference on Soil Resources: Their Inventory, Analysis, and Interpretation of Use in the 21st Century, June 10-12, Minneapolis, MN.

Schaefer, G. R., R. D. Yeck and R. F. Paetzold. 1995. Soil moisture / soil temperature pilot project: A national near-real time monitoring project. Joint mtg. Canadian Geophysical Union and the International GEWEX Workshop on Cold-Season/Region Hydrometeorology. May 22-26, 1995, Banff, Alberta, Canada.

Yeck, R. D. 1998. The nature and applications of the Wisconsin soil moisture and temperature data. Presentation to the Wisconsin Soil Survey Interagency Group Meeting. October 16, 1998. Madison, WI.

Yeck, R. D., D. S. Harms, and R. F. Paetzold. 1999. The case for automating soil moisture and temperature monitoring. Poster presentation for the Second Approximation International Conference on Soil Resources: Their Inventory, Analysis, and Interpretation of Use in the 21st Century, June 10-12, Minneapolis, MN.

Yeck, R. D., D. S. Harms, R. F. Paetzold, and D. J. Hvizdak. 1999. Comparison of soil moisture profiles between soils with dense and friable till horizons. Poster presentation for the Annual Meetings of the Soil Science Society of America, October 31 – November 4, Salt Lake City, Utah.

Yeck, R. D., R. F. Paetzold, D. J. Hvizdak, and D. S. Harms. 1998. An automated soil moisture and temperature monitoring program for Wisconsin glacial till soils. NASA URC Conference, Huntsville, AL

Yeck, R. D., R. F. Paetzold, G. L. Schaefer, and H. R. Mount. 1995. Soil moisture - soil temperature pilot project (SM/ST PP): A national near-real time monitoring project. 31st Annual Conference & Symposia. American Water Resources Association, Nov. 5-9, Houston, Texas.

APPENDIX C

METADATA

The soils metadata has been accessible from the WCC homepage, with soil pedon descriptions on file within the WCC system and the soil survey laboratory characterization data hyperlinked to to soil survey laboratory database in Lincoln, Nebraska. The connection to the laboratory database has not been consistently reliable. Because the laboratory database is not always available, we recommend that the laboratory data be stored in the same computer system as the primary data, as the soil pedon description have been for this project.

Table _5_. Pilot Project sites, soils, and locations.

SITE NAME (Cooperators)	Soil Series	Pedon Number	LATITUDE	LONGITUDE	Classification[1]
Adams Ranch, New Mexico	Flugle	S92NM-027-001	34° 15.13' N	105° 25.17' W	Fine-loamy, mixed mesic Aridic Haplustalfs
Bushland, Texas	Randall	S91TX-381-001	35° 10.48' N	102° 05.67' W	Fine, montmorillonitic, mesic Typic Argiudoll
Crescent Lake, Minnesota	Hubbard	S91MN-141-001	45° 24.90' N	093° 56.86' W	Sandy, mixed, acid, frigid Udorthentic Haploboroll
Ellicott, Maryland	Chester	S91MD-027-001	39° 15.10' N	076° 55.41' W	Classification not Listed
Fort Assiniboine, Montana	Telstad	S92MT-041-003	48° 29.45' N	109° 48.02' W	Fine-loamy, mixed Aridic Argiborolls
Geneva, New York	Honeoye	S91NY-06-001	42° 52.59' N	077° 01.84' W	Fine-loamy, mixed mesic Glossoboric Hapludalf
Lind, Washington	Ritzville	S92WA-001-001	46° 26.34' N	119° 01.22' W	Coarse-silty, mixed mesic Calciorthidic Haploxeroll
Mandan, North Dakota	Wilton	S92ND-059-400	46° 46.62' N	100° 54.45' W	Fine-silty, mixed Pachic Haploboroll
Mason, Illinois	Not Designated	S91IL-125-001	40° 18.79' N	089° 54.10' W	Classification not Listed
Molly Caren, Ohio	Crosby	S92OH-097-001	39° 57.40' N	083° 26.58' W	Fine, mixed, mesic Aeric Ochraqualf
Newton, Mississippi	Savannah	S91MS-101-001	32° 19.93' N	089° 04.98' W	Fine-loamy Typic Fragiudalfs
Nunn, Colorado	Olney	S91CO-23-003	40° 51.61' N	104° 44.42' W	Fine-loamy, mixed, mesic Ustollic Haplargid
Prairie View, Texas	Wockley	S92TX-473-001	30° 05.47' N	095° 58.61' W	Fine-loamy, siliceous, thermic Typic Paleudalf
Princeton, Kentucky	Zanesville	S91KY-033-002	37° 06.15' N	087° 50.45' W	Fine-silty, mixed, mesic Typic Fragiudalf
Rogers Farm, Nebraska	Sharpsburg	S91NE-109-001	40° 50.78' N	096° 27.98' W	Fine-silty, mixed, mesic Typic Argiudoll
Sellers Lake, Florida	Astatula	S92FL-069-000	29° 06.24' N	081° 37.92' W	Hyperthermic, uncoated Typic Quartzipsamments
Tidewater, North Carolina	Plymouth	S91NC-187-001	35° 52.33' N	076° 39.49' W	Classification not Listed
Torrington, Wyoming	Not Designated	S92WY-015-000	42° 03.80' N	104° 09.10' W	Classification not Listed
Wabeno, Wisconsin	Wabeno	S90WI-041-006	45° 28.11' N	088° 35.20' W	Coarse-loamy, mixed, frigid Alfic Fragiorthod
Wakulla, Florida	Not Designated	S92FL-073-001	30° 18.35' N	084° 25.48' W	Classification not Listed
Watkinsville, Georgia	Cecil	S92GA-219-001	33° 53.05' N	083° 25.67' W	Clayey, kaolinitic, thermic, Typic Kanhapludults

[1] Classification at the time of sampling

Pedon descriptions of the pedons listed above are shown in their entirety below.

STATION INSTRUMENTATION
AND
SOIL CHARACTERIZATION

ADAMS RANCH, NEW MEXICO

Table _6_. Station Instrumentation Summary for Adams Ranch, NM.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995_-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Adams Ranch
State: New Mexico
County: Lincoln

NSSL Pedon Descriptions

USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 07/15/1992

Soil Series: Flugle

Site Identification #: S92NM027001 Laboratory Information
Lab Pedon #: 92P0681 Source Lab Id: SSL

Location Information
Soil Survey Area #: 027 MLRA: 70
Latitude: 34 degrees 15 minutes 8 seconds N
Longitude: 105 degrees 25 minutes 10 seconds W

Slope Characteristics Information
Slope: 2 percent
Aspect: 135 degrees
Vertical Shape: Concave

Elevation: 1879 meters

Physiography:
Local: Hillside
Major: Hills
Geomorphic Position: foot slope, of a head slope

Runoff: Very high

Type of Erosion: water erosion
Degree of Erosion: Class 1

Classification: fine-loamy, mixed, mesic Aridic Haplustalfs

Moisture Regime: Ustic moisture regime

Landuse: Rangeland grazed
Permeability: Moderately rapid

Natural Drainage Class: Well drained

Parent Material and/or Bedrock Information

Parent material: Moderately weathered eolian from sandstone-shale

Diagnostic Features: ochric, 0 to 5 cm
argillic, 5 to 104 cm

A--0 to 5 cm; brown (7.5YR 4/3) fine sandy loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; soft, friable, slightly sticky and nonplastic; common fine and medium roots; 1.3 percent clay; 7.8 pH unspecified; very slightly effervescent; clear smooth boundary.

Bt1--5 to 18 cm; brown (7.5YR 4/4) sandy clay loam, dark brown (7.5YR 3/4) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; common fine and medium roots; 2.0 percent clay; 8.0 pH unspecified; few faint continuous clay films on faces of peds and in pores; slightly effervescent; abrupt smooth boundary.

Bt2--18 to 61 cm; brown (7.5YR 5/4) sandy clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard , firm, moderately sticky and moderately plastic; common fine and medium roots; 3.3 percent clay; 8.0 pH unspecified; common distinct continuous clay films on faces of peds and in pores; very slightly effervescent; clear wavy boundary.

Bt3--61 to 81 cm; reddish yellow (7.5YR 6/6) sandy clay loam, brown (7.5YR 4/4) moist; weak medium subangular blocky structure; hard, firm, moderately sticky and moderately plastic; common fine and medium roots; 2.1 percent clay; 8.0 pH unspecified; few distinct continuous clay films on faces of peds and in pores; very slightly effervescent; clear smooth boundary.

Btk--81 to 104 cm; strong brown (7.5YR 5/6) sandy clay loam, strong brown (7.5YR 4/6) moist; massive; slightly hard, friable, slightly sticky and nonplastic; common very fine and fine roots and common coarse; 1.5 percent clay; 8.0 pH unspecified; few faint continuous clay films on faces of peds and in pores; very slightly effervescent; abrupt smooth boundary.

Bk1--104 to 165 cm; reddish yellow (7.5YR 6/6) sandy clay loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and nonplastic; common very fine and fine roots and common coarse; 2.0 percent clay; 8.2 pH unspecified; few fine irregular masses of lime; very slightly effervescent; clear smooth boundary.

Bk2--165 to 185 cm; reddish yellow (7.5YR 7/6) sandy loam, reddish yellow (7.5YR 7/6) moist; massive; hard , friable, slightly sticky and nonplastic; common very fine and fine roots and common coarse; 1.9 percent clay; 8.4 pH unspecified; common medium irregular masses of lime; violently effervescent; clear smooth boundary.

Bk3--185 to 221 cm; light brown (7.5YR 6/4) sandy clay loam, light brown (7.5YR 6/4) moist; massive; hard , friable, slightly sticky and slightly plastic; common very fine and fine roots and common coarse; 2.2 percent clay; 8.4 pH unspecified; common medium irregular masses of lime; violently effervescent.

BUSHLAND, TEXAS

Table _7_. Station Instrumentation Summary for Bushland, TX.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995_-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Bushland
State: Texas
County: Randall

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 09/04/1991

Soil Series: Pullman

Site Identification #: S91TX381001

Laboratory Information
Lab Pedon #: 92P0203   Source Lab Id: SSL

Location Information
Soil Survey Area #: 381
County Name: Randall
Location Description: .95 miles S of I-40; 1 mile W of Bushland, TX;
site is .5 miles E of county road.

Slope Characteristics Information
Slope: 1 percent

Elevation: 1158 meters

Microrelief:
Kind: land leveled or smooth

Degree of Erosion: None - deposition

Classification: fine, montmorillonitic , mesic Typic Argiudolls

Landuse: Other
Permeability: Slow

Natural Drainage Class: Well drained

Vegetative Information
Plant Name: blue grama, buffalograss, rangeland

Notes: Site is in native, undisturbed rangeland and has never been plowed; excellent range condition dominated by blue grama and buffalograss; Parent Material: high plains eolian mantle.

A1--0 to 7 cm; dark brown (7.5YR 3/2) silty clay loam, brown (7.5YR 4/2) dry; weak fine granular and weak medium subangular blocky structure; very hard, firm; few worm casts; clear smooth boundary. abundant roots.

Bt1--7 to 24 cm; dark brown (7.5YR 3/2) silty clay, brown (7.5YR 4/2) dry; moderate medium subangular blocky structure; extremely hard, very firm; common roots; common continuous clay films and few pressure faces; gradual smooth boundary. few vertical cracks.

Bt2--24 to 37 cm; dark brown (7.5YR 3/4) silty clay, brown (7.5YR 4/4) dry; moderate medium subangular blocky structure; extremely hard, very firm; few roots; common continuous clay films and few pressure faces; slightly effervescent; gradual smooth boundary. few small vertical cracks.

Bt3--37 to 50 cm; reddish brown (5YR 4/3) clay, reddish brown (5YR 5/3) dry; moderate medium subangular blocky structure; extremely hard, very firm; few fine roots; common clay films; few carbonate threads; slightly effervescent; gradual smooth boundary.

Bt4--50 to 63 cm; yellowish red (5YR 4/6) clay, yellowish red (5YR 5/6) dry; moderate medium subangular blocky structure; extremely hard, very firm; few very fine roots; common clay films; few carbonate threads; strongly effervescent; gradual wavy boundary.

Btk1--63 to 72 cm; pinkish gray (5YR 7/2) silty clay, pinkish white (5YR 8/2) dry; moderate medium subangular blocky structure; hard , friable; violently effervescent; gradual smooth boundary. about 55% $CaCO_3$ as soft caliche.

Btk2--72 to 90 cm; yellowish red (5YR 4/6) clay loam, yellowish red (5YR 5/6) dry; moderate medium subangular blocky structure; very hard, firm; masses of carbonate; violently effervescent. about 25% CaCO3 as soft bodies.

CRESCENT LAKE, MINNESOTA

Table _8_. Station Instrumentation Summary for Crescent Lake, MN.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995_-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Crescent Lake
State: Minnesota
County: Sherburne

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service

Pedon NSSL Description not available at this time for Crescent Lake, MN

For Primary Characterization Data, click on Site Identification Number below:

Site Identification #: S91MN141001

ELLICOTT, MARYLAND (Discontinued in 1998 due to vandalism)

Table _9_. Station Instrumentation Summary for Ellicott, MD.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Ellicott
State: Maryland
County: Howard

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/27/1991

Soil Series: Chester

Component Name: CHESTER
Component Kind: Series

Site Identification #: S91MD027001

Laboratory Information
Lab Pedon #: 92P0199 Source Lab Id: SSL

Location Information
Soil Survey Area #: 027

Moisture Regime: Udic moisture regime

FORT ASSINIBOINE, MONTANA

Table _10_. Station Instrumentation Summary for Fort Assiniboine, MT.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Fort Assiniboine
State: Montana
County: Hill

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 07/28/1992

Soil Series: Telstad

Site Identification #: S92MT041003
Laboratory Information
Lab Pedon #: 92P0838 Source Lab Id: SSL

Location Information
Soil Survey Area #: 041
County Name: Hill
Location Description: 1917' S and 34' E of NW corner, Section 33,
T32N, R15E.

Slope Characteristics Information
Slope: 1 percent
Aspect: 174 degrees

Elevation: 829 meters

Physiography:
Major: Till Plain
Geomorphic Position: back slope

Type of Erosion: wind and water erosion
Degree of Erosion: Class 1

Classification: fine-loamy, mixed Aridic Argiborolls

Moisture Regime: Udic moisture regime

Permeability: Rapid

Natural Drainage Class: Well drained

Parent Material and/or Bedrock Information

Parent material: glacial till

Vegetative Information
Plant Name: crested wheatgrass

Described by: C. Gordon

Notes: Relief: gently undulating. SNOTEL site at Northern Agriculture Research Station - have global warming.

A--0 to 13 cm; dark brown (10YR 3/3) loam, brown (10YR 5/3) dry; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine roots and common medium; common medium tubular pores; 22.0 percent clay; slightly effervescent; 1 percent gravel and 1 percent cobbles; neutral; abrupt smooth boundary. when mixed to 7", colors are mollic.

Bt--13 to 33 cm; brown (10YR 4/3) clay loam, brown (10YR 5/3) dry; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard, friable, moderately sticky and moderately plastic; common fine and medium roots; common fine tubular pores and few medium tubular pores; 30.0 percent clay; common distinct clay films on faces of peds; slightly effervescent; 1 percent gravel; neutral; clear wavy boundary.

Btk--33 to 48 cm; dark grayish brown (10YR 4/2) clay loam, light brownish gray (10YR 6/2) dry; weak medium prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, moderately sticky and moderately plastic; common medium roots and few fine; few fine and medium tubular pores; 28.0 percent clay; few faint clay films on faces of peds; few fine and medium masses of lime; strongly effervescent; 1 percent gravel; moderately alkaline; clear wavy boundary.

Bk--48 to 84 cm; grayish brown (10YR 5/2) clay loam, light brownish gray (10YR 6/2) dry; moderate medium subangular blocky structure; hard , friable, moderately sticky and moderately plastic; common medium roots; few fine and medium tubular pores; 28.0 percent clay; common fine and medium masses of lime; strongly effervescent; 1 percent gravel and 1 percent cobbles; strongly alkaline; clear wavy boundary.

Bky--84 to 122 cm; grayish brown (2.5Y 5/2) clay loam, light brownish gray (2.5Y 6/2) dry; strong medium subangular blocky structure; very hard, firm, moderately sticky and moderately plastic; few fine roots; few fine tubular pores; few fine lignite chips; 30.0 percent clay; many fine and medium masses of lime and few fine masses of gypsum; violently effervescent; 3 percent gravel and 1 percent cobbles; very strongly alkaline; gradual wavy boundary.

By1--122 to 188 cm; dark grayish brown (2.5Y 4/2) clay loam, light brownish gray (2.5Y 6/2) dry; strong medium angular blocky structure; very hard, firm, moderately sticky and moderately plastic; few fine roots; few fine and medium lignite chips and few medium iron oxide staining; 32.0 percent clay; few medium masses of gypsum; slightly effervescent; 3 percent gravel and 3 percent cobbles; strongly alkaline; gradual wavy boundary.

By2--188 to 254 cm; dark grayish brown (2.5Y 4/2) clay loam, light brownish gray (2.5Y 6/2) dry; strong medium angular blocky structure; very hard, very firm, moderately sticky and moderately plastic; few fine and medium lignite chips and few medium iron oxide staining; 32.0 percent clay; common medium masses of gypsum; slightly effervescent; 3 percent gravel and 3 percent cobbles; strongly alkaline.

GENEVA, NEW YORK

Table _11_. Station Instrumentation Summary for Geneva, NY.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Geneva
State: New York
County: Ontario

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/23/1991

Soil Series: Honeoye

Site Identification #: S91NY069001

Laboratory Information
Lab Pedon #: 92P0198   Source Lab Id: SSL

Location Information

Soil Survey Area #: 069
Location Description: global warming - soil climate station

Slope Characteristics Information
Slope: 2 percent

Classification: fine-loamy, mixed, mesic Glossoboric Hapludalfs

Vegetative Information
Plant Name: grass

Particle Size Control Section: 61 to 84 cm

Ap1--0 to 5 cm; dark grayish brown (10YR 4/2) silt loam; moderate fine and medium granular structure; very friable; many very fine and fine roots; 10 percent gravel; moderately acid; clear smooth boundary.

Ap2--5 to 14 cm; dark grayish brown (10YR 4/2) gravelly silt loam and loam; weak medium and coarse subangular blocky and moderate fine and medium granular structure; friable; common very fine and fine roots; 15 percent gravel; slightly acid; abrupt smooth boundary.

E--14 to 20 cm; brown (10YR 5/3) gravelly loam, very pale brown (10YR 7/3) dry; weak fine and medium subangular blocky structure; friable; common fine roots; 15 percent gravel; neutral; clear wavy boundary.

B/E--20 to 24 cm; brown (7.5YR 4/3) gravelly loam, brown (7.5YR 5/3) dry (B); moderate fine and medium subangular blocky structure; firm; common fine roots; common skeletons on faces of peds; 15 percent gravel; neutral; brown (10YR 5/3), pale brown (10YR 6/3) and light brownish gray (10YR 6/2) dry (E); gradual wavy boundary.

Bt--24 to 33 cm; brown (7.5YR 4/3) and brown (7.5YR 4/4) gravelly silt loam; few fine faint brown (7.5YR 5/4) mottles; moderate medium and coarse subangular blocky structure; firm; few fine roots; common fine pores and few medium pores; common faint clay films on faces of peds; 20 percent gravel; neutral; clear wavy boundary. nearly continuous, thin clay films lining pores; mottles occur in the
lower part.

CB--33 to 38 cm; brown (10YR 5/3) gravelly loam; common medium faint yellowish brown (10YR 5/4) and few medium faint yellowish brown (10YR 5/6) mottles; weak fine and medium prismatic structure; firm; few fine roots; strongly effervescent; 25 percent gravel; moderately alkaline; gradual wavy boundary.

Cd1--38 to 47 cm; brown (10YR 5/3) gravelly loam; few medium faint yellowish brown (10YR 5/4) mottles; moderate medium platy structure; very firm; strongly effervescent; 30 percent gravel; moderately alkaline; clear wavy boundary. texture includes a lens of fine sandy loam 92P1316

Cd2--47 to 58 cm; light brownish gray (10YR 6/2) and brown (10YR 5/3) gravelly loam, light gray (10YR 7/2) dry; few medium faint yellowish brown (10YR 5/4) and few medium faint yellowish brown (10YR 5/6) mottles; moderate medium and coarse platy structure; very firm; strongly effervescent; 30 percent gravel; moderately alkaline; gradual wavy boundary. texture includes a lens of fine sandy loam.

Cd3--58 to 100 cm; brown (10YR 5/3) and yellowish brown (10YR 5/4) very gravelly fine sandy loam, pale brown (10YR 6/3) dry; moderate fine and medium platy structure; firm; strongly effervescent; 35 percent gravel; moderately alkaline.

LIND, WASHINGTON

Table _12_. Station Instrumentation Summary for Lind, WA.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Lind
State: Washington
County: Adams

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
DATE Sampled: 06/11/1992

Soil Series: Ritzville

Site Pedon Identification #: S92WA001001

Map Unit Symbol: RED

Laboratory Information
Lab Pedon #: 92P0680   Source Lab Id: SSL

Location Information
Soil Survey Area #: 001   MLRA: 8
Location Description: T18N., R34E., NW 1/4mi. NW 1/4mi., sec 32, 2 1/2mi. NE of Lind, Washington, WSU dryland research unit.

Latitude: 47 degrees 0 minutes 25 seconds N
Longitude: 118 degrees 34 minutes 25 seconds W

Description Category: Description for research study
Pedon Category: Within range of series

Slope Characteristics Information
Slope: 5 percent
Aspect: 190 degrees
Vertical Shape: Plane
Total Slope Length: 350 meters
Slope Length Above Site: 200 meters

Elevation: 1640 meters

Physiography:
Local: Hillside
Major: Hills
Geographically Associated Soils: willis, ritzcal, roloff, shano

Geomorphic Position: on upper third, shoulder, of a side slope

Microrelief:
Kind: land leveled or smooth
Elevation: 0 cm

Climate Information
Precipitation: 40 mm

Air Temperature		Soil Temperature	
Ann	9 C	Ann	
Sum	22 C	Sum	
Win	-2 C	Win	

Runoff: Low

Type of Erosion: water erosion
Degree of Erosion: Class 2

Classification: coarse-silty, mixed, mesic Calciorthidic Haploxerolls

Moisture Regime: Xeric moisture regime

Landuse: Abandonded cropland
Permeability: moderate over moderate over moderate over moderate over moderate over moderate over moderate over slow

Natural Drainage Class: Well drained

Parent Material and/or Bedrock Information

Parent material: Moderately weathered loess from mixed with a dip of 1 degrees

Vegetative Information
Plant Name: crested wheatgrass

Diagnostic Features: mollic, 0 to 26 cm
cambic, 26 to 147 cm
duripan, 147 to 160 cm

Described by: Jay T. Kehne

Notes: Global warming site location - Lind. WA.. Horizon A1 0 to 3cm
is 1980 Mt. St. Helens volcanic ash deposits.

A1--0 to 3 cm; very pale brown (10YR 8/2), exterior, very fine sandy loam, brown (10YR 5/3), exterior, moist; weak very fine and fine platy structure; soft, very friable, extremely weak; many very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 4.0 percent clay; abrupt smooth boundary.

A2--3 to 14 cm; brown (10YR 5/3), exterior, silt loam, dark brown (10YR 3/3), exterior, moist; fine single grain; slightly hard, friable, very weak; common very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 6.0 percent clay; clear smooth boundary.

A3--14 to 26 cm; brown (10YR 5/3), exterior, silt loam, dark brown (10YR 3/3), exterior, moist; weak fine single grain; slightly hard, friable, very weak; common very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 6.0 percent clay; clear wavy boundary.

BA--26 to 48 cm; yellowish brown (10YR 5/4), exterior, silt loam, dark yellowish brown (10YR 4/4), exterior, moist; moderate fine subangular blocky structure; slightly hard, friable, very weak; common very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 7.0 percent clay; clear wavy boundary.

Bw--48 to 94 cm; yellowish brown (10YR 5/4), exterior, silt loam, dark yellowish brown (10YR 4/4), exterior, moist; moderate fine subangular blocky structure; slightly hard, firm, very weak; common very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 7.0 percent clay; clear wavy boundary.

2Bk1--94 to 125 cm; pale brown (10YR 6/3), exterior, silt loam, brown (10YR 4/3), exterior, moist; strong fine and medium subangular blocky structure; hard, friable, weak; common very fine and fine roots in cracks; common very fine and fine low continuity tubular pores; 8.0 percent clay; distinct continuous carbonate coats on faces of peds and in pores; fine rounded carbonate threads; violently effervescent (HCl, 1 normal); gradual wavy boundary.

2Bk2--125 to 147 cm; pale brown (10YR 6/3), exterior, silt loam, brown (10YR 4/3), exterior, moist; weak very fine and fine subangular blocky structure; soft, very friable, extremely weak; common very fine and fine roots throughout; common very fine and fine low continuity interstitial and tubular pores; 7.0 percent clay; faint discontinuous carbonate coats throughout; fine rounded carbonate threads; violently effervescent (HCl, 1 normal); abrupt wavy boundary.

2Bkqm--147 to 160 cm; pale brown (10YR 6/3) , brown (10YR 4/3) moist; moderate and strong coarse and very coarse massive; extremely hard, extremely firm , weakly cemented , very strong; distinct continuous carbonate coats on faces of peds and in pores; medium and coarse platelike durinodes and fine rounded carbonate threads; violently effervescent (HCl, 1 normal).

MANDAN, NORTH DAKOTA

Table _13_. Station Instrumentation Summary for Mandan, ND.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA	Enclosure	

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
	battery		
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Mandan
State: North Dakota
County: Emmons

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 07/29/1992

Soil Series: Wilton

Site Identification #: S92ND059400

Laboratory Information
Lab Pedon #: 92P1023   Source Lab Id: SSL

Location Information
Soil Survey Area #: 059
County FIPS Code: 059

Slope Characteristics Information
  Slope: 1 percent
  Aspect: 130 degrees
  Horizontal Shape: Plane

Physiography:
  Local: Terrace

Classification: fine-silty, mixed Pachic Haploborolls

Permeability: Moderate

Natural Drainage Class: Well drained

Parent Material and/or Bedrock Information

Parent material: loess over glacial till

Vegetative Information
Plant Name: native grass, western wheat, green needle

Described by: MG, CJ, JT

Notes: discontinuous stone lime at top of 2Bk (stones 1 to 10cm in size), some pebbles are rounded-carbonates on undersides.

A1--0 to 4 cm; black (10YR 2/1) silt loam, dark gray (10YR 4/1) dry; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many very fine and fine roots and common medium; abrupt smooth boundary.

A2--4 to 15 cm; black (10YR 2/1) silt loam, dark gray (10YR 4/1) dry; weak medium subangular blocky and moderate fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots and common fine; abrupt smooth boundary.

A3--15 to 33 cm; black (10YR 2/1) silt loam, dark grayish brown (10YR 4/2) dry; weak fine and medium prismatic and moderate fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots and common fine; clear smooth boundary.

Bw1--33 to 63 cm; very dark brown (10YR 2/2), rubbed, and black (10YR 2/1), exterior, silt loam, very dark grayish brown (10YR 3/2) and dark grayish brown (10YR 4/2) dry; moderate fine and medium prismatic and moderate medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots; clear wavy boundary.

Bw2--63 to 86 cm; olive brown (2.5Y 4/3) silt loam, light olive brown (2.5Y 5/4) dry; few fine distinct yellowish brown (10YR 5/6) mottles; strong medium prismatic and moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine roots; common distinct clay films on faces of peds; clear wavy boundary.

2AB--86 to 97 cm; dark grayish brown (2.5Y 4/2) loam, olive brown (2.5Y 4/3) dry; few fine prominent yellowish brown (10YR 5/6) mottles; moderate medium prismatic and moderate medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common fine roots; common distinct clay films on faces of peds; clear wavy boundary.

2Bk--97 to 140 cm; dark grayish brown (2.5Y 4/2) loam, light olive brown (2.5Y 5/3) dry; few fine prominent dark yellowish brown (10YR 4/6) mottles; moderate medium prismatic and moderate medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common fine roots; gradual wavy boundary.

2BCk--140 to 183 cm; olive brown (2.5Y 4/3) clay loam, light olive brown (2.5Y 5/3) dry; few medium distinct grayish brown (2.5Y 5/2) and few fine prominent yellowish brown (10YR 5/6) mottles; weak medium prismatic and weak medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; gradual wavy boundary.

2C--183 to 280 cm; light olive brown (2.5Y 5/3) loam, light yellowish brown (2.5Y 6/4) dry; massive; soft, friable, slightly sticky and slightly plastic.

MASON, ILLINOIS

Table _14_. Station Instrumentation Summary for Mason, IL.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Mason
State: Illinois
County: Fulton

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/22/1991

Soil Series: SND

Site Identification #: S91IL125001

Laboratory Information
Lab Pedon #: 92P0196   Source Lab Id: SSL

Location Information
Soil Survey Area #: 125
County Name: Mason

Particle Size Control Section: 28 to 78 cm

Notes: Global warming site.

Ap--0 to 9 cm; very dark grayish brown (10YR 3/2) loamy sand, dark grayish brown (10YR 4/2) dry; weak fine granular structure; very friable; many very fine roots; slightly acid; abrupt smooth boundary.

A--9 to 23 cm; very dark grayish brown (10YR 3/2) sandy loam, grayish brown (10YR 5/2) dry; moderate fine granular structure; very friable; few very fine roots; neutral; clear smooth boundary.

BA--23 to 26 cm; brown (7.5YR 4/4) sandy loam; moderate medium subangular blocky structure; very friable; few very fine roots; many faint continuous dark brown (10YR 3/3) coats on faces of peds; neutral; clear smooth boundary. pore linings (10YR 2/2)

Bt1--26 to 36 cm; brown (7.5YR 4/4) sandy clay loam; moderate medium subangular blocky structure; friable; few very fine roots; many faint discontinuous brown (7.5YR 4/3) coats; strongly acid; clear smooth boundary. pore linings (10YR 2/2)

Bt2--36 to 50 cm; brown (7.5YR 4/4) sandy loam; moderate medium subangular blocky structure; friable; few very fine roots; common faint continuous brown (7.5YR 4/3) coats; strongly acid; clear smooth boundary. pore linings (10YR 2/2)

E/Bt1--50 to 63 cm; yellowish brown (10YR 5/8) and brown (7.5YR 4/3) loamy sand (E); massive and weak fine subangular blocky structure; very friable; moderately acid; (Bt); clear smooth boundary.

E/Bt2--63 to 71 cm; yellowish brown (10YR 5/4) and dark yellowish brown (10YR 3/4) sand (E); massive and weak fine subangular blocky structure; very friable; slightly acid; (Bt); clear smooth boundary.

E/Bt3--71 to 87 cm; light yellowish brown (10YR 6/4) and dark yellowish brown (10YR 3/4) sand (E); massive and weak fine subangular blocky structure; very friable; slightly acid; (Bt); clear smooth boundary.

C--87 to 95 cm; pale brown (10YR 6/3) sand; massive; loose; slightly acid.

MOLLY CAREN, OHIO

Table _15_. Station Instrumentation Summary for Molly Caren, OH.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Molly Caren
State: Ohio
County: Madison

NSSL Pedon Descriptions
USDA - National Resource Conservation Service
Pedon NSSL Description

DATE Sampled: 07/15/1992

Soil Series: Crosby

Site Identification #: S92OH097001
Map Unit Symbol: CsB

Laboratory Information
Lab Pedon #: 92P0724 Source Lab Id: SSL

Location Information
Soil Survey Area #: 097 MLRA: 111
Location Description: 66' NE of sensors & 44' S of edge of grass lane.

Latitude: 39 degrees 57 minutes 24 seconds N
Longitude: 83 degrees 26 minutes 35 seconds W

Photograph #: 18

Description Category: Full pedon description
Pedon Category: Within range of series

Slope Characteristics Information
- Slope: 1 percent
- Aspect: 95 degrees
- Horizontal Shape: Plane*
- Vertical Shape: Concave

Physiography:
- Local: Ground Moraine
- Major: Glaciated Upland *

Geomorphic Position: summit, of a interfluve

Climate Information
- Precipitation: 93 mm

Air Temperature	Soil Temperature
Ann 16 C	Ann
Sum	Sum
Win	Win

Water Table Information
- Water Table Depth: 127 cm
- Water Table Kind: Perched

Runoff: Low

Type of Erosion: water erosion

Classification: fine, mixed, mesic Aeric Ochraqualfs*

Moisture Regime: Udic moisture regime

Landuse: Cropland
Natural Drainage Class: Somewhat poorly drained

Parent Material and/or Bedrock Information

Parent material: glacial till

Particle Size Control Section: 0 to 152 cm

Diagnostic Features: ochric, 0 to 25 cm
argillic, 25 to 68 cm

Described by: R. M. Gehring, J.W. Hempel

Notes: Correlated Name: Crosby silt loam.

Ap--0 to 27 cm; dark grayish brown (10YR 4/2) sandy loam, pale brown (10YR 6/3) dry; weak coarse subangular blocky and moderate fine and medium subangular blocky structure; friable; common fine roots throughout; common fine vesicular and tubular pores; few faint discontinuous dark brown (10YR 3/3) organic coats on vertical and horizontal faces of peds; 2 percent gravel; neutral; clear smooth boundary.

Bt1--27 to 37 cm; yellowish brown (10YR 5/4) silty clay loam; common fine distinct gray (10YR 6/1) and common medium strong brown (7.5YR 5/6) mottles; weak medium prismatic and moderate medium subangular blocky structure; firm; common very fine and fine roots throughout; common fine vesicular and tubular pores; few discontinuous dark grayish brown (10YR 4/2) clay films on vertical and horizontal faces of peds and few light brownish gray (10YR 6/2) skeletons and few distinct patchy dark brown (7.5YR 3/2) manganese or iron-manganese stains throughout; 2 percent gravel; slightly acid; clear smooth
boundary.

Bt2--37 to 58 cm; yellowish brown (10YR 5/4) clay loam; common fine distinct gray (10YR 6/1) and common medium distinct strong brown (7.5YR 5/6) mottles; weak medium and coarse prismatic and moderate fine and medium subangular blocky structure; firm; common very fine and fine roots throughout; common fine vesicular and tubular pores; few distinct patchy dark brown (7.5YR 3/2) manganese or iron-manganese stains throughout and common dark grayish brown (10YR 4/2) clay films on vertical and horizontal faces of peds; 2 percent gravel; neutral; clear smooth boundary.

Bt3--58 to 69 cm; yellowish brown (10YR 5/4) clay loam; few fine faint light brownish gray (10YR 6/2) and common medium distinct strong brown (7.5YR 5/6) mottles; moderate fine and medium subangular blocky structure; firm; common very fine roots between peds; common fine vesicular and tubular pores; few distinct patchy dark brown (7.5YR 3/2) organic coats throughout and few discontinuous dark grayish brown (10YR 4/2) clay films on vertical and horizontal faces of peds and few dark gray (10YR 4/1) clay films in root channels and/or pores; 5 percent gravel; neutral; gradual wavy boundary.

BC--69 to 89 cm; brown (10YR 5/3) clay loam; common medium distinct light brownish gray (10YR 6/2) and coarse strong brown (7.5YR 5/6) mottles; weak medium and coarse subangular blocky structure; firm; common very fine roots between peds; common fine and medium vesicular and tubular pores; few faint discontinuous dark grayish brown (10YR 4/2) clay films on vertical and horizontal faces of peds and few distinct patchy light gray (10YR 7/2) carbonate coats on vertical and horizontal faces of peds; 10 percent gravel; slightly alkaline; gradual wavy boundary.

C1--89 to 155 cm; dark yellowish brown (10YR 4/4) loam; common fine distinct strong brown (7.5YR 5/6) mottles; massive; firm; few prominent continuous light gray (10YR 7/1) carbonate coats on vertical faces of peds and few prominent gray (10YR 6/1) carbonate coats; 10 percent gravel and 2 percent cobbles; moderately alkaline; abrupt wavy boundary. split sample 110-155cm.

2C2--155 to 163 cm; dark grayish brown (10YR 4/2) loamy coarse sand; single grain; loose; strongly effervescent (HCl, 1 normal); 2 percent gravel; moderately alkaline; abrupt wavy boundary. No sample obtained from this horizon.

3C3--163 to 200 cm; dark yellowish brown (10YR 4/4) loam; massive; very firm; few distinct patchy light gray (10YR 7/1) carbonate coats on vertical faces of peds; violently effervescent (HCl, 1 normal); 10 percent gravel and 3 percent cobbles; moderately alkaline. Clod sample taken from 175 to 190cm.

NEWTON, MISSISSIPPI

Table _16_. Station Instrumentation Summary for Newton, MS.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Newton
State: Mississippi
County: Newton

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/30/1991

Soil Series: Savannah

Site Identification #: S91MS101001

Laboratory Information
Lab Pedon #: 92P0202 Source Lab Id: SSL

Location Information
Soil Survey Area #: 101

Slope Characteristics Information
Slope: 2 percent

Classification: fine-loamy Typic Fragiudalfs

Natural Drainage Class: Moderately well drained

Notes: Parent Material: loamy sediments

Ap--0 to 5 cm; brown (10YR 4/3) very fine sandy loam; weak fine granular structure; very friable; many fine roots; abrupt smooth boundary.

E--5 to 9 cm; brown (10YR 5/3) very fine sandy loam; weak fine granular structure; very friable; common fine roots; common fine rounded iron-manganese concretions; abrupt smooth boundary.

Bt1--9 to 21 cm; brown (7.5YR 4/4) loam; moderate medium subangular blocky structure; friable; few fine roots; common distinct clay films on faces of peds; few worm casts; clear smooth boundary.

Btx1--21 to 35 cm; dark yellowish brown (10YR 4/6) sandy loam; common medium distinct grayish brown (10YR 5/2) mottles; moderate coarse prismatic and moderate medium subangular blocky structure; firm; common distinct dark yellowish brown (10YR 4/4) clay films on faces of peds; few fine rounded iron concretions; clear wavy boundary. brittle and compact in 60-70" of mass.

Btx2--35 to 50 cm; yellowish brown (10YR 5/6) sandy clay loam; common medium distinct grayish brown (10YR 5/2) and few fine prominent olive brown (2.5Y 4/4) mottles; moderate coarse and very coarse prismatic and moderate fine and medium subangular blocky structure; firm; common distinct dark yellowish brown (10YR 4/4) clay films on faces of peds; clear wavy boundary.
brittle and compact in 70" of mass.

Btx3--50 to 67 cm; 55 percent yellowish brown (10YR 5/6) and 45 percent grayish brown (10YR 5/2) sandy clay loam; few coarse prominent dark yellowish brown (10YR 4/6) mottles; moderate coarse and very coarse prismatic and moderate fine and medium subangular blocky structure; firm; common distinct continuous clay films on faces of peds; gradual wavy boundary. brittle and compact in 70% of mass.

2Btx4--67 to 88 cm; strong brown (7.5YR 5/6) and grayish brown (10YR 5/2) sandy loam; many strong brown (7.5YR 5/6), many grayish brown (10YR 5/2), and many dark yellowish brown (10YR 4/6) mottles; weak coarse and very coarse prismatic structure; firm; common distinct continuous dark yellowish brown (10YR 4/4) clay films on faces of peds; gradual wavy boundary. moist color is mottled.

3Btx5--88 to 102 cm; red (2.5YR 4/8) sandy loam; common medium distinct yellowish brown (10YR 5/8) mottles; weak coarse prismatic structure; firm. (10YR 5/2) seams between prisms; few medium nodules of (10YR 4/6) hematite.

NUNN, COLORADO

Table _17_. Station Instrumentation Summary for Nunn, CO.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Nunn
State: Colorado
County: Weld

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 04/1991

Soil Series: Olney

Site Identification #: S91CO123003

Laboratory Information
Lab Pedon #: 91P0867 Source Lab Id: SSL

Location Information
Soil Survey Area #: MLRA:

Latitude: 40 degrees 00 minutes 00 seconds N
Longitude: 104 degrees 00 minutes 00 seconds W

Slope Characteristics Information
Slope: 1% south facing

Elevation: MSL
Water Table Depth:
Permeability: Moderately slow
Drainage: Well drained
Land Use:
Stoniness:
Erosion or Deposition: Moderate
Runoff:

Parent Material:
Classification: Fine-loamy, mixed, mesic Ustollic Haplargid
Diagnostic Horizons:
Vegetation: Blue Gramma, Buffalograss, Red Three Awn, Opuntia, Thread Leaf Sedge
Parent Material: mixed loamy alluvium

A1 -- 0 to 10 cm; dark brown (10YR 3/3) moist sandy loam; moderate fine granular structure; soft, very friable, slightly sticky, slightly plastic; few fine and medium interstitial and tubular and common very fine interstitial and tubular pores; slightly effervescent; abrupt smooth boundary.

Bt1 -- 10 to 18 cm; dark brown (10YR 3/3) moist sandy clay loam; weak medium subangular blocky structure parting to moderate fine subangular blocky; hard, firm, sticky, plastic; common very fine interstitial and tubular pores; slightly effervescent; clear smooth boundary.

Bt2 -- 18 to 41 cm; brown to dark brown (10YR 4/3) moist sandy clay loam; strong fine and medium prismatic structure parting to moderate fine and medium subangular blocky; hard, firm, sticky, plastic; few fine interstitial and tubular and common very fine interstitial and tubular pores; slightly effervescent; clear wavy boundary.

Bt3 -- 41 to 56 cm;; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; clear wavy boundary.

Bk1 -- 56 to 84 cm; pale brown (10YR 6/3) and very pale brown (10YR 7/4) dry sandy loam and yellowish brown (10YR 5/4) moist sandy loam; weak coarse prismatic structure parting to weak medium subangular blocky; hard, friable, slightly sticky, slightly plastic; common fine interstitial and tubular and many very fine interstitial and tubular pores; strongly effervescent; gradual wavy boundary.

Bk2 -- 84 to 119 cm; very pale brown (10YR 7/3) dry loamy sand and light yellowish brown (10YR 6/4) moist loamy sand; weak medium prismatic structure; slightly hard, friable, nonsticky, nonplastic; common very fine interstitial and tubular and many fine and medium interstitial and tubular pores; violently effervescent; clear smooth boundary.

2Bk3 --119 to 163 cm; very pale brown (10YR 8/3) dry sandy clay loam and light yellowish brown (10YR 6/4) moist sandy clay loam; massive; slightly hard, friable, sticky, plastic; many fine and medium interstitial and tubular pores; violently effervescent.

3Bk4 --163 to 196 cm

PRAIRIE VIES, TEXAS

Table _18_. Station Instrumentation Summary for Prairie View, TX.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Prairie View
State: Texas
County: Waller

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 06/15/1992

Soil Series: Wockley

Site Identification #: S92TX473001

Laboratory Information
Lab Pedon #: 92P0701   Source Lab Id: SSL

Location Information
Soil Survey Area #: 473   MLRA: 150A
Location Description: intersection of US Hwy 290 & Farm Rd. 1098 at
Prairie View, TX. 1.1 mi. N on Farm Rd. 1098
0.6 mi. N thru campus, 0.5 mi. E on Farm Rd.
600' S. in cultivated field.

Latitude: 30 degrees 5 minutes 41 seconds N
Longitude: 95 degrees 58 minutes 18 seconds W

Slope Characteristics Information
Slope: 1 percent
Aspect: 230 degrees
Horizontal Shape: Plane
Vertical Shape: Plane

Elevation: 82 meters

Classification: fine-loamy, siliceous, thermic Typic Paleudalfs

Natural Drainage Class: Moderately well drained

Vegetative Information
Plant Name: watermelons

Described by: Lane Neithsch Chervenka Batte

Notes: Parent Material: laomy marine sediments; Water table: none within 2 meters. (colors are for moist soil). Soil type Wockley fine sandy loam.

Ap1--0 to 18 cm; brown (10YR 4/3) fine sandy loam; weak fine and medium subangular blocky structure; very hard, very friable; many very fine and fine roots; common fine and medium pores; common yellowish brown (10YR 5/4) worm casts; clear smooth boundary.

Ap2--18 to 33 cm; brown (10YR 4/3) fine sandy loam; weak fine and medium subangular blocky structure; very hard, very friable; many very fine and fine roots; common fine and medium pores; common distinct dark yellowish brown (10YR 4/6) iron stains in root channels and/or pores; clear smooth boundary.

E--33 to 53 cm; brown (10YR 5/3) fine sandy loam; common fine distinct dark yellowish brown (10YR 4/6) and common fine distinct yellowish brown (10YR 5/6) mottles; weak coarse prismatic and weak fine and medium subangular blocky structure; very hard, very friable; many very fine and fine roots; common fine and medium pores; very dark grayish brown (10YR 3/2) iron stains in root channels and/or pores; clear smooth boundary.

Bt1--53 to 64 cm; yellowish brown (10YR 5/4) fine sandy loam; common fine and medium faint yellowish brown (10YR 5/6) mottles; weak medium prismatic and weak medium and coarse subangular blocky structure; very hard, very friable; common very fine and fine roots; common fine pores; many very dark grayish brown (10YR 3/2) iron stains in root channels and/or pores and patchy clay films on faces of peds; clear smooth boundary. few crayfish krotovinas 3 to 4 cm across extend to 180cm.

Bt2--64 to 91 cm; brown (10YR 5/3) sandy clay loam; many medium and coarse prominent reddish yellow (7.5YR 6/8) and common fine prominent yellowish red (5YR 4/6) mottles; weak medium prismatic and moderate fine and medium subangular blocky structure; very hard, friable; common very fine and fine roots; common fine pores; patchy clay films on faces of peds; few medium and coarse ironstone nodules; gradual smooth boundary.

Bt3--91 to 122 cm; grayish brown (10YR 5/2) sandy clay loam; many medium and coarse prominent strong brown (7.5YR 5/8) and common fine and medium prominent yellowish red (5YR 4/6) mottles; moderate medium prismatic and strong fine and medium subangular blocky structure; very hard, friable; common very fine and fine roots; common fine pores; continuous clay films on faces of peds and patchy clay films on faces of peds; common medium and coarse ironstone nodules; gradual smooth boundary. few isolated areas 10 to 12 cm across have concentrations of about 25% ironstone nodules. About 3% medium plinthite. 3 to 5% brittle masses.

Bt4--122 to 152 cm; gray (10YR 6/1) sandy clay loam; common medium and coarse prominent yellowish brown (10YR 5/6), many fine prominent reddish brown (5YR 5/4), and common fine and medium prominent red (2.5YR 5/8) mottles; moderate medium prismatic and moderate fine and medium subangular blocky structure; very hard, friable; common very fine and fine roots; common fine pores; continuous clay films on faces of peds and patchy clay films on faces of peds; common medium and coarse ironstone nodules; gradual smooth boundary. few isolated areas 10 to 12cm across have concentrations of about 25% ironstone nodules. About 2% fine plinthite. 3 to 5% brittle masses.

Bt5--152 to 183 cm; gray (10YR 6/1) sandy clay loam; many medium prominent yellowish brown (10YR 5/6), common fine prominent reddish brown (5YR 5/4), and common fine prominent red (2.5YR 5/8) mottles; moderate medium prismatic and moderate fine and medium subangular blocky structure; extremely hard, very firm; common very fine and fine roots; common fine pores; common medium and coarse ironstone nodules; gradual wavy boundary. thin continuous clay films on faces of prism, thin patchy clay films on faces of blocks. very thin coatings of clean sand grains on vertical faces of some peds, few patchy iron manganese coatings on vertical faces of some peds.

Bt6--183 to 200 cm; yellowish brown (10YR 5/8) gravelly sandy clay loam; many medium and coarse prominent light brownish gray (10YR 6/2) mottles; moderate coarse prismatic and moderate fine and medium subangular blocky structure; extremely hard, very firm; common very fine and fine roots; prominent continuous clay films on faces of peds and common prominent manganese or iron-manganese stains on vertical faces of peds; common medium and coarse ironstone nodules.

PRINCETON, KENTUCKY

Table _19_. Station Instrumentation Summary for Princeton, KY.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Princeton
State: Kentucky
County: Caldwell

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/22/1991

Soil Series: Zanesville

Site Identification #: S91KY033002

Laboratory Information
Lab Pedon #: 92P0197   Source Lab Id: SSL

Location Information
Soil Survey Area #: 033
Location Description: global change project site near apple orchard

Slope Characteristics Information
Slope: 4 percent
Horizontal Shape: Convex
Vertical Shape: Convex

Physiography:
Local: Ridge

Classification: fine-silty, mixed, mesic Typic Fragiudalfs

Landuse: Other
Permeability: Moderately slow

Natural Drainage Class: Moderately well drained

Parent Material and/or Bedrock Information

Parent material: loess from sandstone

Vegetative Information
Plant Name: fescue interspersed with walnut trees

Particle Size Control Section: 28 to 78 cm

Diagnostic Features: ochric,   to cm
cambic,   to cm
argillic,   to cm
fragipan,   to cm

Described by: RF, JM, PG

Notes: Land Use: walnut grove; Physiography: narrow upland ridgetop;
described from backhoe pit.

Ap--0 to 6 cm; brown (10YR 4/3) silt loam; weak fine granular structure; friable; common fine and medium roots; neutral; clear smooth boundary.

Bw--6 to 11 cm; dark yellowish brown (10YR 4/4) silt loam; weak fine subangular blocky structure; friable; few fine and medium roots; slightly acid; clear smooth boundary.

Bt1--11 to 17 cm; brown (7.5YR 4/4) silt loam; moderate fine and medium subangular blocky structure; friable; few fine roots; faint continuous clay films; moderately acid; clear smooth boundary.

Bt2--17 to 31 cm; strong brown (7.5YR 4/6) silt loam; moderate medium subangular blocky structure; firm; few very fine roots; faint continuous brown (7.5YR 4/4) clay films; moderately acid; clear smooth boundary.

Btx1--31 to 40 cm; strong brown (7.5YR 4/6) silt loam; common medium prominent gray (10YR 6/1) and common medium distinct yellowish brown (10YR 5/6) mottles; weak coarse prismatic structure; firm; common fine and medium roots; distinct continuous brown (7.5YR 5/2) clay films and distinct continuous manganese or iron-manganese stains; moderately acid; clear smooth boundary. roots occur in gray streaks.

2Btx2--40 to 49 cm; brown (7.5YR 4/4) silt loam; many coarse gray (10YR 6/1) mottles; weak coarse prismatic structure; very firm, brittle; common fine and medium roots; strongly acid; clear smooth boundary. roots occur in gray streaks; mottles occur along prism faces; dense consistency.

2Bx--49 to 65 cm; dark yellowish brown (10YR 4/6) loam; many coarse prominent gray (10YR 6/1) mottles; weak coarse prismatic structure; extremely firm ; few fine roots; 20 percent sandstone; slightly acid. roots occur in gray streaks; very dense consistency; mottles occur along prism faces.

2R--165 cm. not sampled; sandstone bedrock; rock fragments occur in lower 4."

ROGERS FARM, NEBRASKA

Table _20_. Station Instrumentation Summary for Rogers Farm, NE.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	1991-1995
1	MCC 550C transceiver/data collection instrument	Enclosure	1991-1995
1	MCC 545 transceiver	Enclosure	1995-present
1	Campbell CR-10X-2M datalogger.	Enclosure	1995-present
1	Campbell AM416 multiplexer.	Enclosure	1995-present
1	Campbell CH12R charger/regulator.	Enclosure	1995-present
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Rogers Farm
State: Nebraska
County: Lancaster

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 09/18/1991

Soil Series: Sharpsburg

Site Identification #: S91NE109001

Laboratory Information
Lab Pedon #: 92P0204 Source Lab Id: SSL

Location Information
Soil Survey Area #: 109 MLRA: 106

Photograph #: LAN27

Slope Characteristics Information

Slope: 3 percent
Aspect: 135 degrees
Horizontal Shape: Convex
Vertical Shape: Plane

Physiography:
Local: Hillside
Major: Glaciated Upland
Geomorphic Position: back slope, of a side slope

Classification: fine-silty, mixed, mesic Typic Argiudolls

Moisture Regime: Udic moisture regime

Vegetative Information
Plant Name: Grass

Notes: WEATHER STATION AT ROGERS FARM

A1--0 to 13 cm; very dark brown (10YR 2/2) silty clay loam; moderate fine and medium subangular blocky and weak thick platy; hard; many fine and medium roots throughout; abrupt smooth boundary.

A2--13 to 27 cm; very dark brown (10YR 2/2) silty clay loam; moderate fine and medium subangular blocky structure; hard; common fine and medium roots throughout; clear smooth boundary.

Bt1--27 to 46 cm; very dark grayish brown (10YR 3/2) silty clay loam; moderate medium subangular blocky and moderate fine subangular blocky; hard; common fine roots between peds; common discontinuous black (10YR 2/1) organic coats on faces of peds and many continuous clay films on faces of peds; clear smooth boundary.

Bt2--46 to 62 cm; brown (10YR 4/3) silty clay; weak coarse prismatic and strong medium subangular blocky; very hard, very firm; fine and medium roots in cracks; many continuous clay films on faces of peds and few patchy black (10YR 2/1) organic coats; gradual smooth boundary.

Bt3--62 to 83 cm; brown (10YR 4/3) silty clay; few fine grayish brown (2.5Y 5/2) and common fine dark yellowish brown (10YR 4/6) mottles; moderate coarse prismatic and strong medium subangular blocky; very hard; fine roots in cracks; many continuous clay films on faces of peds and few patchy black (10YR 2/1) organic coats on faces of peds; gradual smooth boundary.

Bt4--83 to 117 cm; brown (10YR 5/3) silty clay loam; few fine grayish brown (2.5Y 5/2) and common fine dark yellowish brown (10YR 4/6) mottles; weak medium prismatic and moderate medium subangular blocky; firm; very fine and fine roots in cracks; few discontinuous clay films on faces of peds; gradual smooth boundary.

BC--117 to 139 cm; 50 percent dark yellowish brown (10YR 4/4) and 50 percent grayish brown (2.5Y 5/2) silty clay loam; common fine strong brown (7.5YR 4/6) mottles; weak medium prismatic and weak fine and medium subangular blocky; friable; very fine and fine roots in cracks; few discontinuous pressure faces; gradual smooth boundary.

C1--139 to 187 cm; 50 percent brown (10YR 5/3) and 50 percent grayish brown (2.5Y 5/2) silty clay loam; common fine strong brown (7.5YR 4/6) mottles; friable; very fine roots in cracks; diffuse wavy boundary.

C2--187 to 203 cm; 50 percent brown (10YR 5/3) and 50 percent grayish brown (2.5Y 5/2) silty clay loam; common fine strong brown (7.5YR 4/6) mottles; friable; very fine roots in cracks.

SELLERS LAKE, FLORIDA

Table _21_. Station Instrumentation Summary for Sellers Lake, FL.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Sellers Lake
State: Florida
County: Lake

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/31/1991

Soil Series: SND

Site Identification #: S92FL073001

Laboratory Information
Lab Pedon #: 92P0201   Source Lab Id: SSL

Location Information
Soil Survey Area #: 073
County Name: Leon
Location Description: Sec. 15, T. 2 S., R. 2 W.

Slope Characteristics Information
Slope: 0 percent

Type of Erosion: water erosion
Degree of Erosion: Class 1

Natural Drainage Class: Moderately well drained

Vegetative Information
Plant Name: longleaf pine and turkey, live and larual oaks

Described by: DL, RP

Notes: Parent Material: sandy and loamy marine sediments; global change pilot project, Apalachicola National Forest; the wavy boundary of the argillic at 80" makes the site Foxworth soils with Blanton soils as inclusions.

A--0 to 15 cm; dark brown (10YR 3/3) sand; weak fine granular structure; very friable; abrupt smooth boundary.

C1--15 to 41 cm; light yellowish brown (10YR 6/4) sand; single grain; loose; gradual wavy boundary.

C2--41 to 112 cm; 15 percent very pale brown (10YR 7/3) and light yellowish brown (10YR 6/4) sand; single grain; loose; clear smooth boundary.

C3--112 to 132 cm; very pale brown (10YR 8/2) and very pale brown (10YR 7/3) sand; few fine prominent yellow (10YR 7/8) mottles; single grain; loose; clear wavy boundary.

C4--132 to 157 cm; very pale brown (10YR 7/4) sand; many fine prominent strong brown (7.5YR 5/8) mottles; single grain; loose; gradual wavy boundary.

C5--157 to 203 cm; white (10YR 8/1) sand; few fine distinct very pale brown (10YR 7/4) mottles; single grain; loose; abrupt wavy boundary.

Bt--203 cm; very pale brown (10YR 7/4) sandy loam and loamy sand; many coarse distinct light gray (10YR 7/1) and few medium distinct brownish yellow (10YR 6/6) mottles; weak coarse angular blocky structure; friable.

TIDEWATER, NORTH CAROLINA

Table _22_. Station Instrumentation Summary for Tidewater, NC.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	1991-2002
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	MCC 545 transceiver	Enclosure	2002-present
1	Campbell CR-10X-2M datalogger.	Enclosure	2002-present
1	Campbell AM416 multiplexer.	Enclosure	2002-present
1	Campbell CH12R charger/regulator.	Enclosure	2002-present
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	Vaisala HMP45C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	2002-present
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	2002-present
1	Wind speed & direction RM Young 5105	Met tower 10 ft.	2002-present
1	Precipitation gage – tipping bucket	Met tower 6 ft.	2002-present
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Tidewater
State: North Carolina
County: Washington

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 11/13/1992

Soil Series: Plymouth

Site Identification #: S91NC187001

Laboratory Information
Lab Pedon #: 92P0200   Source Lab Id: SSL

Location Information
Soil Survey Area #: 187

Notes: roots to 52"

Ap--0 to 6 cm; very dark grayish brown (10YR 3/2) fine sandy loam, gray (5Y 5/1) dry; few fine faint grayish brown (2.5Y 5/2) mottles.

A--6 to 19 cm; very dark gray (10YR 3/1) fine sandy loam, gray (10YR 5/1) dry. no mottles.

BA--19 to 24 cm; very dark gray (10YR 3/1) and pale brown (10YR 6/3) loam, gray (10YR 5/1) and light gray (10YR 7/2) dry; few fine yellowish brown (10YR 5/6) mottles.

Bt--24 to 33 cm; grayish brown (10YR 5/2) clay loam, light brownish gray (10YR 6/2) dry; many coarse prominent yellowish brown (10YR 5/6) mottles.

Bt1--33 to 40 cm; grayish brown (10YR 5/2) sandy clay loam, white (10YR 8/1) dry; many coarse prominent yellowish red (5YR 4/6) and many coarse prominent yellowish red (5YR 5/6) mottles.

Bt2--40 to 47 cm; gray (10YR 6/1) sandy clay loam, light gray (10YR 7/2) dry; many coarse prominent reddish brown (2.5YR 4/4) and many coarse prominent yellowish red (5YR 5/6) mottles.

Bt3--47 to 53 cm; grayish brown (2.5Y 5/2) sandy clay loam, very pale brown (10YR 8/2) dry; many medium strong brown (7.5YR 5/6) and many medium strong brown (7.5YR 5/8) mottles.

BC--53 to 65 cm; grayish brown (2.5Y 5/2) sandy clay, light gray (2.5Y 7/2) dry; common medium distinct yellowish brown (10YR 5/8) mottles.

C--65 to 83 cm; very pale brown (10YR 8/2) sand; common coarse faint light yellowish brown (10YR 6/4) mottles.

TORRINGTON, WYOMING

Table _23_. Station Instrumentation Summary for Torrington, WY.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Torrington
State: Wyoming
County: Goshen

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service

Pedon NSSL Description not available at this time for Torrington, WY

For Primary Characterization Data, click on Site Identification Number below:

Site Identification #: S92WY015000

WABENO, WISCONSIN

Table _24_. Station Instrumentation Summary for Wabeno, WI.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Wabeno
State: Wisconsin
County: Forest

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 07/27/1990

Soil Series: Wabeno

Site Identification #: S90WI041006

Laboratory Information
Lab Pedon #: 90P0902   Source Lab Id: SSL

Location Information
Soil Survey Area #: 041
County Name: Forest
Location Description: About 3 miles E and 2 miles N of Wabeno. 1425'

E and 1688' N of the SW corner, Section 35,
T.35N., R.15E.

Latitude: 45 degrees 28 minutes 6 seconds N
Longitude: 88 degrees 35 minutes 12 seconds W

Slope Characteristics Information
Slope: 4 percent
Aspect: 150 degrees
Vertical Shape: Convex

Elevation: 482 meters

Physiography:
Local: Drumlin
Geomorphic Position: summit

Degree of Erosion: None - deposition

Classification: coarse-loamy, mixed, frigid Alfic Fragiorthods

Stoniness: 3 percent
Permeability: Moderately slow

Natural Drainage Class: Moderately well drained

Parent Material and/or Bedrock Information

Parent material: loess over glacial till

Vegetative Information
Plant Name: sugar maple, hop-hornbeam, yellow birch, trillium, sweet cicely, hairy solomon's seal, yellow violet, grasses

Described by: DJH and JRB

Notes: Percent of stones and boulders throughout pit is 1 percent. Relief: subnormal. Knoll is 12' S of the cradle (center to center). Difference in elevation between knoll and cradle is 11".

O--3 to 0 cm; very dark brown (10YR 2/2) ; many very fine and fine roots and common medium and coarse; highly decomposed leaf and root litter; very strongly acid.

E--0 to 1 cm; dark grayish brown (10YR 4/2) silt loam, grayish brown (10YR 5/2) dry; weak fine subangular blocky structure; friable; many very fine and fine roots and common medium and coarse; 2 percent gravel and 1 percent cobbles; very strongly acid; abrupt broken boundary.

Bs--1 to 48 cm; dark yellowish brown (10YR 4/4) silt loam; weak fine and medium subangular blocky structure; friable; many very fine and fine roots and common medium and coarse; many very fine and fine tubular pores and common medium and coarse tubular pores; 2 percent gravel and 1 percent cobbles; very strongly acid; abrupt wavy boundary.

E/B--48 to 71 cm; 85 percent yellowish brown (10YR 5/4) silt loam, 85 percent very pale brown (10YR 7/3) dry (E); weak thick platy structure parting to weak fine subangular blocky; friable; common fine and medium roots; many very fine and fine tubular pores; 5 percent gravel and 2 percent cobbles; very strongly acid; 15 percent dark brown (7.5YR 3/4) silt loam (B); weak fine subangular blocky structure; friable; abrupt wavy boundary.

2Btx1--71 to 147 cm; 70 percent brown (7.5YR 4/4) and 30 percent yellowish brown (10YR 5/4) sandy loam and loamy sand; weak fine and medium subangular blocky structure; firm, brittle; few fine and medium roots; common fine tubular pores and common fine and medium vesicular pores; few distinct reddish brown (5YR 4/4) clay films on faces of peds; 8 percent gravel and 3 percent cobbles; strongly acid; abrupt wavy boundary.

2Btx2--147 to 203 cm; brown (7.5YR 4/4) sandy loam; few fine prominent strong brown (7.5YR 5/8) mottles; weak thick platy structure parting to moderate fine subangular blocky; firm, brittle; few fine roots; common fine tubular pores and many medium and coarse vesicular pores; few distinct reddish brown (5YR 4/4) clay films on faces of peds; 10 percent gravel and 3 percent cobbles; moderately acid; clear wavy boundary.

2C--203 to 229 cm; brown (7.5YR 4/4) sandy loam; few fine prominent strong brown (7.5YR 5/8) mottles; massive; friable; tends to part to thin plates along horizontal cleavage planes; 10 percent gravel and 3 percent cobbles; moderately acid.

WAKULLA, FLORIDA

Table _25_. Station Instrumentation Summary for Wakulla, FL.

QUANTITY	DESCRIPTION	LOCATION	COMMENTS
1	NovaLynx interface instrument	Enclosure	
1	MCC 550C transceiver/data collection instrument	Enclosure	
1	Campbell CH12R charger/regulator.	Enclosure	
1	Campbell BP24 24-amp-hr YUASA battery	Enclosure	
1	Campbell MSX-20 Solar panel.	Tower	
1	Precipitation gage	Air: 8 ft.	
1	Vaisala HMP35C temp/relative humidity sensors in solar radiation shield	Tower: 4 ft.	
1	Licor LI200X pyranometer solar radiation sensors.	Tower: 10 ft.	
1	Met One wind speed & direction sensors	Tower: 10 ft.	
6	Fiberglass electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
6	Watermark electrical resistance type soil moisture sensors	Soil: 2, 4, 8, 20, 40, & 80 in	1990-1995
5	Vitel dielectric constant soil moisture/temperature sensors.	Soil: 2, 4, 8, 20, & 40 in	1995-present
6	Campbell 107B soil temperature sensors	Soil: 2, 4, 8, 20, 40, & 80 in	

Site Name: Wakulla
State: Florida
County: Jefferson

NSSL Pedon Descriptions
USDA - Natural Resources Conservation Service
Pedon NSSL Description
DATE Sampled: 08/31/1991

Soil Series: SND

Site Identification #: S92FL073001
Laboratory Information
Lab Pedon #: 92P0201   Source Lab Id: SSL

Location Information
Soil Survey Area #: 073
County Name: Leon
Location Description: Sec. 15, T. 2 S., R. 2 W.

Slope Characteristics Information
Slope: 0 percent

Type of Erosion: water erosion
Degree of Erosion: Class 1

Natural Drainage Class: Moderately well drained

Vegetative Information
Plant Name: longleaf pine and turkey, live and larual oaks

Described by: DL, RP

Notes: Parent Material: sandy and loamy marine sediments; global change pilot project, Apalachicola National Forest; the wavy boundary of the argillic at 80" makes the site Foxworth soils with Blanton soils as inclusions.

A--0 to 15 cm; dark brown (10YR 3/3) sand; weak fine granular structure; very friable; abrupt smooth boundary.

C1--15 to 41 cm; light yellowish brown (10YR 6/4) sand; single grain; loose; gradual wavy boundary.

C2--41 to 112 cm; 15 percent very pale brown (10YR 7/3) and light yellowish brown (10YR 6/4) sand; single grain; loose; clear smooth boundary.

C3--112 to 132 cm; very pale brown (10YR 8/2) and very pale brown (10YR 7/3) sand; few fine prominent yellow (10YR 7/8) mottles; single grain; loose; clear wavy boundary.

C4--132 to 157 cm; very pale brown (10YR 7/4) sand; many fine prominent strong brown (7.5YR 5/8) mottles; single grain; loose; gradual wavy boundary.

C5--157 to 203 cm; white (10YR 8/1) sand; few fine distinct very pale brown (10YR 7/4) mottles; single grain; loose; abrupt wavy boundary.

Bt--203 cm; very pale brown (10YR 7/4) sandy loam and loamy sand; many coarse distinct light gray (10YR 7/1) and few medium distinct brownish yellow (10YR 6/6) mottles; weak coarse angular blocky structure; friable.

APPENDIX D

GLOBAL CHANGE PILOT PROJECT

TO : Richard J. Gooby, State Conservationist, FNCO" 430-13-5
SCS, Bozeman, Montana
Ronnie L. Clark, State Conservationist,
SCS, Bismarck, North Dakota

Frank S. Dickson, J State Conservationist,
SCS, Casper, Wyoming
Duane L. Johnson, State Conservationist,
SCS, Lakewood, Colorado
Ray T. Margo, Jr State Conservationist,
SCS, Albuquerque,

We have selected 10 states in FY 92 as potential sites for further automation of the gathering of soil moisture and temperature data. We are installing 11 sites this fiscal year. We have contacted the state soil scientist in your state for a tentative agreement. We plan to install these sites between now and October 1992. This project is described in the enclosures. Please review these enclosures and let me know in writing as soon as possible, if you are willing to participate. Texas and Florida do not need to respond since they have sites that were installed in FY 91. Send a copy of your response to Dennis J. Lytle, National Coordinator for Soil Geography, SSIG Staff, NSSC, SCS, Lincoln, Nebraska. We will contact you with further details when we receive your response. We will provide each state with $4,000 in FY 92 only, to help pay the cost of establishing the site. our intent is to eventually have 2,000 sites collecting data across the United States. We have a 1993 budget initiative in support of this further automation.

If you have questions, please contact either Jon Werner, Resources Inventory Division, Washington, D.C., FTS 720-4530 or commercial 202-720-4530, or Dennis Lytle, National Coordinator for Soil Geography, National Soil Survey Center, Lincoln, Nebraska, FTS 541-5423 or commercial 402-437-5423.

W. ARNOLD
Soil Survey Division

GLO1BAL CHANGE PILOT PROJECT

(GCPP)

PROJECT PLAN

TABLE OF CONTENTS

GLOBAL CHANGE PILOT PROJECT

FY91 AND FY-92

PROJECT PLAN

INTRODUCTION:

The soil conservation service (SCS) has federal leadership for conducting soil surveys, undertaking basic soils research in support of soil survey and inventorying the status of the nation's private land resources. In keeping with this responsibility, two SCS divisions, Soils and Resource Inventory (RID) have established a global change research effort that is part of a larger USDA global change research program.

There is currently no national coordinated system to collect, interpret, and archive atmosphere and soil climate data for global change. Baseline information is needed for research. Appropriate near real time data would make it possible for accurate monitoring. Data needed includes air temperature, precipitation, solar radiation, wind, soil moisture, and soil temperature. A number of independent data collection efforts are underway but large gaps in coverage in inconsistencies in data occur.

PROJECT OBJECTIVE:

The Global Change Pilot Project will be carried out to demonstrate the feasibility of a national SCS remote data collection system for gathering the needed global research data. This data will be gathered from ten to twenty nationally distributed locations optimized with respect to geography, topography, climate, vegetative cover, soils, and major cropping patterns. Benchmark soils in Major Land Resource Areas will designate primary regions for location of the remote stations.

This pilot project will resolve some existing technical challenges associated with sensor design, sensor interfaces for remote data transmission and data management. The already field proven meteor-burst radio communications technique that is the backbone of the service's SNOTEL system will be applied to the rest of the continental U.S. during this project.

Data is currently being collected in small and uncoordinated manual or automated systems across our country that could support the global research effort. Another major goal of this pilot project will be to draw that data that is useful into a centralized database providing access to agency and non-agency users via telecommunications.

STATEMENT OF WORK

The Pilot Project will utilize from ten to twenty remote data collection sites located in the Midwest, East and South. These sites will be installed by the SCS. These remote sites will be outfitted with the standard SCS SNOTEL transceivers manufactured by the Meteor Communications Corporation (MCC), model MCC-550B (containing proprietary information in techniques and protocol). Most remote data collection sites in the pilot project will be located outside the range of the two SCS master stations in Boise, Idaho, and Ogden, Utah.

SCS will contract for meteor burst master station access services to be provided by one or more master stations covering the area of the pilot project for eighteen months. Specifications, detailed in, Section II. SYSTEM SPECIFICATIONS, addresses the characteristics required of the master station access services including the management of the collected data. The contractor shall furnish all labor, materials, equipment, facilities, power, and telecommunications arrangements in strict accordance with these specifications to provide meteor burst master station services, data management services, and attendant support for operation and maintenance.

NSSC and state Soils and Field Office staffs will provide support in locating sites, securing authorization agreements and in calibration and installation of the soil moisture and temperature sensing equipment.

1. PROJECT ADMINISTRATION:

PROGRAM DIRECTION:

SCS Resource Inventory Division (RID), Tommy A. George, Director
SCS Soils Division, Richard W. Arnold, Director

LEADERSHIP:

RID Project Leader - Salt Lake City Data Collection
Officer, Jon G. Werner (Nov 90-Sept 91).

SOILS Project Leader - NSSC, National Coordinator for Soils Geography, Dennis J. Lytle.

TECHNICAL SUPPORT:

WNTC, WSFS - SNOTEL technology
- Data base design and management
- Master Station services procurement

NSSC - Soils data collection/calibration
- Soils data management
- Site selection

STC, SSS, FO	- Site selection - Site.installation - Site agreement
DCO	- Site installation leadership - Site Maintenance

FUNDING:

SCS	FY 1991	FY 1992
SOILS	$350,000	$200,000
RID	$200,000	$100,000

PROJECT PLAN:

Completion of plan required in early stages of project.

II. SYSTEM SPECIFICATIONS:

A. PERFORMANCE

1. The master station service will be designed to obtain a performance rate of remote site response to each poll of not less that 95 percent when all remote sites are operating successfully as determined by SCS.
2. The master station service will be designed so that on average over a 24-hour period, 75 percent of the remote sites respond within the first 20 minutes of a poll.
3. Failure of a remote site to respond within the requirements of the performance specifications should only be a random occurrence (no consistent pattern) . Substandard performance in polling a remote site will require remote site remedial maintenance actions by SCS. Where consistent, substandard performance cannot be eliminated by routine remote site remedial actions by SCS, corrections at the master station(s) may be necessary and could include reconfiguration of the receiver antennas.
4. The data management transfer and management facilities will be designed to not introduce any errors into the data.
5. System performance will be monitored and reported monthly.
6. Any performance problem extending over two consecutive days unsolved will require remedial attention.

B. MASTER STATION/DATA CENTER IMPLEMENTATION

1. This item includes all time, materials, and other costs associated with the establishment/modification of a meteor burst master stations to be used for the collection of SCS data in the Midwest, East, and South. This includes:

a. Modify and tune receiver, antennas, transmitter, preamplifier, exciter, and crystals.
b. Modify MS computers and PCA boards (firmware) and software.
c. Design and implement data management and communications software for master stations and central facility.
d. Design and implement data management and communications software for master stations and central facility.
e. Site construction or modification and associated costs.
f. Obtain necessary FCC permits and other licenses as needed.

C. REMOTELY COLLECTED DATA:

Precipitation

- Reported to the nearest millimeter or 1/100 inch - Collected by an electronic weighing device
- Operable year around in normal temperature extremes
- Can be polled at 15-minute frequencies

Air Temperature

- Collected by shielded thermistor
- Sampled at 12 feet above ground surface
- Reported as CURRENT (at time of last update to the transceiver)
- Reported as a calculation of the previous 24 hours' data as:

  DAILY MAXIMUM
  DAILY MINIMUM
  DAILY AVERAGE
- Reported in degrees centigrade (C)

Solar Radiation

- Sampled at 12 feet height
- Daily readings accumulated to provide total incoming energy in terms of gram-calories per square centimeter

Wind Run

- Collected by cup type anemometer
- Sampled continuously at a 12 feet height
- Reported as a daily total of miles of wind run (to the nearest 10 miles)

Soil Temperature

- Collected by buried thermistor type sensors
- Sampled at various specified depths in the soil profile (2", 4", 8", 20", 40", 80")
- Reported in degrees centigrade to the nearest 1/10 degree

- Reported as latest previous 24 hours calculated data (DAILY MAXIMUM, MINIMUM and AVERAGE)

Soil Moisture

- Resistive style sensors (0-5 volts output DC) reporting DAILY MAX., MIN., and AVE.)
- Sampled at various specified depths in the soil profile (2", 4", 8", 20", 40", 80")
- Measuring moisture content over a range of saturated to negative 15.0 millibar pressure
- Calibrate specific soils to electronic readings over the range of moisture contents
- Reporting data in % by weight of moisture content.
- Be as impervious to Soil chemistry and interaction with sensor materials as practical, or be correctable with mathematics coefficients

D. EQUIPMENT AND SENSORS

1. MCC 550B transceiver data channel configuration (10Jun9l)

BATTERY			
PRECIPITATION	PULS 2		
AIR TEMPERATURE	DIR 1		
SOLAR RADIATION	DIR 2		
WIND RUN	DIR 10		
SOIL TEMPERATURE	DIR 3	1	STZI
SOIL TEMPERATURE	DIR 11	2	STZ2
SOIL TEMPERATURE	DIR 4	3	STZ3
SOIL TEMPERATURE	DIR 12	4	STZ4
SOIL TEMPERATURE	DIR 5	5	STZ5
SOIL TEMPERATURE	DIR 13	6	STZ6

AUX 1	SOIL	MOISTURE	LOW	1	SmLzl
AUX 2	SOIL	MOISTURE	LOW	2	SMLZ2
AUX 3	SOIL	MOISTURE	LOW	3	SMLZ3
AUX 4	SOIL	MOISTURE	LOW	4	SMLZ4
AUX 5	SOIL	MOISTURE	LOW	5	SMLZ5
AUX 6	SOIL	MOISTURE	LOW	6	SMLZ6
AUX 7	SOIL	MOISTURE	HIGH	1	SMHZI
AUX 8	SOIL	MOISTURE	HIGH	2	SMHZ2
AUX 9	SOIL	MOISTURE	HIGH	3	SMHZ3
AUX 10	SOIL	MOISTURE	HIGH	4	SMHZ4
AUX 11	SOIL	MOISTURE	HIGH	5	SMHZ5
AUX 12	SOIL	MOISTURE	HIGH	6	SMHZ6

REPORT GROUP DESIGNATION:

GROUP NUMBER 1

1	BATTERY		
2	PULS 2		
3	DIR	1	CURRENT AIR TEMPERATURE
4	DIR	2	SOLAR RADIATION
5	DIR	10	WIND RUN
6	DIR	1	MAX AIR TEMPERATURE
7	DIR	1	MIN
8	DIR	1	AVG
9	DIR	3	MAX STZ1
10	DIR	3	MIN STZ1
11	DIR	3	AVG STZI
12	DIR	11	MAX STZ2
13	DIR	11	MIN STZ2
14	DIR	11	AVG STZ2
15	DIR	4	MAX STZ3
16	DIR	4	MIN STZ3

GROUP NUMBER 2

1	DIR	4	AVG	STZ3
2	DIR	12	MAX	STZ4
3	DIR	12	MIN	STZ4
4	DIR	12	AVG	STZ4
5	DIR	5	MAX	STZ5
6	DIR	5	MIN	STZ5
7	DIR	5	AVG	STZ5
8	DIR	13	MAX	STZ6
9	DIR	13	MIN	STZ6
10	DIR	13	AVG	STZ6
11	AUX	1	MAX	SmLzl
12	AUX	1	MIN	SMLZL
13	AUX	1	AVG	SMLZI
14	AUX	2	MAX	SMLZ2
15	AUX	2	MIN	SMLZ2
16	AUX	2	AVG	SMLZ2

GROUP NUMBER 3

1	AUX	3	MAX	SMLZ3
2	AUX	3	MIN	SMLZ3
3	AUX	3	AVG	SMLZ3
4	AUX	4	MAX	SMLZ4
5	AUX	4	MIN	SMLZ4
6	AUX	4	AVG	SMLZ4

7	AUX	5	MAX	SMLZ5
8	AUX	5	MIN	SMLZ5
9	AUX	5	AVG	SMLZ5
10	AUX	6	MAX	SMLZ6
11	AUX	6	MIN	SMLZ6
12	AUX	6	AVG	SMLZ6
13	AUX	7	MAX	SMHZI
14	AUX	'7	MIN	SMHZL
15	AUX	7	AVG	SMHZL
16	AUX	8	MAX	SMHZ2

GROUP NUMBER 4

1	AUX	8	MIN	SMHZ2
2	AUX	8	AVG	SMHZ2
3	AUX	9	MAX	SMHZ3
4	AUX	9	MIN	SMHZ3
5	AUX	9	AVG	SMHZ3
6	AUX	10	MAX	SMHZ4
7	AUX	10	MIN	SMHZ4
8	AUX	10	AVG	SMHZ4
9	AUX	11	MAX	SMHZ5
10	AUX	11	MIN	SMHZ5
11	AUX	11	AVG	SMHZ5
12	AUX	12	MAX	SMHZ6
13	AUX	12	MIN	SMHZ6
14	AUX	12	AVG	SMHZ6
15				
16				

2. MCC-550B transceiver and sensor/interfacing

One site address per location.

64 channels possible - 62 committed.

E. METEORBURST COMMUNICATIONS:

1. Master Station Services - Specifications

a. Geographical coverage

The master station services will be located and configured to function in accordance with the system performance requir6ments (section II A) within the project area bounded by latitudes 27 degrees north and 47 degrees north and longitudes 67 degrees west and 103 degrees west.

Master stations will not be located within the states of Alabama, California, or Florida, or within the US/Canadian border zone.

b. Transmit frequency, power, and subordinate authorization. The Master station (or stations) will transmit on the SCS authorized SNOTEL frequency of 40.53OMHz at a power not exceeding 1600 watts. All necessary actions and required applications will be made to the Federal Communications Commission (FCC),, in coordination with IRAC for the utilization of the current SNOTEL master station transmit frequency during the 18-month pilot project period. All the operating and performance requirements of the FCC will be met.

c. Receive Frequency
The transceivers at the remote data collection sites will transmit at 41.530 MHz with nominal output power of 100 watts. The master station receivers will be tuned and antennas configured accordingly.

d.Meteor Burst Communication Characteristics
The master station services provided must communicate with the standard SNOTEL transceiver MCC-550B as follows:

Modulation type....... Phase Shift Keylock (PSK)
Data throughput....... 4000 bits per second Harmonic/Spurious attenuation.. 6OdB below full power

e. Master Stations Service Operational Requirements

1.The master station service will be designed to accommodate from 1 to 20 pilot remote data collection sites each utilizing 64 transceiver channels in the standard SNOTEL format.

2.The master station service will poll the remote sites until all sites have responded or for 60 continuous -minutes. A poll will be conducted at least once every 6 hours, but not more than 6 polls will be conducted in a 6-hour period.

One of the polls will begin at midnight, Central Standard Time. A time synchronization poll will be conducted once in each 24 hour period to set the remote sites' internal clock and to collect data for the 8 standard SNOTEL Remote Maintenance Parameters (RMP).

3.Text messages received from remote sites will be transferred to the Data Center with the next scheduled data'transfer.

4.The master station (s) will be equipped with adequate environmental sensors to allow the contractor to monitor operations remotely while the station functions in an unattended mode.

F. DATA MANAGEMENT

1. Remote Site Data Characteristics

All remote site data received by the master stations(s) will be maintained as identified by the Report Group Definition for the remote site. SCS will designate the order in which channels report.

2. Data Management at the Master Station(s)
Data management operations at the master stations (s) will be accomplished on an IBM-AT type or similar personal computer supported by an un-interruptable power source or auxiliary backup power. The transfer of the data collected in each poll to the Active File at the Data Center will be completed within 30 minutes of the completion of the poll. Data transfer must be accomplished using an Error Checking Protocol such as Microcom Networking Protocol (MNP) or similar procedure to ensure data integrity. The Report Group Definition specified in II.FL. (above) will be maintained.

3. Data Management at the Data Center

a. Data and text messages will be available from the Data Center Active File in a dial-up computer access mode within 10 minutes of receipt of the data or text message from the master station(s).

4. Data management at the field level

a. Standard SNOTEL climatological sensor data, wind, solar radiation, soil moisture and soil temperatures will be validated daily by the NSSC. DCO's responsible for remote site maintenance will also monitor this information to enhance maintenance needs awareness.

b. Pencil editing should be accomplished weekly by the NSSC.

c. Edited values should be uploaded on a weekly basis to the CFS/ODB.

d. Annual final editing and uploading to the data base will be done by December lst of each year.

5. Data availability

a. Current and archived data will be available to SCS and other agency users via computer modem and telecommunications.

b. Current and archived data will be available to outside users through the CFS system.

B. SITE SELECTION CRITERIA: May 22, 1991

1. ADMINISTRATIVE CONCERNS
   a. Landowner should be sympathetic to program goals.
      1. First priority - federally managed land.
         Second priority - state land.
         Third priority - private land.
      2. Must enter a minimum 30 year agreement with SCS.

b. The site location must be approved by a qualified cultural resources specialist and appropriate documentation filed with the site agreement for the site.

c. Vehicle access for installation and periodic maintenance must be assured.

d. Fencing to be allowed.

e. Located away from public view.

2. CONSISTENT WITH AGENCY DATA COLLECTION NEEDS AND MOST EFFECTIVE IN DEMONSTRATING AGENCY OBJECTIVE OF DROUGHT AND GLOBAL CRANGE MONITORING.

a. Evaluate existing data network to prevent duplication and to maximize opportunities for collocation with those sites if beneficial (CDAF and other sources).
b. Consider Long Term Ecological Research Sites (LTERS) or other long term monitoring project such as Forest Service Remote Automated Weather Station (RAWS) sites.
c. Consider collocation to existing data collection and research efforts, i.e., Agricultural Research Service and Agricultural Experiment Stations.
d. Consider MLRA coverage.
e. Consider benchmark soils coverage and mapping units of large extent.
f. Soil should be very deep (>60") well drained and preferably medium textured.
g. Landscape position should be typical of the soil map unit.
h. Management status to be stable in a grass vegetation.
i. Within reasonable distance (200 ft) of special/non-standard sampling sites, i.e., soil erosion or other surface soil management types.

3. TECHNICAL CONSIDERATIONS

a. Within 1100 miles of the meteor burst master station.
b. Meets physical requirements for accurate and representative sampling of the data parameters (precipitation, air temperature, wind run, solar radiation, soil moisture and soil temperature, and other parameters).
c. Ground surface slopes less than 5%.
d. Minimum 500 yds from utility lines/stations, and other sources of RF (radio frequency interference) generation.
e. Firm foundation materials for instrument foundations and antenna tower bases.
f. Deep (41) soil for adequate electrical grounding.
g. Technical soils ground truthing (manual data collection) support is available.

C. AUTHORIZING AGREEMENTS:

A document, formalized by the signatures of the SCS State Conservationist and the landowner/manager must be obtained to assure the secure and continued data collection at the master and the remote sites. These arrangements need to be formalized before the installation work can be performed. This responsibility lies with the State Soil Scientist and State Conservationist.

This is a typical one page document that can be applied in most instances with private landowners. Federal or state owned/managed properties may require use of that agencies approval procedures.

LETTER FORMAT

DATE

OWNER

STREET ADDRESS
CITY* USA

DEAR I

THIS LETTER WILL SERVE AS A RECORD OF OUR AGREEMENT BETWEEN ___________________________ AND THE U.S. SOIL CONSERVATION SERVICE AUTHORIZING THE USE OF (SITE NAME)_______________________________________, It (LEGAL LOCATION) ____(APPROX. SIZE IN ACRES)________________ FOR THE PURPOSE OF AUTOMATED CLIMATOLOGICAL DATA COLLECTION. THIS IS BASED UPON OUR MUTUAL INTEREST IN COLLECTION OF DATA TO SUPPORT WATER RESOURCE MONITORING, SOILS DEVELOPMENT RESEARCH, AND OTHER DATA NEEDED TO MONITOR AND PERFORM RESEARCH OF GLOBAL CLIMATOLOGICAL STABILITY.

YOUR SIGNATURE ATTESTS THAT ____WILL:

-ALLOW SCS TO INSTALL, MAINTAIN, AND OPERATE THIS DATA COLLECTION SITE FOR A MINIMUM OF 30 YEARS. -PROVIDE PROTECTION TO THE SITE TO PRESERVE ITS DATA COLLECTION C CTERISTICS.

-ALLOW ACCESS TO THIS SITE BY SCS TECHNICIANS AS REQUIRED TO MAINTAIN SITE OPERATION.

-PRESERVE THE EXISTING VEGETATIVE COVER OF GRASSES, SHRUBS, TREES AND ETC. EXCEPT FOR MANAGEMENT ACTIVITIES THAT ASSURE THE HEALTH AND VIABILITY OF THE NATURAL SPECIES.

-ADVISE SCS IMMEDIATELY OF ANY CHANGES IN YOUR LAND OWNERSHIP/MANAGEMENT STATUS TRAT WOULD AFFECT YOUR ABILITY TO HONOR THIS AGREEMENT.

-PROVIDE INFORMATION ON A LOCAL CONTACT PERSON FOR COORDINATION OF ACCESS TO THE DATA SITE.

SOIL CONSERVATION SERVICE AGREES TO:

-COORDINATE ACCESS NEEDS WITH THE LANDOWNER CONTACT PERSON.

-INSTALL AND MAINTAIN ALL EQUIPMENT AND PRESERVE THE SITE IN A PROFESSIONAL STATE OF WORKMANSHIP, REPAIR AND CLEANLINESS.

-AVOID UNNECESSARY DISTURBANCE TO ROADS, TRAILS, FIELDS ETC IN ACCESSING THE SITE, AND TO REPAIR/RESTORE TO CUSTOMERS SATISFACTION ANY UNACCEPTABLE ACCESS EFFECTS FROM MAINTENANCE VEHICLES.

-REMOVE EQUIPMENT FROM LOCATION IF REQUIRED UPON 60 DAYS WRITTEN NOTICE.

IT IS UNDERSTOOD THAT EITHER MAY CANCEL THIS AGREEMENT WITH 30 DAYS WRITTEN NOTIFICATION.

THANK YOU FOR YOUR PARTICIPATION IN THIS GLOBAL CHANGE PILOT PROJECT. YOUR SUPPORT IS PART OF A VERY CRITICAL DATA COLLECTION EFFORT NECESSARY TO BETTER UNDERSTAND SOILS AND CLIMATE INTERRELATIONSHIPS AND WHAT IT IS THAT CHANGES GLOBAL CONDITIONS.

________________________	________________________	____________
STATE CONSERVATIONIST	LANDOWNER	DATE

CC:
SCS STATE ADMINISTRATIVE Officer
STATE GLOBAL CHANGE PROJECT MANAGER

ENC:
DESCRIPTIVE INFORMATION OF SITE AND ITS EQUIPMENT
LITERATURE ON PILOT PROJECT.

IV. PROCUREMENT:

MASTER STATION SERVICES:

The snow survey and water supply forecasting staff (WSFS) at the WNTC, SCS will utilize its unique expertise that has been gained from the fourteen years of procurement and operation of the SNOTEL meteor burst master stations. This staff will prepare the necessary specifications and carry out the procurement of leased or SCS owned services to complete the pilot project network of ten remote stations in FY-91 and another ten stations in FY-92.

The target date for operation of the new service is set for August 1, 1991.

REMOTE SITES

RID Pilot Project Leader will develop the specifications for data to be collected, the specifications for sensing equipment and other site components to complete a remote station tailored for installation in all climates, locations in continental U.S. and that is compatible with the current meteor burst radio communication technology used in the SNOTEL system..

This staff leader will also prepare the necessary procurement documents and oversee the obtaining and delivery of the necessary site components delivered either to the Salt Lake City, UT Data Collection Office (DCO) , or the appropriate Field Office locations near the selected remote sites.

Procurement of components sufficient for install and maintenance of ten units will be underway during May 1991 with delivery at field locations expected not later than August 1, 1991.

OUTSIDE DATA

The WSFS, WNTC Climatic Data Access Facility, will be tasked to investigate the availability of existing data and databases/systems that meet the needs of Global Change monitoring and research. This staff will also design the necessary modifications to the existing SNOTEL Centralized Forecast System.

It is the goal in this part of the pilot project to pull together into one database all useable data in addition to the new Global Change data that will be collected. Outside user access to the database will be very important.

Procurement will involve software development, purchases of data management services, cooperative agreements with other data collectors, and possibly computer hardware equipment purchase.

V. SENSOR CALIBRATION AND ALGORITHM DEVELOPMENT:

SOIL MOISTURE DATA

Calibration of the electronic soil moisture sensors will be necessary for the particular soil they will be installed in. Since the units utilize a measurement of changing resistance with varying water content, their exact performance varies somewhat with each soil and its chemical make-up.

A. The following procedure is recommended, and will be implemented by the National Soil Survey Center (NSSC) and the state Soil Scientists (.SSSs).

1 . A detailed soil survey will be made at the site selected for the sensor installation. This will include a pedon description.

2. A soils characterization description will be made at the standard depths of placement of the two moisture and one temperature sensors unless bedrock is encountered before the maximum depth of 80 inches.

3. Samples from the specified standard depths will each then be calibrated as follows:

a. Soil sample will be oven dried and weight recorded.

c. A minimum of six different moisture content percentages by weight ie: 5%, 10%, 15%, 20%, 25% & 30%.

d. The sensors, one of each type will be sealed into an airtight container with each of the moistened soil samples in full content with the sensing surfaces of the units.

e. The sensors units will be connected through the appropriate interfacing to the MCC 550B transceiver and SNOTEL test terminal. Readings of voltage output will be taken and recorded several times daily until a stable (consistent) reading is achieved indicating a condition of equilibrium between the sensor and the soil.

f. Records will be kept of each soil and each sensor for each site.

g. Data pairs are then selected, and analyzed to determine an equation to interpret the 0.000 volts -5.000 volts output of the transceiver into t water content by weight. Review statistical indicators of the relationship to verify its acceptability of performance.

h. This equation then becomes the algorithm equation to be inserted into the CFS database and will automatically convert all incoming data reports form the remote sites into % Moisture by Weight, for that channel at that site, and for the Coleman (dry soil) sensor and also for the Watermark (wet soil) sensor.

h. Additional repetitions of a similar procedure in the operational state of the site will continue to improve the accuracy of the conversion equation with more pairs of data to define the relationship.

B. Alternate Method:

1. Perform the soils characterization for the site.
2. Install the automated sensing equipment and begin gathering data.
3. Perform gravimetric analysis of the soils at periodic times during the year to cover the range of moisture contents possible. 4. Develop the conversion algorithms from the pairs of data as the record grows.

SOIL TEMPERATURE DATA

PRECIPITATION DATA

AIR TEMPERATORE DATA

WIND RUN DATA

SOLAR RADIATION DATA

VI. SYSTEM INSTALLATION:

MASTER STATION SERVICES:

Will be done by contractor. Negotiations consummated with Meteor Communications Corporation Inc. Tipton, Missouri master station will be ready for testing by remote site data transmission by July 15th, 1991. Master station will be ready for full operation on August 1, 1991.

Pre-performance period testing will be accomplished by monitoring the reporting of the 4K modified 550B transceiver through the leased master station from several locations including Denver Colorado DCO shop and the Salt Lake City, Utah DCO shop. The Minnesota SNOTEL site may be useful as well with the proper modification of the transceiver.

REMOTE SITES:

GLOBAL CHANGE INSTALLATION SCHEDULE / CREWS / TASKS

STATE	SITE PREPARATION CREW (install footings, instrument shelter, antenna tower bases, precipitation gage, soil moist./temp. fenced location and all trenches for completed for conduit) Crew make up: Supervisor Hydrologic Tech. Hydrologic Tech. Hydrologic Aide Field Office (local) Field Office (local)	SITE COMPLETION CREW (install all towers electronics, wiring, sensors, solar panels, antennas,, power supplies, and precipitation gage electronics, and test all equipment for transmission to master station and for data quality) Crew make up: Supervisor Electronics Tech. Electronics Tech. Soils Represent. Soils Represent. Field Office (local)
NEBRASKA	AUG 5- 8	AUG 5- 8
WISCONSIN	AUG 9-10	AUG 19-21
ILLINOIS	AUG 12-13	AUG 22-23
KENTUCKY	AUG 14-15	AUG 25-26
NEW YORK	AUG 17-18	AUG 28-29
MARYLAND	AUG 19-20	AUG 31- 1
NORTH CAROL.	AUG 21-22	SEP 3- 4
FLORIDA	AUG 4-25	SEP 6- 7
MISSISSIPPI	AUG 26-27	SEP 9-10
TEXAS	AUG 29-30	SEP 13-14

VII. SYSTEM OPERATION:

DATA MANAGEMENT:

COMMUNICATIONS NETWORK MAINTENANCE:

REMOTE SITE MAINTENANCE

APPENDIX E

SOIL MOISTURE/SOIL TEMPERATURE PILOT PROJECT OPERATIONAL IMPLEMENTATION PLAN

Foreword

This report, Soil Moisture /Soil Temperature Project, Operational Implementation Plan, was developed by scientists from the National Soil Survey Center, Lincoln, Nebraska and The National Water and Climate Center, Portland, Oregon. The project is technically administered by the NRCS Soil Temperature and Moisture Team. A complete list of Team members are listed in Appendix B.

Primary authors of this document include Donald J. Huffman, Ron F.Paetzold, Garry L. Schaefer, and Ronald D. Yeck . Other Soil Temperature and Moisture Team members provided editorial suggestions for the final report.

The cover photo shows the Pilot Project installation at the Rogers Farm near Lincoln, Nebraska. The photography is by Henry Mount.

For further information about this project, contact Garry L. Schaefer, Project Leader, at the National Water and Climate Center, Portland, Oregon.

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2.
National Soil Survey Center, USDA-NRCS, Rm. 152 Federal Building, Lincoln, NE 68508

Soil Moisture / Soil Temperature Pilot Project
Operational Implementation Plan
(A Long-Range Planning Strategy)

Soil Moisture / Soil Temperature Pilot Project
Operational Implementation Plan
(A Long-Range Planning Strategy)

Executive Summary

The Soil Moisture/Soil Temperature Pilot Project (SM/ST PP) was initiated as a ten-year pilot in 1990 jointly by the Resource Inventory Division and the Soils Division of the Natural Resources Conservation Service (then the SCS) to provide data for modeling, agency draught prediction and water management, and other natural resource assessments. The project objectives were to test the feasibility of a remote climate data collection network including communications, sensors, sensor interfaces, and data management. Twenty-one sites in nineteen states were established in 1991 and 1992. Precipitation, air and soil temperature, solar radiation, relative humidity, wind, and soil moisture sensors were installed. Data are transmitted from the twenty-one remote stations to master stations using meteor-burst technology. From master stations, data are transmitted by telephone to the central computer in Portland, Oregon.

The pilot has been a success and meteor-burst communications has successfully transmitted data to master stations. The pilot has enabled us to identify and overcome many problems inherent in sophisticated and complex climatic networks that integrate a variety of sensors, communications systems, and sensor communications interfaces. Above-ground sensors have generally performed successfully. Some precipitation gauges initially gave erroneous readings, primarily in the winter because the pumping system failed to properly refill the sensing cylinder. Those gauges have been modified and now provide quality data even in cold weather. The other major challenge has been with the initially installed resistance type soil moisture sensors. They are very difficult to calibrate and seem not to work well with the electronics interface. Those sensors are now being replaced by ones that have a demonstrated reliability and are much easier to calibrate. Review and editing of data remains a very large job and is being addressed both by manual and automated techniques. Less difficult problems and solutions are discussed in the detailed report.

Additional lessons learned include the need to calibrate soil moisture sensors prior to installation, providing extensive grounding for all equipment, and more thorough planning for data management, quality control, and editing.

The demand for climatic data continues to increase for agricultural and environmental applications. A recent congressional termination of support for Agricultural Weather Service Centers in favor of privatization exemplifies a major concern because agriculturists and officials at all levels of government are uncertain that they will have the necessary climatic information required for sound management and emergency action decisions.

Continuation of this pilot project is needed resolve remaining problems, including replacement of all moisture sensors.

Four future options for the SM/ST PP include (1) implementation of a national soil moisture-soil temperature network that will meet the agency and public needs for climatic data, (2) continuation of the current operational level, (3) transfer of ownership to universities or other government agencies and, (4) termination of the pilot project with removal and disposal of all remote site equipment. In light of the increasing public

need for climatic data and the ability and obligation of the NRCS to provide it, implementation of a national network (Option 1) would be the most prudent outgrowth of the experience gained from this pilot project. The proposed Soil Climatic Analysis Network (SCAN), outlined in Appendix C, is an example of an operational outgrowth of this pilot project. Option two could serve as a transition posture until funding and plans are approved for an expanded network. Option four is seen as an extreme measure, to be chosen only in the event of a total change of USDA or NRCS national priorities. Option three would be a less costly, less severe option than option four in the event of de-emphasis of agency inventory and monitoring activities.

Subject to Agency NRI and RCA programs and such national needs as would come from the Office of Science and Technology Programs or the Committee on Environment and Natural Resources, the current priorities for additional climatic monitoring sites appear to be those that are listed below.

* Areas of intensely managed agriculture
* Areas prone to drought
* Rangelands and dryland areas
* Forested areas

Soil Moisture / Soil Temperature Pilot Project
Operational Implementation Plan
(A Long-Range Planning Strategy)

A. Description of the Original Project

Overview

This project was proposed in 1990 to address the lack of consistent soil climate data to meet growing demands for assessment of global climate change and to make better resource management decisions (USDA-SCS, 1991). The Resources Inventory Division (RID) and the Soils Division of the NRCS (then SCS) worked together to form a partnership to address this need.

Installation of Soil Moisture/Soil Temperature Pilot Project (SM/ST PP) sites began in 1991 and was completed the following year. There are 21 sites in 19 states using meteor burst communication technology as a way to obtain near real-time data (Figure 1).

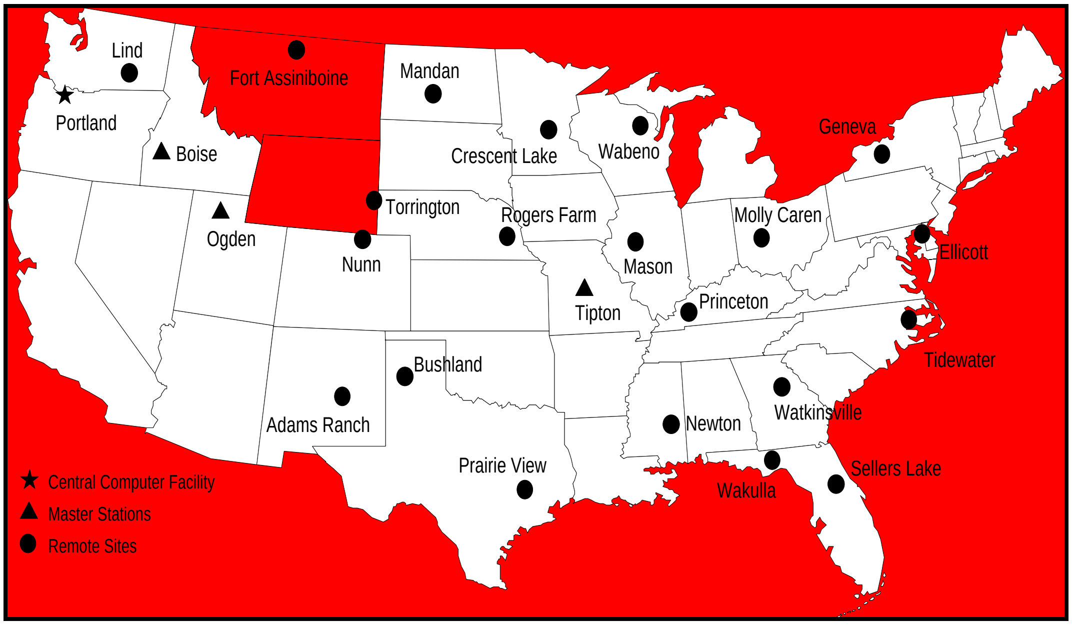

Figure I

Data from the remote sites are transmitted to one of three master stations several times each day. Master stations forward that data via telephone links to the Central Computer Facility at the NRCS, Water and Climate Center (WCC) in Portland, Oregon. The information is processed, stored, and made available for access by users.

Soil Moisture/Soil Temperature Pilot Project Implementation Plan

The SM/ST remote sites are designed to provide near real-time data from a variety of sensors. The aboveground sensors provide the information required for climate analysis and evapotranspiration (ET) calculations. The below ground sensors provide soil temperature and soil moisture at six depths to 80 inches. Modifications and replacements for these initial installation sensors are discussed in sections B and C of this report.

Time-frame

This pilot project was conceived as a 10-year project. Tom Calhoun, Soil Survey Division Program Manager, reaffirmed that time-frame at the first meeting of the Soil Moisture and Temperature Team held in Lincoln, Nebraska June 23-24, 1994 (USDA-SCS, Aug., 1994).

Objectives

The Soil Moisture/Soil Temperature Pilot Project (SM/ST PP), formerly called the Global Climate Change Pilot Project, initial and current objectives are:

· Demonstrate the feasibility of a national, NRCS remote, automated data collection system for gathering the required soil/climate resource information.

· Resolve existing technical challenges associated with site installation, sensor design, sensor interfaces, and data management concerns.

· Assess existing networks to determine what types of soil/climate information is available and if it is accessible.

· Make the data available to a variety of users.

B. Project History and Implementation

People involved

Jon Werner represented the NRCS Resource Inventory Division and Tom Calhoun represented the NRCS Soils Division for the initial project proposal and development phases. Jon Werner was overall site installation coordinator for the first year (1991). Don Huffman was the installation team leader. Otto Baumer, National Soil Survey Laboratory (NSSL), was coordinator for the soils instrumentation, design, and scheduling. Richard Pullman, NSSL, traveled to the first eleven sites (1991) to sample the project soils for laboratory characterization and to assist Don Huffman with installation of the soil moisture and temperature sensors. Otto Baumer installed soil moisture and temperature sensors at the remaining ten sites in 1992 and Don Huffman's crew completed the site installation. The 1991 and 1992 installations were primarily in the eastern and western U.S., respectively. Site characterization, soil descriptions, and laboratory characterization data were completed for the representative soil pedons at each of the twenty-one sites.

During the second project year (1992) Dennis Lytle represented the Soils Division and Garry Schaefer became involved from the NRCS West National Technical Center. Otto Baumer retired in 1994 and was not involved with the pilot project after that year. John Kimble, Soils Division Global Change Projects Manager, became involved because the project was funded through global change monies. Initial installation costs are shown in Appendix A.

In 1994 a Soil Temperature and Moisture Team was formed to serve as an umbrella management group to coordinate the Global Change Pilot Project and related soil moisture and temperature projects. The team also functions to share experiences from one project to the other. The Global Change Pilot Project was redesignated as the Sol] Moisture/Soil Temperature Pilot Project (SM/ST PP) and came under the management of the team along with the Wisconsin Dense Till Project and the Virgin Islands project. Tom Calhoun was designated as team sponsor, Ron Yeck, team leader, and Jon Werner, Garry Schaefer, Ron Paetzold, Tom Gable, Henry Mount, and Ellis Knox as other team members. Garry Schaefer remained the project leader for the SM/ST Pilot Project. In 1995, Ellis Knox retired and Tom Gable left NRCS. Team members added were Jon Vrana, Don Huffman, and Denice Schilling (Appendix B shows the current team membership).

Instruments and Installations-Description and Difficulties Encountered

Each remote site consisted of a meteor-burst data transmission system and associated NovaLynx electronics for data collection and sensor interface. Power was supplied by 12-V batteries charged from solar panels. Batteries did not maintain sufficient charge initially, so additional solar panels were added.

Above-ground sensors consisted of an ETI weighing precipitation gage, a LiCor pyrometer for solar radiation, a wind speed sensor for wind run, a relative humidity sensor, and a thermistor type air temperature sensor for current, daily average, daily maximum, and daily minimum air temperature determination.

The ETI precipitation gauges contain antifreeze for winter operation. A small pump is used to transfer antifreeze from a reservoir to the gauge cylinder. Problems with the gauges resulted from pump failure, which was attributed to a small amount of oil present in some antifreeze and high winter fluid viscosity. It is also extremely sensitive to electrical discharge. Several improvements have been made to this gauge to increase overall reliability, including installation of more heavy duty pumps and an improved grounding system.

Soil Moisture/Soil Temperature Pilot Project Implementation Plan

Soil moisture and temperature sensors were installed in different configurations in 1991 and 1992. The 1991 installation was in a circular (spider) design illustrated on page 15 of the Global Change Pilot Project Plan (USDA-SCS, 1991). Because of concerns that moisture and temperature might be conducted along the PVC sensor holders in the spider design, a stack design was used in 1992. In the stack configuration, the three sensors (Colman, Watermark, and temperature thermistor) were placed side by side at each depth and sensors at each depth were separated by tamped soil. The entire installation was enclosed in a wire cage to prevent rodent damage. "Coleman" and Watermark electrical resistance type soil moisture sensors produce a voltage that must be converted to soil moisture tension through calibration. The ranges within which these sensors are sensitive are shown in Table 1. The initial thermisters were constructed at the Water and Climate Center. Problems have been encountered with failure of the soil temperature sensors. These are being replaced, as needed, with commercial sensors.

The soil moisture sensors were not calibrated before installation. Calibration of these sensors is a time consuming process. From the start, problems with these sensors were apparent. The problems have been attributed variously to lack of calibration and individual variation among sensors, to malfunctioning sensors, to incorrect electrical wiring of the sensor package, to electrode polarization of the sensors due to the signal used to query the sensors. An attempt was made to field calibrate the soil moisture sensors in 1994 and 1995. The effort was unsuccessful for several reasons including (1) individual sensor variation, (2) local soil variability (the soil samples collected for sensor calibration were from a slightly different location than the sensors and the soil samples taken for soil bulk density and soil water retention characteristic were from another slightly different location), (3) normal errors in sample processing, measurement, and sensor readings, (4) small number of gravimetric soil samples collected at each site, (5) the sensor sensitivity to temperature, and (6) time differences between sensor readings and gravimetric soil sampling.

Starting in the summer of 1996, the "Coleman" and Watermark soil moisture sensors are being replaced with Vitel soil moisture sensors. The Vitel sensors measure the soil complex dielectric constant. The output of these sensors is calibrated with volumetric soil water content. These sensors also contain a thermistor for soil temperature determination.

In 1995 lightning struck the site at Sellers Lake, Florida, destroying most of the instrumentation. This site has been repaired.

C. Current Status

Accomplishments

Twenty-one sites, described above, were installed and have been maintained since installation by annual and "as-needed" maintenance. A maintenance program has been established whereby each site is visited yearly and routine maintenance is performed. During these site visits, any upgrades and sensor replacements are made.

Problems with sensor performance have been identified, isolated, and, for the most part, resolved. Individual 'bad' sensors have been replaced. Sensor selection has been refined such that most problems with sensor performance and interface with the data collection instrumentation have been resolved.

Above ground sensors have generally performed well. Problems with the precipitation gauges, discussed in the previous section, have been identified and corrected. The cloth wind baffles on the precipitation gauges were replaced with more durable plastic baffles. In 1996, a new interface card was designed and installed to allow remote commands to be sent to cycle the gauge power and bring it back to an operational condition after a fault occurrence.

Below-ground sensor installation techniques have been refined, changing from a "spider" type installation, in which each sensor was placed into a separate hole, to a "stack" type installation in which all sensors are placed into the same hole. As discussed earlier, the change was made because of concerns that water might follow the PVC sensor holders in the "spider" design and the PVC might alter the soil temperature. While both techniques proved acceptable (Yeck, 1995), the "stack" type is easier to install but sensors are easier to replace with the “spider" type installation.

"Coleman" and Watermark soil moisture sensors are difficult to calibrate and, in addition, apparently have problems interfacing with the data collection instrumentation. These soil moisture sensors are being replaced with Vitel combination moisture and temperature sensors. The "Coleman" and Watermark sensors are based on electrical resistance and are best calibrated with soil moisture tension. They were not calibrated before installation and many of the soil moisture measurement problems result from this. The Vitel sensors measure the complex dielectric constant to determine volumetric soil water content and electrical conductivity. Each sensor also contains a thermistor for soil temperature measurement. These sensors are easier to calibrate than the "Coleman" and Watermark sensors.

Data are downloaded directly from the individual sites to the computers at Portland via the master stations on a daily basis. The raw data are then transformed using appropriate calibration curves and grouped according to a specified format. Some problems still exist with calibration and formatting. Some data quality algorithms have been developed to check for inconsistencies and malfunctioning sensors, while some data are checked by hand. The project has resulted in the production of several publications and presentations. A list of these may be found in the Appendix D.

Lessons learned

Soil moisture sensors need to be calibrated before installation. It is very difficult, time consuming and expensive to calibrate soil moistures after installation. In addition, the quality of a lab-determined calibration curve is much higher than that of one determined in the field. "Coleman" and Watermark sensors are difficult and time consuming to calibrate. They are sensitive to soil temperature and chemistry, which complicates the calibration.

Lightning is a hazard to the electronics and great care must be given to ensure grounding of all equipment. The ETI precipitation gage has its own grounding system to prevent lightning from damaging the weighing mechanism. Although the electronics at each site have been well grounded, protection from a direct strike, which will damage the equipment, cannot be provided.

Rodents can be a problem if allowed to gain access to the PVC pipe that the soil temperature and soil moisture sensor leads are routed through from the sensors to the instrument shelter. Several sites sustained major damage to the soil temperature and soil moisture wiring when field mice gained access to the outside soil NEMA enclosure.

Data management is a larger portion of the project than anticipated. To detect sensor problems, rodent damage, etc., constant quality control and editing is necessary to maintain reliable data and detect the need for field maintenance. Better understanding of the type of data that are being collected and how to use it has resulted in wholesale changes in the collection of some parameters. For example, in the early stages of the project, it was believed that collecting daily maximum, minimum, and average soil moisture values were important, but upon study of the data structure, it became apparent that there was no way to convert the data to a meaningful value, due to the lack of soil temperature correction values obtained at the time of the soil moisture readings. These types of understandings are very helpful in designing a fully implementable system, but are time consuming to handle from a data management standpoint. Beginning in 1995, Denice Schilling has been monitoring and editing the SM/ST data and has improved the data quality greatly.

Current needs/uses/demands

Many diverse groups, including those engaged in environmental modeling, draught prediction, water management, and other natural assessments, have expressed a strong need for the type of data the pilot project is collecting. Some of these groups want to model or document global climate change. Other groups are interested in using data to verify and/or calibrate their climate, soil moisture, water quality, or other models. These models attempt to describe and predict conditions of areas ranging from small local fields to watersheds to global models. Other uses of the information include drought assessment and monitoring, irrigation water management, water reservoir management, calibration and verification of remote sensing instrumentation, soil classification, explaining animal behavior such as snake hibernation, etc.

On April 1, 1996, the NOAA National Weather Service discontinued its Agriculture Weather Program. USDA is a principle user of meteorological data as weather and climate impact all aspects of life within the agricultural environment. Comprehensive soil climate information is required for natural resource conservation and assessment, including such USDA programs as Highly Erodable Land Conservation, Wind Erosion Pilot, On-farm research (Swampbuster), Wetlands MOA as well as USDA research programs such as Rangeland research, Water quality research, and Agricultural research. An initiative has been put forward for the USDA to administer the Agricultural Weather Program. An overview of that initiative and its importance is given in Appendix F. That appendix also provides information on the Congressional termination to privatization of the Agricultural Weather Service Centers (AWSC).

Meeting Pilot Project Objectives

1. Demonstrate the feasibility of a national, NRCS remote, automated data collection system for gathering the required soil/climate resource information. The feasibility of a national NRCS remote data collection system has been demonstrated by the successful transmission of data from remote sites to the central computer facility.

2. Resolve existing technical challenges associated with site installation, sensor design, sensor interfaces, and data management concerns. Many of the technical problems have been identified and resolved such as increasing the number solar panels to provide adequate battery recharge, replacement of pumps in the precipitation gauges, and installing integrated soil moisture and soil temperature sensors. Some sensor interface problems are still being investigated, and sensors of a new design are being installed because of calibration difficulties with the initial sensors.

3. Assess existing networks to determine what types of soil/climate information is available and if it is accessible. The collection of scattered data from small projects to a centralized database is being addressed, but much remains to be done before this objective is met. A project was completed in 1992 to locate existing networks and identify what was being collected in each.

4. Make the data available to a variety of users. Technical challenges involving data management have not all been resolved. Data access by users needs to be improved. Data are available to a limited number of users but not yet to the extent envisioned by the objectives, much because of work yet to be done on sensor calibration. Many data are not yet of the quality required for widespread distribution but are nearly so.

5. New objectives include working with other organizations and operating data collection networks to link data so their data and ours can be accessed from a single source.

D. Future of the Program

Carrying pilot project to completion

Remaining work

Replace the "Coleman" and Watermark soil moisture sensors with Vitel soil moisture sensors. Test the Vitel sensors as to accuracy, precision, and reliability.

Improve data management. Organize the processed data to be user friendly and easy to access. Have the data available over the internet as are the SNOTEL data. Incorporate calibration curves into the data processing procedure. Improve the data quality package to evaluate the quality of the data and spot malfunctioning sensors. Develop a format and order for imputing data into the database computer from various other NRCS outside projects.

Put together some data packages to demonstrate the capabilities of the project. This will also help us evaluate the user friendliness and ease of access of the data. Put out more publications and presentations to publicize the project and its capabilities.

Work with the regional climate center in Lincoln, NE and with the Oklahoma Mesonet to link data.

Decision criteria
We anticipate that these will be primarily based on budgets although need and support, including financial support of some of our future partners will influence criteria for where this project will go.

Alternatives

Operational Implementation
To merely make a name change and call the existing 21 sites an operational program would be inadequate. Implementation of an operational SM/ST system is a two step growth process. Initially, the 21 existing sites would be supplemented to some degree. The density of the network would be such that both regional and national soil moisture determinations and decisions could be made.

Step two would involve the addition of as many sites as would be necessary to be able to adequately assess and predict national climatic and soil moisture conditions within a pre-determined level of confidence. A portion of the analysis of how many sites would be needed to optimize a completed operational SM/ST network includes looking at other existing systems. Some of these, such as the sites within the NRCS SNOTEL system could be easily and inexpensively retrofitted with sensors that would provide the data needed by SM/ST. Other systems could be examined in a similar manner. Appendix C, the 1998 National Agriculture Water and Climate Center budget initiative for a Soil Climate Analysis Network (SCAN), outlines an example approach to moving from the current pilot to an operational network.

In some cases, the necessary soil and climatic information is already being collected by others, but is not readily accessible. Also, other collection sites may not have the complement of sensors necessary to meet NRCS needs. Instead of installing duplicate sensing devices, partnerships would be formed. NRCS Water and Climate Center computers could then link to those existing databases, and retrieve, process, and distribute the information in a very efficient and cost effective manner.

Throughout the entire process, opportunities for economic partnerships with other governmental groups and the private sector would be explored. Funding opportunities and the dedication of other resources would be explored.

Termination of the Pilot Project
Under unfavorable circumstances, the project could be terminated. This would involve the cancellation of the MCC data center/master station lease agreement and the removal and disposal of all remote data site equipment. There would be substantial costs associated with the removal of each of these sites. These costs are estimated at between $75,000 and $1 00,000. Circumstances where project termination might occur include redirection of primary project funding by the agency or a total change in national priorities by the department or agency.

Transfer of ownership

As an alternative to total project termination, ownership and the operation/maintenance of any or all of the 21 existing remote sites could be transferred to interested state, federal, or private entities willing to partner with NRCS. Partners might include groups already using project data in an operational mode who would be forced to substantially modify operations if the data were not available.

Unless all sites could be transferred as a group, it would not be cost effective to maintain the meteor burst telemetry link. Preparing the existing remote sites to operate in a standalone mode would involve removal of the data acquisition/transmission equipment and replacing it with data loggers with cellular modems. It is estimated that each conversion would cost about $5000 dollars.

Priorities for addition of Climate Monitoring Sites

The Agency NRI and RCA programs are examples of resource assessments that are customer driven and will influence the priorities for new and modified climate sites, which would include soil moisture and temperature measurements. Any such national program will fit directly into, and will necessarily be consistent with, The National Environmental Monitoring Activity of the Office of Science and Technology Programs (Executive Office of the President) and the Committee on Environment and Natural Resources. The current priorities appear to be those that follow, for the reasons given.

1. Areas of intensely managed agriculture. These are areas from which political and financial support is expected from state and local units of government and the private sector. Additional climatic data used for agricultural management decisions could increase food production, reduce negative environmental effects, and perhaps positively affect the national balance of trade. Informed management decisions would likely decrease inappropriate application of chemicals, which translates to an environmental benefit.

2. Areas prone to drought. The ability to predict drought provides individuals and units of government the required information to take steps to mitigate drought effects. Those steps include resource management measures such as land use modification, providing supplemental irrigation and implementing special water management practices. Also emergency preparedness measures can be instituted if drought appears likely. This also has regional and perhaps national economic implications in that preparedness measures would be expected to be less costly than relief measures.

3. Rangelands and dryland areas. Much of the same logic applies as in item two. In addition, modification of livestock management practices could be put in place to decrease economic loss.

4. Forest areas. Reliable prediction of climatic conditions, including soil moisture, could lead to better forest management decisions in a given year. Additional fire prevention measures could be put in place when especially dry conditions are anticipated. Likewise, reforestation practices could be timed for highest chance of success based on expected climatic conditions.

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