SNOTEL (SNOwpack TELemetry)
And
SCAN (Soil Climate Analysis Network)

Garry L. Schaefer
USDA-NRCS
National Water and Climate Center, Portland, OR.
Ron F. Paetzold
USDA-NRCS
National Soil Survey Center, Lincoln, NB

ABSTRACT. The Natural Resources Conservation Service (NRCS), National Water and Climate Center (NWCC) operates and manages two unique hydroclimatic data collection systems. For over 20 years the SNOTEL system has provided critical high elevation climate information from the major water yield areas of the mountainous West. This system plays a key role in providing near real-time precipitation, air temperature and snowpack information to forecast streamflow volumes. SNOTEL also provides critical information for emergency management agencies to effectively mitigate floods, avalanches, and other life and property threatening events associated with extreme weather events.

The NRCS has operated a national Soil Moisture/Soil Temperature (SM/ST) Pilot Project since 1991. This project is nearing completion. The project was conceived because the ability of NRCS and its partners to make sound resource assessments and watershed decisions has been severely limited by the lack of quality, historic and real-time soil-climate information. Existing data from other networks are essentially inadequate for most purposes. They tend to be application specific, short-term, incomplete, limited in area of coverage, and often include non-standard data that are difficult to access. SCAN is the next step to implementing a nationwide soil-climate network. When fully funded, it will develop products that increase our customers ability to make sound resource management decisions. This paper describes both networks: SNOTEL and SCAN.

1.0 METEOR BURST COMMUNICATION

Both SNOTEL and SCAN data collection systems use meteor burst communication techniques to obtain near real-time data from remote sites. The NRCS pioneered the use of this technology in the mid 70's for use with SNOTEL. Meteor burst communication was chosen for SCAN because of its proven reliability and cost effectiveness.

Meteor burst communication, developed by the military in the 1950's, uses the ionized gas trail from the billions of sand sized particles (1 gram or larger), that burn up in the 50 to 80 mile high region of the atmosphere to relay radio signals back to the earth (See Figure 1). VHF radio signals can be bounced off this gas trail and reflected back to the earth. Such signals generate a communications footprint on the earth. Remote sites located in the footprint can transmit data to the master station (Western Union, 1977). This technique allows communication to take place between a remote site and a master station up to 1200 miles apart. At the master station, the data are checked for completeness. If complete, an acknowledgment message is sent back to the remote site instructing it not to transmit again until its next scheduled time. All three transmissions take place in less than a tenth of a second.

The NRCS owns and operates two master stations located near Boise, Idaho and Ogden, Utah. Only one master station is required to communicate with the remote site network, but two are used to decrease wait times and provide redundancy for the network. These master stations act as central receiving facilities and are linked with the NWCC Central Computer Facility (CCF) by a packet switched, X.25 telephone communication system with Portland, Oregon. The NRCS currently leases a third master station, located in Tipton, Missouri, to extend coverage to the central and eastern United States. Data received from the master stations are transferred to the CCF continuously.

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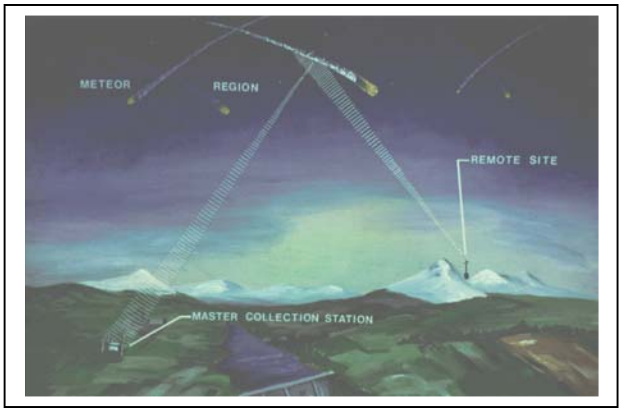

Figure 1
Meteor Burst Communication

2.0 DATA COLLECTION NETWORKS

SNOTEL:

The SNOTEL system began in 1978 sending high elevation climate information in near real-time via meteor burst telemetry. SNOTEL was the first and remains largest user of meteor burst communication technology in the world (Schaefer, 1990). Currently, this network operates over 650 remote sites in the Western United States and Alaska. Table 1 describes the typical sensor array that is commonly available at most remote sites.

Parameter Measured	**Instrument**
Snow Water Content	Snow pillow device and pressure transducer.
Precipitation	Standard 12 inch orifice, alter shielded, all season, storage gage.
Snow Depth	Sonic sensor.
Air Temperature	Shielded thermistor.

Table 1
SNOTEL Site Configuration

The SNOTEL system will accommodate a variety of other sensors, including wind speed, wind direction, relative humidity, solar radiation, water level, soil moisture, soil temperature and others.

Most SNOTEL stations provide multiple measurements per day and can provide hourly data upon request (Schaefer, et al., 1996). Approximately 30% of the 650-station network provide hourly data. All remote sites are operated in an unattended mode and rely on solar panels and batteries for electrical power. Figure 2 shows a typical SNOTEL remote station.

Figure 2
Mt. Rose Ski Area SNOTEL Site, Nevada

System reliability is generally 99%, as measured at midnight when every site is expected to report. The data from the remote sites go through an initial electronic screening before being placed into the database. Once in the NRCS database, numerous automatic reports are generated and the data are made available to the public via the World Wide Web and other means. SNOTEL data are electronically transmitted hourly to the National Weather Service and to other federal and state entities for their use.

The primary uses of the SNOTEL system are for making snowpack assessments and water supply forecasting. SNOTEL also plays a major role in mitigating drought and flood impacts. This system is unique and is the only system that provides high elevation climate information in near real-time.

SCAN:

SCAN uses much of the technology that was developed for SNOTEL. SCAN uses the same meteor burst communication technology as SNOTEL, on a nationwide basis. NRCS leases a third master station, located in Tipton, Missouri, to provide coverage for the central and eastern sections of the United States. The concept of SCAN was developed through collaboration between the Soil Survey and Resources Inventory divisions of the NRCS. The Soil Moisture/Soil Temperature (SM/ST) pilot project was started in 1991 to assess:

1) Develop the technical expertise in monitoring the soil-climate interface
2) Demonstrate the technical feasibility for a nationwide network.

The SM/ST pilot project operates 21 stations in 19 states (NRCS Soil-Climate Team, 1995). This is the final year of the pilot project, but the mission continues in SCAN Cooper, et al, 1992). While SCAN is not currently funded by the agency, cooperators have assisted in beginning the proposed network. Presently the growing SCAN network consists of approximately 40 stations in 25 states, including the original 21 pilot project sites and some SNTOEL sites with soil moisture sensors. Figure 3 shows the locations of current SCAN sites.

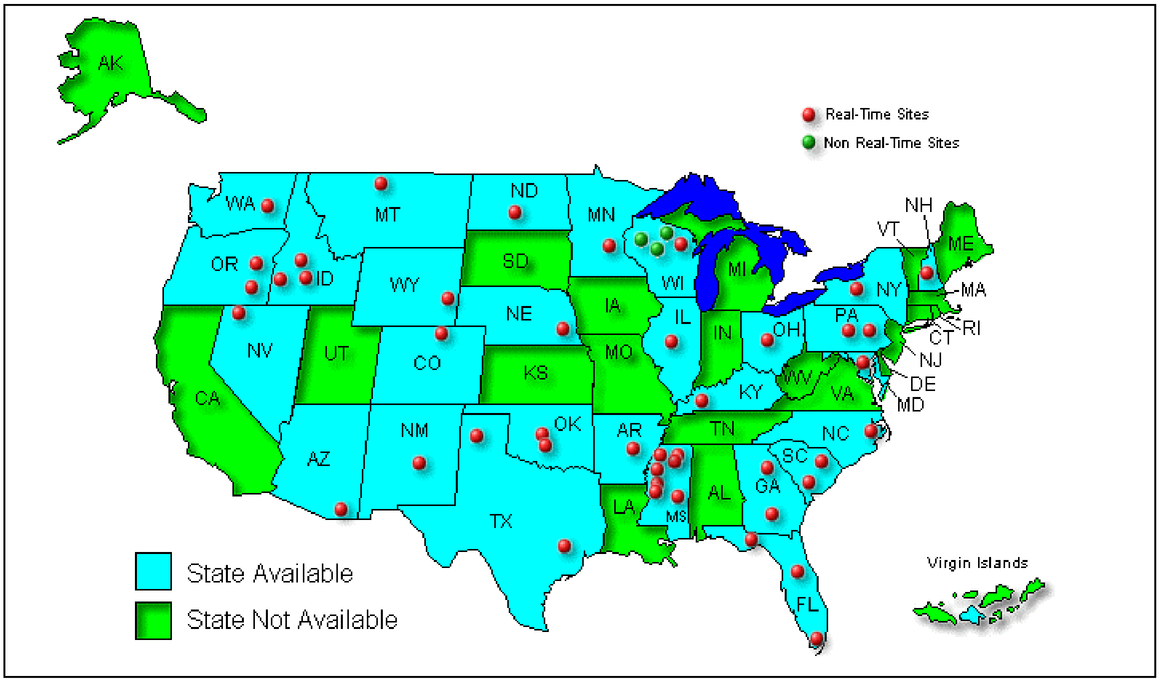

Figure 3
SCAN Site Locations

The SCAN network is configured to report hourly data. SCAN stations use a separate datalogger and meteor burst transceiver for greater flexibility in data acquisition. Table 3 describes a typical SCAN station configuration.

Parameter Measured	**Description**
Precipitation	Storage type gage
Air Temperature	Shielded thermistor
Relative Humidity	Thin film capacitance-type sensor
Wind Speed and Direction	Propeller type anemometer.
Solar Radiation	Pyranometer
Barometric Pressure	Silicon capacitive pressure sensor.
Snow Water Content	Snow pillow device and a pressure transducer. At selected sites.
Snow Depth	Sonic sensor. . At selected sites.
Soil Moisture	Frequency shift dielectric constant measuring device. Measurements are at 2”, 4”, 8”, 20”, and 40” where possible.
Soil Temperature	Thermistor. Measurements are at 2”, 4”, 8”, 20”, and 40” where possible.

Table 3
SCAN Site Configuration

Figure 4 shows a typical SCAN site with a full complement of sensors including a snow pillow and snow depth sensor.

Figure 4
Mahantango Creek SCAN Site, Klingerstone, Pennsylvania

Dataloggers enable the use of a variety of sensors at each site. The initial system combined the meteor burst communication instrumentation and sensor polling instrumentation into one unit. The older type device was less flexible in station configuration, but still allowed for connection of a variety of analog and pulse counter sensors. The new system, not only allows the use of most analog, digital, pulse, and SDI12 sensors, but also the conversion of sensor output directly to engineering units at the station.

3.0 DATA MANAGEMENT

Data management is performed in two stages. The computer automatically validates the incoming value against limits and flags any that fall outside preset windows. Statistical assistants examine any flagged values to determine their accuracy and make corrections. All parameters are graphed and comparisons are made between sensors to verify that the data are within an acceptable range. Based upon the findings from this quality control process, maintenance visits are conducted to correct deficiencies. Presently, the SNOTEL system undergoes more extensive quality control screening than does SCAN which is due do to increased staffing for SNOTEL.

4.0 DATA ACCESS AND USE

SNOTEL and SCAN data are both available via the web. Numerous automated analysis products have been produced using the data provided by SNOTEL. New products are continuously being developed to support user demands. The NWCC homepage is: http://www.wcc.nrcs.usda.gov.

Beginning in May 1998 SCAN data was placed on the NWCC internet homepage. The web site contains the current and historic data for each site. In addition to the data, each site contains all of the soil pedon information, a site picture, and a "hot link" to the National Soil Survey Center Laboratory database, which contains all of the site characterization (chemical, physical, and mineralogical) information. Other

Soil Moisture Team projects data are also available through this web site. Interest has grown dramatically since the data were made available on the Internet. Figure 5 shows the demand for this type of data as awareness of its existence grows.

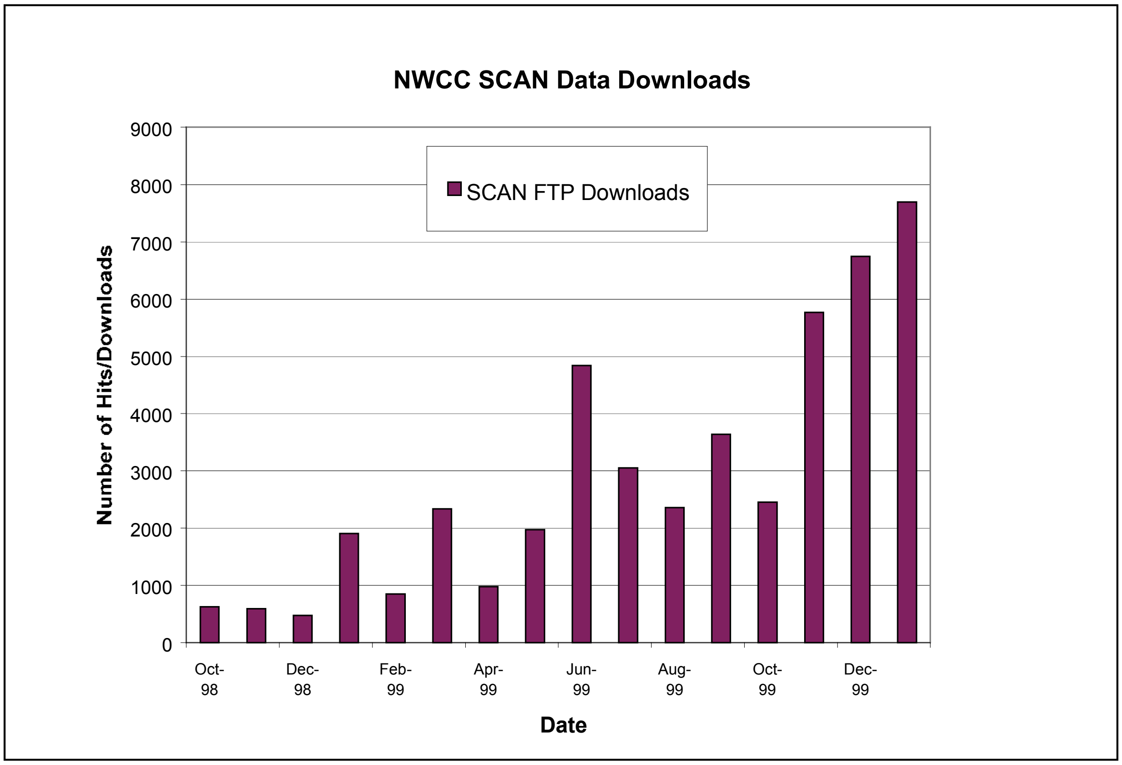

Figure 5
FTP Downloads

The uses that are made from these two unique data sources are extremely varied. Traditionally, SNOTEL data have been used to produce snowpack analysis and streamflow forecasts at approximately 1,000 points in the West (Jones, et al., 1989). Because of the period of record that now exists for SNOTEL, other uses can now be made from this data set. Two examples of new uses of SNOTEL information are PRISM (Daly, et al, 1999) and improved spatially distributed snow melt modeling (Garen, et al, 1996).

The use of the SCAN data is equally varied. Not only are the data being used for traditional agricultural purposes such as evapotranspiration calculation and drought assessment, but also applications ranging from pipeline development to cold season, nitrogen-fixing bacteria population prediction. Additional uses of both networks are:

- To monitor drought development and trigger plans and policies for mitigation
- For soil classification
- For engineering applications
- For Input to global circulation models.
- To develop new soil moisture accounting and risk assessments.
- To monitor and predict changes in crop, range, and woodland productivity in relation to soil moisture-temperature changes.
- To predict regional shifts in irrigation water requirements which may affect reservoir construction and ground water levels.
- To predict shifts in wetlands.
- To predict changes in runoff that affect flooding and flood control structures.
- To be able to verify and groundtruth satellite and soil moisture model information.
- To predict the long-term sustainability of cropping systems, and watershed health.

5.0 BENEFITS

The general benefits of both systems include real-time monitoring, cost efficiency, low maintenance requirements, and the capability of monitoring additional parameters such as water depth, water quality, and soil redox potential.

6.0 CONCLUSIONS AND RECOMMENDATIONS

SNOTEL and SCAN have proven technology with which to meet the ever increasing demands for soil climate information. Additional resources are needed for SNOTEL to adequately cover the snow producing areas in the west (and east?). It is estimated that additional 800 sites are required to meet the growing demands for snowpack and water resource information.

SCAN is currently an unfunded budget initiative. If SCAN were to be fully funded, it is anticipated that 1,000 additional data collection stations would be installed. These new stations will focus on the agricultural areas of the United States. In addition to these new stations, the budget initiative calls for the incorporation of existing networks, through partnerships with NRCS, to add additional 1,000 soil-climate stations for a total network size of 2,000.

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