8.2 # EXPANSION OF U.S. CLIMATE REFERENCE NETWORK CAPABILITIES

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1. Introduction

Since completing network deployment in the continental U.S., several important initiatives have been taken to both improve and expand the set of observations made by the U.S. Climate Reference Network (USCRN). The foremost of these changes is the establishment of the nation's first soil moisture / soil temperature network with triplicate measurements at each site. Instruments are installed in three locations within five meters of the site tower, providing three independent samples of soil moisture and soil temperature measured at 5, 10, 20, 50, and 100 cm. In addition, single atmospheric relative humidity sensors are being added to each station. New programming has been introduced that reduces data latency for real-time data users by providing temperature and precipitation calculations for the last hour ending five minutes before transmission time. This new portion of the data stream is called the "rolling 12", and is currently being utilized by the National Weather Service through the Hydrometeorological Automated Data System. Finally, expansion of the USCRN in Alaska has begun with a goal of deploying 29 stations at a similar spatial resolution to the network in the conterminous United States.

New data types and increasingly lengthy records for standard temperature and precipitation measurements now provide a substantial basis for climate science research. Therefore, a strong effort is being made to make these data more available to the scientific community through our own facilities and those of partners. Examples of science work underway or planned with USCRN data will be described.

2. Soil Moisture/Soil Temperature

The National Integrated Drought Information System (NIDIS) Program has provided support to the USCRN to measure soil moisture, soil temperature, and atmospheric relative humidity at each of its locations where measurements are feasible (i.e., the station is located on soil). A workshop of soil moisture experts was held in Oak Ridge, Tennessee, in March 2009 to gain knowledge regarding the best disposition of measurement equipment based on previous experience and on the needs of various user groups. Satellite calibration/validation interests expressed strongly a need for shallow, 5 cm level measurements of both soil moisture and soil temperature. Agricultural users valued foremost root zone measurements, especially at 10-20 cm. Drought experts and soil moisture modelers were interested in soil moisture information at as many vertical levels as possible, down to a meter if possible. Experiences with various measurement technologies were shared. A final conclusion was reached that the measurement approach used by the U.S. Department of Agriculture National Water and Climate Center's Soil Climate Analysis Network (SCAN) provided the best coverage of all user needs. The USCRN observing philosophy of redundant measurements in triplicate was also adopted. USCRN air temperature measurements use a triplicate configuration to measure one homogenous volume of air, allowing for greater certainty of one measurement. In the case of soil climate observations, a heterogeneous soil matrix is being sampled; therefore, the triplicate configuration of instruments characterizes variance in soil moisture and soil temperature across the station site.

By the end of 2009, 40 USCRN stations had soil moisture/soil temperature probes and atmospheric humidity instruments installed (Figure 1). A dielectric type of instrument was selected for its capability to measure soil moisture and soil temperature simultaneously, and for the extensive experience of the SCAN in using this type of probe. Detailed studies of this probe have led to the creation of well developed relationships of measured dielectric to volumetric water content in most soils (Seyfried et al 2005). As part of the installation of probes at 5, 10, 20, 50, and 100 cm, soil samples are being taken and analyzed for bulk density and many other characteristics. Bulk density relates to porosity, a key measure of soil water capacity for the particular soil. An intermediate data product has been developed with quality control procedures using the porosity as the basis for the acceptable upper range limit of soil moisture at a given site and depth. Further QC procedures check for low values, spikes, and frozen conditions. The individual soil moisture and soil temperature values are then averaged by layer and output. This intermediate soil climate data set can be accessed by going to the USCRN Observations Web page at http://www.ncdc.noaa.gov/crn/observations.htm, and clicking on the "soils data" tab on the far right column for those stations with available data. Quality control systems for the USCRN soil moisture and soil

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temperature observations are continuing to be developed, as well as methods for visualizing the data through the U.S. Drought Portal at http://www.drought.gov.

3. Data Availability

USCRN data have been available since the inception of the project through the main Web site at http://www.ncdc.noaa.gov/crn/. For users requiring data for periods of time of a month or less, the Web tools have been highly functional. However, as the time history of the network increases, requests for annual or period of record data sets for single stations or many stations became increasingly common. Therefore, a new set of ASCII text products updated weekly and available by station-year were deployed in 2009. A set of commonly requested hourly data types are available for public download at ftp://ftp.ncdc.noaa.gov/pub/data/uscrn/products/hourly02/, while another set of daily data types are located at ftp://ftp.ncdc.noaa.gov/pub/data/uscrn/products/daily01/. Each FTP location has a README.txt file indicating the data types available in each product and the format of these data. Space has been reserved in these data products for soil moisture and soil temperature, which will be incorporated in 2010 when their quality control process development is completed.

Once user of the USCRN observations is the National Weather Service Hydrometeorological Automated Data System (HADS). The station data has been transmitted in 3-hour blocks once an hour since program inception, with the last hour ending on the clock hour prior to transmission. If a station transmits data at the beginning of the next hour, there is not much additional lag, but if the station transmits 20, 30, or 40 minutes after the hour, considerable latency is introduced. In order to better served real-time users of the USCRN data and to get these data into HADS as quickly as possible, a new block of data was added to the original 3-hour schema. This new block, called the “Rolling 12”, contains calculated temperature and precipitation values for the 12 5-minute periods previous to the transmission time (Figure 2). Therefore, the latest hour of observations is available only minutes after the hour is completed, no matter when the transmission takes place. Furthermore, instead of being raw unprocessed data from three platinum resistance thermometers and three rain gauge depths, a substantial portion of the actual USCRN temperature and precipitation QC algorithms have been incorporated in the datalogger program, so that the “Rolling 12” values are much more useful for real time use in the HADS.

4. Alaska USCRN

Fairly early in USCRN history, in 2002, two experimental stations were installed near Fairbanks and Barrow, Alaska, with the expectation that experience with polar environments would be necessary for the eventual expansion of the network to Alaska. Further support for station deployments in Sitka and on St. Paul Island in 2005 was provided by the U.S. office of the Global Climate Observing System (GCOS) as part of its focus on improving in situ climate monitoring in polar regions. NCDC and the NWS Alaska Regional Headquarters held a workshop in Alaska in May 2008 to discuss USCRN plans for an Alaska-wide deployment, seeking cooperators and partners for this activity. Finally, dedicated Alaska USCRN funds were received, allowing for the first two of a planned 29 Alaska USCRN stations to be installed at Sand Point and Port Alsworth (Lake Clark National Park) in late summer 2009. In addition, site surveys where completed at five locations in 2009 with the expectation of more installations in 2010. Figure 3 shows the locations of these activities, and the targeted network configuration upon completion.

5. USCRN Science

The primary mission of the science activities of USCRN is to provide high quality climate data and information products for understanding climate change on a national scale, enhancing society’s ability to plan and respond. By means of scientific strategies of site selection, station engineering and maintenance, and data quality assurance, a set of observations is being collected by USCRN that can serve as a reference for other observation networks, for satellite climate product calibration and validation, and for model initialization and verification. The USCRN science activities also serve society’s needs for weather and water information in near-real time, through ongoing development of climate visualization and drought monitoring capabilities. By producing scientific analyses based on USCRN observations, continually enhancing USCRN products, and actively engaging in outreach on behalf of the USCRN, science staff move the project forward and add value to the resulting observations.

5.1 Climate Science

Since USCRN stations were initially commissioned beginning in 2004, the network has grown from 40 stations distributed across the U.S. to the final plan number, with 100 stations observing a full year of data by 2008. While neither 40 nor 100 stations are a large number, statistical analyses of existing stations indicate that the continental U.S. annual air temperature average is well represented in either case, as long as the stations are well distributed at each stage of network deployment (Vose and Menne 2004). Therefore, five useful years of annual continental U.S. air temperatures are available from the USCRN to compare to U.S. Historical Climatology Network Version 2 (USHCN

V2) dataset based on NWS Cooperative Observer Program (COOP) network.

USCRN and USHCN V2 air temperature measurements cannot be directly compared in raw form, as air temperature is measured by an instrument aspirated by a fan in the case of USCRN, and by natural ventilation in USCRN V2. However, a highly significant regression relationship can be constructed between the two data types for a given location, and then used to generate a synthetic time series for the 1971-2000 normals period at the location of the USCRN sites. This time series can then be used to generate 30-year estimated air temperature normals for the USCRN stations (Sun and Peterson 2005). Subtracting the estimated normals from the monthly USCRN air temperatures generates a time series of monthly air temperature departures from normal that are compatible with the predecessor observation technology used in constructing the USHCN V2, but with year-to-year changes that are independently measured.

The USCRN annual continental U.S. air temperature departures for 2004-2008 are extremely well aligned with those derived from the national USHCN V2 (Figure 4). For these five years, the USCRN explains 99.7% of the maximum temperature and 99.5% of the minimum temperature variance in the USHCN V2 annual air temperature departures, with a mean bias of -0.03°C for both maximum and minimum temperature. This finding provides independent verification that the homogenization adjustments made to the USHCN V2 data do not lead in the last five years of the record to a different result than one would derive from science-quality measurements taken at pristine locations.

A variety of other science projects utilizing the USCRN data are underway, both internally at NCDC and at NCDC's USCRN partner, the Atmospheric Turbulence and Diffusion Division (ATDD) of NOAA's Air Resources Laboratory, and also at stakeholder locations. USCRN Program personnel are strongly involved with users interested in using USCRN measurements in satellite calibration/validation studies. With the advent of soil moisture measurements, work on drought monitoring products has commenced. FY 2010 science work will take off from a strong starting point.

5.2 Instrument Science and Data Quality Control

The USCRN Program has a test bed of meteorological instruments at Marshall Field near Boulder, CO, where NCDC's partner, the Atmospheric Turbulence and Diffusion Division (ATDD) of NOAA's Air Resources Laboratory, conducts experiments comparing precipitation gauges and various shield configurations under natural precipitation. Currently, comparisons are being conducted between Geonor weighing precipitation gauges and Hydrological Services heated tipping bucket gauges in double fence intercomparison reference shields and double-Alter shields. Snow depth is also being measure with several SR50 ranging sensors. While the intercomparison studies are not yet complete, significant relationships between shield related errors and wind and air temperature were found, and may prove useful in correcting station precipitation at places with double-Alter shields.

Efforts are being made to improve observation quality, both through engineering at ATDD and through retrospective data analysis and adjustment of quality control procedures by NCDC. ATDD recently engineered a solution to an overvoltage problem affecting the station data logger when solar panels are recharging the station batteries at cold temperatures and low power levels. A separate problem with radio interference between the station antenna and the wetness sensor will be eliminated through reprogramming the station data logger sampling around the time of the hourly transmission. Some issues, however, cannot be solved with engineering approaches, and are approached through improvements in post-processing of the data stream after it arrives at NCDC. A new approach to identifying issues and prioritizing them for scientific analysis is being implemented this year. An exception list will be utilized to record problems as they occur, or as they are found retrospectively, and a scientific analysis will gauge whether a problem really exists, and, if it does, how best to resolve the problem. Problem solutions will be reported for peer review to the USCRN Configuration Control Board as a Configuration Change Request (CCR), where they may be further modified. Once a CCR is approved, the change required will be made in a transparent manner, with a copy of the original data preserved in addition to a record of the changes made to data flags and/or processing software.

Finally, initial work has begun on a suite of data visualization tools that will aid in analyzing data and examining the effectiveness of quality control algorithms. For example, development of a soil moisture spike test was aided by the use of a tool to visualize data steps of a given size. Visualization tools can also be of use to the public. The new soil moisture and soil temperature visualization tool on the drought.gov Web site mentioned earlier is just the beginning of these efforts. Exciting visualizations of hourly soil moisture can clearly show the act of rainfall infiltrating soil and percolating downward over time (Figure 5). This and other visualization improvements will be coming to the USCRN Web site during 2010, at http://www.ncdc.noaa.gov/crn/.

6. Conclusions

The U.S. Climate Reference Network Program is consolidating the advances made under its base program to provide climate science quality measurements of temperature and precipitation for the United States. The core mission of climate change detection is being expanded to Alaska currently. In addition, a new soil moisture/soil temperature network is being deployed to better monitor drought in the United States, and expands the USCRN mission as a reference network, especially to remote sensing and modeling interests. The USCRN Program continues to innovate and grow in its mission while maintaining its adherence to the core principles of climate observations (Karl et al. 1995).

7. References

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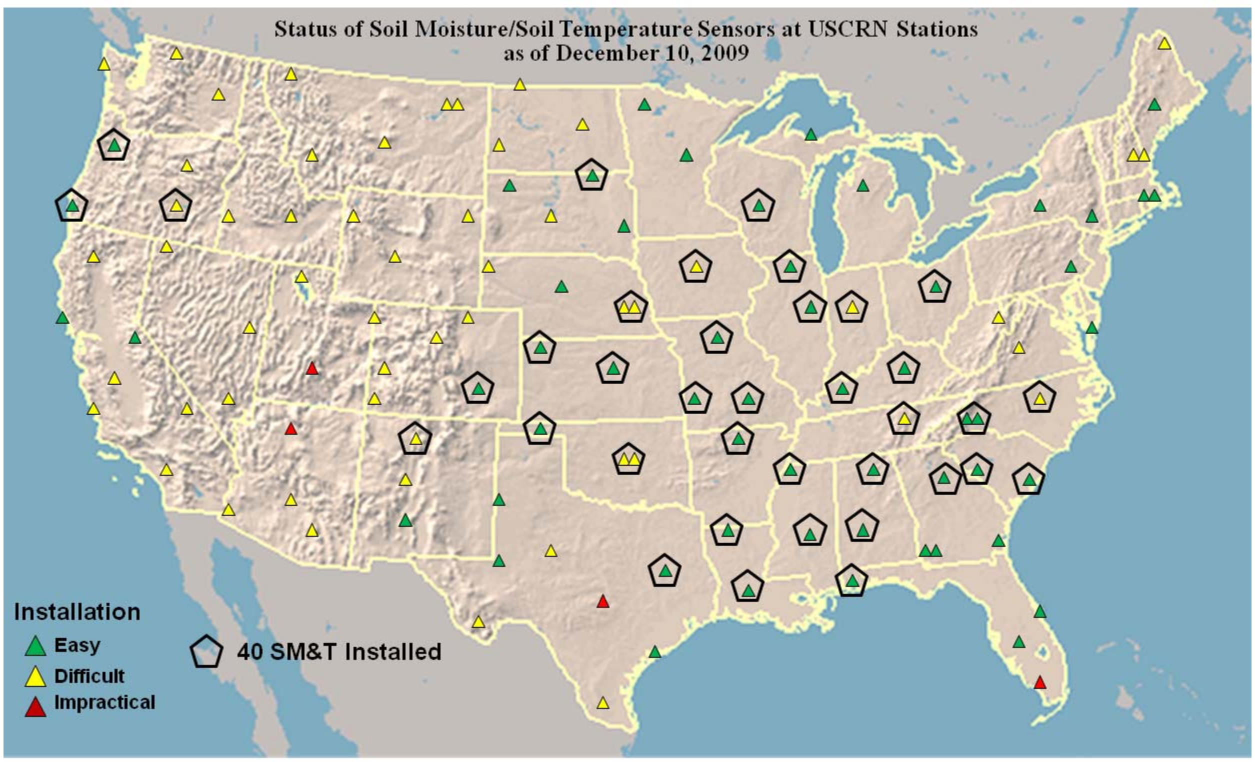

Figure 1. The USCRN locations with soil moisture / soil temperature probes and relative humidity instruments installed in 2009.

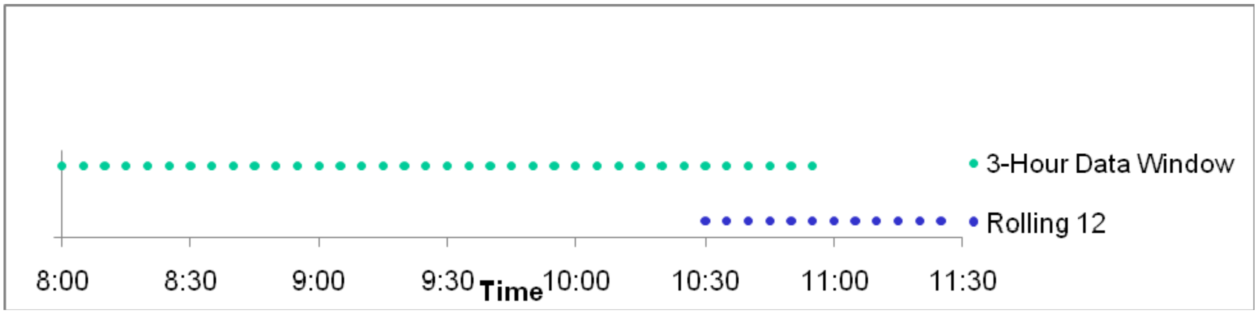

Figure 2. An example of a "Rolling 12" transmission for a USCRN station transmitting at 29 minutes after the hour. In this example, the 11:29 AM transmission contains a "Rolling 12" segment consisting of calculated 5-minute temperature and precipitation for the period 10:25 AM to 11:25 AM.

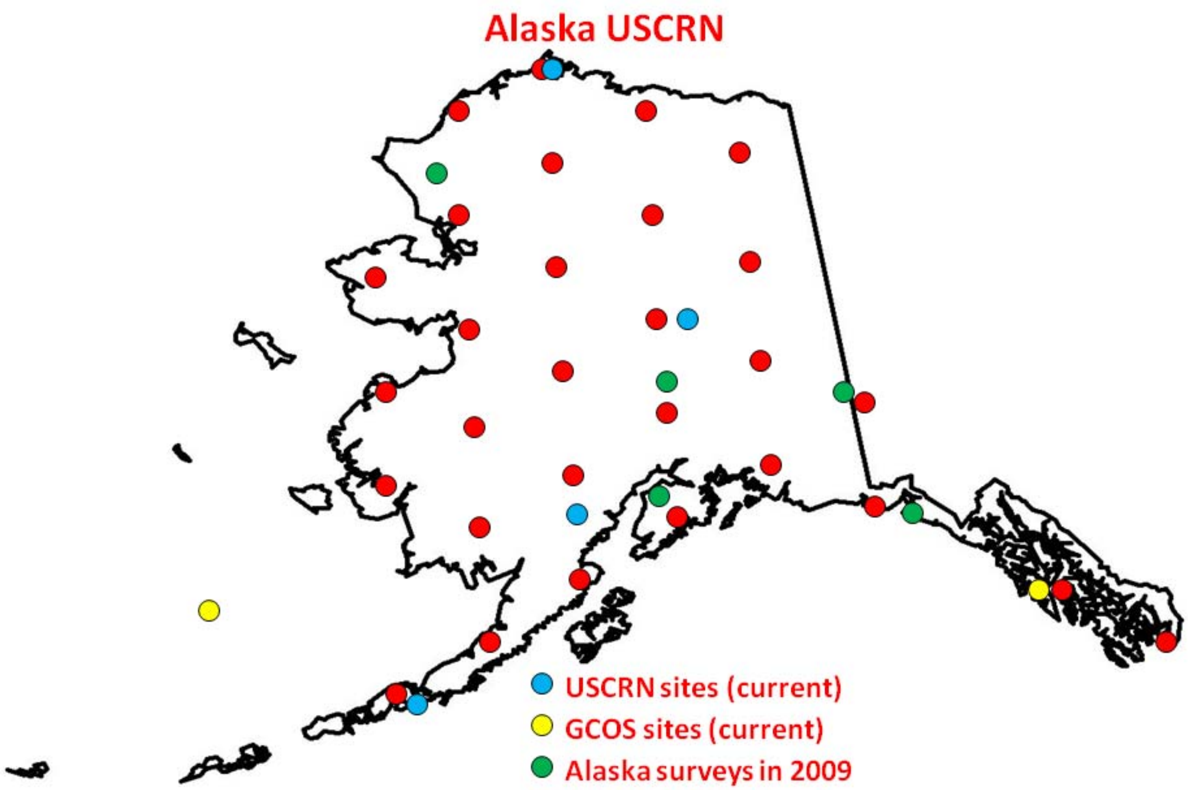

Figure 3. Alaska USCRN target map (29 red dots), with currently installed stations (2 blue dots 2009 installations by Alaska USCRN, 2 blue dots older experimental stations installed by the continental U.S. base USCRN, 2 yellow dots installed by GCOS), and locations surveyed in 2009 for potential 2010 installation (5 green dots).

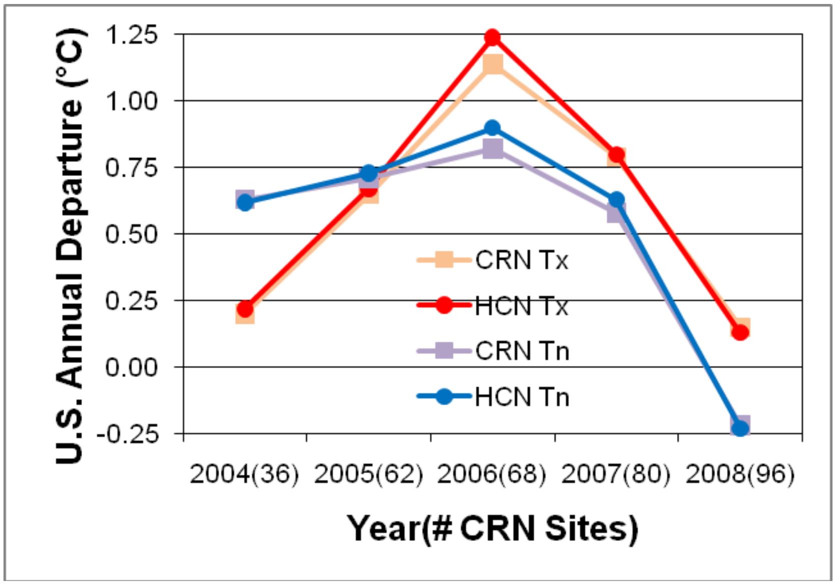

Figure 4. Comparison of the USHCN V2 and USCRN 2004-2008 continental U.S. annual air temperature departures from the 1971-2000 normal (°C). The number of USCRN stations available in each year is given in parentheses next to the year.

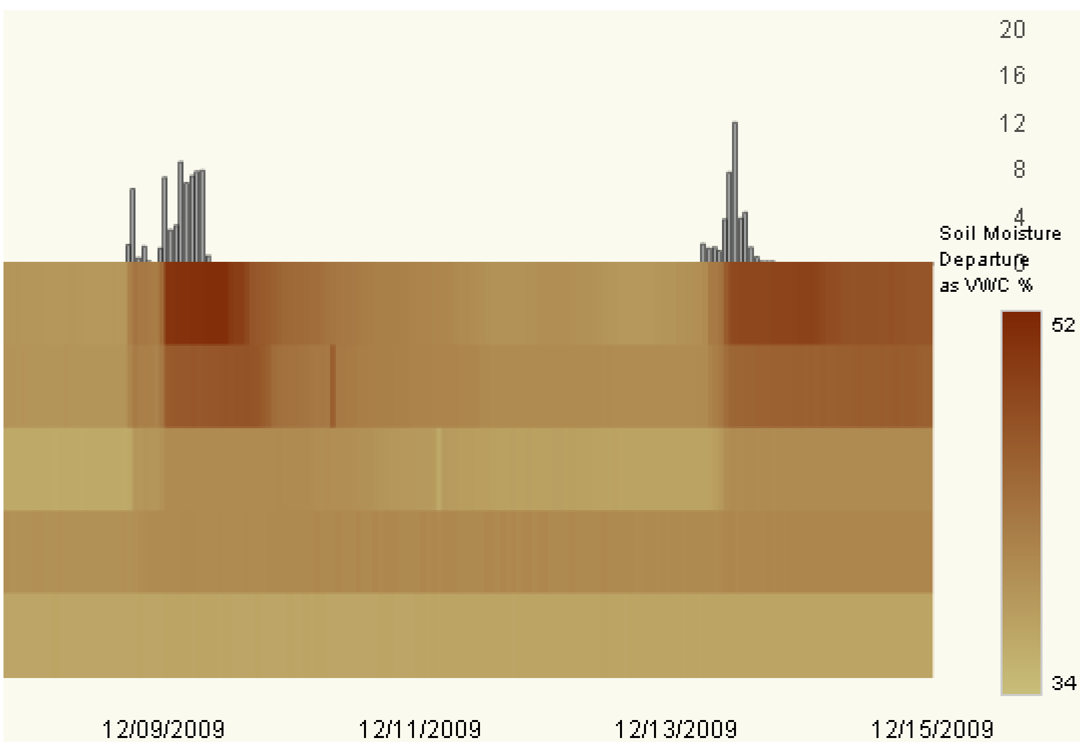

Figure 5. Soil moisture averages for the 5, 10, 20, 50, and 100 cm levels at Crossville, TN, 8-15 Dec 2009 (% volumetric water content). Precipitation (mm) is shown in gray bars above the soil moisture values.