# The United States Climate Reference Network (USCRN)

US Climate Reference Network

Annual Report

Fiscal Year 2010

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Report will be posted on the USCRN Website at:

**http://www.ncdc.noaa.gov/crn/**

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# Preface

Long-term, high-accuracy, stable environmental observations are essential to define the state of the global integrated Earth system, its history, and its future variability and change. Scientifically acceptable observations for climate analyses include: (1) operational weather observations when appropriate care in collection and archival methodologies has been exercised to establish sufficiently high accuracy for climate purposes; (2) limited-duration observations collected as part of research investigations to elucidate chemical, dynamical, biological, or radiative processes that contribute to maintaining climate patterns or to their variability; (3) high-accuracy, high-precision observations to document decadal-to-centennial changes; and (4) observations of well-recognized and scientifically acceptable climate proxies which are non-instrumental but nevertheless sufficiently controlled as to ensure numerical high-precision values that are scientifically valid. The data have been collected and normalized to extend the instrumental climate record to remote regions and back in time to provide information on climate change at millennial and longer time scales.

The USCRN fulfills this need for obtaining long-term sustainable and robust climate observations that are necessary to document long-term climate change trends for the Nation. This report is an annual update of the progress made in FY 2010 towards fulfilling those goals. Previous annual reports can be found on the USCRN Web site at http://www.ncdc.noaa.gov/crn. This report builds on, in particular, the progress made in FY 2009 when two new USCRN sites were installed in Alaska at Port Alsworth and Sand Point. With the installation of two more sites (Kenai and Red Dog Mine) in FY 2010 we are on our way to a total of 29 new sites in Alaska by 2016.

The challenge now is to continue the high level of annual maintenance, equipment refresh, and continued improvements in quality control and quality assurance that will ensure that the USCRN can continue to accurately document climate change on a national scale over the next 50–100 years. This continuous improvement program includes essential work begun in FY 2008 on the installation of new soil moisture, soil temperature, and relative humidity sensors at USCRN stations in the conterminous United States (CONUS), and which has continued into FY 2010. In cooperation with the U.S. Global Climate Observing System Program, a critical international expansion of USCRN approaches to climate observation was launched in support of the International Polar Year, and assistance continued for demonstrations of USCRN observation techniques in high-elevation areas that are under-sampled from a global climate perspective. The polar effort was capped off by the FY 2010 installation of a fully-capable USCRN-design station at the Roshydromet Tiksi observatory in the Russian Arctic of Siberia at 72° North latitude. This Siberian station is particularly important, as it is a geographic and climatic twin of the USCRN experimental station located at Point Barrow, Alaska—which like the station now operating at Tiksi, lies on the immediate shore of the Arctic Ocean. In summary, this report documents a tremendous set of accomplishments on behalf of the Nation and details some significant progress towards providing the data and information to aid in characterizing national (and eventually international) trends in climate change.

Scott A. Hausman, Director (Acting), National Climatic Data Center
October 2010

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# 1. INTRODUCTION

This is the eighth annual report for NOAA's United States Climate Reference Network (USCRN). The primary focus of this report is on the FY 2010 USCRN development and implementation activities. Initial projections of activities planned for FY 2011 are included. FY 2000–03 USCRN activities were reported in the USCRN FY 2003 Annual Report, and FY 2004–09 activities each had individual reports that are all posted on the USCRN Web site at http://www.ncdc.noaa.gov/crn/annual-reports.html.

This report includes reviews of the USCRN, performance measures, and stations installed; research progress and plans; instrument testing and forthcoming new instrumentation deployments; partnership activities at multiple levels; data completeness and data availability via the Internet; and information about NOAA's Global Climate Observing Systems (GCOS) international activities and plans, as well as information about the initial implementations of the USCRN in Alaska and installation of soil moisture (SM)/soil temperature (ST) and relative humidity (RH) sensors throughout the USCRN.

# 2. PROGRAM BASE

The required program capability, purpose, and requirement drivers for the USCRN are detailed below:

## 2.1 Program Capability

The USCRN Program adheres to the precepts incorporated in NOAA's draft Next Generation Strategic Plan v4 [see http://www.ppi.noaa.gov/NGSP2/NOAA_NGSP.pdf] where it states that in order to meet NOAA's objective for "*Improved scientific understanding of the changing climate system and its impacts*" that

> *"To achieve this objective, NOAA will continue its world-class observation, monitoring, research, and modeling efforts and increase efforts to close gaps remaining in our understanding of the climate system.* ***This effort will require expanding and sustaining comprehensive, global and regional-scale climate observing and monitoring networks that provide high-resolution information; conducting and sponsoring fundamental physical, chemical, and biological research to discover new approaches and opportunities to understand the climate system****, along with research to explore the effects of a changing climate on social and economic systems; conducting and sponsoring research on how climate variability and change affect selected regions that are especially vulnerable to climate impacts, such as the Arctic; characterizing key uncertainties (e.g., ocean variability, ocean circulation and heat content, clouds, aerosols, precipitation, ice sheets, global energy budget, biogeochemical cycles, and socio-economic parameters) and integrating this knowledge into models to improve predictive capabilities; increasing the number and quality of climate predictions through high performance computing and model advancements; and actively engaging the external research community through competitive research programs."*

## 2.2 Program Purpose

The USCRN Program provides the United States with a climate variation and change monitoring network that meets national commitments to monitor and document climate change and variability for the conterminous United States (CONUS), and expanding into Alaska. The USCRN Program completed the deployment of 114 operational stations in the continental United States by the end of FY 2008, which achieves target performance measures as documented in section 3 of this report. The USCRN Program has now turned its priority to installing 29 new sites in Alaska with two sites commissioned in FY 2010 that were installed in FY 2009 and with two more sites installed in FY 2010 for commissioning in FY 2011.

The Program's overall purpose is to ensure that future changes and variations in primary measurements at specific locations can be monitored without the need for unexplained adjustments and corrections to the data. Primary measurements at each site will include surface air temperature and precipitation, supplemented with other measurements such as wind speed, solar radiation, and infrared surface temperature, as well as soil temperature and moisture and relative humidity. The network will provide adequate spatial coverage to monitor the annual and decadal-to-centennial temperature and precipitation trends for the CONUS, Alaska, and eventually Hawaii. Fundamental to this goal is the requirement to establish a network that 50 years from now will answer the specific question: "How has the climate of the United States changed over the past 50 years?"

The program adheres as closely as possible in both the spirit and the scientific-technological exactness to the Ten GCOS Climate Monitoring Principles.[1] These Principles have been adopted by the National Research Council (NRC) of the National Academy of Sciences (NAS), as well as the U.S. Global Change Research Program (USGCRP), as defining principles for climate monitoring stations and long-term climate monitoring networks.

## 2.3 Program Requirement Drivers

### 2.3.1 Legislative:

- Federal Data Quality Legislation (Act) (Public Law 106-554 Section 515): Section 515 is known as the Data Quality Act—government must assure the quality of the information disseminated.

- Commerce and Trade-15 USC 313: "establish and record the climate conditions of the United States."

- Global Change Research Act of 1990, 15 U.S.C. 2921 et seq.: **"**Ensures the establishment of global measurements and worldwide observations, and requires an early and continuing commitment to the establishment and maintenance of worldwide observations and related data and information management systems."

- 44 USC 31 PL 81-754 Federal Records Act of 1950: provides for Agency Records Center and in 1951 the National Weather Records Center established an Agency for U.S. weather and climate records [the National Climatic Data Center (NCDC)] with responsibilities of archiving and servicing.

- 33 USC 883b, Agent Agreement: "... authorize activities of processing and publishing data..."

- 15 USC CH29 PL 95-357 National Climate Program Act: authorizing "...Global data collection monitoring and analysis..."; "... management and active dissemination of climatological data..."; and "... increase international cooperation ... monitoring, analysis and data dissemination."

### 2.3.2 Executive/International/Programmatic

- The U.S. high-level response to the Global Framework for Climate Services which calls for the United States to "...lead and participate in a number of existing international frameworks designed to coordinate observation systems for climate and other purposes."

- Earth Observation Summit [and Group on Earth Observation (GEO) Working Group]: The Summit Declaration reaffirmed the need for timely, quality, long-term global information as a basis for sound decision making and called for filling data gaps. The Summit Declaration also affirmed the need for "producing calibrated data sets in useful formats from multiple sensors and venues."

- Climate Change Science Program Strategic Plan: The plan has articulated a number of goals, including (1) "complete required atmosphere and ocean observation elements needed for a physical climate observing system"—this includes the USCRN as an underpinning for providing the highest quality benchmark data for enabling the determination of transfer functions with other U.S. meteorological networks, such as the Automated Surface Observing System (ASOS), Surface Radiation (SURFRAD), and Cooperative Observation (COOP); (2) "...easily accessible information about the data holdings, including quality assessments, supporting ancillary data, and guidance and aid for locating and obtaining data"; and (3)"[p]reservation of all data needed for long-term global change research. For each and every global change data parameter, there should be at least one explicitly designated archive."

1 See http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf

- GCOS Second Adequacy Report: Concerning data accessibility and quality, "[t]here are many observations of the climate system already being taken today. The report notes many times where there are issues with respect to the limited accessibility to much of the data and problems with its quality. Addressing these issues would have an immediate and positive impact on the ability of the current global observing system for climate to meet the needs of the Parties." More pointedly, the report states "notwithstanding the use being made of current information and improvements made in the past few years, the IPCC has recently reported…that additional and sustained climate observations are required to improve the ability to detect, attribute, and understand climate change and to project future climate changes…without urgent action … the Parties will lack the information necessary to plan for and manage their response to climate change."

- World Climate Data and Monitoring Programme (WCDMP) Guidelines on Climate Observation Networks and Systems (WCDMP No. 52) and Guidelines on Climate Metadata and Homogenization (WCDMP No. 53): These World Meteorological Organization (WMO) documents identify the "best practices" for climatological observations, data collection, metadata, and archival activities. These documents bring all WMO members to similar standards using the Ten Primary Climate Principles referred to in Section 2.2 as a base. These standards are a base for USCRN implementation, and are assiduously applied by the NOAA USCRN Team; thus, USCRN stations and their instrumentation suites are qualified as "Principal Climate Observations Stations" and "Reference Climate Stations."

- NOAA Annual Guidance Memorandum: It is necessary to "Take the Pulse of the Planet" by contributing to the Integrated Global Observing System through development of a "comprehensive, NOAA-wide data collection, quality control, storage, and retrieval program." In support of this goal of an Integrated Global Observing System, several bilateral agreements have been agreed upon and are in effect: the U.S/Canada Weather-Climate Memorandum of Understanding, the GCOS initiative to stimulate USCRN-like initiatives in Latin America and other regions, and the Smithsonian Tropical Research Institute (STRI)/NCDC Memorandum of Understanding.

- NOAA Program Decision Memorandums (PDM): FY 2006 "Establish climate monitoring stations to support the Alaskan Climate Reference Network. Reduce temperature and precipitation variance values to less than 5%."; FY 2007 "Complete Deployment of U.S. Climate Reference Network (USCRN)."; FY 2008 "Deploy soil sensors on all 114 CONUS Climate Reference Network sites by FY 2012."; USCRN FY 2009 "Continue Deployment of land based benchmark observing networks, such as Climate Reference Network (CRN)."

- G8 Endorsement: The 2008 G8 summit held in Japan in May 2008 issued a statement on Environment and Climate Change, endorsing the type of work that the USCRN is working towards accomplishing. The following excerpt from the 2008 G8 Declaration on Environment and Climate Change, paragraph 31, summarizes this endorsement quite well:

  *We note the opportunity to promote research on complementary technological approaches which may contribute towards maintaining a stable climate. To respond to the growing demand for Earth observation data, we will accelerate efforts within the Global Earth Observation System of Systems (GEOSS), which builds on the work of UN specialized agencies and programs, in priority areas, inter alia, climate change and water resources management, by strengthening observation, prediction and data sharing. We also support capacity building for developing countries in earth observations and promote interoperability and linkage with other partners.*

### 2.4. Program Objectives and Characteristics

The USCRN Program objectives are to develop, acquire, install, and operate a premier environmental climate monitoring network in the United States. The USCRN provides stable surface air temperature, precipitation, infrared surface temperature, incoming solar radiation, wind speed, soil temperature and moisture, and relative humidity observations that are accurate and representative of local environmental conditions.

Station site location is also particularly important because the environmental conditions around each station site must not ever be affected by encroachment of urban expansion or by other human-induced conditions that create a changed environment. Accurate climate representativeness and long-term maintenance at each USCRN station location are essential requirements for a climate monitoring network.

As required by the climate science community and codified by the NAS-NRC, WMO, and NOAA's NCDC USCRN Functional Requirements Document (FRD) (see link at http://www1.ncdc.noaa.gov/pub/data/uscrn/documentation/program/X040_d0.pdf), the USCRN, as a primary climate monitoring network, has the following attributes:

- triple configuration sensors for surface air temperature and precipitation;
- a very high percentage of data ingest over various periods (e.g., minimum of 98% of all possible observations for a given year must be archived at NOAA's national archive, NCDC) to satisfy requirements for climate science;
- stringent siting standards and an objective, quantitative assessment, which is annually verified and maintained for the long-term for each site as an essential part of the overall metadata pertaining to each site and station;
- rigorous periodic maintenance and calibration program with thorough documentation, which is systematically collected and archived at least once per year;
- an organized archive of complete metadata for all USCRN sensors, sites, and data characteristics, which must be long-term and well maintained at the national archive;
- overlapping observations to develop statistical transfer functions and full metadata for systematic, periodic technology refreshes, which must be maintained for both intra- and inter-network comparisons;
- strict Configuration Management (CM) for systematically documenting network change(s), maintaining standards, and ensuring that requirements growth does not impinge upon the primary purpose of the network for climate monitoring, which will be accomplished through thorough, updated CM documentation to ensure full implementation of sound scientific data stewardship principles;
- maintenance of a continuous data analysis and data quality component for continuous monitoring of both network data and metadata;
- emphasis on the network's primary purpose of satisfying the climate science community's requirements;
- activities that must be implemented to satisfy all standards, with consistency in change management for a period of 50 or more years; and
- capabilities for community, users, and the evolution of requirements; yet remains focused upon and loyal to the constancy and maintenance of the long-term GCOS Climate Monitoring Principles.[2]

When possible, USCRN stations have been colocated with or near existing meteorological observation sites such as those of the NCDC-designated U.S. Historical Climatology Network (USHCN) at National Weather Service (NWS) COOP sites and affiliated USHCN Modernization (USHCN-M) sites, the Canadian Reference Climate System (RCS) Network, the Bureau of Land Management-Forest Service Remote Automated Weather Stations (RAWS), the NOAA SURFRAD, the University of New Hampshire's AIRMAP

2 See http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf

stations, and various state mesonet stations (e.g., Alabama, Kentucky, Oregon, and Washington).

USCRN field stations are designed to operate without planned, daily human obligation, and to continue operations under extreme environmental conditions. NCDC provides data ingest, quality control, monitoring, data processing, archiving, and user access capabilities to both the climate research community and the general public. USCRN field system technology has proven to be highly reliable, precise, robust, and maintainable so that it collects, formats, processes, and communicates measurements of environmental parameters to NOAA's national archive at NCDC, the central data management and processing facility. The tables in Section 3 detail the high capture and archival rates of data across the network.

After the initial four years of development and field operations, the first 40 USCRN stations deployed were verified as having sufficient spatial distribution, reliability, and stability to provide the planned science information value. Therefore, NOAA commissioned the network in January 2004. Since its inception, incremental station improvements have been and will continue to be made under strict CM control. By the end of FY 2008, the network consisted of 114 homogeneous and commissioned stations in 42 States in the CONUS.

### 2.4.1 Capabilities Required

The required capabilities of the USCRN are:

- provision of land-based reference stations and standard land surface observing stations for tiered NOAA ground based observing systems such as NOAA's COOP and ASOS networks;
- coverage of sufficient temporal and spatial resolution to monitor national spatial scales for physical phenomena and to determine with the highest confidence climate variance trends having significant socioeconomic and scientific importance;
- measurements of key variables adhering to the NRC and GCOS Climate Monitoring Principles - the primary variables for USCRN, surface air temperature, precipitation (w/wetness sensor), soil moisture and temperature, and relative humidity are all measured with triple sensor configurations of the highest quality[3];
- reporting recoded measurements hourly;
- data assimilation, archival, and product generation subsystems for observations; and
- observing system management and information delivery infrastructure.

### 2.4.2 Potential Future Issues/Future Considerations

A potential issue with the USCRN communication system arose this year as part of the National Telecommunications and Information Administration (NTIA) effort to evaluate government use of the electromagnetic spectrum. As part of this evaluation, the frequency band used by Geostationary Operational Environmental Satellite (GOES) satellites to communicate with surface downlinks has been identified as a potential target for commercial use in the ever expanding portable broadband communication market. This could only be done by limited use of these frequencies near major GOES downlink sites such as the one at Wallops Island, Virginia, since the GOES frequencies cannot be altered once the satellite is in orbit. The frequencies used by our ground stations to transmit climate data to the GOES satellite are not yet targeted, but the spectrum review is continuing. Careful attention must be paid to these developments, and occasional updates to the USCRN communication study need to be made. However, if there is ever a need to change to another communication method, the impacts of the added expenses to the USCRN program could be severe if not compensated by increasing budgets.

The CONUS national grid of 114 USCRN stations has been stable since the end of FY 2008. Some consideration has been given regarding the continued need for the seven paired sites and the potential reassignment of some of these stations to high-priority locations, especially where there are noteworthy gaps in the national map coverage. This possibility will be examined further in FY 2011. A full

3 The secondary variables of solar radiation, wind velocity, and infrared surface temperature are measured with single high-quality sensors, and are used to help check the primary variables

listing of USCRN stations can be found on the USCRN Web site at <http://www.ncdc.noaa.gov/app/isis/stationlist?networkid=1>.

## 3. PROGRAM-LEVEL PERFORMANCE MEASURES

### 3.1 FY 2001–10 Achievements: Milestones and Performance Measures

The performance measures for these years are summarized along with those from FY 2010 in Tables 1 and 2.

### 3.2 FY 2010 Achievements: Milestones and Performance Measures

#### 3.2.1 FY 2010 Performance Measures: Increased Climate Certainty/Confidence

The deployment and commissioning of the full USCRN network in FY 2008 increased the national Performance Measure (PM) in the CONUS for surface air temperature to the 98.3% confidence level, where it remained in FYs 2009 and 2010. Likewise the national PM for precipitation remained at a 95.1% confidence level, which was reached at the end of FY 2008. The lower confidence of the precipitation PM compared to the temperature PM is due to the greater temporal and spatial resolution (more sites) needed to estimate the national precipitation total with greater confidence.

This is in keeping with the stated Program Goals of an increased national confidence level for temperature of at least 98.0% and for precipitation of a confidence level of at least 95.0%. The increasing growth of the Climate Confidence Performance Measure over time in conjunction with the densification of the USCRN network is depicted in Table 1.

There is now enough data from the commissioned network to confirm that the network indeed meets the temperature confidence level requirement set at 98% and precipitation confidence level set at 95.1%.

Even as the number of stations increased from FY 2004 through FY 2008, it was possible to calculate national annual temperature departures since the network was well distributed across the CONUS in each year. These USCRN annual temperatures could then be compared to national temperature departures calculated from the subset of 1,221 stations from the NWS Cooperative Observer Program Network selected for climate change studies, the U.S. Historical Climatology Network Version 2 (USHCN V2). The analysis is described in more detail in Sec 5.4. For the first five years since commissioning, the USCRN and USHCN V2 national temperature time series share in common more than 99.5% of the variance occurring during this five-year period, exceeding the theoretical performance expectations for the USCRN. This result is a tribute to the hard work and persistence of the personnel involved in this program over the years. Because more stations are needed to explain national precipitation departures, it will be a few more years

**Table 1. USCRN Reduction in Climate Uncertainty**

| USCRN Increased Climate Confidence(Certainty) in the CONUS FY 2004-10 | | | |
|---|---|---|---|
| End of Fiscal Year | *Commissioned* USCRN Stations Fielded | Temperature Increased Confidence | Precipitation Increased Confidence |
| 2004 | 58 | 96.7% | 90.2% |
| 2005 | 72 | 96.9% | 91.1% |
| 2006 | 77 | 97.0% | 91.8% |
| 2007 | 96 | 97.7% | 94.0% |
| 2008 | 114 | 98.3% | 95.1% |
| 2009 | 114 | 98.3% | 95.1% |
| 2010 | 114 | 98.3% | 95.1% |

**Table 2. USCRN in Alaska Reduction in Climate Uncertainty**

| USCRN Increased Climate Confidence (Certainty) in Alaska FY 2010 | | | |
|---|---|---|---|
| End of Fiscal Year | *Commissioned* USCRN Stations Fielded | Temperature Increased Confidence | Precipitation Increased Confidence |
| 2010 | 2 | 59.0% | 58.9% |

before a similar comparison can be made with USHCN V2 precipitation. With the start of USCRN operations in Alaska, a like performance measurement for increasing the confidence (certainty) in temperature and precipitation has begun to be monitored there as well.

### 3.22 FY 2010 Performance Measures: Data Ingest

Since the USCRN Program began in FY 2001, the Data Ingest Performance Measure for data completeness (Table 3) continues to be above what the climate science community specified as an acceptable base level for supporting robust climate science studies (that is, to a minimum of 98% dataset completeness). This 98% base level was first reached in December 2002. The data ingest has remained near the 99% level since that time. The current network-wide data ingest for the period of record is estimated to be above the 99.5% level.

At times, data transmission through the GOES Data Collection System (DCS) and ingest at NCDC can be interrupted due to system outages. Although these outages interfere with near real-time data collection, all data are stored within the station datalogger and eventually downloaded into a laptop computer as needed and always during a scheduled Annual Maintenance Visit (AMV). After each download, the data are delivered to NCDC and entered into the official, permanent archive.

**Table 3. USCRN Data Receipt Rates (%)**

| Fiscal Year | Q1 Avg | Q2 Avg | Q3 Avg | Q4 Avg | Annual Avg |
|---|---|---|---|---|---|
| 2001 | 86.8 | 96.5 | 70.5 | 97.4 | 87.7 |
| 2002 | 95.4 | 96.1 | 98.4 | 96.7 | 97.0 |
| 2003 | 98.5 | 99.4 | 99.8 | 99.5 | 99.4 |
| 2004 | 99.9 | 100.0 | 99.8 | 100.0 | 99.9 |
| 2005 | 98.9 | 99.9 | 100.0 | 100.0 | 100.0 |
| 2006 | 99.9 | 100.0 | 99.9 | 97.4 | 99.3 |
| 2007 | 100.0 | 99.8 | 99.7 | 100.0 | 99.9 |
| 2008 | 99.6 | 99.8 | 99.8 | 99.9 | 99.8 |
| 2009 | 99.9 | 99.8 | 99.9 | 99.2 | 99.8 |
| 2010 | 99.9 | 99.9 | 99.6 | 99.9 | 99.8 |

## 4. FY 2010 INSTALLATIONS AND SURVEYS (USCRN IN ALASKA)

- FY 2010 activities included Site Surveys—Seven detailed site surveys were conducted at four grid locations in Alaska during summer 2010.
- Sites Approved—Sites for five USCRN Alaska grid locations were recommended by the USCRN site selection committee and approved by the NCDC Director.
- Site Licenses Signed—Site license agreements were completed for three Alaskan sites selected in FY 2010, with two more pending agreement.
- Stations Installed—Two stations were installed in Alaska in FY 2010.
- Stations Commissioned—Two stations were commissioned in Alaska in FY 2010.

The conterminous national grid of 114 USCRN stations has been stable since FY 2008. Some consideration has been given regarding the continued need for the seven paired sites and the potential reassignment of some of these stations to high-priority locations, especially where there are noteworthy gaps in the national map coverage. This possibility will be examined further in FY 2011. A full listing of USCRN stations can be found on the USCRN Web site at <http://www.ncdc.noaa.gov/app/isis/stationlist?networkid=1>.

**Table 4. FY 2010 USCRN in Alaska Station Status**

| Station | Licensed | Installed | Commissioned |
|---|---|---|---|
| Sand Point | 02/12/2009 | 08/21/2009 | 09/07/2010 |
| Port Alsworth | 09/09/2009 | 09/25/2009 | 09/07/2010 |
| Red Dog Mine | 07/13/2010 | 08/25/2010 | FY 2011 |
| Kenai | 07/13/2010 | 08/30/2010 | FY 2011 |
| Tetlin | 07/13/2010 | FY 2011 | FY 2012 |
| Yakutat | Pending | FY 2011 | FY 2012 |
| Summit | Pending | FY 2011 | FY 2012 |

## 4.1 USCRN Continues Installation Work in Alaska

Two experimental design and testing USCRN stations were installed at fully qualified USCRN sites in Alaska in FY 2002 (Barrow and Fairbanks), and two more USCRN-design stations were installed via the U.S. GCOS Program in FY 2005 (St. Paul Island and Sitka) to provide extended experience with USCRN technology in severe Arctic environments. NCDC, along with the NWS Alaska Region Headquarters (ARH), held a workshop in Anchorage, Alaska, in May 2008 that focused on plans to expand the USCRN into all of Alaska. The initial start-up funds for USCRN in Alaska were received in FY 2008 and FY 2009, thus allowing for the installation of the first two of the 29 USCRN stations in FY 2009. Full funding began in FY 2010 and two more stations were installed bringing the total of Alaska USCRN stations to four (Figure 1), and the first two operational Alaska USCRN stations at Sand Point and Port Alsworth were commissioned in September 2010. During the 2010 AMV, an AC power line was installed to replace the solar array and two wind power generators which demonstrated unreliable power generation performance resulting from the harsh winter environment. The distance to the AC power source was approximately 700 feet. Trenching in the wire was done by hand to minimize vegetation disturbance. As of the end of August 2010, two additional sites were installed at Red Dog Mine and the Kenai National Wildlife Refuge (NWR).

The intent, based on available resources, is to install and commission USCRN stations across Alaska over the next several years. NCDC and NWS ARH have established partnerships with federal agencies in the state [e.g., U.S. Geological Survey (USGS), U.S. National Park Service, U.S. Fish and Wildlife Service, U.S. Department of Agriculture (USDA)], Environment Canada (with which NCDC has a bilateral climate observing agreement), and the University of Alaska, Fairbanks, to plan for potential USCRN sites in Alaska. Presentations from the workshop can be found online at the following Web site: <ftp://dossier.ogp.noaa.gov/USCRN-in-Alaska-Workshop-May2008>.

In addition to the two stations installed in FY 2010 at Red Dog Mine and the Kenai NWR, three more sites have been selected for future installations, with Tetlin NWR already licensed, and licenses pending from the State of Alaska Department of Transportation for sites at Summit (near Denali) and Yakutat. Four more grid target areas were explored in August 2010, with site surveys completed at Nowitna NWR, Selawik NWR, Katmai National Park (NP), and in the Gustavus area near Glacier Bay NP.

Issues with site surveying, site licensing, and site engineering and installation have all proven to be more complex in Alaska, and some delays have been encountered initially. However, lessons learned in FY 2010 will allow for more rapid progress in FY 2011, including a more rapid site selection and site licensing process. This improvement, along with engineering and logistics experiences gained, will allow for more stations to be installed in Alaska in FY 2011 than in any past year, assuming funding arrives in a timely manner.

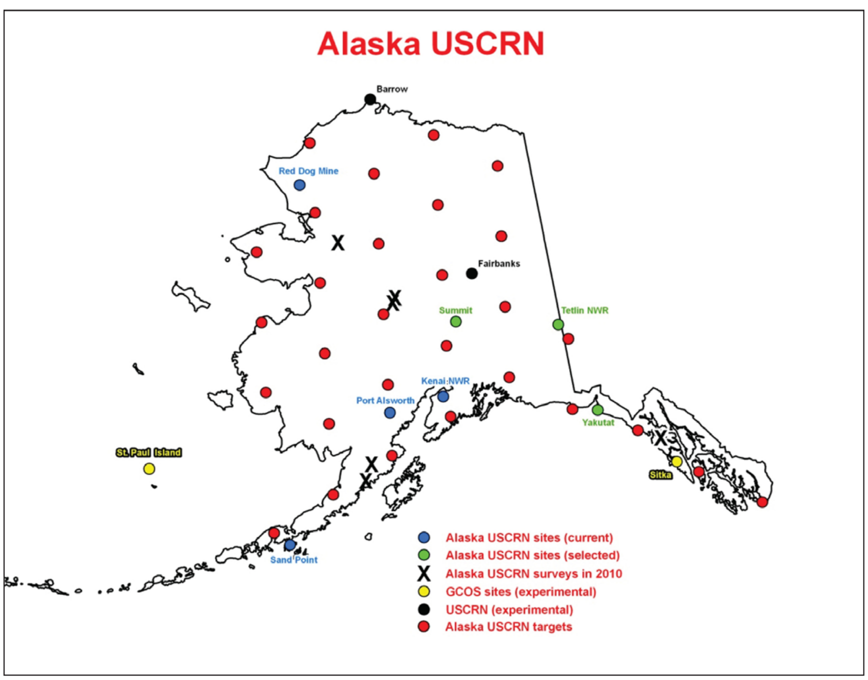



**Figure 1.** Alaska USCRN Target Grid, including stations installed by the Alaska USCRN, GCOS, and USCRN programs, and those sites selected and surveyed by the end of FY 2010.

## 4.2 USCRN Partnerships

The high level of confidence and data ingest for the USCRN could not be accomplished without the support of the various host organizations at each of the sites. The organizational classification of USCRN operational field stations by host agency identity gives an indicator of the breadth of the USCRN partnership with federal and state agencies, universities, foundations, and nongovernmental (not-for-profit) organizations that have been

**Table 5. Site Hosts at Commissioned USCRN Sites**

| Site Host Sponsor/ Organization | CONUS Number | Alaska Number |
|---|---|---|
| Arboreta/NGOs/ Foundations | 16 | |
| University Affiliated | 39 | |
| State Affiliated | 7 | |
| Native American Reservation | 2 | |
| NOAA Facility or Protected Area | 2 | |
| U.S. National Wildlife Refuge | 14 | |
| U.S. National Park Service | 21 | 1 |
| Other Federal Agencies | 13 | 1 |
| **Total** | **114** | **2** |

involved in hosting station sites for this network (Table 5). In addition, we have partnered with other agencies such as in coordinating with the USDA on the eventual installation of soil sensors at select sites in Alaska that will also benefit the International Permafrost Network.

## 4.3 U.S. Historical Climatology Network Modernization (USHCN-M) Program

Beginning in FY 2008, the USCRN program has partnered very closely with the National Weather Service U.S. Historical Climatology Network Modernization (USHCN-M) program. While the primary mission of the USCRN is to determine national climate trends, the complementary USHCN-M mission is to deploy a regional scale observing network to better characterize regional trends for temperature and precipitation. A recent agreement between NWS and the interim Director of the future NOAA Climate Service confirms the intention of NOAA to place the USHCN-M and USCRN programs in the NOAA Climate Service line office if and when it is formed, while maintaining a governance structure that insures NWS and OAR participation in directing the program. As part of this change, the USHCN-M will be renamed the Regional U.S. Historical Climatology Network (RUSHCN), and for the remainder of this report, USHCN-M will now be referred to as RUSHCN.

The long-term plan is to field a modern RUSHCN at sites across the conterminous United States to more fully align regional climate monitoring capabilities with the GCOS Climate Monitoring Principles. With the support of the USCRN program, a RUSHCN pilot project is currently underway in the four-corner states of the U.S. Southwest. The RUSHCN station configuration has been based on a scaled-down version of the USCRN sensor technology suite; experience with a network of 17 prototype sites in Alabama begun in FY 2006 was a starting point for cooperative work between the two programs.

A RUSHCN station maintains the USCRN capability of capturing three independent, high-quality measurements of surface air temperature and precipitation for just over half the cost of a normal USCRN station. It is solar powered with sufficient battery backup for 10 days, and the data loggers, satellite transmitters, and wetness sensors are like those of a USCRN. The temperature measurement is configured with three platinum resistance thermometers within one radiation shield serviced by two fans, a primary and a back-up, to maintain aspiration even if a fan fails. The precipitation gauge is exactly like the primary Geonor gauge of the USCRN, except that a Double Alter (DA) wind shield is used. A diagram illustrating station components is shown in Figure 2, and a station installed near Tropic,

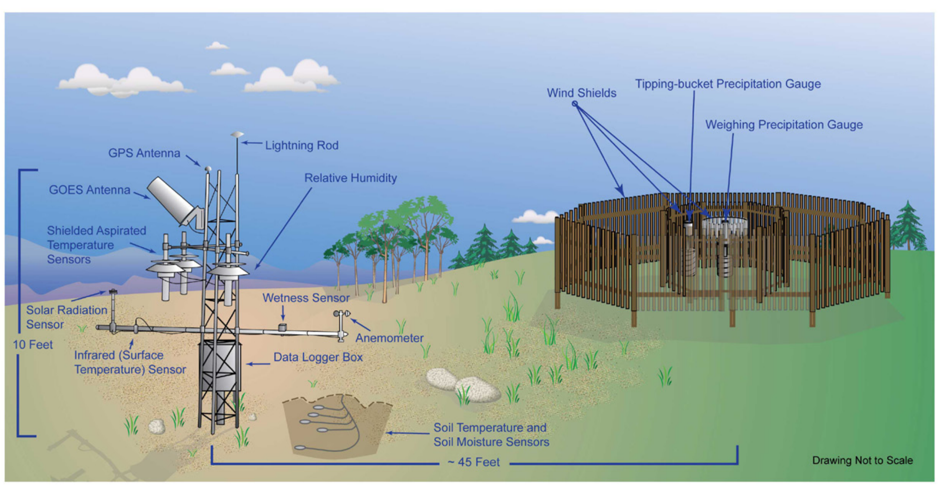



**Figure 2.** The instrument configuration of a RUSHCN station.

Utah, provides a real-world example (Figure 3). Information on the RUSHCN is available at: http://www.ncdc.noaa.gov/crn/hcnm/.

The pilot program involving the installation of 127 RUSHCN sites in the Southwest United States is well under way, and 60 stations were installed within the RUSHCN network by the end of FY 2010 (Figure 4). The continued growth of the RUSHCN program will involve considerable collaboration with the USCRN program as it benefits from lessons learned and successes realized over the past seven years of experience with implementing and maintaining USCRN.

**Figure 3.** The RUSHCN Station in Tropic, Utah.

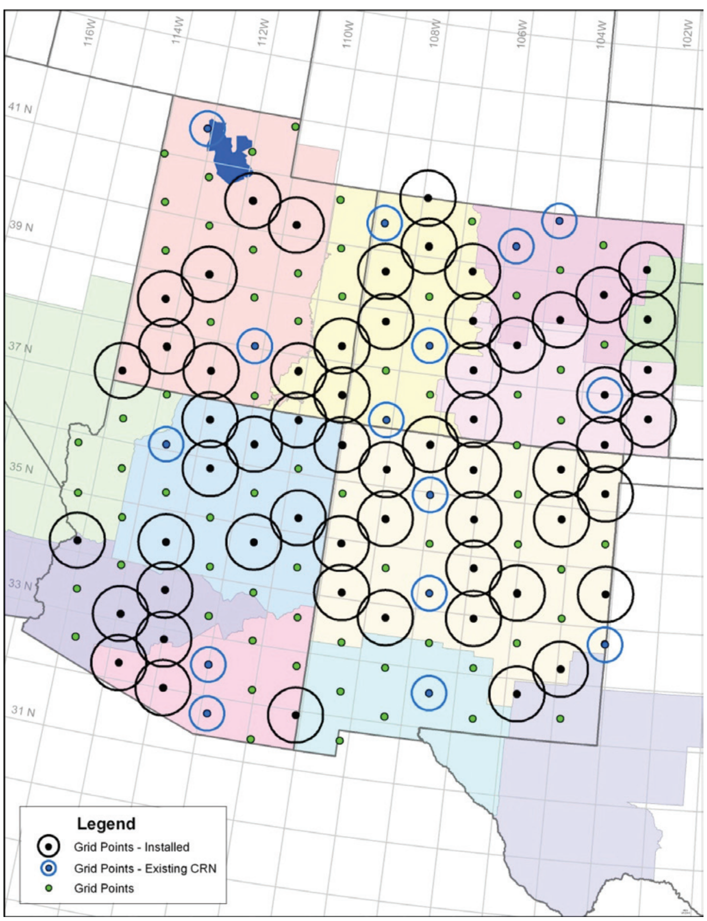



**Figure 4.** RUSHCN Pilot Area and installation status (the black grid points are installed RUSCHCN stations while the green grid points are where RUSHCN stations will be installed).

## 5. FY 2010 USCRN SCIENCE PROGRAM

As the deployment of USCRN in the CONUS was completed in FY 2008, resources were directed to advance the USCRN Science Project in FY 2010. The primary mission of the USCRN Science Project is to provide high-quality climate data and information products for understanding climate variation and change on a national scale, thus enhancing society's ability to plan and respond to climatic variances. By means of established and proven 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, as well as for climate model initialization and verification. These science fundamentals also direct the course of software development for USCRN, including aspects of product and Web design.

### 5.1 Science and Analysis in Support of Station Engineering and Maintenance

The first step in generating a stream of climate-science-quality data from USCRN is to engage in ongoing assessments of current instruments and station engineering practices and to look to the future by testing new instruments and practices at test sites and in test beds. The field work related to test site and test bed activities is conducted by NCDC's partner in the USCRN Program, the Atmospheric Turbulence and Diffusion Division (ATDD) of NOAA's Air Resources Laboratory. ATDD also analyzes test bed observations, sharing data and results with NCDC collaboratively, and actively and seamlessly ports their tested and verified measurement procedures, analyses, and technology back into the USCRN operational program.

#### 5.1.1 Solid Precipitation Studies

Supporting past solid precipitation results from the Marshall winter precipitation test bed[4] near Boulder, Colorado, along with other studies, the standard

4 See section 6.3 for more information on the Marshall test bed facility's role in international precipitation intercomparison studies.

double and single Alter shielded gauges caught significantly less solid precipitation than the (S)DFIR shielded gauges (Figure 5). During typical winter events, the Belfort gauge measurements compared well to the Geonor measurements. There were, however, some exceptions to this, due mainly to malfunctioning and badly configured Belfort heaters, and the manufacturer has been working to resolve this problem. There was one large snow storm in March 2010 that had unusually sticky snow, and the precipitation results during this event varied greatly from the results throughout the rest of the winter. The Belfort gauge heaters had problems during this event (Belfort technicians failed to reconfigure them after upgrading gauge firmware a few days before the storm occurred) which likely contributed to their poor performance.

The SDFIR shielded Belfort, for example, compared quite poorly to the SDFIR shielded Geonor during the March event (Figure 5). Improvements were made to the heaters and control algorithms during the summer of 2010, and continued winter testing of the gauges is forthcoming. The Belfort double Alter (BDA) wind shields performed much better than the standard double Alters (DA) throughout the winter. However, during the March event the Geonor within the BDA (the results of the Geonor with the BDA are in Figure 5) did not perform as well as it did throughout the rest of the winter. The Geonor within the Belfort double Alter did catch more precipitation than the Alter shielded measurements during the unusual March event, but the discrepancies between it and the standard (S)DFIR Geonor measurements were much larger than in past storms. This appears to have been caused by snow accumulation on the shield itself, as determined by images captured at the site during the storm. The wind shield manufacturer has subsequently adjusted the spring tension on the leaves of the shield, which may improve shield performance in these types of conditions.

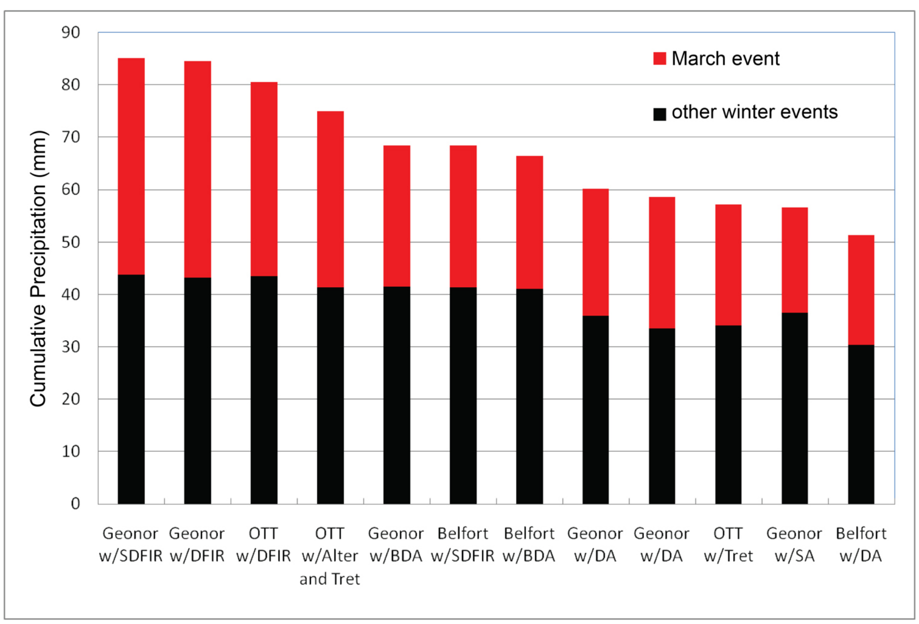



**Figure 5.** Solid (air Temperature < - 2° C) precipitation accumulation during the winter of 2009/10 for all weighing-gauge/shield combinations at the Marshall winter precipitation test bed. Accumulation occurring during the unusual and large event which occurred in March is in red and accumulation from throughout the rest of the winter is in black.

Conclusions:

- The BDA performed significantly better than the standard double Alter.
- Differences between the SDFIR shield and DFIR shield were small
- More events with varied types of solid precipitation are required to test and improve the gauges and shields in their current configuration at the Marshall winter precipitation test bed.

## 5.2 Soil Moisture and Soil Temperature Network Deployment

Soil moisture and temperature probes were first installed at the USCRN site in Crossville, Tennessee, in April 2009, supported by the National Integrated Drought Information System (NIDIS) program. In the time since then, 80 locations have had soil probes and associated data loggers and relative humidity instruments installed fully meeting the performance requirement for this program for FY 2010. The current distribution of stations with soil moisture and temperature measuring probes is mapped in Figure 6. By the end of FY 2011, subject to funding, all stations in the conterminous United States will have received soil moisture probes and RH sensors.

The primary design selected for soil probe configuration is to take three independent samples for each of the target levels at 5, 10, 20, 50, and 100 cm depth. Observations are taken in three plots around the temperature instrument tower, all within a 10 m

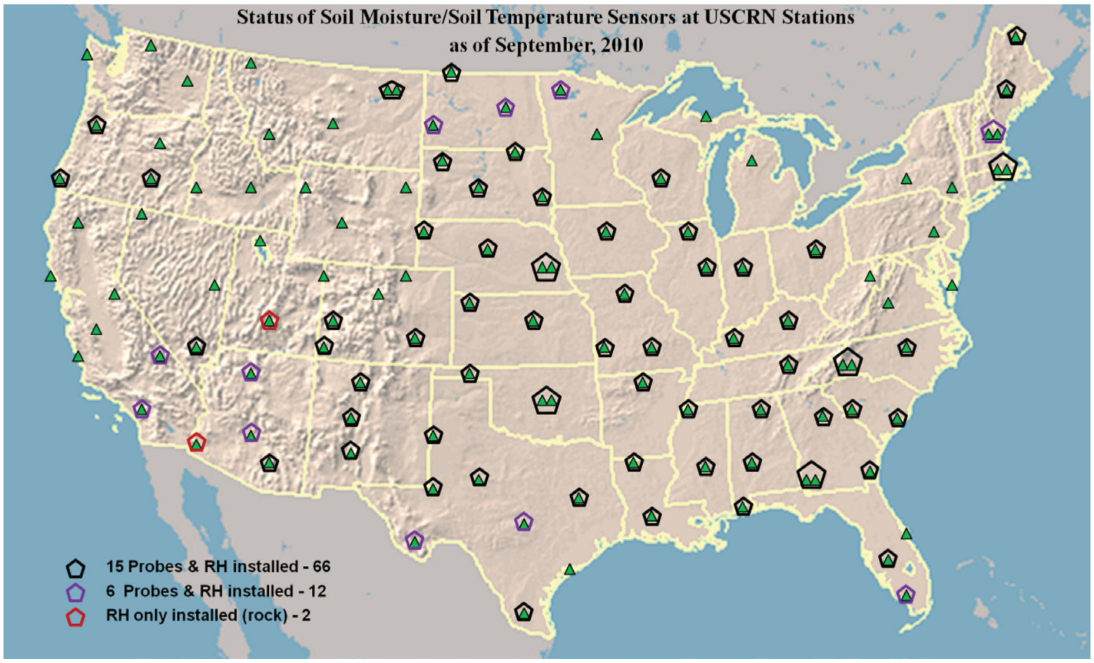



**Figure 6.** USCRN soil probe installation completed as of September 2010. Each green triangle is a USCRN station, and the pentagon color indicates the type of installation: 15 probes, 3 sets at 5, 10, 20, 50, and 100 cm depth (black); 6 probes, 3 sets at 5 and 10 cm depth (purple); and no probes in rock (red).

radius. In locations where solid rock or significant stones prevented deep digging, only the top two levels were instrumented at 5 and 10 cm. Because the original criteria for selecting USCRN sites did not anticipate the need for a deep soil layer, 12 locations so far have been limited to only two layers of soil probes, while two locations are on rock and cannot have soil probes installed. Soil samples have been collected from each soil probe installation plot and depth and are in the process of being analyzed by the USDA lab in Lincoln, Nebraska.

### 5.2.1 Soil Observation Quality Control

Development of quality control procedures for the USCRN soil moisture and temperature observations is continuing. The instrument type utilized measures soil dielectric through the reflection of electromagnetic waves in the soil, and the dielectric observations are range checked for realistic values and converted to units of soil moisture, the volumetric water content. For selected sites that have soil bulk density information, a specific soil porosity maximum can be calculated, providing a customized upper limit to the range of dielectric. All stations will have this information available when the soil sample analysis is completed by USDA. Soil temperatures are measured by thermistors embedded in the probe faceplate, and temperatures are also range checked. Following these range checks, the primary quality tests include spike tests looking for excessive changes in temperature and moisture, tests for frozen soil (this method cannot reliably detect moisture levels in frozen soil), and tests for constant (and therefore, bad) values of temperature and dielectric. The software for performing soil variable quality control has been designed to be compatible with the new data ingest system that is being constructed (see section 5.3.2).

Several difficulties have been detected with the current approach to soil climate measurements. Engineering issues have resulted in some soil probe observations being missed. Since hourly soil climate observations are the average of four measurements taken every 15 minutes, if a single measurement is missed, the data for the hour is corrupted, and the quality control system flags the value. Engineers at ATDD have determined the cause of these intermittent problems, and these will be corrected in the next round of AMVs scheduled for FY 2011. There are also nonengineering systematic issues related to soil characteristics. In some locations, the reflected electromagnetic waves used by the probes for soil moisture measurements are greatly impacted by cation exchange rates in the soil (related to clay chemistry of soil), or soil salinity. With these types of soil, temperature measurements are unaffected, but soil moisture measurements are very far out of range and/or very noisy and cannot be reliably used to measure soil moisture. The program soil climate quality control consultant and lead scientist are working on an automated method for quickly determining if a probe is not functioning adequately, given either environmental issues such as soil characteristics or issues like equipment malfunctions.

Despite the challenges, the vast majority of the soil moisture and soil temperature data being derived from the network are well behaved and highly useful. These data have been made available to the public after a 240 day trial period. After this period, the first 60 days of data are retained in the archives but are not included in the general release of observations to the public, which includes the succeeding 180 days of data and all future data. A total of 45 stations of the 80 installed have reached the 240 day mark as of the end of FY 2010 and have been released to the public. Formatted text tables of the soil moisture and temperature layer averages for each site are available in the Soilsip01 files at the USCRN Products Web page: http://www.ncdc.noaa.gov/crn/products.html. Simple line graphs of soil moisture and soil temperature time series at each station have been displayed on the U.S. Drought Portal Web site since December 2009 at: http://www.drought.gov/portal/server.pt/community/drought.gov/crn_soil_data. New soil moisture visualizations will be discussed in Section 5.3.6.

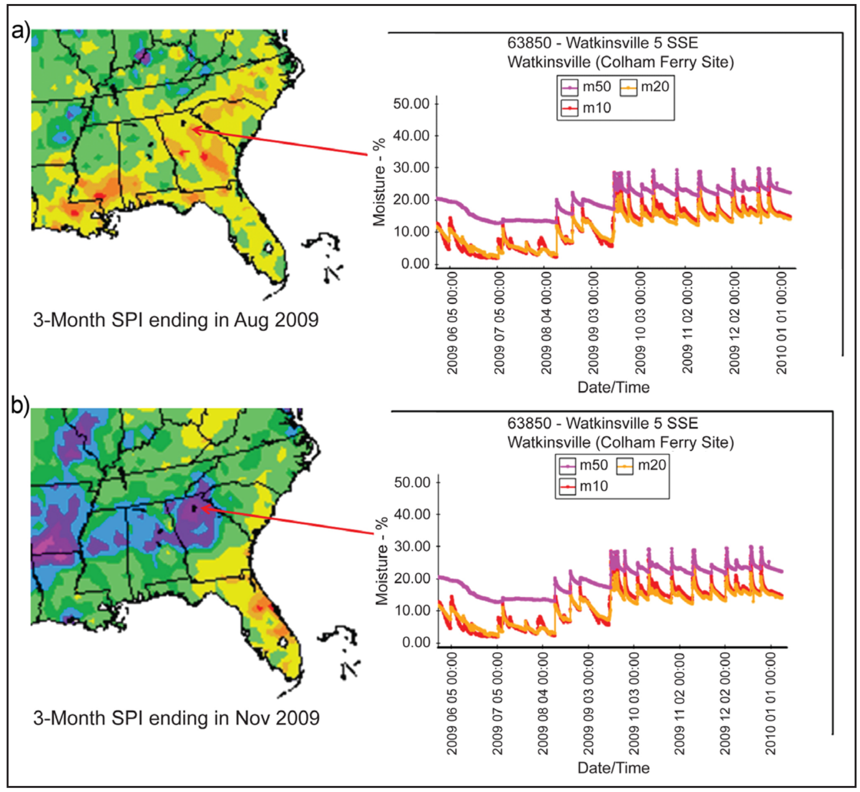



**Figure 7.** Comparison of soil moisture (volumetric water content—%) at the 5, 10, and 20 cm levels at Watkinsville, Georgia with regional map of three-month SPI: a) summer 2009; b) autumn 2009.

### 5.2.2 Soil Moisture Applications

The new soil moisture and temperature observations are quite useful for a variety of applications, especially in agriculture and hydrology. The utility of these measurements is demonstrated by comparing changes in soil moisture over time at the USCRN site near Watkinsville, Georgia, in comparison to other tools used for drought monitoring. This area was quite dry during the summer 2009 season, and quite wet during autumn 2009. Comparing the three-month standardized precipitation index mapped from precipitation measurements to soil moisture at Watkinsville, a strong relationship is seen in the two periods (Figures 7a and 7b). The soil moisture measurements provide considerably finer temporal resolution measurements of the state of drought at that location and, combined with the spatial information available from surface sites, can be quite valuable in drought monitoring. The changeover in U.S. Drought Monitor status matches well the evolution of soil moisture content during the late summer at the Watkinsville site (Figure 8).

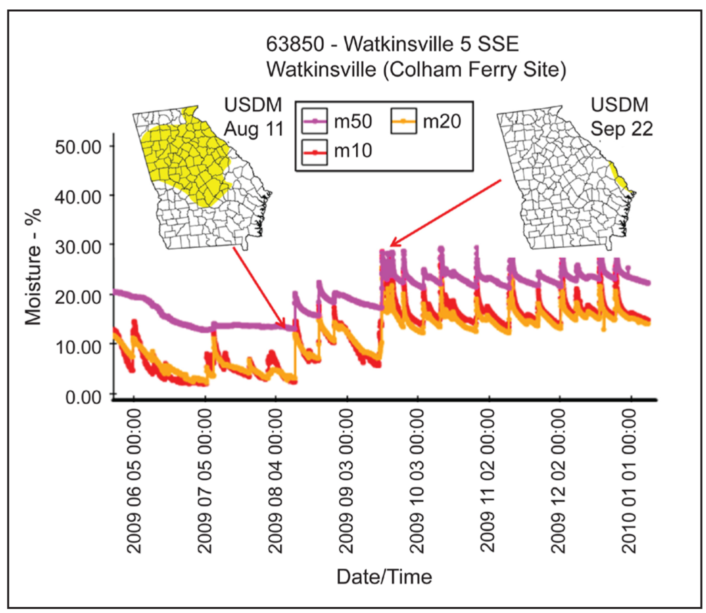



**Figure 8.** U.S. Drought Monitor evolution from the week of Aug 11, 2009, to the week of Sep 22, 2009, as soil moisture conditions improve at Watkinsville, Georgia.

## 5.3 Projects to Improve Data Processing and Product Quality

Much of the effort of USCRN staff at NCDC has been devoted this fiscal year to overhauling the software infrastructure of the program, originally put in place between FY 2004 and FY 2008. The existing infrastructure had a number of vulnerabilities, both in terms of Web security issues and in terms of the fragility of data processing systems. Both of these issues led to concern about the sustainability of this software infrastructure over the long term and the recognition of the need for improvement. This effort can be broken into five components: (1) consolidation of a shared code base; (2) rewriting servlets underlying the Web site and improving its look and function; (3) completely rewriting the ingest system; (4) adding additional functionality to the ingest system, including the soil variables and handling exceptions to normal QC processing; and (5) completing the station monitoring system and improving visualization of USCRN observations.

### 5.3.1 Shared Code Base

The USCRN software infrastructure, like that of many projects grown over a number of years, contained various components written at different times that actually performed similar functions. Four separate areas of code existed: Web site; data ingest and processing; text product generation; and creation of records for the Integrated Surface Dataset archive. Even slight differences in computer code can result in values of climate data being slightly different due to variable definitions, rounding, and inherent programming language characteristics. Therefore, an effort was started in FY 2010 to create a shared Java code base to provide consistency among our software projects, stimulate more rapid development, reduce redundancy, and decrease maintenance costs. This effort is well underway and is already reaping dividends of efficiency in working on the overall improvement of USCRN software systems.

### 5.3.2 Revised Web Site

The USCRN Web site has continued to be improved during FY 2010. While much of the primary Web developer time was devoted to the shared code base project and to rewriting and securing servlets underlying the pages accessing data on the Web site, the additional RUSHCN supported Web developer constantly improved the overall look and feel of the Web site, including the installation of a new USCRN logo (see report cover). In addition, a separate section of the Web site was created for documenting the RUSHCN program and its stations, while separately branding data access to these stations on USCRN Web tools. The figures in Section 4.2 are all available on the RUSHCN portion of the USCRN Web site at http://www.ncdc.noaa.gov/crn/hcnm/. It is through cooperation with the RUSHCN program that sufficient resources were available for this complex programming project to proceed. The key to the Web improvement overall was refreshing the Web site with a modern data access layer. In turn, this data access layer was incorporated into Web services that provide data to several of the new visualization products (see section 5.3.6), and it provides the basis for publishing new Web services for easier data access by end users in FY 2011.

### 5.3.3 New Data Ingest System

The USCRN data ingest rewrite project, which has been officially underway since April 2010, will address significant limitations of the current ingest system. This Java-based application will be easy to maintain and easy to enhance with new functionality, such as new reported and calculated elements. Additionally, it will have extensive unit tests built in to find defects quickly, thereby making it a more stable system.

We are following a strict development process for each milestone (Figure 9), beginning with a design review, implementing with test-driven development,

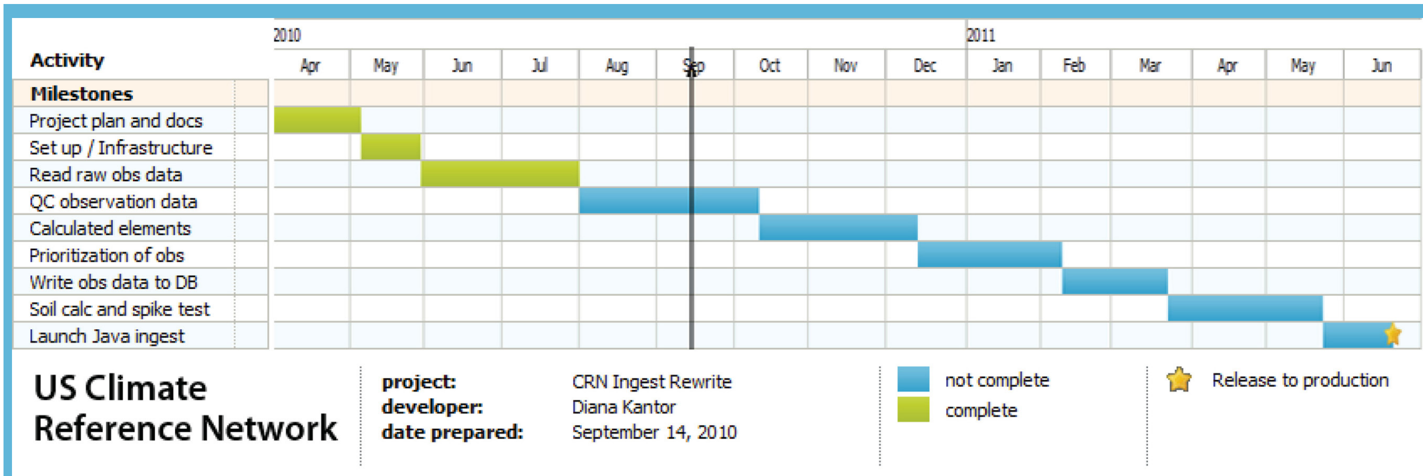



Figure 9. Milestone Chart for USCRN Data Ingest Rewrite Project.

and ending with a code review before moving onto the next group of functionality. This will ensure the highest quality for the application and will foster cross-team knowledge of the data ingest process.

The ingest plan has changed slightly in that the initial launch was originally to include only those pieces of functionality which are currently present in the existing ingest, with new functionality to be added immediately after. The initial launch has been expanded to include soil moisture/soil temperature and RH QC and calculated values, as well as prioritization of observations, i.e., determining whether an observation already in the database should be replaced by new observation data (Figure 10). These new milestones are essential additions after the core functioning is in place. Data exception handling procedures will be the next major addition after completion of the core ingest project.

### 5.3.4 Data Exception Procedures

USCRN is engineered to accurately observe climate, but all complex systems are subject to unanticipated conditions at some point. Exceptions are events which result in erroneous or highly suspicious data which are not automatically recognized and flagged by the USCRN processing systems. During March 2010, the USCRN Configuration Control Board adopted a Configuration Change request to allow for better handling of exceptions. Exceptions may be

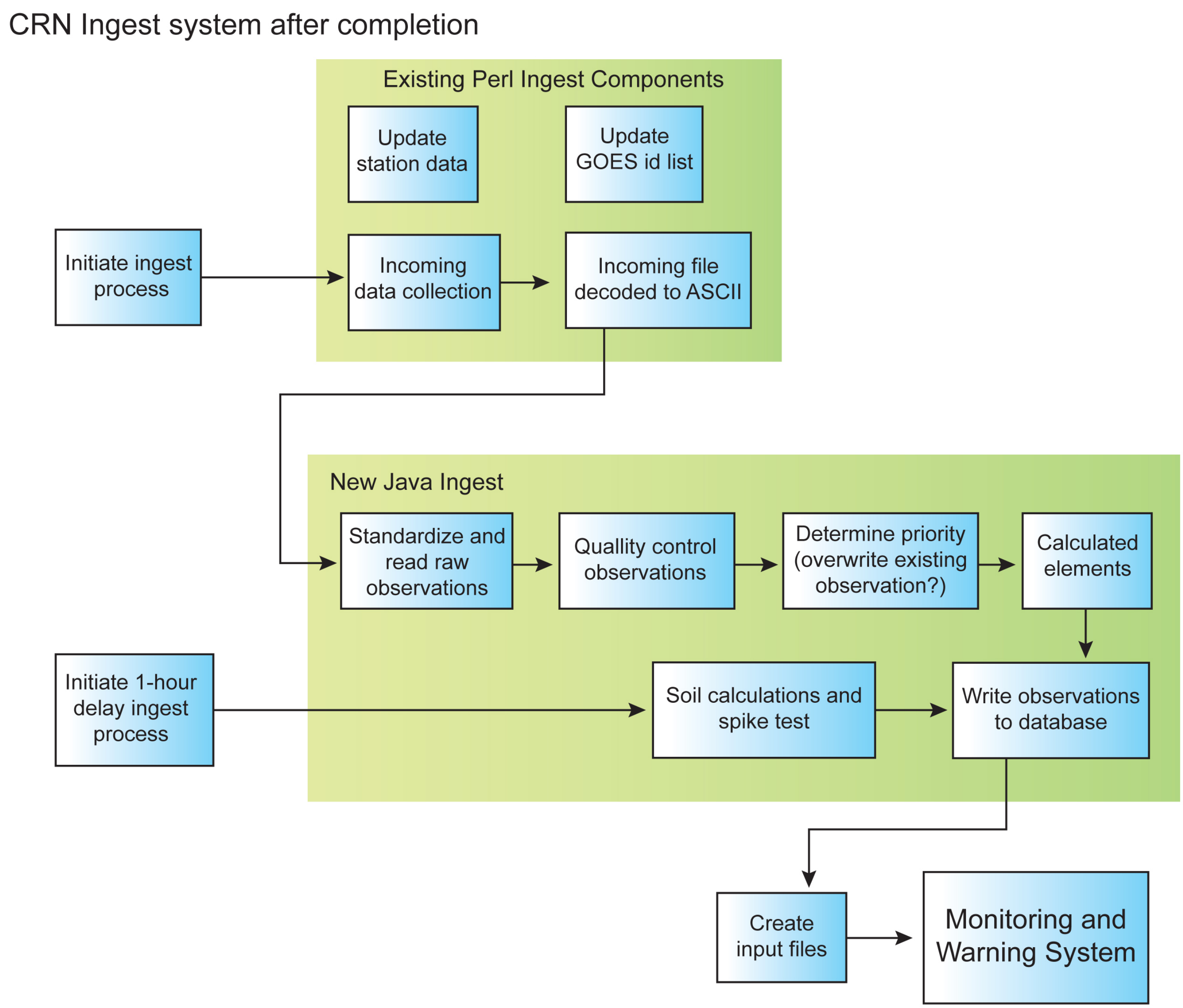



**Figure 10.** Milestone Chart for USCRN Data Ingest Rewrite Project

proposed by NCDC or external data users through submission of evidence documenting the exception to the USCRN Configuration Control Board Secretary.

For each event, the information will be gathered contain the registration date, date of last change to the exception, station identifier(s) (State, location, vector), the beginning and end times of the fault, a description or reference to a description of the fault, the affected variable(s), the impacted product(s) (e.g., hourly01, ISD), the exception, and the status of the exception solution (Suspicious, Under Analysis, Not Feasible, Feasible, Implemented). There is a significant difference between algorithmic fixes which universally detect an exception whenever and wherever it arises and algorithmic fixes which implement exceptions for specific events reported by credible metadata or credible external information. Exceptions will be retired if a fix is engineered at the station or in the communications system.

As is apparent, this is potentially a quite complex process, both in terms of its human components and in terms of its applications to the USCRN database and archive (Figure 11). Due to this complexity, a decision was made to proceed with the ingest rewrite first so that consideration of exception handling procedures would be incorporated in the ingest rewrite. This should allow the software development for an exception handling system to be done in a more straightforward way, fully compliant with the new ingest architecture.

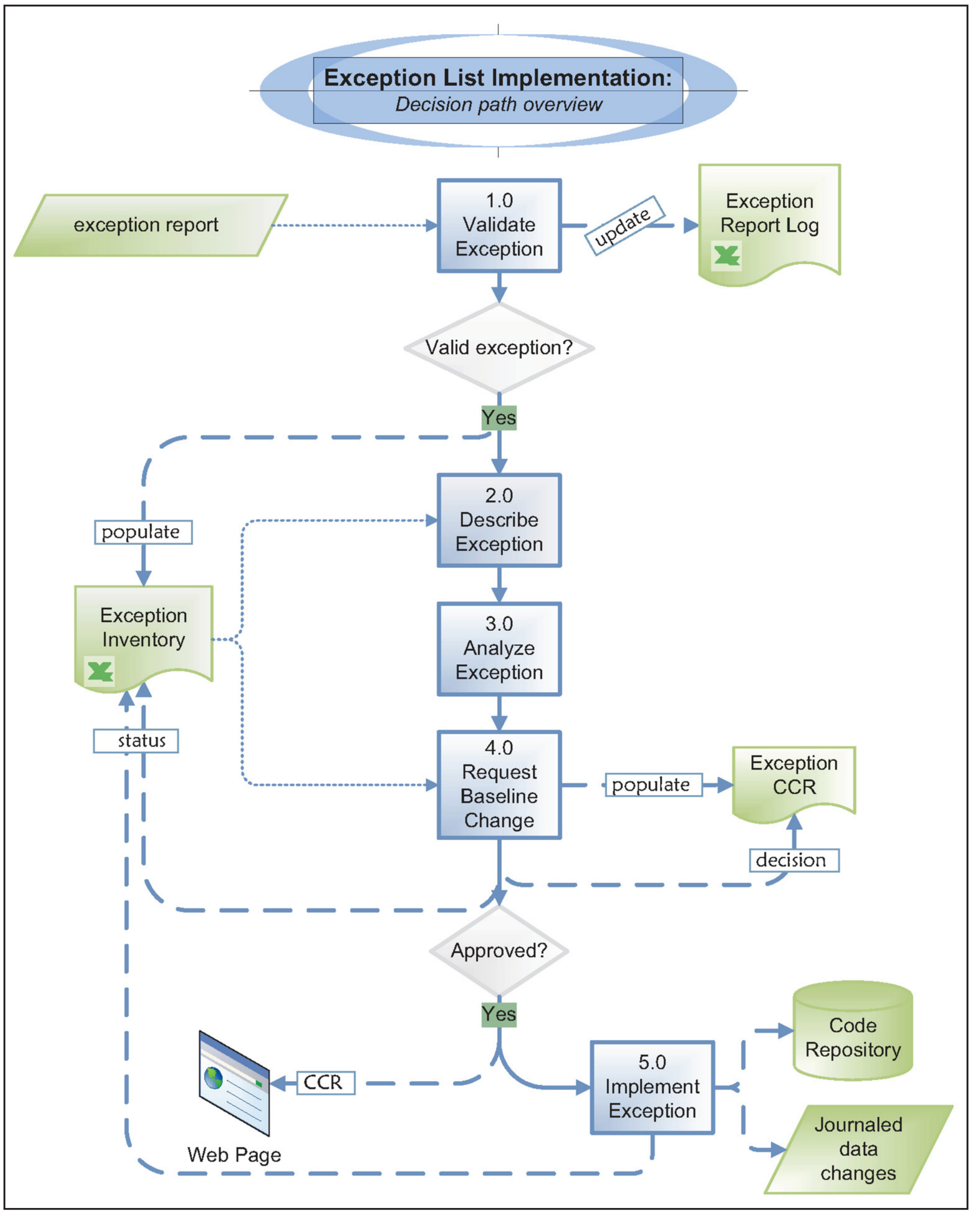



**Figure 11.** Flowchart of USCRN exception validation and handling procedures. Exceptions are events which result in erroneous or highly suspicious data which are not automatically recognized and flagged by the USCRN processing systems.

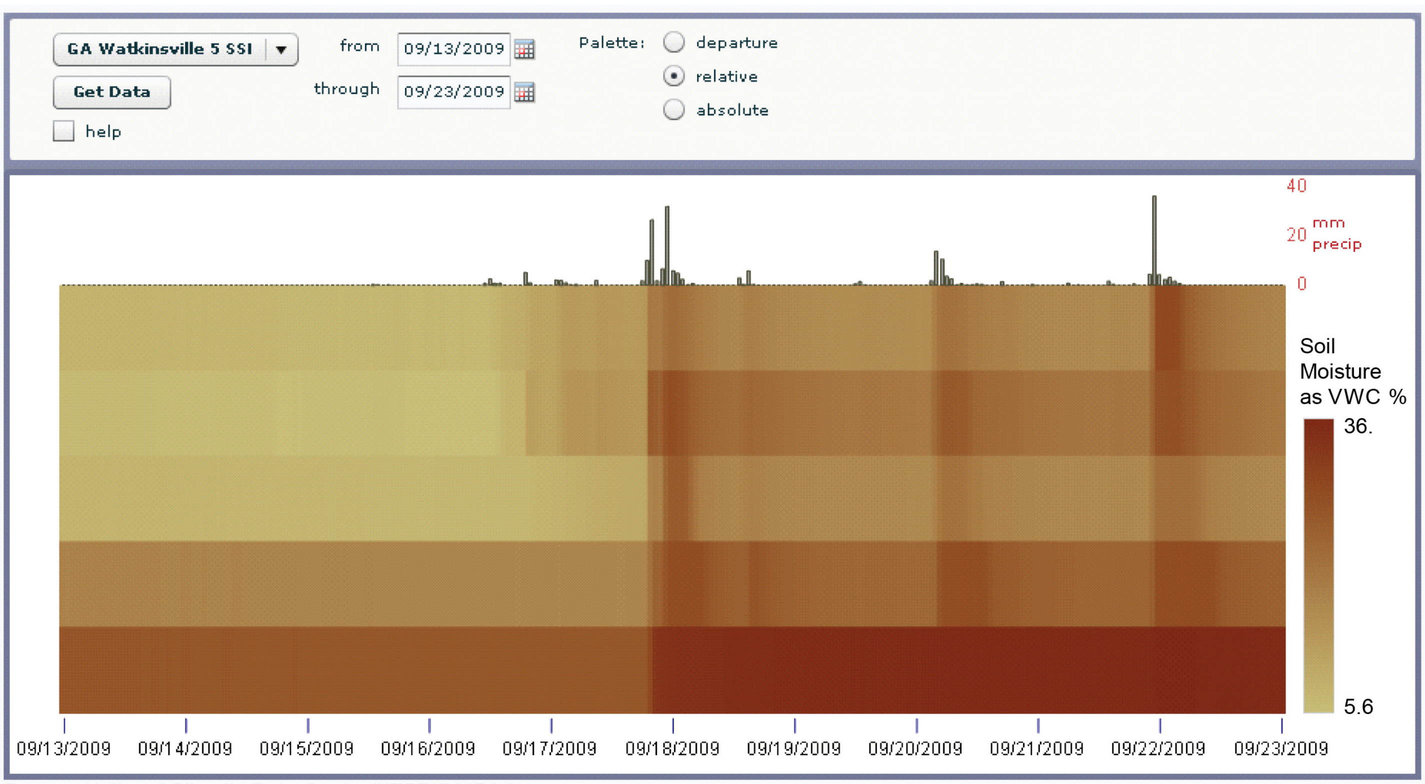
### 5.3.5 Station Monitoring System

With respect to the USCRN and RUSHCN systems, accuracy and reliability are critical attributes which must be maintained in order for collected climate data to be scientifically credible. To ensure the highest degree of credibility, all climate stations in these two networks must be constantly monitored for potential problems. As problems are identified, they must then be prioritized, diagnosed, and scheduled for maintenance. Traditionally, the operation of each station has been closely watched by trained engineers and scientists to look for signs of hardware or software failures. This manual observation approach worked well when the number of climate stations was small and there were enough people available to review climate station data frequently. But with the expected increase in the number of RUSHCN climate monitoring stations in the next few years, manual observation will become increasingly difficult and expensive. If the ability to monitor the networks is compromised, then it is possible that undetected failures at a station will prevent one or more of a climate monitoring network's performance measures from being achieved.

A new Station Monitoring and Reporting Tool (SMART) system has been developed during FY 2010 and is now operational. The system already possesses a growing set of monitors for notifying station engineers of potential problems. In addition, station engineers can configure personalized monitors for precise tracking of specific circumstances within the network. The SMART Web interface provides a straight-forward mechanism for creating and configuring personalized monitors. The interface guides engineers through five simple steps to create a new monitor: 1) selecting the type of monitor from a list of rule sets, 2) configuring parameters, 3) selecting station sensors (if applicable), 4) selecting specific stations, and 5) specifying a timeframe for the monitor to be active. Once the monitor design is finalized, the system will immediately assess incoming observations and begin sending e-mail notifications as necessary. It is envisioned that some of the project scientists will also enter monitors to be notified if a given climate event is measured, such as extreme cold temperatures or high winds, even if not directly related to station performance.

### 5.3.6 Data Visualization

The USCRN Web site now has a link dedicated to visualization of station data: http://www.ncdc.noaa.gov/crn/visualizations.html. The focus in this section has recently been placed on displays of soil moisture states, given the large interest in this variable and its great utility in real-time drought monitoring. Both of the visualizations described in the FY 2009 Annual Report are now operational, with one displaying soil moisture infiltration and percolation using a heat map approach (Figure 12) and one showing inter-hole range at each depth, which is unique for a network (Figure 13). This station at Watkinsville, Georgia, is the same that was used earlier to illustrate the utility of soil moisture measurements. In Figure 7a, it is easy to visualize the results of the first substantial rain in several weeks, when more than 100 mm of rain fell around September 17, 2009. The darkness of the five layers symbolizes the soil moisture content, with postevent soils much drier than before the rain event. Figure 7 showed this change with typical line graphs. In Figure 13, for the first time in a national network, one can see how soil moisture varies in the three




Source: National Climatic Data Center/NESDIS/NOAA

**Figure 12**. Soil moisture infiltration and percolation graph. A soil layer darkens when wetter, and lightens when drier. The time delay can be seen in the moistening of layers downward in response to precipitation events marked by the gray bars on top.

samples taken across the station area, with larger band thicknesses corresponding to larger differences between the wettest and driest individual samples at a depth.

The next step in USCRN visualization work will be to incorporate spatial maps of climate variables into the Web site. Figure 14 shows a prototype map based on Google Maps technology that will allow the display of USCRN solar radiation across the network for a given day. A brighter bulb represents a larger solar radiation total for the day. Placing a mouse on the board will cause the program to provide a text box with the numerical total of energy and draw a small line graph illustrating the diurnal cycle of solar radiation rate by the hour.

## 5.4 USCRN Climate Research

With the commissioning of 114 USCRN sites in the CONUS, there is now a large enough set of observations to allow useful and insightful climate analyses to be performed. During FY 2010, a paper was published (Menne et al. 2010) using USCRN temperature observations to confirm the reliability of national temperature time series derived from homogenized cooperative observer network data. The utility of using USCRN technology for high-elevation climate networks was examined, along with lessons learned from the consideration of how numbers are rounded in USCRN software. An increasing number of users/collaborators are using the USCRN data for various science applications. Finally, USCRN is in the process of hiring two research associates to perform science analysis to support the network and increase our knowledge of climate change and variation in the United States. As the years go by and more data are gathered, increasing amounts of climate science and applications will be based on the USCRN dataset.

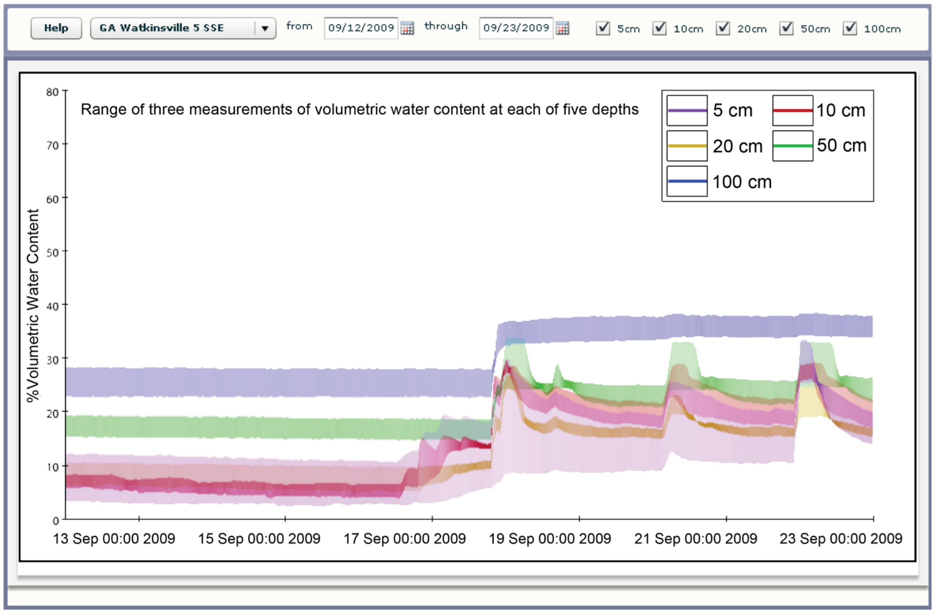



**Figure 13.** Graph of the range of the three soil moisture measurements at each depth for Watkinsville, Georgia, for the same period shown above. The width of each color band for each layer is a function of the difference between the driest and wettest individual samples of the three. Transparency of the graph allows the ranges of all five depths to be seen simultaneously.

### 5.4.1 USCRN Observations Confirm Reliability of U.S. Temperature Record

Since USCRN stations were initially commissioned beginning in FY 2004, the network has grown from 40

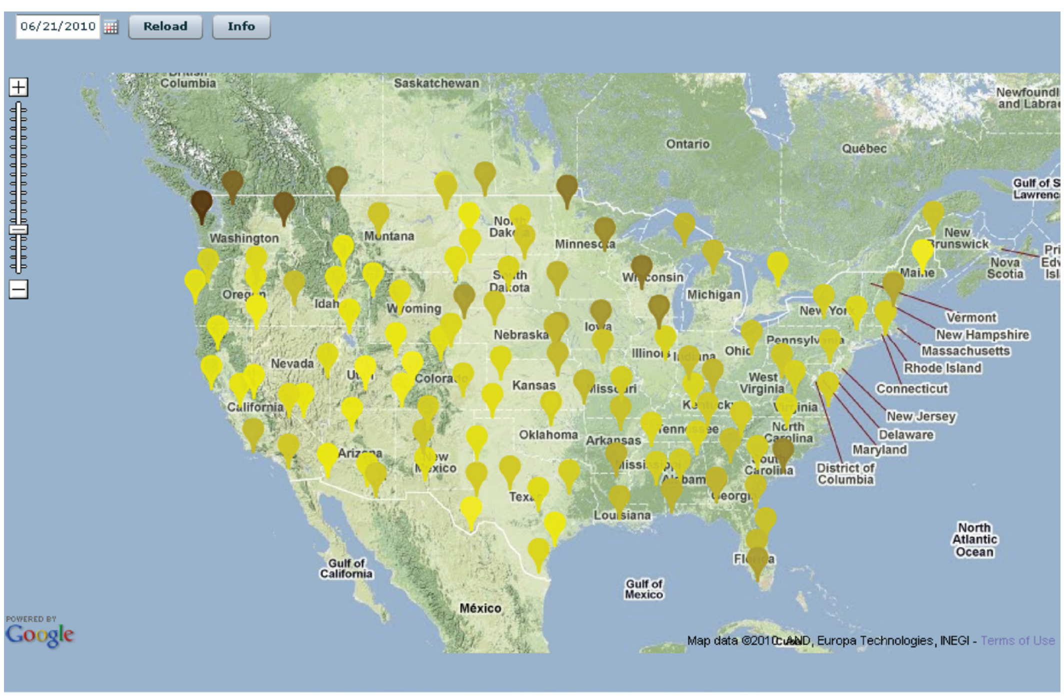



**Figure 14**. Map of solar radiation data received by USCRN on June 21, 2010.

stations distributed across the United States to the final plan number, with 114 stations observing a full year of data in FY 2009. While neither 40 nor 114 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.[5] Therefore, annual U.S. air temperatures from 2004–09 were available from the USCRN to compare to USHCN V2.

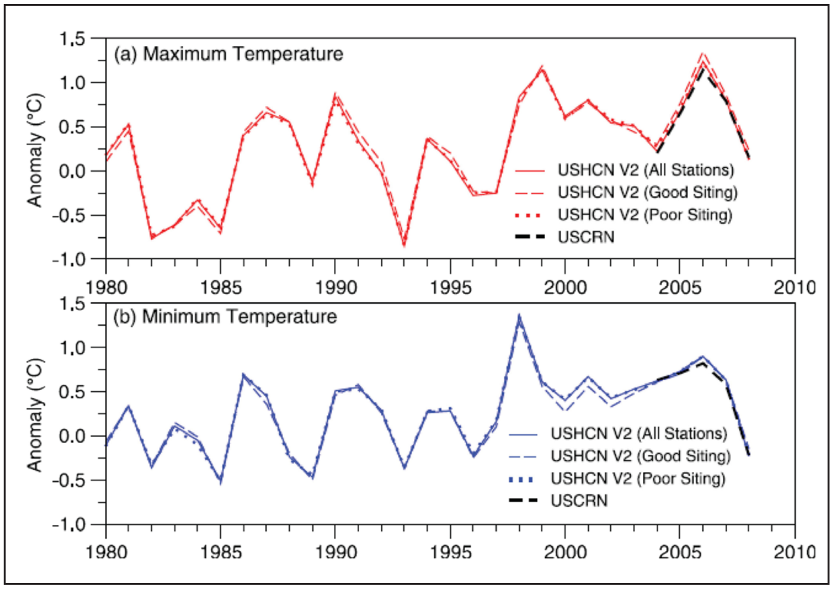



**Figure 15.** Homogenized national temperature departures from all USHCN V2 cooperative observer network stations, and those with good and poor siting, compared in the last five years to USCRN national temperature departures (from Menne et al. 2010).

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, 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.[6] 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 CONUS air temperature departures for the period from 2004–08 are extremely well aligned with those derived from the national USHCN V2 (Figure 15). 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.[7]

### 5.4.2 Application of USCRN Observing Approaches at High Elevations

USCRN stations are engineered to operate largely autonomously with great reliability and accuracy. This approach has proven to be robust in the most extreme environments, from extreme cold (-49°C) to extreme heat (+52°C), in areas of heavy precipitation (4,700 mm per year), and in locations impacted by strong winds, freezing rain, and other hazards. In addition to a number of stations enduring extreme winter environments in Alaska and the northern United States, seven of the USCRN stations are located at elevations over 2,000 m, including stations on Mauna Loa, Hawaii (3,407 m) and on Niwot Ridge above Boulder, Colorado (2,996 m). USCRN compatible temperature instrumentation and a radiation shield have also been installed and run successfully at a station maintained on the Quelccaya Ice Cap by the Climate System Research Center at the University of Massachusetts (see http://www.geo.umass.edu/climate/). A paper was submitted to the AMS Journal of Hydrometeorology examining the high-elevation performance of the USCRN during its brief lifetime and the potential utility of its triplicate temperature instrument configuration for measuring

5 Vose, R.S., and M.J. Menne, 2004: A method to determine station density requirements for climate observing networks. J. Climate, 17, 2961-2971.

6 Sun, B., and T.C. Peterson, 2005: Estimating temperature normals for USCRN stations. Int. J. Climatol., 25, 1809-1817.

7 Menne, M.J., Williams, Jr., C.N., and Palecki, M.A., 2010. On the reliability of the U.S. surface temperature record. J. Geophys. Res., 115, D11108, doi:10.1029/2009JD013094.

climate change at elevation. One of the more important outcomes was the finding that the USCRN triplicate temperature measurement approach did result in a greater coverage of observations over time relative to individual instruments. Even more interesting, in the Western United States, reliability of data availability reached a maximum at midrange elevations (1000–1500 m), with reliability at high elevations no worse than at low elevations (Figure 16).

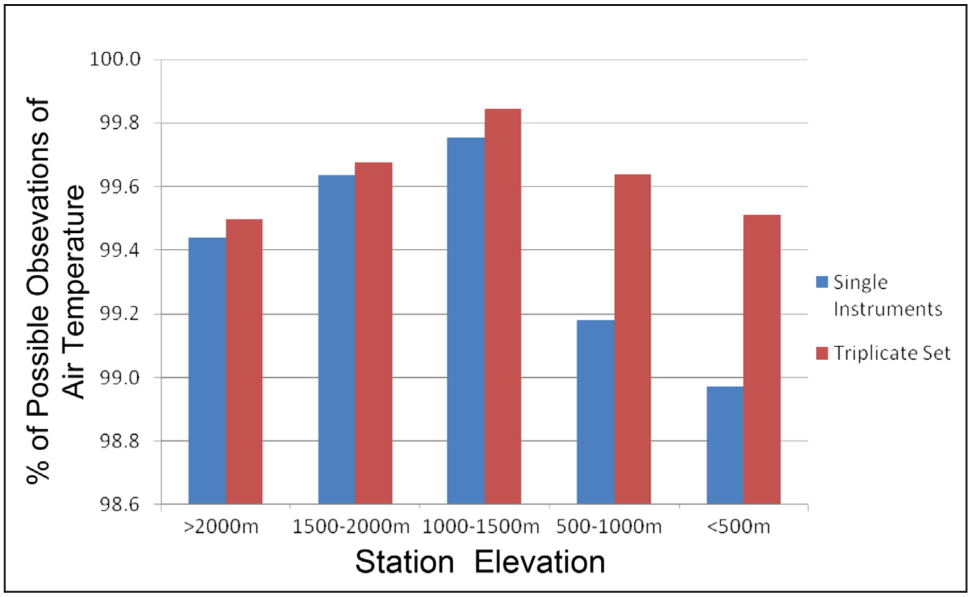



**Figure 16.** Western U.S. USCRN air temperature observations from 2007–09, comparing the percent of possible observations of five-minute air temperature received from the individual PRTs (blue) versus the percent of times when it was feasible to use the three PRT sets to calculate temperature for a five-minute period.

Examining the seasonal temperature departures for 2004–08 from 1971–2000 normals, the USCRN stations in the Western United States at altitudes above 1,800 m displayed substantially more positive temperature departures for the period than low-altitude stations (Table 6). While only five years of data did not yield statistically significant differences, it is clear that if these differences are maintained for several more years, they will become more statistically significant. The study showed that it is very important to cover the full distribution of elevations in a region to accurately determine regional climate departures and trends, and that USCRN approaches work well at high elevations.

**Table 6. USCRN high-elevation (> 1,800 m) and low-elevation (< 800 m) area-averaged maximum and minimum seasonal temperature departures for 2004–08 in the Western United States. The high-elevation seasonal departures are warmer and have more variance than the low-elevation seasonal departures relative to the 1971–2000 normal period, but none of the differences are statistically significant for this brief period.**

| Seasonal Area Averages | High-Elevation Stations | Low-Elevation Stations | Difference High–Low |
|---|---|---|---|
| Maximum Temperature | | | |
| Average (°C) | 0.65 | 0.44 | 0.21 |
| Standard Deviation (°C) | 1.16 | 0.83 | 0.32 |
| | | | |
| Minimum Temperature | | | |
| Average (°C) | 0.50 | 0.33 | 0.17 |
| Standard Deviation (°C) | 0.88 | 0.66 | 0.22 |

### 5.4.3 Rounding Numbers

Prior to developing a shared code base for USCRN software systems, one could find a number of examples where hourly or daily calculated variable values could be slightly different on the USCRN Web site tables compared to Integrated Surface Dataset records or formatted text products. These differences not only motivated the creation of the shared code base but also brought into question the use of rounding in all climatological calculations everywhere. An ad hoc committee was formed in the National Data Stewardship Team, and under USCRN leadership, an analysis of rounding was completed and a set of suggested best practices identified in a paper submitted to the AMS Journal of Applied Meteorology and Climatology. While there were certain limitations to the range of possibilities due to existing WMO and NWS requirements, the implementation of the set of best practices was shown to be highly effective and surprisingly impactful. For example, allowing an additional digit in calculating degree days led to the discovery of substantial biases in many existing calculations (Figure 17). Since single degree day swings can cost energy companies millions of dollars, adopting uniform and more accurate rounding methods could be greatly beneficial.

### 5.4.4 USCRN Science Outreach

The USCRN Program has been very active in working to provide information and data for satellite calibration/validation (cal/val) efforts, and has participated in several projects in FY 2010. NCDC's Remote Sensing and Applications Division is collaborating with the USCRN Program via the Climate Data Records (CDR) program to study the representativeness of the downward infrared derived skin or surface temperature collected at USCRN sites to determine its utility for calibrating and validating surface temperatures measured by polar orbiting satellites. The CDR program has also funded research by Boston University to use high-resolution satellite imagery to estimate the homogeneity of land use around selected USCRN sites, which will have a more general application to all potential satellite cal/val users.

The onset of the collection of soil moisture and temperature data has engendered great interest in using the 5 cm-level observations for satellite cal/val projects. The National Aeronautics and Space Administration (NASA) Soil Moisture Active and Passive (SMAP) satellite program to fly in 2014 has already enlisted USCRN assistance, with members of the science and engineering groups attending both the first cal/val workshop for SMAP, as well as the first SMAP applications workshop. The USCRN has been invited by the USDA and NASA to be participants in the first soil moisture test bed for SMAP, to be located near two USCRN stations in Stillwater, Oklahoma. The utility of USCRN observations for enhancing satellite based CDRs is quite high, and this type of activity is expected to expand in future years.

Without personnel specifically oriented to outreach or education, the communication to potential user communities is largely accomplished through Web activities and attending science meetings. Improvement of content was a key focus of FY 2010, including more data visualization capabilities, and in FY 2011, more reporting pages will be added to the Web site on USCRN-based science. We will encourage the climate community to visit the Web site and use our data products through listserv messages and meeting attendance. At certain milestones, public outreach through NOAA press releases or news items may be suitable.

Engagement with our site hosts is also critical to our efforts, both to inform them about ongoing USCRN activities and to encourage continued diligence on their part regarding site stability and station health. Output for a more personal form of communication with site hosts is being designed that will be customized to the individual station and includes a page of data summaries for the previous year. A set of short videos has been produced giving a tour of a USCRN station and this will be available on the climate portal and on the USCRN Web site eventually. Collaboration with the new communication coordinator for NCDC will lead to a more substantial outreach program being developed for the USCRN Science program in FY 2011.

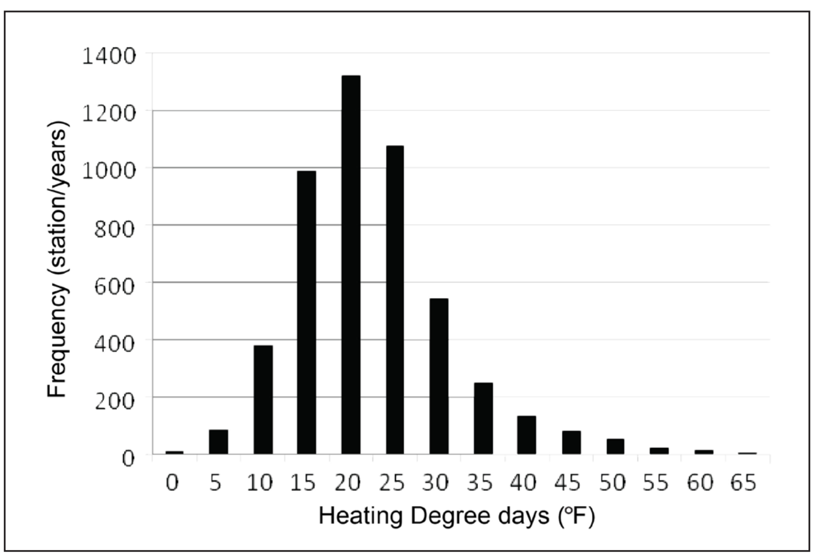



**Figure 17.** The bias in heating degree days (HDDs) for 132 cooperative observer program network stations with 98% data completeness between 1970 and 2007. For each station and year, the HDD total calculated with a rounded integer representing the daily average temperature is differenced from HDD total calculated from daily averages that retain an extra digit of precision and are not rounded. The average bias is +20.1 units, or +0.41% of the annual total.

## 5.5 Research Papers and Meeting Presentations in FY 2010

Palecki, M.A., and M. Brewer, 2009: The U.S. Climate Reference Network Soil Moisture/ Soil Temperature Observations for Drought Monitoring, U.S. Drought Monitor Forum, Austin, TX, October 2009.

Palecki, M.A., and C.B. Baker, 2010: Expansion of U.S. Climate Reference Network capabilities. 15th Symposium on Meteorological Observation and Instrumentation, American Meteorological Society, Atlanta, GA, January 2010.

Palecki, M.A., and C.B. Baker, 2010: Monitoring Drought with the U.S. Climate Reference Network. 18th Conference on Applied Climatology, American Meteorological Society, Atlanta, GA, January 2010.

Palecki, M.A., and C.B. Baker, 2010: U.S. Climate Reference Network: A National Network Monitoring Climate Change (Poster). 18th Conference on Applied Climatology, American Meteorological Society, Atlanta, GA, January 2010.

Williams, C.N., M.J. Menne, and M.A. Palecki, 2010: On the Reliability of the U.S. Surface Temperature Record, 22nd Conference on Climate Variability and Change, American Meteorological Society, Atlanta, GA, January 2010.

Palecki, M.A., 2010: Monitoring drought with U.S. Climate Reference Network Soil Moisture Observations. Annual Meeting, Association of American Geographers, Washington, D.C., April 2010.

Menne, M.J., Williams, Jr., C.N., and Palecki, M.A., 2010. On the reliability of the U.S. surface temperature record. J. Geophys. Res., 115, D11108, doi:10.1029/2009JD013094.

Palecki, M.A., and P. Ya. Groisman, 2010. Observing climate at high elevations: Lessons learned from the United States Climate Reference Network. Submitted to Journal of Hydrometeorology June 2010.

Palecki, M.A., M.C. Knapp, M.C. Kruk, and E.Davis, 2010. Rounding in climatological calculations. Submitted to Journal of Applied Meteorology and Climatology, August 2010.

Palecki, M.A., 2010 : U.S. Climate Reference Network Overview and Historical Climatology Network Modernization. Annual Meeting, NOAA Central Region Team, Asheville, NC, September 2010.

## 6. FY 2010 INTERNATIONAL COOPERATION

### 6.1 The Canadian Climate Partnership and Technology Exchanges

The first nation to duplicate USCRN technology and practices was Canada. In August 2008, a Canadian RCS station was deployed at the USGS EROS Data Center in Sioux Falls, South Dakota, which serves as one of the USCRN formal testing sites. It is anticipated that network transfer functions will be examined between the two networks starting in FY 2011. Such transfer function determinations between these two national nets would increase the geographic spatial area of homogeneous long-term climate observations over North America by more than 100%.

United States/Canada discussions have included:

- The role played by triple temperature and precipitation sensor configurations;
- Processing multiple observations into single temperature and precipitation values using standardized algorithms;
- Field lessons learned, such as experience in measuring solid precipitation;
- Detecting, reporting, and tracking anomalous events for station maintenance;
- Installation, maintenance, and inspection protocols;
- Using the Internet to disseminate data and documentation; and
- Quality control procedures.

Currently, the Canadian RCS has deployed the triple configuration at 303 sites and is in the beginning stages of implementing the USCRN precipitation algorithm.

A representative of Agriculture and Agri-Food Canada expressed interest in colocated soil moisture measurements in anticipation of the deployment of a soil moisture measurement network in Southern Canada. This possibility will be pursued during FY 2011.

## 6.2 The Global Climate Observing System (GCOS) Program and the USCRN

In addition to United States/Canada activities, USCRN stations have been selected for deployment in various environments on other continents where assistance in modernization is desired. Towards this end, two USCRN-technology stations outside the CONUS were configured to be GCOS-USCRN test stations (high-elevation and high-precipitation-environment stations). These two stations on Mauna Loa and in Hilo were deployed to two extreme Hawaiian environments as prototypes[8] for possible future deployments in the Andes and in high-precipitation environments. GCOS has cooperated with a group from the University of Massachusetts in placing the USCRN-type temperature sensor configuration at a station on the Quelccaya Ice Cap in Peru. About two years of measurements yielded a sample of 212,000 five-minute observations, during which the two most closely matched platinum resistance thermometers recorded temperatures within 0.1°C 98.4% of the time, and all four thermometers averaged within 0.025°C for the whole period. The USCRN configuration was robust and accurate through extreme conditions at high elevation.

GCOS-USCRN test stations in Alaska at St. Paul Island and Sitka were instrumental in leading to the development of the Alaska USCRN program. In 2010, GCOS supported the installation of a fully-capable USCRN station at the Roshydromet Tiksi observatory in the Russian Arctic of Siberia at 72°N and 128°E. This is the first fully configured USCRN station installed outside of the Americas and illustrates GCOS' support for expanding globally the application of the USCRN approach to climate monitoring and improving climate change detection in the polar region.

In FY 2008, NCDC entered into a formal Memorandum of Understanding (MOU) with the Smithsonian Tropical Research Institute which, based on available funding, would allow the two agencies to collaborate in installing and maintaining up to 20 sites at STRI tropical research areas around the globe over the next 10 years. At a minimum, the USCRN program is investigating some preliminary site survey work for a possible initial installation of a USCRN station at the STRI site at the Luquillo Experimental Forest station in Puerto Rico. At this time resources preclude installing sites here, but the program still has great interest in this climate region as well.

## 6.3 International Precipitation Test Bed Activities Involving USCRN

Precipitation is one of the most important atmospheric variables in support of applications related to ecosystems, hydrologic systems, climate, and weather forecasting. Despite its importance, the accurate measurement of precipitation remains a challenge. The lack of current and complete intercomparison testing has led researchers to discount the importance and severity of measurement errors. These errors are exacerbated for the automated measurement of solid precipitation and underestimates in the range of 20–50% are common. While solid precipitation measurements have been the subject of many studies, there have been only a limited number of coordinated assessments on the accuracy, reliability, and repeatability of automatic precipitation measurements. The most recent comprehensive study, the "*WMO Solid Precipitation Measurement Intercomparison*" concluded in 1998,[9] focused on manual techniques of solid precipitation measurement. Precipitation gauge technology has changed considerably in the last 12 years and the focus has now shifted to studying automated techniques.

The XV WMO Commission for Instruments and Methods of Observation management meeting in September 2010 approved an international study on solid precipitation that will include snowfall and snow depth measurements in various regions of the world in a multisite experiment. The USCRN precipitation test bed in Marshall, Colorado, will be a participant in this intercomparison along with sites from Canada, Japan, Switzerland, and New Zealand. The goals for

8 The U.S. GCOS program is investigating the possibility of installing a third Hawaiian USCRN experimental station at a high-elevation site at Haleakala National Park on the island of Maui.

9 Goodison B.E., P.Y.T. Louie, and D. Yang, 1998: WMO solid precipitation measurement intercomparison, World Meteorological Organization, Instruments and Observing Methods, Report No. 67, WMO/TD - No. 872, 88 pp.

the intercomparison are to assess the methods of measurement and observation of solid precipitation, snowfall, and snow depth at automatic unattended stations used in cold climates (e.g., polar and alpine), and the following actions will be undertaken:

- Document the needs and assess the compatibility of measurement standards and requirements of WMO Technical Commissions for the measurement of solid precipitation, snowfall and snow depth at automatic unattended stations.

- Prepare national summaries of methods, issues, and challenges of automated solid precipitation measurement in cold climate countries. Information needed includes, the instrumentation used, shielding configuration, measurement intervals, processing algorithms, wind adjustment procedure (if applicable), height of wind measurement, etc.

- Assess need for intercomparison of methods and equipment for automated snowfall/snow depth/precipitation measurements in cold climate regions, on both global and regional basis and develop an intercomparison plan.

## 7. USCRN STATION DATA

Historical meteorological and climatological observations are often compromised by nonstandard equipment, incomplete records, poor sensor exposure or poor siting, observer discontinuities, and other related issues. The impact of these issues concerning historical data provenance, continuity, and general quality becomes more serious over time. Tremendous strides have been made in improving the utility of these historical data through the development of sophisticated statistical approaches for the homogenization of time series. However, a far better pathway for detecting future climate change is the establishment of an observation network that avoids these pitfalls through its design and maintenance.

These issues have been addressed in the design and fielding of the USCRN, and the foundation has been established towards generating high-confidence climate attributions from this network. With completion of the deployment phase and the collection of more than nine years of data at some stations, we are reaching the point of being able to derive meaningful climate insights from this network. While a 10-year period-of-record is recommended for conservative applications of USCRN to the study of climate change at the national level, efforts made in FY 2010 to begin to link these new and relatively brief records to longstanding homogenized climate records for purposes of climate monitoring were successful, as discussed in Sec 5.4. USCRN stations are already serving as robust and stable platforms for monitoring extreme events. The inclusion of battery backup and in some cases solar panels has enabled USCRN stations to continue operating during severe weather conditions.

### 7.1 Operations During Extreme Conditions

The USCRN program learned a lesson right in its own backyard this past December 2009, when a snowstorm brought more than 15 inches of snow to the Asheville, North Carolina, area. The USCRN station at the North Carolina Mountain Horticultural Crops Research Center weathered the storm well and did not lose any data despite widespread power outages. However, when power was lost at the North Carolina Arboretum site, there was an unexpected loss of data due to the failure of a small data logger battery. The system engineers learned from this lesson that as data logger batteries age, they become increasingly vulnerable to sudden loss of charge. Therefore, as stations are visited during AMVs this year and next, the datalogger battery will be eliminated by powering the data loggers directly from the main battery power source, which at an AC station should last 10 or more days while waiting for power restoration.

The most interesting extreme event visited upon the network in FY 2010 was a windstorm that swept across Nebraska on May 24, 2010. A 10-second peak wind gust of 32.46 meters/second (73 mph) was recorded at the 1.5 m-level anemometer on the USCRN station at Whitman, Nebraska, as a squall line passed during late afternoon (Figure 18). This is a very high wind speed at a level so close to the ground and reflects the actual wind forces impacting the station. Despite this station being solar powered with a large surface area solar panel, it was able to continue working through the event and was still operational well after the event.

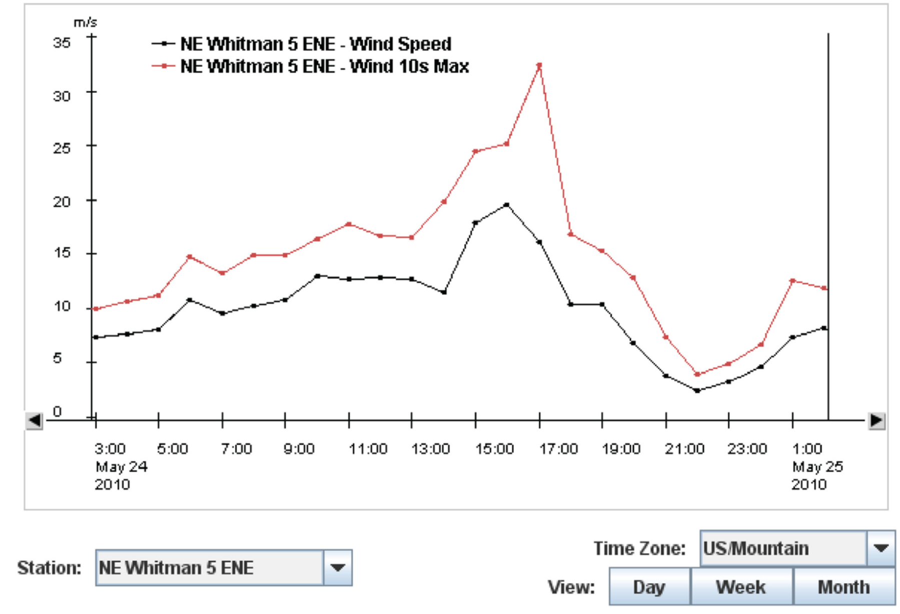



**Figure 18.** Record wind event at the USCRN station at Whitman, Nebraska, May 24, 2010. The peak 10-second wind gust was 73 mph.

Another example of the robustness of the USCRN station design occurred on September 27, 2010, when the official NWS maximum temperature for downtown Los Angeles, California, reached 45°C (113°F), setting a new period-of-record extreme for that location; but unfortunately, the official NWS recording instrument then failed. However, the USCRN station at Fallbrook, California, about 75 miles to the southeast, continued operating, reaching 44.9°C and 44.8°C (both 113°F when converted and rounded) for five-minute periods during the afternoon at 1:25 pm and 2:50 pm local time, respectively (Figure 19). Wind speeds were light, indicating this was not likely due to Santa Ana winds, and humidity levels were less than 10%. Interestingly, the USCRN station in Death Valley reached only 44.7°C (112°F), while the USCRN station on the coast at Santa Barbara, California, was a relatively pleasant 29.7°C (85°F).

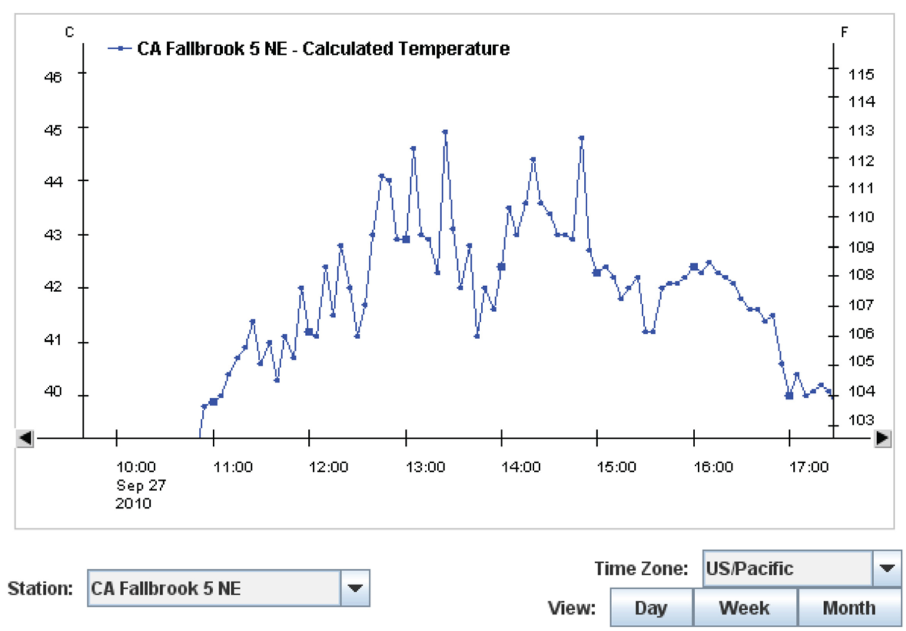



**Figure 19.** Calculated air temperature at the USCRN station near Fallbrook, California, on September 27, 2010, when downtown Los Angeles, California, set a new all-time record for maximum temperature.

Both of these events illustrate the robust materials, configuration, and great physical security of USCRN engineering inherent in the design of this premier climate observing network.

## 7.2 Defining the Ranges of Parameter Records: The Present USCRN Network Records and Ranges

Despite the short period-of-record of the USCRN network, records of various parameters from this network are of interest because of their high confidence levels, the known calibrations of the sensors, and the precision measurement ranges of the various sensors.

The network has already recorded some significant events and it will record more and more varied events in the future, so this early collection of records should be considered only the first part of a dynamic tale.

Variables indicated as records in Tables 7 and 9 are records measured strictly by USCRN stations.

Note: The Quinault 2007 water year record is 52.21” greater than the 37-year mean water year total of 132.69” from the Ranger Station site one mile to the SSW. The greatest water year record total for the Quinault area is 186.22” set during the 1972 water year (Oct 1, 1971–September 30, 1972).

## 8. USCRN DOCUMENTATION ACCESS: SELECTED INTERNET ADDRESSES BY TOPIC

The USCRN Team is aware of and sensitive to the multifunctional, multilevel composition of the climate science community that accesses and uses the USCRN Web pages. As a result, the USCRN Web pages were revised beginning in FY 2009, and continuing into FY 2010, in an effort to conform to as many of the suggestions and needs of the user community as possible. This is an iterative process, that is, the USCRN Team is learning continuously and attempting to satisfy the climate science community needs as they are made known, and as resources allow. This gradual improvement process should match needs with data and with resources. It is most practical to acknowledge that this process will continue as it is not yet at a fully satisfactory level for all possible users.

New applications and products will be forthcoming in the years to come. Because of these changes, there will be some changes in Web addresses for familiar products and Web pages. Therefore, it is suggested that users go to the main level and utilize the new navigation bars to find what is needed.

USCRN Home:
<http://www.ncdc.noaa.gov/crn/>

USCRN Program Documents:
<http://www.ncdc.noaa.gov/crn/docs.html>
This link includes references to the following:

- USCRN Program Development Plan, Functional Requirements, and Configuration Management Documents
- USCRN Site Information Handbook and Station Commissioning Plan

**Table 7. USCRN Temperature Records**

| USCRN Temperature Records (°F) |
|---|
| Highest Air Temperature = 126°F<br>Stovepipe Wells, CA; July 5, 2007 |
| Lowest Air Temperature = –57°F<br>Barrow, AK; February 3, 2006 |
| Highest Ground Surface Temperature = 162°F Stovepipe Wells, CA; June 24, 2006 |
| Lowest Ground Surface Temperature = -58°F<br>Barrow, AK; February 3, 2006 |

**Table 8. USCRN Maximum & Minimum Temperature Duration Streaks (Days)**

| Maximum Temperature Durations: Stovepipe Wells, Death Valley, CA | |
|---|---|
| 120°F: 8 Days | July 13–20, 2005 |
| 110°F: 32 Days | June 13–July 14, 2007 |
| 100°F: 98 Days | June 9–September 14, 2007 |
| 95°F: 126 Days | May 30–October 2, 2008 |
| 90°F: 132 Days | May 12–September 20, 2005 |
| **Minimum Temperature Durations, Barrow, AK** | |
| –50°F: 2 Days | February 3–4, 2006 |
| –30°F: 11 Days | January 8–18, 2008 |
| 0°F: 67 Days | January 8–March 15, 2005 |
| <32°F: 234 Days | October 12, 2006–June 2, 2007 |

**Table 9. USCRN Precipitation Records (inches)**

| USCRN PRECIPITATION RECORDS (INCHES) (November 2000–September 2010) | | | |
|---|---|---|---|
| Event | Amount | Location | Date |
| Greatest 5-minute | 0.73” | Titusville, FL | Jul 7, 2006 |
| Greatest 5-minute | 0.73” | Lander, WY | Jul 25, 2007 |
| Greatest 15-minute | 1.89” | Titusville, FL | Jul 7, 2006 |
| Greatest 30-minute | 3.08” | Titusville, FL | Jul 7, 2006 |
| Greatest 60-minute | 3.77” | Titusville, FL | Jul 7, 2006 |
| Greatest 24-hour | 19.64” | Hilo, HI | Feb 1-2, 2008 |
| Greatest 1-Day | 17.83” | Hilo, HI | Feb 2, 2008 |
| Greatest 5-Day | 42.23” | Hilo, HI | Feb 1–5, 2008 |
| Greatest 7-Day | 46.86” | Hilo, HI | Jan 30–Feb 5, 2008 |
| Greatest 30-Day | 63.46” | Hilo, HI | Jan 16–Feb 14, 2008 |
| Greatest 365-Day | 184.90” | Quinault, WA | Oct 1, 2006–Sep 30, 2007 |

Note: The Quinault 2007 water year record is 52.21” greater than the 37-year mean water year total of 132.69” from the Ranger Station site one mile to the SSW. The greatest water year record total for the Quinault area is 186.22” set during the 1972 water year (Oct 1, 1971–September 30, 1972).

- USCRN Field Maintenance Plan

- USCRN detailed documentation on metadata, data processing, instrument monitoring, data documentation, and station installation/ maintenance

USCRN annual reports dating back to FY 2003 can be found at:
< http://www.ncdc.noaa.gov/crn/annual-reports.html>

Detailed data and documentation about USCRN site hardware, sensors, and calibration hardware can be found at:
< http://www.ncdc.noaa.gov/crn/instrdoc.html>

The most direct way to access the data from the USCRN stations via Web tables:
<http://www.ncdc.noaa.gov/crn/observations.htm>

The most direct way to access the hourly and daily data from USCRN stations in text products:
< http://www.ncdc.noaa.gov/crn/products.html>

The most direct way to access graphics visualizing data from USCRN stations:
< http://www.ncdc.noaa.gov/crn/visualizations.html>

The most direct way to access USCRN station information and metadata:

- Map: <http://www.ncdc.noaa.gov/crn/stationmap.html>

- Photos: < http://www.ncdc.noaa.gov/crn/photos.html>

- Detailed station histories: < http://www.ncdc.noaa.gov/isis/stationlist?networkid=1>

USCRN data are also available from additional sources:
NCDC Customer Services e-mail (NCDC.Orders@noaa.gov)

Direct satellite broadcast on the Global Telecommunication System under World Meteorological Organization (WMO) header SXXX90 KWAL

NOAA's Meteorological Assimilation Data Ingest System (MADIS) at <http://madis.noaa.gov/> and requests to get USCRN data via MADIS can be made on-line at <http://madis.noaa.gov/data_application.html>

## 9. FY 2000–10 SUMMARY

The USCRN has been completed in the CONUS for two years, but is still a very young network. Resources are now being devoted to improve quality control, data systems, and the Web site, making the observations more available and useful to stakeholders. Three major activities proceeded simultaneously during FY 2010. The USCRN Science project focused on the development of data and analysis products and visualizations of USCRN observations for users, and also accomplished some key climate science work. The Alaska USCRN progressed well in FY 2010, and will complete the vision of deploying a network of climate-science-quality stations in Alaska at the same resolution as they exist in the CONUS. The NIDIS-sponsored expansion of the USCRN to include soil moisture and soil temperature probes and relative humidity measurements has progressed as expected, and will lead to increased visibility of the network as a source for information with which to monitor drought. The trajectory of the USCRN Program is still in the ascendancy. However, it is clear that some adjustments to base funding are needed for the USCRN Program, as it has been held flat since FY 2007 in the face of increasing equipment, travel, and personnel costs; as well as the need to continually invest in new equipment and to maintain the scientific integrity of the data.

## 10. FY 2011 PLANNED ACTIVITIES AND GOALS

Research and engineering development activities envisioned for FY 2011 focus and resources include:

- Maintaining the long term integrity of the USCRN stations in the field through improvements to site stability oversight, regularized outreach to site hosts, and completion of a monitoring and warning system for station health.

- Maintaining the long term integrity of the USCRN observations by enhancing data quality control and rewriting data processing software systems with an internally consistent and modular architecture.

- Completing the development of a new Web site, updating and expanding old content and providing easy access to data products and visualizations.

- Producing new climate information products, climate analyses, and scientific content for USCRN stakeholders, especially emphasizing the needs of drought monitoring.

- Promoting the use of USCRN data through publications, presentations at conferences, and Internet-based outreach.

- Continuing to promote the USCRN model for climate reference station design through bilateral and international contacts.

- Building on the success of the Russian Arctic USCRN installation in Tiksi, some consideration will be given to a second Russian station in Yakutsk which is a unique cold weather station from an extremes standpoint. Installation of stations in Russia can be problematic, but the possibility has been factored into FY 2011 planning.

- Developing procedures for closing or moving USCRN stations where site quality has been compromised. Begin to plan for the possibility of closing some of the paired sites to allow new USCRN stations to be placed at key locations that are beneficial to the Program.

## ACRONYMS

| | |
|---|---|
| AMV | Annual Maintenance Visit |
| ASOS | Automated Surface Observing System |
| ATDD | Atmospheric Turbulence and Diffusion Division |
| BDA | Belfort Double Alter |
| °C | Degree Celsius |
| CDR | Climate Data Records |
| CM | Configuration Management |
| CONUS | Conterminous United States |
| COOP | Cooperative Observation |
| CPC | Climate Prediction Center |
| DA | Double Alter |
| DCS | Data Collection System |
| DFIR | Double Fence Intercomparison Reference |
| EROS | Earth Resources Observation Systems |
| °F | Degree Fahrenheit |
| GCOS | Global Climate Observing System |
| GEO | Group on Earth Observations |
| GEOSS | Global Earth Observation System of Systems |
| GHCN-D | Global Historical Climatology Network Daily |
| GOES | Geostationary Operational Environmental Satellite |
| HCN-M | Historical Climatology Network Modernization |
| HDD | Heating Degree Days |
| IPCC | Intergovernmental Panel on Climate Change |
| LCD | Local Climatological Data |
| LDAS | Land Data Assimilation System |
| MADIS | Meteorological Assimilation Data Ingest System |
| MOU | Memorandum of Understanding |
| MTBF | Mean Time Between Failures |
| NAS | National Academy of Sciences |
| NASA | National Aeronautics and Space Administration |
| NCDC | National Climatic Data Center |
| NIDIS | National Integrated Drought Information System |
| NOAA | National Oceanic and Atmospheric Administration |
| NP | National Park |
| NRC | National Research Council |
| NRCS | National Resources Conservation Service |
| NWR | National Wildlife Refuge |
| NWS | National Weather Service |
| PDA | Personal Digital Assistant |
| PM | Performance Measure |
| RAWS | Remote Automated Weather Station |
| RCS | Canadian Reference Climate System |
| RH | Relative Humidity |
| RI | Rainfall Intensity |
| RUSHCN | Regional U.S. Historical Climatology Network |
| SA | Single Alter |
| SCAN | USDA/NRCS Soil Climate Analysis Network |
| SDFIR | Small Double Fence Intercomparison Reference |

| | |
|---|---|
| SNOTEL | USDA/NRCS Snowpack Telemetry System |
| SM | Soil Moisture |
| SMAP | Soil Moisture Active and Passive |
| SMART | Station Monitoring and Reporting Tool |
| ST | Soil Temperature |
| STRI | Smithsonian Tropical Research Institute |
| SURFRAD | NOAA Surface Radiation Budget Network |
| USCRN | United States Climate Reference Network |
| USDA | U.S. Department of Agriculture |
| USDP | U.S. Drought Portal |
| USGS | U.S. Geological Survey |
| WCDMP | World Climate Data and Monitoring Program |
| WMO | World Meteorological Organization |

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