



2011

US Climate Reference Network



Annual Report



Protecting the past... Revealing the future

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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 2011 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 2010 when two new USCRN sites were installed in Kenai and Red Dog Mine (and now commissioned in FY 2011). With the installation of two more sites (Gustavus and Tok) in FY 2011 we continue our plan for a total of 29 commissioned new sites in Alaska by 2018.

The challenge as we enter the second decade of USCRN operations is now 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 with the completion in FY 2011 of the installation of new soil moisture, soil temperature, and relative humidity sensors at all USCRN stations in the conterminous United States (CONUS). 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. This was capped off by the completion of the 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 trends in climate.

Thomas R. Karl, Director, NOAA's National Climatic Data Center
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1. INTRODUCTION

This is the ninth annual report for NOAA's United States Climate Reference Network (USCRN). The primary focus of this report is on the FY 2011 USCRN development and implementation activities. Initial projections of activities planned for FY 2012 are included. FY 2000–03 USCRN activities were reported in the USCRN FY 2003 Annual Report, and FY 2004–10 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 Next Generation Strategic Plan [see http://www.ppi.noaa.gov/wp-content/uploads/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 2011 that were installed in FY 2010, and with two more sites installed in FY 2011 for commissioning in FY 2012.

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

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

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.”
- 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:

- a. triple configuration sensors for surface air temperature and precipitation;
- b. 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;
- c. 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;
- d. rigorous periodic maintenance and calibration program with thorough documentation, which is systematically collected and archived at least once per year;
- e. 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;
- f. 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;
- g. 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;
- h. maintenance of a continuous data analysis and data quality component for continuous monitoring of both network data and metadata;
- i. emphasis on the network's primary purpose of satisfying the climate science community's requirements;
- j. activities that must be implemented to satisfy all standards, with consistency in change management for a period of 50 or more years; and
- k. 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.

When possible, USCRN stations have been co-located 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, 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 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:

- a. 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;

- b. 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;
- c. 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 quality²;
- d. reporting recoded measurements hourly;
- e. data assimilation, archival, and product generation subsystems for observations; and
- f. observing system management and information delivery infrastructure.

2.5 Program Stability Considerations

The near-term environment for the USCRN is potentially challenging from a variety of perspectives. Beyond resourcing, the two major areas of concern are technological issues and site stability. These areas of concern are exacerbated by the stability of personnel, both within the program and with station site host agencies.

2.5.1 TECHNOLOGICAL

A potential issue with the USCRN communication system was discussed in the FY 2010 Annual Report regarding the National Telecommunications and Information Administration (NTIA) effort to evaluate government use of the electromagnetic spectrum. As of now, the threat to the Geostationary Operational Environmental Satellite (GOES) communication frequencies upon which USCRN is dependent has subsided, but careful attention must be paid to further efforts to commercialize government broadband spectrum, 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 USCRN data ingest/processing/distribution system at NCDC was redesigned in FY 2011 to improve its functionality, reduce maintenance requirements, and improve response to system outages. The ingest system is now in a modern, modular, well-documented form that will allow for rapid progress in improving the quality control of data and development of new products. Many more steps are planned in order to address known issues, such as the improved integration of soil moisture/soil temperature data into our products, and the full implementation of an exception procedure that is needed for improved quality control. Ongoing rapid growth of the US Regional Climate Reference Network (USRCRN, Section 4.3) has created a need to evaluate the long-term sustainability of the current data storage schema, which may not be sufficient for hundreds more stations. The current USCRN programming team is well trained and highly familiar with ongoing projects, capable of responding to expanding network requirements, and has put substantial cross-training and team code review processes in place.

2.5.2 SITE STABILITY

The CONUS national grid of 114 USCRN stations has been stable since network completion at 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 to address gaps in national coverage. This possibility will be examined further in FY 2012. 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>.

After up to a decade of field deployment, site stability issues are now coming to the fore, with the notification during FY 2011 that the existing USCRN station at Goodwell, OK, would need to be moved to make way for a gray water spraying system for a new sewage treatment plant for Oklahoma Panhandle State University and the City of Goodwell. Such spraying would compromise precipitation and temperature records at the original site. With the assistance of the site host, a new location outside the range of disturbance was identified, approved by the USCRN site selection committee, and installed in May 2011. The Goodwell, OK station is currently running in parallel with the existing OK Goodwell 2 E station until the sprinkler system

²The 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

is activated, which is expected to be in early 2012. Therefore, 8-10 months of overlapping observations will be collected, with the hope that transfer functions will allow the seven years of existing Goodwell measurements to be joined to observations at the new location.

One of the USCRN paired stations at the University of Rhode Island is also threatened by the planned extension and expansion of a new road within 30 m of the existing Plains Road site (Kingston, RI). The road project has been delayed by the discovery of archeological findings in its path, but seems likely to resume in FY 2012. Unlike Goodwell, there is a paired USCRN site only 1500 meters away, so a climate record would continue even if the removal of the Plains Road station becomes necessary. The current plan is to continue running the Kingston, RI station if it is not required to be moved to facilitate the road construction, and then track the differences between the paired sites to understand the impact of the changed land use environment.

While some changes are inevitable, it has become clear during FY 2011 that the USCRN Program needs to do a far greater amount of outreach to site hosts. Many of the stations have been in the ground long enough that the original signatories to site licenses and original site managers have moved on to other positions, and the current site host management may not have a clear understanding of the USCRN Program or the siting needs of our stations. With increased awareness, site hosts may be in a better position to notify the USCRN Program of potential threats to site land use/land cover, and become proactive in defending the sites from intrusions big and small. The stability of USCRN sites is also subject to possible budget constraints at site host agencies. Working closely with the site host managers has helped the program to forego any station closures in FY 2011, but the USCRN Program needs to reach out to site hosts so that such challenges can be anticipated in advance and addressed before any irreversible decisions are reached. Better site host communications would also improve responsiveness to

Table 1. USCRN Reduction in Climate Uncertainty

USCRN Increased Climate Confidence(Certainty) in the CONUS FY 2004-11			
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%
2011	114	98.3%	95.1%

issues large (natural disaster recovery) and small (draining a Geonor precipitation gauge in a timely manner). Finally, improved communication may aid the USCRN Program in developing and expanding its constituency of supporters.

3. PROGRAM-LEVEL PERFORMANCE MEASURES

3.1 FY 2001–11 Achievements: Milestones and Performance Measures

The performance measures for FY 2011 are summarized along with those from prior years in Tables 1 and 2 below.

3.1.1 FY 2011 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, 2010, and 2011. 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

Table 2. USCRN in Alaska Reduction in Climate Uncertainty

Cumulative USCRN Increased Climate Confidence (Certainty) in Alaska			
End of Fiscal Year	Commissioned USCRN Stations Fielded	Temperature Increased Confidence	Precipitation Increased Confidence
2010	2	59.0%	58.9%
2011	4	62.9%	63.7%

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). 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 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 trend detection has begun to be monitored there as well.

3.1.2 FY 2011 PERFORMANCE MEASURES: DATA INGEST

Since the USCRN Program began in FY 2001, the Data Ingest Performance Measure for data completeness (Table 1) 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
2011	99.9	99.9	99.9	99.9	99.9

4. FY 2011 INSTALLATIONS AND SURVEYS (USCRN IN ALASKA)

FY 2011 activities included

- Site Surveys—14 detailed site surveys were conducted at four grid locations in Alaska during summer 2011.
- Sites Approved—Sites for four 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 com

Table 4. FY 2011 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	09/12/2011
Kenai	07/13/2010	08/30/2010	09/12/2011
Tok (in Tetlin NWR)	07/13/2010	09/2011	FY 2012
Gustavus ^a (near Glacier Bay NP)	06/27/2011	09/2011	FY 2012
King Salmon (in Katmai NP)	06/20/2011	Planned FY12	Planned FY13
Yakutat	Pending	TBD	TBD
Summit	Pending	TBD	TBD
Selawik	Pending	TBD	TBD
Nowitna	Pending	TBD	TBD

^aThe critical Phase I activities of the installation of this site were completed in September 2011; due to unusually wet weather conditions in the area, the site host, concerned about the ground conditions at the site, requested delaying Phase II until the early Spring 2012 timeframe. This minor delay has no impact upon overall program schedules of commissioning plans for 2012, and given the amount of work connected with Phase I of the installation, this site is considered installed for program tracking purposes.

pleted for three Alaskan sites selected in FY 2011

(one of these sites will be installed in FY 2012).

- Stations Installed—Two stations were installed in Alaska in FY 2011.
- Stations Commissioned—Two stations were commissioned in Alaska in FY 2011.

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. As of the end of August 2010, two additional sites were installed at Red Dog Mine and the Kenai National Wildlife Refuge (NWR), and these were commissioned in September 2011.

A new approach to Alaska USCRN station design and power systems was developed in FY 2011 in response to the great challenges of the climate of Tetlin National Wildlife Refuge near Tok, one of the coldest places in North America. This station is fundamentally different in two ways. First, to power a station during winter in a very cold and dark climate with insufficient wind resources, a methanol fuel cell will be utilized for the first time by the USCRN Program. This system produces power when a catalyst causes methanol

and water to react, yielding free electrons. The free electrons are directed into wires and supply a current to the attached systems. Since the system also produces some residual heat, it will help to keep storage batteries warmer and more efficient in the extreme winter cold of Tetlin. During the spring, summer, and fall, the station will be powered predominantly by solar tube panels, which are also a new technology for USCRN and are more effective in diffuse cloudy environments like at Tetlin, receiving light from all angles, even bouncing up off a snow surface. Second, a new configuration of observation systems will be used to maintain measurements while using a smaller amount of electricity and enhancing system redundancy. Two Met One shields each contain three platinum resistance thermometers plus two fans to circulate air through the system, one serving as a back-up fan in case the primary fan fails. This is actually quite similar to the configuration of the USCRN network temperature instruments, but with two redundant systems, each with their own data logger and GOES transmitter. The data loggers are also wired to all instruments, so if a transmitter or data logger fails, all observations are still available through the other transmitter/data logger combination. Finally, there are also redundant wetness sensors for the primary and secondary systems. This new design anticipates Alaska USCRN stations being placed in wild areas with little or no winter site host access.

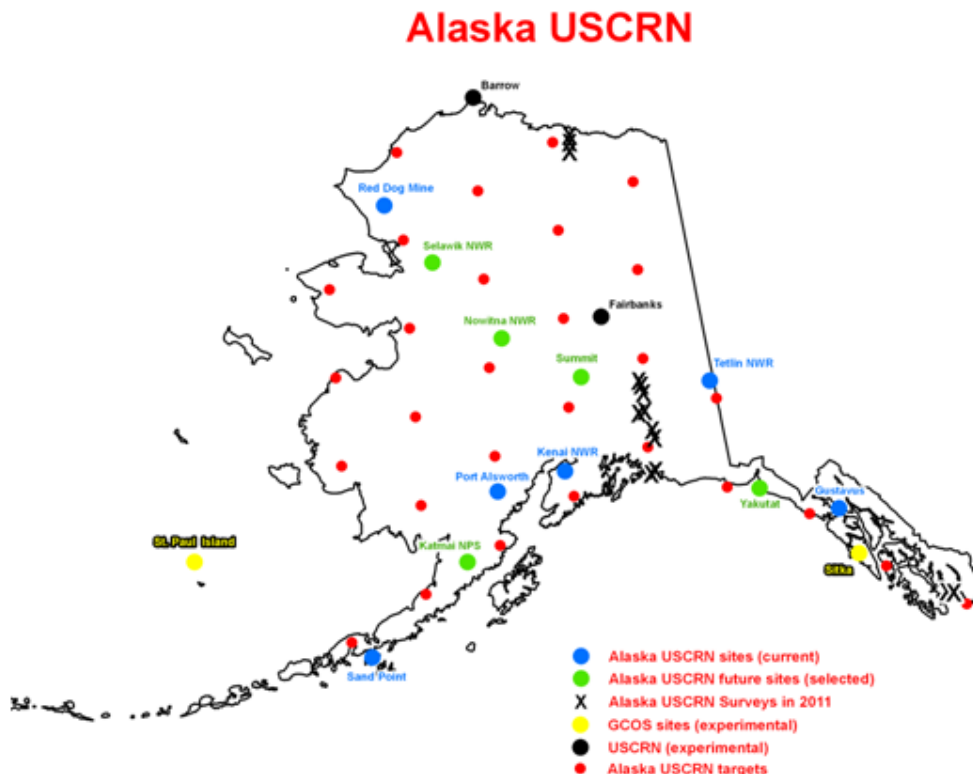


Figure 1. Alaska USCRN Target Grid, including stations installed by the Alaska USCRN, GCOS, and USCRN programs, and those sites selected and surveyed by the end of FY 2011.

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 <ftp://dossier.ogp.noaa.gov/USCRN-in-Alaska-Workshop-May2008>.

In addition to FY 2011 installations, more sites have been selected for future installations, with Katmai National Park already licensed, and licenses pending for sites at Summit (near Denali) and Yakutat, and sites at Selawik and Nowitna National Wildlife Refuges. Four more grid target areas were explored in August 2011 with surveys completed in far northern Alaska near Deadhorse, far southeastern Alaska near Ketchikan, and in southern mainland Alaska from Delta Junction south to Valdez and Cordoba. 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, especially when funding levels are not known until very late in the fiscal year, as happened in FY 2011. Lessons learned each year increase the speed of the processing of site approvals and site licenses. This improvement, along with engineering and logistics experiences gained, will allow for station installation to continue on pace in FY 2012, assuming funding arrives in a timely manner.

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 involved in hosting station sites for this

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	1
Native American Reservation	2	1
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	4

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. Regional Climate Reference Network (USRCRN) Program

Since FY 2008, the USCRN program has partnered closely with the National Weather Service and NOAA's Atmospheric Turbulence and Diffusion Division (ATDD) to establish a climate monitoring network built on the same design principles as USCRN. What was initially known as the U.S. Historical Climatology Network Modernization (USHCN-M) and Regional U.S. Historical Climatology Network is now designated as the U.S. Regional Climate Reference Network (USRCRN). The NWS has programmatic responsibility for USRCRN and has delegated lead responsibilities for development, deployment, and day-to-day operations of the network to NCDC and ATDD. The continued growth of the USRCRN 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.

While the primary mission of the USCRN is to determine national climate trends, the complementary USRCRN mission is to deploy a regional scale observing network to better characterize regional trends for temperature and precipitation. The prototype for USRCRN was designed by the USCRN program as part of a pilot study in Alabama in 2006 and involved the deployment of 17 stations using the same technology as USCRN but equipped with only modified temperature and precipitation instruments (Figure 2).

A USRCRN 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, Utah, provides a real-world example (Figure 3). Information on the USRCRN is available at: <http://www.ncdc.noaa.gov/crn/usrcrn/>.

This design was formally adopted by the USRCRN program, and deployments were initiated in the four-corner states of the Southwest region in 2009 (Figure 4). By the end of FY 2011 the program completed the installation of stations in the last of 72 grids in the region³. Observations and technical information for each USRCRN station are available on the USRCRN website at <http://www.ncdc.noaa.gov/crn/usrcrn/>. Following the completion of tests and evaluation the Southwest region will be commissioned in FY 2012.

With completion of the Southwest region approaching, the USRCRN program initiated the next phase of deployments in the West (California, Nevada) and Northwest (Oregon, Washington, Idaho) regions in March 2011. As it did in the Southwest, USRCRN has partnered with the Western Regional Climate Center (WRCC; <http://www.wrcc.dri.edu/>) to identify the best sites for instal-

³In 2011 NCDC used a new high resolution dataset and improved methodology to determine the number of stations necessary for meeting the objectives of the RCRN program. This resulted in a reduction in the density of the network necessary for achieving a Performance Measure of 95% confidence in the ability to detect regional trends as small as 10% per century for precipitation and as small as 0.2 °C per century for temperature. This can be achieved with a network of 538 grid locations consisting of 95 existing USCRN stations and 443 USRCRN stations.

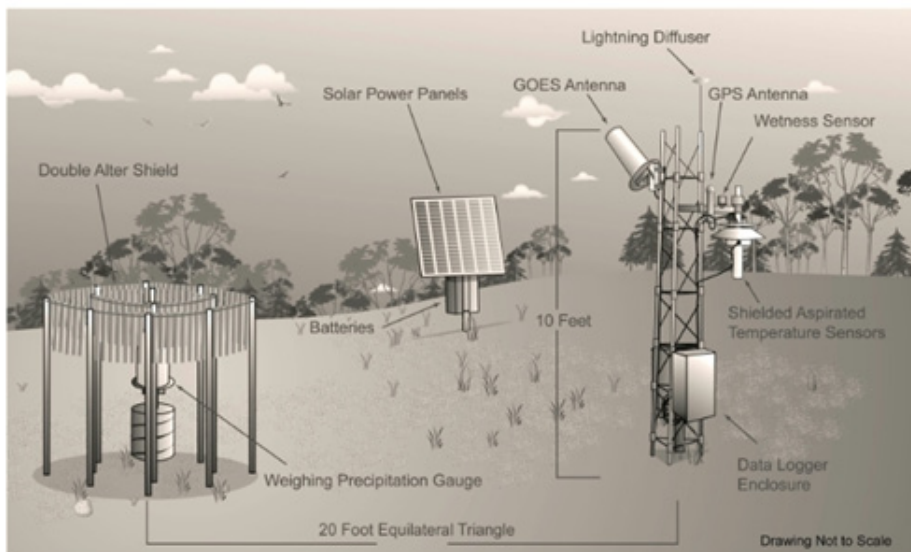


Figure 2. The instrument configuration of a USRCRN station



Figure 3. The USRCRN Station in Tropic, Utah.

lation. Through a lengthy process of background research, contact with potential site hosts, and visits to more than 20 sites each month, scientists at the WRCC provide information that is the basis for sites which are selected by a panel of NCDC, NWS, OAR and ATDD scientists. The panel selects approximately 5 to 6 sites each month. The program then begins a process of establishing Site Land Agreements between NOAA and the host organization which can take from a few months to as much as two years for each site. The program expects to install at least 10 stations in these regions in FY 2012 and to have completed site selections for most of 49 sites in the West region and 44 sites in the Northwest region (Figure 4).

and 44 sites in the Northwest region (Figure 4).

5. FY 2011 USCRN SCIENCE PROGRAM

As the deployment of USCRN in the CONUS was completed in FY 2008, resources were directed to continue to advance the USCRN Science Project in FY 2011. 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

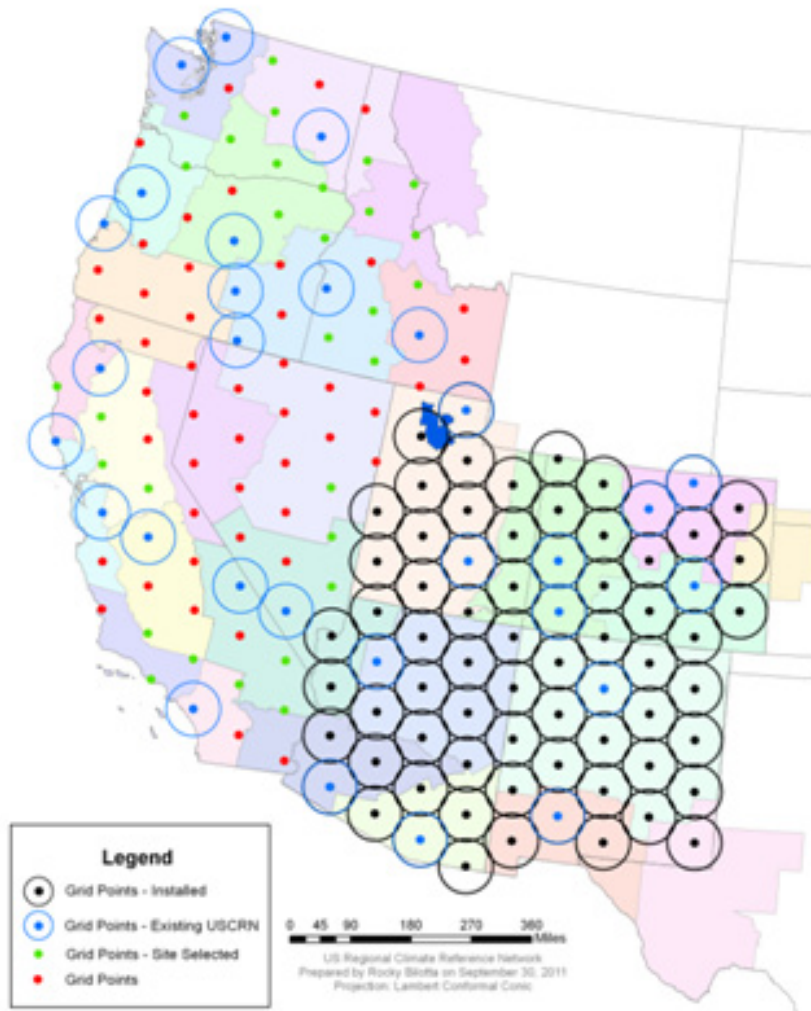


Figure 4. USRCRN installation status for the Southwest, West, and Northwest regions. The black grid points are installed USRCRN stations, and the blue grid points are existing USCRN stations. Green grid points are those where USRCRN sites had been selected as of September 2011, and the red grid points are where site surveys will be conducted.

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 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.

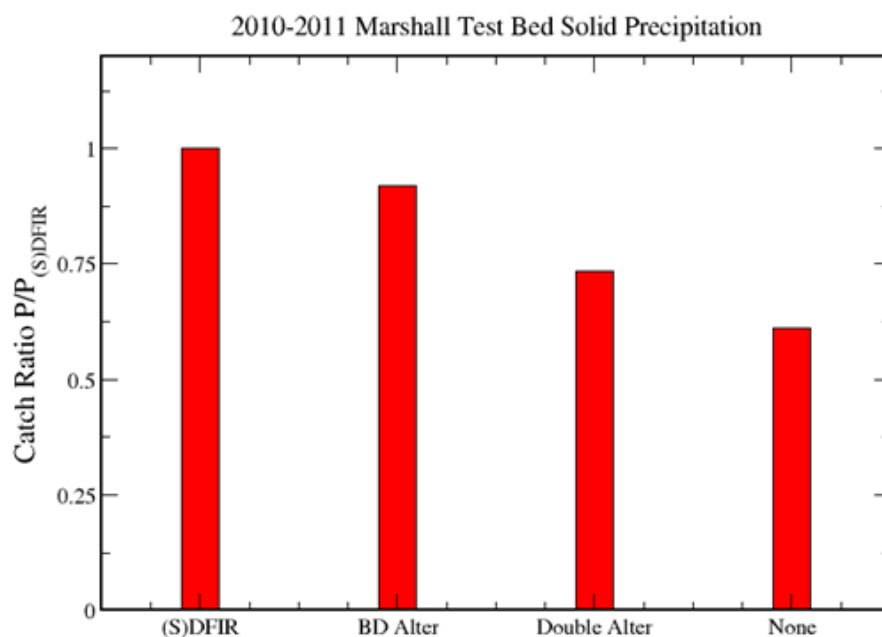


Figure 5. Solid (air Temperature < - 2° C) precipitation catch ratio during the winter of 2010-11 for all weighing-gauge/shield combinations at the Marshall winter precipitation test bed.

5.1.1 SOLID PRECIPITATION STUDIES

Research activities on improving the measurement of solid precipitation continued at the Marshall Winter precipitation test bed⁴ near Boulder, Colorado. Various gauge/shield combinations including the standard double and single Alter shielded gauges, a low porosity double Alter and the regular sized and small double fence intercomparison reference shield (DFIR and SDFIR) continued to be evaluated. Data from the winter of 2010-11 continued to support the idea that the most important factor affecting the measurement of solid precipitation is the wind shield. Combining all of the results from winter 2010-11 (Figure 5), the most effective shield relative to the SDFIR was the low-porosity Belfort double Alter (BDA), which had a catch ratio

exceeding 90% for all events. In addition, during typical winter events, the Belfort gauge compared well to the Geonor in paired wind shield experiments.

Conclusions

- The BDA performed significantly better than the standard double Alter.
- Differences between the SDFIR shield and DFIR shield were small
- The Belfort gauge compared well with the Geonor for all combinations
 - 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.

5.1.2 LAND SURFACE TEMPERATURE STUDIES

NOAA/ATDD is collaborating with the University of Tennessee Space Institute's Aviation Systems and Flight Research Department in Tullahoma, TN, to utilize an instrumented aircraft to perform measurements of land surface skin temperature over selected USCRN sites in the continental U.S. The aircraft-based land surface temperature measurements are compared to in situ, tower based land surface skin temperature measurements. Using land surface modeling to account for sub-pixel scale heterogeneity in the satellite measurements, the in

situ and aircraft measurements are also compared to the National Aeronautics and Space Administration's (NASA) MODIS and ASTER satellite land surface temperature products.

The overall goals are to quantify the spatial variability and representativeness of the single-point skin temperature measurement made at USCRN sites, to validate satellite land surface temperature measurements, such as those that will be made from the NPOESS Preparatory Project and Joint Polar Satellite System satellites by scaling land skin surface temperature measurements up to satellite measurement scales, and to improve the land-surface parameterization of existing up-scaling methods which are based on a land surface model coupled with a radiative transfer model and combined with ground-based measurements and high-resolution satellite data. Recent comparisons between aircraft

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

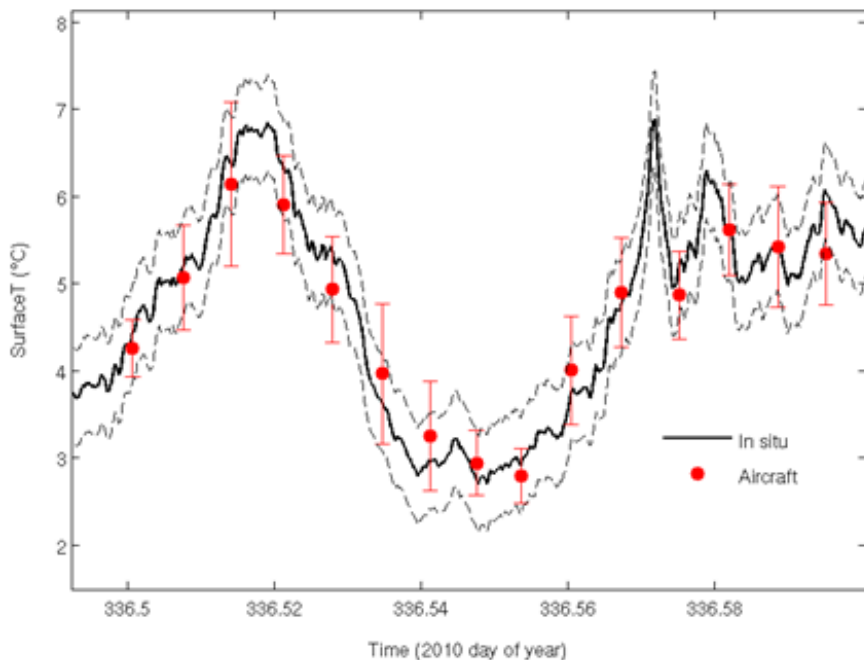


Figure 6. Surface Temperature. Aircraft and in situ land surface measurements at the Crossville, TN, USCRN site. The mean of all four in situ measurements (solid line), the standard deviation of the four in situ measurements (dashed line), the spatially averaged aircraft measurements (red circles), and the standard deviation of the aircraft measurements (red vertical bars) at the site are shown.

and in-situ conducted at the USCRN site in Crossville show excellent agreement (Figure 6).

5.1.3 PLANNING FOR THERMAL IMPACTS EXPERIMENT

Initial funding was provided this year by the USCRN Program for a multi-year experiment to better understand the thermal impacts of buildings with parking lots on air temperature measurements. A site near the offices of ATDD will be instrumented to measure accurately the air temperature and other variables

site environment.

5.1.4 PARTICIPATION IN USDA SOIL MOISTURE TESTBED IN OKLAHOMA

As part of the preparation for the NASA Soil Moisture Active Passive (SMAP) satellite mission scheduled for launch in 2014, the U.S. Department of Agriculture (USDA) has established a soil moisture measurement testbed near Stillwater, OK. The USCRN program is participating in this venture, and has collected about

1.5 years of data at the testbed site. This will allow for us to compare our instrumental output to measurements from other types and model of instruments, and will serve to help us make decisions regarding alternate instrument types for locations in the USCRN network where the Stevens Hydra Probe II is not compatible with soil chemistry conditions. Initial intercomparison work has been started by the USDA.



Figure 7. Active temperature controlled steel building and parking area located near Oak Ridge, TN. Five sampling sites (yellow pins) are seen northeast of the thermal source, corresponding to USCRN thermal site score classes 5 (closest) through 1 (furthest).

5.2 Soil Moisture and Soil Temperature Network Deployment

Soil moisture and temperature probes were first installed at the USCRN site in Crossville, TN, in April 2009, supported by the National Integrated Drought Information System (NIDIS) program. This year, installation of soil probes

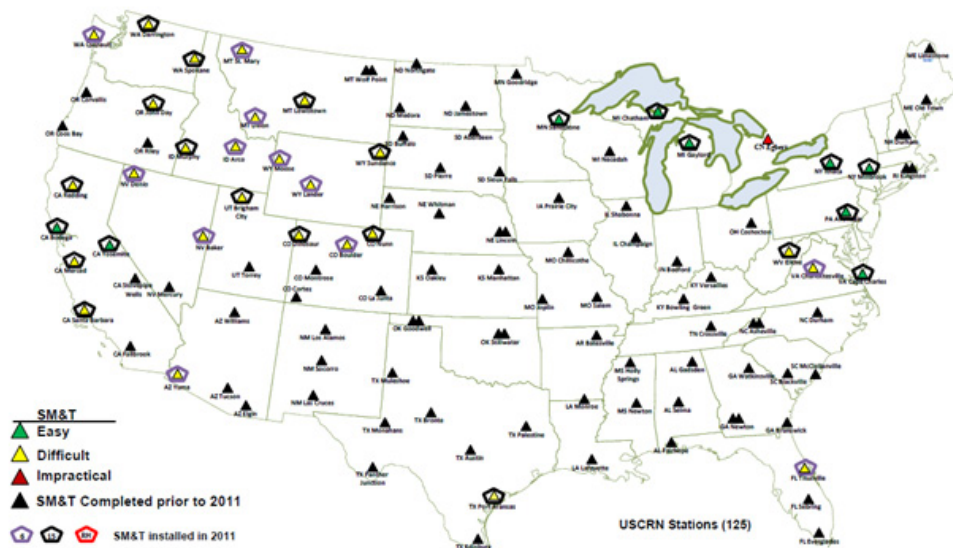


Figure 8. USCRN soil probe installation completed as of September 2011.

at all sites in the USCRN network where possible has now been completed (Figure 8). In all, soil probes and relative humidity sensors were deployed at 36 stations in FY 2011, thus completing installation of all soil and Relative Humidity (RH) sensors at the network of 114 USCRN sites in the CONUS with the final installation at the Denio, NV site on August 10, 2011.

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 5 m 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, 24 locations have been limited to only two layers of soil probes, while the USCRN site near Torrey, UT, is on solid rock in Capitol Reef National Park 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

Initial quality control measures set up early in the soil probe deployment have proven to be substantially correct and adequate for initial real time determination of data. One disappointment has been the application of soil porosities derived from physical measures of soil bulk density as the upper limit for individual probe dielectric. The bulk density measurements are problematic in enough cases to require reestablishment of

a single gross error limit while the measurements underlying the individual probe limits are reevaluated. It may prove to be more fruitful to set individual probe upper limits to measured high stands when wet conditions have led to saturation, but that information is not necessarily available for all stations, especially those in drought regions currently. The new ingest system (see section 5.3.1) is now ready for the addition of the soil quality control software, and this will proceed in FY 2012, fully incorporating the handling of soil moisture and temperature observations within

the standard ingest. Range checks and freezing status determinations will be conducted for the current hour of data ingested. Software improvements at stations initiated in FY 2010 have largely eliminated artificial signal spikes from the soil probe data, allowing a real-time assessment of observation quality without the need for examining the previous time step.

As was noted in the FY 2010 annual report, several more systemic difficulties have been detected with the current approach to soil climate measurements. Engineers at ATDD have determined the cause of one type of intermittent problem, and these have been corrected in the FY 2011 round of AMVs. There are also non-engineering 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 work in the USDA soil moisture testbed should allow USCRN to identify good alternative instruments for measuring soil moisture in these soils incompatible with the current instrument.

An automated method for determining the best way to identify soil probes with poor operating characteristics necessarily involves looking at many days of probe output, so cannot be part of the real time ingest. Instead, a new concept called post-processing will be used to determine the probability that a soil probe needs to be replaced. By accumulating the number of flag states

triggered over time, and their nature, one can apply simple rules that require a notification e-mail be sent to responsible parties. They will determine if there is sufficient evidence to call into question the validity of the soil probe and recommend replacement. This goes above and beyond the routine identification of catastrophic failures that are immediately apparent. In fact, plans are in place to expand the post-processing quality control concept to look at other instruments with the potential for subtle signs of malfunction that only become apparent when evidence is accumulated for weeks or months.

Despite the challenges, the great 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 in case settling processes yield incorrect measurements. The succeeding 180 days of data and all future data are released. The 180-day trial period has not proven to be needed in all cases, so it is likely that many of the stations installed in FY 2011 will be moved to public status sooner. 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 are displayed on the U.S. Drought Portal Web at the following link at: http://www.drought.gov/portal/server.pt/community/drought.gov/crn_soil_data. More complex soil moisture visualizations are available in the Visualizations Web page at: <http://www.ncdc.noaa.gov/crn/visualizations.html>. Early in FY 2012, the soil moisture and temperature layer average data will also be incorporated in the hourly02 and daily01 products, and the soilsip01 eventually discontinued.

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. With longer time series of data now available,

one can watch the entirety of seasonal changes. For example, the 2011 soil moisture time series averaged for each of the five depths for the Asheville, NC, USCRN station show a gradual decline from spring through the summer, with occasional recoveries during rainy periods (Figure 9). However, it is impossible to tell simply by examination what portion of that decline is normal for the location and time of year, and what portion may be indicating below normal soil moisture levels. During FY 2012, model estimated soil moisture time series will be generated for the existing period-of-record, and the overlapping record will be used to tune the model to better simulate the conditions at the station location. Once this is done, a 1981-2010 time series of estimated soil moisture output will be generated to provide the basis for estimated normals that can be used to calculate departures from normal for current observations.

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. Several groups are already using the data collected to date to compare to the observations of the European Space Agency's Soil Moisture and Ocean Salinity satellite. The NASA SMAP has already enlisted USCRN assistance, with members of the USCRN science and engineering groups attending the second calibration/validation workshop for SMAP in May 2011. The utility

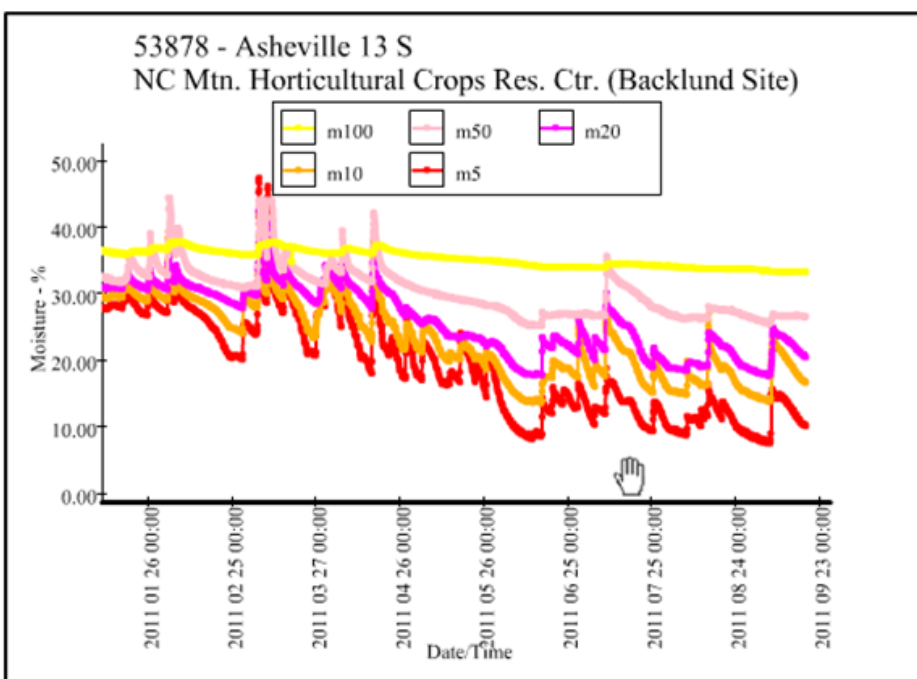


Figure 9. Soil moisture averages for each depth at the NC Asheville 13 S USCRN station, shown as percent volumetric water content for 5, 10, 20, 50, and 100 cm depths, January to September, 2011. Generated by the U.S. Drought Portal at: http://www.drought.gov/portal/server.pt/community/drought.gov/crn_soil_data.

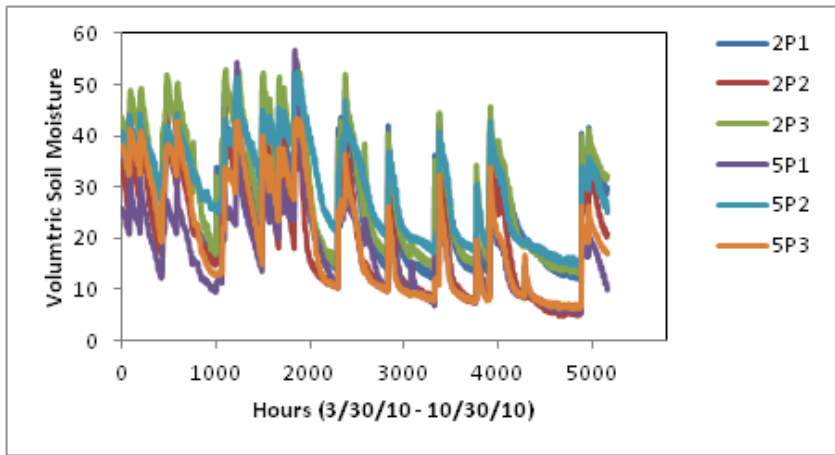


Figure 10. Soil moisture volumetric water content for six USCRN measurements at 5 cm depth near Stillwater, OK, paired sites during the warm season 2010.

of USCRN observations for enhancing satellite based Climate Data Records is quite high, and this type of activity is expected to expand in future years. However, uncertainties in USCRN soil moisture measurements must be quantified for proper application of the data in validating satellite estimates of soil moisture. For example, an examination of the six overlapping time series for 5 cm soil moisture at the USCRN paired sites near Stillwater, OK, shows the need for better understanding the local scale variations of soil moisture measurements (Figure 10). Plans are being prepared for undertaking field calibration efforts at a number of USCRN stations to compare gravimetric measurements of soil moisture in samples of soil literally grabbed from the surface layer, weighed, dried in an oven, weighed again, and then converting the weight difference to a volumetric water content value for the sample.

5.3 Projects to Improve Data Processing and Product Quality

The developer staff effort to refit USCRN data processing and products with modern, stable programming that began in FY 2010 continued through FY 2011. The shared code base expanded, a new data ingest system was completed, the Station Monitoring and Reporting Tool (SMART) was improved and augmented with a visual dashboard, and Web improvement and visualization development continued. In addition to these projects started in FY 2010, several new major projects started in FY 2011, including the use of the Trac software for tracking programming bugs and data exception issues, the new monthly data product and estimated normals, and the creation of a domain specific language for more easily scripting one-off data requests and product mock-ups. Many other operational activities also occupied the developer staff, including installing

a new system for downloading USCRN data relayed via satellite, programming support for scientists, fulfilling data requests, and routine system maintenance and recovery from down states.

5.3.1 CONTINUING SOFTWARE DEVELOPMENT

The crnshared project is a centralized code base, primarily focused on data access, providing a common way for all projects to access observation, station, stream, date/time, and other types of data stored in the USCRN database. It also contains numerous common utilities for helping with such important tasks as rounding, scaling, type conversions, date-time translation, string formatting, and more. The crnshared is in use by the new ingest, crnscript, products and the USCRN website. It will be incorporated into Integrated Surface Data (ISD) record production as time allows. There are now 60 classes and interfaces that make up crnshared. An additional 28 unit test classes and numerous XML files supporting database calls and program configuration are also part of crnshared. The rate of adding new software to crnshared has slowed, but when a software solution is created for a new process or product, it is always evaluated to see if it has utility to other USCRN applications, and written for crnshared if needed.

The new USCRN ingest system was completed in June 2011, and has since been running in parallel to the existing ingest during an extensive testing period. The results are exceedingly good to date, with only very minor adjustments required during the testing phase. This represents 14 months of dedicated work by the lead ingest developer, and is built upon the combined efforts of the development team. The new Java software has a modular and flexible architecture that will allow future additions and improvements to the ingest system to be much more straightforward than with the old system, reducing future development costs. The development team is now able to quickly implement features to support the needs of our users. Extensive automated unit tests prevent errors from being introduced into our climate data when changes are made to the software, further reducing maintenance costs.

Several important new features were incorporated into the new ingest (Figure 11). Prioritization of observation data allows lower quality data to be replaced with higher quality data. Such changes will now be transparent and

CRN Ingest – New Java-based software

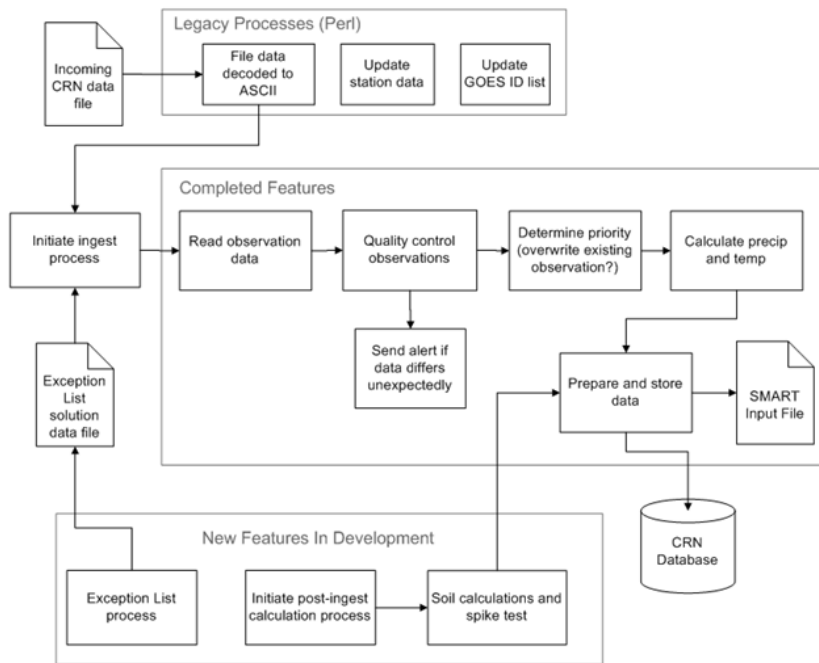


Figure 11. Updated flow chart of the USCRN ingest process, including steps external to the new ingest and new features in development that will become part of the ingest system in FY 2012.

traceable with new “journal” database tables that show how data changed and when those changes occurred. The new ingest system will now detect any unexpected differences between incoming observations, which can alert us to problems with our data sources. Improvements to the calculated precipitation code and a new “frozen soil” flag were also deployed. All existing features of the legacy system were preserved. Work will begin in early FY 2012 on a number of new capabilities, including the code for processing soil moisture and temperature within the core ingest system, and for handling data exceptions.

Work continued during FY 2011 on the Station Monitoring and Reporting Tool (SMART), which now has reached its full capabilities for engineers to specify new custom monitors via a Web interface and receive e-mails with SMART messages when the monitoring criteria are exceeded by an event at a station. Monitors can now be implemented that apply only to certain subsets of stations, such as by power source (solar vs. AC), network (USCRN vs. USRCRN), or location (states or subsets of stations). In addition, a new visualization was created that provides a dashboard for

monitoring USCRN and USRCRN station issues just by glancing at a single screen dashboard. The screen capture in Figure 12 shows a variety of issues arising on a typical morning. A textbox pops up when the mouse is dragged over a symbol, revealing the station location and nature of the fault (as in the case of Thomasville, AL, in Figure 12). The dashboard maps can be panned and zoomed like a typical Google map if more detail is needed, or faults in Alaska or Hawaii need to be examined. The dash board is located at: <http://www.ncdc.noaa.gov/crn/flex/smartvis.html>.

A series of changes were made to the base USCRN web site in FY 2011 to accommodate the needs of the USRCRN for enhanced visibility and functionality. The approach taken was twofold, with one aspect being the addition of USRCRN branding and dedicated USRCRN pages to the combined Web presence (Figure 13a), and the other aspect being the revision of observation and reporting pages to allow the two networks to be listed and viewed separately or together, depending on user choice (Figure 13b).

Daily and hourly solar radiation values are now accessible as a mapped product under the USCRN visualizations Web page at: <http://www.ncdc.noaa.gov/crn/>

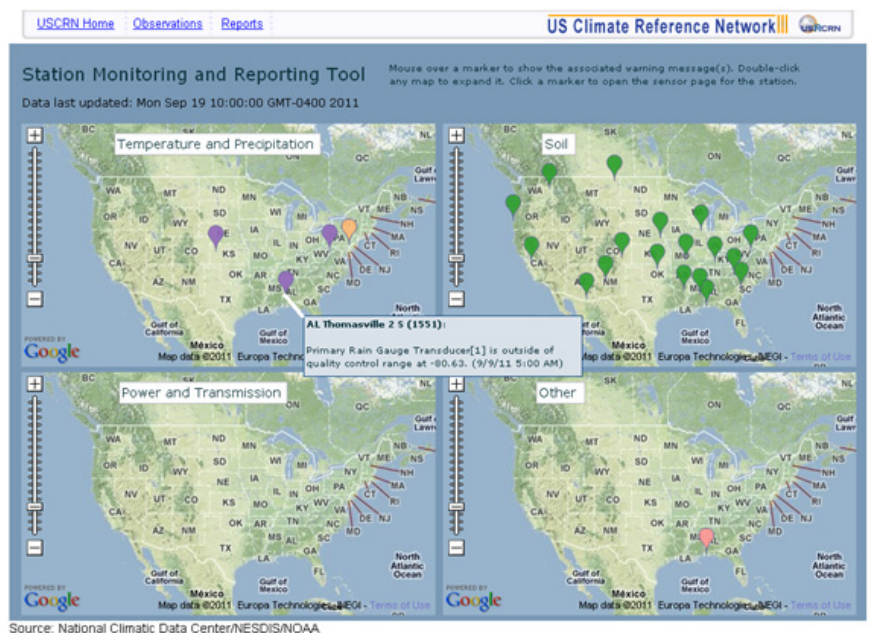


Figure 12. Screen capture of the SMART Visualization, showing station faults with temperature and precipitation in the upper left, power and data transmission in the lower left (none at this time), soil probe faults in the upper right, and other faults in the lower right. Mousing over the purple symbol in Alabama revealed the information in the text pop-up box showing the details of the problem at Thomasville, AL, to the user.



up a similar map of the solar radiation for the most recent hour. In this case the data is given as the average solar radiation rate for the hour, in watts per meter squared. The hourly maps can be animated over the last 20 hours. This product was developed in response to a request from the Southern Region of the National Weather Service (NWS) to create a solar information page in place of NWS solar measurements that had been discontinued.

5.3.2 NEW SOFTWARE DEVELOPMENT

Significant shared code base and Web changes were required to implement two new station options being required by changing circumstances within the networks. It has become apparent that the first station moves required by site hosts in the history of the USCRN are likely to occur during FY 2012, so it has become necessary

Observations
for Sep 22 2011 3:00 PM EDT [Sep 22 2011 19:00 UTC]
[Change Date/Time](#)

[All Stations](#) | [USCRN Stations Only](#) | [USCRN Stations Only](#) | [Closed Stations](#) | [Select Station from Map](#)

Displayed rows: 68 [Reset](#)

State	Station	Temp	Precip	Plot	Sensors	Soil Data
AZ	AZ Ajo 29 S <small>NPS, Organ Pipe Cactus National Monument</small>	Sep 22 2011 2:00 PM EDT 96.6 °F 35.9 °C	0.00 in 0.0 mm			
AZ	AZ Amado 23 W <small>FWS, Buenos Aires National Wildlife Refuge</small>	Sep 22 2011 2:00 PM EDT 89.4 °F 31.9 °C	0.00 in 0.0 mm			
AZ	AZ Bowie 23 SSE <small>NPS, Chiricahua National Monument (NADP site)</small>	Sep 22 2011 3:00 PM EDT 85.6 °F 29.8 °C	0.00 in 0.0 mm			

Figure 13. (a) New separate entry page for the USCRN, with links to content specific to the regional network. The blue main navigation bar still serves to bring users to USCRN content and pages with joint content; (b) The Observations page has joint content, and thus shows both network logos at the top bar on the page, and also allows users to select a USCRN station list.

visualizations.html. This work was completed in the first quarter of FY 2011. Selecting the solar radiation link on the visualizations page will display a map of light bulb symbols ranging from a dark brown to a bright yellow depending on the amount of solar radiation received at each USCRN station. This first map is visualizing the solar data from the previous day, but a calendar tab can be used to look at any other day in the past. The bulb brightness on the daily map (Figure 14) is proportional to the amount of solar radiation expected on a clear day at each location and date. Gliding a pointer over a bulb reveals the actual solar radiation total for the day in megajoules per meter squared, and also activates a simple graph of the solar radiation by hour on that day. Clicking on the button for an hourly view brings

to extensively revise software systems to handle station data and metadata for sites that are discontinued. Up until this point, the programs and Web pages of USCRN expected new stations to be added, but no stations to be discontinued. Now the software is capable of providing access to data for stations that are closed without creating errors if a user asks for current data. To accommodate these changes, certain metadata settings have been re-categorized in the Integrated Station Information System (ISIS). Stations still have both a station type and an operational status, but now those categories have slightly different states than before. Station type may be commissioned (installed to meet network requirements), non-commissioned (installed with the intention of being commissioned),

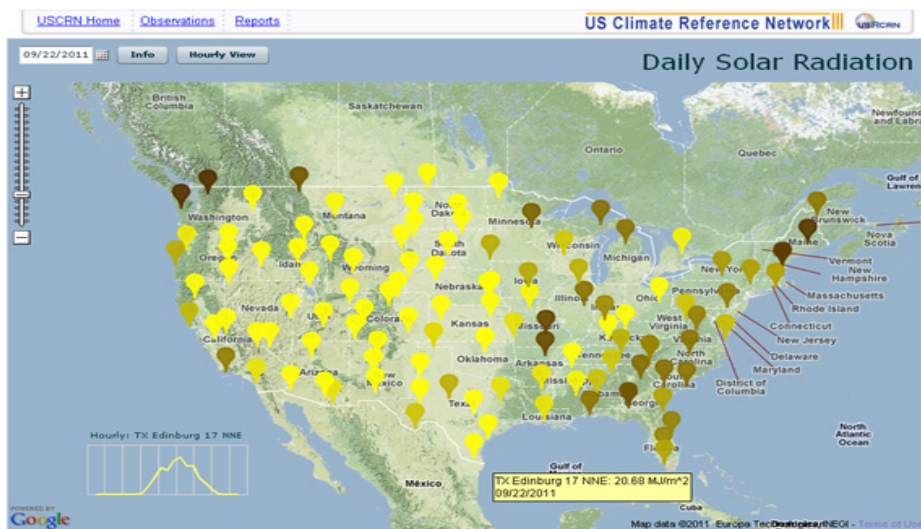


Figure 14. Example of production daily solar radiation map visualization. The screen capture was taken with a mouse over the station at Edinburg, TX, revealing the daily solar radiation total in megajoules and also providing a graph of the hourly solar radiation (lower left).

experimental (not intended to be commissioned), or test site (installed for engineering tests). We have also introduced two new operational status types in addition to operational and non-operational: “closed” (not expected to resume operation, but the period of record contains data worthy of high confidence) and “abandoned” (not expected to resume operation, and there is a lack of confidence in any existing data). Test stations will continue to be excluded from products. Abandoned stations will also be excluded from products, but closed stations will be included through the end of their period of record. Data from test and abandoned stations are archived, and will be made available upon request.

The second set of program changes was required to accommodate the new Tok, AK, station that has redundant data transmissions for a single station. The data for both transmitters will be stored, and the observations for the primary set of instruments will be displayed on the Web site. Metadata systems had to be changed to allow for a set of secondary instruments for a station of this type. Further work will be required in FY 2012 before the dynamic Web pages recognize when the primary data stream is down and switch to the secondary data stream. It is expected that this redundant station configuration will be used at many extremely remote sites in Alaska in the coming years, especially in locations where mid-winter unscheduled maintenance visits will not be feasible.

A new approach is being developed for calculating daily and monthly products. Instead of running a program to create each product separately each time that

product needs to be refreshed, Materialized Views have been created in the USCRN database. Materialized Views compute, store, and incrementally update product values as new and/or updated observations are received. This greatly reduces the demands on the database, and speeds up delivery of new information to users. Using the approach also allows new products to be created more quickly and easily. This work is currently running on the USCRN development database, and will be migrated to the production database in the first half of FY 2012.

An open source software program was identified for use by USCRN developers. Trac is primarily an issue tracking system, but it is flexible enough to be used to support USCRN’s operations in two ways. First, Trac is supporting internal software development by allowing developers to coordinate bug fixes and feature enhancements with speed and clarity that was previously not possible. Second, the Trac workflow features have been used to craft a method for recording data and documentation for the steps required to implement the USCRN exception-list process. The workflow provided by Trac governs the process of recording, analyzing, and correcting these exceptional situations (Figure 15). Tickets created in Trac are kept on permanent record, so that future USCRN users and developers can know about these issues far into the future. This data exception handling process will allow USCRN to improve the quality of data by identifying and managing exceptional situations that our automated quality control mechanisms cannot handle. While the theoretical basis for an exception list procedure was proposed and approved in FY 2010, now after completing the new Java ingest system work can continue on the software required to complete this task. Exception list programming will be a major development project during FY 2012.

Crnscrip is a domain-specific language developed during FY 2011 to make it easy for developers and non-developers alike to obtain, filter, analyze, and graph USCRN data. The project provides a platform-independent turnkey environment for running scripts or using an interactive console. With a single, easily read or written line of code, a user can obtain USCRN data specified by stations, dates, and instruments,

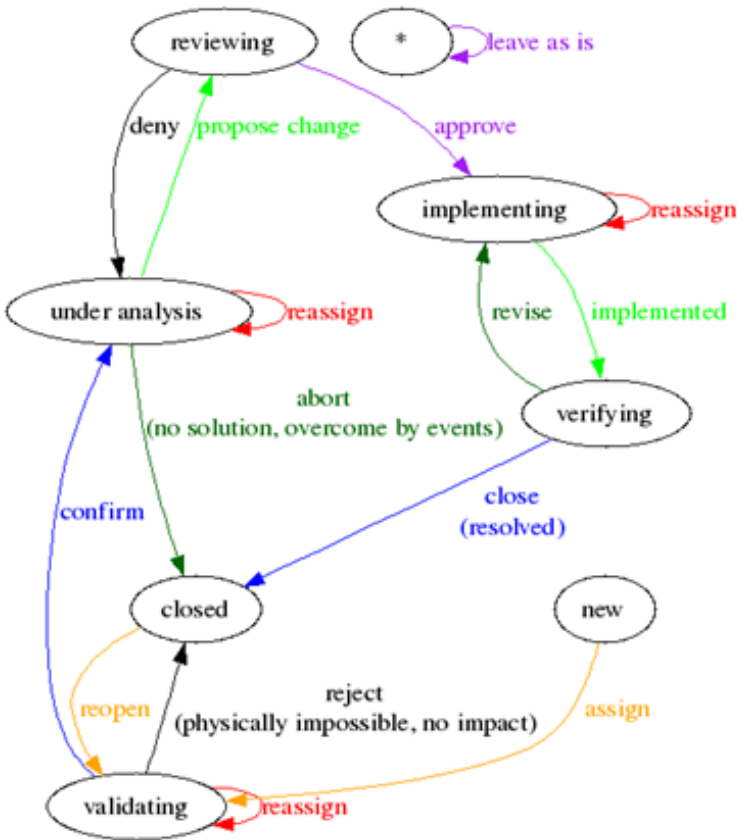


Figure 15. The work flow for exception handling in Trac will provide the mechanism for storing all information about exceptions made to correct database entries that are for known reasons incorrect, but were not captured and flagged by the quality control software working at the time.

returned as a rich custom collection with a broad range of functionality. With only a few additional lines of code, the user can perform complex filtering, transformation, and graphing on the returned data. Crnscrip is accessible enough for use by non-developers, while simultaneously being rich and robust enough for complex data analysis or the development of custom products. Crnscrip is written in Jython in order to take advantage of Python’s suitability for domain-specific language design while leveraging existing USCRN Java shared code base for data access and domain objects. Data requests that used to take customized programs and many hours of effort now can be scripted in minutes with complete fidelity, greatly reducing customer wait times for non-standard data request. Crnscrip has also proven adept at quickly mocking up new data procedures and products for analysis prior to investing the time and effort in writing them in standard Java. The USCRN science program’s efforts are now utilizing this capability.

The USCRN maintains multiple redundant pathways for receiving station climate observations from the field. A critical pathway that is independent of the Internet is through a Local Readout Ground Station (LRGS) on the roof of the Veach-Baley Federal Building in Asheville, NC. The reception of data from the satellite into a server in the building was dependent on the continued performance of a six-year-old machine. This has been replaced by a new rack-mounted appliance, a DOMSAT protocol converter, allowing access from a newly installed service on our network to the data and extending the life of the LRGS system.

Finally, an important effort was made this fiscal year to more formally assign backup roles to the programmers to support production software systems if the person primarily responsible is not available. Approximately a dozen key roles requiring backup were identified among the four developers, and time was scheduled for multiple sessions to exchange key information and insights. While there has always been a general awareness of the production software systems, recent improvement and expansion of the USCRN software base made is necessary to formalize backup arrangements.

5.4 USCRN Climate Research

With the commissioning of 114 USCRN sites in the CONUS, there is now a large enough set of observations

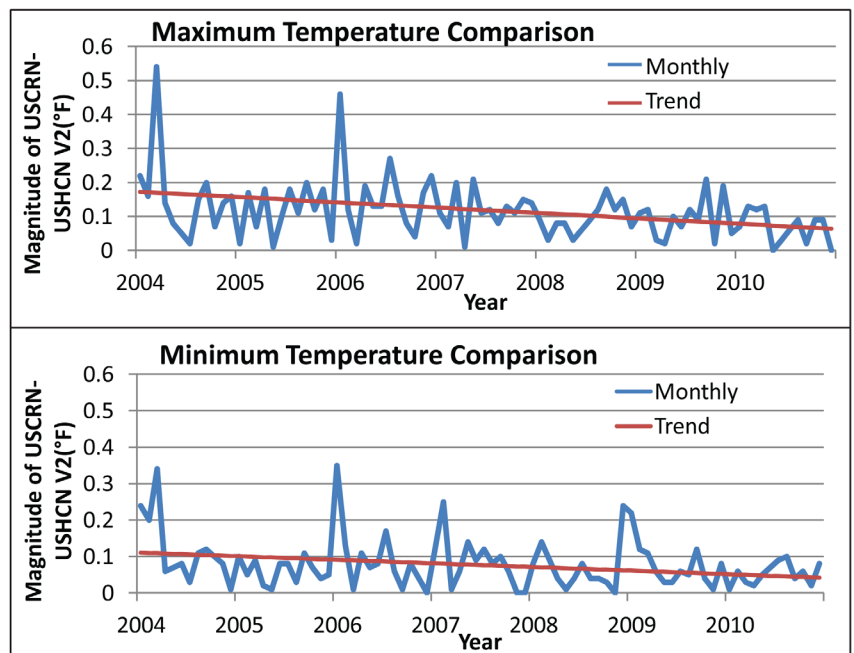


Figure 16. Magnitude of the monthly national temperature departure differences between USCRN and USHCN V2: a) Maximum temperature; b) Minimum temperature

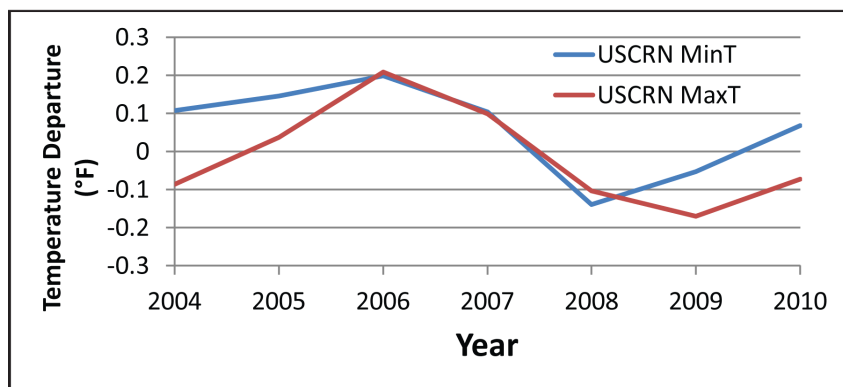


Figure 17. USCRN annual U.S. temperature departures, 2004-2010.

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. During FY 2011, a paper was published by Palecki and Groisman (2011) about the utility of using USCRN technology for high-elevation climate networks. Early in FY 2011, two research associates were hired through the NCDC associated Cooperative Institute for Climate and Satellites, North Carolina (CICS-NC), to perform science analysis to support the network and increase our knowledge of climate change and variation in the United States. They have led a substantial science effort to improve the USCRN precipitation algorithm and soil moisture quality control, and also embarked on intercomparisons between USCRN observations and those of other networks. An increasing number of users/collaborators are using the USCRN data for various science applications. As the years go by and more data are gathered, increasing amounts of climate science and applications will be based on the USCRN dataset.

5.4.1 USCRN TEMPERATURE OBSERVATIONS IN THE CONTERMINOUS U.S.

While 114 locations in the conterminous U.S. are outfitted with USCRN stations, some 20 stations do not have sufficient record length to estimate 1981-2010 normals. The number of stations that can be used to calculate a conterminous U.S. annual temperature departure has grown from 40 at the beginning of network commissioning in 2004 to 95 today. Therefore, the magnitude of the difference between the U.S. Historical Climatology Network Version 2 (USHCN v2) monthly temperature departures for the U.S. and those for USCRN would be expected to decline over time as USCRN better resolves the national climate signal with more stations. This has been found to be true, and is shown in Figure 16. The magnitude of the month-to-month absolute differences

between networks in national departures for both maximum temperature (Figure 16a) and minimum temperature (Figure 16b) have now declined to less than 0.07°F (0.04°C) on average for 2010. Annual national maximum and minimum departures from USCRN are highly correlated to USHCN v2 with an adjusted R-squared above 0.99 in both cases. The USCRN temperature record for the U.S. displays no significant trends during its first seven years (Figure 17).

The application of USCRN observation approaches to high elevations was shown in Palecki and Groisman (2011) to be quite robust. High quality observations will be the key to discerning differences in climate trends between high altitude and low altitude stations in the Western U.S. and other mountainous regions. During the first five years of the USCRN network, there is no discernible tendency for maximum or minimum temperature departures to be more negative or more positive above 1800 m when compared to the same station configuration below 800 m. Figure 18 shows

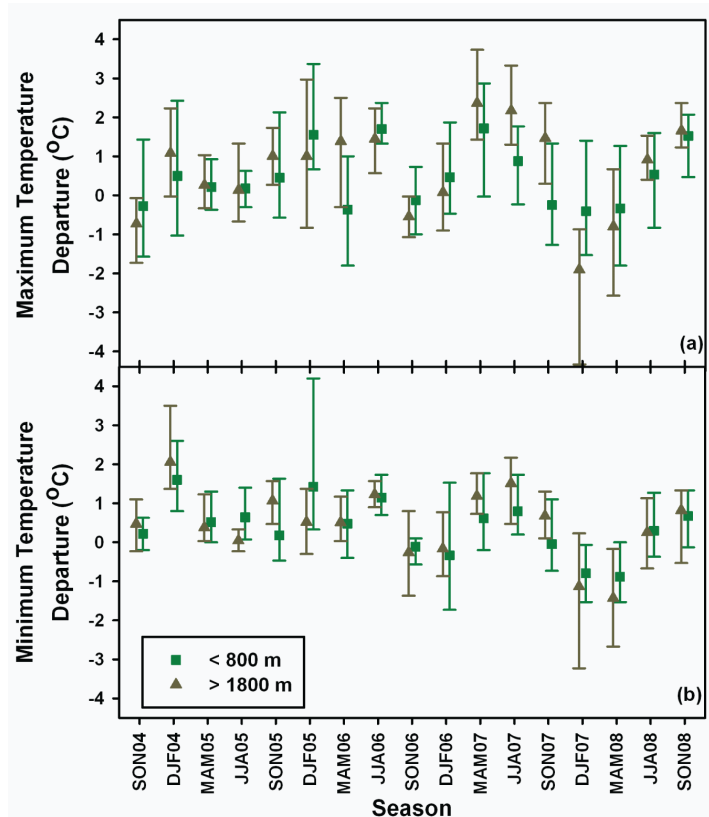


Figure 18. The seasonal temperature departures from estimated station normals for the Western U.S., using 13 USCRN stations above 1800 m elevation (brown) and 12 USCRN stations under 800 m elevation (green): a) Maximum temperature departure (°C); b) Minimum temperature departure (°C). The bars indicate the ranges of individual station maximum and minimum departures.

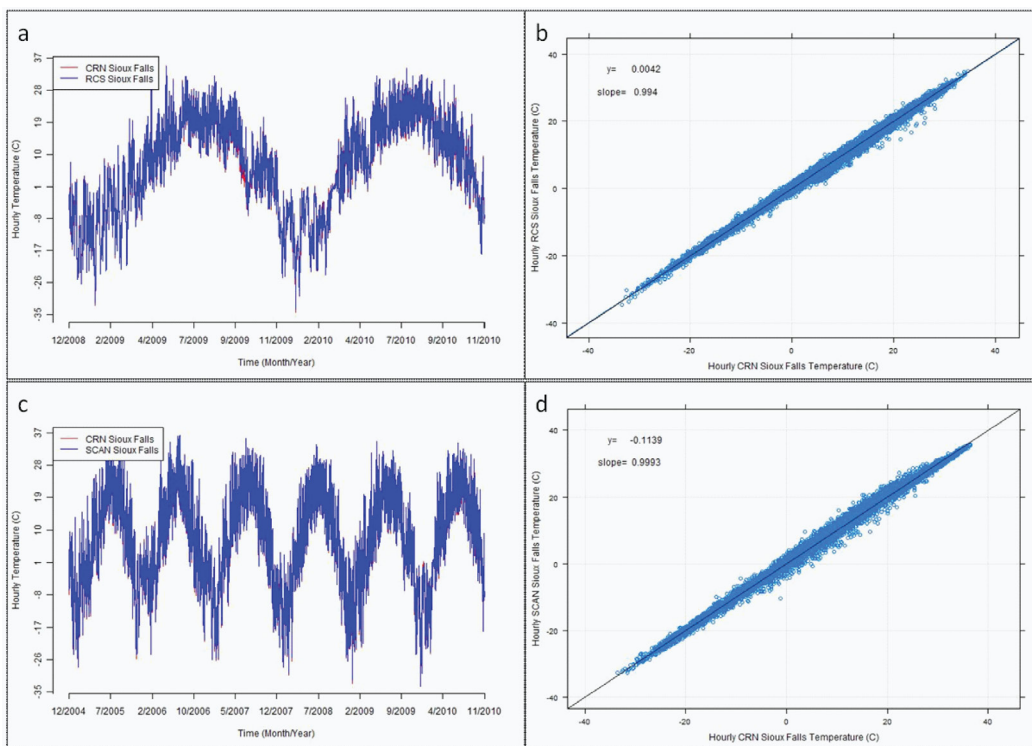


Figure 19. Time series and scatter plots of temperature observations at Sioux Falls, SD between USCRN and: (a,b) RCS, and (c,d) SCAN.

time series and scatter plots between USCRN, and RCS (Figures 19a and b) and SCAN (Figures 19c and d) illustrate well the agreement between observational networks. Comparisons also revealed the importance of site selection and station infrastructure, especially the use of fan aspirated shields in the case of USCRN. Diurnal comparisons between USCRN and RCS showed that RCS naturally-aspirated temperature observations were consistently much warmer (somewhat cooler) than USCRN during the day (night) (Figure 20a). The opposite was true of USCRN and SCAN (Figure 20b). The SCAN naturally-aspirated tempera-

ture observations were on average cooler (warmer) than USCRN during the day (night). This is contrary to the expected relationship between fan aspirated and naturally aspirated temperature instruments, However, these results may be explained by SCAN’s closer proximity to a nearby lake offsetting daytime heating and nocturnal cooling.

that departures at altitude can be more or less positive or negative than those at low elevations, depending on the season. However, this is a short time period, with a sparse station network, and this work should be reassessed when the higher spatial resolution USCRN network is built out in the western U.S.

5.4.2 USCRN INTER-NETWORK COMPARISONS

The Earth Resources and Observation Science (EROS) center in Sioux Falls, South Dakota hosts a variety of ground based observational networks including the US Climate Reference Network (USCRN), USDA Soil Climate Analysis Network (SCAN), and Canadian Reference Climate Stations (RCS) to name a few. Preliminary comparisons of temperature observations among the collocated stations indicated excellent agreement, as shown by a variety of measures in Table 6. In addition,

5.4.3 PRECIPITATION CALCULATION ALGORITHM ACTIVITIES

Precipitation at USCRN stations is observed using a Geonor weighing bucket gauge with three vibrating wires for triplicate redundancy. As with any weighing bucket gauge, observational accuracy depends on how well the weight of the bucket is measured before, during, and after the precipitation event. Hence, gauge evaporation and wire noise make it difficult to precisely determine the weight of the bucket, and therefore are leading factors that contribute to precipitation uncertainty. Observations of gauge depth prior to rainfall indicate that evaporation rates from gauges can be as high as the equivalent of 0.5 mm depth an hour, resulting in under catch of the precipitation event (Figure 21). Even worse, if fallen precipitation is not sufficient to

Table 6 - R2 and d-index Measures of Agreement^b

Compared Stations	R ²	d-index of Agreement	Average Difference (C)	Mean Abs. Deviation (C)	Root Mean Sq. Deviation (C)
USCRN-RCS	0.997	0.999	0.04	0.53	0.77
USCRN-SCAN	0.998	0.999	0.12	0.45	0.65

^bThis table shows the average difference, and mean absolute and root mean square deviations over the period of congruent record between USCRN, PCS (2008-2010), and SCAN (2004-2010) stations at Sioux Falls, SD.

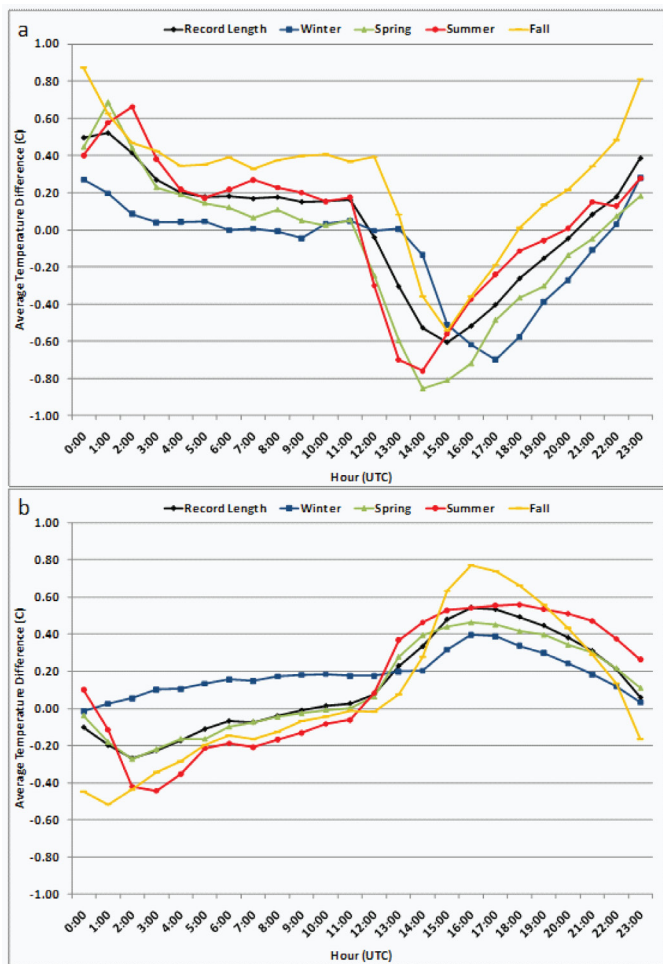


Figure 20. Diurnal hourly average differences computed as USCRN minus (a) RCS and (b) SCAN for the period of congruent record (black), winter (blue), spring (green), summer (red), and fall (orange) seasons.

offset evaporation loss and overcome the gauge minimum detectable threshold (0.2 mm) then no precipitation will be recorded at the beginning of an event. In order to address this and other concerns with the precipitation calculation algorithm, a large effort has been brought to bear in FY 2011 to look at potential alternatives and improvements that can be made to the original algorithm. Two main approaches have been pursued, one based on improving the determination of reference depths in the old algorithm to better capture precipitation events, and the other based on a signal theory approach that combines the information content of the three wires early in the processing.

Method 1: Constrained reference depth. In order to mitigate the negative effects of gauge evaporation, reference depth (gauge depth prior to precipitation) is restricted from increasing when the wetness sensor reads wet

and no precipitation is observed. The current precipitation algorithm has no such constraint on the reference depth. Moreover, in some instances when fallen precipitation is not heavy enough to breach the minimum threshold due to evaporation, wire noise, or very light precipitation rate (common at the start and end of a precipitation event) that precipitation would be missed as reference depth slowly rises despite no recorded precipitation. Comparisons of April 2010 precipitation totals between the current and constrained methods showed the constrained method resulted in increased precipitation totals for nearly every site tested (Table 1). It is anticipated that these differences would be larger during late summer with peak gauge evaporation. In addition, the newer approach was also found to observe the start of a precipitation event earlier than the current method in some cases (Figure 22). However, one limitation of this newer approach is a slightly heightened sensitivity to noisy wires as was seen for Sebring, FL. Additional testing is still underway in order to robustly evaluate the performance of this modification of the USCRN precipitation algorithm.

Method 2: Signal Theory. A new approach to calculating true precipitation from raw USCRN data has been developed which combines the signal of all three wires right at the beginning of the process, rather than keeping the wire signals separate and performing pairwise difference tests on their differences between depth and reference level. In this new method, precipitation is calculated as the average change in depth of each



Figure 21. Five-minute gauge depths from wire 1 (blue), wire 2 (red) and wire 3 (green) at Monahan, TX from August 8th 2010 21:30 UTC to 23:30 UTC. Reported wire depths are purposely offset with relative changes per wire indicating the magnitude of gauge evaporation loss.

Table 7 - Monthly total April 2010 accumulated precipitation calculated from the current and constrained algorithms at several stations across the US.

USCRN Station	Current Method (mm)	Constrained Method (mm)	Difference (mm)
Quinalt, WA	383.7	384.6	-0.9
Bowling Green, KY	86.2	87.2	-1.0
Sioux Falls, SD	77.9	78.4	-0.5
Merced, CA	62.1	62.3	-0.2
Montrose, CO	60.6	61.3	-0.7
Arco, ID	60.3	60.8	-0.5
Old Town, ME	59.1	60.4	-1.3
Sebring, FL	49.5	49.2	0.3
Durham, NC	21.0	21.3	-0.3
Monahan, TX	15.7	15.8	-0.1

wire, with wires inversely weighted according to a measure of their overall noisiness, and with periods of obvious non-precipitation zeroed out. This approach has several advantages over the existing algorithm. First, it is conceptually simpler, and hence easier to implement, maintain, and explain to new developers and outside observers. Second, it appears to capture precipitation early in events and during light events better. Third, it appears to be more efficient, allowing for faster processing and reprocessing of data, although since the prototype is implemented in a different programming language from the production version, the speed improvement has not yet been quantified. Finally, less genuine precipitation is lost to missing data circumstances.

The new approach is outperforming the existing precipitation algorithm in all cases when tested against many random variants of artificially generated precipitation events. These artificial events additionally were treated with a range of instrument noise and evaporation rate impacts. Accuracy is increased substantially under the most common conditions (low noise and low evaporation). Testing on real-world precipitation is more difficult, of course, since the true precipitation signal is not known. Rather than saying that one approach is more accurate than the other, we can only say that it calculates more or less precipitation, and attempt some

manual evaluation of cases where they differ. Comparing performance of the approaches on a month-by-month basis at twelve stations (chosen to be representative of a range of climates) suggests that the new approach catches relatively more precipitation compared to the existing approach by an average of approximately 2% per station, ranging from -1.0% to +6.4%. More importantly, where the two differ substantially, the new algorithm seems to nearly always be more in agreement with other methods of de-

termination, such as an examination of tipping bucket values or manual estimation of wire depth changes during precipitation events. For example, the improved performance of this new precipitation calculation algorithm can be seen during March 2010 in a heavy precipitation environment, Quinalt, WA (Figure 23). The new algorithm agrees well with a co-located tipping bucket, while the existing algorithm detects more than 20 mm less precipitation.

5.4.4 GROWING SEASON AND SOIL TEMPERATURE RESEARCH

While standard practice is to select a set of atmospheric temperature limits to determine growing season length, growing season is actually defined by vegetation itself. Therefore, it is more useful to use plant physiological

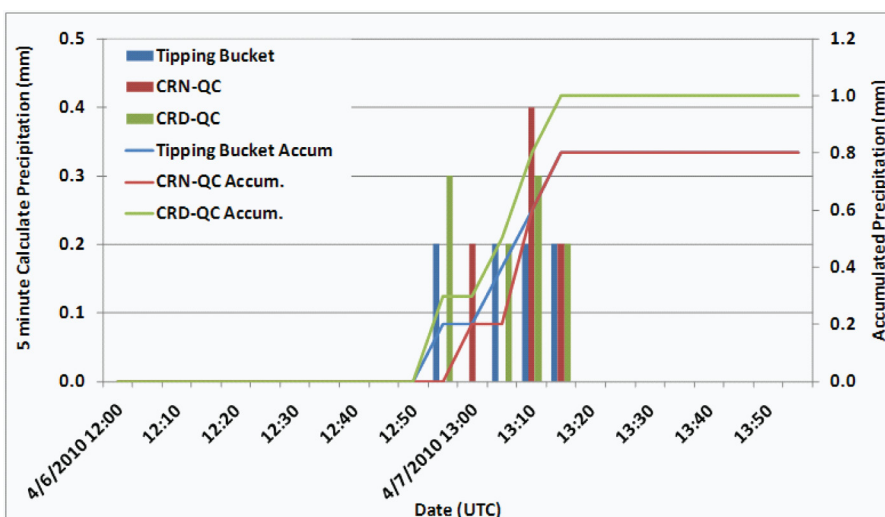


Figure 22. Five minute (bar graph) and accumulated (line graph) precipitation for tipping bucket (blue), current USCRN algorithm (red), and newer constrained algorithm (green) for Sioux Falls, SD from April 6th 2010 12:00 to April 7th 2010 13:40 UTC.

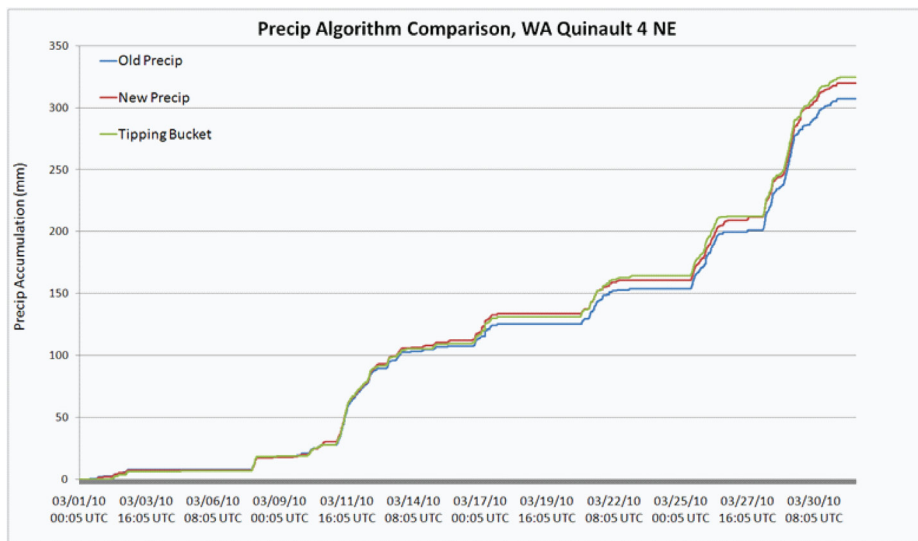


Figure 23. Cumulative precipitation at Quinault, WA, March 2010: 1) a tipping bucket (green), 2) the primary gauge with the current algorithm (blue), and the primary gauge with a new algorithm for calculating precipitation (red).

processes to construct the onset and conclusion of a growing season where possible, and determine the climate limits in relation to these growth stages. Recent research has shown that belowground temperature plays an important role in determining aboveground phenology, especially in herbaceous plants. Growing season and growing degree days were analyzed for a subset of 38 USCRN stations in the southern and central U.S. with soil probes installed in time to record the 2010 growing season. Three separate temperature measurements were taken for several depths (5cm, 10cm, 20cm, and 50cm). A comparison of in situ growing season measurements made by air and soil instruments was

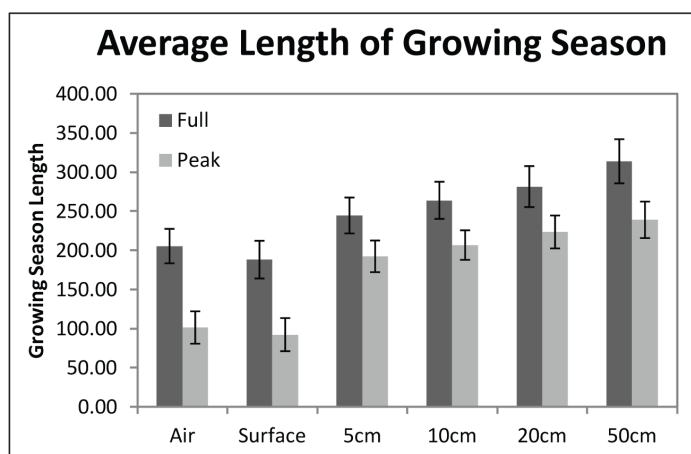


Figure 24. Average length of the growing season for 38 USCRN stations in the continental United States. Growing season for air and surface is defined by the number of days between the first and last day above 0°C. Growing season for 5cm – 50cm is defined by the first and last day above 5°C. Peak growing season for all levels is the number of consecutive days above 10°C. The whiskers determine the standard error of the mean. The full ($P < 0.01$) and peak ($P < 0.01$) soil temperature growing season was longer than the season derived from surface or air temperature.

completed, and showed that the growing season based on subsurface plant activity related to soil temperatures above 5°C were considerably longer than would be estimated from surface temperatures (Figure 24). These results were further compared to the seasonal cycle of plant phenology with remotely sensed Normalized Difference Vegetation Index (NDVI) measurements. The seasonal cycle defined by 5°C at 20 cm depth was related most closely to NDVI (Figure 25). Results to date indicate that soil temperature is a better indicator for the onset of growing season in particular.

5.4.5 USCRN SCIENCE OUTREACH

The USCRN Program continues to collaborate with a variety of external groups, including: 1) U.S. NOAA – Environment Canada Bilateral (Prairie Region Group); 2) Canada Reference Climate Station Program; 3) WMO Solid Precipitation Study; 4) NASA SMAP Mission and soil moisture testbed; 5) NOAA SMAP Preparatory Project; 6) NOAA Cooperative Remote Sensing Science and Technology Center (NOAA-CREST) soil moisture network/SMAP testbed at Millbrook; and 7) USCRN cooperation with surface IR temperature studies by the University of Tennessee and by NCDC’s own Climate Data Records Program.

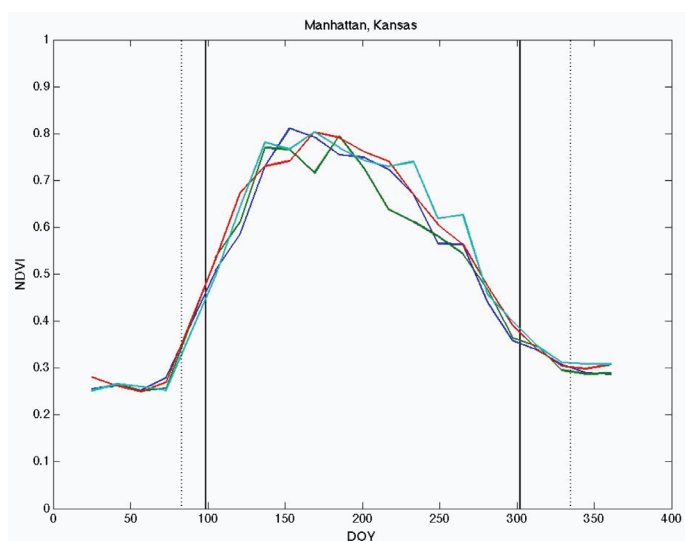


Figure 25. Yearly NDVI measurements for four locations near the USCRN station at Manhattan, KS. Vertical lines represent different measurements at the onset and conclusion of the growing season using various temperature measurements (Solid lines represent 0°C air temperature; dotted lines represent 5°C 20cm temperature).

The U.S. contribution to the Bilateral Prairie Region Group is substantially complete. The USCRN Program has completed the installation of its soil moisture network on the U.S. portion of the Prairie region, and has also commenced intercomparisons of U.S. and Canadian climate measurements at the Sioux Falls, SD, co-location site.

Environment Canada (EC) requested a copy of the algorithms used by the USCRN to calculate temperature and precipitation from triplicate observations. The descriptive documents, flow diagrams, and actual computer programs have been transferred by NCDC to EC. Canada's Reference Climate Station (RCS) Program follows the triplicate measurement philosophy of the USCRN. EC personnel are in the process of changing the software used to process and archive observations they gather from climate networks.

Most of the rest of the external interactions are related to satellite validation. The SMAP mission and USCRN activities were mentioned earlier (see Sec 5.2.2 for SMAP activities), as were the surface IR satellite validation studies in Tennessee (see Sec 5.1.2). These studies are yet another avenue of interest in USCRN observations, indicating the need to maintain even ancillary measurements in good order into the future. Currently, the surface IR temperature instruments at some of the older USCRN stations are beginning to reach the end of their useful lives, and a replacement process will begin in FY 2012.

Without personnel specifically oriented to outreach or education, the communication to potential user communities is largely accomplished through Web activities, attending science meetings, and answering direct phone and e-mail inquiries. The program will continue to encourage the climate community to visit the Web site and use our data products. 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. A considerable increase in this interaction occurred during FY 2011 as senior project personnel spent a great deal of time reaching out to site hosts who had concerns and problems to resolve (see Sec. 2.5.2). An approach to automate a more personalized set of products for site

hosts has been under consideration and will be pursued as developer time becomes available. Also, an effort will be made to free up staff time to allow for more direct personal contact with site hosts to keep them informed of USCRN developments and discuss site stability issues.

5.5 Research Papers and Meeting Presentations in FY 2011⁵

Published Papers:

Bell, J.E., E. Weng, and Y. Luo, 2010. Ecohydrological responses to multifactor global change in a tallgrass prairie: a modeling analysis. *J. Geophys. Res. Biogeosciences*, **115**, G04042, doi:10.1029/2009JG001120.

Leeper, R.D., J.M. Walker, and G.B. Goodrich, 2010. Teleconnective relationships to the Kentucky snowfall impact scale. *J. Kentucky Acad. Sci.*, **71**, 36-46.

Mahmood, R., R. Leeper, and A.I. Quintanar, 2011. Sensitivity of planetary boundary layer atmosphere to historical and future changes of land use/land cover, vegetation fraction, and soil moisture in Western Kentucky. *Glob. and Planet. Change*, **78**, 36-53.

Palecki, M.A., and P.Ya. Groisman, 2011. Observing climate at high elevations using United States Climate Reference Network Approaches. *J. Hydrometeor.* **12**, 1137-1143, doi:10.1175/2011JHM1335.1.

Rasmussen, R., B. Baker, J. Kochendorfer, T. Meyers, S. Landolt, A.P. Fischer, J. Black, J. Theriault, P. Kucera, D. Gochis, C. Smith, R. Nitu, M. Hall, S. Cristanelli, and E. Guttman. The NOAA/FAA/NCAR winter precip test bed: How well are we measuring snow? *Bull. Amer. Meteor. Soc.*, Accepted.

Submitted Papers:

Bell, J.E., E. Weng and Y. Luo. Changes in rain use efficiency across multiple biomes with experimental warming: A meta-analysis. *Ecohydrolog.*

Leeper, R., R. Mahmood, and A.I. Quintanar. Influence of karst landscape on planetary boundary layer atmosphere: A Weather Research and

⁵Underlined authors are from the USCRN team at either NCDC or ATDD.

Forecast (WRF) model-based investigation. *J. of Hydrometeor.*

Conference on Applied Climatology. Asheville, North Carolina. 19 July 2011.

Quintanar, A.I., R. Mahmood, A. Gonzalez, and R. Leeper. Atmospheric sensitivity to roughness length in a regional atmospheric model over the Ohio-Tennessee river valley. *Bound. Layer Meteor.*

Palecki, M.A. (Poster Presentation). U.S. Climate Reference Network Soil Moisture Measurement and Drought Monitoring. 25th Conference on Hydrology, Annual Meeting American Meteorological Society, Seattle, WA, 27 January 2011.

Sherry, R.A., X. Zhou, J.E. Bell, X. Xu, and Y. Luo. Climate warming and land-use can change relationships among diversity, productivity and stability. *Ecology*.

Palecki, M.A. U.S. Climate Reference Network. Hendersonville Rotary Club, Hendersonville, NC, 29 March 2011.

Presentations:

Bell, J.E. (Oral Presentation). Ecohydrological Processes, Carbon-Water Coupling, and Climate Change. NCDP Branch Seminar. Asheville, North Carolina. 24 June 2011.

Palecki, M.A., H.J. Diamond, C.B. Baker, and T.P. Meyers. SMAP Science Product Validation with U.S. Climate Reference Network In Situ Observations. Second Soil Moisture Active Passive Cal/Val Workshop, Oxnard, CA, 4 May 2011.

Bell, J.E. (Poster Presentation). An Evaluation of Air and Soil Temperature for Estimating Growing Season and Growing Degree Days. AMS Conference on Applied Climatology. Asheville, North Carolina. 18 July 2011.

Palecki, M.A. The U.S. Climate Reference Network and Drought Applications. Drought Monitoring & Early Warning Workshop, National Hydrologic Warning Council 2011, San Diego, CA, 10 May 2011.

Bell, J.E. (Invited Speaker). US Climate Reference Network: Soil Moisture/Temperature. NOAA/NESDIS Cooperative Research Program Symposium. Asheville, North Carolina. 18 August 2011. (First Place Oral Presentation)

Palecki, M.A. Maintaining a National Observation Network: Lessons for Hydrologic Warning Systems. National Hydrologic Warning Council 2011, San Diego, CA, 11 May 2011.

Bell, J.E. (Poster Presentation). Air and Soil Temperature for Estimating Growing Season and Growing Degree Days. NOAA/NESDIS Cooperative Research Program Symposium. Asheville, North Carolina. 18 August 2011. (Second Place Poster Presentation)

Palecki, M.A. NOAA's In Situ Climate Observing System: Maintaining the Climate Record. 19th Conference on Applied Climatology, Asheville, NC, 20 July 2011.

Bell, J.E. (Seminar Speaker). US Climate Reference Network Overview and Soil Moisture/Temperature Monitoring. Soil Science Department. Raleigh, North Carolina. 25 August 2011.

Palecki, M.A. U.S. Climate Reference Network Overview and Update for AASC. Annual Meeting of the American Association of State Climatologists, Asheville, NC, 22 July 2011.

Bell, J.E. U.S. Climate Reference Network. NCSU Mountain Horticultural Crops Research and Extension Center. Mills River, North Carolina. 22 September 2011.

Leeper, R. The Role of Network Architecture in Surface-Based In-Situ Climate Observations. AMS

6. FY 2011 INTERNATIONAL COOPERATION

6.1 The Canadian Climate Partnership and Technology Exchanges

The first nation to collaborate with the USCRN program on 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 ex-

amined 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:

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

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 prototypes⁶ 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

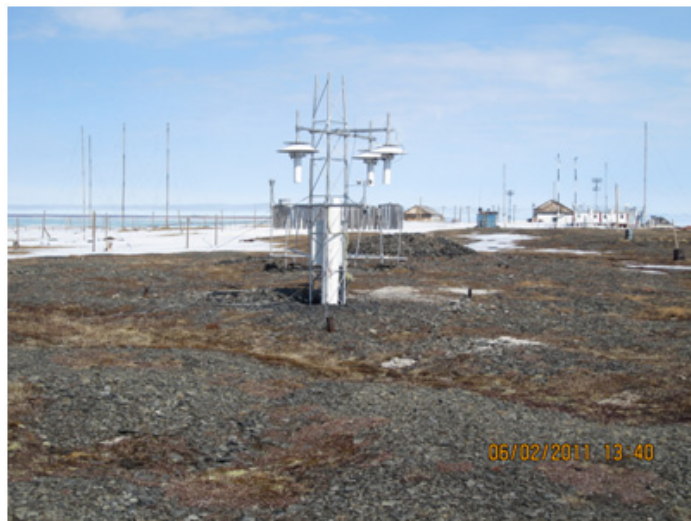


Figure 26. USCRN Station in Tiksi, Russia

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 2011, the station in Tiksi became operational and data from that station will become available from the USCRN web site during FY 2012.

The Tiksi USCRN station was installed in August of 2010 and operated over the winter of 2010-2011, however due to a failure in the communications protocols, data was not archived. In late May of 2011, a U.S. - Russian science team arrived on site and started formal data archiving beginning on April 23, 2011. This date is earlier than the arrival of the science team by several weeks due to the fact that the internal data logger had a backwards archive of data. During this spring visit, one of the Geonor precipitation sensors was adjusted to operate properly. The site was primarily installed by the personnel at the Arctic and Antarctic Research Institute (AARI) of St. Petersburg Russia. AARI is a research laboratory under Roshydromet (The Russian Federal

⁶The 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

Service for Hydrometeorological and Environmental Monitoring). Staff from there made a trip in 2009 to the NOAA/ATDD Oak Ridge laboratories for USCRN installation training. AARI has also filed and received permission for the USCRN data to legally be transmitted from the Russian Federation, and AARI maintains a Tiksi data center in St Petersburg that acquires the data from Tiksi in near real time (every 4 hours) and then forwards data to the NOAA laboratories in Boulder where they can be found at the following site on-line at <ftp://ftp.etl.noaa.gov/psd3/arctic/tiksi/CRN/Incoming/>.

6.3 International Precipitation Test Bed Activities Involving USCRN

The XV World Meteorological Organization's (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 lead facility in this intercomparison along with sites from Norway, China, Canada, Japan, Switzerland, Finland and New Zealand. The goals for 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), with the following objectives:

i. Definition of an in-situ field reference for measuring solid precipitation using an automatic weighing gauge:

Define, develop and validate a field reference using automatic gauges for each parameter being investigated, which would allow an increased reporting resolution (e.g. 1 hour, 30 minutes, 10 minutes, 1 minute).

ii. Assessment of Automatic Gauges used in operational applications for the measurement of Solid Precipitation:

- a. Assess the ability of operational automatic sensors (weighing gauges, tipping buckets, non-catchment instruments) to robustly perform in the required operating conditions (light, heavy, wet, windy, blowing etc):
- b. Determine bias adjustments (function of parameters available at an operational site: wind, temp, RH) of operational automatic gauges;

- c. Make recommendations on the required operational ancillary data, to enable the derivation of adjustments for data from operational sites, on a regular basis, potentially, real-time or near real-time.
- d. Operational data processing and quality management
- e. Assess the minimum practicable time- interval for reporting a valid solid precipitation measurement (precipitation falling and accumulation on the ground);
- f. Evaluate the ability to detect and measure trace and light precipitation;
- g. Assess the temporal resolution of the measurement of the snow on the ground and its relationship to snowfall.

iii. Provide recommendations of best practices and configurations for the operational gauges, in operational environments.

- a. On the exposure and siting specific to various types of instruments;
- b. On the optimal gauge and shield combination for each type of measurement for different collection conditions/climates (e.g., arctic, prairie, coastal snows, windy, mixed conditions);
- c. On instrument specific operational aspects, specific to cold conditions; heating, evaluation of the use of antifreeze: its hygroscopic properties and composition to meet operational requirements;
- d. On instruments and their power management requirements needed to provide valuable measurements in harsh environment;

iv. Investigate and understand the accuracy and precision of gauges and the ability to accurately report solid precipitation.

- a. Assess the sensitivity, accuracy, precision, and response time of operational and emerging automatic sensors;
- b. Assess and report on the sources and magnitude of errors including instrument (sensor), exposure (shielding), data collection and associated processing algorithms with respect to sampling, averaging, filtering, and reporting.

v. Evaluation of new and emerging technology for the measurement of solid precipitation (e.g. non-

catchment), and their potential for use in operational applications.

vi. Enable studies on the homogenization of automatic/manual observations: configure and collect during the experiment a comprehensive data set that could be made available for further data mining, for specific applications.

The USCRN, Canadian, and Finland precipitation testbeds in 2011/2012 will establish the field reference for the automated measurement of solid precipitation that will be used by all other participants starting in 2013. This includes the gauge type, the wind shielding around the gauge, and the heater used to inhibit ‘capping and dumping’ caused by the accumulation of snow in the gauge inlet and on the cover of the gauge, and the measurement resolution. The potential field reference will be compared to the established secondary reference which is the manual Tretyakov gauge inside a Double Fence Intercomparison Reference (DFIR) wind shield.

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 for 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, meaningful climate insights can begin to be drawn 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 and FY2011 to begin to link these new and

relatively brief records to longstanding homogenized climate records for purposes of climate monitoring have been made through the generation of estimated normals linking USCRN and USHCN v2 observations, and through the beginning of network intercomparison activities. 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 and other longer lasting catastrophic events.

7.1 Operations During Extreme Conditions

Southern Tornado Outbreak. The record setting tornado outbreak of April 25-28, 2011, produced its peak damage in Alabama and Tennessee on the 27th. This area includes 17 USRCRN stations and 4 USCRN stations. No USRCRN/USCRN stations in Alabama lost any data due to local and regional AC power outages due to the battery back-up systems of these stations. Only the USCRN station in Crossville, TN, lost the ability to transmit briefly, but only one hour of data was lost. This is quite a testament to the engineering of these systems, and the good fortune of the stations not to receive a direct hit from the most powerful tornadoes. Most stations connected to the electrical grid weathered the storms and retained power through working AC service or through battery backup. All the USCRN stations powered by solar panels continued working throughout the time period.

AC dependent stations with power outages on the 26th or 27th had power restored in time for the most part, including:

1. Crossville, TN - outage April 27, restored May 2 (one hour data loss)
2. Courtland, AL - outage April 27, restored May 1
3. Valley Head, AL - outage April 27, restored May 1
4. Gadsden, AL - outage April 27, restored May 1
5. Monroe, LA - outage April 26, restored April 27

While it is unfortunate that power could not be restored in time at the Crossville, AL, site the overall performance of the networks was excellent during this catastrophic event. Courtland recorded a peak 10-second wind average of 68 mph at a height of 32.8 feet (10 meters), indicating the storm there had the potential to devastate surrounding power grids. In these cases, AC powered stations can be less reliable than solar powered stations.

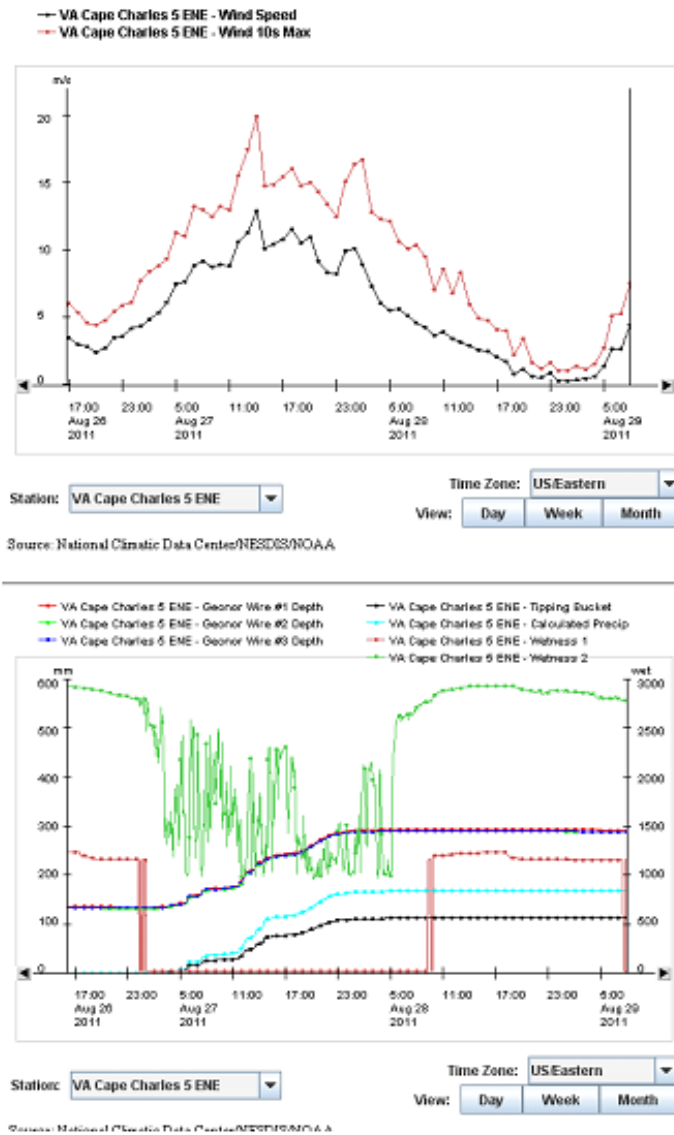


Figure 27. Cape Charles, VA USCRN station wind and precipitation during Hurricane Irene. a) Wind hourly averages and peak gusts (m/s); b) Precipitation (mm) calculated from weighing bucket gauge (light blue) and tipping bucket gauge (black).

Hurricane Irene. All the USCRN stations in the path of Irene fared well during the storm. While it appears that the McClellanville, SC, station lost AC power for the period from 4:00 pm local time on August 26 until 11:00 am on August 27, and the Millbrook, NY, station may have lost AC power from 10:00 am to 8:00 pm on August 28, the battery backup system kept both stations transmitting until AC power was restored, and all the data are up to date for the storm period. USCRN stations from Titusville, FL, to Limestone, ME, recorded precipitation and wind impacts from Irene. The highest USCRN rain totals were 6.61 in (167.9 mm) at Avondale, PA, 6.35 in (161.3 mm) at Millbrook, NY, and 6.21 in (157.8 mm) at Cape Charles, VA, all of which were within the range of nearby NWS precipitation measurements. Cape Charles was also the windiest USCRN site (Figure

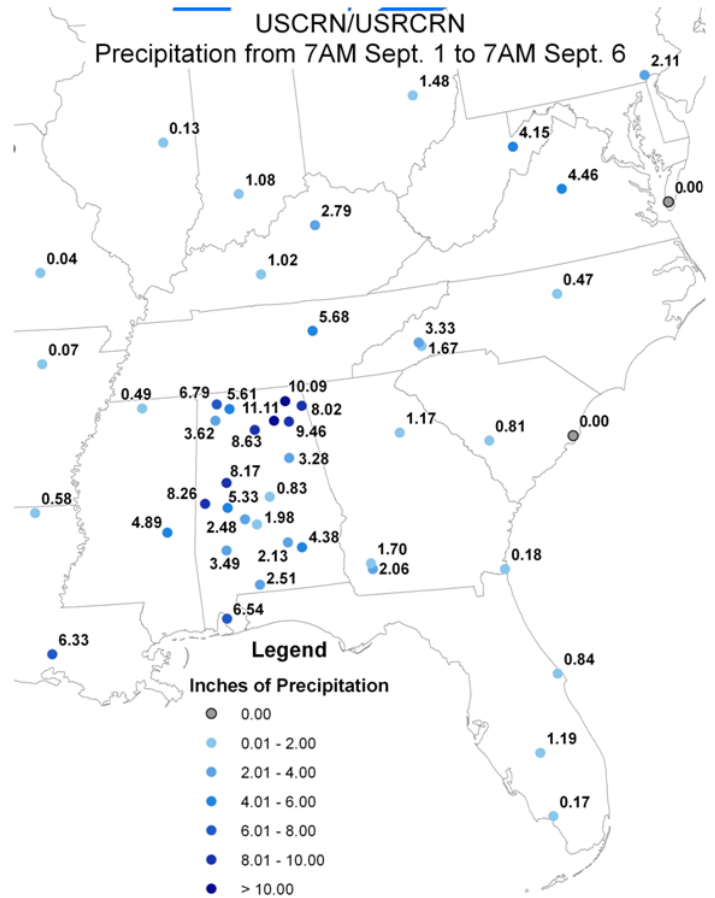


Figure 28. Precipitation totals (inches) during the passage of Tropical Storm Lee over USCRN/USRCRN stations in the Southeastern U.S., September 1-8, 2011.

27a), with a peak 10-second gust of 44.5 mph (19.9 m/s) and peak hourly wind average of 28.7 mph (12.8 m/s). Interestingly, even though this USCRN wind gust measurement was measured at only a height of 5 feet (1.5 meters) above the ground⁷, it was close to nearby peak gusts at Wallops Island (53 mph, 23.7 m/s) and Accomack County Airport (52 mph, 23.2 m/s), which were 3-second gusts measured at the standard level of 32.8 feet (10 meters) above the ground. Also, due to the high winds, the weighing bucket gauge at the station accumulated about 2 inches (50 mm) more precipitation than the co-located tipping bucket gauge (Figure 27b).

Tropical Storm Lee. As noted earlier, a particularly dense network of USCRN operational and regional experimental sites is located in Alabama, and these stations observed large amounts of rain from TS Lee (Figure 28). Regional stations in Guntersville and Scottsboro in northeast Alabama received 11.34 inches (288.10 mm) and 10.51 inches (266.9 mm), respectively, while the USCRN site at Gadsden received 9.91 inches

⁷WMO standard wind measurements are made at a height of 10 meters (or 32.8 feet) above the ground

Table 8 USCRN Temperature Records (°F)

Highest Air Temperature = 126°F
Stovepipe Wells, CA; July 5, 2007
Lowest Air Temperature = -57°F
Barrow, AK; February 3, 2006
Highest Ground Surface Temperature = 162°F
Stovepipe Wells, CA; June 24, 2006
Lowest Ground Surface Temperature = -58°F
Barrow, AK; February 3, 2006

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. Several new records are evident from a reanalysis of the last few years, including a new 60-minute record at Everglades City, FL (4.07 in), and a new 365-day record

Table 9 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: 282 Days	September 19, 2009–June 27, 2010

USCRN/USRCRN
Precipitation from 7AM Aug. 25 to 7AM Sept. 8

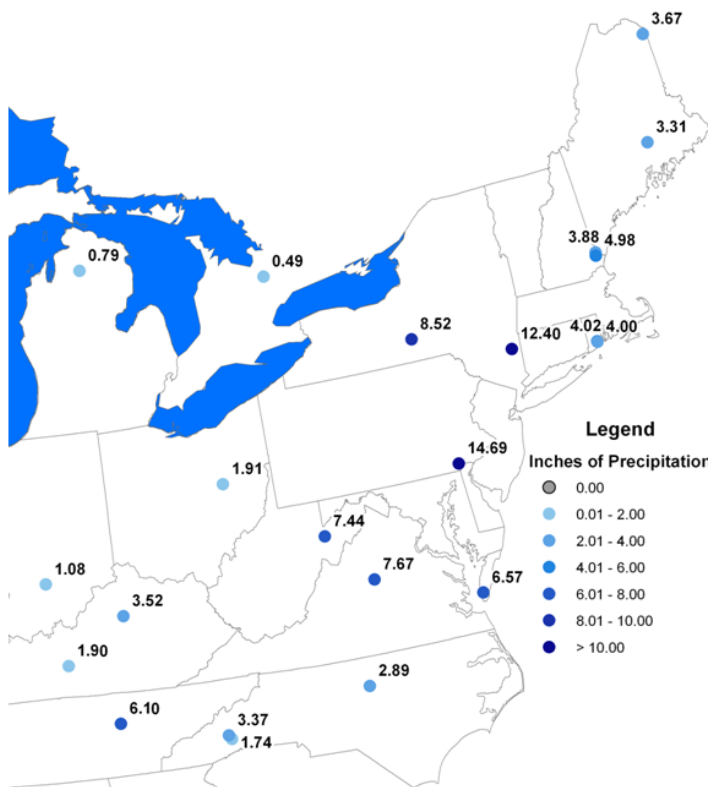


Figure 29. Precipitation totals (inches) during the passages of Hurricane Irene and Tropical Storm Lee over USCRN/USRCRN stations in the Northeastern U.S., August 25 - September 8, 2011.

(251.7 mm). While most USCRN/USRCRN stations in the area recorded copious amount of rain, the dry slot of the storm was also easy to trace, with the USCRN station at Clanton, AL, only recording 0.83 inches (21.1 mm) of rain. After drenching the Gulf Coast states, Lee moved northward, where substantial rain amounts were recorded along its path: 6.85 in (173.9 mm) at Avondale, PA; 6.84 in (173.7 mm) at Ithaca, NY; 6.73 in (171.0 mm) at Charlottesville, VA, 5.67 in (144.0 mm) at Elkins, WV, and 5.42 in (137.6 mm) at Millbrook, NY. Combining the precipitation totals for Irene and Lee, Avondale received 14.69 in (373.2 mm) between August 25 and September 8, Millbrook received 12.40 in (315.0 mm), and Ithaca received 8.52 in (216.3 mm), demarcating the south, east, and north edges of some of the worst flooding in the Mid-Atlantic region in many years (Figure 29). Overall, the USCRN/USRCRN stations performed very well in some very challenging severe weather situations during FY 2011, and this speaks well to the engineering design of the systems.

Table 10. USCRN Precipitation Records (inches)

USCRN PRECIPITATION RECORDS (INCHES) (November 2000–September 2011)			
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:	4.07"	Everglades City, FL	March 29, 2010
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	194.05"	Quinault, WA	April 16, 2010-April 15, 2011
Greatest Water Yr:	186.63"	Quinault, WA	Oct 1, 2006–Sep 30, 2007

Note: The Quinault 2007 water year record is 53.94" 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), which has now been exceeded at the USCRN station

at Quinault, WA (194.02 in). Variables indicated as records in Tables 8 and 10 are records measured strictly by USCRN stations.

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. Improvements continued through FY11, including the introduction of a bulk monthly data product, the Monthly01, in an effort to respond 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
- 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/station-map.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 2000–11 SUMMARY

The USCRN has been completed in the CONUS for three 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 2011. The USCRN Science project focused on the development of improved quality control for all variables, and sought improvements in the precipitation calculation algorithm. The Alaska USCRN progressed well in FY 2011, and will continue to fulfill 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 been completed, 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 2012 PLANNED ACTIVITIES AND GOALS

Research and engineering development activities envisioned for FY 2012 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 continuous improvement of system engineering.

- Developing a new post-processing system to examine observations over longer periods in order to identify defective instruments.
- Merging soil climate observation processing, with the new object oriented ingest architecture, and fully implement the exception list concept.
- Improving our understanding of soil moisture measurements by planning and commencing a long term program of field calibration with gravimetric soil sampling techniques.
- Deploying a new precipitation calculation algorithm to improve the accuracy of measurements from a triplicate configuration system.
- 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.
- Beginning 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.

11. THE VISION FOR USCRN AS IT ENTERS ITS SECOND DECADE OF MONITORING THE NATION'S CLIMATE

The USCRN is just beginning its second decade of service in monitoring the nation's climate; now that the installation of all continental sites has been completed, including the soil sensor and relative humidity sensor add-on, the challenge is to assure that we continue to operate the existing sites to the same high-quality climate standards, as we continue to expand the network into Alaska through 2018. The USCRN is without a doubt the nation's gold standard when it comes to the climate monitoring of surface air temperature and precipitation, as well as for soil moisture and temperature. It is exciting to see that USCRN soil measurements will

form part of the calibration and validation of NASA's SMAP mission scheduled for launch in 2014, and therefore, we have to redouble our efforts to ensure that the calibration of our soil data is at the highest level possible. A continuing challenge is to focus attention on creating good and credible science and data products from USCRN data that can address a broad range of data users. For example, as NCDC has worked to produce a new set of 30-year climate normals for the country from 1981-2010, for the first time, USCRN data is now part of this and is providing enhanced information to assist in this effort. While USCRN has operated at most for 10 years at a few sites, the USCRN scientific staff works to use these data to help enhance efforts at characterizing the nation's climate.

The second decade of USCRN will occur during a time of more constrained resources. However, the primary mission of the Program must remain the ability to maintain stations in peak operating condition, and to encourage site hosts to continue to preserve the stability of the station sites in the face of internal and external pressures to change. It is the stability and quality of measurements that will set the USCRN apart from other observation systems and increase its intrinsic worth to governmental, academic, and private sector users alike. These in situ measurements will become the reference standard for other in situ networks, and for remote sensing systems. Despite resource pressures USCRN must be championed as the best option for understanding surface climate changes and variations as they occur, and its governing principles and techniques need to be promoted internationally. A vision of the future in which this happens sees USCRN-like climate observation systems expanding to all corners of the globe, and in particular to undersampled high-elevation, high-latitude, and tropical climate regimes.

As such, USCRN must continue to make progress both technologically and scientifically. Instruments must continue to undergo intercomparison testing to identify valid replacements for what is currently deployed, and also to identify better and more cost effective methods of climate observing. Quality control research needs to be supported to identify problems and improve our understanding of data deficiencies so that we can properly assess the confidence level of the measurements. Climate science's use of the data must be greatly expanded as more years of data become available. Reliance on the USCRN for representing the state of the surface climate in the US will expand in FY 2012 with the

application of better USCRN normals estimates, and will continue through the next decade. Soil moisture measurements will be blended with soil modeling systems to better use these brief time series to determine if soils are drier or wetter than normal. USCRN will become more connected to an ever increasing set of users, starting with other NOAA offices and branches, such as providing input to NCEP models, satellite validation and algorithm development, and climate models of all types (short term, decadal, century), and ending with many other external and international partners.

The next decade will see USCRN play a larger role in science's ability to better understand the nature of climate change impacting the United States, and modelers will continue to use USCRN data as a key standard for judging the performance of their models over the instrumental period. The USCRN is invaluable to the future of climate science and must continue to make progress and move forward as the gold standard for surface climate observing in the U.S.

ACRONYMS AND ABBREVIATIONS

AARI	Arctic and Antarctic Research Institute
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
GEOS	Global Earth Observation System of Systems
GHCN-D	Global Historical Climatology Network Daily
GOES	Geostationary Operational Environmental Satellite
HDD	Heating Degree Days

IPCC	Intergovernmental Panel on Climate Change	RH	Relative Humidity
LCD	Local Climatological Data	RI	Rainfall Intensity
LDAS	Land Data Assimilation System	SA	Single Alter
MADIS	Meteorological Assimilation Data Ingest System	SCAN	Soil Climate Analysis Network
MOU	Memorandum of Understanding	SDFIR	Small Double Fence Intercomparison Reference
MTBF	Mean Time Between Failures	SNOTEL	USDA/NRCS Snowpack Telemetry System
NAS	National Academy of Sciences	SM	Soil Moisture
NASA	National Aeronautics and Space Administration	SMAP	Soil Moisture Active and Passive
NCDC	National Climatic Data Center	SMART	Station Monitoring and Reporting Tool
NIDIS	National Integrated Drought Information System	ST	Soil Temperature
NOAA	National Oceanic and Atmospheric Administration	STRI	Smithsonian Tropical Research Institute
NP	National Park	SURFRAD	NOAA Surface Radiation Budget Network
NRC	National Research Council	USCRN	United States Climate Reference Network
NRCS	National Resources Conservation Service	USDA	U.S. Department of Agriculture
NWR	National Wildlife Refuge	USDP	U.S. Drought Portal
NWS	National Weather Service	USGS	U.S. Geological Survey
PDA	Personal Digital Assistant	USRCRN	U.S. Regional Climate Reference Network
PM	Performance Measure	WCDMP	World Climate Data and Monitoring Program
RAWS	Remote Automated Weather Station	WMO	World Meteorological Organization
RCS	Canadian Reference Climate System		



Space Shuttle Atlantis Lands for the Last Time in Front of the USCRN Station at the Kennedy Space Center.

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