United States Climate Reference Network (USCRN)

FY 2003 Annual Report

NOAA–NESDIS

October 2003

USCRN Web Site: http://www.ncdc.noaa.gov/oa/climate/uscrn

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1. Introduction

This is the first annual report for the United States Climate Reference Network (USCRN). The primary focus of this report is on FY2003 USCRN development and implementation activities. This report includes a summary of activities undertaken during FY2001 and FY2002 as well as initial projections of activities planned for FY2004 and FY2005.

Reports for each year include reviews of the USCRN, program Performance Measures, stations installed, research progress, instrument testing, partnership development at several levels, data quality, data availability, ***<u>and progress towards the early FY04 goal of USCRN network commissioning.</u>***

2. Program Base

The required program capability and requirement drivers for the United States Climate Reference Network (USCRN) rest on the following:

2.1 Program Capability

The NOAA Strategy of "Monitor and Observe":

"We will invest in high-quality, long-term climate observations and will encourage other national and international investments to provide a comprehensive observing system in support of climate assessments and forecasts." (NOAA Strategic Plan)

2.2 Program Purpose

The United States Climate Reference Network (USCRN) program will provide the United States with a climate monitoring and climate change network that meets national commitments to monitor and document climate change. The USCRN Program will deploy no fewer than 100 operational sites in the continental United States through FY 05 to achieve this goal. The program purpose is to:

> *Ensure that future changes and variations in primary measurements at specific locations can be monitored without the need for uncertain adjustments and corrections to the data. Primary measurements at each site will include air temperature and precipitation supplemented with other measurements such as wind speed, solar radiation, and infrared radiation. The network will provide adequate spatial coverage to monitor the national scale, decadal-to-centennial temperature and precipitation trends across the United States.*

Fundamental to this goal is the requirement to establish a network which 50 years from now will answer the question: *How has the climate of the United States changed over the past 50 years?* To accomplish this goal the program will adhere to the Ten Climate Monitoring Principles[1] as defined by National Research Council of the National Academy of Sciences contained in Appendix A.

The program requirement drivers and program objective and characteristics are given below.

Program Requirement Drivers

A. *<u>Legislative</u>:*

- Federal Data Quality Legislation (Act) (Public Law 106-554 Section 515) - section 515 is known as the 'data quality act' Data Quality Act … government must assure the quality of the information disseminated.
- 15 USC 313 “establish and record the climate conditions of the United States”

- Global Change Research Act of 1990 -- “requires an early and continuing commitment to the establishment, maintenance, global measurements, establishing worldwide observations… and related data and information 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 US weather and climate records with responsibilities of archiving and servicing.
- 33 USC “… authorize activities of processing and publishing data…”
- 15USC 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”

B. ***Executive/International/Programmatic***

- Earth Observation Summit (and Group on Earth Observation (GEO) Working Group) – Summit Declaration reaffirmed need for timely, quality, long-term global information as a basis for sound decision-making and called for filling data gaps. Summit Declaration also affirmed need for “producing calibrated data sets in useful formats from multiple sensors and venues”.
- CCSP Strategic Plan – has a number of goals articulated including: “complete required atmosphere and ocean observation elements needed for a physical climate observing system” – this includes the "US Climate Reference Network" 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 ASOS, SURFRAD, and COOP; “Data archives must include easily accessible information about the data holdings, including quality assessments, supporting ancillary data, and guidance and aid for locating and obtaining data” and “Preservation of all data needed for long-term global change research is required. For each and every global change data parameter, there should be at least one explicitly designated archive.”
- GCOS Second Adequacy Report – Speaking on data accessibility and quality, “There 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, this report confirms the IPCC view that current observations are not adequate to meet the full needs of the Parties and are an increasing barrier to the full provision on advice. Without urgent action … the Parties will lack the information necessary to plan for and manage their response to climate change”
- Annual Guidance Memorandum – “Taking the pulse of the planet – contributing to an Integrated Global Observing System” and that “we should develop a comprehensive, NOAA-wide data collection, quality control, storage, and retrieval program.”

- Several bi-laterals, particularly, U.S/Canada Weather/Climate, and the Global Change Observing Systems (GCOS) initiative to stimulate CRN-like initiatives in Latin America, and eventually to other regions.
- U.S. Climate Change Research Initiative – work to improve global observing systems, including involving those of and/or being built by developing countries; work to improve access to global observations.
- The Administration position is outlined in the speech by President George W. Bush in June 2001 enjoining the climate community to provide decision-makers with the most precise, least controversial climate data and trend analyses than any previously possible in order that public policy decisions of great gravity could be made with the highest confidence.

- The philosophical-technological base of the USCRN is derived from the *Climate Monitoring Principles* as initially formulated with and reviewed by the government and academic climate communities in 1999[2] (see Appendix A).

Program Objectives and Characteristics

The USCRN program objectives are to develop, acquire, field and operate the premier environmental climate-monitoring network of the United States. The USCRN will provide stable surface temperature and precipitation observations that are accurately representative of environmental conditions. Site location is particularly important as environmental conditions must not be affected by encroachment of urban expansion or other conditions that create a changing environment.

As the premier reference network, USCRN site locations must remain stable for a period of 50 to 100 years and, where possible, be co-located with or near existing meteorological observation sites such as the Historical Climate Network (HCN) and the National Weather Service's Cooperative Observer (COOP) network. USCRN co-locations with other networks are also encouraged. Since the network is intended to serve as a model environmental monitoring network for the United States and the international community, the program will develop data transfer functions relating observations from these networks to the USCRN and thereby leverage primary and specialized climate observations over broader coverage areas.

USCRN field system technology is designed to be highly reliable, robust and maintainable so that it will collect, format, process and communicate environmental parameters to the National Climatic Data Center's (NCDC) central data management and processing facility in Asheville NC. The equipment is designed to operate, without human intervention, under a wide variety of environmental conditions. The NCDC will provide data ingest, quality control monitoring, data processing, archiving, and user access capabilities to both the climate research community and the general public. After three years of development, the USCRN deployed network is of sufficient initial density, reliability and stability, and science information value as to move forward to the status of a commissioned network.

The desired outcome, capabilities required, and program-level performance measures are discussed below.

Desired Outcome

A sustained, cost-effective science-driven national and regional climate data and benchmark system complementary to older and less rigorous NOAA in situ (surface) networks. This should result in reliable information related to the state and changing state of the climate system and enable more reliable and higher-confidence climate-related predictions and projections to be made by both national and regional decision-makers.

Capabilities Required

The required capabilities are the following:

- Sustained US tiered network of land-based reference stations and standard land surface observing stations. The USCRN, as the U.S. benchmark backbone network, must adhere to all NRC and GCOS Climate Monitoring Principles.
- Coverage must be of sufficient temporal and spatial resolution to monitor local to national space scales for physical phenomena and trends of significant socio-economic and scientific importance.
- Measurements of key variables adhering to NRC and GCOS Climate Monitoring Principles. The two primary variables for USCRN are very high-quality, redundant measurements of temperature and precipitation, with secondary variables of solar radiation, wind velocity, and infrared radiation being used as primary variable checks.
- Data, assimilation, and product generation subsystems for the observations.
- Observing system management and information delivery infrastructure.

Program-Level Performance Measures

The programmatic level Performance Measures for the USCRN are built upon the simplest, cleanest, most basic purpose of the network:

> *To reduce uncertainty and error range envelopes in producing the most precise in situ temperature and precipitation records possible, and to do it with the fewest possible stations located in areas of minimal human disturbance and with the least likelihood of human development over the coming 50-100 years.*
>
> *The present single goal of USCRN is to reduce Climate Uncertainty at the national level to a statistically insignificant level.*

That is, for temperature Climate Uncertainty at the national level should be reduced by 98% and for precipitation Climate Uncertainty should be reduced by 95%. For reduction of Climate Uncertainty for the nine U.S. regional climate zones to similar values the USCRN would require the density of USCRN stations be increased to 300.

By the end of FY2003, the continental U.S. (CONUS, excluding the States of Alaska and Hawaii and the various Territories) national-level Climate Uncertainty for temperature had been reduced by about 94-95%; the precipitation Climate Uncertainty had been reduced by about 83%. This lag of the precipitation PM behind the temperature PM is normal. These reductions of Climate Uncertainty have been done by the deployment of the first 43 USCRN stations in the continental U.S. (Note that two additional test stations have been deployed to severe environments in Alaska).

Reductions in Climate Uncertainty, as expected, are most pronounced and even dramatic in the first part of this program. Later progress in reducing uncertainty to the required level that results in high-confidence decision-making will be more difficult as USCRN moves towards the middle and end phases of station deployment. It will take a minimum of two more years (FY 2005) to drive these Climate Uncertainty numbers down to the *minimal* levels required by *national-level* decision makers. It would take another five years (FY 2010) to reach similar levels required to empower local, State, and regional decision-makers with data of sufficient precision

See Table 1 below for the relationship between the number of USCRN stations deployed and the Performance Measure of reduction of Climate Uncertainty:

Table 1. US Climate Reference Network Performance Measures, FY2002-2005

U.S. Climate Reference Network (USCRN)	FY 2002	FY 2003	FY 2004	FY 2005
PM: Reduce climate uncertainty concerning variability of temperature and precipitation trends to required levels for monitoring climate variability and change.				
National Goal (% of Climate Uncertainty)	26	<20	<15	<13
Regional Goal(% of Climate Uncertainty)	94	<65	<60	<50
# of Sites to reach National Goals[1]	23	40	71	100

2.3 Program Schedule

The USCRN Program has been organized into broad program phases entitled Development, Demonstration, Limited Implementation, and Full Implementation. Figure 1 depicts the program structure and general schedule.

The recently completed **Development Phase** consisted of organizing and documenting plans system requirements, basic cost and tradeoff analyses. During this phase, prototype site survey, system installation, communications architecture, data processing, and maintenance activities were developed and implemented.

[1] For the Lower 48 States of the continental United States, a total of 100 stations are needed to meet that primary, composite (T & P) Performance Goal of reduction of Climate Uncertainty to <13%.

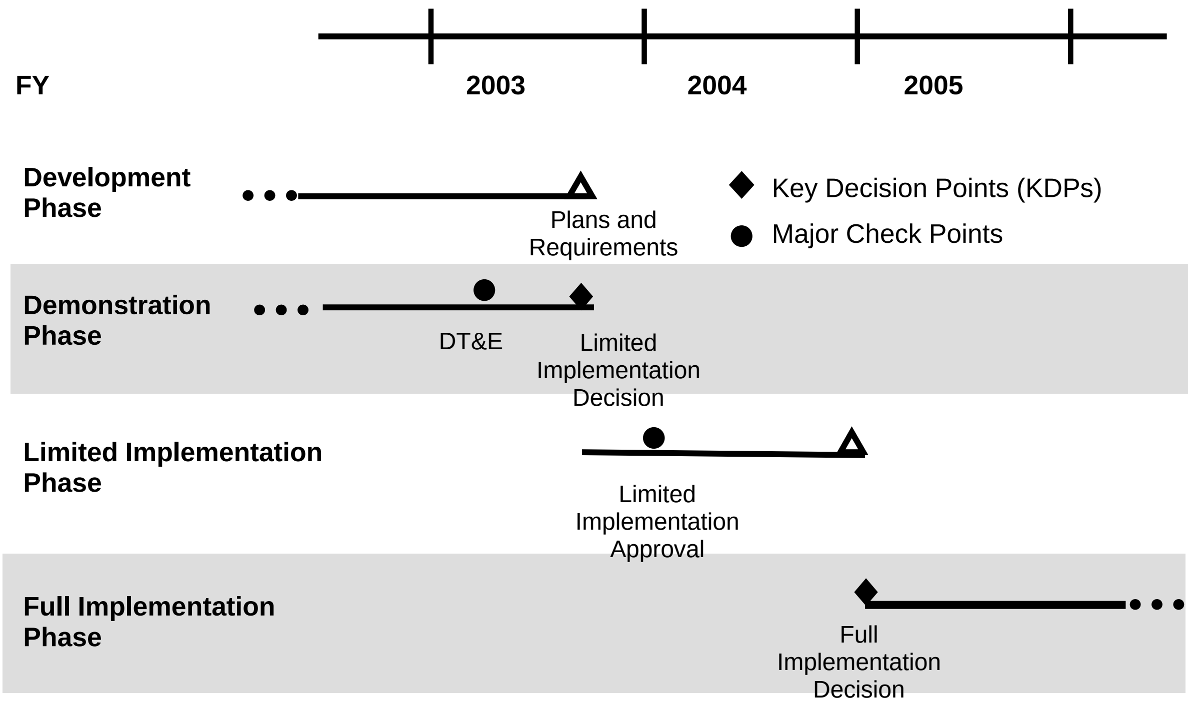


Figure 1. Climate Reference Network Program Phases

The **Demonstration Phase** provided early exposure and quasi-operational use of prototype systems in different climate regimes and a test mechanism for the prototype activities. A demonstration evaluation was conducted to assess the operational and performance characteristics of the first 40 systems and to ensure readiness to proceed to the Limited Implementation phase.

The **Limited Implementation Phase** further serves to reduce risk by incorporating fixes from the demonstration evaluation and evaluating end-to-end system performance, system maintenance effectiveness, and larger scale centralized quality control. Once the objectives of the limited implementation phase have been proven, the Key Decision Point 2 can be exercised for full national deployment.

The **Full Implementation Phase** covers all activities necessary to complete the USCRN network and operational support capabilities.

3. FY 2001 Achievements:

The first two experimental USCRN stations were installed in Asheville, NC, in August, 2001. At that time, the stations were to be installed on a 5-degree geographic grid in pairs for redundancy. Single stations would then be offset from the backbone grid at a denser grid of 2.5 geographic degrees. Paired stations deployments were first priority, and the Asheville pair was to be the lead in order to test reliability, functionality, maintenance procedures and needs, logistics, and scientific veracity.

For verification of the two concept and engineering test stations in Asheville, ten interagency committees were formed during FY2001 to provide critical review of USCRN in all of its aspects (see below).

3.1 Performance Measures

Performance Measures for Climate Uncertainty were not used by NOAA in FY2001, and backward projection of present PM's is not applicable for this year, nor does it yield a useful number with only datapoint occupied out of the 500 originally envisioned.

3.2 Installations and Surveys

More pedantic Performance Measures during FY2001 are the enumeration of USCRN Installations and Surveys:

A. Site Surveys – 20

B. Sites Approved – 13

C. Site Licenses Signed – 9

D. Stations Installed – 2

3.3 Sensor Testing and Science Studies

The USCRN Program initiated meetings to define the USCRN system that involved USDA, NWS, Regional and State Climatologists and Office of the Federal Coordinator for Meteorological Services. These meetings included 10 separate committees which reviewed the program objectives and recommended that USCRN do the following:

1 Determine the specifications and requirements for the meteorological sensors, data logger, and communications system.

2 Develop equipment calibration and validation methodology.

3 Determine equipment installation and maintenance procedures and schedule.

4 Determine alternate permanent backup instrumentation at each CRN site.

5 Identify training needs, schedule, and frequency for observers and maintenance personnel.

6 Define criteria for selecting stations and standards for siting the instrumentation at each station.

7 Develop physical transfer models to relate data from the new automated instrumentation to the conventional (historical) instrumentation, and determine data adjustment methodologies for the historical data.

8 Determine metadata needs (historical as well as new metadata, such as digital photos and GIS information) and create a mechanism for updating the metadata and ensuring their quality.

9 Develop a data quality control and management system to accommodate the CRN data.

10 Coordinate the use of CRN data among the various organizations, including how it will be related to the existing CLIMAT network (international network of monthly reporting stations).

The following peer-reviewed presentations were given at the AMS 12th Conference on Applied Climatology (Asheville, NC) and the AMS 12th Symposium on Meteorological Observations and Instrumentation (Albuquerque, NM).

Sources:

Arnfield, J.D., C.E. Duchon, B.C. Baker, R.G. Quayle, R.R. Heim, K.R. Robbins, M.J. Janis, and A.H. Horvitz, 2000, May 8-11: U.S. climate reference network, part 4: metadata. *Proceedings: Twelfth Conference on Applied Climatology*, American Meteorological Society, Asheville, NC, 30-33.

Robbins, Kevin et.al., 1999, June: Climate Reference Network: Low-tech Permanent Backup Instrumentation. A recommendation report prepared for the National Climate Data Center (NOAA/NESDIS/NCDC), Asheville, NC.

Heim, Richard, 2000, May 8-11: U.S. climate Reference Network, part 1: overview. *Proceedings*: *Twelfth Conference on Applied Climatology*, American Meteorological Society, Asheville, NC, 20-23.

Duchon, C. E. 2000, May 8-11: U.S. Climate Reference Network, part 2: instrumentation. *Proceedings: Twelfth Conference on Applied Climatology*, American Meteorological Society, Asheville, NC, 24-25.

Baker C. Bruce, 2000, May 8-11: U.S. Climate Reference Network, part 3: station selection criteria and station siting standards, *Proceedings*: *Twelfth Conference on Applied Climatology*, American Meteorological Society, Asheville, NC, 26-29.

Arnfield, J.D., C.E. Duchon, B.C. Baker, R.G. Quayle, R.R. Heim, K.R. Robbins, M.J. Janis, and A.H. Horvitz, 2000, May 8-11: U.S. climate reference network, part 4: metadata. *Proceedings: Twelfth Conference on Applied Climatology*, American Meteorological Society, Asheville, NC, 30-33.

Baker, C.B., T.P. Meyers, M.E. Hall, and R.R. Heim Jr., 2001, January 14-18: The precision and accuracy of the temperature measurements for the Climate Reference Network, *Proceedings*: *11th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Albequerque, NM, 5-6.

Duchon, C.E., G.G. Wade, J. Cole, and R.R. Heim, Jr., 2001, January 14-18: Laboratory studies of a vibrating wire precipitation gage. *Proceedings: 11th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Albuquerque, NM, 188-189.

Heim, R.R., Jr., 2001: New network to monitor climate change. *EOS Transactions*, 82 (12 or 3/20/01), 143.

4. FY 2002 Achievements

FY 02 established field studies to support a number of the required 10 Climate Monitoring Principles (Appendix A) that included data continuity, fidelity of the measurements, and interchangability of instrumentation. The field programs were a cross-matrix with the High Plains Regional Climate Center (HPRCC), the Southern Regional Climate Center (SRCC), OAR, NESDIS, and the NWS. These included the following:

1. ***Relative Humidity (RH) Sensor Evaluation and Temperature Sensor Evaluation carried out by the HPRCC and SRCC at their testing facilities***. The objective of this study was to test and compare a variety of RH instrumentation to find one suitable for USCRN field deployment. Budget issues prevented deployment.

2. ***CRN-NWS Long-Term Collaborative Plan***. This plan was to test, compare, and document NWS and CRN instrumentation, and to develop transfer functions between the CRN and NWS COOP/HCN and to provide information for potential networks. Goals included:
    a. Establish a long-term USCRN presence at NWS test facilities. Use facilities when adding new instruments, both NWS and USCRN.
    b. Gather and analyze data and information on USCRN instrument performance, reliability, and maintenance.
    c. Provide potential information for NWS COOP Modernization Planning.

Subsequent papers that were presented to the scientific community included the following.

Baker, C. Bruce, 2002: *The Climate Reference Network*. 6th Symposium on Integrated Observing Systems, Orlando, FL.

Baker, C. Bruce, 2002, June 23-26: *Station Selection Criteria and Station Siting Standards*. Mesonet 2002 Conference, Oklahoma City, OK.

Baker, C. Bruce, 2002, 23 September – 3 October: *The U.S. Climate Reference Network: A national automated baseline reference network to monitor climate change for the next 50 years* C. Bruce Baker NOAA/NCDC. WMO-CIMO-XIII TECO-2002 METEOREX-2002 Bratislava (Czechoslovakia) 23 September - 3 October 2002.

Karl, Thomas R., *NOAA'S Surface Weather Observing Networks*, NOAA/NCDC Annual AMS Meeting, Orlando, FL 2002

4.1 Performance Measures

During FY2002 sufficient USCRN stations were deployed that a significant statistical improvement in the primary National Performance Measure of Reduction of Climate Uncertainty moved from 100% to 26%. The Regional PM was far worse, as expected due to the still loose filling of the nine separate regional grids. The Regional PM moved from 100% down to only 94%.

4.2 Installations and Surveys

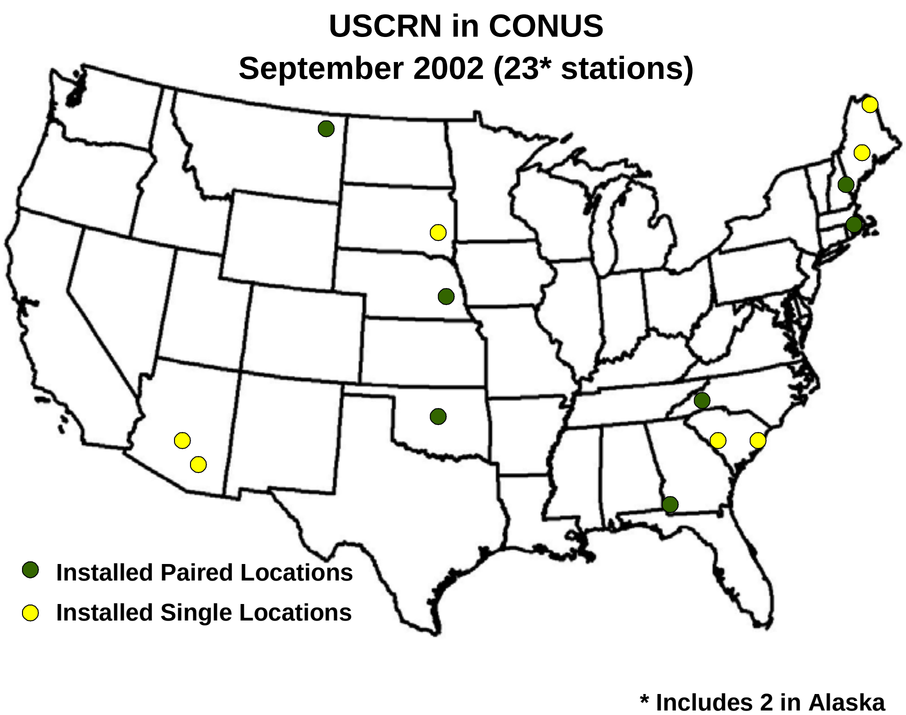
FY2002 installations and surveys included the following:

A. Site Surveys – 171

B. Sites Approved – 17

C. Site Licenses Signed – 17 (note that some but not all site licenses were for both parts of paired stations, thus the apparent inconsistency in the FY02 ratio of licenses :: installations)

D. Stations Installed – 21 (see map below, which includes the FY2001 deploys)



4.3 Sensor Testing and Science Studies

FY03 efforts continued the FY02 studies and in addition a new funding effort to assess the precipitation measurements network wide and assessment of utilizing a clear sky model network wide was initiated. There was a continued assessment of the measurements in the network. This assessment was presented to the scientific community at the AMS 12th Symposium on Meteorological Observations and Instrumentation 2003. An International Workshop on Precipitation measurements was held at NCAR, Boulder, CO, and the results are in journal review and to be published in the Bulletin of the American Meteorological Society.

Sources:

Baker, C. Bruce and M. Gifford, 2003, February 17-21: United States climate reference network (USCRN) precipitation intercomparison study, *Proceedings: 12th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Long Beach, CA, Session 5.4.

Duchon, Claude E. and Charles G. Wade, 2003, February 17-21: Field studies of a vibrating wire precipitation gauge. *Proceedings: 12th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Albuquerque, NM, Session 14.5

Duchon, Claude E.,, 2004, January (accepted): Observations of Temperature Sensitivity in Geonor Vibrating-wire Transducers, *Proceedings: 8th Symposium on Integrated Observations and Data Assimilation*, American Meteorological Society, Seattle, Washington.

Hubbard, K. G., 2003, February 17-21: Preliminary results from a field comparison of relative humidity sensors, *Proceedings: 12th Symposium on Meteorological Observations and Instrumentation,* American Meteorological Society, Long Beach, CA., Session 14.2.

Hubbard, K. G., X. Lin, and C. B. Baker: 2004, January (accepted): A Study on the USCRN Air Temperature Performance, *Proceedings: 8th Symposium on Integrated Observations and Data Assimilation*, American Meteorological Society, Seattle, Washington.

Lin, X., K. G. Hubbard, and C. B. Baker, 2003, February 17-21: The feasibility of field transformation functions for air humidity measurements , *Proceedings: 12th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Long Beach, CA., Session 6.3.

Redmond, Kelly T., M.J. Janis, K. G. Hubbard. 2003, February 17-21: Climate Reference Network site reconnaissance: lessons learned and relearned, *Proceedings: 12th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society, Long Beach, CA. Session 6.4

Weatherhead, Elizabeth C., 2003, (in review): Workshop summary: ensuring quality long-term monitoring with precipitation gauges, *Bulletin of the American Meteorological Society.*

Weatherhead, Elizabeth C., 2003, January: *Developing Operating and Quality Control/Quality Assurance Recommendations for the U.S. Climate Reference Network Geonor Precipitation Gauge.*

5. FY 2003 Achievements

During FY2003, the formal partnership of USCRN was expanded to include the NOAA-NESDIS Office of Systems Development with their expertise in the areas of Configuration Management and Documentation. This resulted in the formal assembly and categorization of CRN engineering, communications, systems, and data documentation (see below).

Additionally an external Test Phase Ad-Hoc Science Advisory working group Panel of science experts from government and academe was asked to analyze the USCRN as a science data provisioning system and to make recommendations that might improve USCRN.

The third external event was the framing of a Memorandum of Understanding between NOAA-NESDIS and the Canadian Atmospheric Environment Service (AES) that allows technology, data, archival, procedural exchanges between USCRN and the AES Reference Climate System (RCS), an already mature climate monitoring network of over 300 stations to date.

During late FY03, the State of California contacted USCRN to probe into the possibility of beginning a five-year enhanced density CRN network in selected California mountain regions. The State has proposed to fund the deployment costs of an additional 3–7 USCRN stations to standardize various USDA, USFS, NOAA, and State mesonets.

5.1 Performance Measures

During FY2003, the USCRN network increased to 46 stations. This reduced the National Climate Uncertainty PM to 10%, and the Regional Climate Uncertainty PM to 80%.

5.2 Installations and Surveys

FY2003 installations and surveys include the following (also see the map on the next page):

A. Site Surveys – 116

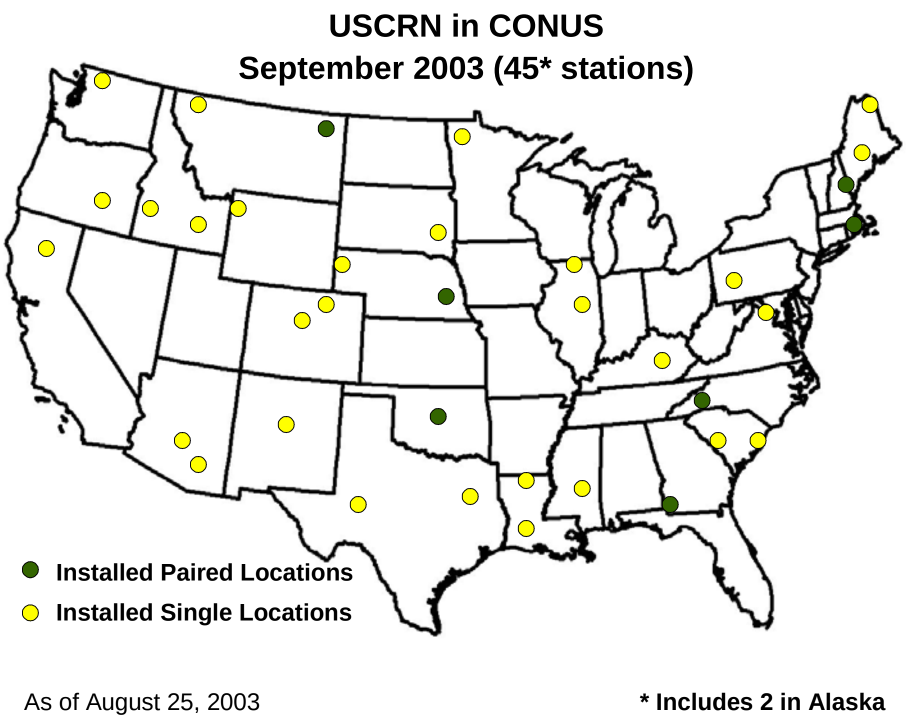
B. Sites Approved – 44

C. Site Licenses Signed – 29

D. Stations Installed – 23

5.3 Sensor Testing and Science Studies

Work continued during FY2003 on developing relationships between the USCRN and other National and International Networks to improve understanding of Climate Variability. Due to recent CRN presentations at national and international conferences, strong interest in linking or exchanging technology and data has been received from nations in Europe, Latin America, Asia, and Australasia. Canada is the only nation who has, thus far, a formal relationship with USCRN. Continued collaboration during FY2003 with the NWS with respect to the COOP Modernization Program has led to adoption of some CRN philosophies and technology as a basis for that program.   The Program has established a partnering relationship with NOAA's National Weather Service to co-locate some of its Cooperative Observer (COOP) sites with USCRN instruments. Data from co-located instruments will support development of transfer functions relating temperature and precipitation gauges and therefore leverage quality observations to areas beyond the established USCRN.



5.4 Program Management

During FY 03, the NESDIS Office of System Development (OSD) in conjunction with the NESDIS-NCDC USCRN Program Office prepared a series of nine documents (see synopses below) which collectively define program management policy, principles, and areas of responsibility for the program. The documents, followed by a brief synopsis of each, are listed below. They are available from the NOAA/NESDIS SATOPS Intranet Documents database located at OSD's Suitland, MD, facility.

1. USCRN Program Development Plan

The USCRN Program Development Plan (PDP), June 2003, provides the framework and guiding management principles for the development and implementation of the USCRN system. The PDP does the following:

- Documents the vision and objectives of the CRN program
- Provides the top-level acquisition and implementation plan describing the overall scope and management approach

- Identifies key decision points (KDPs) and checkpoints for effective management control

2. ***USCRN Test and Evaluation Master Plan***

The Test and Evaluation Master Plan, (TEMP), January 2003**,** documents the strategy used to verify that the CRN satisfies all functional, technical, and support requirements. The TEMP provides a context for more detailed CRN test plans and procedures, identifies the primary functional requirements, describes the major program phases, identifies the Test and Evaluation (T&E) activities in each phase, and documents the T&E management responsibilities.

3. USCRN Demonstration Evaluation Plan

The Demonstration Phase Evaluation Plan, December 2002, defines the strategy for evaluation of the major components of the USCRN program including the site selection and installation activities, field sensor performance, central processing capabilities, communications, quality control, data management, configuration management, archival, and maintenance activities. The demonstration plan also defines the evaluation criteria for one of the key decision points, i.e., the decision to continue national deployment.

4. USCRN Commissioning Plan

The USCRN Commissioning Plan, June 2003, defines a major decision point at which data collected at field sites and archived at NCDC can be used in an official capacity to monitor climate variability and change. The commissioning process requires completion of three activities:

- Successful completion of the Demonstration Phase Evaluation
- Successful completion of individual site acceptance testing and transmission of data to USCRN archives
- Sustained operation of the USCRN network and archival of data from each site 95% of the time within one hour and/or successful entry into the archives within 30 days after the completion of the month of observation.

5. USCRN Functional Requirements Document

The USCRN Functional Requirements Document, June 2003, describes the functional and system performance requirements for the CRN and contains specific requirements defining the following:

- System performance
- Environmental conditions
- Measurement parameters
- Communications reliability
- Data processing, data access, and archival functions

6. USCRN Configuration Management Plan

The USCRN Configuration Management Plan, December 2002, provides a disciplined approach for technical and administrative management of CRN configuration items over the lifecycle of the program. The CM process a mechanism for implementing the following:

- Requirements
- Change management
- Configuration management of hardware and software items
- Metadata management

7. USCRN Site Information Handbook

The USCRN Site Information Handbook, December 2002, documents the criteria used to establish and maintain an instrument site. Site selection criteria are defined and quantified. The document provides a general description of a typical instrument site, site preparation and installation activities, access to power, and minimal maintenance requirements. A sample copy of the Site License Agreement between the CRN Program Office and the site host is included.

8. *USCRN Site Acquisition Plan*

The USCRN Site Acquisition Plan, December 2002, describes the methodology and resources used to identify, select, and acquire a CRN observation site. The manual details the recommended steps to assure the selection process is standardized. It defines the roles and responsibilities within the extended CRN team needed to assure that:

- Site locations meet quantified technical and practical criteria
- All required documentation is accurate and complete
- Survey and installation is scheduled and prioritized

9. USCRN Maintenance Plan

The USCRN Maintenance Plan, September 2003, defines the steps necessary to implement a cost effective maintenance strategy and structure for the USCRN field sites and communication network components unique to the program. The plan covers the following:

- Facilities Maintenance
- Preventive Maintenance and Calibration
- Corrective Maintenance

Based on manufacturers specifications and experience gained during the first three years of operation, estimated failure rates of each component are compiled and corrective maintenance actions are projected. When coupled with the maintenance priorities defined by program management, long-term logistics support costs and staffing projections are calculated and are inserted into the Five Year Budget Plan.

5.5 Demonstration Phase Evaluation

The NESDIS Office of Systems Development in conjunction with NCDC conducted the USCRN Field Operational Demonstration at approximately 30 sites in various climate regimes from Barrow Alaska to Tucson Arizona. The demonstration was conducted from January through June 2003 and was designed to operate the system infrastructure at the central facility and individual sites to evaluate the long-term sustainability of the USCRN system.

The evaluation was conducted is six areas, including site selection, site installation, field equipment and sensors, data processing and quality control, communications, and maintenance. These are described below. The evaluation supported decisions to (1) continue deployment activities, (2) demonstrate sufficient resources to operate the network, and (3) commission the system into operations.

Site Selection

The evaluation found that site selection standards were well documented, objective, and exceeded World Meteorological Organization standards. Sites were strategically located on stable public land near U.S. Historical Climatology sites. Site hosts understood and followed their responsibilities for managing the environment and maintaining basic maintenance activities. Site survey and selection material was archived and accessible to the user community and sufficient resources remain to continue all survey and selection activities.

Site Installation

Site installation and acceptance test procedures were found to be thoroughly defined and documented and were accessible to the user community through metadata archives. Sufficient resources exist to sustain installation activities.

Field Equipment and Sensors

Laboratory and field calibration studies conducted at research facilities and validated during the demonstration indicated sensor accuracy was within +/- 1% of specifications for both the precipitation and temperature sensors. Sensor housings for the precipitation gauge enabled greater catch efficiency when tested against other gauges and temperature sensors compared favorably with other premier systems. Testing against environmental conditions (± 60°C) indicated difficulty at cold temperatures and improvements to field data processing and sensor components were initiated. Testing will continue during the coming winter. Site data processing capabilities met requirements for local programming, remote monitoring, expandability, local data storage and retrieval. System availability requirements were met with only 14 hardware failures recorded over 24 months or one failure per 14 months of operation.

Data Processing and Quality Control

Fault recognition standards supporting manual quality control activities were in place and well documented. Mechanisms for reporting system component failure or anomalous behavior were determined to be in place and functional. Procedures for replacement of failed components were well documented and resources for continuing fault recognition and recovery efforts were determined to be sufficient to support program continuance and system commissioning. The evaluation indicated more automated quality control procedures would support present manual efforts and efforts are in process.

Communications

The communications system design was determined to provide sufficient capacity for stable long-term operations. During the demonstration period, data availability was determined to be in excess of requirements with 97% of the data retrieved at the central facility within 1 hour and more than 98% retrieved, via manual download, within 30 days of the close of the month of observation. Most data availability losses were rooted in communications problems in extremely cold, i.e., –50°C temperatures, which were recorded in Alaska. Engineering improvements to communications antennas and supporting equipment were recommended.

Maintenance

System maintenance currently managed by the Atmospheric Turbulence and Diffusion Division (ATDD) of OAR and performed by a contractor was determined to be sufficient to sustain reliable operations. Preventive maintenance and calibration on field equipment was performed yearly according to manufacturer specifications. Sufficient spare parts to sustain operations were stored at ATDD and sufficient documentation existed to enable efficient replacement by either ATDD contractor personnel or site hosts. Present staffing with minor supplements as more equipment is fielded appeared to be in place.

Anomaly Tracking System

In June 2003, the NESDIS USCRN Anomaly Tracking System (ATS) was formally activated. The ATS provides a web-based system for identifying and tracking details of discrepancies in USCRN system performance. "Incident Reports" (IRs) are entered into the database for corrective action and resolution. The ATS database is accessible only by manual quality control specialists who note and record anomalous behavior and maintenance engineers who diagnose and resolve the problems. The ATS data base is used to provide short-term status of maintenance activity and a long-term statistical record documenting Mean-Time Between Failure (MTBF) and Mean-Time-To- Repair (MTTR) activity. The statistics support corrective engineering analysis and out-year maintenance planning.

Configuration Management System (NOAA and NESDIS/NCDC)

The Configuration Management (CM) Procedures define lines of authority. In June 2003, the USCRN Program Management Committee (PMC) implemented comprehensive Configuration Management (CM) procedures to formally manage assets, requirements, change requests, existing facilities, and records storage capabilities.

The CM procedures are in conformance with the business practices established within the Department of Commerce. CM includes responsibility for all CM functions including monitoring and tracking all hardware and software Configuration Items (CIs), product databases, site metadata, and program management documents. Configuration and change control authority resides with the Director NCDC who delegates authority to specific agents or control boards. Authority levels are identified such that responsibilities are exercised at the lowest possible level while maintaining management control. The PMC consisting of senior NESDIS and NCDC managers provides policy and program direction and assigns actions to and receives recommendations from the Configuration Control Board (CCB). The CCB controls configuration change requests by ranking the impact of proposed changes to specific CIs and science priorities. The CCB receives input from representatives of the user community through the Test Phase Ad Hoc Working Group and representatives of the operations community through the Network Monitoring Team and the Site Selection Committee.

5.6 Network Commissioning

All conditions required for commissioning of the base network as stipulated in the United States Climate Reference Network (USCRN) Commissioning Plan (NOAA/NESDIS CRN Series, X039, June 2003, NOAA-CRN/OSD-2003-0008R0UD0) have been met. Likewise all inquiries and recommendations of the USCRN Test Phase Ad Hoc Working Group have been answered and/or implemented into USCRN operations, deployments, technology, and data streams.

6. Summary

The Climate Reference network has achieved the initial goals and performance measures which were developed at the program’s inception. Sites have been established and maintained with reliability. User feedback from ad hoc working groups has been incorporated into plans and operations. Pre-commissioning statistics have been evaluated and network commissioning is planned for January 2004. After USCRN sites are commissioned, the data will be available online for public use.

Appendix A. Ten Climate Principles[1]

1. Management of Network Change: Assess how and the extent to which a proposed change could influence the existing and future climatology obtainable from the system, particularly with respect to climate variability and change. Changes in observing times will adversely affect time series. Without adequate transfer functions, spatial changes and spatially dependent changes will adversely affect the mapping of climate elements.

2. Parallel Testing: Operate the old system simultaneously with the replacement system over a sufficiently long time period to observe the behavior of the two systems over the full range of variation of the climate variable observed. This testing should allow the derivation of a transfer function to convert between climatic data taken before and after the change. When the observing system is of sufficient scope and importance, the results of parallel testing should be documented in peer-reviewed literature.

3. Metadata: Fully document each observing system and its operating procedures. This is particularly important immediately prior to and following any contemplated change. Relevant information includes: instruments, instrument sampling time, calibration, validation, station location, exposure, local environmental conditions, and other platform specifics that could influence the data history. The recording should be a mandatory part of the observing routine and should be archived with the original data. Algorithms used to process observations need proper documentation. Documentation of changes and improvements in the algorithms should be carried along with the data throughout the archiving process.

4. Data Quality and Continuity: Assess data quality and homogeneity as a part of routine operating procedures. This assessment should focus on the requirements for measuring climate variability and change, including routine evaluation of the long-term, high-resolution data capable of revealing and documenting important extreme weather events.

5. Integrated Environmental Assessment: Anticipate the use of the data in the development of environmental assessments, particularly those pertaining to climate variability and change, as part of a climate observing system's strategic plan. National climate assessments and international assessments, (e.g., international ozone or IPCC) are critical to evaluating and maintaining overall consistency of climate data sets. A system's participation in an integrated environmental monitoring program can also be quite beneficial for maintaining climate relevancy. Time series of data achieve value only with regular scientific analysis.

6. Historical Significance: Maintain operation of observing systems that have provided homogeneous data sets over a period of many decades to a century or more. A list of protected sites within each major observing system should be developed, based on their prioritized contribution to documenting the long-term record.

7. Complementary Data: Give the highest priority in the design and implementation of new sites or instruments within an observing system to data-poor regions, poorly observed variables, regions sensitive to change, and key measurements with inadequate temporal resolution. Data sets archived in non-electronic format should be converted for efficient electronic access.

8. Climate Requirements: Give network designers, operators, and instrument engineers climate monitoring requirements, at the outset of network design. Instruments must have adequate accuracy with biases sufficiently small to resolve climate variations and changes of primary interest. Modeling and theoretical studies must identify spatial and temporal resolution requirements.

9. Continuity of Purpose: Maintain a stable, long-term commitment to these observations, and develop a clear transition plan from serving research needs to serving operational purposes.

10. Data and Metadata Access: Develop data management systems that facilitate access, use, and interpretation of the data and data products by users. Freedom of access, low cost mechanisms that facilitate use (directories, catalogs, browse capabilities, availability of metadata on station histories, algorithm accessibility and documentation, etc.), and quality control should be an integral part of data management. International cooperation is critical for successful data management.

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[1] Adequacy of Climate Observing Systems (NRC), National Academy of Sciences Press, Washington, D.C., 1999 (see pp. 17-18)