United States Climate Reference Network (USCRN)

FY2004 Annual Report

NOAA–NESDIS
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USCRN FY2004 Annual Report
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1. Introduction

This is the second annual report for NOAA's United States Climate Reference Network (USCRN). The primary focus of this report is on the FY2004 USCRN development and implementation activities. Initial projections of activities planned for FY2005 are included. FY2000-FY2003 USCRN activities were reported in the USCRN FY2003 Annual Report.

This report include reviews of the USCRN, Performance Measures, stations installed, research progress, instrument testing, partnership activities at several levels, data quality, data availability, and the January 2004 USCRN network commissioning.

2. Program Base

The required program capability and requirement drivers for the United States Climate Reference Network (USCRN) are 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 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 06 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 annual and decadal-to-centennial temperature and precipitation trends at the National Scale for the United States.

Fundamental to this goal is the requirement to establish a network that 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.

2.3 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 … 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 U.S. 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. <u>Executive/International/Programmatic</u>

- 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".

- Climate Change Science Program 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.”

- Global Change Observing Systems Second Adequacy Report – Concerning 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.”

- World Climate Programme Data and Monitoring (WCDMP) Guidelines on Climate Observation Networks and Systems (WCDMP No. 52) and Guidelines on Climate Metadata and Homogenization (WCDMP No. 53). These WMO documents were written to identify the “best practices” for climatological observations, data collection, metadata, and archival activities. The intent of the documents is to bring all WMO members up to similar standards using the Ten Primary Climate Principles (see Appendix A) as a base. Using these standards for USCRN implementation, the USCRN stations and instrumentation are qualified as “Principal Climate Observations Stations” and “Reference Climate Stations.”

- 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 a 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).

2.4. 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 provides 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. Where possible, USCRN stations are being co-located with or near existing meteorological observation sites such as the Historical Climate Network (HCN), the National Weather Service's Cooperative Observer (COOP) and Modernized COOP networks, the Canadian Reference Climate Network (RCS), the NWS Automated Surface Observing System (ASOS), the Bureau of Land Management/Forest Service Remote Automated Weather Stations (RAWS), the NOAA Surface Radiation Network (SURFRAD), the University of New Hampshire's AIRMAP stations, and various State mesonet stations. As the USCRN 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 between those networks and the USCRN to thereby leverage primary and specialized climate observations over broader coverage areas.

USCRN field system technology is designed to be highly reliable, precise, robust and maintainable so that it collects, formats, processes and communicates measurements of environmental parameters to NOAA's National Climatic Data Center's (NCDC) central data management and processing facility in Asheville, N.C. Network data ingest for FY2004 averaged 99.8% (see Appendix C). The equipment at USCRN field stations is designed to operate, without human intervention, under a wide variety of environmental conditions. The NCDC provides data ingest, quality control monitoring, data processing, archiving, and user access capabilities to both the climate research community and the general public.

After four years of development and implementation, the USCRN stations thus far deployed were verified as having sufficient spatial distribution, reliability and stability, and science information value that NOAA formally commissioned the network in January 2004. The desired outcome, capabilities required, and program-level performance measures of USCRN are discussed below.

2.4.1 Desired Outcome

The USCRN is a sustained, cost-effective science-driven national and regional climate data and benchmark system complementary to older and less rigorous or less precise NOAA in-situ (surface) networks. USCRN provides reliable information related to the state and changing state of the climate system and enables more reliable and higher-confidence climate-related predictions and projections to be made by both national and regional decision-makers.

2.4.2 Capabilities Required

The required capabilities of the USCRN are the following:

- Provides land-based reference stations and standard land surface observing stations for tiered NOAA ground observing systems such as NOAA's COOP and ASOS networks.
- Coverage must be of sufficient temporal and spatial resolution to monitor local-to-national spatial scales for physical phenomena and to determine with the highest confidence trends of significant socio-economic and scientific importance.
- Measurements of key variables adhering to NRC and GCOS/WCDMP 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, archival, and product generation subsystems for the observations.
- Observing system management and information delivery infrastructure.

2.5 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 the uncertainty in the quality of the data and minimize the error in the measurements in order to produce the most accurate 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.
>
> Therefore, the highest level, single goal of USCRN is to reduce Climate Uncertainty at the national level to a statistically insignificant level.

Goals for this primary USCRN Performance Measure are for temperature Climate Uncertainty at the national level to be reduced by at least 98%, and for precipitation Climate Uncertainty to be reduced by at least 95%.

For reduction of Climate Uncertainty for the nine U.S. Standard Climate Regions to similar values as at the national level, the USCRN would require that the spatial distribution of the USCRN grid be increased to 300 stations.

By the end of FY2004, the continental U.S. (CONUS, which excludes Alaska and Hawaii and the various Territories) national-level Climate Uncertainty for temperature has been reduced by about 96%; the precipitation Climate Uncertainty has been reduced by almost 91%. This lag of the precipitation PM behind the temperature PM is normal. These significant reductions of Climate Uncertainty, although not yet at the program end goal level, have been accomplished by the deployment of 69 of the planned 104 operational USCRN stations in the Continental United States.

Reductions in the Climate Uncertainty were most pronounced and even dramatic in the first part of this program, FY2000-2004. Progress in reducing the climate uncertainty to the required national level comes in smaller increments and is approached asymptotically as the USCRN moves into the end phase of station deployment during FY2005-2006. Almost 40 more USCRN stations deployed in a specific geographic pattern are required in FY2005-2006 to meet the minimum acceptable program goals of national decision-maker needs for high-confidence science support.

It would take another five years (FY2007-2011) and a significant increase in the number of USCRN stations to attain similar climate variance confidence levels for local, State, and regional decision-makers as those being developed for the National Decision-Makers by the core 104-station USCRN.

See Tables 1a and 1b below for quantitative definition of the relationship between the number of USCRN stations deployed and the initial National Performance Measure of Reduction of Climate Uncertainty:

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

U.S. Climate Reference Network (USCRN)	FY 2002	FY 2003	FY2004	FY 2005	FY2006
PM: Reduce climate uncertainty concerning variability of temperature trends to required levels for monitoring climate variability and change.					
National Goal (% of Climate Uncertainty)	26	<20	<5	<3	<2
Regional Goal(% of Climate Uncertainty)	94	<65	<15	<10	<7
# of Sites to reach National Goals[1]	23	40	67	84	104

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

U.S. Climate Reference Network (USCRN)	FY 2002	FY 2003	FY2004	FY 2005	FY2006
PM: Reduce climate uncertainty concerning variability of precipitation trends to required levels for monitoring climate variability and change.					
National Goal (% of Climate Uncertainty)	26	<20	<15	< 8	<5
Regional Goal(% of Climate Uncertainty)	94	<25	<24	<23	<20
# of Sites to reach National Goals[1]	23	40	65	84	104

[1] For the Lower 48 States of the continental United States, a total of 104 stations are needed to meet that primary, composite (T & P) National Performance Goal of Reduction of Climate Uncertainty to required levels.

3. FY 2001-2003 Achievements:

The USCRN achievements, milestones, and Performance Measures were presented in detail in the USCRN FY2003 Annual Report, previously submitted.

4. FY 2004 Achievements

In FY2004 the USCRN Program was organized into broad program phases that include Demonstration, continued testing and development, continued deployments, and Full Implementation to a commissioned network.

The program is actively converting into an operational network that includes full documentation of the metadata, timely response to unscheduled repairs, summary and monitoring of all maintenance reports, action item notification chain and check, and quality control/quality assurance of the data. The customers for the data include BLM, EPA, USDA, NOAA, USGS, NPS, NOAA's Regional Climate Centers, State Climatologists, and many others. The continued science component of the USCRN has established the precision and accuracy of the sensors, which has resulted in other international and national networks utilizing the same instrumentation and data processing algorithms.

On the national level the NWS COOP-M program is utilizing the USCRN engineering, calibration and existing test facility infrastructure. This integration is a cross-matrix activity involving three line offices, NESDIS, NWS, and OAR. On the International level USCRN personnel are on the National Canadian Change Management Board and a Canadian scientist is on the USCRN Ad-Hoc Science review panel. In addition, the USCRN has co-located a USCRN station with the Canadian RCS, and the Canadians have co-located a station with a USCRN site in FY04. The Canadian Reference Climate Stations will use a rain gauge configured identically to the USCRN rain gauge and also use the USCRN QA/QC algorithm. For temperature, the Canadian AES will also retrofit their stations with a triple sensor configuration.

4.1 FY2004 Performance Measures

During FY2004, the USCRN network increased to 69 stations. This has had two impacts upon the USCRN primary Performance Measure during FY2004:

a. These deployments have reduced the National Climate Uncertainty PM for temperature to >5% and for precipitation to 10%.

b. The Regional Climate Uncertainty PM for temperature has been reduced to 15%, and that for precipitation has been reduced to 24%.

A secondary Performance Measure, Data Ingest, gives a measure of what percentage of all possible field station measurements are successfully transmitted and then received in the National Archive (NOAA's National Climatic Data Center). The higher the percentage, the more effective are the station maintenance program and the communications systems, and the more confident is the scientific community's interpretation of the dataset.

Since the USCRN program began in FY2001 this Data Ingest Performance Measure has been gradually increasing to a level at least equal to what the climate science community has specified is an acceptable base level for support of exacting climate science studies (a minimum of 98% data set completeness). This base level first reached the 98% level in the 1st Quarter of FY2003. The Data Ingest has now sustained itself above the 99% level since the 1st Quarter of FY2003. Tracking of this Performance Measure is portrayed in the Table below:

Table 2. USCRN Observations Data Ingest (%)*

FY	Q1	Q2	Q3	Q4	Annual
2001	**94.7**	**95.5**	**70.5**	**97.4**	**87.8** *(96.9)*
2002	**98.6**	**96.2**	**98.4**	**96.7**	**96.9**
2003	**99.9**	**99.6**	**99.8**	**99.9**	**99.6**
2004	**99.9**	**99.8**	**99.8**	***(99.8)*****	**99.8****
Average	**98.3**	**97.8**	**98.1** *(99.5)*	**98.4**	**96.0** *(98.3)*

**Percentage of all possible measurements received in the National Archive (National Climatic Data Center) and made available via the Internet.*
***First 3 Quarters of FY04 in full; latest data available for FY04Q4 is 2 September 2004.*

The data and progression of data ingest figures at a high plateau level of >99% for the past eight Quarters indicates that USCRN technologies, redundancies, and communications layering have produced a sufficiently reliable, multi-layered, and robust climate monitoring network as to meet the most stringent climate science criteria (98% data ingest rate) developed by NAS-NRC and the WMO.

The very low FY01Q3 70.5% Data Ingest is due to major upgrading of the two field prototypes (the Asheville NC stations) during that Quarter. This downtime resulted in data gaps while the upgrades were being made. Therefore, performance figures in parentheses in the table are calculations of network performance omitting the anomalous FY01Q3 figures.

A solid improvement from FY2001 Q1 of 94% data ingest has plateaued with sustained very high data ingests (99+%) in October 2002 through FY2004. During this period the network has increased from two prototypes to 69 stations. CRN technology is behaving at a mature level; maintenance programs are both proactive and reactive -- and they are effective. Layered communications have made the difference between good performance and outstanding performance.

USCRN FY01-02 data has been recovered from station dataloggers using PDA's downloaded to NCDC archives (see Appendix C Tables). The network Data Ingest PM for the cumulative period FY01Q1 through FY04Q4 is 99.0%. In the latest network period (FY04Q4), the Data Ingest PM is 99.8%.

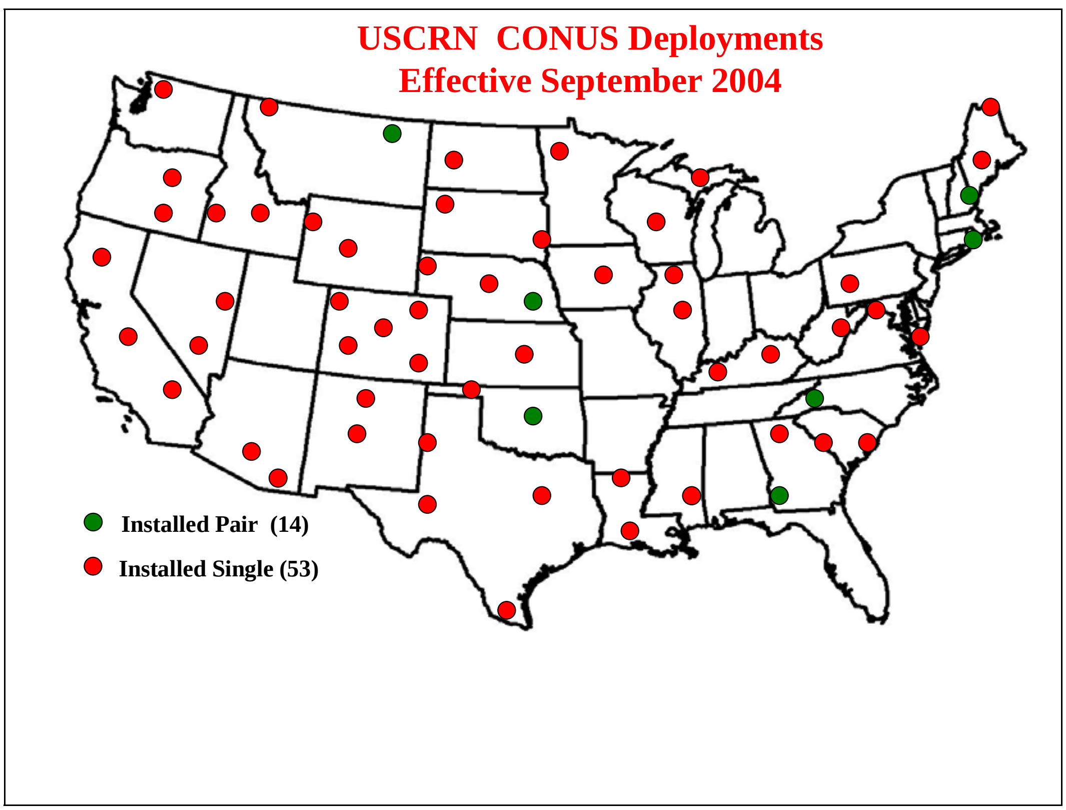
4.2 Installations and Surveys

FY2004 installations and surveys include the following

- Site Surveys – **126**
- Sites Approved – **44**
- Site Licenses Signed – **29**
- Stations Installed – **24**

The following map is the USCRN station field configuration at the end of FY2004.

Figure 1. Map of USCRN CONUS Deployments Through FY2004



4.3 Breadth of USCRN Station Partnership Net

The distribution of USCRN operational field stations by Host Agency identity gives an indicator the USCRN partnership involved in the building of this network

Table 3. Host Agency Affiliations of USCRN Stations

Foundations and arboreta	9
University lands, forests, and farms	26
Native American Indian reservations	2
State parks and forests	3
NOAA facilities (operational stations)	2
National wildlife refuges	7
National parks, seashores, monuments	14
USDA, NASA, DOE, BLM, USGS facilities	8
NOAA facilities (test & engineering stations)	2
Non-US meteorological service test sites	1
NOAA network co-locations (10-mile radius)	53

4.4 FY 2004 Sensor Testing and Science Studies

Work continued in FY2004 on developing relationships between USCRN and other national and international climate networks. Due to recent CRN presentations at national and international conferences, strong interest in linking or exchanging technology, observing standards, and data has been received from nations in Europe, Latin America, Asia, and Australia. Canada is the only nation, thus far, with a formal relationship with USCRN. Continued collaboration with the NWS COOP Modernization Program (COOP-M) has led to adoption of some CRN philosophies and technology by COOP-M. USCRN and COOP-M have also agreed to co-locate COOP-M sites at USCRN stations. Data from co-located instruments supports and speeds temperature and precipitation transfer function developments. This leverages climate- quality observations to higher-density grids from which USCRN is resource-constrained. This co-location and transfer function activity will continue indefinitely.

FY04 sensor testing and science studies included refinements to existing instrumentation such as testing of all rain gauge sensing devices and the addition of a fall protection device (FPD) to the primary CRN precipitation gauge. The FPD allows a valid precipitation measurement to still be made if one of the three sensors on the gauge fails.

The USCRN temperature and relative humidity (RH) testbed is examining accuracy and reliability of RH sensors. Two years of measurements have shown that USCRN temperature sensors are interchangeable and more accurate than the standard they were being compared to.

The USCRN precipitation testbeds are located in Sterling, VA and Johnstown, PA. The transfer functions are being developed separately for liquid and frozen precipitation. These transfer functions are being developed for the current ASOS precipitation gauge, the new ASOS precipitation gauge and will also include the new COOP-M rain gauge in late FY04 and FY05. During FY05 a new wind fence design for the USCRN rain gauge will be tested.

Results from two years of rigorous measurements at the two testbeds have encouraged the Canadian Reference Climate Network to use the USCRN rain gauge and to adopt the USCRN triple temperature sensor configuration. COOP-M is now configuring that network's rain gauge to be identical to the USCRN gauge, will use the identical temperature sensor, and will use the USCRN calibration facility to verify and correct instrumentation prior to field deployment. This integration effort is now cross-matrixed among three NOAA Line Offices, NESDIS, NWS, and OAR.

4.5 FY 2004 Integration with the Modernized COOP Program (COOP-M)

The two NOAA nets (USCRN and COOP-M) are complementary, but not redundant. Differences of level of activity, station siting, instrument redundancy, and observational precision exist between the two networks. Logistics train, maintenance needs, end data uses and user communities are similar. Despite these differences close integration of the USCRN and COOP-M is in the best interest of corporate NOAA.

During FY2004 exchanges with COOP-M of information and technical data on USCRN sensors, communications, data ingest and archival, QA/QC, and management practices began. During FY04Q3 exchange meetings involving USCRN and COOP-M personnel were held to search for common missions, goals, and implementation practices. All USCRN manuals, handbooks, guidelines, and other documentation developed over the past several years were transferred to the COOP-M Program. The COOP-M program is adopting similar standards for measurements as the USCRN and is including their instrumentation suites in the USCRN test facilities. The USCRN precipitation gauge has been selected for deployment by the COOP-M.

4.6 FY 2004 International Cooperation

Interest in the USCRN has grown. USCRN high-quality environmental measurements have been proven in rigorous field tests and four years of field operations. International interest has grown in adopting and adapting USCRN technologies, siting standards, data processing, and archival procedures. The first nation to duplicate USCRN practices and technology is Canada. The USCRN was invited to have a U.S Representative on the Canadian Atmospheric

Environment Service (AES) National Monitoring Change Management Board. This invitation has been accepted.

Likewise, a representative from the Canadian counterpart of the USCRN, the Canadian Reference Climate Network (RCN) program, participates in the activities and deliberations of the USCRN Ad Hoc Science Review Panel.

As a result of the FY2004 side-by-side testing and evaluation of the USCRN precipitation gauge, a decision has been made by the AES to incorporate the USCRN hardware architecture into the Canadian RCN.

During FY2004, an exchange of a Canadian RCN station to a U.S. Test Site, and a USCRN station to the Canadian National Testbed Site was made.

U.S./Canada discussions have included:

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

In addition to U.S. – Canada activities, USCRN stations have been selected as candidates for deployment in various environments on other continents where assistance is desired. Towards this end, during FY2005 two USCRN stations will be configured to be GCOS test stations (high-elevation and high precipitation environment stations). These stations will be deployed to two extreme environments as prototypes for future deployments in the Andes and elsewhere as GCOS takes actions to upgrade global baseline climate monitoring stations.

4.7 FY 2004 USCRN Network Commissioning

After exhaustive testing and verification of USCRN technology, communications robustness, data ingest, and maintainability, the USCRN was officially commissioned January 13, 2004, at the Annual Meeting of the American Meteorological Society in Seattle, Washington.

The USCRN Commissioning Plan defines commissioning as a major decision point at which data collected at USCRN field sites and archived at the national archive (NOAA-NCDC) can be used in an official capacity to monitor climate variability and change. The commissioning process required 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 USCRN archives at the 98% level within 30 days.

The initial commissioning was done using the field records and performance of 46 USCRN stations deployed across the USA. By the end of FY2004, 69 CRN stations are operating in the field. 56 of those stations have now exceeded commissioning criteria. By the end of FY05, an additional 20 stations will be deployed, and deployments for the Phase 1 (U.S. Lower 48) will end by late FY06 with a total of 104 field stations. Station commissioning usually follows station deployment after a burn-in period of 45-90 days.

5. Summary

The Climate Reference network has achieved the initial goals and performance measures that were developed at the program's inception. Stations have been established on schedule and maintained with reliability. The USCRN will provide the United States with a first-class climate and environmental monitoring network that meets national needs, and international commitments to monitor and document climate change. The Climate Reference Network will help fill an important land-based gap in U.S. climate data. These data are needed in a larger and more comprehensive Earth observation system being developed by more than 34 countries.

6. FY2005 Planned Activities and Goals

Research and engineering development activities envisioned for FY2005 attention include:

a. Transfer Function determinations inter-network. This first priority is to determine the transfer functions between the USCRN and the Cooperative

Network. Other networks being considered for transfer function determinations include ASOS, COOP-M, and as far as possible – non-NOAA networks such RAWS, SCAN, SNOTEL, and selected State mesonets.

b. Derivation of Pseudo-normals once transfer functions are established. This work must be approached with great care and critical review.

c. Exercising the capability and fitness of combinations of USCRN sensors providing ground truth points for NOAA satellite systems.

d. Testing and deployment of Wetness Sensors, an activity begun in FY04Q4. Wetness Sensors will be retrofitted to all stations in the USCRN.

e. Acquisition, testing and possible deployment of Relative Humidity Sensors. If instruments considered are of sufficient precision, an RH sensor will be retrofitted to all USCRN stations.

f. Testing of Meteor Burst communications for harsh environs and two-way capabilities.

g. Deeper study of Health of the Network and Data Ingest percentages in order to identify seasonal biases, component failure patterns, and individual stations that are lag in their performance and/or precision.

h. Closer interworking with and support for COOP-M as that program evolves.

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.

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

Appendix B. Relevant FY2004 Science Studies and Scientific Source Papers Relating to USCRN

Baker, C. Bruce and M. Gifford. 2004. United States Climate Reference Network (USCRN) precipitation intercomparison study, Proc 12th Symp on Meteorological Obs and Instrumentation, AMS, Long Beach, CA, Sess 5.4, Feb 17-21.

Duchon, Claude E. and Charles G. Wade. 2004. Field studies of a vibrating wire precipitation gauge. Proc 12th Symp on Meteorological Obs and Instrumentation, AMS, Long Beach, CA5.

Duchon, Claude E. 2004: Observations of Temperature Sensitivity in Geonor Vibrating-wire Transducers, Proc 8th Symp on Integrated Observations and Data Assimilation, AMS, Seattle, WA.

Hubbard, K. G., 2004. Preliminary Results from a Field Comparison of Relative Humidity Sensors, Proc 12th Symp on Meteorological Obs and Instrumentation, AMS, Long Beach, CA..

Hubbard, K. G., X. Lin, and C. B. Baker. 2004. A Study on the USCRN Air Temperature Performance, Proc 8th Symp on Integrated Observations and Data Assimilation, AMS, Seattle, WA.

Lin, X., K. G. Hubbard, and C. B. Baker. 2004. The feasibility of field transformation functions for air humidity measurements, Proc 12th Symp on Meteorological Obs and Instrumentation, AMS, Long Beach, CA.,

Redmond, Kelly T., M.J. Janis, K. G. Hubbard. 2004. Climate Reference Network Site Reconnaissance: Lessons Learned and Relearned, Proc 12th Symp on Meteorological Obs and Instrumentation, AMS, Long Beach, CA.

Weatherhead, Elizabeth C. 2004, (in review): Workshop Summary: Ensuring Quality Long-term Monitoring with Precipitation Gauges, Bull AMS.

Weatherhead, Elizabeth C. 2004. Developing Operating and Quality Control/Quality Assurance Recommendations for the U.S. Climate Reference Network Geonor Precipitation Gauge.

The following papers were presented in Special Sessions dedicated to the USCRN at the Annual Meeting of the American Meteorological Society in Seattle, Washington, in January 2004:

K. G. Hubbard, University of Nebraska, Lincoln, NE; and X. Lin and C. B. Baker. A Study on the USCRN Air Temperature Performance.

X. Lin, University of Nebraska, Lincoln, NE; and K. G. Hubbard. Comparison of ASOS Dewpoint Temperatures: HO-1088 AND DTS1.

Claude E. Duchon, University of Oklahoma, Norman, OK . Obsevations of Temperature Sensitivity in Geonor Vibrating-wire Transducers.

Kenneth Crawford, University of Oklahoma, Norman, OK; and M. Divecchio, R. Dombrowsky, S. Pritchett, T. Ross, R. Leffler, and C. L. Stang. Sustained Surface Meteorological Networks to Monitor Climate Variability and Change; COOP Modernization: Building the National Cooperative Mesonet.

Michael R. Helfert, NOAA/NESDIS/NCDC, Asheville, NC; and M. Changery, D. R. Easterling, M. J. Janis, S. M. Baker, B. M. Summer, D. Y. Graybeal, K. G. Hubbard, and K. T. Redmond. Climate Reference Network Stations: Location, Location, Location....

Christopher A. Fiebrich, David Grimsley and Kris Kesler. The Value of Routine Site Visits in Managing and Maintaining Quality Data from the Oklahoma Mesonet.

Tilden P. Meyers, NOAA/OAR/ARL/ATDD, Oak Ridge, TN; and M. E. Hall, C. B. Baker, R. P. Hosker, Jr., J. A. Jensen, M. P. Helfert, and M. T. Young. Current Configuration of US Climate Reference Network Stations.

Grant Goodge, NOAA/NESDIS/NCDC, Asheville, NC; and D. S. Braun, B. Sun, B. Baker, D. Dellinger, and S. Hinson. Quality Control of Data from the United States Climate Reference Network.

Bomin Sun, NOAA/NESDIS/NCDC, Asheville, NC; and B. Baker. A Comparative Study of ASOS and CRN Temperature Measurements.

Appendix C. USCRN Data Ingest Performance Measure Percentages

Discussion:

Although the USCRN network average (98.8%) for the full Period-of-Record (POR) is outstanding, and above the minimum level recommended (98.0%) as an overall Network Performance Measure for operations, a USCRN target of 100.0% is both the target as well as an unattainable, if not unrealistic, target.

Therefore, the data and metadata from individual stations felt to be adequate (98-99.9%) or underperforming (those less than 98%) are examined in detail to identify diurnal, seasonal anomalies, trends or biases (microclimatic problems) or systemic or systematic engineering problems of a higher order priority. As these biases or shortcomings are identified, engineering upgrades and fixes are applied.

These fixes are captured by the Configuration Management tool of the Configuration Change tracking. Examples of such fixes, which are largely invisible to the data users, include datalogger heaters, better moisture seals, estimation of MTBF (mean time between failures) of small but important components such as anemometer bearings and lifetimes, power issues and backups, battery lifetime extensions and layering, persistent icing conditions in high-latitude and high-elevation stations, and a host of small and incremental improvements to the precipitation gauge over the past four years.

POR statistics on data ingest are also biased, particularly for the early FY2001-2002 prototype stations, by early startup data gaps. Although engineering improvements may have already been applied, the data gaps in the early POR will continue to contaminate (as a decreasing proportion) the longer-term POR, while not affecting the later portions of the POR (e.g., FY2003-2004).

Thus, two tables are presented in the Appendix to demonstrate the differentiation between early POR problems versus the higher performing data ingest percentages that follow the most recent engineering improvements.

The third table demonstrates the impact of the Personal Digital Assistants (PDA's) on maintaining a very high (>99%) USCRN data ingest into the National Archive.

Table A. Cumulative USCRN Individual Station and Overall Network Data Ingest Percentages, FY2001-2004

Reported Obs Summary Oct 1, 2000 – Sep 2, 2004 (LST)

USCRN Network Overall Data Ingest Percentage: 99.1 %

SITEID	STATE	LOCATION	VECTOR	NAME	PCT
012422	AZ	Elgin	5 S	AUDUBON (Appleton-Whittell Research Ranch)	99.8
013754	AZ	Tucson	11 W	Sonora Desert Museum,	98.3
0026D8	CA	Merced	23 WSW	Kesterson Reservoir (US Bureau of Reclamation)	99.8
01745E	CA	Redding	12 WNW	Whiskeytown National Recreation Area (RAWS Site)	99.7
039258	CA	Stovepipe Wells	1 SW	Death Valley National Park (Stovepipe Wells Site)	100.2
02232C	CO	Boulder	14 W	Mountain Research Station, INSTAAR, Univ. of CO, (Hills Mill)	100.4
03C224	CO	Dinosaur	2 E	Dinosaur National Monument (Hdq. Maintenance Site)	98.1
03E4C8	CO	La Junta	17 WSW	USDA Comanche National Grassland	98.1
03D152	CO	Montrose	11 ENE	Black Canyon of the Gunnison National Park (Vernal Mesa)	99.3
016728	CO	Nunn	7 NNE	Ag. Res. Svc., Central Plains Exp. Range (SGS LTER at CSU)	99.9
02B64E	GA	Newton	8 W	Robert W. Woodruff Foundation (Ichauway-George Site)	98.9
02C0DE	GA	Newton	11 SW	Robert W. Woodruff Foundation (Ichauway-Dubignon Site)	98.7
03F7BE	GA	Watkinsville	5 SSE	USDA, ARS, Watkinsville (Colham Ferry Site)	99.6
01D4A6	ID	Arco	17 SW	Craters of the Moon NM & Preserve (Headquarters Area)	99.8
01E13C	ID	Murphy	10 W	ARS, NW Watershed Research Cntr. (Reynolds Creek Site)	99.9
03073A	IL	Champaign	9 SW	Univ. of Illinois (Bondville Environ. & Atmos. Resrch. Stn.)	99.9
03144C	IL	Shabbona	5 NNE	Northern Illinois Agronomy Research Center,	99.8
0076A4	KS	Manhattan	6 SSW	Kansas State University, (Konza Prairie Biological Station)	100.0
02A538	KY	Bowling Green	21 NNE	Mammoth Cave National Park (Job Corps Site)	99.4
027350	KY	Versailles	3 NNW	University of Kentucky (Woodford County Site)	100.0
0152B2	LA	Lafayette	13 SE	University of Louisiana at Lafayette (Cade Farm)	99.7
0141C4	LA	Monroe	26 N	Upper Ouachita National Wildlife Refuge,	99.8
02E632	ME	Limestone	4 NNW	Aroostook National Wildlife Ref. (Fire Training Area)	99.7

02D3A8	ME	Old Town	2 W	University of Maine (Rogers Farm Site)	99.7
0321D6	MN	Goodridge	12 NNW	Agassiz National Wildlife Refuge (Maintenance Shop Site)	100.1
02F544	MS	Newton	5 ENE	Mississippi State University (Coastal Plain Exp. Station)	99.4
02305A	MT	St. Mary	1 SSW	Glacier National Park (St. Mary Site)	100.1
009556	MT	Wolf Point	29 ENE	Fort Peck Indian Res. (Poplar River Site)	99.5
00A0CC	MT	Wolf Point	34 NE	Fort Peck Indian Res. (Give Out Morgan Site)	99.8
0246CA	NC	Asheville	8 SSW	North Carolina Arboretum (Bierbaum Site)	97.6
0255BC	NC	Asheville	13 S	NC Mtn. Horticultural Crops Res. Ctr. (Backlund Site)	96.3
0216B6	NE	Harrison	20 SSE	Agate Fossil Beds National Monument (Visitor Center Site)	99.9
00B3BA	NE	Lincoln	11 SW	Audubon Society (Spring Creek Prairie Site)	99.2
00C52A	NE	Lincoln	8 ENE	University of Nebraska (Prairie Pines Site)	98.7
0332A0	NH	Durham	2 SSW	University of New Hampshire (Thompson Farm Site)	98.1
034430	NH	Durham	2 N	University of New Hampshire (Kingman Farm Site)	98.6
05B47A	NM	Los Alamos	13 W	Valles Caldera National Preserve (Headquarters Site)	84.9
01C7D0	NM	Socorro	20 N	Sevilleta National Wildlife Refuge (LTER Site)	99.9
03A7C2	NV	Baker	5 W	Great Basin National Park (Gravel Pit Site)	99.7
001342	NV	Mercury	3 SSW	Nevada Test Site (Desert Rock Meteorological Lab)	97.8
03812E	OK	Goodwell	2 E	OK Panhandle Research & Extn. Center (Native Grassland Site)	99.2
00D65C	OK	Stillwater	2 W	Oklahoma State Univ. (Ag. Research Farm Site)	99.8
00E3C6	OK	Stillwater	5 WNW	Oklahoma State University (Efaw Farm Site)	99.7
01F24A	OR	Riley	10 WSW	Northern Great Basin Experimental Range (Rainout Site)	100.0
035746	RI	Kingston	1NW	University of Rhode Island (Plains Road Site)	98.5
0362DC	RI	Kingston	1W	University of Rhode Island (Peckham Farm Site)	97.0
0283D4	SC	Blackville	3W	Clemson University (Edisto Research & Edu. Ctr.)	98.5
0290A2	SC	McClellanville	7 NE	SCDNR (Santee Coastal Reserve)	98.9
0111B8	SD	Sioux Falls	14 NNE	EROS Data Center,	99.9
008620	TX	Edinburg	17 NNE	Lower Rio Grande Valley NWR (La Sal Del Rey)	99.5
01B140	TX	Monahans	6 ENE	(Sandhills State Park)	98.7
0371AA	TX	Muleshoe	19 S	Muleshoe National Wildlife Refuge (Headquarters Site)	99.5
01A236	TX	Palestine	6 WNW	NASA (National Scientific Balloon Facility)	99.8
04F58A	VA	Cape Charles	5 ENE	Anheuser Busch Coastal Res. Ctr. Univ. of VA (Oyster)	99.2
0197AC	WA	Darrington	21 NNE	North Cascades National Park (Marblemount)	100.0
0205C0	WV	Elkins	21 ENE	Canaan Valley Resort State Park (Cabins Area)	99.8

06138C	WY	Lander	11 SSE	Nature Conservancy,(Red Canyon Ranch)	98.5
03B4B4	WY	Moose	1 NNE	Grand Teton National Park	99.9

Notes for Appendix C, Table A, above:

1. Only those operational field stations in the Lower 48 States are included in this listing. The record for the John Day, Oregon USCRN site is not included, due to a singular record duplication that is being rectified.

2. A new GOES antenna capable of transmitting through ice and snow is being tested as an option for those stations that experience these severe wintertime conditions. The prototype antennae were first installed at the two Alaskan test sites, and if results are positive, this antenna will be deployed to CONUS sites that have been subjected to wintertime icing.

3. Stations with initially undersized solar panels or too few solar panels (e.g. Sonora Desert Museum, AZ). Additional and upgraded solar panels have been added to prevent communications drops during prolonged cloudy periods.

4. The paired stations at Newton GA, Asheville NC and two South Carolina stations are suspects for moisture penetration during high-precipitation and winter-time periods. Improved seals, GOES transmitters, and dataloggers have been installed.

Table B. FY2004 USCRN Individual Station and Overall Network Data Ingest Percentages, October 2003 - September 2004

USCRN Network Overall Data Ingest Percentage: 99.8 %

SITEID	STATE	LOCATION	VECTOR	NAME	PCT
012422	AZ	Elgin	5 S	AUDUBON (Appleton-Whittell Research Ranch)	99.9
013754	AZ	Tucson	11 W	Sonora Desert Museum,	99.9
0026D8	CA	Merced	23 WSW	Kesterson Reservoir (US Bureau of Reclamation)	99.8
01745E	CA	Redding	12 WNW	Whiskeytown National Recreation Area (RAWS Site)	99.9
039258	CA	Stovepipe Wells	1 SW	Death Valley National Park (Stovepipe Wells Site)	100.2
02232C	CO	Boulder	14 W	Mountain Research Station, INSTAAR, Univ. of CO, (Hills Mill)	100.0
03C224	CO	Dinosaur	2 E	Dinosaur National Monument (Hdq. Maintenance Site)	98.1
03E4C8	CO	La Junta	17 WSW	USDA Comanche National Grassland	98.1
03D152	CO	Montrose	11 ENE	Black Canyon of the Gunnison National Park (Vernal Mesa)	99.3
016728	CO	Nunn	7 NNE	Ag. Res. Svc., Central Plains Exp. Range (SGS LTER at CSU)	100.0
02B64E	GA	Newton	8 W	Robert W. Woodruff Foundation (Ichauway-George Site)	100.0
02C0DE	GA	Newton	11 SW	Robert W. Woodruff Foundation (Ichauway-Dubignon Site)	100.0
03F7BE	GA	Watkinsville	5 SSE	USDA, ARS, Watkinsville (Colham Ferry Site)	99.6
01D4A6	ID	Arco	17 SW	Craters of the Moon NM & Preserve (Headquarters Area)	100.0
01E13C	ID	Murphy	10 W	ARS, NW Watershed Research Cntr. (Reynolds Creek Site)	100.0
03073A	IL	Champaign	9 SW	Univ. of Illinois (Bondville Environ. & Atmos. Resrch. Stn.)	99.9
03144C	IL	Shabbona	5 NNE	Northern Illinois Agronomy Research Center,	99.9
0076A4	KS	Manhattan	6 SSW	Kansas State University, (Konza Prairie Biological Station)	100.0
02A538	KY	Bowling Green	21 NNE	Mammoth Cave National Park (Job Corps Site)	99.4
027350	KY	Versailles	3 NNW	University of Kentucky (Woodford County Site)	100.0
0152B2	LA	Lafayette	13 SE	University of Louisiana at Lafayette (Cade Farm)	100.0
0141C4	LA	Monroe	26 N	Upper Ouachita National Wildlife Refuge,	99.9
02E632	ME	Limestone	4 NNW	Aroostook National Wildlife Ref. (Fire Training Area)	100.0
02D3A8	ME	Old Town	2 W	University of Maine (Rogers Farm Site)	100.0
0321D6	MN	Goodridge	12 NNW	Agassiz National Wildlife Refuge (Maintenance Shop Site)	100.0

02F544	MS	Newton	5 ENE	Mississippi State University (Coastal Plain Exp. Station)	99.9
02305A	MT	St. Mary	1 SSW	Glacier National Park (St. Mary Site)	100.0
009556	MT	Wolf Point	29 ENE	Fort Peck Indian Res. (Poplar River Site)	100.0
00A0CC	MT	Wolf Point	34 NE	Fort Peck Indian Res. (Give Out Morgan Site)	100.0
0246CA	NC	Asheville	8 SSW	North Carolina Arboretum (Bierbaum Site)	99.6
0255BC	NC	Asheville	13 S	NC Mtn. Horticultural Crops Res. Ctr. (Backlund Site)	99.1
0216B6	NE	Harrison	20 SSE	Agate Fossil Beds National Monument (Visitor Center Site)	100.0
00B3BA	NE	Lincoln	11 SW	Audubon Society (Spring Creek Prairie Site)	99.9
00C52A	NE	Lincoln	8 ENE	University of Nebraska (Prairie Pines Site)	100.0
0332A0	NH	Durham	2 SSW	University of New Hampshire (Thompson Farm Site)	100.0
034430	NH	Durham	2 N	University of New Hampshire (Kingman Farm Site)	99.9
05B47A	NM	Los Alamos	13 W	Valles Caldera National Preserve (Hdq. Site)	84.9
01C7D0	NM	Socorro	20 N	Sevilleta National Wildlife Refuge (LTER Site)	99.9
03A7C2	NV	Baker	5 W	Great Basin National Park (Gravel Pit Site)	99.7
001342	NV	Mercury	3 SSW	Nevada Test Site (Desert Rock Meteorological Lab)	97.6
03812E	OK	Goodwell	2 E	OK Panhandle Research & Extn. Center (Native Grassland Site)	99.2
00D65C	OK	Stillwater	2 W	Oklahoma State Univ. (Ag. Research Farm Site)	99.9
00E3C6	OK	Stillwater	5 WNW	Oklahoma State University (Efaw Farm Site)	99.9
01F24A	OR	Riley	10 WSW	Northern Great Basin Experimental Range (Rainout Site)	100.0
035746	RI	Kingston	1NW	University of Rhode Island (Plains Road Site)	99.9
0362DC	RI	Kingston	1W	University of Rhode Island (Peckham Farm Site)	100.0
0283D4	SC	Blackville	3W	Clemson University (Edisto Research & Edu. Ctr.)	99.7
0290A2	SC	McClellanville	7 NE	SCDNR (Santee Coastal Reserve)	100.0
0111B8	SD	Sioux Falls	14 NNE	EROS Data Center,	100.0
008620	TX	Edinburg	17 NNE	Lower Rio Grande Valley NWR (La Sal Del Rey)	99.5
01B140	TX	Monahans	6 ENE	(Sandhills State Park)	98.4
0371AA	TX	Muleshoe	19 S	Muleshoe National Wildlife Refuge (Headquarters Site)	99.5
01A236	TX	Palestine	6 WNW	NASA (National Scientific Balloon Facility)	99.9
04F58A	VA	Cape Charles	5 ENE	Anheuser Busch Coastal Res. Ctr. Univ. of VA (Oyster)	99.2
0197AC	WA	Darrington	21 NNE	North Cascades National Park (Marblemount)	100.0
0205C0	WV	Elkins	21 ENE	Canaan Valley Resort State Park (Cabins Area)	99.8
06138C	WY	Lander	11 SSE	Nature Conservancy,(Red Canyon Ranch)	98.5
03B4B4	WY	Moose	1 NNE	Grand Teton National Park	99.9

Notes for Appendix C, Table B, on pages 27 and 28:

1. Only those operational field stations in the Lower 48 States are included in this listing. The record for the John Day, Oregon USCRN site is not included, due to a singular record duplication that is being rectified.
2. Data Ingest Percentages have increased markedly throughout the network when measured from the earliest period to the most recent period. Some of these improvements are viewed with suspicion as this latest monitoring period is marked by fairly benign atmospheric conditions and extremes. Nevertheless, most of the major shortcomings have been addressed through incremental engineering improvements and the addition of improved operational monitoring procedures based upon a longer experience base with USCRN technology and metadata analysis.
3. The most marked improvements have been in the data ingest performance at the Sonoran Desert Museum AZ (98.2% to 99.9%); the Newton GA station pair (98+% to 100.0%); the Asheville NC station pair (97.6% and 96.2% to 100.0% and 99.0% respectively); one of the New Hampshire stations (98.1% to 100.0%); the Rhode Island station pair (98+% to 100.0%); the South Carolina stations (98+% to 99.6-99.7%), and the EROS Data Center station improvement from 89.9% to 100.0%.

   It should be noted that all of these stations were either the very earliest USCRN paired stations deployed in FY2001, or were the first solar-powered stations deployed (e.g., Sonoran Desert Museum). If there are "lessons learned" in bringing these early stations from the level of "adequate, meeting desired criteria (98%)" to "superior, let's keep it up" they are these:

   a. sensor and station metadata are vital for high network performance;
   b. daily monitoring of metadata and the Health of the Network is vital;
   c. quick response maintenance actions must be a program base;
   d. incremental engineering improvement programs must be ongoing;
   e. expect technological evolution - and – take advantage of it.

4. The addition of correctly sized solar panels and additional batteries at the Sonoran Desert Museum had an immediate impact.

5. Improved moisture seals and GOES transmitters at the Newton GA have increased the data ingest percentage in this very moist and diurnally extreme moisture region of the Northern Gulf of Mexico periphery.

6. The Asheville paired stations were the original prototypes for the USCRN proof-of-concept phase in FY2001. Both of those stations underwent major upgrades prior to the most recent analysis period, and their data ingest has improved from the earlier marginal performance to near perfection as a result.

Table C. Critical Influence of PDA's (Personal Digital Assistants) in Maintaining a Climate-Quality Data Ingest Percentage

Finally, a study of the mode of data ingest is very instructive. The table below demonstrates that the PDA (or a like technology) inclusion as the download of the station datalogger provides a data completeness cushion and is **HIGHLY RECOMMENDED** as a base for other networks where database and observations completeness records are also vital.

In this instance, the data ingest percentages of the two Alaskan stations are included. The influence of the PDA's in bringing the USCRN data ingest performance level to >99% -- and keeping it there -- can be seen below. (The PDA recovery rate, in %, is in the far righthand column):

LOC_STATE	LOCATION	VECTOR	OPERATIONAL	MAX_OBS	% inventory	% 1st hr	% 2nd hr	% 3rd hr	% delayed	% pda
AK	Fairbanks	11 NE	07/22/2002	11040	99.9	88.6	2.5	0.9	4.8	3
AZ	Elgin	5 S	09/14/2002	11040	99.9	92.3	1.3	0.4	4.4	1.5
AZ	Tucson	11 W	09/18/2002	11040	99.6	85.1	3.7	1.3	6.9	2.4
CA	Merced	23 WSW	03/25/2004	3096	99.6	95	1.7	0.5	2.3	0
CA	Redding	12 WNW	03/25/2003	11040	99.9	91.1	1.6	0.7	4.4	2
CA	Stovepipe Wells	1 SW	05/05/2004	2112	99.9	95.9	1.7	0.3	1.8	0
CO	Nunn	7 NNE	07/06/2003	9408	99.8	83.1	10.5	1.5	3.7	0.8
GA	Newton	11 SW	08/20/2002	11040	99.8	91.6	1.4	0.6	4.3	1.8
GA	Newton	8 W	08/20/2002	11040	99.9	84.2	1.7	0.7	3.8	9.4
GA	Watkinsville	5 SSE	04/30/2004	2232	99.2	95.6	1.5	0.3	1.7	0
ID	Arco	17 SW	07/10/2003	9312	99.8	93.2	1.3	0.4	3.2	1.6
ID	Murphy	10 W	06/29/2003	9576	99.8	86.7	1.3	0.7	7.2	3.1
IL	Champaign	9 SW	12/20/2002	11040	99.9	91.8	1.6	0.5	4.1	1.8
IL	Shabbona	5 NNE	08/16/2003	8424	99.7	92.4	1.2	0.4	3.7	1.8
KS	Manhattan	6 SSW	10/01/2003	7320	99.9	92.9	1.1	0.5	4.1	1.3
KY	Bowling Green	21 NNE	05/19/2004	1776	98.9	95.8	1	0.1	2	0
KY	Versailles	3 NNW	06/12/2003	9984	99.9	91.4	1.5	0.8	3.8	2.1
LA	Lafayette	13 SE	01/10/2003	11040	99.9	91.1	1.3	0.4	4.1	2.9
LA	Monroe	26 N	01/15/2003	11040	99.9	92	2	0.4	4.1	1.2
ME	Limestone	4 NNW	09/20/2002	11040	100	92	1.3	0.4	4.4	1.6
ME	Old Town	2 W	09/24/2002	11040	100	91.6	1.3	0.5	4.4	2
MN	Goodridge	12 NNW	08/21/2003	8304	100	87.6	4.8	0.6	3.5	3.3
MS	Newton	5 ENE	11/03/2002	11040	99.9	91.3	2.1	0.6	3.9	2

MT	St. Mary	1 SSW	09/25/2003	7464	100	92.4	1	0.5	3.9	1.9
MT	Wolf Point	29 ENE	12/20/2001	11040	100	89.4	1.2	0.6	4.2	4.5
MT	Wolf Point	34 NE	12/20/2001	11040	99.9	87.6	1.4	0.8	4.5	5.5
NC	Asheville	13 S	11/14/2000	11040	99.3	90.4	1.6	0.8	4.4	0.8
NC	Asheville	8 SSW	11/14/2000	11040	99.7	89.4	1.4	0.8	5	1.7
NE	Harrison	20 SSE	08/27/2003	8160	99.8	90.8	1.3	0.6	4.4	2.5
NE	Lincoln	11 SW	01/14/2002	11040	99.9	86.1	2.3	1.6	7.1	2.6
NE	Lincoln	8 ENE	01/14/2002	11040	100	90.4	1.4	0.8	5.3	1.8
NH	Durham	2 N	12/11/2001	11040	99.5	92.8	1.5	0.4	4.1	0.6
NH	Durham	2 SSW	12/16/2001	11040	100	91.1	3.2	0.6	4.4	0.7
NM	Socorro	20 N	05/24/2003	10440	99.8	92.7	1.4	0.4	3.9	1.4
NV	Baker	5 W	05/09/2004	2016	99.2	95.5	1.4	0.3	1.9	0
NV	Mercury	3 SSW	03/28/2004	3024	97.6	88.4	5.5	1.8	1.9	0
OK	Goodwell	2 E	02/27/2004	3744	98.9	93.8	1.6	0.3	3	0
OK	Stillwater	2 W	03/15/2002	11040	99.9	92.4	1.4	0.7	4.2	1.2
OK	Stillwater	5 WNW	03/15/2002	11040	99.9	92.2	1.5	0.5	4.5	1.3
OR	Riley	10 WSW	07/03/2003	9480	100	88.3	1.2	0.5	3.8	5.8
RI	Kingston	1NW	12/15/2001	11040	99.9	92.6	1.4	0.4	4.2	1.2
RI	Kingston	1W	12/15/2001	11040	99.8	86.1	1.5	0.5	6.7	4.9
SC	Blackville	3W	07/03/2002	11040	99.8	88.7	1.8	0.8	6.9	1.3
SC	McClellanville	7 NE	08/08/2002	11040	99.8	87.3	2.5	1	6.8	2.1
SD	Sioux Falls	14 NNE	09/25/2002	11040	100	92.3	1.3	0.5	5.3	0.4
TX	Edinburg	17 NNE	02/19/2004	3936	99.2	94.1	1.4	0.3	3.4	0
TX	Monahans	6 ENE	05/21/2003	10512	98.6	91.2	1.2	0.4	3.8	1.9
TX	Muleshoe	19 S	02/27/2004	3744	99.2	93.9	1.6	0.5	3.1	0
TX	Palestine	6 WNW	05/25/2003	10416	99.7	93.2	1.4	0.5	3.9	0.7
VA	Cape Charles	5 ENE	03/03/2004	3624	99	94.8	1.1	0.3	2.6	0
WA	Darrington	21 NNE	04/03/2003	11040	100	87.4	2	0.6	4.3	5.5
WV	Elkins	21 ENE	11/17/2003	6192	99.7	89.1	1.4	0.6	4.1	4
-	Totals	-	-	463416	99.8	90.3	1.9	0.6	4.5	2.2

The USCRN experience shows that the PDA downloads, as needed, provide a general gain of 1-5% in the POR dataset completeness. As USCRN completes the retrofit of increased long-term storage (32-month) memory dataloggers to the network stations, confidence increases that long-term dataset completeness will routinely exceed 99%. As recently as 2002, a 98% data completeness standard for an automatic and remotely monitored network such as USCRN was postulated as barely achievable.