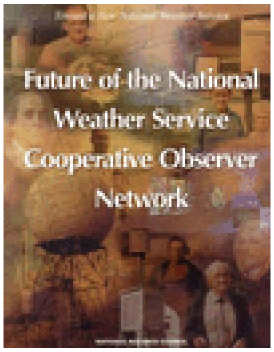

Future of the National Weather Service Cooperative Observer Network

National Weather Service Modernization Committee,
National Research Council

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Toward a New National Weather Service

Future of the National Weather Service Cooperative Observer Network

National Weather Service Modernization Committee
Commission on Engineering and Technical Systems
National Research Council

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PANEL ON CLIMATE RECORD: MODERNIZATION OF THE COOPERATIVE OBSERVER NETWORK

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Preface

As part of its continuing review and evaluation of National Weather Service (NWS) operations and plans, the National Research Council, through its National Weather Service Modernization Committee (NWSMC), has monitored developments in weather observing systems since 1990. In earlier reports, the NWSMC has commented on the Cooperative Observer Network (Coop Network) and its relationship to the climate record. The NWSMC was informed by users of weather observations that they depend on accurate, reliable data from the Coop Network. The Association of State Climatologists, representatives of regional climate centers, universities, and other groups that use weather and climate data have contacted the NWSMC and provided briefings in recent years on growing problems and issues related to the network. Users of the network's observations are deeply concerned that little attention has been paid to this important source of data as the NWS modernization has proceeded and that network capability has deteriorated. In a recent report on NWS hydrologic operations and services, the NWSMC recommended that "NOAA [the National Oceanic and Atmospheric Administration] should review the status of the cooperative observer network and plan for its future in the context of the ongoing modernization."

Accordingly, in October 1996 the NWSMC proposed a study of the status and outlook for the Coop Network. The NRC subsequently authorized the study and approved a Panel on Climate Record: Modernization of the Cooperative Observer Network (the Coop Panel). The panel consisted of several members of the NWSMC and other experts with relevant experience in NWS operations, cooperative observing, and private industry. The panel undertook the following tasks:

- to assess the applications of Coop Network data (see Chapter 1)
- to assess the continuation of the Coop Network (see Chapter 2)
- to assess the NWS plans to modernize the network, including the impact of interagency data requirements on NOAA's program responsibility (see Chapter 4)
- to identify alternative approaches for improving the effectiveness and efficiency of the network through new technology or new organizational structures associated with NWS modernization (see Chapter 3)

To gather information, the Coop Panel met three times with representatives of NOAA, the NWS, and the National Climatic Data Center (NCDC, a unit of the National Environmental Satellite, Data, and Information Service). The panel also met with representatives of the U.S. Department of Agriculture, the U.S. Department of the Interior, the U.S. Army Corps of Engineers, and other providers and users of climate record data.

The panel relied heavily on internal NWS documents, interviews, correspondence with NWS and NCDC employees, and information from state climatologists. The panel conducted its analyses and reviews in the broad context of the NWS modernization and global climate change, identifying emerging needs and applications of Coop Network data. The panel visited NCDC and an NWS weather forecast office and interviewed staff members involved with support activities at various levels of the NWS/NCDC organizational structure. Information-gathering covered everything from data collection and site maintenance to quality control, data analysis, data archiving, forecasting, publication and dissemination of products, and interaction with both cooperative observers and users. A questionnaire about the uses and value of cooperative weather data (see Appendix A) was distributed by the American Association of State Climatologists to its members, and the responses (60 percent of 48 surveys) were provided to the panel.

The panel then reviewed the information that had been gathered and analyzed it in the context of the NWS modernization. The NWSMC reviewed the findings, conclusions, and recommendations of the panel. Finally, the panel presented its analyses, conclusions, and recommendations in this report.

This study could not have been conducted without the full and willing participation of many NCDC and NWS staff members, in particular Messrs. Phillip Clark, John Jensen, Robert Leffler, and Andrew Horvitz. I would like to thank the members of the Coop Panel for the very considerable effort they devoted to this study, including visiting facilities, conducting interviews, and drafting the report. On behalf of the panel and the committee, I wish to express our appreciation to Mr. Floyd Hauth, study director, and Mrs. Mercedes Ilagan, study associate, for their expert organizational and logistical support. Finally, I would like to thank consultant Courtland Lewis for his assistance in the preparation of this report.

WILLIAM D. BONNER, CHAIR

PANEL ON CLIMATE RECORD: MODERNIZATION OF THE COOPERTAIVE OBSERVER NETWORK

Acknowledgments

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

William Bland, University of Wisconsin-Madison
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Although the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committees and the NRC.

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Executive Summary

The Cooperative Observer Network (the Coop Network) is a nationwide weather and climate monitoring network of volunteer citizens and institutions that observe and report weather information on a regular basis. The Coop Network is an important component of the National Weather Service's (NWS) data collection and is a vital component of the national observing capability for monitoring temperature, precipitation, snowfall, and other weather events across the United States. With a total annual cost of less than $10 million, the NWS Coop Program is an exceptional value in terms of benefits to the nation.

Data from the Coop Network represent a historical gold mine. For more than a century this network has provided a wealth of observations defining the climate of our country. Volunteer observers have joined forces with the federal government to provide one of the most comprehensive records of temperature and precipitation available anywhere in the world.

Although the network was initially established to serve agricultural needs, the applications of the data have expanded dramatically. Data from the network are now used in many ways, ranging from the management of water resources and the design and maintenance of infrastructure to predictions of crop yield and local weather forecasting. The data provided by cooperative observers are used in a myriad of important political and economic decisions all across the country by private industry, all levels of government, and private individuals.

Because of its stability over time and the geographic density of its observations, the network is particularly well suited for monitoring and detecting local, regional, and nationwide climate variations and changes. The growing recognition of the far-reaching economic and societal impact of climate variability and potential climate change reinforces the argument for maintaining the Coop Network.

Despite its increasing importance to the nation, over the past several years the Coop Network has been weakened by a combination of technological, organizational, and budgetary factors. The National Research Council's National Weather Service Modernization Committee established the Panel on Climate Record: Modernization of the Cooperative Observer Network to study the Coop Network from both the technical and operational/managerial standpoints, in the context of the ongoing modernization and restructuring of the NWS. The objective of the study was to identify actions that should be taken to strengthen the Coop Network so that it can continue to serve the nation in the next century as well as it has in the past. Key recommendations from the report are provided in this Executive Summary.

Two organizations, the NWS and the National Environmental Satellite, Data, and Information Service (NESDIS), manage the collection and most of the processing and dissemination of coop data. Both are agencies of the National Oceanic and Atmospheric Administration (NOAA). The NWS is responsible for overall management of the Coop Network and for observations—that is, for station operations, instrumentation, and documentation, the recruitment and training of observers, data collection and initial quality control, and the transmission of data to NESDIS. Within NESDIS, the National Climatic Data Center (NCDC) is responsible for long-term stewardship of the data, which involves assimilating and archiving, final quality control, and the generation and dissemination of products derived from the data. The NWS uses coop data primarily for operational meteorology and hydrology; the NCDC uses the data primarily for climatological purposes.

The panel observed that differences in operational priorities and ineffective coordination between high-level NWS and NCDC (under NESDIS) managers in addressing budget and data deficiencies have exacerbated operational and fiscal support problems for the Coop Network and the Coop Program. There is a pervasive sense among participants and users of the network that overall program policy, long-term planning, and budgetary advocacy are inconsistent, at best. The panel concluded that management oversight by NOAA would improve this situation.

Recommendation. The National Oceanic and Atmospheric Administration should improve the overall management of the Cooperative Observer Program. One approach would be to establish a climate observations management office to oversee the activities of the of Cooperative Observer Program of the National Weather Service and National Climatic Data Center. This office would ensure that the Cooperative Observer Program is given a high priority by the National Oceanic and Atmospheric Administration, the National Weather Service, and the National Environmental Satellite, Data, and Information Service. Operational management of the Cooperative Observer Network would continue to be the responsibility of the National Weather Service.

The NOAA climate observations office, in conjunction with the NWS Coop Network and NCDC management teams, should perform the following functions:

- shape the current and future directions of the Coop Program, enlisting interagency support in planning, policy-making, and funding
- provide effective advocacy for the Coop Program in budgetary planning by NOAA, the NWS, and NESDIS
- work with other federal agencies and states that have cooperative observer programs and/or mesonets to develop a coordinated approach to the management and maintenance of the Coop Network and ancillary networks (including setting achievable standards for sensor performance, maintenance, and calibration)
- collaborate with regional climate centers and state climatologists to ensure that high-quality climate data and derived products are available to users on a timely basis and that they are properly archived

The current Coop Network cannot be sustained at present funding levels. Modernization will require substantial new funds, not only for the acquisition of equipment, but also for ongoing operations and maintenance. Even with new appropriations, a mechanism for obtaining funds from other sources—including user agencies, the public, and industry—may be necessary for upgrading the current system.

Perhaps the preeminent management issue for the future of the Coop Network is the question of ownership and stewardship—operation, management, and policy direction. Various other federal agencies that use cooperative data have been frustrated by the apparent low priority and lack of timeliness of cooperative data under NWS management. The NWS already has the infrastructure and the experience to operate the Coop Network successfully, provided the changes recommended in this report are made.

Recommendation. The National Weather Service should improve its management of the Cooperative Observer Network.

The demand for timely data on weather and climate is growing. Users should be able to obtain climate data from a single source. To ensure the consistency and reliability of data, the quality control, archiving, and first point of dissemination of validated data should be the responsibility of a single organization. By virtue of its facilities, experience, and expertise, NCDC is the organization best suited to manage these functions.

Recommendation. The National Climatic Data Center should continue to be the focal point for archiving and disseminating cooperative data and should work with regional climate centers and state climatologists to disseminate data to all interested parties, making databases available in a timely manner. The National Environmental Satellite, Data, and Information Service should make every effort to recover its costs for processing, copying, and providing data over the Internet.

Given the substantial, long-standing interest shown by many federal agencies in the health of the Coop Network and in the use of its data, and considering that the NWS has had difficulties providing adequate operational funding, NOAA should look for a way to facilitate the participation of other agencies in the policy direction and support of the network.

Recommendation. The National Oceanic and Atmospheric Administration should work with other agencies to establish an interagency management council to guide and provide support (including funding) for the Cooperative Observer Network. The Office of the Federal Coordinator for Meteorology could administer the operation of this council.

The Coop Network is comprised primarily of two types of stations. Nearly 5,000 "climatological stations" measure daily maximum and minimum temperatures, precipitation, snowfall, and the temperature and snow depth at the time of observation. Many observers at climatological stations include supplemental information in their reports, such as time of day when precipitation fell and weather conditions, such as fog, freezing rain, thunder, hail, and damaging winds. An even larger number of "hydrologic stations" provide data to the NWS for river and flood forecasting. Many hydrologic stations measure only precipitation and/or river stages. About 3,000 have instruments that measure hourly precipitation. The climatological and hydrologic stations, together with special-purpose stations in different regions of the country, comprise a Coop Network of nearly 12,000 stations.

With a few important exceptions, the instruments used by cooperative observers have not changed significantly in the past century. For measuring liquid precipitation, observers at about 90 percent of the stations use standard 8-inch rain gauges (basically cans with dipsticks for measuring the water level in the magnifier tube) and record their observations by hand on paper forms. About 10 percent of stations use "recording" gauges that automatically weigh and record precipitation on a paper punch tape or analog chart. Two basic types of instruments are used to measure temperature, one liquid-in-glass and one electronic. All temperature observations are recorded manually on paper. The electronic thermistor used for temperature observations and its display equipment are becoming obsolete and increasingly difficult to maintain and calibrate.

Once the measurements have been made, the data flow along different paths depending on the type of data, the frequency of reporting, and the capabilities of individual cooperative stations. Shortly after taking daily readings, observers at hydrologic stations phone or transmit their observations to NWS forecast offices as input for weather or flood forecasts and warnings; the data are recorded on paper forms. Observers at climatological stations also record temperature, precipitation, and other observations manually on paper forms. About 1,000 climatological stations phone in observations of maximum and minimum temperature, liquid precipitation, snowfall and snow depth, and present weather once a day. The paper data forms and rain-gauge tapes from both climatological and hydrologic stations are submitted monthly, by mail, to NWS forecast offices, where the NWS personnel responsible for Coop Network observations review them for obvious errors (preliminary quality control) and forward the forms and tapes to NCDC for further processing, storage, and dissemination. NCDC typically receives the data forms and paper tapes from NWS offices two to four weeks after the end of the calendar month.

The combination of mail-based delivery of the data forms and paper tapes to NWS forecast offices and the limited staff time available at NWS offices for processing them means that the entire process is slow and inefficient. The slowness of this process is a growing problem for many users for whom the earliest availability of the data, even incomplete data, is increasingly important. Therefore, an obvious goal for upgrading Coop Network stations is improving and automating data transmission and collection as much as possible.

The panel envisions a multilevel network that is upgraded according to three main priorities: (1) maintaining a network size and density that satisfies all major needs; (2) ensuring that the quality of the data remains high; and (3) making a large subset of the data available faster—preferably on a near-real-time basis—while continuing to archive data for long-term climatological purposes. Making data available to potential users faster must not compromise the quality of the data. In the interim, near-real-time users should be informed of potential inaccuracies that may not be detected until thorough quality control tests have been done. Standards for instruments and siting must be maintained throughout the Coop Network.

Improved real-time digital communications between cooperative sites and local NWS forecast offices would significantly reduce the time between data collection and dissemination to a wide variety of users, including the NWS, on both a daily and a monthly basis. In addition, automated data transmission would permit the on-site storage of data that could be retrieved in the event of a communication failure. Finally, automated communications would permit more timely and better quality control, on-site, at NWS forecast offices, and at NCDC. Although the NWS has taken steps toward automating communications, so far only about 20 percent of stations have been involved. On-site data storage and quality control have not been part of the automation.

Recommendation. Automating data communications between cooperative sites and local National Weather Service forecast offices should be the first step in automating the cooperative observer sites. The goal should be to make reporting data on at least a daily basis possible at all stations, even if data are still input manually.

Automated data collection would have several advantages. It would eliminate manual input errors, increase the frequency of observations, allow midnight-to-midnight data summaries, enable more detailed data statistics (such as hourly means and variances), and permit collection of data from a wider variety of sensors. Because several thousand electronic temperature measuring systems are already in place, temperature is the obvious starting point for automation. Electronic precipitation gauges could be added later, as the technology becomes more reliable, accurate, and affordable. Other measurements, such as relative humidity and incoming solar radiation, could easily be added.

Recommendation. Wherever feasible, cooperative stations should be provided with personal computers or data loggers for automated ingest of data from one or more electronic sensors. These personal computers or data loggers must be able to operate on battery backup power for at least 10 days and should have user-friendly interfaces for the manual ingest of data. Computers or loggers should also have an on-site error feedback mechanism and quality control during the manual input of data.

In general, automated data recording will not replace cooperative observers. The panel is not recommending that the network be fully automated. Manual observations of precipitation types and amounts, snow depth, and supplemental information will be required for many years to come. Furthermore, observers must be available to serve as backups if automated procedures fail. The panel believes that automation should be implemented slowly and carefully, over a period of years, to allow time for both observers and NWS staff to be trained in the new procedures. Every effort should be made to ensure that the transition to new instruments does not cause a significant discontinuity in the climate record.

Recommendation. New sensors should be introduced gradually across the Cooperative Observer Network. Changes in instrumentation should be tested at selected sites by thorough comparisons with the old instruments for at least a year.

A number of mesonets at the local, state, and regional levels gather high-quality climatic data (except for measurements of snow and other forms of precipitation). In some cases, the density of a mesonet exceeds the density of the Coop Network in the area, and mesonet stations are often located where there are "holes" in the Coop Network. The panel concludes that mesonet stations could reasonably supplement or augment the current Coop Network, as long as they measure the proper weather variables; meet or exceed equipment, exposure, and data quality requirements; and agree to participate in the Coop Program.

Recommendation. Mesonet stations that meet or exceed equipment and exposure requirements should be considered as supplements to, but not replacements for, the Cooperative Observer Network stations. The National Oceanic and Atmospheric Administration should establish a mechanism for evaluating the performance and set instrumentation and data standards for mesonet stations. The National Oceanic and Atmospheric Administration should establish cooperative agreements with states and other mesonet operating authorities. Mesonet operators who wish to associate their networks with the Coop Program should be required to commit to maintaining stations, data formats, and instrumentation that meet the standards of the Cooperative Observer Program for a fixed period of time. In return, the National Oceanic and Atmospheric Administration should provide quality control, archiving, and dissemination of selected data from mesonet stations.

As the Coop Network is modernized, flexibility to expand it and/or modify it should be built in. Although NOAA has developed a concept of a modernized NWS architecture, no comprehensive system planning architecture for surface observations comparable to the architectures for other atmospheric observations has been developed.

Recommendation. The National Oceanic and Atmospheric Administration, in cooperation with other agencies, should conduct an analysis of requirements for surface observations, with periodic follow-ups to develop requirements and specifications for a strong and viable surface observing system. The goal should be to develop and implement, over time, a comprehensive system planning architecture that ensures the effectiveness of the Cooperative Observer Network as part of a composite national surface observing system. This system architecture should be fully integrated with the other components of the overall National Weather System.

The importance of climatic data gathered at Coop Network sites is increasing, along with the range of uses for these data. NOAA has an opportunity to build a modern system that can play an integral role in the nation's weather and climate information networks and to enhance the role the network already plays in matters relating to the health, safety, economic concerns, and general well-being of the nation. The recommendations in this report are neither difficult nor expensive to implement. If they are acted upon, they will bring this important national resource into balance with other surface observing networks so that the Coop Network can continue to play a vital role in the integrated National Weather System of the twenty-first century.

1

Overview

DEFINITION

A Vital Part of the National Infrastructure

For more than a century, public-spirited citizens all across the United States have performed an invaluable service by participating in a network of volunteer cooperative observers managed by the federal government. By donating their time and the use of their property to monitor temperature and precipitation amounts, these volunteers have provided the United States with one of the most comprehensive and complete records of temperature and precipitation anywhere in the world. The Cooperative Observer Network (Coop Network) is the nation's largest and oldest weather network. The data this network provides are vital to a myriad of policy and economic decisions made by industry, government, and individuals.

The Coop Network, as it is commonly called, was established in 1890 to make meteorological observations and establish and record climatic conditions in the United States, primarily for agricultural purposes (see Box 1-1). In response to the recent interest in climate change and variability, the Coop Network has taken on an additional mission—monitoring and detecting climate changes. Although the network was not designed for this purpose, it provides invaluable data. Because it has generated consistent, long-term historical climate data, the network has established an invaluable record of the climate in the United States (see Boxes 1-2 and 1-3).

Today the Coop Network is increasingly used by the National Weather Service (NWS) to support meteorological and hydrological forecasts and warnings and to verify forecasts. The Coop Network is the only nationwide source of data on surface precipitation and the only source of systematic observations of surface snow, which are critical for hydrological forecasting. Network data are used in applied hydrology (especially for long-term forecasts of water resources) and for research (e.g., the development and verification of mesoscale forecast models).

Coop data have been used in recent years for water management, drought assessment, engineering and architectural design, models of energy consumption, environmental impact assessments, environmental monitoring and prediction, litigation, and many other purposes (see Appendix B). Not surprisingly, the range of users has also expanded beyond farmers and government officials to encompass engineers, architects, attorneys, insurance companies, scientists, utility companies, manufacturers, and business planners. Indeed, the uses and users of Coop Network data mirror our society and economy. For example, more than one-fourth of all requests for coop data (which are legally certifiable in a court of law) now come from attorneys. Millions of small and large decisions, by public and private concerns, are based on coop data—when to plant corn, where to site power plants, where (and how) to build buildings or bridges, how many snow days to plan into the school year, how much road salt to buy, where to plan one's retirement, how much to limit emissions, and so on (see Box 1-4).

From any perspective, this little known, low-cost network is a vital element of the nation's infrastructure—arguably the most comprehensive national observing network for monitoring temperature, precipitation, snowfall, and other weather events in the United States.

Network Configuration

The Coop Network consists of thousands of volunteer citizens and institutions. Participants are provided with a set of simple weather instruments and observing instructions by the NWS, which manages the network under the Cooperative Observer Program (the Coop Program). The observers provide basic weather data for their locations, usually on a daily basis.

Within the Coop Network there are several types of stations (see Figure 1-1). At the heart of the network are about 5,000 full "climatological stations" that measure daily maximum and minimum temperatures, precipitation, snowfall, and temperature and snow depth at the time of observation. Many observers also provide supplemental information, such as time of day when the precipitation fell and other weather conditions, such as fog, freezing rain, thunder, hail, and damaging winds. These stations, called "A" stations by NWS officials, are operated predominantly by volunteers—either private individuals or employees of cooperating institutions, such as agricultural businesses, university research stations, reservoir caretakers, and water treatment plant operators. About 35 percent of the cooperative observers are paid a very small monthly fee (usually around $30) to cover personal expenses. Stations are located at universities, research centers, municipal facilities, farms, ranches, homes, and businesses. About 30 percent of stations are located at institutions that also use the local climatic data.

BOX 1-1 HISTORICAL ROOTS OF THE COOPERATIVE OBSERVER NETWORK

1644	John Companius Holm makes the first known regular weather observations in North America
1743	Benjamin Franklin tracks a hurricane while serving as Postmaster General
1797	Thomas Jefferson envisions a nationwide network of observers
1847	The Smithsonian Institution establishes a network of weather observers
1874	A volunteer observer network is organized by the Army Signal Corps Weather Service
1880s	State weather networks are established
1890	The Cooperative Observer Network is established under the Organic Act, managed by the U.S. Weather Bureau in the U.S. Department of Agriculture. The original mandate is to describe U.S. climate (to meet agricultural needs). Hydrological responsibilities are added later.

Source: NOAA, 1993.

In the early years of the Coop Network, nearly all of the stations were full climatological stations. The number of Astations grew from about 1,000 in 1900 to 5,850 in 1972. In recent years, the number has dropped to about 5,000. In 1953, guidelines were developed for the network suggesting a target of one full climatological station for every 625 square miles. This target has never been reached, particularly in the sparsely populated regions of the western United States (see Figure 1-2).

Over time, other types of stations have been added to the network. The Bureau of Reclamation and the U.S. Army Corps of Engineers, which designs, builds, and operates many major water storage, river navigation, and flood control projects, needed hydrologic data. The establishment within the NWS of river forecast centers (RFCs) created an additional need for frequent precipitation measurements from a dense network. As a result, a large number of "hydrologic stations" (also known as "B" stations) were added to the Coop Network, especially during the 1940s and 1950s

BOX 1-2 CLIMATE DATA SUGGEST GLOBAL WARMING

Based on land and ocean surface temperatures, 1997 was the warmest year of this century. A team of scientists from the National Oceanic and Atmospheric Administration's National Climatic Data Center analyzed temperatures from around the globe from 1900 to 1997 and land areas from 1880 to 1997. The Cooperative Observer Network was the source for much of the U.S. data. In 1997, land and ocean temperatures averaged three-quarters of a degree Fahrenheit above normal (normal is defined as 61.7°F). This was 0.15°F higher than the previous record warm year, 1990.

The record-breaking warm conditions of 1997 continue the pattern of very warm global temperatures. Nine of the past 11 years have been the warmest on record. The 10 warmest years have all occurred since 1981, and the warmest five years have occurred since 1990.

With new data factored in, global temperature warming trends now exceed 1°F per 100 years, with land temperatures warming at a somewhat faster rate than ocean temperatures.

Source: NOAA, 1998.

(Figure 1-1), many of which measure only precipitation and/ or river stages. Some stations were equipped with rain gauges to collect and record detailed information on the intensity and duration of precipitation. Many of the B stations were funded by other federal agencies. As the network expanded, the NWS relied partly on funds from these other agencies to maintain the Coop Network.

BOX 1-3 HISTORICAL CLIMATE NETWORK

Of the approximately 5,000 climate stations ("A" stations), about 1,200 in the continental United States comprise the Historical Climate Network (HCN). (A handful of HCN stations do not belong to the Coop Network.) The HCN data establish the baseline for most research and analysis of climate trends. Thus, HCN stations must meet high standards of consistency over time. An HCN station is defined as a site that has provided at least 80 years of high-quality data in a stable environment. HCN stations are the "elite" of the A stations. Their record stretches from the 1800s to the present, with listings of monthly maximum/minimum temperatures (based on average daily maximum/minimum values), mean temperatures, and precipitation. The HCN is an irreplaceable national resource.

Source: Easterling, 1997.

The NWS Agricultural Weather Program greatly expanded the Coop Network across much of the country in the 1960s and 1970s. NWS agricultural meteorologists not only helped to establish new stations, but they also shared in the maintenance of the Coop Network. From the mid-1970s until the end of the NWS Agricultural Weather Program in 1996, NWS agricultural weather offices provided much of the data collection, quality control, and oversight of agricultural data. This greatly reduced the workload of the weather service forecast offices (WSFOs).

As Figure 1-1 shows, A and B stations today make up a network of 11,742 stations. The Coop Network also includes a small number of C stations, which serve a variety of special purposes, such as research on, and forecasts of, frost in fruit growing areas and measurements of precipitation in remote areas. The total number of cooperative observer stations managed and maintained by the NWS in 1997 was 11,866. The locations of these stations are shown in Figure 1-2.

Observing Equipment

With a few important exceptions, the instruments used by cooperative observers have not changed significantly over the past century. Snowfall and snow depth are measured manually with rulers or stakes. Liquid precipitation is measured with two types of rain gauges:

BOX 1-4 COOP DATA: THE STAR WITNESS!

Data from the Cooperative Observer Network can make or break a lawsuit. At times, the disposition of millions of dollars hangs on a few small data points, as in the examples below.

- Monthly precipitation data was the key to determining the outcome of a $2 billion lawsuit brought by several southwest Indian tribes against the U.S. government concerning the over-grazing of reservation rangeland.
- Total storm rainfall amounts and associated short-duration intensities reported by coop stations provided the basic information used by engineers and meteorological consultants to assist the courts in determining the reasons and legal responsibilities for the washout of a major bridge span in Puerto Rico that resulted in 27 deaths and a $65 million lawsuit.
- The dispensation of $500 million in federal drought insurance was decided by precipitation records from coop stations during the 1988 drought in the Midwest. In one case, $6 million was paid on the basis of records from one station.

Source: Jensen, 1997.

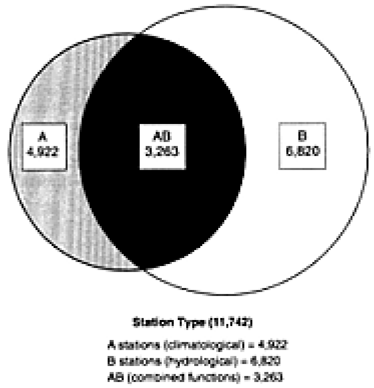

Figure 1-1 Types of Cooperative Observer Network stations.
Source: National Weather Service

- Nonrecording gauges are standard 8-inch rain gauges (basically cans) that require that the observer go outside, take a visual measurement (using a dipstick) of the water level in the magnifier tube, and record the information on a paper form. About 90 percent of the stations that report precipitation use nonrecording gauges.
- Recording gauges can be one of two types, the Belfort Fischer-Porter type or the Belfort Universal type. Recording gauges automatically weigh and record precipitation, using either a paper punch tape or paper analog chart. The paper record must be changed manually and mailed to the National Climatic Data Center (NCDC) for processing. The Belfort Fischer-Porter gauges represent 1960s technology.

Two basic types of instruments are used to measure temperature:

- Liquid-in-glass maximum/minimum thermometers require that the observer go outside to the radiation shelter (known as the cotton region instrument shelter) that houses the thermometers, manually read the thermometer, record the observation on the appropriate paper form, and reset the thermometer. This type of thermometer is used at about 40 percent of the nearly 5,000 A stations.
- Maximum-minimum temperature systems (MMTSs) consist of electric thermistors in pole-mounted plastic radiation shelters and remote display units inside the observer's house. MMTSs are powered by observer-provided electricity. Observations are recorded manually on paper.

Many observers at hydrological stations (B and A/B stations) phone in their observations shortly after taking daily readings. Transmissions of daily observations are mainly by voice, but at more than 2,000 hydrologic stations (the number is growing rapidly) observations are transmitted by coded message entered on a keypad. In the contiguous 48 states, data are transmitted using the Remote Observation System Automation (ROSA) or the Automated Tone Dial Telephone Data Collection System (ATDTDCS). These systems use touch pads or touch-tone telephone systems on which the observer enters observations manually using a prescribed code. Neither system was designed to provide high-quality climate data.

Observers at climatological stations (A, AB, and ABC) make and record observations of significant weather events, such as fog, hail, wind damage, blowing snow, and thunder, which are recorded manually on official forms but are not included in daily transmissions.

OPERATIONAL CONTEXT

Many organizations other than the NWS and NCDC use cooperative data for research, climate analyses, and other purposes and disseminate it to end-users. The Coop Network operates in the context of many other public and private networks that collect weather data for various purposes. It also operates in the context of a far-reaching modernization program that is under way throughout the NWS. The modernization program includes the installation of automated observing systems and changes in staffing at weather offices.

Other Distributors of Coop Network Data

During the 1980s, state agencies and universities formed six regional climate centers (RCCs) to improve climate services at the local, state, and regional levels. The RCCs are stand-alone entities that receive base funding from the National Oceanic and Atmospheric Administration (NOAA), with supplemental funding from the U.S. Department of Agriculture (USDA), states, universities, and industry. The RCCs provide climate data and information, including Coop Network data, in their regions, with an emphasis on near-real-time data made available through interactive computer systems. Both current and historical data sets are stored in RCC computer systems that allow users to compare recent and historical data. This information is in great demand. In 1996, for example, the computerized data were accessed 109,000 times. In 1998, one of the RCCs reported a contact rate of 500,000 per month on the Internet.

Another important group of distributors of Coop Network data are state climatologists, who were funded by NOAA in all 50 states until 1973. The 45 remaining state climatologists,

State	Number of Stations	Standard Rain Gauge	Cotton Region Shelter	Maximum Minimum (therm.)	Maximum Minimum Temp. System	Fischer and Porter (recording rain gauge)	Universal (recording rain gauge)	Tipping Bucket	River Stage
Alabama	164	137	1	24	60	33	3	15	45
Arizona	197	172	79	77	95	28	6	22	2
Arkansas	203	162	1	19	71	55	6	16	61
California	584	399	185	180	134	191	21	58	40
Colorado	302	230	56	77	117	116	9	5	46
Connecticut	47	40	9	16	9	12	6	2	13
Delaware	10	9	0	6	2	2	1	0	1
Florida	140	114	3	39	61	32	13	2	7
Georgia	182	137	1	39	63	51	5	4	27
Idaho	163	136	77	77	60	46	3	1	19
Illinois	318	245	70	73	86	65	11	28	102
Indiana	274	189	17	36	81	62	6	1	71
Iowa	349	192	2	8	118	62	4	96	254
Kansas	470	348	9	32	134	59	6	53	207
Kentucky	213	199	1	65	36	43	10	6	50
Louisiana	224	183	3	27	59	29	4	13	75
Maine	113	83	5	21	37	20	8	0	14
Md. & D.C.	86	63	3	47	11	13	4	4	17
Massachusetts	80	69	16	28	17	10	10	3	15
Michigan	289	225	5	130	50	44	13	3	89
Minnesota	255	189	3	64	109	56	15	2	66
Mississippi	199	160	0	42	69	64	10	14	59
Missouri	303	240	11	43	124	74	9	26	124
Montana	331	248	136	136	90	82	8	2	48
Nebraska	389	260	18	26	141	54	4	5	136
Nevada	118	106	49	45	66	29	1	5	9
New Hampshire	71	62	1	19	21	20	3	0	8
New Jersey	90	88	10	35	18	18	9	2	45
New Mexico	197	186	50	85	94	69	6	5	4
New York	300	240	26	57	90	72	0	4	84

continued

FIGURE 1-2 Coop observer site location map and list of stations and equipment, by state. Source: National Climatic Data Center and National Weather Service

State	Number of Stations	Standard Rain Gauge	Cotton Region Shelter	Maximum Minimum (therm.)	Maximum Minimum Temp. System	Fischer and Porter (recording rain gauge)	Universal (recording rain gauge)	Tipping Bucket	River Stage
Alabama	164	137	1	24	60	33	3	15	45
Arizona	197	172	79	77	95	28	6	22	2
Arkansas	203	162	1	19	71	55	6	16	61
California	584	399	185	180	134	191	21	58	40
Colorado	302	230	56	77	117	116	9	5	46
Connecticut	47	40	9	16	9	12	6	2	13
Delaware	10	9	0	6	2	2	1	0	1
Florida	140	114	3	39	61	32	13	2	7
Georgia	182	137	1	39	63	51	5	4	27
Idaho	163	136	77	77	60	46	3	1	19
Illinois	318	245	70	73	86	65	11	28	102
Indiana	274	189	17	36	81	62	6	1	71
Iowa	349	192	2	8	118	62	4	96	254
Kansas	470	348	9	32	134	59	6	53	207
Kentucky	213	199	1	65	36	43	10	6	50
Louisiana	224	183	3	27	59	29	4	13	75
Maine	113	83	5	21	37	20	8	0	14
Md. & D.C.	86	63	3	47	11	13	4	4	17
Massachusetts	80	69	16	28	17	10	10	3	15
Michigan	289	225	5	130	50	44	13	3	89
Minnesota	255	189	3	64	109	56	15	2	66
Mississippi	199	160	0	42	69	64	10	14	59
Missouri	303	240	11	43	124	74	9	26	124
Montana	331	248	136	136	90	82	8	2	48
Nebraska	389	260	18	26	141	54	4	5	136
Nevada	118	106	49	45	66	29	1	5	9
New Hampshire	71	62	1	19	21	20	3	0	8
New Jersey	90	88	10	35	18	18	9	2	45
New Mexico	197	186	50	85	94	69	6	5	4
New York	300	240	26	57	90	72	0	4	84

continued

FIGURE 1-2 Coop observer site location map and list of stations and equipment, by state. Source: National Climatic Data Center and National Weather Service

only a few of whom are full-time, are now supported by various combinations of state and university funds. State climatologists are involved largely in archiving and analyzing climatological data pertaining to their states and in providing this information to the public, the media, researchers, and state agencies.

Other Surface Weather Observing Networks

The Coop Network is not the only weather observing network in the United States—although it is the oldest and largest. The Coop Network must be seen in the context of several other national observing networks that also serve vital national purposes.

- The NWS and Federal Aviation Administration (FAA) have established a network of about 1,000 Automated Surface Observing System (ASOS) stations that provide 24-hour coverage and report weather data hourly or more frequently (collected in real-time).
- The U.S. Department of the Interior has a network of about 700 stations that report precipitation and other data, frequently in real-time.
- The U.S. Army Corps of Engineers has 882 sites.
- The USDA has snowfall sensors and climate, forestry, and agricultural weather observing networks.

In several cases, the operators of these networks use data from some Coop Network sites to augment their own data. For example, the U.S. Army Corps of Engineers uses (and pays for the operation of) some 1,100 Coop Network stations. The other networks use coop data for a variety of purposes to support their operational missions. Thus, the Coop Network serves many national needs.

Within the NWS, the Coop Network is one of several networks for observing surface weather. ASOS, the joint program of the NWS and the FAA, has equipment at more than 800 airports and about 200 other locations and provides 24-hour coverage. ASOS data include air pressure; temperature; humidity; wind speed and direction; visibility; cloud heights and cloud amounts up to 12,000 feet; and type, intensity, and accumulation of precipitation (other than snow). ASOS precipitation gauges use tipping-bucket technology that provides precipitation measurements that are not compatible with (thus cannot replace) precipitation measurements from the Coop Network. NCDC does not publish data from unattended ASOS locations (mostly airports) in publications of climatological data because of the unreliability of ASOS measurements of liquid precipitation and the absence of measurements of snow or snow depth. NOAA, the NWS's parent agency, operates a network of marine weather data collection platforms, including ships and buoys, through the National Data Buoy Center and the National Ocean Service. Together, these networks provide observations of weather elements from the synoptic scale (ASOS) to the localized scale (the Coop Network). Among the NOAA observing networks, the Coop Network is the least sophisticated technologically, the least automated, and by far the least expensive.

Numerous state, regional, and even private networks (generally called "mesonets") serve more localized and/or specific needs for weather data. Mesonets and regional networks are discussed more fully in Chapter 2.

Coop Network and the Nws Modernization

The NWS began a sweeping national modernization program in the late 1980s with the phased introduction of several new observing systems (NEXRAD, ASOS, and GOES-NEXT) and AWIPS.[1] In addition to installing new technologies, NWS has also made changes in staffing and has restructured forecast offices. Opportunities for real-time and retrospective uses of data from the Coop Network in NWS forecasts and warnings have been greatly expanded and will continue to be expanded as the acquisition of local data increases and locally run mesoscale numerical models are developed.

In 1993, NWS proposed a plan for modernizing the Coop Network by automating certain observations and data communications. Even though the NWS was not able to obtain funding to implement this plan, some changes have been made in recent years. As high-quality liquid-in-glass thermometers have become more expensive and difficult to obtain, an electronic system for measuring temperature (the MMTS) has been introduced in a portion of the network. As the demand for real-time data has increased, methods of communicating daily observations electronically (i.e., ROSA and ATDTDCS) have been selectively introduced in parts of the country. Most recently, a computerized data entry and communication system (PC ROSA) has been introduced to selected observers who supply their own computers and modems.

NWS's highest priority is providing forecasts and warnings for the protection of life and property. Although the overall system of cooperative observations has remained relatively unchanged, NWS modernization-driven changes to Coop Program staffing and responsibilities have resulted in significant changes in the way the Coop Program is managed at the field level. Some of these changes have adversely affected the ability of the Coop Network to contribute to NOAA's weather and climate services. The elimination of the NWS Agricultural Weather Program also increased the management oversight responsibilities of the Coop Network at some WSFOs. Chapter 2 examines a number of technical, operations, and management issues that have affected the Coop Network and the Coop Program in the context of NWS modernization.

[1] NEXRAD = next generation weather radar (also known as the WSR-88D). GOES-NEXT = geostationary operational environmental satellite(s) (includes GOES 8-10 and successors). AWIPS = advanced weather interactive processing system.

2

Operation and Management

This chapter presents the panel's analysis of issues and problems that affect the Coop Network and Coop Program. The first section describes the management structure, the second technical and operational issues, the third management issues, and the fourth overall systems issues.

NETWORK MANAGEMENT

Organizational Roles

Two organizations, NWS and the National Environmental Satellite, Data, and Information Service (NESDIS), manage the collection and most of the processing and dissemination of data. Both are major components of NOAA. The NWS is responsible for observations—that is, for station operations, instrumentation, and documentation, as well as for observer recruitment and training, initial data collection and quality control, and the transmission of data to NESDIS. Within NESDIS, the NCDC is responsible for long-term stewardship of the data, which involves data assimilation and archiving, quality control, and the generation and dissemination of products derived from the data. NWS uses the data primarily for operational meteorology and hydrology; NCDC uses the data primarily for climatological purposes. The volume of data processed by NCDC is quite large—currently more than 142,000 cooperative data forms per year, containing more than 25 million handwritten observations.

Management Structure

Figure 2-1 shows the management structure in the NWS and NESDIS with respect to the Coop Program and coop data. Data collection from the Coop Network is managed by the NWS Office of Systems Operations, acting through the NWS regional and forecast office personnel. Until recently, NWS Coop Program functions were managed at the field office level of the NWS by 51 full-time cooperative program managers (CPMs), with technical assistance from six regional CPMs. A national Coop Program manager oversaw the entire program and established national policy and procedures for the operation of the Coop Network.

In 1995, in conjunction with the modernization and restructuring of NWS offices, the CPM positions at WSFOs were abolished, CPM staff at regional offices were reduced, and management responsibilities for the Coop Program were transferred to data acquisition program managers (DAPMs), who are staff members of the 119 new NWS forecast offices. The DAPMs are assisted by hydrometeorological technicians (HMTs) and by meteorological interns. Both DAPMs and HMTs perform their Coop Program duties on a part-time, as-available basis.

NCDC's management role has not changed much in recent years. Processing and analysis of the coop data are the responsibility of NCDC's Data Operations Branch (DOB), which is also responsible for generating and disseminating products, such as monthly data summaries. A Database Management Branch is responsible for archiving the data. The Climate Services Division provides user services.

TECHNICAL AND OPERATIONAL ISSUES

Data Collection and Transmission

Instrumentation

The range of instruments that cooperative observers use to measure temperature and precipitation was described in Chapter 1. Instruments include liquid-in-glass maximum/ minimum thermometers (housed in cotton region shelters); MMTSs; standard nonrecording rain gauges; and Belfort Fischer-Porter and Belfort Universal recording rain gauges. As these instruments age, they are becoming increasingly difficult to maintain and calibrate (see Box 2-1).

The liquid-in-glass thermometers, for example, are difficult to read and expensive to replace. The cotton region shelters that house them (wooden structures) must be painted periodically; replacements must be built by skilled wood-workers and take about a year to procure. The replacement cost for the thermometers and shelters is about $1,000.

Two types of gauges report precipitation on an hourly (or more frequent) basis and are used at about 2,500 sites in the Coop Network. Both of the devices that record precipitation on a paper tape for the Belfort Fischer-Porter rain gauge and the paper chart for the Belfort Universal gauge are obsolete and are expensive and time-consuming to maintain. The paper punch mechanism of the Fischer-Porter gauge has a history of frequent failures. The Fischer-Porter paper punch tapes and the analog charts of the Belfort Universal gauge are prone to numerous recording errors. The device that NCDC uses to read the Fischer-Porter tapes has become difficult to maintain, and replacement parts are not readily available. The NWS has proposed replacing the Fischer-Porter gauges with an automated device for the collection and transmission of data but has been unable to obtain funding.

In some cases, evolving technology, along with increasing costs and decreasing availability of the old technology, has forced a transition to new instruments. This shift usually has both good and bad consequences. For example, the MMTS was introduced by the NWS in the 1980s as a replacement for the liquid-in-glass thermometer. In contrast to the cotton region shelters, the MMTS is housed in a relatively low-cost radiation shelter made of slow-weathering plastic with a life expectancy of 15 years. Because the display unit is mounted inside the observer's house, it is easy to read. Currently, about 60 percent of the A (climatological) stations have MMTSs.

The MMTS has its share of problems, however. It is prone to failure with fluctuations in power lines and signal lines caused by lightning and other factors. The temperature sensor thermistor and readout equipment are rapidly becoming obsolete and do not permit storage of data. The backup battery supply is limited to four hours; after that, the unit ceases to record, and previously recorded data are lost. In other words, the data that are of most interest (i.e., during storms) are the data most likely to be lost. Burrowing animals sometimes cut the cables, and insects often nest in the shelters. Because MMTSs require cables, the location of the instrument can become an issue. (At one cooperative observer station in Alaska, for example, the new MMTS was installed six feet from the observer's house; the old cotton region shelter was 100 feet from the house. The potential for temperature errors caused by proximity to the house and the consequent discontinuity in measurements are obvious.) Access by NWS personnel and backup observers is difficult because the display is inside the observer's house; consequently, the display unit is often difficult to maintain and/or replace.

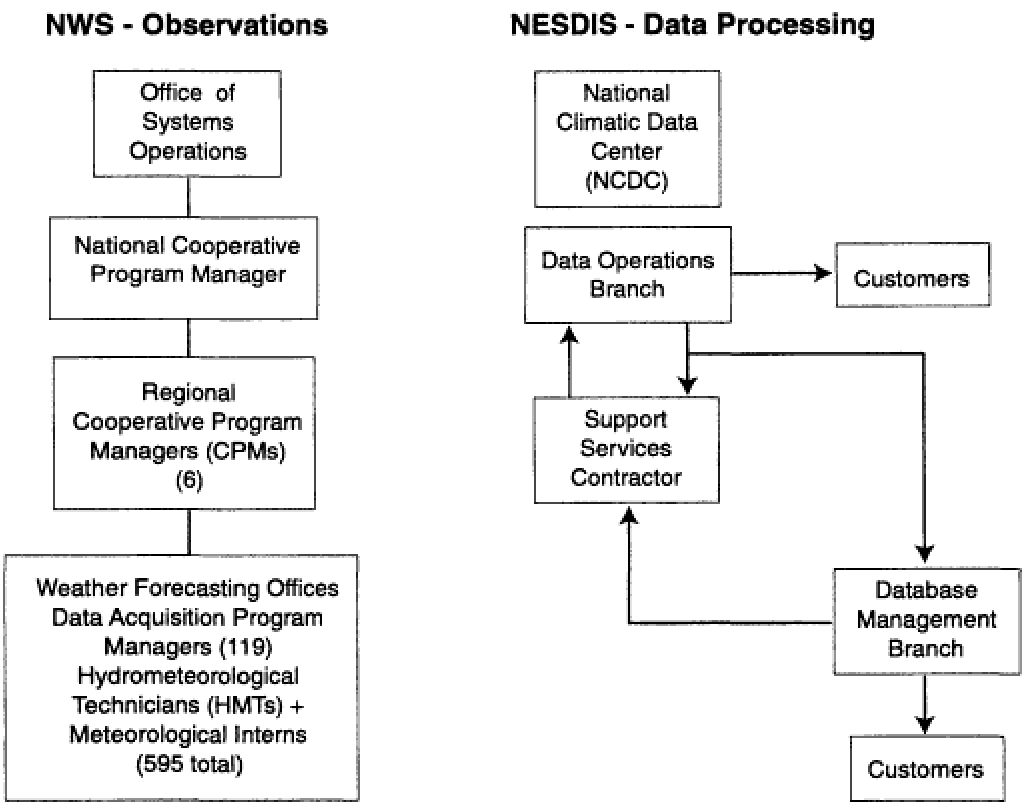

Figure 2-1 Coop Program management structure. Source: National Weather Service

BOX 2-1 EXPOSURE OF TEMPERATURE INSTRUMENTS

The proper exposure of temperature instruments is usually the critical factor for obtaining a long-term record. Liquid-in-glass thermometers or thermistors are the most reliable temperature instruments, but they must be located properly. A temperature instrument in a standard wooden shelter is in a somewhat different environment than an instrument in a much smaller round plastic shelter that houses MMTSs. The shelters differ in thermal capacity and ventilation. The biggest differences, however, are in bright sunlight and calm wind conditions. Differences in exposure can be reflected in maximum/minimum temperatures as well as mean temperatures. About 60 percent of the A stations in the Coop Network now have MMTSs.

If a coop station is moved, even for a distance of 20 or 30 meters, air drainage effects, especially at night, can cause differences in temperature. Factors that affect temperature measurements are land surface (grass, rock, etc.), trees near the shelter, and changes in the number of buildings in the vicinity. NOAA has issued guidelines to help manage exposure effects and maintain the continuity of measurements.

Procedural Errors By Observers

Instrumentation, including the use of paper tapes, represents a serious problem in terms of the accuracy, completeness, and timeliness of coop data. From the standpoint of the climate record, procedural errors by observers are also a serious problem. The high error rate in administrative entries on paper forms submitted to the NWS by cooperative observers represents a substantial problem for data processors at NCDC. But from the standpoint of the climate record, a far more serious problem is created by procedural errors by observers, which result in incomplete, incorrect, or misleading observations.

Monthly average temperatures in the United States are calculated using only the daily maximum and minimum temperatures, preferably derived from the 24-hour period corresponding to a calendar day—midnight to midnight. When the ending time of the 24-hour-climatological day varies from station to station or over a period of years at a given station, bias is introduced into the calculated temperature. This so-called "timeshifting" is a major problem. Since the 1960s, hydrologic uses of coop data have prompted many observers to shift the time of daily observations from evening to morning. Thus, the daily high temperature reading was actually the previous day's high. When an observer arbitrarily changes the standard time of observation at a station, it causes an "apparent" climate change at that location (see Box 2-2). Nationwide, the change can be significant, as Figure 2-2 illustrates. At a time when climate change is an important scientific and policy question, this issue has serious implications.

A related problem is "dateshifting," the practice of entering data for a different date than when the observation was

BOX 2-2 THE PROBLEM OF TIMESHIFTING

Monthly average temperatures in the United States are computed using daily maximum and minimum temperatures. For climatological purposes, the preferred measurement period is midnight-to-midnight. However, because readings by human observers at midnight are not feasible for a "volunteer" network, the vast majority of cooperative observers operate on a "climatological day" that does not correspond to the standard midnight-to-midnight calendar day. If the end of the 24-hour climatological day varies from station to station, or over time at a given station, a nonclimatic time-of-observation bias is introduced into the calculated mean temperatures. Thus, when a station changes its time of observation, an "apparent" climate change is introduced into the data set.

Random changes have been made in the preferred observation time. For personal convenience, observers sometimes switch from a sunset-to-sunset (p.m.) climatological day to a sunrise-to-sunrise (a.m.) schedule or vice versa. Observations as close as possible to midnight are preferred.

Although methodologies have been developed to adjust monthly mean temperatures for differences in observation times, this adjustment introduces uncertainties into the long-term database and adds time to the analysis phase.

made or combining daily totals. For example, some cooperative observers do not measure precipitation during the weekend. Instead, they include weekend precipitation in their Monday observation. This problem is difficult to identify because the monthly totals are consistent with those of nearby stations. However, dateshifting skews daily totals and influences statistics on extreme events—a valuable derivative of Coop Network data.

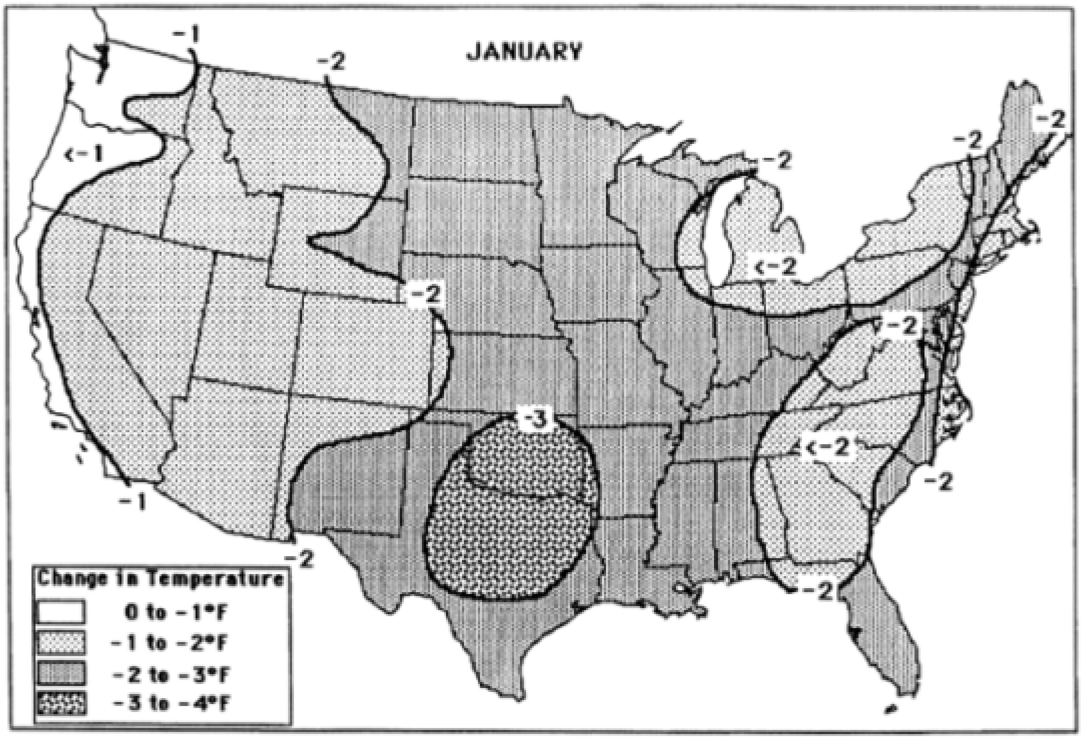

Figure 2-2 Example of the effects of timeshifting. This figure shows the change in January mean monthly temperature resulting from changing the time of observation from 5:00 p.m. local standard time to 7:00 a.m. Source: National Weather Service and National Climatic Data Center

Another problem is dropped or missing observations. Sometimes observers get sick, take vacations, leave home for a weekend or longer, use improperly trained substitutes, forget to take observations, record observations illegibly, or are too busy to take observations. Problems also occur frequently at institutional sites (such as radio stations, public parks, or water treatment plants). Although these sites may have around-the-clock staffing, their observers often have high turnover rates, and, because of inadequate training, motivation, or management, they may not be dedicated to taking consistent observations.

Forms that contain incorrect observations create another set of problems. For example, temperature errors of 5° to 10°F occasionally are noted day after day, or impossible combinations of maximum and minimum temperatures are noted on an observer's form (i.e., one day's minimum exceeds the previous day's maximum). Many observers fail to record snowfall and/or snow on the ground accurately or at all. Some observers, when faced with one or more days of missing observations, enter representative measurements for several days or for a period of time when the temperature equipment was not reset or precipitation gauges were not emptied. Overall, about 10 to 20 percent of the cooperative data submitted to NCDC in any given month, or about 55,000 to 60,000 individual weather elements, are missing or inaccurate. These errors could be reduced through better recruitment, retention, training, and coordination by the NWS.

The cooperative observer's role in transmitting observations also causes problems, especially documentation problems. The manual entry of observations produces a high error rate. Throughout the year, about one-half of all forms received at NCDC (or about 70,000) require some manual correction prior to keying. About 20 percent of the forms that need corrections have entry errors (usually data entered

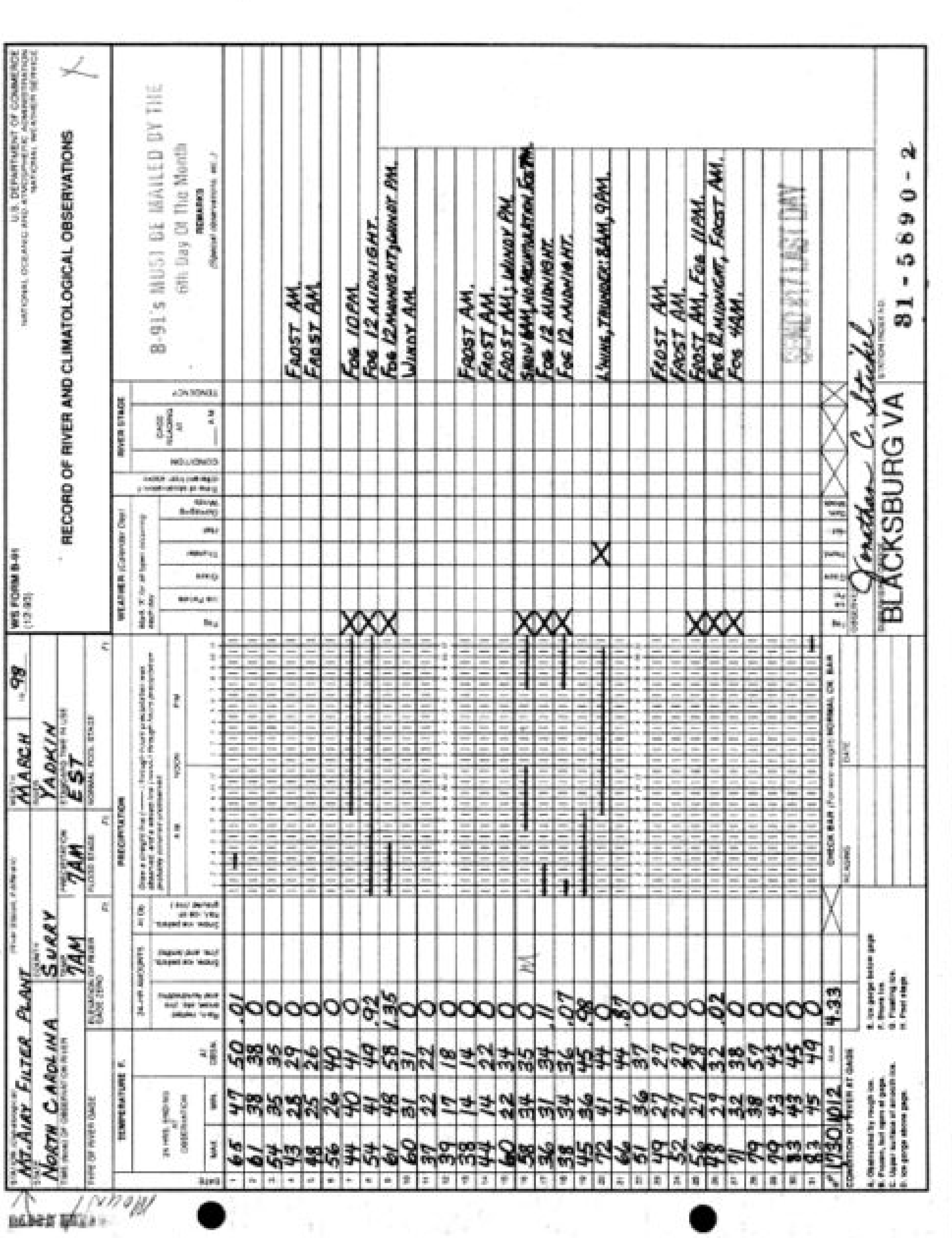

Figure 2-3 Sample form for manual entry of weather observations. Source: National Weather Service

in the wrong column). About 60 percent of the forms requiring corrections have errors in the station data, including administrative information, such as month or time of data observation. About 70 percent contain errors in the recording of meteorological data (not the data values), such as misplaced decimals in precipitation amounts or inconsistencies between the comments on the paper forms and the actual data values. (These percentages exceed 100 percent because a single form may have more than one type of error.)

A major problem is created by the data forms themselves. The blocks for entering data on the forms are small, the headings are difficult to read, and rows of blocks and data are difficult to track visually. Figure 2-3 shows Form B-91 used by observers to record daily data at both climate stations and hydrologic stations. Simple changes in format could considerably improve the user-friendliness of these forms. For example, pre-printing the station administrative information would eliminate one type of problem.

Declining Number of Sites

One continuing problem is "observer drain," the slow but steady decline in the number of cooperative stations. Demographic shifts, such as the demise of small farms and the shift of populations toward the coasts and cities, along with more mobile and faster-paced lifestyles, have made it increasingly difficult to recruit and retain volunteer observers who will record and send reliable daily measurements, year after year and decade after decade. Since its peak in 1972, the number of Coop Network stations has declined by roughly 15 percent (see Figure 2-4). The number of published stations (i.e., those producing high-quality, reliable FIGURE 2-4 Decline in the number of coop stations since 1970. Source: National Weather Service data used in NCDC publications) has also declined significantly. Even the Historical Climate Network (HCN), the most stable group of stations, is losing 1 percent of its sites annually. Unfortunately, meteorological variables, especially precipitation, are not homogeneous throughout a given area, and neighboring stations may have markedly different precipitation totals from the same storm.

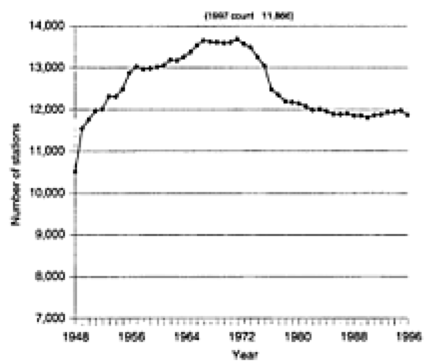

Figure 2-4 Decline in the number of coop stations since 1970.
Source: National Weather Service

Observers move, age, and die; properties change hands. If a new owner does not want the responsibility of being a cooperative observer, either the station must be closed or a new observer must be found in a nearby, but different, location. Only a handful of stations around the country have remained in place for a century; about half last 15 years or less at a given location—not nearly long enough to provide the data required for climate studies (see Figure 2-5). Stability of the Coop Network requires that the best observers be retained and that replacements be recruited promptly.

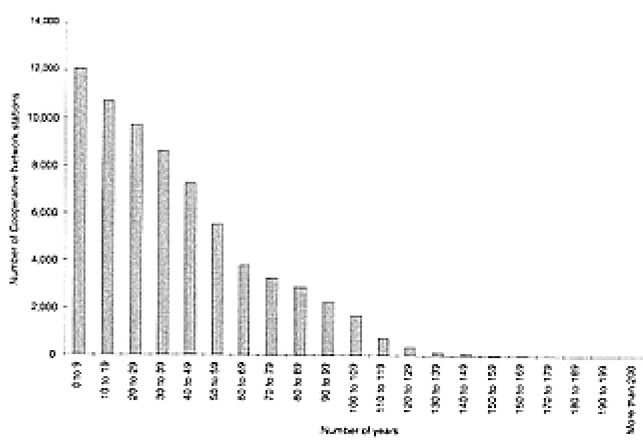

Figure 2-5 Site stability of coop stations.
Source: Climatic Data Center

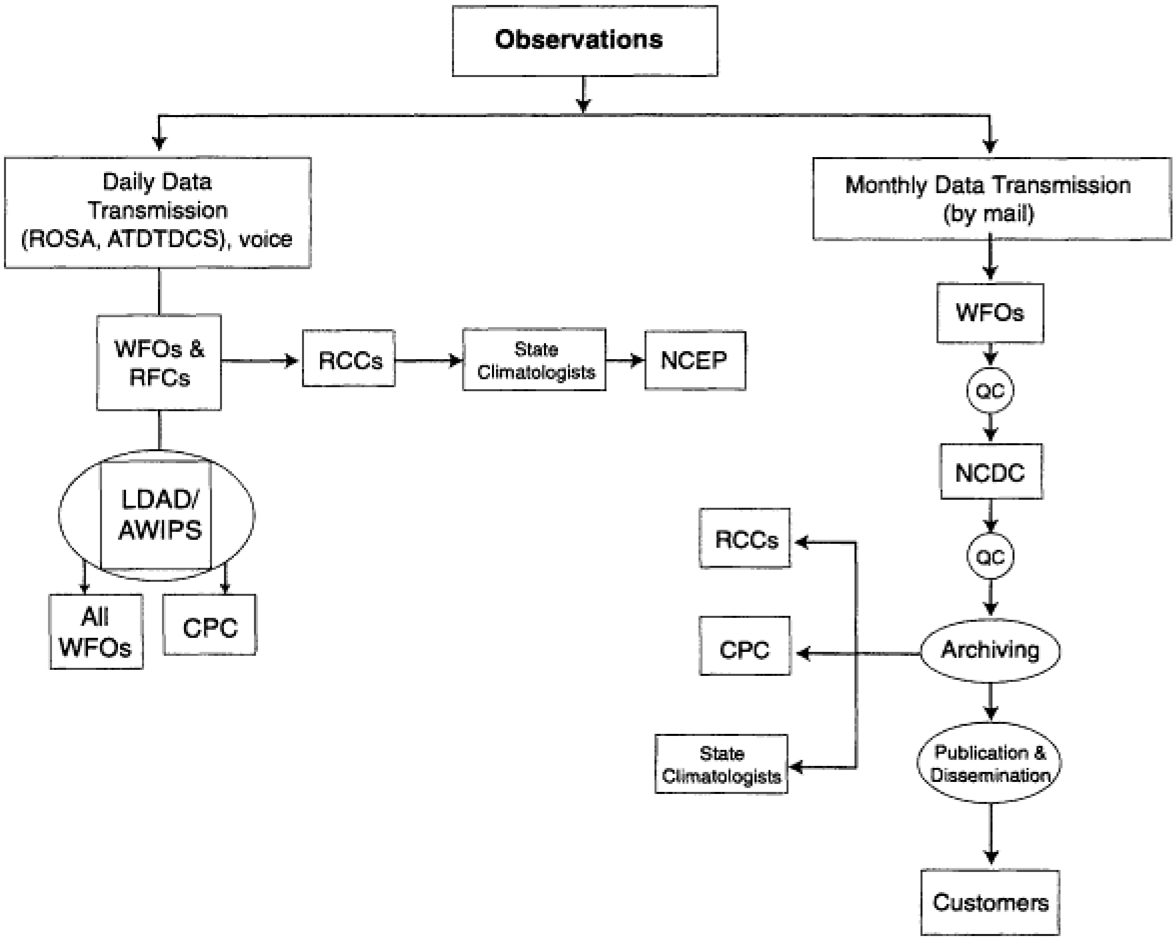

Figure 2-6 Cooperative data flow.
Source: National Climatic Data Center

Data Transmission and Local Quality Control

As Figure 2-6 illustrates, observational data flow along two different paths. Data transmitted daily from Coop Network stations go to NWS WFOs and RFCs. These data are used to prepare forecasts and warnings and are disseminated on the NWS communications network. Data sent via ROSA and ATDTDCS are distributed via transmissions in a standard hydrometeorologic format to other NWS offices and RCCs, and thence to many other users, including most state climatologists. The data are then entered into a precursor to the local data acquisition and dissemination (LDAD) system for widespread daily dissemination. (LDAD is a component of AWIPS, which is scheduled to be installed at all modernized and restructured NWS forecast offices by June 1999.) Since 1988, all monthly transmissions of data from both A and B stations have been sent first to NWS personnel who are responsible for Coop Network observations. After preliminary quality control, the data are forwarded to NCDC for further processing, storage, and dissemination.

The current procedures have created bottlenecks in getting coop data into the system and to those responsible for summarizing and disseminating them. The manual data collection and communication processes are both time consuming and labor intensive. For example, NCDC's summary of the day may not be available until 60 or even 90 days after the end of the data month; the hourly precipitation data take about 65 days. The sooner these data and products can be made available, the more useful they are. Automated transmission would greatly accelerate the availability of near-real-time data (see Box 2-3). One problem with ROSA, which is old technology but currently the closest approach to automated transmission, is that the observer has to encode, rather than simply enter, the data, and encoding is an obvious source of many errors.

The accuracy of the information varies tremendously among coop observers. In the past, NWS CPMs were aware of the lower-quality stations and compensated for the problems with more stringent quality control. Because quality control specialists at NCDC are not as familiar with individual sites, their handling of these problem sites is less efficient. NCDC estimates that a "bad" station requires 30 times as much time for quality control as a "good" one. Automated quality control (one of several tiers performed at NCDC) checks overall patterns (e.g., flags instrument "drift" and "scroll") on a monthly, as well as a dally basis; but subtle problems that occur on a multimonth or yearly basis may go undetected. In general, the closer quality control is to the site of the observation, the better the result.

BOX 2-3 PRECIPITATION DATA FOR THE NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

For daily analyses and forecasts, the National Centers for Environmental Prediction (NCEP) require in-situ observations of precipitation and snow, as well as radar data. The receipt of these data in real-time has been gradually improving. In March 1998, it was about as follows:

- Hourly precipitation data from gauges were received from about 2,800 sites. The main sources were from the U.S. Army Corps of Engineers, the National Forest Service, and the U.S. Geological Survey. The data from another 2,500 stations that use paper tape were not available in real-time.
- 850 ASOS stations reported hourly precipitation, but NCEP only received data from about 300.
- On any given day, NCEP received daily data from 5,500 to 6,000 stations. About 3,500 were estimated to be coop stations. Approximately 10 percent (600) provided only daily summaries of the hourly data.

Daily observations from many stations (mainly B stations) are transmitted to NWS forecast offices either orally or electronically. Precipitation and river stage data from B stations are fed into operational hydrologic models that predict future river conditions, including floods. The data are also shared with the RCCs. But most data are not disseminated directly to interested parties, such as the media, utilities, and agricultural concerns.

Under current procedures, all cooperative observers mail their handwritten observation forms at the end of each month to the NWS.[1] There, the DAPM, assisted by HMTs, visually scans the data entry forms, inventories them, and conducts preliminary quality control (mainly identifying missing forms and identifying missing station identification or "metadata," missing observations, and implausible entries). Because of the severe constraints on NWS staff time, quality control at this stage is cursory; NCDC provides more stringent quality control. The NWS rewinds Fischer-Porter tapes, assembles them in batches, and checks for indications of maintenance problems. Understandably, most of the NWS staff time is focused on the coop data from a meteorological standpoint.

State climatologists generally receive some data, both hydrologic and temperature data, directly from the WFOs and RFCs; but this is an ad hoc, informal arrangement between individual state climatologists and individual WFOs. State climatologists report that, in the past, they were able to obtain relevant data from the CPMs; but now, with more than twice as many DAPMs as CPMs, the data for each state are often fragmented among several WFOs and are more difficult to obtain.

The data are transferred to NCDC via the U.S. Post Office, which also delivers data from cooperative observers to the WFOs. The slowness of this mall-based system is a growing problem because for many users early data is becoming increasingly important, even if they are not complete or fully checked for errors.

Metadata

In the past, management and oversight of the Coop Network "as a system" has been inefficient, partly because important site-descriptive information (generally referred to as "metadata" or station history information) had to be laboriously entered on complicated federal forms known as B-44s. These forms were filed away in various NWS offices and at NCDC and were not readily accessible. Critical information, such as the latitude and longitude of each site, was often estimated by local NWS officials. No doubt, this led to many siting errors. Furthermore, although site photos had been taken, they were not available to outsiders for oversight purposes. Consequently, some sites were located inaccurately, and instruments were placed at some locations that violated siting standards.

Fortunately, technological advances in the last decade, such as desktop computers, file servers with on-line memory, the Internet, hand-held global positioning system (GPS) receivers, and digital cameras, are now available to improve the management and oversight of the Coop Network. It would be relatively easy to equip each NWS office with these tools, require DAPMs to locate coop sites with a GPS receiver, and provide panoramic site photos for on-line computer files.

[1] Neither ROSA nor ATDTDCS is configured to retain data or to deliver climatic quality data. Therefore, the manual entry of each observation onto the observer's form and the monthly mailing of that form are essential.

Manual vs. Automated Observations

Manual observations and data entry clearly result in errors and contribute to a slow, inefficient process. The obvious alternative is an automated process, but automation often brings its own problems—the incompatibility of instruments and unstable power supplies, for example. Trade-offs must be made in cost, accuracy, resolution, stability, and maintainability. Table 2-1 shows the advantages and disadvantages of automated and manual cooperative observations. Greater automation, however, appears to be inevitable. In addition to more accurate observations and more efficient reporting, an automated system would provide more frequent observations, including observations at night and observations during periods of severe weather, which require the immediate transmission of data to the NWS. Volunteer human observers are not always available to meet these needs.

Today, some cooperative stations do report data in near-real-time through ROSA and ATDTDCS. These data are used for forecasts and warnings and as data for public service programs. The need for more near-real-time data is expected to increase as the NWS moves into an era of improved mesoscale analysis and forecasting. Because neither ROSA nor ATDTDCS is configured to retain data, the manual entry of observations on hard copy and the mailing of forms are still required. With automated hourly temperature and precipitation observations, 24-hour summaries could be derived for any time period.

If a clock and a small amount of memory had been designed into the MMTSs, the time of temperature observations at all cooperative stations could have been standardized, and occasional absences of the observer would not be a problem. NCDC officials estimate that, if data input were electronic and quality control were more automated, most cooperative data products could be generated 10 to 15 days after the end of a month (15 to 20 days for precipitation data), compared with the current 60 to 90 days, and preliminary data could be made available immediately.

Complete automation need not (and probably should not) be attempted. Partial automation, a simple "interactive data terminal/modem" concept, with backup to diskette, for example, could be a transition phase between manual and automated observations and electronic transmission. A transition phase is discussed in Chapter 3 in the broader context of approaches to automation.

During any transition to new observing instruments, every effort should be made to maintain the temporal continuity in the database. Many climate researchers are concerned that this continuity may have been damaged or lost with the introduction of the MMTS. Figure 2-7 shows the bias introduced by this change. For analyses of lengthy time series, NCDC analysts adjust the cotton region shelters/liquid-in-glass temperature data to agree with the newer MMTS data; however, the question of which data set is actually more accurate has not been answered.

The automation of cooperative stations should not be done at the expense of data integrity (either of values or consistency). A prudent approach would be to automate selected elements gradually, automating temperature observations first and precipitation data when the technology improves.

TABLE 2-1 Comparison of Automated Coop Observations with Manual Observations

	Automated Observations	Manual Observations
Advantages	Observations can be gathered quickly. Daily observations can be made at several precise times. Other low-cost instruments can be added.	Observations of quantitative precipitation are good. Observations of snow conditions are good. Observations of other events (hail, lightning, wind damage, etc.) can be made.
Disadvantages	Quantitative precipitation measurements are often not accurate enough for climate applications. Snow observations are not available. Hardware or electricity may fail. No information on general weather conditions is available. Costs (initial and often continuing) are higher. Additional maintenance and training are necessary.	Observer may be absent for one or more days. People make mistakes. Time of observation is less precise.
Notes:	Backups for failures of equipment must be planned. Some manual observations will still be needed.	Rapid data collection can still be planned.

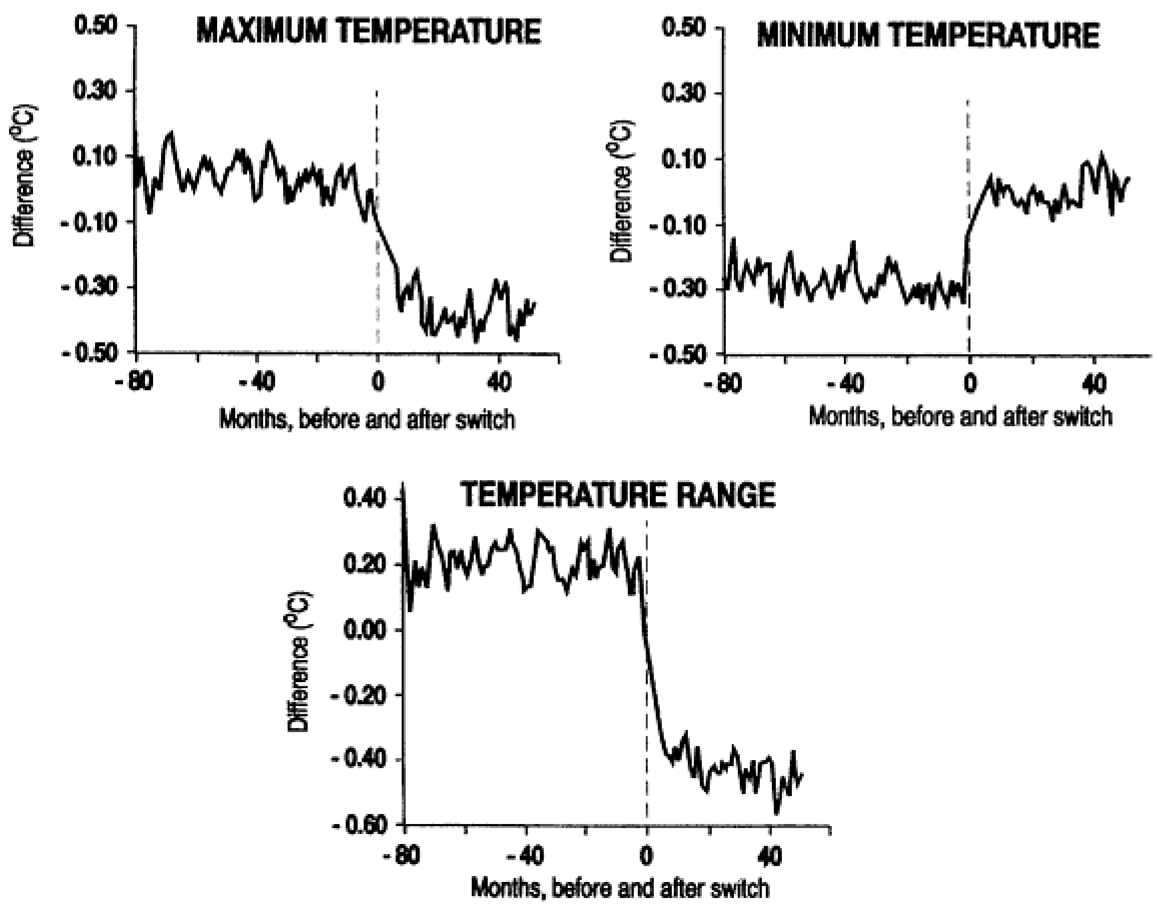

Figure 2-7 Estimated bias introduced by new temperature sensors.
Source: National Climatic Data Center

Currently, no commercially automated system for measuring all types of precipitation is available that works at the necessary resolution, especially for climate monitoring purposes.

Data Assimilation And Quality Control

The NCDC has the primary responsibility for processing and interpreting coop data and for disseminating it to users in useful forms. NCDC typically receives the data forms and paper tapes from NWS forecast offices two to four weeks after the end of the calendar month. Because these forms are sent by mail from 119 NWS offices, the NCDC does not receive them all at the same time. After varying amounts of review and preliminary quality control, NCDC prepares the forms and paper tapes for entry into a preliminary electronic database. More intensive quality control of the coop data is performed after keying. Once all data have undergone full quality control processing, the NCDC prepares various data products.

At the data assimilation stage, NCDC's DOB catalogs the forms and maintains inventory control. Administrative data (e.g., station name, number, and other heading information) must be verified when the material is received to minimize errors. The data are double-keyed and processed through an interactive computer-edit system. Because the handwritten hard copy is used for initial logging and distribution, the data must be entered manually, which is a labor-intensive, slow, expensive process that is prone to errors (see Box 2-4). Because observers enter the data by hand, a significant number of entries are incorrect or illegible (as distinct from errors in the observations themselves).

BOX 2-4 THE COST OF AN ERROR

One precipitation observation that was wrongly keyed during the summer of 1988 almost cost a farmer his drought insurance claim of $70,000. A rainfall of 0.07 inches was keyed as 0.17 inches, putting the seasonal total above the threshold for collecting on the policy. Only when the records were rechecked was the error noticed.

Source: Robinson, 1990.

After the data have been digitized, validation and quality control are performed. Special software is used to flag suspect data, and errors in temperature, precipitation, snowfall, and snow depth are identified and corrected. All data are then prepared for archiving, publication, and dissemination.

At present, nine people in the DOB are assigned to the quality control and preparation of coop data (this figure does not include key-entry personnel or computer specialists). The time involved in manual processing is considerable. Some specific examples are listed below:

- Paper tapes from Fischer-Porter rain gauges require seven minutes of processing per tape; NCDC processes 2,848 of these tapes per month, for a total of 332 staff hours.
- Universal rain gauges require 200 hours of processing time per month (one hour for each of 200 sites).
- Quality control for all manual data forms requires approximately 160 hours per month.

Cooperative observers are only one source of the weather data NCDC receives. Data are also received from ships at sea, satellites, aircraft, NEXRAD, ASOS, and wind profilers. Data also arrives from international sources, including world data centers, and as country-to-country exchanges. The data arrive in many different forms, including diskettes, microfilm, film negatives, magnetic tapes, electronic mail, optical disks, video cassettes, and publications. Although cooperative data are only one of many data streams processed at NCDC, they require a disproportionate amount of time to process because manual entry of data from handwritten forms is a slow, error-prone process.

Data Dissemination

Data from all sources are used in preparing various NCDC products. However, three important products are prepared solely from cooperative data:

- The summary of the day compiles temperature and precipitation data from all Coop Network sites around the nation on a given day.
- The hourly precipitation data report provides rainfall on an hour-by-hour basis for a select number of sites. Fifteen-minute interval rainfall is reported for Fischer-Porter sites.
- The publications, Climatological Data and Hourly Precipitation Data, provide hard copy of daily data for each station on a state-by-state basis.

All three are produced monthly. (An annual edition of Climatological Data is also prepared.) The summary of the day and hourly precipitation data are available in hard copy, on diskette, on CD-ROM, and on the worldwide web. Orders for these products, along with copies of the original cooperative data forms, represent about 36 percent of the orders for NCDC data sets (see Figure 2-8).

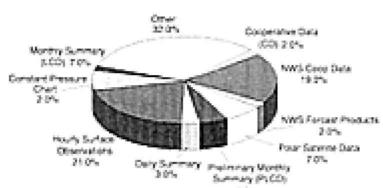

Figure 2-8 Major datasets purchased by NCDC customers.
Source: National Climatic Data Center

The range of customers for NCDC's cooperative data products has expanded greatly in recent years. The highest percentage of requests now comes from the legal, insurance, and business communities. (NCDC performs an average of 50 certifications of data per day for attorneys.) This increase is attributable to three factors:

- Orders from legal and insurance customers have increased because of increased litigation.
- NWS WFOs now refer more customers to NCDC.[2]
- The ASOS installations at airport NWS forecast offices do not measure snowfall, leaving NCDC's Coop Network records as the sole source of data on snowfall near ASOS locations not staffed by NWS personnel.

Given the use of paper data forms and hard copy publications, NCDC is heavily burdened with paper. In a typical year, more than one million copies of data bulletins are printed. Some 700,000 copies are sent to 33,000 subscribers. About 1.5 million original data forms are archived. In fact, NCDC has more than 320 million paper records in its archives. Each day, about 1,000 paper copies of original records are sent to users. The cost of handling this much paper is more than $500,000 per year in contractor payments, plus postage. Distributing the summary of the day alone requires one full-time employee and costs, on average, about $50 per coop station per year.

The media used to disseminate NCDC products have expanded in recent years. For example, in 1997 paper copies of forms accounted for 54 percent of orders, down from about 70 percent in 1982. The demand for electronic data, especially on CD-ROM, diskette, and web access is growing rapidly. Electronic mail service for filling orders was established at NCDC in 1992. The summary of the day and hourly precipitation databases became available on the NCDC Web Page in 1998. With 1.2 million on-line users per year, the

[2] Restructuring of the former weather service offices and WSFOs into fewer weather forecast offices has put pressure on NWS offices to respond to phone and dial-up data demands, which they now tend to pass on to NCDC, RCCs, or state climatologists.

NCDC Web Page is now the single biggest source of orders (although they tend to be small orders from individuals, especially students). Although the shift toward the electronic dissemination of products is necessary and inevitable, a growing problem for NCDC is that orders are becoming smaller and thus less profitable. Figure 2-9 shows orders by medium. In response to NCDC's rapidly growing customer base, as well as more and smaller orders, the emphasis is shifting to electronic dissemination rather than hard copy paper products.

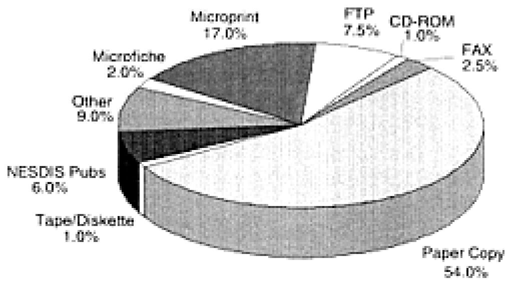

Figure 2-9 NCDC orders by major media type.
Source: National Climatic Data Center

MANAGEMENT ISSUES

National Weather Service's Management Commitment

The priority of the NWS has always been short-range forecasts and warnings. Modernization has, if anything, intensified this focus. Activities related to climate are given a lower priority, even though in recent years climate has become a major driver of policy and funding decisions of government and even businesses. As a result, the priorities of the users of network data and their requirements for how those data are made available have changed while the priority of the NWS management has not.

NWS's decision not to focus on climate and the Coop Network was not an easy one. In part, the NWS is driven by forces beyond its control. For example, the RCCs were transferred to the NWS in the late 1980s, but since 1990 NOAA has attempted to drop support for the RCCs from its budget, and Congress has restored the annual funding. The RCCs have recently been placed under NESDIS. The NWS has sustained budget cutbacks and reductions in staff at some locations; in fact, since 1990 its total spending power has been eroded by about $80 million. Implementing expensive new technologies like NEXRAD, ASOS, and AWIPS has attracted most of NWS's funding and attention. In contrast, upgrades to the Coop Network in recent years (an example is PC ROSA) have not been part of a structured modernization plan. New technology has been introduced on an ad-hoc basis.

For the most part, staff of weather forecast offices do not consider non-real-time cooperative data as operational data. The panel observed that in offices where more of these data are made available in near-real-time, forecasters depend more heavily on cooperative data—for example, in preparing "nowcasts" and zone forecasts. Ironically, just when the NWS is completing its modernization to improve small-scale forecasts, the program that could best provide the data for the preparation and verification of small-scale predictions is in decline.

The NWS's current plan for future operations incorporates a vision of "end-to-end integrated forecasts" (see Figure 2-10). The NWS has continued to focus on short-term, small-scale forecasts, even though its goal is to move toward

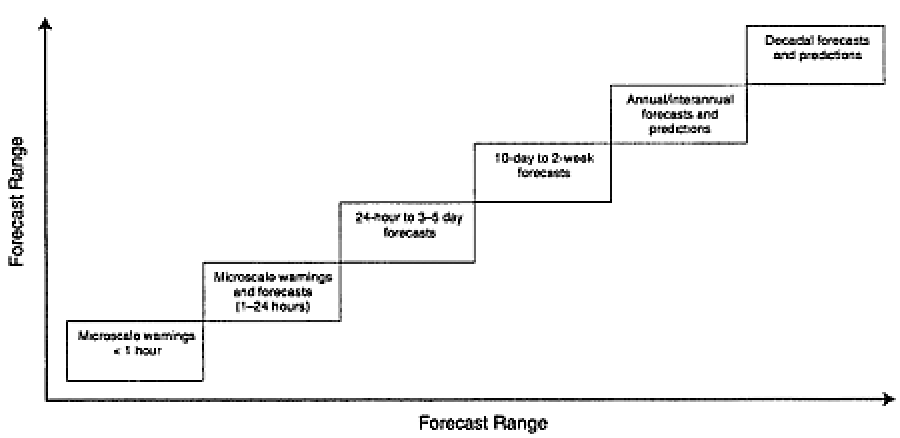

Figure 2-10
NWS's vision of end-to-end-integrated forecasts. Source: National Weather Service

the longer time-scale and eventually to produce very long-term forecasts based on an understanding of long-term phenomena, such as "storm climatologies." Cooperative data will play an increasingly important role in this progression by providing measurements of initial conditions upon which forecasts for 10 to 14 days can be based. These data will also be used for verification of the entire range of forecasts, from mesoscale warnings to decadal forecasts and predictions. With further automation of the collection and transmission of cooperative data, data from the Coop Network could also contribute operationally to short-term, small-scale forecasts. In other words, the Coop Network could directly facilitate the NWS' progress toward its long-term goals while, at the same time, becoming a more integral part of NWS's current operations.

The panel noted a disturbing trend, even during the course of this study. Other government agencies, such as the U.S. Geological Survey and U.S. Department of the Interior, are reducing or eliminating their support for portions of the Coop Network. Rising per-station support costs, a lack of control over data collection, delays in making data available, and the availability of cheaper (but less accurate and reliable) automatic instrument packages were cited as reasons. The NWS will have to reassess and strengthen its policies related to the Coop Program to retain interagency support for the Coop Network.

Effects of NWS Restructuring and Budget Reductions

From the perspective of NWS field managers, the Coop Program workload has increased while the resources have decreased. Table 2-2 summarizes the situation for CPMs of the Coop Program up to 1995, when the responsibilities were shifted to DAPMs and HMTs, and compares it with the situation today.

Some of these changes are associated with the NWS modernization and restructuring. Others, however, are directly related to budget restrictions that have affected travel, training, and hiring throughout the NWS.

Field Management

Prior to the modernization, 51 CPMs across the nation were dedicated to the Coop Program. Now, one DAPM assisted by a staff of part-time HMTs manages coop activities for their WFO's area of responsibility. Although the total staff hours devoted (on paper) to the Coop Program has not changed, and some of the former CPMs are now DAPMs, the people responsible for the program all have additional duties. Because Coop Program duties are part-time, DAPMs and HMTs require time and training in conducting their coop

TABLE 2-2 Changes in Coop Program Operations (based on information provided by NWS field managers)

Prior to 1995	Today
One hydrometeorological staff member (the CPM) fully dedicated to the Coop Program in each given area (roughly each state)	Several staff members involved in the program part-time
Flexibility in scheduling site visits, administrative duties, inspection, recruiting, repair, etc.	Limited flexibility in scheduling visits, inspections, recruiting, etc. due to part-time, shared responsibilities of the staff
Funding adequate to perform the mission	Inconsistent use of time and resources
Good support at the national and regional levels	Good support at the regional level but not at the national level because of the retirement of the national program manager; no one person available full-time at the national level to act as a liaison with regional or forecast offices from September 1996 to October 1997
Annual regional training conference for CPMs	Follow-up training restricted because of funding cutbacks
Availability of experienced personnel to assist new CPMs	Many more inexperienced field personnel
Transportation readily available	Transportation for field work shared in some offices; some of the available vehicles inappropriate
Time available for troubleshooting equipment and testing new procedures for regional and national headquarters	Inadequate time or funding available for troubleshooting or testing new procedures
Time available to perform initial quality control of Fischer-Porter tapes before forwarding them to the NCDC	Quality control time reduced or nonexistent because of operational requirements in the forecast offices, which are considered more important

duties, but most of them have had little or no prior training or experience. The situation is now much more open to conflicts in priorities.

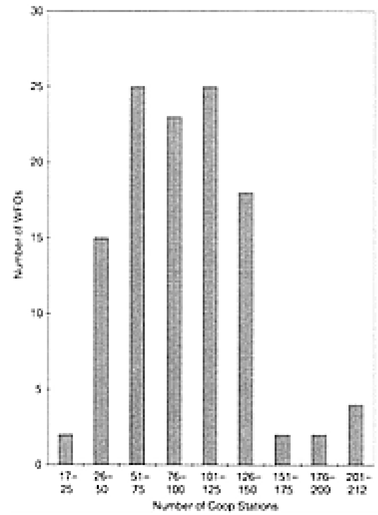

Figure 2-11 Cooperative observing sites per WFO.
Source: National Weather Service

The management change from 51 WSFOs to 119 WFOs has also created great variations in workload. On average, each DAPM is responsible for about 100 coop stations (compared to 200 stations for the former CPMs). However, the number of stations per WFO now ranges from as few as 17 to more than 200 (Figure 2-11). The area of responsibility for each WFO is shown in Figure 2-12. Obviously the same staffing model cannot be applied at all of the WFOs because of differences in topography, weather regimes, and forecast areas. For all of these reasons, the Coop Program is operating less efficiently than it was before the staffing was restructured. Most WFOs are struggling to maintain the visitation rate by DAPMs or HMTs. The WFO-based DAPM/ HMT model will require a number of changes in travel policy, hiring, staffing, training, and incentives.

Site Visits

DAPMs are explicitly required to "ensure the conduct of field visits as required, for the purpose of assuring and/or certifying the establishment, quality, availability, and adequacy of the cooperative and second-order observational programs in the WFO service area" (NWS, 1993). According to former CPMs and current DAPMs, maintaining personal contact with cooperative observers is essential to keeping them motivated, especially if they are located in isolated areas. Cooperative observers either donate their time (the great majority) or provide it for very little pay ($10 to $30 per month, mainly to cover out-of-pocket expenses). In return, they expect recognition of their efforts.

Budget reductions over the past several years and especially the severe budget cuts in fiscal year (FY) 1997 that led to an NWS-wide restriction on travel have also affected the site visitation program. In some NWS regions, WFO staff are not permitted to stay overnight even though many sites are a considerable distance from the home office. In addition, many cooperative observers are away from home during the day, so some cooperative observer sites must be visited in the early morning or evening. If DAPMs or HMTs were allowed to stay overnight en route to a coop site, instead of having to return to the WFO, they could visit many more sites in the same number of days and at a lower overall cost.

Hiring

Because of the hiring freeze, there was a long delay in filling the position of national cooperative program manager after the previous incumbent retired in 1996. Consequently, the Coop Program did not have adequate support from NWS headquarters. The new national program manager was nominated in October 1997, when he took up his duties as acting program manager. The nomination was confirmed in January 1998.

Staffing

Staffing for the Coop Program is supposed to be changing to "5+1" (five HMTs plus one DAPM) per NWS office. In reality, it appears to be changing to "3+1+2" (three HMTs plus one DAPM plus two interns). If this trend continues, the participation of HMTs will effectively be eliminated. Several NWS field managers told the panel that interns often perceive the Coop Network as a low-tech, part-time duty and that they are more interested in forecasting and modeling severe weather than in visiting farmers and laying MMTS cable. HMT staffing at every WFO is necessary to manage the Coop Program effectively.

Training

Because Coop Program duties for DAPMs are part-time, adequate training is essential for them. The NWS Training Center offers a Cooperative Network course five or six times per year, with an enrollment of 16 DAPMs per class (a few

HMTs also take the course). The eight-day course (CPM01) covers the following topics: Coop Program networks; observer recruitment and training; Coop Program administration; requirements for, and maintenance of, equipment; interagency activities; quality control, forms administration. By the end of 1999, the NWS chief of science and training expects that 400 to 500 DAPMs/HMTs will have completed this course.

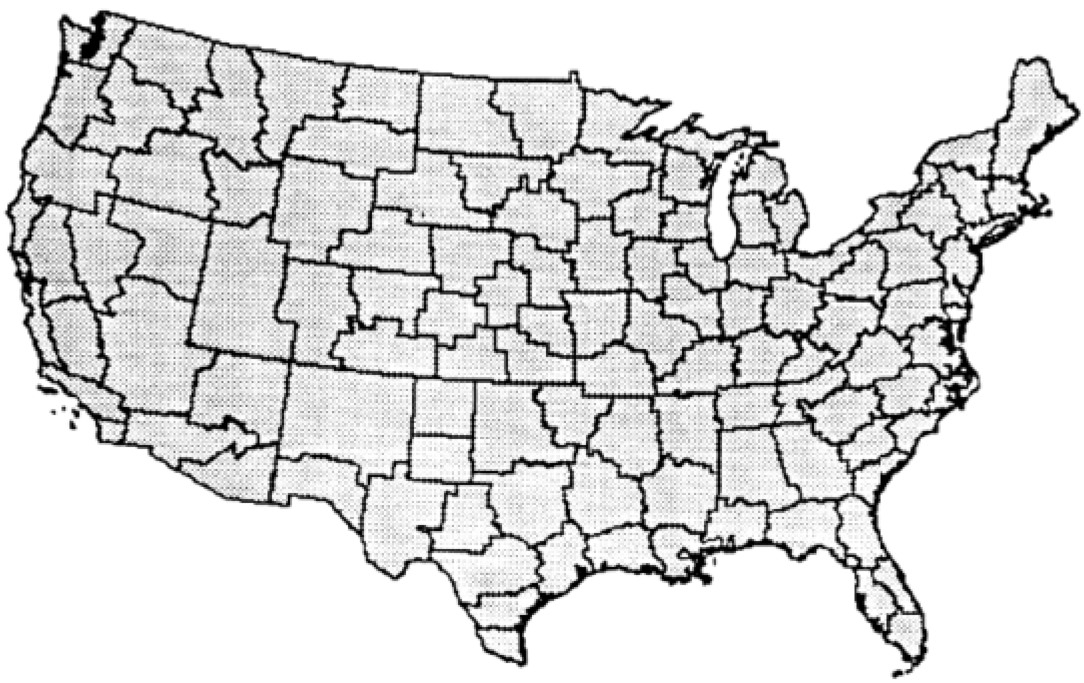

Figure 2-12 Each of the 118 NWS WFOs is responsible for one of the areas outlined above. (A recently established WFO in northern Indiana is not shown.)

Training observers during site visits is also important. Many of the procedural errors could be eliminated with adequate observer training. DAPMs are required to "certify and train weather observers" (NWS, 1993); however, because of limited time and the lack of priority on-site visits, DAPMs have had little opportunity to train observers. The NWS Office of Systems Operations does provide written guidelines to coop observers, but this is not enough (NWS, 1989).

Incentives

Because of the low priority assigned to Coop Program management in most WFOs, DAPMs and HMTs have little incentive to perform their duties fully and conscientiously. A morale problem is making the situation worse. The panel was told that most HMTs do not believe their positions will exist in 10 years. (They expect to be pushed out by the shift toward hiring more science-oriented staff meteorologists.) The absence, until recently, of a national cooperative program manager to ensure that the program received the necessary high-level management resources, attention, and planning also contributed to program deficiencies. Signals from NOAA and the NWS that the Coop Program has a low priority have seriously weakened the management structure.

Cooperative observers also have some morale problems. Limited contact with NWS managers has left many of them feeling isolated and unimportant. The threat of automation (and the fear of changes in technology) has also affected their morale. (The panel was told that, when ROSA was introduced, about 20 percent of the affected cooperative observers quit because ROSA increased their workload.) As more changes are introduced, morale problems may become more serious.

Program Funding

The Coop Program is funded through the operational budget of the NWS but is not treated as a separate program. The funds for communications are usually provided by a mix of national, regional, and local offices. The personnel monies are in the general staffing budget for each office. National, regional, and local offices often share the costs of new equipment. The travel and per diem costs are borne by the local offices. Observers are usually paid from regional offices. Table 2-3 shows Coop Program costs and reimbursements for FY 1996.

TABLE 2-3 Coop Program Costs and Reimbursements for FY 1996

Total NOAA costs (NCDC and NWS)	$9,256,000
NCDC costs	$800,000
NCDC costs recovered	$251,642
NWS costs	$8,456,600
NWS cost recovered from:	
U.S. Army Corps of Engineers	$611,370
Bureau of Reclamation	$77,578
U.S. Department of the Interior	$34,000
Net NCDC costs	$548,358
Net NWS costs	$7,733,652
Net NOAA costs	$8,282,010

Source: NWS

The total annual cost of each coop station to American taxpayers is estimated to be about $700 (including the annual operating cost and the cost of NCDC operations). The annual cost of $8.2 million for the Coop Program (Table 2-3) includes the cost of publishing and disseminating data products, which is approximately equal to the annual cost of upper-air expendables (mainly weather balloons and their instrumentation) and considerably less than the total annual operating cost of the 850 fully automated ASOS installations nationwide (about $12.5 million per year or $15,300 for each).

Many NCDC products are disseminated free of charge to other agencies and to the public. About 30 percent of NCDC's operating budget is underwritten by interagency transfers from government customers and reimbursables from other customers. But income from both is declining. When prices for a number of products were increased, orders from the public went down. In FY 96, cooperative data represented 11 percent of NCDC's reimbursable income, or a little more than $250,000. Thus, the NCDC portion of the Coop Program does not even cover its modest costs. Indeed, the gap between costs and income is widening.

SYSTEM ISSUES

The effective operation and management of the Coop Network requires understanding of the broad system of weather observations and other networks (both national and international). The Coop Network must continue to satisfy its traditional purposes with respect to longer-term climate monitoring and prediction and, at the same time, play a more important role in meeting the national need for near-real-time meteorological data. If stations in the existing Coop Network could report in nearreal-time, the need for parallel networks would be reduced. Some applications that require real-time or near-real-time observations are listed below:

- flood forecasting (data from thousands of stations in conjunction with radar data)
- numerical weather forecasts, forecast verification, and improved models
- calibration of radar data
- monitoring of crops for agriculture
- operational weather forecasting by NWS offices
- highway conditions and road crew work
- fire weather

All of these tasks require a large number of observations that can be gathered quickly. The requirements for the accuracy and the long-term continuity of measurements are less stringent in these applications than when the data are used to determine long-term climate trends and statistics.

Mesonets And Regional Networks

The panel was asked to identify approaches for improving the effectiveness and efficiency of the network through new technology or a new organizational structure associated with the NWS modernization. Automated observing networks, such as state and local mesonets, are reviewed in that context.

Local or regional networks are customized to meet their users' needs and are usually automated to provide near-real-time access to data. Mesonets are operated by federal, state, and local governments, as well as by private-sector organizations. Some state transportation departments have installed automated data stations along the roadsides. Some power utilities and large cities have small networks to provide meteorological data at key locations. Data from many of these networks are also used by the NWS. For example, the NWS collaborated with the University of Georgia's mesonet to provide weather coverage for the 1996 Olympic Games in Atlanta (see Box 2-5). Examples of collaborative local and regional networks are listed below:

- The Regional Observation Cooperative of the Forecast Systems Laboratory is organizing various existing reporting sites into a mesonet to collect, process, analyze, and disseminate surface observations from Colorado and adjoining states.
- A large number of networks of various sizes have been established in agricultural areas around the country.
- An Oklahoma Mesonet of 114 stations, jointly supported by Oklahoma State University and the University of Oklahoma, is operated by the Oklahoma Climatological Survey (see Box 2-6). Data are collected and

transmitted automatically every 15 minutes and are available to users about five minutes later. Figure 2-13 shows a typical station in the Oklahoma Mesonet.

- The Educational Network has 2,000 sites mounted on school roofs; the Four Winds Network is a small network located at schools in the Washington, D.C., metropolitan area. The purpose of both networks is to educate students and communities about the importance of environmental data.

BOX 2-5 OLYMPIC WEATHER WATCH

The XXVIth Olympiad was held during the hot, humid, thunderstorm-prone Atlanta summer. To ensure the success of the games, the NWS provided weather information to athletes, spectators, and the media. Weather conditions were monitored using satellites, Doppler radar, and a network of surface monitoring stations that comprise the University of Georgia's Automated Environmental Monitoring Network (AEMN). The AEMN was supplemented by additional stations installed by NWS in data-void areas to support high-resolution numerical models. Two NWS Olympic weather support offices in Georgia received and analyzed the data and provided weather forecasts for each venue of the games. The forecasts were transmitted to officials, coaches, and athletes through the Atlanta Olympic Committee's information system and were broadcast to numerous hotels and made available to the media.

Source: Hoogenboom and Garza, 1996.

Generally speaking, although mesonets have some important capabilities that the Coop Network does not have, they lack many features that have made cooperative data so valuable. For example, mesonet data are mostly tailored to meet the needs of particular users and are focused on weather data rather than climate; in some cases, there is less quality control of the data, they are less available to the public than the coop data, and their period of record is much shorter than the 100-year record of the Coop Network. In many cases, the type of measurements is limited (e.g., no observations of snow, hail, thunder, etc.). Some mesonets do not archive or summarize their data, and some lack routine maintenance and calibration or do not meet basic exposure standards.

Some mesonets resemble a low-cost ASOS, but with fewer expensive instruments and added low-cost solar sensors. Mesonets can collect data quickly at fixed times, but precipitation measurements usually come from tipping buckets, which are not as reliable or accurate as those from the Coop Network's standard 8-inch precipitation gauges, and no snowfall or snow depth measurements are included.

If mesonets could be standardized, they could possibly be incorporated into the Coop Network. A "network of networks," partly government funded and partly privately funded, could provide increased coverage. However, a

BOX 2-6 THE OKLAHOMA MESONET

The Oklahoma Mesonet, perhaps the most extensive and successful of all mesonets to date, is a joint project of the University of Oklahoma and Oklahoma State University. Built in 1993-94, it has 114 environmental monitoring stations statewide—more than one per county. Each automated station (see Figure 2-13) measures temperature, humidity, wind speed and direction, barometric pressure, solar radiation, soil temperature, soil moisture, and leaf wetness. Data are collected every 15 minutes (3 sets of 5-minute observations) and are available via the statewide law enforcement communications system.

The operating budget for the mesonet is about $1 million per year, with a maintenance budget of about $900,000. The system is partly supported by user fees. As of late 1997, there were 500 authorized users of the data, with the largest categories being K-12 schools and teachers (who use the mesonet data as a classroom teaching tool), university researchers, and agricultural agents. Access is restricted via password and user software. Data are disseminated by means of an electronic bulletin board and the World Wide Web.

Source: Oklahoma Climatological Survey.

serious disadvantage of relying on mesonets is the uncertainty of their long-term sustainability and reliability. Because many local networks are beyond government control, relying on them to support federal programs would be risky. (Cooperative observing networks in other countries are described in Appendix C.)

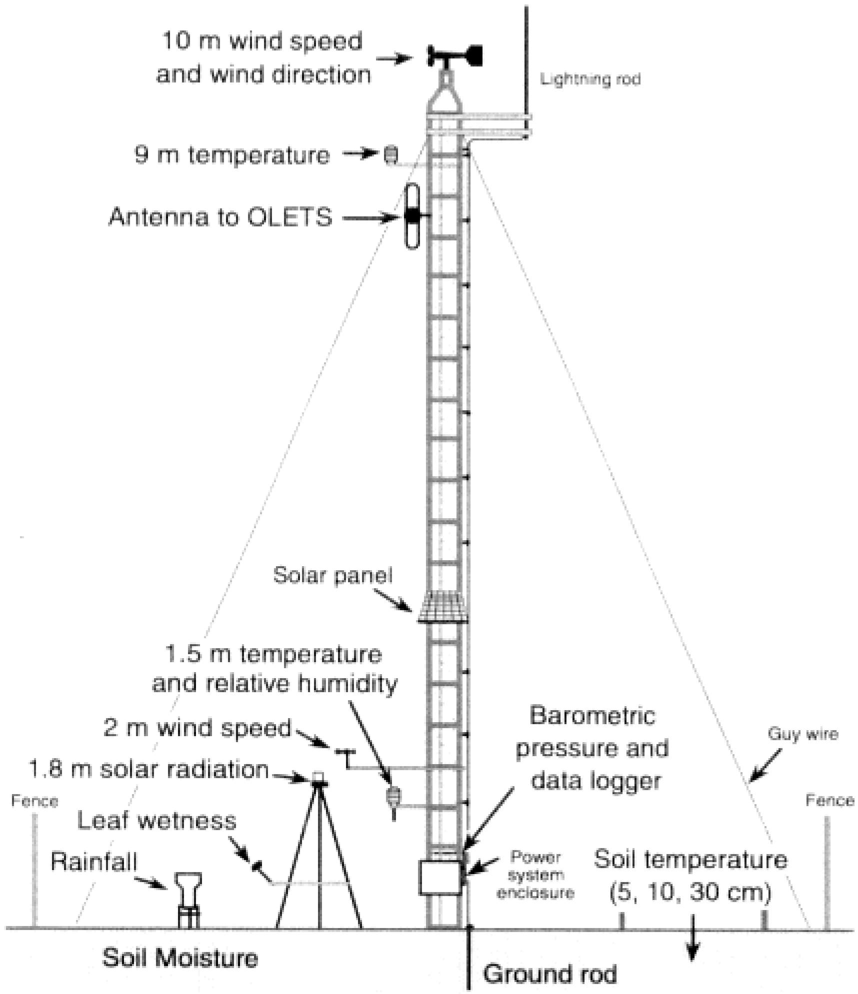

Figure 2-13 Oklahoma Mesonet station configuration. Side view (to the north) of a typical Mesonet station.
Source: Oklahoma Climatological Survey

Noaa's National Weather System

To understand the changes necessary for improving the Coop Network, the network must be seen in the context of the overall system of NOAA weather and climate data services. The place of the Coop Network in the overall system—the relative scope and scale of Cooperative Program activities—is an essential guide to determining its future.

Figure 2-14 shows a high-level view of weather-related activities under NOAA, reflecting the completely modernized NWS. The figure illustrates the overall architecture for the NOAA National Weather System that the NWS plans to use to guide the development of its current and future weather modernization technologies and climate services. Two of the stated objectives for the architecture are to "provide for efficient and timely delivery of data from national observing systems to the NCDC" and to "support the integrity of the long-term climate record from weather systems" (NOAA, 1997).

Cooperative observers (upper left in the figure) are only one of several sources of environmental data; Coop Network data are shown as being transmitted automatically into the LDAD/AWIPS at WFOs. Automated sources in the system (ASOS, other surface observation networks, NEXRAD, satellites, etc.) will soon produce—indeed, are already producing—an ocean of data, and coop data will represent a mere "drop in the bucket" in terms of volume. The NWS Office of Meteorology is currently conducting a study of the status of all federal, state, county, local, and private surface observational networks to determine the feasibility of integrating them into a real-time national network.

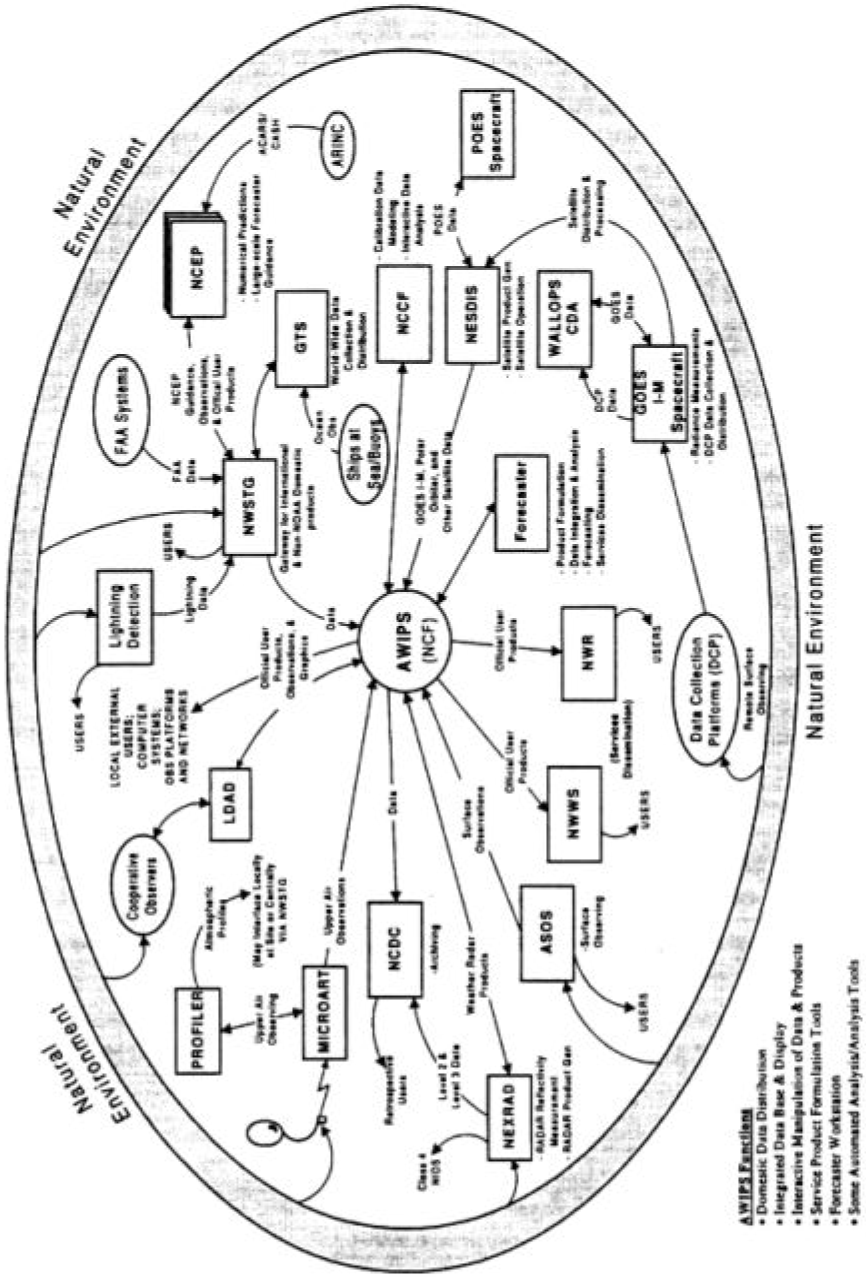

Figure 2-14 NOAA National Weather Service high-level component system view (cooperative observers are on the top left portion of the figure.).
Source: National Weather Service

An integrated surface observation network would maximize the utility and cost effectiveness of the national investment in surface observations. Although NOAA has developed a concept of the modernized National Weather System architecture, there is no comprehensive observing system architecture for surface observations comparable to the planning architecture for atmospheric observations under the auspices of the North American Atmospheric Observing System (NAOS) Program. One of the primary features of NAOS is a scientific evaluation program to assess the value of various combinations of upper-air observing systems to numerical predictions and operational weather forecasts. The NWS Office of Meteorology appears to recognize the need for, and has initiated a study of, an integrated surface observation network to leverage the information and resources of the many independent sources of surface observations throughout the United States. A comprehensive observing system architecture for integrated surface observations would provide a clear blueprint for the future management and operation of the Coop Program as part of the National Weather System.

3

Cooperative Network of the Future

In this chapter, the panel outlines a realistic approach to improving the Coop Network to meet current and future needs. Conclusions and recommendations are based on analysis of data and evidence in this report. The heart of this chapter is a detailed blueprint for a sustainable Coop Network. The panel envisions that the Coop Network will continue to rely fundamentally on volunteer observers and will incorporate strategic upgrades that are feasible with current technology. This upgraded and strengthened network will be a component of a larger national weather observing system that will evolve to meet the nation's needs. The growing demand for accurate and timely cooperative data will probably determine the requirements for the system. The Coop Network exists in the context of other national, regional, and local networks that serve a variety of functions. In some cases, cooperative observing sites are part of those other networks, and vice versa.

To determine the overall design of a surface observing system like the Coop Network, the following questions should be considered: How many sites will be required? What other networks, if any, should be incorporated? What variables should be measured? Which components should be automated? How often should data be sampled? How rapidly should data be made available to users? What tradeoffs of cost against quality and performance should be made? On what schedule should the system design or redesign be implemented? Several of these questions are addressed in this chapter. However, a thorough, detailed system design is a complex undertaking that must take into account the needs of a wide range of users, technical and budgetary trade-offs, and many other factors, and is beyond the scope of this report.

The rapidly growing commercial demand for coop data (especially by resource managers, attorneys, insurance com-parties, and consultants), the growing number of individual users reported by NCDC, and greater use of the coop data for climatological research have a number of direct implications. Perhaps the most pressing need of the greatest number of users is for faster access to data. In response to this demand, limited, but rapidly increasing, amounts of current coop data are now distributed on the Internet through NCDC, the RCCs, the National Centers for Environmental Prediction, and WFOs.

With the increasing demand for weather and climate information and the rapid development of new technologies, mechanisms should be established to provide feedback between the users and the producers of coop data. NCDC provides and receives feedback through regular contacts with clients and in-house climate researchers. The NWS has no feedback mechanism for climate data.

Conclusion. In response to the changing nature of users and applications, the NWS needs more interaction with users of the data and derived products. Links between NWS and users should be formalized organizationally to provide NWS and users, as well as coop observers, with consistent, orderly feedback.

IMPORTANCE OF CONSISTENCY FOR COOP NETWORK DATA

Before going into the subject of changing the Coop Network, the panel would like to stress the importance of carefully managing the introduction of new instruments and procedures. Consistency of measurements has been a critical—perhaps even a unique—attribute of the Coop Network, one that has made it indispensable for assessing long-term climate changes and determining the frequency distribution of climate elements. There are several reasons for that consistency:

- Instrument types are changed only rarely and gradually.
- Many stations have been making observations for long periods of time (20 to 50 years) under constant conditions (i.e., the same site location and equipment).

- Standards for exposure of the instruments have remained constant over the life of the network.

It is vital that this consistency be preserved. For many purposes, consistency is as important as accuracy. For example, even data that are consistently biased because of the poor siting of an instrument shelter can be used to reconstruct past climate fluctuations if the biases are known. Potential biases in the climate record should be evaluated and accommodated to ensure that changes in equipment and/or procedures do not compromise consistency.

Conclusion. Procedures for assessing and accounting for biases introduced by changes in station location, instrumentation, and time of observation (for daily data) are essential. Appendix E lists a number of recommendations made by the panel's parent committee in an earlier report (NRC, 1992) regarding the appropriate procedures for implementing changes in the Cooperative Observer Program. The recommendations are still valid and should be followed.

At the same time, flexibility for expansion and/or modification of the system must be built in. Although volunteer observers will continue to be a necessary and central element of the system, in the network of the future fewer observing stations are likely to remain in one location for many years.

Conclusion. The future Coop Network will have to accommodate a mix of stations with varying levels of automation and sensors contributing observations at different times, as well as stations from other networks.

Recommendation. The National Oceanic and Atmospheric Administration, in cooperation with other agencies, should conduct an analysis of requirements for surface observations, with periodic follow-ups to develop requirements and specifications for a strong and viable surface observing system. The goal should be to develop and implement, over time, a comprehensive system planning architecture that ensures the effectiveness of the Cooperative Observer Network as part of a composite national surface observing system. This system architecture should be fully integrated with the other components of the overall National Weather System.

SPECIFICATIONS AND CHARACTERISTICS

Network Density

The present Coop Network consists of more than 11,800 observing sites, of which about 8,750 are "published stations" whose reports appear regularly in the NCDC summary of the day, hourly precipitation data, and other reports. But how many coop stations will be needed in the future? A complete answer to this question is beyond the scope of this report, but the panel has made several observations. First, the number of current stations is close to, but still below, the NWS goal (consistent with World Meteorological Organization standards) of one station per 625 square miles of area. The Coop Network density is based on a design formulated in an NWS document that states,

> The present *average* spacing of full climatological stations (observing both temperature and precipitation) is approximately 25 miles. Studies made at Iowa State college indicate that if a network of this density were distributed in a *uniform grid* (with due allowance for closer spacing in areas of rugged terrain and somewhat wider spacing in level terrain) the standard sampling error for monthly rainfall averages will be about 10 percent. For temperature, a less variable element, the standard error would be somewhat less. Four times as many stations would cut the sampling *error* only in half. The practical objective is therefore reasonably maintained at about the 600 square mile level per station, in view of existing budget limitations (Weather Bureau, 1953).

Second, the density of observations depends very much on the purposes for which the observations will be used. Different users of cooperative data have different needs. NWS officials told the panel that a density of about one site per county (or around 3,300 sites) would be sufficient to support county forecast and warning programs, provided the sites were largely automated and that the NWS had access to the data on a 24-hour per day basis. The USDA estimates that at least 10,000 stations will be needed in agricultural areas. The U.S. Army Corps of Engineers estimates that 1,100 cooperative observer sites located in critical watersheds, in addition to their automated river gauges, could meet their needs for flood control. Other agencies also have specific requirements. Because a single station could meet the needs of more than one agency, there would be considerable overlap. Climate description/climate reference and climate change data would require a very different density and distribution of stations.

Conclusion. Determining an appropriate size for the Coop Network will involve determining the minimum number of stations that would meet all anticipated needs of major long-term users, taking into account adequate station density and appropriate distribution. This analysis should be part of the comprehensive observing system recommended earlier. (Appendix F presents some general guidelines, developed by NCDC, for this analysis.)

Recommendation. As a first approximation, the panel recommends that the network support the following needs:

- climate change (requires 1,200 suitable observing sites, i.e., the number of stations in the Historical Climate Network)
- operational weather support (requires approximately 3,300 sites, i.e., one station per county)

- climate reference and description (requires at least 5,000 sites, i.e., the total number of A stations plus sites in the Reference Climate Network, part of a global network of stations selected as the "best" climate stations)
- agricultural weather, hydrology, and other applications (requires 10,000 sites, i.e., the number of stations, including B stations, required by USDA)

Because many stations will meet two or more of these needs, determining the required number of stations will entail a detailed analysis incorporating input from all categories of users.

Data from approximately 3,000 of the 11,800 stations in the current Coop Network are not included in NCDC publications, although the raw data forms are archived. Although the data from some of these stations may be used periodically by NWS forecast offices and other customers, the panel was informed by NCDC that the main reason these stations are unpublished is that their records are incomplete or of questionable quality.

Conclusion. Given the shortage of staff for managing the Coop Network, the excess of paper forms clogging the system, the stringency of the program's budget, and the need to improve overall efficiency, it is difficult to justify maintaining a large number of unpublished stations.

Recommendation. The National Weather Service, in coordination with the National Climatic Data Center, should evaluate the roughly 3,000 unpublished stations in the Cooperative Observer Network and determine, on a case-by-case basis, if they should be retained. If data from a given location are necessary, either the cooperative observer should be assisted to meet the network standards or another station should be established nearby.

Technical Features

Standardized Observation Times

A key goal of modernizing the Coop Network is to standardize observation times. Daily records of maximum and minimum temperature, precipitation, snowfall, snow on the ground, and any other available observations should, if at all possible, be collected at midnight (where instruments are automated) or in the early morning (where manual observations are made).

Conclusion. Standardizing observation times will facilitate the evaluation and interpretation of data in the short-term and the long-term. Whatever the observation time, it is critical that observers maintain a consistent time of observation and, if a change is absolutely necessary, that they inform the NWS official(s) responsible for managing their station.

Recommendation. Automated and manual observations of temperature and precipitation should be recorded and reported at standardized times.

Continuous Sensing

In addition to daily extremes and totals, frequent readings of accumulated precipitation and temperature should be gathered from all continuous sensors and retained in an on-site data logger. Hourly precipitation data are planned to help adjust radar estimates of precipitation amounts used to validate NEXRAD estimates, for example, and more frequent data are used to calibrate radar. If two-way communication with the station logger is possible, the station should be equipped to gather data from sensors at different rates (more frequent precipitation data, for instance, when flash floods are imminent).

To maintain an unbroken record of observations, adequate battery backup should be provided for automated sensors, and precipitation gauges should be able to measure frozen precipitation. A means of taking manual observations and entering them into a data logger should be standard in case the instrument-logger interface fails. Furthermore, to allow for interruptions in communication, sufficient memory must be built into the data logger so that at least a month of data (a minimum requirement for the climate record) can be retained.

Recommendation. Automated instruments should be equipped to gather and transmit observations to a data logger frequently, flexibly, and without interruption. Loggers should be able to accommodate manual inputs and store at least a month of data.

Electronic Communication

Ideally, all stations in the modernized Coop Network will be equipped to transmit daily observations electronically to WFOs (ROSA is an example of a similar system for transmitting manual observations). The system would include on-the-spot quality control of the data and would provide feedback to the observer if a data entry is suspect. It would also allow observers to transmit special reports at any time of the day and, perhaps, ask observers for reports as the need arises.

Recommendation. Data loggers for all automated instruments should be interfaced with communications equipment that can transfer observations to weather forecast offices at prescribed times (i.e., hourly, every six hours, or daily). Weather forecast offices should also be able to interrogate data loggers on demand.

Technical Standards

Although stability will always be a core strength of the Coop Network, as phased upgrades in technology are made a mix of different sensor types will coexist. Hardware standards will be necessary to avoid low-quality data and high failure rates. Reasonable cost/benefit trade-offs can be made with commercially available hardware. Once a threshold of accuracy has been reached, it is often more important to have more samples rather than fewer higher-quality samples. Maintenance standards are necessary to ensure that calibration and accuracy requirements are met.

Conclusion. Achievable standards for sensor performance, maintenance, and calibration must be established.

Recommendation. The National Oceanic and Atmospheric Administration, together with other user agencies, should develop standards for sensor performance, maintenance, and calibration based on reasonable trade-offs between accuracy and cost. Data from instruments that meet technical standards should qualify as "official."

Up to now, various elements of metadata (site information) have not been available to most users of coop data, or even to most NWS staff. This shortcoming has introduced an element of uncertainty into the interpretation and analysis of long-term climate data. In addition, management of the Coop Program has been hampered by a lack of tools for effective oversight of the network. As a result, the enforcement of standards has been limited.

Conclusion. New tools, such as the Internet, GPS, and digital cameras, promise to improve the collection, storage, and dissemination of metadata and strengthen NWS management and oversight of the Coop Network. Stronger management will be particularly important if stations from mesonets and other networks are used to augment Coop Network stations.

Recommendation. The modernized Cooperative Observer Network should adopt the oversight practices made possible by new information technology so that all site information is available in on-line computer files. Each site should be located with global positioning system technology, and digital site photos should be placed in on-line files. Siting standards should be reviewed, updated, and applied consistently.

Role Of Human Observers

Human observers will continue to play an important role in the collection of data at most cooperative stations. Even at stations where much of the instrumentation is automated, human observers are needed to monitor and maintain the equipment on a daily to monthly basis and to provide backup observations when necessary. Observers also record rainfall, snowfall, and snow on the ground, as well as weather events, such as hail, thunder, freezing rain, sleet, and high winds.

Conclusion. Automation should be added when and where it allows the NWS to reduce the burden on observers, reduce errors, control the time of observations, and gather more data (such as hourly precipitation) at more sites. Automation will be successful only if it does not increase the observers' burden and if the communication interfaces are very simple.

Recommendation. When automation at any level is introduced at a station, the system and procedures should be thoroughly explained to the observer. The observer should be reassured that his or her role will not be made more difficult or less important.

Training

An important factor in ensuring the consistency of observations, and thus the high-quality of data, is proper training. Modernization, including automation, will provide an opportunity to bring new knowledge and skills to coop observers and to review their previous training.

Conclusion. Personal, hands-on training is an effective way for observers to learn; however, training videos can also be used between visits or if visits are not possible. In addition, training and program updates on the Internet will be increasingly feasible as a larger proportion of the observer population acquires the capability to go on-line. However, experience has shown that there is no substitute for personal visits to stations, twice a year if possible.

Automation will probably require some specialized skills on the part of NWS personnel, as well as additional maintenance of equipment.

Conclusion. NWS's training of Coop Program personnel will have to include new skill requirements, such as first-level maintenance for data loggers or automated sensors.

Recommendation. Observers should receive on-site, personal training from qualified National Weather Service staff at least once a year. In addition, training videos should be produced that can be played on a standard VCR. The National Weather Service should begin planning to offer observer training on the Internet, especially supplemental training and updates. The same mechanisms, in addition to formal training, can be used to train National Weather Service personnel in the new skills required by the automation of cooperative stations.

Relationship To Mesonets

Presently, there are a number of excellent mesonets at the local, state, and regional levels that gather high-quality climatic data. In some cases the density of a mesonet exceeds that of the Coop Network in the area, and mesonet stations are often located where there are gaps in the Coop Network.

Conclusion. It is reasonable to use mesonet stations to supplement or augment the current Coop Network, as long as these stations measure the proper weather variables, meet or exceed equipment and exposure requirements, and agree to participate in the Coop Program. Mesonet managers would have to agree to station maintenance, data formats, and instrumentation acceptable to the Cooperative Observer Program for fixed periods of time. In turn, NOAA could provide support for the quality control, archiving, and dissemination of mesonet data. Mesonets have not existed long enough to prove the long-term reliability of their data.

Recommendation. Mesonet stations that meet or exceed equipment and exposure requirements should be considered as supplements to, but not replacements for, the Cooperative Observer Network stations. The National Oceanic and Atmospheric Administration should establish a mechanism for evaluating the performance and set instrumentation and data standards for mesonet stations. The National Oceanic and Atmospheric Administration should establish cooperative agreements with states and other mesonet operating authorities. Mesonet operators who wish to associate their networks with the Coop Program should be required to commit to maintaining stations, data formats, and instrumentation that meet the standards of the Cooperative Observer Program for a fixed period of time. In return, the National Oceanic and Atmospheric Administration should provide quality control, archiving, and dissemination of selected data from mesonet stations.

Quality Control

Systematic quality control, from data collection to archiving and dissemination, is very important for an effective data collection and distribution system. Quality control should be based on a solid understanding of the sources of error and the different types of errors. A detailed data flow analysis can identify potential sources of error at various points in the data collection and transmission process. Quality control is critical in a network as large and complex as the Coop Network. For automated observations transmitted in real-time, well tested quality control procedures that have already been developed for existing networks can be readily adapted to the Coop Network. These largely automated procedures can alert network technicians to potential problems.

NWS and NCDC, RCCs, and state climatologists have accumulated a wealth of experience about the types of errors made by individuals as they observe, record, and transmit observations of daily temperature, precipitation, and snowfall on paper forms and via telephone. Data entry via a computer or touch pad creates additional potential problems but also offers potential solutions to those problems. As cooperative observers increasingly use automated data entry, immediate checking for errors becomes possible; creative graphical-visual quality control tools are available.

Conclusion. Testing and evaluation of new procedures with selected cooperative observers will be very useful in developing a single-step, friendly procedure for data entry and transmission. It is important that this procedure be as simple, efficient, and satisfying as possible in light of the time constraints on volunteer observers. Problems with instruments or observers should elicit prompt response from the local WFO.

Conclusion. The most effective way to ensure the quality of manual observations of selected climatic elements, such as precipitation and snowfall, may be through initial training and continuing education provided by the personnel at each WFO. The investment of a small amount of time initially could save a great deal of time later. With well trained observers and effective on-site quality control, NCDC should be able to substantially reduce the amount of editing. An added benefit would be a faster turnaround time from the time data are received to the time they are suitable for dissemination.

Recommendation. The modernized Cooperative Observer Network should identify problems as early as possible in the data collection process and provide prompt feedback to both observers and network technicians in order to improve the overall quality of data and reduce the costs of quality control and data turnaround time at National Climatic Data Center.

Dissemination Of Data

The demand for rapid and timely weather and climate data is growing. Ideally, users should be able to obtain the data from a single source. Ensuring the consistency and reliability of data means that the quality control, archiving, and first point of dissemination of validated data should be done by a single organization. The NCDC, by virtue of its facilities, experience, and expertise, is the organization best suited to manage these functions. However, the RCCs and state climatologists are well suited to assist with the dissemination of climate data to the public.

Conclusion. All cooperative data should be routed through NCDC for inspection, quality control, database development, the calculation of indices, and the production of publications. NCDC should also continue to develop the distribution of data via the Internet to all interested parties. Some means of cost recovery for Internet requests would help to defray operating costs at NCDC that are currently only partly covered by revenue from mail and fax requests.

Recommendation. The National Climatic Data Center should continue to be the focal point for archiving and disseminating cooperative data and should work with regional climate centers and state climatologists to disseminate data to all interested parties, making databases available in a timely manner. The National Environmental Satellite, Data, and Information Service should make every effort to recover its costs for processing, copying, and providing data over the Internet.

BLUEPRINT FOR UPGRADING THE COOP NETWORK

On-site observations and data communications to the local NWS forecast office presently require manual techniques, which involve reading one or more sensors once a day, recording the data on a paper form, and mailing the form to the NWS at the end of the month. A subset of Coop Network stations have automated rain gauges and can transfer daily observations digitally via specialized devices connected to touch-tone phones.

One obvious goal of upgrading the field sites is to automate both the data collection and transmission as much as practical. However, the upgraded network will not be entirely automated; indeed, it will still be largely manual in the sense that the degree of automation at stations will vary, and some manual observations will continue to be made at most stations. In effect, the panel envisions a multilevel network that is upgraded in accordance with three main priorities:

- maintaining the size and density of the network to satisfy all major data needs
- ensuring that the quality of data remains high
- making at least a large subset of the cooperative data available faster—preferably on a near-real-time basis—while continuing to archive all data for long-term climatological purposes

The panel reiterates that maintaining the integrity of the climatological database is imperative. Manual stations provide valuable information at low-cost and at a spatial density that has been shown to be necessary for a myriad of climatic applications.

Three-Step Approach To Automation

The automation of equipment at cooperative stations could be a three-stage process. The first stage would be the automation of data transmission from cooperative observer sites to NWS forecast offices. The second stage would be automation of the data ingest process for appropriate sensors. The third stage would be a cost-effective increase in the number of sensors at given cooperative sites. The following brief discussion of these three stages is generally consistent with the NOAA Project Development Plan for Modernization of the NWS Cooperative Observer Network (NOAA, 1993).

Automated Data Transmission

Automated data transmission from cooperative sites to NWS forecast offices, even with manual input of the data by cooperative observers, would have several benefits. First, it would significantly reduce the time between data collection and dissemination to a wide variety of users, including the NWS, on both a daily and a monthly basis. In addition, it would permit on-site storage of data for later retrieval in the event of a communication failure. Finally, it would permit faster and better quality control, both on-site and at NWS forecast offices.

The data communications equipment at each cooperative site must have the following capabilities:

- data storage for a minimum of one month (climate record requirement) in digital format on a transferable medium (e.g., diskette)
- two-way, unattended communication with the local NWS forecast office for data transfer and system maintenance
- accommodation for the observer's comments and observations
- local (on-site) data access and display (graphical displays where feasible), for feedback as well as for the observer's personal benefit
- recognition of obvious input errors
- accurate timekeeping
- easy expansion as requirements change
- a fail-safe mechanism (batteries, solar power, etc.) in case of a power outage

These specifications can be met with current technology and at modest cost, using, for example, a low-end personal computer with a modem attached to the observer's existing telephone line. With an accurate clock, data upload to the NWS forecast office could be initiated at a preset time each day from the cooperative site. The on-site clock could be reset, as needed, as part of the daily communication session with the NWS forecast office. If bandwidth permits, the NWS might also download, as a perquisite for the observer, the latest forecast and warnings for the observer's location. As computer and communications technology improves, these tasks will become easier and more affordable.

The data communications equipment might not be a single network-wide system but could evolve through various stages of automation. However, if many different systems are in place simultaneously across the Coop Network, maintenance and replacement could be complex and expensive.

Recommendation. Automating data communications between cooperative sites and local National Weather Service forecast offices should be the first step in automating the cooperative observer sites. The goal should be to make reporting data on at least a daily basis possible at all stations, even if data are still input manually.

Automated Data Ingest

The second stage, automation of the data ingest process, would have the following advantages:

- elimination of manual input errors
- more frequent observations
- midnight-to-midnight data summaries
- more detailed data statistics (such as hourly means and variations)
- collection of data from a wider variety of sensors

This second stage obviously requires that the site have at least one electronic sensor. Temperature measurement is the obvious starting point. An electronic sensor would permit hourly readings, as well as daily minimum and maximum temperatures (midnight-to-midnight readings or observation time-to-observation time) to be stored for later transmission to an NWS office.

Precipitation gauges would be a logical second sensor. The automated precipitation gauges currently in use, however, are moderately expensive and often require high maintenance. New technologies being developed should be investigated before more Fischer-Porter sites are added.

Recommendation. The National Weather Service should continue to pursue alternatives to Fischer-Porter gauges for providing automated hourly measurements of precipitation. To maintain temporal consistency in the data, manual observations of precipitation should be continued in parallel wherever automated precipitation gauges are used.

Digital data ingest would require either the addition of a suitable circuit board to an on-site personal computer or a specialized data logger. This equipment is widely available with current technology at modest cost. The enhanced computer or data logger must have the following capabilities:

- continuous data collection from a variety of sensors
- operation on battery backup power (for a minimum of 10 days to cover worst-case electrical outages caused by natural disasters)

In most cases, coop stations are located at sites where individuals are available to make daily visual inspections of the equipment, measure snowfall and snow on the ground, and observe weather phenomena (e.g., wind damage, thunder, hail). Ideally, the storage device (data logger) would be interfaced with a keyboard so manual entry could be made of all observations. The user interface should be extremely user friendly.

Recommendation. Wherever feasible, cooperative stations should be provided with personal computers or data loggers for automated ingest of data from one or more electronic sensors. These personal computers or data loggers must be able to operate on battery backup power for at least 10 days and should have user-friendly interfaces for the manual ingest of data. Computers or loggers should also have an on-site error feedback mechanism and quality control during the manual input of data.

Stations with both automated ingest of data and automated communication will provide a wealth of near-real-time information, which will be critical to improving weather and hydrological warnings and forecasts and will be extremely useful for emergency managers, transportation officials, and the general public. More detailed statistics and more frequent observations would also improve on-site monitoring of sensor performance and quality control, which would also improve scheduling of field maintenance.

Additional Sensors

Once a cooperative station has been automated, additional sensors can be installed to meet the needs of federal or state agencies or other users of Coop Network data. Perhaps the easiest one to add would be a sensor to measure relative humidity, which is often measured with a capacitance transducer packaged with a temperature sensor in a single instrument. Another easily added sensor is a pyranometer to measure total incoming solar radiation. Fairly accurate pyranometers are available and require relatively low maintenance. Other sensors would entail a noticeable increase in cost and/or maintenance. High-quality anemometers, for example, are moderately expensive, require good exposure for representative measurements, and, in most cases, must be mounted on a tower. Accurate pressure measurements also require moderately expensive instruments. Soil temperature and moisture sensors are inexpensive and could provide very useful data. However, the soil parameters can vary considerably, so a representative, but still accessible, measurement location must be carefully selected.

Rationale For A Gradual Transition

Because there are 11,800 cooperative observer stations in the United States, automation will necessarily be a gradual process. Some observers may be offended by changes in their role, and training them will take time. Any increase in the complexity of the cooperative observer's role is likely to lead to problems. Also, the continuity of data is a vital feature of the Coop Network, and rapid changes in equipment would inevitably disrupt that continuity. For these reasons, the panel anticipates that automation will be phased in nationwide and that there will be a mix of systems across stations and over time. The panel agrees with the basic NWS proposed strategy for modernizing the Coop Network and does not recommend the full automation of sensors. Substantial participation by volunteer manual observers will be necessary for the foreseeable future to provide backup and maintenance and accurate precipitation measurements for weather and climate applications, to keep costs low, and to report weather phenomena that are not detectable or measurable by automated systems.

Conclusion. The Coop Network should not be completely automated but should continue to have a large manual component. It would be prudent to build on what works well and repair or augment what does not work very well, rather than to start over "from scratch." Maintaining the continuity of data is another factor that favors maintaining as much of the existing network as is feasible.

Conclusion. The panel wishes to specify capabilities rather than specific hardware. The architecture/planning recommended earlier would be invaluable for upgrading coop stations in the next five to ten years.

Transition To New Instruments

The transition to electronic sensors must be made carefully so as not to interrupt the long-term climate record. Long-term continuity is a unique and absolutely indispensable feature of the Coop Network and the data it provides, and it must be protected. As new instruments are introduced, studies to determine adjustment factors to account for differences between old and new sensors, gauges, and shelters should be made. The goal is to preserve the temporal continuity of station databases and make the change of equipment as seamless as possible in terms of the official climate record.

Conclusion. Every effort should be made to ensure that the transition to new instruments does not cause a significant discontinuity in the climate record.

Recommendation. New sensors should be introduced gradually across the Cooperative Observer Network. Changes in instrumentation should be tested at selected sites by thorough comparisons with the old instruments for at least a year.

The comparisons must be done under a wide variety of climatic conditions to account for regional and seasonal differences. Studies of previous instrument changes in the Cooperative Program and at first-order NWS stations have demonstrated the necessity and value of these comparisons. In one study (Quayle et al., 1991), a comparison of electronic MMTS observations with readings taken using liquid-in-glass thermometers situated in cotton region shelters showed that the MMTS daily maximum readings were lower and the minimums higher. Regional differences in this relationship were observed, probably related to snow cover, the intensity of solar radiation, and wind speed, among other variables. Studies of the continuity of climate data conducted for the NWS when the new ASOS was introduced showed that changes in instrument location can lead to temperature differences of as much as 1°F (Guttman and Baker, 1996; McKee et al., 1996; and Schrumph and McKee, 1996).

A predetermined number of cooperative observers should be recruited to participate in comparative studies, which should last for at least a year (ideally two years, to account for inter-seasonal variations). Once the new equipment has been validated for the prescribed interval, the old equipment should be removed to avoid confusion over which instrument is being used to make official measurements at the site. In the event that a full suite of climatic conditions has not been observed, it would be useful to maintain comparative observations for a longer period of time at a subset of stations. This would also test whether the relationships between old and new equipment change with time.

In addition to comparisons of instruments, studies should be done to determine the impact of changes in observation times on the climate record at individual stations, and adjustment factors to account for these differences should be developed. These studies should be patterned after previous studies (Karl et al., 1986) in which adjustments were determined for observations taken in the evening or the morning to a standard midnight observation time.

MODERNIZING THE PROGRAM MANAGEMENT STRUCTURE

In this section, the panel suggests some modifications of the management structure and practices to ensure that improvements in the Coop Network lead to real improvements in services.

Network Ownership

The preeminent management issue for the future of the Coop Network is the question of ownership and stewardship—operation, management, and policy direction. Various other federal agencies that rely on cooperative data have been frustrated with the low priority, slowness, and inconsistent quality of cooperative data under NWS management. Partly for this reason, the Tennessee Valley Authority, the U.S. Army Corps of Engineers, and the Bureau of Reclamation no longer rely as heavily on Coop Network data as they once did. The USDA even made a tentative offer before the panel to take over operation of the network. However, all of the user agencies would prefer to have the NWS continue ownership, if improvements can be made. NWS officials also expressed a desire to continue operating the Coop Network.

Conclusion. The NWS has the infrastructure and experience to continue operating the Cooperative Observer Network successfully if the changes recommended in this report are made.

Recommendation. The National Weather Service should improve its management of the Cooperative Observer Network.

Interagency Management Council

Given the substantial, long-standing interest of many federal agencies in the health of the Coop Network and in the use of its data, and considering the difficulties that the NWS has had providing adequate operational and funding support for the network, it is reasonable for other agencies to participate in the policy direction and support of the network. There are several applicable models. One is the National Atmospheric Deposition program (NADP), which was established in 1977 to address the problem of atmospheric deposition (e.g., acid rain) on crops, forests, surface waters, and other natural resources. The NADP was later merged with a federal acid-rain monitoring and research program and assumed responsibility for a 200-site network of monitoring stations. Seven federal agencies (NOAA, USDA, the Bureau of Land Management, the Environmental Protection Agency, the U.S. Geological Survey, the U.S. Forest Service, and the National Park Service) support this program and participate in policy and technical guidance through various management committees. Support is provided by these agencies, other federal and state agencies, universities, public utilities, and industry. The amount of support from each entity is determined on the basis of need. This arrangement for joint management and support appears to work well.

A similar interagency mechanism more relevant to the Coop Network is the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), which is directed through the Office of the Federal Coordinator for Meteorology (OFCM). The FCMSSR was established in 1964 "to promote coordination and cooperation among the federal agencies having weather-related activities so that the most effective and best possible weather information and user services are provided for the funds made available by the government." Fourteen federal agencies participate, including the U.S. Department of Commerce, the USDA, the U.S. Department of Defense, the U.S. Department of the Interior, the U.S. Department of Transportation, the Federal Emergency Management Agency, and the Environmental Protection Agency.

The OFCM carries out a number of coordinating functions, including the ones listed below:

- the documention of agency programs and activities in coordinated national plans
- the provision of structure and programs to promote the development and coordination of interagency plans and procedures for meteorological services and research
- the preparation of analyses and evaluations for use in the appropriations process
- the review of federal weather programs and requirements for meteorological research, with suggestions for revisions of current programs

At present, the OFCM does not play a substantial role in any climate observing network. However, a number of program councils and other groups are relevant to climate observing networks, including the following:

- Working Group for Climate Services
- Panel for Observing Systems
- Working Group for Meteorological Information Management
- Program Council on Automated Weather Information Systems

These groups have functioned very effectively with respect to meteorological activities in relation to aviation and in a few other focus areas that require strong interagency coordination and where the participating agencies have agreed to let the OFCM play a strong role. For example, the NEXRAD Program Council has done an excellent job coordinating the development and implementation of the radar network to meet multi-agency needs. The structure is in place within the FCMSSR for a similar focus on the Coop Network; indeed, the federal coordinator of FCMSSR has expressed a willingness to use that structure to coordinate interagency participation and support for the Coop Network.

Recommendation. The National Oceanic and Atmospheric Administration should work with other agencies to establish an interagency management council to guide and provide support (including funding) for the Cooperative Observer Network. The Office of the Federal Coordinator for Meteorology could administer the operation of this council.

Noaa Management Responsibilities

The panel observed that differences in operational priorities and ineffective coordination between high-level NWS and NCDC managers in addressing budget and data deficiencies have exacerbated operational and fiscal support problems for the Coop Network and the Coop Program. Under the present organizational structure, policy guidance, long-term planning, and budgetary advocacy are inadequate. The panel attributes this sense of "rudderlessness" to the absence of appropriate management representation for the Coop Network and Coop Program on NOAA's staff.

Conclusion. The National Oceanic and Atmospheric Administration should have a management oversight function for the Cooperative Observer Network and Coop Program. The lack of integrated management of the Coop Program suggests that the program should be managed above the level of the NWS.

Recommendation. The National Oceanic and Atmospheric Administration should improve the overall management of the Cooperative Observer Program. One approach would be to establish a climate observations management office to oversee the activities of the of Cooperative Observer Program of the National Weather Service and National Climatic Data Center. This office would ensure that the Cooperative Observer Program is given a high priority by the National

Oceanic and Atmospheric Administration, the National Weather Service, and the National Environmental Satellite, Data, and Information Service. Operational management of the Cooperative Observer Network would continue to be the responsibility of the National Weather Service.

The NOAA climate observations office should work jointly with the NWS Cooperative Observer Network and NCDC management teams to perform the following functions:

- shape the current and future directions of the Coop Program, enlisting interagency support in planning, policy-making, and funding
- provide effective advocacy for the Coop Program in budgetary planning by NOAA, the NWS, and NESDIS
- work with other federal agencies and states that have cooperative observer programs and/or mesonets to develop a coordinated approach to the management and maintenance of the Coop Network and ancillary networks (including setting standards for sensor performance, maintenance, and calibration)
- collaborate with regional climate centers and state climatologists to ensure that high-quality climate data and derived products are available to users on a timely basis and that they are properly archived

Role Of Nws Cooperative Observer Network Manager

To improve the management of the Coop Network, the NWS must improve the image of the network and give it a higher priority. The recent appointment of a full-time NWS Cooperative Program manager was an important step toward increasing the effectiveness of NWS's management.

Recommendation. To ensure the effectiveness of the Cooperative Observer Program manager, he or she should have direct access to National Weather Service top management and should be well connected with other federal agencies that use both real-time and historic climate data.

The Cooperative Observer Network manager should perform the following functions:

- provide the network with strong, credible leadership
- maintain and improve network site stability and data standards, with due consideration of human factors and methods to ensure that data are representative
- promote volunteerism and public appreciation of the Coop Network
- work with the NOAA climate observations office to oversee the program and provide advocacy
- ensure that specific, consistent, reliable information about the Coop Network and its value to society are readily available to policy makers and the public, as well as to NWS and NCDC managers

Local Management And Staffing

In general, the current WFO staffing for the Coop Program is marginal because Coop Program duties are part-time and vary in priority among WFOs. The staffing model needs to be adjusted for each WFO based on the number of cooperative stations assigned, the distances involved in managing the stations, and other operational factors. Maintaining consistent personal contact with volunteer observers is critical to the Coop Network.

Conclusion. Each WFO should have an individual on staff who is the primary point of contact for cooperative observers in the WFO's area of responsibility.

Recommendation. At each weather forecast office, staffing for the Cooperative Observer Program should focus on the data acquisition program manager as local manager, supported by an adequate number of hydrometeorological technicians to carry out its responsibilities in the forecast area. One of these responsibilities is to maintain consistent personal contact with the volunteer observers.

The meteorologist-in-charge (MIC) sets priorities at each WFO. Ultimately, work assignments, as well as attitudes about the Coop Program, derive from the attitude of the MIC. The panel is aware of some WFOs where the Coop Program operates extremely well because of the innovations, interest, and enthusiasm of the MIC.

Conclusion. The support and involvement of MICs is essential to the success of the Coop Program at WFOs.

Recommendation. The National Weather Service should hold forecast office managers accountable for the health of the portion of the Cooperative Observer Network under their purview. Performance evaluation criteria should be developed to encourage accountability.

FUNDING SUPPORT

The current Coop Network cannot be sustained at present funding levels. Reimbursables are declining (in part because of free Internet access to selected data and the distribution of coop data by state climatologists and RCCs), and support from other agencies is in jeopardy. Modernization of the Coop Network will require substantial new funds, not only for the acquisition of equipment, but also for ongoing operations and maintenance. Appropriate funding levels can be determined by the proposed interagency council after the recommended comprehensive review of requirements for surface observations.

Conclusion. Funding above the current level will be needed to finance the modernization of the Coop Network as outlined in this report. Even with new appropriations, a mechanism for obtaining funds from other sources—including user agencies, the public, and industry—will be necessary for upgrading the current system.

The constituency for cooperative data is extremely diverse (essentially encompassing the entire U.S. population). Therefore, the support for the network that produces those data should also be diverse. However, the various elements of the national climate services structure that are in close contact with this broad constituency have not been effective in gaining public and political support for funding new or upgraded Coop Network capabilities.

NEW VISION AND MISSION

The Coop Network has served the nation well for more than a century. The network and the data it provides have become a crucial resource:

- For the NWS, coop data are the indispensable foundation of the nation's surface weather observing systems, the link between past, present, and future weather.
- For NCDC, state climatologists, and RCCs, coop data are vital for climate research and are essential for meeting the climatic needs of a myriad of customers.
- For the USDA, the Coop Network has been a vital monitoring and warning system for the agricultural community and, with proper upgrading and support, it can continue to provide this much-needed service.
- For the U.S. Army Corps of Engineers, the Coop Network provides the core data for its flood control network.
- For the U.S. Department of the Interior, the network has been a part of its automated observing systems and, in the future, can provide an even larger portion of the information its bureaus and services need to manage the nation's lands and parks.
- For the Federal Emergency Management Agency, the Coop Network offers a way to gauge the relative severity of weather-related disasters and respond appropriately.
- For the Environmental Protection Agency, cooperative data can be an important element in the calculation and prediction of environmental problems and in determining how to mitigate them.
- For the U.S. Department of Transportation, cooperative data already play a role in the design and construction of new and upgraded highways and in determining when to deploy emergency services. In the future, these data will be a necessary component in the management of intelligent highway systems.
- For state governments, cooperative data are vital to the design of facilities, the enforcement of regulations, and the design of highway, water, and agricultural systems.
- For the public and large portions of the private sector, cooperative data are important for literally hundreds of applications in every area of human activity.

The Coop Network should be substantially refurbished and modernized to make it an integral component of the national weather system of the next century. Thus, a new perspective on its mission is in order.

The panel envisions a Cooperative Observer Network that is structured, managed, and equipped to provide high-quality weather and climate data rapidly and cost-effectively to the full spectrum of users who require spatially detailed information for a multitude of purposes, including not only the description and understanding of climate and climate change, but also operational meteorology, hydrology, agriculture, environmental protection, and a myriad of business, legal, economic, and personal decisions. Observations will encompass a very broad range of measurements that are technically and economically feasible, and instruments will be standardized across the network. Automated and manual observations will be combined to maintain the continuity of data for a broad spectrum of weather and climate information. The communication of data to analysts will be rapid and robust. A broad range of useful data products will be available in a variety of forms. Flexibility, compatibility, reliability, quality, and rapid accessibility will be the watchwords of the modernized Cooperative Observer Network. Coordination, cooperation, and integration will be the hallmarks of the revitalized Cooperative Observer Program.

With a modernized Cooperative Observer Program and Network that is part of a national (and perhaps international) observing system, the United States will be in a position to monitor climate with scientific precision, not only as a metric to assist in planning virtually all human enterprises, but also as a gauge for detecting trends and assisting in the construction and verification of predictions of climate changes.

4

Review Of The National Weather Service Proposal

Since FY 94, the NWS has proposed modernizing the National Cooperative Observer Program as part of NOAA's annual initiative (NOAA, 1993). Although NOAA has been supportive of modernizing the network, the U.S. Department of Commerce has decided not to carry the initiative forward. The panel agrees with the objective and goals of NWS's modernization plan for the Coop Network (see Box 4-1). The NWS envisions a mostly automated network that eliminates paper forms and hard copy. Only snowfall and snow depth observations will be made manually, with reporting by observers via interactive data terminals. Temperature and precipitation measurements will be automated and recorded via data loggers. All three types of observations will be transmitted electronically to WFOs and thence into AWIPS before being transmitted to NCDC. Figure 4-1 shows the NWS's conceptual design.

The panel has noted that the NWS's conceptual coop system design envisions a paperless system. In this system, both automated and manual observations would be entered into an interactive electronic data terminal. The terminal would have software that displays an electronic B-91 form that could be filled out automatically by automated sensors and

BOX 4-1 NOAA'S COOP NETWORK MODERNIZATION PLAN

The objective of this program is to further NOAA's mission by developing a low-cost, standardized climate/weather observing system that supports federal multi-agency requirements and is implemented in the Cooperative Observer Network to meet the needs of NOAA and all other climate/weather data users. The standardization of observation techniques and the improved compatibility of interagency data would benefit taxpayers in the long run.

The goals of the modernized Cooperative Observer Program are listed below:

1. Prevent further degradation of the climate database and thereby allow for more timely, reliable assessments of long-term climate conditions and climate changes.

A. Standardize observation times.
B. Reduce the amount of missing/erroneous data due to human factors.
C. Standardize observing biases.
D. Improve quality control of data.

2. Develop nationally standardized observation methodologies for automated surface climate observations.
3. Develop specifications for a low-cost, standardized, accurate, and reliable weather/climate observation system that provides higher quality data in a more timely and efficient manner than the current system.
4. Disseminate daily temperature, rainfall, snowfall, and snow depth observations at least on a daily basis to support all climate/weather data users (including NWS hydrologists and meteorologists).
5. Publish monthly data no more than two months after the end of the calendar month being processed.

Source: NOAA, 1993.

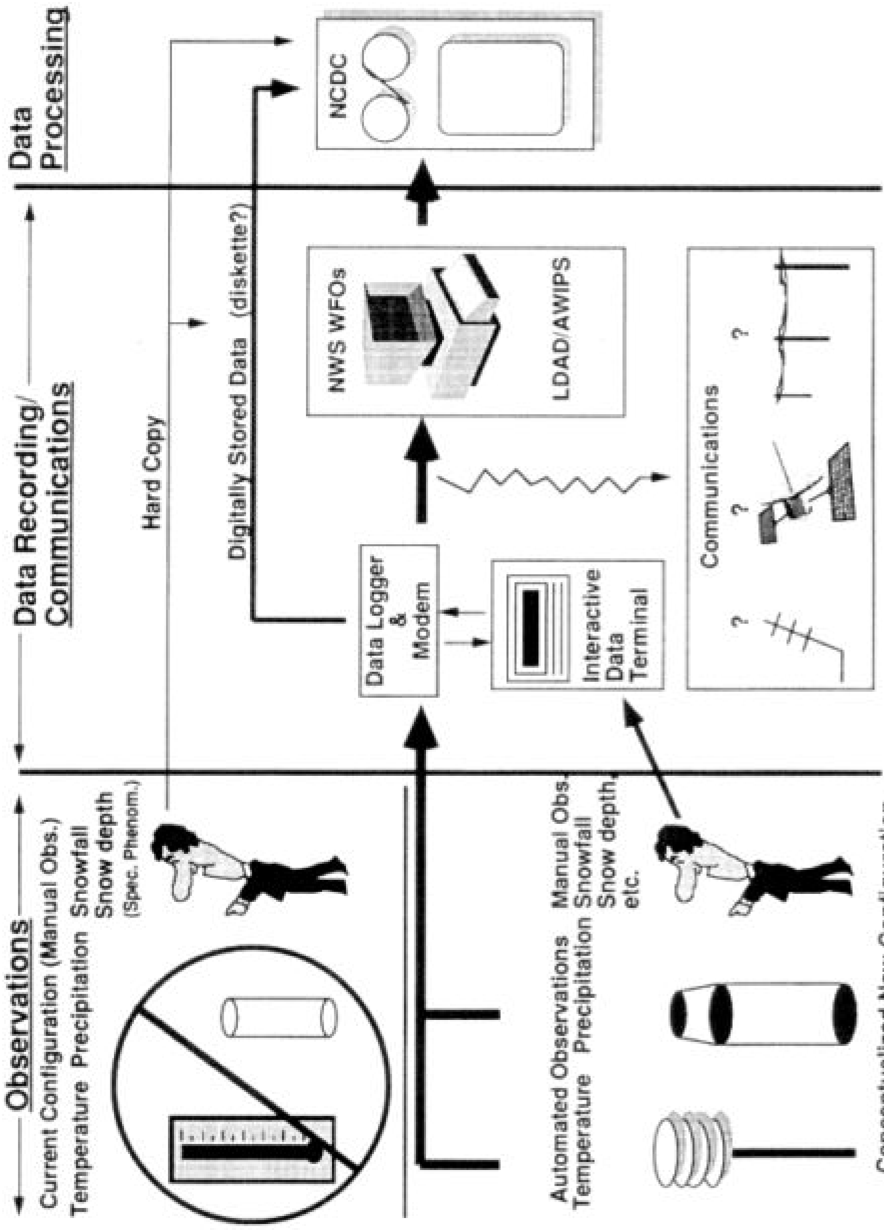

Figure 4-1 NWS's conceptual design for the modernized Cooperative Observer Network.
Source: National Weather Service

could also accommodate manual observations (such as snowfall or snow depth), which could be entered by key stroke. In any case, the data (both manually and automatically entered) would be stored digitally, and periodically transmitted electronically to the NWS and NCDC, probably daily and monthly. Backup data could be mailed (e.g., on diskette) if the electronic transmission failed for some reason. The panel advocates a gradual approach to automation with an emphasis on preserving the continuity of the record, obtaining data faster, and solving the mechanical problems with hourly precipitation gauges.

The panel has reviewed the NWS plan in detail and finds that it is fundamentally sound from a technical standpoint (see Appendix G). The panel's comments on equipment and automation are listed below:

- Thermometers. The maximum/minimum temperature sensor thermistor and readout equipment are rapidly becoming obsolete and do not have the capability of storing data. There are no funds to test and procure replacements. A return to the liquid-in-glass and cotton region shelter configuration is not feasible because of high cost and observer preference for the indoor remote readout. Therefore, a new temperature measuring system will have to be tested, procured, and installed at Coop stations. The consistency of temperature measurements across all NOAA networks (e.g., ASOS and the Coop Network) should be a serious consideration. The new thermometer systems should feed into data collection and communications equipment, as well as having manual readout capability. Modernization cost: about 5,000 new temperature systems.
- Hourly Precipitation. The Belfort (Fischer and Porter) rain gauge punched paper tape technology is obsolete, and the equipment to read the tapes is no longer manufactured, placing data from nearly 2,700 stations at risk. In addition, the pen-and-ink trace universal rain gauge technology is obsolete and labor intensive and should be automated. The new precipitation gauge systems should feed into data collection and communications equipment, as well as having manual readout capability. Modernization cost: about 3,000 hourly precipitation gauges.
- Automated Data Collection. Automated data collection is necessary to solve the problems of recruiting and retaining observers at a given location for the decades necessary to monitor climate conditions and climatic change. Automated data collection is not a requirement for all stations, but it is essential for the 3,300 stations in the network that directly support NWS operations. It is also not a comprehensive solution, because today's precipitation gauge technology does not permit complete automation. Modernization cost: about 3,300 automated data collection computers.
- Automated Communication of Data. The communication of data to NWS and NCDC should be automated for two important reasons: (1) communications is a burden on volunteer observers that could be eased via modem technology. This would also make it easier to recruit and retain observers; (2) automated data communication would speed the delivery of usable digital data to the user community. Modernization cost: about 5,000 data communications systems.

Conclusion. The panel endorses the overall technical approach proposed in the NWS plan. If implemented, the plan would provide important elements of a modernized Cooperative Observer Network.

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Acronyms

AEMN	Automated Environmental Monitoring Network
ASOS	Automated Surface Observing System
ATDTDCS	Automated Tone Dial Telephone Data Collection System
AWIPS	Advanced Weather Interactive Processing System
CPM	cooperative program manager
DAPM	data acquisition program manager
DOB	Data Operations Branch (NCDC/NOAA)
FAA	Federal Aviation Administration
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FY	fiscal year
GOES-NEXT	Next Generation Geostationary Operational Environmental Satellite
GPS	global positioning system
HCN	Historical Climate Network
H MT	hydrometeorological technician
LDAD	local data acquisition and dissemination
MIC	meteorologist-in-charge
MMTS	maximum-minimum temperature system
NADP	National Atmospheric Deposition Program
NAOS	North American Atmospheric Observing System
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
PC ROSA	computerized data entry and communication system (see ROSA)
RCC	regional climate center
RFC	river forecast center
ROSA	remote observation system automation
USDA	U.S. Department of Agriculture
WFO	weather forecast office
WSFO	weather service forecast office

Appendices

Appendix A

Survey Of State Climatologists On The National Weather Service Cooperative Network

July 31, 1997

1. In what year did you assume the position of state climatologist? 19 _______

2. In an average month about how much time do you (and your staff) devote to activities as the state climatologist? (MARK ONE)

_______ *Between 1 - 4 Days*

_______ *Between 5 - 10 Days*

_______ *Between 11 - 15 Days*

_______ *Between 16 - 20 Days*

More Than 20 Days

3a. How many cooperative network stations exist within your state boundaries?

Number

_______ *Climate*

_______ *Hydro*

_______ *Combined Climate And Hydro*

_______ *Total*

3b. How many of these belong to the historical network of cooperative stations?

_______ Number In Historical Network

3c. How many are institutional (vs. individual volunteer) stations?

_______ Number In Institutional Stations

4a. In general, how important is the cooperative network to the work you do as the state climatologist? (MARK ONE)

_______ *Not Important*

_______ *Somewhat Important*

_______ *Very Important*

_______ *Essential*

4b. In your opinion, is the importance of the cooperative network: (MARK ONE)

_______ *Increasing*

_______ *Decreasing*

_______ *Remaining about the same*

4c. How do you use the cooperative network data in your work? (MARK ALL THAT APPLY)

_______ *Research*

_______ *Data requests*

_______ *Teaching*

_______ *Archive development*

_______ *Outreach*

_______ *Other (Please specify*)

5a. In an average month, how often do you (and your staff) provide cooperative network data in response to requests for information from external users in the community?

_______ Number of times

5b. In an average month, how often do you (and your staff) provide cooperative network data to:

_______ Number of Times

_______ *a. Legal community*

_______ *b. Local*

_______ *c. Weather forecasters*

_______ *d. Academic climate and weather researchers*

_______ *e. Agricultural interests*

_______ *f. Local, state, and federal agencies*

_______ *g. Private consultants*

_______ *h. Educational institutions*

_______ *i. General public*

6. In an average month, how much time do you (and your staff) spend on activities related to the cooperative network: (MARK ONE)

_______ *Less than 5 hours*

_______ *From 5 - 10 hours*

_______ *Between 11 - 20 hours*

_______ *Between 21 - 30 hours*

_______ *More than 30 hours*

7. Below is a list of activities that you might have conducted in connection with the cooperative network. In an average month, how many times have you been directly involved in the following:

Number of Times

_______ *a. Interactions with the local Weather Forecast Offices*

_______ *b. Interactions with the National Climate Data Center*

_______ *c. Receipt and processing of cooperative network data*

_______ *d. Visits to cooperative observers*

_______ *e. Fielding requests for weather and climate data*

_______ *f. Interactions with the media*

8. Occasionally, state climatologists get involved in special activities in support of the cooperative network program. In the past year, have you (and your staff) been involved in: (MARK ALL THAT APPLY)

_______ *Special training programs for the cooperative observers*

_______ *Developing or participating in ceremonies having cooperative observers*

_______ *Publicity campaigns for the cooperative program*

_______ *NWS plans for improving or modernizing the cooperative network*

9. Various concerns have been expressed about the functioning of the cooperative network. In your opinion, how important is it to improve the following factors in the network?

		Not Important	Somewhat Important	Very Important	Essential
a.	*Lack of standard instrumentation..........*	1	2	3	4
b.	*Lack of maintenance for instrumentation*	1	2	3	4
c.	*Inconsistent reporting periods in the data reports..*	1	2	3	4
d.	*Insufficient quality control at the local level...*	1	2	3	4
e.	*Lack of timeliness in the data reports.....*	1	2	3	4
f.	*Difficulties in recruiting new volunteers..*	1	2	3	4
g.	*Lack of management commitment to the coop network program............................*	1	2	3	4
h.	*Insufficient resources at the WFOs (e.g., staffing, travel funds) to support the cooperative network program..............*	1	2	3	4
i.	*Outdated data collection and transmission technology...*	1	2	3	4
j.	*Insufficient support (e.g., incentives, training) to the volunteer observers.......*	I	2	3	4

Thank you very much for expressing your opinions,

Appendix B

Applications/Uses Of Weather And Climate Data

This is a list of some of the applications/uses of weather and climate data based on approximately 35,000 to 40,000 requests for information received at the Oregon State Climate Office from 1982 to 1989, and additional requests received at the Western Regional Climate Center from 1989 to 1996. Details may vary for other geographic regions.

Agriculture/Life Sciences

Plant diseases
- cereals/corn/berries/grasses/
- ornamentals/nuts/mints/melons/
- fruits/vegetables/hay/alfalfa/
- tubers/mushrooms/spices/

Plant growth
- planting times
- germination
- dormancy requirements
- frost probabilities
- lodging
- harvest conditions

Product quality
- seed spoilage
- transport conditions
- storage conditions

Product marketing

Chemical tests
- pesticides
- growth retardants
- growth enhancers

Seed certification

Relocations
- introducing new crops
- climate changes/fluctuations

Erosion
- water
- wind

Viticulture

Seed companies

Soil climatologists

Soil chemistry

Degree days - growing/chilling

Water Issues
- water consumption
- water stress

Drought
- frequency
- assessment
- designation

Groundwater recharge rate

Groundwater use rate

Groundwater contamination

Irrigation needs

Soil-water balance

Evapotranspiration

Evaporation climatologists

Runoff and nonpoint pollution

Insects
- moths/worms/beetles/flies/ants/mites/
- maggots/grasshoppers/crickets/caterpillars/
- chilling hours/dormancy egg-laying
- migration
- host plant environment

Pollination conditions

Metabolism rates (=temperature)

Pesticide effectiveness

Introduction of new pests
- helpful (deliberate)
- harmful (accidental)

Wildlife
- severe winters/summers
- habitat conditions
- migration
- transplantation
- breeding success
- birthing/calving success
- endangered species conditions
- refuge management

Fish
- lethal/injurious water temperatures
  - in streams and rivers
  - behind impoundments
  - ice effects
- weather-induced sediment loading
- passage time - anadromous species
- flow volume and timing
- ocean conditions
- hatchery conditions
- disease outbreaks
- condition of redds/eggs

Grazing and forage conditions

Caged and penned animals
- permanent (domesticated species)
- temporary (transplants/relocations)

Bird counts
- growth/hatch timing dispersion

Fungus distributions

Landscaping

Christmas trees

Riparian (stream) conditions

Experiment stations-research
- general databases
- conditions during experiments

Forestry
- reforestation
- viability of nursery stock
- clear-cut/canopied microclimates

Ecosystem management

Parkland grazing conditions

Regeneration rates

Tree-ring growth and density

Fire
- ignition and growth potential
  - triggering events
- firefighting conditions
- labor force
- equipment deployment
- mop-up, restoration, reseeding
- erosion susceptibility
- frequency assessment
- insect kills
- descriptive indices (e.g., Haines)
- lightning climatologists
- slash fire planning

Timber sale requirements

Blowdowns

Long-term climate variability

ENGINEERING

Energy
- audits
- heat loss calculations
- utility costs
- users
- cities/counties/companies/
- private citizens
- providers

utilities
hydropower supply
rate setting
energy demand
fuel planning
strategic planning

Alternative energy
(climate-sensitive sources)
wind - means and extremes
passive solar
small head hydro
heat pumps
passive cooling
rel. hum, alt. fuel motor

Construction
scheduling
equipment inventories
personnel hiring
outdoor painting
environmental conditions

Product testing
specific conditions needed
specific conditions not needed
fog instruments
corrosion tests

Uniform Building Codes

Hazardous phenomena
tornadoes
lightning
hail
ice storms
tropical storms

Depth of frozen soil

Balloon and helicopter logging
hard likelihood
performance standards

Power line routing

Stress on long atmospheric tethers

Airports
runway orientation
runway length
number of runways needed

Instrumentation

Diesel low-temperature additives

Chip manufacturers

Vinyl glue separation

Electric field studies

Design criteria
roofs
culverts, bridges, etc.
storm sewers
sanitary sewers
aquatic center pools
city and industrial ponds
cooling ponds
settling ponds
sewage treatment
hazardous waste containment
mine tailings
evaporation calculations

Lighting

Freeze/thaw cycle climatologies

Frost effects

Drifting snow (depth/orientation)

Dam design

Boiler capacity

Refrigeration needs

Generators

Greenhouse heating/cooling

Structure orientation

Structure strength

Pollution dispertion

Freeze probabilities

Excessive values of
heat
cold
wind
rain
snowfall
snow depth
humidity

Wave Erosion – causeways

LEGAL

Accidents
- cars
- motorcycles/bicycles
- airplanes
- railroads
- hang gliders
- falls on ice

Storm damage

claims adjustors
- real cause of damage
- ''act of God'' or expected
- crop damage
  - wind
  - hail
  - heavy rain
- ocean waves
- open seas/beaches
- event insurance claims
- outdoor gatherings/events

Environmental Impact Statements

Endangered Species Act needs

Biological Opinions

Grazing allotment decisions

Ecosystem Management background
Hazard Rankings

Environmental Assessments

Wetlands determination

Construction overruns

Landslides

Shipment delays/difficulties

Pesticide drift

Crime conditions
- murder/assault/violent crimes
- decomposition rates
- burglaries
- traffic tickets
- evidence reconstruction

Water
- landfill runoff
- frozen/broken pipes
- subdivision runoff
- landlord-tenant disputes
- leaky roofs
- storage of household goods
- industrial painting disruptions
- dike/containment breaches
- seed spoilage

Highway sanding/plowing conditions

Pollutant transport

Firefighting/rescue conditions

Cement hardening conditions

Health/workman's comp. claims

ECONOMIC DEVELOPMENT AND OTHER

Manufacturing/business development
- design criteria
- construction conditions
- marketing and sales impacts
- inventory deployment
- siting of shipping facilities

Relocations from a far
- businesses
- manufacturing plants

Retirement decisions

Weather - sensitive products
- marketing decisions

Agribusiness - development of
- new crops
- new products
- new markets

Outdoor gatherings
- festivals
- concerts
- air shows
- auto/air/water/foot races

Motion picture filming conditions

Hiring of labor
- seasonal industries
- construction
- agriculture/migrant laborers
- forestry
- recreation

News media
- magazines
- newspapers
- radio
- tv
- trade publications

Historical event conditions

Tourism
- vacation planning
- recreation climatology
- hiking/camping/backpacking/rafting/
- bicycling/skiing/windsurfing/fishing/
- hunting/mountain climbing/boating

Health
- relocation influences
- skin problems
- asthma/respiratory allergies
- trace chemical sensitivity
- solar exposure
- melanomas
- uv effects on vision
- cloudiness climatologies
- altitudinal variation of radiation

Chambers of Commerce

Report inclusions

National Weather Service
- background information
- local forecasting studies/tools

Classroom/Educational

Other states/Countries

Local climatologies

Climate trends
- yearly/decadal fluctuations
- regional climates
- el nino/southern oscillation
- global climate change

Home energy and gardening needs

Brochures

Interpretive public displays

General advice and interpretation

Source: Course on Weather and Climate Applications for Resource Management. Kelly T. Redmond. Western Regional Climate Center, Reno, Nevada. 1997.

Appendix C

Cooperative Observer Systems In Other Countries

The Canadian Cooperative Network Had 2,750 Active Stations In 1994. Canada Is Currently Preparing A Network Rationalization Plan That Is Expected To Be Completed In 1998 (A Draft Of The Plan Is Summarized In Appendix D). One Of The Options Being Considered Is The Use Of Automatic Sensors. Unlike The Cooperative Observer Network In The United States, The Canadian System Uses Gridded Estimates To Fill Gaps In Data. Canada Also Has Established National Standards For Data Collection By Any Network; Thus, All Data That Meets These Standards Can Be Considered "Official" Data.

Other Countfides With Cooperative Networks Include Australia, The United Kingdom, Germany, Mexico, China, And Russia. Australia Has About 2,500 Volunteer Observers Who Measure Daily Rainfall And 1,500 Automated Stations Linked Directly To The Bureau Of Meteorology. Mexico Had Thousands Of Stations, But When Payments For Observations Were Stopped In The Early 1990s, About 60 Percent Of The Observers Dropped Out Of The Network. China Has About 2,500 Paid Observers Who Make Three Observations Per Day.

Europe Has A Long History Of Cooperative Networks. Germany Has An Extensive Network That Publishes Quality Controlled Data On A Monthly Basis. Russia Began Taking Measurements In The 1930s And Had Developed A Network Of 13,500 Stations By The 1980s. The Number Has Now Fallen To About 10,000.

The Hydrology Section Of The World Meteorological Organization Maintains Information About Stations That Measure Precipitation In Every Country. At The 1997 Conference On The World Climate Research Programme In Geneva, Switzerland, Members Of The International Climate Research And Policy Communities Agreed That The Decline In Conventional Observation Networks Measuring Key Components Of The Climate System In Some Regions Is A Serious Threat To Climate Research And To The Detection And Attribution Of The Causes Of Climate Change.

Reference

Environment Canada. 1996. Climate Network Rationalization. Ottowa: Atmospheric Environment Service.

Appendix D

Summary Of The Canadian Network Rationalization Plan[1]

The Climate Network meets the needs of a broad range of users that depend on Environment Canada to ensure that there are adequate, reliable and comprehensive climate data. This information is extremely important to all sectors of the Canadian economy, and to the safety and security of Canadians.

The rationalization exercise has shown conclusively that much of the existing network is also essential for addressing five key Departmental priorities:

- understanding climate change and variability
- understanding atmospheric deposition and climate change impacts on the environment;
- meeting international and inter-jurisdictional commitments;
- providing knowledge on the Climates of Canada;
- and, supporting the weather forecasting mandate.

An evaluation of the spatial coverage and network size required to address the broad needs for climate information under Climates of Canada, concluded that on the order of 3,600 stations are required. The Working Group therefore proposes that station closures be minimized and be limited only to what is essential in order to address the budget reductions under Program Review.

In 1994, there were about 2,750 climate stations in the network. Since then, 250 stations have been closed and another 250 are tentatively scheduled to be discontinued to address the proposed reductions. Further reduction opportunities are extremely limited and must be undertaken with caution so as not to seriously undermine the Department's ability to address these key priorities.

The Climate Network is one of the most cost-effective observing networks in the Department. The data collection is done primarily by volunteers, or through partnerships at a marginal cost. A thorough analysis of the program costs identified that there are few areas where there are opportunities to reduce the delivery costs.

In 1994, the beginning of Program Review, the AEP was expending just under $3,500,000 on its climate monitoring activities. To address the proposed 35 percent reduction in this area requires a reduction of about $1,200,000. Salary reductions, cost savings from station closures to date and termination of contracts have resulted in a cost reduction of $730,000 so far. A number of strategies are proposed for reaching the Program Review target. They include: discontinuing lesser quality stations, further reducing of contracts, and reducing network densities in certain geographical regions.

Reference

Environment Canada. 1996. Climate Network Rationalization. National Weather Services Directorate/Direction generale nationale des services meteorologiques. Ottawa: Atmospheric Environment Service.

[1] This is the Executive Summary of the Climate Network Rationalization. November 1996. Ottawa: Environment Canada, Atmospheric Environment Service. National Weather Services Directorate.

Appendix E

Recommendations From The National Weather Service Modernization Committee's 1992 Report

Principles Of Observing And Managing Data For Climate And Climate Change Research

Because observations of basic weather and climate variables differ with instrument exposure to nearby structures and terrain, sensor response characteristics, the time of observation, and the method of recording, care must be taken to understand fully the ramifications of changing an instrument, site, or routine in order to maintain the integrity of decades of observations. As a minimum requirement for new weather observing systems, the following general recommendations are offered:

Recommendation 1.

Develop and apply standard procedures for collecting side-by-side overlapping measurements for all potentially significant changes made in observation and measurement techniques. This period of overlap should span at least one annual cycle.

Recommendation 2.

Make routine assessments of ongoing calibration, maintenance, and climate record homogeneity problems for which corrective action can be taken. Such assessments and subsequent actions must be documented and archived with the data.

Recommendation 3.

Along with routine transmissions of observations, regularly (as opposed to ad hoc) schedule transmissions of station observation and measurement practices, as well as local environmental conditions in the vicinity of the station, that are pertinent to the interpretation of the observations and measurements. Station histories should be a mandatory part of the permanent data archive along with the measurements and observations. They should be treated with importance equal to the data itself.

Recommendation 4.

Ensure that network designers and instrument engineers are provided climate requirements at the outset of network design and instrument design.

Recommendation 5.

Develop, wherever feasible, some level of "low-technology" backup to "high-technology" observing systems to safeguard against unexpected operational failures (power interruptions, lack of replacement parts, etc.).

Recommendation 6.

Archive raw data sensed from the instruments prior to transformation into standard atmospheric variables or products along with the processed data and processing algorithms.

Recommendation 7.

Restrict the number of station relocations to an absolute minimum.

Recommendation 8.

Discontinue observations of atmospheric variables with a long historical record (spanning many decades) only after a thorough evaluation of the impact on the climate record.

Recommendation 9.

Develop standard data packages that fully describe all algorithms, averaging procedures, quality control, homogeneity checks, and corrections that have been applied to the derived data. This now includes quantities such as temperature or precipitation, which can now be measured indirectly.

In addition to these general principles there are a number of specific recommendations relevant to existing and planned observing networks within the NWS.

Cooperative Weather Observer Program

Recommendation 1.

Develop a policy to assess biases introduced by station relocation or changes in instrumentation, and develop and deploy a standard observing system to be operated by part-time volunteer observers that meets accuracy and reliability requirements for climate data.

Recommendation 2.

Quantify the biases introduced by the Maximum-Minimum Temperature System relative to the liquid-in-glass thermometric measurements obtained in Cotton Region shelters. This is likely to be heterogeneous over various weather regimes and should be quantified on this basis.

Recommendation 3.

Quantify the bias associated with unshielded precipitation measurements. This bias is likely to be heterogeneous over various weather regimes and should be quantified on this basis.

Recommendation 4.

Wherever and whenever possible, conduct overlapping simultaneous measurements when there is a necessity to change observation sites. The simultaneous measurements could be discontinued when the impact of the change can be quantified. The National Weather Service Operations Manual (Section B-11) recommends overlapping observations for a period of one to three years. A rededicated commitment to this procedure is required. In an operational environment, this may not always be possible. For this reason it is advisable to operate a dense network of stations designed so that occasional station losses will not badly degrade climatic analyses. The trend over the past two decades of moving toward fewer and fewer temperature monitoring sites should be stopped or reversed.

Recommendation 5.

Site stability needs to be a key criterion in the selection of new sites. National parks should be ideal candidates for sites not likely to undergo substantial changes.

Recommendation 6.

Every effort must be applied to protect the sites and data sets in the network that have provided the crucial, long-term, consistent measurements utilized to assess climate change within the United States. The cooperative observer program should develop a prioritized list of network sites for preservation and continuation based on their contribution to climate change assessment.

Recommendation 7.

Every effort should be made to implement the technology to retain maximum and minimum temperature measurements on a midnight-to-midnight basis.

Recommendation 8.

Routine reports of each station's operations should be included with the monthly data sent to the archives. Ad hoc reporting of changes leads to questions regarding the quality of the station histories.

Reference

NRC. 1992. Toward a New National Weather Service--Second Report. Report of the Committee on National Weather Service Modernization, Commission on Engineering and Technical Systems, National Research Council. Washington, DC: National Academy Press.

Appendix F

Guidelines and Principles for Climate Monitoring

(1) Assess the impact of new systems or changes to existing systems prior to implementation.
(2) Require a suitable period of overlap for new and old observing systems.
(3) Treat the results of calibration, validation, algorithm changes, and data homogeneity assessments with the same care as the data.
(4) Ensure a capability for routine assessments of quality and homogeneity, including high resolution data for extreme events.
(5) Integrate assessments, like the International Panel on Climate Change, into global observing priorities.
(6) Maintain long-term stations.
(7) Put a high priority on increasing observations in datapoor regions and regions sensitive to change.
(8) Provide network operators, designers, and instrument engineers with long-term requirements at the outset of the design and implementation phases of new systems.
(9) Think through the transition from research observing systems to long-term operations carefully.
(10) Focus on data management systems that facilitate access, use, and interpretation of weather data.

Reference

Karl, T. 1997. Briefing to the NRC/NWSMC Panel on Climate Record: Modernization of the Cooperative Network. Asheville, North Carolina, June 16, 1997

Appendix G

National Weather Service Plan For Modernizing The Cooperative Observer Network And Technical Specifications[1]

A.1.5 Timeliness Of Data Availability

Currently, observation availability varies with station type and equipment. The vast majority of cooperative climate station observations are not available until after month's end, while observations from many hydrologic stations are available daily or when a given threshold of precipitation is reached. All climate and hydrologic station data need to be available daily to support NWS forecast and warning operations. For climate stations, daily maximum and minimum temperatures, 24-hour precipitation, and snowfall and snow depth are needed for improving both NWS zone and hydrologic forecasts. The previous week's daily climate station data are needed by the CAC the day after the week ends for their near-real-time climate assessment work. Monthly climate station data are needed as soon as possible after the month's end at the NCDC so that quality control, archiving, publication, and dissemination of the data can begin.

For hydrologic stations, precipitation (or river stage) observations continue to be needed daily or near-real-time if significant events occur to support NWS forecast and warning operations. Also, with the implementation of the WSR-88D, there will be a great increase in the need for real-time ground-based precipitation measurements to support radar information.

A.2 System Requirements

The system for the cooperative observer network will continue to consist of observers and their equipment. The new complete system must have the following general capabilities:

- Provide its own power supply
- Take temperatures and/or other identified observations automatically
- Store all observations digitally through either automated or manual input
- Transmit data automatically from observation site to NWS offices and NCDC
- Allow local readout of data
- Be modular in design to allow for easy future expansion of observing capabilities
- Have programmable memory to allow for the manual entry of data, notes (including maintenance visits), and a variety of transmission schedules
- Be able to operate (take and send observations) on its own power supply and communication equipment (not observers).

It should be noted that not all stations will have a requirement for all capabilities. In addition, somewhat different requirements could exist at individual stations, such as those that lose their observer and are in jeopardy of closing. Special situations and general requirements will be refined as more information becomes available during Phase 1.

A.2.1 Mandatory Design Requirements

The following general design requirements are mandatory features for new equipment:

1. Environment

The sensor elements of the observing equipment will be installed in outdoor environments at both private and public facilities. The climatic conditions will vary from hot desert to arctic. Therefore, the equipment must be sturdy and as inconspicuous as possible.

2. Power Supply

The equipment must have its own power supply and be operable with DC power. This is necessary to minimize

[1] This appendix is an excerpt from the Project Development Plan: Modernization of the National Weather Service Cooperative Observer Network. February 1993. Silver Spring, Md.: NOAA/National Weather Service, Office of Systems Operations, Observing Systems Branch.

observation failures (especially for severe weather events when AC power is prone to failure) and allow for more flexible siting of new equipment. Batteries should be of the "standard" type that are stocked routinely at most retail outlets.

3. Maintenance

A once-a-month calibration and maintenance check by the observer is required. The equipment design should provide simple built-in check routines for all major components of the system. Servicing should be accomplished by the simple replacement of defective modular units. The system calibration should operate in a manner that does not affect the data storage of the sensor. A visit by a technician should not be required more than once a year.

4. Equipment Life Expectancy

The equipment should be designed to last a minimum of 20 years, with a mean time between failure for individual components of 2 years.

5. Type of Record

In addition to the digitally store record, there will be a visual display at the site. Both will be capable of providing all data in both metric and English units. The interactive data terminal will allow manual entry of both administrative information and manually derived observations into the digital record. Administrative information, including observer name, station name and number, latitude, longitude, elevation, etc., shall be protected from change. Manually derived records may include observations of precipitation, temperature, snowfall, snow depth, special phenomena such as hail, and notes.

6. Data Collection

The on-site equipment must allow for both automated and human interaction. The equipment must be able to accept and quality control, process, store, and transmit all data/information from: the cooperative observer or NWS employees (manually entered), or from automated observing equipment.

Software allowing for human interaction must be extremely user-friendly (many cooperative observers are not experienced with computer technology).

The on-site equipment will be capable of automatically transmitting observed data in a self-timed mode and on a criteria basis. Generally, in the self-time mode, data will be transmitted at 7 a.m., 4 p.m., and midnight local time. In addition to current data, redundant data for the past seven transmissions will also be transmitted. The on-site system should also be able to store up to 68 days of data in digital (ASCII) format in a circular file.

7. Frequency of Recording

Temperatures will be recorded hourly. Maximum and minimum temperatures and precipitation will be recorded daily, at 7 a.m., 4 p.m., and midnight local time, or at other times to be determined. "At observation" (midnight) temperatures shall also be recorded. For automated precipitation stations, hourly precipitation shall also be recorded. One-minute and 15-minute hydrologic station data may also need to be recorded (during precipitation events only).

8. Length of Record and Frequency of Data Retrieval

The equipment should have the capacity to digitally record and store observations for 68 days. This will cover data for two calendar months data plus an additional week to allow for transmission delays and other problems. Data may be retrieved and transmitted hourly, three times daily, and monthly.

9. Maintenance

The equipment design should provide simple built-in check routines, and servicing should be accomplished by the simple replacement of defective modular units. A visit by a technician should not be required more than once a year.

10. Quality Control

The equipment will have some ability to detect and visually flag erroneous data entered into the record by an automated sensor or an observer. Data flags will be stored and transmitted as part of the digital data record.

11. The equipment will allow for calibration checks to be performed on all major components of the system by an NWS technician.

A.2.2 Desirable Design Considerations

The following design considerations, although not required, are considered desirable features of the equipment:

1. Cost

Low-cost equipment is very desirable. The cost of each complete stand-alone system should not exceed $5,000.

2. Maintenance

The equipment should be reliable and of modular design so that an observer can easily replace broken parts. The radiation shelter should be easy to clean. Replacement parts should be readily available and reasonably priced.