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1. INTRODUCTION

The COOP network is a nationwide weather. water, and climate-monitoring network of volunteer citizens and institutions that observe and report weather information on a regular basis. The network is managed by the National Oceanic and Atmospheric Administration and its NWS. Other government agencies participate in the program by providing funds and equipment. The network consists of more than 11,000 stations. the majority of which report daily maximum and minimum temperatures and totals. program precipitation The was established more than 100 years ago to meet agricultural needs. Yet, applications of COOP data in today's information-based society have flourished to influence all sectors of the nation's economy.

Unfortunately, the program has not kept pace with these growing demands or with current technology. Processing of the data is labor intensive and does not occur in real time. Quality control and archiving of COOP data are cumbersome and inefficient. The basic observing equipment is, for the most part, unchanged since the program's inception. While the data does meet the most basic demands, the COOP system does not meet the expanded needs of the modern world.

2. WHAT OTHERS ARE SAYING

The National Research Council conducted an extensive review of the Cooperative Observer Network in 1998 and concluded: 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 current COOP Network cannot be sustained [or improved] at present funding levels¹.

The NRC Panel made the following recommendations (among others):

- A multilevel network that is upgraded according to three main priorities:
 - 1. Maintain a network size and density that satisfies all major needs;
 - 2. Ensure that the quality of the data remains high; and
 - 3. Make a large subset of the data available faster preferably on a near-real-time basis.
- Standards for the instruments and siting must be maintained.
- 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 rapid expansion in the use of climate data and information for a wide variety of applications (Changnon and Kunkel 1999) further demonstrates the societal needs for a modernized COOP network. In addition, the academic community listed the

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¹*Future of the National Weather Service Cooperative Observer Network*; National Research Council, 1998

"operational, maintenance, and improvement of the national atmospheric observation and prediction systems" as *its highest priority for NOAA and the NWS* to undertake (Dutton et al. 1998). Unfortunately, "COOP data is the forgotten stepchild of surface data" [comments by John McLaughlin, 2002 President of the National Weather Association during a COOP Partners' Forum in September 2002].

The Program Development Plan (PDP) developed by NOAA/NWS is a response to the many findings and recommendations from the professional and scientific communities. The vast economic dividends from doing so are unquestioned.

3. VISION FOR A NATIONAL COOPERATIVE MESONET

The COOP modernization program will create a modern network that can serve the nation as the backbone of the National Cooperative Mesonet and the sustaining factor around which all surface environmental monitoring networks are integrated to save lives, enhance national security, protect property, support transportation, energy and agriculture, and promote the economic well-being by providing the highest-quality possible of realtime weather, water, and climate information, and possibly air quality and biochemical hazard data.

This vision for an integrated surface observing system is illustrated in Figure 1.

4. SCOPE OF THE COOP MODERNIZATION

The program to modernize the COOP network will produce the following deliverables:

- Consist of many modernized stations with high quality sensors that are sited and maintained at accepted professional levels and follow the accepted principles of climate monitoring (Karl et al. 1995; NRC 1999)
- Produce a contract, based on requirements within its Functional Requirements Document (FRD), for the acquisition, installation, and maintenance of automated NWS sites in the modernized COOP

- Develop an integrated network termed the National Cooperative Mesonet — that is expandable and adaptable to meet future observing needs and requirements
- Provide rigorous quality assurance of network data that are made available in real time through a single operations monitoring facility — to prevent 'bad' data (i.e., data that fail quality assurance procedures) from going public and to assist the national Program Manager with oversight of network operations (Figure 3)
- Provide 5-minute observations transmitted at hourly intervals with a goal for transmission at 15-minute intervals to better sync with WSR-88D scans and to provide initialization and verification data for evolving asynoptic models and the new products from numerical weather prediction
- Provide mesoscale data for public and private sector applications in NWP
- Provide opportunities for the private sector to develop thousands of value-added products and applications
- Emphasize NWS partnering with the public, private and academic sectors
- Create a legacy of providing open and accurate mesoscale data that are reliably available in real time

5. SPATIAL DENSITY OF SITES IN THE MODERNIZED COOP NETWORK

The required spatial density of sites in the modernized COOP was defined by the NWS and by the National Climatic Data Center (NCDC). Based on many competing factors, their review (Del Greco et al. 2000; Del Greco and Smith 2002) recommended a spatial density of one COOP site within each 20 nautical mile by 20 nautical mile grid square. Many respected meteorologists and climatologists also endorse the recommended density as appropriate for the modernized COOP.

Based upon the geographic area of the continental United States (~3 million square miles minus the areas of major lakes and otherwise inaccessible land areas) and the recommendation to place one modernized COOP site every 400 square miles, the modernized COOP will require automated monitoring equipment at ~7500 sites. Because of rugged terrain and large wilderness areas, ~500

Figure 1. The vision for an integrated surface observing system



Variables for Baseline/Enhanced Sites
Measurements at Baseline Sites
Air Temperature (1.5 m)
Precipitation (0.6 m)
Measurements at Enhanced Sites
Air Temperature (1.5 m)
Precipitation (0.6 m)
Plus possible sensors to measure:
Air Quality and Biochemical
Atmospheric Pressure
Incoming Solar Radiation (1.8 m)
Relative Humidity (1.5 m)
Soil Moisture (several depths)
Soil Temperature (several depths)
Wind Speed and Direction (2 m and 10 m)
Other New Sensors

Table 1. Measurements at an Automated COOP Site

automated COOP sites are recommended for Alaska and Hawaii.

Thus, about 8000 sites are required in the modernized COOP — subject to operational, budgetary, and socio-geographical limitations. *Traditional COOP sites that are not automated will continue to report in their current mode and will be maintained by the staff at WFOs.*

6. CONCEPT OF DATA COLLECTION AT A REMOTE COOP SITE

The modernized COOP network will be composed of two types of automated observing sites. All automated sites will provide the current baseline measurements of air temperature and precipitation. Some sites will provide the baseline measurements and enhanced measurements such as wind speed and direction, solar radiation, soil temperature and soil moisture, air quality and biochemical data (see Table 1 for details). Other sensors might include a nationwide array of differential global positioning systems to measure the precipitable water in a column above each COOP site, an array of low-cost radars specially designed to measure phenomena in the planetary boundary layer, or sensors to measure the surface fluxes of sensible and latent heat.

Human observers will continue to be a valued component in the modernized COOP network, though their function may change with

time. Until the manual observations of the liquidwater equivalent of frozen precipitation, the 24hour snowfall, and snow depth can be automated, human observations are indispensable (Figure 2). At some automated sites, the human observer may provide 6-hour snow depth. At other automated sites, a human observer may not be present. Regardless, a backup precipitation gauge is not planned for any site. Instead, automation of these manual elements will be a goal of the new Program Office.

7. REQUIREMENTS FOR THE COOP MODERNIZATION

The modernized COOP network is required to monitor the weather, water, and climate variability of the United States, provide highresolution and precise real-time data for operational warnings, forecasts and their verification, and provide data for use in evolving asynoptic numerical weather prediction and climatic models. The network will be expandable to meet future observational requirements and will collect data with at least a 5-minute time resolution. Data are to be transmitted at least hourly with a goal of 15-minute transmission intervals.

The Functional Requirements Document for COOP Modernization Program (also known as *Building the National Cooperative Mesonet*) provides the technical requirements of NOAA





Figure 2. Data collection and transmission at automated COOP sites

and its partners for sensor performance, siting, installation, data quality assurance, and maintenance. The requirements in the FRD will be approved by NOAA and its partners and constitute the Site Standards for the modernized COOP. A contract, based on the requirements within the FRD, will be established for the acquisition, installation, maintenance and longterm operation of automated NWS sites within the modernized COOP. An overview of system operations for the COOP portion of the National Cooperative Mesonet is shown in Figure 3.

8. CATEGORIES OF OBSERVING SITES IN THE MODERNIZED COOP

Within the two sensor configurations (baseline and enhanced), four (4) categories of observing sites will exist in the modernized COOP network:

- Category-1 New COOP sites where a contractor installs and maintains the new automated equipment that meet the site, sensor, and observing standards established for the modernized COOP (i.e., WMO [World Meteorological Organization] and NWS standards; listed in the PDP).
- 2. **Category-2** Current COOP sites where the contractor replaces and maintains the new automated equipment that meet the site, sensor, and observing standards established for the modernized COOP (i.e., WMO and NWS standards; listed in the PDP).
- 3. **Category-3** Existing sites with non-NWS equipment owned by a variety of partners whose platforms fulfill a spatial requirement of the modernized COOP.
- These sites must meet the established WMO/NWS standards for siting, sensor performance, data availability, data quality, routine maintenance, and required metadata (defined in PDP).
- All equipment is installed and maintained by the platform owner/COOP partner.
- Selection criteria include length of station history and variety of data types, but temperature and precipitation represent the minimum threshold. If the annual performance of a Category-3 site drops below COOP standards, the Program Manager for the modernized COOP will propose corrective

action that must be addressed for the site to continue as part of the modernized COOP.

- Some non-NWS sites may require support for partial upgrades of the resident sensors or its communications equipment to meet the standards for the modernized COOP. The program to build a National Cooperative Mesonet may provide the resources for these upgrades. Requests for these resources should come from the regional teams to the COOP Configuration Control Board.
- Quality-based support incentives are one means to attain climate-quality data from nonfederal observing platforms.
- Memoranda-of-understanding will be developed to define clearly the contributions or exchanges between the Government and COOP partners.
- A traditional COOP site could meet all siting standards and still become a Category-4 site due to the requirement to place only one automated site in each 20 mile grid square
- 4. Category-4 Existing COOP sites that are not automated, but instead, are supported by the NWS (i.e., the WFOs) as <u>traditional or</u> <u>legacy COOP sites</u>. These legacy sites will continue to report in their current mode. Equipment recovered from Category-2 sites will be reconditioned at the NWS Reconditioning Center to support the Category-4 sites.

Other observing sites not needed to meet the required station density or sites whose siting and observing standards fall below those established for the modernized COOP will become complementary additions to the integrated surface observing and data processing system of the National Cooperative Mesonet (Figure 1).

9. DETAILS ABOUT THE DATA

The data logger at each remote site in the modernized COOP will have a capability to store a significant quantity of data (~2-3 months). When communications problems develop, the missing data will be retrieved at the first opportunity — either when two-way communications are re-established or when maintenance personnel are on-site. The late-

arriving (hence missing) data will be entered into the local archives at the Central Facility in the most expeditious manner possible for transmission to system users.

The format of COOP data transmitted from the automated sites will be approved by the CCCB based on options provided by the contractor, but it shall be as simple and as practical as possible. However, the Government may specify a data format such as SHEF or BUFR.

The technology used to ingest automated COOP data into a distributed network of servers for access by the Central Facility will be determined by the COOP Steering Committee (CSC) based on options provided by the COOP Configuration Control Board. NOAA and its partners should investigate cost-effective methods of data transmission that leverage existing communication systems and recommend options. Two-way communications is a goal for automated COOP sites in the National Cooperative Mesonet, though multiple solutions for telecommunications may result. Regardless of the solutions, COTS technology will be used.

The acquisition and processing of automated COOP data will evolve with time and technological changes as will the procedures for data-quality assurance (QA) at the Central Operations and Monitoring Facility. The constant requirement is to acquire, process, quality assure, and disseminate the automated COOP data in real time (Figure 3) so as to avoid single points of failure in accessing network data.

In addition, data transmitted from the Central Facility will identify the platform owner and will have a QA flag that accompanies <u>each</u> datum. It is important to note that <u>original data must never</u> <u>be altered</u>.

10. THE IMPORTANCE OF DATA CONTINUITY STUDIES

Recognizing that changes in sensor technology will occur from the onset of the modernization program and continue through the life of the program, data continuity studies shall be conducted. Based on recommendations from NCDC, the SCs, and the RCCs, the data continuity studies will focus on (but are not limited to) COOP sites in the Historical Climate Network (HCN) which are selected for automation. The NWS will conduct these studies following established practices of the Government that are described in NWS Directive (NDS) 10-21 and its associated instructions.

It is important to note that data continuity studies associated with this modernization plan will be required only at a subset of the Category 2 sites — that is, only at locations where automated sensors are chosen to replace legacy or traditional sensors. Data continuity studies are not possible at Category 1 sites (new locations) or Category 3 sites (non-NWS locations) and are not required at Category 4 sites (traditional sites not automated).

11. REGIONAL SITE SELECTION TEAMS

Among the most important of decisions that will be made during the modernization of the Cooperative Observer Network will be the complicated and lengthy task of site selections. The regional teams must recommend <u>only one</u> automated COOP site for each grid square (20 miles x 20 miles). The design team for modernizing the COOP believes the standards for site and sensor operations are <u>design criteria</u> <u>that must not be compromised</u>. The goal is to have these standards adopted as broadly as possible.

To assist with this arduous selection process, Regional Site Selection Teams will be formed and organized around the domain of each NWS region. These multiple groups will participate in the process to recommend sites and site configurations to the Configuration Control Board to become part of the national modernization. The groups are chartered by the CCCB with a core membership drawn from NWS Forecast Offices (WFOs), River Forecast Centers (RFCs), NWS Regional COOP Program Managers (RCPMs), Regional Climate Centers (RCCs), State Climatologists (SCs), the National Climatic Data Center, the United States Department of Agriculture (USDA), the state Departments of Transportation (DOTs), and other partners who choose to be involved in the modernization process. Other public and private sector partners will be invited into the core membership or be invited to participate on an ad-hoc basis as various private and public mesonetworks are considered for integration





Figure 3. System operation for the COOP portion of the National Cooperative Mesonet

into the modernized COOP and the National Cooperative Mesonet.

12. SITE SELECTION AND SITE CONFIGURATION

The spatial density of sites in the modernized COOP requires a national grid that will be populated with one automated COOP site in each square mesh that measures 20 nautical miles by 20 nautical miles. While thousands of additional automated sites may be integrated into the National Cooperative Mesonet, <u>the Program Development Plan only addresses the first site to be selected for each grid square</u> in the modernized COOP. However, this spacing may not be needed or feasible in some parts of the nation due to terrain or inaccessibility.

The Regional Teams will evaluate Category-3 1. sites that meet the standards of the modernized COOP. whose equipment owners wish to participate in the COOP network and whose platforms fulfill a spatial requirement of the modernized COOP. These teams will make formal recommendations to the CCCB on Category-3 sites that should be included in the modernized COOP, and thereby, fill a void in the national grid. With this information, the Modernization and Acquisition Program Manager will know how many Category-1 and Category-2 sites remain to be automated.

Thus, the regional teams must identify the grid boxes where current COOP sites will not be recommended for automation.

- 2. Two site configurations are designed for automated COOP sites:
 - Baseline Sites All automated COOP sites in the National Cooperative Mesonet will provide baseline measurements of temperature and precipitation. Data transmission will occur in real-time at hourly intervals with a goal of transmitting 5-minute observations at 15-minute intervals. Many of the newly automated COOP sites will have human observers who will have the ability for real-time transmission of manually entered data. These manual observations include 6-(where available) and 24-hourly snowfall, current snow depth, liauid water equivalent of frozen precipitation, and

other elements specified in the observer's handbooks or instructions. Due to budget limitations, the modernized COOP sites will not have backup precipitation gauges should the automated gauge fail.

- Enhanced Sites Additional sensors may be added at the baseline sites to meet other needs of NOAA and its partners. Enhanced sites will be supported by agency requirements and will comply with the siting and observing standards for the modernized COOP.
- The Regional Teams will provide site 3. recommendations by categories, siting and installation priorities along with each site configuration to the CCCB. The Regional Teams will solicit participation from NOAA's public and private sector partners on an ad hoc basis to determine the location of sites where enhanced measurements will be made. All COOP sites with below-standard siting and exposure must be relocated if they are to be automated. Otherwise, traditional COOP site will be considered as a Category-4 site. Even so, a legacy COOP site could meet all siting standards and still become a Category-4 site due to the requirement to place only one automated site in each 20mile grid square.

13. COOP OPERATIONS AND MONITORING CENTER

The COMC represents a vital and independent unit responsible for data ingest, and quality assurance monitoring of data from the automated COOP and from networks that are operated by NWS partners who participate in the National Cooperative Mesonet. Even though the COMC will use a distributed ingest system with mirrored data servers, the center also is responsible for ensuring the timely dissemination of data from the automated COOP and the National Cooperative Mesonet to the broad user community as illustrated in Figures 1 and 3. The COMC will have quality assurance meteorologists and systems analysts who will inform the operational Program Manager of network performance on a weekly basis. The responsibility for maintaining up-to-date metadata files and for initiating trouble tickets will reside within the COMC.

As the modernization nears its end, the COMC will continue with its responsibility to track and oversee the resolution of maintenance decisions

sent to the COOP contractor. The COMC will be responsive to trouble tickets and for directing the resolution of inquiries from all data customers of the National Cooperative Mesonet (i.e., WFOs, RFCs, partner agencies, private companies, SCs, RCCs, and other sophisticated users). On a regular basis (e.g., quarterly), the COMC will provide performance metrics about the modernized COOP to the operational Program Manager.

All data from the National Cooperative Mesonet will have been quality assured in real time. The data and its QA flags will be made available to a distributed network of users. WFOs, RFCs, and NCDC are envisioned to receive their primary feed of COOP and National Cooperative Mesonet data via the Internet and various NWS telecommunications systems (Figure 3). The concept of COOP operations in the context of a National Cooperative Mesonet is illustrated in Figures 1 and 3. Administration of the automated COOP is illustrated in Figure 4.

14. SUMMARY

The COOP Modernization Plan, built around COTZ hardware (Commercial Off-The-Shelf), is a technologically wise and economically sound investment for the nation — IF the established standards of the World Meteorological Organization and the NWS are not compromised, the technology foundation is focused on quality and not quantity, and the quality and timeliness of COOP data is maintained through a Central Facility.

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Administration of the Modernized COOP and the National Cooperative Mesonet



Figure 4. Overview of program and data administration of the modernized COOP