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# DROUGHT MANAGEMENT: THE ROLE OF NEAR- REAL TIME WEATHER DATA

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# DROUGHT MANAGEMENT: THE ROLE OF NEAR-REAL TIME WEATHER DATA

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ABSTRACT

The ability to collect weather data in near-real time has improved because of technological advances, enabling weather data users to obtain more weather data over wider areas, and in a more timely fashion. The number of near-real time climate networks is increasing as new applications are found for climate data. More than fifteen states in the United States have established automated weather station networks. This paper presents an overview of recent developments in automated weather data collection in the United States and gives a detailed description of the network in Nebraska.

Near-real time weather data has many applications in agricultural decision making and in other economic sectors as well. Automated networks such as the one that exists in Nebraska can provide a practical, efficient, and cost-effective way of monitoring drought and assessing its impacts. In the United States, drought monitoring activities have been developed, at times, to support drought planning efforts by state government.

Drought planning can be defined as actions taken by government, industry, individual citizens, and others in advance of drought for the purpose of mitigating some of the impacts associated with its occurrence. Planning for drought /i.e., risk management/ has been shown to be more effective than the traditional approach /i.e., crisis management/. Activities associated with drought planning

include the development of a monitoring or early warning system, operational impact assessment programs, an institutional structure for coordinating governmental actions, appropriate drought assistance programs, financial resources to maintain operational programs and initiate research required to support drought assessment and response activities, and educational programs to promote the adoption of appropriate drought mitigation strategies.

Drought plans must be integrated within national and state or provincial levels of government, including regional organizations and the private sector, where applicable; they must also be adaptable to many sociopolitical situations and levels of government. A ten-step planning process is proposed in this paper as a way of developing drought plans that are appropriate to many sociopolitical situations and levels of government.

Nebraska's Drought Assessment and Response System /DARS/ was established in 1985 to provide timely and systematic data collection, analysis and dissemination of drought-related information. The Automated Weather Data Network /AWDN/ in Nebraska serves as one of the principal sources of information for the DARS. The development and operational characteristics of the AWDN are described in this paper. When properly used, timely data and informational by-products generated by the AWDN can help reduce and sometimes avoid impacts associated with extreme weather.

## INTRODUCTION

Technological advances in computer microelectronics and communication systems continue to decrease computation costs and improve the performance of computer equipment. These hardware improvements, which were initially applied to data logging during the late 1970s, have enabled weather data users to obtain more weather data, over wider areas, with less effort and in a more timely fashion than ever before. Some data loggers now offer a programmable interface between the analog signals coming from meteorological sensors and the digital storage media. Although care must be taken to match meteorological sensor requirements to the characteristics of the data logger, data collection technology is becoming increasingly flexible.

The ability to collect weather data in near-real time is a natural result of the advances in data logging and collection technologies. In the past, data collected at climate stations in the United States by cooperative observers often were not processed and disseminated for several months. The need for and value of current climate information in agricultural decision making has recently been noted /NAS, 1982/.

Many near-real time climate networks are forming because additional applications of the resulting data are anticipated. The near-real time aspect of these networks makes it possible for scientists to develop decision-making computer aids for use in agricultural operations and agribusiness, and in guiding the decisions of government policy makers. For example, near-real time weather networks are used in support of monitoring systems devised by some governments and organizations to provide early warning of the onset of drought conditions and the potential impact of those conditions on agricultural production, transportation, and so forth.

An overview of recent developments in automated weather data collection in the United States is presented in this paper. Particular attention is directed to the network that has evolved in Nebraska and adjacent states since 1981 /Fig. 1/. The concept of

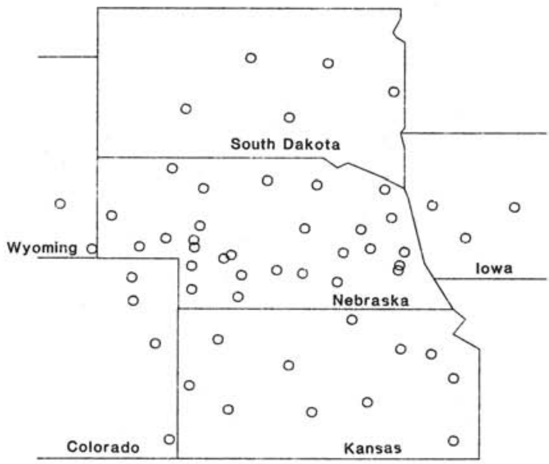


Fig. 1. Automated weather station network in Nebraska, Kansas, South Dakota, Iowa, Wyoming, and Colorado.

drought contingency planning is discussed first in general terms and then in terms of the specific details of Nebraska's Drought Assessment and Response System /DARS/.

AUTOMATED WEATHER DATA COLLECTION: RECENT DEVELOPMENTS

Individual states have been active in using the new computer and datalogging technology to collect information for a variety of meteorological variables. In 1980, researchers in Nebraska /Hubbard, et al., 1983/ and Ohio /Curry, et al., 1981/ began planning and installing automated weather stations. Nebraska's Automated Weather Data Network is discussed in more detail below. In California the NOWCASTING concept was developed /Hauser, 1981/ to provide forest and farm managers with improved local weather information for decision making. To this end, automated stations were installed in the Sacramento Valley.

More than fifteen states have established automated weather observing stations. Other states are considering the need for an automated weather data network. Municipalities, public resource managers, and the private sector are also active in collecting weather data from automated stations.

## DROUGHT MANAGEMENT: THE ROLE OF NEAR-REAL TIME WEATHER DATA

Near-real time weather data has many applications in agricultural decision making and in other economic sectors as well. One such application of these data and informational by-products is in support of federal, state, and regional climate monitoring activities. For example, drought has been widespread at least five times during the past decade in the United States /1976-77, 1980, 1983, 1985, and 1986/. Automated weather data networks can provide a practical, efficient, and cost-effective way of monitoring the onset, spread, and termination of drought and estimating likely impacts.

In the United States, drought monitoring activities have been developed, at times, to support drought planning efforts by state government. In other instances, drought monitoring activities have preceded the establishment of a formal plan. Regardless of the sequence of development, automated weather data networks, if properly managed, provide a particularly effective way of collecting data to ensure timely and reliable assessments of drought severity.

### *Drought Planning: A Definition*

Drought planning can be defined as actions taken by government, industry, individual citizens, and others in advance of drought for the purpose of mitigating some of the impacts associated with its occurrence. Drought planning can occur at many levels, although our discussion will relate particularly to actions taken by government. Regardless of the level, however, the traditional approach to drought management in the United States and elsewhere by individual citizens, governments, and international organizations has been one of reacting to droughts /i.e., employing crisis management/ rather than preparing for them /i.e., initiating risk management/. In the last decade, government officials and the scientific community have increasingly supported the preparation of plans for alleviating some of the worst effects of drought.

Drought planning should include, but is not limited to, the following activities:

1. A monitoring/early warning system to provide decision makers at all levels with information about the onset, spread, and termination of drought conditions and their severity.
2. Operational assessment programs to reliably determine the likely impact of the drought event.
3. An institutional structure for coordinating governmental actions, including information flow within and between levels of government, and drought declaration and revocation criteria and procedures.
4. Appropriate drought assistance programs with predetermined eligibility and implementation criteria.
5. Financial resources to maintain operational programs and initiate research required to support drought assessment and response activities.
6. Educational programs designed to promote the adoption of appropriate drought mitigation strategies among the various economic sectors most affected by drought.

*Drought Planning Objectives*

The objectives of drought planning will, of course, vary between levels of government and from country to country. To be successful, whether in the United States or elsewhere, drought planning must be integrated within the national and state or provincial levels of government, involving existing regional /multistate/ organizations and the private sector where applicable. At the national level in the United States, however, the diversity of impacts associated with drought and the multitude of federal agencies with responsibility for drought assessment and response make it difficult for a single federal agency to assume leadership in the development of a national drought assessment and response plan. The development of a national policy requires an interagency approach in these instances, under the leadership of a single agency. For this as well as other reasons, such as unique local water management problems, Wilhite et al. /1986/ have suggested that where a complex federal bureaucratic structure exists, as it does in the Unites States, drought planning efforts may be most effective if first initiated at the state level. In other settings, such as in less-developed countries, the drought planning process may be coordinated more easily at the national level since the bureaucratic structure may be less formidable.

The objectives of drought policy at the state level will differ from those at the national level, reflecting the unique physical, environmental, socioeconomic, and political characteristics of the area. For example, drought policy objectives at the state level might be:

1. To develop a monitoring system that provides early warning of impending drought conditions and impacts.
2. To develop an organizational structure that enhances drought preparedness and response by linking levels of government.

The development of the organizational structure referred to in the second objective should ensure adequate coordination between the federal and state level. The objectives of a national drought policy might be:

1. To prepare an organizational structure for assessing and responding to drought-related problems and water shortages.
2. To develop standby legislation that adequately addresses the impacts of drought through relevant assistance measures.
3. To encourage and support basic and applied research leading to the development of appropriate management strategies for all drought-prone regions.
4. To foster and support water planning and management activities at both the state and regional level.

*Drought Planning Process*

Drought planning has been described by Wilhite and Easterling /1987/ as a ten-step process /Fig. 2/. This process is intended to be flexible so that it can be easily adapted to many sociopolitical situations and levels of government. The first three steps actually involve mustering the necessary resources to initiate development of the plan. Continuous evaluation and updating of the procedures included within each step of the process is recommended to ensure that the plan remains most responsive to the needs of the region involved.

Our purpose in referring to the ten-step planning process is not to describe this process in detail, but rather to identify the role that automated weather data networks can play in support of drought planning efforts. One of the most important objectives of

Appointment of
Drought Task Force
**(STEP 1)**

Statement of Purpose
and Objectives
**(STEP 2)**

Inventory of Natural and Human
Resources, Financial Constraints
**(STEP 3)**

Development of Drought Plan
**(STEP 4)**

Identification of Research Needs
and Institutional Gaps
**(STEP 5)**

Synthesis of Drought Management
Science and Policy
**(STEP 6)**

Identification of Response Options
**(STEP 7)**

Implementation of Drought Plan
**(STEP 8)**

Development of Educational
and Training Programs
**(STEP 9)**

Development of
System Evaluation Procedures
**(STEP 10)**

Fig. 2. A ten-step drought planning process.

all drought plans is to provide timely and systematic data collection, analysis, and dissemination of drought-related information. This is an important component of Step 4 /see Fig. 1/. The data and informational products emanating from the data collected by automated networks can be the basis for a drought monitoring system. During periods of environmental stress, such as drought, near-real time information can assist users in making critical decisions that can reduce impacts.

Referring once again to Step 4, three primary organizational activities are associated with the development of a drought plan. First, a moisture assessment committee must be established, or coordination achieved with existing mechanisms, to monitor current and estimate likely future moisture conditions /i.e., precipitation, soil moisture, surface water storage, ground water, and stream flow/. Second, an impact assessment committee must be established to identify sectors most likely to be affected by drought. Third, a policy committee of senior-level officials should exist as a coordinating body to oversee the activities of the moisture and impact assessment committees. The role of the data collected by the automated weather network in the operation of the moisture assessment committee is discussed below.

Moisture Situation Committee. The moisture situation committee /MSC/ has four primary objectives: /1/ to inventory data quantity and quality from current observational networks; /2/ to determine the needs of primary users; /3/ to develop a drought monitoring system; and /4/ to develop or modify current data and information delivery systems. The functions of this committee require close interaction with the impact assessment committee.

## NEBRASKA'S DROUGHT ASSESSMENT AND RESPONSE SYSTEM /DARS/

In Nebraska, the MSC is a key component of DARS and is responsible for monitoring water supply and moisture conditions across the state. The committee is composed of representatives from the following organizations:

1. Conservation and Survey Division, University of Nebraska-Lincoln
2. Center for Agricultural Meteorology and Climatology, University of Nebraska-Lincoln
3. National Weather Service
4. Nebraska Department of Water Resources
5. United States Geological Survey
6. Department of Agronomy, University of Nebraska-Lincoln
7. U.S. Soil Conservation Service

The Conservation and Survey Division is responsible for leadership of this committee and arranges meetings when appropriate. An initial meeting is held each year during the first week of April. Subsequently, the frequency of meetings is based on the severity of conditions.

The Moisture Situation Committee is responsible for making assessments of precipitation, stream flow, reservoir levels, groundwater levels, and soil moisture conditions. The committee reports the results of each meeting to the chairman of the System Coordination Group.

In Nebraska, the Automated Weather Data Network /AWDN/ is one of the principal sources of information used by the Moisture Situation Committee to determine current climate conditions. The development of the AWDN, its operational characteristics, and the use of its data for decision making in agriculture is described below.

*Nebraska's Automated Weather Data Network*

In 1981 the Center for Agricultural Meteorology and Climatology /CAMaC/ of the University of Nebraska-Lincoln purchased and installed five automated weather stations in Nebraska to begin continuous collection and reporting of near-real time weather data. More stations were subsequently added to the AWDN. More recently, the network has been extended regionally to support drought monitoring, soil moisture assessment, and other studies. At this time, forty-nine stations in six states are reporting daily by telephone to CAMaC. Each station is able to represent an area fifty miles in diameter. Some of the more specific details of this network have been described by Hubbard et al. /1983/.

Collection. Collection of weather data by the AWDN begins at a remote site where a weather station is installed. A complete weather station consists of a Campbell Scientific Model CR21 or CR21x data logger and associated weather instruments mounted on a 9.8 ft./3 m/ tower. A cup anemometer and wind vane are used to measure wind speed and direction, respectively. These are mounted atop the tower. Air temperature, humidity, and solar radiation are measured at 5 ft. /1.5 m/ above the ground. Air temperature is measured with a thermistor and humidity is measured by an electronic hygrometer. The temperature and humidity sensors are mounted in a small instrument shelter. Global radiation is measured with a silicon pyranometer mounted on a horizontal surface at about 2 m above the ground.

A soil temperature probe consisting of a shielded thermistor is installed at a depth of 4 in. /10 cm/ below the soil surface. This depth was chosen because it is representative of seed placement depth at planting time. Each site is also equipped with a tipping bucket rain gauge for measuring precipitation. The tipping mechanism records each 0.04 in. /1 mm/ of precipitation received.

A microprocessor with solid-state memory is a part of each weather station. The microprocessor serves as an on-site data manager and is linked to a telephone with a DC-powered modem. The calibration constants for the various weather sensors are entered into memory for use in converting an analog sensor signal to digital /in the electronic sense/ form during the collection process. Sensors are monitored by the microprocessor once each minute, and hourly averages or totals are calculated. These hourly values are then stored in the memory of the station microprocessor.

Communication. Collection also involves communication between a microcomputer /IBM PC AT/, located in the CAMaC offices on the University of Nebraska-Lincoln campus, and each of the weather stations. Once daily, a communication link is established over the telephone lines. At the station, a modem receives the incoming call and activates a response from the microprocessor, where the data are stored.Mathematical treatment of the data prior to transmission results is a unique signature for each data grouping to be transmitted. Each data group and corresponding signature are then transmitted to the microcomputer. The process of generating the signature is repeated by the microcomputer and data are retransmitted if the two signatures do not match. This ensures that record received are identical to those transmitted by microprocessors located on-site. All calls take place over conventional phone lines and each weather station site requires only a private telephone line.

Software to accomplish the collection and archiving of weather data automatically was written by CAMaC staff. The computer language used to write the software was Professional Fortran. The telecommunications program was written in Turbo Pascal by Campbell Scientific Inc. of Logan, Utah.

Quality Control. Summarization of the data begins with quality control and flagging procedures that have been implemented on the CAMaC microcomputer. Data are compared to reasonable upper and lower limits for each parameter and any outliers are flagged and checked by the AWDN technician. The diurnal cycle of radiation from the sun is used to double-check the data logger's internal clock. Flags are attached to any data not fitting the diurnal cycle. Intercomparisons of data are routinely made and any bad or missing data are estimated by a distance-weighted interpolation process.

Overview. A general schematic of the linkages present in AWDN is shown in Fig. 3. Near-real time hourly climate data is retrieved

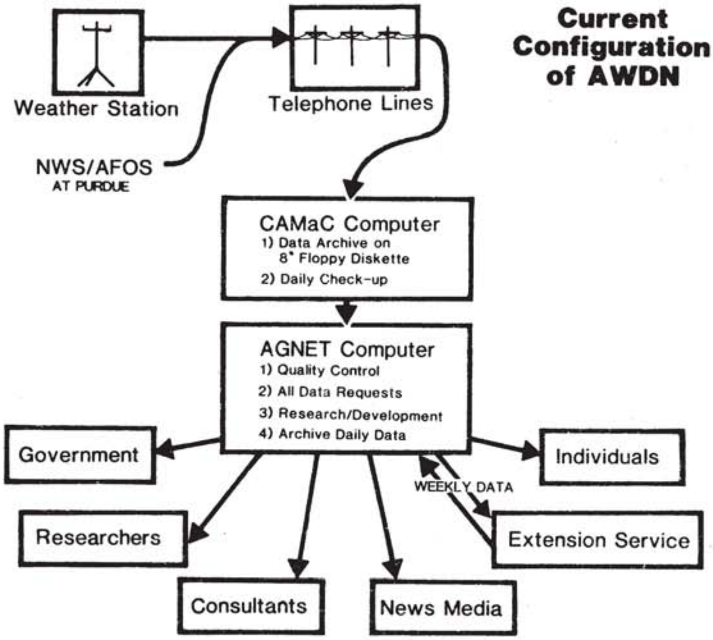


Fig. 3. Current configuration of the Automated Weather Data Network /AWDN/ in Nebraska and adjacent states.

from each weather station at about 1 a.m. The collection of weather data for the previous twenty-four-hour period is automated, requiring no human intervention. The telecommunications package developed by CAMaC also permits manual interrogation of the weather stations at any time.

After calling each weather station, the CAMaC computer stores the new measurements in the master data archive. Another program does a preliminary check of the weather data collected to identify suspicious data. Appropriate meassages are printed so that these data can be checked by a specialist. The computer then organizes the data for the most recent twenty-four-hour period and prepares it for transmittal to a mainframe computer, where subscribing users can conveniently access weather-related programs.

The mainframe computer in this case operates an agricultural management network, known as AGNET. The AGNET system developed at the University of Nebraska /Thompson, 1981/ is an example of a system developed for use in the agricultural management environment. It is an interactive computer system containing more than 200 programs for use by subscribers. Many users have access to the data generated by the AWDN and stored on AGNET. The weather data stored in the AGNET system can be accessed directly or used indirectly in specific programs by telephone communication from any terminal. The weather-related products available on AGNET are accessed 400-2,000 times per month /Table 1/.

TABLE 1.

Weather programs for AGNET-1984.

APPLIED

| | |
|---|---|
| BEEFGROWER | - simulates the performance of beef cattle in the feedlot. |
| BINDRY | - estimates drying time in a natural air grain drying system and the rate at which grain can be loaded in the bin. |
| CROPSTATUS | - provides 20 up-to-date weather summaries related to crops and animals. |
| IRRIGATE | - determines a crop watering schedule, user records rainfall, irrigations and soil moisture and computer projects on irrigation window based on recent weather. |
| ET | - calculates Penman evapotranspiration for selected times and crops by station or for regions of the state. |
| WEATHER | - lists and/or summarizes weather data by stations or in maps of the state. |

RESEARCH

| | |
|---|---|
| GREENHOUSE | - simulates the energy and moisture balance within single span greenhouses. |
| REALSOY | - simulates growth and development of soybean plants and estimates final seed yield. |
| CORNGRO | - simulates growth and development of corn and estimates final seed yield. |
| CUPID | - simulates the environment within a crop canopy. |

## SUMMARY AND CONCLUSIONS

In summary, recent technological advances in microelectronics and communication systems have made it possible to collect near-real time weather information on a variety of meteorological parameters and disseminate that information to a wide range of users. The technology for accomplishing weather data collection, quality control, and archiving on a microcomputer has been demonstrated, and those who are interested in such a near-real time system can employ Nebraska's AWDN as a model to readily implement a weather monitoring system. However, near-real time weather monitoring alone will not solve the problems of every region. Based on Nebraska's experience, a successful system must have the full commitment /people, money, and equipment/ of administrators and the support of users. Scientists, administrators, and users must work together to determine what climatic issues are of highest priority to all groups served by the system and then develop a comprehensive plan to address these issues.

Many potential applications exist for using near-real time weather information in decision making, ranging from farm level to national government. The timely availability of these data and informational by-products provide users with the opportunity to incorporate this information in critical weather-dependent decisions. Proper use of this information can reduce and, in some cases, avoid the impacts associated with extreme weather and climate events.

Drought is a constant menace and occurs almost everywhere around the globe. Governments have traditionally responded to drought in an untimely and ineffective manner. This paper illustrated how near-real time weather data provided by an automated weather data network can enhance a government's ability to manage drought more effectively. These data can form the basis for better and more timely information to decision makers on the spatial and intensity characteristics of drought and its likely impacts. However, it is essential that institutional arrangements be made to guarantee the flow of this information within and between levels of government. Nebraska's Drought Assessment and Response System, established in 1985, is a good example of government's use of this information to achieve more effective drought management in a drought-prone region.

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