AVAILABILITY OF CLIMATE DATA FOR WATER MANAGEMENT

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ABSTRACT. Evapotranspiration from crops causes depletion of soil water reserves and without rainfall or irrigation to replenish the soil moisture serious crop stress can occur. The Nebraska Automated Weather Data Network (AWDN) was initiated in 1981 in order to provide information on weather variables that effect crop water use: air temperature, humidity, solar radiation, wind speed/direction, soil temperature, and precipitation. By 2003 the public access to AWDN and related products reached 12M per year. This paper describes the Automated Weather Data Network (AWDN) and the interfaces that provide near real time climate services with emphasis on evapotranspiration (ET) or crop water use. Currently, automated weather stations are monitored daily at 54 locations in Nebraska and 10 new stations have been purchased with federal drought funds. There are over 150 stations available in a nine state region.

1.0 INTRODUCTION

Several major hurdles must be cleared in order to adequately monitor climate resources. First, an adequate data collection system is needed to monitor critical variables at an acceptable sampling and delivery frequency. Second, quality control (QC) and assurance (QA) are necessary. The QC and QA, when linked to a quick response maintenance and repair capability ensures complete and accurate data for use in summaries and products. Third, regular client feedback (surveys, advisory committees, etc.) is needed in order to meet the needs of decision makers and resource managers in the targeted sectors of the economy. It is essential that the interfaces serve the general consulting communities, so that the private sector can develop and deliver value-added products . In some cases, applied research is needed to develop models and other technological tools for the purpose of relating the current climate situation to the area of interest (agriculture, water resources, energy, transportation, recreation, etc.). Another requirement is adequate technology to deliver the summaries and products in a timely manner.

The use of electronic equipment to automate the collection of measurements from weather-related sensors at remote sites has ushered in a change in the ability to collect weather data and Nebraska was the clear leader in this revolution (Hubbard et al., 1983).

Communication and computer technology have greatly increased the ability of scientists to monitor and disseminate the important climate signals. The High Plains Regional Climate Center (HPRCC) in the School of Natural Resources engages in applied research necessary to improve climate products including crop water use estimates.

2.0 DATA COLLECTION

Automated weather stations are maintained at 54 locations in the state. These stations collect hourly data for variables known to be of importance to agricultural crop and livestock production, including air temperature and humidity, soil temperature, precipitation, wind speed and direction, and solar radiation. A computer calls each station beginning at 1 A.M. The data for the previous 24 hours is downloaded, quality controlled, and archived for use by the HPRCC system. A telephone line or a cell phone is installed at each site. A flow diagram is shown in Fig. 1. Software and system components were developed for this system (Hubbard et al., 1990).

Weather stations at remote sites monitor sensors every 10 sec and calculate the hourly averages and where appropriate totals. The minimum set of sensors is shown in Table 1. The installation heights shown are standard for AWDN stations.

The AWDN in Nebraska has grown from 5 stations in 1981 to 54 stations in 2003. Much of the initial growth was due to the interest of researchers who were operating digital weather stations without the benefit of telecommunication or a data management system. Beginning in 1983, the AWDN began to include sites from surrounding states (currently 100 additional stations are collected from 9 nearby states). As time passed the interest in additional stations came from the private sector, resource management agencies, and communities.

Maintenance is an important and costly activity. Replacement of sensor components includes bearings in the cup anemometer and potentiometers in the wind vanes. Relative humidity sensors are calibrated on an annual cycle. The tipping bucket is checked for level and calibrated each year by using the volume to mass relationship for a known amount of water. Leveling screws are adjusted if needed in order to obtain the correct number of tips. Certain sensors are removed from service for calibration. The silicon cell pyranometers are calibrated as a group against an Eppley Precision Spectral Pyranometer (Aceves-Navarro et al., 1989). In a similar manner anemometers can be calibrated against a "secondary standard." Thermistors and humidity sensors can be calibrated directly under controlled conditions. The AWDN facility maintains dry block calibrators and dew point generators for use in calibrating temperature and humidity sensors. Complete troubleshooting guidelines have been developed. AWDN repair and calibration facilities are maintained.

3.0 DATA MANAGEMENT AND APPLICATIONS PROGRAMS

A tremendous amount of data can be generated with an hourly weather network. About 1 Mb of data is produced annually for any three stations. If this data is to be used effectively it must be easy to access. Thus, data management is a real concern. In the case of the AWDN, the approach has been to develop a data management system written entirely in FORTRAN (Hubbard et al., 1992). This system is indicated as the data base component in Fig. 1.

A suite of utility programs includes tools for data management, quality control, data retrieval, and station selection. Applications software includes programs (see Fig. 1) to analyze data and produce summaries for any variable over any desired time period. Summaries include temperature, precipitation, heating and cooling degree days, growing degree-days, evapotranspiration, leaf wetness, soil water, and crop yield.

On the HPRCC Internet site for on-line subscribers a crop water use report may be generated by selecting inputs from the screen depicted in Fig. 3. The user is able to choose any combination of crops, maturity groups, and emergence dates.

An example of the ET product is shown in Fig. 4 as it would appear on the computer screen.

4.0 RESEARCH NETWORK

The High Plains Automated Weather Data Network has served as a source of data for both research and service efforts. Some of the research aspects will be covered in this section and the service aspects will be covered in the following section.

Evaporation (ET) at the earth's surface is a major component of the hydrological cycle and is critical to irrigation scheduling from a water balance approach. Research in the area of evapotranspiration has included efforts to identify the effect of random and systematic errors in measurements used to calculate potential ET (Meyer et al., 1989) as well as efforts to improve the projections of potential ET (Meyer, et al. 1988). The AWDN has also been essential to determining appropriate limits for potential ET in the very arid parts of the High Plains region (Hubbard, 1992).

Monitoring of drought conditions is another research focal point. Robinson and Hubbard (1990) evaluated the potential use of network data in the assessment of soil water for various crops grown in the High Plains. A Crop Specific Drought Index

(CSDI) for corn has been developed and tested (Meyer, et al. 1992a). Results from the studies indicate that the CSDI for corn will be valuable when applied to drought assessment (Meyer, et al., 1992b). A CSDI for sorghum (Paes de Camargo, 1992) was later developed.

Accuracy of interpolation between stations in a network is a topic of research. The spatial interpolation of potential ET (Harcum and Loftis, 1987) was examined using AWDN data. On a related topic, the AWDN data were used to examine spatial variability of weather data in the High Plains (Hubbard, 1994). Another study examined whether it is better to interpolate the weather variables for computing potential ET at a site or to interpolate the potential ET calculated at the surrounding stations (Ashraf, et al., 1992).

The AWDN system has been used to collect basic meteorological data for various field experiments (e.g. Hubbard, et al., 1988). Data taken by the system are also being used in urban water use studies and in project Storm.

5.0 SERVICE NETWORK

Self-Service Access. The HPRCC staff developed an On-Line Internet system (http://www.hprcc.unl.edu/online/home.html) for users which features interactive use of the entire historical archive of the HPRCC. A revised system was released on May 1, 1996 and users transistioned to the new system.

Digital data disseminated by the HPRCC from the new system can be redistributed several times by HPRCC clientele to their user audiences.

On-Line Access System

The current On-line System offers both opportunities and challenges. The positive features of the system are:

- accessible via the web
- the computing power of a work station.
- clientele have on-line access to the historical data archives that date to the late 1800's.
- users can make general summaries according to their own specifications
- up-to-date data is available for decision makers who require it
- an autopilot feature allows users to schedule future summaries, saving the time otherwise required to logon and re-create the summary

- automated information delivery by email or ftp
- greater simplicity of interface
- decreased learning curve
- navigation by 'mouse' point-and-click

The combined accesses to HPRCC internet resources is currently about 12M per year.

6.0 NEW APPLIED CLIMATE INFORMATION SYSTEM

NOAA's National Climatic Data Center (NCDC) and NOAA's Regional Climate Centers (RCCs) are developing a new internet based system designed to provide directed access for user specified queries to the entire combined climate data archives. The new system is called the Applied Climate Information System (ACIS).

ACIS is a distributed and synchronized system that provides consistent and timely climatic products. The implementation of the system at multiple centers provides redundancy and ensures timely availability. The synchronization and standardization ensures that users will receive the same information regardless of the point of contact. The system was designed with layers of independent modules interconnected by Common Object Request Broker Architecture (CORBA) to ensure flexibility in both the location and programming language of the modules. We have used 'open source' and standards based software to reduce any barrier to usage.

ACIS was designed to allow access through three interfaces that provide a different balance of detail, customization, and ease: 1) low-level CORBA, 2) mid-level XML-RPC and 3) high-level web-based interfaces (html). Even the low-level interface provides a fairly abstracted and coherent view of the climate data. Figure 1 shows a series of program steps in the python programming language. In part A, the program gets the acis_id for a station associated with a Cooperative Observer Network station identifier that reports daily maximum temperature (TMAX). The acis_id is an internal id that will define a climatologically coherent record regardless of how the data is reported (NCDC TD3200 format, shef-encoded or locally keyed). Part B of the program creates a TSVar (time series variable) that represents the TMAX values from that station. When a date range is set and data requested, the data server will collect data from local or remote data stores and return it to the client. The client program does not need to know the data format or location. These data stores will change dynamically to return the best available data at the time of the request.

To avoid a single point of failure and regulate traffic, redundant ACIS computer servers are maintained around the country at the six Regional Climate Centers. Data are available from NOAA networks including the Cooperative Observer Network, the Hourly Surface Airways Network, and the Historical Climatology Network. Additional meso-net data such as the Automated Weather Data Network in the High Plains region is also available. Future plans include access to other network data including the USDA's SnoTel Data and NOAA's Climate Reference Network, and several state networks. ACIS provides seamless access to a continuously updated data stream. As a result, standardized products and maps are available for various climate variables and time frames right up to the current time. Climate data users may subscribe to ACIS to obtain access to both near-real time and historical climate information and will receive the same information regardless of which RCC interface they choose. An example of the RCC user interface (UI) is illustrated in Fig. 2 with the UI from the Northeast Regional Climate Center. The UI is standardized for all RCCs with the exception of organizational logos and locally developed products. The UI provides direct access to products that are available for both single station and multiple station analyses and can include listings, comparisons to normal,rankings, extremes of record, first and last occurrence dates and other statistical information on a daily, monthly, or seasonal basis.

The ACIS system is now available to the public. The link to the ACIS system is available at http://hprcc2.unl.edu/Climod/ . Additional links can be found at http://rcc-acis.org. These links take the user to the UI where it is possible to view sample products and use ACIS to set up "individualized" requests on-line, although you will not be able to receive the actual summaries until you become a subscriber. This approach gives you the opportunity to try out the system and see what stations and years are available, as well as see samples of the product/summary before subscribing. Subscription information is available at the bottom of each UI.

7.0 FUTURE ISSUES

The AWDN network must be properly maintained. Personnel for this network include a field technician, a data QC technician, and a computer support person. The projected cost of the network in Nebraska, not including any expansion, is approximately $200,000 per year.

Further research into the factors affecting crop coefficients for the Nebraska Potential Evapotranspiration equations as well as the utility of using the Penman-Monteith equations for ET is needed. Another challenge is the transformation of variables (like wind speed) from a reference weather station site into a crop field of interest.

Table 1. Sensor installation, accuracy and sampling information.

Sensor	Variable	Installation Ht.	Accuracy	Hourly
Thermistor	Air temperature	1.5 m	0.25 C	Avg.(C)
Thermistor	Soil temperature	-10 cm	0.25 C	Avg.(C)
Si Cell Pyranometer	Radiation-Global	2 m	2%	Flux ($W\ m^{-2}$)
Cup Anemometer	Wind speed	3 m	5%(0.5m/s start-up)	Total Passage (ms^{-1})
Wind Vane	Wind direction	3 m	2°	Vector Direction
Coated Circuit	Relative humidity	1.5 m	5%	Avg. (%)
Tipping Bucket	Precipitation	0.5 to 1 m	5%	Total (mm)

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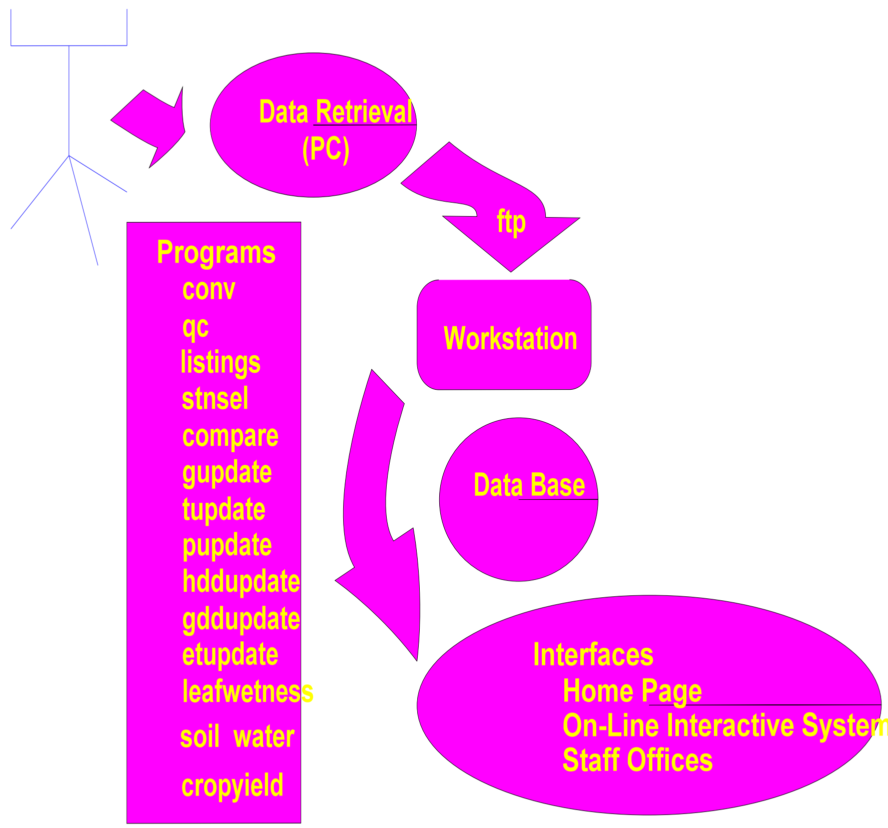


Fig. 1. The flow of data through the automated weather network.

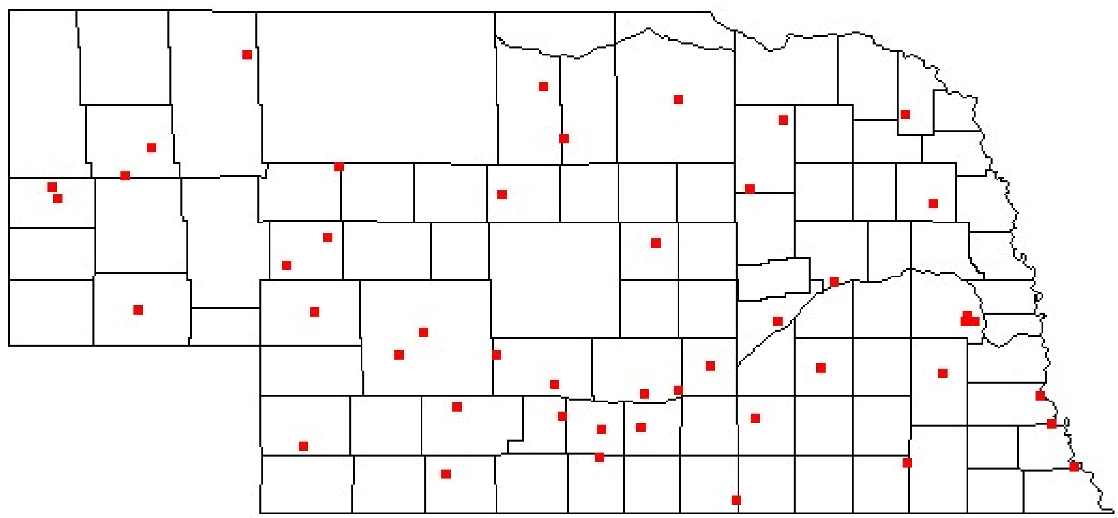


Fig. 2. The AWDN stations in Nebraska. There are eight stations located in the Lincoln vicinity where only one symbol is shown. See other state maps on-line at http://hprcc.unl.edu/awdn/.

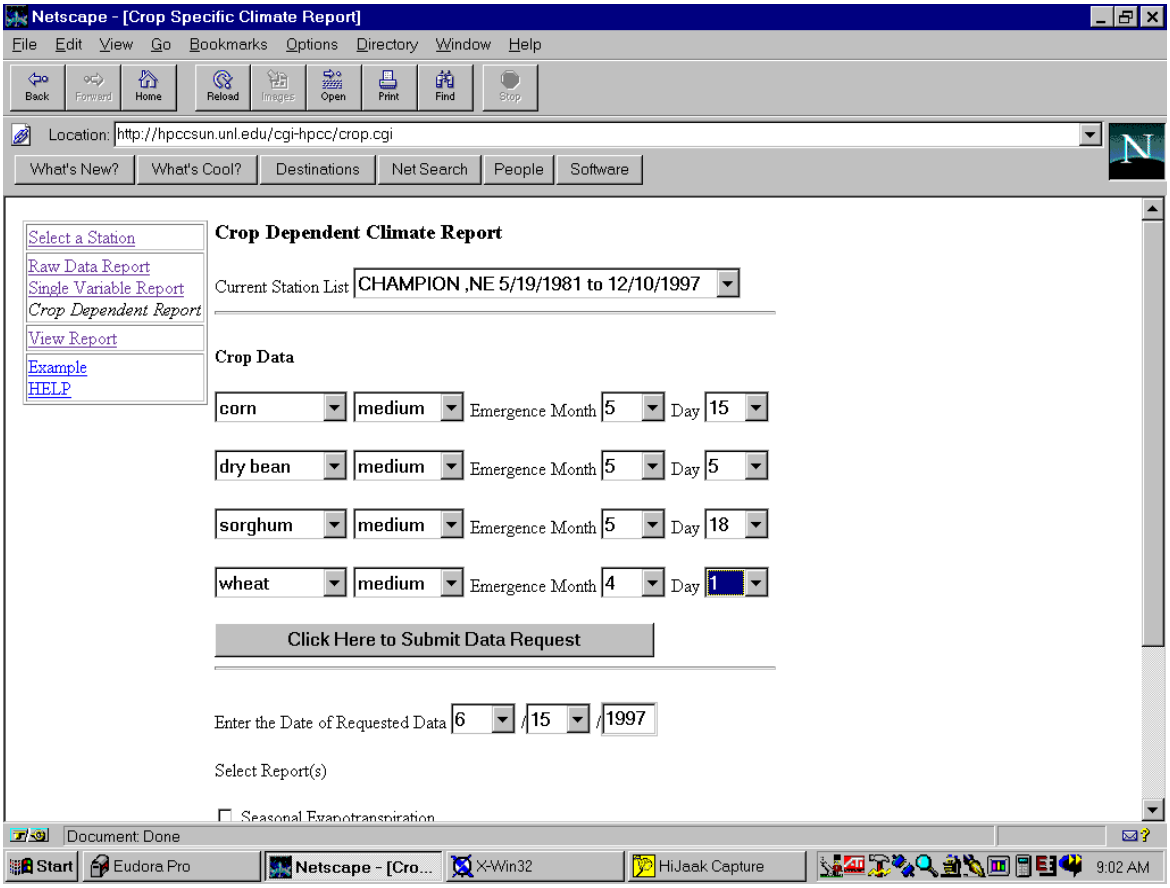
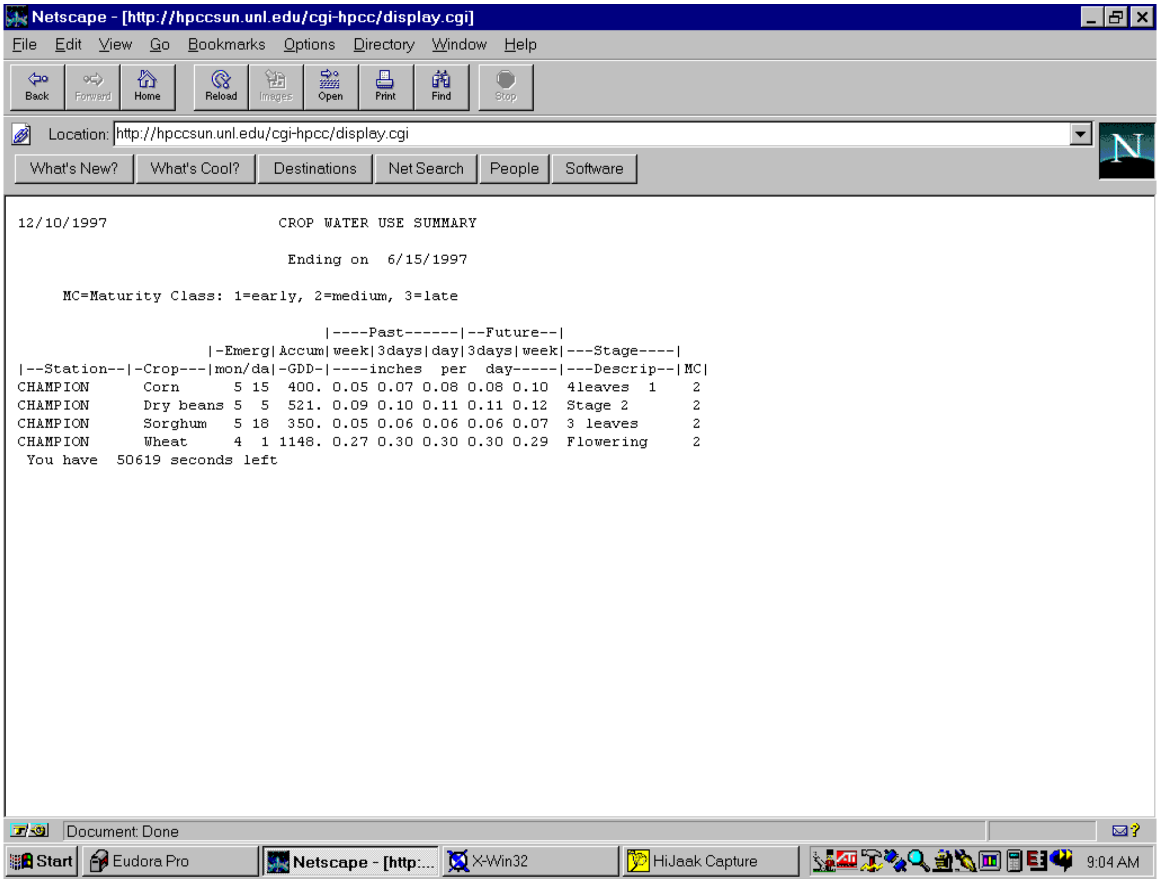


Fig. 3. Input specification screen for the ET Product.

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12/10/1997                  CROP WATER USE SUMMARY

                             Ending on  6/15/1997

     MC=Maturity Class: 1=early, 2=medium, 3=late

                                 |----Past------|--Future--|
                    |-Emerg|Accum|week|3days|day|3days|week|---Stage----|
|--Station--|-Crop---|mon/da|-GDD-|----inches  per  day-----|---Descrip--|MC|
CHAMPION      Corn      5 15  400. 0.05 0.07 0.08 0.08 0.10  4leaves  1    2
CHAMPION      Dry beans 5  5  521. 0.09 0.10 0.11 0.11 0.12  Stage 2       2
CHAMPION      Sorghum   5 18  350. 0.05 0.06 0.06 0.06 0.07  3 leaves      2
CHAMPION      Wheat     4  1 1148. 0.27 0.30 0.30 0.30 0.29  Flowering     2
 You have  50619 seconds left
```

Fig. 4. Format of the ET product from the On-line System.