ACCESS AND USE OF ET DATA ON THE INTERNET

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ABSTRACT. The High Plains Climate Center (HPCC) was established in 1987 and is one of six centers providing coverage of the continental U.S. HPCC is located at the University of Nebraska in Lincoln. HPCC's mission is to carry out applied climate studies to aid in the development of improved climate products for use in an array of climate services, including data collection, analysis, and dissemination in the HPCC region. This paper describes the Automated Weather Data Network (AWDN) and the interfaces that provide near real time climate services with emphasis on ET or crop water use. Automated weather stations are monitored daily at 139 locations in ten states. Data are subjected to quality assurance testing and made available to the public. AWDN data are merged with a stream of data that includes the cooperative network data and historical data dating to the 1800's. Queries by the public to the subscription based On-line interactive system have reached 6000-7000 per month while queries to the HPCC home page average 15-20K per month.

1.0 INTRODUCTION

Regional Climate Centers (RCCs) have been established in response to the need to improve climate services at the local, state, and regional levels (Changnon et al., 1990). One of the fundamental challenges for RCCs is to advance the provision of climate information for the nation's economic, governmental, and social sectors.

Several major requirements must be addressed in order to improve climate services. One requirement is an adequate data collection system in terms of number of variables measured, sampling frequency, and timeliness of data transferal and receipt. A second requirement is the need for sufficient quality control and analyses procedures. This requirement demands that accurate data be available for use in summaries and products and that the content of these be keyed to the needs of decision makers and resource managers in the targeted sector of the economy. In many 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.

Switching to a Pivot

How does the cost of irrigating at 125 foot lift with a diesel gravity system compare with using a diesel center pivot system?

This comparison requires some assumptions on the area to be irrigated and the efficiency of application for the two systems. In the comparison made here, we consider two gravity systems serving 80 acres each versus one center pivot serving 130 acres with 30 acres remaining dryland. Crop water use is 12 AI. The yield from irrigated acres is assumed the same for both systems.

These data suggest the gain from irrigating the additional 30 acres does not cover the additional costs ($2,820 gain vs. $3,713 added costs). This result will depend upon a number of factors including the number of acres each system serves.

Table 4. Flood vs Pivot System.

	Flood	Pivot	
Irrigated Acres	160	130	
Head	148 ft	206 ft.	
Application Efficiency	50%	95%	
Acre-Inches pumped/acre	24	12.6	
GPM	1,000	800	
Pumping hours	1,728	921	
Repairs/hour	$0.80	$1.16	
Fuel and lube/hour	$2.39	$2.84	
Operator labor, hours/acre	1.5	0.4	
Annual Irrigation Costs			
Interest	$3,226	$2,596	
Depreciation	5,514	5,575	
Repairs	1,382	1,068	
Fuel and lube	4,130	2,616	Gravity
Labor @ $7/hour	1,680	364	Added Costs
Total	$15,932	$12,219	$3,713
Pivot Corners	Gravity	Dryland	
Corn yield (bu)	145	65	
Price/bu	$2.25	$2.25	
Revenue/acre	$326	$146	
Operating cost/acre	166	80	
Net/acre	160	66	Gravity Gain
30 Acres	$4,800	$1,980	$2,820

The use of electronic equipment to automate the collection of measurements from weather-related sensors at remote sites has brought about a change in the ability to collect weather data (Hubbard et al., 1983). This advance in the field of data collection has found its way into the National Weather Service program of modernization, as more than 1000 ASOS (Automated Surface Observing System) weather stations were installed over the past decade (ASOS, 1988). Automated state and private networks also were initiated and a survey determined that these networks are comprised of more than 600 weather stations.

Communication and computer technology have greatly increased the ability of climatologists to monitor and disseminate the important characteristics of climate. RCCs are institutions that engage in such applied research as is necessary to improve climate products including crop water use estimates.

2.0 DATA COLLECTION

Automated weather stations are maintained at 139 locations in the ten-state region (CO, IA, KS, MT, MN, MO, ND, NE, SD, and WY). 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 HPCC system. A flow diagram is shown in Fig. 1. Software and system components have been documented for this system (Hubbard et al., 1990).

Weather stations at remote sites monitor sensors every 10 secs 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. Other recommendations for standards have been put forth by the World Meteorological Organization, the United Kingdom Meteorological Office and the National Weather Service. For these standards and those of other Automated Weather Networks in the U.S. see Meyer and Hubbard (1992).

Growth of the AWDN was fairly rapid (see Table 2). Much of the initial growth was due to the interest of researchers who were operating digital weather stations without the benefits of telecommunication or a data management system. In 1983, the AWDN began to grow into surrounding states. As time passed private sector interests offered to add stations. Resource management agencies also have taken an active role in addition and support of stations in the network. One unique class of weather station sponsor is the community consortium. In this case a number of interested parties from a community (eg. agri-chemical dealers, farm elevators, radio station, public power agency etc.) agree to share in the expense of purchasing and maintaining a station.

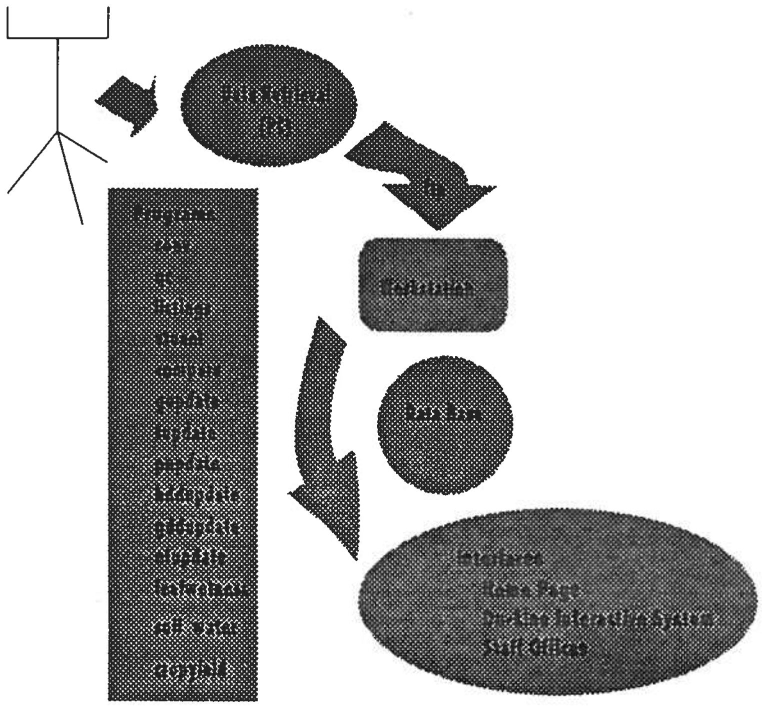

Fig. 1. The flow of data through the automated weather network

Currently the 139 stations in the Network are distributed in the region represented by the High Plains Climate Center as follows: Colorado 4, Iowa 10, Kansas 16, Missouri 2, Minnesota 5, Montana 2, Nebraska 47, North Dakota 42, South Dakota 10, and Wyoming 1. The station locations are plotted in Fig. 2. In general, each state is responsible for maintaining it's weather stations and the states with larger numbers of stations run a near-real time network to serve clientele within it's boundaries. The High Plains Climate Center calls these stations once each day in the early morning hours to download data.

An abbreviated maintenance checklist is given in Table 3. Replacement of sensor components includes bearings in the cup anemometer on a 2 year cycle. Relative humidity sensors are calibrated on an annual cycle. The potentiometer on the wind vane is replaced as needed. The tipping bucket is checked for level and

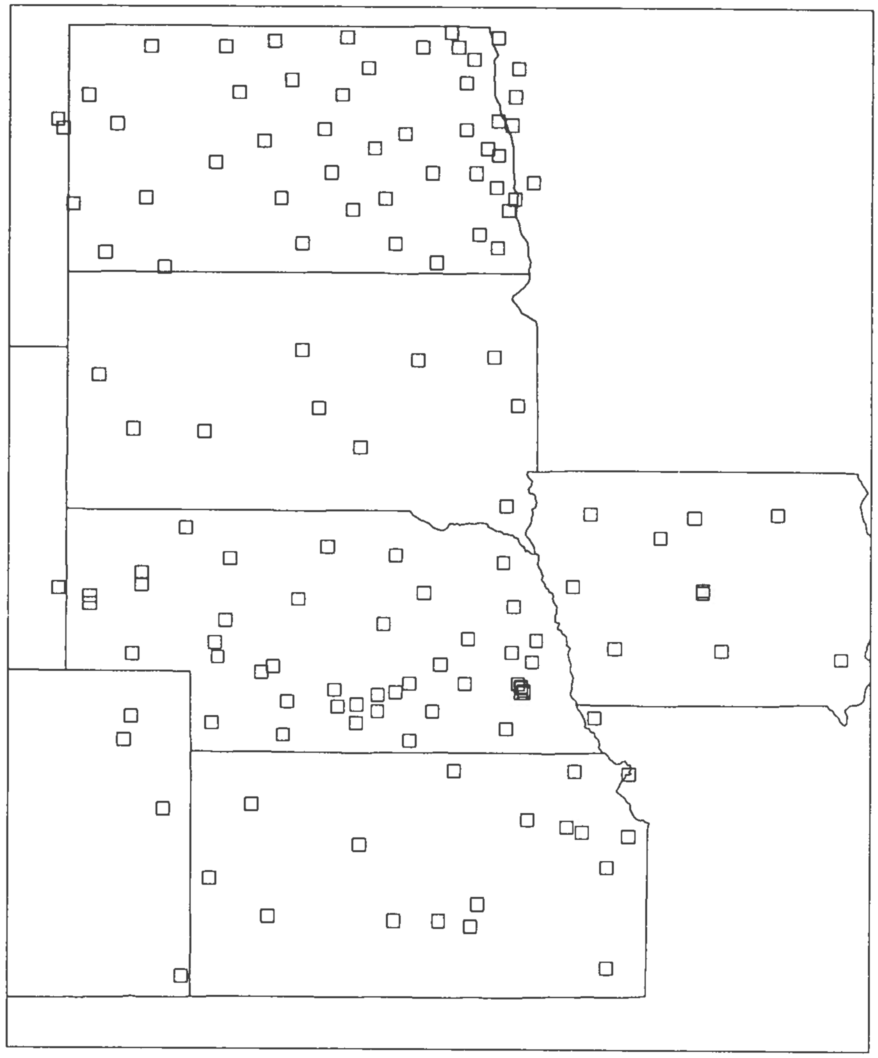

Fig. 2 Location of stations in the Automated Weather Data Network.

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. The wind vane can be tested by simply using a sightable compass and magnetic correction to determine true north. The vane is calibrated so that for example a complete turn produces a range of values from 0° to 358° for a potentiometer with a 2° dead band. 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. Devices like dry block calibrators and dew point generators are useful for this purpose.

Average annual costs associated with the network include: local telephone service ($480), telephone calls ($180), travel ($200), repair costs ($100), replacement costs ($100), and labor ($1,250). The total costs here is $2,310 per year but this cost does vary with the number of stations that are operating and other local rates.

3.0 DATA MANAGMENT AND APPLICATIONS PROGRAMS

A tremendous amount of data can be generated with an hourly weather network. In the High Plains case 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 High Plains network, 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 HPCC 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 as in would appear on the computer screen (see Fig. 4).

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

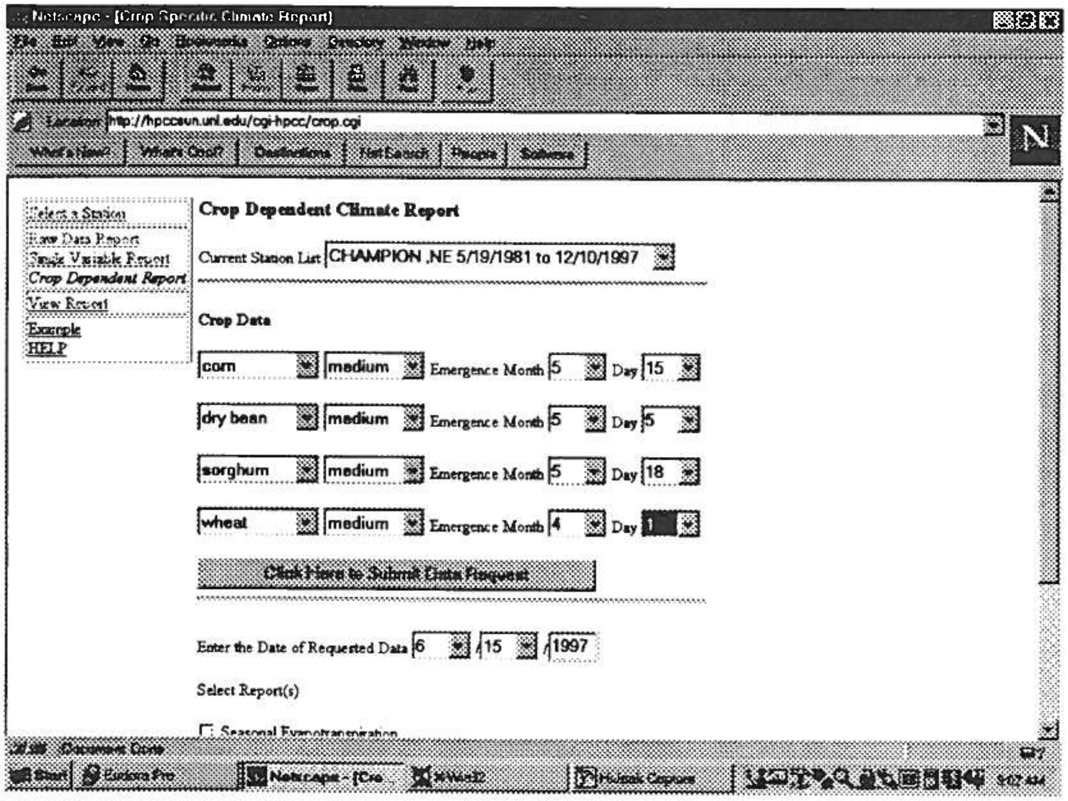

Fig. 3. Input specification screen for the ET product.

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) is also under development.

Accuracy of interpolation between stations in a network is also 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

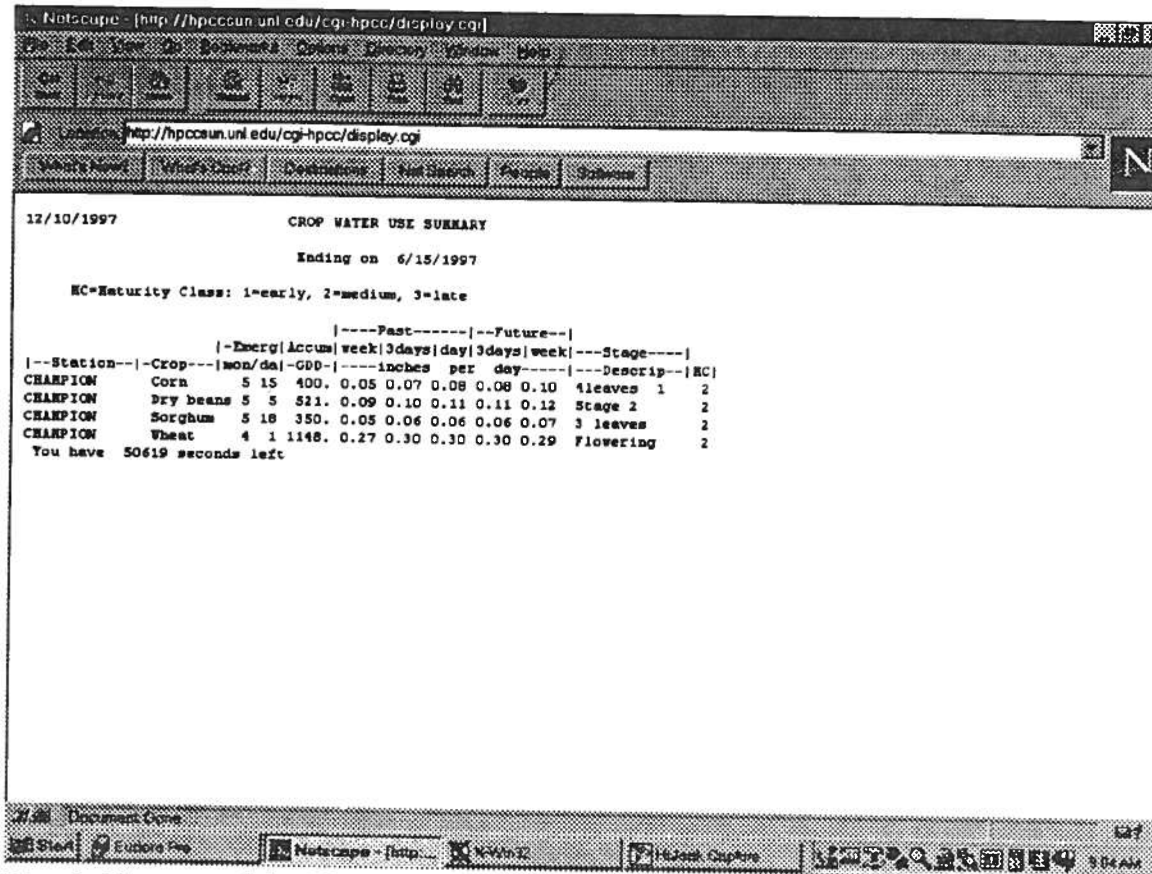

Fig. 4. Format of the ET product from the On-line System.

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 (eg. 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 HPCC staff developed an On-Line Internet system for users which features interactive use of the entire historical archive of the HPCC. A revised system was released on May 1, 1996 and users of the former RBBS were invited to subscribe to the new system. Access to the new system jumped from approximately 2,000 to 6,000 per month in the initial six month period of operation. This is an sizeable increase as can be seen in Table 4 and Figure 5.

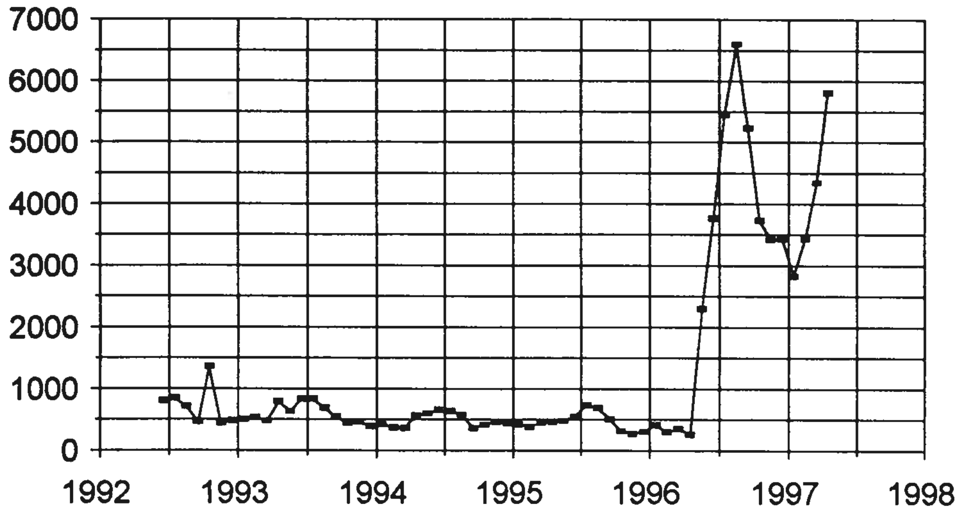

Fig. 5. The requests for climate data handled by the HPCC On-line System.

Digital data disseminated by the HPCC from the new system can be redistributed several times to larger audiences. A clear example is Data Translation Network (DTN). DTN, a private company, accesses HPCC's evapotranspiration, soil temperature, heating degree data and other reports which they broadcast to a network of subscribers. Paid subscribers to DTN are able to view this current information on their TV screen. They choose the pages they wish to view by simply indicating an index number on a push button pad supplied by DTN. There are more than 100,000 clients who subscribe to DTN.

On-Line Access System

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

- accessible by dial-up through direct modem connection or by using Telnet on the Internet
- the new system offers 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

The additional features and power of the new system have led to increaased use by the HPCC clientele. However, improvements are underway including:

- greater simplicity of interface

- decreased learning curve

- navigation by 'mouse' point-and-click

- new products for the system

The HPCC has formed a committee to look into the redesign of the On-Line system and the possibility of combining it with the HPCC home page.

Home Page

The HPCC home page committee designed a new home page (http://hpccsun.unl.edu). The number of accesses to the home page are shown in Fig. 6 and Table 6.

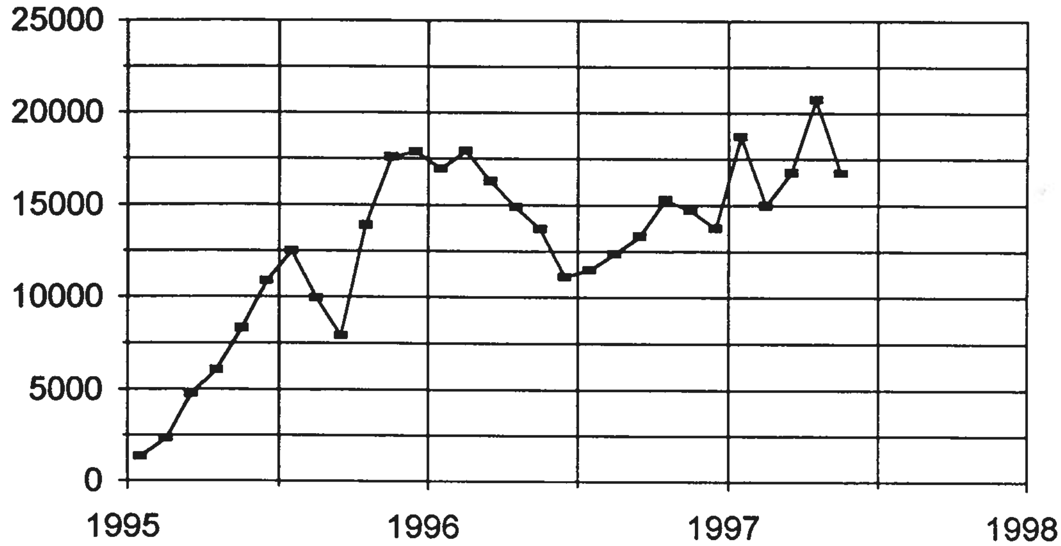

Fig. 6. The number of hits on the HPCC Home Page, http://hpccsun.unl.edu/

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)

Table 2. Number of AWDN stations.

Number of Stations in AWDN by Year					
1981	5	1989	74	1997	139
1982	14	1990	83		
1983	21	1991	93		
1984	29	1992	95		
1985	47	1993	112		
1986	51	1994	119		
1987	49	1995	132		
1988	60	1996	137		

Table 3. Maintenance checklist.

Check sensor readings (daily)
Clipping of vegetation (as needed)
Onsite testing (4-6 months)
Cleaning of sensors (as needed)
Calibration of tipping bucket (annual)
Calibration of solar sensors (annual)
Test and calibration of humidity sensor (annual)
Replace bearings in anemometer (two years)
Replace potentiometer in wind vane (two-three years)

Table 4. Monthly Accesses to the HPCC On-line Service.

		On-Line Requests				
	1992	1993	1994	1995	1996	1997
1		508	428	429	417	2830
2		536	378	385	303	3443
3		483	368	455	351	4343
4		799	578	460	263	5814
5		638	606	483	2304	7065
6	810	837	661	552	3770	
7	846	841	640	736	5452	
8	710	692	584	693	6603	
9	465	545	369	511	5239	
10	1364	441	420	315	3743	
11	448	468	467	271	3429	
12	485	396	441	309	3435	
Total		7184	5940	5599	35309	

Table 5. Origin of self service requests by sector, October 1996-April 1997.

Sector	(%)	Sector	(%)
Agricul. & Forestry	12	Legal	0
Construction	<1	Manufacturing	0
Consulting	4	Media	<1
Education	75	Recreation	0
Energy	<1	Retailing & Service	0
Engineering	<1	Transportation	2
Government	6		
Insurance	0	TOTAL	100

Table 6. Monthly accesses to the HPCC Home Page.

HomePage Hits			
Month	1995	1996	1997
1	1347	16973	18734
2	2330	17949	14993
3	4747	16295	16771
4	6055	14901	20733
5	8320	13718	16757
6	10890	11142	
7	12524	11518	
8	9963	12372	
9	7925	13325	
10	13909	15298	
11	17600	14729	
12	17904	13775	
total	113514	171995	

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