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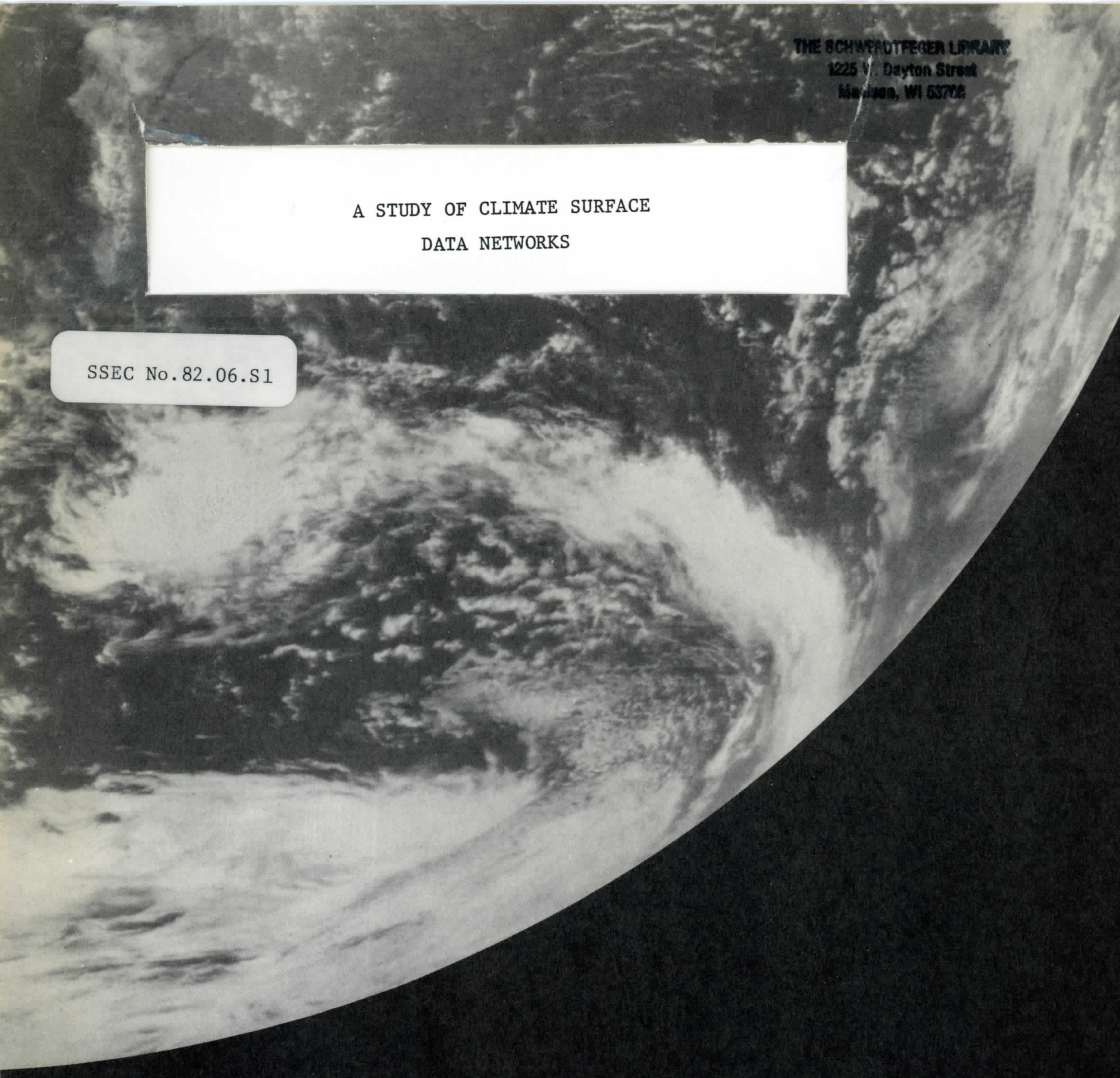

A STUDY OF CLIMATE SURFACE DATA NETWORKS

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A REPORT

from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin

A STUDY OF CLIMATE SURFACE

DATA NETWORKS

FIRST ANNUAL REPORT

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TABLE OF CONTENTS

1. PROJECT BACKGROUND

The importance of surface climate data to the scientific community has been underscored by recent attention from both data users and suppliers. Such data has been the focus of a large number of workshops over the past few years, as well as several reports by the National Academy of Sciences (Climate Research Board, 1978, 1979, 1980); it is even included in the Five-Year National Climate Plan (NCPO, 1980). Climate data is used by the private and public sectors with users ranging from farmers to numerical modelers. These users, while immediately concerned with applying these data for their own purposes, are also interested in how and where the data are collected as well as their storage, archiving and dissemination.

The immediate impetus for this research project stems from the Five-Year National Climate Plan, one of whose goals is to define the requirements for daily surface measurements. This plan singles out three areas of special concern: (1) insuring the integrity of the co-op network and its quality; (2) improving and expanding radiation measurements; and (3) improving and expanding the climate "benchmark" network. In its several studies, the National Academy of Sciences adds improving data referral, quality and data base management to this list.

The Space Science and Engineering Center (SSEC) of the University of Wisconsin-Madison, at the request of the National Climate Program Office (NCPO), undertook a three-year program to study and evaluate the federally funded surface climate data networks. The program, as proposed, was to include five steps:

(1) Determine representative users, applications and requirements of climate data supplied by the federally funded surface climate data networks;

(2) Design an ideal surface climate data system to satisfy the needs set down in item (1);

(3) Define the totality of the current system;

(4) Compare existing networks with the ideal design network; and

(5) Make final recommendations resulting from item (4).

The principal goal for the first year of the program was to complete item (1). As part of the process, we convened a workshop in Madison, during October 1981, with expert intermediate suppliers of local data who know both end user needs and network capabilities. This report is the result of the workshop discussions, information submitted by the workshop participants plus outside research.

Because of NOAA's lead role in the measurement of climate data, we have tried to limit ourselves to those surface climate measurements which are funded by the federal government. Unfortunately, the users of climate data are less interested in where the climate data came from, than its quality and accessibility. Because we have chosen to approach this task from the point of view of the user of climate data, and because users request specific data without specifying their source, we have not always succeeded in limiting ourselves to the federal networks.

This report begins with a discussion of our methodology--how, and why we have chosen our approach. It is followed by a description of the workshop planning, operation and outcome, including a discussion of how the scope of our first year's work shifted. The results of our efforts, mainly a representative set of users and uses of surface climate data, follows. We close with a description of our future plans.

2. METHODOLOGY

Before proceeding to a discussion of user needs and related network requirements, we need to better define our area of concern and our intended method of inquiry. One such consideration is the distinction between climatology and weather forecasting. On paper the difference is clear enough: climate is the long term manifestation of the weather. Around this definition, two different modes of weather data collection have sprung up. On one hand we have the short term practical informational needs of the public and many specialized concerns of business. The emphasis here is on immediate use of the data for such things as forecasting and aviation. Accuracy and consistency over time, while important, take a back seat to timeliness. It does not matter how good the data is if it arrives too late. The requirements for good climatological data are different. Accurate observations free of bias and extending over long periods of time are desirable. Remote, inhospitable regions need regular observational coverage. Even the variables needing observation are somewhat different. Long term changes in solar insolation, turbidity, or snow pack have obvious climatological significance but are often neglected in daily weather concerns. The opposite is true for cloud ceiling height and the location of the freezing level. These differences have resulted in networks with different emphasis on climate versus weather information collection. The cooperative observers network is a good example of the former while the FAA stations are examples of the latter.

Unfortunately, user needs cannot always be easily satisfied by just one of the weather versus climate alternatives. First, some users require short term averages of the weather (over a period of months or years), periods of time which are not strictly speaking climatic (climate averages are generally based on a decade or more of record). Second, some users need to use in real time, data that are being collected primarily for climatic purposes (e.g. from the co-op network). These factors suggest that it is impossible to make a clear distinction between weather and climate data needs in all situations.

In light of the above discussion, we came to the following policy decisions: that in regard to data <u>collection</u>, we are limiting our consideration primarily to the co-op network, even though this network is only a part of the total climate system. This limitation is imposed primarily to make our task more manageable, but we also realize that every meteorological observation made is a potential piece of climate data and may someday be used as such; it would be wise to collect all data with this possibility in mind. Ultimately, some of the improvements suggested for the co-op network may be equally applicable to other observing systems. In regard to data <u>dissemination</u>, a similar observation may be made. While our immediate aim is to describe how co-op network data can be processed, archived, and disseminated to satisfy climatic informational needs, we cannot completely ignore other users of such data. In any data distribution system that we construct, provision should be made not only for the non-climatic user (e.g. allowing the possibility of real-time use of such data) but also for the inclusion of data from non-climatic or non-federal networks. Unnecessary fragmentation of data collection sources on the basis of their primary or original purpose will only hurt our efforts to fill important user needs efficiently.

What sort of user applications will we be considering? If the aim was simply to provide concrete detail, one could present many case studies or examples of different applications. This method has already been use extensively (e.g. Changnon, et al., 1980) and does not particularly suit our purposes here. As opposed to illustrating the particular problems of individuals, we are more interested in directing our attention to major climate users and generalizing their data requirements. Another way to discuss applications is in terms of the climatic variables involved. Thus, under the heading of temperature one can include agriculture, construction, and so forth. The opposite approach may be taken as well, with variables being discussed under the heading of the application. The advantage of the former method is that it corresponds to the way in which climatic uses are usually described (e.g. user x needs to know the mean summer precipitation and the frequency of temperatures above 90°F over region y), and it was in this way that most of our information was solicited from workshop participants and references. However, in terms of our task here, namely to compile needs and later compare them with existing resources, it was more convenient to consider such information under the heading of the separate variables; it is this manner of organization that prevails in this report. We also considered and at times used other categories of climatic data use. These included research (e.g. causes of climatic change, climate prediction) versus application (e.g. farmers, construction engineers), data users versus data providers, and ideal requirements versus actual data provided. These classifications proved useful in eliciting information and organizing workshop events. In terms of what information we wished to have regarding applications, we sought the time and space resolution, the timeliness, and the measurement accuracy of each variable utilized, the form in which the data was provided, and the source of the data (from which network or part of a network).

Our consideration will be further limited to what we consider "significant" uses. State climatologists report that numerically, the largest body of requests for data are for personal information and legal questions. However, in terms of social and economic importance, a much smaller group of users are involved. These latter requests are generally of a more complex nature, involving research based on the use of such data and have an application which is of undeniable significance (e.g. flood control, building site selection). It is these major uses upon which we intend to concentrate. Furthermore, we are interested only in those needs which can be described as "representative" or typical of a large body of users. Again, a nearly infinite number of variations can be found among user requirements, but we have concentrated on those that come up frequently in many different contexts.

Finally, it was necessary for us to define how we would go about translating user needs into network requirements. For instance, how would we decide whether a particular application of climate data falls within our area of interest (i.e. the co-op network) as opposed to some other state, federal, or local network jurisdiction? First of all there is the complex matter of translating user requests into data needs. The nature of this process is amply demonstrated in Figure 1. Although this chart was devised to consider rainfall network design, it applies with minor modifications to almost any parameter and network selection process. The point to be made is simple: the data needs of a particular user are highly specific and there is little point in considering such individual needs in isolation. In trying to arrive at general network requirements we need to consider broad categories of users, knowing that such general designs will not satisfy everyone. It should also be noted that network requirements can in any case only be specified in certain dimensions, short of actual experimentation in the field. We can say what sort of instrumentation is required, roughly how dense the station interval should be, what length of record is required, and some general requirements for station location (e.g. on every major river tributary). We cannot specify the exact density, nor the actual distribution of stations short of a field study to test parameter variability in space and time. In other words, the best we can do is to specify minimum network requirements, not optimal network requirements. Ultimately, we will consider all these minimum requirements together in an attempt to arrive at a consensus for needed network improvements.

We have still left our original question unanswered, however. Having decided in some fashion what is required, how do we determine whether such needs are among those that concern us here (however legitimate they might in general be)? Let us take two examples. Suppose that user type X needs solar radiation measurements on a scale

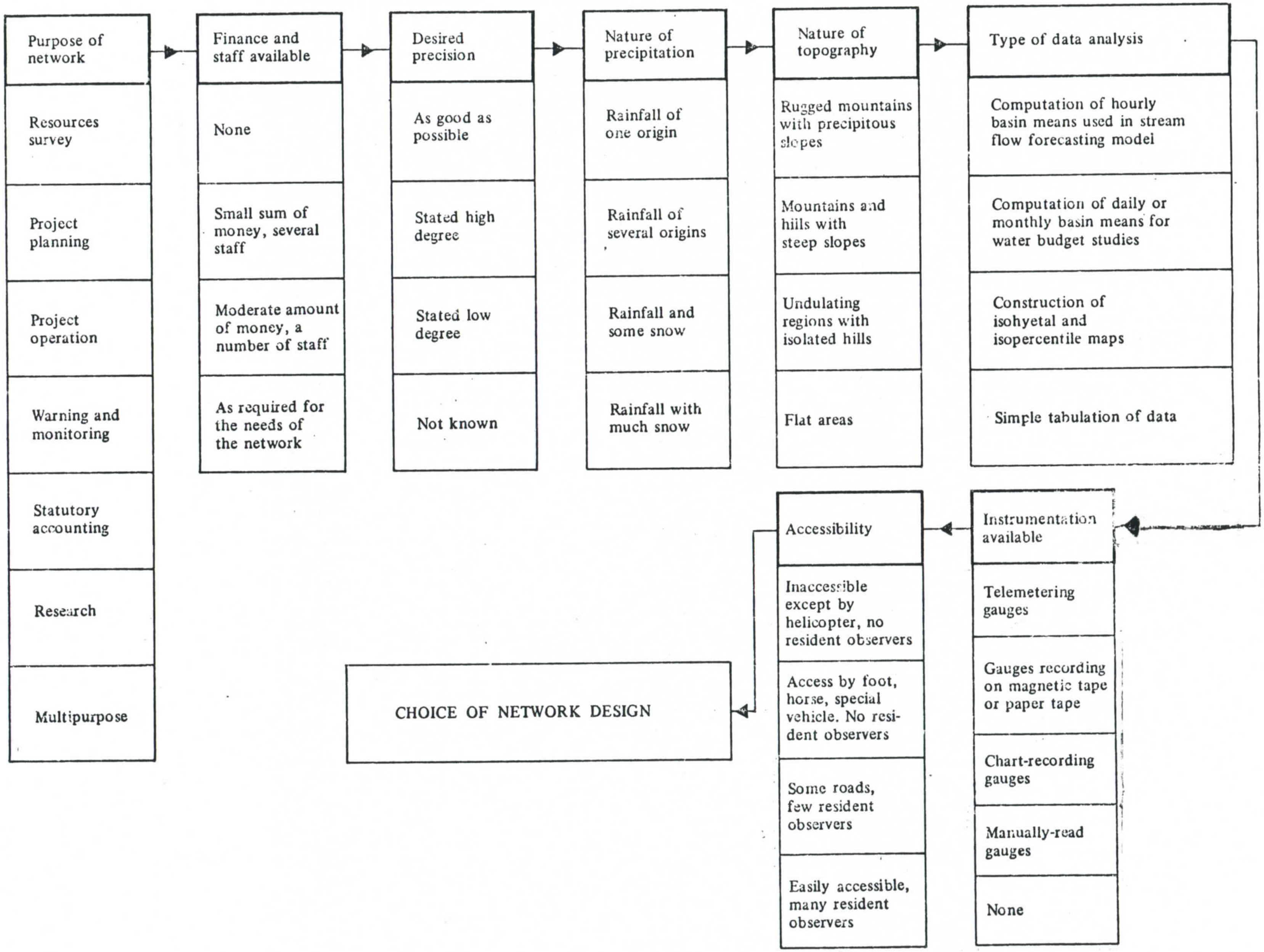

FIGURE 1: Network consideration for rainfall (after Radda, 1972).

comparable to or greater than the current co-op net. This would involve installing additional instrumentation at some currently operational sites. If this need is echoed by a significant group of users over a wide area, then it would be legitimate to consider this as a possible area of recommended improvement. Let us suppose that user type Y wants solar radiation in a distribution pattern considerably different from the current co-op network distribution, or at a considerably greater density. In such cases, the following considerations will apply:

a) Will such changes in the co-op network entail abandonment of existing stations in considerable number, such as would be required if redistribution were needed?

b) Will such changes require the creation of a large number of new sites, such as would be required by a substantial increase in station density?

If the answer to questions a or b is yes, then we will ask:

c) Can these needs be reasonably met through the use of other network systems or through the creation of a special network financed locally or privately (perhaps only on a temporary basis)?

d) Is this user type an isolated example (as opposed to part of a national pattern of unmet needs)?

If the answer to either of these questions is yes, then this users' needs would not be considered as part of our concerns here. In short, what we are seeking to do here is make small modifications in the current system, with possible major modifications where there is an important national need and no other way to remedy this need.

We have presented here a basic outline of what we intended our methodology to be for the entire program. This first year's report focuses on detailing user needs, while paying only slight attention to how these needs are being met now, and how data services could be improved--that will come in the program's final years when this information on user needs will be expanded to determine network requirements, and to isolate areas of greatest concern that need our immediate attention.

3. WORKSHOP ORGANIZATION

The main goal of the first year was to formulate and produce a "representative set" of uses and requirements of surface climate data obtained from the federally funded networks. As a means of accomplishing this goal we planned a workshop to which we could invite ten intermediate suppliers of local data--people who both dealt with climate data as an intermediary, and who also used it themselves.

The first task was to decide upon and invite a group of people who were representative of a larger population. In terms of employer-type we wanted people from all divisions of government, private industry and universities. In addition, we needed a wide breadth of expertise--climatologists, forecast meteorologists, hydrologists, agricultural meteorologists, data suppliers, etc., who dealt with the research as well as the applications aspect of meteorology. Finally, we also tried to obtain geographical diversity.

Eleven invitations (see Appendix A) were sent out with ten acceptances received. Among the participants, we had three state climatologists, two private meteorologists, three "data providers", two agricultural meteorologists, two hydrologists, three who worked for the federal government, plus three from universities (see Appendix A--many of the participants fell into more than one category).

The workshop was held in Madison on October 12-14, 1981. The meeting was divided into large group sessions and smaller working group sessions. On the first day, each participant gave an introductory talk on the nature of his work and experience in the data acquisition/dissemination area. These talks centered on: the general nature of their climate work, the number and kind of clients or contacts in their area, the types of data they use or are familiar with and whether the current availability of data meets their needs or the needs of other users they are familiar with. In addition we also discussed: Do we need all of the current stations? How do we maintain them? Can the system be modified to better meet user needs? How can we integrate new data sources into the current system? What are likely future demands on the system? All of the discussions of the entire workshop were recorded and reviewed carefully prior to the preparation of this document.

The smaller groups were more or less arranged by the participant's background--research, applications, or data provider--but these classifications were not exclusive. (For a detailed agenda, see Appendix A). These working groups were where we hoped to obtain most of the details on the uses of surface climate data. Specifically, we requested information on: key variables including their accuracy, timeliness, time and space resolution and ease of availability; uses of this data including types of users supplied and their data needs; where the data comes from, and the representativeness of these users and uses. We also tried to distinguish the frequent from the important uses. In addition to the presentations, many of the participants brought supporting documentation and references.

4. WORKSHOP OUTCOME

As previously described, the workshop began with introductory presentations and discussion by the workshop participants. These presentations laid the foundation for future discussions by outlining the goals of the NCPO in the area of surface climate data sets, the general three-year plan for the project, and what we hoped this workshop would accomplish (see Table 1). From the outset, it was apparent that in addition to describing their dealings with surface climate data, many participants came with related problems to discuss. Rather than stifle discussion, we decided to let the individuals air their ideas completely, thus widening the scope of the workshop. These problems in turn led the group to decide that a statement of concerns along with recommendations should be one immediate consequence of the meeting. Thus, the third day's meetings were devoted to drafting and approving such a document. An explanation as to how the focus of the workshop shifted now follows.

The opening workshop discussions involved brief presentations by each workshop participant describing his specific work role as a supplier and user of climate data. Furthermore, many participants gave explanations of problems inherent in the present climate data system with specific suggestions and recommendations for change. Major problem areas concerned data acquisition, dissemination and timeliness, data station density, and quality control among others. A complete listing is presented in Table 2.

TABLE 1.

1. FEDERAL GOALS

   A. To develop an objective basis for assessing proposed changes in the surface data networks.

   B. To identify the limits of the federally funded or managed networks.

   C. To bridge the abyss in getting satellite data more involved in applied uses.

   D. Determine where modern techniques can make cost effective improvements in data acquisition, management, and dissemination.

2. PROJECT GOALS

   A. To identify the important and frequent uses of climate data.

   B. To identify the existing federal networks.

   C. Use this information to design an ideal network.

   D. Compare the ideal with the actual network and make recommendations for improvement.

3. WORKSHOP GOALS

   - To determine a "representative set" of uses and requirements of surface climate data in the United States.

TABLE 2.

1. Specific suggestions and recommendations from individual participants relating to how a climate data network should function.

   A. Data processing--complete (from data collection to applications) programs should be stressed.

   B. People who use the data should pay for it generally.

   C. Users need to be able to access data at any point in the processing.

   D. High priority climate stations should be selected which would receive special attention and serve as a minimum base.

   E. The federal offices can serve as a clearinghouse for state data.

   F. High priority should be given to data dissemination and timeliness.

   G. Accelerate the dissemination of climatology.

   H. A total system should be developed so that the data is brought together in an optimal way.

2. Problem areas in the current climate network as stated by individual participants.

   A. Data often not utilized well--often organized by platforms rather than by uses.

   B. Hourly observations--not enough stations--poor distribution in all states.

   C. Urban networks are generally inadequate.

   D. NWS wind instruments are too insensitive to define critical pollution situations.

E. Observations are oriented toward aviation--not useful in many climate applications.

F. A more complete precipitation network is needed (supplemented with radar, satellite and automated rainguage data).

G. Concern over the polarization of climate related organizations.

H. Soil moisture network is poor.

I. More work needed on droughts (water supply) and archiving and dissemination of data from federal agencies.

On the second day of the workshop, working subgroups were organized for the immediate purpose of fulfilling the workshop goals. Individual reports were presented to the group as a whole documenting the subgroup discussions. It became evident during these discussions that the entire focus of the workshop had changed. Many of the recommendations and problems that arose during the opening day exchanges were discussed in further detail by each subgroup as was shown by the subgroup reports. In addition, the thrust of the general discussion did not concern the uses of climate data but concerned the problems of climate data dissemination. Lack of data accessibility, quality control and referral as well as the filling of specialized data gaps were the main problems discussed. It was very evident that the participants of the workshop perceived the difficulties with data access and dissemination as a more immediate concern than those with data observations.

Of prime concern was the distribution of the cost and responsibility for the selection of the aforementioned system problems. There were several specific questions raised concerning the costs of equipment, maintenance, data base support, communication, and personnel. In addition, an issue of cost sharing by people or organizations who use the data (i.e., general public, private meteorologists) was discussed. Unfortunately, few cost figures were presented by the individuals. As a result, the discussion was basically limited to general across the board system costs with just a scattering of specifics.

The discussions of cost lead to talk of whose responsibility it was to collect and distribute climate data. Should the states themselves take responsibility for their individual concerns or should a federal organization take full responsibility? Should we encourage the development of networks that involve the people who perceive they need the information (i.e., private meteorologists, county agents, public health agencies, etc.)? A major concern was that climate data has not been treated as a continuum in either space or time. Artificial boundaries have tended to fragmentize its utility. Since the states' data needs are heterogeneous, and it is in the states' long term interest to have climate data as a resource, there needs to be a higher-up coordination of all climatic data gathering and archiving.

The consensus of the group was that the federal government should take on the role as the leader of national climate monitoring. This was the underlying theme in a statement of concern regarding the present climate data system. The main points of this statement are:

1) There is a proliferation in climate data collection, with great variability in instrumentation and data quality;
2) There is a lack of timely data access; and
3) There is a need to maintain "benchmark" stations, as well as obtaining new data in some specific cases.

To remedy these problems, a plan of action to support a national climate data and information service was also presented. The plan states the need for a bold national program to plan and manage the whole data system from data collection to documentation. In addition, the plan recommends that NOAA coordinate and define the roles of the federal, state, local, and private sectors within the entire national climate data operation.

At the suggestion of the workshop participants, a statement of concern containing a list of recommendations for a plan of action was drafted on October 14, 1981 at the conclusion of the workshop. This document plus background information are contained in a journal article (see Appendix B). It should be pointed out that at the outset of the workshop we had not intended to draft such a declaration. Several of the participants had attended many of the 27 previous climate workshops and commented that little in the way of action had resulted from them. Many felt that proposed funding cutbacks in the area of climate data might do damage to the many good points of the existing climate system. Hence, these recommendations and plan for action were unanimously agreed to. Once reviewed and approved by all participants, this document was then sent to a wider range of climate experts throughout the United States (see Appendix C) for their comments and suggestions.

As a further clarification of the original recommendations, a workshop background document was drafted (following the workshop) from suggestions by the participants. Expanding upon the three points mentioned previously, this document contains a summary of the main thrusts of the workshop discussions (see Appendix B). The document elaborates on the many issues brought about during the discussions concerning climate data bases, their acquisition, dissemination, archival, and quality control. In addition, statements dealing with data network organization, their cooperative potential, and the inclusion of new technology into these networks are included. In conclusion, the document itemizes the concerns relating to federal coordination and provides guidelines to fulfill the stated objectives.

It was felt that this background information from the workshop was necessary to better understand the motivation behind the initial document. Once again, after review and approval, the document was sent to a wide range of climate experts (see Appendix C).

The evolution of the workshop recommendations and the summary of the main thrusts of the workshop discussions which led to the drafting of the recommendations bears a close similarity to a Climate Research Board of the National Academy of Sciences' (NAS) report, "Toward a U.S. Climate Program Plan, 1979." This release reports on the Workshop to Review the U.S. Climate Program Plans, held at Woods Hole, Massachusetts, July 12-19, 1978.

One of the sections of the report deals with climate data, information and services. An introductory paragraph to this section states:

> "While acknowledging the fundamental roles of the collection, management, and services of climate data, the U.S. Climate Program plans also recognize the difficulty of providing them. The plans propose many pertinent actions and state the need for a broad coordinated effort throughout the federal government. Nevertheless, present plans of the individual federal agencies are highly variable in completeness and feasibility, revealing disparities of interest and capability in a large scale cooperative program: (Section 3, pp. 16)

Dealing with similar subject matter, both workshops emphasize the need for a coordinated effort by the federal government.

At the conclusion of the third section of the NAS release, the report lists its principle recommendations concerning climate data, information, and services. Once again, although differing in context in several respects, both the NAS list and the list in Appendix B reveal a similar evolutionary process. The efforts of both workshops began with the theme of federal coordination which in turn led to a statement of concern and subsequent plan of action with relation to climate data, information and services in the United States.

5. RESULTS

A. General - Climate Data Users and Uses

As stated in Section 2, the details of the users' needs of climate data will be presented by parameter. First, however, we will briefly describe who these users are, and what they use climate data for.

During 1980, the National Climate Center (NCC) received over 100,000 requests for climate data; of these, about 22,000 were for data from the co-op network. The largest number (19%) of requests came from private individuals, whether farmers or just people planning a vacation. Next, came requests from engineers (13.2%) for uses such as plant sitings, air and water quality, etc., the business community (10.3%) such as manufacturers, financial and transportation concerns, attorneys (8.5%) and the federal government (6.1%). Other large users of NCC include university researchers, insurance companies, private meteorologists, and other government concerns. The chief users of co-op network data follow the same pattern as described above.

The main uses of climate data generally fall into the following categories (not listed in any special order):

1. Agriculture - crop modeling, spraying, fertilization, irrigation, land use and other farm planning;
2. Energy - rate structure determination, storage planning, pipeline design, plant sitings, degree day statistics;
3. Construction - highways, dams, drainage systems, sewage systems, general building design;
4. Government (all levels) - snow removal planning, design of

construction codes, sewage system design, strip mining regulations, public safety, fire weather, zoning;

5. Commerce - loan evaluation, insurance rate determination, litigation;
6. Public Health - disease control, water quality regulations; and
7. Research - ground truth for new instrumentation, radar verification, numerical modeling, prediction studies.

While the above list is not meant to be exhaustive, it does make one important point--climate data is used by many people for a wide variety of purposes. Hence, it is truly a national resource, one that should be treated with great care.

B. User Needs (by Parameter)

What follows are what the workshop participants and our own research considered to be the main user needs of surface climate data, presented in terms of the parameters most often mentioned. We also add breif discussions of system and measurement problems where appropriate, though this has not been part of our original plan for the program's initial year.

1. Hydrologic Parameters

i. Precipitation

<u>Applications</u>

Precipitation along with temperature are the two major climatological variables with which nearly every application is concerned. It will be adequate, in terms of the general survey we intend, to look at those applications which depend in a major way on precipitation information and have a significant impact on the nation. In considering precipitation we will also include soil moisture, snowpack, and stream flow measurement since these variables have a close dependence on precipitation either in its liquid or frozen form.

These areas of major application are:

a) Hydrology - Included here are river flow forecasting, flood warnings and control; water supply management; hydroelectric power production; navigation activities; and model calibration, development, and testing. Sampling requirements* vary widely among these activities. Water resources need daily as well as monthly stream flow data, weekly soil moisture (root and surface zones), along with daily or monthly precipitation averaged over a basin or subbasin. Flash flood protection requires temporal precipitation resolutions down to the order of minutes, while snow-pack monitoring can be done from measurements separated by weeks (Hudlow, 1981). Length of record is another consideration. For model calibration, records need cover only a few years (Peck and Monro, 1977). Flood control on the other hand needs a long period of record, twenty years or more, in order to provide good estimates of peak demands on dams and other stream flow control devices.

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* Many of the sampling requirements in these applications sections can be found in Won, 1980.

b) Agriculture - Crop modeling and yield analysis, fertilization, planting, irrigation, crop insurance, and land use management are included in this area. Requirements here are more uniform than they are for hydrology. Generally a long period of record (30 to 50 years) covering daily precipitation amounts, weekly soil moisture, monthly mean rainfall rates, and yearly extremes are of importance. Daily snow depth is also of interest. As one would expect, minimum coverage should include all major agricultural field stations (Dale, 1981).

c) Industrial design and urban planning - This area covers construction near streams, strip mining, construction codes and regulation, highway construction, zoning, safety, sewer design, and street maintenance. Important requirements here include storm events over a five-year period and hourly to daily precipitation amounts, rates, and types over a twenty-year period.

Often special networks, especially in urban areas, should be set up to monitor events in the immediate vicinity of the site. In Illinois, for example, networks with time resolutions of from 5 to 60 minutes, and space resolutions as small as 0.3 km have been used (Changnon, 1979).

d) Miscellaneous - Many other important applications of precipitation data exist although they do not loom as large economically as do the previous areas. These include fire weather estimation, energy production, transportation, communications, recreation, and tourism. These activities generally need daily precipitation amounts and types over a twenty-year period.

General Requirements

Precipitation is temporally and spatially highly variable in its distribution, frequency, and rate, making its measurement particularly problematic. An example of this variability is given by Huff and Shipp (1969): to explain 75% of the variance for one-minute rainfall rates a gauge spacing of 0.5 km is needed (12 km if one seeks the same variance for an entire summer storm). While many climatologists have been able to specify certain minimum features a precipitation network should have, optimization of such a network is possible only after a dense system has been in operation for a considerable time (Duhreuil, 1972). As pointed out under methodology, such optimization can take place only with respect to specific applications. Even with these limitations, however, it is possible to specify a number of requirements which a precipitation network should fulfill. Some of these have been outlined by WMO (1974) in regard to hydrometeorological needs although these points are generally valid for other variables and applications as well. First, one should be clear about the desired accuracy applying to one's minimal and optimal needs. This accuracy can be specified by error limits in percent or in absolute amount per unit time, but these limits should take into account, at the very least, population density, economic activity, topography, and rainfall regime. Second, with respect to the actual data, uniformity in times of observation need to be observed, a directory of station characteristics should be available, and the data should be reduced to statistical form with short periods of time being compared to longer ones.

Let us consider the problems of spatial and temporal resolution from a number of points of view. Certainly a major consideration in any applied use is the spatial scale on which one wishes to describe detail accurately. Using Kreitzberg (1979), and starting from the dimension of a single cumulus or cumulonimbus cloud, the size and lifetime of the rainfall from such a feature would be on the order of a mere 2.5 to 10 km and 15 minutes respectively, and would mainly be of interest to those wishing accurate measurements associated with a summer convective storm. Moving to the mesoscale, urban and local environmental studies need space resolutions of at least 10 to 40 km and time resolutions of about an hour. Finally we have synoptic scale with time and space resolutions of 40 to 160 km and 6 hours, and very large scale with 160 to 640 km and 24 hours.

Another way of considering the problem of scale is in terms of topography. Here, WMO (1974) has suggested that appropriate space resolutions are: 5 km for small mountainous islands, 10 to 16 km for mountainous regions, 25 to 30 km for flat areas, and 39 to 100 km for arid and polar regions. Comparing these figures with those from the previous paragraph, the reader can see that the requirement for islands is similar to the cumulus scale figure, both the mountains and the flatland fall within the mesoscale and the synoptic scale coincides most closely with the arid/polar regions There is, in other words, a consistency between the two sets of guidelines, despite the fact that they are really meant to be used in different ways. The spatial scale requirements are most useful for those considering specific user applications, while the topographical considerations are more pertinent for those considering general purpose networks covering wide areas and diverse terrain.

Having considered these physically based spatial and temporal resolutions, it is logical to consider next some of the general requirements arrived at by national and international agencies as guidelines for the U.S. and other countries. NASA (1977) made one of the first attempts to define a national standard and suggested (for Climate B--one month to one decade) a space resolution of 500 km, and a 12 to 24 hour time resolution. More recently, the 1978 JOC Level II-C Data Management Plan (WMO, 1982) has suggested a 250 km, one day resolution with a maximum error of 10% or 2 mm per week error, the World Climate Programme (WMO, 1982) 250 km, 12 to 24 hour resolutions, and the WMO-ICSU (1975) a one millimeter per day optimal, 3 millimeter per day maximum, error. Finally, the NASA climate plan (1977) suggests a maximum 10% per week error for regional studies (25% for energy studies). We can say that basically these plans are in general agreement. Space resolutions should be from 250 to 500 km, time resolutions between 12 hours and a day, and maximum errors 10%/week or about 2 mm.

Comparing the above requirements with those arising from the topographical and physical considerations previously cited, these general requirements of 250 to 500 km suggest a synoptic scale resolution (10^2 km). Since these figures represent an average resolution, it is obvious that in mountainous regions station density will be higher and the opposite will be true in desert regions, the WMO topographical guidelines being an indication of how dense good coverage should be. The assumption behind this emphasis on the synoptic is that it is impractical to attempt smaller scale federal networks except where topography, population or other special circumstances make it economical or socially desirable.

Data System Problems--Precipitation

There were a sufficient number of data system problems discussed in regard to the precipitation network to warrant separate mention. One of the reasons for this added concern is that precipitation is currently being measured by three totally different systems, each with their own characteristics and limitations: ground-based conventional gauges, digital and analogue radar, and satellite (both visible/infrared and microwave). All of these systems should be complementary but in practice it has proved difficult to develop an objective means of taking data from these various sources and mixing them optimally. This is an unfortunate situation: disaster teams point out repeatedly the need for more real-time precipitation information. Even if data from multiple sources exist, it is not necessarily pooled in time to be useful. Often this lack of coordination has stemmed from: a) errors in converting radar reflectivities into precipitation rates; b) incompatible procedures among the various river forecast centers and other agencies; and c) insufficient development of techniques to merge successfully different data sources.

Some encouraging work has been done in this latter area (e.g. Eddy and Crawford, 1977; Gandin, 1963) but further research is needed before such procedures become operational. Even without such objective data merging, however, better compositing of river station rainfall data should be instituted with a grid network file covering the entire United States and accessible to all through a central computer.

In the area of data quality assessment, current exposure records are poor and field technicians of uneven quality. Workshop participants were united in assigning these problems to the termination of the State Climatologist Program. In particular, this loss has meant lack of consistency between states in precipitation (and other) quality control through on-site inspection. Finally, there is often no one to facilitate research and provide an interface between the user and the data.

ii. Soil Moisture

Soil moisture is not currently measured by the Federal Network except in a program started by the Soil Conservation Service over basin areas. (Some states take their own measurements.) However, NASA (1977) and others have recommended that both surface and root zone measurements or estimates of soil moisture are needed for hydrology, agriculture, and drought assessment. The actual measurement of this parameter everywhere is unnecessary; the best system would be one which obtained a few sample measurements for calibration of aircraft and satellite remote sensing plus some measurements in remote areas. These data would then be fed into a model which shows moisture at varying depths. Unfortunately, this system does not work well currently because the aircraft and satellite measure only surface moisture well, down to about 2 cm if there is little vegetation. The World Climate Programme (WMO,1982) has recommended that soil moisture be measured at 250 km, one week resolutions at four levels in the soil, to an accuracy of .05 g water per cc of soil. NASA (1977) has less stringent requirements of 500 km^2 and one month.

iii. Snowpack Coverage and Water Content

NASA (1977) has indicated that while both snow coverage and water content are needed, especially for hydrological estimates, only percent coverage is currently being measured. Percent coverage is by far the easier of the two to monitor. A combination of surface and satellite data does the job well, with the possibility of using microwave to detect fresh snow. Snow cover moisture content would also depend on surface and satellite monitoring, but these would be inputs into currently available models which include precipitation, temperature, evaporation, and solar input among other variables to estimate the snowpack. The 1978 JOC Plan (WMO, 1982) recommends a 200 km space resolution, one-week time resolution for both coverage and content with an error of 0.5 cm water equivalent. The World Climate Programme (WMO,1982) suggest 250 km, one week resolution with a 3 to 5% error in coverage and a 0.5 to 1.0 cm water equivalent error.

iv. Runoff--Streamflow

Runoff is also an important hydrologic variable that is a vital input into water resource management and flood control. It is necessary to monitor every important stream in the U.S. since even small river impact energy, navigation, and/or population centers. The World Climate Programme (WMO,1982) calls for 500 km space resolutions and once-a-day measurements with errors not exceeding 5% per week or 300 $m^2 sec^{-1}$.

Workshop Contributions

Workshop participants considered a number of areas in precipitation network requirements. These areas were network design problems seen from the standpoint of the researcher, operational problems including modeling and combinations of different data sources, event oddity assessment, data quality assessment, and technology assessment.

Proper network design is an important problem especially in the western U.S. where precipitation is more highly variable. In general, design becomes more difficult as the space and time variations of the precipitation events increase (this takes into account climate type and topography) and the tolerance for error decreases. Actual sampling needs are also affected by the error rate and the measurement abilities of the data source (see Hudlow's [1981] article on the use of satellite and ground truth to estimate precipitation) and by the need for unusual detail, as for example in large cities. For precipitation, the ground network data should have a long period of record and needs to be supplemented by high quality digital radar data. Satellite data could be useful in this context but currently the accuracy is insufficient (about a 50% error, [WMO, 1982] from a NASA report). Network design should also provide for the possibility of extending infromation from data rich areas into data poor ones. The usual method of such extension is to take a model storm, develop depth/area relationships and then expand into other areas using the same model. One can also calibrate the digital radar using stations of long record and then apply the radar to regions lacking good ground truth (Wilson, 1970).

Provided digital radar becomes available to fill in the gaps left by the current rain gauge network, the participants felt that basically the current network is adequate of all but special research or operational problems (granting the reservation listed under item b of the conclusions). Also, in terms of the length of record, we have enough long historical records to do predictive relations for long term climate trends, mean values, and regional outlooks. We do need more automated rain gauges which can be used quickly and sampled often. WMO (1974) recommends that 5 to 10% of all stations should have recording gauges, especially in urban areas and river basins with major river control systems. The participants specified that 70% of the current hydrologic stations should be automated, with some additional automated stations put in to fill holes.

With regard to event oddity, data quality, and technology assessment (the latter being important to agriculture for crop management, irrigation, and application of herbicides), there really is no such thing as an adequate network given the extreme variation to be found for many events and situations. Undoubtedly remote sensing by radar and satellite will help to fill in the gaps as their application becomes better understood and more accurate.

The final conclusions were these:

a) We do not have adequate historical precipitation data to serve all research needs.

b) We will (or could) have all the precipitation data we need for most future climatic research, if:

i) digital radar were available. Often this data cannot be used quantitatively because there is no provision for computer processing;

ii) existing federal networks are sustained;

iii) existing federal network quality is sustained;

iv) all data sources are known and accessible;

v) better access to data technologies is developed;

vi) we can develop objective procedures to extract and use maximum information.

2. Temperature

Temperature, along with precipitation, are the two most frequently mentioned climatic parameters in terms of importance. In fact, temperature and precipitation measurements from first order stations are the two most common data requests from NCC. Unlike precipitation, however, temperature is not as variable over small spatial distances and is therefore easier to measure. The areas of major applications of temperature data include:

Energy - Utilities use degree day statistics to monitor energy consumption and plan for future usage; the same is true of fuel oil companies and other energy related concerns. In addition, outlooks for the probability of hot and cold periods based on past temperature records help energy concerns with long-term planning.

Agriculture - Temperature measurements are often a more accurate monitor than precipitation in estimating crop yields, and hence in planning farm strategies. Temperature extremes are valuable both in determining the suitability of certain crops for a given location, and also in monitoring heat stress on existing crops and probabilities of frost.

Industry - Designer and user groups representing architects and engineers use temperature data in designing buildings and determining stress on various building materials. Highway design and maintenance monitors both temperature extremes, duration of freezing temperatures and freezing and thawing cycles as a means of best allocating resources and designing highways for the local climate.

Health - As cities become more crowded, temperature stress during times of extremes has become more critical in recent years. When these periods are adequately predicted or monitored, their effects on human health can be diminished. Public health officials also use temperature data to predict and track seasonal disease outbreaks.

There are many variations of temperature which are used in the above applications. These include hourly measurements, daily maxima and minima, heating or cooling degree days, growing degree days, daily and monthly averages, length of growing and/or frost free season, etc. In general, it is believed that one temperature station every 750 km^2 is adequate for most needs, but in urban areas, the resolution increases to one station per 40 km^2 (optimally). Currently, there are over 5,000 substations across the United States that measure temperature daily.

While the temperature measurement network is adequate, the major problem has been the switch to a thermometer-hydrometer instrumentation which tends to register colder temperatures--this has required an adjustment in the stated heating/cooling degree days. A second measurement problem is the need for standardization of all temperature readings to morning hours (e.g. 7 or 8 AM). Finally, we should consider using shelters for all temperature measurements. Workshop participants did not indicate any knowledge of studies on the effects of different types of shelter.

If there are ways in which the measurement of temperature can be improved it would be in meeting more specialized needs with higher density networks. One that was a frequent topic of discussion is the monitoring and prediction of heat stress, particularly in urban areas. In many cities, meteorological stations are now located at airports, which are open, usually in rural or suburban areas, and removed from areas of high population. More people live in regions of many buildings, much concrete and few grassy areas. Thus, temperature measurements in airports cannot adequately reflect the degree of heat stress during the summer months. In addition, temperature gradients within urban areas are usually more pronounced than in comparable rural areas. What is needed is a denser network within the cities: minimally at least one central city location, one suburban and one rural. The many urban networks that already exist (private, municipal, special interest) could supplement this system if there were adequate checks on data quality and data accessibility. Other more specific needs include snowpack monitoring, where station density of temperature measurements in the mountainous regions have proven to be inadequate, and evapotranspiration, where the reverse has been true in the agricultural areas.

The one problem with the temperature measurement network that was brought up in most every discussion was the need for better data availability on a real-time basis. Possible solutions to this include the use of automated weather sensors, specialized computer systems, or communication satellites to help speed the data flow.

3. Solar Radiation

There has been an ever increasing awareness of alternate energy sources, such as solar energy, over recent years. This solar awareness is evident in many newly designed residential and commercial structures. Research and development into solar systems that provide thermal and electrical energy is also continuing.

The aforementioned uses of solar radiation information by no means constitutes a complete list. Some of the major uses of solar data include:

a) Agriculture and Hydrology - Solar radiation data has such varied applications as crop modeling and crop yield analysis, assessment of planting procedures, forest meteorology, irrigation planning, soil moisture analysis, and water resources work. For hydrologic equations, solar radiation data is considered useful in the calculation of snow melt.

b) Industry, Commerce, and Government - Among the applications are commercial and residential site selection, planning, and design of structures, communications, recreation, and health safety concerns.

c) Energy - Radiation is crucial for the design of alternate energy systems as well as biomass energy interests and solar power concerns.

d) Research - Included in this category are solar-climate interaction analysis, solar fluctuation research, and radiation budget studies.

The general requirements of solar data (NASA Plan, 1977) include an accuracy base of 25 wm^{-2} for net surface solar data. In addition, a 500 km horizontal resolution is also desirable. Temporal resolutions on the order of one month are considered acceptable.

Workshop discussion of solar radiation data was initiated on two occasions. For agricultural applications, the workshop participants ranked solar radiation third in importance behind temperature and precipitation measurements for agricultural strategies and assessments. In the area of energy applications, it was mentioned that telecommunication companies in the United States are able to tap data on solar activity developed mostly by the military. Although it is not clear how this is done.

There were several problem areas mentioned concerning the present solar radiation network and solar radiation information availability. The participants concluded that a much denser solar radiation network was probably needed to support a developing solar industry. For design utilization, additional solar information is needed for use in siting solar usage in commercial and residential construction units. Finally, consensus among the participants was that the solar radiation network is inadequate in station density, location, and timeliness of data availability.

4. Wind

Wind measurements constitute one of the most highly variable climatological parameters in both space and time. Speed and/or direction of the wind may be measured in the range of microscale to global scale. Measurement systems are just as varied ranging from ground based to airborne, and stationary to mobile platforms.

As varied as the measurements themselves are the applications. Some of the major uses of wind data include:

a. Agriculture - Applications include erosion, frost forecasting, crop spraying, severe weather damage, soil moisture prediction, and forest meteorology. As expected, low-level winds play the most important role in agricultural considerations. Hourly surface wind speeds and monthly maximums are considered to be of moderate importance.
b. Industry, Commerce and Government - Here, the applications include construction and stress load information, site selection and planning, transportation, communication, and recreation. Also included are health and safety factors and insurance concerns. A larger variability of measurement requirements exist among these applications: boundary layer to upper level wind velocities are all considered important.
c. Energy - In this category, we include utility site selection and operation preparedness, dispersion analysis, environmental impact/monitoring, and wind energy production

including the siting of wind generators. A majority of these energy applications are more appropriate for privately funded studies and special projects than for federal (e.g. co-op network) concerns. Measurement requirements in this category are also quite varied. Types of measurement systems, their design and implementation may be quite elaborate, and depend upon the specific application involved. This is particularly true for air quality interests.

d. Climate Research - Wind data for research needs are applied to circulation models and statistics, transport analysis, and mixing and interaction analyses. Research needs for wind information may be the most varied with respect to data requirements and system orientation. Special networks outside of the domain of the federal (co-op) network may be assembled to produce project specific data sets that may only be saved for a few months. Scales of analysis and sampling intervals are just as varied.

General requirements for the measurement of wind velocity have been documented (NASA Plan, 1977). For accuracy, a base requirement of 3 m/sec is desired. Horizontal and vertical resolution of 500 km and 200 mb respectively, and a temporal resolution of 12 to 14 hours have been set as a base.

As variable as the wind data are, specific requirements should be mentioned that rank high in importance to each application (Won, 1980). Several of these requirements, especially those concerning wind energy applications, are more applicable to private concerns and should not be interpreted as being federal requirements.

a. Industry, Commerce, and Government - Twenty-year records of hourly mean, yearly extremes, and one-minute maximum wind velocity are of high importance to the communications, transportation, and the construction industries. Yearly gust speed is also important. Of slightly less importance are twenty-year records of boundary layer wind velocities. Six hourly upper level wind velocities are of moderate importance to recreation interests as are hourly surface observations.

b. Energy Related Applications - Wind energy interests, as expected, are heavily dependent on several measurement types and lengths of record. Twenty-year records of hourly wind velocity and one-minute maximum speed are ranked high in importance. Thirty-year records of yearly extreme wind velocity and gusts are also important.

   Hourly surface, six-hourly upper air, and turbulence information for specially selected networks on the order of ten-minute sampling intervals are important measurements with regard to environmental impact analysis. Hydraulic energy requirements of importance involve hourly one-minute maximum wind velocity.

There are two major areas of concern with respect to wind data network problems. First, a report supplied by Robert Dale, (Dale, 1981) states that the National Weather Service (NWS), Federal Aviation Administration (FAA), and the Supplemental Aviation Weather Reporting Stations (SAWRS) provide the only wind information in some states. This was deemed inadequate for most agricultural uses. Even when supplemented with the agricultural weather network, the quantity of information may still be inadequate for some agricultural needs.

In addition to network density, the adequacy of wind measurements for air quality needs was a strong issue. Airport wind sensors have threshold speeds of 2-3 mph which are too high for the analysis of dispersion of harmful pollutants. The need is for lower thresholds of the order of .5 to 1 mph with the possible addition of low-level rawinsondes. To accomplish this, the suggestion was to use low threshold sensors and sigma-theta meter.

5. Evaporation

Evaporation and its measurement, in the form of evaporation pan measurements, were discussed mainly in an agricultural context. Some of the major uses of evaporation data include:

a. Agriculture - Included here are crop yields and planning, irrigation, soil moisture, and forest meteorology. Evaporation pan data is taken at most agricultural stations (i.e., "B" co-op substations and the U.S. Bureau of Reclamation Substations).

b. Hydrology - This would include water resources, water loss, and lake evaporation modelling. Evaporation information is generally supplemented with other information in most application methods.

General requirements (NASA Plan, 1977) for evaporation data deal with climate changes of one month to one decade (i.e., climate "B"). Measurements require a base accuracy to 25% with a desired accuracy as high as 10%. Horizontal resolution of 500 km and temporal resolutions of one month are also base requirements.

More rigorous requirements are needed for some specially selected network applications. For example, in agriculture, and even more so in hydrology, a ten-year record of daily measurements are considered important.

There exist standardization problems with evaporation pan data. Differing A.M. and P.M. observation times lead to difficulties in comparisons (the A.M. observation was recommended). Installation of recording or direct readout should solve this problem as well as monitoring of splashout by rainfall and wind. In addition, there are differences due to whether the pan is painted or not. All in all, the network is considered adequate when supplemented with readings of temperature, wind, humidity, and solar radiation which allow estimation of daily evaporative demand.

6. Humidity

Humidity (or the measure of the water vapor content of the air) is closely related to precipitation in some of its uses, though valuable on its own. Its principal applications include:

Agriculture - It is used for planning of farming activities such as irrigation and choosing crops for the short-term management of farm operations such as spraying, and for helping in the assessment of crop status.

Hydrology - In this context, humidity is used as an aid to determining evaporation, drought strategies, and runoff.

Construction - A knowledge of humidity is important in the planning of construction projects as well as material design.

Health - Humidity, especially when coupled with temperature extremes, helps health officials plan for heat/cold stress as well as respiratory problems.

Humidity measurements take many forms. Some of the most common are absolute humidity, relative humidity, specific humidity, mixing ratio, dew point temperature and wet-bulb temperature. The first order NWS stations measure dew point and wet-bulb temperatures; in the daily summary of FAA and first order stations, one finds maximum and minimum relative humidity; finally, in the co-op data network daily summary, the relative humidity is included. Herein lies a problem: while various forms of water vapor content are recorded, dew point, widely regarded as the most useful parameter (certainly better than relative humidity), is absent from many of the data sets.

The density of network stations are adequate for most needs. The quality of the measurements is one area where improvements were suggested: this means both better quality instrumentation and possibly a softwear system to help clean up the data.

7. Soil Temperature

Soil temperature is a meteorological variable that is often associated with agriculture, though it is used by other concerns. Some of its applications include:

Agriculture - Soil temperature is monitored during the planting and fall plowing seasons. It is used to develop probabilities for planting which helps farmers save labor, fertilizer and energy.

Construction - It is important for building foundations, laying pipelines, etc.

Soil temperature is not regularly reported by NWS stations, but there are over 300 publishing stations that do measure soil temperature. These measurements often appear as weekly maps during the planting season.

Ideally, one would like to have one or two soil temperature stations per crop reporting district. Presently, this measurement frequency depends upon the state. Measurements should conform to some standard such as that given by the WMO which requires measurements at the top, 5, 10, 20, 50 and 100 cm, and a maximum/minimum reading in the depth from the surface to 20 cm.

8. Severe Weather Events

A final area of weather information which the workshop participants considered important, but which is not usually one of the typical "weather parameters", is severe weather events. This includes occurrences of tornados, hail, high winds, heavy rains or snows, droughts, floods, temperature extremes, dust storms, etc. It is mainly the probabilities of such events that are used in the following applications:

Utility Companies: ice storm, lightning strike and high wind statistics;

Agriculture: crop-hail loss information for determination of insurance rates;

Transportation: snowfall patterns to aid snow removal planning, routing information and roadway and bridge design;

Government: assessment of severe weather to plan for worker absenteeism, accident probabilities; and

Energy: the probability of freezing rain or hail as they may impede the functioning of solar collectors.

First order NWS, FAA and co-op stations all include information on days with high winds, thunder, tornado, hail, glaze, sleet/ice pellets as well as snowfall information. Other government publications discuss significant severe weather events in greater detail. There was little discussion on suggestions for improvements in this area, implying that there was little dissatisfaction with severe weather reports.

6. SUMMARY AND FUTURE PLANS

The first year of this program saw us accomplish our immediate goals (to determine representative uses, applications and requirements of surface climate data), as well as bring to light a wide variety of system problems. Workshop participants alerted us to areas needing immediate attention, including improved observational requirements and procedures, data processing, archiving and dissemination. At the same time, they also stressed the importance of maintaining the integrity of the current system so that a long uninterrupted data set would always be available.

The original plan for the second year of this program contained two elements: (1) define the current federally funded climate observing system; and (2) define an <u>ideal</u> climate observing system based upon the users and uses just compiled. Considering the anticipated funding, plus the widened scope of our work, we have had to revise our plans accordingly. We therefore plan, in accordance with workshop results, to concentrate our efforts on the areas needing the most attention, with the understanding that there are two important principles guiding our actions:

(1) There is a need for continuity in climate measurements; and

(2) Every meteorological observation is potentially a climatic observation--it may be more efficient to bring meteorological observations up to climatological standards rather than to make extensive changes in network configuration.

The areas of greatest concern (in order of priority) as stated elsewhere in this report are:

(1) Making the data that currently exists more accessible to users;

(2) Maintaining the continuity of the current system, especially the benchmark stations, by determining minimum standards for quality control, instrumentation, observation times, etc.;

(3) Filling the gaps in the precipitation network, by examining methods of combining precipitation measurements from various platforms;

(4) Maintaining the solar radiation network and making it more accessible to users; and

(5) Determining how the current federal monitoring of "urban climate" can be improved.

Each of the above problems could take all the efforts of those employed by this project, consequently, we do not expect to solve or even investigate any of them in their entirety. We do, however, expect to survey all of them before concentrating our efforts in the area (or areas) where we feel we can make the most meaningful contribution.

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APPENDIX A: Workshop Information

SPACE SCIENCE AND ENGINEERING CENTER

UNIVERSITY of WISCONSIN - MADISON
1225 West Dayton Street
Madison, Wisconsin 53706
TWX (910) 286-2771

Dear Sir:

The Space Science and Engineering Center at the University of Wisconsin, under the sponsorship of NOAA via the National Climate Program Office, is undertaking a study of the federally funded climate surface data networks. We will proceed in five steps: (1) Determine representative uses, applications and requirements of climate data supplied by the federally funded climate surface data networks; (2) Design an ideal system to satisfy the needs set down in (1); (3) Define the totality of the current system; (4) Compare existing networks with the ideal design network; and (5) Make final recommendations resulting from item (4).

As part of the first step, we will be convening a workshop in Madison on Oct. 12-14, 1981 with expert intermediate suppliers of local data who know both end user needs and network capabilities. The goal of this workshop will be to formulate and produce a "representative set" of uses and requirements. We hope to have participants representing diverse geographical areas, including climatologists, private and industrial meteorologists, government researchers and forecasters, hydrologists, land management specialists, agricultural representatives and others.

Because of your area of expertise, we would like to invite you to participate in this two and one half day workshop. We will pay all of your travel, food and lodging expenses. In addition, we will also be able to pay you an honorarium at the rate of $150/day. We hope that the 10-12 participants at this workshop will be able to produce a working document which will then be distributed to a wider body of the user community.

To facilitate our planning we would appreciate a response to our invitation within three weeks. At that point, I can provide you with more details regarding an agenda, travel arrangements and other participants. If you have any questions, I can be reached at 608:262-5772.

Thank you for your cooperation, and I hope to hear from you soon.

Sincerely yours,

David Suchman
Associate Scientist

SPACE SCIENCE AND ENGINEERING CENTER

UNIVERSITY of WISCONSIN - MADISON
1225 West Dayton Street
Madison, Wisconsin 53706
TWX (910) 286-2771

Thank you for accepting our invitation to attend the workshop dealing with the federally funded climate surface data networks. The workshop will run two full and one half day, ending at mid-day on Wednesday, October 14. We have already reserved a block of rooms, so no reservations or confirmations are needed. Madison is directly served by three airlines (Northwest, Republic, Ozark), with a fourth one (Frontier) scheduled to begin October 1. If you would like us to make reservations for you, please let us know.

The three main questions we will address are: (1) Who uses surface climate data?; (2) What do they use this data for?; and (3) What are the special requirements of the user community for this data? Each participant will be expected to make a short (15-20 min) presentation to the group as a whole on the nature of his work and experience in the data acquisition/dissemination area. Specific references to the type of data used, how it is obtained, how it is processed, to whom or for what it is used, and whether the data adequately fits the need would be most useful.

The bulk of the workshop will be broken into smaller working groups divided along the lines of the type of service performed: research, applications, or data supplier/processor. Each group will address the three questions mentioned above and try and come up with draft reports as to how their activities relate to the surface climate data networks. As we hope to make this workshop as quantitative as possible, any specific statistics or case study information you can provide will be most helpful.

About six weeks prior to the workshop we will provide you with a complete agenda, list of attendees, and further suggestions for preparations, etc. If you have any questions or comments, please call me at (608) 262-5772. In addition, I will be at the State Climatologists meeting in Fort Collins in mid-August, and will be glad to discuss the workshop and project with you.

Thank you again for your cooperation, and I am looking forward to seeing you in Madison.

Sincerely yours,

David Suchman

SPACE SCIENCE AND ENGINEERING CENTER

UNIVERSITY of WISCONSIN - MADISON
1225 West Dayton Street
Madison, Wisconsin 53706
TWX (910) 286-2771

September 1, 1981

Thank you again for agreeing to participate in our Surface Climate Data Workshop. Enclosed you will find the following:

List of Participants
General Information (including expense information)
Agenda
Visitor Expense Report
Restaurant List and Map
Campus Map
Visitor Information

To enable the workshop to proceed smoothly, we are also enclosing some suggestions for advance workshop preparation. Each participant will give a 15-20 minute presentation to the group as a whole on his work with surface climate data and his dealings with users of this data. In addition, you will be a member of one of three working groups (see list of participants). The main goal of this workshop is to determine a <u>representative</u> set of users, applications and requirements for climate data as supplied by the federally funded surface climate data networks. In addition to the above, we hope to touch on the following questions: Do we need all of the current stations? How do we maintain them (financially or physically)? Can the system be modified to better meet user needs? How can we integrate new data sources into the current system? What are likely future demands on the system? The results of the workshop will be contained in a working document to be circulated to a wider group of scientists for their reactions. It will eventually form the basis for a series of recommendations to be made to NOAA for (or against) modifications in the current system.

The introductory talks should center on the following: general nature of your climatic work; the number and kind of clients or contacts in this area; the types of data you use or are familiar with; whether the current availability of data meets your needs or those of other users you are familiar with. For the working groups we would like specific information on: key data variables you deal with--their accuracy, timeliness, time and space resolution and ease of availability; uses of this data--type of users supplied and their data needs, etc.; where the data comes from--the network that measured it and the location of its archive; and the representativeness of these users and uses. Any statistics pertaining to the above that could either be written or sent prior to the workshop will greatly ease our task in preparing a working document.

If you have any comments or questions concerning any of the information sent to you, or suggestions for modifications in the scope or format of this workshop, please either call or write me. I look forward to seeing you in Madison and to a very productive workshop.

Sincerely yours,

David Suchman

DS:ac
Encl.

AGENDA: Monday, October 12

8:30 A.M.	Registration, Room 351	
8:45	Welcoming Remarks:	Verner Suomi, SSEC
		Dudley McConnell, NCPO/NOAA
9:25	Introductory Remarks:	David Suchman, SSEC
10:00	General Presentations:	August Shumbera, National Climate Center
		Roy Jenne, NCAR
10:40-11:00	Break	
11:00	General Presentations:	Tom McKee, Colorado State University
		Wayne Decker, Univ. of Missouri-Columbia
		Stan Changnon, Illinois Inst. of Nat. Res.
Noon-1:30 P.M.	Lunch	
1:30 P.M.	General Presentations:	Richard Boyd, Dames & Moore
		Peter Leavitt, Weather Services Corp.
		Robert Dale, Purdue University
		Mike Hudlow, NOAA
		Stan Sauer, U.S. Geological Survey
3:20-3:45	Break	
3:45-5:15 P.M.	Organize Working Groups	
	Free Evening	

AGENDA: Tuesday, October 13

9:00-10:15 A.M.	Working Group Meetings
10:15-10:30	Break
10:30-Noon	Working Group Meetings
Noon-1:30 P.M.	Lunch
1:30-2:30	Present Interim Working Group Reports
2:30-3:30	Complete Working Group Discussions
3:30-3:45	Break
3:45-5:15	Preparation of Outlines/Drafts by Working Groups
6:30	Dinner and discussion

AGENDA: Wednesday, October 14

8:45-10:00 A.M.	Discussion: Suggestions for Changes in the Climate Data Measuring Network
10:00-10:15	Break
10:15-11:15	Final Working Group Meetings (if necessary)
11:15-12:30	Discussion: Where Do We Go From Here?
1:00 P.M.	-Workshop Ends-

List of Conference Participants
(and Working Groups)

Tom McKee; Colorado State University, Ft. Collins, CO (Group 3)

Wayne Decker; Univ. of Missouri-Columbia, MO (Group 2)

Stanley Changnon; Illinois Institute of Natural Resources; Champaign, IL (Group 1)

Peter Leavitt; Weather Services Corp., Bedford, MA (Group 2)

Roy Jenne; NCAR, Boulder, CO (Group 3)

Richard Boyd; Dames & Moore, Park Ridge, IL (Group 2)

Michael Hudlow; Hydrologic Research Lab/NOAA, Silver Spring, MD (Group 1)

Stanley Sauer; U. S. Geologic Survey, Reston, VA (Group 3)

Robert Dale; Purdue University, Lafayette, IN (Group 1)

August Shumbera; National Climate Center, Asheville, NC (Group 3)

HOSTS

David Suchman; SSEC, Univ. of Wisconsin-Madison (Group 3)

Brian Auvine; SSEC, Univ. of Wisconsin-Madison (Group 1)

Raymond Lord; SSEC, Univ. of Wisconsin-Madison (Group 2)

Dudley McConnell; National Climate Program Office/NOAA

OBSERVOR

David Miller; Univ. of Wisconsin-Milwaukee (Group 2)

APPENDIX B: A Workshop on Surface Climate Data

(to appear in Bull. Amer. Meteor. Soc., July 1982)

A Workshop on Surface Climate Data

David Suchman
Brian Auvine
Raymond Lord

Space Science and Engineering Center
University of Wisconsin-Madison
Madison, Wisconsin 53706

Dudley McConnell

National Climate Program Office
U. S. Department of Commerce
Rockville, Maryland 20852

January 1982

The Space Science and Engineering Center at the University of Wisconsin-Madison has begun a study of ways to improve the utility of data from the federally funded surface climate measurement networks. These measurement networks include the co-op, hydrologic, fire-weather, and synoptic, among others. As part of the first step of this program, a workshop was convened in Madison, WI on October 12-14, 1981, with a goal of formulating a "representative set" of uses and requirements of surface climate data. These uses, along with other statements of requirements, would then form the basic input for an "ideal" climate measuring system to be designed later during the project. This "ideal" network would be then compared with the existing network, and this comparison used as a basis for recommending improvements in the current system.

In order to begin formulating the representative set of uses of climate data, we assembled a small cross-section of intermediate suppliers and users of local data, expert in both user needs and network capabilities. The Workshop was organized into small subgroups which, besides compiling uses and requirements, also expressed concern regarding the continuing ability of the climate data system to meet user needs. Chief among the concerns was the possibility of government policy changes which could affect the current surface climate observing system. Because any interruption of the continuity of climate data could have profound effects on many users, the need for a statement of concern and recommendations for action become very clear: this statement appears at the end of the article. What immediately follows is a brief summary of the main issues along with related commentary and recommendations. Although the discussions contained some differences of opinion, the recommendations were unanimously endorsed.

1. Much of the surface data that are currently collected is primarily obtained for short-term weather forecasts; however, such data are in many ways inadequate for climatic purposes. To adequately study climate, we need standardized measurements at the same time, under the same conditions and at the same location for a long time period. In addition, we need the same quality control applied to all measurements. While we still need to define what measurements are needed, and evaluate what currently exists in these terms, it is clear now that parts of the present data network could be improved to better meet climatic needs. An illustration of this concern is that a cornerstone of the synoptic network, the FAA stations, emphasize aviation support, not surface data activities; these stations take good cloud and visibility observations, but their wind,* temperature and precipitation measurements could be improved.

2. There is an inadequate data base for certain important applications. Four significant climatic areas of national concern are air quality, energy, water resources and agriculture. Hence, we must pay special attention to the following: soil temperature and moisture, precipitation, wind, solar radiation, snow pack and evaporation. We must examine the ability of the networks to measure each of the above and determine when changes are desirable. One possible solution is to give the co-op substation (climate) network more support to achieve greater uniformity in equipment and in some instances, automation

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*For example, airport wind sensors have threshold start speeds (2-3 mph) that are too high for those interested in air pollution dispersion.

(e.g. touch tone pads, automated sensors).

One critical area of concern is the lack of the ability to adequately characterize urban climate. The FAA stations which are often located in outlying areas (such as airports) cannot therefore be representative of the climate of the regions where most of the people live. In order to deal with urban problems, we need to be able to adequately describe the city environment.

3. Network operation should involve people who perceive they need the data. Climatic measurements could be more reliable if people who have a stake in the data (e.g. industry, agriculture, city planning) would help measure them. Private sources who apply the data could share the responsibility for, and the expense of quality control.

4. Certain data once recorded must be made available to users in near real-time with adequate checks on quality control. There are certain atmospheric variables which are most valuable in near real-time: these should be culled out first, with the complete data set archived for future use.

5. A wealth of data exists already, but needs to be accessible. This is a high priority task. In addition, there are often no adequate records of how data are collected, or how they are checked for quality. Hence, we need a plan to standardize the acquisition and management of climate data. Because climate knows no state boundaries, this should be a federally coordinated national plan.

6. <u>All government agencies need to catalogue and describe their holdings.</u> There is no referral service between federal agencies; if one does not initially know where the data are, they cannot be located. In addition, the federal holdings are not often computer catalogued, leading to a lack of efficiency and timeliness in data dissemination. Many state holdings are not widely known, and there may be duplication of many data sets.

7. <u>The technology for improving the efficiency of the climate observing and disseminating system currently exists, but is not being widely used.</u> Some of the measuring and disseminating advances now include the use of a touch tone access system to a central computer for transferring data from the co-op network; transfer of information via communications satellites; and, the use of automated weather sensors that transmit to satellites for an automated archive. These advances have not only made possible better systems of storage, access, and processing of data, but also have brought about new techniques of measurement (e.g. thru satellite microwave and infrared sensors). We have not yet learned how to take maximum advantage of the data management aspects of these systems; nor have we had complete success in integrating these new measurement resources into our conventional data system (e.g. in combining satellite, radar, and surface gauge precipitation measurements).

8. <u>We need federal coordination and guidelines to accomplish the above goals.</u> These guidelines should: insure that local agencies have responsibility for local data; help improve the state climatology programs--we need state-to-state consistency in quality control and

interfaces between data and user; and to establish cost sharing between the state, federal and private sectors. Because so many interests are involved in the climate measuring system, we have a large number of non-uniform, non-compatible climate measuring systems. Thus, the total system must be examined from the network design and management of observing stations to the validation and distribution of data sets.

Based on this analysis, the statement of recommendations as approved by the participants follows:

Statement

The climate of the United States is a major national resource. The health, economic vitality, and security of the United States are very dependent upon our climate and how effectively we manage and use climate information. Climate is a pervasive resource that extends across state and international boundaries and hence requires uniformity in data collection and management.

Many federal agencies, most states and municipalities, and various industries collect most of the climate data needed to address climate-affected designs, operations, and assessments; however, the nation's climate data management effort is largely fragmented, and does not adequately serve many national, state, and local needs. We have witnessed a proliferation of climate data collection systems involving: 1) a variety of instruments that make data non-comparable, 2) inadequate maintenance and data quality programs, and 3) archives that are often stored in locales unknown to many users and that employ a myriad of incompatible formats. Thus, the support of a national climate data and information system must be a national objective. The first priority should be given to the cooperative network data beginning with local observations and concluding with interactive dissemination of information to users.

Most providers and users of climate data and information believe we need to create a system that produces cost efficiencies by facilitating access to the data and actively disseminating them. The sizeable local, state, federal and private efforts that now contribute towards collecting, checking, storing, and providing climate data and information to users need integration into a truly national effort. Federal, state, and local bodies, through sharing both costs and responsibility in network operations, would together ensure data collection with minimal redundancy, high uniformity and quality, and easy access.

Consequently, we recommend that the federal government with input from federal, state and private groups, develop a plan to provide a national program to acquire, manage, archive, and disseminate surface climate data.

The national climate data acquisition plan from observation through archival, and to dissemination would:

1. Define the roles of the federal/state/local governments and private sectors in the aquisition, archiving and dissemination of surface climate data.

2. Reduce redundancy by coordinating the many data collecting activities by various agencies in both the public and private sectors.

3. Improve access by providing a clearinghouse and referral service for all surface and related climate data.

4. Establish standardized field instrumentation and software formats designed for the present as well as future data collection, quality control and access. In addition, much of the data (especially for agriculture and hydrology) should be available for use in near real-time.

5. Establish guidelines for cost sharing with the states and private users, which will insure the integrity of the cooperative climate data network.

6. Provide possible cost savings with available new technologies.

Consequently, we recommend that a single agency, probably NOAA, be assigned overall responsibility for coordinating the acquisition and dissemination of surface climatic data.

Madison, Wisconsin
October 14, 1981

Representatives
David Suchman, Chairman, Univ. of Wisconsin-Madison
Brian Auvine, Univ. of Wisconsin-Madison
Richard Boyd, Dames & Moore
Stanley Changnon, Illinois Climate Data Director
Robert Dale, Purdue University
Wayne Decker, Agricultural Climatologist, Univ. of Missouri
Michael Hudlow, Office of Hydrology, NWS/NOAA
Roy Jenne, National Center for Atmospheric Research
Peter Leavitt, Weather Services Corp.
Raymond Lord, Univ. of Wisconsin-Madison
Stanley Sauer, U. S. Geological Survey
August Shumbera, National Climate Center, EDIS/NOAA
Verner Suomi, Univ. of Wisconsin-Madison

These summary comments are based on an overview of the problems confronting our climate data system along with some suggested remedies. Because they were developed by a small group in a two and one half day workshop, they may be biased and unrepresentative of many users. Before any recommendation is acted upon, further consideration should be given to these problems along with other as yet unarticulated concerns. Therefore we are publishing these summary results to stimulate wider discussion and benefit from a broad range of views. The authors would appreciate your comments at their addresses as shown. We hope, nonetheless, that these comments will help serve as a basis for the development of plans for improving the climate data network.

Acknowledgments

This project and workshop were supported by the National Climate Project Office of NOAA under Grant NA81AA-D-00052. The views reported here are those expressed at the workshop by the participants, and are not necessarily endorsed by the federal agencies or by the National Climate Program Office. We greatly appreciate all those attending the workshop for their cooperation and dilligence. Typing was provided by Angela Crowell.

APPENDIX C: Workshop Document Mailing List

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