11-42-CR

P. 37

PENNSTATE

1855

AN ASSESSMENT OF NASA MASTER DIRECTORY/CATALOG INTEROPERABILITY FOR INTERDISCIPLINARY STUDY OF THE GLOBAL WATER CYCLE

Final Report

Grant No. NSG 5-1437

Submitted To
Goddard Space Flight Center
National Aeronautics and Space Administration

May 1, 1991

Principal Investigator:

Dr. Donna J. Peuquet
Department of Geography

AN ASSESSMENT OF NASA MASTER DIRECTORY/CATALOG INTEROPERABILITY FOR INTERDISCIPLINARY STUDY OF THE GLOBAL WATER CYCLE

Final Report

Grant No. NSG 5-1437

Submitted To
Goddard Space Flight Center
National Aeronautics and Space Administration

May 1, 1991

Principal Investigator:

Dr. Donna J. Peuquet
Department of Geography

TABLE OF CONTENTS

1. INTRODUCTION

The most important issue facing science, and the world in general, is understanding global change; the causes, the processes involved and their consequences. The key to success in this massive Earth science research effort will depend on efficient identification and access to the most appropriate data available across the atmospheric, oceanographic and land sciences. In fact, finding who has what data and how good the data are has been identified as the dominant single problem facing scientists in addressing global change.

Current mechanisms used by earth scientists for accessing these data fall far short of meeting this need. With the large number of independent agencies and organizations that possess Earth science data and the variety of methods that have been implemented to support these collections, the identification of potential sources followed by the search through the source data collections to find specific subsets of interest has historically been a massive, time consuming and frequently frustrating undertaking. The magnitude of such a procedure obviously tends to grow in direct proportion to the total size of the geographic area to be studied as well as the disciplinary scope of the issue being addressed.

Scientists must as a result frequently rely on a priori knowledge and informal person-to-person networks to find relevant data. In either case, to acquire the data of interest in a locally useable form, they are often faced with a complex of obstacles including an inadequate infrastructure, a mire of inconsistent technologies and lack of documentation.

The Master Directory/Catalog Interoperability Program (MD/CI) undertaken by NASA is an important step in overcoming these problems. The stated goal of the Master Directory project is to enable researchers to efficiently identify, locate, and obtain access to space and Earth science data. The intent of that project is to work with existing data information systems and to influence newly developing systems to make them more interoperable by enabling a user to efficiently perform data searches.

1.1 Purpose and Objectives

The purpose of the work reported upon here is to provide NASA with input from non-NASA scientists toward the development of improved data management systems for Earth science research. More specifically, this work consisted of an evaluation of NASA's currently available prototype Master Directory facility from the perspective of the Penn State Earth Systems Science Center (ESSC) Eos interdisciplinary program to study the global water cycle.

A structured and independent assessment of the Master Directory system and the Catalog Interoperability concept was performed relative to the data requirements identified with specific selected projects that are specifically part of or directly related to the ESSC interdisciplinary Eos effort.

The overall objective of the effort reported upon here is to provide NASA with some input toward the development of performance requirements for future data management systems via a compilation of the data management needs of individual, non-NASA scientists involved in the Eos program.

1.2 The Scenarios

Toward the above objectives, three scenarios were developed. These were designed to represent a variety of situations and operational modes in which scientists involved in the Eos program currently operate. To provide situations (and resulting information to NASA) that is as concrete as possible, emphasis was on projects currently ongoing or in the immediate planning stage.

The scenarios were developed via direct interaction with individual Eos investigators at The Pennsylvania State University. One scenario involves a team of faculty investigators, the other two involve an individual investigator. All of these scenarios involve a range of required data types from varying sources. Each scenario includes the following elements;

* overall description of the research project - overview, goals

* the research plan with emphasis on data processing elements
    - phenomena to be investigated
    - general data/variables of interest
    - products/output

* data requirements (as appropriate)
    - association of variables to specific data sets of interest
    - temporal resolution and extent

- spatial resolution and extent
- source instrument and organization
- anticipated acquisition procedures, including names of non-public data sources known to the investigators

* report of Master Directory Search
    - empirical results
    - usefulness of the database contents
    - functionality of the Master Directory user interface

The three scenarios presented below include:

1. Title: Ice-Atmosphere Interactions in the Polar Oceans
   PI: Dr. Robert Crane, Dept. of Geography
   Summary: The purpose of this project is to examine sea ice - atmospheric interactions in terms of the atmospheric controls on ice cover, and the resulting feedbacks to the climate system. The primary objective is to determine the role of sea ice in global climate change.

2. Title: Determination and Impact of Surface Radiative Processes
   PI: Dr. Judith Curry, Dept. of Meteorology
   Co-PI's: Dr. Thomas Ackerman, Dept. of Meteorology
   Dr. William Rossow, Dept. of Meteorology
   Dr. Peter Webster, Dept. of Meteorology
   Summary: The purpose of this project is to study the interactions between variations in the sea surface temperature in the tropical western Pacific Ocean warm pool region and atmospheric circulation. A key element of this research is the establishment of validation methods that use data in addition to that provided by TOGA COARE.

3. Title: Climate and Society in 20th Century Mexico
   PI: Dr. Diana Liverman, Dept. of Geography
   Summary: The purpose of this project is to study how technological and social context can alter the impact of climate on food and agricultural systems.

The first of these projects was chosen as typifying an "easy" project in terms of data needs with the expectation of finding everything within the Master Directory. The second was chosen because of its more complex data needs and the greater chance that some things expected in the Master Directory will not be there. The third is a clear case of "going shopping" with some hopes of finding some useful data. This third project was also chosen as a response to a desire expressed by NASA to include some cultural types of data sets in the Master Directory.

In addition to the individual scenarios, a summary of data and data search requirements in addition to an overall assessment with respect to the ESSC Eos global water cycle effort are included in this report.

-46
3-465
P. 5

2. ICE-ATMOSPHERE INTERACTIONS IN THE POLAR OCEANS

Lead Investigator: Dr. Robert Crane

N91-27598

2.1 Overview

Sea ice forms a major reservoir in the global water cycle and both polar regions undergo a large seasonal variation in their sea ice cover. The extent of this sea ice cover is a function of both dynamic and thermodynamic interactions with the atmosphere and ocean. Changes in the ice cover can be regarded as an indicator of climate change and variability, while interactions between the sea ice and climate make it likely that changes in the ice cover will also feed back to effect a further change in climate over a variety of temporal scales.

This research examines these sea ice - atmospheric interactions in terms of the atmospheric controls on ice cover, and the resulting feedbacks to the climate system. The primary objective is to determine the role of sea ice in global climate change.

As a subset of the overall project, we are interested in examining the relationship between sea ice and the synoptic-scale atmospheric circulation in the North Atlantic. This region is chosen for more detailed study because, first, the project involves land ice and we have a focus on Greenland. Second, there have been several previous international field programs in the region, and a couple more are planned for the early 1990's.

2.2 Research Plan

A significant feature of all General Circulation Model experiments is an enhanced high latitude response to a doubling of atmospheric CO_2. Unfortunately, both sea ice and cloud processes are poorly dealt with in current GCM's. Given this situation, it is important to examine polar energy budgets through observational and empirical analyses in order to improve on GCM performance in the polar regions, and to use the models to estimate the consequences of global climate warming. A major constraint to both the empirical analyses and GCM validation has been the lack of adequate data -- a situation that should improve with the new observational possibilities offered by the Eos Program.

The synoptic circulation modes of the observed and GCM climates will be extracted using rotated principal components analysis, and the GCM modes will be assessed in terms of the observational fields. The circulation modes will be further categorized using ancillary data such as temperature, humidity, winds, cloud cover, etc. The analysis will be used to assess the results obtained from GCM experiments of past or future climate states.

2.3 Data Needs

This study focuses on ice-atmosphere interactions and requires data on ice extent type and concentration, and on the composition and state of the atmosphere.

2.3.1 Ice data

Ice extent, concentration, and ice type will be derived from passive microwave radiometry. The primary source of these will be the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR). This source provides a continuous and consistent 10 year record of brightness temperatures that can be used to calculate ice concentration and the multiyear ice fraction at a 50km resolution. These data are currently available from the National Snow and Ice Data Center, which will be a node on EosDis.

2.3.2 Atmospheric data

Three types of atmospheric data will be used:

1) *long-term 'observational' data from the National Meteorological Center* - These are gridded products based on station observations, which will be used for GCM validation and as a consistency check for the Diagnostic Model fields. These data are available from the National Center for Atmospheric Research.

2) *Atmospheric fields from the European Center for Medium Range Forecasting diagnostic model* - These will be used for the actual ice-atmosphere interaction studies as the fields are more complete than the observational data, and are internally consistent. I would not expect to see either of these two data streams in EosDis, although I would expect to be able to find information on these data sets in the Master Directory database.

3) *Cloud cover data derived from NOAA AVHRR* - In this case I would expect to find both the brightness counts and temperatures, and the derived cloud products in EosDis.

2.3.3 GCM data

GCM sea ice and atmospheric data is to be compared with present day data sets to determine how well GCM's simulate the interactions observed in the empirical data, and the doubled CO_2 runs will be used to examine how these processes may change in the future. This type of analysis requires daily data for as long a time period as is available. It is assumed that baseline data sets of the major GCM's will be available in EosDis.

A breakdown of needed data variables, their characteristics and expected sources are given in the table on the following page.

2.4 Results of Master Directory Search

This particular project was chosen as one of the scenarios from among Penn State's interdisciplinary Eos program components because this effort is characterized as having data needs that were expected to be included in the Master Directory database.

The Master Directory search was performed from Penn State utilizing a SUN SparcStation running SUN OS and a Micro VAX II running VMS. NSSDC's on-line data and information services were accessed via Internet.

2.4.1 Usefulness of the database contents

In searching the Master Directory database for the desired specific data sets, there was a good although not complete inclusion of needed data sets. There were some derived data sets (e.g., generated via a General Circulation Model) that potentially could have been included. These were not found. SMMR data was found in the Master Directory database, however. This entry also seemed to be up-to-date in its description of the data set. Some AVHRR data was found, but not for the required geographical area.

Variable	Temporal Resolution	Temporal Extent	Spatial Resolution	Spatial Extent	Source Instrument	Source Organization
Ice Extent Concentration Type	3 days	1979-1989	50km	80°N-50°N 70°W-90°E	 SMMR SMMR SMMR	National Snow & Ice Data Center
Atmospheric (diagnostic model) Sea level pressure Surface air temperature Cloud extent Surface wind 3-d moisture fields 500 mb heights	Daily	1979-1989	4° x 5°	80°N-50°N 70°W-90°E		European Center for Medium Range Forecasting
Atmospheric (observational) Sea level pressure Surface air temperature Surface wind 500 mb heights Cloud extent	Daily	1965-1990	4° x 5°	80°N-50°N 70°W-90°E	AVHRR	National Meteo. Center (via NCAR) NOAA
General Circulation Model Sea Ice Sea level pressure Surface air temperature 500 mb heights Clouds 3-d moisture	Daily	3 - 10 years	4° x 5°	80°N-50°N 70°W-90°E		Goddard Inst. for Space Studies NCAR Geophysical Fluid Dynamics Lab U.K. Meteo. Office

Information in the 'brief' description for specific data sets found in the Master Directory database was seen as overly brief and often inconsistent. Information on how to actually obtaining some data sets was incomplete (e.g., AVHRR data for Spitsbergen).

2.4.2 Functionality of the user interface

For individuals with a priori knowledge of the specific data sets desired, the strictly hierarchical, menu-driven interface was found to be more of a hindrance than a help. This was true even for such a person who was using the Master Directory for the first time. For example, once a specific data set was located on the database, it did not seem possible to go directly to the 'contact' level without first going through generalized descriptions.

After some initial searches utilizing a SUN workstation, it was decided to try the same exercise on a Micro VAX running the VMS operating system. The reason for this was that one of the initial dialogue screens for NSSDC's on-line data and information services asks for terminal type. Since the choices included 'VT compatible', 'Tektronix 4025' and 'other', there was hope that using a 'VT compatible' terminal on a system compatible with NSSDC's computer might provide some additional screen/menu capabilities. Although there was some improvement in the apparent speed of generating displays on our remote terminal, the user interface mechanism was identical.

-3-46
36466
p.12

3. DETERMINATION AND IMPACT OF SURFACE RADIATIVE PROCESSES FOR TOGA COARE

Principal Investigator: Judith A. Curry

Co-principal Investigators:
Thomas Ackerman
William B. Rossow
Peter J. Webster

N91-27599

3.1 Overview

Experiments using atmospheric general circulation models (e.g., Palmer and Mansfield, 1984; 1986) have shown that the atmospheric circulation is very sensitive to small changes in sea surface temperature in the tropical western Pacific Ocean warm pool region. At the same time, sea surface temperature and the ocean mixed layer structure in the western Pacific Ocean warm pool region are very sensitive to changes in the surface heat, momentum and freshwater fluxes that are driven by the atmospheric circulation. The mutual sensitivity of the ocean and the atmosphere in the warm pool region places stringent requirements on models of the coupled ocean-atmosphere system. At present, the situation is such that diagnostic studies using available datasets have been unable to balance the surface energy budget in the warm pool region to better than 50-80 W m^{-2} (TOGA COARE Science Plan, 1989).

The TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) is an observation and modelling program that aims specifically at the elucidation of the physical process which determine the mean and transient state of the warm pool region and the manner in which the warm pool region interacts with the global ocean and atmosphere. This project focusses on one very important aspect of the ocean-atmosphere interface component of TOGA COARE as described by the TOGA COARE Science Plan (1989), namely the temporal and spatial variability of surface radiative fluxes in the warm pool region.

A key aspect of understanding the principal processes responsible for the coupling of the ocean and atmosphere in the western Pacific warm pool region is the assessment of surface radiation fluxes and their variations. Solar radiation reaching the sea surface is mainly modulated by variations of cloudiness and solar zenith angle, both of which have large amplitude on short time scales. The amount absorbed by the ocean is determined by the surface reflectance which can be influenced by variations in surface wind speed and the turbidity of the upper ocean layers. The precise effect of the absorbed energy on the ocean mixed layer depends on its vertical distribution, which, since it is a strong function of wavelength, varies with cloudiness. Cooling of the ocean mixed layer is dominated by evaporative cooling; however, this process is strongly constrained by the fact that the large thermal radiative fluxes between the ocean surface and the atmospheric boundary layer strongly couple their temperatures. Thus, understanding how the coupled system responds to rapid transients of energy input requires examination of the variations of the solar and thermal radiation fluxes on short time scales to determine how the combined atmospheric-oceanic boundary layers integrate over these rapid and large variations.

Clouds decrease the amount of incoming shortwave radiation and increase the amount of downwelling longwave radiation. The effect of clouds on the surface radiation flux depends primarily on the cloud optical properties, with cloud base height (temperature) being an important parameter for determining the surface longwave flux. The extent to which cloud base temperature becomes the effective radiating temperature to the surface depends on the water vapor content of the subcloud layer (Stephens and Webster, 1979; 1981). Because of the high water vapor amount characteristic of the western Pacific Ocean, water vapor continuum emission in the atmospheric window region renders the subcloud layer nearly opaque (Stephens and Webster 1981), with most of the radiation emitted from the cloud being absorbed in the subcloud layer before reaching the surface. Because of the relative insensitivity of the surface downwelling longwave flux to clouds, the impact of cloudiness in the tropics on the surface irradiance is mainly to reduce the intensity of the solar flux (Stephens and Webster, 1979), although the importance of accurately determining the downwelling longwave flux should not be underestimated.

Besides varying the magnitude of the total surface irradiance, clouds change the spectral distribution of radiation at the surface, since clouds absorb in the infrared and do not absorb in the visible. Additionally, the presence of clouds enhances the absorption due to water vapor and thus modifies the spectral distribution by increasing the photon path length via multiple scattering by the cloud. In the presence of clouds, the shortwave portion of the spectrum as received at the surface will be relatively enriched in visible radiation compared with near infrared radiation. Thermal infrared radiation will also be enhanced. The change in spectral distribution of the incoming radiation in the presence of clouds affects the attenuation of radiation in the ocean, which varies spectrally. In the upper ocean, the attenuation coefficient of the radiation is a strong function of the wavelength (Simpson and Dickey, 1981), and both downwelling long-wave radiation and incoming solar radiation are selectively absorbed in the upper ocean. The absorption of solar radiation shows a strong spectral dependence, with the red and near infrared radiation absorbed within a few centimeters and the shorter wavelength radiation absorbed at considerably greater depths (e-folding depth for visible radiation is 8 m). Thus changes in cloudiness could alter the vertical distribution of heating in the boundary layer of the oceans as well as its magnitude. For most ocean mixed layer regimes this may not be very important, but it may be crucial in the low mean wind speed and high fresh water input regime of the western Pacific warm pool.

Although much information must come from in situ observations, obtaining an integrated perspective of the surface radiation fluxes over the entire warm pool region requires analysis of satellite measurements. The principal difficulty with the retrieval of longwave fluxes is determination of cloud base height and boundary layer water vapor amount. Surface longwave flux in the tropics is likely to be more sensitive to boundary layer water vapor amount, which is the easier problem to address via remote sensing, than to cloud base height.

3.2 Research Plan

This project has two principal goals: the establishment and validation of data analysis methods for the remote sensing of surface radiation fluxes that can be used routinely after the field phase of TOGA COARE; and an improved understanding of the atmospheric forcing of fluctuations in the surface radiation balance and the impacts of these fluctuations on the ocean mixed layer.

The key scientific problems to be addressed in this research are:

- *What are the microphysical and radiative properties of clouds in the warm pool region and how do they vary spatially and temporally?*
- *What are the temporal and spatial variability of surface radiation fluxes in the Pacific warm pool region and how are they influenced by clouds?*
- *How do the cloud properties and surface radiative fluxes vary with mesoscale and synoptic scale forcing?*
- *How sensitive is the sea surface temperature and the ocean mixed layer to high frequency (the order of several hours) fluctuations in the surface radiative flux associated with changes in cloudiness?*

Because of the complementary information obtained from different measurements and using different analysis techniques, the best results will come from a combined analysis of several datasets. Especially during the TOGA COARE IOP, the availability of many special surface and aircraft datasets will significantly augment the remote sensing analysis results. This research will therefore be accomplished in three stages:

- *remote sensing pilot study to develop and compare satellite algorithms;*
- *validation of remote sensing algorithms using TOGA COARE IOP surface and aircraft observations and preparation of high-resolution analyses for the IOP; and*
- *diagnostic and modelling studies utilizing the analyzed fields.*

The investigators are planning to provide the following high-resolution analyses for the entire TOGA COARE IOP initial primary domains of:

- *sea surface "skin" temperature*
- *surface reflectance*
- *surface wind speed*
- *atmospheric precipitable water*
- *cloud properties including cloud fractional coverage and optical depth*
- *surface radiation fluxes*
- *tropospheric radiative heating and cooling rates.*

The analyses will be accomplished principally by satellite remote sensing, largely based on the International Satellite and Cloud Climatology algorithms developed by Rossow and colleagues (Rossow et al, 1988; Rossow et al., 1989a,b; Rossow and Lacis, 1990; Rossow et al., 1990; Bishop and Rossow, 1990). The analyses will be produced on a spatial scale of 30 km and a temporal scale of 3 h for the entire TOGA COARE IOP domain and period. These analyses will be made available to other TOGA COARE investigators, and we expect them to have widespread utility in many aspects of TOGA COARE.

Available surface and aircraft data will be utilized to validate the remote sensing algorithms and will also be blended with the satellite retrievals for the final analysis products. An aircraft sub-program is proposed specifically to investigate cloud radiative properties and to validate the satellite-derived surface radiative fluxes.

3.3 Satellite Remote Sensing Data

The principal datasets utilized for the remote sensing studies are the ISCCP datasets (radiances from imaging instruments and analysis results), the High Resolution Infrared Radiometer Sounder and Microwave Sounding Unit (HIRS2/MSU) infrared/microwave radiances (as well as the operational analyses of these data, called TOVS products) and the DMSP Special Sensor Microwave Imager (SSM/I) brightness temperatures.

The basic satellite radiance data used in deriving the ISCCP high resolution results for the TOGA COARE region are obtained from the Japanese Geostationary Meteorological Satellite (GMS-4) every 3 hours at the synoptic reporting times. However, four-times-daily observations (at approximately 2:30, 8:30, 14:30 and 20:30 local time) are also available from the AVHRRs on two NOAA polar orbiters. The ISCCP datasets include the original radiances (Schiffer and Rossow 1985, Rossow et al. 1987) and analysis results containing information about clouds and the surface sampled every 30 km and 3 hr (Rossow et al. 1988, Rossow and Schiffer 1991).

The standard ISCCP retrievals can be extended by combining the additional spectral channels in the AVHRR data with the HIRS2/MSU data. The HIRS2 radiances are obtained four-times-daily from the two NOAA polar orbiters with a spatial resolution of about 15 km. Current analysis techniques reduce the spatial resolution to 60 km (Susskind et al 1984); but the operational analysis is only available at a resolution of about 250 km and only once per day. However, special analysis of these data for the TOGA COARE IOP will supplement the basic imaging datasets.

The Special Sensor Microwave/Imager (SSM/I) is on the polar-orbiting Defense Meteorological Satellite Program (DMSP) F8 satellite (Hollinger, 1988). This satellite makes twice-daily passes at roughly local noon and midnight. The SSM/I has four frequencies (19.35, 22.234, 37.0 and 85.5 GHz) and dual polarization capabilities on all except the 22.235-GHz frequency which records only the vertical polarization. The effective ground resolution of the 85.5 GHz data is 15 km, ranging to 69 km at 19.35 GHz.

Broadband total flux measurements may also be available from the French-Soviet SCARAB experiment during the TOGA COARE IOP. If these data are available, they can be used to provide a consistency check on the surface radiative flux calculations as well as more direct constraints on surface albedos.

3.3.1 Sea surface "skin" temperature

To properly diagnose energy exchanges between the atmospheric and oceanic boundary layers, the actual "skin" temperature of the ocean must be determined, rather than the bulk mixed layer temperature. Fortunately, satellite radiometers measure skin temperature directly, although all current analysis methods have been tuned to produce bulk temperatures for comparison with ship measurements. During TOGA COARE, we intend to compare and separate the quantities measured by ships and satellites in some detail as this may provide some insight into the mixed layer dynamics in this region.

We plan to compare different techniques for retrieval of sea surface temperatures from satellite data to develop a standard of accuracy independent of ship measurements. The ISCCP cloud analysis (Rossow et al. 1988) currently uses one IR channel (wavelength about 11 microns) to obtain SST from clear radiance values and the operational atmospheric profiles of temperature and humidity. A new technique is being developed, similar to the NOAA operational method, that uses all of the IR channels on the AVHRR (at 3.5, 10.5 and 11.5 mm) to remove residual cloud and water vapor effects. This new study is also examining ways to monitor the calibration of these channels. These results will be obtained at a spacing of 25 km. Other methods of determining SST include that of Susskind et al (1984) using HIRS2/MSU data. Although SSM/I does not have the lower frequency channels required for retrieval of SST (Wilheit et al. 1984, Petty 1990), the MSU instrument maybe useful for this purpose.

3.3.2 Ocean surface reflectance

Ocean surface reflectance is required to determine the net shortwave irradiance at the surface. The ocean surface albedo is small (about 6%), but it can vary by about a factor of two because of changes in the particulate amount in the upper 10 meters of the ocean and by even larger factors as a function of solar zenith angle and wind roughening of the surface. Although these variations only change the total absorbed solar flux by amounts less than 10-20 W m-2, this is still about 10% of the net radiative flux. Current techniques to remotely sense surface albedo only work under clear-sky conditions (e.g., Rossow et al., 1989a), so surface reflectance under overcast conditions can only be determined by modelling. Our model (Rossow et al. 1989a) determines the ocean reflectance as a function of angle wind speed. Turbidity effects can also be included. A comparison of modeled with retrieved surface reflectances by Rossow et al. (1989a) showed the model to be correct to within 2% for geometries away from glint conditions.

We plan to combine surface wind analyses with the satellite measurements to determine whether wind and turbidity effects play any significant role in determining the variability of the surface radiative fluxes.

3.3.3 Surface wind speed

Wind roughening of the sea surface alters the reflectance of the ocean surface by causing surface bubbles (Tanaka and Nakajima, 1977). Modelling of oceanic surface albedo therefore requires determination of surface wind speed.

Surface wind speed will be determined using the SSM/I data after Wentz et al. (1986). New coefficients have been determined for the SSM/I channels, which will be published shortly (Wentz, personal communication).

3.3.4 Precipitable water

Water vapor amount is needed for the retrievals of surface temperature from satellite radiances and for the calculation of radiative fluxes, particularly the transient variations of the net thermal fluxes. Moreover, water vapor and skin temperature are the key to determining the latent heat fluxes that are the first-order balance to the solar heating. Since a correlation has been found between precipitable water amount and surface-level humidity over oceans, satellite-based estimates of precipitable water amounts have been used to determine the surface latent heat flux (Liu 1986). By combining several estimates of water vapor amounts and short-term skin temperature variations, we plan to examine this relationship more closely.

The infrared radiances measured by HIRS2 and AVHRR are also sensitive to precipitable water vapor amounts. The CO2 band channels, used for temperature sounding, are affected by water vapor, so that retrieval of the temperature profile also implies a first-order calculation of water vapor absorption. However, this can be improved by taking advantage of the remaining channels that have stronger dependence on water amounts (Hayden et al., 1981). The very strong pressure dependence of the water vapor continuum absorption makes measurements at 10-12 mm much more sensitive to the water vapor nearest the surface. If we are able to improve SST retrievals to an accuracy of 1 degree or better, then we may be able to isolate the signal associated with near surface water vapor by combining microwave, IR sounder and AVHRR radiance measurements. The intense TOGA COARE IOP in situ measurements provide a unique opportunity to attempt this analysis.

3.3.5 Cloud properties

Our principal interest in cloud properties is to determine their effect on the surface radiative fluxes. The primary dataset is the ISCCP analysis (Rossow et al., 1988; Rossow and Schiffer, 1991), which describes the cloud optical thickness and cloud top temperature and pressure for each image pixel. Using an approach similar to that employed by Rossow et al. (1989a; 1989b) and Rossow and Lacis (1990), these quantities are retrieved from visible and "window" infrared radiance measurements by satellites (see also Rossow et al., 1985). At night, only the cloud top temperature/pressure is retrieved because there is no visible radiance data. The retrieval is done by comparison of radiative transfer model calculations of narrowband radiances to the satellite measurements as a function of viewing geometry, of atmospheric composition and temperature structure, and of surface reflectances and emittances. These same quantities are then employed in the flux calculation model.

Since only two wavelengths are analyzed, only the two most important cloud properties are retrieved (optical thickness and temperature). However, the retrieval model is based on a detailed cloud microphysical model that is assumed to be unvarying in the ISCCP analysis but can be varied if other information is available.

Comparison of the satellite-based values of LWP to in situ measurements of cloud water content and surface-based measurements of cloud base altitude also allows for study of the relations between the remotely sensed parameters and the cloud water content, which depends on the vertical extent of the clouds. This will be key to determining whether the cloud base location and temperature can be inferred from existing satellite datasets. Cloud base temperature is needed to determine cloud effects on downwelling thermal fluxes at the surface.

3.3.6 Surface radiation fluxes

The radiative transfer model to be employed in the retrievals is that used in the GISS climate GCM (Hansen et al., 1983). All radiatively significant atmospheric constituents are included and vertical inhomogeneities are explicitly represented. The modeled atmosphere is vertically divided into twelve layers, with eight in the troposphere and four in the stratosphere (model layers can be varied). The properties of the stratosphere above the 5 mb level are specified from the climatology used in the GCM.

Clouds are described by two "microphysics" models (cloud particle size distribution and phase), one representing water clouds and one representing ice clouds; these model parameters can also be varied. Cloud optical properties are determined using the ISCCP dataset from radiances at 0.6 mm wavelength. The spectral variation of cloud optical thickness is determined by referencing the optical parameters to those at 0.6 mm using the microphysical models. Thus, specification of the cloud optical thickness at this single wavelength sets values of optical thickness at all wavelengths for the flux calculations.

Ocean directional albedo is specified as a function of solar zenith angle and wind speed (after Minnis and Harrison 1984). Surface emissivities are set to unity, consistent with ISCCP radiative retrievals; however, spectrally dependent emissivities can be specified as a function of surface type.

The relevant model output quantities are: upward and downward solar (two wavelength bands corresponding to visible and near-IR) and thermal (total and "window") fluxes at the surface for clear, totally cloudy and fractionally cloud conditions.

3.3.7 Tropospheric radiative heating and cooling rates

Although tropospheric heating and cooling rates are not required to determine surface radiative fluxes, they are easily obtained as a by-product of the ISCCP algorithm. We expect to provide these analyses for eight levels in the troposphere.

3.4 In Situ Validation Data

TOGA COARE provides a unique opportunity to validate satellite retrieval algorithms in the tropics due to the high density of surface and aircraft observations of relevant parameters. The following in situ measurements will have particular utility in validating the satellite retrieval methods:

- *ship-borne and land-based observations of surface radiation fluxes*
- *ship-borne and land based observations of near-surface air temperature and humidity*
- *ship-borne observations of ocean "skin" and "bulk" temperatures*
- *ship-borne and buoy observations of ocean mixed layer vertical structure*
- *radiosonde measurements of atmospheric water vapor and temperature profiles*

- *aircraft measurements of cloud microphysical properties and radiative fluxes*
- *aircraft microwave measurements of sea surface temperature*

In the TOGA COARE Intensive Flux Array it is planned that there will be six ships. On each ship will be an Integrated Sounding System (ISS) consisting of a RASS system which provides a high resolution vertical profile of the water vapor content up to about 600 mb, a 915 MHz profiler, an omega-sonde system, and a suite of surface radiometers which will measure incoming shortwave radiation and both upwelling and downwelling longwave radiation.

3.5 Results of Master Directory Search

As stated in Section 1.2 of this report, the project just described was chosen as one of the scenarios from among Penn State's interdisciplinary Eos-related projects because of its varied and complex earth science data needs.

The Master Directory search was performed from PSU utilizing a SUN SparcStation 1+ running SUN OS. NSSDC's on-line data and information services were accessed via Internet.

3.5.1 Usefulness of the database contents

A loosely constrained database search was performed in order to find what data sets might be available (unanticipated as well as anticipated) with appropriate characteristics. The best results given the intended goals of this project in particular will come from a combined analysis of a number of different data sets. The discovery of additional data sets for use in this project was therefore a hoped-for outcome in the MD database search. In this initial, broad-based search, 263 entries were returned using 'earth atmosphere' as the only topical search parameter. No additional parameters were used as search constraints for fear of unknowingly eliminating some potentially interesting but unanticipated data set. Nevertheless, no 'interesting' data sets were found before giving up in frustration when faced with searching a very long list that had no meaningful ordering.

In searching for data on a project basis, some major inconsistencies were found. The list of investigators associated with specific data sets that were familiar to Drs. Curry and Ackerman did not match the names of the people that they personally knew had a major association with a given data set. This problem was apparent with the entry for the 'Fire' data set. There was also a lack of cross-referencing between investigators and data set names (e.g., Rossow - Fire).

As a further exploration of the Master Directory aside from the TOGA COARE related work, aircraft data on Antarctic ozone was searched for but not found.

3.5.2 Functionality of the user interface

Browsing the large number of entries returned as a result of loosely constrained queries proved to be quite tedious, since the entries were not in any order that allowed the user to search the list in anything other than in an exhaustive, top-to-bottom fashion. Sorting or grouping the returned entries into some user-requested order (e.g., alphabetical by project, investigator or by geographical area) would have been a significant aid in manually searching the returned entries.

Again, similar to the experience in the preceeding scenario (c.f. Section 2), the strictly hierarchical, menu-driven interface was very quickly found to be more of a hindrance than a help. It proved to be particularly frustrating for a user who wanted to retrieve information on specific data sets or highly constrained groups of data sets that were known or assumed to be in the MD database. Single parameter values among multiple search parameters could not be individually changed without backtracking through the menu structure. The available value choices were also extremely limited for most search parameters, and some combinations simply didn't seem to be allowed (e.g., campaign/project description).

A method for inputting user-specified search keywords or values and a more flexible means of combining them without abandoning the non query language approach seemed to be needed.

References

Gautier, C., 1988. Surface solar irradiance in the Central Pacific during Tropic Hear: Comparisons between in situ measurements and satellite estimates. **Journal of Climatology**, 1: 600-608.

Gupta, S.K., 1989. A parameterization for Longwave surface radiation from sun-synchronous satellite data. **Journal of Climatology**, 2: 305-320.

Njoku, E., 1985: Satellite-derived sea surface temperature: Workshop comparisons. **Bulletin of the American Meteorological Society**, 66: 274-281.

-3-47
5 4467
p-10

4. CLIMATE AND SOCIETY IN 20TH CENTURY MEXICO

Principal Investigator: Diana M. Liverman

N91-27600

4.1 Overview

Mexican agriculture has been dramatically transformed through the widespread introduction of "Green Revolution" technologies (such as irrigation, chemical fertilizers, and improved seeds), through land reform, and by land use policies oriented to export crops and grain production. Drought prone Mexico provides an excellent case to study how technological and social changes alter the impact of drought on food and agricultural systems. The goal of this project is to document and understand how relationships between climate and agriculture in Mexico have changed in the last fifty years. The results from this study for several locations will be interpreted in light of the prospects of regional climate change due to global warming.

Meteorological records, agricultural censuses and reports, and the popular press will be used to reconstruct the climate, specifically drought, and agriculture of twentieth century Mexico. Detailed data from six censuses will be used to map patterns of agricultural production and losses, and to relate them to meteorological, technological, and socioeconomic conditions. Statistical analyses will assess: 1) whether climate determines reported drought losses, 2) whether technology buffers the agricultural system against climatic variability, and 3) the differences in drought impacts between land tenure sectors.

This analysis will be complimented by four case studies of vulnerability to drought which will use local records and interviews to try and show how environmental, technological, and social changes may have altered the impacts of climate on local agricultural systems.

In one case study of maize cultivation in the Valley of Oaxaca in southern Mexico, possible responses to potential regional climate change due to global warming will be assessed. This facet of the project will begin with a detailed study of the regional climate including both historical meteorological data and the dynamics of global, regional and local-scale atmospheric circulation, as historically and spatially related to maize yield in the valley. This analysis will be supplemented by a study of other technical, social, ecological and cultural factors involved in maize cultivation. The implications of the results in terms of the vulnerability of the region to potential climate changes will be discussed.

Every ten years since 1930, the agricultural census has reported yields, hazard losses, land tenure, and the use of agricultural technology for more than one thousand local administrative districts called municipios. These data will be used to map patterns of agricultural production and losses, and relate them to meteorological, technological and socioeconomic conditions. The following hypotheses will be examined:

- *The pattern of drought loss and agricultural production is determined by physical geography, especially climate.*
- *Irrigation reduces the impact of drought on agricultural production.*
- *The use of improved seeds and other Green Revolution technologies is associated with higher yields and lower drought losses.*
- *Small and communally-owned (ejido) farms are disproportionately vulnerable to drought.*

4.2 Research Plan

The following specific research activities and analyses will be undertaken:

4.2.1 Compilation and analysis of meteorological records

The pattern and severity of meteorological drought from 1925 to 1985 in Mexico will be documented using meteorological data available in the library of the meteorological observatory in Mexico City. Preliminary visits to this library suggest that fairly good temperature and precipitation records are available for this sixty-year period for most regions of Mexico. It should be noted that most of these data are not computerized and will need to be hand copied from the original weather records. For this reason, most of the climate analysis will be based on monthly data. It is possible that some digital data sets may be available from climate researchers in Mexico, and could be obtained through personal working relationships, particularly at the Universidad Autonoma Nacional de Mexico or in the Oficina de Climatología. Some recent records for Mexican stations are also available in international data sets. Recent climate records, if available in digital form, would be extremely useful in detailing the current situation.

Current and historical data will be organized and mapped using standard computer-based geographic analysis packages (e.g. ARC/INFO & ERDAS). Drought occurrence will be identified through the analysis of precipitation variability, and through the development of drought indices which include temperature and antecedent conditions. Although the Palmer Drought index will probably be used, we plan to discuss alternative indices with Mexican researchers.

This research task should produce a useful climatology of Mexican drought and will be used as input into the analysis of drought impacts and vulnerability. The data set will also provide a basis for longer term research into Mexican climate and climate change and will be made available to other researchers.

4.2.2 Compilation of data on agricultural yields and production

National-level yield and production data have been published for all major crops in Mexico since 1925. We will attempt to obtain desegregated yield data (by state or municipio) for this time period. We will attempt to compile time series of yields, production, and, if possible, reported hazard losses, at the state level, so that we can compare our record of physical drought severity with agricultural conditions. We will focus on major crops, particularly maize and wheat. This information should be available from the archives of the Secretaria de Agricultura in Mexico City. This data will permit an analysis of relationships between drought and agriculture over time in Mexico. We will seek, in particular, evidence of increased yield variability and yield sensitivity to drought using statistical techniques used by Hazell (1984, 1986) and Michaels (1979) - changes in the coefficient of variation or regression coefficients respectively. We will also focus on how agricultural production has responded in severe drought years to see if the response has changed over time. The research task may be constrained by data limitations, and by methodological problems associated with crop-weather analysis such as the assumption of linear technology trends. It may, at a minimum, be possible to construct a few case study data sets from newspapers or agricultural projects. I have had some success in obtaining time series data (1950-1980) on technology and yields in Sonoran irrigation districts and in the valley of Puebla (1960 onwards).

This task will provide a context for the subsequent analysis of the decadal agricultural census, and a general sense of the changing relationships between drought and agricultural production in Mexico. If desegregated and reliable data is available, and if adequate information about technological change (irrigation, improved seeds, fertilizer use) is found, this research activity will be expanded into a comprehensive statistical analysis of regional relationships between climate, technology, and crop yields in Mexico.

4.2.3 Analysis of decadal agricultural censuses

This research task will use data from the general summaries of the Mexican "Censo Agricultura, Ganadero y Ejidal" for the years 1930, 1940, 1950, 1960, 1970 and 1980. Most of these censuses (not, as yet, 1980) report information on total agricultural losses from natural hazards for each state, and municipio. They also distinguish between losses in the ejido and private sectors, and after 1950, between large private (over 5 hectares) and small private (under 5 hectares) holdings. After 1950, hazard losses are reported by hazard types, including drought, floods, hail, and "plagas" (pests and diseases). Hazard losses are reported in terms of land area planted but not harvested. Hazard related yield declines are not reported in the census, presumably because data on mean yields was not available. In the more recent censuses, detailed information is also provided on the use of various agricultural technologies such as irrigation, fertilizer, improved seeds, and pesticides. It should be noted that the decadal census actually reports on the previous years crop season. Thus, the 1970 census refers to the 1969 growing season.

There are potential problems with the quality of census data in Mexico. Yates (1981) discusses many of the problems with Mexican agricultural data, and suggests techniques for ensuring the comparability of data between different censuses and government agencies. His major doubt seems to lie in the quality of the data for the livestock sector, fallow land, and some of the detailed land tenure information. He and Coll-Hurtado (1982) both suggest the errors in census reporting are generally random rather than systematic, and are not serious enough to merit the total rejection of the census as a source of research data. In a previous study (Liverman 1990), the consistencies between variables reported in different parts of the 1970 census (such as drought loss and yields) increased my confidence in the utility of the information.

The census data will be used to map and analyze the changing pattern of hazard losses in Mexico (focusing on drought in those censuses where drought losses are reported separately). Census data will be transcribed and computerized from state level census reports, available through interlibrary loan in the United States, or in government libraries in Mexico. The municipio level will provide a very detailed scale of analysis. We will note information on reported hazard losses, not only for drought, but also for floods, frosts, pests and hail, as a basis for other possible studies on hazards in Mexican agriculture. Drought losses will be compared, graphically and statistically, to meteorological conditions in the census years to see if reported drought losses reflect the physical climate conditions. Hazard losses will also be investigated in relation to physical geography (soils, topography), land use, and agricultural technologies. For example, we will examine how hazard losses in municipios growing rain fed maize compare to those in municipios growing irrigated wheat. And we will examine whether municipios with more irrigation seem to suffer lower drought losses. Statistical procedures will include difference of means, correlation, and regression. We will try to identify the relative significance of irrigation, improved seeds, crop type, and fertilizer use in relation to the severity and pattern of reported hazard losses.

Secondly, the differences in hazard losses on farms of different size and tenure will be compared. We will compare the losses on ejidos, large private holdings and small private holdings. Preliminary analysis suggests that the ejido sector is disproportionately vulnerable to drought. We will attempt to explain any differences in terms of the climatology, physical geography, crop mix, and technology of the different groups, and in terms of the political and economic conditions in each sector.

This research task will provide a detailed example of how census data may be used to study the vulnerability of agricultural systems to drought and other meteorological hazards. The data set on hazard losses in Mexican agriculture will provide a basis for further studies and analyses of natural hazard losses and vulnerability.

4.2.4 Local case studies

It is clear from my work in Sonora and Puebla that large scale statistical analysis provides only partial insights into hazard vulnerability. Thus, an important component of this study will be a set of local case histories of drought impacts and vulnerability. These case histories will be compiled using local newspapers and agricultural records, supplemented by interviews with farmers and local officials. We will ask about past droughts and their impacts, and will seek information and opinions on whether social and technological changes have altered hazard vulnerability. Case studies will be selected to represent a range of agricultural systems. One case study will include a region of rain fed maize production on ejidos and small farms in the valley of Puebla, and a second will examine the impacts of drought on irrigated, high input crop production on larger properties in Sonora. Other case studies will be carried out by graduate students and will partly reflect their interests and expertise.

This study will provide analyses of the relationships between climate, agricultural technology, land tenure, and agricultural production in Mexico which should further our understanding of interactions between social, technological and climatic change in developing countries. The documentation of past relationships between environment and society in Mexico should provide insights into the future human dimensions of climate change the region. It will parallel a project, already underway in collaboration with Mexican scientists, on the impacts of global warming in Mexico. The study will establish a useful data set of information on Mexican agriculture and climate which can be used to investigate a range of other questions and will be the basis of a long-term commitment to the study of Mexican climatology and agricultural development.

4.3 Data Needs

The following summarizes the data requirements for the four points of the research plan described above, and their likely sources:

4.3.1 Climate data

Item: Monthly temperature and precipitation data for all available Mexican weather stations from 1925 through 1985

Expected Sources: Hand written records of the library of the meteorological observatory in Mexico City.
Digital data sets from the Universidad Autonoma Nacional de Mexico.
Global Daily Summary of the Day TD-9618 daily weather from the National Climatic Data Center.

Item: Daily sea-level pressure, 850 millibar geopotential height, temperature and wind direction and 500 millibar geopotential height and temperature for grid points corresponding to Mexico from 1962 through 1985.

Expected Source: National Meteorological Center Compact Disk Grid Point Data Set

Item: Daily meteorological observations for the Cuajimoloyas, Tejocotes, Ixtepeji, Oaxaca de Juarez, Etla, Tlacolula and Ocotlán weather stations in and around the Oaxaca Valley in the State of Oaxaca. These would include temperature, dew point temperature, sky cover, pressure, visibility and wind direction, if available, from 1925 to the present.

Expected Sources: Hand written records of the library of the meteorological observatory in Mexico City.
Digital data sets from the Universidad Autonoma Nacional de Mexico.
Local Oaxaca station archives.

4.3.2 Yield Data

Item: Annual crop yield data, particularly maize, desegregated to the distrito or municipio level for the years 1925 through the present.

Expected Sources: Library of the Secretaria de Agricultura in Mexico City has partial coverage of the country. This will be supplemented with data obtained from local sources in the case study areas.

4.3.3 Agricultural census and mapping data

Item: State and municipio level data on crop losses due to natural hazards (particularly drought)

Information concerning agricultural technology levels: usage levels of fertilizer, irrigation, pesticides and improved varieties for all states.

Expected Sources: Mexican decadal Censo Agricola, Ganadero y Ejidal 1930, 1940, 1950, 1960, 1970 and 1980.

Item: Digitized boundaries of Mexican states and municipios.

Expected Sources: Mexican Database Project, University of California, MexUS, Riverside California.
Digitization of existing base maps.

4.3.4 Local sources

Item: Local-level information for the case study areas on the impacts of drought.

Expected
Sources: Newspaper archives
Local authorities
Interviews
Local agricultural records

4.4 Results of Master Directory Search

As stated earlier in this report, this particular project was chosen as one of the scenarios for our Master Directory evaluation for two reasons. First, it is a clear case of some very useful data being potentially available that would, in the 'usual' circumstance, only be available through a priori knowledge and personal contacts. Second, the research involves the use of a number of culturally-related data variables, in response to NASA's expressed interest in including such data in the Master Directory database.

The Master Directory search was performed from Penn State utilizing a SUN SparcStation. NSSDC's on-line information services were accessed via Internet.

4.4.1 Usefulness of the database contents

In searching the Master Directory database for specific data sets relevant to the items listed above, very few data sets of any type were found for Mexico. In fact, few data sets were listed for land areas outside of the U.S. and Western Europe. The few coverages available were highly generalized global coverages. Only one data set of interest was found. This was the global daily weather summary from NCDC.

Information given in the 'brief' description within the Master Directory database was very inconsistent. Critical information (e.g., data resolution) is often omitted. Some guidelines for entering these elements of information would be useful in promoting uniformity and preventing omissions of important information. Lesser-known acronyms should be defined.

Information on the acquisition of specific data sets was often limited to a contact name and address. More complete information (e.g., available media, cost, date of entry into the MD) would be very helpful, even if such information cannot be kept completely up-to-date. It was because of this lack of more detailed acquisition information that the global daily weather summary mentioned above is in reality being obtained from a secondary source for use in this project.

4.4.2 Functionality of the user interface

The overall reaction of the participants in this particular project when using the MD to search for relevant data sets was that the menu-driven user interface was fairly intuitive. It required no time to learn, and individual researchers could perform a database search with no assistance after a connection was established to NSSDC's VAX.

Nevertheless, a number of shortcomings in the user interface became quickly apparent and were perceived as making the search process slower and more awkward than necessary:

- *It did not seem possible to use more than one value for a given search parameter (e.g., discipline). This resulted in the retrieval of a much higher proportion of 'uninteresting' data references for any individual search query.*

- *When changing search parameters, the interface forces the user to re-enter all parameters from that point in the menu downward. A SUN-compatible screen-based editing feature or other means of quickly selecting/modifying any combination of menu elements in any order seems to be needed.*

- *A strict, hierarchical navigation of the menus rapidly became obstructive, even for a first-time user.*

- *No capability such as file transfer or report generation is available for electronically saving wanted information.*

References

Coll-Hurtado, A. 1982. **Es Mexico un Pais Agricola ?** Mexico: Siglo XXI.

Hazell, P.B.R. 1984. Sources of Increased Instability in Indian and U.S. Cereal Production. **American Journal of Agricultural Economics** 66:302-311.

Hazell, P.B.R. ed. 1986. Summary proceedings of a workshop on cereal yield variability. Washington DC: International Food Policy Research Institute.

Liverman D.M. 1990. 'Drought in Mexico: The cases of Puebla and Sonora in 1970'. **Annals of the Association of American Geographers** (forthcoming).

Michaels. P.J. 1979. The Response of the Green Revolution to Climatic Variability. **Climatic Change** 5:255-279.

Yates, P. Lamartine 1981. **Mexico's Agricultural Dilemma**. Tucson: University of Arizona Press.

5. SUMMARY OF RESULTS

Overall, the MD is a potentially powerful (and clearly needed) tool for providing earth scientists with a comprehensive, generally accessible on-line data resource. In its present state, however, its performance is perhaps best described as that of a tantalizing preliminary prototype. All users found the interface overly rigid and therefore awkward to use. Users with broader-based and complex requirements (i.e., those who had the most need for a centralized data directory capability) also became quickly inundated with long and unstructured lists of data sets. In one case the investigator gave up before complete visual scan was performed on the returned list of entries. The database contents also were found to contain gaps and inconsistencies.

Its strengths and present weaknesses in specific areas from our specific application perspective are summarized as follows:

* Scope of available information

  Information relating to oceanic and atmospheric phenomena is extensive, although obviously not comprehensive. The scope of other available earth-related information is limited, with a distinct lack of land related data outside of the U.S or Europe. Information directly relating to human activity is particularly lacking.

* Quality of available information

  Data included in the Master Directory is kept current. The descriptions given for various data sets, however, tend to be very inconsistent with important information (e.g., resolution, definition of lesser-known acronyms) frequently omitted. Some of the information stored on specific data sets (e.g., investigators) appears to be incomplete or inconsistent. More specific guidelines for entering information are needed to avoid such omissions and encourage at least a generally standard format for these descriptions.

* Linkages with other systems

  A primary value envisioned for MD is its ability to link to other data systems. However, significant improvements are needed in this area. Very little on-line access to data is now available. Information on actually obtaining data sets other *than an organizational contact is also lacking. Although costs and timing to receive data via mail or pre-arranged electronic transfer will vary, some general guidelines (with the appropriate caveats) would be most helpful.*

* User interface

The Master Directory is simple to learn and does provide the user quickly with a broad perspective of what data are available within a given area. Nevertheless, the strict hierarchical structure of the menus, limited keywords and lack of the ability to use more than one value for a given search parameter are definite areas for improvement. The option to use more than one value or a range of values for any of the parameters, as well as the need to also use these parameters as sorting or grouping keys for the ordering of long lists of entries that could be returned from more unconstrained queries were clearly needed. There is also a very restricted number of recognized terminal types based on a least common denominator view. The use of a modern windowing system that runs on a variety of platforms would be a significant aid in greatly expanding the capabilities, flexibility and overall user friendliness of the user interface.