# The Prototype Digital Weather Laboratory at Colorado State University

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### Abstract

A new weather laboratory for teaching and applied research has been developed at Colorado State University (CSU). The laboratory uses DEC workstations and also hosts various microcomputers via a local area network to interface with the Cooperative Institute for Research in the Atmosphere (CIRA) computer system shared by the Department of Atmospheric Science. This computer system centers on a cluster of VAX 700-class computers and includes several user-interactive subsystems, such as the Interactive Research Imaging System (IRIS), Direct Readout Satellite Earth Station (DRSES), and a weather display system (using General Meteorological Software Package [GEMPAK]). Through direct communication lines, the VAX 700-class computer cluster is linked to the mainframe computers of CSU, National Center for Atmospheric Research (NCAR), and National Oceanic and Atmospheric Administration/Environmental Research Laboratory (NOAA/ERL). Since the computer system has such broad interface with other computer systems, a unique feature of the new weather laboratory is its capability to provide not only current weather data but also real-time satellite, radar, mesonet, and profiler data. Examples of the products of the new weather laboratory are presented. Options and trade-offs encountered in the design of the new weather laboratory are discussed.

## 1. Introduction

Traditionally, the weather-laboratory classroom's teaching tools have consisted of daily weather maps, teletype messages, and a video-display system to show educational video programs. With today's advanced technology, various powerful minicomputers and personal-computer workstations, as well as graphical display devices, are available at a relatively low cost. The use of these systems has been pioneered for research applications through (CIRA) at Colorado State University (Vonder Haar, et al., 1982; Vonder Haar and Brubaker, 1981). This earlier pioneering research has contributed to the early development of the Program for Regional Observation of Forecast Services (PROFS) system (Beran and Little, 1979; Schlatter, et al., 1985). These new computer and display systems are currently being adopted for a new "teaching" weather laboratory—this new undergoing project is a very close complement to the University Corporation for Atmospheric Research/National Science Foundation (UCAR/NSF) University Weather Data System (UNIDATA) program.

The new CSU digital weather laboratory will not only use the traditional weather data broadcasted by the National Weather Service (NWS), but also will utilize digital satellite images, remote data-collection platforms, and radar data sets provided in real time. Another important data source, the "grid-point" model data produced by the National Meteorological Center, is also going to be available in the near future. Such combined usage of current as well as archived meteorological data through computer analysis-display software will help both education and student research projects in the atmospheric sciences. Two specific improvements are noted for educational purposes:

1) Using computer analysis-display software saves considerable time when compared to manual plotting and analysis of weather maps. However, the individual interpretation and modification of the analyses are still retained. Thus, students learn more by spending the time saved in discussing the structure of weather systems and analyses of weather in real time.
2) By testing various methodologies of displaying weather information, the students can obtain a better and more-vivid kinesthetic feeling of the weather. This is especially effective when results of weather analysis and numerical models are presented for intercomparison.

Student research projects also benefit from the new digital weather system. For example, to support the field experiments in atmospheric research (ranging from the study of cloud-radiation processes to mesoscale dynamics), it is very important to be able to display current weather information in real time in order to make effective and appropriate experiment decisions. Another aid to student and faculty research in the field is the use of weather-lab capabilities for follow-up debriefing and select processing of collected data. Using software modules implemented in the new weather laboratory, data can be displayed with ease and reliability. Faculty and students who recently participated in the Oklahoma-PRESTORM experiment used this capability to good advantage (Purdom, et al., 1985). In addition to the above benefits, the CSU digital weather lab also can serve as a testbed for selected hardware and software development in larger-research and extension activities. An example is given in Fig. 1, where a real-time display of the digitized NWS five-minute-interval radar from the Limon, Colorado site on 20 July 1986 is shown. Such products provide the weather lab with a very up-to-date view of the weather along the front range of Colorado.

## 2. System design

Figure 2 schematically illustrates the computer and data-ingest system configuration supporting the new digital weather

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laboratory, which is a distinct division of the larger CIRA research-data-collection and processing system. Technical features of the VAX 11/750 and VAX Workstation I are listed in Table 1. The VAX workstations of the digital weather laboratory are connected to the VAX 11/750 through the Ethernet. Ethernet provides for data transmission over a coaxial cable at the rate of 10 megabits per second and uses DECNet software for communications. Figures 3 and 4 demonstrate the capability of displaying products of our weather lab software on the VAX workstation and the Comtal Vision One/20 Image Processing Workstation (COMTAL) station. As shown in Fig. 2, the primary weather-data ingest is through a commercial-satellite downlink, which includes National Weather Service Facsimile (NWS FAX), National Meteorological Center (NMC) grid data, and FAA604 data. Additional weather data, such as PROFS mesonet, NWS radar, Automation of Field Observations and Services (AFOS), as well as PROFILER data, are also available via direct links to NOAA/ERL. In conjunction with Direct Readout Satellite Earth Station (DRSES), real-time, digital, full-resolution Geostationary Operational Environmental Satellite (GOES) satellite data that includes imager and sounder (e.g. Visible Infrared Spin Scan Radiometer [VISSR], VISSR Atmos-

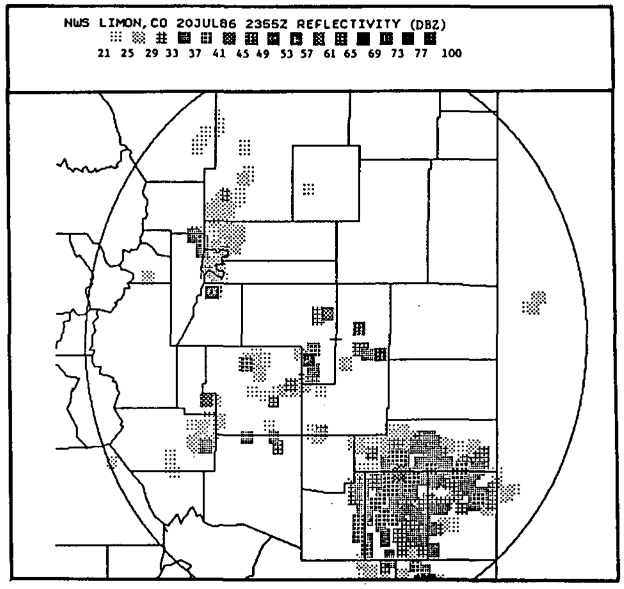


FIG. 1. An example of a real-time display of the NWS five-minute interval radar data from the Limon, Colo. site on 20 July 1986.

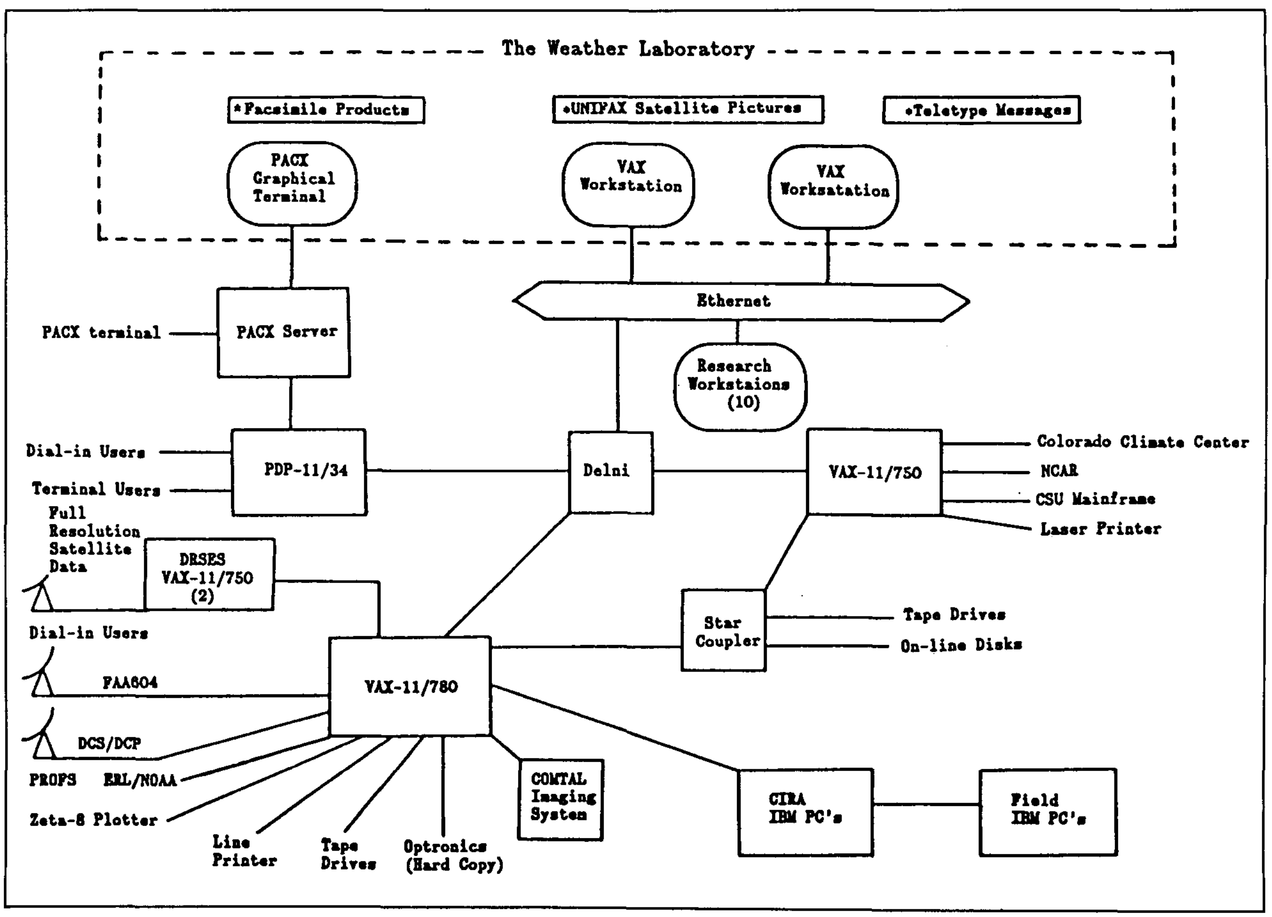


FIG. 2. The computer and data-ingest system configuration of the new CSU digital weather laboratory.

TABLE 1. Technical specifications of the host computer, VAX-11/750, and VAX Workstation I of the Digital Weather Laboratory.

| | Hardware | Software |
|---|---|---|
| VAX-11/750 | DEC minicomputer featuring 32-bit virtual memory. | VMS operating system. |
| | 4 megabytes of main memory. | Fortran compiler. |
| | Ethernet interface for networking. | DECNet software for data communications, using the Ethernet interface. |
| | Interface for clustering with two. HSC-50 controllers supplying access to two 6250 BPI 125 IPS tape drives and 3.6 gigabytes of disk storage with an access rate of about 3.5 megabytes per second. | Pascal compiler. VAX macro. |
| VAX Workstation I | Stand alone MicroVAX I microcomputer featuring 32-bit virtual memory. | MicroVMS operating system. |
| | 2 megabytes of main memory. | Fortran compiler. |
| | 1K × 2K bit-mapped video RAM area | DECNet software for data communications, using the Ethernet interface. |
| | 19-inch noninterlaced monochrom monitor supporting a 960 by 864 with a resolution of 78 pixels per inch. | MicroVMS Workstation software supporting multiple window management. |
| | One internal and one external 31 megabyte, 5 1/4 inch Winchester disks. | GKS graphics programming interface. |
| | Dual 5 1/4 inch, 400 Kbyte floppy disks. | VT-100 or VT-200 terminal emulation. |
| | Ethernet interface for networking. | Tektronix-4014 terminal emulation. |
| | Mouse pointing device with 3 function buttons. | |

pheric Sounder [VAS]) data as well as Data Collection System/Data Collection Platform (DCS/DCP) data are collected. Figure 2 shows that the system includes several special data-ingest lines (both direct and dial up), notably those to the PROFS, NCAR, the CSU University Computer Center facilities, and the Colorado Climate Center.

All data sets mentioned above are input in digital format, in either binary or American Standard Code for Information Interchange (ASCII) codes. Because GEMPAK software uses packed binary data, these ASCII data sets are converted into a binary format. Currently, two decoder programs (one for surface data, and the other for upper-air sounding data)

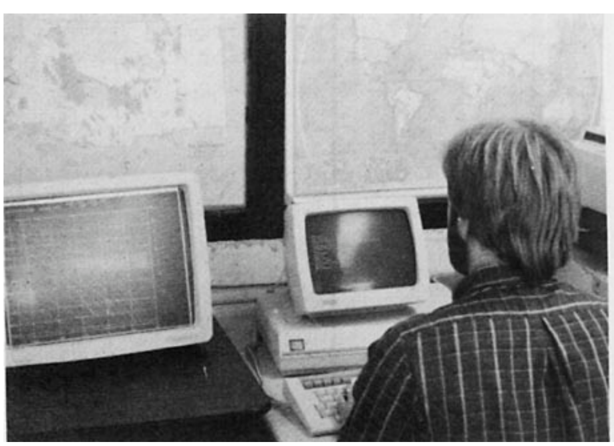

FIG. 3. The VAX workstation used in the new digital weather laboratory.

FIG. 4. The products of weather-lab software being displayed on the COMTAL Imaging System.

are used, as shown in Fig. 5. Besides translating and packing the data from ASCII into binary format, these programs also do error checking to some extent. Two examples of the results of the error-checking routines are discussed in section 4.

Through long collaboration with NASA's Goddard Space Flight Center (which also operates a large DEC/VAX-based system), the system uses the Transportable Applications Executive (TAE) software system developed there (des Jardins, 1985). Their GEMPAK and General Meteorological Plotting Software Package (GEMPLT) software, which will be discussed in the next section has also been adopted. The software aspects of a digital weather lab are extensive and should not be underestimated.

## 3. Weather lab capability and products

All new weather labs must face decisions regarding their software and hardware configurations. We recommend these be "output oriented" with a prioritized list of output products matrixed against budget resources. However, some other important factors must also be considered. These include intra-university collaborations (e.g. with electrical engineering [as at CSU], computer science, etc.), as well as collaboration with other national groups in research data analysis. With all these factors considered, the CSU digital weather laboratory has emerged with specific definitions. We have chosen some developed software (e.g. NASA's) to fit the computer hardware. Hardware decisions were heavily influenced by joint research work with electrical engineering. Thus, our weather lab has evolved from research origins. Many other university weather labs also can be expected to emerge from such a process, rather than arrive as a turnkey system.

Because of the features of the NASA GEMPAK software for display of weather data and previous research experience with their TAE-software system, it was decided to use GEMPAK for the weather laboratory. Four main advantages of using GEMPAK are

*1) It is user friendly.*
Because GEMPAK is a menu-driven package, it is easy to use and well documented even for the first-time user. This feature certainly encourages the students to use the weather data, and has been applied successfully in a classroom environment during the fall 1985 and spring 1986 semesters (e.g. Fig. 6 displays the surface observations over Colorado on 10 September 1986 at 2200 UTC; this display required less than a minute to complete and was available only a short time after 2200 UTC). Also, in each menu session a user can save the parameters entered in a parameter file for future use, and the parameters entered the last time are always saved. In this way, a user can always recall the parameters saved without memorizing them.

*2) The weather-analysis options.*
As mentioned in the introduction, automated plotting and analysis saves considerable time. GEMPAK allows the option of merely plotting the data, ready for hand analysis as shown in Fig. 6. But if desired, an automated analysis may be added to the data plot (see Fig. 7). Also

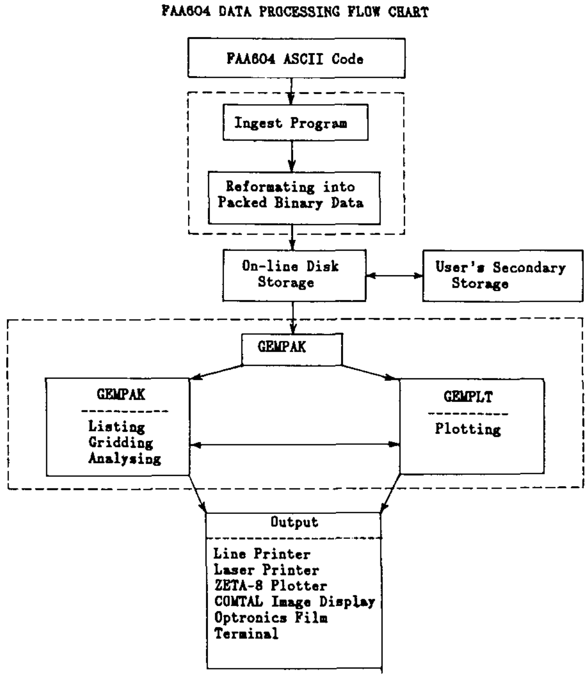


FIG. 5. Flowchart showing FAA604 data processing.

notice that the GEMPAK software is flexible enough to accommodate local needs; we found it very easy to automatically add PROFS mesonet stations to the surface data set. Figures 6 and 7 are examples of surface and temperature analyses including PROFS mesonet data. Various indices exist for evaluating thunderstorm and severe weather potential; GEMPAK has subroutines to calculate them. For example, the total totals index, K index, and sweat index are included in the analysis section of GEMPAK. Although these calculations are performed using computer algorithms, the students still are taught how these indices are computed in order to use them correctly.

*3) Archiving weather data.*
Since GEMPAK uses a binary format for both surface and sounding data, it is more economical to save weather data in this format. GEMPAK has input-output routines available, or users can simply invoke operating-system routines to do this. Therefore, there is no difficulty in saving or restoring surface and sounding data.

*4) Gridded data.*
Because weather stations are not uniformly distributed, interpolation between stations is necessary in order to perform analyses or to be used for numerical-model input data. In GEMPAK, there exist gridding routines that can generate grid data sets from original data. Using upper-air sounding data over the United States, for example, the 500-mb temperature analysis and geopotential analysis can be generated (Fig. 8). Earth Radiation Budget Experiment (ERBE) data was applied to create the gridded analysis in Fig. 9 using GEMPAK software. In addition to the above features, a new procurement will soon enable the display of current weather data on a large "screen

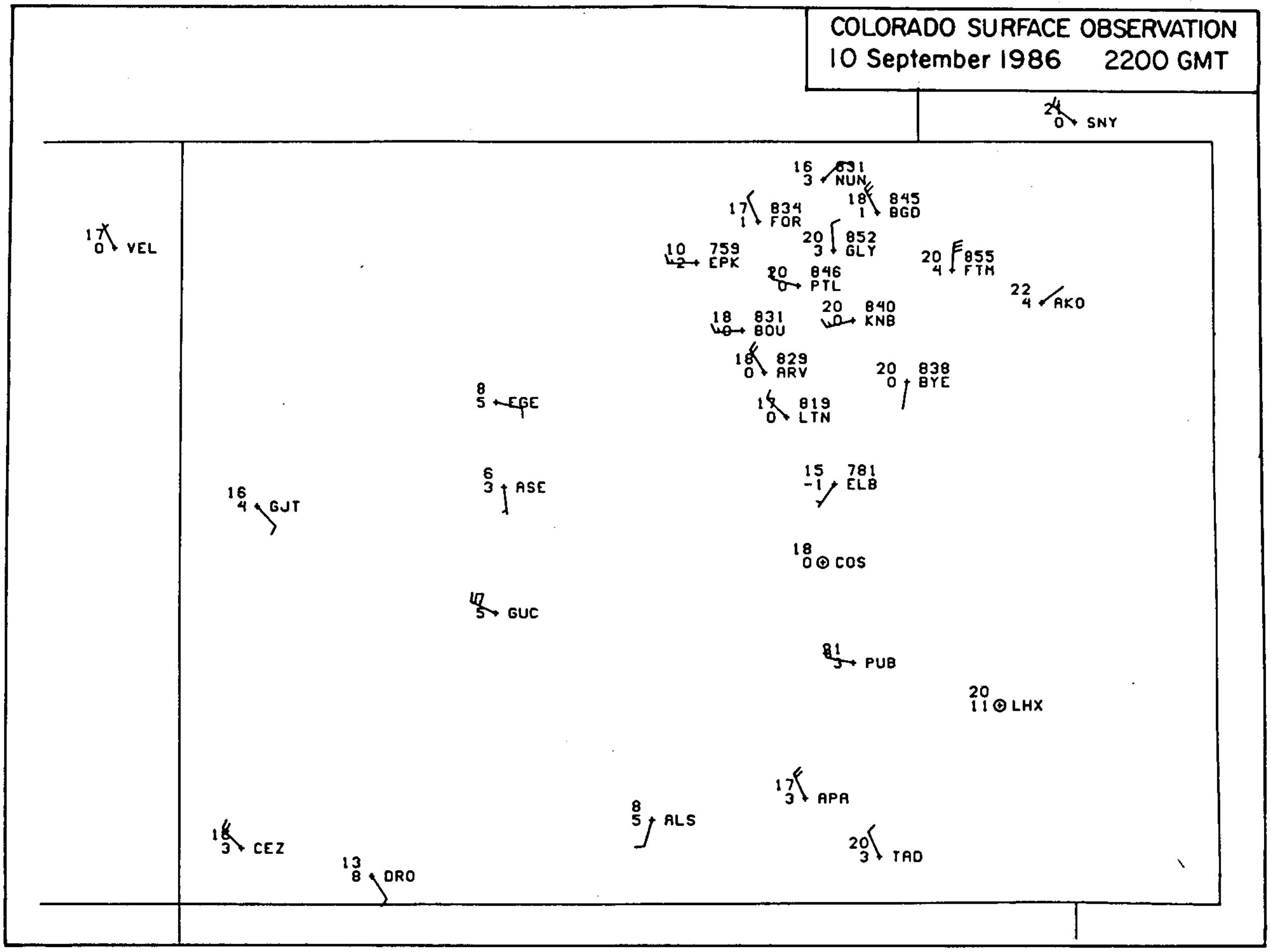


FIG. 6. Surface-weather observations in Colorado on 10 September 1986 at 2200 UTC.

wall" directly from the computer system. This new feature will make weather-map discussions clear to a larger audience.

## 4. Discussion

Since monitoring the weather in real time is one main objective of our weather laboratory, very large amounts of weather data need to be saved. Some difficulties have been experienced in accurately maintaining the huge flow of data. For example, errors caused either by initial coding or during the transmission process could not be corrected or removed completely by the first decoder programs (e.g. see Fig. 10). Between the initial coding errors and the transmission errors, it was determined that the latter happen more often and vary with time in the weather-data system.

As shown in Fig. 1, our FAA604 data is collected via a satellite downlink. Ideally, if the receiving antenna was kept tuned and aligned to the broadcasting satellite, the transmission errors would be minimized. However, the antenna points at the broadcasting geostationary satellite that drifts, and its direction is not adjusted continuously to be kept aligned with the satellite. Two examples are shown in Fig. 10

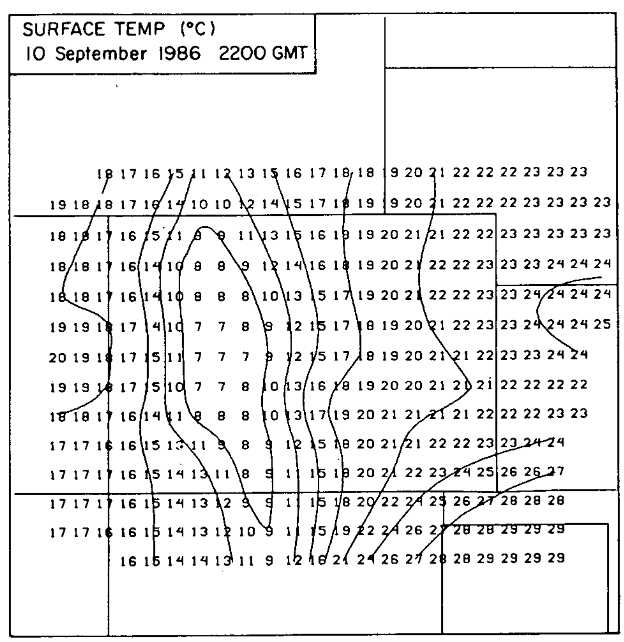


FIG. 7. Temperature analysis of Fig. 6 using GEMPAK grid-analysis software.

to demonstrate the possible effects of transmission error. Figure 10a lists out the ingested FAA604 upper-air sounding data for stations 72645 and 72655. Their decoded sounding data was listed in Fig. 10b using GEMPAK routines. For station 72645, the errors started at the 700-mb wind data and ended at the 500-mb temperature measurement in FAA604 code (Fig. 10a). After being decoded (Fig. 10b), the 700-mb wind information of station 72645 was listed as missing and all information of 500-mb measurements was dropped. For station 72655, the errors started at the 250-mb temperature measurement (Fig. 10a) but successfully passed through the error-checking routines of the decoder program to give an abnormally high temperature of 104.4°C (Fig. 10b). One way to solve such data-error problems is to add an interactive checking procedure to the decoder program. However, this approach is unrealistic for very large-scale, real-time operations at universities because of the continuous transmission of weather data. This difficulty may be eased by modifying the error-checking procedure in the decoder program when a new type of error happens. Overall, a more-complete error-checking routine is desired. The experience of using weather data via the satellite-downlink method and knowing that UNIDATA is planning to use this method to distribute weather data, the possible contamination caused by the transmission process is important to be considered.

Weather labs must also face the on-line–storage problem. Every computer system has limits to its on-line disk-storage capacity. Currently, all surface and upper-air sounding data are kept in on-line storage for a week.

The digital weather lab already has been applied to several "outside-the-classroom" uses. In summer 1985, there were field observations associated with the PRESTORM project that focused on the study of mesoscale convective systems. FAA604 data was used to help make decisions concerning flight plans. At the same time, FAA604 data was saved for postanalysis. In fall 1985, the weather-forecast contest in our department gave a number of students, staff, and faculty their first occasion to use the new weather lab.

Another application involves collaboration with UCAR that has sponsored the initiation of the UNIDATA project to develop weather-data distribution and analysis among universities in the near future (Fulker, 1985). In order to determine the hardware and software standards, various tests need to be performed as part of UNIDATA. Because of the various computer systems in the local area network, the possible advantages of testing some portions of UNIDATA in the CSU weather laboratory are recognizable.

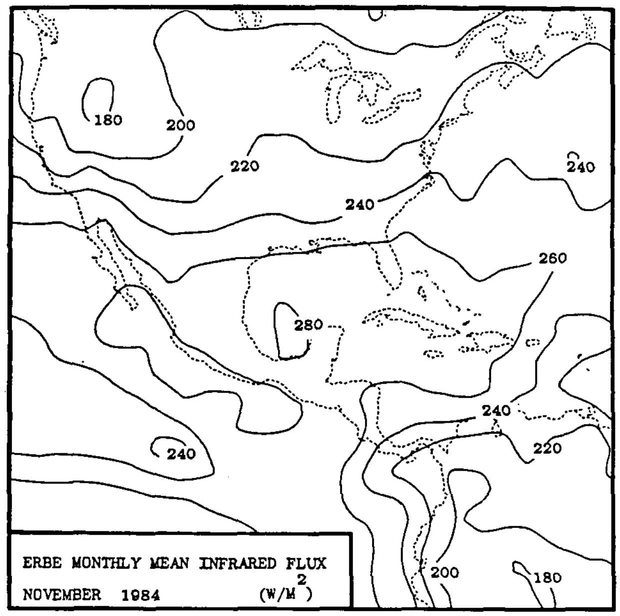


FIG. 9. The November 1984 monthly mean map of outgoing infrared flux as measured by the ERBE satellite.

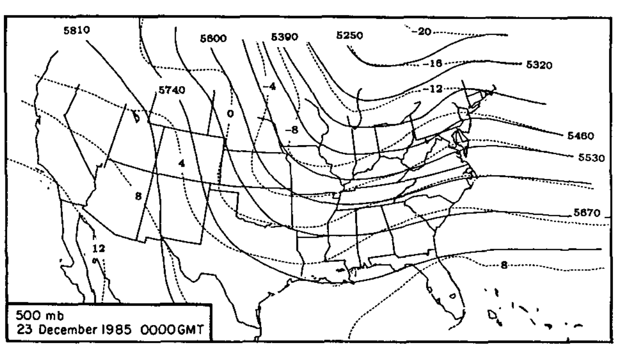


FIG. 8. 500-mb temperature analysis and geopotential analysis of the United States. The solid lines are contours of geopotential height (in meters). The dashed lines represent the isotherms (in °C).

(a)

```
FAA604 DATA (ORIGINAL)

04900333
     UW/US NORTH AMERICA 161257

72645 TTAA  66121 72645 99990 13324 29005 00132 ///// /////
 85363 15309 29522 70820 19711 280cpAk'525 35945 26554 40677   ←
 437// 27080 30865 547// 26594 25981 577// 27091 20124 543//
 27093 15308 541// 27082 10566 575// 26574 88278 571// 26593
 77196 27096 41732 51515 10164 00013 10194 30015 28533=

72655 TTAA  66121 72655 99983 19934 31005 00189 ///// /////
 85396 19356 32031 70833 22560 30544 50524 38558 30058 40675
 457// 29567 30862 539// 28570 25979 5dH5// 29067 20122 549//  ←
 6^
2[S
c 1530!
 .19}E/ 28560 10562 605// 28074 88263 561// 29066
 77280 28573 41107 51515 10164 00015 10194 32525 31040=
```

(b)

```
GEMPAK LIST (DECODED FROM ORIGINAL)

GRB  72645   Date/Time= 851216/1200   Latitude=  44.48   Longitude= -88.13
       PRES      HGHT     TEMP     DWPT     DRCT      SKNT
     990.00    210.00   -13.30   -15.70   290.00      3.89
     850.00   1363.00   -15.30   -16.20   295.00     21.38
     700.00   2820.00   -19.70   -20.80 99999.00  99999.90  ←
     400.00   6770.00   -43.70   -92.70   270.00     79.70
     300.00   8650.00   -54.70  -103.70   265.00     93.30
     250.00  19810.00   -57.70  -106.70   270.00     89.41
     200.00  11240.00   -54.30  -103.30   270.00     91.36
     150.00  13080.00   -54.10  -103.10   270.00     81.64
     100.00  15660.00   -57.50  -106.50   265.00     73.86

STC  72655   Date/Time= 851216/1200   Latitude=  45.55   Longitude= -94.08
       PRES      HGHT     TEMP     DWPT     DRCT      SKNT
     983.00    317.00   -19.90   -23.30   310.00      3.89
     850.00   1396.00   -19.30   -25.30   320.00     29.16
     700.00   2833.00   -22.50   -32.50   305.00     42.76
     500.00   5240.00   -38.50   -46.50   300.00     42.76
     400.00   6750.00   -45.70   -94.70   295.00     56.37
     300.00   8620.00   -53.90  -102.90   285.00     66.09
     250.00  19790.00   104.40    99.50 99999.00  99999.90  ←
     200.00  11220.00   -54.90  -103.90 99999.00  99999.90
     150.00  12850.00  -177.10  -160.00 99999.00  99999.90
     100.00  15620.00   -60.50  -109.50   280.00     73.86
```

FIG. 10. Examples to show the effects of transmission errors in the FAA604 data (a) and the resulting GEMPAK lists (b). The arrows mark the lines containing transmission errors.

## 5. Summary

A new weather laboratory is being developed at the Department of Atmospheric Science at Colorado State University. Various weather data including FAA604, PROFS, PROFILER, and satellite data are available in digital format for analyses. Traditional facsimile, teletype, UNIFAX, and GOES-TAP data are also available for laboratory usage. The software used in our weather laboratory is based on the GEMPAK system, which includes various subroutine modules written in FORTRAN 77. GEMPAK is easy to use to analyze either current data or past data stored on disk. It is planned that satellite data will be used in combination with traditional weather information. Since we have already completed classroom and outside-the-classroom use of our prototype digital weather laboratory, it provides a testing site for the ongoing UNIDATA system.

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