# The Man computer Interactive Data Access System: 25 Years of Interactive Processing

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**ABSTRACT**

On 12 October 1998, it was the 25th anniversary of the Man computer Interactive Data Access System (McIDAS). On that date in 1973, McIDAS was first used operationally by scientists as a tool for data analysis. Over the last 25 years, McIDAS has undergone numerous architectural changes in an effort to keep pace with changing technology. In its early years, significant technological breakthroughs were required to achieve the functionality needed by atmospheric scientists. Today McIDAS is challenged by new Internet-based approaches to data access and data display. The history and impact of McIDAS, along with some of the lessons learned, are presented here.

## 1. Introduction

The Man computer Interactive Data Access System (McIDAS) has had a substantial influence on the computerization of the atmospheric sciences. McIDAS made its first major impact analyzing cloud drift winds derived from time sequences of geostationary satellite images. In its early years, McIDAS was used to produce television broadcasts and was the unparalleled forerunner of the television weather graphics industry of today. In 1977, McIDAS provided a major impetus to the computerization of the college classroom following the National Science Foundation (NSF)-sponsored Interactive Video Displays for Atmospheric Studies Workshop. Eventually, the Unidata program was born out of that workshop. McIDAS was the first interactive system in operation at the Forecast Systems Laboratory, a research laboratory of the National Oceanic and Atmospheric Administration (NOAA) in 1980.

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The McIDAS systems installed at the National Meteorological Center [NMC, now the National Centers for Environmental Prediction (NCEP)], National Severe Storms Forecast Center [NSSFC, now the Storm Prediction Center (SPC)], and the National Hurricane Center [NHC, now the Tropical Prediction Center (TPC)] were used to help define the technical requirements for the Advanced Weather Information Processing System (AWIPS). AWIPS is one leg of the NWS Modernization Program, which, in addition to AWIPS, includes the new Doppler Weather Surveillance Radar, the Automated Surface Observing System, a new generation of Geostationary Operational Environmental Satellites, and the National Center for Advanced Computer Systems. AWIPS is an advanced weather data processing system that will aid meteorologists and hydrologists to rapidly manipulate, display, and analyze critical weather data.

Research and forecasting worldwide have improved using the geostationary atmospheric sounder analyses and derived products first developed with McIDAS. Since its initial use in a meteorological research project in 1973 (D. Martin 1973, personal communication), McIDAS has been through four major architectural changes, has been distributed and used globally for both meteorological operations and research, and has set a standard for all other interactive meteorological data systems. Now it is headed toward a fifth architectural change.

## 2. WINDCO: Before McIDAS (1971–72)

*a. Motivation*

In the 1950s and 1960s, Professors V. Suomi and R. Parent played a key role in establishing an earth-imaging program using instruments on several of the National Aeronautics and Space Administration's (NASA) first geostationary communications satellites, the Applications Technology Satellite (ATS) series (Suomi and Parent 1967, 1968; McQuain 1967). The striking images sparked many new research initiatives. In 1965, Suomi established the Space Science and Engineering Center (SSEC) at the University of Wisconsin—Madison to better focus his team's research efforts on extracting quantitative information from the images.

Suomi was enthralled with the meteorological phenomena apparent in time sequence film loops of the images. He wanted to derive quantitative measurements of the winds based on cloud motion. While F. Hasler, a Suomi student at the time, was the first to successfully measure cloud motion using a cinematic technique (Hasler et al. 1968), this technique could not be automated. The early efforts were quite laborious, requiring pasted together printouts covering 1000 $ft^2$ or more just to show a portion of one image using printer characters such as . , ; / 0 * M to simulate a grayscale. Once these printout composites were completed, staff would walk around in stocking feet to find a landmark or cloud.

Suomi established an internal SSEC competition between engineers trying to measure cloud motion with an optical correlator and a group trying to apply software techniques to the problem. E. Smith and D. Phillips were the principal developers of the computer techniques (Smith and Phillips 1972). They were able to measure cloud motion using a cross-correlation algorithm to determine the cloud displacement in successive images, and then producing displacement vectors using a satellite navigation algorithm developed by Phillips (Phillips and Smith 1974).

Following this success, Suomi obtained funding from NASA and NOAA to implement a proof-of-concept system dedicated to measuring cloud drift winds. The requirements for the new system were challenging. The only computer-generated video system available at that time required the largest IBM mainframe to run it; that solution was not viable. The new computer system had to allow the user to specify the image coordinates of a cloud in at least three successive images. Since the digital images were stored on computer tape, some method was required to map and display coordinates to and from tape.

*b. Design and capabilities*

The proof-of-concept system used to demonstrate winds processing was called WINDCO (Smith and Phillips 1972). This system used a new product in the television industry: an instant replay analog disk. The analog disk could support image animations of up to 520 500 × 640 frames at 15 frames per second (loading a frame took about a minute). The data were written by a Raytheon 440 computer to precise locations on the analog disk using a fixed timing track, also on the disk. A joystick controlled cursor location with the same timing track. When the user pressed a button on the console, the frame number and cursor location of the target clouds were punched into paper tape. The paper tape data were transferred to punch cards by the Raytheon 440. The target location cards, navigation parameters, image tapes, and the analysis program were submitted to the university's Univac 1108 mainframe. The output was cloud displacement vectors

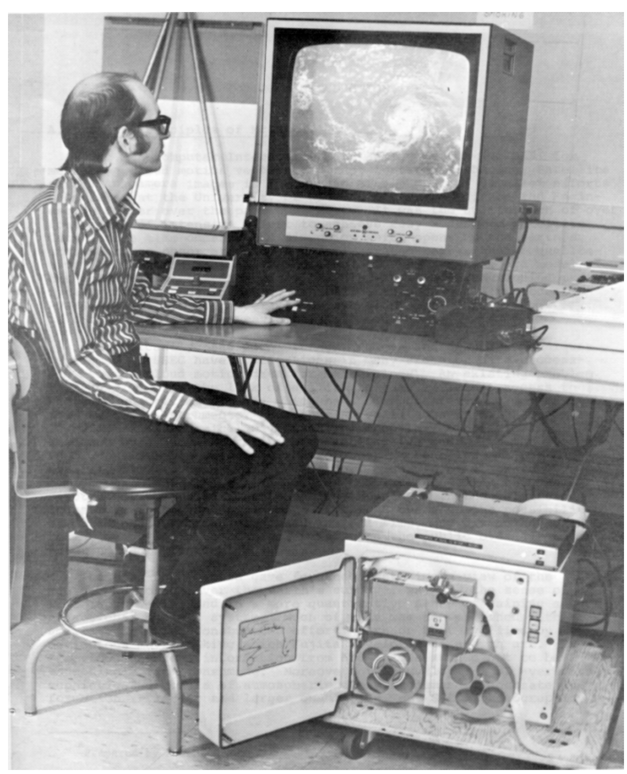

FIG. 1. User at the WINDCO terminal.

plotted over a map of the earth (Smith and Phillips 1972).

*c. Impacts*

The prototype system was demonstrated to officials from NOAA, NASA, and NSF on 12 April 1972 (Schwalenberg 1972). The demonstration showed that about 1000 cloud displacement vectors per hour could be measured accurately from geostationary satellite imagery. The attendees encouraged Suomi to build an operational version of WINDCO. A major limitation recognized in the design of WINDCO was the inability to intercompare other data sources with cloud drift winds. What is now called data fusion was addressed in the design of the next generation.

WINDCO (and later McIDAS) realized a data processing method in which high-volume raw data with low information density could be processed by the computer (with user input) to produce low-volume data with high information density. Figure 1 shows a user at the WINDCO terminal.

## 3. First-generation McIDAS: The first Harris System (1973–78)

*a. Motivation*

With encouragement from NASA, NOAA, and NSF, a design team was formed shortly after the WINDCO demonstration. J. Benson was the system designer and principal architect. E. Smith was the applications programmer and architect; D. Phillips was the mathematician and programmer; T. Schwalenberg was the electronics engineer; S. Sitts was the hardware assembly engineer; R. Krauss was the software developer and systems integrator; and J. T. Young participated in the design and implementation by representing the science requirements. Professor Suomi was the principal investigator (J. Benson 1972, personal communication; Krauss 1972).

*b. Design and capabilities*

The first task was to find a computer fast enough to handle the data volume, control of the display, and computational load. One computer system met the requirements at a reasonable cost: the Datacraft /5 (later to become the Harris/5). This system had 96 kbyte of programmable memory, 1 microsecond per memory fetch or store, a 5-MB fixed hard disk, and a 5-MB removable hard disk (see Figs. 2 and 3). From their WINDCO experience, the design team realized that the user should input control information to the computer. The computer, in response, should adjust the display and make it continuously available to all applications. This design put the computer in the role of supporting the user and handling as much of the process as possible. No assumptions were made about the user's computer science expertise. The user's role was to control the processes and perform the judgment tasks that were difficult for the computer. The user selected and staged the satellite data, evaluated and corrected the navigation, and selected the clouds.

In addition, the user evaluated the quality of the computed wind vectors. Display of both the vectors and upper-level wind measurements from conventional sources was required for the quality assessment process (Fig. 4). Image enhancement was also added to the design requirements to allow vector selection in low-light regions near the terminators, the border between night and day. The ability to efficiently produce vector graphics on a raster display was essential to meet these needs (Whittaker and Dedecker 1977). This display design would continue until hardware

FIG. 2. First-generation McIDAS terminal.

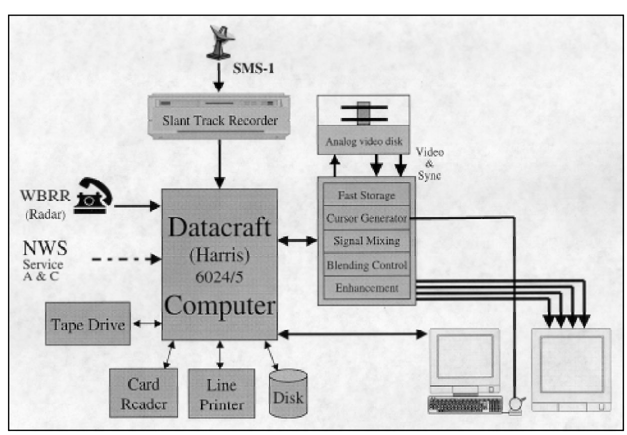


FIG. 3. The components of the first-generation McIDAS.

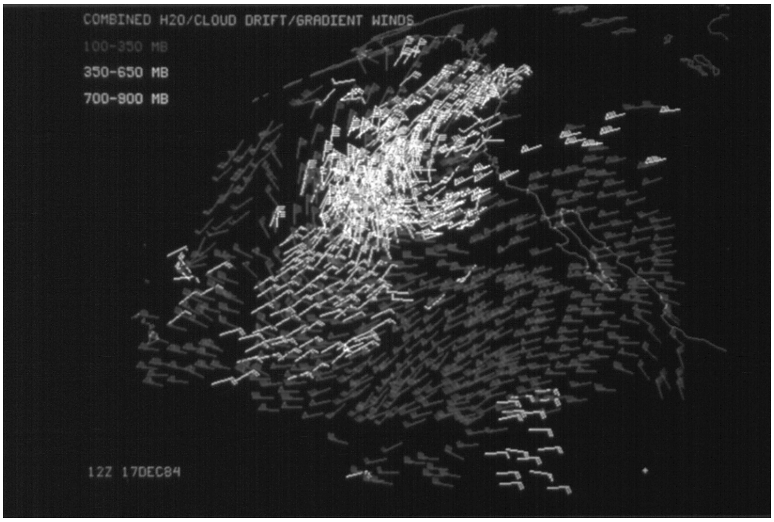


FIG. 4. Example of wind vectors.

allowed graphics to be displayed independently of images. This original interface design, however, continues to be used today.

The software was divided into logical modules and implemented as separate programs. Each was tested, modified, and retested independently of the rest of the system. Each module was a tool that the user could include in the processing strategy as needed. From this implementation strategy arose the tool-kit concept that has been central to the evolution of McIDAS. The modularity of the software facilitated another concept that has served McIDAS well: to implement a component of the system in a way that will work and iterate until it works to the user's satisfaction. Application programs were written in FORTRAN, while system-level programs were written in Assembler.

McIDAS was able to accept data input from a variety of sources [memorandum by J. T. Young on inputs and outputs of the system (1972); Krauss 1972]:

- ATS archive image data (via tape)
- Synchronous Meteorological Satellite archive and real-time data (1.7 MB $s^{-1}$)
- Earth Resource Technology Satellite, a predecessor to Landsat data (via tape)
- Mariner planetary data (via tape)
- FAA (Federal Aviation Administration) service-A and C conventional meteorological data (75 baud; 1 baud ~ 1 $bs^{-1}$)
- computer programs
- National Weather Service Radar real-time data (1200 Hz)
- hand-digitized base maps

The ability to accept such a wide variety of data input was done by building one-of-a-kind hardware interfacing that would take in the data stream and make it available on the McIDAS system. Various data fusion applications were implemented to facilitate ground truth and advanced product generation (Fig. 5).

McIDAS offered a variety of output formats, many similar to the output of the WINDCO system (Young 1972, personal communication). All were "TV compatible," or compliant with the National Television Standards Committee. The demand for hardcopy output was addressed in this and subsequent generations, but was always second or third priority to new interactive capabilities:

- cloud displacement vectors for selected clouds;
- analysis on the wind data (vectors, streamlines, vorticity, divergence);
- cloud temperatures, brightness, type, height, and size information;

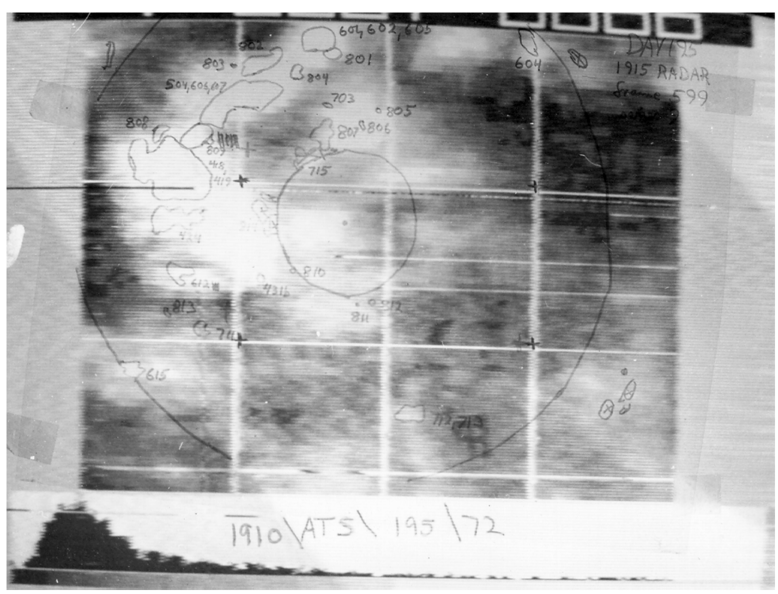


FIG. 5. An *ATS-III* visible satellite image centered at 25.8°N and 80.2°W displayed on McIDAS with overlaid radar data, hand traced from a previous display. (Radar data courtesy of W. L. Woudley, NOAA's Experimental Meteorology Laboratory.)

- statistics including means, distributions, and gradients of temperatures and brightness;
- false-color enhancements;
- time sequences of aligned data;
- remapped data;
- conventional data overlaid on satellite/image data; and
- data for use by other computer systems.

A command line language was developed to allow users to control the data display, the analysis of the data, and the flow of data. This language consisted of an action, or command, with an argument or parameter list. For example, "YK T 500 1200 USA" would generate a graphic overlay of the 500-mb temperature analysis from 1200 UTC data covering the contiguous 48 states. The command "XK T 1200 USA" would do the same type of analysis using 1200 UTC surface data. The McIDAS system has continued to use this language through all of its generations. McIDAS provided an important interface between the user, the computer, and the database. True to its name, the "man" interacts with the computer to access data on the system. Professor Suomi often noted that accessing the data streams available even to the first generation of McIDAS was like "drinking from a fire hydrant." McIDAS allowed users to manage this untamed flow of data and derive the needed information from it.

*c. Impacts*

The system integration was complete by June 1972. Fine-tuning for performance and complete functionality for winds continued for the next four months. During the same period, T. Whittaker designed and implemented the ingest, storage, and display of conventional surface and upper-air observations (Whittaker and Dedecker 1977). Local Weather Bureau regional radar images were ingested as well. In October 1973, a live video feed to the WHA-TV state educational television network was put in place (Young 1997, personal communication). A daily weather program covering current conditions and forecasts using the McIDAS feed was broadcast from the WHA studios. This was the first real-time computer-generated animation used in broadcast meteorology.

Over the next few years, a number of projects supported the development of McIDAS. Image filtering tools were developed to support the processing of early Landsat data. The real-time ingestor for the Geostationary Operational Environmental Satellite (GOES) was implemented in 1976. Tools for cloud height measurement, a macro language, and satellite image renavigation were developed to support the data systems tests in preparation for the First Global Atmospheric Research Program (GARP) Global Experiment (FGGE). Statistical image analysis tools were developed to facilitate research on rain-rate estimation from satellite and radar data.

User pressure became so high that scientists were scheduled on the workstation around the clock. Therefore, in 1975, the analog disk output was split to support two simultaneous workstations (then called terminals). Later a digital drum was added as a frame storage device and after its failure, a digital disk was used in the third workstation. In 1976, the system was moved to the University of Wisconsin—Milwaukee to become the first remote workstation supported by a processor in Madison. In this same period, external interest in McIDAS grew as it became better known. The U.S. Air Force Cambridge Research Laboratory received the first export of this early version of McIDAS in 1975.

The implementation of the system as a collection of tools, without the usual analysis of system requirements and top-down design, came to be known as bottom-up design. McIDAS would not have been possible without this type of design approach, because requirements continuously evolved. The implementers and users learned about interactive data processing through iterative development: as the implementer presented new functionality to the users, users provided feedback and additional suggestions to the implementers.

## 4. Second-generation McIDAS: The distributed Harris System (1978–83)

*a. Motivation*

In 1977, work on satellite sounder science began in preparation for the new geostationary sounder to be launched on *GOES-4* in 1979. A group of NOAA employees under the leadership of Dr. W. Smith moved to Madison to develop the processing capabilities for the Visible Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS). The McIDAS team had to adapt to a new class of users, scientists who needed to develop applications as well as use the tool kit. The system was expanded to include new tools for multispectral analysis.

The workload from the number of users, the satellite sounder processing, and the support requirements for the FGGE, which was to start in November 1978, required significant changes to McIDAS (Suomi et al. 1977). This prompted the development of the second generation of the McIDAS system.

*b. Design and capabilities*

The transition from the first to the second generation of McIDAS was primarily a move from a centralized to a distributed processing system. The system, implemented in 1978, consisted of eight Harris/6 computers connected with a high-performance, SSEC-built network designed by W. Hibbard. (The network connections were known as "burn lines" since they were considered very fast at the time.) Two computers (named Mom and Dad) were the database build systems and the remaining six (named Abe, Liz, Sue, Ken, Eva, and Rex) were applications processors supporting as many as 18 workstations. The Harris 6024/6 computers had 144- or 192-kbyte memory, 20–200 nanoseconds per memory fetch or store, and 300-MB digital disk drives (on the database build systems) or 80-MB digital disk drives (on the application processors). All computers had synchronous and asynchronous interfaces and available 9-track, 1600-bpi tape drives. As in the first generation, applications were written in FORTRAN, and system-level programs were written in Assembler. Late in the second generation, the system was also running on an Amdahl computer system at the West German Space Agency. By 1978, portions of the system had been used on 16-bit minicomputers with some difficulty (Haig 1978).

The system continued to support the same activities as the first generation of the McIDAS, but ingesting satellite data became more important and difficult in the new system. For example, polar-orbiting satellite imagery was added to the data sources. [Polar Orbiting Environmental Satellite (POES), represented by the Television and Infrared Observing Satellite (TIROS) series of spacecraft, is designated as "NOAA-##", where ## is the consecutive number of the spacecraft in the series.] This presented new and unique challenges across most aspects of McIDAS from geostationary data because of the changing perspective and the continuous image strip nature of polar-orbiting data versus the discrete image and constant perspective nature of geostationary data.

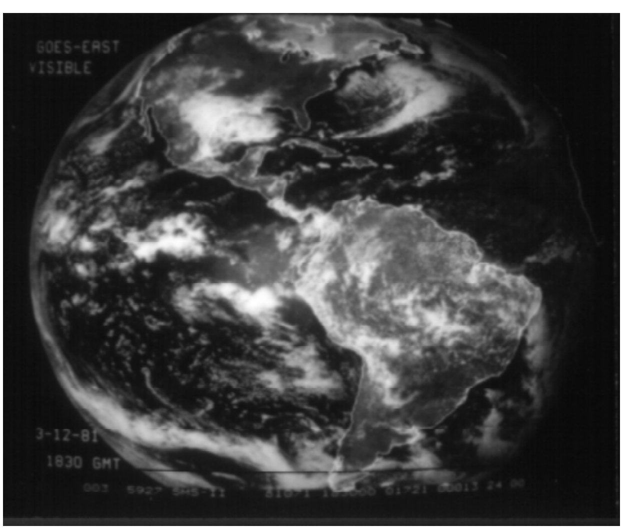


FIG. 6. Full Earth image from VISSR data from GOES-East (SMS II).

Input sources for McIDAS in this generation, along with their nominal data rate, included the following:

- VISSR GOES/SMS satellite data (1.7 MB $s^{-1}$),
- VAS data from the new GOES sounder system (2.11 MB $s^{-1}$),
- TIROS-N data via two Very High Frequency antennas (1200 pixels $s^{-1}$),
- National Center for Atmospheric Research (NCAR) model data via dial-up access (4800 baud),
- NMC model data via dial-up access (9600 baud),
- conventional data via the FAA 604 circuit (1200 baud), and
- radar data via direct dial-up (1200 baud).

In addition to the first-generation output formats, McIDAS could now also send commands to the new GOES VAS satellites via dial-up access to Goddard Space Flight Center and the groundstation at Wallops Island, Virginia.

Archiving GOES/SMS data continued formally during this era, using three videocassette recorders to store the raw signal from the VISSR and VAS data streams (Fig. 6). The system used four 9-track tape drives for archiving and restoring other data types to and from the system. During this era, the McIDAS system saw some unique applications working with a variety of nonmeteorological data. The X-ray scans, aircraft thermal mappings, Landsat imagery, images of crystal structures, biochemical protein scans (Fig. 7), and planetary applications (imagery from the Mariner Missions to Venus and Voyager missions, Fig. 8) were all tasks the McIDAS system took on during this period (Haig 1978).

A typical McIDAS terminal at the time included a command cathode-ray tube (CRT), keyboard, joystick, printer, color CRT with solid state image display (using Intel technology), bisync communications to the

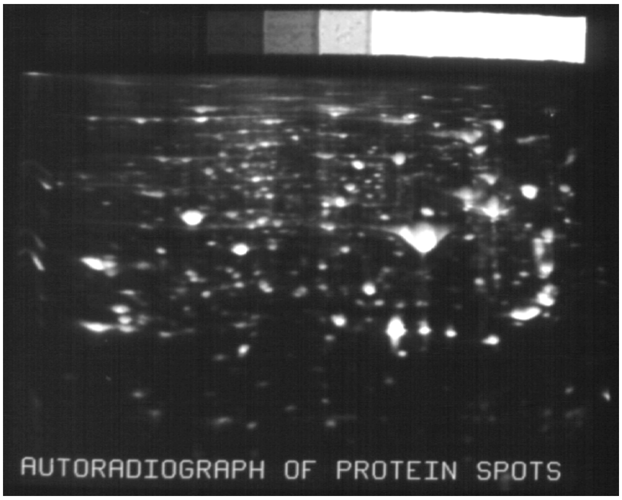


FIG. 7. Scan of biochemical protein spots.

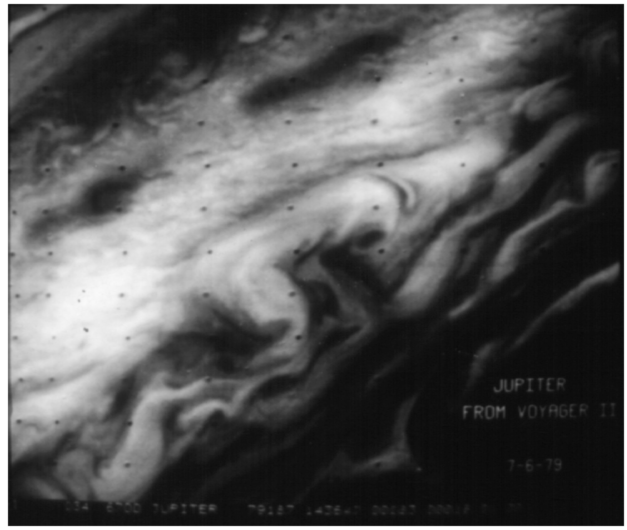


FIG. 8. *Voyager-II* image of Jupiter, displayed on McIDAS.

Harris computers, and solid state memory or analog disk refresh (see Figs. 9 and 10).

*c. Impacts*

This generation of McIDAS saw the expanded use of remote terminals. During the first generation of McIDAS a remote terminal was set up at University of Wisconsin—Milwaukee and was connected to SSEC's McIDAS system via a 9600-baud line. Later, a remote terminal was set up at the National Environmental Satellite Service facility in Kansas City. By 1978, as many as 14 terminals, at the University of Wisconsin—Madison or elsewhere, were connected.

The McIDAS system was used during this period for the testing and acceptance of the new GOES VAS system. This effort included the Cooperative Institute for Satellite Studies, SSEC, and NOAA. In addition, McIDAS was increasingly used in broadcasting, education, private sector, and government applications.

In November 1978, the FGGE project started processing cloud drift winds for use in global data analysis. Cloud drift wind information was generated four times per day from the five geostationary satellites. Production of these wind datasets continued through December 1979 and demonstrated that McIDAS could sustain operational commitments for long periods of time. Figure 11 shows Asia in a satellite image taken during the FGGE year.

A major turning point in the evolution of McIDAS occurred on 15 July 1979. Congress conducted an investigation into the loss of life in a Wichita Falls, Texas, tornado that spring. One portion of the investigation was held at the SSEC. As a result, Congress directed NASA to install McIDAS at NSSFC. The system was installed in January 1981 (Norton 1981). Improved forecasts by the National Weather Service's (NWS) Severe Local Storms unit soon demonstrated

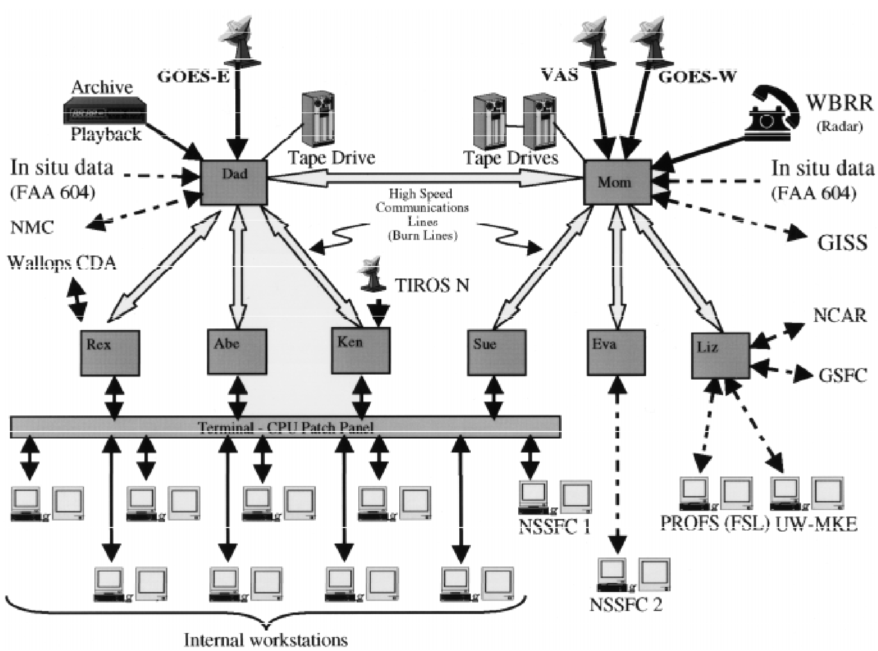


FIG. 9. The components of second-generation McIDAS.

FIG. 10. Users at second-generation McIDAS terminals.

the value of a system like McIDAS for real-time data access and decision making (Norton 1985).

## 5. Third-generation McIDAS: The meteorologist's dream machine (1983–96)

*a. Motivation*

The third generation of McIDAS had its roots in the installation of the McIDAS software on the Amdahl computer at the West German Space Agency in 1976, and later at NASA/Goddard Laboratory for Atmospheric Science in 1979. In addition, while the visibility of operational projects raised the interest of other operational facilities, all were concerned with the dependence on Harris computers, which were too small for their operations. A number of these potential sites, including the People's Republic of China, requested a port of McIDAS to an IBM 370–based mainframe architecture. China funded the porting effort and in 1983 the port to an IBM 4331 was completed and delivered. The SSEC McIDAS facility was changed to an IBM 4341 (five times faster than the Harris/6) by June 1983 and the Harris-based systems were retired. Shortly after the implementation of the IBM-based system, it became obvious that this architecture had lost the interactivity that was so valued in the Harris-based architecture. This generation of McIDAS saw two eras of the IBM mainframe system; the "dumb" terminal era eventually gave way to the "smart" terminal era (personal computer or PC-based terminals or workstations).

In June 1977, NSF sponsored a workshop on Interactive Video Systems for Atmospheric Sciences at the University of Wisconsin—Madison (Haig 1977). Representatives from about 80 colleges and universities attended. A variety of applications of McIDAS for education were presented, as were applications from other schools developing interactive systems. This workshop ultimately led to the formation of the Unidata program in the early 1980s under the University Corporation for Atmospheric Research (UCAR), which provides applications software and near–real time data distribution to UCAR members. The need for a low-cost, stand-alone, interactive terminal was identified following the workshop. This was further motivation for the development of a smart terminal.

*b. Design and capabilities*

1) THE DUMB TERMINAL ERA

Third-generation McIDAS saw a return to a centralized processing architecture (Suomi et al. 1983). While the terminal hardware included a computer chip, terminals were limited to controlling the display and sending commands to the mainframe. By this time, the SSEC-built terminals used solid state memory to refresh the display. The re-

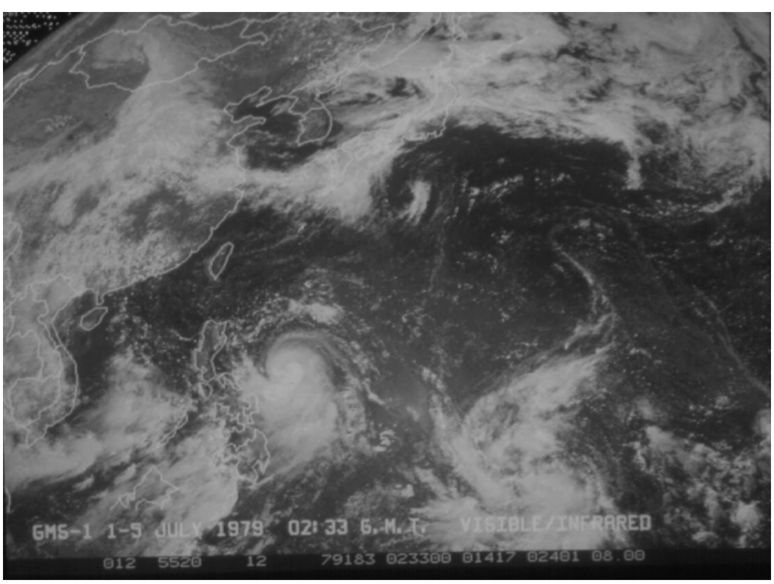


FIG. 11. Asia, centering on China, during FGGE year 1978–79 from Japan's Geostationary Meteorological Satellite. During FGGE, SSEC was asked to archive geostationary data globally.

fresh memory was organized to output three frames simultaneously. Two frames contained images and the third, graphics. This configuration facilitated two-frame, interactive image combination with an eight-level graphic overlay. With sufficient memory, the workstations could animate up to 128 image frames with 64 frames of graphics. Image and graphic frames could be written, erased, color enhanced, and animated independently. The first implementation of McIDAS on the IBM mainframes was under Operating System/Virtual System 1 (OS/VS1). Later, this was upgraded to IBM's Multiple Virtual Storage (MVS) operating system. Eventually, this platform of McIDAS would be known as McIDAS-MVS (Young and Fox 1994). McIDAS terminals changed little from the second generation to the early portion of the third generation of McIDAS (see Figs. 12 and 13). This new system had the following hardware and software components:

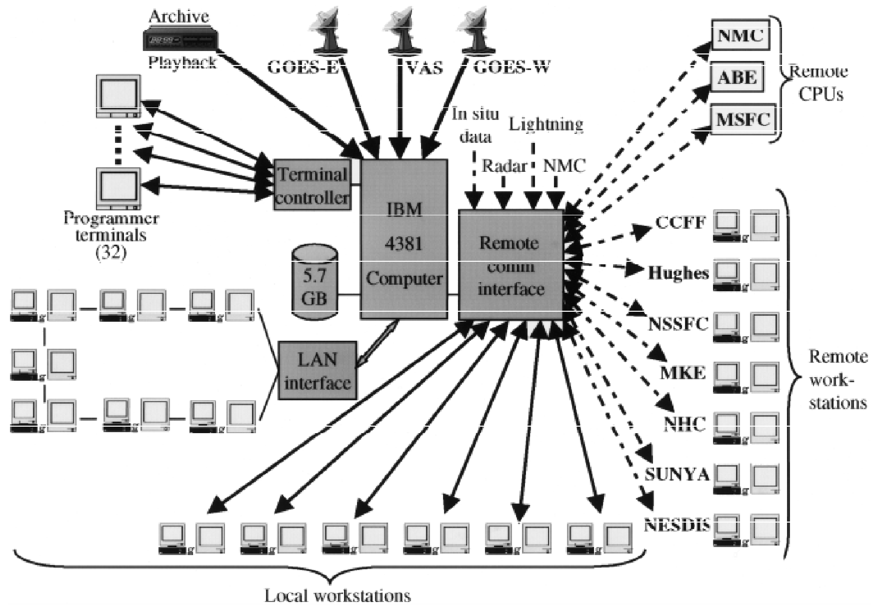


FIG. 12. The components of third generation of McIDAS.

Hardware
- data-acquisition hardware
- general purpose computer
- local and remote terminals

Software
- computer operating system
- McIDAS control program
- application and analysis programs

One of the advances of the software portion of the system was the development by M. Barrett of meteorological data files for storing conventional and other ancillary data, such as satellite sounding retrievals. He also developed, along with J. Benson, the standard argument-fetching system that allowed an interface between user applications and the subsystem of McIDAS. During this generation of McIDAS, assembler language was used for system programming and FORTRAN was used for the applications.

2) THE SMART TERMINAL (WORKSTATION) ERA

The McIDAS team quickly learned that the dumb terminal architecture was incapable of the tight user–computer interactivity that was so valued in the Harris-based architecture. At the same time, PCs were becoming more widely available. In 1984, development started on a stand-alone, IBM PC-based version of McIDAS. Only some of the user applications available in mainframe McIDAS were available in this version, called PC-McIDAS. Assembler with some FORTRAN was used to develop this version. The PC-McIDAS ran under the DOS operating system and used an Enhanced Graphics Array (EGA) or Video Graphics Array (VGA) display. These workstations were made available to users in 1985 (Ide 1987) and ushered in the "smart workstation" era of McIDAS.

FIG. 13. A user at a third-generation McIDAS terminal.

In 1987, work started on the IBM Operating System/2 (OS/2) version of McIDAS. This version worked with the SSEC-built display hardware (Dengel et al. 1989) and the mainframe. This type of terminal, or workstation, allowed users to process data on either the mainframe or the PC. This version used FORTRAN with minor use of Assembler. The first IBM mainframe smart workstation systems were delivered in 1988 to the National Environmental, Satellite, Data and Information Service; NMC (now NCEP); NHC (now TPC); and NSSFC (now SPC). While the PC workstations were used to process some data, these systems still used the mainframe to build the databases and run the major applications.

During the smart workstation era, McIDAS workstations changed dramatically. In addition to the new EGA/VGA display, the tower of hardware that drove the existing McIDAS color CRT displays was also available. This new workstation configuration was known as the tower workstation. The tower hardware was driven by the PC with 3-bit encoding to get 6-bit display for imagery. These workstations saw over 15 years of service worldwide. Some tower displays may still be in use today.

With the demand for a greater frame space to display more imagery at larger sizes, the WIDEWORD Workstation was developed using a more compact set of hardware than in the tower. This display worked as the tower workstations did, along with the McIDAS-OS2. This workstation was the first true 8-bit display for imagery.

Two additional display systems were developed as well: the SSEC Display Adapter (SDA) and, later, the Presentation Manager (PM).

The SDA was the functional combination of the WIDEWORD and VGA displays onto one card in an expansion slot on the Personal System/2 (PS/2) computers used to run McIDAS-OS2. With a second Super Video Graphics Array monitor, the display had capabilities similar to the WIDEWORD, for less money.

The PM display mode used the OS/2 window manager (named “Presentation Manager” by IBM) to show the text and image/graphics information in windows on the display’s normal desktop, right along with any other applications. It was designed to be run without special hardware and thus overcame the restriction that McIDAS-OS2 could only be run on IBM PCs.

The growing use of high-performance, UNIX-based workstations by the research community and the decision by segments of the federal government to use UNIX-based data systems, drove the McIDAS team to start yet another port of McIDAS. In 1990 work began on porting the system to UNIX, with the first release one year later (Santek 1991). FORTRAN use continued; however, system level programming was done using C. This McIDAS-X system initially ran on IBM RS/6000 on Silicon Graphics workstations, and later expanded to Sun in 1992 and Hewlett Packard in 1993.

Inability to repair the older hardware and availability of new McIDAS-X workstations in the mid-1990s brought the sunset of the older display systems. In June 1999, the PM display will be retired.

### c. *Impacts*

In January 1985, the U.S. Air Force Launch Support Center for the Eastern Test Range and the Kennedy Space Center were the first recipients of this new generation of McIDAS for use with the space shuttle program. The Unidata program used the new PC-McIDAS, and, later, McIDAS-OS2 and McIDAS-X workstations. Up to 120 colleges and universities used McIDAS for daily educational and research activities. Other sites worldwide used this generation of McIDAS, including the Australian Bureau of Meteorology, the National Meteorological Institute in Spain, and NASA/Marshall Space Flight Center.

Pressure from the operational user community was growing to stabilize the software, test and document it more thoroughly, and establish a formal release process. In response, the McIDAS Users Group (MUG) was formed. The MUG provided software configuration management, organized the development of the documentation, and provided a help desk for registered users. The user community appreciated the improvements in McIDAS and its support. However, the desire for professional software testing and documentation slowed the delivery of new capabilities and increased the cost of development. Gradually, members of the research community felt disenfranchised by this process because they saw McIDAS developers as unresponsive to their needs and under the primary influence of the operational user community.

The impact of the port to UNIX was significant in three ways. First, McIDAS became available to an expanding segment of the research community, and the user community grew. Second, the cost of support of McIDAS grew disproportionately because the lack of standards in the UNIX systems required far more testing and tailoring to the supported UNIX environments. Third, UNIX-based systems had enough processing power to support all McIDAS applications, reducing the need for an expensive mainframe computer. The increased power made possible more complex applications (Figs. 14 and 15).

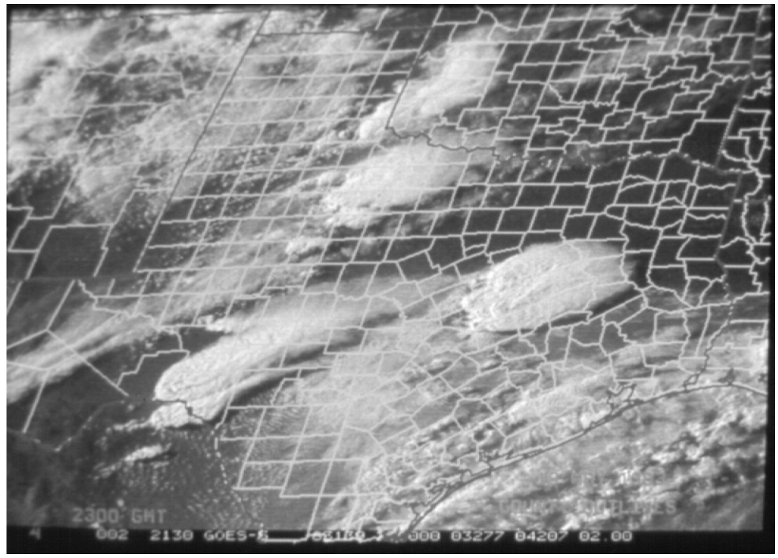

FIG. 14. Storms over Texas showing county outlines.

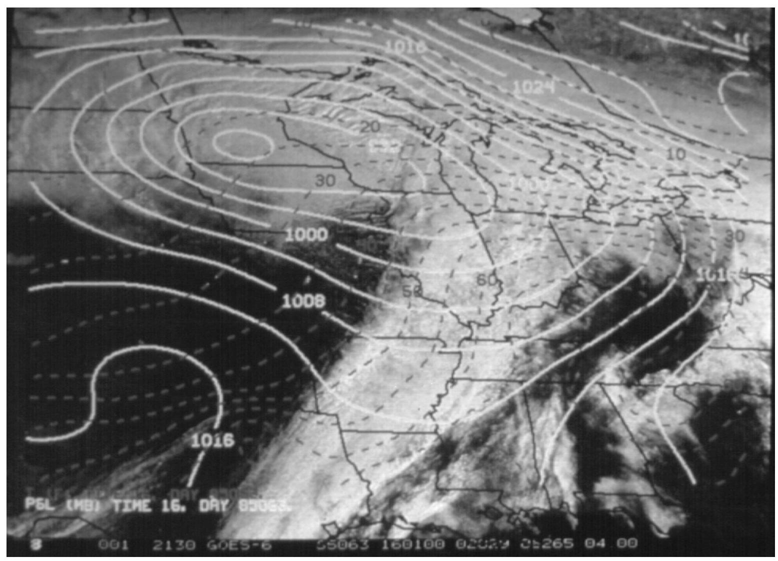

FIG. 15. Streamline analysis over a classic spring storm.

## 6. Fourth-generation McIDAS: A return to a distributed system (1996–present)

### *a. Motivation*

The port of McIDAS to UNIX enabled the capability to move back to a distributed system. The move was motivated by the need to remove mainframe-processing elements from McIDAS. In 1993, a rewrite of McIDAS was started. The functionality of old applications was analyzed and redistributed to a new set of applications. These new applications used a client-server data access concept developed by the McIDAS team called Abstract Distributed Data Environment (ADDE) (Taylor et al. 1995). In 1996, the system-level interface portion of McIDAS-X was recoded in an effort to eliminate UNIX system dependencies.

### *b. Design and capabilities*

The fourth generation of McIDAS is a return to the distributed environment previously seen in the second generation. The workstation versions of McIDAS (McIDAS-X and -OS2) from the third generation continued in the fourth. The biggest change was the sunset of the McIDAS-MVS mainframe software. Without this central system collecting, ingesting, decoding, and storing data, alternatives had to be found. The first step was developing workstations dedicated to the ingest of satellite and conventional data. Later efforts focused on developing a client–server protocol for distributing the data.

In the meantime, the McIDAS-X system's interface with the UNIX operating system was re-evaluated and recoded to allow for a more seamless implementation of McIDAS-X across the variety of UNIX platforms. Although many of the applications are written in FORTRAN, C programming language is used for both system-level and application-level programs, to take advantage of UNIX capabilities. This work resulted in a system that allowed for better integration of the McIDAS environment with UNIX applications, scripts, and other elements. It was also the foundation for software versions of hardware functions found in the previous generation of McIDAS such as independent and bit-plane graphics and briefing windows.

The McIDAS-XCD (conventional data) platform was the first success of the fourth generation. Built ahead of the full development of the fourth generation, this system was able to keep up with the rapid changes of conventional data circuit ingestion, decoding, and

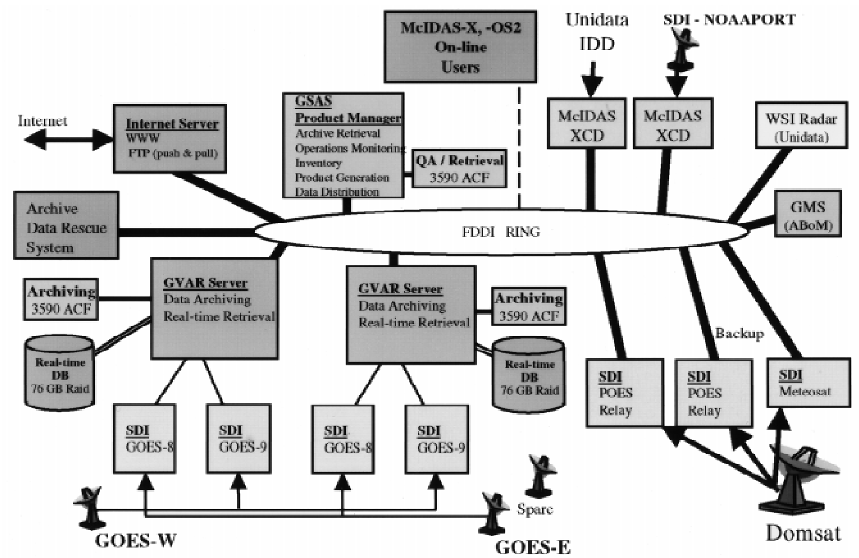


FIG. 16. The components of fourth-generation McIDAS.

filing. Later in the fourth generation, this same system was able to handle both the NOAA Family of Services circuits as well as the broadcast called NOAAPORT, the NWS transmission system that supplies data to NOAA's AWIPS.

The satellite ingesting effort was a two-step process. The first development was the McIDAS-XSD (Satellite Data) system. This system combined Hughes hardware and SSEC-developed software and protocol. It was developed initially for data from the Japanese Geostationary Meteorological Satellite, and then, chronologically, for GOES, METEOSAT (the European Meteorological Satellite Organisation's Meteorological Satellite), POES, and Defense Meteorological Satellite Program (DMSP) signals. Competing ingest systems were CTA, Global Imaging, or site-developed systems. McIDAS-XSD did not live up to expectations and proved to be too expensive to maintain and evolve. The second effort was the SSEC Desktop Ingestor (SDI). This system, with only an expansion card in a desktop PC running the Solaris x86 operating system, is able to inexpensively and cleanly ingest data from GOES, Meteosat, POES, and DMSP satellites. In addition, SDI is able to ingest conventional data (NOAAPORT) for use with McIDAS-XCD.

With sources of data available on mainframes and workstations at the end of the third generation, the return to a distributed environment began with the development of the Data Distribution Environment (DDE). This demonstration package was a proof of concept for a client–server method to access data over local- and wide-area networks. In the previous generation, data access required logging on to mainframe McIDAS and downloading data using a private protocol between McIDAS-MVS and McIDAS-X or -OS2. Now, data were available from a variety of servers and to a variety of clients. As Transmission Control Protocol/Internet Protocol (TCP/IP) and Internet communications became commonplace, the use of dial-up communications or direct-wire communications connecting workstations and mainframes declined.

After the success of DDE, the implemented version of this system, termed ADDE, was developed for McIDAS-X and McIDAS-OS2. McIDAS-X can be both server and client, while McIDAS-OS2 remains only a client in this system. With the sunset of McIDAS-OS2 platform and the important need to utilize a low-cost, low-end system, future work will strive toward running the McIDAS-X software on Intel-based platforms (e.g., Solaris x86, Windows-NT with Interix software, etc.). Workstations such as McIDAS-XCD run McIDAS-X with the -XCD pack built on top. SDI units can also function as ADDE servers (see Figs. 16 and 17).

FIG. 17. A user at a fourth-generation McIDAS workstation.

### *c. Impacts*

Following the port to UNIX, the conversion to a distributed system offered the hope of removing mainframes from the McIDAS architecture altogether, taking advantage of advances in networking to reduce the overall cost of a system. By 1998, most McIDAS-MVS systems were decommissioned.

With the tight budget climate of the late 1990s, development funds for completing ADDE applications came slowly compared to user demand. Also, with focus on keeping existing functionality in the new environment, few new scientific applications were added in the initial implementation of the fourth-generation McIDAS. As the fourth generation matures, renewed emphasis will be placed on scientific applications.

## 7. Conclusions

For 25 years, McIDAS has provided the meteorological community with a standard for data access and tools for data analysis and data fusion, using a system concept that embraces a broad spectrum of users. Despite weaknesses, it continues to lead the community as a highly integrated system of applications tailored to scientific analysis of diverse databases (see Figs. 18 and 19).

We have learned five principal lessons over the 25 years of McIDAS evolution.

1) In an environment of change and evolution, the bottom-up design approach produces a system more satisfactory to users than a top-down approach. Build basic tools in an environment that allows users freedom to combine tools to accomplish their purpose. Build tools to explore the science in the data, with little or no assumptions about the user or the user's environment.
2) Requirements are not our final goal, user satisfaction is. Therefore, include users on the development team. Use specific user requests to help understand the general problems or issues. Design the general solution to encompass the specific request. The designers must understand user problems better than the users do. Implement the solution in an evolutionary fashion. Evolve from something that works to something that works better based on feedback from users at each revision.
3) Many research users will not be satisfied with the tool kit that is provided. They will want to modify the source code to add algorithms specific to their investigation. Therefore, the tool-kit software should be organized into modules that are logical, easy-to-understand, extensible, and well documented.

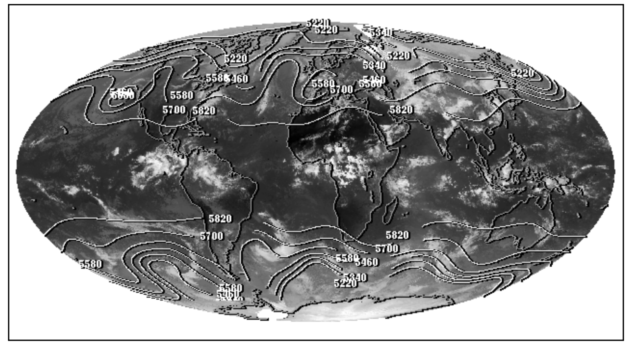

FIG. 18. An infrared (11.0 $\mu$m) composite image in Mollweide projection of *GOES-8, GOES-9, GMS-5, METEOSAT-6, NOAA-12*, and *NOAA-14* satellite data with overlaid contours of forecast 500-hPa NCEP Medium Range Forecast Model (MRF) geopotential heights (m) made on McIDAS for 11 May 1998 at 1800 UTC.

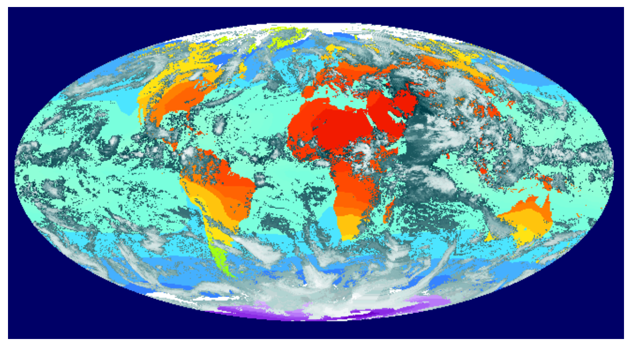

FIG. 19. A global Mollweide montage image showing cloud cover from GOES, GMS, METEOSAT, and NOAA satellites as well as sea surface and land surface temperatures from 14 April 1995 at 1200 UTC.

4) A tool-kit user interface and documentation should make it easy for the user to find out how to accomplish a task.
5) The tool kit should consist of independent programs, based on the science the users need, that have been made a component of the system, and iterated until they work to the user's satisfaction.

McIDAS will continue to evolve, adding capabilities and new data sources while staying current with new technology. The McIDAS team looks forward to the new opportunities and challenges presented by the Earth Observing System satellite series, particularly by Moderate Resolution Imaging Spectroradiometer and Atmospheric Infrared Sounder instruments. The explosive development of the Internet will affect the evolution of the fifth generation of McIDAS.

*Acknowledgments.* The legacy of Professor Suomi continues in the evolution and contributions to McIDAS. The spirit of his dynamic leadership continues to inspire the McIDAS team. Over the past 28 years, the development of WINDCO and McIDAS has been supported by many organizations. Of particular note are NASA, NOAA, NSF, and the Department of Defense. Thanks to the McIDAS team over the years, especially Frederick Mosher and William Hibbard for their valuable insights and innovative solutions to architectural problems. And finally, thanks to the many McIDAS users who have helped improve McIDAS through their ideas and feedback.

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