McIDAS III: A Modern Interactive Data Access and Analysis System

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ABSTRACT

A powerful facility for meteorological analysis called the Man Computer Interactive Data Access System (McIDAS) was designed and implemented in the early 1970's at the Space Science and Engineering Center of the University of Wisconsin-Madison. Hardware and software experience gained via extensive use of that facility and its derivatives have led to a newer implementation of McIDAS on a larger computer with significant enhancements to the supporting McIDAS software. McIDAS allows remote and local access to a wide range of data from satellites and conventional observations, time lapse displays of imagery data, overlaid graphics, and current and past meteorological data. Available software allows one to perform analyses of a wide range of digital images as well as temperature and moisture sounding data obtained from satellites. McIDAS can generate multicolor composites of conventional and satellite weather data, radar and forecast data in a wide variety of two- and three-dimensional displays as well as time lapse movies of these analyses. These and other capabilities are described in this paper.

1. Introduction

A Man Computer Interactive Data Access System (McIDAS) was first developed in the early 1970's for processing geosynchronous satellite images of earth as well as meteorological data at the Space Science and Engineering Center (SSEC). Although there were other commercial systems being developed at about the same time, they did not have the capability to process the vast amounts of digital data from the meteorological satellites interactively. Continued use of that facility, with increased data volume as well as technological developments in computers and peripheral hardware, have been responsible for constant improvements in the McIDAS hardware and software. Specifically, we can identify three distinct versions or generations of McIDAS. Many of these developments have come through the fabrication of similar facilities by SSEC for other institutions (see Appendix B). The first generation was based on a minicomputer, had two video display terminals (VDT's) for users, and was primarily used for research. This generation has been described by Smith (1975) and by Chatters and Suomi (1975). The second generation of McIDAS took the form of a network of eight minicomputers and was used for both research and quasi-operational use in support of the First GARP (Global Atmospheric Research Program) Global Experiment (FGGE). This generation is described briefly in Appendix A of this paper. The latest generation of McIDAS, the McIDAS III, although functionally the same, is a departure from the minicomputer as an element of the system and represents a more standardized facility built to work on several scales of mainframe computers. The improvements in this new version are apparent in peripheral equipment hardware such as the video terminals, as well as software and user interface to the system.

We intend to describe here what this facility is and what it can do. A full description of the system and its software and hardware components is beyond the scope of this paper and is not necessary for using the system.

2. McIDAS III architecture

The distinctive feature of McIDAS III is its ability to ingest meteorological satellite and conventional data in real time and to make it easily available to both local and remote users. It is thus a Data Management System as well as an Analysis System. It is clear then that in addition to the usual components of any image processing system [a Data Base Manager (DBM), a general purpose computer, and video display terminals], McIDAS has another fundamental component: special Data Acquisition Hardware and Software. Indeed, McIDAS is best described in terms of six distinct components as follows:

**HARDWARE**
1) Data Acquisition Hardware
2) A general purpose computer
3) Local and remote user terminals

**SOFTWARE**
1) Computer Operating System
2) McIDAS Control Program
3) Applications Programs

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These components are described below. There are other features to this facility that are not described here, and they include an off-line meteorological satellite data archive, the antenna sub-systems for receiving the satellite data, the communications links between McIDAS and other facilities, etc.

Applications programs described in the next section represent the immense flexibility of McIDAS in a wide variety of research and operational situations. Most of these programs can be run on any computer, and indeed, the current software is derived from the early generations of McIDAS which used different (smaller) computers. However, the choice of a particular computer dictates the nature of the interfaces required between other hardware systems such as those to the data acquisition hardware. The McIDAS Control Program is really an applications executive that controls the communications between the user terminals and the host computer.

a. Meteorological data acquisition

McIDAS III ingests GOES (Geostationary Operational Environmental Satellite) visible and infrared (Visible Infrared Spin Scan Radiometer, or VISSR) images as well as the VISSR Atmospheric Sounder (VAS) multispectral imagery and sounding data in real time through three antennas located on the roof of the building housing SSEC. Polar orbiting satellite imagery and sounding data can be ingested via dedicated lines from remote receiving stations and from antennas located adjacent to the GOES antennas.

Meteorological data for North America (FAA Service A hourly weather data), the Service C radiosonde observations, weather radar pictures, pilot reports, NMC forecast products, etc., are ingested via dedicated and dial-up communications lines as well. The McIDAS III CPU can also communicate with other computers via dedicated communications lines. Most of the satellite and conventional data are ingested into the system for real-time applications and are also archived for research analyses in a separate off-line archive system.

SSEC has a large digital archive of GOES imagery dating back to 1974. Since the FGGE (First GARP Global Experiment) beginning in 1978, SSEC has maintained a 24 h digital archive of VISSR imagery from all the operational U.S. geostationary weather satellites. This represents a data volume of over 10 billion bytes per satellite per day which is maintained on high density digital versions of video cassette recorders (Suomi, 1982). (At present, data from three GOES/VAS satellites are being archived.) Archived GOES VISSR data can be ingested into McIDAS III from a separate channel interface on an off-line basis without affecting the real-time ingests. In addition, SSEC also has a large planetary data archive comprised of Mariner 10, Voyager and Pioneer Venus spacecraft imagery data. These and other data can be ingested into the system via two 9-track tape drives.

b. McIDAS III computer

The current hardware configuration is shown schematically in Fig. 1. The previous generation of

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**Fig. 1.** A schematic diagram showing the current McIDAS III hardware configuration.
McIDAS was based on a Harris /6 minicomputer. McIDAS III is based on a medium-scale computer (IBM 4341 Group II). The OS/VSE operating system under which McIDAS operates is available on many different machines having a wide range of computing power. Since quick data access is a key factor of McIDAS, large memory storage is important. The current memory capacity of the McIDAS III is 4 Mbytes (the maximum memory capacity is 16 Mbytes). Peripheral data storage is provided by five IBM 3350 disk units each of which is capable of storing 640 Mbytes. User access to the CPU is provided through three different input devices: 1) locally connected terminals (IBM 3278 or equivalent) through the terminal controller, 2) asynchronous or bisynchronous terminals through a communications controller, and 3) bisynchronous McIDAS video terminals.

c. McIDAS video terminals

Present McIDAS video terminals are controlled by a microprocessor that also oversees the communications to the host CPU. They are “dumb” in the sense that they cannot perform any application functions without being connected to a host computer. A new generation of video terminals is being developed that will be more intelligent, with the ability to act as a “smart” local display device with its associated limited storage.

McIDAS III services both remote and local users with video terminals. A typical installation is shown in Fig. 2. Local McIDAS terminals are capable of burst communication rates of 10 megabits per second. To save communication costs, the bandwidth to the remote terminals is lower but it is impractical to operate the remote video terminals at data rates below 9600 bits per second since image access delays become too large. Fig. 3 shows the terminal configuration schematically. It consists of an image display CRT, an alphanumeric CRT, a keyboard, and two cursor control joy-sticks. Additionally, other devices such as a video cassette recorder and an image hardcopy device can be attached for recording animated or still video output. When a user logs onto a terminal, the local microprocessor informs the user of the current terminal hardware configuration (e.g., number of image frames, number of graphic frames, local or remote, etc.). The user can also determine the terminal characteristics from utility programs within an application program. It controls graphic overlays, the number of the graphic and image frames being displayed, current text output device (CRT or any other printer, local, remote, or system) or whether the program is being run in background or foreground. The terminal components are described next.

1) VIDEO DISPLAY

A typical McIDAS terminal has a number of image and graphic frames that are stored locally for rapid

![Fig. 2. A view of a typical McIDAS video terminal. The two racks on the right-hand side on and under the table contain all the electronics hardware that is part of the terminal. A CRT for alphanumeric output, RGB color monitor for the image and graphic display, a pair of joy-sticks and a data tablet can be seen in the picture. A local printer for hard copy of textual information can also be seen on the left.](image-url)
access. Each image frame is $480 \times 640$ pixels of six-bits, while each graphic frame is also $480 \times 640$ pixels, but only three bits per pixel. The number of image and graphic frames is determined by the user needs and cost rather than technical limitations. Additional memory can be installed to store and display more frames as needed. The graphic memory is separate from the image memory, and is typically capable of displaying eight levels or colors. The image memory and graphic memory can be combined to display an image on a high-resolution color monitor with a graphic overlay that can be toggled in or out from the terminal keyboard. All available frames and graphic overlays can be displayed in a movie loop at variable rates up to 15 frames per second. The red, green and blue guns of the color monitor are controlled by separate image refresh memories, but they can also be fed to a standard television color encoder so they can be displayed on a commercial television or recorded on any NTSC compatible video recording medium such as cassettes or video disks.

2) TEXT/DATA OUTPUT DEVICE

The terminal output routines allow the program output to be directed to virtually any CRT terminal and/or local or system printer. The relevant routing code can also be changed from the terminal by a special command.

3) JOY-STICKS

A wide variety of types and sizes of cursors are generated by the local microprocessor and can be positioned anywhere on the monitor display under keyboard control or via a pair of coarse and vernier joy-sticks. The joy-sticks can also be used to define functions such as image enhancement, control of video frame display rates, and drawing on the screen. It is also possible to change the joy-stick functions in specific application programs as needed. For example, the velocity of the cursor can be controlled to follow the paths of moving clouds in a “movie loop.”

4) ENHANCEMENT TABLES

A displayed image can be enhanced locally by changing from the default display mode, where the displayed brightness is proportional to the digital data numbers. This change is usually done via look-up tables. On McIDAS one can perform this not only for single image displays but also for a single image display based on the brightness of another separate image. Two video channels (frames) can be displayed...
together through 12-bit enhancement tables (6 bits per channel). The use of a local microprocessor in the terminal design allows easy insertion of multichannel custom enhancement tables. These enhancement tables have been used to generate pseudo three-color composites from two Voyager images taken in different colors, true and false stereo images, radar/satellite composite cloud images and the like. The available display frames and graphic frames can be looped in a rapid time sequence even in the combined mode of display. Customized enhancement tables can be either entered from the keyboard or generated within a program. The enhancement tables for each frame can be different and can be automatically loaded respectively for displayed frames. Thus, it is possible to loop through a sequence of frames while at the same time loading separate enhancement tables for each displayed image. Examples of color composite displays of two independent channels can be seen in Fig. 4.

5) **Data Tablets**

As one can imagine, there are very many commands to accomplish a wide variety of tasks. In order to simplify entering commands, data tablets have been added. These data tablets can be programmed such that a specific location selected by a pointer can perform a specific function. The data tablet is proving to be a very efficient means of manipulating the complex data in an operational environment.

d. **Computer operating system**

The 4341 CPU is run under the OS/VS1 (virtual memory system) operating system. Languages include the Assembler and the VS Fortran. As such, the VS operating system is batch oriented and interactive program editing and computing and video processing support is instead provided by either the Editor or the McIDAS control program, respectively. These two control programs do away with the need for the usual interactive processors most commonly found on IBM machines; the TSO (Time Sharing Option) and the CMS (Conversational Monitoring System), and yet allow greater and easier user interaction with the data and programs.

e. **McIDAS Control Program**

The virtual system environment allows separate "partitions" within which programs can be executed independently and simultaneously. The number of these partitions can be changed as needed, although the McIDAS Control Program requires only one partition. All the partitions are in virtual memory. For easy editing of source programs and access to textual data, a text editor executes in a separate partition. Other partitions are used to execute background or batch jobs which may or may not be McIDAS programs or macro commands (see below). All video terminals are accessed via the McIDAS Control Program (including telephone dial-up CRT terminals). Thus, the McIDAS Control Program appears as an applications program to the computer operating system, and as an operating system to its applications programs. It executes in a single partition of OS/VS1 or in a single address space in OS/MVS. In addition to simultaneous execution of different tasks (or batch jobs), the system is capable of simultaneously executing McIDAS (application) commands from the user terminals. The degree of "multi-tasking" is controlled at system start-up time by the allocation of the number of "sub-tasks" or initiators in the system start list. Each key-in made by a user at a McIDAS terminal creates a request block which is routed by the Control Program to one of the initiators. More than one request can be active from any single terminal at any one time, but the routing strategy guards against CPU monopolization.

Extensive program and data protection is provided by error abort and/or recovery mechanisms if erroneous command parameters are entered via a key-in. This prevents "crashing" the system, and is crucial in an operational environment. A potential user or program error situation generally results in an elegant exit of the initiator in which the problem program was operational, and not the entire control program. System service subroutines also provide error traceback capability for problem determination and solution.

A log of CPU time and resource usage for each request (by both batch jobs and McIDAS application programs) is kept for performance monitoring and billing purposes. These data can be used to "tune" the VS1 environment for optimum performance under changing conditions.

1) **McIDAS Command Language**

There are two ways in which commands can be entered to the executive: (i) single letter key-ins that perform both fixed and user defined functions and (ii) explicit commands that can accept an argument list. The single letter commands are used to control the video display or other programmed tasks. For example, the A key advances the video display to the next frame in a sequence, the W key toggles the graphic overlay (WRBM display) on and off, and the L key starts or stops a video loop between predefined loop bounds, etc.

Frequently-used McIDAS key-ins or commands that tell the CPU to execute a user defined application task are simple to use and remember, and typically constitute only a few parameters that can be coded by position or key words. If necessary a HELP command provides instructions on the command format.
and parameters. In addition, a manual of all programs is provided for further assistance. All commands have the structure

**TASK (parameter list)**

where TASK is the name of an executable program and the parameter list includes the processing parameters. The parameter list can be specified either as an argument list or as a keyword-oriented list. If necessary, specific inputs can be solicited from the program itself. For example, a commonly used command is the LA (List Area Directory) command

**LA 100 200**

This command causes the directory for the areas 100 to 200 to be listed. An area in this context refers to an image matrix stored in the system. The output is the pertinent directory information for each image such as the satellite/spacecraft code, day and time of acquisition, size of the image, etc. If the images are to be listed by specific days, the command is typed as

**LA 100 200 DAY = 79100 to 79120**

which lists only the images between areas 100 and 200 that were acquired between days 100 and 120 of the year 1979.

It is possible for an application program to solicit input from the user to direct the further execution of that program based on the solicited input. It is also possible to deliberately terminate the execution of an application program at any time.

Finally, there is an additional method in which McIDAS programs can be executed and that is through an application program itself. One can start a second application program through a prior application program; this is frequently done to minimize the need for user input for frequently used operations.

2) **COMMAND PROCEDURES (MACRO FACILITY)**

Frequently repeated tasks or processing steps can be chained in a single macro command (procedures) or entered in short form via a string handling program. The McIDAS III macro language allows use of standard Fortran statements in addition to a few specific commands, and is thus very powerful in constructing complicated processing run-streams from McIDAS applications programs. Such macro procedures are entered as any other McIDAS commands. The parameters from the macro command are then passed on to the component McIDAS commands as needed in the user-defined macro procedure.

Additionally, any or all of the terminal keyboard keys can be programmed to perform a prescribed sequence of tasks through the use of 126 programmable command registers. These registers render each key as a “function key.” Each register has a “name” (the alphabetic keys) or a number (the ten numeric keys plus the numbers 11 through 100). The commands entered in these registers can then be executed conveniently by simply entering the register number or its alpha-numeric name.

3) **McIDAS DATA MANAGEMENT**

McIDAS does its own data management. It “owns” several large data sets from which it allocates space for files as requested for applications. Utility routines provide highly flexible input/output operations to the user files with none of the limitations imposed by the operating systems on its files. Through locking conventions these files can be shared by multiple applications programs, permitting both batch and interactive data manipulation.

User “files” for image or other data are actually members of some generic data sets (i.e., they are members of a Partitioned Ordered Data Set), thus allowing greater flexibility in dynamic “file” creation and manipulation without the need for the normal control information that is required by the computer operating system. Sometimes the user data can be organized into a pre-defined scheme format that allows even greater data sorting capabilities without additional overhead. Examples of these are the meteorological data files, spacecraft orbit elements files, etc. Through standard utility commands the contents of these files can be edited or viewed by key words denoting particular data types. For example, the following key-in will list all stations reporting an observed weather condition in the times specified:

**MDE LIS MD = 100 WX = SNOW TIME**

= 1000 TO 2000,

wherein the Meteorological Data Editor (MDE) is invoked with the key words LIS and MD to denote the list option and the data file number (100), respectively. The same basic format can be used with proper key words for selectively displaying other data stored in the scheme format. This is a powerful method of accessing a wide variety of data with the same basic utility programs and thus the need for writing customized data sorting and editing routines is eliminated.

Finally, archival and restore utility programs allow many different kinds of data to be saved for future use. Different data catalogs can be maintained for keeping track of the data save tapes by different categories.

3. **McIDAS applications programs**

Almost all McIDAS applications programs are written in Fortran (1977 standard) making the software very portable. Over 300 000 lines of source code are currently operative on McIDAS III, all of which
Fig. 4a (top). An example of McIDAS meteorological capabilities. This is a photograph obtained within half an hour of receipt of the satellite images on 12 November 1982, and shows the first winter storm of the season to produce heavy snow and cold-air outbreaks in the midwest. The photograph shows a portion of the visible and infrared images color composited together. The map outlines are drawn on the overlay display using precise navigation data. The overlaid analyses depict the topography of the pressure surfaces at the 295 K potential temperature level (cyan), and the streamlines on this theta surface that shows the air flow. The descent of cold air from the 400 mb level to the 1000 mb level (assuming adiabatic motions) in the midwest is readily apparent, thus forecasting colder temperatures in the Midwest.

Fig. 4b (bottom). An example of a multi-channel color composite that can be created using the 12-bit enhancement table. This photograph taken from the McIDAS display terminal is a composite of two Voyager 1 images of Titan, a satellite of Saturn. Images taken through the violet and green filters from the Voyager narrow angle camera are simultaneously displayed through the use of special enhancements. All the processing was done interactively and the following tasks were performed on both the images in the following order: 1) photometric correction for vidicon shading, 2) remapping to remove vidicon geometric distortions, 3) reseau removal, 4) image navigation, 5) Minnaert scattering law parameters determined, 6) image normalization based on the Minnaert law to remove scattering geometry effects, 7) contrast enhancement to bring out maximum detail, and 8) color compositing.
Fig. 4c (top). An example of cloud tracer and gradient winds obtained on McIDAS. This figure shows observations obtained from VAS and TIROS temperature profile observations (gradient winds) and tracer winds obtained from a triplet of VAS images.

are accessible on-line. Extensive subroutine libraries and the modular design of programs make the creation of new application programs a fairly easy task.

They include low-level data access routines as well as high-level utility routines for gridding and interpolation, plotting, Fourier analysis, etc. Usually out-

Fig. 4d (bottom). A simultaneous display of a satellite image and a concurrent digital radar image remapped into the GOES-East satellite projection. Tilted PPI scans from 2 to 11° made by the WSR-57 radar of NOAA’s Severe Storm Laboratory (NSSL) were combined into a Constant Altitude PPI (CAPPI) composite at 10 km above the surface. Green areas denote regions of the cloud with radar reflectivities > 10 dBZ while blue areas denote >40 regions.
side program libraries can be installed with little or no change depending on the language and the input/output operations.

The applications software can be broadly categorized as being image data oriented or non-image data oriented. There is of course a somewhat limited class of programs that deal with the simultaneous manipulation of both the image data and non-image data. Examples of these include displaying conventional weather data on satellite images, contouring of this information in the satellite projection, or the computation of a vertical temperature and moisture sounding from satellite radiance data at a geographical location selected by positioning a cursor on a satellite image.

There is another class of programs for both image and non-image data archival and retrieval. The database services are an important part of McIDAS as all data ingested in real time are archived for later use by the scientists. In addition to the data, the image navigation data are also routinely archived so that one may use the image data quantitatively at a later time as far as earth locations are concerned. A short summary of the applications programs follows.

a. Image data oriented applications programs

Any kind of data that can be represented as a two-dimensional spatial image with brightness representing the data can be handled on McIDAS. There are some basic operations that can be performed on a given digital image either for cosmetic or quantitative purposes. The image oriented application software can thus be further categorized as follows:

1) DIGITAL PROCESSING OF IMAGE DATA

In many instances the “raw” image data must be processed for cosmetic or data integrity reasons. Examples of these include programs for digitally filtering the image data to bring out certain features of specific spatial frequencies, noise removal programs, camera shading and geometry corrections, etc. It is also frequently necessary to remap the image data into another projection, be it cartographic or the perspective view of another satellite. For example, for stereo analysis of GOES images, a user can remap an east satellite image into the projection that would be obtained from the location of the west satellite, so that the two could be viewed together. Or, for comparative analysis of polar-orbiting satellite data, a remapping into the projection of the GOES satellite may be necessary. McIDAS applications software allows a user to custom design a program to generate any kind of projection and execute it in an efficient manner.

2) IMAGE NAVIGATION

Image navigation software is a key part of McIDAS, as it is required for almost any quantitative image analysis. Programs exist for image navigation (i.e., the process of determining the geographical coordinates of the data points and vice versa) for many different kinds of observing platforms such as geostationary, polar, planetary fly-by spacecraft and orbiters. These programs are modular, and they are used by many other applications programs such as for cloud tracking, rainfall estimates, etc. In addition, there are programs for modelling the behavior of the attitude of the spin-stabilized geosynchronous satellites. The value of this latter class of programs is in predictive alignment of real-time satellite images by determining ahead of the precise satellite orientation.

3) QUANTITATIVE IMAGE ANALYSIS

This class of programs is mainly oriented to user needs and thus consists of some commonly used programs and some highly specialized ones. Perhaps the most used programs are those for determining cloud motions not only from earth images but also from planetary images. Indeed, this was the prime motivation for development of McIDAS. A user can set up multi-frame digital time lapse sequences to show the evolution of a time-dependent weather system on the video terminal. Custom designed enhancement programs can be automatically loaded for each frame on the fly as the loop is being displayed. In addition to providing the capability to interactively track clouds visually as well as digitally, the programs enable the user to display the results as overlay graphics on the images, animate them, and provide editing capability also.

Another type of image analysis program is the multispectral temperature/water vapor sounding software that is routinely used for analyzing the TIROS and GOES infrared and microwave sounding data. This allows a user to interactively determine the temperature and moisture profile in the atmosphere at any chosen location in the data area. In this way, soundings can be concentrated in meteorologically active areas and the product can be contour analyzed, displayed over the satellite image with ancillary observations (e.g., cloud motion vectors or radiosonde winds), and manually edited to insure a high-quality result.

Rainfall estimation from the satellite and radar imagery is another area where applications software is heavily used on McIDAS. In addition, area statistics programs enable one to outline certain image portions and determine statistical parameters such as one- and two-dimensional histograms, means and standard deviations, etc.

Cloud top altitude and optical thickness determination is also achieved using GOES multispectral data. Cloud top pressure heights are determined while they are being tracked for the altitude assignment of the cloud “wind” vectors.
Edge detection programs are used for not only planetary applications (in image navigation by determining the bright limb location) but also in protein research for quantitative analysis of electrophoreograms.

4) STEREO IMAGE DISPLAY

Through software control it is possible to display both true and false stereo images on McIDAS. True stereo display is obtained from simultaneous display of two separate images of the same geographical area obtained from two satellites at different observing positions such as the GOES east and west satellites (Bryson, 1978). The two images can be either displayed in different colors (typically one is shown in red and the other in green) simultaneously and viewed with red and green glasses so that one eye sees the east image and the other, the west image. The drawback of this mode is that color images cannot be displayed due to the necessity of showing each image in separate colors.

Another method of stereo viewing that employs color displays is to use special electronically shuttered glasses that allow each eye to see only one of the two alternate fields on the television monitor. In this case the two images are blended together at one-half the normal vertical resolution so that each image is displayed on alternate fields on the television and the electronic glasses then make possible the stereo view. When true stereo images are not available, a false stereo method can be used to create the illusion of stereo through software. For example, a false image can be created from the visible image so that the apparent parallax of the visible clouds is proportional to the cloud top altitudes estimated from the infrared cloud temperature data. A simultaneous display of the real visible image and the false one creates an illusion of stereo. Another method of displaying false stereo images is through the use of multiple frames each of which is created from a single image by artificially creating parallax by some amount, and then rapidly displaying these frames in a loop. Typically three or more frames displayed three to five times per second create a reasonable illusion of stereo view that is similar to rapidly obtaining different perspective views in a very short amount of time. This mode does not require wearing any glasses at all, and by its very nature cannot be reproduced in hard copy form.

b. Non-image data analysis

The non-image data applications software includes statistical and graphical analysis programs. Most of these are self-explanatory and hence need only a brief mention. They include the following:

- Graphical analysis (x-y plots, contouring, etc.).
- Statistical analysis of user data.
- "Nowcasting" or display of current conventional and satellite weather data.
- Simple advective forecasting of short term mesoscale weather phenomena.
- Forecast impact experiments with a sophisticated limited area mesoscale primitive equation numerical prediction model.

Of these, the nowcasting and advective forecasting functions are particularly interesting and heavily used on McIDAS. They allow contouring and display on the graphics frames and animation of current and past weather data along with a chosen base map outline. Thus, they are analogous to conventional weather maps with the added benefit of animation for monitoring the weather evolution. The ability also exists to determine and display the derived quantities at will. For example, in a tornadic situation it is possible to compute the equivalent potential temperature distribution and watch it as it evolves in time. The areas of deepest and fastest northward penetration are frequently areas where severe weather develops. The hourly interval VAS profile observations now enable the changing thermodynamic stability of the atmosphere to be monitored to delineate local areas where intense convective storms will occur. Advections, divergences, Laplacians, etc., of any meteorological quantity can be computed and displayed for weather nowcasting purposes.

Finally, as mentioned earlier, it is possible and generally useful to display quantitative data products in the satellite projection along with the satellite image itself. For example, the 300 mb winds can be displayed as isotachs and streamlines on a satellite image enabling a better presentation of the relationship between the cloud patterns observed and the air mass movements.

Fig. 4 shows examples of the image and graphic analysis via the applications programs. Fig. 4a was generated within 30 min of completion of the satellite picture transmission and shows a color composite of the North American portion of a GOES image with an isentropic analysis of the pressure surface topography and the air flow. The visible and the window channel images are displayed at reduced resolution on the monitor. An enhancement program is used to assign different tints to the clouds based on their cloud top temperatures (determined from the infrared data). Thus, magenta clouds are the highest clouds in this photograph obtained from the terminal display, and the white clouds are the lowest. The geographic and political map outlines are drawn in magenta and the pressure topography on the 295 K isentropic surface is depicted in yellow. Finally, another program generates a streamline analysis from these data with the resultant streamlines shown in cyan, in the satellite projection.
A very vivid representation of the onsetting cold air flow upon the Midwest from the upper reaches of the atmosphere is readily apparent in this figure. This example combines many of the software capabilities of the system such as real-time data ingestion, color compositing, image navigation and registration, conventional weather data ingestion, data gridding and interpolation, contouring, and simultaneous display of the satellite image and graphics.

Fig. 4b shows a color composite of Titan, a satellite of Saturn, and the only satellite known to have an atmosphere. This was made from two Voyager 1 images taken through orange and green filters. Both the images were first processed to remove the photometric and geometric distortions resulting from the vidicon cameras; they were then navigated and were brightness normalized to remove the effects of varying scattering geometry after determining the Minnaert law coefficients for the normalization. A color compositing program that uses the known filter responses generated the final, lifelike, although grossly exaggerated color display. This processing was all done interactively in a relatively short amount of time and was useful in that only after this processing could the darker northern (top) polar regions and the wispy, bright veil in the northern mid-latitudes be seen. The brighter southern hemisphere of Titan is also strongly emphasized after the brightness normalization.

Fig. 4c shows wind vectors derived from cloud tracking and from horizontal temperature gradients determined from geostationary (VAS) as well as polar-orbiting satellite (TOVS) data. The winds are displayed over a blend of images of radiances within the water vapor absorption and atmospheric window channels of the VAS. The white areas denote high clouds and blue areas high upper atmospheric water vapor concentrations. The vectors reveal the upper tropospheric circulation associated with Hurricane Debby (1982).

Finally, Fig. 4d shows an example of one type of data used in severe storm research. This is a composite of a satellite image over Oklahoma with a Constant Altitude Plan Position Indicator (CAPPI) image from the National Severe Storm Laboratory (NSSL) WSR-57 radar image mapped into the satellite projection. The radar echoes are color enhanced so that regions of higher reflectivity can be displayed inside the storm as seen by the satellite.

There is a capability that is difficult to show in this format and that is animation of different kinds of data. Several video sequences are routinely used for weather nowcasting and in classrooms either directly from McIDAS or via video cassettes.

4. Summary

McIDAS has evolved over the past decade into a general system which enables rapid access to a wide variety of weather data from satellites, from radar, from aircraft, and conventional observations in real time or from archives. McIDAS is only a tool, albeit a powerful one, and in the hands of a skillful operator can bring together a wide variety of data sources for display or computations.

Applications software is an area that needs constant attention, as it needs to adapt quickly to the environment under which it is used. The use of a current standard language at least for McIDAS applications software should make the task somewhat easier than it has been in the past. The hardware on which the software is used is becoming less and less important than in the past as technology advances and the reliability and flexibility of the computers increase. Indeed not all terminals need to be high-performance ones. Some very useful work is being done through McIDAS using the so-called personal computers.

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While a number of individuals have contributed to the success of McIDAS, John Benson is its true systems architect. He has guided the early work using a single Harris minicomputer and as needs grew, expanded it into the second generation system in the form of a network. Of the many people involved in the development of McIDAS III, the following deserve special mention: J. T. Young for the important interface between McIDAS users and its hardware and software engineers; Marty Barrett, Dave Erickson and Joe Rueden for the design of the McIDAS application software interfaces; Ralph Dedecker for the video terminal software design, Rob Uram for system integration, Tom Whittaker and Dave Santek for meteorological software foundations, and Ron Steiner and Jim Maynard for the video terminal hardware design. Other individuals who have played a key role in this McIDAS system include Paul Menzel, Bob Krauss, Bob Oehlers, and others. Fred Mosher managed the development of the CSIS (Centralized Storm Information System) version of McIDAS for the National Severe Storms Forecast Center in Kansas City.

Important applications software support has been provided by Hal Woolf, Christopher Hayden, Fred Nagle, Ben Howell, Geary Callan and Leroy Herman of the NOAA/NESDIS Development Laboratory at UW-Madison (Dr. W. L. Smith, Director), and by Gail and Russ Dengel, and Anne LeBlanc of SSEC.

The GOES data archive system was developed by Eric W. Suomi, and current management of that archive is the responsibility of Elsa Althen. Three op-
APPENDIX A

The Network Implementation of McIDAS

The second generation McIDAS took the form of a network of several Harris /6 mini-computers. The network (schematically shown in Fig. A1), which is still currently in use, has two computers acting as data base managers (DBM) with over 1 giga-bytes of shared peripheral storage. The two DBM's communicate with each other via wide-band communication links (WCL). In addition each DBM communicates with several other computers [the Applications Processors (AP's)] via similar links. Both local and remote interactive video terminals for the users are connected through a terminal switch to the individual AP's. The Application Processors have their own local peripheral disk storage of typically 160 Mbytes, as well as access to the data managed by the two DBM's. Each application processor has the same McIDAS applications and system software so that they provide the same interactive and computational capabilities and thus serve as back-ups to one another in an emergency if one computer were to fail temporarily.

The network also provides access to the computers via conventional CRT terminals for editing programs or data files, or even executing McIDAS programs in the foreground without the benefit of a video display. Unlike the IBM 4341 implementation, no capability exists on the Harris McIDAS network to execute programs in the background.

Fig. A1. A schematic diagram of the second generation of McIDAS (the network implementation). MOM and DAD are the two central Data Base Managers (DBM's) and REX, ABE, KEN, SUE, EVA and LIZ are the applications processors that handle the user terminals through a patch panel. The numbers indicate the location of a given terminal. In addition, there are several programmers' terminals (either dial-up or direct connect) that allow non-video interaction with the Applications Processors.
Following is a list of institutions which have acquired McIDAS hardware and/or software for their use.

<table>
<thead>
<tr>
<th>Year</th>
<th>Institution</th>
<th>McIDAS hardware/Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>Air Force Geophysics Laboratory</td>
<td>Datacraft 6024/5 CPU</td>
</tr>
<tr>
<td>1976</td>
<td>DFVLR, West Germany</td>
<td>McIDAS software (on AMDAHL V6)</td>
</tr>
<tr>
<td>1976</td>
<td>UW-Milwaukee</td>
<td>McIDAS remote terminal</td>
</tr>
<tr>
<td>1977</td>
<td>WTVT, Tampa, FL</td>
<td>McIDAS hardware (Harris/6 CPU)</td>
</tr>
<tr>
<td>1978</td>
<td>VIRGS, NESS</td>
<td>McIDAS hardware (6 CPU)</td>
</tr>
<tr>
<td>1979</td>
<td>LAS/GSFC, NASA, Greenbelt, MD</td>
<td>McIDAS software on AMDAHL V6</td>
</tr>
<tr>
<td>1980</td>
<td>California State University at Chico, CA</td>
<td>McIDAS hardware (Harris/6 CPU)</td>
</tr>
<tr>
<td>1980</td>
<td>Prototype Regional Observational and Forecasting System, NOAA, Boulder</td>
<td>McIDAS remote terminal</td>
</tr>
<tr>
<td>1981</td>
<td>Florida State University, Tallahassee</td>
<td>McIDAS hardware (Harris/6 CPU)</td>
</tr>
<tr>
<td>1981</td>
<td>Marshall Space Flight Center, NASA, Huntsville</td>
<td>McIDAS remote terminals</td>
</tr>
<tr>
<td>1981</td>
<td>Institute for Atmospheric Physics, Peoples Republic of China</td>
<td>McIDAS hardware (IBM 4331 CPU)</td>
</tr>
<tr>
<td>1982</td>
<td>National Severe Storms Forecast Center, NOAA, Kansas City</td>
<td>McIDAS hardware (two Harris/6 CPU’s) and a terminal to SSEC McIDAS</td>
</tr>
<tr>
<td>1982</td>
<td>IFFA, World Weather Building</td>
<td>McIDAS hardware (two Harris/6 CPU’s)</td>
</tr>
<tr>
<td>1982</td>
<td>National Hurricane Center, Miami</td>
<td>McIDAS remote terminal</td>
</tr>
<tr>
<td>1982</td>
<td>State University of New York at Albany</td>
<td>McIDAS remote terminal</td>
</tr>
<tr>
<td>1983</td>
<td>Hughes Aircraft Company, El Segundo, CA</td>
<td>McIDAS remote terminal</td>
</tr>
</tbody>
</table>

REFERENCES AND SELECTED BIBLIOGRAPHY


