THE METPRO WORKSTATION VERSION 2.0

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1. INTRODUCTION

The METPRO meteorological workstation is a powerful meteorological data analysis and display system. It provides a comprehensive set of programs to analyze satellite, radar, surface, and upper-air data. METPRO generates products for both operational and research meteorology environments. The preparation of products can be customized by the user to meet the needs of the particular site where METPRO is installed. METPRO workstations are now successfully meeting the requirements of operational weather centers in several countries.

The METPRO workstation system software is designed to be highly portable and expandable. The METPRO system is UNIX-based and currently hosted on the Silicon Graphics, Inc. (SGI) Personal IRIS series of computers. The Personal IRIS utilizes the Reduced Instruction Set Computing (RISC) technology, a powerful graphics engine, and the IRIX operating system, which is an enhanced version of AT&T System V.3. Steranka and Ku (1991) provide further details regarding the Personal IRIS workstation hardware.

In this paper, the major features of the METPRO system are discussed and sample METPRO products are presented. In addition, new features of the METPRO workstation Version 2.0 are highlighted.

2. METPRO SYSTEM OVERVIEW

The METPRO system includes the METPRO groundstation for data ingest and formatting, and the METPRO workstation for product generation and display. Figure 1 illustrates the data flow for a complete METPRO installation.

2.1 METPRO Input Data Summary

The METPRO groundstation ingests meteorological data in real time and preprocesses, calibrates, and stores the data in the appropriate METPRO files.

The fully outfitted METPRO groundstation ingests and formats the following data types:

- Global Telecommunications System (GTS) Data. These data include conventional observations such as surface synoptic reports and upper-air radiosonde reports, and numerical weather prediction (NWP) model output. GTS data are decoded and stored in METPRO surface, sounding, and grid files. Grid files may either contain grids ingested by METPRO (i.e., NWP model output) or girds generated by objective analysis of surface or upper-air data.

- Satellite Data. These data include polar-orbiting and geostationary satellite data. Polar-orbiting data, that originate from the NOAA series satellites, generate High Resolution Picture Transmission (HRPT), Advanced Very High Resolution Radiometer (AVHRR) image sectors, and TIROS Operational Vertical Sounder (TOVS) sounding retrievals. AVHRR image data are sectorized, calibrated, and stored in METPRO image files. TOVS data are Earth located and calibrated. TOVS retrievals are generated and stored in sounding files. Geostationary satellite data originate from the Japanese GMS, United States GOES, and European METEOSAT satellites. These data are ingested, sectorized, calibrated, and stored in METPRO image files.

- Radar Data. Radar data consist of images with field types such as reflectivity, rain rate, and Doppler velocity. These data are stored in METPRO image files.

It should be noted that the METPRO software is flexible enough to handle other types of data. The basic requirement is that the data be stored in an appropriate METPRO data file format.

2.2 METPRO Workstation Product Summary

The METPRO workstation generates a complete set of products, including surface weather maps, upper-air constant pressure maps, thermodynamic diagrams, vertical cross sections, satellite and radar images, and composite products (surface and upper-air maps combined with images). These products can be grouped into four major categories, as indicated in Figure 1.

A summary of the products for each category and sample product components are provided in Tables 1, 2, and 3. Composite products are a combination of images and graphics products. For brevity, they are not listed in the tables.

2.3 METPRO Workstation Product Features

METPRO provides a powerful set of applications and flexible features to generate its products.

The METPRO graphics applications perform the plotting, contouring, listing, and editing of meteorological data stored in the METPRO database. This database includes surface, upper-air, and grid files as indicated in Figure 1. Grid data are generated from surface or upper-air data by Barnes objective analysis or ingested from model grids and converted to the METPRO grid format.

Some of the features provided by METPRO for graphics products include:

- Meteorological parameters and diagnostics are computed from parameters stored in the database. For example, if wind data are contained in a grid file, vorticity advection is computed and contoured "on the fly." Units conversions (e.g., meters/sec to knots) are also available.

- An extensive set of over 100 grid scalar and vector functions is available for computed grid diagnostics. These functions operate on any scalar or vector parameter which can be computed. Generic operations, such as spatial and temporal derivatives, arithmetic functions, and various vector operations are also available. Some product examples are listed in Tables 1 and 2.

- Parameters and diagnostics are listed, plotted, contoured, or streamlined at user-specified heights, pressure levels, or isentropic levels for upper-air and grid data sets.

- Parameters and diagnostics are listed, plotted, contoured, or streamlined by user-specified geographic region and map projections. The geographic region is specified by latitude/longitude bounds, geographical abbreviations including country, state, or province, or station identification code. Areas may be expanded or reduced. Valid METPRO map projections include:

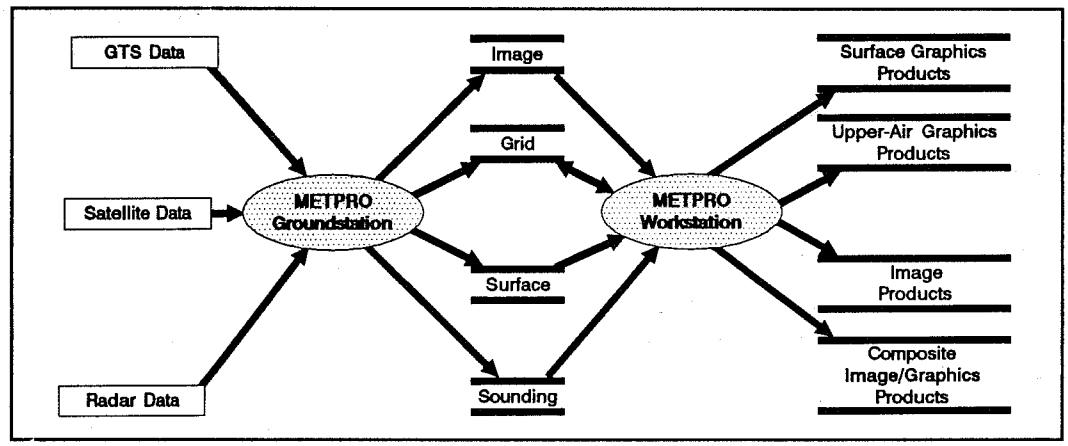

Figure 1. METPRO Data Flow

TABLE 1. SURFACE GRAPHICS PRODUCTS
(Multiple Map Projections and Geographic Regions)

Product Category	Samples
Standard Surface Charts	Station Model Plots Isotherms Isobars
Customized Surface Charts (Over 100 user-specified parameters and diagnostics)	Convergence Isallobaric Wind Temperature Advection Pressure Tendency Streamlines Precipitation Amount
Meteograms	Temperature Present Weather Symbol Precipitation Visibility
Image-Derived Surface Charts	Vegetation Index Sea Surface Temperature

TABLE 2. UPPER-AIR GRAPHICS PRODUCTS
(Multiple Map Projections and Geographic Regions)

Product Category	Samples
Standard Pressure Charts	Station Model Plot Isotherms Height Contours Isotachs
Customized Upper-Air Charts (Over 100 user-specified parameters and diagnostics, available in pressure, height, and isentropic coordinates)	Vorticity Geostrophic Wind Vorticity Advection Precipitable Water Divergence Thickness Thermal Wind Ageostrophic Wind Frontogenesis Mixing Ratio Potential Temperature Equivalent Potential Temperature
Thermodynamic Diagrams (Over 20 different stability parameters available)	Skew T/Log P Stüve
Vertical Cross Sections (Sounding, Grid, and Time Cross Sections)	Potential Temperature Grid Diagnostics for Grid Cross Sections Isotachs Mixing Ratio Contours

TABLE 3. IMAGE PRODUCTS SUMMARY	
Product Category	Samples
Color/Grey Enhancement	Cloud Top Temperature Radar Reflectivity Cloud Height Radar-derived Rain Rate
Cloud Analysis Products	Temperature Display Temperature Contours Temperature Statistics Temperature Slice/Profile Cloud-Tracked Winds Cloud Type/Amount
Multi-Spectral Products	Sea Surface Temperature Arithmetic Combined Image Vegetation Index Cloud Amount
Remapped Image Products	Satellite Mosiac Satellite in Common Map Projections Radar Mosaic Three-Dimensional Perspective
Generic Image Products	Zoomed/Panned Images Smoothed/Filtered Images Histogram Equalization Animation Histogram Analysis Linear Contrast Stretch

  - — Mercator
  - — North Polar Stereographic
  - — South Polar Stereographic
  - — Northern Hemisphere Lambert Conic Conformal
  - — Southern Hemisphere Lambert Conic Conformal
  - — Cylindrical Equidistant
  - — Universal Transverse Mercator
  - — North Orthographic
  - — South Orthographic
  - — Satellite Coordinate System
  - — Graphic products may be remapped into the native satellite coordinate system such as GMS or AVHRR

- METPRO contains a global map database. Geopolitical boundaries are drawn in any valid METPRO projection for any user-specified geographic region. In addition, latitude/longitude grids at user-specified grid spacing are plotted.

- Specification of contour line color, type, width, contour interval, contour labeling, and size is allowed for any parameter or diagnostic quantity.

- METPRO provides an interactive graphics editing and annotation facility. Fronts, pattern fills, weather symbols, and annotation are drawn, toggled, erased, and shifted. These capabilities provide the user with the capability to generate "hand-drawn" analysis charts, such as weather depiction charts.

- Plotting of vertical cross and time sections for any meteorological parameter that can be computed is provided. In addition, vertical cross sections through a three-dimensional grid can be drawn with scalar and vector quantities displayed.

Figure 2 shows an example of an upper-air graphics product. The product includes contours of vorticity advection in addition to standard 500 mb analysis.

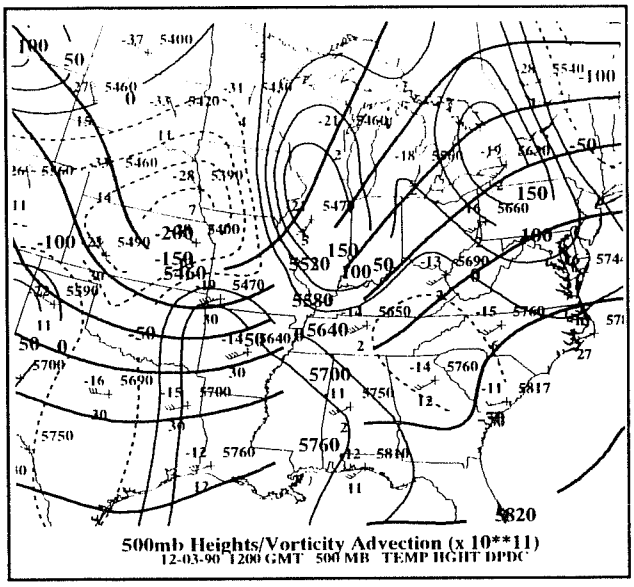

Figure 2. Upper-Air Graphics Product

The METPRO image processing applications perform a wide variety of functions to enhance satellite, radar, or derived image products. Many of the image processing applications are highly interactive providing the user with a great deal of flexibility. Some of the features provided by METPRO for image products include:

- METPRO displays up to ten 8-bit, 1024 lines x 1024 pixels images. Forty 512 x 512 images can be displayed.

- Images are color or grey-scale enhanced to highlight features of interest. Psuedo-coloring and grey shading is performed on the image grey value or field value (e.g., cloud top temperature), radar reflectivity, etc. Grey or field value image slicing is also available.

- Grey or field value statistics and histograms are calculated for the entire image or user-defined regions of interest. Users may define polygons, boxes, and paths as regions of interest.

- The display of navigation information, such as Earth location is displayed for any position on a satellite or radar image, or graphics product. The nominal navigation solution for satellite images are improved by techniques such as landmark registration.

- Image, composite, and graphics products are animated. Animation sequences are either user-defined in an interactive fashion or are automatically displayed.

Composite products are created by remapping image products to common map projections or by overlaying graphics products onto image products in the satellite projection. In either case, the image and graphics data are properly co-registered. Composite products provide a powerful tool for the integration of several types of meteorological data into a single product display.

3. METPRO MODES OF OPERATION

The METPRO workstation is designed to accommodate the needs of both the operational and research environments and the user's level of expertise. These requirements vary widely among the METPRO customer base. For example, in highly operational settings, the forecaster may only have time to display pre-generated products. On the other hand, at national centers, or in more research oriented centers, the meteorologist may desire the flexibility to generate custom products tailored for his needs. METPRO provides three modes of operation to satisfy these varying user needs.

3.1 Automated Mode

The automated mode is the simplest mode of operation. In this mode, products are automatically generated by the system as soon as the data are ingested and transferred to the workstation database from the groundstation system. Generated products are stored in the system database and optionally can be output to system plot devices for hardcopy. The user can rapidly survey the product database and display products by running one METPRO application. The automated mode is most suitable to the operational environment.

Products are automatically generated by employing METPRO script files. Script files contain a list of METPRO application names and user input file names necessary to generate a product. Most products that can be generated by METPRO in the interactive mode (see description below) can be automatically generated, if desired. This capability provides for the full range of METPRO products to be pre-generated. In addition, the full range of METPRO product characteristics (e.g., contour color, line type, etc.) may be specified in the script files.

3.2 Semi-Automated Mode

The semi-automated mode allows the user to generate his own set of products in a rapid fashion. In this mode, a user-defined METPRO script file is executed to generate and display products. The script is invoked by a simple mouse click. The product can be stored in the user's database for future access. The semi-automated mode allows the user to generate different products or products having different characteristics than the system-generated products. For example, there may be products that users prefer to generate for particular weather events (e.g., snow storm) that are not automatically generated by the system.

3.3 Interactive Mode

The interactive mode allows the user to generate products or product components by running individual applications in an interactive fashion. This mode provides the greatest flexibility in creating products by allowing interactive control of product characteristics. The interactive mode is especially suitable for some image processing functions which are highly interactive in nature. Also, because it provides the greatest amount of flexibility, the interactive mode is well-suited for research applications. The interactive mode requires the greatest amount of user expertise.

4. METPRO SOFTWARE SUMMARY

The METPRO software is designed with the future in mind. Virtually every design decision made considered the necessity to take full advantage of current hardware technologies and software algorithms, without placing significant limits or restrictions on future capabilities.

METPRO uses software standards wherever possible. The software takes advantage of features of the UNIX operating system without depending too heavily upon a specific vendor implementation. The graphical user interface (GUI) is built entirely on the X Window System and the vector graphics products are stored in the Common Graphics Metafile (CGM) format to allow easy access by other software packages which support the Graphic Kernel System (GKS). All data display is done using the SGI Graphics Library (GL) which is rapidly becoming accepted as the industry standard for 2- and 3-dimensional graphics display.

METPRO is written entirely in portable structured languages such as C, FORTRAN-77, and C++. These languages allow for a modular, expandable approach to programming. Most importantly, this software structure facilitates incorporation of new meteorological applications into METPRO.

The METPRO GUI is built upon the X Window System using the Transportable Applications Environment (TAE+), a tool developed by the National Aeronautics and Space Administration (NASA). TAE+ is available from the Computer Software Management and Information Center (COSMIC), the distribution center for NASA software. The interface was designed to be as clear and consistent as possible. Standard colors and fonts are used throughout. There is an on-line help facility which allows the user to get an explanation of every parameter and application in the system with a minimum of mouse button clicks. For any parameter in which there are a finite number of possible selections, the user has the option of entering the selection manually or being prompted with a list of all the possibilities from which selections may be chosen.

METPRO uses the General Meteorological Software Package (GEMPAK) Version 5.0 subroutines and data structures to analyze surface, upper-air, and grid data sets. The use of GEMPAK provides METPRO with a powerful and flexible set of applications for generation of graphics products. GEMPAK was developed at NASA/Goddard Space Flight Center and is available from COSMIC. See desJardins et al. (1991) for further details about GEMPAK.

METPRO uses a relational database schema for accessing data files and products. A Query By Example (QBE) interface is provided for easy and rapid database access. There are a number of keys which the user may use to subset the available data in the system. These keys include date, time, geographic area, data source, and others. The user may subset the data set based upon one or any combination of keys using keywords, inequalities, and ranges. For example, the user may enter "911225" as a date to get all the data from Christmas day, 1991, or may enter "> 911224 < 911224 + 8" to get all the data between Christmas 1991 and New Year's day, 1992. In addition, special keywords exist, such as TODAY, to access all the data pertaining to the present date. This approach is used for any type of data or product within the system.

5. METPRO VERSION 2.0 FEATURES

Several enhancements have been added to METPRO in the last year to increase the capabilities of the system, to improve the system performance, and to improve the user-interface appearance and ease of use.

5.1 GEMPAK Version 5.0

METPRO has been upgraded to use the GEMPAK 5.0 software algorithms. Previously, METPRO used GEMPAK 4.1 subroutines. The upgrade to GEMPAK 5.0 adds many new features and applications.

New features include:

- Generalized grid diagnostics
- Improved objective analysis
- Improved contouring algorithm
- Additional sounding diagnostics
- Parameter thresholding for station model plots or listings

New applications and algorithms include:

- Sounding hodograph
- Grid cross section
- Time sections and meteograms

See desJardins et al. (1991) for further details about GEMPAK 5.0.

5.2 TAE Version 5.1 and IRIX Version 4.0

In the Fall of 1991, SGI released IRIX Version 4.0, their latest version of the operating system. GSC obtained a Beta Release of 4.0, and TAE Version 5.1 was ported to the Personal IRIS. Porting of METPRO has been completed, and following the official release of IRIX 4.0, all METPRO releases will operate under IRIX 4.0 and TAE Version 5.1.

The porting of METPRO to TAE 5.1 and IRIX 4.0 provides several improvements in the user interface and in system performance. Some of the major benefits include:

- OSF/Motif Widgets for the GUI. The OSF/Motif widgets are now supported in TAE 5.1. They provide a much improved appearance over the Athena widgets used in earlier versions of TAE. They also give the METPRO GUI the standard Motif look and feel.

- Greatly Improved X Window Server Performance. With IRIX 4.0, the SGI workstations will support a native implementation of the X Window System Release 4.0 and will operate in an OSF/Motif environment. The Network Extensible Windowing System (NeWS) server, present in previous IRIX versions, has been removed. The SGI Graphic Library (GL), which operated on NeWS Windows, operates on X Windows directly. 4Sight, the previous IRIS window manager based upon NeWS, has been replaced with 4Dwm, SGI's version of the Motif Window Manager (MWM). These changes have increased the speed of the METPRO GUI and improved the performance of many of the image processing applications. For example, the maximum image animation speed has been increased by more than a factor of four.

- IRIX 4.0 and thus METPRO will comply with the following standards:

  — X11 Release 4
  — Display Postscript
  — POSIX 1003.1
  — X/OPEN XPG 3

6. REFERENCES

desJardins, M.L., K.B. Brill, and S.S. Schotz, 1991: Use of GEMPAK on UNIX Workstations. Preprints, Seventh International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Amer. Meteor. Soc., New Orleans, LA, 449-453.

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