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Global Meteorological Data Facility for Real-Time Field Experiments Support and Guidance

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Nomenclature

ABLE	Amazon Boundary-Layer Experiment
AGC	Automatic Gain Control
ASD	Atmospheric Sciences Division
ATS	Applications Technology Satellite
Bd	baud
CNS	Computer Network System
CPU	central processing unit
CRT	cathode-ray tube
DMA	Direct Memory Access
DOM	domestic
DWIPS	Digital Weather Image Processing System
ECMWF	European Center for Medium-Range Weather Forecasting
EIRP	Effective Irradiated Power
EMI	electromagnetic interference
ERBE	Earth Radiation Budget Experiment
e.s.t.	eastern standard time
FD	full disk
FRP	Full Resolution Processor
FTS	Federal Telecommunications System
GALE	Genesis of Atlantic Lows Experiment
GMDF	Global Meteorological Data Facility
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GTE	Global Tropospheric Experiment
INMARSAT	International Marine Satellite
INT	international
IPS	Information Processing System
IR	infrared
LAN	Local Area Network
LaRC	Langley Research Center
LNA	low noise amplifier
lpm	line per minute
MAPS	Measurement of Air Pollution from Satellites
MASS	Mesoscale Atmospheric Simulation System
MB	megabyte
McIDAS	Man-Computer Interactive Data Analysis System
METEOSAT	European Geostationary Meteorological Satellite
MICOM	Telecommunications Network Switching Device
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NMC	National Meteorological Center
NOAA-9	National Oceanic and Atmospheric Administration—Polar Orbiting Satellite
PAM	Portable Area Mesonet
PSC	Polar Stratospheric Cloud
PROFS	Prototype Regional Observing and Forecasting Service
RIM	Relational Information Management System
SAGE	Stratospheric Aerosol and Gas Experiment
SAM II	Stratospheric Aerosol Measurement II
SDLC	standard data link communications

SFSS	Satellite Field Service Station
UNIDATA	Universal Data Format
UV-DIAL	Ultraviolet Differential Absorption Lidar
u.t.	universal time
VAS	visible atmospheric sounder
VIS	visible
VISSR	Visible-Infrared-Spin-Scan-Radiometer

Introduction

A Global Meteorological Data Facility (GMDF) has been developed at NASA Langley Research Center (LaRC) to provide near-real-time specialized meteorological support at experimental sites in an economical manner. This type of support has become a critical issue for mission success as experimental goals are increasingly complex. After collection and analysis of meteorological data bases at the GMDF location, tailored meteorological products are transmitted to experimental field sites by conventional ground link or satellite communication techniques.

The criterion for the GMDF design was based on the flexibility of the system. The GMDF injests satellite data from either GOES TAP or directly from a mode AAA downlink. Data available for transmission include satellite images from GOES, METEOSAT, GMS, and NOAA-9 (composite views) as well as analyzed graphic products derived from the worldwide radiosonde data, and model outputs from the National Meteorological Center (NMC), the European Center for Medium-Range Weather Forecasting (ECMWF), and LaRC. The model capabilities available to LaRC include isentropic trajectory software (Danielsen, 1961, and Petersen and Uccellini, 1979) and the Mesoscale Atmospheric Simulation System (MASS) (Kaplan et al., 1982). Communications are primarily based on voice-grade links for the transmission of facsimile grey-scale images. Conventional telephone lines have been used successfully for transcontinental images communications. Remote Western Hemisphere locations have been accessed by radio using ATS-3 satellite VHF transponders.

The GMDF was used to support the NASA Global Tropospheric Experiment (GTE) Amazon Boundary Layer Experiment 2A (ABLE/2A) based in Manaus, Brazil, during July and August 1985 (McNeal et al., 1983). An airborne lidar mission in the Arctic designed to observe polar stratospheric clouds and survey the latitudinal distribution of stratospheric aerosols was supported during January 1986 (Poole and Kent, 1986). Operational mesoscale forecast support was also provided to the Genesis of Atlantic Lows Experiment (GALE) during January, February, and March 1986 (GALE Project Office, 1985). This paper outlines GMDF operations during these three field experiments and discusses the benefits of real-time meteorological support to atmospheric field measurement programs.

Field Experiments

The GTE ABLE/2A mission to Brazil used the GMDF as a data resource for economical operations in a remote area. GOES and NOAA-9 images of tropical South America and Africa were transmitted to the Brazil field station via the ATS-3 VHF communication capability. Early morning transmission periods concentrated on the relay of GOES full disk (fig. 1) and Amazon Basin images in the infrared (IR) with 3-hour time resolution. This information was used by the principal investigators at Manaus, Brazil, on a daily basis to plan airborne and ground-based operations over remote rain forest areas (GTE ABLE/2 Expedition Plan, 1985). Postanalysis air mass trajectories were computed for selected time periods to support interpretations of the in situ atmospheric measurements. The capability for trajectory analysis in near real time is planned for future missions.

The 1986 Arctic mission used airborne and ground-based ATS-3 communications systems to provide a VHF radio link from an aircraft and a ground station to the GMDF base station for high latitude operations. This field experiment used airborne lidar and in situ instrumentation onboard a Lockheed P3 aircraft to study polar stratospheric aerosols and clouds at high latitudes during the polar night. The daily latitudinal movement of the ATS-3 satellite restricted communication between either the aircraft or a high-gain ground station at Thule, Greenland, and LaRC to the early morning hours. Communications en route to Thule and at the ground station were severely degraded under daylight or twilight conditions at LaRC, in part because of atmospheric propagation effects. However, under nighttime conditions, good voice contact was established, providing early morning communication with the investigators at high latitudes.

For GALE, six real-time 36-hour MASS mesoscale forecasts were produced by using the Langley VPS-32 supercomputer (enhanced CDC® CYBER 205) to analyze winter storm development over the eastern United States. Selected MASS model graphics were transmitted in facsimile form to the GALE field headquarters in Raleigh, North Carolina. The DWIPS image system was also used to retransmit the GOES TAP facsimile broadcast to the GALE briefing room in Raleigh on a 24-hour basis over both commercial and FTS telephone links to provide GALE researchers with GOES images on a near-real-time basis.

Interactive real-time operations, such as the examples that are presented in this paper, improve data sampling strategies, increase the amount of expert personnel available for interaction between those at LaRC and those in the field, and, in general, enhance the probability for experimental mission success. By tailoring each meteorological data set to the field application, the total information volume can be reduced to a manageable number of video images and data files, allowing efficient communication over dial-up voice grade lines. Time delays for access to meteorological information are reduced, and sophisticated meteorological support techniques are made available in the field with minimal logistical impact.

Global Meteorological Data Facility (GMDF)

A global meteorological data management and analysis facility has been constructed at NASA LaRC to support aircraft and satellite-borne experiments such as the Measurement of Air Pollution from Satellites (MAPS) (Reichle et al., 1982), the Stratospheric Aerosol and Gas Experiment (SAGE) (McCormick et al., 1982), the volcanic aerosol surveys (McCormick et al., 1984), the Ultra-Violet Differential Absorption Lidar (UV-DIAL) (Browell et al., 1983), the Global Tropospheric Experiment (GTE) (McNeal et al., 1983), and the Earth Radiation Budget Experiment (ERBE) (Barkstrom, 1984). The GMDF provides economical access to satellite images and meteorological data on a global scale in real time with the provision for digital data archival.

The GMDF concept is shown schematically in figure 1. Satellite images are received at the base station from either the Washington GOES TAP, or directly from the GOES satellite with a digital mode AAA downlink. Digital and facsimile meteorological data and products are relayed to the GMDF by the Hughes Galaxy communication satellite using the Zephyr Weather Information Service, Inc. Weather data from the NOAA Family of Services (Friday, 1983) are received at the GMDF base station in Hampton, Virginia, and can be archived by use of a DEC PDP-11/73 minicomputer with 300-megabyte (MB) Winchester disk mass storage. The GMDF computer system is connected to the LaRC Local Area Network (LAN) and allows high-speed data transfers to local computer mainframes such as the LaRC VPS-32 or the ASD DEC VAX-11/780. The NASA Computer Network System (CNS) also allows high-speed transmission of ASCII files to mainframes at other locations such as NASA Ames Research Center, Moffett Field, California. Dial-in and dial-out capabilities are also available for access by or to external computer equipment at bit rates up to 9600 baud (Bd). For example, the NCAR Portable Area Mesonet (PAM) data can be accessed in real time to allow current meteorological parameters to be plotted on a graphics terminal (Corbet and Burghart, 1987). Since GMDF field communication concepts are based on voice grade facsimile transmissions, future upgrades in communications techniques such as INMARSAT UHF can be implemented.

Image Processor

The GMDF uses a standard IPS GOES image system with options including fast animation, data tablet graphics, and video freeze frame photography. The IPS GOES image system is a combination of two separate microprocessor systems known as the DWIPS and the Full Resolution Processor (FRP). The FRP ingests facsimile images from a GOES TAP or similar audio bandwidth line and automatically downloads all or part of these images to the DWIPS for real-time processing and display. The DWIPS stores a maximum of 120 8-bit images, 640 pixels by 480 lines each, on Winchester disk storage, and allows for user interactive operations such as image magnification, enhancement, and animation. Animation from disk allows loops of any length up to the disk capacity at 1 frame per second. Animation from fast image memory provides up to 27 frame loops at programmable rates up to 30 frames per second. A data tablet enables "graphic overlays" to be drawn freehand by the system operator. These overlays can be superimposed on images displayed by the system and allow the user to record analyses or comments directly on the images for subsequent storage or facsimile transmission. Textual overlay capability is also provided and enables keyboard entry of alphanumeric characters onto video image files for display and/or storage. A block diagram of the IPS GOES image system is shown in figure 2.

The DWIPS/FRP combination has the capability to receive and transmit standard GOES facsimile images in 12 min, or alternately to receive and transmit "Fast Fax" facsimile images in 90 sec. The Fast Fax capability transmits 480 lines with approximately a 640-pixel resolution at a 5.5-line sec scan rate. This 174 msec/line signal transmission is preceded by 2.176-msec white and 2.176-msec black sync pulses. A 3-sec duration 450-Hz tone (standard GOES TAP stop tone) is used to initiate Fast Fax signal reception. The Fast Fax start tone is followed by a 5-sec maximum carrier tone with no sync pulses for Automatic Gain Control (AGC) calibration. This fast image transmission is conducted by using standard AM modulation on a 2400-Hz carrier. However, the option is available for image transmissions using FM modulation (1500 to 2300 Hz).

The GOES TAP 120-line/min (lpm) facsimile broadcast provides selected views of the Western Hemisphere from the GOES satellite in the visible and infrared full disk water vapor images four times daily, and NOAA-9 polar orbiter composite views of selected regions on a global basis at least once per day. The GOES TAP also provides image sectors from the GMS and METEOSAT satellites at 240 lpm. The DWIPS automatically selects one of the 24 Washington SFSS GOES TAP channels by using programmable time commands to receive selected images on a predetermined basis. During the field operations discussed in this paper, the DWIPS was programmed to receive GOES full disk IR images every 3 hours and GOES water vapor images every 6 hours. Hourly east coast IR and visible views were obtained when no conflicts existed, and NOAA-9 composite and METEOSAT views were received when selected. The FRP digitizes the GOES TAP facsimile broadcast into 1920 pixel by 1440 line images with 8-bit resolution. The five latest image files are stored in the FRP and can be downloaded to the DWIPS with or without magnification or averaging. A 3-times magnification of the FRP file into a 640 pixel by 480 line image produces display resolutions which are close to the actual bandwidth of the GOES TAP transmission.

GOES Mode AAA Downlink

An economical GOES mode AAA downlink has been developed to enable reception of the stretched VISSR data stream in mode AAA format direct from a GOES satellite. A block diagram of the mode AAA downlink is shown in figure 3. VISSR data are received from a GOES satellite on the 1687.1-MHz carrier using a 3.8-m diameter antenna. The signal is amplified and down-converted to 70 MHz at the antenna for transmission over 30 m of RG8 coaxial cable to the downlink demodulator. The demodulator extracts the VISSR signal information and presents it to a bit synchronizer to derive serial clock and image data. These serial data signals are then processed by the frame synchronizer to provide image data in a parallel byte format for ingestion by the VISSR processor.

The VISSR processor is an IBM PC AT clone with 640 kilobytes of system memory, and additional memory and interface boards necessary to simultaneously ingest and store full resolution IR and partial resolution visible VISSR images every half hour. A visible sectorizer board determines the resolution and location of the visible sector while passing all the IR data through to the VISSR processor DMA control board. Two 4 megabyte memory boards store the IR and visible images as 1911 pixel by 1820 line files. The GOES satellite views may then be stored on the VISSR processor hard disk, output to magnetic tape at partial or full resolution, or sent to the GOES Image System for display and storage as 640 pixel by 480 line images. In addition to the normal output to the VISSR processor for image processing and display, a separate port from the frame synchronizer provides all VISSR information on an external port for connection to an external user interface. Data available on this external port include the full resolution and unsectorized visible data plus all auxiliary data blocks and complete line documentation data.

Visible Sectorizer

One GOES satellite spin produces output from eight visible sensors (15 288 6-bit pixels each) plus two infrared channel sensors (3822 10-bit pixels each). Because the infrared sensors overlay horizontally, the effective resolution across the line is approximately 1911 pixels, or one half the data rate. The IR data are, therefore, stored as a file 1911 pixels wide by 1820 lines long or about 3.5 MB. The visible sectorizer gives the user the option of downloading to DWIPS a high resolution sector (640 pixels by 480 lines by 8 bits) or an averaged full disk IR picture (637 pixels by 480 lines), which is similar to the existing DWIPS/FRP image scheme for full disk images from the GOES TAP. Since 15 288 pixels times 8 sensors/line times 1820 scan lines produces an image file over 220 MB in size, some practical yet versatile method of reduction needs to be available for reducing the visible data volume for GMDF operations. Therefore, the visible data are sectorized in a user-selected area to a user-specified resolution by sampling data points. The sectorizer hardware is based on a high-speed Motorola MC68000 processor, which also allows programming for user-supplied averaging algorithms "on the fly."

Four visible sector resolutions are available, corresponding to the GOES TAP full disk IR image or D sector, C sector, B sector, and A sector (Clark, 1983). Figure 4 shows the geographic coverage of these four user-selected sectors, and specifications for image sector construction are presented in table 1. For example, a B sector at 2-km resolution is normally created by sampling and storing every other horizontal scan point along a horizontal line scan of 3822 data points, providing 1911 pixels. In the vertical, only 455 of the 1820 full Earth scans and only four of the eight sensors are used in the sampling process. Choice of the geographic coverage is specified by the system operator using a movable window overlay on a monitor display of the full disk image to select the horizontal and vertical location for the A, B, and C sectors. The window position defines the hardware line and pixel counter setup values which are used by the sectorizer. Alternately, the hardware line counter setups may be preset under software control.

VISSR Processor

The VISSR processor ingests and stores GOES data from the frame synchronizer and visible sectorizer and downloads images to the DWIPS system for subsequent display and animation. The VISSR processor is based on an IBM PC AT bus system with an Intel 80286 CPU for high-speed data processing. By using this standard computer architecture, many low-cost, off-the-shelf devices and interfaces are available for user applications. In addition to the sectorized visible and full disk IR images, multispectral VAS data can be alternately ingested and processed.

The ingestion and storing of the VISSR data are performed under the 80286 CPU operating system as a task which is transparent to the user. User-supplied programs can be used in real time to access the image memories for image filtering and compression. The VISSR processor is supplied with a 112-MB fixed disk for data and program storage, and a standard $5\frac{1}{4}$-in. floppy disk drive compatible with IBM PC DOS for software transport. A controller board has been included for the archiving of images to standard IBM compatible magnetic tape drives such as the Cipher model F880 or M990. Software has been provided to allow scheduled downloading of images to magnetic tape. A serial port is also available to supply RS-232-C format data to an external computer at a user-determined baud rate up to 19 600 Bd. The maximum asynchonous data rate is 38 400 Bd. Synchronous data at up to 300 kilobits per second in SDLC protocol may be alternately programmed.

Meteorological Data

As shown in figure 5, the GMDF uses a DEC PDP-11/73 microprocessor to receive the NOAA Family of Services (Friday, 1983) in real time. These data are made available through the Zephyr Weather Information Service using a 3.7-m-diameter downlink from the Galaxy Communication Satellite. The signal from the 91 K low noise amplifier is routed to a downconverter over 30 m of low-loss 0.5-inch coaxial (foam) cable. The Wegener model 1606-10 downconverter subsequently routes the meteorological data streams to the appropriate devices or serial data ports for archival or display. The DIFAX meteorological chart service is distributed to several Alden DIFAX devices at LaRC. The DEC PDP-11/73 uses the DEC RSX-11M multiuser operating system to support data archival and general processing tasks in a real-time environment. The 1800-Bd asynchronous Domestic and International ASCII data channels are acquired line by line by independent background programs. These data are organized into hourly files with unique names which identify the date and time of reception. For example, data received between 1200 and 1300 universal time (u.t.) on August 30, 1986, would appear in the directory as 12Z30AUG86.DOM and 12Z30AUG86.INT for the Domestic and International channels, respectively. The data fields are purged of control characters and are stored in an as-is basis. Because of storage constraints, all Domestic and International data files are automatically purged from the temporary archive data buffer after 5 days. Conventional editors or user-generated programs are used after the data are acquired to scan or process the textual data. The GMDF uses a FORTRAN 77 program adapted from PROFS to decode and manipulate upper air data on a global basis. Decoded upper air data fields are then input to the Relational Information Management System (RIM, Version 7.0) on a VAX-11/780 computer. RIM allows users to recall all or part of the upper air data base using user friendly interactive commands.

Users access the meteorological data fields through an interactive MICOM network or through a file-oriented LAN. The LAN is an ethernet/token passing ring fiber optic network supporting ASCII and binary file transfers to and from supported computers at LaRC. A CDC CYBER 185 system provides access to the NASA CNS, allowing direct ASCII file transfers to remote computers such as the CRAY or VAX at NASA Ames Research Center. The asynchronous MICOM network allows direct user access to the PDP-11/73 with terminals connected either directly at LaRC, through Telenet, or by direct dial. MICOM also provides dial-out capabilities at rates up to 1200 Bd.

Use of Communication Satellite for Experimental Support

The Applications Technology Satellite (ATS-3) VHF transponders were used to achieve voice grade communications to ground field sites in both the Northern and Southern Hemispheres, and to an instrumented aircraft in flight. Figure 6 shows the communication coverage from ATS-3. The GMDF ATS-3 capability was used to contact field personnel during 1985 and 1986 in Manaus, Brazil, in Thule, Greenland, and in Belmont, California. In addition, radio contact was established with an instrumented Lockheed P3 (Orion) aircraft during the Greenland high-latitude flight in January 1986. Specifications for the GMDF ATS-3 radio instrumentation are given in table 2. The ground systems were operated at or near 2000 watts effective irradiated power (EIRP), close to the saturation limit of the ATS-3 VHF transponder capability. A Dorne and Margolin C-33 aircraft antenna was operated near 500 watts EIRP, the lower power due mainly to limitations of the 3-dB gain antenna and electromagnetic interference (EMI) restrictions imposed by other aircraft systems.

The GMDF ATS-3 radio communications field system is shown in figure 7. The KLM-manufactured transmit and receive antennas are shown in the background mounted 2 m apart on an extra strong nonconducting polyvinyl chloride (PVC) pipe. The antennas are connected to an RF Power Labs 180-watt linear amplifier and a Motorola MAXAR-80 15-watt radio using two 75-foot (23 m) RG8 coaxial cables. The IPS DWIPS (f) and FRP (g) GOES Image System were used to transmit and receive image facsimile broadcasts in 90 sec (Fast Fax) or 12 min (Slow Fax) transmissions. Examples of 480 line Fast Fax and 1440 line Slow Fax afternoon transmissions over ATS-3 during the period of greatest atmospheric interference are shown in figures 8(a) and 8(b), respectively. The FRP processor uses 3 pixel by 3 line averaging on the received Slow Fax signal to construct a 640 pixel by 480 line image, effectively reducing the transmission noise by a factor of 3.

ATS-3 VHF communications were generally fair during the transient flight to the Thule staging location, with periods of signal degradation encountered during daylight hours at LaRC. The times and locations for ATS-3 communications during the Arctic mission are given in table 3. The ground station at Thule, Greenland, achieved very good communications with LaRC during total darkness, but the communications were degraded or completely lost during and after twilight due either to solar-related ionospheric activity or satellite occultation. The ATS-3 capability was used for ground-based communications only during early morning hours when the satellite drifted north on its $\pm 12°$ latitudinal wobble. No evening tests were attempted. The aircraft system experienced variable signal quality at high latitudes, with excellent communications achieved only in total darkness. The low-gain aircraft system also displayed sensitivity to aircraft heading and bank during flight tests over Maryland in January 1986. The Dorne and Margolin C-33 aircraft antenna was mounted in the P3 (Orion) aircraft at station 420, 10.7 m (35 ft) aft of the aircraft nose. The rack-mounted radio system shown in figure 7 was located at station 860, with 40 ft (12 m) of RG8 coaxial cable running through the aircraft to the antenna. No significant EMI was measured on any aircraft system during these tests. Our flight tests of the ATS-3 equipment were assisted by Jim Lewis in Schenectady, New York, and by Paul Eden in Melbourne, Florida. Lewis and Eden provided "phone patch" contact to the lower power aircraft radio system at times when direct communications to LaRC were not possible.

Example of GMDF Usage To Support a Field Experiment

The MASS mesoscale model was operated in real time to investigate the effectiveness of mesoscale support during experimental field operations in conjunction with the Genesis of Atlantic Lows Experiments project (GALE Project Office, 1985) based in Raleigh, North Carolina. The MASS mesoscale model was run in real time on the LaRC VPS-32 to provide six 36-hour forecasts over North America at 50 km spatial resolution with 14 vertical levels. Given initialization data bases at 0000 and 1200 u.t., the model was usually started after a delay of 5 to 8 hours. The model ran for approximately 1 hour, and forecast digital fields were available for post-processing 6 to 9 hours after normal model initialization time. Rapid transmission of model graphics to the GALE field site at the GALE forecast office was accomplished by using the DWIPS GOES Image System. The mesoscale forecast fields were drawn interactively on a Tektronix model 4554 graphics terminal at LaRC, and a DWIPS image was then obtained by using high resolution freeze frame video photography. After Fast Fax transmission to the field site over a commercial phone link, the transmitted graphic images were stored at the field site for real-time playback and animation. MASS model products were plotted at 3-hour intervals over the 36-hour forecast period and were chosen in real time from the following graphic options:

1. Total precipitation over 3 hours
2. Convective precipitation (as opposed to stratiform)
3. Mean sea level pressure with level 1 temperature
4. Level 1 pressure change with winds
5. 850-millibar height with winds
6. 850-millibar pressure change over 3 hours
7. 500-millibar temperatures with 3-hour height change
8. 500-millibar temperatures and heights with vorticity
9. 300-millibar temperatures with winds
10. 300-millibar pressure change over 3 hours

MASS model run initialization times and actual time delays encountered during real-time operations are listed in table 4. The best run time on January 25, 1986, represents optimal operation of all facilities.

These MASS model runs were initialized with the NMC analysis for North America and available rawinsonde information. This initialization data base was obtained from the Bureau of Reclamation in Denver, Colorado, with a CDC 200 user terminal protocol at 4800 Bd synchronous. The initialization data base was typically available by 1130 e.s.t. (1630 u.t.). The NMC analysis was then reformatted and revised to reintroduce shorter-wavelength features from the rawinsonde data (Kocin et al., 1985). The time delays to model output shown in table 4 were due to various problems in acquisition of the initialization data base and availability of the LaRC VPS-32 computer.

The January 18, 1986, 12 u.t. model output was used by Ron Smith from Yale University (personal communication, 1986) to assist the deployment of his Sabreliner-based experiment into the exit region of the jet stream at 300 mb on January 19. McIDAS-based forecasters used historical data analyses and nowcasting techniques at 2000 e.s.t. on January 18, 1986, to project jet positions over southern Alabama and the Gulf of Mexico. However, the MASS model correctly positioned the jet exit region wind maximum over Tennessee and Kentucky at 0600 u.t. on January 19, 1986. The MASS 300-millibar wind forecast in real time was verified using in situ winds measured in transit to the Nashville airport. Subsequently, Smith used the same 300-millibar wind forecast in flight to select the radial from Nashville airport which would provide the greatest sampling opportunities with excellent results. The MASS 300-millibar wind forecast for 0600 u.t. on January 19, 1986, is shown in figure 9.

Concluding Remarks

The GMDF concept enhanced field experiment operations for the experiments discussed in this paper. The greatest benefit arose from the ability to communicate with field personnel in real time. The ATS-3 VHF radio capability provided a transmission path for images and voice communications to ground stations and a mobile platform in remote areas, allowing for the rapid exchange of information on atmospheric state and experiment needs. A good example of such a benefit is the repair of a Gould computer at a remote location near Manaus, Brazil, using an ATS-3 phone patch to connect experimenters with the manufacturer. Experiment flight planning required access to updated satellite imagery during both the ABLE/2A and GALE programs. The GMDF supplied this information with satellite image animation at the field station in near real time at low cost and with a nominal amount of equipment in the field.

These field experiments used the GMDF primarily for experiment support using one-way (base-to-field) transmission of meteorological information. The GMDF concept enables interactive operations as well, allowing the use of field-generated information to modify model projections or meteorological analyses in real time. Attempts to achieve such an interactive experiment (such as the GTE flight mission to Bermuda in August 1982) have not yet been successful, with failure due mainly to an inability to communicate. However, the timely exchange of relevant meteorological information has led to improvements in flight mission planning and data acquisition, reducing the amount and number of resources expended in the acquisition of unwanted data. Given the ever-increasing expense of field operations, a centralized and interactive real-time meteorological support facility such as the GMDF can provide invaluable assistance to the management of scarce experimental resources.

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Table 1. Visible Image Sectors (Sampling of Ingested VISSR Visible Image Data)

Sample size	Image resolution, km	Vertical sampling (1820 lines)		Horizontal sampling (1911 pixels/line)		
		Vertical scans represented in sample	Sensors used in sampling	Portion of 15 288-point horizontal scan used in sampling	Horizontal scan points used in sampling	Resulting 1911 points derived from sampling—
D Sector complete FD	8	1820	1 of 8	All	15 288	Every 8th scan point
C Sector 1/4 FD	4	910	2 of 8	1/2	7644	Every 4th scan point
B Sector 1/16 FD	2	455	4 of 8	1/4	3822	Every other scan point
A Sector 1/64 FD	1	277	All 8	1/8	1911	Every scan point

Table 2. ATS-3 VHF Radio Instrumentation for Ground- and Aircraft-Based Stations

ATS-3 satellite:
- Position . . . . . . 105°W, $\leq \pm 12°$ latitude
- Transponder . . . . . . Channel 2, VHF
- Frequency:
  - Up . . . . . . 149.195 MHz
  - Down . . . . . . 135.575 MHz
- Maximum power . . . . . . Approx. 2000 watts EIRP

Ground system:
- Antenna:
  - Receive . . . . . . KLM manufactured
  - Transmit . . . . . . KLM manufactured
- Antenna gain . . . . . . 11 dB
- Preamp gain . . . . . . 10 dB and 24 dB
- Radio . . . . . . Motorola 15-watt MAXAR-80
- Linear amplifier . . . . . . RF Power Labs
- Transmit power . . . . . . 180 watts
- Effective radiated power . . . . . . 2000 watts

Aircraft system:
- Antenna . . . . . . Dorne & Margolin C-33
- Antenna gain . . . . . . 3 dB
- Preamp gain . . . . . . 10 dB
- Radio . . . . . . Motorola 15-watt MAXAR-80
- Linear amplifier . . . . . . TPL model 2002
- Transmit power . . . . . . 220 watts
- Effective radiated power . . . . . . 500 watts

Table 3. ATS-3 Communications During SAGE II/SAM II Polar Intercomparison Mission

Date	Location	Antenna	Time, e.s.t.	Comments
Oct. 30, 1985	WFC	D&M[a] ground test	1100	Good contact with Jim Lewis
Nov. 20, 1985	WFC	D&M ground test	1100	Poor contact, snowing
Jan. 2, 1986	SBY	D&M airborne	1145 to 1300	Marginal[b] contact with Paul Eden
Jan. 6, 1986	41°N, 75°W	D&M airborne	1400	Good
Jan. 8, 1986	42°N, 61°W	D&M airborne	0500–0540	Good, rapidly degrades at 0540 e.s.t.
Jan. 9, 1986	45°N, 65°W	D&M ground	0450–0530	Good
Jan. 10, 1986	66°N, 74°W	D&M airborne	0800–1030	Good on ground, intermittently fair to poor in flight
Jan. 12, 1986	73°N, 68°W	KLM ground	0500–0800	Very good, rapidly degrades at 0800 e.s.t.
Jan. 14, 1986	73°N, 68°W	KLM ground	0720–0800	Fair, rapidly degrades at 0800 e.s.t.

[a]Dorne and Margolin C-33 VHF aircraft antenna.
[b]Signal varies with aircraft heading and bank.

Table 4. Mass Mesoscale Model Forecasts for GALE

Run	Date	Initialization time, u.t.	Available time, e.s.t.	Time delay, hr
1	Jan. 18, 1986	1200	1455	8.0
2	Jan. 24, 1986	1200	1429	7.5
3	Jan. 25, 1986	1200	1315	6.3
4	Feb. 10, 1986	1200	1403	7.0
5	Feb. 14, 1986	0000	1127	16.5
6	Feb. 26, 1986	1200	1631	9.5

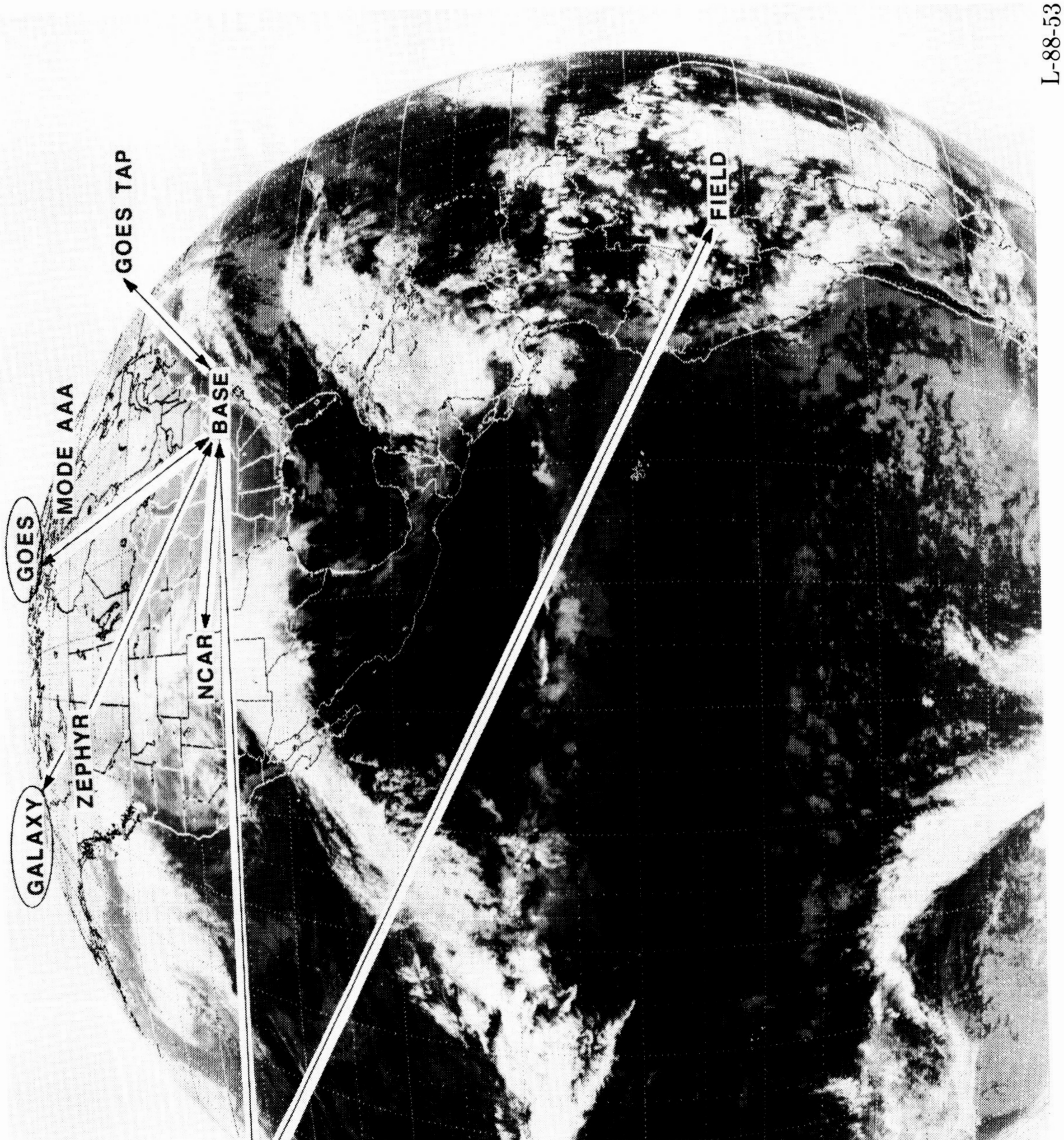

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Figure 1. Schematic for GMDF showing data paths. Raw meteorological data and Earth images are received via Hughes Galaxy communication satellite, GOES mode AAA, and from GOES TAP. Field communications use conventional phone links or ATS-3 VHF transponders.

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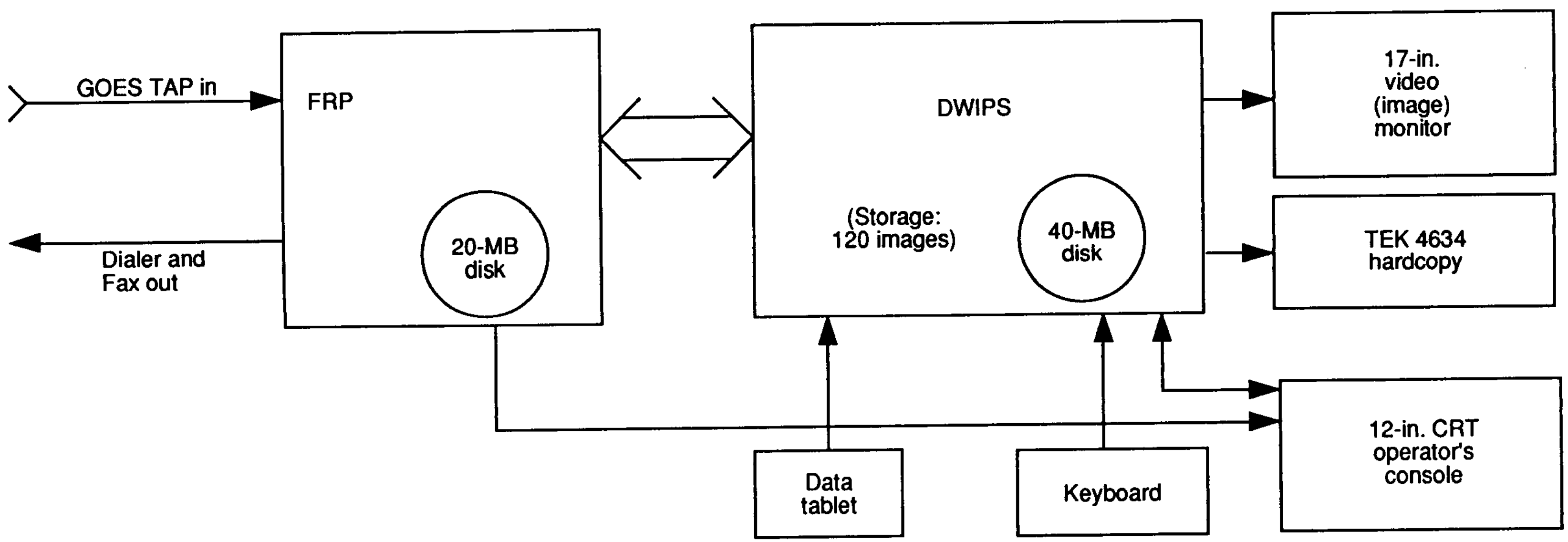


Figure 2. IPS GOES image system showing data paths for image and operator control information. GOES TAP is digitized and stored by Full Resolution Processor (FRP) for later use by Digital Weather Image Processing System (DWIPS). Alternately, digital image data are downloaded directly to DWIPS from a GOES mode AAA downlink.

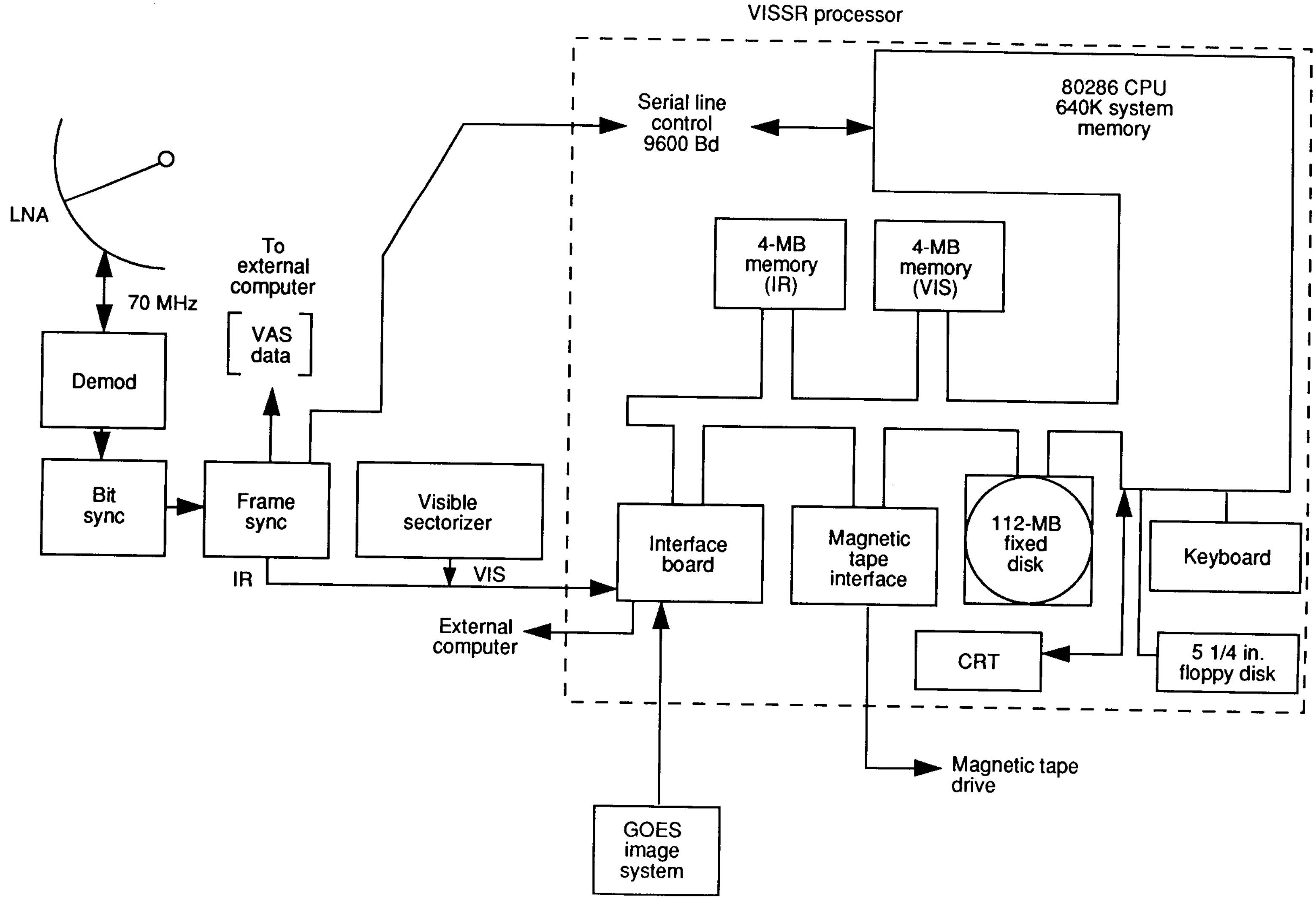
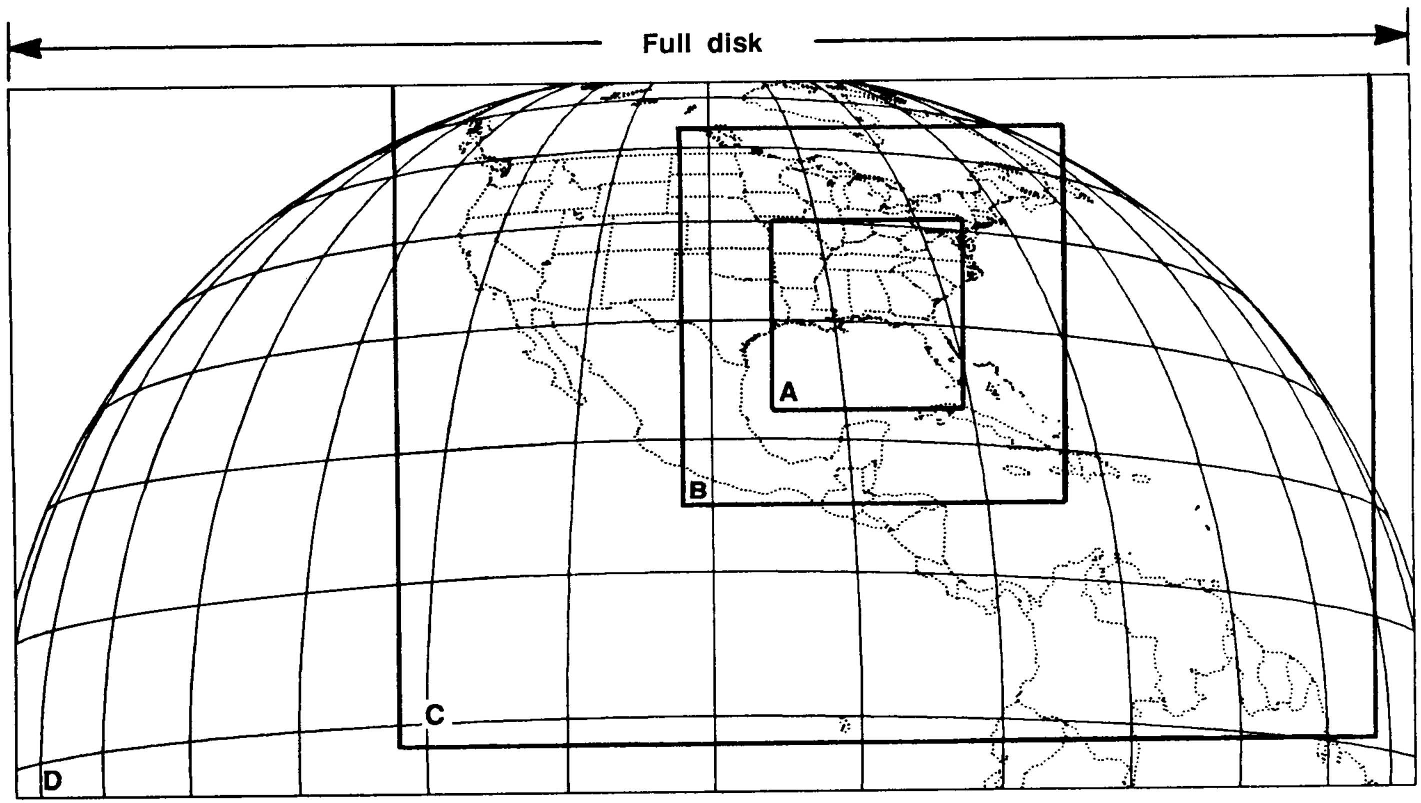


Figure 3. Schematic for IPS mode AAA GOES downlink. Visible and infrared images are stored at full or partial resolution in 4-megabyte files. Image processing can be performed "on the fly" by the Motorola MC68000 based visible sectorizer.



A 1/2 mile resolution, approximately 1000 miles square

B 1 mile resolution, approximately 2000 miles square

C 2 miles resolution, approximately 4000 miles square

D Full disk IR, 4 miles resolution, 8000-mile or full disk diameter

Figure 4. Resolutions and geographical coverage for visible sectors: A (1 km), B (2 km), C (4 km), and full disk D (8 km).

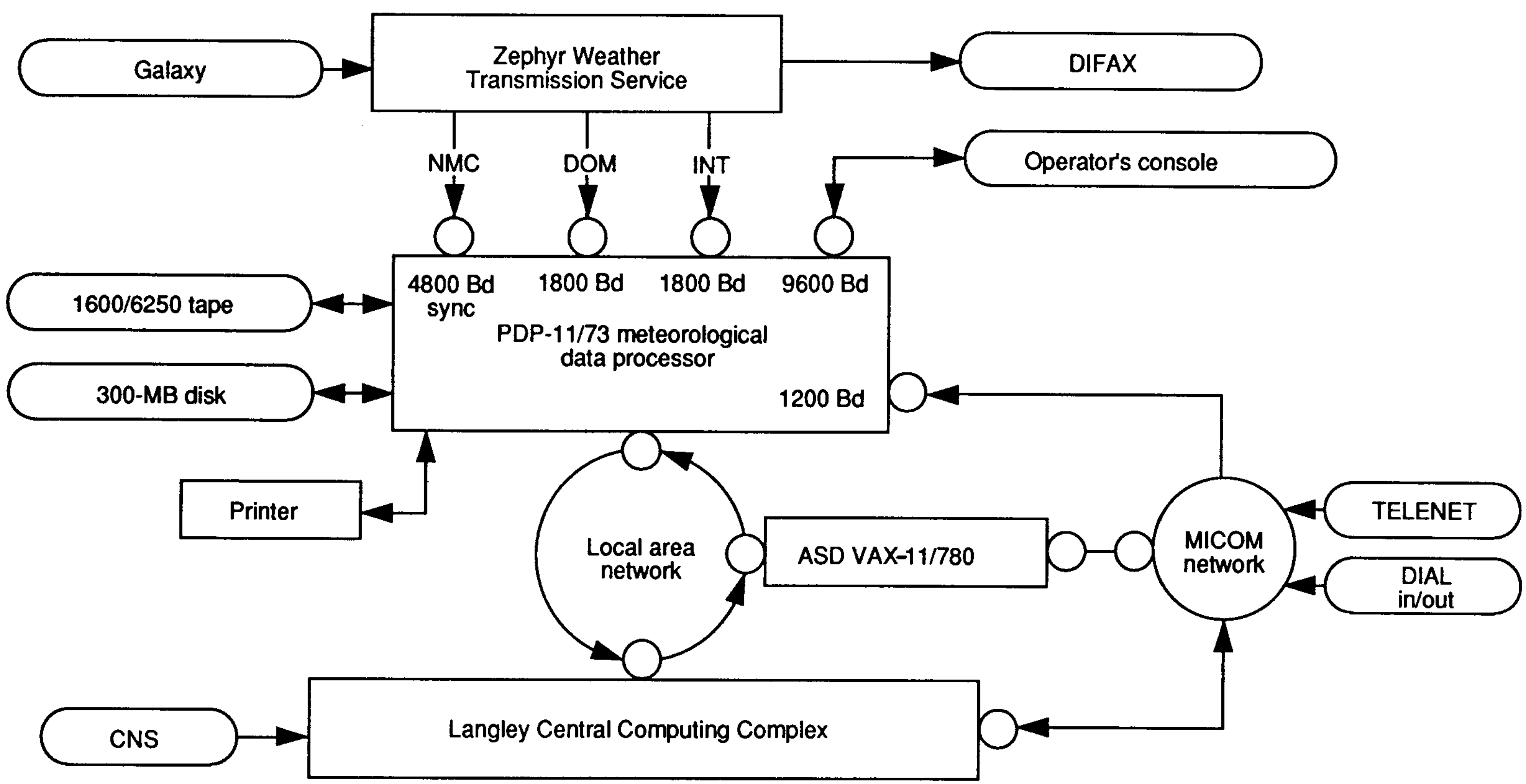


Figure 5. Data flow for the Zephyr downlink from Galaxy and meteorological data processor. Meteorological data are available over 3 lines: NMC products at 4800 baud synchronous and Domestic and International data at 1800 baud asynchronous. External equipment can be connected through MICOM (interactive) or through the LAN and CNS file-oriented networks.

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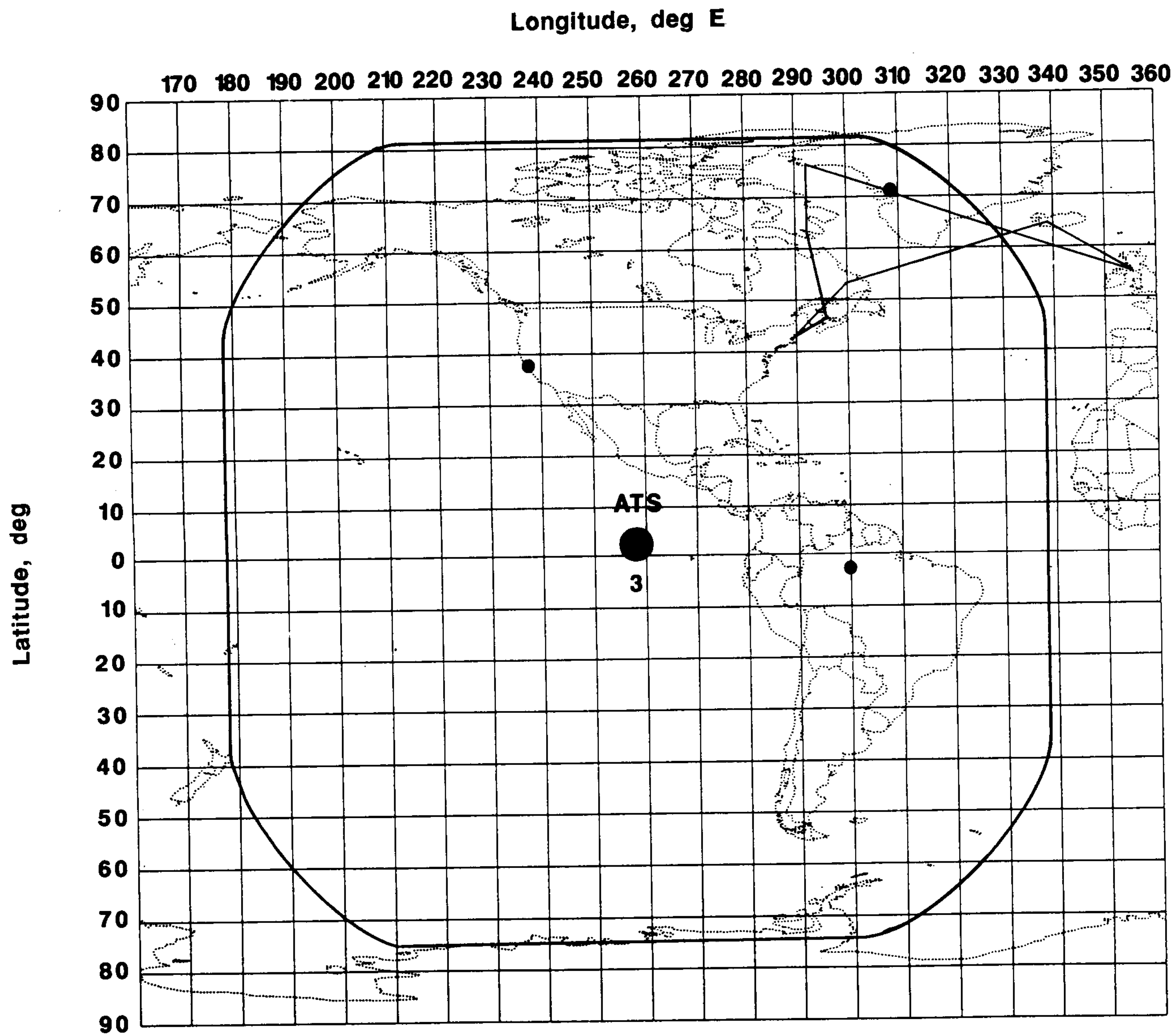

Figure 6. ATS-3 VHF radio coverage, showing positions of GMDF ground stations and the Lockheed P3 (Orion) airplane flight track.

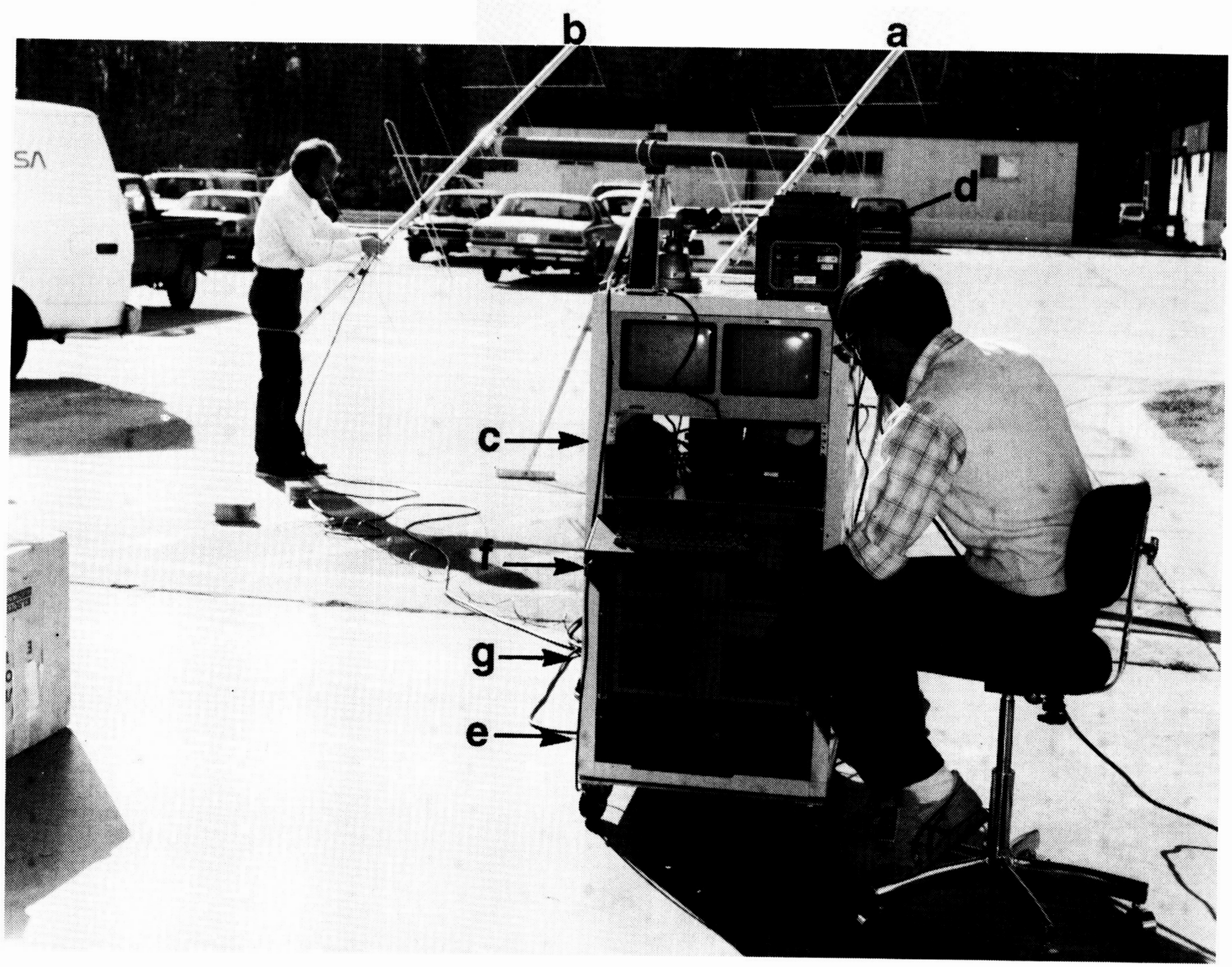

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Figure 7. GMDF field station in operation with the KLM ground transmit (a) and receive (b) antennas. The Motorola MAXAR-80 radio system (c) is shown with the RF Power Labs (d) and TPL (e) linear amplifiers. The IPS GOES Image System is included in the aircraft rack mounting, including the DWIPS (f) and FRP (g).

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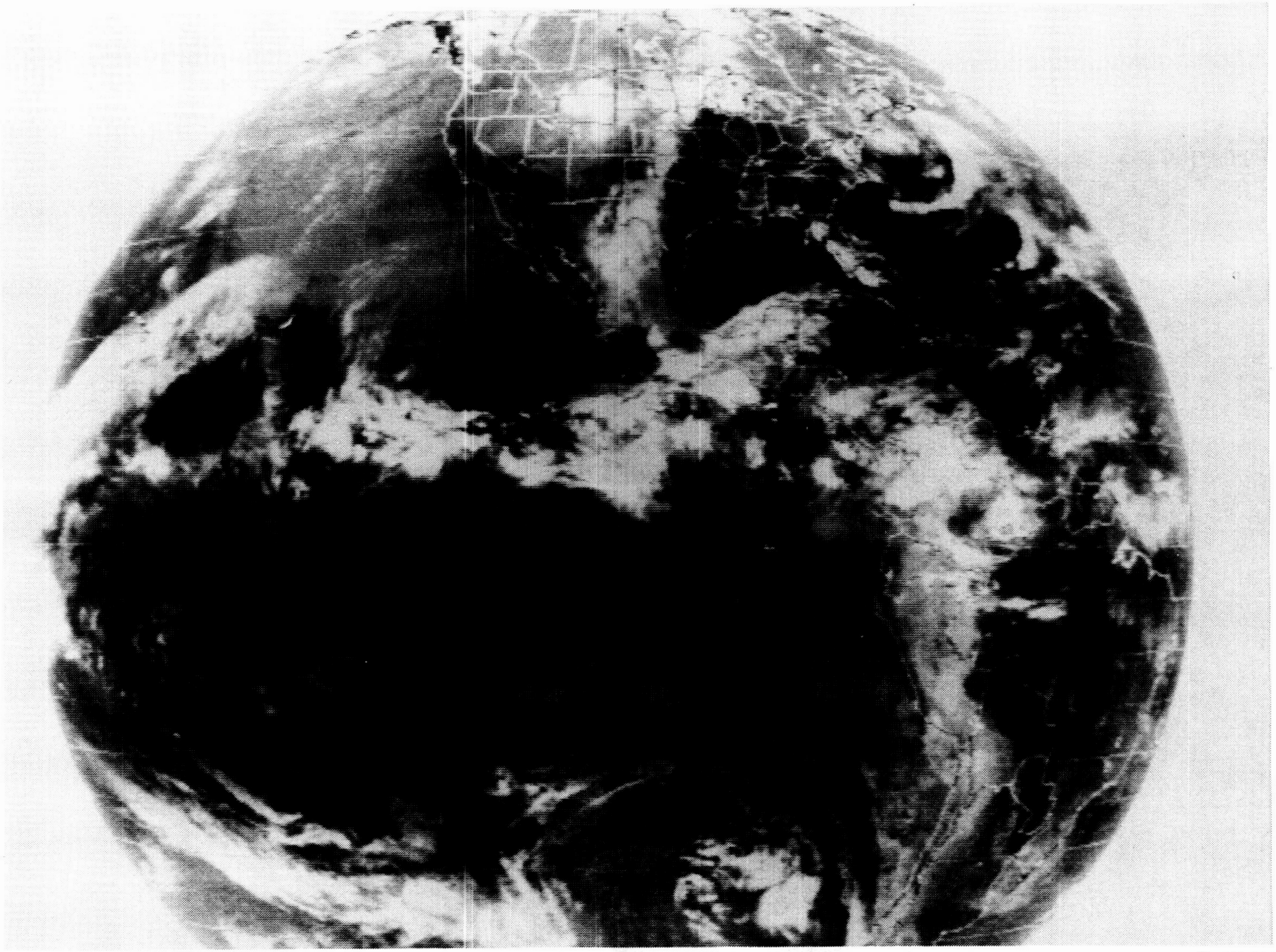

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(a) Fast Fax received in 90 sec at 1530 u.t.

Figure 8. Image transmission received on June 25, 1985, using the ATS-3 ground system.

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(b) Slow Fax received in 12 min at 1545 u.t.

Figure 8. Concluded.

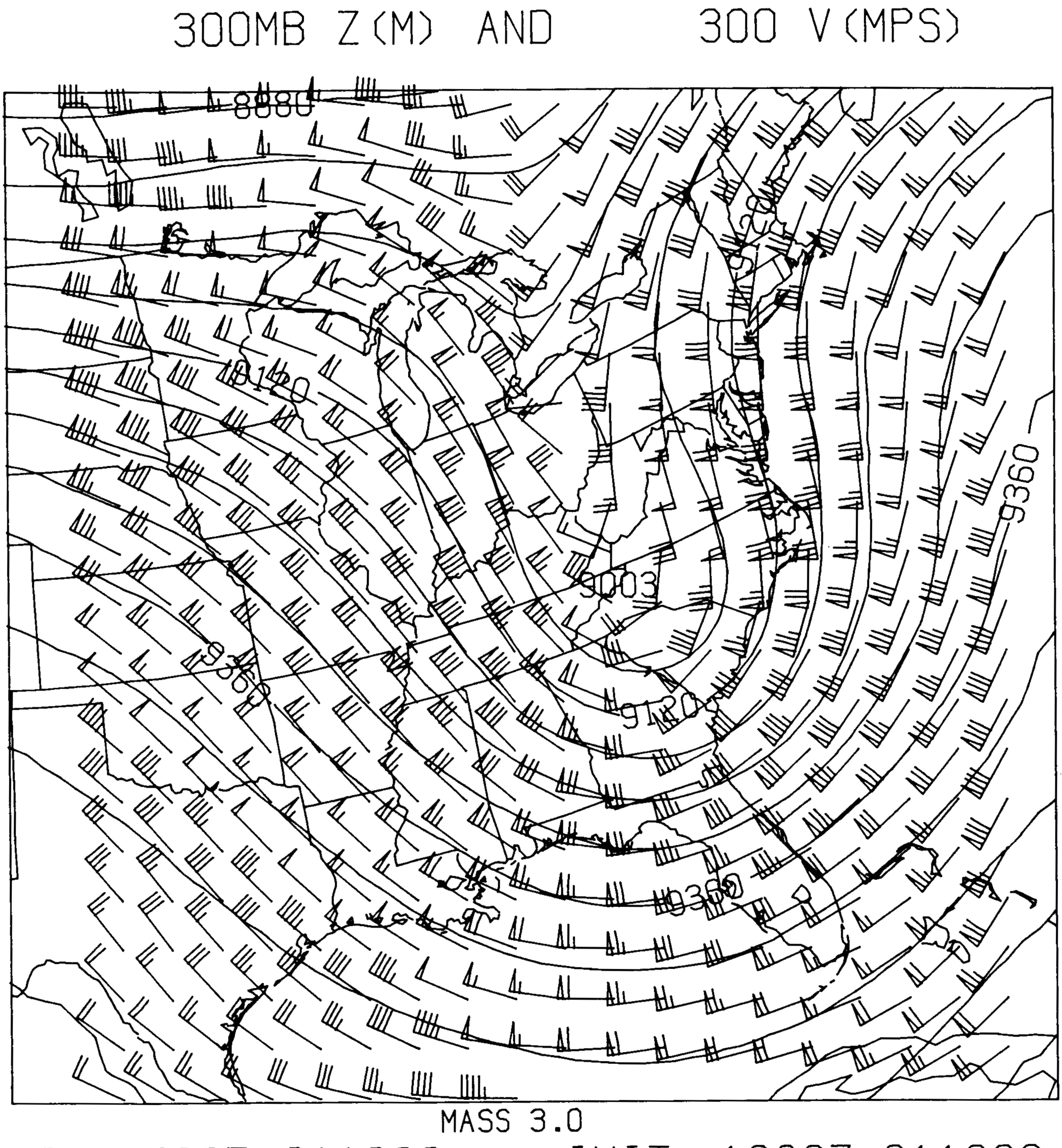

Figure 9. Real-time MASS mesoscale model output for 300-millibar winds and heights at 0600 u.t. on January 19, 1986, initialized at 1200 u.t. on January 18.

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15. Supplementary Notes

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16. Abstract

A Global Meteorological Data Facility (GMDF) has been constructed to provide economical real-time meteorological support to atmospheric field experiments. After collection and analysis of meteorological data sets at a central station, tailored meteorological products are transmitted to experiment field sites using conventional ground link or satellite communication techniques. The GMDF supported the Global Tropospheric Experiment Amazon Boundary Layer Experiment (GTE-ABLE II) based in Manaus, Brazil, during July and August 1985; an Arctic airborne lidar survey mission for the Polar Stratospheric Clouds (PSC) experiment during January 1986; and the Genesis of Atlantic Lows Experiment (GALE) during January, February, and March 1986. The GMDF structure is similar to the UNIDATA concept, including meteorological data from the Zephyr Weather Transmission Service, a mode AAA GOES downlink, and dedicated processors for image manipulation, transmission, and display. The GMDF improved field experiment operations in general, with the greatest benefits arising from the ability to communicate with field personnel in real time.

17. Key Words (Suggested by Authors(s))	18. Distribution Statement
ABLE—Amazon Boundary Layer Experiment DWIPS—Digital Weather Image Processing System FRP—Full Resolution Processor GMDF—Global Meteorological Data Facility GTE—Global Tropospheric Experiment	Unclassified—Unlimited Subject Category 47

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