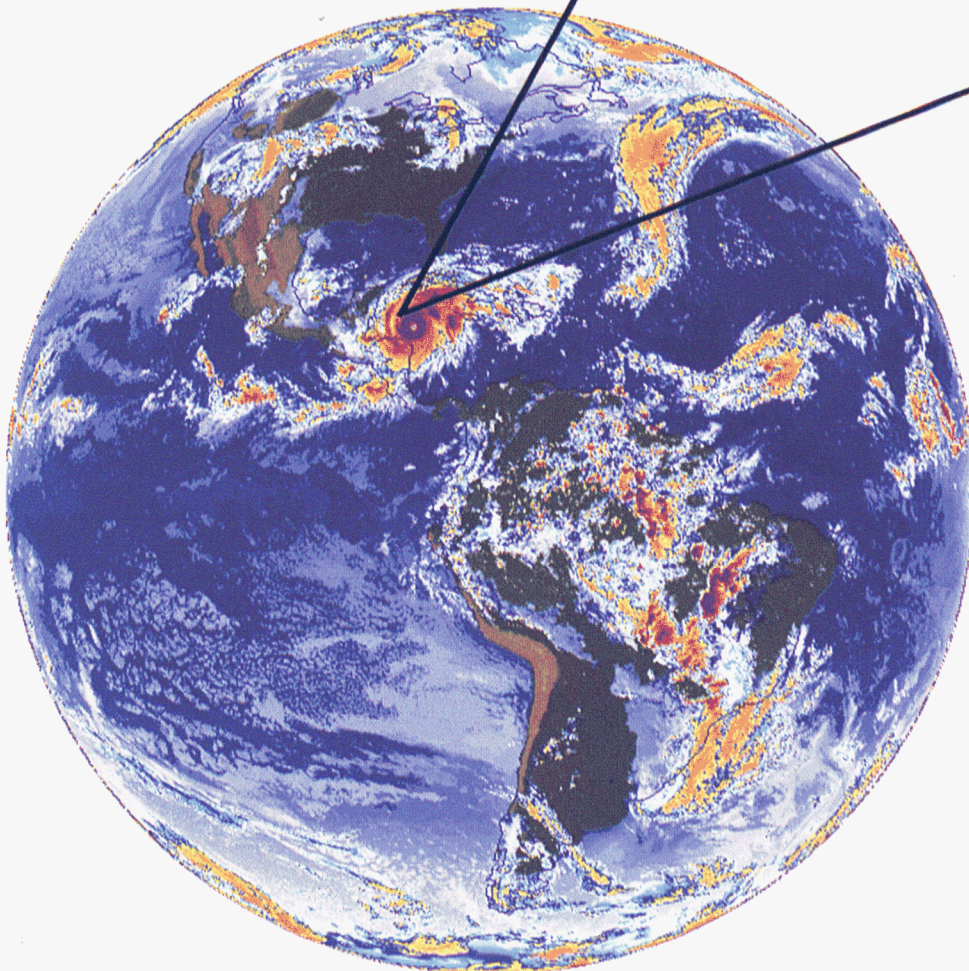
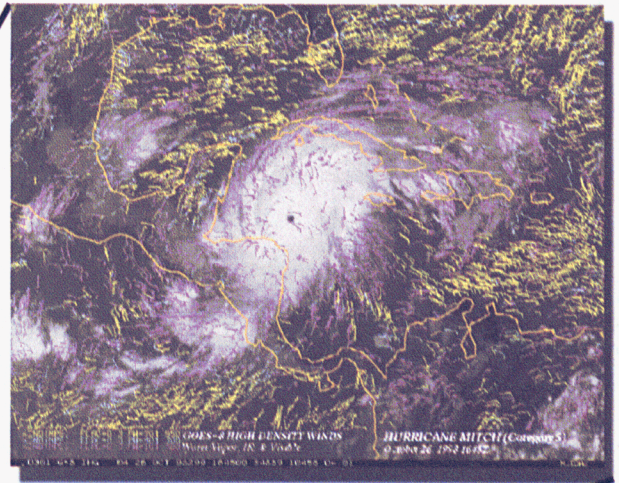


QC
875.2
.G64
2nd ed.
1999

GOES DUCTS AND SERVICES CATALOG



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Front Cover

Full disk visible imagery from GOES-8. GOES-8 sector with high density wind product from GOES-8 over and in the vicinity of Hurricane Mitch at 1645 UTC on October 26, 1998 when it was a Category 5 hurricane. High level (100-400mb) wind vectors are in red, mid-level (401-700 hPa) wind vectors are in blue, and low level (701-1000 hPa) wind vectors are in yellow.

GOES
PRODUCTS AND SERVICES
CATALOG
(Second Edition)

Frances C. Holt
NOAA/NESDIS/ARAD
Camp Springs, MD 20746

and

Steven R. Olson
Research and Data Systems Corp.
Greenbelt, MD 20770-3211

Contributors: NESDIS

Steve Arnett	John Paquette
Tom Baldwin	Elaine Prins
Jamie Daniels	Rod Scofield
Gary Ellrod	Timothy Schmit
George Hughes	Dan Tarpley
Otto Karst	Marcia Weak
Elaine Maturi	Michael Weinreb
W. Paul Menzel	

NWS

John Janowiak
Howard J. Singer
David M. Speich

CIMSS, Madison, WI 53706

Steve Nieman
Fred Wu

SSAI, Lanham, MD 20706

Dennis Pepe

Washington, D.C.

June 1999



U.S. DEPARTMENT OF COMMERCE

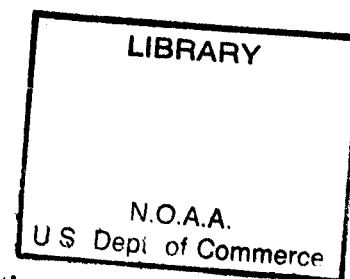
William M. Daley, Secretary

National Oceanic and Atmospheric Administration

D. James Baker, Under Secretary

National Environmental Satellite, Data, and Information Service

Gregory W. Withee, Assistant Administrator



National Oceanic and Atmospheric Administration TIROS Satellites and Satellite Meteorology

ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been a co-operative project between the NOAA Central Library and the Climate Database Modernization Program, National Climate Data Center (NCDC). To view the original document contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x124 or Library.Reference@noaa.gov.

HOV Services
Imaging Contractor
12200 Kiln Court
Beltsville, MD 20704-1387
January 26, 2009

TABLE OF CONTENTS

	Page
I. Introduction	1
II. Data Acquisition and Processing	3
III. Using This Data Product Catalog	8
IV. Data Availability	8
A. Real-time Imagery Products	8
B. Retrospective Image Products	8
V. Imager Products	9
A. Real-time Remapped Imagery	9
B. Weather Facsimile (WEFAX) Imagery	11
C. Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite Demonstration and Information System (RAMSDIS)	14
VI. Imager Atmospheric Parameters	16
A. Winds	16
Low Level Winds (Picture Triplet)	16
High-Density Winds (Low, mid and high levels)	18
Low-level High Density Visible Winds (Experimental)	27
B. Clouds	29
Imager Based Satellite Cloud Product (Experimental)	29
C. Precipitation	33
Interactive Flash Flood Analyzer (IFFA)	33
AutoEstimator (Experimental)	39
Multichannel Precipitation (Experimental)	41
Precipitation Index Histograms	43

D. Northern Hemisphere Snow and Ice Chart	46
E. Tropical Cyclone Position and Intensity Estimates	49
F. Volcanos	54
Volcano Ash Advisory Statements	54
Volcano Ash Product (Experimental)	57
G. Aviation	59
Fog (Experimental)	59
Aircraft Icing (Experimental)	61
H. Fire, Smoke and Aerosol	63
Reflectivity (Experimental)	63
Automated Biomass Burning Algorithm (Experimental)	66
Automated Smoke/Aerosol Detection Algorithm (Experimental)	70
I. Global Energy and Water-Cycle Experiment (GEWEX)	73
Radiance	73
VII. Sounder Atmospheric Parameters	75
A. Channel Brightness Temperature	75
B. Atmospheric Measurements	80
Vertical Temperature and Moisture Profiles	82
Layer Precipitable Water	83
Geopotential Heights	85
Thermal Wind Profiles	87
WINDEX (Experimental)	89
Sounder-Based Winds	91
Satellite Cloud Product	93
VIII. Derived Product Imagery	100
A. Lifted Index	100
Imager	100
Sounder (Experimental)	102
B. Total Precipitable Water	104
Imager	104
Sounder (Experimental)	106

VIII.	Derived Product Imagery (Cont'd)	108
	C. Surface Skin Temperature	108
	Imager	108
	Sounder (Experimental)	110
	D. Cloud Top Pressure	112
	E. Effective Cloud Amount (Experimental)	114
	F. Sea Surface Temperature (Experimental)	116
IX.	Imager and Sounder Calibration	119
X.	GOES Calibration Data Base	122
XI.	Product Archive	123
XII.	Space Environment Monitor	125
	A. GOES SEM Instruments	125
	B. System Effects, Customers, and Data Utility	127
	C. Operational Products and Services	129
	Alerts/Warnings	129
	Daily Products	129
	Weekly Publication	133
	International URISgram and World Days Service	134
	Specialized Services	134
	Outside User Systems	134
XIII.	Data Collection System	136
XIV.	Search and Rescue	139

XV.	Summary	142
	A. Web Sites	142
	B. Technical Information	144
XVI.	Acknowledgements	145
XVII.	Acronym List	146

GOES PRODUCTS AND SERVICES CATALOG (Second Edition)

Frances C. Holt and Steven R. Olson

ABSTRACT. This catalog describes the current products and services available from the National Environmental Satellite, Data, and Information Service (NESDIS) from the Geostationary Operational Environmental Satellite (GOES) satellites. It updates the GOES Products and Services Catalog published in 1996, and is also a partial update of *NESS TM 109: National Environmental Satellite Service Catalog of Products, Third Edition*. A product or service is defined as any item routinely produced. An example of each product along with a short description of the elements or processing steps, frequency, accuracy, and availability are presented. References to technical documents providing more details or scientific algorithms are also included.

I. INTRODUCTION

On April 13, 1994, the National Oceanic and Atmospheric Administration (NOAA) launched the first in the series of new GOES I-M satellites, GOES-8. Nearly a year later, GOES-9 was launched. GOES-10 was launched April 25, 1997, and became the operational West satellite on July 9, 1998 due to the imminent failure of GOES-9. GOES-L (GOES-11) is scheduled for launch in the spring of 1999. Previous geostationary satellites (GOES 1-7) were spin stabilized spacecraft; the GOES I-M satellites are three-axis stabilized spacecraft (Figure 1). This design provides improvements in the data availability and resolution. Most notable are the independent image and sounding operations, multispectral imaging with improved resolution, more accurate atmospheric sounding, and more frequent imaging (Menzel and Purdom, 1994 and Ellrod et al. 1998).

Since the launch of the first GOES in 1975, the Visible and Infrared Spin Scan Radiometer (VISSR) instrument has provided a wealth of data that has expanded our understanding of the atmosphere and improved forecasting on all scales. In 1981, more spectral bands were added to the VISSR instrument. The resulting VISSR Atmospheric Sounder (VAS) was designed to provide more details of the vertical structure of the atmosphere. The new VAS was first flown on the GOES-4 satellite in 1980.

VAS demonstrated the potential for atmospheric sounding from geostationary altitudes. However, the spin stabilized satellites were limited in that they could not image and sound at the same time. GOES-8/9/10 carry independent imaging and sounding subsystems as well as six additional sounding channels. Other improvements on GOES-8/9/10 include better resolution in the water vapor (WV) and infrared (IR) imagery and the addition of a shortwave IR channel and a split window channel. GOES-8/9/10 imager channels are shown in Table 1. Table 2 shows the sounder channels on these spacecraft. The back cover shows sounder data in image form.

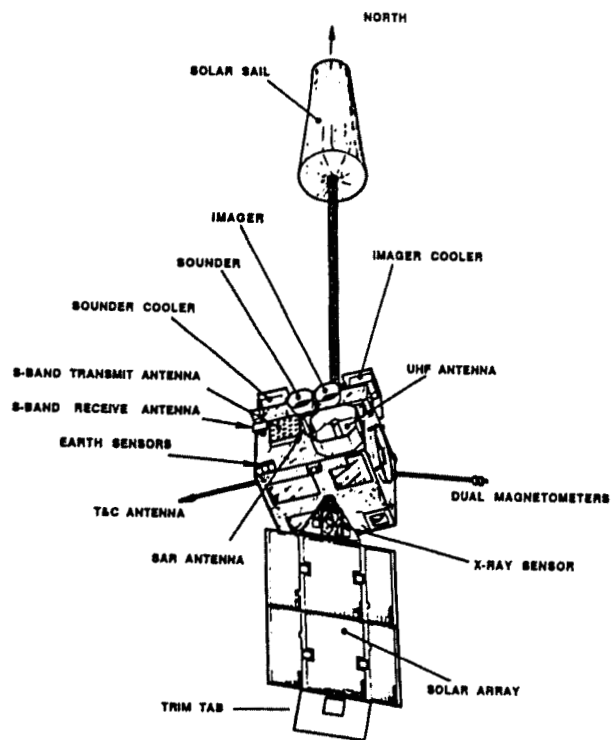


Figure 1. GOES I-M Spacecraft.

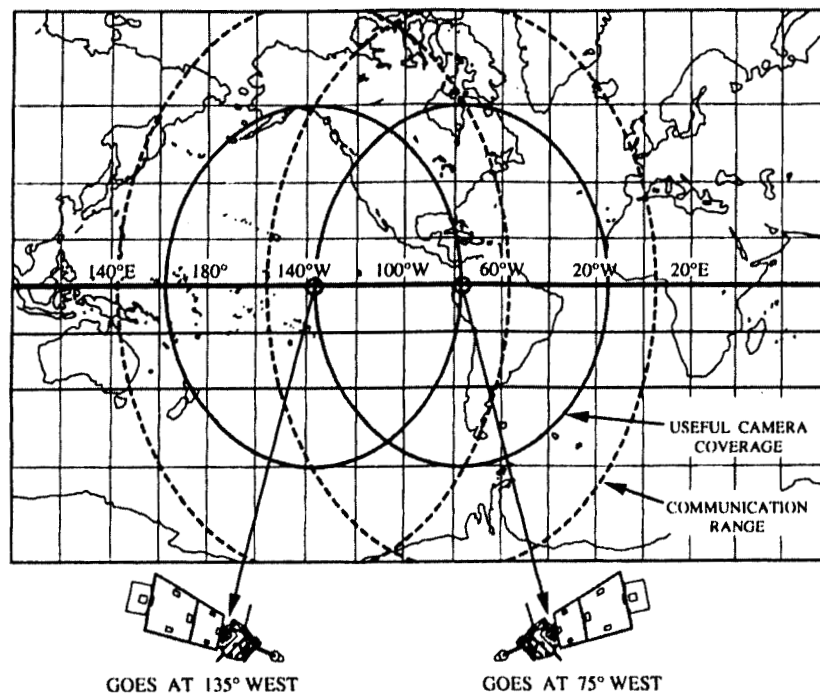


Figure 2. Data coverage of GOES East and West spacecraft.

TABLE 1. GOES-8/9/10 SATELLITE IMAGING CHANNELS

GOES-8/9/10		
Channel	Wavelength (μm)	Nominal Resolution (km)
Visible	0.55 - 0.75	1
Middle-IR	3.80 - 4.0	4
Infrared	6.50 - 7.0	8
Infrared	10.20 - 11.2	4
Infrared	11.50 - 12.5	4

The body-stabilized design that allows the satellite detectors to be continuously facing the Earth provides more flexibility in scan scenarios. Areal coverage of GOES-East at 75° W and GOES-West at 135° W is shown in Figure 2. Routine imagery of the continental U.S. is taken at 15 minute intervals compared to the half hourly intervals available from GOES-7. The new satellites have the capability to scan portions of the Earth at more frequent intervals (e.g., seven, five, and one minute intervals) to support NOAA's warning programs and special research projects.

These spacecraft also carry a Data Collection System (DCS) (Nestlebush, 1994); weather facsimile (WEFAX) transponders; Search and Rescue broadcast monitoring; and a Space Environment Monitoring (SEM) package. The SEM package includes an Energetic Particles Sensor (EPS); High Energy Proton and Alpha Particle Detector (HEPAD), X-ray Sensor (XRS) and magnetometers.

II. DATA ACQUISITION AND PROCESSING

The ground system processing of the new GOES data is far more complex than that employed in the earlier spin-stabilized generation of geostationary satellites. Internal momentum wheels provide the three axis attitude control system for the GOES I-M satellites. Corrective action to compensate for thermal gradients, solar winds, and radiance gradients is required by ground controllers. A new ground system was developed for the GOES I-M satellites to assure navigation, registration, and accuracy of the data. It is composed of two major systems: Spacecraft Support and Product Generation and Distribution (Figure 3).

TABLE 2. GOES-8/10 SOUNDING CHANNELS

Channel	GOES-8/10 Wavelength (μm)	Band
1	14.7	Carbon Dioxide
2	14.4	Carbon Dioxide
3	14.1	Carbon Dioxide
4	13.9	Carbon Dioxide
5	13.4	Carbon Dioxide
6	12.7	Water Vapor
7	12.0	Window
8	11.0	Window
9	9.7	Ozone
10	7.5	Water Vapor
11	7.0	Water Vapor
12	6.5	Water Vapor
13	4.6	Carbon Dioxide
14	4.5	Carbon Dioxide
15	4.4	Carbon Dioxide
16	4.1	Nitrogen
17	3.9	Window
18	3.7	Window
19	0.9	Visible

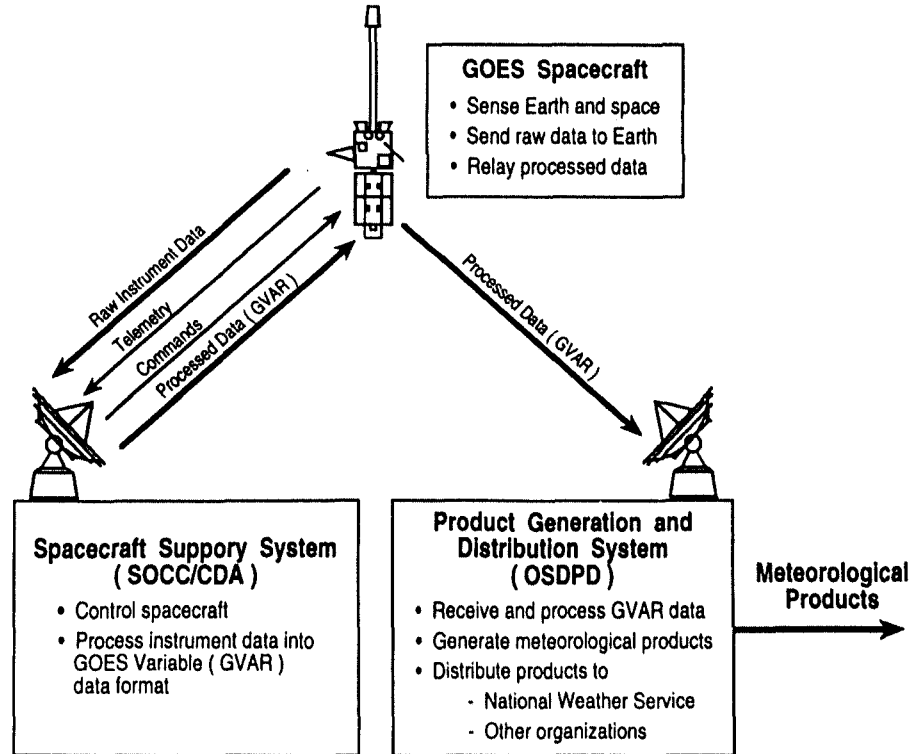


Figure 3. GOES Spacecraft Support and Product Distribution Systems.

A. Spacecraft Support System

The GOES I-M Spacecraft Support System includes the Command and Data Acquisition (CDA) Station at Wallops, VA and the Satellite Operations and Control Center (SOCC) at Suitland, MD (Figure 3). At the CDA station, raw instrument data and telemetry are read out from the satellite. Data are processed, calibrated, earth-located and converted to GOES Variable data format (GVAR) and rebroadcast to the satellite along with spacecraft command schedules (Komajda and McKenzie, 1994). Details are shown in Figure 4. This digital imager and sounder GVAR data is then broadcast to direct readout users. SOCC is responsible for overall safety of the spacecraft, scheduling of the instruments, data quality, and performance. Continuous monitoring and checks are conducted on orbital position, image navigation and registration, and various subsystems including primary imager and sounder instruments. It is also responsible for planning and operating the ground system equipment for GVAR acquisition at NESDIS, the initial stage of product processing.

B. Product Generation and Distribution System

The GVAR satellite data are received at the Wallops Island, Virginia CDA station and relayed to SOCC in Suitland, Maryland for data monitoring at SOCC and product generation at the Office

of Satellite Data Processing and Distribution (OSDPD) Central Environmental Satellite Computer System (CEMSCS). SOCC also forwards its GVAR data via microwave line-of-sight communications to the NOAA Science Center in nearby Camp Springs, Maryland for product processing. Figure 5 is a simplified diagram of the GOES Product Generation and Distribution (PG&D) System. There are six functional subsystems used to produce GOES products. The names and locations of the processing and distribution systems are found in parentheses; selected output products are listed to the right of the PG&D System block.

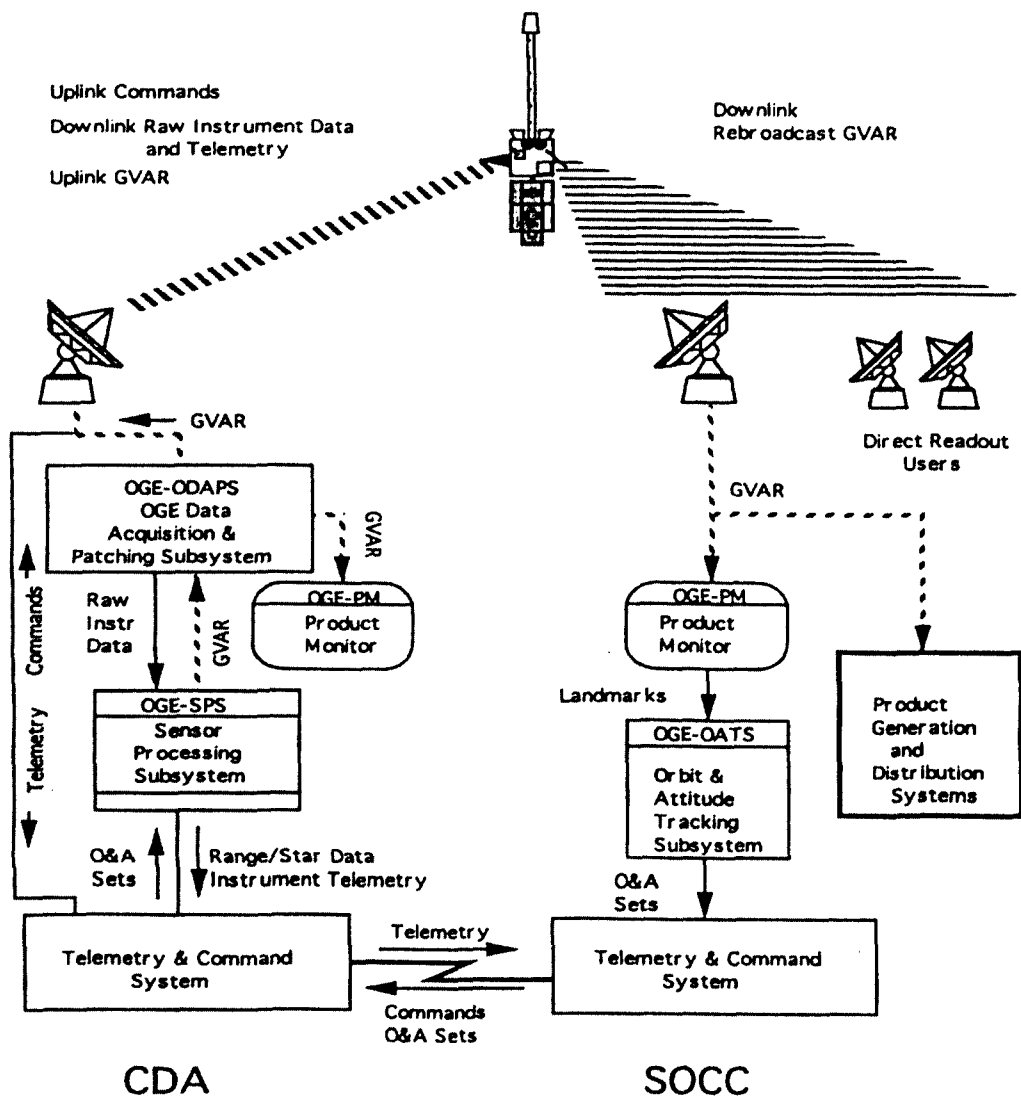


Figure 4. GOES I-M Ground System.

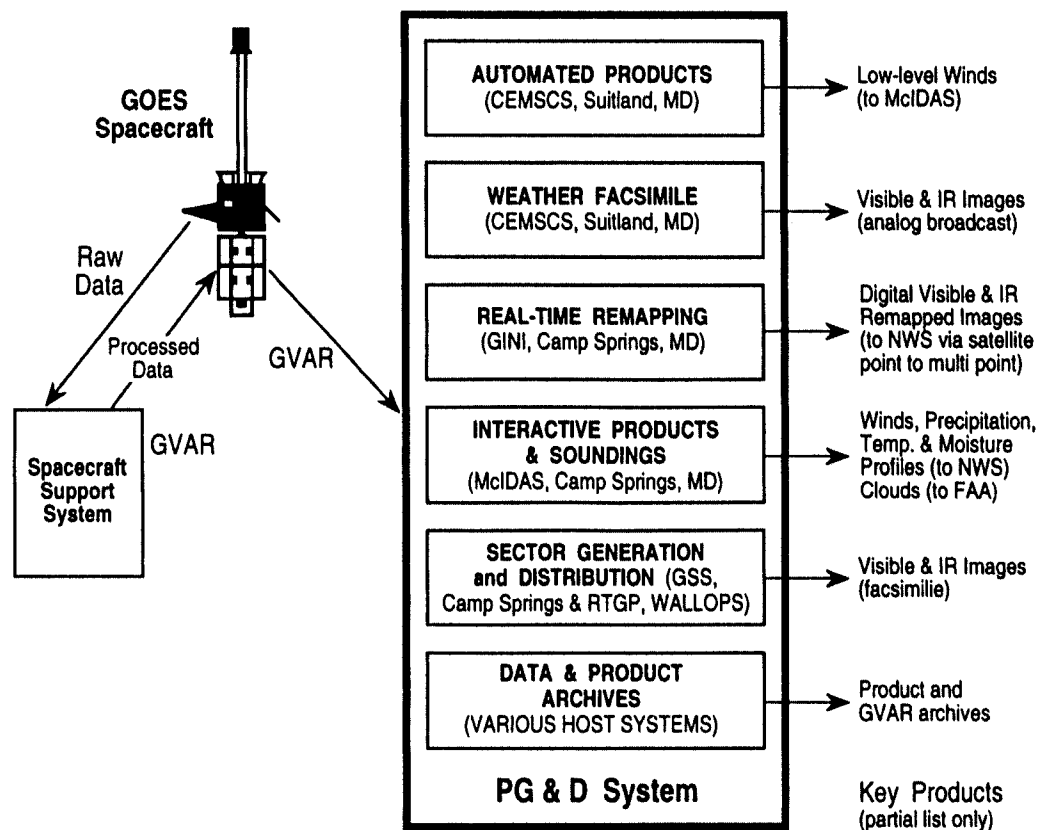


Figure 5. GOES Product Generation and Distribution System.

References.

- Ellrod, G.P., R.V. Achutuni, J.M.Daniuels, E.M. Prins, and J.P. Nelson, 1998: An assessment of GOES-8 imager data quality. *Bull. Amer. Meteor. Soc.*, **79**, 2509-2526.
- Komajda, R.J. and K. McKenzie, 1994: An Introduction to the GOES I-M Imager and Sounder Instruments and the GVAR Retransmission Format. *NOAA Technical Report NESDIS 82*, U.S. Department of Commerce, Washington, D.C., 61 pp.
- Menzel, W.P. and J.F. Purdom, 1994: Introducing the GOES I: The First of a New Generation of Geostationary Operational Environmental Satellites. *Bull. Amer. Meteor. Soc.*, **75**, 757-781.
- Nestlebush, M.J., 1994: The Geostationary Operational Environmental Satellite Data Collection System. *NOAA Technical Memorandum NESDIS 40*, U.S. Department of Commerce, Washington, D.C., 65 pp.

III. USING THIS DATA PRODUCT CATALOG

This catalog only focuses on the current operational and experimental product suite from the operational satellites in the GOES I-M line. A description and an example of the product, its accuracy (as applicable), primary users, and a list of references for further reading are included in this publication.

IV. DATA AVAILABILITY

A. Real-time Imagery Products

Data and products from the GOES satellite are available to users either through direct readout or prior arrangement. For more information, please contact

Office of Satellite Data Processing and Distribution, E/SP
National Environmental Satellite, Data, and Information Service/NOAA
Federal Bldg. 4, Rm. 1069
5200 Auth Road
Camp Springs, MD 20746-4304

Telephone: (301) 457-5120
E-Mail: satinfo@ssd.wwb.noaa.gov

Fax: (301) 456-5184

B. Retrospective Image Products

For access to data and products from the past, please address your requests to

National Climatic Data Center (NCDC)
Climate Services Division (CSC)
151 Patton Avenue
Asheville, NC 28801-5001

Telephone: (828) 271-4850
E-Mail: satorder@ncdc.noaa.gov

Fax: (828) 271-4876

A browse and ordering site is also available on the internet at <http://www.ncdc.noaa.gov/oi/satellite/satelliteresources.html>. Servicing of retrospective products is provided on a cost recovery basis. A user charge to cover the cost of reproduction will be specified prior to processing.

V. IMAGER PRODUCTS

A. Real-time Remapped Imagery

Description. The GOES Telecommunication Access Program (GOES-TAP) distribution system was decommissioned in October 1998. Its successor, the GOES Ingest and NOAAPORT Interface (GINI) system generates a suite of real-time GOES products from “raw” GOES GVAR data. GINI processing involves sectorizing, scaling, and remapping digital products in various projections such as lambert conformal, mercator, and polar stereographic (Figure 6). GINI is the central remapping system for the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS), a data display and applications platform. Remapped image files (sectors) are relayed from the GINI to a NOAAPORT interface that will further distribute the products to more than 200 NWS Weather Forecast Offices (WFOs) via a point to-multipoint satellite broadcast. Satellite relay of GINI products via NOAAPORT enables access by the general public.

Utilizing all GOES imager channels, up to 120 remapped digital sectors can be generated concurrently. The process of sector generation and remapping is data driven, not scheduled like the former GOES-TAP service. A predefined sector is generated when most of the data covering the specified geographic area is received. GINI does not superimpose grids on the imagery prior to dissemination, but provides navigational data in the AWIPS header to enable local generation of a local grid map data base. The output sectors are transmitted serially. Transmission of the highest priority sector begins immediately after the first data for that sector is received; lower priority sectors are then transmitted. An overview of the NOAAPORT program can be found on the internet at: http://www.nws.noaa.gov/noaaport/html/prd_gini_shtml.

Accuracy. Sectors are available in 8, 4, and 1 km resolutions. Accuracy in the depiction and location of meteorological features is a function of the spacecraft sensor or channel and fluctuations in GOES Image and Navigation Registration performance.

Users. NWS Forecast Offices (FOs), NWS National Centers for Environmental Prediction (NCEP), and various private users and enterprises.

Reference.

National Weather Service, AWIPS-90 System Requirements Specification, Appendix K. (undated).

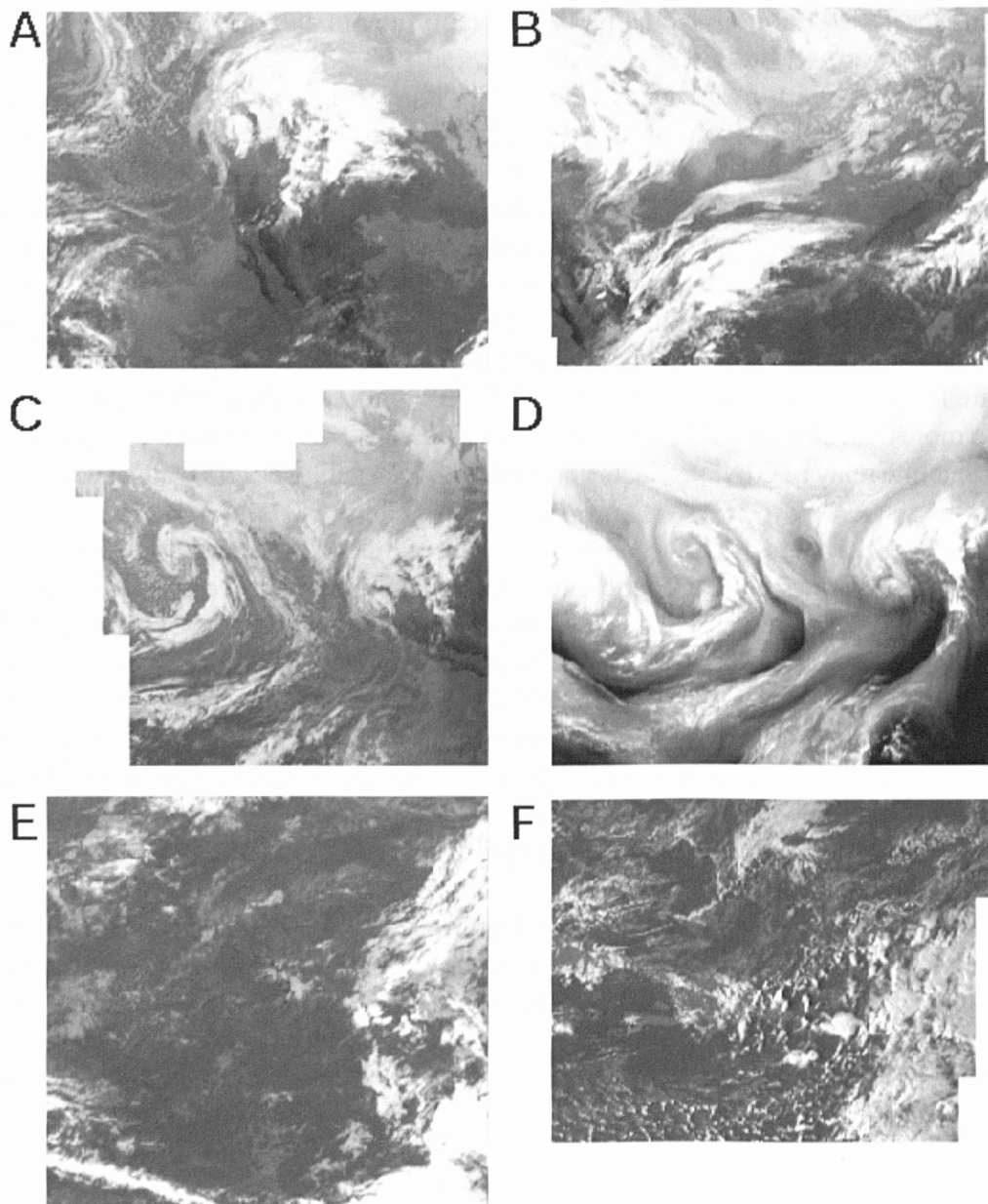


Figure 6. AWIPS image sectors for the U.S. and Puerto Rico. U.S. sectors, Lambert Conformal projection, are shown in panels a) West CONUS IR image; b) East CONUS IR; c) Alaska Regional IR; d) Alaska Regional Water Vapor; e) Hawaii Regional IR; f) Puerto Rico Regional Visible.

V. IMAGER PRODUCTS

B. WEFAX Imagery

Description. GOES imagery is transmitted on WEFAX circuits to direct receive broadcast users over a large portion of North and South America. Three types of sectorized images are transmitted: (1) visible, (2) IR, and (3) WV. The images display sectorized portions of a full disk scan. There are a total of seven sectors available including an 8 km Northern Hemisphere (NH) IR sector transmitted hourly throughout the day and a visible NH sector transmitted hourly during daylight hours. In addition, there are four 8 km sectors (NE, SE, NW and SW), a 4 km continental United States sector, and a 16 km full disk image transmitted every 3 hours. A full suite of 8 km WV sectors is transmitted twice daily. All sectors contain implanted geographic boundaries and latitude/longitude reference lines. Sample images are shown in Figures 7 and 8.

The WEFAX image products are generated on the CEMSCS located at Federal Building 4 in Suitland, Maryland, and then transmitted on the Facsimile Transmission System (FXTS) to the Wallops Island, Virginia CDA via a T1 communications circuit. The CDA then uplinks the signal to the GOES satellites for final distribution to users. Each image requires about 3.5 minutes to transmit.

Accuracy. The GOES WEFAX images are transmitted in 8-bit (256 gray shades) pixels. It has been determined the GOES-8 WEFAX transponder is noisy and can only support 5-bit (32 gray shades) pixel resolutions. Converting from a 4-bit (16 gray shades) pixel resolution to an 8-bit pixel has smoothed out the images, but did not provide the depth of resolution expected. A test of GOES-9 revealed it was much quieter and could support over 6-bit (64 gray shades) image pixel resolution.

Users. Primary users are meteorological agencies outside the U.S., schools, system manufacturers, and hobbyists.

Reference.

Data Collection Direct Broadcast WEFAX Coordinator and PRC, Inc. 1994: *WEFAX User's Guide*. U.S. Department of Commerce, Washington, D.C., 64 pp.

USA NOAA GOES-10 11/10/98 1200Z FD IR03

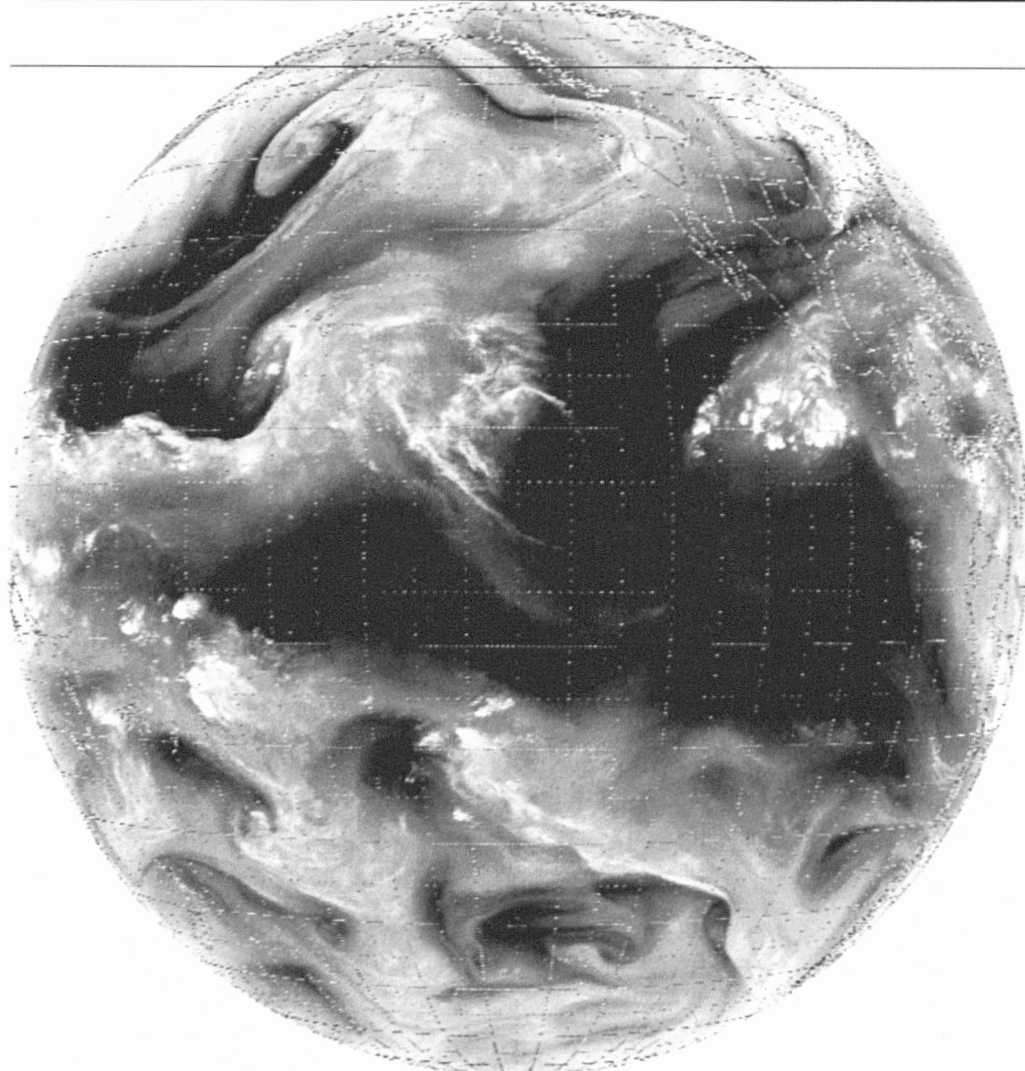


Figure 7. A WEFAX WV U.S. sector from GOES-10 at 1200 Universal Time Clock (UTC), November 10, 1998.

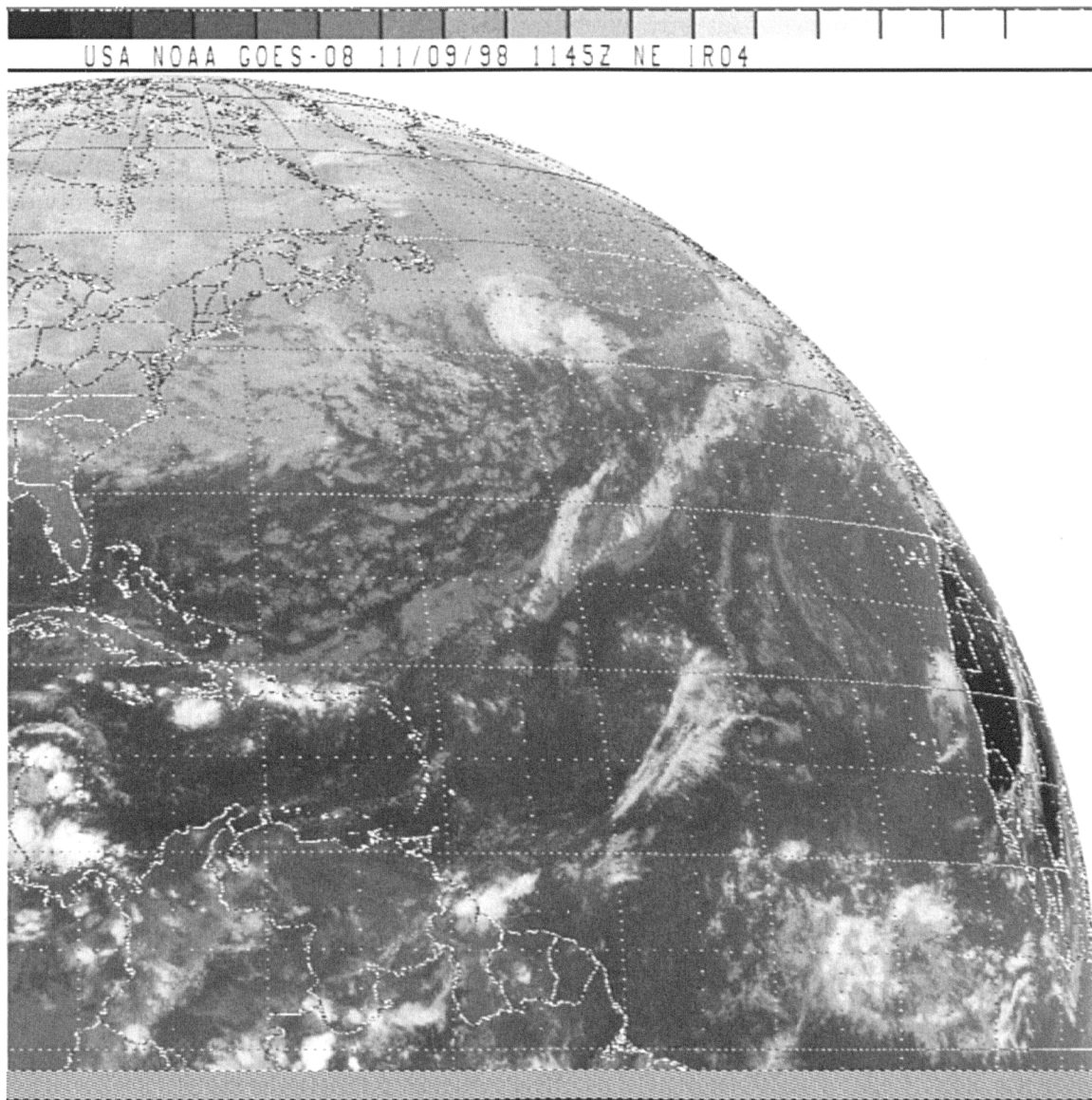


Figure 8. A WEFAX IR (Channel 4) U.S. sector from GOES-8 at 1145 UTC, November 9, 1998.

V. IMAGER PRODUCTS

C. Regional and Mesoscale Meteorology (RAMM) Branch Advanced Meteorological Satellite Demonstration and Information System (RAMSDIS)

Description. The RAMM Team of the Office of Research and Applications (ORA), together with NOAA's Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University, has developed the RAMSDIS. The RAMSDIS program is a demonstration, with the goal of providing routine, high quality digital satellite data (for the first time) to NWS forecasters in preparation for the operational implementation of the AWIPS. RAMSDIS routinely delivers high-quality digital GOES data (both imagery and derived display products) to over 60 sites, including NWS National Centers and over 50 WFOs. In addition to these near-realtime ingest RAMSDIS sites, research RAMSDIS units are located at the World Meteorological Organization (WMO) headquarters, in Geneva, and two of its Regional Meteorology Training Centers, in Barbados and Costa Rica; and at the University of Reading in Reading, England. Research RAMSDIS workstations contain periodically updated satellite data-based case studies and provide a platform for both distance learning and joint research activities.

RAMSDIS software is an adaptation of the Man-computer Interactive Data Access System (McIDAS), developed by the University of Wisconsin's Space Science and Engineering Center (SSEC). Customized applications for the NWS WFOs were developed at CIRA. The system consists of low-cost Pentium PC workstations, running McIDAS-OS2, with enhancements such as SuperVGA image displays (640x480 pixels, with 256 colors), separate image and text monitors and a user-friendly menu system accessible via function keys. A RAMSDIS file server, located at the NOAA Science Center in Camp Springs, MD, provides GOES visible, IR and WV data to the NWS RAMSDIS demonstration sites via the Internet. Additional derived products such as remapped imagery and the fog and reflectivity products are prepared at CIRA and also served to the RAMSDIS sites via the internet. A new service RAMSDIS ONLINE (Figure 9) is available to the public.

Accuracy. Products are available at a range of resolutions (1, 4, 8, 12 and 16 km), depending upon the sensor or product and the associated map projection.

Users. This is both a demonstrational and an educational tool, serving selected NWS WFOs and centers in the first case, and the WMO and the University of Reading in the latter.

References.

Molenaar, D.A., J.F.W. Purdom, C.E. Vaughn, B.H. Connell and J.F. Dostalek, 1997: RAMSDIS Use in Regional Meteorological Training Centers. *13th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology*, Long Beach, CA, Amer. Meteor. Soc., 88-90.

Schrab, K.J., D.A. Molenaar, J.F.W. Purdom, L. Dunn and B. Colman, 1994: Use of Digital Satellite Data Via a Menu System in NWS Offices. *Proceedings from the Seventh Conference on Satellite Meteorology and Oceanography*, Monterey, CA, Amer. Meteor. Soc., 448-451.

RAMSDIS Online

What is it?

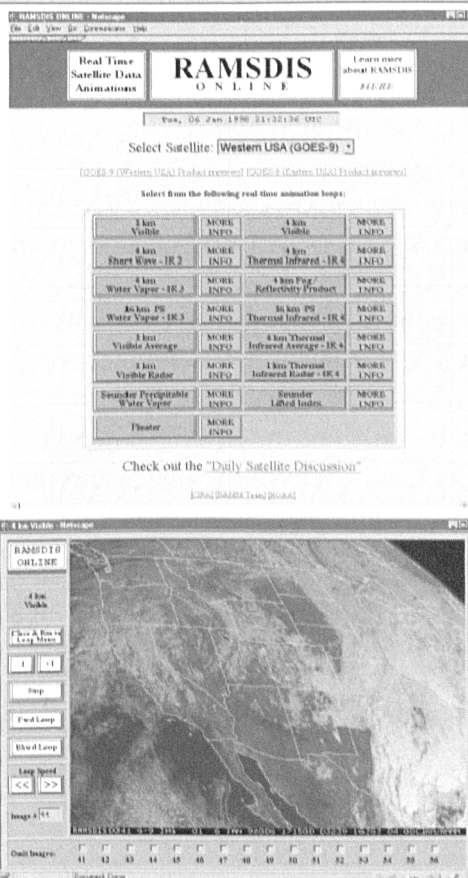
- ◆ Animation of satellite data via the World Wide Web

How does it work?

- ◆ GIF images are generated on a RAMSDIS system for each product ingest
- ◆ GIF's are named according to the frame number displayed on RAMSDIS
- ◆ GIF's are then automatically FTP'd to a server overwriting the old GIF for that frame number
- ◆ Each product available on RAMSDIS Online corresponds to a sequence of frame numbers
- ◆ Javascript code then downloads those frame numbers and loops them (The images are about 200kb each in size so it might take some time to download depending on your Internet connection)

How do you use it?

- ◆ Bring up web page from **Netscape 3.0+** or Internet **Explorer 4.0+**. Then from web page select a product to view
- ◆ A new window pops up and begins to download and loop the corresponding GIF images
- ◆ Features include:
 - 'Select Satellite' option for each product GOES-8 (East) & GOES-9 (West) <main menu>
 - 'More Info' button provides basic help on the uses of each product <main menu>
 - Close window and return to main menu
 - Advance frame up/down by 1
 - Stop player
 - Start Player Forward
 - Start Player Backward
 - Decrease/Increase player speed
 - Image number displayed
 - Omit images (check each box of image number to omit)



Contact Dave Watson (Colorado State University, CIRA, RAMM Team) with comments/questions/suggestions
watson@cira.colostate.edu

Figure 9. Graphical representation of RAMSDIS ONLINE.

VI. IMAGER ATMOSPHERIC PARAMETERS

A. Winds

Low Level Winds (Picture Triplet)

Description. Cloud motion winds at low levels (below 700 hecta Paschals (hPa)) have been produced operationally at NESDIS by automated methods using GOES images since the early 1970s. The current process (Picture Triplet) makes use of three successive IR images (11 μ m window channel). For three images A, B, C (nominally 30 minutes apart), a target array from image B at 2 1/2° lat/lon intersections is examined for clouds below 700 hPa. Using pattern recognition methods, a valid target is tracked forward to C and backward to A. The two motions are compared and if their difference is below an allowable tolerance, the measurements are averaged to produce a wind. A McIDAS autocorrelation technique is also used to complement the picture triplet methodology.

This process is repeated four times daily on the CEMSCS using images taken within three hours prior to synoptic times: 0000, 0600, 1200, and 1800 UTC. For GOES, all combinations of full disc, NH and Southern Hemisphere (SH) sectors are examined and the 90 minute sequence yielding maximum coverage is chosen. Figure 10 shows low-level winds in the SH from GOES-8. All low level winds are assigned to a height of 900 hPa. Upon completion of a given production run, the resulting field of wind vectors is analyzed for consistency with the previous run and the surviving winds are delivered to the NCEP and broadcast via Global Telecommunications System (GTS).

Accuracy. The accuracy of GOES-8 low-level winds appear as good or better than GOES-7 low-level winds which had an accuracy of 3 meters/second (m/s).

Users. The primary users of the low-level winds are the numerical modeling centers, the NCEP and European Center for Medium-range Weather Forecasting (ECMWF).

Reference.

Green, R., G. Hughes, C. Novak and R. Schreitz, 1975: The Automatic Extraction of Wind Estimates from VISSR Data. *NOAA Technical Memorandum NESS 64*, U.S. Department of Commerce, Washington, D.C., 110 pp.

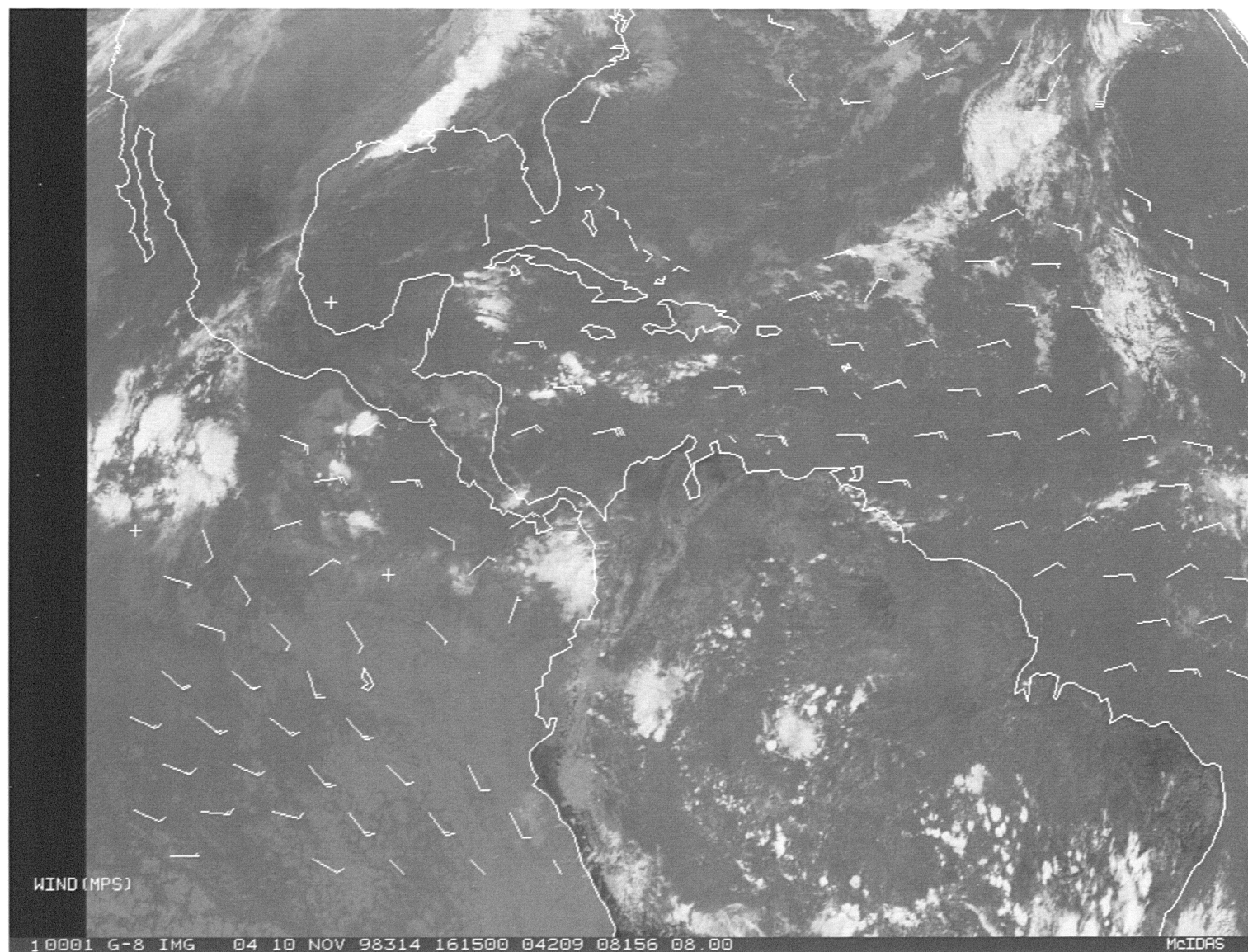


Figure 10. Low-level picture triplet winds on a GOES-8 SH sector for 1615 UTC, November 10, 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

A. Winds

High Density Winds (Low, Mid and High Levels)

Description. Recent advances in numerical weather prediction (NWP) models, both at NOAA's Environmental Modeling Center (EMC)/NCEP and other major International NWP Centers, require higher quality satellite derived winds, particularly over the traditionally data void oceanic regions of the globe. In March 1998, NOAA/NESDIS implemented an upgraded operational wind production suite which provides high quality imager-based cloud-drift (IR) and water vapor (WV) motion winds at significantly increased spatial and temporal resolution. The system is totally automated and uses a series of geostationary satellite images to derive wind estimates. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite WV and IR brightness temperature data to assign heights to these derived wind estimates. With increased computer resources, a ten-fold increase in the yield of wind vectors for GOES-8 and GOES-10 are being generated every 3 hours for the Northern and Southern Hemisphere. Approximately 20,000 wind vectors are derived from both satellites for each cycle and distributed to EMC and to the GTS. EMC/NCEP now uses these new operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems.

An overview of the operational NOAA/NESDIS winds processing system is shown in Figure 11. The major components of the system include: automated image registration quality control, target selection, wind target height assignment, target tracking, and automated quality control of derived winds. Automated quality control of the image registration is a new and important addition to the NESDIS GOES winds processing suite. The quality of the satellite derived winds are much more sensitive to changes in registration than to errors in absolute navigation. Manual corrections to the winds imagery are no longer performed. Automation of this function has become a necessity because of the increasing number of operational wind products generated and the increased frequency at which these products are generated. This algorithm makes use of the pattern matching techniques used in the automated tracking algorithm (Veldon et al., 1997) to track land features of predetermined landmarks deemed to be cloud free. Recent refinements have been made to the algorithm which have resulted in improved registration adjustments and fewer occurrences where the algorithm fails to arrive at a usable solution.

In the next step, targets are identified and assigned heights via several methods. Targets are identified in the first image based on brightness temperature gradients and an analysis of the spatial coherence of the scene (Figure 12). Height assignments take advantage of information from the WV and carbon dioxide (CO₂) absorption bands, if available, to help correctly represent semitransparent clouds (Nieman et. al, 1993). After the target selection process is completed, an auto-correlation technique is employed to search the subsequent imagery for each target's pattern. An estimate of where a given target should move is obtained from one of EMC's numerical forecast models,

currently the aviation model, and the search domain is centered accordingly. Allowable deviations from the guess vary with the wind speed. A vector of 50 m/s would typically be allowed to deviate approximately 25 degrees in direction or 12 m/s in speed from the model prediction. Slower vectors are allowed a larger percentage of the deviation. Initial vectors result when the patterns are successfully located, with an acceptable level of confidence, in all three images (Figure 13). The final step in the winds process is the automated quality control algorithm (Hayden, 1993) which removes suspect vectors and adjusts the heights of others to produce the final wind products (Figure 14). A wealth of information is used in this process, including differences between the first and second vector pairs for each target, comparisons with surrounding vectors and comparisons against EMC model prediction wind and thermal profiles. A weighting function incorporating these factors drives the 3D recursive filter algorithm that performs the objective evaluation.

Nearly three times more WV vectors are produced from the WV imagery which contributes important information in areas void of clouds. Figures 15 and 16 show operational cloud-drift and WV winds, respectively, for the same time period. These wind products can be viewed on the internet at the following addresses: <http://orbit-net.nesdis.noaa.gov/goes/winds> and <http://cimss.ssec.wisc.edu/goes/satwind/satwind.html>.

Accuracy. Neither the satellite winds nor rawinsonde observations can be used as an absolute standard. However, the traditional means of verification for the satellite derived winds is a comparison to collocated rawinsondes. The root mean square error (RMSE) for cloud-drift (IR) and WV winds is about 6 m/s and 7 m/s respectively. The mean bias error for both sets of winds is about zero.

Users. Operational GOES-8 and GOES-10 cloud-drift and water vapor winds are made available on a operational NESDIS server. The wind products are also distributed over the GTS as a text message (Figure 17). The primary users of the GOES winds are the major numerical weather prediction centers which include the EMC, ECMWF, United Kingdom Meteorological Office (UKMET), and the U.S. Navy.

References.

Hayden, C. M., 1993: Recent research in the automated quality control of cloud motion vectors at cloud/NESDIS. *2nd International Wind Workshop*, Tokyo, Japan, 219-226.

Nieman, S.J., J. Schmetz and W.P. Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers. *J. Appl. Meteor.*, **32**, 1559-1568.

Velden, C.S., C.M. Hayden, S.J. Nieman, W.P. Menzel, S. Wanzong, and J. Goerss, 1997: Upper-tropospheric winds derived from geostationary satellite water vapor observations. *Bull. Amer. Meteor. Soc.*, **78**, 173-195.

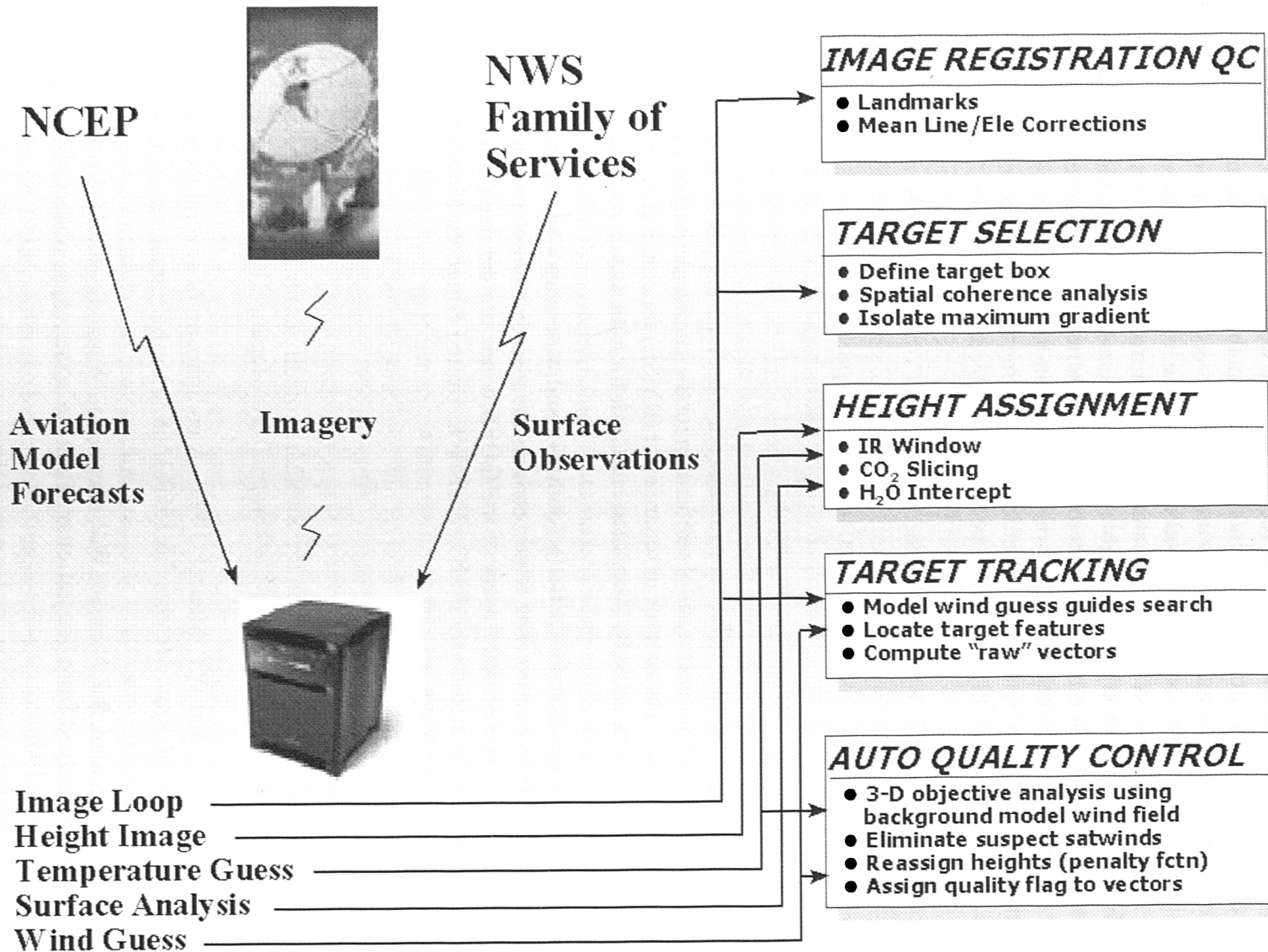


Figure 11. Overview of operational NOAA/NESDIS Winds Processing System.

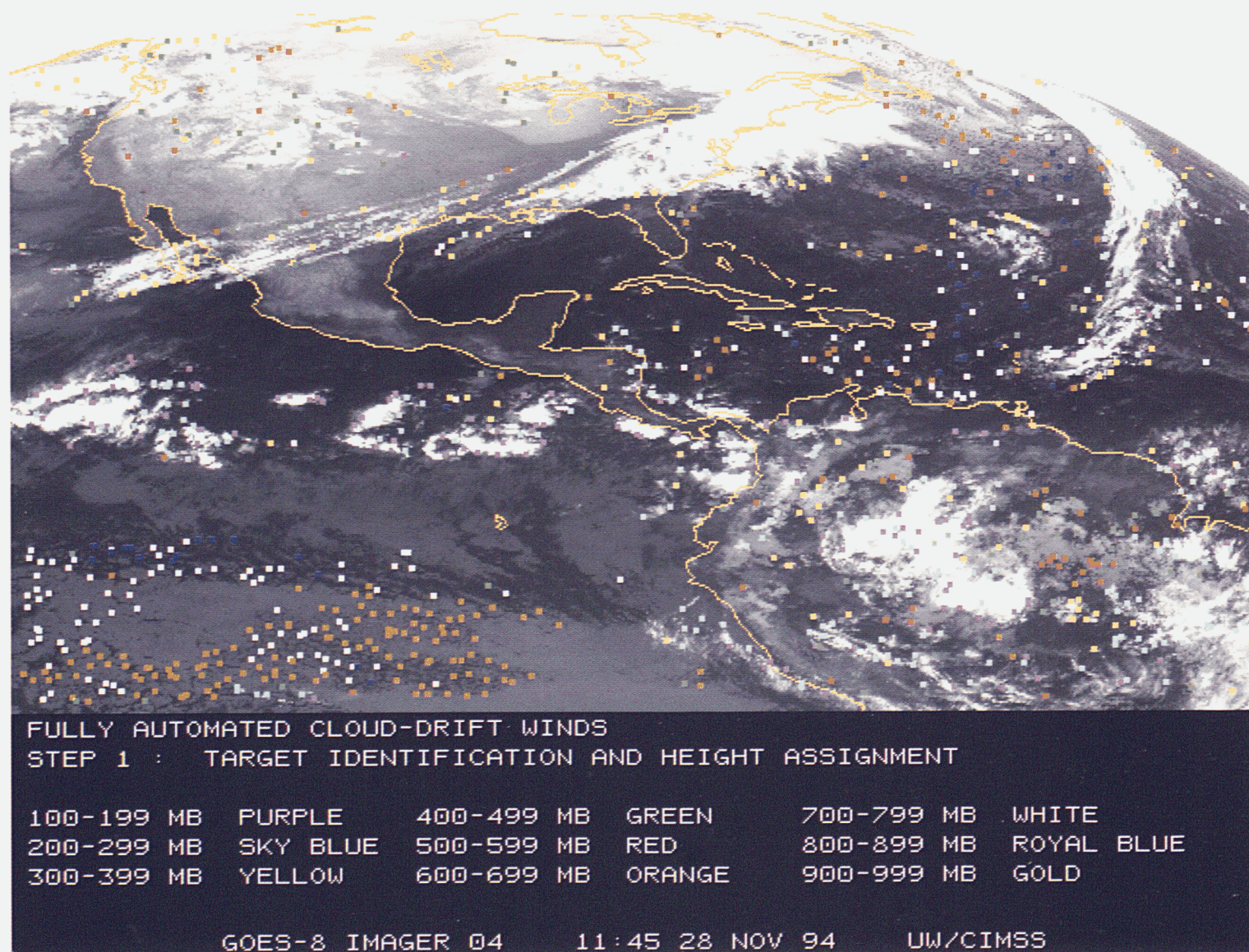


Figure 12. Target selection and height assignment of cloud elements, the first step of the automated wind program.

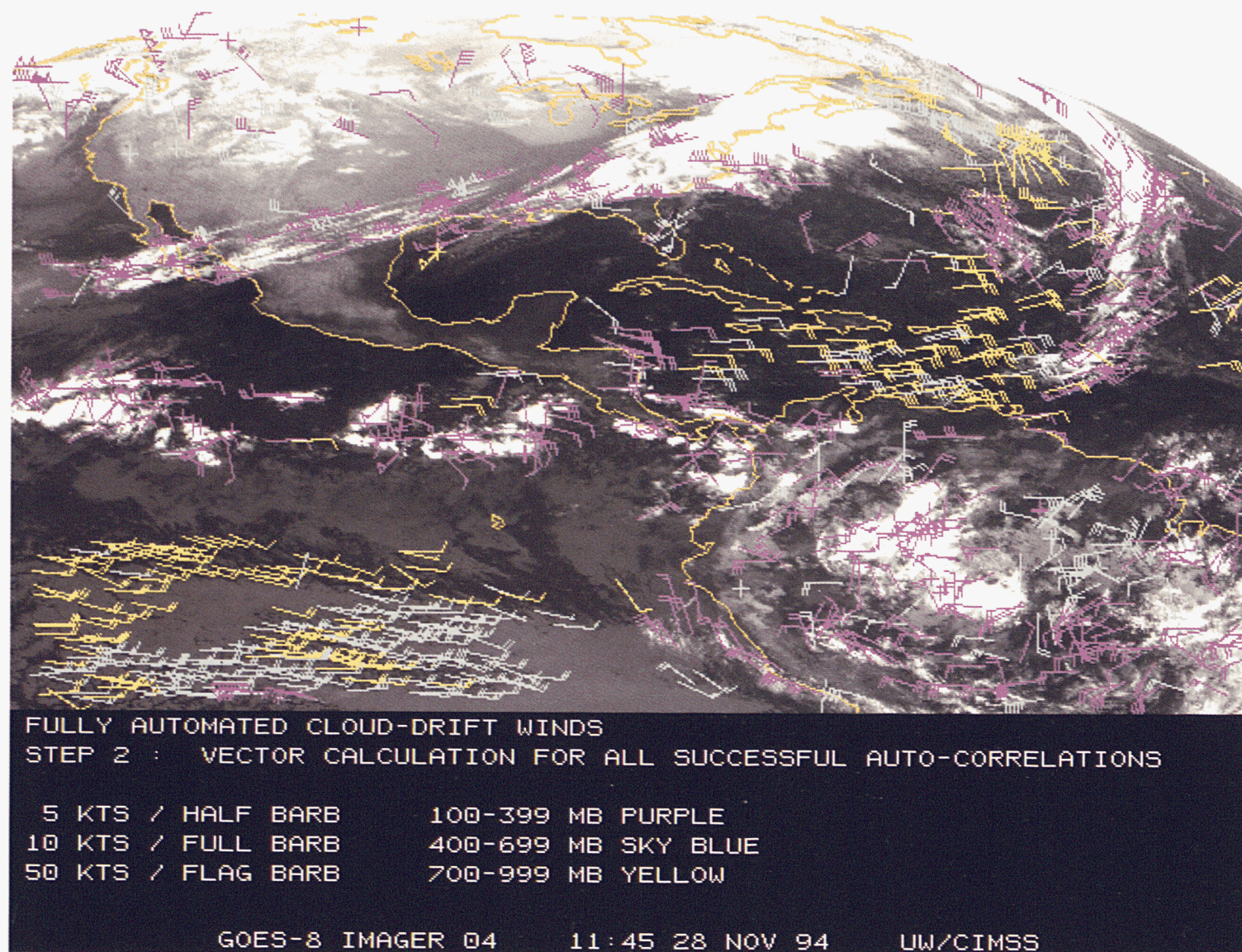


Figure 13. Target tracking for cloud drift winds.

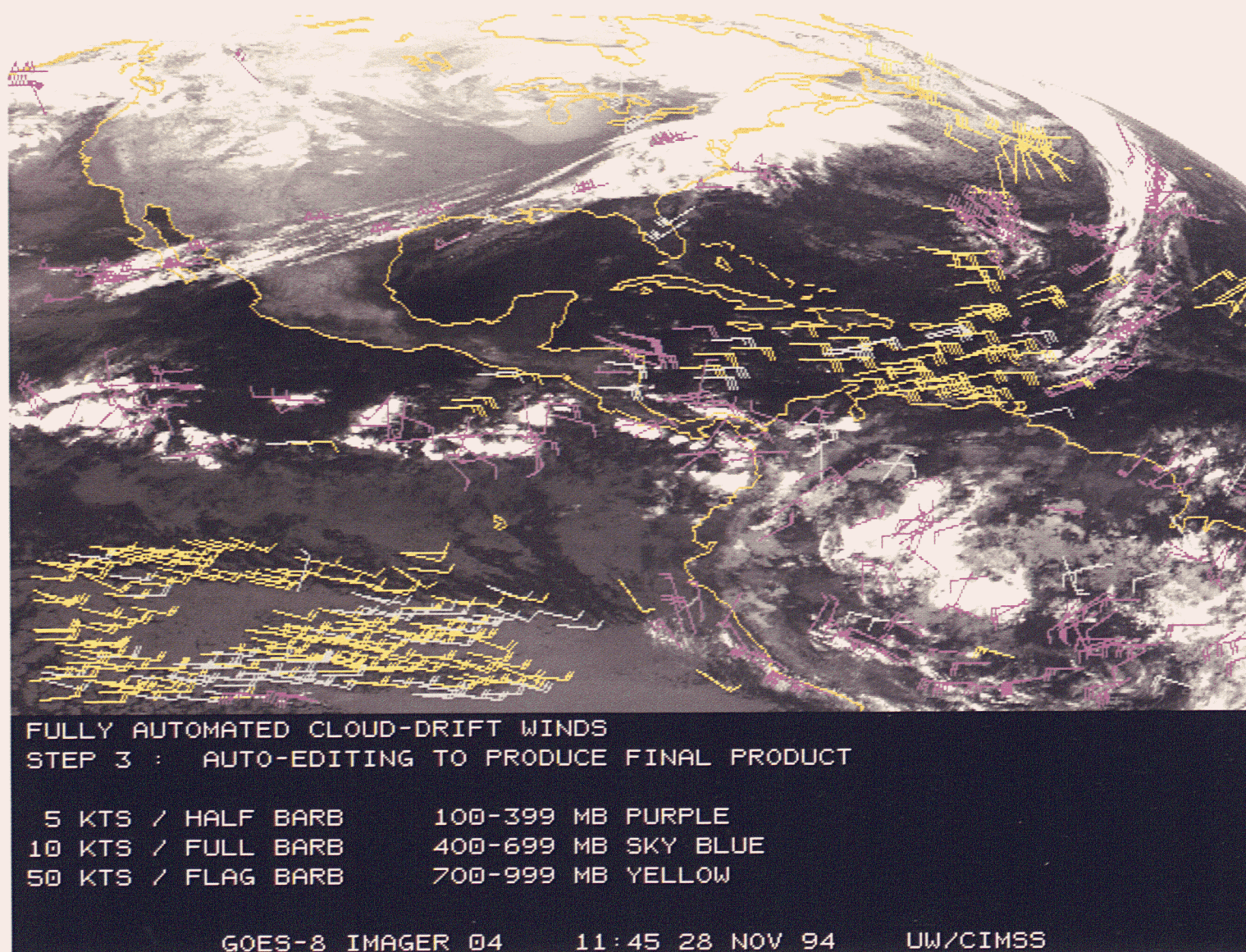


Figure 14. Final edited and quality controlled cloud drift wind product for 1145 UTC, November 28, 1994.

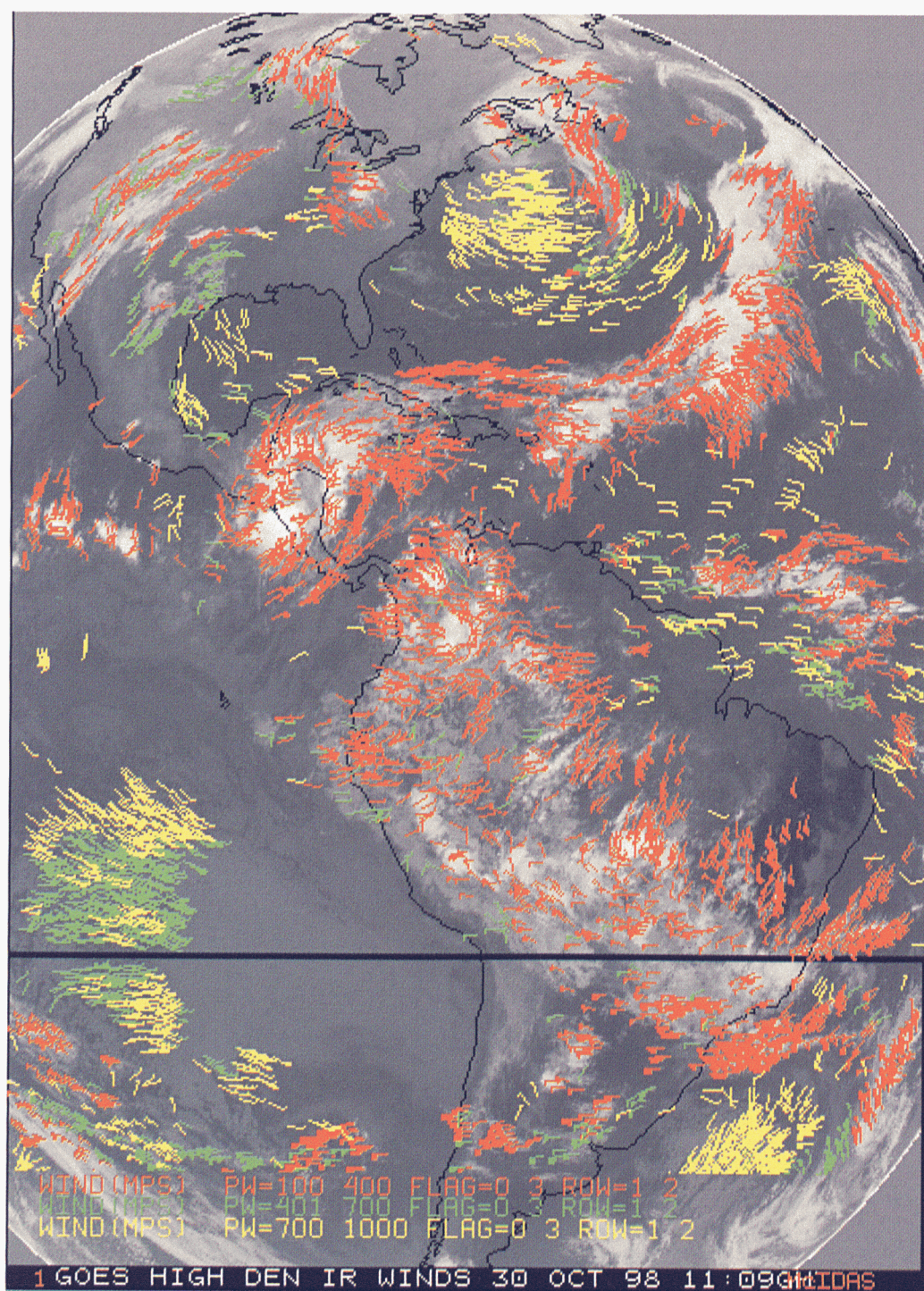


Figure 15. Cloud drift winds from IR imagery for 1109 UTC, October 30, 1998. High level (100-400 hPa) wind vectors are in red, mid-level (401-700 hPa) vectors are in green, and low level (701-1000 hPa) vectors are in yellow.

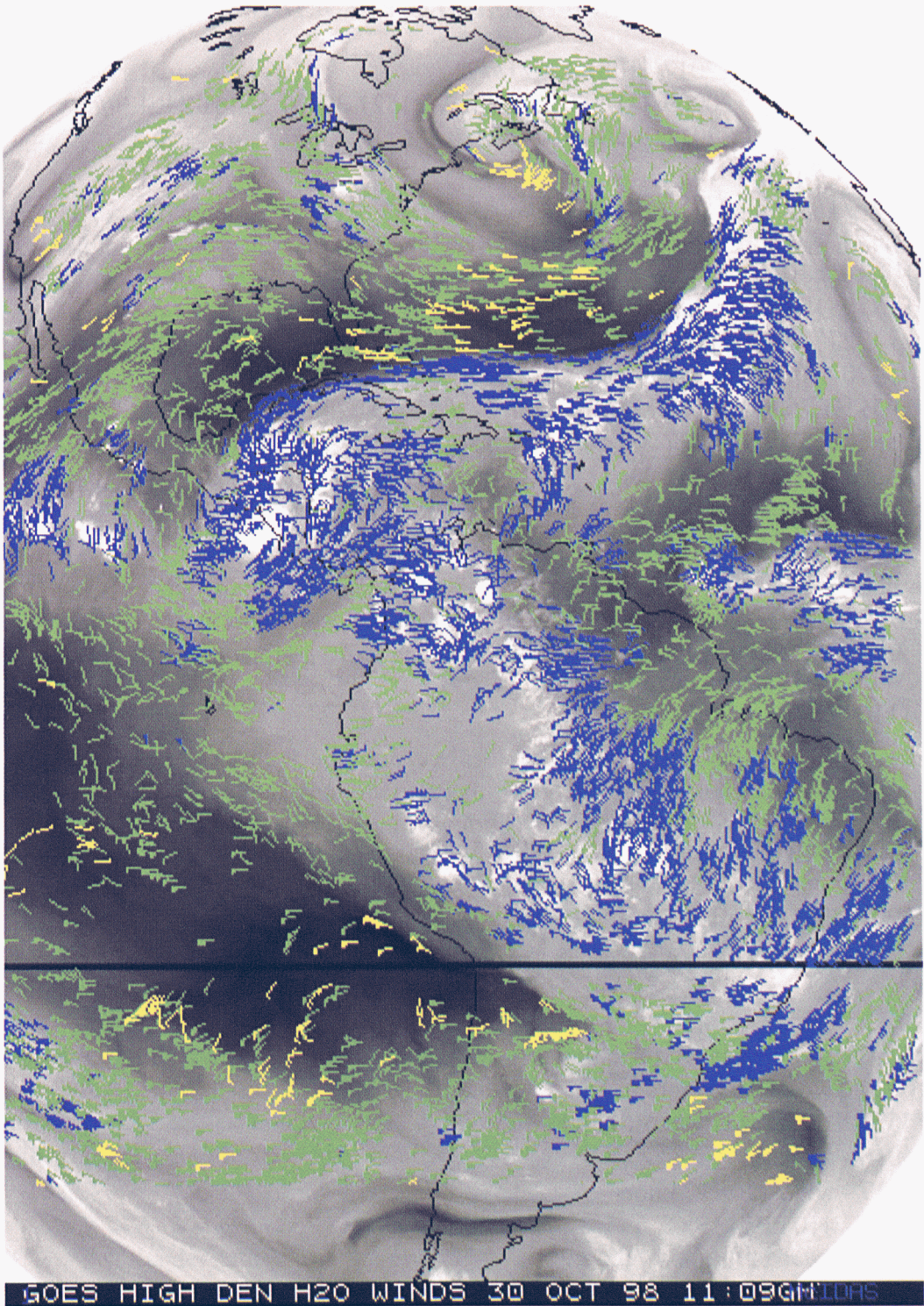


Figure 16. WV winds for same period as Figure 15. High level (100-250 hPa) wind vectors are in blue, mid-level (251-400 hPa) vectors are in green, and low level (401-700 hPa) vectors are in yellow.

TWZY11 KWBC 011100##,
 YYXX 51026 11001 222//##,
 222 10002 7552/ 65010 12017 41081 12021##,
 10104 9949/ 36321 20009 74140 08021 3429/ 21521 30507 34481 24013##,
 10203 3532/ 25321 32011 26561 25013 21/// 23611 2453##,
 10301 43/// 89140 10525##,
 10402 7871/ 63130 130 07 65130 11517##,
 10501 55/// 89170 10017##,
 10601 84/// 63021 14505##,
 10701 85/// 19461 30513##,
 11106 4727/ 25301 31029 15521 21015 3719/ 78100 06009 40311 21015##,
 2707/ 16481 22517 34401 23013##,
 11203 5117/ 76040 06505 72060 10017 14/// 55010 07005##,
 11406 8280/ 33491 25027 28441 26029 9086/ 28451 25529 25421 21558##,
 8026/ 26441 26031 21611 24533##,
 11505 4441/ 39421 24515 33411 23527 1611/ 51050 28009 33281 27034##,
 20/// 44151 23019##,

Line 1:

TWZ - GOES-9 (TWY - GOES-8)
 ZY11 - indicates quadrant of the globe
 KWBC - issuing site, Washington, D.C.
 011100## - time of observation

Line 2:

YYXX - SATOB (satellite observation)
 51026 - Date group; February 6, 1996 (50 is added to number to indicate winds in knots.)
 11001 - Time of midpoint of the observation (1100 UTC); 1 indicated IR winds.
 222 - Issuing agency; USA

Line 3:

222 - Designates data type; cloud drift wind and cloud temperature data available.
 1002 - Two wind vectors in area bounded by 10-20N and 100-110W
 7552/ - Location of vector; 17.5N, 105.2W
 65010 - 650 hPa -1.0°C
 12017 - wind 120° 17 knots
 41081 - 410 hPa -31°C
 12021 - 120° 21 knots

Details concerning GTS messages can be found in the World Meteorological Organization, Manual on Codes, Volume 1, International Codes, Part A - Alphanumeric Codes, 1988 edition.

Figure 17. GOES-9 GTS Winds Message.

VI. IMAGER ATMOSPHERIC PARAMETERS

A. Winds

Low Level High Density Visible Satellite Winds (Experimental)

Description. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower-tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region which is an important region when assessing storm motion.

The automated wind vector extraction processing from the visible imagery closely follows the IR cloud tracking methodology (See previous section). The target density parameters are adjusted to allow for the increased data resolution of the visible imagery. Only tracer heights below 600 hPa are considered when using visible imagery. Brightness temperature thresholds are relaxed to allow tracers to be selected in low light conditions. Initial heights assigned to tracers are based on collocated IR data. Tighter constraints are imposed on acceleration checks due to the shorter sampling interval. Figure 18 shows an example of the visible wind field generated from GOES-8 visible data over the Atlantic Ocean at 1645 UTC.

Accuracy. Neither the satellite winds nor rawinsonde observations can be used as an absolute standard. However, the traditional means of verification for the satellite derived winds is a comparison to collocated rawinsondes. The RMSE for low level ($p > 700$ hPa) visible winds is about 4.5 m/s and the mean bias error for this dataset is about 0.5 m/s.

Users. The visible winds are not yet operational, but the primary users are expected to be the major NWP centers which include the EMC, ECMWF, and UKMET, the Tropical Prediction Center (TPC), and the U.S. Navy.

References.

Goerss, J.S., C. Veldon and J. Hawkins, 1997: The impact of multispectral GOES-8 wind information on Atlantic tropical cyclone forecasts in 1995. Part II: NOGAPS Forecasts. *Mon. Wea. Rev.*, **126**, 1219-1227.

Velden, C.S., T. Olander and S. Wanzong, 1997: The impact of multispectral GOES-8 wind information on Atlantic tropical cyclone forecasts in 1995. Part I: Data methodology, description, and case analysis. *Mon. Wea. Rev.*, **126**, 1202-1218.

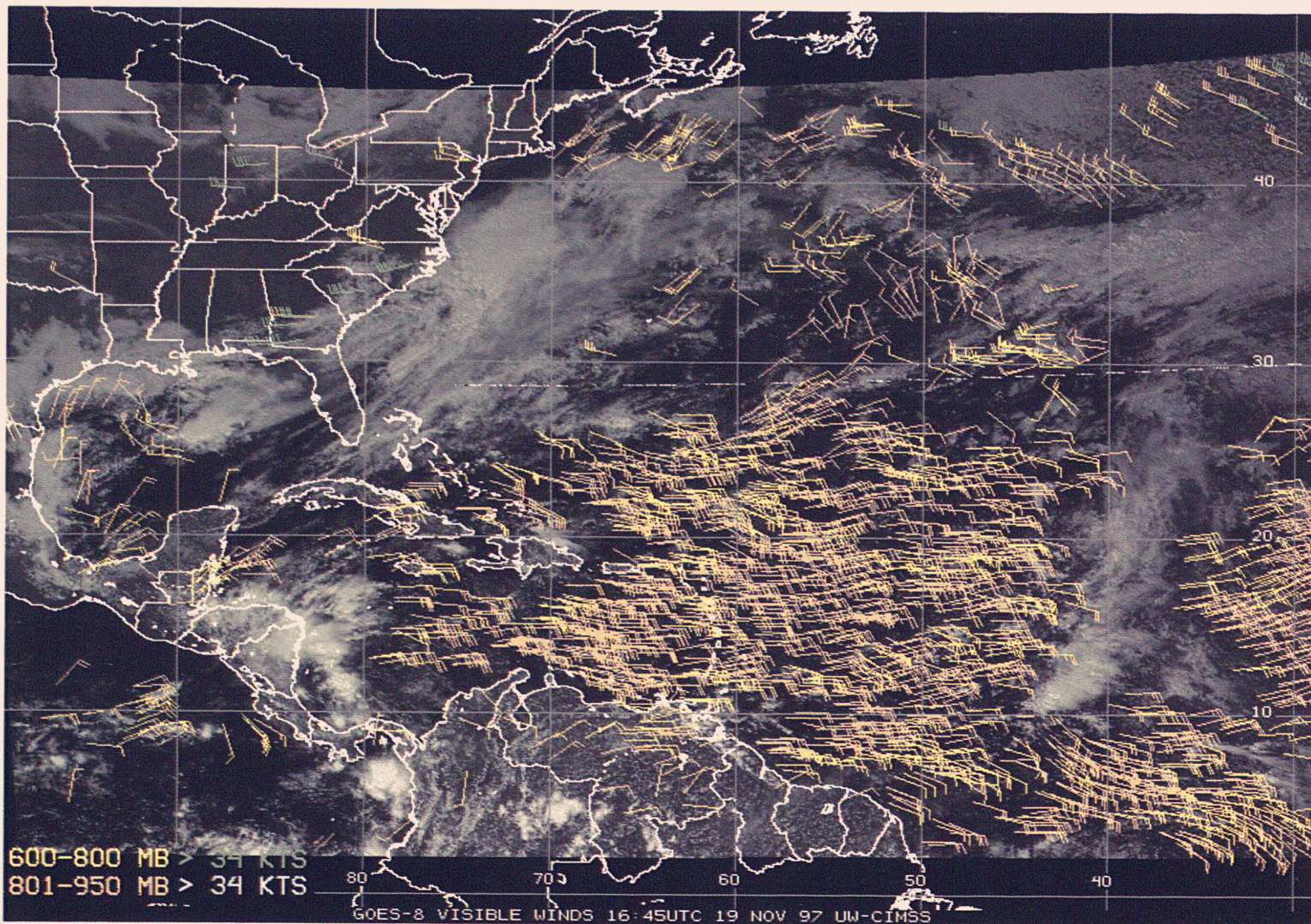


Figure 18. Visible wind field generated from GOES-8 visible data over the Atlantic Ocean at 1645 UTC, November 19, 1997. Yellow vectors are 600-800 hPa, tan vectors are at 801-950 hPa and green vectors represent speeds greater than 34 knots (kts) in the 600-800 hPa layer.

VI. IMAGER ATMOSPHERIC PARAMETERS

B. Clouds

Imager-based Satellite Cloud Product (Experimental)

Description. The GOES imager radiance information can also be used to generate a satellite cloud product (SCP) of cloud top height and effective cloud amount. The purpose of the SCP is to complement the Automated Surface Observing System (ASOS), which has a maximum limit of 12,000 ft. for cloud detection. A composite product for mid- and high-level clouds is calculated from hourly radiative measurements over selected locations, that are either commissioned or soon to be commissioned ASOS sites. Although this product is deemed experimental, imager-based ASOS SCP products are being generated and distributed routinely for ASOS stations in Hawaii and Puerto Rico that are outside of the domain covered by the GOES-W and GOES-E sounders, respectively. In addition, the imager-based ASOS SCP is available as a backup cloud product should either of the sounder instruments aboard GOES-E or GOES-W fail.

Three steps are required to produce the hourly-derived SCP. The first step is defining a 11x21 field-of-view (fov) box at each selected site. A cloud top pressure and cloud amount is calculated for the entire box using coincident window channel (10.7 μm) and WV channel (6.7 μm) information from all of the available fovy by the WV-IR intercept method (Schmetz, et. al. ,1993). Examples of the products are shown in Figures 19 and 20. Cloud-top pressure and effective cloud amount (ECA) (in percent) are generated at specific sites. From these computed cloud-top pressures and amounts, a categorical cloud amount (clear, scattered, broken, or overcast) and cloud level (mid, high) sky condition is determined for each station. For mid-level clouds, the IR histogram technique is used.

As with the sounder-based SCP (See section VII, part B), the imager-based SCP is sent out through the Gateway communication network in two forms. A shortened text form is sent to all NWS regions as part of the hourly roundup. It consists of the station three letter identification, satellite scan line time over the site, cloud top level (MID and HIGH), cloud amount (CLEAR, SCATTERED, BROKEN, and OVERCAST), range of cloud tops in feet, and average cloud amount. The ASOS SCP and cloud height and amounts can also be viewed on the internet at: <http://orbit-net.nesdis.noaa.gov/goes/asos/>.

Accuracy. Only cloud tops above 631 hPa (MID and HIGH levels) are given in the SCP. Recent analysis of imager-based GOES-8 and GOES-9 ASOS/SCP observations with manual surface observations have shown exact agreement in categorical cloud amount 75-80% of the time. The GOES ASOS/SCP and manual observations of categorical cloud amount agree within +/-1 cloud category 95% of the time. Analysis of the imager-based cloud product has identified it to have problems detecting very thin cirrus and delineating cloud in very cold atmospheric conditions when snow cover or an inversion is present.

References.

Nieman, S.J., J. Schmetz and W.P. Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers. *J. Appl. Meteor.*, **32**, 1559-1568.

Schmetz, J.K., K. Holmlund, J. Hoffman and B. Strauss, 1993: Operational cloud motion wind fields from meteosat infrared images. *J. Appl. Meteor.*, **32**, 1207-1225.

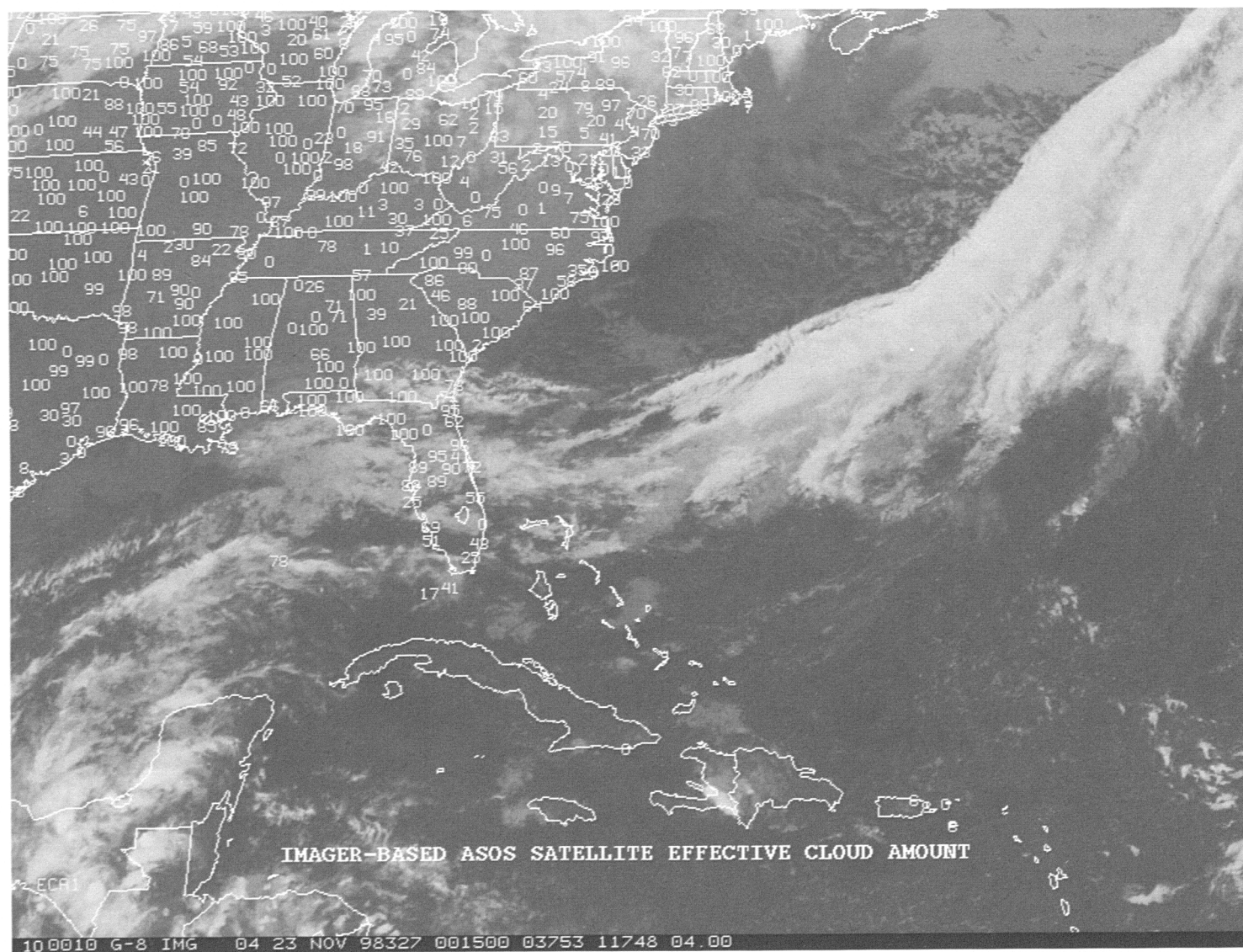


Figure 19. ASOS satellite effective cloud amount (percent) at 1500 UTC, November 23, 1998.

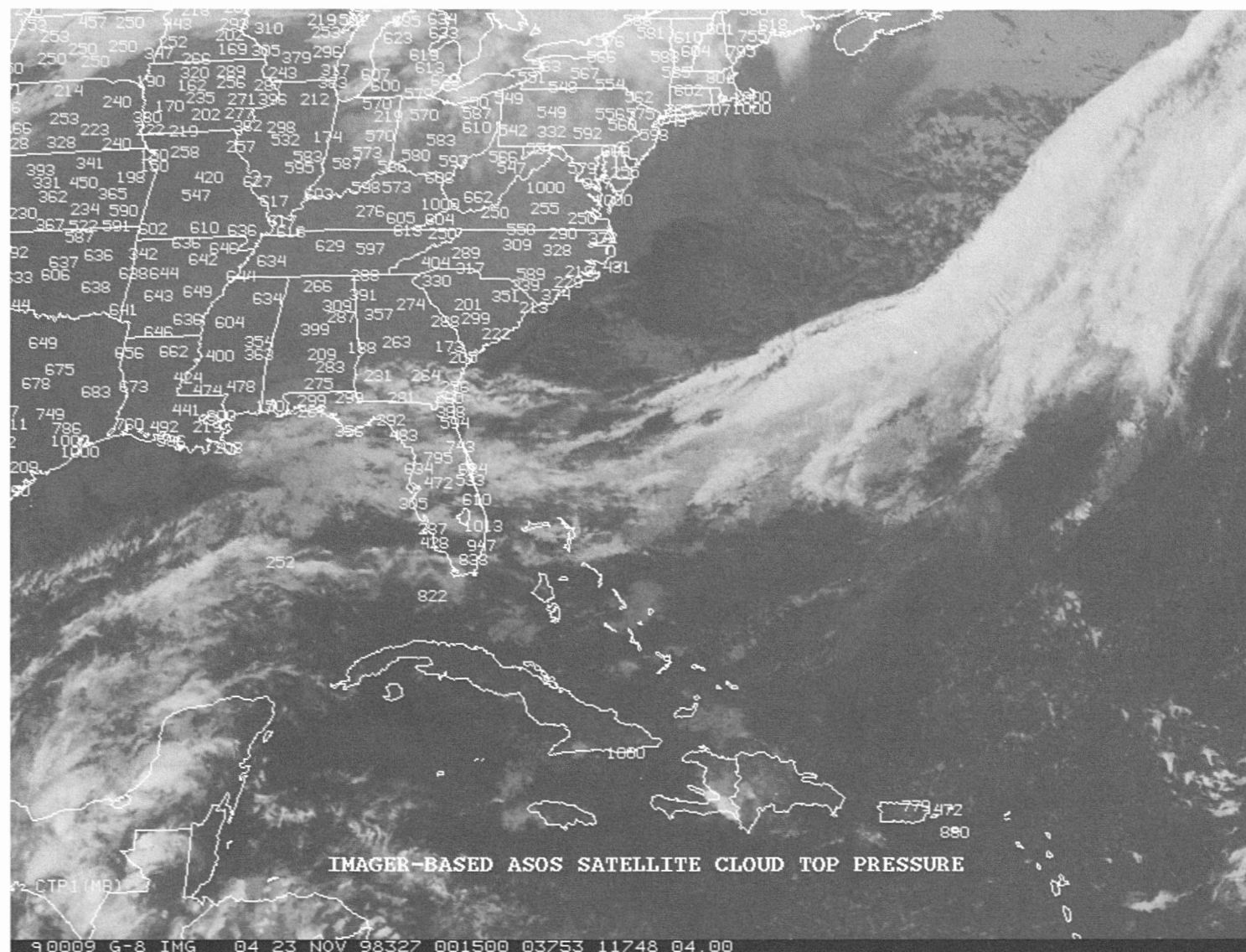


Figure 20. ASOS satellite cloud top pressure (hPa) at 1500 UTC, November 23, 1998. Note that 1000 indicates clear conditions.

VI. IMAGER ATMOSPHERIC PARAMETERS

C. Precipitation Estimates

Interactive Flash Flood Analyzer (IFFA)

Description. The IFFA is a manual technique used to estimate heavy precipitation amounts. Estimates are produced by analyzing the changes of cloud top temperatures in two consecutive (half-hourly) GOES images (visible and IR). Analysts utilize a flow diagram or decision tree. The IFFA technique was initially designed for deep convective systems (cloud top temperatures colder than -30°C) that occur in tropical air masses with high tropopause and equilibrium levels. An IR temperature enhancement curve, the “MB” curve, is the primary tool used for computing the convective rainfall estimates. This MB curve is only useful for deep convective systems occurring with high tropopause and cloud tops colder than -62°C . The technique has been modified to take into account warmer top convection by comparing the observed anvil temperature with the nearby radiosonde sounding derived equilibrium level. Cloud top temperatures equal to or colder than the equilibrium level would indicate heavier rainfall rates than clouds that were warmer.

Three steps are used to estimate convective rainfall amounts.

STEP 1 - Locate the active portion of the thunderstorm system. IR temperatures and gradients and bright, textured clouds in the visible are used for making this decision.

STEP 2 - Compute half-hourly rainfall estimates from the following factors: 1) cloud top temperature and cloud growth, (2) overshooting tops, (3) mergers, (4) speed of movement, and (5) a moisture correction factor based on the sounding derived 1000-500 hPa precipitable water and relative humidity.

STEP 3 - Sum up the half-hourly estimates computed from the above factors multiplied by the moisture correction factor. This convective technique has been modified to handle precipitation from extratropical and tropical storm systems. More details on these techniques can be found in Scofield (1987 and 1990) and Scofield and Spayd (1984) and Spayd and Scofield (1984).

SAB Precipitation Products. The Synoptic Analysis Branch (SAB) of NESDIS makes satellite rainfall estimates nationwide whenever heavy rains are threatening to produce, or are already producing, flash flooding (Borneman, 1988). Estimates are disseminated to the NWS over the Automation of Field Operations and Service (AFOS) system in an alphanumeric message called “SPENES.” These are directed to the affected area through the alarm/alert feature of the AFOS system. In addition to the estimated amounts of rainfall, the message also contains information on trends as seen in the satellite imagery and short-range forecasting (nowcasting) information. The

purpose of the messages is to provide heavy rainfall guidance to the NWS for issuance of flash flood warnings, watches, and advisories. Messages can be sent as frequently as every half hour (approximately 20 minutes after the latest satellite image) to the appropriate weather service office. Supplemental satellite data from the GOES derived product imagery, the GOES sounder, and the Defense Meteorological Satellite Program (DMSP) microwave imagery are received continuously in the SAB, and analyses and quantitative data from these sources are often included in the messages as additional guidance. Along coastal areas, especially in the West, rainfall estimates from the DMSP Special Sensor Microwave Imager (SSM/I) are used to help adjust the GOES estimates. A sample SPENES is presented in Figure 21.

IFFA-derived graphics products are sent via facsimile to the River Forecast Centers in Fort Worth, Texas and Slidell, Louisiana. An example of a graphical GOES-8 IFFA estimate for a flash flood event is shown in Figure 22. The precipitation products of the SAB are also on the internet under the Satellite Services Division (SSD) home page located at: <http://hpssd1en.wwb.noaa.gov/>.

The SPENES messages and colorful graphics of the IFFA estimates are included there. The graphics of rainfall estimates correspond with the time periods covered by the messages, and the IFFA totals for 24 hour periods ending at 1200 UTC are also included. An example of an internet graphic is shown in Figure 23.

Accuracy. There is a tendency to underestimate extreme rainfall events of 4 inches or more in a 24 hour period and overestimate the lighter events of less than 4 inches in the same time period. The estimates have an average error of about 30% and correlations with rain gauges that range from 0.4 to 0.7 (Borneman, 1988, Achutuni et al. 1993 and Achutuni et al. 1998).

Users. The primary users of this product are NWS Forecast Offices, River Forecast Centers, and NCEP, especially the Hydrometeorological Prediction Center which is collocated with the SAB in the National Precipitation Prediction Unit.

References.

Achutuni, R., R. Scofield and R. Borneman, 1998: Statistical evaluation of satellite derived precipitation estimates. *Special Symposium on Hydrology*, 113-116.

Achutuni, R., R. Scofield and R. Borneman, 1993: Statistical evaluation of an operational quantitative precipitation estimation technique. *13th Conference on Weather Analysis and Forecasting Including Symposium on Flash Floods*, 389-392.

Borneman, R., 1988: Satellite rainfall estimating program of the NOAA/NESDIS Synoptic Analysis Branch. *Nat. Wea. Dig.*, **13**, 7-15.

Scofield, R.A., 1990: Instability Bursts Associated with Extra-tropical Cyclone Systems (ECSs) and a Forecast Index of 3-12 hour Heavy Precipitation. *NOAA Technical Memorandum NESDIS 30*, U.S. Department of Commerce, Washington, D.C., 77 pp.

Scofield, R.A., 1987: The NESDIS operational convective precipitation estimation technique. *Mon. Wea. Rev.*, **115**, 1773-1792.

Scofield, R.A., and L.E. Spayd, Jr., 1984: A Technique that Uses Satellite, Radar and Conventional Data for Analyzing and Short-range Forecasting of Precipitation from Extratropical Cyclones. *NOAA Technical Memorandum NESDIS 8*, U.S. Department of Commerce, Washington, D.C., 51 pp.

Spayd, L.E., Jr., and R.A. Scofield, 1984: A Tropical Cyclone Precipitation Estimation Technique Using Geostationary Satellite Data. *NOAA Technical Memorandum NESDIS 5*, U.S. Department of Commerce, Washington, D.C., 36 pp.

Vicente, G.A., and R.A. Scofield, 1997: Real time rainfall rate estimates derived from the GOES 8-9 satellites for flash flood forecasting, numerical modeling, and operational hydrology. *13th Conference on Hydrology*, J115-J118.

ZCZC NFDSPENES ALL DDHHMM;410,0935 410,0945 350,0985 350,0965;
TTAA00 KNFD DDHHMM

SATELLITE PRECIPITATION ESTIMATES..DATE/TIME 10/5/98 0345Z
THE SATELLITE ANALYSIS BRANCH/NESDIS---NPPU--- TEL.301-763-8678
VALUES ARE MAX OR SGFNT EST. NO OROGRAPHIC CORRECTION UNLESS NOTED.
...EST'S FM: /GOES8-CNTRL AND E. U.S. / GOES10 - W. U.S...
REFER TO TPB#375 FOR DETAILS. LATEST DATA USED: GOES-8 0315Z SJK
DMSP SSMI 0036Z WESTERN GULF OF MEX

	TOTALS (2345-0315Z)
C TO NE OK COUNTIES...	
PAYNE	2.7"
OSAGE TO NR TULSA COUNTY BDR	3.6"MAX
PAYNE-NOBLE BDR	3.1"MAX
POTTAWATOMIE TO NR LINCOLN BDR	2.4"
CLEVELAND	1.8"
S KS...	
MONTGOMERY	3.0"
LABETTE	2.3"
CRAWFORD-BOURBON BDR	2.5"
W CENTRAL TO N CENTRAL MO...	
PLATTE	3.0"
RAY	2.5"
LIVINGSTON TO LINN	2.6"-3.1"

REMARKS...LOW LVL MOISTURE IN THE FORM OF HIGH PRECIP WATER VALUES
FROM WESTERN GULF OF MEXICO LIFTING NWD THRU EASTERN TX/LA AND COULD
ALLOW FF POTENTIAL TO EVEN WORSEN FROM C TO NE OK THRU SE KS INTO
W CENTRAL MO (S OF MKC) NXT SEVERAL HRS AS JET AND HIGHLY DIFFLUENT
FLOW INTERACT WITH THE EXCESSIVE MOISTURE FOR THIS TIME OF YEAR
FEEDING INTO AREA...FF POTENTIAL CONDITIONS COULD WORK THEIR WAY AS
FAR EAST AS C MO/SW MO NXT SEVERAL HRS...HOWEVER CONVECTIVE BOUNDARY
WILL BE HARD PRESSED TO MAKE IT MUCH EAST OF THESE AREAS IN THE SHT
TERM...WILL CONTINUE TO MONITOR...

GRAPHICAL PRODUCT OF ESTIMATES FOR PERIOD 2345-0315Z IS ON THE
INTERNET AT THE ADDRESS BELOW.

SEE HPC QPF GRAPHICS AND DISCUSSIONS FOR FCST...

<http://www.ssd.noaa.gov/SSD/ML/pcpn-ndx.html>
[ONLINE SSD PRECIPITATION PRODUCT INDEX]

NNNN

Figure 21. IFFA Satellite Precipitation Estimate, SPENES, Message.

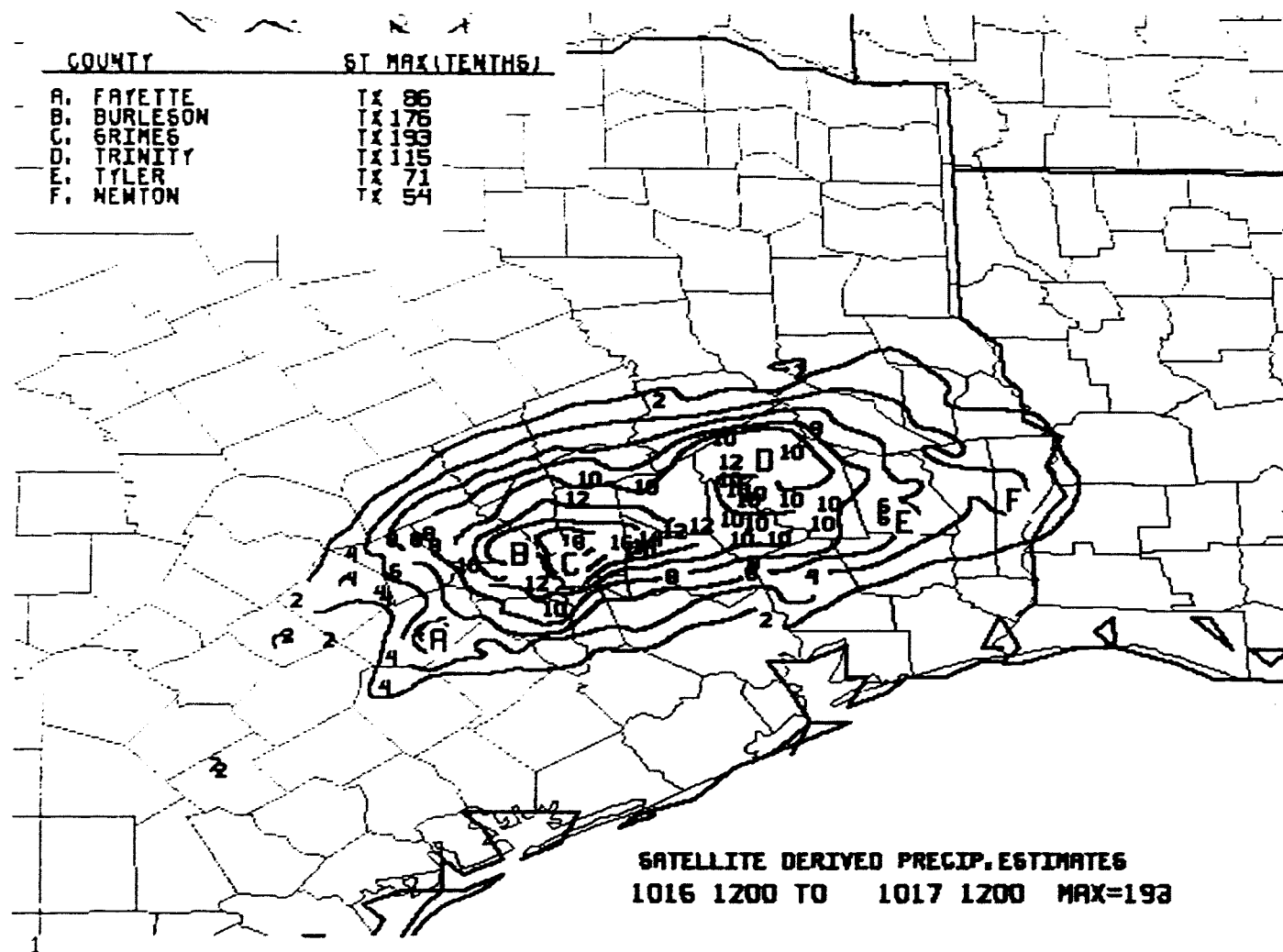


Figure 22. Graphical IFFA Precipitation Estimates in inches.

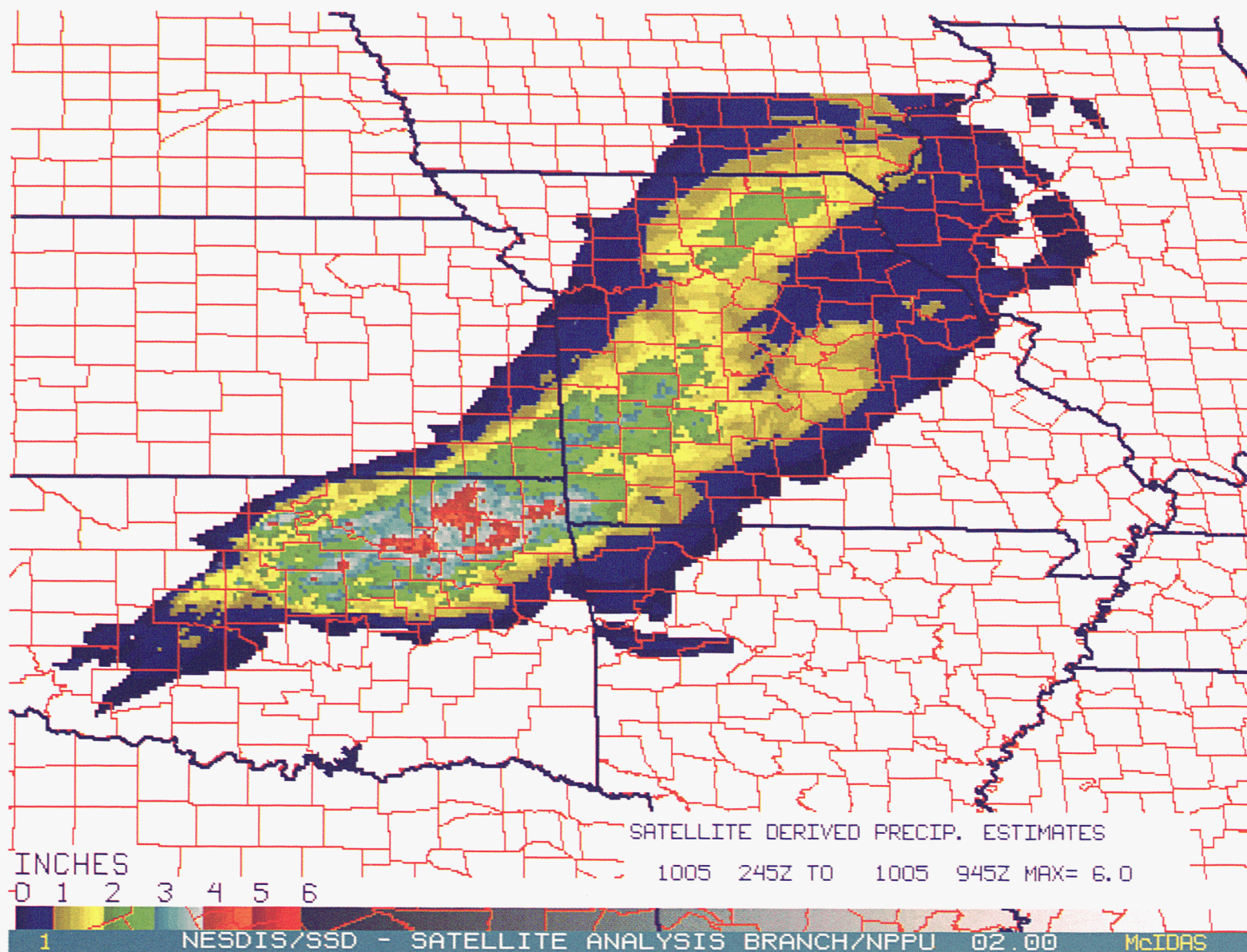


Figure 23. Internet graphic of IFFA Precipitation Estimates in inches.

VI. IMAGER ATMOSPHERIC PARAMETERS

C. Precipitation Estimates

AutoEstimator (Experimental)

Description. The Automatic Estimator uses IR cloud top temperatures, temperature changes and gradients, and a moisture correction to produce rain rates every half hour. Adjustments are made for the warmer top convection. The rates are totaled into 1 hour, 3 hour, 6 hour, and 24 hour estimated amounts (Vicente et al. 1998). The Automatic Estimator will be used operationally, in parallel with IFFA, for convective storms for the next 1 to 2 years before replacing IFFA estimates. IFFA estimates will probably still be used for winter storms since the Automatic Estimator does not produce acceptable estimates for non-convective systems. Automatic estimates will greatly increase the timeliness and coverage of satellite estimates compared with the manually derived IFFA estimates. Improvements such as incorporating additional GOES satellite, radar, and satellite microwave data into the Automatic Estimator are planned. An example of the AutoEstimator can be found in Figure 24. This data can also be accessed on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/ht/ff/>.

Accuracy. Preliminary results indicate that the autoestimator precipitation values exhibit a high bias when compared with rain gauge data and short term radar data, and have correlation values between 0.3 and 0.5.

Users. The primary user of this data currently is the SAB.

Reference.

Vicente G.A., R.A. Scofield and W.P. Menzel, 1998: The Operational GOES Infrared Rainfall Estimation Technique. *Bull. Amer. Meteor. Soc.*, **79**, 1883-1898.

NOAA/NESDIS RAINFALL AUTOESTIMATOR EXPERIMENTAL PRODUCT

ESTIMATED RAINFALL FOR 24 HOURS ENDING 1200 Z 30 OCT 98

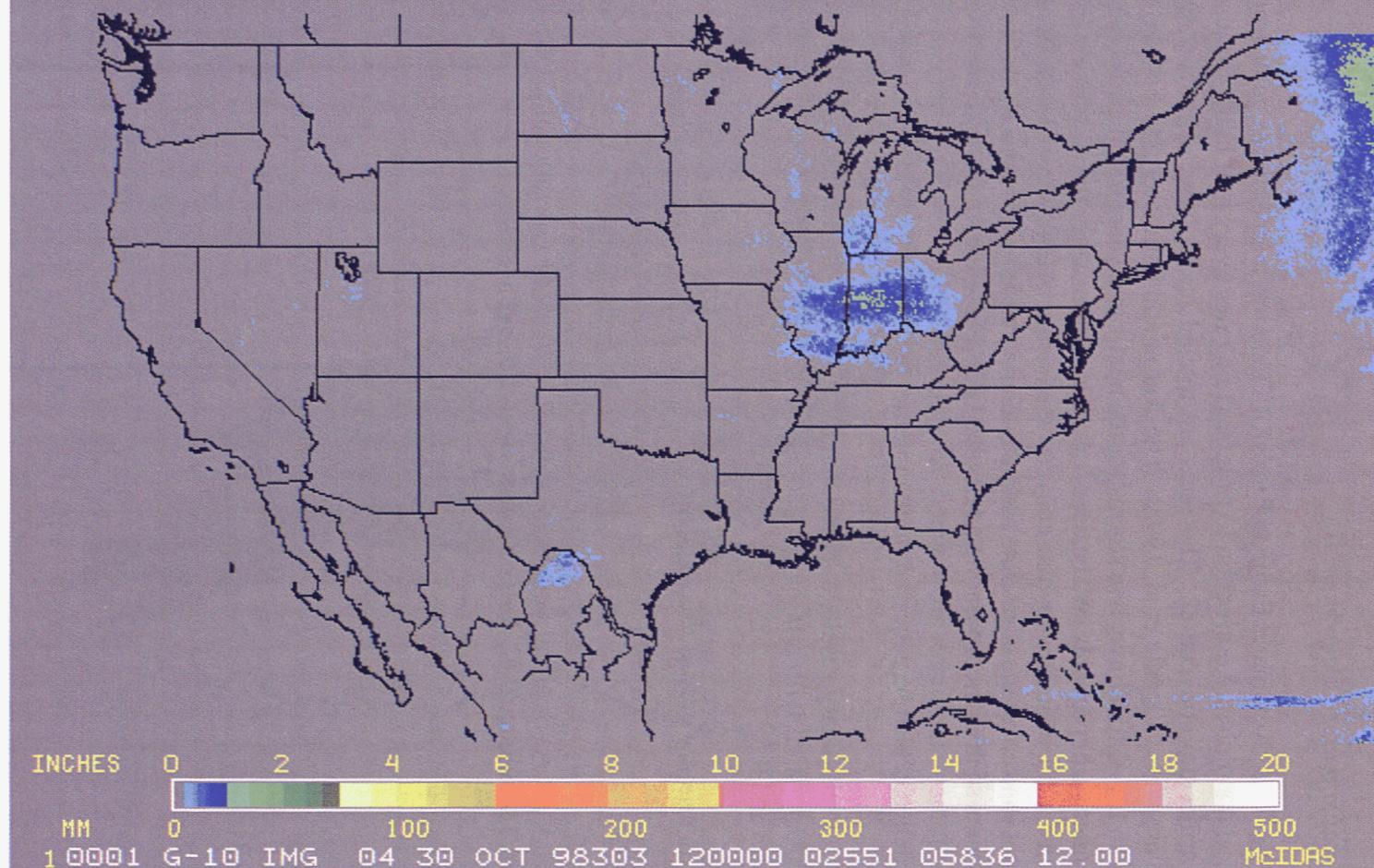


Figure 24. Rainfall estimator for 24 hour period ending 1200 UTC, October 30, 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

C. Precipitation Estimates

Multichannel Precipitation (Experimental)

Description. The GOES Multispectral Rainfall Algorithm (GMSRA) uses combined information from visible (0.65 μm), near-IR (3.9 μm) and IR (6.7 μm , 11 μm , and 12 μm) GOES measurements. For daytime rainfall, the first step consists of identifying optically thick clouds having a visible reflectance greater than 0.40. Non-precipitating cirrus is screened empirically using a gradient temperature based on the 11 μm channel, and the effective radius of cloud particles near their tops is derived from the reflected solar irradiance at 3.9 μm . Negative Brightness Temperature Difference (BTD) IR-WV(11 μm - 6.7 μm), which corresponds well with rainfall areas for very deep convective cores (Inoue, 1997), is also used for the identification of rain for cloud tops colder than 230K. The algorithm uses the effective radius to separate raining from non-raining warm clouds during daytime. The algorithm relies on IR and WV only during nighttime when rainfall is estimated for clouds having brightness temperatures colder than 240K.

For each pixel classified as containing raining clouds, the associated instantaneous rain rate is computed using a pre-calibrated probability of rain and mean rain rate for cloud top brightness temperature (11 μm) groups of 10K. The rain rate is obtained by the product of the probability of rain and the mean rain rate. A cloud growth rate, defined as the difference between the current and the previous images, and a correction factor accounting for the available moisture are used to adjust the rainfall estimates. An example of a 24 hour estimate of rainfall using the Multispectral rainfall algorithm can be found in Figure 25.

Accuracy. Preliminary results indicate that the multichannel precipitation values have somewhat of a high bias when compared with rain gauge data and short term radar data, and have correlation values between 0.2 and 0.4.

Users. The primary user of this product is the SAB.

References.

Ba, M., and A. Gruber, 1998: Development of a GOES multispectral rainfall algorithm (GMSRA), *J. Appl. Met.*, (in revision).

Inoue, T., 1997: Day-to-night cloudiness change of cloud types inferred from split-window measurements aboard NOAA Polar Orbiting satellites. *J. Met. Soc.*, Japan, **75**, 59-66.

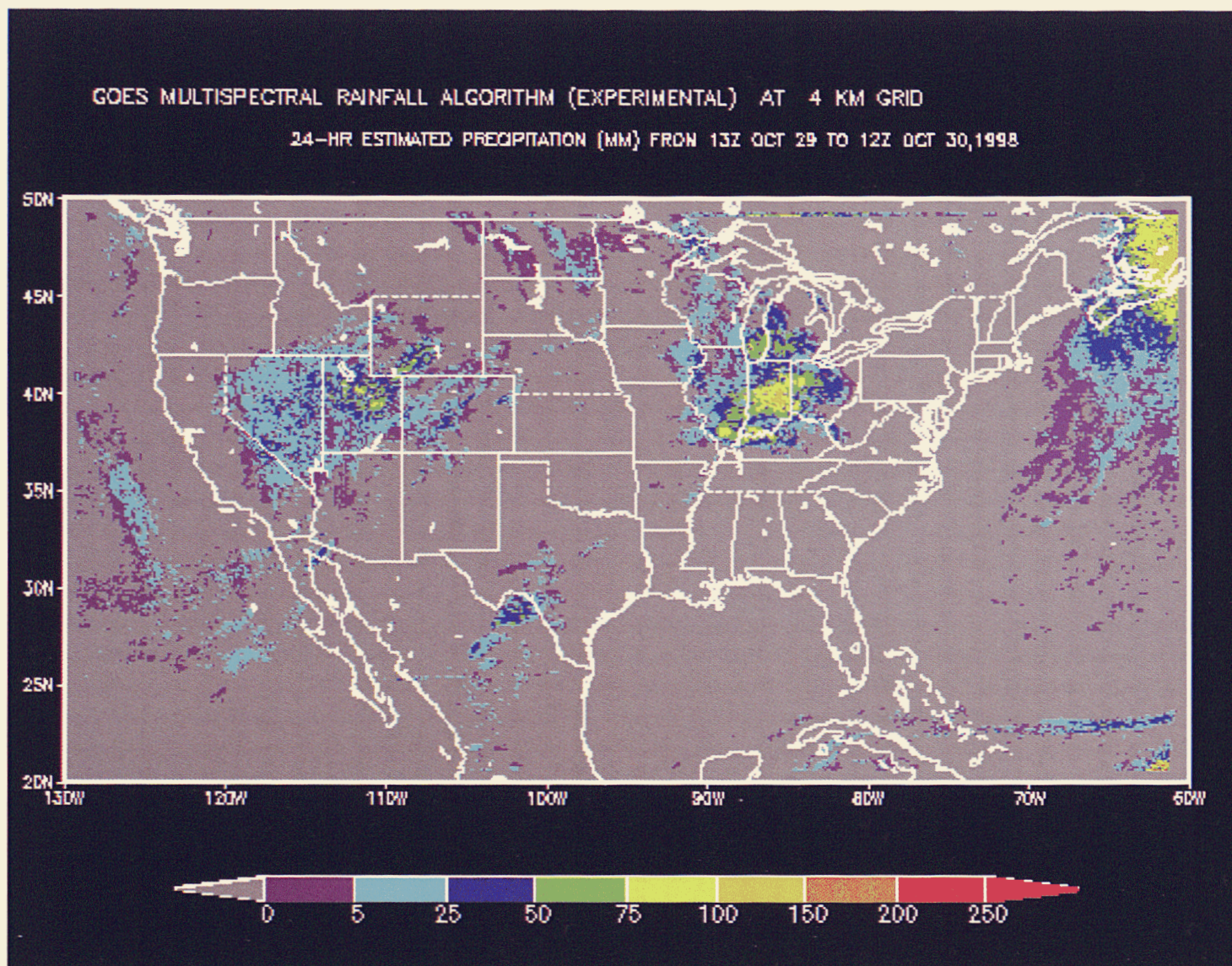


Figure 25. 24 hour multichannel rainfall estimation valid 1200 UTC, October 30, 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

C. Precipitation Estimates

Precipitation Index Histograms

Description. GOES IR images (11 μm) are converted to histograms of brightness temperatures for $1^\circ \times 1^\circ$ latitude/longitude boxes for access by the Climate Prediction Center (CPC). The CPC produces estimates of precipitation using the GOES Precipitation Index (GPI) (Arkin and Meisner, 1987) from the GOES histograms (and from those of other satellites) for the Global Precipitation Climatology Project (GPCP) (Arkin and Xie, 1994).

The Precipitation Histogram software accesses three-hourly GOES IR images on the CEMSCS (0000, 0300, 0600...2100 UTC); extracts the samples corresponding to each 1° box from 50° North to 50° South; converts the pixel value to brightness temperature; generates a 24 class histogram of the temperatures and computes the mean and spatial variance of the temperatures. The histograms, means and variances are stored on disk files for access, processing and archive by CPC. A graphical display of this product is shown in Figure 26.

At the CPC, obliquity and calibration adjustments are applied and the GPI estimates are merged with similar estimates from other geostationary satellites (including at present ECMWF Meteorological Satellite (METEOSAT) and Japanese Meteorological Agency (JMA) Geostationary Meteorological Satellite (GMS)), and, if necessary to fill gaps, from polar orbiting satellites. The resulting complete tropical fields are used for climate monitoring and diagnostics studies, and are used as one source for the global analyses produced by the GPCP (Xie and Arkin, 1996).

Accuracy. The accuracy of the temperature boundaries used in the histogram processing has not been assessed thoroughly, but is thought to be $\pm 1^\circ\text{K}$. The GPI estimates produced from different satellites for a specific region differ by up to 50%, but nearly all of the differences are removed through empirical corrections for an obliquity bias and intersatellite calibration differences. The resulting estimates have been validated on climatic time scales against rain gauge observations; the Root Mean Square (RMS) difference between monthly 2.5° averages over a 3-year period is approximately 50% with a bias of $<10\%$ (Xie and Arkin, 1995). Available evidence indicates, however, that a considerable portion, probably more than half, of that random error results from mediocre sampling in the gauge data.

Users. The primary users of these data are the NWS, universities, and the international research community.

References.

Arkin, P.A., and B.N. Meisner, 1987: The relationship between large-scale convective rainfall and cold cloud over the western hemisphere during 1982-84. *Mon. Wea. Rev.*, **115**, 51-74.

Arkin, P.A., and P. Xie, 1994: The Global Precipitation Climatology Project: First Algorithm Intercomparison Project. *Bull. Amer. Meteor. Soc.*, **75**, 401-419.

Xie, P., and P.A. Arkin, 1996: Analyses of global monthly precipitation using gauge observations, satellite estimates and numerical model predictions. *J. Climate*, **9**, 840-858.

Xie, P., and P.A. Arkin, 1995: An intercomparison of satellite estimates and gauge observations of climatic-scale monthly precipitation. *J. Appl. Meteor.*, **34**, 1143-1160.

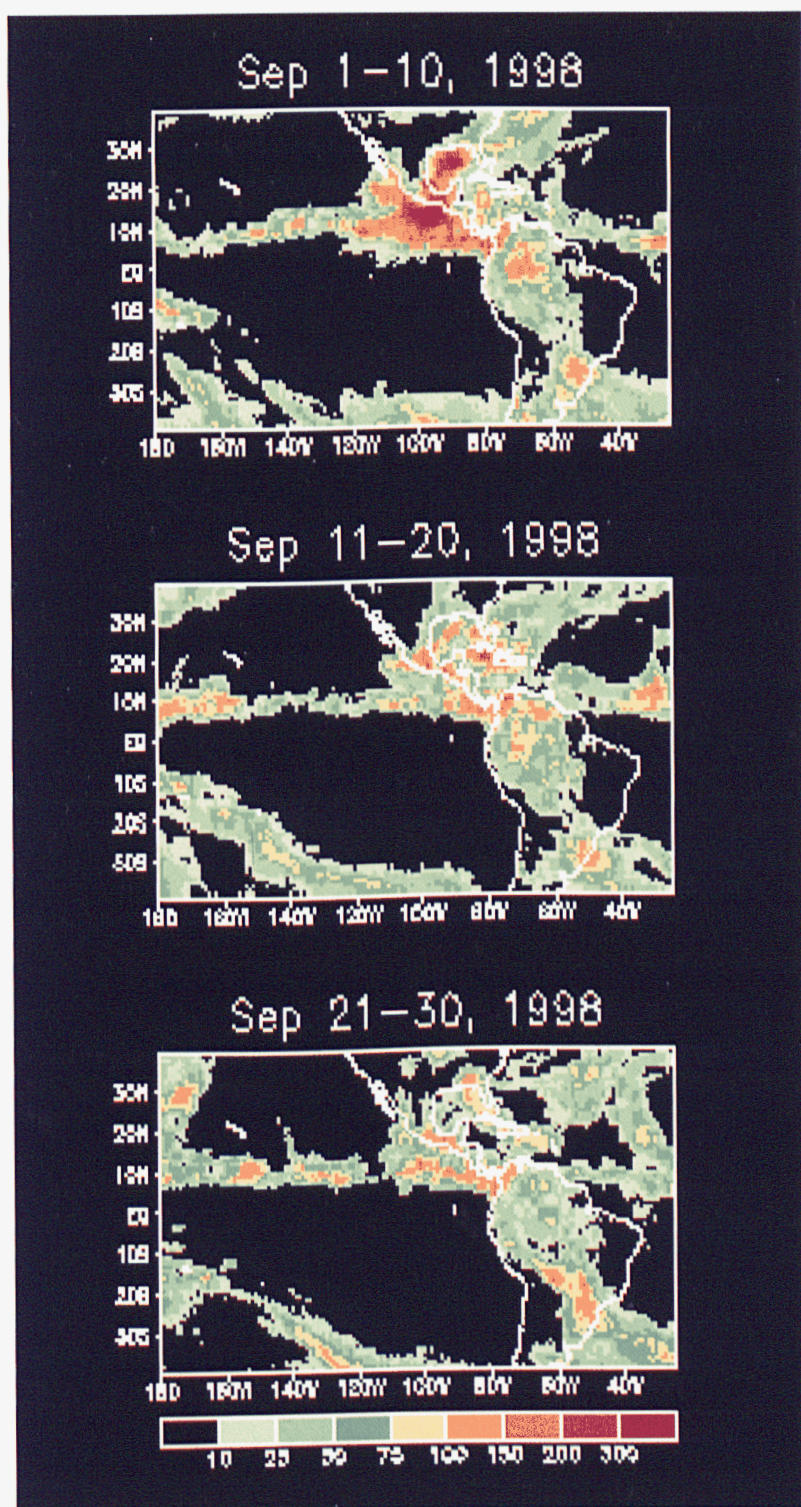


Figure 26. GPI estimates from GOES 8 and 10 for three successive 10-day periods during September 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

D. Daily and Weekly Northern Hemisphere Snow and Ice Chart

Description. NESDIS has an extensive history of monitoring snow and ice coverage. The SAB at NESDIS first began generating NH Weekly Snow and Ice Cover analysis charts derived from visible satellite imagery in November 1966. A hand drawn analysis is converted to a digital polar stereographic map showing unit areas covered by >50% snow. The data are particularly critical for depicting the total snow cover during the NH winter when albedo effects, ground surface temperatures, and evaporative properties are used as input to the NWP models. An example of the weekly product is shown in Figure 27.

In response to evolving user requirements, SAB is now producing snow/ice analyses at a higher resolution and on a daily basis (~25 km / 1024 x 1024 grid). The newer Daily NH Snow and Ice Chart, generated since February 1997, uses an array of remote sensing satellite and surface imagery products. Clear-sky imagery from both the Polar Orbiting Environmental Satellite (POES) and GOES sensors, augmented by other METEOSAT and GMS imagery, show snow/ice boundaries very well (Figure 28). In addition, microwave data from the DMSP satellite provide additional information in cloudy areas. Using several other derived snow/ice products, such as those from the National Ice Center (NIC) and the NCEP, the analysts are able to interactively compare the products so that a more accurate composite map can be produced.

Accuracy.

Weekly Product- Although no studies have been made of the chart's accuracy, as satellite data over the years has improved, so have the analyses. The accuracy varies for location and persistence of cloud cover. The North American portion is generally thought to have an accuracy better than 15 km.

Daily Product - A study is currently underway to determine the accuracy of the Daily NH Snow and Ice Chart. The production of the chart on a daily basis enables the analysts to respond faster to additions or deletions in the snow/ice cover with greater detail and accuracy.

Users.

Weekly Product - The weekly chart will be produced through Spring 1999, while validation studies for the daily chart continue. Primary users include the National Climatic Data Center (NCDC), NWS River Forecast Centers, Oceanic and Atmospheric Environmental Research Laboratories, and the U.S. Army Corp of Engineers.

Daily Product- The primary user of this chart is the NWS/NCEP for assimilation in the operational NWP models. The analysis also serves as a data source supporting NOAA's hydrometeorological and climate programs.

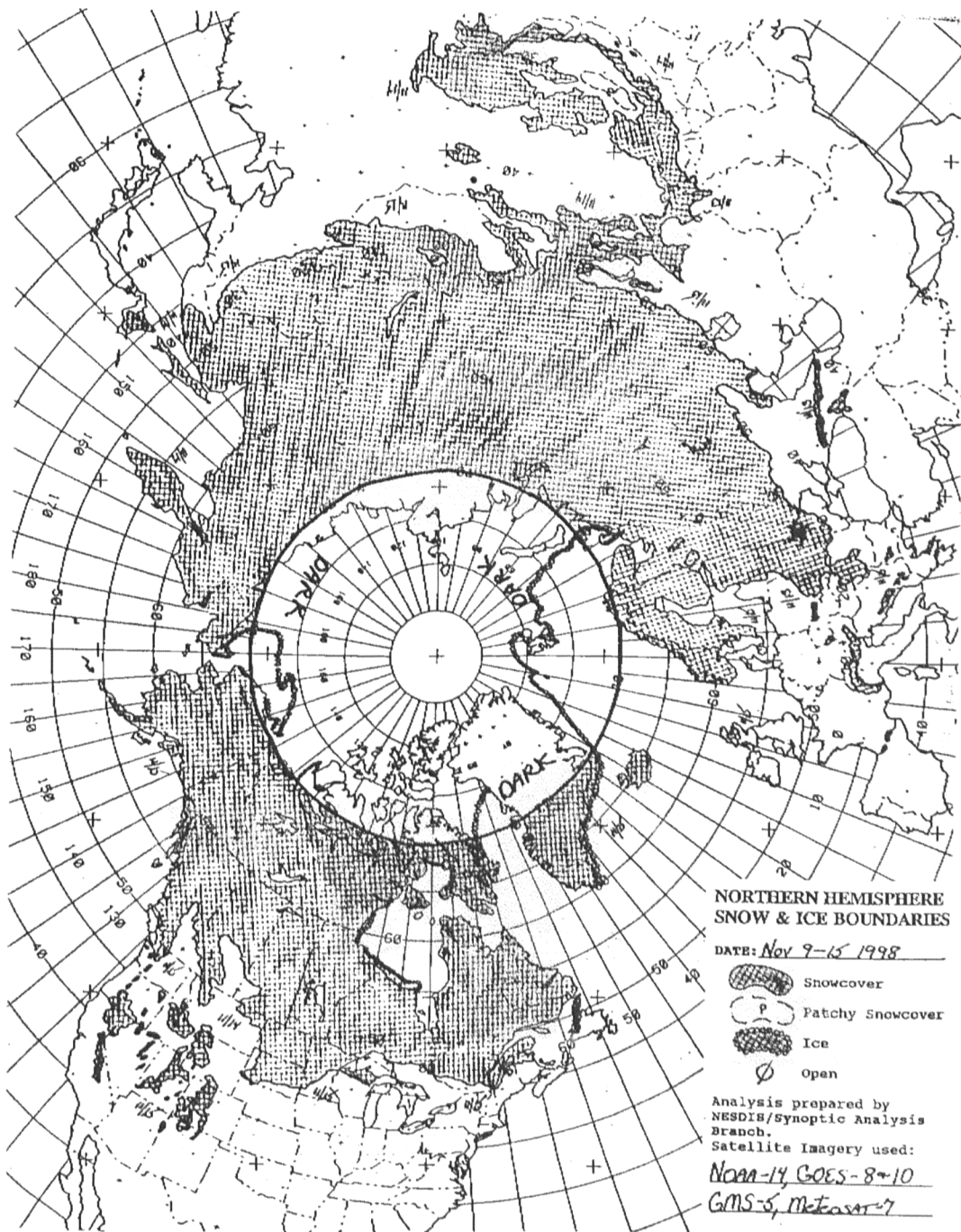


Figure 27. North American portion of the NH Snow and Ice Chart for the week of November 9-15, 1998.

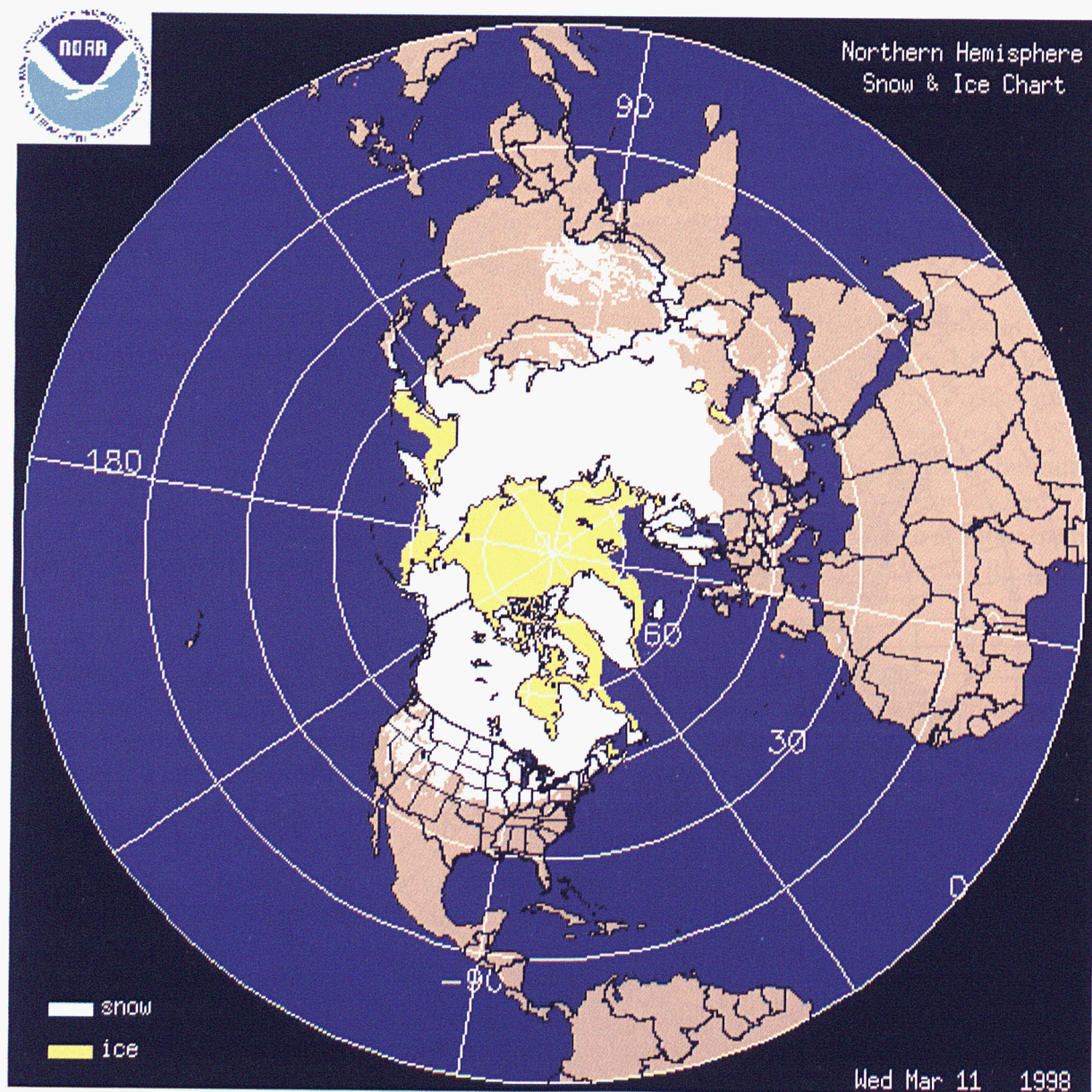


Figure 28. NH snow and ice chart for March 11, 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

E. Tropical Cyclone Position and Intensity Estimates

Description. GOES IR (channel 2 (3.9 μm) and channel 4 (11 μm)) and visible imagery (channel 1 (0.6 μm)) are used to classify tropical systems, every 6 hours, using the internationally recognized Dvorak technique. Tropical disturbances in the Atlantic, East Pacific, and Central Pacific are positioned and analyzed for intensity four times per day at synoptic times (0000, 0600, 1200, and 1800 UTC). This analysis is coordinated by phone with the appropriate hurricane center. The improved Dvorak digital technique installed on McIDAS-based workstations is used to analyze the hourly satellite imagery, and animated data loops are used to track systems. Systems are positioned to the nearest tenth of a degree using visible imagery (Figure 29), various enhancement curves (i.e., BD curve, Figure 30), and parallax corrections for storms with eyes. Intensities are measured to the nearest half T-number and entered on the Tropical Cyclone Analysis Worksheet (Figure 31). While this method performs well enough in most cases to be employed operationally, there are situations when analyst judgment can lead to discrepancies between different analysis centers estimating the same storm. In an attempt to eliminate this subjectivity, a computer-based algorithm which operates objectively on digital infrared information has been developed. The modified version has been significantly modified and advanced to include selected "Dvorak rules", additional constraints and a time averaging scheme. This modified version, the Objective Dvorak Technique (ODT), is applicable to tropical cyclones which have attained tropical storm or hurricane strength. The performance of the ODT was evaluated on cases from the 1995 and 1996 Atlantic hurricane seasons. Reconnaissance aircraft measurements of minimum surface pressure were used to validate the satellite-based estimates. Statistical analysis indicated the technique was competitive with, and in some cases superior to the Dvorak-based intensity estimates produced operationally by satellite analysts from tropical analysis centers. An example of the performance of the ODT algorithm can be found in Figure 30a.

Accuracy. Cyclone positions with well-defined eyes are regarded as being accurate to within 10 nm, while weaker systems can be considerably less accurate. Preliminary studies in the Atlantic basin suggest intensity errors average one half T-number compared to operational reconnaissance data.

Users. The main users are the TPC in Miami, Florida, and the Central Pacific Hurricane Center (CPHC) in Honolulu, Hawaii.

References.

Dvorak, V. F., 1993: *Workbook on Tropical Clouds and Cloud Systems Observed in Satellite imagery. Tropical Cyclones, Volume 2.* U. S. Department of Commerce, Washington, D.C., 366 pp.

Dvorak, V.F., 1975: Tropical Cyclone intensity analysis and Forecasting from Satellite Imagery, *Mon. Wea. Rev.*, **103**, 420 - 430.

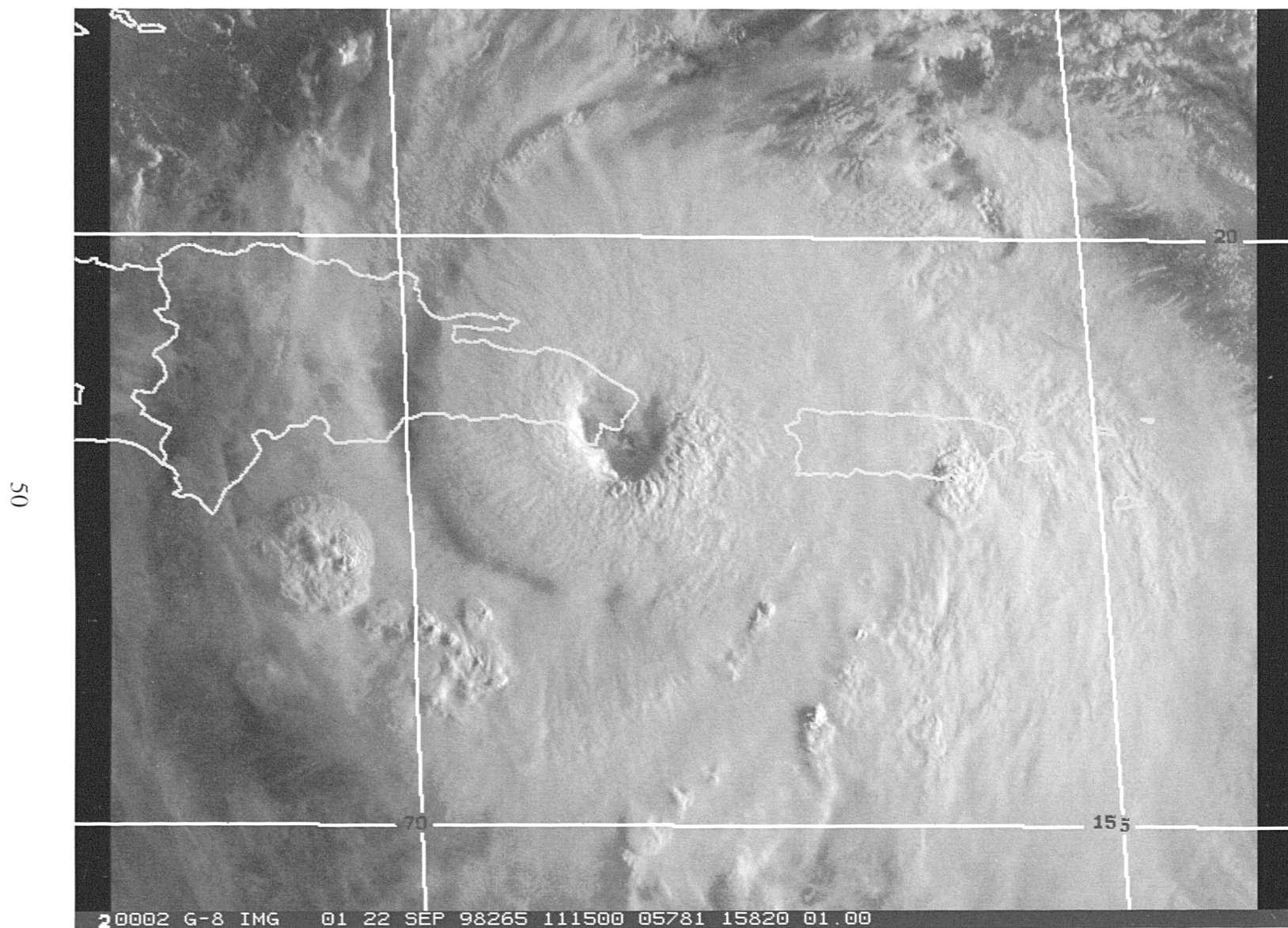


Figure 29. Hurricane Georges, visible satellite image, taken at 1115 UTC, September 22, 1998.

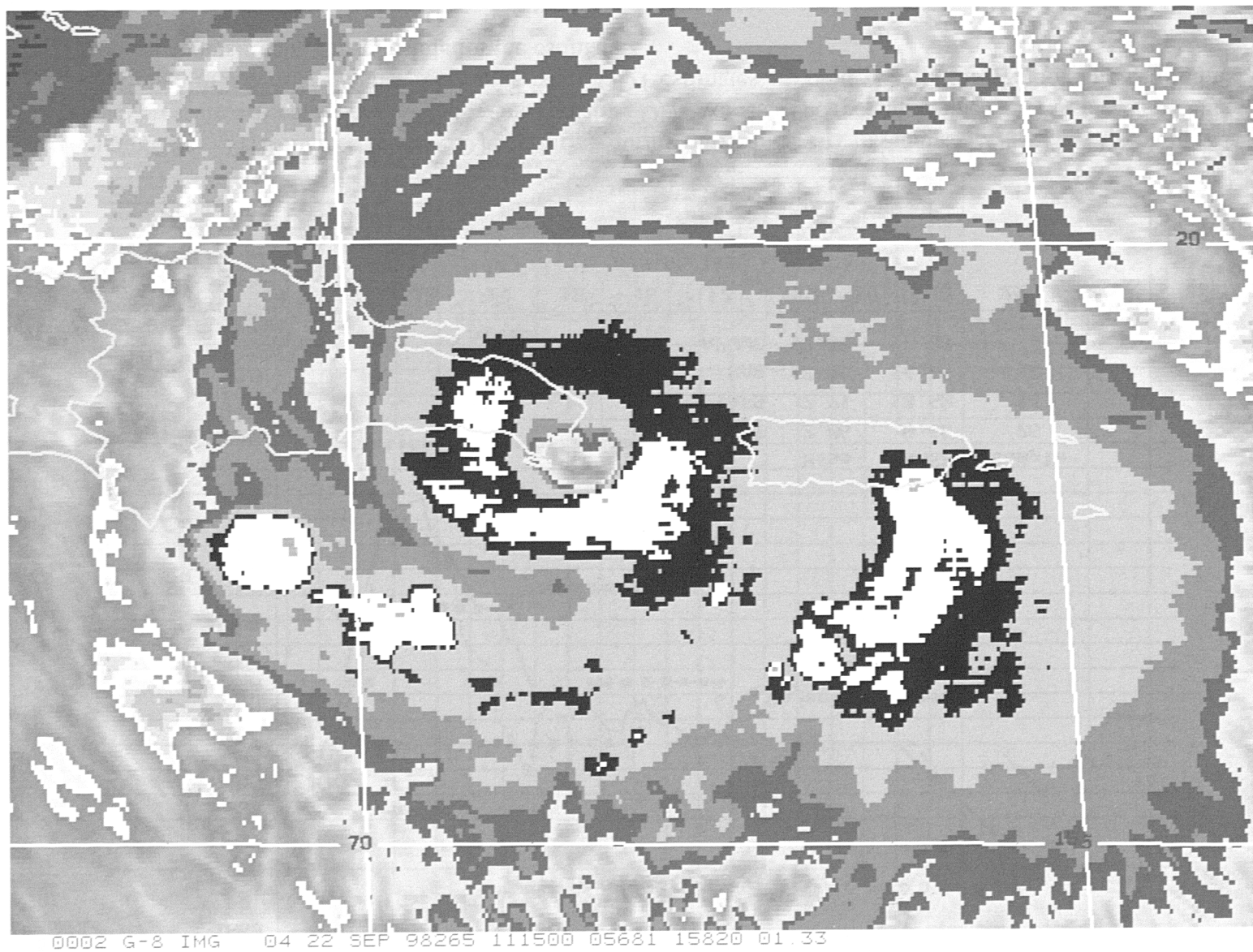


Figure 30. Hurricane Georges, displayed with the BD enhancement curve, taken at 1115 UTC, September 22, 1998.

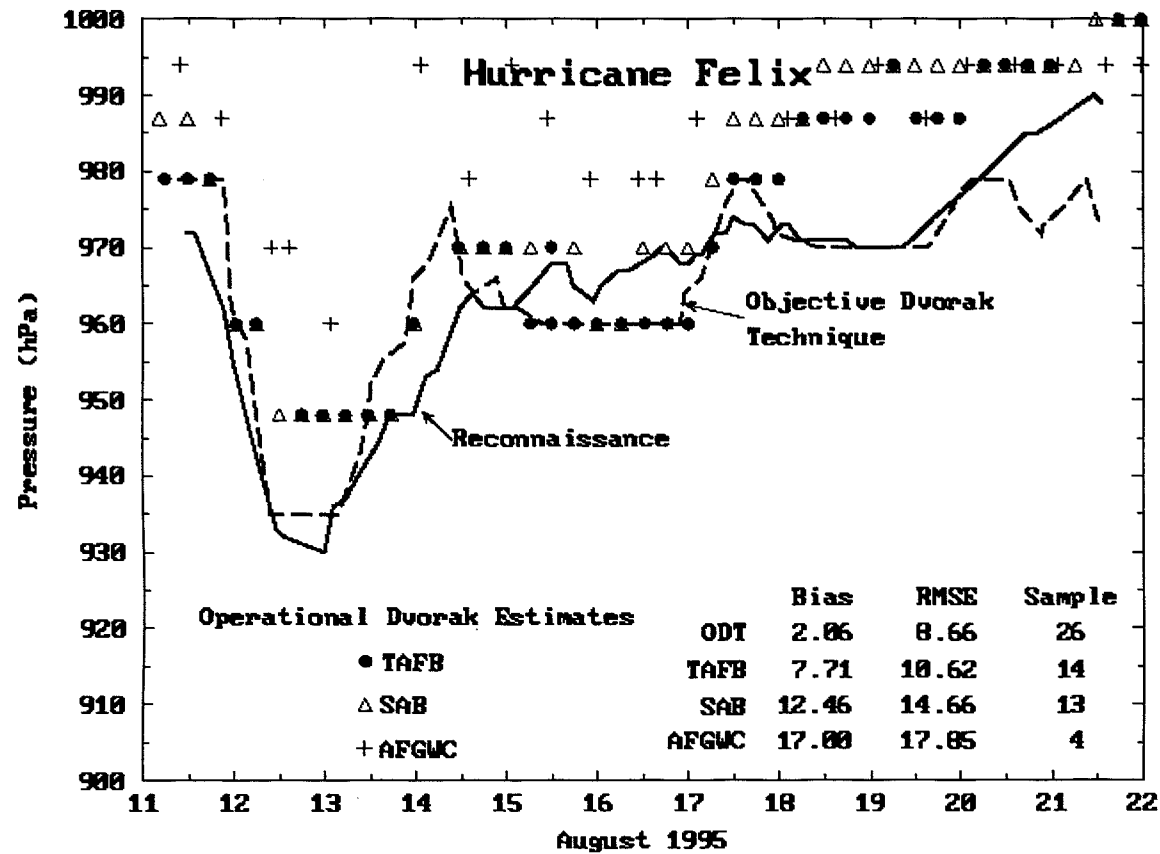


Figure 30a. Performance of the ODT algorithm during hurricane Felix in August 1995. The minimum sea level pressure estimates are graphed by interpolating ODT values. The reconnaissance aircraft measurements are drawn in a similar manner for comparison. ODT estimates are plotted, with the symbols indicating the tropical analysis center responsible for the estimate.

VI. IMAGER ATMOSPHERIC PARAMETERS

F. Volcanos

Volcano Ash Advisory Statements

Description. On November 1, 1997 the Washington Volcano Ash Advisory Center (VAAC) was established under the International Airways Volcano Watch, coordinated by the International Civil Aviation Organization (ICAO) to help warn aircraft of the major hazards associated with volcanic ash. GOES data for North America, Central America, and South America are used by the Washington VAAC to prepare Volcano Ash Advisory Statements (VAAS) (Figure 32). These are updated every 6 hours or as required and include information as to the vertical extent, aerial extent, onset and duration of explosive eruptions. Upon notification and confirmation of an explosive volcanic eruption, NESDIS continuously analyzes and issues VAAS's to the aviation community using IR, visible and multispectral imagery. Included with these messages are graphical analyses of detectable ash clouds (Figure 33). Analyses are prepared and disseminated by GTS and Internet as often as necessary when ash poses a serious threat to aviation. Assistance can be provided worldwide to other VAACs through the use of METEOSAT, GMS, and POES satellite imagery.

Accuracy. No studies have been done on the accuracy of GOES Volcanic Hazard Alert Messages. The amount and type of ash cloud differs from eruption to eruption, making the ability to track it quite variable. However, messages derived from the GOES imagery are by far the most timely and precise.

Users. Primary users include the aviation and geophysical community within NOAA Federal Aviation Administration (FAA), U.S. Geological Survey (USGS), Department of Defense (DoD), and the Smithsonian Institute.

References.

Matson, M., J.S. Lynch and G. Stephens, 1991: Monitoring Eruptions Using NOAA Satellites. *U.S. Geological Survey Bulletin 2047- Proceedings of the 1st International Symposium on Volcanic Ash and Aviation Safety*, 373-376.

Stephens, G., 1993: Volcano Detection and Monitoring Using Satellite Data. *Proceedings to the Japan- United States Technology Workshop on the Application of Remote Sensing To Natural Disaster Reduction*, 67.

Streett, D., 1999: Satellite-based volcanic ash advisories and an ash trajectory model from the Washington VAAC. *Preprint Volume, 8th Conference on Aviation, range, and Aerospace Meteorology*, 290-294.

FVXX20 KWBC 051215

.
VOLCANIC ASH ADVISORY STATEMENT
ISSUED 1215 UTC 05 AUG 1997 BY THE WASHINGTON VAAC

.
SOUFRIERE HILLS VOLCANO 97-226 (WEST INDIES) 16.72N 62.18W

.
BACKGROUND: SOUFRIERE HILLS MONTSERRAT (1600-05)
SUMMIT HEIGHT 3000 FT (915 M)

.
SOURCES OF INFORMATION: GOES-8 VISIBLE INFRARED AND MULTISPECTRAL
IMAGERY 0000Z GUADELOUPE SOUNDING AND MVO

.
ERUPTED AT 0845 UTC ON 05 AUG 1997

.
DETAILS OF ASH CLOUD: GOES-8 HIGH RESOLUTION VISIBLE AND INFRARED
IMAGERY THROUGH 1115 UTC SHOWED TWO PLUMES EXTENDING OFF THE ISLAND OF
MONTSERRAT. THERE ARE ALSO SOME SCATTERED LOW BUT BUILDING CLOUDS AND
SOME THIN HIGH LEVEL CLOUD COVER ACROSS THE REGION. THE LOW LEVEL PLUME
WHICH IS ESTIMATED BELOW FL200 SNAKES CONTINUOUSLY FROM THE SUMMIT TO
THE WEST NORTHWEST (300 DEGREES) OUT 200 KM (108 NMI) AND IS ROUGHLY 66 KM
(36 NMI) WIDE AND CONTAINED WITHIN POINTS 16.76N62.2W 16.85N63.4W 17.74N63.8W
17.75N63.2W 17.31N62.9W 17.02N62.2W. THE HIGHER LEVEL PLUME ESTIMATED BETWEEN
FL200 AND FL350 EXTENDS EAST (90 DEGREES) FROM THE SUMMIT OUT 112 KM (60 NMI)
TO POINT 16.8N61.1W AND IS ROUGHLY 55 KM (30 NMI) WIDE.

.
TRAJECTORY: THE LOWER PLUME IS MOVING TO THE WEST NORTHWEST
BETWEEN 25 AND 35 KNOTS. THE HIGH LEVEL PLUME IS MOVING EAST AROUND 10 TO
20 KNOTS.

.
OUTLOOK: SEE LATEST VAFTAD MODEL RUN AND SIGMETS.

.
NEXT ADVISORY WILL BE ISSUED AROUND 05/1530 UTC.

.
PLEASE REFER TO SIGMETS FOR CURRENT WARNINGS.

.
NNNN

Figure 32. Volcanic Hazards Alert Message for the Soufriere Hills eruption.

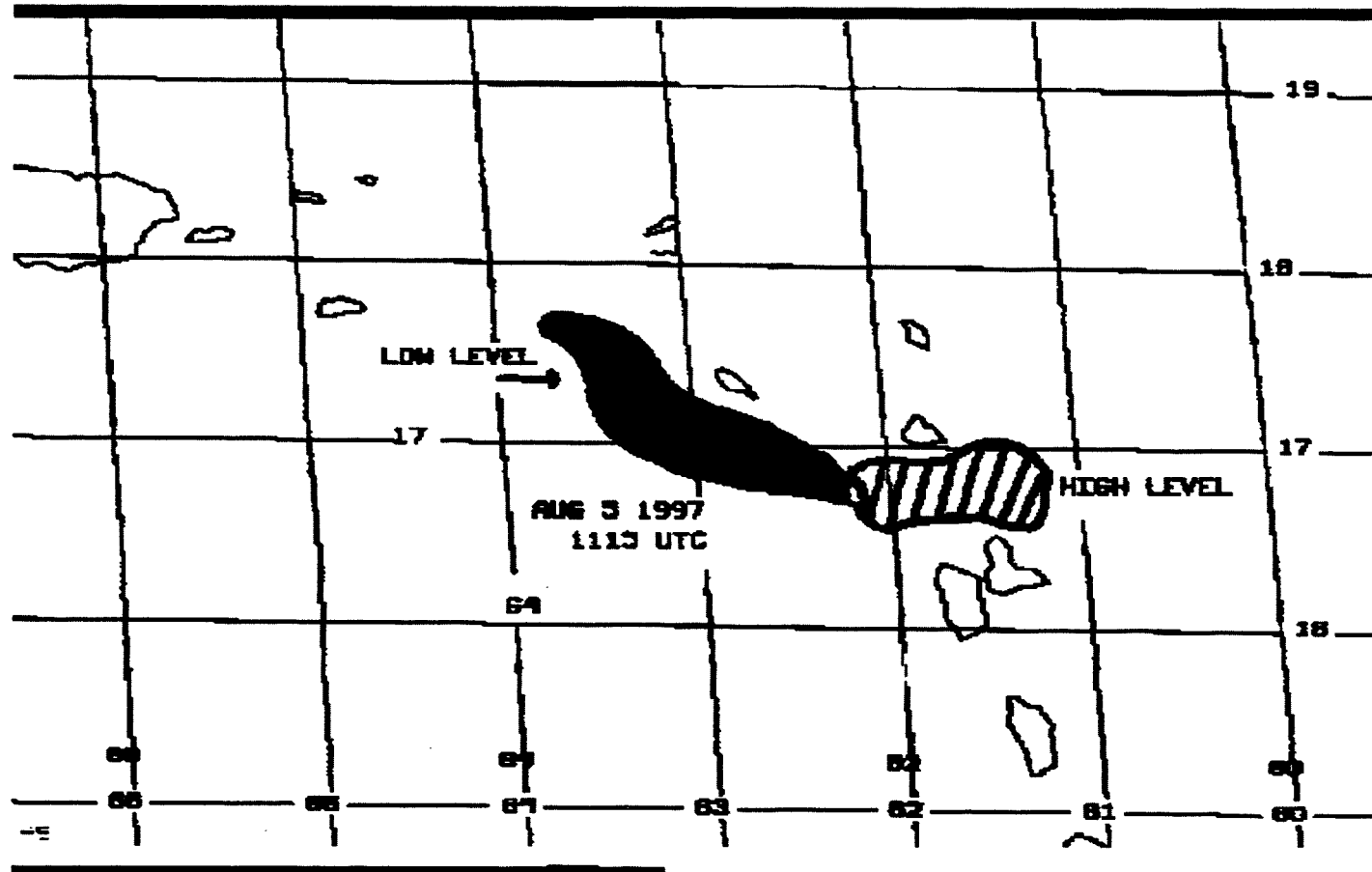


Figure 33. Graphical analysis of the ash plume from SOUFRIERE HILLS

VI. IMAGER ATMOSPHERIC PARAMETERS

F. Volcanos

Volcanic Ash Product (Experimental)

Description. Volcanic ash can result in a serious hazard to the operation of jet aircraft downwind from erupting volcanos. The primary tool that is used to detect ash clouds from the GOES satellite is the temperature difference between the 10.7 μm and 12.0 μm IR bands, often referred to as the “split window” technique. Sometimes, however, the ash is not distinctly visible in this imagery, especially when there is a low level ash plume in moist tropical environments. Recently, an improved technique was developed to detect ash that uses a shortwave IR channel centered at 3.7 μm . By taking the temperature difference in the 3.7 μm and 10.7 μm channels, then adding that to the “split window” image described previously, the ash cloud stands out more readily. The example shown in Figure 34 is for an eruption of Mt. Popocatepetl volcano in southern Mexico near Mexico City on April 27, 1998. The volcanic ash cloud is displayed as a bright white area to the east of the volcano. The white patch near the volcano could be due to release of volcanic ash, sulfur dioxide, or the “hot spot” of the volcano cone itself.

Accuracy. Extensive validation of this product has not been completed, since volcanic eruptions are such rare events. Operational experience so far has shown that this product provides improved detection of volcanic ash, but with some false alarms caused by certain types of cirrus clouds.

Users. Current and potential users of this product include: VAACs, the NWS Aviation Weather Center, USGS volcano observatories, and the FAA.

Reference.

Ellrod, G. P., and B. Connell, 1999: Improvements in volcanic ash detection using GOES multispectral image data. *Preprint Volume, 8th Conference on Aviation, range, and Aerospace Meteorology*, 326-329.

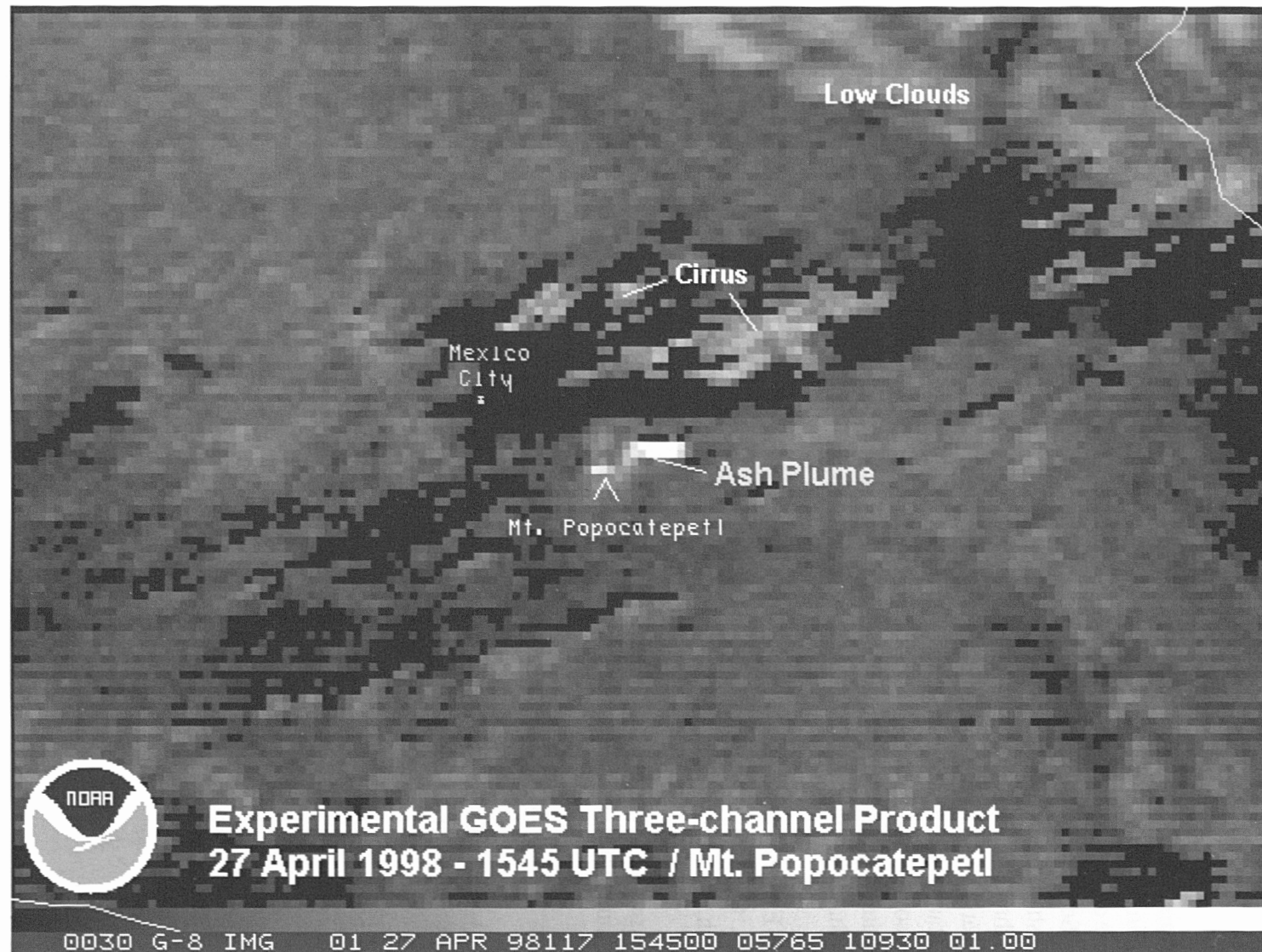


Figure 34. Three channel volcanic ash product for Mt. Popocatepetl volcano near Mexico City on April 27, 1998.

VI. IMAGER ATMOSPHERIC PARAMETERS

G. Aviation

Fog (Experimental)

Description. Because low clouds and fog have temperatures similar to clear ground, they are often difficult to detect using a single IR window channel. This is a problem, particularly at night, when no visible imagery is available. However, there is a significant enough difference between the emissivity of liquid water clouds at 3.9 μm and 10.7 μm that an image created from the brightness temperature difference between the two channels can be used to locate regions which are covered by fog and other low level liquid water clouds. Figure 35 compares the fog product (upper panel) with the 10.7 μm infrared window channel (lower panel) for nighttime images over the Great Plains. The thunderstorm over Nebraska is clearly evident in both products, but low level liquid water clouds over Kansas, eastern New Mexico, and northern Texas are seen only in the fog product. When used in combination with 10.7 μm imagery, the fog product may be used to assess supercooled cloud potential. This product is also available on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/fog.html>.

Accuracy. The GOES' 3.9 and 10.7 μm channels, and thus the fog product, have a 4 sq. km instantaneous geometric fov.

Users. This product is available on all RAMSDIS systems and will be available to all NWS forecasters on AWIPS.

References.

Ellrod, G.P., 1994: Detection and analysis of fog at night using GOES multispectral infrared imagery. *NOAA Technical Report NESDIS 75*, 22pp.

RAMM, 1996: GOES 3.9 μm channel tutorial. <http://www.cira.colostate.edu/ramm/goes39/cover.htm> (10 November 1998).

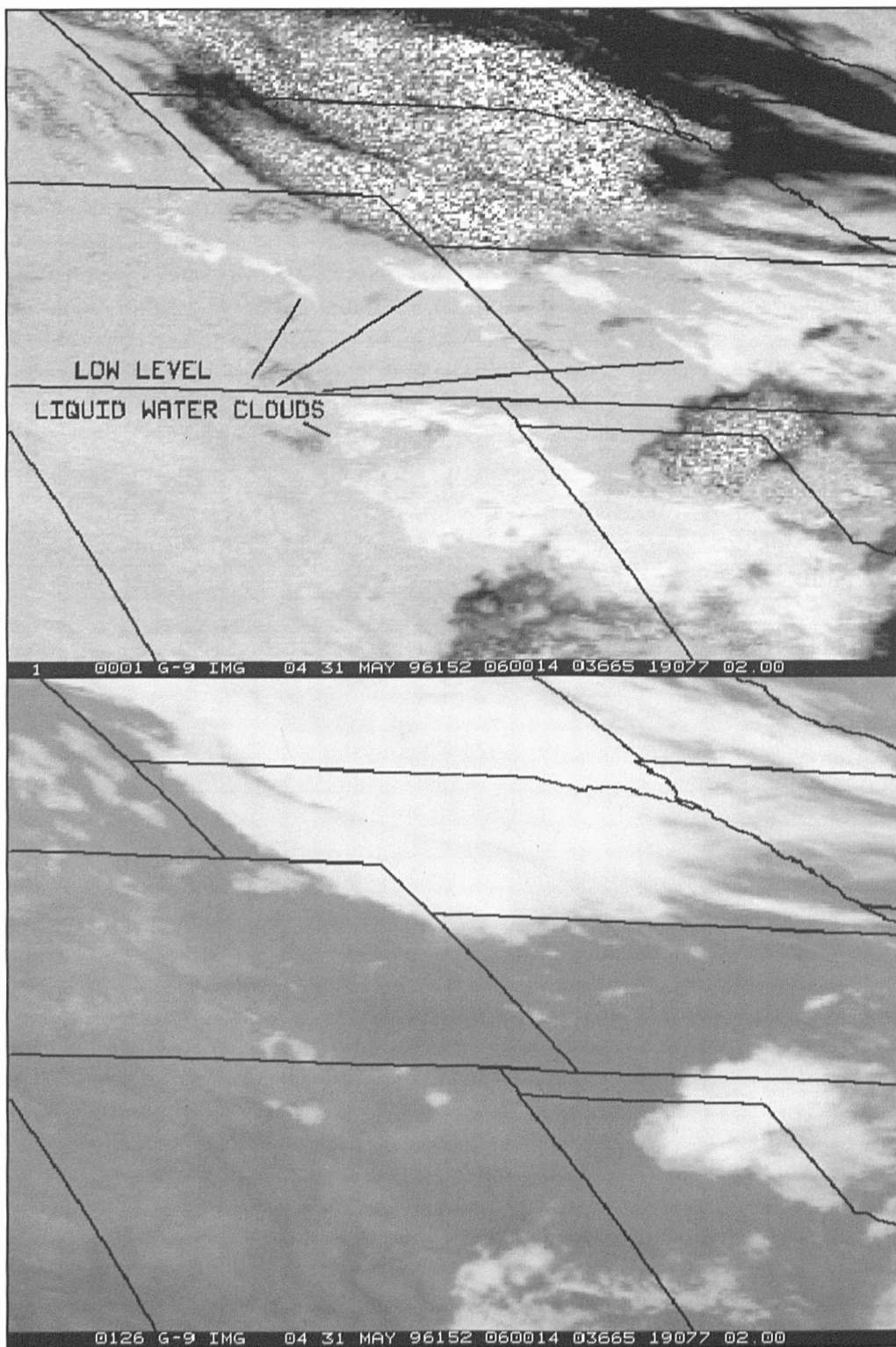


Figure 35. Fog product (upper) and 10.7 μm channel (lower) images from 0600 UTC, May 31, 1996.

VI. IMAGER ATMOSPHERIC PARAMETERS

G. Aviation

Aircraft Icing (Experimental)

Description. An experimental satellite image product has been developed for the detection of supercooled water clouds conducive to in-flight aircraft icing. The product uses multispectral data in three IR channels (3.9 μm , 10.7 μm , and 12.0 μm), and the visible channel (0.6 μm) from the imagers onboard the GOES. The icing imagery may be produced day or night using separate procedures.

The technique used to produce the image is a series of successive threshold tests. The tests determine factors such as the proper range of IR cloud top temperatures (0 to -15°C), dual IR channel temperature differences, and visible channel brightness for each image pixel. A decision tree determines if icing is likely to be present. Figure 36 provides an example of the experimental product. Potential icing areas are color enhanced light blue. The remainder of the image shows the basic IR data with no enhancement.

The icing imagery cannot show any icing areas that are covered by higher cloud layers. Due to the need to remove subfreezing ground scenes from the imagery during the colder months of the year, there is a period within two hours after sunrise and two hours before sunset when no icing can be detected. This product is available on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/icg.html>.

Accuracy. Preliminary verification by the FPDT of NESDIS during the winter of 1996-97 showed that the experimental icing images can detect around 70% of all icing situations during the middle part of the day, based on analysis of aircraft pilot reports. The false alarm rate is believed to be low (10% or less).

Users. The products are accessed on the internet at the address above by various aviation interests: pilots, FAA, NWS forecasters, and researchers.

Reference.

Ellrod, G. P., and J. P. Nelson, 1997: Detection of potential aircraft icing regions with GOES multispectral data. *Proceedings, 35th Aerospace Sciences Meeting, American Institute for Aeronautics and Astronautics (AIAA)*, paper #AIAA 97-0412, AIAA, Reston, VA, 9pp.

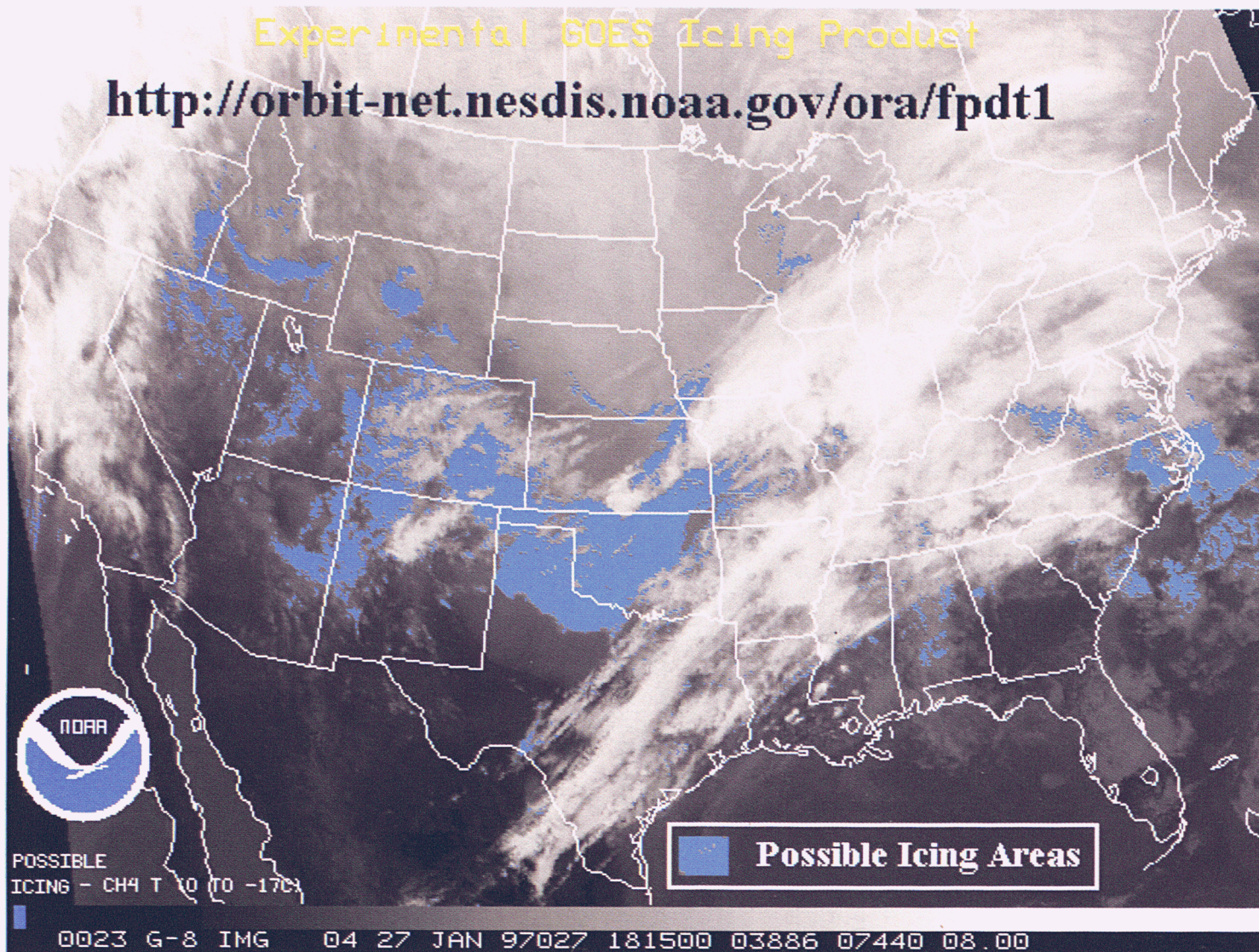


Figure 36. Experimental GOES icing product for detecting supercooled water clouds conducive to in-flight aircraft icing.

VI. IMAGER ATMOSPHERIC PARAMETERS

H. Fire, Smoke and Aerosol

Reflectivity (Experimental)

Description. The reflectivity product, which is a combination of 3.9 μm and 10.7 μm imagery, estimates the reflected solar component of 3.9 μm radiation. Liquid water clouds are much more reflective at 3.9 μm than ice water clouds and may be distinguished from one another using the reflectivity product. Figure 37 compares the appearance of the two types of clouds with a visible image. When the reflectivity product is used with the 10.7 μm channel, it is possible to assess supercooled cloud potential. When it is used with the visible channel, liquid water clouds over snow fields can be located.

The reflectivity product (as well as the fog product and 3.9 μm imagery) is also useful for the detection of fires. In this case, the signal is not due to the solar component or emissivity of the 3.9 μm image, but rather to that channel's sensitivity to subpixel 'hot spots'. Figure 38 shows a fire in California as tracked through a sequence of images, beginning with the fog product and moving to the reflectivity product. This product is available on the internet at: <http://www.cira.colostate.edu/ramm/goes39/cover.htm>.

Accuracy. The GOES 3.9 μm and 10.7 μm channels, and thus the reflectivity product, have a 4 sq. km instantaneous geometric fov. Detection of fires is limited by cloud obscuration and by the size and intensity of the fire. Weaver et al. (1995) have estimated that unexpectedly small wildfires burning actively at 325 K, 450 K, and 800 K would appear significantly warmer against a background temperature of 286 K.

Users. This product is available on all RAMSDIS systems and may be available on AWIPS.

References.

RAMM, 1996: GOES 3.9 μm channel tutorial. <http://www.cira.colostate.edu/ramm/goes39/cover.htm> (10 November 1998).

Weaver, J.F., J.F.W. Purdom and T.L. Schneider, 1995. Observing forest fires with the GOES-8, 3.9 μm imaging channel. *Wea. and Fcstg.*, **10**, 803-808.

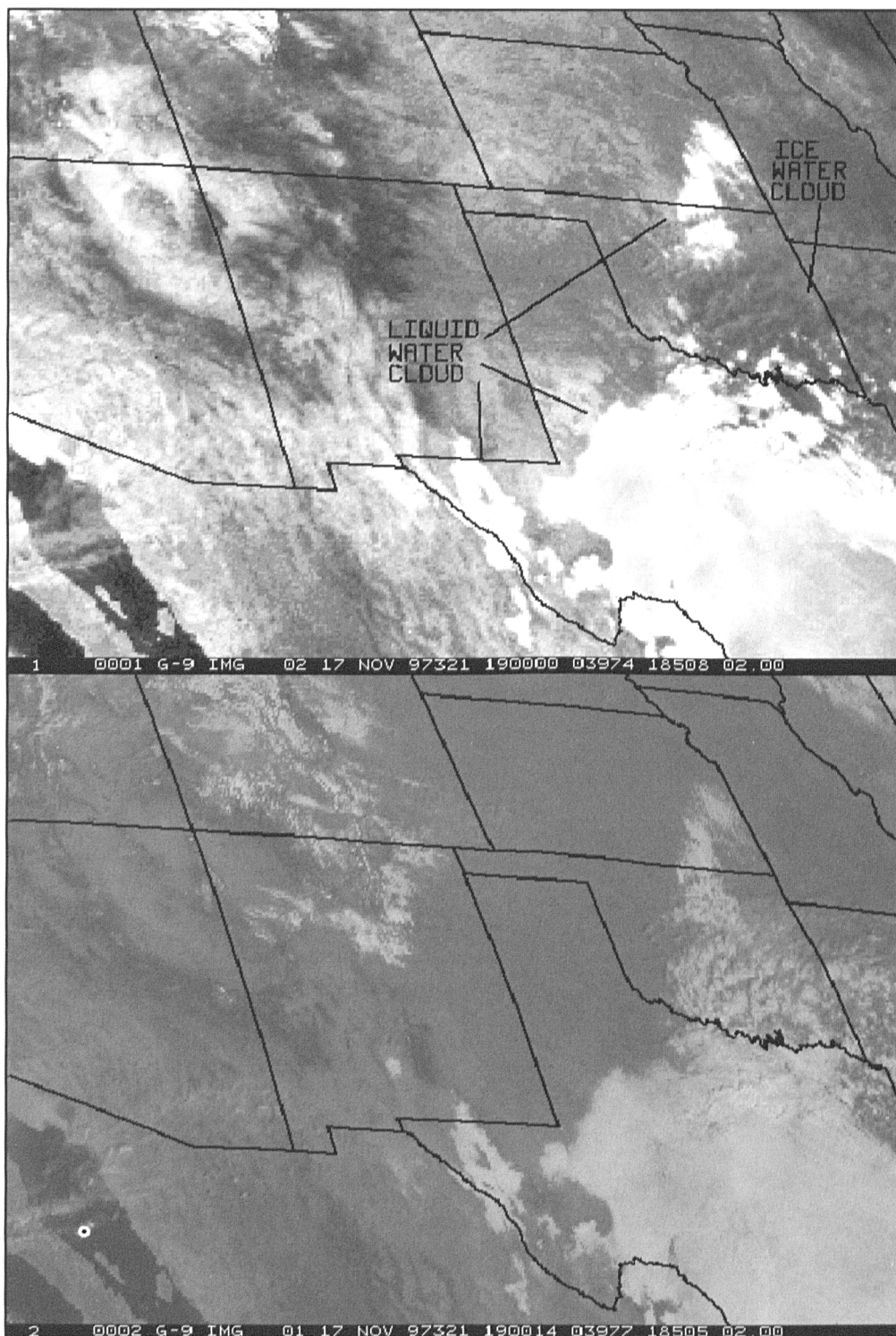


Figure 37. The reflectivity product (upper) and the visible image (lower) over Texas at 1900 UTC, November 17, 1997.

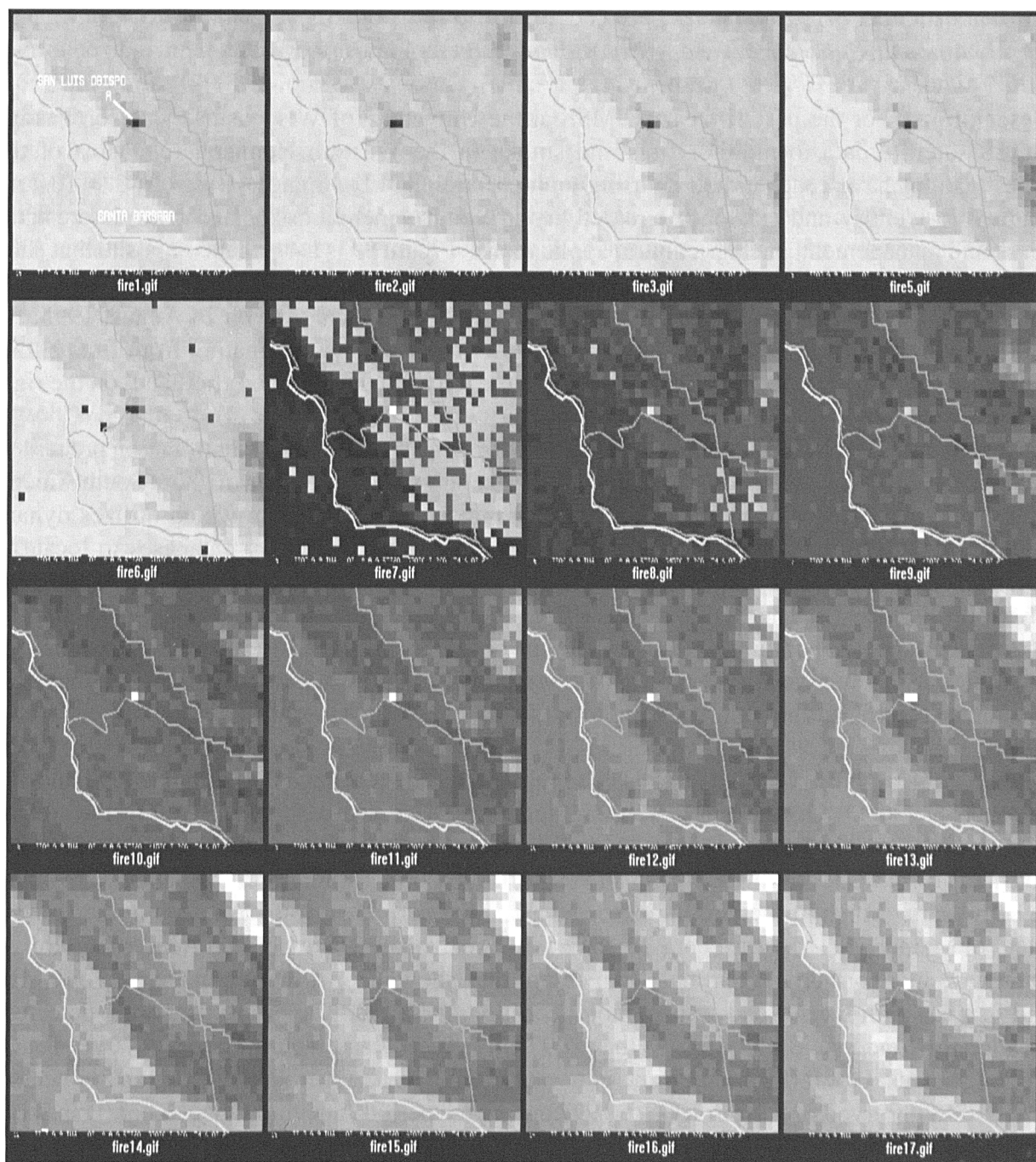


Figure 38. Multiple panel image depicting a California fire on August 8, 1997 (dark pixels) as seen in the fog product (first six images), and the reflectivity product (light colored pixels) in the remaining images.

VI. IMAGER ATMOSPHERIC PARAMETERS

H. Fire, Smoke and Aerosol

Automated Biomass Burning Algorithm (ABBA) (Experimental)

Description. For the past 10 years CIMSS at the University of Wisconsin - Madison has used GOES satellite data to monitor fires and smoke in the Western Hemisphere. Most of their investigations have concentrated on using multispectral GOES-8 imagery (visible, 3.9, 10.7, and 12 μm) to identify and catalogue fire activity in South America associated with deforestation, grassland management, and agricultural applications. Figure 39 is a 4-panel composite that shows how fires are observed in South America in multispectral GOES imagery. Each panel represents a region 780 by 800 km centered in central Brazil at 1:45 P.M. local time on 24 August 1995. The milky regions in the GOES-8 "visible" panel show smoke plumes emanating from fires burning along the boundary between the selva (forest, on the left) and the cerrado (grassland, on the right).

In order to monitor fire activity in GOES imagery for large areas, the fire identification process was automated. CIMSS developed ABBA to characterize sub-pixel burning throughout South America. The GOES ABBA is a contextual multispectral thresholding algorithm which utilizes dynamic local thresholds derived from the GOES satellite imagery and ancillary databases to locate fire pixels and provide estimates of the sub-pixel area and mean temperature of the fire(s) (Prins and Menzel, 1992; 1994). The GOES-8 ABBA fire product includes: fire location (lat./lon.), estimates of fire size and temperature, 3.9 and 10.7 μm observed brightness temperatures, background brightness temperatures, albedo statistics, ecosystem type, and a flag for non-processed fire pixels to indicate the reason for not processing.

Diurnal (1145, 1445, 1745 and 2045 UTC) multispectral data collected during the 1995 and 1997 fire seasons (June - October) in South America were processed with version 5.6 of the GOES-8 ABBA (Prins et. al., 1998). Figure 40 represents composites of the GOES-8 ABBA fire pixels detected at 1745 UTC during the 1995 and 1997 fire seasons. Similar burning patterns are evident in both years. Much of the burning occurred along the perimeter of the Amazon in the Brazilian states of Maranhao, Tocantins, Para, Mato Grosso, Amazonas, Rondonia, and Acre, and in Bolivia, Paraguay, and Northern Argentina. Both composites show distinct burning patterns along rivers and in areas with recent road construction (Locations A, B, and C). More fires were detected at location C (Rondonia, Brazil) in 1995 than 1997. In 1997, increased burning was observed near the city of Manaus, Brazil (location B) and in northeastern Brazil. Overall, there was an 8% decrease in GOES-8 observed fires from 1995 to 1997 during the period June through October (Prins et. al., 1998).

Accuracy. Validation of the GOES-8 ABBA was attempted with one prescribed burn in the state of Washington during the Smoke Clouds and Radiation Experiment in California (SCAR-C, 1994)

and two prescribed burns in Brazil during SCAR-B (1995). The prescribed burns ranged from 3 to 50 acres in size. Although limited in scope, the results indicated that the GOES-8 can identify fires that are on the order of a few acres in size and that the GOES-8 ABBA sub-pixel size and temperature estimates are within 30% of ground truth estimates. These case studies also demonstrated the importance of using high temporal resolution data to capture fires as they occur (Menzel and Prins, 1996; Prins et al., 1998). More validation activities are planned for the 1999 fire season in North and South America.

Users. This product is disseminated via a web site at CIMSS (<http://cimss.ssec.wisc.edu/goes/burn/abba.html>). Users include the international climate change research and modeling community, NASA and the Brazilian Instituto Nacional de Pesquisas Espaciais (INPE). The experimental North American wildlife detection version of the ABBA is being used by Environmental Canada.

References.

Menzel, W.P., and E.M. Prins, 1996: Monitoring biomass burning with the new generation of geostationary satellites. *Biomass Burning and Global Change*, edited by J.S. Levine, The MIT Press, Cambridge, MA, 56-64.

Prins, E.M., J.M. Feltz, W.P. Menzel and D.E. Ward, 1998: An overview of GOES-8 diurnal fire and smoke results for SCAR-B and the 1995 fire season in South America. Accepted by SCAR-B Special Issue, *J. Geo. Res.*

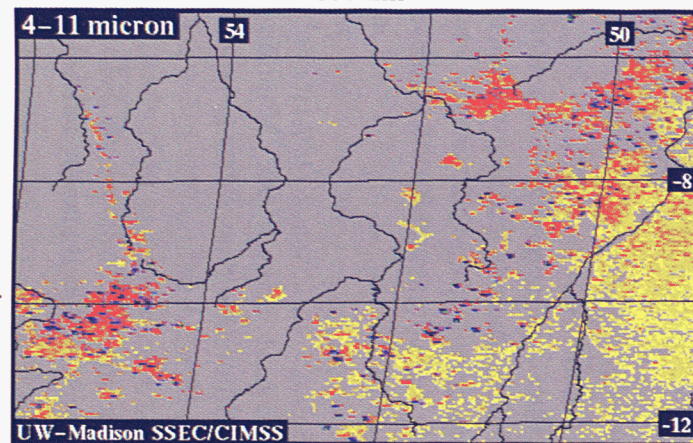
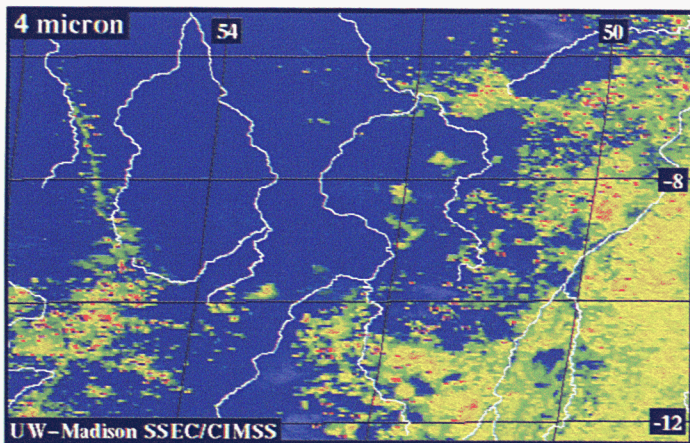
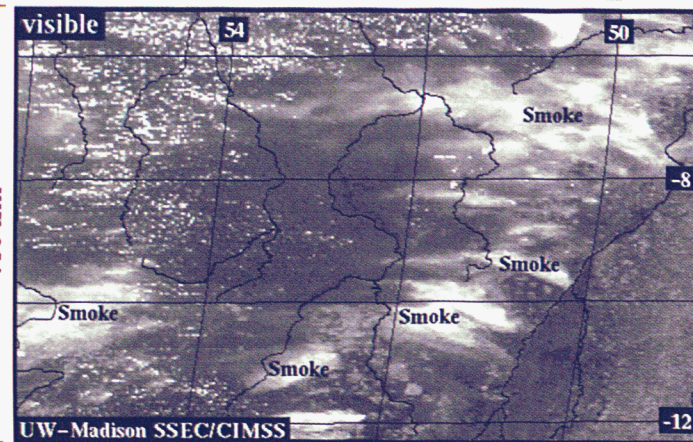
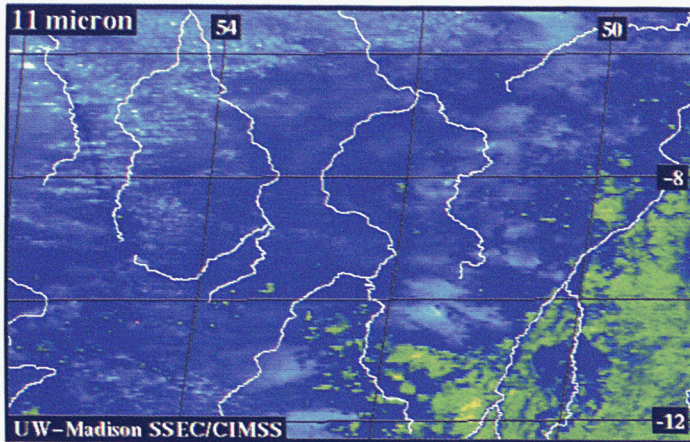
Prins, E.M., and W.P. Menzel, 1994: Trends in South American biomass burning detected with the GOES visible infrared spin scan radiometer atmospheric sounder from 1983 to 1991. *J. Geo. Res.*, **99**, 16719-16735.

Prins, E.M., and W.P. Menzel, 1992: Geostationary Satellite detection of biomass burning in South America. *Int. J. of Remote Sensing*, **13**, 2783-2799.

GOES-8 Multispectral Fire Detection in South America

Date: 24-Aug-95 Time: 17:45 UTC

UW-Madison
SSEC/CIMSS



290 300 310 320 330 340
Brightness Temperature (K)

0 5 10 15 20 25 30 35 40 45 50
4 - 11 micron Brightness Temperature Difference (K)

Figure 39. GOES Multispectral Fire Detection in South America at 1745 UTC, August 24, 1995.

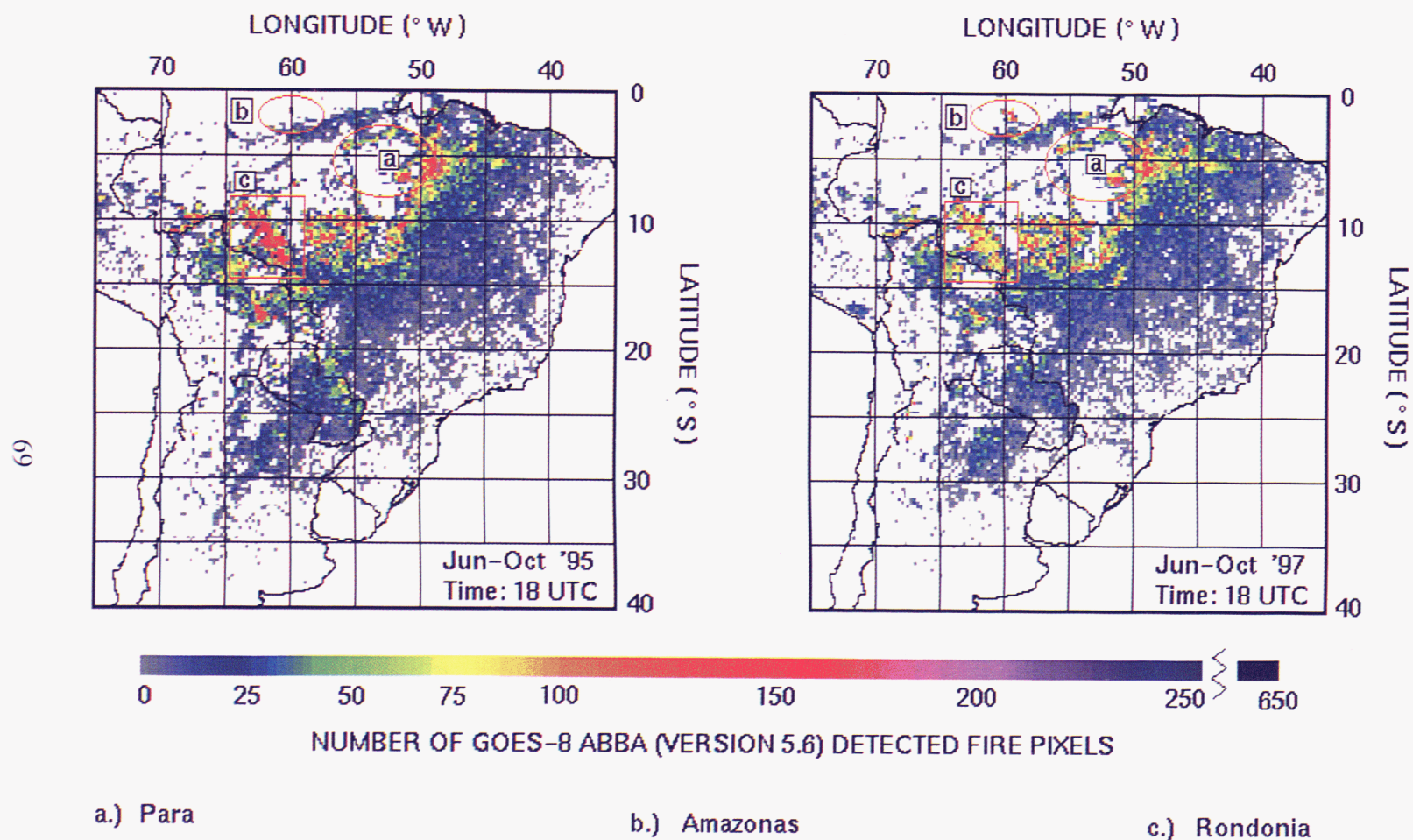


Figure 40. Summary of GOES-8 ABBA detected fire pixels for the 1995 and 1997 fire seasons in South America (0.25° grid).

VI. IMAGER ATMOSPHERIC PARAMETERS

H. Fire, Smoke and Aerosol

Automated Smoke/Aerosol Detection Algorithm (ASADA) (Experimental)

Description. The GOES-8 Automated Smoke/Aerosol Detection Algorithm (ASADA) incorporates multispectral data including the visible, 3.9 μm , 10.7 μm , and 12 μm data to map smoke and other aerosols. The ASADA includes single and multi-band difference thresholds, contextual information, solar zenith angle corrected albedo, and solar and satellite viewing geometry to distinguish smoke/haze from multi-level clouds, low-level moisture, and sun glint (Prins et al, 1998). The GOES-8 ASADA product consists of composite imagery and grids that provide a summary of the extent of smoke/aerosol coverage and smoke albedo estimates which give a general indication of the smoke intensity. Figure 41 summarizes the distribution and relative intensity of smoke/aerosol (on a 0.5° grid) throughout the Amazon Basin and the South Atlantic for the 1995 and 1997 fire seasons. Panels a and b show the percentage of time the GOES-8 ASADA reported smoke/aerosol coverage for a given location in 1995 and 1997, respectively. Panels c and d indicate the average albedo in both years. These composites show the highest smoke/aerosol occurrences and albedo estimates along the front range of the Andes Mountains in Brazil, Bolivia, and Paraguay and along the boundary between the forest and grassland in central Brazil. The occurrence of smoke and derived albedos were slightly higher in 1995. Transport over the Atlantic was observed in both years, although it was more pronounced in 1995 (Prins et al., 1998).

Accuracy. Validation studies have included comparisons with other satellite derived smoke products (TOMS, AVHRR) and ground truth observations in South America. These preliminary studies have indicated that the GOES-8 ASADA is capable of distinguishing between smoke and most cloud types and provides a consistent mapping of smoke extent. More detailed, quantitative validation studies are planned.

Users. This product is disseminated via a web site at CIMSS (<http://cimss.ssec.wisc.edu/goes/burn/asada.html>). Users include the international climate change research and modeling community, the Brazilian INPE, and NASA. The product is also being used in epidemiological research studies.

References.

Prins, E.M., J.M. Feltz, W.P. Menzel and D.E. Ward, 1998: An overview of GOES-8 diurnal fire and smoke results for SCAR-B and the 1995 fire season in South America. Accepted by SCAR-B Special Issue, *J. Geo. Res.*

Prins, E.M., and W.P. Menzel, 1996: Investigation of biomass burning and aerosol loading and transport utilizing geostationary satellite data. *Biomass Burning and Global Change*, edited by J.S. Levine, The MIT press, Cambridge, MA, 65-72.

Prins, E.M., and W.P. Menzel, 1994: Trends in South American biomass burning detected with the GOES visible infrared spin scan radiometer atmospheric sounder from 1983 to 1991, *J. Geo. Res.*, **99**, 16719-16735.

Prins, E.M., and W.P. Menzel, 1992: Geostationary Satellite detection of biomass burning in South America. *Int. J. of Remote Sensing*, **13**, 2783-2799.

GOES-8 ASADA Smoke/Aerosol Detection in 1995 & 1997

UW-Madison/SSEC/CIMSS NOAA/NESDIS/ORA/ASPT Prins, Menzel, and Feltz, 1998

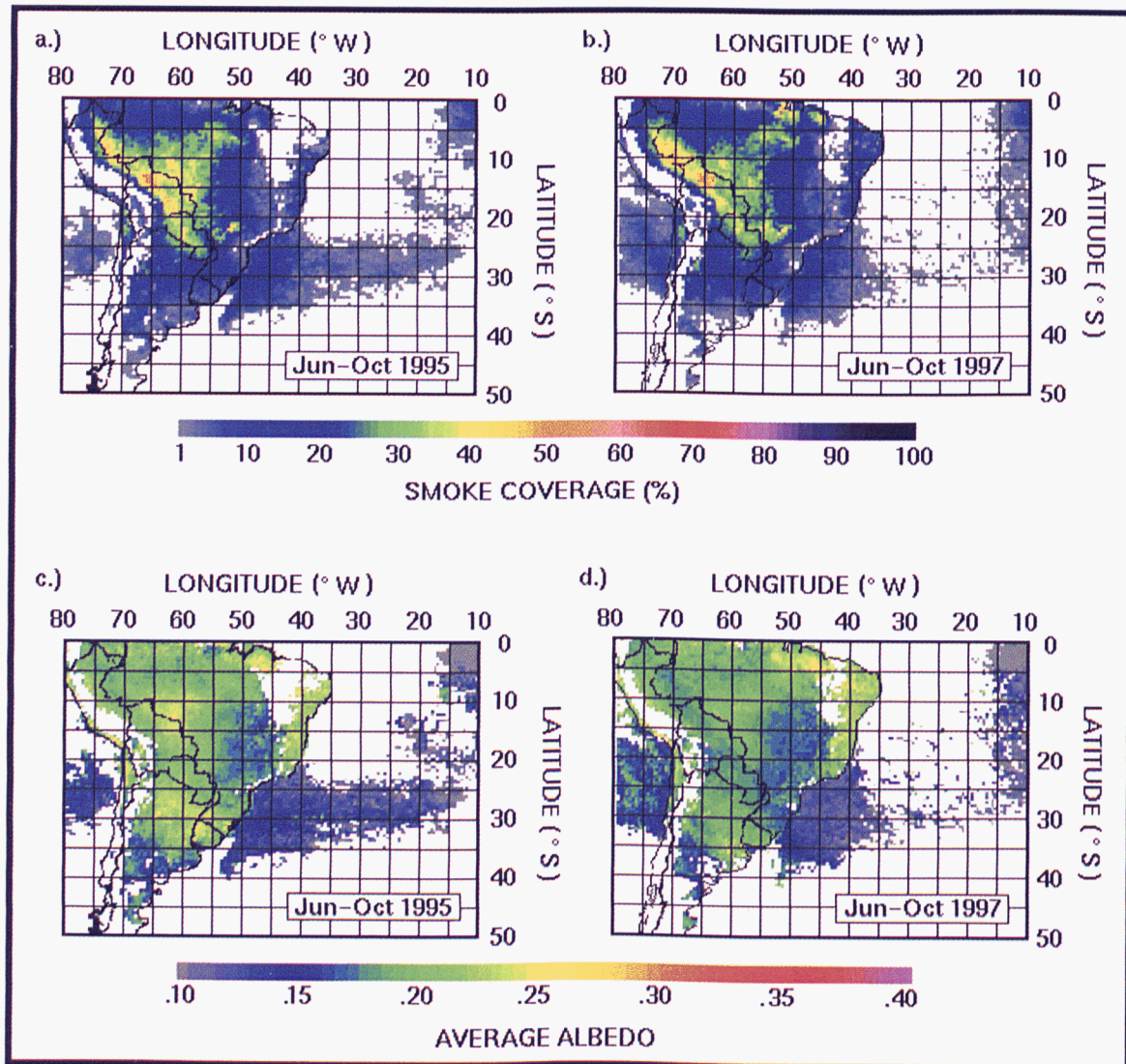


Figure 41. GOES ASADA Smoke/Aerosol Detection over Amazon Basin and the South Atlantic for 1995 and 1997.

VII. IMAGER ATMOSPHERIC PARAMETERS

I. Global Energy and Water-Cycle Experiment (GEWEX)

Radiances

Description. Beginning in late 1995 a set of hourly surface radiation, cloud and surface temperature products have been produced routinely in real time from the GOES-East imager. The process uses 4 km resolution data from the GOES Imager that are aggregated to 0.5° lat/long targets. In the aggregating process, a cloud detection procedure is performed on each pixel and quantities needed by the insolation algorithm (clear and cloudy radiances, cloud fraction) are calculated for the target. Snowcover and total precipitable water from the Eta model are used to estimate insolation and Photo Synthetically Active Radiation (PAR). A split window algorithm for surface temperature is run for the clear targets to obtain an estimate of surface temperature. In addition to derived products, the imager radiances and statistics for each target for each hour are collected. The data and derived products are archived at the University of Maryland. An example of the clear-sky radiances can be found in Figure 42. Insolation from the GOES has been compared to coincident pyranometer data and the errors in the insolation are usually less than 10% of the insolation estimate. One of the purposes of the GOES products is to validate the radiation, cloud and surface parameterizations in regional NWP models, especially the NCEP Eta model. To do this a coincident Eta model/GOES data set is being constructed that merges selected variables from 3 hour Eta forecasts with coincident GOES estimates of the same quantities or of quantities that have been judged to be useful in comparing model and satellites quantities. The matchups are being done at 1500, 1800, 2100, and 0000 UTC which corresponds to mostly daylight hours over the GEWEX Continental Scale International Project (GCIP) area. Quantities in the matchup database include cloud fraction, insolation, surface (skin) temperature from both the Eta model and GOES. Other quantities include target mean and standard deviations of albedo and temperatures from the GOES and soil moisture, surface energy fluxes, vegetation fraction and snow water equivalent from the Eta. This data set will be made available to the GCIP science community.

Accuracy. Preliminary studies on insolation have shown errors to be approximately 10% on a daily basis, and somewhat less on a monthly basis.

Users. This product is used experimentally by NCEP and by the scientific community.

References.

Pinker, R.T., I. Laszlo, Y. Wang and J. D. Tarpley, 1996: GCIP GOES shortwave radiation budgets: validation activity. *Second International Scientific Conference on the Global Energy and Water Cycle*, 17-21 June, 1996, Washington, D.C.

Pinker, R.T., J. D. Tarpley, I. Laszlo and K. Mitchell, 1999: Surface radiation budgets in support of the GEWEX continental-scale International Project (GCIP). Submitted to JGR.

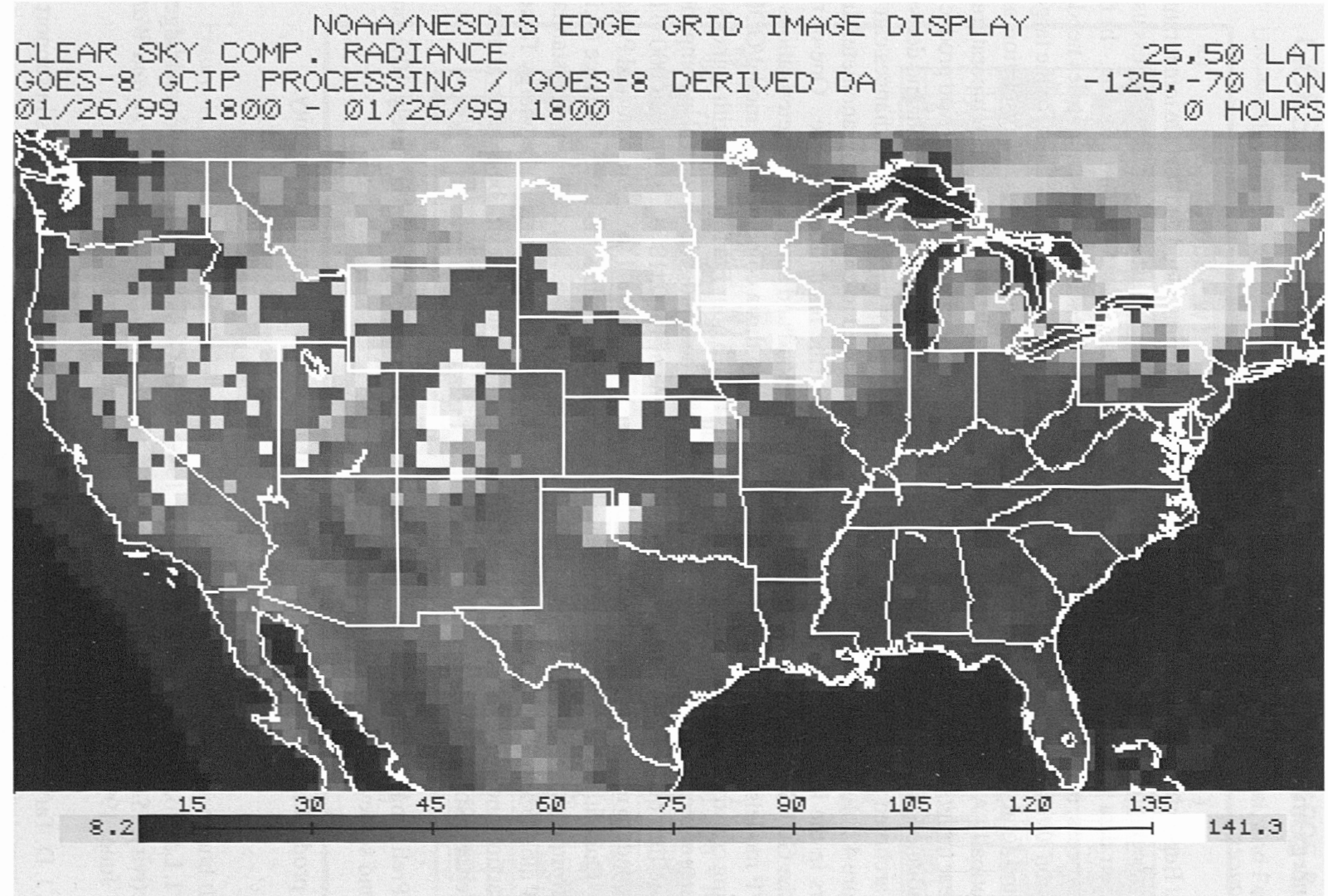


Figure 42. Clear-sky composite radiances from GOES-8 for January 26, 1999 at 1800 UTC.

VII. SOUNDER ATMOSPHERIC PARAMETERS

A. Channel Brightness Temperature

Description. The new GOES spacecraft carry separate imager and sounder systems. The sounder is a 19-channel discrete filter radiometer that provides data used to describe the vertical profile of temperature and WV. Table 3 lists the wavelengths, absorption bands and spectral peaks for each of the 19 channels on the sounder, and the atmospheric parameter that each sounder channel measures. Of these 19 channels or spectral bands, seven are longwave (channels 1-7), five are mid-wave (channels 8-12), six are shortwave (channels 13-18), and one is a visible channel (channel 19). Most of these channels reside in the carbon dioxide, window, and water vapor absorption regions of the atmosphere.

The operation of the sounder is done in two steps as shown in Figure 43. Soundings are produced hourly, but since it takes approximately 40 minutes to scan the continental U.S., there is inadequate time to process the satellite SCP for the ASOS (see Section VII-B, Site Satellite Cloud Product) and have it available for the hourly observational roundup. Consequently, the sounding operation is split into two portions denoted ASOS 1 and 2 (shown in Figure 43) so that observations in ASOS 1 can be processed in time for the NWS hourly roundup. Because of the oblique view and increasing atmospheric path, no soundings are generated north of 62.5° N.

The first step in producing the suite of atmospheric soundings and products described in this section is the computation of observed brightness temperatures for each of the sounder channels. Images of GOES sounder bands 8 (11 μm) and 11 (7 μm) are shown in Figures 44 and 45.

Accuracy. Resolution of the sounder is 8km at nadir and the horizontal spacing of the sounding radiances is 10 km. The processing box average is stored at 50 km spacing and the radiance accuracy is the instrument noise reduced by averaging 9 to 25 samples.

Users. This dataset is used internally to produce atmospheric temperature and moisture soundings, ASOS satellite cloud product, and other derived products. These data are also used by EMC for use in the global data assimilation system (GDAS).

References.

Hayden, C.M., 1995: Initial evaluation of the GOES-8 sounder. *Proceedings of the 9th Symposium on Meteorological Observations & Instrumentation*, Amer. Meteor. Soc., 385-390.

Hayden, C.M. and T.J. Schmit, 1994: GOES-I temperature moisture retrievals and associated gradient wind estimates. *Proceedings of the 7th Conf. on Satellite Meteorology and Oceanography*, Amer. Meteor. Soc., 477-480.

Hayden, C.M., 1988: GOES-VAS simultaneous temperature-moisture retrieval algorithm. *J.Appl. Meteor.*, **27**, 705-733.

TABLE 3. GOES-8 AND -10 SOUNDING CHANNELS

Channel	GOES-8/10 wavelength (μm)	Band	Purpose
1	14.7	Carbon Dioxide	Stratospheric Temperature
2	14.4	Carbon Dioxide	Tropospheric Temperature
3	14.1	Carbon Dioxide	Upper-Level Temperature
4	13.9	Carbon Dioxide	Mid-Level Temperature
5	13.4	Carbon Dioxide	Low-Level Temperature
6	12.7	Water Vapor	Total Precipitable Water
7	12.0	Window	Surface Temperature, Moisture
8	11.0	Window	Surface Temperature
9	9.7	Ozone	Total Ozone
10	7.5	Water Vapor	Low-Level Moisture
11	7.0	Water Vapor	Mid-Level Moisture
12	6.5	Water Vapor	Upper-Level Moisture
13	4.6	Carbon Dioxide	Low-Level Temperature
14	4.5	Carbon Dioxide	Mid-Level Temperature
15	4.4	Carbon Dioxide	Upper-Level Temperature
16	4.1	Nitrogen	Boundary Layer Temperature
17	3.9	Window	Surface Temperature
18	3.7	Window	Surface Temperature, Moisture
19	0.9	Visible	Clouds

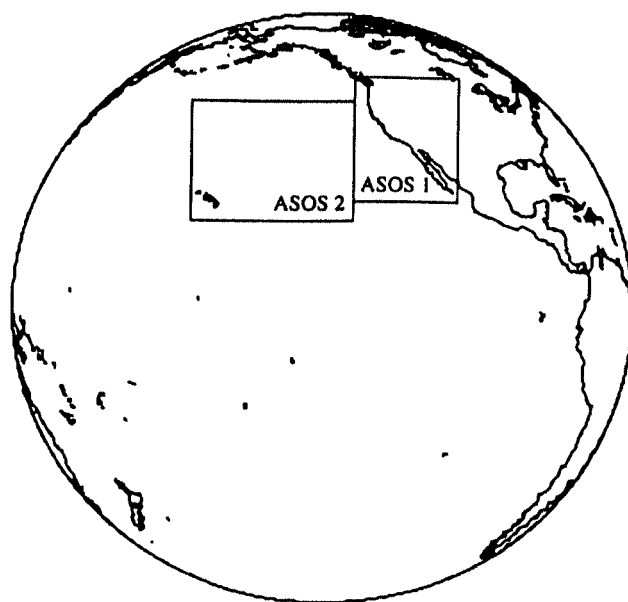


Figure 43. GOES-8 and GOES-10 Sounding Areas are shown on top and bottom respectively.

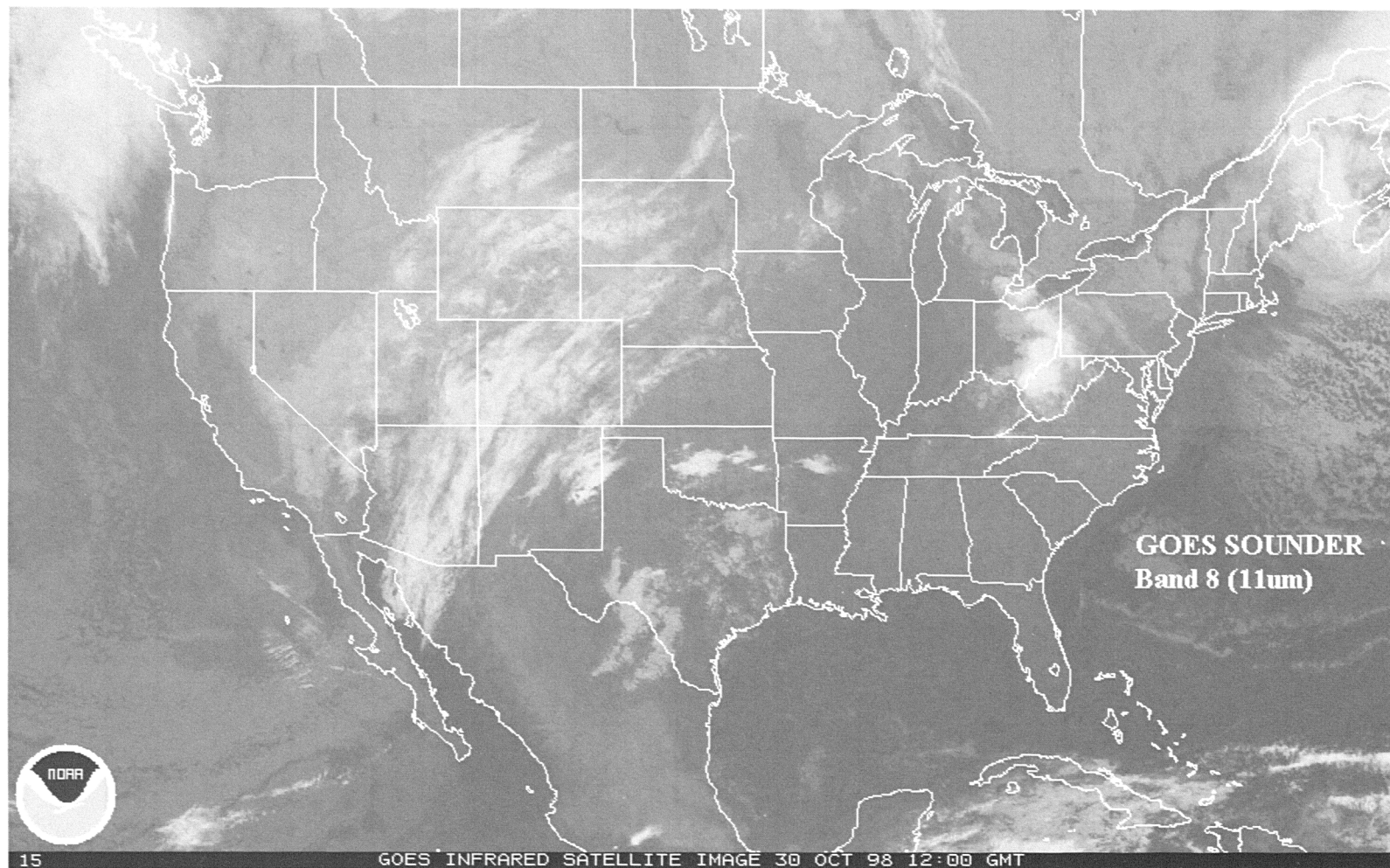


Figure 44. Image of GOES-8 sounder channel 8 taken at 1246 UTC, November 8, 1994.

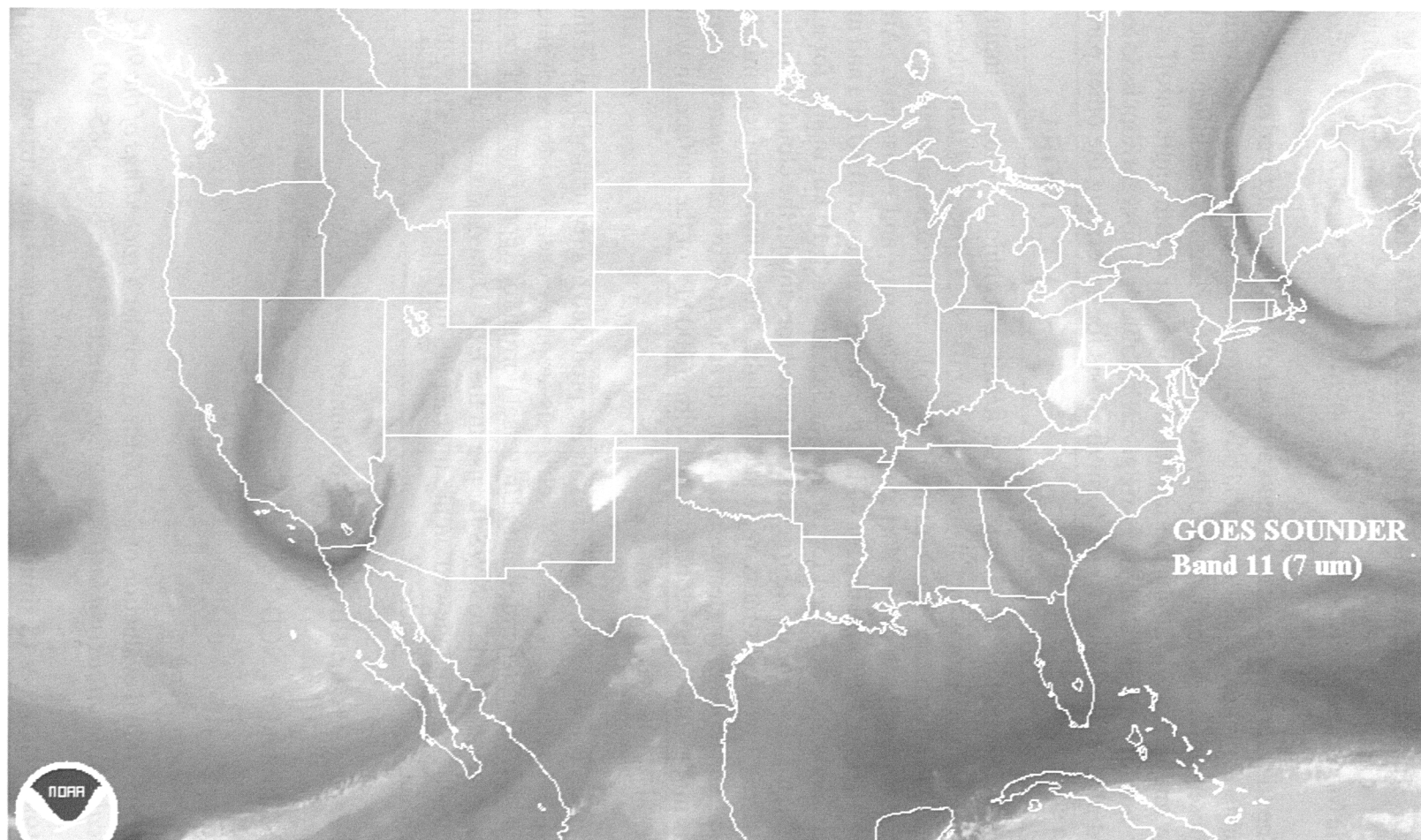


Figure 45. Image from the GOES-8 sounder channel 11 taken at 1246 UTC, November 8, 1994.

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Description. The sounder atmospheric products are a set of parameters derived from the 19 channel radiances available from the GOES sounders, NWS numerical model forecast information, and hourly surface observations. Soundings are only computed for clear sky conditions, and because of the oblique view and increasing atmospheric path, a 62.5° solar zenith angle cutoff is employed. The derived products from these soundings are given in Table 4. The algorithm used to derive the temperature and moisture profiles, which form the basis for generating the other parameters, is described in Ma et. al 1999.

The hourly retrieved sounding is derived by an iterative technique using as input: radiance observations from the GOES sounder (channels 1-8 and 10-16), a space and time interpolated first guess temperature and moisture profile from the ETA model, an objective analysis of hourly surface observations, and an estimate of the surface skin temperature and emissivity. Atmospheric temperature measurements are inferred for 40 levels from the surface to 0.10 hPa and moisture up to 300 hPa. Retrievals are attempted for an area of 5x5 fov each 10 km in size for a horizontal resolution of (50 km)². Each of the 25 fov sites are tested for clouds; the cloud clearing tests seek to identify thin cirrus, low level stratus, reflected sunlight, and variable surface emissivity. Each fov is classified as clear, possibly clear, or not clear. If at least 9 fovs are clear, they are averaged and a retrieval is made, unless the cloud tops are within 100 hPa of the surface, in which case an “overcast” retrieval is made.

The sounding system is automated, and retrievals are produced hourly primarily over the U.S. and adjacent waters. Between 2,000 and 3,000 retrievals are made each hour for each satellite. The sounder products are reformatted into Binary Universal Format for Representation of meteorological data (BUFR) and made available to NWS for use in the ETA Data Assimilation System (EDAS). Many of these products can be viewed on the internet at: <http://cimss.ssec.wisc.edu> and <http://orbit-net.nesdis.noaa.gov/arad/fpdt/>.

Accuracy. See Table 4, Products from GOES-8 Sounder.

Users. NWS, NCEP, and the NCDC.

References.

Hayden, C.M., 1995: Initial evaluation of the GOES-8 sounder. *Proceedings of the 9th Conference on Meteorological Observations and Instrumentation*, Amer. Meteor. Soc., 385-390.

Hayden, C.M., 1988: GOES-VAS simultaneous temperature-moisture retrieval algorithm,. *J. of Appl. Meteor.*, **27**, 705-733.

Hayden, C.M., and T.J. Schmit, 1994: GOES-I temperature and moisture retrievals and associated gradient wind estimates. *Proceedings of the 7th Conference on satellite Meteorology and Oceanography*, Amer. Meteor. Soc., 477-480.

Ma, X.L., T. Schmit and W. Smith, 1999: A non-linear physical retrieval algorithm - Its application to the GOES-8/9 sounder, *J. Appl. Meteor*, **38**, 501-503.

TABLE 4. PRODUCTS FROM THE GOES-8/10 SOUNDER SYSTEM

PRODUCT	ACCURACY
Retrievals at Forty Pressure Levels: (50 km resolution at nadir)	
Temperature	Equivalent to NCEP forecast except slight improvement over data sparse regions, such as Gulf of Mexico and ocean areas
Dew Point Temperature	Improvement over NCEP forecast of dewpoint profile; improvement more substantial than temperature
Geopotential Height	Between accuracy of temperature and dewpoint profiles
Layer Precipitable Water (3 layers)	+/- 20%, lowest two layers and +/- 25% for top layer
Total Precipitable Water	+/- 10%
Channel Brightness Temperature	Equivalent to channel noise; reduced by sample size
Lifted Index	+/- 1.5 Degrees Kelvin
Thermal (Gradient) Wind Estimates	+/- 4 meters/second

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Vertical Temperature and Moisture Profiles

Description. The computation of soundings is described in the preceding section. Temperatures and dew point temperatures are inferred for 40 pressure levels. A sample temperature and dewpoint sounding is shown in Figure 46.

Accuracy. See Table 4, Products from GOES-8 Sounder.

Users. NWS, NCEP, and the NCDC.

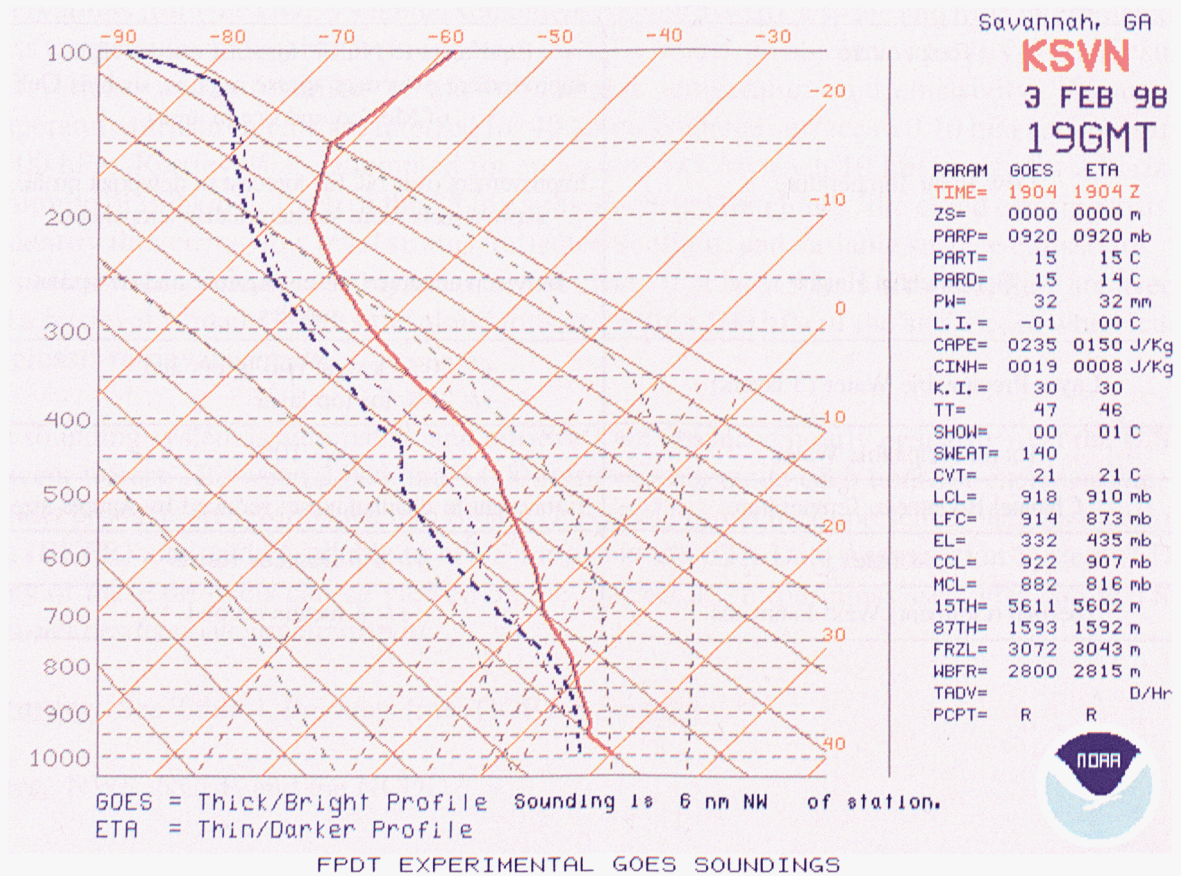


Figure 46. A GOES temperature and moisture profile for Savannah, GA at 1900 UTC February 3, 1998.

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Layer Precipitable Water

Description. The computation of soundings is described in the preceding section. Precipitable water for three layers of the atmosphere: surface to 900 hPa; 900 - 700 hPa; and 700 - 300 hPa are computed from the soundings (Hayden and Schmit 1995). Total precipitable water (TPW) for the entire atmospheric column, from the earth's surface to the "top" of the atmosphere, is also computed. These precipitable water products are particularly valuable for short-term forecasting of precipitation, thunderstorms, and fog. Hourly updates of this information provide useful information for the NWS regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to EDAS which provides the initialization for the ETA forecast model. Figure 47 shows the retrieved TPW product for GOES-8 and GOES-10 at 14 UTC on October 30, 1998. Green and blue numbers represent moist areas (20mm, 30mm+ respectively), while yellow (10-20mm) and orange (<10mm) indicate a drier atmosphere. This product can be viewed on the internet at: <http://orbit-net.nesdis.noaa.gov/goes/soundings/>.

Accuracy. Accuracy of the precipitable water values is +/- 20 to 25%.

Users. NWS, NCEP, and the NCDC.

References.

Hayden, C.M., and T.J. Schmit, 1995: Initial evaluation of the GOES-8 sounder. *Ninth Symposium on Meteorological Observations and Instrumentation*, Amer. Meteor. Soc., 385-390.

Ma, X.L., T. Schmit and W. Smith, 1999: A non-linear physical retrieval algorithm - Its application to the GOES-8/9 sounder, *J. Appl. Meteor*, **38**, 501-503.

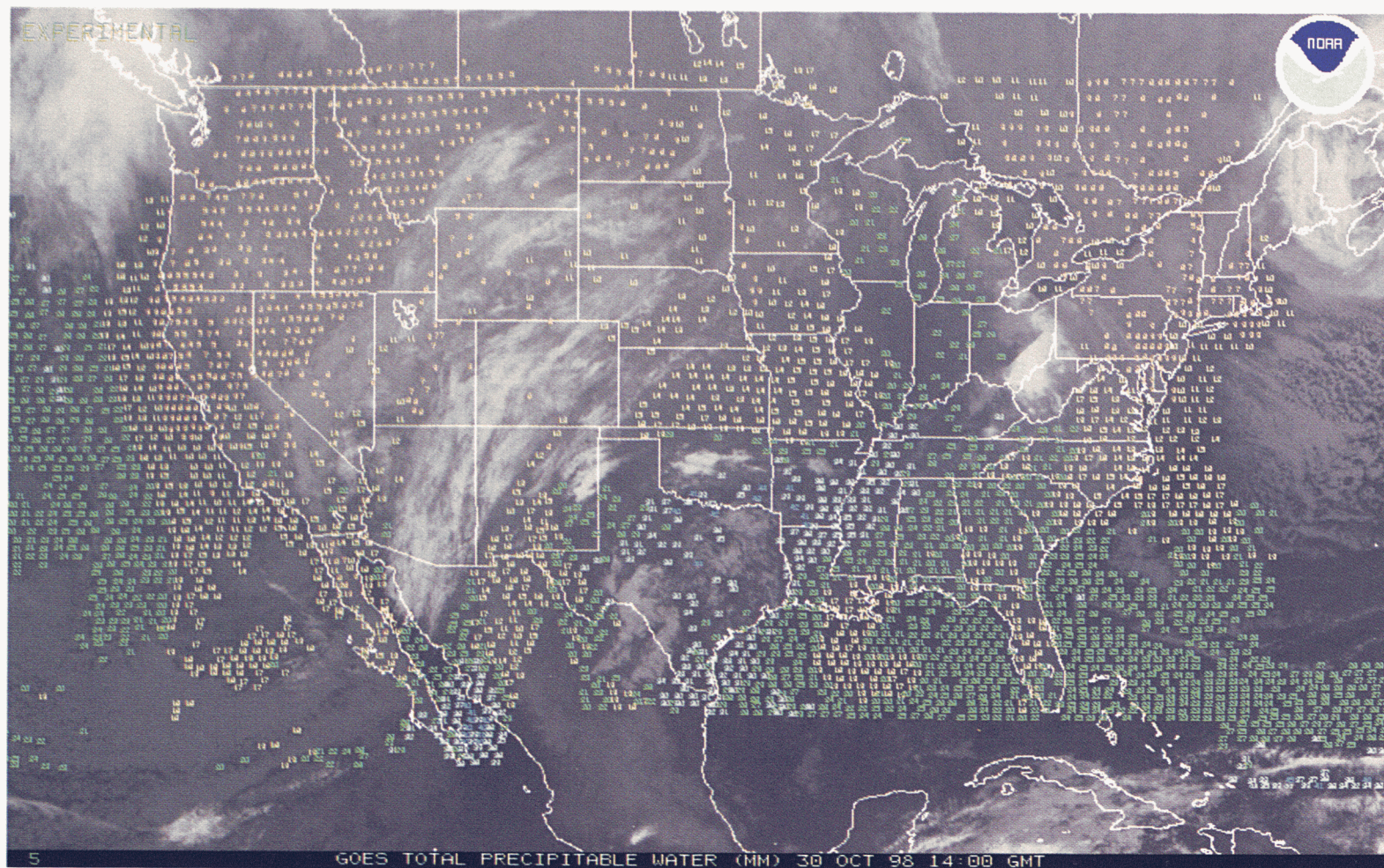


Figure 47. Retrieved TPW product for GOES-8 and GOES-10 at 1004 UTC, October 30, 1998. The orange and yellow areas depict a dry atmosphere (<10mm and 10-20mm respectively), while the green and blue areas represent a moist atmosphere (20-30mm and >30mm respectively).

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Geopotential Heights

Description. Geopotential height is a measure of gravitational potential height rather than geometric height. This product defines isobaric surfaces (surfaces of constant pressure in three dimensional space) that are useful for establishing atmospheric dynamics. At the surface geopotential and geometric heights are similar, but at higher altitudes where gravity decreases, the value of the geopotential heights becomes lower.

This product is an array of two dimensional (latitude and longitude) heights, for each of 40 pressure surfaces. A satellite image overlaid with the computed geopotential heights is shown in Figure 48.

Accuracy. The accuracy at 500 hPa is +/- 10 m.

Users. NWS, NCEP, and the NCDC.

References.

Hayden, C.M., and T.J. Schmit, 1995: Initial evaluation of the GOES-8 sounder. *Ninth Symposium on Meteorological Observations and Instrumentation*, Amer. Meteor. Soc., 385-390.

Ma, X.L., T. Schmit and W. Smith, 1999: A non-linear physical retrieval algorithm - Its application to the GOES-8/9 sounder, *J. Appl. Meteor*, **38**, 501-503.

9660

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Thermal Wind Profiles (Gradient Winds)

Description. Thermal winds are a measure of the vertical wind shear. They are derived from the horizontal gradient of temperature using the geostrophic wind hydrostatic equations and the equation of state. A wind field is defined from the geopotential height observations at two reference levels and temperature profiles over the area of interest. Thus the GOES soundings plus surface observations provide adequate information to determine the three dimensional distribution of thermal wind velocities.

Thermal winds are provided with each profile. These are derived from objective analysis of the geopotential profiles calculated with each retrieval. The objective analysis is a 3-dimensional invariate recursive filter that uses as a background the same fields that provide the first guess to the temperature retrieval algorithm. The analyses are performed on a 1° latitude/longitude grid. Gradient winds are calculated using finite difference operators which involve surface-fitting over 5 x 5 gridpoints centered at the gridpoint closest to each retrieval. Each vector is representative of a surface smoothed over approximately 700 square km. Wind estimates are analyzed at standard pressure levels of 850, 700, 500, 400, and 300 hPa. An example is shown at 500 hPa in Figure 49.

Accuracy. It is estimated that they are +/- 4m/s.

Users. At the present time, this product is not being generated operationally at NESDIS.

References.

Hayden, C.M., and R.J. Purser, 1995: Recursive filter objective analysis of meteorological fields: applications to NESDIS operational processing. *J. of Appl. Meteor.*, **34**, 3-15.

Hayden, C.M., and T.J. Schmit, 1994: Temperature and moisture retrievals and associated gradient wind estimates. *Proceedings of the 7th Conference on Satellite Meteorology and Oceanography*, Amer. Meteor. Soc., 477-480.

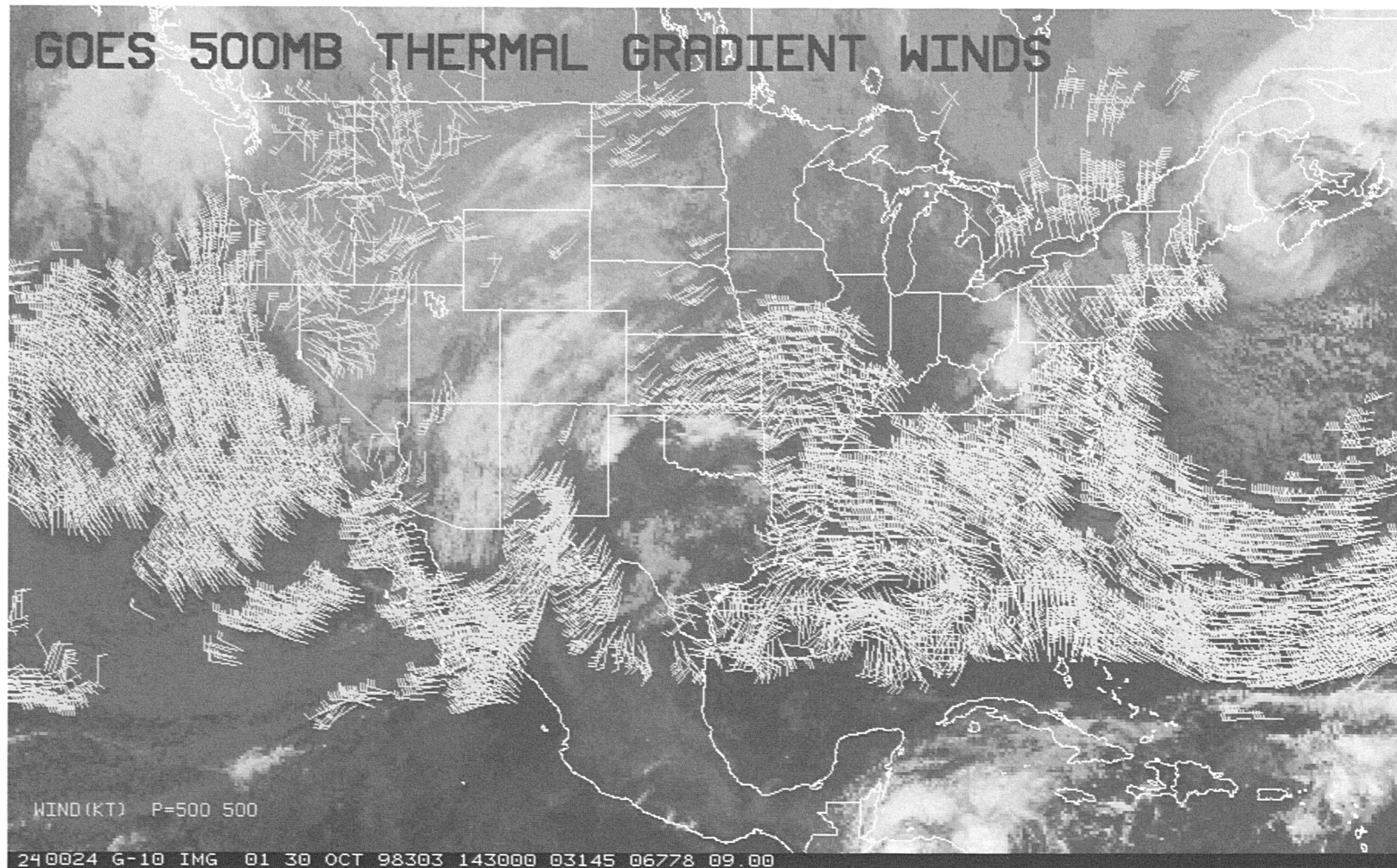


Figure 49. GOES-10 500 hPa gradient winds (kts) on October 30, 1998.

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

WINDEX (Experimental)

Description. The Wind Index (WINDEX) shows the highest wind gusts (knots) possible if showers or thunderstorms were to occur. It uses the change in temperature with height (lapse rate), the height of the melting level, and the moisture (specific humidity) at the melting level and near the surface. WINDEX (Figure 50) was developed by McCann (1994), based on prior research by Wolfson (1990), Proctor (1989), and Srivastava (1985). It was derived using the vertical equations of momentum and continuity with some simplifying assumptions. The hourly WINDEX product consists of a GOES image (Vis or IR) with a color coded graphic overlay. The data are also available in a tabular format. This product is available on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html>.

Accuracy. Based on preliminary data, the mean absolute values of GOES WINDEX differed from the mean observed maximum surface wind gusts by less than 5 knots. The WINDEX product is most reliable over the eastern and central United States during daylight hours.

Users. The WINDEX product is used mostly by NWS and DoD forecasters.

References.

Atkins, N.T., and R.M. Wakimoto, 1991: Wet microburst activity over the southeastern United States: Implications for forecasting. *Wea. and Fcstg.*, **6**, 470-482.

McCann, D.W., 1994: WINDEX - A new index for forecasting microburst potential. *Wea. and Fcstg.*, **9**, 532-541.

Nelson, J.P. and G.P. Ellrod, 1997: Recent Developments in a microburst risk image product derived from GOES I-M satellite sounder data. *Preprint Volume, 7th Conf. on Aviation, Range, and Aerospace Meteorology*, Amer. Met. Soc., 262-267.

Proctor, F.H., 1989: Numerical Simulations of an isolated microburst, Part II: Sensitivity experiments. *J. Atmos. Sci.*, **46**, 2143-2165.

Srivastava, R.C., 1985. A simple model of evaporatively driven downdraft: Application to microburst downdraft. *J. Atmos. Sci.*, **42**, 1004-1023.

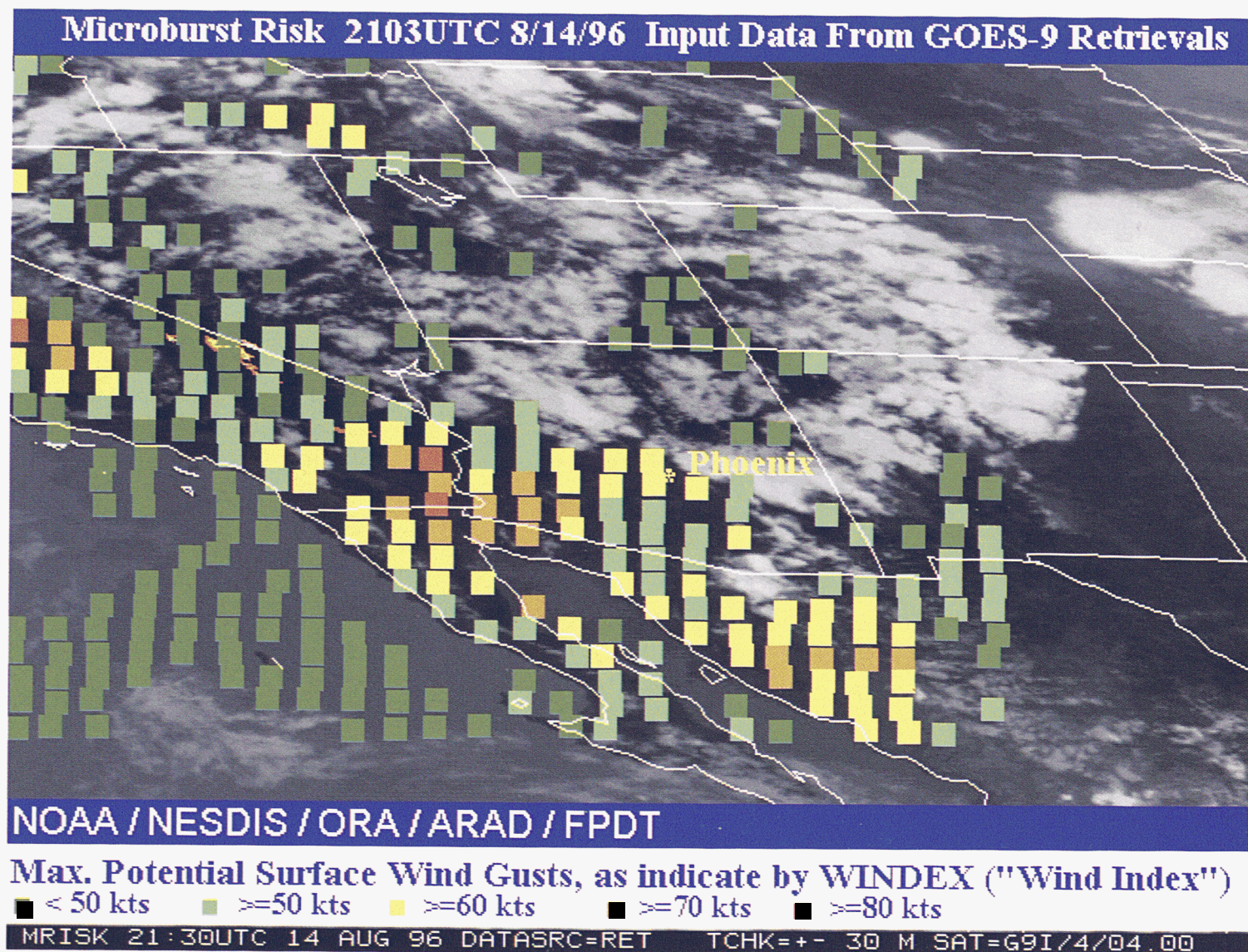


Figure 50. WINDEX maximum potential convective wind gusts superimposed on image at 2130 UTC on August 14, 1996.

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Sounder-based Water Vapor Winds

Description. The GOES satellites have an atmospheric sounder that includes two WV channels centered at 7.0 μm and 7.5 μm . These sounder channels can be employed as surrogate imagers to track WV features radiating from the lower and middle layers of the troposphere. The weighting function of the 7.0 μm channel peaks around 450 hPa and the weighting function of the 7.5 μm channel peaks around 550 hPa. WV winds generated from these two channels complement the imager-based cloud-drift and WV winds, resulting in an improved three-dimensional depiction of the wind field.

The automated wind vector extraction processing from the sounder WV imagery closely follows the methodology described in (Section VI, part A). The target density parameters are adjusted to allow for the data resolution (8km) of the sounder imagery visible imagery. Figure 51 shows examples of the WV wind field generated from the GOES-8 sounder 7.0 μm data (top) and 7.5 μm data (bottom). Current limitations in using the sounder for generating WV winds include the reduced resolution of the data (8km), the reduced temporal frequency of the imagery (1 hour), and limited geographic coverage. Despite these limitations, useful information can be extracted from the sounder WV measurements in order to generate WV motion wind fields which compliment other satellite-derived wind fields.

Accuracy. Neither the satellite winds nor rawinsonde observations can be used as an absolute standard. However, the traditional means of verification for the satellite derived winds is a comparison to collocated rawinsondes. The RMS error for sounder WV winds is about 7.5 m/s and the mean bias error for this dataset is about 0.5 m/s.

Users. The sounder WV are not yet operational, but the primary users are expected to be the major NWP centers which include the EMC, ECMWF, UKMET and the TPC.

Reference.

Velden, C.S., C.M. Hayden, S.J. Nieman, W.P. Menzel, S. Wanzong, and J. Goerss, 1997: Upper-tropospheric winds derived from geostationary satellite water vapor observations. *Bull. Amer. Meteor. Soc.*, **78**, 173-195.

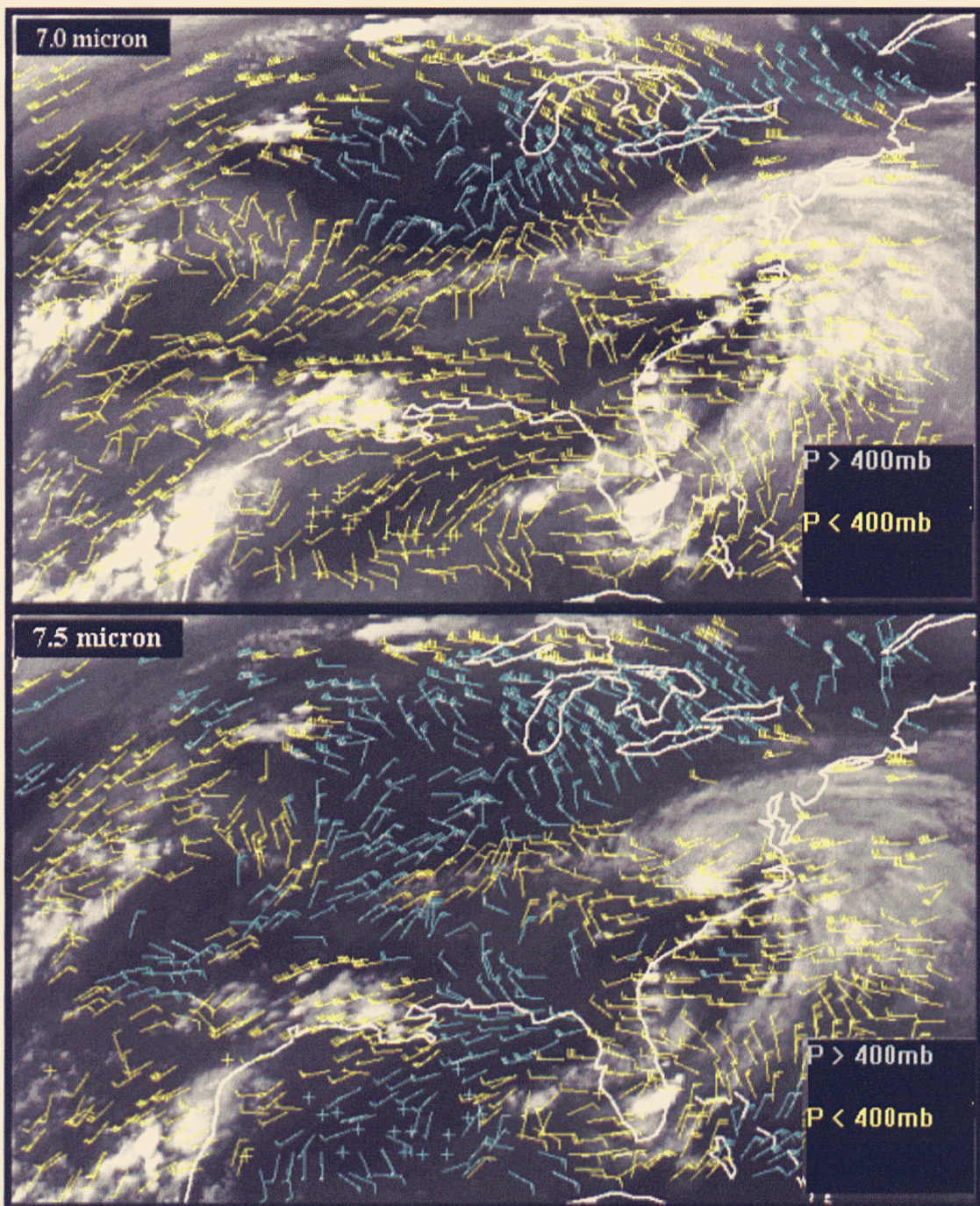


Figure 51. Water vapor wind field generated from the GOES-8 sounder 7.0 μm data (top) and 7.5 μm data (bottom).

VII. SOUNDER ATMOSPHERIC PARAMETERS

B. Atmospheric Measurements

Satellite Cloud Product (SCP)

Description. GOES sounder radiance information over the continental United States (CONUS) is used to generate a SCP of cloud top height and effective cloud amount (ECA). The purpose of the SCP is to complement the ASOS observing system, which has a maximum limit of 12,000 ft. for cloud detection. A composite product for mid- and high-level clouds is calculated from hourly radiative measurements over selected locations, that are commissioned ASOS sites within the CONUS.

Three steps are required to produce the hourly-derived SCP. The first step is defining a 5 x 5 fov box (upper right, Figure 52) at each selected site. A cloud top pressure and cloud amount is calculated at each fov using the CO₂ Absorption Technique (Schreiner et al., 1993; Menzel et al., 1983). An example of the remotely-sensed product is shown in Figure 52. From the 25 remotely-sensed cloud calculations (25 box array, Figure 52) a composite observation is derived. The second step is defining a histogram composed of four height and four amount categories. A distribution within the histogram is depicted based on the calculated cloud parameters for a given site. Table 5 gives the histogram for the example in Figure 52. Step three utilizes a "Decision Tree" (Kluepfel et al., 1993) to determine an integrated or composite satellite observation over the surface site.

The SCP is sent out through the Gateway communication network in two forms. A shortened text form (Figure 53) is sent to all NWS regions as part of the hourly roundup. It consists of the station three letter identification, satellite scan line time over the site, cloud top level (CLEAR, MID, and HIGH), cloud amount (SCATTERED, BROKEN, and OVERCAST), range of cloud tops in feet, and average cloud amount for the 25 fovs. The second transmission preserves the gridded or matrix information of the 5 x 5 box (Figure 52). It consists of the output of the first form above plus the cloud top pressures (in hPa) and cloud amount (in percent) for each fov at each location. Currently, the primary purpose of this extended product is for archive at the NCDC to be used in future climatic studies.

Figures 54 and 55 show SCP cloud heights and cloud amounts superimposed on a GOES image. Figure 56 shows a plot of the ASOS text product designation (CLEAR, SCATTERED, BROKEN, or OVERCAST) for each ASOS station site. These experimental display formats of the ASOS SCP and cloud height and amounts can also be viewed on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/>.

Accuracy. Only cloud tops above 631 hPa (MID and HIGH levels) are given in the SCP. Comparisons between manual observations and the ASOS/SCP observations were conducted on GOES-7 data (Schreiner, 1993). Agreement between manual and ASOS/SCP observations for all

categories combined occurred 69% of the time. The greatest agreement between observations occurred during clear (77%) and overcast conditions (93%). Recent analysis of GOES-8 and GOES-9 ASOS/SCP observations with manual surface observations have shown exact agreement in categorical cloud amount 80-85% of the time. The GOES ASOS/SCP and manual observations of categorical cloud amount agree within +/-1 cloud category 98% of the time. Cloud height accuracies are within 50 hPa.

TABLE 5. SATELLITE CLOUD PRODUCT HISTOGRAM

Cloud Height (hPa)	Cloud Amount			
	< 0.33	< 0.66	< 0.95	<= 1.00
PCT < 400	0	0	0	0
400 <= PCT < 631	28	4	4	0
PCT > 631	0	0	0	28
PCT = 1000	36	0	0	0

TABLE 5. The values across the top represent cloud amount in hundredths. The vertical column (PCT) denotes cloud height categories in hPa. The numbers for a given cloud height and amount category are frequency of occurrence in percent.

Users. The primary users of these data are the NWS, FAA, private meteorologists, universities, research facilities, and the communication media.

References.

Kluepfel, C.K., A.J. Schreiner and D.A. Unger, 1994: The satellite-derived cloud cover product (sounder). *NWS Technical Procedures Bulletin 410*, 15 pp.

Menzel, W.P., W.L. Smith, and T.R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. *J. Clim. Appl. Meteor.*, **22**, 377-384.

Schreiner, A.J., D.A. Unger, W.P. Menzel, G.P. Ellrod, K.I. Strabala and J.L. Pellett, 1993: A comparison of ground and satellite observations of cloud cover. *Bull. Amer. Meteor. Soc.*, **74**, 1851-1861.

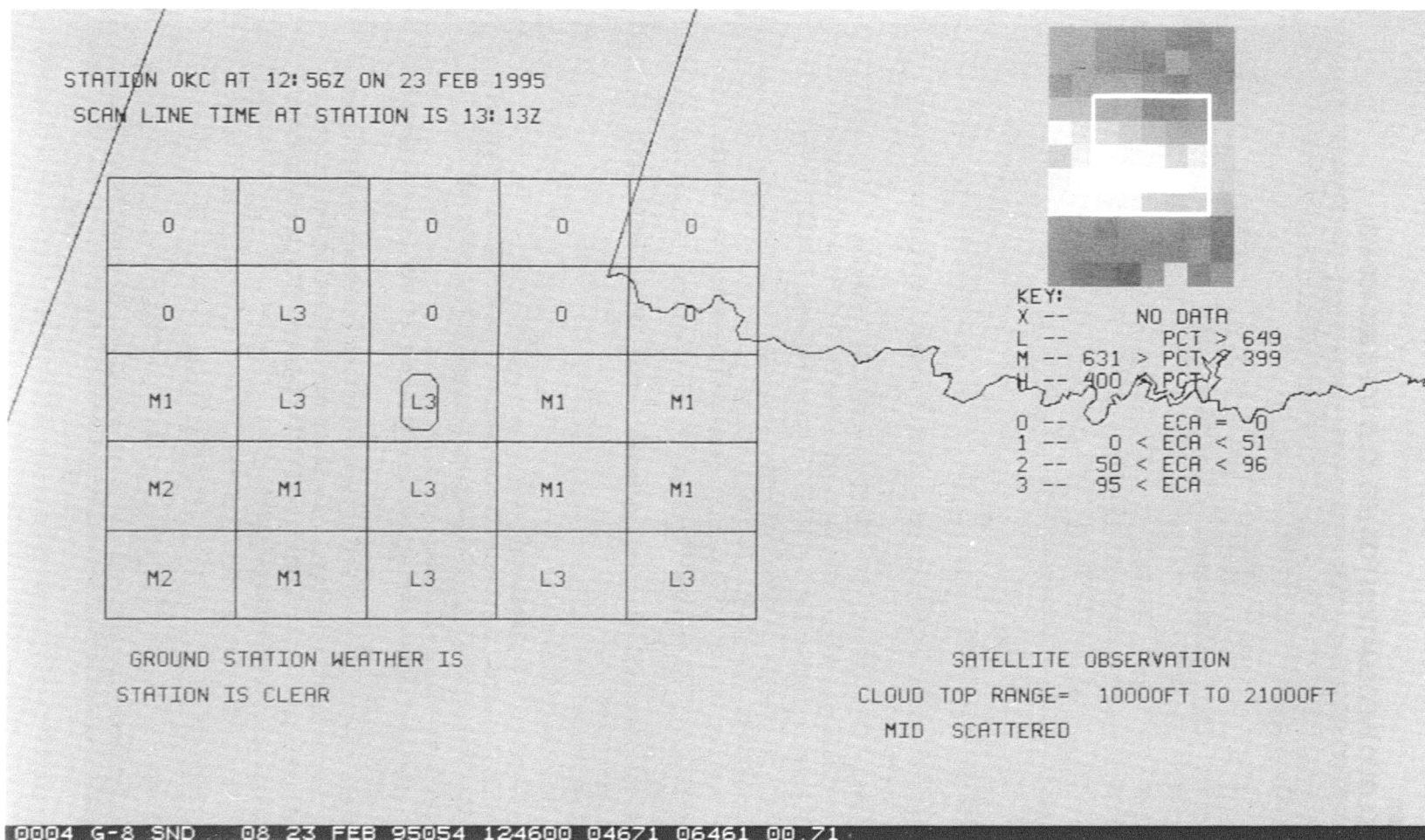


Figure 52. Upper right, a GOES-8 field-of-view (fov) of infrared radiance observation at 1256 UTC, February 23, 1995. The 25 box array are cloud calculations for the satellite fov. The key to the symbols (L3,M1,M2) appears under the satellite fov box, lower right. Letters define the cloud top pressure and numbers and the numbers define the Effective Cloud Amount. For this case, the ground or ASOS weather observation is clear; the complementary SCP is middle (cloud top range is 10,000-21,000 ft), scattered.

NMCSCPER1
 TBUS20 KWBC 181841
 SATELLITE-DERIVED CLOUD INFORMATION FOR MID (CLD TOPS 631-400 MB)
 AND HIGH LEVEL (CLD TOPS ABOVE 400 MB)
 (SEP)

STA	DA/TIMEZ	MID	HIGH	CLD TOP	ECA
ACY	18/1823		OVC	280-440	93
CHS	18/1825	SCT	SCT	120-330	27
CLT	18/1824	SCT	SCT	210-380	1
DAY	18/1823	CLR			0
IAD	18/1823	SCT		150-230	7
PIT	18/1823	SCT		150-210	8
ROA	18/1824	MCLR		120-200	3

The following is a description of each line:

Line 1. AFOS Header (displayed for AFOS users only). Sample shown is the Eastern Region collective (xxx = ER1);

Also available: xxx = CR1 (Central), SR1 (Southern), or WR1 (Western)

Line 2. WMO Header and date/time group. Sample shown is the Eastern Region collective (TBUS20 KWBC); Also available: TBUS21 KWBC (Central Region), TBUS22 KWBC (Southern Region), or TBUS23 (Western Region)

dd = Date of month (i.e. 01,02,...,30,31)

hhmm = hour and minute (UTC) NESDIS generated the collective. Sample shown was generated at 1841 UTC.

Lines 3-4. Title of product

Line 5. Month during which observations were taken (mmm = JAN, FEB, ..., NOV, DEC). Sample shown is from September.

Line 6. Table Header line

Lines 7-end. Parameters for each station:

a) STA: Station id (1 - 5 characters)

b) DA/TIMEZ: Date/time of the satellite observation in the format dd/hhmm (UTC)

c) MID: Mid-level cloud coverage (for clouds between 631 and 400 mb [approximately 12,000-23,600 ft MSL]).

d) HIGH: High level cloud coverage (for clouds above 400 mb [approximately 23,600 ft MSL]).

e) CLD TOP: Heights of lowest and highest cloud tops (hundreds of ft MSL), as seen by the satellite in a 50 x 50 km box centered on the station.

f) ECA: Average effective cloud amount (ECA) in percent. ECA is a function of cloud top coverage and emissivity.

Figure 53. Sample eastern region satellite derived cloud cover product (SCP) collective for September 18, 1993 at 1841 UTC. The generic decoding information appears below the sample product.

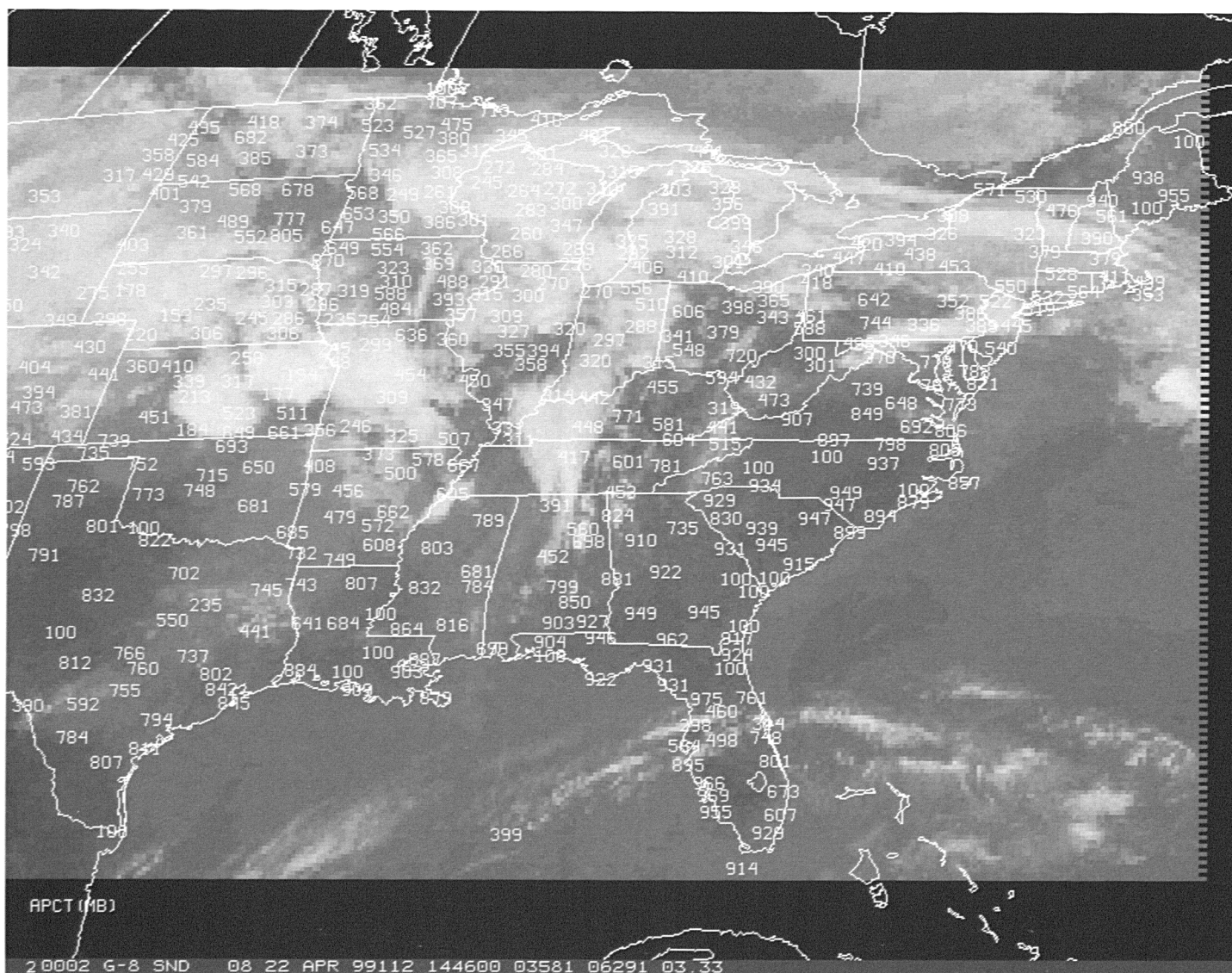


Figure 54. ASOS cloud top height superimposed on a GOES-8 infrared image at 1446 UTC, April 22, 1999.

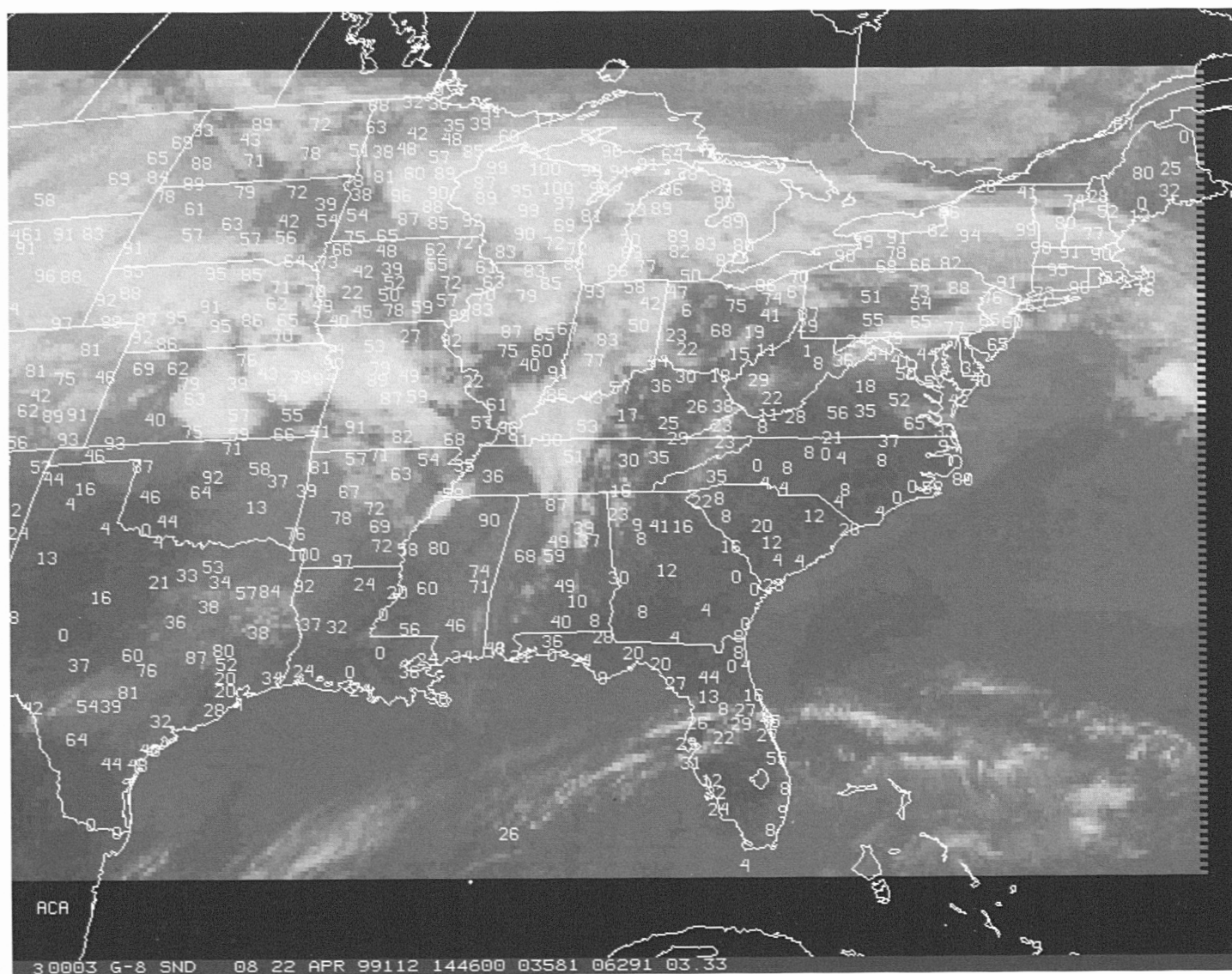


Figure 55. ASOS cloud amount (percent covered) superimposed on a GOES-8 infrared image at 1446 UTC, April 22, 1999.

GOES SUPPLEMENTAL ASOS PLOT: 14GMT 30 OCT 98

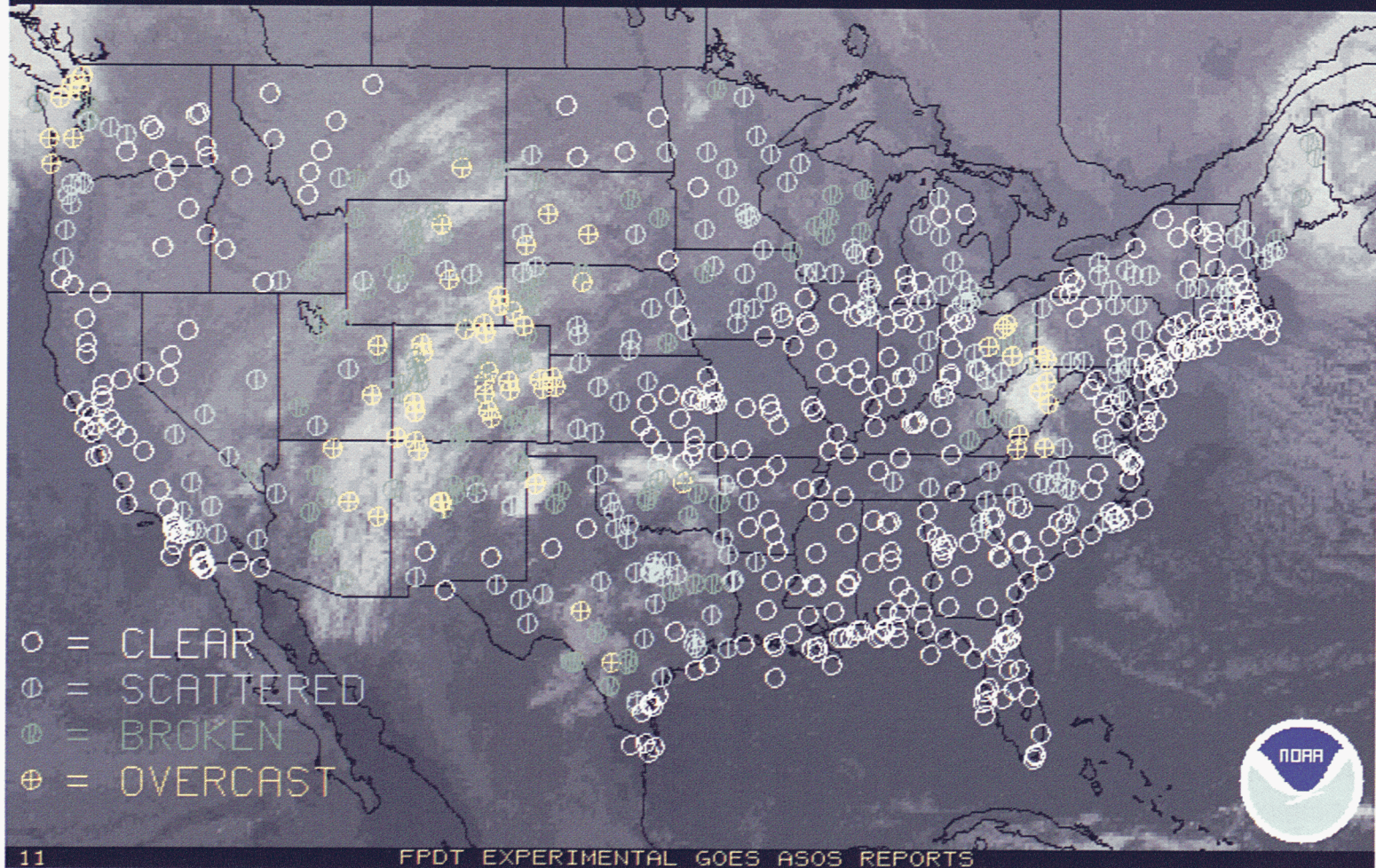


Figure 56. Composite GOES-8/-10 ASOS/SCP text product designation for each ASOS station site at 1400 UTC, October 30, 1998. The white areas indicate where clear skies are present, blue areas indicates scattered clouds, green areas indicates broken clouds and yellow indicates overcast conditions.

VIII. DERIVED PRODUCT IMAGERY

A. Lifted Index

Operational (Imager based)

Description. The lifted index (LI) is an estimate of atmospheric stability. It represents the buoyancy which an air parcel would experience if mechanically lifted to the 500 hPa level. The lifted index expresses the difference in the temperature between the ambient 500 hPa temperature and the temperature of the lifted parcel. A negative value (warmer than the environment) suggests positive buoyancy (continued rising); whereas a positive value suggests stability (returning descent). The formulation used to derive LI is a statistical relationship requiring a mean pressure temperature and moisture for the boundary layer and 500 hPa temperatures.

The computation of the LI is limited to clear areas over the CONUS and adjacent ocean areas (Figure 57). Since it is produced hourly, sequential maps of LI clearly show the diurnal and dynamic changes associated with weather events. Based on user experience, it is recommended that more emphasis should be placed on the location of the most unstable (lowest values) and most stable (highest values) area(s) than the absolute values. It has also been demonstrated that the most unstable areas (lowest LI values and greatest instability) are good candidates for the short term (0-12 hour) forecasting of strong convective (thunderstorm) development and heightened flash flood potential. This product can be viewed on the internet at: <http://orbit-net.nesdis.noaa.gov/goes/sdpi/>.

Accuracy. Lifted Index accuracies at 500 hPa are $\pm 1.5K$.

Users. At the present, the known distribution of this product is to the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is slated for implementation on AWIPS workstations at all NWS WFOs.

Reference.

Hayden, C.M., G.S. Wade and T.J. Schmit, 1996: Derived Product Imagery from GOES-8., *J. Appl. Meteor.*, **35**, 153-162.

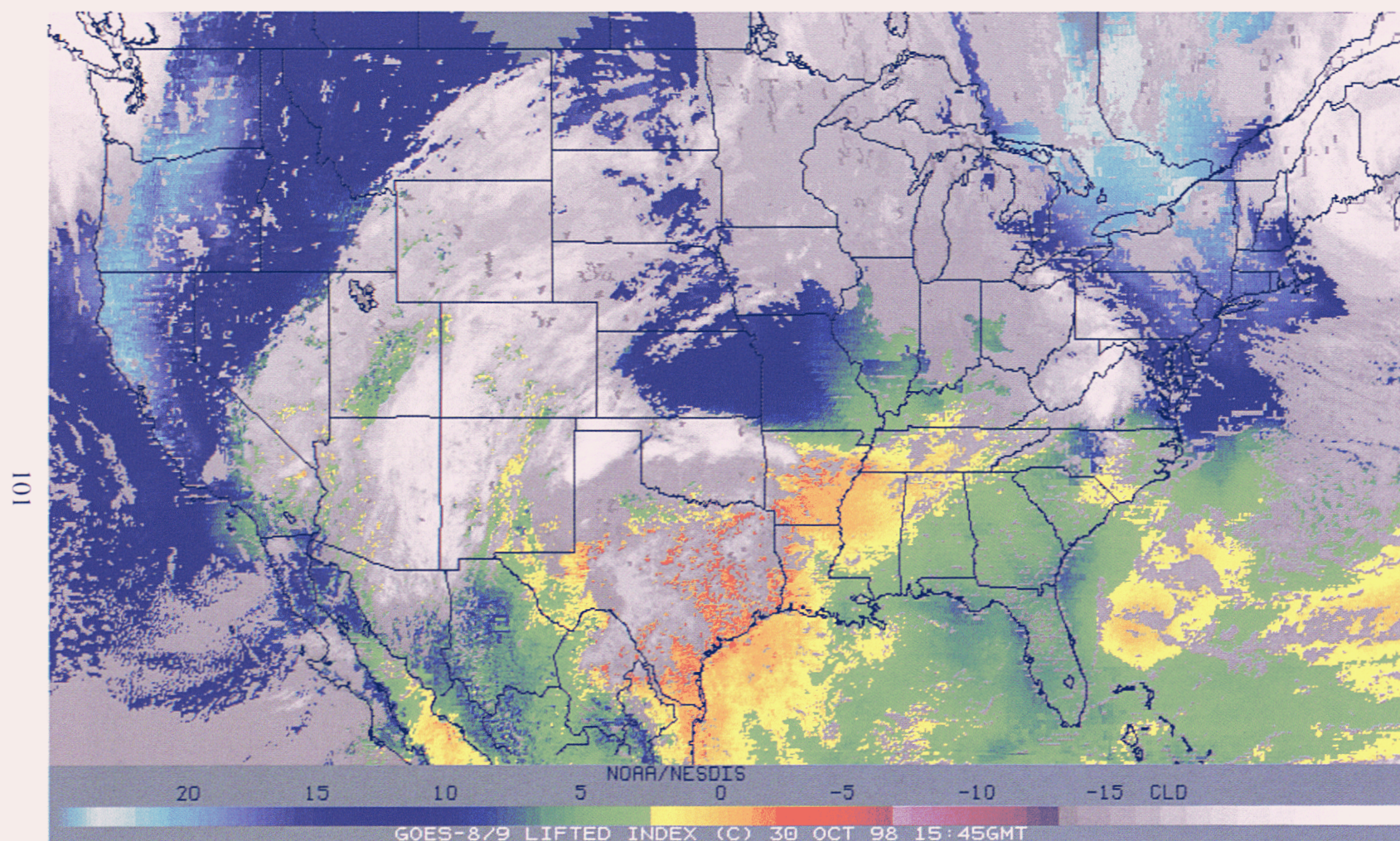


Figure 57. Lifted Index (imager) composite GOES-8/-10 image for 1545 UTC, on October 30, 1998. The green and blue areas depict a stable atmosphere, whereas the red and pink areas depict an unstable atmosphere.

VIII. DERIVED PRODUCT IMAGERY

A. Lifted Index

Experimental (Sounder based)

Description. Lifted index (LI) is also computed from the sounder and output in image format. The LI product is derived from the full physical retrieval algorithm (Ma, et. al., 1998). Figure 58 shows an example of this product which is purposely shown at full resolution for viewing of smaller scale features. The nominal GOES Sounder fov is 10 km at the satellite sub-point. Spatial averaging over a 3x3 fov box is currently employed to increase the signal-to-noise. The sounder-based LI product displayed is an atmospheric stability parameter which estimates the tendency of a low-level parcel of air to continue to rise if it was 'lifted' to the middle of the atmosphere. The units are in °C. A negative value indicates an unstable airmass, while a positive value implies a stable air mass. The value is color-coded with reds and yellows being the most unstable and blues and beige's more stable; clouds are represented as a gray color. For example, the brightest yellow corresponds to an LI of -7°C; while the brightest red, to -8°C. A time sequence of the images is the best way to monitor stability trends. This product can be viewed on the internet at: <http://cimss.ssec.wisc.edu/goes/goes.html> and <http://orbit-net.nesdis.noaa.gov/arad/fpdt/>.

Accuracy. Collocations with radiosondes show root mean square errors of 2-3°C and mean bias errors of +/- 1°.

Users. Anticipated users of this experimental product include the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is currently distributed over RAMSDIS and is slated for implementation on AWIPS workstations.

References.

Ma, X.L., T. Schmit and W. Smith, 1999: A non-linear physical retrieval algorithm - Its application to the GOES-8/9 sounder, *J. Appl. Meteor*, **38**, 501-503.

Menzel, W.P., F.C. Holt, T.J. Schmit, R.M. Aune, A.J. Schreiner, G.S. Wade and D.G. Gray, 1998: Application of GOES 8/9 soundings to weather forecasting and nowcasting. *Bull. Amer. Meteor. Soc.*, **79**, 2059-2077.

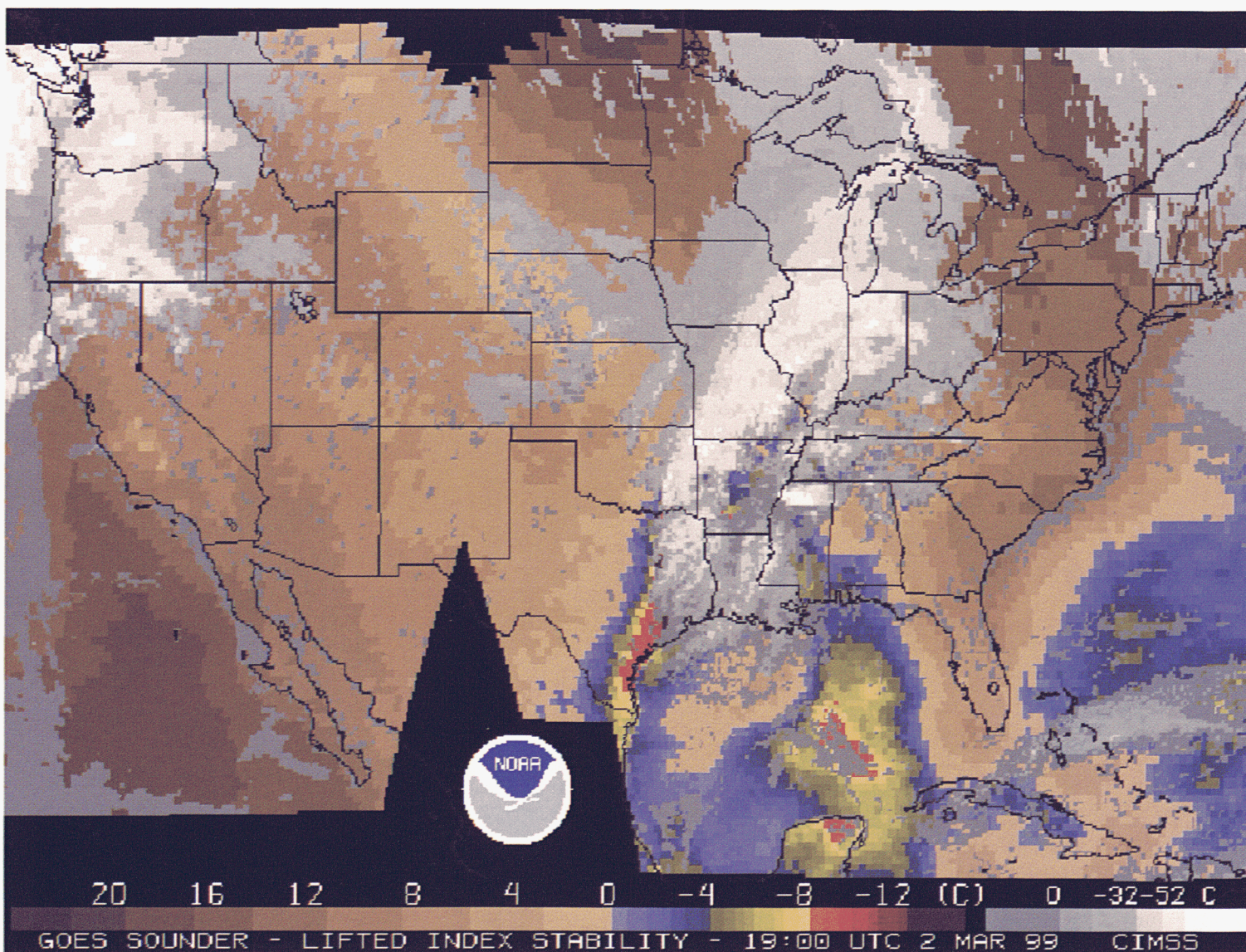


Figure 58. Lifted Index as computed from GOES sounder at 1900 UTC, March 2, 1999.

VIII. DERIVED PRODUCT IMAGERY

B. Total Precipitable Water

Operational (Imager based)

Description. This product represents the total atmospheric water vapor, in millimeters, contained in a vertical column extending from the Earth's surface to the "top" of the atmosphere. An example of the composite total precipitable water image is shown in Figure 59.

The computation of the TPW is limited to clear areas over the CONUS and adjacent ocean areas (Figure 59). Based on user experience, it is recommended that more emphasis should be placed on the location of the absolute maximum and minimum TPW areas than the absolute values. Concentrations of maximum precipitable water values produce an increased potential for heavy precipitation and flash flooding. This product can be viewed on the internet at: <http://orbit-net.nesdis.noaa.gov/arad/fpdt/>.

Accuracy. Product accuracy is +/- 10%.

Users. Presently, the known distribution of this product is to the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is slated for implementation on AWIPS workstations at all NWS WFOs.

Reference.

Gray, D.G., and C.M. Hayden, 1996: Review of quantitative satellite products derived from GOES-8/9 imager and sounder instrument data. *Proceedings of the 8th Conference on Satellite Meteorology and Oceanography*, Amer. Meteor. Soc., 159-163.

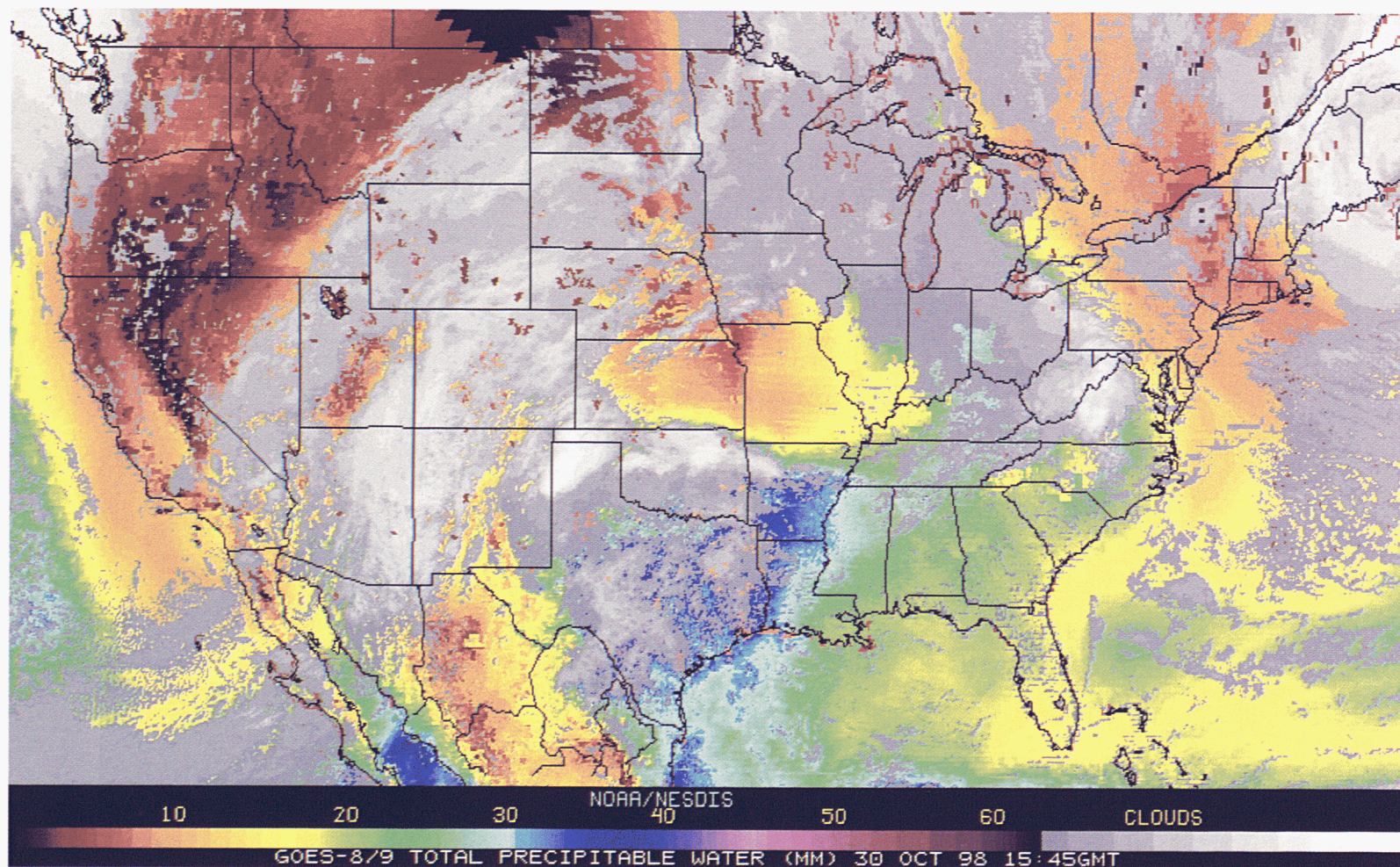


Figure 59. Total Precipitable Water (imager) composite GOES-8/-9 image for 1545 UTC, October 30, 1998.

VIII. DERIVED PRODUCT IMAGERY

B. Total Precipitable Water

Experimental (Sounder based)

Description. This product represents the total atmospheric WV, in millimeters, contained in a vertical column extending from the Earth's surface to the "top" of the atmosphere. This quantity is computed from the entire retrieval profile described in Section VII-b using sounder radiance measurements. An example of the TPW derived product image is shown in Figure 60. Included in this figure are radiosonde reports of TPW. Comparisons between the radiosonde measurements and the satellite derived TPW show good agreement. These images of derived products have been generated from the GOES-8 and GOES-10 sounder data using the physical retrieval method described in Ma, et. al, 1998. The product displayed is the total atmospheric precipitable water vapor value. The value is color-coded with browns being the driest and reds being the most moist. Clouds are represented as a series of gray shades (see the color bar at the bottom of the image). A time sequence of the images is the best way to monitor drying and moistening trends. Superimposing low-level winds as shown in Figure 60 assists in assessing potential moisture advection. This product can be viewed on the internet at: <http://cimss.ssec.wisc.edu/goes/goes.html>.

Accuracy. Collocations with radiosondes show root mean square errors of 4-6 mm and mean bias errors of +/- 1 mm.

Users. Anticipated users of this experimental product include the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is currently distributed over RAMSDIS and is slated for implementation on AWIPS workstations at all NWS WFOs.

References.

Ma, X.L., T. Schmit and W. Smith, 1999: A non-linear physical retrieval algorithm - Its application to the GOES-8/9 sounder, *J. Appl. Meteor*, **38**, 501-503.

Menzel, W.P., F.C. Holt, T.J. Schmit, R.A. Aune, A.J. Schreiner, G.S. Wade and D.G. Gray: Application of GOES-8/9 Soundings to Weather Forecasting and Nowcasting. *Bull. Amer. Met. Soc.*, **79**, 2059-2077.

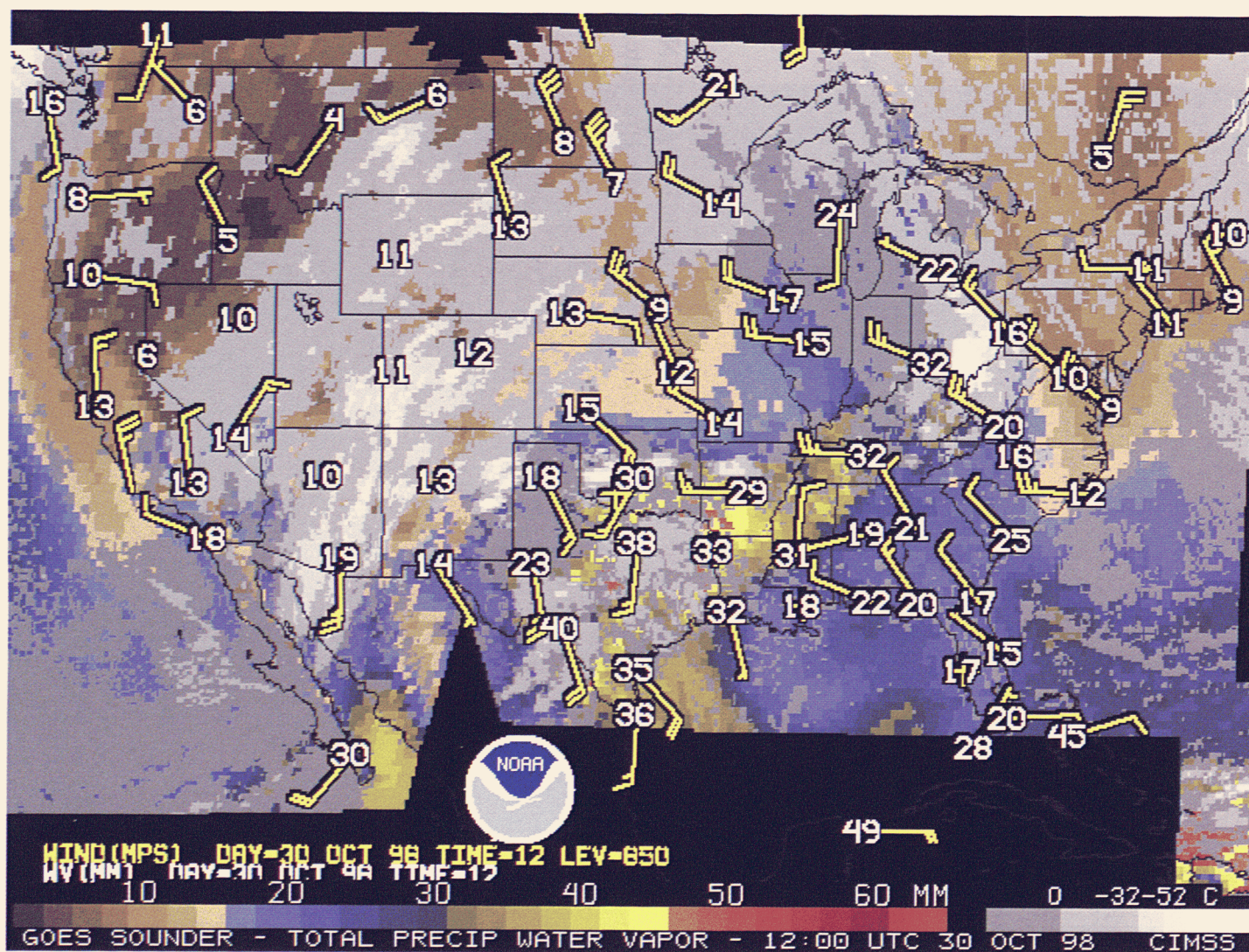


Figure 60. Total Precipitable Water (sounder) composite GOES-8/-10 image for 1200 UTC, October 30, 1998, with 850 hPa winds and TPW from radiosondes.

VIII. DERIVED PRODUCT IMAGERY

C. Surface Skin Temperature

Operational (Imager based)

Description. The surface skin temperature product is generated from GOES Channel 4 and 5 imager radiances. Differences of these two channels are used to determine low-level moisture and to monitor the influence of precipitation on the observed surface skin temperatures.

Figure 61 shows an example of this product. Cloud cover is represented by light gray to white tones. The warm surface skin temperatures along the lower Mississippi Valley and Central Florida are apparent. Time sequences of this product are most beneficial. Obscuring clouds move across the scene permitting users to monitor changes in the temperature field. This may become a valuable tool for local or mesoscale applications. Identification of “hot” or “cold” locations may assist in forecasting thunderstorms, fog, or local temperatures. This product is available on the internet at: <http://orbit-net.nesdis.noaa.gov/goes/sdpi/>.

Accuracy. Spatial accuracy is 4 km for the imager.

Users. At the present, the known distribution of this product is to the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is slated for implementation on AWIPS workstations at all NWS WFOs.

Reference.

Hayden, C.M., G.S. Wade and T.J. Schmit, 1996: Derived Product Imagery from GOES-8., *J. Appl. Meteor.*, **35**, 153-162.

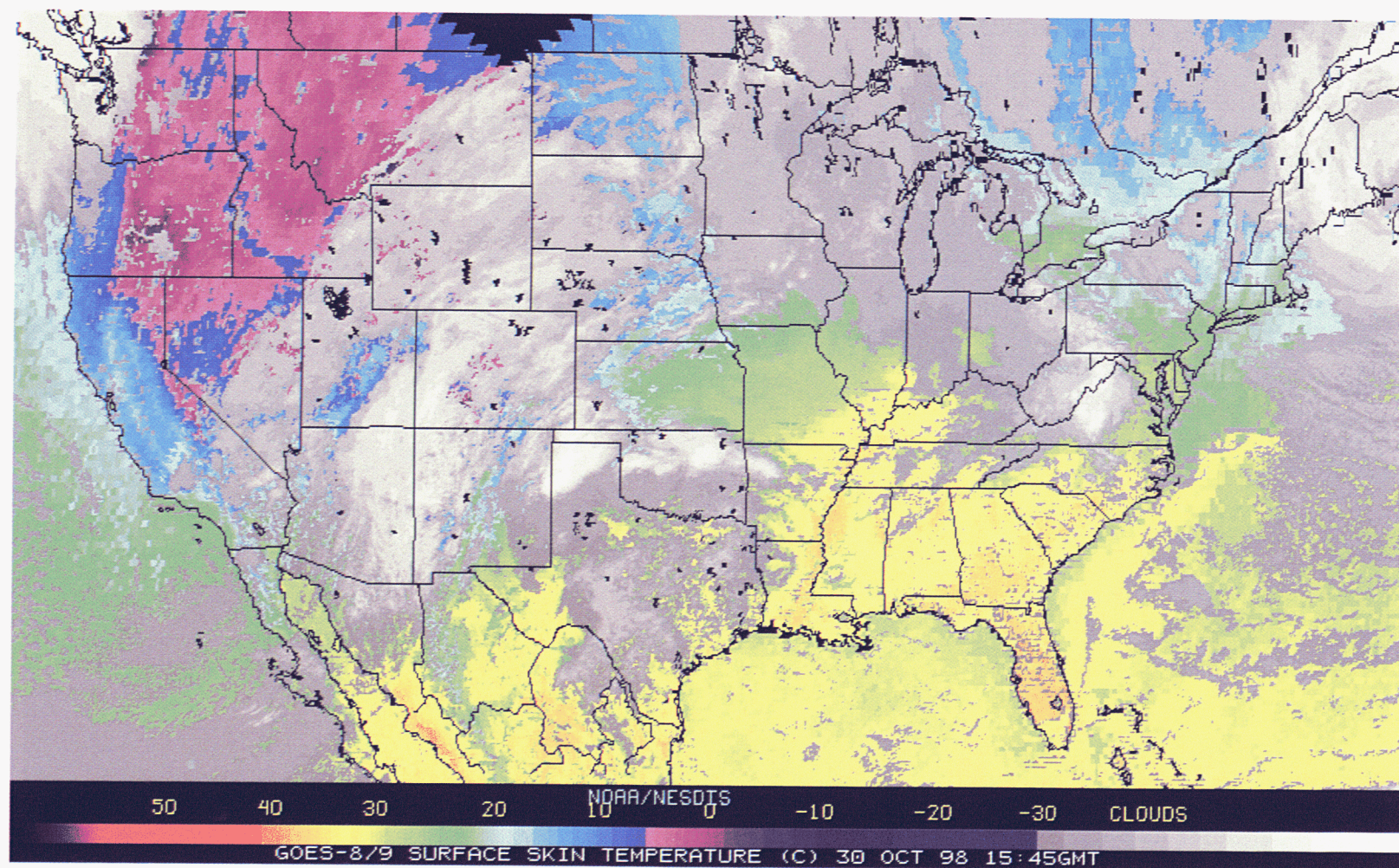


Figure 61. Surface Skin Temperature (imager) composite GOES-8/-9 image for 1545 UTC, October 30, 1998.

VIII. DERIVED PRODUCT IMAGERY

C. Surface Skin Temperature

Experimental (Sounder based)

Description. The surface skin temperature product is generated from GOES sounder radiances. Figure 62 shows an example of this product. Cloud cover is represented by light gray to white tones. Differences of these two channels are used to determine low-level moisture and to adjust the influence of this moisture on the observed surface skin temperatures. Note how Figure 62 shows a gradual warming of temperatures from north to south in the Florida Peninsula. Time sequences of this product are most beneficial. Obscuring clouds move across the scene permitting users to monitor changes in the temperature field. This may become a valuable tool for local or mesoscale applications. Identification of “hot” or “cold” locations may assist in forecasting thunderstorms, fog, or local temperatures. This product can be viewed on the internet at: <http://cimss.ssec.wisc.edu/goes/goes.html>.

Accuracy. Spatial accuracy is 10 km.

Users. At the present, the known distribution of this product is to the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country. This product is slated for implementation on AWIPS workstations at all NWS WFOs.

Reference.

Hayden, C.M., 1988: GOES-VAS simultaneous temperature-moisture retrieval algorithm,. *J. of Appl. Meteor.*, **27**, 705-733.

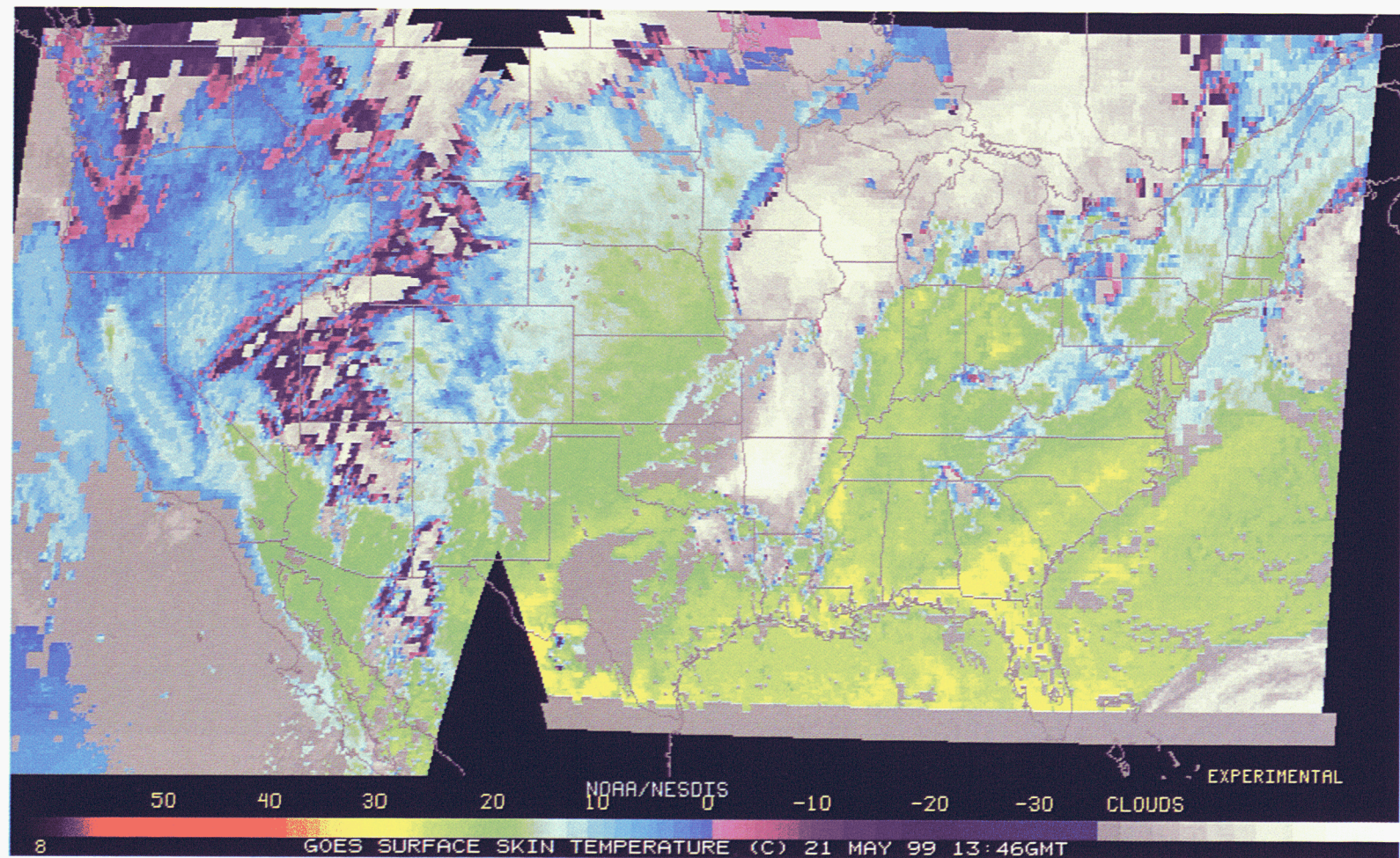


Figure 62. Surface Skin Temperature (sounder) composite GOES-8/9 image for 1346 UTC, May 21, 1999.

VIII. DERIVED PRODUCT IMAGERY

D. Cloud Top Pressure

Experimental (Sounder based)

Description. Cloud top pressure (CTP) is derived from the GOES sounder radiance information routinely at hourly intervals. Calculations, using the CO₂ Absorption Technique, are made at each field of view. A derived product image of the cloud top pressure is then constructed and color enhanced to display cloud tops at 100 hPa intervals. Due to the low-level atmospheric signal being dominated by surface emissions, this technique is less reliable for clouds near the surface. Figure 63 shows an example of this product.

This cloud product is also constructed on a grid with a horizontal resolution of 30 km². Experiments are currently being run using this quantitative product as input to the EDAS in order to properly initialize the ETA model cloud field. Model impact analyses are being performed to assess the usefulness of this product on model precipitation forecasts. This product is available on the internet at: <http://cimss.ssec.wisc.edu/goes/goes.html>.

Accuracy. The accuracy of the cloud-top pressures is +/- 50 hPa.

Users. Anticipated users include the EMC, NWS, NCDC and the SAB.

References.

Menzel, W.P., W.L. Smith and T.R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. *J. Clim. Appl. Meteor.*, **22**, 377-384.

Menzel, W.P., F.C. Holt, T.J. Schmit, R.A. Aune, A.J. Schreiner, G.S. Wade and D.G. Gray: Application of GOES-8/9 Soundings to Weather Forecasting and Nowcasting. *Bull. Amer. Met. Soc.*, **79**, 2059-2077.

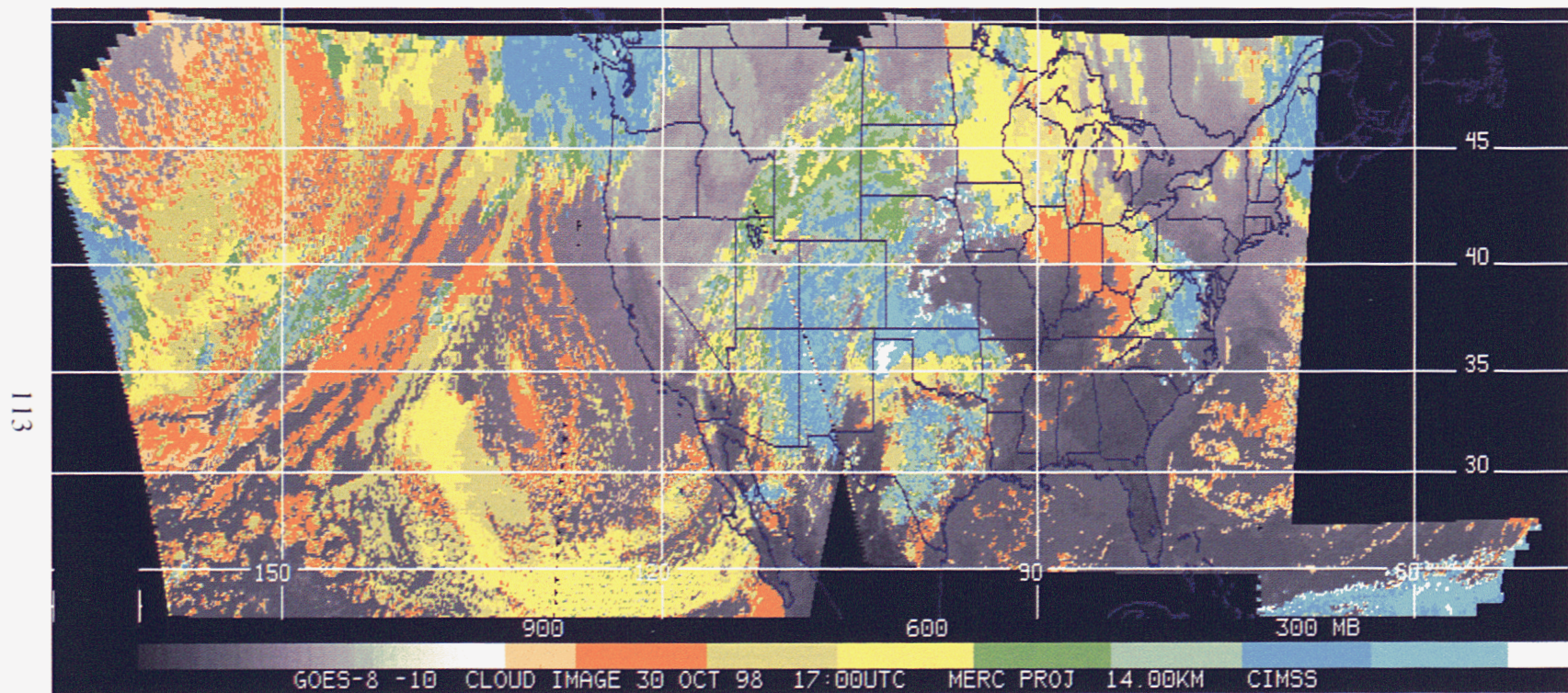


Figure 63. GOES 8/10 composite Cloud Top Pressure sounder image for 17 UTC, October 30, 1998. The orange and yellow colors depict low-level clouds (900-600hPa) and the green and blue colors show mid and high-level clouds.

VIII. DERIVED PRODUCT IMAGERY

E. Effective Cloud Amount

Experimental (Sounder based)

Description. Once a cloud height (pressure) has been determined via the CO₂ absorption technique, the ECA for each fov can be computed from the infrared channel data. ECA shown in Figure 64 is also referred to as effective fractional cloud cover. The ECA is a function of cloud top coverage and emissivity and can be helpful in distinguishing between thin and opaque clouds.

Accuracy. The accuracy of the effective cloud amount is +/- 10%.

Users. Anticipated users of this experimental product include the National Centers of NCEP, SAB, NESDIS, and selected NWS WFOs across the country.

Reference.

Menzel, W.P., W.L. Smith and T.R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. *J. Clim. Appl. Meteor.*, **22**, 377-384.

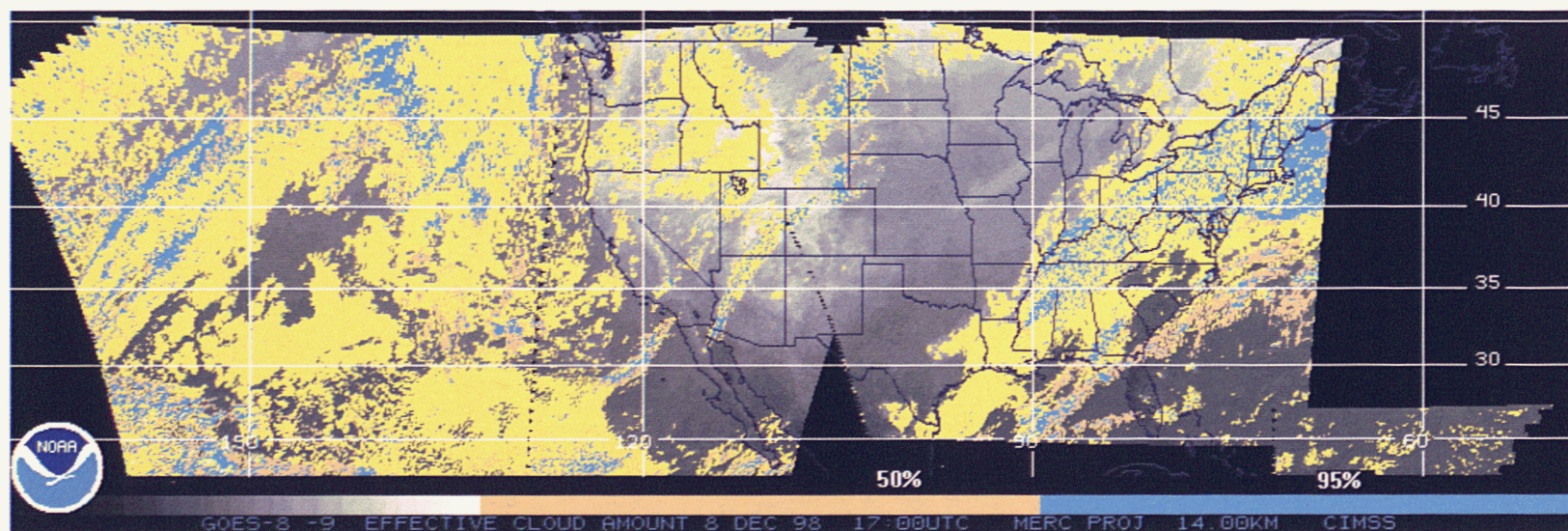


Figure 64. Sounder-based Effective Cloud Amount for 1700 UTC, December 8, 1998.

VIII. DERIVED PRODUCT IMAGERY

F. Sea Surface Temperature

Experimental (Imager based)

Description. One of the newest GOES products is the Sea Surface Temperature (SST) image. The SST algorithm uses the GOES 8/10 multispectral information for channels 1, 2, 4 and 5. Extensive screening for cloud and aerosol contamination, wind effects, and other factors which would effect the regression equation are performed on these channel measurements to yield clear sky radiance values. Two regression equations are produced, one for GOES-8 and one for GOES-10.

$$\text{GOES-8/9} \quad \text{SST} = -6.4110 + 1.0260 T_4 + 1.1900 (T_4 - T_5) + 0.2017 (T_4 - T_5)^2 \quad (1)$$

$$\text{GOES-10} \quad \text{SST} = 18.3500 + 0.9459 T_4 + 0.4261 (T_4 - T_5) + 0.4473 (T_4 - T_5)^2 \quad (2)$$

Production of experimental GOES SSTs began on October 1, 1998. Figure 65 shows an SST composite for GOES-8 from the Gulf of Mexico to Newfoundland. The color bar indicates the (deep reds) warmest water is around 33°C in the Gulf of Mexico and the coolest water (magenta) approximately 0°C around Newfoundland. The image depicts the Gulf Stream boundaries, eddies, and the cooler shelf slope waters. Figure 66 shows GOES-SST image which combines GOES-8 and GOES-10 SSTs for the Northern and Southern Hemispheres. The image extends from 45 S to 60 N and 30 to 180 W. The temperature ranges from red (warmest) to black (coldest) and the white represents areas of no data. Frequent imaging allows clouds to transit the scene and provide a more complete SST picture. Several images can be blended together. GOES SST validation can be found on the internet at: <http://manati.wwb.noaa.gov/sst/index.html>.

Accuracy. The regression equations were verified by comparing the GOES and buoy SSTs. The standard deviation varied from 0.6 to 0.8 K. Validation of the experimental GOES-SSTs will be completed next year for production of an operational GOES-SST product. Spatial accuracy is 4 km at satellite sub point.

References.

Menzel, W. P., and J. F. W. Purdom, 1994: Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites. *Bull. Amer. Met. Soc.*, **75**, 757-781.

Wu, X., W. P. Menzel and G. S. Wade, 1999: Estimation of sea surface temperatures using GOES-8/9 radiance measurements. *Bull. Amer. Met. Soc.*, (accepted).

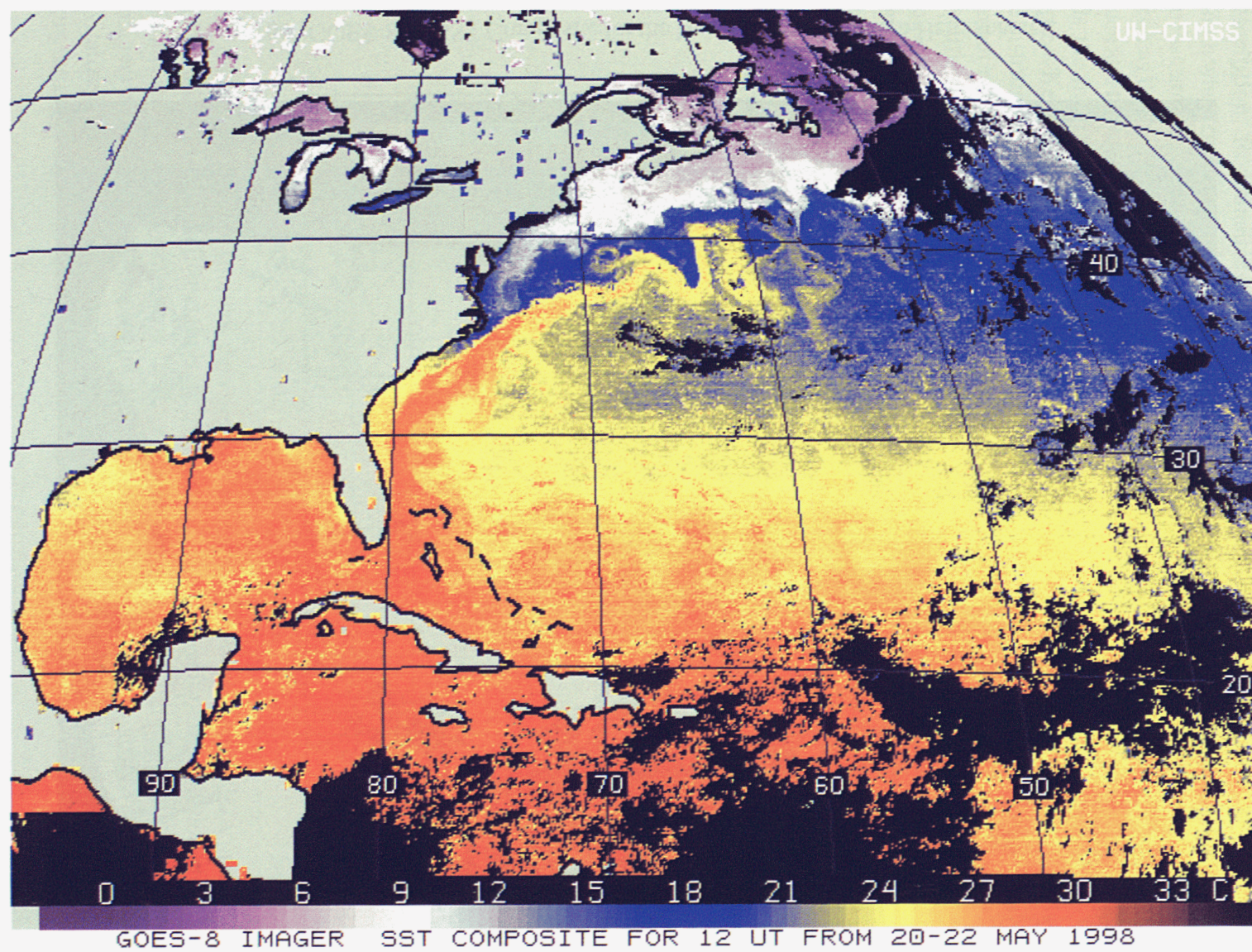


Figure 65. GOES-8 SST Composite from the Gulf of Mexico to Newfoundland.

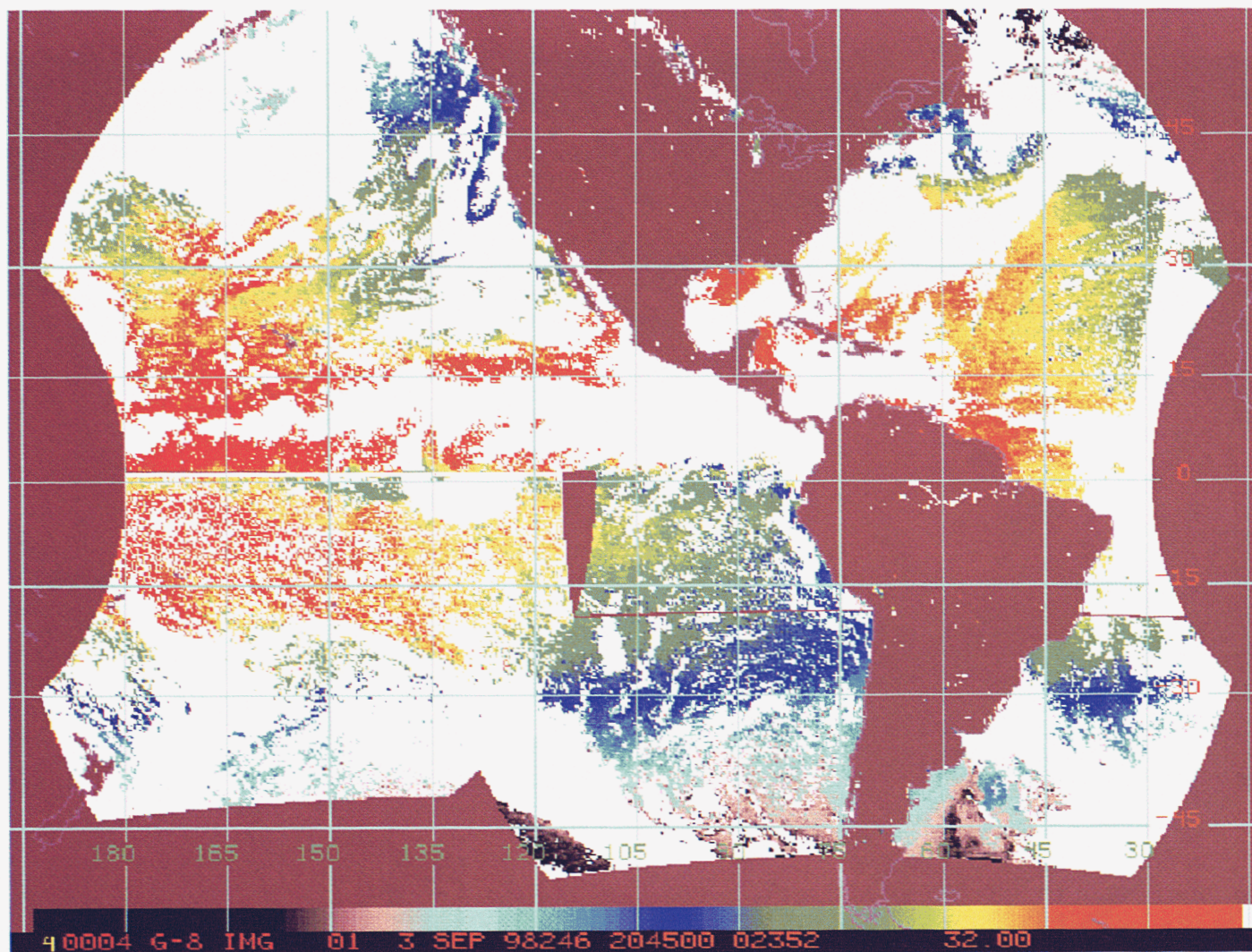


Figure 66. GOES-8/10 SST Composite for the Northern and Southern Hemispheres.

IX. IMAGER AND SOUNDER CALIBRATION

Description. Radiometric calibration of the imagers and sounders begins in the laboratory before launch when each instrument's performance is characterized and data needed in the orbit calibration process are determined. On orbit, the infrared channels of the instrument are calibrated with data taken as they view space and their onboard warm blackbodies. This is a full system calibration, as space and the blackbodies are entirely outside the optical chains of the instruments, and their radiation fills the instruments' apertures. Since temperature in the instruments vary diurnally by tens of degrees Kelvin, with the most rapid variations usually occurring in the hours around satellite midnight, the instruments' infrared responsivities vary considerably throughout the day. Therefore, to maintain measurement accuracy and precision, the infrared channels are calibrated frequently. The imager, in particular, must view space (the zero reference) as frequently as possible, not only to account for temperature-driven changes, but also to minimize $1/f$ noise in the infrared channels, which is manifested as drifts in the output. (Since the sounder clamps electronically at approximately 5Hz on its filter wheel, $1/f$ -noise drifts are not a problem for it.) The intervals between infrared calibration measurements are shown in Table 6. The visible channels are calibrated before launch but not on orbit as the imager and sounder carry no radiation sources for this purpose.

TABLE 6. INTERVALS BETWEEN CALIBRATION MEASUREMENTS

Measurement Type	Imager	Sounder
Space	2.2, 9.2, or 36.6 sec	2 min
blackbody	30 min	20 min

Raw digital imager and sounder data are transmitted continuously to the CDA station, where the calibration is performed in real time. In the infrared channels, calibration coefficients are computed and are applied to the raw scene data, producing radiances, which are then converted to ten-bit (imager) or sixteen-bit (sounder) integers by a linear scaling. In the visible channels, the data are revitalized (i.e., the signal from the space view is subtracted from the raw scene data), and the data from the eight detectors are normalized to minimize the appearance of artificial east-west stripes in

the images. The visible scene data, the infrared scaled radiances, and calibration and scaling coefficients are transmitted to users in the GVAR data stream. Users can derive the infrared radiances from the digital GVAR data by inverting the scaling operation. NESDIS also supplies algorithms and coefficients to users for deriving scene brightness temperatures from the GVAR data. Details can be found in Weinreb et al., 1997.

The calibration processing has been modified since the launch of GOES-8 in 1994 to mitigate the effects of several unexpected instrument performance problems. These include artificial east-west gradients in infrared channels, caused by the east-west scan-position variation of the reflectance of the scan mirror (Weinreb et al., 1997), and striping in infrared images from the imagers, caused primarily by 1/f noise (Baucom and Weinreb 1996).

Accuracy. The responses of the eight silicon photodiode detectors of the visible channels of the GOES-8, -9, and -10 imagers are well behaved, and image striping has been minimal, typically less than two counts (out of 1023). The noise in these channels is of the order of three counts. The responsivities of the imager visible channels have been decreasing with time. Preliminary estimates of the rates of decrease, based on two very different vicarious calibration techniques, are 8% / yr. for GOES-8 and 5% / yr. for GOES-9 (Bremer et al., 1998), and approximately 5% / yr. for GOES-8 and 2% for GOES-9 (Rao et al., 1998).

In the infrared channels of both imager and sounder, the absolute calibration uncertainty, primarily a result of uncertainties in the transfer of the calibration from the National Institute of Standards and Technology (NIST) standard, is believed to be less than 1K at 300K. Relative errors, e.g., scan line-to-scan line and detector-to-detector differences, are caused primarily by instrument noise during the day and a combination of noise and temperature-driven drifts at night. For the imagers, the relative errors (ms) are of the order of 0.13K at 300K for GOES-8 and 0.07K at 300K for the GOES-9 and -10. Because of the strong temperature dependence of the Planck function, brightness temperature errors increase rapidly with decreasing scene temperature. For scenes with temperatures near 220K, for example, detector-to-detector differences of over 1K occur occasionally, especially in GOES-8 imager infrared channels. Sounder relative errors vary significantly from channel to channel and are of the order of 0.1K at 300K. Solar heating of instrument components occurs in the six hours surrounding midnight when the sun is in the Northern Hemisphere. This causes calibration errors in the short-wave channels (imager channel 2 and sounder channels 13-18) which can artificially depress scene measurements by up to 1K. An algorithm exists (Johnson and Weinreb, 1996) to overcome this effect, but it had not been made operational as of September 1998.

Users. Calibration is a necessary step in the observing process. Stable and accurate calibration is needed for the production of stable and accurate data products. Besides, NESDIS operations, users include atmospheric scientists and climate researchers in academia, government, and industry in the US and abroad. GOES calibration information is found on the Internet at www.nnic.noaa.gov/SOCC/geoscal.html.

References

Baucom, J.G., and M.P. Weinreb, 1996: Characteristics of E/W Stripes in Infrared Images from the GOES-8 Imager. In *GOES-8 and Beyond*, Edward R. Washwell, Editor, Proc. Society of Photo-Optical Instrumentation Engineers (SPIE), **2812**, pp. 587-595.

Bremer, J.C. J.G. Baucom, H. Vu, M. P. Weinreb and N. Pinkine, 1998. Estimation of long-term Throughout Degradation of GOES-8 &-9 Visible Channels by Statistical Analysis of Star Measurements., W.L. Barnes, Ed., Proc., SPIE, **3439**, (To appear in *Earth Observing Systems III*).

Johnson, R.X., and M.P. Weinreb, 1996: GOES-8 Imager Midnight Effects and Slope Correction. In *GOES-8 and Beyond*, Edward R. Washwell, Editor, *Proc. Society of Photo-Optical Instrumentation Engineers (SPIE)*, **2812**, pp. 596-607.

Rao, C.R.N., J. Chen, N. Zhang and J. Sullivan, 1998: Post Launch Calibration of Meteorologist Sensors. (To appear in *Advances in Space Research*).

Weinreb, M.P., M. Jamieson, N. Fulton, Y. Chen, J.X. Johnson, C. Smith, J. Brener and J. Baucom, 1997: Operational Calibration of GOES-8 and -9 Imagers and Sounders. *Applied Optics*, **36**, 6895-6904.

X. GOES CALIBRATION DATA BASE

Description. A data base for use in calibrating the imager channels on the GOES-8/9/10 spacecraft has been designed and coded. The data base consists of 50 targets selectable by latitude and longitude for which IR data are collected every 3 hours on synoptic times (0000, 0300, 0600, ...2100 UTC) or as near to synoptic times as the hourly GOES data are ingested. The visible data are collected 5 times daily centered at local noon. Data saved consists of arrays of coincident pixels from each channel. The visible data are at 1 km resolution and an array of 24 x 24 pixels is collected. For Channels 2, 4, and 5, the coincident array is a 6 x 6 array, and for Channel 3, the array is 3 x 3 pixels. Statistical data for each target array, such as mean, standard deviation, minimum and maximum values will also be included. The latitude and longitude of the center of each target is also saved. Data base target locations may change from time to time as calibration and research needs change.

Accuracy. See Section IX.

Users. This data base is used internally for research and development and quality control.

XI. PRODUCT ARCHIVE

The NESDIS NCDC archives the operational GOES imagery. Selected GOES products described in the previous sections are also available from NCDC. Table 7 summarizes the GOES products, area of coverage, and product frequency that are available. To order data or products, customers should contact NCDC at the phone, facsimile, or E-mail points listed in Section III.

TABLE 7. GOES PRODUCTS AVAILABLE FROM THE NCDC ARCHIVES.

Product Name	Area	Product Frequency
Vertical Temperature Profiles ($^{\circ}\text{K}$ at 40 pressure levels), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Vertical Moisture Profiles (mm H_2O integrated in 3 pressure layers), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Layer Precipitable Water (mm H_2O at 14 pressure levels), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Total Precipitable Water (derived product images mm H_2O), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Channel Brightness Temperatures (Intensity of each of the 18 sounder IR channels, expressed in $^{\circ}\text{K}$), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Lifted Index ($^{\circ}\text{K}$ at 500 hPa pressure level), 8 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Geopotential Heights (m at 14 pressure levels), 50 km resolution at nadir	CONUS and adjacent ocean areas	1/hour
Thermal Wind Profiles (m/s at 14 pressure levels), 50 km at nadir	CONUS and adjacent ocean areas	1/hour
Input Archives (includes all inputs needed to regenerate the products listed below)		1/hour
Cloud Drift Winds, low-level 4 km resolution at nadir; ocean areas only	+/- 50 Deg. Lat., +/- 50 Deg. from Nadir Lon.	1/6 hours
Cloud Drift Winds, mid-level, 4 km resolution at nadir	+/- 50 Deg. Lat., +/- 50 Deg. from Nadir Lon.	1/6 hours
Cloud Drift Winds, high-level, 4 km resolution at nadir	+/- 50 Deg. Lat., +/- 50 Deg. from Nadir Lon.	1/6 hours
Moisture Drift Winds, mid and high-levels, 8 km resolution at nadir	+/- 50 Deg. Lat., +/- 50 Deg. from Nadir Lon.	1/6 hours

TABLE 7. GOES PRODUCTS AVAILABLE FROM THE NCDC ARCHIVES (CONT'D).

Product Name	Area	Product Frequency
Moisture Analysis (Relative Humidity at each of 6 pressure levels), 2.5 geodetic degree resolution	Ocean Areas adjacent to North America	1/12 hour
Total Precipitable Water (mm), 8 km resolution at nadir	CONUS, Hawaii, Puerto Rico	2/hour
Lifted Index (°K at hPa pressure level), 8 km resolution at nadir	CONUS, Hawaii, Puerto Rico	2/hour
ASOS Cloud Top Height Pressure Altitude Coverage (clear, scattered, broken, overcast), 50 km resolution at nadir	Approximately 120 CONUS locations coincident with ASOS stations	1/hour
Cloud Top Temperatures (hPa), 50 km resolution at nadir	CONUS	1/hour
Rainfall Estimates (inches per 1/2 hour), 50 km resolution at nadir	CONUS, Hawaii, Puerto Rico	1/30 minutes

A GOES browse homepage has been established to assist users in selecting imagery from the archive. This browse file can be accessed at <http://goesshp.wwb.noaa.gov>.

XII. SPACE ENVIRONMENT MONITOR

GOES Space Environment Monitor Data Sets

Introduction

The Space Environment Center (SEC) is one of the NCEP centers. The Space Weather Operations (SWO) division continuously monitors the Sun and the state of the near-Earth environment, acquiring data in real time from both ground-based and satellite-based sensors. Solar activity is monitored from satellites and observatories around the world on a 24 hour-a-day, 7 day-a-week basis. SWO forecasters issue alerts of significant solar and geophysical events. They also create products and provide services that summarize and predict space weather. Alerts, warnings, and products are disseminated worldwide via a variety of delivery systems. The products and services are generally available to customers without cost.

SWO is operated jointly with the U.S. Air Force Space Forecast Center (50th Weather Squadron) in Colorado Springs, Colorado. Products are coordinated and issued jointly, with the SWO serving the civilian and government communities and 50th Weather Squadron serving Department of Defense customers.

SWO collects data, in real time, to create the most timely and extensive space weather data base in the world. Because of the real time nature of the mission, data gathered are considered preliminary in nature. Final corrected ground and space-based archive data are available from the National Geophysical Data Center in Boulder, Colorado.

SEM data from GOES form the core data for monitoring the solar-terrestrial environment. These data are accessed by other forecasting centers, user communities, and researchers around the world. Therefore, many SWO alerts, warnings, predictions, and products include the GOES SEM data sets.

A. GOES SEM Instruments

1. The Solar X-Ray Sensor (XRS)

The XRS provides continuous monitoring of the disk-integrated solar flux in the 0.1-0.8 nanometer (nm) and 0.05-0.4 nm ranges. Fluxes are recorded at 0.5 second intervals. XRS tracks solar x-ray fluxes over five orders of magnitude with a precision of 0.4 to 4% (depending on the flux and range setting) and an absolute flux calibration of 10%. The peak 0.1-0.8 nm flux during a solar flare is used to classify the event as C, M, or X (peak fluxes of 1, 10, and 100 x 10E-6 Watts/square meter) class flare. XRS observed solar fluxes are used to estimate the magnitude of associated solar-terrestrial disturbances. XRS provides a warning that a solar flare has occurred, and the peak flux

and duration are used to estimate whether a solar-terrestrial disturbance will occur at Earth. These disturbances include ionospheric changes that disrupt or alter radio communication and increase satellite drag; energetic particle fluxes that can damage humans in space, upset spacecraft circuits, and degrade components; and geomagnetic storms that can disturb power grids, increase pipeline corrosion, alter spacecraft charging, and disturb magnetic guidance systems.

2. *The Energetic Particle Sensor (EPS)*

The EPS is comprised of three detector assemblies: the EPS Telescope, the EPS Dome Detector Assembly, and the HEPAD. Together, these detectors monitor the energetic electron, proton, and alpha particle environment at geostationary orbit from about 600 kilo electron volt (keV) to relativistic energies. The EPS detectors are rigorously calibrated prior to flight. Once on-orbit, the particle measurement accuracies are compared to other GOES EPS detectors and other spacecraft such as IMP-8.

The particle environment at geostationary orbit, observable by the EPS, consists generally of three components: first, a geomagnetically trapped and highly variable population of electrons of up to some tens of Mega electron volt (MeV), and protons up to several MeV in energy; second, sporadic, sometimes large, fluxes of electrons, protons, and alpha particles (usually a few percent of the proton flux) of solar origin, with both trapped and solar fluxes superposed on a background resulting from ever present Galactic Cosmic Rays ranging from several MeV to highly relativistic energies. Knowledge of the near-Earth energetic particle environment is important in establishing the natural radiation hazard to humans at aircraft altitudes and in space, as well as risk assessment and warning of episodes of surface charging, deep dielectric charging, and single event upset of satellite systems. Further, the state of the ionosphere is strongly modified by varying energetic particle precipitation into the Earth's atmosphere. These modifications result in disturbance and occasional disruption of radio communications and navigation systems, in addition to their being associated with geomagnetic disturbance phenomena.

3. *Magnetometer*

The magnitude and direction of the ambient magnetic field are measured by two (redundant) Schonstedt magnetometers. The three-axis orthogonal sensors are located in a sensor assembly and attached to a boom that places the sensors 3 m and 2.7 m away from the body of the spacecraft. The sampling rate is 0.512 second. The magnetometer provides a sensitivity of about 0.1 nanoTesla (nT) while accommodating fields within the range of +/- 1000 nT. The measurement accuracy is 4 nT uncorrected, and 1 nT with temperature correction. The magnetometer data can be used to characterize the general level of geomagnetic activity; to monitor current systems in space; to detect magnetopause crossings, storm sudden commencements, and substorms for general use by the operational and scientific communities.

B. System Effects, Customers, and Data Utility

1. ***Satellite Operations:*** The GOES SEM instruments provide the definitive environmental data sets for assessing geosynchronous satellite anomalies. These anomalies can range from minor induced noise in sensors to catastrophic vehicle failure. Knowledge of disturbed conditions allows spacecraft operators to recover affected systems more quickly if there is a history of cause/effect between the affected system and environmental conditions. Spacecraft designers also utilize GOES SEM data to execute designs capable of withstanding the wildly varying space environment. The following table compares SEM data sets with observed satellite anomalies and failures.

TABLE 8. SEM DATA SETS AND OBSERVED SATELLITE EFFECTS

EFFECT	SEM SENSOR
Surface Charging	Magnetometer
Deep Dielectric Charging	Energetic Electrons
Telemetry Interference	XRS
Single Event Upsets	Energetic Protons
Solar Cell Damage	Energetic Protons
Orientation Problems	Magnetometer
Total Dose Degradation	Energetic Protons

In addition to specifying the environment, data from the GOES SEM aid forecasters in predicting energetic proton events, geomagnetic, and ionospheric storms.

2. ***Induced Currents:*** The Sun creates “gusts” of the solar wind that impinge upon the Earth’s magnetic field and result in geomagnetic storms. During these storms, the intensity and direction of the Earth’s magnetic field vary greatly. In the presence of a long conductor such as a power line or pipeline, a moving magnetic field will induce currents into the structure. Pipeline corrosion rates increase if a canceling current cannot be maintained. The power industry can be catastrophically affected. A severe storm in March 1989 resulted in a complete failure of the power grid in the province of Quebec for over 9 hours. Some U.S. systems experienced millions of dollars of damage during this storm. In part, GOES XRS and Magnetometer data are used to predict and detect these disturbances.

3. **Communications**: The electromagnetic and particle outputs from the Sun affect almost all frequencies utilized for communications. The effects include anomalous propagation, signal loss or modification, and even complete blackout. The XRS data are used to predict, in real time, the short-wave frequencies that are lost when transmitting high frequencies into or through the sunlit hemisphere. Solar proton events detected by the GOES EPS sensors specify directly the amount of absorption of high-frequency signals traversing the polar zones. Extremely low frequencies used by submarine communications experience disturbances during geomagnetic storms. Spacecraft communications utilize very high frequencies that propagate through the ionosphere. These frequencies are disrupted by scintillation during ionospheric storms or interrupted during large solar flares when the Sun is in the field of view of the ground antenna.

4. **Navigation**: The Loran, Omega, and Global Positioning Satellite (GPS) systems are the primary navigation methods available to aircraft and watercraft. The older Loran and Omega systems are disrupted during solar flares, energetic proton events, and/or geomagnetic storms. Positional fixes can be in error by as much as 10 miles during some or all of these disturbances. The GPS system is less susceptible to space environment variations but not immune. Scintillation of the GPS signal during ionospheric storms degrades the accuracy of locations derived from this navigation system.

5. **Magnetic Surveying/Sensing**: Geomagnetic storms interfere with magnetic mapping and surveying. These surveys are used to locate natural resource deposits below the Earth's land and ocean surfaces. Other devices, such as drilling heads, utilize the Earth's magnetic field to navigate their drilling paths. These paths can be erratic during geomagnetic storms.

6. **Solar-Terrestrial Research**: The GOES SEM data are utilized extensively by various research communities. Solar research relies upon XRS data to document solar flare activity and background fluxes. GOES XRS data are sent in near real time to several research satellite operations centers and used to schedule solar observations. Magnetospheric investigators utilize the EPS and Magnetometer data to specify the widely varying particle and magnetic field environments at geosynchronous altitude.

C. Operational Products and Services

1. Alerts/Warnings

GOES SEM data are used extensively to alert the above customers to observed conditions or to warn them of impending occurrences. The SWO issues the following alerts and warnings based on GOES SEM data:

XRS - Solar Flares of M5 or X1 intensity (observed or predicted)

EPS - Energetic Proton Events

10 pfu at energies >10 MeV (observed and predicted)

100 pfu at energies >100 MeV (observed and predicted)

High flying aircraft radiation hazard (observed)

Energetic Electron Events

Flux > 1×10^3 at energies >2 MeV

Magnetometer - Magnetopause Crossing Alert for geosynchronous spacecraft is under development

2. Daily Products

SWO issues several daily operational products jointly with the USAF (50th Weather Squadron). These products routinely use GOES SEM data or event durations and magnitudes derived from those data. A list of these daily products follows:

Report and Forecast of Solar and Geophysical Activity (see Figure 67)

Solar and Geophysical Activity Summary

High Frequency Radio Propagation Forecast

GEOALERT

WWV/WWVH Voice Broadcast

These daily products are available from several delivery systems described in the section Outside User Systems.

Report and Forecast of Solar and Geophysical Activity

The Report and Forecast of Solar and Geophysical Activity is the primary daily report prepared by SESC. It provides a summary and analysis of solar and geomagnetic activity during the previous 24 hours as well as the most recent solar indices. It also provides a forecast of activity and indices for the next 3 days. In September 1992, SESC added a new probability forecast for geomagnetic activity, providing users with a quantitative measure of certainty in the forecast.

Issue time: Daily at 2200 UT.

Period Covered: Activity from 2100 UT the previous day to 2100 UT on the current day, and predicted activity for the next 3 days.

Delivery Systems: SELDADS, electronic file transfer, the Bulletin Board system, and the COMEDS teletype network.

Sample:

JOINT USAF/NOAA REPORT OF SOLAR AND GEOPHYSICAL ACTIVITY
SDF NUMBER 293 ISSUED AT 2200Z ON 19 OCT 1992

IA. ANALYSIS OF SOLAR ACTIVE REGIONS AND ACTIVITY FROM 18/2100Z TO 19/2100Z: SOLAR ACTIVITY WAS MODERATE DUE TO AN M1/1F FLARE AT 19/1759Z IN REGION 7315 (N05E19). THIS REGION ALSO PRODUCED SEVERAL C-CLASS FLARES, INCLUDING A C5/1F AT 19/0124Z, A C6/1F AT 19/0412Z, AND A C7/1N AT 19/0601Z. THIS REGION IS INCREASING IN COMPLEXITY AND MAY BE DEVELOPING A DELTA CONFIGURATION IN ITS CENTRAL SUNSPOTS. THE OTHER DISK REGIONS WERE QUIET. NEW REGION 7318 (N11W63) WAS NUMBERED.

IB. SOLAR ACTIVITY FORECAST: SOLAR ACTIVITY IS EXPECTED TO BE LOW TO MODERATE. ANOTHER M-CLASS FLARE IS POSSIBLE IN REGION 7315.

IIA. GEOPHYSICAL ACTIVITY SUMMARY FROM 18/2100Z TO 19/2100Z: THE GEOMAGNETIC FIELD WAS QUIET TO UNSETTLED FOR MOST OF THE DAY. ISOLATED STORM CONDITIONS WERE OBSERVED AT SOME HIGH LATITUDE LOCATIONS FROM 19/1200-1800Z.

IIB. GEOPHYSICAL ACTIVITY FORECAST: THE GEOMAGNETIC FIELD IS EXPECTED TO BE QUIET TO UNSETTLED. ISOLATED HIGH-LATITUDE SUBSTORMS ARE POSSIBLE.

Figure 67. Report and Forecast of Solar Geophysical Activity.

III. EVENT PROBABILITIES 20 OCT-22 OCT

CLASS M 30/20/20
CLASS X 05/01/01
PROTON 01/01/01
PCAF GREEN

IV. PENTICTON 10.7 CM FLUX

OBSERVED 19 OCT 125
PREDICTED 20 OCT-22 OCT 130/135/135
90 DAY MEAN 19 OCT 117

V. GEOMAGNETIC A INDICES

OBSERVED AFR/AP 18 OCT 009/009
ESTIMATED AFR/AP 19 OCT 012/015
PREDICTED AFR/AP 20 OCT-22 OCT 010/010-010/010-010/010

VI. GEOMAGNETIC ACTIVITY PROBABILITIES 20 OCT-22 OCT

A. MIDDLE LATITUDES

ACTIVE 10/10/10
MINOR STORM 01/01/01
MAJOR-SEVERE STORM 01/01/01

B. HIGH LATITUDES

ACTIVE 15/15/15
MINOR STORM 05/05/05
MAJOR-SEVERE STORM 01/01/01

Part IA A summary of significant solar features and activity observed during the reporting period, including characteristics of sunspot groups, magnetic fields, flares, radio bursts, and active filaments associated with significant solar regions. Significant solar limb and disk features, including major filament disappearances, are also included.

Part IB A summary of the potential for solar activity during the next 3 days.

Part IIA A description of significant geophysical activity including geomagnetic activity and proton events, polar cap absorption (PCA) events, and satellite-level particle enhancements observed during the reporting period.

Part IIB A forecast of the level of geophysical activity during the next 3 days.

Part III Class M and class X: Probability forecast of the occurrence of one or more class-M or class-X x-ray flares for each of the next 3 days.

Proton flare: Probability forecast of a flare that will cause a significant proton event at satellite altitudes (at least 10 pfu at energies greater than 10 MeV) for each of the next 3 days.

PCAF: A 24-hour forecast of a polar cap absorption (PCA) event. The PCA forecasts are color coded:

Figure 67 (cont'd). Report and Forecast of Solar Geophysical Activity.

PCAF Green: No active sunspot region on the Sun is likely to produce a PCA event in the next 24 hours.

PCAF Yellow: A sunspot region showing characteristics favorable for producing a PCA event is present on the Sun. If an energetic flare occurs in this region, the probability of a significant PCA event is very high.

PCAF Red: An energetic solar event has occurred or a proton event has been observed at satellite altitudes, and there is a high probability that a significant PCA event will result within the next 24 hours.

In Progress: A significant PCA event is in progress at forecast time.

Part IV Observed: The current day's 10.7 cm solar radio flux observed at 2000 UT from Penticton, British Columbia, Canada.

Predicted: Daily 3-day forecasts of the 10.7 cm flux.

90-Day Mean: The 90-day mean of the observed 10.7 cm flux.

Part V Observed, estimated, and predicted daily geomagnetic A_{Fr}-indices (A-indices from Fredericksburg, VA), and daily A_P-indices (planetary A-indices). A_p indices are estimated in near-real time using a network of up to 12 North American stations.

Observed A_{Fr} / A_P: The observed indices for the previous day.

Estimated A_{Fr} / A_P: The estimated indices for the current day.

Predicted A_{Fr} / A_P: 3-day predictions.

Part VI Probability forecast of geomagnetic conditions at middle and high latitudes-the probability of at least one 3-hour K index, at the indicated level, for each of the next 3 days.

Active: K = 4.

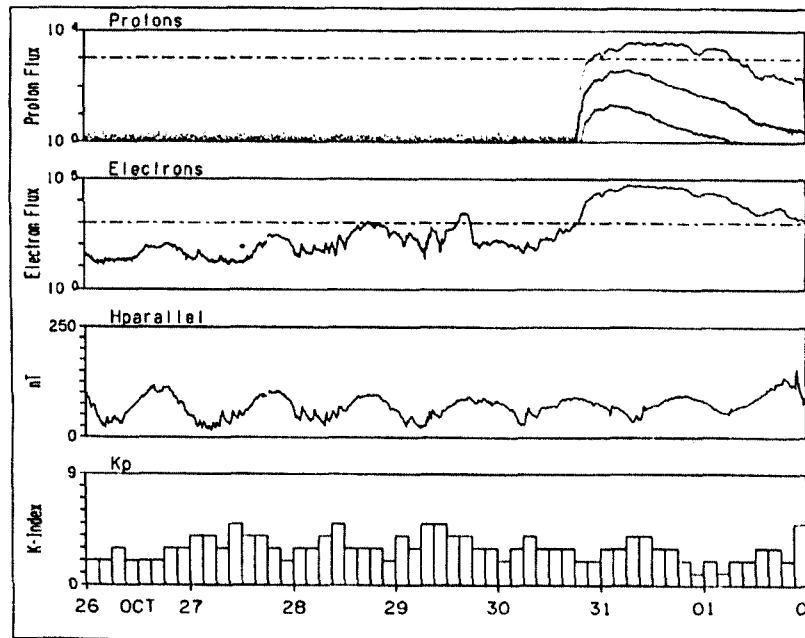
Minor storm: K = 5.

Major or Severe storm: K > 6.

Figure 67 (cont'd). Report and Forecast of Solar Geophysical Activity.

Weekly Publication

The SWO division publishes weekly a Preliminary Report and Forecast of Solar and Geophysical Data. It is distributed to over 1,500 subscribers worldwide. GOES SEM data, events, and derived parameters are major sections in this publication. Figure 68 below provides an example of an operational product for spacecraft operators.



*Weekly Geosynchronous Satellite Environment Summary
Week Beginning 26 October 1992*

Protons plot contains the five minute averaged integral proton flux (protons/cm²-sec-sr) as measured by GOES-7 (W108) for each of three energy thresholds: greater than 10, 50, and 100 MeV.

Electrons plot contains the five minute averaged integral electron flux (electrons/cm²-sec-sr) with energies greater than 2 MeV at GOES-7.

Hparallel plot contains the five minute averaged magnetic field H component in nanoteslas (nT) as measured by GOES-7. The H component is parallel to the spin axis of the satellite, which is nearly parallel to the Earth's rotation axis.

Kp plot contains the estimated planetary 3-hour K-index derived in real time from magnetometers at College, Alaska; Goose Bay, Newfoundland; Loring, Maine; Boulder, Colorado; and Upper Heyford, England (courtesy of the USAF Global Weather Central). These may differ from the final Kp values derived from a more extensive network of magnetometers.

The data included here are those now available in real time at the SESC and are incomplete in that they do not include the full set of parameters and energy ranges known to cause satellite operating anomalies. The proton and electron fluxes and Kp are "global" parameters that are applicable to a first order approximation over large areas. Hparallel is subject to more localized phenomena and the measurements generally are applicable to within a few degrees of longitude of the measuring satellite.

Figure 68. Excerpt from weekly Preliminary Report and Forecast of Solar Geophysical Activity.

International URSIgram and World Days Service (IUWDS)

The SEC is designated the World Warning Agency of the IUWDS for space weather monitoring and forecasting. The IUWDS is made up of nine space weather forecasting centers around the world. Exchange of solar-terrestrial data between these sites occurs several times daily. The GOES SEM data are utilized by these sites to provide space weather services to the geographical regions assigned to them. The GOES SEM sensors are not duplicated on any other spacecraft because of the continuous coverage GOES provides and the quality and calibration of the data.

Specialized Services

The GOES SEM data provide input to several of the SEC's specialized services. These services include:

- Satellite Anomaly Assessments
- Shuttle Radiation Support (and future Space Station support)
- Customer/Press Inquiries
- Spacecraft Launch/Mission Support

Outside User Systems

The SEC uses many product distribution methods to make solar-terrestrial data available to the operational and research communities. These methods include:

- World Wide Web (<http://www.sec.noaa.gov>)
- GOPHER (<gopher://gopher.sec.noaa.gov>)
- ANONYMOUS FTP (<ftp.sec.noaa.gov>)
- Public Bulletin Board System (303-497-5000)
- Satellite Broadcast
- Air Weather Service Teletype Systems (AWN and COMEDS)

Figure 69 is an example of the SEC's Home Page on the World Wide Web. Many GOES SEM products are available on adjoining pages. During active conditions, this number increases greatly. Over 160,000 calls have been made to the Public Bulletin Board System to retrieve space weather products and data.

References.

Space Environment Services Center Products and Services User Guide, Space Environment Laboratory, Boulder, CO, January 1993.

GOES I-M Databook, Space Systems/Loral, Palo Alto, CA, 1992.



Space Environment Center

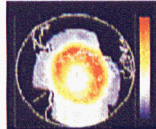
National Oceanic and Atmospheric Administration

Providing space weather alerts and warnings to the nation and the world for disturbances that can affect people and equipment working in space and on Earth

Advisories



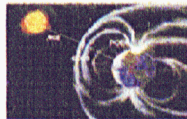
Data and Products



About this image

Latest Space Weather
Reports and Special Products
Geomagnetic Data
Solar Images
Gopher Data Directories

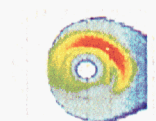
Research and Development



About this image

Research and Development at SEC
SEC's Rapid Prototyping Center
Cooperative Science Programs
Satellite Data Visualization
SEC Publications

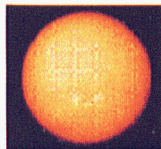
Partners and Collaborators



About this image

National Collaborators
International Collaborators
Cooperative Science Programs
Information for Vendors

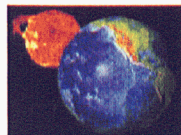
About SEC



About this image

Overview and Mission Statement
Programs and Plans, Milestones
Research and Development Division
Space Weather Operations Center
Media Contacts

Education and Outreach



About this image

Space Weather Topics Papers
Glossary of Solar-Terrestrial Terms
A Primer on the Space Environment
Materials for Teachers and Students
Links to Other Space Weather Sites

Figure 69. Sample Home Page from the Space Environment Center.

XIII. DATA COLLECTION SYSTEM

Description. The GOES DCS is a communications relay system that handles information gathered by remotely located Data Collection Platforms (DCPs). The GOES transponder relays UHF transmissions from DCPs via S-band (1694.5 MHz) communications to properly equipped Direct Readout Ground Stations (DRGS) including the NESDIS Wallops Island, Virginia CDA. Observations and information are relayed from the CDA through a domestic communications satellite (DOMSAT) to users, Figure 70. They are also relayed through the NWS Telecommunications Gateway System located in Silver Spring, Maryland.

Several types of platforms are serviced through this system. These include: self-timed; random reporting; interrogate; self-timed/random; self-timed/interrogate; and random/interrogate. Platforms operating in the interrogate mode must be polled by the NESDIS CDA, through the GOES satellite before data can be received. Self-timed platforms are assigned specific broadcast time slots and channels. These platforms contain a timing device that regulates the DCP's transmissions. DCPs operating in the random reporting mode broadcast to the satellite when a preset threshold or a critical measurement parameter, e.g., a river height, is reached. Random reporting messages are triggered by environmental events and are transmitted in short 2 to 4 second intervals. The message is retransmitted in a random manner to assure that these critical observations are collected by the satellite. The DCS on each satellite can handle at least 25,320 messages in a one hour period.

Accuracy. Generally a data bit error probability of 10^{-5} or better can be expected. Many factors affect the data quality including location of the DCP with respect to the satellite, ionospheric signal propagation conditions, instantaneous spacecraft usage, satellite eclipse periods, and the antenna positioning and performance of the DCP.

Users. DCS service operates under international agreements that limit the frequencies that can be used by the GOES for the relay of environmental data. Environmental data includes observations and measurements of physical, chemical and biological properties of oceans, rivers, lakes, solid Earth, and the atmosphere. The collected data are considered in the public domain and are utilized by a wide variety of NOAA and other government agency programs. Applications and further information is available from the

Data Collection System Program Manager
NOAA/NESDIS
Satellite Services Division
NOAA Science Center, Rm. 607
5200 Auth Road
Camp Springs, MD 20746-4304
E-mail: mperkins@nesdis.noaa.gov

Reference.

Nestlebush, M. J., 1994: The Geostationary Operational Environmental Satellite Data Collection System. *NOAA Technical Memorandum NESDIS 40*, U.S. Department of Commerce, Washington, D.C., 65 pp.

DAPS DATA DISTRIBUTION NETWORK

138

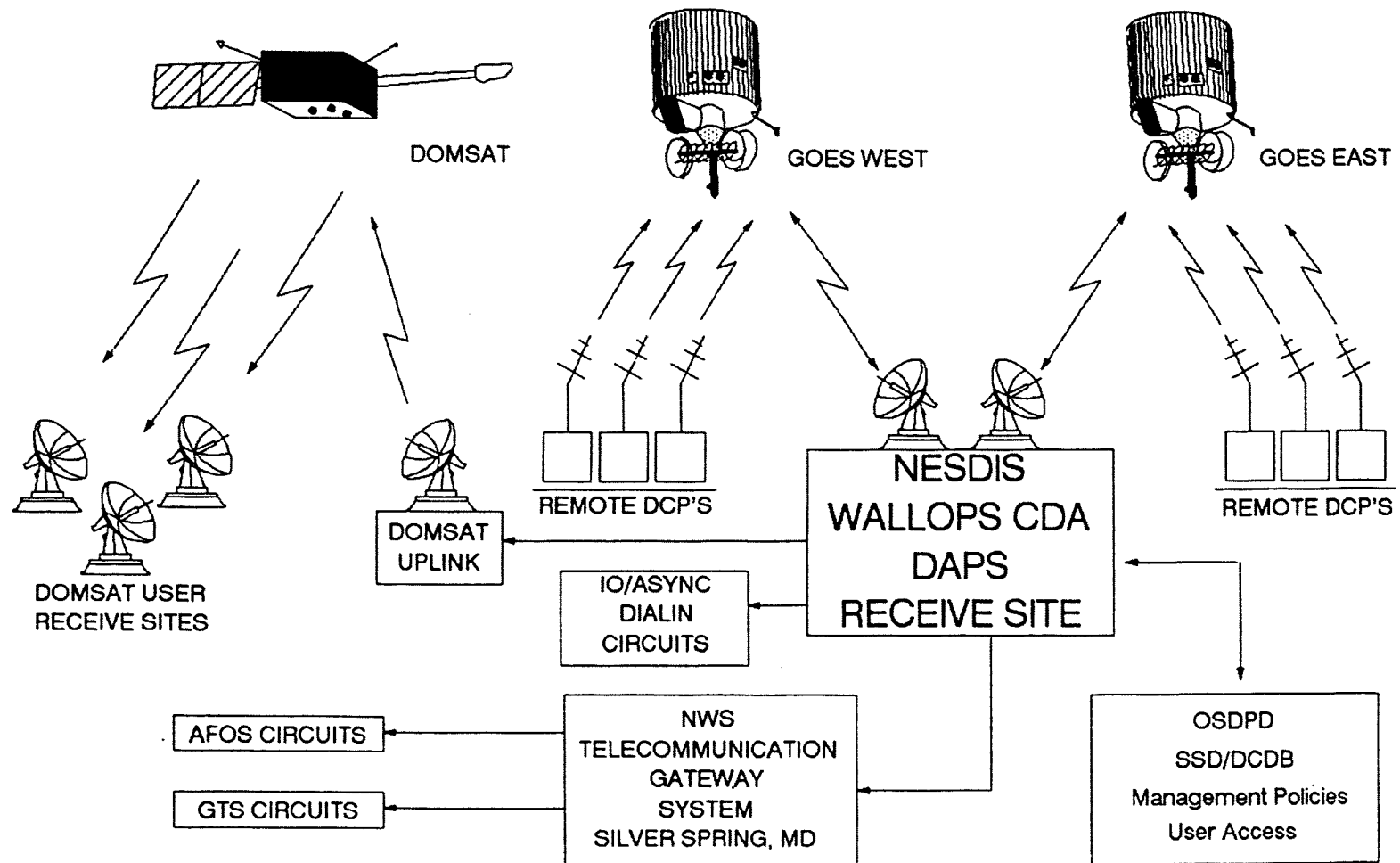


Figure 70. GOES Data Collection System.

XIV. SEARCH AND RESCUE

COSPAS-SARSAT

Description. NOAA satellites are used to help save the lives of people in distress who activate emergency beacons. Search And Rescue Satellite-Aided Tracking (SARSAT) and COSPAS, the equivalent acronym in the Russian language, is an international cooperative program. Since 1982, nearly 6,000 lives have been saved using the search and rescue capabilities onboard satellites. The program insignia, Figure 71, shows the cooperating countries.

The United States flies polar orbiting environmental satellites, the NOAA series, with a search and rescue payload provided by Canada and France. The Russian polar orbiting satellites, part of their maritime navigation system, are also equipped with similar tracking systems. These satellites use the Doppler principle to provide the location of the emergency beacons to rescue forces. For the older 121.5 MHz frequency beacons, the satellites must be mutually visible to signal from the beacon and a ground receiving antenna. However, the new 406 MHz frequency beacon data can be stored aboard the satellites and relayed to a series of ground stations throughout the world. The 406 MHz signal gives the system a truly global capability.

The 406 MHz repeaters aboard GOES-8 and -9 provide real time alert notification, but not location data. Since the geostationary satellites have no relative motion with the Earth, the GOES cannot use the Doppler method for determining location. However, 406 MHz alert data from the GOES, supplemented with beacon registration information provides the rescue forces with sufficient information to investigate the emergency signal. GOES and geostationary satellites from the European Space Agency, India, Japan, and Russia carry 406 MHz repeater payloads. The geostationary satellites may become a formal adjunct to the COSPAS-SARSAT System in the near future.

Accuracy. The older 121.5 MHz beacons have an analog signal that produce a location accuracy of 10-20 km. Digital signals from the newer 406 MHz beacons yield a location accuracy of 2-5 km. 406 MHz beacons can be equipped with a navigational receiver that uses the Global Positioning System (GPS). GPS position information, with an accuracy of nearly 100 meters, is included in the 406 MHz digital emergency signal. In this case, GOES can relay the 406 MHz emergency signal in real time with superior accuracy. Combining the use of 406 MHz, GPS and GOES the search is removed from search and rescue operations.

Users. The primary users of the COSPAS-SARSAT system are aviators and mariners who are in distress and activate their emergency beacons on a frequency of 121.5 MHz or 406.025 MHz. Each 406 MHz beacon has its own unique digital code that can be identified with its owner. The United States and many other countries created a national 406 MHz beacon registration database. The

data base records the beacon code, beacon owner's name, address and telephone number, primary and alternate 24 hour emergency numbers, type of vessel or aircraft, home port or primary airport, and communications equipment. When a 406 MHz beacon is detected (Figure 72) by the COSPAS-SARSAT System, the information in the registration data base is a supplement to the location and other alert data information. Registration of 406 MHz beacons is mandatory in the United States.

For more information concerning this program, contact:

Chief, Direct Services Division
NOAA/NESDIS, E/SP3
Federal Building 4, Rm. 0160
5200 Auth Road
Camp Springs, MD 20746-4304
Phone: (301) 457-5678
Fax: (301) 568-8649

References.

Klass, P. J., 1983: NOAA-8 to speed search and rescue. *Aviation Week & Space Technology*, **118**, p. 75.

Pepe, D., and L. Andreeva, 1986: COSPAS-SARSAT EPERB's and IMO/FGMDSS. *J. of Marine Electronics*, p. 39.



Figure 71. COSPAS-SARSAT program insignia.

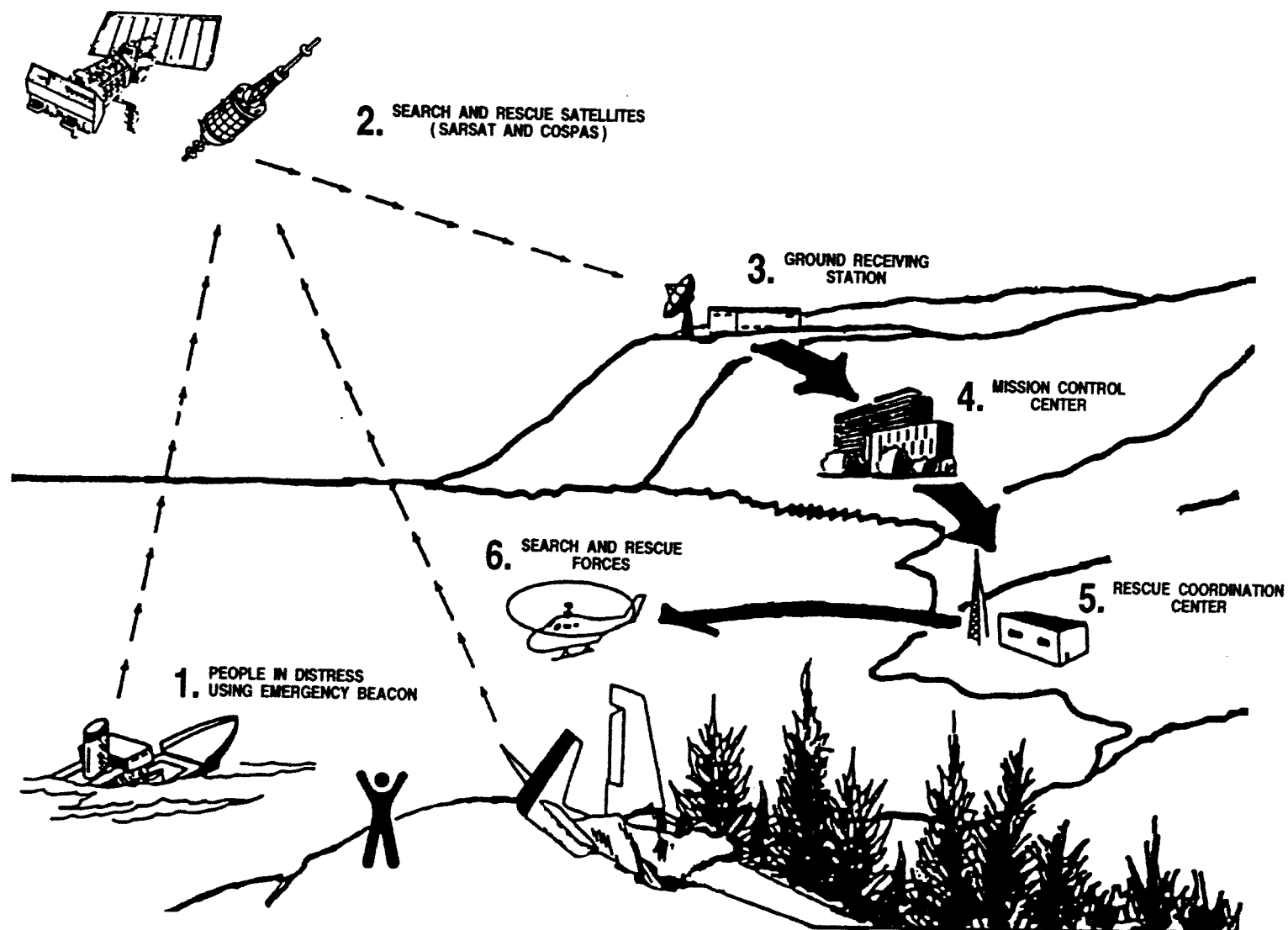


Figure 72. Schematic of the COSPAS-SARSAT search and rescue monitoring and location system.

XV. SUMMARY

The purpose of this section is to summarize the GOES products and services available within NOAA/NESDIS. It has three parts: Web sites, technical information and future updates.

1. *Web Sites*

The WWW is an important source for the dissemination of NOAA/NESDIS data products, services and information. In an effort to make this section as user-friendly as possible, web sites will be broken down by major categories and specific disciplines within those categories.

TABLE 9. WEB ADDRESSES FOR GOES PRODUCTS AND SERVICES

Data Product	Web Location	Type of Product
Aviation	orbit-net.nesdis.noaa.gov/arad/fpdt/ www.awc-kc.noaa.gov/awc/Aviation_Weather_Center.html	Research Research
Clouds	cimss.ssec.wisc.edu/goes/asos/asos.html www.cira.colostate.edu/ramm/ orbit-net.nesdis.noaa.gov/goes/asos/ cimss.ssec.wisc.edu/goes/dpi/dpi.html	Research Research Research Research
Fire, Smoke, Aerosol	www.cira.colostate.edu/ramm/goes39/cover.htm cimss.ssec.wisc.edu/goes/burn/abba.html cimss.ssec.wisc.edu/goes/burn/asada.html	Research Research Research
GEWEX	orbit-net.nesdis.noaa.gov/goes/gcip/	Research
Imager & Sounder Calibration	www.nnic.noaa.gov/SOCC/goescal.html	Research
Lifted Index	www.goes.noaa.gov/derived.html cimss.ssec.wisc.edu/goes/dpi/dpi.html orbit-net.nesdis.noaa.gov/goes/soundings/ cimss.ssec.wisc.edu/goes/realtime/realtime.html	Operational Research Research Research
Precipitation	www.ssd.noaa.gov/SSD/ML/realtime.html www.goes.noaa.gov/derived.html orbit-net.nesdis.noaa.gov/arad/ht/fi/ www.cira.colostate.edu/ramm/ psbgi1.nesdis.noaa.gov/OSDPD/PRODUCTS.html	Operational Operational Research Research Operational
Product Archive	goesshp.wwb.noaa.gov/	Operational
Sea Surface Temperature	140.90.191.231/oppt/loops/goes_sst/ sgiot2.wwb.noaa.gov/COASTWATCH/goessst.html psbgi1.nesdis.noaa.gov/OSDPD/PRODUCTS.html cimss.ssec.wisc.edu/goes/realtime/realtime.html	Operational Experimental Operational Research

TABLE 9 (Cont'd). WEB ADDRESSES FOR GOES PRODUCTS AND SERVICES

Data Product	Web Location	Type of Product
SEM	www.ngdc.noaa.gov/GOIN/GOES/SEM/goesinfo.html	Operational
Sounder Atmospheric Measurements	cimss.ssec.wisc.edu/goes/asos/asos.html orbit-net.nesdis.noaa.gov/arad/fpdt/ psbgsil.nesdis.noaa.gov/OSDPD/PRODUCTS.html orbit-net.nesdis.noaa.gov/goes/soundings/ cimss.ssec.wisc.edu/goes/realtime/realtime.html	Operational Research Operational Research Research
Snow & Ice	www.ssd.noaa.gov/SSD/ML/realtime.html www.goes.noaa.gov/derived.html psbgsil.nesdis.noaa.gov/OSDPD/PRODUCTS.html	Operational Operational Operational
Surface Skin Temperature	www.goes.noaa.gov/derived.html cimss.ssec.wisc.edu/goes/dpi/dpi.html orbit-net.nesdis.noaa.gov/arad/fpdt/	Operational Research Research
Total Precipitable Water	www.goes.noaa.gov/derived.html cimss.ssec.wisc.edu/goes/dpi/dpi.html orbit-net.nesdis.noaa.gov/arad/fpdt/ cimss.ssec.wisc.edu/goes/realtime/realtime.html	Operational Research Research Research
Tropical Cyclone	www.ssd.noaa.gov/SSD/ML/realtime.html www.goes.noaa.gov/derived.html www.cira.colostate.edu/ramn/	Operational Operational Research
Volcano	www.ssd.noaa.gov/SSD/ML/realtime.html www.goes.noaa.gov/derived.html	Operational Operational
WEFAX	psbgsil.nesdis.noaa.gov/COB/wefax.html	Operational
Winds	www.ssd.noaa.gov/SSD/ML/realtime.html orbit-net.nesdis.noaa.gov/arad/fpdt/ www.goes.noaa.gov/derived.html orbit-net.nesdis.noaa.gov/goes/winds/ psbgsil.nesdis.noaa.gov/OSDPD/PRODUCTS.html cimss.ssec.wisc.edu/tropic/tropic.html	Operational Research Operational Research Research Research

2. *Technical Information*

Since the launch of the first Synchronous Meteorological Satellite (SMS), there have been 13 launches of the geostationary weather satellites. Table 10 provides the launch dates for current and upcoming satellites of the GOES I-M series.

Satellite	Launch Date
GOES-8	April 13, 1994
GOES-9	May 23, 1995
GOES-10	April 25, 1997
GOES-L	May 1999
GOES-M	October 2000

This generation of GOES satellites will continue to provide 15 minute radiometric observations to environmental service agencies, who need continuous, dependable, timely, and high-quality observations of the Earth and its environment. Issues of a technical nature should be directed to NOAA/NESDIS as referenced in Section III of this guide.

3. *Future Product Updates*

A web version of this publication has been created and can be viewed at <http://orbit-net.nesdis.noaa.gov/arad/fpdt/goescat/index.html>. Updates and additions to this document will be posted as products become operational and new products are introduced. This website will also link readers to the latest versions of the operational products.

XVI. ACKNOWLEDGEMENTS

We would like to thank all the contributors to this document as well as many others who consulted on various product specifications. Special thanks to Gary Gray, Raytheon and Gary S. Wade, NESDIS for their technical assistance, and Nancy Everson, Don G. Gray and Timothy J. Schmit for their reviews of this manuscript.

XVII. ACRONYM LIST

AFOS	Automation of Field Operations and Service
ARAD	Atmospheric Research and Application Division
ARL	Air Resources Lab
ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
BTD	Brightness Temperature Difference
BUFR	Binary Universal Format for the Representation of meteorological data
CDA	Command and Data Acquisition
CEMSCS	Central Environmental Satellite Computer System
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CO ₂	Carbon Dioxide
CONUS	continental United States
CPC	Climate Prediction Center
CPHC	Central Pacific Hurricane Center
DCP	Data Collection Platform
DCS	Data Collection System
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DOMSAT	Domestic communication Satellite

DRGS	Direct Readout Ground Stations
ECA	Effective Cloud Amount
ECMWF	European Center for Medium-range Weather Forecasting
EDAS	ETA Data Assimilation System
EMC	Environmental Modeling Center
EPE	Energetic Proton Events
EPS	Energetic Particles Sensor
FAA	Federal Aviation Administration
FO	Forecast Office
fov	field of view
FPDT	Forecast Product Development Team
FXTS	Facsimile Transmission System
GCIP	GEWEX Continental Scale International Project
GDAS	Global Data Assimilation System
GEWEX	Global Energy and Water-Cycle Experiment
GINI	GOES Ingest and NOAAPORT Interface
GMS	Geostationary Meteorological Satellite
GMSRA	GOES Multispectral Rainfall Algorithm
GOES	Geostationary Operational Environmental Satellite
GOES-TAP	GOES Telecommunications Access Program
GPCP	Global Precipitation Climatology Project

GPI	GOES Precipitation Index
GPS	Global Positioning Satellite
GPS	Global Positioning System
GSS	GOES Sectorizer System
GTS	Global Telecommunications System
GVAR	GOES Variable data format
HEPAD	High Energy Proton and Alpha Detector
hPa	hecta Paschals
ICAO	International Civil Aviation Organization
IFFA	Interactive Flash Flood Analyzer
IIPS	Interactive Information and Processing System
IPB	Interactive Processing Branch
IR	InfraRed
IUWDS	International URSIgram and World Days Service
JMA	Japanese Meteorological Agency
KeV	Kilo electron volt
LI	Lifted Index
McIDAS	Man-computer Interactive Data Access System
METEOSAT	Meteorological Satellite
MeV	Mega electron volt
m/s	meters/second

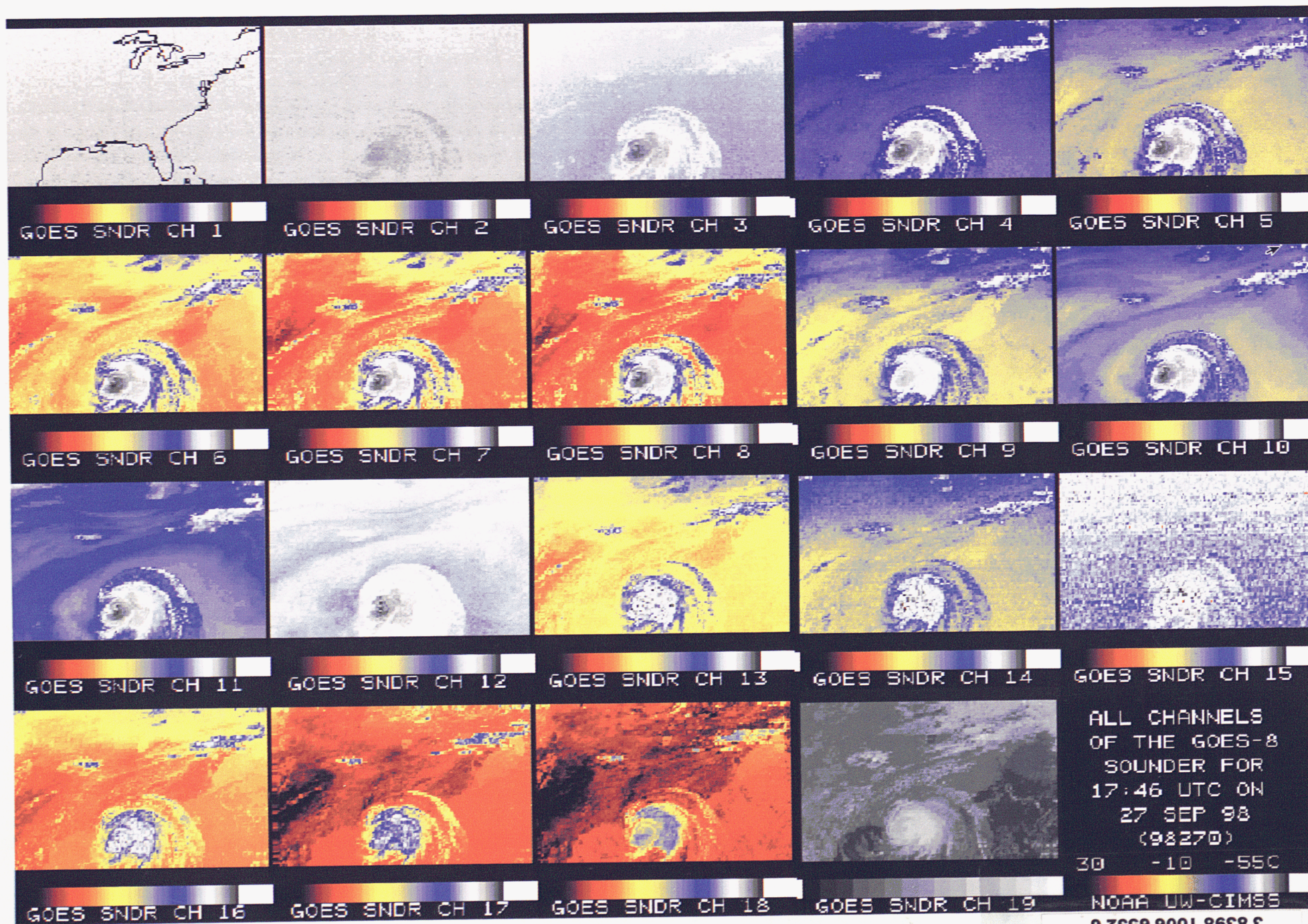
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NESS	National Environmental Satellite Service
NH	Northern Hemisphere
NIC	National Ice Center
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
NWS	National Weather Service
ODT	Objective Dvorak Technique
ORA	Office of Research and Applications
OSDPD	Office of Satellite Data Processing and Distribution
PAR	Photo Synthetically Active Radiation
PCA	polar cap absorption
PG&D	Product Generation and Distribution
POES	Polar-orbiting Operational Environmental Satellite
RAMM	Regional and Mesoscale Meteorology Branch
RAMSDIS	Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite Demonstration and Information System
rms	root mean square
rmse	root mean square error

SAB	Synoptic Analysis Branch
SARSAT	Search And Rescue Satellite-Aided Tracking
SATOB	Satellite Observation
SCP	Satellite Cloud Product
SEC	Space Environment Center
SEM	Space Environment Monitor
SFDFS	Satellite Field Distribution Facilities
SH	Southern Hemisphere
SOCC	Satellite Operations and Control Center
SSD	Satellite Services Division
SSEC	Space Science and Engineering Center
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
SWO	Space Weather Operations
TPC	Tropical Prediction Center
TPW	Total Precipitable Water
UKMET	United Kingdom Meteorological Office
USGS	United States Geological Service
UTC	Universal Time Clock
VAAC	Volcano Ash Advisory Center
VAAS	Volcano Ash Advisory Statements

VAS	VISSR Atmospheric Sounder
VAFTAD	Volcanic Ash Forecast Transport and Dispersion
VISSR	Visible and Infrared Spin Scan Radiometer
WEFAX	Weather Facsimile
WFOs	Weather Forecast Offices
WMO	World Meteorological Organization
WV	Water Vapor
XRS	X-Ray Sensor

Back Cover

Hurricane Georges as depicted in all 19 channels of the GOES-8 sounder at 1746 UTC on September 17, 1998.



ALL CHANNELS
OF THE GOES-8
SOUNDER FOR
17:46 UTC ON
27 SEP 98
(98270)

30 -10 -55C

NOAA UW-CIMSS

3 8398 1006 6532 6



NOAA CENTRAL LIBRARY