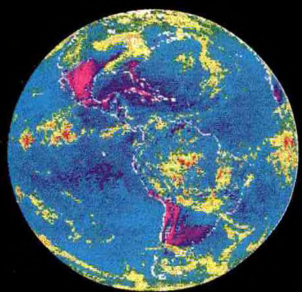
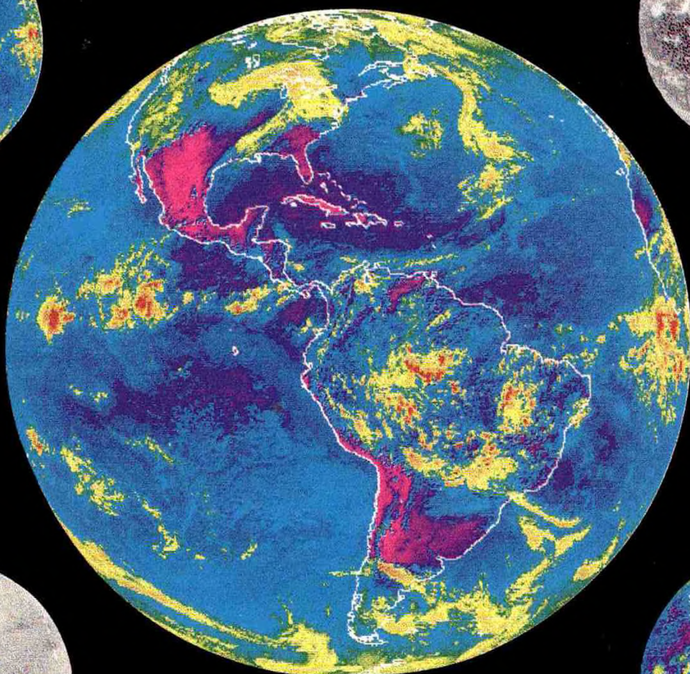
GOES
PRODUCTS and SERVICES CATALOG


Channel 4


Channel 1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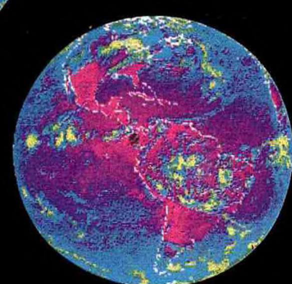
Channel 2

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

Front Cover

Miniature full-disc views from GOES 8. Clockwise, Channel 1 visible, Channel 2 short-wave infrared (3.8-4.0 microns); Channel 3 water vapor (6.5-7.0 microns); Channel 4 window infrared (10.2-11.3 microns); and center Channel 5 split-window infrared (11.5-12.5 microns). Imagery of channels 2, 4, and 5 have been colorized with the same enhancement curve.

GOES
PRODUCTS AND SERVICES CATALOG

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GOES PRODUCTS AND SERVICES CATALOG

Edited by: Frances C. Holt

ABSTRACT. This catalog describes the initial or Day-1 products and services available from the National Environmental Satellite, Data, and Information Service (NESDIS) for the new generation of GOES (I-M) satellites. It 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 Geostationary Operational Environmental Satellite (GOES) of the new GOES I-M series of satellites, GOES-8. Nearly a year later, GOES-9 was launched. 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).

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 carry independent imaging and sounding subsystems as well as seven additional sounding channels. Other improvements on GOES-8/9 include better resolution in the water vapor and infrared imagery and the addition of a shortwave infrared channel and a split window channel. A comparison of GOES-7 and GOES-8/9 imager channels is shown in Table 1. Table 2 compares the sounder channels on these spacecraft.

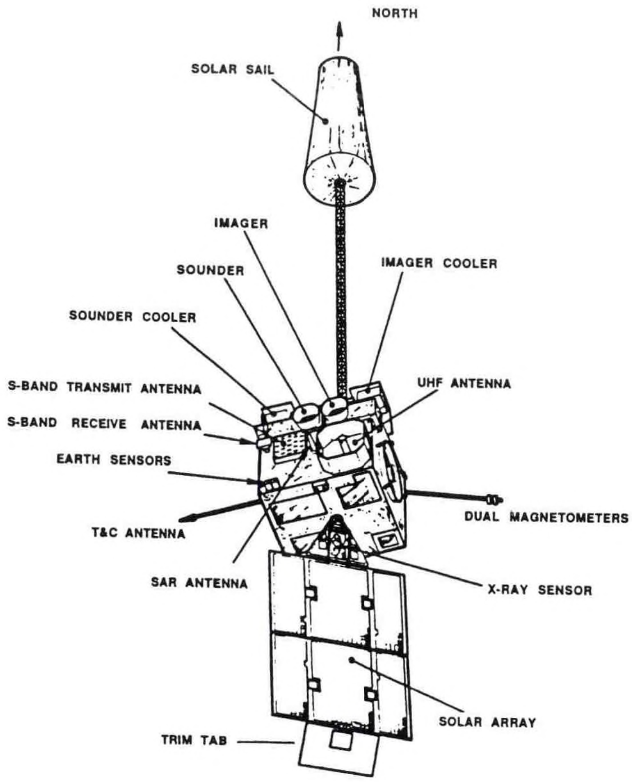


Figure 1. GOES I-M Spacecraft.

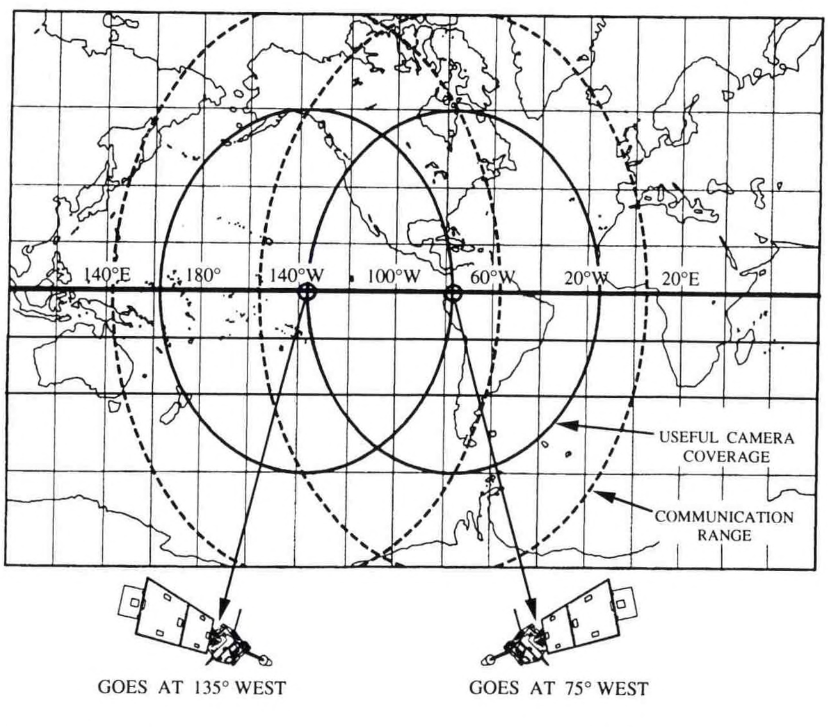


Figure 2. Data coverage of GOES East and West spacecraft.

TABLE 1. COMPARISON OF GOES-7 AND -8/9 SATELLITE IMAGING CHANNELS

	GOES-7		GOES-8/9	
	Wavelength (μm)	Resolution	Wavelength (μm)	Resolution
VISIBLE	0.55-0.75	1 km	0.55-0.75	1 km
INFRARED	--------	----	3.80-4.00	4 km
	(6.725)*	14 km	6.50-7.00	8 km
	10.0-12.5	7 km	10.20-11.20	4 km
	(see above)		11.50-12.50	4 km

* Images were produced from VAS sounder data.

This body-stabilized design that allows the satellite detectors to be continuously facing the Earth provides more flexibility in scan scenarios. Areal coverage of GOES-8 at 75° W and GOES-9 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. Both the GOES-8 and -9 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 (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 and magnetometers.

II. DATA ACQUISITION AND PROCESSING

The ground system processing of GOES-8/9 data is far more complex than that used for 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.

TABLE 2. COMPARISON OF GOES-7 AND -8 SOUNDING CHANNELS

Channel	GOES 8/9 Spectral Peak	Band	GOES 7 Spectral Peak	Channel
1	14.71 μm	Carbon Dioxide	14.73 μm	1
2	14.37 μm	Carbon Dioxide	N/A	
3	14.06 μm	Carbon Dioxide	14.01 μm	4
4	13.96 μm	Carbon Dioxide	N/A	
5	13.37 μm	Carbon Dioxide	13.33 μm	5
6	12.66 μm	Water Vapor	12.66 μm	7
7	12.02 μm	Window	N/A	
8	11.08 μm	Window	11.17 μm	8
9	9.71 μm	Ozone	N/A	
10	7.43 μm	Water Vapor	N/A	
11	7.02 μm	Water Vapor	N/A	
12	6.51 μm	Water Vapor	N/A	
13	4.57 μm	Carbon Dioxide	N/A	
14	4.52 μm	Carbon Dioxide	4.525 μm	6
15	4.45 μm	Carbon Dioxide	4.444 μm	11
16	4.13 μm	Nitrogen	N/A	
17	3.98 μm	Window	N/A	
18	3.74 μm	Window	N/A	
19	0.969 μm	Visible	N/A	
	N/A	Window	3.945 μm	12
	N/A	Water Vapor	6.725 μm	10
	N/A	Water Vapor	7.261 μm	9
	N/A	Carbon Dioxide	14.25 μm	3
	N/A	Carbon Dioxide	14.48 μm	2

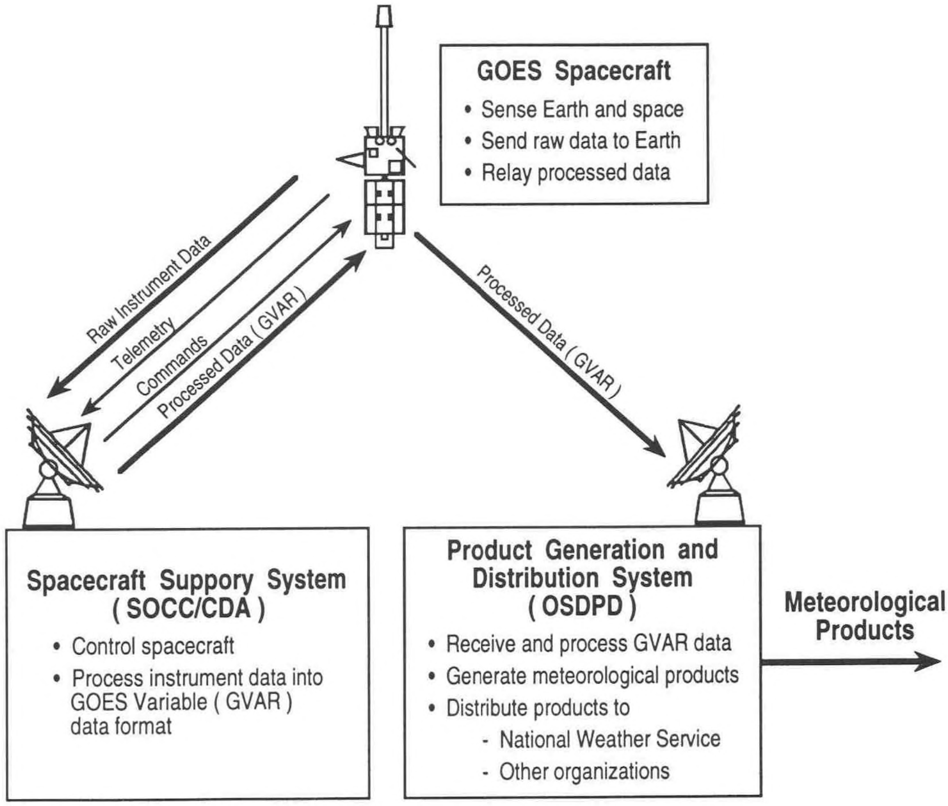


Figure 3. GOES Spacecraft Support and Product Distribution Systems.

a. Spacecraft Support System

The GOES I-M Spacecraft Support System includes the Command and Data Acquisition (CDA) Station at Wallops, Virginia and the Satellite Operations and Control Center (SOCC) at Suitland, MD (Figure 3). At the CDA station, raw instrument data and telemetry are readout 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, VA CDA station and relayed to SOCC in Suitland, MD 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 forwards its GVAR data via microwave line-of-sight communications to the NOAA Science Center in nearby Camp Springs, MD. Figure 5 is a simplified diagram of the GOES I Product Generation and Distribution (PG&D) System. There are six functional subsystems used to produce GOES I 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.

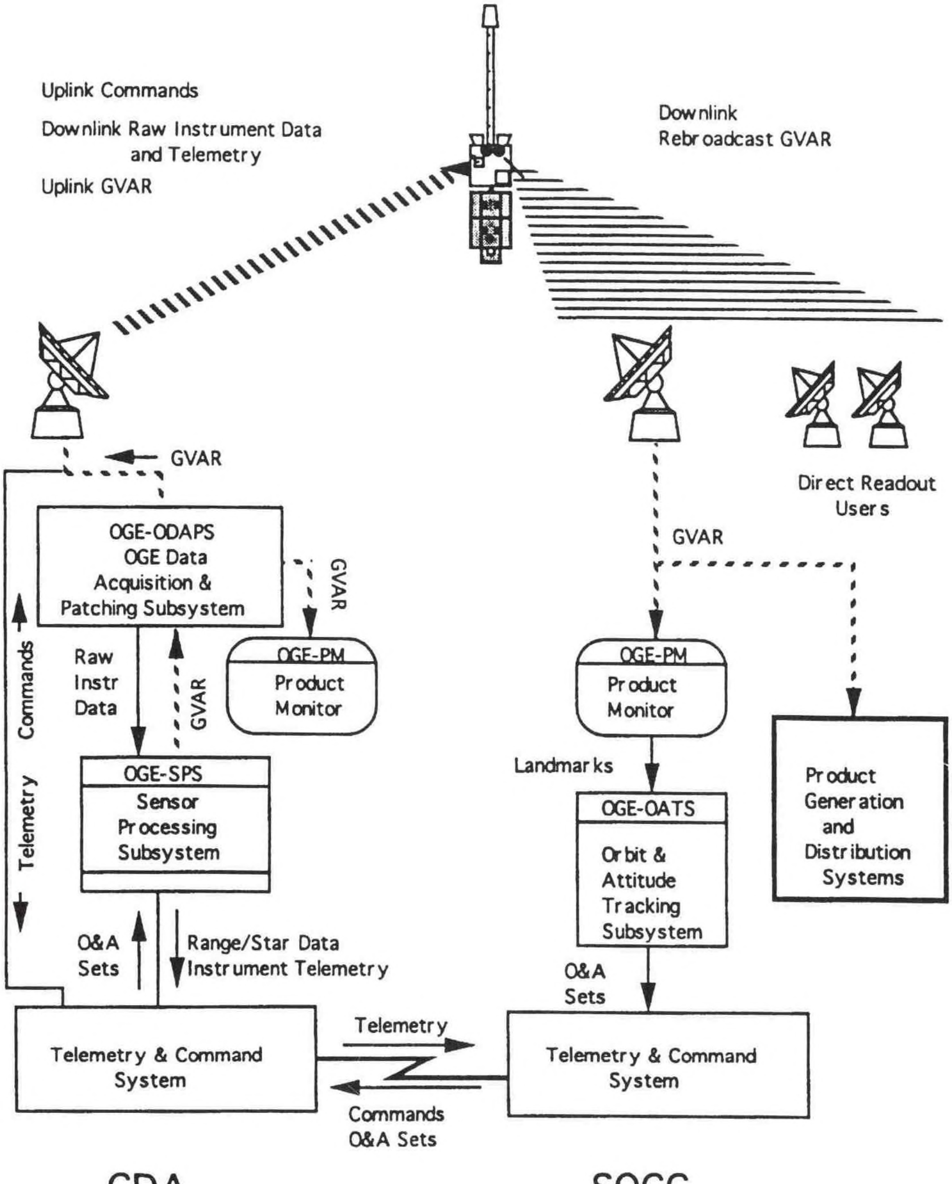


Figure 4. GOES I-M Ground System.

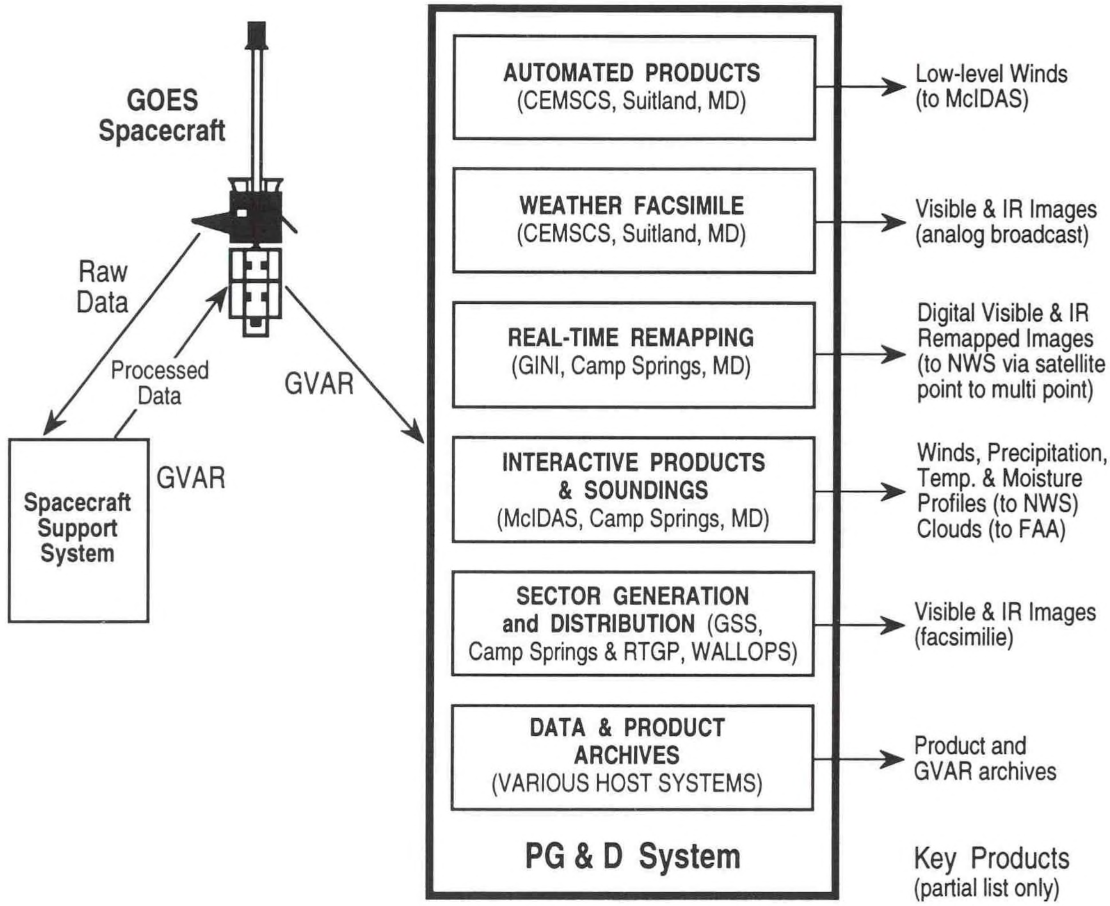


Figure 5. GOES Product Generation and Distribution System.

<u>References.</u>

Komajda, R. J and McKenzie, K. 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, DC, 61 pp.

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

III. USING THIS DATA PRODUCT CATALOG

This catalog only focuses on the Day 1 product suite for the GOES-8 and -9 satellites, the first two spacecraft 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
Washington, D.C. 20233

Telephone: (301) 457-5120 Fax: (301) 456-5184
E-Mail: satinfo@ssd.wwb.noaa.gov

b. Retrospective Image Products

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

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

Telephone: (704) 271-4800 Fax: (704) 271-4876
E-Mail: satorder@ncdc.noaa.gov

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. GOES Sectorizer System

Description. The GOES Sectorizer System (GSS) generates sectors or segments of a GOES imager scan and relays these products in an analog facsimile format over conditioned telephone circuits for further distribution to National Weather Service (NWS) Satellite Field Distribution Facilities (SFDFs). The SFDFs relay these images over the GOES Telecommunications Access Program (GOES-TAP) to local NWS offices and to subscribers including the military, aviation, academia, and the public over voice grade leased telephone lines.

Approximately 44 sectors are usually produced by the GSS from the routinely scanned GOES-8 and -9 fields-of-view shown in Figures 6 and 7. These sectors are constructed from decoded GVAR imager data. Each sector is spatially expanded or contracted to the desired resolution, geographic coverage, and in some cases enhanced with varying gray shades to highlight critical temperature/brightness values. Grids and standard GOES-TAP header information are appended to the product. The GSS has a maximum production capacity of 48 products. A sample of the EC1 sector from GOES-8 is shown in Figure 8.

The GSS is operated by the Satellite Services Division, located in the NOAA Science Center, Camp Springs, MD. Two Real-Time GOES Processors are also located at Wallops Island, VA. They serve as back-up systems that enable a limited capability in case of a catastrophic failure of the GSS or associated communication links.

Accuracy. Visible sectors are available in 8, 4, 2, and 1 km resolutions. Equivalent scale infrared sectors are also generated. Accuracy in the depiction and location of meteorological features is a function of the spacecraft sensor or channel and the Image and Navigation Registration system. Navigation irregularities are seasonally based and vary in magnitude.

Users. Primary users of GOES-TAP imagery are the NWS's Weather Forecast Offices (WFOs), the National Centers for Environmental Prediction (NCEP), and the military. Additionally, these data are used by the aviation community, academia, and the public. Using designated dial codes at the regional SFDFs, a user can select the sectors that best support the forecast region. These can be changed at any time; this provides flexibility for changing meteorological events.

Figure 6a

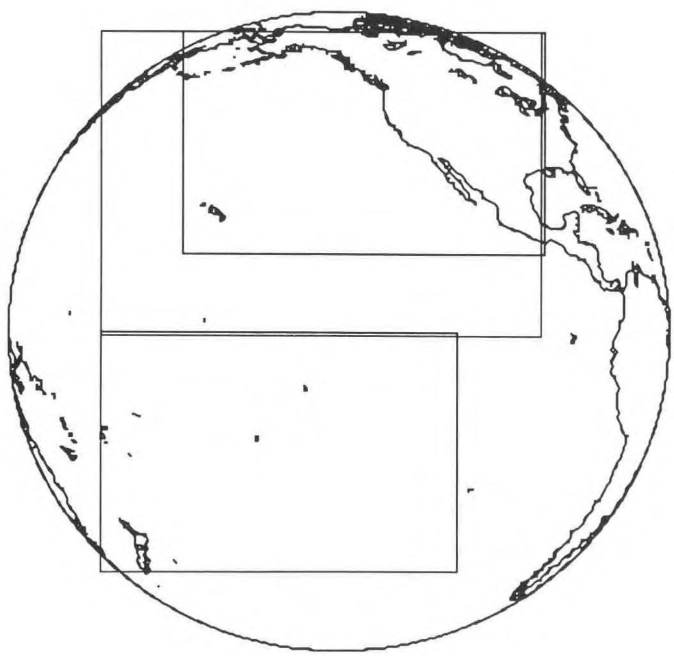


Figure 6b

Figure 6. a) GOES 8 routine scan sectors; b) GOES 9 routine scan sectors.

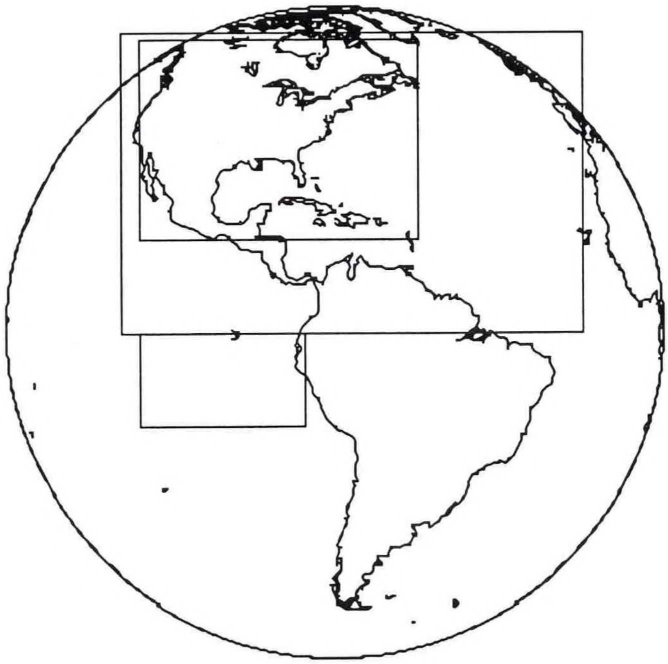


Figure 7a

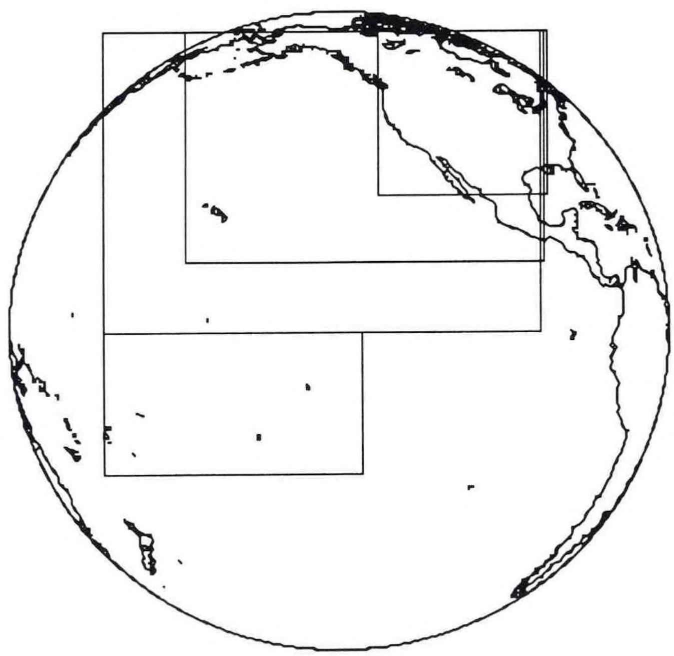


Figure 7b

Figure 7. a) GOES 8 rapid scan sectors; b) GOES 9 rapid scan sectors.

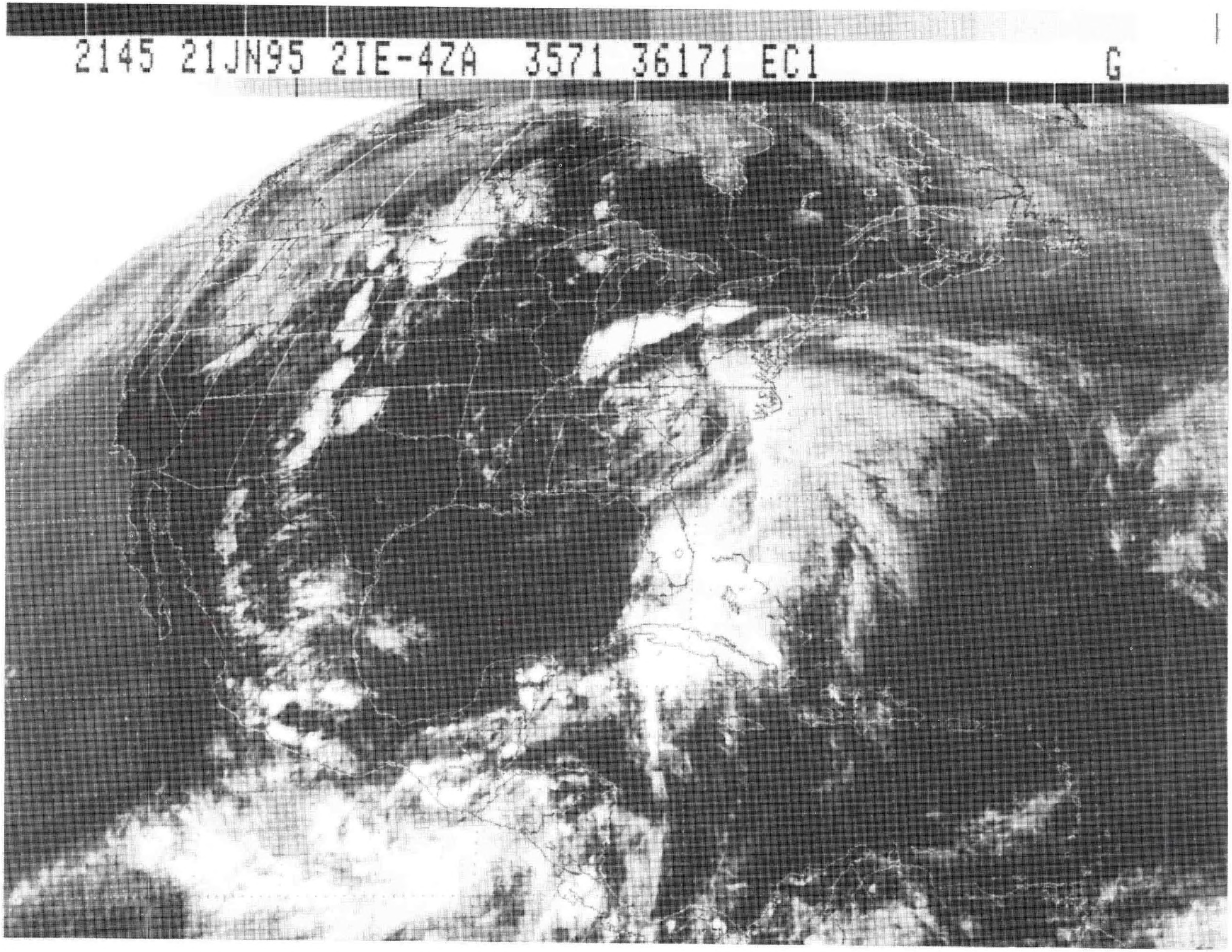


Figure 8. A GOES 8 EC1 infrared sector taken at 2145 UTC, June 21, 1995.

V. IMAGER PRODUCTS

b. Real-time Remapped Imagery

Description. The GOES Ingest and NOAAPORT Interface (GINI) system generates standard map projections from the GOES imager. The GINI crops, scales, and remaps this input into standard map projections such as Lambert Conformal, Mercator, and polar stereographic (Figure 9). GINI is the central remapping system for the NWS's Advanced Weather Interactive Processing System (AWIPS). Remapped image files are sent to a NOAAPORT interface that will distribute images to more than 100 NWS WFOs via a point-to-multipoint satellite broadcast. The sectors are also available to the public via commercial communications satellite broadcast.

GINI generated image sectors are digital. Up to 27 remapped sectors can be generated concurrently. The process of sector remapping is data driven, not scheduled like the older 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. The resulting output sectors are transmitted serially. Transmission of the highest priority sector begins immediately after the first data for the sector is received; lower priority sectors are then transmitted.

Accuracy. Sectors are available in 8, 4, 2, and 1 km resolutions. Accuracy in the depiction and location of meteorological features is a function of the spacecraft sensor or channel and the Image and Navigation Registration system.

Users. NWS Forecast Offices.

Reference.

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

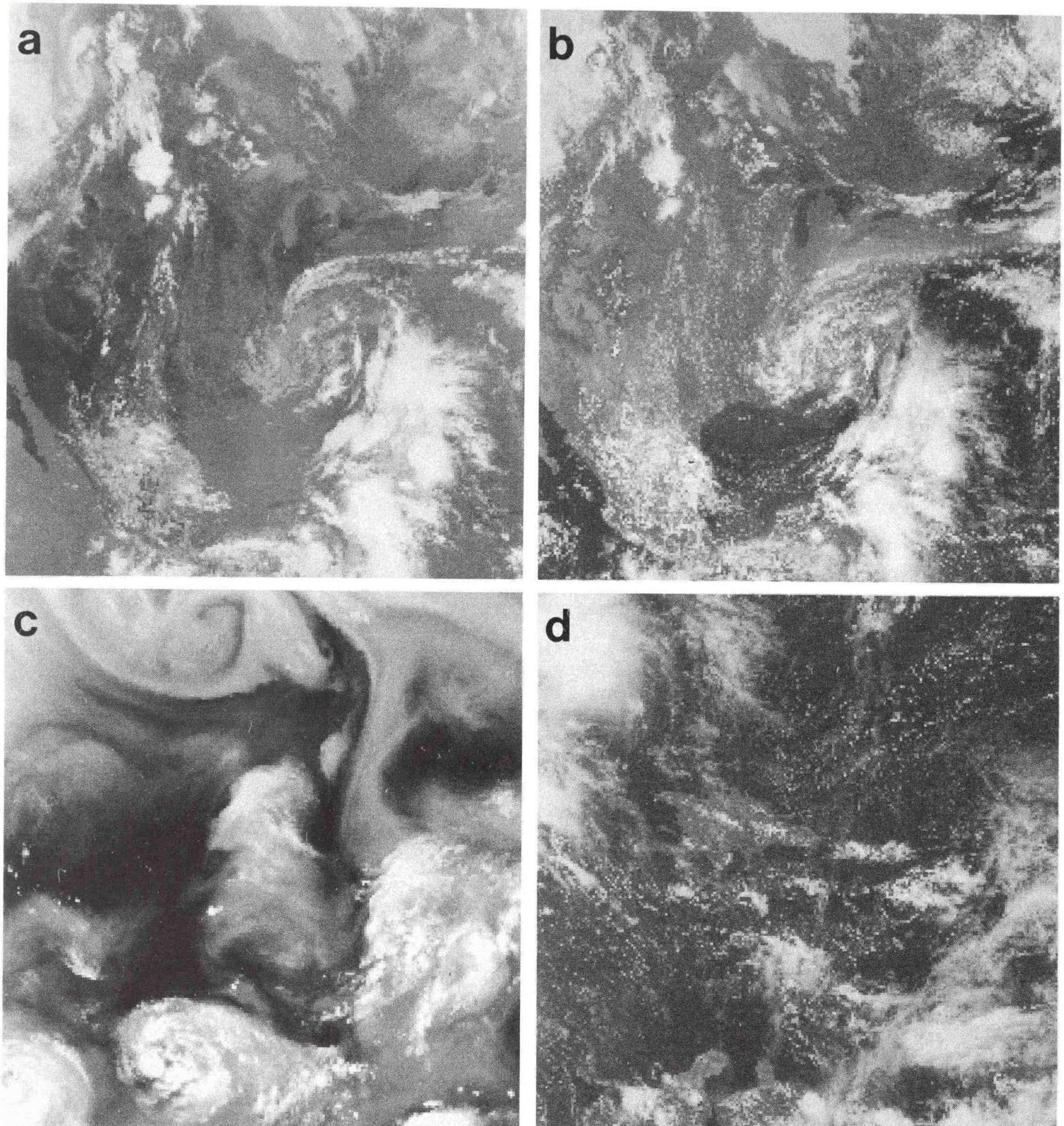


Figure 9. AWIPS image sectors for the U.S. and Puerto Rico. U.S. sectors, Lambert Conformal projection, are shown in panels a) visible image; b) infrared (Channel 4); and c) water vapor. A visible Mercator sector over Puerto Rico is shown in panel d.

V. IMAGER PRODUCTS

c. WEFAX Imagery

Description. GOES-8/9 imagery is transmitted on Weather Facsimile (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) infrared, and (3) water vapor. 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) infrared 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 water vapor sectors is transmitted twice daily. All sectors contain implanted geographic boundaries and latitude/longitude reference lines. Sample images are shown in Figures 10 and 11.

The GOES-8/9 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.

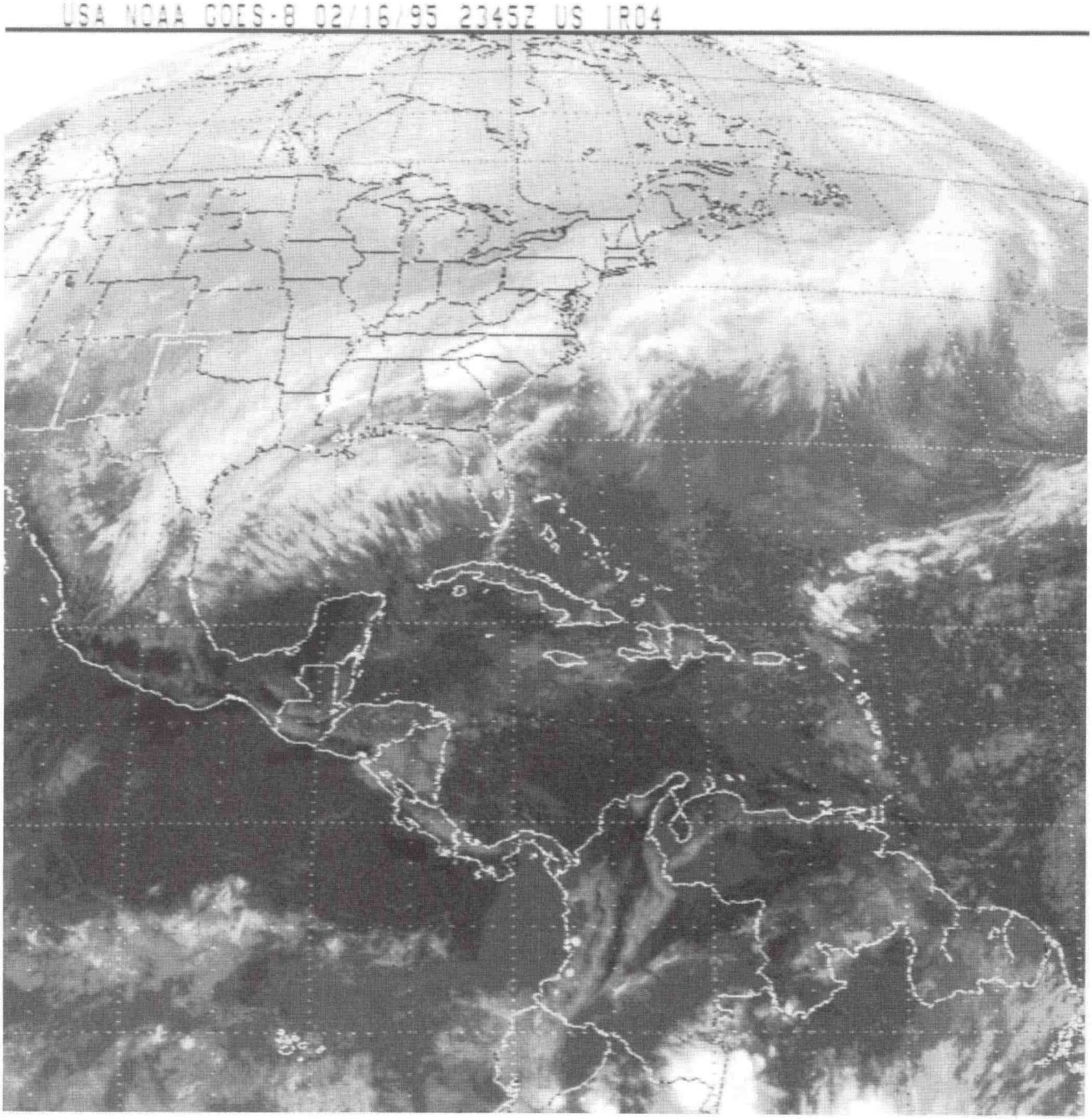


Figure 10. A WEFAX infrared U.S. sector from GOES 8 at 2345 UTC, February 16, 1995.

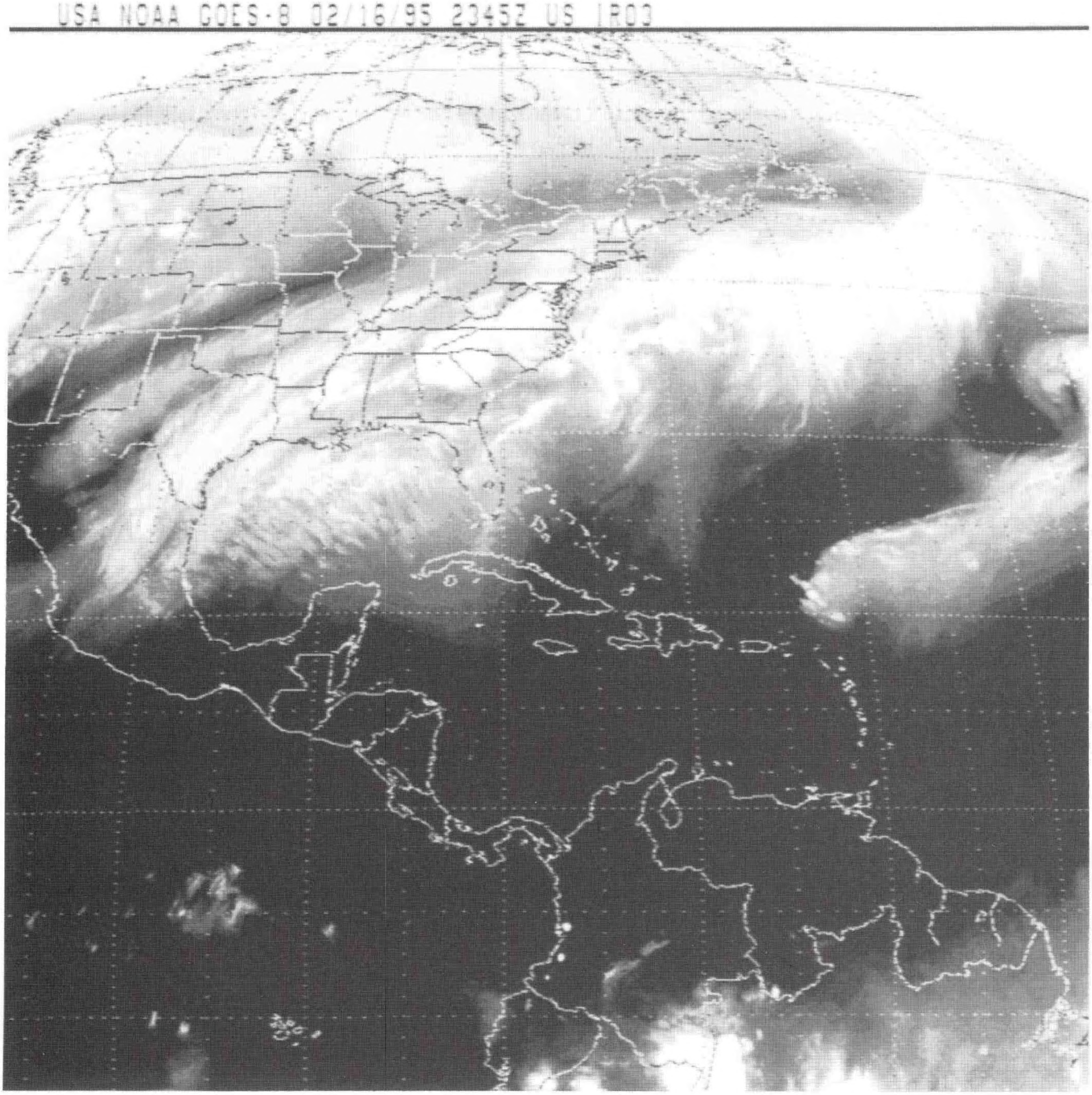


Figure 11. A WEFAX water vapor (Channel 3) U.S. sector from GOES 8 at 2345 UTC, 16 February 1995.

V. IMAGER PRODUCTS

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

Description. The Regional and Mesoscale Meteorology (RAMM) Branch of the Office of Research and Applications together with NOAA's Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University has developed a system, the RAMM Advanced Meteorological Satellite Demonstration and Information System (RAMSDIS), that routinely delivers high-quality, digital satellite data (images and derived display products) to a limited number of operational NWS forecast offices. This demonstration project allows forecasters to utilize digital data in preparation for future AWIPS installations. Software is an adaptation of the Man-computer Interactive Data Access System (McIDAS), developed by the University of Wisconsin Space Science and Engineering Center (SSEC) and custom applications for the targeted NWS offices participating in this demonstration program.

A RAMSDIS file server, located at the NOAA Science Center in Camp Springs, Maryland provides GOES visible, infrared, and water vapor data and some derived products, e.g., remapped imagery, fog product, etc. to the designated WFO's via Internet.

Accuracy. Products are available at various resolutions (2 km, 4 km, 8 km, 12 km, and 24 km) depending on satellite sensor/channel and map projection.

Users. This is a demonstration project providing service to selected NWS WFOs.

Reference.

Schrab, K.J., D. Molenar, J.F.W. Purdom, L. Dunn, and B. Colman, 1994: The Use of Digital Satellite Data via a Menu System in NWS Offices. *Proceeding of the 7th Conference on Satellite Meteorology and Oceanography*, June 6-10, 1994, Monterey, CA, Amer. Meteor. Soc., pp. 448-451.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

a. Winds

Low Level Winds

Description. Cloud motion winds at low levels (below 700 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 infrared images (11 micron window channel). For three images A, B, C (nominally 30 minutes apart), a target array from image B at 2½° 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, Northern Hemisphere and Southern Hemisphere sectors are examined and the 90 minute sequence yielding maximum coverage is chosen. Figure 12 shows low-level winds in the Southern Hemisphere from GOES-8. All low level winds are assigned to 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 have yet to be compiled, but they appear as good or better than GOES-7 low-level winds which had an accuracy of 3 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.

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.

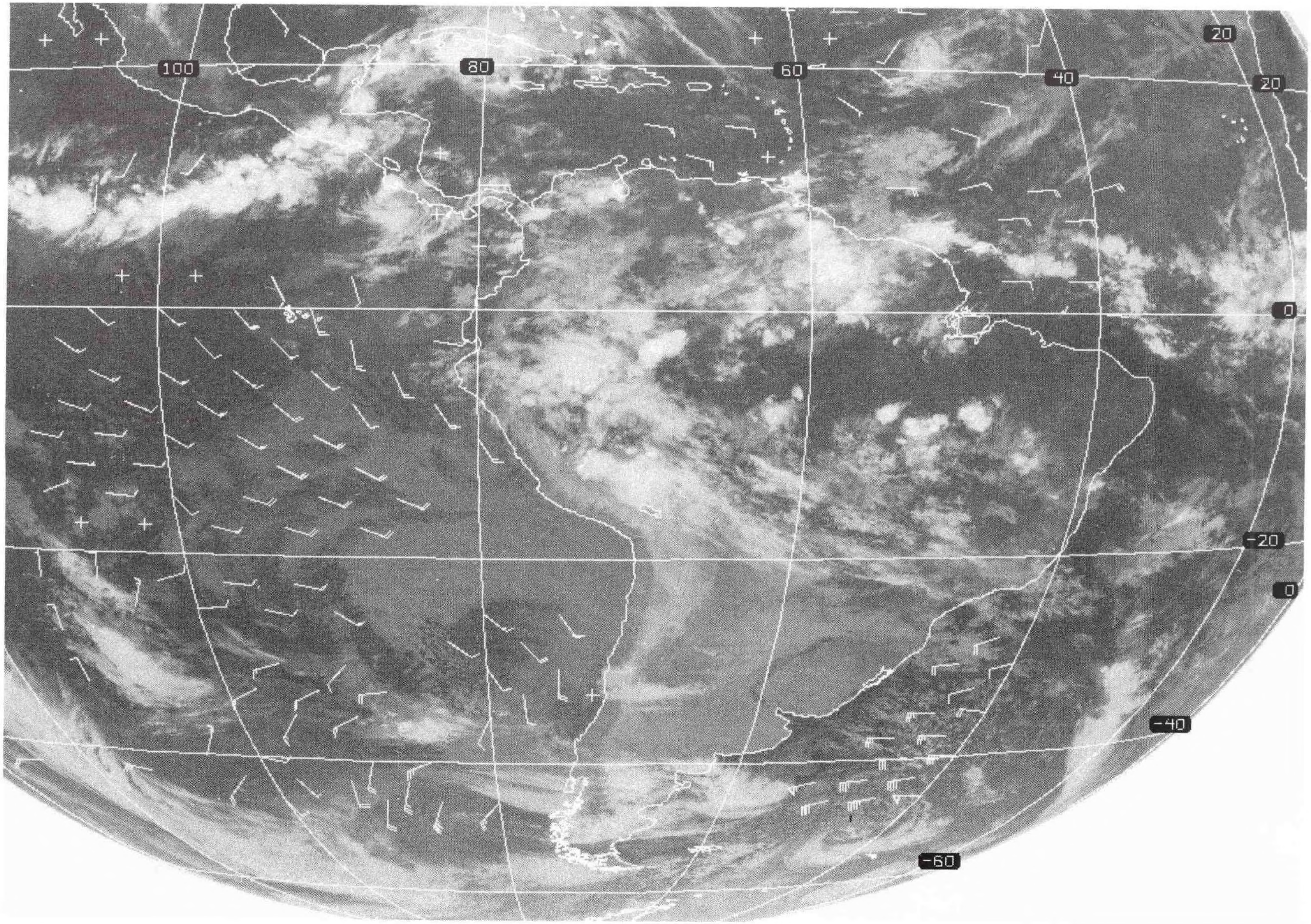


Figure 12. Low-level picture triplet winds on a GOES 8 Southern Hemisphere sector for 1200 UTC, May 21, 1996.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

a. Winds

Mid- and High-Level Winds

Description. Operational mid- and high-level winds are produced from a series of geostationary satellite images using a fully automated system. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperatures to assign heights. GOES cloud-drift and water-vapor motion winds are produced four times daily at 0000, 0600, 1200 and 1800 UTC on a RISC 6000 workstation. Winds are computed within 60 degrees latitude and longitude of the sub-satellite point for each product.

The automated wind derivation process is comprised of three main steps (Merrill et al., 1991). In the first 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 13). Height assignments take advantage of information from the water vapor and CO_2 absorption bands, if available, to help correctly represent semi-transparent clouds (Nieman et al., 1993).

As a second step, 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 the NCEP numerical forecast models, currently the aviation, and the search domain is centered accordingly. Allowable deviations from the guess vary with 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 deviation. Initial vectors result when the patterns are successfully located, with an acceptable level of confidence, in all three images (Figure 14).

The third step is the implementation of an automated quality control algorithm (Hayden, 1993) that removes questionable vectors and adjusts the heights of others to produce the final products (Figure 15). 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 the NCEP model prediction of wind and thermal profiles. A weighting function incorporating these factors drives the 3D recursive filter algorithm which makes the evaluation.

Nearly three times more vectors are produced from the water vapor data which contributes important information in areas without clouds. Figure 16 shows operational cloud drift winds; Figure 17 is the water vapor wind set computed for the same time period. These operational wind products can be viewed on the Sounding Implementation Branch's Internet homepage at http://orbit7i.nesdis.noaa.gov:8080/.

Accuracy. Neither the satellite winds nor rawinsonde observations can be used as an absolute standard. However, a traditional means of verification for cloud-drift winds is a comparison to collocated rawinsondes. Early results show that GOES-8 cloud drift winds have a root-mean- square error (rmse) of about 7.0 m/s; a rmse of 7.6 m/s for water vapor winds. The slow bias of the cloud motion water vapor winds is typically less than 1 m/s with respect to rawinsondes. This is a great improvement over even a few years ago when rms-errors in the winter often rose to 8.0 m/s or above.

Users. Operational GOES-8 and -9 cloud drift and water vapor winds are available from the GTS as a text message (Figure 18). The primary users of cloud motion winds are the NCEP and European Center for Medium-range Weather Forecasting (ECMWF) numerical forecast models.

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.

Merrill, R.T., W.P. Menzel, W. Baker, J. Lynch, and E. Legg, 1991: A report on the recent demonstration of NOAA's upgraded capability to derive cloud motion satellite winds. *Bull. Amer. Meteor. Soc.*, **72**, 372-376.

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.

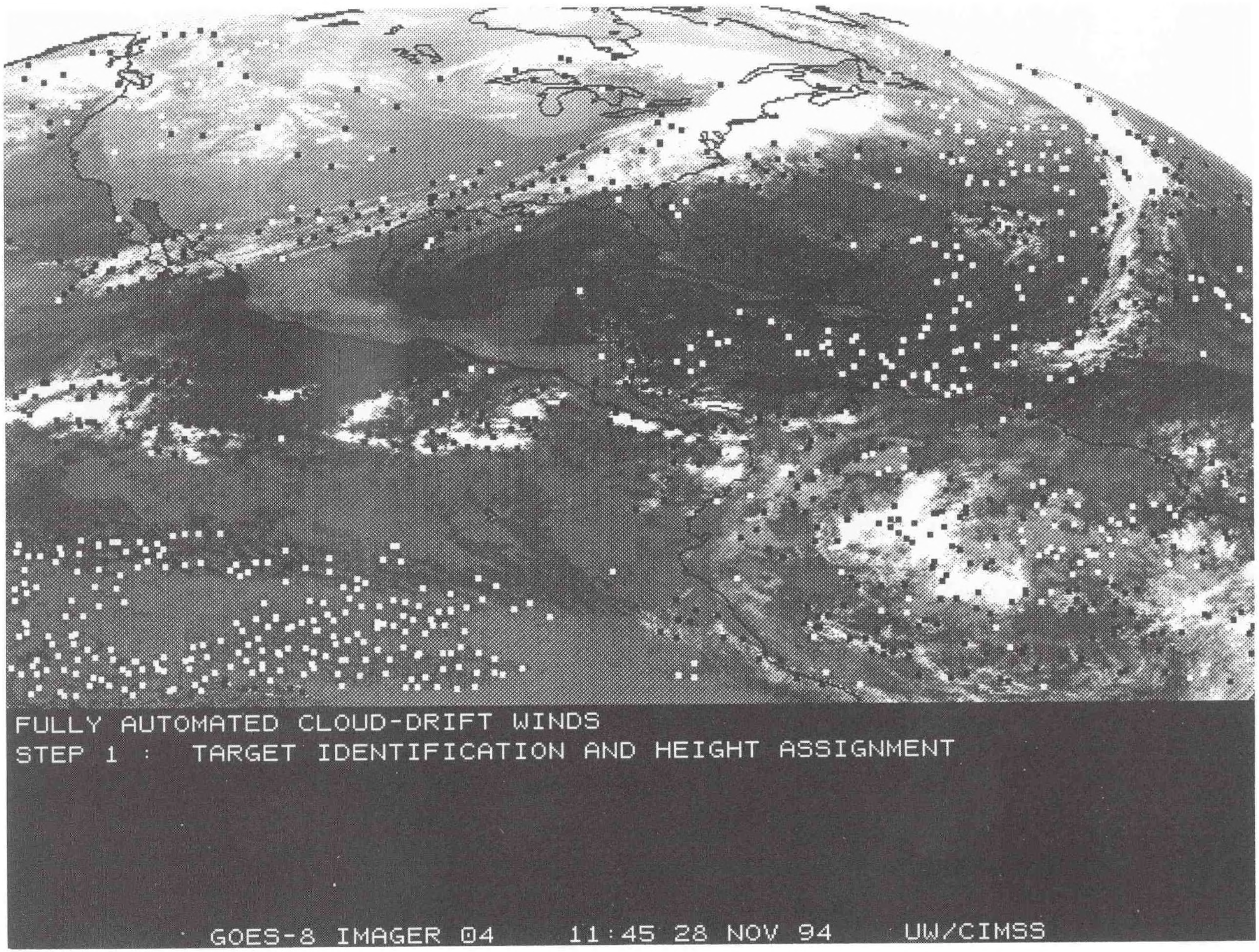


Figure 13. Target identification and height assignment of cloud elements, the first step of the automated wind program.

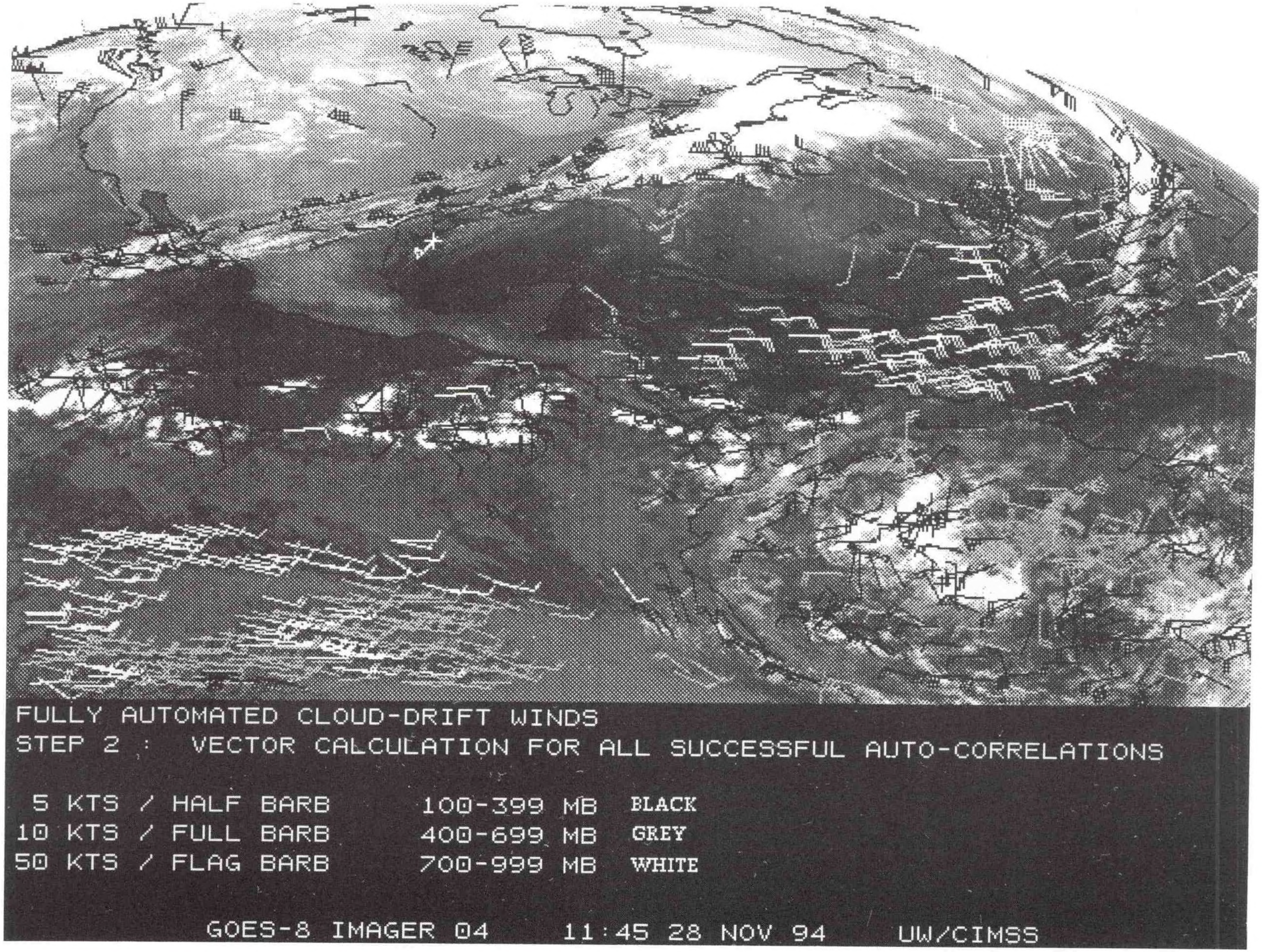


Figure 14. Vector calculation for cloud drift winds.

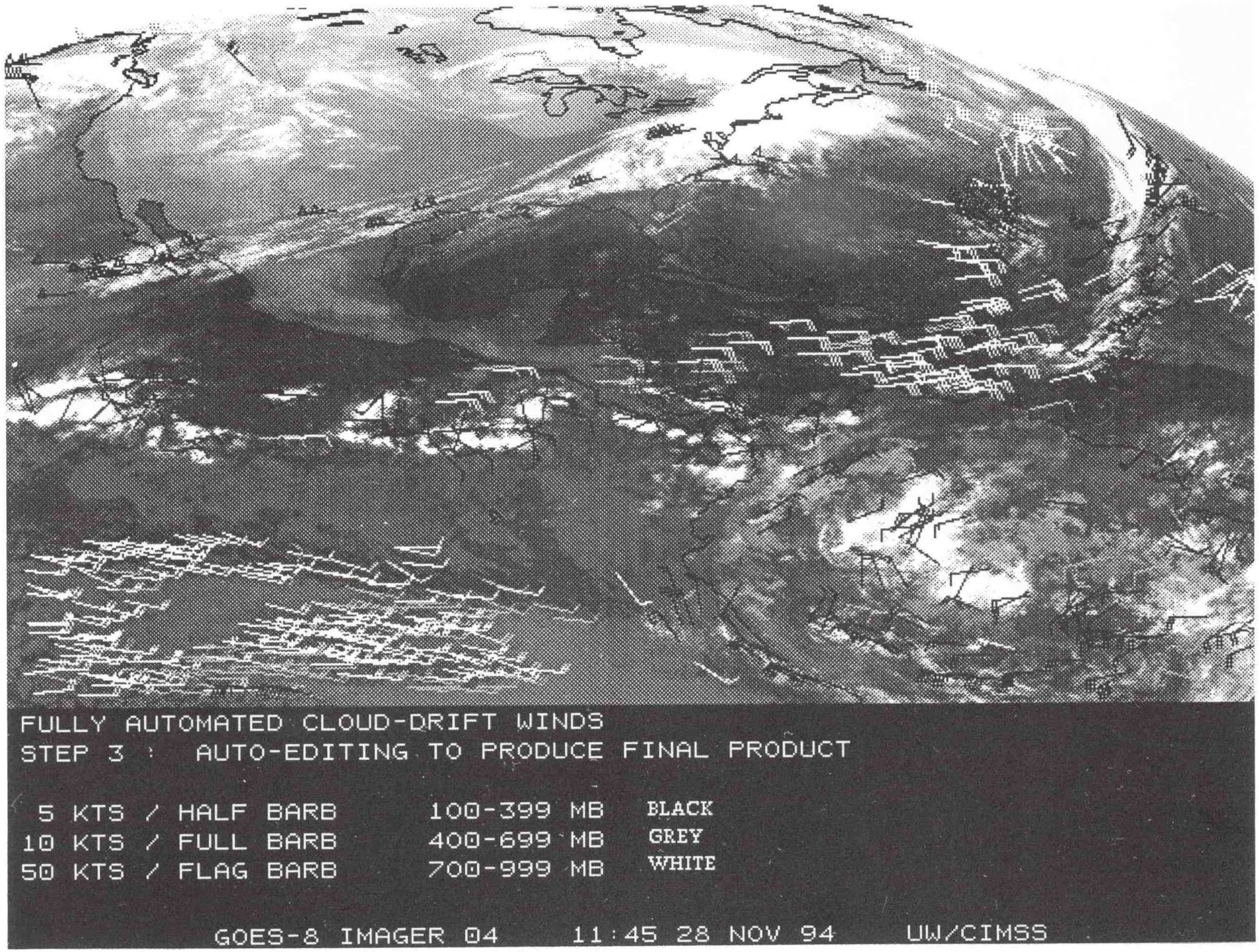


Figure 15. Final edited cloud drift wind product for 1200 UTC, November 24, 1994.

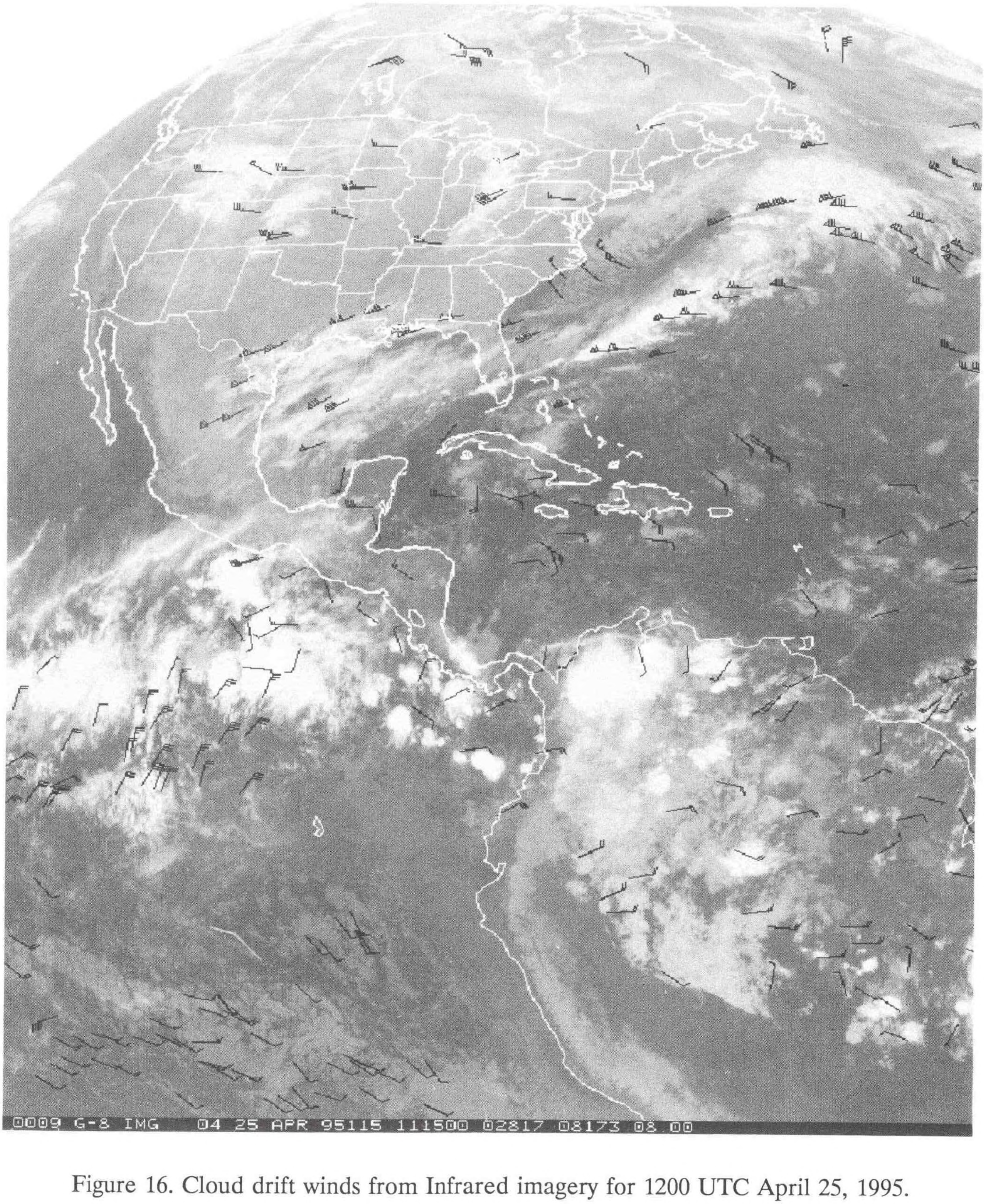


Figure 16. Cloud drift winds from Infrared imagery for 1200 UTC April 25, 1995.

Figure 17. Water vapor winds for same period as figure 16.

```
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 24513##,
    10301 43/// 89140 10525##,
    10402 7871/ 63130 13007 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, DC
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 mid-point 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 18. GOES 9 GTS Winds Message.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

b. Convective Cloudtops

Description. A convective cloudtop analysis based on GOES imagery has been produced at NESDIS since the late 1970s. The tops of oceanic thunderstorms displayed in hundreds of feet (Figure 19) are produced by comparing temperatures from the digital infrared GOES imagery to an atmospheric profile based on climatology. The convective cloudtop analyses cover the tropics and middle latitudes between 30° W and 170° W. They are produced four times a day at 12, 18, 21, and 06 UTC. This cloudtop analysis is used in the 24 hour high altitude SIG WX forecast charts.

Accuracy. The accuracy of the current climatology based program is estimated within 5,000 feet.

Users. The primary user of the convective cloudtop analysis is the Aviation Weather Center Transition Aviation Project at NCEP.

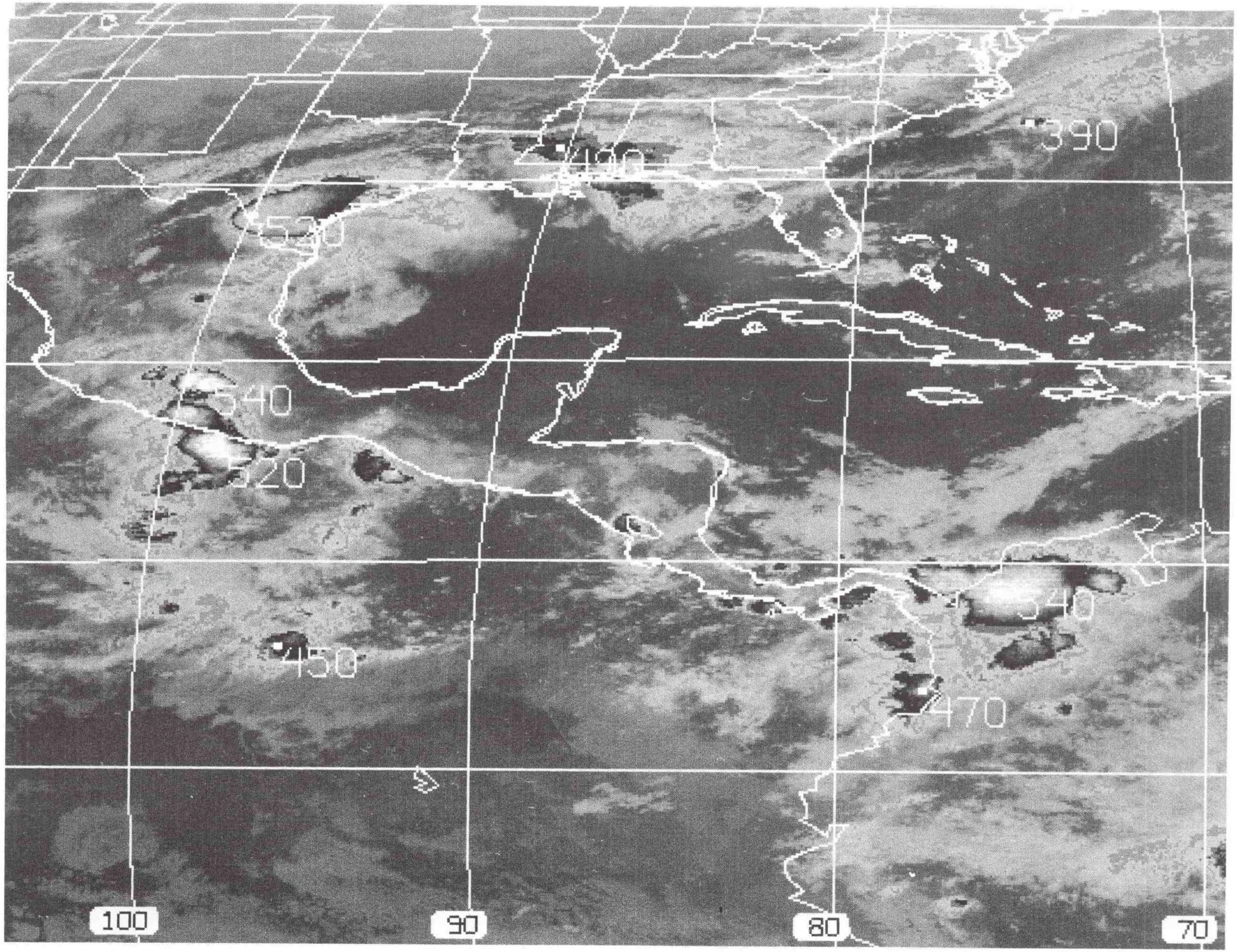


Figure 19. Convective cloudtop product for 06 UTC, May 29, 1996.

c. Moisture Analysis

Description. The moisture analysis is a description of the vertical water vapor structure of the troposphere (1000 hPa to 300 hPa) over the oceanic regions around North America. It is determined from satellite cloud signatures.

The analysis is prepared at the oceanic grid points of the ETA and NGM models for data assimilation in the 00 UTC and 12 UTC numerical models at NCEP. One of 14 moisture categories is applied to each grid point. Thirteen of the categories are predefined and contain a unique vertical moisture profile for the troposphere. For example, a Category-1 profile contains relative humidity of about 95 percent from the surface to 500 hPa, representing an area of vertically solid cloudiness with heavy precipitation typical of strong fronts, hurricanes, and the Intertropical Convergence Zone. Whereas, a Category-8 represents moderate relative humidity at the boundary layer with very low humidity above 700 hPa, typical of low-level stratocumulus beneath a large area of subsidence often observed in the eastern Pacific. The relative humidity for each category is listed in Table 3.

To create the moisture analysis the meteorologist first reviews the "first guess" deep layer (1000 hPa to 300 hPa) relative humidity field from the ETA model (12 hour forecast from the previous model cycle) (Figure 20). Where the model "first guess" appears unreasonable or inaccurate, the meteorologist assigns one of 13 moisture categories which most accurately reflects the vertical distribution of the moisture for the entire area representing the grid point (approximately 20,000 km^2). This decision is based on interpretation of infrared, water vapor, and visible satellite imagery. Where the model "first guess" appears reasonable, the meteorologist selects Category-0, representing no value input (this allows the model assimilation to default to the "first guess"). In this example, the analyst has altered the values of the moisture field in the eastern Gulf of Alaska (Figure 21). Category 6 (see Table 3) has an average relative humidity of 60%. Note that this area was forecast to have a relative humidity greater than 70% (Figure 22). In the tropics from the equator to approximately ~22°N, only Categories-1, -2, and -3 are used. These categories represent clusters of active thunderstorms and organized tropical disturbances.

The entire process (image analysis, "first guess" evaluation, and moisture category selection) is performed on a McIDAS workstation. The "first guess", grid points, and moisture category are displayed on several graphic planes overlaid onto GOES imagery (Figure 20). The satellite imagery can be animated independently from the graphics. The current process utilizes two mid-latitude sectors and three tropical sectors to provide moderate resolution coverage of the oceanic analysis area. Selection of moisture category is performed interactively on the workstation.

TABLE 3. MOISTURE ANALYSIS CATEGORIES AND RELATIVE HUMIDITIES

Category No.	Pressure Levels (mb)					
	1000	850	700	500	400	300
1	95 %	98 %	95 %	90 %	85 %	75 %
2	90 %	93 %	87 %	83 %	74 %	55 %
3	80 %	86 %	76 %	67 %	67 %	53 %
4	72 %	70 %	62 %	54 %	44 %	34 %
5	68 %	39 %	50 %	85 %	50 %	10 %
6	84 %	92 %	79 %	20 %	10 %	10 %
7	76 %	89 %	50 %	25 %	10 %	10 %
8	73 %	65 %	25 %	15 %	10 %	10 %
9	69 %	60 %	25 %	25 %	70 %	70 %
10	45 %	35 %	10 %	10 %	10 %	10 %
11	90 %	92 %	90 %	85 %	20 %	10 %
12	76 %	89 %	50 %	32 %	70 %	70 %
13	68 %	50 %	25 %	85 %	70 %	70 %

Accuracy. The analysis is prepared on a 2.5° x 2.5° grid. Timchalk (1986) evaluated the moisture analysis against TOVS soundings and rawinsonde observations. The moisture analysis is most accurate for areas of vertically deep moisture and precipitation (Categories-1, -2, and -3), and less accurate for partly cloudy and nonprecipitating areas. Each grid point is analyzed to be representative of the entire area surrounding the point (approximately 20,000 km^2), and may not be representative of a point or mesoscale feature.

Users. The grid point analysis is electronically transferred to the NCEP for assimilation into the regional numerical weather prediction models. No additional customers access this information.

Reference.

Timchalk, A. (1986): Satellite-Derived Moisture Profiles. *NOAA Technical Report NESDIS 24*, U.S. Department of Commerce, Washington, D.C., 60 pp.

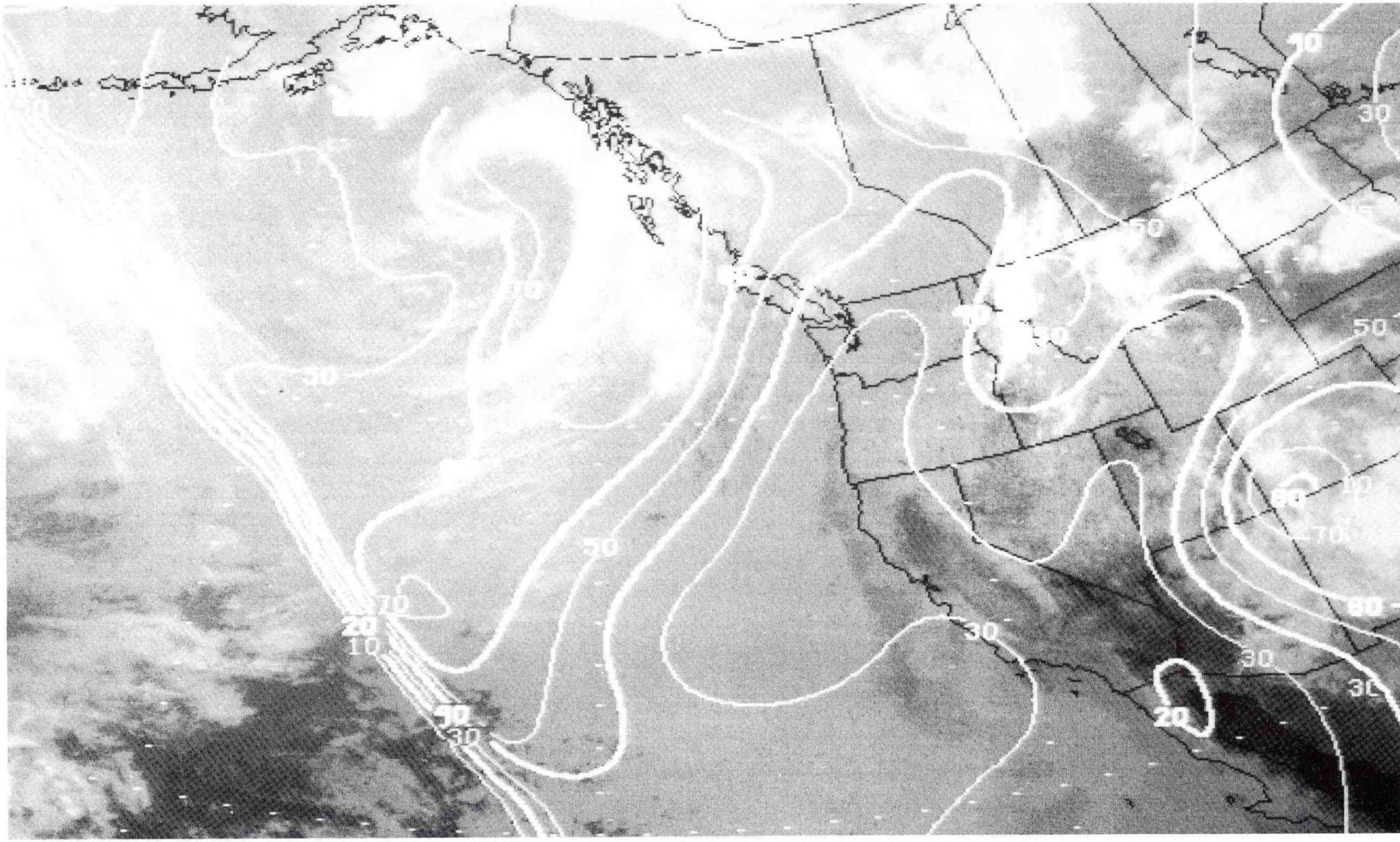


Figure 20. ETA 12-hour forecast of average relative humidity (1000 - 300 hPa) overlaid on a GOES 9 infrared image for 1200 UTC, June 14, 1996.

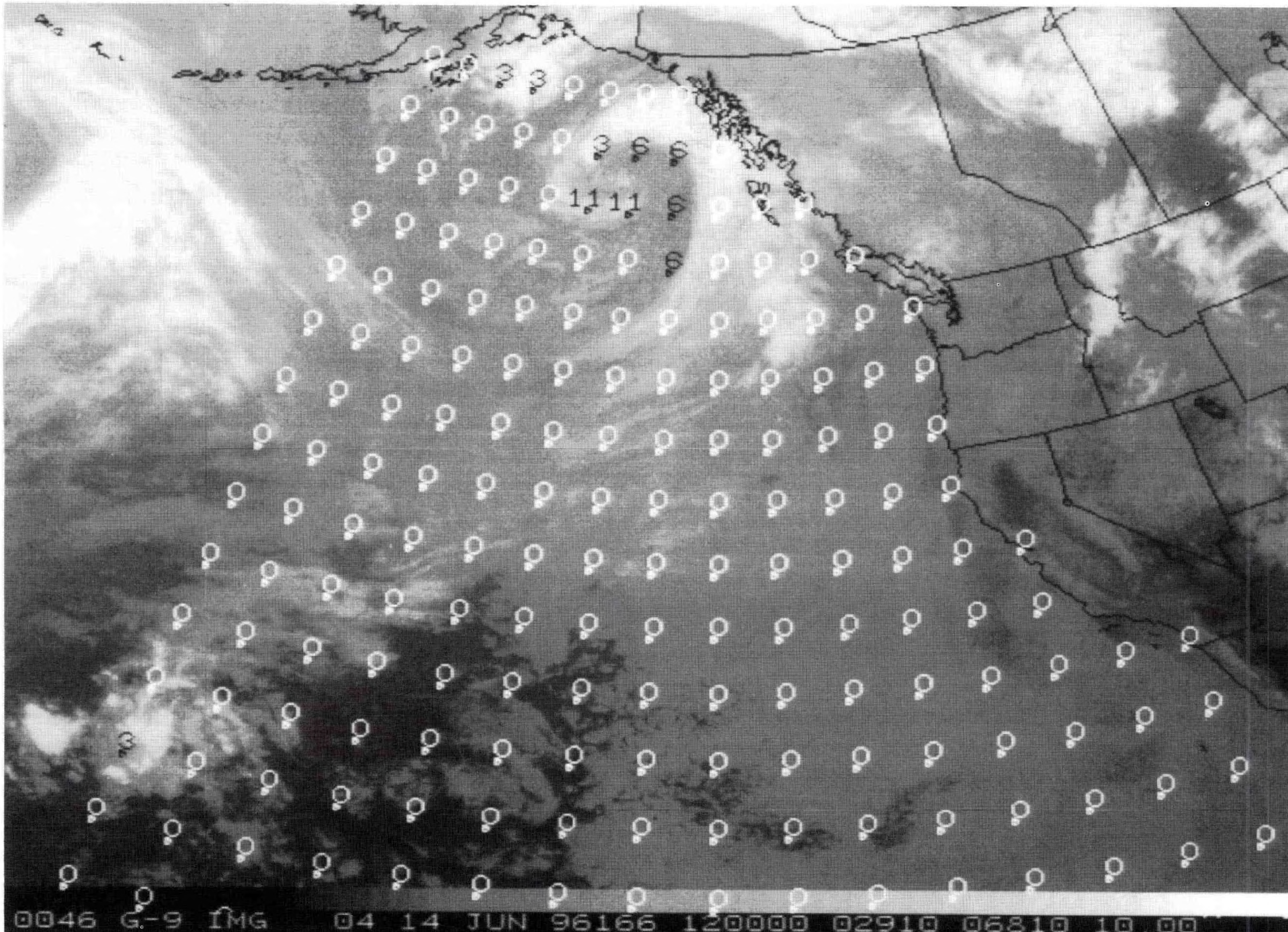


Figure 21. Moisture Analysis Product; numbers refer to categories in Table 3.

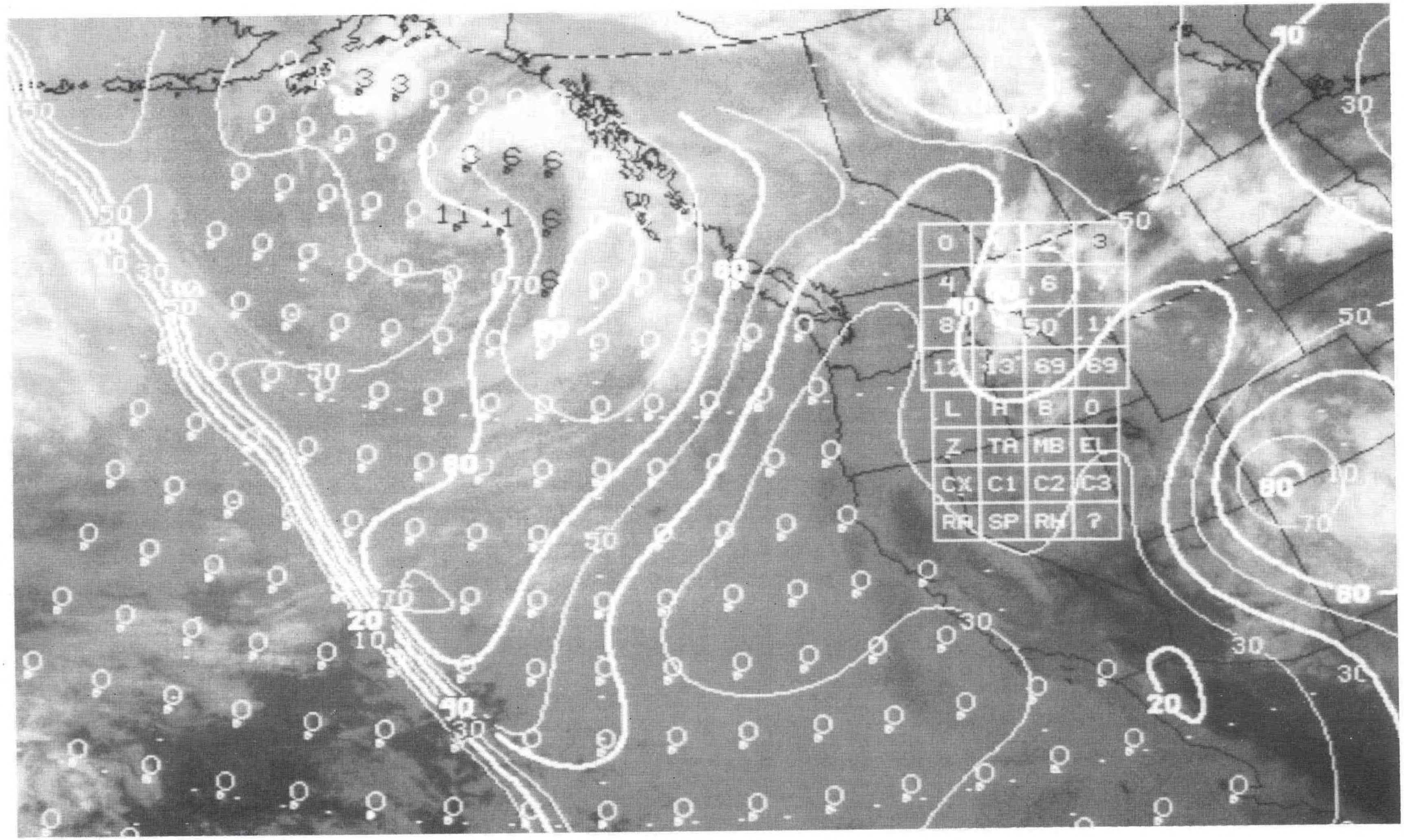


Figure 22. Comparison of the relative humidity forecast (contours) and moisture analysis (numbers).

VI. ATMOSPHERIC PARAMETERS (IMAGER)

d. Precipitation Estimates

Interactive Flash Flood Analyzer (IFFA)

Description. The Interactive Flash Flood Analyzer (IFFA) is 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 infrared). 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 tropopauses and equilibrium levels. An infrared 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 tropopauses 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 warmer ones.

Three steps are used to estimate convective rainfall amounts.

STEP 1 - locate the active portion of the thunderstorm system. Infrared 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 (factor 5). 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).

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. Messages can be sent as frequently as every half hour (approximately 20 minutes after the latest satellite picture) to the appropriate weather service office. A sample SPENES is illustrated in Figure 23. IFFA-derived graphics products are sent 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 24. Along coastal areas, especially in the western region, rainfall estimates from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) are used to help adjust the GOES estimates.

Accuracy. Cirrus debris from thunderstorms limits the accuracy of visible and infrared precipitation estimation techniques. Nevertheless, 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 that range from 0.4 to 0.7 (Borneman, 1988 and Achutuni, 1993).

Users. The primary users of this product are Weather Service Offices, River Forecast Centers, and NCEP, especially the National Precipitation Prediction Unit.

References.

Scofield, R.A., 1987: The NESDIS operational convective precipitation estimation technique. *Mon. Wea. Rev.*, **115** (8), 1773-1792.

Borneman, R., 1988: Satellite rainfall estimating program of the NOAA/NESDIS Synoptic Analysis Branch. *Nat. Wea. Dig.*, **13** (2), 7-15.

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*, Vienna, VA, August 2-6, 1993, 389-392.

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.

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 Extra-tropical Cyclones. *NOAA Technical Memorandum NESDIS 8*, U.S. Department of Commerce, Washington, D.C., 51 pp.

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.

```
SATELLITE PRECIPITATION ESTIMATES...DATE/TIME 10/5/95  0105Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS TEL.301-763-8678
VALUES REFLECT MAX OR SGFNT EST. OROGRAPHIC EFFECTS NOT ACCTD FOR.
...ESTIMATES FM: GOES8 - CNTRL AND EAST U.S./GOES7 - WEST U.S....
REFER TO TPB#375 FOR DETAILS. LATEST DATA USED:    042345Z   MGR

LOCATION...                 TOTALS    TIME
FL CNTYS...
 S OKALOOSA/SANTA ROSA       14.4"   1145-2345Z
 WASHINGTON                   8.8"      "    "

AL CNTYS...
 CONECUH                     10.4"      "    "
 MONTGOMERY                   5.1"      "    "
 WILCOX                       5.7"      "    "
 BALDWIN                      8.1"      "    "

REMARKS...BAND ON NORTH SIDE OF EYE WALL HAS COOLED TO -83C SINCE MVG
ONSHORE IN FL PANHNDL. AM ESTMTG ABT 3"/HR ALTHO DIFFICULT TO KNOW HOW
MUCH IS REALLY FALLING. OTHER LRG CNVTV BND MVG INTO CNTRL AL LKLY
BRINGING 2"/HR AS IT PASSES.
```

```
SATELLITE PRECIPITATION ESTIMATES...DATE/TIME 10/5/95  0130Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS TEL.301-763-8678
VALUES REFLECT MAX OR SGFNT EST. OROGRAPHIC EFFECTS NOT ACCTD FOR.
...ESTIMATES FM: GOES8 - CNTRL AND EAST U.S./GOES7 - WEST U.S....
REFER TO TPB#375 FOR DETAILS. LATEST DATA USED:    042345Z   MGR

LOCATION...                 TOTALS    TIME
NC CNTYS...
 ANSON                        5.2"   1145-2345Z
 WAKE                         4.8"      "    "
 FRANKLIN                     4.8"      "    "
 PERQUIMANS                   4.7       "    "
 SAMPSON                      4.9"      "    "

REMARKS...12 HR RAINFALL ETSMTS SHOW A LRG SWATH OF 4+" EXTNDS FM
CNTRL TO NE NC AS MAINLY WRM TOPPED CNVTN/OVRNG TYPE PRECIP TRAINED
OVR RGN. TOPS HAV WRMD EVN MORE NOW AND THERE SHUD BE A RESPITE OF THE
HVY RAIN UNTIL NEXT SURGE ASCD WITH BAND FM OPAL...NOW IN NE GA...MOVS
INTO AREA LTR TNGT.
```

Figure 23. IFFA Satellite Precipitation Estimate, SPENES, Message.

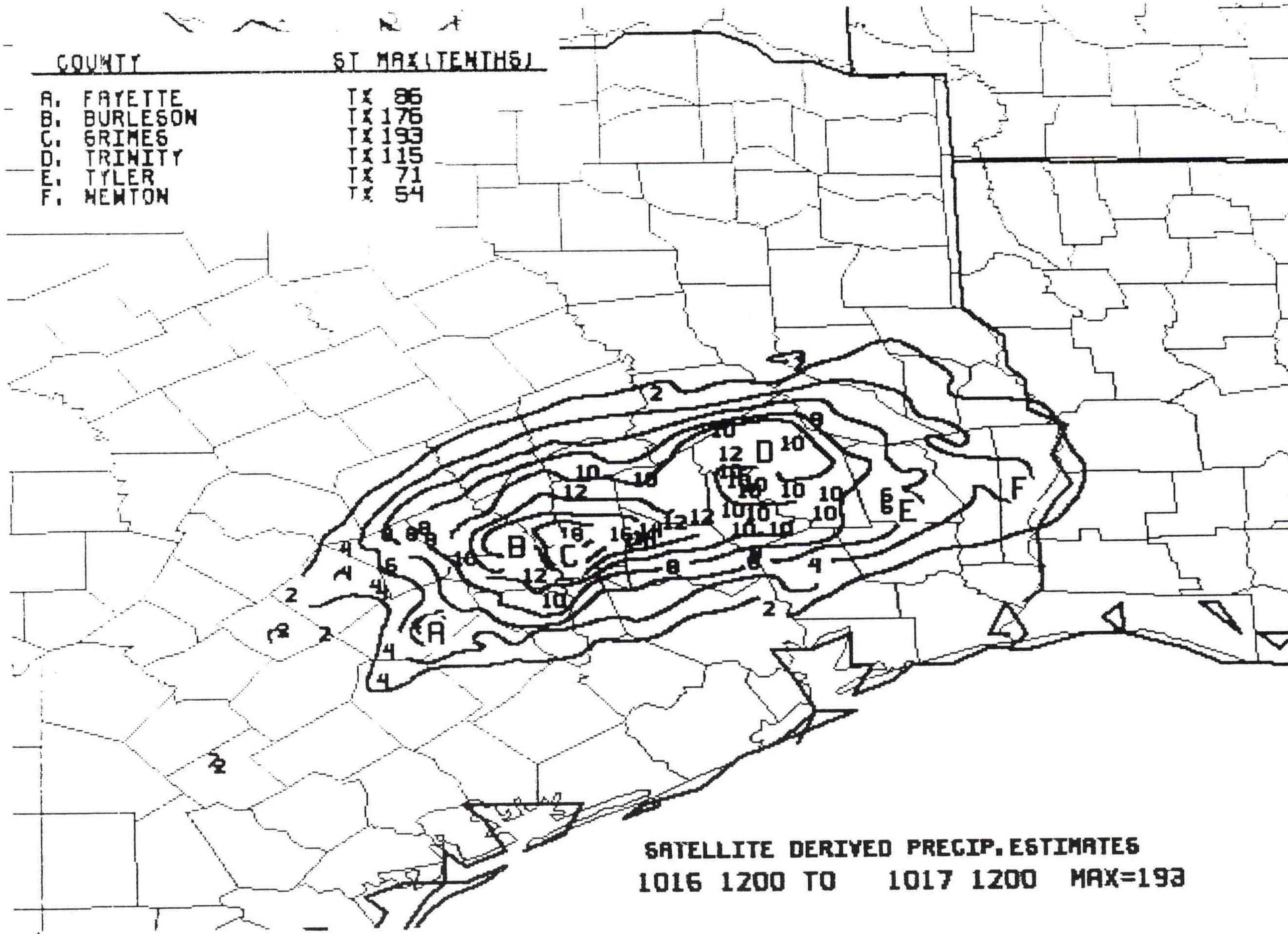


Figure 24. Graphical IFFA Precipitation Estimates in inches.

d. Precipitation Estimates

Precipitation Histograms

Description. GOES infrared images (11 micron) are reduced to histograms of brightness temperatures for 2½° x 2½° latitude/longitude boxes for access by the Climate Analysis Center (CAC), NCEP. The CAC 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 Infrared images on the CEMSCS (00, 03, 06...21 UTC); extracts the samples corresponding to each 2½° box from 50° North to 50° South; converts the pixel value to brightness temperature; generates a 16 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 CAC. A graphical display of this product is shown in Figure 25.

At the CAC, obliquity and calibration adjustments are applied and the GPI estimates are merged with similar estimates from other geostationary satellites (including at present Meteosat and 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 ± 1°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 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, 1995: An intercomparison of satellite estimates and gauge observations of climatic-scale monthly precipitation. *J. Appl. Meteor.*, **34**, 1143-1160.

Xie, P. and P.A. Arkin, 1996: Analyses of global monthly precipitation using gauge observations, satellite estimates and numerical model predictions. *J. Climate*, (accepted).

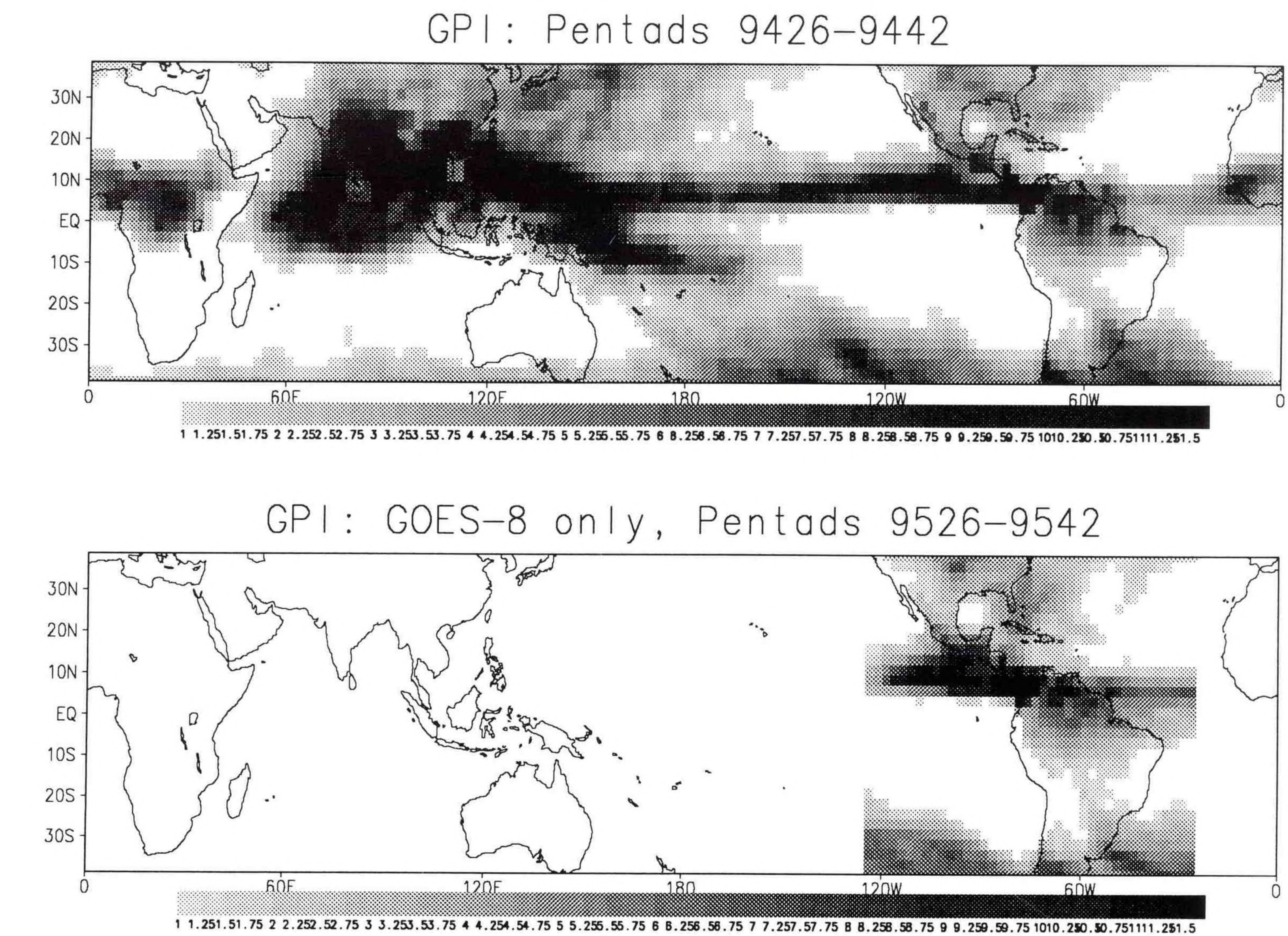


Figure 25. GPI estimates from GOES 8 for pentads 26-42 (roughly May - July) in 1995 (lower panel) and from the merged geostationary/polar orbiting satellite data set from the same period during 1994 (upper panel) in mm/day.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

e. Northern Hemisphere Snow and Ice Chart

Description. The Northern Hemisphere Snow and Ice Chart has been produced operationally at NESDIS since 1966. The North American portion of this weekly chart is generated primarily from GOES visible imagery. The remainder of the analysis is prepared primarily from the NOAA Polar-orbiting Operational Environmental Satellite (POES) imagery, augmented by other METEOSAT and GMS imagery. Animated GOES visible imagery is used to draw a 1:50,000,000 hand analysis and is most useful for detecting snow fields from cloud cover (Figures 26 and 27). The final-hand drawn analysis is digitized onto an 89 x 89 square polar stereographic map (Figure 28) where boxes that are ≥50% snow covered are included in the digitized analysis. Computerized formats of this digitized chart also include monthly means and anomalies. The data is particularly critical for depicting the total snow cover during the Northern Hemisphere winter when albedo effects, ground surface temperatures, and evaporative properties are especially important for Numerical Weather Prediction.

Accuracy. 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. Currently, the North American portion is generally thought to have an accuracy better than 15 km.

Users. The primary user of this chart is the NWS/NCEP for inclusion into the operational numerical weather prediction models. The analysis also serves as a data source supporting NOAA's hydrometeorological and climate programs. Other users include the National Climatic Data Center, NWS River Forecast Centers, Oceanic and Atmospheric Environmental Research Laboratories, and the U.S. Army Corp of Engineers.

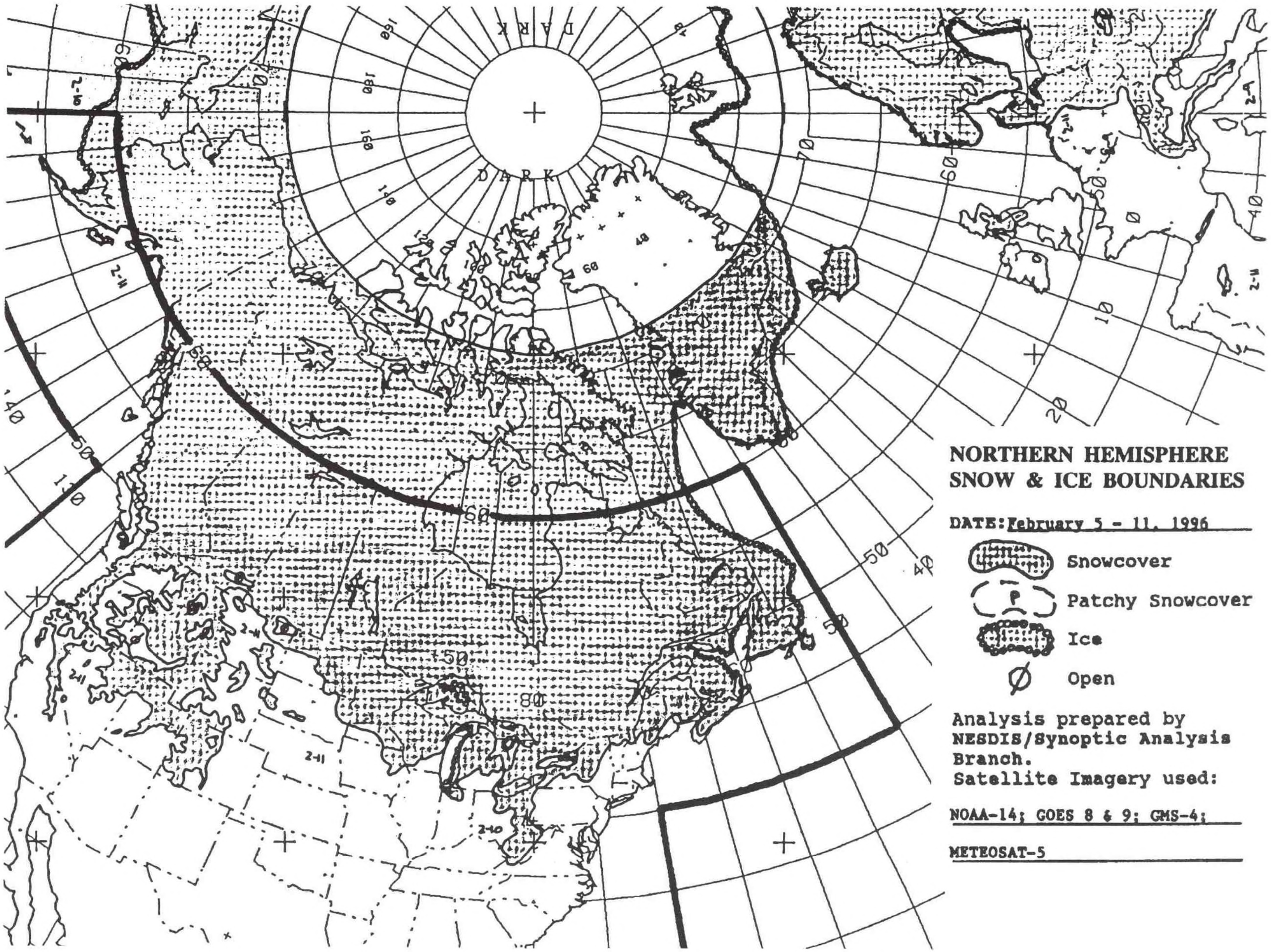


Figure 26. North American portion of the Northern Hemisphere Snow and Ice Chart for the week of February 5-11, 1996.

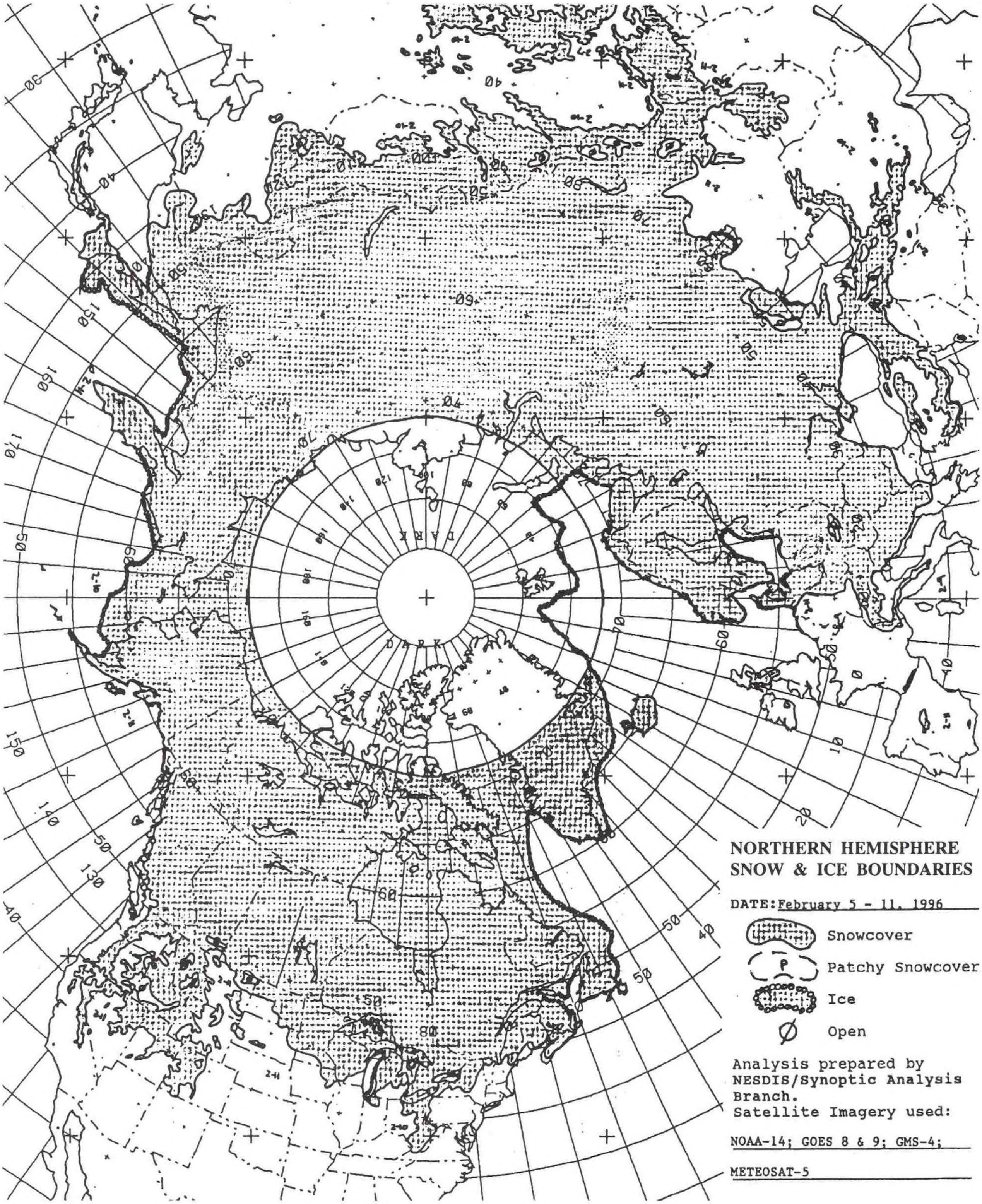
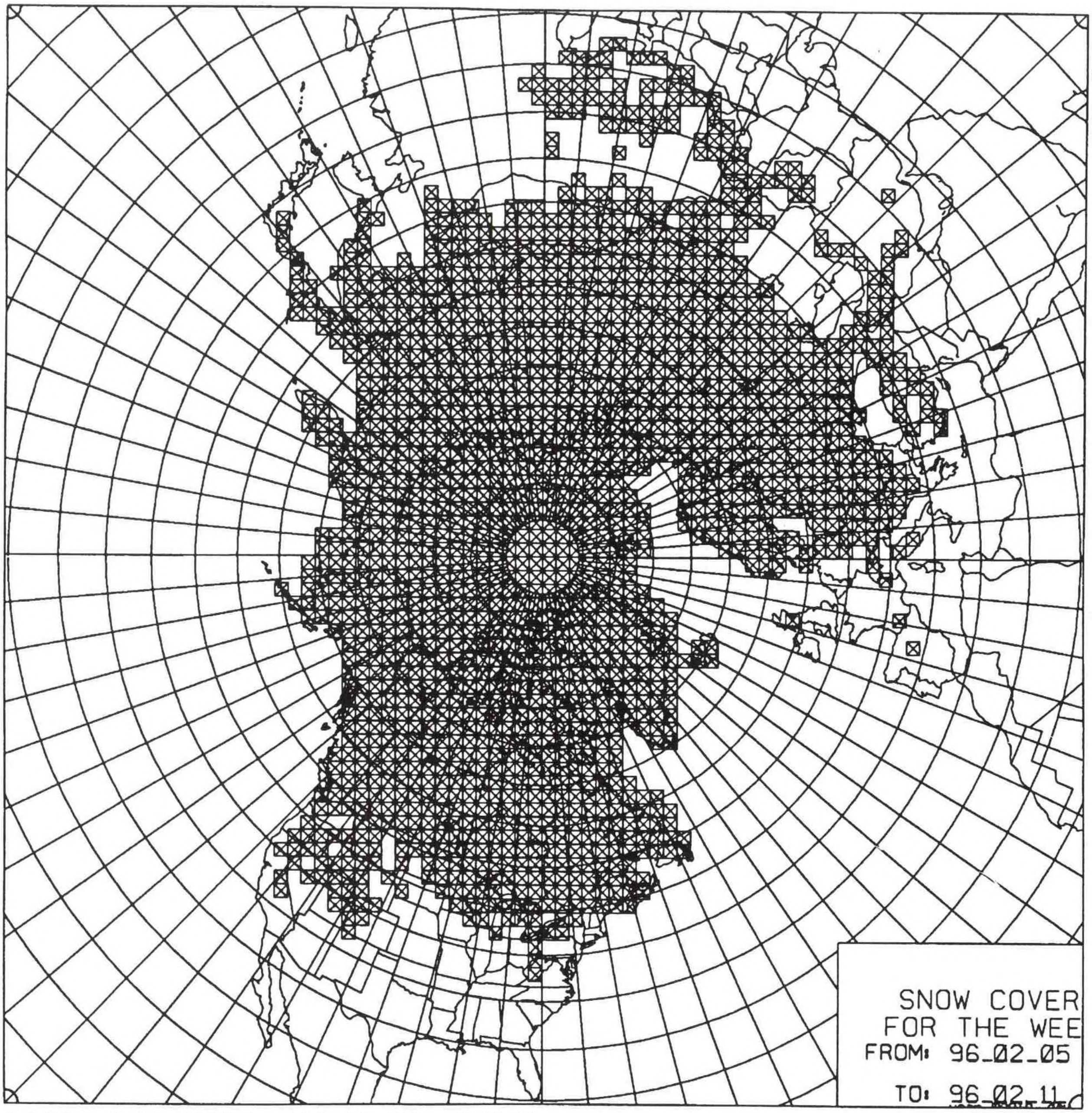


Figure 27. Northern Hemisphere snow and ice chart for the week of February 5-11, 1996.



/usr2/home/sab/sn29606.dgn Feb. 12, 1996 18:29:31

Figure 28. Digitized Northern Hemisphere snow map, week of February 5-11, 1996.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

f. Tropical Cyclone Position and Intensity Estimates

Description. GOES infrared and visible imagery 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 (00, 06, 12, and 18 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 3-hourly remapped imagery, and animated data loops are used to track systems. Using various enhancement curves (i.e., BD curve, Figure 29) and parallax corrections for storms with eyes, systems are positioned to the nearest tenth of a degree and intensities are measured to the nearest half T-number and entered on the Tropical Cyclone Analysis Worksheet (Figure 30).

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 from operational reconnaissance data.

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

Reference.

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.

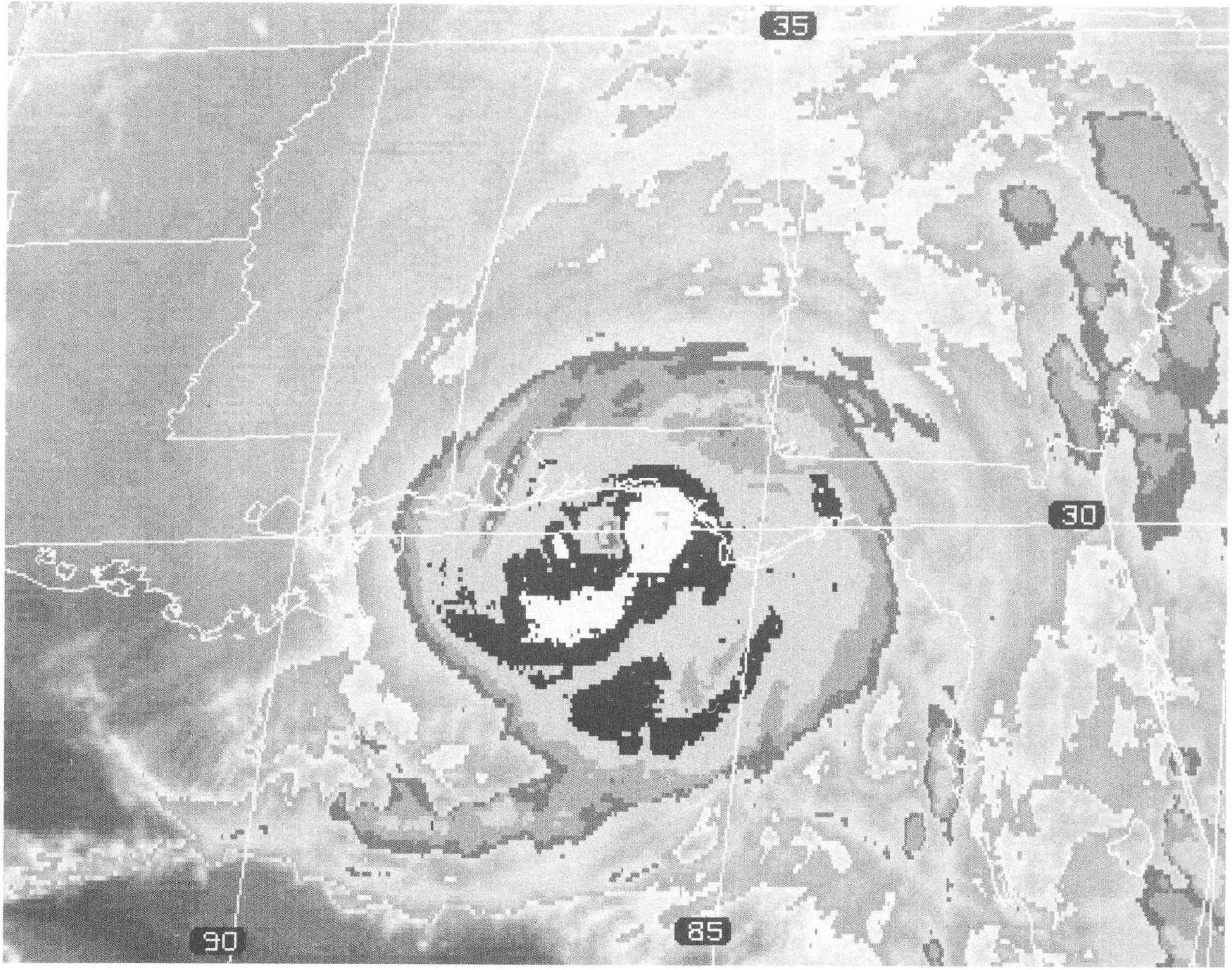


Figure 29. Hurricane Erin, displayed with the BD enhancement curve, taken August 3, 1995.

Atlantic
OCEAN AREA

Aug 1995
MONTH / YEAR

TROPICAL CYCLONE ANALYSIS WORKSHEET

Erin (05)

Vernon F. Dvorak
May 1982

	T-NUMBER ESTIMATE FROM MEASUREMENTS FOR DATA T-NUMBER (DT) COMPUTATION															T-NUMBER ESTIMATE FROM MODEL AND DT CONSTRAINTS								
STEP →	1		2A,B				2C				2D	2E				3	4	5	6	7,8	9			
DESCRIPTION →	Location		Curved Band or Shear				Eye		$E_{No}+E_{Adj}=CF$		CDO	Emb. Centr.	Data T-Number Computation			CCC	Trend	MET	PAT	FT	CI			
RULES →	Locate Cloud System Center at focal point of cloud curvature		Use Spiral Arc Length								Use Size		CF+BF=DT			Use Rules	24-Hr change			Use Rules				
			DT 1.5	DT 2.5	DT 3.5	DT 4.5	(VIS) Use Embedded Distance	(EIR) Use Surrounding Temperature	From Rules	Eye Definition	Central Dense Overcast	(EIR) Use Surrounding Temperature				Central Cold Cover	D-developing W-weakening S-same	Model Expected T-Number	Pattern T-Number	Final T-Number	Current Intensity Number	Bulletin Sent In TES		
DATE/TIME	LAT	LONG							E_{No}	E_{Adj}			CF	BF	DT								CODE	INITIALS
03/1145	*29.9N*	*86.6W*		*$\overline{DVOR}_{6hr}$ = 5.4*				*LG*	*5.0*	*0.0*			*5.0*		*5.0*		*D*	*5.0*	*5.0*	*5.0*	*5.0*		*T5.0/5.0*	*JSL*
	30.0N	*86.7W*																					*T5.0/5.0*	*MIA*

Figure 30. Tropical Cyclone Analysis Worksheet.

VI. ATMOSPHERIC PARAMETERS (IMAGER)

g. Volcanic Hazard Alert Messages

Description. In 1989, the Federal Aviation Administration (FAA) and NOAA initiated a Memorandum of Understanding to help warn aircraft of the major hazards associated with volcanic ash. GOES data for North America, Central America, and South America are used to develop volcanic hazard alert messages (Figure 31). These are issued, 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 these messages to the aviation community using infrared, visible and multispectral imagery. Included with these messages are graphical analyses of detectable ash clouds (Figure 32) and graphical output of the Volcanic Ash Forecast Transport and Dispersion (VAFTAD) model. These forecasts are from NCEP and NOAA's Air Resources Lab (ARL). Analyses are prepared and disseminated by facsimile as often as every 3 hours when ash poses a serious threat to aviation. Products are prepared worldwide from METEOSAT, GMS, and POES 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, FAA, U.S. Geological Service, Department of Defense, 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*, July 8-12, Seattle, Washington, 373-376.

Stephens, G., 1993, Volcano Detection and Monitoring Using Satellite Data. *Proceedings of the Japan-United States Technology Workshop on the Application of Remote Sensing To Natural Disaster Reduction*, November 17-20, Tsukuba, Japan, 67.

SYNOPTIC ANALYSIS BRANCH
NOAA/NESDIS
301-763-8444
FAX 301-763-8333

Volcano Hazards Alert
Message Number: 37
NOAA/NESDIS Synoptic Analysis Branch
September 19, 1992
1400Z

Mt. Spurr (61.3N 152.3W)
Alaska
Times of initial eruptions: 17 Sept. 0637Z and 0804Z

===

PLEASE REFER TO SIGMETS/NOTAMS FOR CURRENT WARNINGS

===

At 1300 UTC, GOES visible imagery showed the most optically dense portion of the ash cloud extended from central Michigan, across extreme southeastern Ontario into southern Quebec (darkened portion). More difuse ash was faintly visible over the outer ring. A note of caution... the outer edge of the thin ash boundary is hard to interpret and light ash probably extends outside our boundary lines.

Recent aircraft reports from around the Great Lakes Region are noting ash. Many of the reports are giving a base of the ash cloud to be around 20,000 ft. There have been various depths to the cloud reported. Around Flint, Michigan, ash has been reported up to 32,000 ft. Most aircraft are flying 21,000 ft or below to avoid ash encounters.

Attachments:
Graphical Satellite Analysis
ARL Experimental Dispersion/Transport Guidance

The next advisory will be issued around 1730Z.

END...END...END

Figure 31. Volcanic Hazards Alert Message for the Mount Spur, Alaska eruption.

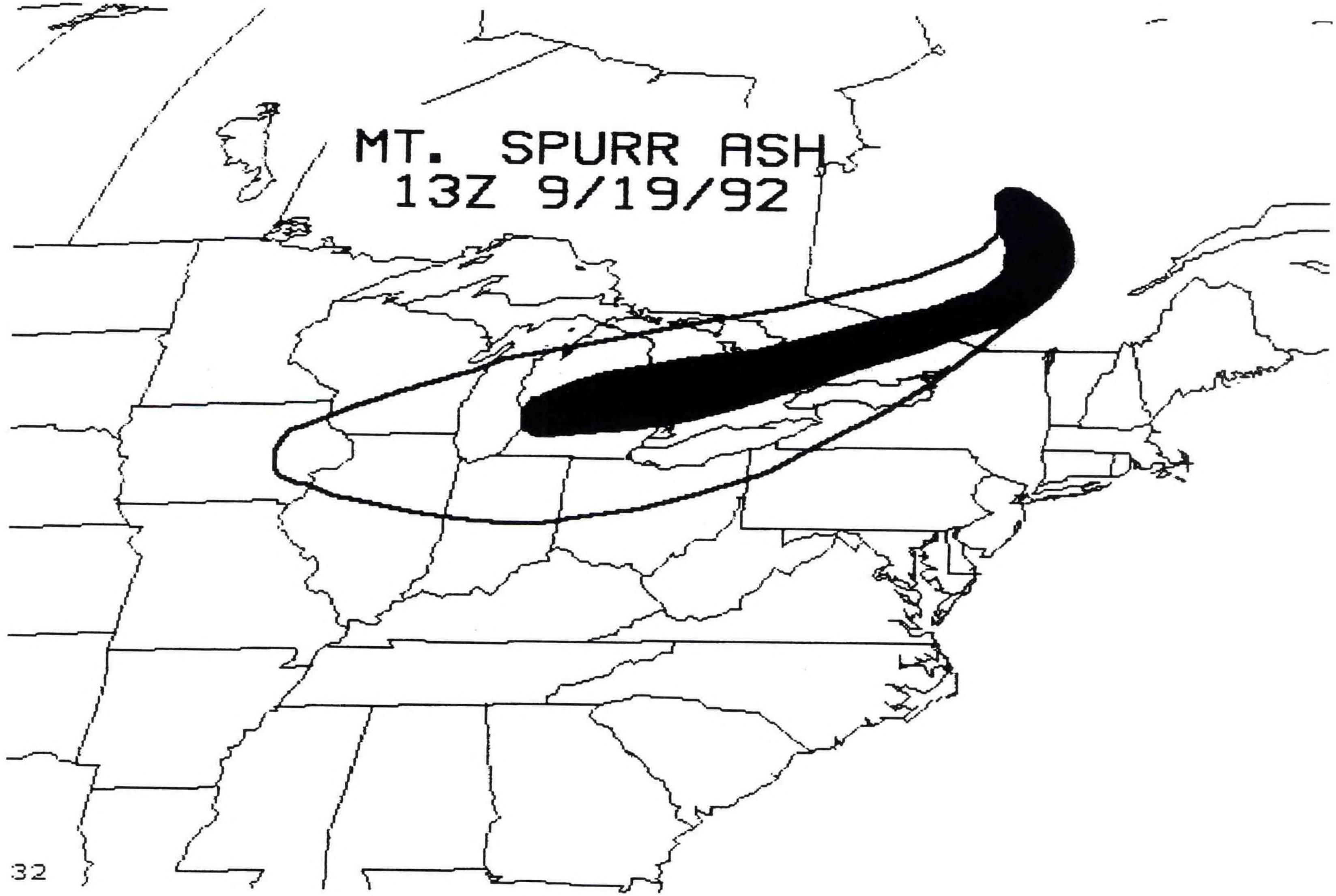


Figure 32. Graphical analysis of the ash plume from Mount Spur, Alaska.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

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 water vapor. Table 4 lists the wavelengths and bands of the 19 channels of the sounder, spectral peak, and the atmospheric parameter that the 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 33. 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 supplemental cloud product for the Automated Surface Observing System (ASOS) (see Section VII-b, Site Specific Cloud Product) and have it available for the hourly observational round-up. Thus, the sounding operation is split into two portions denoted ASOS 1 and 2 (shown in Figure 33) so that observations in ASOS 1 can be processed in time for the NWS hourly round-up. Because of the oblique view, and increasing atmospheric path, no soundings are done north of 50°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 Channels 4 and 11 are shown in Figures 34 and 35. These figures illustrate the noise characteristics of these channels (Hayden, 1995).

Accuracy. 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 data set is used internally to produce atmospheric soundings and derived products.

Reference.

Hayden, C.M., 1995: Initial evaluation of the GOES-8 sounder. *Proceedings of the 9th Symposium on Meteorological Observations & Instrumentation*, March 27-31, 1995, Charlotte, NC, Amer. Meteor. Soc., 385-390.

TABLE 4. GOES-8 AND -9 SOUNDING CHANNELS

Channel	GOES-8/9 Spectral Peak	Band	Purpose
1	14.71 μm	Carbon Dioxide	Stratospheric Temperature
2	14.37 μm	Carbon Dioxide	Tropospheric Temperature
3	14.06 μm	Carbon Dioxide	Upper-level Temperature
4	13.96 μm	Carbon Dioxide	Mid-level Temperature
5	13.37 μm	Carbon Dioxide	Low-level Temperature
6	12.66 μm	Water Vapor	Total Precip. Water
7	12.02 μm	Window	Surface Temperature, moisture
8	11.08 μm	Window	Surface Temperature
9	9.71 μm	Ozone	Total Ozone
10	7.43 μm	Water Vapor	Low-level Moisture
11	7.02 μm	Water Vapor	Mid-level Moisture
12	6.51 μm	Water Vapor	Upper-level Moisture
13	4.57 μm	Carbon Dioxide	Low-level Temperature
14	4.52 μm	Carbon Dioxide	Mid-level Temperature
15	4.45 μm	Carbon Dioxide	Upper-level Temperature
16	4.13 μm	Nitrogen	Boundary-layer Temperature
17	3.98 μm	Window	Surface Temperature
18	3.74 μm	Window	Surface Temp., Moisture
19	0.969 μm	Visible	Clouds

Figure 33a

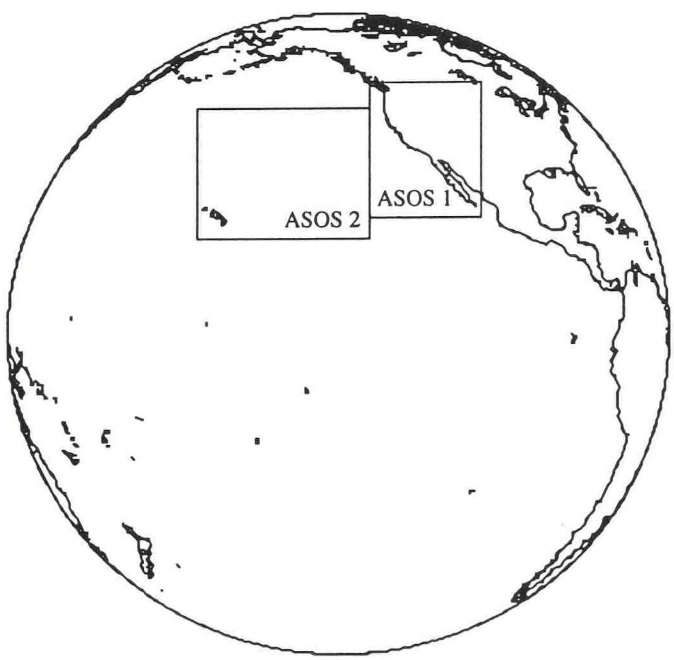


Figure 33b

Figure 33. a) GOES 8 and b) GOES 9 Sounding Areas.

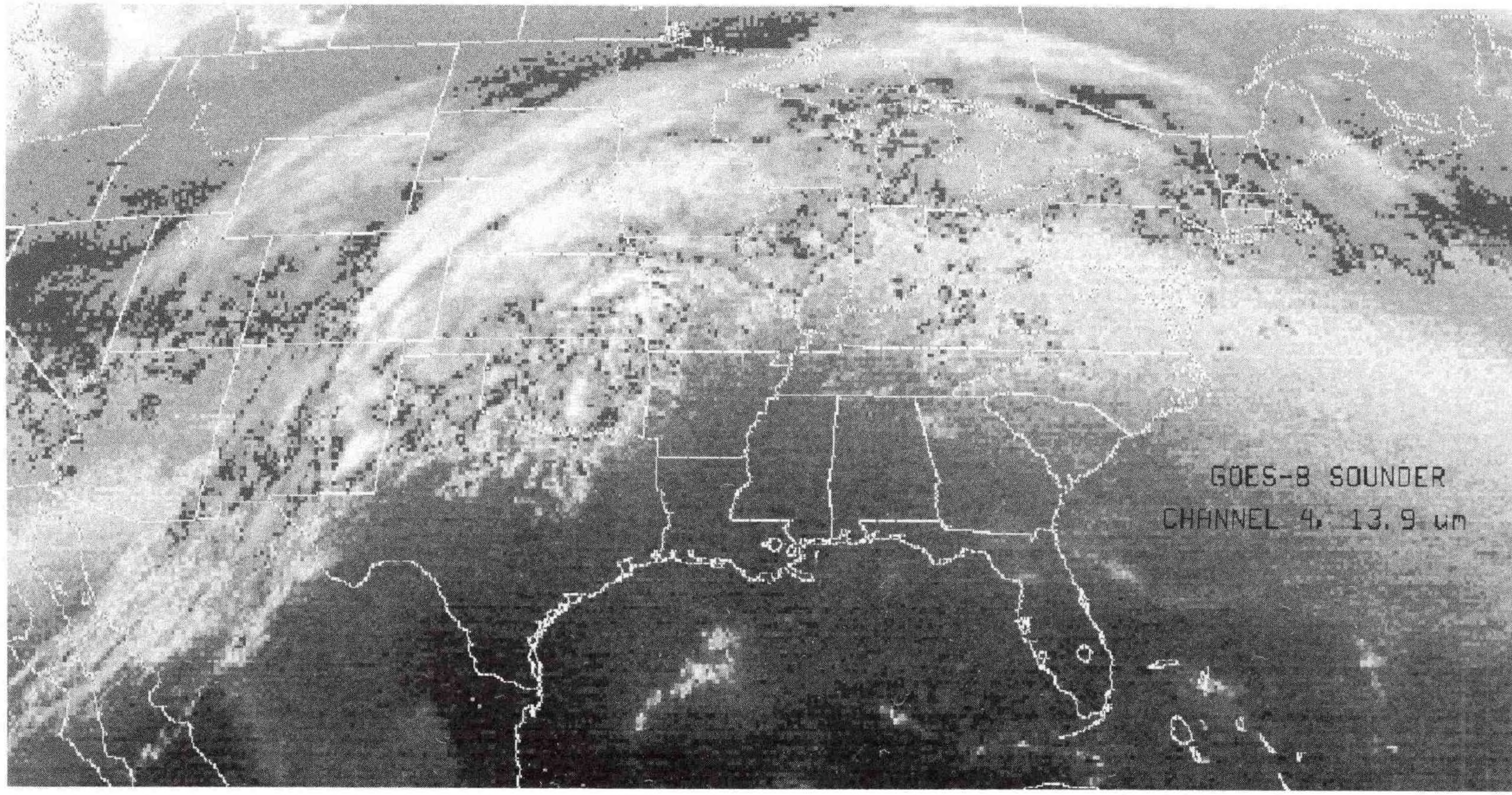


Figure 34. Image of GOES-8 sounder channel 4 taken at 1246 UTC, November 8, 1994.

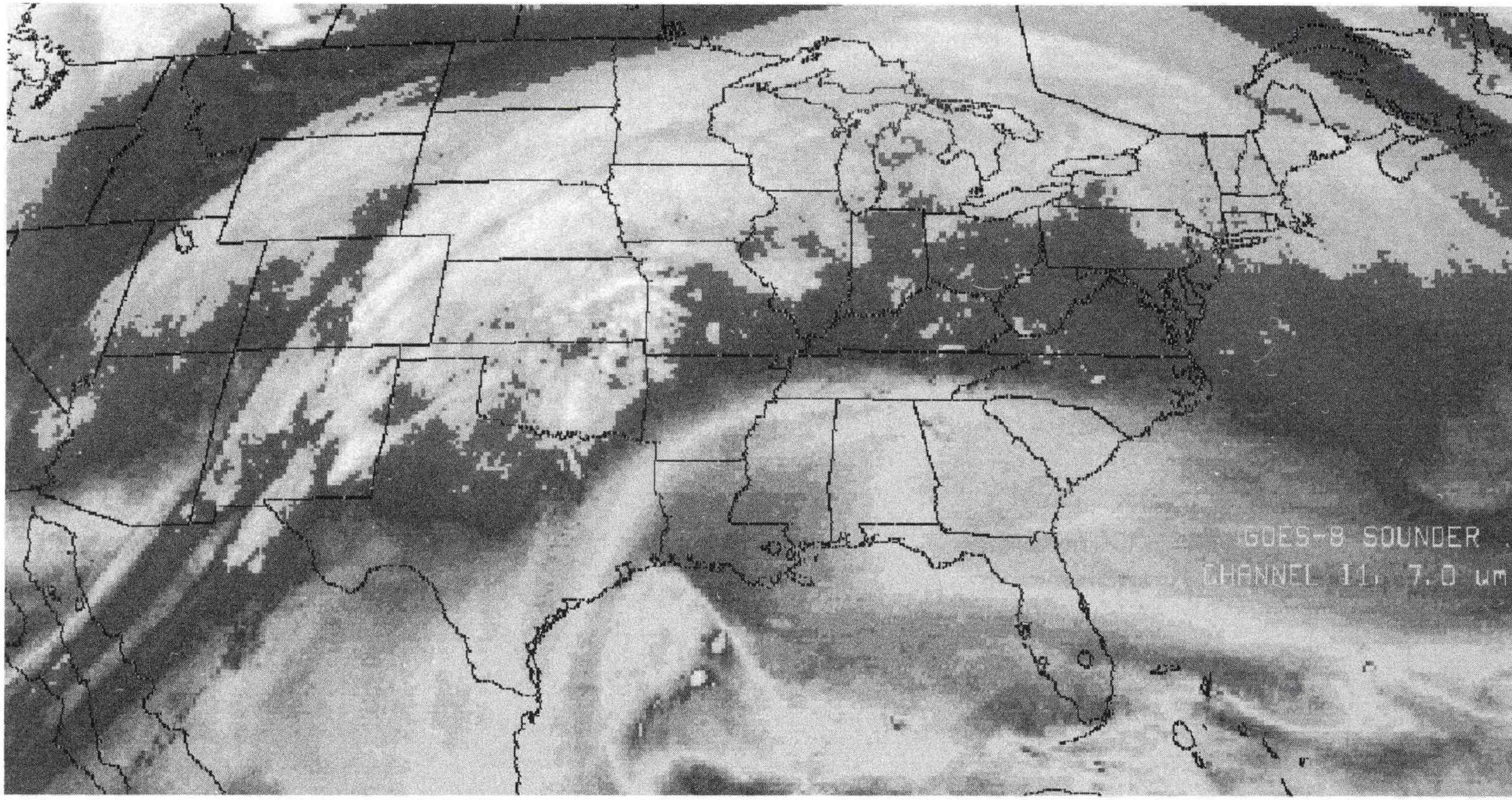


Figure 35. Image from the GOES-8 sounder channel 11 taken at 1246 UTC, November 8, 1994.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

b. Atmospheric Measurements

Description. The sounder atmospheric products are a set of parameters derived from the 19 channel radiances available from the GOES-8/9 sounders, NCEP numerical model forecast information and hourly surface observations. The derived products are given in Table 5. The algorithm used to derive the temperature and moisture profiles which form the basis for the other parameters is described in Hayden and Schmit (1994) and Hayden (1988).

The hourly retrieved sounding is derived from an iterative technique using as input: radiance observations from the GOES-8/9 sounder channels 1-8 and 10-16, a space and time interpolated first guess temperature and moisture profile from the NCEP ETA model, an objective analysis of the hourly surface observations, and an estimate of the surface skin temperature and emissivity. The retrieved sounding contains temperature and moisture values for 40 levels in the atmosphere from the surface to .10 hPa. Retrievals are attempted for an area of 5 x 5 fields-of-view (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 clear, possibly clear, or not clear. If at least 9 fovs are clear, they are averaged and a retrieval is made. If less than 9 fovs are clear then a retrieval is not 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 by the Interactive Processing Branch (IPB) on an IBM RISC/6000 UNIX workstation. The soundings are provided to NCEP for use in numerical forecast models.

Accuracy. See Table 5, Products from GOES-8 Sounder.

Users. NWS, NCEP, and the National Climate Data Center. Many of these products can be viewed on the Internet homepages at these addresses: http://cimss.ssec.wisc.edu, and http://orbit7i.nesdis.noaa.gov:8080/.

References.

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*, June 6-10, 1994, Monterey, CA, Amer. Meteor. Soc., 477-480.

Hayden, C.M., 1995: Initial evaluation of the GOES-8 sounder. *Proceedings of the 9th Conference on Meteorological Observations and Instrumentation*, March 27-31, 1995, Charlotte, NC, Amer. Meteor. Soc., 385-390.

Hayden, C.M., H.E. Fleming, T.J. Schmit, 1996: GOES Radiance Bias Tuning and Temperature Moisture Sounding Validation. *J. Appl. Meteor.*, (submitted).

TABLE 5. PRODUCTS FROM THE GOES-8/9 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 Temperatures	Equivalent to channel noise; reduced by sample size.
Lifted Index	+/- 1.5 Degrees Kelvin
Thermal (Gradient) Wind Estimates	+/- 4 meters/second

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

b. Atmospheric Measurements

Vertical Temperature and Moisture Profiles

Description. The computation of soundings is described in the preceding section. Temperatures are generated for 40 pressure levels. A sample temperature and dewpoint sounding is shown in Figure 36.

Accuracy. See Table 5, Products from GOES-8 Sounder.

Users. NWS, NCEP, and the National Climate Data Center.

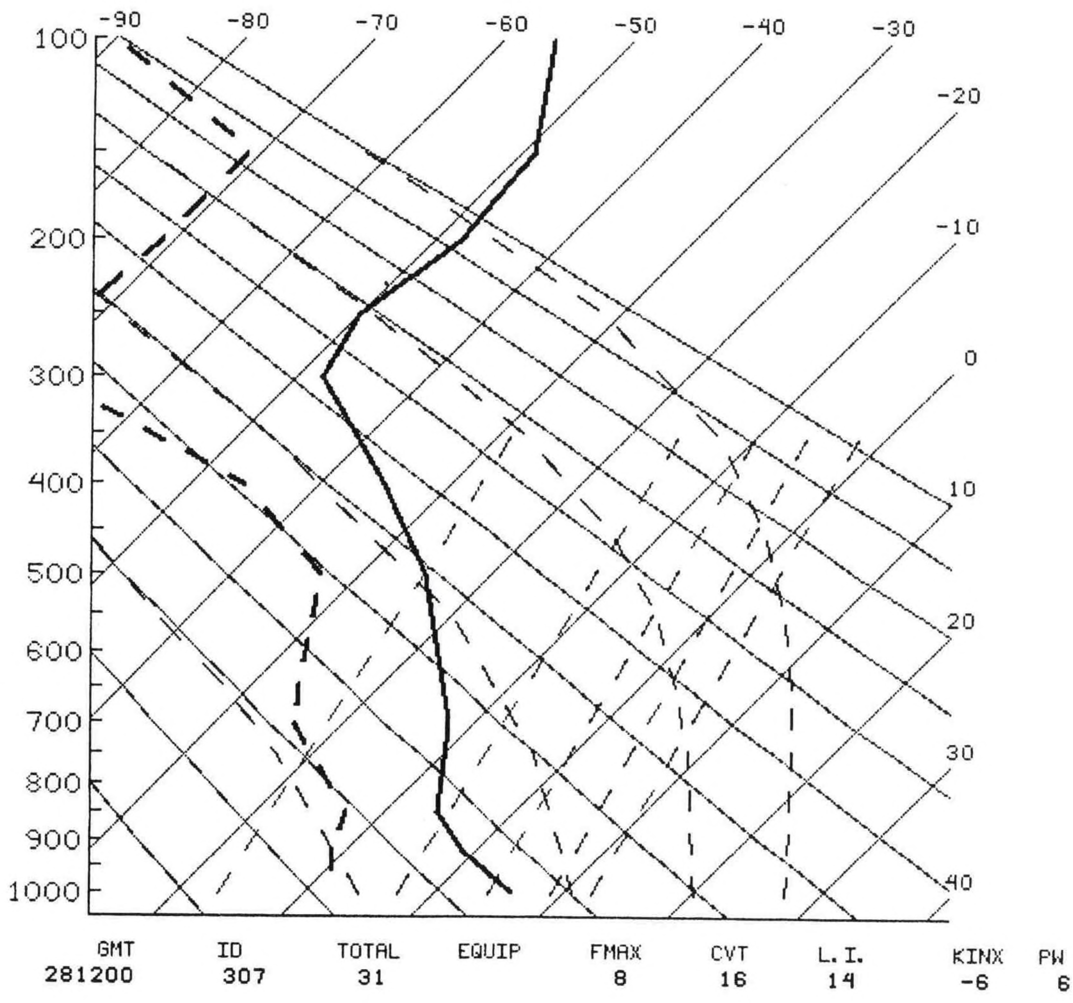


Figure 36. A GOES temperature and moisture profile.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

b. Atmospheric Measurements

Layer Precipitable Water

Description. Soundings or retrievals are calculated for clear areas. 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). This product is displayed as an image in Figure 37.

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

Users. NWS, NCEP, and the National Climatic Data Center. This product can be viewed on the Internet homepages at these addresses: http://cimss.ssec.wisc.edu and http://orbit7i.nesdis.noaa.gov:8080/.

References.

Hayden, C.M. and T.J. Schmit, 1995: Initial evaluation of the GOES-8 sounder. *Ninth Symposium on Meteorological Observations and Instrumentation,* March 27-31, 1995, Charlotte, NC, Amer. Meteor. Soc., 385-390.

Hayden, C. M., H.E. Fleming, T.J. Schmit, 1996: GOES radiance bias tuning and temperature moisture sounding validation. *J. Appl. Meteor.*, (submitted).

Figure 37. GOES 8 300-700 hPa layer precipitable water product for 1146 UTC, December 13, 1994.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

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 38.

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

Users. NWS, NCEP, and the National Climatic Data Center. This product can be viewed on the Internet homepages at these addresses: http://cimss.ssec.wisc.edu and http://orbit7i.nesdis.noaa.gov:8080/.

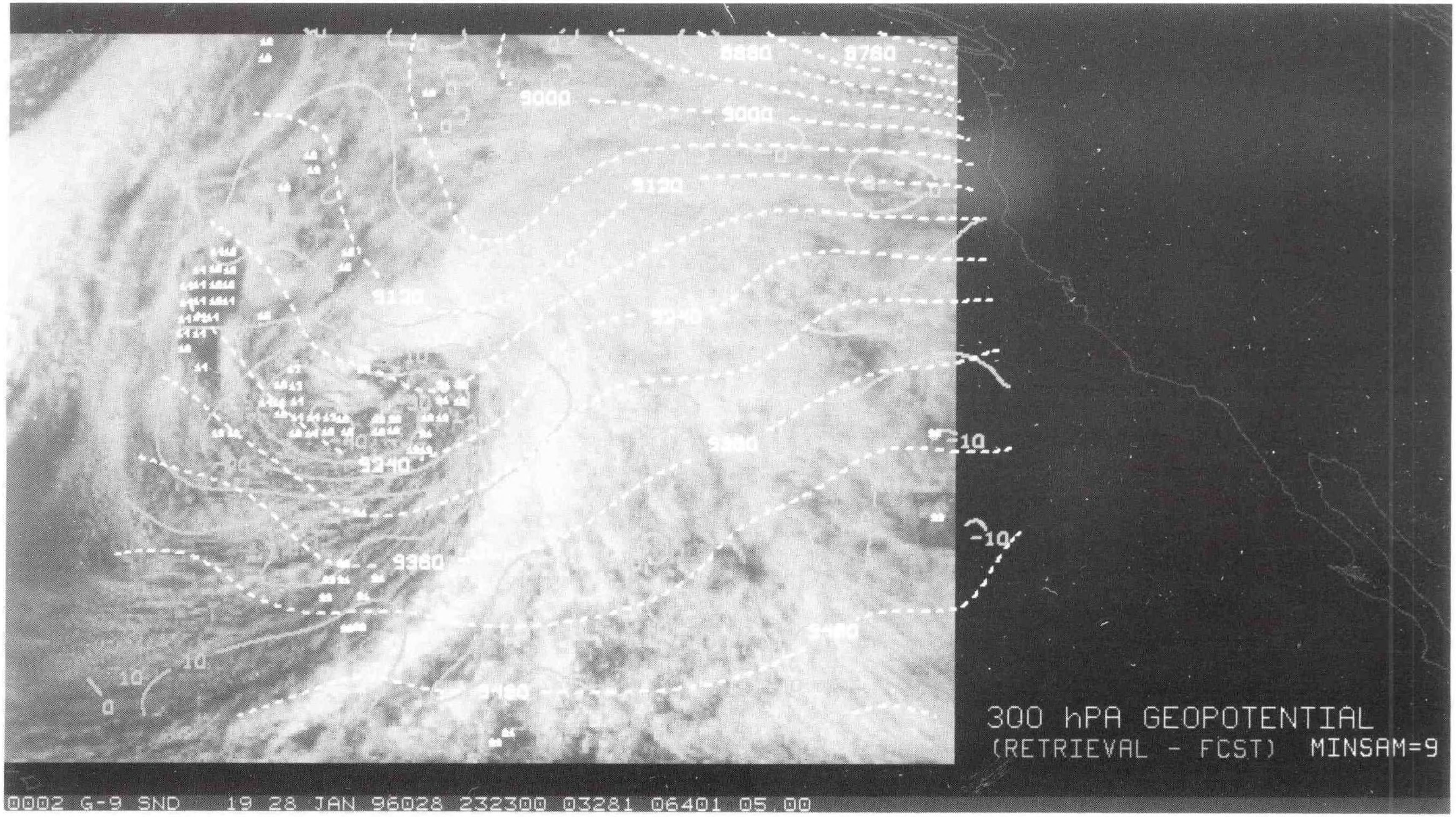


Figure 38. GOES 9 300 hPa contours of geopotential heights (dashed white lines), overlaid on the 2323 UTC, Jan 28, 1996, visible image. Contours of the difference (GOES 9 retrieval-forecast) are solid lines. The GOES 9 soundings indicated the Pacific low was 40m deeper than forecast.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

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 degree 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 in Figure 39.

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

Users. Distribution of this product is limited to the NCEP.

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*, June 6-10, 1994, Monterey, CA, Amer. Meteor. Soc., 477-480.

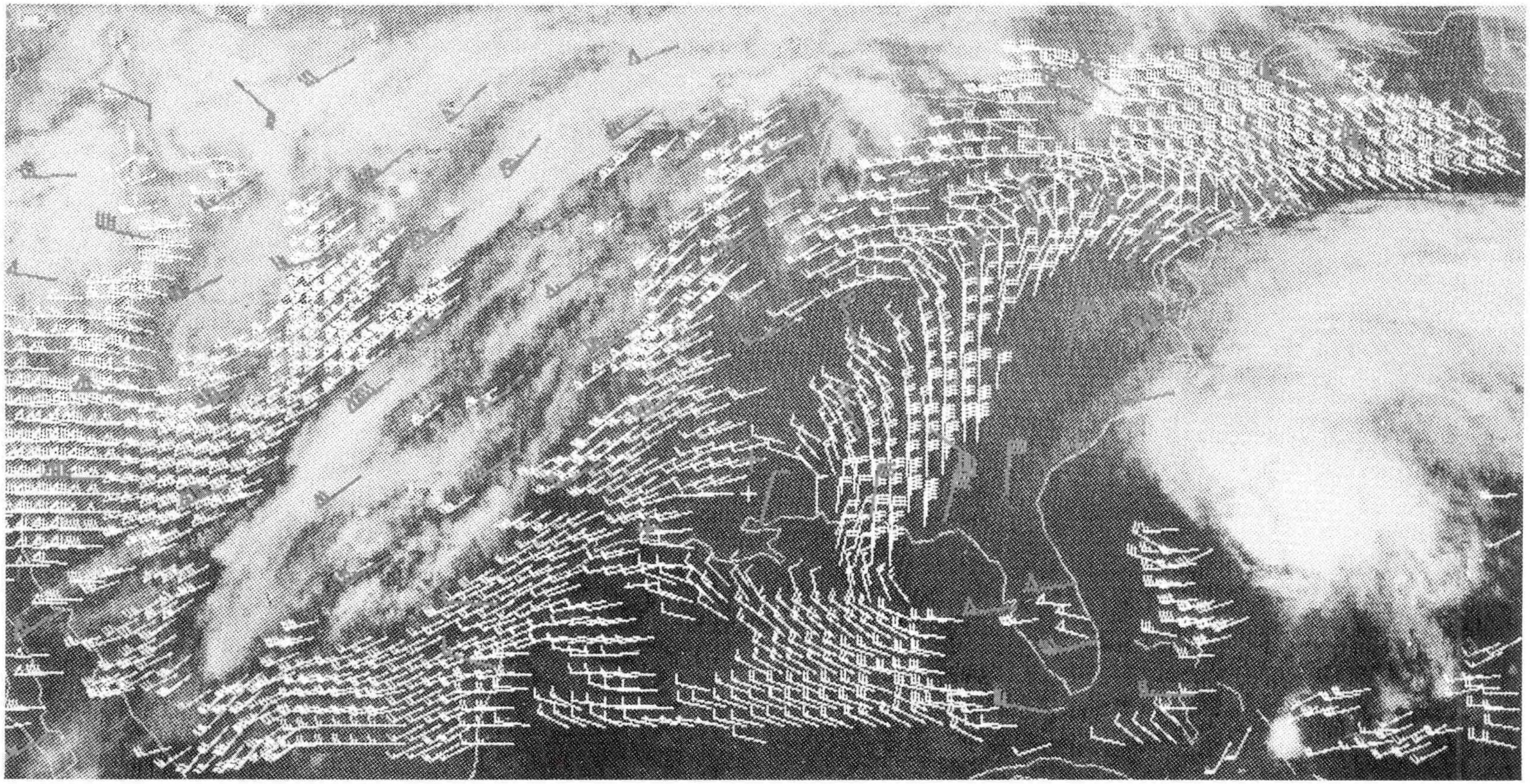


Figure 39. GOES 8 500 hPa gradient winds, November 17, 1994.

VII. ATMOSPHERIC PARAMETERS (SOUNDER)

b. Atmospheric Measurements

Site Specific Cloud Product

Description. GOES-8 sounder radiance information over the continental United States (CONUS) is 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 Observation 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 within the CONUS.

Three steps are required to produce the hourly-derived SCP. The first step is defining a 5 x 5 field-of-view (fov) box (upper right, Figure 40) at each selected site. A cloud top pressure and cloud amount is calculated at each fov using the CO_2 Absorption Technique (Schreiner et al., 1993; Menzel et al., 1983). An example of the remotely-sensed product is shown in Figure 40. From the 25 remotely-sensed cloud calculations (25 box array, Figure 40) 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 6 gives the histogram for the example in Figure 40. Step three utilizes a "Decision Tree" (Kluepfel et al., 1993) to determine an integrated or composite satellite observation over the surface site. This is shown in the lower right hand side of Figure 40.

The SCP is sent out through the Gateway communication network in two forms. A shortened text form (Figure 41) 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, MOSTLY 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 40). 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 National Climatic Data Center to be used in future climatic studies.

Figures 42 and 43 show SCP cloud heights and cloud amounts superimposed on a GOES image. The ASOS SCP and cloud height and amounts can also be viewed on the Forecast Products Development Team Internet homepage at http://orbit7i.nesdis.noaa.gov:8080/.

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%). Cloud height accuracies are within 50 hPa.

TABLE 6. SATELLITE CLOUD PRODUCT HISTOGRAM

	< 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 6. 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.

Menzel, W.P., W.L. Smith, and T.R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. *J. Climate 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.

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.

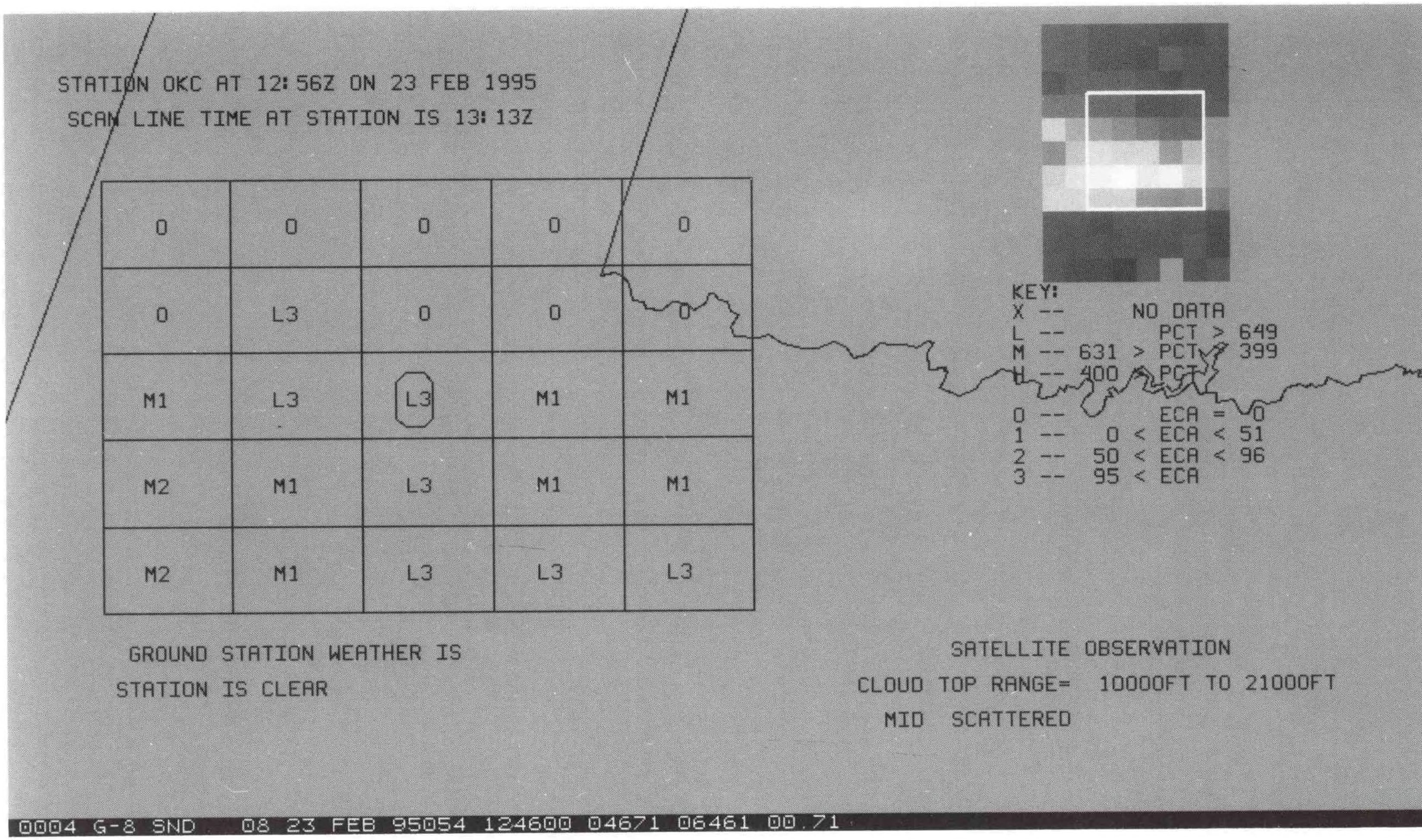


Figure 40. Upper right, a GOES 8 field of view (fov) of infrared radiance observation at 1256 UTC, February 23, 1995. The 25 box array are cloud calculations for the satellite fov. The key to the symbols (L3,M1,M2) appears under the satellite fov box, lower right. Letters define the cloud top pressure 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 41. 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.

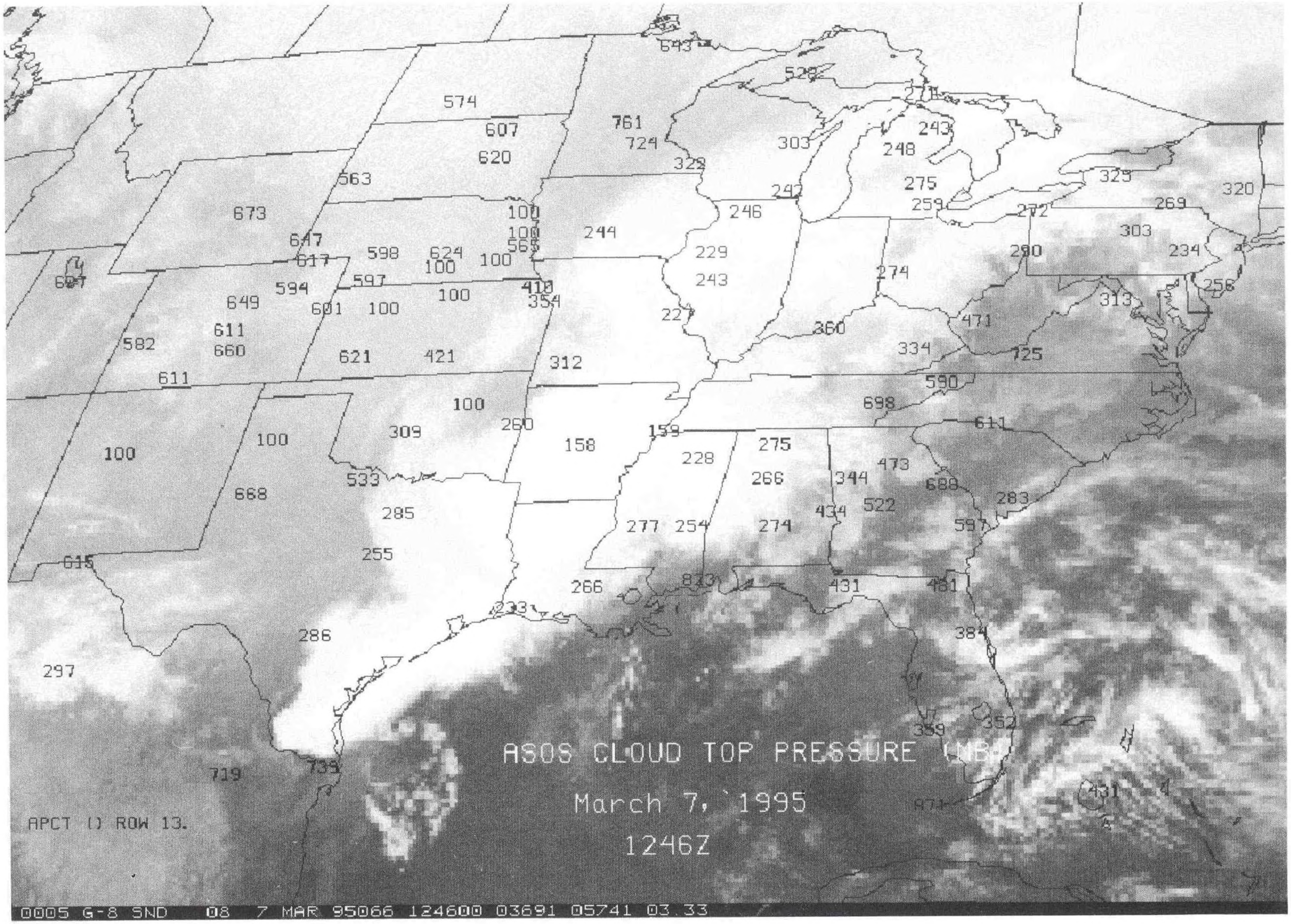


Figure 42. ASOS cloud top height superimposed on a GOES 8 infrared image at 1246 UTC, March 7, 1995.

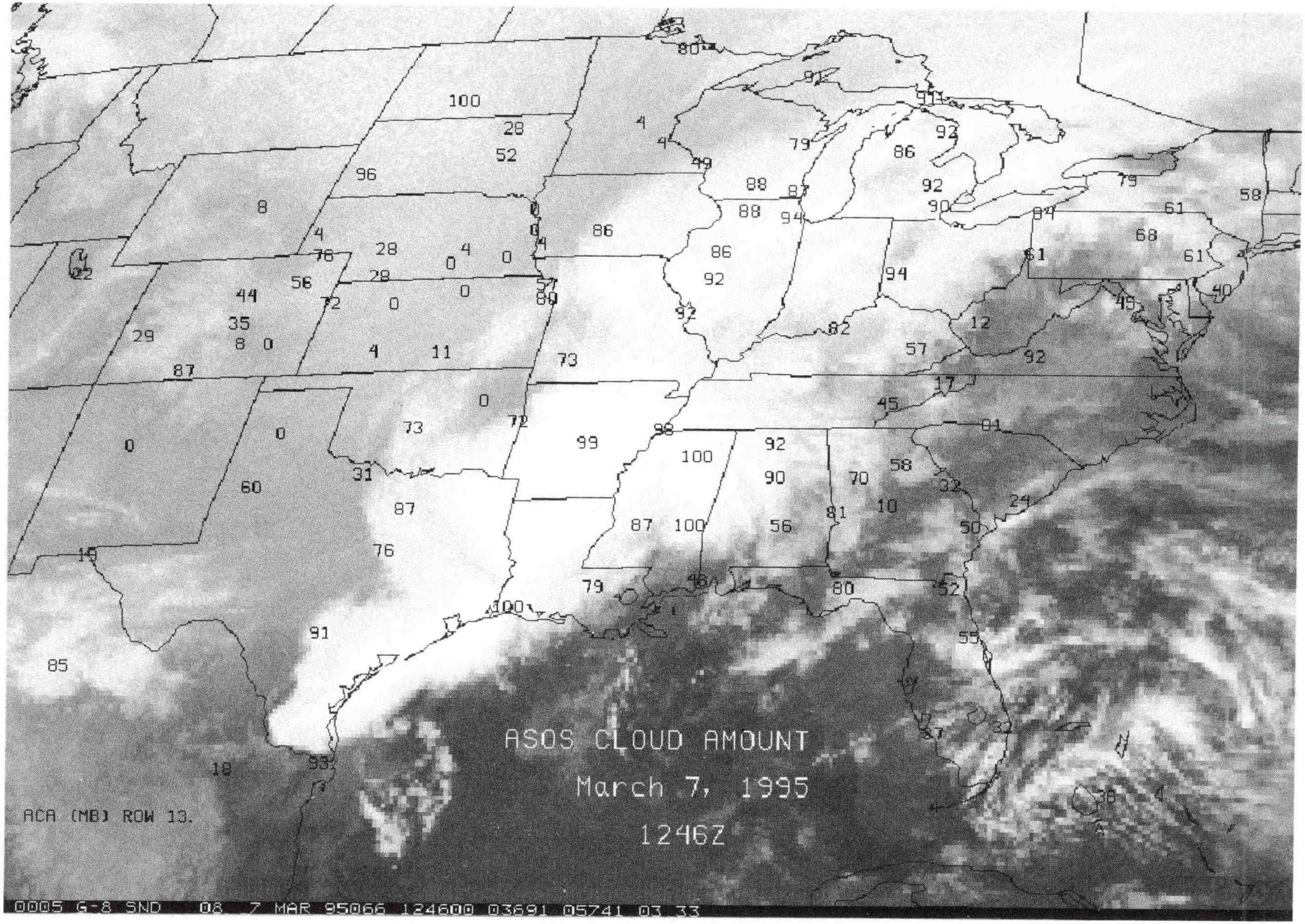


Figure 43. ASOS cloud amount (percent covered) superimposed on a GOES 8 infrared image at 1246 UTC, March 7, 1995.

VIII. DERIVED PRODUCT IMAGERY

a. Lifted Index

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. These quantities are available from the retrieved profile.

The computation of the LI is limited to clear areas over the CONUS and adjacent ocean areas (Figure 44). Since it is produced hourly, sequential maps of LI clearly shows the diurnal and dynamic changes associated with weather events. It is particularly valuable for the short-term forecasting of thunderstorms.

Accuracy. Temperature accuracies at 500 hPa are +/ 1.5K. See Table 5.

Users. At present, the distribution of this product is limited to the National Centers of NCEP. It is also available on two Internet homepages: http://cimss.ssec.wisc.edu and http:// orbit7i.nesdis.noaa.gov:8080/.

Reference.

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

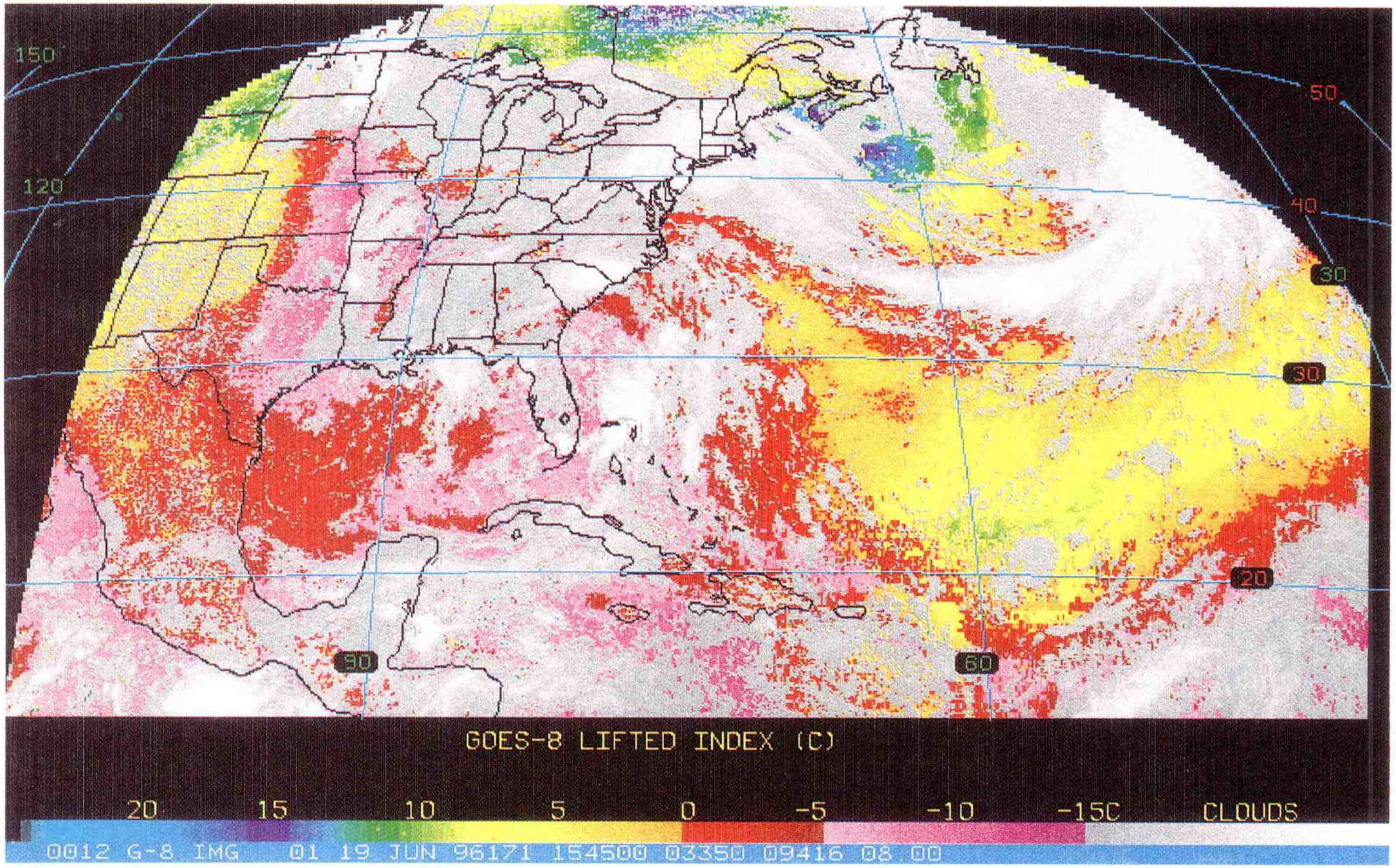


Figure 44. Lifted index image for 1545 UTC, June 19, 1996. The most unstable areas (0 to -10) in this image are found in the mid and eastern portions of Texas to Nebraska. This product is available as a colorized display on the Internet pages listed with the product description.

VIII. DERIVED PRODUCT IMAGERY

b. Total Precipitable Water

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. This quantity is computed from the entire retrieval profile described in Section VII-b. An example of the total precipitable water soundings is shown in Figure 45.

Accuracy. Product accuracy is +/- 10%. See Table 5.

Users. At present, the distribution of this product is limited to the NCEP centers. It is also available on two Internet homepages: http://cimss.ssec.wisc.edu and http://orbit7i.nesdis.noaa.gov:8080/.

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*, January 28-February 2, 1996, Atlanta, GA, Amer. Meteor. Soc., 159-163.

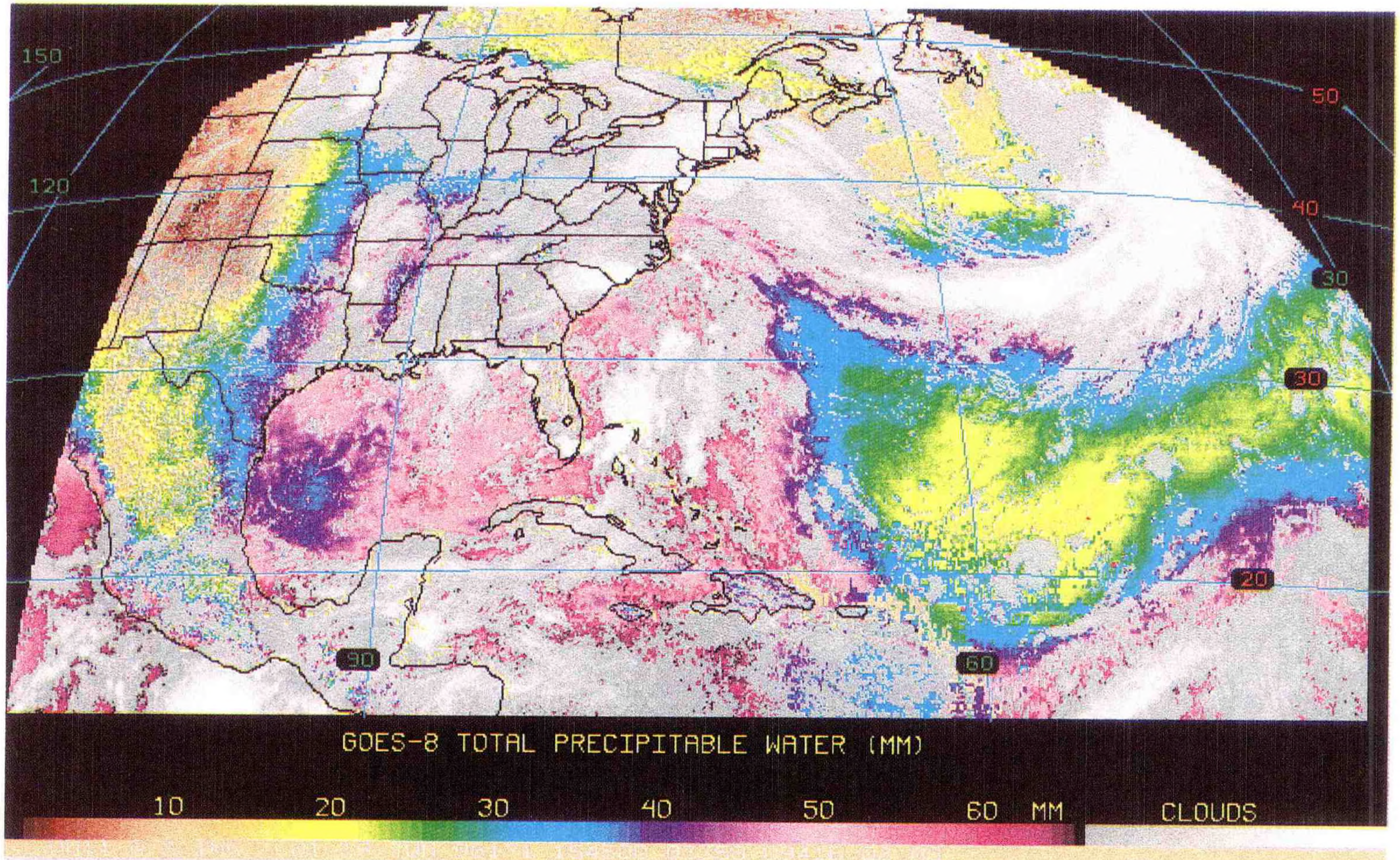


Figure 45. Total Precipitable Water (mm) from GOES 8, June 19, 1996, 1545 UTC. A band of 40 mm (purple tones) extends from the Missouri-Kansas border southward through Brownsville, TX and into the Gulf of Mexico; this marks the moist return flow of air on the backside of high pressure in the Ohio Valley. Much lower values (10-20 mm) of precipitable water are found in the area of the subtropical high near 25°N, 50°W. A colorized version of this product can be found at the Internet address previously listed.

VIII. DERIVED PRODUCT IMAGERY

c. Surface Skin Temperature

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 adjust the influence of this moisture on the observed surface skin temperatures. 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.

Figure 46 shows four mapped images of the surface skin temperatures (2 panels, left top and bottom) taken 8 hours apart. Cloud cover is represented by light gray to white tones. This imagery indicates the presence of a very warm area over the eastern third of the U.S. ahead of a storm system moving out of Texas. Of particular interest is the composite image, upper right. This is produced by saving the warmest pixels from 19 images over a 25 hour period. The red/orange shades over land represent temperatures from 25° to 30°C; the darkest red-gray areas are 30° to 35° C. A cooler area 15° to 25°C can be seen over northern Georgia and Alabama. The patterns seen in the Gulf of Mexico show the temperature structure of the Loop current system. The cool composite (bottom right) shows the nighttime pattern of cooling (blue tones) over land.

Accuracy. Spatial accuracy is 4 km for the imager.

Users. At present, the distribution of this product is limited to the NCEP centers. It is also available on two Internet homepages: http://cimss.ssec.wisc.edu and http://orbit7i.nesdis.noaa.gov:8080/.

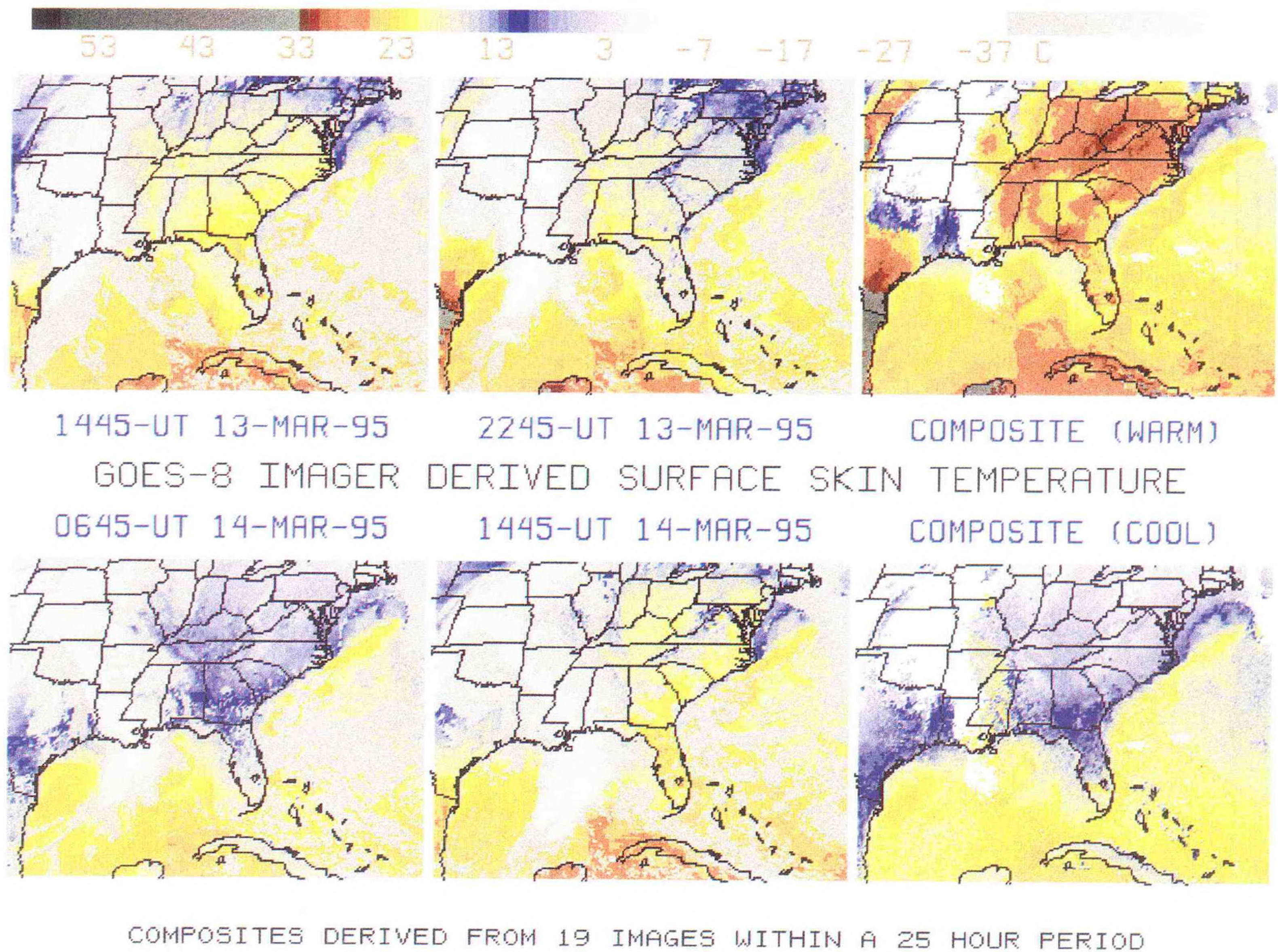


Figure 46. GOES 8 surface skin temperatures. The four images on the left show the diurnal temperature changes in eight hour increments. The two panels on the right are composite images produced from 19 images within a 25 hour period. The coolest areas are shown in the bottom image, the warmest in the upper right-hand image.

IX. IMAGER AND SOUNDER CALIBRATION

Description. Radiometric calibration of the imagers and sounders is a multi-stage process. Before launch, the performance of the instruments is established by measurements made by the manufacturer. Once in space, the instruments are calibrated with data taken as they view space and the onboard warm blackbody. Since the GOES I -M satellites are in three-axis stabilized orbits, and the temperatures of the instruments vary diurnally by tens of degrees Kelvin, the instruments must be calibrated often to preserve the accuracy of the measurements. The greatest variations in onboard temperatures occurs near midnight.

Space is utilized by imager as its zero reference; thus it must view space frequently to avoid excessive drift or 1/f noise. (The sounder clamps on its filter wheel, not space.) The space-looks are programmed into the scan pattern. Blackbody measurements are done by command. The intervals between calibration measurements are shown in Table 7.

TABLE 7. INTERVAL BETWEEN CALIBRATION MEASUREMENTS

	Imager	Sounder
Space	2.2, 9.2, or 36.6 sec	2 minutes
Blackbody	30 minutes	20 minutes

Raw imager and sounder data are transmitted to the CDA station continuously in real-time. Calibration coefficients are applied to the raw data converting the measurements to radiances. The radiances are then converted to ten-bit integers by a linear transformation called scaling. The scaled radiances, the calibration coefficients, and scaling coefficients are transmitted to the satellite and retransmitted to users in real-time. Users can derive the radiances from the counts in the retransmitted data by inverting the scaling operation. The raw data can be retrieved from radiances by inverting the calibration. Details can be found in Weinreb et. al., 1994.

Accuracy. The visible channel of GOES-8 has been producing excellent images of the Earth. The responsivities of the eight silicon-photodiode detectors have been uniform, with minimal east-west striping. Although there is no onboard calibration, aircraft measurements indicate that visible responsivity has decreased 9% (+5%) from its prelaunch value (Weinreb, 1995).

After launch of GOES-8, an east-west variation in the radiances measured in imager Channels 3, 4, and 5 was observed. A region of space near the east edge of the Earth was approximately 0.7mW/(m^2-sr-cm^{-1}) higher in radiance than space near the west edge.

This radiance difference corresponds to 0.4°K for a 300°K scene. This causes east-west gradients in the images and can cause entire images to be biased hot or cold by a degree or more. Software to correct these biases have been developed and are now part of the ground processing system.

During the first 8 months of GOES-8 operations, the responsivity of the sounder's channels showed a slow decrease with time. Channels 9 and 18 (2670 cm^{-1}) were affected the most with decreases of 0.2-0.3% a day. This phenomenon is attributed to the gradual deposition of a hydrocarbon contaminant upon an internal window and occurs only when the window is below 210K. Heating of the window completely reverses the responsivity loss. This has been done weekly since the fall of 1994.

Users. Calibration is used by NESDIS to assure stable and accurate products. Other users include scientists and climate researchers. GOES calibration information can be found at these Internet addresses: http://www.nnic.noaa.gov/SOCC/gvarconv.html and http://www.nnic.noaa.gov/SOCC/SOCC_Home.html.

References.

Weinreb, M.P., 1996: Real-world calibration of GOES-8 and -9 sensors. *Preprints SPIE Intl Symposium on Optical Science, Engineering and Instrumentation*, August 4-9, 1996, Denver, CO, SPIE, (in press).

Weinreb, M.P., 1995: GOES-8 Calibration and Radiometric Performance, internal report.

Weinreb, M.P., W. Bryant, M. Maxwell, and J. Bremer, 1994: Operational in-orbit calibration of GOES-I imager and sounder. *Preprints Seventh Conference on Satellite Meteorology and Oceanography*, June 6-10, 1994, Monterey, CA, Amer. Meteor. Soc., 473-476.

X. GOES CALIBRATION DATA BASE

Description. A data base for use in calibrating the imager channels on the GOES-8/9 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 (00, 03, 06, ...21 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 National Climatic Data Center (NCDC) archives the operational GOES imagery. Selected GOES products described in the previous sections are also available from NCDC. Table 8 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 8. GOES PRODUCTS AVAILABLE FROM THE NCDC ARCHIVES.

Product Name	Area	Product Frequency
Vertical Temperature Profiles (^oK at 40 pressure levels), 50 km resolution at nadir	CONUS and adjacent ocean area	1/hour
Vertical Moisture Profiles (mm H_2O in each of 3 pressure levels), 50 m resolution at nadir	CONUS and adjacent ocean area	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 ^oK) 50 m resolution at nadir	CONUS and adjacent ocean areas	1/hour
Lifted Index (^oK 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 m at nadir	CONUS and adjacent ocean areas	1/hour
Input Archives (includes all inputs needed to regenerate the products listed above)		1/hour
Cloud Drift Winds, low-level 4 m 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 8. 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 (^{o}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, Northern Mexico	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 National Centers for Environmental Prediction. 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.

Space Environment Monitor (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

The Solar X-Ray Sensor (XRS)

The X-Ray Sensor (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.

The Energetic Particle Sensor (EPS)

The Energetic Particle Sensor (EPS) is comprised of three detector assemblies: the EPS Telescope, the EPS Dome Detector Assembly, and the High Energy Proton and Alpha Detector (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 rigoriously 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.

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 9. 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

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 > 1x10E3 at energies >2 MeV

Magnetometer - Magnetopause Crossing Alert for geosynchronous spacecraft is under development

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 47)

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.

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		B. HIGH LATITUDES	
ACTIVE	10/10/10	ACTIVE	15/15/15
MINOR STORM	01/01/01	MINOR STORM	05/05/05
MAJOR-SEVERE STORM	01/01/01	MAJOR-SEVERE STORM	01/01/01

Figure 47. Report and Forecast of Solar Geophysical Activity.

Report and Forecast of Solar and Geophysical Activity-cont.

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:

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 AP-indices (planetary A-indices). Ap indices are estimated in near-real time using a network of up to 12 North American stations.

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

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

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

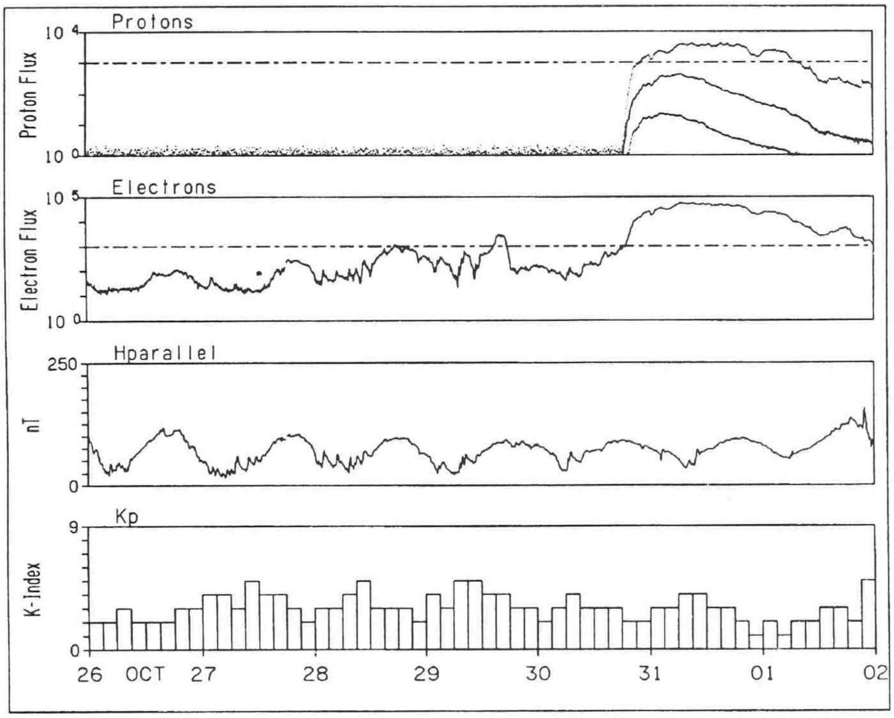
Part VI Probability forecast of geomagnetic conditions at middle and high latitudes-the probability of at least one 3-hour K index, at the indicated level, for each of the next 3 days.

Active:	K = 4.
Minor storm:	K = 5.
Major or Severe storm:	K > 6.

Figure 47 (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 48 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 48. 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:

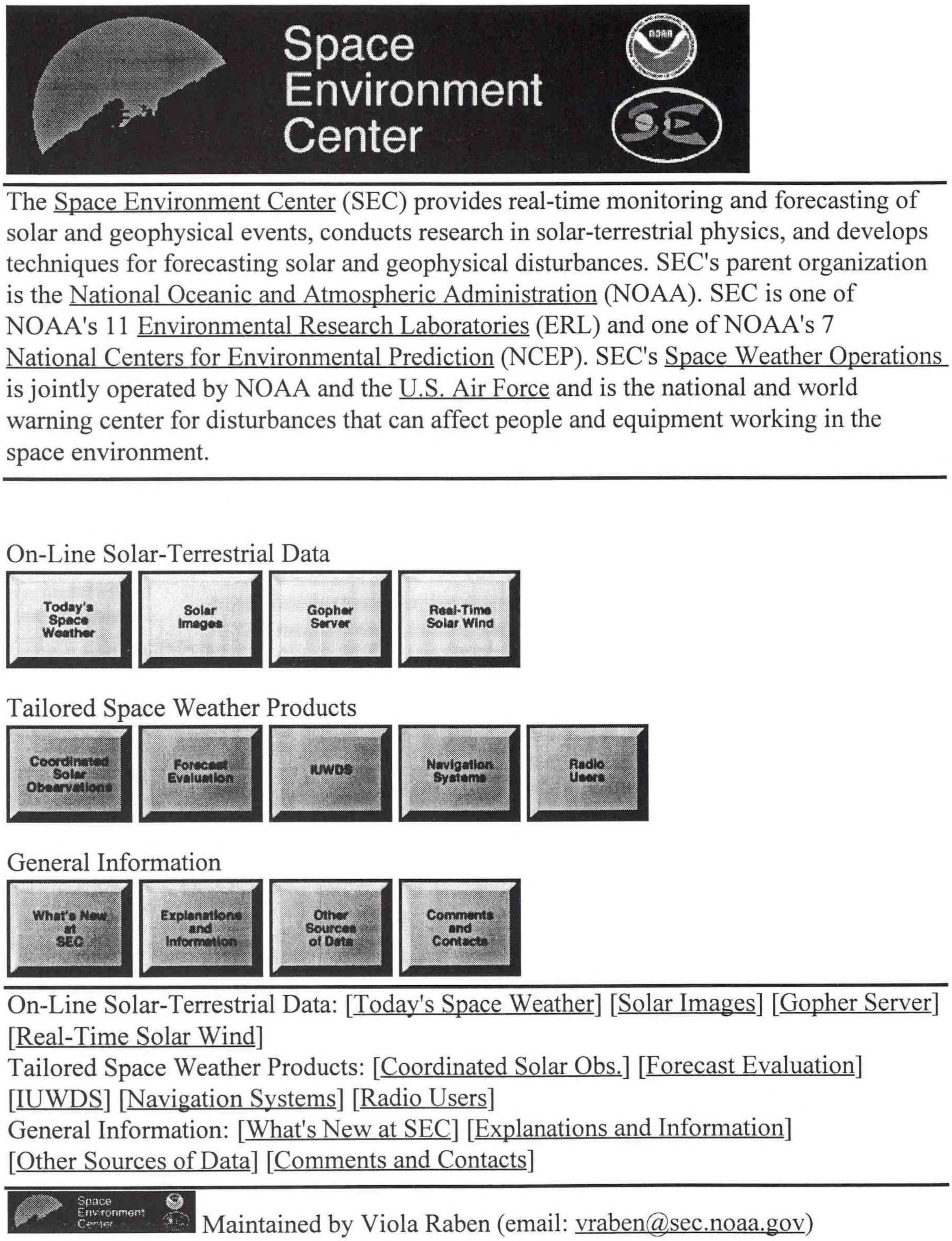
World Wide Web (http://www.sec.noaa.gov)
GOPHER (gopher://gopher.sec.noaa.gov)
ANONYMOUS FTP (ftp.sec.noaa.gov)
Public Bulletin Board System (303-497-5000)
Satellite Broadcast
Air Weather Service Teletype Systems (AWN and COMEDS)

Figure 49 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

The Space Environment Center (SEC) provides real-time monitoring and forecasting of solar and geophysical events, conducts research in solar-terrestrial physics, and develops techniques for forecasting solar and geophysical disturbances. SEC's parent organization is the National Oceanic and Atmospheric Administration (NOAA). SEC is one of NOAA's 11 Environmental Research Laboratories (ERL) and one of NOAA's 7 National Centers for Environmental Prediction (NCEP). SEC's Space Weather Operations is jointly operated by NOAA and the U.S. Air Force and is the national and world warning center for disturbances that can affect people and equipment working in the space environment.

On-Line Solar-Terrestrial Data

Today's Space Weather | Solar Images | Gopher Server | Real-Time Solar Wind

Tailored Space Weather Products

Coordinated Solar Observations | Forecast Evaluation | IUWDS | Navigation Systems | Radio Users

General Information

What's New at SEC | Explanations and Information | Other Sources of Data | Comments and Contacts

On-Line Solar-Terrestrial Data: [Today's Space Weather] [Solar Images] [Gopher Server] [Real-Time Solar Wind]
Tailored Space Weather Products: [Coordinated Solar Obs.] [Forecast Evaluation] [IUWDS] [Navigation Systems] [Radio Users]
General Information: [What's New at SEC] [Explanations and Information] [Other Sources of Data] [Comments and Contacts]

Space Environment Center Maintained by Viola Raben (email: vraben@sec.noaa.gov)

Figure 49. Sample Home Page from the Space Environment Center.

XIII. DATA COLLECTION SYSTEM

Description. The GOES Data Collection System (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 50. 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.

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
Washington, DC 20233
E-mail: mperkins@nesdis.noaa.gov

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.

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.

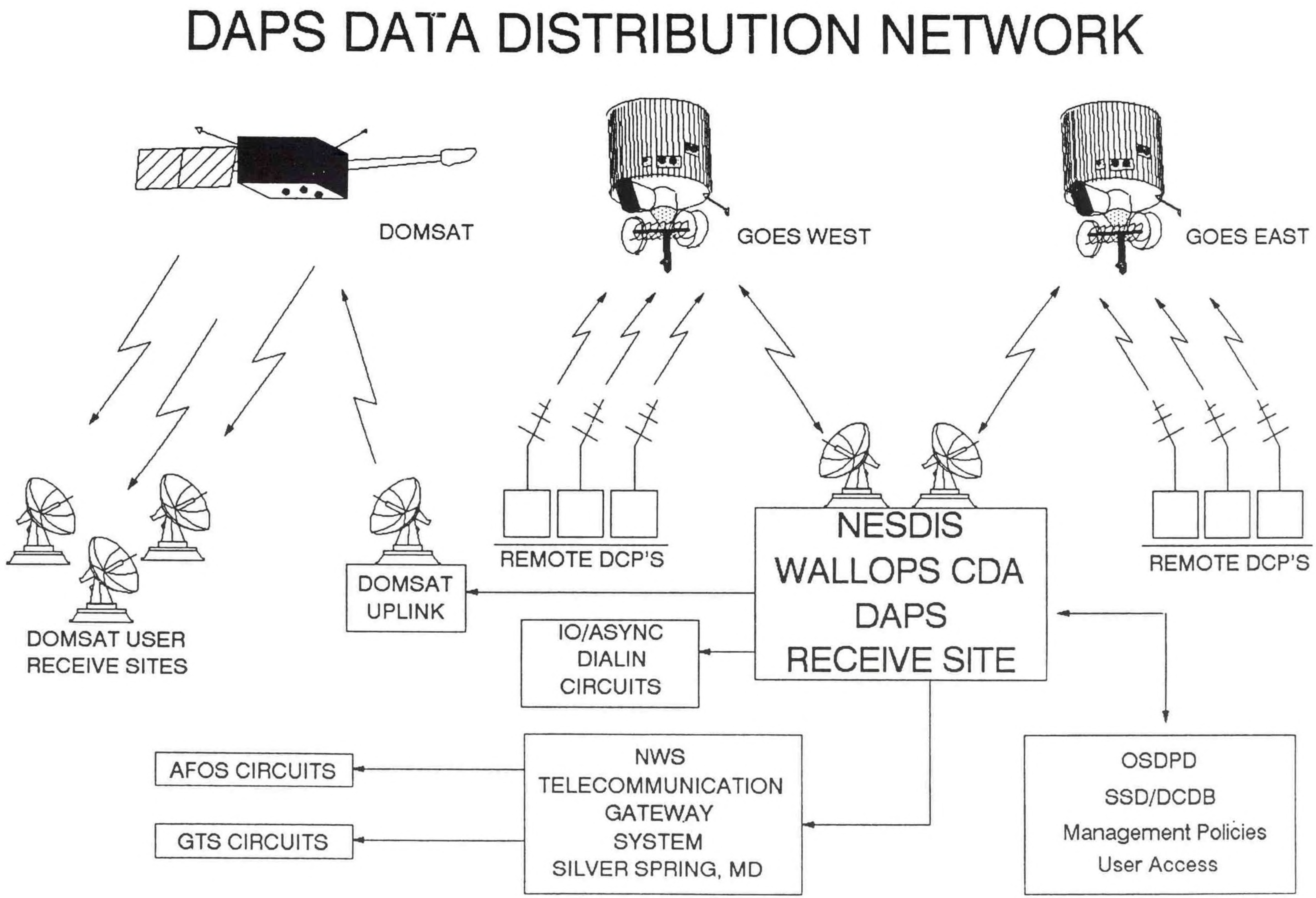


Figure 50. GOES Data Collection System.

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 51, 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 data base. 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 52) 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
Washington, D.C. 20233
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** (9), p. 75.

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

Figure 51. COSPAS-SARSAT program insignia.

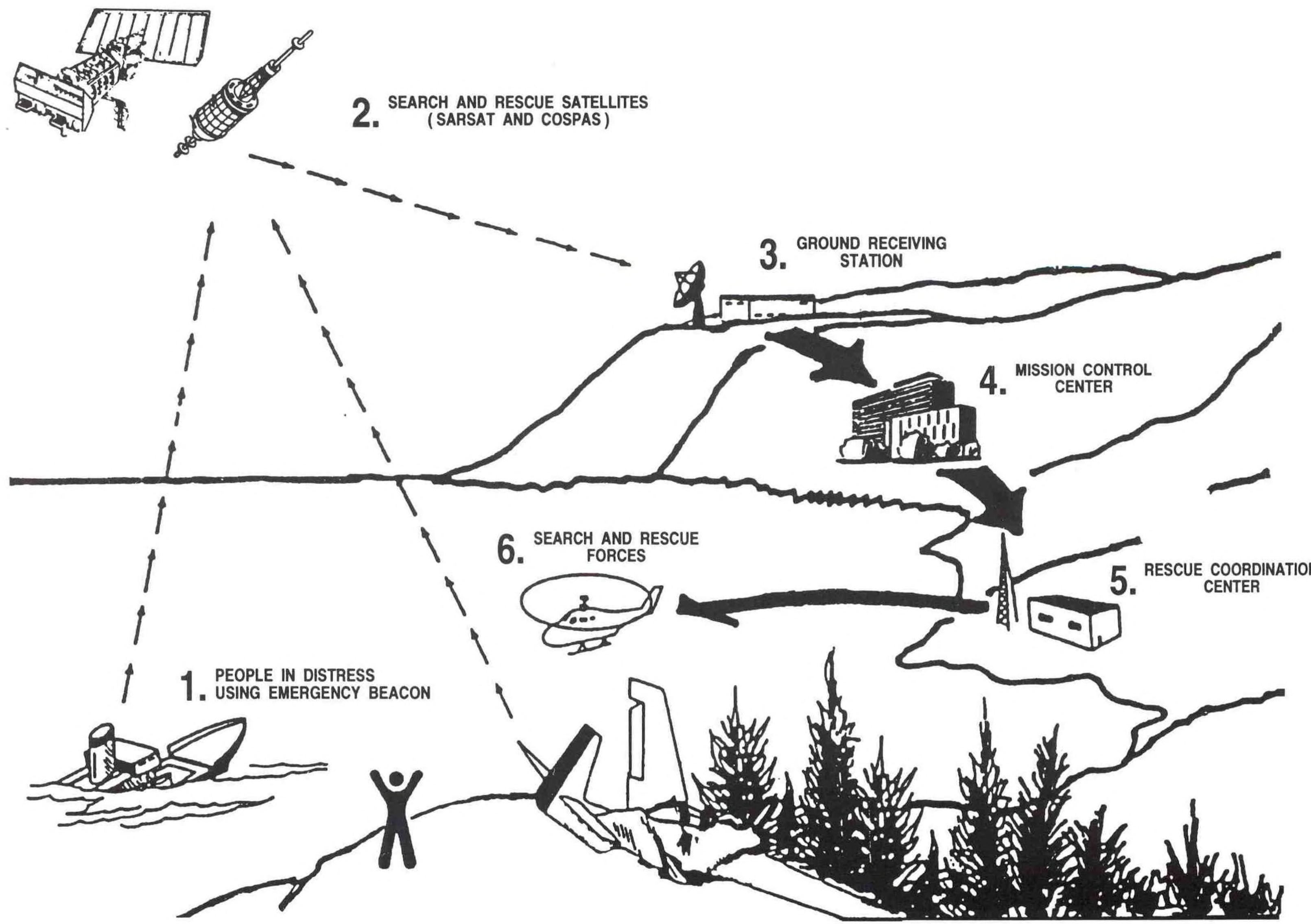


Figure 52. Schematic of the Cospas-Sarsat search and rescue monitoring and location system.

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ACRONYM LIST

AFOS	Automation of Field Operations and Service
ARL	Air Resources Lab
ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
CAC	Climate Analysis Center
CDA	Command and Data Acquisition
CEMSCS	Central EnvironMental Satellite Computer System
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CO_2	Carbon Dioxide
CONUS	continental United States
CPHC	Central Pacific Hurricane Center
DCPs	Data Collection Platforms
DCS	Data Collection System
DMSP	Defense Meteorological Satellite Program
DRGS	Direct Readout Ground Stations
ECMWF	European Center for Medium-range Weather Forecasting
EPE	Energetic Proton Events
EPS	Energetic Particles Sensor
fov	fields of view
FXTS	Facsimile Transmission System
GINI	GOES Ingest and NOAAPORT Interface

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
IFFA	Interactive Flash Flood Analyzer
IPB	Interactive Processing Branch
IUWDS	International URSIgram and World Days Service
LI	Lifted Index
McIDAS	Man-computer Interactive Data Access System
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
NH	Northern Hemisphere
NOAA	National Oceanic and Atmospheric Administration

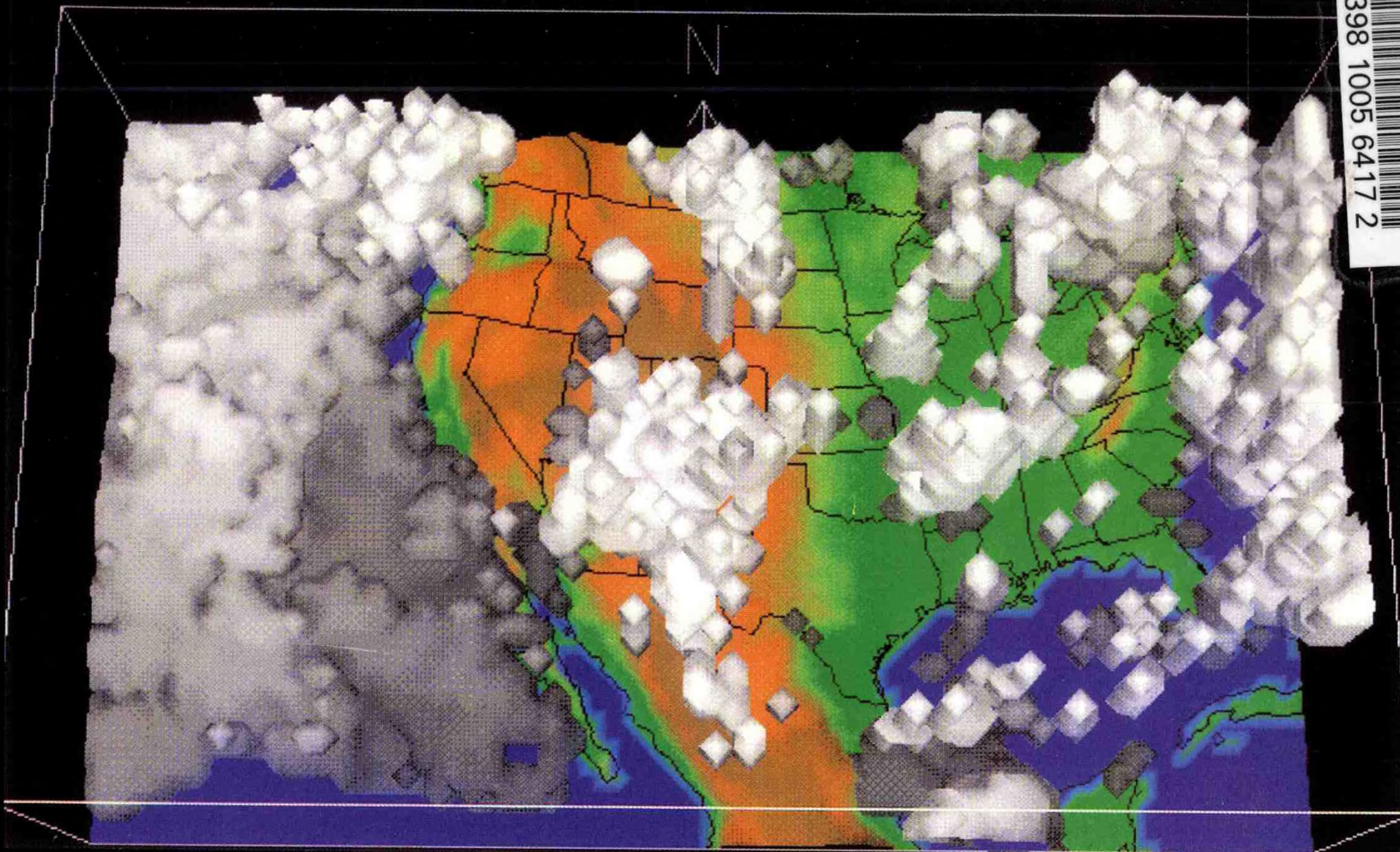
NWS	National Weather Service
OSDPD	Office of Satellite Data Processing and Distribution
PCA	polar cap absorption
PG&D	Product Generation and Distribution
POES	Polar-orbiting Operational Environmental Satellite
RAMM	Regional and Mesoscale Meteorology Branch
RAMSDIS	Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite Demonstration and Information System
rmse	root mean square error
SAB	Synoptic Analysis Branch
SARSAT	Search And Rescue Satellite-Aided Tracking
SCP	Satellite Cloud Product
SEC	Space Environment Center
SEM	Space Environment Monitor
SFDFS	Satellite Field Distribution Facilities
SOCC	Satellite Operations and Control Center
SSEC	Space Science and Engineering Center
SSM/I	Special Sensor Microwave Imager
SWO	Space Weather Operations
TPC	Tropical Prediction Center
UTC	Universal Time Clock
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
XRS	X-Ray Sensor

Back Cover

Top: A 3-d rendering of the initial cloud water field for the CIMSS Regional Assimilation System (CRAS) forecast valid at 1200 UTC, June 13, 1996. The field is derived using a multispectral retrieval of cloud-top pressure from the GOES-8/9 sounders. Here cloud temperature is mapped onto the cloud water iso-surfaces; gray represents warm and white representing cold. Cloud initialization is only applied where the measured effective emissivity if greater than 50% and the cloud-top pressure is less than 850 hPa. The sounder was able to detect the large marine stratus deck off the west coast and numerous areas of active convection throughout the model domain.

Bottom: Combined GOES 8/9 infrared image (11 micron) valid at 1200 UTC June 13, 1996 is shown for comparison.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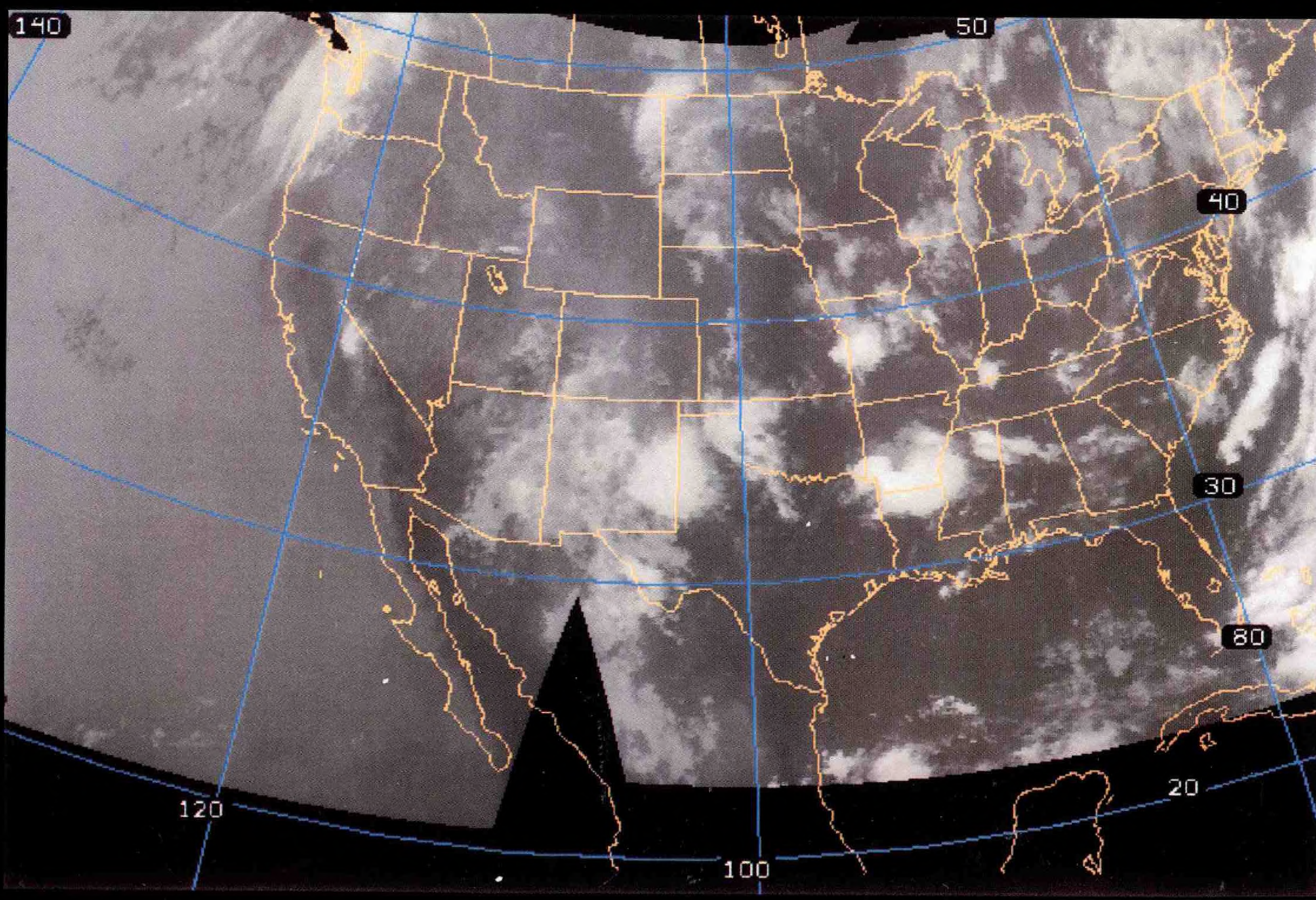
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