POTENTIAL APPLICATIONS OF DIGITAL, VISIBLE, AND INFRARED DATA FROM GEOSTATIONARY ENVIRONMENTAL SATELLITES

D.B. Miller, M.P. Waters, III, J.D. Tarpley
R.N. Green, and D.C. Dismachek

U.S. Department of Commerce, NOAA
National Environmental Satellite Service
Washington, D.C. 20233

ABSTRACT

The National Environmental Satellite Service (NESS) is experimenting with an hourly, digital data base from the Visible/Infrared Spin-Scan Radiometer (VISSR) instrument on the GOES-1 and SMS-2 geostationary satellites. The general characteristics of this experimental VISSR data base (VDB) are described. Several examples of developmental applications of these quantitative digital data are presented. These include a review of recent attempts to develop products that are of use to meteorologists who provide services to aviation, agriculture, forestry, hydrology, oceanography, and climatology. The sample products include high resolution thermal gradients of land and ocean surfaces, thermal change analyses, fruit frost/freeze application, cloud-top altitude analysis, analysis of hurricane characteristics, and analyses of solar insolation. The poster session audience is invited to comment on the utility of these developmental products and to suggest applications that may be useful to the meteorological community services.

1. INTRODUCTION

The two geostationary satellites currently operated by NESS view the earth's disk through the VISSR instruments. Complete technical details of this dual geostationary satellite system are contained in the technical memorandum edited by Bristor (1975). This paper describes the general characteristics of the experimental VDB and presents examples of experimental applications of these quantitative digital data.

2. THE EXPERIMENTAL VISSR DATA BASE

The digital data from the VISSR instruments on the Western and Eastern satellites (currently GOES-1 located at 75W longitude and SMS-2 located at 135W longitude over the equator) are processed into an experimental VDB. These digital data may be obtained from each satellite at 30-minute intervals. The Western satellite's data are normally acquired at 15 minutes and 45 minutes after the hour. The Eastern satellite's data are acquired on the hour and half hour. The data from the full earth disk view are currently reduced to areas extending from 50N latitude to 38S latitude* and approximately 50 degrees longitude east and west of the satellite's subpoints. Thus, the VDB contains half-hourly digital data from the Western satellite representative of the area from 50N to 38S latitudes and 85W longitude to 175E longitude. Data from the Eastern satellite cover the area bounded by the same latitude range and from 25W to 125W longitudes.

The VISSR instrument provides concurrent observations in the infrared (IR) spectrum (10.5 to 12.6 μm) and in the visible (VIS) spectrum (0.55 to 0.75 μm). The IR and VIS digital data in the VDB are at a 7x7-km spatial resolution.

*This southern limit will be expanded to 50S when more computer storage is available in mid 1977.

The IR data are expressed as 8-bit count values that can be converted to equivalent blackbody temperatures. The VIS data are expressed as 6-bit count values that can be related to albedo values. The IR and VIS values are calibrated in terms of sensor output. Additionally, information is appended to the data tha allows the values to be located with respect to the earth's surface.

The VDB is processed from data ingested in near real time and physically resides on four IBM 3330 disk packs that comprise a portion of the NOAA IBM S360/195 computer facility at Suitland, Maryland. The data are maintained for 24 hours in the experimental system. The characteristics of the experimental VDB are presented in Table 1.

3. POTENTIAL APPLICATIONS

The ability to retrieve quantitative digital data at half-hourly intervals opens a new world of potential applications. The absolute and relative changes in thermal and visible radiation patterns are available for quantification as to magnitudes of change, rates of change, departures from a specified or variable time average, time series analyses, etc. Derived quantities such as cloud cover and cloud-top altitude are open to analysis of their changes with time. Changes in surface thermal field can be analyzed on time and space scales that heretofore have been available only from a limited mesoscale network of conventional surface-based instruments.

4. TIME COMPOSITING

The arrangement of the data lends itself to the application of so-called "time compositing" techniques. This method takes advantage of the ability of the large-scale computers to store and fetch quantities very rapidly and efficiently. The method entails saving the warmest (darkest) or coldest (brightest) of the IR (VIS) values. A "save the warmest" composite over the ocean over an extended time period allows cold clouds to move through the scene and not affect the surface (warmest) values that are retained from each scene. The "warm" composite field contains only the warmest values viewed in the time sequence. Any "cold" areas remaining after a several-hour or several-day compositing period can be interpreted as areas of persistent cloudiness. A "save the coldest" composite results in a field that represents both the movement and vertical development of clouds. In clear areas, a "cold" composite can be used to show the movement of a cold air mass (for freeze-line analysis) and to show the areas of minimum radiative temperature.

5. EXAMPLES OF POTENTIAL APPLICATIONS

The Computer Techniques Branch (CTB) of the Sensor Processing and Applications Division of the NESS has been working with the Satellite Field Service Stations (SFSS's) (Washington, D.C., Kansas City, and Miami) and the Analysis and Evaluation Branch (A&EB) of NESS to determine the usefulness of the VISSR digital data from the VDB, as well as product needs that might be developed from it. The CTB has developed several digital products from the VISSR digital data accessed from the VDB and has made such products available to interested users at the SFSS's. The products are provided on a nonoperational basis for experimental evaluation and assessment. Examples of these products are displayed at the poster session and are explained below.

5.1. SEA SURFACE THERMAL GRADIENT ANALYSIS

Since the digital data are geographically registered in the VDB, data can be retrieved, processed, and displayed in near real time to any site operating with the NOAA 360/195 computer using computer printer alphanumerics. By specifying the picture time, latitude, longitude, and the dimension to be displayed, one could receive an alphanumeric array of both VIS and IR data. When a threshold of brightness in the VIS is assumed (or mapped) for land and cloud coverage, then the IR data can be screened pixel for pixel. This is possible since both the VIS and IR data are collocated in the VDB. Figure 1 is an example of this type of digital display.

5.2. SEA SURFACE THERMAL GRADIENT FROM TIME COMPOSITES

When the technique described above is applied over time and the warmest temperature saved, more extensive coverage is possible. This time compositing allows for cloud-edge, as well as partially clouded IR data, to be eliminated from the composite.

An experimental digital display of the Gulf of Mexico and the Coastal Zone of the Eastern United States is currently produced daily and sent to the Miami SFSS for use and evaluation. This composite uses four pairs of VIS and IR digital pictures with each picture pair separated by two hours. The sea surface thermal gradient alphanumeric display is sent via the National Hurricane Center (NHC) computer terminal. The experimental display is printed on eight pages of computer paper and represents coverage with about 8-km resolution. The product is used to position the Gulf of Mexico Loop Current and the Gulf Stream Wall. Figure 2 is an example of this composite and display technique.

5.3. ANALYSIS OF HURRICANE VISIBLE AND THERMAL CHARACTERISTICS

The use of digital VIS and IR data is also useful for making near real time hurricane rain- and flood-potential estimates. Currently, VIS and IR negatives or positive transparencies are analyzed at the National Hurricane and Experimental Meteorology Laboratory (NHEML) in Miami, Florida. Image data sent to the Miami SFSS are analyzed on a scanning, false-color, microdensitometer. The storm canopy areas are measured at three specified brightness thresholds of the sun-sensor-target normalized visible data (Griffith, et al., 1976) or three temperature thresholds for the IR data (Grube, et al., 1976). By accessing the VDB in near real time, image data and the microdensitometer processing are eliminated. To date, an experimental product has been provided NHEML, which "slices" the thermal IR digital data into three specified temperature regions, counts the pixels, and displays the IR on a computer printer using alphanumerics. Personnel at NHEML select the picture (VIS and/or IR) times (one up to eight, any combination) and the center latitude/longitude of interest for each picture time. Software is submitted via NHC's computer terminal. The digital data are selected from the VDB (1,000x1,000-km area each picture time) as NHEML directs, processed, and returned to NHC Miami.

Last year, several examples of this product were sent via computer to NHEML. For this hurricane season, NHEML will select pictures from the VDB on an experimental basis using software developed specifically for this purpose by the CTB at NESS. Figure 3 is an example of this product.

5.4. CLOUD-TOP HEIGHT ANALYSIS

When the height/temperature relationship is known at a location, the height value can be assigned to thermal IR digital data. The CTB has developed a cloud height display technique that utilizes RAOB data located in NMC's observation file, the VDB, and computer printer alphanumerics to produce the cloud height display.

Thermal IR data are retrieved from the VDB for a given latitude/longitude and array size (i.e., area). The latest radiosonde observation closest to the center latitude/longitude of the digital IR is extracted from NMC observation file. A height/temperature relationship is then obtained from the radiosonde pressure-height/temperature profile data. Using computer printer alphanumerics, height values are assigned each pixel of the IR data based on the height/temperature profile information. Successive "pictures" of the IR height display allow for differences in the scene to be analyzed and displayed temporally, spatially, and in vertical extent. This product is one of the initial digital satellite products being developed by NESS/CTB for the AFOS system of NWS. Figure 4 shows an example of this type of display.

5.5. SCENE CHANGE ANALYSIS BY TIME SERIES

Digital IR, when taken from the same location over time, can be analyzed for scene change characteristics. When cloud-only IR is analyzed in this fashion, then movement and growth (both vertical and horizontal) can be displayed.

The CTB has only recently begun to develop scene change display techniques. Two products under development are cloud-top height change and surface thermal IR scene change. Image data have suggested that surface heating patterns of clear areas may be key zones from which convective activity develops later in the day. Digital scene analysis can map, not only the areas of influence but also, the relative changes of visible and thermal characteristics of the area.

5.6. SURFACE THERMAL FIELDS RELATED TO THE FROST LINE

Changes in the thermal IR over land with time have also been used to monitor freeze events in fruit crop growing regions. This past winter enhanced IR pictures were sent to the Ruskin, Florida, WSO through the Miami SFSS. The image data, specially enhanced, showed the ground location of the freeze line and the temperature distribution on either side of the line. These data, along with other ground data, have been used to provide a frost warning service to farmers and fruit growers in Florida. The digital thermal IR data from the VDB were also provided researchers of the joint NASA/NWS/NESS University of Florida study. Since the Ruskin WSO is not serviced by the NOAA 360/195 computer, which contains the VDB, data were mailed to cooperators for evaluation and assessment.

The digital thermal IR from the VDB was found to be much superior than the enhanced IR images. Plans are now underway to provide the Ruskin WSO with a dial-up computer terminal to access the VDB directly, via RJE (remote job entry) using software and display algorithms developed by the CTB. This will allow near real-time access to digital thermal IR on freeze event nights.

5.7. SOLAR INSOLATION ESTIMATES

An experiment is planned for the summer of 1977 to investigate methods for determining surface insolation from satellite and ground-based meteorological data. This experiment will collect coincident satellite, meteorological, and pyranometer measurements over the portion of the Great Plains bounded by the 29N and 49N parallels of latitude and the 95W and 105W meridians.

The data collection procedure is illustrated in Figure 5. The Great Plains will be divided into targets 0.5 degrees latitude and longitude on a side (about 50-km square) and data collected for each target. A minimum of six to eight observations distributed over daylight hours will be made each day. The data will be collected for 60 days, although the days will not necessarily be consecutive.

Shortwave solar radiation incident on the earth is either reflected to space, absorbed in the atmosphere, or absorbed by the earth's surface. Surface insolation, the quantitiy of interest, is a function of incident solar radiation, and the amounts of energy reflected to space and absorbed by the atmosphere.

The fraction of incoming radiation that is reflected to space is primarily controlled by cloud amount and cloud thickness, both of which can be estimated from satellite data. Cloud amount will be computed by the two-threshold method (Shenk and Salomonson, 1972) in which the number of pixels in clear, partly cloudy, and cloudy classes are weighted to yield percentage cloud cover. The clear threshold is obtained by regression against functions of local solar zenith angle and the azimuth angle between satellite and sun. The mean brightness of the clouds is determined by averaging the count value of all pixels brighter than the cloudy threshold. Mean target brightness will also be computed for another measure of reflected radiation.

The amount of incoming radiation that is absorbed in the atmosphere is controlled by cloud cover, atmospheric moisture, dust, and the atmospheric mass traversed by the beam. Precipitable water and surface pressure are available from NMC and together with the cloud characteristics should provide enough information to account for radiation absorbed by the atmosphere. The precipitable water and surface pressure will be accessed from NMC fields whose resolution is lower than the one-half degree grid used for the Great Plains.

REFERENCES

Bristor, C.L., Ed., "Central Processing and Analysis of Geostationary Satellite Data," NOAA Technical Memorandum NESS 64, U.S. Department of Commerce, NESS, Washington, D.C., March 1975.

Griffith, C.G., W.L. Woodley, S. Browner, J. Teijeiro, M. Maier, D.W. Martin, J. Stout, and D.N. Sikdar, "Rainfall Estimation from Geosynchronous Satellite Imagery During Daylight Hours," NOAA Technical Report ERL 356, WMPO 7, 1976, 106 pp.

Grube, P.G., W.L. Woodley, and C.G. Griffith, "Rainfall Estimation from Geo-Synchronous Infrared Satellite Imagery" (in progress).

Shenk, W.E. and V.V. Salomonson, "A Simulation Study Exploring the Effects of Sensor Spatial Resolution on Estimates of Cloud Cover from Satellites," Journal Appl. Met., II, 1972, 214.

TABLE I. THE EXPERIMENTAL VISSR DATA BASE (VDB)

SATELLITE	SUBPOINT	ACQUISITION TIMES	ACQUISITION INTERVALS	DATA COVERAGE	DATA RESIDENCE TIME
East (GOES-1)	75W	On the hour and half hour	30 min	50N-38S; 25W-125W	24 hrs
West (SMS-2)	135W	15 minutes and 45 minutes after the hour	30 min	50N-38S; 85W-175E	24 hrs

Sensor Data Characteristics:

DATA TYPE	SPECTRAL INTERVAL	UNITS	CONVERTIBLE TO	NOMINAL SUBPOINT SPATIAL RESOLUTION
IR	10.5-12.6 μm	8-bit count values	Equivalent blackbody radiative temperatures	7x7 km
VIS	0.55-0.75 μm	6-bit count values	Albedo	7x7 km

Other Characteristics:

- Earth location and calibration information are appended.
- Resides on four IBM 3330 disk packs in the NOAA IBM S360/195 computer system.
- Currently, some 55 of the possible 144 pictures are processed.
- Data volume is approximately 7×10^8 bits per 24 hours.
- The processing system, format, and data coverages are experimental and, thus, subject to interruption at any time by operational priorities and requirements.

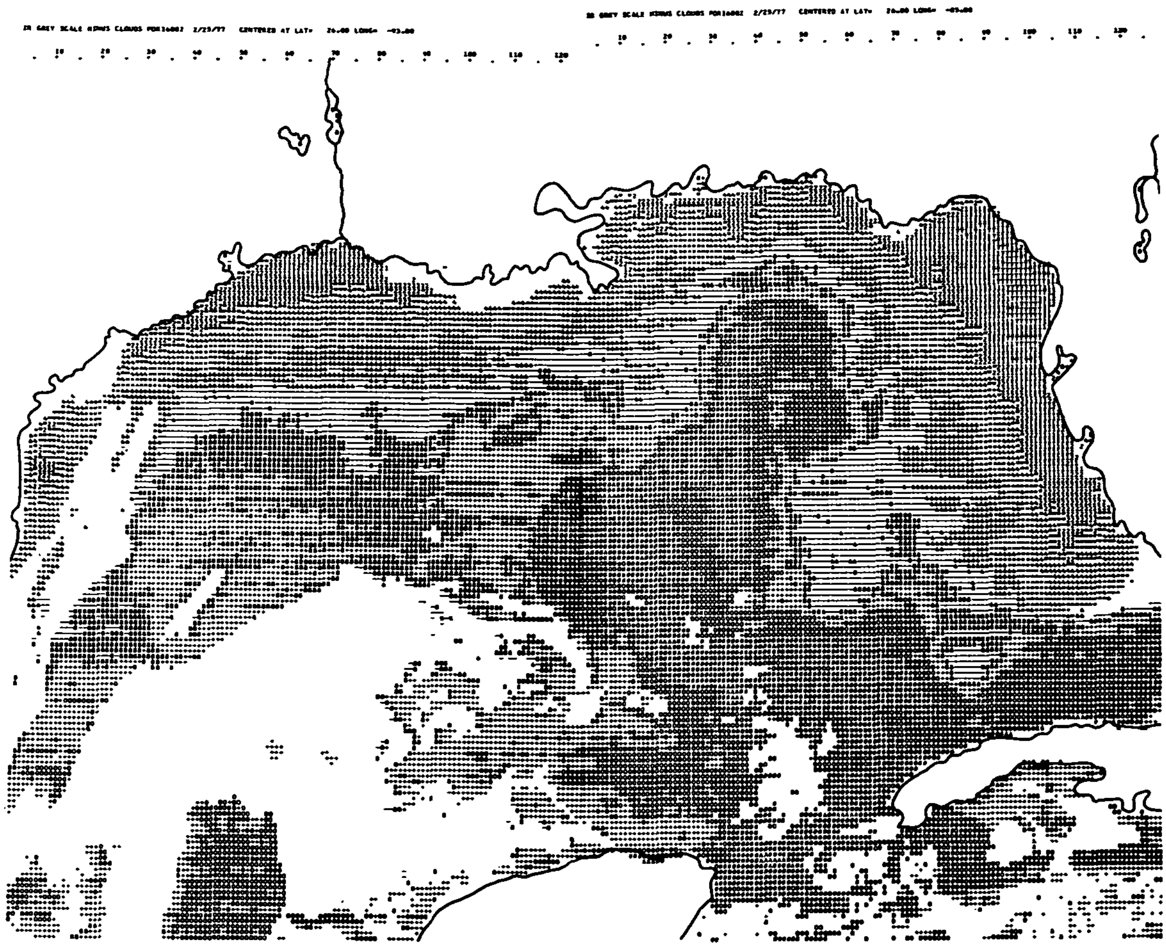


FIGURE 1.--SEA SURFACE DIGITAL GRADIENT DISPLAY OF THE GULF OF MEXICO LOOP CURRENT. Thermal IR digital data were taken from the GOES-1 satellite at 1600 GMT of February 25, 1977. Area displayed is the Gulf of Mexico with States bordering the Gulf, a portion of Western Cuba, and the Northern Yucatan Peninsula outlined by solid black lines. White areas in the display are either land, shallow water areas, or cloud-covered regions at picture time.

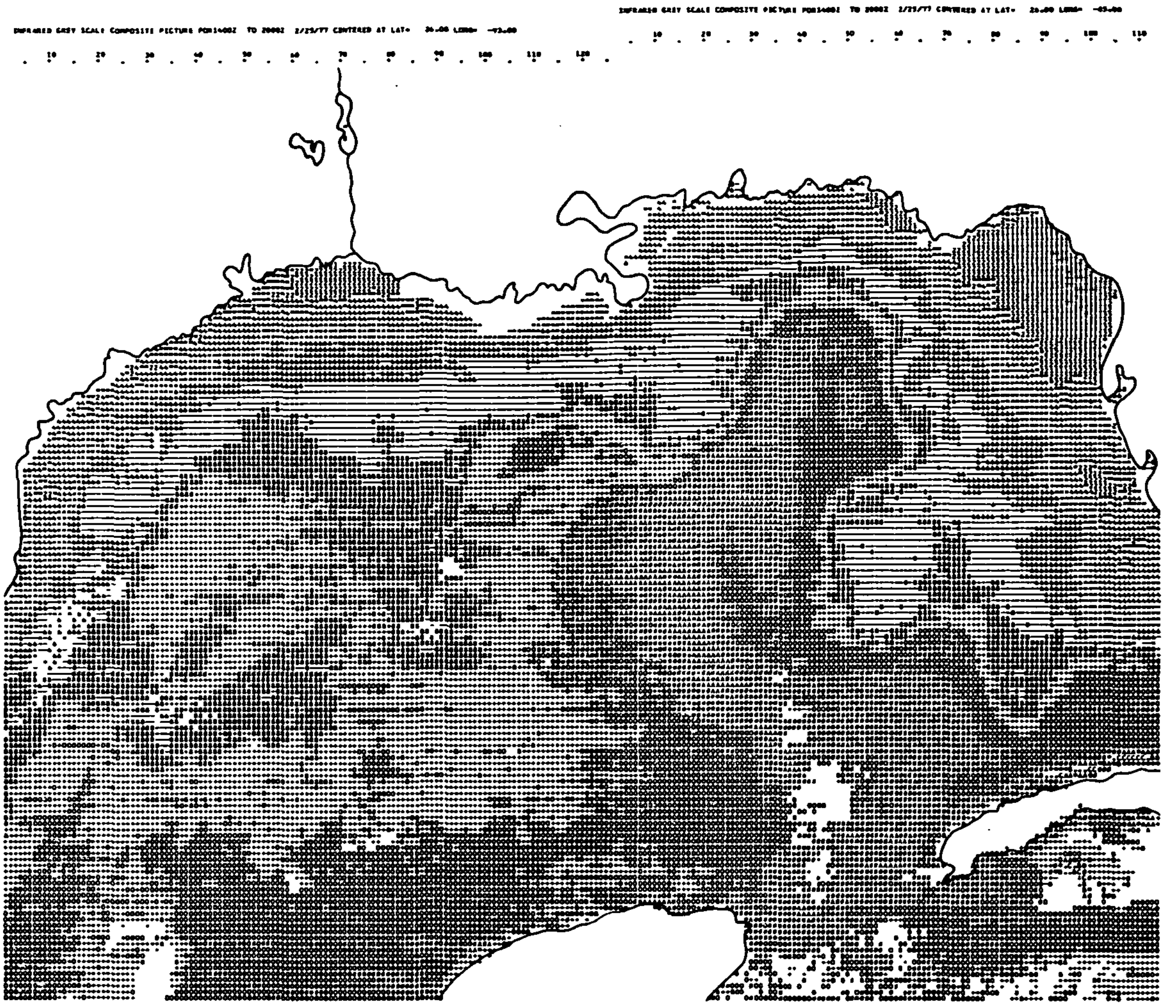
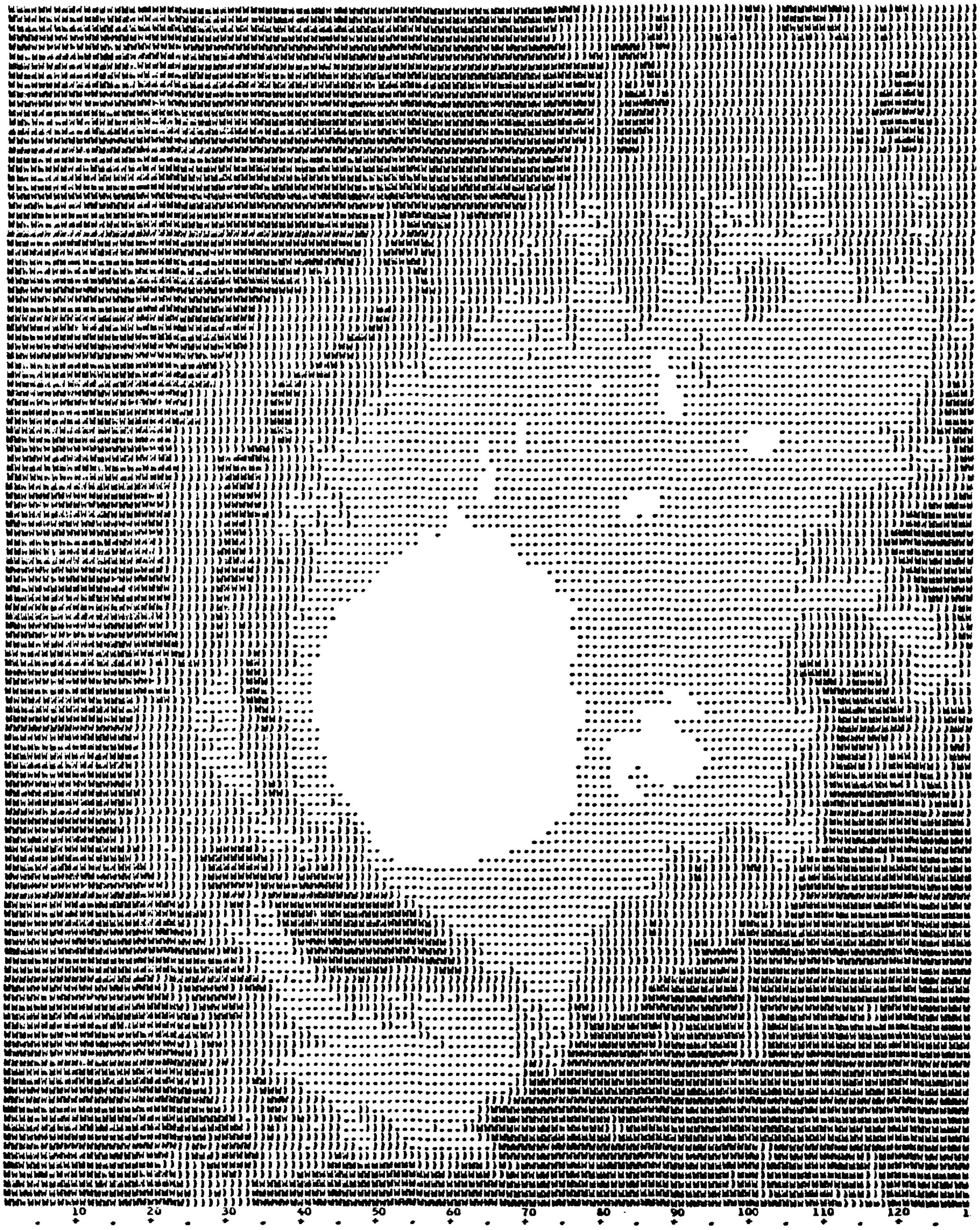


FIGURE 2.--SEA SURFACE DIGITAL GRADIENT DISPLAY OF THE GULF OF MEXICO LOOP CURRENT USING TIME COMPOSITING TECHNIQUES. Thermal IR digital data were taken from the GOES-1 satellite at 1400, 1600, 1800, and 2000 GMT of February 25, 1977. Area displayed is the Gulf of Mexico with States bordering the Gulf, a portion of Western Cuba, and Northern Yucatan Peninsula outlined by solid black lines. White areas in the display are either land, shallow water areas, or persistent cloud-covered regions at the different picture times.



VALUES GE 0 AND LT 154 7226
VALUES GE 154 AND LT 186 4216
VALUES GE 186 AND LT 210 4033
VALUES GT 210 1166

FIGURE 3.--THERMAL IR DIGITAL DISPLAY OF STORM CANOPY SLICED INTO FOUR DIFFERENT REGIONS FOR ESTIMATING RAIN AND FLOOD POTENTIAL BY THE NATIONAL HURRICANE AND EXPERIMENTAL LABORATORY, MIAMI, FLORIDA. Data displayed were taken from SMS-2 of storm located 22.0N,110.0W at 1545 GMT on October 28, 1976.

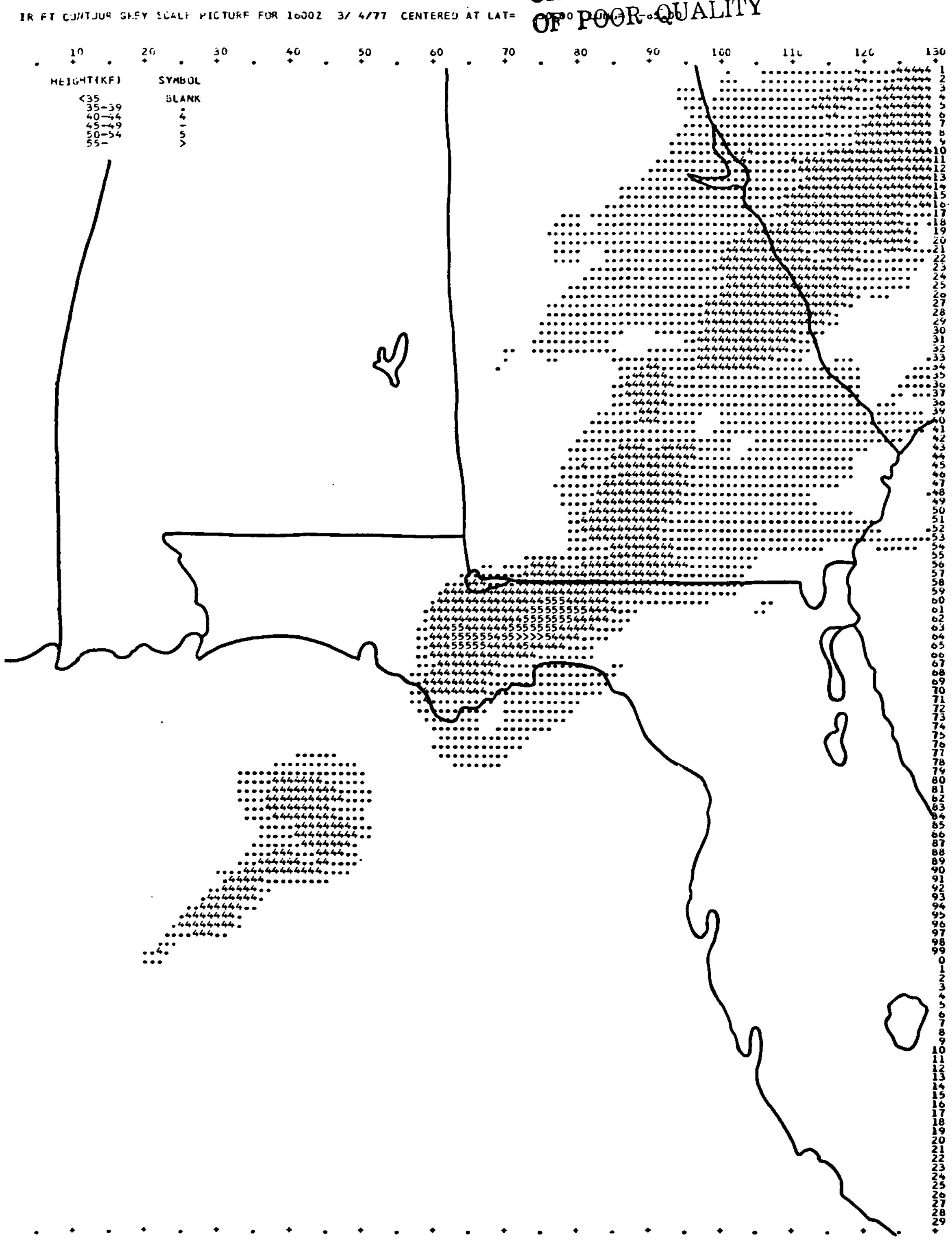


FIGURE 4.--THERMAL IR DIGITAL HEIGHT DISPLAY OF CLOUD SYSTEM, WITH EMBEDDED THUNDERSTORMS, IN THE SOUTHEASTERN UNITED STATES. Data, centered at 30.0N, 85.0W, were taken from GOES-1 at 1600 GMT of March 4, 1977. White areas in the display are either cloud heights below 35,000 feet or clear areas. Symbol table is located at upper left of display.

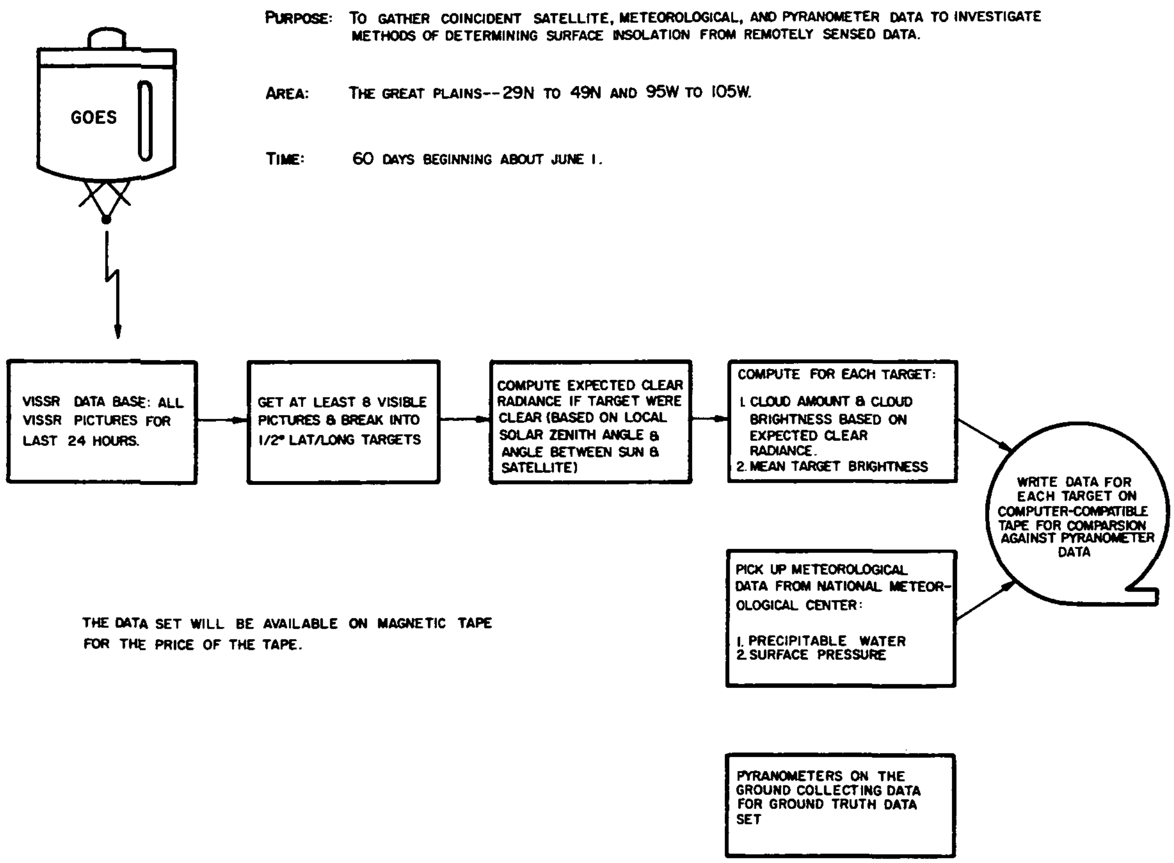


FIGURE 5.--ILLUSTRATION OF DATA COLLECTION PROCEDURE FOR INSOLATION EXPERIMENT TO BE CONDUCTED IN THE SUMMER OF 1977.