Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A209 938

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
Unclassified	
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
	Approved for Public Release;
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	Distribution Unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
GL-TR-89-0148	

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
Geophysics Laboratory	LYS	

6c. ADDRESS (City, State, and ZIP Code)	7b. ADDRESS (City, State, and ZIP Code)
Hanscom AFB Massachusetts 01731-5000	

DTIC
ELECTE
JUN 22 1989
D

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
Geophysics Laboratory	LYS	

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
Hanscom AFB Massachusetts 01731-5000	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
	62101F	6670	17	10

11. TITLE (Include Security Classification)

Multispectral Image Analysis of Hurrican Gilbert (unclassified)

12. PERSONAL AUTHOR(S)

Kleespies, Thomas J. (GL/LYS)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Reprint	FROM _____ TO _____	1989 June 13	5

16. SUPPLEMENTARY NOTATION

Preprints, Fourth Conference on Satellite Meteorology and Oceanography, 16-19 May 1989, San Diego CA, AMS

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Satellite Imagery, Meteorological Satellites, Satellite Image Display, Hurricanes,

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Observation of tropical cyclones using conventional image display techniques have been done for some time. Using suitable enhancements it is possible to observe the cloud patterns associated with the outflow or the inflow, but it is difficult to unambiguously differentiate various clouds levels in a multilayer system. However, multispectral image display techniques using visible, infrared and water vapor imagery help resolve this ambiguity. When the different spectral bands are displayed on a full color image processing system, low clouds appear bright red, midlevel clouds appear green, and high level clouds appear yellow and white. Dry descending air as part of the secondary circulation outside of the hurricane has a dark blue tint, whereas moist air at midlevels has a green tint. This paper discusses the principles of multispectral image display techniques and applies this technique to Hurricane Gilbert.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Thomas J. Kleespies	(617)377-3136	GL/LYS

DD Form 1473, JUN 86   Previous editions are obsolete.   SECURITY CLASSIFICATION OF THIS PAGE

89   6   20   134

MULTISPECTRAL IMAGE ANALYSIS OF HURRICANE GILBERT

Thomas J. Kleespies
Satellite Meteorology Branch
Atmospheric Sciences Division
Air Force Geophysics Laboratory
Hanscom AFB MA 01731

1.0 INTRODUCTION

One of the early applications of meteorological satellite imagery was positioning of tropical cyclones. However, since these early satellites were polar orbiting, a particular tropical cyclone was viewed only a few times per day. This task became much easier with the advent of geosynchronous satellites. But the early geosynchronous satellites ATS 1,2 and 3 in the late 1960's and early 1970's carried only visible imagers, and thus were restricted to observations during the local daylight. The launch of ATS-6 in 1974 brought the first infrared imager to geosynchronous orbit, and weather forecasters for the first time were able to observe and track tropical cyclones from space twenty-four hours a day (Duback and Ng, 1988)

When GOES 4 became operational in 1980 it brought new and improved imaging capabilities with the VAS instrument. The VAS is a 13 channel spin-scan radiometer, able to produce imagery or sounding data. When producing imagery, it can simultaneously image in the visible, plus two, three or four different infrared bands. When sounding, visible and up to twelve infrared bands are acquired, with the scan mirror dwelling on a particular scan line for a number of spins in order to observe the same area with different bands and to reduce instrumental noise (NASA, 1980).

A good example of early bispectral techniques to deduce cloud properties is given by Reynolds and Vonder-Haar(1977). The use of infrared water vapor imagery to observe the near storm environment around tropical storms was explored by Rodgers and Stout (1983), Nunez and Stout (1984), and Velden(1987). Menzel et al (1983) use the VAS sounding channels in a retrieval type approach to estimate cloud top height.

Multispectral image analysis can be considered to be a mature field in the area of land resources remote sensing (see for example Moik (1980), Schowengerdt (1983)). However, there seems to be few references to multispectral image analysis of scenes of meteorological interest, possibly because full color image processors have only recently become "affordable" to the meteorological community. Notable among these references are d'Entremont and Thomason (1987) who discussed some of the theory behind multispectral AVHRR imagery in some detail, and Kleespies et al, (1987) who presented SMMR and GOES multispectral imagery. The particular three bands used to create the imagery discussed in this paper were first brought to the author's attention by Zehr (1984). In his oral presentation, he showed GOES imagery which combined the visible, 11 μm infrared, and 6.7 μm water vapor channels into a single false color image. This paper uses these three channels to examine the near environmental features of the atmosphere around Hurricane Gilbert.

2.0 METHODOLOGY

The AFGL Interactive Meteorological System (AIMS) is a cluster of VAX minicomputers and workstations used for research purposes at AFGL. AIMS routinely acquires and processes North American surface and upper air data, and GOES Multispectral Imagery. Imagery can be displayed on any one of three Adage 3000 image processors. Each of the Adages has a minimum address space of 1024x1024x32 bits deep. In low resolution mode, any 512x512 portion can be displayed. The image depth can be partitioned in a large number of ways, depending upon the application. Since the Adage is a full color display device, it requires that the video chain contain at least twenty-four bits of imagery; eight bits each for the red, green and blue channels. These channels can actually be remapped arbitrarily at the bit level via a cross-bar-switch. The high level eight bits are nominally reserved for overlays. Monochrome image display, such as for a single channel image, is accomplished by copying the same eight bit image to all three channels (red, green and blue). Full color image display, such as with a color photograph, is attained by placing the monochrome intensity of the red component of the image in the red channel, and similarly for the green and blue channels. Multispectral imagery is achieved in the same fashion as for full color imagery, but since there is not necessarily a correspondence between the spectral regions used and the human range of vision, the selection as to which spectral band to place into which RGB channel is somewhat arbitrary, and relies to some degree on individual taste (there is a human factors consideration when applied to individuals with impaired color vision). Figure 1 is a schematic of the spectral band/channel selection for the multispectral imagery discussed in this paper. The infrared band is VAS band 8 and the water vapor band is VAS band 10.
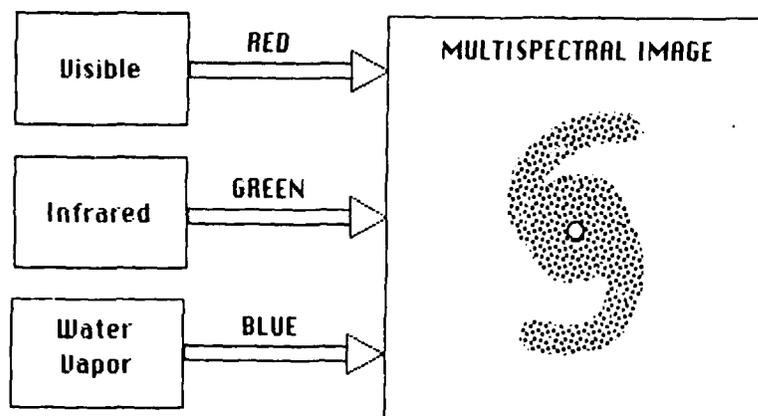
Figure 1. Spectral Band-Channel assignment for display of multispectral imagery on AIMS Adage 3000.
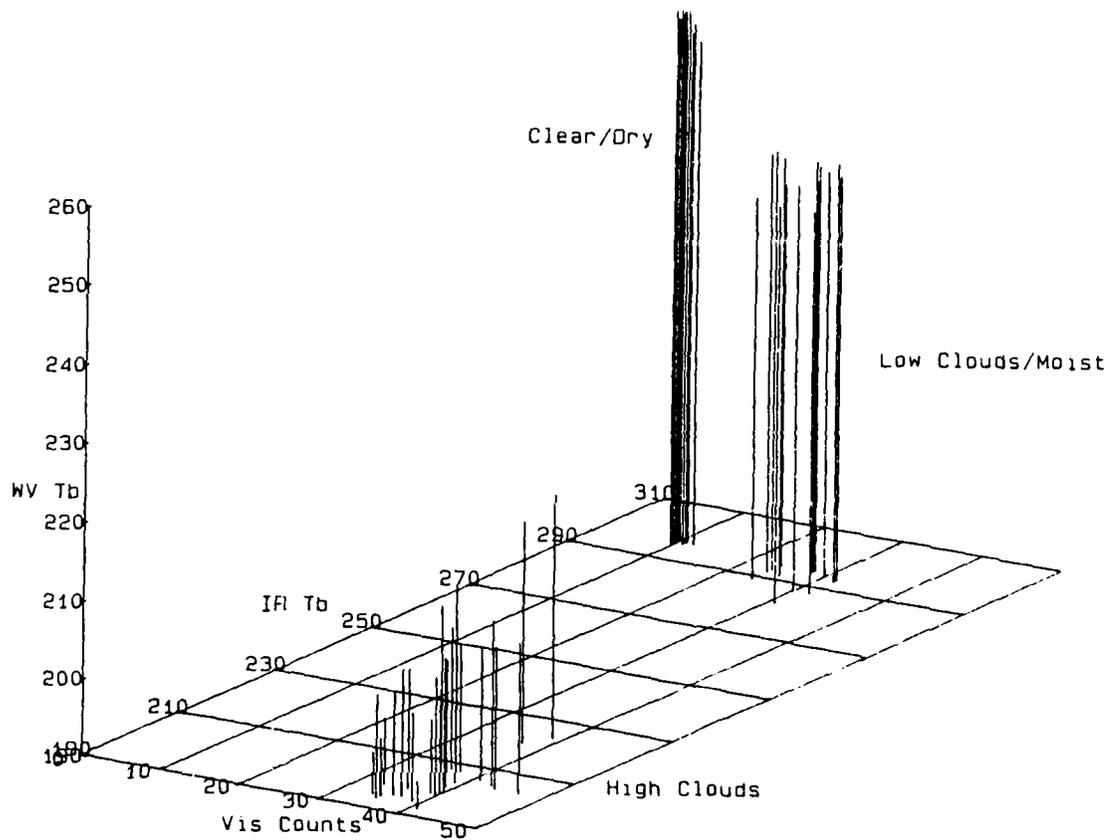
Figure 3. Three-space scatter diagram of selected cloud features from the 2130 UT 13 Sep 1988 GOES E multispectral image of Hurricane Gilbert. The coordinates represented by the pixel values for visible counts, infrared and water vapor brightness temperatures are at the top of the vertical lines. The drop lines from these coordinates to the visible-infrared plane are to help relieve the ambiguity of perception when viewing a three-space plot in perspective. As per Figure 1, the visible axis can be thought of the red axis in the RGB model, similarily the infrared can be thought as the green axis, and the water vapor can be thought as the blue axis.

3.0 RESULTS

In daylight, all clouds appear to be some degree of brightness in the visible, although there has been reported some relationship between albedo and cloud height (Griffith and Woodley, 1973). Away from sunglint the ocean surface appears fairly dark. In the infrared there is a general inverse relationship between brightness temperature and cloud height, the warm clouds tops are lower in the atmosphere, and the cold cloud tops are higher in the atmosphere. Water vapor imagery requires some interpretation. In the water vapor absorption band around 6.7 µm, virtually no radiation emitted from the surface reaches the instrument, so a scene with no clouds appears to be quite cold compared to a window channel. The VAS instrument measures the integrated radiance emitted by the water vapor in the upper troposphere. Since this channel is near the center of the absorption band, it saturates fairly high in the troposphere. If the upper troposphere is relatively dry, some the radiation that is sensed by the instrument is emitted deep in the atmosphere, and with normal lapse rates, the resulting brightness temperature is consequently warmer than that emitted from an atmosphere with a relatively moist upper troposphere.

The interplay between these three bands when displayed as multispectral imagery yield a rich diversity of color. The general features are quite clear. Low clouds appear red or magenta, since they are bright in the visible (red), dark in the infrared (green) and non discernable in water vapor (blue). High clouds appear yellow or white, since they are relatively bright in all three bands. In clear air, regions of dry-subsiding air have a dark appearance (dark in the visible over the ocean, warm-dark in the infrared, dry-dark in the water vapor band). Moist areas in the upper troposphere have a blue tint, even over the underlying low and mid-level clouds (water vapor band is cold-bright). Figure 2 is an example of the the three images that produced the multispectral imagery described in this paper. Figure 4 is the multispectral representation and is the color insert to these proceedings. Of real interest is the fact that the subsidence associated with the hurricane dynamics is very apparent in the water vapor imagery in the northwest sector outside of the outer rain band. Additionally, it is possible to see the low level clouds between the rain bands in the multispectral imagery, which would be difficult to discern with single channel imagery.

Figure 3 is a three-space scatter diagram of visible counts versus infrared and water-vapor brightness temperatures for a few select cloud types in the hurricane Gilbert environment. Since the three axes in Figure 3 correspond directly to the red, green and blue axes of a RGB color model, it is clear why the different cloud types come out so distinctly in the multispectral imagery.
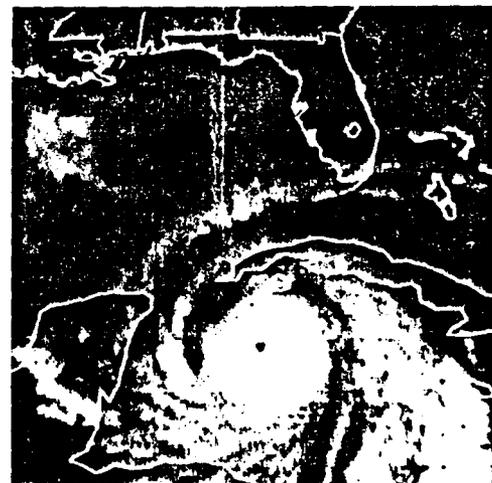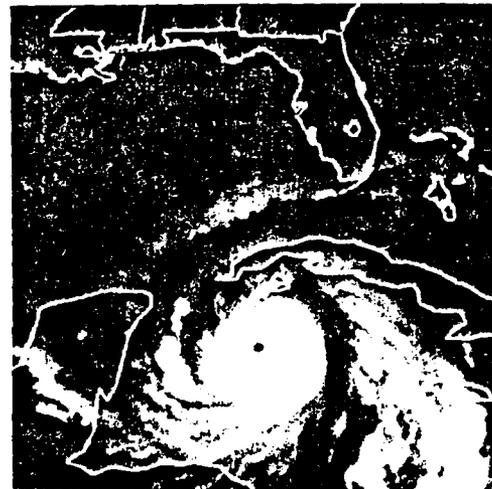

Figure 2. GOES E imagery of Hurricane Gilbert at 2130 UT 13 Sep 1988. Top picture is Visible, middle is 11 µm infrared, bottom is 6.7 µm water vapor.

4.0 SUMMARY

This paper presents a method of multispectral display and analysis of VAS imagery and applies it to the case of Hurricane Gilbert. The technique allows the viewer to unambiguously differentiate between low and high level clouds at a glance, and to identify regions of subsidence associated with the secondary circulation of a major tropical storm.

5.0 REFERENCES

d'Entremont, R. P., and L. W. Thomason, (1987): Interpreting Meteorological Satellite Images Using a Color-Composite Technique, *Bull. Am. Met. Soc.*, 68(7), pp 762-768.

Duback, Leland L, and Carolyn Ng, 1988: *Compendium of Meteorological Space Programs, Satellites and Experiments*, National Space Science Data Center, World Data Center A for Rockets and Satellites, 88-03,

Griffith, C. G. and Woodley, W. L., 1973: On the Variation with Height of the Top Brightness of Precipitating Convective Clouds, *J. Appl. Met.*, 12, pp 1086-1089.

Kleespies, T. J., R. P. d'Entremont, G. W. Felde, K. R. Hardy, L. W. Thomason, G. B. Gustafson C. F. Ivaldi, 1987: Application of the AFGL Interactive Meteorological System to Atmospheric Research, *Preprints, Third International Conference, Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, New Orleans, LA, AMS, Boston MA, pp 198-201.

Menzel, W. P., W. L. Smith, and T. R. Stewart, 1983: Improved Cloud Motion Wind Vector and Altitude Assignment using VAS, *J. of Climate and App. Met.*, 22, pp377-384.

Moik, J. G., 1980: Digital Processing of Remotely Sensed Images, *NASA SP-341*, GSFC, Greenbelt, MD., 330pp.

NASA, and Hughes Aircraft Company, 1980: *Geostationary Operational Environmental Satellite GOES D,E,F Data Book*

Nunez, E., and J. Stout, 1984: Tropical Storm Moisture and Subsidence Patterns as revealed by the VISSR Atmospheric Sounder (VAS) Water Vapor Channel. *Postprints of the 15th Conf. on Hurricanes and Tropical Meteorology*, Miami, FL, AMS, Boston, MA, pp 256-260.

Reynolds, D.W., and T.H. VonderHaar, 1976: A Bispectral Method for Cloud Parameter Determination, *Monthly Weather Review*, 105, pp 446-457.

Rodgers, E. B., and J. Stout, 1983: The Inference of Tropical Cyclone Dynamics using GOES/VISSR/VAS data. *VISSR Atmospheric Sounder (VAS) Research Review*, J. R. Greaves, Editor. NASA Conf. Publications 2253, GSFC, Greenbelt, MD.

Schowengerdt, R. A., 1983: *Techniques for Image Processing and Classification in Remote Sensing*, Academic Press, 249 pp.

Velden, C. S., 1987: Satellite Observations of Hurricane Elena (1985) using the VAS 6.7 μm "Water-Vapor" Channel, *Bull. Am. Met. Soc.*, 68(3), pp 210-215.

6.0 LIST OF ACRONYMS

AFGL	Air Force Geophysics Laboratory
AIMS	AFGL Interactive Meteorological System
ATS	Applied Technology Satellite
AVHRR	Advanced Very High Resolution Radiometer
GOES	Geostationary Operational Environmental Satellite
RGB	Red-Green-Blue
SMS	Synchronous Meteorological Satellite
SMMR	Scanning Multichannel Microwave Radiometer
VAS	VISSR Atmospheric Sounder
VAX	Virtual Address eXtension
VISSR	Visible Infrared Spin Scan Radiometer

A-1 20