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DMSP Water Vapor Radiances–A Preliminary Evaluation

FRANCIS R. VALOVCIN

6 October 1980

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

John Howard

Chief Scientist

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SSH data from the Defense Meteorological Satellite Program were received for analysis and evaluation. Valuable inherent water vapor information is contained in the eight DMSP Water Vapor Channels that operate in the 18-30 μm rotational water vapor band. Middle and/or high tropospheric cloudiness may be determined by analysis of the spectral radiances measured by the various DMSP water vapor channels. Clear or cloudy conditions may be determined by analysis of the slope of the spectral radiance of only three DMSP SSH Channels.

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20. Abstract (Continued)

A GLARE OBSTRUCTOR (GLOB) problem was more extensive on SSH Flight III than on SSH Flight II and at certain right-hand viewing positions, the DMSP SSH data are highly questionable. Finally, the cloud-free radiance/radiosonde sets contain many that are cloud contaminated.

Preface

The author wishes to acknowledge the following organizations and individuals: the Air Force Global Weather Center for supplying the DMSP HPKG data; the USAF Environmental Technical Applications Center for supplying the ground truth data; Dr. Robert McClatchey for critically reviewing both the investigation and the manuscript; Ed. Lefebvre for his programming skills.

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1. INTRODUCTION

Onboard the Defense Meteorological Satellite Program (DMSP) Block 5D satellite is a Special Meteorological Sensor H (SSH) package. Nichols[1] provides an excellent review of the optical subsystem and the spectral characteristics of this SSH package. Infrared energy is measured in 16 spectral bands by the SSH package: 6 spectral channels are located in the 15 μm carbon dioxide bands, 8 in the 18-30 μm rotational water vapor band, 1 in the 9.6 μm ozone band, and 1 in the atmospheric window near 12 μm. The various channel spectral centers, widths and NESR's as per the original specification are given in Table 1.

The purposes of this study are: 1) to evaluate the DMSP multichannel water vapor radiances (emissions) for informational content, and 2) to recommend some operational techniques whereby moisture parameters may be derived directly from the DMSP radiance measurements. Thus, in this investigation, the emphasis is placed on the eight spectral channels located in the 18-30 μm rotational water vapor band, and the one located in the atmospheric window near 12 μm. On occasion, one or two channels located in the 15 μm carbon dioxide were used to explain some problems in the radiance measurements. The radiance sets analyzed were from

(Received for publication 3 October 1980)

1. Nichols, D.A. (1975) DMSP Block 5D Special Meteorological Sensor H, Optical Subsystem, Opt. Engr. (14), 284-283, July–August.

Table 1. SSH Channel Characteristics*

Band	Center µm	Center cm^{-1}	Width cm^{-1}	Species	NESR**
E1†	15.0	668.5	3.5	CO_2	0.30
E2†	14.8	676.0	10.0	CO_2	0.09
E3†	14.4	695.0	10.0	CO_2	0.10
E4†	14.1	708.0	10.0	CO_2	0.11
E5†	13.8	725.0	10.0	CO_2	0.11
E6†	13.4	747.0	10.0	CO_2	0.12
E7/F5	18.7	535.0	16.0	H_2O	0.15
E8	12.0	835.0	8.0	Window	0.11
F1	28.2	355.0	15.0	H_2O	0.25
F2	25.2	397.5	10.0	H_2O	0.16
F3	23.8	420.0	20.0	H_2O	0.12
F4	22.7	441.5	18.0	H_2O	0.09
F6	24.5	408.5	12.0	H_2O	0.14
F7	26.7	374.0	12.0	H_2O	0.18
F8	28.3	353.5	11.0	H_2O	0.33
Z1†	9.8	1022.0	12.5	O_3	0.05

*After Nichols[1]

**NESR = Noise Equivalent Spectral Radiance in mW/m^2 sr cm^{-1}

†Not used in this study

Flight II SSH aboard spacecraft Wx 13536 and Flight III SSH aboard spacecraft Wx 14537. Flight II SSH was launched in July 1977, and Flight III SSH was launched in April 1978.

2. WATER VAPOR RADIANCE DATA

Printouts of SSH spectral radiance data for the period 00Z 30 Jan 79 to 00Z 6 Feb 79 were forwarded by the Air Force Global Weather Central (AFGWC) to the

Air Force Geophysics Laboratory (AFGL) for this investigation. Each radiance set specified the hemisphere (north or south), the 3DNEPH box, the latitude (north positive, south negative), the longitude (positive westward from Greenwich through 360°), zenith angle (positive left side of scan, negative right side of scan), the date and the hour, along with the spectral radiance measurement for the 16 spectral channels. Radiance sets for spacecraft Wx13536 and Wx14537 were received. This type of format is identified by AFGWC as "UNPACK SAVER H package" data. An example of UNPACK SAVER H package data covering a scan of zenith angles from $+18.22^{\circ}$ to -18.22° is shown in Figure 1. The location of these data were in or adjacent to the 3DNEPH box numbers where the eight radiosonde/rocketsonde stations of Thule, Primrose Lake, Churchill, White Sands, Point Mugu, Wallops, Cape Canaveral and Coolidge Field are located.

The DMSP SSH sounder scan pattern is shown in Figure 2 as a function of I, J in 3DNEPH boxes 43 and 44. Cross orbit track scanning is accomplished in 25 4-degree incremental steps from -48° to $+48^{\circ}$ of nadir. From left to right, the scan spots are designated 1 through 25. Nadir is located at spot 13. At nadir, the scan spot on the earth's surface is approximately 21 nmi (39 km), and increases to approximately 35 × 25 nmi (65 × 46 km) at a zenith angle of 32° at scan spots No. 6 and No. 20. Zenith angles are designated positive on the left and negative on the right. The range of zenith angles for the 25 scan spots are $+57^{\circ}$ to -57°. The distance in nmi between scan spots and scan lines is also shown in Figure 2. An example of the areal coverage of an orbit track from Texas, U.S. to Alberta, Canada is shown in Figure 3.

The matchup of the SSH package and radiosonde/rocketsonde data covering the period from 00Z 30 Jan 79 to 00Z 6 Feb 79 for the previously mentioned eight rocketsonde stations was disappointing (see Table 2). A matchup is defined as radiosondes/rocketsondes within +/- 3 hours and 100 nmi (185 km) of a satellite scan spot.

In view of this small sample of matches, another request was made for additional data. The additional data consisted of a dump of the HPKG * RADISAVE HPKG for the period 12Z 6 Feb 79 to 12Z 18 Oct 79 from spacecraft Wx13536 only. This HPKG * RADISAVE HPKG file contains the date-time, latitude and longitude of a single scan spot, zenith angle, 3DNEPH and data base parameters, the spectral radiance measurement for the 16 DMSP spectral channels along with the closest radiosonde station report of temperatures and dew point depression for the mandatory levels. This single scan spot is the first cloud-free SSH radiance set based on the 3DNEPH files and selected by AFGWC's HPKG software. An example of HPKG * RADISAVE HPKG data is shown in Figure 4. The difference between the HPKG * RADISAVE HPKG data and the previously mentioned UNPACK SAVER H PACKAGE is the following: HPKG * RADISAVE HPKG data gives the first

HEM = NORTH BOX = 60 LAT = 2.8 LON = 89.5 ZENITH ANGLE = -18.22
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.50	39.70	37.90	54.00	71.70	83.00	99.40	99.10	79.20	90.00	95.50	100.50	98.70	85.30	75.80	109.30	59.90

HEM = NORTH BOX = 60 LAT = 2.8 LON = 88.9 ZENITH ANGLE = -13.64
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.30	39.60	38.00	53.70	70.70	81.40	97.50	97.10	78.50	89.00	94.20	99.20	97.50	84.40	74.30	106.90	59.70

HEM = NORTH BOX = 60 LAT = 2.7 LON = 88.4 ZENITH ANGLE = -9.05
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.30	39.50	38.10	54.80	72.20	82.90	96.70	96.20	80.10	90.60	96.30	101.40	99.20	86.20	75.80	109.70	58.90

HEM = NORTH BOX = 60 LAT = 2.7 LON = 87.8 ZENITH ANGLE = -4.53
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	F6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.00	39.50	38.30	55.30	73.30	84.40	99.30	99.40	79.90	90.20	95.40	100.30	98.10	85.70	76.10	109.50	59.70

HEM = NORTH BOX = 60 LAT = 2.7 LON = 87.3 ZENITH ANGLE = .00
1/30/79/ 200Z JULHR = 97154

E1-668	F2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.30	39.40	38.60	56.10	73.70	85.10	100.90	101.10	79.90	90.00	94.80	99.50	97.20	85.50	76.50	108.30	[illegible]

HEM = NORTH BOX = 60 LAT = 2.7 LON = 86.7 ZENITH ANGLE = 4.53
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.00	39.40	38.50	56.90	74.10	84.50	96.50	95.80	79.00	89.10	93.80	98.60	96.80	84.60	75.80	108.10	57.60

HEM = NORTH BOX = 60 LAT = 2.6 LON = 86.2 ZENITH ANGLE = 9.05
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.00	39.50	38.80	56.90	70.70	79.30	83.60	82.50	79.40	89.00	93.30	97.60	95.40	84.70	76.50	104.90	[illegible]

HEM = NORTH BOX = 60 LAT = 2.6 LON = 85.6 ZENITH ANGLE = 13.64
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.30	39.50	38.90	56.10	68.10	76.00	76.60	77.70	78.10	87.30	91.60	95.40	93.10	83.30	75.40	100.30	42.40

HEM = NORTH BOX = 60 LAT = 2.6 LON = 85.0 ZENITH ANGLE = 18.22
1/30/79/ 200Z JULHR = 97154

E1-668	E2-677	E3-695	E4-708	E5-725	E6-747	E8-835	SL-835	F1-355	F2-397	F3-420	F4-441	F6-408	F7-374	F8-353	E7/F5-535	Z1
54.00	39.40	36.30	42.20	45.30	46.10	40.30	41.30	62.10	64.70	66.50	66.70	66.30	63.60	60.60	65.20	[illegible]

Figure 1. "UNPACK SAVER II PACKAGE" Data

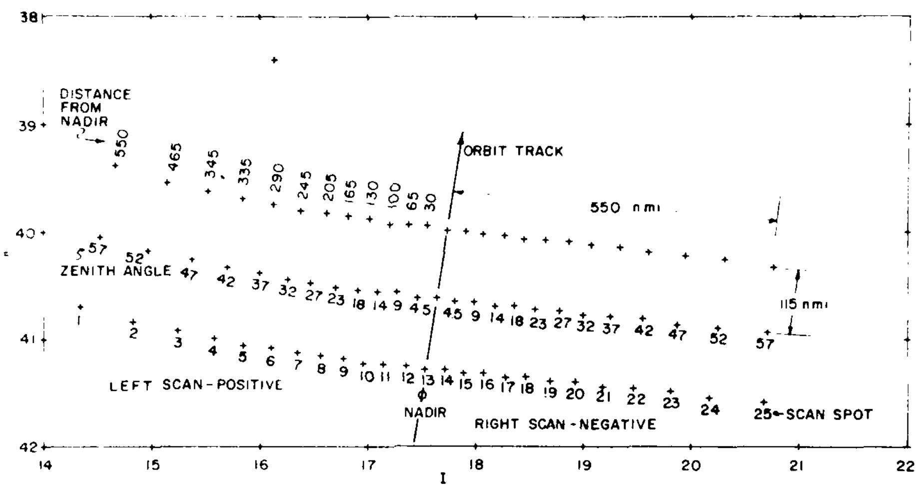

Figure 2. DMSP Sounder Scan Pattern

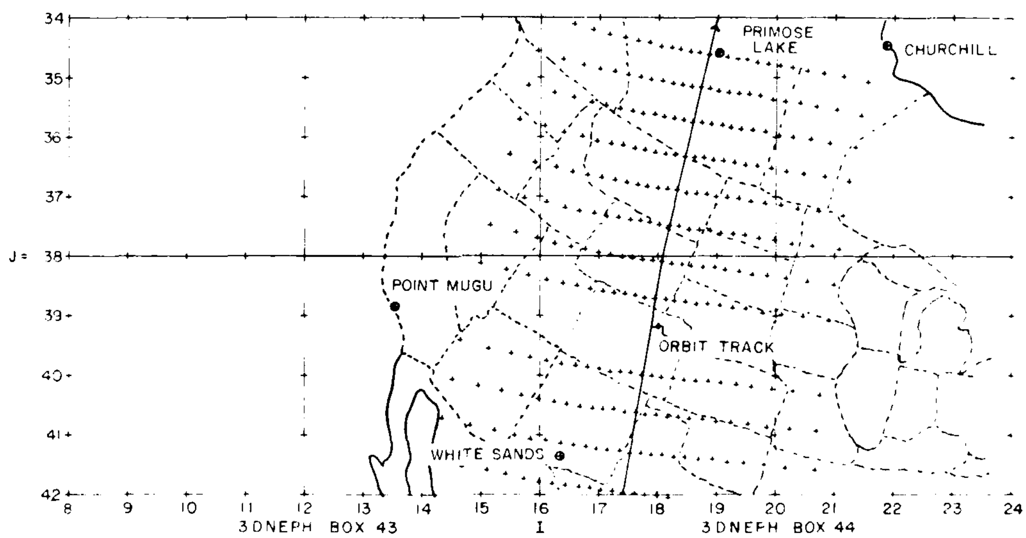

Figure 3. DMSP Wx14537, NREV 3909–1/31/79–1300Z Sounder Scan Pattern

JULIAN HOUR 99624 DATE TIME GROUP 5/13/79/ 0 Z LAT = 24.40 LON = 82.50 ZENITH ANGLE = -32.14

3D NEPH AND DATA BASE PARAMETERS

GRAY SHADE AMOUNT OF COLDEST MODE (EIGHTS) 8
GRAY SHADE HEIGHT (100S OF FEET) 0 SFC-IR TEMP DIFF 61
TERRAIN HEIGHT (METERS) 0 SFC TEMP 299.2
TOTAL CLOUD AMOUNT (PERCENT) 0 AVERAGE IR GRAY SHADE 50
LAND-SEA INDICATOR 1

RADIANCES

E1	E2	E3	E4	E5	E6	E8	E8	F1	F2	F3	F4	F6	F7	F8	E7/F5	Z1
60.2	46.9	42.6	56.2	76.3	89.9	115.3	115.3	75.0	87.1	93.4	99.9	98.3	82.2	71.7	114.8	60.4

...RAOB...
LAT 24.58 LON 81.70
TROP TEMP 197.9 PRESSURE 89.0
TEMPERATURES AND DEWPOINT DEPRESSIONS FOR MANDATORY LEVELS

LEVEL	1000	850	700	500	400	300	250	200	150	100	70	50	30	20	10
	299.2	289.0	281.0	264.1	255.5	240.3	231.9	219.3	208.3	201.5	203.1	212.3	223.5	226.3	236.1
	4.5	7.0	13.0	30.0	30.0	30.0	409.5	409.5	409.5	409.5					

Figure 4. "HPKG * RADISAVE HPKG" Data

Table 2. SSH Spectral Radiance Match with Radiosonde/Rocketsonde Stations—00Z 30 Jan 79 to 00Z 06 Feb 79

Rocketsonde Station	Total Matches Spot 1-25 +/- 57°	Sub-Total Matches Spot 6-20 +/- 32°	Sub-Total Spot 6-20 With Radiosonde	Cloud Contaminated (Clear)	Clear With Rocketsonde
Thule	88	79	44	44(0)	0
Primose Lake	37	26	2	2(0)	0
Churchill	21	17	17	17(0)	0
White Sands	27	18	8	5(3)	0
Point Mugu	22	10	5	4(1)	0
Wallops	30	15	13	6(7)	0
Cape Canaveral	32	24	11	7(4)	2
Coolidge Field	13	9	1	0(1)	1
Total	270	198	101	85(16)	3

cloud-free radiance set or one scan spot whereas the UNPACK SAVER H PACKAGE gives all the scan spots within a 3DNEPH box number. Thus, the UNPACK SAVE H PACKAGE data allows one to check the spatial variability of the radiance sets across an entire scan. This feature is especially important in identifying portions of clear and/or cloudy scans.

3. SSH WATER VAPOR RADIANCE ANALYSIS

3.1 AFGWC Scan Data

3.1.1 DMSP SATELLITE 13536—FLIGHT II SSH (LAUNCHED JULY 1977)

The SSH package data on spacecraft Wx13536 were beset with a GLARE OBSTRUCTOR (GLOB) problem. According to AFGWC, the GLOB interference on Flight II was limited to zenith angles of -37° to -57° or the viewing positions at No. 21 through No. 25 on the right-hand scan. AFGWC eliminated these radiances of the last five viewing positions by setting them to zero in their processing software. Because of this GLOB interference, viewing positions No. 6 through No. 20 were chosen for analysis in this investigation. Thus, the analysis is limited to zenith angles of +/- 32°, or approximately +/- 245 miles from nadir.

Figure 5 shows the theoretical weighting functions based on the U.S. Standard Atmosphere of 1962 for the eight DMSP water vapor channels. On the left side of Figure 5 is shown the more opaque water vapor channels and on the right is shown the less opaque water vapor channels. The most opaque DMSP water vapor channel is F8-353 cm^{-1}, and the channel with the least water vapor absorption is F5-535 cm^{-1}.

Figure 6 shows the spatial variability of the spectral radiance as a function of viewing position for the eight water vapor channels and the window channel in the Caribbean Sea. The scan covers viewing positions No. 6 through No. 20 or zenith angles of +/- 32^{o}, and covers a generally clear area. The data presented in Figure 6 are also shown in Figure 7 as a function of the various DMSP water vapor/window channels. The range of the spectral radiance and the general pattern of the spectral radiance in a clear situation is depicted for the various DMSP channels in Figure 7. Also in Figure 7, the range or vertical spread of the data for any one channel represents the zenith angle dependence.

The spatial variability of the spectral radiance as a function of viewing position in a middle cloud situation (500 mb–700 mb) in the vicinity of Cape Canaveral, FL is shown in Figure 8 (left side). The DMSP water vapor channels that are affected are F3, F4, F5 and F6. This can be seen as a dip in the scan swath at viewing position No. 16/zenith angle: -14^{o}.

In addition, by using the inverse of Planck's equation for the referenced frequency, that is, Eq. (1), the observed spectral radiance may be converted to equivalent blackbody temperature (T_B).

$$T_B(\nu_i) = C_2\ \nu_i / \ln[(C_1(\nu_i)^3/B\ (\nu_i)) + 1] \qquad (1)$$

Where

ν_i = reference frequency

$C_1 = 1.1906 \times 10^{-5}$ mW/m^2 sr cm^{-1}

$C_2 = 1.4387$ $cm^{o}K$

$B(\nu_i)$ = observed spectral radiance.

The spectral radiance for each DMSP water vapor channel may be converted to equivalent blackbody temperature. This is shown on the right in Figure 8. Again, the most opaque DMSP water vapor channel is F8-353 cm^{-1} (lowest T_B) and the channel with the least absorption is F5-535 cm^{-1} (highest T_B). Notice that except for DMSP channels F4 and F6, there is general agreement both in the sequencing of spectral radiance and equivalent blackbody temperature.

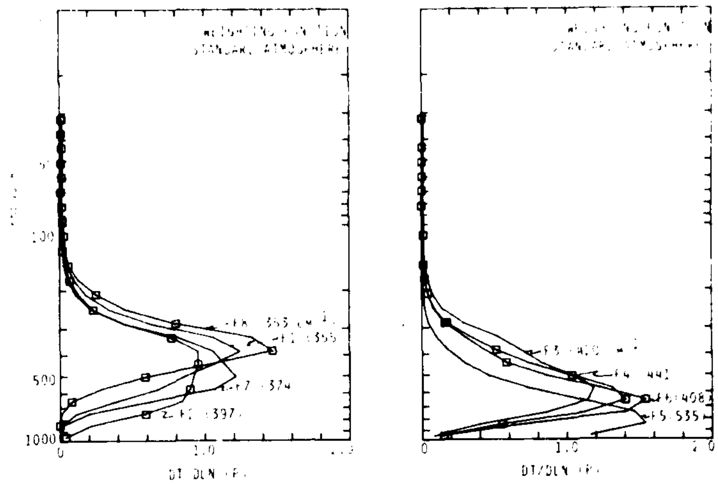

Figure 5. Weighting Functions for DMSP Water Vapor Channels

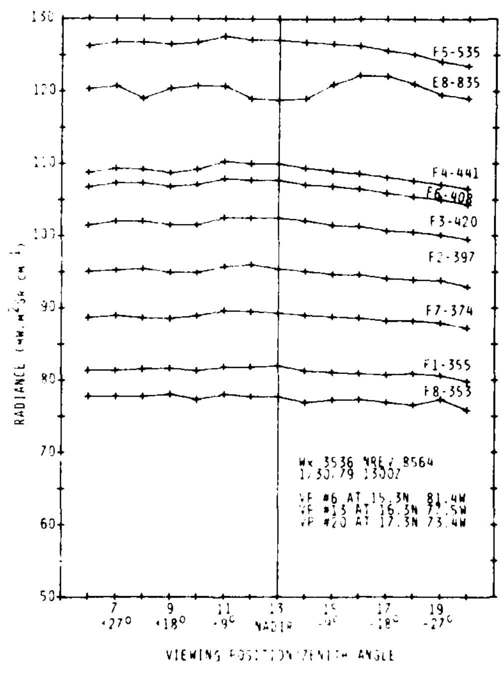

Figure 6. Spectral Radiance as a Function of Viewing Position Wx13536, NREV 8564–1/30/79–1300Z–Clear

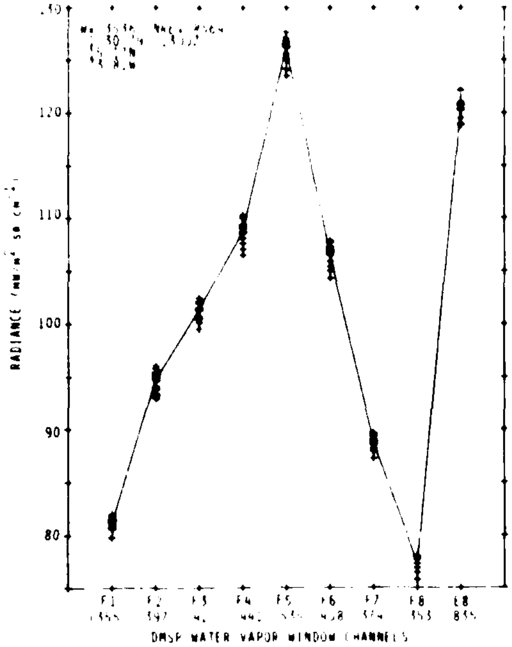

Figure 7. Spectral Radiance as a Function of DMSP Water Vapor/Window Channels—Clear

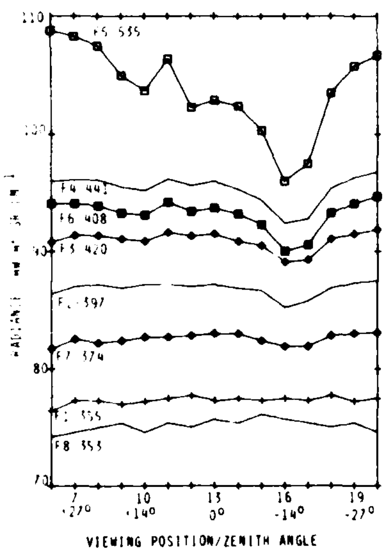

Figure 8a. Spectral Radiance as a Function of Viewing Position—Middle Cloudiness—Wx13536—1/30/79—0200Z

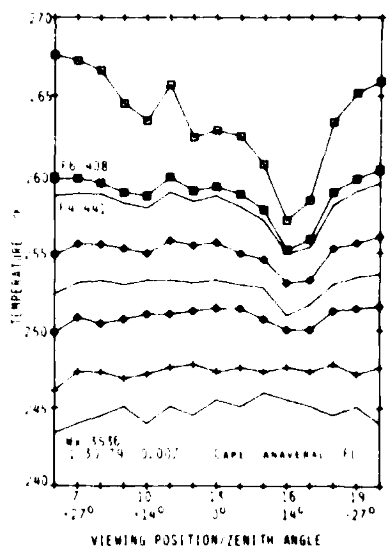

Figure 8b. Equivalent Blackbody Temperature as a Function of Viewing Position—Wx13536—1/30/79—0200Z

A DMSP scan in the presence of high clouds in the vicinity of 25,000 ft (7.6 km) and a clear situation is shown in Figure 9. At position No. 10/zenith angle +14°, the crowding of all eight of the water vapor channels and the dip of the window channel to 35 mW/m^2 sr cm^{-1} indicates the presence of a high cloudiness. The equivalent blackbody temperatures in the water vapor channels range from 223-225°K, and the window channel gives an effective temperature of 226°K. The spreading out of the radiance values at position No. 16/zenith angle -14° is indicative of a clear spot. Again, the radiance data presented in Figure 9 are shown as a function of the various DMSP water vapor/window channels in Figure 10. The range of the spectral radiance and the general pattern of the various DMSP channels are shown for both a high cloud and a clear situation. The upper three or four scan spots are representative of a clear situation, whereas the lower seven scan spots are representative of a high cloud situation. A better appreciation of the general pattern of the DMSP radiances for clear and cloudy situations may be seen in the comparison of Figures 7 and 10.

In view of these patterns in the DMSP water vapor radiances, it appears possible to separate clear and cloudy situations, especially when the surface temperature is greater than -15°C. This criteria of the surface temperature being greater than -15°C is found for scan spots located south of 60°N. For those scan spots located north of 60°N in the winter, the spectral radiance patterns may be indeterminate because of the vertical temperature structure, the amount of humidity, and the frequency dependence of the Planck functions. For example, the spectral radiance for channel E8-835 cm^{-1} at T_B = 258°K is 66.5 mW/m^2 sr cm^{-1}, whereas this same spectral radiance converts to a T_B = 233° for F8-353 cm^{-1}. Using the radiance pattern on only three DMSP channels, namely, F5-535 cm^{-1} (least water vapor absorption), F8-353 cm^{-1} (most absorption) and the E8-835 cm^{-1} (window) in a DMSP scan or a scan spot, clear or cloudy situations may be determined. The radiance pattern usually associated with cloudy or clear situations whenever the surface temperature is greater than -15°C is shown in Figure 11.

In the high cloudiness situation (shown on the left in Figure 11), the radiance patterns between bands F5 and F8 appears either neutral, slightly positive, or slightly negative. Between bands F8 and E8, the radiance slope is negative, whereas in the clear situation, the radiance pattern between F5-F8-E8 takes on the form of the letter "V." The slope of the spectral radiance is definitely negative between bands F5-F8 and positive between F8 and E8. In the case of a scan spot located north of 60°N, the patterns may take either form for both clear or cloudy conditions. An example of this indeterminate pattern for both clear or cloudy conditions is shown for Khatanga, USSR in Figure 12.

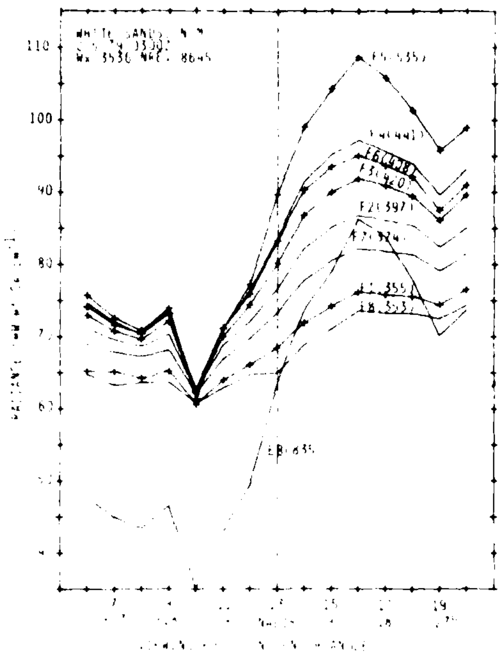

Figure 9. Spectral Radiance as a Function of Viewing Position—High Cloudiness/Clear—Wx13536—1/30/79—0200Z

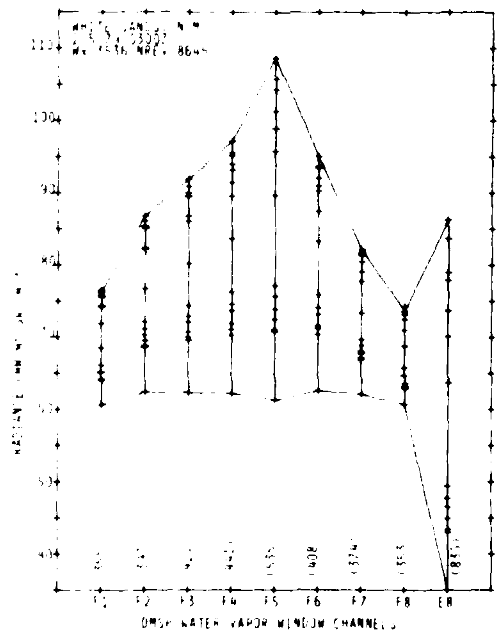

Figure 10. Spectral Radiance as a Function of DMSP Water Vapor/Window Channels—High Cloudiness/Clear Wx13536—2/5/79—0300Z

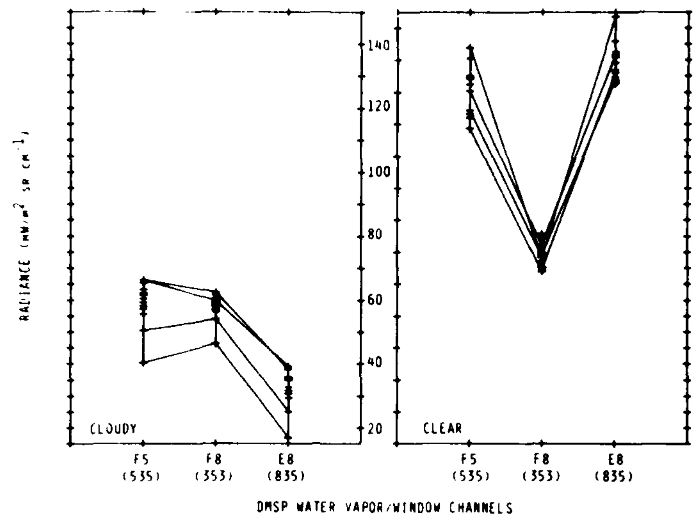

Figure 11. Spectral Radiance as a Function of DMSP Water Vapor/Window Channels for Cloudy and Clear Conditions

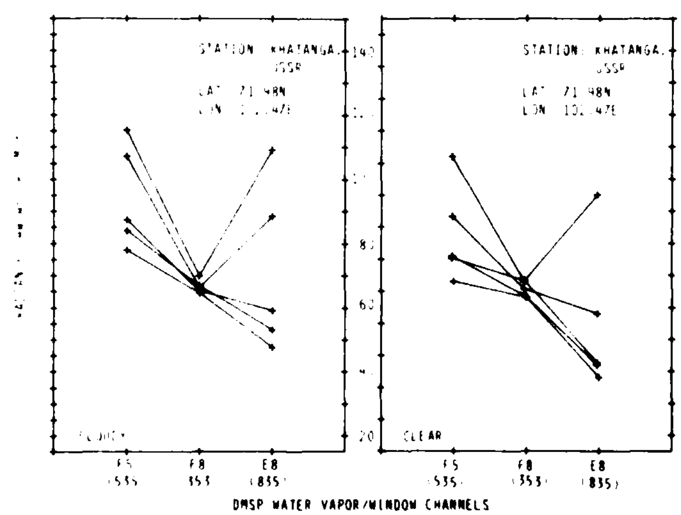

Figure 12. Spectral Radiance as a Function of DMSP Water Vapor/Window Channels for Cloudy and Clear Conditions for Khatanga, USSR

3.1.2 DMSP SATELLITE 14537—FLIGHT III SSH (LAUNCHED AUGUST 1978)

The SSH package data on spacecraft Wx14537 were also beset with GLOB problems. This interference was more extensive on Flight III than on Flight II. This GLOB interference was seen not only in viewing positions No. 21 through No. 25, but on occasions could be seen in the vicinity of nadir (viewing position No. 13). The interference is variable throughout the right-hand side of the scan. Some seven to nine viewing positions may be affected, leaving a possibility of some three to five scan spots with good data which also may be variable.

An example of GLOB interference is shown in Figures 13 and 14. Note that in Figures 13 and 14, all 25 viewing positions are plotted. Four spectral channels are plotted: DMSP channels E1-668 cm^{-1} and E2-677 cm^{-1} in the CO_2 absorption band, and F5-535 cm^{-1} and F8-353 cm^{-1} in the water vapor rotational band. The

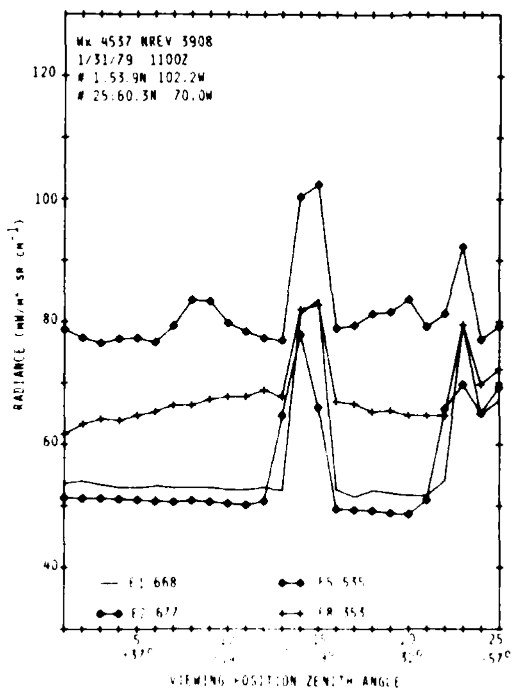

Figure 13. Spectral Radiance as a Function of Viewing Position—GLOB Interference—Wx14537 NREV 3908—1/31/79—1100Z 53.9N—60.3N, 70.0W—102.2W

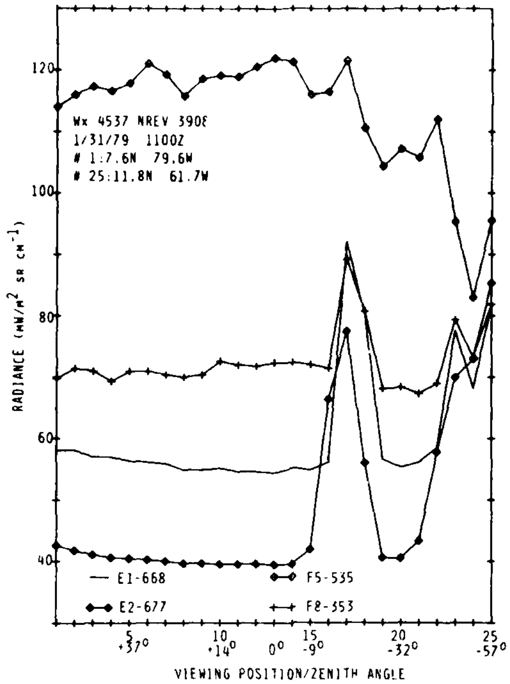

Figure 14. Spectral Radiance as a Function of Viewing Position—GLOB Interference—Wx14537 NREV 3908—1/31/79—1100Z 7.6N—11.8N, 61.7W—79.6W

upwelling radiance in channels E1 and E2 originates in the stratosphere at approximately the 10 mb and 30 mb pressure levels (McClatchey et al 1979). Based on the U.S. Standard Atmosphere, the upwelling radiance for channel F8 (most opaque) originates in the upper troposphere in the vicinity of 380 mb, and for channel F5 (least opaque) in the lower troposphere around 850 mb pressure level. The dramatic increase/decrease in radiance at viewing positions No. 13 through No. 15 and No. 21 through No. 25 in Figure 13 and viewing positions No. 15 through No. 18 and No. 21 through No. 25 in Figure 14 is an example of GLOB interference. This dramatic increase/ decrease in radiance for three to five scan spots, especially in the two channels whose upwelling radiance originates in the stratosphere, is physically impossible. The GLOB interference affects all 16 channels and is more easily recognized in a scan swath in those channels whose upwelling radiance originates in the upper troposphere. For example, see the plot patterns of

E1-668 cm^{-1}, E2-677 cm^{-1} and F8-353 cm^{-1} in both Figures 13 and 14 in which the GLOB interference is easily recognized. However, those channels whose upwelling radiance originates in the lower troposphere, such as F5-535 cm^{-1}, on occasion, although affected by the GLOB interference, may be difficult to recognize. An example of this is shown in the plot pattern of F5 in Figure 14 (not recognizable) as compared to its pattern in Figure 13 (recognizable). The reason for this is because those channels whose upwelling radiance originates in the lower troposphere, that is, F3, F4, F5 and F6, can be affected by clouds in the FOV, and their patterns may show dramatic increase/decrease in radiance values without GLOB interference.

In addition, notice that in both Figures 13 and 14, the GLOB interference is first seen in DMSP channel E2-677 cm^{-1}. This anomaly was reported by the author at a METSAT Technical Exchange Group meeting in May 1979 at AFGL. Information received from AFGWC (Savage[2]) indicated that channel E2 gathers one of its two data samples while the telescope is in motion toward the next scene. Therefore, based on this information, the GLOB interference in the SSH scan should be defined and based on the analysis of band E2-677 cm^{-1}. The reason for this is the design of the SSH sensor.

The variability of the GLOB interference may be seen in Figure 15 for spacecraft Wx14537–NREV 3908–1/31/79 between 8.8N to 59.5N. Plots of channel E1-668 cm^{-1} over various latitudes shows that the GLOB interference may vary between viewing positions No. 13 through No. 18. Although not shown, the GLOB interference appears one viewing position before for channel E2-667 as noted above. This variability of the GLOB interference on spacecraft Wx14537 makes it very difficult to evaluate the water vapor radiances, especially those that are observed at or near nadir and throughout the entire right-hand scan. At certain right-hand viewing positions, the GLOB interference data are definitely unreasonable and highly suspect.

3.2 AFGWC Cloud-Free Scan Spot Data

As previously mentioned, the HPKG * RADISAVE HPKG data are coincident radiosonde/radiance combinations. The radiance set is the first cloud-free set available within a 3° by 3° area as selected by AFGWC's HPKG software (based on the 3DNEPH files). The radiosonde data are obtained through a search of the AFGWC's upper air data base within +/- 3 hours and 100 nmi (185 km) of a satellite sounding. AFGWC provided HPKG * RADISAVE HPKG data to AFGL on computer tape for satellite Wx13536. No attempt was made to access Wx14537 for this type of data because of the extensive GLOB interference problem.

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2. Savage, R.C. (1980) (Private Communication).

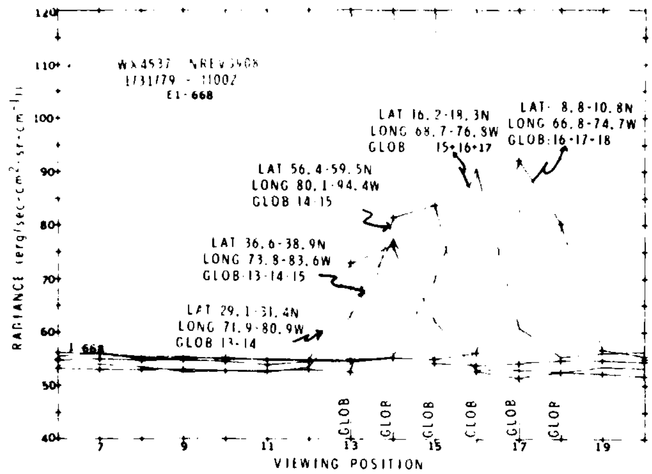

Figure 15. Variability of GLOB Interference—Wx14537—NREV 3908—1/31/79—1100Z—Channel E1-688 cm^{-1}

Table 3 shows the location of the HPKG * RADISAVE HPKG data. As can be seen in Table 3, certain areas have more than sufficient data whereas other areas are inadequate. Nevertheless, a total of some 3703 coincident radiosonde/radiance sets were received from AFGWC. If zenith angles greater than the absolute value of 32^{o} are eliminated, the total number of coincident sets are reduced to 2255. Another criteria that was arbitrarily chosen to refine the data from cloud contamination was DEL=(T_{E8} - T_{SFC}). DEL=(T_{E8} - T_{SFC}) is defined as the difference between the computed equivalent blackbody temperature of the DMSP window channel E8-835 cm^{-1} and the temperature of the surface. Computation of T_{E8} is accomplished by using Eq. (1) for the referenced frequency, 835 cm^{-1}. The T_{SFC} is obtained from the AFGWC 3DNEPH data file. Since T_{E8} is the computed equivalent blackbody temperature of the most transparent DMSP window channel, the value of T_{E8} should be approximately equal to T_{SFC}. Large negative DEL-(T_{E8} - T_{SFC}) values, that is, less than -10^{o}K, should be suspect of cloud contamination. An example of a large negative DEL=(T_{E8} - T_{SFC}) value is shown in Figure 16. The spectral radiance for the window channel, E-8 was observed by Wx13536 as 17.0 mW/m^2 sr cm^{-1}, which converts to a T_B = 199.8^{o}K (-73.4^{o}C). The surface temperature was reported as 301.6^{o}K and the DEL-(T_{E8} - T_{SFC}) = -101.8^{o}K. As can be seen in Figure 16, all the DMSP water vapor/window channels are tightly grouped around the 130-135 mb (14.9-15.2 km) level, which indicates that the FOV was contaminated with high thick clouds. Surface observations,

Table 3. Location of HPKG * RADISAVE HPKG Data

Latitude		180W–135W	135W–90W	90W–45W	45W–0	0–45E	45E–90E	90E–135E	135E–180E	Total
90N–62N	F-M:	10	9	21	20	41	32	59	27	
	A-M:	28	11	21	8	51	57	108	90	
	J-O:	67	12	10	7	34	83	57	61	
	Total:	105	32	52	35	126	172	224	178	924
62N–26N	F-M:	5	54	79	65	117	141	253	82	
	A-M:	5	40	162	37	115	129	269	128	
	J-O:	11	66	141	23	29	1	10	53	
	Total:	21	160	382	125	261	271	532	263	2015
26N–0	F-M:	0	5	33	5	7	6	75	17	
	A-M:	2	3	40	7	4	11	100	18	
	J-O:	0	1	6	0	0	0	0	5	
	Total:	2	9	79	12	11	17	175	40	345
0–26S	F-M:	0	0	39	22	3	0	22	25	
	A-M:	0	0	21	24	2	0	13	11	
	J-O:	0	0	1	3	0	0	0	2	
	Total:	0	0	61	49	5	0	35	38	188
26S–62S	F-M:	1	0	18	6	0	0	12	44	
	A-M:	1	0	31	3	0	0	12	31	
	J-O:	0	0	6	0	0	1	0	11	
	Total:	2	0	55	0	0	1	24	86	177
62S–90S	F-M:	0	0	1	10	0	1	6	10	
	A-M:	0	0	3	11	0	2	3	6	
	J-O:	0	0	0	0	0	0	0	1	
	Total:	0	0	4	21	0	3	9	17	54
									Total	3073

	All	Zen ∡ +/- 32°	DEL (T_{E8} - T_{SFC}) > -10°C
Feb-March 79	1383	792	379
Apr-May 79	1618	1051	669
June-Oct 79	702	412	412
	3703	2255	1460

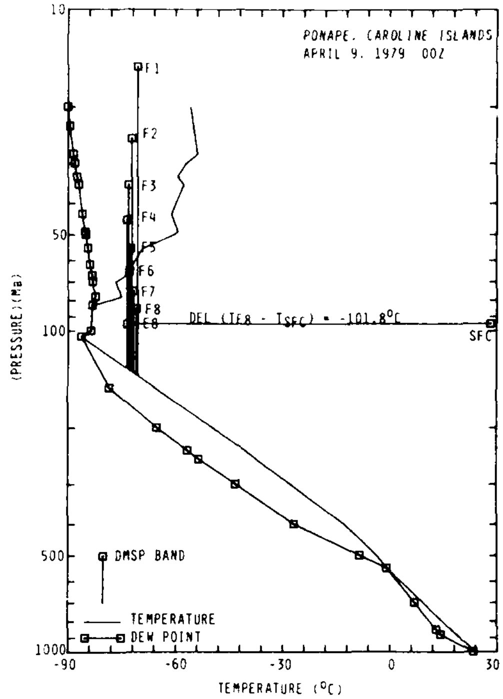

Figure 16. Radiosonde—Ponape, Caroline Islands—April 9, 1979, 00Z DEL=(T_{E8} - T_{SFC}) = -101.8°K

3DNEPH, and radiosonde data which were obtained from USAFETAC showed that Ponape was definitely not clear. Moderate to heavy rain was observed with an overcast and maximum cloud tops in the vicinity of 40,000 ft (12 km).

For comparison, Figure 17, the radiosonde for Charleston, S.C. on August 20, 1979, 00Z, illustrates a clear scan spot condition. This condition was verified by surface observations and 3DNEPH data. The DEL (T_{E8} - T_{SFC}) is only -3.3°K. Notice the separation between the various DMSP water vapor/window bands. The most opaque water vapor band, F8-[illegible] cm^{-1}, has a T_B [illegible] 236.8°K, which is found at approximately 28[illegible] (10.[illegible]). The [illegible] transparent water vapor band, F5-535 cm^{-1}, has a T_B [illegible] found at 635 mb (4.0 km). The window band, E8-8[illegible] K, which is found at 940 mb (0.7 km). In addition, notice the [illegible] F2-397 cm^{-1} and F7-374 cm^{-1} along with F4-441 [illegible].

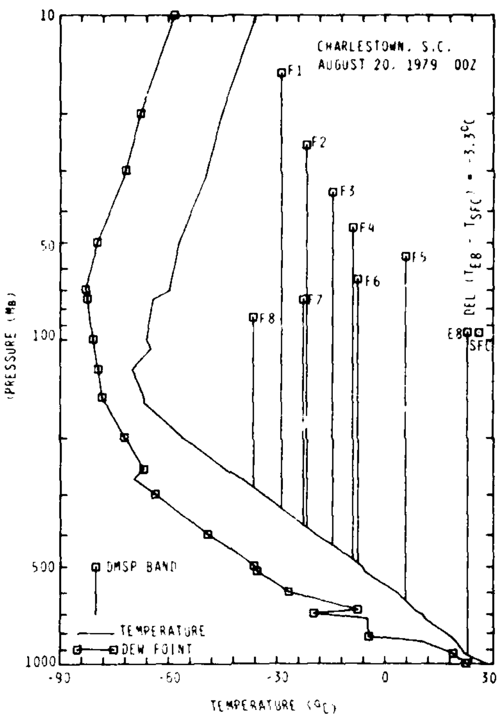

Figure 17. Radiosonde—Charleston, S.C. — August 10, 1979, 00Z DEL $=(T_{E8} - T_{SFC}) = -3.3^{\circ}K$

A histogram of DEL $=(T_{E8} - T_{SFC})$ based on the HPKG * RADISAVE HPKG data with zenith angles of +/- 32° for various periods in the year 1979 is shown in Figure 18. The HPKG software at AFGWC selects the first cloud-free radiance set (based on the 3DNEPH files) for inversion within a 3° by 3° area. As can be seen in Figure 18, large negative DEL $=(T_{E8} - T_{SFC})$ values in Feb-Mar 79 and Apr-May 79 are contained in the data of allegedly cloud-free spots. During the period June-Oct 79, there are no negative DEL $=(T_{E8} - T_{SFC})$ values less than $-10^{\circ}C$ and the number of spot samples selected for a 5-month period has been reduced dramatically. In comparison, almost 52 percent in Feb-Mar 79 and 36 percent in Apr-May 79 of the number of spot samples have negative DEL $(T_{E8} - T_{SFC})$ values less than $-10^{\circ}C$, and should be suspect for possible middle-high cloud contamination. The scan spots during the period June-Oct 1979 may be cloud contaminated, but the contamination is most likely due to low cloudiness at or below 1.5 km. In addition, since there are no Deltas less than $-10^{\circ}C$,

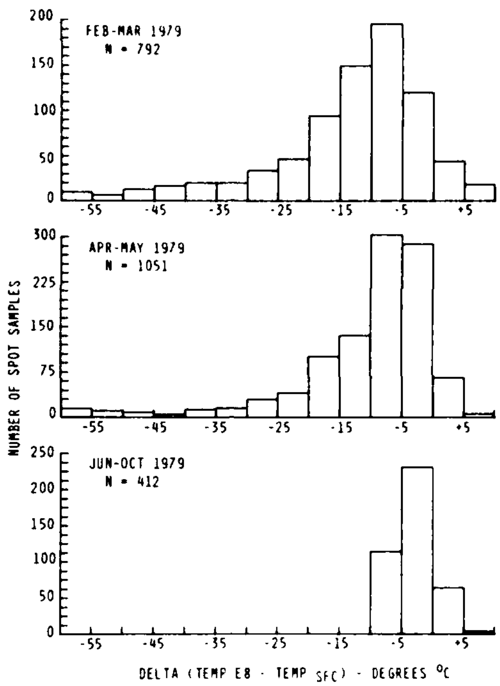

Figure 18. Histogram of Delta=(Temp E8 - Temp SFC) for Period Feb-Oct 1979

and considering the general shape of the histogram for the period June-Oct 1979, it would appear that AFGWC's cloud-free criterion decision was operationally changed for the better sometime in June-July 1979. This has been confirmed by personnel at AFGWC.

4. SUMMARY AND CONCLUSIONS

SSH data from the DMSP block 5D satellites Wx13536 and Wx14537 were received at AFGL from AFGWC in the UNPACK SAVER H PACKAGE and HPKG * RADISAVE HPKG format for analysis and evaluation. Results of the preliminary analysis indicate that the SSH data contain valuable inherent water vapor information in the eight DMSP water vapor channels that operate in the 18 to 30 μm rotational water vapor band.

Examination of the spectral radiances measured by the various DMSP water vapor channels gives an indication of the presence of middle and/or high tropospheric cloudiness. Crowding or tight packing of the spectral radiance measured by all eight DMSP water vapor channels as a function of scan spot or viewing position indicates high tropospheric cloudiness. A dip in the spectral radiance for DMSP channels F3-420 cm^{-1}, F4-441 cm^{-1}, F5-535 cm^{-1}, and F6-408 cm^{-1} indicates the presence of middle cloudiness between 500-700 mb in the FOV. Low tropospheric cloudiness at 850 mb or below or clear conditions are difficult to determine using any of the DMSP water vapor channels because of their water vapor absorption or transmission characteristics. In addition, the general shape of the slope of the spectral radiance of only three DMSP SSH channels may also given an indication of clear or cloudy conditions. By examining the slope of the spectral radiance between the most transparent water vapor channel F5-535 cm^{-1}, the most opaque water vapor channel F8-353 cm^{-1}, and the window channel E8-835 cm^{-1}, clear and/or cloudy conditions may be determined. In the case of clear or low tropospheric cloudiness, the slope between the DMSP channels F5-F8-E8 takes on the shope of a "V," namely a negative slope between F5-F8 and a positive slope between F8-E8. In the middle or high tropospheric cloudiness situation, the slope of the spectral radiance between F5-F8 is only slightly positive or negative and negative between F8-E8. This pattern appears valid whenever the surface temperature is greater than -15°C (258°K) or the scan spot is located south of 60°N latitude. The Glare Obstructor (GLOB) problem was more extensive on spacecraft Wx14537-SSH Flight III than on spacecraft Wx13536-SSH Flight II. In view of this problem, only the first 10 or 11 scan spots on the left-hand side of the scan on spacecraft Wx14537 should be considered in any analysis. In addition, because of the design of the SSH sensor, the GLOB interference is first seen in the DMSP channel E2-677 cm^{-1}.

Finally, the cloud-free radiance/radiosonde sets obtained from AFGWC in the HPKG * RADISAVE HPKG data contain quite a few middle-high tropospheric cloud contamination. This is true, especially during the period Feb-May 79. However, the cloud-free criteria appears to have been operationally changed by AFGWC after June 79 and the HPKG * RADISAVE HPKG data were greatly improved.

Further in-house research will be done on the applicability of the DMSP water vapor radiances. A data base, mostly from spacecraft Wx13536, for the period of Feb-Oct 1979 is now available for a statistical analysis and for ground truth correlation. These analyses and correlations will be done both in clear and cloud contaminated columns for the purpose of recommending operational techniques and deriving pertinent moisture parameters from the DMSP water vapor radiance measurements.

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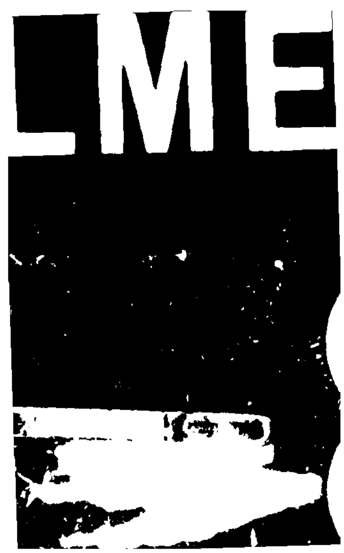
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