4.0 TOVS Level 1b Data

This section describes the TOVS system, which includes three separate sensors: HIRS/2, MSU and SSU. A fourth sensor, a Solar Backscattered Ultraviolet system (SBUV/2) for ozone measurement, was added to the instrument complement starting with the NOAA-9 spacecraft. SSB began archiving SBUV data in 1985. Separate documentation entitled: *Solar Backscattered Ultraviolet Radiometer Version 2 (SBUV/2) User's Guide (November 15, 1990),* is available from SSB upon request. Although SBUV/2 data is available from SSB, there exists no selection software. Therefore, when ordering SBUV/2 data, the only option is tape-to-tape copies.

Table 4.0-1 lists the instrument parameters for the HIRS/2, MSU, and SSU sensors on the TIROS-N series. The spectral response of every channel for each TOVS sensor can be found in Section 1.4 (in each satellite's corresponding subsection).

Section 4.1 describes the HIRS/2 instrument, data characteristics, and the tape formats available (full copy, unpacked format, and selective extract subsets). Similarly, Sections 4.2 and 4.3 contain specific information about SSU and MSU data, respectively. Section 4.4 contains general information pertaining to the SBUV/2 data, although specific tape formats are not included. Section 4.5 describes the procedures for calibrating TOVS data (both visible and thermal).

Table 4.0-1. Instrument Parameters for TOVS Sensors.

TOVS Instrument Parameters	HIRS/2	SSU	MSU
Calibration	Stable blackbodies (2) and space background	Stable blackbody and space	Hot reference body and space background each scan cycle
Cross-track scan angle (degrees from nadir)	+/- 49.5	+/- 40.0	+/- 47.35
Scan time (seconds)	6.4	32.0	25.6
Number of steps	56	8	11
Angular FOV (degrees)	1.25	10.0	7.5
Step angle (degrees)	1.8	10	9.47
Step time (seconds)	0.1	4.0	1.84
Ground IFOV at nadir (km diameter)	17.4	147.3	109.3
Ground IFOV at end of scan	58.5 km cross-track x 29.9 km along-track	244 km cross-track x 186.1 km along-track	323.1 km cross-track x 178.8 km along-track
Distance between IFOV centers (km along-track)	42.0	62.3	168.1
Swath width	+/- 1120 km	+/- 737 km	+/- 1174 km

Data rate (bits per second)	2880	480	320
Data precision (bits)	13	12	12
Time between start of each scan line	6.4 sec	32 sec	25.6 sec
Step and dwell time	0.1 sec	4.0 sec	1.81 sec
Time *	0.5 sec	2.0 sec	0.9 sec
* Time- The difference between the start of each scan and the center of the first dwell period.			

4.1 HIRS/2 Data

This section describes the instrument, data characteristics, and magnetic tape formats of the High Resolution Infrared Radiation Sounder/2 (HIRS/2). Section 4.1.1 contains a description of the instrument and data characteristics. Section 4.1.2 contains the tape formats for full data set copies, 16-bit unpacked format, and selective extract subsets.

4.1.1 Instrument Description and Data Characteristics

The HIRS/2 instrument measures incident radiation primarily in the infrared region of the spectrum including both longwave (15 micrometers) and shortwave (4.3 micrometers) regions (see Table 4.0-1). The IFOV of the HIRS/2 channels are stepped across the satellite track by use of a rotating mirror. This cross-track scan, combined with the satellite's motion in orbit, will provide coverage of a major portion of the Earth's surface. The width of the crosstrack scan is 99 degrees or 2240 km and consists of 56 steps. The mirror is stepped from home position in 55 steps of 1.8 degrees. At the end of the scan (at position 56) the mirror rapidly returns to the home position and repeats the scanning pattern. Each scan takes 6.4 seconds to complete (100 milliseconds per step) and there are 42 km between IFOVs along the sub-orbital track. The optical FOV is 1.25 degrees which gives a ground IFOV of 17.4 km diameter at the nadir. At the end of the scan, the ground IFOV is 58.5 km cross-track by 29.9 km along-track.

HIRS/2 can be commanded to automatically enter a calibration mode every 256 seconds. When the instrument is in the calibration mode, the mirror (starting from the beginning of a scan line) rapidly slews to a space view and samples all channels for the equivalent time of one complete scan line of 56 scan steps. Next, the mirror is moved to a position where it views a cold calibration target and data is taken for the equivalent of 56 scan steps. The mirror is then stepped to view an internal warm target for another 56 scan steps.

Upon completion of the calibration mode, the mirror continues its motion to the home position where it begins normal Earth scan. The total calibration sequence is equivalent to three scan lines (no Earth data are obtained during this period). The analog data output from the HIRS/2 sensor is digitized onboard the satellite at a rate of 2880 bits per second. At this rate, there are 288 bits per step (step time = 100 milliseconds) which includes all 20 channels. The data is digitized to 13-bits precision.

Table 4.1.1-1 contains typical values of the HIRS/2 spectral characteristics and Noise Equivalent differential Radiance (NEdN's in units of mW/(m^2-sr-cm^{-1})). There will be some variation in the parameters from one HIRS/2 instrument to another.

Table 4.1.1-1. Typical HIRS/2 Channel Characteristics.

Channel	Half-power Bandwidth (cm-1)		Maximum Scene Temperature (K)		Specified NEdN	
1	3		280		3.00	
2	10		265		0.67	
3	12		240		0.50	
4	16		250		0.31	
5	16		265		0.21	
6	16		280		0.24	
7	16		290		0.20	
8	35		330		0.10	
9	25		270		0.15	
10	60	17*	290	310*	0.16	0.09*
11	40		275		0.20	
12	80		260		0.19	
13	23		300		0.006	
14	23		290		0.003	
15	23		280		0.004	
16	23		260		0.002	
17	23	26*	280	350*	0.002	
18	35		340		0.002	
19	100		340		0.001	
20	1000		100%A		0.10%A	

* NOAA-11 and all subsequent satellites (except NOAA-12) have channels 10 and 17 at different locations in the spectrum. An * (asterisk) indicates the values for NOAA-11.

4.1.2 Magnetic Tape Formats

The data set format for full data set copies (all channels) is different from the format for selective extract subsets (selected channels). Sections 4.1.2.1 and 4.1.2.2 contain formats for HIRS/2 full data set copies and HIRS/2 selective extract subsets, respectively. Section 4.1.2.1 also includes an explanation of the 16-bit unpacked data format for HIRS/2 data.

4.1.2.1 Full Data Set Copies

Each HIRS/2 data set normally contains an individual satellite recorder playback in chronological order. Each record of HIRS/2 data contains the data for one HIRS/2 scan. Each record is written in binary and contains 4253 bytes in the format contained in Table 4.1.2.1-1.

Table 4.1.2.1-1. Format of HIRS/2 Data Record.		
Byte #	**# Bytes**	**Content**
1-2	2	Scan Line
3-8	6	Time Code
9-12	4	Scan Quality Indicators
13-16	4	Earth Location Delta
17-736	720	Calibration Coefficients
737-740	4	Height and Local Zenith Angle
741-964	224	Earth Location
965-3780	2816	HIRS/2 Data
3781-3844	64	Minor Frame Quality
3845-4253	409	Spare

The **scan line** number is from 1 to n. In the case of data gaps which cover one or more complete scans, the scan line number will be incremented to compensate for the data gap.

The **time code** consists of the year, Julian day, and UTC time of day in milliseconds. The year is contained in the first 7 bits of the first two bytes, the 9-bit day of year is right-justified in the first two bytes and the 27-bit millisecond UTC time of day is right-justified in the last four bytes. All other bits are zero. The time code has the same format for all Level 1b data sets.

The **scan quality information** is contained in four bytes. The first two bytes contain processing detected conditions, the third byte contains DACS quality indicators, and the last byte is spare. The scan quality indicators contain a summary of the quality of the 64 TIP minor frames which make up a HIRS/2 scan. The quality bytes are defined in Table 4.1.2.1-2.

Table 4.1.2.1-2. Format of the HIRS/2 Scan Quality Information.		
Byte	**Bit**	**Definition**
9	7	FATAL FLAG - Data should not be used for product generation.
	6	TIME ERROR - A time sequence error was detected while processing this scan.
	5	DATA GAP - A data gap of one or more scans precedes this scan.
	4	DWELL - Data gap was due to dwell mode condition.
	3	DATA FILL - The scan contains partial data fill due to a data gap of less than one scan. Each halfword of data fill is set to hex 7FFF.
	2	DACS ERROR - This scan contains data that is suspect due to DACS QC error(s).
	0-1	SCAN TYPE - The type of data found in this scan line (01=space calibration view, 10=cold BB view, 11=main BB view, and 00=normal Earth view)
10	7	MIRROR LOCKED - The mirror was in a locked position during this scan. Normal Earth scanning was disrupted.
	6	MIRROR POSITION ERROR - A scan mirror sequence error was detected during this scan.

	5	MIRROR REPOSITION - This scan was used to reposition the mirror.
	4	FILTER SYNC - Improper filter synchronization during this scan.
	3	SCAN PATTERN ERROR - HIRS/2 line counter not incrementing properly.
	2	CALIBRATION - Insufficient data collected to calibrate this scan. If calibration coefficients are available, they will be the old coefficients.
	1	NO EARTH LOCATION DATA - Earth location data was not available.
	0	EARTH LOCATION DELTA - Predicted less actual time exceeds tolerance of 3 seconds.
11	7	BIT SYNC STATUS - Drop lock during this scan. The scan line is suspect.
	6	SYNC ERROR - Frame sync word error greater than zero during this scan.
	5	FRAME SYNC LOCK - Frame sync lock during this scan.
	4	FLYWHEELING - Flywheeling detected during this scan. The scan line is suspect.
	3	BIT SLIPPAGE - Bit slippage detected during this scan. The scan line is suspect.
	2	TIP PARITY - DACS TIP parity detected during this scan. The scan line is suspect.
	1	AUXILIARY FRAME SYNC ERRORS - The number of bit errors in auxiliary frame sync was non-zero during this scan.
	0	SPARE
12	7-4	MAJOR FRAME COUNTER
	3-0	SCAN SEQUENCE COUNTER - Number (0-4) of scan position within the 32-second cycle.

The **Earth location delta** is the time difference between the scan time code and the time code associated with the Earth location data appended to this record. The value is in milliseconds and is right-justified in the four bytes.

The twenty HIRS/2 channels occur in the Level 1b data record in the following order: 1, 17, 2, 3, 13, 4, 18, 11, 19, 7, 8, 20, 10, 14, 6, 5, 15, 12, 16, and 9.

The HIRS/2 **calibration coefficients** are contained in three groups. The first group of 240 bytes contains the three manually calibrated coefficients for each of the 20 channels stored in descending order. The second group of 240 bytes contain the three auto-calibrated coefficients for each of the 20 channels stored in descending order. The third group of 240 bytes contains the normalization coefficients by channel used in auto calibration stored in ascending order. Each value is stored in four bytes and contains a scaled number of fractional bits. The scaling factor for the coefficients in ascending order is 2^{22}, 2^{30} and 2^{44}, respectively, and fields for non-computed values are set to zero. The order of the coefficients is shown in Table 4.1.2.1-3.

Table 4.1.2.1-3. Order of the HIRS/2 calibration coefficients.
Channel 1 manual coefficient 1 (2nd order term)
Channel 1 manual coefficient 2 (1st order term)

Channel 1 manual coefficient 3 (0th order term)
Channel 17 manual coefficient 1 (2nd order term)
...
Channel 1 auto coefficient 1 (2nd order term)
Channel 1 auto coefficient 2 (1st order term)
Channel 1 auto coefficient 3 (0th order term)
Channel 17 auto coefficient 1 (2nd order term)
...
Channel 1 normalization coefficient 1 (0th order term)
Channel 1 normalization coefficient 2 (1st order term)
Channel 1 normalization coefficient 3 (2nd order term)
Channel 17 normalization coefficient 1 (0th order term)
...

The sets of coefficients for the HIRS/2 channels are present in the same sequence in which the channels are present in the data record (ascending/descending refers to sequence of the three terms of each coefficient).

Calibration intercepts whose absolute values exceed 512 are truncated when they are scaled and inserted into the Level 1b database by the program DEFERT. For most channels of most TIROS-N series satellites instruments, this presents no problem because the absolute values of their intercepts are less than 512. However, Channels 1 and 2 of the NOAA-12 HIRS/2 and Channel 1 of the HIRS/2 instruments on NOAA-6, -7, -8, -10, -11, -13 and -14 are exceptions. In these channels, the absolute values of the intercepts exceed 512, and the scaled intercept values in the Level 1b database are truncated. Consequently, the intercepts for these channels are incorrect when they are descaled by users of the Level 1b data. Users may recover the correct values by adjusting the descaled values using the following procedures:

NOAA-12 Channel 1:

If the absolute value of the descaled intercept is less than 200, increase the absolute value by 2048 (and maintain the original sign). For example, if the descaled intercept is -11, the correct intercept is -2059.

If the absolute value of the descaled intercept is greater than or equal to 200, increase the absolute value by 1536 (and maintain the original sign). For example, if the descaled intercept is -511, the correct intercept is -2047.

NOAA-12 Channel 2;
and NOAA-6, -7, -8, -10, -11, -13 and -14 Channel 1:

If the absolute value of the descaled intercept is less than 200, increase the absolute value by 512 (and maintain the original sign). For example, if the descaled intercept is -38, the correct intercept is -550; if the descaled intercept is 95, the correct intercept is 607.

If the absolute value of the descaled intercept is greater than or equal to 200, make no adjustment.

Also note that the HIRS/2 instrument can have negative numbers for the calibration coefficients. The HIRS/2 auto coefficient 2 will be negative for all channels except Channel 20. Typical values for auto coefficient 2 range from .-0.5 for Channel 1 to.-0.5 x 10^{-3} for Channel 19. The auto coefficient 3 can be positive or negative depending on the channel. Values usually range from several hundred for Channel 1 to .1 for Channel 19.

See Section 4.5 on how to use the HIRS/2 calibration coefficients.

The **height and Local Zenith Angle** of the scan is contained in four bytes. The height is stored in the first two bytes in kilometers. The Local Zenith Angle is stored in the last two bytes in 128ths of a degree. The Local Zenith Angle is the angle from the observed point on the earth to the satellite as measured from the local vertical. The Local Zenith Angle given here is for the fields of view at the edge of scan. The Earth location data consists of latitude and longitude pairs for each of the 56 field of views (FOV) in the scan. The latitude and longitude values are stored in two-byte fields in 128ths of a degree. The order of the data is: FOV 1 latitude, FOV 1 longitude, FOV 2 latitude, FOV 2 longitude, etc.

Each TIP minor frame contains 286 bits of **HIRS/2 data** packed into 36 bytes. The 286 bits are made up of 22 13-bit words. The 22 13-bit words will be repacked into 44 bytes according to the following scheme.

(a) The first two 13-bit words will be packed left-justified into the first four bytes of the 44-byte group. The least significant six bits of the four bytes will be zero filled. These two words describe the encoder position, electronic calibration level, Channel 1 period monitor, element number, and filter sync designator.

(b) The last 20 13-bit words will be repacked into 20 halfwords (right justified). These 13-bit words consist of a sign bit (MSB) and the 12 remaining bits represent the radiant signal output for the 20 HIRS/2 channels for the first 56 minor frames. If the sign bit is zero, then the radiant signal is negative (cooler than the filter wheel); if the sign bit is one, then the radiant signal is positive (warmer than the filter wheel). Minor frames 56-63 also contain these 20 words as described in Table 4.1.2.1-4.

The 44-byte group will be packed sequentially in the scan record. The content of the 286 bits found in each of the 64 **TIP minor frames** within the HIRS/2 scan is found in Table 4.1.2.1-4.

Table 4.1.2.1-4. Format of TIP HIRS/2 data output for one scan.

Bit #	Description
Minor Frames 0-55	
285-278	Encoder Position (1-56=Earth view, 68=space, 105=cold BB,

	156=warm BB)
277-273	Electronic Calibration Level (0-31, any level indicates both + and -)
272-267	Channel 1 Period Monitor
266-261	Element Number (one less than encoder value for Earth views)
260	Filter Sync Designator (out of sync=0)
259-0	Radiant signal Output (20 channels x 13 bits)
Minor Frames 55-63	
285-260	Same as above
Minor Frame 56	
259-0	Positive Electronic Calibration (calibration level advanced one of 32 equal levels on succeeding scans)
Minor Frame 57	
259-0	Negative Electronic Calibration
Minor Frame 58 (Thermistors)	
259-195	Internal Warm Target #1, 5 times (independent samples, counts)
194-130	Internal Warm Target #2, 5 times (independent samples, counts)
129-65	Internal Warm Target #3, 5 times (independent samples, counts)
64-0	Internal Warm Target #4, 5 times (independent samples, counts)
Minor Frame 59 (Thermistors)	
259-195	Internal Cold Target #1, 5 times
194-130	Internal Cold Target #2, 5 times
129-65	Internal Cold Target #3, 5 times
64-0	Internal Cold Target #4, 5 times
Minor Frame 60 (Thermistors)	
259-195	Filter Housing Temperature #1, 5 times
194-130	Filter Housing Temperature #2, 5 times
129-65	Filter Housing Temperature #3, 5 times
64-0	Filter Housing Temperature #4, 5 times
Minor Frame 61	
259-195	Patch Temperature Expanded, 5 times
194-130	First State Temperature, 5 times
129-65	Filter Housing Control Current, 5 times
64-0	Electronic Calibration DAC, 5 times (expected count for electronic calibration)
Minor Frame 62	
259-247	Scan Mirror Temperature
246-234	Primary Telescope Temperature
233-221	Secondary Telescope Temperature
220-208	Baseplate Temperature
207-195	Electronics Temperature
194-182	Patch Temperature
181-169	Scan Motor Temperature

168-156	Filter Motor Temperature	
155-143	0 Volts to ADC	
142-130	Patch Control Power	
129-117	Scan Motor Current	
116-104	Filter Motor Current	
103-91	+15 VDC	
90-78	-15 VDC	
77-65	+7.5 VDC	
64-52	-7.5 VDC	
51-39	+10 VDC	
38-26	+5.0 VDC TLM	
25-13	Analog Ground	
12-0	Analog Ground	
Minor Frame 63		
259-247	HIRS/2 Line Count	
246-245	Zero Fill	
244-242	Serial Number	
241-234	Command Status	
233-229	Fill Zeroes	
228-221	Command Status	
	Binary Code	Decimal Code
220-208	(1,1,1,1,1,0,0,1,0,0,0,1,1)	+3875
207-195	(...)	+1443
194-182	(...)	-1552
181-169	(...)	-1882
168-156	(...)	-1631
155-143	(...)	-1141
142-132	(...)	-1125
131-117	(...)	-3655
116-104	(...)	-2886
103-91	(...)	-3044
90-78	(...)	-3764
77-65	(...)	-3262
64-52	(...)	-2283
51-39	(...)	-2251
38-26	(...)	+3214
25-13	(...)	+1676
12-0	(...)	+1992

The 64 bytes of the **minor frame quality** field contains data quality information for each of the 64 minor frames making up a scan line. The format for each byte is contained in Table 4.1.2.1-5.

Table 4.1.2.1-5. HIRS/2 minor frame quality field format.	
Bit	**Description**
7	TIME ERROR - This 44-byte group contains data that is suspect due to a time error.
6	MISSING DATA - This 44-byte group contains data fill due to a data gap.
5	DWELL DATA - This 44-byte group contains data fill due to a TIP dwell condition.
4	DACS - This 44-byte group contains data that is suspect due to DACS QC error(s) (DROP LOCK, SYNC ERROR, FLYWHEEL, BIT SLIP, TIP PARITY).
3	MIRROR LOCKED - The mirror was determined as locked during this minor frame.
2	MIRROR POSITION ERROR - A scan mirror sequencing error was detected during this minor frame.
1	SLEW INDICATOR - The mirror was moving during this minor frame. This includes normal movement (e.g., moving between targets).
0	PARITY BIT - Minor word parity bit (odd parity). This is not an error indicator.

The 16-bit unpacked data format for full copy HIRS/2 data has the same format as the "packed" data described above except for the format of the HIRS/2 channel data. Also, the minor frame quality has the same format as described above but it starts on the first halfword (16 bits) boundary following the end of the HIRS/2 channel data.

The channel data itself (contained in halfwords 3-22 when all channels are requested) will be packed in consecutive halfwords for TIP minor frames 0-55. The other eight minor frames (56-63) still retain their 44-byte format. The unpacked data format for full copy HIRS/2 data is shown in Table 4.1.2.1-6. Note that the order of the channels is the same as for the packed format in Section 4.1.2.1. The record for the HIRS/2 full copy unpacked data format contains 3620 bytes.

Table 4.1.2.1-6. Format for unpacked full copy HIRS/2 data.			
Minor Frame #	**Byte #**	**Bit #**	**Content**
0-55	1-2	15-13	Zero filled
		12-0	Channel 1 data value
	3-4	15-13	Zero filled
		12-0	Channel 17 data value
	5-6	15-13	Zero filled
		12-0	Channel 2 data value
	...	...	...
	39-40	15-13	Zero filled
		12-0	Channel 9 data value
56-63	...	285-0	See Table 4.1.2.1-4 for bit description

4.1.2.2 **Selective Extract Subsets**

When channels are selected for HIRS/2 data, the format is like that described in Section 4.1.2.1, except that the format of the HIRS/2 channel data changes. Also, the minor frame quality has the

same format described in Section 4.1.2.1 but it starts on the first halfword (16 bits, half of a 32-bit word) boundary following the end of the HIRS/2 channel data.

The channel data itself (contained in halfwords 3-22 when all channels are requested) will be packed in consecutive halfwords for TIP minor frames 0-55 (corresponding to the 56 FOVs per scan). The other eight minor frames (56-63) will still retain their 44-byte format. Note: The channels will be in ascending order when packed into the record. Table 4.1.2.2-1 shows the structure of the HIRS channel data when two channels (1 and 2) are selected.

Table 4.1.2.2-1. Format of the HIRS/2 channel data for two-channel select.

Minor Frame #	Bit #	Content
0-55	31-29	Zero Filled
	28-16	Channel 1 Data Value
	15-13	Zero Filled
	12-0	Channel 2 Data Value
56-63	285-0	See Table 4.1.2.1-4 for bit description

4.2 SSU Data

This section describes the Stratospheric Sounding Unit (SSU), its data characteristics, and magnetic tape formats. Section 4.2.1 contains a description of the SSU instrument and its data characteristics. Section 4.2.2 contains the tape formats for full data set copies, 16-bit unpacked format, and selective extract subsets.

4.2.1 Instrument Description and Data Characteristics

The SSU is a step-scanned far-infrared spectrometer with three channels in the 15 micrometer carbon dioxide absorption band (the SSU instruments have been contributed to the TIROS-N series satellites by the British government). It makes use of the pressure modulation technique to measure radiation emitted from carbon dioxide at the top of the Earth's atmosphere. The principles of operation are based on the selective chopper radiometer flown on Nimbus 4 and 5, and the pressure modulator radiometer flown on Nimbus 6. The three SSU channels have the same frequency, but different cell pressures, as shown in Table 4.2.1-1.

Table 4.2.1-1. Cell pressures of the SSU channels.

Channel #	Central Wave # (cm-1)	Cell Pressure (mb)	Pressure of Weighting Function Peak (mb)	Typical NEdN*
1	668	100	15	0.30
2	668	35	5	0.40
3	668	10	1.5	1.00
* NEdN is Noise Equivalent differential radiance (mW/(m2-sr-cm-1))				

The SSU consists of a single primary telescope with a 10 degree IFOV which is step-scanned perpendicular to the satellite subpoint track. Each scan line is composed of eight individual 4.0

second steps and requires a total of 32 seconds, including time for the mirror retrace. The 10 degree IFOV gives a resolution of 147 km at the satellite subpoint and the stepping produces an underlap between adjacent scan lines of approximately 62 km at nadir. A calibration sequence is initiated every 256 seconds (8 scans) during which the radiometer is in turn, stepped to a position to view unobstructed space and an internal blackbody at a known temperature. This calibration mode is synchronized with the HIRS/2 instrument.

Data is sampled at the rate of 40 samples per second, and is digitized to 12-bit precision. Therefore, the SSU data rate is 480 bits per second.

4.2.2 Magnetic Tape Formats

The data set format for full data set copies (all channels) is different from the format for selective extract subsets (selected channels). Sections 4.2.2.1 and 4.2.2.2 contain formats for SSU full data set copies and SSU selective extract subsets, respectively. Section 4.2.2.1 also includes the unpacked format for SSU data.

4.2.2.1 Full Data Set Copies

Each SSU data set normally contains an individual satellite recorder playback. Data within each SSU data set are in chronological order with one record for each SSU scan. Each record is written in binary and contains 2498 bytes in the format as shown in Table 4.2.2.1-1.

Table 4.2.2.1-1. Format of SSU data.

Byte #	# Bytes	Content
1-2	2	Identifier Field
3-4	2	Scan Line
5-10	6	Time Code
11-14	4	Scan Quality Indicator
15-16	2	Earth Location Delta
17-112	96	Calibration Coefficients
113-116	4	Height and Local Zenith Angle
117-148	32	Earth Location Data
149-2068	1920	SSU Data
2069-2100	32	Scan Position Quality
2101-2498	398	Spare

The **identifier field** contains the Spacecraft ID in the first byte (see Spacecraft ID in Section 2.0.1) and the SSU data set code in the second byte. The SSU data set code is always the number 7.

The **scan line**, **time code**, and **height and Local Zenith Angle** fields have the same format as the HIRS/2 data in Section 4.1.2.1.

The **scan quality information** is contained in four bytes. The first two bytes contain processing detected conditions, the third byte contains DACS quality indicators, and the last byte is spare. The scan quality indicators contain a summary of the quality of the 320 TIP minor frames which make up an SSU scan. The definition of the quality bytes is contained in Table 4.2.2.1-2.

Table 4.2.2.1-2. Format of the SSU scan quality information.

Byte	Bit	Definition
1	7	FATAL FLAG - Data should not be used for product generation.
	6	DATA GAP - A data gap of one or more scans precedes this scan.
	5	DATA FILL - The scan contains partial data fill. Each halfword of data fill is set to hex AFFFF@.
	4	DWELL - Data gap was due to dwell data.
	3	TIME ERROR - This scan contains data that is suspect due to time error(s).
	2	DACS - This scan contains data that is suspect due to DACS QC.
	1	NO EARTH LOCATION - Earth location data not available.
	0	EARTH LOCATION DELTA - Predicted less actual time exceeds tolerance of 3 seconds.
2	7	CALIBRATION - Insufficient data was collected to calibrate this scan, for at least one channel. On TIROS-N, Channel 3 was not working properly and this bit is set quite often. However, calibration data for the other two channels is current.
	6	SPACE VIEW - This scan contains space view data.
	5	BLACKBODY VIEW - This scan contains blackbody view data.
	4	MIRROR LOCKED - The mirror was in a locked position during this scan. Normal Earth scanning was disrupted.
	3	SCAN SEQUENCE - A scan mirror sequence error was detected during this scan.
	2	MIRROR SYNC - Mirror sync was lost during this scan. Normal Earth scanning was disrupted.
	1	LINEARITY - ADC non-linearity was detected during this scan. Usually not an error unless detected continuously.
	0	SPARE
3	7	BIT SYNC STATUS - Drop lock during this scan. The scan line is suspect.
	6	SYNC ERROR - Number of bit errors in frame sync was non-zero during this scan. The scan line is suspect.
	5	FRAME SYNC LOCK - Frame sync lock during this scan.
	4	FLYWHEELING - Flywheeling detected during this scan. The scan line is suspect.
	3	BIT SLIPPAGE - Bit slippage detected during this scan. The scan line is suspect.
	2	TIP PARITY - DACS TIP parity detected during this scan. The scan line is suspect.
	1	AUXILIARY FRAME SYNC ERRORS - The number of bit errors in

		auxiliary frame sync was non-zero during this scan. The scan line is suspect.
	0	SPARE
4	7-4	MAJOR TIP FRAME (0-7) from which this scan was generated.
	3-0	SPARE

The **Earth location delta** contains the time difference between the scan time code and the time code associated with the Earth location data appended to this record. The value is right-justified in the two bytes and is in milliseconds.

The **calibration coefficients** for SSU data contain three groups. Each group contains coefficients for all three channels. The first group of 24 bytes contains the manual calibration slope and intercept coefficients. The second group of 24 bytes contains the auto calibration slope and intercept coefficients. The third group of 48 bytes contains the normalization coefficients, stored in ascending order. Each value is stored in four bytes and contains a scaled number of fractional bits. The scaling factor for the lowest order coefficients, the constants, is 2^{22} , with increasing order coefficients scaled by 2^{30}, 2^{44} and 2^{56}, respectively. All fields for non-computed values are set to zero. The coefficients are stored as shown in Table 4.2.2.1-3.

Table 4.2.2.1-3. Storage of SSU calibration coefficients.
Channel 1 manual slope coefficient
Channel 1 manual intercept coefficient
Channel 2 manual slope coefficient
...
Channel 1 auto slope coefficient
Channel 1 intercept coefficient
Channel 2 auto slope coefficient
...
Channel 1 normalization coefficient 1 (0th order term)
Channel 1 normalization coefficient 2 (1st order term)
Channel 1 normalization coefficient 3 (2nd order term)
Channel 1 normalization coefficient 4 (3rd order term)
Channel 2 normalization coefficient 1 (0th order term)
...

See Section 4.5 on how to use the SSU calibration coefficients. The Earth location field contains the latitude and longitude for each of the 8 Earth FOVs in the scan. The latitude and longitude values are stored in the two-byte fields in 128ths of a degree. The Earth location data is ordered as follows: FOV 1 latitude, FOV 1 longitude, FOV 2 latitude, FOV 2 longitude, etc.

Each TIP minor frame contains six bytes (3 two-byte pairs) of **SSU data**. The data is organized into 60-byte groups (10 TIP minor frames) and placed in the SSU Level 1b data set. Each 60-byte group contains data for one-fourth of an SSU FOV so that each SSU data set record contains 32 of the 60-byte groups. The order of the data in each 60-byte group is defined in Table 4.2.2.1-4.

Table 4.2.2.1-4. Format of each 60-byte group of SSU data.		
SSU Data	**Bytes**	**Tip Minor Frame**
Digital Word 1	1,2	1
Digital Word 2	3,4	
Digital Word 3	5,6	
Space Port Temperature	7,8	2
Earth Port Temperature	9,10	
PMC Bulkhead Temperature	11,12	
Detector Temperature	13,14	3
Blackbody Temperature (Space Side)	15,16	
Blackbody Temperature (Sun Side)	17,18	
Cell Temperature Channel 1	19,20	4
Cell Temperature Channel 2	21,22	
Cell Temperature Channel 3	23,24	
Base Plate Temperature	25,26	5
Middle Bulkhead Temperature	27,28	
Optics Baseplate Temperature	29,30	
Signal Output Channel 1	31,32	6
Signal Output Channel 2	33,34	
Signal Output Channel 3	35,36	
Thermistor Reference	37,38	7
Mirror Fine Position	39,40	
Blackbody Temperature (Point)	41,42	
PMC Amplitude Channel 1	43,44	8
PMC Amplitude Channel 2	45,46	
PMC Amplitude Channel 3	47,48	
ADC Calibration 5% of Full Scale	49,50	9
ADC Calibration 50% of Full Scale	51,52	
ADC Calibration 90% of Full Scale	53,54	
Signal Output Channel 1	55,56	10
Signal Output Channel 2	57,58	
Signal Output Channel 3	59,60	

The **scan position quality** is contained in 32 bytes, one byte for each 60-byte group of SSU data. The definition of the quality byte is contained in Table 4.2.2.1-5.

Table 4.2.2.1-5. Definition of the scan position quality for SSU data.		
Byte	**Bit**	**Definition**
1	1	TIME ERROR - This 30-word group contains data that is suspect due to a time error.

	2	MISSING DATA - This 30-word group contains data fill due to a data gap.
	5	DWELL - This 30-word group contains data fill due to a dwell condition.
	4	DACS - This 30-word group contains data that is suspect due to DACS QC error(s) (DROP LOCK, SYNC ERROR, FLYWHEEL, BIT SLIP, TIP PARITY).
	5	SCAN SEQUENCE ERROR - A scan mirror position sequence error was detected for this 30-word block.
	6	MIRROR SYNC ERROR - The mirror sync was lost during this 30-word block.
	7-8	SPARE

The unpacked format for a full copy SSU data set is very similar to the "packed" format described above except for the field containing the SSU data. The signal output for each selected channel (contained in TIP minor frames 6 and 10) is substituted for the complete SSU data field. The unpacked full copy SSU data field has the format shown in Table 4.2.2.1-6. Note: the 400 spare bytes have been eliminated, so the unpacked full copy SSU data record contains only 564 bytes.

Table 4.2.2.1-6. Format of unpacked full copy SSU data.

Byte #	# Bytes	Content
149-150	2	Signal Output Channel 1, Group 1, TIP Minor Frame 6
151-152	2	Signal Output Channel 2, Group 1, TIP Minor Frame 6
153-154	2	Signal Output Channel 3, Group 1, TIP Minor Frame 6
155-156	2	Signal Output Channel 1, Group 1, TIP Minor Frame 10
157-158	2	Signal Output Channel 2, Group 1, TIP Minor Frame 10
159-160	2	Signal Output Channel 3, Group 1, TIP Minor Frame 10
161-162	2	Signal Output Channel 1, Group 2, TIP Minor Frame 6
...	...	...
527-528	2	Signal Output Channel 1, Group 32, TIP Minor Frame 10
529-530	2	Signal Output Channel 2, Group 32, TIP Minor Frame 10
531-532	2	Signal Output Channel 3, Group 32, TIP Minor Frame 10
533-564	32	Scan position quality

4.2.2.2 **Selective Extract Subsets**

When channels are selected for SSU data sets, the format of the SSU data is the only field that changes from the format described in Section 4.2.2.1. The signal output for each selected channel (contained in TIP minor frames 6 and 10) is substituted for the complete SSU data field. One or two channels can be selected for the SSU data sets. If Channels 2 and 3 were selected, the SSU data field would have the format shown in Table 4.2.2.2-1. Immediately following the SSU data values, the scan position quality is written starting on the next halfword boundary.

Table 4.2.2.2-1. Format of SSU data field when Channels 2 and 3 are selected.

Byte #	# Bytes	Content

149-150	2	Signal Output Channel 2, Group 1, TIP Minor Frame 6
151-152	2	Signal Output Channel 3, Group 1, TIP Minor Frame 6
153-154	2	Signal Output Channel 2, Group 1, TIP Minor Frame 10
155-156	2	Signal Output Channel 3, Group 1, TIP Minor Frame 10
157-158	2	Signal Output Channel 2, Group 2, TIP Minor Frame 6
...	...	...
397-398	2	Signal Output Channel 2, Group 32, TIP Minor Frame 6
399-400	2	Signal Output Channel 3, Group 32, TIP Minor Frame 6
401-402	2	Signal Output Channel 2, Group 32, TIP Minor Frame 10
403-404	2	Signal Output Channel 3, Group 32, TIP Minor Frame 10

4.3 MSU Data

This section describes the Microwave Sounding Unit (MSU), its data characteristics, and magnetic tape formats. Section 4.3.1 contains a description of the instrument and its data characteristics. Section 4.3.2 describes the tape formats for full data set copies, 16-bit unpacked format, and selective extract subsets.

4.3.1 Instrument Description and Data Characteristics

MSU is a passive scanning microwave spectrometer with four channels in the 5.5 micrometer oxygen region. The four channels respond to the following respective spectral frequencies: 50.3, 53.74, 54.96, and 57.95 GHz with a channel bandwidth of 200 MHz in each case, and a typical NEdT of 0.3 K. The MSU sensors consist of two four-inch diameter antennas, each having an IFOV of 7.5 degrees. The antennas are step-scanned through eleven individual 1.84-second Earth viewing steps and require a total of 25.6 seconds to complete. The 124 km IFOV resolution at the subpoint creates an underlap of approximately 115 km between adjacent scan lines. See Table 4.0-1.

The MSU data output represents an apparent brightness temperature after a 1.84-second integration period per step. The data is quantized to 12-bit precision and combined with telemetry and step position information to produce an effective output data rate of 320 bits per second.

Unlike the HIRS/2 and SSU instruments, the MSU has no special calibration sequence that interrupts normal scanning. The calibration data is included in a scan line of data. From the last Earth view position, the reflector rapidly moves 4 steps to view space, 10 additional steps to view the housing, and then returns to the home position to begin another scan line. Since each scan line requires 25.6 seconds, synchronization of MSU within the other two TOVS instruments occurs every 128 seconds (5 scan lines).

4.3.2 Magnetic Tape Formats

The data set format for full data set copies (all channels) is different from the format for selective extract subsets (selected channels). Sections 4.3.2.1 and 4.3.2.2 contain formats for MSU full

data set copies and MSU selective extract subsets, respectively. Section 4.3.2.1 also includes the unpacked format for MSU data (all channels).

4.3.2.1 **Full Data Set Copies**

Each MSU data set normally contains an individual satellite recorder playback. Data within each MSU data set are in chronological order with one record for each MSU scan. Each record is written in binary and contains 437 bytes. Table 4.3.2.1-1 contains the format for the MSU data.

Table 4.3.2.1-1. Format of MSU Data.

Byte #	# Bytes	Content
1-2	2	Scan Line
3-8	6	Time Code
9-12	4	Scan Quality Indicators
13-16	4	Earth Location Delta
17-112	96	Calibration Coefficients
113-116	4	Height and Local Zenith Angle
117-160	44	Earth Location Data
161-384	224	MSU Data
385-400	16	Scan Position Quality
401-437	37	Spare

The **scan line**, **time code**, and **height and Local Zenith Angle** fields have the same format as the HIRS/2 data in Section 4.1.2.

The **scan quality** information is stored in four bytes. The first two bytes contain processing detected conditions, the third byte contains DACS quality indicators, and the last byte is spare. The scan quality indicators contain a summary of the quality of the 256 TIP minor frames which make up a MSU scan. The definition of the quality bytes is contained in Table 4.3.2.1-2.

Table 4.3.2.1-2. Format of the MSU scan quality bytes.

Byte	Bit	Definition
9	7	FATAL FLAG - Data should not be used for product generation.
	6	DATA GAP - A data gap of one or more scans precedes this scan.
	5	DATA FILL - This scan contains partial data fill due to missing data. Each halfword of fill is set to hex A7FFF@.
	4	DWELL - Data gap and/or data fill was due to dwell data.
	3	TIME ERROR - This scan contains data that is suspect due to time error(s).
	2	DACS - This scan contains data that is suspect due to DACS QC.
	1	NO EARTH LOCATION - Earth location data not available.
	0	EARTH LOCATION DELTA - Predicted less actual time exceeds tolerance of 3 seconds.
10	7	CALIBRATION - Insufficient data was collected to calibrate this scan, for at

		least one channel. If calibration coefficients are available, they will be old coefficients.
	6-5	SPARE
	4	SCAN DISABLE - The scan disable condition was detected during this scan. Normal Earth scanning was disrupted. Scan line is suspect.
	3	SCAN SEQUENCE - A scan mirror sequence error was detected during this scan.
	2	MIRROR SEQUENCE - A mirror sequence error was detected during this scan.
	1-0	SPARE
11	7	BIT SYNC STATUS - Drop lock during this scan. Scan line is suspect.
	6	SYNC ERROR - Frame sync word error greater than zero during this scan.
	5	FRAME SYNC LOCK - Frame sync lock during this scan.
	4	FLYWHEELING - Flywheeling detected during this scan.
	3	BIT SLIPPAGE - Bit slippage detected during this scan.
	2	TIP PARITY - DACS TIP parity detected during this scan.
	1	AUXILIARY FRAME SYNC ERRORS - The number of bit errors in auxiliary frame sync was non-zero during this scan.
	0	SPARE
12	7-4	MAJOR FRAME COUNTER
	3-0	SCAN SEQUENCE COUNTER - Number (0-4) of scan position within the 128-second cycle.

The **Earth location delta** field contains the time differences between the scan time code and the time code associated with Earth location data appended to this record. The value, in milliseconds, is right-justified in the four bytes.

The **calibration coefficient** field contains two groups of calibration coefficients. Each group contains coefficients for all four channels. The first group of 32-bytes contains the calibration slope and intercept coefficients stored in ascending order. Each value is stored in four bytes and contains a scaled number of fractional bits. The scaling factor for the lowest order coefficients, the constants, is 2^{22}, with increasing order coefficients scaled by 2^{30}, 2^{44} and 2^{56}, respectively. See Section 4.5 on how to use MSU calibration coefficients. The coefficients for MSU are stored as shown in Table 4.3.2.1-3.

Table 4.3.2.1-3. Order of MSU calibration coefficients.
Channel 1 slope coefficient (1st order term)
Channel 1 intercept coefficient (0th order term)
Channel 2 slope coefficient (1st order term)
...
Channel 1 normalization coefficient 1 (0th order term)
Channel 1 normalization coefficient 2 (1st order term)
Channel 1 normalization coefficient 3 (2nd order term)

Channel 1 normalization coefficient 4 (3rd order term)
Channel 2 normalization coefficient 1 (0th order term)
...

The **Earth location** field contains the latitude and longitude for each of the 11 Earth FOVs in the scan. The latitude and longitude values are stored in two-byte fields in 128ths of a degree. The order of this data is: FOV 1 latitude, FOV 1 longitude, FOV 2 latitude, FOV 2 longitude, etc.

The **MSU data** is extracted from the TIP frames (256 TIP minor frames per MSU scan), all zero words are discarded, and the meaningful 224 bytes (112 halfword groups) are organized by scan position and placed in the Level 1b MSU data set as shown in Table 4.3.2.1-4.

Table 4.3.2.1-4. Format of MSU data.

TELEMETRY				EARTH VIEW				
Scan Spot	**Instrument Voltages**	**Instrument Temperature**	**Instrument Temperature**	**Channel 1 Data**	**Channel 2 Data**	**Channel 3 Data**	**Channel 4 Data**	**Scan Position Line Count (2)**
1	INSTR. SER. # [0]	T1 CAL LO [1]	T2 CAL LO [2]	CH.1 DATA [3]	CH.2 DATA [4]	CH. 3 DATA [5]	CH. 4 DATA [6]	SCAN POS 0 SCAN CT [7]
2	E CAL LO [8]	T1 CAL HI	T2 CAL HI	A	A	A	A	SCAN POS 1 SCAN CT [15]
3	F CAL HI [16]	OTHER 1 TEMP	OTHER 2 TEMP	A	A	A	A	[23]
4	XTAL 1+ [24]	LO 1 TEMP	LO 2 TEMP	A	A	A	A	[31]
5	XTAL 1- [32]	LO 3 TEMP	LO 4 TEMP	A	A	A	A	[39]
6	XTAL 2+ [40]	DICKE LOAD 1 TEMP	DICKE LOAD 2 TEMP	A	A	A	A	[47]
7	XTAL 2- [48]	DICKE LOAD 3 TEMP	DICKE LOAD 4 TEMP	A	A	A	A	[55]
8	XTAL 3+ [56]	TARGET 1A TEMP	TARGET 1B TEMP	A	A	A	A	[63]
9	XTAL 3- [64]	TARGET 2A TEMP	TARGET 2B TEMP	A	A	A	A	[71]
10	XTAL 4+ [72]	ANTENNA 1 BEARING TEMP	ANTENNA 2 BEARING TEMP	A	A	A	A	[79]
11	XTAL 4- [80]	MOTOR TEMP	MOTOR TEMP	A	A	A	A	[87]
SPACE VIEW	-15 +5 VOLTS [88]	RF CHASSIS	RF CHASSIS	A	A	A	A	[95]
BLACK BODY VIEW	+5 VOLTS [96]	PROG TEMP	PROG TEMP	A	A	A	A	SCAN POS 12 SCAN CT [103]

SCAN TO SPOT #1	E ZERO [104]	PROG TEMP [105]	PROG TEMP [106]	CH 1 REF [107]	CH 2 REF [108]	CH 3 REF [109]	CH 4 REF [110]	SCAN POS X SCAN CT [111]
Note: All 12-bit words; 112 words = 1 scan line = 25.6 seconds. Counts to 5 and resets every 128 seconds. Numbers in brackets[ ] indicate the halfword number.								

The bit description for the MSU data is described in Tables 4.3.2.1-5 and 4.3.2.1-6.

a) Typical Format for all words except Scan Position-Line Count is described in Table 4.3.2.1-5.

Table 4.3.2.1-5. Typical format for all MSU words (except scan position-line count).

Bit position	Description
1 (MSB)	= 1 when word is a Areal@ word; = 0 only for an Aall zero@ word.
1	= 1 when it is the first word in a scan; = 0 at all other words.
0	= 0 for the first 6 words.
Z	= 1 when in zero reference disable mode; = 0 at all other times.
D11	Data
D10	Data
D9	Data
D8	Data
D7	Data
D6	Data
D5	Data
D4	Data
D3	Data
D2	Data
D1	Data
D0 (LSB)	Data

b) Scan Position - Line Count (Word 7) is described in Table 4.3.2.1-6.

Table 4.3.2.1-6. Format of MSU scan position - line count (Word 7).

Bit Position	Description
1 (MSB)	= 1 when the word is a Areal@ word
0	= 0 when this is not the first word in a scan.
1	= 1 when this is the 8th word in the scan position.
Z	= 1 when in zero reference disable mode.

S	= 1 when in scan disabled mode; = 0 at all other times.
R2	Scan line count (reset by 128 sec sync).
R1	Scan line count
R0	Scan line count
E7	Scan angle (position) data
E6	Scan angle (position) data
E5	Scan angle (position) data
E4	Scan angle (position) data
E3	Scan angle (position) data
E2	Scan angle (position) data
E1	Scan angle (position) data
E0 (LSB)	Scan angle (position) data

The **scan position quality** is contained in 16 bytes. The first 14 bytes contain quality information for each of the 14 MSU scan positions. The last two bytes are spares. The definition of the quality byte for each scan position is contained in Table 4.3.2.1-7.

Table 4.3.2.1-7. Format of the MSU scan position quality.

Byte	Bit	Definition
1	7	TIME ERROR - This scan line position contains data that is suspect due to a time error.
	6	MISSING DATA - The scan line position contains data fill due to a data gap. Each halfword of data fill is set to hex A7FFF@.
	5	DWELL - This scan line position contains data fill due to a dwell condition.
	4	DACS - This scan line position contains data that is suspect due to DACS QC error(s) (DROP LOCK, SYNC ERROR, FLYWHEEL, BIT SLIP, TIP PARITY).
	3	SCAN DISABLED - The instrument was in the scan disable condition during this scan line position. Normal Earth scanning is disrupted.
	2	SCAN SEQUENCE - A scan sequence error was detected in this scan line position. Normal Earth scanning may be disrupted.
	1	MIRROR SEQUENCE - A mirror sequence error was detected in this scan line position.
	0	SPARE

The 16-bit unpacked format for full copy MSU data has the same format as the "packed" data described above except for the MSU channel data field. The unpacked format for full copy MSU data for the channel data field has the format shown in Table 4.3.2.1-8. Note that the 40 bytes of spare have been eliminated and the record length is 280 bytes.

Table 4.3.2.1-8. Unpacked format for full copy MSU data (channel data field).

Byte #	.# Bytes	Content

161-162	2	Channel 1, scan spot 1
163-164	2	Channel 2, scan spot 1
165-166	2	Channel 3, scan spot 1
167-168	2	Channel 4, scan spot 1
169-170	2	Channel 1, scan spot 2
...	...	...
247-248	2	Channel 4, scan spot 11
249-250	2	Channel 1, Space view
251-252	2	Channel 2, Space view
253-254	2	Channel 3, Space view
255-256	2	Channel 4, Space view
257-258	2	Channel 1, Blackbody view
259-260	2	Channel 2, Blackbody view
261-262	2	Channel 3, Blackbody view
263-264	2	Channel 4, Blackbody view
265-280	16	Scan position quality

4.3.2.2 **Selective Extract Subsets**

When channels are selected for MSU data sets, the format of the MSU channel data is the only field that changes from the format described in Section 4.3.2.1. One, two, or three channels can be selected for the MSU data sets. Table 4.3.2.2-1 shows the format of the MSU data field when Channels 1 and 4 are selected. Immediately following the MSU channel values, the scan position quality is written starting in the first available halfword.

Table 4.3.2.2-1. Format of MSU data field if Channels 1 and 4 are selected.

Byte #	# Bytes	Content
161-162	2	Channel 1, scan spot 1
163-164	2	Channel 4, scan spot 1
165-166	2	Channel 1, scan spot 2
167-168	2	Channel 4, scan spot 2
...	...	...
201-202	2	Channel 1, scan spot 11
203-204	2	Channel 4, scan spot 11
205-206	2	Channel 1, Space view
207-208	2	Channel 4, Space view
209-210	2	Channel 1, Blackbody view
211-212	2	Channel 4, Blackbody view

4.4 **SBUV/2 Data**

This section describes the instrument and data characteristics of the Solar Backscattered Ultraviolet system/Version 2 (SBUV/2). Section 4.4.1 contains a description of the instrument

and data characteristics. Section 4.4.2 contains general information about the actual data for the three types of SBUV/2 data archived by SSB: 1) Level 1b; 2) Historical Instrument File; and 3) Product Master File. Tape formats are not included in this document but are thoroughly covered in a separate document entitled: *Solar Backscattered Ultraviolet Radiometer Version 2 (SBUV/2) User's Guide (November 15, 1990).*

4.4.1 Instrument Description and Data Characteristics

The SBUV/2 is an operational remote sensor designed to map total ozone concentrations and the vertical distribution of ozone in the earth's atmosphere on a global scale. The purpose of the SBUV/2 instrument is to provide data on an operational basis, from which the distribution of ozone can be determined on the ground. The SBUV/2 system was chosen by NOAA because of the precision and reliability demonstrated by its predecessors, the SBUV and BUV, developed by NASA and flown on the NIMBUS-7 and NIMBUS-4 satellites, respectively.

The SBUV/2 contains a scanning double monochromator and a cloud cover radiometer (CCR) designed to measure ultraviolet (UV) spectral intensities. In its primary mode of operation, the monochromator measures solar radiation Backscattered by the atmosphere in 12 discrete wavelength bands in the near-UV, ranging from 252.0 to 339.8 nanometers (nm), each with a bandpass of 1.1 nm. The total-ozone algorithm uses the four longest wavelength bands (312.5, 317.5, 331.2 and 339.8 nm), whereas the profiling algorithm uses the shorter wavelengths. The cloud cover radiometer operates at 379 nm (i.e., outside the ozone absorption band) with a 3.0 nm bandpass and was designed to measure the reflectivity of the surface in the IFOV. The SBUV/2 also makes periodic measurements of the solar flux by deploying a diffuser plate into the FOV to reflect sunlight into the measurement.

The monochromator and the cloud cover radiometer are mounted so that they look in the nadir direction with coincident FOV's of 11.3 by 11.3 degrees. As the satellite moves in a sun synchronous orbit, the FOV traces 160 km wide paths on the ground. The earth rotates approximately 26 degrees during each orbit. The satellite footprint moves at a speed of about 6 km/sec. In discrete mode, a set of 12 measurements, one for each discrete wavelength band, is taken every 32 seconds. The order of measurements is 252.0 to 339.9 nm and the integration time is 1.25 seconds per measurement. For each monochromator measurement, there is a cloud cover radiometer measurement.

The SBUV/2 instrument can also measure the solar irradiance or the atmospheric radiance with a continuous spectral scan from 160 to 400 nm in increments of nominally 0.148 nm.

4.4.2 Magnetic Tape Formats

Three operational products based on the data collected from the SBUV/2 instrument (on NOAA-9 and NOAA-11) are archived and available through SSB. All products are archived on IBM 3480 cartridges. The NOAA-9 SBUV/2 data (Level 1b) have been reprocessed for data from 1985 to the present. For NOAA-9, SSB archives the reprocessed Level 1b data and the original Level 1b,

and HIF data (no PMF). The NOAA-11 Level 1b data has been reprocessed and is available in the archive (original Level 1b not available).
SSB has no selection software for any type of SBUV/2 data. Tape-to-tape copies of the data is the only option available at this time. Each of the three types of SBUV/2 data is stored on one IBM 3480 cartridge per month of data.

4.4.2.1 **Level 1b Data Set**

The Level 1b data set contains: 1) all SBUV/2 sensor data and support data necessary for the derivation of atmospheric ozone and solar flux; 2) instrument in-flight calibration data and housekeeping functions for monitoring post-launch instrument changes; and 3) prelaunch calibration factors, and computed current-day instrument calibration and albedo correction factors to adjust the ozone algorithm for actual instrument performance.

The SBUV/2 sensor data consists of radiance and irradiance measurements taken in both the discrete mode (12 wavelengths) and the sweep mode (1680 wavelengths at approximately 2Δ intervals). The support data includes cloud and temperature data from TOVS, ancillary data to initialize the algorithm, surface pressure data, and snow/ice data.

4.4.2.2 **Product Master File**

The Product Master File (PMF) contains the ozone information derived by the algorithm, located in space and time, other meteorological information developed in support of the ozone computation, parameters indicating the validity of the individual ozone retrievals, and the radiance information derived from the SBUV/2 measurements.

4.4.2.3 **Historical Instrument File**

The Historical Instrument File (HIF) is a collection of data files, created by the Instrument Support Subsystem which provide the data to characterize the instrument performance and albedo correction over time.

4.5 **Calibration of TOVS Data**

TOVS thermal data values (HIRS/2 Channels 1-19, SSU Channels 1-3, and MSU Channels 1-4) may be converted to brightness temperatures, and TOVS visible data values (HIRS/2 Channel 20) may be converted to percent albedo, by the following calibration procedures.

The format and order of the calibration coefficients is described in Sections 4.1.2.1, 4.2.2.1, 4.3.2.1 for HIRS/2, SSU, and MSU data, respectively. Once the calibration coefficients have been extracted they must be scaled and normalized in that order. The scale factors for the coefficients from lowest to highest in order are 2^{22}, 2^{30}, 2^{44} and 2^{56}. (The 0th order term is a constant or in this case the intercept value, and has a scale factor of 2^{22}. Similarly, the 3rd order term has a scale factor of 2^{56}.) To scale the raw calibration values, they must be divided by their

respective scale factor. HIRS/2 users should refer to adjustments necessary to obtain correct intercept values in Section 4.1.2.1.

Once the coefficients have been scaled, the raw data (in counts) should be normalized or corrected for non-linearity by using the normalization coefficients which are supplied with the calibration coefficients. The equation for the normalized count value C_i= is as follows:

$$C_i^{'} = L_{i,0} + L_{i,1} C + L_{i,2} C^2 + L_{i,3} C^3 \qquad 4.5\text{-}1$$

where L is the normalization coefficient, C is the raw data in counts, subscript i indicates the channel, and the subscripts 0, 1, 2, and 3 indicate the order of the normalization coefficient. This is a generalized equation since the HIRS/2 calibration coefficients do not contain a 3rd order normalization coefficient (i.e., drop the $L_{i,3} C^3$ term in Equation 4.5-1). When the condition of $L_{i,0} = 0$, $L_{i,1} = 1$, $L_{i,2} = 0$ and $L_{i,3} = 0$, is met, then C_i= = C_i . This means that channel i is linear and no non-linearity correction is necessary. At this time, the normalization coefficients for HIRS/2 and SSU data have this condition. The scaled calibration coefficients and normalized data may now be used as described below.

4.5.1 Thermal Channel Calibration

The scaled thermal channel zero order coefficients (intercept) are in units of mW/(m^2-sr-cm^{-1}) , the 1st order coefficients (slope) are in units of mW/(m^2-sr-cm^{-1}) per count, etc.

The radiance measured by the sensor (Channel i) is computed as a function of the input data value as follows:

$$E_i = A_{i,2} C_i^{'\,2} + A_{i,1} C_i^{'} + A_{i,0} \qquad 4.5.1\text{-}1$$

where E_i is the radiance value, in mW/(m^2-sr-cm^{-1}) , C_i= is the normalized count value (computed from Equation 4.5-1), A is the calibration coefficient (auto or manual), subscript i indicates the channel, and subscripts 0, 1 and 2 indicate the order of the calibration coefficients. The $A_{i,2} C_i$=^{2} term in Equation 4.5.1-1 should be dropped for SSU and MSU data.

For the SSU and MSU data, the conversion to "brightness" temperature from energy is performed using the inverse of Planck's radiation equation (which is Equation 3.3.1-2 in Section 3.3.1). The same values should be used for the constants C_1 and C_2, and the central wave number values can be found in Section 1.4 (see the corresponding subsection for the desired satellite).

For the conversion to "brightness" temperatures for the HIRS/2 data, the same procedure is followed as with the MSU and SSU data, except that a band correction algorithm must be applied to the results of the inverse of Planck's equation. The inverse of Planck's equation actually produces an apparent brightness temperature, T*, which is corrected using the following equation:

$$T = \frac{T^{*} - b}{c} \qquad 4.5.1\text{-}2$$

where T is the corrected brightness temperature, and b and c are the band correction coefficients which are supplied in Section 1.4 (see the corresponding subsection for the desired satellite).

4.5.2 **Visible Channel Calibration**

The scaled visible channel calibration values are in units of percent □lbedos for the zero order term (intercept), percent □lbedos/count for the 1st order term (slope), etc. The only visible channel for the TOVS is the HIRS/2 Channel 20, so the equation to compute the percent □lbedos, B, is as follows:

$$B = A_{20,2} C_{20}^{'\ 2} + A_{20,1} C_{20}^{'} + A_{20,0} \qquad 4.5.2\text{-}1$$

where A is the calibration coefficient (auto or manual), C_{20}' is the normalized count value for Channel 20, subscript 20 indicates Channel 20, and subscripts 0, 1, and 2 indicate the order of the calibration coefficients. At this time, the second order term ($A_{20,2} C_{20}'^{\,2}$) in Equation 4.5.2-1 can be dropped since $A_{20,2}$ is usually 0.