SSM/I Temperature Data Record (TDR) Data Sets

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1.0 Introduction

This README file contains information on the Special Sensor Microwave Imager (SSM/I) Temperature Data Record (TDR) data sets. Brief descriptions of the Defense Meteorological Satellite Program (DMSP) satellites, the SSM/I instrument, the computation of antenna temperatures and brightness temperatures and the format of the data sets are included. Included is the source code for three software programs. The first program, ssmitdrlatlon.c, extracts the portion of the daily file which contains a user specified latitude/longitude range. The second program, ssmitdrta.c, reads a NESDIS SSM/I TDR data file and outputs antenna temperatures. The third program, ssmitdrtb.f, converts the antenna temperatures produced by the second program into brightness temperatures. Pertinent scientific references are also included.

The Defense Meteorological Satellite Program (DMSP) is a Department of Defense program which is responsible for designing, building, launching and operating polar orbiting meteorological satellites. The SSM/I was first launched on June 19, 1987 aboard the DMSP Block 5D-2 Spacecraft F8. Since that time, additional launches have been made aboard DMSP Block 5D-2 Spacecraft F10 and DMSP Block 5D-2 Spacecraft F11. The F10 and F11 Spacecrafts are both still operational but the F8 Spacecraft has completed it's mission as of July 31, 1994. The launch aboard DMSP Block 5D-2 Spacecraft F13 was made in March 1995. Additionally the launch aboard DMSP Block 5D-2 Spacecraft F14 was made in early 1997.

Note: From March 19, 1997 - April 20, 1997 the F11 satellite was not operational.

The satellites can broadcast visual, infrared and microwave imagery directly to transportable tactical sites around the world. The data is also stored for transmission to the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) and to the Air Force Global Weather Central (AFGWC). The Naval Oceanography Command (NOC) and the Air Weather Service process the SSM/I data to obtain near real-time global maps of cloud water, rain rates, water vapor over oceans, marine wind speeds, sea ice location, age and concentration, snow water content and land surface type, moisture and temperature.

Each of the DMSP satellites fly in a sun-synchronous, near-polar orbit. For a satellite in sun synchronous orbit, the ascending equatorial crossing time remains relatively constant with respect to the local time throughout the lifetime of the satellite. The table below summarizes the orbits for each spacecraft (valid for the orbit shown).

Spacecraft	F-10	F-11	F-13
Launch Date	1 Dec 1990	28 Nov 1991	24 Mar 1995
Information Valid For	Rev 719	Rev 1276	Not Available
Ascending Equator Crossing Time (Local Time)	19:42	17:04	17:36
Inclination	98.8 Deg	98.8 Deg	98.8 Deg
Degrees Period	100.7 Min	101.9 Min	101.9 Min
Maximum Altitude	853 Km	878 Km	875 Km
Minimum Altitude	740 Km	841 Km	840 Km
Eccentricity	0.00814	0.00129	0.00075
Semi Major-Semi Minor	238 Meters	6 Meters	5 Meters
Distance	117 Km	19 Km	Not Available

2.0 Special Sensor Microwave Imager (SSM/I)

The information in this section is quoted from the DMSP Special Sensor Microwave /Imager Calibration/ Validation Report, Volume I, Hollinger, et al. (1989) and the DMSP SSM/I Calibration/Validation Report, Volume II, Hollinger, et al. (1990).

The SSM/I is a seven-channel, four-frequency, linearly-polarized, passive microwave radiometric system. The SSM/I receives both horizontally and vertically linearly polarized radiation at 19.3,37.0, and 85.5 GHz and vertical only at 22.2 GHz. The following table summarizes satellite specific instrument details.

Spacecraft	F-10	F-11	F-13
Launch Date	1 Dec 1990	28 Nov 1991	24 Mar 1995
Information Valid For	Rev 719	Rev 1276	Not Available
Instrument Viewing Direction	Forward	Forward	Forward
Maximum Swath Width	1427 Km	1483 Km	Not Available
Minimum Swath Width	1226 Km	1414 Km	Not Available
Maximum Incidence Angle	53.29 Deg	53.56 Deg	Not Available
Minimum Incidence Angle	52.10 Deg	53.16 Deg	Not Available
Maximum Incidence Angle Change for All Orbits	1.4 Deg	0.5 Deg	Not Available

2.1 Instrument Description

The information in this section is quoted from the DMSP Special Sensor Microwave /Imager Calibration/ Validation Report, Volume I, Hollinger, et al. (1989) and the DMSP SSM/I Calibration/Validation Report, Volume II, Hollinger, et al. (1990).

The SSM/I instrument consists of an offset parabolic reflector with dimensiions of 61 by 66 cm. This reflector is illuminated by a corrugated, broad-band, seven-port horn antenna. The feed-horn antenna and the reflector are mounted on a drum which contains the radiometers, digital data subsystem, mechanical scanning subsystem, and power subsystem. The entire feed-horn, reflector and drum assembly rotate about the axis of the drum by a coaxially mounted bearing and power transfer system (BAPTA). All data, commands, power, timing and telemetry signals pass through the BAPTA on slip ring connectors to the rotating assembly.

A small mirror and a hot reference absorber are mounted on the BAPTA and do not rotate with the drum assembly. They are positioned off axis such that they pass between the feed horn and the parabolic reflector, occulting the feed horn once each scan. The mirror reflects cosmic background radiation (3 K) into the feed horn thus serving, along with the hot reference absorber, as calibration references for the SSM/I. This scheme provides an overall end-to-end absolute calibration which includes the feed horn. The combination of the calibration scheme and the use of total power radiometers greatly improve the SSM/I performance in comparison with previous spaceborne radiometeric systems. Corrections for spillover and antenna pattern effects from the parabolic reflector are incorporated in the data processing algorithms.

The SSM/I employs a total-power radiometer configuration. A balanced mixer down-converts the output of the feed horn and amplifies it. Then a square-law detector converts that output to a video voltage. A bandpass filter defines the receiver passband and improves the out-of-band rejection. The component of receiver output due to receiver noise is removed through the amplification and offset of the detected video signal. The output of the video amplifier is integrated by an integrate and dump filter for 7.95 msec for all frequencies, except the 85.5 GHz frequency which is integrated for 3.89 msec. Following this integration, the output is delivered to the data processing system. The time between samples is the same for all frequencies (12.5 msec) except for the 85.5 GHz frequency (4.22 msec).

The data processor uses an anolog multiplexer to multiplex the seven radiometer output signals. The data processor then samples and holds the signals prior to them being digitized into 12-bit words. Twelve channels, which contain three hot target temperature measurements, two temperature sensor measurements within the radiometer, reference voltage, and reference return data, are multiplexed with radiometer data.

A microprocessor supervises instrument timing, control, and data buffering with the DMSP Operational Line Scanner (OLS) instrument (collocated on the satellite) which records all SSM/I data. The average data rate of the SSM/I including zeros required to match the OLS interface is 3276 bps.

2.2 Scan Geometry

The information in this section is quoted from the DMSP Special Sensor Microwave /Imager Calibration/ Validation Report, Volume I, Hollinger, et al. (1989) and the DMSP SSM/I Calibration/Validation Report, Volume II, Hollinger, et al. (1990).

The SSM/I continuously rotates about an axis paralled to the local spacecraft vertical at 31.6 rpm. The SSM/I measures, over an angular section of 102.4 degrees about the sub-satellite track, the upwelling scene brightness temperatures. When looking in the forward direction of the spacecraft, the scan is directed from left to right with active scene measurements lying 51.2 degree about the forward direction. The resulting swath width is 1400 km, which results in 24 hour global coverage. The spacecraft sub-satellite point travels 12.5 km during the 1.9 second period. For each scan, 128 uniformly spaced 85.5 GHz scene data are taken over a 102.4 degree scan region. The sampling interval is 4.22 msec and equals the time for the beam to travel 12.5 km in the cross track direction. Radiometer data at the remaining frequencies are sampled every other scan with 64 uniformly spaced samples being taken and have an 8.44 msec interval. Scan A denotes scans in which all channels are sampled and Scan B denotes scans in which only 85.5 GHz data are taken. The start and stop times of the integrate and dump filters at 19.35, 22.235, and 37.0 GHz are selected to maximize the radiometer integration time and achieve concentric beams for all sampled data. The effect of the radiometer integration times isto increase the effective along scan beam diameter and make the beams at 37 and 85 GHz nearly circular.

2.3 Antenna Beam Characteristics

The information in this section is quoted from the DMSP Special Sensor Microwave /Imager Calibration/ Validation Report, Volume I, Hollinger, et al. (1989) and the DMSP SSM/I Calibration/Validation Report, Volume II, Hollinger, et al. (1990).

The data in Table 2.1 apply to the S/N 002 Sensor on F-10 and F-11 and represents measurements of the instantaneous field of view (IFOV)3 dB beamwidths of the secondary radiation patterns as a function of the channel frequency and polarization for SSM/I. The data are based on measurements, taken prior to launch, of antenna temperatures which were averaged over the RF bands. An effective field of view (EFOV) can be defined for each sampled radiometer brightness temperature that takes into account the integration time. For the along-track direction, the IFOV and the EFOV are basically the same but in the cross track direction, or H-plane direction, the IFOV is signficantly smaller than the EFOV. Table 2.1 provides information on both the EFOV 3-dB beamwidths and the IFOV beamwidths to allow for intercomparison. The table also provides the along-track and cross track dimensions of the EFOV beamwidths as projected onto the surface of the Earth.

Table 2.1. SSM/I Antenna Beamwidths (S/N 002)

Channel	Pol.	IF Pass-Band	Beamwidth (Deg)			EFOV on Earth Surface	
Frequency (GHz)	(V/H)	(MHz)	E-Plane IFOV	H-Plane IFOV	H-Plane EFOV	Along-Track	Cross-Track
19.35	V	10-250	1.86	1.87	1.93	69 km	43 km
19.35	H	10-250	1.88	1.87	1.93	69 km	43 km
22.235	V	10-250	1.60	1.65	1.83	60 km	40 km
37.0	V	100-1000	1.00	1.10	1.27	37 km	28 km
37.0	H	100-1000	1.00	1.10	1.31	37 km	29 km
85.5	V	100-1500	0.41	0.43	0.60	15 km	13 km
85.5	H	100-1500	0.42	0.45	0.60	15 km	13 km

The main beam efficiency is an important parameter in the antenna performance. The main beam efficiency is defined as the percentage of energy received within the main beam of the far-field radiation pattern in the desired polarization within the prescribed bandwidth to the total energy received.

Another important antenna performance parameter is the main beam efficiency which is defined as the percentage of energy received within the main beam of the far-field radiation pattern in the desired polarization within the prescribed bandwidth to the total energy received. The far-field antenna pattern is the combination of the radiation patterns of the feedhorn antenna and the parabolic reflector antenna. The antenna beam efficiencies as a function of channel frequency and polarization for the S/N 002 instrument are provided in Table 2.2. The data are based upon the S/N 002 instrument antenna range measurements of both the feedhorn patterns and the radiation patterns from the reflector. The antenna sidelobe column denotes the percentage of energy lying outside 2.5 times the 3-dB beamwidth of the far-field pattern when normalized to the sum of the co- and cross-polarization energies. The cross-polarization column is defined as the percentage of cross-polarized energy appearing at the output of the feedhorn and includes contributions from the reflector and feedhorn. The feedhorn spillover factor refers to the loss of the energy in the far-field pattern which is not intercepted by the reflector. Thus, in the computation of beam efficiency, the feedhorn spillover loss is a multiplicative factor.

Table 2.2. SSM/I Beam Efficiencies (S/N 002)

Channel Frequency (GHz)	Pol. (V/H)	Antenna Sidelobe (%)	Cross-Polarization (%)	Feedhorn Spillover Factor	Beam Efficiency (%)
19.35	V	0.8	0.35	0.969	96.1
19.35	H	0.4	0.30	0.969	96.5
22.235	V	2.0	0.65	0.974	95.5
37.0	V	7.3	1.80	0.986	91.4
37.0	H	4.7	1.20	0.986	94.0
85.5	V	5.7	0.60	0.988	93.2
85.5	H	7.8	1.40	0.988	91.1

The loss in beam efficiency due to small scale surface roughness is very small at all frequencies and was therefore not included in Table 3.2. The rms surface roughness, which is less than 0.025 mm, translates to a loss of less than 0.15% all frequencies except the 85.5 GHz frequency which has a loss of less than 0.8%.

3.0 SSM/I TDR Data Set Summary

3.1 File Naming Conventions

The FNMOC TDRs provided by the GHRC are in a file containing a day's worth of orbit files. The daily files are named tallmiyy.jd_ds_daily.tar, where ta = abbreviation for antenna temperatures, ll=satellite number (10 for F-10, 11 for F-11), mi = abbreviation for sensor SSM/I, yy = the year of the century, jd = julian day of the year, ds = data source (i.e., fnmoc), and daily.tar = the file type where all information has been put together in one file and tarred. A sample file name for the data from the F-10 sensor for julian day 364 in 1994 would be: ta10mi94.364_fnmoc_daily.tar.

Each orbit file concatenated into the daily tar file follows the NESDIS file naming convention of NSS.TDRR.Sx.Dyyddd.Shhmm.Ehhmm.Annnnnnn, where S = "satellite", x = the satellite identification number minus 6, D = "day", yy = the year of the century, ddd = the Julian day of the year, S = "orbit file start time", hh = start hour of orbit file, mm = start minute of orbit file, E = "orbit file end time", hh = end hour of orbit file, mm = end minute of orbit file, and A = the processing sequence designator. The satellite identification numbers for F-8, F-10, and F-13 are, respectively, 2, 4, and 7. The processing sequence designator in either an "A" or a "B".

Note that the orbit file names are generated by NESDIS using the information found in the file header. The file header is created by FNMOC and does not always accurately reflect the start and end times of the data in the file.

3.2 Data Set Format

***************************PLEASE NOTE***********************
NESDIS TDR format has changed. Each A-B scan pair now occupies one record of 3604 bytes. The data records are preceded by a 3604-byte header record. Here are the record layouts. Lengths are in bytes. At the GHRC, the new format begins with the May 1997 data (D97121).

HEADER RECORD

Length	Type
28	Product ID Block
32	Data Sequence Block
190	Pass HDR Data Description Block
370	Scan HDR1 Data Description Block
1138	Scan HDR2 Data Description Block
370	TDR Data Description Block
30	Pass HDR Data Block
1446	Fill (X'00')

DATA RECORD

Length	Type
76	Scan HDR1 Data Block
194	Scan HDR2 Data Block
3334	TDR Data Block

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The TDR files are stored in the Shared Processing Network Data Exchange Format (SPN DEF). This format consists of data description (DD) blocks and data blocks. All blocks begin with a block identification and a block length and end with a checksum. The data description blocks are used to store acronyms, start bytes, lengths, units, signs, and exponents for the corresponding data blocks. There are 7 nonrepeating header blocks, three repeating scan blocks, and a nonrepeating trailer block. Table 3.1 lists the blocks in the order that they appear in the file. The data blocks will be described in subsequent sections. For detailed information on all the blocks, please refer to the SSM/I Data Requirements Document (Hughes Aircraft, 1986) and the software in Appedices A, B, and C.

Table 3.1 TDR Blocks

Product Identification Block	(nonrepeating)
Data Sequence Block	(nonrepeating)
Revolution Header Data Description (DD) Block	(nonrepeating)
Scan Header #1 DD Block	(nonrepeating)
Scan Header #2 DD Block	(nonrepeating)
Scan Data DD Block	(nonrepeating)
Revolution Header Data Block	(nonrepeating)
Scan Header #1 Data Block	(repeating)
Scan Header #2 Data Block	(repeating)
Scan Data Block	(repeating)
End of Product Block	(nonrepeating)

3.2.1 Revolution Header Data Block

This block contains the spacecraft identification, the revolution number, the data start time, the data end time, and the nearest ascending node time. The times are stored as Julian Day, hours, minutes, seconds.

3.2.2 Scan Header #1 Data Block

This block contains the parameters listed in Table 3.2 for the respective scan data block. The Scan Header #1 block is repeated at the beginning of every new scan A/B pair.

Table 3.2 Scan Header #1

Scan number of current scan
Scan start time for the current B-scan
Position vector time
Position vector latitude

Position vector longitude
Position vector altitude
Thermistor Hot Load Temperature Sample #3
Thermistor Hot Load Temperature Sample #2
Thermistor Hot Load Temperature Sample #1
Calibration Reference Voltage Sample #1
Calibration Reference Voltage Sample #2
RF Mixer Temperature
Forward Radiator Temperature
Scan Automatic Gain Control (AGC) Setting #1 for A Scan
Scan AGC Setting #2 Setting #2 for A Scan
Scan AGC Setting #3 Setting #3 for A Scan
19V Slope
19V Offset
19H Slope
19H Offset
22V Slope
22V Offset
37V Slope
37V Offset
37H Slope
37H Offset
85V Slope
85V Offset
85H Slope
85H Offset

3.2.3 Scan Header #2

This block contains the parameters listed in Table 3.3 for the respective scan data block. The Scan Header #2 block is repeated at the beginning of every new scan A/B pair.

Table 3.3 Scan Header #2

Scan number of current scan
Five 19V Cold Calibration Counts for A Scan
Five 19H Cold Calibration Counts for A Scan
Five 22V Cold Calibration Counts for A Scan
Five 37V Cold Calibration Counts for A Scan
Five 37H Cold Calibration Counts for A Scan
Five 85V Cold Calibration Counts for A Scan
Five 85H Cold Calibration Counts for A Scan
Five 19V Hot Calibration Counts for A Scan
Five 19H Hot Calibration Counts for A Scan
Five 22V Hot Calibration Counts for A Scan
Five 37V Hot Calibration Counts for A Scan
Five 37H Hot Calibration Counts for A Scan
Five 85V Hot Calibration Counts for A Scan
Five 85H Hot Calibration Counts for A Scan
Scan AGC Setting #1 for B Scan
Scan AGC Setting #2 for B Scan
Scan AGC Setting #3 for B Scan
Five 85V Hot Calibration Counts for B Scan
Five 85H Hot Calibration Counts for B Scan

3.2.4 Scan Data Block

This block contains the latitude (LAT), longitude (LON), surface type (SFT), pixel number, and antenna temperature data listed in Table 3.4 for an A/B scan pair.

Table 3.4

A Scan Odd Pixels:	LAT	LON	19V	19H	22V	37V	37H	85V	85H	SFT	Pixel#
A Scan Even Pixels:	LAT	LON						85V	85H	SFT	Pixel#
B Scan Odd Pixels:	LAT	LON						85V	85H	SFT	Pixel#
B Scan Even Pixels:	LAT	LON						85V	85H	SFT	Pixel#

4.0 References

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