Report 12621
Cage/Facility Ident:70143
29 Jul 2002

ALGORITHM AND DATA USER MANUAL (ADUM) FOR THE SPECIAL SENSOR MICROWAVE IMAGER/SOUNDER (SSMIS)

Northrop Grumman
Contract No: F04710-00-C-0001

TECHNICAL REPORT

Prepared by:

Northrop Grumman Corporation
Space Systems Division
1100 West Hollyvale Street
P.O. Box 296
Azusa, California 91702-0296

TABLE OF CONTENTS

Page

Figures

Tables

Appendices

1. INTRODUCTION

This Algorithm and Data User Manual describes data processing and environmental algorithms as implemented for the SSMIS. Specific information is provided for users regarding the SSMIS sensor characteristics, on-board processing, and ground processing algorithm implementation.

1.1 Purpose of Document

The purpose of this document is to provide a reference source for the SSMIS sensor characteristics and algorithm implementation to the SSMIS data and algorithm users.

1.2 Revision History

Revision	Report Date	Comments
Original	29 Jul 2002	Original Release

1.3 Reference Documents

The following documents are referenced or relevant to the scope of this document. If no issue date is listed, the latest revision is applicable.

1.3.1 Northrop Grumman Documents

SPECIFICATIONS

S-DMSP-882 27 Aug 96	Software Requirements Specification for the Flight Software of Special Sensor Microwave Imager Sounder (SSMIS)
SS-DMSP-875A 21 Jul 00	System Specification for the DMSP Block 5D-3 Special Sensor Microwave Imager/Sounder (SSMIS)
S-DMSP-881	Software Requirements Specification for the Ground Processing Software of Special Sensor Microwave Imager/Sounder (SSMIS)

OTHER

AE 26775B 29 Jul 2002	Interface Design Document for the Special Sensor Microwave Imager/Sounder (SSMIS) Ground Processing Software (GPS)
RE-11796B 29 Jul 2002	Software User's Manual For The Special Sensor Microwave Imager/Sounder (SSMIS)

1.3.2 Other Publications

P9152-20-03 13 Jan 89	Proposal for Special Sensor Microwave Imager Sounder (SSMIS) Program, Vol. II Technical Proposal
20 June 1990	Critical Design Review (CDR) for the Operational Software Segment of the Special Sensor Microwave Water Vapor Profiler (SSM/T-2)
19 Sep 1990	Video Integrator Matching for SSMIS, Interoffice Memo from C. A. Haapala, 1/5721/1407, #499
17 July 1991	Ground Processing Algorithms Technical Interchange Meeting (TIM) for the Special Sensor Microwave Imager Sounder (SSMIS)
S-DMSP-898 (AE-26360) 17 January 1991	Software Design Document for the Special Sensor Microwave Water Vapor Profiler (SSM/T-2)
Report 10625 1995	Upper Air Sounding Retrieval Algorithm for the DMSP Block 6 Microwave Sounder Suite (MISS), Algorithm Description Document, Aerojet
Report 11298 21 March 1999	Final Acceptance Test Report for the Special Sensor Microwave Imager Sounder (SSMIS), Serial Number 01

AS 32268-100 6 Jan 2000	Special Sensor Microwave/Imager (SSM/I) Algorithm Specification Document (ASD), Raytheon Systems Company
19 Jan 01	DMSP Satellite Raw Sensor Data Record (RSDR) File Format Specification", version 1.0, Capt. David M. Paal, HQ AFWA / Space Missions Branch

2. OVERVIEW

2.1 System Overview

Figure 1 shows the SSMIS scan geometry. The system scans at a constant 45° angle from nadir and intersects the Earth's surface at a constant incidence angle of 53.1°. The sensor collects data to the aft of nadir for a morning ascending node spacecraft orbit, and collects data forward of nadir for a morning descending node spacecraft orbit. One scan is produced every 1.9 sec by rotating the system counter-clockwise at 31.6 rpm. Earth scene data for 24 channels are collected at 180 sample positions along the active portion of the scan, an angle of 143.2°. At the nominal orbital height of 833 km this produces a swath width on the ground of 1707 kilometers with 12.5 km scene spacing. The achieved swath width applies uniformly to all channels of the SSMIS. The 1.9 sec inter-scan period provides along-track sample spacing (12.5 km) equivalent to the along-scan spacing.

Beam size and sampling characteristics are described in section 2.3.

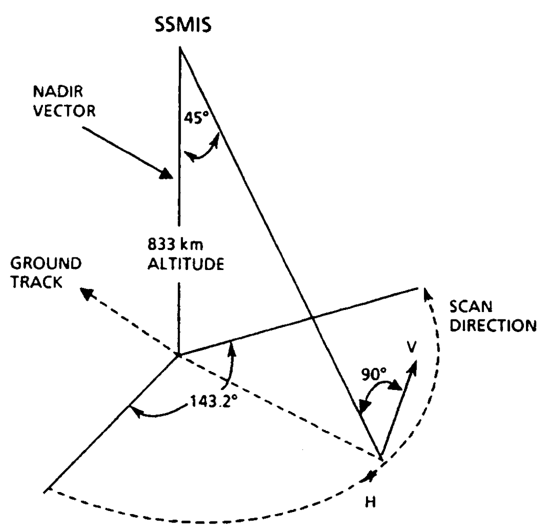


Figure 1 SSMIS Scan Geometry

Figure 2 shows a simplified block diagram of the SSMIS system. The SSMIS collects microwave energy from the Earth's surface and atmosphere with a rotating 24-inch parabolic reflector. This reflector focuses the energy on an assembly consisting of six feedhorns, which provide the initial frequency multiplexing for the 24 channels. The reflector and the six feedhorns rotate with the entire sensor canister. Located at the top of the canister are a cold calibration reflector and a warm calibration source, which do not rotate with the canister. The feedhorns view a fixed cold calibration reflector and a fixed warm calibration source for each revolution of the sensor. These calibration data are used to convert the sensor output to absolute radiometric brightness temperatures.

The feedhorn data are input to the receiver subsystem where frequency multiplexing occurs to produce 24 channels of data. Receiver channel characteristics are summarized in Section 2.2. The receiver outputs are converted to the video spectrum, digitized and formatted, and sent to the Operational Linescan System

(OLS) under control of the sensor signal processor and the flight software. The SSMIS data are transmitted to the ground by the OLS. Ground processing is performed at Air Force Weather Agency (AFWA) and Fleet Numerical Meteorological Oceanography Center (FNMOC) to convert the sensor data into calibrated and Earth-located sensor data records (SDRs) and finally into a variety of environmental data records (EDRs).

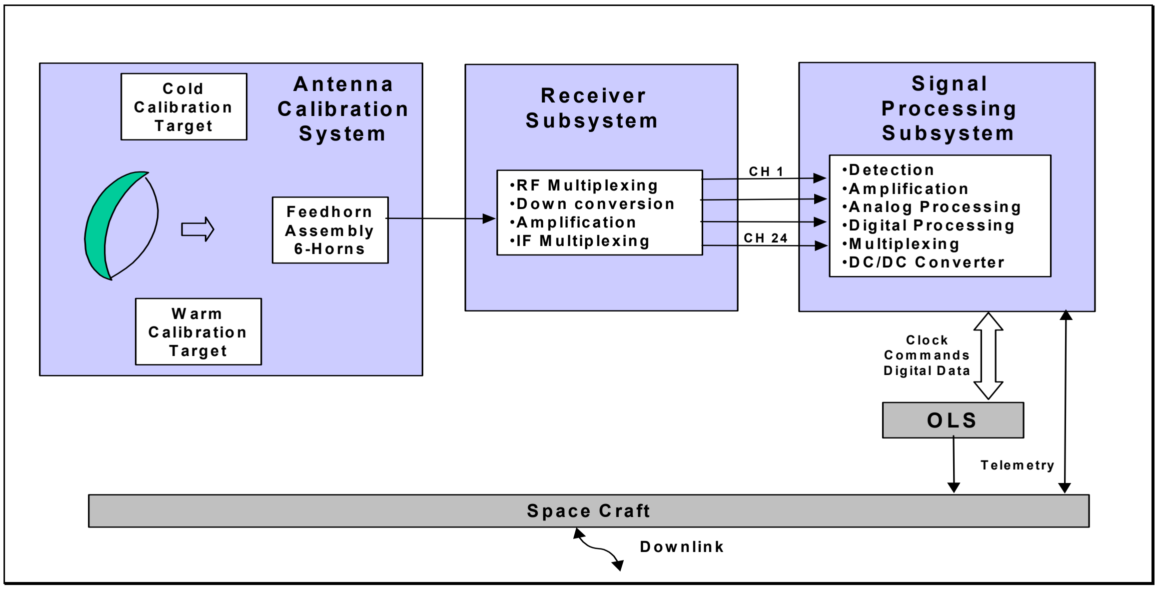


Figure 2 Simplified SSMIS Block Diagram

2.2 Receiver Channel Characteristics

Frequency bands suitable for air temperature sounding, humidity sounding, and the retrieval of Earth surface parameters are selected on the basis of the absorption and emission spectra of the Earth's atmosphere and surface. The general locations of the channels selected for the SSMIS coincide with those of the earlier DMSP microwave instruments. Table 1 summarizes receiver channel characteristics.

Table 1 SSMIS Receiver Channel Characteristics

Channel Number	Center Frequency (GHz)	1^{st} IF (MHz)	2^{nd} IF (MHz)	Nominal Bandwidth per passband (MHz)	Polarization
1	50.3	0.	0.	400.	H
2	52.8	0.	0.	400.	H
3	53.596	0.	0.	400.	H
4	54.40	0.	0.	400.	H
5	55.50	0.	0.	400.	H

Channel Number	Center Frequency (GHz)	1st IF (MHz)	2nd IF (MHz)	Nominal Bandwidth per passband (MHz)	Polarization
6	57.29	0.	0.	350.	RC
7	59.4	0.	0.	250.	RC
8	150.0	1250.	0.	1500.	H
9	183.31	6600.	0.	1500.	H
10	183.31	3000.	0.	1000.	H
11	183.31	1000.	0.	500.	H
12	19.35	0.	0.	400.	H
13	19.35	0.	0.	400.	V
14	22.235	0.	0.	450.	V
15	37.0	0.	0.	1500.	H
16	37.0	0.	0.	1500.	V
17	91.655	900.	0.	1500.	V
18	91.655	900.	0.	1500.	H
19	63.283248	285.271	0.	1.5	RC
20	60.792668	357.892	0.	1.5	RC
21	60.792668	357.892	2.	1.5	RC
22	60.792668	357.892	5.5	3.0	RC
23	60.792668	357.892	16.	8.0	RC
24	60.792668	357.892	50.	30.0	RC

Table 2 lists SSMIS environmental parameters and the corresponding channels used in the measurement of the environmental parameters. Channels 1 - 7 lie within the oxygen absorption band covering the 50- to 70-GHz spectral region and are used for temperature sounding up to 10 mb. Channels 8 - 11 and 18 are used for humidity sounding and have frequencies that lie on the wings and near the peak of the 183-GHz water vapor absorption line. Channels 19 - 24 are intended for the upper air sounding option, and are located in the region of highest absorption in the oxygen spectrum. They provide for superior upper air sounding capability compared to any feasible infrared instrument. Channels 12 - 18 are used for determining Earth surface characteristics, cloud liquid and rain rate, and surface wind speeds over the ocean. These channels lie within atmospheric windows, and thus respond strongly to surface conditions under clear sky conditions. The absorption by liquid constituents of the atmosphere at these frequencies is in the proper range to allow measurement of cloud droplet masses by Channels 12 - 18 over the ocean. Channels 12 - 18 also respond well to rain.

Table 2 SSMIS Environmental Parameters and Corresponding Channels

Environmental Parameter	Channels
Atmospheric Temperature Profiles	
Lower Air Temperature:	1 – 7, 24
Upper Air Temperature:	19 - 24
Atmospheric Humidity Profiles	1 - 4
	18
	8
	9 - 11
Other Environmental Parameters	12,13
	14
	15,16
	17,18

2.3 Beam Size and Sampling Characteristics

The SSMIS sampling may be described in terms of 180 basic beam positions each separated by an azimuthal angle of exactly 0.8°. The 4.22-ms basic integration time for a single beam combined with the frequency-dependent antenna pattern result in the Effective Field-of-View (EFOV) given in Table 3 for each channel.

Table 3 SSMIS Beam Size and Sampling Characteristics

Channel Number	EFOV* along scan (km)	EFOV* 90° to scan (km)	Spatial Averaging** (# Samples)	Footprint Size** (km)	Footprint Spacing** (km)
1	17.6	27.3	3 x 3	37.7 x 38.8	37.5
2	17.6	27.3	3 x 3	37.7 x 38.8	37.5
3	17.6	27.3	3 x 3	37.7 x 38.8	37.5
4	17.6	27.3	3 x 3	37.7 x 38.8	37.5
5	17.6	27.3	3 x 3	37.7 x 38.8	37.5
6	17.6	27.3	3 x 3	37.7 x 38.8	37.5
7	17.6	27.3	3 x 3	37.7 x 38.8	37.5
8	13.2	15.5	1 x 1	13.2 x 15.5	12.5
9	13.2	15.5	1 x 1	13.2 x 15.5	12.5

Channel Number	EFOV* along scan (km)	EFOV* 90° to scan (km)	Spatial Averaging** (# Samples)	Footprint Size** (km)	Footprint Spacing** (km)
10	13.2	15.5	1 x 1	13.2 x 15.5	12.5
11	13.2	15.5	1 x 1	13.2 x 15.5	12.5
12	44.8	73.6	2 x 1	46.5x 73.6	25
13	44.8	73.6	2 x 1	46.5x 73.6	25
14	44.8	73.6	2 x 1	46.5x 73.6	25
15	27.5	45.0	2 x 1	31.2 x 45.0	25
16	27.5	45.0	2 x 1	31.2 x 45.0	25
17	13.2	15.5	1 x 1	13.2 x 15.5	12.5
18	13.2	15.5	1 x 1	13.2 x 15.5	12.5
19	17.6	27.3	6 x 6	75.2 x 75.0	75
20	17.6	27.3	6 x 6	75.2 x 75.0	75
21	17.6	27.3	6 x 6	75.2 x 75.0	75
22	17.6	27.3	6 x 6	75.2 x 75.0	75
23	17.6	27.3	6 x 6	75.2 x 75.0	75
24	17.6	27.3	3 x 3	37.7 x 38.8	37.5

* raw data resolution (prior to on-board and SDRP averaging) based on measured half-power beamwidth and spacecraft altitude of 833 km

** minimum available in Sensor Data Records

Spatial averaging of the sampled brightness temperatures is applied for two reasons: 1) to improve channel signal-to-noise ratio, and therefore retrieval accuracy; and 2) to match footprint sizes for multichannel algorithms. For the atmospheric temperature and humidity profiling channels it is needed to obtain acceptable levels of NEΔT. The effective system sensitivity is improved by the square root of the number of samples averaged, due to an effective increase in integration time. For example, averaging 9 samples, i.e., 3 along-scan x 3 along-track, results in a $\sqrt{9} = 3$ improvement in system NEΔT. For water vapor and air temperature sounding up to 10 mb, at least a 3 x 3 sample array is required to achieve an acceptable NEΔT for accurate inversion. Table 4 gives the channel NEΔT after spatial averaging has been applied.

Table 4 Radiometer Channel Sensitivity after Spatial Averaging

Channel Number	# Samples Averaged	NEΔT (K)	
		Requirement	Measurement (for 305K Scene)
1	3 x 3	0.4	0.21
2	3 x 3	0.4	0.20
3	3 x 3	0.4	0.21
4	3 x 3	0.4	0.20
5	3 x 3	0.4	0.22
6	3 x 3	0.5	0.26
7	3 x 3	0.6	0.25
8	3 x 3	0.875	0.53
9	3 x 3	1.2	0.56
10	3 x 3	1.0	0.39
11	3 x 3	1.25	0.38
12	2 x 1	0.7	0.35
13	2 x 1	0.7	0.34
14	2 x 1	0.7	0.45
15	2 x 1	0.5	0.26
16	2 x 1	0.5	0.22
17	3 x 3	0.9	0.19
18	3 x 3	0.9	0.19
19	6 x 6	2.375	1.23
20	6 x 6	2.375	1.18
21	6 x 6	1.75	0.86
22	6 x 6	1.0	0.58
23	6 x 6	0.6	0.37
24	6 x 6	0.7	0.38

*from System Calibration Test for SN01

This improvement in NEΔT comes at the cost of spatial resolution. Table 3 shows the footprint sizes after spatial averaging, as well as the distance between adjacent footprints. A calculation of ground resolution must take into account the motion of the antenna during integration time and the antenna pattern overlap when averaging samples. Averaging samples results in a decrease of spatial resolution, i.e., a net larger footprint will result. For the temperature sounding channels the resulting averaged temperature represents a footprint size of 38 x 39 km vs. 13 x 15 km for the single beam. Averaging a 4 x 4 array of temperatures would further reduce the NEΔT but would also produce a footprint size of 50 km. The additional improvement in NEΔT is considered less important than preserving the 38 x 39 km resolution of the 3 x 3 average.

The upper air sounding option requires extremely narrow channel bandwidths (see Table 1). Because system sensitivity is a function of channel bandwidth as well as integration time, it is necessary to increase the effective system integration time by averaging more footprints to compensate for the narrower bandwidth. An average of more than 3 x 3 footprints is necessary to meet the air temperature retrieval accuracy requirements above 10 mb. A 6 x 6 array produces the necessary improvement in NEΔT and an effective ground resolution of 75 x 75 km.

All channels with frequencies greater than 90 GHz have the same small basic footprint (13 x 15 km) which is important for imaging purposes. However, since the SSMIS has beam diameters that vary with channel frequency, it is also desirable to average the higher resolution data to the same scale as the lower resolution data when the retrieval algorithm employs channels with different resolutions. For example, during the land surface typing the 91.65 GHz channels (13 x 15 km beam) are used with the 37 GHz channels (27 x 45 km beam) in a number of threshold decision tests as well as in subsequent retrieval of land parameters. Because inhomogeneities in surface emissions appear on scales near 15 km (and lower) it is important that the 91.65 GHz data be averaged so that the resulting beam has essentially the same resolution as the 37 GHz. This averaging is described in Section 3.5.

2.4 On Board Processing

The data processor onboard the SSMIS consists of dual microprocessing units (one active and one standby) and circuits interfacing to the video processor, scan drive, and OLS subsystems. The data processor is driven by interrupts generated by the sensor signal processing subsystem to acquire: (1) digital radiometric data from each of the frequency channels, (2) sensor physical temperatures, and (3) housekeeping data. Tasks performed by the flight software resident in the processor include radiometer data acquisition, Doppler shift compensation, multiplexing of housekeeping parameters into the data stream, and averaging, compressing, and formatting the data for output to the OLS.

2.4.1 Radiometric Data Acquisition and Calibration

Raw radiometric data are acquired from each of the 24 channels during the active 180 scene sector positions and during the four cold calibration and four warm calibration positions of each scan. The data are saved in an input buffer. An interrupt is generated at the beginning of each scan (sensor revolution) and at 450 discrete intervals of 0.8° each, through each scan. From these 450 interrupts, the Earth-looking 180 scene positions (corresponding to 143.2°) for each channel and the housekeeping and calibration positions are selected for the start of data integration.

Integrator calibration is necessary because the SSMIS instrument uses two different sets of integrators for each of the 24 channels – one set is used for the even-numbered beam positions of the 180 scene sector positions and the 4 warm cal positions and the 4 cold cal positions, and one set for the odd-numbered positions. One set integrates for the 4.22 milliseconds of its beam position, then holds for 3.1 milliseconds of the next beam position and dumps during the remaining time of this position. During the hold and dump time of this set of integrators, the second set is integrating the corresponding second beam position. Since the two sets of integrators are not perfectly matched electronically they must be calibrated each scan and the resulting coefficients used to 'match' the outputs of the two sets.

This calibration is done by collecting data from sixteen consecutive beam positions after completion of the raw radiometric data acquisition. A high voltage calibrate signal is applied to the first eight positions and a low calibrate signal is applied to the final eight positions. Data from the four odd-numbered high and four odd-numbered low voltage positions are averaged, as are the data from the four even-numbered high and four even-numbered low voltage positions. The 'even' and 'odd' averages are then averaged with those from the previous seven scans. These 8-scan 'even' and 'odd' averages are used to compute the GAIN and OFFSET coefficients to be applied to all odd-numbered positions to compensate for the integrator hardware differences.

Antenna temperature calibration is described in Section 3.2.

2.4.2 Doppler Shift Compensation

This section discusses the effect of Doppler shift and the onboard compensation applied to incoming signal frequencies for Channels 19-24.

Upper Air Temperature Sounding (see Appendix E) requires that the SSMIS measure radiation with filter bandwidths < 1.5 MHz centered on four O_2 resonance lines in the 60 to 65 GHz frequency range. Due to the narrowness of these filters, the system must correct for the Doppler shift in the passive radiation from the Earth's atmosphere due to the motion of the satellite and the conical scan geometry of the sensor. The Doppler shift is a function of the direction that the scanning antenna is looking, with a maximum of approximately 1 MHz in the flight direction (scan center) and decreasing to zero in the direction perpendicular to the flight direction. This value also varies with frequency (ν) for the four O_2 resonance lines used for the upper air sounding. For radiation received by the SSMIS with a 45° cone angle and in a 833 km circular orbit, the scan center Doppler shifts ($\Delta\nu$) for the four lines are:

Line	ν (GHz)	$\Delta\nu$ (MHz)
+7	60.434776	1.059
+9	61.15056	1.072
+15	62.997977	1.104
+17	63.568519	1.114

The Doppler shift is compensated for by tuning the frequency of the air temperature sounding receiver local oscillator as a function of scan angle. The onboard correction for this Doppler shift is implemented by applying a voltage offset to the 141 MHz Voltage Controlled Oscillator (VCO) which varies as the sine of the scan angle ϕ, $\phi = 90°$ in the flight direction. Values of the voltage offset at each scan position are read from a precalculated "Doppler Table" resident in the flight software. There are separate Doppler Tables for descending and ascending orbits, for primary and backup PLOs, and for the "zero Doppler" (i.e. no compensation) case which can be uplinked as appropriate.

This voltage offset creates a Doppler offset frequency at the VCO that generates frequency shifts of the local oscillators (LOs) for the first and second down conversions of these temperature sounding channels. The purpose of this shift is to keep the incoming signal centered in the narrow bandwidths of the SAW filters. The frequency shifts at the first and second LOs are related to the VCO Doppler offset frequency as follows:

Shift to 1st LO @ 56400 MHz = 1200 x VCO Doppler offset frequency

Shift to 2nd LO @ 4512 MHz = 96 x VCO Doppler offset frequency

Shift to 2nd LO @ 6768 MHz = 144 x VCO Doppler offset frequency

For example, if the VCO Doppler offset frequency is +100 Hz, the frequency of the 1st LO is shifted to 56400.12 MHz.

The calculations presented in Table 5 show how the application of the Doppler offset frequency (817.708Hz at scan center) compensates for the Doppler shift relative to the centers of the SAW filters. The case of the 7+ and 9+ lines used for Channel 20 is given as an illustration.

Table 5 Doppler Shift Compensation Channel 20

Channel 20	7+	9+
Unshifted line center frequencies:	60.434776GHz	61.15056GHz
Doppler shift (looking forward):	+1.059 MHz	+1.072 MHz
Incoming center frequencies:	60.435835GHz	61.15163GHz
1st down conversion - subtract 56.4 +1200*817.708e-9 GHz:	4.034854GHz	4.75065GHz
2nd down conversion - subtract 4.512 + 96*817.708e-9 GHz and reflect negative:	477.22475MHz	238.57225MHz
Centers of the SAW filters	477.224MHz	238.560MHz

These calculations demonstrate that the Doppler offset frequency of 817.708 Hz (scan center) effectively compensates for the Doppler shift relative to the center of the SAW filter. The maximum difference of approximately 15 KHz for the +17 line represents only 1% of the SAW filter bandwidth (~ 1.3 MHz) and will have little impact on the measured signal.

In principal all channels should be compensated for the Doppler effect, but only for the narrow-band upper-air channels is compensation required to reduce the potential for significant errors in absolute brightness temperature accuracy. And because all air temperature sounding channels share a common local oscillator, the correction is applied simultaneously to Channels 1-7 and 19-24. Unfortunately, in addition to compensating for the Doppler effect, this frequency tuning also causes gain changes in the temperature-sounding channels and bias changes in some non-temperature-sounding channels. These unwanted changes to the brightness temperatures of the other channels are removed by the ground processing software. (See Section 3.3 Doppler Correction.)

2.4.3 On-Board Averaging

Spatial averaging in the along-scan direction is accomplished with on-board spacecraft data processing. Table 6 details the channels to be averaged, the number of positions to be averaged, and the resulting number of average values per scan. For Channels 1-7 and 24 (tropospheric and stratospheric temperature sounding channels) three along-scan beams are averaged to give an integration time of 12.66 msec per sample. This results in 60 samples per scan, starting from basic beam position 2 and separated from each other by an azimuthal angle of 2.4°. For Channels 12 - 16 (19.35 H/V, 22.235V, 37 H/V) two adjacent along-scan beams are averaged to give an integration time of 8.44 msec per sample with 90 samples per scan spaced 1.6° in azimuth. And for channels 19-23 (mesospheric temperature sounding channels) six along-scan beams are averaged to give an integration time of 25.32 msec with 30 samples per scan spaced 4.8° . No beam averaging of Channels 8 - 11 and 17 - 18 is done so that 180 samples are taken each scan spaced at 0.8°.

Table 6 Along-Scan Sampling Characteristics and Averaging Parameters

Channel Number	Azimuth Angle First Sample (deg)	Azimuth Increment (deg)	Positions to Average	Resulting Number of Average Values Per Scan
8-11,17-18	-71.6	0.8	1	180
12-16	-71.2	1.6	2	90
1-7,24	-70.8	2.4	3	60
19-23	-69.6	4.8	6	30

2.4.4 Data Compression and Formatting

The Flight Software performs a data compression operation on the radiometric counts from the scene postions, and formats the resulting information into the data stream collected by the OLS. Interrupts are generated at the start and end of each read gate so the software can synchronize the output of the data to the OLS data requirements.

According to these requirements, the maximum data rate is not to exceed 27,000 bits per scan. In order to satisfy this requirement, two procedures are employed to reduce the data rate without degrading the sensor performance significantly: 1) scene averaging, and 2) data compression. The scene averaging as described above yields 2160 scene stations per scan, which if the full resolution of 16 bits from the SDC are used exceeds the maximum allowable data rate (without any calibration values from the reference loads or any housekeeping parameters). If 12 bits per scene position is used, a more reasonable 25,920 bits per scan is achieved.

To translate the 16-bit data to 12 bits, the data are normalized according to the formula:

$$C_R = \frac{C_N - C_C}{C_W - C_C} K$$

where

C_R = 12 bit result

C_N = 16 bit scene count

C_W = 16 bit warm count

C_C = 16 bit calibration count

K = 32 bit scale factor

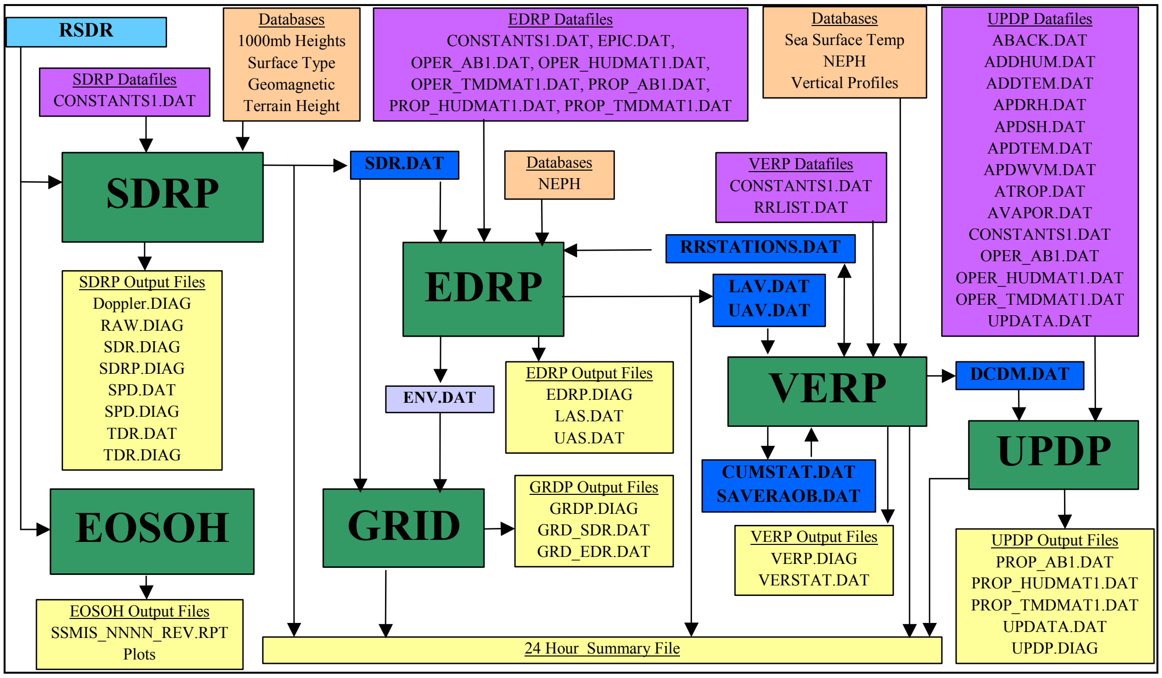
The calibration load values, C_W and C_C, are to be maintained at 16 bits, with each warm and cold value being an average of four samples from each load per scan. These are then averaged with the respective warm and cold averages from the previous 7 scans (for an average over a total of 8 scans) prior to inclusion in the output data stream.

2.5 SSMIS Ground Processing

Figure 3 presents a flow diagram of the SSMIS ground processing tasks. The SSMIS ground processing consists of six programs: (1) Sensor Data Records Processor (SDRP), (2) Environmental Data Records Processor (EDRP), (3) GRID Processor (GRID), (4) Verification Processor (VERP), (5) Update Processor (UPDP), and (6) the Early Orbit / State of Health (EOSOH) Processor. Each CSC is a separate, executable program that runs on a UNIX workstation.

For the purposes of this algorithm and data user manual, only the SDRP, EDRP, and data relevant to the algorithms and environmental products are discussed here. See the SSMIS GPS User Manual for a detailed description of the entire GPS processing and data files.

Figure 3 SSMIS Ground Processing



2.5.1 Sensor Data Records Processor (SDRP)

The primary purpose of the SDRP is to read raw sensor data, geo-locate scene data, and convert raw radiometric counts to brightness temperatures.

2.5.1.1 SDRP Input

2.5.1.1.1 Raw Sensor Data Record File

The SDRP reads the Raw Sensor Data Record (RSDR) file. The RSDR file is created from the raw data files ("Simple" files) by running the RSDR generator program (developed by Raytheon). The RSDR generator will extract the SSMIS data from the Simple files to create an RSDR file specifically for SSMIS ground processing.

Specifications for the RSDR file format can be found in "DMSP Satellite Raw Sensor Data Record (RSDR) File Format Specification", Version 1.0, 19 Jan 01, Capt. David M. Paal, HQ AFWA / Space Missions Branch.

2.5.1.1.2 Constants File

The Constants File is read by the SDRP for information regarding a specific sensor. This information includes the spacecraft direction, warm and cold calibration coefficients, spill-over and cross polarization coefficients, Doppler correction coefficients, and other data that are specific to a particular SSMIS sensor. For more information regarding the Constants File, see the SSMIS Interface Design Document, and the SSMIS Software User's Manual.

2.5.1.2 SDRP Processing

The Sensor Data Records Processor reads the SSMIS raw sensor data and generates Sensor Data Records (SDR) and Temperature Data Records (TDR). The basic functions required to create the SDR and TDR are:

- Read the raw sensor data RSDR File;
- Earth locate the sensor data;
- Calibrate raw data using cold and warm load readings;
- Correct for Doppler compensation, cross polarization, and spillover;
- Retrieve 1000 Mb heights, terrain heights, surface tags, and geomagnetic fields;
- Compute brightness temperatures for channels
- Compute averaged brightness temperatures for various channels
- Write data to output SDR and TDR files

2.5.1.3 SDRP Outputs

2.5.1.3.1 Sensor Data Records (SDR) File

Table 7 lists the data elements contained within the SDR File. This list does not imply a particular record or file structure. Data elements for file management and record keeping are not included here. For information regarding file format, see the SSMIS Interface Design Document.

Table 7 SDR File Data Elements

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Revolution number	Revolution number (full)	None	0 to 2147483647	Integer
Year	Starting year	Years	4 digits	Integer
Julian Day	Starting Julian day	Days	1 to 366	Integer
Hour	Starting hour	Hours	0 to 23	Integer
Minute	Starting minute	Minutes	0 to 59	Integer
Satellite ID	Satellite ID 1=F16, SSMIS Ser# 1 2=unassigned 3=unassigned	None	1 to 3	Integer
Imager scan times	Milliseconds since midnight for 0..28 scans	msec	0 to 86400000	Integer
Imager scene counts	Count of scenes for each imager scan	None	0 to 180	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Environmental scan times	Milliseconds since midnight for 0..24 scans	msec	0 to 86400000	Integer
Environmental scene counts	Count of scenes for each environmental scan	None	0 to 90	Integer
LAS scan times	Milliseconds since midnight for 0..8 scans	msec	0 to 86400000	Integer
LAS scene counts	Count of scenes for each LAS scan	None	0 to 60	Integer
UAS scans	Milliseconds since midnight for 0..4 scans	msec	0 to 86400000	Integer
UAS scene counts	Count of scenes for each UAS scan	None	0 to 30	Integer
Latitude	Scene latitude (+ north)	degrees *100	-9000 to 9000	Integer
Longitude	Scene longitude (+ east)	degrees *100	-18000 to 18000	Integer
Surface tag	Static surface tag -1 = Unknown 0 = Land 1 = Spare 2 = Near coast 3 = Ice 4 = Possible ice 5 = Ocean 6 = Coast 7 = Spare	None	-1 to 7	Integer
Rain flag	Rain flag -1 = indeterminate 0 = no rain 1 = rain	None	-1 to 1	Integer
Channel brightness temperatures	Channel 8-11, 17,18 brightness temperatures	Celsius *100	-19500 to 6000	Integer
Channel brightness temperatures	Channel 12-16 brightness temperatures	Celsius *10	-1950 to 600	Integer
Channel brightness temperatures (5x5,5x4)	Channel 15-18 (5x5), 17-18 (5x4) brightness temperatures	Celsius*100	-19500 to 6000	Integer
Channel brightness temperatures	Channel 1-7, 8-11,18 (5x5) , 24 (3x3) brightness temperatures	Celsius *100	-19500 to 6000	Integer
Channel brightness temperatures	Channel 19-24 (6X6) brightness temperatures	Celsius *100	-19500 to 6000	Integer
Sea ice flag	Sea ice flag 0 = No ice 3 = Ice	None	0, 3, 5, 6	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
	5 = Ocean 6 = Coast			
1000 mb height	Height of 1000 mb pressure level -999 = Undetermined	meters	-999, -500 to 500	Integer
Lower temperature quality flag	Sum of #valid scenes when computing 3x3 averages for channels 1-7, 24. (3 scans per channel x 8 channels = 24 possible valid scenes)	Total #valid scenes used in the averaging.	0 to 24	Integer
Lower humidity quality flag	Sum of #valid scans and scenes when computing 3x3 averages for channels 1-4 (3 scans per channel x 4 channels = 12 possible valid scans), and 5x5 averages for channels 8-11,18 (25 scenes x 5 channels = 125 possible valid scenes). (12 + 125 possible valid scenes = 137)	Total #valid scenes used in the averaging.	0 to 137	Integer
Terrain height	Terrain height -32768 = Undetermined	meters	-32768, -400 to 7000	Integer
Temperature quality flag	Sum of #valid scans / scenes when computing 6x6 averages for channels 19-23 (6 scans x 5 channels = 30 possible valid scans), and 6x6 average for channel 24 (6 scans x 2 scenes x 1 channels = 12 possible valid scenes). (30 + 12 possible valid scans = 42)	Total #valid scenes used in the averaging.	0 to 42	Integer
Geomagnetic Field	Squared geomagnetic field strength	uTesla**2	48400 to 450000	Integer
B dot K	Dot product of geomagnetic field with propagation vector	uTesla**2	0 to 450000	Integer

2.5.1.3.2 Temperature Data Record File (TDR)

Table 8 is a list of data elements contained within the TDR File. This list does not imply a particular record or file structure. Data elements for file management and record keeping are not included here. For information regarding file format, see the SSMIS Interface Design Document.

Table 8 TDR File Data Elements

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Satellite ID	Satellite ID 1=F16, SSMIS Ser# 1 2=unassigned 3=unassigned	None	1 to 3	Integer
Revolution number	Revolution number (full)	None	0 to 2147483647	Integer
Year	Starting Year	Years	4 digits	Integer
Julian Day	Starting Julian day	Days	1 to 366	Integer
Hour	Starting hour	Hours	0 to 23	Integer
Minute	Starting minute	Minutes	0 to 59	Integer
Scan times	Milliseconds since midnight for 0..28 scans	msec	0 to 86400000	Integer
Ephemeris Latitude	latitude (+ north)	degrees *10000	-900000 to 900000	Integer
Ephemeris Longitude	longitude (+ east)	degrees *10000	-1800000 to 1800000	Integer
Ephemeris Altitude	Altitude	Kilometers *10000	8000000 to 9000000	Integer
Ephemeris Julian Day	Scan Julian Day	Days	1 to 366	Integer
Ephemeris Time	Time	Msecs	1 to 86400000	Integer
Latitude	Scene latitude (+ north)	degrees *100	-9000 to 9000	Integer
Longitude	Scene longitude (+ east)	degrees *100	-18000 to 18000	Integer
Surface tag	Static surface tag -1 = Unknown 0 = Land 1 = Spare 2 = Near coast 3 = Ice 4 = Possible ice 5 = Ocean 6 = Coast 7 = Spare	None	-1 to 7	Integer
Rain flag	Rain flag 1 -1 = indeterminate 0 = no rain 1 = rain	None	-1 to 1	Integer
Channel brightness temperatures	Channel 8-11, 17,18 (1x1) brightness temperatures prior to Doppler, cross-polarization, or spillover correction.	Celsius *100	-19500 to 6000	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Channel brightness temperatures	Channel 12-16 (1x2) brightness temperatures prior to Doppler, cross-polarization, or spillover correction.	Celsius *100	-19500 to 6000	Integer
Channel brightness temperatures	Channel 1-7 (3x3), 24 (3x3) brightness temperatures prior to Doppler, cross-polarization, or spillover correction.	Celsius *100	-19500 to 6000	Integer
Channel brightness temperatures	Channel 19-23 (6X6) brightness temperatures prior to Doppler, cross-polarization, or spillover correction.	Celsius *100	-19500 to 6000	Integer
WL Cal	Warm Load Calibration by channel 1-24	Counts	0 to 65535	Integer
Cold Cal	Cold Calibration by channel 1-24	Counts	0 to 4095	Integer
WLT	Warm load temperatures 1-3	Celsius*100	-9000 to 10000	Integer
Subframe ID	Subframe ID number	None	0 to 7	Integer
MUX Housekeeping	MUX housekeeping values 1-4	counts	0 to 4095	Integer
Base PT Latitude	Base Point latitude # 1-28 (+ north)	Degrees*100	-9000 to 9000	Integer
Base PT Longitude	Base Point longitude # 1-28 (+ east)	Degrees*100	-18000 to 18000	Integer
Base PT EIA	Base Point EIA # 1-28	Degrees*100	-9000 to 9000	Integer
Base PT Azimuth	Base Point Azimuth # 1-28	Degrees*100	-18000 to 18000	Integer

2.5.2 Environmental Data Records Processing (EDRP)

The primary purpose of the EDRP to read the SDR file, derive the imagery, temperature/humidity sounding profiles, and compute other environmental parameters from the radiometric measurements.

2.5.2.1 EDRP Input

2.5.2.1.1 Sensor Data Records (SDR) File

The EDRP reads the SDR file that is generated by the SDRP.

2.5.2.1.2 D-Matrices

The EDRP reads in a temperature D-Matrix and a humidity D-Matrix. These are tables of coefficients used in the computation of the temperature and humidity profiles for 25 different atmospheric types over different backgrounds and heights. For more information regarding the D-Matrices, see the SSMIS Interface Design Document and the SSMIS Software User's Manual.

2.5.1.2.3 Alpha-Beta File

The EDRP reads in a file of Alpha-Beta coefficients. These coefficients are also used in the computation of the sounding profiles. For more information regarding the Alpha-Beta file, see the SSMIS Interface Design Document, and the SSMIS Software User's Manual.

2.5.1.2.4 Cloud Data

The EDRP will read cloud information from site-specific databases. The cloud information is used to make decisions on whether specific environment parameters should be computed. Cloud amount and cloud mass parameters are also computed from the cloud information.

2.5.2.2 EDR Processing

The Environmental Data Records Processor reads the SDR file and generates the Imager Environmental Parameter (IEP) file, also referred to as the EDR file. The EDRP also creates a Lower Air Sounding (LAS) and Upper Air Sounding (UAS) file. The basic processing steps of the EDRP are:

- Read the Sensor Data Records (SDR) File and other input files;
- Align the Environmental and Imager scans by selecting data based on scan times
- Compute environmental parameters (ocean, ice, and land parameters)
- Compute the lower sounding profile (temperatures, heights, thicknesses, humidities)
- Compute the upper sounding profile (temperatures, heights)
- Write data to output IEP, LAS, and UAS files

2.5.2.3 EDRP Output

The following sub-sections describe the list of data elements contained within the EDRP output files. These lists do not imply a particular record or file structure. Data elements for file management and record keeping are not included. For information regarding file format, see the SSMIS Interface Design Document.

Table 9 describes the requirements for the EDR output. The temperature and humidity profiles are written to the LAS and UAS files. The other environmental parameters are written to the IEP file.

Table 9 IEP File Data Elements

Column					
1	2	3	4	5	6
Item No.	Sounding (S)/ Imagery (I) Parameter	Environ-mental Parameter	Chan. No.	Polarization	Output Environmental Parameter Specifications
1	S	Air Temp-erature Profiles	1 2 3 4 5 6 7 19 20 21 22 23 24	H H H H H RC RC RC RC RC RC RC RC	Determine atmospheric temperature at pressure levels of 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 millibars. Accuracy (RMS error) shall be 8K at 1000 mb, 6K at 850 mb, and 2K from 700 to 10 mb. The temperature bias shall be less than 1K from 1000 to 10 mb. The lower sounding spatial resolution shall be to ≤ 50 km and the swath width shall be 1707 km. Also determine atmospheric temperature at pressure levels of 7, 5, 2, 1, 0.4, 0.2, 0.1, and 0.03 mb. Accuracy shall be 5K for the 7, 5, 2, 1, 0.4, and 0.2 mb levels. A goal for the 0.1 and 0.03 mb levels will be 7K. The thickness between all pressure levels and the 10-7 mb level shall also be determined. Pressure of the tropopause shall be determined to an RMS error goal of 20 mb. Temperature of the tropopause shall be determined to an accuracy of 5K rms.
2	S	Humidity Profiles	1 2 3 4 8 9 10 11 18	H H H H H H H H H	Determine the total water vapor mass, and the water vapor mass between the surface and 1000 mb, 1000 and 850 mb, 850 and 700 mb, 700 and 500 mb, 500 and 400 mb, 400 and 300 mb, and above 300 mb. Determine specific humidity and relative humidity at 1000 mb, 850 mb, 700 mb, 500 mb, 400 mb, and 300 mb. The specific humidity shall have an accuracy of ±20 percent or 1.5 g/kg, whichever is greater, over ocean background in clear conditions, and an accuracy goal of ± 20 percent or 1.5 gm/kg, whichever is greater, over other backgrounds. The spatial resolution shall be ≤ to 50 km and the swath width shall be 1707 km.
3	I	Ocean Surface Wind	12 13 14 15 16	H V V H V	Determine ocean surface wind speed to accuracy of 2 meters/second with a 1 meter/second quantization interval. Scene spacing shall be 25 km, and the swath width shall be 1707 km.
4	I	Rain Over Land/ Ocean	12 13 14 15	H V V H	Determine Rain flag. Determine rain rate to an accuracy of 5 mm/hr goal on regional basis. Swath width shall be equal to 1707 km.

Column					
1	2	3	4	5	6
Item No.	Sounding (S)/ Imagery (I) Parameter	Environ-mental Parameter	Chan. No.	Polarization	Output Environmental Parameter Specifications
			16 17 18	V V H	
5	I	Cloud Water Over Ocean	12 13 14 15 16 18	H V V H V H	Determine cloud water over the ocean to an accuracy of 0.10 kg/m^2 with a 0.05 kg/m^2 quantization level. Scene spacing shall be 25 km with a swath width of 1707 km.
6	I	Soil Moisture	12 13 14 15 16 17 18	H V V H V V H	Determine soil moisture to an accuracy goal of ±10 percent with 5 percent quantization intervals. Scene spacing shall be 25 km and the swath width shall be 1707 km.
7	I	Ice Concen-tration	12 13 16 15	H V V H	Determine ice concentration (percent area covered) to an accuracy of ±10 percent with 5 percent quantization intervals. Scene spacing shall be 25 km and the swath width shall be 1707 km.
8	I	Ice Age	12 13 15 16	H V H V	Quantize sea ice into first year or multi-year ice with a scene spacing of 25 km and swath width of 1707 km.
9	I	Ice Edge and Snow Edge	12 13 15 16 17 18	H V H V V H	Flag ice and snow edges with a scene spacing of 25 km and swath width of 1707 km.
10	I	Water Vapor Over Ocean	12 13 14 16	H V V V	Determine water vapor over the ocean to an accuracy of ±3 kg/m^2 (tropics), ±2 kg/m^2 (mid latitudes) and ±1 kg/m^2 (polar) with a quantization interval of 0.5 kg/m^2. Scene spacing shall be 25 km and swath width shall be 1707 km.
			12	H	

Column					
1	2	3	4	5	6
Item No.	Sounding (S)/ Imagery (I) Parameter	Environ-mental Parameter	Chan. No.	Polarization	Output Environmental Parameter Specifications
11	I	Surface Type	13 14 15 16 17 18	V V H V V H	Determine surface type in categories of ocean, ice, coast and land. Land subtypes are: standing water or flooded, dense vegetation (jungle), agricultural/ rangeland (some vegetation), arable soil (dry), soil (moist surface), semi-arid surface, desert, and snow. Swath width shall be 1707 km and scene spacing shall be 25 km. There is no accuracy requirement.
12	I	Snow Water Content	12 13 14 15 16 17 18	H V V H V V H	Determine snow water content with an accuracy goal of ±3 cm and a quantization interval of 0.5 cm. Scene spacing shall be 25 km and swath width shall be 1707 km.
13	I	Surface Temper-ature Over Land	12 13 14 15 16 17	H V V H V V	Determine surface temperature over land with an accuracy goal of ±2.5K with a 1K quantization interval. Scene spacing shall be 25 km and swath width shall be 1707 km.

2.5.2.3.1 Imager Environmental Parameter (IEP) File

Table 10 presents a list of data elements contained within the IEP File.

Table 10 IEP File Data Elements

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Revolution number	Revolution number (full)	None	0 to 2147483647	Integer
Satellite ID	Satellite ID 1=F16, SSMIS Ser# 1 2=unassigned 3=unassigned	None	1 to 3	Integer
Year	Scan Year	Years	4 digits	Integer
Julian Day	Scan Julian day	Days	1 to 366	Integer
Hour	Scan hour	Hours	0 to 23	Integer
Minute	Scan minute	Minutes	0 to 59	Integer
Environmental scan time	Milliseconds since midnight	Milliseconds	0 to 86400000	Integer
Latitude	Scene latitude (+ north)	degrees *100	-9000 to 9000	Integer
Longitude	Scene longitude (+ east)	degrees *100	-18000 to 18000	Integer
Rain flag 1	Rain flag for previous imager scene -1 = indeterminate 0 = no rain 1 = rain	None	-1 to 1	Integer
Rain flag 2	Rain flag for next imager scene -1 = indeterminate 0 = no rain 1 = rain	None	-1 to 1	Integer
Rain rate	Rain rate	mm/hour	-1 to 127	Integer
Surface tag	Surface tag -1 = Unknown 0 = Land 1 = Spare 2 = Near coast 3 = Ice 4 = Possible ice 5 = Ocean 6 = Coast 7 = Spare	None	-1 to 7	Integer
Land SFC type	Land surface type	None	-1 to 21	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
	-1 = Undetermined 0 to 6 = Spare 7 = Floods 8 = Dense vegetation 9 = Agricultural/Range Vegetation 10 = Dry arable soil 11 = Moist soil 12 = Semi-Desert 13 = Desert 16 = Composite vegetation and water 17 = Composite soil and water 18 = Dry snow 19 = Wet snow 20 = Refrozen snow 21 = Glacial ice		See description.	
Surface snow water content	Snow water content over land -1 = Undetermined	mm	-1 to 250	Integer
Snow depth	Snow depth over land -1 = Undetermined	mm	-1 to 16 bits	Integer
Soil moisture	API converted -1 = Undetermined	mm	-1 to 70	Integer
Land surface temp	Surface temperature over land -99 = Undetermined	Celsius	-99, -95 to 67	Integer
Ice edge, Snow edge	Sea ice edge or snow edge 0 = No edge 1 = Ice edge 9 = Undetermined	None	0, 1, 9	Integer
Ice concentration	Sea ice concentration -1 = Undetermined	Percent	-1 to 100	Integer
Ice age	Sea ice age -1 = Undetermined 2 = First year 4 = Multiyear	Years	-1, 2, 4	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Ocean surface wind speed flag	Wind speed accuracy -1 = Undetermined 0 = < 2 m/sec 1 = 2 - 5 m/sec 2 = 5 - 10 m/sec 3 = > 10 m/sec	None	-1 to 3	Integer
Ocean water vapor	Water vapor mass over ocean -1 = Undetermined	kg/m**2 *10	-1, 0 to 800	Integer
Ocean surface wind speed	Wind speed over ocean -1 = Undetermined	m/sec *10	-1, 0 to 500	Integer
Ocean cloud water	Cloud water over ocean -1 = Undetermined	kg/m**2 *100	-1, 0 to 600	Integer
Ocean cloud amount	Cloud amount over ocean -1 = Undetermined	Percent	-1 to 100	Integer

2.5.2.3.2 Lower Air Sounding (LAS) File

Table 11 is a list of data elements contained within the LAS File.

Table 11 LAS File Data Elements

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Revolution number	Revolution number (full)	None	0 to 2147483647	Integer
Satellite ID	Satellite ID 1=F16, SSMIS Ser# 1 2=unassigned 3=unassigned	None	1 to 3	Integer
Year	Scan Year	Years	4-digits	Integer
Julian Day	Scan Julian day	Days	1 to 366	Integer
Hour	Scan hour	Hours	0 to 23	Integer
Minute	Scan minute	Minutes	0 to 59	Integer
Lower scan time	Milliseconds since midnight	Milliseconds	0 to 86400000	Integer
Latitude	Scene latitude (+ north)	degrees *100	-9000 to 9000	Integer
Longitude	Scene longitude (+ east)	degrees *100	-18000 to 18000	Integer
Relative humidity	Relative humidity at 1000, 850, 700, 500, 400, and 300 mb -1 = Undetermined	Percent	-1 to 100	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Specific humidity	Specific humidity at 1000, 850, 700, 500, 400, and 300 mb -100 = Undetermined	g/kg * 100	-100 to 2500	Integer
Water vapor mass	Water vapor mass between surface and 1000mb, 1000 and 850, 850 and 700, 700 and 500, 500 and 400, 400 and 300, and above 300 mb -100 = Undetermined	(kg/m**2) * 100	-100 to 10000	Integer
Lower temperature	Temperature at 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 mb 999 = Undetermined	Celsius * 10	-1200 to 999	Integer
Tropopause pressure	Tropopause pressure 999 = Undetermined	mb	50 to 999	Integer
Tropopause temperature	Tropopause temperature 999 = Undetermined	Celsius * 10	-1000 to 999	Integer
Terrain height	Terrain height -32768 = Undetermined	meters	-32768, -400 to 7000	Integer
Surface tag	Static surface tag -1 = Unknown 0 = Land 1 = Spare 2 = Near coast 3 = Ice 4 = Possible ice 5 = Ocean 6 = Coast 7 = Spare	None	-1 to 7	Integer
Cloud mass data	Cloud mass -100 = Undetermined If Surface tag is Ocean then values are flags 1 = clear	(g/m**2) * 100	-100, 0 to 127	Integer

Data Element	Description	Unit of Measure	Limit/Range	Data Type
	15 = heavy cloud If Surface tag is NOT Ocean then values are density in g/m**2 in the range 0.0 to 1.27 (unscaled)			
Humidity D-Matrix id	Atmospheric type See section 3.27 Operational Humidity D-Matrix for definitions.	None	1 to 25	Integer
Temperature D-Matrix id	D-Matrix level 1 = Atm type 26, Trop pressure (P < 120 Mb) 2 = Atm type 27, Trop pressure (120 <= P <= 250 Mb) 3 = Atm type 28, Trop pressure category (P > 250 Mb)	None	1 to 3	Integer
Lower temperature quality flag	Sum of #valid scenes when computing 3x3 averages for channels 1-7, 24. (3 scans per channel x 8 channels = 24 possible valid scenes)	Total #valid scenes used in the averaging.	0 to 24	Integer
Lower humidity quality flag	Sum of #valid scans and scenes when computing 3x3 averages for channels 1-4 (3 scans per channel x 4 channels = 12 possible valid scans), and 5x5 averages for channels 8-11,18 (25 scenes x 5 channels = 125 possible valid scenes). (12 + 125 possible valid scenes = 137)	Total #valid scenes used in the averaging.	0 to 137	Integer
1000 mb height	Height of 1000 mb pressure level -999 = Undetermined	meter	-500 to 500	Integer
Lower heights	Lower heights at 1000, 850, 700, 500, 400, 300, 250, 200, 150 mb -999 = Undetermined	meters	-999 to 14000	Integer
Lower heights	Lower heights at 100, 70, 50, 30, 20, 10 mb -999 = Undetermined	decameters	-999, 1500 to 8500	Integer

2.5.2.3.3 Upper Air Sounding (UAS) File

Table 12 lists data elements contained within the UAS File.

Table 12 UAS File Data Elements

Data Element	Description	Unit of Measure	Limit/Range	Data Type
Revolution number	Revolution number (full)	None	0 to 2147483647	Integer
Satellite ID	Satellite ID 1=F16, SSMIS Ser# 1 2=unassigned 3=unassigned	None	1 to 3	Integer
Year	Scan Year	Years	4-digits	Integer
Julian Day	Scan Julian day	Days	1 to 366	Integer
Hour	Scan hour	Hours	0 to 23	Integer
Minute	Scan minute	Minutes	0 to 59	Integer
Upper scan time	Milliseconds since midnight	msec	0 to 86400000	Integer
Latitude	Scene latitude (+ north)	degrees*100	-9000 to 9000	Integer
Longitude	Scene longitude (+ east)	degrees*100	-18000 to 18000	Integer
Temperature	Temperatures at 7,5,2,1, 0.4, 0.2, 0.1, 0.03 mb	Celsius * 10	-150 to 50	Integer
Height	Heights at 10, 7, 5, 2, 1, 0.4, 0.2, 0.1, 0.03 mb	decameter	0 to 12000	Integer
Geomagnetic Field	Squared geomagnetic field strength	uTesla**2	0 to 5000	Integer
B dot K	Dot product of geomagnetic field with propagation vector	uTesla**2	0 to 5000	Integer
Temperature quality flag	Sum of #valid scans / scenes when computing 6x6 averages for channels 19-23 (6 scans x 5 channels = 30 possible valid scans), and 6x6 average for channel 24 (6 scans x 2 scenes x 1 channels = 12 possible valid scenes). (30 + 12 possible valid scans = 42)	Total #valid scenes used in the averaging.	0 to 42	Integer

3. SDR Algorithm Descriptions

3.1 Beam Location

One of the primary tasks of the SDRP is to provide Earth location coordinates (geodetic latitude and longitude) for each output data sample. This is accomplished with the beam location algorithm. Data samples used for atmospheric profiling from the 1000 mb level to the 10 mb level are referenced to a height of 11 km and are located with an accuracy of 12.5 km. The Earth location of data samples for upper air temperature profiles from the 7 mb level to the 0.03 mb level are referenced to a height of 60 km, and are accurate to 12.5 kilometers. Data from the imaging channels and from channels used to obtain the other environmental parameters are Earth-located to within 7 km (at the Earth's surface).

The beam location algorithm essentially combines the scan geometry and sampling characteristics described in Sections 2.1 and 2.3 above, with spacecraft ephemeris information (altitude, subsatellite latitude and longitude, time, and attitude) to compute the latitude and longitude of each of the 180 beam positions. The SSMIS beam location algorithm, like that used for the SSM/I, determines a full scan of beam positions once a given scan is targeted for location. However the exact location of every beam in a scan requires a large number of computer operations and, hence, is not a desirable procedure. Thus, similar to the method used for the SSM/I, only certain points (referred to as base points) are located exactly. The others are located by means of third degree interpolatory polynomials.

Even though considerably more than the 128 beam positions per scan applicable to the SSM/I are located, the SSMIS algorithm is both faster and more accurate due to improvements made in choosing base points and carrying out the interpolation. Ignoring deviations from non-ideal behavior such as radiometer mounting misalignment, spacecraft attitude misalignment, and possible errors in predicted ephemeris data, the maximum beam location error found using the SSMIS algorithm is less than 2.7 km for a nominal 833 km orbit. This occurs at high latitudes. Considerably smaller errors are found in tropic and temperate regions. As for the effects of non-ideal behavior, provision is made in the algorithm to accommodate alignment effects as they are discovered. A detailed description of the beam location algorithm is presented in Appendix A.

3.2 Radiometric Calibration

The purpose of the radiometric calibration algorithm is to convert the raw scene counts to antenna temperatures using the radiometric counts and temperatures of the reference cold and warm loads. Figure 4 presents an example plot of warm and cold load calibration reference points. This step must be completed before corrections for Doppler compensation, cross-polarization coupling, and feedhorn spillover can be applied.

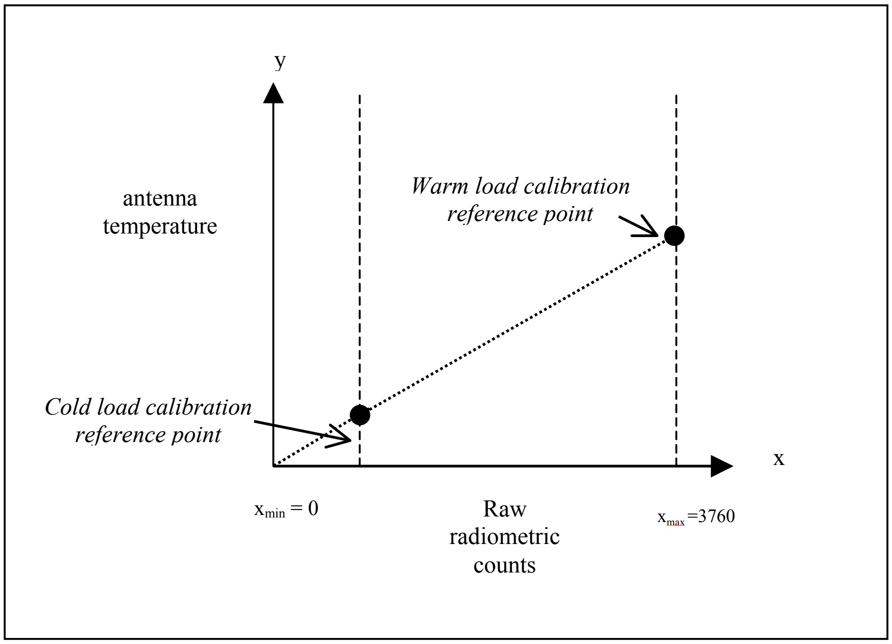


Figure 4 Antenna Temperature Model

The usual equation for converting counts to antenna temperatures is

$$T_A = T_C + \frac{T_W - T_C}{C_W - C_C}(C_N - C_C)$$

where

T_A = antenna temperature for the scene

T_W = warm load temperature (including load bias corrections)

T_C = cold load temperature (including cold path bias corrections)

C_W = warm load count

C_C = cold load count

C_N = scene count

As indicated in Section 2.4.4, the data stream output from the SSMIS contains a reduced 12 bit scene count (C_R) rather than C_N . The definition of C_R implies that

$$\frac{C_N - C_C}{C_W - C_C} = \frac{C_R}{K}$$

so that the usual equation reduces to

$$T_A = T_C + \frac{T_W - T_C}{K} C_R$$

This equation will be applied separately to each of the 24 channels. The factor T_W - T_C will be computed once per scan so that one multiply and one add will be required per scene station.

3.3 Doppler Correction

This section describes the correction for the RF gain and bias changes due to the Doppler shift compensation performed onboard the SSMIS.

The combination of conical scan and spacecraft nonzero ground velocity cause the RF signals received by the SSMIS to be Doppler shifted. The Doppler shifts, dependent on the scan angle, are significant relative to bandwidths of some frequency channels. Thus, in principal all channels, but especially narrow-band upper-air channels, must be compensated for the Doppler effect. As described in Section 2.4.2, the SSMIS sensor compensates for the Doppler shifts in the air-temperature-sounding channels by appropriately adjusting the local-oscillator frequency. However, in addition to compensating for the Doppler shift, this frequency tuning also causes gain changes in the temperature-sounding channels and bias changes in some non-temperature-sounding channels.

The effect of these changes on brightness temperature was measured during calibration testing and quantified in terms of a Doppler-correction coefficient ($\Delta T_{B,Doppler}$). These measurement were made for all channels, but were found to be significant (of order 0.1K or greater) for Channels 1-7 and 19-24 on all five SSMIS sensors, and for Channels 15-16 on some sensors. $\Delta T_{B,Doppler}$ was tabulated in terms of sensor look-direction (i.e., forward or backward relative to the satellite flight direction), device mode (i.e. primary or backup PLO), and instrument temperature. Measurements were performed for peak Doppler shift (scan center) only.

The Doppler Correction algorithm of the SSMIS GPS uses the appropriate Doppler-correction coefficient table to correct scene brightness temperatures for the effect of the gain and bias changes. Because this correction is essentially a modification of the counts-to-brightness temperature transfer function, it is performed after calibration and before the polarization cross-coupling and feed-horn spillover corrections. The expression used to correct the scene brightness temperature is

$$T_{B,a} = T_{B,b} - \left|\sin(\text{Scan Angle})\right| \cdot \Delta T_{B,Doppler} \cdot \frac{(T_{B,b} + T_R)}{(305 + T_R)}$$

where $T_{B,b}$ and $T_{B,a}$ are the scene brightness temperatures before and after the Doppler correction, respectively; $\Delta T_{B,Doppler}$ is the Doppler-correction coefficient for a combination of sensor serial number, sensor-look direction, device mode, and instrument temperature; and T_R is the receiver temperature for the channel. The ratio $\frac{(T_{B,b} + T_R)}{(305 + T_R)}$ is only applicable to the channels where the Doppler compensation causes a gain modulation (the temperature sounding channels) and is set to unity for the other channels where the compensation causes a bias change. The numerator is the system noise temperature for the scene of interest, whereas the denominator is the system temperature for the conditions under which the Doppler-correction coefficients were measured (i.e. a target temperature of 305K was used).

A detailed description of the Doppler correction algorithm is provided in Appendix C.

3.4 Antenna Spillover and Cross Polarization Correction

The scene antenna temperature T_A may be expressed in terms of an integral of the scene brightness temperature distribution T_S incident on the antenna reflector and the effective co- and cross-polarized far-field antenna gain functions. For channel center frequency v_o, polarization p, and with the antenna pointed in direction $\hat{k}$, T_A may be written as

$$T_A(p,\hat{k}) = \int_{earth} d\Omega \left[G_{pv}(\hat{k},\hat{k}')T_S(v,\hat{k}') + G_{ph}(\hat{k},\hat{k}')T_S(h,\hat{k}') \right] + (1-\eta_P)T_{\cos mic}$$

where

$G_{pq}(\hat{k},\hat{k}')$ = effective (i.e. includes low pass filter effect) far-field antenna gain functions

T_{cosmic} = cold space brightness temperature at frequency v_o

η_p = feedhorn spillover factor

In principal the accuracy of the SSMIS estimate of the scene brightness temperature (i.e. SDRs) may be improved by making antenna corrections intended to remove the effects of:

a) Feedhorn spillover loss η_p

b) Cross-polarization coupling G_{pq} $(p \neq q)$

The feedhorn spillover factor is defined as the fraction of energy received from the reflector in polarization p to the total energy received by the feedhorn. η_p therefore corrects for the fact that the reflector solid angle does not include all of the feedhorn pattern as is assumed during calibration testing. In practice η_p is approximated by numerically integrating the feedhorn pattern over the solid angle of the reflector.

Cross-polarization coupling refers to the undesired reception of signal from the orthogonal polarization channel. Maximum cross-polarization contribution occurs when the SSMIS views a cloudless dry atmosphere over calm ocean surface.

The Antenna Pattern Correction (APC) algorithm consists of a linear correction for feedhorn spillover loss and cross-polarization coupling. For the vertical polarization it may be written as:

$$\hat{T}_s(v,\hat{k}) = \frac{1}{\eta_v(1-b_v)} \left[T_A(v,\hat{k}) - b_v T_A(h,\hat{k}) \right]$$

where $T_A(v,\hat{k})$ and $T_A(h,\hat{k})$ are the antenna temperatures (i.e., TDRs) for the vertical and horizontal polarizations for antenna boresight direction $\hat{k}$, and $T_S(v,\hat{k})$ is the desired SDR corresponding to

$T_A\left(v,\hat{k}\right)$. The justification for this algorithm is based on the fact that the spillover factor η_p is essentially the same for the v- and h- polarization at each frequency and that the cross-polarization coupling occurs primarily within the mainbeam of G_{pp}. Also note that the form of the correction uses the fact that η_v is close to unity for all channels and hence the cosmic background contribution may be neglected. A similar expression applies for the horizontal polarization.

Values for η_p are required for all SSMIS channels and are obtained as indicated above by numerical integration of the measured feedhorn patterns.

The quantity b_v is a measure of the integrated cross-polarized coupling for the v-polarization and is selected on the basis of eliminating the cross-polarization coupling when the vertical and horizontal scene temperatures are uniform but not necessarily equal over the antenna field-of-view. It is given by

$$b_v = \frac{\int_{Earth} d\Omega' G_{vh}}{\int_{Earth} d\Omega' G_{hh}}$$

A similar expression holds for b_h. The actual values of b_v and b_h used in the algorithm were obtained from measurement data collected during Beam Efficiency and Polarization Purity tests.

The accuracy of the algorithm in removing cross-polarization coupling depends on the spatial variability of the incident cross-polarized scene brightness temperature. For a temperature distribution essentially uniform over the main beam, the correction is extremely accurate. The accuracy degrades slightly in the event significant cross-polarized variations occur within the main beam.

The accuracy of the algorithm in removing the feedhorn spillover loss depends on the accuracy of the determination of the spillover loss factor η_p which is currently obtained by integrating the feedhorn antenna pattern over the solid angle subtended by the reflector. Accurate knowledge of η_p is important because a 10% error in a spillover loss of 3% can result in a ~1 K error in the SDR.

3.5 Scene Averaging

As detailed in Section 2.4.3, spatial averaging in the along-scan direction is accomplished with onboard spacecraft data processing. One of the tasks of the ground data processing is to complete the spatial averaging process begun onboard the spacecraft. For Channels 1 - 7 and 24, three along-track beam averages are needed to complete the 3 x 3 array required for improving the NEΔT. Likewise for Channels 19 - 24 six along-track beam averages must be performed. (Note Channel 24 is averaged to two scales). Because the retrieval algorithm for the humidity profiles employ Channels 1 - 4 in addition to Channels 8 - 11 and 17 – 18, and because Channels 1 - 4 are averaged (3 along-track x 3 along-scan) it is desirable to average Channels 8 - 11 and 17 - 18 to the averaged resolution of Channels 1 - 4. In addition it is desirable to beam average the 91.65 GHz to the resolution of the 37 GHz for the surface typing and land parameter retrievals.

The algorithm to spatially average Channels 8 - 11 and 17 - 18 to the resolution of the 3 x 3 averaged temperature sounding channels may be expressed as a weighted linear combination of 5 along-track and 5 along-scan samples surrounding the averaged temperature sounding channel sample position. The beam center of the averaged humidity channel lies at the center of the 5 by 5 array which is also the beam center of the averaged temperature sounding channels. Figure 5 illustrates the beam separation near the subsatellite track. Although the 5 x 5 configuration remains fixed across the scan, the distances between the pixels change dramatically near the edges of the swath. This configuration is repeated across each scan of the 3 x 3 averaged temperature sounding data.

Figure 5 Spatial Averaging of Channels 8 - 11 and 17 - 18

x	x	x	x	x
x	x	x	x	x
x	x	o	x	x
x	x	x	x	x
x	x	x	x	x

x - sample positions of the humidity channels

o - position of the 3 x 3 averaged temperature channels

The weighting coefficients vary across the scan so that there will be 60 sets of coefficients for each humidity channel.

The algorithm for averaging the 91.65 GHz sampled brightness temperatures to the resolution of the 37 GHz data may also be expressed as a weighted linear combination of 5 along-track by 4 along-scan samples surrounding the center of the 37 GHz sample position as shown in Figure 6.

Figure 6 Spatial Averaging of 91.65 GHz Brightness Temperatures

x	x		x	x
x	x		x	x
x	x	o	x	x
x	x		x	x
x	x		x	x

x - sampled 91.65 GHz data

o - 37 GHz position

This configuration remains fixed across the scan. There are 90 sets of coefficients for both Channels 17 and 18. However, since the environmental parameters are retrieved on a 25 km spacing the above averaging need be done only on a 25 km grid. This means that the 5 x 4 weighted average is done on every other scan even though the 37 GHz data are available every scan.

Table 13 is a matrix of spatial averaging vs. channels and output data type. The imager data have a maximum of 180 scenes per scan and include Channels 8 - 11 (frequencies of 150 GHz and 183 GHz) and Channels 17 and 18 (91.65 GHz). The channels output as imager data do not undergo scene averaging. The environmental data have a maximum of 90 scenes per scan and include Channels 12 through 18. Channels 12 through 16 undergo 2 x 1 scene averaging onboard only. In SDRP Channels 15 and 16 (37 GHz) undergo an additional 5 x 5 scene averaging for the odd scans only. Channels 17 and 18 (91.65 GHz) undergo a a 5 x 4 scene averaging (to match the 37 GHz footprint) followed by 5 x 5 scene averaging for the odd scans only, to match the averaged 37 GHz footprint.

For the LAS data, there is a maximum scene count of 60 scenes per scan. In SDRP three scans of Channels 1 – 7, and 24 are averaged (3 along-scan sample averaging has been done onboard), while Channels 8 - 11 and 18 undergo 5 x 5 scene averaging. The UAS data output have a maximum of 30 scenes per scan and include Channels 19 through 24, and undergo 6 scan averaging.

Table 13 Matrix of Scene Averaging Configurations vs. Channel and SDRP Output Type

	Imager	**Environmental**	**Lower Air Soundings (LAS)**	**Upper Air Soundings (UAS)**
Number Scenes per Scan	180	90	60	30
Channels:				
1			3 x 3	
2			3 x 3	
3			3 x 3	
4			3 x 3	
5			3 x 3	
6			3 x 3	
7			3 x 3	
8	1 x 1		5 x 5	
9	1 x 1		5 x 5	
10	1 x 1		5 x 5	
11	1 x 1		5 x 5	
12		1 x 2		
13		1 x 2		
14		1 x 2		

15		1 x 2 5 x 5 (odd scans only)		
16		1 x 2 5 x 5 (odd scans only)		
17	1 x 1	5 x 4 5 x 5 (odd scans only)		
18	1 x 1	5 x 4 5 x 5 (odd scans only)	5 x 5	
19				6 x 6
20				6 x 6
21				6 x 6
22				6 x 6
23				6 x 6
24			3 x 3	6 x 6

3.6 Rain Flag

The rain flag (rain/no rain) is computed by the SDRP_RAINFG routine of the GPS. SDRP_RAINFG uses SSMIS Channels 8 - 18 and executes the following steps:

1. Initialize the rain flag to "Rain."
2. Compute polarization corrected temperature for the 91 GHz frequency (SSMIS channels 17 (V) and 18 (H))
3. Test the polarization corrected temperature for possible rain. If the corrected temperature is greater than or equal to the threshold, there is no rain. Tests for possible rain > 3mm/h using Spencer's polarization corrected brightness temperatures with filtering to remove ambiguities due to snow, glacial ice, desert sand, and sea ice.
4. If the polarization corrected temperature is less than 255, there is possible rain and the next step is to proceed to test for possible ambiguities.
5. If the SSMIS Cal/Val has been done and the coefficients for the 150 GHz and 183 GHz channels have been determined, use these channels to check for rain over land, Otherwise, use Grody's snow/glacial ice, desert sand tests for land background and a simple threshold test of the 19 GHz, horizontal polarization channel to identify the presence of sea ice for ocean background for latitudes greater than 44.5 deg and less than -52 deg.

6. If there is sea ice, then set the rain flag to “No rain.”

3.7 Sea Ice Flag

The SDRP_SEAICE routine is used to compute the sea ice flag. The sea ice flag is set to ice, coast, sea, or no ice. The algorithm uses SSMIS Channels 12 - 14 with the following combination of frequencies/polarizations: 19 GHz, horizontal polarization (Channel 12); 19 GHz, vertical polarization (Channel 13); and 22 GHz, vertical polarization (Channel 14). The algorithm employs the following steps:

1. If the surface is sea or ice, check the Channel 12 threshold brightness temperature to determine if it is sea ice, coast, or sea.

2. If the Channel 12 brightness temperature is greater than 210 K, the “Sea Ice” tag is used and the “Coast” flag is used if the Channel 12 brightness temperature is greater than 130 K; else the “Sea” flag is used. Otherwise there is no sea ice and the flag is set to “No Ice.”

3. If the surface tag is “Ice,” set ice flag for “Ice.” If the surface tag is “Sea,” then compute threshold values TT1 and TT2:

   a) TT1 = 44.0 + 0.85 * B19V

   b) TT2 = B22V - B19V

4. If the brightness temperature in Channel 14 is less than or equal to TT1 or if the Channel 14 brightness temperature is greater than 264 K and TT2 is less than 2.0, then the flag is set to “Sea Ice,” else, no sea ice is present.

4. EDR Algorithm Descriptions

4.1 Sounding Algorithm Descriptions

4.1.1 Lower Air Temperature

The SSMIS system is required to determine air temperatures at a fixed set of pressure levels from 1000 mb to 0.03 mb. The lower air portion of the retrievals concerns the soundings up to 10 mb (corresponding to a height of approximately 30 km). Above this level retrievals require a consideration of physical phenomena arising from the Zeeman splitting of the oxygen molecule absorption lines due to the Earth's magnetic field and demand specialized treatment (see Section 4.1.4 Upper Air Sounding).

The lower air temperature algorithm retrieves the air temperature at 15 mandatory pressure levels: 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20 and 10 mb. In addition, estimates of the tropopause pressure and temperature are also obtained. A regression matrix approach is used. In order to meet accuracy requirements, a number of matrices are required. However, in contrast to the earlier SSM/T-1, which used a fixed stratification based on four seasons of the year and three geographical zones, the SSMIS employs a dynamical stratification method where the choice of the inversion matrix to be used is determined by an initial estimate of the tropopause pressure, P_{trop}, obtained from an analysis of the microwave data. Three regimes are distinguished: (1) $P_{trop} < 120$ mb, which corresponds to high tropopause heights and typically to warm or hot mean tropospheric air temperatures, (2) a middle range 120 mb $< P_{trop} <$ 250 mb, and (3) $P_{trop} > 250$ mb, which corresponds to low tropopause heights and typically to cool or cold mean tropospheric air temperatures. After the proper matrix is selected, the air temperatures are retrieved together with the tropopause temperature and a final estimate of the tropopause pressure.

In order to apply the regression technique mentioned above, some accounting for Earth surface effects must be made because the emissivity and reflectivity of the Earth can vary over a wide range and because the Earth's surface is not always at sea level but can vary over a height of several thousand meters. To accommodate these effects without introducing a host of regression matrices representing different backgrounds, a technique, which was pioneered in the SSM/T-1 program, is used where each element of the data vector is not simply the measured brightness temperature but consists of that part of the brightness temperature which depends only on the atmospheric state and is independent of the background. The data vector elements for those channels that receive energy only from higher levels of the atmosphere and do not "see" the surface reduce to the brightness temperatures. For the SSMIS, significant refinements in the SSM/T-1 background correction algorithms have been made so that greater accuracy is achieved.

The algorithm retrieves air temperatures with the required RMS accuracy at all pressure levels (8K at 1000 mb, 6K at 850 mb, and 2K from 700 to 10 mb). In most instances, the retrieval accuracy is significantly better than the stated requirement. For the tropopause temperature, the required 5K accuracy is met with wide margin. However, the goal of 1K accuracy is not achieved. Nor is the goal of a tropopause pressure accuracy of $\pm$20 mb (RMS) achieved. The fact that these very stringent goals for the tropopause were not reached is not surprising in view of the wide variability of the tropopause height and the width of the weighting functions. However, the accuracy achieved by the SSMIS in this area is significantly better than that reached by its predecessor, the SSM/T-1. The mean calculated error in the retrieved air temperature at each of the levels from 1000 mb to 10 mb showed that the temperature bias requirement of less than 1K is fully satisfied.

A detailed description of the SSMIS lower air temperature retrieval algorithm is provided in Appendix B.

4.1.2 Lower Air Thicknesses

The SSMIS is required to retrieve the thickness of the atmosphere between the pressure levels at which the air temperature is retrieved up to 10 mb. Specifically, the thickness is required for the 14 pressure intervals 1000-850, 850-700, 700-500, 500-400, 400-300, 300-250, 250-150, 150-100, 100-70, 70-50, 50-30, 30-20, and 20-10 mb.

A separate calculation of the atmospheric thicknesses between the specified pressure levels is made using the derived air temperatures and a knowledge of the specific humidity (which is obtained from humidity retrieval algorithm contained in the SSMIS software package; see Section 4.1.3). The dependence of the thicknesses upon humidity data requires that, in the ordinary running of the SSMIS software, the humidity algorithm be exercised before the thickness algorithm. The air temperature retrieval is independent of the humidity algorithm and may be run either before or after the humidity algorithm. If, for any reason, the humidity algorithm is not run, atmospheric thicknesses may still be obtained by setting the specific humidity equal to zero at each of the levels where it is required in the thickness algorithm. In this case, the accuracy of the derived thicknesses is decreased in the lowest portion of the atmosphere. However, the retrieval results are still quite satisfactory. The thickness algorithm should not be exercised without air temperature data.

A direct, physically based retrieval is performed using the assumptions of hydrostatic equilibrium and that the temperature difference between two mandatory levels (P_1 and P_2) is small. A detailed description of the SSMIS lower air thickness algorithm is provided in Appendix B. The general equation for atmospheric thickness ($z_2 - z_1$) is:

$$z_2 - z_1 = -(R / 2g)\ln(P_2 / P_1)\left[T_1 + T_2\right]$$

where R = gas constant for dry air and g = acceleration due to gravity. T1 and T2 represent virtual temperatures. These are related to the air temperature, T, and specific humidity, q, by:

$$T_V = T\left[1 + .608\text{x}10^{-3} q\right]$$

Results using a test data set showed that the accuracies of layer thickness retrieved with this algorithm exceed accuracies based on climatological estimates. Once the thicknesses have been calculated, the height at each level can be determined by stacking the thicknesses starting with the height of the 1000 mb level.

4.1.3 Lower Air Humidity

The SSMIS system is required to determine relative humidity and specific humidity at 6 pressure levels (1000, 850, 700, 500, 400, and 300 mb) as well as the water vapor mass in the intervals surface (SFC)-850, 850-700, 700-500, 500-400, 400-300, and above 300 mb. If the surface is below the 1000 mb level, the SFC-850 interval is replaced by two intervals, SFC-1000 and 1000-850 mb. The total water vapor mass (the integral of the profile) is also determined.

The algorithm used for obtaining these products from SSMIS-measured brightness temperatures is the same as that currently in use with the SSM/T-2 (T2) [Aerojet, 1990; 1991], except regression coefficients are required for one scan angle only.

The humidity sounding algorithm uses the same basic regression matrix approach used for lower air temperature retrievals. In this algorithm brightness temperatures are used without modification except for retrievals over coasts. In this case only six channels are used: the three 183 GHz channels and the three temperature channels from which the surface contribution has been removed as described in the lower air temperature algorithm description (Appendix B).

In order to achieve the required retrieval accuracy, a total of 25 D-matrices are used. In addition to stratification based on the static terrain type (ocean, land, sea ice, coast), the algorithm also applies a dynamical stratification according to air mass characteristics (temperature and vapor content) derived from the data themselves. Over land, further discrimination is made on the basis of terrain height (derived from a data base). Cloud effects are not explicitly accounted for in the retrieval algorithm. Retrievals in the presence of heavy cloud cover are flagged at the end of the retrieval process.

Based on global accuracy statistics for mixed clear and cloudy cases, the algorithm meets the accuracy goals of 20% for relative humidity and 1.5 g/kg for specific humidity. However the retrieval error varies with surface type. The algorithm performs best over ocean and sea ice, and shows larger errors over land (e.g. ~18% RMS error in column average RH for land vs. ~13% RMS error for ocean).

A detailed description of the SSMIS lower air humidity algorithm is provided in Appendix D.

4.1.4 Upper Air Sounding

The purpose of the SSMIS Upper Air Sounding (UAS) algorithm is to retrieve atmospheric temperature (in K) at 8 pressure levels (7, 5, 2, 1, 0.4, 0.2, 0.1 and 0.03 mb), and geometric thickness (in m) for 8 layers (10-7, 7-5, 5-2, 2-1, 1-0.4, 0.4-0.2, 0.2-0.1, and 0.1-0.03 mb). These thickness values are then used to determine geometric height (m) based on the 10 mb height found with the Lower Air Thickness algorithm. The UAS algorithm is based on a multivariate regression technique in which the effects of the Earth's magnetic field are treated in a deterministic manner. It has been developed and demonstrated by Aerojet [Stogryn, 1989b].

The approach to recovering upper stratospheric and mesospheric temperature profiles from spectral brightness temperature measurements is much the same as for recovering lower atmospheric profiles. Like the Lower Air Temperature and Humidity algorithms, the UAS algorithm makes use of *a priori* statistics for global atmospheric conditions, derived from the Aerojet RAOB/ROCOB database. However, because of the strong dependence of the brightness temperatures used for upper-air temperature retrieval on local magnetic field conditions, portions of the D-matrix must be computed within the algorithm once the measurement location is known and the local field strengths and orientation relative to the look-direction can be determined. For this purpose the most recent model of the main magnetic field, the International Geomagnetic Reference Field (IGRF), is used. A detailed description of the SSMIS upper air sounding algorithm is provided in Appendix E.

Three external data files are required to support the UAS algorithm: (1) Sensor Constants File; (2) Alpha Beta File; and (3) Geomagnetic Field File. All three files are part of the GPS.

The Sensor Constants file contains the *a priori* statistics that depend on sensor configuration but are independent of magnetic field. Updates to these constants would be required if (a) the RAOB/ROCOB database were substantially expanded, or (b) spectroscopic research indicates that major changes in the radiative transfer code are needed.

The Alpha Beta File contains the squared RMS delta temperatures (DTRMS) for each of the six upper atmospheric channels as well as the linear regression correction coefficients alpha (actually alpha inverse) and beta that account for instrumental biases and possible inaccuracies in the *a priori* brightness temperature computations. During operational processing these variables are derived from coincident satellite and rocketsonde observations and updated in the GPS UPD processor.

The Geomagnetic Field File contains the X, Y, Z components of the geomagnetic field (in microTesla) on a 0.625º x 0.625º grid. Files were generated from the 2000 IGRF for a height of 60 km and for time intervals of 6 months through 1 January 2005. At that time a new model field should be available as model coefficients are updated every 5 years. Information on the IGRF for the current epoch and the table of coefficients (igrf2000tab.cof) can be obtained from the WEB site http://www.ngdc.noaa.gov/IAGA/wg8/igrf2000.html.

The performance of the UAS algorithm varies with magnetic field conditions and sounding geometries and degrades with height. Based on retrieval statistics using the in-house RAOB/ROCOB database, worst case RMS errors ranged from 1.5K to ~ 5K for pressure levels from 7mb to 0.2mb, and were ~ 6K and 6.5K for pressure levels 0.1 and 0.03 mb, respectively. The accuracy requirements are for 5k at levels from 7 to 1 mb, 5.5K at 0.4 mb, and 8K (goal) at 0.2 mb and above.

4.2 Environmental Algorithm Descriptions

4.2.1 Ocean Surface Wind

The SSMIS algorithm for wind speed over ocean is derived from the original Goodberlet algorithm (1990) that was subsequently modified by Petty (1993). The wind speed over ocean algorithm, OSFCWS, computes wind speed (SW) by using a linear combination of channels. The SSMIS instrument is required to retrieve ocean surface wind speed between 3 and 25 m/s with an accuracy of better than 2 m/s. The surface wind speed is referenced to a height of 19.5 m above the surface. The quantization level is 0.1 m/s on a 25-km grid in both the along-scan and along-track directions.

Light rain and water vapor significantly attenuate microwave radiation at the selected SSM/I frequencies (i.e., 19, 22, and 37 GHz). The SSMIS instrument uses the same set to derive the sea-surface wind speed. Specifically, microwave radiation that is emitted from the ocean surface contains information about wind speed. This radiation must pass through the water-laden atmosphere (i.e., the rain) before any passive sensor (e.g., SSM/I or SSMIS) can measure the masked radiation. The sea-surface wind speed is inferred from the measured brightness temperature. Thus, the rain is the fundamental limit on the retrieval accuracy of any passive wind speed algorithm. The stated accuracy refers to cases without rain in the antenna beams. Rain is present in approximately 15% of the scenes (Hollinger, 1991). Thus, the accuracy of the retrievals should be less than 2 m/s about 85% of the time. Accuracy flags are created to represent the accuracy of the wind-speed estimator in the presence and absence of rain. The higher the rain, the more deterioration in the accuracy of sea-surface wind speed.

Four criteria correspond to four accuracy flags between 0 and 3. The following table lists the criteria for the accuracy flags. Accuracy flag of zero indicates no rain. Accuracy flag of three corresponds to heavy rain. The accuracy flag can also be used to indicate the amount of atmospheric moisture.

Table 14 Accuracy Flags for Ocean Surface Wind Speed

Accuracy Flag	Criteria for Accuracy Flags	Accuracy
0	T_{B37V} - $T_{B37H} \geq 50$ K and $T_{B19H} \leq 165$ K	< 2 m/s
1	T_{B37V} - $T_{B37H} < 50$ K or $T_{B19H} > 165$ K	2-5 m/s
2	T_{B37V} - $T_{B37H} < 37$ K	5-10 m/s
3	T_{B37V} - $T_{B37H} < 30$ K	> 10 m/s

The algorithm sequence for the computation of ocean surface wind speed is detailed below.

1. If rain is present, then ocean surface wind speed cannot be determined.

2. Apply standard Goodberlet Wind Speed Algorithm.

   VMPSEC = 147.9 + 1.0969*B19V -0.4555*B22V - 1.760*B37V + 0.7860*B37H

3. Determine if necessary to correct for water vapor contamination and correct if necessary.

   It is necessary to correct for water vapor contamination if:

   ((300.0 - B19V) > 0) AND ((300.0 - B22V) > 0) AND ((300.0 - B37H) >0)

   The correction is made as follows:

   WV = 174.1 + 4.638*ALOG(300.0 - B19V) - 61.76*ALOG(300.0 - B22V) + 19.58*ALOG(300.0 - B37H)
   MPSEC = VMPSEC - 2.130 + WV*(0.2198 - 0.004008*WV)

   If no correction for water vapor contamination is required, then:

   MPSEC = VMPSEC

4. Check the bounds and scale to 10*m/s, and limit MPSEC to 0 - 25 m/s.

   IF (MPSEC < 0) then set MPSEC = 0
   IF (MPSEC > MXWISP) then set MPSEC = MAXOWS

5. Quantize the wind speed times 10 (SFOSWS = 10)

   WINDSP = NINT (MPSEC * SFOSWS)

6. Calculate delta average brightness temperature for 37 GHz V - H.

   PD37 = B37V - B37H

7. Check the value of PD37 to set ocean surface wind speed flag.

WINDFL = OSWSFU
IF (PD37 > 50.0) AND (B19H < 165.0) THEN
WINDFL = accuracy less than 2 m/sec (best)
ELSE
WINDFL = accuracy 2 to 5 m/sec
IF (PD37 < 37.0) then WINDFL = accuracy 5 to 10 m/sec

IF (PD37 < 30.0) then WINDFL = accuracy greater than 50 m/sec (worst)

4.2.2 Rain over Land/Ocean

The Rain over land/ocean algorithms were developed by Ferraro and Grody of NOAA/ NESDIS (Ferraro, 1997). The SSMIS SDRP determines the presence of rain for a 12.5-km scene station spacing from brightness temperatures of 19V, 19H, 22V, 37V, 37H, 91V, and 91H channels. The rain rate over land and ocean is determined by the GPS subroutine called RAINDT. The RAINDT subroutine computes the rain rate (mm/hr) over the surface tags of ocean or land and disregards sea ice or coast scenes. The rain rate (amount of rain over a delta time) has a resolution of 25 km, an accuracy of 5mm/hour (goal on a regional basis), and a quantization interval of 1mm/hour. RAINDT first computes rain over ocean and then computes rain over land. The algorithm processing sequence performed by the RAINDT subroutine is detailed below.

The following algorithm sequence is employed in subroutine RAINDT:

A. Rain over Ocean

1. Check if Brightness Temperatures within bounds before checking surface tags:

If ((B19V ≥ 100) and (B19V ≤ 300) and (B91V ≥ 80) and (B91V ≤ 300)) then proceed to check surface tags.

2. Check each surface tag for ocean or land

If the tag is SEATAG, then compute the rain over the ocean:
SI91 = -174.4 + 0.715*B19V + B22V*(2.439 - B22V*0.00504)- B91V

3. Check if rain or sea ice is possible

If (SI91 ≥ 10.0) then rain is possible
MMPHR = 0.00188 * SI91**2.034

Else check the Rain Emission Component if there is NO Scattering
Q19 = 0.0
Q37 = 0.0

4. Recompute the Rain Rate using 19 and 22 GHz

If (B19V < 285.0) and (B22V < 285.0) then
Q19 = -2.70*(ALOG(290.0-B19V)-.40*ALOG(290.0-B22V)-2.84)

5. If the following statement is TRUE, then RAIN is present:

IF (Q19 ≥ 0.6) THEN
MMPHR = 0.001707*(Q19*100.)**1.7359

6. If not true, then Recompute Rain Rate using 37 and 22 GHz

If (B37V < 285.0) and (B22V < 285.0) then
Q37 = -1.15*(ALOG(290.0 - B37V) – 0.32*ALOG(290.0 - B22V) - 2.99)

7. If the following statement is TRUE, then RAIN is present:

IF (Q37 ≥ 0.2) then MMPHR = 0.001707*(Q37*100.)**1.7359

8. IF (MMPHR < 0.0) MMPHR = 0.0

B. Rain over Land

1. If the tag is Land or Coast, then**:**

SI91 = 451.9 - 0.44*B19V + B22V*(-1.775 + B22V*0.00574) - B91V

If (SI91 ≥ 10.0) then

MMPHR = 0.00513 * SI91**1.9468

TT = 175 + 0.49*B91V

PD19 = B19V - B19H

2. Check for Snow Cover

IF (B22V < 264.0 .AND. B22V < TT) MMPHR = 0.0

3. Check for Desert

IF (PD19 > 20.0) MMPHR = 0.0

4. Check for Semi-Desert

If (B91V > 253.0) and (PD19 > 7.0) then MMPHR = 0.0

Else MMPHR = 0.0

If (MMPHR .LT. 0.0) then MMPHR = 0.0

Else

Rain Rate cannot be determined

MMPHR = RAINRU

5. Limit the range of Rain Rate to 0 - 35 mm/hr

IF (MMPHR < 0.0) MMPHR = 0.0

IF (MMPHR > 35.0) MMPHR = 35.0

6. Quantize Rain Rate to nearest 1 mm/hr

RAINRT = MMPHR

4.2.3 Cloud Water over Ocean

The cloud water over ocean (CWO) EDR algorithm was developed by Weng et al. (1997). This algorithm calculates the integrated ocean cloud water (or columnar cloud liquid water) in 100 kg/m^2 with an accuracy of 0.1 kg/m^2 and a quantization interval of 0.5 kg/m^2. The cloud water droplets measure less than 100 micrometers in diameter. The Weng et al. (1997) algorithm is executed by the OCLH20 subroutine of the GPS. The sequence of steps performed by the OCLH2O subroutine is detailed below.

1. Retrieve water vapor mass (SSM/I Cal/Val) (mm)

RWVP = 232.89393 - 0.148596*B19V + B22V*(-1.829125 + B22V*0.006193) - 0.36954*B37V

2. Use 19V as Primary Channel

If (B19V < 285) and (B22V < 285) then

ALG1 = 3.20* (2.84 + 0.40*ALOG(290.0 - B22V) - ALOG(290.0 - B19V))

Else ALG1 = 0.0

3. Use 37V as Primary Channel

If (B37V < 285) and (B22V < 285) then

ALG2 = -1.66* (ALOG(290.0 - B37V) - 2.99 - 0.32*ALOG(290.0 - B22V))

Else ALG2 = 0.0

4. Use 91H as Primary Channel

If (B91H < 285) and (B22V < 285) then

ALG3 = -0.44* (ALOG(290.0 - B91H) + 1.11 - 1.26*ALOG(290.0 - B22V))

Else ALG3 = 0.0

5. Determine which retrieval to use depending on value and RWVP

If (ALG1 > 0.70) then KGPM2 = ALG1

Else if (ALG2 > 0.28) then KGPM2 = ALG2

Else if (RWVP < 30) then KGPM2 = ALG3

Else KGPM2 = ALG2

6. Limit Range of Water Vapor: 0-6 mm

If (KGPM2 < 0) then KGPM2 = 0.0
If (KGPM2 > 6) then KGPM2 = 6.0

7. Quantize Cloud Water * 100

CLOUD = (KGPM2*100)

4.2.4 API/Soil Moisture

The algorithm used to compute API/Soil moisture was developed by MacFarland and Neale (1990). The API/soil moisture algorithm employs a normalized brightness temperature ratio (T_{19H}/T_{37H}) and a series of tests to determine vegetation density classes. Soil moisture is computed by the FDSOIL subroutine of the GPS.

Several factors affect the remote sensing of soil moisture at different microwave frequencies. The short wavelengths of the SSMIS instrument are inappropriate for soil moisture due to their small penetration depth in soil and consequently small moisture sensing depth. At short wavelengths (e.g., SSMIS frequencies), brightness temperatures only correspond to a shallow layer at the soil surface. Roughness and texture of soil surface decreases the sensitivity to soil moisture. Vegetation cover decreases the sensitivity to soil moisture due to self-emission, scattering, and de-polarization of microwave radiation. Additional noise in the soil-moisture retrieval is introduced by the surface-type variability and random patterns within a SSMIS scene. However, the quantity of water retained on the surface after a heavy rainfall event as well as moisture in the immediate soil surface layer down to a few millimeters can be assessed under sparse or incomplete vegetation cover.

EDRP estimates soil moisture at 25-km scene spacing over land for moist soil with accuracy of only ±10% at quantization interval of 5%. EDRP also computes the antecedent precipitation index (API). API is intended to be used as a basis for analysis. Its accuracy will be verified from the empirical relationship between API and soil moisture.

The API/soil moisture algorithm first classifies a moist-soil scene into the proper vegetation density (low, medium, or high). The conditions for low, medium, and high-density vegetation are,

$$\text{Low Density:} \quad B > 8$$

$$\text{Medium Density:} \quad 6 < B \le 8$$

$$\text{High Density:} \quad 4 < B \le 6$$

where:

$$B = \frac{\left(T_{B,19V} + T_{B,37V}\right)}{2} + \frac{\left(T_{B,19H} + T_{B,37H}\right)}{2}$$

EDRP then computes API and soil moisture SM over a moist-soil scene. Several field experiments have generally shown a linear relationship between brightness temperatures and soil moisture. The expressions for API and SM for low, medium, and high-density vegetation cases are,

$$API(low) = 659.35 - 675.22 * \frac{T_{B,19H}}{T_{B,37V}}$$

$$API(medium) = 1126.58 - 1145.48 * \frac{T_{B,19H}}{T_{B,37V}}$$

$$API(high) = 1707.24 - 1724.14 * \frac{T_{B,19H}}{T_{B,37V}}$$

$$SM = A + B * API + C * API^2$$

where $A = 0$, $B = 0.5$, and C=0.

If the estimate of soil moisture or API is negative, then it is arbitrarily set to zero. The soil moisture and API of other land types are indeterminate.

4.2.5 Ice Concentration

The upwelling brightness temperature of an ice scene is a function of the ice concentration, ice emissivity (i.e., ice type), the physical temperatures, and the amount of water vapor and liquid water in the intervening atmosphere. First-year ice is optically opaque because of its high salinity. Thus, its microwave signature is almost frequency independent. Old ice is optically thin because of its low salinity. Volume scattering due to air pockets in old ice decreases its radiation. As a result, brightness temperature of old ice is generally lower than that of first-year ice. The variability in brightness temperature of old ice is also larger at higher frequencies because its sensitivity to volume scattering is inversely related to wavelength.

The SSMIS instrument should retrieve the ice concentration at 25-km scene spacing at accuracy of ±10% and quantization interval of 5%. The ice concentration (i.e., total area ice cover C_{ice}) is the percentage of ice within a SSMIS 19 GHz footprint. The York University ice-concentration algorithm (Rubenstein, 1991) is implemented in SSMIS EDRP.

Brightness temperatures of channels 19V and 37V are first used to calculate fractions of two ice types (i.e., multi- and first-year ice) that could be within the footprint. The sum of multi- and first-year ice fractions is the total ice concentration. If the total ice concentration is less than 70%, another method combines brightness temperatures of channels 19H, 19V, 37H, and/or 37V to verify the presence of ice and to recalculate the ice concentration.

The GPS employs the ICEALG subroutine to compute the ice concentration (percent area covered) at a 25 km resolution with an accuracy of +/- 10% and a quantization interval of 5%. The ice concentration is only defined for ice flagged scenes at latitudes above 44.5° N or below -52° S. The steps implemented by the ICEALG subroutine are presented below.

1. Restrict sea ice concentrations to latitudes above the northern and below the southern limits.
2. Test for whether sea ice concentration is indeterminate. Sea ice concentration is indeterminate if:

   (B19V≤ 151) or (B19H ≤ 92) or (B37V ≤ 171) or (B37H ≤125) or

   (B19V-B19H ≥ 80) or (B37V-B37H ≥ 80) or (B19H > B19V) or

   (B37H > B37V)
3. If sea ice concentration is not indeterminate, compute sea ice concentration depending on season
   a. If the season is Winter, then

      ICONC = -1.677645 - 0.013656219*B37V + 0.024412842*B19V
   b. If the season is NOT Winter, then

      ICONC = -1.656920 - 0.015231617*B37V + 0.025911011*B19V
4. Check weather effects and compute Discriminant D

D = 1.0 - 0.0513*(B37V - B19V)

If (ICONC ≤ 0.7) and D ≤ 0.7) then

IF ((D ≤ 0.3) and ((1.5*B37V - B19V) > 120)), then ICONC = 0.0

If (B37V ≤ 215) then WCUT = 6.0

Else WCUT = 8.5

IF((D ≤ 0.15) or ((B37H-2.0*B37V+270.0) ≥ WCUT)) then ICONC = 0.0

5. Recompute sea ice concentration using only 37GHz

IF ((ICONC ≤ 0.5) and (D > 0.15)) ICONC = 0.01*(B37V + 0.5*B37H - 265.0)

6. Set limits of ice concentration and quantize (%)

ICONC = ICONC * SFICE

If (ICONC > ICEMIN), then the tag is equal to ICETAG

If (ICONC > MAXICE), then ICONC = MAXICE

If (ICONC < ICEMIN), then ICONC = 0.0

Else there is NO sea ice and ICONC = 0.0

7. Set Ice Edge Or Snow Edge

If (ICONC ≥ ICTHR) then XEDGE = EDGE

Else if ice concentration is undetermined then XEDGE = ISEDGU

Else XEDGE = NOEDGE

4.2.6 Ice Age

SSMIS EDRP can classify four ice types: summer, new, first-year, multi-year ice at 25-km scene spacing. The York University ice-age algorithm (Rubenstein, 1991) is implemented in SSMIS EDRP. The ice-concentration algorithm is integral to the ice-age algorithm.

The ice-age classification involved the total ice concentration C_{ice} about 70%. If C_{ice} is equal to or greater than 70%, then *a priori* knowledge of the sea ice signatures, and the weather and/or snow cover effects on the sea ice surface emitting/scattering properties can be used to correct some of the misclassification of the predominant ice type. Before the estimation of ice concentration and type, a multi-step testing procedure determines if the underlying surface is an ice-covered area or open ocean. The surface can be open ocean, under heavy cloud cover, and/or with different surface roughness. Another test distinguishes low ice concentration areas from open ocean with low winds and low to moderate cloud cover. Ocean parameters such as wind speed and columnar cloud liquid water for an ice-free scene are used to enhance the algorithm. The ocean parameters should suggest a misclassification of ice type if significant ice is present in the ice-free scene.

The GPS subroutine used to compute ice age is ICAGE. The sequence of steps executed in the ICAGE algorithm is presented below.

1. Check if ice age is indeterminate

   If (ICONC ≤ 25.0) then ice age is undetermined

2. Set total concentration (TC) according to Season:

   a. If Season is Winter then TC = 6.8

   b. If Season is NOT Winter then TC = 14.0

3. Compute Ice Age Algorithm:

   TV = 100*(B19V - TC - 1.8*(100.0 - ICONC)) / ICONC

   a. If (TV < 238.0) then Ice Age = Multi-Year Ice

   b. Else Ice Age = First-Year Ice

4.2.7 Ice Edge and Snow Edge

The DMSP SSM/I calibration/validation effort suggests no classification rule to detect snow edge due to lack of precise ground truth data. The determination of a scene as an ice or snow edge in SSMIS EDRP relates to surface types of surrounding scenes. The edge-detection algorithm involves the use of the Sobel operators (Garcia, 1978). Simulation results showed that the edge-detection algorithm correctly identified snow edges within different land scenes, ice edges between ocean and ice scenes, and ice edges between land and ice scenes.

SSMIS EDRP sets a flag to indicate the presence of a snow/ice edge. The edge flag in EDRs does not indicate if it corresponds to a snow or ice edge. The flag for snow/ice edge has three states: (1 - snow/ice edge, 0 - no snow/ice edge, 9 - indeterminate). EDRP uses the Sobel operators to detect snow/ice edges at 25-km scene spacing. A snow/ice edge occurs at scene X_5 if the following inequality is satisfied:

$$|S_1 X| + |S_2 X| \geq 4$$

where

$$S_1 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, \quad S_2 = \begin{bmatrix} -1 & 0 & -1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \text{ and } X = \begin{bmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{bmatrix}$$

The parameters S_1 and S_2 are the Sobel operators. For scene X_1 through X_9, if any scene is missing or contains rain, then the edge flag for scene X_5 is indeterminate. For land surface type of dry or refrozen snow at X_i, X_i is unity if and only if its snow water equivalent is greater than or equal to 3 millimeters. For an ice scene at X_i, X_i is unity if and only if the ice concentration is greater than or equal to 10%. Otherwise, X_i should be zero irrespective of the surface type.

The FDIESE subroutine of the GPS computes the Ice Edge/Snow Edge algorithm. The major steps employed in the FDIESE subroutine are to:

1. Loop through all scans
2. Loop through all scenes
3. Find partial Sobel products
4. Check for undetermined ice or snow edge scenes
5. Check for Sobel product ≥ 4 for edge.
6. Flag the computed edge values as follows:
   a. 0 = No edge
   b. 1 = Edge
   c. 9 = Undetermined.

4.2.8 Water Vapor over Ocean

SSMIS EDRP can retrieve two useful geophysical parameters: columnar water vapor mass and cloud liquid water between the ocean's surface and the top of the atmosphere. The water content of the atmosphere is very important for meteorology, climatology, and hydrology. The evaporation of water from the ocean surface and its condensation into clouds and precipitation is an important energy transport mechanism for the dynamics of the atmosphere. The amount of liquid water in clouds affects the incoming and outgoing radiative fluxes. The water that eventually falls as precipitation over land comes from the ocean.

The low emissivity of ocean makes it a good background for viewing the intervening atmosphere. The emissivities of different targets are based on their dielectric properties. Water has a very large dielectric constant at microwave frequencies. As a result, its reflectivity and emissivity are large and low, respectively, for surface such as ocean. Most solid surfaces have emissivities between 0.8 and 0.95. Thus, microwave signatures of liquid water surfaces (e.g., lakes and ocean) and solid surfaces (e.g., land and sea ice) should significantly contrast.

The required accuracy for water-vapor retrievals in SSMIS over ocean at 25-km scene spacing is 3 kg/m^2 over tropics, 2 kg/m^2 over mid-latitude regions, and 1 kg/m^2 over polar regions with quantization interval of 0.5 kg/m^2. The SSMIS water-vapor algorithm is almost identical to the SSM/I water-vapor algorithm. The original SSM/I algorithm is the Hughes algorithm. The Hughes algorithm is divided into eleven climate codes for each hemisphere, each of which relates to appropriate latitude zones and/or seasons. The SSM/I calibration/validation report (Hollinger, 1991) proposed a water-vapor algorithm that reduces the rms. retrieval errors (relative to those from the Hughes algorithm) on a global and zonal basis and removes the discontinuities at boundaries of the zonal regions.

SSMIS EDRP uses the following expression (Alishouse, 1990; Hollinger, 1991) to estimate columnar water vapor mass WV (i.e., total precipitable water) over ocean. If the estimate is negative, then it is arbitrarily set to zero. Note that the brightness temperature of channel 22V dominates the water-vapor estimation.

$$WV = 232.894 - 0.148596 * T_{B,19V} - 1.82912 * T_{B,22V} + 0.006193 * (T_{B,22v})^2 - 0.36954 * T_{B,37V}$$

The use of the above nonlinear water-vapor algorithm increases the sensitivity of water-vapor retrievals to cloud-water amount, and presence of precipitation or ice. The report strongly suggests the test of the following inequality for precipitation presence before the estimation of water vapor:

$$-11.7939 - 0.02727 * T_{B,37V} + 0.0992 * T_{B,37H} > 0$$

EDRP does not implement the above inequality in this algorithm. EDRP currently estimates column water vapor mass regardless of the rain-flag status or the outcome of the inequality. Thus, water-vapor estimates at scenes whose rain is present should be interpreted accordingly.

Whenever rain at an ocean scene is absent, EDRP checks if the scene is partially filled with ice before the water-vapor estimation. The surface type of a scene with partially filled ice is classified as ice instead of ocean. Thus, rain-rate estimate should be indeterminate for an ice scene.

The GPS employs the OH2OVA subroutine to compute water vapor over ocean. The OH2OVA subroutine employs limit range bounds of water vapor of 0 and 80 mm and applies a scaling factor of 10 to quantize the water vapor.

4.2.9 Surface Type

SSMIS EDRP classifies thirteen land types: flooded condition or standing water, dense vegetation, range land (dense agriculture and/or range vegetation), dry arable soil, moist soil, semi-arid surface, desert, dry snow, refrozen snow, wet snow, composition vegetation and water, composition soil and water, and indeterminate. An indeterminate land type is assigned to a land scene when all conditions of the other twelve land types are not met. EDRP assigns an integer of 13 to represent an indeterminate land type.

If vegetation partially or totally covers a SSMIS footprint, then the land scene has a land type of dense vegetation. Over land, a large variability of natural surface types occurs within a SSMIS footprint. The variability includes different degrees of vegetation cover, topographic characteristics, and the presence of water bodies such as lakes and reservoirs. Dense vegetation occurs in agricultural regions with crops at different stages of growth or canopy cover, on rangeland with grasses and shrub type vegetation at peak growth, or on combinations of these. This category of vegetation is still considered dense with respect to surface soil moisture retrievals.

Passive microwave emissions are different for three types of soil: dry arable soil, semi-arid soil, and desert. Passive microwave emission from a water surface is highly polarized, with an emissivity of about 0.4 for the 19H channel. The emission from bare soil is relatively less polarized, with higher emissivities (typically 0.9 and above the horizontally polarized channels for a dry surface). The effect of the presence of water in an essentially bare soil is to decrease the brightness temperatures and to increase the polarization difference. If vegetation is present, the vegetative scattering process decreases the polarization difference.

The three soil types are from a dynamic combination of bare soil, water in or on the soil surface, and different degrees of vegetation cover. The natural vegetation cover varies as a function of season and the soil water content. The water present on the soil surface varies as a function of the rainfall and the hydrologic response. The brightness temperature is also a function of frequency due to the variation of the real component of the dielectric constant with frequency. The dielectric constant of water is higher at longer wavelengths. The depth of the emitting layer is also greater at the longer wavelengths. The net effect is a broad range of brightness temperatures and polarization.

The Central Plains of the United States is an example of dry arable soil. The semi-arid classification corresponds to areas where natural vegetation is sparse and of a desertic type (e.g., Sonoran Basin and Range). Very smooth, sandy surfaces such as the Sahara desert and the total absence of vegetation cover cause extreme polarization differences.

Moist-soil surfaces and scenes with larger water bodies are differentiated from dry surfaces with the 37V, 37H, 91V, and 91H channel combinations. The table below allows EDRP to differentiate between moist soil and other land types. Several classification rules are used to identify surface moisture and surface water bodies (i.e., flooded soil, moist soil, composite water and soil, and composite water and vegetation). Brightness temperatures of a scene would not be lower due to the lower physical temperature of the soil or vegetation but as a result of the contamination by a surface with completely different microwave emission properties.

A scene with composite water and soil includes locally flooded soil, lakes, large rivers, and other surface waters. The land scene with water as a component would have a complicated passive microwave signature. Water has a much lower emissivity and a much higher polarization difference than other land surfaces. The brightness temperatures of this land scene would be very difficult to interpret in terms of physical surface temperature.

The classification rule for a scene with composite dense vegetation and water is similar to that for a scene with composite soil and water. Dense vegetation has a strong unpolarized signature with usually warm brightness temperatures. Water has a low emissivity, thus colder brightness temperatures, and a highly polarized signature. Threshold values for this rule were from observations of vegetation/river footprints in the Amazon jungle.

A land scene with flooded soil (i.e., standing water) has large amounts of water on the soil surface due to heavy precipitation events, melting snow, and/or the presence of large natural lakes and reservoirs. The water in the land scene lowers the brightness temperatures at all frequencies due to the high permittivity of water. Brightness temperatures of the 22V channel are greater than that of the 19V channel because the microwave emissivity of water increases with frequency.

Microwave emissions from snow covered surfaces depend on several factors. Some factors are: 1) the underlying surface type, 2) the moisture content of the underlying soil and if the water is frozen or in liquid form, 3) the depth of the snowpack, 4) the density of the snowpack, 5) the shape and size of the snow crystals and, 6) the liquid water content of the snowpack. Thus the classification of snow is complicated as the microwave signature from a snowpack with constant depth can vary with snow morphology, snow ripeness, and cycles of melting and re-freezing under spring weather conditions. Therefore, the interpretation of microwave signatures from a snow-covered surface at any point in time would benefit from the history of previous weather and snowpack conditions.

The normal microwave signature of dry snow is the depression of brightness temperatures in the 37 GHz channels with respect to the 19 GHz channels due to volume scattering. At 37 GHz, the scattering process dominates in the total extinction coefficient. When snow is present, brightness temperatures of the 19 GHz channels decrease partly due to scattering and partly due to the decreased physical temperature of the snow and the underlying soil. The classification rule for dry snow includes discrimination of cold bare soil, large precipitation thunderstorm clouds, and dry arable soil.

For high volumetric water contents, scattering is insignificant and the wet or melted snow begins to behave like a blackbody radiator. The partial melting of the top layer causes an increase in the volumetric water content of snow. A small amount of liquid water (e.g., volumetric water content of 0.01) will increase the volume absorption coefficient to be greater than the scattering coefficient. As a result, the scattering albedo is reduced to a very small value (Ulaby, 1986). As a result, the microwave brightness temperatures at 37H and 37V channels will increase with respect to that at 19H channel.

Refrozen snow has a distinct signature from dry and wet snow. Brightness temperatures decrease with increasing frequency in 37V and 37H channels. Thawing at the snow surface usually occurs when the air temperature is warm. The refreezing process starts when air temperature is sufficiently cold. The thawing and refreezing processes increase the size and change the shape of ice crystals. The ice crystals likely become spherical and larger in size as the snowpack undergoes several thawing and refreezing cycles. The size change of ice crystals increases the scattering albedo and decreases the polarization dependence. The polarization dependence causes additional scattering at longer wavelengths and lowering brightness temperatures.

The DMSP SSM/I calibration/validation effort proposed three sets of surface-type classification rules. Three sets correspond to three conditions of SSM/I channels. The conditions are:

1. All seven SSM/I channels are available,
2. SSM/I 85V channel is unavailable, and
3. SSM/I 85V and 85H channels are unavailable.

SSMIS EDRP uses the first set. In order to apply a set of rules in SSMIS EDRP, brightness temperatures of SSMIS 91V and 91H channels are used in place of those of SSM/I 85V and 85H channels.

Table 15 Accuracy Flags for Ocean Surface Wind Speed

Land Type	**Threshold Values for Brightness-Temperature Combination, T_B**							
	[a]	**[b]**	**[c]**	**[d]**	**[e]**	**[g]**	**[h]**	**[j]**
Standing Water	> 4							
Dense Vegetation	< 4	< 1.9		> -1	< 4.5	> 262		
Dense Agriculture/ Range Vegetation	< 4	< 4 > 1.9		> -1	< 4.5	> 262		
Dry Arable Soil	< 4	> 4 ≤ 9.8	> -6.5	< 0.5 ≥ -5	< 4.2			
Moist Soil	< 4	> 4 < 19.7	> -6.5	> 0.5 < 4	< 4.2			
Semi-Arid Surface	< 4	> 9.8 < 19.7		< 0.5	< 6			< -1.8
Desert	< 2	> 19.7			> -1	> 268		
Dry Snow[1]	< 4	> 4	< -6.5				> 225 ≤ 257	

Refrozen Snow[2]	< 4	> 4	< -6.5				< 225	
Wet Snow	< 4	> 9.8	< -0.8 ≥ -6.5	< 0.5			< 268 > 253	< -1.8 ≤ 6.5
Composition Vegetation/Water	< 4	< 6.4		> -1	> 4.5	> 257		
Composition Soil/Water	< 4	> 6.4	> 6.5	> 0.5	> 4.2			

[a] $T_{B,22V} - T_{B,19V}$
[b] $(T_{B,19V} + T_{B,37V})/2 - (T_{B,19H} + T_{B,37H})/2$
[c] $T_{B,37V} - T_{B,19V}$
[d] $T_{B,91V} - T_{B,37V}$
[e] $T_{B,91H} - T_{B,37H}$
[f] $T_{B,37V} - T_{B,37H}$
[g] $T_{B,19V}$ [h] $T_{B,37V}$
[j] $T_{B,37H} - T_{B,19H}$

<u>Additional Conditions</u>:

[1] $T_{B,19V} - T_{B,19H} \geq 5$

[2] $T_{B,19V} > T_{B,37V} > T_{B,91V}$ and $T_{B,19H} > T_{B,37H} > T_{B,91H}$

The SSMIS GPS employs the FDSFCT subroutine which performs the surface type characterization algorithms. The steps employed in FDSFCT are detailed below.

1. Compute Average Polarization Difference

   APD = 0.5 * (B19V + B37V - B19H - B37H)

2. Check for Snow Cover:

   a. Compute 37 GHz and 91 GHz Snow Scattering Indices

      SC37 = B19V - B37V - 3.0
      SC91 = B22V - B91V - 3.0
      SCX = B37V - B91V - 1.0
      SCAT = SC91

   b. Compute Polarization Differences

      PD19 = B19V - B19H
      PD91 = B91V - B91H
      If (SC37 > SCAT) SCAT = SC37
      IF (SCX > SCAT) SCAT = SCX

   c. Check if Snow Possible

If (SCAT > 0) then SNOW is Present

LSTYPE = DSNOW1

d. Remove Cold Rains

IF (B22V ≥ 260 and PD91 ≥ 3.0 and SCAT ≤ 3.0) LSTYPE = LSTYPU

e. Remove Other Rain Events

TT = 169.0 + 0.5*B91V
IF (B22V ≥ 264 or B22V ≥ TT) LSTYPE = LSTYPU

f. Remove Cold Deserts

IF (PD19 ≥ 18 and SC37 ≤ 10 and SCX ≤ 10) LSTYPE = LSTYPU

g. Remove Frozen Grounds

IF (PD19 ≥ 8 and SC91≤ 6.0 and SC37 ≤ 2.0) LSTYPE = LSTYPU

h. Check for Glacial Ice

IF(B22V ≤ 216 or (B22V ≤ 235 and PD19 ≥ 23)) LSTYPE = GLACIAL

i. Check for types of Snow only if NOT Undetermined or Glacial

IF (LSTYPE = DSNOW1) THEN

(1) Determine DRY or WET Snow
Test first for DRY Snow

If (((B22V - B19V) ≤ 4.0) and (APD > 4.0) and ((B37V - B19V) < -6.5) and (B37V > 225.0) and (B37V≤ 257.0) and ((B19V - B19H) ≥ 5.0)) then
LSTYPE = DSNOW1

(2) Test next for WET Snow

If (((B22V - B19V) ≤ 4.0) and (APD > 9.8) and ((B37V-B19V) ≤-0.8) and ((B37V-B19V) ≥ -6.5) and ((B91V - B37V) < 0.5) and (B37V ≤ 268.0) and (B37V > 253.0) and ((B37H - B19H) ≥ -1.8) and ((B37H - B19H) ≤ 6.5)) then LSTYPE (ISCENE, ISCAN) = WSNOW

(3) Test next for REFROZEN Snow

If (((B22V-B19V) ≤ 4.0) and (APD > 4.0) and ((B37V-B19V) < -6.5) and (B37V ≤ 225.0) and (B19V > B37V) and (B37V > B91V) and (B19H > B37H) and (B37H > B91H)) then
LSTYPE = RSNOW

ELSE

j. Check for Flooded Surface

If ((B22V - B19V) > 4.0) Then LSTYPE = FLOODE

k. Check for Dense Vegetation

Else if (((B22V - B19V) ≤ 4.0) and (APD ≤ 1.9) and ((B91V-B37V) ≥ -1.0) and ((B91H-B37H) < 4.5) and (B19V > 262.0)) then
LSTYPE = DNSVEG

l. Check for Less Dense Vegetation

Else if (((B22V - B19V) ≤ 4.0) and (APD ≤. 4.0) and (APD > 1.9) and ((B91V - B37V) ≥ -1.0) and ((B91H-B37H) < 4.5) and (B19V> 262.0)) then
LSTYPE = LDVEG

m. Check for Dry Arable Soil

Else if (((B22V - B19V) ≤ 4.0) and (APD ≤ 9.8) and (APD > 4.0) and ((B37V - B19V) ≥ -6.5) and ((B91V-B37V) < 0.5) and ((B91V-B37V) ≥ -5.0) and ((B91H-B37H) < 4.2)) then
LSTYPE = DRYARA

n. Check for Moist Arable Soil

Else if (((B22V - B19V) ≤ 4.0) and (APD < 19.7) and (APD > 4.0) and ((B37V - B19V) ≥ -6.5) and ((B91V-B37V) ≥ 0.5) and ((B91V-B37V) < 4.0) and ((B91H-B37H) < 4.2)) then
LSTYPE = MSTARA

o. Check for Semi-Desert

Else if (((B22V - B19V) ≤ 4.0) and (APD < 19.7) and (APD > 9.8) and ((B91V - B37V) < 0.5) and ((B91H-B37H) < 6.0) and ((B37H-B19H) < -1.8)) then
LSTYPE (ISCENE, ISCAN) = SEMDS1

p. Check for Desert

Else if (((B22V - B19V) ≤ 2.0) and (APD ≥ 19.7) and ((B91H-B37H) > -1.0) and (B19V > 268.0)) then
LSTYPE = DESERT

q. Check for Composite Water and Vegetation

Else if (((B22V - B19V) ≤ 4.0) and (APD ≤ 6.4) and ((B91V-B37V) ≥ -1.0) and ((B91H-B37H) ≥ 4.5) and (B37V > 257.0)) then
LSTYPE = WATVEG

r. Check for Wet Soil

Else if (((B22V - B19V) $\leq$ 4) and (APD $\geq$ 6.4) and ((B37V-B19V) $\geq$ -6.5) and ((B91V-B37V) $\geq$ 0.5) and ((B91H-B37H) $\geq$ 4.2)) then
LSTYPE = WATSOI

s. Else Land Surface type is Indeterminate

LSTYPE = LSTYPU

4.2.10 Snow Depth and Snow Water Content

Snow depth is highly correlated with microwave brightness temperatures. Snow particles behave as volume scatterers. Passive microwave radiation from a snowpack is a function of the frequency distribution of snow crystal and grain sizes. This frequency distribution is highly correlated with snow depth. The DMSP SSM/I calibration/validation report (Hollinger, 1991) concluded excellent correlation between snow depth and microwave brightness temperatures. Moreover, the use of the 37V channel provides the highest correlation coefficient of any SSM/I channel or channel combination only for dry and refrozen snow (Hollinger, 1991).

Dry and refrozen snow have many microwave properties. Vegetation and roughness in a dry- or refrozen-snow scene decrease the polarization differences. In contrast, bare and moist soil increases the differences. At shorter wavelengths (e.g., 91V, 91H, 37V, and 37H channels), the primary effect of a new, dry snow is to depress brightness temperatures. The polarization differences should increase dramatically. Brightness temperatures in longer wavelengths are likely unchanged from those prior to the new and dry snow.

The SSMIS GPS uses the FDSH2O subroutine to compute the land snow water content (mm) and snow depth (mm) over surface types of only dry snow or refrozen snow at 25 km resolution. Snow water content is computed using snow depth values derived from the Kunzi (1982) algorithm.

$$SWE = D * \overline{P}$$

$$D = 1.46(T_{B,19H} - T_{B,37H}) + 1.6$$

where $\overline{P} = 0.27$ and is an approximation of the average density of snow. Output snow water content values have an accuracy of +/- 3 cm goal and a quantization interval of 0.5 cm. Snow depth (in mm) is calculated using the SSM/I algorithm:

$$SD = 4445.0 - 17.95T_{B,37V}$$

The SSM/I algorithm uses the 37V channel only and generates the depth of snow in mm from 0 to 400 mm with a quantization interval of 5 mm.

The sequence of steps executed by the FDSH2O subroutine are:

1. For snow water content:
   a. Initialize snow water content to a constant term (the last coefficient)
   b. Loop through each of the coefficients
   c. Multiply each non-zero coefficient by the brightness temperature and sum them
   d. Check the minimum and maximum bounds on LSSWC
   e. Convert centimeters to millimeters and quantize.

2. For snow depth:
   a. Compute snow depth using SSM/I algorithm.

   b. Check minimum and maximum bounds and quantize.

4.2.11 Surface Temperature over Land

SSMIS estimates surface temperature over land at 25-km scene spacing with accuracy of ±2.5 Kelvin and quantization interval of 1 Kelvin. SSMIS EDRP estimates surface temperature for eight land surface types: dense vegetation, range land, arable soil, moist soil, semi-arid surface, desert, composition soil/water, and composition vegetation/water. EDRP assigns a large negative (i.e., –99 Celsius) as indeterminate surface temperature for other land types.

Land surface temperatures can be retrieved without a priori knowledge of land emissivity, absorption, or scattering. The DMSP SSM/I calibration/validation effort reports excellent correlations between the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) in the 18 and 37 GHz vertical and horizontal channels, and air temperature for dry range and prairie areas in the northern Great Plains (Lambert, 1987; Hollinger, 1991). Thus, the temperatures of densely vegetated or dry land surfaces can be estimated accurately from linearly polarized brightness temperatures. Information from the 22V channel can be used to correct for atmospheric water vapor absorption. Information from the 19H or 37H can reduce the effects of surface or soil water on the emissivity. The surface-temperature retrieval from passive microwave radiometry was likely meaningless in the presence of snow, ice, or water (Hollinger, 1991).

The relationship between land surface temperature in Kelvin and brightness temperatures is (Hollinger, 1991):

$$T_{SUR} = c_0 + c_1 T_{B,19H} + c_2 T_{B,22V} + c_3 T_{B,37V} + c_4 T_{B,91V}$$

The values of the coefficients for the different land types are presented in the following table.

Table 16 Accuracy Flags for Ocean Surface Wind Speed

Land Surface Type	C_0	C_1	C_2	C_3	C_4
Dense Vegetation	24.94	-1.2784	0.8800	0.5933	0.7299
Range Land/Arable Soil	6.97	-0.6266	0.2716	-0.1297	1.4820
Moist Soil	23.16	-0.1873	0.5221	-0.6271	1.2320
Semi-Arid Surface/Desert	72.68	0.4598	0.5984	0.8828	-0.2623
Composition Soil/Vegetation	26.46	-0.3133	0.7327	-0.4469	0.9540

The SSMIS GPS employs the subroutine named FDLTEM to compute the land surface temperature (°C) as a function of surface type at 25 km resolution with an accuracy of +/- 2.5 K goal and a quantization interval of 1 K. The sequence of algorithm processing steps executed by FDLTEM are detailed below.

1. Compute Surface Temperature over Vegetation

   a. If the land surface type = dense vegetation (DNSVEG) or (WATVEG) then
   TEMP = 24.94 - 1.2784*B19H + 0.8800*B22V + 0.5933*B37V + .7299*B91V
   b. If the land surface type = (LDVEG) then
   TEMP = 6.97 - 0.6266*B19H + 0.2716*B22V - 0.1297*B37V + 1.4820*B91V
   c. If the land surface type = MSTARA or WATSOI then
   TEMP = 23.16 - 0.1873*B19H + 0.5221*B22V - 0.6271*B37V + 1.2320*B91V
   d. If the land surface type = desert (DESERT) or Semi-Desert (SEMDS1) or Dry Arid (DRYARA) then
   TEMP = 72.68 - 0.4598*B19H + 0.5984*B22V + 0.8828*B37V - 0.2623*B91V
   e. Else Temperature is Indeterminate
   TEMP = LSTEMU
   LSTEMP (ISCENE, ISCAN) = TEMP

2. Compute Degrees C and Quantize

   a. If (LSTEMP ≠ LSTEMU) then CTEMP = TEMP - CONK2C
   b. If (CTEMP < MNLTEM) then LSTEMP = MINLTE
   c. Else if (CTEMP > MXLTEM) then LSTEMP = MAXLTE
   d. Else LSTEMP = CTEMP

5. Notes

5.1 Acronyms and Definitions

ADUM	Algorithm and Data User Manual
AFWA	Air Force Weather Agency
AFSC	Air Force Headquarters Space System Division
ARK	Archive Processor
ASCII	American Standard Code for Information Interchange
ASD	Algorithm Specification Document
CAGE	Commercial and Government Entity
CDR	Critical Design Review
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
DC	Data Computed
DD	Data-Data
DM	Data Measured
DMSP	Defense Meteorological Satellite Program
DTRMS	Delta Root Mean Square
EDR	Environmental Data Records
EDRP	Environmental Data Records Processor
EFOV	Effective Field of View
EIA	Earth Incident Angle
EOSOH	Early Orbit / State of Health Processor
FNMOC	Fleet Numerical Meteorological Oceanography Center
GHz	Gigahertz
GPS	Ground Processing Software
GRID	GRID Processor
IEP	Imager Environmental Parameters
IGRF	International Geomagnetic Reference Field
km	Kilometer
LAS	Lower Air Sounding
LO	Local Oscillator
mb	Millibar
MISS	Microwave Sounder Suite
MHz	Megahertz
NEΔT	Noise Equivalent Delta Threshold
OLS	Operational Linescan System
PLO	Phase Loop Oscillator
RAOB	Radiosonde
RMS	Root Mean Square
ROCOB	Rocketsonde
RSDR	Raw Sensor Data Record
SDR	Sensor Data Record
SDRP	Sensor Data Records Processor
SN01	Serial Number 1, SSMIS Sensor
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager / Sounder
TDR	Temperature Data Record

TIM	Technical Interchange Meeting
UAS	Upper Air Sounding
UPDP	Update Processor
VCO	Voltage Controlled Oscillator
VERP	Verification Processor

5.2 Appendices

The following Appendices are located in separately provided files or documents.

Appendix A SSMIS Beam Location Algorithm

Appendix B SSMIS Lower Air Temperature and Thickness Retrieval Algorithm

Appendix C Doppler Correction Algorithm In Brightness-Temperature Computation

Appendix D SSMIS Lower Air Humidity Sounding Algorithm

Appendix E SSMIS Upper Air Sounding Algorithm