USER'S MANUAL

SSM/I ANTENNA TEMPERATURE TAPES

Remote Sensing Systems

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Issued: March 25, 1988

RSS Technical Report 032588

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ACKNOWLEDGMENTS

We would like to acknowledge the support of NASA's Oceanic Processes Program under Contract NASW-4046 for the SSM/I ocean products investigation. We are also grateful to J. Wilkerson at NOAA/NESDIS and J. Hollinger at NRL for supplying the SSM/I DEF tapes.

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SECTION 1. INTRODUCTION

On June 19, 1987, the Special Sensor Microwave/Imager (SSM/I) was launch aboard the Defense Meteorological Satellite Program (DMSP) Block 5D-2 Spacecraft F8. This satellite radiometer is observing the microwave emission from the Earth at four frequencies, 19.35, 22.235, 37.0, and 85.5 GHz, and is providing information on a variety of environmental parameters, including atmospheric water, wind speed, and sea ice.

This document describes the SSM/I antenna temperature (T_A) data set produced by Remote Sensing Systems. This data set is essentially a compacted, chronologically-ordered version of the Temperature Data Records (TDR's) being produced by Fleet Numerical Oceanographic Center. The compacted T_A data are available on a series of 6250 cpi magnetic tapes (8 tapes per month of data). These tapes are intended to provide interested investigators with conveniently formatted SSM/I sensor data that can serve a wide range of applications.

SECTION 2. SENSOR DESCRIPTION

The SSM/I orbit is circular, sun-synchronous, and near-polar, with an altitude of 860 km and an inclination of 98.8°. The orbital period is 102 minutes, and the local time for the ascending equatorial crossing is 6:12 am. This orbit provides complete coverage of the Earth, except for two small circular sectors of 2.4° centered on the North and South poles.

SSM/I is actually 7 separate total-power radiometers, each simultaneously measuring the microwave emission coming from the Earth and the intervening atmosphere. Table 1 gives the frequencies, polarizations, and temporal and spatial resolutions of the 7 channels. Dual-polarization measurements are taken at 19.35, 37.0, and 85.5 GHz, and only vertical polarization is observed at the 22.235 GHz water vapor channel.

The antenna portion of the SSM/I consists of an offset parabolic reflector of dimensions 61 by 66 cm, which focuses the microwave radiation into a corrugated, broad-band, 7-port antenna feedhorn. The radiometer and antenna spin as a unit about an axis parallel to nadir. The rotation period is 1.9 s. A cold calibration reflector and a hot reference load are attached to the spin axis and do not rotate. The rotating antenna feedhorn observes the fixed cold reflector and hot load once each scan. In this way, calibration observations are taken every scan.

Earth observations are taken during a 102.4° segment of the rotation when the SSM/I is looking in the aft direction, as is shown in Figure 1. The 102.4° arc is centered on the spacecraft subtrack and corresponds to a 1394-km wide swath on the Earth's surface. During each scan, the 85 GHz channels are sampled 128 times over the 102.4° arc. The integration period for a single sample is 3.89 ms. This sampling scheme results in 128 v-pol footprints and 128 h-pol footprints having an effective 3-dB resolution of about 15 km.

Observations at the lower three frequencies are only taken every other scan. Scans during which the lower channels are sampled are called 'A-scans', and the other scans are called 'B-scans'. During the 102.4° arc of an A-scan, 64 samples of each of the lower channels are taken, with the integration period being 7.95 ms. The spatial resolutions of the samples depends upon the frequency and are given in Table 1.

More information on the SSM/I is given in the *Special Sensor Microwave/Imager User's Guide* [*Hollinger et al.*, 1987], which is available from the Naval Research Laboratory.

Table 1. Temporal and Spatial Resolution of SSM/I Channels

Frequency (GHz)	Polarization	Integration Period	3 dB Footprint Size Along-track	Cross-track
19.35	vertical	7.95 ms	69 km	43 km
19.35	horizontal	7.95 ms	69 km	43 km
22.235	vertical	7.95 ms	50 km	40 km
37.0	vertical	7.95 ms	37 km	28 km
37.0	horizontal	7.95 ms	37 km	29 km
85.5	vertical	3.89 ms	15 km	13 km
85.5	horizontal	3.89 ms	15 km	13 km

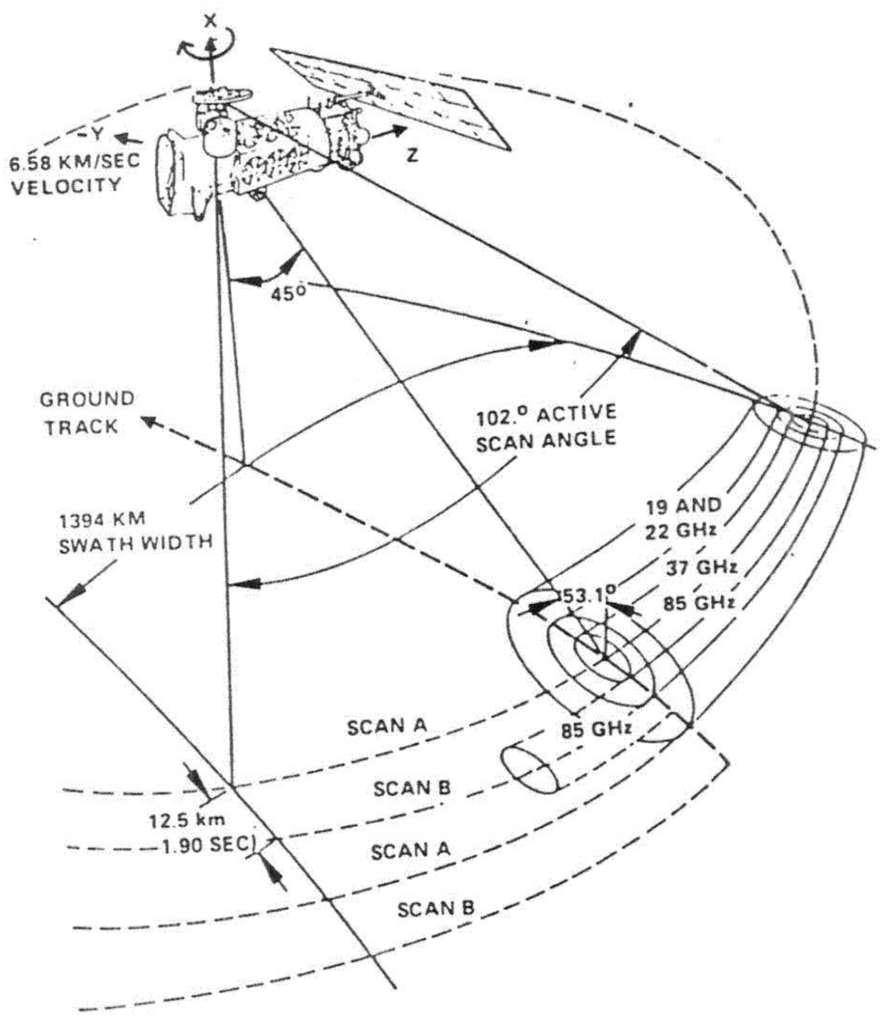

Fig. 1. SSM/I orbit and scan geometry (from *Hollinger et al.* [1987]).

SECTION 3. COMPARISON OF SSM/I AND SMMR SENSOR DESIGN

The predecessor to SSM/I is the Scanning Multichannel Microwave Radiometers (SMMR) that were flown aboard SeaSat and Nimbus-7, both launched in 1978. The SSM/I sensor design has several advantages compared to the SMMR's. First, the parabolic reflector and feedhorn spin as a unit. For SMMR, the feedhorn was stationary, while the parabolic reflector scanned back and forth. As the reflector scanned above the fixed feedhorn, the orientation of the reflected Earth's vertical and horizontal polarization vectors were rotated relative to the feedhorn polarization vectors. Thus the mixture of v-pol and h-pol radiation continuously varied during the scan. The polarization rotation effect was further complicated by spacecraft attitude variations. To some degree, these effects were compensated for during data processing. However, the corrections for polarization rotation coupled with attitude variations were subject to error, thereby degrading the quality of the SMMR data. SSM/I is free of the polarization rotation problem, and the SSM/I spacecraft attitude is much more stable than that for SeaSat or Nimbus-7.

The second advantage is the simplified, external calibration of SSM/I. The SSM/I has a single horn with 7 ports that go to 7 separate radiometers. No switching is required, and all channels observe the same two calibration sources. Compare this calibration design with that used for the SMMR. For SMMR, a separate cold calibration horn was used for observing the 2.7 K cosmic background radiation, and ferrite switches were used to switch back and forth between the cold horn and the earth-viewing horn. The hot reference load for SMMR was a internal matched waveguide load at ambient temperature. Again, ferrite switches were used to toggle between the hot load and earth observations. Additional ferrite switches were used to switch between the horizontal and vertical polarization ports of the feedhorn. Except at 37 GHz, SMMR did not have separate radiometers for v-pol and h-pol. The resulting design was a maze of waveguides and ferrite switches, having different ohmic and reflection loss factors. Furthermore, the physical temperature of these various components had to be measured to determine the emission characteristics of the waveguides and switches. Laboratory measurements in a thermal-vacuum chamber were made to determine the losses and the effects of temperature gradient. Based on these laboratory measurements, an algorithm was derived for calibrating the SMMR antenna temperatures [*Swanson and Riley*, 1980]. However, experience showed that this calibration method worked poorly. It appears that the ohmic and reflective losses of the SMMR components in orbit were different than those measured in the thermal-vacuum chamber (or possibly the thermal-vacuum measurements were in error). Furthermore, it appears that the loses varied with time during the SeaSat and Nimbus-7 missions [*Wentz et al.*, 1986; *Francis*, 1987].

Finally, the spatial and temporal coverage of SSM/I is better than that for the SeaSat and Nimbus-7 SMMR's. The 1394-km wide swath of SSM/I is about twice that of the SMMR. Furthermore, in the case of the Nimbus-7 SMMR, the sensor only operated every other day. Besides reducing coverage, turning the instrument on and off caused calibration problems. When the SMMR was warming up after being turned on, a drift in calibration occurred.

A detailed description of the systematic errors experienced by the Nimbus-7 SMMR is given by *Francis* [1987]. It appears that, to a large degree, the systematic errors can be detected and removed using statistical consistency techniques [*Francis*, 1987]. However, these techniques require considerable data processing and the size of the residual error is difficult to determine. We expect that the improved design of SSM/I will substantially reduce the systematic error problem and simplify the process of in-orbit calibration.

SECTION 4. SSM/I ANTENNA TEMPERATURES

In computing the SSM/I antenna temperatures, the basic assumption is that the radiometer output counts are linearly related to the input power at the mixer/preamplifier. Nonlinear effects such as imperfections in the square-law detector and IF amplifier compression are assumed negligible. Expressing the input power in terms of radiation temperature, one has

$$C_i = P + Q\,T_{Mi} \tag{1}$$

where C_i is the radiometer output counts and T_{Mi} is the radiation temperature at the input of the mixer/preamplifier. The subscript i denotes either a cold-space observation (i=c), a hot-load observation (i=h), or an earth observation (i=e). The coefficients P and Q depend on the radiometer receiver gain and are assumed stable over the period of one scan, i.e., 1.9 s. The relationship between the radiation temperature T_{Mi} and the antenna temperature T_A entering the feedhorn is

$$T_{Mi} = (1 - \alpha)\,T_{Ai} + \alpha\,T_o \tag{2}$$

where α is the absorption of the feedhorn, isolator, and other front-end waveguide components and T_o is the average physical temperature of the horn, isolator, and waveguide.

Combining (1) and (2) for i = c, h, and e gives

$$T_A = A\,C_e + B \tag{3}$$

$$A = (T_{Ah} - T_{Ac})/(C_h - C_c) \tag{4}$$

$$B = (\,T_{Ac}C_h - T_{Ah}C_c)/(C_h - C_c) \tag{5}$$

For each SSM/I scan, five cold counts and five hot counts are recorded for each channel (B-scans have counts for only the 85 GHz channels). The quantities C_c and C_h are found by averaging the five individual counts. The cold space antenna temperature T_{Ac} is set to 2.7 K for all channels. The hot reference antenna temperature is found from

$$T_{Ah} = T_{oh} + 0.01(T_{op} - T_{oh}) \tag{6}$$

where T_{oh} and T_{op} are the physical temperatures of the hot load and the radiator plate facing the hot load. The small correction for the radiator plate is to account for radiative coupling between the hot load and the top plate of the rotating drum assembly which faces the hot load. There are three temperature sensors on the hot load and one on the radiator plate. The temperature T_{oh} is found by averaging the three hot load temperature sensors.

The above T_A equation clearly shows the advantage of the SSM/I external calibration. The effects of front-end absorption α and temperature T_0 cancel when combining the equations and have no effect on the computation of T_A. Compare this simple equation to the calibration equation for SMMR that involved 5 different α's and T_0's for each SMMR channel [*Swanson and Riley*, 1980].

The A and B coefficients in (3) are stored on the SSM/I antenna temperature tapes. These coefficients provide the means to recover the original counts. The B coefficients on the T_A tapes were incorrectly stored for the first four months of SSM/I data and are sometimes in error for later months. The error is due to an overflow problem for the 2-byte integer. Fortunately the B coefficients can be recomputed from (5) using the other information available on the tapes. The subroutine DECODE described in Section 7 recomputes the B coefficients from (5) rather than using the values on the tape.

SECTION 5. COMPUTATION OF BRIGHTNESS TEMPERATURES

The antenna temperature (T_A) is a measure of the radiation power entering a feedhorn port. It is computed by integrating over the gain pattern of the parabolic reflector and feedhorn assembly.

$$T_{Ap} = \int d\Omega \, (G_{vp} \, T_{Bv} + G_{hp} \, T_{Bh}) \tag{7}$$

where $d\Omega$ is the differential solid angle and the integral is over the entire 4π steradians of a sphere. The subscript p equals h or v and denotes the feedhorn port. The terms G_{vp} and G_{hp} are the antenna gains in the direction $d\Omega$ for the vertically and horizontally polarized radiation entering port p. The terms T_{Bv} and T_{Bh} are the vertically and horizontally polarized brightness temperatures coming from the $d\Omega$ direction. The polarization is referenced to the Earth's surface. Note that the gains G_{vp} and G_{hp} included both the directional dependence of the antenna pattern and the polarization coupling of the earth-referenced polarization and the feedhorn polarization.

Before the launch of SSM/I, two properties of the antenna gain patterns for each SSM/I channel were measured: 1) the relative antenna gain (both co-pol and cross-pol) in the near-boresight direction and 2) the feedhorn spillover. The near-boresight gains were measured out to 6° for the 19 and 22 GHz channels, out to 4° for the 37 GHz channels, and out to 3° for the 85 GHz channels. The feedhorn spillover is a measure of the power that enters the feedhorn directly from space, as opposed to the primary component of power that enters the feedhorn from the parabolic reflector. The feedhorn spillover is computed by measuring the percentage of the feedhorn antenna pattern that is not subtended by the parabolic reflector, which is typically a few percent. Since the brightness temperature of space is much less than the Earth's brightness temperature (2.7 K compared to 150-280 K), the spillover has an appreciable effect.

In order to specify G_{vp} and G_{hp} for all directions, we model the antenna gain using the vector Kirchhoff approximation for a circular aperture illuminated by a plane wave [*Jackson*, 1967], with an amplitude that tapers off according to the SSM/I feedhorn pattern. The effective radius of the aperture is chosen so as to match the SSM/I near-boresight measurements. Thus, the model agrees with the near-boresight and spillover measurements and provides the means to specify the antenna sidelobes that were not measured.

The integral in (7) is computed using an ocean brightness temperature model [*Wentz*, 1983] to compute T_{Bv} and T_{Bh} over the entire field of view as seen by the SSM/I at an altitude of 860 km. The ocean environment is assumed uniform over the field of view. For the part of integral that corresponds to cold space, T_{Bv} and T_{Bh} are set to 2.7 K. In this way, the antenna temperature is computed for various environmental conditions ranging from clear skies to light rain. An excellent approximation for all environmental conditions is found to be

$$T_{Ap} = Q_{vp}\, T_{Bvb} + Q_{hp}\, T_{Bhb} + 2.7\, Q_{op} \tag{8}$$

where T_{Bvb} and T_{Bhb} are the v-pol and h-pol brightness temperatures in the antenna boresight direction (subscript b denotes boresight) and the Q terms are functions of the spillover factor δ and the cross-polarization leakage factor χ:

$$Q_{vv} = (1 - \delta)/(1 + \chi_v) \tag{9}$$

$$Q_{hv} = \chi_v(1 - \delta)/(1 + \chi_v) \tag{10}$$

$$Q_{hh} = (1 - \delta)/(1 + \chi_h) \tag{11}$$

$$Q_{vh} = \chi_h(1 - \delta)/(1 + \chi_h) \tag{12}$$

$$Q_{ov} = Q_{oh} = \delta \tag{13}$$

Note that the Q's are normalized such that

$$Q_{vp} + Q_{hp} + Q_{op} = 1 \tag{14}$$

The spillover factor δ is given by the integral of the antenna pattern over cold space

$$\delta = \int_{\text{space}} d\Omega\, (G_{vp} + G_{hp}) \tag{15}$$

The leakage factor χ_p is a measure of the amount of radiation entering port p that has a polarization orthogonal to the port-p polarization mode. It is determined by fitting the above approximation (8) for T_A to the exact integral computation of T_A. Table 2 gives the values of δ and χ_p for the seven SSM/I channels. For a given frequency, δ is independent of the polarization. Over the considered range of environmental conditions, the error between the T_A approximation and integral is about 0.1 K. Note that the 0.1 K figure only indicates the accuracy of the linear approximation to the integral, assuming the modeled antenna patterns. This does not mean that we know the antenna pattern accurately enough to compute T_A to an accuracy of 0.1 K.

At 19, 37 and 85 GHz, dual-polarization antenna temperature measurements are taken.

$$T_{Av} = Q_{vv}\, T_{Bv} + Q_{hv}\, T_{Bh} + 2.7\, Q_{ov} \tag{16}$$

$$T_{Ah} = Q_{hh}\, T_{Bh} + Q_{vh}\, T_{Bv} + 2.7\, Q_{oh} \tag{17}$$

where we have dropped the subscript b and it is understood that the brightness temperatures are in the boresight direction. This system of two linear equation is easily inverted to express brightness temperature in terms of the antenna temperatures:

Table 2. Spillover and Polarization Leakage Factors

Frequency (GHz)	Polarization	Spillover, δ	Leakage, χ
19.35	vertical	0.03199	0.00379
19.35	horizontal	0.03199	0.00525
22.235	vertical	0.02685	0.00983
37.0	vertical	0.01434	0.02136
37.0	horizontal	0.01434	0.02664
85.5	vertical	0.01186	0.01387
85.5	horizontal	0.01186	0.01967

$$T_{Bv} = A_{vv}\, T_{Av} + A_{hv}\, T_{Ah} + 2.7\, A_{ov} \tag{18}$$

$$T_{Bh} = A_{hh}\, T_{Ah} + A_{vh}\, T_{Av} + 2.7\, A_{oh} \tag{19}$$

where the factor of 2.7 is the temperature of cold space. The A coefficients are functions of the spillover factor δ and the cross-polarization leakage factor χ_p:

$$A_{vv} = (1 + \chi_v)/[(1 - \chi_v\chi_h)(1 - \delta)] \tag{20}$$

$$A_{hv} = -\chi_v(1 + \chi_h)/[(1 - \chi_v\chi_h)(1 - \delta)] \tag{21}$$

$$A_{hh} = (1 + \chi_h)/[(1 - \chi_v\chi_h)(1 - \delta)] \tag{22}$$

$$A_{vh} = -\chi_h(1 + \chi_v)/[(1 - \chi_v\chi_h)(1 - \delta)] \tag{23}$$

$$A_{ov} = A_{oh} = -\delta/(1 - \delta) \tag{24}$$

Note that the δ term is computed directly from the antenna patterns and does not depend on the assumed environmental scene. The χ term does has a small dependence on the choice of scene. For the range of ocean scenes considered (clear skies to light rain), the variation in χ translates to about a 0.1 K variation in T_B. Although the value of χ for land and ice observations differs slightly from the ocean values given in Table 2, this has a negligible effect on the computation of brightness temperature because the T_B polarization difference for ice and land is small compared to water. As the scene becomes unpolarized, the T_B computation becomes independent of χ (see equation (26) below).

At 22 GHz, only v-pol antenna temperatures are available. In order to derive an expression giving T_B as a function of T_A at 22 GHz, we use the ocean brightness temperature model in conjunction with the above Q coefficients values to compute T_A for a wide range of environmental conditions. A least-squares regression yields the following relationship:

$$T_{Bv} = 1.01993\, T_{Av} + 1.994 \tag{25}$$

This proved to be a very accurate fit, with the rms error between the regressed T_{Bv} value and the actual value being 0.1 K, or less, for the range of antenna temperatures from 176 to 270 K. The reason for the good fit is that the small cross-polarization h-pol leakage is highly correlated with the v-pol radiation. Note that this expression was derived for ocean observations. Over land, the brightness temperature is depolarized. Assuming that $T_{Bv} = T_{Bh}$, one can directly invert the T_A equation, and obtain a second expression for T_{Bv} at 22 GHz.

$$\begin{aligned} T_{Bv} &= T_{Av}/(1 - \delta) - 2.7\, \delta/(1 - \delta) \\ &= 1.02759\, T_{Av} - 0.074 \end{aligned} \tag{26}$$

Fortunately, these two expressions yield similar values in the 240 K to 300 K range, where they differ by 0.2 K, or less. They intersect at 270 K. Thus, the ocean-derived expression appears to be quite adequate for over-land observations. A small error will occur for cases in which the brightness temperatures have relatively low values (below 240 K) and the polarization ratio is markedly different from the ocean polarization ratio.

The above computation of brightness temperature assumes a horizontally-uniform ocean scene. Any horizontal variability will be spatially smoothed by the antenna pattern, and as a result the T_B computed from the above expressions will be a smoothed representation of the actual brightness temperature field. Image enhancement techniques can be applied to the computed T_B's in order to partially restore the actual T_B contrast. The selection of the appropriate enhancement depends upon the particular application, and we leave this problem to the user.

Our final comment on brightness temperature is with regards to systematic errors. Errors in T_A (due to mismodeling the counts-to-T_A conversion) and errors in modeling the antenna patterns will produce systematic errors in T_B. A preliminary analysis of the SSM/I T_B's indicates that these systematic errors are small. The first two months of SSM/I T_B's were compared to brightness temperatures computed from the T_B model. At 19V, 19H, 22V, 37V, and 37H, the mean differences between the observations minus the model are 2.0, 2.3, 2.7, -1.2, and 0.7, respectively. It is quite encouraging to see such small differences. It is not clear if the differences are due to the errors in observations, model, or both. No such analysis of the 85 GHz channels has yet been done.

SECTION 6. ORGANIZATION OF ANTENNA TEMPERATURE DATA TAPES

The SSM/I antenna temperature data reside on a series of 6250-cpi, 2400-ft magnetic tapes. The total information content for each tape is about 160 megabytes. The first file on the tape contains header information for the tape written in ASCII characters. The remaining files contain the antenna temperature data written as binary positive integers. Each data file corresponds to a single SSM/I orbit. The beginning of an orbit is defined as the equator ascending crossing of the spacecraft (i.e., south-to-north crossing). The data files (i.e., orbits) are chronologically ordered.

For each month, eight data tapes are produced, except for a non-leap-year February for which there are only seven tapes. Table 3 shows the time periods corresponding to each of the tapes. A single tape contains either 3 or 4 days of data, except for February during a leap year, in which the eighth tape contains only 1 day of data. Each tape begins at the first equator ascending crossing for the specified Greenwich day.

The orbit period is 102 minutes, and thus there are 14.1 orbits per day. A tape containing three (four) days of data will have either 42 or 43 (56 or 57) data files, if there are no data gaps.

Table 3. The Eight SSM/I T_A Tapes per Month

Tape Number	Time Period (Day of Month)	
	Except February	February
1	1 through 4	1 through 4
2	5 through 8	5 through 8
3	9 through 12	9 through 12
4	13 through 15	13 through 16
5	16 through 19	17 through 20
6	20 through 23	21 through 24
7	24 through 27	25 through 28
8	28 through end of month	29 (for leap year)

The following is an example of the information written to the first file on the tape:

```
COMPACT TA TAPE 1987_JUL_P3_A, 48 DATA FILES
SPEC. BEG DAY  190 Thu Jul  9, 1987 01:26:55
ACTUAL BEG DAY 190 Thu Jul  9, 1987 13:38:34
SPEC. END DAY  194 Mon Jul 13, 1987 00:37:32
ACTUAL END DAY 194 Mon Jul 13, 1987 00:37:31
SPECIFIED ORBITS:  000268 - 000323
ACTUAL ORBITS:     000275 - 000323
BEGIN GAP = 731.65 MIN, END GAP =     .02 MIN
PERCENTAGE OF MISSING DATA =   27.965 %
PRODUCED BY REMOTE SENSING SYSTEMS
1101 COLLEGE AVE., SANTA ROSA, CA 95404
CONTACT FRANK WENTZ 707-545-2904 (F.WENTZ/OMNET)
```

This is the header file for the third compact T_A tape in July 1987. The first line identifies the tape according to year, month, part of month (P1 through P8), and revision ('A' indicates first version). The first line also gives the number of data files on the tape that follow the header file. The next four lines give the specified and actual begin and end times for the tape. The day of year is given along with the date and time. Because of data gaps, the actual begin time may occur later than the specified begin time, and the actual end time may occur sooner than the specified end time. The next two lines give the specified and actual range of orbits. The differences (i.e., time gaps) between the specified and actual begin and end times are then given, and the following line shows the percentage of missing data for the specified time period. The remaining lines give the name and address of the person responsible for producing the tape.

The header file contains 21408 bytes divided into 12 logical records, with each record containing 1784 ASCII characters. This record length is chosen to match the record length of the logical records in the T_A data files. The logical records correspond to the 12 lines shown above, with trailing ASCII blanks.

The remaining files on the tape are T_A data files, each consisting of a series of chronologically-ordered logical records. Each record corresponds to a pair of A and B scans. The length of a logical record is 1784 bytes. The logical records are grouped into tape data blocks, which are separated by a 0.3 inch interblock gap. Each data block, except the last block in a file, contains 28544 bytes, which is 16 logical records. The last block in a file can contain any multiple of 1784 bytes, but not exceeding 28544 bytes.

Table 4 shows the byte format for a logical record. The record is divided into 23 fields, with each field corresponding to a different set of data items. The table gives the number for the first byte in the field, the number of bytes in the field, the number of items in the field, the bias and scale factors to convert to the units specified, and a brief description of the data items. For example, Field 8 starts at byte 29, is 6 bytes long, and contains 3 hot load temperatures each stored as a 2-byte integer.

Table 4. Description of Logical Records on SSM/I Antenna Temperature Tapes

field no.	first byte	field bytes	items	bias	scale	units	description
1	1	4	1	0	1.0	seconds	integer time for scan from beginning of 1987
2	5	4	1	0	0.0001	none	orbit number
3	9	4	1	0	1.0	seconds	time of spacecraft ephemeris from beginning of 1987
4	13	4	1	90000000	0.000001	degrees	geodetic latitude of spacecraft ephemeris
5	17	4	1	10000	0.0001	seconds	fractional time for scan from beginning of 1987
6	21	4	1	0	0.000001	degrees	east longitude of spacecraft ephemeris
7	25	4	1	0	0.001	km	altitude of spacecraft ephemeris
8	29	6	3	0	0.01	kelvin	hot load temperature sensors
9	35	4	2	0	1.0	counts	reference voltages
10	39	2	1	0	0.01	kelvin	r.f. mixer temperature sensor
11	41	2	1	0	0.01	kelvin	forward radiator temperature sensor
12	43	6	3	0	1.0	counts	automatic gain control readings for A-scan
13	49	28	14	0	note 1	note 1	counts-to-T_A conversion coefficients
14	77	70	35	0	1.0	counts	cold counts for A-scan, see note 2
15	147	70	35	0	1.0	counts	hot counts for A-scan, see note 2
16	217	6	3	0	1.0	counts	automatic gain control readings for B-scan
17	223	20	10	0	1.0	counts	cold counts for B-scan, see note 2
18	243	20	10	0	1.0	counts	hot counts for B-scan, see note 2
19	263	38	19	9000	0.01	degrees	geodetic latitudes for A-scan
20	301	38	19	0	0.01	degrees	east longitudes for A-scan
21	339	38	19	note 3	note 3	degrees	B-scan minus A-scan latitude/longitude differences
22	377	640	320	note 4	note 4	kelvin	19, 22, 37 GHz T_A's and surface-type, see note 4
23	1017	768	384	note 5	note 5	kelvin	85 GHz T_A, see note 5

Note 1: The order of the counts-to-T_A conversion coefficients is A(19V), B(19V), A(19H), B(19H), A(22V), B(22V), A(37V), B(37V), A(37H), B(37H), A(85V), B(85V), A(85H), B(85H). The scales for the A and B coefficients are 0.00001 and -0.01, respectively. The units for the A and B coefficients are kelvin/counts and kelvin, respectively. There is sometimes a problem with the B coefficient, and the user should recompute it rather than using the value in Field 13 (see Section 4. SSM/I Antenna Temperatures).

Note 2: The A-scan cold counts are ordered in 7 groups corresponding to the 7 channels: 19V, 19H, 22V, 37V, 37H, 85V, and 85H. Each group contains five counts for the given channel. Thus, the first five items in Field 14 are the 5 counts for 19V. The hot counts in Field 15 are ordered the same way. The cold and hot counts for the B-scan are similarly ordered, except that there are only two channels: 85V and 85H.

Note 3: The latitude and longitude differences between the A-scan and B-scan are stored in a packed format. Subroutine Decode unpacks Field 21 and converts the differences to degrees.

Note 4: The 19V, 19H, 22V, 37V, and 37H T_A's are stored in a packed format. The surface-type indices for the A-scan and B-scan cells are also stored in Field 22. Subroutine Decode unpacks Field 22, converts the T_A's to Kelvin units, and recovers the surface-type indices.

Note 5: The 85V and 85H T_A's are stored in a packed format. Subroutine Decode unpacks Field 22 and converts the T_A's to Kelvin units.

All data items in a logical record are stored as positive binary integers that are either 2 or 4 bytes in length. The values under the headings 'bias' and 'scale' are used to convert these integers to the units listed under the heading 'units'. The conversion is as follows:

$$\text{units} = \text{scale} \times (\text{integer} - \text{bias})$$

Section 7 discusses the Fortran Subroutine DECODE that reads in one logical record from the tape, scales and biases the data, and stores the data in terms of the proper units in a common area. We strongly recommend that this subroutine be used when reading the SSM/I T_A data tapes.

SECTION 7. DECODING THE ANTENNA TEMPERATURE DATA

A Fortran subroutine named DECODE is provided to the user for decoding the information in a logical record. The subroutine is written in Fortran 77 and can be easily adapted to the user's particular computer system. Each time DECODE is called, it reads a logical record from unit 2, which should correspond to the SSM/I T_A tape. The information in the logical record is unpacked, properly scaled and biased, and then put into the common area /OUTDAT/. The user can then interface directly with the common /OUTDAT/, without having to be concern with the details of the logical record format.

Subroutine DECODE has two input arguments, I85GHZ and ITB, and one output argument, IEOF. The argument IEOF is normally returned as 0, except when an end of file is encountered on unit 2. In this case IEOF is set to 1, and common /OUTDAT/ is not updated. The input arguments designate the following:

1. The user should set I85GHZ=0 if information on the 85 GHz channels is not required. When I85GHZ=0, DECODE does not process the 85 GHz information, thereby substantially reducing the processing time. In this case, values for the /OUTDAT/ arrays BLAT, BLON, ATAHI, BTAHI, and IBTOIL are not computed. Also, values for the even-numbered elements in the arrays ALAT, ALON, and IATOIL are not computed. The even-numbered elements on an A-scan correspond to cells for which only 85 GHz observations are made. The description of the various arrays in /OUTDAT/ is given below. When I85GHZ is set to 1, all information is processed.

2. If the user requires antenna temperatures, then ITB should be set to 0. In this case the arrays TALO, ATAHI, and BTAHI will contain T_A's. If the user requires brightness temperatures, then ITB should be set to 1. In this case the arrays TALO, ATAHI, and BTAHI will contain T_B's computed from (18), (19), and (25).

The operation of DECODE is relatively simple. A T_A logical record is first read into the common /INDATA/. Various parameters on orbit location, incidence angle, and radiometer calibration are computed and stored in /OUTDAT/. The subroutine FDLTLN is then called to compute the latitudes and longitudes for the 128 cells on the A-scan and the 128 cell on the B-scan. The logical record contains 19 latitudes and longitudes for each scan. FDLTLN performs an interpolation to compute the complete set of 128 latitudes and longitudes. The error in the interpolation is less than 2 km, which is smaller than the error in the original computation of the latitudes and longitudes from the ephemeris. The subroutine FDTA is then called. This subroutine unpacks and scales the antenna temperatures and the surface-type indices. Finally, if ITB=1, the subroutine FDTB, which converts the antenna temperatures to brightness temperatures, is called.

The remainder of this section describes the variables and arrays in common /OUTDAT/. All variables and arrays are four bytes unless otherwise specified.

REV

This real, double precision variable is the orbit number for the spacecraft. It is referenced to the ascending equator crossing. For example, REV = 100.5 indicates that the spacecraft is halfway through orbit 100, i.e., it is crossing the equator in the descending, north-to-south direction.

XTIME

This real, double precision variable is the time of the observation in terms of seconds from beginning of 1987.

ITIME

This integer variable is the closest integer to XTIME, i.e., ITIME=NINT(XTIME).

ITIMSC

This integer variable is the time of the spacecraft ephemeris in terms of seconds from beginning of 1987. The spacecraft ephemeris is provided once every minute. ITIMSC is not the time for the current observation. Rather it is the time for one of the ephemeris vectors that bracket the current spacecraft position. ITIMSC toggles back and forth (increasing then decreasing by 60 seconds) between the two bracketing ephemeris vectors for successive records.

XLATSC

This real variable is the spacecraft nadir geodetic latitude in units of degrees at the ephemeris time ITIMSC. It is not the spacecraft latitude for the current observation. Negative latitudes correspond to south latitudes, and positive values correspond to north latitudes.

XLONSC

This real variable is the nadir longitude of the spacecraft at the ephemeris time ITIMSC. It is not the spacecraft longitude for the current observation. The longitude is in units of degrees east of the prime meridian.

ALTSC

This real variable is the spacecraft altitude in units of kilometers at the ephemeris time ITIMSC.

THT

This real variable is the incidence angle made by the antenna electric boresight vector and the vector normal to the Earth's surface at the point where the boresight vector intersects the Earth's surface. It is computed from ALTSC, and hence in referenced to time ITIMSC. The incidence angle is in units of degrees and is required for subsequent geophysical processing. The average value of the incidence angle is 53.1°.

HLTEMP(3)

This real array contains the temperature readings for the three temperature sensors attached to the SSM/I external hot load. These temperatures are in units of Kelvin and are physical temperatures rather than radiation temperatures. The average of these three temperatures is denoted by T_{oh} in equation (6),

IVOLTS(2)

This integer array contains two reference voltages for the SSM/I receiver. These voltages are in terms of counts, and it does not appear that they are required by any of the processing algorithms.

RFTEMP

This real variable is the physical temperature recorded by the temperature sensor attached to the SSM/I r.f. mixer. It is in units of Kelvin and is used to monitor the internal temperature of the receiver. It is not actually used by any of the algorithms.

FRTEMP

This real variable is the physical temperature recorded by the temperature sensor attached to the top plate of the rotating drum assembly which faces the hot load. It is in units of Kelvin. FRTEMP is denoted by T_{op} in equation (6).

IAGC(6)

This integer array contains the automatic gain control readings in units of counts. The first three elements are the three reading for the A-scan, and the last three elements are the readings for the B-scan. It does not appear that they are required by any of the processing algorithms

CALSLP(7)

This real array contains the A coefficients in equation (3) for the counts-to-T_A conversion. The array is ordered according to channel: 19V, 19H, 22V, 37V, 37H, 85V, and 85H. The units for the coefficients are Kelvin/counts.

CALOFF(7)

This real array contains the B coefficients in equation (3) for the counts-to-T_A conversion. The array is ordered according to channel: 19V, 19H, 22V, 37V, 37H, 85V, and 85H. The units for the coefficients are Kelvin.

ICOLDA(5,7)

This integer array contains the cold calibration counts for the SSM/I A-scan. The first dimension of the array denotes the five samples of counts that are taken for each channel. The second dimension of the array denotes the channel, with the order being 19V, 19H, 22V, 37V, 37H, 85V, and 85H.

IHOTA(5,7)
This integer array contains the hot calibration counts for the SSM/I A-scan. The first dimension of the array denotes the five samples of counts that are taken for each channel. The second dimension of the array denotes the channel, with the order being 19V, 19H, 22V, 37V, 37H, 85V, and 85H.

ICOLDB(5,2)
This integer array contains the cold calibration counts for the SSM/I B-scan. The first dimension of the array denotes the five samples of counts that are taken for each channel. The second dimension of the array denotes the channel, with the order being 85V and 85H.

IHOTB(5,2)
This integer array contains the hot calibration counts for the SSM/I B-scan. The first dimension of the array denotes the five samples of counts that are taken for each channel. The second dimension of the array denotes the channel, with the order being 85V and 85H.

ALAT(128)
This real array contains the geodetic latitudes in units of degrees for the 128 cells in the SSM/I A-scan. Negative latitudes correspond to south latitudes, and positive values correspond to north latitudes. The odd elements in this array correspond to those cells for which observations are taken at all 7 SSM/I channels. The even elements correspond to those cells for which only the 85 GHz channels are sampled.

ALON(128)
This real array contains the longitudes for the 128 cells in the SSM/I A-scan. The longitude is in units of degrees east of the prime meridian. The odd elements in this array correspond to those cells for which observations are taken at all 7 SSM/I channels. The even elements correspond to those cells for which only the 85 GHz channels are sampled.

BLAT(128)
This real array contains the geodetic latitudes in units of degrees for the 128 cells in the SSM/I B-scan. Negative latitudes correspond to south latitudes, and positive values correspond to north latitudes. On the B-scan, only the 85 GHz channels are sampled.

BLON(128)
This real array contains the longitudes for the 128 cells in the SSM/I B-scan. The longitude is in units of degrees east of the prime meridian. On the B-scan, only the 85 GHz channels are sampled.

TALO(5,64)

This real array contains the antenna temperatures (or brightness temperatures if ITB=1) in units of Kelvin for the SSM/I five lower channels. The first dimension denotes the channel, with the order being 19V, 19H, 22V, 37V, and 37H. The second dimension denotes the cell position on the A-scan. The 64 cell positions corresponds to the odd elements in the ALAT and ALON arrays. For example, the latitudes for TALO(ich,1), TALO(ich,32), and TALO(ich,64) are given by ALAT(1), ALAT(63), and ALAT(127), respectively.

ATAHI(2,128)

This real array contains the antenna temperatures (or brightness temperatures if ITB=1) in units of Kelvin for the 85 GHz channels on the A-scan. The first dimension denotes the 85V and 85H channel, respectively. The second dimension denotes the cell position.

BTAHI(2,128)

This real array contains the antenna temperatures (or brightness temperatures if ITB=1) in units of Kelvin for the 85 GHz channels on the B-scan. The first dimension denotes the 85V and 85H channel, respectively. The second dimension denotes the cell position.

IATOIL(128)

This integer array contains the surface-type indices for the 128 cells in the SSM/I A-scan. The order of this array is the same as ALAT and ALON. The odd elements in this array correspond to those cells for which observations are taken at all 7 SSM/I channels. The even elements correspond to those cells for which only the 85 GHz channels are sampled. Table 5 gives the definition of the surface-type indices.

IBTOIL(128)

This integer array contains the surface-type indices for the 128 cells in the SSM/I B-scan. The order of this array is the same as BLAT and BLON. Table 5 gives the definition of the surface-type indices.

Table 5. Definition of Surface-Type Index

surface-type index	definition
0	land
1	vegetal-covered land
2	not used
3	ice
4	possible ice
5	water
6	coast
7	not used

SECTION 8. REFERENCES

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APPENDIX A. SUBROUTINE DECODE

```
      SUBROUTINE DECODE(I85GHZ,ITB, IEOF)
C
C     I85GHZ=0 PROCESSES ONLY THE 19, 22, AND 37 GHZ OBS.
C     I85GHZ=1 PROCESSES ALL CHANNELS
C     ITB=0 COMPUTES TA'S, ITB=1 COMPUTES TB'S
C
      INTEGER*2 LREC(892),IWORK2(2)
      INTEGER*4 IWORK4
C
C     SPECIFY COMMON /INDATA/
C
      INTEGER*4 ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC
      INTEGER*2 ZENVSC,ZCAL,ZCOLDA,ZHOTA,ZGAINB,ZCOLDB,ZHOTB
      INTEGER*2 ZLAT,ZLON,ZDLTLN,ZTALO,ZTAHI
      COMMON/INDATA/ ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC,
     1 ZENVSC(10),ZCAL(2,7),ZCOLDA(5,7),ZHOTA(5,7),
     2 ZGAINB(3),ZCOLDB(5,2),ZHOTB(5,2),
     3 ZLAT(19),ZLON(19),ZDLTLN(19),ZTALO(5,64),ZTAHI(6,64)
C
C     SPECIFY COMMON /OUTDAT/
C
      REAL*8 REV,XTIME
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB
      INTEGER*4 IATOIL,IBTOIL
      REAL*4 XLATSC,XLONSC,ALTSC,THT,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,ATAHI,BTAHI
      COMMON/OUTDAT/ REV,XTIME,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,THT,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),ATAHI(2,128),BTAHI(2,128),IATOIL(128),IBTOIL(128)
C
C     SPECIFY EQUIVALENCES
C
      EQUIVALENCE(LREC(1),ZTIME),(IWORK4,IWORK2(1))
C
C     DATA INITIALIZATION
C
      DATA IWORK4/0/
C     SINBOR IS ACTUALLY SIN(135.247) WHERE THE 0.247 IS THE
C     MISMATCH BETWEEN MECHANICAL AND ELECTROCAL BORESIGHTS
C     SEE TABLE 2.3B IN SSMI USER'S MANUAL
      DATA EARTHR,SINBOR,RAD/6371.,.704051909,0.017453293/
```

```
C
C     BEGIN EXECUTION
C
      IEOF=0
      READ(2,2001,END=900) LREC
 2001 FORMAT(892A2)
      ITIME=ZTIME
      REV=1.D-4*ZREV
      IF(ZFRCTM.EQ.0) XTIME=ITIME
      IF(ZFRCTM.NE.0) XTIME=ITIME+1.D-4*(ZFRCTM-10000)
      ITIMSC=ZTIMSC
      XLATSC=1.D-6*ZLATSC-90.
      XLONSC=1.D-6*ZLONSC
      ALTSC=1.D-3*ZALTSC
      THT=ASIN(SINBOR*(EARTHR+ALTSC)/EARTHR)/RAD
C
      DO 100 IP=1,3
      IWORK2(2)=ZENVSC(IP)
      HLTEMP(4-IP)=0.01*IWORK4
  100 CONTINUE
C
      IWORK2(2)=ZENVSC(4)
      IVOLT(2)=IWORK4
      IWORK2(2)=ZENVSC(5)
      IVOLT(1)=IWORK4
      IWORK2(2)=ZENVSC(6)
      RFTEMP=0.01*IWORK4
      IWORK2(2)=ZENVSC(7)
      FRTEMP=0.01*IWORK4
C
      DO 200 IP=8,10
      IWORK2(2)=ZENVSC(IP)
      IAGC(11-IP)=IWORK4
  200 CONTINUE
C
      DO 300 ICH=1,7
      IWORK2(2)=ZCAL(1,ICH)
      CALSLP(ICH)=1.E-5*IWORK4
  300 CONTINUE
C
```

```
      DO 400 ICH=1,7
      DO 400 IP=1,5
      IWORK2(2)=ZCOLDA(IP,ICH)
      ICOLDA(IP,ICH)=IWORK4
      IWORK2(2)=ZHOTA(IP,ICH)
      IHOTA(IP,ICH)=IWORK4
  400 CONTINUE
C
      DO 500 IP=1,3
      IWORK2(2)=ZGAINB(IP)
      IAGC(7-IP)=IWORK4
  500 CONTINUE
C
      DO 600 ICH=1,2
      DO 600 IP=1,5
      IWORK2(2)=ZCOLDB(IP,ICH)
      ICOLDB(IP,ICH)=IWORK4
      IWORK2(2)=ZHOTB(IP,ICH)
      IHOTB(IP,ICH)=IWORK4
  600 CONTINUE
C
C     COMPUTE COUNTS-TO-TA B COEFFICIENTS, I.E., CALOFF
C
      THAVG=(HLTEMP(1)+HLTEMP(2)+HLTEMP(3))/3.
      THAVG=THAVG+0.01*(FRTEMP-THAVG)
      DO 620 ICH=1,7
      AVGC=0.2*(ICOLDA(1,ICH)+ICOLDA(2,ICH)+ICOLDA(3,ICH)+
     1 ICOLDA(4,ICH)+ICOLDA(5,ICH))
      AVGH=0.2*(IHOTA(1,ICH)+IHOTA(2,ICH)+IHOTA(3,ICH)+
     1 IHOTA(4,ICH)+IHOTA(5,ICH))
      CALOFF(ICH)=(2.7*AVGH-THAVG*AVGC)/(AVGH-AVGC)
  620 CONTINUE
C
      CALL FDLTLN(I85GHZ)
      CALL FDTA(I85GHZ)
      IF(ITB.EQ.1) CALL FDTB(I85GHZ)
      RETURN
C
C     END OF FILE ENCOUNTERED
C
  900 CONTINUE
      IEOF=1
      RETURN
      END
CFF
```

```
      SUBROUTINE FDLTLN(I85GHZ)
C
C     THIS SUBROUTINE FINDS THE LATS AND LONS FOR THE SSMI CELLS
C     I85GHZ=0 DOES NOT DO 85 GHZ LAT/LON, I85GHZ=1 DOES 85 GHZ LAT LON
C
      INTEGER*4 INDEX(19),JNDEX(3,109),IWORK4
      INTEGER*2 IWORK2(2)
C
C     SPECIFY COMMON /INDATA/
C
      INTEGER*4 ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC
      INTEGER*2 ZENVSC,ZCAL,ZCOLDA,ZHOTA,ZGAINB,ZCOLDB,ZHOTB
      INTEGER*2 ZLAT,ZLON,ZDLTLN,ZTALO,ZTAHI
      COMMON/INDATA/ ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC,
     1 ZENVSC(10),ZCAL(2,7),ZCOLDA(5,7),ZHOTA(5,7),
     2 ZGAINB(3),ZCOLDB(5,2),ZHOTB(5,2),
     3 ZLAT(19),ZLON(19),ZDLTLN(19),ZTALO(5,64),ZTAHI(6,64)
C
C     SPECIFY COMMON /OUTDAT/
C
      REAL*8 REV,XTIME
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB
      INTEGER*4 IATOIL,IBTOIL
      REAL*4 XLATSC,XLONSC,ALTSC,THT,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,ATAHI,BTAHI
      COMMON/OUTDAT/ REV,XTIME,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,THT,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),ATAHI(2,128),BTAHI(2,128),IATOIL(128),IBTOIL(128)
C
C     SPECIFY EQUIVALENCE
C
      EQUIVALENCE(IWORK2(1),IWORK4)
```

```
C
C     DATA INITIALIZATION
C
      DATA RAD/0.017453293/
      DATA INDEX/1,9,17,25,33,41,49,57,65,73,81,89,97,105,113,121,123,
     1 127,128/
      DATA JNDEX/
     1   5,  1,  9, 13,  9, 17, 21, 17, 25, 29, 25, 33, 37, 33, 41,
     1  45, 41, 49, 53, 49, 57, 61, 57, 65, 69, 65, 73, 77, 73, 81,
     1  85, 81, 89, 93, 89, 97,101, 97,105,109,105,113,117,113,121,
     1   3,  1,  5,  7,  5,  9, 11,  9, 13, 15, 13, 17, 19, 17, 21,
     1  23, 21, 25, 27, 25, 29, 31, 29, 33, 35, 33, 37, 39, 37, 41,
     1  43, 41, 45, 47, 45, 49, 51, 49, 53, 55, 53, 57, 59, 57, 61,
     1  63, 61, 65, 67, 65, 69, 71, 69, 73, 75, 73, 77, 79, 77, 81,
     1  83, 81, 85, 87, 85, 89, 91, 89, 93, 95, 93, 97, 99, 97,101,
     1 103,101,105,107,105,109,111,109,113,115,113,117,119,117,121,
     1 125,123,127,  2,  1,  3,  4,  3,  5,  6,  5,  7,  8,  7,  9,
     1  10,  9, 11, 12, 11, 13, 14, 13, 15, 16, 15, 17, 18, 17, 19,
     1  20, 19, 21, 22, 21, 23, 24, 23, 25, 26, 25, 27, 28, 27, 29,
     1  30, 29, 31, 32, 31, 33, 34, 33, 35, 36, 35, 37, 38, 37, 39,
     1  40, 39, 41, 42, 41, 43, 44, 43, 45, 46, 45, 47, 48, 47, 49,
     1  50, 49, 51, 52, 51, 53, 54, 53, 55, 56, 55, 57, 58, 57, 59,
     1  60, 59, 61, 62, 61, 63, 64, 63, 65, 66, 65, 67, 68, 67, 69,
     1  70, 69, 71, 72, 71, 73, 74, 73, 75, 76, 75, 77, 78, 77, 79,
     1  80, 79, 81, 82, 81, 83, 84, 83, 85, 86, 85, 87, 88, 87, 89,
     1  90, 89, 91, 92, 91, 93, 94, 93, 95, 96, 95, 97, 98, 97, 99,
     1 100, 99,101,102,101,103,104,103,105,106,105,107,108,107,109,
     1 110,109,111,112,111,113,114,113,115,116,115,117,118,117,119,
     1 120,119,121,122,121,123,124,123,125,126,125,127/
C
C     BEGIN EXECUTION
C
C     SET TABLE LAT/LON FOR A-SCAN
C
      DO 100 JCEL=1,19
      ICEL=INDEX(JCEL)
      ALAT(ICEL)=0.01*(ZLAT(JCEL)-9000)
      IWORK2(2)=ZLON(JCEL)
      ALON(ICEL)=0.01*IWORK4
      IF(ALON(ICEL).LT.0.) ALON(ICEL)=ALON(ICEL)+360.
      IF(ALON(ICEL).GE.360.) ALON(ICEL)=ALON(ICEL)-360.
  100 CONTINUE
```

```
C
C     SET MID-POINTS FOR A-SCAN
C
      NCEL=46
      IF(I85GHZ.EQ.1) NCEL=109
      DO 200 JCEL=1,NCEL
      ICEL=JNDEX(1,JCEL)
      I1=JNDEX(2,JCEL)
      I2=JNDEX(3,JCEL)
      DIFLAT=ALAT(I2)-ALAT(I1)
      AVGLAT=0.5*(ALAT(I1)+ALAT(I2))
      DIFLON=ALON(I2)-ALON(I1)
      IF(DIFLON.GT.180.) DIFLON=DIFLON-360.
      IF(DIFLON.LT.-180.) DIFLON=DIFLON+360.
      AVGLON=ALON(I1)+0.5*DIFLON
C     ALAT(ICEL)=AVGLAT+0.0625*RAD*DIFLON*DIFLON*SIN(2.*RAD*AVGLAT)
      XSQ=(2.*RAD*AVGLAT)**2
      XFAC=1.-0.16627142*XSQ+0.00807934*XSQ*XSQ-0.000151880*XSQ*XSQ*XSQ
      ALAT(ICEL)=AVGLAT*(1.+0.125*(RAD*DIFLON)**2*XFAC)
C     ALON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TAN(RAD*AVGLAT)
      X=RAD*(90.-ABS(AVGLAT))
      TANLAT=1./(X+X*X*X/3.)
      IF(AVGLAT.LT.0.) TANLAT=-TANLAT
      ALON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TANLAT
      IF(ALON(ICEL).LT.0.) ALON(ICEL)=ALON(ICEL)+360.
      IF(ALON(ICEL).GE.360.) ALON(ICEL)=ALON(ICEL)-360.
  200 CONTINUE
      IF(I85GHZ.EQ.0) RETURN
C
C     SET TABLE LAT/LON FOR B-SCAN
C
      DO 300 JCEL=1,19
      ICEL=INDEX(JCEL)
      IDEL=ZDLTLN(JCEL)
      LATDEL=(IDEL+30000)/1000-30
      LONDEL=IDEL+29100-1000*(LATDEL+30)
      BLAT(ICEL)=0.01*(ZLAT(JCEL)+LATDEL-9000)
      IWORK2(2)=ZLON(JCEL)
      BLON(ICEL)=0.01*(IWORK4+LONDEL)
      IF(BLON(ICEL).LT.0.) BLON(ICEL)=BLON(ICEL)+360.
      IF(BLON(ICEL).GE.360.) BLON(ICEL)=BLON(ICEL)-360.
  300 CONTINUE
```

```
C
C     SET MID-POINTS FOR B-SCAN
C
      DO 400 JCEL=1,109
      ICEL=JNDEX(1,JCEL)
      I1=JNDEX(2,JCEL)
      I2=JNDEX(3,JCEL)
      DIFLAT=BLAT(I2)-BLAT(I1)
      AVGLAT=0.5*(BLAT(I1)+BLAT(I2))
      DIFLON=BLON(I2)-BLON(I1)
      IF(DIFLON.GT.180.) DIFLON=DIFLON-360.
      IF(DIFLON.LT.-180.) DIFLON=DIFLON+360.
      AVGLON=BLON(I1)+0.5*DIFLON
C     BLAT(ICEL)=AVGLAT+0.0625*RAD*DIFLON*DIFLON*SIN(2.*RAD*AVGLAT)
      XSQ=(2.*RAD*AVGLAT)**2
      XFAC=1.-0.16627142*XSQ+0.00807934*XSQ*XSQ-0.000151880*XSQ*XSQ*XSQ
      BLAT(ICEL)=AVGLAT*(1.+0.125*(RAD*DIFLON)**2*XFAC)
C     BLON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TAN(RAD*AVGLAT)
      X=RAD*(90.-ABS(AVGLAT))
      TANLAT=1./(X+X*X*X/3.)
      IF(AVGLAT.LT.0.) TANLAT=-TANLAT
      BLON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TANLAT
      IF(BLON(ICEL).LT.0.) BLON(ICEL)=BLON(ICEL)+360.
      IF(BLON(ICEL).GE.360.) BLON(ICEL)=BLON(ICEL)-360.
  400 CONTINUE
      RETURN
      END
CFF
```

```
      SUBROUTINE FDTA(I85GHZ)
C
C     THIS SUBROUTINE FINDS THE ANTENNA TEMPERATURES AND SURFACE TYPES
C
      INTEGER*2 IBUF2(6)
      INTEGER*4 IWORK4
      REAL*4 TAHI(8)
      CHARACTER*1 IWORK1(4),IBUF1(12)
C
C     SPECIFY COMMON /INDATA/
C
      INTEGER*4 ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC
      INTEGER*2 ZENVSC,ZCAL,ZCOLDA,ZHOTA,ZGAINB,ZCOLDB,ZHOTB
      INTEGER*2 ZLAT,ZLON,ZDLTLN,ZTALO,ZTAHI
      COMMON/INDATA/ ZTIME,ZREV,ZTIMSC,ZLATSC,ZFRCTM,ZLONSC,ZALTSC,
     1 ZENVSC(10),ZCAL(2,7),ZCOLDA(5,7),ZHOTA(5,7),
     2 ZGAINB(3),ZCOLDB(5,2),ZHOTB(5,2),
     3 ZLAT(19),ZLON(19),ZDLTLN(19),ZTALO(5,64),ZTAHI(6,64)
C
C     SPECIFY COMMON /OUTDAT/
C
      REAL*8 REV,XTIME
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB
      INTEGER*4 IATOIL,IBTOIL
      REAL*4 XLATSC,XLONSC,ALTSC,THT,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,ATAHI,BTAHI
      COMMON/OUTDAT/ REV,XTIME,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,THT,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),ATAHI(2,128),BTAHI(2,128),IATOIL(128),IBTOIL(128)
C
C     SPECIFY EQUIVALENCES
C
      EQUIVALENCE (IWORK4,IWORK1(1)),(IBUF1(1),IBUF2(1))
C
C     BEGIN EXECUTION
C
```

```
      DO 100 ICEL=1,64
      JCEL=2*ICEL-1
C
C     FIND THE TA'S FOR THE 3 LOWER FREQUENCIES
C
      IBUF2(1)=ZTALO(1,ICEL)
      IBUF2(2)=ZTALO(2,ICEL)
      IBUF2(3)=ZTALO(3,ICEL)
      IBUF2(4)=ZTALO(4,ICEL)
      IBUF2(5)=ZTALO(5,ICEL)
      III=-2
      DO 50 ICH=1,5,2
      III=III+3
      IWORK4=0
      IWORK1(2)=IBUF1(III)
      IWORK1(3)=IBUF1(III+1)
      IWORK1(4)=IBUF1(III+2)
      ITAV=INT(IWORK4/4096)
      TALO(ICH,ICEL)=0.1*ITAV
      IF(ITAV.GT.3800) TALO(ICH,ICEL)=ITAV-3420
      ITAH=IWORK4-4096*ITAV
      IF(ICH.EQ.5) GO TO 60
      TALO(ICH+1,ICEL)=0.1*ITAH
      IF(ITAH.GT.3800) TALO(ICH+1,ICEL)=ITAH-3420
   50 CONTINUE
   60 CONTINUE
C
C     REORDER CHANNELS
C
      TA37V=TALO(3,ICEL)
      TA37H=TALO(4,ICEL)
      TALO(3,ICEL)=TALO(5,ICEL)
      TALO(4,ICEL)=TA37V
      TALO(5,ICEL)=TA37H
C
C     FIND THE TOIL FLAGS
C
      ITOIL1=INT(ITAH/512)
      IRES=ITAH-ITOIL1*512
      ITOIL2=IRES/64
      IRES=IRES-ITOIL2*64
      ITOIL3=IRES/8
      ITOIL4=IRES-ITOIL3*8
      IATOIL(JCEL)=ITOIL1
      IF(I85GHZ.EQ.0) GO TO 100
```

```
      IBTOIL(JCEL)=ITOIL2
      IATOIL(JCEL+1)=ITOIL3
      IBTOIL(JCEL+1)=ITOIL4
C
C     FIND 85 GHZ TA'S
C
      IBUF2(1)=ZTAHI(1,ICEL)
      IBUF2(2)=ZTAHI(2,ICEL)
      IBUF2(3)=ZTAHI(3,ICEL)
      IBUF2(4)=ZTAHI(4,ICEL)
      IBUF2(5)=ZTAHI(5,ICEL)
      IBUF2(6)=ZTAHI(6,ICEL)
      III=-2
      DO 70 ICH=1,7,2
      III=III+3
      IWORK4=0
      IWORK1(2)=IBUF1(III)
      IWORK1(3)=IBUF1(III+1)
      IWORK1(4)=IBUF1(III+2)
      ITAV=INT(IWORK4/4096)
      TAHI(ICH)=0.1*ITAV
      IF(ITAV.GT.3800) TAHI(ICH)=ITAV-3420
      ITAH=IWORK4-4096*ITAV
      TAHI(ICH+1)=0.1*ITAH
      IF(ITAH.GT.3800) TAHI(ICH+1)=ITAH-3420
   70 CONTINUE
      ATAHI(1,JCEL)=TAHI(1)
      ATAHI(2,JCEL)=TAHI(2)
      BTAHI(1,JCEL)=TAHI(3)
      BTAHI(2,JCEL)=TAHI(4)
      ATAHI(1,JCEL+1)=TAHI(5)
      ATAHI(2,JCEL+1)=TAHI(6)
      BTAHI(1,JCEL+1)=TAHI(7)
      BTAHI(2,JCEL+1)=TAHI(8)
  100 CONTINUE
      RETURN
      END
CFF
```

```
      SUBROUTINE FDTB(I85GHZ)
C
C     THIS SUBROUTINE CONVERTS ANTENNA TEMPS. TO BRIGHTNESS TEMPS.
C
      REAL*4 DELTA(4),CHI(2,4)
      REAL*4 AVV(4),AHV(4),AOV(4),AHH(4),AVH(4),AOH(4)
C
C     SPECIFY COMMON /OUTDAT/
C
      REAL*8 REV,XTIME
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB
      INTEGER*4 IATOIL,IBTOIL
      REAL*4 XLATSC,XLONSC,ALTSC,THT,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,ATAHI,BTAHI
      COMMON/OUTDAT/ REV,XTIME,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,THT,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),ATAHI(2,128),BTAHI(2,128),IATOIL(128),IBTOIL(128)
C
C     DATA INITIALIZATION
C
      DATA ISTART/1/
      DATA DELTA/0.03199,0.02685,0.01434,0.01186/
      DATA CHI/.00379,.00525,.00983,0.0,.02136,.02664,.01387,.01967/
C
C     BEGIN EXECUTION
C
      IF(ISTART.EQ.0) GO TO 20
      ISTART=0
      DO 10 IFREQ=1,4
      IF(IFREQ.EQ.2) GO TO 10
      XFAC=(1.-CHI(1,IFREQ)*CHI(2,IFREQ))*(1.-DELTA(IFREQ))
      AVV(IFREQ)=(1.+CHI(1,IFREQ))/XFAC
      AHV(IFREQ)=-CHI(1,IFREQ)*(1.+CHI(2,IFREQ))/XFAC
      AOV(IFREQ)=(1.-AVV(IFREQ)-AHV(IFREQ))*2.7
      AHH(IFREQ)=(1.+CHI(2,IFREQ))/XFAC
      AVH(IFREQ)=-CHI(2,IFREQ)*(1.+CHI(1,IFREQ))/XFAC
      AOH(IFREQ)=(1.-AHH(IFREQ)-AVH(IFREQ))*2.7
   10 CONTINUE
   20 CONTINUE
```

```
      DO 100 ICEL=1,64
      TB19V=AVV(1)*TALO(1,ICEL)+AHV(1)*TALO(2,ICEL)+AOV(1)
      TB19H=AHH(1)*TALO(2,ICEL)+AVH(1)*TALO(1,ICEL)+AOH(1)
      TB37V=AVV(3)*TALO(4,ICEL)+AHV(3)*TALO(5,ICEL)+AOV(3)
      TB37H=AHH(3)*TALO(5,ICEL)+AVH(3)*TALO(4,ICEL)+AOH(3)
      TALO(1,ICEL)=TB19V
      TALO(2,ICEL)=TB19H
      TALO(3,ICEL)=1.01993*TALO(3,ICEL)+1.994
      TALO(4,ICEL)=TB37V
      TALO(5,ICEL)=TB37H
  100 CONTINUE
      IF(I85GHZ.EQ.0) RETURN
      DO 200 ICEL=1,128
      TB85V=AVV(4)*ATAHI(1,ICEL)+AHV(4)*ATAHI(2,ICEL)+AOV(4)
      TB85H=AHH(4)*ATAHI(2,ICEL)+AVH(4)*ATAHI(1,ICEL)+AOH(4)
      ATAHI(1,ICEL)=TB85V
      ATAHI(2,ICEL)=TB85H
      TB85V=AVV(4)*BTAHI(1,ICEL)+AHV(4)*BTAHI(2,ICEL)+AOV(4)
      TB85H=AHH(4)*BTAHI(2,ICEL)+AVH(4)*BTAHI(1,ICEL)+AOH(4)
      BTAHI(1,ICEL)=TB85V
      BTAHI(2,ICEL)=TB85H
  200 CONTINUE
      RETURN
      END
```

Remote Sensing Systems

1101 COLLEGE AVE., SUITE 220, SANTA ROSA, CA 95404 (707) 545-2904

April 8, 1988

Dear Colleague:

Please find enclosed the SSM/I User's Manuals for the Antenna Temperature Data Set and the Ocean Products Data Set. Also, for those of you who are currently receiving SSM/I data tapes, we have enclosed a floppy disc (360 kb) that contains the Fortran routines DECODE and UNPACK for reading the T_A and Ocean Products tapes, respectively.

There are a few items of interest that were omitted from the User's Manuals. First, all tapes end with a double end-of-file mark. This is a convenient way to detect the end of information on the tapes without having keep track of the number of tape files.

Second, a wind speed value of -11 m/s indicates that no wind speed could be found due to anomalous T_A values. This rarely occurs. A more frequent occurrence is wind speeds that are slightly negative due to measurement and modeling error. In this case, the wind speed should simply be set to zero.

Third, the location information for the time period from day 236 14Z to day 238 24Z is erroneous due to an incorrect ephemeris. The locations are way off by thousands of kilometers, and this time period should be discarded.

aug 25, 1987 14:00
aug 28, 1987 00:00

Finally, there appears to be a small location error that affects all the data. The magnitude of the error is about 25 km, depending on swath position. The error is systematic and most likely can be easily corrected. Our plan is to distribute a Fortran routine for correcting the latitudes and longitudes on a scan-by-scan basis once the error is quantified.

We intend to issue quarterly reports that will keep you informed on the status of the SSM/I sensor, the T_A and ocean data processing, the data quality, and related problems. In turn, we will appreciate hearing from you via F.WENTZ on Telemail.

Sincerely,

Frank

Frank J. Wentz

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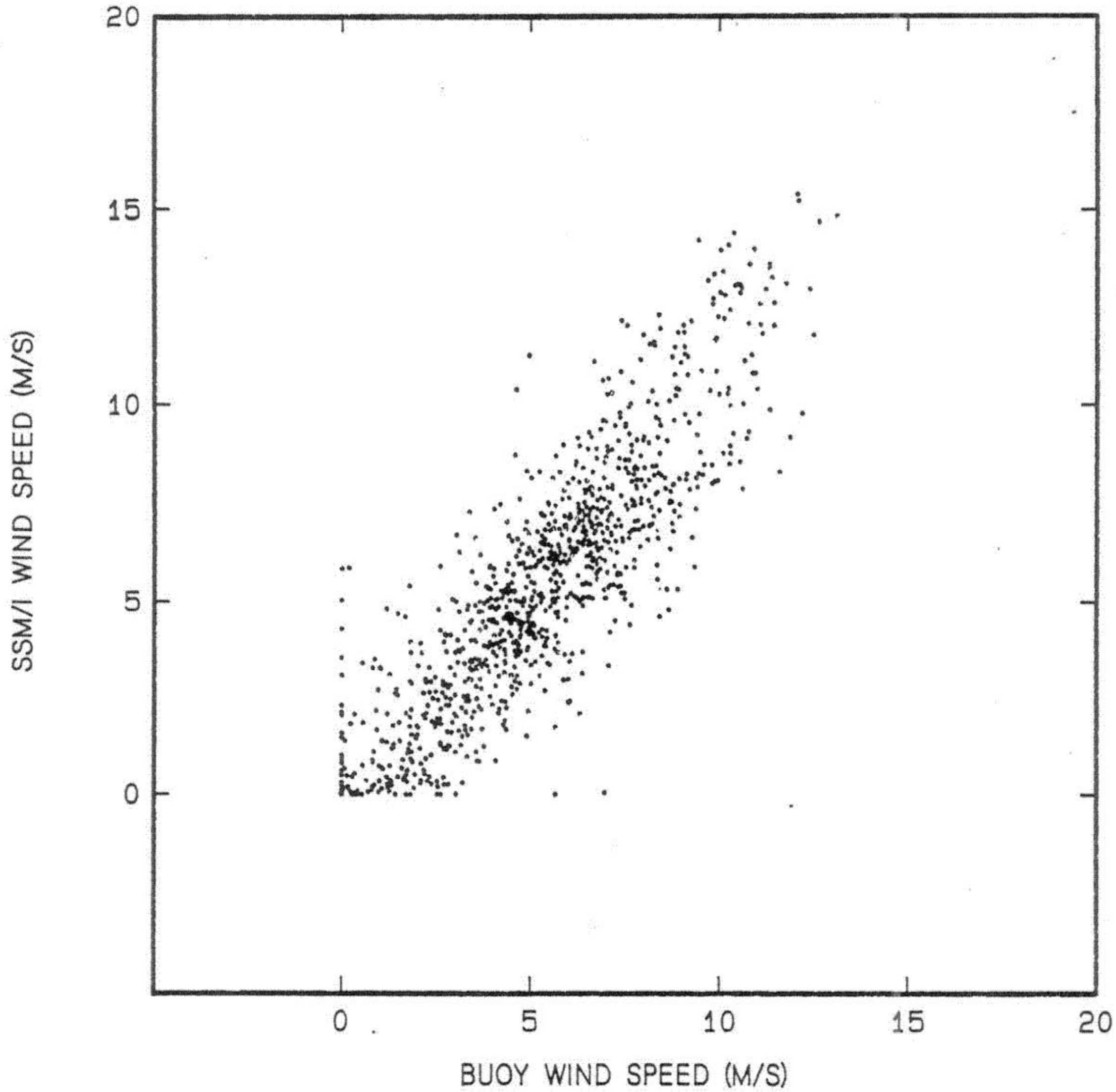
For those of you interested in SSM/I wind speeds, the attached plot shows the SSM/I derived winds versus 979 wind speeds reported by 18 NOAA buoys located in the Gulf of Mexico and off the Atlantic and Pacific Coasts. The SSM/I winds within a 75 km radius and within 30 min. of a buoy observation are first averaged and then compared to the buoy wind. When the SSM/I geophysical algorithm indicates rain, the cell is excluded from the average.

The 979 comparisons show a 1.6 m/s rms variation with no appreciable bias. The geophysical algorithm is essentially the same as we used for SeaSat, and there has been no retrospective tuning or adjustments to the algorithm based on the buoy winds.

We would like to thank Cal Swift and Mark Goodberlet of the University of Massachusetts for compiling the NOAA buoy winds.



Least-Squares Fit of SSM/I Winds to Buoy Winds:

$$W_{ssmi} = 1.02475\ W_{buoy} + 0.01$$

Statistics of Wind Speed Differences:

< > denote average over 979 buoy observations

$$\langle W_{ssmi} - W_{buoy} \rangle = 0.1 \text{ m/s}$$

$$\mathrm{SQRT}\{\langle (W_{ssmi} - W_{buoy})^2 \rangle\} = 1.6 \text{ m/s}$$

W_{ssmi} vs. W_{buoy} correlation = 0.87

Fig. 1. Comparison of SSM/I wind speed retrievals with 979 buoy observations