Nimbus-7 SMMR Pathfinder Brightness Temperatures

Overview

Platform	Nimbus-7
Sensors	SMMR
Spatial Coverage and Resolution	84 degrees South to 84 degrees North and longitudes of 180 degrees West to 180 degrees East with a 780 km swath
Temporal Coverage and Resolution	25 October 1978 to 20 August 1987 with a resolution of every other day
Parameters	Brightness Temperatures
Data Format	HDF
Metadata Access	View Metadata Record
Get Data	FTP

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Citing These Data

Data Citation

As a condition of using these data, you must cite the use of this data set using the following citation. For more information, see our Use and Copyright Web page.

Njoku, E. G. 2003. *Nimbus-7 SMMR Pathfinder Brightness Temperatures*. [indicate subset used]. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center.

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2. Detailed Data Description

Introduction

The Nimbus-7 SMMR Pathfinder Brightness Temperatures data set contains global brightness temperatures in swath format (level 1b) from October 25, 1978 to August 20, 1987. The instrument obtained near-global coverage at five frequencies (6.6, 10.7, 18, 21, and 37 GHz) in both horizontal and vertical polarizations, at a constant incidence angle of 50.3 degrees, every six days. Data are stored as daily orbit files in compressed Hierarchical Data Format (HDF) and are available on FTP.

measured the Earth's microwave radiation at five frequencies (6.6, 10.7, 18, 21, and 37 GHz) in both horizontal and vertical polarizations at a constant incidence angle of 50.3 degrees. Near-global coverage was obtained every six days. Details of the SMMR instrument, the data processing algorithms, and early geophysical results are provided by Gloersen and Barath (1977), Njoku et al. (1980), Swanson and Riley (1980), Njoku (1980), Gloersen et al. (1984), Gloersen (1987) and Fu et al. (1988).

This data set is the outcome of a project to reprocess the original level 1B data. The primary objectives were to remove (or reduce) known calibration anomalies in the data (Milman and Wilheit 1985, Liu and Mock 1986, Frances 1987, and McMillan and Han 1990) and to provide a globally-consistent data set, available on compact media, for global change research (ocean, land, atmosphere, and cryosphere). The processed data are in swath format with the original sampling and resolution of the data maintained. Processing details provided by Njoku et al. (1998). The data are available in the Hierarchical Data Format (HDF).

Each data file contains a complete orbit, defined as beginning and ending at successive descending node equator crossings (approximately midnight local time). The orbital period is approximately 104.16 minutes, resulting in approximately 13.8 orbits per day. The file size for an uncompressed SMMR orbit file is 4.3 megabytes. Due to spacecraft power constraints, the SMMR was limited to acquiring data on alternate days for most of the mission. Additional time gaps occur in the data, primarily due to gaps in acquisition, transmission, or processing of the raw data. The size of the entire (approximately nine-year) data set is 59 gigabytes compressed, and 101 gigabytes uncompressed.

Objective/Purpose

Production of this data set was motivated by the desire to improve upon earlier versions of archived Nimbus-7 SMMR brightness temperatures by providing: (1) data corrected to the extent feasible for observed calibration anomalies in all radiometer channels; (2) data processed globally in swath format at the original sensor sampling and resolution (i.e. without gridding to Earth-fixed coordinates); (3) data processed for the full mission duration using a uniform set of processing algorithms and procedures; (4) data archived, documented, and accessible, on compact media and in standard format, and available at an EOSDIS DAAC, for use in global change research.

Summary of File Variables

Table 1 provides a brief description of the information and variables contained in the HDF data files. For complete details, see the SMMR Level 1B Pathfinder Data Set document.

Table 1. HDF File Variable Description

Variable	Abbreviation	HDF Object Type	Reference #	Description
File Description	N/A	Annotation	N/A	Contains a textual description of the data in the HDF files. See section 3.1 in SMMR Level 1B Pathfinder Data Set for complete details.
Spacecraft Position and Scan Info-1	SP1	Scientific Data Set (SDS)	3	Contains spacecraft information such as yaw, pitch, and roll and sun ascension and declination information as well as date and time. See section 3.2 in SMMR Level 1B Pathfinder Data Set for complete details.
Spacecraft Position and Scan Info-2	SP2	Scientific Data Set (SDS)	5	Contains spacecraft information such as x, y, and z coordinates and altitude. See section 3.3 in SMMR Level 1B Pathfinder Data Set for complete details.
Scan Angle and Location Info	SAL	Scientific Data Set (SDS)	7	Contains the latitude and longitude of the data as well as antenna scan angles, reflected sun-footprint angles, and footprint incidence angles. See section 3.4 in SMMR Level 1B Pathfinder Data Set for complete details.
Calibration Data	CAL	Scientific Data Set (SDS)	9	Contains values used to calibrate the radiometric data for the corresponding scan. See section 3.5 in SMMR Level 1B Pathfinder Data Set for complete details.
6.6 GHz Horizontal Data	06H	Scientific Data Set (SDS)	11	Brightness temperature data from the 6 GHz horizontal channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
6.6 GHz Vertical Data	06V	Scientific Data Set (SDS)	13	Brightness temperature data from the 6 GHz vertical channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
10.69 GHz Horizontal Data	10H	Scientific Data Set (SDS)	15	Brightness temperature data from the 10 GHz horizontal channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
10.69 GHz Vertical Data	10V	Scientific Data Set (SDS)	17	Brightness temperature data from the 10 GHz vertical channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
18 GHz Horizontal Data	18H	Scientific Data Set (SDS)	19	Brightness temperature data from the 18 GHz horizontal channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
18 GHz Vertical Data	18V	Scientific Data Set (SDS)	21	Brightness temperature data from the 18 GHz vertical channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
21 GHz Horizontal Data	21H	Scientific Data Set (SDS)	23	Brightness temperature data from the 21 GHz horizontal channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
21 GHz Vertical	21V	Scientific	25	Brightness temperature data from the 21 GHz vertical channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for

Horizontal Data		Data Set (SDS)		for complete details.
37 GHz Vertical Data	37V	Scientific Data Set (SDS)	29	Brightness temperature data from the 37 GHz vertical channel. See section 3.6 in SMMR Level 1B Pathfinder Data Set for complete details.
Surface Type Indices	SFT	Scientific Data Set (SDS)	31	Contains an indicator of the surface type based on the radiometric data latitudes and longitudes in conjunction with the Fleet Numeric Meteorological and Oceanographic Center SSM/I surface type database. See section 3.7 in SMMR Level 1B Pathfinder Data Set for complete details.

In addition, daily, global browse images of selected brightness temperature channels are available as follows:

- 6.6 GHz Horizontal Ascending (Day)
- 6.6 GHz Horizontal Descending (Night)
- 37 GHz Horizontal Ascending (Day)
- 37 GHz Horizontal Descending (Night)

Discussion

This data set is unique in that it contains brightness temperatures processed in swath format at the original instrument sampling resolution. It includes corrections for instrument calibration anomalies found to be present in data processed originally by the Nimbus Satellite Project. Other reprocessed data sets have also been published, using subsets of the SMMR channels in Earth-gridded format and over specific geographic regions (Wentz and Frances 1992, Gloersen et al. 1992). Comparisons of the present data with these other data sets has not been performed as of the publication date of this Guide (September, 1995).

Spatial Characteristics

Spatial Coverage and Resolution

The data set extends from latitudes of 84 degrees South to 84 degrees North and longitudes of 180 degrees West to 180 degrees East. The 50 degree scan provided a 780 km swath of the Earth's surface.

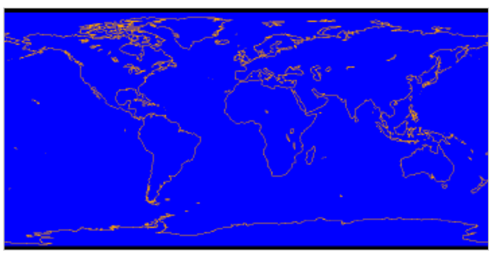

Figure 1. Spatial Coverage Map

Projection

The data set has been produced in swath format.

Temporal Characteristics

Temporal Coverage

The data set covers 25 October 1978 to 20 August 1987. The SMMR operated continuously during the three week checkout period from October 25, 1978 to November 16, 1978. After that, the instrument was switched on and off on alternate days. From April 3 to June 6, 1986, a special operation was under way during which the SMMR was switched off more frequently. The off periods averaged length of 75 minutes and the on periods averaged 30 minutes.

Temporal Coverage Graph

The following graphic shows the percentage of missing data for the SMMR instrument. The value for 1986 does not include the period of special operation which was from April 3 to June 6, 1986.

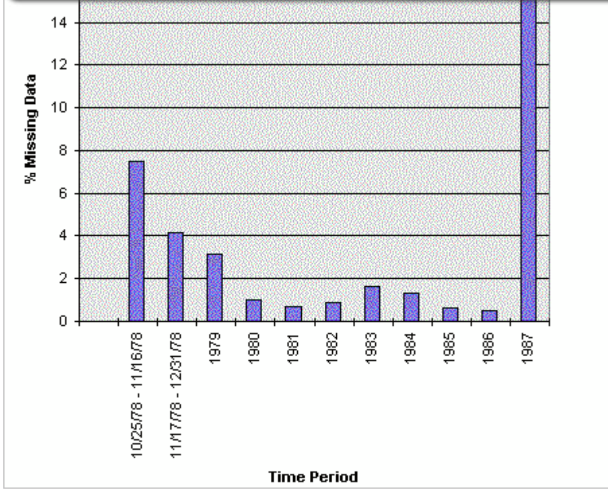

Figure 2. Temporal Coverage Graph

Temporal Resolution

Switching of the instrument on and off on alternate days was the normal mode of operation for the SMMR for most of its mission due to power sharing constraints among instruments on the spacecraft. The SMMR was routinely turned on at close to midnight GMT (corresponding to a descending node equator crossing near 0 longitude), and turned off at approximately the same time the following day. The satellite completes nominally 13.8 orbits in a day. Each level 1B orbit file covers a time period of approximately 104.16 minutes.

Data Characteristics

Parameter/Variable

Brightness Temperatures

Variable Description/Definition

Brightness temperature is the effective temperature of a blackbody radiating the same amount of energy per unit area at the same wavelengths as the observed body.

Unit of Measurement

All temperatures are stored in Kelvins * 0.1.

Data Source

The SMMR Pathfinder brightness temperature data set was generated from SMMR measurements.

Data Range

The range for the brightness temperatures is approximately 65 K to 325 K.

Sample Data Record

Each processed level 1B orbit file contains the following HDF objects:

ITEM	HDF OBJECT TYPE	REF#
File Description	Annotation	N/A
Spacecraft Position and Scan Info-1 (SP1)	Scientific Data Set	3
Spacecraft Position and Scan Info-2 (SP2)	Scientific Data Set	5
Scan Angle and Location Info (SAL)	Scientific Data Set	7
Calibration Data (CAL)	Scientific Data Set	9
6.6 GHz Horizontal Data (06H)	Scientific Data Set	11
6.6 GHz Vertical Data (06V)	Scientific Data Set	13
10.69 GHz Horizontal Data (10H)	Scientific Data Set	15
10.69 GHz Vertical Data (10V)	Scientific Data Set	17
18 GHz Horizontal Data (18H)	Scientific Data Set	19
18 GHz Vertical Data (18V)	Scientific Data Set	21
21 GHz Horizontal Data (21H)	Scientific Data Set	23
21 GHz Vertical Data (21V)	Scientific Data Set	25
37 GHz Horizontal Data (37H)	Scientific Data Set	27
37 GHz Vertical Data (37V)	Scientific Data Set	29
Surface Type Indices (SFT)	Scientific Data Set	31

Data Granularity

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format

The data are stored in Hierarchical Data Format (HDF).

3. Data Access and Tools

Data Access

These products are available on FTP.

Software Tools

HDF files can be viewed using HDFView from the HDF Group.

4. Data Acquisition and Processing

The current input data for the Nimbus-7 SMMR Pathfinder Brightness Temperatures data set is the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) Antenna Temperatures data set created at NSIDC.

The original Level-1A antenna temperature tapes (TAT) data provided by A. Chang and D. Han of GSFC were produced and archived originally by the Nimbus-7 Satellite Project at GSFC.

Theory of Measurements

On the Nimbus-7 platform the SMMR instrument measures passive microwave radiances. The SMMR is a ten channel instrument delivering orthogonally polarized antenna temperatures at five microwave frequencies, 6.6, 10.69, 18, 21 and 37 GHz.

Sensor or Instrument Description

The SMMR instrument employed a 79-cm diameter offset-fed parabolic reflector to direct Earth-emitted radiation into a 10-channel multi-frequency feed horn. At the ports of the feed horn the radiation was split into the designated frequency and polarization channels (frequencies of 6.6, 10.7, 18, 21, and 37 GHz, each with horizontal and vertical polarizations) and transmitted via wave guide or coaxial line to the respective radiometers for detection. Scanning was accomplished by sinusoidal oscillation of the parabolic reflector (offset at 42 degrees from nadir) about a vertical axis with a period of 4.096 seconds. The antenna orientation was forward-looking, with a symmetric angular scan between azimuth angles of +25 and -25 degrees to each side of the suborbital track. This resulted in a conical scan, with a constant incidence angle at the Earth's surface of 50.3 degrees. The scan pattern mapped out a swath width of 780 km at the Earth's surface.

The spatial resolutions at the various frequencies ranged from approximately 27 km at 37 GHz to 148 km at 6.6 GHz. The radiometer sensitivities ranged from 0.7 K at 6.6 GHz to 1.4 K at 37 GHz, for radiometer integration times ranging from 128 to 32 ms, respectively. Calibration data were acquired at the scan extremes by alternately switching the radiometers to sky horns viewing cold space and internal calibration loads at the instrument ambient temperature. A summary of the nominal SMMR operating characteristics is shown in Table 1. Further details on the instrument design and operation are given in Refs [2] and [3].

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Table 1: Nimbus-7 SMMR Nominal Operating Characteristics
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Frequency (GHz)              6.6      10.7     18       21       37
Sampling period (ms)         128      64       64       64       32
Sensitivity (K)              0.7      0.8      0.9      1.0      1.4
3-dB beam width (deg)         4.2      2.6      1.6      1.4      0.8
Footprint resolution (km)    148x95    91x59   55x41    46x30    27x18

Antenna aperture (cm)        79
Offset angle (deg)           42
Azimuth scan range (deg)     -25 to +25
Scan period (s)              4.096
Earth-incidence angle (deg)  50.3

Orbit type                  Circular, sun-synchronous, local noon
                            (ascending) and midnight (descending)
                            equator crossings
Altitude (km)               955
Inclination (deg)           99
Period (min)                104.16
Nodal progression (deg)     26.1 (westward)
Subsatellite vel. (km/s)    6.4
Swath width (km)            780

Launch date:                October 24, 1978

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Collection Environment

Satellite.

Source/Platform

duty cycle. The SMMR was constrained to a 50 percent duty cycle, and was turned on and off on alternate days.

The attitude control system was designed to maintain spacecraft stability to within 0.7 degrees in pitch, and 1 degree in roll and yaw. Nominally, a sun sensor was used to sense the spacecraft attitude during daytime portions of the orbit, and horizon sensors were used during nighttime portions. Spacecraft pitch, roll, and yaw angles, and ephemeris data, were used to compute footprint latitude and longitude locations and incidence angles. These data were placed on the TAT data record.

Source/Platform Mission Objectives

The SMMR was an experimental Earth-imaging passive microwave sensor launched as a follow-on to earlier experimental radiometers (ESMR, NEMS, and SCAMS) launched by NASA on previous satellites in the Nimbus series (Nimbus-5 and -6). The SMMR was designed primarily for remote observations of oceanic, cryospheric, and tropospheric moisture-related phenomena. Key geophysical variables observable by the SMMR included sea surface temperature, sea surface wind speed, columnar water vapor over the ocean, cloud liquid water over the ocean, rain rate, sea-ice concentration and type, snow extent and depth, and potentially other land parameters such as soil moisture, surface temperature, and vegetation extent.

Key Variables

The SMMR instrument measures passive microwave radiances at 6.6, 10.69, 18, 21 and 37 GHz frequencies.

Principles of Operation

Six conventional Dicke-type radiometers are used. Those operating at the four longest wavelengths measure alternate polarizations during successive scans of the antenna; the others, at the shortest wavelength, operate continuously for each polarization. A two point reference signal system is used, consisting of an ambient RF termination and a horn antenna viewing deep space. A switching network of latching ferrite circulators selects the appropriate polarization or calibration input for each radiometer. For more details on the principles of operation of the SMMR instrument, see the Scanning Multi-channel Microwave Radiometer guide document.

Manufacturer of Sensor/Instrument

Final design and fabrication was accomplished at the Jet Propulsion Laboratory by a team under the direction of J. Johnston.

Derivation Techniques and Algorithms

For information on the derivation techniques and algorithms, see Gloersen (1987) and Fu et al. (1988).

Data Processing Sequence

A description of the theory and implementation of the processing is given in Njoku et al. (1998). Care was taken to ensure that instrument-related effects (and not geophysical signatures) were removed in the processing. The approach synthesized results and analyses from previous SMMR calibration studies (Swanson and Riley 1980, Njoku 1980, Gloersen 1987, Fu et al. 1988, Frances 1987, McMillan and Han 1990, Gloersen et al. 1992).

The following were the main steps in the procedure:

(1) Calibration of the radiometric data to convert from raw counts to antenna temperatures.

The basic calibration equation used was described in the Nimbus-7 SMMR CELL-ALL tape User's Guide (Ref [8]). This equation was derived from theoretical models of the instrument, data acquired during pre-launch thermal vacuum testing, and post-launch data analysis (Swanson and Riley 1980, Gloersen 1987, Fu et al. 1988).

The equation converted radiometer counts to antenna temperature, making use of the cold sky and warm load calibration counts. Terms in the equation included off-line-derived coefficients to account for losses in the component waveguides, horns, and switches, and in-orbit engineering temperatures measured by thermistors mounted on these components (Fu et al. 1988).

Anomalous cold-sky calibration counts were recorded by the SMMR during a period each orbit when solar radiation entered the sky horns. This occurred over a time interval of about one-sixth of each orbit, and resulted from the spacecraft's orientation relative to the sun as a function of orbit position. The anomalous data were corrected by replacing them with cold counts interpolated linearly between the weighted-average values immediately before and after the anomaly periods. (To reduce effects of noise and other occasional errors in calibration counts and component temperatures, these data were smoothed by computing them as weighted running-averages, and by using thresholds to exclude large error values.)

(2) Adjustment for (a) calibration bias errors, (b) long-term calibration drifts, and (c) calibration drifts with respect to the sun-spacecraft (ecliptic) angle.

(a) Adjustments for calibration bias errors were performed in a manner similar to that described by Gloersen (1987). A renormalization was done to correct for portions of the antenna sidelobes viewing cold space. A linear correction was made to the calibration equation in order to adjust the observed ocean brightness temperatures to those computed from a radiative transfer model (Hofer and Njoku 1981) for similar ocean-atmosphere conditions. This was done by using modeled brightness temperatures, with averaged ocean and atmosphere climatological conditions as inputs, as a "cold temperature" reference point, and the internal warm load as a "warm temperature" reference point. The assumed climatological conditions were typical of average conditions for December in the latitude range 40 to 50 degrees South. Averaged SMMR data from December 1978 nighttime passes over ocean in the latitude range 40 to 50 degrees South were used to obtain the coefficients for the linear adjustment. Two passes of this procedure were performed to minimize the effects of clouds.

(b) Corrections for long-term calibration drifts were implemented in a manner similar to the procedures described in Frances 1987, McMillan and Han 1990, and Gloersen et al. (1992).

Six-day global ocean averages of SMMR brightness temperatures (away from land or ice) were generated for the duration of the mission. The annual cycle was removed, and the residual trends in each channel were fit by least squares to polynomial functions of time. These polynomials were applied as corrections for long-term drift at the "cold temperature" reference of the calibration equation. In applying this approach, it was assumed that the global ocean average brightness temperatures (with the annual cycle removed) should be approximately constant with time, and that any residual, secular long-term trends, uncorrelated by radiometer channel, could be ascribed to calibration drifts, such as due to gradual degradations of instrument components. A correction for long-term drift was not applied at the "warm temperature" reference of the calibration equation since averaged land brightness temperatures, which might be appropriate as a warm calibration reference, do not exhibit the temporal stability of averaged ocean temperatures. However, degradations of instrument components, leading to increased resistive losses, normally have much larger relative effects at cold brightness temperatures than at warm brightness temperatures. Hence, most probably this is not a serious omission.

On January 4, 1984, the recorded SMMR incidence angles and some of the brightness temperatures (predominantly the vertical polarizations) exhibited small but significant discontinuous jumps in their mean values. (The mean recorded incidence angle changed from 50.2 degrees to 49.8 degrees.) The nature and magnitudes of these jumps appeared to be consistent with the possibility that a discontinuous change in the mean spacecraft attitude had occurred. However, these jumps were not discovered in the SMMR data until after the mission when long-term trend analyses were performed, and the cause could not be determined retrospectively, and conclusively from the spacecraft and instrument data records. For this reason, the long-term trend polynomial fits described above were computed and applied in two segments - before and after January 4, 1984. Between these two segments, the fitted trends exhibited the discontinuities shown in Table 2. It is recommended that the brightness temperature "delta" values shown should be added as a calibration offset to all ocean brightness temperatures subsequent to the

Table 2: Offset adjustments ("deltas") recommended to be added to the SMMR ocean brightness temperatures after January 4, 1984.

Channel	Delta (K)
6.6 GHz (V)	1.04
10.7 GHz (V)	0.81
18 GHz (V)	0.79
21 GHz (V)	0.0
37 GHz (V)	0.88
6.6 GHz (H)	0.0
10.7 GHz (H)	0.0
18 GHz (H)	0.0
21 GHz (H)	0.0
37 GHz (H)	0.0

(c) Calibration drifts with respect to the so-called "ecliptic" angle (the angular distance of the spacecraft in its orbit from the point of closest approach to the sun) were caused by variations in solar heating of the SMMR instrument at different positions in the orbit. The solar heating induced dynamic temperature gradients in the horns, waveguides, and other instrument components, that could not be fully compensated by the basic calibration equation. The calibration drift characteristics were repetitive each orbit since the Nimbus-7 orbit was sun-synchronous. The drifts were estimated and corrected using a procedure similar to that described by Frances (1987) (and also used by Gloersen et al. 1992). In this procedure, differences between co-located brightness temperatures from ascending and descending orbital crossings over the ocean were accumulated for each year, averaged by latitude band (related to ecliptic angle) and six-day period. It was assumed that, averaged over the year, these differences should be zero, and that departures from zero represented calibration drift errors. A weighted least squares procedure was used to estimate these errors as a function of ecliptic angle for each year of the mission. The functional dependence varied slightly from year to year, hence a linear interpolation between years was computed. The final corrections were used as adjustments to the "cold temperature" reference in the calibration equation.

(3) Interpolation of the radiometric data for all channels to the locations of the 37 GHz vertical radiometric data.

As described by Njoku (1980), the sampling sequences of the SMMR radiometers were non-coincident. Also, the vertical and horizontal polarizations (except at 37 GHz) were sampled on alternate halves of the oscillating scan cycle. In order to correct for polarization mixing of the brightness temperatures co-located vertical and horizontal data at each frequency were required. This was accomplished by interpolating the measured brightness temperatures along- and across-scan so that vertical and horizontal channels were co-registered at each frequency. In actual implementation all channels were in fact interpolated to be co- registered to the locations of the 37 GHz vertical samples. This additional density of interpolation provided uniform, co-located data arrays at each channel, and simplified the further processing steps considerably. However, it should be remembered that the interpolation does not increase the inherent resolution of the data channels (as given in Table 1). Conversely, the interpolations are over distances that are relatively small with respect to footprint size, and hence should not adversely affect the accuracy or fidelity of the data.

(4) Correction of the antenna temperatures for polarization mixing.

Mixing of the received vertical and horizontal brightness temperatures occurred due to antenna effects (cross-polarization and scan-induced polarization coupling) and also due to polarization switch leakage. Since these effects, in particular the switch leakages, could not be adequately characterized prior to launch, correction coefficients had to be estimated and applied post-launch. The effects were asymmetrical as a function of scan position, but could be corrected by applying a simple 2x2 matrix operation to convert "measured" vertical and horizontal data to "corrected" vertical and horizontal data at each scan position. The correction coefficients were estimated by fitting brightness temperatures, averaged by scan angle over ocean regions between latitudes 30 and 50 degrees South for December 1978, to modeled functions of the azimuthal scan angle. These coefficients were assumed to be constant in space and time, and were applied globally and for the entire mission.

(5) Setting of flags to identify anomalous conditions and possible losses of data quality.

Each scan of data in the SMMR output includes a 16-bit "scan status word". Six bits of this word are set to indicate possible losses of data quality in the data output for that scan. Details of the interpretations of these data quality flags are described in Section 8.

Table 3: Interpretation of Scan Status Word

(16-bit word --- all bits will be zero except as follows:)

Bit 0 = 1: Possible loss of data quality in level 1A processing (flag passed from input TAT data).

Bit 1 = 1: Scan is in period of initialization of calibration and engineering data running averages. Brightness temperature calibrations may be less reliable during this period.

Bit 2 = 1: One or more of the instrument component temperatures used in the radiometric calibrations has deviated by more than +/- 3K from its running average value in the previous scan. The accuracy of the brightness temperature calibrations in this scan may be reduced.

Bit 3 = 1: Pitch, roll, or yaw error value is greater than +/- 0.95 degrees. This indicates an anomalous spacecraft attitude variation.

Bit 4 = 1: The average value of the footprint incidence angles in the scan has deviated by more than +/- 0.1 degrees from the average value for in previous scan. This indicates where caution should be exercised in using incidence angles in subsequent geophysical processing.

Bit 5 = 1: Scan is in the "sun-in-the-cold-horn" period. Cold calibration counts have been interpolated and brightness temperature calibration accuracy may be reduced.

Processing Steps

The steps performed in reprocessing the SMMR data from uncalibrated sensor data (level 1A) to calibrated brightness temperatures (level 1B) included the following:

(1) Calibration of the radiometric data to convert from raw counts to antenna temperatures.
(2) Adjustment for calibration bias errors, long-term calibration drifts, and calibration drifts with respect to the sun- spacecraft (ecliptic) angle.
(3) Interpolation of the radiometric data for all channels to the locations of the 37 GHz vertical radiometric data.
(4) Correction of the antenna temperatures for polarization mixing.
(5) Setting of flags to identify anomalous conditions and possible losses of data quality.

The processed data were stored as orbit files in HDF format. The files were created on a Sun SPARCstation IPX with version 3.3 of the HDF library. They were transferred to 8-mm tape via the UNIX tar utility. All files were compressed with the UNIX compress command.

Software Description

Software for the processing algorithms was written in FORTRAN 77 and C. The code was compiled and run in a UNIX environment on a SUN IPX Sparcstation. The output files are in Hierarchical Data Format (HDF).

Calculations

Special Corrections/Adjustments

For information on the special corrections, please refer to Data Processing Sequence.

Calculated Variables

Brightness Temperatures

Sources of Error

The purpose of the SMMR instrument calibration was to relate raw sensor output (counts) to radiance received at the antenna aperture (brightness temperature). It was desired that the calibration be accurate and stable over the duration of the mission. To accomplish this, time- varying effects including thermal gradients in the components, polarization mixing in the antenna and switches, and component losses and degradation had to be accounted for. After processing the data to account for these effects residual errors may remain in the data, but these are expected to be significantly smaller than the original errors. A discussion of expected residual errors, based on analysis of the processed data, is given by Njoku et al. (1998).

No comparisons with independent data sources have been performed.

Quality Assessment

Quality indicator flags are provided in the scan status word for each scan. These flags indicate conditions in the original data or in the data processing which may give rise to reduced-quality calibrated output.

Limitations of the Data

Antenna effects:

Corrections are made for antenna sidelobes viewing space and for cross polarization mixing. However, no corrections are made for the antenna pattern beam shape or sidelobes within the Earth field of view. (Such corrections are difficult to perform for the SMMR due to the variable antenna pattern and sampling characteristics across the swath (Njoku 1980). Attempted improvements may be of questionable accuracy when applied globally. Hence, it has been left at the discretion of the user to perform this step in subsequent processing if the improvement obtainable appears to justify the effort involved.) Thus, although the term "brightness temperature" is applied to this level 1B product, it should be kept in mind that these data are smoothed versions of the actual brightness temperatures. The smoothing functions are the antenna patterns, whose half-power beamwidths provide the equivalent footprint dimensions at each frequency as shown in Table 1.

Operational Anomalies and Missing Data:

Acquisition of Nimbus-7 SMMR data commenced on October 25, 1978. The SMMR operated continuously during a three-week checkout period from start-up until November 16, 1978, at which time it began alternate-day operation. Switching of the instrument on and off on alternate days was the normal mode of operation for the SMMR for most of its mission due to power sharing constraints among instruments on the spacecraft. A special operations period occurred from April 3 to June 24, 1986, during which the SMMR was switched on and off more frequently, with "off" periods averaging 75 minutes and "on" periods averaging 30 minutes. The antenna scanning mechanism was turned off on August 20, 1987 marking the end of the SMMR data set.

Time gaps in the SMMR data of varying durations occurred during the mission. The table below summarizes the total instrument "on" and "off" times each year, with percentage estimates of missing data during "on" time. The tabulated values were estimated from data times recorded on the input TAT tapes. The high percentage of data missing during 1987 is due to the presence of several large data gaps in the 8- to 20-hour range. At this stage in the mission, the Nimbus-7 spacecraft had begun to exhibit power supply degradation, and the instrument on-off cycling modes were changed to conserve power and to focus on priority science objectives between instruments.

Any missing data within an orbit file are indicated by zeros in all data fields for the corresponding scan.

Table 4: Nimbus-7 SMMR Operations Summary

Time Period	"Off" Time (days)	"On" Time (days)	% Data Missing (During "On" Time)
10/25/78 - 11/16/78	0	22.04	7.51
11/17/78 - 12/31/78	24.32	20.68	4.17

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1983                    180.61       184.39         1.66
1984                    188.56       177.44         1.32
1985                    187.85       177.15         0.64
SOP*                     62.57        20.43         *
1986 (excl. SOP)        147.77       134.23         0.50
1987                    101.58       130.42        17.00

TOTAL                  1612.71      1608.33         2.60

*SOP - Special Operations Period: April 3 to June 24, 1986

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The data on the input TAT tapes contained some periods in which all antenna angle values were zero. This condition impeded proper calculation of the output brightness temperatures since the data interpolation step in the processing require accurate antenna angles.

All occurrences of zero-value antenna angles were in 1980 on the days shown below. No data were processed on these dates:

- January 5,7,9
- February 28
- March 1,3,17,19,21
- April 10,12

Known Problems with the Data

Although corrections applied to the data compensate for most of the long-term drift and in-orbit variations, some residual errors may still exist. Additional fine-tuning iterations and small-scale adjustments may be necessary for applications requiring higher precision in calibration than could be provided here, for instance, for sea surface temperature measurement (Njoku et al. 1998).

Errors in the input engineering data, which affect output brightness temperatures through the calibration equation, are simply flagged by the processing software. These flags can be used to screen bad data if necessary in further processing. Major deviations of brightness temperature from expected values can usually be traced to anomalous instrument component temperatures. For example, high 37 GHz horizontal brightness temperatures for June 19, 1979 can be attributed directly to unreliable calibration horn waveguide temperatures.

Individual instances of anomalously high or low brightness temperatures in a scan are usually traceable directly to "bad" or "questionable" antenna counts in the input TAT data. No provision has been made to screen out these scattered anomalies since it is best left at the user's discretion to place error-bar filters on the brightness temperature data. There is a high frequency of this type of error during 1986, especially during and for some time after the Special Operations Period (April - October). Interpolating radiometric samples within scans and between adjacent scans tends to smear the effect of these "bad" antenna counts, which are most noticeable in browse image maps of 6.6 GHz horizontal polarization data.

Usage Guidance

It is recommended that users should apply the offsets given in Table 2, and should use the quality indicator flags given in Table 3 to examine the data for possible screening. Users should also observe that the footprint incidence angles, though nominally constant at 50.3 degrees, do exhibit small variations with scan position, position in orbit, and with time during the mission (especially the jump in January 1984). The characteristics of these variations have been described by McMillan and Han (date TK), and should be taken into account for estimations of geophysical parameters that are sensitive to the brightness temperature dependence on incidence angle.

Application of the Data Set

Key geophysical variables that can be derived from the SMMR Brightness Temperature (Level 1B) Dataset include:

- Sea surface temperature
- Sea surface wind speed
- Columnar water vapor over the ocean
- Columnar cloud liquid water over the ocean
- Precipitation rate
- Sea-ice concentration and type
- Snow extent and depth
- Possibly land parameters such as soil moisture and vegetation extent.

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Related Data Sets

- Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) Antenna Temperatures
- Nimbus-7 SSMR Pathfinder Daily EASE-Grid Brightness Temperatures
- DMSP SSM/I-SSMIS Pathfinder Daily EASE-Grid Brightness Temperatures
- DMSP SSM/I-SSMIS Daily Polar Gridded Brightness Temperatures
- Nimbus-5 ESMR Polar Gridded Brightness Temperatures, Revision 1
- Nimbus-5 ESMR Polar Gridded Sea Ice Concentrations
- Nimbus-7 SMMR Polar Radiances and Arctic and Antarctic Sea Ice Concentrations

6. Document Information

Document Revision Date

August 28, 2014: Content was put into the new guide document template and information was updated about how to find the latitude and longitude in the files.
September 10, 1996: Initial release

Document Review Date

September 10, 1996

Document Authors

NSIDC Writers

Document URL

http://nsidc.org/data/docs/daac/nsidc0036_smmr_pathfinder_tbs.gd.html