RSS SSMIS Version-7 Brightness Temperature Data Set netCDF File Format Specification

Version-7, Release 01

July 4, 2014

1. INTRODUCTION

This document describes the Version-7 (V7) SSMIS Brightness Temperature (T_B) Dataset produced by Remote Sensing Systems (RSS) in netCDF version 4.0 format for the NOAA CDR program. The purpose of this document is to provide further details of the metadata listed in the netCDF files.

The V7 T_B dataset is a fully calibrated, accurately geolocated time series of Earth brightness temperatures. Commonly available SSMIS temperature data records (TDRs) are first reverse engineered back to the raw telemetry data which is the starting point for RSS data processing. We process raw counts to T_B using a standard set of proven algorithms developed in a consistent manner with other microwave radiometer data at RSS. The F17 SSMIS data have been carefully intercalibrated with the SSM/I, WindSat, and AMSR-E. This allows investigators to confidently use the SSMIS products for detailed interannual and decadal trend studies.

The SSMIS data set described in this document is a subset of the complete SSMIS channel set. It includes the following 7 channels: 19.35V, 19.35H, 22.235V, 37V, 37H, 91.7V, 91.7H. Two sets of geolocation parameters are provided: one for the lower channels (19-37 GHz) and the other for the 92 GHz channels. Each 1.9 second scan contains 90 lower channel observations and 180 92 GHz observations. The odd numbered 92 GHz observations are in close proximity to the lower channel observation locations, but there are some differences so we provide locations for both types of observations. Note that the locations of 19 and 22 GHz observations are slightly different from those of the 37 GHz observations. Fortunately, the footprints of the 19 and 22 GHz observations have sufficient overlap so that optimum interpolation can be used to move the 19 and 22 GHz footprints to the location of the 37 GHz footprints thereby avoiding the need to have a third set of geolocation parameters. The adjustment of the locations via optimum interpolation is highly accurate and should be of no concern to most (if not all) users.

A number of adjustments and corrections are applied to the data to achieve full calibration. These include:

1. Adjustments applied to the SSMIS pointing angles to achieve proper geolocation.
2. Corrections applied to remove the effects of the SSMIS emissive antenna. The emissive antenna affects all SSMIS channels.
3. Corrections applied to remove the moon intrusion into the cold mirror.
4. Corrections applied to remove the sun intrusion into the hot load.
5. Flagging of anomalous jumps in the radiometer counts.
6. Application of extensive quality control with respect to geolocation information and radiometer performance.
7. Adjustments to the antenna pattern coefficients to provide precise (0.1K or better) intercalibration with all other microwave imagers.

The netCDF files are generated from the V7 binary brightness temperature files using an IDL program.

2. FILE NAME STRUCTURE and FORMAT

The SSMIS brightness temperature data are stored in orbital files. The file names have the form:

RSS_SSMIS_FCDR_V07R00_F@@_Dyyyymmdd_Stttt_Etttt_R#####.nc

where

@@ is the SSMIS satellite number (i.e. 16, 17, 18, 19)

yyyy is the long year, mm is month, dd is day of month

tttt is hour and minute of UTC day (24 hour clock), start time and end time

is the orbit number (i.e., 00001 to 99999), also referred to as the granule number.

By definition, an SSMIS orbit begins at the southernmost latitude near the South Pole at the point where the z-component (i.e., north-south) of the spacecraft velocity vector changes from a negative value to a positive value. This convention of V7 brings uniformity to all RSS SSM/I, SSMIS, WindSat, and AMSR-E data.

Each orbital file contains 5% redundant data at both the beginning and end of each orbit. For example, the file for orbit 10000 contains scans starting with orbit position 9999.95 and ending with orbit position 10001.05. The data at the end of orbit file 10000 are then given again in orbit file 10001. This 5% overlap of the orbit files facilitates user requirements that involve scan averaging.

Each file contains a different number of scan lines. A typical file will contain a maximum of about 3800 scan records. All channels are taken at every scan. Twice as many 92 GHz measurements are taken for every scan line than for the lower resolution channels. The total number of observations taken during the Earth-viewing portion of the scan is 180 for the 92 GHz channel and 90 for the lower channels (19 to 37 GHz). Thus the arrays of 92 GHz observations are 180 by the number of scan lines, and the arrays for the lower-frequency observations are 90 by number of scan lines. We refer to the 92 GHz grid as hi-res, and the lower-frequency grid as lo-res.

3. SUMMARY OF DATA FIELDS

Each netCDF SSMIS brightness temperature file contains the following scalars, vectors, and arrays.
Dimension definitions:
scan_number = varies by orbit, should be less than 3800 for any one orbit file
footprint_number_hires = 180
footprint_number_lores = 90
eleven_flags = 11
four_flags = 4

Scalar variable:

Name	Long Name / Description	Units	_Fill Value	Valid Range	Type
iorbit	integer orbit number	n/a	0	1 to 100000	Integer4

Variable arrays that do not depend on scan position

Name	Description	Units	_Fill Value	Valid Range (when scaled)	Type	Scale Factor
scan_time(scan_number)	Scan start time UTC for scans in a referenced or elapsed time format	seconds since 2000-01-01 00:00:00	-1.0E30	-1.0E9 to 1.0E9	Double	n/a
orbit_position (scan_number)	Orbit number with position in orbit in fraction (eg. 999.95)	n/a	0.0	1.0 to 100000.0	Double	n/a
sc_lat(scan_number)	Spacecraft nadir geodetic latitude	degrees North	-500.0	-90.0 to 90.0	Float	n/a
sc_lon(scan_number)	Spacecraft nadir east longitude	degrees East	-500.0	0.0 to 360.0	Float	n/a
sc_alt(scan_number)	Spacecraft nadir altitude	meters	-500.0	400000.0 to 1200000.0	Float	n/a
iscn_flag(scan_number,eleven_flags)	Scan quality flag (**Note 1**)	n/a	0	0=QC_not_fail 1=QC fail	Byte	n/a
ical_flag_hires(scan_number,four_flags)	Calibration quality flag for hi-res scans (**Note 2**)	n/a	0	0 or 1	Byte	n.a
ical_flag_lores(scan_number,four_flags)	Calibration quality flag for lo-res scans (**Note 2**)	n/a	0	0 or 1	Byte	n.a

Variable arrays that depend on the 90 scan positions for the lower channels (19-37 GHz)

Name	Description	Units	_Fill Value	Valid Range (when scaled)	Type	Scale Factor
Latitude_lores(footprint_number_lores,scan_number)	Geodetic latitude for lo-res channels	degrees North	30000	-90.0 to 90.0	Integer2	0.01
Longitude_lores(footprint_number_lores,scan_number)	Geodetic longitude for lo-res channels	degrees East	30000	-180. to 180.	Integer2	0.01
Earth_incidence_angle_lores(footprint_number_lores,scan_number)	Observation earth incidence angle for lo-res footprint	degrees	30000	50.0 to 58.0	Integer2	0.002
Earth_azimuth_angle_lores(footprint_number_lores,scan_number)	Observation earth azimuth angle for lo-res footprint (clockwise from North)	degrees	30000	-180. to 180.	Integer2	0.01
Sun_glitter_angle_lores(footprint_number_lores,scan_number)	Observation sun glint angle for lo-res footprint (**Note 3**)	degrees	30000	0. to 180.	Integer2	0.01
Land_flag_lores(footprint_number_lores,scan_number)	Observation land flag for lo-res footprint	n/a	-1B	0=no land 1=some land 2=land	Byte	n/a
Ice_flag_lores(footprint,number_lores,scan_number)	Observation sea ice flag (**Note 4**)	n/a	255	0=no ice 1=ice possible	Integer2	n/a
FCDR_brightness_temperature_19v(footprint_number_lores,scan_number)	19.35GHz V-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a
FCDR_brightness_temperature_19h(footprint_number_lores,scan_number)	19.35GHz H-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a
FCDR_brightness_temperature_22v(footprint_number_lores,scan_number)	22.235GHz V-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a
FCDR_brightness_temperature_37v(footprint_number_lores,scan_number)	37.0GHz V-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a
FCDR_brightness_temperature_37h(footprint_number_lores,scan_number)	37.0GHz H-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a

Arrays that depend on the 180 scan positions for the higher channels (91.7 GHz):

Name	Description	Units	_Fill Value	Valid Range (when scaled)	Type	Scale Factor
Longitude_hires(footprint_number_hires,scan_number)	Geodetic longitude for hi-res channel footprints	degrees East	30000	-180. to 180.	Integer2	0.01
Latitude_hires(footprint_number_hires,scan_number)	Geodetic latitude for hi-res channel footprints	degrees North	30000	-90.0 to 90.0	Integer2	0.01
Earth_incidence_angle_hires(footprint_number_hires,scan_number)	Observation earth incidence angle for hi-res footprints	degrees	30000	50 to 58	Integer2	0.002
Earth_azimuth_angle_hires(footprint_number_hires,scan_number)	Observation earth azimuth angle for hi-res footprints (clockwise from North)	degrees	30000	-180. to 180.	Interger2	0.01
Sun_glitter_angle_hires(footprint_number_hires,scan_number)	Observation sun glint angle for hi-res footprints (**Note 3**)	degrees	30000	0. to 180.	Integer2	0.01
Land_flag_hires(footprint_number_hires,scan_number)	Observation land flag	n/a	-1B	0=no land 1=some land 2=land	Byte	n/a
Ice_flag_hires(footprint,number_hires,scan_number)	Observation sea ice flag (**Note 4**)	n/a	255	0=no ice 1=ice possible	Integer2	n/a
FCDR_brightness_temperature_92V(footprint_number_hires,scan_number)	91.7 GHz V-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a
FCDR_brightness_temperature_92H(footprint_number_hires,scan_number)	91.7 GHz H-pol T_B	kelvin	-100.0	50.0 to 350.0	Float	n/a

Note 1. Scan Flags:

The iscn_flag variable indicates the quality of the scan. If the flags are set equal to 1, there is a problem and we advise users to skip the scan. Be sure the sum of all flags is zero. The individual flags have the following meanings (*see errata and fixes #4 at end of document for issues in R00 files, fixed in R01*):

Flag 1: not used
Flag 2: The scan is missing or there is no time value for the scan.
Flag 3: The thermistor mux index is out of bounds.
Flag 4: The time for the ephemeris data is out of bounds.
Flag 5: There is insufficient information to compute the spacecraft position.
Flag 6: The location of the ephemeris is out of bounds.
Flag 7: The ephemeris times are more than 90 sec from the scan time.
Flag 8: The ephemeris times are not bracketing the scan time.
Flag 9: The ephemeris times are too close in time.
Flag 10: There are inconsistent ephemeris times versus location.
Flag 11: The hot load thermistor values are out of bounds.

Note 2. T_B Quality Flags:

The ical_flag_lores and ical_flag_hires quality flags indicate the quality of the brightness temperatures for the lower channels (19 – 37 GHz) and higher channels (92 GHz) respectively. We advise the user to exclude all scans for which any of the 4 flags are set to 1. The definition of each flag is as follows:

Flag 1: The scan position index is out of sync (this has not yet happened).
Flag 2: The reverse engineered counts are not integers (extremely rare).
Flag 3: There is an anomalous jump in the counts.
Flag 4: The removal of the moon contamination in the cold mirror was not possible.

Note 3. Sun Glint:

The sun-glitter angle is defined as the angle between two vectors **a** and **b**. Vector **a** is the vector going from the Earth SSMIS footprint to the sensor antenna. Vector **b** is the vector pointing in the direction of sunlight reflected off the Earth surface at the location of the SSMIS footprint, assuming that the earth surface is a specular reflector. Low sun-glitter angles mean that reflected sunlight is being received by the SSMIS sensor.

Note 4. Sea Ice Flag:

The ice flag is based on a monthly climatology. A value of ice_flag=0 means that we have never seen sea ice at that location and month since the first SSM/I was launched in 1987. Hence, it is extremely unlikely that the footprint will contain ice. The one exception to this is icebergs, which may pass through grid cells located off the east coast of Argentina, yielding an ice_flag=0 during passage.

4. MISSING T_B VALUES

A T_B value of -100.0 indicates no T_B value is available to the User. The fill value of -100.0 T_B occurs when the following events occur: 1) if scan flags or quality flags indicate a problem, or 2) if the calibration counts or the Earth counts are out of bounds.

<u>Depending on your software capabilities, you may or may not need to check if T_B = -100.0 to exclude these missing values.</u>

5. QUALITY FLAG VALUES AND SUGGESTED FILTERING

For a given observation cell, look at the T_B values required for your particular application. If any of these T_B values is -100.0, skip the cell. Also if your application requires the low frequency channels (19-37 GHz) and any of the ical_flags_lores are = 1, skip the cell. Likewise, if your application requires the high frequency channels (92 GHz) and any of the ical_flags_hires are =1, skip the cell.

6. DATA USE CITATION

Please acknowledge use of these data in your publications. Development of this type of data set has taken many years and much effort on the part of the scientists involved. These scientists rely on the fair use and proper acknowledgment of the CDR to sustain their professional reputations and careers. Please use the suggestions below:

Acknowledgement Request: The SSMIS CDR used in this study was acquired from NOAA's National Climatic Data Center (http://www.ncdc.noaa.gov). This CDR was developed by Frank Wentz and colleagues for the NOAA CDR Program.

Citation Request: Hilburn, K.A., and F.J. Wentz, 2008: Intercalibrated Passive Microwave Rain Products from the Unified Microwave Ocean Retrieval Algorithm (UMORA). Journal of Applied Meteorology and Climatology, 47, 778–794.

NOAA's CDR Program and/or its official distribution partners provide sustained open access to released CDR packages and related information. To ensure use of official products and access to the latest codes, data sets and usage information (e.g., known issues), users agree to not redistribute the CDR, in whole or in part, to others.

7. REFERENCES

There are differences between the SSMIS and SSM/I netCDF files from RSS. Many users make use of both files to construct longer time series of data. Please be sure to read the SSM/I and the SSMIS documents if this is the case. The SSM/I netCDF documentation describes the RSS SSM/I Version-7 Brightness Temperature Data Set netCDF file format.

In addition, the SSMI Version 7 Calibration.Report, January 10, 2012 provides important background on how the SSM/I radiometer data are processed from instrument measurements to brightness temperatures at RSS. This document is very applicable to how SSMIS data are calibrated.

These and other documents are available from Remote Sensing Systems. This document you are reading is primarily intended to describe the format of the RSS V7 netCDF SSMIS files available from the NOAA CDR program.

8. netCDF GLOBAL FILE ATTRIBUTES

Below is an example of global file attributes for one SSMIS netCDF file.

```
// global attributes:

:Conventions = "CF-1.6";
:Metadata_Conventions = "CF-1.6, Unidata Dataset Discovery v1.0, NOAA CDR v1.0, GDS v2.0";
:standard_name_vocabulary = "CF Standard Name Table (v16, 11 October 2010)";
:id = "RSS_SSMIS_FCDR_V07R01_F17_D20130401_S0553_E0745_R33050.nc";
:naming_authority = "gov.noaa.ncdc";
:metadata_link = "gov.noaa.ncdc:C00810";
:title = "RSS Version-7 SSMIS FCDR";
:product_version = "v07r01";
:date_issued = "2012-12-31";
:summary = "Remote Sensing Systems (RSS) Version-7 Special Sensor Microwave Imager Sounder
        (SSMIS) Fundamental Climate Data Record (FCDR); intercalibrated and homogenized brightness
        temperature polar-orbiting product with quality flags starting from January 2007";
:keywords = "EARTH SCIENCE > SPECTRAL/ENGINEERING > MICROWAVE > BRIGHTNESS
        TEMPERATURE";
```

:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Earth Science Keywords, Version 6.0";
:platform = "DMSP 5D-2/F17 > Defense Meteorological Satellite Program-F17";
:sensor = "SSMIS > Special Sensor Microwave Imager Sounder";
:cdm_data_type = "Swath";
:cdr_program = "Climate Data Record Program for satellites, FY 2011";
:cdr_variable="fcdr_brightness_temperature_19V,fcdr_brightness_temperature_19H, fcdr_brightness_temperature_22V,fcdr_brightness_temperature_37V, fcdr_brightness_temperature_37H,fcdr_brightness_temperature_92V, fcdr_brightness_temperature_92H";
:source = "F17_r33050.dat";
:date_created = "20140721T152818Z";
:creator_name = "Carl Mears";
:creator_url = "http://www.remss.com/";
:creator_email = "mears@remss.com";
:institution = "Remote Sensing Systems";
:processing_level = "NOAA Level 2";
:references = "doi:10.1175/2007JAMC1635.1, doi:10.1126/science.1140746, SSM/I Users Interpretation Guide UG32268-900 Rev C 29 Nov 2000";
:history = "1) 2011-09-30, Carl Mears, Remote Sensing Systems, created initial netCDF file converted from the original RSS data format";
:geospatial_lat_min = -89.25f; // float
:geospatial_lat_max = 89.02f; // float
:geospatial_lon_min = -180.0f; // float
:geospatial_lon_max = 179.98999f; // float
:geospatial_lat_units = "degrees_north";
:geospatial_lon_units = "degrees_east";
:spatial_resolution = "19 V/H GHz: 46.5km X 73.6km, 22 V GHz: 46.5km X 73.6km, 37 V/H GHz: 31.2km X 45.0km, 92 V/H GHz: 13.2km X 15.5km";
:time_coverage_start = "2013-04-01 05:53:42Z";
:time_coverage_end = "2013-04-01 07:45:47Z";
:time_coverage_duration = "PT6725S";
:license = "No restrictions on access or use";
:contributor_name = "Frank Wentz, Carl Mears";
:contributor_role = "Principal investigator and originator of input/source or antenna temperature data, Processor and author of entire driver routine (write_ssmi_tbs_netcdf.pro) which converts RSS native brightness temperature format to netCDF-4.";

9. Known Problems/Errata and Fixes/Changes in RSS SSMIS V7 netCDF Data Set

The RSS SSMIS V7 netCDF data set files are produced using an IDL program to translate the RSS V7 binary format L1B brightness temperature data files available from RSS into netCDF format.

Some problems were identified in V07 Release 00 that have been fixed in Release 01:

Version 7, Release00 -> Release01

1. The variable scan_time_hires is misnamed. It should be called scan_time. The SSMIS instrument makes a measurement for all channels at every scan. For this reason, the variable should be scan_time as it represents both low and high resolution channels. The dimension of the variable (a number less than 3800 that varies by orbit) is correct.

   Users who also use the RSS SSM/I V7R00 netCDF data will notice the differences between these two data sets that are related to the operational differences between the two instruments. SSMIS measures all channels every scan, while SSM/I measures both high and low resolution channels on scan A and only the high resolution channels on scan B. Therefore, the SSM/I T_B netCDF file contains both a scan_time_hires variable and a scan_time_lores variable. The table in this document has been updated to list the new name, scan_time, as given in the V07R01 netcdf files. Only one set of scan time values are needed for SSMIS.

2. The scan_time values in the V07R00 files are seconds since Jan 1 2000, 0Z These values were obtained from an integer second variable in the original RSS binary TB files, so even though the scan_time in this file is stored as a double float, the resolution of the time is to the full second. At the request of some users, we have changed this for the V07R01 files. scan_time values are now obtained from the 24 character time value in the RSS binary files which contains fractional seconds as opposed to integer seconds. These fractional seconds are stored in a double float variable.
3. The ice_flag_hires variable is mistakenly a byte type in the V07R00 file. It should be integer2. This was changed in the V07R01 files. This change makes ice_flag_hires the same data type as ice_flag_lores and the ice flag variables in the SSM/I netcdf V07R00 files.
4. The time variable in V07R00 has fill values of 0.0. This is different from SSM/I V07R00 files. We have changed the fill value to -1E30 in SSMIS V07R01 files to bring consistency between the SSMIS and SSM/I files.
5. In the SSMIS V07R00 files there are numerous instances where the data values were set to missing without any corresponding scan flags being set. We have located these instances and changed the scan flags in the V07R01 files to indicate missing data.