SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 6

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Piepmeier, J. R., P. Mohammed, J. Peng, E. J. Kim, G. De Amici, J. Chaubell, and C. Ruf. 2023. *SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 6*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/GWYQTF307Y9Y. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL1BTB

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

The SMAP L-Band Radiometer measures antenna temperatures referenced to the instrument feedhorn before and after mitigation of Radio Frequency Interference (RFI). SMAP antenna temperatures are then used to calculate the four Stokes parameters: TV, TH, T3, and T4 at 1.41 GHz. These parameters represent the vertically and horizontally polarized brightness temperatures (TBs), and the third and fourth cross-polarized brightness temperatures, respectively. The cross-polarized T3-channel measurement can be used to correct for possible Faraday rotation caused by charged particles in the upper atmosphere.

Refer to the Appendix of this document for details on all parameters.

1.2 File Information

1.2.1 Format

Data are in HDF5 format. For software and more information, including an HDF5 tutorial, visit the HDF Group's HDF5 website.

1.2.2 File Contents

As shown in Figure 1, each HDF5 file is organized into the following main groups, which contain additional groups and/or data sets:

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-1B brightness temperature product, refer to the Appendix.

1.2.3 Data Fields

Each file contains the main data groups summarized in this section. For a complete list and description of all data fields within these groups, refer to the Appendix of this document. Note that data array dimensions and sizes vary for this product.

Brightness Temperature

Includes brightness temperatures at each footprint referenced to the surface of the Earth with error sources and undesirable radiometric sources removed, such as atmospheric effects and solar, lunar, and galactic emissions. A second set of further corrected brightness temperatures are also provided, such as *tb_h_surface_corrected* (as opposed to *tb_h).* For these brightness temperatures, an additional correction procedure has been applied to correct anomalous water and land values; see the "Water/Land Contamination Correction" section for details.

This group also includes antenna temperatures (TAs) referenced to the feedhorn before and after RFI mitigation, error source values, brightness temperature error, and Noise Equivalent Delta Temperature (NEDT). Many parameters are specifically designated for horizontal and vertical polarizations as well as the 3rd and 4th Stokes parameters.

Calibration Data

Includes fullband and subband calibration coefficients. Among these coefficients are instrument component losses, noise temperatures, physical temperatures, calibration gain and offset factors and phase values. The contents were corrected for detected RFI.

High Resolution Calibration Data

Includes subband calibration coefficients. Among these coefficients are instrument component losses, noise temperatures, physical temperatures, calibration gain and offset factors and phase values. The contents were corrected for detected RFI.

Spacecraft Data

Includes elements that specify either geometric or geographic information that are representative of each entire antenna scan of the instrument swath. Major elements include the spacecraft time, position, velocity, and attitude. Values in the spacecraft data group are representative of all brightness temperatures acquired during the corresponding antenna scan.

1.2.4 Metadata Fields

Includes all metadata that describe the full content of each file. For a description of all metadata fields for this product, refer to the Product Specification Document (Mohammed-Tano, 2016).

1.2.5 File Naming Convention

Files are named according to the following convention:

```
SMAP_L1B_TB_[Orbit#]_[A/D]_yyyymmddThhmmss_RLVvvv_NNN.[ext]
```

For example:

```
SMAP_L1B_TB_03891_D_20151024T155359_R13242_001.h5
```

Table 1 describes the variables within a file name:

Table 1. File Naming Convention

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>SMAP</td><td>Indicates SMAP mission data</td></tr>
<tr><td>L1B_TB</td><td>Indicates specific product (L1B: Level-1B; TB: Brightness Temperature)</td></tr>
<tr><td>[Orbit#]</td><td>5-digit sequential number of the orbit flown by the SMAP spacecraft when data were acquired. Orbit 00000 began at launch. Orbit numbers increment each time the spacecraft flies over the southernmost point in the orbit path.</td></tr>
<tr><td>[A/D]</td><td>Half-orbit pass of the satellite, such as:
A: Ascending (where satellite moves from South to North, and 6:00 p.m. is the local solar time)
D: Descending (where satellite moves from North to South, and 6:00 a.m. is the local solar time)</td></tr>
<tr><td>yyyymmddThhmmss</td><td>Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where:<table><tr><td>yyyymmdd</td><td>4-digit year, 2-digit month, 2-digit day</td></tr><tr><td>T</td><td>Time (delineates the date from the time, i.e. yyyymmddThhmmss)</td></tr><tr><td>hhmmss</td><td>2-digit hour, 2-digit minute, 2-digit second</td></tr></table></td></tr>
<tr><td>RLVvvv</td><td>Composite Release ID, where:<table><tr><td>R</td><td>Release</td></tr><tr><td>L</td><td>Launch Indicator (1: post-launch standard data)</td></tr><tr><td>V</td><td>1-Digit CRID Major Version Number (Note: the data set's major version does not necessarily coincide with the CRID major version)</td></tr><tr><td>vvv</td><td>3-Digit CRID Minor Version Number</td></tr></table>Example: R13242 indicates a post-launch data product with a version of 3.242.</td></tr>
<tr><td>NNN</td><td>Number of times the file was generated under the same version for a particular date/time interval (002: 2nd time)</td></tr>
<tr><td>.[ext]</td><td>File extensions include:<table><tr><td>.h5</td><td>HDF5 data file</td></tr><tr><td>.qa</td><td>Quality Assurance file</td></tr><tr><td>.xml</td><td>XML Metadata file</td></tr></table></td></tr>
</table>

1.3 Spatial Information

1.3.1 Coverage

Coverage spans from 180°W to 180°E, and from approximately 86.4°N to 86.4°S. The swath width is 1000 km, enabling nearly global coverage every two to three days. Figure 2 shows the spatial coverage of the SMAP L-Band Radiometer for one descending half orbit, which comprises one file of this data set.

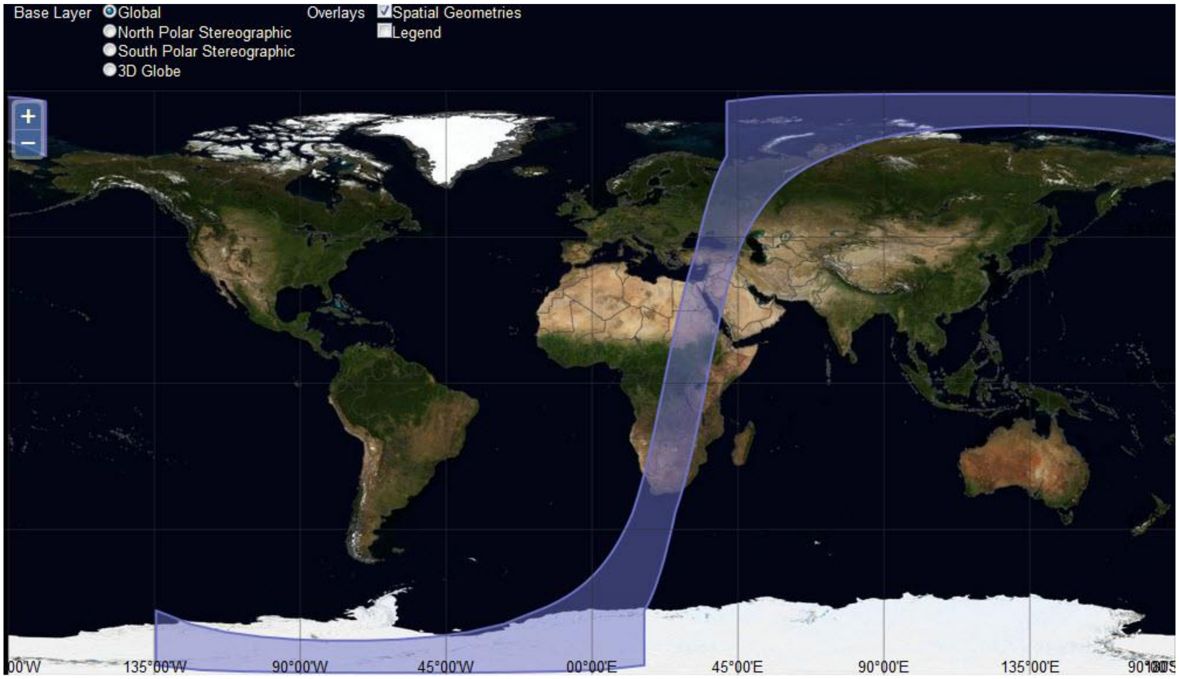

Figure 2. Spatial coverage map displaying one descending half orbit of the SMAP L-Band Radiometer.

1.3.2 Resolution

The instantaneous field of view of the radiometer footprint is approximately 36 x 47 km; the effective field of view of brightness temperatures in the Level-1B brightness temperature product is 39 x 47 km. The native spatial resolution of the radiometer footprint is approximately 36 km.

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 31 March 2015 to present.

1.4.2 Satellite and Processing Events

Due to instrument maneuvers, data downlink anomalies, data quality screening, and other factors, small gaps in the SMAP time series will occur. Details of these events are maintained on two master lists:

SMAP On-Orbit Events List for Instrument Data Users
Master List of Bad and Missing Data

Significant gaps in coverage occurred between 19 June and 23 July 2019 and between 6 August and 20 September 2022 after the SMAP satellite went into Safe Mode. A brief description of the event and its impact on data quality is available in the SMAP Post-Recovery Notice.

1.4.3 Latencies

FAQ: What are the latencies for SMAP radiometer data sets?

1.4.4 Resolution

Each Level-1B half-orbit file spans approximately 49 minutes. The SMAP orbit yields a 2-3 day average revisit frequency and repeats the exact swath every 8 days.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The objective of the Level-1B brightness temperature algorithm is to convert digital counts in the instrument telemetry into time-ordered, geolocated brightness temperatures within the main beam referenced to the Earth's surface. The algorithm theory is similar to what has been developed and implemented for decades for other satellite radiometers. SMAP includes two key features heretofore absent from satellite-borne radiometers: RFI detection and mitigation, and measurement of the third and fourth Stokes parameters using digital correlation.

This section contains a description of the sources contributing to the total apparent temperature seen at the input to the SMAP main reflector. The brightness temperature of a source (measured in kelvins) can be described in terms of the product of the physical temperature and the emissivity of the source. Emissivity is, in general, polarization dependent, thus differentiating brightness temperature into TBV and TBH for the vertical and horizontal polarizations, respectively. These are the first two modified Stokes parameters. The real part of the complex correlation between these two components is measured by the third modified Stokes parameter, represented in brightness temperatures as T3. The fourth Stokes parameter, T4, measures the imaginary part of the correlation. For this document, a vector of modified Stokes parameters is shown by:

$$\bar{T}_B(\theta,\phi) = \begin{bmatrix} T_v \\ T_h \\ T_3 \\ T_4 \end{bmatrix} \qquad \text{(Equation 1)}$$

where θ and Φ are the elevation and azimuth of a spherical coordinate system centered on the radiometer antenna boresight vector. Important sources of radiation at L-band are the Earth's land and sea, the cosmic background radiation, the sun, radiation sources outside our solar system, and the moon.

For an in-depth description of the theory of these measurements, refer to Section 4 of the Algorithm Theoretical Baseline Document (ATBD) for this data set (Piepmeier et al., 2021).

2.2 Instrumentation

For a detailed description of the SMAP instrument, visit the SMAP Instrument page at Jet Propulsion Laboratory (JPL) SMAP website.

2.3 Acquisition

SMAP Level-1B radiometer brightness temperatures are processed from SMAP L1A Radiometer Time-Ordered Parsed Telemetry (SPL1AP). The Level-1A radiometer product contains parsed radiometer instrument telemetry.

2.4 Derivation Techniques and Algorithms

The raw radiometer instrument counts are converted to antenna temperatures and then to brightness temperatures to produce SMAP Level-1A and Level-1B products. The input data to the Level-1B brightness temperature algorithm are the SMAP L1A Radiometer Time-Ordered Parsed Telemetry data. The Level-1A Science Processing Software produces the Level-1A product in accordance with the Earth Observing System (EOS) Data Product Levels definition, which states that Level-1A data products are reconstructed, unprocessed instrument data at full resolution, are time-referenced and annotated with ancillary information.

The Level-1B radiometer brightness temperature Science Processing Software geolocates and radiometrically calibrates the Level-1A data to obtain antenna temperatures. Subsequent processing applies algorithms that detect and flag pixels for RFI. The data are then time and frequency averaged near the antenna's angular Nyquist rate. The Level-1B algorithm also compensates for sources of error or sources of radiometric energy not associated with emissivity of the Earth's surface. Those sources include Faraday rotation, energy detected by antenna sidelobes and spillover, atmospheric effects, solar radiation, lunar radiation, cosmic microwave background, galactic emission, and water/land contamination.

2.4.1 Geolocation and Antenna Point Error Detection (ASA Error)

SMAP L1B geolocation data containing the location and the altitude of the spacecraft and the antenna spin are computed from NASA SPICE kernel files. Errors in the SPICE kernels cause a ripple effect in SMAP L1B data leading to three types of antennae scan angle (ASA) errors. Described in detail in the ATBD (2021) they can be summarized briefly as:

- Type 1: an error in a single data file significantly outside the nomial range,
- Type 2: an error in multiple and continuous scans in one half orbit shifting the ASA curve a few degrees from its nominal shape, and
- Type 3: an error in multiple continuous scans with varied values between 0° and 360°.

The following image provides additional insight.

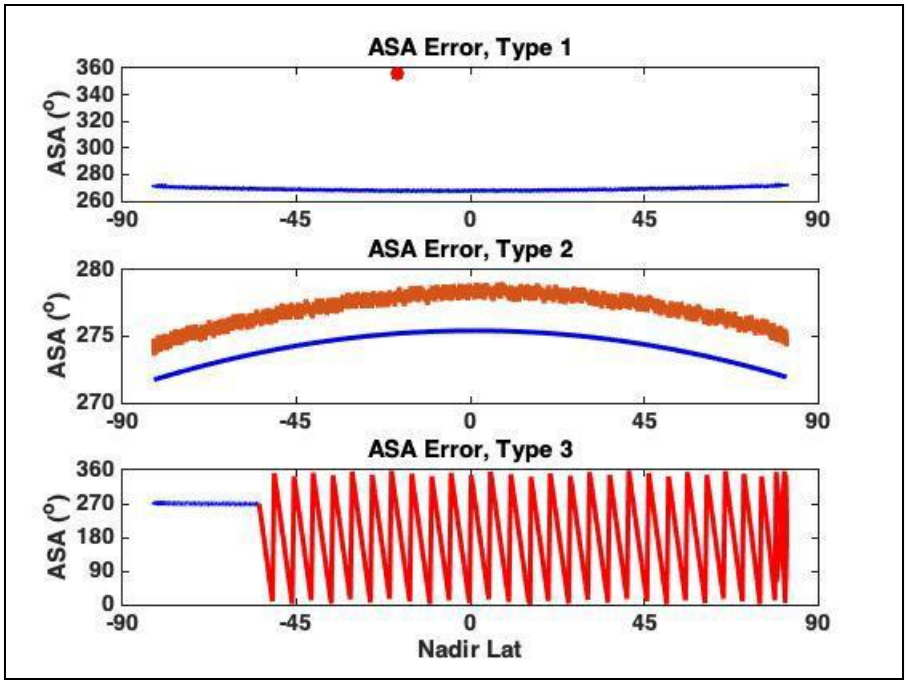

Figure 3. ASA error types. Problematic values are in red and nominal values are in blue. (Top Panel) Type 1: Error in one scan in a half orbit; (Middle Panel) Type 2: Error in multiple scans in a half orbit. ASA values are shifted a few degrees from their nominal values. (Bottom Panel) Type 3: The ASA value is varied between [0, 360] degrees.

2.4.2 Water/Land Contamination Correction

To mitigate water and land contamination, the Level-1B algorithm includes a surface correction procedure for the brightness temperature contribution due to water (when the antenna boresight falls on a land location) or land (when the antenna boresight falls on a water location). Both the horizontally and vertically polarized L1B brightness temperatures are corrected for the presence of water or the presence of land within the antenna field of view (FOV). Over land, the resulting brightness temperatures will become warmer upon the removal of the contribution of water to the original uncorrected observations. Over water, the resulting brightness temperatures will become cooler upon the removal of the contribution of land to the original uncorrected observations.

For example, the total measured temperature can be separated into two contributions:

$$TB_p = (1 - f) * TB_p^{land} + f * TB_p^{water} \quad \text{(Equation 2)}$$

If the footprint in on the land, the following formula is applied:

$$TB_p^{land} = \frac{TB_p - f * \overline{TB}_p^{water}}{1-f} \quad \text{(Equation 3)}$$

If the footprint is on water, the following formula is applied:

$$TB_p^{water} = \frac{TB_p - (1-f) * \overline{TB}_p^{land}}{f} \quad \text{(Equation 4)}$$

Where f is the water fraction, $f = 1$ for pure water, and $f = 0$ for pure land.

$$f = \int G.Md\Omega = \int_{\theta=[0,\pi],\psi=[0,2\pi]} G(\theta,\psi)\, M(\theta,\psi) \sin\theta \, d\theta d\psi \cong$$

$$\int_{\theta=[0,10*\pi/180],\psi=[0,2\pi]} G(\theta,\psi)\, M \sin\theta \, d\theta d\psi \quad \text{(Equation 5)}$$

These water/land contamination corrections are performed when the following criteria are met:

- If footprint boresight is over land as indicated by a static high-resolution land/water mask, then water contamination correction is performed
- If footprint boresight is over water as indicated by a static high-resolution land/water mask, then land contamination correction is performed
- Over land, water contamination correction is performed if antenna-gain-weighted water fraction </=0.9
- Over water, land contamination correction is performed if antenna-gain-weighted water fraction > 0.1
- Correction is performed only if sea ice fraction=0
- Valid range for TB V polarization [50K: 310K]; values outside this range are replaced with fill values
- Valid range for TB H polarization [30K: 310K]; values outside this range are replaced with fill values
- Over land, if *tb_surface_corrected* < TB, then value is replaced with fill value
- Over water, if *tb_surface_corrected* > TB, then value is replaced with fill value

For more details regarding the algorithm used to generate this product, refer to the latest ATBD, Piepmeier et al. (2021).

2.5 Processing

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate this product, the processing software ingests both descending and ascending half-orbit files of the Level-1A brightness temperature data. The descending half orbits contain data acquired at very nearly 6:00 a.m. local solar time. The ascending half orbits contain data acquired at very nearly 6:00 p.m. local solar time.

The radiometer uses various targets to calibrate its measurement. The targets include the external targets (the Cold Sky, the global ocean – or part of the ocean –, the Amazonian rainforest, among others) and internal sources (reference load, noise diode, etc). The brightness temperatures of the targets are modeled. Some of them are well-modeled and some of them might need further investigation. In general, at least two targets are chosen. One has smaller TB and is treated as the Cold Target, while the other has larger TB and is treated as the Hot Target. In Version 5 and subsequent versions of this data set, the Hot Target is now the reference load (i.e., an internal source), as opposed to the global ocean (external) that was used in previous versions (for more details on the calibration methods and the impacts of this change on globally averaged TBs, see the latest Assessment Report (Peng et al., 2020) and Peng et al. (2019).

The total number of radiometer science packets per antenna scan varies depending on the antenna rotation rate and integration time of the instrument. The resulting number of antenna footprints per scan is therefore variable. To preserve the shape of stored data elements, the size of certain dimensions is assigned a maximum value. Thus, fill values appear in the SMAP Level-1B brightness temperature product when a particular scan does not contain the maximum possible number of footprints.

Antenna temperatures are processed by RFI detection and mitigation algorithms (see Section 2.6.1) where the pixels for a footprint that are flagged for RFI are removed and the remaining clean pixels are averaged to form an RFI-free antenna footprint. If all pixels for a particular footprint are flagged for RFI then the footprint antenna temperature is assigned the null value. The corresponding footprint brightness temperature (TB) value will also be assigned the null value since the RFI-free antenna footprint antenna temperatures are used to produce the time-ordered brightness temperature product. Subsequently, after pixels with RFI are flagged and dropped, the remaining clean pixels are used to compute the NEDT for that footprint. If all pixels are removed, the null value is assigned to the NEDT for that footprint. For more details, refer to Section C. RFI Detection and Mitigation (p. 33) of the SMAP Handbook.

Lastly, additional corrections are applied to brightness temperatures to correct for anomalous data values as a result of water/land contamination (described in the previous section).

2.6 Quality, Errors, and Limitations

2.6.1 Error Sources

L-Band anthropogenic Radio Frequency Interference (RFI), especially from ground-based surveillance radars, can contaminate radiometer measurements. Early measurements and results from the European Space Agency Soil Moisture and Ocean Salinity (SMOS) mission indicate that, in some regions, RFI is present and detectable. The SMAP radiometer electronics and algorithms have been designed to include features to mitigate the effects of RFI. The SMAP radiometer implements a combination of time and frequency diversity, kurtosis detection, and the use of 3rd and 4th Stokes parameter thresholds to detect and where possible mitigate RFI (Piepmeier et al., 2021, Bringer et al., 2017, Piepmeier et al., 2014). Data elements associated with subbands are included in the Level-1B radiometer product to track and enable RFI detection and mitigation. Further corrections are applied to mitigate water/land contamination.

The input Level-1A radiometer data can also contain bit errors caused by noise in communication links and memory storage devices. The packets produced by the Consultative Committee on Space Data Systems (CCSDS) include error-detecting Cyclic Redundancy Checks (CRCs), which the Level-1A processor uses to flag errors.

2.6.2 Quality Assessment

For in-depth details regarding the quality of these data, refer to the Assessment Report (Peng et al., 2020).

2.6.3 Quality Overview

SMAP data sets provide multiple means to assess quality. Each data set contains bit flags, uncertainty measures, and file-level metadata that provide quality information. The Appendix of this document and the Product Specification Document (Mohammed-Tano, 2016) describe the specific bit flags, uncertainty measures, and file-level metadata contained in this data set.

Each SMAP HDF5 data file contains metadata with Quality Assessment (QA) metadata flags. These QA metadata flags are calculated and set by the SDS at JPL prior to delivery to the National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). A separate, ISO 19115-compliant metadata file with an `.xml` file extension is also delivered to NSIDC DAAC with the HDF5 data file; it contains the same information as the file-level metadata.

A separate QA file with a `.qa` file extension is also associated with each data file. QA files are ASCII text files that contain statistical information in order to help users better assess the quality of the associated data file.

In addition, various levels of QA are conducted with Level-1B data. If a file passes QA, the SDS applies that file for higher-level processing, browse generation, active science QA, and data archive and distribution. If a product fails QA, it is never delivered to NSIDC DAAC.

3 SOFTWARE AND TOOLS

For tools that work with SMAP data, refer to the Tools web page.

4 VERSION HISTORY

Table 2. Version History Summary

Version	Release Date	Description of Changes
V1	July 2015	First public data release
V2	October 2015	No science change. CRID incremented to coincide with DOI correction for SPL2SMP and SPL3SMP.
V3	April 2016	Changes to this version include: • Updated reflector thermal model • Reflector emissivity value back to baseline • All calibration coefficients updated back to 3/31/15 • Direct Galaxy quality flag changed: set when s/c nadir > 5 degrees • Reflected Sun quality flag changed: set when specular solar theta <15 degrees • Sea ice fraction computation implemented
V4	June 2018	Changes to this version include: • Added procedure to correct brightness temperatures for water/land contamination near coastlines. New data fields for this correction include: *footprint_surface_status*, *surface_water_fraction_mb_h*, *surface_water_fraction_mb_v*, *tb_h_surface_corrected*, and *tb_v_surface_corrected*. • Improved Level-1 calibration coefficients and reflected galaxy correction. To refine reflected galaxy correction over ocean, NOAA NCEP ocean roughness data have been added (*wind_direction_ancillary*, *wind_speed_ancillary*).

V5	August 2020	Changes to this version include:
		• An improved calibration methodology was applied to Level-1 brightness temperatures, which uses:
		    ○ the internal instrument reference load (instead of the global ocean as in V4) and deep space measurements during monthly cold sky maneuvers and special cold sky maneuvers with stable open-ocean background to concurrently retrieve all calibration parameters
		    ○ a longer temporal baseline of cold sky records.

Version	Release Date	Description of Changes

V6	December 2023	Changes to this version include:
		• A new 1-km land-water mask based on the MODIS44w V6 data is used to determine land-water Tb corrections. The mask:
		  ○ more accurately portrays current coastal and inland water body boundaries
		  ○ adds an ice shelf type to determine an ice shelf fraction for a given footprint or grid cell, reflected in new data elements *ice_shelf_fraction_h* and *ice_shelf_fraction_v*
		• The maximum Tb threshold has been reduced from 340K to 310K to further remove RFI contamination

5 RELATED DATA SETS

SMAP Data at NSIDC | Overview

SMAP Radar Data at the ASF DAAC

6 RELATED WEBSITES

SMAP at NASA JPL

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Bringer, A., J. T. Johnson, P. N. Mohammed, J. R. Piepmeier, 2017. Performance of SMAP radiometer RFI detection algorithms and analysis of residual RFI sources. *In Geoscience and Remote Sensing Symposium (IGARSS)*, *2017 IEEE International,* 1243-1246.

Mohammed-Tano. 2016. SMAP Level 1B_TB Product Specification Document. Revision B. JPL D-92339, Jet Propulsion Laboratory, Pasadena, CA.(see PDF).

Peng, J., Misra, S., Piepmeier, J. R., Dinnat, E. P., Yueh, S. H., Meissner, T., Le Vine, D. M., Shelton, K. E., Freedman, A. P., Dunbar, R. S., Chan, S. K., Bindlish, R., De Amici, G., Mohammed, P. N., Hong, L., Hudson, D., & Jackson, T. (2019). Soil Moisture Active/Passive (SMAP) L-Band Microwave Radiometer Post-Launch Calibration Upgrade. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 12(6), 1647–1657. https://doi.org/10.1109/jstars.2019.2902492

Peng, J., S. Misra, S. Chan, J. Chaubell, R. Bindlish, A. Bringer, A. Colliander, G. De Amici, E. P. Dinnat, D. Hudson, T. Jackson, J. Johnson, D. Le Vine, T. Meissner, P. Mohammed, J. Piepmeier, D. Entekhabi, S. Yueh. 2020. SMAP Radiometer Brightness Temperature Calibration for the L1B_TB, L1C_TB (Version 5), and L1C_TB_E (Version 3) Data Products. SMAP Project, Jet Propulsion Laboratory, Pasadena, CA. (see PDF).

Piepmeier, J., G. De Amici, P. Mohammed, and J. Peng. 2017. Improved Calibration through SMAP RFI Change Detection.

Piepmeier, J. R., et al., (2021). SMAP Algorithm Theoretical Basis Document: L1B Radiometer Data Product: L1B_TB (Includes L1A and L1B), Rev.D. SMAP Project, NASA GSFC SMAP-006, NASA Goddard Space Flight Center, Greenbelt, MD. (See Technical References).

Piepmeier, J. R., J. T. Johnson, P. N. Mohammed, D. Bradley, C. Ruf, M. Aksoy, R. Garcia, D. Hudson, L. Miles, and M. Wong. 2014. Radio-Frequency Interference Mitigation for the Soil Moisture Active Passive Microwave Radiometer. *IEEE Transactions on Geoscience and Remote Sensing.* 52(1):761-775. https://dx.doi.org/10.1109/TGRS.2013.2281266.

Piepmeier, J. R., D. G. Long, and E. G. Njoku. 2008. Stokes Antenna Temperatures. *IEEE Trans. Geosci. Remote Sens*. 46(2):516-527.

9 DOCUMENT INFORMATION

9.1 Publication Date

September 2020

9.2 Date Last Updated

December 2023

APPENDIX – DATA FIELDS

This appendix provides a description of all data fields within the *SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures* product.

- Brightness_Temperature
- Calibration_Data
- High_Resolution_Calibration_Data
- Metadata
- Spacecraft_Data

For a description of metadata fields for this product and for explanations on the conventions adopted for their use, please refer to the Product Specification Document (Mohammed-Tano, 2016).

Brightness_Temperature

Table A1 lists the elements in the *Brightness_Temperature* group. This group provides the time-ordered, footprint-averaged brightness temperatures (TBs) referenced to the Earth's surface with error sources removed. The group also includes geolocation information, antenna temperatures referenced to the feedhorn, before and after Radio Frequency Interference (RFI) mitigation, error sources, quality flags, brightness temperature error, and Noise Equivalent Delta Temperature (NEDT).

Within the *Brightness_Temperature* group, a distinct HDF5 data set stores each data element. The name of each data set object matches the data element that it stores. Table A1 lists the elements in the Brightness Temperature group. All the data elements in the Brightness Temperature group have the *AntennaScan_Tb_Array* shape. The*AntennaScan_Tb_Array* shape describes a two-dimensional array. The slowest moving dimension represents a particular antenna scan and the second dimension represents the footprint.

Table A1. Brightness Temperature Data Fields

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
antenna_earth_azimuth	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
antenna_look_angle	Float32	AntennaScan_Tb_Array	0.0	180.0	degrees	-9999.0
antenna_scan_angle	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
antenna_sideloble_correction_3	Float32	AntennaScan_Tb_Array	-0.5	6.0	K	-9999.0
antenna_sideloble_correction_4	Float32	AntennaScan_Tb_Array	-0.5	6.0	K	-9999.0
antenna_sideloble_correction_h	Float32	AntennaScan_Tb_Array	-0.5	6.0	K	-9999.0
antenna_sideloble_correction_v	Float32	AntennaScan_Tb_Array	-0.5	6.0	K	-9999.0
atm_correction_h	Float32	AntennaScan_Tb_Array	0.0	4.0	K	-9999.0
atm_correction_v	Float32	AntennaScan_Tb_Array	0.0	4.0	K	-9999.0
atm_loss	Float32	AntennaScan_Tb_Array	1.0	1.02	K	-9999.0
earth_boresight_azimuth	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
earth_boresight_incidence	Float32	AntennaScan_Tb_Array	0.0	90.0	degrees	-9999.0
faraday_rotation_angle	Float32	AntennaScan_Tb_Array	-90.0	90.0	degrees	-9999.0
faraday_rotation_correction_h	Float32	AnntenaScan_Tb_Array	-3.9	5.6	K	-9999.0
faraday_rotation_correction_v	Float32	AntennaScan_Tb_Array	-3.9	5.6	K	-9999.0
footprint_surface_status	Uint16	AntennaScan_Tb_Array	0	1	N/A	65534
galactic_direct_correction_h	Float32	AntennaScan_Tb_Array	0.3	0.6	K	-9999.0
galactic_direct_correction_v	Float32	AntennaScan_Tb_Array	0.3	0.6	K	-9999.0
galactic_reflected_correction_3	Float32	AntennaScan_Tb_Array	-0.4	4	K	-9999.0
galactic_reflected_correction_4	Float32	AntennaScan_Tb_Array	-0.4	4	K	-9999.0
galactic_reflected_correction_h	Float32	AntennaScan_Tb_Array	-0.4	4.0	K	-9999.0
galactic_reflected_correction_v	Float32	AntennaScan_Tb_Array	-0.4	4.0	K	-9999.0
lunar_direct_phi	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
lunar_direct_theta	Float32	AntennaScan_Tb_Array	0.0	180.0	degrees	-9999.0
lunar_specular_correction_3	Float32	AntennaScan_Tb_Array	-0.2	2.0	K	-9999.0

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
lunar_specular_correction_4	Float32	AntennaScan_Tb_Array	-0.2	2.0	K	-9999.0
lunar_specular_correction_h	Float32	AntennaScan_Tb_Array	-0.2	2.0	K	-9999.0
lunar_specular_correction_v	Float32	AntennaScan_Tb_Array	-0.2	2.0	K	-9999.0
lunar_specular_lat	Float32	AntennaScan_Tb_Array	-90	90	degrees	-9999.0
lunar_specular_lon	Float32	AntennaScan_Tb_Array	-180.0	179.999	degrees	-9999.0
lunar_specular_phi	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
lunar_specular_reflection_coefficient_h	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
lunar_specular_reflection_coefficient_v	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
lunar_specular_theta	Float32	AntennaScan_Tb_Array	0.0	180.0	degrees	-9999.0
nedt_3	Float32	AntennaScan_Tb_Array	0.5	3.0	K	-9999.0
nedt_4	Float32	AntennaScan_Tb_Array	0.5	3.0	K	-9999.0
nedt_h	Float32	AntennaScan_Tb_Array	0.5	3.0	K	-9999.0
nedt_v	Float32	AntennaScan_Tb_Array	0.5	3.0	Kelvin	-9999.0
polarization_rotation_angle	Float32	AntennaScan_Tb_Array	0.0	90.0	degrees	-9999.0
sea_ice_fraction	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
solar_direct_correction_h	Float32	AntennaScan_Tb_Array	0.0	0.6	K	-9999.0
solar_direct_correction_v	Float32	AntennaScan_Tb_Array	0.0	0.6	K	-9999.0
solar_direct_phi	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
solar_direct_theta	Float32	AntennaScan_Tb_Array	0.0	180.0	degrees	-9999.0
solar_specular_correction_3	Float32	AntennaScan_Tb_Array	-0.5	1.0	K	-9999.0
solar_specular_correction_4	Float32	AntennaScan_Tb_Array	-0.5	1.0	K	-9999.0
solar_specular_correction_h	Float32	AntennaScan_Tb_Array	-0.5	1.0	K	-9999.0
solar_specular_correction_v	Float32	AntennaScan_Tb_Array	-0.5	1.0	K	-9999.0
solar_specular_lat	Float32	AntennaScan_Tb_Array	-90.0	90.0	degrees	-9999.0
solar_specular_lon	Float32	AntennaScan_Tb_Array	-180.0	179.999	degrees	-9999.0
solar_specular_phi	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
solar_specular_reflection_coefficient_h	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
solar_specular_reflection_coefficient_v	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
solar_specular_theta	Float32	AntennaScan_Tb_Array	0.0	99.9	degrees	-9999.0
specular_declination	Float32	AntennaScan_Tb_Array	-90.0	90.0	degrees	-9999.0
specular_right_ascension	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
surface_water_fraction_mb_h	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
surface_water_fraction_mb_v	Float32	Antena_Scan_Tb_Array	0.0	1.0	N/A	-9999.0
ta_3	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
ta_4	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
ta_filtered_3	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
ta_filtered_4	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
ta_filtered_h	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
ta_filtered_v	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
ta_h	Float32	AntennaScan_Tb_Array	-0.0	310.0	K	-9999.0
ta_v	Float32	AntennaScan_Tb_Array	-0.0	310.0	K	-9999.0
tb_3	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
tb_4	Float32	AntennaScan_Tb_Array	-50.0	-50.0	K	-9999.0
tb_declination	Float32	AntennaScan_Tb_Array	-90.0	90.0	degrees	-9999.0
tb_h	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
tb_h_surface_corrected	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
tb_lat	Float32	AntennaScan_Tb_Array	-90	90	degrees	-9999.0
tb_lon	Float32	AntennaScan_Tb_Array	-180	179.999	degrees	-9999.0
tb_mode_flag	Bit flag	AntennaScan_Tb_Array	N/A	N/A	N/A	N/A
tb_qual_flag_3	Bit flag	AntennaScan_Tb_Array	N/A	N/A	N/A	N/A
tb_qual_flag_4	Bit flag	AntennaScan_Tb_Array	N/A	N/A	N/A	N/A
tb_qual_flag_h	Bit flag	AntennaScan_Tb_Array	N/A	N/A	N/A	N/A

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
tb_qual_flag_v	Bit flag	AntennaScan_Tb_Array	N/A	N/A	N/A	N/A
tb_right_ascension	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
tb_time_seconds	Float64	AntennaScan_Tb_Array	0.0	9.46E8	seconds	-9999.0
tb_time_utc	Char	AntennaScan_Tb_Array	N/A	N/A	N/A	-9999.0
tb_upwelling	Float32	AntennaScan_Tb_Array	0.0	4.0	K	-9999.0
tb_v	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
tb_v_surface_corrected	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
toa_3	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
toa_4	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
toa_h	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
toa_v	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
toi_3	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
toi_4	Float32	AntennaScan_Tb_Array	-50.0	50.0	K	-9999.0
toi_h	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
toi_v	Float32	AntennaScan_Tb_Array	0.0	310.0	K	-9999.0
wind_direction_ancillary	Float32	AntennaScan_Tb_Array	0.0	359.999	degrees	-9999.0
wind_speed_ancillary	Float32	AntennaScan_Tb_Array	0.0	75.0	m/s	-9999.0
ice_shelf_fraction_h	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0
Ice_shelf_fraction_v	Float32	AntennaScan_Tb_Array	0.0	1.0	N/A	-9999.0

Calibration_Data

Table A2 lists the elements in the Calibration Data group. The Calibration Data provides information about the instrument component losses and noise temperatures which the SMAP Level-1B brightness temperature data product employs in the calibration algorithm. Included are values for the vertical and horizontal polarization for the fullband. All of the product elements in the Calibration Data group are stored in a single HDF5 Group named Calibration_Data. A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table A2 lists the elements in the Calibration Data group.

The data elements in the Calibration Data group have varying shapes depending on whether data is stored for both the vertical and horizontal channels. The *AntennaScan_VHPol_Array* shape describes a two-dimensional array. The slowest moving dimension represents a particular antenna scan. The second dimension represents the polarization. The element that represents vertical polarization always precedes the element that represents horizontal polarization.

Table A2. Calibration Data Fields

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
cal_loss12_radome	Float32	AntennaScan_Array	1.0	2.0	N/A	-9999.0
cal_loss1_reflector	Float32	AntennaScan_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_loss2_feed	Float32	HighResolutionScan_Subband_Array	1.0	2.0	N/A	-9999.0
cal_loss3_omt	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_loss4_coupler	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_loss5_diplexer	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_nd_phase	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0
cal_rx_phase	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0
cal_temp12_radome	Float32	AntennaScan_Array	110.0	260.0	K	-9999.0
cal_temp1_reflector	Float32	AntennaScan_Array	330.0	400.0	K	-9999.0
cal_temp2_feed	Float32	AntennaScan_Array	253.15	313.15	K	-9999.0
cal_temp3_omt	Float32	AntennaScan_VHPol_Array	253.15	313.15	K	-9999.0
cal_temp4_coupler	Float32	AntennaScan_VHPol_Array	253.15	313.15	K	-9999.0
cal_temp5_deplexer	Float32	AntennaScan_VHPol_Array	253.15	313.15	K	-9999.0
cal_temp_nd	Float32	HighResolutionScan_Subband_Array	253.15	313.15	K	-9999.0
cal_temp_ref	Float32	AntennaScan_VHPol_Array	253.15	313.15	K	-9999.0
cal_temp_xnd	Float32	HighResolutionScan_Subband_Array	-253.15	314.15	K	-9999.0
cal_tempref_offset	Float32	HighResolutionScan_Subband_VHPol_Array	-1.0	1.0	K	-9999.0
cal_tnd	Float32	HighResolutionScan_Subband_VHPol_Array	218.0	658.0	K	-9999.0
cal_tref	Float32	HighResolutionScan_Subband_VHPol_Array	252.15	314.15	K	-9999.0
cal_txnd	Float32	HighResolutionScan_Subband_VHPol_Array	62.0	216.0	K	-9999.0
cal_xnd_phase	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0

High_Resolution_Calibration_Data

Table A3 lists the elements in the High Resolution Calibration Data group. The High Resolution Calibration Data provides information about the instrument component losses and noise temperatures which the SMAP Level-1B brightness temperature data product employs in the calibration algorithm. Included are values for the vertical and horizontal polarization for all 16 subbands. All of the product elements in the High Resolution Calibration Data group are stored in a single HDF5 Group named HighResolution_Calibration_Data. A distinct HDF5 data set stores each data element. The name of each data set object matches the data element that it stores. Table A3 lists the elements in the High Resolution Calibration Data group.

The data elements in the High Resolution Calibration Data group have varying shapes depending on whether data is stored for both the vertical and horizontal channels. The *HighResolutionScan_Subband_VHPol_Array* shape describes a three-dimensional array. The slowest moving dimension represents a particular antenna scan. The second dimension represents the 16 subbands. The third dimension represents the polarization. The element that represents vertical polarization always precedes the element that represents horizontal polarization.

Table A3. High Resolution Calibration Data Fields

Data Field Name	Type	Shape	Valid_Min	Valid_Max	Units	Fill/Gap Value
cal_loss2_feed16	Float32	HighResolutionScan_Subband_Array	1.0	2.0	N/A	-9999.0
cal_loss3_omt16	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_loss4_coupler16	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_loss5_diplexer16	Float32	HighResolutionScan_Subband_VHPol_Array	1.0	2.0	N/A	-9999.0
cal_nd_phase16	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0
cal_rx_phase16	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0
cal_temp_nd16	Float32	HighResolutionScan_Subband_Array	253.15	313.15	K	-9999.0
cal_temp_xnd16	Float32	HighResolutionScan_Subband_Array	253.15	313.15	K	-9999.0
cal_tempref_offset16	Float32	HighResolutionScan_Subband_VHPol_Array	-1.0	1.0	K	-9999.0
cal_tnd16	Float32	HighResolutionScan_Subband_VHPol_Array	212.0	676.0	K	-9999.0
cal_tref16	Float32	HighResolutionScan_Subband_VHPol_Array	252.15	314.15	K	-9999.0
cal_txnd16	Float32	HighResolutionScan_Subband_VHPol_Array	61.0	217.1	K	-9999.0
cal_xnd_phase16	Float32	HighResolutionScan_Subband_Array	-3.1415927	3.1415927	radians	-9999.0
calibration_time_seconds	Float64	HighResolutionScan_Array	-0.0	9.46E8	seconds	-9999.0
highresolution_scan_index	Uint32	HighResolutionScan_Array	0	800	N/A	-9999.0

Spacecraft_Data

Tables A4 describes the data fields within the HDF5 Group called Spacecraft_Data. All the HDF5 data sets in the Spacecraft Data group have *AntennaScan_Array* shape. The *AntennaScan_Array* shape describes a one-dimensional array, where each array element represents one rotation of the SMAP antenna. The representative time instant for each antenna scan takes place when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system. The X-axis of the spacecraft coordinate system approximates the direction of motion of the SMAP spacecraft. Thus, array element *x_pos(212)* lists the representative spacecraft position in the x dimension, array element *yaw(212)* lists the representative spacecraft yaw, and array element *sc_geodetic_alt(212)* lists the representative spacecraft altitude at the instant during each antenna scan when the boresight aligns with the X-axis of the spacecraft coordinate system. The time of that event appears in array element *antenna_scan_time_utc (212)*. The precise range of time covered by each antenna scan depends on the antenna rotation rate. The mission selected one of two likely antenna rotation rates. They are either 14.6 revolutions per minute or 13 revolutions per minute.

Table A4. Spacecraft Data Fields

Data Field Name	Type	Shape	Valid Min	Valid Max	Unit	Fill/Gap Value
antenna_scan_mode_flag	Uint16	AntennaScan_Array	0	65535	N/A	65534
antenna_scan_qual_flag	Uint16	AntennaScan_Array	N/A	N/A	N/A	65534
antenna_scan_time	Float64	AntennaScan_Array	0.0	9.46E8	seconds	-9999.0
antenna_scan_time_utc	FixedLenString (24 characters)	AntennaScan_Array	2014-10-31T00:00:00.000Z	2030-12-31T23:59:60.999Z	N/A	N/A
footprints_per_scan	Uint16	AntennaScan_Array	0	300	N/A	65534
pitch	Float32	AntennaScan_Array	-90.0	90.0	degrees	-9999.0
roll	Float32	AntennaScan_Array	-90.0	90.0	degrees	-9999.0
sc_alongtrack_velocity	Float32	AntennaScan_Array	-8000.0	8000.0	m/s	-9999.0
sc_geodetic_alt_ellipsoid	Float32	AntennaScan_Array	650000.0	900000.0	meters	-9999.0
sc_nadir_angle	Float32	AntennaScan_Array	0.0	180.0	degrees	-9999.0
sc_nadir_lat	Float32	AntennaScan_Array	-90	90	degrees	-9999.0
sc_nadir_lon	Float32	AntennaScan_Array	-180	179.999	degrees	-9999.0
sc_radial_velocity	Float32	AntennaScan_Array	-8000.0	8000.0	m/s	-9999.0
tbs_per_scan	Uint16	AntennaScan_Array	0	300	N/A	65534
x_pos	Float32	AntennaScan_Array	-999999.0	9999999.0	m	-9999.0
x_vel	Float32	AntennaScan_Array	-8000.0	8000.0	m/s	-9999.0
y_pos	Float32	AntennaScan_Array	-999999.0	9999999.0	m	-9999.0
y_vel	Float32	AntennaScan_Array	-8000.0	8000.0	m/s	-9999.0
yaw	Float32	AntennaScan_Array	-180.0	180.0	degrees	-9999.0
z_pos	Float32	AntennaScan_Array	-999999.0	9999999	m	-9999.0
z_vel	Float32	AntennaScan_Array	-8000.0	8000.0	m/s	-9999.0

Data Field Definitions

antenna_earth_azimuth
The is angle from due North to the projection of the antenna scan angle onto a plane tangent to the Earth at the spacecraft nadir point. The spacecraft nadir point serves as the vertex of this angle.

antenna_look_angle
The angle defined by the antenna boresight vector and the spacecraft nadir vector.

antenna_scan_angle
The angle in the X-Y plane of the instrument fixed coordinate system that indicates the angular position of the antenna assembly. The angle is measured in the counterclockwise direction from the X axis, which approximates the direction of motion of the spacecraft.

antenna_sidelobe_correction_3
TB correction to TA for earth sidelobe contribution for 3rd Stokes.

antenna_sidelobe_correction_4
TB correction to TA for earth sidelobe contribution for 4th Stokes.

antenna_sidelobe_correction_h
TB correction to TA for earth sidelobe contribution for horizontal polarization.

antenna_sidelobe_correction_v
TB correction to TA for earth sidelobe contribution for vertical polarization.

atm_correction_h
TB correction to TA for atmospheric emission for horizontal polarization.

atm_correction_v
TB correction to TA for atmospheric emission for vertical polarization.

atm_loss
The reduction in power density of the brightness temperature signal as it propagates through the Earth's atmosphere.

earth_boresight_azimuth
The angle defined by the vector that extends from the intersection of the spacecraft geodetic nadir vector on the Earth's surface to geographic North and the vector that extends from the intersection of the spacecraft geodetic nadir on the Earth's surface to the pierce point of the boresight vector. The angle measure is clockwise from the northward vector.

earth_boresight_incidence
The angle defined by the antenna boresight vector and the mean surface normal vector.

faraday_rotation_angle
The Faraday rotation angle.

faraday_rotation_correction_h
TB correction to TA for Faraday Rotation for horizontal polarization.

faraday_rotation_correction_v
TB correction to TA for Faraday Rotation for vertical polarization.

footprint_surface_status
Indicates if the footprint center lies on land (0) or water (1).

galactic_direct_correction_h
TB correction to TA for direct galactic contamination for horizontal polarization.

galactic_direct_correction_v
TB correction to TA for direct galactic contamination for vertical polarization.

galactic_reflected_correction_3
The brightness temperature correction to the antenna temperature, TA, for reflected galactic and cosmic contamination to derive *tb_3*. The *galactic_reflected_correction_3* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

galactic_reflected_correction_4
TB correction to TA for reflected galactic contamination for 4th Stokes.

galactic_reflected_correction_h
TB correction to TA for reflected galactic contamination for horizontal polarization.

galactic_reflected_correction_v
TB correction to TA for reflected galactic contamination for vertical polarization.

ice_shelf_fraction_h
Fraction of ice shelf surface covered by the TB footprint for the H pol TB.

ice_shelf_fraction_v
Fraction of ice shelf surface covered by the TB footprint for the V pol TB.

lunar_direct_phi
The angle defined by the +X axis of the Antenna Beam Frame Coordinate System and the vector that extends from the origin to the Moon projected onto the XY plane of the Antenna Beam Frame Coordinate System.

lunar_direct_theta
The angle defined by the +Z axis of the Antenna Beam Frame Coordinate System, which is equivalent to the electrical boresight vector, and the vector that extends from the origin of the Antenna Bean Frame Coordinate System to the Moon.

lunar_specular_correction_3
TB correction to TA for reflected lunar contamination for 3rd Stokes.

lunar_specular_correction_4
TB correction to TA for reflected lunar contamination for 4th Stokes.

lunar_specular_correction_h
TB correction to TA for reflected lunar contamination for horizontal polarization.

lunar_specular_correction_v
TB correction to TA for reflected lunar contamination for vertical polarization.

lunar_specular_lat
Latitude of the center of the lunar specular reflection point on the Earth's surface relative to the spacecraft position.

lunar_specular_lon
Longitude of the center of the lunar specular reflection point on the Earth's surface relative to the spacecraft position.

lunar_specular_phi
The angle defined by the +X axis of the Antenna Beam Frame Coordinate System and the vector that extends from the origin to the lunar glint spot on the Earth's surface projected onto the XY plane of the Antenna Beam Frame Coordinate System.

lunar_specular_reflection_coefficient_h
Reflection coefficient of surface at lunar specular point for horizontal polarization.

lunar_specular_reflection_coefficient_v
Reflection coefficient of surface at lunar specular point for vertical polarization.

lunar_specular_theta
The angle defined by the +Z axis of the Antenna Beam Frame Coordinate System, which is equivalent to the electrical boresight vector, and the vector that extends from the origin of the Antenna Bean Frame Coordinate System to the lunar glint spot on the Earth's surface.

nedt_3
NEDT after RFI removal for third Stokes.

nedt_4
NEDT after RFI removal for fourth Stokes.

nedt_h
NEDT after RFI removal for horizontal polarization.

nedt_v
NEDT after RFI removal for vertical polarization.

polarization_rotation_angle
The angle between the plane of polarization and the reference plane used to calculate the Stokes vector. The *polarization_rotation_angle* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

sea_ice_fraction
The angle between the plane of polarization and the reference plane used to calculate the Stokes vector.

solar_direct_correction_h
TB correction to TA for direct solar contamination for horizontal polarization. Limits for all error sources contributions will be determined with the orbit simulator.

solar_direct_correction_v
TB correction to TA for direct solar contamination for vertical polarization. Limits for all error sources contributions will be determined with the orbit simulator.

solar_direct_phi
The angle defined by the +X axis of the Antenna Beam Frame Coordinate System and the vector that extends from the origin to the Sun projected onto the XY plane of the Antenna Beam Frame Coordinate System.

solar_direct_theta
The angle defined by the +Z axis of the Antenna Beam Frame Coordinate System, which is equivalent to the electrical boresight vector, and the vector that extends from the origin of the Antenna Bean Frame Coordinate System to the Sun.

solar_specular_correction_3
TB correction to TA for reflected solar contamination for 3rd Stokes.

solar_specular_correction_4
TB correction to TA for reflected solar contamination for 4th Stokes.

solar_specular_correction_h
TB correction to TA for reflected solar contamination for horizontal polarization.

solar_specular_correction_v
TB correction to TA for reflected solar contamination for vertical polarization.

solar_specular_lat
The geodetic latitude of the center of the solar specular reflection point on the Earth's surface relative to the spacecraft position. The *solar_specular_lat* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

solar_specular_lon
The longitude of the center of the solar specular reflection point on the Earth's surface relative to the spacecraft position. The *solar_specular_lon* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

solar_specular_phi
The angle defined by the +X axis of the ABFCS and the vector that extends from the origin to the solar glint spot on the Earth's surface projected onto the XY plane of the ABFCS. The *solar_specular_phi* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

solar_specular_reflection_coefficient_h
Reflection coefficient of surface at solar specular point for horizontal polarization.

solar_specular_reflection_coefficient_v
Reflection coefficient of surface at solar specular point for vertical polarization.

solar_specular_theta
The angle defined by the +Z axis of the Antenna Beam Frame Coordinate System, which is equivalent to the electrical boresight vector, and the vector that extends from the origin of the Antenna Bean Frame Coordinate System to the solar glint spot on the Earth's surface.

specular_declination
Declination of the specular reflection vector relative to each footprint in the product. The specular reflection vector is in the same plane as the boresight vector and the spacecraft nadir vector.

specular_right_ascension
Right ascension of the specular reflection vector relative to each footprint in the product. The specular reflection vector is in the same plane as the boresight vector and the spacecraft nadir vector.

surface_water_fraction_mb_h
Areal fraction of static water within the radiometer H pol antenna pattern.

surface_water_fraction_mb_v
Areal fraction of static water within the radiometer V pol antenna pattern.

ta_3
The antenna temperature for the 3rd Stokes parameter before RFI filtering.

ta_4
The antenna temperature for the 4th Stokes parameter before RFI filtering.

ta_filtered_3
Antenna temperature for the 3rd Stokes parameter after RFI filtering.

ta_filtered_4
Antenna temperature for the 4th Stokes parameter after RFI filtering.

ta_filtered_h
Horizontally polarized antenna temperature after RFI filtering.

ta_filtered_v
Vertically polarized antenna temperature after RFI filtering.

ta_h
The horizontally polarized antenna temperature before RFI filtering.

ta_v
The vertically polarized antenna temperature before RFI filtering.

tb_3
The 3rd Stokes parameter at the surface of the Earth after RFI filtering. The *tb_3* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

tb_4
The 4th Stokes parameter at the surface of the Earth after RFI filtering.

tb_declination
The declination of the spacecraft boresight vector.

tb_h
The horizontally polarized brightness temperature at the surface of the Earth after RFI filtering.

b_h_surface_corrected
The horizontally polarized water/land contamination corrected brightness temperature at the surface of the Earth after RFI filtering. This value represents the corrected land brightness temperature if *footprint_surface_status* is “0” or represents the corrected water brightness temperature if *footprint_surface_status* is “1.”

tb_lat
Latitude of the intersection of the antenna boresight vector and the Earth's surface.

tb_lon
Longitude of the intersection of the antenna boresight vector and the Earth's surface.

tb_mode_flag
Bit flags that indicate instrument and ambient conditions when the TB measurements were acquired. The *tb_mode_flag* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan. See Table A5 for more details.

tb_qual_flag_3
Bit flags that indicate the quality of the 3rd Stokes parameter. The *tb_qual_flag_3* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan. See Table A6 for more details.

tb_qual_flag_4
Bit flags that indicate the quality of the 4th Stokes parameter. The *tb_qual_flag_4* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan. See Table A7 for more details.

tb_qual_flag_h
Bit flags that indicate the quality of the horizontally polarized brightness temperature. The *tb_qual_flag_h* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan. See Table A8 for more details.

tb_qual_flag_v
Bit flags that indicate the quality of the vertically polarized brightness temperature. The *tb_qual_flag_v* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan. See Table A9 for more details.

tb_right_ascension
Right ascension of the spacecraft boresight vector.

tb_time_seconds
J2000 time (in s) when TBs were recorded.

tb_time_utc
UTC time when TBs were recorded.

tb_upwelling
The component of the top of the atmosphere apparent brightness temperature that is due to upwelling thermal radiation of the atmosphere. The *tb_upwelling* field is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Table A5. Description of *tb_mode_flag*

Bits	Interpretation	Value	Description
0	Data resolution flag (land/ocean)	0	High resolution data contribute to this scan
		1	Low resolution data contribute to this scan
1	Scan view flag	0	Brightness temperature footprint is forward of spacecraft position
		1	Brightness temperature footprint is aft of spacecraft position
2	Spacecraft viewing mode	0	Instrument is in normal Earth viewing mode
		1	Instrument boresight does not view the Earth's surface
3	Ocean calibration region	0	Pixel views external calibration region over the ocean
		1	Pixel does not view ocean calibration region over the ocean
4	Antarctic calibration region	0	Correction for reflected sun operated successfully on the 4th Stokes parameter
		1	Correction for reflected sun did not function or yielded poor results on the 4th Stokes parameter
5	Lunar visible flag	0	The moon is not visible from the SMAP spacecraft.
		1	The moon is visible from the SMAP spacecraft.
6	Solar visible flag	0	The sun is not visible from the SMAP spacecraft.
		1	The sun is visible from the SMAP spacecraft.
7-15	Undefined	N/A	N/A

Table A6. Description of *tb_qual_flag_3*

Bits	Interpretation	Value	Description
0	3rd Stokes quality flag	0	3rd Stokes parameter measurement has acceptable quality
		1	Use of 3rd Stokes parameter measurement not recommended
1	3rd Stokes range flag	0	3rd Stokes parameter measurement falls in expected range
		1	3rd Stokes parameter measurement is out of range
2	3rd Stokes RFI detection flag	0	RFI not detected for 3rd Stokes brightness temperatures in the grid cell
		1	RFI detected for 3rd Stokes brightness temperatures in the grid cell
3	3rd Stokes RFI correction flag	0	If RFI was detected, the 3rd Stokes brightness temperature was corrected to remove RFI
		1	If RFI was detected, the software was unable to correct the 3rd Stokes brightness temperature for RFI
4	3rd Stokes NEDT flag	0	3rd Stokes has acceptable NEDT
		1	Use of 3rd Stokes not recommended, since NEDT exceeds pre-determined threshold
5	3rd Stokes direct sun correction	0	Correction for direct sun operated successfully on the 3rd Stokes parameter
		1	Correction for direct sun did not function or yielded poor results on the 3rd Stokes parameter
6	3rd Stokes reflected sun correction	0	Correction for reflected sun operated successfully on the 3rd Stokes parameter
		1	Correction for reflected sun did not function or yielded poor results on the 3rd Stokes parameter
7	3rd Stokes reflected moon correction	0	Correction for reflected moon operated successfully on the 3rd Stokes parameter
		1	Correction for reflected moon did not function or yielded poor results on the 3rd Stokes parameter
8	3rd Stokes direct galaxy correction	0	Correction for direct galaxy operated successfully on the 3rd Stokes parameter
		1	Correction for direct galaxy did not function or yielded poor results on the 3rd Stokes parameter
9	3rd Stokes reflected galaxy correction	0	Correction for reflected galaxy operated successfully on the 3rd Stokes parameter
		1	Correction for reflected galaxy did not function or yielded poor results on the 3rd Stokes parameter
10	3rd Stokes correction for atmospheric conditions	0	Correction for atmospheric conditions operated successfully on the 3rd Stokes parameter
		1	Correction for atmospheric conditions did not function or yielded poor results on the 3rd Stokes parameter
12	3rd Stokes null value	0	The corresponding 3rd Stokes parameter element contains a calculated value.
		1	The corresponding 3rd Stokes parameter element is null.
11, 13-15	Undefined	N/A	N/A

Table A7. Description of *tb_qual_flag_4*

Bits	Interpretation	Value	Description
0	4th Stokes quality flag	0	4th Stokes parameter measurement has acceptable quality
		1	Use of 4th Stokes parameter measurement not recommended
1	4th Stokes range flag	0	4th Stokes parameter measurement falls in expected range
		1	4th Stokes parameter measurement is out of range
2	4th Stokes RFI detection flag	0	RFI not detected for 4th Stokes brightness temperatures in the grid cell
		1	RFI detected for 4th Stokes brightness temperatures in the grid cell
3	4th Stokes RFI correction flag	0	If RFI was detected, the 4th Stokes brightness temperature was corrected to remove RFI
		1	If RFI was detected, the software was unable to correct the 4th Stokes brightness temperature for RFI
4	4th Stokes NEDT flag	0	4th Stokes has acceptable NEDT
		1	Use of 4th Stokes not recommended, since NEDT exceeds pre-determined threshold
5	4th Stokes direct sun correction	0	Correction for direct sun operated successfully on the 4th Stokes parameter
		1	Correction for direct sun did not function or yielded poor results on the 4th Stokes parameter
6	4th Stokes reflected sun correction	0	Correction for reflected sun operated successfully on the 4th Stokes parameter
		1	Correction for reflected sun did not function or yielded poor results on the 4th Stokes parameter
7	4th Stokes reflected moon correction	0	Correction for reflected moon operated successfully on the 4th Stokes parameter
		1	Correction for reflected moon did not function or yielded poor results on the 4th Stokes parameter
8	4th Stokes direct galaxy correction	0	Correction for direct galaxy operated successfully on the 4th Stokes parameter
		1	Correction for direct galaxy did not function or yielded poor results on the 4th Stokes parameter
9	4th Stokes reflected galaxy correction	0	Correction for reflected galaxy operated successfully on the 4th Stokes parameter
		1	Correction for reflected galaxy did not function or yielded poor results on the 4th Stokes parameter
10	4th Stokes correction for atmospheric conditions	0	Correction for atmospheric conditions operated successfully on the 4th Stokes parameter
		1	Correction for atmospheric conditions did not function or yielded poor results on the 4th Stokes parameter
12	4th Stokes null value	0	The corresponding 4th Stokes parameter element contains a calculated value.
		1	The corresponding 4th Stokes parameter element is null.
11, 13-15	Undefined	N/A	N/A

Table A8. Description of *tb_qual_flag_h*

Bits	Interpretation	Value	Description
0	Horizontal polarization quality flag	0	Horizontal polarization brightness temperature measurement has acceptable quality
		1	Use of horizontal polarization brightness temperature not recommended
1	Horizontal polarization range flag	0	Horizontal polarization brightness temperature measurement falls in expected range
		1	Horizontal polarization brightness temperature value is out of range
2	Horizontal polarization RFI detection flag	0	RFI not detected for Horizontal polarization brightness temperatures in the grid cell
		1	If RFI was detected, the software was unable to correct the horizontal polarization brightness temperature for RFI
3	Horizontal polarization RFI correction flag	0	If RFI was detected, the horizontal polarization brightness temperature was corrected to remove RFI
		1	If RFI was detected, the software was unable to correct the horizontal polarization brightness temperature for RFI
4	Horizontal polarization NEDT flag	0	Horizontal polarization brightness temperature measurement has acceptable NEDT
		1	Use of horizontal polarization brightness temperature not recommended, since NEDT exceeds pre-determined threshold
5	Horizontal polarization direct sun correction	0	Correction for direct sun operated successfully on the horizontal polarization brightness temperature
		1	Correction for direct sun did not function or yielded poor results on the horizontal polarization brightness temperature
6	Horizontal polarization reflected sun correction	0	Correction for reflected sun operated successfully on the horizontal polarization brightness temperature
		1	Correction for reflected sun did not function or yielded poor results on the horizontal polarization brightness temperature
7	Horizontal polarization reflected moon correction	0	Correction for reflected moon operated successfully on the horizontal polarization brightness temperature
		1	Correction for reflected moon did not function or yielded poor results on the horizontal polarization brightness temperature
8	Horizontal polarization direct galaxy correction	0	Correction for direct galaxy operated successfully on the horizontal polarization brightness temperature

Bits	Interpretation	Value	Description
		1	Correction for direct galaxy did not function or yielded poor results on the horizontal polarization brightness temperature
9	Horizontal polarization reflected galaxy correction	0	Correction for reflected galaxy operated successfully on the horizontal polarization brightness temperature
		1	Correction for reflected galaxy did not function or yielded poor results on the horizontal polarization brightness temperature
10	Horizontal polarization correction for atmospheric conditions	0	Correction for atmospheric conditions operated successfully on the horizontal polarization brightness temperature
		1	Correction for atmospheric conditions did not function or yielded poor results on the horizontal polarization brightness temperature
11	Horizontal polarization Faraday rotation correction	0	Correction for Faraday rotation operated successfully on the horizontal polarization brightness temperature
		1	Correction for Faraday rotation did not function or yielded poor results on the horizontal polarization brightness temperature
12	Horizontal polarization null value	0	The corresponding horizontal polarization brightness temperature element contains a calculated value.
		1	The corresponding horizontal polarization brightness temperature element is null.
13-15	Undefined	N/A	N/A

Table A9. Description of *tb_qual_flag_v*

Bits	Interpretation	Value	Description
0	Vertical polarization quality flag	0	Vertical polarization brightness temperature measurement has acceptable quality
		1	Use of vertical polarization brightness temperature not recommended
1	Vertical polarization range flag	0	Vertical polarization brightness temperature measurement falls in expected range
		1	Vertical polarization brightness temperature value is out of range
2	Vertical polarization RFI detection flag	0	RFI not detected for vertical polarization brightness temperatures in the grid cell
		1	If RFI was detected, the software was unable to correct the vertical polarization brightness temperature for RFI
3	Vertical polarization RFI correction flag	0	If RFI was detected, the vertical polarization brightness temperature was corrected to remove RFI
		1	If RFI was detected, the software was unable to correct the vertical polarization brightness temperature for RFI
4	Vertical polarization NEDT flag	0	Vertical polarization brightness temperature measurement has acceptable NEDT
		1	Use of vertical polarization brightness temperature not recommended, since NEDT exceeds pre-determined threshold
5	Vertical polarization direct sun correction	0	Correction for direct sun operated successfully on the vertical polarization brightness temperature
		1	Correction for direct sun did not function or yielded poor results on the vertical polarization brightness temperature
6	Vertical polarization reflected sun correction	0	Correction for reflected sun operated successfully on the vertical polarization brightness temperature
		1	Correction for reflected sun did not function or yielded poor results on the vertical polarization brightness temperature
7	Vertical polarization reflected moon correction	0	Correction for reflected moon operated successfully on the vertical polarization brightness temperature
		1	Correction for reflected moon did not function or yielded poor results on the vertical polarization brightness temperature
8	Vertical polarization direct galaxy correction	0	Correction for direct galaxy operated successfully on the vertical polarization brightness temperature

Bits	Interpretation	Value	Description
		1	Correction for direct galaxy did not function or yielded poor results on the vertical polarization brightness temperature
9	Vertical polarization reflected galaxy correction	0	Correction for reflected galaxy operated successfully on the vertical polarization brightness temperature
		1	Correction for reflected galaxy did not function or yielded poor results on the vertical polarization brightness temperature
10	Vertical polarization correction for atmospheric conditions	0	Correction for atmospheric conditions operated successfully on the vertical polarization brightness temperature
		1	Correction for atmospheric conditions did not function or yielded poor results on the vertical polarization brightness temperature
11	Vertical polarization Faraday rotation correction	0	Correction for Faraday rotation operated successfully on the vertical polarization brightness temperature
		1	Correction for Faraday rotation did not function or yielded poor results on the vertical polarization brightness temperature
12	Vertical polarization null value	0	The corresponding vertical polarization brightness temperature element contains a calculated value.
		1	The corresponding vertical polarization brightness temperature element is null.
13-15	Undefined	N/A	N/A

toa_3
The apparent 3rd Stokes parameter at the top of the atmosphere. The top of atmosphere is equivalent to the bottom of the ionosphere.

toa_4
The apparent 4th Stokes parameter at the top of the atmosphere. The top of atmosphere is equivalent to the bottom of the ionosphere.

toa_h
The horizontally polarized apparent brightness temperature at the top of the atmosphere. The top of atmosphere is equivalent to the bottom of the ionosphere.

toa_v
The vertically polarized apparent brightness temperature at the top of the atmosphere. The top of atmosphere is equivalent to the bottom of the ionosphere.

toi_3
Apparent 3rd Stokes parameter at the top of the ionosphere.

toi_4
Apparent 4th Stokes parameter at the top of the ionosphere.

toi_h
Horizontally polarized apparent brightness temperature at the top of the ionosphere.

toi_v
Vertically polarized apparent brightness temperature at the top of the ionosphere.

wind_direction_ancillary
The interpolated direction of sea surface winds at the center of the corresponding Tb. Wind direction is measured as the clockwise rotation from local North (meteorological convention). Wind measurements are based on data provided by the National Centers for Environmental Prediction (NCEP) of the National Oceanographic and Atmospheric Administration (NOAA).

wind_speed_ancillary
The interpolated speed of sea surface winds at the center of the corresponding Tb. Wind measurements are based on data provided by the National Centers for Environmental Prediction (NCEP) of the National Oceanographic and Atmospheric Administration (NOAA).

cal_loss12_radome
Calibration model lumped loss factor of radome (stored V then H).

cal_loss1_reflector
Calibration model lumped loss factor of reflector (stored V then H).

cal_loss2_feed
Calibration model lumped loss factor of feed.

cal_loss3_omt
Calibration model lumped loss factor of OMT (stored V then H).

cal_loss4_coupler
Calibration model lumped loss factor of coupler (stored V then H).

cal_loss5_diplexer
Calibration model lumped loss factor of the diplexer (stored V then H).

cal_nd_phase
The calibration model noise diode phase applied in the calibration of fullband data. The *cal_nd_phase* field is a one-dimensional array with one value for each antenna scan.

cal_rx_phase
The calibration model receiver phase for calibration of radiometer fullband data. The *cal_rx_phase* field is a one-dimensional array with one value for each antenna scan.

cal_temp12_radome
Calibration model, physical temperature, radome (same for V and H as the radome temp will most likely act on the 2 polarizations in the same way).

cal_temp1_reflector
Calibration model, physical temperature, reflector (same for V and H as the reflector temp will most likely act on the 2 polarizations in the same way).

cal_temp2_feed
Calibration model, physical temperature, feed.

cal_temp3_omt
Calibration model, physical temperature, OMT (stored V then H).

cal_temp4_coupler
Calibration model, physical temperature, coupler (stored V then H).

cal_temp5_deplexer
Calibration model, physical temperature, diplexer (stored V then H).

cal_temp_nd
Calibration model, physical temperature, noise diode.

cal_temp_ref
Calibration model, physical temperature, reference (stored V then H).

cal_temp_xnd
Calibration model, physical temperature, external noise diode.

cal_tempref_offset
Calibration model, physical temperature offset, reference (stored V then H).

cal_tnd
Calibration model, brightness temperature, noise diode (stored V then H).

cal_tref
Calibration model, brightness temperature, reference (stored V then H).

cal_txnd
Calibration model, brightness temperature, external noise diode (stored V then H).

cal_xnd_phase
Calibration model, external noise diode phase.

cal_loss2_feed16
Calibration model lumped loss factor of feed, 16 subbands.

cal_loss3_omt16

Calibration model lumped loss factor of OMT (stored V then H), 16 subbands.

cal_loss4_coupler16

Calibration model lumped loss factor of coupler (stored V then H), 16 subbands.

cal_loss5_diplexer16

Calibration model lumped loss factor of the diplexer (stored V then H), 16 subbands.

cal_nd_phase16

Calibration model, noise diode phase, 16 subbands.

cal_rx_phase16

Calibration model, receiver phase, 16 subbands.

cal_temp_nd16

Calibration model, physical temperature, noise diode, 16 subbands.

cal_temp_xnd16

Calibration model, physical temperature, external noise diode, 16 subbands.

cal_tempref_offset16

Calibration model, physical temperature offset, reference (stored V then H), 16 subbands.

cal_tnd16

Calibration model, brightness temperature, reference (stored V then H), 16 subbands.

cal_tref16

Calibration model, brightness temperature, external noise diode (stored V then H), 16 subbands.

cal_txnd16

Calibration model, brightness temperature, external noise diode (stored V then H), 16 subbands.

cal_xnd_phase16

Calibration model, external noise diode phase, 16 subbands.

calibration_time_seconds

Number of seconds since midnight on 1/1/1993 for each antenna rotation interpolated to antenna boresight azimuth of 0 degrees.

highresolution_scan_index

An array of indices of the high-resolution antenna scan rotations in the current granule. The value in this array references in the matching index in the Antenna Scan array.

antenna_scan_mode_flag

Operational mode of attitude/ephemeris telemetry and associated calculations at each instance when antenna boresight azimuth is 0 degrees. See Table A10 for more details.

antenna_scan_qual_flag

Quality of attitude/ephemeris telemetry and associated calculations at each instance when antenna boresight azimuth is 0 degrees. The *antenna_scan_qual_flag* is a one-dimensional array. Each array index is representative of a specific antenna scan. See Table A11 for more details.

Table A10. Description of *antenna_scan_mode_flag*

Bits	Interpretation	Value	Description
0	Instrument viewing mode	0	Spacecraft antenna is positioned so that the SMAP instrument views locations on the Earth's surface.
		1	Spacecraft antenna is positioned so that the SMAP instrument does not view the Earth. SMAP spacecraft is either in maneuver, running a cold sky calibration for the radiometer or in transition state.
1	Ephemeris Usage Flag	0	Processing employed reconstructed ephemeris
		1	Processing employed predicted ephemeris
2	Data Resolution Flag	0	High resolution data contribute to this scan
		1	Low resolution data contribute to this scan
3	Eclipse Flag	0	The SMAP spacecraft is not in eclipse. The Sun is visible from the SMAP spacecraft.
		1	The SMAP spacecraft is in eclipse. The Sun is not visible from the SMAP spacecraft.
4-15	Undefined	N/A	N/A

Table A11. Description of antenna_scan_qual_flag

Bits	Interpretation	Value	Description
0	Ephemeris Quality	0	Quality and frequency of the ephemeris data is within acceptable range.
		1	Quality or frequency of the ephemeris data may not be adequate to yield an accurate measure of spacecraft location.
1	Attitude Quality	0	Quality and frequency of the attitude data is within acceptable range.
		1	Quality or frequency of the attitude data may not be adequate to yield an acceptable measure of spacecraft orientation.
2	Antenna Pointing Quality	0	Quality and frequency of the antenna pointing data is within acceptable range.
		1	Quality or frequency of the antenna pointing data may not be adequate to yield an acceptable measure of antenna position.
3	Spacecraft half orbit location	0	All of the footprints associated with this spacecraft orbit location lie within the half orbit specified in the file name.
		1	Some or all of the footprints associated with this spacecraft orbit location lie outside of the half orbit specified in the file name.
4-15	Undefined	N/A	N/A

antenna_scan_time
Number of seconds in the J2000 epoch for each antenna rotation interpolated to antenna scan angle of 0 degrees.

antenna_scan_time_utc
UTC time stamp for each antenna rotation when antenna scan angle is 0 degrees.

footprints_per_scan
Number of brightness temperature footprints acquired in the current scan.

pitch
SC pitch interpolated to antenna scan angle of 0 degrees.

roll
SC roll interpolated to antenna scan angle of 0 degrees.

sc_alongtrack_velocity
Spacecraft velocity in the direction of the spacecraft orbital track interpolated to antenna scan angle of 0 degrees.

sc_geodetic_alt_ellipsoid
Spacecraft altitude above Earth WGS84 reference ellipsoid along the nadir track interpolated to antenna scan angle of 0 degrees.

sc_nadir_angle
The angle defined by the spacecraft geodetic nadir vector and the negative Z axis of the spacecraft coordinate system at each instance when the antenna scan angle is 0 degrees.

sc_nadir_lat
Spacecraft latitude along nadir track interpolated to antenna scan angle of 0 degrees.

sc_nadir_lon
Spacecraft longitude along nadir track interpolated to antenna scan angle of 0 degrees.

sc_radial_velocity
Spacecraft velocity in the direction of the radius of the orbital track. Velocity that records change in altitude.

tbs_per_scan
Number of brightness temperature footprints acquired in the current scan.

x_pos
SC position in x direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

x_vel
SC velocity in x direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

y_pos
SC position in y direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

y_vel
SC velocity in y direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

yaw
SC yaw interpolated to antenna scan angle of 0 degrees.

z_pos

SC position in z direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

z_vel

SC velocity in z direction of Earth Centered Rotating system interpolated to antenna scan angle of 0 degrees.

Fill/Gap Values

Fill values appear in the SMAP Level-1B brightness temperature product in any of the following circumstances:

- No measured data for the maximum possible number of footprints. The total number of radiometer science packets per antenna scan varies depending on the antenna rotation rate and integration time of the instrument. The resulting number of antenna footprints per scan is therefore variable. To preserve the shape of stored data elements, the size of certain dimensions is assigned a maximum value. Thus, fill values appear in the SMAP Level-1B brightness temperature product when a particular scan does not contain the maximum possible number of footprints.
- RFI detection algorithms flag all pixels which make up a footprint. High resolution radiometer instrument data contains radiometer counts which are integrated every approximately 300 Âµs per PRI and every 1 ms per packet. These radiometer counts are calibrated to produce antenna temperatures referenced to the feedhorn. The antenna temperatures are then processed by RFI detection and mitigation algorithms where the pixels for a footprint that are flagged for RFI are removed and the remaining clean pixels are averaged to form an RFI free antenna footprint. If all pixels for a particular footprint are flagged for RFI, then the footprint TA is assigned the null value. The corresponding footprint brightness temperature, brightness temperature value will also be assigned the null value since the RFI-free antenna footprint TAs are used to produce the time-ordered brightness temperature product. Subsequently, after pixels with RFI are flagged and dropped, the remaining clean pixels are used to compute the NEDT for that footprint. If all pixels are removed the null value is assigned to the NEDT for that footprint.
- The NEDT for the footprint after RFI removal is 0. A single pixel may be left after RFI removal. The product will contain an associated footprint TA and TB value; however the NEDT will be 0. The null value will be assigned to the NEDT value in this case but the corresponding TA and TB values will be reported.

SMAP data products employ a specific set of data values to connote that an element is fill. The selected values that represent fill are dependent on the data type.

No valid value in the Level-1B brightness temperature product is equal to the values that represent fill. If any exceptions should exist in the future, the Level-1B brightness temperature content will provide a means for users to discern between elements that contain fill and elements that contain genuine data values. This document will also contain a description of the method used to ascertain which elements are fill and which elements are genuine.

The Level-1B brightness temperature product records gaps when entire frames within the time span of a particular data granule do not appear. Gaps can occur under one of two conditions:

- One or more complete frames of data are missing from all data streams.
- The subset of input data that is available for a particular frame is not sufficient to process any frame output.

The Level-1B brightness temperature product records gaps in the product-level metadata. The following conditions will indicate that no gaps appear in the data product:

- Only one instance of the attributes *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* will appear in the product metadata.
- The character string stored in metadata element *Extent/rangeBeginningDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStartDateTime*.
- The character string stored in metadata element *Extent/rangeEndingDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStopDateTime*.

One of two conditions will indicate that gaps appear in the data product:

- The time period covered between *Extent/rangeBeginningDateTime* and *Extent/RangeEndingDateTime* does not cover the entire half orbit as specified in *OrbitMeasuredLocation/halfOrbitStartDateTime* and *OrbitMeasuredLocation/halfOrbitStartDateTime*.
- More than one pair of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* appears in the data product. Time periods within the time span of the half orbit that do not fall within the sets of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* constitute data gaps.

Bit flag elements in the Level-1B brightness temperature product often provide additional information about missing data. For example, the data element *tb_v* in the Level-1B brightness temperature product is associated with bit flags that indicate the quality of data for each footprint. Each of the *tb_qual_flag_v* variables indicates the quality of the data in each footprint. When a data frame is deemed unusable, the appropriate bits in the *tb_qual_flag_v* should indicate the rationale.

If data values associated with any particular footprint of the radiometer instrument creates untenable algorithmic conditions, the Level-1B brightness temperature Science Production Software (SPS) may curtail processing for that footprint. When these conditions take place, the Level-1B brightness temperature product displays whatever values the SPS was able to calculate. When a *tb_v* measure for a particular footprint has been deemed unusable, the appropriate bits in the *tb_qual_flag_v* will provide users with a rationale for the missing data.

Acronyms and Abbreviations

Table A12. Acronyms and Abbreviations

Abbreviation	**Definition**
ABFCS	Antenna Beam Frame Coordinate System
ATBD	Algorithm Theoretical Basis Document
Char	8-bit character
Int8	8-bit (1-byte) signed integer
Int16	16-bit (2-byte) signed integer
Int32	32-bit (4-byte) signed integer
ET	Ephemeris Time
Float32	32-bit (4-byte) floating-point integer
Float64	64-bit (8-byte) floating-point integer
H-pol	Horizontally polarized
N/A	Not Applicable
NEDT	Noise Equivalent Delta Temperature
PRI	Pulse Repetition Interval
RFI	Radio Frequency Interference
SI	International System of Units
SPS	Science Production Software
TA	Antenna Temperature
TB	Brightness Temperature
Uint8	8-bit (1-byte) unsigned integer
Uint16	16-bit (2-byte) unsigned integer
UTC	Universal Coordinated Time
V-pol	Vertically polarized