Soil Moisture Active Passive (SMAP) Project

Level 1B_TB
Product Specification Document

Revision B

Prepared by:

Priscilla Mohammed-Tano — 05/04/2016 — Date

Priscilla Mohammed-Tano
SMAP Algorithm Development Team for
SMAP L1B_TB Data Product

Approved by:

5/4/16 — Date

Jeffrey Piepmeier
Radiometer Instrument Scientist

4-27-16 — Date

David Cuddy
SMAP SDS Systems Engineer

4-26-16 — Date

Maher Hanna
SMAP SDS Project Element Manager

4-27-16 — Date

Simon Yueh
SMAP Project Scientist

Concurred by:

4/22/16 — Date

Elias Sayfi
SMAP SDS Systems Engineer

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March 31, 2016
D-92339

JPL
Jet Propulsion Laboratory
California Institute of Technology

DOCUMENT CHANGE LOG

Revision	Date	Sections Changed	Reason for Change
-	12 Aug 2014		Initial Release
A	20 Jul 2015	3.2	New Section describes Spacecraft Attitude and Modeling Spacecraft Slews
A	20 Jul 2015	4.2	Updated product data volume estimates
A	20 Jul 2015	4.4	Added paragraph that describes metadata elements that contain MD5 checksums for ISO XML files
A	20 Jul 2015	4.4	Added polygonPosList, westBoundLongitude, eastBoundLongitude, southBoundLatitude and northBoundLatitude to the Extent Metadata
A	20 Jul 2015	4.4	Added taFilteredDifferenceThreshold to the ProcessStep Metadata
A	20 Jul 2015	4.4	Added/modified longName and ECSVersionID to the SeriesIdentification Metadata
A	20 Jul 2015	4.5.1, 4.6.2, 4.6.3	Modified the antenna_scan_mode_flag and the antenna_scan_qual_flag in the Spacecraft Data Group
A	20 Jul 2015	4.5.2, 4.6.36	Added the highresolution_scan_index to the High Resolution Calibration Data Group

A	20 Jul 2015	4.5.3, 4.6.45, 4.6.46	Corrected specifications for cal_temp12_radome and cal_temp1_reflector in the Calibration Data Group
A	20 Jul 2015	4.5.4, 4.6.64, 4.6.66	Added specular_declination and specular_right_ascension to the Brightness Temperature Data Group
A	20 Jul 2015	4.5.4, 4.6.83, 4.6.84, 4.6.85, 4.6.86	Added toi_v, toi_h, toi_3 and toi_4 to the Brightness Temperature Data Group
A	20 Jul 2015	4.5.4, 4.6.79, 4.6.80, 4.6.81, 4.6.82	Added toa_v, toa_h, toa_3 and toa_4 to the Brightness Temperature Data Group.
A	20 Jul 2015	4.5.4, 4.6.146	Added tb_upwelling to the Brightness Temperature Data Group
A	20 Jul 2015	4.5.4, 4.6.124	Removed atm_loss_v and atm_loss_h. Added atm_loss in their place.
A	20 Jul 2015	4.5.4, 4.6.129	Removed surface_water_fraction_sidelobe from the Brightness Temperature Data Group. Retained surface_water_fraction_mb.
A	20 Jul 2015	4.5.4, 4.6.132, 4.6.133	Modified earth_boresight_azimuth and antenna_earth_azimuth in the Brightness Temperature Data Group
A	20 Jul 2015	4.5.4, 4.6.141, 4.6.142, 4.6.143, 4.6.144	Modified tb_qual_flag_v, tb_qual_flag_h, tb_qual_flag_3 and tb_qual_flag_4 in the Brightness Temperature Data Group
A	20 Jul 2015	4.5.4, 4.6.140	Added sea_ice_fraction to the Brightness Temperature Data

			Group
A	20 Jul 2015	4.6.69	Modified description of tb_3 to account for all zero value.
A	20 Jul 2015	4.6.122, 4.6.123	Valid_min for atm_correction_v and atm_correction_h is 0.
B	25 March 2016	4.6.94	Updated max angle to 99.9 for solar_specular_theta
B	25 March 2016	3.1, 3.2, 4.6.7, 4.6.8, 4.6.17, Appendix F	Updated descriptions of Spacecraft Attitude, yaw, pitch, roll

TBD LOG

Section/Page	Description	Due Date
Appendix E	References the other Product Specification Documents. None have been written at the time of this publication. Thus, dates of publication are not available. In some cases, document identifiers are not available as well.	2/13/14

1 INTRODUCTION

1.1 Identification

This is the Product Specification Document (PSD) for Level 1B_TB data for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The Level 1B_TB product provides calibrated estimates of time-ordered geolocated brightness temperatures, T_B, within the main beam. Brightness temperatures are referenced to the Earth's surface with radiometric error sources removed. Radiometric error sources include Faraday rotation, antenna sidelobes and spillover, solar radiation, cosmic microwave background and galactic emission. This document applies to any standard Level 1B_TB product acquired by the SMAP radiometer instrument.

1.2 Scope

This Product Specification Document describes the file format of the Level 1B_TB Product. Its intent is to elucidate the Level 1B_TB data structure and content for external software interfaces. The SMAP Science Data Management and Archive Plan provides a more comprehensive explanation of these data within the complete context of the SMAP instrument, algorithms, and software.

1.3 The SMAP Experiment

The Soil Moisture Active Passive (SMAP) mission will enhance the accuracy and the resolution of space-based measurements of terrestrial soil moisture and freeze-thaw state. SMAP data products will have a noteworthy impact on multiple relevant and current Earth Science endeavors. These include:

- Understanding of the processes that link the terrestrial water, the energy and the carbon cycles,
- Estimations of global water and energy fluxes over the land surfaces,
- Quantification of the net carbon flux in boreal landscapes
- Forecast skill of both weather and climate,
- Predictions and monitoring of natural disasters including floods, landslides and droughts, and
- Predictions of agricultural productivity.

To provide these data, the SMAP mission will deploy a satellite observatory in a near polar, sun synchronous orbit. The observatory contains an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments will share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath.

As the spacecraft flies from north to south on *descending* orbits, the SMAP instruments will view Earth locations at approximately 06:00 local time. As the spacecraft flies from south to north, on *ascending* orbits, the SMAP instruments will view Earth locations at approximately 18:00 local time. The spacecraft will operate in a cycle of 117 repeatable orbits.

Each time that the spacecraft repeats the orbit cycle, the nadir path on the Earth's surface may not vary by more than 20 km. The flight plan enables scientists to collect data over any region of the Earth over seasonal and annual cycles and avoid diurnal variations. The combined flight pattern and viewing design will enable the observatory to view almost all of the Earth's land mass once every three days.

The SMAP radiometer records microwave emissions from the top 5 cm in the soil with a spatial resolution of about 40 km. Scientific applications based on radiometer measure in the same frequency range have established this approach as an accurate means to detect the presence or water in near surface soil. SMAP radar will provide backscatter measurements at 3 km resolution. The combined instrumentation will enable SMAP to generate highly accurate global soil moistures at 9 km resolution.

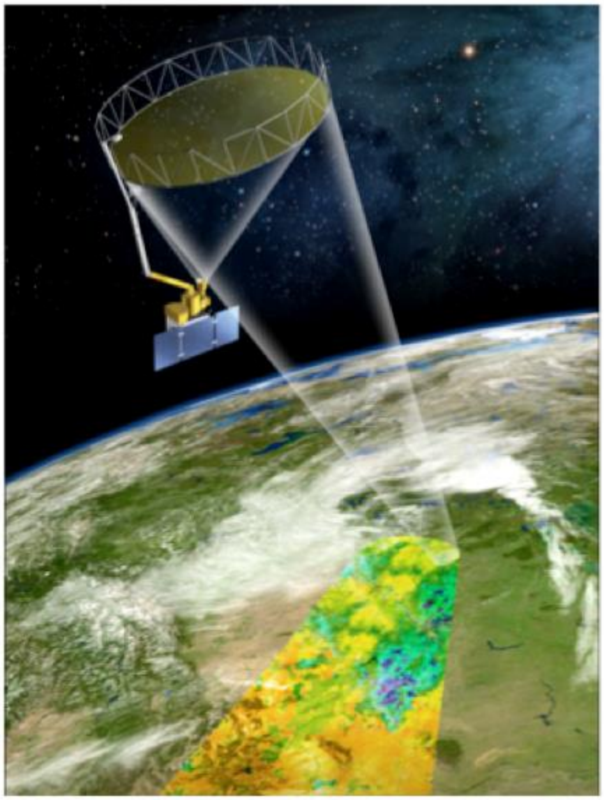

Figure 1: Artist's Concept of SMAP Observatory

Geophysical retrievals based on SMAP radar will indicate the presence of standing water, the freeze/thaw condition of the surface as well as measures of surface roughness and vegetation. The additional information will enable SMAP processors to select appropriate locations for soil moisture retrievals and modeling. In addition, the freeze/thaw data will contribute to models that measure the Net Ecosystem Exchange (NEE) of carbon between the Earth's surface and the atmosphere in Boreal regions.

1.4 SMAP Data Products

The SMAP mission will generate 15 different distributable data products. The products represent four levels of data processing. Level 1 products contain instrument related data. Level 1 products appear in granules that are based on half orbits of the SMAP satellite. The Northernmost and Southernmost orbit locations demarcate half orbit boundaries. Level 2 products contain output from geophysical retrievals that are based on instrument data. Level 2 products also appear in half orbit granules. Level 3 products contain global output of the Level 2 geophysical retrievals for an entire day. Level 4 products contain output from geophysical models that employ SMAP data.

Table 1 lists the distributable SMAP data products. The colors in the table categorize the products by level. The table specifies two sets of short names. The SMAP Mission product short names were adopted by the SMAP mission to identify products. Users will find those short names in SMAP mission documentation, SMAP product file names and in the product metadata. The Data Centers will use short names defined for the Earth Observing System Data and Information System (EOSDIS) Core System (ECS). These short names categorize data products in local databases managed by the ECS. ECS short names will also appear in SMAP product metadata.

SMAP Mission Product Short Name	ECS Short Names	Description
L1A_Radar	SPL1AA	Parsed Radar Instrument Telemetry
L1A_Radiometer	SPL1AP	Parsed Radiometer Instrument Telemetry
L1B_S0_LoRes	SPL1BS0	Low Resolution Radar σ_o in Time Order
L1C_S0_HiRes	SPL1CS0	High Resolution Radar σ_o on Swath Grid
L1B_TB	SPL1BTB	Radiometer T_B in Time Order
L1C_TB	SPL1CTB	Radiometer T_B
L2_SM_A	SPL2SMA	Radar Soil Moisture, includes Freeze/Thaw State
L2_SM_P	SPL2SMP	Radiometer Soil Moisture
L2_SM_AP	SPL2SMAP	Active-Passive Soil Moisture
L3_FT_A	SPL3FTA	Daily Global Composite Freeze/Thaw State
L3_SM_A	SPL3SMA	Daily Global Composite Radar Soil Moisture
L3_SM_P	SPL3SMP	Daily Global Composite Radiometer Soil Moisture
L3_SM_AP	SPL3SMAP	Daily Global Composite Active-Passive Soil Moisture
L4_SM	SPL4TSM	Surface and Root Zone Soil Moisture
L4_C	SPL4C	Carbon Net Ecosystem Exchange

Table 1: SMAP Data Products

1.5 Content Overview

The SMAP Level 1B_TB data product contains a time-ordered geolocated series of calibrated brightness temperatures within the main beam referenced to the Earth's surface as well as measurements of the third and fourth Stokes parameters. The SMAP mission distributes this data product in half orbit granules. The northernmost and southernmost locations on the SMAP spacecraft path demarcate granule boundaries.

SMAP orbits begin at the southernmost point on the orbit path. The SMAP spacecraft will launch into orbit 0. Orbit 1 will begin as the spacecraft crosses the southernmost location for the first time. The SMAP radiometer instrument gathers instrument data whenever the instrument is on. Based on acquired thermal emissions from the Earth's surface, the radiometer performs sub-channelization, cross-correlation for measurement of the 3rd and 4th Stokes parameters, as well as detection and integration of the first four raw moments of the horizontal and vertical polarization signals. These data are packetized and sent to the ground for calibration and further processing.

The SMAP Level 1B_TB data product contains calibrated antenna temperatures (TAs) which have been processed by radio frequency interference detection and mitigation algorithms. The RFI filtered antenna temperatures are further processed to remove the effects the antenna sidelobes outside the radiometer antenna main beam, cross-polarizations, Faraday rotation, atmospheric effects (excluding rain) and solar, galactic and cosmic radiation. The resulting data are surface-references brightness temperatures (TBs).

1.6 Related SMAP Project Documents

SMAP L1B_TB Algorithm Theoretical Basis Document, J. Piepmeier, GSFC SMAP-ALGMS-RPT-0026, August, 2014.

SMAP Science Data Management and Archive Plan, JPL D-45973, August 29, 2011.

SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems, JPL D-46018, Revision B, April 15, 2014

1.7 Applicable Documents

ISO 19115:2003(E) International Standard – Geographic Information – Metadata, May 1, 2003.

ISO 19115-2:2009 International Standard – Geographic Information – Part 2:Extensions for imagery and gridded data, December 12, 2009.

ISO 19139:2007 International Standard – Geographic Information – Metadata – XML schema implementation, May 14 2009.

Introduction to HDF5, The HDF Group, http://www.hdfgroup.org/HDF5/doc/H5.intro.html.

HDF5: API Specification Reference Manual, The HDF Group http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Front.html

HDF5 User's Guide Release 1.8.9, The HDF Group, http://hdfgroup.com/HDF5/doc/UG, May 2012.

NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, December 5, 2011.

2 DATA PRODUCT ORGANIZATION

2.1 File Format

All SMAP standard products are in the Hierarchical Data Format version 5 (HDF5). HDF5 is a general purpose file format and programming library for storing scientific data. The National Center for Supercomputing Applications (NCSA) at the University of Illinois developed HDF to help scientists share data regardless of the source. Use of the HDF library enables users to read HDF files on multiple platforms regardless of the architecture the platforms use to represent integer and floating point numbers. HDF files are equally accessible to routines written either in Fortran, C or C++.

A spin-off organization of the NCSA, named The HDF Group, is responsible for development and maintenance of HDF. Users should reference The HDF Group website at http://www.hdfgroup.org to download HDF software and documentation.

2.2 HDF5 Notation

HDF5 represents a significant departure from the conventions of previous versions of HDF. The changes that appear in HDF5 provide flexibility to overcome many of the limitations of previous releases. The basic building blocks have been largely redefined, and are more powerful but less numerous. The key concepts of the HDF5 Abstract Data Model are Files, Groups, Datasets, Datatypes, Attributes and Property Lists. The following sections provide a brief description of each of these key HDF5 concepts.

2.2.1 HDF5 File

A File is the abstract representation of a physical data file. Files are containers for HDF5 Objects. These Objects include Groups, Datasets, and Datatypes.

2.2.2 HDF5 Group

Groups provide a means to organize the HDF5 Objects in HDF5 Files. Groups are containers for other Objects, including Datasets, named Datatypes and other Groups. In that sense, groups are analogous to directories that are used to categorize and classify files in standard operating systems.

The notation for files is identical to the notation used for Unix directories. The root Group is "/". A Group contained in root might be called "/myGroup." Like Unix directories, Objects appear in Groups through "links". Thus, the same Object can simultaneously be in multiple Groups.

2.2.3 HDF5 Dataset

The Dataset is the HDF5 component that stores user data. Each Dataset associates with a Dataspace that describes the data dimensions, as well as a Datatype that describes the basic unit of storage element. A Dataset can also have Attributes.

2.2.4 HDF5 Datatype

A Datatype describes a unit of data storage for Datasets and Attributes. Datatypes are subdivided into Atomic and Composite Types.

Atomic Datatypes are analogous to simple basic types in most programming languages. HDF5 Atomic Datatypes include Time, Bitfield, String, Reference, Opaque, Integer, and Float. Each atomic type has a specific set of properties. Examples of the properties associated with Atomic Datatypes are:

- Integers are assigned size, precision, offset, pad byte order, and are designated as signed or unsigned.
- Strings can be fixed or variable length, and may or may not be null-terminated.

- References are constructs within HDF5 Files that point to other HDF5 Objects in the same file.

HDF5 provides a large set of predefined Atomic Datatypes. Table 2 lists the Atomic Datatypes that are used in SMAP data products.

Table 2: HDF5 Atomic Datatypes

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	unsigned, 8-bit, little-endian integer
H5T_STD_U16LE	unsigned, 16-bit, little-endian integer
H5T_STD_U32LE	unsigned, 32-bit, little-endian integer
H5T_STD_U64LE	unsigned, 64-bit, little-endian integer
H5T_STD_I8LE	signed, 8-bit, little-endian integer
H5T_STD_I16LE	signed, 16-bit, little-endian integer
H5T_STD_I32LE	signed, 32-bit, little-endian integer
H5T_STD_I64LE	Signed, 64-bit, little-endian integer
H5T_IEEE_F32LE	32-bit, little-endian, IEEE floating point
H5T_IEEE_F64LE	64-bit, little-endian, IEEE floating point
H5T_C_S1	character string made up of one or more bytes

Composite Datatypes incorporate sets of Atomic datatypes. Composite Datatypes include Array, Enumeration, Variable Length and Compound.

- The Array Datatype defines a multi-dimensional array that can be accessed atomically.
- Variable Length presents a 1-D array element of variable length. Variable Length Datatypes are useful as building blocks of ragged arrays.
- Compound Datatypes are composed of named fields, each of which may be dissimilar Datatypes. Compound Datatypes are conceptually equivalent to structures in the C programming language.

Named Datatypes are explicitly stored as Objects within an HDF5 File. Named Datatypes provide a means to share Datatypes among Objects. Datatypes that are not explicitly stored as Named Datatypes are stored implicitly. They are stored separately for each Dataset or Attribute they describe.

None of the SMAP data products employ Enumeration or Compound data types.

2.2.5 HDF5 Dataspace

A Dataspace describes the rank and dimension of a Dataset or Attribute. For example, a “Scalar” Dataspace has a rank of 1 and a dimension of 1. Thus, all subsequent references to “Scalar” Dataspace in this document imply a single dimensional array with a single element.

Dataspaces provide considerable flexibility to HDF5 products. They incorporate the means to subset associated Datasets along any or all of their dimensions. When associated with specific properties, Dataspaces also provide the means for Datasets to expand as the application requires.

2.2.6 HDF5 Attribute

An Attribute is a small aggregate of data that describes Groups or Datasets. Like Datasets, Attributes are also associated with a particular Dataspace and Datatype. Attributes cannot be subsetted or extended. Attributes themselves cannot have Attributes.

2.3 SMAP File Organization

2.3.1 Structure

SMAP data products follow a common convention for all HDF5 Files. Use of this convention provides uniformity of data access and interpretation.

The SMAP Project uses HDF5 Groups to provide an additional level of data organization. All metadata that pertain to the complete data granule are members of the “/Metadata” Group. All other data are organized within Groups that are designed specifically to handle the structure and content of each particular data product.

2.3.2 Data

All data in HDF5 files are stored in individual Datasets. All of the Datasets in an SMAP product are assigned to an HDF5 Group. A standard field name is associated with each Dataset. The field name is a unique string identifier. The field name corresponds to the name of the data element the Dataset stores. This document lists these names with the description of each data element that they identify.

Each Dataset is associated with an HDF5 Dataspace and an HDF5 Datatype. They provide a minimally sufficient set of parameters for reading the data using standard HDF5 tools.

2.3.3 Element Types

SMAP HDF5 employs the Data Attribute “Type” to classify every data field as a specific data type. The “Type” is an embellishment upon the standard HDF5 Datatypes that is designed specifically to configure SMAP data products.

Table 3 lists all of the “Type” strings that appear in the SMAP data products. The table maps each SMAP “Type” to a specific HDF5 Datatype in both the HDF5 file and in the data buffer. The table also specifies the common conceptual data type that corresponds to the “Type” in SMAP executable code.

Table 3: Element Type Definitions

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
Unsigned8	H5T_STD_U8LE	H5T_NATIVE_UCHAR	unsigned integer
Unsigned16	H5T_STD_U16LE	H5T_NATIVE_USHORT	unsigned integer
Unsigned24	H5T_STD_U16LE, with precision set to 24 bits, and size set to 3 bytes.	H5T_NATIVE_INT	unsigned integer
Unsigned32	H5T_STD_U32LE	H5T_NATIVE_UINT	unsigned integer
Unsigned64	H5T_STD_U64LE	H5T_NATIVE_ULLONG	unsigned integer
Signed8	H5T_STD_I8LE	H5T_NATIVE_SCHAR	signed integer
Signed16	H5T_STD_I16LE	H5T_NATIVE_SHORT	signed integer
Signed32	H5T_STD_I32LE	H5T_NATIVE_INT	signed integer
Signed64	H5T_STD_I64LE	H5T_NATIVE_LLONG	signed

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
			integer
Float32	H5T_IEEE_F32LE	H5T_NATIVE_FLOAT	floating point
Float64	H5T_IEEE_F64LE	H5T_NATIVE_DOUBLE	floating point
FixLenStr	H5T_C_S1	H5T_NATIVE_CHAR	character string
VarLenStr	H5T_C_S1, where the length is set to H5T_VARIABLE	H5T_NATIVE_CHAR	character string

SMAP HDF5 files employ two different types of string representation. "VarLenStr" are strings of variable length. "VarLenStr" provides greater flexibility to represent character strings. In an effort to make SMAP HDF5 more friendly to users who wish to use netCDF software, SMAP products restrict the use of "VarLenStr". "FixLenStr" are strings with a prescribed fixed-length. "FixLenStr" are useful for fixed length strings that are stored in large multi-dimension array. UTC time stamps are an excellent example of the type of data that store well in a "FixLenStr".

2.3.4 File Level Metadata

All metadata that describe the full content of each granule of the SMAP data product are stored within the explicitly named "/Metadata" Group. SMAP metadata are handled using exactly the same procedures as those that are used to handle SMAP data. The contents of each Attribute that stores metadata conform to one of the SMAP Types. Like data, each metadata element is also assigned a shape. Most metadata elements are stored as scalars. A few metadata elements are stored as arrays.

SMAP data products represent file level metadata in two forms. One form appears in one or more Attributes within the Metadata Group. Combined, those Attributes contain a complete representation of the product metadata. The content conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

The second form of the metadata appears in a set of HDF5 Groups under the "/Metadata" Group. Each of these HDF5 Groups represents one of the major classes in the ISO 19115-2 model. These HDF5 Groups contain a set of HDF5 Attributes. Each HDF5 Attributes represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the iSO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

2.3.5 Local Metadata

SMAP standards incorporate additional metadata that describe each HDF5 Dataset within the HDF5 file. Each of these metadata elements appear in an HDF5 Attribute that is directly associated with the HDF5 Dataset. Wherever possible, these HDF5 Attributes employ names that conform to the Climate and Forecast (CF) conventions. Table 4 lists the CF names for the HDF5 Attributes that SMAP products typically employ.

Table 4: SMAP Specific Local Attributes

CF Compliant Attribute Name	Description	Required?
units	Units of measure. Appendix E lists applicable units for various data elements in this product.	Yes
valid_max	The largest valid value for any element in the Dataset. The data type in valid_max matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_max will also be float32.	No
valid_min	The smallest valid value for any element in the Dataset. The data type in valid_min matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_min will also be float32.	No
_FillValue	Specification of the value that will appear in the Dataset when an element is missing or undefined. The data type of _FillValue matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding _FillValue will also be float32.	Yes for all numeric data types
long_name	A descriptive name that clearly describes	Yes

CF Compliant Attribute Name	Description	Required?
	the content of the associated Dataset.	
coordinates	Identifies auxiliary coordinate variables in the data product.	No
flag_values	Provides a list of flag values that appear in bit flag variables. Should be used in conjunction with local HDF5 attribute *flag_meanings*. Only appears with bit flag variables.	No
flag_masks	Provides a list of bit fields that express Boolean or enumerated flags. Only appears with bit flag variables or enumerated data types.	No
flag_meanings	Provides descriptive words or phrases for each potential bit flag value. Should be used in conjunction with local HDF5 attribute *flag_values*.	No

2.4 Data Definition Standards

Section 4.6 of this document specifies the characteristics and definitions of every data element stored in this SMAP data product. Table 5 defines each of the specific characteristics that are listed in that section of this document. Some of these characteristics correspond with the SMAP HDF5 Attributes that are associated with each Dataset. Data element characteristics that correspond to SMAP HDF5 Attributes bear the same name. The remaining characteristics are descriptive data that help users better understand the data product content.

In some situations, a standard characteristic may not apply to a data element. In those cases, the field contains the character string 'n/a'. Hexadecimal representation sometimes indicates data content more clearly. Numbers represented in hexadecimal begin with the character string '0x'.

Table 5: Data Element Characteristic Definitions

Characteristic	Definition
Type	The data representation of the element within the storage medium. The storage class specification must conform to a valid SMAP type. The first column in table 3 lists all of the valid values

Characteristic	Definition
	that correspond to this characteristic.
Shape	The name of the shape data element that specifies the rank and dimension of a particular data set. Appendix C lists all of the valid shapes that appear in this data product.
Valid_max	The expected minimum value for a data element. In most instances, data element values never fall below this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that fall below this limit.
Valid_min	The expected maximum value for a data element. In most instances, data element values never exceed this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that exceed this limit.
Valid Values	Some data elements may store a restricted set of values. In those instances, this listing specifies the values that the data element may store.
Nominal Value	Some data elements have an expected value. In those instances, this listing provides that expected value. Nominal values are particularly common among a subset of the metadata elements.
String Length	This characteristic specifies the length of the data string that represents a single instance of the data element. This characteristic appears exclusively for data elements of FixLenStr type.
Units	Units of measure. Typical values include “deg”, “degC”, “Kelvin”, “meters/second”, “meters”, “m**2”, “seconds” and “counts”. Appendix A and Appendix E include references to important data measurement unit symbols.

2.4.1 Double Precision Time Variables

SMAP double precision time variables contain measurements relative to the J2000 epoch. Thus, these variables represent a real number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC.

2.4.2 Array Representation

This document employs array notation to demonstrate and clarify the correspondence among data elements in different product data elements. The array notation adopted in this document is similar to the standards of the Fortran programming language. Indices are one based. Thus, the first index in each dimension is one. This convention is unlike C or C++, where the initial index in each dimension is zero. In multidimensional arrays, the leftmost subscript index changes most rapidly. Thus, in this document, array elements ARRAY(15,1,5) and ARRAY(16,1,5) are stored contiguously.

HDF5 is designed to read data seamlessly regardless of the computer language used to write an application. Thus, elements that are contiguous using the dimension notation in this document will appear in contiguous locations in arrays for reading applications in any language with an HDF5 interface.

This document differentiates among array indices based on relative contiguity of storage of elements referenced with consecutive numbers in that index position. A faster or fastest moving index implies that the elements with consecutive numbers in that index position are stored in relative proximity in memory. A slower or slowest moving index implies that the elements referenced with consecutive indices are stored more remotely in memory. For instance, given array element ARRAY(15,1,5) in Fortran, the first index is the fastest moving index and the third index is the slowest moving index. On the other hand, given array element array[4][0][14] in C, the first index is the slowest moving index and the third index is the fastest moving index.

3 INTERFACE CHARACTERISTICS

3.1 Coordinate Systems

The SMAP mission will use the Science Orbit Reference Frame (SRF) and the Instrument Fixed Coordinate System (INFS) and the Earth Centered Rotating (ECR) coordinate systems to represent spacecraft attitude, position and relative motion.

The Science Orbit Reference Frame (SRF) is a right-handed coordinate system with its three axes mutually orthogonal. The SRF is defined such that the origin is at the spacecraft center of mass (CM). The +Z axis points toward Geodetic Nadir. The +X axis is coplanar with both the +Z axis and the spacecraft inertial velocity vector. The +X axis points along the inertial spacecraft velocity. The +Y axis completes the right-handed, orthogonal coordinate system. The +Y axis is normal to the orbit plane with positive sense in the direction opposite the orbit angular momentum vector; the +Y axis points in the direction of the anti-sun. Due to the oblateness of the Earth, the vector from the spacecraft to the geometric center of the Earth (Geocentric Nadir) is different from the vector from the spacecraft to the local WGS84 ellipsoid normal (Geodetic Nadir). The SRF is independent from the orientation of the spacecraft and corresponds to the ideal Science Reference attitude.

The Instrument Fixed Coordinate System (INFS) is a right-handed coordinate system with its three axes mutually orthogonal. The INSF has its origin at the intersection of the spin axis and the spacecraft top deck. The +X axis is directed toward from the center of the bus toward the stowed reflector side of the bus; under nominal operations, it closely adheres to the spacecraft inertial velocity vector.

The INSF is rotated 180 deg from the SRF around the SRF’s X axis, so that the sign of the Y and Z axis is the INSF is opposite the sign of those axis in the SRF. Furthermore, the INSF is offset from the SRF by small angles around the Y and X axis (see “SMAP spacecraft frame definitions kernel” for details and full discussion and figure 1 for a depiction of the nominal layout of these reference frames). The INSF is the “true” dynamic representation of the orientation of the SMAP spacecraft at any given time.

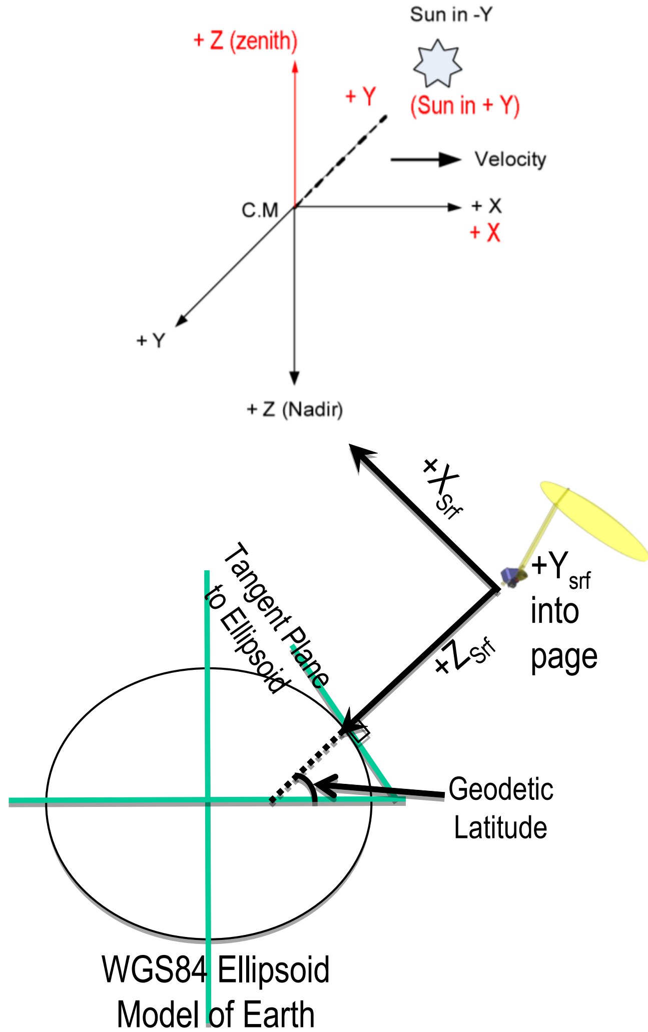

Figure 2: The Science Orbit Reference Frame Coordinate System (SRF, in black) and the Instrument Fixed Coordinate System (INFS, in red) under nominal conditions.

The Earth Centered Rotating (ECR) or Earth Centered Fixed coordinate system is a right-handed coordinate system with three mutually orthogonal axes. The origin of the system is the Earth's center of mass. The positive x-axis extends from the origin through the intersection of the Equator and the Greenwich Meridian at coordinates (0, 0) deg. The positive z-axis extends directly North from the origin of the ECR system. Due to a slight wobbling of the Earth, the z-axis does not coincide exactly with the instantaneous rotation axis of the Earth. The y-axis completes the right-handed coordinate system as a vector from the origin to the intersection of the Equator and 90° East longitude.

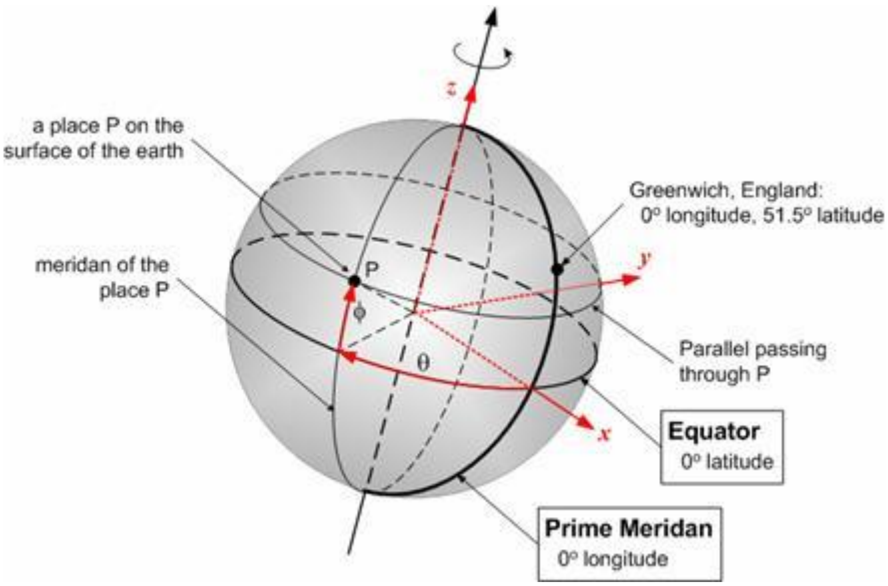

Figure 3: Earth Centered Rotating Coordinate System

The SMAP mission adopted the World Reference System WGS84 ellipsoid to define the horizontal Earth reference coordinates. The WGS84 geoid was adopted as the vertical Earth reference coordinates. Geodetic measure is used to define both the spacecraft location and the instrument target location relative to the Earth's surface.

3.2 Spacecraft Attitude

The SMAP SDS receives spacecraft attitude data on a regular basis from the Navigation and Ancillary Information Facility (NAIF) at JPL. Upon arrival from NAIF, these data specify the orientation of the Spacecraft Coordinate System with respect to J2000 coordinates. The NAIF data are represented in quaternions.

The attitude angles (pitch, roll and yaw) of the spacecraft are referred to the Science Orbit Reference Frame (SRF). They are measured in a counterclockwise direction and should be depicted as the angles between the SRF and the INSF. A slight offset (measured before launch) between the INSF and the Spacecraft Coordinate system (SC) is included in the values of pitch, roll and yaw. The SC is equivalent to the SRF defined above, except that the SRF's +Z axis points toward Nadir (the SC's points toward Zenith) and the +/- Y axes are switched.

The attitude angles are measured in a counterclockwise direction (as seen from the origin of the axes looking toward the positive ends) around the rotation axis.

Because of the unfortunate choice of definitions for the INSF and SRF, the common definition of euler angles would yield large values for pitch and for roll (about 180 deg). The angles are therefore defined to be the angle, measured counterclockwise from each one of the SRF axis, to the corresponding INSF axis AFTER THE SRF HAS BEEN ROTATED 180 deg AROUND THE SRF's +X AXIS.

- The pitch angle is the rotation around the +Y axis, with positive values indicating that the +X axis moves toward the +Z direction. The pitch angle is 0 when the +X axis of the INSF is aligned with the tangent to the orbit path and the nominal velocity vector. For +90 deg pitch, +X and +Z change place, and +Z and –X change place. A passenger standing on the SMAP would experience a positive pitch angle as a raising of the SMAP 'nose'.
- The roll angle is the rotation around the +X axis, with positive values indicating that the +Z axis moves toward the +Y direction. The roll angle is 0 when the Y axis of the INSF is perpendicular to the plane of the orbit and the +Z axis points to zenith. For +90 deg roll, +Z and +Y change place, and +Y and –Z change place. A passenger standing on the SMAP would experience a positive roll angle as a tilting of the SMAP to port.
- The yaw angle is the rotation around the +Z axis, with positive values indicating that the +Y axis moves toward the +X direction. The yaw angle is 0 when the +X axis of the INSF is pointed along the nominal velocity vector. For +90 deg yaw, +Y and +X change place, and +X and –Y change place. A passenger standing on the SMAP would experience a positive yaw angle as a pointing of the SMAP to the right of the orbital track.

The Science Orbit Reference Frame (SRF) and the Instrument Fixed Frame (INSF) and the Spacecraft Coordinate (SC) systems are defined and fully described in the SMAP Pointing, Positioning, Phasing and Coordinate System Volume 0, Revision B, April 15, 2014

During nominal operations, the pitch, yaw and roll angles will be very small. Indeed, in order to retain anticipated incidence angles for radar and radiometer measure, these angles will almost always be less than 1 degree. The order of rotation that users should employ is pitch, followed by roll and then yaw. A brief worked example is provided in Section 11 (appendix G)

3.3 Fill and Gap Values

SMAP data products employ fill and gap values to indicate when no valid data appear in a particular data element. Fill values ensure that data elements retain the correct shape. Gap values locate portions of a data stream that do not appear in the output data file.

Fill values appear in the SMAP L1B_TB 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 L1B_TB product when a particular scan does not contain the maximum possible number of footprints.
- RFI detection algorithms flag all pixels that make up a footprint. High resolution radiometer instrument data contains radiometer counts which are integrated every ~300 µs per Pulse Repetition Interval (PRI) and every ~1 ms per packet. These radiometer counts are calibrated to produce antenna temperatures (TAs) that are referenced to the feedhorn. The TAs are then processed by RFI detection and mitigation algorithms. These algorithms flag and remove pixels that meet specific critieria in any given footprint for RFI. The algorithm then averages the remaining clean pixels 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, TB value will also be assigned the null value. Subsequently, after pixels with RFI are flagged and dropped, the remaining clean pixels are used to compute the Noise Equivalent Delta Temperature (NEDT) for that footprint. If all pixels are removed a null value is also assigned to the NEDT for that footprint.
- A single pixel remains in the footprint after RFI removal. The product will contain an associated footprint TA and TB value. For user clarity, the software assigns the NEDT a null value under this condition. 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. Table 6 lists the values that represent fill in SMAP products based on data type:

Table 6: SMAP Product Fill Values

Type	Value	Pattern
Float32, Float64	-9999.0	Large, negative number

Type	Value	Pattern
Signed8, NormSigned8	-127	Type minimum + 1
Signed16, NormSigned16	-32767	Type minimum + 1
Signed24	-8388607	Type minimum + 1
Signed32	-2147483647	Type minimum + 1
Signed64	-9223372036854775807	Type minimum + 1
Unsigned8	254	Type maximum - 1
Unsigned16	65534	Type maximum - 1
Unsigned24	16777214	Type maximum - 1
Unsigned32	4294967294	Type maximum - 1
Unsigned64	18446744073709551614	Type maximum - 1
FixedLenString, VarLenString	N/A	Not available

No valid value in the L1B_TB product is equal to the values that represent fill. If any exceptions should exist in the future, the L1B_TB 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 L1B_TB 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 L1B_TB 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 L1B_TB product often provide additional information about missing data. For example, the data element *tb_v* in the L1B_TB product contains 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.

In addition, each of the *tb_qual_flag* variables include a bit that indicates whether one of the brightness temperature values for any particular footprint are null. Thus, if the bit assigned for null value specification in the *tb_qual_flag_v* is set with a value of 1, users may assume that no value exists for the vertical polarization brightness temperature in the associated footprint.

If data values associated with any particular look of the radiometer instrument creates untenable algorithmic conditions, the L1B_TB SPS may curtail processing for that look. When these conditions take place, the L1B_TB 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.

3.4 Flexible Data Design

HDF5 format gives the SMAP Level Products a high degree of flexibility. This flexibility in turn gives SMAP end product users the capability to write software that does not need to be modified to accommodate unforeseeable changes in the SMAP products. Since changes to the products are certain to take place over the life of the SMAP mission, users are encouraged to use software techniques that take advantage of some of the features in HDF5.

For example, users can write a product reader that selects only those product data elements they wish to read from an SMAP Level Product file. With the appropriate design, this software will not need to change, regardless of the number, the size, or the order of the current data product entries. Indeed, the only changes users need to implement would take place if they should choose to read a newly defined data element after a product upgrade.

For those users who wish to extract a specific subset of the data from an SMAP Product, the HDF5 routines H5Dopen and H5Dread (h5dopen_f and h5dread_f in FORTRAN) are very useful. H5Dopen requires two input parameters, the first is an HDF5 file/group identifier, the second is a character string that contains the name of a Dataset. H5Dopen returns the identifier for the specified Dataset in the product file. HDF5 routine H5Dread then uses the Dataset identifier to fetch the contents. H5Dread places the contents of the Dataset in a specified output variable.

Once the data element is located and read, users can generate standardized code that reads the metadata associated with each element. Users of the SMAP Level Products should employ the same methods to read metadata and standard data elements.

3.5 Access to Product Element Dimensions

Each data element in every SMAP data product is assigned a specific shape. Elements with the same shape have the same number of dimensions, and each of those dimensions have the same extent and meaning. Thus, if two data elements have the same shape, then their constituent array elements with identical indices correspond.

The SMAP L1B_TB Product employs a naming convention for shapes. The convention specifies the component dimensions. The final word in all shape names is always “Array”. The text that precedes the word “Array” provides the order of dimensions. The word that just precedes “Array” represents the dimension with the “fastest moving” index. In other words, consecutive indices in this dimension, provided the other dimension indices are identical, represent contiguous storage. For example, the Shape name AntennaScan_Tb_Array implies that the dimension where consecutive indices imply contiguous storage represents brightness temperatures TBs. The other, slower moving, dimension represents antenna scans. Appendix C provides the nominal rank and dimension sizes for each shape that appears in the L1B_TB Product.

Appendix D provides the nominal or expected maximum product dimensions.

Appendix F contains an example of code that reads dimensions for a particular data element directly from the L1B_TB Radiometer product.

4 DATA DEFINITION

4.1 Product Overview

4.1.1 Level 1B_TB Product

Each Level 1B_TB product granule incorporates all of the radiometer data that were downlinked from the SMAP spacecraft for one specific half orbit. The SMAP project delineates half orbits at the northernmost and southernmost point of each orbit path.

The major contents of the Level 1B_TB product include:

- Fullband and subband calibration coefficients. Among these coefficients are instrument component losses, noise temperatures, physical temperatures, and phase values.
- Antenna temperatures (TAs), calibrated to the feedhorn before and after RFI detection and mitigation.
- Brightness temperatures (TBs) referenced to the surface of the Earth with error sources removed as well as error source values and brightness temperature error and NEDT. These values are included for both horizontal and vertical polarization as well as the 3rd and 4th Stokes parameters.
- Geolocation and time information for each footprint brightness temperature.

Elements in the Level 1B_TB product appear in time order.

Ancillary data elements in the product provide measures of data acquisition time and geometry as well as data quality.

4.1.2 Level 1B_TB Metadata

The SMAP Level 1B_TB metadata are representative of the entire contents of the file. The metadata appear in two forms. One form of the metadata appears in single HDF5 Attribute. That Attribute contains the complete representation of the product metadata that conforms to the ISO 19115-2 model in ISO 19139 compliant XML. The second form of the metadata appears in a set of HDF5 groups. Each HDF5 group contains a set of HDF5 attributes. The arrangement and names of the groups and their attribute components approximate major contents of the ISO model.

Metadata in ISO 19139 conformant XML enables users who are familiar with the ISO metadata standards to extract the metadata they need using software that operates with the ISO 19115-2 model and its formal representation. The set of groups and attributes enable users who are not as familiar with the ISO standard to find the particular metadata elements they need to better comprehend product content and format.

4.1.3 Level 1B_TB Data

All product elements in the Level 1B_TB Product are stored as HDF5 Datasets. Each of these datasets belongs to one of three distinct HDF5 Groups. The data design employs HDF5 Groups to categorize datasets that have corresponding array elements and that relate to a common application.

The HDF5 Groups in the Level 1B_TB product include the Spacecraft Data Group, the High Resolution Calibration Data Group, the Calibration Data Group and the Brightness Temperature Group. Section 4.5 of this document includes more detailed descriptions of each of the HDF5 Groups in the data product.

All of the Level 1B_TB HDF5 Groups are organized relative to the SMAP antenna scan. The single array index for all data elements in the Spacecraft Data Group denotes the representative position of the spacecraft for each antenna scan. This single index in the Spacecraft Data Group corresponds to the slowest moving index for all elements in all the Data Groups. Within each data granule, the time the spacecraft flew over any given antenna scan is a monotonically increasing function of the antenna scan index. Thus, a smaller antenna scan index represents an antenna scan that took place earlier during flight. A larger antenna scan index represents an antenna scan that took place later during flight.

4.2 Data Volume Estimates

L-band anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate radiometer measurements. Early measurements and results from the 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. To combat this, the SMAP radiometer will implement 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. Data elements associated with subbands are used to track and enable RFI detection and mitigation. Since RFI is expected to be significantly less over the ocean, the algorithm does not require frequency diversity over this region. Thus, with one major exception, the High Resolution Calibration Data Group is not included for data collected over the ocean.

The radiometer team employs a select region over the tropical Pacific for data calibration and validation. Since effective calibration and validation require the subband data, the High Resolution Calibration Data Group does appear for data acquired in this select ocean region.

Table 7 provides users with an estimated average uncompressed volume of L1B_TB products. The volumetric estimate assumes an entire half orbit where land covers about 30% of the region that the spacecraft overflew. The table specifies the contribution of each of the HDF5 data Groups to the total data volume of the product. The final row in each table provides an estimate of the volume of an average data granule.

Table 7: Data Volume Estimates for Data Acquired at 06:00 Local Time

Group	Number of Entries	Bytes Per Entry	Expected Total Volume (MBytes)
Level 1B_TB Metadata	1	10000	0.010
XML Version of ISO Metadata	1	124000	0.124
Spacecraft Data Group	640	100	0.064
High Resolution Calibration Group	192	1290	0.275
Calibration Group	640	140	0.090
Brightness Temperature Group	193274	370	71.511
Level 1B_TB			72.075

4.3 SMAP Level 1B_TB Product File Names

Distributable SMAP L1B_TB data product file names are 50 characters in length. The first 5 characters in the name of all mission distributable products are ‘SMAP_’. These characters identify all products generated by the SMAP mission. The following 7 characters are always ‘L1B_TB_’. These characters identify the Level 1B_TB Science Data Product. The following 35 characters uniquely identify the data stored in the file. The final 3 characters of each SMAP Product file name are ‘.h5’. These characters specify the format of the data in the file.

More specifically, all SMAP Level 1B_TB data product file names must conform to the following convention:

SMAP_L1B_TB_[Orbit Number]_[A|D]_[First Date/Time Stamp]_[Composite Release ID]_[Product Counter].[extension]

The outline below describes the content of each field in the file naming convention:

Orbit Number – The sequential number of the orbit that the SMAP spacecraft flew when the data in the associated product were acquired. Orbit 0 will begin at launch. The orbit number must occupy five digits. Orbit numbers that are smaller than 10000 will appear with leading zeroes.

The Half Orbit Designator - SMAP divides orbits into two distinct parts. Division of half orbits takes place at the northernmost and southernmost point on the spacecraft path. Half orbits where the spacecraft moves from North to South are *descending* half orbits. Local time for measurements acquired during a *descending* half orbit is approximately 6 AM. The character "D" appears as the Half Orbit Designator in the file names of products that contain data representing *descending* half orbits. Half orbits where the spacecraft moves from South to North are classified as *ascending* half orbits. Local time for measurements acquired during an *ascending* half orbit is approximately 6 PM. The character "A" appears as the Half Orbit Designator in the file names of products that contain data represent *ascending* half orbits.

First Date/Time Stamp – The date/time stamp of the first data element that appears in the product. Date/time stamps in SMAP file names are always recorded in Universal Coordinated Time (UTC). Date/time stamps conform to the following convention:

YYYYMMDD**T**hhmmss

where:

YYYY is the calendar year. The full calendar year must appear in the file name.

MM designates the month of the year. The month designator always occupies two digits. Months that can be represented with fewer than two digits must employ a leading zero.

DD designates the day of the month. The day designator always occupies two digits. Days of the month that can be represented with fewer than two digits must employ a leading zero.

T delineates the date from the time, and is a required character in all time stamps in product names.

hh designates the hour of the day on a 24 hour clock in UTC. The hour designator always occupies two digits. Hours that can be represented with fewer than two digits must employ a leading zero.

mm designates the minute of the hour in UTC. The minute designator always occupies two digits. Minutes that can be represented with fewer than two digits must employ leading zeroes.

ss designates the truncated second of the minute in UTC. Fractional second specification is not necessary in file names. The second designator always occupies two digits. Seconds that can be represented with fewer than two digits must employ leading zeroes.

Composite Release ID – The Composite Release ID incorporates changes to any processing condition that might impact product results. The format of the Composite Release ID is as follows:

"R"	The character "R" always precedes this identifier
Launch indicator	Distinguishes between pre-launch or pre-instrument commissioned data and data generated under mission operation conditions. A launch indicator of "0" implies the data are simulated or acquired under early mission conditions that exempt the content from mission requirements. A launch indicator of "1" implies the data are acquired by the instrument at or after the time of instrument commissioning, and must therefore meet mission requirements.
Major ID	One digit that indicate major releases. Major changes in algorithm or processing approach will generate an update to this identifier.
Minor ID	Three digits that indicate minor releases. Any change to any component that impacts data processing, such as algorithm, software or parameters will lead to a change in this identifier.

Product Counter – Files that represent the same half orbit of any particular product type may be generated multiple times. In some instances, the same half orbit may be processed multiple times using the same version of the software. This counter tracks the number of times that a particular product type for a specific half orbit was generated under the same Composite Release ID. The system assigns the first instance of a file that represents a half orbit of a particular Composite Release ID and product type with a Product Counter of 001. The system assigns each subsequent instance of the same half orbit, same Composite Release ID and same product type with the next consecutive integer. The Product Counter always occupies three digits. Product Counters that do not require three digits contain leading zeroes.

Extension – The extension for all SMAP L1B_TB data products is "h5". That extension indicates that the product contents are in HDF5 format. The SMAP SDS will generate a QA file with every data granule. The QA file contains statistical information that will enable users to better assess the quality of the associated granule. QA products bear exactly the same name as the products that they represent. The only difference in names is the extension. The extension for all QA products is ".qa".

Example File Names – Based on the above standard, the following name describes a simulated data product from pre-launch release 4 of the Level1B_TB data product that is labeled to cover the ascending half of orbit 934. The first data point acquired 7:49:51 UTC on December 25, 2014. The file represents the second time an L1B_TB product was generated for the ascending half of orbit 924:

`SMAP_L1B_TB_00934_A_20141225T074951_ R00400_002.h5`

The name of the QA product that assesses the output of the above L1B_TB granule would be:

`SMAP_L1B_TB_00934_A_20141225T074951_ R00400_002.qa`

4.4 Level 1B_TB Product Metadata

As mentioned in section 4.1.2, the metadata elements in the Level 1B_TB product appear in two forms. One form appears in one or more Attributes within the Metadata Group. Combined, those Attributes contain a complete representation of the product metadata. The content conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

The second form of the metadata appears in a set of HDF5 groups under the Metadata Group. Each of these HDF5 Groups represents one of the major classes in the ISO structure. These groups contain a set of HDF5 attributes. Each HDF5 Attributes represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the ISO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

In addition, the Metadata group includes two attributes that contain MD5 checksums. These two checksum attributes specify the size of the two ISO metadata sets expressed in XML. Thus, *attribute iso_19139_dataset_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_dataset_xml*. Likewise, attribute *iso_19139_series_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_series_xml*.

Table 8 describes the subgroups of the Metadata group, and the attributes within each group. The first column of table 8 specifies a major class in the ISO 19115 metadata model. The second column provides the name of the HDF5 Group under "/Metadata" where attributes associated with the corresponding class will appear. The third column lists the names of the subgroups and attributes where specific metadata values appear. The fourth column provides valid values for each element. Constant values appear with no diacritical marks. Variable values are encapsulated by brackets <>. All of the metadata elements that appear in table 8 should also appear in every Level 1B_TB Product file.

Table 8: Granule Level Metadata in the L1B_TB Product

ISO Major Class	SMAP HDF5 Metadata SubGroup	Subgroup/Attribute in SMAP HDF5	Valid Values

DQ_DataQuality	DataQualiity	Scope	tb_v, tb_h
		CompletenssOmission/evaluationMethodType	directInternal
		CompletenessOmission/measureDescription	Percent of radiometer footprints in the product relative to the expected number of footprints that the radiometer should acquire based on the instrument pulse rate and the time period covered by a spacecraft half orbit.
		CompletenessOmission/nameOfMeasure	Percent of Missing Data
		CompletenessOmission/value	<A measure between 0 and 100>
		CompletenessOmission/unitOfMeasure	Percent
		RFICompletenssOmission/evaluationMethodType	directInternal
		RFICompletenessOmission/measureDescription	Percent of the radiometer footprints where RFI was detected and the algorithm was unable to remove the RFI contamination relative to the expected number of footprints that the radiometer would acquire based on the instrument pulse rate and the time period covered by a spacecraft half orbit.
		RFICompletenessOmission/nameOfMeasure	Percent of Data Missing Due to Radio Frequency Interference (RFI)

		RFICompletenessOmission/value	<A measure between 0 and 100>
		RFICompletenessOmission/unitOfMeasure	Percent
		SubbandCompletenssOmission/evaluationMethodType	directInternal
		SubbandCompletenessOmission/measureDescription	Percent of sub-band radiometer footprints in the product relative to the expected number of sub-band footprints that the radiometer should acquire based on the instrument pulse rate and the time period covered by a spacecraft half orbit.
		SubbandCompletenessOmission/nameOfMeasure	Percent of Sub-band Data
		SubbandCompletenessOmission/value	<A measure between 0 and 100>
		SubbandCompletenessOmission/unitOfMeasure	Percent
		domainConsistency/evaluationMethodType	directInternal
		DomainConsistency/measureDescription	Percent of brightness temperature measures in the data product that fall within a predefined acceptable range of measure.
		DomainConsistency/nameOfMeasure	Percent of Brightness Temperatures that fall within Acceptable Range

		DomainConsistency/value	<A measure between 0 and 100>
		DomainConsistency/unitOfMeasure	Percent
EX_Extent	Extent	description	The SMAP spacecraft downlinks radiometer data over a 1000 km wide swath. Data acquired over land or over identified external calibration sources are classed as high resolution and contain sub-band information. Data acquired over ocean are classed as low resolution and are limited to full band data.
		polygonPosList	<An array of vertices of a polygon the defines the region occupied by the data set in the corresponding data product. Each vertex is represented by an ordered pair. Latitudes precede longitudes. Vertices appear in clockwise order. Spaces delineate each value.>
		westBoundLongitude	<Longitude measure between -180 degrees and 179.999 degrees>
		eastBoundLongitude	<Longitude measure between -180 degrees and 179.999 degrees>
		southBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		northBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		rangeBeginningDateTime	<Time stamp that indicates the initial

			time element in the product>
		rangeEndingDateTime	<Time stamp that indicates the final time of data in the product.>
LI_Lineage/LE_ProcessStep	ProcessStep	processor	Soil Moisture Active Passive (SMAP) Mission Science Data System (SDS) Operations Facility
		stepDateTime	< A date time stamp that specifies when the product was generated.>
		processDescription	Converts instrument telemetry into a data set that contains horizontal polarization brightness temperatures, vertical polarization brightness temperatures as well as third and fourth Stokes parameters for each discrete instantaneous field of view acquired by the SMAP radiometer.
		documentation	<A reference to software description document.>
		identifier	L1B_TB_SPS
		RFIThreshold	<Specify any run time parameters if they were used.>
		taFilteredDifferenceThreshold	<Threshold value between ta and ta_filtered the signals inability to completely remove RFI contamination for brightness temperature measure.>
		SWVersionID	<A software version identifier that

			runs from 001 to 999>
		softwareDate	<A date stamp that specifies when software used to generate this product was released.>
		softwareTitle	L1B_TB_SPS
		timeVariableEpoch	J2000
		epochJulianDate	2451545.00
		epochUTCDate	2000-01-01T11:58:55.816Z
		ATBDTitle	Soil Moisture Active Passive (SMAP) L1B_TB Algorithm Theoretical Basis Document
		subBandDataPresent	Indicates whether subBand data are available in the data product. Value is either “True” or “False”.
		ATBDDate	<Time stamp that specifies the release date of the ATBD>
		ATBDVersion	<version identifier>
		algorithmDescription	The Soil Moisture Active Passive (SMAP) radiometer algorithm converts L0 radiometer digital count into calibrated estimates of brightness temperatures within the antenna main beam as referenced to the Earth's surface. Most algorithmic steps are typical implementation for satellite radiometers. The SMAP

			algorithm includes two key features that are new for satellite borne radiometers. These are algorithmic steps that detect and remove radio frequency interference (RFI) detection, as well as measurement of the third and fourth Stokes parameters using digital correlation.
		algorithmVersionID	<An algorithm version identifier that runs from 001 to 999>
LI_Lineage/LE_Source	L1A_Radiometer. Ephemeris. Attitude, Antenna Azimuth. SCLK-UTC Correlation, GMAO_Inst3, SolarRadioFlux, DirectGalaxyLUT, ReflectedGalaxyLUT, ReflectedSunLUT, AntennaPattern, LeapSeconds, Reconstructed High Resolution Earth Orientation, FullbandCoeffs, SubBandCoeffs, LinearCoeffs, RFIParameters, RFIKurtosisParameter, AntennaPatternCorrection, SurfaceWaterFraction, SeaSurfaceTemperature, SeaIceFraction	description	<Description of each of the lineage products that contribute to generation of the output.>
		fileName	<Complete file name of the input data product>
		creationDate	<A date stamp that specifies when the input data product was generated.>
		version	<The SMAP Composite Version ID associated with the input data product.>
		identifier	<The short name associated with the product.>
		DOI	<A digital object identifier associated with the product, if available>

DS_Dataset/MD_DataIdentification	DataSetIdentification	creationDate	<Date when the L1B_TB data product file was created>
		CompositeReleaseID	<SMAP Composite Release ID associated with this data product – See section 4.3>
		fileName	<Name of the L1B_TB output data file.>
		originatorOrganizationName	Jet Propulsion Laboratory
		shortName	SPL1BTB
		SMAPShortName	L1B_TB
		UUID	<A universally unique identifier for each data granule.>
		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>
		abstract	Time ordered geolocated horizontal polarization and vertical polarization brightness temperatures as well as third and fourth Stokes parameters. Each product covers a half orbit with boundaries at the northernmost and southernmost points along the nadir path of the SMAP spacecraft trajectory.
		purpose	The SMAP L1B_TB Science Processing Software generates data

			products with sufficient accuracy to retrieve soil moisture at 36 km resolution. Subsequent SMAP processes employ these data, along with radar data acquired simultaneously, to disaggregate the L1B_TB brightness temperatures into higher resolution samples, and thus generate higher resolution soil moisture products.
		characterSet	utf8
		credit	The software that generates the Level 1B_TB product was designed and at the Goddard Space Flight Center in Greenbelt, Maryland. The software was implemented at the Goddard Space Flight Facility as well as at the Jet Propulsion Laboratory, California Institute of Technology, in Pasadena, California. The data system that automates its production was designed and implemented at the Jet Propulsion Laboratory.
		language	eng
		purpose	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
		status	onGoing

		spatialRepresentationType	vector
		topicCategory	geoscientificInformation
DS_Dataset/MD_DataIdentification/MD_AggregateInformation	QADatasetIdentification	creationDate	<The date that the QA product that accompanies the L1B_TB data granule was generated.>
		fileName	<The name of QA product.>
		abstract	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
DS_Series/MD_DataIdentification	SeriesIdentification	revisionDate	<Date and time of the software release that was used to generate this data product.>
		CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product – See section 4.3>
		longName	SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures
		shortName	SPL1BTB
		identifier_product_DOI	http://dx.doi.orgn/10.5067/1V33MVRRLCCT

		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>
		resourceProviderOrganizationName	National Aeronautics and Space Administration
		abstract	Time ordered geolocated horizontal polarization and vertical polarization brightness temperatures as well as third and fourth Stokes parameters. Each product covers a half orbit with boundaries at the northernmost and southernmost points along the nadir path of the SMAP spacecraft trajectory.
		purpose	The SMAP L1B_TB Science Processing Software generates data products with sufficient accuracy to retrieve soil moisture at 36 km resolution. Subsequent SMAP processes employ these data, along with radar data acquired simultaneously, to disaggregate the L1B_TB brightness temperatures into higher resolution samples, and thus generate higher resolution soil moisture products.
		characterSet	utf8
		credit	The software that generates the Level 1B_TB product was designed and at the Goddard Space Flight Center in Greenbelt, Maryland. The software was implemented at the

			Goddard Space Flight Facility as well as at the Jet Propulsion Laboratory, California Institute of Technology, in Pasadena, California. The data system that automates its production was designed and implemented at the Jet Propulsion Laboratory.
		language	eng
		status	onGoing
		spatialRepresentationType	vector
		topicCategory	geoscientificInformation
		pointOfContact	National Snow and Ice Data Center, Boulder, Colorado
		mission	Soil Moisture Active Passive (SMAP)
		maintenanceAndUpdateFrequency	asNeeded
		maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
		format	HDF5
		formatVersion	1.8.11
		language	eng
		characterSet	utf8
		publicationDate	<Date of publication of the Product

			Specification Document>
	ProductSpecificationDocument	edition	<Edition identifier for the Product Specification Document>
		title	Soil Moisture Active Passive Mission L1B_TB Product Specification Document
		SMAPShortName	L1B_TB
MD_AcquisitionInformation	AcquisitionInformation	platform/antennaRotationRate	14.6 rpm OR 13.0 rpm
		platformDocument/publicationDate	<The date of publication of the document that describes the SMAP platform, if available to the general public>
		platformDocument/edition	<The edition of publication of the document that describes the SMAP platform, if available to the general public.>
		platformDocument/title	<The title of the publication of the document that describes the SMAP platform, if available to the general public.>
		platform/description	The SMAP observatory houses an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath. The bus is a 3 axis stabilized spacecraft

			that provides momentum compensation for the rotating antenna.
		platform/identifier	SMAP
		radarDocument/publicationDate	<The date of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/edition	<The edition of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/title	<The title of the publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radar/description	The SMAP radar instrument employs an L-band conically scanned system and SAR processing techniques to achieve moderate resolution (1 km) backscatter measurements over a very wide 1000 km swath.
		radar/identifier	SMAP SAR
		radar/type	L-band Synthetic Aperture Radar
		radiometerDocument/publicationDate	<The date of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>

		radiometerDocument/edition	<The edition of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/title	<The title of the publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometer/description	The SMAP L-band Radiometer records V-pol, H-pol, 3rd and 4th Stokes brightness temperatures at 40 km resolution at 4.3 Megatbits per second with accuracies of 1.3 Kelvin or better.
		radiometer/identifier	SMAP RAD
		radiometer/type	L-band Radiometer
		argumentOfPerigee	<The angle in the satellite's orbit plane between the point of perigee and ascending node. The angle is measured in the direction of spacecraft motion.>
		cycleNumber	<The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies the cycle of orbits when the data were taken. First cycle is assigned the number 1.>

		eccentricity	<The eccentricity of the satellite orbit.>
		epoch	<The effective time of the data in the OrbitMeasuredLocation class. This may be identical to the equatorCrossingDateTime.>
		equatorCrossingDateTime	<A time stamp that specifies the date and time of ascending node crossing for the current orbit.>
		equatorCrossingLongitude	<The longitude of the ascending node crossing for the current orbit.>
		inclination	<The angle between the spacecraft's orbital plane and the Earth's equatorial plane. An angle greater than 90 degrees indicates a orbit retrograde path.>
		meanMotion	<The constant angular speed that would be required for a body travelling in an undisturbed elliptical orbit with the specified semi-major axis to complete one revolution in the actual orbital period, expressed as a number of revolutions per day.>
		orbitDirection	<SMAP Level 1 and Level 2 products appear in half orbit granules. This element provides direction of orbital path relative to equatorial plane. Values are "ascending" or "descending":>

		halfOrbitStartDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the beginning of the half orbit.>
		halfOrbitStopDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the end of the half orbit.>
		orbitPathNumber	< The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies which of the 117 possible paths the spacecraft flew when the data in the file were acquired. The orbitPathNumber varies from 1 to 117.>
		orbitPeriod	<Time required to complete a the spacecraft orbit.>
		reference_CRS	<A description of the coordinate reference system used to describe spacecraft orbital data.>
		revNumber	<The count of orbits from beginning of mission to the orbit that the spacecraft flew when the data in the file were acquired. Orbit zero begins at launch and extends until the spacecraft crosses the southernmost point in its path for the first time.

			Orbit one commences at that instant.>
		rightAscensionAscendingNode	<The angle eastward on the equatorial plan from the vernal equinox to the orbit ascending node.>
		semiMajorAxis	<The length of the semi-major axis of the spacecraft orbit.>

[1] The metadata will allocate a group for each input data set that requires provenance tracking. The most critical ones listed in this document are those that are likely to vary from one orbit granule to the next. The metadata will track and list additional files for user information.

4.5 Data Structure

4.5.1 Spacecraft Data Group

The Spacecraft Data contain elements that specify either geometric or geographic information that are representative of each entire antenna scan of the instrument swath that appear in the Level 1B_TB product. All of the product elements in the Spacecraft Data Group are stored in a single HDF5 Group named "/Spacecraft_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 9 lists all of the elements in the Spacecraft Data Group.

All the HDF5 Datasets 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 9: The Spacecraft Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
antenna_scan_time	Float64	AntennaScan_Array	0	946000000	seconds
antenna_scan_time_utc	FixedLenString	AntennaScan_Array	n/a	n/a	n/a
antenna_scan_mode_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
antenna_scan_qual_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a
sc_nadir_lat	Float32	AntennaScan_Array	-90	90	degrees
sc_nadir_lon	Float32	AntennaScan_Array	-180	179.999	degrees
sc_nadir_angle	Float32	AntennaScan_Array	0	180	degrees
sc_geodetic_alt_ellipsoid	Float32	AntennaScan_Array	650000	750000	meters
sc_alongtrack_velocity	Float32	AntennaScan_Array	-8000	8000	meters/second
sc_radial_velocity	Float32	AntennaScan_Array	-8000	8000	meters/second
x_pos	Float32	AntennaScan_Array	-9999999	9999999	meters
y_pos	Float32	AntennaScan_Array	-9999999	9999999	meters
z_pos	Float32	AntennaScan_Array	-9999999	9999999	meters
x_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
y_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
z_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
roll	Float32	AntennaScan_Array	-3.0	3.0	degrees
pitch	Float32	AntennaScan_Array	-3.0	3.0	degrees
yaw	Float32	AntennaScan_Array	-3.0	3.0	degrees

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
tbs_per_scan	Uint16	AntennaScan_Array	0	300	n/a
footprints_per_scan	Uint16	AntennaScan_Array	0	300	n/a

4.5.2 High Resolution Calibration Data Group

The High Resolution Calibration Data provides information about the instrument component losses and noise temperatures which the SMAP L1B_TB 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 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 10 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 3-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 10: The High Resolution Calibration Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
cal_loss5_diplexer16	Float32	HighResolutionScan_Subband_VHPol_Array	1	2	n/a
cal_loss4_coupler16	Float32	HighResolutionScan_Subband_VHPol_Array	1	2	n/a
cal_loss3_omt16	Float32	HighResolutionScan_Subband_VHPol_Array	1	2	n/a
cal_loss2_feed16	Float32	HighResolutionScan_Subband_Array	1	2	n/a
cal_tempref_offset16	Float32	HighResolutionScan_Subband_VHPol_Array	-1	1	Kelvin
cal_temp_nd16	Float32	HighResolutionScan_Subband_Array	253.15	313.15	Kelvin
cal_tnd16	Float32	HighResolutionScan_Subband_VHPol_Array	212	676	Kelvin
cal_tref16	Float32	HighResolutionScan_Subband_VHPol_Array	252.15	314.15	Kelvin

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
cal_nd_phase16	Float32	HighResolutionScan_Subband_Array	-π	π	radians
cal_temp_xnd16	Float32	HighResolutionScan_Subband_Array	253.15	313.15	Kelvin
cal_txnd16	Float32	HighResolutionScan_Subband_VHPol_Array	61	217	Kelvin
cal_xnd_phase16	Float32	HighResolutionScan_Subband_Array	-π	π	radians
cal_rx_phase16	Float32	HighResolutionScan_Subband_Array	-π	π	radians
calibration_time_seconds	Float64	HighResolutionScan_Array	0	946000000	seconds
highresolution_scan_index	Uint32	HighResolutionScan_Array	0	800	n/a

4.5.3 Calibration Data Group

The Calibration Data provides information about the instrument component losses and noise temperatures which the SMAP L1B_TB 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 11 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 2-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 11: The Calibration Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
cal_loss5_diplexer	Float32	AntennaScan_VHPol_Array	1	2	n/a
cal_loss4_coupler	Float32	AntennaScan_VHPol_Array	1	2	n/a
cal_loss3_omt	Float32	AntennaScan_VHPol_Array	1	2	n/a
cal_loss2_feed	Float32	AntennaScan_Array	1	2	n/a
cal_loss1_reflector	Float32	AntennaScan_VHPol_Array	1	2	n/a
cal_loss12_radome	Float32	AntennaScan_Array	1	2	n/a
cal_temp5_diplexer	Float32	AntennaScan_VHPol_Array	253.15	313.15	Kelvin

cal_temp4_coupler	Float32	AntennaScan_VHPol_Array	253.15	313.15	Kelvin
cal_temp3_omt	Float32	AntennaScan_VHPol_Array	253.15	313.15	Kelvin
cal_temp2_feed	Float32	AntennaScan_Array	253.15	313.15	Kelvin
cal_temp12_radome	Float32	AntennaScan_Array	110.0	260.0	Kelvin
cal_temp1_reflector	Float32	AntennaScan_VHPol_Array	330.0	400.0	Kelvin
cal_temp_ref	Float32	AntennaScan_VHPol_Array	253.15	313.15	Kelvin
cal_tempref_offset	Float32	AntennaScan_VHPol_Array	-1	1	Kelvin
cal_temp_nd	Float32	AntennaScan_Array	253.15	313.15	Kelvin
cal_tnd	Float32	AntennaScan_VHPol_Array	218	658	Kelvin
cal_tref	Float32	AntennaScan_VHPol_Array	252.15	314.15	Kelvin
cal_nd_phase	Float32	AntennaScan_Array	$-\pi$	π	radians
cal_temp_xnd	Float32	AntennaScan_Array	253.15	313.15	Kelvin
cal_txnd	Float32	AntennaScan_VHPol_Array	62	216	Kelvin
cal_xnd_phase	Float32	AntennaScan_Array	$-\pi$	π	radians
cal_rx_phase	Float32	AntennaScan_Array	$-\pi$	π	radians

4.5.4 Brightness Temperature Group

The Brightness Temperature 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 mitigation, error sources, quality flags, TB error and Noise Equivalent Delta Temperature (NEDT).

All of the product elements in the Brightness Temperature Group are stored in a single HDF5 Group named "/Brightness_Temperature_Group". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 12 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 2-dimensional array. The slowest moving dimension represents a particular antenna scan and the second dimension represents the footprint.

Table 12: The Brightness Temperature Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
tb_time_seconds	Float64	AntennaScan_Tb_Array	0	946000000	seconds
tb_time_utc	Char	AntennaScan_Tb_Array	n/a	n/a	n/a
tb_lat	Float32	AntennaScan_Tb_Array	-90	90	degrees
tb_lon	Float32	AntennaScan_Tb_Array	-180	179.999	degrees
tb_declination	Float32	AntennaScan_Tb_Array	-90	90	degrees

tb_right_ascension	Float32	AntennaScan_Tb_Array	0	359.999	degrees
specular_declination	Float32	AntennaScan_Tb_Array	-90	90	degrees
specular_right_ascension	Float32	AntennaScan_Tb_Array	0	359.999	degrees
tb_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
tb_surface_corrected_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
tb_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
tb_surface_corrected_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
tb_3	Float32	AntennaScan_Tb_Array	0	0	Kelvin
tb_4	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
ta_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
ta_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
ta_3	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
ta_4	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
toi_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
toi_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
toi_3	Float32	AntennaScan_Tb_Array	-50	50	Kelvin

toi_4	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
toa_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
toa_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
toa_3	Float32	AntennaScan_Tb_Array	0	0	Kelvin
toa_4	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
ta_filtered_v	Float32	AntennaScan_Tb_Array	0	340	Kelvin
ta_filtered_h	Float32	AntennaScan_Tb_Array	0	340	Kelvin
ta_filtered_3	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
ta_filtered_4	Float32	AntennaScan_Tb_Array	-50	50	Kelvin
solar_direct_phi	Float32	AntennaScan_Tb_Array	0	359.999	degrees
solar_direct_theta	Float32	AntennaScan_Tb_Array	0	180	degrees
solar_direct_correction_v	Float32	AntennaScan_Tb_Array	0	0.6	Kelvin
solar_direct_correction_h	Float32	AntennaScan_Tb_Array	0	0.6	Kelvin
solar_specular_lat	Float32	AntennaScan_Tb_Array	-90	90	degrees
solar_specular_lon	Float32	AntennaScan_Tb_Array	-180	179.999	degrees
solar_specular_phi	Float32	AntennaScan_Tb_Array	0	359.999	degrees
solar_specular_theta	Float32	AntennaScan_Tb_Array	0	99.9	degrees

solar_specular_reflection_coefficient_v	Float32	AntennaScan_Tb_Array	0	1	n/a
solar_specular_reflection_coefficient_h	Float32	AntennaScan_Tb_Array	0	1	n/a
solar_specular_correction_v	Float32	AntennaScan_Tb_Array	-0.5	1	Kelvin
solar_specular_correction_h	Float32	AntennaScan_Tb_Array	-0.5	1	Kelvin
solar_specular_correction_3	Float32	AntennaScan_Tb_Array	-0.5	1	Kelvin
solar_specular_correction_4	Float32	AntennaScan_Tb_Array	-0.5	1	Kelvin
lunar_direct_phi	Float32	AntennaScan_Tb_Array	0	359.999	degrees
lunar_direct_theta	Float32	AntennaScan_Tb_Array	0	180	degrees
lunar_specular_lat	Float32	AntennaScan_Tb_Array	-90	90	degrees
lunar_specular_lon	Float32	AntennaScan_Tb_Array	-180	179.999	degrees
lunar_specular_phi	Float32	AntennaScan_Tb_Array	0	359.999	degrees
lunar_specular_theta	Float32	AntennaScan_Tb_Array	0	180	degrees
lunar_specular_reflection_coefficient_v	Float32	AntennaScan_Tb_Array	0	1	n/a
lunar_specular_reflection_coefficient_h	Float32	AntennaScan_Tb_Array	0	1	n/a
lunar_specular_correction_v	Float32	AntennaScan_Tb_Array	-0.2	2	Kelvin
lunar_specular_correction_h	Float32	AntennaScan_Tb_Array	-0.2	2	Kelvin
lunar_specular_correction_3	Float32	AntennaScan_Tb_Array	-0.2	2	Kelvin

lunar_specular_correction_4	Float32	AntennaScan_Tb_Array	-0.2	2	Kelvin
galactic_direct_correction_v	Float32	AntennaScan_Tb_Array	0.3	0.6	Kelvin
galactic_direct_correction_h	Float32	AntennaScan_Tb_Array	0.3	0.6	Kelvin
galactic_reflected_correction_v	Float32	AntennaScan_Tb_Array	-0.4	4	Kelvin
galactic_reflected_correction_h	Float32	AntennaScan_Tb_Array	-0.4	4	Kelvin
galactic_reflected_correction_3	Float32	AntennaScan_Tb_Array	-0.4	4	Kelvin
galactic_reflected_correction_4	Float32	AntennaScan_Tb_Array	-0.4	4	Kelvin
faraday_rotation_angle	Float32	AntennaScan_Tb_Array	-90.0	90.0	degrees
atm_correction_v	Float32	AntennaScan_Tb_Array	0	4	Kelvin
atm_correction_h	Float32	AntennaScan_Tb_Array	0	4	Kelvin
tb_upwelling	Float32	AntennaScan_Tb_Array	0	4	Kelvin
atm_loss	Float32	AntennaScan_Tb_Array	1	1.02	Kelvin
antenna_sideloble_correction_v	Float32	AntennaScan_Tb_Array	-0.5	6	Kelvin
antenna_sideloble_correction_h	Float32	AntennaScan_Tb_Array	-0.5	6	Kelvin
antenna_sideloble_correction_3	Float32	AntennaScan_Tb_Array	-0.5	6	Kelvin
antenna_sideloble_correction_4	Float32	AntennaScan_Tb_Array	-0.5	6	Kelvin
faraday_rotation_correction_v	Float32	AntennaScan_Tb_Array	-3.9	5.6	Kelvin

faraday_rotation_correction_h	Float32	AnntenaScan_Tb_Array	-3.9	5.6	Kelvin
footprint_surface_status	Uint16	AnntenaScan_Tb_Array	0	1	n/a
surface_water_fraction_mb_h	Float32	AntennaScan_Tb_Array	0	1	n/a
surface_water_fraction_mb_v	Float32	AntennaScan_Tb_Array	0	1	n/a
antenna_look_angle	Float32	AntennaScan_Tb_Array	0	180	degrees
antenna_scan_angle	Float32	AntennaScan_Tb_Array	0	359.999	degrees
earth_boresight_azimuth	Float32	AntennaScan_Tb_Array	0	359.999	degrees
earth_boresight_incidence	Float32	AntennaScan_Tb_Array	0	90	degrees
antenna_earth_azimuth	Float32	AntennaScan_Tb_Array	0	359.999	degrees
polarization_rotation_angle	Float32	AntennaScan_Tb_Array	0	90	degrees
tb_qual_flag_v	Bit flag	AntennaScan_Tb_Array	n/a	n/a	n/a
tb_qual_flag_h	Bit flag	AntennaScan_Tb_Array	n/a	n/a	n/a
tb_qual_flag_3	Bit flag	AntennaScan_Tb_Array	n/a	n/a	n/a
tb_qual_flag_4	Bit flag	AntennaScan_Tb_Array	n/a	n/a	n/a
tb_mode_flag	Bit flag	AntennaScan_Tb_Array	n/a	n/a	n/a
nedt_v	Float32	AntennaScan_Tb_Array	0.5	3	Kelvin
nedt_h	Float32	AntennaScan_Tb_Array	0.5	3	Kelvin

nedt_3	Float32	AntennaScan_Tb_Array	0.5	3	Kelvin
nedt_4	Float32	AntennaScan_Tb_Array	0.5	3	Kelvin
sea_ice_fraction	Float32	AntennaScan_Tb_Array	0.0	1.0	n/a
wind_direction_ancillary	Float32	AntennaScan_Tb_Array	0	359.999	degrees
wind_speed_ancillary	Float32	AntennaScan_Tb_Array	0.0	75.0	m/s

4.6 Element Definitions

4.6.1 antenna_scan_mode_flag

Bit flags that indicate operational conditions of the attitude and ephemeris telemetry and associated calculations at each instance when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

Table 13 specifies the meaning of individual bits in the *antenna_scan_mode_flag*:

Table 13: The antenna_scan_mode_flag

Bits	Value	Interpretation
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**

antenna_scan_mode_flag is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Units: n/a

4.6.2 antenna_scan_qual_flag

Bit flags that indicate the quality of the attitude, the ephemeris and the antenna pointing telemetry. The L1B_TB product contains calculated values for these measures at each instance when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

Table 14 specifies the meaning of individual bits in the *antenna_scan_qual_flag*:

Table 14: The antenna_scan_qual_flag

Bits	Value	Interpretation
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.

Bits	Value	Interpretation
	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**

antenna_scan_qual_flag is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Units: n/a

4.6.3 antenna_scan_time

The time for each antenna rotation interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system. Time values are counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch begins on January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC).

antenna_scan_time is a one-dimensional array. Each array index is representative of a specific cross antenna scan.

Type: Float64

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.6.4 antenna_scan_time_utc

The Universal Coordinated Time (UTC) for each antenna rotation. The representative time for each scan takes place when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system. For each antenna scan, the *antenna_scan_time_utc* records the same time instant as the *antenna_scan_time*. The *antenna_scan_time_utc* appears as an easily interpretable character string.

The format of the *antenna_scan_time_utc* is YYYY-MM-DDThh:mm:ss.dddZ, where YYYY represents the calendar year, MM represents the month of the year and DD represents the day of the month. The character 'T' demarcates the date from the time. hh represents the hour in twenty-four hour time, mm represents the minutes, ss represents the seconds, and ddd represents thousandths of a second. The character 'Z' designates Greenwich Mean Time. All numerical fields must occupy the allotted space. If any numerical value does not require the allotted space to represent the appropriate number, the field that specifies the number must contain leading zeroes.

antenna_scan_time_utc is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	FixLenStr
String Length:	24 characters
Group:	Spacecraft Data
Shape:	AlongTrack_Array
Valid_min:	'2014-10-31T00:00:00.000Z'
Valid_max:	'2030-12-31T23:59:60.999Z'
Units:	n/a

4.6.5 footprints_per_scan

The number of brightness temperature footprints based on the instrument pulse repetition interval (PRI) and the antenna rotation rate. For any given antenna scan, if the index of a particular footprint is greater than footprints_per_scan for that scan, then the contents of those array elements with that index should contain null values.

footprints_per_scan is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 300

Units: n/a

4.6.6 tbs_per_scan

The number of brightness temperature footprints output within each antenna scan. The number of footprints that provide valid brightness temperatures may be fewer than the value represented in footprints_per_scan. The variable tbs_per_scan provides the number of brightness temperatures that are deemed valid in each antenna scan.

tbs_per_scan is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 300

Units: n/a

4.6.7 pitch

The angular rotation of the spacecraft body about the Y axis of the Science Orbit Reference Frame (SRF). The pitch angle is 0 when the +X axis of the INSF is aligned with the tangent to the orbit path and the nominal velocity vector. For +90 degree pitch, +X and +Z change place, and +Z and –X change place. A passenger standing on the SMAP would experience a positive pitch angle as a raising of the SMAP ‘nose’.

The Y axis of the SRF is normal to the spacecraft orbital plane. Pitch values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Pitch is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -180

Valid_max: +180

Units: degrees

4.6.8 roll

The angular rotation of the spacecraft body about the X axis of the Science Orbit Reference Frame (SRF). The roll angle is 0 when the Y axis of the INSF is perpendicular to the plane of the orbit and the +Z axis points to zenith. For +90 degree roll, +Z and +Y change place, and +Y and –Z change place. A passenger standing on the SMAP would experience a positive roll angle as a tilting of the SMAP to port.

The X axis of the SRF approximates the direction of spacecraft motion. Roll values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Roll is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.9 sc_alongtrack_velocity

The instantaneous velocity of the SMAP spacecraft that is tangent to the spacecraft path within the orbital plane interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_alongtrack_velocity is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -8000

Valid_max: 8000

Units: meters/second

4.6.10 sc_geodetic_alt_ellipsoid

The geodetic altitude of the spacecraft above the Earth's reference ellipsoid interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_geodetic_alt_ellipsoid is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 650000

Valid_max: 750000

Units: meters

4.6.11 sc_nadir_lat

The geodetic latitude of the ground track position interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_nadir_lat is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.12 sc_nadir_lon

The longitude of the ground track position interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_nadir_lon is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-180
Valid_max:	179.999
Units:	degrees

4.6.13 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 boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_nadir_angle is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	0
Valid_max:	180
Units:	degrees

4.6.14 sc_radial_velocity

The velocity of the SMAP spacecraft in the direction of the vector that runs from the instantaneous spacecraft position to the center of the Earth interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

sc_radial_velocity is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-8000
Valid_max:	8000

Units: meters/second

4.6.15 x_pos

The spacecraft position in the X direction of the Earth Centered Rotating system interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

x_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.16 x_vel

The spacecraft velocity in the X direction of the Earth Centered Rotation system interpolated to when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

x_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-8000
Valid_max:	8000
Units:	meters/second

4.6.17 yaw

The angular rotation of the spacecraft body about the Z of the Science Orbit Reference Frame (SRF). The yaw angle is 0 when the +X axis of the INSF is pointed along the nominal velocity vector. For +90 degree yaw, +Y and +X change place, and +X and –Y change place. A passenger standing on the SMAP would experience a positive yaw angle as a pointing of the SMAP to the right of the orbital track.

The Z axis of the SRF runs from the center of mass of the spacecraft toward geodetic nadir. Yaw values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Yaw is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-180
Valid_max:	180
Units:	degrees

4.6.18 y_pos

The spacecraft position in the Y direction of the Earth Centered Rotating system interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

y_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.19 y_vel

The spacecraft velocity in the Y direction of the Earth Centered Rotation system interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

y_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array

Valid_min:	-8000
Valid_max:	8000
Units:	meters/second

4.6.20 z_pos

The spacecraft position in the Z direction of the Earth Centered Rotating system interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

z_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-9999999
Valid_max:	9999999
Units:	meters

4.6.21 z_vel

The spacecraft velocity in the Z direction of the Earth Centered Rotation system interpolated to the instant when the antenna boresight aligns with the X-axis of the SMAP spacecraft coordinate system.

z_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-8000
Valid_max:	8000
Units:	meters/second

4.6.22 calibration_time_seconds

The time for each antenna rotation containing high resolution calibration data interpolated to antenna boresight azimuth of 0 degrees. Time values are counts of International System (SI) seconds based on the J2000 epoch in Ephemeris

Time (ET). The J2000 epoch begins on January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC).

calibration_time_seconds is a one-dimensional array. Each array index is representative of a specific high resolution antenna scan.

Type:	Float64
Group:	High Resolution Calibration Data
Shape:	HighResolutionScan_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.6.23 cal_nd_phase16

The calibration model noise diode phase applied in the calibration of subband data.

cal_nd_phase16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type:	Float32
Group:	High Resolution Calibration Data
Shape:	HighResolutionScan_Subband_Array
Valid_min:	$-\pi$
Valid_max:	π
Units:	radians

4.6.24 cal_loss2_feed16

The loss factor attributed to the feedhorn applied in the calibration of subband data to obtain antenna temperature referenced to the feedhorn.

cal_loss2_feed16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type:	Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.25 cal_loss3_omt16

The loss factor attributed to the OMT (orthomode transducer) applied in the calibration of subband data to obtain antenna temperature referenced to the feedhorn.

cal_loss3_omt16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.26 cal_loss4_coupler16

The loss factor attributed to the coupler applied in the calibration of subband data to obtain antenna temperature referenced to the feedhorn.

cal_loss4_coupler16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.27 cal_loss5_diplexer16

The loss factor attributed to the diplexer applied in the calibration of subband data to obtain antenna temperature referenced to the feedhorn.

cal_loss5_diplexer16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.28 cal_rx_phase16

The calibration model receiver phase applied in the calibration of subband data.

cal_rx_phase16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_Array

Valid_min: $-\pi$

Valid_max: π

Units: radians

4.6.29 cal_temp_nd16

The calibration model physical temperature of the internal noise diode applied in the calibration of subband data.

cal_temp_nd16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_Array

Valid_min: 253.15

Valid_max: 313.15

Units: Kelvin

4.6.30 cal_tempref_offset16

The calibration model physical temperature offset of the reference load applied in the calibration of subband data. The brightness temperature of the reference load is the sum of its physical temperature and this offset.

cal_tempref_offset16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: -1

Valid_max: 1

Units: Kelvin

4.6.31 cal_temp_xnd16

The calibration model physical temperature of the external noise diode applied in the calibration of subband data.

cal_temp_xnd16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_Array

Valid_min: -253.15

Valid_max: 313.15

Units: Kelvin

4.6.32 cal_tnd16

The calibration model brightness temperature of the internal noise diode applied in the calibration of subband data.

cal_tnd16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 212

Valid_max: 676

Units: Kelvin

4.6.33 cal_tref16

The calibration model brightness temperature of the reference load applied in the calibration of subband data. This is the sum of the physical temperature of the reference load and its offset. The physical temperature of the reference load is stored in the Calibration Data Group since the same value is used for calibrating both fullband and subband data.

cal_tref16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 252.15

Valid_max: 314.15

Units: Kelvin

4.6.34 cal_txnd16

The calibration model brightness temperature of the external noise diode applied in the calibration of subband data.

cal_txnd16 is a 3-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands and the third is polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: High Resolution Subband Calibration Data

Shape: HighResolutionScan_Subband_VHPol_Array

Valid_min: 61

Valid_max: 217

Units: Kelvin

4.6.35 cal_xnd_phase16

The calibration model receiver external noise diode phase applied in the calibration of subband data.

cal_xnd_phase16 is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the 16 subbands.

Type: Float32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Subband_Array

Valid_min: $-\pi$

Valid_max: π

Units: radians

4.6.36 highresolution_scan_index

The *highresolution_scan_index* correlates the HighResolutionScan index of data elements in the High Resolution Calibration Data Group with the AntennaScan index of data elements in the Spacecraft Data Group, Calibration Data Group and Brightness Temperature Data Group of the L1B_TB Product. Thus, if *highresolution_scan_index[215]* = 450, then elements with a HighResolutionScan index of 215 in the High Resolution Calibration Data Group correlate to elements with an AntennaScan index of 450 in the other data groups of the L1B_TB product.

highresolution_scan_index is a one dimensional array. Each array index is representative of a specific high resolution antenna scan.

Type: Uint32

Group: High Resolution Calibration Data

Shape: HighResolutionScan_Array

Valid_min: 0

Valid_max: 800

Units: n/a

4.6.37 cal_nd_phase

The calibration model noise diode phase applied in the calibration of fullband data.

cal_nd_phase is a one dimensional array with one value for each antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: $-\pi$

Valid_max: π

Units: radians

4.6.38 cal_loss1_reflector

The loss factor attributed to the reflector applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn. This loss factor is also used to obtain antenna temperatures for each of the 16 frequency bands in the subband data.

cal_loss1_reflector is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.39 cal_loss12_radome

The loss factor attributed to the radome applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn. This loss factor is also used to obtain antenna temperatures for each of the 16 frequency bands in the subband data.

cal_loss1_radome is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, then horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.40 cal_loss2_feed

The loss factor attributed to the feedhorn applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn.

cal_loss2_feed is a one-dimensional array with one value for each antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.41 cal_loss3_omt

The loss factor attributed to the OMT (orthomode transducer) applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn.

cal_loss3_omt is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.42 cal_loss4_coupler

The loss factor attributed to the coupler applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn.

cal_loss4_coupler is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.43 cal_loss5_diplexer

The loss factor attributed to the diplexer applied in the calibration of fullband data to obtain antenna temperature referenced to the feedhorn.

cal_loss5_diplexer is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 1

Valid_max: 2

Units: n/a

4.6.44 cal_rx_phase

The calibration model receiver phase for calibration of radiometer fullband data.

cal_rx_phase16 is a one dimensional array with one value for each antenna scan.

Type:	Float32
Group:	Calibration Data
Shape:	AntennaScan_Array
Valid_min:	$-\pi$
Valid_max:	π
Units:	radians

4.6.45 cal_temp1_reflector

The outcome of the algorithm that calculates the physical temperature of the reflector surface. The algorithm includes factors that account both for surface emissivity and loss. The algorithm identifies 96 facets on the reflector surface. The software provides a loss factor and physical temperature for each facet. The physical temperatures that the software reads depend upon the position of the spacecraft in Earth orbit as well as the time of year. The algorithm integrates both the physical temperatures and the loss factors over the entire surface of the reflector, and then divides the integrated temperature by the integrated loss. Thus, cal_temp1_reflector would equivalent to the reflector's physical temperature if the loss factor is negligible.

cal_temp1_reflector is a two dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical then horizontal.

Type:	Float32
Group:	Calibration Data
Shape:	AntennaScan_VHPol_Array
Valid_min:	330.0
Valid_max:	400.0
Units:	Kelvin

4.6.46 cal_temp12_radome

The calibration model physical temperature of the radome applied to the calibration of fullband data. This temperature is also used with each of the 16 frequency bands for the calibration of subband data.

cal_temp12_radome is a one dimensional array. Each element represents a specific antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: 110.0

Valid_max: 260.0

Units: Kelvin

4.6.47 cal_temp2_feed

The calibration model physical temperature of the feedhorn applied in the calibration of fullband data. This temperature is used for each of the 16 frequency bands for calibration of subband data.

cal_temp2_feed is a one dimensional array with a value for each antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: 253.15

Valid_max: 313.15

Units: Kelvin

4.6.48 cal_temp3_omt

The calibration model physical temperature of the OMT (orthomode transducer) applied in the calibration of fullband data. This temperature is used for each of the 16 frequency bands for calibration of subband data.

cal_temp3_feed is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan and the second dimension index represents the polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 253.15

Valid_max: 313.15

Units: Kelvin

4.6.49 cal_temp4_coupler

The calibration model physical temperature of the coupler applied in the calibration of fullband data. This temperature is used for each of the 16 frequency bands for calibration of subband data.

cal_temp4_coupler is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan and the second dimension index represents the polarization. The order of storage is vertical, horizontal.

Type:	Float32
Group:	Calibration Data
Shape:	AntennaScan_VHPol_Array
Valid_min:	253.15
Valid_max:	313.15
Units:	Kelvin

4.6.50 cal_temp5_diplexer

The calibration model physical temperature of the diplexer applied in the calibration of fullband data. This temperature is used for each of the 16 frequency bands for calibration of subband data.

cal_temp5_diplexer is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan and the second dimension index represents the polarization. The order of storage is vertical, horizontal.

Type:	Float32
Group:	Calibration Data
Shape:	AntennaScan_VHPol_Array
Valid_min:	253.15
Valid_max:	313.15
Units:	Kelvin

4.6.51 cal_temp_nd

The calibration model physical temperature of the internal noise diode applied in the calibration of fullband data.

cal_temp_nd is a one dimensional array with one value for each antenna scan.

Type:	Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: 253.15

Valid_max: 353.15

Units: Kelvin

4.6.52 cal_temp_ref

The calibration model physical temperature of the reference load applied in the calibration of fullband data. The brightness temperature of the reference load is the sum of this physical temperature and its offset.

cal_temp_ref is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 253.15

Valid_max: 313.15

Units: Kelvin

4.6.53 cal_tempref_offset

The calibration model physical temperature offset of the reference load applied in the calibration of fullband data. The brightness temperature of the reference load is the sum of its physical temperature and this offset.

cal_tempref_offset is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: -1

Valid_max: 1

Units: Kelvin

4.6.54 cal_temp_xnd

The calibration model physical temperature of the external noise diode applied in the calibration of fullband data.

cal_temp_xnd is a one dimensional with one value for each antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: 253.15

Valid_max: 313.15

Units: Kelvin

4.6.55 cal_tnd

The calibration model brightness temperature of the internal noise diode applied in the calibration of fullband data.

cal_tnd is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 218

Valid_max: 658

Units: Kelvin

4.6.56 cal_tref

The calibration model brightness temperature of the reference load applied in the calibration offullband data. The brightness temperature of the reference load is the sum of its physical temperature and its offset.

cal_tref is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 252.15

Valid_max: 314.15

Units: Kelvin

4.6.57 cal_txnd

The calibration model brightness temperature of the external noise diode applied in the calibration of fullband data.

cal_txnd is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents polarization. The order of storage is vertical, horizontal.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_VHPol_Array

Valid_min: 62

Valid_max: 216

Units: Kelvin

4.6.58 cal_xnd_phase

The calibration model receiver external noise diode phase applied in the calibration of fullband data.

cal_xnd_phase is a one dimensional array with a value for each antenna scan.

Type: Float32

Group: Calibration Data

Shape: AntennaScan_Array

Valid_min: $-\pi$

Valid_max: π

Units: radians

4.6.59 tb_time_seconds

The time when each brightness temperature footprint within the antenna scan was recorded in seconds. Time is recorded for the middle of the footprint. Time values are counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch starting point is January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC).

tb_time_seconds is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension is the number of footprints within the scan.

Type:	Float64
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.6.60 tb_time_utc

The Universal Coordinated Time (UTC) for each brightness temperature footprint within the antenna scan. Time is recorded for the middle of the footprint. For each antenna scan, the *tb_time_utc* records the same footprint times as the *tb_time_seconds*. The *tb_time_utc* appears as an easily interpretable character string.

The format of the *tb_time_utc* is YYYY-MM-DDThh:mm:ss.dddZ, where YYYY represents the calendar year, MM represents the month of the year and DD represents the day of the month. The character 'T' demarcates the date from the time. hh represents the hour in twenty-four hour time, mm represents the minutes, ss represents the seconds, and ddd represents thousandths of a second. The character 'Z' designates Greenwich Mean Time. All numerical fields must occupy the allotted space. If any numerical value does not require the allotted space to represent the appropriate number, the field that specifies the number must contain leading zeroes.

tb_time_utc is a 2-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension represents each of the footprints within the scan.

Type:	FixLenStr
String Length:	24 characters
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	'2014-10-31T00:00:00.000Z'
Valid_max:	'2030-12-31T23:59:60.999Z'
Units:	n/a

4.6.61 tb_lat

The geodetic latitude of the intersection of the antenna boresight vector and the Earth's surface.

tb_lat is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.62 tb_lon

The longitude of the intersection of the antenna boresight vector and the Earth's surface.

tb_lon is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -180

Valid_max: 179.999

Units: degrees

4.6.63 tb_declination

The declination of the spacecraft boresight vector.

tb_declination is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.64 specular_declination

The 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_declination is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.65 tb_right_ascension

The right ascension of the spacecraft boresight vector.

tb_right_ascension is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.6.66 specular_right_ascension

The 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.

specular_right_ascension is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	359.999
Units:	degrees

4.6.67 tb_v

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

tb_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	340
Units:	Kelvin

4.6.68 tb_v_surface_corrected

The vertically 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_v_surface_corrected is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	340
Units:	Kelvin

4.6.69 tb_h

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

tb_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	340
Units:	Kelvin

4.6.70 tb_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_h_surface_corrected is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 340

Units: Kelvin

4.6.71 tb_3

The 3rd Stokes parameter at the surface of the Earth after RFI filtering. The Faraday Rotation Correction algorithm in the L1B_TB executable sets the 3rd Stokes to zero and then recalculates an equivalent brightness temperature vector with non-zero vertical and horizontal brightness temperatures. Thus, this element always displays a value of 0. Users who are interested in 3rd Stokes measure derived from instrument data should inspect either the antenna temperatures or the top of ionosphere temperatures. Details of the Faraday Rotation Correction algorithm appear in the Algorithm Theoretical Basis Document for the SMAP Level 1B Radiometer Data Product.

tb_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 0

Units: Kelvin

4.6.72 tb_4

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

tb_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -50

Valid_max: 50

Units: Kelvin

4.6.73 ta_v

The vertically polarized antenna temperature before RFI filtering.

ta_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -20

Valid_max: 340

Units: Kelvin

4.6.74 ta_h

The horizontally polarized antenna temperature before RFI filtering.

ta_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -20

Valid_max: 340

Units: Kelvin

4.6.75 ta_3

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

ta_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -50

Valid_max: 50

Units: Kelvin

4.6.76 ta_4

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

ta_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -50

Valid_max: 50

Units: Kelvin

4.6.77 ta_filtered_v

The vertically polarized antenna temperature after RFI filtering.

ta_filtered_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -20

Valid_max: 340

Units: Kelvin

4.6.78 ta_filtered_h

The horizontally polarized antenna temperature after RFI filtering.

ta_filtered_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-20
Valid_max:	340
Units:	Kelvin

4.6.79 ta_filtered_3

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

ta_filtered_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-50
Valid_max:	50
Units:	Kelvin

4.6.80 ta_filtered_4

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

ta_filtered_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-50
Valid_max:	50
Units:	Kelvin

4.6.81 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.

toa_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-20
Valid_max:	340
Units:	Kelvin

4.6.82 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_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-20
Valid_max:	340
Units:	Kelvin

4.6.83 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.

The Faraday Rotation Correction algorithm in the L1B_TB executable sets the 3rd Stokes to zero and then recalculates the apparent top of atmosphere temperature vector with non-zero vertical and horizontal brightness temperatures. Thus, this element always displays a value of 0. Users who are interested in 3rd Stokes measure derived from instrument data should inspect either the antenna temperatures or the top of ionosphere temperatures. Details of the Faraday Rotation Correction algorithm appear in the Algorithm Theoretical Basis Document for the SMAP Level 1B Radiometer Data Product.

toa_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 0

Units: Kelvin

4.6.84 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_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -50

Valid_max: 50

Units: Kelvin

4.6.85 toi_v

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

toi_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -20

Valid_max: 340

Units: Kelvin

4.6.86 toi_h

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

toi_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -20

Valid_max: 340

Units: Kelvin

4.6.87 toi_3

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

toi_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -50

Valid_max: 50

Units: Kelvin

4.6.88 toi_4

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

toi_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-50
Valid_max:	50
Units:	Kelvin

4.6.89 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_phi is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	359.999
Units:	degrees

4.6.90 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_direct_theta is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 180

Units: degrees

4.6.91 solar_direct_correction_v

The brightness temperature correction to the antenna temperature, TA, for direct solar contamination to derive tb_v. Limits on the contribution of all error sources will be determined using the orbit simulator.

solar_direct_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 0.6

Units: Kelvin

4.6.92 solar_direct_correction_h

The brightness temperature correction to the antenna temperature, TA, for direct solar contamination to derive tb_h. Limits on the contribution of all error sources will be determined using the orbit simulator.

solar_direct_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 0.6

Units: Kelvin

4.6.93 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.

solar_specular_lat is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-90
Valid_max:	90
Units:	degrees

4.6.94 solar_specular_lon

The longitude of the center of the solar specular reflection point on the Earth's surface relative to the spacecraft position.

solar_specular_lon is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-180
Valid_max:	179.999
Units:	degrees

4.6.95 solar_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 solar glint spot on the Earth’s surface projected onto the XY plane of the Antenna Beam Frame Coordiante System.

solar_specular_phi is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.6.96 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 Beam Frame Coordinate System to the solar glint spot on the Earth's surface.

solar_specular_theta is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 99.9

Units: degrees

4.6.97 solar_specular_reflection_coefficient_v

The quasi-specular reflection coefficient of the surface at the solar specular point used to derive tb_v.

solar_specular_reflection_coefficient_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 1

Units: n/a

4.6.98 solar_specular_reflection_coefficient_h

The quasi-specular reflection coefficient of the surface at the solar specular point used to derive tb_h.

solar_specular_reflection_coefficient_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 1

Units: n/a

4.6.99 solar_specular_correction_v

The brightness temperature correction to the antenna temperature, TA, for the solar specular reflection detected within range of the antenna pattern to derive tb_v.

solar_specular_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 1

Units: Kelvin

4.6.100 solar_specular_correction_h

The brightness temperature correction to the antenna temperature, TA, for the solar specular reflection detected within range of the antenna pattern to derive tb_h.

solar_specular_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 1

Units: Kelvin

4.6.101 solar_specular_correction_3

The brightness temperature correction to the antenna temperature, TA, for the solar specular reflection detected within range of the antenna pattern to derive the 3rd Stokes parameter.

solar_specular_correction_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 1

Units: Kelvin

4.6.102 solar_specular_correction_4

The brightness temperature correction to the antenna temperature, TA, for the solar specular reflection detected within range of the antenna pattern to derive the 4th Stokes parameter.

solar_specular_correction_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 1

Units: Kelvin

4.6.103 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 Mood projected onto the XY plane of the Antenna Beam Frame Coordinate System.

lunar_direct_phi is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	359.999
Units:	degrees

4.6.104 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 Beam Frame Coordinate System to the Moon.

lunar_direct_theta is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	180
Units:	degrees

4.6.105 lunar_specular_lat

The geodetic latitude of the center of the lunar specular reflection point on the Earth's surface relative to the spacecraft position.

lunar_specular_lat is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.6.106 lunar_specular_lon

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

lunar_specular_lon is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -180

Valid_max: 179.999

Units: degrees

4.6.107 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_phi is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.6.108 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 Beam Frame Coordinate System to the lunar glint spot on the Earth's surface.

lunar_specular_theta is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	180
Units:	degrees

4.6.109 lunar_specular_reflection_coefficient_v

The quasi-specular reflection coefficient of the surface at the lunar specular point used to derive tb_v.

lunar_specular_reflection_coefficient_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	1
Units:	n/a

4.6.110 lunar_specular_reflection_coefficient_h

The quasi-specular reflection coefficient of the surface at the lunar specular point used to derive tb_h.

lunar_specular_reflection_coefficient_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 1

Units: n/a

4.6.111 lunar_specular_correction_v

The brightness temperature correction to the antenna temperature, TA, for reflected lunar contamination to derive tb_v.

lunar_specular_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.2

Valid_max: 2

Units: Kelvin

4.6.112 lunar_specular_correction_h

The brightness temperature correction to the antenna temperature, TA, for reflected lunar contamination to derive tb_h.

lunar_specular_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.2

Valid_max: 2

Units: Kelvin

4.6.113 lunar_specular_correction_3

The brightness temperature correction to the antenna temperature, TA, for reflected lunar contamination to derive the 3rd Stokes parameter.

lunar_specular_correction_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.2

Valid_max: 2

Units: Kelvin

4.6.114 lunar_specular_correction_4

The brightness temperature correction to the antenna temperature, TA, for reflected lunar contamination to derive the 4th Stokes parameter.

lunar_specular_correction_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.2

Valid_max: 2

Units: Kelvin

4.6.115 galactic_direct_correction_v

The brightness temperature correction to the antenna temperature, TA, for direct galactic and cosmic contamination to derive the 4th Stokes parameter.

galactic_direct_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0.3

Valid_max: 0.6

Units: Kelvin

4.6.116 galactic_direct_correction_h

The brightness temperature correction to the antenna temperature, TA, for direct galactic and cosmic contamination to derive tb_h.

galactic_direct_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0.3

Valid_max: 0.6

Units: Kelvin

4.6.117 galactic_reflected_correction_v

The brightness temperature correction to the antenna temperature, TA, for reflected galactic and cosmic contamination to derive tb_v.

galactic_reflected_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.4

Valid_max: 4

Units: Kelvin

4.6.118 galactic_reflected_correction_h

The brightness temperature correction to the antenna temperature, TA, for reflected galactic and cosmic contamination to derive tb_h.

galactic_reflected_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.4

Valid_max: 4

Units: Kelvin

4.6.119 galactic_reflected_correction_3

The brightness temperature correction to the antenna temperature, TA, for reflected galactic and cosmic contamination to derive the 3rd Stokes parameter.

galactic_reflected_correction_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.4

Valid_max: 4

Units: Kelvin

4.6.120 galactic_reflected_correction_4

The brightness temperature correction to the antenna temperature, TA, for reflected galactic and cosmic contamination to derive the 4th Stokes parameter.

galactic_reflected_correction_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.4

Valid_max: 4

Units: Kelvin

4.6.121 faraday_rotation_angle

The net rotation of the polarization plane of signal detected by the L-band radiometer.

faraday_rotation_angle is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -90.0

Valid_max: 90.0

Units: degrees

4.6.122 faraday_rotation_correction_v

The correction that the radiometer processing algorithm applies to the vertical polarization antenna temperature due to Faraday rotation.

faraday_rotation_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -3.9

Valid_max: 5.6

Units: Kelvin

4.6.123 faraday_rotation_correction_h

The correction that the radiometer processing algorithm applies to the horizontal polarization antenna temperature due to Faraday rotation.

faraday_rotation_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -3.9

Valid_max: 5.6

Units: Kelvin

4.6.124 footprint_surface_status

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

footprint_surface_status is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 1

Units: n/a

4.6.125 atm_correction_v

The brightness temperature correction to antenna temperature, TA, for atmospheric emission to derive tb_v.

atm_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 4

Units: Kelvin

4.6.126 atm_correction_h

The brightness temperature correction to antenna temperature, TA, for atmospheric emission to derive tb_h.

atm_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	4
Units:	Kelvin

4.6.127 atm_loss

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

atm_loss is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	1
Valid_max:	1.02
Units:	n/a

4.6.128 antenna_sidelobe_correction_v

The brightness temperature correction to the antenna temperature, TA, for the energy detected within the antenna pattern sidelobes to derive tb_v.

antenna_sidelobe_correction_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 6

Units: Kelvin

4.6.129 antenna_sidelobe_correction_h

The brightness temperature correction to the antenna temperature, TA, for the energy detected within the antenna pattern sidelobes to derive tb_h.

antenna_sidelobe_correction_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 6

Units: Kelvin

4.6.130 antenna_sidelobe_correction_3

The brightness temperature correction to the antenna temperature, TA, for the energy detected within the antenna pattern sidelobes to derive the 3rd Stokes parameter.

antenna_sidelobe_correction_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: -0.5

Valid_max: 6

Units: Kelvin

4.6.131 antenna_sidelobe_correction_4

The brightness temperature correction to the antenna temperature, TA, for the energy detected within the antenna pattern sidelobes to derive the 4^{th} Stokes parameter.

antenna_sidelobe_correction_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	-0.5
Valid_max:	6
Units:	Kelvin

4.6.132 surface_water_fraction_mb_h

The antenna pattern weighted areal fraction of static water within the radiometer beam. The algorithm uses the antenna pattern and the land mask defined over a 1km EASE2 grid to compute the integrated water fraction.

surface_water_fraction_mb_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	1
Units:	n/a

4.6.133 surface_water_fraction_mb_v

The antenna pattern weighted areal fraction of static water within the radiometer main beam. The algorithm uses the antenna pattern and the land mask defined over a 1km EASE2 grid to compute the integrated water fraction.

surface_water_fraction_mb_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 1

Units: n/a

4.6.134 antenna_scan_angle

The angular position of the antenna boresight projected onto the X-Y plane of the spacecraft coordinate system. The antenna_scan_angle is zero when the antenna boresight aligns with the X axis of the spacecraft coordinate system. Angular measure increases as the antenna rotates counterclockwise. .

antenna_scan_angle is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.6.135 antenna_look_angle

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

antenna_look_angle is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 180

Units: degrees

4.6.136 antenna_earth_azimuth

The antenna_earth_azimuth records the clockwise rotation from the projection of the Earth's North polar axis onto the XY plane of the SMAP Spacecraft Coordinate System to the projection of the antenna boresight vector onto the XY plane of the SMAP spacecraft coordinate system. The vertex of the angle is at the origin of the Spacecraft Coordinate System.

antenna_earth_azimuth is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	359.999
Units:	degrees

4.6.137 earth_boresight_azimuth

The angle defined by the clockwise rotation from local North of the projection of antenna boresight vector onto the Earth's surface. The vertex of the angle is at the intersection of the antenna boresight vector with the Earth.

earth_boresight_azimuth is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0
Valid_max:	359.999
Units:	degrees

4.6.138 earth_boresight_incidence

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

earth_boresight_incidence is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 90

Units: degrees

4.6.139 polarization_rotation_angle

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

polarization_rotation_angle is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 90

Units: degrees

4.6.140 nedt_v

The Noise Equivalent Delta Temperature (NEDT) after RFI removal for vertical polarization.

nedt_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0.5

Valid_max: 3

Units: Kelvin

4.6.141 nedt_h

The Noise Equivalent Delta Temperature (NEDT) after RFI removal for horizontal polarization.

nedt_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0.5
Valid_max:	3
Units:	Kelvin

4.6.142 nedt_3

The Noise Equivalent Delta Temperature (NEDT) after RFI removal for the 3rd Stokes parameter value.

nedt_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0.5
Valid_max:	3
Units:	Kelvin

4.6.143 nedt_4

The Noise Equivalent Delta Temperature (NEDT) after RFI removal for the 4th Stokes parameter value.

nedt_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature

Shape:	AntennaScan_Tb_Array
Valid_min:	0.5
Valid_max:	3
Units:	Kelvin

4.6.144 sea_ice_fraction

The guassian weighted average of the sea ice concentration within the main beam of the antenna pattern.

sea_ice_fraction is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type:	Float32
Group:	Brightness Temperature
Shape:	AntennaScan_Tb_Array
Valid_min:	0.0
Valid_max:	1.0
Units:	n/a

4.6.145 tb_qual_flag_v

Bit flags that indicate the quality of the vertically polarized brightness temperature. Table 15 specifies the meaning of individual bits in the *tb_qual_flag_v*:

Table 15: The tb_qual_flag_v

Bits	Value	Interpretation
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	RFI detected for vertical polarization brightness temperatures in the grid cell
3		**Vertical polarization RFI correction flag**
	0	Either RFI was not detected, or the algorithm that removes RFI operated successfully
	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
	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		**Vertical polarization half orbit location**
	0	The corresponding vertical polarization brightness temperature lies within the half orbit specified in the file name.
	1	The corresponding vertical polarization brightness temperature lies outside of the half orbit specified in the file name.
14		**Vertical polarization RFI check**
	0	The difference between ta and ta_filtered for the corresponding vertical polarization brightness temperature is less than taFilteredDifferenceThreshold.
	1	The difference between ta and ta_filtered for the corresponding vertical polarization brightness temperature is greater than or equal to taFilteredDifferenceThreshold. The resultant brightness temperature remains contaminated with RFI.
15		**RFI Clean Flag**
	0	The vertical polarization brightness temperature measure is free of RFI.
	1	The vertical polarization brightness temperature measure is RFI contaminated.

The criterion for bit three is the success or failure of the RFI removal algorithm. The software will indicate that the RFI algorithm functions successfully if a sufficient number of pixels remain in the spectrogram when the algorithm completes. Note that the presence of a sufficient number of pixels does not necessarily imply that the data are RFI free when the algorithm completes. Additional information on the RFI removal algorithm is available in the SMAP L1B_TB Algorithm Theoretical Basis Document.

tb_qual_flag_v is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Units: n/a

4.6.146 tb_qual_flag_h

Bit flags that indicate the quality of the horizontally polarized brightness temperature. Table 16 specifies the meaning of individual bits in the *tb_qual_flag_h*:

Table 16: The tb_qual_flag_h

Bits	Value	Interpretation
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	RFI detected for horizontal polarization brightness temperatures in the grid cell
3		**Horizontal polarization RFI correction flag**
	0	Either RFI was not detected, or the algorithm that removes RFI operated successfully
	1	If RFI was detected, the software was unable to correct the horizontal polarization brightness temperature for RFI

Bits	Value	Interpretation
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
	1	Correction for direct galaxy did not function or yielded poor results on the horizontal polarization brightness temperature

Bits	Value	Interpretation
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		**Horizontal polarization half orbit location**
	0	The corresponding horizontal polarization brightness temperature lies within the half orbit specified in the file name.
	1	The corresponding horizontal polarization brightness temperature lies outside of the half orbit specified in

Bits	Value	Interpretation
		the file name.
14		**Horizontal polarization RFI check**
	0	The difference between ta and ta_filtered for the corresponding horizontal polarization brightness temperature is less than taFilteredDifferenceThreshold.
	1	The difference between ta and ta_filtered for the corresponding horizontal polarization brightness temperature is greater than or equal to taFilteredDifferenceThreshold. The resultant brightness temperature remains contaminated with RFI.
15		**RFI Clean Flag**
	0	The horizontal polarization brightness temperature measure is free of RFI.
	1	The horizontal polarization brightness temperature measure is RFI contaminated.

The criterion for bit three is the success or failure of the RFI removal algorithm. The software will indicate that the RFI algorithm functions successfully if a sufficient number of pixels remain in the spectrogram when the algorithm completes. Note that the presence of a sufficient number of pixels does not necessarily imply that the data are RFI free when the algorithm completes. Additional information on the RFI removal algorithm is available in the SMAP L1B_TB Algorithm Theoretical Basis Document.

tb_qual_flag_h is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Units: n/a

4.6.147 tb_qual_flag_3

Bit flags that indicate the quality of the 3rd Stokes parameter measurement. Table 17 specifies the meaning of individual bits in the *tb_qual_flag_3*:

Table 17: The tb_qual_flag_3

Bits	Value	Interpretation
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	Either RFI was not detected, or the algorithm that removes RFI operated successfully
	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**

Bits	Value	Interpretation
	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

Bits	Value	Interpretation
11		**Undefined**
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.
13		**3rd Stokes half orbit location**
	0	The corresponding 3rd Stokes lies within the half orbit specified in the file name.
	1	The corresponding 3rd Stokes parameter lies outside of the half orbit specified in the file name.
14		**3rd Stokes RFI check**
	0	The difference between ta and ta_filtered for the corresponding 3rd Stokes parameter is less than taFilteredDifferenceThreshold.
	1	The difference between ta and ta_filtered for the corresponding 3rd Stokes parameter is greater than or equal to taFilteredDifferenceThreshold. The resultant pixel measure remains contaminated with RFI.
15		**RFI Clean Flag**
	0	The 3rd Stokes parameter measure is free of RFI.
	1	The 3rd Stokes parameter measure is RFI contaminated.

The criterion for bit three is the success or failure of the RFI removal algorithm. The software will indicate that the RFI algorithm functions successfully if a sufficient number of pixels remain in the spectrogram when the algorithm completes. Note that the presence of a sufficient number of pixels does not necessarily imply that the data are RFI free when the algorithm completes. Additional information on the RFI removal algorithm is available in the SMAP L1B_TB Algorithm Theoretical Basis Document.

tb_qual_flag_3 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Units: n/a

4.6.148 tb_qual_flag_4

Bit flags that indicate the quality of the 4th Stokes parameter measurement. Table 18 specifies the meaning of individual bits in the *tb_qual_flag_4*:

Table 18: The tb_qual_flag_4

Bits	Value	Interpretation
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	Either RFI was not detected, or the algorithm that removes RFI operated successfully
	1	If RFI was detected, the software was unable to correct the 4th Stokes brightness temperature for RFI
4		**4th Stokes NEDT flag**

Bits	Value	Interpretation
	0	4^{th} Stokes has acceptable NEDT
	1	Use of 4^{th} Stokes not recommended, since NEDT exceeds pre-determined threshold
5		**4^{th} Stokes direct sun correction**
	0	Correction for direct sun operated successfully on the 4^{th} Stokes parameter
	1	Correction for direct sun did not function or yielded poor results on the 4^{th} Stokes parameter
6		**4^{th} Stokes reflected sun correction**
	0	Correction for reflected sun operated successfully on the 4^{th} Stokes parameter
	1	Correction for reflected sun did not function or yielded poor results on the 4^{th} Stokes parameter
7		**4^{th} Stokes reflected moon correction**
	0	Correction for reflected moon operated successfully on the 4^{th} Stokes parameter
	1	Correction for reflected moon did not function or yielded poor results on the 4^{th} Stokes parameter
8		**4^{th} Stokes direct galaxy correction**
	0	Correction for direct galaxy operated successfully on the 4^{th} Stokes parameter
	1	Correction for direct galaxy did not function or yielded poor results on the 4^{th} Stokes parameter
9		**4^{th} Stokes reflected galaxy correction**
	0	Correction for reflected galaxy operated successfully on the 4^{th} Stokes parameter
	1	Correction for reflected galaxy did not function or yielded poor results on the 4^{th} Stokes parameter

Bits	Value	Interpretation
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
11		**Undefined**
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.
13		**4th Stokes half orbit location**
	0	The corresponding 4th Stokes lies within the half orbit specified in the file name.
	1	The corresponding 4th Stokes parameter lies outside of the half orbit specified in the file name.
14		**4th Stokes RFI check**
	0	The difference between ta and ta_filtered for the corresponding 4th Stokes parameter is less than taFilteredDifferenceThreshold.
	1	The difference between ta and ta_filtered for the corresponding 4th Stokes parameter is greater than or equal to taFilteredDifferenceThreshold. The resultant pixel measure remains contaminated with RFI.
15		**RFI Clean Flag**
	0	The 4th Stokes parameter measure is free of RFI.
	1	The 4th Stokes parameter measure is RFI contaminated.

The criterion for bit three is the success or failure of the RFI removal algorithm. The software will indicate that the RFI algorithm functions successfully if a sufficient number of pixels remain in the spectrogram when the algorithm completes. Note that the presence of a sufficient number of pixels does not necessarily imply that the data are RFI free when the algorithm completes. Additional information on the RFI removal algorithm is available in the SMAP L1B_TB Algorithm Theoretical Basis Document.

tb_qual_flag_4 is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Units: n/a

4.6.149 tb_mode_flag

Bit flags that indicate instrument and ambient conditions when the brightness temperature measurements were acquired. Table 19 specifies the meaning of individual bits in the *tb_mode_flag*:

Table 19: The tb_mode_flag

Bits	Value	Interpretation
0		**Data resolution flag (land/ocean)**
	0	High resolution data contribute to this pixel
	1	Low resolution data contribute to this pixel
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**

Bits	Value	Interpretation
	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**

tb_mode_flag is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Uint16

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Units: n/a

4.6.150 tb_upwelling

The component of the top of the atmosphere apparent brightness temperature that is due to upwelling thermal radiation of the atmosphere.

tb_upwelling is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 4

Units: Kelvin

4.6.151 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 direction is not used in any SMAP radiometer data processor but is provided for thoroughness.

wind_direction_ancillary is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.6.152 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). SMAP radiometer data processing uses the *wind_speed* over the ocean surface during the wind-dependent reflected galaxy correction.

wind_speed_ancillary is a 2-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents each of the footprints in the scan.

Type: Float32

Group: Brightness Temperature

Shape: AntennaScan_Tb_Array

Valid_min: 0.0

Valid_max: 75.0

Units: m/s

5 APPENDIX A – ACRONYMS AND ABBREVIATIONS

This is the standard Soil Moisture Active Passive (SMAP) Science Data System (SDS) list of acronyms and abbreviations. Not all of these acronyms and abbreviations appear in every SMAP SDS document.

ADT	Algorithm Development Team
AMSR	Advanced Microwave Scanning Radiometer
ANSI	American National Standards Institute
AOS	Acquisition of Signal
APF	Algorithm Parameter File
ARS	Agricultural Research Service
ASF	Alaska Satellite Facility
ATBD	Algorithm Theoretical Basis Document
ATLO	Assembly Test Launch and Operations
BFPQ	Block Floating Point Quantization
BIC	Beam Index Crossing
CARA	Criticality and Risk Assessment
CBE	Current Best Estimate
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
CEOS	Committee on Earth Observing Systems
CF	Climate and Forecast (metadata convention)
CM	Configuration Management
CM	Center of Mass
CONUS	Continental United States
COTS	Commercial Off the Shelf
CR	Change Request
DAAC	Distributed Active Archive Center
DB	Database
DBA	Database Administrator
dB	decibels
deg	degrees
deg/sec	degrees per second

deg C	degrees Celsius
DEM	Digital Elevation Model
DFM	Design File Memorandum
DIU	Digital Interface Unit
DN	Data Number
DOORS	Dynamic Object Oriented Requirements
DQC	Data Quality Control
DSK	Digital Skin Kernel
DVD	Digital Versatile Disc
EASE	Equal Area Scalable Earth
ECMWF	European Centre for Medium Range Weather Forecasts
ECHO	EOS Clearing House
ECI	Earth Centered Inertial Coordinate System
ECR	Earth Centered Rotating Coordinate System
ECR	Engineering Change Request
ECS	EOSDIS Core System
EDOS	EOS Data Operations System
EM	Engineering Model
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EPO	Education and Public Outreach
ESDIS	Earth Science Data and Information System Project
ESDT	Earth Science Data Type
ESH	EDOS Service Header
ESSP	Earth Science System Pathfinder
ET	Ephemeris TIme
EU	Engineering Units
FOV	Field of View
FRB	Functional Requirements Baseline
FS	Flight System
FSW	Flight Software

F/T	Freeze/Thaw
FTP	File Transfer Protocol
GByte	gigabyte
GDS	Ground Data System
GHA	Greenwich Hour Angle
GHz	gigahertz
GLOSIM	Global Simulation
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GN	Ground Network
GPMC	Governing Program Management Council
GPP	Gross Primary Production
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HK	Housekeeping (telemetry)
Hz	Hertz
HSD	Health and Status Data
ICE	Integrated Control Electronics
ICESat	Ice, Cloud and Land Elevation Satellite
IDL	Interactive Data Language
I&T	Integration and Test
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IFOV	Instantaneous Field of View
I/O	Input/Output
IOC	In-Orbit Checkout
IRU	Inertial Reference Unit
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
ITAR	International Traffic in Arms Regulations

I&T	Integration and Test
JPL	Jet Propulsion Laboratory
KHz	kilohertz
km	kilometers
LAN	Local Area Network
LBT	Loopback Trap
LEO	Low Earth Orbit
LEOP	Launch and Early Operations
LOE	Level Of Effort
LOM	Life Of Mission
LOS	Loss of Signal
LSK	Leap Seconds Kernel
LZPF	Level Zero Processing Facility
m	meters
MHz	megahertz
MIT	Massachusetts Institute of Technology
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Mission Operations System
m/s	meters per second
ms	milliseconds
MS	Mission System
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Protection
NCP	North Celestial Pole
NCSA	National Center for Supercomputing Applications
NEDT	Noise Equivalent Delta Temperature
NEE	Net Ecosystem Exchange
NEN	Near Earth Network

netCDF	Network Common Data Form
NFS	Network File System/Server
NISN	NASA Integrated Services Network
NRT	Near Real Time
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NVM	Non-Volatile Memory
NWP	Numerical Weather Product
n/a	not applicable
OCO	Orbiting Carbon Observatory
OEF	Orbit Events File
ORBNUM	Orbit Number File
OODT	Object Oriented Data Technology
ORR	Operational Readiness Review
ORT	Operational Readiness Test
OSSE	Observing System Simulation Experiment
OSTC	One Second Time Command
PALS	Passive and Active L-Band System
PALSAR	Phased Array L-Band Synthetic Aperture Radar
PcK	Planetary Constants Kernel
PDR	Preliminary Design Review
PPPCS	Pointing, Position, Phasing and Coordinate System
PR	Problem Report
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PROM	Programmable Read Only Memory
PSD	Product Specification Document
QA	Quality Assurance
rad	radians
RAM	Random Access Memory
RBA	Reflector Boom Assembly
RBD	Rate Buffered Data

RBE	Radiometer Back End
RDD	Release Description Document
RDE	Radiometer Digital Electronics
RF	Radio Frequency
RFA	Request For Action
RFE	Radiometer Front End
RFI	Radio Frequency Interference
RMS	root mean square
RSS	root sum sqaure
ROM	Read Only Memory
RPM	revolutions per minute
RVI	Radar Vegetation Index
SA	System Administrator
SAR	Synthetic Aperture Radar
S/C	Spacecraft
SCE	Spin Control Electronics
SCLK	Spacecraft Clock
SDP	Software Development Plan
SDS	Science Data System
SDT	Science Definition Team
SI	International System
SITP	System Integration and Test Plan
SMAP	Soil Moisture Active Passive
SMEX	Soil Moisture Experiment
SMOS	Soil Moisture and Ocean Salinity Mission
SMP	Software Management Plan
SNR	signal to noise ratio
SOC	Soil Organic Carbon
SOM	Software Operators Manual
SQA	Software Quality Assurance
SPDM	Science Process and Data Management
SPG	Standards Process Group

SPK	Spacecraft Kernel
SQA	Software Quality Assurance
SPS	Science Production Software
SRF	Science Orbit Reference Frame
SRR	System Requirements Review
SRTM	Shuttle Radar Topography Mission
SSM/I	Special Sensor Microwave/Imager
STP	Software Test Plan
sec	seconds
T_a	Antenna Temperature
TAI	International Atomic Time
T_b	Brightness Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Specified
TCP/IP	Transmission Control Protocol/Internet Protocol
TEC	Total Electron Content
TM	Trademark
TOA	Time of Arrival
TPS	Third Party Software
UML	Unified Modeling Language
U-MT	University of Montana
USDA	United States Department of Agriculture
UTC	Coordinated Universal Time
V&V	Verification and Validation
VWC	Vegetation Water Content

6 APPENDIX B - SMAP Data Product Specification Documents

SMAP Level 1A Radar Product Specification Document, JPL D-72543 Revision B, July 20, 2015.

SMAP Level 1B Radar (L1B_S0_LoRes) Product Specification Document, JPL D-72544 Revision A, July 20, 2015.

SMAP Level 1C Radar (L1C_S0_HiRes) Product Specification Document, JPL D-72554 Revision B, July 20, 2015.

SMAP Level 1A Radiometer Product Specification Document, JPL D-92340 Revision A, July 20, 2015.

SMAP Level 1C Radiometer (L1C_TB) Product Specification Document, JPL D-72545, Date (**TBD)**.

SMAP Level 2 Active Soil Moisture (L2_SM_A) Product Specification Document, JPL D-72546, Date (**TBD)**.

SMAP Level 2 Passive Soil Moisture (L2_SM_P) Product Specification Document, JPL D-72547, Date (**TBD)**.

SMAP Level 2 Active/Passive Soil Moisture (L2_SM_AP) Product Specification Document, JPL D-72548, Date (**TBD)**.

SMAP Level 3 Freeze-Thaw (L3_FT_A) Product Specification Document, JPL D-72549, Date (**TBD)**.

SMAP Level 3 Active Soil Moisture (L3_SM_A) Product Specification Document, JPL D-72550, Date (**TBD)**.

SMAP Level 3 Passive Soil Moisture (L3_SM_P) Product Specification Document, JPL D-72551, Date (**TBD)**.

SMAP Level 3 Active/Passive Soil Moisture (L3_SM_AP) Product Specification Document, JPL D-72552, Date (**TBD)**.

SMAP Level 4 Carbon (L4_C) Product Specification Document, Document Identifier (**TBD)**, Date (**TBD)**.

SMAP Level 4 Soil Moisture (L4_SM) Product Specification Document, Document Identifier (**TBD)**, Date (**TBD)**.

7 APPENDIX C – SHAPES IN THE L1B_TB PRODUCT

Table 20 lists all of the Shapes that appear in the L1B_TB Product. The table also lists the rank, the nominal dimensions and the maximum anticipated dimensions for each Shape in the L1B_TB Product. The maximum anticipated values are based on limitations in the SMAP hardware design rather than software construction.

The naming convention for shape names places the dimension where consecutive indices represent contiguous storage positions last. The naming convention thus conforms to index representation in the C language.

On the other hand, since a large contingent of the SMAP science community programs are in Fortran, index order of arrays in this document conforms to the Fortran standard. Thus, in array dimension representation, the dimension where consecutive indices represent contiguous storage appears first.

Table 20: Shapes in the SMAP L1B_TB Data Product

Shape	Rank	Nominal Product Dimensions	Maximum Anticipated Product Dimensions
AntennaScan_Array	1	(640)	(719)
HighResolutionScan_Array	1	(320)	(359)
AntennaScan_Tb_Array	2	(640,300)	(719,300)
HighResolutionScan_Subband_Array	2	(320,16)	(359,16)
AntennaScan_VHPol_Array	2	(640,2)	(719,2)
HighResolutionScan_Subband_VHPol_Array	3	(320,16,2)	(359,16,2)

8 APPENDIX D – L1B_TB DIMENSIONS

Table 21 lists all of the Dimensions that are used by data elements in the Level L1B_TB Product. The name of each Dimension matches the name given in the Dimension column below. The table also lists the anticipated nominal value and the maximum value for each dimension that appears in the L1B_TB Product.

Table 21: Dimensions in the SMAP L1B_TB Product

Dimension	Nominal Size	Maximum Size
AntennaScan	640	719
HighResolutionScan	320	359
Tb	270	300
Subband	16	16
VHPol	2	2

9 APPENDIX E – L1B_TB UNITS

Table 22 lists the Units that are used by the L1B_TB product elements. The SMAP implementation of HDF5 stores unit information for each data element in local metadata. The first column in the Table 22 identifies units that apply to data in the L1B_TB Product. The second column lists the Common Symbol used to represent the unit. The third column lists the matching Label that appears in the local metadata in the L1B_TB Product.

Table 22: Units in the SMAP L1B_TB Product

Unit	Common Symbol	Level 1B_TB Label	Typical Use
counts	Counts	counts	number of elements in a set
degrees	degrees	degrees	angular measure
dimensionless	n/a		dimensionless quantity
Gigahertz	GHz	GHz	frequency measure
meters per second	m/s	meters/second	velocity measure
megabytes	MBytes	MBytes	computer storage units
meters	m	meters	distance measure
kilometers	km	km	distance measure
percent	%	percent	per hundred
seconds	s	seconds	time measure
revolutions per minute	rpm	Rpm	rotational measure
degrees Celsius	°C	degrees_Celsius	temperature measure
Kelvin	K	Kelvin	temperature measure
radians	rad	radians	angular measure
Counts/Kelvin	Counts/Kelvin	Counts/Kelvin	radiometer gain measure

10 APPENDIX F - Modeling Spacecraft Slews

The SMAP mission will maneuver the spacecraft from time to time. Of particular interest are maneuvers that enable the spacecraft antenna to view cold sky. Knowledge of the Euler angles that represents the spacecraft attitude during these maneuvers is critical. Generation of the Euler angle requires specification of the proper order of rotation from the science orbit reference frame to the spacecraft frame. The order of rotation that users should employ is pitch, followed by roll and then yaw.

If SMAP product users wish to reconstruct the Euler angles associated with spacecraft maneuvers, they should employ the following processing steps based on provided values of pitch, yaw and roll:

- Rotate the spacecraft attitude angles by 180 degrees around the +X axis of the SRF. The roll aligns the Z axis of the Instrument Fixed Coordinate System with the SMAP Science Orbit Reference Frame (it also changes the sign of the pitch and yaw).
- Perform a pitch rotation. The pitch rotation is executed in counterclockwise direction about the position of the +Y axis of the Instrument Fixed Coordinate System at the completion of the previous adjustment. This position should be very close to (but not necessarily the same as) the position of the +Y axis of the SRF
- Perform roll rotation. The roll rotation is executed in counterclockwise direction about the position of the +X axis of the Instrument Fixed Coordinate System at the completion of the previous pitch rotation. Because of the pitch rotation, this position can be quite different from the position of the +X axis of the SRF.
- Perform the yaw rotation. The yaw rotation is executed in counterclockwise direction about the position of the +Z axis of the Instrument Fixed Coordinate System at the completion of the roll rotation. Because of the pitch and roll rotations, this position can be quite different from the position of the +Z axis of the SRF.

To enable representation of maneuver conditions, the pitch, roll and yaw angles will need to take on large measures values. SMAP software thus enables pitch values to range from –180 degrees to 180 degrees, roll values to range from –90 to 90 degrees and yaw values to range from –180 degrees to 180 degrees.