Soil Moisture Active Passive (SMAP) Mission

Level 3 Enhanced Freeze-Thaw Passive Product (L3_FT_P_E) Specification Document

Initial Release

R. Scott Dunbar

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National Aeronautics and
Space Administration

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109-8099
California Institute of Technology

Soil Moisture Active Passive (SMAP)
Level 3 Freeze-Thaw Passive
Product Specification Document

Initial Release

Prepared by:

R. Scott Dunbar SMAP Algorithm Development Team	Date

Approved by:

Maher Hanna SMAP SDS Project Element Manager	Date
Simon Yueh SMAP Project Scientist	Date

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1 INTRODUCTION

1.1 Identification

This is the Product Specification Document (PSD) for the Level 3 Freeze-Thaw Passive Product for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The product provides gridded daily global composite of SMAP freeze-thaw retrievals, ancillary data, and quality-assessment flags on a 36-km Earth-fixed grid.

1.2 Scope

This document describes the file format and data contents of the Level 3 Freeze-Thaw Passive Product (hereafter referred to as 'L3_FT_P' for brevity) for external software interfaces. The SMAP Science Data Management and Archive Plan Document provides a more comprehensive explanation of this product within the context of the SMAP instrument, algorithms, and software.

1.3 The SMAP Mission

The SMAP mission combines passive (radiometer) and active (radar) observations to provide global mapping of soil moisture and freeze/thaw state with unprecedented accuracy, resolution, and coverage. The resulting space-based hydrosphere state measurements will improve:

- Understanding of the processes that link the terrestrial water, energy and carbon cycles
- Estimate of global water and energy fluxes at the land surface
- Measurement of net carbon flux in boreal landscapes
- Weather and climate forecast skill
- Flood prediction and drought monitoring capabilities

Table 1 is a summary of the SMAP instrument functional requirements derived from its science measurement needs. The goal is to combine the various positive attributes of the radar and radiometer observations, including spatial resolution, sensitivity to soil moisture, surface roughness, and vegetation, to estimate soil moisture at a resolution of 10 km and freeze-thaw state at a resolution of 1-3 km.

Table 1: SMAP Mission Requirements

Scientific Measurement Requirements	Instrument Functional Requirements
Soil Moisture: ~± 0.04 cm^3/cm^3 volumetric accuracy (1-sigma) in the top 5 cm for vegetation water content ≤ 5 kg/m^2 Hydrometeorology at ~10 km resolution Hydroclimatology at ~40 km resolution	**L-Band Radiometer (1.41 GHz):** Polarization: V, H, T_3, and T_4 Resolution: 40 km Radiometric Uncertainty*: 1.3 K **L-Band Radar (1.26 and 1.29 GHz):** Polarization: VV, HH, HV (or VH) Resolution: 10 km Relative accuracy*: 0.5 dB (VV and HH) Constant incidence angle** between 35° and 50°
Freeze/Thaw State: Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision at the spatial scale of landscape variability (~3 km)	**L-Band Radar (1.26 GHz & 1.29 GHz):** Polarization: HH,VV,VV+HH Resolution: 3 km Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used) Constant incidence angle** between 35° and 50°
Sample diurnal cycle at consistent time of day (6 am/6 pm Equator crossing); Global, ~3 day (or better) revisit; Boreal, ~2 day (or better) revisit	Swath Width: ~1000 km Minimize Faraday rotation (degradation factor at L-band)
Observation over minimum of three annual cycles	Baseline three-year mission life
* Includes precision and calibration stability ** Defined without regard to local topographic variation	

The SMAP instrument incorporates an L-band radar and an L-band radiometer that share a single feed horn and parabolic mesh reflector. As shown in Figure 1, the reflector is offset from nadir and rotates about the nadir axis at 14.6 rpm (nominal), providing a conically scanning antenna beam with a surface incidence angle of approximately 40°. The provision of constant incidence angle across the swath simplifies data processing and enables accurate repeat-pass estimates of soil moisture and freeze/thaw change. The reflector has a diameter of 6 m, providing a radiometer 3 dB antenna footprint of 40 km (root-ellipsoidal-area). The real-aperture radar footprint is 30 km, defined by the two-way antenna beamwidth. The real-aperture radar and radiometer data will be collected globally during both ascending and descending passes.

To obtain the desired high spatial resolution, the radar employs range and Doppler discrimination. The radar data can be processed to yield resolution enhancement to 1-3 km spatial resolution over the outer 70% of the 1000-km swath. Data volume constraints prohibit the downlinking of the entire radar data acquisition. Radar measurements that enable high-resolution processing will be collected during the morning overpass over all land regions as well as over surrounding coastal oceans. During the evening overpass, data north of 45° N will be collected and processed to support robust detection of landscape freeze/thaw transitions. The SMAP baseline orbit parameters are:

- Orbit altitude: 685 km (2-3 day average revisit globally and 8-day exact repeat)
- Inclination: 98 degrees, sun-synchronous
- Local time of ascending node: 6 pm (6 am descending local overpass time)

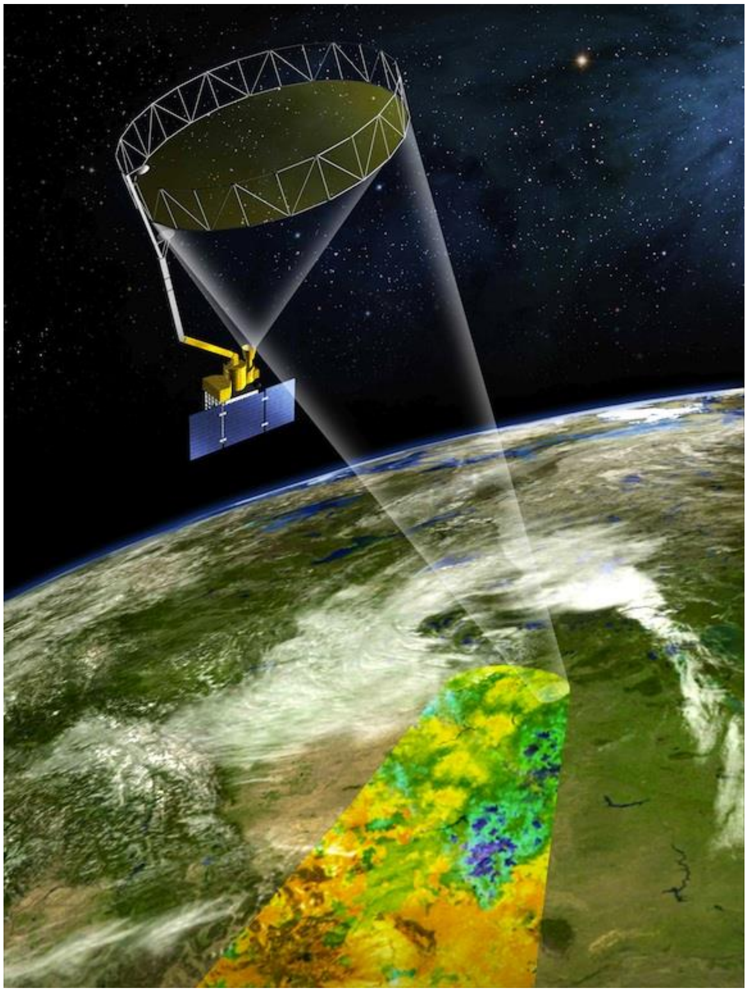


Figure 1: The SMAP mission concept consists of an L-band radar and radiometer sharing a single spinning 6-m mesh antenna in a sun-synchronous dawn / dusk orbit.

The SMAP radiometer measures the four Stokes parameters, T_H, T_V, T_3, and T_4 at 1.41 GHz. The T_H and T_V channels are the pure horizontally and vertically polarized brightness temperatures. The cross-polarized T_3-channel measurement can be used to correct for possible Faraday rotation caused by the ionosphere. Mission planners expect that the selection of the 6 am sun-synchronous SMAP orbit should minimize the effect of Faraday rotation.

Anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate both radar and radiometer measurements at L-band. Early measurements and results from ESA's Soil Moisture and Ocean Salinity (SMOS) mission indicate that in some regions RFI is present and detectable. The SMAP radar and radiometer electronics and algorithms include design features to mitigate the effects of RFI. The SMAP radar utilizes selective filters and an adjustable carrier frequency to tune to predetermined RFI-free portions of the spectrum while on orbit. The SMAP radiometer will implement a combination of time and frequency diversity, kurtosis detection, and use of T_4 thresholds to detect and where possible mitigate RFI.

1.4 Data Products

The SMAP mission will generate 15 different 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 2 lists the standard SMAP data products. 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 ECS short names to categorize data products in their local databases. ECS short names will also appear in SMAP product metadata.

Table 2: Standard SMAP data products

Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer T_B in Time-Order	(36x47 km)	12 hrs	
L1B_TB_E	Radiometer T_B Optimally Interpolated on EASE2.0 grid	9 km	12 hrs	
L1B_S0_LoRes	Low Resolution Radar σ_o in Time-Order	(5x30 km)	12 hrs	
L1C_S0_HiRes	High Resolution Radar σ_o in Half-Orbits	1 km (1-3 km)	12 hrs	
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
L1C_TB_E	Radiometer T_B in Half-Orbits, Enhanced	9 km	12 hrs	
L2_SM_A	Soil Moisture (Radar)	3 km	24 hrs	Science Data (Half-Orbit)
L2_SM_P	Soil Moisture (Radiometer)	36 km	24 hrs	
L2_SM_P_E	Soil Moisture (Radiometer, Enhanced))	9 km	24 hrs	
L2_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	24 hrs	
L2_SM_SP	Soil Moisture (Sentinel Radar + Radiometer)	3 km	Best effort	
L3_FT_A	Freeze/Thaw State (Radar)	3 km	50 hrs	Science Data (Daily Composite)
L3_FT_P	Freeze/Thaw State (Radiometer)	36 km	50 hrs	
L3_FT_P_E	Freeze/Thaw State (Radiometer, Enhanced)	9 km	50 hrs	
L3_SM_A	Soil Moisture (Radar)	3 km	50 hrs	
L3_SM_P	Soil Moisture (Radiometer)	36 km	50 hrs	
L3_SM_P_E	Soil Moisture (Radiometer, Enhanced)	9 km	50 hrs	
L3_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	50 hrs	
L4_SM	Soil Moisture (Surface and Root Zone)	9 km	7 days	Science Value-Added
L4_C	Carbon Net Ecosystem Exchange (NEE)	9 km	14 days	

1.5 L3_FT_P_E Overview

The SMAP L3_FT_P_E product is a daily global composite of the AM and PM radiometer data and freeze-thaw states, intended as a replacement for the L3_FT_A active (radar-based) freeze-thaw product following the failure of the SMAP radar in July 2015. The final L3_FT_P_E product contains gridded data of SMAP radiometer-based brightness temperature data, freeze-thaw states, ancillary data, and quality-assessment flags on the north polar 36-km Equal-Area Scalable Earth (EASE-2.0) Grid designed by the National Snow and Ice Data Center

(NSIDC) for SMAP.To generate the standard L3_FT_P_E product, the processing software ingests one day's worth of L1C_TB_E processed half-orbit granules and creates global composites as two-dimensional arrays for each output parameter defined in the L3_FT_P_E product. Wherever data overlap occurs (typically at high latitudes), data points with acquisition time closest to 6:00 am (for descending passes) or 6:00 pm (ascending passes) local solar time is chosen.

The enhanced L1C_TB_E product contains brightness temperatures from the L1B_TB_E optimal interpolation, which uses the Backus-Gilbert algorithm to generate a 9 km gridded product from the original L1B_TB radiometer footprints.

Because the input L1C_TB_E granules are available both for descending (6:00 am) and ascending (6:00 pm) passes in the boreal zone north of 45N latitude, the resulting L3_FT_P_E granules contain data for both AM and PM data, maintained as separate two-dimensional layers in the third dimension of the 3-D output elements. **For the AM/PM index of those arrays, the AM layer is assigned to the index value 0 and the PM layer is assigned to index value 1.**

2 DATA PRODUCT ORGANIZATION

2.1 File Format

All SMAP standard products are in the Hierarchical Data Format version 5 (HDF5). The 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 more easily. Use of the HDF library enables users to read HDF files regardless of the underlying computing environments. HDF files are equally accessible in Fortran, C/C++, and other high-level computation packages such as IDL or MATLAB.

The HDF Group, a spin-off organization of the NCSA, 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 3 lists the Atomic Datatypes that are used in SMAP data products.

Table 3: 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 4 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 4: 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 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 5 lists the CF names for the HDF5 Attributes that SMAP products typically employ.

Table 5: 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	No

CF Compliant Attribute Name	Description	Required?
	type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_min will also be float32.	
_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 the content of the associated Dataset.	Yes
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 6 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 6: 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

Characteristic	Definition
	first column in table 3 lists all of the valid values that correspond to this characteristic.
Shape	The name of the shape data element that specifies the rank and dimension of a particular data set.
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”, “Kelvins”, “m/s”, “m”, “m**2”, “s” and “counts”. Appendix A and Appendix E include references to important data measurement unit symbols.

2.4.1 **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.

2.5 Fill/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 L3_FT_P_E Product when the L3_FT_P_E SPS can process some, but not all, of the input data for a particular swath grid cell. Fill data may appear in the product in any of the following circumstances:

- One of Science Production Software (SPS) executables that generate the SMAP L3_FT_P_E Product is unable to calculate a particular science or engineering data value. The algorithm encounters an error. The error disables generation of valid output. The SPS reports a fill value instead.
- Some of the required science or engineering algorithmic input are missing. Data over the region that contributes to particular grid cell may appear in only some of the input data streams. Since data are valuable, the L3_FT_P_E Product records any outcome that can be calculated with the available input. Missing data appear as fill values.
- Non-essential information is missing from the input data stream. The lack of non-essential information does not impair the algorithm from generating needed output. The missing data appear as fill values.
- Fill values appear in the input L1C_TB_E product granules.

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 7 lists the values that represent fill in SMAP products based on data type:

Table 7: Fill Values in SMAP Data Products

Type	Value	Pattern
Float32, Float64	-9999.00	Large, negative number
Signed8, NormSigned8	-127	Type minimum + 1
Signed16, NormSigned16	-9999	Type minimum + 1
Signed24	-8388607	Type minimum + 1
Signed32	-9999	Type minimum + 1
Signed64	-9999	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	NA	Not available

No valid value in the L3_FT_P_E product is equal to the values that represent fill. If any exceptions should exist in the future, the L3_FT_P_E 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 L3_FT_P_E 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 L3_FT_P_E 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.

2.6 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 EASE2 Grid

The data in the SMAP L3_FT_P_E product are presented on a north polar azimuthal projection. The projections are based on NSIDC's EASE2 Grid specifications for SMAP.

The EASE2 Grid has a flexible formulation. By adjusting one scaling parameter it is possible to generate a family of multi-resolution grids that "nest" within one another. The nesting can be made "perfect" in that smaller grid cells can be tessellated to form larger grid cells, as shown in Fig. 2.

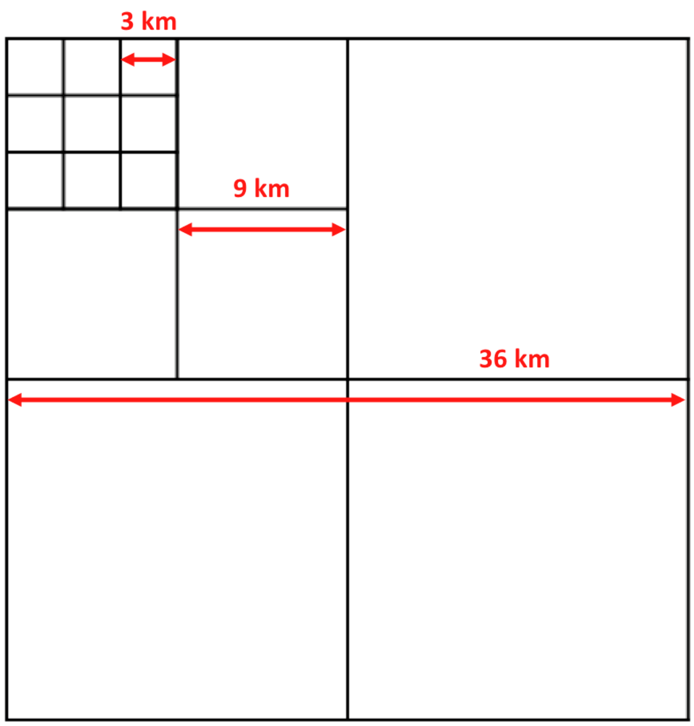


Figure 2: Perfect nesting in EASE2 Grid – smaller grid cells can be tessellated to form larger grid cells.

This feature of perfect nesting provides SMAP data products with a convenient common projection for both high-resolution radar observations and low-resolution radiometer observations, as well as their derived geophysical products.

A nominal EASE2 grid dimension of 36 km has been selected for the L1C_TB and L2/3_SM_P products. This spatial scale is close to the 40-km resolution of the radiometer footprint and it scales conveniently with the 3 km and 9 km grid dimensions that have been selected for the radar (L2/3_SM_A) and combined radar/radiometer (L2/3_SM_A/P) soil moisture products, respectively. A comparison of EASE2 Grid at these three grid resolutions is shown in Fig. 3.

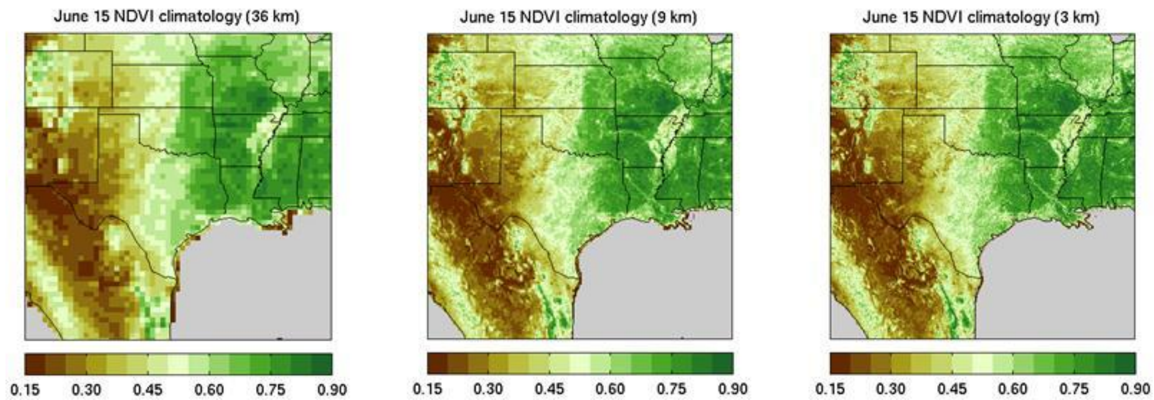
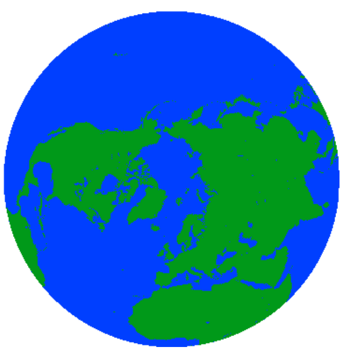


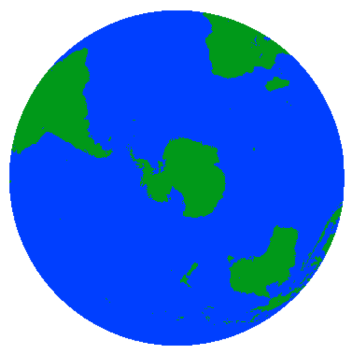
Figure 3: Example of ancillary NDVI climatology data displayed on the SMAP 36-km, 9-km, and 3-km grids.

For brevity, the three projections (global, north polar and south polar) used by the SMAP products are assigned with the following three-letter designators thereafter in this document. These projections are shown in Fig. 4.

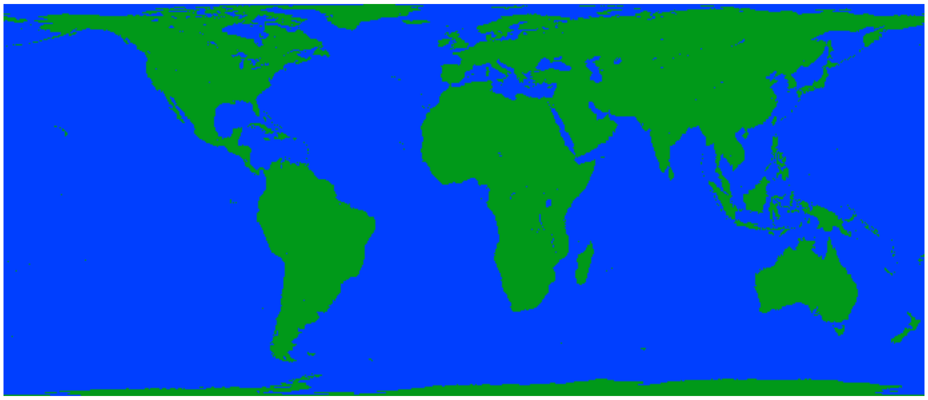
- Global: M36
- North Polar: N36
- South Polar: S36



(a) Northern Hemisphere on EASE2-Grid projection (Figure credited to NSIDC)



(b) Southern Hemisphere on EASE2-Grid projection (Figure credited to NSIDC)



(c) Global EASE2-Grid projection
(Figure credited to NSIDC)

Figure 4: EASE2 Grid examples: (a) N36, (b) S36, and (c) M36.

The data in the SMAP L3_FT_P_E product are available on the 9-km north polar (N09) projection. All elements in L3_FT_P_E are stored as HDF5 Datasets. Table 8 lists the designators and parameters for the twelve standard SMAP EASE-2.0 grids.

Table 8: SMAP EASE-2.0 grids

Global Grids	Equal-Area Cylindrical Projections			Polar Grids	Azimuthal Equal-Area Projections, North and South		
Grid Designator	Resolution	Number of Columns	Number of Rows	Grid Designator	Resolution	Number of Columns	Number of Rows
M01	1 km	34704	14616	N01, S01	1 km	18000	18000
M03	3 km	11568	4872	N03, S03	3 km	6000	6000
M09	9 km	3856	1624	N09, S09	9 km	2000	2000
M36	36 km	964	406	N36, S36	36 km	500	500

4 PRODUCT DEFINITION

4.1 Overview

The SMAP L3_FT_P_E product is a daily composite of the SMAP L1C_TB_E processor product, which provides gridded SMAP radiometer brightness temperatures, and adds retrieval of freeze-thaw states, ancillary data, and quality-assessment flags on the polar 9-km EASE2 Grid designed by NSIDC for SMAP. To generate the standard L3_FT_P_E product the processing software ingests one day's worth of L1C_TB_E granules and creates composites as full-grid arrays for each output parameter. Wherever data overlap occurs (typically at high latitudes), data whose acquisition time is closest to the 6:00 am (for descending passes) or 6:00pm (for ascending passes) local solar time is chosen.

The input L1C_TB_E granules are generated for both descending (6:00 am) and ascending (6:00 pm) passes. The L3_FT_P_E products maintain separate AM and PM layers for most data elements (backscatter, freeze-thaw state).

4.2 Product Names

L3_FT_P_E data product file names conform to the following convention:

SMAP_L3_FT_P_E_[Data_Date]_[Composite Release ID]_[Product Counter].[extension]

Example: SMAP_L3_FT_P_E_20150415_ R00400_002.h5

Data Date	Data-date stamp in Universal Coordinated Time (UTC) of the date of the data that appears in the product. The stamp conforms to the *YYYYMMDD* convention.
Composite Release ID	An ID that incorporates changes to any processing condition that might impact product results. The Composite Release ID contains three other shorter ID's: [R][Launch Indicator][Major ID][Minor ID]. The Launch Indicator distinguishes between pre-launch or pre-instrument commissioned data. ('0' for simulated or preliminary observations whereas '1' for observations at or after the time of instrument commissioning) A two-digit Major ID indicates major releases due to changes in algorithm or processing approach. A two-digit Minor ID indicates minor releases due to changes not considered by a change in Major ID.
Product Counter	A three-digit counter that tracks the number of times that a particular product type for a specific half orbit has been generated.
Extension	'.h5' for science product data and '.qa' for QA product data.

4.3 Volume

The following estimates represent the combined data volume of metadata and the actual science data of the product:

Daily volume: 85 MBytes

Yearly volume: 31 GBytes

4.4 L3_FT_P_E Product Metadata

The metadata elements in the L3_FT_P_E 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 Attribute set 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.

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 carats <>. All of the metadata elements that appear in table 8 should also appear in every L3_FT_P_E Product file.

Table 9: Granule Level Metadata in the L3_FT_P_E Product

Representative ISO Class	SMAP HDF5 Metadata Subgroup	SMAP HDF5 Sub-path	SMAP HDF5 Attribute	Definition
MD_AcquisitionInformation	AcquisitionInformation	platform	antennaRotationRate	<The antenna rotation rate in revolution per minute (rpm)>
			description	The SMAP observatory houses an L-band radiometer that operates at 1.40 GHz and an L-band radar that operates at 1.26 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.
			identifier	SMAP
		radar, radiometer	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.
			identifier	SMAP SAR
			type	L-band Synthetic Aperture Radar
		platformDocument, radarDocument, radiometerDocument	edition	<The edition of publication of the reference document, if available to the general public.>
			publicationDate	<The date of publication of the reference document, if available to the general public.>
			title	<The title of the publication of the reference document, if available to the general public.>
DQ_DataQuality	DataQuality	DomainConsistency	evaluationMethodType	<The type of data quality evaluation method. "directInternal" means the method of evaluating the quality of a dataset based on inspection of items within the dataset, where all data required is internal to the dataset being evaluated.>
			measureDescription	<The description of the Domain Consistency measurement.>
			nameOfMeasure	<The name of the measurements>
			unitOfMeasure	Percent
			value	<A measure between 0 and 100>
		CompletenessOmission	evaluationMethodType	<The type of data quality evaluation method. "directInternal" means the method of evaluating the quality of a dataset based on inspection of items

				within the dataset, where all data required is internal to the dataset being evaluated.>
			measureDescription	<The description of the Completeness Omission measurement.>
			nameOfMeasure	Percent of Missing Data
			unitOfMeasure	Percent
			value	<A measure between 0 and 100>
			scope	<A list of data elements of the product, that are used for DataQuality measurement>
DS_Dataset/MD_DataIdentification	DatasetIdentification		CompositeReleaseID	<SMAP Composite Release ID associated with this data product>
			ECSVersionID	<Identifier that specifies major version delivered to ECS (EOSDIS Core System). Value runs from 001 to 999>
			SMAPShortName	<The SMAP Mission product short name of this data product.>
			UUID	<A universally unique identifier for each data granule.>
			abstract	<A short description of this data product.>
			characterSet	utf8
			creationDate	<Date when this data product file was created>
			credit	<Identify the institutional authorship of the product generation software and the data system that automates its production.>
			fileName	<The name of this data product file.>
			language	eng
			originatorOrganizationName	Jet Propulsion Laboratory
			otherCitationDetails	<The description of the state of the product generation software for this data product file.>
			purpose	<The description of the purpose of this data product file.>
			shortName	<The ECS short name of this data product in 8 characters.>
			spatialRepresentationType	grid
			status	onGoing
			topicCategory	geoscientificInformation
EX_Extent	Extent		description	<The description of the spatial and temporal extents of the data product.>
			eastBoundLongitude	<The most eastern boundary of the spatial extent the data product covers (Longitude measure between -180 degrees and 180 degrees)>
			northBoundLatitude	<The most northern boundary of the spatial extent the data product covers (Latitude measure between -90 degrees and 90 degrees)>

			rangeBeginningDateTime	<Character string that indicates the date and time of the initial data element in the product>
			rangeEndingDateTime	<Character string that indicates the date and time of the final data element in the product.>
			southBoundLatitude	<The most southern boundary of the spatial extent the data product covers (Latitude measure between -90 degrees and 90 degrees)>
			westBoundLongitude	<The most western boundary of the spatial extent the data product covers (Longitude measure between -180 degrees and 180 degrees)>
MD_GridSpatialRepresentation	GridSpatialRepresentation	GridDefinitionDocument	edition	<The version of the grid definition document>
			publicationDate	<The publication date of the grid definition document>
			title	<The title of the grid definition document>
		Column, Row	dimensionSize	<The size of the dimension of the arrays in this specific projection are organized in this data product file>
			resolution	<The spatial resolution each data point represents, in kilometer>
		GridDefinition	description	<The description of the grid definition applied for the data product generation>
			identifier	<The short name identifying the grid definition of this data product>
			cellGeometry	<Indication of grid data as point or area>
			controlPointAvailability	<Indication of whether or not control points are available (0 implies not available and 1 implies available)>
			georeferencedParameters	<The parameters used for the conversion of the geographic location information to the map projection of interest>
			numberOfDimensions	<The number of dimensions of the arrays in this specific projection are organized in this data product file>
			orientationParameterAvailability	<Indication of whether or not orientation parameters are available (0 implies not available and 1 implies available)>
			transformationParameterAvailability	<The indication of whether the parameters for transformation exists or not (0 implies not available and 1 implies available)>
LI_Lineage/LE_Source	Lineage	EASEGRID_LAT_N, EASEGRID_LON_N, InputConfiguration, MetadataConfiguration, OutputConfiguration, RunConfiguration	creationDate	<Date when the corresponding ancillary input file was created>
			description	<Description of each ancillary input file used to generate this data product.>
			fileName	<The name of the ancillary input file.>
			version	<The version number of the ancillary input file.>

			DOI	<A digital object identifier associated with the input product. This field appears only for the Lineage class that describes the SMAP science data product.>
			creationDate	<Date when the corresponding input product file was created>
			description	<Description of each of the input files used to generate this data product.>
			fileName	<The name of the corresponding input product file.>
			identifier	<The short name associated with the input SMAP science data product.>
			resolution	<The spatial resolution each data point represents, in kilometer>
			version	<The SMAP Composite Version ID associated with the input data product.>
		L1C_TB_E, L3_FT_P_E		
			startRevNumber	<The lowest orbit number among the input product granules>
SD_OrbitMeasuredLocation	OrbitMeasuredLocation		stopRevNumber	<The highest orbit number among the input product granules>
			ATBDDate	<Time stamp that specifies the release date of the ATBD>
			ATBDTitle	<The title of the ATBD>
			ATBDVersion	<Version identifier for the ATBD.>
			SWVersionID	<A software version identifier that runs from 001 to 999>
			algorithmDate	<Date associated with current version of the algorithm.>
			algorithmDescription	<Descriptive text about the algorithm(s) in the product generation software for this data product.>
			algorithmTitle	<The representative name of the algorithm for this data product.>
			algorithmVersionID	<Identifier that specifies the current algorithm version. Value runs from 001 to 999>
			documentDate	<Release date for the software description document.>
			documentVersion	<Version identifier for the software description document.>
			documentation	<A reference to software description document.>
			epochJulianDate	<Julian Date of the Epoch J2000, 2451545>
			epochUTCDateTime	<UTC Date Time of the Epoch J2000, 2000-01-01T11:58:55.816Z>
			identifier	<Name of the product generation software for this data product>
			parameterVersionID	<Identifier that specifies the current version of processing parameters. Value runs from 001 to 999.>
LI_Lineage/LE_ProcessStep	ProcessStep		processDescription	<Short description of the data processing concept by the product

				generation software.>
			processor	<Name of the product generation facility>
			softwareDate	<A date stamp that specifies when software used to generate this product was released.>
			softwareTitle	<The title of the product generation facility>
			stepDateTime	< A character string that specifies the date and the time when the product was generated.>
			timeVariableEpoch	<The Epoch of the time variable for the SMAP mission>
DS_Series/MD_DataIdentification	ProductSpecificationDocument		SMAPShortName	<The SMAP Mission product short name of this data product.>
			characterSet	utf8
			edition	<Edition identifier for the Product Specification Document>
			language	eng
			publicationDate	<Date of publication of the Product Specification Document>
			title	<The title of the product specification document>
DQ_DataQuality	QA		MissingSamples	<The number of samples missing in this data products>
			OutOfBoundsSamples	<The number of samples that are exceeding the predefined boundary>
			QAPercentOutOfBoundsData	<Percent of the samples that are exceeding the predefined boundary with respect tot the total samples in this data product>
			TotalSamples	<The number of all samples in this data product>
DS_Dataset/MD_DataIdentification	QADatasetIdentification		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.
			creationDate	<The date that the QA product was generated.>
			fileName	<The name of QA product.>
DS_Series/MD_DataIdentification	SeriesIdentification		CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product>
			ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999>
			abstract	<A short description of this data product series.>
			characterSet	utf8
			credit	<Identify the institutional authorship of the product generation software and the data system that automates its production.>
			format	HDF5

			formatVersion	<The version of the HDF5 library used for the product generation>
			identifier_product_DOI	<digital object identifier for the Level 1C TB Product>
			language	eng
			longName	<The long name of this data product (up to 80 characters long)>
			maintenanceAndUpdateFrequency	asNeeded
			maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
			mission	Soil Moisture Active Passive (SMAP)
			otherCitationDetails	<The description of the state of the product generation software for this data product file.>
			pointOfContact	<The name of the DAAC this data product is distributed from.>
			purpose	<The description of the purpose of this data product file.>
			resourceProviderOrganizationName	National Aeronautics and Space Administration
			revisionDate	<Date and time of the software release that was used to generate this data product.>
			shortName	<The ECS short name of this data product in 8 characters.>
			spatialRepresentationType	grid
			status	onGoing
			topicCategory	geoscientificInformation

[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

The SMAP L3_FT_P_E product is a daily global composite of the SMAP L1C_TB_E processor product, which provides gridded SMAP radiometer brightness temperatures, and adds retrieved freeze-thaw states, ancillary data, and quality-assessment flags on the north polar 36-km EASE2 Grid. This organization is reflected schematically in Fig. 5. All data elements appear in the HDF5 Global Projection Group.

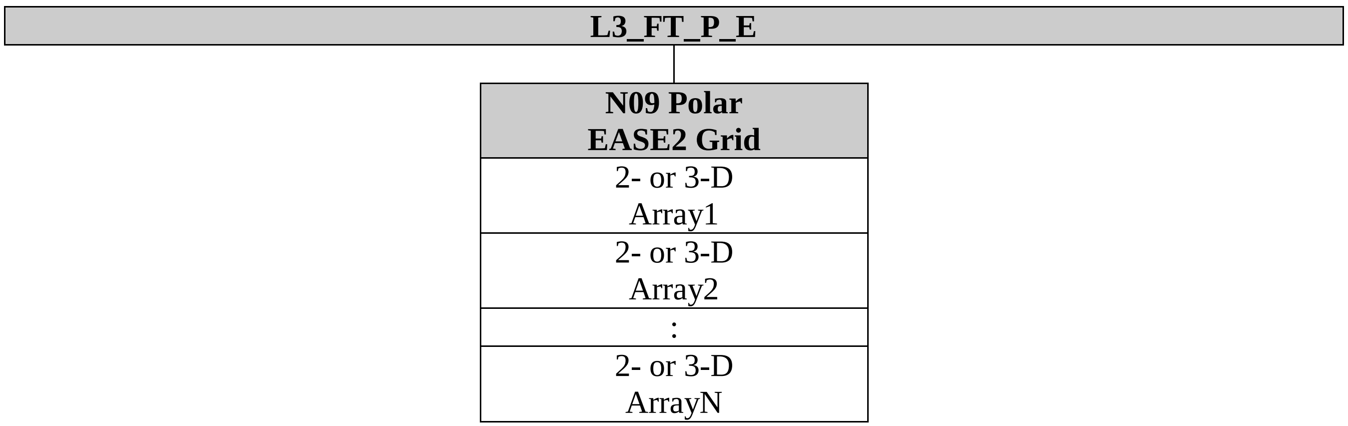


Figure 5: L3_FT_P_E data organization.

Table 9 describes the output parameters of a typical L3_FT_P_E granule based on its associated L1C_TB_E half-orbit input granules, for both AM and PM passes, acquired within a day. Most data element arrays are three-dimensional with 6000 rows and 6000 columns in each AM or PM layer. **For the AM/PM index of the array, the AM layer is assigned to the index value 0 and the PM layer is assigned to index value 1.**

Freeze-Thaw Retrieval Data Group

Element	Shape	Concept	Storage	Bytes	Unit	Min	Max
EASE_column_index	AMPM_LatCell_LonCell_Array	integer	uint16	2		0	499
EASE_row_index	AMPM_LatCell_LonCell_Array	integer	uint16	2		0	499
latitude	AMPM_LatCell_LonCell_Array	real	float32	4	degrees	-90	90
longitude	AMPM_LatCell_LonCell_Array	real	float32	4	degrees	-180	180
freeze_thaw_time_seconds	AMPM_LatCell_LonCell_Array	real	float64	8	seconds		
freeze_thaw_time_utc	AMPM_LatCell_LonCell_Array	string	char	13		00:00:00.000Z	00:00:00.000Z
freeze_thaw	AMPM_LatCell_LonCell_Array	boolean	uint8	1		0	1
transition_state_flag	LatCell_LonCell_Array	boolean	uint8	1		1	2
transition_direction	LatCell_LonCell_Array	boolean	uint8	1		1	2
normalized_polarization_ratio	AMPM_LatCell_LonCell_Array	real	float32	4	normalized		
freeze_thaw_uncertainty	AMPM_LatCell_LonCell_Array	real	float32	4			
retrieval_qual_flag	AMPM_LatCell_LonCell_Array	bit flag	uint16	4			
surface_flag	AMPM_LatCell_LonCell_Array	bit flag	uint16	4			
freeze_reference	AMPM_LatCell_LonCell_Array	real	float32	4	dB	-100.0	20.0
thaw_reference	AMPM_LatCell_LonCell_Array	real	float32	4	dB	-100.0	20.0
freeze_reference_date	AMPM_LatCell_LonCell_Array	string	char	10		2014-10-31	2030-12-31
thaw_reference_date	AMPM_LatCell_LonCell_Array	string	char	10		2014-10-31	2030-12-31
reference_image_threshold	AMPM_LatCell_LonCell_Array	real	float32	4	normalized	0	1.0
data_sampling_density	AMPM_LatCell_LonCell_Array	real	float32	4	km	0	500

Radiometer Data Group

Element	Shape	Concept	Storage	Bytes	Unit	Min	Max
tbh_mean	AMPM_LatCell_LonCell_Array	real	float32	4	Kelvin	0.0	1.0
tbv_mean	AMPM_LatCell_LonCell_Array	real	float32	4	Kelvin	0.0	1.0
tbh_error	AMPM_LatCell_LonCell_Array	real	float32	4	normalized	0.0	5.0
tbv_error	AMPM_LatCell_LonCell_Array	real	float32	4	normalized	0.0	5.0
tbh_qual_flag	AMPM_LatCell_LonCell_Array	bit flag	uint32	4	n/a	n/a	n/a
tbv_qual_flag	AMPM_LatCell_LonCell_Array	bit flag	uint32	4	n/a	n/a	n/a

Ancillary Data Group

Element	Shape	Concept	Storage	Bytes	Unit	Min	Max
landcover_class	AMPM_LatCell_LonCell_Array	enum	uint8	1	n/a	0	16
open_water_body_fraction	AMPM_LatCell_LonCell_Array	real	float32	4	normalized	0	1
altitude_std_dev	AMPM_LatCell_LonCell_Array	real	float32	4	m	0	1000
altitude_dem	AMPM_LatCell_LonCell_Array	real	float32	4	m	0	20000

4.6 L3_FT_P_E Element Definitions

4.6.1 **altitude_dem**

The Earth surface elevation within the 9 km cell.

Type: Float32
Group: Ancillary Data
Shape: AM_PM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 20000.00
Units: meters

4.6.2 **altitude_std_dev**

The standard deviation of the Earth surface elevation within the 9 km cell. This element provides a surface roughness measure.

Type: Float32
Group: Ancillary Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 1000.00
Units: meters

4.6.3 **data_sampling_density**

Number of brightness temperature measurements gridded in the freeze-thaw data cell.

Type: Float32
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 500
Units: n/a

4.6.4 **EASE_column_index**

The EASE grid column index of the freeze-thaw data cell on the 500x500 north polar grid.

Type: Uint16
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0

Valid_max:	5999
Units:	n/a

4.6.5 **EASE_row_index**

The EASE grid row index of the freeze-thaw data cell on the 500x500 north polar grid.

Type:	Uint16
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	0
Valid_max:	5999
Units:	n/a

4.6.6 **freeze_reference**

Reference normalized polarization ratio (NPR) value used as a basis to indicate frozen conditions. The AM (AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type:	Float32
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	-100.00
Valid_max:	20.00
Units:	dB

4.6.7 **freeze_reference_date**

Date of the data used to determine the reference freeze condition. The AM (AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type:	Fixed-length string
String Length:	10 characters
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	‘2014-10-31‘
Valid_max:	‘2030-12-31’
Units:	n/a

4.6.8 **freeze_thaw**

Boolean that indicates whether soil within cell is frozen or thawed. A value of 0 implies thawed, a value of 1 implies frozen.

Type:	Uint8
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	0
Valid_max:	1
Units:	n/a

4.6.9 **freeze_thaw_time_seconds**

Time of spacecraft overpass relative to ground swath in UTC seconds from the J2000 epoch (1 January 2000 12:00z).

Type:	Float64
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	0.000000
Valid_max:	1.0d+09
Units:	seconds

4.6.10 **freeze_thaw_time_utc**

Time of spacecraft overpass relative to ground swath in UTC.

Type:	Character
String Length:	24 characters
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	‘2014-10-31T00:00:00.000Z’
Valid_max:	‘2030-12-31T23:59:60.999Z’
Units:	n/a

4.6.11 **freeze_thaw_uncertainty**

Uncertainty assigned to quantify the confidence in the retrieved freeze-thaw state. Method to determine uncertainty is TBD. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type:	Float32
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	TBD
Valid_max:	TBD
Units:	TBD

4.6.12 **landcover_class**

An enumerated type that specifies the predominant surface vegetation found in the grid cell. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Uint8
Group: Ancillary Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 16
Units: n/a

Value	Interpretation
0	Water
1	Evergreen needleleaf forest
2	Evergreen broadleaf forest
3	Deciduous needleleaf forest
4	Deciduous broadleaf forest
5	Mixed forest
6	Closed shrubland
7	Open shrubland
8	Woody savanna
9	Savanna
10	Grassland
11	Permanent Wetland
12	Croplands
13	Urban and Built-up
14	Cropland/Natural Vegetation Mosaic
15	Permanent Snow and Ice
16	Barren or Sparsely Vegetated
>16	TBD

4.6.13 **latitude**

Latitude of the center of the Earth based grid cell.

Type: Float32
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: -90.00

Valid_max: 90.00
Units: degrees

4.6.14 **longitude**

Longitude of the center of the Earth based grid cell.

Type: Float32
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: -180.00
Valid_max: 180.00
Units: degrees

4.6.15 **normalized_polarization_ratio**

A parameter sensitive to freeze-thaw that is expressed as the ratio NPR = (TB_H – TB_V)/(TB_H + TB_V), used in the L3_FT_P change-detection retrieval algorithm.

Type: Float32
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: -180.00
Valid_max: 180.00
Units: degrees

4.6.16 **open_water_body_fraction**

Fraction of the grid cell area covered by open water. Open water areas do not have vegetation at or on the water surface. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32
Group: Ancillary Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 1.00
Units: n/a

4.6.17 **reference_image_threshold**

Threshold based on reference freeze and thaw to differentiate between freeze and thaw conditions. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 1.00
Units: n/a

4.6.18 **retrieval_qual_flag**

Sequence of bit flags that indicate the conditions and the quality of the freeze-thaw retrieval.

Type: Uint16
Group: Freeze-Thaw Retrieval Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 65535
Units: n/a

Flag Definition	Bit Position	Bit Value and Interpretation
Reserved	0-2	0 = Always set (no SM retrieval in FT)
Radar water body detection success flag	3	0 = Radar water body detection successful
		1 = Radar water body detection attempted but failed
Freeze-thaw retrieval success flag	4	0 = Freeze-thaw retrieval deemed good quality
		1 = Freeze-thaw retrieval unsuccessful or poor quality
RVI retrieval success flag	5	0 = RVI retrieved successfully
		1 = RVI retrieval unsuccessful
Reserved	6-15	0 = Always clear

4.6.19 **surface_flag**

Bit flags that record ambient surface conditions for the grid cell.

Type: Uint16
Group: Freeze-Thaw Retrieval Data

Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 65535
Units: n/a

Bit Position	Bit Definition	Bit Value and Interpretation
0	Static Water Body Flag	0 = The fraction of the 9 km grid cell area that is over a permanent water body is less than metadata element PermanentWaterBodyThreshold.
		1 = The fraction of the 9 km grid cell area that is over a permanent water body is greater than or equal to metadata element PermanentWaterBodyThreshold.
1	Radar Water Body Detection Flag	0 = Transient water body not detected within 9 km cell
		1 = Transient water body detected within 9 km cell
2	Coastal Proximity Flag	0 = Cell is more than 1 grid cell from coastline
		1 = Cell is within on grid cell of coastline
3	Urban Area Flag	0 = The fraction of the 9 km grid cell area that is over urban development is less than metadata element UrbanAreaThreshold.
		1 = The fraction of the 9 km grid cell area that is over urban development is greater than or equal to metadata element UrbanAreaThreshold.
4	Precipitation Flag	0 = No significant precipitation detected within the 9 km grid cell when data were being acquired.
		1 = Precipitation greater than threshold was detected within the 9 km grid cell.
5	Snow/Ice Flag (dynamic)	0 = Snow or ice cover less than threshold was detected within the 9 km grid cell.
		1 = Snow and/or ice greater than threshold were detected within the 9 km grid cell.
6	Permanent Snow/Ice Flag	0 = Cell landcover (from IGBP) is not dominantly permanent snow or ice
		1 = Cell landcover (from IGBP) is dominantly permanent snow or ice
7	Frozen Ground Flag (Radiometer FT algorithm)	0 = No frozen ground detected within the 9 km grid cell.
		1 = Frozen ground detected within the 9 km grid cell.
8	Frozen Ground Flag (from TSURF)	0 = No frozen ground detected within the 9 km grid cell. TSURF > 0C.
		1 = Frozen ground detected within the 9 km grid cell. TSURF < 0C.
9	Mountainous Terrain	0 = The variability of land elevation in the 9 km grid

	Flag	cell is less than metadata element MountainousTerrainThreshold.
		1 = The variability of land elevation in the 9 km grid cell is greater than or equal to metadata element MountainousTerrainThreshold.
10	Dense Vegetation Flag	0 = The vegetation density within the 9 km grid cell is less than metadata element DenseVegetationThreshold.
		1 = The vegetation density within the 9 km grid cell area is greater than or equal to metadata element DenseVegetationThreshold.
11	Nadir Swath Flag	0 = Data within the the grid cell were not acquired in the nadir region of the swath where sigma0s may not meet the 36 km resolution requirement.
		1 = A significant fraction (TBD) of the 9 km grid cell data were acquired within the nadir region of the swath where sigma0s may not meet the 9 km resolution requirement.
12-15		Always clear

NOTE: Bits defined in the above table shaded in yellow are not used in the L3_FT_P_E product, and are always set to 0.

4.6.20 **tbh_error**

Overall error measure for H-pol Tb within the 9 km cell based on Level 1C NEDT values, includes calibration, RFI and contamination effects. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32
Group: Radiometer Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 10.00
Units: Kelvin

4.6.21 **tbh_mean**

Mean of fore/aft 36 km instrument resolution H-pol Tb in the 9 km Earth grid cell. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32

Group: Radiometer Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 400.00
Units: Kelvin

4.6.22 tbh_qual_flag

Representative quality flags of horizontal polarization Tb measures in the grid cell.

Type: Uint32
Group: Radar Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 65535
Units: n/a

Flag Definition	Bit Position	Bit Value and Interpretation
Mean horizontal polarization quality flag	0	0 = The mean of the forward looking and aft looking horizontal polarization Tb has acceptable quality.
		1 = The mean of the forward looking and aft looking horizontal polarization Tb does not have acceptable quality.
Mean horizontal polarization range flag	1	0 = The mean of the forward looking and aft looking horizontal polarization Tb falls within the expected range.
		1 = The mean of the forward looking and aft looking horizontal polarization Tb is out of range.
Mean horizontal polarization RFI detected flag	2	0 = Insignificant RFI was detected in the mean of the forward looking and aft looking horizontal polarization Tb.
		1 = RFI was detected in the mean of the forward looking and aft looking horizontal polarization Tb.
Mean horizontal polarization RFI repair flag	3	0 = Some components of the mean of the forward looking and aft looking horizontal polarization Tb are based on corrections for RFI contamination.
		1 = Unable to correct the mean of the forward looking and aft looking horizontal polarization Tb for RFI contamination.
Mean horizontal	4	0 = The mean horizontal polarization Tb had

polarization NEDT flag		acceptable NEDT. 1 = NEDIT is unsuitably high for the mean horizontal polarization Tb.
Horizontal polarization direct sun correction flag	5	0 = Direct sun correction was successful. 1 = Direct sun correction was not successful.
Horizontal polarization reflected sun correction flag	6	0 = Reflected sun correction was successful. 1 = Reflected sun correction was not successful.
Horizontal polarization reflected moon correction flag	7	0 = Reflected moon correction was successful. 1 = Reflected moon correction was not successful.
Horizontal polarization direct galaxy correction flag	8	0 = Direct galaxy correction was successful. 1 = Direct galaxy correction was not successful.
Horizontal polarization reflected galaxy correction flag	9	0 = Reflected galaxy correction was successful. 1 = Reflected galaxy correction was not successful.
Horizontal polarization atmospheric correction flag	10	0 = Atmospheric correction was successful. 1 = Atmospheric correction was not successful.
Horizontal polarization Faraday rotation correction flag	11	0 = Faraday rotation correction was successful. 1 = Faraday rotation correction was not successful.
Horizontal polarization null value bit	12	0 = Tb has a valid value. 1 = Tb has a null value.
Horizontal polarization water correction	13	0 = Water correction was not performed. 1 = Water correction was performed.
Horizontal polarization RFI check	14	0 = TA minus TA_FILTERED was less than a threshold 1 = TA minus TA_FILTERED was greater than a threshold
Horizontal polarization RFI clean	15	0 = TB was free of RFI 1 = TB was RFI contaminated

4.6.23 **tbv_error**

Overall error measure for V-pol Tb within the 9 km cell based on Level 1C NEDT values, includes calibration, RFI and contamination effects. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32
Group: Radiometer Data
Shape: AMPM_LatCell_LonCell_Array

Valid_min: 0.00
Valid_max: 10.00
Units: normalized

4.6.24 **tbv_mean**

Mean of fore/aft 36 km instrument resolution H-pol Tb in the 9 km Earth grid cell. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type: Float32
Group: Radiometer Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0.00
Valid_max: 400.00
Units: Kelvin

4.6.25 **tbv_qual_flag**

Representative quality flags of vertical polarization Tb measures in the grid cell.

Type: Uint32
Group: Radar Data
Shape: AMPM_LatCell_LonCell_Array
Valid_min: 0
Valid_max: 65535
Units: n/a

Flag Definition	Bit Position	Bit Value and Interpretation
Mean vertical polarization quality flag	0	0 = The mean of the forward looking and aft looking vertical polarization Tb has acceptable quality.
		1 = The mean of the forward looking and aft looking vertical polarization Tb does not have acceptable quality.
Mean vertical polarization range flag	1	0 = The mean of the forward looking and aft looking vertical polarization Tb falls within the expected range.
		1 = The mean of the forward looking and aft looking vertical polarization Tb is out of range.
Mean vertical	2	0 = Insignificant RFI was detected in the mean

polarization RFI detected flag		of the forward looking and aft looking vertical polarization Tb.
		1 = RFI was detected in the mean of the forward looking and aft looking vertical polarization Tb.
Mean vertical polarization RFI repair flag	3	0 = Some components of the mean of the forward looking and aft looking vertical polarization Tb are based on corrections for RFI contamination.
		1 = Unable to correct the mean of the forward looking and aft looking vertical polarization Tb for RFI contamination.
Mean vertical polarization NEDT flag	4	0 = The mean vertical polarization Tb had acceptable NEDT.
		1 = NEDIT is unsuitably high for the mean vertical polarization Tb.
Vertical polarization direct sun correction flag	5	0 = Direct sun correction was successful.
		1 = Direct sun correction was not successful.
Vertical polarization reflected sun correction flag	6	0 = Reflected sun correction was successful.
		1 = Reflected sun correction was not successful.
Vertical polarization reflected moon correction flag	7	0 = Reflected moon correction was successful.
		1 = Reflected moon correction was not successful.
Vertical polarization direct galaxy correction flag	8	0 = Direct galaxy correction was successful.
		1 = Direct galaxy correction was not successful.
Vertical polarization reflected galaxy correction flag	9	0 = Reflected galaxy correction was successful.
		1 = Reflected galaxy correction was not successful.
Vertical polarization atmospheric correction flag	10	0 = Atmospheric correction was successful.
		1 = Atmospheric correction was not successful.
Vertical polarization Faraday rotation correction flag	11	0 = Faraday rotation correction was successful.
		1 = Faraday rotation correction was not successful.
Vertical polarization null value bit	12	0 = Tb has a valid value.
		1 = Tb has a null value.
Vertical polarization water correction	13	0 = Water correction was not performed.
		1 = Water correction was performed.
Vertical polarization RFI check	14	0 = TA minus TA_FILTERED was less than a threshold
		1 = TA minus TA_FILTERED was greater than a threshold
Vertical polarization RFI clean	15	0 = TB was free of RFI
		1 = TB was RFI contaminated

4.6.26 **thaw_reference**

Reference normalized polarization ratio (NPR) value used as a basis to indicate thawed conditions. The AM (dimension AMPM=0) and PM (AMPM=1) observations are stored separately in the array.

Type:	Float32
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	-100.00
Valid_max:	20.00
Units:	normalized

4.6.27 **thaw_reference_date**

Date of the data used to determine the reference thawed condition.

Type:	Fixed-length string
String Length:	10 characters
Group:	Freeze-Thaw Retrieval Data
Shape:	AMPM_LatCell_LonCell_Array
Valid_min:	‘2014-10-31‘
Valid_max:	‘2030-12-31’
Units:	n/a

4.6.28 **transition_direction**

Boolean that indicates transitional direction. 2 indicates AM frozen, PM thawed, 1 indicates AM thawed, PM frozen. Value is always zero if not in transition state.

Type:	Uint8
Group:	Freeze-Thaw Retrieval Data
Shape:	LatCell_LonCell_Array
Valid_min:	0
Valid_max:	2
Units:	n/a

4.6.29 **transition_state_flag**

Boolean that indicates whether soil is in transitional state from AM to PM on the same day. 1 indicates state is not in transition (does not change from AM to PM), 2 indicates state is in transition (AM and PM states are different).

Type:	Uint8

Group: Freeze-Thaw Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 1
Valid_max: 2
Units: n/a

5 REFERENCES

5.1 Requirements

- SMAP Level 1 Mission Requirements and Success Criteria. (Appendix O to the Earth Systematic Missions Program Plan: Program-Level Requirements on the Soil Moisture Active Passive Project.). NASA Headquarters/Earth Science Division, Washington, DC.
- SMAP Level 2 Science Requirements. SMAP Project, JPL D-45955, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Science Algorithms and Validation Requirements. SMAP Project, JPL D-45993, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Mission System Requirements. SMAP Project, JPL D-45962, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 4 Science Data System Requirements. SMAP Project, JPL D-61680, Jet Propulsion Laboratory, Pasadena, CA.

5.2 Plans

- SMAP Science Data Management and Archive Plan. SMAP Project, JPL D-45973, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Science Data Calibration and Validation Plan. SMAP Project, JPL D-52544, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Applications Plan. SMAP Project, JPL D-53082, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Science Data System Operation Plan. SMAP Project, JPL D-80765, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Project Implementation Plan. SMAP Project, JPL D-45939, Jet Propulsion Laboratory, Pasadena, CA.

5.3 Algorithm Theoretical Basis Documents

- SMAP Algorithm Theoretical Basis Document: L1B and L1C Radar Products. SMAP Project, JPL D-53052, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L1B Radiometer Product. SMAP Project, GSFC-SMAP-006, NASA Goddard Space Flight Center, Greenbelt, MD.
- SMAP Algorithm Theoretical Basis Document: Enhanced L1B_TB_E Radiometer Brightness Temperature Data Product. SMAP Project, JPL D-56287, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L1C Radiometer Product. SMAP Project, JPL D-53053, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radar Soil Moisture (Active) Products. SMAP Project, JPL D-66479, Jet Propulsion Laboratory, Pasadena, CA.

- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radiometer Soil Moisture (Passive) Products. SMAP Project, JPL D-66480, Jet Propulsion Laboratory, Pasadena, CA.
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- SMAP Algorithm Theoretical Basis Document: L3 Radar Freeze/Thaw (Active) Product. SMAP Project, JPL D-66482, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L3 Radiometer Freeze/Thaw (Passive) Product. SMAP Project, JPL D-56288, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L4 Surface and Root-Zone Soil Moisture Product. SMAP Project, JPL D-66483, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L4 Carbon Product. SMAP Project, JPL D-66484, Jet Propulsion Laboratory, Pasadena, CA.

5.4 Product Specification Documents

- SMAP Level 1A Radar Product Specification Document. SMAP Project, JPL D-72543, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1B Radar (L1C_S0_LoRes) Product Specification Document. SMAP Project, JPL D-72544, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1A Radiometer Product Specification Document. SMAP Project, JPL D-72554, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1B Radiometer (L1B_TB) Product Specification Document. SMAP Project, JPL D-72552, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Enhanced Level 1B Radiometer (L1B_TB_E) Product Specification Document. SMAP Project, JPL D-56289, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1C Radiometer (L1C_TB) Product Specification Document. SMAP Project, JPL D-72545, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Enhanced Level 1C Radiometer (L1C_TB_E) Product Specification Document. SMAP Project, JPL D-56290, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 2 Active Soil Moisture (L2_SM_A) Product Specification Document. SMAP Project, JPL D-72546, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 2 Passive Soil Moisture (L2_SM_P) Product Specification Document. SMAP Project, JPL D-72547, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 2 Enhanced Passive Soil Moisture (L2_SM_P_E) Product Specification Document. SMAP Project, JPL D-56291, Jet Propulsion Laboratory, Pasadena, CA.

- SMAP Level 2 Active/Passive Soil Moisture (L2_SM_AP) Product Specification Document. SMAP Project, JPL D-72548, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Freeze-Thaw (L3_FT_A) Product Specification Document. SMAP Project, JPL D-72549, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Freeze-Thaw Passive (L3_FT_P) Product Specification Document. SMAP Project, JPL D-56293, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Enhanced Freeze-Thaw Passive (L3_FT_P_E) Product Specification Document. SMAP Project, JPL D-56294, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Active Soil Moisture (L3_SM_A) Product Specification Document. SMAP Project, JPL D-72550, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Passive Soil Moisture (L3_SM_P) Product Specification Document. SMAP Project, JPL D-72551, Jet Propulsion Laboratory, Pasadena, CA.
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- SMAP Level 3 Active/Passive Soil Moisture (L3_SM_AP) Product Specification Document. SMAP Project, JPL D-72552, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 4 Carbon (L4_C) Product Specification Document. SMAP Project, University of Montana, Missoula, MT.
- SMAP Level 4 Soil Moisture (L4_SM) Product Specification Document. SMAP Project, Global Modeling and Assimilation Office, Goddard Space Flight Center, Greenbelt, MD.

5.5 Others

- Interface Control Document Between the Soil Moisture Active Passive (SMAP) Science Data System (SDS) and the Alaska Satellite Facility (ASF) and National Snow and Ice Data Center (NSIDC) Distributed Active Archive Centers (DAACs), Goddard Space Flight Center.
- SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems. SMAP Project, JPL D-46018, Jet Propulsion Laboratory, Pasadena, CA.
- 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. URL: http://www.hdfgroup.org/HDF5/doc/H5.intro.html
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- NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, December 5, 2011.
- EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets, Brodzik, M.J., et. al., National Snow and Ice Data Center, Cooperative Institute of Environmental Sciences, University of Colorado, ISPRS International Journal of Geo-Information, ISSN 2220-9964, DOI: 10.3390/igji1010032.

6 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
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
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	Government 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 Diode Temperature
NEE	Net Ecosystem Exchange
NEN	Near Earth Network
netCDF	Network Common Data Form
NFS	Network File System/Server
NISN	NASA Integrated Services Network
NPR	Normalized Polarization Ratio
NRT	Near Real Time
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NVM	Non-Volatile Memory
NWP	Numerical Weather Prediction
N\A	Not applicable

OCO	Orbiting Carbon Observatory
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 square
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
TAI	International Atomic Time
TB	Brightness Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
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