# Soil Moisture Active Passive (SMAP) Mission

# Level 2 Passive Soil Moisture Product Specification Document

**Version 8.0**
**R18 Release**

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# Soil Moisture Active Passive (SMAP)
# Level 2 Passive Soil Moisture
# Product Specification Document

**Version 8.0 Extended Mission Release**

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## DOCUMENT CHANGE LOG

| REVISION | DATE | SECTIONS CHANGED | REASON FOR CHANGE |
|---|---|---|---|
| - | Jun 12, 2014 | | Initial Release |
| - | Aug 31, 2015 | | Beta Release |
| | Apr 7, 2017 | | 4.6.21 Flag definition |
| | Apr 30, 2018 | 4.6.3, 4.6.[19-22] | Prime Mission Release |
| | Nov 13, 2018 | 4.6.27 | Synchronized code and PSD text |
| | May 13,2019 | 4.6.[24-27], 4.6.[36-40] | Removed option4 and option5 elements (MPRA, EDCA), added bulk_density and clay_fraction elements, added roughness_coeff_option3 and albedo_option3 for MDCA |
| 7.0 | August 31, 2020 | 4.6[24-26], 4.6.34, 4.6.36 | Change name of Modified Dual Channel Algorithm (MDCA) to Dual Channel Algorithm (DCA). |
| 8.0 | September 30, 2021 | 4.5 (Table 9), 4.6.41, 4.6.42; 4.6.[24-26] | Add sand_fraction and organic_content data elements. Change baseline pointer elements to point to DCA retrieval outputs. |

# TBD, TBR, TBS LOG

| Section/Page | Description | Due Date |
|---|---|---|
| 4.3 | More accurate estimate of data volume to be determined from simulations | Mar 2013 |
| References | Information on references was updated | Aug 2015 |
| | | |

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# 1 INTRODUCTION

## 1.1 Identification

This is the Product Specification Document (PSD) for the SMAP Level 2 Passive Soil Moisture Product for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The product provides gridded data of 6:00 am (descending) and 6:00 pm (ascending) SMAP radiometer-only soil moisture retrieval, ancillary data, and quality-assessment flags on a 36-km Earth-fixed grid. Only cells that are covered by the actual swath are written into the product.

## 1.2 Scope

This document describes the file format and data contents of the SMAP Level 2 Passive Soil Moisture Product (hereafter referred to as 'L2_SM_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 is a unique mission that 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 and 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 |
|---|---|
| **<u>Soil Moisture</u>**:<br>~± 0.04 m3/m3 volumetric accuracy (1-sigma) in the top 5 cm for vegetation water content ≤ 5 kg/m$^2$<br>Hydrometeorology at ~10 km resolution<br>Hydroclimatology at ~40 km resolution | **<u>L-Band Radiometer (1.41 GHz)</u>:**<br>Polarization: $T_H$, $T_V$, $T_3$, and $T_4$<br>Resolution: 40 km<br>Radiometric Uncertainty*: 1.3 K<br>**<u>L-Band Radar (1.26 and 1.29 GHz)</u>:**<br>Polarization: VV, HH, HV (or VH)<br>Resolution: 10 km<br>Relative accuracy*: 0.5 dB (VV and HH)<br>Constant incidence angle** between 35° and 50° |
| **<u>Freeze/Thaw State</u>:**<br>Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision at the spatial scale of landscape variability (~3 km) | **<u>L-Band Radar (1.26 GHz & 1.29 GHz)</u>:**<br>Polarization: HH<br>Resolution: 3 km<br>Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used)<br>Constant incidence angle** between 35° and 50° |
| Sample diurnal cycle at consistent time of day (6 am/6 pm Equator crossing);<br>Global, ~3 day (or better) revisit;<br>Boreal, ~2 day (or better) revisit | Swath Width: ~1000 km<br>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<br>** Defined without regard to local topographic variation | |

The SMAP instrument incorporates an L-band radar and an L-band radiometer that share a single feedhorn 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, radar 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)

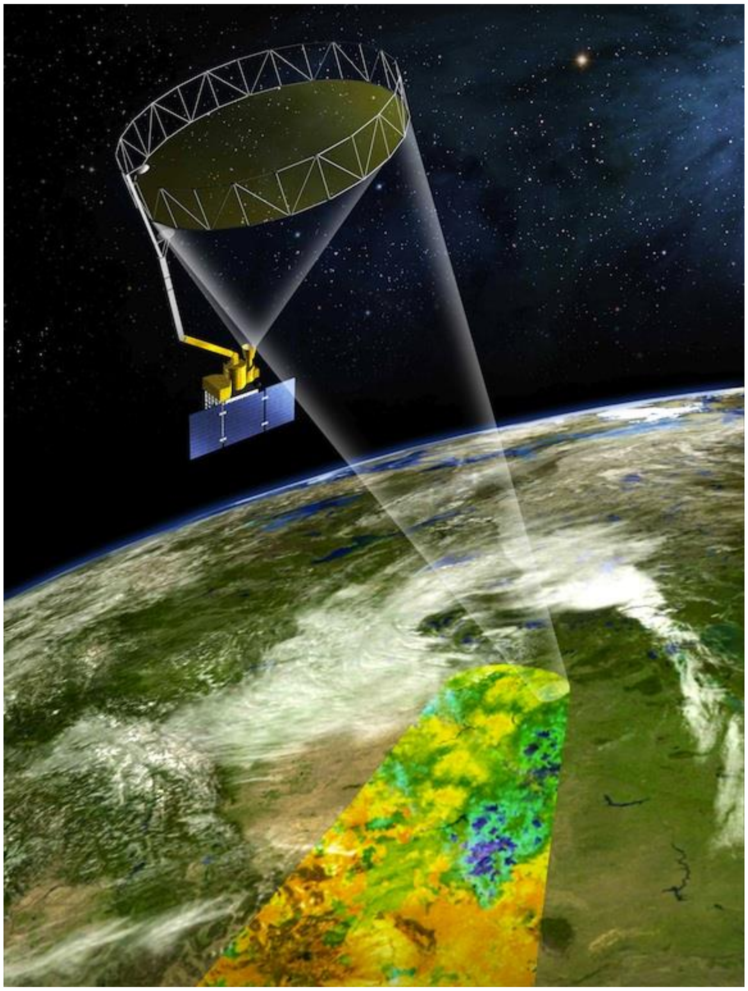

**Figure 1**: The SMAP mission concept consists of an L-band radar and radiometer sharing a single spinning 6-m mesh antenna in a sun-synchronous dawn / dusk orbit.

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.

NOTE: On July 7, 2015 the SMAP radar stopped functioning after only a few months of on-orbit operations, leaving the SMAP radiometer as the only operating instrument on the spacecraft. The following sections have been revised accordingly from the original PSD to acknowledge the current status of the SMAP observatory.

## 1.4 Data Products

The SMAP 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 (24-hour period). Level 4 products contain output from geophysical models that employ SMAP data.

Table 2 lists the official SMAP data products. The SMAP Mission product short names were adopted by the SMAP mission to identify products. Users will find these short names in SMAP mission documentation, SMAP product file names, and in the product metadata.

**Table 2**: Standard and Enhanced 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 | (36 x 47 km) | 12 hrs | |
| L1B_TB_E | Radiometer $T_B$ Interpolated on EASE Grid 2.0 | 9 km | 12 hrs | |
| L1B_S0_LoRes | Low Resolution Radar $\sigma_o$ in Time-Order | (5 x 30 km) | 12 hrs | |
| L1C_S0_HiRes | High Resolution Radar $\sigma_o$ 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 | |

* SMAP radar products were no longer produced operationally after the SMAP radar failed on July 7, 2015. The L2_SM_SP is a product added after the SMAP radar failure which uses Sentinel-1 C-band radar data merged with SMAP L-band radiometer data.

## 1.5 L2_SM_P Overview

The SMAP L2_SM_P product is derived from the SMAP L1C_TB product, which represents gridded data of SMAP Level 1B radiometer observations, ancillary data, and quality-assessment flags. To generate the L2_SM_P product, the processing software ingests half-orbit granules (either 6:00 am descending or 6:00 pm ascending half orbits) of the L1C_TB product. The ingested data are then inspected for retrievability according to input data quality, ancillary data availability, and land surface conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm along with other option algorithms to generate soil moisture retrieval fields[1]. Only cells that are covered by the actual swath are written in the product.

The SMAP L2_SM_P product contains gridded data of SMAP passive soil moisture retrieval, ancillary data, and quality-assessment flags on the 36-km global cylindrical Equal-Area Scalable Earth (EASE) Grid 2.0 designed by the National Snow and Ice Data Center (NSIDC).

[1] Both baseline and option algorithms are executed and their results are stored in separate retrieval fields in the product.

# 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. | Yes |
| valid_max | The largest valid value for any element in the Dataset. The data type in valid_max 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_max will also be float32. | |
| 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 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 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_min | 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_max | 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”, “deg C”, “Kelvins”, “m/s”, “m”, “m**2”, “s” and “counts”. |

### 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 L2_SM_P Product when the L2_SM_P 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 L2_SM_P 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 L2_SM_P 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 radiometer L1C_TB product.

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 | -9999.0 | Large, negative number |
| 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 |

| Type | Value | Pattern |
|---|---|---|
| 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 L2_SM_P product is equal to the values that represent fill. If any exceptions should exist in the future, the L2_SM_P 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 L2_SM_P 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 L1C_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.

## 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 a 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 EASE Grid 2.0

The data in the SMAP L2_SM_P product are presented on a 36-km global cylindrical projection. The projection is based on the NSIDC's EASE Grid 2.0 specifications for SMAP. The EASE Grid 2.0 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.

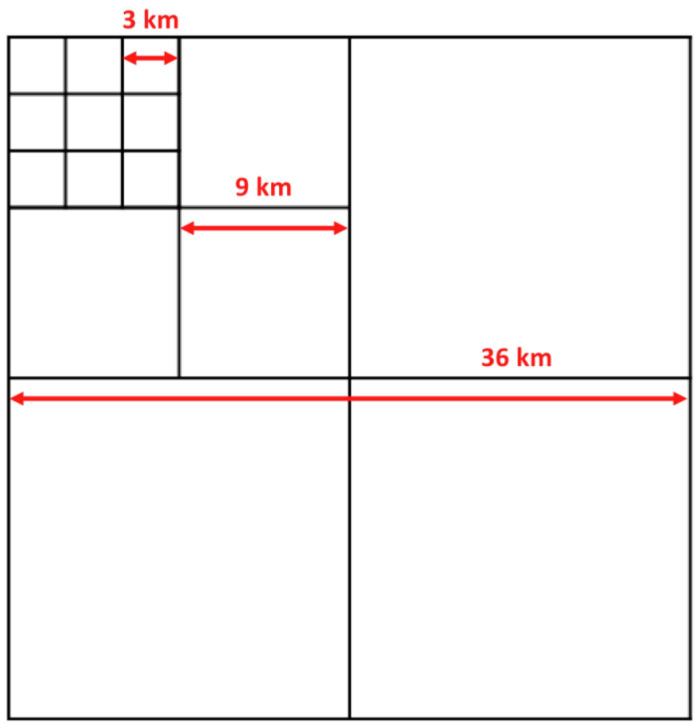


**Figure 2**: Perfect nesting in EASE Grid 2.0 – smaller grid cells can be tessellated to form larger grid cells.

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 EASE Grid 2.0 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_AP) soil moisture products, respectively. A comparison of EASE Grid 2.0 at these three grid resolutions is shown in Fig. 3.

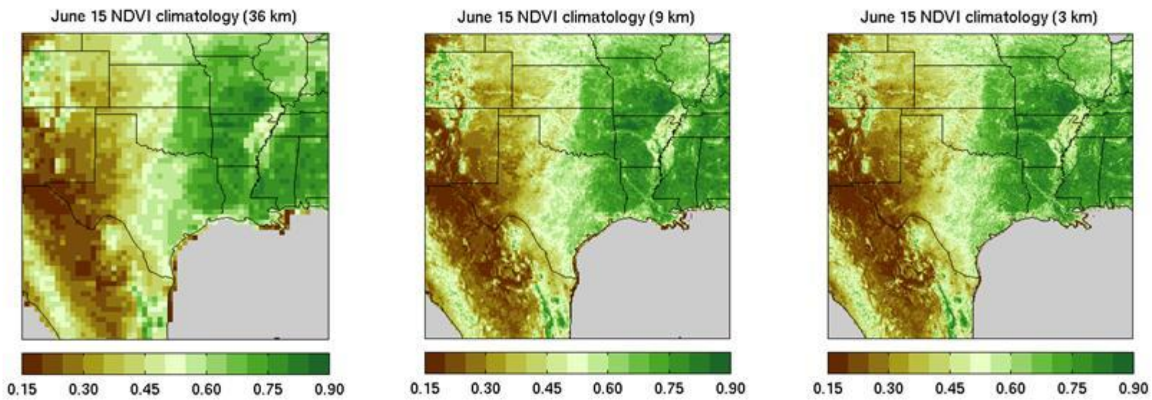


**Figure 3**: Example of ancillary NDVI climatology data displayed on the SMAP 36-km, 9-km, and 3-km grids.

The 36-km global cylindrical EASE Grid 2.0 projection is shown in Fig. 4. Each grid cell has a nominal area of about 36 × 36 $km^2$, regardless of longitudes and latitudes. Under this projection, all global data arrays have dimensions of 406 rows and 964 columns.

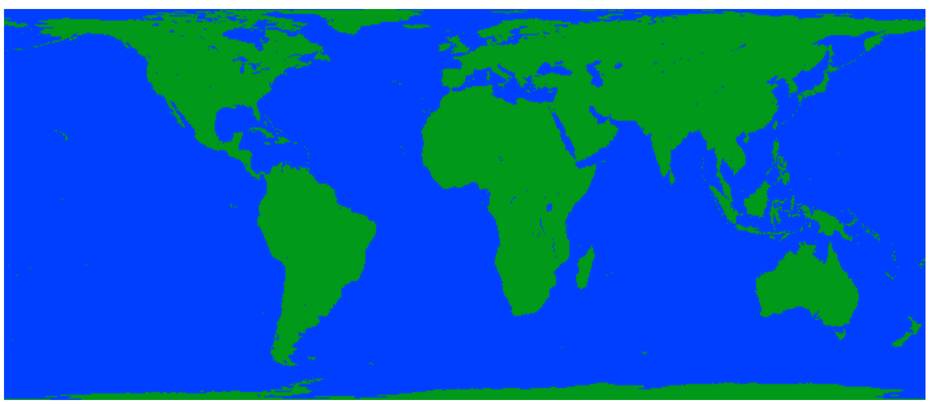

**Figure 4**: Global Cylindrical EASE Grid 2.0 projection
(Figure credited to NSIDC)

# 4 PRODUCT DEFINITION

## 4.1 Overview

The SMAP L2_SM_P product is derived from the SMAP L1C_TB product, which represents gridded data of SMAP Level 1B radiometer observations, ancillary data, and quality-assessment flags. To generate the standard L2_SM_P product, the processing software ingests half-orbit granules (either 6:00 am descending or 6:00 pm ascending half orbits) of the L1C_TB product data. The ingested data are then inspected for retrievability according to input data quality, ancillary data availability, and land surface conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm along with other option algorithms to generate soil moisture retrieval fields[2]. Only cells that are covered by the actual swath for a given projection are written in the product.

## 4.2 Product Names

L2_SM_P data product file names conform to the following convention:

**SMAP_L2_SM_P_**[Orbit Number]_[A|D]_[First Date/Time Stamp]_[Composite Release ID]_[Product Counter].[extension]

***Example***: SMAP_L2_SM_P_00934_D_20141225T074951_ R00400_002.h5

| | |
|---|---|
| *Orbit Number* | A five-digit sequential number of the orbit flown by the SMAP spacecraft when the data was acquired. Orbit 0 begins at launch. |
| *Half Orbit Designator* | 'D' for 6:00 am descending pass; 'A' for 6:00 pm ascending pass |
| *First Date/Time Stamp* | Date/time stamp in Universal Coordinated Time (UTC) of the first data element that appears in the product. The stamp conforms to the YYYYMMDD**T**hhmmss 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 |

[2] Both baseline and option algorithms are executed and their results are stored in separate soil moisture retrieval fields in the product.

| | |
|---|---|
| | 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: 36.63 MBytes

Yearly volume: 13.05 GBytes

## 4.4 L2_SM_P Product Metadata

The metadata elements in the L2_SM_P 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 angle brackets. All of the metadata elements that appear in table 8 should also appear in every L2_SM_P Product file.

**Table 8**: Granule Level Metadata in the L2_SM_P Product

| Representative ISO Class | SMAP HDF5 Metadata Subgroup | SMAP HDF5 Subpath | SMAP HDF5 Attribute | Definition |
|---|---|---|---|---|
| | | | | |
| MD_AcquisitionInformation | AcquisitionInformation | platform | antennaRotationRate | <The antenna rotation rate in revolutions 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,<br>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,<br>radarDocument,<br>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 |
| | | | 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> |
| | | | | |

| | | | | |
|---|---|---|---|---|
| | | 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)> |
| | | | dimensionSize | <The size of the dimension of the arrays in this specific projection are organized in this data product file> |
| | | | 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)> |
| | | | resolution | <The spatial resolution each data point represents, in kilometer> |
| | | | 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 | DEMSLP,<br>LANDCOVER_CLASS,<br>LANDCOVER_CLASS_FRACTION_TOP3,<br>LANDCOVER_CLASS_TOP3,<br>MetadataConfiguration,<br>NDVI,<br>NDVI_MAX,<br>OutputConfiguration,<br>PRECIP,<br>RunConfiguration,<br>SNOW,<br>SOIL_TEXTURE_BULK,<br>SOIL_TEXTURE_CLAY,<br>SOIL_TEXTURE_SAND,<br>SURFACE_ROUGHNESS_COEFF,<br>TSURF,<br>URBAN_FRACTION, | creationDate | <Date when the corresponding ancillary input file was created> |
| | | | description | <Collective external ancillary data for geophysical inversion> |
| | | | fileName | <The name of the ancillary input file.> |
| | | | version | <The version number of the ancillary input file.> |
| | | | | |
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|---|---|---|---|---|
| | | WATER_FRACTION | | |
| | | | | |
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| | | | | |
| | | L1C_TB,<br>L2_SM_A | 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.> |
| | | | | |
| | | InputConfiguration/L1C_TB,<br>InputConfiguration/L2_SM_A | 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.> |
| | | | | |
| | | | | |
| SD_OrbitMeasuredLocation | OrbitMeasuredLocation | | argumentOfPerigee | <The angle in the orbit plane of SMAP satellite 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 that 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.> |
| | | | 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.> |
| | | | inclination | <The angle between the orbital plane of the spacecraft and the equatorial plane of the Earth. 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 semimajor 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"> |
| | | | 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.> |
| | | | referenceCRS | <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.> |
| | | | | |
| LI_Lineage/LE_ProcessStep | ProcessStep | | ATBDDate | <Time stamp that specifies the release date of the ATBD> |
| | | | ATBDTitle | <The title of the ATBD> |
| | | | ATBDVersion | <Version identifier for the ATBD.> |
| | | | FrozenGroundFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | FrozenGroundFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | IceFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | IceFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | MountainousTerrainLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | MountainousTerrainUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | RainFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | RainFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | SWVersionID | <A software version identifier that runs from 001 to 999> |
| | | | SnowFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | SnowFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |

| | | | | |
|---|---|---|---|---|
| | | | UrbanFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | UrbanFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | VWCLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | VWCUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | WaterFractionLowerThreshold | <The threshold value used in the scientific algorithm software> |
| | | | WaterFractionUpperThreshold | <The threshold value used in the scientific algorithm software> |
| | | | 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.> |
| | | | algorithmSelection | <The algorithm(s) applied to generate 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.> |
| | | | 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> |
| | | | 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 S0 HiRes Product> |
| | | | language | eng |
| | | | longName | <The long name of this data product (up to 80 characters long)> |
| | | | maintenanceAndUpdateFrequency | As needed |
| | | | maintenanceDate | <Specifies a date when the next update to this product might be anticipated> |
| | | | mission | Soil Moisture Active Passive (SMAP) |
| | | | otherCitiationDetails | JIRA RAD-166 |
| | | | 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 |

## 4.5 Data Structure

The L2_SM_P product contains gridded data of SMAP radiometer-based soil moisture retrieval, ancillary data, and quality-assessment flags on the 36-km global EASE Grid 2.0 projection. This organization is reflected schematically in Fig. 5. All data elements appear in the HDF5 Global Projection Group.

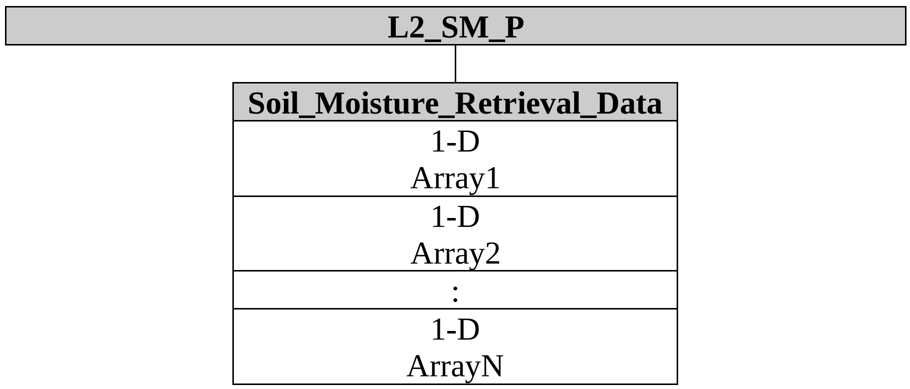


**Figure 5**: L2_SM_P data organization.

Table 9 describes the output parameters of a typical L2_SM_P half-orbit granule. All data element arrays are one-dimensional with a size *N*, where *N* is the number of valid cells covered by the radiometer swath on the grid.

**Table 9**: L2_SM_P output parameters

| Output Parameter | Precision | Byte | Unit | Note | Section |
|---|---|---|---|---|---|
| EASE_row_index | Uint16 | 2 | N\A | 2 | 4.6.1 |
| EASE_col_index | Uint16 | 2 | N\A | 2 | 4.6.2 |
| grid_surface_status | Uint16 | 2 | N\A | 7 | 4.6.3 |
| latitude | Float32 | 4 | Degree | 2 | 4.6.4 |
| longitude | Float32 | 4 | Degree | 2 | 4.6.5 |
| tb_time_seconds | Float64 | 8 | Second | 1 | 4.6.6 |
| tb_time_utc | Char24 | 24 | N\A | 1 | 4.6.7 |
| latitude_centroid | Float32 | 4 | Degree | 1 | 4.6.8 |
| longitude_centroid | Float32 | 4 | Degree | 1 | 4.6.9 |
| boresight_incidence | Float32 | 4 | Degree | 1 | 4.6.10 |
| tb_h_corrected | Float32 | 4 | Kelvin | 1 | 4.6.11 |
| tb_v_corrected | Float32 | 4 | Kelvin | 1 | 4.6.12 |
| tb_3_corrected | Float32 | 4 | Kelvin | 1 | 4.6.13 |
| tb_4_corrected | Float32 | 4 | Kelvin | 1 | 4.6.14 |
| tb_qual_flag_h | Uint16 | 2 | N\A | 4 | 4.6.15 |
| tb_qual_flag_v | Uint16 | 2 | N\A | 4 | 4.6.16 |
| tb_qual_flag_3 | Uint16 | 2 | N\A | 4 | 4.6.17 |

| | | | | | |
|---|---|---|---|---|---|
| tb_qual_flag_4 | Uint16 | 2 | N\A | 4 | 4.6.18 |
| tb_h_uncorrected | Float32 | 4 | Kelvin | 1 | 4.6.19 |
| tb_v_uncorrected | Float32 | 4 | Kelvin | 1 | 4.6.20 |
| surface_water_fraction_mb_h | Float32 | 4 | N\A | 1 | 4.6.21 |
| surface_water_fraction_mb_v | Float32 | 4 | N\A | 1 | 4.6.22 |
| soil_moisture_error | Float32 | 4 | m3/m3 | 4 | 4.6.23 |
| soil_moisture* | Float32 | 4 | m3/m3 | 4 | 4.6.24 |
| soil_moisture_option1 | Float32 | 4 | m3/m3 | 4 | 4.6.24 |
| soil_moisture_option2 | Float32 | 4 | m3/m3 | 4 | 4.6.24 |
| soil_moisture_option3 | Float32 | 4 | m3/m3 | 4 | 4.6.24 |
| vegetation_opacity* | Float32 | 4 | N\A | 6 | 4.6.25 |
| vegetation_opacity_option1 | Float32 | 4 | N\A | 6 | 4.6.25 |
| vegetation_opacity_option2 | Float32 | 4 | N\A | 6 | 4.6.25 |
| vegetation_opacity_option3 | Float32 | 4 | N\A | 5 | 4.6.25 |
| retrieval_qual_flag* | Uint16 | 2 | N\A | 4 | 4.6.26 |
| retrieval_qual_flag_option1 | Uint16 | 2 | N\A | 4 | 4.6.26 |
| retrieval_qual_flag_option2 | Uint16 | 2 | N\A | 4 | 4.6.26 |
| retrieval_qual_flag_option3 | Uint16 | 2 | N\A | 4 | 4.6.26 |
| surface_flag | Uint16 | 2 | N\A | 4 | 4.6.27 |
| vegetation_water_content | Float32 | 4 | $kg/m^2$ | 6 | 4.6.28 |
| surface_temperature | Float32 | 4 | Kelvin | 6 | 4.6.29 |
| static_water_body_fraction | Float32 | 4 | N\A | 6 | 4.6.30 |
| radar_water_body_fraction | Float32 | 4 | N\A | 6 | 4.6.31 |
| freeze_thaw_fraction | Float32 | 4 | N\A | 6 | 4.6.32 |
| landcover_class | Uint8 | 1 | N\A | 6 | 4.6.33 |
| landcover_class_fraction | Float32 | 4 | N\A | 6 | 4.6.34 |
| albedo | Float32 | 4 | N\A | 6 | 4.6.35 |
| albedo_option3 | Float32 | 4 | N\A | 6 | 4.6.36 |
| roughness_coefficient | Float32 | 4 | N\A | 6 | 4.6.37 |
| roughness_coefficient_option3 | Float32 | 4 | N\A | 6 | 4.6.38 |
| clay_fraction | Float32 | 4 | N\A | 6 | 4.6.39 |
| bulk_density | Float32 | 4 | N\A | 6 | 4.6.40 |
| sand_fraction | Float32 | 4 | N\A | 6 | 4.6.41 |
| organic_content | Float32 | 4 | g/kg | 6 | 4.6.42 |

* HDF5 soft link to baseline value (currently DCA [option3])

Method:

1. From L1C_TB.
2. From 36-km EASE Grid 2.0 array definition.
3. Value corrected for the presence of water wherever water/land areal fraction is below a threshold. When the fraction is zero, no correction is performed.
4. Determined by L2_SM_P processing software.
5. Available only with option algorithms that use two polarization channels.

6. From external lookup tables or ancillary data whose location and time stamp coincide with those of the input data as applicable.
7. Nearest-neighbor interpolation.

## 4.6 Parameter Definitions

### 4.6.1 EASE_row_index

Zero-based row index of a 36-km EASE Grid 2.0 cell. In most grid cells, both fore-looking L1C_TB data and aft-looking L1C_TB data are available for soil moisture retrieval. But when one group (e.g., fore-looking group) is not available, the row index parameter of the other group (i.e., aft-looking group) will be written into this parameter.

| | |
|---|---|
| Precision: | Uint16 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 405 (Global Cylindrical projection) |
| Unit: | N\A |

### 4.6.2 EASE_col_index

Zero-based column index of a 36-km EASE Grid 2.0 cell. In most grid cells, both fore-looking L1C_TB data and aft-looking L1C_TB data are available for soil moisture retrieval. But when one group (*e.g.*, fore-looking group) is not available, the column index parameter of the other group (i.e., aft-looking group) will be written into this parameter.

| | |
|---|---|
| Precision: | Uint16 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 963 (Global Cylindrical projection) |
| Unit: | N\A |

### 4.6.3 grid_surface_status

Surface type (land or water) as determined by the antenna boresight location.

| | |
|---|---|
| Precision: | Uint16 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0: land |
| Valid_max: | 1: water |
| Unit: | N\A |

### 4.6.4 **latitude**

Latitude of the center of a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | −90.0 |
| Valid_max: | +90.0 |
| Unit: | Degree |

### 4.6.5 **longitude**

Longitude of the center of a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | −180.0 |
| Valid_max: | +180.0 |
| Unit: | Degree |

### 4.6.6 **tb_time_seconds**

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the average of UTC acquisition times of L1B_TB observations whose boresights fall within a 36-km EASE Grid 2.0 cell. The result is then expressed in J2000 seconds (the number of seconds since 12:00:00.000 on January 1, 2000 Barycentric Dynamical Time (TDB)).

| | |
|---|---|
| Precision: | Float64 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | N\A |
| Unit: | Second |

### 4.6.7 **tb_time_utc**

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the average of UTC acquisition times, in ASCII representation, of L1B_TB observations whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Char24 |
| Dimensions: | *N* = Number of grid cells covered by the swath |

| | |
|---|---|
| Valid_min: | ‘2014-10-31T00:00:00.000Z’ |
| Valid_max: | N\A |
| Unit: | N\A |

#### 4.6.8 latitude_centroid

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of latitudes of L1B_TB observations whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | −90.0 |
| Valid_max: | +90.0 |
| Unit: | Degree |

#### 4.6.9 longitude_centroid

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of longitudes of L1B_TB observations whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | −180.0 |
| Valid_max: | +180.0 |
| Unit: | Degree |

#### 4.6.10 boresight_incidence

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of incidence angles of L1B_TB observations whose boresights fall within a 36-km EASE Grid 2.0 cell. The incidence angle is defined as the included angle between the antenna boresight vector and the normal to the Earth’s surface.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 90.0 |
| Unit: | Degree |

### 4.6.11 tb_h_corrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB horizontally polarized brightness temperatures whose boresights fall within a 36-km EASE Grid 2.0 cell. Wherever water fraction is below a threshold, water brightness temperature correction is applied to this parameter prior to L2_SM_P inversion. This value represents the corrected land brightness temperature if grid_surface_status (Section 4.6.3) is "0" and the water fraction is lower than 0.9 (otherwise no correction is applied) or represents the corrected water brightness temperature if grid_surface_status (Section 4.6.3) is "1" and water fraction is greater than 0.1 (otherwise no correction is applied).

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 330.0 |
| Unit: | Kelvin |

### 4.6.12 tb_v_corrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB vertically polarized brightness temperatures whose boresights fall within a 36-km EASE Grid 2.0 cell. Wherever water fraction is below a threshold, water brightness temperature correction is applied to this parameter prior to L2_SM_P inversion. This value represents the corrected land brightness temperature if grid_surface_status (Section 4.6.3) is "0" and the water fraction is lower than 0.9 (otherwise no correction is applied) or represents the corrected water brightness temperature if grid_surface_status (Section 4.6.3) is "1" and water fraction is greater than 0.1 (otherwise no correction is applied).

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 330.0 |
| Unit: | Kelvin |

### 4.6.13 tb_3_corrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB 3rd Stokes polarized brightness temperatures whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | −50.0 |
| Valid_max: | +50.0 |
| Unit: | Kelvin |

#### 4.6.14 tb_4_corrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB 4th Stokes polarized brightness temperatures whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | −50.0 |
| Valid_max: | +50.0 |
| Unit: | Kelvin |

#### 4.6.15 tb_qual_flag_h

A 16-bit or two-byte binary number formed by applying a Boolean ‘AND’ operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB granule. A ‘0’ indicates that both the fore-looking and aft-looking L1C_TB observations satisfy a given quality criterion described in L1B_TB’s tb_qual_flag_h output parameter; a ‘1’ indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB observations. Bit position '0' refers to the least significant digit.

| | |
|---|---|
| Precision: | Uint16 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 65,536 |
| Unit: | N\A |

| Bit Position | Bit Value and Interpretation |
|---|---|
| 0 | 0 = Observation has acceptable quality |
| | 1 = Observation does not have acceptable quality |
| 1 | 0 = Observation within physical range |
| | 1 = Observation beyond physical range |
| 2 | 0 = RFI was not detected in the observation |

| | |
|---|---|
| | 1 = RFI was detected in the observation |
| 3 | 0 = RFI was detected and corrected in the observation |
| | 1 = RFI was detected but not correctable in the observation |
| 4 | 0 = Observation had acceptable NEDT |
| | 1 = Observation did not have acceptable NEDT |
| 5 | 0 = Direct sun correction was successful |
| | 1 = Direct sun correction was not successful |
| 6 | 0 = Reflected sun correction was successful |
| | 1 = Reflected sun correction was not successful |
| 7 | 0 = Reflected moon correction was successful |
| | 1 = Reflected moon correction was not successful |
| 8 | 0 = Direct galaxy correction was successful |
| | 1 = Direct galaxy correction was not successful |
| 9 | 0 = Reflected galaxy correction was successful |
| | 1 = Reflected galaxy correction was not successful |
| 10 | 0 = Atmosphere correction was successful |
| | 1 = Atmosphere correction was not successful |
| 11 | 0 = Faraday rotation correction was successful |
| | 1 = Faraday rotation correction was not successful |
| 12 | 0 = Observation was a valid value |
| | 1 = Observation was a null value |
| 13 | 0 = Water correction was not performed |
| | 1 = Water correction was performed |
| 14 | 0 = TA minus TA_FILTERED was less than a threshold |
| | 1 = TA minus TA_FILTERED was greater than a threshold |
| 15 | 0 = Observation was free of RFI |
| | 1 = Observation was RFI contaminated |

#### 4.6.16 **tb_qual_flag_v**

A 16-bit or two-byte binary number formed by applying a Boolean ‘AND’ operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB granule. A ‘0’ indicates that both the fore-looking and aft-looking L1C_TB observations satisfy a given quality criterion described in L1B_TB’s tb_qual_flag_v output parameter; a ‘1’ indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB observations. Bit position '0' refers to the least significant digit.

| | |
|---|---|
| Precision: | Uint16 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 65,536 |
| Unit: | N\A |

| Bit Position | Bit Value and Interpretation |
|---|---|
| 0 | 0 = Observation has acceptable quality |
| | 1 = Observation does not have acceptable quality |
| 1 | 0 = Observation within physical range |
| | 1 = Observation beyond physical range |
| 2 | 0 = RFI was not detected in the observation |
| | 1 = RFI was detected in the observation |
| 3 | 0 = RFI was detected and corrected in the observation |
| | 1 = RFI was detected but not correctable in the observation |
| 4 | 0 = Observation had acceptable NEDT |
| | 1 = Observation did not have acceptable NEDT |
| 5 | 0 = Direct sun correction was successful |
| | 1 = Direct sun correction was not successful |
| 6 | 0 = Reflected sun correction was successful |
| | 1 = Reflected sun correction was not successful |
| 7 | 0 = Reflected moon correction was successful |
| | 1 = Reflected moon correction was not successful |
| 8 | 0 = Direct galaxy correction was successful |
| | 1 = Direct galaxy correction was not successful |
| 9 | 0 = Reflected galaxy correction was successful |
| | 1 = Reflected galaxy correction was not successful |
| 10 | 0 = Atmosphere correction was successful |
| | 1 = Atmosphere correction was not successful |
| 11 | 0 = Faraday rotation correction was successful |
| | 1 = Faraday rotation correction was not successful |
| 12 | 0 = Observation was a valid value |
| | 1 = Observation was a null value |
| 13 | 0 = Water correction was not performed |
| | 1 = Water correction was performed |
| 14 | 0 = TA minus TA_FILTERED was less than a threshold |
| | 1 = TA minus TA_FILTERED was greater than a threshold |
| 15 | 0 = Observation was free of RFI |
| | 1 = Observation was RFI contaminated |

### 4.6.17 **tb_qual_flag_3**

A 16-bit or two-byte binary number formed by applying a Boolean ‘AND’ operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB granule. A ‘0’ indicates that both the fore-looking and aft-looking L1C_TB observations satisfy a given quality criterion described in L1B_TB’s tb_qual_flag_3 output parameter; a ‘1’ indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB observations. Bit position '0' refers to the least significant digit.

Precision: Uint16
Dimensions: *N* = Number of grid cells covered by the swath
Valid_min: 0
Valid_max: 65,536
Unit: N\A

| Bit Position | Bit Value and Interpretation |
|---|---|
| 0 | 0 = Observation has acceptable quality |
| | 1 = Observation does not have acceptable quality |
| 1 | 0 = Observation within physical range |
| | 1 = Observation beyond physical range |
| 2 | 0 = RFI was not detected in the observation |
| | 1 = RFI was detected in the observation |
| 3 | 0 = RFI was detected and corrected in the observation |
| | 1 = RFI was detected but not correctable in the observation |
| 4 | 0 = Observation had acceptable NEDT |
| | 1 = Observation did not have acceptable NEDT |
| 5 | 0 = Direct sun correction was successful |
| | 1 = Direct sun correction was not successful |
| 6 | 0 = Reflected sun correction was successful |
| | 1 = Reflected sun correction was not successful |
| 7 | 0 = Reflected moon correction was successful |
| | 1 = Reflected moon correction was not successful |
| 8 | 0 = Direct galaxy correction was successful |
| | 1 = Direct galaxy correction was not successful |
| 9 | 0 = Reflected galaxy correction was successful |
| | 1 = Reflected galaxy correction was not successful |
| 10 | 0 = Atmosphere correction was successful |
| | 1 = Atmosphere correction was not successful |
| 11 | intentionally left undefined |
| 12 | 0 = Observation was a valid value |
| | 1 = Observation was a null value |
| 13 | 0 = Observation was within half orbit |
| | 1 = Observation was outside half orbit |
| 14 | 0 = TA minus TA_FILTERED was less than a threshold |
| | 1 = TA minus TA_FILTERED was greater than a threshold |
| 15 | 0 = Observation was free of RFI |
| | 1 = Observation was RFI contaminated |

#### 4.6.18 tb_qual_flag_4

A 16-bit or two-byte binary number formed by applying a Boolean 'AND' operation between the same parameters from both fore- and aft-looking groups in the input

L1C_TB granule. A ‘0’ indicates that both the fore-looking and aft-looking L1C_TB observations satisfy a given quality criterion described in L1B_TB’s tb_qual_flag_4 output parameter; a ‘1’ indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB observations. Bit position '0' refers to the least significant digit.

Precision: Uint16
Dimensions: *N* = Number of grid cells covered by the swath
Valid_min: 0
Valid_max: 65,536
Unit: N\A

| Bit Position | Bit Value and Interpretation |
|---|---|
| 0 | 0 = Observation has acceptable quality |
| | 1 = Observation does not have acceptable quality |
| 1 | 0 = Observation within physical range |
| | 1 = Observation beyond physical range |
| 2 | 0 = RFI was not detected in the observation |
| | 1 = RFI was detected in the observation |
| 3 | 0 = RFI was detected and corrected in the observation |
| | 1 = RFI was detected but not correctable in the observation |
| 4 | 0 = Observation had acceptable NEDT |
| | 1 = Observation did not have acceptable NEDT |
| 5 | 0 = Direct sun correction was successful |
| | 1 = Direct sun correction was not successful |
| 6 | 0 = Reflected sun correction was successful |
| | 1 = Reflected sun correction was not successful |
| 7 | 0 = Reflected moon correction was successful |
| | 1 = Reflected moon correction was not successful |
| 8 | 0 = Direct galaxy correction was successful |
| | 1 = Direct galaxy correction was not successful |
| 9 | 0 = Reflected galaxy correction was successful |
| | 1 = Reflected galaxy correction was not successful |
| 10 | 0 = Atmosphere correction was successful |
| | 1 = Atmosphere correction was not successful |
| 11 | intentionally left undefined |
| 12 | 0 = Observation was a valid value |
| | 1 = Observation was a null value |
| 13 | 0 = Observation was within half orbit |
| | 1 = Observation was outside half orbit |
| 14 | 0 = TA minus TA_FILTERED was less than a threshold |
| | 1 = TA minus TA_FILTERED was greater than a threshold |
| 15 | 0 = Observation was free of RFI |
| | 1 = Observation was RFI contaminated |

### 4.6.19 tb_h_uncorrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB horizontally polarized brightness temperatures *prior to surface correction* whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 340.0 |
| Unit: | Kelvin |

### 4.6.20 tb_v_uncorrected

Arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB granule. The resulting parameter thus describes the weighted average of L1B_TB vertically polarized brightness temperatures *prior to surface correction* whose boresights fall within a 36-km EASE Grid 2.0 cell.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 340.0 |
| Unit: | Kelvin |

### 4.6.21 surface_water_fraction_mb_h

Water fraction with the SMAP radiometer main-beam (mb) IFOV weighted by antenna gain pattern at the horizontal polarization.

| | |
|---|---|
| Precision: | Float32 |
| Dimension: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

### 4.6.22 surface_water_fraction_mb_v

Water fraction with the SMAP radiometer main-beam (mb) IFOV weighted by antenna gain pattern at the vertical polarization.

| | |
|---|---|
| Precision: | Float32 |
| Dimension: | *N* = Number of grid cells covered by the swath |

| | |
|---|---|
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

### 4.6.23 soil_moisture_error

Estimated '1-sigma' error of the *soil_moisture* output parameter. The valid minimum and maximum below are subject to further analysis on real data. This data field is currently filled with FillValue.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.00 |
| Valid_max: | Soil porosity |
| Unit: | m3/m3 |

### 4.6.24 soil_moisture, soil_moisture_option[1-3]

Estimated soil moisture at 36-km grid posting, as returned by the L2_SM_P processing software. The *soil_moisture* field is internally linked to the output produced by the baseline algorithm (option 3 as of now).

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.02 |
| Valid_max: | Soil porosity |
| Unit: | m3/m3 |
| Legend: | Option 1: Single Channel Algorithm (H-pol) |
| | Option 2: Single Channel Algorithm (V-pol) |
| | Option 3: Dual Channel Algorithm (DCA) |

### 4.6.25 vegetation_opacity, vegetation_opacity_option[1-3]

Estimated vegetation opacity at 36-km grid posting, as returned by the L2_SM_P processing software. Note that this parameter is the same 'tau' parameter normalized by the cosine of the incidence angle in the 'tau-omega' model.

$$\tau = \frac{b * VWC}{\cos\theta}$$

where $b$ is a landcover-based parameter described in the SMAP Level 2/3 Passive Soil Moisture Product ATBD, VWC is vegetation water content in kg/m$^2$ derived from NDVI climatology, and $\theta$ is the incidence angle (= 40 deg) for SMAP. The valid minimum and maximum below are subject to further analysis on real data. The *vegetation_opacity* field is internally linked to the output produced by the baseline algorithm (option 3 as of now).

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.00 |
| Valid_max: | 5.00 |
| Unit: | N\A |
| Legend: | Option 1: Single Channel Algorithm (H-pol)<br>Option 2: Single Channel Algorithm (V-pol)<br>Option 3: Dual Channel Algorithm (DCA) |

### 4.6.26 **retrieval_qual_flag, retrieval_qual_flag_option[1-3]**

A 16-bit binary string of 1's and 0's that indicate whether retrieval was performed or not at a given grid cell. When retrieval was performed, it contains additional bits to further indicate the exit status and quality of the retrieval. A summary of bit definition of the *retrieval_qual_flag* field is listed below. The *retrieval_qual_flag* field is internally linked to the output produced by the baseline algorithm (option 3 as of now).

| | |
|---|---|
| Precision: | Uint16 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 65,536 |
| Unit: | N\A |
| Legend: | Option 1: Single Channel Algorithm (H-pol)<br>Option 2: Single Channel Algorithm (V-pol)<br>Option 3: Dual Channel Algorithm (DCA) |

| Bit | Retrieval Information | Bit Value and Interpretation |
|---|---|---|
| 0 | Recommended Quality | 0: Soil moisture retrieval has recommended quality |
| | | 1: Soil moisture retrieval doesn't have recommended quality |
| 1 | Retrieval Attempted | 0: Soil moisture retrieval was attempted |
| | | 1: Soil moisture retrieval was skipped |
| 2 | Retrieval Successful | 0: Soil moisture retrieval was successful |
| | | 1: Soil moisture retrieval was not successful |
| 3 | Retrieval Successful | 0: Freeze/thaw state retrieval was successful |
| | | 1: Freeze/thaw state retrieval was not successful |
| 4-15 | Undefined | 0 (not used in L2_SM_P) |

### 4.6.27 **surface_flag**

A 16-bit binary string of 1's and 0's that indicate the presence or absence of certain surface conditions at a grid cell. In Table 10, a '0' indicates the presence of a surface condition favorable to soil moisture retrieval. Each surface condition is numerically compared against two non-negative thresholds: T1 and T2, where T1 < T2. In most cases, when a surface condition is found to be below T1, retrieval is attempted and flagged for recommended quality. Between T1 and T2, retrieval is still attempted but flagged for uncertain quality. Above T2, retrieval is skipped. A summary of surface conditions and their thresholds are listed below.

| | |
|---|---|
| Precision: | Uint16 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 65,536 |
| Unit: | N\A |

**Table 10**: L2_SM_P surface condition bit flag definition. Bit position '0' refers to the least significant bit. Final bit positions and definitions are subject to future revision and expansion as needed.

| Bit | Surface Condition | T1 | T2 | Bit Value and Interpretation |
|---|---|---|---|---|
| 0 | Static Water | 0.05 | 0.50 | 0: Water areal fraction ≤ T1 and IGBP wetland fraction < 0.5:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |
| 1 | Radar-derived Water Fraction | 0.05 | 0.50 | 0: Water areal fraction ≤ T1 and IGBP wetland fraction < 0.5:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise.<br>• Retrieval skipped for fraction > T2 |
| 2 | Coastal Proximity | N\A | 1.0 | 0: Distance to nearby significant water bodies > T2 (number of 36-km grid cells) |
| | | | | 1: Otherwise. |
| 3 | Urban Area | 0.25 | 1.00 | 0: Urban areal fraction ≤ T1:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |
| 4 | Precipitation | 2.78e-04 (equivalent to 1.0 mm/hr) | 7.06e-03 (equivalent to 25.4 mm/hr) | 0: Precipitation rate ≤ T1:<br>• Retrieval attempted for rate ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for rate > T2 |
| 5 | Snow | 0.05 | 0.50 | 0: Snow areal fraction ≤ T1:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |

| | | | | |
|---|---|---|---|---|
| 6 | Permanent Ice | 0.05 | 0.50 | 0: Ice areal fraction ≤ T1:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |
| 7 | Frozen Ground (from radiometer-derived FT state) | 0.05 | 0.50 | 0: Frozen ground areal fraction ≤ T1:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |
| 8 | Frozen Ground (from modeled effective soil temperature) | 0.05 | 0.50 | 0: Frozen ground areal fraction ≤ T1:<br>• Retrieval attempted for fraction ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for fraction > T2 |
| 9 | Mountainous Terrain | 3° | 6° | 0: Slope standard deviation ≤ T1 |
| | | | | 1: Otherwise. |
| 10 | Dense Vegetation | 5.0 | 30.0 | 0: VWC ≤ T1:<br>• Retrieval attempted for VWC ≤ T2 |
| | | | | 1: Otherwise:<br>• Retrieval skipped for VWC > T2 |
| 11 | Nadir Region / Undefined | | | 0 (not used in the product) |
| 12-15 | Undefined | | | 0 |

As with any satellite retrieval data product, proper data usage is encouraged. The following two simple practices are recommended for using SMAP soil moisture retrievals with maximum scientific benefits:

- Use the **retrieval_qual_flag** field to identify retrievals in the **soil_moisture** field estimated to be of recommended quality. A **retrieval_qual_flag** value of either 0 or 8 indicates high-quality retrievals. Proper use of the **retrieval_qual_flag** field is an effective way to ensure that only retrievals of recommended quality will be used in data analyses.

  For further investigation, use the **surface_flag** field and the associated definitions to determine why the **retrieval_qual_flag** field did not report recommended quality at a given grid cell.

### 4.6.28 vegetation_water_content

Vegetation water content at 36-km grid posting. This parameter is used as an input ancillary data parameter to the L2_SM_P processing software when the baseline algorithm is used. The valid minimum and maximum below are subject to further analysis on real data.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 30.0 |
| Unit: | $kg/m^2$ |

### 4.6.29 surface_temperature

Effective soil temperature (Choudhury, *J. Geophysical Research*, 1982) at 36-km spatial scale. This parameter is used as an input ancillary data parameter to the L2_SM_P processing software for both baseline and option algorithms, ***and is not to be confused with an actual physical temperature measured at a single depth***. The valid minimum and maximum below are subject to further analysis on real data.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 253.15 |
| Valid_max: | 313.15 |
| Unit: | Kelvin |

### 4.6.30 static_water_body_fraction

Static water body areal fraction at 36-km grid posting. The fraction is computed based on the number of water pixels and land pixels reported on a 250-meter grid. If there are NW water pixels and NL land pixels within a 36-km grid cell, this parameter refers to the fraction of NW / (NW + NL). Note that NW is the number of water pixels regardless of their temporal span – NW captures both static water pixels and transient water pixels when the original data were acquired.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

### 4.6.31 radar_water_body_fraction

Radar-derived water body areal fraction at 36-km grid posting. The fraction is computed based on the number of water pixels and land pixels reported on the 3-km global cylindrical EASE 2.0 Grid projection in the SMAP Level 2 Active Soil Moisture Product (L2_SM_A). If there are NW water pixels and NL land pixels within a 36-km grid cell, this parameter refers to the fraction of NW / (NW + NL). Note that NW is the number of water pixels regardless of their temporal span – NW captures both static water pixels and transient water pixels. **Since the failure of the SMAP radar, this field has been set to the *static_water_body_fraction* field**.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |

| | |
|---|---|
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

### 4.6.32 **freeze_thaw_fraction**

Freeze/thaw areal fraction at 36-km grid posting. The fraction is computed based on the number of frozen land pixels and thawed land pixels reported on the 3-km global cylindrical EASE Grid 2.0 projection in the SMAP Level 2 Active Soil Moisture Product (L2_SM_A). If there are NF frozen ground pixels and NT thawed land pixels within a 36-km grid cell, this parameter refers to the fraction of NF / (NF + NT). At present the L2_SM_P processing software can be configured to provide this parameter from a dynamic ancillary data database or from the SMAP L2_SM_A product. **Since the failure of the SMAP radar, this field has been derived from external soil temperature ancillary data.**

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

### 4.6.33 **landcover_class**

The first three most dominant land cover classes according to the IGBP land cover map. The relative dominance is determined based on ranking among land cover classes using the mode statistic.

| | |
|---|---|
| Precision: | Uint8 |
| Dimensions: | $N \times 3$ = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 16 |
| Unit: | N\A |

### 4.6.34 **landcover_class_fraction**

The areal fractions of the first three most dominant land cover classes according to a 500-meter MODIS IGBP land cover map. The relative dominance is determined based on ranking among all land cover classes using the mode statistic. For example, if there are N1 pixels that correspond to the first class and there are NT pixels comprising all land cover classes within a 36-km grid cells, the corresponding percentage refers to (N1 / NT).

| | |
|---|---|
| Precision: | Float32 |

| | |
|---|---|
| Dimensions: | $N \times 3$ = Number of grid cells covered by the swath |
| Valid_min: | 0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

#### 4.6.35 **albedo**

Single-scattering albedo at 36-km grid posting. Note that this parameter is the same ‘omega’ parameter in the ‘tau-omega’ model for a given polarization channel.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

#### 4.6.36 **albedo_option3**

Single-scattering albedo at 36-km grid posting derived from a landcover-based table used for the Dual Channel Algorithm (DCA). Note that this parameter is the same ‘omega’ parameter in the ‘tau-omega’ model when used in DCA.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

#### 4.6.37 **roughness_coefficient**

Roughness coefficient at 36-km grid posting. Note that this parameter is the same ‘h’ coefficient in the ‘tau-omega’ model for a given polarization channel.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | $N$ = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 3.0 |
| Unit: | N\A |

#### 4.6.38 roughness_coefficient_option3

Roughness coefficient at 36-km grid posting derived from 3 km global map of ‘h’ created for the Dual Channel Algorithm (DCA). Note that this parameter is the same ‘h’ coefficient in the ‘tau-omega’ model when used in DCA.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 3.0 |
| Unit: | N\A |

#### 4.6.39 clay_fraction

Clay fraction at 36-km grid posting.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

#### 4.6.40 bulk_density

Bulk density at 36-km grid posting.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 2.65 |
| Unit: | N\A |

#### 4.6.41 sand_fraction

Sand fraction at 36-km grid posting.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1.0 |
| Unit: | N\A |

#### 4.6.42 **organic_content**

Organic content at 36-km grid posting.

| | |
|---|---|
| Precision: | Float32 |
| Dimensions: | *N* = Number of grid cells covered by the swath |
| Valid_min: | 0.0 |
| Valid_max: | 1000.0 |
| Unit: | g/kg |

# 5 REFERENCES

Many of these documents can be found on the NSIDC SMAP Technical References page: https://nsidc.org/data/smap/technical-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: 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.
- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radar/Radiometer Soil Moisture (Active/Passive) Products. SMAP Project, JPL D-66481, Jet Propulsion Laboratory, Pasadena, CA.
- 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: 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 Level 1C Radiometer (L1C_TB) Product Specification Document. SMAP Project, JPL D-72545, 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 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 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.
- 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
- HDF5: API Specification Reference Manual, The HDF Group. URL: http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Front.html
- HDF5 User's Guide Release 1.8.9, The HDF Group. URL: http://hdfgroup.com/HDF5/doc/UG
- 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.
- Choudhury, B., Schmugge, T., and Mo, T, "A Parameterization of Effective Soil Temperature for Microwave Emission," *J. Geophys. Res*., 87: 1301-1304, 1982.

# 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 |
| 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 |

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|---|---|
| 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 |