Soil Moisture Active Passive (SMAP) Mission

Level 2 SMAP/Sentinel Active/Passive Soil Moisture Product Specification Document

Release 2

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1 INTRODUCTION

1.1 Identification

This is the Product Specification Document (PSD) for the Level 2 SMAP/Sentinel Active-Passive Soil Moisture Product for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The product provides gridded data of SMAP soil moisture combined radar and radiometer retrieval, ancillary data, and quality-assessment flags on 3-km and 1-km Earth-fixed grids. Only cells that are covered by the actual swath are written in the product.

In this version, there are no changes to the data file contents or format. Internal changes to the processing for both the Sentinel backscatter (L2_S0_S1) and the active-passive soil moisture retrieval in L2_SM_SP have been made to improve product quality.

1.2 Scope

This document describes the file format and data contents of the Level 2 SMAP/Sentinel Active-Passive Soil Moisture Data Product (hereafter referred to as ‘L2_SM_SP’ for brevity) for external software interfaces.

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, sensitivity to soil moisture, surface roughness, and vegetation, to estimate soil moisture at a resolution of 10 km and freeze-thaw state at a resolution of 1-3 km.

Table 1: SMAP Mission Requirements

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

The SMAP instrument incorporates an L-band radar and an L-band radiometer that share a single 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, data north of 45° N will be collected and processed to support robust detection of landscape freeze/thaw transitions. The SMAP baseline orbit parameters are:

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

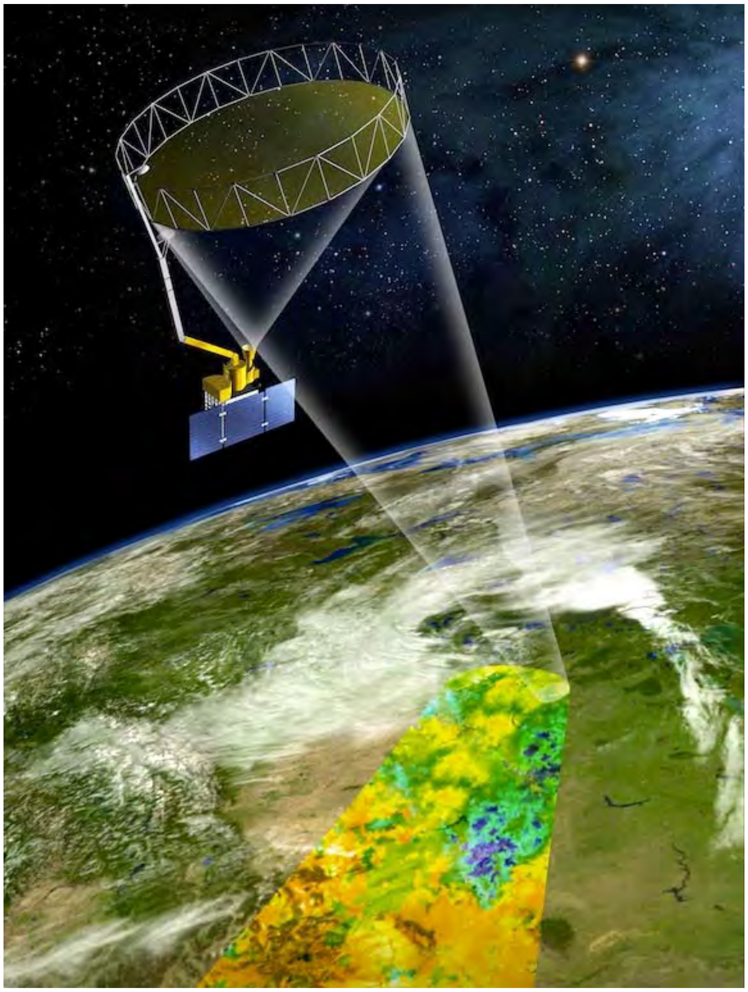


Figure 1: The SMAP mission concept consists of an L-band radar and radiometer sharing a single spinning 6-m mesh antenna in a sun-synchronous dawn / dusk orbit.

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

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

1.4 Data Products

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

Table 2 lists the distributable SMAP data products. The "enhanced" products include passive freeze-thaw and 9-km interpolated radiometer-based products developed post-launch to recover capabilities lost when the SMAP radar ceased operation. The SMAP radar-based products are now considered "legacy" products; no further development of these products is planned.

The L2_SM_SP SMAP/Sentinel active-passive product, which is the subject of this document, is the latest of the "enhanced" SMAP products to be added to the science product suite. The objective of the L2_SM_SP is to recover the capability to use the active-passive algorithms developed for SMAP using collocated Sentinel-1A and -1B data as backscatter fields for brightness temperature disaggregation and high-resolution soil moisture retrieval.

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

1.5 L2_SM_SP Overview

The SMAP L2_SM_SP product is derived from the Sentinel L2_S0_S1 and SMAP L3_SM_P_E products, which provide gridded Sentinel radar backscatter and SMAP radiometer brightness temperature observations (corrected to remove influence of waterbodies), ancillary data, and quality-assessment flags. To generate the standard L2_SM_SP product, the processing software ingests a Sentinel-based L2_S0_S1 1 km backscatter file and the 9 km L3_SM_P_E files for the three days nearest the time of the Sentinel data, along with the required static and dynamic ancillary data that cover the three days. The ingested data are then inspected for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. The nearest SMAP data in time at the location of the Sentinel scene is determined, both for AM-only (descending SMAP orbits) and for AM-or-PM SMAP data. In general, when SMAP-Sentinel matchups can be made, the AM-or-PM matchups will be closer in time to the Sentinel data time. When retrievability criteria are met, the software invokes the brightness temperature disaggregation algorithm followed by the retrieval algorithm to generate soil moisture. Only cells that are covered by the actual swath for a given projection are written in the product.

The final L2_SM_SP product contains gridded data of SMAP radiometer-based soil moisture retrieval, ancillary data, and quality-assessment flags on the global 3-km and 1-km EASE2 Grids designed by NSIDC for SMAP, for the patch covering the Sentinel scene grid.

2 DATA PRODUCT ORGANIZATION

2.1 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

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
VarLenStr	H5T_C_S1, where the length is set to H5T_VARIABLE	H5T_NATIVE_CHAR	character string

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

2.3.4 File Level Metadata

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

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

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

2.3.5 Local Metadata

SMAP standards incorporate additional metadata that describe each HDF5 Dataset within the HDF5 file. Each of these metadata elements appear in an HDF5 Attribute that is directly associated with the HDF5 Dataset. Wherever possible, these HDF5 Attributes employ names that conform to the Climate and Forecast (CF) conventions. Table 5 lists the CF names for the HDF5 Attributes that SMAP products typically employ.

Table 5: SMAP Specific Local Attributes

CF Compliant Attribute Name	Description	Required?
units	Units of measure. Appendix E lists applicable units for various data elements in this product.	Yes
valid_max	The largest valid value for any element in the Dataset. The data type in valid_max matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_max will also be float32.	No
valid_min	The smallest valid value for any element in the Dataset. The data type in valid_min matches the 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”, “degC”, “Kelvins”, “m/s”, “m”, “m**2”, “s” and “counts”. Appendix A and Appendix E include references to important data measurement unit symbols.

2.4.1 Double Precision Time Variables

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

2.4.2 Array Representation

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

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

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

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_SP Product when the L2_SM_SP 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_SP 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_SP 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 Sentinel L2_S0_S1 or L3_SM_P_E products. If only some of the input that contributes to a particular grid cell is fill data, the L2_SM_SP SPS will most likely be able to generate some output. However, some portion of the L2_SM_SP output for that grid cell may appear as fill values.

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	-9999	Type minimum + 1
Signed24	-9999	Type minimum + 1
Signed32	-9999	Type minimum + 1
Signed64	-9999	Type minimum + 1
Unsigned8	254	Type maximum - 1
Unsigned16	65534	Type maximum - 1
Unsigned24	16777214	Type maximum - 1
Unsigned32	4294967294	Type maximum - 1
Unsigned64	18446744073709551614	Type maximum - 1
FixedLenString, VarLenString	NA	Not available

No valid value in the L2_SM_SP product is equal to the values that represent fill. If any exceptions should exist in the future, the L2_SM_SP 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_SP product records gaps when entire frames within the time span of a particular data granule do not appear. Gaps can occur under one of two conditions:

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

The Level L2_SM_SP Product records gaps in the product level metadata. The following conditions will indicate that no gaps appear in the data product:

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

- The character string stored in metadata element *Extent/rangeEndingDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStopDateTime*.

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

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

2.6 Flexible Data Design

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

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

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

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

3 EASE2 Grid

The data in the SMAP L2_SM_SP product are presented on a global cylindrical projection. The projection is based on NSIDC's 3-km and 1-km EASE2 Grid specifications for SMAP.

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

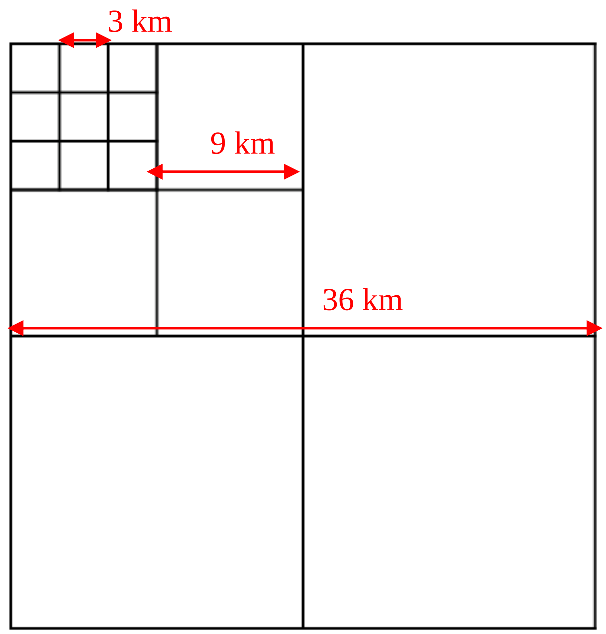


Figure 2: Perfect nesting in EASE2 Grid – smaller grid cells can be tessellated to form larger grid cells.

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

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

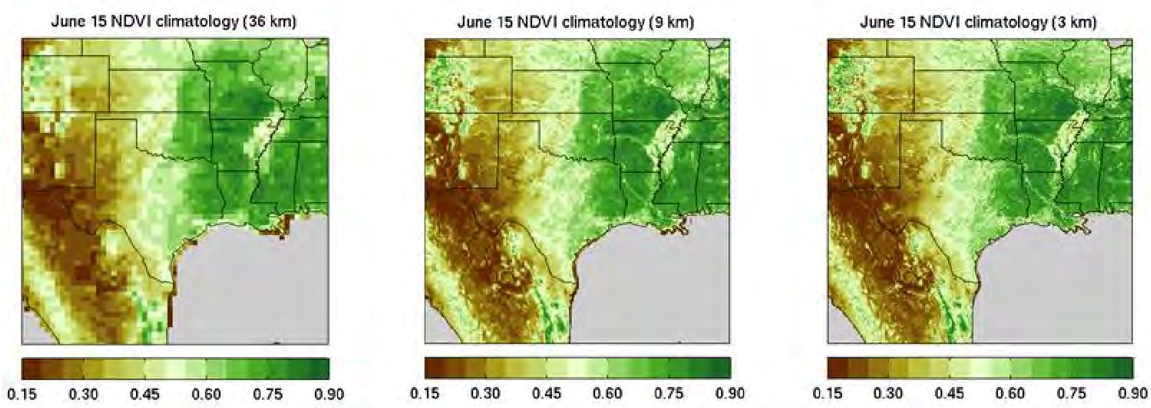
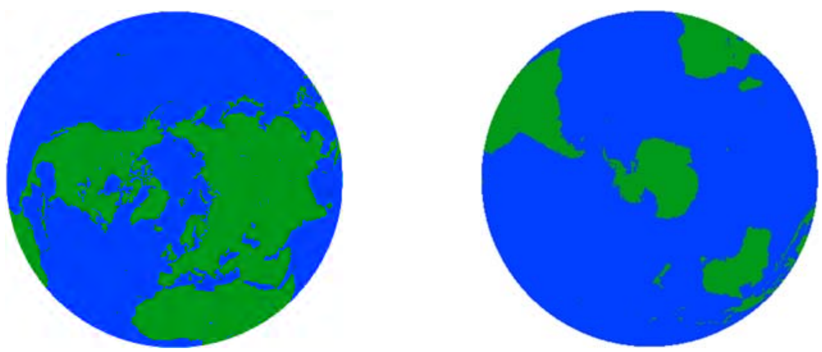


Figure 3: Example of ancillary NDVI climatology data displayed on the SMAP 36-km, 9-km, and 3-km grids.

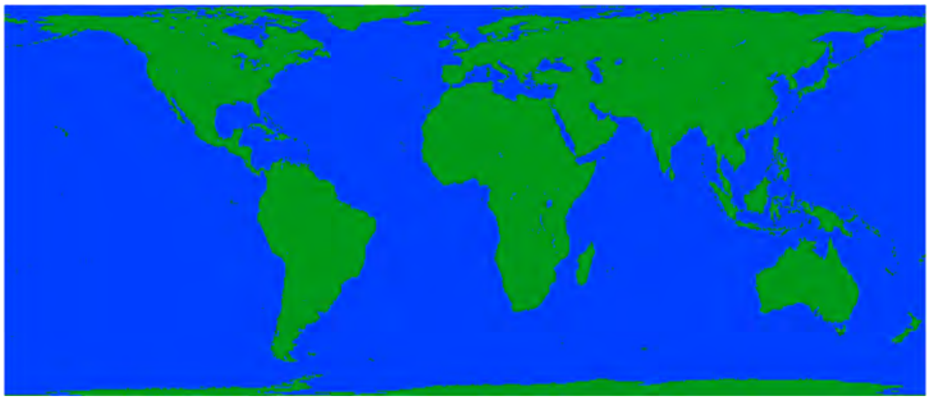
The three projections (global, north polar and south polar) used by SMAP products are assigned with the following three-letter designators. These projections are shown in Fig. 4.

- Global: M[36,09,03,01]
- North Polar: N[36,09,03,01]
- South Polar: S[36,09,03,01]



(a) Northern Hemisphere on EASE2-Grid projection

(b) Southern Hemisphere on EASE2-Grid projection



(c) Global EASE2-Grid projection

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

The data in the SMAP L2_SM_SP product are available on the global 3 km and 1 km projections (M03 & M01). All elements in L2_SM_1P are stored as HDF5 Datasets. Each dataset belongs to an HDF5 Group.

Table 8: SMAP EASE-2.0 grids

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

4 PRODUCT DEFINITION

4.1 Overview

The SMAP L2_SM_SP product is derived using the Sentinel-1A or -1B radar backscatter from L2_S0_S1 (aggregated at 1 km resolution on EASE grid) and the 9 km enhanced radiometer brightness temperature available in the SMAP L3_SM_P_E products, respectively. The brightness temperature available in L3_SM_P_E is corrected from presence of waterbodies (up to 0.05 fraction) and then used in L2_SM_SP product generation, and beyond waterbody fraction of 0.05 no correction is conducted. The L2_SM_SP product generation process also uses the quality flags, surface flags from the SMAP L3_SM_P_E products, and ancillary data. The ingested data are then inspected for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm to generate soil moisture retrieval. Retrievals are performed on both 3 km (baseline) and 1 km (experimental) resolution science grids.

4.2 Product Names

L2_SM_SP data product file names conform to the following convention:

SMAP_L2_SM_SP_[SatModePol]_[SMAP Start Date/Time Stamp]_[Sentinel Start Date/Time Stamp]_[Scene Center Location]_[Composite Release ID]_[Product Counter].[extension]

Example:
SMAP_L2_SM_SP_1BIWDV_20170228T231824_20170227T224358_110E42N_R15000_001.h5

SatModePol	Identifies the Sentinel-1 satellite (1A or 1B), the SAR mode (IW = wide-swath interferometric), and polarization mode (DV = dual-polarization V, VH).
SMAP Start Date/Time Stamp	Date/time stamp in Universal Coordinated Time (UTC) of the first SMAP data element that appears in the product. The stamp conforms to the *YYYYMMDD**T**hhmmss* convention.
Sentinel Start Date/Time Stamp	Date/time stamp in Universal Coordinated Time (UTC) of the first Sentinel data element that appears in the product. The stamp conforms to the *YYYYMMDD**T**hhmmss* convention.
Scene Center Location	Approximate longitude (E or W) and latitude (N or S) of the center of the EASE grid patch containing the Sentinel radar scene. This is useful for finding data over regional subsets.
Composite Release ID	An ID that incorporates changes to any processing condition that might impact product results. The Composite Release ID contains three other shorter ID's: [R][Launch Indicator][Major ID][Minor ID]. The Launch Indicator distinguishes between pre-launch or pre-instrument commissioned data. ('0' for simulated or preliminary observations whereas '1' for observations at or after the time of instrument commissioning) A two-digit Major ID indicates major releases due to changes in algorithm or processing approach. A two-digit Minor ID indicates minor releases due to changes not considered by a change in Major ID.
Product Counter	A three-digit counter that tracks the number of times that a particular product type for a specific half orbit has been generated.
Extension	'.h5' for science product data and '.qa' for QA product data.

4.3 Volume

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

Daily volume: ~900-3600 Mbytes (depending on Sentinel coverage)

Yearly volume: 325-1300 GBytes (depending on Sentinel coverage)

4.4 L2_SM_SP Product Metadata

As mentioned in section 4.1.2, the metadata elements in the L2_SM_SP 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 9 describes the subgroups of the Metadata group, and the attributes within each group. The first column of table 9 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 9 should also appear in every L2_SM_SP Product file.

Table 9: Granule Level Metadata in the L2_SM_SP Product

ISO Major Class	SMAP HDF5 Metadata SubGroup	Subgroup/Attribute in SMAP HDF5	Valid Values
DQ_DataQuality	DataQualiity	Scope	soil_moisture, downscaled brightness temperature
		CompletenssOmission/evaluationMethodType	directInternal
		CompletenessOmission/measureDescription	Percentage of grid cells that lack soil moisture retrieval values relative to the total number of grid cells that are attempted for retrieval.
		CompletenessOmission/nameOfMeasure	Percentage of Missing Data
		CompletenessOmission/value	<A measure between 0 and 100>
		CompletenessOmission/unitOfMeasure	Percentage
		domainConsistency/evaluationMethodType	directInternal
		DomainConsistency/measureDescription	Percentage of grid cells whose soil moisture retrieval values fall within a predefined acceptable range of measure.
		DomainConsistency/nameOfMeasure	Percentage of grid cells whose soil moisture retrieval values that are within the Acceptable Range.
		DomainConsistency/value	<A measure between 0 and 100>
		DomainConsistency/unitOfMeasure	Percentage
EX_Extent	Extent	description	The SMAP radar-radiometer based soil moisture retrieval over non-excluded regions from descending (6:00 am) half-orbit Backscatter and TB data.
		westBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		eastBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		southBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>

		northBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		rangeBeginningDateTime	<Time stamp that indicates the initial time element in the product>
		rangeEndingDateTime	<Time stamp that indicates the final time of data in the product.>
LI_Lineage/LE_ProcessStep	ProcessStep	processor	Soil Moisture Active Passive (SMAP) Mission Science Data System (SDS) Operations Facility
		stepDateTime	< A date time stamp that specifies when the product was generated.>
		processDescription	Estimate soil moisture over non-excluded regions from descending (6:00 am) half-orbit radiometer TB data and radar backscatter data. The final result is projected on a 9-km global Earth-fixed grid.
		documentation	<A reference to software description document.>
		identifier	L2_SM_SP
		runTimeParameters	<Specify any run time parameters if they were used.>
		SWVersionID	<A software version identifier that runs from 001 to 999>
		softwareDate	<A date stamp that specifies when software used to generate this product was released.>
		softwareTitle	L2_SM_SP_SPS
		RFIThreshold	<A threshold the algorithm uses to specify whether a particular measure was contaminated by Radio Frequency Interference.>
		timeVariableEpoch	J2000
		epochJulianDate	2451545.00
		epochUTCDate	2000-01-01T11:58:55.816Z

		ATBDTitle	Soil Moisture Active Passive (SMAP) L2_SM_AP Algorithm Theoretical Basis Document
		ATBDDate	Apr 2017
		ATBDVersion	Preliminary/Initial Release
		algorithmDescription	Single channel algorithm
		algorithmVersionID	<An algorithm version identifier that runs from 001 to 999>
		algorithmMaturity	Beta
LI_Lineage/LE_Source	L2_S0_S1, L3_SM_P_E, 9-km global water-body fraction database, 9-km global soil texture database, 9-km global NDVI database, 9-km global soil temperature database, 9-km global surface temperature database, 9-km global DEM database, 9-km global precipitation database, 9-km global urban fraction database, 9-km global IGBP land cover classification database 9-km urban fraction database 9-km snow and ice database 9-km surface roughness database	description	Sentinel Radar Product , Level 3 Enhanced Radiometer Soil Moisture Product, Static water-body fraction, soil texture, NDVI, soil temperature, surface temperature, DEM, precipitation, snow/ice, urban fraction, and IGBP land cover classification
		fileName	TBD
		creationDate	<A date stamp that specifies when the input data product was generated.>
		version	<The SMAP Composite Version ID associated with the input data product.>
		identifier	<The short name associated with the product.>
		DOI	<A digital object identifier associated with the product, if available>

DS_Dataset/MD_DataIdentification	DataSetIdentification	creationDate	<Date when the L2_SM_SP data product file was created>
		CompositeReleaseID	<SMAP Composite Release ID associated with this data product – See section 3.3>
		fileName	<Name of the L2_SM_SP output data file.>
		originatorOrganizationName	Jet Propulsion Laboratory
		shortName	SPL2SMAP_S
		SMAPShortName	L2_SM_SP
		abstract	The SMAP L2_SM_SP product provides soil moisture estimates over non-excluded regions from descending (6:00 am) half-orbit backscatter and TB data. The final result is projected on a 3-km global Earth-fixed grid.
		characterSet	utf8
		credit	The software that generates the L2_SM_SP product and the data system that automates its production were designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		Language	eng
		purpose	The SMAP L2_SM_SP product delivers soil moisture estimates over non-excluded regions from descending (6:00 am) half-orbit backscatter and TB data. The final result is projected on a 3-km global Earth-fixed grid.
		status	on-going
		topicCategoryCode	geoscientificInformation
		QACreationDate	<The date that the QA product that accompanies the L2_SM_SP data granule was generated.>

		QAFileName	<The name of QA product.>
		QAAbstract	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
DS_Series/MD_DataIdentification	SeriesIdentification	revisionDate	<Date and time of the software release that was used to generate this data product.>
		CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product – See section 3.3>
		longName	SMAP Radiometer Soil Moisture Product. Soil moisture estimate over a 3-km global Earth-fixed grid.
		shortName	SPL2SMAP_S
		identifier_product_DOI	<digital object identifier – **TBS**>
		resourceProviderOrganizationName	National Aeronautics and Space Administration
		abstract	The SMAP L2_SM_SP product provides soil moisture estimates over non-excluded regions from descending (6:00 am) half-orbit backscatter and TB data. The final result is projected on a 9-km global Earth-fixed grid.
		characterSet	utf8
		credit	The software that generates the L2_SM_SP product and the data system that automates its production were designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		language	eng
		purpose	The SMAP L2_SM_SP product delivers soil moisture estimates over non-

			excluded regions from descending (6:00 am) half-orbit backscatter and TB data. The final result is projected on a 3-km global Earth-fixed grid.
		status	on-going
		topicCategoryCode	geoscientificInformation
		pointOfContact	National Snow and Ice Data Center, Boulder, Colorado.
		PSDPublicationDate	<Date of publication of the Product Specification Document>
		PSDEdition	<Edition identifier for the Product Specification Document>
		PSDTtitle	Soil Moisture Active Passive Mission L2_SM_SP Product Specification Document
		SMAPShortName	L2_SM_SP
		mission	Soil Moisture Active Passive (SMAP)
		maintenanceAndUpdateFrequency	asNeeded
		maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
		format	HDF5
		formatVersion	1.8.9
MD_GridSpatialRepresentation	GridSpatialRepresentation	crossTrack/dimensionSize	1
		crossTrack/resolution	3 km
		track/dimensionSize	N = Number of 3-km global EASE2-Grid cells covered by the radiometer swath
		track/resolution	3 km
MD_AcquisitionInformation	AcquisitionInformation	platform/antennaRotationRate	14.6 rpm (13.0 rpm)
		platformDocument/publicationDate	<The date of publication of the document that describes the SMAP platform, if available to the general public>
		platformDocument/edition	<The edition of publication of the document that describes the SMAP platform, if available to the general

			public.>
		platformDocument/title	<The title of the publication of the document that describes the SMAP platform, if available to the general public.>
		platform/description	The SMAP observatory houses an L-band radiometer that operates at 1.40 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.
		platform/identifier	SMAP
		radarDocument/publicationDate	<The date of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/edition	<The edition of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/title	<The title of the publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radar/description	The Sentinel-1 radar instrument employs a C-band side-scanned system and SAR processing techniques to achieve high resolution (20 m) backscatter measurements over a wide 300 km swath.
		radar/identifier	Sentinel-1 SAR
		radar/type	C-band Synthetic Aperture Radar
		radiometerDocument/publicationDate	<The date of publication of the document that describes the SMAP

			radiometer instrument, if available to the general public.>
		radiometerDocument/edition	<The edition of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/title	<The title of the publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometer/description	The SMAP L-band Radiometer records V-pol, H-pol, 3^{rd} and 4^{th} Stokes brightness temperatures at 40 km resolution at 4.3 Megatbits per second with accuracies of 1.3 Kelvin or better.
		radiometer/identifier	SMAP RAD
		radiometer/type	L-band Radiometer
SD_OrbitMeasuredLocation	OrbitMeasuredLocation	argumentOfPerigee	<The angle in the satellite's orbit plane between the point of perigee and ascending node. The angle is measured in the direction of spacecraft motion.>
		cycleNumber	<The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies the cycle of orbits when the data were taken. First cycle is assigned the number 1.>
		eccentricity	<The eccentricity of the satellite orbit.>
		epoch	2000-01-01T11:58:55.816Z
		equatorCrossingDateTime	<A time stamp that specifies the date and time of ascending node crossing for the current orbit.>
		equatorCrossingLongitude	<The longitude of the ascending node crossing for the current orbit.>
		inclination	<The angle between the spacecraft's orbital plane and the Earth's equatorial plane. An angle greater than 90 degrees

			indicates a orbit retrograde path.>
		meanMotion	<The constant angular speed that would be required for a body travelling in an undisturbed elliptical orbit with the specified semi-major axis to complete one revolution in the actual orbital period, expressed as a number of revolutions per day.>
		orbitDirection	<SMAP Level 1 and Level 2 products appear in half orbit granules. This element provides direction of orbital path relative to equatorial plane. Values are “ascending” or “descending”:>
		halfOrbitStartDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the beginning of the half orbit.>
		halfOrbitStopDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the end of the half orbit.>
		orbitPathNumber	< The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies which of the 117 possible paths the spacecraft flew when the data in the file were acquired. The orbitPathNumber varies from 1 to 117.>
		orbitPeriod	<Time required to complete a the spacecraft orbit.>
		reference_CRS	<A description of the coordinate reference system used to describe spacecraft orbital data.>
		revNumber	<The count of orbits from beginning of mission to the orbit that the spacecraft flew when the data in the file were

			acquired. Orbit zero begins at launch and extends until the spacecraft crosses the southernmost point in its path for the first time. Orbit one commences at that instant.>
		rightAscensionAscendingNode	<The angle eastward on the equatorial plan from the vernal equinox to the orbit ascending node.>
		semiMajorAxis	<The length of the semi-major axis of the spacecraft orbit.>

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

4.5 L2_SM_SP Data Structure

The L2_SM_SP product contains gridded data of SMAP radiometer-based soil moisture retrieval, Sentinel backscatter data, ancillary data, and quality-assessment flags on the 3-km and 1-km global EASE2 Grids. This organization is reflected schematically in Fig. 5. All data elements appear in the HDF5 Global Projection Group.

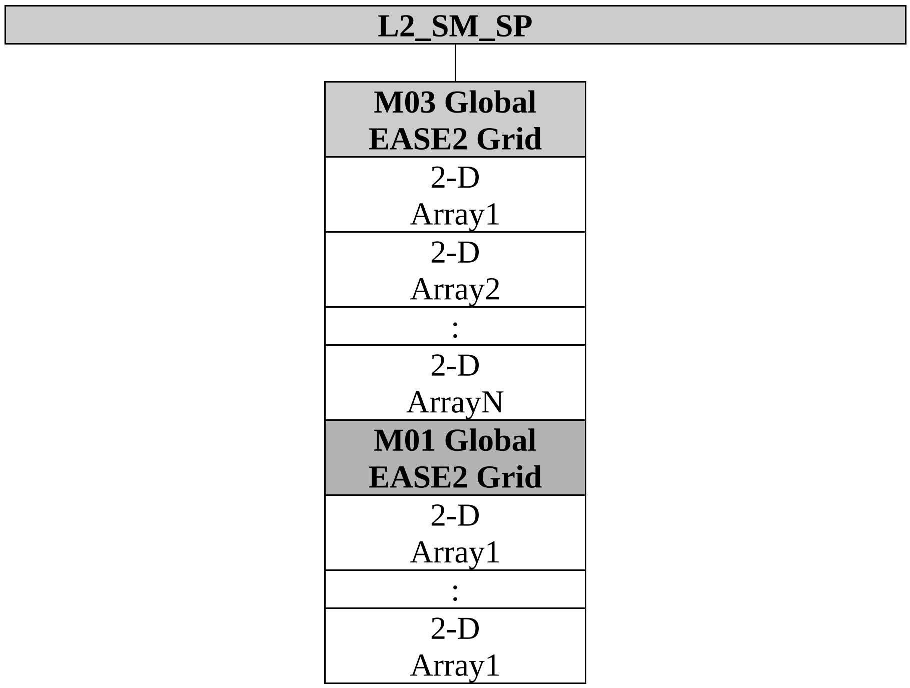


Figure 5: L2_SM_SP data organization.

Table 9 describes the output parameters of a typical L2_SM_SP descending half-orbit granule. Each 2-D data element represents a sub-patch of the global grid which contains the pixels of the Sentinel data swath, and the SMAP data that is overlaid on the Sentinel scene. The data in each scene covers approximately a 300km x 300km spatial extent, equivalent to about 30 seconds of Sentinel-1 observation time.

Table 10: L2_SM_SP output parameters

Soil Moisture Retrieval Data 3km Group

AM-only 3km elements

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
EASE_column_index_3km	EASEGridCell_Array _3km	integer	2	count	0	65535	The column index of the 3 km EASE grid cell that contains the associated data.
EASE_row_index_3km	EASEGridCell_Array _3km	integer	2	count	0	65535	The row index of the 3 km EASE grid cell that contains the associated data.
SMAP_Sentinel_overpass_timediff_hr _3km	EASEGridCell_Array _3km	real	4	hours	0.0	36.0	The time difference in hours between the Sentinel data and the collocated SMAP data
albedo_3km	EASEGridCell_Array _3km	real	4	normalized	0.0	1.0	Diffuse reflecting power of the Earth's surface within the grid cell.
bare_soil_roughness_retrieved_3km	EASEGridCell_Array _3km	real	4	meters	0.0	0.1	Retrieved soil roughness provided by the active soil moisture algorithm.
beta_tbv_vv_3km	EASEGridCell_Array _3km	real	4	Kelvins/dB	-25	0	Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbv and sigma0_vv
disagg_soil_moisture_3km	EASEGridCell_Array _3km	real	4	cm^3/cm^3	0.02	0.5	Representative optional (disaggregated) soil moisture measurement for the Earth based grid cell.
disaggregated_tb_v_qual_flag_3km	EASEGridCell_Array _3km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated

							for the grid cell.
gamma_vv_xpol_3km	EASEGridCell_Array_3km	real	4	normalized	0	2	Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using high resolution sigma0_vv and sigma0_xpol
landcover_class_3km	EASEGridCell_Array_3km	enum	1	NA	NA	NA	An enumerated type that specifies the predominant surface vegetation found in the grid cell.
latitude_3km	EASEGridCell_Array_3km	real	4	degrees_north	-90.0	90.0	Latitude of the center of the Earth based grid cell.
longitude_3km	EASEGridCell_Array_3km	real	4	degrees_east	-180.0	180.0	Longitude of the center of the Earth based grid cell.
retrieval_qual_flag_3km	EASEGridCell_Array_3km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the retrieval algorithms that generate baseline soil moisture for the grid cell.
sigma0_incidence_angle_3km	EASEGridCell_Array_3km	real	4	degrees	20°	60°	Angle of radar incidence relative to the local normal.
sigma0_vv_aggregated_3km	EASEGridCell_Array_3km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 3 km vertical polarization radar backscatter measurements into a 3 km EASE grid cell.
sigma0_vh_aggregated_3km	EASEGridCell_Array_3km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 3 km cross-polarized radar backscatter measurements into a 3 km EASE grid cell.
soil_moisture_3km	EASEGridCell_Array_3km	real	4	cm^3/cm^3	0.02	0.5	Representative baseline soil moisture measurement for the Earth based grid cell.
soil_moisture_std_dev_3km	EASEGridCell_Array_3km	real	4	cm^3/cm^3	0.0	0.2	Standard deviation of soil moisture measure for the 3 km Earth based grid cell.
spacecraft_overpass_time_seconds_3km	EASEGridCell_Array_3km	real	8	seconds	0	999999.9	Number of seconds since a specified epoch that represents the spacecraft overpass relative to the 3 km EASE grid cell represented

							in this data product.
surface_flag_3km	EASEGridCell_Array_3km	bit flag	2	NA	NA	NA	Bit flags that record ambient surface conditions for the grid cell
surface_temperature_3km	EASEGridCell_Array_3km	real	4	degrees Celsius	-50.0	60.0	Temperature at land surface based on GMAO GOES.
tb_v_disaggregated_3km	EASEGridCell_Array_3km	real	4	Kelvins	0.0	330.0	Vertical polarization brightness temperature from option1 adjusted for the presence of water bodies and disaggregated from the 9 km EASE grid cells into 3 km EASE grid cells.
tb_v_disaggregated_std_3km	EASEGridCell_Array_3km	real	4	Kelvins	0.0	330.0	Standard deviation of disaggregated Tb in the 3 km cell.
vegetation_opacity_3km	EASEGridCell_Array_3km	real	4	normalized	0	1	The measured opacity of the vegetation in the grid cell.
vegetation_water_content_3km	EASEGridCell_Array_3km	real	4	kg/m^2	0.0	30	Representative measure of water in the vegetation within the 3 km grid cell.
water_body_fraction_3km	EASEGridCell_Array_3km	real	4	normalized	0.0	1.0	Fraction of the area of 3 km grid cell that is a permanent or transient water body. Derived from the DEM and radar processing.

AM-or-PM 3km elements

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
EASE_column_index_apm_3km	EASEGridCell_Array_3km	integer	2	count	0	65535	The column index of the 3 km EASE grid cell that contains the associated data.
EASE_row_index_apm_3km	EASEGridCell_Array_3km	integer	2	count	0	65535	The row index of the 3 km EASE grid cell that contains the associated data.
SMAP_Sentinel_overpass_timediff_hr_apm_3km	EASEGridCell_Array_3km	real	4	hours	0.0	36.0	The time difference in hours between the Sentinel data and the collocated SMAP data
albedo_apm_3km	EASEGridCell_Array	real	4	normalized	0.0	1.0	Diffuse reflecting power of the

	_3km						Earth's surface within the grid cell.
bare_soil_roughness_retrieved_apm_3km	EASEGridCell_Array_3km	real	4	meters	0.0	0.1	Retrieved soil roughness provided by the active soil moisture algorithm.
beta_tbv_vv_apm_3km	EASEGridCell_Array_3km	real	4	Kelvins/dB	-25	0	Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbv and sigma0_vv
disagg_soil_moisture_apm_3km	EASEGridCell_Array_3km	real	4	cm^3/cm^3	0.02	0.5	Representative optional (disaggregated) soil moisture measurement for the Earth based grid cell.
disaggregated_tb_v_qual_flag_apm_3km	EASEGridCell_Array_3km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell.
gamma_vv_xpol_apm_3km	EASEGridCell_Array_3km	real	4	normalized	0	2	Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using high resolution sigma0_vv and sigma0_xpol
landcover_class_apm_3km	EASEGridCell_Array_3km	enum	1	NA	NA	NA	An enumerated type that specifies the predominant surface vegetation found in the grid cell.
latitude_apm_3km	EASEGridCell_Array_3km	real	4	degrees_north	-90.0	90.0	Latitude of the center of the Earth based grid cell.
longitude_apm_3km	EASEGridCell_Array_3km	real	4	degrees_east	-180.0	180.0	Longitude of the center of the Earth based grid cell.
retrieval_qual_flag_apm_3km	EASEGridCell_Array_3km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the retrieval algorithms that generate baseline soil moisture for the grid cell.
sigma0_incidence_angle_apm_3km	EASEGridCell_Array_3km	real	4	degrees	20°	60°	Angle of radar incidence relative to the local normal.

sigma0_vv_aggregated_apm_3km	EASEGridCell_Array_3km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 3 km vertical polarization radar backscatter measurements into a 3 km EASE grid cell.
sigma0_vh_aggregated_apm_3km	EASEGridCell_Array_3km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 3 km cross-polarized radar backscatter measurements into a 3 km EASE grid cell.
soil_moisture_apm_3km	EASEGridCell_Array_3km	real	4	cm^3/cm^3	0.02	0.5	Representative baseline soil moisture measurement for the Earth based grid cell.
soil_moisture_std_dev_apm_3km	EASEGridCell_Array_3km	real	4	cm^3/cm^3	0.0	0.2	Standard deviation of soil moisture measure for the 3 km Earth based grid cell.
spacecraft_overpass_time_seconds_apm_3km	EASEGridCell_Array_3km	real	8	seconds	0	999999.9	Number of seconds since a specified epoch that represents the spacecraft overpass relative to the 3 km EASE grid cell represented in this data product.
surface_flag_apm_3km	EASEGridCell_Array_3km	bit flag	2	NA	NA	NA	Bit flags that record ambient surface conditions for the grid cell
surface_temperature_apm_3km	EASEGridCell_Array_3km	real	4	degrees Celsius	-50.0	60.0	Temperature at land surface based on GMAO GOES.
tb_v_disaggregated_apm_3km	EASEGridCell_Array_3km	real	4	Kelvins	0.0	330.0	Vertical polarization brightness temperature from option1 adjusted for the presence of water bodies and disaggregated from the 9 km EASE grid cells into 3 km EASE grid cells.
tb_v_disaggregated_std_apm_3km	EASEGridCell_Array_3km	real	4	Kelvins	0.0	330.0	Standard deviation of disaggregated Tb in the 3 km cell.
vegetation_opacity_apm_3km	EASEGridCell_Array_3km	real	4	normalized	0	1	The measured opacity of the vegetation in the grid cell.
vegetation_water_content_apm_3km	EASEGridCell_Array_3km	real	4	kg/m^2	0.0	30	Representative measure of water in the vegetation within the 3 km grid cell.
water_body_fraction_apm_3km	EASEGridCell_Array	real	4	normalized	0.0	1.0	Fraction of the area of 3 km grid

	_3km						cell that is a permanent or transient water body. Derived from the DEM and radar processing.

Soil Moisture Retrieval Data 1km Group

AM-only 1km elements

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
EASE_column_index_1km	EASEGridCell_Array _1km	integer	2	count	0	65535	The column index of the 1 km EASE grid cell that contains the associated data.
EASE_row_index_1km	EASEGridCell_Array _1km	integer	2	count	0	65535	The row index of the 1 km EASE grid cell that contains the associated data.
SMAP_Sentinel_overpass_timediff_hr _1km	EASEGridCell_Array _1km	real	4	hours	0.0	36.0	The time difference in hours between the Sentinel data and the collocated SMAP data
albedo_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	Diffuse reflecting power of the Earth's surface within the grid cell.
bare_soil_roughness_retrieved_1km	EASEGridCell_Array _1km	real	4	meters	0.0	0.1	Retrieved soil roughness provided by the active soil moisture algorithm.
beta_tbv_vv_1km	EASEGridCell_Array _1km	real	4	Kelvins/dB	-25	0	Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbv and sigma0_vv
disagg_soil_moisture_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.02	0.5	Representative optional (disaggregated) soil moisture measurement for the Earth based grid cell.
disaggregated_tb_v_qual_flag_1km	EASEGridCell_Array	bit flag	2	NA	NA	NA	Bit flags that record the conditions

	_1km						and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell.
gamma_vv_xpol_1km	EASEGridCell_Array _1km	real	4	normalized	0	2	Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using high resolution sigma0_vv and sigma0_xpol
landcover_class_1km	EASEGridCell_Array _1km	enum	1	NA	NA	NA	An enumerated type that specifies the predominant surface vegetation found in the grid cell.
latitude_1km	EASEGridCell_Array _1km	real	4	degrees_no rth	-90.0	90.0	Latitude of the center of the Earth based grid cell.
longitude_1km	EASEGridCell_Array _1km	real	4	degrees_ea st	-180.0	180.0	Longitude of the center of the Earth based grid cell.
retrieval_qual_flag_1km	EASEGridCell_Array _1km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the retrieval algorithms that generate baseline soil moisture for the grid cell.
sigma0_incidence_angle_1km	EASEGridCell_Array _1km	real	4	degrees	20°	60°	Angle of radar incidence relative to the local normal.
sigma0_vv_aggregated_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 1 km vertical polarization radar backscatter measurements into a 1 km EASE grid cell.
sigma0_vh_aggregated_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 1 km cross-polarized radar backscatter measurements into a 1 km EASE grid cell.
soil_moisture_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.02	0.5	Representative baseline soil moisture measurement for the Earth based grid cell.
soil_moisture_std_dev_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.0	0.2	Standard deviation of soil moisture measure for the 1 km Earth based grid cell.
spacecraft_overpass_time_seconds_1k	EASEGridCell_Array	real	8	seconds	0	999999.9	Number of seconds since a

m	_1km						specified epoch that represents the spacecraft overpass relative to the 1 km EASE grid cell represented in this data product.
surface_flag_1km	EASEGridCell_Array _1km	bit flag	2	NA	NA	NA	Bit flags that record ambient surface conditions for the grid cell
surface_temperature_1km	EASEGridCell_Array _1km	real	4	degrees Celsius	-50.0	60.0	Temperature at land surface based on GMAO GOES.
tb_v_disaggregated_1km	EASEGridCell_Array _1km	real	4	Kelvins	0.0	330.0	Vertical polarization brightness temperature from option1 adjusted for the presence of water bodies and disaggregated from the 9 km EASE grid cells into 1 km EASE grid cells.
tb_v_disaggregated_std_1km	EASEGridCell_Array _1km	real	4	Kelvins	0.0	330.0	Standard deviation of disaggregated Tb in the 1km cell.
vegetation_opacity_1km	EASEGridCell_Array _1km	real	4	normalized	0	1	The measured opacity of the vegetation in the grid cell.
vegetation_water_content_1km	EASEGridCell_Array _1km	real	4	kg/m^2	0.0	30	Representative measure of water in the vegetation within the 1 km grid cell.
water_body_fraction_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	Fraction of the area of 1 km grid cell that is a permanent or transient water body. Derived from the DEM and radar processing.

AM-or-PM 1km elements

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
EASE_column_index_apm_1km	EASEGridCell_Array _1km	integer	2	count	0	65535	The column index of the 1 km EASE grid cell that contains the associated data.
EASE_row_index_apm_1km	EASEGridCell_Array _1km	integer	2	count	0	65535	The row index of the 1 km EASE grid cell that contains the associated data.
SMAP_Sentinel_overpass_timediff_hr	EASEGridCell_Array	real	4	hours	0.0	36.0	The time difference in hours

_apm_1km	_1km						between the Sentinel data and the collocated SMAP data
albedo_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	Diffuse reflecting power of the Earth's surface within the grid cell.
bare_soil_roughness_retrieved_apm_1 km	EASEGridCell_Array _1km	real	4	meters	0.0	0.1	Retrieved soil roughness provided by the active soil moisture algorithm.
beta_tbv_vv_apm_1km	EASEGridCell_Array _1km	real	4	Kelvins/dB	-25	0	Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbv and sigma0_vv
disagg_soil_moisture_apm_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.02	0.5	Representative optional (disaggregated) soil moisture measurement for the Earth based grid cell.
disaggregated_tb_v_qual_flag_apm_1 km	EASEGridCell_Array _1km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell.
gamma_vv_xpol_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0	2	Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using high resolution sigma0_vv and sigma0_xpol
landcover_class_apm_1km	EASEGridCell_Array _1km	enum	1	NA	NA	NA	An enumerated type that specifies the predominant surface vegetation found in the grid cell.
latitude_apm_1km	EASEGridCell_Array _1km	real	4	degrees_no rth	-90.0	90.0	Latitude of the center of the Earth based grid cell.
longitude_apm_1km	EASEGridCell_Array _1km	real	4	degrees_ea st	-180.0	180.0	Longitude of the center of the Earth based grid cell.
retrieval_qual_flag_apm_1km	EASEGridCell_Array _1km	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the retrieval algorithms that generate baseline

							soil moisture for the grid cell.
sigma0_incidence_angle_apm_1km	EASEGridCell_Array _1km	real	4	degrees	20°	60°	Angle of radar incidence relative to the local normal.
sigma0_vv_aggregated_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 1 km vertical polarization radar backscatter measurements into a 1 km EASE grid cell.
sigma0_vh_aggregated_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	The outcome of aggregating a set of 1 km cross-polarized radar backscatter measurements into a 1 km EASE grid cell.
soil_moisture_apm_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.02	0.5	Representative baseline soil moisture measurement for the Earth based grid cell.
soil_moisture_std_dev_apm_1km	EASEGridCell_Array _1km	real	4	cm^3/cm^3	0.0	0.2	Standard deviation of soil moisture measure for the 1 km Earth based grid cell.
spacecraft_overpass_time_seconds_ap m_1km	EASEGridCell_Array _1km	real	8	seconds	0	999999.9	Number of seconds since a specified epoch that represents the spacecraft overpass relative to the 1 km EASE grid cell represented in this data product.
surface_flag_apm_1km	EASEGridCell_Array _1km	bit flag	2	NA	NA	NA	Bit flags that record ambient surface conditions for the grid cell
surface_temperature_apm_1km	EASEGridCell_Array _1km	real	4	degrees Celsius	-50.0	60.0	Temperature at land surface based on GMAO GOES.
tb_v_disaggregated_apm_1km	EASEGridCell_Array _1km	real	4	Kelvins	0.0	330.0	Vertical polarization brightness temperature from option1 adjusted for the presence of water bodies and disaggregated from the 9 km EASE grid cells into 1 km EASE grid cells.
tb_v_disaggregated_std_apm_1km	EASEGridCell_Array _1km	real	4	Kelvins	0.0	330.0	Standard deviation of disaggregated Tb in the 1km cell.
vegetation_opacity_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0	1	The measured opacity of the vegetation in the grid cell.

vegetation_water_content_apm_1km	EASEGridCell_Array _1km	real	4	kg/m^2	0.0	30	Representative measure of water in the vegetation within the 1 km grid cell.
water_body_fraction_apm_1km	EASEGridCell_Array _1km	real	4	normalized	0.0	1.0	Fraction of the area of 1 km grid cell that is a permanent or transient water body. Derived from the DEM and radar processing.

4.6 Parameter Definitions

NOTE: All definitions given here are for the "AM-only" data elements. The definitions for the "AM-or-PM" (_apm_) elements for each resolution are the same, other than the "_apm_" tag in the element names; they are not repeated here for brevity.

4.6.1 albedo_1km

Diffuse reflecting power of the Earth's surface within the grid cell at 1 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 1.0
Units: n/a

4.6.2 albedo_3km

Diffuse reflecting power of the Earth's surface within the grid cell at 3 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 1.0
Units: n/a

4.6.3 bare_soil_roughness_retrieved_1km

Roughness coefficient at 1-km spatial scale. Note that this parameter is the same 'h' coefficient in the 'tau-omega' model for a given polarization channel.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 2.0
Units: n/a

4.6.4 bare_soil_roughness_retrieved_3km

Roughness coefficient at 3-km spatial scale. Note that this parameter is the same 'h' coefficient in the 'tau-omega' model for a given polarization channel.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km

Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 2.0
Units: n/a

4.6.5 beta_tbv_vv_1km

Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. Prior beta is derived from the time series of brightness temperature at 9 km EASE2 grid and aggregated co-pol (vv) backscatter at 9 km EASE2 grid. The length of the time series to estimate alpha especially depends on the region and the landcover.

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: -20.0
Valid_max: 0.0
Units: Kelvin/dB

4.6.6 beta_tbv_vv_3km

Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. Prior abeta is derived from the time series of brightness temperature at 9 km EASE2 grid and aggregated co-pol (vv) backscatter at 9 km EASE2 grid. The length of the time series to estimate alpha especially depends on the region and the landcover.

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: -20.0
Valid_max: 0.0
Units: Kelvin/dB

4.6.7 disagg_soil_moisture_1km

Retrieved soil moisture estimate from the disaggregated/downscaled 9km soil moisture measurements representative of the 1-km grid cell.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.01
Valid_max: 0.60
Units: cm^3/ cm^3

4.6.8 disagg_soil_moisture_3km

Retrieved soil moisture estimate from the disaggregated/downscaled 9km soil moisture measurements representative of the 3-km grid cell.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.01
Valid_max: 0.60
Units: cm^3/ cm^3

4.6.9 disaggregated_tb_v_qual_flag_1km

Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell.

Precision: Uint16
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0
Valid_max: 32767
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Disaggregated brightness temperature v-pol quality	0	off	Disaggregated vertical polarization brightness temperature has acceptable quality.
		on	Unable to disaggregate vertical polarization brightness temperatures into 9 km resolution cells.
Sigma0_vv quality flag	1	off	All vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		on	Some vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Sigma0_xpol quality flag	2	off	All cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		on	Some cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Brightness temperature v-pol quality flag	3	off	Vertical polarization brightness temperature input that was used for disaggregation was deemed as good quality.
		on	Some vertical polarization brightness temperature input that was used for soil moisture retrieval was of questionable or poor quality.
Brightness temperature v-pol RFI detected flag	4	off	Insignificant levels of RFI detected in the vertical polarization radiometer brightness temperature input.
		on	Significant levels of RFI were detected in the vertical polarization radiometer brightness temperature input.

Brightness temperature v-pol RFI corrected flag	5	off	The vertical polarization radiometer brightness temperature input is based on data that were repaired for the effects of RFI.
		on	Unable to repair the vertical polarization radiometer brightness temperature input for the effects of RFI.
Sigma0_vv RFI detected flag	6	off	Insignificant levels of RFI detected in the vertical polarization radar sigma0 input.
		on	Significant levels of RFI were detected in the vertical polarization radar sigma0 input.
Sigma0_vv RFI corrected flag	7	off	The input for retrieval is based on vertical polarization radar sigma0s that were repaired for the effects of RFI.
		on	Unable to repair the vertical polarization radar sigma0 input for the effects of RFI.
Sigma0_xpol RFI detected flag	8	off	Insignificant levels of RFI detected in the cross polarized radar sigma0 input.
		on	Significant levels of RFI were detected in the cross polarized radar sigma0 input.
Sigma0_xpol RFI corrected flag	9	off	The input for retrieval is based on cross polarized radar sigma0s that were repaired for the effects of RFI.
		on	Unable to repair the cross polarized radar sigma0 input for the effects of RFI.
Negative sigma0_vv flag	10	off	The input for retrieval is based on vertical polarization radar sigma0s that are greater than zero.
		on	The input for retrieval is based on vertical polarization radar sigma0s that are less than or equal to zero.
Negative sigma0_xpol flag	11	off	The input for retrieval is based on cross polarized radar sigma0s that are greater than zero.
		on	The input for retrieval is based on cross polarized radar sigma0s that are less than or equal to zero.
Waterbody correction flag	12	off	Waterbody correction successfully done and the percentage waterbody with 36 TB grid cell is <= 5%, TB deemed good quality.
		on	Waterbody correction successfully done and the percentage waterbody with 36 TB grid cell is > 5%, TB quality is suspected.

4.6.10 **disaggregated_tb_v_qual_flag_3km**

Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell.

Precision: Uint16
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0
Valid_max: 32767
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Disaggregated brightness temperature v-pol quality	0	off	Disaggregated vertical polarization brightness temperature has acceptable quality.
		on	Unable to disaggregate vertical polarization brightness

			temperatures into 9 km resolution cells.
Sigma0_vv quality flag	1	off	All vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		on	Some vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Sigma0_xpol quality flag	2	off	All cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		on	Some cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Brightness temperature v-pol quality flag	3	off	Vertical polarization brightness temperature input that was used for disaggregation was deemed as good quality.
		on	Some vertical polarization brightness temperature input that was used for soil moisture retrieval was of questionable or poor quality.
Brightness temperature v-pol RFI detected flag	4	off	Insignificant levels of RFI detected in the vertical polarization radiometer brightness temperature input.
		on	Significant levels of RFI were detected in the vertical polarization radiometer brightness temperature input.
Brightness temperature v-pol RFI corrected flag	5	off	The vertical polarization radiometer brightness temperature input is based on data that were repaired for the effects of RFI.
		on	Unable to repair the vertical polarization radiometer brightness temperature input for the effects of RFI.
Sigma0_vv RFI detected flag	6	off	Insignificant levels of RFI detected in the vertical polarization radar sigma0 input.
		on	Significant levels of RFI were detected in the vertical polarization radar sigma0 input.
Sigma0_vv RFI corrected flag	7	off	The input for retrieval is based on vertical polarization radar sigma0s that were repaired for the effects of RFI.
		on	Unable to repair the vertical polarization radar sigma0 input for the effects of RFI.
Sigma0_xpol RFI detected flag	8	off	Insignificant levels of RFI detected in the cross polarized radar sigma0 input.
		on	Significant levels of RFI were detected in the cross polarized radar sigma0 input.
Sigma0_xpol RFI corrected flag	9	off	The input for retrieval is based on cross polarized radar sigma0s that were repaired for the effects of RFI.
		on	Unable to repair the cross polarized radar sigma0 input for the effects of RFI.
Negative sigma0_vv flag	10	off	The input for retrieval is based on vertical polarization radar sigma0s that are greater than zero.
		on	The input for retrieval is based on vertical polarization radar sigma0s that are less than or equal to zero.
Negative sigma0_xpol flag	11	off	The input for retrieval is based on cross polarized radar sigma0s that are greater than zero.
		on	The input for retrieval is based on cross polarized radar sigma0s that are less than or equal to zero.
Waterbody correction flag	12	off	Waterbody correction successfully done and the percentage waterbody with 36 TB grid cell is <= 5%, TB deemed good quality.
		on	Waterbody correction successfully done and the

			percentage waterbody with 36 TB grid cell is > 5%, TB quality is suspected.

4.6.11 EASE_column_index_1km
EASE grid cell at 1 km row index on world grid in longitude direction.

Precision: Uint16
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 1
Valid_max: 3856 (M09)
Units: n/a

4.6.12 EASE_column_index_3km
EASE grid cell at 3 km row index on world grid in longitude direction.

Precision: Uint16
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 1
Valid_max: 3856 (M03)
Units: n/a

4.6.13 EASE_row_index_1km
EASE grid cell at 1 km row index on world grid in latitude direction.

Precision: Uint16
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 1
Valid_max: 1624 (M09)
Units: n/a

4.6.14 EASE_row_index_3km
EASE grid cell at 3 km row index on world grid in latitude direction.

Precision: Uint16
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 1
Valid_max: 1624 (M03)
Units: n/a

4.6.15 gamma_vv_xpol_1km

Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (vv) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 9 km grid cell.

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 2.0
Units: dB/dB

4.6.16 gamma_vv_xpol_3km

Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (vv) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 9 km grid cell.

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 2.0
Units: dB/dB

4.6.17 landcover_class_1km

An enumerated type that specifies the predominant surface vegetation found in the EASE2 grid cell at 1-km.

Precision: Uint16
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0
Valid_max: 16
Units: n/a

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

4.6.18 landcover_class_3km

An enumerated type that specifies the predominant surface vegetation found in the EASE2 grid cell at 3 km.

Precision: Uint16
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0
Valid_max: 16
Units: n/a

Value	Interpretation
0	Water
1	Evergreen needleleaf forest
2	Evergreen broadleaf forest
3	Deciduous needleleaf forest
4	Deciduous broadleaf forest
5	Mixed forest

6	Closed shrubland
7	Open shrubland
8	Woody savanna
9	Savanna
10	Grassland
11	Permanent Wetland
12	Croplands
13	Urban and Built-up
14	Cropland/Natural Vegetation Mosiac
15	Permanent Snow and Ice
16	Barren or Sparsely Vegetated
>16	TBD

4.6.19 latitude_1km

Latitude of the center of the Earth based grid cell at 1 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: -90.0
Valid_max: +90.0
Units: degree

4.6.20 latitude_3km

Latitude of the center of the Earth based grid cell at 3 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: -90.0
Valid_max: +90.0
Units: degree

4.6.21 longitude_1km

Longitude of the center of the Earth based grid cell at 1 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: -180.0
Valid_max: +180.0
Units: degree

4.6.22 longitude_3km

Longitude of the center of the Earth based grid cell at 3 km.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: -180.0
Valid_max: +180.0
Units: degree

4.6.23 retrieval_qual_flag_1km

Bit flags that record the conditions and the quality of the retrieved baseline soil moisture. When translated to decimal representation, this parameter contains an integer indicating one of the following inversion outcomes.

Precision: Uint32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0
Valid_max: 4,294,967,295
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Retrieval recommended flag	0	off	Use of the soil moisture value retrieved for this pixel is recommended.
		on	Use of soil moisture value retrieved for this pixel is not recommended.
Retrieval attempted flag	1	off	The algorithm attempted to retrieve soil moisture for this grid cell.
		on	The algorithm did not attempt to retrieve soil moisture for this grid cell.
Retrieval success flag	2	off	Retrieval for this algorithm was successfully executed or the algorithm was not attempted.
		on	The retrieval for this algorithm was attempted but failed.
Radar water body detection success flag	3	off	Radar water body detection ran successfully
		on	Unable to detect water bodies using retrieval techniques based on radar.
Freeze-thaw retrieval success flag	4	off	Freeze-thaw retrieval ran successfully
		on	Unable to ascertain freeze-thaw conditions
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful
Disaggregated brightness temperature quality	6	off	Disaggregated brightness temperature retrieval ran successfully
		on	Unable to disaggregate brightness temperatures into 1 km resolution cells.
Anomalously high SM retrieval	7	off	Retrieved soil moisture is within normal range, between 0.02 and porosity, as determined by soil texture.
		on	Retrieved soil moisture is beyond normal range, above porosity, as determined by soil texture.

4.6.24 retrieval_qual_flag_3km

Bit flags that record the conditions and the quality of the retrieved soil moisture. When translated to decimal representation, this parameter contains an integer indicating one of the following inversion outcomes.

Precision: Uint32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0
Valid_max: 4,294,967,295
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Retrieval recommended flag	0	off	Use of the soil moisture value retrieved for this pixel is recommended.
		on	Use of soil moisture value retrieved for this pixel is not recommended.
Retrieval attempted flag	1	off	The algorithm attempted to retrieve soil moisture for this grid cell.
		on	The algorithm did not attempt to retrieve soil moisture for this grid cell.
Retrieval success flag	2	off	Retrieval for this algorithm was successfully executed or the algorithm was not attempted.
		on	The retrieval for this algorithm was attempted but failed.
Radar water body detection success flag	3	off	Radar water body detection ran successfully
		on	Unable to detect water bodies using retrieval techniques based on radar.
Freeze-thaw retrieval success flag	4	off	Freeze-thaw retrieval ran successfully
		on	Unable to ascertain freeze-thaw conditions
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful
Disaggregated brightness temperature quality	6	off	Disaggregated brightness temperature retrieval ran successfully
		on	Unable to disaggregate brightness temperatures into 3 km resolution cells.
Anomalously high SM retrieval	7	off	Retrieved soil moisture is within normal range, between 0.02 and porosity, as determined by soil texture.
		on	Retrieved soil moisture is beyond normal range, above porosity, as determined by soil texture.

4.6.25 sigma0_incidence_angle_1km

The angle of radar incidence relative to the local normal at the location of the scene pixel, aggregated at 1 km resolution on the EASE grid.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km

Valid_min: 20.0
Valid_max: 60.0
Units: degrees

4.6.26 sigma0_incidence_angle_3km
The angle of radar incidence relative to the local normal at the location of the scene pixel, aggregated at 3 km resolution on the EASE grid.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 20.0
Valid_max: 60.0
Units: degrees

4.6.27 sigma0_vv_aggregated_1km
The outcome of aggregating a set of 3-km co-pol vertical polarization radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 1.0
Units: normalized (linear)

4.6.28 sigma0_vv_aggregated_3km
The outcome of aggregating a set of 3-km co-pol vertical polarization radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 1.0
Units: normalized (linear)

4.6.29 sigma0_vh_aggregated_1km
The outcome of aggregating a set of 3-km cross-polarization (*hv* or *vh*) radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 1.0
Units: normalized (linear)

4.6.30 sigma0_vh_aggregated_3km

The outcome of aggregating a set of 3-km cross-polarization (*hv* or *vh*) radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 1.0
Units: normalized (linear)

4.6.31 SMAP_Sentinel_overpass_timediff_hr_1km

The time difference in hours between the mean SMAP overpass time and the Sentinel overpass time at the location of the Sentinel scene.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 36.0
Units: hours

4.6.32 SMAP_Sentinel_overpass_timediff_hr_3km

The time difference in hours between the mean SMAP overpass time and the Sentinel overpass time at the location of the Sentinel scene.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 36.0
Units: hours

4.6.33 soil_moisture_1km
Retrieved soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 1-km grid cell.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.01
Valid_max: 0.60
Units: cm^3/ cm^3

4.6.34 soil_moisture_3km
Retrieved soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 3-km grid cell.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.01
Valid_max: 0.60
Units: cm^3/ cm^3

4.6.35 soil_moisture_std_dev_1km
Estimated '1-sigma' error of the soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.01
Valid_max: 0.30
Units: cm^3/ cm^3

4.6.36 soil_moisture_std_dev_3km
Estimated '1-sigma' error of the retrieved v-pol soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.01
Valid_max: 0.30
Units: cm^3/ cm^3

4.6.37 spacecraft_overpass_time_seconds_1km

Number of seconds since a specified epoch that represents the spacecraft overpass relative to ground swath. The 9-km EASE2-Grid cell is assigned the UTC time of 36-km EASE2-Grid cell that is used for downscaling. The field describes the average of UTC acquisition times, in ASCII representation, of L1B_TB observations whose boresights fall within a 36-km EASE2-Grid cell.

Precision: Float64
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: n/a
Units: seconds

4.6.38 spacecraft_overpass_time_seconds_3km

Number of seconds since a specified epoch that represents the spacecraft overpass relative to ground swath. The 3 km EASE2-Grid cell is assigned the UTC time of 36-km EASE2-Grid cell that is used for downscaling. The field describes the average of UTC acquisition times, in ASCII representation, of L1B_TB observations whose boresights fall within a 36-km EASE2-Grid cell.

Precision: Float64
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: n/a
Units: seconds

4.6.39 surface_flag_1km

Bit flags that record ambient surface conditions for the grid cell at 1 km.

Precision: Uint16
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0
Valid_max: 65,535
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
1 km static water body flag	0	off	The fraction of the 1 km grid cell area that is over a permanent water body is less than metadata element PermanentWaterBodyThreshold. Determined by DEM.
		on	The fraction of the 1 km grid cell area that is over a permanent water body is greater than or equal to metadata element PermanentWaterBodyThreshold.

			Determined by DEM.
1 km radar water body detection flag	1	off	Not used in L2_SM_SP.
		on	Not used in L2_SM_SP.
1 km coastal mask flag	2	off	Data within the grid cell were not acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
		on	Data within the grid cell were acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
1 km urban area flag	3	off	The fraction of the 1 km grid cell area that is over urban development is less than metadata element UrbanAreaThreshold.
		on	The fraction of the 1 km grid cell area that is over urban development is greater than or equal to metadata element UrbanAreaThreshold.
1 km precipitation flag	4	off	No precipitation detected within the 1 km grid cell when data were being acquired.
		on	Precipitation detected within the 1 km grid cell when data were being acquired
1 km snow or ice flag	5	off	No or insignificant quantities of snow or ice were detected within the 1 km cell.
		on	Significant quantities of snow and/or ice were detected within the 1 km grid cell.
1 km permanent snow or ice flag	6	off	The fraction of the 1 km grid cell area that is over permanent snow or ice is less than a specified algorithmic threshold.
		on	The fraction of the96 km grid cell area that is over permanent snow or ice is greater than or equal to a specified algorithmic threshold.
1 km frozen ground flag	7	off	No frozen ground detected within the 1 km grid cell.
		on	Frozen ground detected within the 1 km grid cell.
1 km frozen ground flag based on surface temperature	8	off	No frozen ground detected within the 1 km grid cell.
		on	Frozen ground detected within the 1 km grid cell.
1 km mountainous terrain flag	9	off	The variability of land elevation in the 1 km grid cell is less than metadata element MountainousTerrainThreshold.
		on	The variability of land elevation in the 1 km grid cell is greater than or equal to metadata element MountainousTerrainThreshold.
1 km dense vegetation flag	10	off	The vegetation density within the 1 km grid cell is less than metadata element DenseVegetationThreshold.
		on	The vegetation density within the 1 km grid cell area is greater than or equal to metadata element DenseVegetationThreshold.
1 km edge cell flag	11	off	Data within the grid cell were not acquired at the edge of the Sentinel scene where disaggregation can be suspect.
		on	Data within the grid cell were acquired at the edge of the Sentinel scene where disaggregation can be suspect.
1 km anomalous sigma0 flag	12	off	Sentinel sigma0 data in the grid cell were within

			nominal expected range for the scene.
		on	Sentinel sigma0 data in the grid cell were outside the nominal expected range for the scene.

4.6.40 surface_flag_3km

Bit flags that record ambient surface conditions for the grid cell at 3 km.

Precision: Uint16
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0
Valid_max: 65,535
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
3 km static water body flag	0	off	The fraction of the 3 km grid cell area that is over a permanent water body is less than metadata element PermanentWaterBodyThreshold. Determined by DEM.
		on	The fraction of the 3 km grid cell area that is over a permanent water body is greater than or equal to metadata element PermanentWaterBodyThreshold. Determined by DEM.
3 km radar water body detection flag	1	off	Not used in L2_SM_SP.
		on	Not used in L2_SM_SP.
3 km coastal mask flag	2	off	Data within the grid cell were not acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
		on	Data within the grid cell were acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
3 km urban area flag	3	off	The fraction of the 3 km grid cell area that is over urban development is less than metadata element UrbanAreaThreshold.
		on	The fraction of the 3 km grid cell area that is over urban development is greater than or equal to metadata element UrbanAreaThreshold.
3 km precipitation flag	4	off	No precipitation detected within the 3 km grid cell when data were being acquired.
		on	Precipitation detected within the 3 km grid cell when data were being acquired
3 km snow or ice flag	5	off	No or insignificant quantities of snow or ice were detected within the 3 km cell.
		on	Significant quantities of snow and/or ice were detected within the 3 km grid cell.
3 km permanent snow or ice flag	6	off	The fraction of the 3 km grid cell area that is over permanent snow or ice is less than a specified algorithmic threshold.
		on	The fraction of the 3 km grid cell area that is over

			permanent snow or ice is greater than or equal to a specified algorithmic threshold.
3 km frozen ground flag	7	off	No frozen ground detected within the 3 km grid cell.
		on	Frozen ground detected within the 3 km grid cell.
3 km frozen ground flag based on surface temperature	8	off	No frozen ground detected within the 3 km grid cell.
		on	Frozen ground detected within the 3 km grid cell.
3 km mountainous terrain flag	9	off	The variability of land elevation in the 3 km grid cell is less than metadata element MountainousTerrainThreshold.
		on	The variability of land elevation in the 3 km grid cell is greater than or equal to metadata element MountainousTerrainThreshold.
3 km dense vegetation flag	10	off	The vegetation density within the 3 km grid cell is less than metadata element DenseVegetationThreshold.
		on	The vegetation density within the 3 km grid cell area is greater than or equal to metadata element DenseVegetationThreshold.
3 km edge cell flag	11	off	Data within the grid cell were not acquired at the edge of the Sentinel scene where disaggregation can be suspect.
		on	Data within the grid cell were acquired at the edge of the Sentinel scene where disaggregation can be suspect.
3 km anomalous sigma0 flag	12	off	Sentinel sigma0 data in the grid cell were within nominal expected range for the scene.
		on	Sentinel sigma0 data in the grid cell were outside the nominal expected range for the scene.

4.6.41 surface_temperature_1km

Soil temperature (averaged over the top 5-cm soil layer) at 9-km spatial scale. This parameter is used as input ancillary data parameter to the L2_SM_AP processing software for the baseline algorithms. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 253.15
Valid_max: 313.15
Units: Kelvin

4.6.42 surface_temperature_3km

Soil temperature (averaged over the top 5-cm soil layer) at 3-km spatial scale. This parameter is used as input ancillary data parameter to the L2_SM_AP processing software for the baseline algorithms. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km

Shape: EASEGridCell_Array_3km
Valid_min: 253.15
Valid_max: 313.15
Units: Kelvin

4.6.43 tb_v_disaggregated_1km

Vertical polarization brightness temperature option1 at 9-km obtained by disaggregating/downscaling the 36 km EASE grid cells vertical polarization brightness temperature.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 340.0
Units: Kelvin

4.6.44 tb_v_disaggregated_3km

Vertical polarization brightness temperature at 3-km obtained by disaggregating/downscaling the 36 km EASE grid cells vertical polarization brightness temperature.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 340.0
Units: Kelvin

4.6.45 tb_v_disaggregated_std_1km

Standard deviation of the vertical polarization brightness temperature option1 adjusted for the presence of water bodies and disaggregated from the 36 km EASE grid cells into 9 km EASE grid cells.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 100.0
Units: Kelvin

4.6.46 tb_v_disaggregated_std_3km

Standard deviation of the vertical polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE grid cells into 3 km EASE grid cells.

Precision: Float32

Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 100.0
Units: Kelvin

4.6.47 vegetation_opacity_1km

Estimated vegetation opacity at 9-km spatial scale. Note that this parameter is the same 'tau' parameter normalized by the cosine of the incidence angle in the 'tau-omega' model. That's,

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

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 5.0
Units: n/a

4.6.48 vegetation_opacity_3km

Estimated vegetation opacity at 3-km spatial scale. Note that this parameter is the same 'tau' parameter normalized by the cosine of the incidence angle in the 'tau-omega' model. That's,

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

The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 5.0
Units: n/a

4.6.49 vegetation_water_content_1km

Vegetation water content at 9-km spatial scale. This parameter is used as input ancillary data parameter to the L2_SM_AP processing software when the baseline algorithm is used. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0.0
Valid_max: 30.0
Units: kg/m^2

4.6.50 vegetation_water_content_3km

Vegetation water content at 3-km spatial scale. This parameter is used as input ancillary data parameter to the L2_SM_AP processing software when the baseline algorithm is used. The valid minimum and maximum below are subject to further analysis on real data.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km
Valid_min: 0.0
Valid_max: 30.0
Units: kg/m^2

4.6.51 water_body_fraction_1km

Water body fraction at 9-km spatial scale. If there are NW water pixels and NL land pixels within a 9-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. At present the L2_SM_AP processing software can be configured to provide this parameter from a static water fraction database or from the SMAP L2_SM_A product.

Precision: Float32
Group: Soil Moisture Retrieval Data 1km
Shape: EASEGridCell_Array_1km
Valid_min: 0
Valid_max: 1
Units: n/a

4.6.52 water_body_fraction_3km

Water body fraction at 3-km spatial scale. If there are NW water pixels and NL land pixels within a 3-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. At present the L2_SM_AP processing software can be configured to provide this parameter from a static water fraction database or from the SMAP L2_SM_A product.

Precision: Float32
Group: Soil Moisture Retrieval Data 3km
Shape: EASEGridCell_Array_3km

Valid_min: 0
Valid_max: 1
Units: n/a

5 REFERENCES

5.1 Requirements

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

5.2 Plans

- SMAP Science Data Management and Archive Plan. SMAP Project, JPL D-45973, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Science Data Calibration and Validation Plan. SMAP Project, JPL D-52544, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Applications Plan. SMAP Project, JPL D-53082, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Science Data System Management Plan. SMAP Project, 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.
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- 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: L2 SMAP/Sentinel Active-Passive Soil Moisture Product. SMAP Project, JPL D-56547, 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

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- 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-92340, 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, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 4 Soil Moisture (L4_SM) Product Specification Document. SMAP Project, Jet Propulsion Laboratory, Pasadena, CA.

5.5 Enhanced Products (December 2016)

- SMAP Level 1B_TB_E Product Specification Document, JPL D-56289, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1C_TB_E Product Specification Document. SMAP Project, JPL D-56290, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 2_SM_P_E Product Specification Document. SMAP Project, JPL D-56291, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3_SM_P_E Product Specification Document. SMAP Project, JPL D-56292, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Freeze-Thaw Passive Product Specification Document (L3_FT_P). SMAP Project, JPL D-56293, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 3 Enhanced Freeze-Thaw Passive Product Specification Document (L3_FT_P_E). SMAP Project, JPL D-56294, Jet Propulsion Laboratory, Pasadena, CA.

5.6 SMAP/Sentinel Product (April 2017)

- Level 2 SMAP/Sentinel Active-Passive Soil Moisture (L2_SM_SP) Product Specification Document. SMAP Project, JPL D-56548, Jet Propulsion Laboratory, Pasadena, CA.

5.7 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.
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- Introduction to HDF5, The HDF Group. URL: http://www.hdfgroup.org/HDF5/doc/H5.intro.html
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- EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets, Brodzik, M.J., et. al., National Snow and Ice Data Center, Cooperative Institute of Environmental Sciences, University of Colorado, ISPRS International Journal of Geo-Information, ISSN 2220-9964, DOI: 10.3390/igji1010032.

6 APPENDIX A: ACRONYMS AND ABBREVIATIONS

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

ADT	Algorithm Development Team
AMSR	Advanced Microwave Scanning Radiometer
ANSI	American National Standards Institute
APF	Algorithm Parameter File
ARS	Agricultural Research Service
ASF	Alaska Satellite Facility
ATBD	Algorithm Theoretical Basis Document
ATLO	Assembly Test Launch and Operations
BFPQ	Block Floating Point Quantization
BIC	Beam Index Crossing
CARA	Criticality and Risk Assessment
CBE	Current Best Estimate
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
CEOS	Committee on Earth Observing Systems
CF	Climate and Forecast (metadata convention)
CM	Configuration Management
CM	Center of Mass
CONUS	Continental United States
COTS	Commercial Off the Shelf
CR	Change Request
DAAC	Distributed Active Archive Center
DB	Database
DBA	Database Administrator
dB	Decibels
deg	Degrees
deg/sec	Degrees per second
deg C	Degrees Celsius
DEM	Digital Elevation Model
DFM	Design File Memorandum
DIU	Digital Interface Unit
DN	Data Number
DOORS	Dynamic Object Oriented Requirements
DQC	Data Quality Control
DSK	Digital Skin Kernel
DVD	Digital Versatile Disc
EASE	Equal Area Scalable Earth
ECMWF	European Centre for Medium Range Weather Forecasts
ECHO	EOS Clearing House

ECI	Earth Centered Inertial Coordinate System
ECR	Earth Centered Rotating Coordinate System
ECR	Engineering Change Request
ECS	EOSDIS Core System
EDOS	EOS Data Operations System
EM	Engineering Model
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EPO	Education and Public Outreach
ESDIS	Earth Science Data and Information System Project
ESDT	Earth Science Data Type
ESSP	Earth Science System Pathfinder
ET	Ephemeris Time
EU	Engineering Units
FOV	Field of View
FRB	Functional Requirements Baseline
FS	Flight System
FSW	Flight Software
F/T	Freeze/Thaw
FTP	File Transfer Protocol
Gbyte	Gigabyte
GDS	Ground Data System
GHA	Greenwich Hour Angle
GHz	Gigahertz
GLOSIM	Global Simulation
GMAO	Government Modeling and Assimilation Office
GMT	Greenwich Mean Time
GN	Ground Network
GPMC	Governing Program Management Council
GPP	Gross Primary Production
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HK	Housekeeping (telemetry)
Hz	Hertz
HSD	Health and Status Data
ICE	Integrated Control Electronics
ICESat	Ice, Cloud and Land Elevation Satellite
IDL	Interactive Data Language
I&T	Integration and Test
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IFOV	Instantaneous Field of View
I/O	Input/Output
IOC	In-Orbit Checkout

IRU	Inertial Reference Unit
ISO	International Organization for Standardization
IV&V	Independent Verification and Validation
ITAR	International Traffic in Arms Regulations
I&T	Integration and Test
JPL	Jet Propulsion Laboratory
kHz	Kilohertz
km	Kilometers
LAN	Local Area Network
LBT	Loopback Trap
LEO	Low Earth Orbit
LEOP	Launch and Early Operations
LOE	Level Of Effort
LOM	Life Of Mission
LOS	Loss of Signal
LSK	Leap Seconds Kernel
LZPF	Level Zero Processing Facility
m	Meters
MHz	Megahertz
MIT	Massachusetts Institute of Technology
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Mission Operations System
m/s	Meters per second
ms	Milliseconds
MS	Mission System
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Protection
NCP	North Celestial Pole
NCSA	National Center for Supercomputing Applications
NEDT	Noise Equivalent Diode Temperature
NEE	Net Ecosystem Exchange
NEN	Near Earth Network
netCDF	Network Common Data Form
NFS	Network File System/Server
NISN	NASA Integrated Services Network
NRT	Near Real Time
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NVM	Non-Volatile Memory
NWP	Numerical Weather Prediction
N\A	Not applicable
OCO	Orbiting Carbon Observatory

ORBNUM	Orbit Number File
OODT	Object Oriented Data Technology
ORR	Operational Readiness Review
ORT	Operational Readiness Test
OSSE	Observing System Simulation Experiment
OSTC	One Second Time Command
PALS	Passive and Active L-Band System
PALSAR	Phased Array L-Band Synthetic Aperture Radar
PcK	Planetary Constants Kernel
PDR	Preliminary Design Review
PPPCS	Pointing, Position, Phasing and Coordinate System
PR	Problem Report
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PROM	Programmable Read Only Memory
PSD	Product Specification Document
QA	Quality Assurance
rad	Radians
RAM	Random Access Memory
RBA	Reflector Boom Assembly
RBD	Rate Buffered Data
RBE	Radiometer Back End
RDD	Release Description Document
RDE	Radiometer Digital Electronics
RF	Radio Frequency
RFA	Request For Action
RFE	Radiometer Front End
RFI	Radio Frequency Interference
RMS	Root mean square
RSS	Root sum square
ROM	Read Only Memory
RPM	revolutions per minute
RVI	Radar Vegetation Index
SA	System Administrator
SAR	Synthetic Aperture Radar
S/C	Spacecraft
SCE	Spin Control Electronics
SCLK	Spacecraft Clock
SDP	Software Development Plan
SDS	Science Data System
SDT	Science Definition Team
SI	International System
SITP	System Integration and Test Plan
SMAP	Soil Moisture Active Passive
SMEX	Soil Moisture Experiment
SMOS	Soil Moisture and Ocean Salinity Mission

SMP	Software Management Plan
SNR	Signal to noise ratio
SOC	Soil Organic Carbon
SOM	Software Operators Manual
SQA	Software Quality Assurance
SPDM	Science Process and Data Management
SPG	Standards Process Group
SPK	Spacecraft Kernel
SQA	Software Quality Assurance
SPS	Science Production Software
SRF	Science Orbit Reference Frame
SRR	System Requirements Review
SRTM	Shuttle Radar Topography Mission
SSM/I	Special Sensor Microwave/Imager
STP	Software Test Plan
sec	Seconds
TAI	International Atomic Time
TB	Brightness Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
TCP/IP	Transmission Control Protocol/Internet Protocol
TEC	Total Electron Content
TM	Trademark
TOA	Time of Arrival
TPS	Third Party Software
UML	Unified Modeling Language
U-MT	University of Montana
USDA	United States Department of Agriculture
UTC	Coordinated Universal Time
V&V	Verification and Validation
VWC	Vegetation Water Content