Soil Moisture Active Passive (SMAP) Mission

Level 3 Active Soil Moisture Product Specification Document

Revised Release

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Soil Moisture Active Passive (SMAP)
Level 3 Active Soil Moisture
Data Product Specification Document

Initial Release

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DOCUMENT CHANGE LOG

REVISION	DATE	SECTIONS CHANGED	REASON FOR CHANGE (ECR #)
-	12 June 2014		Initial Release
	31 October 2015		Revised Release

TBD, TBR, TBS LOG

Section/Page	Description	Due Date
4.3	More accurate estimate of data volume to be determined from simulations	May 2013
References	Some document numbers to be fleshed out	May 2013
Appendix B	MATLAB code examples from MathWorks website	May 2013
4.4	ISO Metadata model is TBD	May 2013

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1 INTRODUCTION

1.1 Identification

This is the Data Product Specification (DPS) Document for the Level 3 Active Soil Moisture Product for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The product provides daily global composite of gridded data of SMAP radar-based soil moisture retrieval, ancillary data, and quality-assessment flags on a 3-km Earth-fixed grid.

1.2 Scope

This document describes the file format and data contents of the Level 3 Active Soil Moisture Data Product (hereafter referred to as 'L3_SM_A' for brevity) for external software interfaces. The SMAP Science Data Management and Archive Plan Document provides a more comprehensive explanation of this product within the context of the SMAP instrument, algorithms, and software.

1.3 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 attributes of the radar and radiometer observations (in terms of their spatial resolution and sensitivity to soil moisture, surface roughness, and vegetation) to estimate soil moisture at a resolution of 10 km and freeze-thaw state at a resolution of 1-3 km.

Table 1: SMAP Mission Requirements

Scientific Measurement Requirements	Instrument Functional Requirements
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 the data processing and enables accurate repeat-pass estimation 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 allow high-resolution processing will be collected during the morning overpass over all land regions and extending a short distance into the surrounding coastal oceans. During the evening overpass, data poleward of 45° N will be collected and processed as well 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)

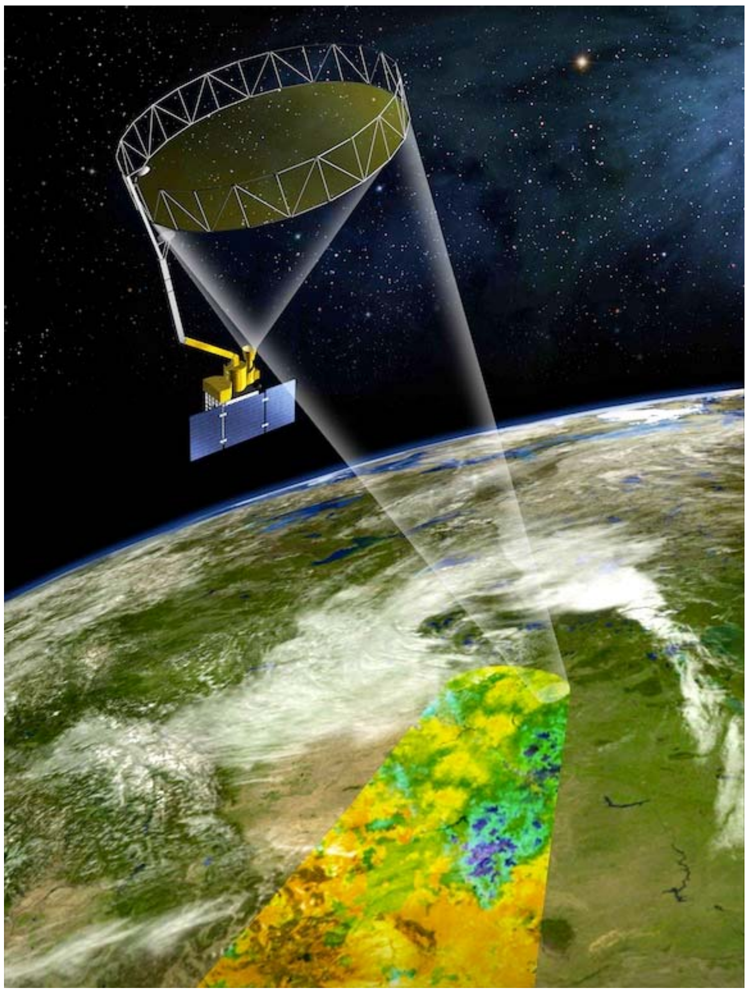

Figure 1: The SMAP mission concept consists of an L-band radar and radiometer sharing a single spinning 6-m mesh antenna in a sun-synchronous dawn / dusk orbit.

The SMAP radiometer measures the four Stokes parameters, T_H, T_V, T_3, and T_4 at 1.41 GHz. The T_3-channel measurement can be used to correct for possible Faraday rotation caused by the ionosphere, although such Faraday rotation is minimized by the selection of the 6 am sun-synchronous SMAP orbit.

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 have been designed to include features to mitigate the effects of RFI. The SMAP radar utilizes selective filters and an adjustable carrier frequency in order 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 data products. The planned data products are listed in Table 2. The SMAP product short names are adopted by the project to identify the products. Users will find these short names in SMAP documentation, SMAP product file names and product metadata. The Data Centers will use the ECS short names to categorize the products in their local databases. ECS short names will also appear in SMAP product metadata.

In the SMAP prelaunch time frame, baseline algorithms are being developed for generating (1) Level 1 calibrated, geolocated surface brightness temperature and radar backscatter measurements, (2) Level 2 and Level 3 surface soil moisture products both from radiometer measurements on a 36 km grid and from combined radar/radiometer measurements on a 9 km grid, (3) Level 3 freeze/thaw products from radar measurements on a 3 km grid, and (4) Level 4 surface and root zone soil moisture and Level 4 net ecosystem exchange (NEE) of carbon on a 9 km grid.

Table 2: Standard SMAP data products

SMAP Product Short Name	ECS Short Name	Description	Granularity
L1A_Radar	SPL1AA	Parsed radar instrument telemetry	—
L1A_Radiometer	SPL1AP	Parsed radiometer instrument telemetry	—
L1B_S0_LoRes	SPL1BS0	Low resolution radar σ_o in time order	Half orbit
L1C_S0_HiRes	SPL1CS0	High resolution radar σ_o on swath grid	Half orbit
L1B_TB	SPL1BTB	Radiometer T_B in time order	Half orbit
L1C_TB	SPL1CTB	Radiometer T_B on Earth-fixed grids	Half orbit
L2_SM_A	SPL2SMA	Radar soil moisture	Half orbit
L2_SM_P	SPL2SMP	Radiometer soil moisture	Half orbit
L2_SM_AP	SPL2SMAP	Radar-radiometer soil moisture	Half orbit
L3_FT_A	SPL3FTA	Daily global composite freeze/thaw	North of

		state	45°N
L3_SM_A	SPL3SMA	Daily global composite radar soil moisture	Global
L3_SM_P	SPL3SMP	Daily global composite radiometer soil moisture	Global
L3_SM_AP	SPL3SMAP	Daily global composite radar-radiometer soil moisture	Global
L4_SM	SPL4TSM	Surface and root-zone soil moisture	Global
L4_C	SPL4C	Carbon net ecosystem exchange	North of 45°N

1.5 L3_SM_A Overview

The SMAP L3_SM_A product is a daily global composite of the SMAP L2_SM_A product, which represents gridded data of SMAP radar-based soil moisture retrieval, ancillary data, and quality-assessment flags on the global 3-km EASE2 Grid designed by NSIDC for SMAP. To generate the standard L3_SM_A product the processing software ingests one day's worth of L2_SM_A granules and create individual global composites as two-dimensional arrays for each output parameter defined in the L2_SM_A product. Wherever data overlap occurs (typically at high latitudes), data whose acquisition time is closest to the 6:00 am local solar time is chosen.

Because the input L2_SM_A granules are available only for descending (6:00 am) passes, the resulting L3_SM_A granules are also available only for descending (6:00 am) passes.

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. Appendix C lists all of the valid shapes that appear in this data product.
Valid_max	The expected minimum value for a data element. In most instances, data element values never fall below this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that fall below this limit.
Valid_min	The expected maximum value for a data element. In most instances, data element values never exceed this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that exceed this limit.
Valid Values	Some data elements may store a restricted set of values. In those instances, this listing specifies the values that the data element may store.
Nominal Value	Some data elements have an expected value. In those instances, this listing provides that expected value. Nominal values are particularly common among a subset of the metadata elements.
String Length	This characteristic specifies the length of the data string that represents a single instance of the data element. This characteristic appears exclusively for data elements of FixLenStr type.
Units	Units of measure. Typical values include “deg”, “degC”, “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 L3_SM_A Product when the Level 3_SM_A SPS can process some, but not all, of the input data for a particular swath grid cell. Fill data may appear in the product in any of the following circumstances:

- One of Science Production Software (SPS) executables that generate the SMAP L3_SM_A Product is unable to calculate a particular science or engineering data value. The algorithm encounters an error. The error disables generation of valid output. The SPS reports a fill value instead.
- Some of the required science or engineering algorithmic input are missing. Data over the region that contributes to particular grid cell may appear in only some of the input data streams. Since data are valuable, the L3_SM_A Product records any outcome that can be calculated with the available input. Missing data appear as fill values.
- Non-essential information is missing from the input data stream. The lack of non-essential information does not impair the algorithm from generating needed output. The missing data appear as fill values.

- Fill values appear in the input radiometer L1B_TB product. If only some of the input that contributes to a particular grid cell is fill data, the Level L3_SM_A SPS will most likely be able to generate some output. However, some portion of the L3_SM_A 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	-9999.00	Large, negative number
Signed8, NormSigned8	-127	Type minimum + 1
Signed16, NormSigned16	-9999	Type minimum + 1
Signed24	-8388607	Type minimum + 1
Signed32	-9999	Type minimum + 1
Signed64	-9999	Type minimum + 1
Unsigned8	254	Type maximum - 1
Unsigned16	65534	Type maximum - 1
Unsigned24	16777214	Type maximum - 1
Unsigned32	4294967294	Type maximum - 1
Unsigned64	18446744073709551614	Type maximum - 1
FixedLenString, VarLenString	NA	Not available

No valid value in the L3_SM_A product is equal to the values that represent fill. If any exceptions should exist in the future, the L3_SM_A content will provide a means for users to discern between elements that contain fill and elements that contain genuine data values. This document will also contain a description of the method used to ascertain which elements are fill and which elements are genuine.

The L3_SM_A 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 3_SM_A 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.

3 EASE2 Grid

The data in the SMAP L3_SM_A product are presented on a 3-km global projection. The projection is based on NSIDC's EASE2 Grid specifications for SMAP. The EASE2 Grid has a flexible formulation. By adjusting one scaling parameter it is possible to generate a family of multi-resolution grids that "nest" within one another. The nesting can be made "perfect" in that smaller grid cells can be tessellated to form larger grid cells, as shown in Fig. 2.

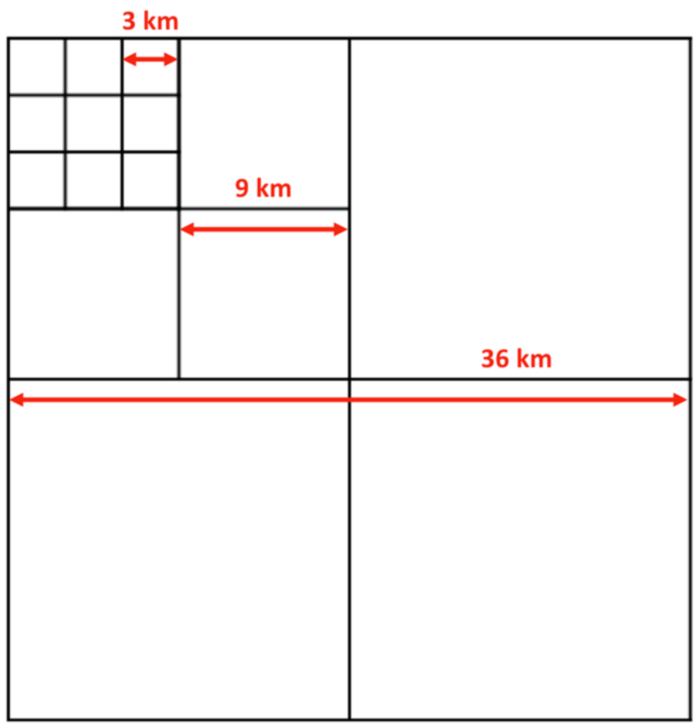

Figure 2: Perfect nesting in EASE2 Grid – smaller grid cells can be tessellated to form larger grid cells.

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

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

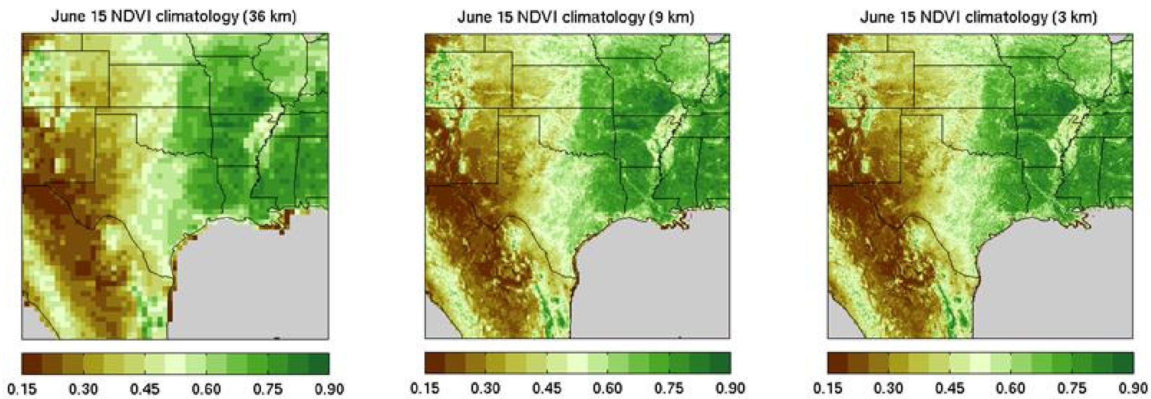

Figure 3: Example of ancillary NDVI climatology data displayed on the SMAP 36-km, 9-km, and 3-km grids.

For brevity, the 3-km global EASE2-Grid projection is denoted by 'M03' thereafter in this document. The projection is shown in Fig. 4 below. Each grid cell has a nominal area of about 3 × 3 km^2, regardless of longitudes and latitudes. Under this projection, all global data arrays have dimensions of 4872 rows and 11568 columns.

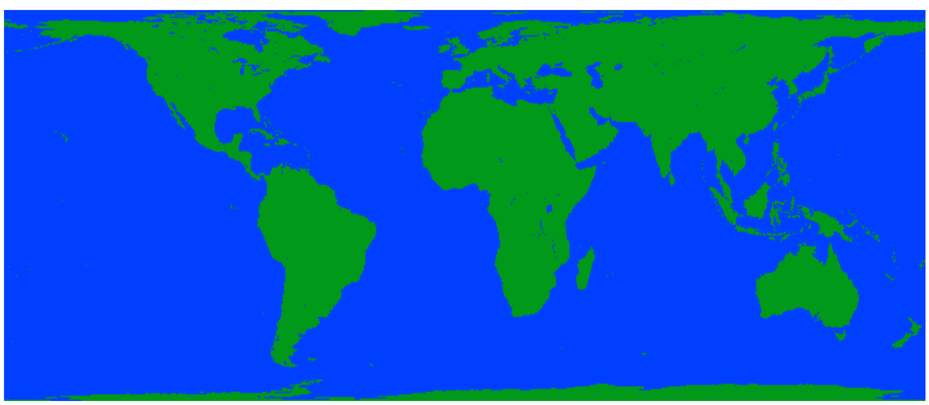

Figure 4: Global EASE2 Grid
(Figure credited to NSIDC)

4 PRODUCT DEFINITION

4.1 Overview

The SMAP L3_SM_A product is a daily global composite of the SMAP L2_SM_A product, which represents gridded data of SMAP radiometer-based soil moisture retrieval, ancillary data, and quality-assessment flags on the global 3-km EASE2 Grid designed by NSIDC for SMAP. To generate the standard L3_SM_A product the processing software ingests one day's worth of L2_SM_A granules and create individual global composites as two-dimensional arrays for each output parameter defined in the L2_SM_A product. Wherever data overlap occurs (typically at high latitudes), data whose acquisition time is closest to the 6:00 am local solar time is chosen.

Because the input L2_SM_A granules are available only for descending (6:00 am) passes, the resulting L3_SM_A granules are also available only for descending (6:00 am) passes.

4.2 Product Names

L3_SM_A data product file names conform to the following convention:

SMAP_L3_SM_A_[Orbit Number]_[A|D]_[First Date/Time Stamp]_[Composite Release ID]_[Product Counter].[extension]

Example: SMAP_L3_SM_A_00934_D_20141225T000000_ R00400_002.h5

Orbit Number	A five-digit sequential number of the orbit flown by the SMAP spacecraft when the data was acquired. Orbit 0 begins at launch.
Half Orbit Designator	'D' for 6:00 am descending pass.
First Date/Time Stamp	Date/time stamp in Universal Coordinated Time (UTC) of the first data element that appears in the product. The stamp conforms to the *YYYYMMDD**T**hhmmss* convention.
Composite Release ID	An ID that incorporates changes to any processing condition that might impact product results. The Composite Release ID contains three other shorter ID's: [R][Launch Indicator][Major ID][Minor ID]. The Launch Indicator distinguishes between pre-launch or pre-instrument commissioned data. ('0' for simulated or preliminary observations whereas '1' for observations at or after the time of instrument commissioning) A two-digit Major ID indicates major releases due to changes in algorithm or processing approach. A 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: 1.4 GBytes

Yearly volume: 512 GBytes

4.4 L3_SM_A Product Metadata

As mentioned in section 4.1.2, the metadata elements in the Level 3 SM_A product appear in two forms. One form appears in one or more Attributes within the Metadata Group. Combined, those Attributes contain a complete representation of the product metadata. The content conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

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

Table 8 describes the subgroups of the Metadata group, and the attributes within each group. The first column of table 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 carats <>. All of the metadata elements that appear in table 9 should also appear in every Level 3_SM_A Product file.

Table 8: Granule Level Metadata in the L3_SM_A Product

Representative ISO Class	SMAP HDF5 Metadata Subgroup	SMAP HDF5 Sub-path	SMAP HDF5 Attribute	Definition
			antennaRotationRate	<The antenna rotation rate in revolution per minute (rpm)>
			description	The SMAP observatory houses an L-band radiometer that operates at 1.40 GHz and an L-band radar that operates at 1.26 GHz. The instruments share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath. The bus is a 3 axis stabilized spacecraft that provides momentum compensation for the rotating antenna.
			identifier	SMAP
		platform		
			description	The SMAP radar instrument employs an L-band conically scanned system and SAR processing techniques to achieve moderate resolution (1 km) backscatter measurements over a very wide 1000 km swath.
			identifier	SMAP SAR
			type	L-band Synthetic Aperture Radar
		radar, radiometer		
			edition	<The edition of publication of the reference document, if available to the general public.>
			publicationDate	<The date of publication of the reference document, if available to the general public.>
			title	<The title of the publication of the reference document, if available to the general public.>
MD_AcquisitionInformation	AcquisitionInformation	platformDocument, radarDocument, radiometerDocument		
			evaluationMethodType	<The type of data quality evaluation method. "directInternal" means the method of evaluating the quality of a dataset based on inspection of items within the dataset, where all data required is internal to the dataset being evaluated.>
			measureDescription	<The description of the Domain Consistency measurement.>
			nameOfMeasure	<The name of the measurements>
			unitOfMeasure	Percent
			value	<A measure between 0 and 100>
		DomainConsistency		
			evaluationMethodType	<The type of data quality evaluation method. "directInternal" means the method of evaluating the quality of a dataset based on inspection of items within the dataset, where all data required is internal to the dataset being evaluated.>
			measureDescription	<The description of the Completeness Omission measurement.>
DQ_DataQuality	DataQuality	CompletenessOmission	nameOfMeasure	Percent of Missing Data

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

				measure between -90 degrees and 90 degrees)>
			westBoundLongitude	<The most western boundary of the spatial extent the data product covers (Longitude measure between -180 degrees and 180 degrees)>
MD_GridSpatialRepresentation	GridSpatialRepresentation	GridDefinitionDocument	edition	<The version of the grid definition document>
			publicationDate	<The publication date of the grid definition document>
			title	<The title of the grid definition document>
		Column, Row	dimensionSize	<The size of the dimension of the arrays in this specific projection are organized in this data product file>
			resolution	<The spatial resolution each data point represents, in kilometer>
		GridDefinition	description	<The description of the grid definition applied for the data product generation>
			identifier	<The short name identifying the grid definition of this data product>
			cellGeometry	<Indication of grid data as point or area>
			controlPointAvailability	<Indication of whether or not control points are available (0 implies not available and 1 implies available)>
			georeferencedParameters	<The parameters used for the conversion of the geographic location information to the map projection of interest>
			numberOfDimensions	<The number of dimensions of the arrays in this specific projection are organized in this data product file>
			orientationParameterAvailability	<Indication of whether or not orientation parameters are available (0 implies not available and 1 implies available)>
			transformationParameterAvailability	<The indication of whether the parameters for transformation exists or not (0 implies not available and 1 implies available)>
LI_Lineage/LE_Source	Lineage	EASEGRID_LON_M, InputConfiguration, MetadataConfiguration, OutputConfiguration, RunConfiguration	creationDate	<Date when the corresponding ancillary input file was created>
			description	<Description of each ancillary input file used to generate this data product.>
			fileName	<The name of the ancillary input file.>
			version	<The version number of the ancillary input file.>
		L2_SM_A	DOI	<A digital object identifier associated with the input product. This field appears only for the Lineage class that describes the SMAP science data product.>
			creationDate	<Date when the corresponding input product file was created>
			description	<Description of each of the input files used to generate this data product.>

			fileName	<The name of the corresponding input product file.>
			identifier	<The short name associated with the input SMAP science data product.>
			resolution	<The spatial resolution each data point represents, in kilometer>
			version	<The SMAP Composite Version ID associated with the input data product.>
			startRevNumber	<The lowest orbit number among the input product granules>
SD_OrbitMeasuredLocation	OrbitMeasuredLocation		stopRevNumber	<The highest orbit number among the input product granules>
			ATBDDate	<Time stamp that specifies the release date of the ATBD>
			ATBDTitle	<The title of the ATBD>
			ATBDVersion	<Version identifier for the ATBD.>
			SWVersionID	<A software version identifier that runs from 001 to 999>
			algorithmDate	<Date associated with current version of the algorithm.>
			algorithmDescription	<Descriptive text about the algorithm(s) in the product generation software for this data product.>
			algorithmTitle	<The representative name of the algorithm for this data product.>
			algorithmVersionID	<Identifier that specifies the current algorithm version. Value runs from 001 to 999>
			documentDate	<Release date for the software description document.>
			documentVersion	<Version identifier for the software description document.>
			documentation	<A reference to software description document.>
			epochJulianDate	<Julian Date of the Epoch J2000, 2451545>
			epochUTCDateTime	<UTC Date Time of the Epoch J2000, 2000-01-01T11:58:55.816Z>
			identifier	<Name of the product generation software for this data product>
			parameterVersionID	<Identifier that specifies the current version of processing parameters. Value runs from 001 to 999.>
			processDescription	<Short description of the data processing concept by the product generation software.>
			processor	<Name of the product generation facility>
			softwareDate	<A date stamp that specifies when software used to generate this product was released.>
			softwareTitle	<The title of the product generation facility>
			stepDateTime	< A character string that specifies the date and the time when the product was generated.>
LI_Lineage/LE_ProcessStep	ProcessStep		timeVariableEpoch	<The Epoch of the time variable for the SMAP mission>

			SMAPShortName	<The SMAP Mission product short name of this data product.>
			characterSet	utf8
			edition	<Edition identifier for the Product Specification Document>
			language	eng
			publicationDate	<Date of publication of the Product Specification Document>
DS_Series/MD_DataIdentification	ProductSpecificationDocument		title	<The title of the product specification document>
			MissingSamples	<The number of samples missing in this data products>
			OutOfBoundsSamples	<The number of samples that are exceeding the predefined boundary>
			QAPercentOutOfBoundsData	<Percent of the samples that are exceeding the predefined boundary with respect tot the total samples in this data product>
DQ_DataQuality	QA		TotalSamples	<The number of all samples in this data product>
			abstract	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
			creationDate	<The date that the QA product was generated.>
DS_Dataset/MD_DataIdentification	QADatasetIdentification		fileName	<The name of QA product.>
			CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product>
			ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999>
			abstract	<A short description of this data product series.>
			characterSet	utf8
			credit	<Identify the institutional authorship of the product generation software and the data system that automates its production.>
			format	HDF5
			formatVersion	<The version of the HDF5 library used for the product generation>
			identifier_product_DOI	<digital object identifier for the Level 1C S0 HiRes Product>
			language	eng
			longName	<The long name of this data product (up to 80 characters long)>
			maintenanceAndUpdateFrequency	asNeeded
			maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
			mission	Soil Moisture Active Passive (SMAP)
DS_Series/MD_DataIdentification	SeriesIdentification		otherCitationDetails	<The description of the state of the product generation software for this data product

				file.>
			pointOfContact	<The name of the DAAC this data product is distributed from.>
			purpose	<The description of the purpose of this data product file.>
			resourceProviderOrganizationName	National Aeronautics and Space Administration
			revisionDate	<Date and time of the software release that was used to generate this data product.>
			shortName	<The ECS short name of this data product in 8 characters.>
			spatialRepresentationType	grid
			status	onGoing
			topicCategory	geoscientificInformation

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

4.5 Data Structure

The SMAP L3_SM_A product is a daily global composite of the SMAP L2_SM_A product, which represents gridded data of SMAP radar-based soil moisture retrieval, ancillary data, and quality-assessment flags on the global 3-km EASE2 Grid. This organization is reflected schematically in Fig. 5:

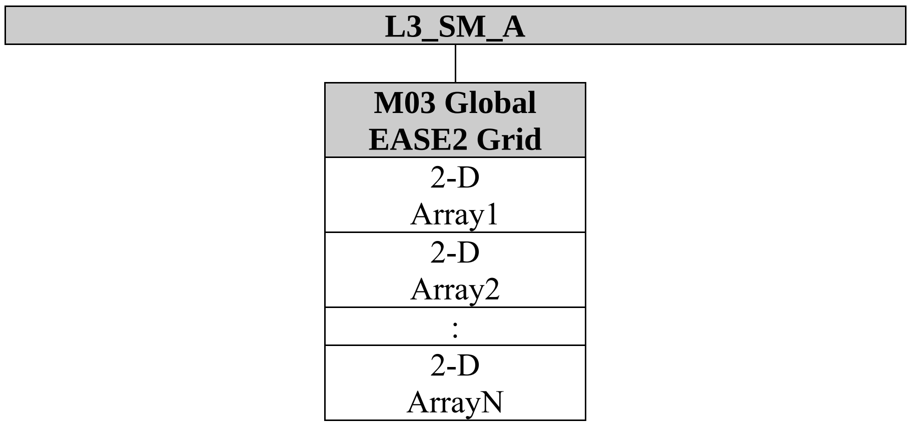

Figure 5: L3_SM_A data organization.

Table 9 describes the output parameters of a typical L3_SM_A granule based on its associated descending L2_SM_A half-orbit granules acquired within a day.

Table 9. L3_SM_A Product Structure

Soil Moisture Retrieval Data Group

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
sigma0_qual_flag_hh	LatCell_LonCell_Array	bit flag	4	NA	NA	NA	Representative quality flags of horizontal polarization sigma0 measures in the grid cell
sigma0_qual_flag_vv	LatCell_LonCell_Array	bit flag	4	NA	NA	NA	Representative quality flags of vertical polarization sigma0 measures in the grid cell
sigma0_qual_flag_xpol	LatCell_LonCell_Array	bit flag	4	NA	NA	NA	Representative quality flags of cross polarization sigma0 measures in the grid cell
retrieval_qual_flag	LatCell_LonCell_Array	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the soil moisture and the freeze-thaw retrieval for the grid cell.
retrieval_qual_flag_kvz	LatCell_LonCell_Array	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the soil moisture and the freeze-thaw retrieval for the grid cell.
retrieval_qual_flag_wagner	LatCell_LonCell_Array	bit flag	2	NA	NA	NA	Bit flags that record the conditions and the quality of the soil moisture and the freeze-thaw retrieval for the grid cell.
surface_flag	LatCell_LonCell_Array	bit flag	2	NA	NA	NA	Bit flags that record ambient surface conditions for the grid cell
EASE_row_index	LatCell_LonCell_Array	integer	2	count	0	65535	The row index of the 3 km EASE grid cell that contains the associated data.
EASE_column_index	LatCell_LonCell_Array	integer	2	count	0	65535	The column index of the 3 km EASE grid cell that contains the associated data.
num_input_sigma0s_hh	LatCell_LonCell_Array	integer	2	count	0	100	Total number of horizontal polarization sigma0s from the Level 1C product that were used for retrievals in an EASE grid cell.
num_input_sigma0s_vv	LatCell_LonCell_Array	integer	2	count	0	100	Total number of vertical polarization sigma0s from the Level 1C product that

							were used for retrievals in an EASE grid cell.
num_input_sigma0s_xpol	LatCell_LonCell_Array	integer	2	count	0	100	Total number of cross polarized sigma0s from the Level 1C product that were used for retrievals in an EASE grid cell.
num_time_series	LatCell_LonCell_Array	integer	1	count	0	255	The number of time-series data used to retrieve soil moisture in the corresponding grid cell.
latitude	LatCell_LonCell_Array	real	4	degrees _north	-90.0	90.0	Average in latitude of the 1km Level 1 cells that contribute to 3km EASE grid cell. (temporary)
longitude	LatCell_LonCell_Array	real	4	degrees _east	-180.0	180.0	Average in longitude of the 1km Level 1 cells that contribute to the 3km EASE grid cell. (temporary)
distance_from_nadir	LatCell_LonCell_Array	real	4	meters	0.0	500000.0	The distance from the center of the 3 km EASE grid cell to the spacecraft's sub-nadir track on the Earth's surface.
spacecraft_overpass_time_seconds	LatCell_LonCell_Array	real	8	seconds	-999999.9	999999.9	Number of seconds since midnight on 1/1/93 that represents the spacecraft overpass relative to ground swath.
soil_moisture_snapshot	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Representative soil moisture measurement for the Earth based grid cell, retrieved using the snapshot algorithm
soil_moisture_snapshot_DVZ	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Retrieved soil moisture for the Earth based grid cell, retrieved using the Dubois/van Zyl snapshot algorithm (this field is not evaluated)
soil_moisture_snapshot_shi	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Retrieved soil moisture for the Earth based grid cell, retrieved using the Shi snapshot algorithm (this field is not evaluated)
soil_moisture_time_series (same as soil_moisture)	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Retrieved soil moisture for the Earth based grid cell retrieved using the time series algorithm (this field is the baseline)

soil_moisture_kvz	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Representative soil moisture measurement for the Earth based grid cell retrieved using the Kim/van Zyl time series algorithm
soil_moisture_wagner	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.02	0.5	Retrieved normalized change in soil moisture.
soil_moisture_error	LatCell_LonCell_Array	real	4	cm**3/ cm**3	0.0	0.2	Net uncertainty measure of soil moisture measure for the Earth based grid cell. - Calculation method is TBD. May be replaced by other quality indicators.
radar_vegetation_index	LatCell_LonCell_Array	real	4	normalized	-999999.9	999999.9	Vegetation index derived from radar backscatter
bare_soil_roughness_retrieved	LatCell_LonCell_Array	real	4	meters	0.0	0.05	Bare soil roughness measure retrieved using the active soil moisture algorithm.
spacecraft_overpass_time_utc	LatCell_LonCell_Array	string	24	NA	NA	NA	Time of spacecraft overpass relative to ground swath in UTC.

Radar Data Group
(the units the values of sigma0 and Kp are natural unit).

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
cell_radar_mode_flag	LatCell_LonCell_Array	bit flag	2	NA	NA	NA	Bit flags that specify modes or conditions of radar instrument operation that impact the data represented in the Level 2 SM A Product.
earth_boresight_azimuth_fore	LatCell_LonCell_Array	real	4	degrees	0.0	360.0	Fore-looking azimuth of the antenna boresight vector on the Earth's surface relative to North within 3 km cell. - Level 1C azimuth is based on instrument coordinate system, not geographical North
earth_boresight_azimuth_aft	LatCell_LonCell_Array	real	4	degrees	0.0	360.0	Aft-looking azimuth of the antenna boresight vector on the Earth's surface relative to North within 3 km cell. - Level 1C azimuth is based on instrument coordinate system, not geographical North
altitude_std_dev	LatCell_LonCell_Array	real	4	meters	0.0	1000.0	The standard deviation of the Earth surface elevation within the 3km cell
sigma0_hh_mean	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_mean	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_mean	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
sigma0_hh_std_dev	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_std_dev	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_std_dev	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
kp_hh	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for HH-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_vv	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for HH-pol Sigma0 within

							the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_xpol	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for HH-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
sigma0_hh_mean_fore	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of forward looking 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_mean_fore	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of forward looking 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_mean_fore	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of forward looking 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
sigma0_hh_std_dev_fore	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of forward looking 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_std_dev_fore	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of forward looking 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_std_dev_fore	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of forward looking 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
kp_hh_fore	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for forward looking HH-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_vv_fore	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for forward looking VV-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_xpol_fore	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for forward looking cross-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

sigma0_hh_mean_aft	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of aft looking 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_mean_aft	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of aft looking 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_mean_aft	LatCell_LonCell_Array	real	4	normalized	-0.01	10.0	Mean of aft looking 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
sigma0_hh_std_dev_aft	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of aft looking 1 km instrument resolution HH-pol Sigma0 in the 3 km Earth grid cell.
sigma0_vv_std_dev_aft	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of aft looking 1 km instrument resolution VV-pol Sigma0 in the 3 km Earth grid cell.
sigma0_xpol_std_dev_aft	LatCell_LonCell_Array	real	4	normalized	0.0	5.0	Standard deviation of aft looking 1 km instrument resolution cross-pol Sigma0 in the 3 km Earth grid cell.
kp_hh_aft	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for aft looking HH-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_vv_aft	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for aft looking VV-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
kp_xpol_aft	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	Overall error measure for aft looking cross-pol Sigma0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Ancillary Data Group

Element	Shape	Concept	Bytes	Unit	Min	Max	Comment
landcover_class	LatCell_LonCell_Array	enum	1	NA	NA	NA	An enumerated type that specifies the predominant surface vegetation found in the grid cell.
surface_temperature	LatCell_LonCell_Array	real	4	degrees Celsius	-50.0	60.0	Temperature at land surface based on ECMWF or NCEP.
normalized_difference_vegetation_index	LatCell_LonCell_Array	real	4	normalized	-1.0	10.0	Normalized difference vegetation index. A measure of the green character of vegetation. (IR-Red)/(IR+Red)
vegetation_water_content_NDVI	LatCell_LonCell_Array	real	4	kg/m**3	0.0	10.0	Representative measure of water in the vegetation within the 3 km grid cell based on the normalized difference vegetation index.
vegetation_water_content_RVI	LatCell_LonCell_Array	real	4	kg/m**3	0.0	10.0	Representative measure of water in the vegetation within the 3 km grid cell based on the radar vegetation index.
bare_soil_roughness_tabular	LatCell_LonCell_Array	real	4	meters	0.0	0.1	Measure of soil roughness from tabular source.
faraday_rotation_angle	LatCell_LonCell_Array	real	4	degrees	-999999.9	999999.9	Faraday rotation angle
static_water_body_fraction	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	The fraction of the area of the 3 km grid cell that is covered by static water based on a Digital Elevation Map.

4.6 Parameter Definitions

4.6.1 altitude_std_dev

The standard deviation of the Earth surface elevation within the 3km cell.

Precision: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 1000.0
Units: meters

4.6.2 bare_soil_roughness_retrieved

Bare soil roughness measure retrieved using the active soil moisture algorithm.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: ‘0’
Valid_max: ‘0.05’
Units: meter

4.6.3 bare_soil_roughness_tabular

Measure of soil roughness from tabular source.

Type: Float32
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 0.05
Units: meters

4.6.4 boresight_incidence_std_dev

Standard deviation of the angle between the antenna boresight vector and the normal to the Earth's surface based on the selected DEM.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 360.0
Units: degrees

4.6.5 **cell_radar_mode_flag**

Bit flags that specify modes or conditions of radar instrument operation that impact the data represented in the Level 2 SM A Product.

Type: uint16 (bit flag)
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Units: n/a

Bit Position	Bit Value and Interpretation
0	0 = Radar is operating in transmit-receive mode
	1 = Radar is operating in receive only mode
1	Always clear (This bit is used to designate the nadir region in Level 1. It's redundant in Level 2.)
2	0 = Cross polarized data are v-pol transmitted, h-pol received.
	1 = Cross polarized data are h-pol transmitted, v-pol received.
3-15	Always clear (Bits 5 through 7 are reserved for Radar Level 1C use. Bits 8 through 15 are reserved for Level 2 use.)

4.6.6 **distance_from_nadir**

The distance from the center of the 3 km EASE grid cell to the spacecraft's sub-nadir track on the Earth's surface.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 300.0
Units: km

4.6.7 **earth_boresight_azimuth_mean**

Mean direction of the projection of the antenna boresight vector on the Earth's surface relative to North within 3 km cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 360.0
Units: degrees

4.6.8 **EASE_column_index**

EASE grid column index of cell on world grid in longitude direction.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 11568
Units: dimensionless

4.6.9 EASE_row_index

EASE grid row index of cell on world grid in latitude direction.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 4872
Units: dimensionless

4.6.10 faraday_rotation_angle

Faraday rotation angle.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 360.0
Units: degrees

4.6.11 freeze_thaw

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

Type: boolean uint8
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 1
Units: n/a

4.6.12 kp_hh

Overall error measure for HH-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.13 **kp_hh_aft**

Overall error measure for aft-looking HH-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.14 **kp_hh_fore**

Overall error measure for fore-looking HH-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.15 **kp_vv**

Overall error measure for VV-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.
Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.16 **kp_vv_aft**

Overall error measure for aft-looking VV-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32

Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.17 **kp_vv_fore**
Overall error measure for fore-looking VV-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.18 **kp_xpol**
Overall error measure for cross-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.19 **kp_xpol_aft**
Overall error measure for aft-looking cross-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.20 **kp_xpol_fore**
Overall error measure for fore-looking cross-pol σ0 within the 3 km cell based on Level 1C kp values, includes calibration, RFI and contamination effects.

Type: Float32

Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 4
Units: natural unit

4.6.21 **landcover_class**

An enumerated type that specifies the predominant surface vegetation found in the grid cell.

Type: enum uint16
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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	Mixed forest
12	Closed shrubland
13	Open shrubland
14	Woody savanna
15	Savanna
16	Grassland
>16	TBD

4.6.22 **latitude**

Average in latitude of the 1km Level 1 cells that contribute to 3km EASE grid cell. (temporary)

Type: Float32

Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: -90.0
Valid_max: 90.0
Units: degrees

4.6.23 **longitude**

Average in longitude of the 1km Level 1 cells that contribute to the 3km EASE grid cell. (temporary)

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: -180.0
Valid_max: 180.0
Units: degrees

4.6.24 **normalized_difference_vegetation_index**

Normalized difference vegetation index. A measure of the green character of vegetation. (IR-Red)/(IR+Red)

Type: Float32
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
Units: n/a

4.6.25 **num_input_sigma0s_hh**

Total number of horizontal polarization sigma0s from the Level 1C product that were used for retrievals in an EASE grid cell.

Type: uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 100
Units: n/a

4.6.26 **num_input_sigma0s_vv**

Total number of vertical polarization sigma0s from the Level 1C product that were used for retrievals in an EASE grid cell.

Type: uint16
Group: Soil Moisture Retrieval Data

Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 100
Units: n/a

4.6.27 **num_input_sigma0s_xpol**

Total number of cross-polarization sigma0s from the Level 1C product that were used for retrievals in an EASE grid cell.

Type: uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 100
Units: n/a

4.6.28 **num_time_series**

The number of time-series data used to retrieve soil moisture in the corresponding grid cell.

Type: uint8
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 6
Units: n/a

4.6.29 **radar_vegetation_index**

Vegetation index derived from radar backscatter

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 2
Units: n/a

4.6.30 **retrieval_qual_flag**

Bit flags that record the conditions and the quality of the soil moisture and freeze-thaw retrieval for the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data

Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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 succesfully
		on	Unable to ascertain freeze-thaw conditons
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful

4.6.31 retrieval_qual_flag_cube

Bit flags that record the conditions and the quality of the soil moisture and freeze-thaw retrieval for the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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 succesfully
		on	Unable to ascertain freeze-thaw conditons
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful

4.6.32 **retrieval_qual_flag_kvz**

Bit flags that record the conditions and the quality of the soil moisture and freeze-thaw retrieval for the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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 succesfully

		on	Unable to ascertain freeze-thaw conditons
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful

4.6.33 **retrieval_qual_flag_wagner**

Bit flags that record the conditions and the quality of the soil moisture and freeze-thaw retrieval for the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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 succesfully
		on	Unable to ascertain freeze-thaw conditons
Radar vegetation index retrieval success flag	5	off	Radar vegetation index retrieval ran successfully
		on	Radar vegetation index retrieval unsuccessful

4.6.34 **sigma0_hh_mean**

Mean of 1 km instrument resolution HH-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data

Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.35 **sigma0_hh_mean_aft**

Mean of 1 km instrument resolution aft-looking HH-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.36 **sigma0_hh_mean_fore**

Mean of 1 km instrument resolution fore-looking HH-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.37 **sigma0_hh_std_dev**

Standard deviation of 1 km instrument resolution HH-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.38 **sigma0_hh_std_dev_aft**

Standard deviation of 1 km instrument resolution aft-looking HH-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.39 **sigma0_hh_std_dev_fore**

Standard deviation of 1 km instrument resolution fore-looking HH-pol σ0 in the 3 km Earth grid cell.

Type:	Float32
Group:	Radar Uncertainty Data
Shape:	LatCell_LonCell_Array
Valid_min:	0
Valid_max:	10
Units:	natural unit

4.6.40 **sigma0_xpol_mean**

Mean of 1 km instrument resolution cross-pol σ0 in the 3 km Earth grid cell.

Type:	Float32
Group:	Radar Uncertainty Data
Shape:	LatCell_LonCell_Array
Valid_min:	0
Valid_max:	10
Units:	natural unit

4.6.41 **sigma0_xpol_mean_aft**

Mean of 1 km instrument resolution aft-looking cross-pol σ0 in the 3 km Earth grid cell.

Type:	Float32
Group:	Radar Uncertainty Data
Shape:	LatCell_LonCell_Array
Valid_min:	0
Valid_max:	10
Units:	natural unit

4.6.42 **sigma0_xpol_mean_fore**

Mean of 1 km instrument resolution fore-looking cross-pol σ0 in the 3 km Earth grid cell.

Type:	Float32
Group:	Radar Uncertainty Data
Shape:	LatCell_LonCell_Array
Valid_min:	0
Valid_max:	10
Units:	natural unit

4.6.43 **sigma0_xpol_std_dev**

Standard deviation of 1 km instrument resolution cross-pol σ0 in the 3 km Earth grid cell.

Type:	Float32

Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.44 sigma0_xpol_std_dev_aft

Standard deviation of 1 km instrument resolution aft-looking cross-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.45 sigma0_xpol_std_dev_fore

Standard deviation of 1 km instrument resolution fore-looking cross-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.46 sigma0_qual_flag_hh

Representative quality flags of horizontal polarization sigma0 measures in the grid cell

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Mean horizontal polarization quality flag	0	off	The mean of the forward looking and aft looking horizontal polarization sigma0s has acceptable quality.
		on	The mean of the forward looking and aft looking horizontal polarization sigma0s does not have acceptable quality.
Forward looking horizontal polarization	1	off	The forward looking horizontal polarization sigma0 has acceptable quality.

quality flag			
		on	The forward looking horizontal polarization sigma0 has questionable or poor quality.
Aft looking horizontal polarization quality flag	2	off	The aft looking horizontal polarization sigma0 has acceptable quality.
		on	The aft looking horizontal polarization sigma0 has questionable or poor quality.
Mean horizontal polarization range flag	3	off	The mean of the forward looking and aft looking horizontal polarization sigma0s falls within the expected range.
		on	The mean of the forward looking and aft looking horizontal polarization sigma0s is out of range.
Forward looking horizontal polarization range flag	4	off	The forward looking horizontal polarization sigma0 falls within the expected range.
		on	The forward looking horizontal polarization sigma0 is out of range
Aft looking horizontal polarization range flag	5	off	The aft looking horizontal polarization sigma0 falls within the expected range.
		on	The aft looking horizontal polarization sigma0 is out of range.
Mean horizontal polarization RFI clean flag	6	off	Insignificant RFI detected in the mean of the forward looking and aft looking horizontal polarization sigma0s.
		on	RFI level is unsuitably high for the mean of the forward looking and aft looking horizontal polarization sigma0s.
Mean horizontal polarization RFI repair flag	7	off	Some components of the mean of the forward looking and aft looking horizontal polarization sigma0s are based on repairs for RFI contamination.
		on	Unable to repair the mean of the forward looking and aft looking horizontal polarization sigma0s for RFI contamination.
Forward looking horizontal polarization RFI clean flag	8	off	Insignificant RFI detected in the forward looking horizontal polarization sigma0s.
		on	RFI level is unsuitably high for the forward looking horizontal polarization sigma0s.
Forward looking horizontal polarization RFI repair flag	9	off	At least one of the input forward looking horizontal polarization sigma0s is based on repairs for RFI contamination.
		on	Unable to repair the forward looking horizontal polarization sigma0s for RFI contamination.
Aft looking horizontal polarization RFI clean flag	10	off	Insignificant RFI detected in the aft looking horizontal polarization sigma0s.
		on	RFI level is unsuitably high for the aft looking horizontal polarization sigma0s.
Aft looking horizontal polarization RFI repair flag	11	off	At least one of the input aft looking horizontal polarization sigma0s is based on repairs for RFI contamination.
		on	Unable to repair the aft looking horizontal polarization sigma0s for RFI contamination.
Mean horizontal	12	off	Faraday Rotation has little or no impact on the mean

polarization Faraday Rotation Flag			of the forward looking and aft looking horizontal polarization sigma0s.
		on	Faraday Rotation has significant impact on the mean of the forward looking and aft looking horizontal polarization sigma0s.
Forward looking horizontal polarization Faraday Rotation Flag	13	off	Faraday Rotation has little or no impact on the forward looking horizontal polarization sigma0.
		on	Faraday Rotation has significant impact on the forward looking horizontal polarization sigma0.
Aft looking horizontal polarization Faraday Rotation Flag	14	off	Faraday Rotation has little or no impact on the aft looking horizontal polarization sigma0.
		on	Faraday Rotation has significant impact on the aft looking horizontal polarization sigma0.
Mean horizontal polarization Kp flag	15	off	Kp for the mean of the forward and aft looking horizontal polarization sigma0s is acceptably low.
		on	Kp for the mean of forward and aft looking horizontal polarization sigma0s is unacceptably high.
Forward looking horizontal polarization Kp flag	16	off	Kp for the forward looking horizontal polarization sigma0 is acceptably low.
		on	Kp for the forward looking horizontal polarization sigma0 is unacceptably high.
Aft looking horizontal polarization Kp flag	17	off	Kp for the aft looking horizontal polarization sigma0 is acceptably low.
		on	Kp for the aft looking horizontal polarization sigma0 is unacceptably high.
Mean horizontal null value flag	18	off	sigma0 value is valid.
		on	There is no valid sigma0.
Forward looking horizontal null value flag	19	off	forward looking sigma0 value is valid.
		on	There is no valid forward looking sigma0.
Aft looking horizontal polarization null value flag	20	off	aft looking sigma0 value is valid.
		on	There is no valid aft looking sigma0.

4.6.47 **sigma0_qual_flag_xpol**

Representative quality flags of cross polarization sigma0 measures in the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation

Mean cross polarized quality flag	0	off	The mean of the forward looking and aft looking cross polarized sigma0s has acceptable quality.
		on	The mean of the forward looking and aft looking cross polarized sigma0s does not have acceptable quality.
Forward looking cross polarized quality flag	1	off	The forward looking cross polarized sigma0 has acceptable quality.
		on	The forward looking cross polarized sigma0 has questionable or poor quality.
Aft looking cross polarized quality flag	2	off	The aft looking cross polarized sigma0 has acceptable quality.
		on	The aft looking cross polarized sigma0 has questionable or poor quality.
Mean cross polarized range flag	3	off	The mean of the forward looking and aft looking cross polarized sigma0s falls within the expected range.
		on	The mean of the forward looking and aft looking cross polarized sigma0s is out of range.
Forward looking cross polarized range flag	4	off	The forward looking cross polarized sigma0 falls within the expected range.
		on	The forward looking cross polarized sigma0 is out of range
Aft looking cross polarized range flag	5	off	The aft looking cross polarized sigma0 falls within the expected range.
		on	The aft looking cross polarized sigma0 is out of range.
Mean cross polarized RFI clean flag	6	off	Insignificant RFI detected in the mean of the forward looking and aft looking cross polarized sigma0s.
		on	RFI level is unsuitably high for the mean of the forward looking and aft looking cross polarized sigma0s.
Mean cross polarized RFI repair flag	7	off	Some components of the mean of the forward looking and aft looking cross polarized sigma0s are based on repairs for RFI contamination.
		on	Unable to repair the mean of the forward looking and aft looking cross polarized sigma0s for RFI contamination.
Forward looking cross polarized RFI clean flag	8	off	Insignificant RFI detected in the forward looking cross polarized sigma0s.
		on	RFI level is unsuitably high for the forward looking cross polarized sigma0s.
Forward looking cross polarized RFI repair flag	9	off	At least one of the input forward looking cross polarized sigma0s is based on repairs for RFI contamination.
		on	Unable to repair the forward looking cross polarized sigma0s for RFI contamination.
Aft looking cross polarized RFI clean flag	10	off	Insignificant RFI detected in the aft looking cross polarized sigma0s.
		on	RFI level is unsuitably high for the aft looking cross polarized sigma0s.
Aft looking cross polarized RFI repair flag	11	off	At least one of the input aft looking cross polarized sigma0s is based on repairs for RFI contamination.

		on	Unable to repair the aft looking cross polarized sigma0s for RFI contamination.
Mean cross polarized Faraday Rotation Flag	12	off	Faraday Rotation has little or no impact on the mean of the forward looking and aft looking horizontal polarization sigma0s.
		on	Faraday Rotation has significant impact on the mean of the forward looking and aft looking cross polarized sigma0s.
Forward looking cross polarized Faraday Rotation Flag	13	off	Faraday Rotation has little or no impact on the forward looking cross polarized sigma0.
		on	Faraday Rotation has significant impact on the forward looking cross polarized sigma0.
Aft looking cross polarized Faraday Rotation Flag	14	off	Faraday Rotation has little or no impact on the aft looking cross polarized sigma0.
		on	Faraday Rotation has significant impact on the aft looking cross polarized sigma0.
Mean cross polarized Kp flag	15	off	Kp for the mean of the forward and aft looking horizontal polarization sigma0s is acceptably low.
		on	Kp for the mean of forward and aft looking cross polarized sigma0s is unacceptably high.
Forward looking cross polarized Kp flag	16	off	Kp for the forward looking horizontal polarization sigma0 is acceptably low.
		on	Kp for the forward looking cross polarized sigma0 is unacceptably high.
Aft looking cross polarized Kp flag	17	off	Kp for the aft looking horizontal polarization sigma0 is acceptably low.
		on	Kp for the aft looking cross polarized sigma0 is unacceptably high.
Mean cross polarized null value flag	18	off	sigma0 value is valid.
		on	There is no valid sigma0.
Forward looking cross polarized null value flag	19	off	forward looking sigma0 value is valid.
		on	There is no valid forward looking sigma0.
Aft looking cross polarized polarization null value flag	20	off	aft looking sigma0 value is valid.
		on	There is no valid aft looking sigma0.

4.6.48 **sigma0_qual_flag_vv**

Representative quality flags of vertical polarization sigma0 measures in the grid cell.

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
Units: n/a

Name	Bit Position	Value (0:off, 1:on)	Interpretation
Mean vertical polarization quality flag	0	off	The mean of the forward looking and aft looking vertical polarization sigma0s has acceptable quality.
		on	The mean of the forward looking and aft looking vertical polarization sigma0s does not have acceptable quality.
Forward looking vertical polarization quality flag	1	off	The forward looking vertical polarization sigma0 has acceptable quality.
		on	The forward looking vertical polarization sigma0 has questionable or poor quality.
Aft looking vertical polarization quality flag	2	off	The aft looking vertical polarization sigma0 has acceptable quality.
		on	The aft looking vertical polarization sigma0 has questionable or poor quality.
Mean vertical polarization range flag	3	off	The mean of the forward looking and aft looking vertical polarization sigma0s falls within the expected range.
		on	The mean of the forward looking and aft looking vertical polarization sigma0s is out of range.
Forward looking vertical polarization range flag	4	off	The forward looking vertical polarization sigma0 falls within the expected range.
		on	The forward looking vertical polarization sigma0 is out of range
Aft looking vertical polarization range flag	5	off	The aft looking vertical polarization sigma0 falls within the expected range.
		on	The aft looking vertical polarization sigma0 is out of range.
Mean vertical polarization RFI clean flag	6	off	Insignificant RFI detected in the mean of the forward looking and aft looking vertical polarization sigma0s.
		on	RFI level is unsuitably high for the mean of the forward looking and aft looking vertical polarization sigma0s.
Mean vertical polarization RFI repair flag	7	off	Some components of the mean of the forward looking and aft looking vertical polarization sigma0s are based on repairs for RFI contamination.
		on	Unable to repair the mean of the forward looking and aft looking vertical polarization sigma0s for RFI contamination.
Forward looking vertical polarization RFI clean flag	8	off	Insignificant RFI detected in the forward looking vertical polarization sigma0s.
		on	RFI level is unsuitably high for the forward looking vertical polarization sigma0s.
Forward looking vertical polarization RFI repair flag	9	off	At least one of the input forward looking vertical polarization sigma0s is based on repairs for RFI contamination.
		on	Unable to repair the forward looking vertical polarization sigma0s for RFI contamination.
Aft looking vertical polarization RFI clean	10	off	Insignificant RFI detected in the aft looking vertical polarization sigma0s.

flag			
		on	RFI level is unsuitably high for the aft looking vertical polarization sigma0s.
Aft looking vertical polarization RFI repair flag	11	off	At least one of the input aft looking vertical polarization sigma0s is based on repairs for RFI contamination.
		on	Unable to repair the aft looking vertical polarization sigma0s for RFI contamination.
Mean vertical polarization Faraday Rotation Flag	12	off	Faraday Rotation has little or no impact on the mean of the forward looking and aft looking horizontal polariziation sigma0s.
		on	Faraday Rotation has significant impact on the mean of the forward looking and aft looking vertical polarization sigma0s.
Forward looking vertical polarization Faraday Rotation Flag	13	off	Faraday Rotation has little or no impact on the forward looking vertical polarization sigma0.
		on	Faraday Rotation has significant impact on the forward looking vertical polarization sigma0.
Aft looking vertical polarization Faraday Rotation Flag	14	off	Faraday Rotation has little or no impact on the aft looking vertical polarization sigma0.
		on	Faraday Rotation has significant impact on the aft looking vertical polarization sigma0.
Mean vertical polarization Kp flag	15	off	Kp for the mean of the forward and aft looking horizontal polariziation sigma0s is acceptably low.
		on	Kp for the mean of forward and aft looking vertical polarization sigma0s is unacceptably high.
Forward looking vertical polarization Kp flag	16	off	Kp for the forward looking horizontal polariziation sigma0 is acceptably low.
		on	Kp for the forward looking vertical polarization sigma0 is unacceptably high.
Aft looking vertical polarization Kp flag	17	off	Kp for the aft looking horizontal polariziation sigma0 is acceptably low.
		on	Kp for the aft looking vertical polarization sigma0 is unacceptably high.
Mean vertical null value flag	18	off	sigma0 value is valid.
		on	There is no valid sigma0.
Forward looking vertical null value flag	19	off	forward looking sigma0 value is valid.
		on	There is no valid forward looking sigma0.
Aft looking vertical polarization null value flag	20	off	aft looking sigma0 value is valid.
		on	There is no valid aft looking sigma0.

4.6.49 **sigma0_vv_mean**

Mean of 1 km instrument resolution VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0

Valid_max: 10
Units: natural unit

4.6.50 sigma0_vv_mean_aft

Mean of 1 km instrument resolution aft-looking VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.51 sigma0_vv_mean_fore

Mean of 1 km instrument resolution fore-looking VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.52 sigma0_vv_std_dev

Standard deviation of 1 km instrument resolution VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.53 sigma0_vv_std_dev_aft

Standard deviation of 1 km instrument resolution aft-looking VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.54 sigma0_vv_std_dev_fore

Standard deviation of 1 km instrument resolution fore-looking VV-pol σ0 in the 3 km Earth grid cell.

Type: Float32
Group: Radar Uncertainty Data
Shape: LatCell_LonCell_Array
Valid_min: 0
Valid_max: 10
Units: natural unit

4.6.55 soil_moisture_change_index_wagner

Retrieved normalized change in soil moisture based on Wagner.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.02
Valid_max: 0.5
Units: cm^3/cm^3

4.6.56 soil_moisture_error

Net uncertainty measure of soil moisture measure for the Earth based grid cell. - Calculation method is **TBD**. May be replaced by other quality indicators.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max:
Units: cm^3/cm^3

4.6.57 soil_moisture_snapshot

Representative soil moisture measurement for the Earth based grid cell, retrieved using the snapshot algiorithm.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.02
Valid_max: 0.7
Units: cm^3/cm^3

4.6.58 soil_moisture_snapshot_DVZ

Retrieved soil moisture for the Earth based grid cell, retrieved using the Dubois/van Zyl snapshot algorithm.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array

Valid_min: not evaluated
Valid_max: not evaluated
Units: n/a

4.6.59 **soil_moisture_snapshot_shi**

Retrieved soil moisture for the Earth based grid cell, retrieved using the Shi snapshot algorithm.

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: not evaluated
Valid_max: not evaluated
Units: n/a

4.6.60 **soil_moisture_time_series**

Retrieved soil moisture for the Earth based grid cell retrieved using the time series algorithm

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.02
Valid_max: 0.7
Units: cm^3/cm^3

4.6.61 **soil_moisture_time_series_KVZ**

Retrieved soil moisture for the Earth based grid cell retrieved using the Kim/van Zyl time series algorithm

Type: Float32
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: 0.02
Valid_max: 0.7
Units: cm^3/cm^3

4.6.62 **spacecraft_overpass_time_seconds**

Number of seconds since a specified epoch that represents the spacecraft overpass relative to ground swath.

Type: Float64
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
Units: seconds

4.6.63 spacecraft_overpass_time_utc

Time of spacecraft overpass relative to ground swath in UTC.

Type: char
String Length: 24 characters
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min: '2014-10-31T00:00:00.000Z'
Valid_max: '2030-12-31T23:59:60.999Z'
Units: n/a

4.6.64 surface_flag

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

Type: bit flag uint16
Group: Soil Moisture Retrieval Data
Shape: LatCell_LonCell_Array
Valid_min:
Valid_max:
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	Radar retrieval algorithm did not detect significant surface water within the 3 km grid cell.
		on	Radar retrieval algorithm detected significant surface water withing the 3 km grid cell.
3 km coastal proximity flag	2	off	No or insignificant presence of open water bodies was detected near the 3 km cell
		on	Significant presence of open water bodies was detected near the 3 km cell
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 snow or ice detected within the 3 km grid cell.
		on	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 radar frozen ground flag	7	off	No or insignificant presence of frozen ground (according to SMAP freeze/thaw algorithm) was detected within the 3 km grid cell
		on	Significant presence of frozen ground (according to SMAP freeze/thaw algorithm) was detected within the 3 km grid cell
3 km model frozen ground flag	8	off	No or insignificant presence of frozen ground (according to land surface model TSOIL output) was detected within the 3 km grid cell
		on	Significant presence of frozen ground (according to land surface model TSOIL output) was 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 nadir region flag	11	off	Data within the grid cell were not acquired in the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
		on	A significant fraction (>25%) of the 3 km grid cell data were acquired within the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
9 km nadir region flag	15	off	Data within the grid cell were not acquired in the nadir region of the swath where sigma0s may not meet the 9 km resolution requirement.
		on	A significant fraction (>25%) of the 3 km grid cell data were acquired within the nadir region of the swath where sigma0s may not meet the 9 km resolution requirement.

4.6.65 **surface_temperature**

Temperature at land surface based on ancillary data.

Type: Float32
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min: -50.0

Valid_max: 60.0
Units: deg Celsius

4.6.66 **vegetation_water_content_NDVI**

Representative measure of water in the vegetation within the 3 km grid cell based on the normalized difference vegetation index.

Type: Float32
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 10.0
Units: kg/m^3

4.6.67 **vegetation_water_content_RVI**

Representative measure of water in the vegetation within the 3 km grid cell based on the radar vegetation index.

Type: Float32
Group: Ancillary Data
Shape: LatCell_LonCell_Array
Valid_min: 0.0
Valid_max: 10.0
Units: kg/m^3

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, JPL D-xxxxx, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Project Implementation Plan. SMAP Project, JPL D-45939, Jet Propulsion Laboratory, Pasadena, CA.

5.3 Algorithm Theoretical Basis Documents

- SMAP Algorithm Theoretical Basis Document: L1B and L1C Radar Products. SMAP Project, JPL D-53052, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L1B Radiometer Product. SMAP Project, GSFC-SMAP-006, NASA Goddard Space Flight Center, Greenbelt, MD.
- SMAP Algorithm Theoretical Basis Document: L1C Radiometer Product. SMAP Project, JPL D-53053, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radar Soil Moisture (Active) Products. SMAP Project, JPL D-66479, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radiometer Soil Moisture (Passive) Products. SMAP Project, JPL D-66480, Jet Propulsion Laboratory, Pasadena, CA.

- SMAP Algorithm Theoretical Basis Document: L2 & L3 Radar/Radiometer Soil Moisture (Active/Passive) Products. SMAP Project, JPL D-66481, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L3 Radar Freeze/Thaw (Active) Product. SMAP Project, JPL D-66482, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L4 Surface and Root-Zone Soil Moisture Product. SMAP Project, JPL D-66483, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Algorithm Theoretical Basis Document: L4 Carbon Product. SMAP Project, JPL D-66484, Jet Propulsion Laboratory, Pasadena, CA.

5.4 Product Specification Documents

- SMAP Level 1A Radar Product Specification Document. SMAP Project, JPL D-72543, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1B Radar (L1C_S0_LoRes) Product Specification Document. SMAP Project, JPL D-72544, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1A Radiometer Product Specification Document. SMAP Project, JPL D-xxxxx, Jet Propulsion Laboratory, Pasadena, CA.
- SMAP Level 1B Radiometer (L1B_TB) Product Specification Document. SMAP Project, JPL D-xxxxx, 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, JPL D-xxxxx, Jet Propulsion Laboratory, Pasadena, CA.

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

5.5 Others

- Interface Control Document Between the Soil Moisture Active Passive (SMAP) Science Data System (SDS) and the Alaska Satellite Facility (ASF) and National Snow and Ice Data Center (NSIDC) Distributed Active Archive Centers (DAACs), Goddard Space Flight Center 423-xx-xx, TBD.
- SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems. SMAP Project, JPL D-46018, Jet Propulsion Laboratory, Pasadena, CA.
- ISO 19115:2003(E) International Standard – Geographic Information – Metadata, May 1, 2003.
- ISO 19115-2:2009 International Standard – Geographic Information – Part 2:Extensions for imagery and gridded data, December 12, 2009.
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- Introduction to HDF5, The HDF Group. URL: http://www.hdfgroup.org/HDF5/doc/H5.intro.html
- HDF5: API Specification Reference Manual, The HDF Group. URL: http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Front.html
- HDF5 User's Guide Release 1.8.9, The HDF Group. URL: http://hdfgroup.com/HDF5/doc/UG
- NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, December 5, 2011.
- EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets, Brodzik, M.J., et. al., National Snow and Ice Data Center, Cooperative Institute of Environmental Sciences, University of Colorado, ISPRS International Journal of Geo-Information, ISSN 2220-9964, DOI: 10.3390/igji1010032.

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

6 APPENDIX B: CODE EXAMPLES

[To be typeset in Courier. MATLAB, IDL, Fortran, or C is fine]