

# Soil Moisture Active Passive (SMAP) Mission

## Level 3 Active Soil Moisture Product Specification Document

**Initial 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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### TBD, TBR, TBS LOG

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## TABLE OF CONTENTS

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>INTRODUCTION.....</b>               | <b>9</b>  |
| 1.1      | Identification .....                   | 9         |
| 1.2      | Scope .....                            | 9         |
| 1.3      | Mission .....                          | 9         |
| 1.4      | Data Products.....                     | 12        |
| 1.5      | L3_SM_A Overview .....                 | 13        |
| <b>2</b> | <b>DATA PRODUCT ORGANIZATION .....</b> | <b>14</b> |
| 2.1      | Format .....                           | 14        |
| 2.2      | HDF5 Notation .....                    | 14        |
| 2.2.1    | HDF5 File .....                        | 14        |
| 2.2.2    | HDF5 Group .....                       | 14        |
| 2.2.3    | HDF5 Dataset.....                      | 15        |
| 2.2.4    | HDF5 Datatype.....                     | 15        |
| 2.2.5    | HDF5 Dataspace .....                   | 16        |
| 2.2.6    | HDF5 Attribute.....                    | 16        |
| 2.3      | SMAP File Organization .....           | 16        |
| 2.3.1    | Structure .....                        | 16        |
| 2.3.2    | Data.....                              | 17        |
| 2.3.3    | Element Types .....                    | 17        |
| 2.3.4    | File Level Metadata .....              | 18        |
| 2.3.5    | Local Metadata .....                   | 18        |
| 2.4      | Data Definition Standards.....         | 19        |
| 2.4.1    | Double Precision Time Variables .....  | 20        |
| 2.4.2    | Array Representation.....              | 21        |
| 2.5      | Fill/Gap Values .....                  | 21        |
| <b>3</b> | <b>EASE2 GRID.....</b>                 | <b>24</b> |
| <b>4</b> | <b>PRODUCT DEFINITION.....</b>         | <b>26</b> |
| 4.1      | Overview.....                          | 26        |
| 4.2      | Product Names.....                     | 26        |
| 4.3      | Volume .....                           | 27        |

|        |  |    |
|--------|--|----|
| 4.4    | L3_SM_A Product Metadata.....                | 27 |
| 4.5    | Data Structure .....                         | 34 |
| 4.6    | Parameter Definitions .....                  | 42 |
| 4.6.1  | altitude_std_dev .....                       | 42 |
| 4.6.2  | bare_soil_roughness_retrieved .....          | 42 |
| 4.6.3  | bare_soil_roughness_tabular .....            | 42 |
| 4.6.4  | boresight_incidence_std_dev .....            | 42 |
| 4.6.5  | cell_radar_mode_flag .....                   | 43 |
| 4.6.6  | distance_from_nadir .....                    | 43 |
| 4.6.7  | earth_boresight_azimuth_mean .....           | 43 |
| 4.6.8  | EASE_column_index.....                       | 44 |
| 4.6.9  | EASE_row_index.....                          | 44 |
| 4.6.10 | faraday_rotation_angle.....                  | 44 |
| 4.6.11 | freeze_thaw.....                             | 44 |
| 4.6.12 | kp_hh.....                                   | 44 |
| 4.6.13 | kp_hh_aft.....                               | 45 |
| 4.6.14 | kp_hh_fore .....                             | 45 |
| 4.6.15 | kp_vv .....                                  | 45 |
| 4.6.16 | kp_vv_aft .....                              | 45 |
| 4.6.17 | kp_vv_fore .....                             | 46 |
| 4.6.18 | kp_xpol.....                                 | 46 |
| 4.6.19 | kp_xpol_aft .....                            | 46 |
| 4.6.20 | kp_xpol_fore .....                           | 47 |
| 4.6.21 | landcover_class.....                         | 47 |
| 4.6.22 | latitude.....                                | 48 |
| 4.6.23 | longitude.....                               | 48 |
| 4.6.24 | normalized_difference_vegetation_index ..... | 48 |
| 4.6.25 | num_input_sigma0s_hh .....                   | 48 |
| 4.6.26 | num_input_sigma0s_vv.....                    | 49 |
| 4.6.27 | num_input_sigma0s_xpol.....                  | 49 |
| 4.6.28 | num_time_series .....                        | 49 |
| 4.6.29 | radar_vegetation_index.....                  | 49 |

|        |   |    |
|--------|---|----|
| 4.6.30 | retrieval_qual_flag .....               | 50 |
| 4.6.31 | retrieval_qual_flag_cube .....          | 50 |
| 4.6.32 | retrieval_qual_flag_kvz.....            | 51 |
| 4.6.33 | retrieval_qual_flag_wagner .....        | 52 |
| 4.6.34 | sigma0_hh_mean.....                     | 53 |
| 4.6.35 | sigma0_hh_mean_aft.....                 | 53 |
| 4.6.36 | sigma0_hh_mean_fore.....                | 53 |
| 4.6.37 | sigma0_hh_std_dev .....                 | 53 |
| 4.6.38 | sigma0_hh_std_dev_aft .....             | 53 |
| 4.6.39 | sigma0_hh_std_dev_fore .....            | 54 |
| 4.6.40 | sigma0_xpol_mean .....                  | 54 |
| 4.6.41 | sigma0_xpol_mean_aft .....              | 54 |
| 4.6.42 | sigma0_xpol_mean_fore .....             | 54 |
| 4.6.43 | sigma0_xpol_std_dev.....                | 55 |
| 4.6.44 | sigma0_xpol_std_dev_aft.....            | 55 |
| 4.6.45 | sigma0_xpol_std_dev_fore.....           | 55 |
| 4.6.46 | sigma0_qual_flag_hh .....               | 55 |
| 4.6.47 | sigma0_qual_flag_xpol.....              | 57 |
| 4.6.48 | sigma0_qual_flag_vv.....                | 59 |
| 4.6.49 | sigma0_vv_mean .....                    | 61 |
| 4.6.50 | sigma0_vv_mean_aft .....                | 61 |
| 4.6.51 | sigma0_vv_mean_fore .....               | 61 |
| 4.6.52 | sigma0_vv_std_dev.....                  | 62 |
| 4.6.53 | sigma0_vv_std_dev_aft.....              | 62 |
| 4.6.54 | sigma0_vv_std_dev_fore.....             | 62 |
| 4.6.55 | soil_moisture_change_index_wagner ..... | 62 |
| 4.6.56 | soil_moisture_error.....                | 63 |
| 4.6.57 | soil_moisture_snapshot.....             | 63 |
| 4.6.58 | soil_moisture_snapshot_DVZ.....         | 63 |
| 4.6.59 | soil_moisture_snapshot_shi .....        | 63 |
| 4.6.60 | soil_moisture_time_series .....         | 64 |
| 4.6.61 | soil_moisture_time_series_KVZ .....     | 64 |

|          |   |           |
|----------|---|-----------|
| 4.6.62   | spacecraft_overpass_time_seconds .....              | 64        |
| 4.6.63   | spacecraft_overpass_time_utc.....                   | 64        |
| 4.6.64   | surface_flag.....                                   | 64        |
| 4.6.65   | surface_temperature .....                           | 66        |
| 4.6.66   | vegetation_water_content_NDVI.....                  | 66        |
| 4.6.67   | vegetation_water_content_RVI .....                  | 66        |
| <b>5</b> | <b>REFERENCES.....</b>                              | <b>68</b> |
| 5.1      | Requirements .....                                  | 68        |
| 5.2      | Plans.....  | 68        |
| 5.3      | Algorithm Theoretical Basis Documents .....         | 68        |
| 5.4      | Product Specification Documents.....                | 69        |
| 5.5      | Others.....   | 70        |
| <b>6</b> | <b>APPENDIX A: ACRONYMS AND ABBREVIATIONS .....</b> | <b>71</b> |
| <b>6</b> | <b>APPENDIX B: CODE EXAMPLES.....</b>               | <b>76</b> |



# 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

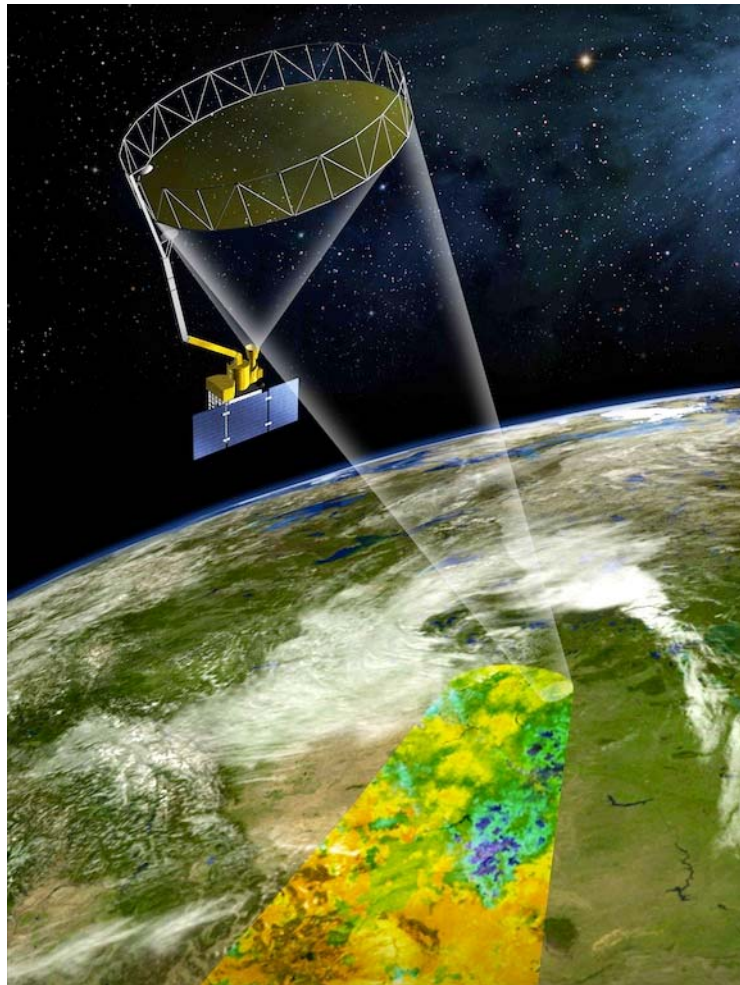
| <b>Scientific Measurement Requirements</b>  | <b>Instrument Functional Requirements</b>  |
|---|--|
| <p><b><u>Soil Moisture:</u></b><br/> <math>\sim \pm 0.04 \text{ cm}^3/\text{cm}^3</math> volumetric accuracy (1-sigma) in the top 5 cm for vegetation water content <math>\leq 5 \text{ kg}/\text{m}^2</math><br/>                     Hydrometeorology at <math>\sim 10 \text{ km}</math> resolution<br/>                     Hydroclimatology at <math>\sim 40 \text{ km}</math> resolution</p> | <p><b><u>L-Band Radiometer (1.41 GHz):</u></b><br/>                     Polarization: V, H, T<sub>3</sub>, and T<sub>4</sub><br/>                     Resolution: 40 km<br/>                     Radiometric Uncertainty*: 1.3 K<br/> <b><u>L-Band Radar (1.26 and 1.29 GHz):</u></b><br/>                     Polarization: VV, HH, HV (or VH)<br/>                     Resolution: 10 km<br/>                     Relative accuracy*: 0.5 dB (VV and HH)<br/>                     Constant incidence angle** between 35° and 50°</p> |
| <p><b><u>Freeze/Thaw State:</u></b><br/>                     Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision at the spatial scale of landscape variability (<math>\sim 3 \text{ km}</math>)</p>  | <p><b><u>L-Band Radar (1.26 GHz &amp; 1.29 GHz):</u></b><br/>                     Polarization: HH<br/>                     Resolution: 3 km<br/>                     Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used)<br/>                     Constant incidence angle** between 35° and 50°</p>   |
| <p>Sample diurnal cycle at consistent time of day (6 am/6 pm Equator crossing);<br/>                     Global, <math>\sim 3 \text{ day}</math> (or better) revisit;<br/>                     Boreal, <math>\sim 2 \text{ day}</math> (or better) revisit</p>  | <p>Swath Width: <math>\sim 1000 \text{ km}</math><br/>                     Minimize Faraday rotation (degradation factor at L-band)</p>  |
| <p>Observation over minimum of three annual cycles</p>  | <p>Baseline three-year mission life</p>  |
| <p>* Includes precision and calibration stability<br/>                     ** Defined without regard to local topographic variation</p>   |  |

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 $\sigma_0$ in time order  | Half orbit  |
| L1C_S0_HiRes            | SPL1CS0        | High resolution radar $\sigma_0$ 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 <i>flag_meanings</i> . 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 <i>flag_values</i> .   | 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*.

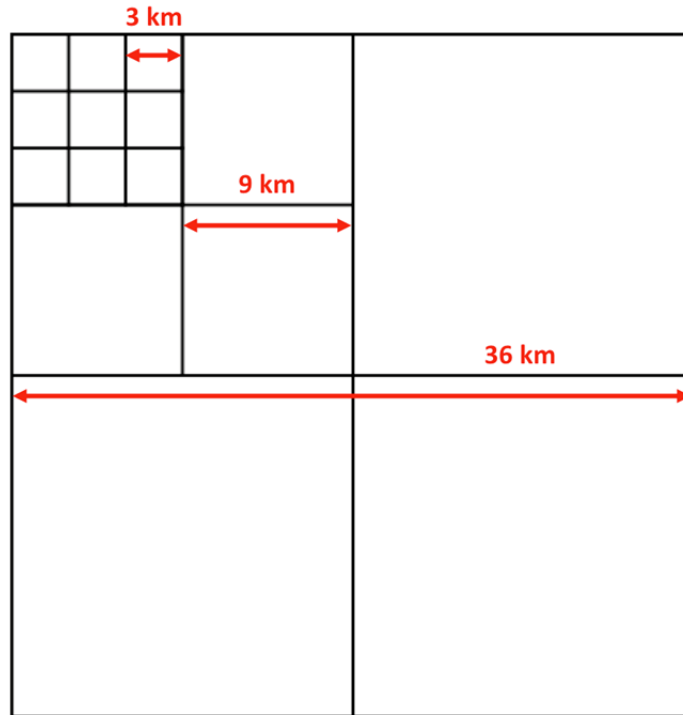
- The character string stored in metadata element *Extent/rangeEndingDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStopDateTime*.

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/halfOrbitStopDateTime*.
- 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.

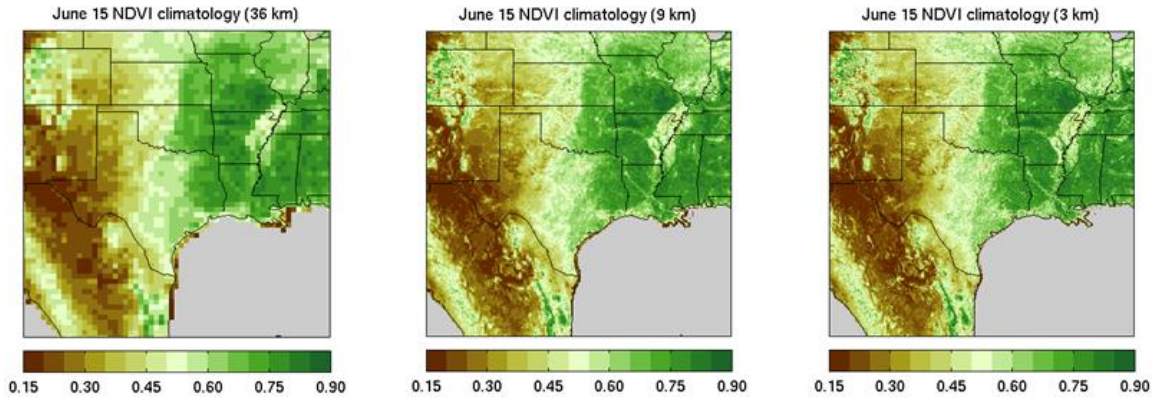


**Figure 2:** Perfect nesting in EASE2 Grid – smaller grid cells can be tessellated to form larger grid cells.

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.

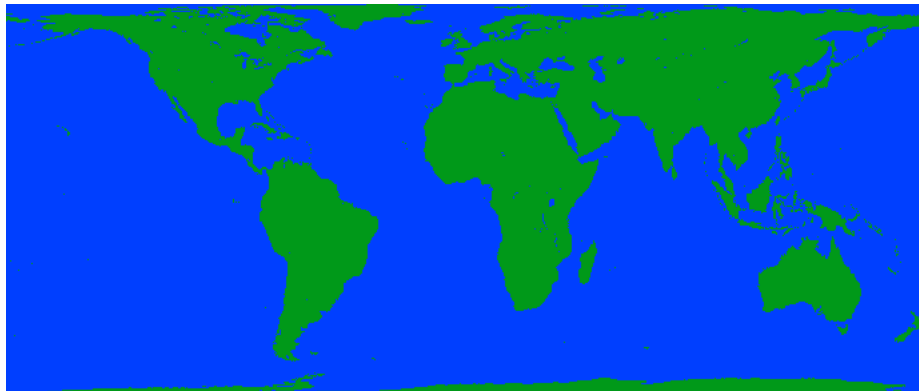
A nominal EASE2 grid dimension of 36 km has been selected for the L2/3\_SM\_P products. This spatial scale is close to the 40-km resolution of the radiometer footprint and it scales conveniently with the 3 km and 9 km grid dimensions that have been selected for the radar (L2/3\_SM\_A) and combined radar/radiometer (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  $3 \times 3 \text{ km}^2$ , 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

|                              |  |
|------------------------------|--|
| <i>Orbit Number</i>          | A five-digit sequential number of the orbit flown by the SMAP spacecraft when the data was acquired. Orbit 0 begins at launch.   |
| <i>Half Orbit Designator</i> | 'D' for 6:00 am descending pass.   |
| <i>First Date/Time Stamp</i> | Date/time stamp in Universal Coordinated Time (UTC) of the first data element that appears in the product. The stamp conforms to the <i>YYYYMMDDThhmmss</i> convention.  |
| <i>Composite Release ID</i>  | 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.

|                        |  |
|------------------------|--|
| <i>Product Counter</i> | A three-digit counter that tracks the number of times that a particular product type for a specific half orbit has been generated. |
| <i>Extension</i>       | ‘.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 <math>\langle \rangle</math>. 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  |
|---------------------------|-----------------------------|---|----------------------|---|
| MD_AcquisitionInformation | AcquisitionInformation      | platform  | antennaRotationRate  | <The antenna rotation rate in revolution per minute   |
|                           |                             |   | description          | The SMAP observatory houses an L-band radiometer and an L-band radar that operates at 1.26 GHz. The instrument is mounted on a 6 meter aperture that scans over a 1000 km swath from a stabilized spacecraft that provides momentum compensation. |
|                           |                             |   | identifier           | SMAP  |
|                           |                             | radar, radiometer                                   | description          | The SMAP radar instrument employs an L-band coherent processing techniques to achieve moderate resolution measurements over a very wide 1000 km swath.  |
|                           |                             |   | identifier           | SMAP SAR  |
|                           |                             |   | type                 | L-band Synthetic Aperture Radar   |
|                           |                             | platformDocument, radarDocument, radiometerDocument | edition              | <The edition of publication of the reference document, public.>   |
|                           |                             |   | publicationDate      | <The date of publication of the reference document, public.>  |
|                           |                             |   | title                | <The title of the publication of the reference document, public.>   |
|                           |                             |   |                      |   |
| DQ_DataQuality            | DataQuality                 | DomainConsistency                                   | evaluationMethodType | <The type of data quality evaluation method. "direct" evaluating the quality of a dataset based on inspection where all data required is internal to the dataset being inspected.   |
|                           |                             |   | measureDescription   | <The description of the Domain Consistency measure.>  |
|                           |                             |   | nameOfMeasure        | <The name of the measurements.>   |
|                           |                             |   | unitOfMeasure        | Percent   |
|                           |                             |   | value                | <A measure between 0 and 100.>  |
|                           |                             | CompletenessOmission                                | evaluationMethodType | <The type of data quality evaluation method. "direct" evaluating the quality of a dataset based on inspection where all data required is internal to the dataset being inspected.   |
|                           |                             |   | measureDescription   | <The description of the Completeness Omission measure.>   |
|                           |                             |   | 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.>                               |
|                           |                       |                      |   |
| SD_OrbitMeasuredLocation  | OrbitMeasuredLocation | startRevNumber       | <The lowest orbit number among the input product granules>  |
|                           |                       | 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>  |
| LI_Lineage/LE_ProcessStep | ProcessStep           | stepDateTime         | < A character string that specifies the date and the time when the product was generated.>            |
|                           |                       | timeVariableEpoch    | <The Epoch of the time variable for the SMAP mission>   |
|                           |                       |                      |   |

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

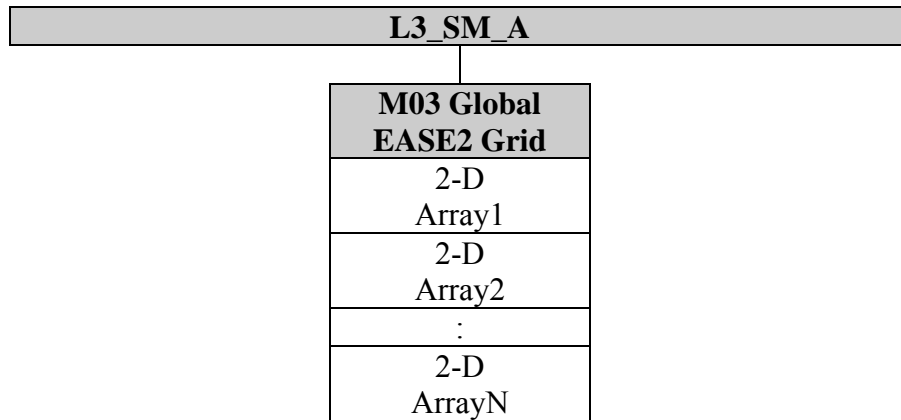


|  |  |                                  |  |
|--|--|----------------------------------|--|
|  |  |                                  | file.>   |
|  |  | pointOfContact                   | <The name of the DAAC this data product is distributed from.>                        |
|  |  | purpose                          | <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   |

<sup>1</sup> 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**

| <b>Element</b>             | <b>Shape</b>          | <b>Concept</b> | <b>Bytes</b> | <b>Unit</b> | <b>Min</b> | <b>Max</b> | <b>Comment</b>  |
|----------------------------|-----------------------|----------------|--------------|-------------|------------|------------|---|
| 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      | Representative soil moisture measurement for the Earth based grid cell, retrieved using the Dubois/van Zyl snapshot algorithm |
| 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                             |
| soil_moisture                    | 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 time series algorithm              |
| soil moisture kvz                | LatCell_LonCell_Array | real    | 4 | cm**3/cm**3   | 0.02      | 0.5      | Representative soil moisture  |

|                               |                       |        |    |                 |           |          |   |
|-------------------------------|-----------------------|--------|----|-----------------|-----------|----------|---|
|                               |                       |        |    | cm**3           |           |          | 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/<br>cm**3 | 0.02      | 0.5      | Retrieved normalized change in soil moisture.   |
| soil_moisture_error           | LatCell_LonCell_Array | real   | 4  | cm**3/<br>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  | normali<br>zed  | -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

| 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:** '2014-10-31T00:00:00.000Z'  
**Valid\_max:** '2030-12-31T23:59:60.999Z'  
**Units:** n/a

### 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:** 0.04  
**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

| Name                               | Bit Position | Value (0:off, 1:on) | Interpretation  |
|------------------------------------|--------------|---------------------|---|
| Receive only mode                  | 0            | off                 | Radar is operating in transmit-receive mode   |
|                                    |              | on                  | Radar is operating in receive only mode   |
| Cross polarization data flag       | 1            | off                 | Cross polarized data are v-pol transmitted, h-pol received.   |
|                                    |              | on                  | Cross polarized data are h-pol transmitted, v-pol received  |
| Cross polarization transition flag | 2            | off                 | Cross polarized data are consistent within this EASE grid cell.   |
|                                    |              | on                  | Cross polarized data are in transition, some are v-pol transmitted, h-pol received, others are h-pol transmitted, v-pol received. |

#### 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:** 360.0  
**Units:** degrees

#### 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:** 360.0  
**Units:** degrees

#### 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:** 360.0  
**Units:** degrees

#### 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  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.13 **kp\_hh\_aft**

Overall error measure for aft-looking HH-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.14 **kp\_hh\_fore**

Overall error measure for fore-looking HH-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.15 **kp\_vv**

Overall error measure for VV-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.16 **kp\_vv\_aft**

Overall error measure for aft-looking VV-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.17 **kp\_vv\_fore**

Overall error measure for fore-looking VV-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.18 **kp\_xpol**

Overall error measure for cross-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.19 **kp\_xpol\_aft**

Overall error measure for aft-looking cross-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.20 **kp\_xpol\_fore**

Overall error measure for fore-looking cross-pol  $\sigma_0$  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:**  
**Valid\_max:**  
**Units:** dB

#### 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:** TBD  
**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:**  
**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 successfully   |
|   |              | 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 successfully   |
|   |              | 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 successfully                                   |
|   |   | 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 successfully   |
|   |              | 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  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.35 **sigma0\_hh\_mean\_aft**

Mean of 1 km instrument resolution aft-looking HH-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.36 **sigma0\_hh\_mean\_fore**

Mean of 1 km instrument resolution fore-looking HH-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.37 **sigma0\_hh\_std\_dev**

Standard deviation of 1 km instrument resolution HH-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.38 **sigma0\_hh\_std\_dev\_aft**

Standard deviation of 1 km instrument resolution aft-looking HH-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.39 **sigma0\_hh\_std\_dev\_fore**

Standard deviation of 1 km instrument resolution fore-looking HH-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.40 **sigma0\_xpol\_mean**

Mean of 1 km instrument resolution cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.41 **sigma0\_xpol\_mean\_aft**

Mean of 1 km instrument resolution aft-looking cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.42 **sigma0\_xpol\_mean\_fore**

Mean of 1 km instrument resolution fore-looking cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array

**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

**4.6.43 sigma0\_xpol\_std\_dev**

Standard deviation of 1 km instrument resolution cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

**4.6.44 sigma0\_xpol\_std\_dev\_aft**

Standard deviation of 1 km instrument resolution aft-looking cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

**4.6.45 sigma0\_xpol\_std\_dev\_fore**

Standard deviation of 1 km instrument resolution fore-looking cross-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

**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, | Interpretation |
|------|--------------|---------------|----------------|
|------|--------------|---------------|----------------|

|   |    | <b>1:on)</b> |  |
|---|----|--------------|--|
| 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 quality flag    | 1  | off          | The forward looking horizontal polarization sigma0 has acceptable quality.   |
|   |    | 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           | 10 | off          | Insignificant RFI detected in the aft looking horizontal polarization sigma0s.   |



|   |    |     |  |
|---|----|-----|--|
| flag  |    |     |  |
|   |    | 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 polarization 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 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.  |

#### 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 | 0            | off                 | The mean of the forward looking and aft looking |

|   |    |     |  |
|---|----|-----|--|
| quality flag                                    |    |     | 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.  |

#### 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 flag      | 10 | off | Insignificant RFI detected in the aft looking vertical polarization sigma0s.   |
|   |    | 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 polarization sigma0s.                 |

|   |    |     |  |
|---|----|-----|--|
|   |    | on  | Faraday Rotation has significant impact on the mean of the forward looking and aft looking vertical polarization $\sigma_0$ s. |
| Forward looking vertical polarization Faraday Rotation Flag | 13 | off | Faraday Rotation has little or no impact on the forward looking vertical polarization $\sigma_0$ .                             |
|   |    | on  | Faraday Rotation has significant impact on the forward looking vertical polarization $\sigma_0$ .                              |
| Aft looking vertical polarization Faraday Rotation Flag     | 14 | off | Faraday Rotation has little or no impact on the aft looking vertical polarization $\sigma_0$ .                                 |
|   |    | on  | Faraday Rotation has significant impact on the aft looking vertical polarization $\sigma_0$ .                                  |
| Mean vertical polarization Kp flag                          | 15 | off | Kp for the mean of the forward and aft looking horizontal polarization $\sigma_0$ s is acceptably low.                         |
|   |    | on  | Kp for the mean of forward and aft looking vertical polarization $\sigma_0$ s is unacceptably high.                            |
| Forward looking vertical polarization Kp flag               | 16 | off | Kp for the forward looking horizontal polarization $\sigma_0$ is acceptably low.   |
|   |    | on  | Kp for the forward looking vertical polarization $\sigma_0$ is unacceptably high.  |
| Aft looking vertical polarization Kp flag                   | 17 | off | Kp for the aft looking horizontal polarization $\sigma_0$ is acceptably low.   |
|   |    | on  | Kp for the aft looking vertical polarization $\sigma_0$ is unacceptably high.  |

#### 4.6.49 $\sigma_0$ \_vv\_mean

Mean of 1 km instrument resolution VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.50 $\sigma_0$ \_vv\_mean\_aft

Mean of 1 km instrument resolution aft-looking VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.51 $\sigma_0$ \_vv\_mean\_fore

Mean of 1 km instrument resolution fore-looking VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data

**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.52 **sigma0\_vv\_std\_dev**

Standard deviation of 1 km instrument resolution VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.53 **sigma0\_vv\_std\_dev\_aft**

Standard deviation of 1 km instrument resolution aft-looking VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 4.6.54 **sigma0\_vv\_std\_dev\_fore**

Standard deviation of 1 km instrument resolution fore-looking VV-pol  $\sigma_0$  in the 3 km Earth grid cell.

**Type:** Float32  
**Group:** Radar Uncertainty Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:**  
**Valid\_max:**  
**Units:** dB

#### 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<sup>3</sup>/cm<sup>3</sup>

#### 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:**  $\text{cm}^3/\text{cm}^3$

#### 4.6.57 **soil\_moisture\_snapshot**

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

**Type:** Float32  
**Group:** Soil Moisture Retrieval Data  
**Shape:** LatCell\_LonCell\_Array  
**Valid\_min:** 0.02  
**Valid\_max:** 0.5  
**Units:**  $\text{cm}^3/\text{cm}^3$

#### 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:** 0.02  
**Valid\_max:** 0.5  
**Units:**  $\text{cm}^3/\text{cm}^3$

#### 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:** 0.02  
**Valid\_max:** 0.5  
**Units:**  $\text{cm}^3/\text{cm}^3$

#### 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:** 0.5  
**Units:** cm<sup>3</sup>/cm<sup>3</sup>

#### 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:** 0.5  
**Units:** cm<sup>3</sup>/cm<sup>3</sup>

#### 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 within the 3 km grid cell.  |
| 3 km urban area flag                 | 2            | 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              | 3            | 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                | 4            | 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      | 5            | off                 | The fraction of the 3 km grid cell area that is over permanent snow or ice is less than a specified algorithmic threshold.   |
|                                      |              | on                  | The fraction of the 3 km grid cell area that is over permanent snow or ice is greater than or equal to a specified algorithmic threshold.                                |
| 3 km frozen ground flag              | 6            | off                 | No frozen ground detected within the 3 km grid cell.   |
|                                      |              | on                  | Frozen ground detected within the 3 km grid cell.  |
| 3 km mountainous terrain flag        | 7            | 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           | 8            | 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 | 9  | off | Data within the 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 (TBD) 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.                                  |
| 3 km coastal mask flag | 10 | off | Data within the the grid cell were not acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presense of water. |
|                        |    | on  | Data within the the grid cell were acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presense of water.     |

#### 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<sup>3</sup>

#### 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<sup>3</sup>



## 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.
- ISO 19139:2007 International Standard – Geographic Information – Metadata – XML schema implementation, May 14 2009.
- Introduction to HDF5, The HDF Group. URL: <http://www.hdfgroup.org/HDF5/doc/H5.intro.html>
- HDF5: API Specification Reference Manual, The HDF Group. URL: [http://www.hdfgroup.org/HDF5/doc/RM/RM\\_H5Front.html](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>
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- EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets, Brodzik, M.J., et. al., National Snow and Ice Data Center, Cooperative Institute of Environmental Sciences, University of Colorado, ISPRS International Journal of Geo-Information, ISSN 2220-9964, DOI: 10.3390/igji1010032.

## 6 APPENDIX A: ACRONYMS AND ABBREVIATIONS

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

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

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



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

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

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

## 6 APPENDIX B: CODE EXAMPLES

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