



# SMAP L3 Radar Global Daily 3 km EASE-Grid Soil Moisture, Version 3

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## USER GUIDE

### How to Cite These Data

As a condition of using these data, you must include a citation:

Kim, S., J. Van Zyl, R. S. Dunbar, E. G. Njoku, J. T. Johnson, M. Moghaddam, and L. Tsang. 2016. *SMAP L3 Radar Global Daily 3 km EASE-Grid Soil Moisture, Version 3*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/IGQNPB6183ZX>. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT [NSIDC@NSIDC.ORG](mailto:NSIDC@NSIDC.ORG)

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/SPL3SMA>



National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

## 1.1 Parameters

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Surface soil moisture (0-5 cm) in  $\text{cm}^3/\text{cm}^3$  derived from sigma naught measurements is output on a fixed 3 km EASE-Grid 2.0.

Sigma naught ( $\sigma_0$ ), or the backscatter coefficient, is a measure of the strength of radar signals reflected back to the instrument from a target, and is defined as per unit area on the ground.

Usually expressed in dB, it is a normalized dimensionless number, comparing the strength observed to that expected from a defined area. The SMAP L-band Radar measures  $\sigma_0$  using VV, HH, and HV transmit-receive polarizations, and uses separate transmit frequencies for the H (1.26 GHz) and V (1.29 GHz) polarizations.  $\sigma_0$  measurements are derived using Synthetic-Aperture Radar (SAR) processing.

Refer to the Appendix of this document for details on all parameters.

## 1.2 File Information

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### 1.2.1 Format

Data are in HDF5 format. For software and more information, including an HDF5 tutorial, visit the HDF Group's HDF5 Web site.

#### File Size

Each file is approximately 765 MB.

#### File Volume

The daily data volume is approximately 765 MB.

### 1.2.2 File Contents

As shown in Figure 1, each HDF5 file is organized into the following main groups, which contain additional groups and/or data sets:

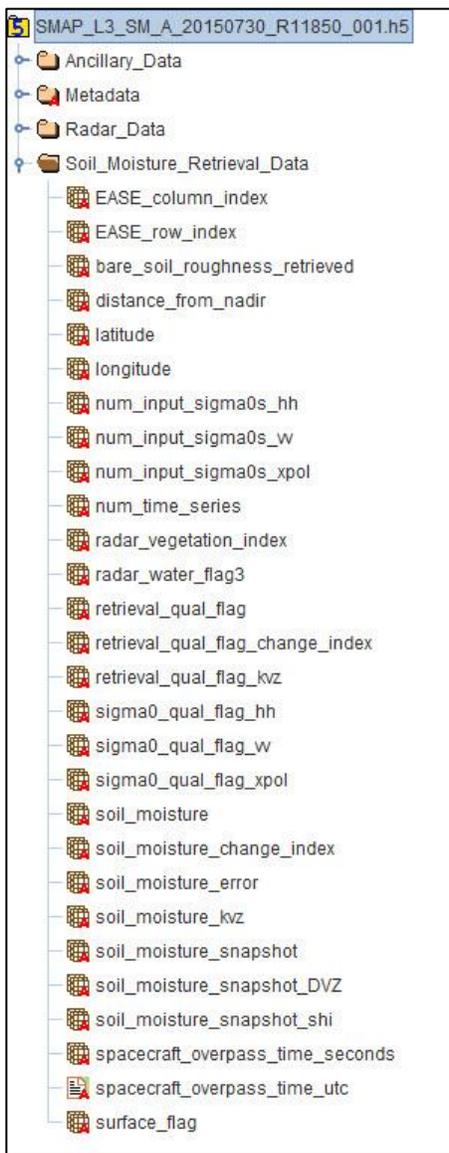


Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-3 radar soil moisture product, refer to the Appendix.

### 1.2.2.1 Data Fields

Each file contains the main data groups summarized in this section. For a complete list and description of all data fields within these groups, refer to the Appendix of this document.

All data element arrays are one-dimensional with a size N, where N is the number of valid cells from the radar swath that appear on the grid.

#### ANCILLARY DATA

Includes all ancillary data, such as surface temperature and vegetation water content.

**RADAR DATA**

Includes all radar data, such as cross-polarized sigma naught (also referred to as sigma0 or  $\sigma_0$ ) data.

**SOIL MOISTURE RETRIEVAL DATA**

Includes soil moisture data and quality assessment flags.

### 1.2.3 Metadata Fields

Includes all metadata that describe the full content of each file. For a description of all metadata fields for this product, refer to the Product Specification Document.

### 1.2.4 Naming Convention

Files are named according to the following convention, which is described in Table 1:

SMAP\_L3\_SM\_A\_yyyymmdd\_RLVvvv\_NNN.[ext]

For example:

SMAP\_L3\_SM\_A\_20141225\_R12130\_002.h5

Where:

Table 1. File Naming Conventions

Variable	Description								
SMAP	Indicates SMAP mission data								
L3_SM_A	Indicates specific product (L3: Level-3; SM: Soil Moisture; A: Active)								
yyyymmdd	4-digit year, 2-digit month, 2-digit day; date in Universal Coordinated Time (UTC) of the first data element that appears in the product.								
RLVvvv	Composite Release ID, where: <table border="1" style="margin-left: 20px;"> <tr> <td>R</td> <td>Release</td> </tr> <tr> <td>L</td> <td>Launch Indicator (1: Post-launch standard data)</td> </tr> <tr> <td>V</td> <td>1-Digit Major Version Number</td> </tr> <tr> <td>vvv</td> <td>3-Digit Minor Version Number</td> </tr> </table> <p><b>Example:</b> R12130 indicates a standard data product with a version of 2.130. Refer to the <a href="#">SMAP Data Versions</a> page for version information.</p>	R	Release	L	Launch Indicator (1: Post-launch standard data)	V	1-Digit Major Version Number	vvv	3-Digit Minor Version Number
R	Release								
L	Launch Indicator (1: Post-launch standard data)								
V	1-Digit Major Version Number								
vvv	3-Digit Minor Version Number								
NNN	Number of times the file was generated under the same version for a particular date/time interval (002: 2nd time)								

Variable	Description	
. [ext]	File extensions include:	
	.h5	HDF5 data file
	.qa	Quality Assurance file
	.xml	XML Metadata file

## 1.3 Spatial Information

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### 1.3.1 Coverage

Coverage spans from 180°W to 180°E, and from approximately 85.044°N and 85.044°S. The gap in coverage at both the North and South Pole, called a pole hole, has a radius of approximately 400 km. The swath width is 1000 km, enabling nearly global coverage every three days.

### 1.3.2 Resolution

The native spatial resolution of the radar footprint is 1 km. Data are then gridded using the 3 km EASE-Grid 2.0 projection.

### 1.3.3 EASE-Grid 2.0

These data are provided on the global cylindrical EASE-Grid 2.0 (Brodzik et al. 2012). Each grid cell has a nominal area of approximately 3 x 3 km<sup>2</sup> regardless of longitude and latitude. Using this projection, all global data arrays have dimensions of 4872 rows and 11568 columns.

EASE-Grid 2.0 has a flexible formulation. By adjusting a single scaling parameter, a family of multi-resolution grids that nest within one another can be generated. The nesting can be adjusted so that smaller grid cells can be tessellated to form larger grid cells. Figure 2 shows a schematic of the nesting.

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 for their derived geophysical products.

For more on EASE-Grid 2.0, refer to the [EASE-Grid 2.0 Format Description](#).

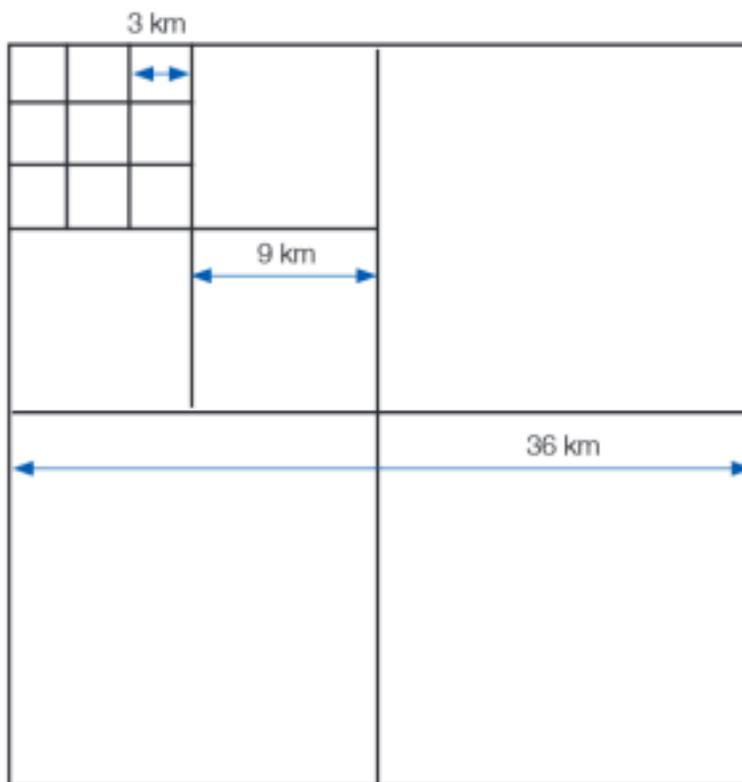


Figure 2. Perfect Nesting in EASE-Grid 2.0

## 1.4 Temporal Information

### 1.4.1 Coverage

Coverage spans from 13 April 2015 to 07 July 2015.

Note: Temporal coverage for this data set is limited due to the premature failure of the SMAP L-Band Radar. On 07 July 2015, the radar stopped transmitting due to an anomaly involving the instrument's high-power amplifier (HPA). For details, refer to the [SMAP News Release](#) issued 02 September 2015 by the Jet Propulsion Laboratory (JPL).

#### Satellite and Processing Events

Due to instrument maneuvers, data downlink anomalies, data quality screening, and other factors, small gaps in the SMAP time series will occur. Details of these events are maintained on two master lists:

[SMAP On-Orbit Events List for Instrument Data Users](#)

[Master List of Bad and Missing Data](#)

## 1.4.2 Resolution

Each Level-3 file is a daily composite of half-orbit files/swaths.

# 2 DATA ACQUISITION AND PROCESSING

## 2.1 Background

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Retrieval of soil moisture from measured backscatter data typically implies an inversion of the radar forward scattering process. Bare rough surfaces can be characterized in terms of their Root Mean Square (RMS) roughness height, correlation length, and moisture content (a surrogate for dielectric constant). The use of time-series data makes the retrieval a well-constrained estimation problem, under the assumption of a time invariant surface roughness. By taking a co-polarized ratio the soil moisture retrieval becomes insensitive to the correlation length except for very rough surfaces, which enables an accurate retrieval of soil moisture without correlation length information. This approach has been extended to the vegetated surface by introducing a vegetation axis to the lookup table (Kim et al. 2014). A one-axis representation of the vegetation effect is clearly a simplification, considering that different sets of vegetation parameters result in different backscattering coefficients. However, with SMAP's three measurement channels—HH, VV, and HV—at most three independent parameters can be uniquely estimated, and therefore simplified forward models must be represented in terms of at most three dominant parameters. The simplification results in some errors in soil moisture retrieval, especially in heavily vegetated areas such as forests. Allometric relationships reduce the number of unknowns and may improve the retrievals. The three parameters used to simplify the scattering model are then the dielectric constant of soil,  $\epsilon$ , soil surface roughness,  $s$ , and VWC.

The SMAP radar HV-channel measurements are reserved for possible use in correcting vegetation effects. The remaining two co-polarized (co-pol) measurements (HH and VV) are not always sufficient to determine  $s$  and  $\epsilon$  (Kim et al. 2014). One of the main causes is the ambiguity in bare surface scattering: a wet and smooth surface may have the same backscatter as a dry and moderately rough surface. Very often the timescale of the change in  $s$  is longer than that of  $\epsilon$  (Jackson et al. 1997). Then  $s$  may be constrained to be a constant in time, thus resolving the ambiguity (Kim et al. 2014).

The SMAP baseline approach (Kim et al. 2012; Kim et al. 2014) is a multichannel retrieval algorithm that searches for a soil moisture solution such that the difference between modeled and observed backscatter is minimized in the least squares sense. A look-up table representation, or data cube, of a complicated forward model has been demonstrated to be an accurate and fast tool for retrieval (Kim et al. 2012; Kim et al. 2014). The algorithm estimates  $s$  first and then

retrieves  $\epsilon_r$  using the estimated  $s$ . Vegetation effects are included by selecting the  $\sigma_0$  of the forward model at the VWC level given by an ancillary source. Note that the VWC provided by ancillary information is allowed to vary throughout the time series.

For in-depth information regarding the physics involved in deriving soil moisture from backscatter, refer to the [ATBD](#) for this product, Section 2: Physics of the Scattering Problem.

## 2.2 Acquisition

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SMAP Level-3 radar soil moisture data (SPL3SMA) are composited from [SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture, Version 3 \(SPL2SMA\)](#) data.

## 2.3 Derivation Techniques and Algorithms

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This SMAP Level-3 radar soil moisture data set is a daily gridded composite of the [SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture, Version 3 \(SPL2SMA\)](#) data set. The derivation of soil moisture from SMAP brightness temperatures occurs in the Level-2 processing of the radar data set.

## 2.4 Processing

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The SPL3SMA product is a daily global product. This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate this product, the processing software ingests one day's worth of [SPL2SMA](#) files and creates individual global composites as two-dimensional arrays for each output parameter defined in the SPL2SMA product. Wherever data overlap occurs (typically at high latitudes), data whose acquisition times are closest to the 6:00 a.m. local solar times are chosen. Because the input SPL2SMA files are available only for descending 6:00 a.m. passes, the resulting SPL3SMA files are available only for descending 6:00 a.m. passes.

## 2.5 Quality, Errors, and Limitations

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### 2.5.1 Error Sources

Anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate both radar and radiometer measurements at L-band. Early measurements and results from ESA's Soil Moisture and Ocean Salinity (SMOS) mission indicate that in some regions RFI is present and detectable. The SMAP radar and radiometer electronics and algorithms include design features to mitigate the effects of RFI. The SMAP radar utilizes selective filters and

an adjustable carrier frequency to tune to predetermined RFI-free portions of the spectrum while on orbit.

More information about error sources is provided in Section 3.5: Error Budget of the ATBD (O'Neill et al. 2018).

## 2.5.2 Quality Assessment

For in-depth details regarding the quality of these Version 3 Validated data, refer to the following reports:

[Validated Assessment Report](#)

[Beta Assessment Report](#)

## 2.5.3 Quality Overview

SMAP products provide multiple means to assess quality. Each product contains bit flags, uncertainty measures, and file-level metadata that provide quality information. For information regarding the specific bit flags, uncertainty measures, and file-level metadata contained in this product, refer to the Appendix and the [Product Specification Document](#).

Each HDF5 file contains metadata with Quality Assessment (QA) metadata flags that are set by the Science Data Processing System (SDS) at the JPL prior to delivery to NSIDC. A separate metadata file with an .xml file extension is also delivered to NSIDC with the HDF5 file; it contains the same information as the HDF5 file-level metadata.

A separate QA file with a .qa file extension is also associated with each data file. QA files are ASCII text files that contain statistical information in order to help users better assess the quality of the associated data file.

If a product does not fail QA, it is ready to be used for higher-level processing, browse generation, active science QA, archive, and distribution. If a product fails QA, it is never delivered to NSIDC DAAC.

## 2.5.4 Data Flags

Quality flags provide information as to whether the ground is frozen, snow-covered, or flooded, or whether it is actively precipitating at the time of the satellite overpass. Other flags indicate whether masks for steeply sloped topography, or for urban, heavily forested, or permanent snow/ice areas are in effect.

For a description of the data flag types and methods of flagging, refer to the [Quality Flags](#) section in the SPL2SMA user guide.

## 2.6 Instrumentation

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### 2.6.1 Description

For a detailed description of the SMAP instrument, visit the [SMAP Instrument](#) page at the Jet Propulsion Laboratory (JPL) SMAP Web site.

## 3 SOFTWARE AND TOOLS

For tools that work with SMAP data, refer to the [Tools](#) Web page.

## 4 VERSION HISTORY

Version	Date	Version Changes
Version 2	November 2015	First public data release
Version 3	April 2016	Changes to this version include: Transitioned to Validated-Stage 1 Uses SPL2SMA V3 Validated data as input; inherited all changes and improvements of the new version

## 5 RELATED DATA SETS

[SMAP Data at NSIDC | Overview](#)

[SMAP Radar Data at the ASF DAAC](#)

## 6 RELATED WEBSITES

[SMAP at NASA JPL](#)

## 7 CONTACTS AND ACKNOWLEDGMENTS

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## 9 DOCUMENT INFORMATION

### 9.1 Publication Date

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07 January 2019

### 9.2 Date Last Updated

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03 December 2020

# 1 APPENDIX A – DATA FIELDS

This Appendix provides a description of all data fields within the *SMAP L3 Radar Global Daily 3 km EASE-Grid Soil Moisture* product. The data are grouped into four main HDF5 groups:

- Ancillary\_Data
- Metadata
- Radar\_Data
- Soil\_Moisture\_Retrieval\_Data

For a description of metadata fields for this product, refer to the [Product Specification Document](#).

## 1.1 Ancillary\_Data

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Table A1 describes the data fields of a typical SPL3SMA descending half-orbit granule. All data element arrays are one-dimensional with a size N, where N is the number of valid cells from the radar swath that appear on the grid.

Table A - 1. Data Fields for Ancillary\_Data

Data Field Name	Shape	Concept	Byte	Signed	Unit	Min	Max	Fill/Gap Value
bare_soil_roughness_tabular	LatCell_LonCell_Array	real	4	N/A	meters	0.0	0.1	-9999.0
faraday_rotation_angle	LatCell_LonCell_Array	real	4	N/A	degrees	-999999.9	999999.9	-9999.0
landcover_class	LatCell_LonCell_Array	enum	1	N/A	N/A	N/A	N/A	254
normalized_difference_vegetation_index	LatCell_LonCell_Array	real	4	N/A	normalized	-1.0	10.0	-9999.0
static_water_body_fraction	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
surface_temperature	LatCell_LonCell_Array	real	4	N/A	degrees Celsius	-50.0	60.0	-9999.0
vegetation_water_content_NDVI	LatCell_LonCell_Array	real	4	N/A	kg/m**3	0.0	10.0	-9999.0
vegetation_water_content_RVI	LatCell_LonCell_Array	real	4	N/A	kg/m**3	0.0	10.0	-9999.0

## 1.2 Radar\_Data

All data element arrays are one-dimensional with a size N, where N is the number of valid cells from the radar swath that appear on the grid (Table A2).

Table A - 2. Data Fields for Radar\_Data

Data Field Name	Shape	Concept	Byte	Signed	Unit	Min	Max	Fill/Gap Value
altitude_std_dev	LatCell_LonCell_Array	real	4	N/A	meters	0.0	1000.0	-9999.0
cell_radar_mode_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	N/A	65534
earth_boresight_azimuth_aft	LatCell_LonCell_Array	real	4	N/A	degrees	0.0	360.0	-9999.0
earth_boresight_azimuth_fore	LatCell_LonCell_Array	real	4	N/A	degrees	0.0	360.0	-9999.0
kp_hh	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_hh_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_hh_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_vv	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_vv_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_vv_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_xpol	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_xpol_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
kp_xpol_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	1.0	-9999.0
sigma0_hh_mean	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_hh_mean_aft	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_hh_mean_fore	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_hh_std_dev	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0

Data Field Name	Shape	Concept	Byte	Signed	Unit	Min	Max	Fill/Gap Value
sigma0_hh_std_dev_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_hh_std_dev_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_vv_mean	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_vv_mean_aft	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_vv_mean_fore	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_vv_std_dev	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_vv_std_dev_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_vv_std_dev_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_xpol_mean	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_xpol_mean_aft	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_xpol_mean_fore	LatCell_LonCell_Array	real	4	N/A	normalized	-0.01	10.0	-9999.0
sigma0_xpol_std_dev	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_xpol_std_dev_aft	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0
sigma0_xpol_std_dev_fore	LatCell_LonCell_Array	real	4	N/A	normalized	0.0	5.0	-9999.0

## 1.3 Soil\_Moisture\_Retrieval\_Data

All data element arrays are one-dimensional with a size N, where N is the number of valid cells from the radar swath that appear on the grid (Table A

Table A - 3. Data Fields for Soil\_Moisture\_Retrieval\_Data

Data Field Name	Shape	Concept	Byte	Signed	Unit	Min	Max	Fill/Gap Value
EASE_column_index	LatCell_LonCell_Array	integer	2	false	count	0	65535	65534
EASE_row_index	LatCell_LonCell_Array	integer	2	false	count	0	65535	65534
bare_soil_roughness_retrieved	LatCell_LonCell_Array	real	4	N/A	meters	0.0	0.05	-9999.0
distance_from_nadir	LatCell_LonCell_Array	real	4	N/A	meters	0.0	500000.0	-9999.0
latitude	LatCell_LonCell_Array	real	4	N/A	degrees_north	-90.0	90.0	N/A
longitude	LatCell_LonCell_Array	real	4	N/A	degrees_east	-180.0	180.0	N/A
num_input_sigma0s_hh	LatCell_LonCell_Array	integer	2	false	count	0	100	65534
num_input_sigma0s_vv	LatCell_LonCell_Array	integer	2	false	count	0	100	65534
num_input_sigma0s_xpol	LatCell_LonCell_Array	integer	2	false	count	0	100	65534
num_time_series	LatCell_LonCell_Array	integer	1	false	count	0	255	254
radar_vegetation_index	LatCell_LonCell_Array	real	4	N/A	normalized	-999999.9	999999.9	TBD
radar_water_flag3	LatCell_LonCell_Array	integer	1	false	count	0	255	254
retrieval_qual_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	N/A	65534
retrieval_qual_flag_change_index	EASEGridCell_Array	bit flag	2	N/A	N/A	N/A	N/A	65534
retrieval_qual_flag_kvz	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	N/A	65534
sigma0_qual_flag_hh	LatCell_LonCell_Array	bit flag	4	N/A	N/A	N/A	N/A	4294967294
sigma0_qual_flag_vv	LatCell_LonCell_Array	bit flag	4	N/A	N/A	N/A	N/A	4294967294

Data Field Name	Shape	Concept	Byte	Signed	Unit	Min	Max	Fill/Gap Value
sigma0_qual_flag_xpol	LatCell_LonCell_Array	bit flag	4	N/A	N/A	N/A	N/A	4294967294
soil_moisture	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
soil_moisture_change_index	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
soil_moisture_error	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.0	0.2	-9999.0
soil_moisture_kvz	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
soil_moisture_snapshot <sup>1</sup>	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
soil_moisture_snapshot_DVZ <sup>1</sup>	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
soil_moisture_snapshot_shi <sup>1</sup>	LatCell_LonCell_Array	real	4	N/A	cm <sup>3</sup> /cm <sup>3</sup>	0.02	0.5	-9999.0
spacecraft_overpass_time_seconds	LatCell_LonCell_Array	real	8	N/A	seconds	0.00000	999999.9	-9999.0
spacecraft_overpass_time_utc	LatCell_LonCell_Array	string	24	N/A	N/A	N/A	N/A	N/A
surface_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	N/A	65534
<sup>1</sup> Algorithms that are not currently being used for these data include Snapshot, Dubois/van Zyl (DVZ), and Shi. Thus, the data fields corresponding to these algorithms contain a fill value of -9999.0.								

## 1.4 Data Field Definitions

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**bare\_soil\_roughness\_tabular**

Measure of soil roughness from tabular source.

**faraday\_rotation\_angle**

Faraday rotation angle.

**landcover\_class**

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

Table A - 4. Landcover Classification Values

Value	Description
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

**normalized\_difference\_vegetation\_index**

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

**static\_water\_body\_fraction**

The fraction of the area of the 3 km grid cell that is covered by static water based on a Digital Elevation Map.

**surface\_temperature**

Temperature at land surface based on ancillary data.

**vegetation\_water\_content\_NDVI**

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

**vegetation\_water\_content\_RVI**

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

**altitude\_std\_dev**

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

**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.

Table A - 5. Bit Values and Interpretation

Bit Position	Bit Value and Interpretation
0	0 = Radar is operating in transmit-receive mode
	1 = Radar is operating in receive only mode
1	Always clear (This bit is used to designate the nadir region in Level 1. It is redundant in Level 2.)
2	0 = Cross polarized data are v-pol transmitted; h-pol received.
	1 = Cross polarized data are h-pol transmitted; v-pol received.
3	0 = Cross polarized data are consistent within this EASE grid cell.
	1 = Cross polarized data are in transition, some are v-pol transmitted, h-pol received, others are h-pol transmitted, v-pol received.
4-15	Always clear (Bits 5 through 7 are reserved for Radar Level 1C use. Bits 8 through 15 are reserved for Level 2 use.)

**earth\_boresight\_azimuth\_aft**

Mean direction of the projection of the antenna boresight vector on the Earth's surface relative to North for aft looking  $\sigma_0$ s within 3 km cell. Level 1C azimuth is based on instrument coordinate system, not geographical North.

**earth\_boresight\_azimuth\_fore**

Mean direction of the projection of the antenna boresight vector on the Earth's surface relative to North for forward looking  $\sigma_0$ s within 3 km cell. Level 1C azimuth is based on instrument coordinate system, not geographical North.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**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.

**sigma0\_hh\_mean**

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

**sigma0\_hh\_mean\_aft**

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

**sigma0\_hh\_mean\_fore**

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

**sigma0\_hh\_std\_dev**

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

**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.

**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.

**sigma0\_vv\_mean**

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

**sigma0\_vv\_mean\_aft**

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

**sigma0\_vv\_mean\_fore**

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

**sigma0\_vv\_std\_dev**

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

**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.

**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.

**sigma0\_xpol\_mean**

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

**sigma0\_xpol\_mean\_aft**

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

**sigma0\_xpol\_mean\_fore**

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

**sigma0\_xpol\_std\_dev**

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

**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.

**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.

**EASE\_column\_index**

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

**EASE\_row\_index**

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

**bare\_soil\_roughness\_retrieved**

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

**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.

**latitude**

Latitude of the center of the Earth based grid cell.

**longitude**

Longitude of the center of the Earth based grid cell.

**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.

**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.

**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.

**num\_time\_series**

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

**radar\_vegetation\_index**

Vegetation index derived from radar backscatter.

**radar\_water\_flag3**

Radar waterbody flag at 3km.

**retrieval\_qual\_flag**

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

Table A - 6. Quality Bit Flag Definitions

Name	Bit Position	Interpretation of Values (0:off, 1:on)
Retrieval recommended flag	0	0: Use of the soil moisture value retrieved for this pixel is recommended.
		1: Use of soil moisture value retrieved for this pixel is not recommended.
Retrieval attempted flag	1	0: The algorithm attempted to retrieve soil moisture for this grid cell.
		1: The algorithm did not attempt to retrieve soil moisture for this grid cell.
Retrieval success flag	2	0: Retrieval for this algorithm was successfully executed or the algorithm was not attempted.
		1: The retrieval for this algorithm was attempted but failed.
Radar water body detection success flag	3	0: Radar water body detection ran successfully.
		1: Unable to detect water bodies using retrieval techniques based on radar.
Freeze-thaw retrieval success flag	4	0: Freeze-thaw retrieval ran successfully.
		1: Unable to ascertain freeze-thaw conditions.
Radar vegetation index retrieval success flag	5	0: Radar vegetation index retrieval ran successfully.
		1: Radar vegetation index retrieval unsuccessful.

**retrieval\_qual\_flag\_change\_index**

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

**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.

**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.

**sigma0\_qual\_flag\_hh**

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

Table A - 7. Sigma Quality Bit Flag Definitions

Name	Bit Position	Description of Values (0: off, 1: on)
Mean horizontal polarization quality flag	0	0: The mean of the forward looking and aft looking horizontal polarization sigma0s has acceptable quality.
		1: The mean of the forward looking and aft looking horizontal polarization sigma0s does not have acceptable quality.
Forward looking horizontal polarization quality flag	1	0: The forward looking horizontal polarization sigma0 has acceptable quality.
		1: The forward looking horizontal polarization sigma0 has questionable or poor quality.
Aft looking horizontal polarization quality flag	2	0: The aft looking horizontal polarization sigma0 has acceptable quality.
		1: The aft looking horizontal polarization sigma0 has questionable or poor quality.
Mean horizontal polarization range flag	3	0: The mean of the forward looking and aft looking horizontal polarization sigma0s falls within the expected range.
		1: The mean of the forward looking and aft looking horizontal polarization sigma0s is out of range.
Forward looking horizontal polarization range flag	4	0: The forward looking horizontal polarization sigma0 falls within the expected range.
		1: The forward looking horizontal polarization sigma0 is out of range.
Aft looking horizontal polarization range flag	5	0: The aft looking horizontal polarization sigma0 falls within the expected range.
		1: The aft looking horizontal polarization sigma0 is out of range.
Mean horizontal polarization RFI clean flag	6	0: Insignificant RFI detected in the mean of the forward looking and aft looking horizontal polarization sigma0s.
		1: 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	0: Some components of the mean of the forward looking and aft looking horizontal polarization sigma0s are based on repairs for RFI contamination.

Name	Bit Position	Description of Values (0: off, 1: on)
		1: 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	0: Insignificant RFI detected in the forward looking horizontal polarization sigma0s.
		1: RFI level is unsuitably high for the forward looking horizontal polarization sigma0s.
Forward looking horizontal polarization RFI repair flag	9	0: At least one of the input forward looking horizontal polarization sigma0s is based on repairs for RFI contamination.
		1: Unable to repair the forward looking horizontal polarization sigma0s for RFI contamination.
Aft looking horizontal polarization RFI clean flag	10	0: Insignificant RFI detected in the aft looking horizontal polarization sigma0s.
		1: RFI level is unsuitably high for the aft looking horizontal polarization sigma0s.
Aft looking horizontal polarization RFI repair flag	11	0: At least one of the input aft looking horizontal polarization sigma0s is based on repairs for RFI contamination.
		1: Unable to repair the aft looking horizontal polarization sigma0s for RFI contamination.
Mean horizontal polarization Faraday Rotation Flag	12	0: Faraday Rotation has little or no impact on the mean of the forward looking and aft looking horizontal polarization sigma0s.
		1: 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	0: Faraday Rotation has little or no impact on the forward looking horizontal polarization sigma0.
		1: Faraday Rotation has significant impact on the forward looking horizontal polarization sigma0.
Aft looking horizontal polarization Faraday Rotation Flag	14	0: Faraday Rotation has little or no impact on the aft looking horizontal polarization sigma0.
		1: Faraday Rotation has significant impact on the aft looking horizontal polarization sigma0.

Name	Bit Position	Description of Values (0: off, 1: on)
Mean horizontal polarization Kp flag	15	0: Kp for the mean of the forward and aft looking horizontal polarization sigma0s is acceptably low.
		1: Kp for the mean of forward and aft looking horizontal polarization sigma0s is unacceptably high.
Forward looking horizontal polarization Kp flag	16	0: Kp for the forward looking horizontal polarization sigma0 is acceptably low.
		1: Kp for the forward looking horizontal polarization sigma0 is unacceptably high.
Aft looking horizontal polarization Kp flag	17	0: Kp for the aft looking horizontal polarization sigma0 is acceptably low.
		1: Kp for the aft looking horizontal polarization sigma0 is unacceptably high.

**sigma0\_qual\_flag\_vv**

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

**sigma0\_qual\_flag\_xpol**

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

**soil\_moisture**

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

**soil\_moisture\_change\_index**

Retrieved normalized change in soil moisture.

**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.

**soil\_moisture\_kvz**

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

**soil\_moisture\_snapshot**

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

**soil\_moisture\_snapshot\_DVZ**

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

**soil\_moisture\_snapshot\_shi**

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

**soil\_moisture\_time\_series**

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

**spacecraft\_overpass\_time\_seconds**

Number of seconds since a specified epoch (J2000) that represents the spacecraft overpass relative to ground swath.

**spacecraft\_overpass\_time\_utc**

Time of spacecraft overpass relative to ground swath in UTC.

**surface\_flag**

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

Table A - 8. Surface Quality Bit Flag Definitions

Name	Bit Position	Description of Values (0: off, 1: on)
3 km static water body flag	0	0: 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.
		1: 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	0: Radar retrieval algorithm did not detect significant surface water within the 3 km grid cell.
		1: Radar retrieval algorithm detected significant surface water within the 3 km grid cell.
3 km urban area flag	2	0: The fraction of the 3 km grid cell area that is over urban development is less than metadata element UrbanAreaThreshold.
		1: 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	0: No precipitation detected within the 3 km grid cell when data were being acquired.
		1: Precipitation detected within the 3 km grid cell when data were being acquired
3 km snow or ice flag	4	0: No snow or ice detected within the 3 km grid cell.
		1: Snow and/or ice were detected within the 3 km grid cell.
3 km permanent snow or ice flag	5	0: The fraction of the 3 km grid cell area that is over permanent snow or ice is less than a specified algorithmic threshold.
		1: 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	0: No frozen ground detected within the 3 km grid cell.
		1: Frozen ground detected within the 3 km grid cell.
3 km mountainous terrain flag	7	0: The variability of land elevation in the 3 km grid cell is less than metadata element MountainousTerrainThreshold.

Name	Bit Position	Description of Values (0: off, 1: on)
		1: 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	0: The vegetation density within the 3 km grid cell is less than metadata element DenseVegetationThreshold.
		1: 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	0: 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.
		1: 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	0: 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.
		1: 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.

## 1.5 Fill/Gap Values

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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 SPL3SMA Product when the SPL3SMA 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 SPL3SMA 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 SPL3SMA 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 SPL3SMA SPS will most likely be able to generate some output. However, some portion of the SPL3SMA 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.

No valid value in the SPL3SMA product is equal to the values that represent fill. If any exceptions should exist in the future, the SPL3SMA 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 SPL3SMA product records gaps when entire frames within the time span of a particular data granule do not appear. Gaps can occur under one of two conditions:

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

The Level 3\_SM\_A Product records gaps in the product level metadata. The following conditions will indicate that no gaps appear in the data product:

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

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

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

## 1.6 Notations

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Table A - 9. Notation Definitions

Notation	Definition
Int8	8-bit (1-byte) signed integer
Int16	16-bit (2-byte) signed integer
Int32	32-bit (4-byte) signed integer
UInt8	8-bit (1-byte) unsigned integer
UInt16	16-bit (2-byte) unsigned integer
Float32	32-bit (4-byte) floating-point integer
Float64	64-bit (8-byte) floating-point integer
Char	8-bit character
H-pol	Horizontally polarized
V-pol	Vertically polarized