SMAP L3 Radar/Radiometer Global Daily 9 km EASE-Grid Soil Moisture, Version 3

USER GUIDE

How to Cite These Data

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

Entekhabi, D., N. Das, E. G. Njoku, J. T. Johnson, and J. Shi. 2016. SMAP L3 Radar/Radiometer Global Daily 9 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/10.5067/7KKNQ5UURM2W. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL3SMAP

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

Surface soil moisture (0-5 cm) in cm3/cm3 derived from brightness temperature and sigma nought measurements is output on a fixed 9 km EASE-Grid 2.0.

Brightness temperature (TB) is a measure of the radiance of the microwave radiation welling upward from the top of the atmosphere to the satellite. The SMAP L-Band Radiometer measures four brightness temperature Stokes parameters: TH, TV, T3, and T4 at 1.41 GHz. TH and TV are the horizontally and vertically polarized brightness temperatures, respectively, and T3 and T4 are the third and fourth Stokes parameters, respectively.

Sigma nought (sigma0), 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 sigma0 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. Sigma0 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

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 74 MB.

File Volume
The daily data volume is approximately 74 MB.

1.2.2 File Contents

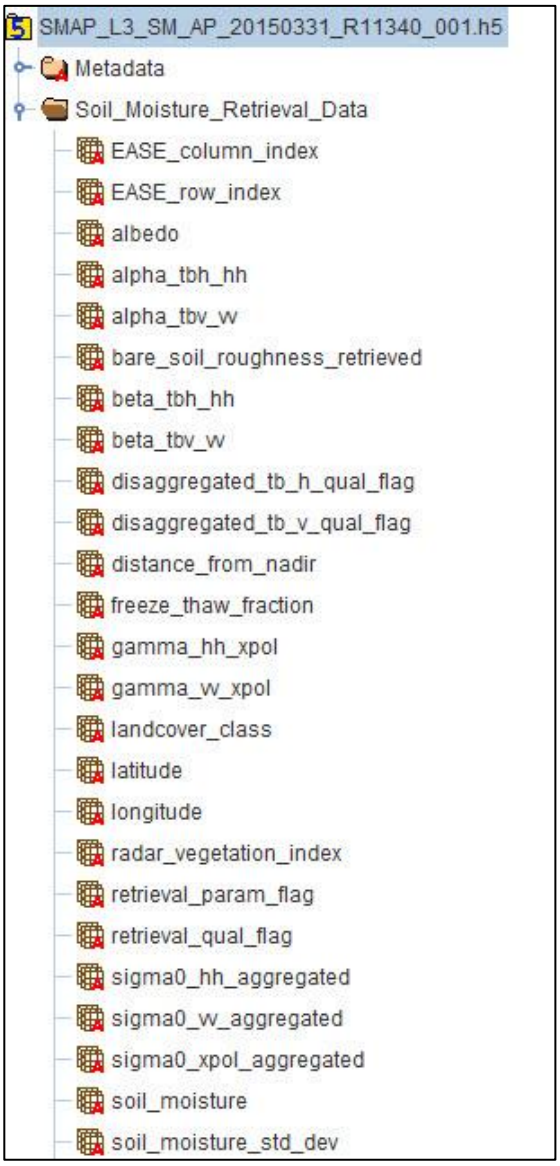

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-3 radar/radiometer soil moisture product, refer to the Appendix.

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 swath that appear on the grid.

SOIL MOISTURE RETRIEVAL DATA

Includes all combined radar and radiometer soil moisture data, ancillary data, and quality assessment flags.

1.2.2.2 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.

1.2.3 Naming Convention

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

SMAP_L3_SM_AP_yyyymmdd_RLVvvv_NNN.[ext]

For example:

SMAP_L3_SM_AP_20151225_R13171_002.h5

Where:

Table 1. File Naming Conventions

Variable	Description
SMAP	Indicates SMAP mission data
L3_SM_AP	Indicates specific product (L3: Level-3; SM: Soil Moisture; AP: Active/Passive)
yyyymmdd	4-digit year, 2-digit month, 2-digit day; date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product.
RLVvvv	Composite Release ID, where: R — Release L — Launch Indicator (1: Post-launch standard data) V — 1-Digit Major Version Number vvv — 3-Digit Minor Version Number **Example:** R13171 indicates a standard data product with a version of 3.171. Refer to the SMAP Data Versions page for version information.
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

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

SMAP 3 km Synthetic Aperture Radar (SAR) backscatter data and 36 km radiometer brightness temperature data are combined using the SMAP Active-Passive algorithm to create soil moisture data that are then gridded using the 9 km EASE-Grid 2.0 global 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 9 x 9 km2 regardless of longitude and latitude. The SPL3SMAP data product is posted on a 9 km EASE-Grid that is nested consistently with the 36 km brightness temperatures and 3 km radar backscatter cross-section data. Figure 2 shows a schematic of the nesting to a resolution of 3 km (4872 rows x 11568 columns on global coverage), 9 km (1624 rows x 3856 columns on global coverage) and 36 km (406 rows x 964 columns on global coverage).

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.

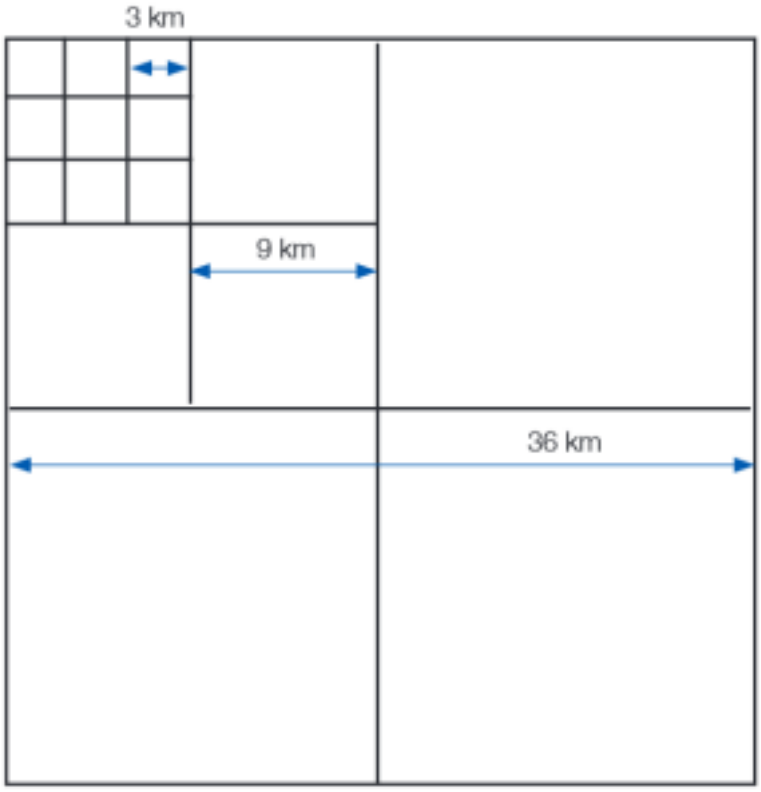

Figure 2. Perfect Nesting in EASE-Grid 2.0

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 13 April 2015 through 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).

1.4.2 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

1.4.3 Resolution

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

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The goal of SMAP mission is to combine the favorable attributes of SMAP L-Band Radar and Radiometer observations in terms of their spatial resolution and sensitivity to soil moisture, surface roughness, and vegetation in order to estimate soil moisture at a resolution of 10 km, and freeze-thaw state at a resolution of 1-3 km. Microwave radiometry and radar are well-established techniques for surface remote sensing. Combining passive and active sensors provides complementary information contained in the surface emissivity and backscatter signatures, which make it possible to obtain optimal accuracy of retrieved soil moisture at higher resolutions. Over land, it has been demonstrated that L-band radiometer and radar measurements both provide information to retrieve optimal soil moisture estimates (Das et al. 2011, Das et al. 2014, and Das et al. 2015).

2.2 Acquisition

SMAP Level-3 radar/radiometer soil moisture data (SPL3SMAP) are composited from SMAP L2 Radar/Radiometer Global Daily 9 km EASE-Grid Soil Moisture, Version 3 (SPL2SMAP).

2.3 Derivation Techniques and Algorithms

The SMAP Level-3 radar and radiometer soil moisture data set is a daily gridded composite of the SMAP L2 Radar/Radiometer Global Daily 9 km EASE-Grid Soil Moisture, Version 3 (SPL2SMAP) data set. The derivation of soil moisture from SMAP brightness temperatures occurs in the Level-2 processing of the separate radar and radiometer data sets.

Please refer to the Derivation Techniques section in the SPL2SMAP user guide for details on algorithms and ancillary data.

2.4 Processing

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate the standard SPL3SMAP product, the processing software ingests one day's worth of SPL2SMAP files and creates individual

global composites as two-dimensional arrays for each output parameter defined in the SPL2SMAP product. Wherever data overlap occurs (typically at high latitudes), data acquired closest to the 6:00 a.m. local solar time are chosen. Because the input SPL2SMAP files are available only for descending 6:00 a.m. passes, the resulting SPL3SMAP files are available only for descending 6:00 a.m. passes.

2.5 Quality, Errors, and Limitations

2.6 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. The SMAP radiometer implements a combination of time and frequency diversity, kurtosis detection, and use of T4 thresholds to detect and, where possible, mitigate RFI.

Other sources of error, such as disaggregation process errors and calibration and gridding errors, are quantified analytically for the disaggregated brightness temperatures and retrieved soil moisture at 9 km and 3 km. (Entekhabi et al. 2012 and Das et al. 2015)

For more information, refer to the Error Sources section of the SMAP L2 Radar/Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 3 (SPL2SMAP) user guide.

2.7 Quality Assessment

For in-depth details regarding the quality of these Version 3 Validated data, refer to the Beta Assessment Report.

2.8 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 of this document or the Product Specification Document.

Each HDF5 file contains metadata with Quality Assessment (QA) metadata flags that are set by the 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 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 fails QA, it is never delivered to NSIDC DAAC.

2.9 Data Flags

Bit flags generated from input SMAP data and ancillary data are also employed to help determine the quality of the retrievals. Ancillary data help determine either specific aspects of the processing (such as corrections for transient water) or the quality of the retrievals (e.g. precipitation flag). These flags will 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 will 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 Data Flags section in the SPL2SMAP user guide.

2.10 Instrumentation

2.10.1 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	Date	Version Changes
Version 3	April 2016	Changes to this version include: Transitioned to Validated-Stage 2 Using SPL2SMAP V3 Validated data as input

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

O7 January 2020

9.2 Date Last Updated

03 December 2020

1 APPENDIX A – APPENDIX A TITLE

This page provides a description of all data fields within the SMAP L3 Radar/Radiometer Global Daily 9 km EASE-Grid Soil Moisture product. The data are grouped into two main HDF5 groups:

- Metadata
- Soil_Moisture_Retrieval_Data

For a description of metadata fields for this product, refer to the Product Specification Document.

Soil_Moisture_Retrieval_Data

Table A1 describes the data fields of a typical SPL3SMAP 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 radiometer swath that appear on the grid.

Table A - 1. Data Fields for Soil_Moisture_Retrieval_Data

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Values
EASE_column_index	LatCell_LonCell_Array	integer	2	count	0	65535	65534
EASE_row_index	LatCell_LonCell_Array	integer	2	count	0	65535	65534
albedo	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0
alpha_tbh_hh	LatCell_LonCell_Array	real	4	Kelvins	0	350.0	-9999.0
alpha_tbv_vv	LatCell_LonCell_Array	real	4	Kelvins	0	350.0	-9999.0
bare_soil_roughness_retrieved	LatCell_LonCell_Array	real	4	meters	0.0	0.1	-9999.0
beta_tbh_hh	LatCell_LonCell_Array	real	4	Kelvins/dB	-25	0	-9999.0
beta_tbv_vv	LatCell_LonCell_Array	real	4	Kelvins/dB	-25	0	-9999.0
distance_from_nadir	LatCell_LonCell_Array	real	4	meters	0.0	500000.0	-9999.0
freeze_thaw_fraction	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0
gamma_hh_xpol	LatCell_LonCell_Array	real	4	normalized	0	2	-9999.0
gamma_vv_xpol	LatCell_LonCell_Array	real	4	normalized	0	2	-9999.0
landcover_class	LatCell_LonCell_Array	enum	1	N/A	N/A	N/A	254
latitude	LatCell_LonCell_Array	real	4	degrees_north	-90.0	90.0	N/A
longitude	LatCell_LonCell_Array	real	4	degrees_east	-180.0	180.0	N/A
radar_vegetation_index	LatCell_LonCell_Array	real	4	normalized	0	2	-9999.0
retrieval_qual_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	65534
sigma0_hh_aggregated	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_vv_aggregated	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_xpol_aggregated	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0
soil_moisture	LatCell_LonCell_Array	real	4	cm3/cm3	0.02	0.5	-9999.0

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Values
soil_moisture_std_dev	LatCell_LonCell_Array	real	4	cm3/cm3	0.0	0.2	-9999.0
spacecraft_overpass_time_seconds	LatCell_LonCell_Array	real	8	seconds	0	999999.9	-9999.0
spacecraft_overpass_time_utc	LatCell_LonCell_Array	string	24	N/A	N/A	N/A	N/A
surface_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	65534
surface_temperature	LatCell_LonCell_Array	real	4	degrees Celsius	-50.0	60.0	-9999.0
tb_h_disaggregated	LatCell_LonCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_h_disaggregated_qual_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	65534
tb_h_disaggregated_std	LatCell_LonCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
tb_v_disaggregated	LatCell_LonCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_v_disaggregated_qual_flag	LatCell_LonCell_Array	bit flag	2	N/A	N/A	N/A	65534
tb_v_disaggregated_std	LatCell_LonCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
vegetation_opacity	LatCell_LonCell_Array	real	4	normalized	0	1	-9999.0
vegetation_water_content	LatCell_LonCell_Array	real	4	kg/m2	0.0	30	-9999.0
water_body_fraction	LatCell_LonCell_Array	real	4	normalized	0.0	1.0	-9999.0

1.1 Data Field Definitions

EASE_column_index

EASE grid cell at 9 km row index on world grid in longitude direction.

EASE_row_index

EASE grid cell at 9 km row index on world grid in latitude direction.

albedo

Diffuse reflecting power of the Earth's surface within the grid cell at 9 km.

alpha_tbh_hh

Alpha parameter derived for the corresponding EASE2 grid cell at the most recent prior instance when the grid cell was processed. Prior alpha is derived from the time series of brightness temperature at 36 km EASE2 grid and aggregated co-pol (hh) backscatter at 36 km EASE2 grid. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

alpha_tbv_vv

Alpha parameter derived for the corresponding EASE2 grid cell at the most recent prior instance when the grid cell was processed. Prior alpha is derived from the time series of brightness temperature at 36 km EASE2 grid and aggregated co-pol (vv) backscatter at 36 km EASE2 grid. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

bare_soil_roughness_retrieved

Roughness coefficient at 9-km spatial scale. Note that this parameter is the same ‘h’ coefficient in the ‘tau-omega’ model for a given polarization channel.

beta_tbh_hh

Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbh and sigma0_hh.

beta_tbh_vv

Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell, derived using time series Tbv and sigma0_vv.

distance_from_nadir

The distance from the center of the 9 km EASE grid cell to the spacecraft's sub-nadir track on the Earth's surface.

freeze_thaw_fraction

Fraction of the 9 km grid cell that is denoted as frozen. Based on binary flag that specifies freeze thaw conditions in each of the component 3 km grid cells.

gamma_hh_xpol

Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (hh) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 36 km grid cell. The valid minimum and maximum below are subject to further analysis.

gamma_vv_xpol

Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE grid cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (vv) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 36 km grid cell. The valid minimum and maximum below are subject to further analysis.

landcover_class

An enumerated type that specifies the predominant surface vegetation found in the EASE2 grid cell at 9-km. See Table A2 for more details.

Table A - 2. 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

Value	Description
9	Savanna
10	Grassland
11	Mixed forest
12	Closed shrubland
13	Open shrubland
14	Woody savanna
15	Savanna
16	Grassland
>16	TBD

latitude
Latitude of the center of the Earth based grid cell at 9 km.

longitude
Longitude of the center of the Earth based grid cell at 9 km.

radar_vegetation_index
Radar vegetation index derived from the co-pol and cross-pol radar backscatter data aggregated to 9-km mentioned in sections 4.6.10, 4.6.11, and 4.6.12.

Radar vegetation index = 8*(sigma0_hv) / (sigma0_vv + sigma0_hh + 2* sigma0_hv)

In the above equation, sigma0_hh, sigma0_vv, and sigma0_hv are from Sections 4.6.10, 4.6.11, and 4.6.12, respectively. The valid minimum and maximum below are subject to further analysis.

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

Table A - 3. Quality Bit Flag Definitions

Name	Bit Position	Description 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.
Disaggregated brightness temperature quality	6	0: Disaggregated brightness temperature retrieval ran successfully.
		1: Unable to disaggregate brightness temperatures into 9 km resolution cells.

sigma0_hh_aggregated
The outcome of aggregating a set of 3-km co-pol horizontal polarization radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_vv_aggregated
The outcome of aggregating a set of 3-km co-pol vertical polarization radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_xpol_aggregated
The outcome of aggregating a set of 3-km cross-polarization (*hv* or *vh*) radar backscatter measurements that are encompassed within 9 km EASE2 grid cell. This aggregated radar backscatter at 9-km does not include the undesirable 3-km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

soil_moisture
Retrieved soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9-km grid cell.

soil_moisture_std_dev
Estimated ‘1-sigma’ error of the soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis.

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

spacecraft_overpass_time_utc
The 9-km EASE2-Grid cell is assigned the UTC time of 36-km EASE2-Grid cell that is used for downscaling. The field describes the average of UTC acquisition times, in ASCII representation, of L1B_TB observations whose boresights fall within a 36-km EASE2-Grid cell.

surface_flag
Bit flags that record ambient surface conditions for the grid cell at 9-km.

Table A - 4. Quality Bit Flag Definitions

Name	Bit Position	Description of Values (0:off, 1:on)
9 km static water body flag	0	0: The fraction of the 9 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 9 km grid cell area that is over a permanent water body is greater than or equal to metadata element PermanentWaterBodyThreshold. Determined by DEM.
9 km radar water body detection flag	1	0: Flag indicates either water less than given threshold, or water that was not detected in locations other than were permanent water is known to exist.
		1: Flag indicates either water greater than given threshold, or water that was detected in locations other than were permanent water is known to exist.
9 km urban area flag	2	0: The fraction of the 9 km grid cell area that is over urban development is less than metadata element UrbanAreaThreshold.
		1: The fraction of the 9 km grid cell area that is over urban development is greater than or equal to metadata element UrbanAreaThreshold.
9 km precipitation flag	3	0: No precipitation detected within the 9 km grid cell when data were being acquired.
		1: Precipitation detected within the 9 km grid cell when data were being acquired
9 km snow or ice flag	4	0: No or insignificant quantities of snow or ice were detected within the 9 km cell.
		1: Significant quantities of snow and/or ice were detected within the 9 km grid cell.
9 km permanent snow or ice flag	5	0: The fraction of the 9 km grid cell area that is over permanent snow or ice is less than a specified algorithmic threshold.
		1: The fraction of the96 km grid cell area that is over permanent snow or ice is greater than or equal to a specified algorithmic threshold.
9 km frozen ground flag	6	0: No frozen ground detected within the 9 km grid cell.
		1: Frozen ground detected within the 9 km grid cell.

Name	Bit Position	Description of Values (0:off, 1:on)
9 km mountainous terrain flag	7	0: The variability of land elevation in the 9 km grid cell is less than metadata element MountainousTerrainThreshold.
		1: The variability of land elevation in the 9 km grid cell is greater than or equal to metadata element MountainousTerrainThreshold.
9 km dense vegetation flag	8	0: The vegetation density within the 9 km grid cell is less than metadata element DenseVegetationThreshold.
		1: The vegetation density within the 9 km grid cell area is greater than or equal to metadata element DenseVegetationThreshold.
9 km nadir region flag	9	0: Data within the grid cell were not acquired in the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
		1: A significant fraction (TBD) of the 9 km grid cell data were acquired within the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
9 km coastal mask flag	10	0: Data within the grid cell were not acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
		1: Data within the grid cell were acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.

surface_temperature
Soil temperature (averaged over the top 5-cm soil layer) at 9-km spatial scale. This parameter is used as input ancillary data parameter to the SPL2SMAP processing software for the baseline algorithms. The valid minimum and maximum below are subject to further analysis on real data.

tb_h_disaggregated
Horizontal polarization brightness temperature at 9-km obtained by disaggregating/downscaling the 36 km EASE grid cells horizontal polarization brightness temperature.

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

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

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

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

Table A - 5. Quality Bit Flag Definitions

Name	Bit Position	Description of Values (0:off, 1:on)
Disaggregated brightness temperature v-pol quality	0	0: Disaggregated vertical polarization brightness temperature has acceptable quality.
		1: Unable to disaggregate vertical polarization brightness temperatures into 9 km resolution cells.
Sigma0_vv quality flag	1	0: All vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		1: Some vertical polarization sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Sigma0_xpol quality flag	2	0: All cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures were deemed as good quality.
		1: Some cross polarized sigma0 input that contributed to disaggregation of vertical polarization brightness temperatures was of questionable or poor quality.
Brightness temperature v-pol quality flag	3	0: Vertical polarization brightness temperature input that was used for disaggregation was deemed as good quality.
		1: Some vertical polarization brightness temperature input that was used for soil moisture retrieval was of questionable or poor quality.
Brightness temperature v-pol RFI detected flag	4	0: Insignificant levels of RFI detected in the vertical polarization radiometer brightness temperature input.
		1: Significant levels of RFI were detected in the vertical polarization radiometer brightness temperature input.
Brightness temperature v-pol RFI corrected flag	5	0: The vertical polarization radiometer brightness temperature input is based on data that were repaired for the effects of RFI.
		1: Unable to repair the vertical polarization radiometer brightness temperature input for the effects of RFI.
Sigma0_vv RFI detected flag	6	0: Insignificant levels of RFI detected in the vertical polarization radar sigma0 input.

Name	Bit Position	Description of Values (0:off, 1:on)
		1: Significant levels of RFI were detected in the vertical polarization radar sigma0 input.
Sigma0_vv RFI corrected flag	7	0: The input for retrieval is based on vertical polarization radar sigma0s that were repaired for the effects of RFI.
		1: Unable to repair the vertical polarization radar sigma0 input for the effects of RFI.
Sigma0_xpol RFI detected flag	8	0: Insignificant levels of RFI detected in the cross polarized radar sigma0 input.
		1: Significant levels of RFI were detected in the cross polarized radar sigma0 input.
Sigma0_xpol RFI corrected flag	9	0: The input for retrieval is based on cross polarized radar sigma0s that were repaired for the effects of RFI.
		1: Unable to repair the cross polarized radar sigma0 input for the effects of RFI.
Negative sigma0_vv flag	10	0: The input for retrieval is based on vertical polarization radar sigma0s that are greater than zero.
		1: The input for retrieval is based on vertical polarization radar sigma0s that are less than or equal to zero.
Negative sigma0_xpol flag	11	0: The input for retrieval is based on cross polarized radar sigma0s that are greater than zero.
		1: The input for retrieval is based on cross polarized radar sigma0s that are less than or equal to zero.

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

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

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

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

vegetation_water_content
Vegetation water content at 9-km spatial scale. This parameter is used as input ancillary data parameter to the SPL2SMAP processing software when the baseline algorithm is used. The valid minimum and maximum below are subject to further analysis.

water_body_fraction
Water body fraction at 9-km spatial scale. If there are NW water pixels and NL land pixels within a 9-km grid cell, this parameter refers to the fraction of NW / (NW + NL). Note that NW is the number of water pixels regardless of their temporal span. NW captures both static water pixels and transient water pixels. At present the SPL2SMAP processing software can be configured to provide this parameter from a static water fraction database or from the SPL2SMA product.

1.2 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 SPL3SMAP product when the Level 3_SM_AP 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 SPL3SMAP 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 SPL3SMAP 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 SPL3SMAP SPS will most likely be able to generate some output. However, some portion of the SPL3SMAP 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 SPL3SMAP product is equal to the values that represent fill. If any exceptions should exist in the future, the SPL3SMAP 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 SPL3SMAP 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 SPL3SMAP 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* wil l 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.

1.3 Notations

Table A - 6. 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