SMAP Enhanced L3 Radiometer Global and Polar Grid Daily 9 km EASE-Grid Soil Moisture, Version 6

USER GUIDE

How to Cite These Data

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

O'Neill, P. E., S. Chan, E. G. Njoku, T. Jackson, R. Bindlish, J. Chaubell, and A. Colliander. 2021. *SMAP Enhanced L3 Radiometer Global and Polar Grid Daily 9 km EASE-Grid Soil Moisture, Version 6*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/M20OXIZHY3RJ. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL3SMP_E

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Parameters

The main output of this data set is surface soil moisture (representing approximately the top 5 cm of the soil column on average, given in m^3/m^3) presented on the global and polar 9 km EASE-Grid 2.0 projections. The data fields on global and polar grids are organized in separate HDF5 data groups called Soil_Moisture_Retrieval_Data [AM|PM] and Soil_Moisture_Retrieval_Data_Polar [AM|PM], respectively. Each group contains the same data fields and their associated definitions. The polar grid projection offers a more uniform spatial sampling at high latitudes (less distortion than the global grid at these high latitudes), which will facilitate studies with soil moisture in the boreal and arctic regions.

Also included are brightness temperature (T_B) measurements (K), representing SMAP enhanced Level-1B brightness temperatures as resampled to the 9 km EASE2 grid (O'Neill et al., 2021a). Refer to the *Appendix – Data Fields* Section of this document for details on all parameters.

This product includes soil moisture retrievals from three algorithms:

- **Dual Channel Algorithm (DCA)**
- Single Channel Algorithm – Vertical polarization (SCA-V)
- Single Channel Algorithm – Horizontal polarization (SCA-H)

Beginning with **Version 5**, released in 2021, **the new baseline algorithm is the Dual Channel Algorithm (DCA). This marks a departure from prior versions** where the baseline algorithm was the Single Channel Algorithm-Vertical Polarization (SCA-V). The DCA has been shown to perform slightly better than SCA-V over some agricultural cropland core validation sites (CVS), although their overall performance is similar. Additional information about site performance can be found in the R18 Assessment Report (O'Neill et al., 2021b).

Table 1 shows soil moisture algorithms and their associated variables. **Error! Reference source not found.**

Table 1. Variables Associated with each Soil Moisture Algorithm Option

DCA	SCA-V	SCA-H
soil_moisture_dca^	soil_moisture_scav	soil_moisture_scah
vegetation_opacity_dca^	vegetation_opacity_scav	vegetation_opacity_scah
retrieval_quality_flag_dca^	retrieval_quality_flag_scav	retrieval_quality_flag_scah
roughness_coefficient_dca^	roughness_coefficient_scav	roughness_coefficient_scah
albedo_dca^	albedo_scav	albedo_scah
^ these variables also correspond to the pointer elements listed in the table below		

DCA	SCA-V	SCA-H
NOTE: The variable names in the Soil_Moisture_Retrieval_Data_[Polar_]PM data group have the suffix "_pm" attached.		

The baseline retrieval algorithm is linked to the pointer elements for soil_moisture, vegetation_opacity, retrieval_quality_flag, roughness_coefficient, and albedo, as shown in Table 2.

Table 2. Pointer Elements and Corresponding Variables

Pointer Element	Variable
soil_moisture[_pm]	soil_moisture_dca[_pm]
vegetation_opacity[_pm]	vegetation_opacity_dca[_pm]
retrieval_quality_flag[_pm]	retrieval_quality_flag_dca[_pm]
roughness_coefficient[_pm]	roughness_coefficient_dca[_pm]
albedo[_pm]	albedo_dca[_pm]

For a more extensive discussion of the algorithms, users should refer to the SPL2/3SMP/_E Algorithm Theoretical Basis Document, or ATBD (O'Neill et al., 2021a).

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 website.

1.2.2 File Contents

As shown in Figure 1, each HDF5 file is organized into group, Metadata, Soil_Moisture_Retrieval_Data_[AM|PM], and Soil_Moisture_Retrieval_Data_ Polar_[AM|PM], all of which contain sub-groups and/or data sets:

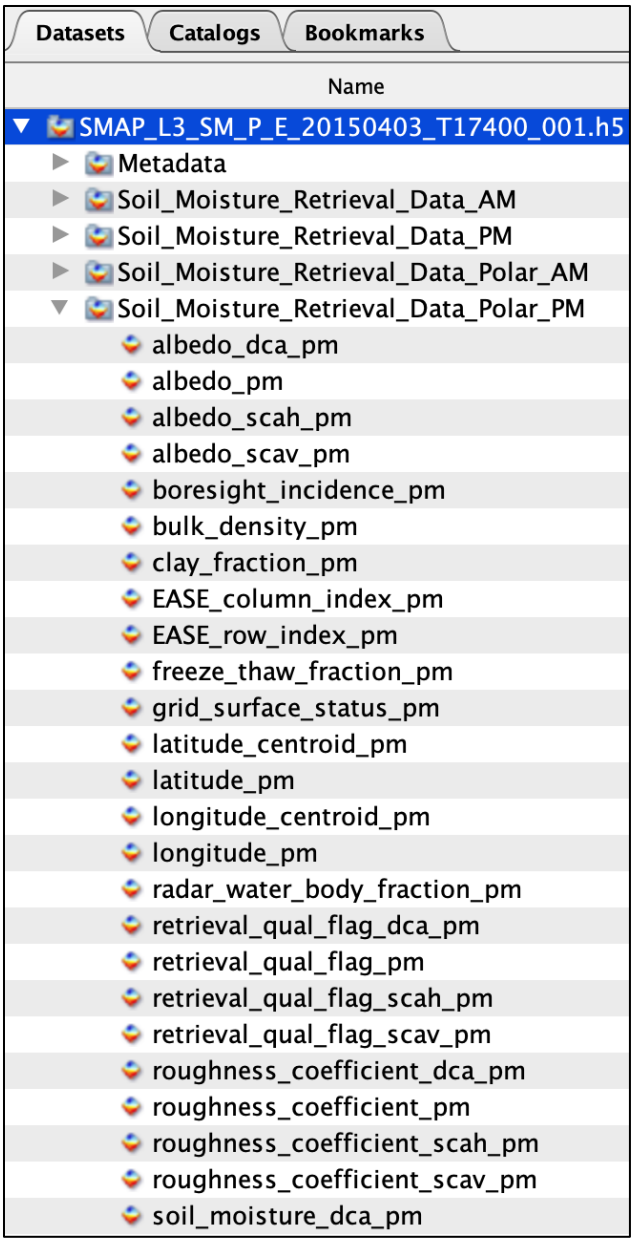

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP enhanced Level-3 soil moisture product, refer to the *Appendix – Data Fields* Section of this User Guide.

1.2.3 Data Fields

The Soil_Moisture_Retrieval_Data_AM (Global/Polar) groups contain soil moisture data, ancillary data, and quality assessment flags. The AM groups retrieve data on each descending half-orbit pass of the satellite (where the satellite moves from North to South and 6:00 a.m. is the Local Solar Time (LST) at the equator).

The Soil_Moisture_Retrieval_Data_PM (Global/Polar) groups contain soil moisture data, ancillary data, and quality assessment flags. The PM groups retrieve data on each ascending half-orbit pass of the satellite (where the satellite moves from South to North and 6:00 p.m. is the LST at the equator).

Corrected brightness temperatures are also provided for each AM and PM group.

1.2.4 Metadata Fields

This group includes metadata that describes the full content of each file. For a description of all metadata fields for this product, refer to the Product Specification Document (Chan & Dunbar, 2021).

1.2.5 File Naming Convention

Files are named according to the following convention:

`SMAP_L3_SM_P_E_yyyymmdd_RLVvvv_NNN.[ext]`

For example:

`SMAP_L3_SM_P_E_20150403_R17400_001.h5`

Table 3 describes the variables within a file name:

Table 3. File Naming Convention

Variable	Description
SMAP	Indicates SMAP mission data
L3_SM_P_E	Indicates specific product (L3: Level-3; SM: Soil Moisture; P: Passive; E: Enhanced)
yyyymmdd	4-digit year, 2-digit month, 2-digit day 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 CRID Major Version Number (Note: the data set's major version does not necessarily coincide with the CRID major version) vvv: 3-Digit CRID Minor Version Number Example: R17400 indicates a post-launch data product with a version of 7.400. Refer to the SMAP Data Version History 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

Global-grid coverage spans from 180°W to 180°E, and from approximately 85.044°N and 85.044°S. The north-polar grid coverage spans the Northern Hemisphere or from 180°W to 180°E and from the equator to 90°N.

1.3.2 Resolution

The native spatial resolution of the radiometer footprint is approximately 36 km. Data are then interpolated, using the Backus-Gilbert optimal interpolation algorithm (with a contributing domain of ~33 km) to a 9 km grid resolution.

1.3.3 Geolocation

These data are provided on the 9-km EASE-Grid 2.0 equal-area Global and Northern Hemisphere projections. The following tables provide information for geolocating this data set. For more information on EASE-Grid 2.0, refer to the EASE Grids website.

Table 4. Geolocation details for the Global and Northern Hemisphere EASE-Grid 2.0

Geographic coordinate system	WGS 1984	WGS 1984
Projected coordinate system	EASE-Grid 2.0 Global	EASE-Grid 2.0 Northern Hemisphere
Longitude of true origin	0	0
Latitude of true origin	30	90
Scale factor at longitude of true origin	N/A	N/A
Datum	WGS 1984	WGS 1984
Ellipsoid/spheroid	WGS 1984	WGS 1984
Units	Meter	Meter
False easting	0	0
False northing	0	0
EPSG code	6933	6931

PROJ4 string	`+proj=cea +lon_0=0 +lat_ts=30 +x_0=0 +y_0=0 +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs`	`+proj=laea +lat_0=90 +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs`
Reference	http://epsg.io/6933	http://epsg.io/6931

Table 5. 9 km Resolution EASE Grids

	Global, Equal-Area	**Northern Hemisphere, Lambert Azimuthal**
Grid cell size (x, y pixel dimensions)	9,024.31 m (x) 9,024.31 m (y)	9,000 m (x) 9,000 m (y)
Number of rows	1624	2000
Number of columns	3856	2000
Nominal gridded resolution	9 km by 9 km	9 km by 9 km
Grid rotation	N/A	N/A
ulxmap – x-axis map coordinate of the center of the upper-left pixel (XLLCORNER for ASCII data)	-17367530.45	-9000000.0
ulymap – y-axis map coordinate of the center of the upper-left pixel (YLLCORNER for ASCII data)	7314540.83	9000000.0

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 31 March 2015 to present.

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

Significant gaps in coverage occurred between 19 June and 23 July 2019 and between 6 August and 20 September 2022 after the SMAP satellite went into Safe Mode. A brief description of the 2019 event and its impact on data quality is available in the SMAP Post-Recovery Notice. The SMAP data acquired after the 2022 event were determined to be of high quality and consistent with the data acquired prior to the event.

1.4.3 Latencies

For further information, see What are the latencies for SMAP radiometer data sets? web page.

1.4.4 Resolution

Each Level-3 file is a daily composite of half-orbit files/swaths. Note that data from descending passes (a.m.) and ascending passes (p.m.) are stored separately in the same daily composite granule.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The microwave portion of the electromagnetic spectrum, which includes wavelengths from a few centimeters to a meter, has long held the most promise for estimating surface soil moisture remotely. Passive microwave sensors measure the natural thermal emission emanating from the Earth's surface. The variation in the intensity of this radiation depends on the dielectric properties and temperature of the target medium, which for the near-surface soil layer is a function of the amount of moisture present. Low microwave frequencies (long wavelengths), at L-band or approximately 1 GHz (20-30 cm), offer the following advantages:

- The atmosphere is almost completely transparent, providing all-weather sensing.
- Transmission of signals from the underlying soil is possible through sparse and moderate vegetation layers (up to at least 5 kg/m^2 of vegetation water content).
- Measurement is independent of solar illumination which allows for day and night observations.

For more details, refer to Section 2 of the Algorithm Theoretical Basis Document (ATBD) for this product (O'Neill et al., 2021a), which is available as a Technical Reference.

2.2 Instrumentation

For a detailed description of the SMAP instrument, visit the SMAP Instrument page at Jet Propulsion Laboratory (JPL) SMAP website.

2.3 Acquisition

The SMAP enhanced Level-3 radiometer soil moisture product (SPL3SMP_E) is a daily gridded composite of the SMAP Enhanced L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 6 (SPL2SMP_E) data. The derivation of soil moisture from SMAP brightness temperatures occurs in the Level-2 processing. Refer to the SPL2SMP_E User Guide for details on soil moisture algorithms and ancillary data. For information regarding the Backus-Gilbert optimal interpolation algorithm used to enhance these data, refer to the SPL1CTB_E user guide.

2.4 Processing

The SPL3SMP_E data set is a daily global and north-polar product. Individual SPL2SMP_E half-orbit files, acquired over the course of a 24-hour period, are composited to produce a daily multi-orbit global or polar map of retrieved soil moisture. Where the SPL2SMP_E swaths overlap, poleward of approximately +/- 65° latitude, three options were considered for compositing multiple data points at a given grid cell:

1. Use the most recent (or last-in) data point
2. Take the average of all data points within the grid cell
3. Choose the data points observed closest to 6:00 a.m. Local Solar Time (LST) for observations derived from SMAP descending passes and closest to 6:00 p.m. LST for observations derived from SMAP ascending passes

The current approach for the SPL3SMP_E product is to use the third option - choosing the nearest 6:00 a.m. LST and nearest 6:00 p.m. LST pass to perform Level-3 compositing separately for descending and ascending passes, respectively. For a given L2 half-orbit granule whose time stamp (yyyymmddThhmmss) is expressed in UTC, only the hhmmss part is converted into local solar time (O'Neill et al., 2021a).

2.5 Quality, Errors, and Limitations

2.5.1 Error Sources

Anthropogenic RFI (Radio Frequency Interference), principally from ground-based surveillance radars, can contaminate both radar and radiometer measurements at L-band frequencies. The SMAP radar and radiometer electronics and algorithms include design features to mitigate the effects of RFI. The SMAP radiometer implements a combination of time and frequency diversity, kurtosis detection, and use of thresholds to detect and, where possible, mitigate RFI (Bringer et al., 2021).

Level-2/3 radiometer data can also contain bit errors caused by noise in communication links and memory storage devices. More information about error sources is provided in Section 4.6 of the ATBD (O'Neill et al., 2021a).

2.5.2 Quality Assessment

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 Product Specification Document (Chan & Dunbar, 2021). For in-depth details regarding the quality of these data, refer to the Assessment Report (O'Neill et al., 2021b).

Each HDF5 file contains metadata with Quality Assessment (QA) metadata flags that are set by the SDS at the JPL prior to delivery to the National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). 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.

2.5.3 Data Flags

Bit flags generated from input SMAP data and ancillary data are 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, such as the precipitation flag. These flags provide information as to whether the ground is frozen, covered with snow, 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. Unless otherwise stated, all areal fractions defined below refer to 36 x 36 km^2 inversion domain.

Table 6. Retrieval Quality Flag Definition

Bit	Retrieval Information	Bit Value and Interpretation
0	Recommended Quality	0: Soil moisture retrieval has recommended quality
		1: Soil moisture retrieval doesn't have recommended quality
1	Retrieval Attempted	0: Soil moisture retrieval was attempted
		1: Soil moisture retrieval was skipped
2	Retrieval Successful	0: Soil moisture retrieval was successful
		1: Soil moisture retrieval was not successful
3	Retrieval Successful	0: Freeze/thaw state retrieval was successful
		1: Freeze/thaw state retrieval was not successful

Bit	Retrieval Information	Bit Value and Interpretation
4-15	Undefined	0 (not used)

A brief description of the retrieval quality flags (*retrieval_qual_flag_[_dca | _scah | _scav]*) is provided in Table 6. A description of each surface flag bit is provided below, with Bit 0 being the "rightmost" or the least significant bit. For more details on all data flags, users should refer to the *Appendix – Data Fields* Section of this User Guide and the Product Specification Document (Chan & Dunbar, 2021).

- **Open Water Flag (Bits 0 and 1)**
  Open water fraction is determined by *a priori* information on permanent open freshwater from the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD44W v006 database. Open water fraction is reported in Bits 0 and 1 in the *surface_flag* field of the SPL2SMP product, with Bit 0 using the MOD44W v006 database. Bit 1 was set to be equal to Bit 0 after the failure of the SMAP radar on July 5, 2015. This water fraction information serves as a flag to affect soil moisture retrieval processing in the following ways:
  - If water fraction is 0.00–0.05, then retrieve soil moisture, but flag for recommended quality.
  - If water fraction is 0.05–0.50, then retrieve soil moisture, and flag for uncertain quality.
  - If water fraction is 0.50–1.00, then flag, but do not retrieve soil moisture.

- **Urban Area Flag (Bit 3)**
  Since the T_B of man-made, impervious, and urban areas cannot be estimated theoretically, the presence of urban areas in the 36 km Level-2 soil moisture grid cell cannot be corrected for during soil moisture retrieval. Thus, the presence of even a small amount of urban area in the radiometer footprint is likely to adversely bias the retrieved soil moisture. The SMAP urban flag is set based on the Columbia University Global Rural-Urban Mapping Project (GRUMP) data set (O'Neill et al., 2021a). The urban fraction affects soil moisture retrieval processing in the following ways:
  - If urban areal fraction is 0.00–0.25, then retrieve soil moisture, but flag for recommended quality.
  - If urban areal fraction is 0.25–1.00, then flag for uncertain quality, and retrieve soil moisture.

- **Precipitation Flag (Bit 4)**
  The SMAP precipitation flag is set based on either forecasts of precipitation or using data from the Global Precipitation Mission (GPM). It is a binary *precipitation/no precipitation* flag which indicates the presence or absence of precipitation in the 36 km grid cell at the time of the SMAP overpass. The presence of liquid precipitation at the time of the SMAP overpass can adversely bias the retrieved soil moisture due to its large impact on T_B; corrections for precipitation are part of the Level-1B T_B processing. Unlike other flags, soil moisture retrieval will always be attempted even if precipitation is flagged unless precipitation is very heavy. However, this flag serves as a warning to users to view the retrieved soil moisture with some skepticism if precipitation is present.

- If precipitation is 0–1 mm/hr, then retrieve soil moisture, but flag for recommended quality.
- If precipitation is 1–25.4 mm/hr, then flag for uncertain quality, and retrieve soil moisture.
- If precipitation is above 25.4 mm/hr, then flag, but do not retrieve soil moisture.

- **Snow Flag (Bit 5)**
  Although the SMAP L-Band Radiometer can theoretically see through dry snow to the soil underneath a snowpack, the snow flag is set based on the snow fraction as reported in the National Oceanic and Atmospheric Administration (NOAA) Interactive Multisensor Snow and Ice Mapping System (IMS) database. The snow flag affects soil moisture retrieval processing in the following ways:
  - If snow areal fraction is 0.00–0.05, then retrieve soil moisture, but flag for recommended quality.
  - If snow areal fraction is 0.05–0.50, then flag for uncertain quality, and retrieve soil moisture.
  - If snow areal fraction is above 0.50, then flag, but do not retrieve soil moisture.

- **Frozen Ground Flag (Bits 7 and 8)**
  Frozen ground conditions are reflected in Bits 7 and 8 of the *surface_flag*. Bit 7 is determined by the SMAP radiometer-derived freeze/thaw state and Bit 8 is determined by the effective soil temperature (T_{eff}) estimated using NASA Global Modeling and Assimilation Office (GMAO) model soil temperatures (which is stored in the *surface_temperature* data field). The SMAP Level 2 passive soil moisture retrieval processor uses T_{eff} to determine if frozen ground is observed by the SMAP radiometer. When frozen ground is detected, the frozen ground bit (Bit 8) will be set to 1 in the *surface_flag* data field in the product. The frozen soil flag affects soil moisture retrieval processing in the following ways:
  - If frozen ground areal fraction is 0.00–0.05, then retrieve soil moisture, but flag for recommended quality.
  - If frozen ground areal fraction is 0.05–0.50, then flag for uncertain quality, and retrieve soil moisture.
  - If frozen ground areal fraction is 0.50–1.00, then flag, but do not retrieve soil moisture.

Note: SMAP radiometer freeze/thaw flags are presently validated only for all land regions north of 45°N. While the SPL3SMP_E product contains global SMAP freeze/thaw flags, uncertainty in the flags is higher south of 45°N due to small differences in the SMAP radiometer-derived reference freeze and thaw states upon which the freeze/thaw algorithm is based. More information is available in the SMAP Level-3 Freeze/Thaw (SPL3FTP) Assessment Report (Xu et al., 2020).

Additionally, although the current flag encodes the presence/absence of frozen ground based on the GMAO/GEOS model temperatures in Bit 8 and the SMAP radiometer-based freeze/thaw detection algorithm in Bit 7, only the GMAO/GEOS model temperatures are used to guide the operation of the SMAP baseline passive soil moisture retrieval algorithm over non-frozen ground at the present time. It is recommended that Bit 8 in the *surface_qual_flag* field or the effective soil temperature values in the *surface_temperature* field be used to indicate the presence/absence of frozen ground alongside the investigation and analysis of SMAP passive soil moisture estimates. At present, the SMAP radiometer-based freeze/thaw detection algorithm is observed to produce false flags at low latitudes during the growing season of vegetation. Work is underway to mitigate the confounding impacts of dynamic vegetation phenology on the observed Normalized Polarization Ratio (NPR) on which the SMAP radiometer-based freeze/thaw detection algorithm is based.

- **Mountainous Area Flag (Bit 9)**
  Large and highly variable slopes present in the radiometer footprint will adversely affect the retrieved soil moisture. The SMAP mountainous area flag is derived from high elevation information from a DEM coupled with a statistical threshold based on the slope variability within each 36 km grid cell.
  - If slope standard deviation is 0.0–3.0°, then retrieve soil moisture, but flag for recommended quality.
  - If slope standard deviation is 3.0°–6.0°, then flag for uncertain quality, and retrieve soil moisture.
  - If slope standard deviation is above 6.0°, then flag, but do not retrieve soil moisture.

As with any satellite retrieval data product, proper data usage is encouraged. The following two simple practices are recommended for using SMAP soil moisture retrievals with maximum scientific benefits:

1. Use the *retrieval_qual_flag* field to identify retrievals in the *soil_moisture* field estimated to be of recommended quality. A *retrieval_qual_flag* value of either 0 or 8 indicates high-quality retrievals (8 because a failed F/T retrieval does not affect soil moisture retrieval). Proper use of the *retrieval_qual_flag* field is an effective way to ensure that only retrievals of recommended quality will be used in data analyses.

2. For further investigation, use the *surface_flag* field and the associated definition described above to determine why the *retrieval_qual_flag* field did not report recommended quality at a given grid cell.

3 SOFTWARE AND TOOLS

For tools that work with SMAP data, refer to the Tools web page.

4 VERSION HISTORY

Table 7. Version History

Version	Release Date	Description of Changes
V1	December 2016	First public data release
V2	June 2018	Changes to this version include: • Level-1B water-corrected brightness temperatures are used in passive soil moisture retrieval. This procedure corrects for anomalous soil moisture values seen near coastlines in the previous version and should result in less rejected data due to waterbody contamination. Five new data fields accommodate this correction: *grid_surface_status, surface_water_fraction_mb_h, surface_water_fraction_mb_v, tb_h_uncorrected*, and *tb_v_uncorrected.* • Improved depth correction for effective soil temperature used in passive soil moisture retrieval; new results are captured in the *surface_temperature* data field. This correction reduces the dry bias seen when comparing SMAP data to in situ data from the core validation sites. • Frozen ground flag updated to reflect improved freeze/thaw detection algorithm, providing better accuracy; new results are captured in Bit 7 of the *surface_flag*.
V3	August 2019	Changes to this version include: • As part of the option algorithm changes in SPL2SMP_E, the following data fields were added: *bulk_density, clay_fraction, bulk_density_pm, clay_fraction_pm*. • The baseline algorithm (SCA-V) remains unchanged. • Improved aggregation of values in input ancillary data, e.g. roughness, soil texture, NDVI. The fix has negligible impacts on retrievals estimated to be of recommended quality.

Version	Release Date	Description of Changes
V4	August 2020	Changes to this version include: • Improved calibration methodology was applied to the Level-1B radiometer brightness temperatures. • Improved land surface model outputs from the NASA Global Modeling and Assimilation Office (GMAO) were used to estimate the effective soil temperature used as input to Level-2 soil moisture geophysical inversion. This effective soil temperature is not to be confused with the physical soil temperature at a given depth (Choudhury et al., 1982). • Improved retrieval performance of DCA (formerly known as MDCA or "the option 3" option algorithm in previous releases). DCA retrieves both soil moisture and vegetation optical depth (VOD or tau). • Use of a new global 250-m resolution soils data base called SoilGrid250m, available at https://openlandmap.org. Work is underway to address limited spatial anomalies of these soil property estimates at high latitudes over areas rich in organic soils. • Data quality flags were updated and corrected where faulty. • The baseline algorithm (SCA-V) remains unchanged.
V5	October 2021	Changes to this version include: • Dual Channel Algorithm (DCA) replaces Single Channel Algorithm – Vertical Polarization (SCA-V) as the baseline algorithm • Addition of AM and PM north polar grid soil moisture retrievals which are intended to mitigate the distortion of global grid cells at high northern latitudes (> 50N). • Bulk_density maximum value changed from 1.0 to 2.65.
V6	December 2023	Changes to this version include: • An improved processing methodology was applied to the input enhanced Level-2 radiometer brightness temperatures. • The data algorithms, structure, content, or processor code are otherwise unchanged from the previous 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 REFERENCES

Bringer, A., J. Johnson, Y. Soldo, D. Le Vine, P. Mohammed, S. Misra, P. de Matthaeis, and J. Piepmeier, "Properties of the RFI Environment at 1400–1427 MHz as Observed by the Soil Moisture Active/Passive Mission Microwave Radiometer. 2021. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 7259-7267,https://doi.org/10.1109/JSTARS.2021.3092996.

Chan, S. and S. Dunbar, 2021. SMAP Enhanced Level 3 Passive Soil Moisture Product Specification Document, Version 5.0, R18 Extended Mission Release. JPL D-56292, Jet Propulsion Laboratory, Pasadena, CA. (see PDF)

Choudhury, B. J., T. J. Schmugge, and T. Mo. 1982. A Parameterization of Effective Soil Temperature for Microwave Emission. *Journal of Geophysical Research*. 87(C2): 1301-1304. https://doi.org/10.1029/JC087iC02p01301.

O'Neill, P. E., R. Bindlish, S. Chan, J. Chaubell, A. Colliander, E. Njoku, and T. Jackson, 2021a. SMAP Algorithm Theoretical Basis Document: Level 2 & 3 Soil Moisture (Passive) Data Products, Revision G, October 12, 2021, SMAP Project, JPL D-66480, Jet Propulsion Laboratory, Pasadena, CA. (see PDF).

O'Neill, P., S. Chan, R. Bindlish, M. Chaubell, A. Colliander, F. Chen, S. Dunbar, T. Jackson, J. Peng, M. Mousavi, M. Cosh, T. Bongiovanni, J. Walker, X. Wu, A. Berg, H. McNairn, M. Thibeault, J. Martínez-Fernández, Á. González-Zamora, E. Lopez-Baeza, K. Jensen, M. Seyfried, D. Bosch, P. Starks, C. Holifield Collins, J. Prueger, Z. Su, R. van der Velde, J. Asanuma, M. Palecki, E. Small, M. Zreda, J. Calvet, W. Crow, Y. Kerr, S. Yueh, and D. Entekhabi, October 12, 2021b. Calibration and Validation for the L2/3_SM_P Version 8 and L2/3_SM_P_E Version 5 Data Products, SMAP Project, JPL D-56297, Jet Propulsion Laboratory, Pasadena, CA. (see PDF).

Xu, X., S. Dunbar, A. Colliander, Y. Kim, J. Kimball, and C. Derksen, October 30, 2020. Soil Moisture Active Passive (SMAP) Project Calibration and Validation for the L3_FT_P and L3_FT_P_E Data Product (Version 3), SMAP Project, JPL D- 56296, Jet Propulsion Laboratory, Pasadena, CA. (see PDF).

8 DOCUMENT INFORMATION

8.1 Publication Date

December 2023

8.2 Date Last Updated

January 2024

APPENDIX – DATA FIELDS

This appendix provides a description of all data fields within the SMAP Enhanced L3 Radiometer Global and Polar Daily 9 km EASE-Grid Soil Moisture (SPL3SMP_E) product. The data are grouped into these main HDF5 groups:

- Metadata
- Soil_Moisture_Retrieval_Data_AM
- Soil_Moisture_Retrieval_Data_PM
- Soil_Moisture_Retrieval_Data_Polar_AM
- Soil_Moisture_Retrieval_Data_Polar_PM

For a description of metadata fields for this product, refer to the Product Specification Document (Chan & Dunbar, 2021). Table A - 1 describes the Soil_Moisture_Retrieval_Data groups associated with this product, with a more detailed description of each data field below.

Table A - 1. Data Fields for Soil_Moisture_Retrieval_Data_AM/PM and Soil_Moisture_Retrieval_Data_Polar_AM/PM Groups

Data Field Name	Type	Byte	Unit	Valid Min	Valid Max	Fill/Gap Value	Derivation Method(s)**
EASE_column_index	Uint16	2	N/A	0	963	65534	2
EASE_row_index	Uint16	2	N/A	0	405	65534	2
albedo* (albedo_dca | _scah | _scav)	Float32	4	N/A	0	1	-9999.0	6
boresight_incidence	Float32	4	degrees	0	90	-9999.0	1
bulk_density	Float32	4	N/A	0	2.65	-9999.0	6
clay_fraction	Float32	4	N/A	0	1	-9999.0	6
freeze_thaw_fraction	Float32	4	N/A	0	1	-9999.0	6
grid_surface_status	Uint16	2	N/A	0	1	65534	7
landcover_class	Uint8	1	N/A	0	16	254	6
landcover_class_fraction	Uint8	1	N/A	0	1	-9999.0	6
latitude	Float32	4	degrees	-90	90	-9999.0	2
latitude_centroid	Float32	4	degrees	-90	90	-9999.0	1
longitude	Float32	4	degrees	-180	180	-9999.0	2
longitude_centroid	Float32	4	degrees	-180	180	-9999.0	1
radar_water_body_fraction	Float32	4	N/A	0	1	-9999.0	6
retrieval_qual_flag* (retrieval_qual_flag _dca | _scah | _scav)	Uint16	2	N/A	0	65536	65534	4
roughness_coefficient* (roughness_coefficient)_dca | _scah | _scav)	Float32	4	N/A	0	3	-9999.0	6
soil_moisture* (soil_moisture_dca | _scah | _scav)	Float32	4	m^3/m^3	0.02	soil porosity	-9999.0	4
soil_moisture_error	Float32	4	m^3/m^3	0.02	soil porosity	-9999.0	4
static_water_body_fraction	Float32	4	N/A	0	1	-9999.0	6
surface_flag	Uint16	2	N/A	0	65536	65534	4

surface_temperature	Float32	4	K	253.15	313.15	-9999.0	6
surface_water_fraction_mb_h	Float32	4	N/A	0	1	-9999.0	1
surface_water_fraction_mb_v	Float32	4	N/A	0	1	-9999.0	1
tb_3_corrected	Float32	4	K	-50	50	-9999.0	1
tb_4_corrected	Float32	4	K	-50	50	-9999.0	1
tb_h_corrected	Float32	4	K	0	330	-9999.0	1
tb_h_uncorrected	Float32	4	K	0	340	-9999.0	1
tb_qual_flag_3	Uint16	2	N/A	0	65536	65534	4
tb_qual_flag_4	Uint16	2	N/A	0	65536	65534	4
tb_qual_flag_h	Uint16	2	N/A	0	65536	65534	4
tb_qual_flag_v	Uint16	2	N/A	0	65536	65534	4
tb_time_seconds	Float64	8	seconds	0	N/A	-9999.0	1
tb_time_utc	Char24	24	N/A	2015-01-31T00:00:00.000Z	N/A	N/A	1
tb_v_corrected	Float32	4	K	0	330	-9999.0	1
tb_v_uncorrected	Float32	4	K	0	340	-9999.0	1
vegetation_opacity*	Float32	4	N/A	0.01	5	-9999.0	6
vegetation_opacity(_dca	Float32	4	N/A	0.01	5	-9999.0	5
vegetation_opacity(_scah | _scav)	Float32	4	N/A	0.01	5	-9999.0	6
vegetation_water_content	Float32	4	kg/m^2	0.0	30.0	-9999.0	6

** **Derivation methods are:**

1. From enhanced Level-1C brightness temperature data
2. From 9 km EASE-Grid 2.0 array definition
3. Value corrected for the presence of water wherever water/land areal fraction is below a threshold; when the fraction is zero, no correction is performed
4. Determined by enhanced Level-2 radiometer soil moisture processing software
5. Available only with option algorithms that use two polarization channels.
6. From external lookup tables or ancillary data whose location and time stamp coincide with those of the input data
7. Nearest-neighbor interpolation

Data Field Definitions

NOTE: All data element names apply to both the global and north polar data AM groups. Data in the PM groups have the suffix "_pm" appended to the names.

EASE_col_index
Zero-based column index of a 9 km EASE-Grid 2.0 cell.

EASE_row_index
Zero-based row index of a 9 km EASE-Grid 2.0 cell.

albedo (albedo_scah, albedo_scav, albedo_dca)
Daily global composite of single-scattering albedo at 9 km grid posting. Note that this parameter is the same 'omega' parameter in the 'tau-omega' model for a given polarization channel. The generic albedo field is internally linked to the output produced by the baseline algorithm (DCA currently).

boresight_incidence
Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of incidence angles of L1B_TB_E observations whose boresights fall within a 9 km EASE-Grid 2.0 cell. The incidence angle is defined as the included angle between the antenna boresight vector and the normal to the Earth's surface.

bulk_density
Daily global composite of bulk density at 9 km grid posting.

clay_fraction
Daily global composite of clay fraction at 9 km grid posting.

freeze_thaw_fraction
Daily global composite of freeze/thaw fraction at 9 km grid posting. The fraction is computed based on the number of frozen land pixels and thawed land pixels reported on the 3-km global cylindrical EASE-Grid 2.0 projection in the SMAP Level 2 Active Soil Moisture Product (L2_SM_A). If there are NF frozen ground pixels and NT thawed land pixels within a 9-km grid cell, this parameter refers to the fraction of NF / (NF + NT). At present the L2_SM_P processing software can be configured to provide this parameter from a dynamic ancillary data database or from the SMAP L2_SM_A product. **Since the failure of the SMAP radar this field has been derived from external soil temperature ancillary data.**

grid_surface_status
Surface type (land or water) as determine by the antenna boresight location. Indicates if the grid point lies on land (0) or water (1).

latitude
Latitude of the center of a 9 km EASE-Grid 2.0 cell.

latitude_centroid
Daily global composite of the arithmetic average of the same parameters found in the

fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of latitudes of L1B_TB_E observations whose boresights fall within a 9 km EASE-Grid 2.0 cell.

longitude

Longitude of the center of a 9 km EASE-Grid 2.0 cell.

longitude_centroid

Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of longitudes of L1B_TB_E observations whose boresights fall within a 9 km EASE-Grid 2.0 cell.

radar_water_body_fraction

Daily global composite of the radar-derived water body fraction at 9 km spatial scale. The fraction is computed based on the number of water pixels and land pixels reported on the 3-km global cylindrical EASE-Grid 2.0 projection in the SMAP Level 2 Active Soil Moisture Product (L2_SM_A). 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. **Since the failure of the SMAP radar, this field has been set to the *static_water_body_fraction* field**.

retrieval_qual_flag

Daily global composite of a 16-bit binary string that indicates whether retrieval was performed or not at a given grid cell. When retrieval is performed, it contains additional bits to further indicate the exit status and quality of the retrieval. A summary of bit definition of the *retrieval_qual_flag* field is listed in Table A - 2. The generic retrieval_qual_flag field is internally linked to the output produced by the baseline algorithm (DCA currently).

Table A - 2. Retrieval Quality Flag Definition

Bit	Retrieval Information	Bit Value and Interpretation
0	Recommended Quality	0: Soil moisture retrieval has recommended quality
		1: Soil moisture retrieval doesn't have recommended quality
1	Retrieval Attempted	0: Soil moisture retrieval was attempted
		1: Soil moisture retrieval was skipped
2	Retrieval Successful	0: Soil moisture retrieval was successful
		1: Soil moisture retrieval was not successful
3	Retrieval Successful	0: Freeze/thaw state retrieval was successful
		1: Freeze/thaw state retrieval was not successful
4-15	Undefined	0 (not used)

roughness_coefficient (roughness_coefficient_scah, roughness_coefficient_scav, roughness_coefficient_dca)
Daily global composite of roughness coefficient at 9-km grid posting. There is a value of *roughness_coefficient* for each of the algorithm options. Note that this parameter is the same 'h' coefficient in the 'tau-omega' model for a given polarization channel. The 'h' for the DCA is derived from a special retrieval process and provided as a static ancillary table. The generic *roughness_coefficient* field is internally linked to the output produced by the baseline algorithm (DCA currently).

soil_moisture (soil_moisture_scah, soil_moisture_scav, soil_moisture_dca)
Daily global composite of the estimated soil moisture at 9 km grid posting, as returned by the L2_SM_P_E processing software. The generic *soil_moisture* field is internally linked to the output produced by the baseline algorithm (DCA currently).

soil_moisture_error
Daily global composite of the estimated '1-sigma' error of the *soil_moisture* output parameter. The valid minimum and maximum are subject to further analysis on real data. This data field is currently filled with FillValue.

static_water_body_fraction
Daily global composite of the static water body fraction at 9 km grid posting. The fraction is computed based on the number of water pixels and land pixels reported on a 250-meter grid. 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 from when the original data were acquired.

surface_flag
Daily global composite of a 16-bit binary string that indicates the presence or absence of certain surface conditions at a grid cell. Table A - 3 includes a summary of surface conditions and their thresholds, where '0' indicates the presence of a surface condition favorable to soil moisture retrieval. Each surface condition is numerically compared against two non-negative thresholds: T1 and T2, where T1 < T2. In most cases, when a surface condition is found to be below T1, retrieval is attempted and flagged for recommended quality. Between T1 and T2, retrieval is still attempted but flagged for uncertain quality. Above T2, retrieval is skipped.
Note: Bit position '0' refers to the least-significant bit. Final bit positions and definitions are subject to future revision and expansion as needed.

surface_temperature
Daily global composite of the effective soil temperature (Choudhury et al., 1982) at 9-km grid spacing. This parameter is used as an input ancillary data parameter to the L2_SM_P processing software for both baseline and option algorithms, **and is not to be confused with an actual physical temperature measured at a single depth**.

The valid minimum and maximum below are subject to further analysis on real data.
Note: The designation “effective” signifies an attempt to capture the soil integrated temperature and canopy temperature in a single parameter, as is widely reported in the literature. Depending on the actual emission sensing depth (which varies with soil moisture), this parameter usually does not coincide with a thermal physical temperature at a fixed depth (e.g. 5 cm or 10 cm).

surface_water_fraction_mb_h
Water fraction with the SMAP radiometer main-beam (mb) IFOV weighted by antenna gain pattern at the horizontal polarization.

Table A - 3. Surface Condition Bit Flag Definition

Bit	Surface Condition	T1	T2	Bit Value and Interpretation
0	Static Water	0.05	0.50	0: Water areal fraction ≤ T1 and IGBP wetland fraction < 0.50: ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
1	Radar-derived Water Fraction (no longer available and now defaults to match Bit 0)	0.05	0.50	0: Water areal fraction ≤ T1 and IGBP wetland fraction < 0.50: ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
2	Coastal Proximity	N/A	1.0	0: Distance to nearby significant water bodies > T2 (# of 9-km grid cells)
				1: Otherwise
3	Urban Area	0.25	1.00	0: Urban areal fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
4	Precipitation	2.78e-04 (= 1.0 mm/hr)	7.06e-03 (= 25.4 mm/hr)	0: Precipitation fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise: ⇒ Retrieval skipped for fraction > T2
5	Snow	0.05	0.50	0: Snow areal fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise: ⇒ Retrieval skipped for fraction > T2
6	Permanent Ice	0.05	0.50	0: Ice areal fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
7	Frozen Ground (from radiometer-derived FT state)	0.05	0.50	0: Frozen ground areal fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
8	Frozen Ground (from modeled effective soil temperature)	0.05	0.50	0: Frozen ground areal fraction ≤ T1 ⇒ Retrieval attempted for fraction ≤ T2
				1: Otherwise ⇒ Retrieval skipped for fraction > T2
9	Mountainous Terrain	3°	6°	0: Slope standard deviation ≤ T1
				1: Otherwise
10	Dense Vegetation	5.0	30.0	0: Vegetation Water Content (VWC) ≤ T1 ⇒ Retrieval attempted for VWC ≤ T2
				1: Otherwise ⇒ Retrieval skipped for VWC > T2
11	Nadir Region / Undefined			0 (not used in SPL2SMP)
12-15	Undefined			0

surface_water_fraction_mb_v
Daily global composite of the water fraction with the SMAP radiometer main-beam (mb) IFOV weighted by antenna gain pattern at the vertical polarization.

tb_3_corrected
Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of L1B_TB_E 3rd Stokes polarized brightness temperatures whose boresights fall within a 9 km EASE-Grid 2.0 cell.

tb_4_corrected
Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of L1B_TB_E 4th Stokes polarized brightness temperatures whose boresights fall within a 9 km EASE-Grid 2.0 cell.

tb_h_corrected
Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of L1B_TB_E horizontally polarized brightness temperatures whose boresights fall within a 9 km EASE-Grid 2.0 cell. Wherever water fraction is below a threshold, water brightness temperature correction is applied to this parameter prior to L2_SM_P_E inversion. This value represents the corrected land brightness temperature if grid_surface_status is “0” and the water fraction is lower than 0.9 (otherwise no correction is applied) or represents the corrected water brightness temperature if grid_surface_status is “1” and water fraction is greater than 0.1 (otherwise no correction is applied).

tb_h_uncorrected
Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter describes the weighted average of the L1B_TB_E horizontally polarized brightness temperatures *prior to surface correction* whose boresights fall within a 9 km EASE-Grid 2.0 cell.

tb_qual_flag_3
Daily global composite of a 16-bit or two-byte binary number formed by applying a Boolean 'AND' operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB_E granule. A '0' indicates that both the fore-looking and aft-looking L1C_TB_E observations satisfy a given quality criterion described in L1B_TB_E 's *tb_qual_flag_3* output parameter; a '1' indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB_E observations. Bit position '0' refers to the least-significant digit. The possible values for each bit position are shown in Table A - 4.

tb_qual_flag_4
Daily global composite of a 16-bit or two-byte

binary number formed by applying a Boolean 'AND' operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB_E granule. A '0' indicates that both the fore-looking and aft-looking L1C_TB_E observations satisfy a given quality criterion described in L1B_TB_E 's *tb_qual_flag_4* output parameter; a '1' indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB_E observations. Bit position '0' refers to the least significant digit. The possible values for each bit position are shown in Table A - 4.

tb_qual_flag_h

Daily global composite of a 16-bit or two-byte binary number formed by applying a Boolean 'AND' operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB_E granule. A '0' indicates that both the fore-looking and aft-looking L1C_TB_E observations satisfy a given quality criterion described in L1B_TB_E 's *tb_qual_flag_h* output parameter; a '1' indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB_E observations. Bit position '0' refers to the least significant digit. The possible values for each bit position are shown in Table A - 4.

tb_qual_flag_v

Daily global composite of a 16-bit or two-byte binary number formed by applying a Boolean 'AND' operation between the same parameters from both fore- and aft-looking groups in the input L1C_TB_E granule. A '0' indicates that both the fore-looking and aft-looking L1C_TB_E observations satisfy a given quality criterion described in L1B_TB_E 's *tb_qual_flag_v* output parameter; a '1' indicates that the same criterion is violated by either fore-looking or aft-looking (or both) L1C_TB_E observations. Bit position '0' refers to the least significant digit. The possible values for each bit position are shown in Table A - 4.

tb_time_seconds

Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the average of UTC acquisition times of L1B_TB_E observations whose boresights fall within a 9 km EASE-Grid 2.0 cell. The result is then expressed in J2000 seconds [the number of seconds since 12:00:00.000 on January 1, 2000 Barycentric Dynamical Time (TDB)].

tb_time_utc

Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the average of UTC acquisition times, in ASCII representation, of L1B_TB_E observations whose boresights fall within a 9 km EASE-Grid 2.0 cell.

tb_v_corrected

Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter thus describes the weighted average of

L1B_TB_E vertically polarized brightness temperatures whose boresights fall within a 9 km EASE-Grid 2.0 cell. Wherever water fraction is below a threshold, water brightness temperature correction is applied to this parameter prior to L2_SM_P_E inversion. This value represents the corrected land brightness temperature if grid_surface_status (as noted in Section 4: Version History) is “0” and the water fraction is lower than 0.9 (otherwise no correction is applied) or represents the corrected water brightness temperature if grid_surface_status (as noted in Section 4: Version History) is “1” and water fraction is greater than 0.1 (otherwise no correction is applied).

Table A - 4. Bit Definitions for Brightness Temperature Quality Flags

Bit Position	Bit Value and Interpretation for *tb_qual_flag_3|4*	Bit Value and Interpretation for *tb_qual_flag_h|v*
0	0 = Observation had acceptable quality	
	1 = Observation does not have acceptable quality	
1	0 = Observation within physical range	
	1 = Observation beyond physical range	
2	0 = RFI was not detected in the observation	
	1 = RFI was detected in the observation	
3	0 = RFI was detected and corrected in the observation	
	1 = RFI was detected but not correctable in the observation	
4	0 = Observation has acceptable NEDT	
	1 = Observation did not have acceptable NEDT	
5	0 = Direct sun correction was successful	
	1 = Direct sun correction was not successful	
6	0 = Reflected sun correction was successful	
	1 = Reflected sun correction was not successful	
7	0 = Reflected moon correction was successful	
	1 = Reflected moon correction was not successful	
8	0 = Direct galaxy correction was successful	
	1 = Direct galaxy correction was not successful	
9	0 = Reflected galaxy correction was successful	
	1 = Reflected galaxy correction was not successful	
10	0 = Atmosphere correction was successful	
	1 = Atmosphere correction was not successful	
11	*Intentionally left undefined*	0 = Faraday rotation correction was successful
		1 = Faraday rotation correction was not successful

Bit Position	Bit Value and Interpretation for *tb_qual_flag_3|4*	Bit Value and Interpretation for *tb_qual_flag_h|v*
12	0 = Observation was a valid value	
	1 = Observation was a null value	
13	0 = Observation was within half orbit	0 = Water correction was not performed
	1 = Observation was outside half orbit	1 = Water correction was performed
14	0 = TA minus TA_FILTERED was less than a threshold	
	1 = TA minus TA_FILTERED was greater than a threshold	
15	0 = Observation was RFI-free	
	1 = Observation was RFI-contaminated	

tb_v_uncorrected

Daily global composite of the arithmetic average of the same parameters found in the fore- and aft-looking groups in the input L1C_TB_E granule. The resulting parameter describes the weighted average of the L1B_TB_E vertically polarized brightness temperatures **prior to surface correction** whose boresights fall within a 9 km EASE-Grid 2.0 cell.

vegetation_opacity

Daily global composite of the estimated vegetation opacity at 9-km grid posting, as returned by the L2_SM_P_E processing software. Note that this parameter is the same 'tau' parameter normalized by the cosine of the incidence angle in the 'tau-omega' model:

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

where b is a landcover-based parameter described in the SMAP Level 2/3 Passive Soil Moisture Product ATBD, VWC is vegetation water content in kg/m^2 derived from NDVI climatology, and θ is the incidence angle (= 40°) for SMAP. The valid minimum and maximum below are subject to further analysis on real data. For the DCA, the vegetation opacity is retrieved directly along with soil moisture, without referring to the NDVI climatology. The generic vegetation_opacity field is internally linked to the output produced by the baseline algorithm (DCA currently).

vegetation_water_content

Daily global composite of the vegetation water content at 9 km grid posting. This parameter is used as input ancillary data parameter to the L2_SM_P_E processing software when the baseline algorithm is used. The valid minimum (0.0) and maximum (30.0) are subject to further analysis on real data.

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 SPL3SMP_E product when the enhanced Level-3 soil moisture Science Production Software (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 SPS executables that generate the SPL3SMP_E 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 SPL3SMP_E 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 SPL2SMP_E product.

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 SPL3SMP_E product is equal to the values that represent fill. If any exceptions should exist in the future, the SPL3SMP_E 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.

Acronyms and Abbreviations

Table A - 5. Acronyms and Abbreviations

Abbreviation	Definition
Char	8-bit character
IGBP	International Geosphere-Biosphere Programme
Int8	8-bit (1-byte) signed integer
Int16	16-bit (2-byte) signed integer
Int32	32-bit (4-byte) signed integer
Float32	32-bit (4-byte) floating-point integer

Abbreviation	Definition
Float64	64-bit (8-byte) floating-point integer
H-pol	Horizontally polarized
N/A	Not Applicable
NF	Number of frozen ground pixels
NL	Number of land pixels
NT	Number of thawed land pixels
NW	Number of water pixels
SI	International System of Units
SPL3SMP_E	SMAP Enhanced L3 Radiometer Daily Global 36 km EASE-Grid Soil Moisture
SPS	Science Production Software
T1, T2	Threshold 1, Threshold 2
TB	Brightness Temperature
Uint8	8-bit (1-byte) unsigned integer
Uint16	16-bit (2-byte) unsigned integer
UTC	Universal Coordinated Time
V-pol	Vertically polarized
VWC	Vegetation Water Content