SMAP L2 Radiometer Half-Orbit 36 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, and J. Chaubell. 2019. *SMAP L2 Radiometer Half-Orbit 36 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/R50VUC07OM4W. [Date Accessed].

Literature Citation

As a condition of using these data, we request that you acknowledge the author(s) of this data set by referencing the following peer-reviewed publication.

Chan, S., R. Bindlish, P. E. O'Neill, E. G. Njoku, T. Jackson, A. Colliander, F. Chen, M. Burgin, S. Dunbar, J. R. Piepmeier, S. Yueh, D. Entekhabi, M. Cosh, T. Caldwell, J. Walker, A. Berg, T. Rowlandson, A. Pacheco, H. McNairn, M. Thibeault, J. Martinez-Fernandez, A. González-Zamora, D. Bosch, P. Starks, D. Goodrich, J. Prueger, M. Palecki, E. E. Small, M. Zreda, J. Calvet, W. T. Crow, and Y. Kerr. 2016. *Assessment of the SMAP passive soil moisture product, IEEE Transactions on Geoscience and Remote Sensing.* 54. 4994–5007. https://doi.org/10.1109/TGRS.2016.2561938

National Snow and Ice Data Center

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1   DATA DESCRIPTION

1.1 Parameters

The main output of this data set is 0-5 cm surface soil moisture (cm3/cm3) presented on the global 36 km EASE-Grid 2.0. Also included are Brightness Temperature (Tb) measurements (K), representing the weighted average of SMAP Level-1B brightness temperatures whose boresights fall within each 36 km EASE-Grid 2.0 grid cell.

Refer to the Product Specification Document for details on all parameters.

1.2 Format

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

1.3 File Contents

As shown in Figure 1, each HDF5 file is organized into the following main groups, which contain additional groups and/or data sets:
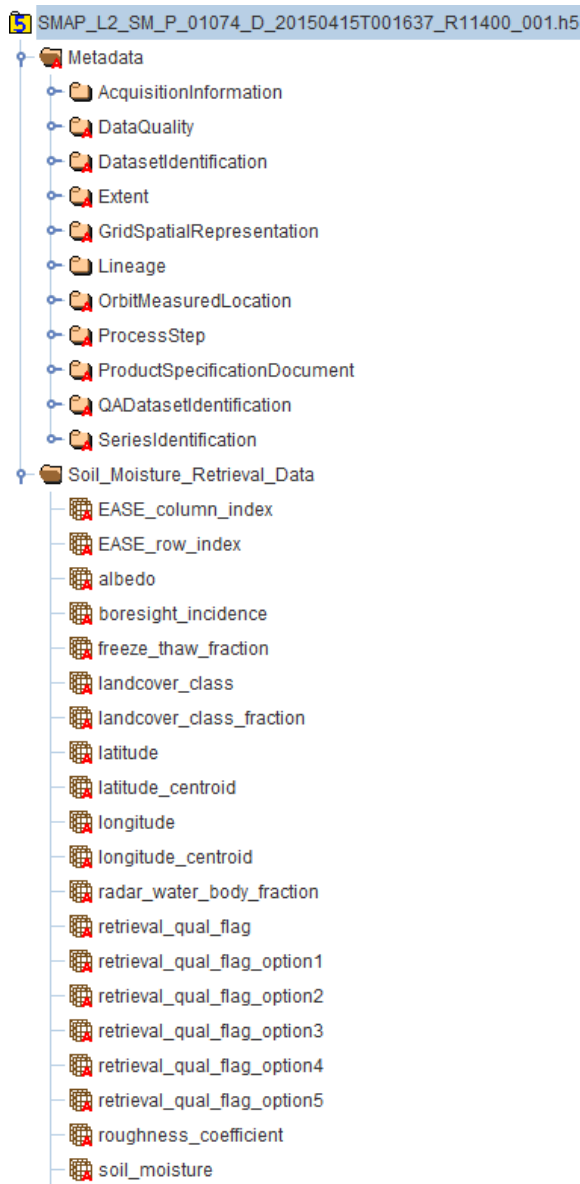
SMAP_L2_SM_P_01074_D_20150415T001637_R11400_001.h5
- Metadata
  - AcquisitionInformation
  - DataQuality
  - DatasetIdentification
  - Extent
  - GridSpatialRepresentation
  - Lineage
  - OrbitMeasuredLocation
  - ProcessStep
  - ProductSpecificationDocument
  - QADatasetIdentification
  - SeriesIdentification
- Soil_Moisture_Retrieval_Data
  - EASE_column_index
  - EASE_row_index
  - albedo
  - boresight_incidence
  - freeze_thaw_fraction
  - landcover_class
  - landcover_class_fraction
  - latitude
  - latitude_centroid
  - longitude
  - longitude_centroid
  - radar_water_body_fraction
  - retrieval_qual_flag
  - retrieval_qual_flag_option1
  - retrieval_qual_flag_option2
  - retrieval_qual_flag_option3
  - retrieval_qual_flag_option4
  - retrieval_qual_flag_option5
  - roughness_coefficient
  - soil_moisture

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-2 radiometer soil moisture product, refer to the Product Specification Document.

The Soil Moisture Retrieval Data group contains soil moisture data, ancillary data, and quality assessment flags. Corrected brightness temperatures are also provided.

The Metadata Fields group includes all the 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.

All data element arrays are one-dimensional, with the exception of *landcover_class* and *landcover_class_fraction,* which are two-dimensional arrays.

1.4 File Naming Convention

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

`SMAP_L2_SM_P_[Orbit#]_[D]_yyyymmddThhmmss_RLVvvv_NNN.[ext]`

For example:

`SMAP_L2_SM_P_03468_D_20150925T165424_R13242_001.h5`

Table 1. File Naming Conventions

Variable	Description
SMAP	Indicates SMAP mission data
L2_SM_P	Indicates specific product (L2: Level-2; SM: Soil Moisture; P: Passive)
[Orbit#]	5-digit sequential number of the orbit flown by the SMAP spacecraft when data were acquired. Orbit 00000 began at launch. Orbit numbers increment each time the spacecraft flies over the southernmost point in the orbit path.
D	D: Descending half-orbit pass of the satellite (where satellite moves from North to South, and 6:00 a.m. is the local solar time)
yyyymmddThhmmss	Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where: | yyyymmdd	4-digit year, 2-digit month, 2-digit day
T	Time (delineates the date from the time, i.e. yyyymmdd*T*hhmmss)
hhmmss	2-digit hour, 2-digit month, 2-digit second	
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: R13242 indicates a standard data product with a version of 3.242. 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

1.5 File Size

Each half-orbit file is approximately 1.5 MB.

1.6 Volume

The daily data volume is approximately 10 MB.

1.7 Spatial Information

1.7.1 Coverage

Data set 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.

Figure 2 shows the spatial coverage of the SMAP L-Band Radiometer for one descending half orbit, which comprises one file of this data set:
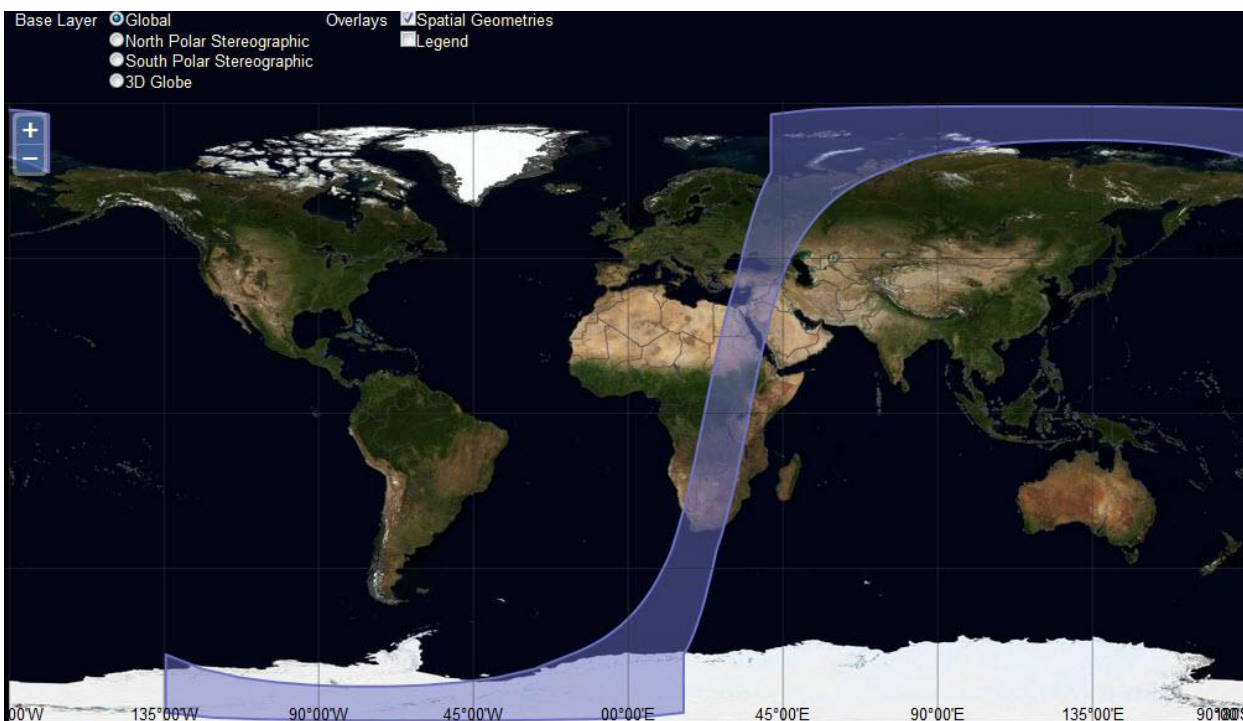
Figure 2. Spatial Coverage Map displaying one descending half orbit of the SMAP L-Band Radiometer. The map was created using the Reverb | ECHO tool.

1.8 Resolution

36 km

1.9 Geolocation

Data are gridded using the 36 km EASE-Grid 2.0 projection.The following tables provide information for geolocating this data set. For more on EASE-Grid 2.0, refer to the EASE Grids website.

Table 2. Geolocation Details for the Global EASE-Grid

Geographic coordinate system	WGS 84
Projected coordinate system	EASE-Grid 2.0 Global
Longitude of true origin	0
Standard Parallel	30
Scale factor at longitude of true origin	N/A
Datum	WGS 84

Ellipsoid/spheroid	WGS 84
Units	meter
False easting	0
False northing	0
EPSG code	6933
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
Reference	http://epsg.io/6933

Table 3. Grid Details for the Global EASE-Grid

Grid cell size (x, y pixel dimensions)	36,032.22 projected meters (x) 36,032.22 projected meters (y)
Number of columns	964
Number of rows	406
Geolocated lower left point in grid	85.044° S, 180.000 ° W
Nominal gridded resolution	36 km by 36 km
Grid rotation	N/A
ulxmap – x-axis map coordinate of the outer edge of the upper-left pixel	-17367530.45 m
ulymap – y-axis map coordinate of the outer edge of the upper-left pixel	7314540.83 m

1.10 Temporal Information

1.10.1 Coverage

Coverage spans from 31 March 2015 to 27 August 2020.

1.10.2 Temporal Coverage Gaps

1.10.2.1   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

A significant gap in coverage occurred between 19 June and 23 July 2019 after the SMAP satellite went into Safe Mode. A brief description of the event and its impact on data quality is available in the SMAP Post-Recovery Notice.

1.10.2.2   Latencies

FAQ: What are the latencies for SMAP radiometer data sets?

1.10.3 Temporal Resolution

Each Level-2 half-orbit file spans approximately 49 minutes.

2   DATA ACQUISITION AND PROCESSING

2.1 Data Source

SMAP Level-2 radiometer soil moisture data (SPL2SMP) are derived from SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 3 (SPL1CTB).

2.2 Theory of Measurements

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 soil 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, at L-band or approximately 1 GHz, offer the following additional 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), and
- measurement is independent of solar illumination which allows for day and night observations. (O'Neill et al. 2015)

For an in-depth description of the theory of these measurements, refer to Section 2: Passive Remote Sensing of Soil Moisture in the Algorithm Theoretical Basis Document (ATBD) for this product.

2.3 Derivation Techniques and Algorithms

2.3.1   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 soil 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, at L-band or approximately 1 GHz, offer the following additional 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: Passive Remote Sensing of Soil Moisture" of the Algorithm Theoretical Basis Document (ATBD) for this product (O'Neill et al. 2018), which is available as a technical reference.

2.3.2   Acquisition

SMAP Level-2 radiometer soil moisture data (SPL2SMP) are derived from SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 4 (SPL1CTB) and generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL).

2.3.3   Processing

SDS processing software ingests the 6:00 a.m. descending and 6:00 p.m. ascending half-orbit files of the SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 4 product. The ingested data are then inspected for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm, plus two optional soil moisture algorithms, to generate soil moisture retrieval; all algorithms convert SMAP brightness temperatures into estimates of the 0-5 cm surface soil moisture (m^3/m^3). Only cells that are covered by the actual swath for a given projection are included in this data set.

The three soil moisture retrieval algorithms are described below. Users should refer to O'Neill et al. 2016 and O'Neill et al. 2018 for more details.

2.3.4   Algorithm Inputs and Outputs

The main input to the processing algorithm is the SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 4 (SPL1CTB) data set. This product contains time-ordered, geolocated, and calibrated Brightness Tempeartuers (T_b) that have been resampled to the fixed 36 km EASE-Grid 2.0. In addition to general geolocation and calibration, the Level-1B T_b data have also been corrected for atmospheric effects, Faraday rotation, and low-level RFI effects prior to regridding. If the RFI encountered is too large to be corrected, the T_b data are flagged accordingly and no soil moisture retrieval is attempted. Refer to the SPL1BTB and SPL1CTB ATBDs for additional details.

Starting in Version 5 of this product, the input Level-1C T_b data (SPL1CTB) have been corrected for cases where a significant percentage of the grid cell contains a mix of land and open water (Water/Land Contamination Correction). This procedure corrects for anomalous soil moisture values seen near coastlines in previous versions and should result in less rejected data due to waterbody contamination. The correction is performed in the SPL1BTB product at the footprint level using the SMAP radiometer antenna gain pattern. When the antenna-gain-weighted water fraction within the antenna field of view (FOV) is less than or equal to 0.9, and when the antenna boresight falls on a land location as indicated by a static high-resolution land/water mask, the correction is applied. Conversely, when the antenna boresight falls on a water location, and when the water fraction within the antenna field of view (FOV) is greater than or equal to 0.1, the correction is applied. Over land, the resulting brightness temperatures will become warmer upon the removal of the contribution of water compared to the original uncorrected observations. Further details are provided in the Water/Land Contamination Correction section of the SPL1BTB user guide.

In addition to brightness temperature observations, the SPL2SMP algorithm requires ancillary data sets for soil moisture retrieval. In order for soil moisture to be retrieved accurately, a variety of global static and dynamic ancillary data are required. Static ancillary data are data which do not change during the mission, while dynamic ancillary data require periodic updates in time frames ranging from seasonally to daily. Static data include parameters such as permanent masks (land, water, forest, urban, mountain, etc.), the grid cell average elevation and slope derived from a Digital Elevation Model (DEM), permanent open water fraction, and soils information (primarily sand and clay fraction). Dynamic ancillary data include land cover, surface roughness, precipitation, vegetation parameters, and effective soil temperatures. The specific parameters and sources of ancillary data are listed in "Section 6: Ancillary Data Sets" of the ATBD (O'Neill et al. 2018).

Ancillary data are also employed to set flags that help determine either specific aspects of the processing, such as corrections for open water and frozen ground, or the quality of the retrievals, such as the precipitation flag. Other parameters used by the SPL2SMP algorithm include a

freeze/thaw flag, an open water fraction, and a vegetation index. Refer to the Data Flags section below for more details.

Note: all input brightness temperatures and ancillary data sets are mapped to the 36 km EASE-Grid 2.0 prior to entering the SPL2SMP processor.

2.3.5   Soil Moisture Algorithms

Decades of research by the passive microwave soil moisture community have resulted in a number of viable soil moisture retrieval algorithms that can be used with SMAP brightness temperature data. The European Space Agency (ESA) Soil Moisture and Ocean Salinity Mission (SMOS) mission currently flies an aperture synthesis L-band radiometer which produces brightness temperature data at multiple incidence angles over the same ground location. The baseline SMOS retrieval algorithm is based on the tau-omega model described in the ATBD, Section 2.1: Physics of the Problem, but utilizes the SMOS multiple-incidence-angle capability to retrieve soil moisture. SMAP retrievals are also based on the tau-omega model, but use the constant-incidence-angle brightness temperature data produced by the SMAP conically-scanning radiometer. Other necessary parameters in the retrieval are obtained as ancillary data.

Prior to implementing the actual soil moisture retrieval, a preliminary step in the processing is to perform a water body correction to the brightness temperature data for cases where a significant percentage of the grid cell contains open water. For more information on the water brightness temperature correction and soil moisture algorithms, refer to Section 4: Retrieval Algorithms of the ATBD for this product.

The Version 3 SPL2SMP product contains soil moisture retrieval fields produced by a baseline and several optional algorithms (Refer to Table 3). Inside an SPL2SMP file, the *soil_moisture* field is the one that links to the retrieval result produced by the currently-designated baseline algorithm, the Single Channel Algorithm V-pol (SCA-V). At present, the operational SPL2SMP Science Production Software (SPS) produces and stores soil moisture retrieval results from the following five algorithms:

Table 4. Soil Moisture Algorithm Options

Algorithm Options	Corresponding Data Field
Single Channel Algorithm H-pol (SCA-H)	*soil_moisture_option1*
Single Channel Algorithm V-pol (SCA-V) – Current Baseline	*soil_moisture_option2* (Internally linked to the *soil_moisture* field)
Dual Channel Algorithm (DCA)	*soil_moisture_option3*
Microwave Polarization Ratio Algorithm (MPRA)	*soil_moisture_option4*

Algorithm Options	Corresponding Data Field
Extended Dual Channel Algorithm (E-DCA)	*soil_moisture_option5*

Given preliminary results from current SPL2SMP Calibration/Validation (Cal/Val) analyses, the SCA-V algorithm seems to deliver slightly better performance than the SCA-H algorithm, which was designated as the pre-launch baseline retrieval algorithm. For this reason, the SCA-V is designated as the current baseline algorithm for the validated release of SPL2SMP. However, all five algorithms will be continuously assessed; the choice of the operational algorithm for the validated release of the product will be evaluated on a regular basis as analyses of new observations and Cal/Val data become available, and algorithm parameters are tuned based on a longer SMAP radiometer brightness temperature time series record.

All five algorithms operate on the same zeroth-order microwave emission model commonly known as the tau-omega model. In essence, this model relates brightness temperatures (SMAP L1 observations) to soil moisture (SMAP L2 retrievals) through ancillary information (e.g. soil texture, soil temperature, and vegetation water content) and a soil dielectric model. The algorithms differ in their approaches to solve for soil moisture from the model under different constraints and assumptions. The following sections provide concise descriptions of each algorithm. Further details are provided in O'Neill et al., 2015.

2.3.6   Baseline Single Channel Algorithm V-pol (SCA-V)

In the SCA-V, the vertically polarized brightness temperature (TB) observations are converted to emissivity using a surrogate for the physical temperature of the emitting layer. The derived emissivity is corrected for vegetation and surface roughness to obtain the soil emissivity. The Fresnel equation is then used to determine the dielectric constant from the soil emissivity. Finally, a dielectric mixing model is used to solve for the soil moisture given knowledge of the soil texture. Analytically, SCA-V attempts to solve for one unknown variable (soil moisture) from one equation that relates the vertically polarized TB to soil moisture. Vegetation information is provided by a 13-year climatological data base of global Normalized Difference Vegetation Index (NDVI) and a table of parameters based on land cover and polarization.

2.3.6.1 Single Channel Algorithm H-pol (SCA-H)

The SCA-H is similar to SCA-V, in that the horizontally polarized TB observations are converted to emissivity using a surrogate for the physical temperature of the emitting layer. The derived emissivity is corrected for vegetation and surface roughness to obtain the soil emissivity. The Fresnel equation is then used to determine the dielectric constant. Finally, a dielectric mixing model is used to obtain the soil moisture given knowledge of the soil texture. Analytically, SCA-H attempts to solve for one unknown variable (soil moisture) from one equation that relates the horizontally

polarized TB to soil moisture. Vegetation information is provided by a 13-year climatological data base of global NDVI and a table of parameters based on land cover and polarization.

2.3.6.2 Dual Channel Algorithm (DCA)

In the DCA, both the vertically and horizontally polarized TB observations are used to solve for soil moisture and vegetation optical depth. The algorithm iteratively minimizes a cost function ($\Phi2$) that consists of the sum of squares of the differences between the observed and estimated TBs:

$$\min \Phi^2_{DCA} = (T^{obs}_{B,v} - T^{est}_{B,v})^2 + (T^{obs}_{B,h} - T^{est}_{B,h})^2$$

(Equation 1)

In each iteration step, the soil moisture and vegetation opacity are adjusted simultaneously until the cost function attains a minimum in a least square sense. Similar to SCA-V and SCA-H, ancillary information such as effective soil temperature, surface roughness, and vegetation single scattering albedo must be known *a priori* before the inversion process. Unlike Microwave Polarization Ratio Algorithm (MPRA), DCA permits polarization dependence of coefficients in the forward modeling of TB observations. As implemented for the Version 2 Beta release, the H and V parameters are set the same. During the intensive Cal/Val period leading up to release of the Version 3 Validated SPL2SMP data, implementing polarization dependence for the tau-omega model parameters was investigated.

2.3.6.3 Microwave Polarization Ratio Algorithm (MPRA)

The MPRA is based on the Land Parameter Retrieval Model (Owe 2015) and was first applied to multi-frequency satellites such as AMSR-E. Like DCA, MPRA attempts to solve for soil moisture and vegetation optical depth using the vertically and horizontally polarized TB observations. However, it does so under the assumptions that (1) the soil and canopy temperatures are considered equal, and (2) vegetation transmissivity (γ) and the single-scattering albedo (ω) are the same for both H and V polarizations. When these assumptions are satisfied, it can be shown that the soil moisture and vegetation optical depth can be solved analytically in closed form, resulting in the same solutions as would be obtained iteratively using DCA. Similarly to DCA, ancillary information such as effective soil temperature, surface roughness, and vegetation single scattering albedo must be known *a priori* before the inversion process.

2.3.6.4 Extended Dual Channel Algorithm (E-DCA)

The E-DCA is a variant of DCA. Like DCA, E-DCA uses both the vertically and horizontally polarized TB observations to solve for soil moisture and vegetation optical depth. In E-DCA, however, the cost function ($\Phi2$) is formulated in a way different from that of DCA. Instead of

minimizing the sum of squares of the differences between the observed and estimated TBs as in DCA (see Equation 1), the E-DCA attempts to minimize the sum of squares of the difference between the observed and estimated normalized polarization differences (expressed in natural logarithm) and the difference between the observed and estimated TBs (also expressed in natural logarithm) as follows:

$$\min \Phi^2_{E-DCA} = \left[\log\left(\frac{T^{obs}_{B,v} - T^{obs}_{B,h}}{T^{obs}_{B,v} + T^{obs}_{B,h}} \right) - \log\left(\frac{T^{est}_{B,v} - T^{est}_{B,h}}{T^{est}_{B,v} + T^{est}_{B,h}} \right) \right]^2 + \left[\log(T^{obs}_{B,h}) - \log(T^{est}_{B,h}) \right]^2$$

(Equation 2)

In each iteration step, soil moisture and vegetation opacity are adjusted simultaneously until the cost function attains a minimum in a least square sense. It is clear that when both Φ_DCA^2 and $\Phi\_(E-DCA)^2$ attain their theoretical minimum value (i.e. zero) in the absence of uncertainties of modeling, observations, and ancillary data, $T\_(B,v)^{obs} = T\_(B,v)^{est}$ and $T\_(B,h)^{obs} = T\_(B,h)^{est}$, implying that DCA and E-DCA converge to the same solutions. The advantage of E-DCA over DCA, however, is apparent when in reality there is finite uncertainty (e.g., a dry bias associated with the ancillary soil temperature data); this uncertainty will be cancelled from the numerator and denominator in the calculation of the normalized polarization difference in $\Phi\_(E-DCA)^2$, leaving such uncertainty affecting only one component of the cost function instead of two components as in Φ_DCA^2. This reduction in the impact of soil temperature uncertainty on soil moisture retrieval should make E-DCA more tolerant of soil temperature uncertainty, resulting in fewer instances of retrieval failure than DCA. At present, there are a few caveats associated with E-DCA: (1) its exact performance is being evaluated in the ongoing Cal/Val activities, and (2) the choice of the horizontally polarized TB in the formulation is subject to further assessment as analyses of new observations and Cal/Val data become available.

2.4 Processing Steps

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL). To generate this product, the processing software ingests the 6:00 a.m. descending half-orbit files of the SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 3 product. The ingested data are then inspected for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm to generate soil moisture retrieval. Only cells that are covered by the actual swath for a given projection are written in the product.

2.5 Quality, Errors, Limitations

2.5.1 Errors

Anthropogenic RFI, principally from ground-based surveillance radars, can contaminate both radar and radiometer measurements at L-band. 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.

Level-2 radiometer data can also contain bit errors caused by noise in communication links and memory storage devices. Consultative Committee on Space Data Systems (CCSDS) packets include error-detecting Cyclic Redundancy Checks (CRCs), which are used to flag errors.

More information about error sources is provided in Section 4.6: Algorithm Error Performance of the ATBD. (O'Neill et al. 2015)

2.5.2 Quality Assessment

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

Validated Assessment Report

Beta Assessment Report

2.5.2.1 Quality Overview

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

A separate QA file with a .qa file extension is also associated with the HDF5 file; it contains useful statistics such as the percentage of elements having various quality conditions. If a product does not fail QA, it is ready to be used for higher-level processing, browse generation, active science QA, archive, and distribution. If a product fails QA, it is never delivered to NSIDC DAAC.

The information in the following sections has been adapted from O'Neill et al. (2015).

2.5.2.2 6:00p.m. Ascending half Orbits

Data from both 6:00 a.m. descending and 6:00 p.m. ascending half-orbit passes are used as input for soil moisture derivation in this Version 4 Validated product. However, the radiometer soil moisture algorithm assumes that the air, vegetation, and near-surface soil are in thermal equilibrium in the early morning hours; thus, retrievals from 6:00 p.m. ascending half-orbit passes show a slight degradation in quality. Nonetheless, ubRMSE (unbiased root mean square error) and correlation of the p.m. and a.m. retrievals are relatively close.

2.5.2.3 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, 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.

The flags described below, for example, are used in the *surface_flag*. Refer to Table 4 of the Product Specification Document for more details.

2.5.2.3.1   Open Water Flag

Open water fraction can be determined from SMAP high-resolution radar and/or *a priori* information on permanent open freshwater from the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD44W database. The SPL2SMP Version 3 product uses the MOD44W database due to the maturity of the SMAP radar open-water algorithm and availability of radar measurements, and are reported in Bit 0 and 1 in the *surface_flag* of the SPL2SMP product. This information serves as a flag to affect soil moisture retrieval processing in the following ways:

- If water fraction is 0.00–0.25, then do not flag, but retrieve soil moisture.
- If water fraction is 0.25–0.75, then flag and retrieve soil moisture.
- If water fraction is 0.75–1.00, then flag, but do not retrieve soil moisture.

2.5.2.3.2   Precipitation Flag

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 in precipitation incident on the ground at the time of the SMAP overpass can adversely bias the retrieved soil moisture due to its large impact on SMAP brightness

temperatures, as precipitation in the atmosphere is part of the atmospheric correction done in Level-1B brightness temperature processing. Unlike other flags, soil moisture retrieval will always be attempted even if precipitation is flagged. However, this flag serves as a warning to the user to view the retrieved soil moisture with some skepticism if precipitation is present.

2.5.2.3.3   Snow Flag

Although the SMAP L-Band Radiometer can theoretically see through dry snow with its low dielectric to the soil underneath a snowpack, the snow flag is currently envisioned as a binary *snow/no snow* flag based on 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 the snow flag indicates "no snow," then retrieve soil moisture.
- If the snow flag indicates "snow," then do not retrieve soil moisture.

2.5.2.3.4   Frozen Ground Flag

The frozen ground flag can be determined from the flag passed through from the SPL2SMA, which is based on the SMAP radar Freeze/Thaw algorithm, or from modeled surface temperature information (TSURF) from the Global Modeling and Assimilation Office (GMAO). The SPL2SMP Version 3 product uses the GMAO modeled TSURF parameter.

The frozen soil flag affects soil moisture retrieval processing in the following ways:

If frozen ground areal fraction is 0.00–0.05, then do not flag, but retrieve soil moisture.
   If frozen ground areal fraction is 0.05–0.50, then flag and retrieve soil moisture.

 If frozen ground areal fraction is 0.50–1.00, then flag, but do not retrieve soil moisture.

Using the SMAP radiometer freeze/thaw algorithm for the frozen ground flag replaces the SMAP radar-based freeze/thaw algorithm which was used in all previous versions of the SPL2SMP product until the radar failed on 07 July 2015. For more detail regarding the SMAP radiometer freeze/thaw algorithm, refer to the SPL3FTP user guide.

Note: SMAP radiometer freeze/thaw flags are presently validated only for all land regions north of 45°N latitude. While the SPL2SMP product contains global SMAP freeze/thaw flags, uncertainty in the flags is higher south of 45°N latitude due to small differences in the SMAP radiometer-derived reference freeze and thaw states upon which the freeze/thaw algorithm is based. Further information is available in the SPL3FTP Validated Assessment Report.

2.5.2.3.5 Urban Area Flag

Since the brightness temperature 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. 2015). The urban fraction affects soil moisture retrieval processing in the following ways:

- If the urban fraction is below the threshold, then retrieve soil moisture.
- If the urban fraction is above the threshold, then do not retrieve soil moisture.

2.5.2.3.6 Mountainous Area Flag

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 a combination of high elevation information from the DEM coupled with a statistical threshold based on the slope and slope variability within each 36 km grid cell. Most likely, soil moisture retrieval will still be attempted in most areas flagged as mountainous.

2.6 Instrumentation

2.6.1 Description

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

3 SOFTWARE AND TOOLS

For tools that work with SMAP data, see the Tools Web page.

4 VERSION HISTORY

Table 5. Summary of Version Changes

Version	Date	Description of Changes
V6	January 2021	Changes to this version include: Extended temporal coverage to 27 August 20

Version	Date	Description of Changes
V6	August 2019	Changes to this version include: The Dual Channel Algorithm (DCA) has been replaced by the Modified Dual Channel Algorithm (MDCA). MDCA achieves better retrieval performance through the modeling of polarization mixing between the vertically and horizontally polarized brightness temperature channels, as well as new estimates of single-scattering albedo and roughness coefficients. MDCA supersedes optional algorithms MPRA (option 4) and E-DCA (option 5). As part of the option algorithm changes, the following data fields were removed: *soil_moisture_option4, vegetation_opacity_option4, retrieval_qual _flag_option4, soil_moisture_option5, vegetation_opacity_option5, retrieval _qual_flag_option5*. As part of the option algorithm changes, the following data fields were added: *albedo_option3, roughness_coefficient_option3, bulk_density, clay_fraction*. 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.
V5	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.
V4	December 2016	Changes to this version include: Added 6:00 p.m. ascending half orbits, which provide: More frequent regional/global coverage (critical in flood monitoring) Soil moisture diurnal variability information (useful in data assimilation systems) Consistency with other similar satellite-based soil moisture products Contains frozen ground flag (bit 7 of *surface_flag*) derived using Normalized Polarization Ration (NPR)-based SMAP passive freeze-thaw retrieval; replaces former SMAP radar-based freeze/thaw flag

Version	Date	Description of Changes
V3	April 2016	Changes to this version include: Transitioned to Validated-Stage 2 Uses updated SPL1CTB V3 Validated data as input
V2	October 2015	Changes to this version include: Uses SPL1CTB V2 Validated-Stage 1 data as input Corrects the retrieval quality flag error
V1	September 2015	First public release

5 CONTACTS AND ACKNOWLEDGMENTS

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7 DOCUMENT INFORMATION

7.1 Publication Date

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7.2 Date Last Updated

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