



SMAP L2 Radiometer Half-Orbit 36 km EASE-Grid Soil Moisture, Version 3

USER GUIDE

How to Cite These Data

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

O'Neill, P. E., S. Chan, E. G. Njoku, T. Jackson, and R. Bindlish. 2016. *SMAP L2 Radiometer Half-Orbit 36 km EASE-Grid Soil Moisture, Version 3*. [Indicate subset used]. Boulder, Colorado USA.

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National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

Surface soil moisture (0-5 cm) in cm^3/cm^3 derived from brightness temperatures is output on a fixed global 36 km EASE-Grid 2.0.

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

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:

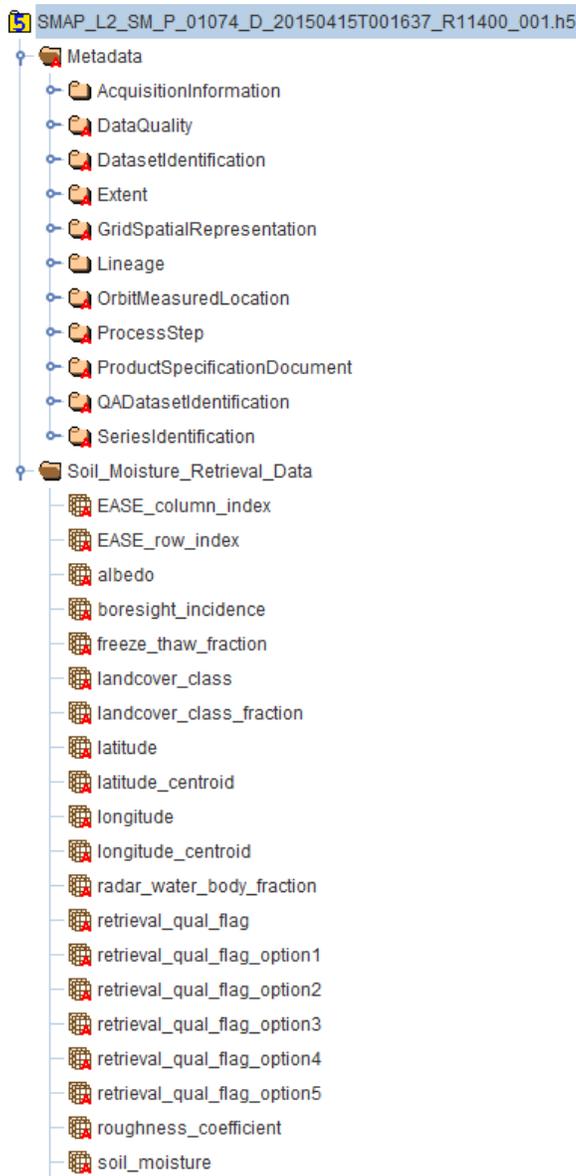


Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-2 radiometer soil moisture product, refer to the Product Specification Document.

1.3.1 Data Fields

Each file contains the main data groups summarized in this section. For a complete list and description of all data fields within these groups, refer to the [Product Specification Document](#).

All data element arrays are one-dimensional with a size of N , with the exception of *landcover_class* and *landcover_class_fraction*, which are two-dimensional arrays with a size of $N \times 3$; where N is the number of valid cells covered by the radiometer swath on the grid.

1.3.2 Soil Moisture Retrieval Data

Includes soil moisture data, ancillary data, and quality assessment flags.

1.3.3 Metadata Fields

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

1.4 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)						
yyyymmddT hhmmss	Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where: <table border="1" data-bbox="423 1394 1235 1631"> <tbody> <tr> <td>yyyymmdd</td> <td>4-digit year, 2-digit month, 2-digit day</td> </tr> <tr> <td>T</td> <td>Time (delineates the date from the time, i.e. yyyymmddThhmmss)</td> </tr> <tr> <td>hhmmss</td> <td>2-digit hour, 2-digit month, 2-digit second</td> </tr> </tbody> </table>	yyyymmdd	4-digit year, 2-digit month, 2-digit day	T	Time (delineates the date from the time, i.e. yyyymmddThhmmss)	hhmmss	2-digit hour, 2-digit month, 2-digit second
yyyymmdd	4-digit year, 2-digit month, 2-digit day						
T	Time (delineates the date from the time, i.e. yyyymmddThhmmss)						
hhmmss	2-digit hour, 2-digit month, 2-digit second						

Variable	Description								
RLVvvv	<p>Composite Release ID, where:</p> <table border="1"> <tr> <td>R</td> <td>Release</td> </tr> <tr> <td>L</td> <td>Launch Indicator (1: post-launch standard data)</td> </tr> <tr> <td>V</td> <td>1-Digit Major Version Number</td> </tr> <tr> <td>vvv</td> <td>3-Digit Minor Version Number</td> </tr> </table> <p>Example: R13242 indicates a standard data product with a version of 3.242. Refer to the SMAP Data Versions page for version information.</p>	R	Release	L	Launch Indicator (1: post-launch standard data)	V	1-Digit Major Version Number	vvv	3-Digit Minor Version Number
R	Release								
L	Launch Indicator (1: post-launch standard data)								
V	1-Digit Major Version Number								
vvv	3-Digit Minor Version Number								
NNN	Number of times the file was generated under the same version for a particular date/time interval (002: 2nd time)								
.[ext]	<p>File extensions include:</p> <table border="1"> <tr> <td>.h5</td> <td>HDF5 data file</td> </tr> <tr> <td>.qa</td> <td>Quality Assurance file</td> </tr> <tr> <td>.xml</td> <td>XML Metadata file</td> </tr> </table>	.h5	HDF5 data file	.qa	Quality Assurance file	.xml	XML Metadata file		
.h5	HDF5 data file								
.qa	Quality Assurance file								
.xml	XML Metadata file								

1.5 File Size

Each half-orbit file is approximately 1.4 MB.

1.6 Volume

The daily data volume is approximately 21 MB.

1.7 Spatial Coverage

Coverage spans from 180°W to 180°E, and from approximately 85.044°N and 85.044°S for EASE-Grid, Version 2.0. The gap in coverage at both the North and South Pole, called a pole hole, has a radius of approximately 400 km. The swath width is 1000 km, enabling nearly global coverage every three days.

1.7.1 Spatial Coverage Map

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.

Each half-orbit file is approximately 1.4 MB.

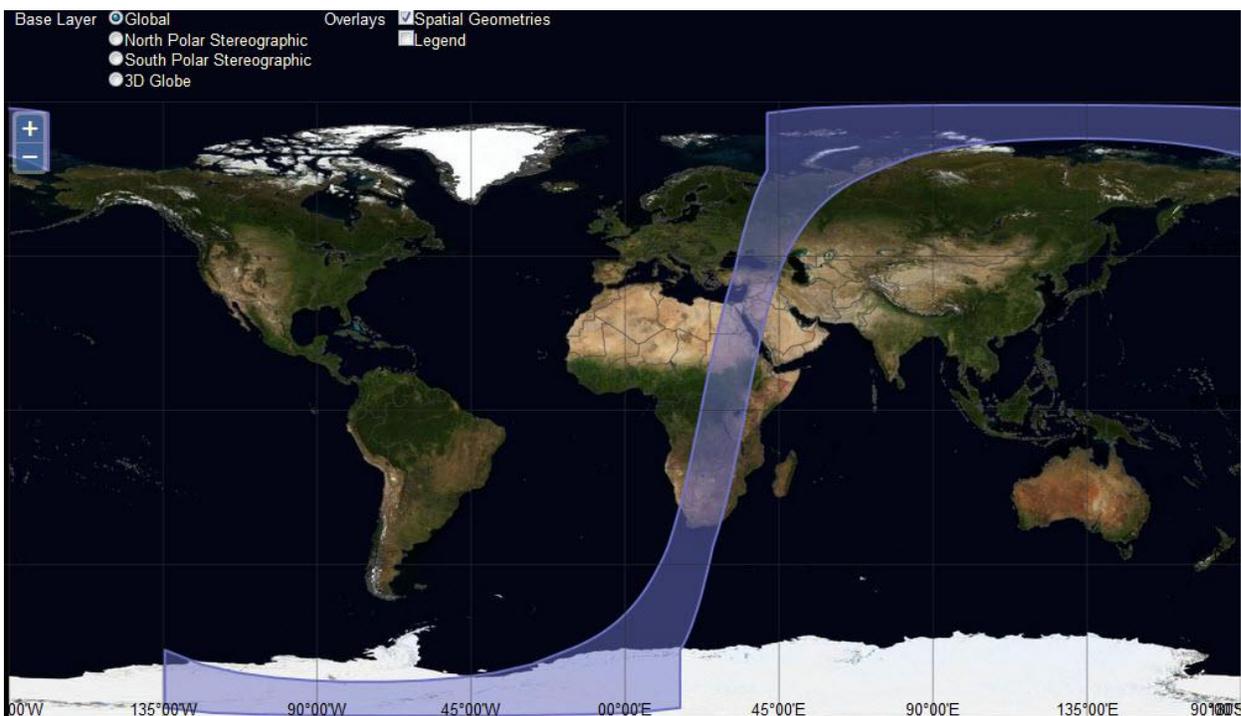


Figure 2. Spatial Coverage Map displaying one descending half orbit of the SMAP L-Band Radiometer. The map was created using the Reverb | ECHO tool.

1.8 Resolution

The native spatial resolution of the radiometer footprint is approximately 40 km. Data are then gridded using the 36 km EASE-Grid 2.0 projection.

1.9 Projection and Grid Description

1.9.1 EASE-Grid 2.0

Level-2 data are provided on the global cylindrical EASE-Grid 2.0 (Brodzik et al. 2012). Each grid cell has a nominal area of approximately 36 x 36 km² regardless of longitude and latitude.

EASE-Grid 2.0 has a flexible formulation. By adjusting a single scaling parameter, a family of multi-resolution grids that nest within one another can be generated. The nesting can be adjusted so that smaller grid cells can be tessellated to form larger grid cells. Figure 3 shows a schematic of the nesting.

This feature of perfect nesting provides SMAP data products with a convenient common projection for both high-resolution radar observations and low-resolution radiometer observations, as well as

for their derived geophysical products. For more on EASE-Grid 2.0, refer to the [EASE-Grid 2.0 Format Description](#).

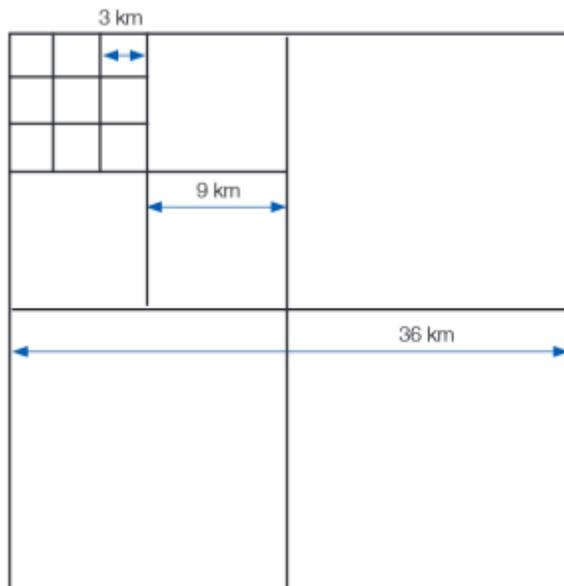


Figure 3. Perfect Nesting in EASE-Grid 2.0

1.10 Temporal Information

1.10.1 Coverage

Coverage spans from 31 March 2015 to present.

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 time series will occur. Refer to the [SMAP On-Orbit Events List for Instrument Data Users](#) page for details regarding these gaps.

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/m² 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

SMAP Level-2 radiometer soil moisture data (SPL2SMP) are derived from [SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 3 \(SPL1CTB\)](#). Utilizing a baseline plus four optional [soil moisture algorithms](#) discussed below, SMAP brightness temperatures are converted into an estimate of the 0-5 cm surface soil moisture in units of cm³/cm³.

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

2.3.1 Algorithm Inputs and Outputs

The main input to the processing algorithm for this product is the [SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 3 \(SPL1CTB\)](#) product that contains the time-ordered, geolocated, calibrated [SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness](#)

[Temperatures \(SPL1BTB\)](#), [Version 3](#) that have been resampled to the fixed 36 km EASE-Grid 2.0. In addition to general geolocation and calibration, the Level-1B brightness temperature 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 brightness temperature data are flagged accordingly and no soil moisture retrieval is attempted. Refer to the [SPL1BTB](#) and [SPL1CTB](#) ATBDs for additional details.

In addition to brightness temperature observations, the SPL2SMP algorithm also requires ancillary data sets for the soil moisture retrieval. The specific parameters and sources of these and other externally provided ancillary data are listed in Section 6: Ancillary Datasets of the [ATBD](#). 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.

Ancillary data are also employed to set flags that help to 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. Refer to the [Data Flags](#) below. All input data to the SPL2SMP process are pre-mapped using the 36 km EASE-Grid 2.0 projection. Other parameters used by the SPL2SMP algorithm include a freeze/thaw flag, an open water fraction, and a vegetation index. All input brightness temperatures and ancillary data sets used in the retrievals are mapped to the 36 km EASE-Grid 2.0 prior to entering the SPL2SMP processor. All input data, retrieved soil moisture data, and flags utilize the same grid.

The primary contents of output SPL2SMP data are the retrieved soil moisture and associated Quality Assessment (QA) flags, as well as the values of the ancillary parameters needed to retrieve the output soil moisture for that grid cell.

2.3.2 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:

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.

Table 2. Soil Moisture Algorithm Options

Algorithm Options	Corresponding Data Field
Single Channel Algorithm H-pol (SCA-H)	<i>soil_moisture_option1</i>
Single Channel Algorithm V-pol (SCA-V) – Current Baseline	<i>soil_moisture_option2</i> (Internally linked to the <i>soil_moisture</i> field)
Dual Channel Algorithm (DCA)	<i>soil_moisture_option3</i>
Microwave Polarization Ratio Algorithm (MPRA)	<i>soil_moisture_option4</i>
Extended Dual Channel Algorithm (E-DCA)	<i>soil_moisture_option5</i>

2.3.3 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.

2.3.3.1 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.

2.3.3.2 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 (Φ_2) that consists of the sum of squares of the differences between the observed and estimated TBs:

$$\min \Phi_{DCA}^2 = (T_{B,v}^{obs} - T_{B,v}^{est})^2 + (T_{B,h}^{obs} - T_{B,h}^{est})^2$$

(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.

2.3.3.3 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.

2.3.3.4 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 (Φ_2) 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:

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

(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 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.

2.5.2.2.1 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.

2.5.2.2.2 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.

2.5.2.2.3 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.

2.5.2.2.4 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 ground flag is a binary *frozen/not frozen* flag where the frozen threshold is 273.15 K. The frozen soil flag affects soil moisture retrieval processing in the following ways:

- If the frozen soil flag indicates *not frozen*, then retrieve soil moisture.
- If the frozen soil flag indicates *frozen*, then do not retrieve soil moisture.

2.5.2.2.5 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.

2.5.2.2.6 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.

2.5.2.2.7 RFI Flag

The presence of radio frequency interference can markedly impact SMAP brightness temperatures, and in turn can adversely affect soil moisture retrieval accuracy or prevent a retrieval from being attempted. RFI is detected and corrected for in the SPL1BTB product, which sets an RFI flag that is eventually passed to the SPL2SMP processor. Refer to the [SPL1BTB ATBD](#). The RFI flag affects soil moisture retrieval processing in the following ways:

- If RFI flag is 0, then no RFI detected; retrieve soil moisture.
- If RFI flag is 1, then some RFI has been detected but TB have been corrected; retrieve soil moisture.
- If RFI flag is 2, then large RFI has been detected and TB cannot be corrected; do not retrieve soil moisture.

For in-depth details on all data flags, refer to the [Product Specification Document](#).

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.

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5 REFERENCES

Brodzik, M. J., B. Billingsley, T. Haran, B. Raup, and M. H. Savoie. 2014. Correction: Brodzik, M. J. et al. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data

Sets. *ISPRS Int. J. Geo-Inf* 2012. 1(1):32-45 *ISPRS Int. J. Geo-Inf.* 3(3):1154-1156. <http://dx.doi.org/10.3390/ijgi3031154>.

Brodzik, M. J., B. Billingsley, T. Haran, B. Raup, and M. H. Savoie. 2012. EASE-Grid 2.0: Incremental but Significant Improvements for Earth-Gridded Data Sets. *ISPRS Int. J. Geo-Inf.* 1(1):32-45. <http://dx.doi.org/10.3390/ijgi1010032>.

Chan, S., R. Bindlish, P. O'Neill, E. Njoku, T. Jackson, A. Colliander, F. Chen, M. Mariko, S. Dunbar, J. Piepmeier, S. Yueh, D. Entekhabi, M. Cosh, T. Caldwell, J. Walker, X. Wu, A. Berg, T. Rowlandson, A. Pacheco, H. McNairn, M. Thibeault, J. Martinez-Fernandez, A. Gonzalez-Zamora, M. Seyfried, D. Bosch, P. Starks, D. Goodrich, J. Prueger, M. Palecki, E. Small, M. Zreda, J. Calvet, W. Crow, and Y. Kerr. 2016, in press. Assessment of the SMAP Passive Soil Moisture Product. *IEEE Trans. Geosci. Remote Sens.*

Chan, Steven, and R. Scott Dunbar. 2015. Soil Moisture Active Passive (SMAP) Level 2 Passive Soil Moisture Product Specification Document, Beta Release. Pasadena, CA USA: SMAP Project, JPL D-72547, Jet Propulsion Laboratory. ([SMAP L2_SM_P Beta-Level PSD \(PRIMARY\).pdf](#), 421 KB)

Entekhabi, Dara et al. 2014. SMAP Handbook—Soil Moisture Active Passive: Mapping Soil Moisture and Freeze/Thaw from Space. SMAP Project, JPL CL#14-2285, Jet Propulsion Laboratory, Pasadena, CA.

Jackson, T., P. O'Neill, E. Njoku, S., Chan, R. Bindlish, A. Colliander, F. Chen, M. Burgin, S. Dunbar, J. Piepmeier, M. Cosh, T. Caldwell, J. Walker, X. Wu, A. Berg, T. Rowlandson, A. Pacheco, H. McNairn, M. Thibeault, J. Martínez-Fernández, Á. González-Zamora, M. Seyfried, D. Bosch, P. Starks, D. Goodrich, J. Prueger, M. Palecki, E. Small, M. Zreda, J. Calvet, W. Crow, Y. Kerr, S. Yueh, and D. Entekhabi. 2015. Calibration and Validation for the L2/3_SM_P Beta-Release Data Products, Version 2. SMAP Project, JPL D - 93981. Jet Propulsion Laboratory, Pasadena, CA. ([SMAP L2_SM_P Beta-Level Assessment Report FINAL.pdf](#), 3 MB)

Jackson, T., P. O'Neill, E. Njoku, S., Chan, R. Bindlish, A. Colliander, F. Chen, M. Burgin, S. Dunbar, J. Piepmeier, M. Cosh, T. Caldwell, J. Walker, X. Wu, A. Berg, T. Rowlandson, A. Pacheco, H. McNairn, M. Thibeault, J. Martínez-Fernández, Á. González-Zamora, M. Seyfried, D. Bosch, P. Starks, D. Goodrich, J. Prueger, M. Palecki, E. Small, M. Zreda, J. Calvet, W. Crow, Y. Kerr, S. Yueh, and D. Entekhabi. 2016. Calibration and Validation for the L2/3_SM_P Version 3 Data Products. SMAP Project, JPL D - 93720. Jet Propulsion Laboratory, Pasadena, CA. ([L2SMP Version 3 Report \(FINAL\)2.pdf](#), 4.11 MB)

Jet Propulsion Laboratory (JPL). "SMAP Instrument." JPL SMAP Soil Moisture Active Passive. <http://smap.jpl.nasa.gov/observatory/instrument/> [20 August 2015].

NASA EOSDIS Land Processes DAAC. 2015. Land Water Mask Derived from MODIS and SRTM L3 Global 250m SIN Grid. Version 005. NASA EOSDIS Land Processes DAAC, USGS Earth

Resources Observation and Science (EROS) Center, Sioux Falls, SD.

(https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod44w), [20 August 2015].

O'Neill, P. E., E. G. Njoku, T. J. Jackson, S. Chan, and R. Bindlish. 2015. SMAP Algorithm Theoretical Basis Document: Level 2 & 3 Soil Moisture (Passive) Data Products. SMAP Project, JPL D-66480, Jet Propulsion Laboratory, Pasadena, CA. ([L2_SM_P_ATBD_v7_Sep2015-poen.pdf](#), 3.3 MB)

Owe, M., De Jeu, R. A. M., and Walker, J. P. A Methodology for Surface Soil Moisture and Vegetation Optical Depth Retrieval Using the Microwave Polarization Difference Index. *IEEE Transactions on Geoscience and Remote Sensing*, 39(8):1643–1654, 2001.

Piepmeyer, J.R., D.G. Long, and E.G. Njoku. 2008. Stokes Antenna Temperatures. *IEEE Trans. Geosci. Remote Sens.* 46(2):516-527.

6 DOCUMENT INFORMATION

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