SMAP L2 Radar/Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 3

USER GUIDE

How to Cite These Data

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

Entekhabi, D., N. Das, E. G. Njoku, J. T. Johnson, and J. Shi. 2016. *SMAP L2 Radar/Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture*, Version 3. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/8YTYSV6JGBK2. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL2SMAP

NSIDC 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 and sigma nought measurements is output on a fixed 9 km EASE-Grid 2.0.

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

Sigma nought (sigma0), or the backscatter coefficient, is a measure of the strength of radar signals reflected back to the instrument from a target, and is defined as per unit area on the ground. Usually expressed in dB, it is a normalized dimensionless number, comparing the strength observed to that expected from a defined area. The SMAP L-band Radar measures sigma0 using VV, HH, and HV transmit-receive polarizations, and uses separate transmit frequencies for the H (1.26 GHz) and V (1.29 GHz) polarizations. Sigma0 measurements are derived using Synthetic-Aperture Radar (SAR) processing.

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

1.2 File Information

1.2.1 Format

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

1.2.2 File Contents

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

Figure 1. For a complete list of file contents for the SMAP Level-2 radar/radiometer soil moisture product, refer to the Appendix of this document.

1.2.3 Data Fields

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

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

SOIL MOISTURE RETRIEVAL DATA

Includes combined radar and radiometer soil moisture data at 9 km resolution, ancillary data, and quality assessment flags.

SOIL MOISTURE RETRIEVAL DATA 3 KM

Includes combined radar and radiometer soil moisture data at 3 km resolution, ancillary data, and quality assessment flags. Soil moisture data retrieved in the 3 km group were acquired at nadir.

1.2.4 Metadata Fields

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

1.2.5 Naming Convention

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

SMAP_L2_SM_AP_[Orbit#]_D_yyyymmddThhmmss_RLVvvv_NNN.[ext]

For example:

SMAP_L2_SM_AP_00934_D_20151225T074951_R13171_002.h5

Where:

Table 1. File Naming Conventions

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>SMAP</td><td>Indicates SMAP mission data</td></tr>
<tr><td>L2_SM_AP</td><td>Indicates specific product (L2: Level-2; SM: Soil Moisture; AP: Active/Passive)</td></tr>
<tr><td>[Orbit#]</td><td>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.</td></tr>
<tr><td>D</td><td>Descending half-orbit pass of the satellite (where satellite moves from North to South, and 6:00 a.m. is the local solar equator crossing time)</td></tr>
<tr><td>yyyymmddThhmmss</td><td>Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where:
<table>
<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>
</table></td></tr>
</table>

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>RLVvvv</td><td>Composite Release ID, where:
<table>
<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>
Example: R13171 indicates a standard data product with a version of 3.171. Refer to the SMAP Data Versions page for version information.</td></tr>
<tr><td>NNN</td><td>Number of times the file was generated under the same version for a particular date/time interval (002: 2nd time)</td></tr>
<tr><td>.[ext]</td><td>File extensions include:
<table>
<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></td></tr>
</table>

1.2.6 File Size

Each half-orbit file is approximately 27 MB.

1.2.7 File Volume

The daily data volume is approximately 500 MB.

1.3 Spatial Information

1.3.1 Coverage

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

1.3.2 Spatial Coverage Map

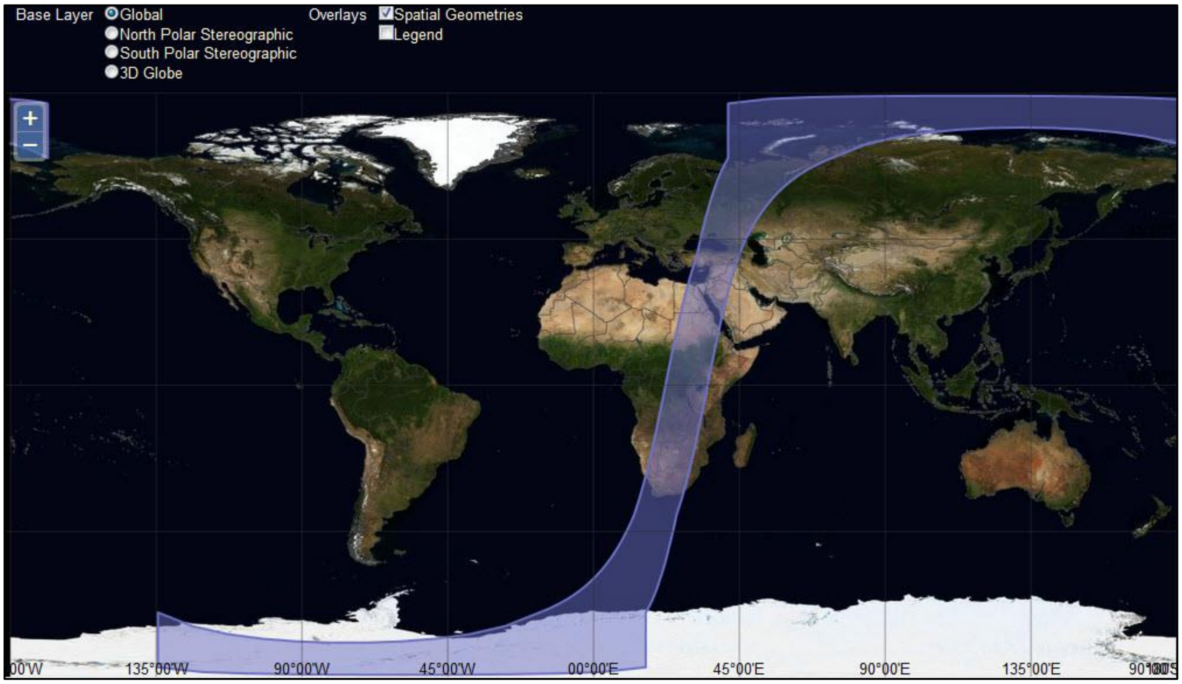

Figure 2. Spatial Coverage Map displaying one descending half orbit of the SMAP L-Band Radar and Radiometer

1.3.3 Resolution

SMAP 3 km Synthetic Aperture Radar (SAR) backscatter data and 36 km radiometer brightness temperature data are combined using the SMAP Active-Passive algorithm to derive soil moisture data that are then gridded using the 9 km EASE-Grid 2.0 projection.

1.3.4 EASE-Grid 2.0

These data are provided on the global cylindrical EASE-Grid 2.0 (Brodzik et al. 2012). Each grid cell has a nominal area of approximately 36 x 36 km^2 regardless of longitude and latitude. The SPL2SMAP data product is posted on a 9 km EASE-Grid that is nested consistently with the 36 km brightness temperatures and 3 km radar backscatter cross-section data.

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.

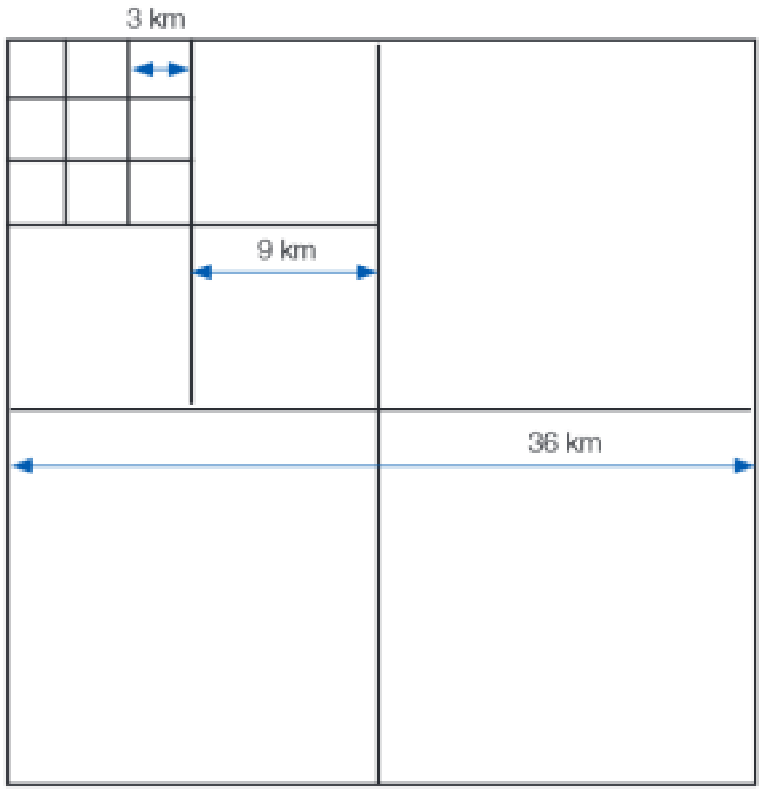

Figure 3. Perfect Nesting in EASE-Grid 2.0

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 13 April 2015 through 07 July 2015.

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

1.4.1.1 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

1.4.2 Resolution

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

2 DATA ACQUISITION AND PROCESSING

2.1 Background

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

2.2 Acquisition

SMAP Level-2 radar/radiometer soil moisture data (SPL2SMAP) are derived from the following:

- SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture, Version 3 (SPL2SMA)
- SMAP L2 Radiometer Half-Orbit 36 km EASE-Grid Soil Moisture, Version 3 (SPL2SMP)

2.3 Derivation Techniques and Algorithms

This section has been adapted from Entekhabi et al. 2012, Entekhabi et al. 2014, and Das et al. 2014.

SPL2SMAP data are based on the merger of SMAP radiometer and radar data at two discrete grid resolutions: 36 km and 3 km, respectively. The Equal-Area-Scalable-Earth Grid (EASE-Grid) cells of the radiometer and radar products nest perfectly; refer to the EASE-Grid 2.0 section of this document. Therefore, the SPL2SMAP 9 km soil moisture product has 16:1 and 1:9 correspondence with the radiometer and radar products, respectively. The grid definition used in the algorithms is illustrated in Fig. 2 of the ATBD (Entekhabi et al. 2014). The baseline and optional algorithms disaggregate the coarse resolution radiometer brightness temperature product based on the spatial variation in high resolution radar backscatter. In addition, the algorithms require static and dynamic ancillary data. These ancillary data are resampled to the same EASE-Grid prior to ingest in the SPL2SMAP processing. The dynamic ancillary data used to retrieve soil moisture for a particular 9 km grid cell at a specific point in time are listed in the SMAP SPL2SMAP and SPL3SMAP output files for the benefit of end users.

Refer to the Appendix of this document for a description of all data fields.

2.3.1 Baseline Algorithm

The SPL2SMAP baseline algorithm is based on the disaggregation of the radiometer brightness temperatures using the radar backscatter spatial patterns within the radiometer footprint. The spatial patterns need to account for the different levels of radar backscatter cross-section sensitivity to soil moisture, vegetation cover, and soil surface roughness. For this reason, the radar measurements within the radiometer footprint are scaled by parameters that are derived from the temporal fluctuations in the spatially averaged radar and radiometer measurements. The derivation of the parameters are physically possible because SMAP made coincident and constant look-angle radar and radiometer measurements; the co-variations at a coarse scale (radiometer grid scale) over specified periods of time (short relative to plant phenology) are mostly related to surface soil moisture changes rather than contributions of vegetation and surface roughness. These derived parameters from the radar and radiometer measurements addresses the high-resolution variability of soil moisture within the coarse radiometer grid cell. However, the high-resolution variability of vegetation and surface roughness with the coarse radiometer grid cell is addressed by the parameter derived using the high-resolution snapshot co-pol and x-pol radar measurements.

The basis for the brightness temperature disaggregation based on radar measurements begins with relating the radiometer measurements with the radar backscatter cross-section measurements in a simple conceptual framework outlined in the Algorithm Theoretical Basis Document (ATBD) (Entekhabi et al. 2014) for this product (refer to Section 2: Physics of the Problem). Note: The analysis provided therein is meant to simply demonstrate the dependencies and it is not directly (such as algebraically) part of the baseline SPL2SMAP algorithm formulation.

Once the disaggregated brightness temperatures at 9 km and 3 km are produced, the Single Channel Algorithm (SCA)/Tau-Omega model is applied that uses high-resolution ancillary information at 9 km and 3 km to produce the SPL2SMAP product.

2.3.2 Formulation of the Baseline SPL2SMAP Algorithm

The SMAP L-band radiometer measures the natural microwave emission in the form of the brightness temperature (TB) of the land surface, while the L-band radar measures the energy backscattered (σ0) from the land surface after transmission of an electromagnetic pulse. On short time scales, an increase of surface soil moisture produces an increase in soil dielectric constant, which leads to a decrease in radiometer TB and an increase in radar backscatter, and vice-versa. Thus, over short time periods variations soil moisture cause TB and σ0 to be negatively correlated. This time period is generally shorter than the seasonal phenology of vegetation.

The land surface vegetation and surface roughness factors are expected to vary on time scales longer that those associated with soil moisture variability. However, over a short time periods the SMAP measured TB and σ0 are expected to have a linear functional relationship: $TB = \alpha + \beta \times \sigma0$. The unknown parameters α and β are dependent on the dominant vegetation and soil roughness characteristics. The TB polarization can either be v or h and the σ polarization is either vv or hh. The parameter β can be statistically estimated based on a time-series regression of pairs of SMAP radiometer TB and spatially-averaged radar data σ0 from successive observations of the same Earth grid cell. The parameter β, which represents the sensitivity of backscatter to changes in brightness temperature is highly dependent on vegetation characteristics. It is possible to categorize grid cells based on a radar vegetation index (RVI), which is directly proportional to the amount of vegetation on the land surface. RVI can be derived directly from SMAP radar measurements. Across low vegetation cover regions (low RVI), the changes in radiometer brightness temperature are also reflected in changes in radar backscatter, leading to large (negative) values of β. When the vegetation cover is dense and there is complete volume scattering from the vegetation canopy RVI reaches the upper limit of unity. For bare smooth surfaces, the cross-pol radar backscatter cross-section is insensitive to soil moisture and is much smaller than the co-pol values. This leads to a near-zero RVI.

The statistically-estimated parameter β is unique for each location since it is a sensitivity parameter relating TB and σ0 and it is a function of surface characteristics like the local vegetation cover and soil roughness for a particular period of time. The parameter varies seasonally as well as geographically. Therefore, the time-series pairs of TB and σ0 are used for a location in the regression span a moving-window period over which vegetation phenology and surface characteristics can be considered constant. To develop the satellite-based active-passive algorithm further the relationship between TB and σ0 can also be conceptually evaluated at the 9 km scale within the radiometer footprint. At this scale brightness temperature is not available given the SMAP radiometer instrument resolution. In fact, determining TB at this scale is the target of the algorithm and it is referred to as the disaggregated brightness temperature. The way to incorporate the effects of the variations of the regression parameters at the 9 km scale with respect to the coarser 36 km scale is to determine subgrid heterogeneity from high-resolution cross-polarization radar backscatter measurements. The methodology is described in Section 3.2 of the ATBD (Entekhabi et al. 2014).

The performance of the brightness temperature disaggregation is heavily dependent on robust estimates of statistically estimated parameters, which are specific for a given location and reflect the local roughness and vegetation cover conditions. The parameters vary seasonally; therefore, the time-series pairs of T_B and σ0 used for a location in the regression should be limited to a finite-length moving-window over which vegetation phenology can be considered constant. Depending on the dominant land cover vegetation, this may be as short as a few weeks for croplands and a few months for natural landscapes, especially those with evergreen (tropical or boreal) plant types. This translates to anywhere from two to about twenty or at most thirty pair of TB and σ0 for the regression analysis. The issue is further complicated by the fact that robust estimation is possible only if there is adequate soil moisture variation within the window period (drydown or wetting event) to cause variations in both TB and σ0. Estimates of β are based on the β-RVI relationships that are established over time. Observations from airborne field experiments show that RVI is indeed a unique and reliable estimator of β. More importantly, RVI isolates the impact of vegetation and separates the effect of surface roughness. From this point tau-omega (τ-ω) brightness temperature retrieval algorithms with considerable heritage can be used to retrieve surface soil moisture.

2.3.3 Algorithm Process Flow

Figure 3 is a simplified depiction of process flow for the current SPL2SMAP baseline algorithm. The process flow diagram captures important processes that involve input data streams and static and ancillary data used in the algorithm to generate the SPL2SMAP soil moisture product. The brightness temperatures at 9 km are converted to soil moisture using algorithms described in SPL2SMP, but based on 9 km resolution ancillary data. Note that the disaggregation is not performed if the coarse resolution brightness temperature does not meet the quality requirements, especially if large water bodies and RFI are present.

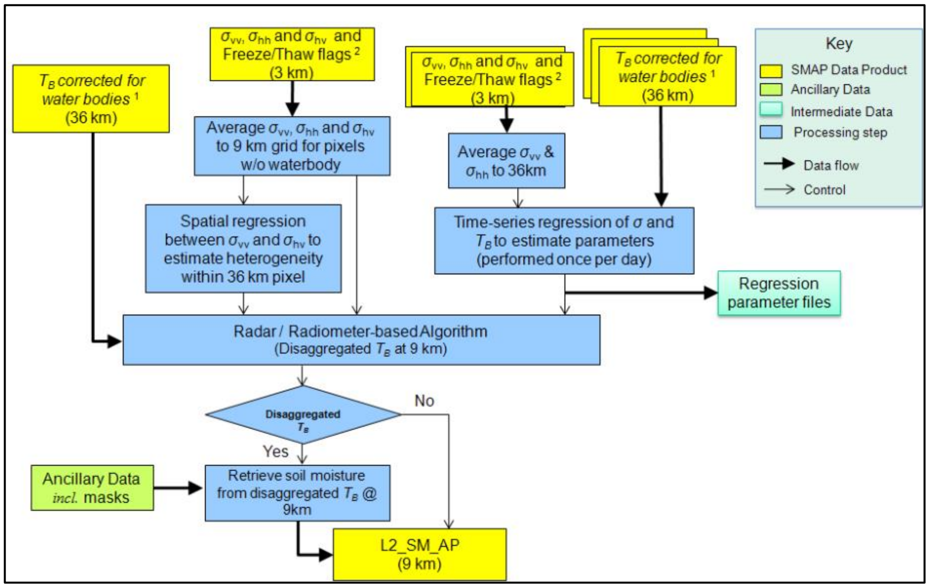

Figure 4. Process Flow Diagram of the Baseline SPL2SMAP Algorithm

2.4 Processing

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate this product, the processing software ingests the 6:00 a.m. descending half-orbit files of the SMAP SPL2SMA and SPL2SMP products. The brightness temperature available in SPL2SMP is corrected from the presence of waterbodies (up to 0.05 fraction) and then used in SPL2SMAP product generation. Beyond waterbody fraction of 0.05, no correction is conducted as it introduces high errors due to uncertainty present in the water fraction information. The SPL2SMAP product generation process also uses the ancillary data, as well as the quality and surface flags from the SPL2SMA and SPL2SMP products. To generate the standard SPL2SMAP product, the processing software ingests the 6:00 a.m. descending half-orbit files of the SPL2SMA and SPL2SMP data. 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 swath are written in the product.

2.5 Quality, Errors, and Limitations

2.5.1 Error Sources

Errors in SPL2SMAP data come from various sources with the most prominent potential error source being anthropogenic Radio Frequency Interference (RFI). Principally from ground-based surveillance radars and ancillary data, RFI can contaminate both radar and radiometer measurements at L-band. Early measurements and results from European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission indicate RFI is a major source of concern because of high RFI present and detectable in many parts of the world. The SMAP radar and radiometer electronics and algorithms include design features to mitigate the effects of RFI. The SMAP radar utilized selective filters and an adjustable carrier frequency to tune to predetermined RFI-free portions of the spectrum while on orbit. The SMAP radiometer implements a combination of time and frequency diversity, kurtosis detection, and use of T4 thresholds to detect and, where possible, mitigate RFI. Owing to such robust measures in the SMAP radiometer and radar hardware and data processing, the SPL2SMAP product has lesser impact than SMOS measurements from anthropogenic RFI. Other sources of error, such as disaggregation process errors and calibration and gridding errors, are quantified analytically for the disaggregated brightness temperatures and retrieved soil moisture at 9 km and 3 km. (Entekhabi et al. 2012, Entekhabi et al. 2014, and Das et al. 2015)

More information about error sources is provided in Section 4.3: Error Budget of Baseline Algorithm of the ATBD (Entekhabi et al. 2014).

2.5.2 Quality Assessment

For in-depth details regarding the quality of these Version 3 data, refer to SMAP Technical References.

2.5.3 Quality Overview

SMAP products provide multiple means to assess quality. Each product contains bit flags, uncertainty measures, and file-level metadata that provide quality information. For information regarding the specific bit flags, uncertainty measures, and file-level metadata contained in this product refer to the appendix.

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

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

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

2.5.4 Data Flags

Quality control (QC) is an integral part of the SPL2SMAP processing. The QC steps of SPL2SMAP processing are based on the flags that are provided with the input data streams (SPL2SMP, and SPL2SMA), different types of masks, flags, and fractional coverage of other variables provided by ancillary data. The SPL2SMAP will process all data that have favorable conditions for soil moisture retrieval (VWC <= 5 kg/m2, no rain, no snow cover, no frozen ground, no RFI, sufficient distance from open water). However, soil moisture retrieval will also be conducted for regions with VWC > 5, rain, RFI repaired data, and places closer to water bodies, but appropriate flags are added to these data points indicating their susceptibility to potentially high errors. The product specification table provided in Section 6 of the ATBD (Entekhabi et al. 2014) elaborates the fields for QC bit flags. A flow diagram in Fig. 39 of the ATBD (Entekhabi et al. 2014) illustrates the decision tree to perform SPL2SMAP retrieval. As shown in Fig. 39, the SPL2SMAP processing involves merging of two data streams i.e., SPL2SMP and SPL2SMA. Therefore, the QC of SPL2SMAP output is influenced by these input data streams. In other words, the QC flags of SPL2SMAP output are the union of QC flags from SPL2SMP and SPL2SMA data streams. However, due to differences in spatial resolution of the (SPL2SMAP), the assignment of QC flags in SPL2SMAP may differ from the flags associated with the inputs. The thresholds of ancillary data that initiate flagging in the SPL2SMAP product are mentioned below. For example, TB data in SPL2SMP are corrected for the presence of water bodies. Studies are being conducted to assess the quality of corrected TB data that are acceptable and within the desired uncertainty level that could be used in SPL2SMAP processing. Preliminary assessment shows that 5% waterbodies fraction within the 36 km grid cell of SPL2SMP has acceptable quality and have low error level in degree Kelvins. All the 9 km nested grid cells of SPL2SMAP within the 36 km grid cell of SPL2SMP are flag for suspected quality if the waterbodies fraction is >5%. The water body fraction is reported for all land-based 9 km grid cells in SPL2SMAP product file, and the water body flag bit is set in the retrieval quality field if the water body fraction is greater than a threshold value of 5%. In the case of VWC, SPL2SMAP retrieval is performed at all the grid cells irrespective of VWC but QC flag set only for grid cell having VWC >5 kg/m2. Retrievals are performed for SPL2SMAP grid cells that are associated with RFI and water body fraction above a particular threshold; however, appropriate QC flags are raised to inform the user about the suspected quality of disaggregated brightness temperature and retrieved soil moisture. No retrievals are performed over frozen ground, presence of snow, and 100% urban fraction. Thresholds from masks that will initiate flags and operational decisions to process SPL2SMAP product are mentioned as follows:

OPEN WATER BODY FLAG

Open water fraction is 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 SPL2SMAP Version 3 product uses the MOD44W database due to the maturity of the SMAP radar open-water algorithm and availability of radar measurements. This information is used to flag grid cells during soil moisture retrieval processing in the following way:

- Water fraction is 0.00–0.05: Retrieve soil moisture, do not flag.
- Water fraction is 0.05–0.10: Flag and retrieve soil moisture.
- Water fraction is 0.10–1.00: Flag but do not retrieve soil moisture.

RFI FLAG

Presence of RFI in the SMAP brightness temperature and radar backscatter data adversely affects the SMAP Active-Passive algorithm. Therefore, specific logics are built into the SMAP Active-Passive processor to initiate flag during soil moisture retrievals. The RFI flag is initiates as follows:

- No RFI detected in TB and σ0: Retrieve soil moisture, do not flag.
- RFI detected in TB and repaired: Flag and retrieve soil moisture.
- RFI detected in σ0 and repaired: Flag and retrieve soil moisture.
- RFI detected in TB and not repaired: Flag and do not retrieve soil moisture.

RFI detected in σ0 and not repaired: Flag and do not retrieve soil moisture.

SNOW FLAG

The ancillary data that provide a binary indicator for presence of snow is used for flagging in the following way:

- Snow data indicates no snow is present in the cell: Retrieve soil moisture and do not flag.
- Snow data indicates any amount of snow is present in the cell: Flag, do not retrieve soil moisture.

PRECIPITATION FLAG

Presence of heavy rainfall during SMAP data acquisition may adversely affect the TB and σ0 measurements. The precipitation data from Global Modeling and Assimilation Office (GMAO) is used to flag the 9 km and 3 km grid cells. SPL2SMAP retrievals will be performed irrespective of rainfall; however, the grid cell will be flagged in case of the presence of precipitation.

VWC FLAG

SPL2SMAP retrievals are conducted for all the locations irrespective of VWC level. The grid cells are flagged for VWC greater than 5 kg/m2.

URBAN AREA FLAG

Presence of urban area adversely affects the L-band radiometric measurements. The presence of urban area within the SMAP measurement is likely to bias soil moisture retrievals. Currently the SPL2SMAP processor flag the regions having urban area as follows:

- Urban fraction is 0.00–0.25: Retrieve soil moisture, do not flag.
- Urban fraction is 0.25 - < 1.0: Flag and retrieve soil moisture.
- Urban fraction is = 1.0: Flag but do not retrieve soil moisture.

MOUNTAIN AREA FLAG

Statistics of mountainous regions are used to initiate flags and operational decisions during SPL2SMAP processing. The standard deviation of slope is used as a threshold to detected uneven terrain and mountainous regions. For QC related to mountainous regions, the SPL2SMAP processing is consistent with the SPL2SMP and SPL2SMA processing. Currently the SPL2SMAP processor flags any region where DEM slope standard deviation is more than three degrees. However, retrievals are performed for all locations.

For more information regarding data flags, refer to the Appendix of this 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.

2.6.2 Trajectory and Attitude

3 SOFTWARE AND TOOLS

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

4 VERSION HISTORY

Version	Date	Version Changes
V2	November 2015	First public data release

Version	Date	Version Changes
V3	April 2016	Changes to this version include: Transitioned to Validated-Stage 2 Uses SPL2SMA V3 Validated and SPL2SMP V3 Validated as input Snapshot beta parameter estimation Updated soil texture files (renormalized cases where sand+clay > 100%) Updated default beta parameter

5 RELATED DATA SETS

- SMAP Data at NSIDC | Overview
- SMAP Radar Data at the ASF DAAC

6 RELATED WEBSITES

- SMAP at NASA JPL

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Bolten, J., V. Lakshmi, and E. Njoku. 2003. Soil Moisture Retrieval Using the Passive/Active L- and S-band Radar/Radiometer. *IEEE Trans. Geosci. Rem. Sens*., 41:2792-2801.

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.

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.

Das, N. N., D. Entekhabi, S. Dunbar, E. G. Njoku, and S. Yueh. 2015. Uncertainty Estimates in the SMAP Combined Active-Passive Downscaled Brightness Temperature*. IEEE- TGARS*. Accepted, in press.

Das, N. N., and R. S. Dunbar. 2015. SMAP Level 2 Active/Passive Soil Moisture (L2_SM_AP) Product Specification Document. SMAP Project, JPL D-72548, Jet Propulsion Laboratory, Pasadena, CA. (SMAP L2_SM_AP PSD_10312015.pdf, 3 MB)

Das, N. N., D. Entekhabi, E. G. Njoku, J. Johnston, J. C. Shi, and A. Colliander. 2014. Tests of the SMAP Combined Radar and Radiometer Brightness Temperature Disaggregation Algorithm Using Airborne Field Campaign Observations. *IEEE-TGARS*. 52:2018–2028.

Das, N. N., D. Entekhabi, and E. G. Njoku, 2011. An Algorithm for Merging SMAP Radiometer and Radar Data for High Resolution Soil Moisture Retrieval. *IEEE-TGARS*. 9: 1504-1512.

Das, N. N., et al. 2015. Soil Moisture Active Passive (SMAP) Project Calibration and Validation for the L2/3_SM_AP Beta-Release Data Products. SMAP Project, JPL D-93984. Jet Propulsion Laboratory, Pasadena, CA. (SMAP-AP_Assessment_Report_Final.pdf, 4 MB)

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

Entekhabi, D., N. Das, E. Njoku, J. Johnson, and J. Shi. 2014.SMAP Algorithm Theoretical Basis Document: L2 & L3 Radar/Radiometer Soil Moisture (Active/Passive) Data Products. SMAP Project, JPL D-66481. Jet Propulsion Laboratory, Pasadena, CA. (277_L2_3_SM_AP_RevA_web.pdf, 16.6 MB)

9 DOCUMENT INFORMATION

9.1 Publication Date

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9.2 Date Last Updated

01 December 2020

1 APPENDIX A – DATA FIELDS

This appendix provides a description of all data fields within the *SMAP L2 Radar/Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture (SPL2SMAP)* product. The data are grouped into three main HDF5 groups:

- Metadata
- Soil_Moisture_Retrieval_Data
- Soil_Moisture_Retrieval_Data_3km

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

1.1 Soil_Moisture_Retrieval_Data

Table A1 describes the data fields of a typical SPL2SMAP descending half-orbit granule. All data element arrays are one-dimensional with a size "N," where N is the number of valid cells from the swath that appear on the grid.

Table A - 1. Data Fields for Soil_Moisture_Retrieval_Data

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Value
EASE_column_index	EASEGridCell_Array	integer	2	count	0	65535	65534
EASE_row_index	EASEGridCell_Array	integer	2	count	0	65535	65534
albedo	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0
alpha_tbh_hh	EASEGridCell_Array	real	4	Kelvins	0	350.0	-9999.0
alpha_tbv_vv	EASEGridCell_Array	real	4	Kelvins	0	350.0	-9999.0
bare_soil_roughness_retrieved	EASEGridCell_Array	real	4	meters	0.0	0.1	-9999.0
beta_tbh_hh	EASEGridCell_Array	real	4	Kelvins/dB	-25	0	-9999.0
beta_tbv_vv	EASEGridCell_Array	real	4	Kelvins/dB	-25	0	-9999.0
disaggregated_tb_h_qual_flag_option1	EASEGridCell_Array	bit flag	2	NA	NA	NA	66534
disaggregated_tb_h_qual_flag_option2	EASEGridCell_Array	bit flag	2	NA	NA	NA	66534
disaggregated_tb_v_qual_flag_option1	EASEGridCell_Array	bit flag	2	N/A	N/A	N/A	66534
disaggregated_tb_v_qual_flag_option2	EASEGridCell_Array	bit flag	2	N/A	N/A	N/A	66534
distance_from_nadir	EASEGridCell_Array	real	4	meters	0.0	500000.0	-9999.0
freeze_thaw_fraction	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0
gamma_hh_xpol	EASEGridCell_Array	real	4	normalized	0	2	-9999.0
gamma_vv_xpol	EASEGridCell_Array	real	4	normalized	0	2	-9999.0
landcover_class	EASEGridCell_Array	enum	1	N/A	N/A	N/A	254
latitude	EASEGridCell_Array	real	4	degrees_north	-90.0	90.0	-9999.0
longitude	EASEGridCell_Array	real	4	degrees_east	-180.0	180.0	-9999.0
radar_vegetation_index	EASEGridCell_Array	real	4	normalized	0	2	-9999.0

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Value
retrieval_qual_flag	EASEGridCell_Array	bit flag	2	NA	NA	NA	65534
retrieval_qual_flag_option1	EASEGridCell_Array	bit flag	2	NA	NA	NA	66534
retrieval_qual_flag_option2	EASEGridCell_Array	bit flag	2	NA	NA	NA	66534
sigma0_hh_aggregated	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_vv_aggregated	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_xpol_aggregated	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0
soil_moisture	EASEGridCell_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_option1	EASEGridCell_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_option2	EASEGridCell_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_option3	EASEGridCell_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_std_option1	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_h_std_option2	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_h_std_option3	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_option1	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_option2	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_option3	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_std_dev	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_option1	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_option2	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_option3	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_std_option1	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_std_option2	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_std_option3	EASEGridCell_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Value
spacecraft_overpass_time_seconds	EASEGridCell_Array	real	8	seconds	0	999999.9	-9999.0
spacecraft_overpass_time_utc	EASEGridCell_Array	string	24	NA	NA	NA	-9999.0
surface_flag	EASEGridCell_Array	bit flag	2	NA	NA	NA	-9999.0
surface_temperature	EASEGridCell_Array	real	4	degrees Celsius	-50.0	60.0	-9999.0
tb_h_disaggregated	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_h_disaggregated_option1	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_h_disaggregated_option2	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_h_disaggregated_qual_flag	EASEGridCell_Array	bit flag	2	N/A	N/A	N/A	65534
tb_h_disaggregated_std_option1	EASEGridCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
tb_h_disaggregated_std_option2	EASEGridCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
tb_v_disaggregated	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_v_disaggregated_option1	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_v_disaggregated_option2	EASEGridCell_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_v_disaggregated_qual_flag	EASEGridCell_Array	bit flag	2	N/A	N/A	N/A	65534
tb_v_disaggregated_std_option1	EASEGridCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
tb_v_disaggregated_std_option2	EASEGridCell_Array	real	4	Kelvins	0.0	100.0	-9999.0
vegetation_opacity	EASEGridCell_Array	real	4	normalized	0	1	-9999.0
vegetation_water_content	EASEGridCell_Array	real	4	kg/m2	0.0	30	-9999.0
water_body_fraction	EASEGridCell_Array	real	4	normalized	0.0	1.0	-9999.0

1.2 Soil_Moisture_Retrieval_Data_3km

Table A - 2. Data Fields for Soil_Moisture_Retrieval_Data_3km

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Value
EASE_column_index_3km	EASEGridCell3km_Array	integer	2	count	0	65535	66534
EASE_row_index_3km	EASEGridCell3km_Array	integer	2	count	0	65535	66534
albedo_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0
bare_soil_roughness_retrieved_3km	EASEGridCell3km_Array	real	4	meters	0.0	0.1	-9999.0
disaggregated_tb_h_qual_flag_3km	EASEGridCell3km_Array	bit flag	2	NA	NA	NA	66534
disaggregated_tb_v_qual_flag_3km	EASEGridCell3km_Array	bit flag	2	NA	NA	NA	66534
distance_from_nadir_3km	EASEGridCell3km_Array	real	4	meters	0.0	500000.0	-9999.0
landcover_class_3km	EASEGridCell3km_Array	enum	1	NA	NA	NA	254
latitude_3km	EASEGridCell3km_Array	real	4	degrees_north	-90.0	90.0	-9999.0
longitude_3km	EASEGridCell3km_Array	real	4	degrees_east	-180.0	180.0	-9999.0
radar_vegetation_index_3km	EASEGridCell3km_Array	real	4	normalized	0.0	2.0	-9999.0
retrieval_qual_flag_3km	EASEGridCell3km_Array	bit flag	2	NA	NA	NA	66534
sigma0_hh_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_vv_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0
sigma0_xpol_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0
soil_moisture_3km	EASEGridCell3km_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_3km	EASEGridCell3km_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0
soil_moisture_h_std_3km	EASEGridCell3km_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
soil_moisture_v_3km	EASEGridCell3km_Array	real	4	cm^3/cm^3	0.02	0.5	-9999.0

Data Field Name	Shape	Concept	Byte	Unit	Min	Max	Fill/Gap Value
soil_moisture_v_std_3km	EASEGridCell3km_Array	real	4	cm^3/cm^3	0.0	0.2	-9999.0
spacecraft_overpass_time_seconds_3km	EASEGridCell3km_Array	real	8	seconds	0	99999999.9	-9999.0
surface_flag_3km	EASEGridCell3km_Array	bit flag	2	NA	NA	NA	66534
surface_temperature_3km	EASEGridCell3km_Array	real	4	degrees Celsius	-50.0	60.0	-9999.0
tb_h_disaggregated_3km	EASEGridCell3km_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_h_disaggregated_std_3km	EASEGridCell3km_Array	real	4	Kelvins	0.0	100.0	-9999.0
tb_v_disaggregated_3km	EASEGridCell3km_Array	real	4	Kelvins	0.0	330.0	-9999.0
tb_v_disaggregated_std_3km	EASEGridCell3km_Array	real	4	Kelvins	0.0	100.0	-9999.0
vegetation_opacity_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0
vegetation_water_content_3km	EASEGridCell3km_Array	real	4	kg/m**3	0.0	30.0	-9999.0
water_body_fraction_3km	EASEGridCell3km_Array	real	4	normalized	0.0	1.0	-9999.0

1.3 Data Field Definitions

EASE_row_index
EASE-Grid 2.0 cell at 9 km row index on world grid in latitude direction.

EASE_column_index
EASE-Grid 2.0 cell at 9 km row index on world grid in longitude direction.

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

alpha_tbh_hh
Alpha parameter derived for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. Prior alpha is derived from the time series of brightness temperature at 36 km EASE-Grid 2.0 and aggregated co-pol (hh) backscatter at 36 km EASE-Grid 2.0. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

alpha_tbv_vv
Alpha parameter derived for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. Prior alpha is derived from the time series of brightness temperature at 36 km EASE-Grid 2.0 and aggregated co-pol (vv) backscatter at 36 km EASE-Grid 2.0. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

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

beta_tbh_hh
Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. Prior abeta is derived from the time series of brightness temperature at 36 km EASE-Grid 2.0 and aggregated co-pol (vv) backscatter at 36 km EASE-Grid 2.0. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

beta_tbv_vv
Beta parameter used in the Active/Passive retrieval algorithm for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. Prior abeta is derived from the time series of brightness temperature at 36 km EASE-Grid 2.0 and aggregated co-pol (vv) backscatter at 36 km EASE-Grid 2.0. The length of the time series to estimate alpha especially depends on the region and the landcover. The valid minimum and maximum below are subject to further analysis.

disaggregated_tb_h_qual_flag_option1
Bit flags that record the conditions and the quality of the disaggregated horizontal polarization brightness temperature generated for the grid cell. See Table A3.

disaggregated_tb_h_qual_flag_option2

Bit flags that record the conditions and the quality of the disaggregated horizontal polarization brightness temperature generated for the grid cell. See Table A3.

disaggregated_tb_v_qual_flag_option1
Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell. See Table A3.

disaggregated_tb_v_qual_flag_option2
Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell. See Table A3.

Table A - 3. Quality Bit Flag Definitions

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

Name	Bit Position	Description of Values (0:off, 1:on)
		1: Unable to repair the vertical polarization radiometer brightness temperature input for the effects of RFI.
Sigma0_vv RFI detected flag	6	0: Insignificant levels of RFI detected in the vertical polarization radar sigma0 input.
		1: Significant levels of RFI were detected in the vertical polarization radar sigma0 input.
Sigma0_vv RFI corrected flag	7	0: The input for retrieval is based on vertical polarization radar sigma0s that were repaired for the effects of RFI.
		1: Unable to repair the vertical polarization radar sigma0 input for the effects of RFI.
Sigma0_xpol RFI detected flag	8	0: Insignificant levels of RFI detected in the cross polarized radar sigma0 input.
		1: Significant levels of RFI were detected in the cross polarized radar sigma0 input.
Sigma0_xpol RFI corrected flag	9	0: The input for retrieval is based on cross polarized radar sigma0s that were repaired for the effects of RFI.
		1: Unable to repair the cross polarized radar sigma0 input for the effects of RFI.
Negative sigma0_vv flag	10	0: The input for retrieval is based on vertical polarization radar sigma0s that are greater than zero.
		1: The input for retrieval is based on vertical polarization radar sigma0s that are less than or equal to zero.
Negative sigma0_xpol flag	11	0: The input for retrieval is based on cross polarized radar sigma0s that are greater than zero.
		1: The input for retrieval is based on cross polarized radar sigma0s that are less than or equal to zero.

distance_from_nadir
The distance from the center of the 9 km EASE-Grid 2.0 cell to the spacecraft's sub-nadir track on the Earth's surface.

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

gamma_hh_xpol
Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (hh) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 36 km grid cell. The valid minimum and maximum below are subject to further analysis.

gamma_vv_xpol

Gamma parameter used in the Active/Passive retrieval algorithm for the corresponding EASE-Grid 2.0 cell at the most recent prior instance when the grid cell was processed. The parameter is obtained by regression between aggregated co-pol (vv) backscatters at 9 km and cross-pol (hv) backscatters at 9 km that are contained within the respective 36 km grid cell. The valid minimum and maximum below are subject to further analysis.

landcover_class

An enumerated type that specifies the predominant surface vegetation found in the EASE-Grid 2.0 cell at 9 km. Table A4 contains a description of each landcover classification.

Table A - 4. Landcover Classification Values

Value	Description
0	Water
1	Evergreen needleleaf forest
2	Evergreen broadleaf forest
3	Deciduous needleleaf forest
4	Deciduous broadleaf forest
5	Mixed forest
6	Closed shrubland
7	Open shrubland
8	Woody savanna
9	Savanna
10	Grassland
11	Mixed forest
12	Closed shrubland
13	Open shrubland
14	Woody savanna
15	Savanna
16	Grassland
>16	TBD

latitude

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

longitude

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

radar_vegetation_index

Radar vegetation index derived from the co-pol and cross-pol radar backscatter data aggregated to 9 km. .

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

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

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

retrieval_qual_flag_option1
Bit flags that record the conditions and the quality of the retrieved soil moisture. When translated to decimal representation, this parameter contains an integer indicating one of the following inversion outcomes. See Table A5.

Table A - 5. Quality Bit Flag Definitions

Name	Bit Position	Description of Values (0:off, 1:on)
Retrieval recommended flag	0	0: Use of the soil moisture value retrieved for this pixel is recommended.
		1: Use of soil moisture value retrieved for this pixel is not recommended.
Retrieval attempted flag	1	0: The algorithm attempted to retrieve soil moisture for this grid cell.
		1: The algorithm did not attempt to retrieve soil moisture for this grid cell.
Retrieval success flag	2	0: Retrieval for this algorithm was successfully executed or the algorithm was not attempted.
		1: The retrieval for this algorithm was attempted but failed.
Radar water body detection success flag	3	0: Radar water body detection ran successfully.
		1: Unable to detect water bodies using retrieval techniques based on radar.
Freeze-thaw retrieval success flag	4	0: Freeze-thaw retrieval ran successfully.
		1: Unable to ascertain freeze-thaw conditions.
Radar vegetation index retrieval success flag	5	0: Radar vegetation index retrieval ran successfully.
		1: Radar vegetation index retrieval unsuccessful.
Disaggregated brightness temperature quality	6	0: Disaggregated brightness temperature retrieval ran successfully.
		1: Unable to disaggregate brightness temperatures into 9 km resolution cells.

retrieval_qual_flag_option2

Bit flags that record the conditions and the quality of the retrieved soil moisture. When translated to decimal representation, this parameter contains an integer indicating one of the following inversion outcomes. See Table A5.

sigma0_hh_aggregated
The outcome of aggregating a set of 3 km co-pol horizontal polarization radar backscatter measurements that are encompassed within 9 km EASE-Grid 2.0 cell. This aggregated radar backscatter at 9 km does not include the undesirable 3 km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_vv_aggregated
The outcome of aggregating a set of 3 km co-pol vertical polarization radar backscatter measurements that are encompassed within 9 km EASE-Grid 2.0 cell. This aggregated radar backscatter at 9 km does not include the undesirable 3 km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_xpol_aggregated
The outcome of aggregating a set of 3 km cross-polarization (*hv* or *vh*) radar backscatter measurements that are encompassed within 9 km EASE-Grid 2.0 cell. This aggregated radar backscatter at 9 km does not include the undesirable 3 km grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

soil_moisture
Retrieved baseline (option1) soil moisture estimate from the disaggregated/downscaled brightness temperature at 9 km grid cell.

soil_moisture_h_option1
Retrieved h-pol option1 soil moisture estimate from the disaggregated/downscaled horizontal polarization brightness temperature at 9 km grid cell.

soil_moisture_h_option2
Retrieved h-pol option2 soil moisture estimate from the disaggregated/downscaled horizontal polarization brightness temperature at 9 km grid cell.

soil_moisture_h_option3
Retrieved h-pol option3 soil moisture estimate from the disaggregated/downscaled horizontal polarization brightness temperature at 9 km grid cell.

soil_moisture_h_std_option1
Estimated '1-sigma' error of the retrieved h-pol option1 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

soil_moisture_h_std_option2
Estimated '1-sigma' error of the retrieved h-pol option2 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

soil_moisture_h_std_option3
Estimated '1-sigma' error of the retrieved h-pol option3 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

soil_moisture_option1
Retrieved v-pol option1 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_v_option1* field. For more details, refer to Section 3.3: Option Algorithms in the ATBD.

soil_moisture_option2
Retrieved v-pol option2 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_v_option2* field. For more details, refer to Section 3.3: Option Algorithms in the ATBD.

soil_moisture_option3
Retrieved v-pol option3 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_v_option3* field. For more details, refer to Section 3.3: Option Algorithms in the ATBD.

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

soil_moisture_v_option1
Retrieved v-pol option1 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_option1* field.

soil_moisture_v_option2
Retrieved v-pol option2 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_option2* field.

soil_moisture_v_option3
Retrieved v-pol option3 soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 9 km grid cell. This field is internally linked to the *soil_moisture_option3* field.

soil_moisture_v_std_option1
Estimated '1-sigma' error of the retrieved v-pol option1 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

soil_moisture_v_std_option2
Estimated '1-sigma' error of the retrieved v-pol option2 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

soil_moisture_v_std_option3
Estimated '1-sigma' error of the retrieved v-pol option3 soil_moisture output parameter. The valid minimum and maximum below are subject to further analysis on real data.

spacecraft_overpass_time_seconds

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

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

surface_flag
Bit flags that record ambient surface conditions for the grid cell at 9 km. See Table A6.

Table A - 6. Quality Bit Flag Definitions

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

Name	Bit Position	Description of Values (0:off, 1:on)
		1: The fraction of the96 km grid cell area that is over permanent snow or ice is greater than or equal to a specified algorithmic threshold.
9 km frozen ground flag	6	0: No frozen ground detected within the 9 km grid cell.
		1: Frozen ground detected within the 9 km grid cell.
9 km mountainous terrain flag	7	0: The variability of land elevation in the 9 km grid cell is less than metadata element MountainousTerrainThreshold.
		1: The variability of land elevation in the 9 km grid cell is greater than or equal to metadata element MountainousTerrainThreshold.
9 km dense vegetation flag	8	0: The vegetation density within the 9 km grid cell is less than metadata element DenseVegetationThreshold.
		1: The vegetation density within the 9 km grid cell area is greater than or equal to metadata element DenseVegetationThreshold.
9 km nadir region flag	9	0: Data within the grid cell were not acquired in the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
		1: A significant fraction (TBD) of the 9 km grid cell data were acquired within the nadir region of the swath where sigma0s may not meet the 3 km resolution requirement.
9 km coastal mask flag	10	0: Data within the grid cell were not acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.
		1: Data within the grid cell were acquired in the coastal region of the large water bodies where especially brightness temperature on land may get severely contaminated due to presence of water.

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

tb_h_disaggregated
Horizontal polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_h_disaggregated_option1
Horizontal polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_h_disaggregated_option2
Horizontal polarization brightness temperature from option 1 adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_h_disaggregated_qual_flag
Bit flags that record the conditions and the quality of the disaggregated horizontal polarization brightness temperature for option1 generated for the grid cell.

tb_h_disaggregated_std_option1
Standard deviation of the horizontal polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_h_disaggregated_std_option2
Standard deviation of the horizontal polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated
Vertical polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated_option1
Vertical polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated_option2
Vertical polarization brightness temperature from option 1 adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated_qual_flag
Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature for option1 generated for the grid cell.

tb_v_disaggregated_std_option1
Standard deviation of the vertical polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated_std_option2
Standard deviation of the vertical polarization brightness temperature adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

vegetation_opacity
Estimated vegetation opacity at 9 km spatial scale. Note that this parameter is the same ‘tau’ parameter normalized by the cosine of the incidence angle in the ‘tau-omega’ model. See the ATBD for more details and for valid minimums and maximums.

vegetation_water_content

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

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

EASE_row_index_3km
EASE-Grid 2.0 cell at 3 km row index on world grid in latitude direction.

EASE_column_index_3km
EASE-Grid 2.0 cell at 3 km row index on world grid in longitude direction.

albedo_3km
Diffuse reflecting power of the Earth's surface within the grid cell at 3 km.

bare_soil_roughness_retrieved_3km
Roughness coefficient at 3 km spatial scale. Note that this parameter is the same ‘h’ coefficient in the ‘tau-omega’ model for a given polarization channel.

disaggregated_tb_v_qual_flag_3km
Bit flags that record the conditions and the quality of the disaggregated vertical polarization brightness temperature generated for the grid cell. See Table A6.

disaggregated_tb_h_qual_flag_3km
Bit flags that record the conditions and the quality of the disaggregated horizontal polarization brightness temperature generated for the grid cell.

distance_from_nadir_3km
The distance from the center of the 9 km EASE-Grid 2.0 cell to the spacecraft's sub-nadir track on the Earth's surface.

landcover_class_3km
An enumerated type that specifies the predominant surface vegetation found in the EASE-Grid 2.0 cell at 3 km.

latitude_3km
Latitude of the center of the Earth based grid cell at 3 km.

longitude_3km
Longitude of the center of the Earth based grid cell at 3 km.

radar_vegetation_index_3km
Radar vegetation index derived from the co-pol and cross-pol radar backscatter data aggregated to 3 km mentioned in sections 4.6.10, 4.6.11, and 4.6.12.

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

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

retrieval_qual_flag_3km
Bit flags that record the conditions and the quality of the retrieved soil moisture. When translated to decimal representation, this parameter contains an integer indicating one of the following inversion outcomes. See Table A6.

sigma0_hh_3km
The outcome of aggregating a set co-pol horizontal polarization radar backscatter measurements that are encompassed within 3 km EASE-Grid 2.0 cell. This radar backscatter at 3 km does not include the undesirable grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_vv_3km
The outcome of aggregating a set of 3-m co-pol vertical polarization radar backscatter measurements that are encompassed within 3 km EASE-Grid 2.0 cell. This radar backscatter at 3 km does not include the undesirable grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

sigma0_xpol_3km
The outcome of aggregating a set of cross-polarization (*hv* or *vh*) radar backscatter measurements that are encompassed within 3 km EASE-Grid 2.0 cell. This radar backscatter at 3 km does not include the undesirable grid cells, mainly the grid cells having water, snow/ice and RFI contaminated pixels.

soil_moisture_3km
Retrieved soil moisture estimate from the disaggregated/downscaled vertical polarization brightness temperature at 3 km grid cell.

soil_moisture_h_3km
Representative soil moisture measurement at hpol for the Earth based grid cell at 3 km.

soil_moisture_h_std_3km
Representative soil moisture measurement standard deviation at hpol for the Earth based grid cell at 3 km.

soil_moisture_v_3km
Representative soil moisture measurement at vpol for the Earth based grid cell at 3 km.

soil_moisture_v_std_3km
Representative soil moisture measurement standard deviation at vpol for the Earth based grid cell at 3 km.

spacecraft_overpass_time_seconds_3km
Number of seconds since a specified epoch that represents the spacecraft overpass relative to ground swath. The 3 km EASE2-Grid cell is assigned the UTC time of 36 km EASE2-Grid cell that

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

surface_flag_3km
Bit flags that record ambient surface conditions for the grid cell at 3 km. See Table A6.

surface_temperature_3km
Soil temperature (averaged over the top 5-cm soil layer) at 3 km spatial scale. This parameter is used as input ancillary data parameter to the SPL2SMAP processing software for the baseline algorithms. The valid minimum and maximum below are subject to further analysis on real data.

tb_h_disaggregated_3km
Horizontal polarization brightness temperature at 3 km obtained by disaggregating/downscaling the 36 km EASE-Grid 2.0 cells horizontal polarization brightness temperature.

tb_h_disaggregated_std_3km
Horizontal polarization brightness temperature standard deviation adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

tb_v_disaggregated_3km
Vertical polarization brightness temperature at 3 km obtained by disaggregating/downscaling the 36 km EASE-Grid 2.0 cells vertical polarization brightness temperature.

tb_v_disaggregated_std_3km
Vertical polarization brightness temperature standard deviation adjusted for the presence of water bodies and disaggregated from the 36 km EASE-Grid 2.0 cells into 9 km EASE-Grid 2.0 cells.

vegetation_opacity_3km
Estimated vegetation opacity at 3 km spatial scale. Note that this parameter is the same ‘tau’ parameter normalized by the cosine of the incidence angle in the ‘tau-omega’ model.

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

vegetation_water_content_3km
Vegetation water content at 3 km spatial scale. This parameter is used as input ancillary data parameter to the SPL2SMAP processing software when the baseline algorithm is used. See the ATBD for more details and for valid minimums and maximums.

water_body_fraction_3km
Water body fraction at 3 km spatial scale. If there are NW water pixels and NL land pixels within a 3 km grid cell, this parameter refers to the fraction of NW / (NW + NL). Note that NW is the number of water pixels regardless of their temporal span NW captures both static water pixels and transient water pixels. At present the SPL2SMAP processing software can be configured to provide this parameter from a static water fraction database or from the SPL2SMA product.

1.4 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 SPL2SMAP Product when the SPL2SMAP SPS can process some, but not all, of the input data for a particular swath grid cell. Fill data may appear in the product in any of the following circumstances:

- One of Science Production Software (SPS) executables that generate the SPL2SMAP 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 SPL2SMAP 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 SPL2SMA or SPL2SMP products. If only some of the input that contributes to a particular grid cell is fill data, the Level SPL2SMAP SPS will most likely be able to generate some output. However, some portion of the SPL2SMAP output for that grid cell may appear as fill values.

SMAP data products employ a specific set of data values to connote that an element is fill. The selected values that represent fill are dependent on the data type. No valid value in the SPL2SMAP product is equal to the values that represent fill. If any exceptions should exist in the future, the SPL2SMAP content will provide a means for users to discern between elements that contain fill and elements that contain genuine data values. This document will also contain a description of the method used to ascertain which elements are fill and which elements are genuine.

The SPL2SMAP product records gaps when entire frames within the time span of a particular data granule do not appear. Gaps can occur under one of two conditions:

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

The Level SPL2SMAP Product records gaps in the product level metadata. The following conditions will indicate that no gaps appear in the data product:

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

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

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

1.5 Notations

Table A7 lists the notations used in this document.

Table A - 7. Notation Definitions

Notation	Definition
Int8	8-bit (1-byte) signed integer
Int16	16-bit (2-byte) signed integer
Int32	32-bit (4-byte) signed integer
Uint8	8-bit (1-byte) unsigned integer
Uint16	16-bit (2-byte) unsigned integer
Float32	32-bit (4-byte) floating-point integer
Float64	64-bit (8-byte) floating-point integer
Char	8-bit character
H-pol	Horizontally polarized
V-pol	Vertically polarized