SMAP/Sentinel-1 L2 Radiometer/Radar 30-Second Scene 3 km EASE-Grid Soil Moisture, Version 1

USER GUIDE

How to Cite These Data

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

Das, N., D. Entekhabi, S. Kim, S. Yueh, R. S. Dunbar, and A. Colliander. 2017. *SMAP/Sentinel-1 L2 Radiometer/Radar 30-Second Scene 3 km EASE-Grid Soil Moisture, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/9UWR1WTHW1WN. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL2SMAP_S

National Snow and Ice Data Center

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These data are Beta-release quality, meaning that they have not undergone full validation and may still contain significant errors.

1 DATA DESCRIPTION

1.1 Parameters

Surface soil moisture (approximately 0-5 cm) in cm^3/cm^3 derived from brightness temperatures and sigma nought measurements is output on a fixed 3 km and 1 km* EASE-Grid 2.0.

Brightness temperatures (TBs) in kelvin are derived from native 36 km SMAP footprint using Backus-Gilbert interpolation on the 9 km EASE-Grid, and are then disaggregated to 3 km and 1 km grid cells by comparison with the background Sentinel-1 radar backscatter data to produce high-resolution soil moisture retrievals. Brightness temperature 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. It is a normalized dimensionless number comparing the strength observed to that expected from a defined area, and is provided in natural units (not dB) in this product. The Copernicus Sentinel-1 C-band Synthetic Aperture Radar (C-SAR) measures dual polarization VV + VH in the Interferometric Wide Swath Mode (IW) over land with a center frequency of 5.405 GHz. Sigma0 measurements are derived using Synthetic-Aperture Radar (SAR) processing.

[*] 1 km data are research quality, meaning they have not undergone validation.

Refer to the Data Fields 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:

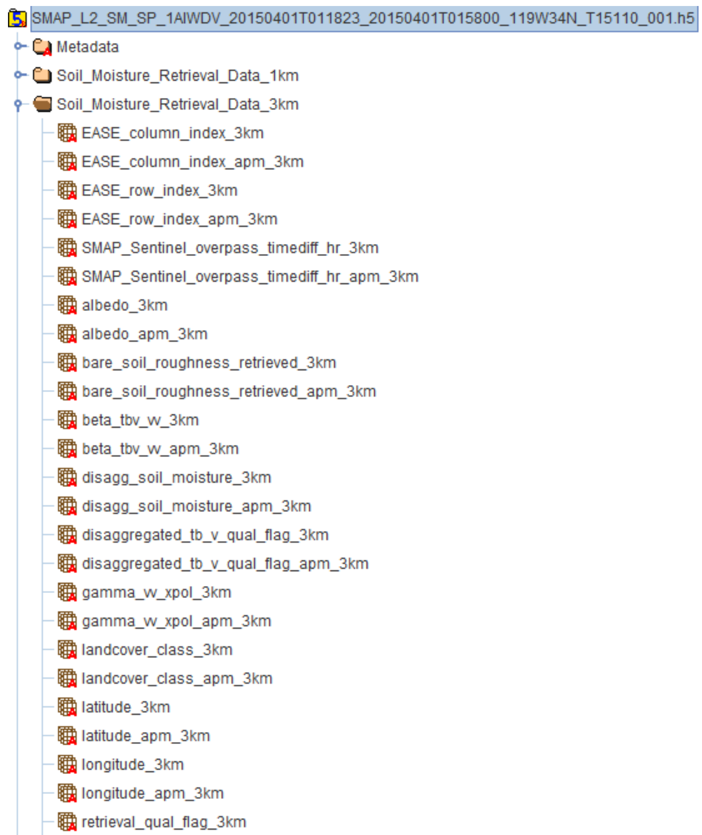

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP/Sentinel-1 Level-2 radar/radiometer soil moisture product, refer to the Data Fields page.

1.4 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 Data Fields document.

All data arrays are two dimensional. Each two-dimensional data field (or element) represents a subset of the grid which contains the pixels of Sentinel-1 data along with the SMAP data that are overlaid on the grid within +/- 24 hours. The arrays in the 1 km data group have the same dimensions as the Sentinel-1 (L2_S0_S1) data. The dimensions of the arrays in the 3 km group are about one-third the size in each direction.

1.4.1 Soil Moisture Retrieval Data 3 km

Includes combined radar and radiometer soil moisture data at 3 km resolution, ancillary data, and quality assessment flags. Data are provided in two different sets of fields, including;

- **SMAP a.m.-only**— Only the closest SMAP a.m. data (from 6:00 a.m. descending half orbits) in time are used to spatially match up with the Sentinel-1 scene
- **SMAP a.m.-or-p.m.**— The closest SMAP a.m. or p.m. data (from 6:00 a.m. descending or 6 p.m. ascending half orbits) are used to spatially match up with the Sentinel-1 scene

Note: Data fields containing SMAP a.m.-or-p.m. data are named with *apm,* such as *disaggregated_tb_v_qual_flag_**apm**_3km.* Note that if the SMAP a.m. pass is the closest, the two arrays will have the same values.

1.4.2 Soil Moisture Retrieval Data 1 km

Includes combined radar and radiometer soil moisture data at 1 km resolution, ancillary data, and quality assessment flags. As with the 3 km group, data are provided in two sets of fields:

- **SMAP a.m.-only**—Only the closest SMAP a.m. data (from 6:00 a.m. descending half orbits) in time are used to spatially match up with the Sentinel-1 scene
- **SMAP a.m.-or-p.m.**—The closest SMAP a.m. or p.m. data (from 6:00 a.m. descending or 6 p.m. ascending half orbits) are used to spatially match up with the Sentinel-1 scene

Note: 1 km data are research quality, meaning they have not undergone validation.

1.5 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 Metadata Fields document.

1.6 File Naming Convention

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

SMAP_L2_SM_SP_[Sat/Mode/Pol]_[SMAP]yyyymmddThhmmss_[Sentinel-1]yyyymmddThhmmss_[Scene Center Location]_RLVvvv_NNN.[ext]

For example:
SMAP_L2_SM_SP_1AIWDV_20160901T061527_20160901T184245_007W06N_R15180_001.h5

Table 1. File Naming Conventions

Variable	Description
SMAP	Indicates SMAP mission data
L2_SM_SP	Indicates specific product [L2: Level-2; SM: Soil Moisture; S: Sentinel-1; P: Passive (refers to SMAP passive radiometer)]
[Sat/Mode/Pol]	Identifies specific Sentinel-1 satellite (1A or 1B), the SAR mode (IW: Interferometric Wide-swath), and the polarization mode (DV: Dual-polarization VV and VH)
[SMAP]yyyymmddThhmmss	Date/time in Universal Coordinated Time (UTC) of the first SMAP data element that appears in the product, where: yyyymmdd: 4-digit year, 2-digit month, 2-digit day T: Time (delineates the date from the time, i.e. yyyymmdd*T*hh hhmmss: 2-digit hour, 2-digit month, 2-digit second
[Sentinel-1]yyyymmddThhmmss	Date/time in Universal Coordinated Time (UTC) of the first Sentinel-1 data element that appears in the product, where: yyyymmdd: 4-digit year, 2-digit month, 2-digit day T: Time (delineates the date from the time, i.e. yyyymmdd*T*hhmmss) hhmmss: 2-digit hour, 2-digit month, 2-digit second
[Scene Center Location]	Approximate longitude (E or W) and latitude (N or S) of the center of the EASE-Grid area containing the Sentinel-1 radar scene. Note: This is useful for finding data over regional subsets.
RLVvvv	Composite Release ID, where: R: Release data L: Launch Indicator (1: post-launch standard data) V: 1-Digit Major CRID Version Number vvv: 3-Digit Minor CRID Version Number Refer to the SMAP Data Versions page for version information.
NNN	Number of times the file was generated under the same version for a particular date/time interval (002: 2nd time)
.[ext]	File extensions include: .h5: HDF5 data file .xml: XML Metadata file

1.7 File Size

Each file is approximately 4 to 6 MB.

Note: File sizes vary due to the time span of the Sentinel-1 data, characteristics of the SMAP/Sentinel-1 match-up scenes, and the HDF compression factor.

1.8 Volume

The daily data volume is approximately 900 to 3600 MB.

1.9 Spatial Information

1.9.1 Spatial Coverage

Coverage spans from 180°W to 180°E, and from approximately 60°N and 60°S. Latitude coverage for this product is constrained by the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) data used for terrain correction of the Sentinel-1A/1B radar data. In addition, Sentinel-1A/1B coverage is predominantly over land targets. Note that it takes 12 consecutive days of data to obtain global coverage.

1.9.2 Spatial Coverage Map

Figure 2 shows the spatial coverage of this product for one day.

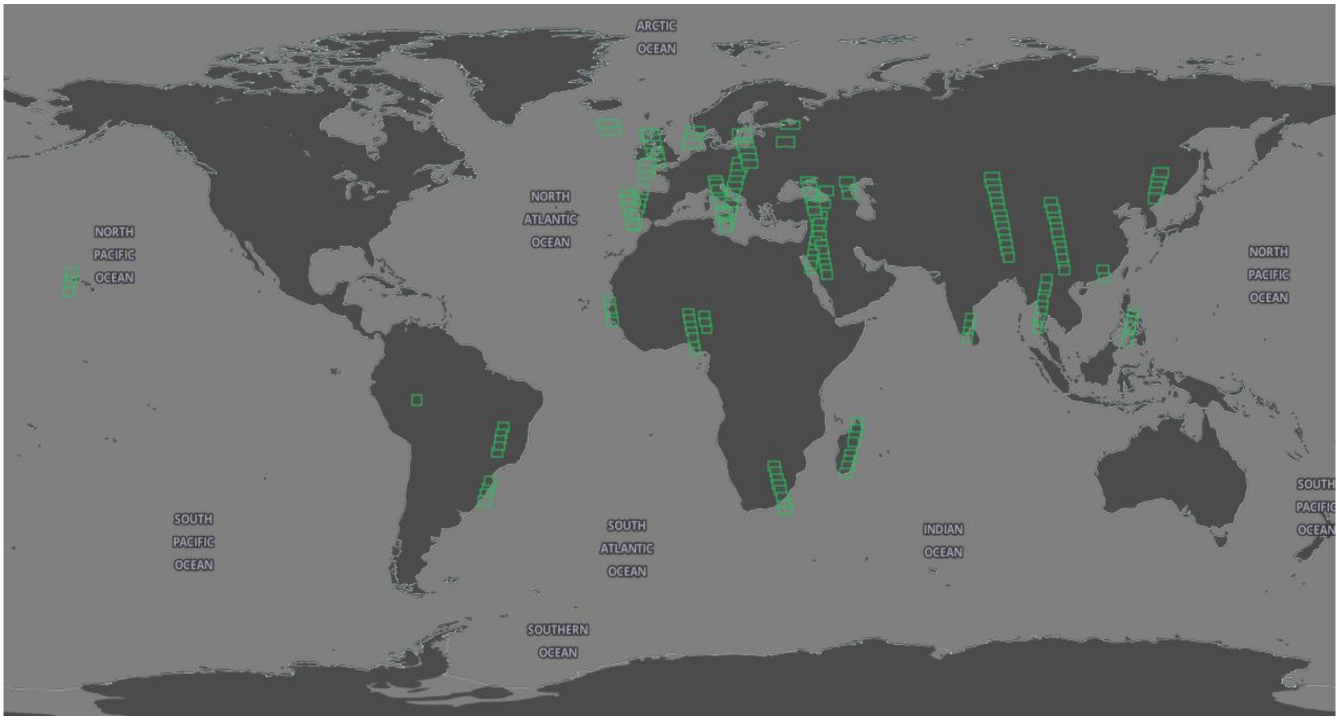

Figure 2. Spatial Coverage Map displaying SMAP/Sentinel-1A/1B match-up scenes for 01 November 2017. The map was created using the NASA Earthdata Search tool.

1.9.3 Resolution

SMAP 9 km radiometer brightness temperature data (SPL3SMP_E) and Sentinel-1 1 km SAR backscatter data (L2_S0_S1) are combined using the SMAP Active-Passive algorithm to derive soil moisture data that are gridded using the 3 km and 1 km EASE-Grid 2.0 projections. The gridded 9 km SMAP brightness temperatures are derived from the native 36 km* SMAP radiometer footprint by Backus-Gilbert interpolation directly to the 9 km EASE-Grid 2.0. The 1 km backscatter data from Sentinel-1 are aggregated and regridded on the 1 km EASE-Grid 2.0 starting from raw intensities at approximately 20 m native resolution.

* **Note:** The effective native resolution of the SMAP radiometer can range from approximately 25 km to 36 km depending on parameter extraction methods.

1.10 Projection and Grid Description

1.10.1 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 3 x 3 km^2 regardless of longitude and latitude. The SPL2SMAP_S data product is posted on both 3 km and 1 km EASE-Grids that are nested consistently with the 9 km brightness temperatures, and the 3 km and 1 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.

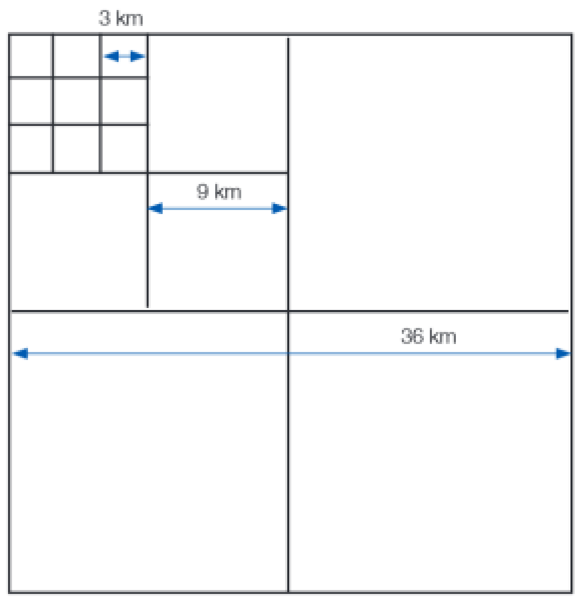

Figure 3. Perfect Nesting in EASE-Grid 2.0

1.11 Temporal Information

1.11.1 Coverage

Coverage spans from 01 April 2015 to present, but is not continuous. Please note the following gaps:

WARNING: Temporary Gaps Due to Reprocessing

On 04 January 2018, the SMAP Science Data System (SDS) temporarily suspended reprocessing for this product, resulting in limited coverage. Reprocessed data are currently available for portions of November 2016 through March 2017 and September through October 2017. All data from November 2017 to present are also available, with forward processing continuing as expected. As of 01 March 2018, the SDS resumed reprocessing for all remaining data.

Ongoing Temporal Coverage Gaps

- The less frequent coverage of Sentinel-1 data results in more gaps for this match-up product than exist in the standard SMAP time series.
- In addition, the Sentinel-1 data stream varies considerably; data from many days/months prior may be received and/or downtimes may interrupt coverage, for example.
- SPL3SMP_E data from the previous, current, and next day are used to create this product, resulting in at least a day or two of standard latency.
- Small gaps in the SMAP time series will also occur due to instrument maneuvers, data downlink anomalies, data quality screening, and other factors. 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

1.11.2 Temporal Resolution

Each match-up file spans approximately 30 seconds.

Note that although each Sentinel-1 scene is approximately 30 seconds, the resolution varies based on how closely SMAP half-orbit passes match up with Sentinel-1 scenes. While SMAP half-orbit passes acquire 49 minutes of data, it is the overlap of Sentinel-1 scenes that determines the temporal resolution of this product.

2 DATA ACQUISITION AND PROCESSING

2.1 Sensor or Instrument Description

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

For information regarding the SAR satellites Sentinel-1A and -1B, refer to the European Space Agency (ESA) Copernicus Sentinel-1 Web site.

2.2 Data Sources

SMAP/Sentinel-1 Level-2 radiometer/radar soil moisture data (SPL2SMAP_S) are derived from the following:

- SMAP Enhanced L3 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 1 (SPL3SMP_E)
- Copernicus Sentinel-1A C-SAR Data
- Copernicus Sentinel-1B C-SAR Data

2.3 Theory of Measurements

The goal of SMAP mission is to combine the favorable attributes of 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, 2014, and 2016).

The SMAP Active-Passive algorithm is capable of incorporating other SAR measurements to obtain high-resolution brightness temperature and subsequently high-resolution soil moisture. The SMAP radar stopped functioning on 07 July 2015, and various radar data were explored to find suitable alternatives for SAR data. Sentinel-1 was found to suitable to fulfill most of the requirements of the radar measurements as input to the SMAP Active-Passive algorithm. Few modifications needed to be made in the SMAP Active-Passive algorithm to accommodate the Sentinel-1 SAR measurements. Details of these modifications will be included in the forthcoming Algorithm Theoretical Basis Document (ATBD) for this product and are provided in the Beta Assessment Report (Das et al. 2017).

2.4 Derivation Techniques and Algorithms

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

SPL2SMAP_S data are based on the merger of SMAP radiometer and Sentinel-1 radar data at two discrete grid resolutions: gridded 9 km and 1 km, respectively. The Equal-Area-Scalable-Earth Grid (EASE-Grid) cells of the radiometer and radar products nest perfectly; refer to the Projection and Grid Description section of this document. Therefore, the SPL2SMAP_S 3 km soil moisture product has 16:1 and 1:9 correspondence with the radiometer and radar products, respectively. The grid definition used in the algorithm is illustrated in Figure 2 of the Algorithm Theoretical Basis Document (ATBD) for the SPL2SMAP product. (The ATBD for this product is forthcoming). The SPL2SMAP_S baseline algorithm disaggregates the coarse resolution radiometer brightness temperature product based on the spatial variation in high-resolution radar backscatter. In addition, the algorithm requires static and dynamic ancillary data. These ancillary data are resampled to the same EASE-Grid prior to ingest in the SPL2SMAP_S processing. The dynamic ancillary data used to retrieve soil moisture for a particular 3 km or 1 km grid cell at a specific point in time are listed in the SPL2SMAP_S output files for the benefit of end users.

Refer to the Data Fields document for a description of all data fields.

2.4.1 Baseline Algorithm

The SPL2SMAP_S 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 spatially averaged radar and radiometer measurements over the scene. 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 radiometer and radar measurements address 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 ATBD for the SPL2SMAP 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 SPL2SMAP_S algorithm formulation.

Once the disaggregated brightness temperatures at 3 km and 1 km are produced, the Single Channel Algorithm (SCA)/Tau-Omega model is applied that uses high-resolution ancillary information at 3 km and 1 km to produce the SPL2SMAP_S product.

2.4.2 Formulation of the SPL2SMAP_S Baseline Algorithm

The SMAP L-band radiometer measures the natural microwave emission in the form of the brightness temperature (T_B) of the land surface, while the Sentinel-1 C-band radar measures the energy backscattered (sigma0, or 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, variations in soil moisture cause TB and sigma0 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 TB and Sentinel-1 sigma0 are expected to have a linear functional relationship: $T_B = \alpha + \beta \times \sigma0$. 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 can be *vv, hh* (though *hh* is not used for this product), or *vh*. The parameter β can be derived in a snapshot approach based on pairs of SMAP radiometer TB and spatially-averaged radar sigma0 from successive observations of the same Earth grid cell (Jagdhuber et al, 2017). The parameter β, which represents the sensitivity of backscatter to changes in brightness temperature, is highly dependent on vegetation characteristics.

The parameter β is unique for each location since it is a sensitivity parameter relating TB and sigma0 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. To develop the satellite-based Active-Passive algorithm further, the relationship between TB and sigma0 can also be conceptually evaluated at the 3 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 parameter β at the 3 km and 1 km scale with respect to the coarser 9 km scale is to determine subgrid heterogeneity parameter Γ from high-resolution co- and cross-polarization. The methodology is described in Section 3.2 of the ATBD for the SPL2SMAP product.

The performance of the brightness temperature disaggregation is heavily dependent on robust estimates of β and Γ parameters, which are specific for a given location and reflect the local roughness and vegetation cover conditions. The parameters vary seasonally as well as due to change in local surface conditions; therefore, it is optimal to derive these parameters for every SMAP and Sentinel-1 overlap instance.

2.4.3 Algorithm Process Flow

Figure 4 shows a simplified process flow diagram of the SPL2SMAP_S baseline algorithm.

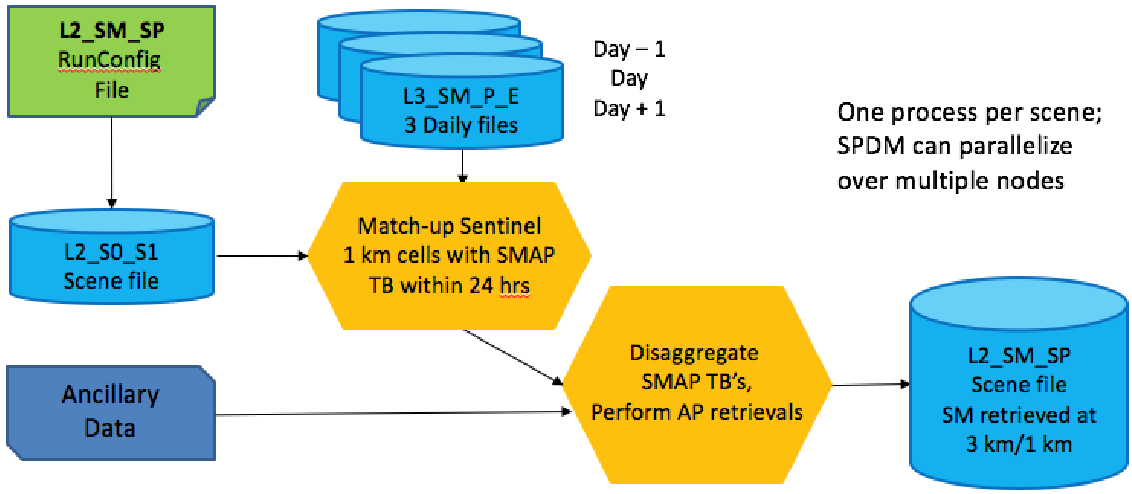

Figure 4. Process Flow Diagram of the SPL2SMAP_S Baseline Algorithm

Note: As shown in this figure and reflected in the file names, L2_SM_SP is an abbreviation for this product (also referred to as SPL2SMAP_S), SPDM refers to the Science Processing and Data Management system that can parallelize, or run many single-thread processes on multiple nodes, to process a scene.

2.4.3.1 Optional Algorithm

Alternatively, the optional algorithm (also referred to as Option 1) directly disaggregates the 9 km soil moisture available in SPL2SMP_E using the Sentinel-1 backscatter cross-sections. This optional algorithm approach does not require any new soil moisture retrieval within SPL2SMAP_S processing, in contrast to the baseline algorithm. This SPL2SMAP_S Beta product contains soil moisture fields produced by both the baseline and the optional algorithms.

2.5 Processing Steps

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. Prior to generating this product, Copernicus Sentinel-1A and -1B satellite imagery were acquired by the European Space Agency (ESA) and distributed through the Alaska Satellite Facility (ASF). To generate this product, the processing software:

1. Ingests one file containing a single scene of Sentinel-1 1 km L2_S0_S1 backscatter data from either Sentinel-1A or Sentinel-1B and three daily files of SMAP gridded 9 km SPL3SMP_E brightness temperature data. The SMAP files include SMAP data for the three days nearest the time of the Sentinel-1 data, along with the required static and dynamic ancillary data that cover those three days.

- The brightness temperatures available in SPL3SMP_E have been corrected for the presence of water bodies (up to 0.05 fraction) before being used in SPL2SMAP_S product generation. Beyond water body fraction of 0.05, no correction is conducted as it introduces high errors due to uncertainty present in the water fraction information.
- The sigma0 measurements have been calibrated, terrain-corrected, and aggregated onto 1 km EASE-Grid 2.0 pixels before being used in SPL2SMAP_S product generation. Level-2 sigma0 Sentinel-1 data (also referred to as L2_S0_S1) in dual-polarization "SDV" mode (VV,VH) are used exclusively for SMAP/Sentinel-1 SPL2SMAP_S processing.

2. The ingested data are then inspected for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. The nearest SMAP data in time at the location of the Sentinel-1 scene is determined, including:
   - Data from SMAP a.m.-only (6:00 a.m. descending) orbits
   - Data from SMAP a.m.-or-p.m. (6:00 a.m. descending or 6 p.m. ascending) orbits

Within each resolution data group (3 km and 1 km) there are two sets of outputs: SMAP a.m.-only and SMAP a.m.-or-p.m. One of the following four outcomes are possible:

- No match — Neither SMAP a.m. nor p.m. data match the Sentinel-1 scene, resulting in no output file.
- SMAP a.m.-only is closest — In this case the values of the SMAP a.m.-only and SMAP a.m.-or-p.m. elements are identical.
- SMAP a.m.-only and SMAP a.m.-or-p.m. are different — In general, the SMAP a.m.-or-p.m. data are the closest of all in time to the Sentinel-1 scene, but there are two different sets of retrievals due to SMAP data from different times.
- SMAP a.m.-only has fill values, SMAP a.m.-or-p.m. has valid data — This occurs when there are no SMAP a.m.-only matches, but a p.m. match can be found.

3. When retrievability criteria are met, the software invokes the brightness temperature disaggregation algorithm followed by the baseline retrieval algorithm to generate soil moisture. The brightness temperatures gridded at 9 km are converted to soil moisture using algorithms described in SPL2SMP_E and based on approximately 33 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. Only cells that are covered by the actual swath for a given projection are written in the product.

2.6 Quality, Errors, Limitations

2.6.1 Error Sources

Errors in SPL2SMAP_S 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 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 T4 thresholds to detect and, where possible, mitigate RFI. Owing to such robust measures in the SMAP radiometer hardware and data processing, the SPL2SMAP_S product has lesser impact than SMOS measurements from anthropogenic RFI. The Sentinel-1 C-band radar data have no RFI indicators; the expectation is that the impact of RFI on the Sentinel-1 radar is reduced due to the radar frequency relative to the L-band SMAP radiometer. 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 3 km and 1 km. (Entekhabi et al. 2012 and Das et al. 2016)

More information about error sources is provided in Section 4.3: Error Budget of Baseline Algorithm of the ATBD for the SPL2SMAP product.

2.6.2 Quality Assessment

Science and application communities should take certain caveats into consideration before using the SPL2SMAP_S product. There is a tradeoff between adding spatial resolution with C-band SAR data and noise levels. The high resolution (3 km) of this product comes at a cost of degradation in temporal statistics of disaggregated brightness temperature and retrieved soil moisture. Whereas the more spatially-averaged SPL2SMP_E product may have less temporal noise and temporal uncertainty when compared to SPL2SMAP_S, the SPL2SMAP_S will have more spatial resolution in terms of resolving sharp and large-contrast features below the radiometer resolution. Therefore, users of SMAP data who require more frequent revisit and temporal accuracy can use the SPL2SMP_E product (posted at 9 km), and those users who need high resolution soil moisture patterns and details with slightly degraded accuracy and less frequent revisit can use SPL2SMSP_E data (posted at 3 km) for their science studies and geophysical applications. For in-depth details regarding the quality of these Version 1 Beta data, refer to the Beta Assessment Report (Das et al. 2017).

2.6.2.1 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 Data Fields and Metadata Fields documents.

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.

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.

2.6.3 Data Flags

Quality control (QC) is an integral part of the SPL2SMAP_S processing. The QC steps of SPL2SMAP_S processing are based on the flags that are provided with the SMAP input data stream (SPL3SMP_E), different types of masks, flags, and fractional coverage of other variables provided by ancillary data. The SPL2SMAP_S will process all data that have favorable conditions for soil moisture retrieval (VWC <= 3 kg/m^2, 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 > 3 kg/m^2, 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. In addition, due to differences in spatial resolution of the input data, the assignment of QC flags in SPL2SMAP_S may differ from the flags associated with the inputs. The thresholds of ancillary data that initiate flagging in the SPL2SMAP_S product are mentioned below. For example, TB data in SPL3SMP_E 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_S processing. Preliminary assessment shows that 5% water body fraction within the 9 km grid cell of SPL3SMP_E has acceptable quality and low error level in kelvins. All the 3 km and 1 km nested grid cells of SPL2SMAP_S within the 9 km grid cell of SPL3SMP_E are flagged for suspected quality if the water body fraction is >5%. The water body fraction is reported for all land-based 3 km and 1 km grid cells in SPL2SMAP_S 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_S retrieval is performed at all the grid cells irrespective of VWC but the QC flag is set only for a grid cell having VWC >3 kg/m^2. Retrievals are performed for SPL2SMAP_S 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 the SPL2SMAP_S product are mentioned as follows:

2.6.3.1 Open Water Body Flag

Open water fraction is determined from Sentinel-1 high-resolution radar and/or *a priori* information on permanent open freshwater from the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD44W database. The SPL2SMAP_S Version 1 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.

2.6.3.2 RFI Flag

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

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

2.6.3.3 Snow Flag

The ancillary data that provide a binary indicator for the 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 and do not retrieve soil moisture.

2.6.3.4 Precipitation Flag

Presence of heavy rainfall during data acquisition may adversely affect the TB and sigma0 measurements. The precipitation data from Global Modeling and Assimilation Office (GMAO) is used to flag the 9 km and 3 km grid cells. SPL2SMAP_S retrievals will be performed irrespective of rainfall; however, the grid cell will be flagged in case of the presence of precipitation.

2.6.3.5 VWC Flag

SPL2SMAP_S retrievals are conducted for all locations irrespective of VWC level. The grid cells are flagged for VWC greater than 3 kg/m^2.

2.6.3.6 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_S processor flags 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 and do not retrieve soil moisture.

2.6.3.7 Mountain Area Flag

Statistics of mountainous regions are used to initiate flags and operational decisions during SPL2SMAP_S processing. The standard deviation of slope is used as a threshold to detect uneven terrain and mountainous regions. For QC related to mountainous regions, the SPL2SMAP_S processing is consistent with the SPL2SMP processing. Currently the SPL2SMAP_S 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 Data Fields document.

3 SOFTWARE AND TOOLS

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

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4.1 Technical References

For a list of all SMAP technical references, such as ATBDs, calibration and validation reports, and product specification documents, see the SMAP Technical References page.

5 CONTACTS AND ACKNOWLEDGMENTS

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5.2 Acknowledgments:

This data set contains modified Copernicus Sentinel-1 data (2015-present), acquired by the European Space Agency (ESA), distributed through the Alaska Satellite Facility (ASF), and processed by the SMAP Science Data System.

6 DOCUMENT INFORMATION

6.1 Publication Date

September 2017

6.2 Date Last Updated

2 November 2020