SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture, Version 2

This Level-2 (L2) soil moisture product provides estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) active radar during 6:00 a.m. descending half-orbit passes, as well as ancillary data such as surface temperature and vegetation water content. Input backscatter data used to derive soil moisture are resampled to an Earth-fixed, global, cylindrical 3 km Equal-Area Scalable Earth Grid, Version 2.0 (EASE-Grid 2.0).

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

Overview

Platform	SMAP Observatory
Sensor	SMAP L-Band Radar
Spatial Coverage	Global, between 85.044°N and 85.044°S
Spatial Resolution	3 km
Temporal Coverage	13 April 2015 – 07 July 2015
Temporal Resolution	49 minutes
Parameters	Soil Moisture Sigma Nought
Data Format	Hierarchical Data Format, Version 5 (HDF5)
Metadata Access	View Metadata Record
Version	V2. Refer to the SMAP Data Versions page for version information. **Maturity State:** Beta **Note:** These data are Beta-release quality, meaning that they have not undergone full validation and may still contain significant errors.
Error Sources	Radio Frequency Interference (RFI)
Get Data	FTP HTTPS Reverb | ECHO

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Citing These Data

As a condition of using these data, you must cite the use of this data set using the following citation. For more information, see our Use and Copyright Web page.

Kim, S. B., J. van Zyl, R. S. Dunbar, E. Njoku, J. Johnson, M. Moghaddam, and L. Tsang. 2015. *SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture.* Version 2. [Indicate subset used]. Boulder, Colorado USA: NASA National Snow and Ice Data Center Distributed Active Archive Center. doi:http://dx.doi.org/10.5067/6O6GPHUJ2QXM. [Date accessed].

1. Detailed Data Description

Format

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

File Structure

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

- `Ancillary_Data`
- `Metadata`
- `Radar_Data`
- `Soil_Moisture_Retrieval_Data`

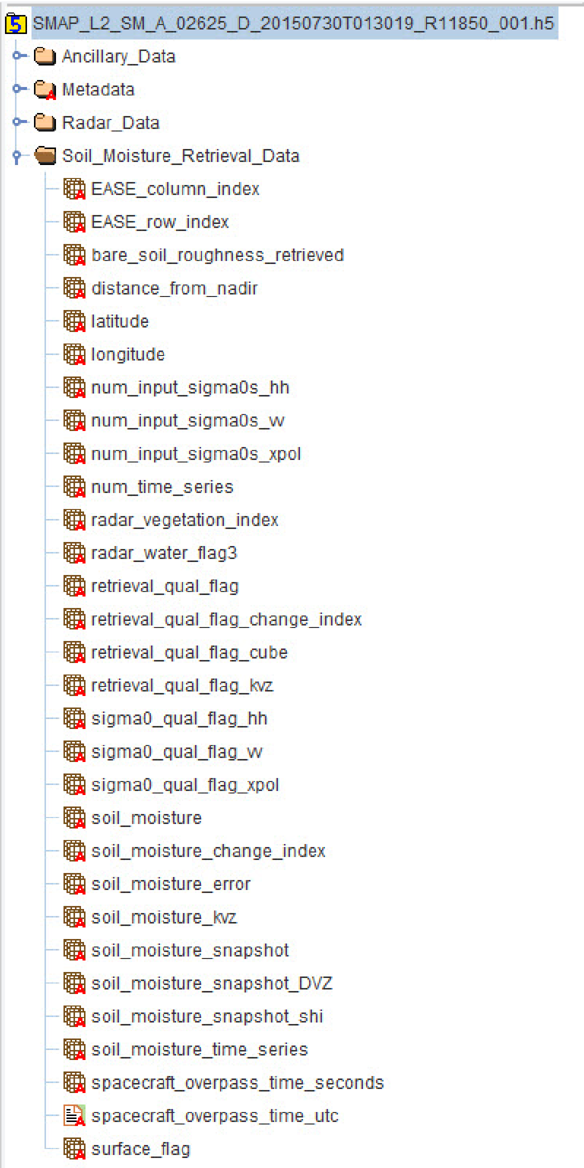

Figure 1. Sample of the HDF5 File Structure

Data Fields Overview

Each Level-2 radar soil moisture file contains the following:

Ancillary Data

Includes all ancillary data, such as surface temperature and vegetation water content.

Metadata

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.

Radar Data

Includes all radar data, such as cross-polarized sigma nought (also referred to as sigma0 or σ0) data.

Soil Moisture Retrieval Data

Includes soil moisture data and quality assessment flags.

Data Fields

For a complete list and description of all data fields, refer to the Data Fields document.

File Naming Convention

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

`SMAP_L2_SM_A_[Orbit#]_D_yyyymmddThhmmss_RLVvvv_NNN.[ext]`

For example:

`SMAP_L2_SM_A_00934_D_20141225T074951_R12130_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_A</td><td>Indicates specific product (L2: Level-2; SM: Soil Moisture; A: Active)</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>
<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: R12130 indicates a standard data product with a version of 2.130.</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>

File Size

Each half-orbit file is approximately 59 MB using HDF compression.

Volume

The daily data volume is approximately 1.5 GB.

Spatial 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.

Spatial Coverage Map

Figure 2 shows the spatial coverage of the SMAP L-Band Radar for one descending half orbit, which comprises one granule of this data set.

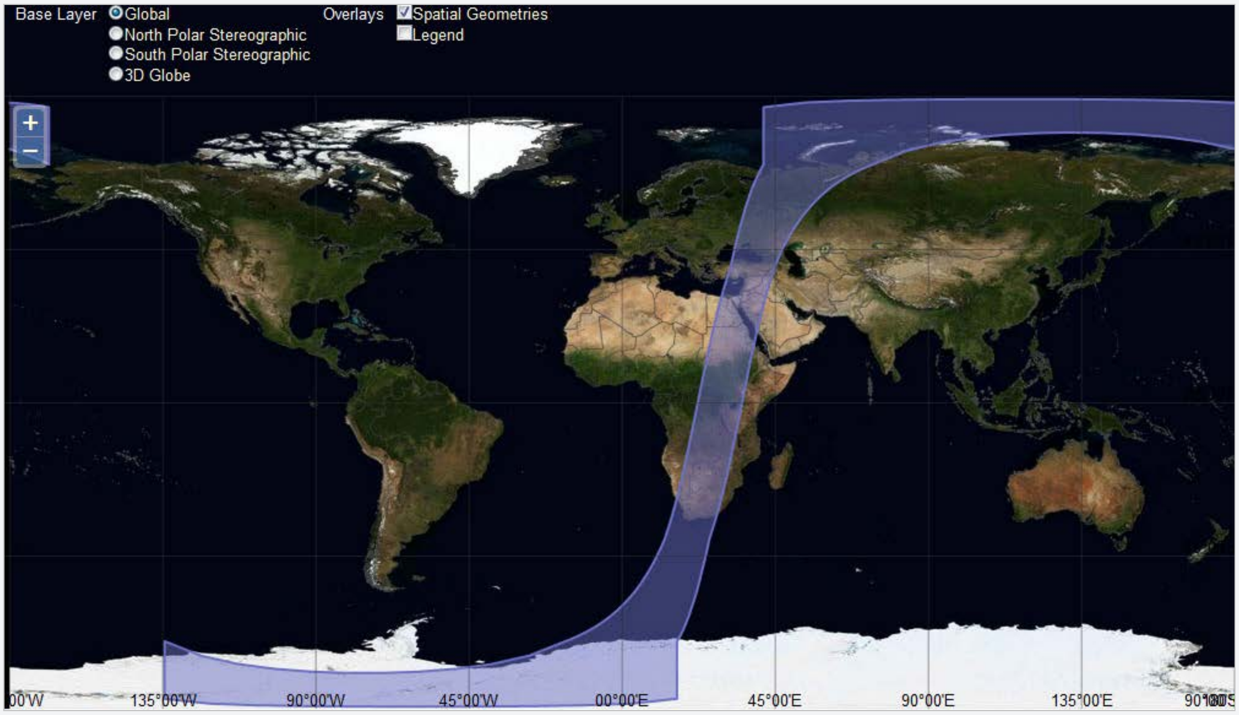

Figure 2. Spatial Coverage Map displaying one descending half orbit of the SMAP L-Band Radar. The map was created using the Reverb | ECHO tool.

Spatial Resolution

The native spatial resolution of the radar footprint is 1 km. Data are then gridded using the 3 km EASE-Grid 2.0 projection.

Projection and Grid Description

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.

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.

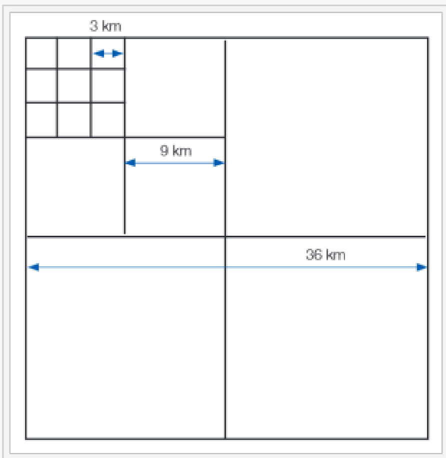

Figure 3. Perfect Nesting in EASE-Grid 2.0

Temporal Coverage

Data were collected from 13 April 2015 to 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).

Temporal Resolution

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

Parameter Description

Surface soil moisture (0-5 cm) in cm^3/cm^3 derived from the SMAP radar is output on a fixed 3 km EASE-Grid 2.0.

Refer to the Data Fields document for details on all parameters.

2. Data Access and Tools

Get Data

Data are available via FTP and HTTPS.

Data are also available through Reverb | ECHO, a NASA search and order tool for subsetting, reprojecting, and reformatting data.

Software and Tools

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

3. Data Acquisition and Processing

Sensor or Instrument Description

For a detailed description of the SMAP instrument, visit the SMAP Instrument page at the JPL SMAP Web site.

Data Source

SMAP Level-2 radar soil moisture data (SPL2SMA) are derived from SMAP High-Resolution Radar Sigma Nought, Version 1 (SPL1CS0) data.

Theory of Measurements

Retrieval of soil moisture from measured backscatter data typically implies an inversion of the radar forward scattering process. Bare rough surfaces can be characterized in terms of their Root Mean Square (RMS) roughness height, correlation length, and moisture content (a surrogate for dielectric constant). The use of time-series data makes the retrieval a well-constrained estimation problem, under the assumption of a time invariant surface roughness. By taking a co-polarized ratio the soil moisture retrieval becomes insensitive to the correlation length except for very rough surfaces, which enables an accurate retrieval of soil moisture without correlation length information. This approach has been extended to the vegetated surface by introducing a vegetation axis to the lookup table (Kim et al. 2014). A one-axis representation of the vegetation effect is clearly a simplification, considering that different sets of vegetation parameters result in different backscattering coefficients. However, with SMAP's three measurement channels—HH, VV, and HV—at most three independent parameters can be uniquely estimated, and therefore simplified forward models must be represented in terms of at most three dominant parameters. The simplification results in some errors in soil moisture retrieval, especially in heavily vegetated areas such as forests. Allometric relationships reduce the number of unknowns and may improve the retrievals. The three parameters used to simplify the scattering model are then the dielectric constant of soil, ε, soil surface roughness, s, and VWC.

The SMAP radar HV-channel measurements are reserved for possible use in correcting vegetation effects. The remaining two co-polarized (co-pol) measurements (HH and VV) are not always sufficient to determine s and ε (Kim et al. 2014). One of the main causes is the ambiguity in bare surface scattering: a wet and smooth surface may have the same backscatter as a dry and moderately rough surface. Very often the timescale of the change in s is longer than that of ε (Jackson et al. 1997). Then s may be constrained to be a constant in time, thus resolving the ambiguity (Kim et al. 2014).

The SMAP baseline approach (Kim et al. 2012; Kim et al. 2014) is a multichannel retrieval algorithm that searches for a soil moisture solution such that the difference between modeled and observed backscatter is minimized in the least squares sense. A look-up table representation, or data cube, of a complicated forward model has been demonstrated to be an accurate and fast tool for retrieval (Kim et al. 2012a; Kim et al. 2014).The algorithm estimates s first and then retrieves ε_r using the estimated s. Vegetation effects are included by selecting the sigma0 of the forward model at the VWC level given by an ancillary source. Note that the VWC provided by ancillary information is allowed to vary throughout the time series.

For in-depth information regarding the physics involved in deriving soil moisture from backscatter, refer to the ATBD for this product, Section 2: Physics of the Scattering Problem.

Derivation Techniques and Algorithms

SMAP Level-2 active soil moisture data are derived from SMAP High-Resolution Radar Sigma Nought, Version 1 (SPL1CS0) data. Utilizing the soil moisture algorithms discussed below, SMAP sigma0 measurements are converted into an estimate of the surface soil moisture of the 0-5 cm surface soil moisture in units of cm^3/cm^3 .

The following information has been adapted from the ATBD. (Kim et al. 2015)

Algorithm Inputs and Outputs

Table 3 lists the required input data sets to the radar-only soil moisture inversion. These include the primary choices that meet the ancillary data requirements. Ancillary data sets are defined as external data sets that are required as inputs to SMAP retrieval algorithms in the generation of the standard Level-2 and Level-3 active products. Ancillary data needed by the SMAP mission fall into two categories: static ancillary data, which do not change during the mission, and dynamic ancillary data, which require periodic updates in timeframes ranging from seasonally to daily. Static data include parameters such as permanent masks (land/water/forest/urban/mountain), the grid cell average elevation and slope derived from a Digital Elevation Model (DEM), permanent open water fraction, and soils information (primarily sand and clay fraction). All static ancillary data are resampled to the 3 km EASE-Grid 2.0 as the output products. The dynamic ancillary data include land cover, precipitation, and effective soil temperatures. The choice of which ancillary data set to use for a particular SMAP product is based on a number of factors, including its availability and ease of use, and its inherent error and resulting impact on the overall soil moisture or freeze/thaw retrieval accuracy. Latency, spatial resolution, temporal resolution, and global coverage are also important. The choice of a primary source for each of the ancillary data parameters is fully documented in individual SMAP Ancillary Data Reports (refer to Section 6.1 in the ATBD). Brief descriptions are provided below for the input radar backscatter, and for the ancillary parameters generated by the SPL2SMA processor.

Table 3. List of Input Data for the Level-2 Active Soil Moisture Algorithm

Data Type	Data Source
Radar Backscatter (HH/VV/HV)	SPL1CS0
Land Cover Class	MODIS-International Geosphere Biosphere Programme (IGBP)
Crop Type	Cropland Data Layer (US) Environment Canada (Canada) ECOCLIMAP (Europe) Global Crop Map (Rest of the world)
Vegetation Water Content	SPL2SMA MODIS Normalized Difference Vegetation Index (NDVI)
Data Cube	SMAP Science Team
Soil Texture	Harmonized World Soil Database + Regional + Food Agricultural Organization (FAO)
Soil Surface Temperature	Global Modeling and Assimilation Office (GMAO) or European Center for Medium Range Weather Forecasting (ECMWF)
Mountain Area	Combination of Shuttle Radar Topography Mission (SRTM), Alaska United States Geological Survey (USGS) DEM, Canada Geobase DEM, and GTOPO30 (a global DEM with a horizontal grid spacing of 30 arc seconds or approximately 1 km)
Freeze/Thaw Flag	GMAO
Permanent Ice	MODIS IGBP
Snow	Snow & Ice Mapping System (IMS) - NOAA
Static Water Body	MODIS MOD44W
Transient Water Body	SPL2SMA
Precipitation	ECMWF Total Precipitation Forecasts [or Global Precipitation Measurement (GPM) once launched]
Urban Area	Global Rural-Urban Mapping Project (GRUMP)
RFI Contamination	SPL1CS0

Radar Backscatter

As previously stated, the primary input to the SPL2SMA algorithm is the Level-1C gridded radar product. This product consists of the calibrated high-resolution (SAR-mode) multiple polarization radar backscatter measurements and associated parameters, Earth-located and mapped to a swath-based, along-track/cross-track, 1 km EASE-Grid 2.0. It is assumed that the backscatter measurements have been fully calibrated and corrected for atmospheric attenuation and ionospheric effects such as Faraday rotation. Information provided in the Level-1C data set or in ancillary calibration files should enable estimates of the sigma nought ($\sigma 0$) accuracy (Kp) for each measurement based on instrument characteristics.

Vegetation Water Content derived from Radar Vegetation Index

The SPL2SMA algorithm requires information on the VWC. One potential source of vegetation information is a polarimetric parameter derived from SMAP data such as the Radar Vegetation Index (RVI) (Kim and van Zyl 2000).

Alternatively, the vegetation amount may be derived based on low-order polynomial of the NDVI and optical remote-sensing images (refer to the SPL2SMP ATBD). In principle the RVI or any other parameter based on the radar backscatter should correlate with the vegetation amount more strongly than the optical NDVI, because fundamentally optical radiation cannot penetrate vegetation canopies while the L-band microwave signal can. Furthermore the RVI is concurrent with the radar observation. Studies are ongoing with regard to whether the radar backscatter may improve estimates of vegetation effects.

Radar Water Bodies

An algorithm for discriminating transient water bodies from land surfaces is also part of the SPL2SMA processor. There are many combinations of water surfaces adjoined by land surfaces, (depending on both land and water surface roughness and presence of vegetation) that affect this discrimination capability. At present, the case of a calm water surface next to lightly vegetated land was studied. It was found that a threshold (3 dB) applied to the ratio of HH to VV effectively separated water from land at SMAP's 40 deg incidence angle. In this study, Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) images were analyzed over fairly flat terrain. Despite the apparent differences between UAVSAR and SMAP, the measurement quality for both instruments is determined by the same statistical processes inherent in SAR imaging. Calibration error and the number of single looks of one UAVSAR pixel are similar to those of one pixel of the SMAP SAR.The algorithm was tested over numerous locations with a detection error of smaller than 10% (Kim et al. 2015).

Algorithm Processing Flow

The SPL2SMA processor reads in 1 km resolution σ0 from the SPL1CS0. The 1 km data in natural units are aggregated onto the 3 km EASE-Grid 2.0, during which various quality flags are applied. Two quality flags are derived using the 3 km σ0: radar vegetation index and radar water body. Static and dynamic ancillary data are sampled for each pixel of the SPL2SMA product. Sigma0 values from the past are sampled and used by the time-series algorithm. For each 3 km pixel, land cover class information is obtained from the mostly annual ancillary data. The land cover information allows to choose an appropriate data cube for each pixel. The retrieval over the different land cover classes is spatially assembled to create a half-orbit output, followed by the conversion from the dielectric constant to soil moisture.

For more information on each portion of the algorithm processing flow, and the details of the retrieval methods and options, refer to Section 3: Retrieval Algorithms of the ATBD for this product.

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

Processing Steps

This data set is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate this data set, the processing software ingests the descending half-orbit granules of the SMAP High-Resolution Radar Sigma Nought, Version 1 (SPL1CS0) data set. The SPL1CS0 data set contains swath-gridded radar backscatter observations acquired by the radar and processed using synthetic-aperture processing providing measurements at 1 km resolution. After the 1 km sigma0 data are gridded on a 3 km EASE-Grid, the gridded data are then tested for retrievability criteria according to input data quality, ancillary data availability, and land cover conditions. When retrievability criteria are met, the software invokes the baseline retrieval algorithm to generate soil moisture retrieval. Only cells that are covered by the actual swath for a given projection are written in the product.

Error Sources

Anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate both radar and radiometer measurements at L-band. Early measurements and results from ESA's Soil Moisture and Ocean Salinity (SMOS) mission indicate that in some regions RFI is present and detectable. The SMAP radar and radiometer electronics and algorithms include design features to mitigate the effects of RFI. The SMAP radar utilizes 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.

More information about error sources is provided in Section 3.5: Error Budget of the ATBD.

Quality Assessment

These Version 2 data are Beta-quality, which means they employ preliminary algorithms that are still being validated and are thus subject to uncertainties.

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 document.

Each HDF5 file contains metadata with Quality Assessment (QA) metadata flags that are set by the Science Data Processing System (SDS) at the JPL prior to delivery to the National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). A separate metadata file with an `.xml` file extension is also delivered to NSIDC DAAC 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 file/granule fails QA, the SDS does not send the granule to NSIDC DAAC until it is reprocessed. Level-2 products that fail QA are never delivered to NSIDC DAAC. Only a QA file is produced when there are no data that qualify for retrieval.

Quality Flags

Note: As SPL2SMA is a research product, the accuracy requirements are tentative and are set to 0.06 cm^3/cm^3 for soil moisture and up to 5 kg/m^2 for vegetation water content (VWC).

Quality Control (QC) is an integral part of the SPL2SMA processing. The QC steps of the SPL2SMA processing are based on the flags that are provided with the input data stream (SPL1CS0), different types of masks, flags, and fractional coverage of other variables provided by ancillary data. The soil moisture retrieval flags are listed in Table 4.

Table 4. Soil Moisture Retrieval Flags

Flag Type
Sigma0 Quality (HH): Forward Look, Aft Look, RFI
Sigma0 Quality (VV)
Sigma0 Quality (HV)
Retrieval Success
Freeze/Thaw
Radar Vegetation Index
Radar/Permanent Water Body
Dense Vegetation (VWC)
Nadir Region
Urban
Precipitation
Snow, Ice, Frozen Surface
Mountain

The 'sigma0 quality flag' is deemed good if all of the sub-flags (fore, aft, RFI) are good. Generally '0' is assigned to the favorable condition for soil moisture retrieval. The SPL2SMA processes 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 is also conducted for regions with high VWC, rain, data with RFI removed, and places in close proximity to water bodies, but appropriate flags are added to these data points indicating their susceptibility to high errors. On places such as frozen or water surfaces, soil moisture will not be retrieved. Therefore, there are three flagging states associated with soil moisture retrieval:

- Retrieve and assign good flag (retrieval recommend)
- Retrieve and assign bad flag (retrieval success)
- Do not retrieve and assign bad flag (retrieval attempt)

Interface Assumptions

The SPL2SMA product uses the radar backscatter and RFI flag from the SPL1CS0. The aggregated 3 km resolution of radar backscatter is used as an input to SPL2SMAP. The soil moisture output from the SPL2SMA provides an input to the SPL3SMA and to the optional algorithm of the SPL2SMAP. The radar vegetation index from the SPL2SMA is used by the SPL2SMP and SPL2SMAP.

The SPL2SMA freeze/thaw flag is generated from modeled surface temperature information called TSURF from the Global Modeling and Assimilation Office (GMAO). The SPL2SMA Version 2 Beta product uses the GMAO-modeled TSURF parameter due to the maturity of the SMAP radar Freeze/Thaw algorithm and availability of radar measurements.

The SPL2SMA water body flag is generated from *a priori* information on permanent open freshwater from the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD44W database. The SPL2SMA Version 2 Beta product uses the MOD44W database due to the maturity of the SMAP radar open-water algorithm and availability of radar measurements.

Nadir Gap

The SPL2SMA product has a nadir gap where the effective resolution in the cross-track direction gradually becomes 36 km. A flag is assigned to identify this region and the region is excluded during the Level-3 compositing. Over three days on average the gaps will be filled except for the pixels near the equator, where it takes longer to fill the gaps.

For more information regarding data flags, refer to the Data Fields document.

4. References and Related Publications

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5. Contacts and Acknowledgments

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