Integrated SMAP and SMOS Soil Moisture Data Products, Version 1

SMOS-Based SMAP L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture and SMAP/SMOS L3 Radiometer 9 km EASE-Grid Soil Moisture

USER GUIDE

How to Cite These Data

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

Chaubell, J., Bindlish, R., Hayashi, A., Colliander, A., Yueh, S., Dunbar, S., and D. Entekhabi. 2024. SMOS-Based SMAP L2 Radiometer Half-Orbit 9 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/GXBB46ZD0CLE. [Date Accessed].

Chaubell, J., Bindlish, R., Hayashi, A., Colliander, A., Yueh, S., Dunbar, S., and D. Entekhabi. 2024. SMAP/SMOS L3 Radiometer 9 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/E1NLXI1VJJ7M. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0799 or https://nsidc.org/data/NSIDC-0800

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION 2
1.1 Summary 2
1.2 Parameters 2
1.3 File Information 3
1.3.1 Format 3
1.3.2 File Contents 3
1.4 Spatial Information 9
1.4.1 Coverage 9
1.4.2 Resolution 9
1.4.3 Geolocation 9
1.5 Temporal Information 10
1.5.1 Coverage 10
1.5.2 Resolution 11
2 DATA ACQUISITION AND PROCESSING 11
2.1 Background 11
2.2 Acquisition 11
2.3 Processing 12
2.4 Quality, Errors, and Limitations 13
3 VERSION HISTORY 13
4 RELATED DATA SETS 13
5 RELATED WEBSITES 14
6 REFERENCES 14
7 DOCUMENT INFORMATION 14
7.1 Publication Date 14
7.2 Date Last Updated 14

This user guide applies to the following data sets:

SMOS-Based SMAP L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture (NSIDC-0799, referred to as the "L2 Product")

SMAP/SMOS L3 Radiometer 9 km EASE-Grid Soil Moisture (NSIDC-0800, referred to as the "L3 Product")

1 DATA DESCRIPTION

1.1 Summary

The Soil Moisture Active Passive (SMAP, launched in 2015) and the Soil Moisture and Ocean Salinity (SMOS, launched in 2009) missions are each L-band satellites that provide brightness temperature and soil moisture estimates and vegetation optical depth approximately every 2-3 days with a spatial resolution of ~40 km. By integrating brightness temperature observations from both satellites, these data products reduce the revisit time to about one day, improving the ability to monitor fast-response processes such as groundwater drainage and recharge, early dry-down after storms, and pre-storm soil moisture conditions for runoff determination.

The Integrated SMAP and SMOS Soil Moisture Data is available in two products:

- SMOS-Based SMAP L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture (NSIDC-0799): This product is generated by processing half-orbit granules (either 6 AM ascending or 6 PM descending) from the pre-processed SMOS product. The L2 product consists solely of SMOS-based data, incorporating information after SMOS brightness temperatures (TBs) at a 40° incidence angle were inter-calibrated and the soil moisture (SM) and vegetation optical depth (VOD) were retrieved using the SMAP Dual Channel Algorithm (DCA).
- SMAP/SMOS L3 Radiometer 9 km EASE-Grid Soil Moisture (NSIDC-0800): To generate this product, processing software ingests one day's worth of granules from both the SMAP SPL2SMP_E product and the SMOS-derived L2 data. The L3 product contains both SMAP and SMOS descending (6:00 AM/PM) and ascending (6:00 PM/AM) data stored in separate arrays.

1.2 Parameters

The main parameters of both data products are surface soil moisture (SM) and vegetation optical depth (VOD) presented on the Global EASE-Grid 2.0 projection. Data is derived by integrating brightness temperatures from two L-band satellites: Soil Moisture Active Passive (SMAP) enhanced Level-2 and Soil Moisture Ocean Salinity (SMOS).

1.3 File Information

1.3.1 Format

The data are available as HDF5-formatted files.

1.3.2 File Contents

The integrated SMAP and SMOS soil moisture data consists of two main products: SMOS-Based SMAP L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture (NSIDC-0799, the L2 Product) and SMAP/SMOS L3 Radiometer 9 km EASE-Grid Soil Moisture (NSIDC-0800, the L3 Product). File details for both are described below.

1.3.2.1 L2 Product

As shown in Figure , each HDF5 file is organized into two top-level groups: `Metadata_SMOS` and `SMOS_Based`.

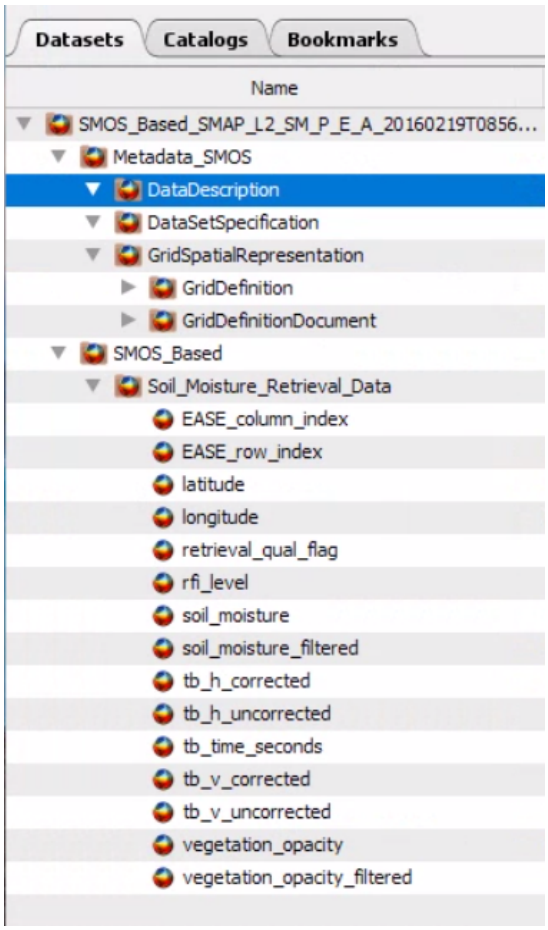

Figure 1. L2 Product File Contents

The `Metadata_SMOS` group includes metadata that describe the full content of each file. This includes when the data were created, swath width, information about grid spatial extent, and publications for further reading.

The `Soil_Moisture_Retrieval_Data` group contains data regarding both corrected/filtered and uncorrected/unfiltered values, spatial information, SM, VOD, and quality flags. Each parameter is described in Table 1.

Table 1. L2 Product Data Parameters

Parameters	Description
tb_time_seconds	Average TB sample acquisition time in a grid cell
EASE_row_index	Zero-based row index of a 9-km EASE Grid 2.0 cell
EASE_col_index	Zero-based column index of a 9-km EASE Grid 2.0 cell
latitude	EASE-2 grid center latitude
longitude	EASE-2 grid center longitude
tb_h_uncorrected	H-polarized TB without water correction and before relative calibration applied
tb_v_uncorrected	V-polarized TB without water correction and before relative calibration applied
tb_h_corrected	H-polarized TB with water correction and relative calibration applied
tb_v_corrected	V-polarized TB with water correction and relative calibration applied
soil_moisture	Retrieved soil moisture using the DCA algorithm
vegetation_opacity	Retrieved vegetation optical depth using the DCA algorithm
soil_moisture_filtered	Retrieved soil moisture using the DCA algorithm filtered by RFI. RFI level = 0
vegetation_opacity_filtered	Retrieved vegetation optical depth using the DCA algorithm filtered by RFI. RFI level = 0
retrieval_qual_flag	Quality flag of retrieved soil moisture using DCA
rfi_level	RFI probability value * 200

1.3.2.1.1 Naming Convention

Files are named according to the following convention:

`NSIDC-0799_SMOS-SMAP-L2_[pass direction]_YYYYMMDDThhmmss-YYYYMMDDThhmmss_V01.0.h5`

For example:

`NSIDC-0799_SMOS-SMAP-L2_D_20150501T035011-20150501T044325_V01.0.h5`

The variables within a file name are described in Table .

Table 2. File Naming Convention of the L2 Product

Variable	Description
NSIDC-0799	National Snow and Ice Data Center (NSIDC) data set authoritative identification
SMOS-SMAP-L2	Indicate SMOS mission data used in conjunction with SMAP enhanced Level-2 data
[pass direction]	Half Orbit Designator, where 'A' represents 6:00 am ascending pass; 'D' represents 6:00 pm descending pass
YYYYMMDDThhmmss	First/End Date/Time Stamp: Date/time stamp in Universal Coordinated Time (UTC) of the first and last data element, specified as 4-digit year (YYYY), 2-digit month (MM), 2-digit day (DD), with Time (T) designated as 2-digit hour (hh), 2-digit minutes (mm), 2-digit seconds (ss)
V01.0	Indicates Version number 1.0
.h5	File extension for an HDF5 data file

1.3.2.2 L3 Product

As shown in Figure 2, each HDF5 file is organized into five top-level groups: Metadata, Metadata_SMAP, Metadata_SMOS, SMAP_Based, and SMOS_Based.

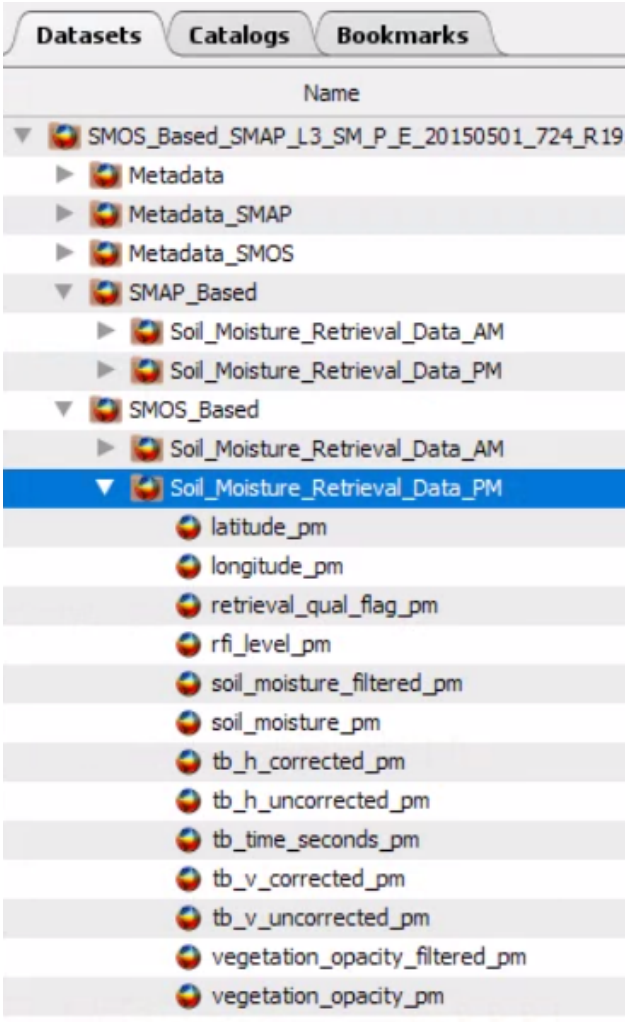

Figure 2. L3 Product File Contents

The `Metadata`, `Metadata_SMAP`, `Metadata_SMOS` groups include metadata that describe the full content of each file. This includes information about grid spatial extent, description of the data through abstracts, and publications for further reading.

There are two groups of data in the product: `SMAP_based` and `SMOS_based.` The `SMAP_based` group contains fields copied from the SMAP Enhanced L3 Radiometer Global and Polar Grid Daily 9 km EASE-Grid Soil Moisture, Version 6 (SPL3SMP_E) product without further processing. The `SMOS_based` group contains the same information but derived using the SMOS-based TBs, which were inter-calibrated with SMAP, with the SM and VOD data retrieved by means of the SMAP DCA.

Further, these two groups contain two subgroups: `Soil_Moisture_Retrieval_Data_AM` and `Soil_Moisture_Retrieval_Data_PM`. The subgroups contain data regarding both corrected/filtered and

uncorrected/unfiltered values, spatial information, SM, VOD, and quality flags. Each parameter is described in Table 3.

Table 3. L3 Product File Parameters

Parameters	Description
tb_time_seconds_(am/pm)	Average TB sample acquisition time in a grid cell
latitude_(am/pm)	EASE-2 grid center latitude
longitude_(am/pm)	EASE-2 grid center longitude
tb_h_uncorrected_(am/pm)	H-polarized TB without water correction and before relative calibration applied
tb_v_uncorrected_(am/pm)	V-polarized TB without water correction and before relative calibration applied
tb_h_corrected_(am/pm)	H-polarized TB with water correction and relative calibration applied
tb_v_corrected_(am/pm)	V-polarized TB with water correction and relative calibration applied
soil_moisture_(am/pm)	Retrieved soil moisture using the DCA algorithm
vegetation_opacity_(am/pm)	Retrieved vegetation optical depth using the DCA algorithm
soil_moisture_filtered_(am/pm)	Retrieved soil moisture using the DCA algorithm filtered by RFI. RFI level = 0
vegetation_opacity_filtered_(am/pm)	Retrieved vegetation optical depth using the DCA algorithm filtered by RFI. RFI level = 0.
retrieval_qual_flag_(am/pm)	Quality flag of retrieved soil moisture using DCA
rfi_level	RFI probability value * 200 (only in SMOS data group)

1.3.2.2.1 Naming Convention

Files are named according to the following convention:

```
NSIDC-0800_SMOS-SMAP-L3_YYYYMMDD_V01.0.h5
```

For example:

```
NSIDC-0800_SMOS-SMAP-L3_20150501_V01.0.h5
```

The variables within a file name are described in Table 4.

Table 4. File Naming Convention of the L3 Product

Variable	Description
NSIDC-0800	National Snow and Ice Data Center (NSIDC) data set authoritative identification
SMOS-SMAP-L3	Indicate SMOS mission data used in conjunction with SMAP data
YYYYMMDD	Date stamp, specified as 4-digit year (YYYY), 2-digit month (MM), 2-digit day (DD)
V01.0	Indicates Version number 1.0
.h5	File extension for an HDF5 data file

1.4 Spatial Information

1.4.1 Coverage

Both data products have global, gridded coverage.

1.4.2 Resolution

Both data products have 9 km grid resolution.

1.4.3 Geolocation

Both data products are provided on the Global 9 km EASE-Grid 2.0 projection. The following tables provide information for geolocating this data set. For more information on EASE-Grid 2.0, refer to the EASE Grids website.

Table 5. Geolocation Details for the Global 9 km EASE-Grid 2.0

Geographic coordinate system	WGS 1984
Projected coordinate system	EASE-Grid 2.0 Global
Longitude of true origin	0
Latitude of true origin	30
Scale factor at longitude of true origin	N/A
Datum	WGS 1984
Ellipsoid/spheroid	WGS 1984
Units	Meters
False easting	0
False northing	0
EPSG code	6933
PROJ4 string	+proj=cea +lat_ts=30 +lon_0=0 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.org/crs_6933/WGS-84-NSIDC-EASE-Grid-2-0-Global.html

Table 6. 9 km Resolution EASE-Grid 2.0 Global Grid Details

Grid cell size (x, y pixel dimensions)	9,008.05 m (x) × 9,008.05 m (y)
Number of rows	1624
Number of columns	3856
Nominal gridded resolution	9 km by 9 km
Grid rotation	N/A
ulxmap – x-axis map coordinate of the center of the upper-left pixel (XLLCORNER for ASCII data)	-17367530.44
ulymap – y-axis map coordinate of the center of the upper-left pixel (YLLCORNER for ASCII data)	7314540.83

1.5 Temporal Information

1.5.1 Coverage

Both data products span 01 May 2015 to 31 Dec 2021.

1.5.2 Resolution

The L2 and L3 products have different temporal resolutions:

- L2 Product: Each half-orbit file spans approximately 45 minutes.
- L3 Product: Each file spans one day, where AM and PM passes are contained in the same file.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The SMAP and SMOS missions provide TB and SM estimates, as well as vegetation optical depth VOD approximately every 2–3 days with a spatial resolution of ~40 km. Due to their sun-synchronous orbits, they have an overpass time of approximately 6 AM and 6 PM local time. The integration of the brightness temperature observations (both AM and PM) from both L-band satellites (SMAP and SMOS) can reduce the revisit time to about 1 day and thus help to address fast-response processes, such as drainage and recharge to groundwater, early dry down after storms, and pre-storm soil moisture for runoff determination. However, due to their different instrument configurations, ancillary data, retrieval algorithms, and calibration strategies, it is very difficult to develop an integrated brightness temperature, surface SM, and VOD data product through a simple merging of the corresponding products. A successful integration of both missions' products requires: (1) processing of the SMAP-like TB at a fixed 40° incidence angle, (2) processing of SMAP ancillary data over the 9 km EASE 2.0 grid at the SMOS overpass time, (3) elimination of the water contamination over SMOS TB over land, (4) removal of bias between the SMOS and SMAP TB, and (5) application of SMAP retrieval algorithm to obtain a new set of SM and VOD.

2.2 Acquisition

The L2 Product is derived from the pre-processed SMOS L1B and L1C Version 724 TBs at a 40° incidence angle and posted on the 9 km grid.

The L3 Product is a daily global composite of the SMAP Enhanced L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 6, R19 (SPL2SMP_E) product and the SM and VOD retrieved from relatively calibrated SMOS brightness temperatures using SMAP ancillary data and the SMAP Dual Channel Algorithm (DCA).

2.3 Processing

To generate the L2 Product, the processing software ingests half-orbit granules (either 6 AM ascending or 6 PM descending half orbits) of the pre-processed SMOS product. The ingested data are then inspected for retrievability according to input data quality, ancillary data availability, and land surface conditions. When retrievability criteria are met, the software invokes the baseline retrieval to generate soil moisture and vegetation optical depth fields. Only cells that are covered by the actual swath are included in the product. The L2 product consists solely of SMOS-based data, including information after the SMOS-based TBs at 40° were inter-calibrated and the SM and VOD were retrieved using the SMAP DCA.

To generate the L3 Product, the processing software ingests one day's worth of granules from the SMAP SPL2SMP_E product and SMOS-derived data, then creates individual global composites as two-dimensional arrays. SMAP/SMOS descending (6:00 AM/PM) and ascending (6:00 PM/AM) data are integrated and stored in separate arrays within the L3 product. Wherever data overlap occurs (typically at high latitudes due to overlapping orbits), the data point where acquisition time is closest to the 6:00 AM local solar time or 6:00 PM local solar time is chosen.

The SMAP-SMOS integration methodology can be summarized as follows:

1. Converting SMOS TB to 40° incidence angle using a multi-step regression and curve fitting approach to process SMOS L1C brightness temperatures to a constant incidence angle observed by the SMAP radiometer.
2. Inter-calibration between SMOS and SMAP to remove bias between the two data sets.
3. SMOS TB processing to perform a water body correction to the brightness temperature data for cases where a significant percentage of the grid cell contains open water.
4. Retrieval of soil moisture and vegetation optical depth via utilization of the SMAP DCA.

The DCA, the baseline SMAP retrieval algorithm, requires *a priori* determination of several ancillary data: the dynamic parameter (effective surface temperature) and the static parameters, including clay fraction, bulk fraction, roughness coefficient, single scattering albedo ω, and the NDVI τ for which day-of-the-year climatology was used. To mimic the SMAP algorithm as closely as possible, the *a priori* parameters mentioned above were obtained directly from the SMAP Enhanced L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 6, R19 (SPL2SMP_E) product instead of using the direct input from the SMAP ancillary files. It is important to note that the SMAP processing algorithm applies a 33 km averaging over the data on the ancillary files. The DCA is based on the zeroth order radiative transfer equation known as the *tau-omega* model.

More details on data processing and methodology can be found in Chaubell et al. (2024).

2.4 Quality, Errors, and Limitations

An inter-comparison between SMOS TBs and SMAP TBs and a linear regression of SMAP TBs vs SMOS TBs provided the relative calibration parameters (slope and offset) to remove bias. Only brightness temperatures separated by less than 1 km at the surface from both missions were used in the inter-comparison. To minimize inter-comparison errors associated with temporal changes in soil moisture and temperature, a maximum time window between the two satellite observations of 30 minutes was used. The analysis utilized quality flags from both missions. Only brightness temperature observations with quality flag set to zero were used in the match-up analysis.

The data was also filtered by the radio frequency interference (RFI) probability information included in the SMOS data files. Because the presence of RFI can affect the inter-calibration parameters and therefore the resulting SM and VOD, only data with RFI probability equal to zero were considered. Because most of the RFI affects a large region between approximately 10° and 50° North in the Eastern Hemisphere, areas with higher VOD values were removed due to their high probability of RFI contamination. The analysis was done for both the horizontal and vertical polarizations over land only. To minimize the error caused by water contamination, only TBs over grid cells with water fraction less than 0.01 were compared.

During assessment of the soil moisture retrievals over the SMAP Calibration Validation Sites, the Twente and Hobe sites were found to have poor quality data available. Specifically, if Twente and Hobe are not included for both the AM and PM half orbit passes, values for unbiased Root Mean Square Differences Mean Differences; and Root Mean Square Differences decreased.

For further discussion of data quality and removal of bias or errors, see Chaubell et al. (2024).

3 VERSION HISTORY

Table 7. Version History

Version	Date Implemented	Impacted Temporal Coverage	Description of Changes
v01.0	January 2025	01 May 2015 to 31 Dec 2021	Initial release

4 RELATED DATA SETS

SMAP Enhanced L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture, Version 6 (SPL2SMP_E)

SMOS L1B and L1C Version 724

5 RELATED WEBSITES

Soil Moisture Active Passive Data (SMAP) | Overview

SMOS L1 and L2 Science data | Overview

6 REFERENCES

Chaubell, J., A. Hayashi, S. Dunbar, A. Colliander, S. Yueh, and R. Bindlish. (2024). Integrated SMAP and SMOS Soil Moisture Data Algorithm Theoretical Basis Document: Level 2-3 Soil Moisture Integrated Data Product. SMAP project, JPL D-110706. Jet Propulsion Laboratory, Pasadena, CA. (see PDF)

7 DOCUMENT INFORMATION

7.1 Publication Date

February 2025

7.2 Date Last Updated

February 2025