SMAP L4 Global 9 km EASE-Grid Surface and Root Zone Soil Moisture, Version 5: 3-hourly Analysis Update, 3-hourly Geophysical Data, and Land Model Constants

USER GUIDE

How to Cite These Data

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

Reichle, R., G. De Lannoy, R. D. Koster, W. T. Crow, J. S. Kimball, and Q. Liu. 2020. *SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Analysis Update, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/0D8JT6S27BS9. [Date Accessed].

Reichle, R., G. De Lannoy, R. D. Koster, W. T. Crow, J. S. Kimball, and Q. Liu. 2020. *SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Geophysical Data, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/9LNYIYOBNBR5. [Date Accessed].

Reichle, R., G. De Lannoy, R. D. Koster, W. T. Crow, J. S. Kimball, and Q. Liu. 2020. *SMAP L4 Global 9 km EASE-Grid Surface and Root Zone Soil Moisture Land Model Constants, Version 5*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/5C36BVQZW28K. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL4SMAU (or SPL4SMGP or SPL4SMLM)

National Snow and Ice Data Center

TABLE OF CONTENTS

This user guide applies to the following data sets:

SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Analysis Update

SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Geophysical Data

SMAP L4 Global 9 km EASE-Grid Surface and Root Zone Soil Moisture Land Model Constants

1 DATA DESCRIPTION

1.1 Parameters

SMAP Level-4 soil moisture data include the following parameters:

- Surface soil moisture (0-5 cm vertical average)
- Root zone soil moisture (0-100 cm vertical average)
- Additional research products (not validated), including surface meteorological forcing variables, soil temperature, evapotranspiration, net radiation, and error estimates for select output fields that are produced internally by the SMAP Level-4 soil moisture algorithm

Soil moisture is output in volumetric units, in wetness (or relative saturation) units, and in percentile units (except surface soil moisture).

Refer to the Appendix of this document for details on all parameters. Parameters are further described in Section 3 of the Algorithm Theoretical Basis Document (ATBD) for this product (Reichle et al., 2014).

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 website.

1.2.2 File Contents

SMAP Level-4 soil moisture data consists of three main products:

- Geophysical Data (SPL4SMGP)
- Analysis Update Data (SPL4SMAU)
- Land Model Constants (SPL4SMLM)

For each 3-hour interval, there are two files: one geophysical (gph) file and one analysis update (aup) file. Land model constants (lmc) are provided in a single file per Science Version. Science Version IDs (such as Vv3030) are included in all file names, and are defined in the **File Naming Convention** section of this User Guide.

1.2.2.1 Geophysical Data

The Geophysical Data (gph) product includes a series of 3-hourly time-averaged geophysical data fields from the assimilation system, such as surface and root zone soil moisture. Figure 1 shows a subset of the gph file contents.

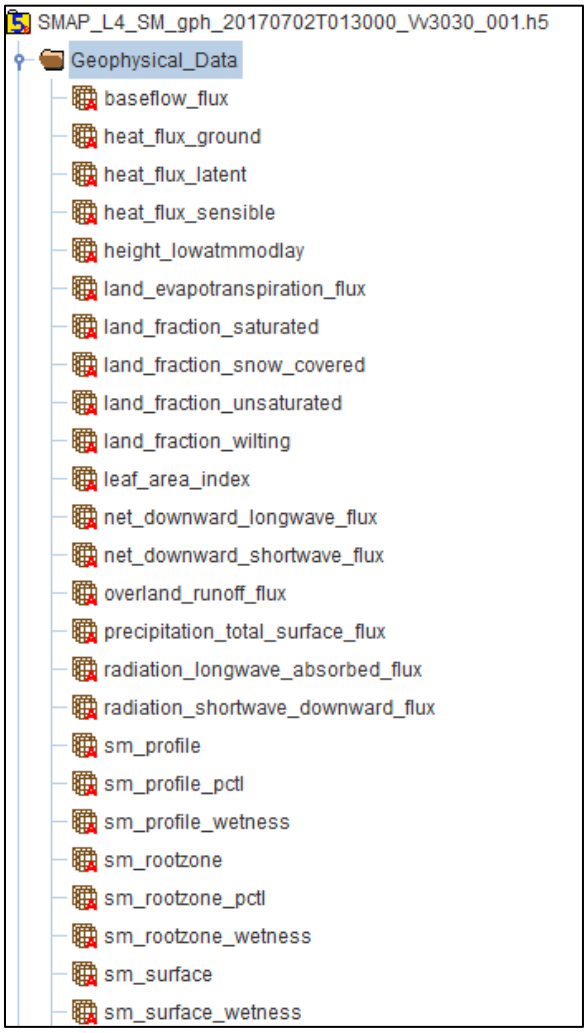

Figure 1. Subset of Geophysical Data File Contents. For a complete list of file contents for the SMAP Level-4 soil moisture product, refer to the Appendix.

1.2.2.2 Analysis Update

The Analysis Update (aup) product includes a series of 3-hourly instantaneous/snapshot files that contain the following:

- Analysis Data: Soil moisture and temperature analysis estimates, including error estimates
- Forecast Data: Land model predictions of brightness temperature, soil moisture, and soil temperature
- Observations Data: Assimilated SMAP brightness temperature observations and data assimilation diagnostics

Figure 2 shows a subset of the aup file contents.

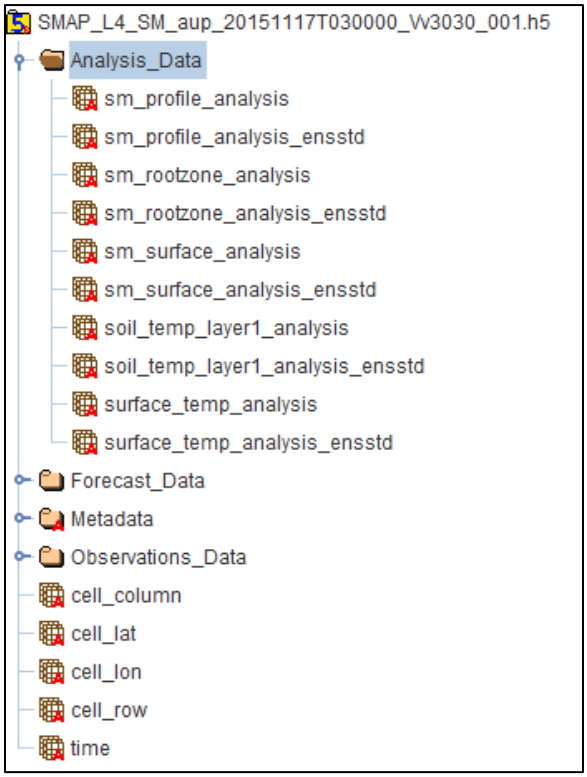

Figure 2. Subset of Analysis Update File Contents. For a complete list of file contents for the SMAP Level-4 soil moisture product, refer to the Appendix.

1.2.2.3 Land Model Constants

The Land Model Constants (lmc) product includes static land surface model constants that provide further interpretation of the geophysical land surface fields. Figure 3 shows a subset of the lmc file contents.

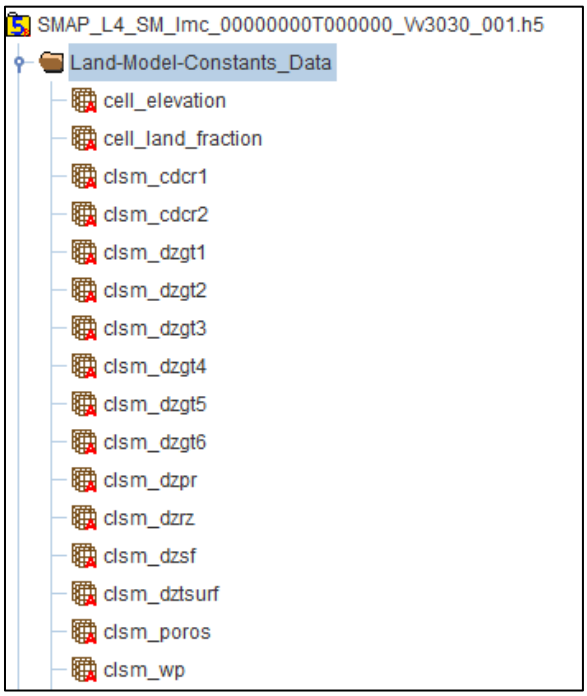

Figure 3. Subset of Land Model Constants File Contents. For a complete list of file contents for the SMAP Level-4 soil moisture product, refer to the Appendix.

1.2.3 Data Fields

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

All global data fields have dimensions of 1624 rows and 3856 columns (6,262,144 pixels per array).

1.2.4 Metadata Fields

Each product also contains 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 (Reichle et al., 2018).

1.2.5 File Naming Convention

Files are named according to the following convention:

`SMAP_L4_SM_pid_yyyymmddThhmmss_VLMmmm_NNN.[ext]`

For example:

```
SMAP_L4_SM_gph_20151015T133000_Vv3030_001.h5
```

Table 1 describes the variables within a file name:

Table 1. File Naming Convention

Variable	Description
SMAP	Indicates SMAP mission data
L4_SM	Indicates specific product (L4: Level-4; SM: Soil Moisture)
pid	Product ID (PID), where: gph — Geophysical Data — The date/time corresponds to the center point of the 3-hourly time averaging interval. For example, T013000 corresponds to the time average from 00:00:00 UTC to 03:00:00 UTC on a given day. aup — Analysis Update Data — The date/time indicates the time of the analysis update. For example, T030000 indicates an analysis for 03:00:00 UTC on a given day. This analysis would typically assimilate all SMAP data observed between 01:30:00 UTC and 04:30:00 UTC. lmc — Land Surface Model Constants — For the LMC product (time-invariant constants), which consists of only one file per Science Version, the date/time is 00000000T000000.
yyyymmddThhmmss	Date/time in Universal Coordinated Time (UTC) of the first 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. yyyymmddThhmmss) hhmmss — 2-digit hour, 2-digit minute, 2-digit second
VLMmmm	Composite Release ID, where: V — Version L — Launch Indicator (v: Validated Data) M — 1-Digit CRID Major Version Number (Note: the data set's major version does not necessarily coincide with the CRID major version) mmm — 3-Digit CRID Minor Version Number Example: Vv3040 indicates a Validated-quality data product with a version of 3.040. 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 .qa — Quality Assurance file .xml — XML Metadata file

1.2.6 File Size

Table 2 provides file sizes and daily volume estimates for each product. File subsetting services are available via *Other Access Options* under the Data Download tab.

Table 2. Approximate File Sizes and Total Volume for SMAP L4 Soil Moisture Products

Product	File Size	Total Volume
gph	138 MB	1.1 GB (Daily)
aup	85 MB	0.7 GB (Daily)
lmc	35 MB	35 MB*
* Not a daily product. LMC data are provided in a single file per Science Version.		

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. Coverage is for the global land surface excluding inland water and permanently frozen areas.

1.3.2 Resolution

The native spatial resolution of the radiometer footprint is approximately 36 km. Data are then assimilated into a land surface model that is gridded using the 9 km global EASE-Grid 2.0 projection.

1.3.3 Geolocation

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

Table 3. Geolocation details for the EASE-Grid 2.0 projections used in this product

	Global
Geographic coordinate system	WGS 84
Projected coordinate system	EASE-Grid 2.0 Global
Longitude of true origin	0
Standard Parallel	30° N
Scale factor at longitude of true origin	N/A
Datum	WGS 84
Ellipsoid / spheroid	WGS 84
Units	meter
False easting	0
False northing	0
EPSG code	6933
PROJ4 string	+proj=cea +lon_0=0 +lat_ts=30 +x_0=0 +y_0=0 +ellps=WGS84 +towgs84=0,0,0,0,0,0,0 +units=m +no_defs
Reference	http://epsg.io/6933

Table 4. Grid details for the EASE-Grid 2.0 projections used in this product

	Global
Grid cell size (x, y pixel dimensions)	9,024.13 m (x) 9,024.13 m (y)
Number of columns	3856
Number of rows	1624
Geolocated lower left point in grid	85.044° S, 180.000° W
Nominal gridded resolution	9 km by 9 km
Grid rotation	N/A
ulxmap – x-axis map coordinate of the outer edge of the upper-left pixel	-17367530.45
ulymap – y-axis map coordinate of the outer edge of the upper-left pixel	7314540.83

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 31 March 2015 to present.

1.4.2 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

A significant gap in coverage occurred between 19 June and 23 July 2019 after the SMAP satellite went into Safe Mode. A brief description of the event and its impact on data quality is available in the SMAP Post-Recovery Notice.

1.4.3 Latencies

FAQ: What are the latencies for SMAP radiometer data sets?

1.4.4 Resolution

Three basic time steps are involved in the generation of the Level-4 soil moisture products, including:

1. The land model computational time step (7.5 minutes)
2. The Ensemble Kalman Filter (EnKF) analysis update time step (3 hours)
3. The reporting/output time step for the instantaneous and time-average geophysical fields that are stored in the data products (3 hours)

SMAP observations are assimilated in an EnKF analysis update step at the nearest 3-hourly analysis time such as 0z, 3z, ..., and 21z (where z indicates UTC). A broad variety of geophysical parameters are provided as 3-hourly averages between these update times. Moreover, instantaneous forecast and analysis soil moisture and temperature estimates are provided along with the assimilated observations. These snapshots are nominally for 0z, 3z,…, or 21z.

2 DATA ACQUISITION AND PROCESSING

This section has been adapted from the Algorithm Theoretical Basis Document (ATBD) for this product (Reichle et al. 2014). Additional documentation of the algorithm is provided by Reichle et al. 2017a, Reichle et al. 2017b, and Reichle et al. 2019.

2.1 Background

The primary SMAP measurements, land surface microwave emission at 1.41 GHz, are directly related to surface soil moisture (in the top 5 cm of the soil column). Several of the key applications targeted by SMAP, however, require knowledge of root zone soil moisture (defined here as soil moisture in the top 1 m of the soil column), which is not directly linked to SMAP observations. The foremost objective of the SMAP Level-4 Surface and Root Zone Soil Moisture (SPL4SM) products is to fill this gap and provide estimates of root zone soil moisture that are informed by and consistent with SMAP observations. Such estimates are obtained by merging SMAP observations with estimates from a land surface model in a soil moisture data assimilation system.

The land surface model component of the assimilation system is driven with observation-based surface meteorological forcing data, including precipitation, which is the most important driver for soil moisture. The model also encapsulates knowledge of key land surface processes, including the vertical transfer of soil moisture between the surface and root zone reservoirs. Finally, the assimilation system uses the land model to interpolate and extrapolate SMAP observations in time and in space. The SPL4SM products thus provide a comprehensive and consistent picture of land surface hydrological conditions based on SMAP observations and complementary information from a variety of sources. The assimilation algorithm considers the respective uncertainties of each component and, if properly calibrated, yields a product that is superior to both satellite and land model data. Error estimates for the SPL4SM products are generated as a by-product of the data assimilation system.

The ATBD provides a detailed description of the SPL4SM products, their algorithms, and how the products are validated.

2.2 Instrumentation

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

2.3 Acquisition

SMAP Level-4 soil moisture products are derived from the following data sets:

- SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures, Version 5 (SPL1CTB)
- GEOS Forward Processing (FP) Model Data from the NASA Global Modeling and Assimilation Office (GMAO): Daily surface meteorology from observation-constrained global model analysis; includes precipitation corrections using the NOAA Climate

Prediction Center "Unified" global, 0.5 degree, daily gauge-based data product. (Reichle et al. 2017a, Reichle et al. 2017b, Reichle et al. 2019)

Utilizing the baseline data assimilation algorithm discussed below, input data sources are used with the SMAP Level-4 soil moisture model to provide enhanced estimates of surface soil moisture, root zone soil moisture, and related geophysical variables.

2.4 Derivation Techniques and Algorithms

2.4.1 Baseline Algorithm

The SPL4SM science algorithm consists of two key processing elements:

- GEOS Catchment Land Surface and Microwave Radiative Transfer Model
- GEOS Ensemble-Based Land Data Assimilation Algorithm

The GEOS Catchment Land Surface and Microwave Radiative Transfer Model is a numerical description of the water and energy transport processes at the land-atmosphere interface, augmented with a model that describes the land surface microwave radiative transfer (refer to section 4.1.1 of the ATBD: Reichle et al. 2014). The GEOS Ensemble-Based Land Data Assimilation System is the tool used to merge SMAP observations with estimates from the land model as it is driven with observation-based surface meteorological forcing data.

The SMAP Level-4 soil moisture baseline algorithm, described in detail in the ATBD, includes a soil moisture analysis based on the ensemble Kalman filter and a rule-based freeze/thaw analysis. However, data users should note that for Validated Version 5 data, the algorithm ingests only the SPL1CTB radiometer brightness temperatures, contrary to the planned use of downscaled brightness temperatures from the SPL2SMAP product and of landscape freeze-thaw state retrievals from the SPL2SMA product. The latter two products—SPL2SMAP and SPL2SMA—are based on radar observations and are only available for the period from 13 April 2015 through 07 July 2015 due to an anomaly that caused the premature failure of the SMAP L-band radar. Neither of these two radar-based products is assimilated in the SMAP Level-4 soil moisture algorithm.

2.5 Processing

SMAP Level-4 soil moisture data are generated by the GMAO located at the NASA Goddard Space Flight Center (GSFC), using the High-End Computing Facilities at the NASA Center for Climate Simulation (NCCS), also located at GSFC in Greenbelt, Maryland.

SMAP SPL1CTB data are required for the baseline algorithm. Aside from SMAP observations, the data assimilation system requires initialization, parameter, and forcing inputs for the Catchment

Land Surface Model, as well as input error parameters for the ensemble-based data assimilation system. These ancillary data requirements are described in detail in Section 4.1.3 of the ATBD. The precipitation observations used to correct the GMAO precipitation estimates are obtained from the NOAA Climate Prediction Center (Reichle et al. 2017a, Reichle et al. 2017b, Reichle et al. 2019). In the Version 4 release, the model background precipitation forcing is rescaled to match the climatology of the Global Precipitation Climatology Project (v2.2), which results in substantial changes in the precipitation and soil moisture climatology in Africa and the high latitudes, where the gauge-based Climate Prediction Center Unified precipitation is not used.

For more information on each portion of the algorithm processing flow, refer to the ATBD.

2.5.1 Land Surface Modeling System and SMAP Nature Run

An improved version of the land surface modeling system is used for the Version 5 SPL4SM products. A corresponding model-only Nature Run (NRv8.3) simulation is used to derive brightness temperature scaling parameters, model soil moisture initial conditions, and the soil moisture climatology. For this release, the land surface modeling system was revised in the following ways:

- Improved surface aerodynamic roughness length (z0) formulation, including the use of a stem area index and an increase in the minimum z0 value, consistent with that of the current GEOS FP (version 5.25) product.
- Fixed fitting procedure used for one of the topography-related functions in the Catchment model, which potentially affected the simulation of soil moisture in about 2% of all land surface elements (De Lannoy et al. 2014).
- Updated calibration of the microwave radiative transfer model (mwRTM) parameters using SMAP Nature Run (NRv7.2) soil moisture and temperature for improved consistency between mwRTM parameters and Catchment model boundary conditions.

2.6 Quality, Errors, and Limitations

2.6.1 Quality Assessment

For in-depth details regarding the quality of these data, refer to the Assessment Report (Reichle et al., 2020; preliminary – full report is forthcoming).

2.6.2 Quality Overview

SMAP products provide multiple means to assess quality. Uncertainty measures and file-level metadata that provide quality information are provided within each product. For details, refer to the Appendix of this document and the Product Specification Document (Reichle et al., 2018).

Each HDF5 file contains file-level metadata. A separate metadata file with an `.xml` file extension is available from the NSIDC DAAC with every HDF5 file; it contains essentially the same information as the file-level metadata. In addition, a Quality Assessment (QA) file with a `.qa` file extension is provided for every HDF5 file. QA files contain spatial statistics across the SMAP Level-4 soil moisture products, such as the global minimum, mean, and maximum of each data field.

Level-4 surface and root zone soil moisture estimates are validated to a Root Mean Square Error (RMSE) requirement of 0.04 m^3/m^3 after removal of the long-term mean bias. This accuracy requirement is identical to Level-2 soil moisture product validation and excludes regions with snow and ice cover, frozen ground, mountainous topography, open water, urban areas, and vegetation with water content greater than 5 kg/m^2. Research outputs (not validated) include the surface meteorological forcing fields, land surface fluxes, soil temperature and snow states, runoff, and error estimates that are derived from the ensemble.

2.6.3 Quality Control

Quality control is also an integral part of the soil moisture assimilation system. Two kinds of quality control (QC) measures are applied. The first set of QC steps is based on the flags that are provided with the SMAP observations. Only SMAP brightness temperature data that have favorable flags for soil moisture estimation are assimilated, such as acceptably low vegetation density, no rain, no snow cover, no frozen ground, no RFI, sufficient distance from open water, etc.

The second set of QC steps are additional rules that exclude SMAP observations from assimilation in the EnKF soil moisture update whenever the land surface model indicates that (1) heavy rain is falling, (2) the soil is frozen, or (3) the ground is fully or partly covered with snow. The assimilation system will typically provide some weight to the model background and thus buffers the impact of anomalous observations that are not caught in the flagging process.

Note: Brightness temperature observations from Version 5 SPL1CTB granules that have known deficiencies were excluded from assimilation in the Version 5 SPL4SM algorithm.

For more quality control information, refer to the ATBD of the SPL4SM products.

2.6.4 Error Sources

The data assimilation system weighs the relative errors of the assimilated lower-level product (such as radiance or retrieval) and the land model forecast. Estimates of the error of the assimilation product are dynamically determined as a by-product of this calculation. How useful these error estimates are depends on the accuracy of the input error parameters and needs to continue to be determined through validation; refer to the ATBD, Section 4.2.4. The target accuracy of the assimilated brightness temperatures is discussed in the SPL1CTB product documentation. Error

estimates of the land surface model and required input error parameters are discussed in the ATBD for this product.

Each instantaneous land model field is accompanied with a corresponding instantaneous error field which is provided for select variables. The relevant outputs are listed in the Appendix of this User Guide. Specifically, the error estimates are derived from the ensemble standard deviation of the analyzed fields. For soil moisture, the ensemble standard deviation is computed from the analysis ensemble in volumetric units (m^3/m^3). For temperatures, the ensemble standard deviation is provided in kelvins. These error estimates will vary in space and time.

More information about error sources is provided in Section 4.1.2 of the ATBD. For more information on data product accuracy, refer to Reichle et al., 2017a, Reichle et al., 2017b, Reichle et al., 2019, and the Assessment Report (Reichle et al., 2020).

3 SOFTWARE AND TOOLS

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

4 VERSION HISTORY

Table 5. Version History

Version	Release Date	Description of Changes
V1	October 2015	First public data release
V2	April 2016	Changes to this version include: • Transitioned to Validated-Stage 2 • Using updated SPL1CTB V3 Validated data as input • Minor bug fixes
V3	July 2017	Changes to this version include: • SMAP observations are now assimilated in Eastern Europe, the Middle East, and East Asia due to expanded coverage of the brightness temperature scaling parameters. The latter are based on two years of SMAP Version 3 brightness temperature observations where the SMOS climatology is unavailable due to RFI. • An improved version of the model-only Nature Run (NRv4.1) simulation is used to derive the brightness temperature scaling parameters, the model soil moisture initial conditions, and the soil moisture climatology. • Minor bug fixes.

Version	Release Date	Description of Changes

V4	June 2018	Changes to this version include:
		• The land surface modeling system was revised in the following ways:
		  ○ Improved input parameter data sets for land cover, topography, and vegetation height are based on more recent data sets. Land cover inputs were updated to the GlobCover2009 product, resulting in a slightly different land mask between Version 3 and Version 4. Topographic statistics now rely on observations from the Shuttle Radar Topography Mission. Finally, vegetation height inputs are derived from space-borne lidar measurements.
		  ○ The model background precipitation forcing is rescaled to match the climatology of the Global Precipitation Climatology Project (v2.2), which results in substantial changes in the precipitation and soil moisture climatology in Africa and the high latitudes, where the gauge-based Climate Prediction Center Unified precipitation is not used.
		  ○ SMAP Level-2 soil moisture retrievals and in situ soil moisture measurements from the Soil Climate Analysis Network and U.S. Climate Reference Network were used to calibrate a particular Catchment model parameter that governs the recharge of soil moisture from the model's root-zone excess reservoir into the surface excess reservoir. Specifically, the replenishment of soil moisture near the surface from below under non-equilibrium conditions was substantially reduced, which brings the model's surface soil moisture more in line with the SMAP Level-2 and in situ soil moisture.
		  ○ Additional model changes include revisions to the parameters and parameterizations of the surface energy balance and the snow depletion curve.
		• The Version 4 brightness temperature scaling parameters are based on eight years of SMOS observations and three years of SMAP observations where the SMOS climatology is unavailable due to radio frequency interference. Note that the calibration of the assimilated SMAP brightness temperatures changed substantially from Version 3 to Version 4.
		• Analysis increments are no longer computed for the "catchment deficit" model prognostic variable in the Ensemble Kalman filter update step.
		• Minor bug fixes.
		• Added x and y coordinate variables [including arrays of EASE-Grid 2.0 coordinate values, Climate and Forecast (CF)-compliant metadata, and HDF-5 dimension scales] as well as an EASE-Grid 2.0 projection grid mapping variable. This augmentation of L4 soil moisture data files improves interoperability and user workflow via ArcGIS/QGIS, OPeNDAP, and programmatic access. Three new data fields accommodate this change: *EASE2_global_projection*, *x*, and *y*.

Version	Release Date	Description of Changes

V5	August 2020	Changes to this version include:
		• The Level-4 soil moisture algorithm was recalibrated to work with the substantially changed calibration of the assimilated Level-1C brightness temperatures.
		• The brightness temperature scaling parameters in the updated Level-4 soil moisture algorithm are based on five years of SMAP observations (April 2015 – March 2020).
		• The land surface modeling system underpinning the updated Level-4 soil moisture algorithm was revised in the following ways:
		  ○ Improved surface aerodynamic roughness length (z0) formulation, including the use of a stem area index and an increase in the minimum z0 value.
		  ○ Corrected an error in the fitting procedure used for one of the topography-related functions in the Catchment model, which potentially affected the simulation of soil moisture in about 2% of all land surface elements (De Lannoy et al. 2014).
		  ○ Updated calibration of the microwave radiative transfer model parameters.
		• The updated Level-4 soil moisture algorithm includes major software upgrades, including full compliance with the Earth System Modeling Framework, a modular and extensible software design approach, for improved support of future science development.
		• Minor bug fixes.

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

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9 DOCUMENT INFORMATION

9.1 Publication Date

September 2020

9.2 Date Last Updated

12 May 2021

APPENDIX – DATA FIELDS

This appendix provides a description of all data fields within the *SMAP L4 Global 3-hourly 9 km Surface and Rootzone Soil Moisture Geophysical Data*, *SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Analysis Update*, and *SMAP L4 Global 9 km EASE-Grid Surface and Root Zone Soil Moisture Land Model Constants* products. The data are grouped in the following main HDF5 groups:

- Geophysical Data (gph)*
- Analysis Data (aup)
- Forecast_Data (aup)
- Observations_Data (aup)
- Land-Model-Constants Data (lmc)
- Metadata

* As reflected in the file names, *gph*, *aup*, and *lmc* indicate three different file collections: geophysical, analysis, and land-model-constants data, respectively. Note that analysis, forecast, and observations data are contained in the *aup* collection.

All SPL4SM** HDF5 data fields, with the exception of *EASE2_global_projection*, have */cell_lat /cell_lon* shape. This shape is a two-dimensional array, where each data field represents a specific grid cell in the 9 km global cylindrical EASE-Grid 2.0 as specified by the *cell_lat* and *cell_lon* arrays. For example, the field *surface_temp* (234,789) represents the land surface temperature of the grid cell located at *cell_lat* (234,789) and *cell_lon* (234,789), where *cell_row* (234,789)=234 and *cell_column* (234,789)=789.

For a description of metadata fields for this product, refer to the Product Specification Document (Reichle et al., 2018).

Geophysical_Data (gph)

Table A - 1 describes the data fields in the Geophysical_Data group stored in the *gph* file collection. This group contains fields that specify time-average geophysical data (including soil moisture, soil temperature, and land surface fluxes). Time and space coordinate information is stored in the HDF5 root data group.

Table A - 1. Data Fields for Geophysical_Data

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
EASE2_global_projection	String	N/A	N/A	N/A	N/A
baseflow_flux	Float32	kg m^{-2} s^{-1}	0.0	0.01	-9999.0
heat_flux_ground	Float32	W m^{-2}	-1000.0	1000.0	-9999.0
heat_flux_latent	Float32	W m^{-2}	-2500.0	3000.0	-9999.0
heat_flux_sensible	Float32	W m^{-2}	-2500.0	3000.0	-9999.0
height_lowatmmodlay	Float32	m	40.0	80.0	-9999.0
land_evapotranspiration_flux	Float32	kg m^{-2} s^{-1}	-0.001	0.001	-9999.0
land_fraction_saturated	Float32	dimensionless	0.0	1.0	-9999.0
land_fraction_snow_covered	Float32	dimensionless	0.0	1.0	-9999.0
land_fraction_unsaturated	Float32	dimensionless	0.0	1.0	-9999.0
land_fraction_wilting	Float32	dimensionless	0.0	1.0	-9999.0
leaf_area_index	Float32	m^2 m^{-2}	0.0	10.0	-9999.0
net_downward_longwave_flux	Float32	W m^{-2}	-1000.0	200.0	-9999.0
net_downward_shortwave_flux	Float32	W m^{-2}	0.0	1365.0	-9999.0
overland_runoff_flux	Float32	kg m^{-2} s^{-1}	0.0	0.05	-9999.0
precipitation_total_surface_flux	Float32	kg m^{-2} s^{-1}	0.0	0.05	-9999.0
radiation_longwave_absorbed_flux	Float32	W m^{-2}	35.0	800.0	-9999.0
radiation_shortwave_downward_flux	Float32	W m^{-2}	0.0	1500.0	-9999.0
sm_profile	Float32	m^3 m^{-3}	0.0	0.9	-9999.0
sm_profile_pctl	Float32	percent	0.0	100.0	-9999.0
sm_profile_wetness	Float32	dimensionless	0.0	1.0	-9999.0
sm_rootzone	Float32	m^3 m^{-3}	0.0	0.9	-9999.0
sm_rootzone_pctl	Float32	percent	0.0	100.0	-9999.0
sm_rootzone_wetness	Float32	dimensionless	0.0	1.0	-9999.0
sm_surface	Float32	m^3 m^{-3}	0.0	0.9	-9999.0

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
sm_surface_wetness	Float32	dimensionless	0.0	1.0	-9999.0
snow_depth	Float32	m	0.0	50.0	-9999.0
snow_mass	Float32	kg m^{-2}	0.0	10000.0	-9999.0
snow_melt_flux	Float32	kg m^{-2} s^{-1}	0.0	0.05	-9999.0
snowfall_surface_flux	Float32	kg m^{-2} s^{-1}	0.0	0.05	-9999.0
soil_temp_layer1	Float32	K	210.0	340.0	-9999.0
soil_temp_layer2	Float32	K	210.0	330.0	-9999.0
soil_temp_layer3	Float32	K	215.0	325.0	-9999.0
soil_temp_layer4	Float32	K	220.0	325.0	-9999.0
soil_temp_layer5	Float32	K	225.0	325.0	-9999.0
soil_temp_layer6	Float32	K	230.0	320.0	-9999.0
soil_water_infiltration_flux	Float32	kg m^{-2} s^{-1}	0.0	0.05	-9999.0
specific_humidity_lowatmmodlay	Float32	kg kg^{-1}	0.0	0.4	-9999.0
surface_pressure	Float32	Pa	40000.0	110000.0	-9999.0
surface_temp	Float32	K	180.0	350.0	-9999.0
temp_lowatmmodlay	Float32	K	180.0	350.0	-9999.0
vegetation_greenness_fraction	Float32	dimensionless	0.0	1.0	-9999.0
windspeed_lowatmmodlay	Float32	m s^{-1}	-60.0	60.0	-9999.0
cell_column	Unsigned32	dimensionless	0	3855	4294967294
cell_lat	Float32	degrees	-90.0	90.0	-9999.0
cell_lon	Float32	degrees	-180.0	179.999	-9999.0
cell_row	Unsigned32	dimensionless	0	1623	4294967294
time	Float64	seconds since 2000-01-01 11:58:55.816	N/A	N/A	N/A
x	Float64	m	-17367531	17367531	0.0
y	Float64	m	-7342231	7342231	0.0

Analysis_Data (aup)

Table A - 2 describes the data fields in the Analysis_Data group stored in the *aup* file collection. This group contains soil moisture and temperature estimates after the ensemble Kalman filter analysis update, along with their corresponding uncertainty estimates. Soil moisture and temperature values are snapshots/instantaneous data. Time and space coordinate information is stored in the HDF5 root data group.

Table A - 2. Data Fields for Analysis_Data group

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
EASE2_global_projection	String	N/A	N/A	N/A	N/A
sm_profile_analysis	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
sm_profile_analysis_ensstd	Float32	$m^3\ m^{-3}$	0.0	1.0	-9999.0
sm_rootzone_analysis	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
sm_rootzone_analysis_ensstd	Float32	$m^3\ m^{-3}$	0.0	1.0	-9999.0
sm_surface_analysis	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
sm_surface_analysis_ensstd	Float32	$m^3\ m^{-3}$	0.0	1.0	-9999.0
soil_temp_layer1_analysis	Float32	K	210.0	340.0	-9999.0
soil_temp_layer1_analysis_ensstd	Float32	K	0.0	50.0	-9999.0
surface_temp_analysis	Float32	K	180.0	350.0	-9999.0
surface_temp_analysis_ensstd	Float32	K	0.0	50.0	-9999.0
cell_column	Unsigned32	dimensionless	0	3855	4294967294
cell_lat	Float32	degrees	-90.0	90.0	-9999.0
cell_lon	Float32	degrees	-180.0	179.999	-9999.0
cell_row	Unsigned32	dimensionless	0	1623	4294967294
time	Float64	seconds since 2000-01-01 11:58:55.816	N/A	N/A	N/A
x	Float64	m	-17367531	17367531	0.0
y	Float64	m	-7342231	7342231	0.0

Forecast_Data (aup)

Table A - 3 describes the data fields in the Forecast_Data group stored in the *aup* file collection. This group is the land model equivalent of the Observations_Data group; it provides the land surface model's predictions of the assimilated observations. These forecasts, or observation predictions, are based on propagating the land surface model forward in time from the previous

analysis time step. The Forecast_Data group does *not* contain a medium-range (5-day) forecast of land surface conditions. Soil moisture and temperature values are snapshots/instantaneous data. Time and space coordinate information is stored in the HDF5 root data group.

Table A - 3. Data Fields for Forecast_Data group

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
EASE2_global_projection	String	N/A	N/A	N/A	N/A
sm_profile_forecast	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
sm_rootzone_forecast	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
sm_surface_forecast	Float32	$m^3\ m^{-3}$	0.0	0.9	-9999.0
soil_temp_layer1_forecast	Float32	K	210.0	340.0	-9999.0
surface_temp_forecast	Float32	K	180.0	350.0	-9999.0
tb_h_forecast	Float32	K	100.0	350.0	-9999.0
tb_h_forecast_ensstd	Float32	K	0.0	50.0	-9999.0
tb_v_forecast	Float32	K	100.0	350.0	-9999.0
tb_v_forecast_ensstd	Float32	K	0.0	50.0	-9999.0
cell_column	Unsigned32	dimensionless	0	3855	4294967294
cell_lat	Float32	degrees	-90.0	90.0	-9999.0
cell_lon	Float32	degrees	-180.0	179.999	-9999.0
cell_row	Unsigned32	dimensionless	0	1623	4294967294
time	Float64	seconds since 2000-01-01 11:58:55.816	N/A	N/A	N/A
x	Float64	m	-17367531	17367531	0.0
y	Float64	m	-7342231	7342231	0.0

Observations_Data (aup)

Table A - 4 describes the data fields in the Observations_Data group stored in the *aup* file collection. This group provides information about the assimilated SMAP observations. Time and space coordinate information is stored in the HDF5 root data group.

Table A - 4. Data Fields for Observations_Data group

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
EASE2_global_projection	String	N/A	N/A	N/A	N/A
tb_h_obs	Float32	K	100.0	350.0	-9999.0
tb_h_obs_assim	Float32	K	100.0	350.0	-9999.0
tb_h_obs_errstd	Float32	K	0.0	50.0	-9999.0
tb_h_obs_time_sec	Float64	seconds	4.65156E8	9.46E8	-9999.0
tb_h_orbit_flag	Unsigned32	dimensionless	0	2	4294967294
tb_h_resolution_flag	Unsigned32	dimensionless	1	2	4294967294
tb_v_obs	Float32	K	100.0	350.0	-9999.0
tb_v_obs_assim	Float32	K	100.0	350.0	-9999.0
tb_v_obs_errstd	Float32	K	0.0	50.0	-9999.0
tb_v_obs_time_sec	Float64	seconds	4.65156E8	9.46E8	-9999.0
tb_v_orbit_flag	Unsigned32	dimensionless	0	2	4294967294
tb_v_resolution_flag	Unsigned32	dimensionless	1	2	4294967294
cell_column	Unsigned32	dimensionless	0	3855	4294967294
cell_lat	Float32	degrees	-90.0	90.0	-9999.0
cell_lon	Float32	degrees	-180.0	179.999	-9999.0
cell_row	Unsigned32	dimensionless	0	1623	4294967294
time	Float64	seconds since 2000-01-01 11:58:55.816	N/A	N/A	N/A
x	Float64	m	-17367531	17367531	0.0
y	Float64	m	-7342231	7342231	0.0

Land-Model-Constants_Data (lmc)

Table A5 describes the data fields in the Land-Model-Constants_Data group stored in the *lmc* file collection. This group contains fields that specify static/time-invariant parameters (or constants) of the Catchment Land Surface Model (CLSM) and its associated L-band Microwave Radiative Transfer Model (MWRTM). Time and space coordinate information is stored in the HDF5 root data group.

Note: Due to the time-invariant nature of the file contents, the *lmc* file collection consists of only one granule per data product version (as identified by a distinct Science Version ID).

Table A - 5. Data Fields for Land-Model-Constants_Data group

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
EASE2_global_projection	String	N/A	N/A	N/A	N/A
cell_elevation	Float32	m	-500.0	6000.0	-9999.0
cell_land_fraction	Float32	dimensionless	0.0	1.0	-9999.0
clsm_cdcr1	Float32	kg m^{-2}	30.0	3000.0	-9999.0
clsm_cdcr2	Float32	kg m^{-2}	200.0	6000.0	-9999.0
clsm_dzgt1	Float32	m	0.0988	0.0988	-9999.0
clsm_dzgt2	Float32	m	0.1952	0.1952	-9999.0
clsm_dzgt3	Float32	m	0.3859	0.3859	-9999.0
clsm_dzgt4	Float32	m	0.7626	0.7626	-9999.0
clsm_dzgt5	Float32	m	1.5071	1.5071	-9999.0
clsm_dzgt6	Float32	m	10.0	10.0	-9999.0
clsm_dzpr	Float32	m	1.33	10.0	-9999.0
clsm_dzrz	Float32	m	1.0	1.0	-9999.0
clsm_dzsf	Float32	m	0.05	0.05	-9999.0
clsm_dztsurf	Float32	m	0.0	0.05	-9999.0
clsm_poros	Float32	m^3 m^{-3}	0.3	0.9	-9999.0
clsm_veghght	Float 32	m	0.0	60.0	-9999.0
clsm_wp	Float32	m^3 m^{-3}	0.001	0.3	-9999.0
mwrtm_bh	Float32	dimensionless	0.0	0.7	-9999.0
mwrtm_bv	Float32	dimensionless	-0.15	0.85	-9999.0
mwrtm_clay	Float32	dimensionless	0.0	1.0	-9999.0
mwrtm_lewt	Float32	kg m^{-2}	0.0	2.0	-9999.0
mwrtm_omega	Float32	dimensionless	0.0	0.3	-9999.0
mwrtm_poros	Float32	m^3 m^{-3}	0.3	0.9	-9999.0
mwrtm_rghhmax	Float32	dimensionless	0.0	3.0	-9999.0
mwrtm_rghhmin	Float32	dimensionless	0.0	2.0	-9999.0
mwrtm_rghnrh	Float32	dimensionless	0.0	1.75	-9999.0
mwrtm_rghnrv	Float32	dimensionless	-1.0	2.0	-9999.0
mwrtm_rghpolmix	Float32	dimensionless	0.0	0.0	-9999.0
mwrtm_rghwmax	Float32	m^3 m^{-3}	0.3	0.9	-9999.0
mwrtm_rghwmin	Float32	m^3 m^{-3}	0.1	0.4	-9999.0
mwrtm_sand	Float32	dimensionless	0.0	1.0	-9999.0
mwrtm_soilcls	Unsigned32	dimensionless	1	253	4294967294
mwrtm_vegcls	Unsigned32	dimensionless	1	16	4294967294

Data Field Name	Type	Unit	Valid Min	Valid Max	Fill Value
mwrtm_wangwp	Float32	$m^3\ m^{-3}$	0.0	0.4	-9999.0
mwrtm_wangwt	Float32	$m^3\ m^{-3}$	0.1	0.4	-9999.0
cell_column	Unsigned32	dimensionless	0	3855	4294967294
cell_lat	Float32	degrees	-90.0	90.0	-9999.0
cell_lon	Float32	degrees	-180.0	179.999	-9999.0
cell_row	Unsigned32	dimensionless	0	1623	4294967294
time	Float64	seconds since 2000-01-01 11:58:55.816	N/A	N/A	N/A
x	Float64	m	-17367531	17367531	0.0
y	Float64	m	-7342231	7342231	0.0

Data Field Definitions

Table A - 6 lists all Level-4 soil moisture data fields and their definitions. All fields are two-dimensional and Float32 unless otherwise indicated in the description.

Table A - 6. Description of Data Fields for SPL4SM**

Data Field Name	GEOS Name	Data group	Description
baseflow_flux	BASEFLOW	Geophysical	Baseflow
cell_column	CELL_COLUMN_INDEX	[*All Data groups*][1]	The column index of each cell in the cylindrical 9 km Earth-fixed EASE-Grid 2.0. Type is Unsigned32.
cell_elevation	CELL_ELEVATION	LandModel Constants	Mean elevation above sea Level-of land within each grid cell.
cell_land_fraction	FRLAND	LandModel Constants	Area fraction of land within each grid cell.
cell_lat	LATITUDE	[*All Data groups*][1]	The geodetic latitude of the center of each cell in the cylindrical 9 km Earth-fixed EASE-Grid 2.0. Zero latitude represents the Equator. Positive latitudes represent locations North of the Equator. Negative latitudes represent locations South of the Equator.
cell_lon	LONGITUDE	[*All Data groups*][1]	The geodetic longitude of the center of each cell in the cylindrical 9 km Earth-fixed EASE-Grid 2.0. Zero longitude represents the Prime Meridian. Positive longitudes represent locations to the East of the Prime Meridian. Negative longitudes represent locations to the West of the Prime Meridian.
cell_row	CELL_ROW_INDEX	[*All Data groups*][1]	The row index of each cell in the cylindrical 9 km Earth-fixed EASE-Grid 2.0. Type is Unsigned32.
clsm_cdcr1	CLSM_cdcr1	LandModel Constants	Catchment model: Catchment deficit at which baseflow ceases
clsm_cdcr2	CLSM_cdcr2	LandModel Constants	Catchment model: Maximum water holding capacity of land field
clsm_dzgt1	CLSM_dzgt1	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 1
clsm_dzgt2	CLSM_dzgt2	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 2
clsm_dzgt3	CLSM_dzgt3	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 3
clsm_dzgt4	CLSM_dzgt4	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 4
clsm_dzgt5	CLSM_dzgt5	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 5
clsm_dzgt6	CLSM_dzgt6	LandModel Constants	Catchment model: Thickness of soil heat diffusion model layer 6

Data Field Name	GEOS Name	Data group	Description
clsm_dzpr	CLSM_dzpr	LandModel Constants	Catchment model: Thickness of profile soil moisture layer ("depth-to-bedrock" in the Catchment model)
clsm_dzrz	CLSM_dzrz	LandModel Constants	Catchment model: Thickness of root zone soil moisture layer
clsm_dzsf	CLSM_dzsf	LandModel Constants	Catchment model: Thickness of surface soil moisture layer
clsm_dztsurf	CLSM_DZTSURF	LandModel Constants	Catchment model: Thickness of soil layer associated with surface_temp
clsm_poros	CLSM_poros	LandModel Constants	Catchment model: Soil porosity
clsm_veghght	CLSM_veghght	LandModel Constants	Catchment model: Vegetation canopy height
clsm_wp	CLSM_WP	LandModel Constants	Catchment model: Soil wilting point
EASE2_global_ projection	grid_mapping	[*All Data groups*][1]	Defines the parameters of the cylindrical 9 km Earth-fixed EASE-Grid 2.0 projection and the mapping from latitude/longitude to grid-native coordinates
heat_flux_ground	GHLAND	Geophysical	Downward ground heat flux into layer 1 of soil heat diffusion model
heat_flux_latent	LHLAND	Geophysical	Latent heat flux from land[2]
heat_flux_sensible	SHLAND	Geophysical	Sensible heat flux from land[2]
height_lowatmmodlay	HLML	Geophysical	Center height of lowest atmospheric model layer
land_evapotranspiration _flux	EVLAND	Geophysical	Evapotranspiration from land[2]
land_fraction _saturated	FRSAT	Geophysical	Fractional land area that is saturated and snow-free[2]
land_fraction_ snow_covered	FRSNO	Geophysical	Fractional land area that is snow-covered[2]
land_fraction_ unsaturated	FRUNSAT	Geophysical	Fractional land area that is unsaturated (but non-wilting) and snow-free[2]
land_fraction_wilting	FRWLT	Geophysical	Fractional land area that is wilting and snow-free[2]
leaf_area_index	LAI	Geophysical	Vegetation leaf area index
mwrtm_bh	MWRTM_BH	LandModel Constants	Microwave radiative transfer model: H-pol. Vegetation b parameter

Data Field Name	GEOS Name	Data group	Description
mwrtm_bv	MWRTM_BV	LandModel Constants	Microwave radiative transfer model: V-pol. Vegetation b parameter
mwrtm_clay	MWRTM_CLAY	LandModel Constants	Microwave radiative transfer model: Clay fraction
mwrtm_lewt	MWRTM_LEWT	LandModel Constants	Microwave radiative transfer model: Parameter to transform leaf area index into vegetation water content
mwrtm_omega	MWRTM_OMEGA	LandModel Constants	Microwave radiative transfer model: Scattering albedo
mwrtm_poros	MWRTM_POROS	LandModel Constants	Microwave radiative transfer model: Porosity
mwrtm_rghhmax	MWRTM_RGHHMAX	LandModel Constants	Microwave radiative transfer model: Maximum microwave roughness parameter
mwrtm_rghhmin	MWRTM_RGHHMIN	LandModel Constants	Microwave radiative transfer model: Minimum microwave roughness parameter
mwrtm_rghwmax	MWRTM_RGHWMAX	LandModel Constants	Microwave radiative transfer model: Soil moisture value above which *minimum* microwave roughness parameter is used
mwrtm_rghwmin	MWRTM_RGHWMIN	LandModel Constants	Microwave radiative transfer model: Soil moisture value below which *maximum* microwave roughness parameter is used
mwrtm_rghnrh	MWRTM_RGHNRH	LandModel Constants	Microwave radiative transfer model: H-pol. Exponent for rough reflectivity parameterization
mwrtm_rghnrv	MWRTM_RGHNRV	LandModel Constants	Microwave radiative transfer model: V-pol. Exponent for rough reflectivity parameterization
mwrtm_rghpolmix	MWRTM_RGHPOLMIX	LandModel Constants	Microwave radiative transfer model: Polarization mixing parameter
mwrtm_sand	MWRTM_SAND	LandModel Constants	Microwave radiative transfer model: Sand fraction
mwrtm_soilcls	MWRTM_SOILCLS	LandModel Constants	Microwave radiative transfer model: Soil class. Type is Unsigned32.
mwrtm_vegcls	MWRTM_VEGCLS	LandModel Constants	Microwave radiative transfer model: Vegetation class. Type is Unsigned32.
mwrtm_wangwp	MWRTM_WANGWP	LandModel Constants	Microwave radiative transfer model: Wang dielectric model wilting point soil moisture
mwrtm_wangwt	MWRTM_WANGWT	LandModel Constants	Microwave radiative transfer model: Wang dielectric model transition soil moisture

Data Field Name	GEOS Name	Data group	Description
net_downward_ longwave_flux	LWLAND	Geophysical	Net downward longwave flux over land[2]
net_downward_ shortwave_flux	SWLAND	Geophysical	Net downward shortwave flux over land[2]
overland_runoff_flux	RUNOFF	Geophysical	Overland (surface) runoff (including throughflow)[2]
precipitation_total _surface_flux	PRECTOT	Geophysical	Total surface precipitation (incl. snow fall)
radiation_longwave _absorbed_flux	LWGAB	Geophysical	Absorbed (downward) longwave radiation at the surface
radiation_shortwave _downward_flux	SWGDN	Geophysical	Downward shortwave flux incident on the surface
sm_profile	PRMC	Geophysical	Total profile soil moisture (0 cm to model bedrock depth)
sm_profile_pctl	PRMC_PRCNTL	Geophysical	Total profile soil moisture (0 cm to model bedrock depth; percentile units) **Note:** There are known shortcomings in the underlying climatology, and the soil moisture fields in percentile units have not been validated.
sm_profile_wetness	GWETPROF	Geophysical	Total profile soil wetness (0 cm to model bedrock depth; wetness units[5])
sm_profile_wetness _analysis	GWETPROF_ANA	Analysis	Analysis total profile soil moisture (0 cm to model bedrock depth; wetness units[5])
sm_profile_wetness _analysis_ensstd	GWETPROF_ANA_ENSSTD	Analysis	Uncertainty of analysis total profile soil moisture (0 cm to model bedrock depth; ensemble std-dev; wetness units[5])
sm_profile_wetness _forecast	GWETPROF_FCST	Forecast	Catchment model forecast total profile soil moisture (0 cm to model bedrock depth; wetness units[5])
sm_rootzone	RZMC	Geophysical	Root zone soil moisture (0-100 cm)
sm_rootzone_pctl	RZMC_PRCNTL	Geophysical	Root zone soil moisture (0-100 cm; percentile units) **Note:** There are known shortcomings in the underlying climatology, and the soil moisture fields in percentile units have not been validated.
sm_rootzone_wetness	GWETROOT	Geophysical	Root zone soil wetness (0-100 cm; wetness units[5])
sm_rootzone_wetness _analysis	GWETROOT_ANA	Analysis	Analysis root zone soil moisture (0-100 cm; wetness units[5])
sm_rootzone_wetness _analysis_ensstd	GWETROOT_ANA_ENSSTD	Analysis	Uncertainty of analysis root zone soil moisture (0-100 cm; ensemble std-dev; wetness units[5])
sm_rootzone_wetness _forecast	GWETROOT_FCST	Forecast	Catchment model forecast root zone soil moisture (0-100 cm; wetness units[5])
sm_surface	SFMC	Geophysical	Top layer soil moisture (0-5 cm)

Data Field Name	GEOS Name	Data group	Description
sm_surface_wetness	GWETTOP	Geophysical	Top layer soil wetness (0-5 cm; wetness units[5])
sm_surface_wetness _analysis	GWETTOP_ANA	Analysis	Analysis surface soil moisture (0-5 cm; wetness units[5])
sm_surface_wetness _analysis_ensstd	GWETTOP_ANA_ENSSTD	Analysis	Uncertainty of analysis surface soil moisture (0-5 cm; ensemble std-dev; wetness units[5])
sm_surface_wetness _forecast	GWETTOP_FCST	Forecast	Catchment model forecast surface soil moisture (0-5 cm; wetness units[5])
snow_depth	SNODP	Geophysical	Snow depth within snow-covered land fraction of grid cell[2]
snow_mass	SNOMAS	Geophysical	Average snow mass (or snow water equivalent) over land fraction of grid cell[2]
snow_melt_flux	SNOMLT	Geophysical	Snowmelt[2]
snowfall_surface_flux	PRECSNO	Geophysical	Surface snow fall
soil_temp_layer1	TSOIL1	Geophysical	Soil temperature in layer 1 of soil heat diffusion model
soil_temp_layer1 _analysis	TSOIL1_ANA	Analysis	Analysis soil temperature in layer 1 of soil heat diffusion model
soil_temp_layer1 _analysis_ensstd	TSOIL1_ANA_ENSSTD	Analysis	Uncertainty of analysis soil temperature in layer 1 of soil heat diffusion model (ensemble std-dev)
soil_temp_layer1 _forecast	TSOIL1_FCST	Forecast	Catchment model forecast soil temperature in layer 1 of soil heat diffusion model
soil_temp_layer2	TSOIL2	Geophysical	Soil temperature in layer 2 of soil heat diffusion model
soil_temp_layer3	TSOIL3	Geophysical	Soil temperature in layer 3 of soil heat diffusion model
soil_temp_layer4	TSOIL4	Geophysical	Soil temperature in layer 4 of soil heat diffusion model
soil_temp_layer5	TSOIL5	Geophysical	Soil temperature in layer 5 of soil heat diffusion model
soil_temp_layer6	TSOIL6	Geophysical	Soil temperature in layer 6 of soil heat diffusion model
soil_water_ infiltration_flux	QINFIL	Geophysical	Soil water infiltration rate
specific_humidity _lowatmmodlay	QLML	Geophysical	Air specific humidity at center height of lowest atmospheric model layer
surface_pressure	PS	Geophysical	Surface pressure
surface_temp	TSURF	Geophysical	Mean land surface temperature (incl. snow-covered land area)[2]
surface_temp_analysis	TSURF_ANA	Analysis	Analysis surface temperature
surface_temp _analysis_ensstd	TSURF_ANA_ENSSTD	Analysis	Uncertainty of analysis surface temperature (ensemble std-dev)

Data Field Name	GEOS Name	Data group	Description
surface_temp_forecast	TSURF_FCST	Forecast	Catchment model forecast surface temperature
tb_h_forecast	TBHCOMP_FCST	Forecast	Composite resolution Catchment model forecast 1.41 GHz H-pol brightness temperature[4]
tb_h_forecast_ensstd	TBHCOMP_FCST_ ENSSTD	Forecast	Uncertainty (ensemble std-dev) of *tb_h_forecast*[4]
tb_h_obs	TBHCOMP_OBS	Observations	Composite resolution observed SPL1CTB H-pol brightness temperature, represented as the average of fore and aft observations from the SMAP antenna[3] **Note:** These brightness temperature observations passed all quality control steps but could not be assimilated for lack of brightness temperature scaling parameters. For such observations, the variables *tb_h_obs_assim* and *tb_v_obs_assim* are equal to no-data values.
tb_h_obs_assim	TBHCOMP_OBS_ASSIM	Observations	Assimilated value after model-based quality control and climatological adjustment (scaling) *tb_h_obs*[3] for consistency with the land model's seasonally varying mean brightness temperature climatology Output for this field is only stored at times and locations for which input SMAP Level-1 or Level-2 data are assimilated. If more than one overpass occurs for a given grid cell within the assimilation window, the Level-1 or Level-2 observations from all overpasses within the analysis update time window are averaged. **Note:** These brightness temperature observations passed all quality control steps but could not be assimilated for lack of brightness temperature scaling parameters. For such observations, the variables *tb_h_obs_assim* and *tb_v_obs_assim* are equal to no-data values.
tb_h_obs_errstd	TBHCOMP_OBS_ERRSTD	Observations	Observation error std-dev for *tb_h_obs_scaled*[3]
tb_h_obs_time_sec	TBHCOMP_OBS_TIME_SEC	Observations	Time values as counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch starting point is January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC). Type is Float64. Time stamps for H-polarization and V-polarization observations are provided in the fields *tb_h_obs_time_sec* and *tb_v_obs_time_sec*, respectively. If observations from more than one overpass time at the same location (grid cell) are assimilated, the observation time stamps reflect the average over the spacecraft overpass times. Furthermore, the fields *tb_h_orbit_flag* and *tb_v_orbit_flag* indicate whether the observation is exclusively from ascending orbits (*orbit_flag*=1), exclusively from descending orbits (*orbit_flag*=2), or from an average over ascending and descending orbits (*orbit_flag*=0). The latter case may occur at very high latitudes.

Data Field Name	GEOS Name	Data group	Description
tb_h_orbit_flag	TBHCOMP_ORBFLAG	Observations	Flag indicating the orbit direction of H-pol brightness temperature composite fields (*tb_h_obs*, *tb_h_forecast*, etc.): 0=average over ascending and descending orbits, 1=ascending orbits only, 2=descending orbits only, Type is Unsigned32. Time stamps for H-polarization and V-polarization observations are provided in the fields *tb_h_obs_time_sec* and *tb_v_obs_time_sec*, respectively. If observations from more than one overpass time at the same location (grid cell) are assimilated, the observation time stamps reflect the average over the spacecraft overpass times. Furthermore, the fields *tb_h_orbit_flag* and *tb_v_orbit_flag* indicate whether the observation is exclusively from ascending orbits (orbit_flag=1), exclusively from descending orbits (orbit_flag=2), or from an average over ascending and descending orbits (orbit_flag=0). The latter case may occur at very high latitudes.
tb_h_resolution_flag	TBHCOMP_RESFLAG	Observations	Flag indicating the effective resolution of H-pol brightness temperature composite fields (*tb_h_obs*, *tb_h_forecast*, etc.): 1=36 km, 2=9 km. Type is Unsigned32. The fields *tb_h_resolution_flag* and *tb_v_resolution_flag* indicate whether the model forecast brightness temperature for a given grid cell corresponds to a 36 km observation from the SPL1CTB product. Model forecast brightness temperatures that correspond to 36 km observations from the SPL1CTB product are aggregated from 9 km to 36 km and then posted at 9 km for convenience. Brightness temperature output is only stored at times and locations for which input SPL1CTB brightness temperature data are assimilated. If more than one overpass occurs for a given grid cell within the assimilation window, the latest overpass time prevails.
tb_v_forecast	TBVCOMP_FCST	Forecast	Composite resolution Catchment model forecast 1.41 GHz V-pol brightness temperature[4]
tb_v_forecast_ensstd	TBVCOMP_FCST_ENSSTD	Forecast	Uncertainty (ensemble std-dev) of *tb_v_forecast*[4]

Data Field Name	GEOS Name	Data group	Description
tb_v_obs	TBVCOMP_OBS	Observations	Composite resolution observed SPL1CTB V-pol brightness temperature, represented as the average of fore and aft observations from the SMAP antenna[3] Output for this field is only stored at times and locations for which input SMAP Level-1 or Level-2 data are assimilated. If more than one overpass occurs for a given grid cell within the assimilation window, the Level-1 or Level-2 observations from all overpasses within the analysis update time window are averaged. **Note:** These brightness temperature observations passed all quality control steps but could not be assimilated for lack of brightness temperature scaling parameters. For such observations, the variables *tb_h_obs_assim* and *tb_v_obs_assim* are equal to no-data values.
tb_v_obs_assim	TBVCOMP_OBS_ASSIM	Observations	Assimilated value after model-based quality control and climatological adjustment (scaling) of tb_v_obs[3] for consistency with the land model's seasonally varying mean brightness temperature climatology **Note:** These brightness temperature observations passed all quality control steps but could not be assimilated for lack of brightness temperature scaling parameters. For such observations, the variables *tb_h_obs_assim* and *tb_v_obs_assim* are equal to no-data values.
tb_v_obs_errstd	TBVCOMP_OBS_ERRSTD	Observations	Observation error std-dev for *tb_v_obs_scaled*[3]
tb_v_obs_time_sec	TBVCOMP_OBS_TIME_SEC	Observations	Time values as counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch starting point is January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC). Type is Float64. Time stamps for H-polarization and V-polarization observations are provided in the fields *tb_h_obs_time_sec* and *tb_v_obs_time_sec*, respectively. If observations from more than one overpass time at the same location (grid cell) are assimilated, the observation time stamps reflect the average over the spacecraft overpass times. Furthermore, the fields *tb_h_orbit_flag* and *tb_v_orbit_flag* indicate whether the observation is exclusively from ascending orbits (orbit_flag=1), exclusively from descending orbits (orbit_flag=2), or from an average over ascending and descending orbits (orbit_flag=0). The latter case may occur at very high latitudes.

Data Field Name	GEOS Name	Data group	Description
tb_v_orbit_flag	TBVCOMP_ORBFLAG	Observations	Flag indicating the orbit direction of V-pol brightness temperature composite fields (*tb_v_obs*, *tb_v_forecast*, etc.): 0=average over ascending and descending orbits, 1=ascending orbits only, 2=descending orbits only. Type is Unsigned32. Time stamps for H-polarization and V-polarization observations are provided in the fields *tb_h_obs_time_sec* and *tb_v_obs_time_sec*, respectively. If observations from more than one overpass time at the same location (grid cell) are assimilated, the observation time stamps reflect the average over the spacecraft overpass times. Furthermore, the fields *tb_h_orbit_flag* and *tb_v_orbit_flag* indicate whether the observation is exclusively from ascending orbits (*orbit_flag*=1), exclusively from descending orbits (*orbit_flag*=2), or from an average over ascending and descending orbits (*orbit_flag*=0). The latter case may occur at very high latitudes.
tb_v_resolution_flag	TBVCOMP_RESFLAG	Observations	Flag indicating the effective resolution of V-pol brightness temperature composite fields (*tb_v_obs*, *tb_v_forecast*, etc..): 1=36 km, 2=9 km. Type is Unsigned32. The fields *tb_h_resolution_flag* and *tb_v_resolution_flag* indicate whether the model forecast brightness temperature for a given grid cell corresponds to a 36 km observation from the SPL1CTB product. Model forecast brightness temperatures that correspond to 36 km observations from the SPL1CTB product are aggregated from 9 km to 36 km and then posted at 9 km for convenience. Brightness temperature output is only stored at times and locations for which input SPL1CTB brightness temperature data are assimilated. If more than one overpass occurs for a given grid cell within the assimilation window, the latest overpass time prevails.
temp_lowatmmodlay	TLML	Geophysical	Air temperature at center height of lowest atmospheric model layer
time	TIME	[*All Data groups*][1]	Time accrued since 2000-01-01 11:58:55.816. Type is 64-bit floating-point and array is one dimensional.
vegetation_ greenness_fraction	GRN	Geophysical	Vegetation “greenness” or fraction of transpiring leaves averaged over the land area[2] of the grid cell.
windspeed_ lowatmmodlay	SPEEDLML	Geophysical	Surface wind speed at center height of lowest atmospheric model layer
x	projection_x_coordinate	[*All Data groups*][1]	The x coordinate values from the cylindrical 9 km Earth-fixed EASE-Grid 2.0 projection
y	projection_y_coordinate	[*All Data groups*][1]	The y coordinate values from the cylindrical 9 km Earth-fixed EASE-Grid 2.0 projection

Data Field Name	GEOS Name	Data group	Description

[1] The time and space coordinate data sets are stored in the HDF5 root data group, not in any particular group (i.e Geophysical_Data).

[2] Excluding areas of open water and permanent ice. Output is only stored at times and locations for which input SMAP Level-1 or Level-2 data are assimilated. If more than one overpass occurs for a given grid cell within the assimilation window, output represents average over all overpass times.

[3] Observed brightness temperatures that originate from 36 km SPL1CTB files are posted at 9 km here for convenience (as average over fore and aft brightness temperature if stored separately in SPL1CTB product).

[4] Model forecast brightness temperatures that correspond to 36 km observations from the SPL1CTB product are aggregated from 9 km to 36 km and then posted at 9 km for convenience.

[5] Soil wetness units (dimensionless) vary between 0 and 1, indicating relative saturation between completely dry conditions and completely saturated conditions, respectively.

- Soil moisture output in the Geophysical Data (gph) group is provided in three different units:
- m^3/m^3 (or volumetric percent): the volume of water / total volume of soil including solids, water, and air
- dimensionless wetness units (or relative saturation): volume of water / volume of pore space
- percentile units: root zone and profile soil moisture only (**Note:** There are known shortcomings in the underlying climatology, and the soil moisture fields in percentile units have not been validated).

Soil moisture output in the Analysis Update (*aup*) group is provided only in m^3/m^3 (volumetric percent); for applications, the *gph* output is likely more appropriate. For more details, refer to Appendix D (page 81) of the Product Specification Document (Reichle et al. 2015a).

Fill/Gap Values

SMAP data products employ fill and gap values to indicate when no valid data appear in a particular data field and ensure that data fields retain the correct shape. Gap values locate portions of a data stream that do not appear in the output data file. Yet because the SPL4SM data product is partially based on modeling, gaps are not expected to occur in the SPL4SM data stream. Note, however, that there might well be 3-hour intervals for which no SMAP data were assimilated. This situation would be reflected in the *aup* collection when the total number of assimilated observations for the time interval in question is zero.

Fill values appear in the SPL4SM data product over ocean and water surfaces or for variables that are not meaningful (such as snow temperatures in the absence of snow). Fill values are also used, for example, in the *aup* file collection for all grid cells for which SMAP observations were not assimilated. The latter may occur for any of the following circumstances:

- There was no SMAP overpass for the grid cell in question during the assimilation time window.
- The SMAP observations were not available due to quality control, missing science or engineering input data, or any other reason in the Level-1, -2, or -3 processing algorithms.
- The SMAP observations were rejected for assimilation due to quality control by the SPL4SM algorithm.

SMAP data products employ a specific set of data values to connote that a field is fill. The selected values that represent fill are dependent on the data type.

No *valid* value in the SPL4SM data product is equal to the values that represent fill. If any exceptions should exist in the future, the SPL4SM content will provide a means for users to discern between fields that contain fill and fields that contain genuine data values.

Acronyms and Abbreviations

Table A - 7. Acronyms and Abbreviations

Abbreviation	Definition
Char	8-bit character
IGBP	International Geosphere-Biosphere Programme
Int8	8-bit (1-byte) signed integer
Int16	16-bit (2-byte) signed integer
Int32	32-bit (4-byte) signed integer
Float32	32-bit (4-byte) floating-point integer
Float64	64-bit (8-byte) floating-point integer

Abbreviation	Definition
N/A	Not Applicable
QA	Quality Assurance
Uint8	8-bit (1-byte) unsigned integer
Uint16	16-bit (2-byte) unsigned integer
UTC	Universal Coordinated Time