SMAP L4 Global 9 km EASE-Grid Surface and Root Zone Soil Moisture, Version 7:

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.H., G. De Lannoy, R.D. Koster, W.T. Crow, J.S. Kimball, Q. Liu, and M. Bechtold. 2022. *SMAP L4 Global 3-hourly 9 km EASE-Grid Surface and Root Zone Soil Moisture Analysis Update, Version 7*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/LWJ6TF5SZRG3. [Date Accessed].

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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

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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 (L4_SM) 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).

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.

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.

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 Vv7032) 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. The general contents of the `gph` granule file are shown in Figure 1. Note that in this version update, there are three new fields: `depth_to_water_table_from_surface_in_peat`; `free_surface_water_on_peat_flux`; and `mwrtm_vegopacity`.

Figure 1. Contents of a Geophysical Data file. For a complete list of file contents for the SMAP Level-4 soil moisture product, refer to the L4_SM Product Specification Document (Reichle et al., 2022a) available in the Documentation section of the landing page.

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

Within an `aup` file, the various folders can be expanded to show all its contents (Figure 2).

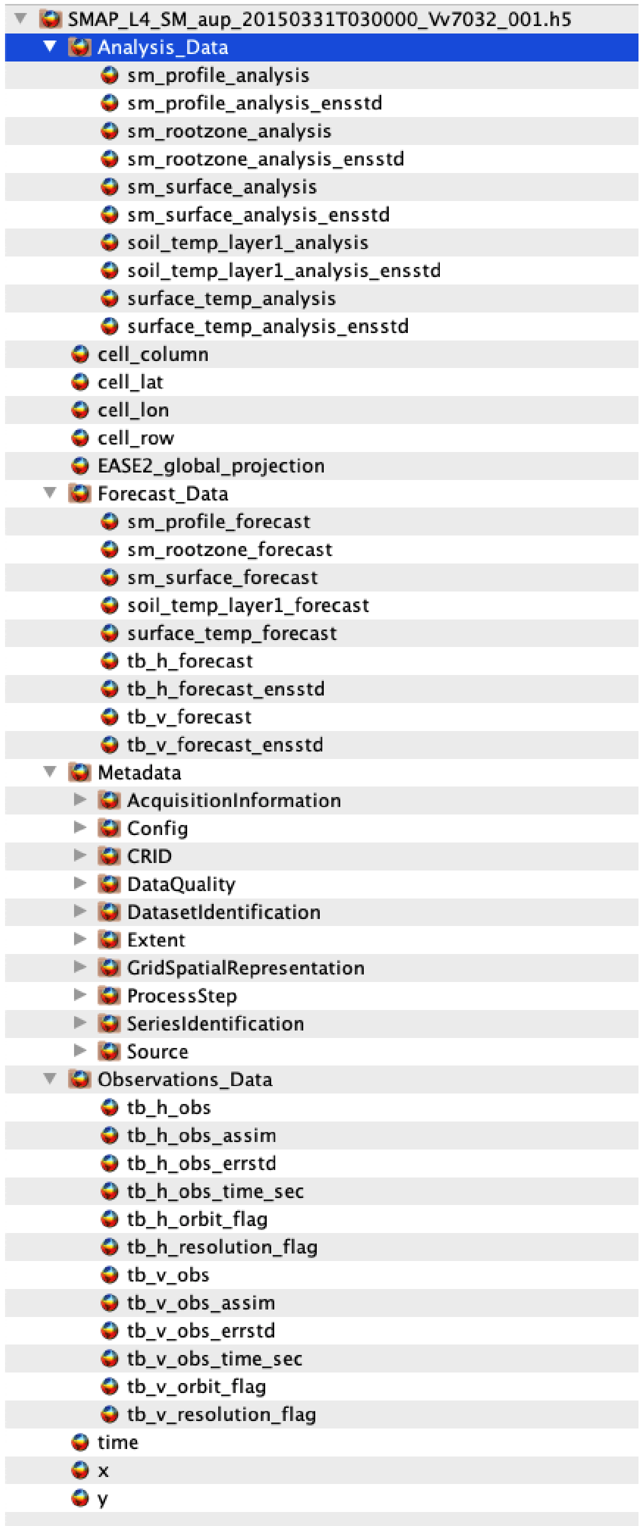

Figure 2. Contents of an Analysis Update file. For a complete list of file contents for the SMAP Level-4 soil moisture product, refer to the L4_SM Product Specification Document (Reichle et al., 2022a) available in the Documentation section of the landing page.

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 the contents within an `lmc` file.

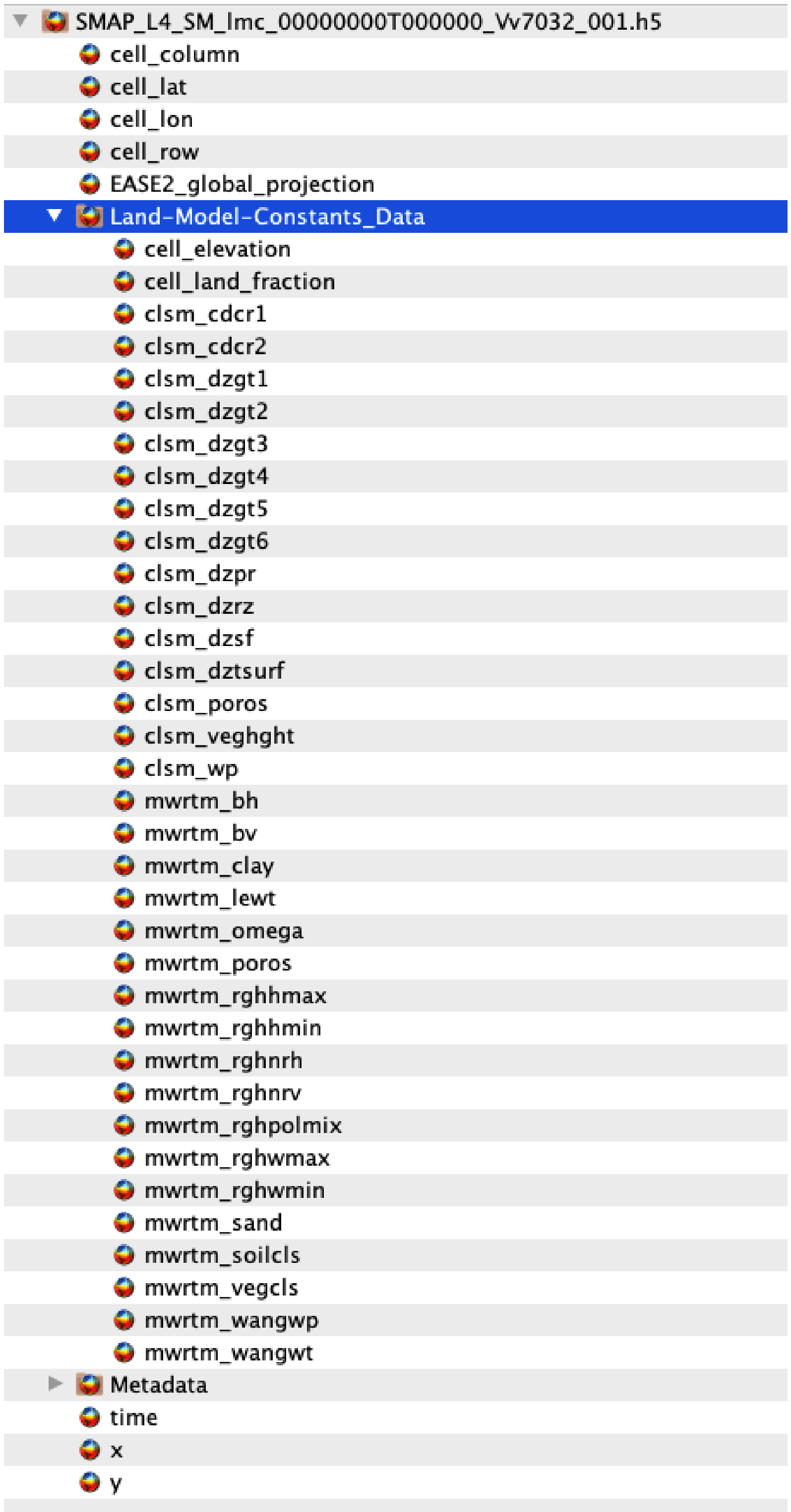

Figure 3. Contents of a Land Model Constants file. For a complete list of file contents for the SMAP Level-4 soil moisture product refer to the L4_SM Product Specification Document (Reichle et al., 2022a) available in the Documentation section of the landing page.Data Fields

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 product specification document in the Documentation section of the landing page.

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

1.2.3 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., 2022a).

1.2.4 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_20150331T013000_Vv7032_001.h5

Table 1 describes the variables within a file name:

Table 1. File Naming Convention

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>SMAP</td><td>Indicates SMAP mission data</td></tr>
<tr><td>L4_SM</td><td>Indicates specific product (L4: Level-4; SM: Soil Moisture)</td></tr>
<tr><td>pid</td><td>Product Identification (PID), where:
<table>
<tr><td>gph</td><td>Geophysical Data</td><td>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.</td></tr>
<tr><td>aup</td><td>Analysis Update Data</td><td>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.</td></tr>
<tr><td>lmc</td><td>Land Surface Model Constants</td><td>For the LMC product (time-invariant constants), which consists of only one file per Science Version, the date/time is 00000000T000000.</td></tr>
</table></td></tr>
<tr><td>yyyymmddThhmmss</td><td>Date/time in Coordinated Universal 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 minute, 2-digit second</td></tr>
</table></td></tr>
<tr><td>VLMmmm</td><td>Composite Release ID, where:
<table>
<tr><td>V</td><td>Version</td></tr>
<tr><td>L</td><td>Launch Indicator (v: Validated Data)</td></tr>
<tr><td>M</td><td>1-Digit Composite Release ID (CRID) Major Version Number

Note: the data set's major version does not necessarily coincide with the CRID major version</td></tr>
<tr><td>mmm</td><td>3-Digit CRID Minor Version Number</td></tr>
</table>
Example: Vv7032 indicates a Validated-quality data product with a version of 7.032. Refer to the SMAP Data Versions page for version information.</td></tr>
<tr><td>NNN</td><td>Number of times the file was generated under the same version for a particular date/time interval (e.g., 002 denotes 2nd time)</td></tr>
<tr><td>.[ext]</td><td>File extensions include:
<table>
<tr><td>.h5</td><td>HDF5 data file</td></tr>
<tr><td>.qa</td><td>Quality Assurance file</td></tr>
<tr><td>.xml</td><td>XML Metadata file</td></tr>
</table></td></tr>
</table>

1.2.5 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`	145 MB	1.16 GB (Daily)
`aup`	92 MB	0.74 GB (Daily)
`lmc`	51 MB	51 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 to 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 SMAP 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. Table 3 and Table 4 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

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

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

Significant gaps in coverage occurred between 19 June and 23 July 2019 and between 6 August and 20 September 2022 after the SMAP satellite went into Safe Mode. A brief description of the

2019 event and its impact on data quality is available in the SMAP Post-Recovery Notice. The SMAP data acquired after the 2022 event were determined to be of high quality and consistent with the data acquired prior to the event. Note, SPL4SM data were available during the 2019 and 2022 gaps in SMAP coverage, albeit based primarily on the modeling system and not on concomitant SMAP observations.

1.4.3 Latencies

Please see the following 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) (Reichle et al. 2014). Additional documentation of the algorithm is provided by Reichle et al. 2017a, Reichle et al. 2017b, Reichle et al. 2019, and Reichle and Liu 2021.

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 (Reichle et al., 2014) 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 on the Jet Propulsion Laboratory (JPL) SMAP website.

2.3 Acquisition

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

- SMAP L1C Radiometer Half-Orbit 36 km EASE-Grid Brightness Temperatures (SPL1CTB), Version 5, both R17 and R18 iterations (or Level 1 Composite Release Identifiers), and Version 6 R19. There are no significant science differences between the R17, R18, and R19 brightness temperature data for SPL1CTB. This allows for the use of data from all iterations as input for the Level 4 soil moisture products. See the SMAP Data Versions page for more details.

Note: Brightness temperature observations from Version 5 and Version 6 SPL1CTB granules that have known deficiencies were excluded from assimilation in the Version 7 SPL4SM algorithm

- Goddard Earth Observing System (GEOS) Forward Processing (FP) global, 0.25-degree, hourly surface meteorology from observation-constrained global weather model analysis

- NOAA Climate Prediction Center "Unified" (CPCU) global, 0.5 degree, daily, gauge-based precipitation data
- NASA Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement mission (IMERG) quasi-global, 0.1-degree, ½-hourly, satellite- and gauge-based (IMERG-Final) and satellite-only (IMERG-Late) precipitation data

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 (Reichle et al. 2017a, Reichle et al. 2017b, Reichle et al. 2019, Reichle and Liu 2021).

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 (EnKF) and a rule-based freeze/thaw analysis. However, data users should note that for Validated Version 7 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 (L4_SM) data are generated by the NASA Global Modeling and Assimilation Office (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. Details regarding the ancillary data requirements are described in Section 4.1.3 of the ATBD (Reichle et al., 2014). Depending on the time and location, the precipitation observations used to correct the GEOS precipitation estimates are obtained from the CPCU gauge-based product, the NASA IMERG satellite- and gauge-based (IMERG-Final) product, or the IMERG satellite-only (IMERG-Late) data product (Reichle et al. 2017a, Reichle et al. 2017b, Reichle et al. 2019, Reichle and Liu 2021).

For more information on each portion of the algorithm processing flow, refer to the ATBD (Reichle et al., 2014). The remainder of this section discusses the new features and changes in the SPL4SM Version 7 algorithm relative to Version 6.

2.5.1 Land Surface Modeling and Assimilation System

An improved treatment of peatlands is used in the Catchment land surface model of the SPL4SM Version 7 algorithm. For peatlands, the Catchment model now uses the newly developed PEATCLSM module of Bechtold et al. (2019, 2020). PEATCLSM features completely revised, peatland-specific parameterizations and parameters, replacing the amended TOPMODEL approach of the original Catchment model (Koster et al. 2000) with a microtopography-based approach for peatlands. In addition to the standard Catchment model output variables such as soil moisture and temperature, PEATCLSM produces two peatland-specific output variables, the water level relative to the mean elevation of the peatland surface and a free surface water flux that represents the change in the free surface water storage when part of the microtopography is flooded during high water level events (i.e., the variables listed in Figure 1 as `depth_to_water_table_from_surface_in_peat` and `free_surface_water_on_peat_flux`). In Addition to this, the global distribution of peatlands in SPL4SM Version 7 is based on new information from the PEATMAP database (Xu et al. 2018) being integrated into the blend of the Harmonized World Soil Database (HWSD; version 1.21) and the State Soil Geographic (STATSGO2) soil data (De Lannoy et al. 2014) that was used exclusively in all previous SPL4SM versions.

The SPL4SM Version 7 algorithm also uses revised parameters in the L-band radiative transfer model that converts the simulated soil moisture and temperature estimates into brightness temperature (Tb) predictions for the radiance-based L4_SM analysis. Specifically, the L-band parameters for scattering albedo climatology, soil roughness climatology, and (seasonally-varying) vegetation opacity climatology are obtained from the SMAP Enhanced L2 Radiometer Half-Orbit 9 km EASE-Grid Soil Moisture (SPL2SMP_E), Version 5 (R18290) dual-channel retrieval product (April 2015 – March 2022), with gaps filled using averages from a 5-by-5 grid cell neighborhood.

A corresponding model-only Nature Run (NRv10.0) simulation is used to derive model soil moisture initial conditions, the soil moisture climatology, and brightness temperature scaling parameters for the SPL4SM algorithm. The SPL4SM Version 7 soil moisture climatology is based on 21 years of data (2001-2021), and the brightness temperature scaling parameters are based on seven years of SMAP observations and model simulation (April 2015 – March 2022).

The Catchment model variables comprising the EnKF state vector for mineral (non-peat) soil in SPL4SM Version 7 remain the same as in Version 6. For peatlands, the EnKF state vector in SPL4SM Version 7 additionally includes the “catchment deficit” model prognostic variable.

2.6 Quality, Errors, and Limitations

2.6.1 Quality Assessment

For in-depth details regarding the quality of these data, refer to Version 6 of the SMAP Project Assessment Report (Reichle et al., 2022b).

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 Product Specification Document (Reichle et al., 2022a).

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.

For more quality control information, refer to the ATBD of the SPL4SM products (Reichle et al., 2014).

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. The usefulness of these error estimates depends on the accuracy of the input error parameters and needs continual evaluation; refer to the ATBD, Section 4.2.4 (Reichle et al., 2014). The target accuracy of the assimilated brightness temperatures is discussed in the SPL1CTB product documentation (Chan et al., 2015). Error estimates of the land surface model and required input error parameters are discussed in the ATBD for the SPL4SM product (Reichle et al., 2014).

Each instantaneous land model field is accompanied by a corresponding instantaneous error field which is provided for select variables. The relevant outputs are listed in the product specification document located in the Documentation section of the landing page. 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 (Reichle et al., 2014). For more information on data product accuracy and its development over time, refer to Reichle et al., 2017a; Reichle et al., 2017b, Reichle et al., 2019, Reichle et al. 2021, Colliander et al. 2022, and the Version 6 Assessment Report (Reichle et al., 2022b).

3 VERSION HISTORY

Table 5 provides a brief overview of past quasi-annual updates to the Level 4 soil moisture products.

Table 5. Version History

Version	Release Date	Description of Changes
V1	Oct 2015	First public data release
V2	Apr 2016	Changes to this version include: • Transitioned to Validated-Stage 2. • Using updated SPL1CTB V3 validated data as input. • Minor bug fixes.
V3	Jul 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.

<table>
<tr><th>Version</th><th>Release Date</th><th>Description of Changes</th></tr>
<tr><td>V4</td><td>Jun 2018</td><td>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.
</td></tr>
</table>

Version	Release Date	Description of Changes
V5	Aug 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.
V6	Nov 2021	Changes to this version include: • The climatology to which all L4_SM precipitation forcing inputs are rescaled is now based on the climatology of the NASA IMERG-Final (Version 06B) product. Where the IMERG climatology is not available (primarily poleward of 60ºN latitude), L4_SM precipitation inputs are rescaled to the climatology of the Global Precipitation Climatology Project (GPCP) v2.3 product. • The L4_SM precipitation forcing outside of North America and the high latitudes is now corrected to match the daily totals from the NASA IMERG (Version 06B) product. As in Version 5, precipitation corrections based on CPCU data are used in North America. The latitude band for the linear tapering of the daily precipitation corrections is now 50-60ºN/S. The IMERG-Final product, which is informed by satellite observations and monthly totals from precipitation gauges, was used during L4_SM reprocessing. Forward-processing of L4_SM uses the satellite-only IMERG-Late product, which is not informed by precipitation gauges. A change in the L4_SM Science Version ID indicates the switch from IMERG-Final to IMERG-Late inputs. • Minor change in a parameter related to the multiplicative, lognormal perturbations of precipitation and shortwave radiation forcing to reduce minor bias between perturbed and unperturbed forcing. • The brightness temperature scaling parameters in the updated Level-4 soil moisture algorithm are based on six years of SMAP observations (April 2015 – March 2021).

Version	Release Date	Description of Changes
V7	Nov 2022	Changes to this version include: • The Catchment model now includes the PEATCLSM hydrology module for peatlands and uses an updated global map of peatland distribution. • Revised parameters are used in the L-band radiative transfer model that converts the simulated soil moisture and temperature estimates into Tb predictions for the radiance-based L4_SM analysis. Specifically, the L-band parameters for scattering albedo climatology, soil roughness climatology, and (seasonally-varying) vegetation opacity climatology are obtained from the SPL2SMP_E, Version 5, dual-channel retrieval product (April 2015 – March 2022). • The brightness temperature scaling parameters in the updated Level-4 soil moisture algorithm are based on seven years of SMAP observations and model simulations (April 2015 – March 2022). • For peatlands, the EnKF state vector now additionally includes the “catchment deficit” model prognostic variable.
	Mar 2024	Change to this version include: • Using updated SPL1CTB V6 R19 validated data as input.

4 RELATED DATA SETS

SMAP Data at NSIDC | Overview

SMAP Radar Data at the ASF DAAC

5 RELATED WEBSITES

SMAP at NASA JPL

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8 DOCUMENT INFORMATION

8.1 Publication Date

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8.2 Revision Date

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