SMAP Enhanced L1C Radiometer Half-Orbit 9 km EASE-Grid Brightness Temperatures, Version 1

USER GUIDE

How to Cite These Data

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

Chaubell, J., S. Chan, R. S. Dunbar, J. Peng, and S. Yueh. 2016. *SMAP Enhanced L1C Radiometer Half-Orbit 9 km EASE-Grid Brightness Temperatures, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/2C9O9KT6JAWS. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL1CTB_E

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

Brightness temperatures (TBs) in kelvin derived from interpolated Level-1B antenna temperatures (TAs) are output on the EASE-Grid 2.0 at 9 km in three different equal-area projections: a global cylindrical, and a Northern and Southern Hemisphere azimuthal. Level-1B antenna temperatures, calibrated to the feedhorn after RFI detection and mitigation, were interpolated at the 9 km grid cells using the Backus-Gilbert (BG) optimal interpolation method.

Refer to the Product Specification Document for details on all parameters.

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 Web site.

1.2.2 File Contents

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

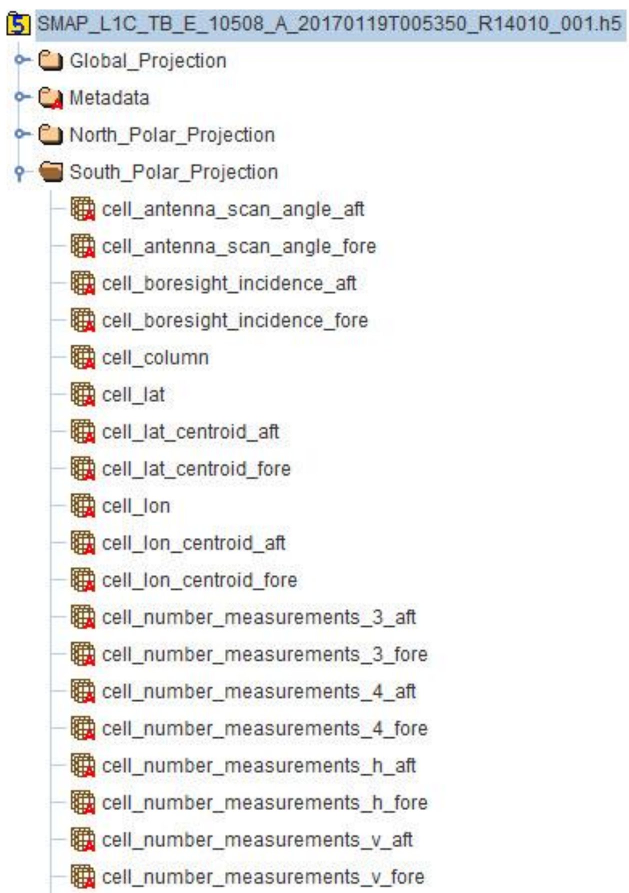

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP enhanced Level-1C brightness temperature product, refer to the Product Specification Document.

1.2.2.1 Data Fields

Each file contains the main data groups summarized in this section. For a complete list and description of all data fields within these groups, refer to the Product Specification Document.

Data fields are stored as one-dimensional arrays of size *N*, where *N* is the number of valid cells covered by the radiometer swath on the grid. Note that *N* varies with projections, but remains the same for both fore-looking and aft-look ing views within a given projection.

1.2.2.1.1 Global Projection

The global EASE-Grid 2.0 projection data group contains data that represent fore- and aft-looking views of the 360° antenna scan, including enhanced brightness temperatures, instrument viewing geometry information, and quality bit flags.

1.2.2.1.2 North Polar Projection

The north polar EASE-Grid 2.0 projection data group contains data that represent fore- and aft-looking views of the 360° antenna scan for latitudes above zero, including enhanced brightness temperatures, instrument viewing geometry information, and quality bit flags.

1.2.2.1.3 South Polar Projection

The south polar EASE-Grid 2.0 projection data group contains data that represent fore- and aft-looking views of the 360° antenna scan for latitudes below zero, including enhanced brightness temperatures, instrument viewing geometry information, and quality bit flags.

1.2.3 Metadata Fields

Includes all metadata that describe the full content of each file. For a description of all metadata fields for this product, refer to the Product Specification Document.

1.2.4 Naming Convention

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

```
SMAP_L1C_TB_E_[Orbit#]_[A/D]_yyyymmddThhmmss_RLVvvv_NNN.[ext]
```

For example:

```
SMAP_L1C_TB_E_10508_A_20170119T005350_R14010_001.h5
```

Table 1. File Naming Conventions

Variable	Description
SMAP	Indicates SMAP mission data
L1C_TB_E	Indicates specific product (L1C: Level-1C; TB: Brightness Temperature; E: Enhanced)
[Orbit#]	5-digit sequential number of the orbit flown by the SMAP spacecraft when data were acquired. Orbit 00000 began at launch.
[A/D]	Half-orbit pass of the satellite, such as: A: Ascending (where satellite moves from South to North, and 6:00 p.m. is the local solar equator crossing time) D: Descending (where satellite moves from North to South, and 6:00 a.m. is the local solar equator crossing time)

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>yyyymmddThhmmss</td><td>Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where:
<table>
<tr><td>yyyymmdd</td><td>4-digit year, 2-digit month, 2-digit day</td></tr>
<tr><td>T</td><td>Time (delineates the date from the time, i.e. yyyymmddThhmmss)</td></tr>
<tr><td>hhmmss</td><td>2-digit hour, 2-digit month, 2-digit second</td></tr>
</table></td></tr>
<tr><td>RLVvvv</td><td>Composite Release ID (CRID), where:
<table>
<tr><td>R</td><td>Release</td></tr>
<tr><td>L</td><td>Launch Indicator (1: Post-launch standard data)</td></tr>
<tr><td>V</td><td>1-Digit Major CRID Version Number</td></tr>
<tr><td>vvv</td><td>3-Digit Minor CRID Version Number</td></tr>
</table>
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 (002: 2nd time)</td></tr>
<tr><td>.[ext]</td><td>File extensions include:
<table>
<tr><td>.h5</td><td>HDF5 data file</td></tr>
<tr><td>.qa</td><td>Quality Assurance file</td></tr>
<tr><td>.xml</td><td>XML Metadata file</td></tr>
</table></td></tr>
</table>

1.3 File Size

Each half-orbit file is approximately 50 MB.

1.4 File Volume

The daily data volume is approximately 1.5 GB.

1.5 Spatial Information

1.5.1 Coverage

Coverage spans from 180°W to 180°E, and from approximately 85.044°N and 85.044°S for the global EASE-Grid 2.0 projection. The gap in coverage at both the North and South Pole, called a pole hole, has a radius of approximately 400 km. The swath width is approximately 1000 km, enabling nearly global coverage every three days.

1.5.2 Spatial Coverage Map

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

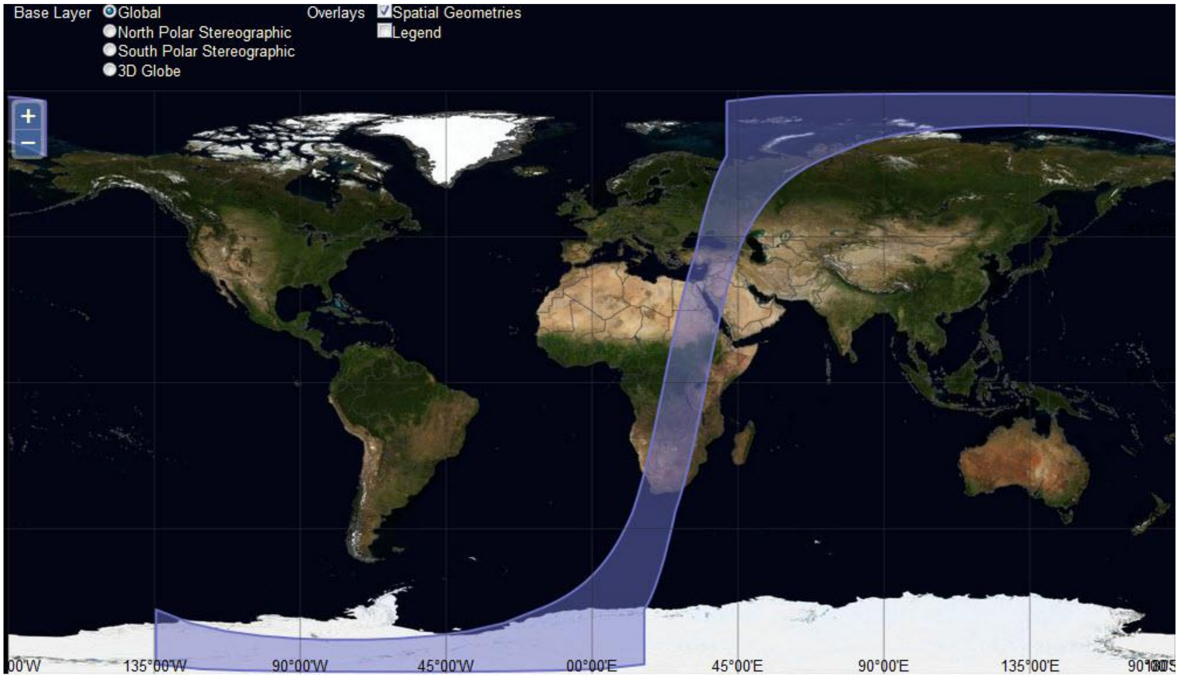

Figure 2. Spatial Coverage Map displaying one descending half orbit of the SMAP L-Band Radiometer. The map was created using the Reverb | ECHO tool.

1.5.3 Resolution

The native spatial resolution of the radiometer footprint is 36 km. Data are then interpolated using the Backus-Gilbert optimal interpolation algorithm into the global cylindrical, and Northern and Southern Hemisphere azimuthal EASE-Grid 2.0 projections with 9 km spacing.

1.5.4 Projection and Grid Description

These data are provided on the EASE-Grid 2.0 in three different equal-area projections: a global cylindrical, and both a Northern and Southern Hemisphere azimuthal. Each grid cell has a nominal area of approximately 9 x 9 km2 regardless of longitude and latitude.

EASE-Grid 2.0 has a flexible formulation. By adjusting a single scaling parameter, a family of multi-resolution grids that nest within one another can be generated. The nesting can be adjusted so that smaller grid cells can be tessellated to form larger grid cells. Figure 3 shows a schematic of the nesting to a resolution of 3 km (4872 rows x 11568 columns on global coverage), 9 km (1624 rows x 3856 columns on global coverage), and 36 km (406 rows x 964 columns on global coverage).

This feature of perfect nesting provides SMAP data products with a convenient common projection for both high-resolution radar observations and low-resolution radiometer observations, as well as for their derived geophysical products.

For more on EASE-Grid 2.0, refer to the EASE-Grid 2.0 Format Description.

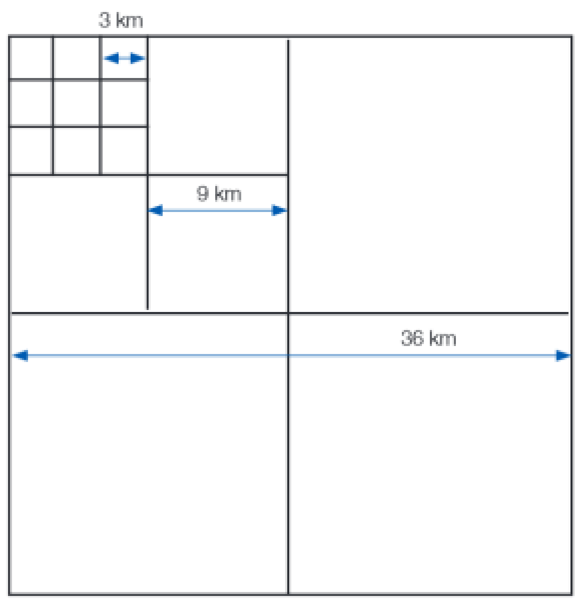

Figure 3. Perfect Nesting in EASE-Grid 2.0

1.6 Temporal Information

1.6.1 Coverage

Coverage spans from 31 March 2015 to present.

1.6.2 Temporal Coverage Gaps

1.6.2.1 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

1.6.2.2 Latencies

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

1.6.3 Temporal Resolution

Each enhanced Level-1C half-orbit file spans approximately 49 minutes.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This section has been adapted from Chaubell et al. (2016).

2.2 Sensor or Instrument Description

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

2.3 Data Source

Antenna temperatures from the baseline SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 3 (SPL1BTB) product are used as input to calculating this enhanced Level-1C brightness temperature product, SPL1CTB_E.

2.4 Theory of Measurements

The enhanced Level-1C brightness temperature product is an interpolated and gridded version of SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 3 and thus shares most of the same major output data fields, data granularity (one half-orbit per file), and theory of measurements. Refer to the Level-1B Theory of Measurements for more details.

2.5 Derivation Techniques and Algorithms

2.5.1 Backus-Gilbert Optimal Interpolation Algorithm Format

The baseline SMAP Level-1B brightness temperature product (SPL1BTB) contains global surface brightness temperature estimates over a 36 km regular global grid. The aim of the SMAP enhanced Level-1B brightness temperature product (SPL1BTB_E) is to provide an optimal interpolation of the radiometer measurements onto a global 9 km grid. The SMAP sampling pattern results in overlapping measurements which, together with optimal interpolation, results in more accurate estimation of brightness temperature.

There are a number of algorithms directed towards the goal of image reconstruction and interpolation. A long-standing approach and one with extensive heritage in microwave radiometry is the Backus-Gilbert (BG) interpolation (Backus and Gilbert, 1970). This technique has been applied to the Special Sensor Microwave/Imager (SSM/I) measurements (Stogryn, 1978; Poe, 1990; Robison et al., 1992; Farrar and Smith, 1992; Sethmann et al., 1994; Long and Daum, 1998; Migliaccio and Gambardella, 2005) and the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) measurements (Chakraborty et al., 2008). A unique feature of the BG interpolation is that it is optimal in the sense that the resulting interpolated data is closest to what would have been measured had the radiometer actually made the measurements with the interpolation point as its bore-sight center (Poe, 1983). In this sense and in this respect, it is superior to ad hoc or empirical interpolation techniques. According to Long and Brodzik (2016), BG provides higher spatial resolution surface brightness temperature images with smaller total error compared with conventional drop-in-the-bucket gridded image formation. The SPL1CTB_E algorithm uses the polarimetric implementation of the BG optimal interpolation algorithm derived by Dr. Simon Yueh to interpolate baseline SMAP Level-1B antenna temperatures on the EASE-Grid 2.0 points within the boundaries of the orbit path.

For details regarding the BG theory and implementation, refer to the enhanced Level-1B ATBD, Section 2: Optimal Interpolation of Polarimetric Brightness Temperatures.

2.5.2 Gridding Algorithm

As mentioned previously, the SPL1CTB_E algorithm uses BG optimal interpolation to interpolate SMAP Level-1B antenna temperatures on the EASE-Grid 2.0 points within the boundaries of the orbit path.

In other words, calling *ρd* a point on the EASE-Grid 2.0, we compute the antenna temperature at *ρd* as

$$T_A(\rho_d) = \sum_{i=1}^{N} a_i \cdot T_{A_i}$$ **(Equation 1)**

where T_{Ai} are the antenna temperatures at the SMAP footprint locations *ρd*, i=1…N.

The coefficients are given by

$$\bar{a} = \bar{\bar{g}}^{-1} \cdot \bar{v} + \left(\frac{2 - \bar{u}^T \cdot \bar{\bar{g}}^{-1} \cdot \bar{v}}{\bar{u}^T \cdot \bar{\bar{g}}^{-1} \cdot \bar{u}}\right) \bar{\bar{g}}^{-1} \cdot \bar{u},$$ **(Equation 2)**

where the elements of the matrix *g* are

$$g_{im} = \sum_{j,k=1}^{4} \int dA G_{jk}(\bar{\rho}_i, \bar{\rho}) G_{jk}(\bar{\rho}_m, \bar{\rho})$$ **(Equation 3)**

and the vectors *v* and *μ* are given by

$$v_i = \sum_{j,k=1}^{4} \int dA G_{jk}(\bar{\rho}_i, \bar{\rho}) G_{jk}(\bar{\rho}_d, \bar{\rho})$$ **(Equation 4)**

and

$$u_i = \int dA G_{11}(\bar{\rho}_i, \bar{\rho}) + G_{21}(\bar{\rho}_i, \bar{\rho}) + G_{12}(\bar{\rho}_i, \bar{\rho}) + G_{22}(\bar{\rho}_i, \bar{\rho}).$$ **(Equation 5)**

These equations are the bases for the direct evaluation of the vector *u* and *v* and the matrix *g,* necessary to obtain the coefficients *a*. These calculations can be computationally very expensive. In order to make our algorithm more computationally efficient, we implemented the some approximations. Details of this approximation and its error evaluation can be found in the SPL1BTB_E ATBD.

2.6 Processing Steps

This enhanced product is generated by the SMAP Science Data Processing System (SDS) at JPL in Pasadena, California USA. To generate the product, the processing software ingests a half-orbit file of the SMAP enhanced Level-1B radiometer brightness temperature data set (L1B_TB_E) to extract and transfer key data fields to the SPL1CTB product. Only cells that are covered by the actual swath for a given projection are written in the product.

Prior to the production of the SPL1CTB_E product, the L1B_TB_E processor reads from the SPL1BTB product the baseline Level-1B antenna temperatures, which have been calibrated (by removing sun/moon/galactic contributions and applying reflector emissivity corrections) and processed by radio frequency interference detection and mitigation algorithms. The L1B_TB_E algorithm applies the Backus-Gilbert interpolation theory to interpolate Level-1B antenna temperatures on the EASE-Grid 2.0 points within the boundaries of the orbit path. The algorithm uses six SMAP footprints from the baseline SPL1BTB product to perform the interpolation. The selection of those points is explained in the SPL1BTB_E ATBD. If one of those selected points is a fill value, then the value assigned to the antenna temperature is a fill value. The interpolated antenna temperatures are further processed to remove the effects of the antenna sidelobes outside the radiometer antenna main beam, cross-polarizations, Faraday rotation, and atmospheric effects (excluding rain). The resulting L1B_TB_E data represent enhanced surface-referenced brightness temperatures.

2.7 Error Sources

This enhanced Level-1C brightness temperature product (SPL1CTB_E) contains a subset of data fields of the input L1B_TB_E data set. Two-dimensional arrays that are transferred from L1B_TB_E are reformatted as one-dimensional arrays for compactness and improved I/O speed in Level 2 processing. In terms of noise performance, SPL1CTB_E inherits the same Error Sources that affect SPL1BTB. These error sources include RFI, radiometric noise and calibration error, modified by the process of Backus-Gilbert interpolation in SPL1BTB_E. The interpolation process is not expected to affect the calibration errors, such as biases and drifts, but will reduce the radiometric noise, such as the random component of the brightness temperature error. Conversely, the interpolation process may enlarge the effective antenna pattern footprint of the brightness temperature measurement.

In addition, because image reconstruction includes a trade-off between noise and resolution, estimated noise variances in the interpolated fields are reported in the SPL1BTB_E ATBD. However, the noise levels obtained for SPL1BTB_E and thus SPL1CTB_E measurements are improved over the baseline SPL1BTB single footprint measurements due to the interpolation performed, and are similar to the noise levels of the baseline SPL1CTB product, which also performs an interpolation of single footprint measurements in mapping to a 36 km grid.

For more information, please refer to the ATBD for this product.

2.8 Quality Assessment

For in-depth details regarding the quality of these Version 1 data, refer to the following reports:
Validated Assessment Report
Beta Assessment Report

2.8.1 Quality Overview

Each HDF5 file contains metadata with Quality Assessment (QA) metadata flags that are set by the SDS at the JPL prior to delivery to the National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). A separate metadata file with an .xml file extension is also delivered to NSIDC DAAC with the HDF5 file; it contains the same information as the HDF5 file-level metadata.

A separate QA file with a .qa file extension is also associated with each data file. QA files are ASCII text files that contain statistical information in order to help users better assess the quality of the associated data file.

Various levels of QA are conducted with Level-1C data. If a product does not fail QA, it is ready to be used for higher-level processing, browse generation, active science QA, archive, and distribution. If a product fails QA, it is never delivered to NSIDC DAAC.

In addition, during the post-launch Calibration/Validation period, the performance of the Level-1C brightness temperature product relative to the Level-1B brightness temperature product are evaluated in a number of ways. These include:

- Comparing images and examining differences between the two products over coastlines and other discrete boundaries, and heterogeneous terrain (lakes, mountains, rivers).
- Comparing TB and TB-gradient histograms of the two products over regions of varying heterogeneity.

Refer to the Product Specification Document for details on all data flags.

3 SOFTWARE AND TOOLS

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

4 CONTACTS AND ACKNOWLEDGMENTS

4.1 Investigators

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6 DOCUMENT INFORMATION

6.1 Publication Date

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6.2 Date Last Updated

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