SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 4

USER GUIDE

How to Cite These Data

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

Piepmeier, J. R., P. Mohammed, J. Peng, E. J. Kim, G. De Amici, J. Chaubell, and C. Ruf. 2018. *SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 4.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/VA6W2M0JTK2N. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SPL1BTB/

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

The SMAP L-Band Radiometer measures antenna temperatures referenced to the instrument feedhorn before and after RFI mitigation. SMAP antenna temperatures are then used to calculate the four Stokes parameters: TV, TH, T3, and T4 at 1.41 GHz. These parameters represent the vertically and horizontally polarized brightness temperatures (TBs), and the third and fourth cross-polarized brightness temperatures, respectively. The cross-polarized T3-channel measurement can be used to correct for possible Faraday rotation caused by charged particles in the upper atmosphere.

Refer to the Appendix of this 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 website.

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:

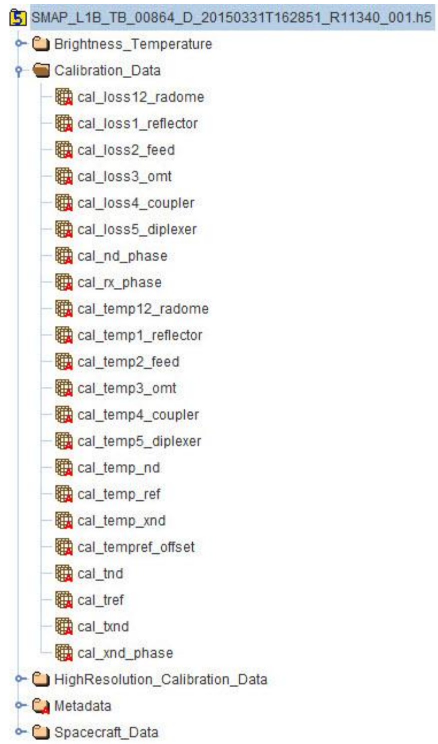

Figure 1. Subset of File Contents. For a complete list of file contents for the SMAP Level-1B brightness temperature product, refer to the Appendix.

1.2.3 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 Appendix of this document. Note that data array dimensions and sizes vary for this product.

1.2.3.1 Brightness Temperature

Includes brightness temperatures at each footprint referenced to the surface of the Earth with error sources and undesirable radiometric sources removed, such as atmospheric effects and solar, lunar, and galactic emissions. A second set of further corrected brightness temperatures are also provided, such as tb_h_surface_corrected (as opposed to tb_h). For these brightness temperatures, an additional correction procedure has been applied to correct anomalous water and land values; see the "Water/Land Contamination Correction" section for details.

This group also includes antenna temperatures (TAs) referenced to the feedhorn before and after RFI mitigation, error source values, brightness temperature error, and Noise Equivalent Delta Temperature (NEDT). Many parameters are specifically designated for horizontal and vertical polarizations as well as the 3rd and 4th Stokes parameters.

1.2.3.2 Calibration Data

Includes fullband and subband calibration coefficients. Among these coefficients are instrument component losses, noise temperatures, physical temperatures, calibration gain and offset factors and phase values. The contents were corrected for detected RFI.

1.2.3.3 High Resolution Calibration Data

Includes subband calibration coefficients. Among these coefficients are instrument component losses, noise temperatures, physical temperatures, calibration gain and offset factors and phase values. The contents were corrected for detected RFI.

1.2.3.4 Spacecraft Data

Includes elements that specify either geometric or geographic information that are representative of each entire antenna scan of the instrument swath. Major elements include the spacecraft time, position, velocity, and attitude. Values in the spacecraft data group are representative of all brightness temperatures acquired during the corresponding antenna scan.

1.2.4 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.

1.2.5 Naming Convention

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

```
SMAP_L1B_TB_[Orbit#]_[A/D]_yyyymmddThhmmss_RLVvvv_NNN.[ext]
```

For example:

```
SMAP_L1B_TB_03891_D_20151024T155359_R13242_001.h5
```

Table 1. File Naming Conventions

Variable	Description
SMAP	Indicates SMAP mission data
L1B_TB	Indicates specific product (L1B: Level-1B; TB: Brightness Temperature)
[Orbit#]	5-digit sequential number of the orbit flown by the SMAP spacecraft when data were acquired. Orbit 00000 began at launch. Orbit numbers increment each time the spacecraft flies over the southernmost point in the orbit path.

<table>
<tr><th>Variable</th><th>Description</th></tr>
<tr><td>[A/D]</td><td>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 time)
D: Descending (where satellite moves from North to South, and 6:00 a.m. is the local solar time)</td></tr>
<tr><td>yyyymmddThhmmss</td><td>Date/time in Universal Coordinated Time (UTC) of the first data element that appears in the product, where:
<table>
<tr><td>yyyymmdd</td><td>4-digit year, 2-digit month, 2-digit day</td></tr>
<tr><td>T</td><td>Time (delineates the date from the time, i.e. yyyymmddThhmmss)</td></tr>
<tr><td>hhmmss</td><td>2-digit hour, 2-digit month, 2-digit second</td></tr>
</table></td></tr>
<tr><td>RLVvvv</td><td>Composite Release ID, where:
<table>
<tr><td>R</td><td>Release</td></tr>
<tr><td>L</td><td>Launch Indicator (1: post-launch standard data)</td></tr>
<tr><td>V</td><td>1-Digit Major Version Number</td></tr>
<tr><td>vvv</td><td>3-Digit Minor Version Number</td></tr>
</table>
Example: R13242 indicates a post-launch data product with a version of 3.242.</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>

1.2.6 File Size

Each half-orbit file is approximately 46 MB.

1.2.7 File Volume

The daily data volume is approximately 1.4 GB.

Coverage spans from 180°W to 180°E, and from approximately 86.4°N to 86.4°S. The gap in coverage at both the North and South Pole, called a pole hole, has a radius of approximately 400 km. The swath width is 1000 km, enabling nearly global coverage every two to three days.

1.3 Spatial Information

1.3.1 Coverage

Coverage spans from 180°W to 180°E, and from approximately 86.4°N to 86.4°S. The gap in coverage at both the North and South Pole, called a pole hole, has a radius of approximately 400 km. The swath width is 1000 km, enabling nearly global coverage every two to three days.

1.3.2 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.

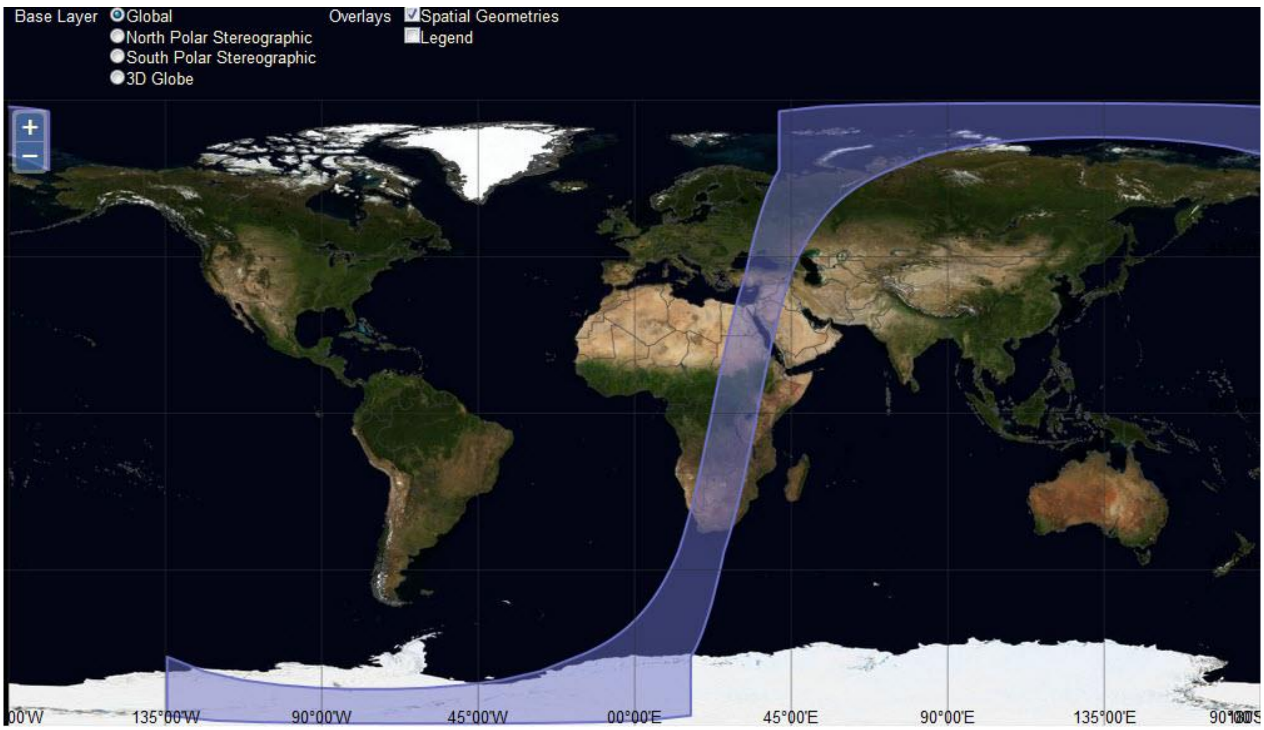

Figure 2. Spatial coverage map displaying one descending half orbit of the SMAP L-Band Radiometer.

1.3.3 Resolution

The instantaneous field of view of the radiometer footprint is approximately 36 x 47 km; the effective field of view of brightness temperatures in the Level-1B brightness temperature product is 39 x 47 km. The native spatial resolution of the radiometer footprint is approximately 36 km.

1.4 Temporal Information

1.4.1 Coverage

Coverage spans from 31 March 2015 27 August 2020

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

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

2 DATA ACQUISITION AND PROCESSING

2.1 Background

The objective of the Level-1B brightness temperature algorithm is to convert digital counts in the instrument telemetry into time-ordered, geolocated brightness temperatures within the main beam referenced to the Earth's surface. The algorithm theory is similar to what has been developed and implemented for decades for other satellite radiometers. SMAP includes two key features heretofore absent from satellite-borne radiometers: RFI detection and mitigation, and measurement of the third and fourth Stokes parameters using digital correlation.

This section contains a description of the sources contributing to the total apparent temperature seen at the input to the SMAP main reflector. The brightness temperature of a source (measured in kelvins) can be described in terms of the product of the physical temperature and the emissivity of the source. Emissivity is, in general, polarization dependent, thus differentiating brightness temperature into TBV and TBH for the vertical and horizontal polarizations, respectively. These are the first two modified Stokes parameters. The real part of the complex correlation between these two components is measured by the third modified Stokes parameter, represented in brightness temperatures as T3. The fourth Stokes parameter, T4, measures the imaginary part of the correlation. For this document, a vector of modified Stokes parameters is shown by:

$$\overline{T}_B(\theta,\phi) = \begin{bmatrix} T_v \\ T_h \\ T_3 \\ T_4 \end{bmatrix}$$ (Equation 1)

where θ and Φ are the elevation and azimuth of a spherical coordinate system centered on the radiometer antenna boresight vector. Important sources of radiation at L-band are the Earth's land and sea, the cosmic background radiation, the sun, radiation sources outside our solar system, and the moon.

For an in-depth description of the theory of these measurements, refer to Section 4: Forward Model (TA to TB) of Piepmeier et al. (2016).

2.2 Acquisition

SMAP Level-1B radiometer brightness temperatures are processed from SMAP L1A Radiometer Time-Ordered Parsed Telemetry (SPL1AP). The Level-1A radiometer product contains parsed radiometer instrument telemetry.

2.3 Derivation Techniques and Algorithms

The raw radiometer instrument counts are converted to antenna temperatures and then to brightness temperatures to produce SMAP Level-1A and Level-1B products. The input data to the Level-1B brightness temperature algorithm are the SMAP L1A Radiometer Time-Ordered Parsed Telemetry data. The Level-1A Science Processing Software produces the Level-1A product in accordance with the Earth Observing System (EOS) Data Product Levels definition, which states that Level-1A data products are reconstructed, unprocessed instrument data at full resolution, are time-referenced and annotated with ancillary information.

The Level-1B radiometer brightness temperature Science Processing Software geolocates and radiometrically calibrates the Level-1A data to obtain antenna temperatures. Subsequent processing applies algorithms that detect and flag pixels for RFI. The data are then time and frequency averaged near the antenna's angular Nyquist rate. The Level-1B algorithm also compensates for sources of error or sources of radiometric energy not associated with emissivity of the Earth's surface. Those sources include Faraday rotation, energy detected by antenna sidelobes and spillover, atmospheric effects, solar radiation, lunar radiation, cosmic microwave background, galactic emission, and water/land contamination.

2.3.1 Water/Land Contamination Correction

To mitigate water and land contamination, the latest Level-1B algorithm includes a surface correction procedure for the brightness temperature contribution due to water (when the antenna boresight falls on a land location) or land (when the antenna boresight falls on a water location). Both the horizontally and vertically polarized L1B brightness temperatures are corrected for the presence of water or the presence of land within the antenna field of view (FOV). Over land, the resulting brightness temperatures will become warmer upon the removal of the contribution of water to the original uncorrected observations. Over water, the resulting brightness temperatures will become cooler upon the removal of the contribution of land to the original uncorrected observations.

For example, the total measured temperature can be separated into two contributions:

$$TB_p = (1 - f) * TB_p^{land} + f * TB_p^{water}$$ **(Equation 2)**

If the footprint is on land, the following formula is applied:

$$TB_p^{land} = \frac{TB_p - f * \overline{TB}_p^{water}}{1 - f}$$ **(Equation 3)**

If the footprint is on water, the following formula is applied:

$$TB_p^{water} = \frac{TB_p - (1 - f) * \overline{TB}_p^{land}}{f}$$ **(Equation 4)**

where f is the water fraction, f=1 for pure water, and f=0 for pure land.

$$f = \int G.M d\Omega = \int_{\theta=[0,\pi],\psi=[0,2\pi]} G(\theta,\psi)\, M(\theta,\psi) \sin\theta \;\, d\theta d\psi$$

$$\cong \int_{\theta=[0,10*\pi/180],\psi=[0,2\pi]} G(\theta,\psi) M \sin\theta \;\, d\theta d\psi$$

(Equation 5)

These water/land contamination corrections are performed when the following criteria are met:

- If footprint boresight is over land as indicated by a static high-resolution land/water mask, then water contamination correction is performed
- If footprint boresight is over water as indicated by a static high-resolution land/water mask, then land contamination correction is performed
- Over land, water contamination correction is performed if antenna-gain-weighted water fraction </=0.9
- Over water, land contamination correction is performed if antenna-gain-weighted water fraction > 0.1
- Correction is performed only if sea ice fraction=0
- Valid range for TB V polarization [50K: 340K]; values outside this range are replaced with fill values
- Valid range for TB H polarization [30K: 340K]; values outside this range are replaced with fill values
- Over land, if *tb_surface_corrected* < TB, then value is replaced with fill value
- Over water, if *tb_surface_corrected* > TB, then value is replaced with fill value

For more details regarding the algorithm used to generate this product, refer to the latest ATBD, Piepmeier et al. (2018).

2.4 Processing

This product is generated by the SMAP Science Data Processing System (SDS) at the Jet Propulsion Laboratory (JPL) in Pasadena, California USA. To generate this product, the processing software ingests both descending and ascending half-orbit files of the Level-1A brightness temperature data. The descending half orbits contain data acquired at very nearly 6:00 a.m. local solar time. The ascending half orbits contain data acquired at very nearly 6:00 p.m. local solar time.

The total number of radiometer science packets per antenna scan varies depending on the antenna rotation rate and integration time of the instrument. The resulting number of antenna footprints per scan is therefore variable. To preserve the shape of stored data elements, the size of certain dimensions is assigned a maximum value. Thus, fill values appear in the SMAP Level-1B brightness temperature product when a particular scan does not contain the maximum possible number of footprints.

Antenna temperatures are processed by RFI detection and mitigation algorithms (see Error Sources) where the pixels for a footprint that are flagged for RFI are removed and the remaining clean pixels are averaged to form an RFI-free antenna footprint. If all pixels for a particular footprint are flagged for RFI then the footprint antenna temperature is assigned the null value. The corresponding footprint brightness temperature (TB) value will also be assigned the null value since the RFI-free antenna footprint antenna temperatures are used to produce the time-ordered brightness temperature product. Subsequently, after pixels with RFI are flagged and dropped, the remaining clean pixels are used to compute the NEDT for that footprint. If all pixels are removed, the null value is assigned to the NEDT for that footprint. For more details, refer to Section C. RFI Detection and Mitigation (p. 33) of the SMAP Handbook.

Lastly, additional corrections are applied to brightness temperatures to correct for anomalous data values as a result of water/land contamination.

2.5 Quality, Errors, and Limitations

2.5.1 Error Sources

L-Band anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate radiometer measurements. Early measurements and results from the European Space Agency Soil Moisture and Ocean Salinity (SMOS) mission indicate that, in some regions, RFI is present and detectable. The SMAP radiometer electronics and algorithms have been designed to include features to mitigate the effects of RFI. The SMAP radiometer implements a combination of time and frequency diversity, kurtosis detection, and the use of 3rd and 4th Stokes parameter thresholds to detect and where possible mitigate RFI (Piepmeier et al. 2016, Bringer et al. 2017, Piepmeier et al. 2014). Data elements associated with subbands are included in the Level-1B radiometer product to track and enable RFI detection and mitigation. Further corrections are applied to mitigate water/land contamination.

The input Level-1A radiometer data can also contain bit errors caused by noise in communication links and memory storage devices. The packets produced by the Consultative Committee on Space Data Systems (CCSDS) include error-detecting Cyclic Redundancy Checks (CRCs), which the Level-1A processor uses to flag errors.

2.5.2 Quality Assessment

For in-depth details regarding the quality of these data, refer to the Validated Assessment Report.

SMAP data sets provide multiple means to assess quality. Each data set contains bit flags, uncertainty measures, and file-level metadata that provide quality information. The Appendix of this document and the Product Specification Document describe the specific bit flags, uncertainty measures, and file-level metadata contained in this data set.

Each SMAP HDF5 data file contains metadata with Quality Assessment (QA) metadata flags. These QA metadata flags are calculated and set by the SDS at JPL prior to delivery to the National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC). A separate, ISO 19115-compliant metadata file with an .xml file extension is also delivered to NSIDC DAAC with the HDF5 data file; it contains the same information as the 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.

In addition, various levels of QA are conducted with Level-1B data. If a file passes QA, the SDS applies that file for higher-level processing, browse generation, active science QA, and data archive and distribution. If a product fails QA, it is never delivered to NSIDC DAAC.

3 INSTRUMENTATION

3.1 Description

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

4 SOFTWARE AND TOOLS

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

5 VERSION HISTORY

Table 2. Version History

Version	Date	Version Changes
V1	July 2015	First public data release
V2	October 2015	No science change. CRID incremented to coincide with DOI correction for SPL2SMP and SPL3SMP.
V3	April 2016	Changes to this version include: Updated reflector thermal model Reflector emissivity value back to baseline All calibration coefficients updated back to 3/31/15 Direct Galaxy quality flag changed: set when s/c nadir > 5 degrees Reflected Sun quality flag changed: set when specular solar theta <15 degrees Sea ice fraction computation implemented
V4	June 2018	Changes to this version include: Added procedure to correct brightness temperatures for water/land contamination near coastlines. New data fields for this correction include: f*ootprint_surface_status, surface_water_fraction_mb_h, surface_water_fraction_mb_v, tb_h_surface_corrected*, and *tb_v_surface_corrected*. Improved Level-1 calibration coefficients and reflected galaxy correction. To refine reflected galaxy correction over ocean, NOAA NCEP ocean roughness data have been added (*wind_direction_ancillary, wind_speed_ancillary*).
V4	January 2021	Changes to this version included: Extended temporal coverage to 27 August 2020

6 RELATED DATA SETS

SMAP Data at NSIDC | Overview

SMAP Radar Data at the ASF DAAC

7 RELATED WEBSITES

SMAP at NASA JPL

8 CONTACTS AND ACKNOWLEDGMENTS

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9 REFERENCES

Bringer, A., J. T. Johnson, P. N. Mohammed, J. R. Piepmeier, 2017. Performance of SMAP radiometer RFI detection algorithms and analysis of residual RFI sources. In Geoscience and Remote Sensing Symposium (IGARSS), 2017 IEEE International, 1243-1246.

Piepmeier, J., G. De Amici, P. Mohammed, and J. Peng. 2017. Improved Calibration through SMAP RFI Change Detection.

Piepmeier, J. R. et al. 2018. SMAP Algorithm Theoretical Basis Document: L1B Radiometer Product: Includes L1A and L1B, Rev. C. SMAP Project, NASA GSFC SMAP-006, NASA Goddard Space Flight Center, Greenbelt, MD. (PDF, 1.95 MB; see Technical References).

Piepmeier, J. R. et al. 2016. SMAP Algorithm Theoretical Basis Document: L1B Radiometer Product: Includes L1A and L1B. SMAP Project, NASA GSFC SMAP-006, NASA Goddard Space Flight Center, Greenbelt, MD. (PDF, 1.94 MB; see Technical References).

Piepmeier, J. R. , J. T. Johnson, P. N. Mohammed, D. Bradley, C. Ruf, M. Aksoy, R. Garcia, D. Hudson, L. Miles, and M. Wong. 2014. Radio-Frequency Interference Mitigation for the Soil Moisture Active Passive Microwave Radiometer. IEEE Transactions on Geoscience and Remote Sensing. 52(1):761-775. doi: https://dx.doi.org/10.1109/TGRS.2013.2281266.

Piepmeier, J. R., D. G. Long, and E. G. Njoku. 2008. Stokes Antenna Temperatures. IEEE Trans. Geosci. Remote Sens. 46(2):516-527.

10 DOCUMENT INFORMATION

10.1 Publication Date

21 December 2018

10.2 Date Last Updated

28 January 2021