CloudSat Project

A NASA Earth System Science Pathfinder Mission

Level 2B-TB94 Process Description and Interface Control Document

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31 October 2019	0	Initial Release	All

Contents

1. Introduction

The new CloudSat Brightness Product (2B-TB94) 94 GHz Brightness Temperature is calculated from the radiometric measure obtained by processing the noise floor data contained in 1B-CPR. This document presents the calibration theory and defines the Level 2B-TB94 contents.

2. Algorithm

2.1. Algorithm: Overview

The 2B-TB94 product is created by first calculating the filtered noise measured by CPR, then applying coefficients to convert to Brightness Temperature. Since CPR lacks native radiometric calibration sources, the filtered noise to TB94 conversion coefficients are calculated via radiative transfer modeling.

2.2. Algorithm: Creating Filtered Noise

The 2B-TB94 product includes as many range bins as possible when creating a noise value for a given profile. The algorithm for 2B-TB94 filtered noise is described below, starting with the single profile noise and then filtered noise.

Received Echo power from the CloudSat 1B-CPR product is read and for each profile (a vertical column corresponding to a single CPR footprint), the max number of bins are used to calculate noise as described below, more than the 20 bins used in R04 2B-GEOPROF if possible. 2B-GEOPROF CPR_cloud_mask is used to aid in determining which bins are filled with noise without cloud nor surface backscatter. An iterative process is used to flag bins that are outside the noise threshold. The noise value for each profile and the standard deviation of the noise is saved.

The temperature of the CPR receiver varies throughout the orbit and the season effecting the TB94 measurement. This variation is minimized through empirical means.

Profile noise is filtered along track with six window sizes: 1 profile, 5 profiles, 11 profiles, 31 profiles, 61 profiles and 101 profiles. The determination of what window to use is made individually for each profile based on minimizing the standard deviation; the standard deviation of each valid window size was calculated, then the window with the smallest standard deviation was used. If there was no valid window size, the original, unfiltered value was used.

2.3. Algorithm: Creating Conversion Coefficients

Kummerow's Eddington model is used with the Lui (2011) model for surface emissivity and the Leibe (1993) reduced Rosenkranz gaseous attention model to map 94GHz filtered noise to brightness temperature. The model takes in a pressure, temperature and water vapor profile from ECMWF-AUX. The water vapor profile is rescaled to match the

column total of AMSR-E. AMSR-E TB89 is used to account for bias in the model by comparing modeled versus measured TB89, and then correcting the modeled TB94. Modeled TB94 is plotted against filtered noise to obtain the linear fit coefficients. The coefficients are applied and the value is reported as tb94_BrightnessTemperature.

3. 2B-TB94 Algorithm Inputs

3.1. CloudSat Input Data

3.1.1. CloudSat Engineering Data

The following field from CloudSat engineering data is processed at JPL:

Receiver Temperature

3.1.2. CloudSat Level 1B CPR P_R05 Data

The following fields from 1B-CPR are used in 2B-TB94:

RecievedEchoPowers
RangetoFirstBin
Range_to_intercept
RayStatus_pulses_transmitted
RayStatus_pri
RayStatus_data_quality
SurfaceBinNumber

3.1.3. CloudSat Level 2B-GEOPROF P1_R05 Data

The following fields from 2B-GEOPROF are used in 2B-TB94:

Radar_Reflectivity
CPR_Cloud_mask
sem_NoiseFloor
sem_NoiseFloorVar
SurfaceHeightBin

3.1.1. CloudSat ECMWF-AUX P_R05 Data

The following fields from ECMWF-AUX are used in 2B-TB94:

Skin_temperature
Pressure
Specific_humidity
Temperature

3.2. Non-CloudSat Input Data

3.2.1. AMSR-E data

The following fields from AMSR-E 89GHz are used in 2B-TB94:

89GHz brightness temperature
Medium resolution wind speed

4. Data Product Output Format

4.1. Format Overview

The CPR 2B-TB94 product contains the 94GHz Brightness Temperature product along with fields used to create TB94, as well as geolocation and data quality fields passed through from 1B-CPR. The format is similar to 1B-CPR with some data fields reported as 1 x number of profiles per granule or one value per granule.

4.2. CPR Level 2B-TB94 HDF-EOS Data Contents

The following lists the contents of the CPR Level 2B-TB94 HDF files.

Profile time (array size nray, 4 byte float, range: 0 to $6x10^3$, missing value: none): seconds since start of granule.

UTC_start (scalar, 4 byte float, range: 0 to 86400, missing value: none): UTC seconds since 00:00Z in first profile of granule.

TAI_start (scalar, 8 byte float, range: 0 to 6e8, missing value: none): contains the International Atomic Time (TAI time) as the number of seconds since January 1, 1993 00:00:00Z.

Navigation data (each are size nray)

Name	Format	Description
Latitude (range: -90 degrees to 90 degrees, missing value: none)	4-byte float	The latitude (degrees) of the boresight/geoid intersection.
Longitude (range: -180 degrees to 180 degrees, missing value: none)	4-byte float	The geodetic longitude (degrees) of the boresight/geoid intersection.
Range_to_intercept (range 600 km to 800 km, missing value: none)	4-byte float	Range from spacecraft to CPR boresight intercept with the Earth Geoid (km)
DEM_elevation (range: -9999 to 8850 m, missing value: 9999)	2-byte integer	Surface elevation at geodetic lat/lon (m) above the Earth Ellipsoid. –9999 indicates ocean, 9999 indicates an error in its calculation.

The geodetic latitude and longitude are represented as floating point decimal degrees. Latitude is positive north, negative south. Longitude is positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.

Pitch_offset (scalar, 4-byte float, range: -90 to 90):
along track pointing offset of CPR, with positive corresponding to forward pointing.

Roll_offset (scalar, 4-byte float, range: -90 to 90):
across track pointing offset of CPR, with positive corresponding to right pointing.

Data_quality (array size nray, 1-byte integer, range: 0 to 127):
0 for nominal operations, otherwise interpret as a bit flag (0=false, 1=true)

Bit 0: RayStatus_validity not normal[1]
Bit 1: GPS data not valid
Bit 2: Temperatures not valid[2]
Bit 3: Radar telemetry data quality not normal[3]
Bit 4: Peak power not normal[4]
Bit 5: CPR calibration maneuver
Bit 6: Missing frame
Bit 7: Data advisory, check website

[1]This bit is set if bits 0, 1, or 2 of RayStatusValidty = 1 or Poor Pointing is set to 1.
[2]Valid temperature range is −10°C to 50°C.
[3]Valid Radar parameter ranges are: Pulse Width [0, 7]; PTT [475, 704]; Range to first bin [650, 750] Km; PRI [142,196]; Data Window Delay [0, 31].
[4]Valid Peak power range is [500, 2200] watts.

Sigma zero noise corrected (Sigma_Zero_nc) (100*dB) (array size nray, 2-byte integer, range: -1000 to 4000, missing value: -9999):
The Sigma-Zero is the normalized surface cross section (not corrected for attenuation, with the L1B sem_NoiseFloor removed). It's multiplied by 100 and stored as 2-byte integers.

tb94_new_sem_NoiseFloor (array size nray, 4-byte float):
Single footprint noise estimate using as many bins as possible, not just the highest 20 bins that sem_NoiseFloor uses.

tb94_new_sem_NoiseFloorStd (array size nray, 4-byte float):
Standard deviation of tb94_new_sem_NoiseFloor.

tb94_BrightnessTemperature (array size nray, 4-byte float):
94GHz brightness temperature.

tb94_window_size (array size nray, 4-byte float):
The size of the window used in along-track averaging to calculate the brightness temperature. The number of footprints averaged equals (2 * tb94_window_size) + 1.

tb94_new_num_bins (array size nray, 4-byte float):
The number of range bins used to calculate tb94_new_sem_NoiseFloor.

tb94_c1c2 (array size 2 elements, 4-byte float):
The coefficients linking the 94GHz brightness temperature with the along track averaged noise. tb94_Brightness_Temperature = (along track filtered noise) * tb94_c1c2(1) + tb94_c1c2(2).

unused (scalar):
This field intentionally left zero filled.

The following fields have a value of zero for nominal operations during the pre-DO-Op period (2006 to April 2011); a more detailed explanation for how these fields should be interpreted can be found in the 1B-CPR documentation:

Data _status (array size nray, 1-byte integer, range: 0 to 65535) Contains 15 bit flag
Data_targetID (array size nray, 1-byte unsigned integer, range: 0 to 203)
RayStatus_validity (array size nray, 1-byte unsigned integer, range: 0 to 31)

5. References

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6. Acronym List

AMSR-E	Advanced Microwave Scanning Radiometer for EOS
CIRA	Cooperative Institute for Research in the Atmosphere
CPR	Cloud Profiling Radar
DO-Op	Daylight Only Operations
ECMWF-AUX	European Centre for Medium-Range Weather Auxiliary data
EOS	Earth Observing System
HDF	Hierarchical Data Format