README Document for

TRMM 1B01, Version 006

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Introduction

Data Product Description

This document applies to the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Radiance (VIRS/1B01) product. The TRMM VIRS 1B01 file contains calibrated radiances and auxiliary geolocation information for each pixel in the scan. The

Level 1B data are stored in the Hierarchical Data Format (HDF), which includes both core and product specific metadata applicable to the VIRS measurements. A file contains a single orbit of data with a file size of about 87 MB (uncompressed). The HDF-EOS "swath" structure is used to accommodate the actual geophysical data arrays. There are 16 files of VIRS 1B01 data produced per day.

Spatial coverage is approximately between 38º North and 38º south owing to the 35º inclination of the TRMM satellite. This orbit provides extensive coverage in the tropics and allows each location to be covered at a different local time each day, enabling the analysis of the diurnal cycle of precipitation.

There are in general 18,026 scans along the orbit pre-boost and 18,223 post-boost, with each scan consisting of 261 pixels. The scan width is about 720 km pre-boost and 833 km post-boost.

Temporal coverage begins 1997-12-21. The average operating altitude for TRMM was changed from 350 to 403 km during the period of August 7-24, 2001. This orbit boost maneuver extended the mission life significantly. All post-boost data products had been released by the TRMM Science Project, as of early December 2001. All TRMM data products (post- and pre-boost) are available via the TRMM data search-and-order system at http://disc.gsfc.nasa.gov/data/datapool/TRMM_DP/. The time period before August 7, 2001 is referred to as **pre-boost**, and the time period after August 24, 2001 is referred to as **post-boost**.

Latitude Resolution (pre/post boost): 2.2/2.4 km
Longitude Resolution (pre/post boost): 2.2/2.4 km
Temporal Resolution: 16 orbits per day
Data are reprocessed every 1-3 years as algorithms are improved. The current version of the data is Version 6.

VIRS Instrument Description

The Visible and Inferred Scanner is one of three instruments on the TRMM platform that indicate rainfall. The instrument is sensitive in 5 regions: visible at 0.63µm; near infrared at 1.60, 3.75, and 10.8µm; and infrared at 12.0µm. In addition to delineating rainfall, data from the VIRS instrument can use to used to determine the brightness or temperature of the source.

For more information on the VIRS Instrument see:

- http://trmm.gsfc.nasa.gov/overview_dir/virs.html
- The Tropical Rainfall Measuring Mission (TRMM) Sensor Package
- Four Years of TRMM/VIRS On-Orbit Calibrations and Characterization Using Lunar Models and Data from Terra/MODIS

1B01 Algorithm Description

TRMM VIRS 1B01 data is derived from the VIRS Level 1A (1A01) product.

For channels 1 and 2, Level 1B radiances are derived from the Level 1A (1A01) sensor counts by computing calibration parameters (gain and offset) derived from the counts registered during space and solar and/or lunar views. New calibration parameters are produced every one to four weeks. Channels 3, 4, and 5 are calibrated using the internal blackbody and the space view. These calibration parameters, together with a quadratic term determined pre-launch, are used to generate a counts vs. radiance curve for each band, which is then used to convert the earth-view pixel counts to spectral radiances.

For more information on the VIRS/1B01 algorithm see

- An Overview of the Visible and Infrared Scanner Radiometric Calibration Algorithm
- 1B01 Algorithm Status page

Data Citation

NASA **requests that you include the following acknowledgment in papers published using these data:**

"The data used in this study were acquired as part of the NASA's Earth-Sun System Division and archived and distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC)."

We would appreciate receiving a copy of your publication, which can be forwarded to the following address:

Goddard DAAC Help Desk
Code 610.2
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Data Organization

Each TRMM 1B01 file contains data gathered in one nodal orbit. Each orbit is centered on it's longitude of maximum latitude. The temporal range for each file is about 91.5 minutes (pre-boost) and 92.5 minutes (post boost).

Filenaming Convention

TRMM 1BO1 files are named in accordance to the following convention:

1B01.<date>.<orbit number>.<product version>.HDF

The format for the date is YYMMDD.

For example, VIRS version 6 data gathered on 22 April 2007 for orbit 53742 can be found in the file named “1B01.070422.53742.HDF”.

File Format and Structure

TRMM VIRS 1B01 data files were created using **Hierarchical Data Format (HDF)**.The following table summarizes the contents and structure of the VIRS Calibrated Radiance (1B01) file. Further information can be found in Volume 3 of the "File Specifications for TSDIS Products - Level 1”:

Name	*HDF Name*	*Type*	*Record Size (byte)*	*Dim Size/ # of Records*
ECS Core Metadata	ArchiveMetadata.0	Attribute (Char)	10,000	-
PS Metadata	CoreMetadata.0	Attribute (Char)	10,000	-
Swath Structure	SwathStructure	Attribute (Char)	5,000	-
Scan Time	scan_time	Vdata Table	8	nscan
Geolocation	Geolocation	SDS Float	4	2*261*nscan
Scan Status	scan_status	Vdata Table	19	nscan
Navigation	Navigation	Vdata Table	88	nscan
Solar Cal	solarCal	Vdata Table	32	nscan
Calibration Counts	calCounts	SDS Integer	2	5*2*3*nscan
Temperature Counts	tempCounts	SDS Integer	2	6*nscan
Local Direction	localDirection	SDS Float	4	2*2*27*nscan
Channels	Channels	SDS Integer	2	5*261*nscan

Key Metadata Fields

OrbitNumber	The orbit number to be used in calculating the spatial extent of this data.
RangeBeginningDate	The date when coverage began.
RangeBeginningTime	The time when coverage began
RangeEndingDate	The date when coverage ended.
RangeEndingTime	The time when the granule coverage ended

LongitudeOfMaximumLatitude	Longitude of the northernmost extent of the satellite orbit. Decimal degrees with 6 figures precision after the decimal point. Positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.
OrbitAdjustFlag	Orbit Adjust Flag. Values are as follows: 0 = no orbit adjust activity during this orbit. 1 = orbit adjustment control modes occurred during this orbit
AttitudeModeFlag	Attitude Mode Flag. Values are as follows: 0 = forward mode (+X forward) throughout this orbit –S to N scanning 1 = backward mode (-X forward) throughout this orbit –N to S scanning 2 = yaw maneuver during this orbit
OrbitSize	Number of scans in Orbit. If the granule is empty, Orbit Size = 0.

Data Contents

Geophysical Parameters

Before being store in its sds as a two-byte integer, radiance values for each channel are multiplied by the scaling factors specified in the '**VIRS Range and Accuracy**' table found in the **Data Interpretation** section of this document.

The maximum and minimum value for temperature counts is listed in the table below. The maximum and minimum values for each of the radiance channels can be found in the '**VIRS Range and Accuracy**' table.

Name	Description	Scaled by	Range	Unit
Scan Time	Time associated with each scan	-	-	-
Geolocation	Earth location of the center of the IFOV at the altitude of the earth ellipsoid	-	-	degree
Scan Status	Status of each scan	-	-	-
Navigation	Spacecraft geocentric information	-	-	-
Solar Cal	Solar unit vector in Geocentric Inertial Coordinates, and the Sun-Earth distance	-	-	-
Calibration Counts	Raw calibration counts data	-	-	-
Temperature Counts	Primary and redundant temperatures for the black body, radiant cooler, and the electronics module	-	0 - 4095	counts
Local Direction	Angles to the satellite and sun from the IFOV pixel position on the earth	-	-	degree

Name	Description	Scaled by	Range	Unit
Channels	Scene data for the five channels (mW = milliwatts, sr = steradian). Accuracy depends on channels	depends on channels	depends on channels	(mW $cm^{-2}\mu m^{-1}$ sr^{-1})

Options for Reading the Data

There are several options for reading the data. The HDF Toolkit ships with two binary executables, hdp and ncdump, that can be used to extract values from any HDF file. In addition, the GES DISC provides sample read software in both C and Fortran.

hdp and ncdump

These are also available as standalone executables in the utilities subdirectory for each operating system at: ftp://ftp.hdfgroup.org/HDF/HDF_Current/bin, e.g., ftp://ftp.hdfgroup.org/HDF/HDF_Current/bin/linux/utilities.

To dump entire file:

`hdp` <*file name*>

`ncdump` <*file name*>

Example:

```
hdp 1B01.070312.53103.6.HDF

ncdump 1B01.070312.53103.6.HDF
```

To dump an sds:

`hdp dumpsds -n` <*sds name*> <*file name*>

`ncdump -v` <*sds name*> <*file name*>

where *sds name* is one of:

```
geolocation
calCounts
tempCounts
localDirection
```

```
channels
```

Example:

```
hdp dumpsds -n channels 1B01.070312.53103.6.HDF

ncdump –v channels 1B01.070312.53103.6.HDF
```

To dump vdata:

`hdp dumpvd –n` <*vdata name*> <*file name*>

where *vdata name* is one of :

```
ArchiveMetadata.0          satsun
CoreMetadata.0             scan
bb_sv_sd                   scan_status
channel                    scan_time
dataword                   solarCal
latlon                     SwathStructure
navigation                 tempindex
pixel                      VIRSChannelsScalingFactors.0
pixel_ld                   zenazm
```

Example:

```
hdp dumpvd –n navigation 1B01.070312.53103.6.HDF
```

TSDIS Toolkit

TSDIS developed the TSDIS Science Algorithm Toolkit to assist the TRMM Science Team's algorithm developers. The toolkit provides a library of commonly used routines, constants, and macros. It also allows seamless integration of TRMM algorithms into the TSDIS environment.

The toolkit provides routines for reading and writing data to and from the HDF files; routines are provided for Levels 1-3 products and for both satellite and GV. Each of the routines in the toolkit are callable in either C or Fortran. The toolkit also includes routines for reading land/sea data and topographical data.

Support for the TSDIS Tookit can be found at TSDIS Toolkit Homepage or by contacting TSDIS at ***toolkit@tsdis.gsfc.nasa.gov***.

Visualizing Data

Tools are available to help users visualize data in the Hierarchical Data Format (HDF).

TSDIS Orbit Viewer

The TSDIS Orbit Viewer is a menu-driven graphical interface for dynamically generating images from TRMM HDF files. The viewer can display, at the full instrument resolution, TRMM satellite, Ground Validation, browse, and Coincidence Subsetted Intermediate (CSI) products, as well as other derived products.

The software runs on Microsoft Windows and UNIX.

The source code and installation instructions for the Orbit Viewer are available from the Goddard DISC's TRMM ftp site (ftp://disc2.nascom.nasa.gov/software/trmm_software/Orbit_Viewer).

Please note: TSDIS can provide technical support for the Orbit Viewer only to certain members of the TRMM Science Team. Other users should contact the DISC's Hydrology Data Support Team (hydrology-disc@listserv.gsfc.nasa.gov).

HDFView

HDFView is a Java based graphical user interface created by the HDF Group which can be used to browse TRMM VIRS HDF files. The utility allows users to view all objects in an HDF file hierarchy which is represented as a tree structure.

HDFView can be downloaded at ftp://ftp.hdfgroup.org/HDF5/hdf-java/. Documentation for HDFView can be view at

http://hdf.ncsa.uiuc.edu/hdf-java-html/hdfview/UsersGuide/index.html.

Sample Read Software

TRMM HDF Data File Read Software

The Goddard DISC Hydrology Team has developed the TRMM HDF Data File Read Software, first released in February 1999. The software reads TRMM HDF data files and

writes out to flat binary files. The software has been tested with most of the TRMM standard products, as well as with some derived subset products. Both C and Fortran versions are available from ftp://disc2.nascom.nasa.gov/software/trmm_software/Read_HDF/.

TSDIS Sample Software

TSDIS offers examples of TRMM read software written in C, Fortran, and IDL on their tutorial page.

Mathlib

A sample Mathlib routine for reading TRMM data can be viewed at http://tsdis02.nascom.nasa.gov/tsdis/Documents/2A23_Users_Guide_V5

Data Interpretation and Screening

Scaling factors, range and accuracy for the 5 channels of the TRMM VIRS are found in the table below. Values of radiance for a channel can be found by dividing the integer values found in the SDS for a channel by the scale factor for that channel.

VIRS Range and Accuracy				
Channel	**Scale Factor**	**Minimum ($mW\ cm^{-2}\ \mu m^{-1}\ sr^{-1}$)**	**Maximum ($mW\ cm^{-2}\ \mu m^{-1}\ sr^{-1}$)**	**Accuracy**
1	500	0	55.840	10%
2	1000	0	32.7	10%
3	100000	0	0.111	2%
4	10000	0	1.371	2%
5	10000	0	1.15	2%

Information provided in the 'scan_status' Vdata section of a VIRS HDF file can be used to quality-screen the data. The "Scan Status Table" in the appendices describes each field of the 'scan_status' record.

If data is missing for a scan, the "missing" byte of the scan status will be 1. Missing radiance data is denoted by -9999 in the channels sds. In general any missing data in the

VIRS HDF file will be denoted by values less that or equal to -99 for 1-byte integers, -9999 for 2-type integers, and -9999.9 for 4-byte and 8-byte floats.

Troubleshooting

- Common mistakes in reading or interpreting the data

  - Failure to take boost into account when interpreting VIRS data

    The altitude of the TRMM platform was changed between August 7th and 24th of 2001 resulting in a slight decrease in resolution of the VIRS data

  - Failure to screen missing data values

  - Attempts to read empty files

    Not all VIRS files contain data. If the OrbitSize metadata item found in the 'ArchiveMetadata.0' Vdata HDF section equals zero, the file contains no data. Check the TRMM Outage Page for a list of orbit number for which the associated file contains no data.

More Information

- Articles discussing product validity and quality

  - Spurious Signals in TRMM/VIRS Reflectance Channels and Their Effect on Aerosol Retrievals (Alexander Ignatov)

  - A first comparison Remote sensing of fires with the TRMM **VIRS**son of global merged precipitation analyses withTropical Rainfall Measuring Mission (TRMM) data (Bolvin, D.T. Adler, R.F. Huffman, G.J. Nelkin, E.J.)

  - Four Years of TRMM/VIRS On-Orbit Calibrations and Characterization Using Lunar Models and Data from Terra/MODIS (Cheng-Hsuan Lyu and William L. Barnes)

- Articles using the data

  - Retrieval of Sea Surface Temperature from TRMM VIRS (Lei Guan, Hiroshi Kawamura and Hiroshi Murakami)

- Remote sensing of fires with the TRMM **VIRS** (L GIGLIO)
- Ice Cloud Properties in Ice-Over-Water Cloud Systems Using TRMM VIRS and TMI Data (Patrick Minnis1, Jianping Huang, Bing Lin1, Yuhong Yi, Robert F. Arduini,Tai-Fang Fan, J. Kirk Ayers, and Gerald G. Mace)

Acknowledgments

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The TSDISToolkit and Orbit Viewer were produced by the TRMM Science Data and Information System.

Hdp and HDFview were created by the HDF Group.

Ncdump was produced by Unidata.

Appendices

Description of Metadata Fields

CoreMetadata.0:

ECS Metadata Element	***Description***
Short Name	The unique identifier of an ECS collection to which this granule belongs (i.e. “Total Power, Noise”).
Size MB ECS Data Granule	The size attribute will indicate the volume of data contained in the granule.
Spatial Coverage Type	This attribute denotes whether the locality/coverage requires horizontal, vertical or both spatial domain and coordinate system definitions.
Ellipsoid Name	Name of the ellipsoid.
Equatorial Radius	Equatorial radius of the earth ellipsoid (meters).

ECS Metadata Element	***Description***
Denominator of Flattening Ratio	The reciprocal of the flattening ratio, *f*, where $f = 1 - b / a$, *a* = Equatorial radius of the earth ellipsoid and *b* = Polar radius of the earth ellipsoid
Orbit Model Name	The reference name to the orbital model to be used to calculate the geolocation of this data to determine global spatial extent.
Orbit Number	The orbit number to be used in calculating the spatial extent of this data.
Semi Major Axis	Half of the long axis of the orbit ellipse (meters).
Mean Anomaly	Angle around the orbit at the Epoch Time about the Ellipse center from the ascending node (radians).
Right Ascension of Ascending Node	Right Ascension in Geocentric Inertial Coordinates of the north bound equator crossing (radians).
Argument of Perigee	Angle from the ascending node to perigee (radians).
Eccentricity	Eccentricity of ellipse (unit-less).
Inclination	Angle between Orbit plane and Earth Equatorial plane (radians).
Epoch date	Reference date for orbital elements.
Epoch time	Reference time for orbital elements.
Epoch milliseconds	Reference milliseconds for orbital elements.
West Bounding Coordinate	The degree value for the west longitude of boundary.
East Bounding Coordinate	The degree value for the east longitude of boundary.
North Bounding Coordinate	The degree value for the north latitude of boundary.
South Bounding Coordinate	The degree value for the south latitude of boundary.
Temporal Range Type	This tells the system how temporal coverage is specified for the granule.
Range Beginning Date	The date when the granule coverage began. Granule coverage is defined as the orbit for Level-1 and Level-2 satellite data, as the hour of the granule for Level-1 and Level-2 ground validation data, as the day of the granule for rain gauge and disdrometer data, and as the pentad or month of the granule for Level-3 data.
Range Beginning Time	The time when the granule coverage began. See beginning date.
Range Ending Date	The date when the granule coverage ended. See beginning date.
Range Ending	The time when the granule coverage ended. See beginning date.

ECS Metadata Element	***Description***
Time	
QA Parameter Name	"ScienceQualityFlag"
QA Parameter Value	A post processing indication of quality by the algorithm developer. The Quality Indicator takes the form of 4 possible ASCII strings: `"NOT BEING INVESTIGATED", "BEING INVESTIGATED", "FAILED",` or `"PASSED"`.
Reprocessing Actual	This attribute identifies the intent of the product author to reprocess the data (i.e. data gaps, geolocation accuracy, scientist review quality flags).
Browse Pointer	This attribute will contain a system-resolvable reference to an HDF package containing a collection of browse granules.
Contact Name	The name of the algorithm developer related to this granule. The contact name supplied here must exist in the ECS contact database.

ArchiveMetadata.0:

PS Metadata Element	***Description***
GranulePointer	TSDIS granule ID
Algorithm ID	Name of the algorithm (i.e. 1B21)
Algorithm Version	The version of the science algorithm is written as "*M.m*", where *M* is an integer corresponding to major revisions of the code. Major revisions are changes in the science algorithm which do affect the science, are delivered to TSDIS in an official delivery package, and require reprocessing. "*m*" is an integer corresponding to minor revisions or corrections. Minor revisions or corrections are made so the science algorithm will function properly in TSDIS, do not affect the science, are not delivered to TSDIS in an official delivery package, and do not require reprocessing. "*M*" is written without leading zeroes, with a range from 1 to 99. "*m*" is written with leading zeroes, with a range from 00 to 99. At launch, the version of all science algorithms is "1.00".
Product Version	A single integer indicating the version of the product. The first Product Version Number is 1. The Product Version Number is incremented every time the product is reprocessed due to the fact that the algorithm creating it changes or the algorithms creating the input to the algorithm change.
Toolkit Version	Version of Toolkit used to create this granule

Anomaly Flag	This flag indicates if and why a granule is empty. The possible values are: “EMPTY: GENERATED AFTER SOFTWARE ERROR” * “EMPTY: NO DATA DUE TO NO RAIN” “EMPTY: NO DATA RECORDED” “EMPTY: DATA RECORDED BUT STILL MISSING” “EMPTY: REASON UNKNOWN” * “NOT EMPTY: POSSIBLE PROBLEM” “NOT EMPTY” * It is expected that satellite data would use only the three values followed by an asterisk. GV data is expected to use all seven values.
Missing Data	Number of missing scans in the orbit (satellite data) or missing rays (ground radar data).
Percentage of bad or missing pixels	List by channel of the percentage of bad or missing pixels in the orbit (satellite data) or granule (GV data).
Number of Data Gaps	The number of data gaps in the data in the orbit (satellite data) or granule (GV data).
Data Gaps	The sum of the durations of the data gaps in seconds in the orbit (satellite data) or granule (GV data).
Data Accuracy	List by channel of the accuracies of the data.
Maximum valid value of channel	List by channel of the maximum valid value (value specified by the instrument scientist).
Minimum valid value of channel	List by channel of the minimum valid value (value specified by the instrument scientist).
Min Max Units	Units of the Minimum and Maximum valid values.
Input Files	List of input granule IDs.
Date of Generation of input files	List of the generation dates of the input files. For ingested files, this is the date TSDIS received the file.
Data center source of input files	List of the data centers generating the input files, e.g., TSDIS, NMC
Generation date	Date the dataset was generated
DayNight	Percentage scans during the orbit in daytime mode
SolarChannelGains	Channel 1 Mirror Side A, Channel 1 Mirror Side B Channel 2 Mirror Side A, Channel 2 Mirror Side B
Longitude of Maximum Latitude	Longitude of the northernmost extent of the satellite orbit. Decimal degrees with 6 figures precision after the decimal point. Positive east, negative west. A point on the 180th meridian is assigned to the western hemisphere.
Mean Motion	Number of orbits per day, including fractions of orbits.
Orbit Adjust Flag	Orbit Adjust Flag. Values are as follows: 0 = no orbit adjust activity during this orbit. 1 = orbit adjustment control modes occurred during this orbit.
Attitude Mode Flag	Attitude Mode Flag. Values are as follows: 0 = forward mode (+X forward) throughout this orbit 1 = backward mode (-X forward) throughout this orbit 2 = yaw maneuver during this orbit

Solar beta angle at beginning of granule	Elevation of sun in the orbit plane at the orbit start (degrees).
Solar beta angle at end of the granule	Elevation of sun in the orbit plane at the orbit end (degrees).
Sensor Alignment	Euler Sequence (3 integers) and Euler angles for rotation from spacecraft coordinates to sensor coordinates in degrees. (These are to be provided by the science team)
Sensor Alignment Channel Offsets	Euler Sequence (3 integers) and Euler angles for rotation from sensor coordinates to Channel coordinates with angles separately for each channel in degrees. (These are to be provided by the science team if needed, but they are not nominally used in TSDIS processing since geolocation is not done per channel)
Scan Path Model	Parameters describing the scan path as used for pixel geolocation. For a (nominal) conical scan model the following parameters are used: Axis of Scan (±1, 2, or 3). Reference Axis for zero rotation angle (±1, 2, or 3), and Scan cone angular radius in degrees. Starting rotation angle relative to the scan axis in degrees, Total rotation angle spanned in degrees, Active scan duration time in seconds (between first and last pixel), and Time Offset between spacecraft time of the sensor data packet and the first pixel time, in seconds.
Scan Path Parameters Per Channel	Parameters describing the scan path separately for each channel in degrees. (These are to be provided by the science team if needed, but they are not nominally used in TSDIS processing since geolocation is not done per channel)
Ephemeris File Descriptor	TSDIS granule ID for the ephemeris file. The format is EPHEM.*YYMMDD.nn*, where *YY* is year, *MM* is month, *DD* is day of the month, and *nn* is the version number.
Orbit Size	Number of scans in Orbit. If the granule is empty, Orbit Size = 0.
Orbit First Scan UTC Date	Orbit First Scan UTC Date in the format described in Section 3. If the granule is empty, the value is ‘0/0/0’.
Orbit First Scan UTC Time	Orbit First Scan UTC Time in the format described in Section 3. If the granule is empty, the value is ‘0:0:0’.
Orbit First Scan UTC Milliseconds	Orbit First Scan UTC Milliseconds in the format described in Section 3
Orbit First scan time - Spacecraft clock - seconds	The seconds field of the spacecraft clock time of the first scan in the orbit
OrbitFirstSCSecs	The subseconds field of the spacecraft clock time of the first scan in the orbit
Orbit Last Scan UTC Date	Orbit Last Scan UTC Date in the format described in Section 3. If the granule is empty, the value is ‘0/0/0’.
Orbit Last Scan UTC Time	Orbit Last Scan UTC Time in the format described in Section 3. If the granule is empty, the value is ‘0:0:0’.
Orbit Last Scan UTC Milliseconds	Orbit Last Scan UTC Milliseconds in the format described in section 3

Orbit Last scan time - Spacecraft clock - seconds	The seconds field of the spacecraft clock time of the last scan in the orbit
OrbitLastSCSubsecs	The subseconds field of the spacecraft clock time of the last scan in the orbit
UTCF seconds	The seconds field of the UTCF for the granule.
UTCF subseconds	The subseconds field of the UTCF for the granule.
UTCF flag	Flag that indicates the origin of the UTCF. 0 = UTCF was derived from the first ACS packet in the orbit. 1 = a corrected UTCF was used.
Leap second flag	Flag that indicates if a leap second or UTCF update occurred within the granule. 0 = none; 1 = leap second; 2 = UTCF change; 3 = both leap second and UTCF change

Description of Data Fields

Calibration Counts (SDS, array size 5 × 2 × 3 × *nscan*, 2-byte integer):
Raw calibration counts are given in four dimensions. The first dimension is the channel number, the second dimension is the data word, the third dimension is blackbody, space view and solar diffuser, in that order, and the fourth dimension is the number of scans.

Temperature Counts (SDS, array size 6 × *nscan*, 2-byte integer):
Temperatures of the black body, primary and redundant, the radiant cooler temperatures, primary and redundant, the mirror temperature, and the electronics module temperature. All quantities have units of counts, and have minimum values of 0, and maximum values of 4095.

Local Direction (SDS, array size 2 × 2 × 27 × *nscan*, 4-byte float):
Angles (degrees) to the satellite and sun from the IFOV pixel position on the earth are given in 4 dimensions. The first dimension is zenith and azimuth angles, in that order. The zenith angle is measured between the local pixel geodetic zenith and the direction to the satellite. The azimuth angle is measured clockwise from the local North direction around toward the local East direction. The second dimension is the object to which the directions point, namely the satellite and the sun, in that order. The third dimension is the pixel number. Angles are given only for every tenth pixel along a scan: pixel 1, 11, 21, ..., and 261. For the pixel dimension, Offset = 0 and Increment = -10. The fourth dimension is the scan number.

Channels (SDS, array size 5 × 261 × *nscan*, 2-byte integer):

Scene data for the five channels, measured in Radiance (mW cm^{-2} μm^{-1} sr^{-1}) multiplied by a scale factor and stored as 2-byte integers. sr means steradian. The scale factors are 500, 1000, 100000, 10000, and 10000 for channels 1, 2, 3, 4, and 5, respectively. The three dimensions are channel, pixel, and scan.

Other Data Fields

The Vdata object "solarCal" contain one 32-byte record per scan. The contents and format of each record is specified in the following table:

Solar Unit Vector		
Name	**Format**	**Description**
Solar Position [3]	3*8-byte float	Sun Unit Vector (X-component) Sun Unit Vector (Y-component) Sun Unit Vector (Z-component) (Geocentric Inertial Coord)
Distance	8-byte float	Sun-Earth Distance (m)

Raw calibration counts data is stored in the sds object "calCounts". The data is stored in a $5 \times 2 \times 3 \times$ *nscan* array. The dimensions of this array are described in the following table:

Raw Calibration Counts Data	
Dimension	**Data Stored**
1	Channel number
2	Data word
3	Blackbody, space view, solar diffuser
4	Number of scans

Local direction angles are found in a 4-dimensonal array in the sds 'localDirection'. The dimension of the $2 \times 2 \times 27 \times$ *nscan* array are described in the following table:

Local Direction Angles		
Dimension	**Data Stored**	**Description**
1	zenith, azimuth	Zenith angle is measured between the local pixel geodetic zenith and the direction to the satellite. Azimuth angle is measured clockwise from the local North direction around toward the local East direction.

2	object	The object to which the directions point, namely the satellite and the sun
3	pixel number	Angles are given only for every tenth pixel along a scan: pixel 1, 11, 21, ..., and 261.
4	scan number	Scan line number

Navigation data for the TRMM platform can be found in the "navigation" vdata object. There is one record for each scan. The contents of each record are specified in the table below:

TRMM Navigation		
Name	**Format**	**Description**
Spacecraft Geocentric Position [3]	3 × 4-byte float	The position (m) of the spacecraft in Geocentric Inertial Coordinates at the Scan mid-Time (i.e., time at the middle pixel/IFOV of the active scan period). The order of components is: *x*, *y*, and *z*. Geocentric Inertial Coordinates are also commonly known as Earth Centered Inertial coordinates. These coordinates will be True of Date (rather than Epoch 2000 which are also commonly used), as interpolated from the data in the Flight Dynamics Facility ephemeris files generated for TRMM.
Spacecraft Geocentric Velocity [3]	3 × 4-byte float	The velocity (ms $^{-1}$) of the spacecraft in Geocentric Inertial Coordinates at the Scan mid-Time. The order of components is: *x*, *y*, and *z*.
Spacecraft Geodetic Latitude	4-byte float	The geodetic latitude (decimal degrees) of the spacecraft at the Scan mid-Time.
Spacecraft Geodetic Longitude	4-byte float	The geodetic longitude (decimal degrees) of the spacecraft at the Scan mid-Time. Range is -180 to 179.999999.
Spacecraft Geodetic Altitude	4-byte float	The altitude (m) of the spacecraft above the Earth Ellipsoid at the Scan mid-Time.
Spacecraft Attitude [3]	3 × 4-byte float	The satellite attitude Euler angles at the Scan mid-Time. The order of the components in the file is roll, pitch, and yaw. However, the angles are computed using a 3-2-1 Euler rotation sequence representing the rotation order yaw, pitch, and roll for the rotation from Orbital Coordinates to the spacecraft body coordinates. Orbital Coordinates represent an orthogonal triad in Geocentric Inertial Coordinates where the Z-axis is

		toward the geocentric nadir, the Y-axis is perpendicular to the spacecraft velocity opposite the orbit normal direction, and the X-axis is approximately in the velocity direction for a near circular orbit. Note this is geocentric, not geodetic, referenced, so that pitch and roll will have twice orbital frequency components due to the onboard control system following the oblate geodetic Earth horizon. Note also that the yaw value will show an orbital frequency component relative to the Earth fixed ground track due to the Earth rotation relative to inertial coordinates.
Sensor Orientation Matrix [3 X 3]	3 × 3 × 4-byte float	The rotation matrix from the instrument coordinate frame to Geocentric Inertial Coordinates at the Scan mid-Time.
Greenwich Hour Angle	4-byte float	The rotation angle (degrees) from Geocentric Inertial Coordinates to Earth Fixed Coordinates.

Description of Flags and Bit Masks

The VIRS scan status data is found in the "scan_status" Vdata object. Each scan status record contains 16 items which are described in the table below:

TRMM VIRS Scan Status			
Name	**Format**	**Values**	**Description**
Missing	1-byte integer	Value and meaning	Indicates whether information is contained in the scan.
Validity	1-byte integer	Bit and meaning	A summary of status modes.
QAC	1-byte integer	0: No decoding error occurred.	The Quality and Accounting Capsule of the Science packet as it appears in Level-0 data.
Geolocation Quality	1-byte integer	Bit and Meaning	A summary of geolocation quality in the scan.
Data Quality[5]	5 × 1-byte integer		The quality of Channel Data for a given channel on given scan line is the percentage of pixels whose value are within the acceptable range listed in the metadata.
Fractional Orbital	4-byte float		The orbit number and fractional part of the orbit at Scan Time. The orbit fraction part

Number			is calculated as: (Time-Orbit Start Time)/(Orbit End Time-Orbit Start Time)
Current Spacecraft Orientation	1-byte integer	Value and Meaning	Current spacecraft orientation.
Current ACS Mode	1-byte integer	Value and Meaning	Current ACS mode.
Yaw Update Status	1-byte integer	0: Inaccurate 1: Indeterminate 2: Accurate	Yaw update Status.
VIRS Instrument Status	1-byte integer	Bit and Meaning	VIRS instrument status.
VIRS mode	1-byte integer	Bit and Meaning	VIRS mode.
VIRS Abnormal Conditions	1-byte integer	Bit and Meaning	Bit 0 is the most significant bit.

Value and Meaning of Missing	
Value	**Meaning**
0	Scan data elements contain information.
1	Scan was missing in the telemetry data.
2	Scan data contain no elements with rain.

Bit and Meaning of Validity	
Bit	**Meaning if bit=1**
0	Spare (always 0)
1	Non routine spacecraft orientation (2 or 3)
2	Non routine RAC mode (other than 4)
3	Non routine yaw update status (0 or 1)
4	Non routine instrument status (other than 1)
5	Non routine QAC (non-zero)
6	VIRS in non-mission mode (non-zero)
7	VIRS condition is abnormal (non-zero)

Bit and Meaning of Geolocation Quality

Bit	Meaning if bit=1
0	Grossly bad geolocation results: ▪ Spacecraft position vector magnitude outside range: pre-boost 6720 to 6740 km, and post-boost 6773 to 6793 km. ▪ Z component of midpoint of scan outside range -4100 to 4100 km. ▪ Distance from S/C to midpoint of scan outside range: pre-boost 340 to 360 km, and post-boost 393 to 413 km.
1	Unexpectedly large scan to scan jumps in geolocated positions in along and cross track directions for first, middle, and last pixels in each scan. Allowed duration from nominal jump in along track motion = 0.06 km (first pixel), 0.04 km (middle pixel), and 0.06 km (last pixel). Allowed duration from nominal jump in cross track motion = 0.05 km (first pixel), 0.04 km (middle pixel), and 0.05 km (last pixel). Bit set in normal mode only.
2	Scan to scan jumps in yaw, pitch, and roll exceed maximum values. Values are : yaw = 0.0001 radians; pitch = 0.0001 radians; roll = 0.0001 radians. Bit set in normal control mode only.
3	In normal mode, yaw outside range (-0.003, 0.003) radians; pitch outside range (-0.007, 0.007) radians; roll outside range (-0.007, 0.007).
4	Satellite undergoing maneuvers during which geolocation will be less accurate.
5	Questionable ephemeris quality (including use of predicted Ephemeris for quicklook) or questionable UTCF quality.
6	Geolocation calculations failed (fill values inserted in the per pixel geolocation products, but not in metadata).
7	Missing attitude data. ACS data gap larger than 20 seconds.

Bit and Meaning of Data Quality	
Bit	**Meaning if bit=1**
0	Missing
5	Geolocation quality is not normal
6	Validity is not normal
Note: Unless this is 0 (normal), the scan data are meaningless to higher processing. Bit 0 is the least significant bit (i.e., if bit i=1 and other bit = 0, the unsigned integer value is 2**i).	

Value and Meaning of Current Spacecraft Orientation	
Value	**Meaning**
0	+x forward
1	-x forward

2	-y forward
3	Inertial -- CERES Calibration
4	Unknown Orientation

Value and Meaning of Current ACS Mode	
Value	**Meaning**
0	Standby
1	Sun Acquire
2	Earth Acquire
3	Yaw Acquire
4	Nominal
5	Yaw Maneuver
6	Delta-H (Thruster)
7	Delta-V (Thruster)
8	CERES Calibration

Value and Meaning of VIRS Instrument Status	
Value	**Meaning**
0	Day (no calibration occurring)
1	Night
2	Monitor Scan Stability
3	Day with Calibration

Value and Meaning of VIRS Mode	
Value	**Meaning**
0	Missing Mode
1	Safehold Mode
2	Outgas Mode
3	Activation Mode

Value and Meaning of VIRS Abnormal Conditions		
Bit	**Value**	**Meaning**

Value and Meaning of VIRS Abnormal Conditions		
Bit	**Value**	**Meaning**
0	0 1	Normal Scan phase error
1	0 1	Normal Selftest error
2	0 1	Normal Thermal data missing
3	0 1	Normal Moon in space view
4	0 1	Normal H/K data drop-out suspected
5	0 1	Normal SV counts for channel 4 or 5 great than L1B01_MIN_DNSV
6	0	Not used
7	0	Not used

Acronyms

A
ACS.....Attitude Control System
APID .....Application Process ID
C
CCSDS.....Consultative Committee for Space Data Standards
D
DORADE.....Doppler Radar Data Exchange
E
ECS .....EOSDIS Core System
EOSDIS.....EOS Data and Information System
F
FORTRAN.....Formula Translation
G
GMT.....Greenwich Mean Time
GV.....Ground Validation
H
HDF.....Hierarchical Data Format
I
ID .....Identifier
IFOV .....Instantaneous Field of View
IPSDU.....Instrument Power Switching and Distribution Unit

M

MDUL.....Missing Data Units List

N

NASDA.....National Space Development Agency
NCSA.....National Center for Supercomputing Applications
NEXRAD.....Next Generation Radar
NMC .....National Meteorological Center

O

ODL .....Object Development Language (defined in the Planetary Data System Standards Reference)

P

PR.....Precipitation Radar
PS .....Product Specific

Q

QAC .....Quality and Accounting Capsule

S

SDS .....Scientific Data Set
SFDU .....Standard Format Data Unit
SSPA.....Solid State Power Amplifier

T

TBD.....To Be Determined
TMI .....TRMM Microwave Imager
TRMM .....Tropical Rainfall Measuring Mission
TSDIS .....TRMM Science Data and Information System

U

UTC.....Universal Time Coordinated
UTCF .....Universal Time Correlation Factor

V

VIRS .....Visible Infrared Scanner
VOS.....Volume Scan