README Document for

TRMM 2A12, Version 006

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Last revised, February 27, 2008

Revision History

Revision Date	***Changes***	***Author***
2/28/2008	Initial version	John Bonk

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Introduction

Background

Applicable Data Products

The information in this README applies to the TRMM 2A12 product and its associated 2A12 CSI (Coincidence Subsetted Intermediate) products

General description

This document provides basic information for using 2A12, the TRMM Microwave Imager (TMI) Level 2 Hydrometeor Profile Product.

The TMI profiling algorithm (2A12) generates vertical profiles of hydrometeors latent heating from TMI brightness temperatures by blending the radiometric data with dynamical cloud models. For each pixel, the algorithm assigns a surface type (land/ocean/coast) and a freezing height; and computes surface rain, convective surface rain, and profiles of hydrometeors (cloud liquid, cloud ice, water vapor, etc.) and latent heating at 14 vertical levels.

Data Profile

The profile layers are specified in the following tables:

14 Vertical Profiling Layers		**14 Vertical Heating Levels**	
Layer Index	**Layer Height**	**Level Index**	**Level Height**
1	surface - 0.5 km	1	0 km
2	0.5 - 1.0 km	2	1 km
3	1.0 - 1.5 km	3	2 km
4	1.5 - 2.0 km	4	3 km
5	2.0 - 2.5 km	5	4 km
6	2.5 - 3.0 km	6	5 km
7	3.0 - 3.5 km	7	6 km
8	3.5 - 4.0 km	8	7 km
9	4.0 - 5.0 km	9	8 km
10	5.0 - 6.0 km	10	9 km
11	6.0 - 8.0 km	11	10 km

12	8.0 -10.0 km	12	12 km
13	10.0 -14.0 km	13	14 km
14	14.0 - 18.0 km	14	16 km

The TRMM 2A12 Hydrometeor Profile Product is derived from the TRMM 1B11 Brightness Temperature product.

The data are stored in the Hierarchical Data Format (HDF), which includes both core and product specific metadata applicable to the hydrometeor profile as well as geolocation confidence, navigation, data quality, and other information pertinent to the dataset.

A file contains a single orbit of data with a file size of about 103 MB (uncompressed); a 2A12 CSI file contains a subset of an orbital file and is considerably smaller—size will vary by site and degree of coincidence.

Resolution

Note: The average operating altitude for the TRMM platform was changed from 350 to 403 km during the period of August 7-24, 2001. This orbit boost maneuver extended the mission life significantly. 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**.

Resolution and coverage information for the TMI instrument is summarized in the table below:

TRMM Microwave Imager (TMI) Data Characteristics		
	Pre-boost (before 2001-08-07)	**Post-boost (after 2001-08-24)**
Temporal Coverage	Start Date: 1997-12-08 Stop Date: 2001-08-07	Start Date: 2001-08-24 Stop Date: -
Geographic Coverage	Latitude: 38°S - 38°N Longitude:180°W – 180°E	Latitude: 38°S - 38°N Longitude:180°W - 180°E
Temporal Resolution	About 91.5 minutes per orbit About 16 orbits per day	About 92.5 minutes per orbit About 16 orbits per day
Horizontal Resolution	4.4 km at 85.5 GHz	5.1 km at 85.5 GHz
Vertical Resolution	0.5 km from surface to 4 km 1.0 km from 4 to 6 km 2.0 km from 6 to 10 km 4.0 km from 10 to 18 km	0.5 km from surface to 4 km 1.0 km from 4 to 6 km 2.0 km from 6 to 10 km 4.0 km from 10 to 18 km
Scan	Swath Width: 760 km	Swath Width: 878 km

Characteristics	Pixels/Scan: 104 (low resolution) 208 (high resolution) Scans/Second (SS): 36.100/60 Seconds/Orbit (SO): 5490 Average Scans/Orbit: nscan = SS*SO+100 = 2991	Pixels/Scan: 104 (low resolution) 208 (high resolution) Scans/Second (SS): 36.100/60 Seconds/Orbit (SO): 5550 Average Scans/Orbit: nscan = SS*SO+100 = 3023

Reprocessing Schedule

Data are reprocessed every 1-3 years as algorithms are improved. The current version of the data is Version 6.

TMI Instrument Description

The TRMM Microwave Imager (TMI) is a passive microwave radiometric system which measures atmospheric and surface brightness temperatures at 5 frequencies: 10.7, 19.4, 21.3, 37.0, and 85.5 GHz. Each frequency, except for 21.3 GHz has two channels—one vertically polarized and one horizontally polarized; the 21.3 GHz frequency has one vertically polarized channel. The 85.5 GHz channels are considered high resolution (5.1 km post-boost, 4.4 km pre-boost); the other channels are considered low resolution.

Characteristics for the TRMM Microwave Instrument are summarized in the appendix.

The TMI instrument rotates about a vertical axis, giving it a conical scanning geometry. Data is measured on an annular sector of 130 degrees. The conical scan results in radiation being measured at an angle of 49 degrees with respect to the platform's nadir.

2A12 Algorithm Description

The 2A12 algorithm uses a Bayesian method to compute hydrometeor profiles using TMI brightness temperatures (1B11) and the Goddard Cumulus Ensemble model as input.

See *TRMM Data Users Handbook* for a detailed description of the TRMM 2A12 algorithm.

Also see:
Kummerow, C., Olson, W.S., and Giglio, L., 1996: A simplified Scheme for Obtaining Precipitation and Vertical Hydrometeor Profiles from Passive Microwave Sensors. *IEEE Trans. on Geosci. and Remote Sensing* , **34** , 1213-1232.

Algorithm 2A12 - TMI Rainfall

Data Disclaimer

The latent heating products of TRMM 2A12 over ocean surfaces should be regarded as experimental. Please confer first with the algorithm developers (by contacting the GES DISC) when using the latent heating product over ocean. Over-land latent heating estimates from TRMM products 2A12 should not be used, as they have not been evaluated quantitatively or qualitatively.

Data Citation Information

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 file for this product contains data gathered for one nodal orbit plus 100 scans. Each orbit is centered on it's longitude of maximum latitude. Due to the conical nature of the TMI scan, each nodal orbit in a 2A12 data file is framed by a 50 scan Preorbit Overlap and a 50 scan Postorbit Overlap.

A TMI CSI file contains a subset of an orbital file coincident with a specified location.

The temporal range for each file is about 91.5 minutes (pre-boost) and 92.5 minutes (post boost).

File Naming Convention

TRMM 2A12 files are named in accordance to the following convention:

2A12.<date>.<orbit number>.<product version>.HDF

The format for the date is YYMMDD.

For example, 2A12 version 6 data gathered on 22 April 2007 for orbit 53742 can be found in the file named "2A12.070422.53742.6.HDF". On January 1st of 2008, an 'L' will be added to the version number in the file name to indicate that the file was produced on a Linux system.

The naming convention of CSI files is

2A12_CSI. >.<orbit number>.<site>.<product version>.HDF

Example: 2A12_CSI.080201.58190.KWAJ.6.HDF

File Format and Structure

TMI 2A12 data files were created using **Hierarchical Data Format (HDF)**.The following table describes the major components of the TMI Hydrometeor Profile (2A12) HDF structure. More information can be found in Volume 4 of the TRMM ICD, *File Specifications for TRMM Products - Level 2 and Level 3*.

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	9	nscan
Geolocation	geolocation	Float SDS	4	2*208*nscan
Scan Status	scan_status_tmi	Vdata Table	21	nscan
Navigation	navigation	Vdata Table	88	nscan
Data Flag	dataFlag	Integer SDS	1	npixel*nscan
Rain Flag	rainFlag	Integer SDS	1	npixel*nscan
Surface Flag	surfaceFlag	Integer SDS	1	npixel*nscan
Surface Rain	surfaceRain	Float SDS	4	npixel*nscan
Convective Surface Rain	convectRain	Float SDS	4	npixel*nscan
Confidence	confidence	Float SDS	4	npixel*nscan
Cloud Liquid Water	cldWater	Integer SDS	2	nlayer*npixel*nscan
Precipitation Water	precipWater	Integer SDS	2	nlayer*npixel*nscan
Cloud Ice Water	cldIce	Integer SDS	2	nlayer*npixel*nscan
Precipitation Ice	precipIce	Integer SDS	2	nlayer*npixel*nscan
Latent Heating	latentHeat	Integer SDS	2	nlayer*npixel*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

Information on the contents and structure of the TMI Hydrometeor Profiles (2A12) product can be found in Volume 4 of the TRMM ICD, *File Specifications for TRMM Products - Level 2 and Level 3*.

Name	Description	Scaled by	Range	Unit
Geolocation	Earth location of the center of the IFOV at the altitude of the earth ellipsoid. The first dimension is latitude and longitude, in that order. The next dimensions are numbers of pixels and scans.	-	Lat ~ +/-40; -180 <= Longitude < 180	degree
Surface Rain	Instantaneous rain rate at the surface for each pixel.	-	0.0 ~ 3000.0	mm/h
Convective Surface Rain	Instantaneous convective rain rate at the surface for each pixel.	-	0.0 ~ 3000.0	mm/h
Confidence	Associated with the surface rain, and measured as an rms deviation in temperatures.	-	0.0 ~ 300.0	K
Cloud	Cloud liquid water content for each	1000	0.00 ~ 10.00	g m^{-3}

Liquid Water	pixel at 14 layers.			
Precipitation Water	. Precipitation water content for each pixel at 14 layers.	1000	0.00 ~ 10.00	g m^{-3}
Cloud Ice Water	Cloud ice water content for each pixel at 14 layers.	1000	0.00 ~ 10.00	g m^{-3}
Precipitation Ice	Precipitation content for each pixel at 14 layers.	1000	0.00 ~ 10.00	g m^{-3}
Latent Heating	Latent heating release for each pixel at 14 levels.	10	-256 ~ 256	°C/hour

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 2A121.070312.53103.6.HDF
ncdump 2A12.070312.53103.6.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	confidence
dataFlag	cldWater
rainFlag	precipWater
surfaceFlag	cldIce
surfaceRain	precipIce
convectRain	latentHeat

example:
hdp dumpsds -n surfaceRain 2A12.070312.53103.6.HDF
ncdump –v surfaceRain 2A12.070312.53103.6.HDF

to dump vdata:
hdp dumpvd –n <vdata name> <file name>

where vdata name is one of :

CoreMetadata.0	pixel
ArchiveMetadata.0	scale_factor
add_offset	scale_factor_err
add_offset_err	scan
calibrated_nt	scan_time
latlon	SwathStructure
layer	tmi_scan_status
navigation	

example:
hdp dumpvd –n navigation 2A12.070312.53103.6.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 SW 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 Services

To find a specific TRMM granule use

http://mirador.gsfc.nasa.gov/

or

http://disc.gsfc.nasa.gov/data/datapool/TRMM/

If you need assistance or wish to report a problem:

Email: gsfc-help-disc@lists.nasa.gov

Voice: 301-614-5224

Fax: 301-614-5268

Address:
Goddard Earth Sciences Data and Information Services Center
NASA Goddard Space Flight Center
Code 610.2
Greenbelt, MD 20771 USA

Data Interpretation and Screening

Scales and Offsets

The 2A12 profiled data items (except for Latent Heat), namely

Cloud Liquid Water
Precipitation Water
Cloud Ice Water
Precipitation Ice

are multiplied by 1000 and stored as integers in their respective SDSs. Latent Heat is multiplies by 10 before being stored in its SDS.

Geolocation

Geolocation information in decimal degrees is stored as 4-byte floating point numbers in a 2 x 208 x nscan SDS array. Latitude is stored first for a given IFOV. The latitude-longitude pair represents the earth location of the center of a high resolution IFOV at the altitude of the earth ellipsoid. East longitude is positive; west longitude (including the 180 meridian) is negative. A longitude or latitude value less than or equal to -9999.9 denotes off-earth.

Quality Screening and Interpretation

A value of -9999 in integer data (or a value less than or equal to -9999.9 in floating point data) indicates a missing datum.

In addition to Date Flag, Rain Flag, Surface Flag, and Confidence data-- described below—information pertinent to quality and screening can be found in the Navigation and Scan Status Vgroups discussed in the appendix.

Data Flag

Each 2A12 file contains a dataFlag SDS. There are 208 * nscan values contained in a dataFlag SDS. The values are 1-byte integers. A value greater than or equal to zero in this SDS indicate good data. Negative values can be interpreted as follows:

-9 Channel brightness temperature outside valid range
-15 The neighboring 5 x 5 pixel array is incomplete due to edge or bad data quality
-21 Surface type invalid
-23 Date time invalid
-25 Latitude or longitude invalid

To access the dataFlag SDS:

```
hdp dumpsds -n dataFlag -d <data file>
```

Rain Flag

The rainFlag SDS is a 208 * nscan array containing 1-byte integers. A value greater than or equal to zero indicates a possibility of rain. A negative value indicates the corresponding pixel has be pre-screened as non-raining with the value indicating the specific screen.

To access the rainFlag SDS:

```
hdp dumpsds -n rainFlag -d  <data file>
```

Surface Flag

The surfaceFlag SDS is a 208 * nscan array or 1-byte integers which indicate the type of surface for each pixel:

0: ocean;
1: land;
2: coast;
3: other

To access the SurfaceFlag SDS:

hdp dumpsds -n surfaceFlag –d <data file>

Confidence

The Confidence SDS is a 208 * nscan 4- byte floating point array which contain confidence values associated with surface rain and measured as an rms deviation in temperatures with units in degrees (K).

To access the confidence SDS:

hdp dumpsds -n confidence –d <data file>

Troubleshooting

Common mistakes in reading and interpreting data

- Failure to take boost into account when interpreting 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 TRMM data
- Attempts to read empty files: Not all TRMM 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

D. Katsanos, N. Viltard, K. Lagouvardos, and V. Kotroni
Performance of a rain retrieval algorithm using TRMM data in the Eastern Mediterranean

H. Masunaga, T. Iguchi, R. Oki, and M. Kachi Comparison of Rainfall Products Derived from TRMM Microwave Imager and Precipitation Radar

Articles Using the Data

R. T. Tibbetts, T. N. Krishnamurti An intercomparison of hurricane forecasts using SSM/I and TRMM rain rate algorithm(s)

Stephen W. Nesbitt and Galdino V. Mota A Comparison of Precipitation Estimates Over the Himalayas and Andes

Acknowledgments

The distribution TRMM data set is funded by NASA's Science Mission Directorate

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

Appendix

Description of Metadata Fields

CoreMetadata.0

CoreMetadata is specifed in the table below. To access CoreMetadata:

ncdump -v CoreMetadata.0 <file name>

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).
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	The degree value for the south latitude of boundary.

Coordinate	
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 Time	The time when the granule coverage ended. See beginning date.
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:

ArchiveMetadata is described in the table below. To access ArchiveMetadata:

ncdump -v ArchiveMetadata.0 <file name>

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

Surface Rain

The Surface Rain is the instantaneous rain rate (mm h^{-1}) at the surface for each of the 208 * nscan pixels. It ranges between 0.0 and 3000.0 mm/h and is stored as a 4-byte float.

To access:

hdp dumpsds -n surfaceRain –d <data file>

Convective Surface Rain

The Convective Surface Rain is the instantaneous convective rain rate (mm h^{-1}) at the surface for each of the 208 * nscan pixels. It ranges between 0.0 and 3000.0 mm/hr and is stored as a 4-byte float.

To access:

hdp dumpsds -n convectRain –d <data file>

Cloud Liquid Water

This is the cloud liquid water content for each of the 208 * nscan pixels at 14 layers. It ranges from 0.00 to 10.00 g m^{-3} and is multiplied by 1000 and stored as a 2-byte integer.

To access:

hdp dumpsds -n cldWater –d <data file>

Precipitation Water

This is the precipitation water content for each of the 208 * nscan pixels at 14 layers. It ranges from 0.00 to 10.00 g m^{-3} and is multiplied by 1000 and stored as a 2-byte integer.

To access:

hdp dumpsds -n precipWater –d

Cloud Ice Water

This is the cloud ice water content for each of the 208 * nscan pixels at 14 layers. It ranges from 0.00 to 10.00 g m^{-3} and is multiplied by 1000 and stored as a 2-byte integer.

To access:

hdp dumpsds -n cldIce –d <data file>

Precipitation Ice

This is the precipitation content for each of the 208 * nscan pixels at 14 layers. It ranges from 0.00 to 10.00 g m^{-3} and is multiplied by 1000 and stored as a 2-byte integer.

To access:

hdp dumpsds -n precipIce –d <data file>

Latent Heating

This is the latent heating release (°C/day) for each of the 208 * nscan pixels at 14 layers. It is multiplied by 10 and stored as a 2-byte integer. Ranges are -256 deg/hour to 256 deg/hour.

To access:

hdp dumpsds -n latentHeat <data file>

Scan Time

There is one 9-byte record for each scan in the Scan Time Vdata Table. The Scan Time record is described in the table below. To access the Time Scan data:

hdp dumpvd -name scan_time -d <file name>

Scan Time		
Name	**Format**	**Description**
Year	2-byte integer	4-digit year, e.g., 1998
Month	1-byte integer	The month of the Year
Day of Month	1-byte integer	The day of the Month
Hour	1-byte integer	The hour (UTC) of the Day
Minute	1-byte integer	The minute of the Hour
Second	1-byte integer	The second of the Minute
Day of Year	2-byte integer	The day of the Year

TMI Scan Status

Scan Status is a Vdata record described in the table below. There is one 21 byte record for each scan.

Scan status can be accessed with the following commands:
hdp dumpvd -n tmi_scan_status <file name>

Name	**Format**	**Description**
Missing	1-byte integer	Missing indicates whether information is contained in the scan data. The values are: 0 Scan data elements contain information 1 Scan was missing in the telemetry data 2 Scan data contains no elements with rain

Validity	1-byte integer	Validity is a summary of status modes. If all status modes are routine, all bits in Validity = 0. Routine means that scan data has been measured in the normal operational situation as far as the status modes are concerned. Validity does not assess data or geolocation quality. Validity is broken into 8 bit flags. Each bit = 0 if the status is routine but the bit = 1 if the status is not routine. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). The non-routine situations follow: Bit Meaning if bit = 1 0 Spare (always 0) 1 Non-routine spacecraft orientation (2 or 3) 2 Non-routine ACS mode (other than 4) 3 Non-routine yaw update status (0 or 1) 4 Non-routine TMI instrument status (Bit 0 = 0 or bit 1 = 0) 5 Non-routine QAC (non-zero) 6 Spare (always 0) 7 Spare (always 0)
QAC	1-byte integer	The Quality and Accounting Capsule of the Science packet as it appears in Level-0 data. If no QAC is given in Level-0, which means no decoding errors occurred, QAC in this format has a value of zero.
Geolocation Quality	1-byte integer	Geolocation Quality is broken into 8 one-bit flags. Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(7-i). A value of 0 indicates ‘good’ quality, and 1 indicates ‘bad’ quality. Each flag is listed below. Note that ranges indicated will be refined in early-orbit check out. Bit Meaning if bit = 1 0 Grossly bad geolocation results: • Spacecraft position vector magnitude outside range 6720 to 6740 km. • Z component of midpoint of scan outside range -4100 to 4100 km. • Distance from S/C to midpoint of scan outside range 340 to 360 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. 1-byte integer 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.
Data Quality [9]	9 X 1-byte integer	The Quality of Channel Data for a given channel on a given scan line is the percentage of pixels whose values are within the acceptable range listed in the Metadata. Quality is given for each channel in the order of the channel number.
Current Spacecraft Orientation	1-byte integer	Value Meaning 0 +x forward 1 -x forward 2 -y forward 3 Inertial - CERES Calibration 4 Unknown Orientation
Current ACS Mode	1-byte integer	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
Yaw Update Status	1-byte integer	Value Meaning 0 Inaccurate 1 Indeterminate 2 Accurate
TMI Instrument Status	1-byte integer	Bit 0 is the most significant bit (i.e., if bit i = 1 and other bits = 0, the unsigned integer value is 2**(8-i) - 1). Bit Meaning 00 Receiver Status (1=ON, 0=OFF) 01 Spin-up Status (1=ON, 0=OFF) 02 Spare Command 1 Status 03 Spare Command 2 Status 04 1 Hz Clock Select (1=A, 0=B) 05 21 GHz Cold Count Flag 06 Spare Command 4 Status 07 Spare Command 5 Status
Fractional Orbit Number	4-byte float	The orbit number and fractional part of the orbit at Scan Time. The orbit number will be counted from the beginning of the mission. The fractional part is calculated as: (Time - Orbit Start Time) / (Orbit End Time - Orbit Start Time)

TRMM Navigation

There is one 88-byte Navigation record for each scan. The record is described in the table below.

To access the navigation records:

hdp dumpvd -name navigation <file name>

TRMM Navigation

Name	Format	Description
Spacecraft Geocentric Position [3]	3 X 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 X 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 X 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 X 3 X 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.

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