Real-Time TRMM Multi-Satellite Precipitation Analysis Data Set Documentation

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News About the TMPA-RT

14 April 2011 Another hung computer process at NASA/MSFC caused the AMSR-E data to be missing from both 3B40RT and 3B42RT for the date/times 20110413/21 through 20110414/09 (UTC). The subscription service has been restarted, all missing files have been ingested, and the files were reposted. Users who pulled the original files for this timespan should discard them and re-pull them.

11 April 2011 A hung computer process at NASA/MSFC caused the AMSR-E data to be missing from both 3B40RT and 3B42RT for the date/times 20110407/15 through 20110411/09 (UTC). The subscription service has been restarted, all missing files have been ingested, and the files were reposted. Users who pulled the original files for this timespan should discard them and re-pull them.

20 February 2011 The AMSR-E gridder process locked up and so failed to provide AMSR-E input for 03-20UTC/20 February 2011.

16 February 2011 Tests in the Version 6 TMPA show an apparent degradation in the NOAA-16 AMSU estimates in cold ocean regimes, likely as the result of gradually increasing instrument noise. Accordingly, that data feed was terminated as of 12Z 16 February 2011.

14 February 2011 The TMPA-RT cut over to a new AMSR-E data feed starting with the 09Z 14 February 2011 products. Shutdown of the NOAA server Nanuk ended access (at least temporarily) to JAXA L1B AMSR-E data, which we had been converting to precipitation using GPROF-AMSR (roughly equivalent to GPROF2004). Now we are using the V11 real-time L2B (swath) precipitation estimates available on the NASA server LANCE. These estimates are computed at the GHRC DAAC from RSS V7 Tb's using GPROF2004. Users should not notice a large difference. Over ocean we see somewhat heavier values for light rain and lighter values for heavy rain, while over land there seems to be a general slight reduction in rain. Fractional coverages seem similar. It is possible that the new data have fewer coastal artifacts.

6 January 2011 A coding error at NESDIS resulted in bad date/time information for MetOp MHS data in the granule bridging the start of 2011, which corrupted some intermediate files in TMPA-RT. As a result, no MetOp MHS data are included in the TMPA-RT products during 0000UTC/01-0940UTC/04 January 2011. No reprocessing was done, meaning the products depend more than usual on the IR estimates during that period. Similar date/time problems also exist for at least a few recent previous year boundaries.

16 November 2010 Network issues prevented the timely reception of MHS data from early on 11 November 2010 through early on 12 November 2010. As a result, the 03 UTC 11 November 3B40RT and 3B42RT has under half the normal MHS coverage, there is only a small amount at 06 UTC, and then essentially no more until the 03 UTC 12 November 2010 time slot, when coverage returns to normal. Subsequently the entire 3B40RT, 3B41RT, 3B42RT sequence was reprocessed for the affected period.

6 October 2010 NOAA-17 AMSU data effectively ended at 15 UTC, 16 December 2009. NOAA-15 AMSU became intermittent on 29 August 2010 and effectively ended at 22 UTC, 14 September 2010.

5 August 2010 Missing-file error processing was improved for 3B40RT starting with the 15Z run on 5 August 2010. It is expected that this will control the occasional loss of 3B40RT when an input filename is passed in that lacks a file.

17 February 2010 A long-standing inconsistency between counting total pixels and counting ambiguous and precipitating pixels was uncovered in 3B40RT. The effect was to under-screen (over-screen) ambiguous grid boxes for SSM/I (AMSR) data. Corrected data began with 18 UTC on 16 February 2010. The impact is primarily at high latitudes and along coasts. While there is no reprocessing for earlier times using the new scheme, the following files were reprocessed to recover from processing failures:

3B40RT from 03-09 UTC 2/14/10
3B41RT from 03-11 UTC 2/14/10
3B42RT from 03-09 UTC 2/14/10

As well, NOAA-17 data ceased providing useful data at 0224 UTC 17 December 2009 due to an AMSU-B anomaly.

14 December 2009 Problematic IR input files caused re-runs of

3B41RT for 01-04 UTC on 14 December 2009
3B42RT for 03UTC on 14 December 2009

18 November 2009 Additional problems with the CPC server caused a string of dropped IR input files, which have now been reprocessed through 3B41RT and 3B42RT. The datetimes are

10-19 UTC on 14 Nov 2009
08 UTC 15 Nov through 19 UTC 16 Nov 2009

The current assessment is that it was coincidental that the last two sets of failures occurred on consecutive weekends.

12 November 2009 We have now recovered and regenerated all the files affected over the weekend by the IR data server's problems. The affected date/times for 3B41RT and 3B42RT are: 11/7: 07-23 UTC; 11/8:02,09-20 UTC; 11/9:23 UTC; 11/10:00 UTC.

13 May 2009 Due to hardware difficulties at the data providers' end, the RT products did not include AMSR-E during the period 16 UTC 9 May to 14 UTC 11 May 2009 or Merged IR input during the period 03 UTC 08 May to 17 UTC 11 May 2009. Subsequently, 3B41RT and 3B42RT were recomputed for the period 03 UTC 08 May to 02 UTC 12 May 2009 to include the Merged IR.

27 March 2009 MHS data from MetOp-A was added to the suite of input data for file creation dates after 20:08 UTC 27 March 2009. For 3B42RT, that means the first file with MetOp-A data is for 09 UTC. Users are encouraged to report anomalous results that they observe.

12 March 2009 Local networking administration rule updates caused IR and SSM/I input data to be blocked for data times roughly spanning 17Z on 11 March 2009 to 11Z, 12 March 2009. Reloaded IR files were used to recompute 3B41RT and 3B42RT, which were re-posted for this span. However, we chose to accept the relatively small loss of coverage by the lone SSM/I and did not recomputed 3B40RT.

17 February 2009 The new Version 6 of the TMPA-RT (not to be confused with the on-going Version 6 of the official TRMM products) was released effective 00 UTC, Tuesday, 17 February 2009. This is the upgrade that many of you have heard me discuss for over a year, during which time we tested and discarded several alternative schemes. The new version includes the following:

1. The combined precipitation field in 3B42RT is calibrated to the calendar month's climatology of TRMM Version 6 3B42 using local histogram matching of 3-hourly 2A12 (TMI) to 2B31 (TRMM Combined Instrument, or TCI) and ratio adjustment of TCI to 3B43 Version 6. Over land, the major effect is to reduce the bias of 3B42RT, while over ocean it brings 3B42RT into approximate calibration by the 2B31 estimator.
2. To support continued operations with current-style estimates, the uncalibrated combined precipitation field will continue to be provided in 3B42RT, as an additional field at the end of the data file.
3. A data source field is being added at the end of the 3B40RT file, tracking which microwave sensor type provided the input to each grid box; the source field in 3B42RT is being upgraded to pass through the microwave sensor type.
4. MHS-based precipitation estimates from NOAA-18 were quietly added to the then-current TMPA-RT starting on 27 November 2007; and the new version continues to use them.
5. The new release includes the archive of "new" data available starting 00 UTC 01 October 2008 that were processed as part of the beta test. This gives users a backlog of data for starting calibration activities with the new-style data.
6. Upon this release we have deleted all data considered obsolete, namely from versions before 3 February 2005. Data computed with the remaining versions that pre-date Version 6 are moved to subdirectory *old*.
7. Once the new system is stable, MetOp-A MHS data will be enabled. This enhancement will be announced when it occurs.

Contents

Keywords

2A12RT
3B40RT
3B41RT
3B42
3B42RT
accuracy
ambiguous pixels
AMSR-E
AMSR-E error detection/correction
AMSU-B
AMSU-B precipitation data set
AMSU-B error detection/correction
archive and distribution sites
data access policy
data file access technique
data file identifier
data file layout
data providers
data set archive
data set creators
data set inventory

units of the TMPA-RT estimates
VAR

1. Data Set Names and General Content

The formal **data set name** is the "Version 6 TRMM Real-Time Multi-Satellite Precipitation Analysis." For convenience, it is referred to in this document as the "TMPA-RT." Note that there are other products in the general TRMM real-time system. Also, note that the TMPA-RT version numbering is not related to the official TRMM product version numbering, although both happen to be number 6 at the present.

The data set currently contains three products, providing merged microwave, microwave-calibrated infrared (IR), and combined microwave-IR estimates of precipitation on quasi-global grids computed in near-real time starting in late January 2002. Current-version data are available beginning with 00 UTC 01 October 2008.

Huffman et al. (2007) is the primary refereed citation for the TMPA, Huffman et al. (2010) describe the 2009 updates, and this documentation is the primary source of technical information on the TMPA-RT. Huffman et al. (2003) and Huffman et al. (2005) provide earlier short formal summaries (all references are listed in section 13).
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2. Related Projects, Data Networks, and Data Sets

The **data set creators** are G.J. Huffman, R.F. Adler, D.T. Bolvin, and E.J. Nelkin, working in the Laboratory for Atmospheres, NASA Goddard Space Flight Center, Code 613.1, Greenbelt, Maryland, 20771 USA, and E.F. Stocker, working in the Precipitation Processing System (PPS, formerly the TRMM Science Data and Information System, TSDIS), NASA Goddard Space Flight Center, Code 610.2, Greenbelt, Maryland, 20771 USA
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The work is being carried out as part of the Tropical Rainfall Measuring Mission (**TRMM**), an international project of NASA and JAXA designed to provide improved estimates of precipitation in the Tropics, where the bulk of the Earth's rainfall occurs. The TRMM home page is located at *http://trmm.gsfc.nasa.gov/* .
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The TMPA-RT draws on data from several **data providers**:

1. NASA/GSFC level 1 TMI Tb's (processed with TRMM algorithm 2A12RT at PPS);
2. a) JAXA Level 1B AMSR-E Tb's (processed with GPROF-AMSR at PPS) up to 09Z 14 February 2011, and
   b) RSS Level 2A AMSR-E Tb’s (processed with GPROF2004 at GHRC DAAC as near-real-time Version 11) thereafter;
3. Navy/FNMOC SDR's of SSM/I Tb's (processed with GPROF-SSMI at PPS);

4. NESDIS operational level 2 AMSU-B precipitation estimates;
5. NESDIS operational level 2 MHS precipitation estimates;
6. EUMETSAT operational level 2 MHS precipitation estimates; and
7. NOAA/NWS/CPC Merged 4-Km Geostationary Satellite IR Brightness Temperature Data (processed into VAR at PPS).

These data sets extend beyond the TMPA-RT period in their original archival locations.
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There are numerous **similar data sets**, although no other matches all the attributes of being routinely produced, publicly available, fine-scale in space and time, quasi-global, near-real-time, intercalibrated, formed by combining multiple data sources, providing multiple combined estimates, and being associated with a research-grade post-real-time product that is similarly processed. The closest include the sets of estimates based on:

- Turk (1999), which uses individual SSM/I overpasses to calibrate geo-IR precipitation estimates;
- Sorooshian et al. (2000), which applies the PERSIANN neuralnetwork to calibrate IR with microwave; and
- Joyce et al. (2004), which applies the CMORPH morphing scheme to time-interpolate microwave patterns with IR-based motion vectors.
- Kubota et al. (2007), which applies the GSMaP morphing scheme to time-interpolate microwave patterns with IR-based motion vectors.

Several SSM/I-based data sets are available as gridded single-sensor data sets with significant data voids in cold-land, snow-covered, and ice-covered areas, including those computed with the GPROF 6.0 and 2004a algorithms (based on Kummerow et al. 1996) and the NOAA Scattering algorithm (Grody 1991), among others. Other daily, single-sensor data sets are available for open-water regions based on SSM/I data (Wentz and Spencer 1998, Jost et al. 2002), MSU data (Spencer 1993), AMSR-E, AMSU-B, MHS, QuickScat, and WindSat data. Numerous daily single-sensor or combination data sets are available at the regional scale, but are not really "similar."

The Version 6 TRMM product 3B42 is being computed with the TMPA after real time, and constitutes the research-grade archive of TMPA estimates. See "3B42" for details.
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The Version 6 TRMM product **3B42** is being computed with the TMPA after real time, and constitutes the research-grade archive of TMPA estimates. Note that the version numbering for the TMPA-RT and official TRMM products are not related, although both are currently numbered 6. The post-real time computation allows several improvements in 3B42 compared to 3B42RT:

1. Data are processed starting with the first full month of TRMM data, which begins 1 January 1998.

2. The IR calibration period is the calendar month in which the observation time falls, rather than a trailing 30-day accumulation.
3. The TRMM Combined Instrument product (2B31) is used as the calibrating standard, which should give better estimates than the TMI by itself.
4. For each grid box, the individual 3B42 3-hourly precipitation values are scaled to sum to a combination of monthly 3B42 and gauge analysis, which is TRMM product 3B43.

Reprocessing for Version 6 began in May 2004 and completed in late August 2005; 3B42RT continues to march forward in real time, and 3B42 estimates are considered to supersede the 3B42RT estimates as each month of 3B42 is computed, during the following month.

Both 3B42RT and 3B42 were upgraded to include AMSR-E and AMSU-B precipitation estimates in late 2004. The next version of 3B4XRT began operational use at 08Z 3 February 2005, and current-data processing for Version 6 3B42/43 began in July 2005. The entire available archive of AMSR-E and AMSU-B estimates is incorporated in the Version 6 3B42. As well, the reprocessed record of CPC Merged 4-km IR Tb data through December 2001 is included in the Version 6 3B42. Subsequently, CPC reprocessed through November 2002, but the changes after December 2001 are not significant to 3B42. MHS was added to 3B42RT on 27 November 2007, but was not added to 3B42 due to the frozen algorithm until the last AMSU developed noise-related problems, whereupon it was dropped and the two MHS data streams added in January. The TMPA-RT was upgraded to Version 6 as of 17 February 2009, without affecting the Version 6 3B42.

The next upgrade to 3B42, Version 7, is expected in late 2011 as part of the general TRMM reprocessing to Version 7. It will feature a complete reprocessing back to the start of the TRMM data set in January 1998.
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3. Storage and Distribution Media

The **data set archive** consists of unformatted binary files. Each hour or 3-hour dataset is contained in a separate file with a self-documenting ASCII header. The TMPA-RT is distributed by anonymous FTP over the Internet. Each 3B40RT (3B41RT, 3B42RT) file occupies ~7 (3) MB uncompressed, or ~350 KB (150 KB) compressed.

The full collection of TMPA-RT files are provided and archived on the anonymous FTP site *ftp://trmmopen.gsfc.nasa.gov/pub/merged/* .
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The TRMM Online Visualization and Analysis System (**TOVAS**) is created and supported by the Goddard Earth Sciences Data and Information Services Center (GES DISC). It provides a web-based resource for accessing 3B40RT, 3B41RT, 3B42RT, 3B42, 3B43, and other data, performing basic subsetting, time- and space-averaging, and outputting results in plots or ASCII text. The TOVAS URL is *http://disc2.nascom.nasa.gov/Giovanni/tovas/* . TOVAS is currently being upgraded to Version 3.
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4. Reading the Data

A **data file identifier** is embedded in the data file name as

<product>.<datetime>.bin

where

<product> is the product identifier:
3B40RT = high-quality (HQ) estimate from merged microwave;
3B41RT = variable rainrate (VAR) IR estimate;
3B42RT = combined HQ and VAR.

<datetime> is the nominal UTC date/time as YYYYMMDDHH (i.e., numerical 4-digit year, month, day, hour)

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The **data file access technique** is the same for all files. These files are accessible by standard data analysis application programs that support “raw” data access and by programming in third-generation computer languages (FORTRAN, C, etc.).

Each file consists of a 2880-byte header record containing ASCII characters (which is the same size as one 2-byte-integer row of data), then the grid of scaled 2-byte integer precipitation estimates, the grid of scaled 2-byte integer random error estimates, and other 1-byte integer grids. The header line makes the file nearly self-documenting, in particular spelling out the variable and version names, and giving the units of the variables. The header line may be read with standard text editor tools or output under program control. Grid boxes without valid data are filled with the (2-byte integer) "missing" value -31999. The data may be read with standard data-display tools (after skipping the 2880-byte header) or output under program control.

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The **data file layout** is somewhat different for the different products, as shown in Table 1.

Table 1. File layout for 3B40RT, 3B41RT, 3B42RT.

	3B40RT		*3B41RT*		*3B42RT*	
Block	*Byte Count*	*Field*	*Byte Count*	*Field*	*Byte Count*	*Field*
1	2880	header	2880	header	2880	header
2	2073600*	precip	1382400&	precip	1382400&	precip
3	2073600*	error	1382400&	error	1382400&	error
4	1036800+	# pixels	691200@	# pixels	691200@	source
5	1036800+	# ambig. pixels	-	-	1382400&	uncal precip
6	1036800+	# rain pixels	-	-	-	-
7	1036800+	source				

* INTEGER*2, 90ºN-S & INTEGER*2, 60ºN-S
\+ INTEGER*1, 90ºN-S @ INTEGER*1, 60ºN-S

Header:

Each file starts with a header that is one 2-byte-integer row in length, or 2880 bytes. The header is ASCII in a "PARAMETER=VALUE" format that makes the file self-documenting (e.g., "algorithm_id=3B40RT"). As such, the header can be read with standard text editors, output as text with simple application programs, or parsed for input into applications. Successive "PARAMETER=VALUE" sets are separated by spaces, and no spaces or "=" are permitted in either PARAMETER or VALUE. The current PARAMETER entries and definitions are:

PARAMETER	Definition
algorithm_ID	TRMM algorithm identifier (e.g., "3B40RT")
algorithm_version	Version of the science algorithm
granule_ID	PPS granule identifier (e.g., "3B40RT.2001121809.bin")
header_byte_length	Number of bytes in the header
file_byte_length	Number of bytes in the file, expressed as a formula describing the file structure
nominal_YYYYMMDD	Nominal UTC year, month, and day of the month
nominal_HHMMSS	Nominal UTC hour, minute, and second
begin_YYYYMMDD	Start UTC year, month, and day of the month
begin_HHMMSS	Start UTC hour, minute, and second
end_YYYYMMDD	End UTC year, month, and day of the month
end_HHMMSS	End UTC hour, minute, and second
creation_YYYYMMDD	Date the file was created as year, month, and day of the month
west_boundary	Longitude of the western edge of the data domain
east_boundary	Longitude of the eastern edge of the data domain
north_boundary	Latitude of the northern edge of the data domain
south_boundary	Latitude of the southern edge of the data domain
origin	Geographical direction of the first grid box from the grid center
number_of_latitude_bins	Number of grid boxes in the meridional direction
number_of_longitude_bins	Number of grid boxes in the zonal direction
grid	Size of one grid box
first_box_center	Geolocation of the first grid box center
second_box_center	Geolocation of the second grid box center
last_box_center	Geolocation of the last grid box center
number_of_variables	Number of data fields
variable_name	List of the data field names, separated by commas
variable_units	List of data field units, separated by commas, in the same order as the variable_name list
variable_scale	List of data field scaling factors, separated by commas, in the same order as the variable_name list
variable_type	List of data field word types, separated by commas, in the same order as the variable_name list
byte_order	Order of bytes in a data word ("big_endian" or "little_endian")
flag_value	List of special values, separated by commas
flag_name	List of special value names, separated by commas, in the same order as the flag_value list

contact_name	Name of the person to contact with questions
contact_address	Postal address of the contact_name
contact_telephone	Telephone number of the contact_name
contact_facsimile	Facsimile number of the contact_name
contact_email	Email address of the contact_name

Thereafter the data fields follow. All the fields are on a 0.25º lat./lon. grid that increments most rapidly to the east (from the Prime Meridian) and then to the south (from the northern edge). Grid box edges are on multiples of 0.25º. The data fields are written as flat binary data in big-endian byte order.

<u>3B40RT</u>:

Following the header, 6 data fields appear:

precipitation	(2-byte integer)
precipitation_error	(2-byte integer)
total_pixels	(1-byte integer)
ambiguous_pixels	(1-byte integer; highly uncertain values)
rain_pixels	(1-byte integer)
source	(1-byte integer; the values are: 0 = no observation 1 = AMSU 2 = TMI 3 = AMSR 4 = SSMI 5 = SSMIS 6 = MHS 30 = AMSU&MHS avg. 31 = conical avg.)

All fields are 1440x720 grid boxes (0-360ºE,90ºN-S). The first grid box center is at (0.125ºE,89.875ºN). Files are produced every 3 hours on synoptic observation hours (00 UTC, 03 UTC, ..., 21 UTC) as an accumulation of all HQ swath data observed within +/-90 minutes of the nominal file time. Estimates are only computed for the band 70ºN-S.

<u>3B41RT</u>:

Following the header, 3 data fields appear:

precipitation	(2-byte integer)
precipitation_error	(2-byte integer)
total_pixels	(1-byte integer)

All fields are 1440x480 grid boxes (0-360ºE,60ºN-S). The first grid box center is at (0.125ºE,59.875ºN). Files are produced every hour from the on-hour IR image (except for the previous half-hour image for GMS), with fill-in by the previous half-hour image (except for GMS, where the on-hour image is used for fill-in). Valid estimates are only provided in the band 50ºN-S.

<u>3B42RT</u>:

Following the header, 4 data fields appear:

precipitation	(2-byte integer)

precipitation_error	(2-byte integer)			
source	(1-byte integer; the values are:			
	0 = no observation	1 = AMSU	2 = TMI	3 = AMSR
	4 = SSMI	5 = SSMIS	6 = MHS	30 = AMSU&MHS avg.
	31 = conical avg.	50 = IR	1,2,3,4,5,6 + 100 = sparse-sample HQ)	
uncal. precip	(2-byte integer)			

All fields are 1440x480 grid boxes (0-360ºE,60ºN-S). The first grid box center is at (0.125ºE,59.875ºN). Files are produced every 3 hours on synoptic observation hours (00 UTC, 03 UTC, ..., 21 UTC) using that hour's 3B40RT and 3B41RT data sets. Valid estimates are only provided in the band 50ºN-S. See "decode high-latitude VAR and HQ+VAR precipitation values" for discussion of retrieving values outside 50ºN-S. The leading precipitation field has a climatological bias correction to the 3B42 Version 6 estimates, while the last field is the multi-satellite precipitation before this calibration.

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The *originating machine* on which the data files were computed is a Silicon Graphics, Inc. Unix workstation, which uses the "big-endian" representation of unformatted binary words. Some CPUs, such as PCs and DEC machines, might require a change of representation (i.e., byte swapping) before using the data.

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It is possible to *read the header record* with most text editor tools, although the size (2880 bytes) may be longer than some tools will support. Alternatively, the header record may be output under program control, as demonstrated in "Read the Header Record FORTRAN Example" in the Appendices. The header is written in a "PARAMETER=VALUE" format documented in "data file layout," where PARAMETER is a string without embedded blanks that gives the parameter name, VALUE is a string that gives the value of the parameter, and blanks separate each "PARAMETER=VALUE" set. To prevent ambiguity, no spaces or "=" are permitted as characters in either PARAMETER or VALUE.

See "Read the Header Record, FORTRAN Example" in the Appendices for specifics.

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It is possible to *read a file of data* with many standard data-display tools. The 2880-byte header is designed to be exactly the size of one row of data, so the header may be bypassed by skipping 2880 bytes or 1440 2-byte integer data points or one row. Alternatively, the data may be output under program control as demonstrated in the "Read a File of Data" example programs in the Appendices. Once past the header, there are always a precipitation field, a random error field, and 1-5 auxiliary fields. As documented in “Data File Layout”, the grids are either 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT) and the data are either scaled 2-byte integer (precipitation, random error, and uncalibrated precipitation) or 1-byte integer (all others). Grid boxes without valid data are filled with the "missing" value -31999 for 2-byte integer fields and 0 for 1-byte integer fields.

See the "Read a File of Data" examples in the Appendices for specifics.

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It is possible to **decode high-latitude VAR and HQ+VAR precipitation values** with

p = -0.01 * (v + 1)

where p is the floating-point value,
v is the scaled-integer value, and
v is not equal to the 2-byte-integer missing value (-31999).

This encoding is done because the data set developers consider the high-latitude values to be very unreliable, but they wish to have the values available for data set development work and special data-set user needs.
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It is possible to **decode highly ambiguous HQ values** with

p = -0.01 * (v + 1)

where p is the floating-point value,
v is the scaled-integer value, and
v is not equal to the 2-byte-integer missing value (-31999).

This encoding is done because it is likely that HQ values with a large fraction of pixels flagged as "ambiguous" contain artifacts. However, the full population of ambiguous pixels must be available to subsequent processing for the VAR calibration, so these values are not set to "missing" until they are combined with VAR to create HQ+VAR (3B42RT). See "ambiguous pixels" for more details.
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5. Definitions and Defining Algorithms

The **time zone** for this data set is Universal Coordinated Time (UTC, also as GMT or Z).

Because the data are provided at nominal UTC hours, each data set represents a nominal +/-30-minute (90-minute) span around the nominal hour for 3B41RT (3B40RT, 3B42RT). Thus, the 00Z images include data from the very end of the previous UTC day.
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The **Merged 4-Km IR Tb data set** is produced by the Climate Prediction Center (CPC), NOAA National Centers for Environmental Prediction, Washington, DC, 20233 USA under the direction of J. Janowiak. Each cooperating geostationary (geo) satellite operator (the Geosynchronous Operational Environmental Satellites, or GOES, United States; the Geosynchronous Meteorological Satellite, or GMS, Japan; and the Meteorological Satellite, or Meteosat, European Community) forwards infrared (IR) imagery to CPC. Then global geo-IR are zenith-angle corrected (Joyce et al. 2001), renavigated for parallax, and merged on a global grid. In the event of duplicate data in a grid box, the value with the smaller zenith angle is taken. The data are provided on a 4-km-equivalent grid over the latitude band 60ºN-S, with a total grid size of 9896x3298.

The data set was first produced in late 1999. A series of processing upgrades were introduced in the first three years, but none were critical to the TMPA-RT during its period of record starting February 2002. CPC began using the code in place since November 2002 to systematically reprocess their entire data set from January 2000 (the start of their digital archive of input data), and these data are being used in the Version 6 3B42. Due to reprocessing schedules, PPS reprocessing overtook CPC reprocessing, so Version 6 uses the original CPC archive after December 2001. However, as noted above, the differences are small in this period. CPC plans to extend the record back to November 1998, hoping to finish in Q2 2010.

All 5 geo-IR satellites are used, with essentially continuous coverage during the TMPA-RT period of record. GMS-5 was replaced by GOES-9 starting 01Z 22 May 2003, which introduced slightly different instrument characteristics, and then starting 19Z 17 November 2005 the new Japanese MTSat-1R took over. The associated format change prevented use of the new MTSat-1R data by CPC, and consequently provoked a loss of coverage in the GMS sector in the period 19Z 17 November 2005 to 09Z 23 March 2006 for the RT (and to 00Z 23 March 2006 for Version 6). Data from adjacent geo-IR satellites partially fills this shortfall. More generally, as an operational system, the Merged 4-km IR data record suffers the usual gaps due to processing errors, down time on receivers, etc

Each UTC hour file contains 2 data fields. All geo-IR images with start times within 15 minutes of the UTC hour are accumulated in the "on-hour" field. Images with start times within 15 minutes of the UTC hour plus 30 minutes are accumulated in the "half-hour" field. The nominal image start times for the various satellites and their assignment to half-hour fields are shown in Table 2.

Table 2. Nominal sub-satellite longitude (in degrees longitude) and image start time (in minutes past the hour) for the various geosynchronous satellites. The start times are displayed according to their assignment to either the on-hour or half-hour fields in the CPC Merged 4-Km IR Tb data set. Full-disc views are guaranteed only at 00Z, 03Z, ..., 21Z. These appear in the on-hour field except MTSat appears in the previous half-hour for all hours. For images not at these times, a satellite's "image" may be assembled from various operator-specified regional sectors. MTSat provides N. Hemisphere sectors (only) on-hour, except S. Hemisphere sectors (only) at 00Z, 06Z, 12Z, 18Z.

Satellite	*Sub-sat. Lon.*	*on-hour*	*half-hour*
MTSat-1R (old GMS)	140E	00	30
GOES-E (8, now 12)	75W	45	15
GOES-W (10, now 11)	135W	00	30
Meteosat-8 (old 7)	0E	00	30
Meteosat-5	63E	00	30

These data are used as input to TMPA-RT processing.
....

The Goddard Profiling Algorithm (*GPROF*) is based on Kummerow et al. (1996) and Olson et al. (1999). GPROF is a multi-channel physical approach for retrieving rainfall and vertical structure information from satellite-based passive microwave observations (here, SSM/I and TMI). The GPROF-SSM/I estimates are computed from the SSM/I SDRs as part of the TMPA-RT, while the GPROF-TMI estimates are computed by PPS as 2A12RT. The current version applies a Bayesian inversion method to the observed microwave brightness temperatures using an extensive library of cloud-model-based relations between hydrometeor profiles and microwave brightness temperatures. Each hydrometeor profile is associated with a surface precipitation rate. GPROF includes a procedure that accounts for inhomogeneities of the rainfall within the satellite field of view. Over land and coastal surface areas the algorithm reduces to a scattering-type procedure using only the higher-frequency channels. This loss of information arises from the physics of the emission signal in the lower frequencies when the underlying surface is other than all water.

The respective versions of this algorithm are applied to the SSM/I, TMI, and AMSR-E Tb data, and the estimates are used as input to TMPA-RT processing. All AMSR-E estimates have been computed using Version 1 of GPROF-AMSR. The TMI estimates were computed using GPROF-TMI Version 5 up through 4 January 2005, at which time Version 6 was instituted. The SSM/I estimates were computed using GPROF-SSM/I Version 6 up through 11 February 2004, at which time Version 6.5 was instituted. The AMSR-E estimates were computed using GPROF-AMSR Version 1 at PPS using JAXA Level 1B before 09Z 14 February 2011 and GPROF2004 at GHRC DAAC thereafter using RSS Level 2A.
....

Satellite Data Records (*SDR*) containing level 2 (scan-pixel) SSM/I Tb data are provided by the Department of the Navy, Fleet Numerical Meteorological and Oceanographic Center (FNMOC), Monterey, CA. Each file contains a "contact" of downlinked data, which can be up to 2 orbits. The data have had some quality control, and are converted from sensor units to Ta, then to Tb, as well as providing numerous other physical quantities and metadata.

These data are used as input to GPROF-SSM/I for use in TMPA-RT processing.
....

PPS algorithm *2A12RT* contains level 2 (scan-pixel) GPROF estimates of precipitation based on TMI data. These are provided by PPS, led by Erich Stocker. Each file contains an orbit of estimates. The data have had some quality control, and are converted from sensor units to Ta, then to Tb, then to precipitation.

These data are used as input to TMPA-RT processing.
....

The *AMSU-B precipitation data set* is computed operationally at the National Environmental Satellite Data and Information Service (NESDIS) based on the Zhao and Weng (2002) and Weng et al. (2003) algorithm. Ice water path (IWP) and particle effective diameter size (De) are computed from the 89 and 150 GHz channels. As such, it is a primarily a scattering approach.

Surface screening is carried out using Advanced Very High Resolution Radiometer (AVHRR) infrared data and Global Data Assimilation System (GDAS) surface temperature and surface type data to discriminate desert, snowy, or icy surfaces. Precipitation rate is computed based on IWP–precipitation rate relations derived from the NCAR/PSU Mesoscale Model Version 5 (MM5). The precipitation rate is approximated as a second-degree polynomial in IWP, with coefficients that are derived separately for convective and non-convective situations, based upon a series of comparisons between the three AMSU-B channels centered at the 183.31 GHz water vapor absorption band. Additionally, the algorithm identifies regions of falling snow over land through the use of AMSU-A measurements at 53.8 GHz. At present, falling snow is assigned a rate of 0.1 mm/hr, although an experimental snowfall rate is being tested and evaluated.

The data set was first produced in early 2000. The algorithm was upgraded on 31 July 2003 and again on 31 May 2007. In the latter, an emission component was added to increase the areal coverage of rainfall over oceans through the use of a liquid water estimation using AMSU-A 23.8 and 31 GHz (Vila et al. 2007). Additionally, an improved coastline rainrate module was added that computes a proxy IWP using the 183 GHz bands (Kongoli et al. 2007). The first upgrade did not affect the TMPA-RT because the TMPA-RT only started using AMSU-B estimates on 3 February 2005, but the second did. [NESDIS did not reprocess the prior AMSU-B data set in the first upgrade, but it did in the second. The Version 6 3B42 reprocessing carried out at the start of Version 6 for 3B42/43 occurred before the full reprocessing associated with the second AMSU-B upgrade, so 3B42 had to account for two different AMSU-B epochs. When NESDIS did reprocess the full AMSU-B record, Version 6 was frozen. Thus, yet a third set of AMSU-B inter-satellite calibrations was introduced in 3B42 to account for changed behavior in the second AMSU-B upgrade, and the version number for 3B42 and 3B43 was set to 6a for subsequent months.]

NOAA-17 ceased providing useful data at 0224 UTC 17 December 2009 due to an AMSU-B anomaly. NOAA-15 AMSU became intermittent on 29 August 2010 and effectively ended at 22 UTC, 14 September 2010. NOAA-16 was ended at 1200 UTC 16 February 2011 due to increased noise.

The level 2 version of these data are used as input to TMPA-RT processing.
....

The *MHS precipitation data set* is computed operationally at the National Environmental Satellite Data and Information Service (NESDIS) based on the algorithm previously developed to compute the AMSU-B precipitation data set (which see for details). The channel differences between the sensors are accounted for by computing synthetic 150 and 183±7 GHz channels before the precipitation is computed.

The level 2 version of these data are used as input to TMPA-RT processing.
....

The High Quality (*HQ*) combined microwave precipitation estimate provides a global 0.25ºx0.25º-averaged 3-hourly combination of all available TMI, SSM/I, AMSR-E, AMSU-B, and MHS estimates:

1. Offline, the GPROF-SSM/I, GPROF-AMSR, AMSU-B, and MHS have been probability-matched to 2A12RT. Prior to 08Z 3 February 2005, this was done routinely for GPROF-SSM/I as 2 sets, one for ocean and one for land, computed every 5 days from the last 30 days of SSM/I-IR match-ups. Thereafter, the calibrations of AMSU-B, MHS, and AMSR-E to TMI each have one set of coefficients for land and a separate set for ocean, while SSM/I uses one set for land and 5 for ocean, covering the latitude bands 90-30ºS, 30-10ºS, 10ºS-N, 10-30ºN, and 30-90ºN. AMSR-E uses a 2-month set of match-ups to ensure sufficient sampling, while all of the others work with single-month accumulations. The AMSR-E, AMSU-B, and MHS coefficients apply to the entire year, while SSM/I uses a separate set for each season.
2. The GPROF-SSM/I, GPROF-AMSR, AMSU-B, MHS, and 2A12RT estimates are gridded to a 0.25ºx0.25º grid for a 3-hour period centered on the major synoptic times (00Z, 03Z, ..., 21Z). Prior to 08Z 3 February 2005, only GPROF-SSM/I and 2A12RT estimates were used.
3. The GPROF-SSM/I, GPROF-AMSR, AMSU-B, and MHS estimates are calibrated to 2A12RT.
4. The rain rate in each grid box is the pixel-weighted average of 2A12RT, GPROF-SSM/I, and GPROF-AMSR grid boxes contributing during the 3 hours, or the pixel-weighted average of AMSU-B and MHS if no other HQ estimates are available.
5. Additional fields in the data file include the number of pixels, the number of pixels with non-zero rain, the number of pixels for which the estimate is "ambiguous," or highly uncertain, and the sensor providing the estimate.
6. The SSM/I and AMSR-E data are available in the latitude band 85ºN-S, but GPROF only returns estimates in the band 70ºN-S. AMSU-B and MHS data are available over the entire globe, and estimates are attempted in the entire domain. However, all of the HQ algorithms are unable to provide estimates in regions with frozen or icy surfaces.
7. In a future upgrade the random error will be estimated. Currently the random error field is set to missing.

These data are output as 3B40RT in TMPA-RT processing.

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**3B40RT* is the official PPS identifier of the HQ data set. The identifier indicates that it is a level 3 (gridded) product with input from multiple sensors ("B") using non-TRMM data ("40"-series), running in Real Time.

....

The Variable Rainrate (**VAR**) IR precipitation estimate converts 0.25ºx0.25º-averaged geo-IR Tb to rainrates that are HQ-calibrated locally in time and space:

1. Both geo-IR Tb and HQ are averaged to a 0.25ºx0.25º to ensure consistent spatial scale, and time-space matched data are accumulated over pentads (5-day period).
2. Before 08Z 3 February 2005, every 5 days the previous 30 days (6 pentads) of data are summed and used to compute a new set of rainrate coefficients. Thereafter, the computation is done every 3 hr on match-ups contained in the 5 previous pentads, plus whatever part of the current pentad has been observed.

3. In each calibration, the Tb-rainrate curve is set locally by probability matching the 30-day histograms of coincident IR Tb and HQ rain rate.

In parallel, the current VAR Tb-rainrate curve is applied to each Merged 4-Km IR Tb data set as it becomes available:

1. Over most of the globe the on-hour data field is taken as the input data, with fill-in by the previous half-hour image. The exception is the GMS sector, where the previous half-hour is primary, since GMS does not schedule images on the hour. [In that case, much of the GMS sector is filled with data from METEOSAT5 and GOES-W at very high zenith angles.]
2. The Tb-to-rainrate conversion is a simple look-up, using whatever set of VAR calibration coefficients is current.
3. The additional field in the file is the number of pixels.
4. The IR estimates are available in the latitude band 60ºN-S, but values outside the band 50ºN-S are encoded to negative because they are considered highly uncertain. Accordingly, users generally should not employ these values.
5. In a future upgrade the random error will be estimated. Currently the random error field is set to missing.

These data are output as 3B41RT in TMPA-RT processing.
....

**3B41RT* is the official PPS identifier of the VAR data set. The identifier indicates that it is a level 3 (gridded) product with input from multiple sensors ("B") using non-TRMM data ("40"-series), running in Real Time.
....

The combination of **HQ+VAR** is computed every 3 hours from that hour's HQ and VAR fields. See Huffman et al. (2009) for a discussion.

1. The present combination scheme is to take the HQ field wherever it is non-missing, and fill in with VAR elsewhere.
2. Offline, 10 years of matched instantaneous TCI and TMI have been used to compute climatological monthly calibration histograms, working with 0.25° grid values accumulated on a 1°x1° grid smoothed with a 3x3 moving boxcar template. As well, 10 years of monthly TCI and 3B43 Version 6 estimates have been used to compute climatological monthly calibration ratios, starting with 0.5° averages, smoothing the TCI with a 5x5 moving boxcar template, and averaging both to 1°. For both steps, the statistics are smooth-filled over 36-40° N and S (just outside the TCI zone), and then the 40° N and S values are extended to all higher latitudes. In use, the TMI-TCI and TCI-3B43 calibrations are applied sequentially to the initial 3-hourly HQ+VAR fields.
3. The additional fields in the file are the source of the estimate and the uncalibrated HQ+VAR estimate.
4. The VAR estimates are only trusted for the latitude band 50ºN-S, so both the calibrated and uncalibrated HQ+VAR fields are clipped to 50ºN-S, with estimates outside that encoded to negative values. Accordingly, users generally should not employ these values.

5. It is planned to do a more sophisticated combination in a future release.
6. In a future upgrade the random error will be estimated. Currently the random error field is set to missing.

These data are output as 3B42RT in TMPA-RT processing.
....

3B42RT is the official PPS identifier of the HQ+VAR data set. The identifier indicates that it is a level 3 (gridded) product with input from multiple sensors ("B") using non-TRMM data ("40"-series), running in Real Time.
....

The **units of the TMPA-RT estimates** are mm/hour for the precipitation and random error estimates, dimensionless for the source field, and number of pixels for the other fields. The precipitation value is best thought of as an instantaneous rate, valid at the nominal observation time.
....

6. Temporal and Spatial Coverage and Resolution

The **file date** is the UTC year, month, day in which the nominal time of the data set occurs. All dates are UTC.
....

The **temporal resolution** of the products varies:
3B40RT is 3 hr
3B41RT is 1 hr
3B42RT is 3 hr

The 3-hour period is driven by the need for the HQ to accumulate a reasonable sample without encompassing too large a fraction of the diurnal cycle. Note that both the microwave and IR data are instantaneous, except for small regions in which 2 (or more) overlapping microwave scenes are averaged in the HQ field (3B40RT, used in 3B42RT). This is done to make the statistics of the data sets as comparable as possible. The precipitation value is best thought of as an instantaneous rate, valid at the nominal observation time. It is not computed as an accumulation, although Villarini and Krajewski (2007) argue that it represents a roughly 1.5-hour average.
....

The **period of record** for the TMPA-RT is late January 2002 through the present. The start is based on the establishment of a stable version of the TMPA-RT production system. The Version 6 TRMM product3B42 provides after-real-time processing of the TMPA from 1 January 1998 to the delayed present. See "3B42" for more details.

Data produced with early versions up to 3 February 2005 are considered obsolete and should not be used. Subsequent data up until 01 October 2008 have reasonable continuity with the current processing system's output, but lack the calibration and additional data fields. Note that the new

processing system provided data computed in parallel to the then-current version until the new version went live at 00 UTC 17 February 2009. In all cases, users are urged to work with the 3B42 Version 6 research product whenever possible.
....

The *grid* on which each field of values is presented is a 0.25ºx0.25º latitude--longitude (Cylindrical Equal Distance) global array of points. It is size 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT), with X (longitude) incrementing most rapidly West to East from the Prime Meridian, and then Y (latitude) incrementing North to South from the northern edge. Quarter-degree latitude and longitude values are at grid edges:

Location	*3B40RT*	*3B41RT,3B42RT*
First point center	89.875ºN,0.125ºE	59.875ºN,0.125ºE
Second point center	89.875ºN,0.375ºE	59.875ºN,0.375ºE
Last point center	89.875ºS,0.125ºW	59.875ºS,0.125ºW

The reference datum is WGS84.
....

The *spatial resolution* of the products is 0.25°x0.25° lat/lon.
....

The *spatial coverage* of the products varies:

Product	Grid coverage	Maximum extent of data
3B40RT	90ºN-S	70ºN-S
3B41RT	60ºN-S	50ºN-S (encoded negative at higher lat)
3B42RT	60ºN-S	50ºN-S (encoded negative at higher lat)

....

7. Production and Updates

Production and updates for the TMPA-RT are a joint activity of the precipitation research group in NASA Goddard Space Flight Center in the Laboratory for Atmospheres and PPS.

The latency of the products after observation time is governed by the latency of the individual input products. At this time the pacing item is the delivery of all AMSR-E granules that contain data for a given HQ file. Because the "contact" needed to get the last few minutes of a 3-hour HQ window may contain up to 2 orbits, the HQ production job is set to run some 7 hours past the nominal hour. Once initiated, the processing occurs in a matter of minutes.

Updates will be released to (1) extend the data record, (2) take advantage of improved combination techniques, or (3) correct errors. Updates resulting from the last two cases will be given new version numbers.

NOTE: The changes described in this section are typical of the changes that are required to keep the TMPA-RT abreast of current requirements and science. Users are strongly encouraged to check back routinely for additional upgrades and to refer other users to this site rather than redistributing data that are potentially out of date.

Starting 09Z 28 February 2003 a corrected scheme was implemented for controlling artifacts in the HQ field due to insufficient screening of "ambiguous pixels" (in frozen/snowy surface regions). The change was extended to VAR starting 00Z 2 March 2003. Of course, these changes affect the HQ+VAR estimates at the same times.

On 12 February 2004, GPROF-SSM/I Version 6.5 was installed, which features the ocean code from Version 6 and the land and coast code from Version 7. We chose not to rework the TMI-SSM/I calibration coefficients, so estimates over land and coast (and the corresponding IR calibration) will be somewhat less accurate for the following 2-week period, most likely having a small negative bias that improves with each additional pentad of Version 6.5 data.

On 6 April 2004, the calibration of microwave estimates to the TMI was upgraded starting with the 00Z data:

1. Zeroes are now included in the calibration histograms, improving the treatment of fractional coverage.
2. The calibrations are adjusted so that each microwave estimate reproduces the precipitation volume of the matched TMI. This should boost the total rain volume slightly, as some sensors have a fractional coverage by rain that is less than the TMI's.
3. A second ambiguous pixel screening was introduced to control a residue of artifacts, mostly in high polar latitudes.

On 15 April 2004, the calibration of IR Tb's to the HQ estimates was upgraded starting with the 04Z data:

1. IR coefficients are no longer smooth-filled across areas lacking HQ data (mostly due to cold/icy/frozen surface-induced drop-outs). Instead, IR-coincident accumulated precipitation and fractional coverage by precipitation are smooth-filled, then used to derive the IR coefficients. This should improve instantaneous fields in cold land areas substantially, although the resulting accumulations will continue to have high uncertainty.
2. The coldest-Tb rain rates are no longer set to a constant (determined locally by match-ups with the HQ). Instead, a climatological Tb-rainrate curve is applied with the rainrates adjusted to be piecewise continuous to the curve determined from the match-ups. This should alleviate cold-Tb areas showing constant rainrates.

On 4 January 2005 the real-time GPROF-TMI (2A12RT) was upgraded to Version 6 around 16Z.

On 08Z 3 February 2005, several important upgrades occurred:

1. Precipitation estimates from the AMSR-E and the 3 AMSU-B sensors are incorporated in the HQ product (3B40RT), which nearly doubles the coverage by HQ data in the latitude band 50ºN-S from ~45% to nearly 80%.
2. Inter-satellite calibration in the HQ product is climatological, reducing the real-time computational load and preparing for the eventual termination of TRMM. The calibrations of AMSU-B and AMSR-E to TMI each have one set of coefficients for land and a separate set for ocean, while SSM/I uses one set for land and 5 for ocean, covering the latitude bands 90-30ºS, 30-10ºS, 10ºS-N, 10-30ºN, and 30-90ºN. AMSR-E uses a 2-month set of match-ups to ensure sufficient sampling, while all of the others work with single-month accumulations. The AMSR-E and AMSU-B coefficients apply to the entire year, while SSM/I uses a separate set for each season.
3. VAR coefficients are recomputed every 3 hr to better control unrealistically high VAR estimates when a batch of unusually cold IR Tb's are encountered in a region. The calculation is now done with all of the HQ-IR match-ups observed in the previous 5 pentads, plus whatever match-ups have occurred in the current pentad.

Individually, and certainly taken together, these changes are significant enough that one should not expect the data computed before this date to have the same statistical behavior as data computed after that date. Dramatic statistical improvement has been demonstrated in various studies, such as Tian et al. 2009. On the other hand, it's not fair to say that the prior data are all "bad". Regions with snowy surface are, indeed, much worse before Feb. 2005, with regions having sudden heavy precip also likely suffering much higher errors. But in the remaining regions, the higher IR data content before Feb. 2005 will lead to subtle problems with timing of the diurnal cycle and more-frequent attribution of heavy rain to cold, but relatively quiescent anvils. These considerations led us to label prior data as “obsolete” and remove them from active distribution.

Starting 10 March 2005 a short-coming in GPROF's treatment of SSM/I input data was corrected. Previous to 10 March 2005 the GPROF-SSM/I estimates used in the TMPA-RT would very rarely display a rain area that had the correct shape, but unrealistically high values covering the entire feature. The problem was tracked to a lack of screening for unrealistic values in an interpolation routine, and subsequent processing that caused these values to damage all non-zero rain estimates in a 200-scan block, which is a chunk of the orbit about 22º of lat. in length. Known examples of this problem were all observed over ocean, but it is possible that less-obvious cases occurred over land as well. Very sporadic examples of such errors are embedded in the entire TMPA-RT record before 10 March 2005; 3B40RT and 3B42RT were directly affected because they incorporate the GPROF-SSM/I estimates, while 3B41RT was slightly affected to the extent that the occasional erroneous precipitation area was pooled with a month of other, normal estimates for the calibration. This short-coming is believed to affect all versions of GPROF, but only becomes a problem when the input data contain bad values. In particular, the Version 6 GPROF-SSM/I estimates are computed from the Remote Sensing Systems (RSS) version of Tb's, which contains significantly stronger quality controls than the FNMOC SDR Tb's used in the TMPA-RT.

In late May 2005 the developers realized that 3B41RT (and so 3B42RT to a lesser extent) episodically displayed unrealistic histograms of rain rate. By 1 June 2005 the problem had been traced to overflows in intermediate accumulation arrays and fixed. Both 3B41RT and 3B42RT were subsequently recomputed in mid-June 2005 for the entire period with questionable data, namely 3 February - 31 May 2005.

A corrupted intermediate file halted processing with the 09Z 19 July 2005 data; the first restart on 20 July resulted in errors in 3B40RT (and so for 3B42RT) for 09-21Z 19 July 2005. This second problem was diagnosed and all affected fields recomputed and reposted within 6 hours.

A long-standing inconsistency between counting total pixels and counting ambiguous and precipitating pixels was uncovered in 3B40RT. The effect was to under-screen (over-screen) ambiguous grid boxes for SSM/I (AMSR) data. Corrected data began with 18 UTC on 16 February 2010, but there is no reprocessing for earlier times. The impact is primarily at high latitudes and along coasts.

Missing-file error processing was improved for 3B40RT starting with the 15Z run on 5 August 2010. It is expected that this will control the occasional loss of 3B40RT when an input filename is passed in that lacks a file.

The TMPA-RT cut over to a new AMSR-E data feed starting with the 09Z 14 February 2011 products. Shutdown of the NOAA server Nanuk ended access (at least temporarily) to JAXA L1B AMSR-E data, which we had been converting to precipitation using GPROF-AMSR (roughly equivalent to GPROF2004). Now we are using the V11 real-time L2B (swath) precipitation estimates available on the NASA server LANCE. These estimates are computed at the GHRC DAAC from RSS V7 Tb's using GPROF2004. Users should not notice a large difference. Over ocean we see somewhat heavier values for light rain and lighter values for heavy rain, while over land there seems to be a general slight reduction in rain. Fractional coverages seem similar. It is possible that the new data have fewer coastal artifacts.

In the future, all products will be provided with random error estimates.

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8. Sensors

The TRMM Microwave Imager (**TMI*) is a multi-channel passive microwave radiometer, that has flown on TRMM since December 1997. TRMM is placed in a (46-day) precessing orbit at a 35° inclination with a period of about 91.5 min. The channels have effective fields of view that vary from 4.6x6.9 km for the 85 GHz (oval due to the slanted viewing angle) to 29.1x55.2 km for the 10 GHz. Consequently, the 85 GHz is undersampled, and all other channels are more or less oversampled.

The TMI is an operational sensor, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, etc. There were outages for an operational anomaly in May 2000, and the boost to a higher orbit during the first part of August 2001.

The 35° inclination provides nominal coverage over the latitudes 40°N-S, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land or sea ice (if there happened to be any).

Further details are available in Kummerow et al. (1998).
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The Advanced Microwave Scanning Radiometer for the Earth Observing System (*AMSR-E*) is a multi-channel passive microwave radiometer provided by the Japan Aerospace Exploration Agency that has flown on Aqua since mid-2003. Aqua is placed in a sun-synchronous polar orbit with a period of about 102 min. The AMSR-E provides vertical and horizontal polarization values for 6, 10, 18, 23, 36, and 89 GHz frequencies (except only vertical at 23) with conical scanning, similar to the SSM/I. Pixels and scans are spaced 10 km apart at the suborbital point, except the 85-GHz channels are collected at 5 km spacing. Every other high-frequency pixel is co-located with the low-frequency pixels, starting with the first pixel in the scan and the first scan in a pair of scans. The channels have resolutions that vary from 4x6 km for the 89 GHz (oval due to the slanted viewing angle) to 43x74 km for the 6 GHz.

The polar orbit provides nominal coverage over the latitudes 85°N-S, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land or sea ice.

The AMSR-E is an operational sensor, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, etc. Over time the coverage has improved as the operational system has matured. As well, the B-scan sensor, which provides the 89 GHz scan between the lower-frequency scans, failed around 4 November 2004.

Further details are available at *http://www.ghcc.msfc.nasa.gov/AMSR/*.
....

The Special Sensor Microwave/Imager (*SSM/I*) is a multi-channel passive microwave radiometer that has flown on selected Defense Meteorological Satellite Program (DMSP) platforms since mid-1987. The DMSP is placed in a sun-synchronous polar orbit with a period of about 102 min. The SSM/I provides vertical and horizontal polarization values for 19, 22, 37, and 85 GHz frequencies (except only vertical at 22) with conical scanning. Pixels and scans are spaced 25 km apart at the suborbital point, except the 85-GHz channels are collected at 12.5 km spacing. Every other high-frequency pixel is co-located with the low-frequency pixels, starting with the first pixel in the scan and the first scan in a pair of scans. The channels have resolutions that vary from 12.5x15 km for the 85 GHz (oval due to the slanted viewing angle) to 60x75 km for the 19 GHz.

The polar orbit provides nominal coverage over the latitudes 85°N-S, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land or sea ice.

The SSM/I is an operational sensor, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, etc. Over time the coverage has improved as the operational system has matured. As well, the first 85 GHz sensor to fly degraded quickly due to inadequate solar shielding. After launch in mid-1987, the 85.5 GHz vertical- and horizontal-polarization channels became unusable in 1989 and 1990, respectively. Another issue arose on 14 August 2006: DoD activated the RADCAL beacon on the F15 DMSP, which interfered with the 22V and 85.5V channels, preventing reliable estimates using current GPROF code.

Further details are available in Hollinger et al. (1987, 1990).

The inventory of SSM/I data used in the TMPA-RT includes:

DMSP	*Period of Record*	*Status*
F13	29 January 2002 - 18 November 2009	inactive
F14	29 January 2002 - 23 August 2008	inactive
F15	29 January 2002 - 14 August 2006	active, but unusable

....

The Advanced Microwave Sounding Unit B (**AMSU-B**) is a multi-channel passive microwave radiometer that has flown on selected National Oceanic and Atmospheric Administration (NOAA) platforms since early 2000. The NOAA satellites are placed in sun-synchronous polar orbits with periods of about 102 min. The complete AMSU contains 20 channels, the first 15 referred to as AMSU-A, and the last 5 as AMSU-B. These channels (identified as 16 through 20) cover the frequencies 89.0±0.9, 150.0±0.9, and 183.31±1, 3, and 7, all in GHz, with cross-track scanning. Pixels and scans are spaced 16.3 km apart at nadir, with the pixels increasing in size and changing from circular to elongated in the cross-track direction as one moves away from nadir.

The polar orbit provides nominal coverage over the entire globe, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land or sea ice.

The AMSU-B is an operational sensor, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, etc. Over time the coverage has improved as the operational system has matured. As well, the NOAA-17 50-GHz channel failed in late October 2003, apparently due to solar flare activity, so this defect affects the entire period of record for the TMPA-RT.

Further details are available in the NOAA KLM User's Guide (September 2000 revision) at *http://www2.ncdc.noaa.gov/docs/klm/index.htm*, specifically at *http://www2.ncdc.noaa.gov/docs/klm/html/c3/sec3-4.htm* .

The inventory of AMSU-B data used in the TMPA-RT includes:

Satellite	*Period of Record*	*Status*
NOAA-15	3 February 2005 - 14 September 2010	inactive
NOAA-16	3 February 2005 - 16 February 2011	inactive
NOAA-17	3 February 2005 - 16 December 2009	inactive

....

The Microwave Humidity Sounder (*MHS*) is a multi-channel passive microwave radiometer that has flown on selected National Oceanic and Atmospheric Administration (NOAA) platforms since mid-2005 as a follow-on to AMSU-B and on the EUMETSAT MetOp since late 2006. The satellites are placed in sun-synchronous polar orbits with periods of about 102 min. The MHS contains 5 channels, similar to AMSU-B. These channels cover the frequencies 89.0, 157.0, 183.311±1 and 3, and 190.311, all in GHz, with cross-track scanning. Pixels and scans are spaced 16.3 km apart at nadir, with the pixels increasing in size and changing from circular to elongated in the cross-track direction as one moves away from nadir.

The polar orbit provides nominal coverage over the entire globe, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land or sea ice.

The AMSU-B is an operational sensor, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, etc. Over time the coverage has improved as the operational system has matured.

Further details are available in the NOAA KLM User's Guide (September 2000 revision) at *http://www2.ncdc.noaa.gov/docs/klm/index.htm*, specifically at *http://www2.ncdc.noaa.gov/docs/klm/html/c3/sec3-9.htm*.

The inventory of MHS data used in the TMPA includes:

Satellite	*Period of Record*	*Status*
NOAA-18	27 November 2007 - Current	active
NOAA-19	pending	inactive
MetOp-1	27 March 2009 - Current	active

....

The infrared (*IR*) data are collected from a variety of sensors flying on the international constellation of geosynchronous-orbit meteorological satellites – the Geosynchronous Operational Environmental Satellites (GOES, United States), the Geosynchronous Meteorological Satellite (GMS, Japan), and the Meteorological Satellite (Meteosat, European Community). There are usually two GOES platforms active, GOES-EAST and -WEST, which cover the eastern and western United States, respectively. The geosynchronous IR data are collected by scanning (parts of) the earth's disk. By international agreement, all satellite operators collect full-disk images at the synoptic observing times (00Z, 03Z, ..., 21Z) at a minimum.

Subsequent processing is described in "Merged 4-Km IR Tb data set".

The various IR instruments are operational sensors, so the data record suffers the usual gaps in the record due to processing errors, down time on receivers, sensor failures, etc. Most notably during the TMPA period of record, GMS-5 was replaced by GOES-9 starting 01Z 22 May 2003, which introduced slightly different instrument characteristics. Starting 19Z 17 November 2005 the new MTSat-1R went operational, but NOAA/CPC was unable to process the new format through 09Z 23 March 2006 for the RT (and 00Z 23 March 2006 in Version 6).

Further details are available in Janowiak and Arkin (1991).
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9. Error Detection and Correction

TMI error detection/correction is quite similar to that of the SSM/I because it is a modified SSM/I with the 10 GHz channels added. Built-in hot- and cold-load calibration checks are used to convert counts to Antenna Temperature (Ta). An algorithm converts Ta to Brightness Temperature (Tb) for the various channels (eliminating cross-channel leakage). As well, systematic navigation corrections are performed. All pixels with non-physical Tb and local calibration errors are deleted.

Accuracies in the Tb's are within the uncertainties of the precipitation estimation techniques. For the most part, tests show stable cross-calibration with the fleet of SSM/I's.

TRMM is designed to precess over a 46-day period. There is no direct effect on the accuracy of the TMI data, but the continually changing diurnal sampling can cause significant fluctuations in the resulting TMI-only precipitation estimates.

One important test for artifacts is screening the data for "excessive" numbers of "ambiguous pixels"; see that topic for an explanation. Because the 2A12RT files do not contain the ambiguous flag field, the SSM/I fraction of pixels registering as ambiguous is used as a proxy.
....

AMSR-E error detection/correction has several parts. Built-in hot- and cold-load calibration checks are used to convert counts to Antenna Temperature (Ta). An algorithm has been developed to convert Ta to Brightness Temperature (Tb) for the various channels (eliminating cross-channel leakage). As well, systematic navigation corrections are performed. All pixels with non-physical Tb and local calibration errors are deleted.

Accuracies in the Tb's are within the uncertainties of the precipitation estimation techniques.

One important test for artifacts is screening the data for "excessive" numbers of "ambiguous pixels"; see that topic for an explanation.
....

SSM/I error detection/correction has several parts. Built-in hot- and cold-load calibration checks are used to convert counts to Antenna Temperature (Ta). An algorithm has been developed to convert Ta to Brightness Temperature (Tb) for the various channels (eliminating cross-channel leakage). Differences between the Ta-to-Tb conversions employed by RSS and the U.S. Navy's Fleet Numerical Meteorological and Oceanographic Center imply that uncertainties in the Ta-to-Tb conversion are much larger than any other known uncertainty. As well, systematic navigation corrections are performed. All pixels with non-physical Tb and local calibration errors are deleted.

Accuracies in the Tb's are within the uncertainties of the precipitation estimation techniques. For the most part, tests show only small differences among the SSM/I sensors flying on different platforms.

Some satellites experienced significant drifting of the equator-crossing time during their periods of service. There is no direct effect on the accuracy of the SSM/I data, but it is possible that the systematic change in sampling time could introduce biases in the resulting SSM/I-only precipitation estimates.

One important test for artifacts is screening the data for "excessive" numbers of "ambiguous pixels"; see that topic for an explanation.
....

AMSU-B error detection/correction has several parts. Built-in hot- and cold-load calibration checks are used to convert counts to Antenna Temperature (Ta). Systematic navigation corrections are performed. All pixels with non-physical Tb and local calibration errors are deleted.

Accuracies in the Tb's are within the uncertainties of the precipitation estimation techniques. The main difficulty results from the loss of the NOAA-17 50-GHz channel.

Some satellites experienced significant drifting of the equator-crossing time during their periods of service. There is no direct effect on the accuracy of the AMSU-B data, but it is possible that the systematic change in sampling time could introduce biases in the resulting AMSU-B-only precipitation estimates.
....

MHS error detection/correction has several parts. Built-in hot- and cold-load calibration checks are used to convert counts to Antenna Temperature (Ta). Systematic navigation corrections are performed. All pixels with non-physical Tb and local calibration errors are deleted.

Accuracies in the Tb's are within the uncertainties of the precipitation estimation techniques.

The initial years of the relevant satellites show little drift in the equator-crossing time during their brief periods of service. Should it develop, there is no direct effect on the accuracy of the MHS data, but it is possible that the systematic change in sampling time could introduce biases in the resulting MHS-only precipitation estimates.
....

In common with other microwave algorithms, GPROF flags pixels with certain ranges of Tb values as **ambiguous pixels** because such ranges are associated with both real precipitation and artifacts, compared to coincident weather observations. GPROF leaves it to the user to evaluate such pixels for use or deletion. In the TMPA-RT the ambiguous pixels are handled as follows:

In the HQ (3B40RT), experience shows that when the fraction of ambiguous (FA) exceeds 40% or the 5x5-grid box average FA exceeds 20%, the precipitation value is likely an artifact. Accordingly, users generally should not employ these values. The likely artifact value is stored as its decremented negative:

$$v = (-100 * p) - 1$$

where p is the floating-point value,
v is the scaled-integer value, and
v is not equal to the 2-byte-integer missing value (-31999).

This encoding creates a non-physical value that is easy to screen, but preserves the value for subsequent use. [The full version of this screening was implemented starting with 09Z 28 February 2003. Earlier screens lacked the 5x5-grid box test.]

In the calibration for VAR, all flagged precipitation values are accumulated along with the presumably good values. Experience shows that the month-accumulated values should be discarded when accumulated FA exceeds 20%, or the 5x5-grid-box-average accumulated FA exceeds 10%, or the grid box has fewer than 60% of the nominal number of samples for the month at the box's latitude. The resulting holes in the coefficient field are smooth-filled from surrounding grid boxes. In some cases, such as January in Eurasia, these fill-ins can be quite extensive. As a result, our confidence in VAR over wintertime land is reduced. [The full version of this screening was implemented starting with 00Z 2 March 2003. Earlier screens were not consistent and allowed significant artifacts.]

In the combination of HQ and VAR (3B42RT), the HQ values previously judged to be suspect are set to missing before combination with VAR.

The 2A12RT files do not provide ambiguous pixel flags for TMI, so we take the percentage of ambiguous as determined from SSM/I for the trailing 30-day (6 pentad) period as a reasonable proxy.
....

The dominant **IR data correction** is for slanted paths through the atmosphere. Referred to as "limb darkening correction" in polar-orbit data, or "zenith-angle correction" (Joyce et al. 2001) in geosynchronous-orbit data, this correction accounts for the fact that a slanted path through the atmosphere increases the chances that (cold) cloud sides will be viewed, rather than (warm) surface, and raises the altitude dominating the atmospheric emission signal (almost always lowering the equivalent Tb). The slant path also creates an offset to the geolocation of the IR pixel due to parallax. That is, the elevated cloud top, viewed from an angle, is located closer to the satellite than where the line of sight intersects the Earth's surface. Pixels are moved according to a standard height-Tb-zenith angle profile, at the price of holes created when tall clouds are moved further than shallow clouds behind them. In addition, the various sensors have a variety of sensitivities to the IR spectrum, usually including the 10-11 micron band. Inter-satellite calibration differences are documented, but they are not implemented in the current version. They are planned for a future release. The VAR largely corrects inter-satellite calibration, except for small effects at boundaries between satellites. The satellite operators are responsible for detecting and eliminating navigation and telemetry errors.

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A number of **known errors** are contained in part or all of the current 3B42RT archive. They have been uncovered by visual inspection and other diagnostics, but it is outside the scope of a real-time system to reprocess the old data. Items 1, 2, 4, 5, and 6 are incorporated in the reprocessing for TRMM Version 6 3B42, but without changing the archive of 3B42RT. Other items will be included in future re-processing cycles as possible. For ease of document maintenance, some of the following items imply the known error by stating what upgrade was applied.

1. The half-hour IR field initially used was that from the current IR hour file. The system was modified to bring in the previous hour's half-hour field starting in March 2002.
2. A corrected screening for microwave artifacts was implemented in the HQ starting 09Z 28 February 2003, and in VAR starting 00Z 2 March 2003 (see "production and updates"). Prior to those times, all three products have at least occasional large artifacts in areas with frozen and/or snowy surfaces. The regions primarily affected were in Eurasia north of 40ºN.
3. There is no inter-satellite calibration applied to the IR data.
4. On 12 February 2004 GPROF-SSM/I Version 6.5 was installed, which features the ocean code from Version 6 and the land and coast code from Version 7. We chose not to rework the TMI-SSM/I calibration coefficients, so estimates over land and coast (and the corresponding IR calibration) will be somewhat less accurate for the following 2-week period, most likely having a small negative bias that improves with each additional pentad of Version 6.5 estimates.
5. On 31 March 2004 the calibration of microwave estimates to the TMI was upgraded:
   - Zeroes are now included in the calibration histograms, improving the treatment of fractional coverage.
   - The calibrations are adjusted so that each microwave estimate reproduces the precipitation volume of the matched TMI. This should boost the total rain volume slightly, as some sensors have a fractional coverage by rain that is less than the TMI's.
   - A second ambiguous pixel screening was introduced to control a residue of artifacts, mostly in high polar latitudes. At the same time, the calibration of IR Tb's to the HQ estimates was upgraded:
   - IR coefficients are no longer smooth-filled across areas lacking HQ data (mostly due to cold/icy/frozen surface-induced drop-outs). Instead, IR-coincident accumulated precipitation and fractional coverage by precipitation are smooth-filled, then used to derive the IR coefficients. This should improve instantaneous fields in cold land areas substantially, although the resulting accumulations will continue to have high uncertainty.
   - The coldest-Tb rain rates are no longer set to a constant (determined locally by match-ups with the HQ). Instead, a climatological Tb-rainrate curve is applied with the rainrates adjusted to be piecewise continuous to the curve determined from the matchups. This should alleviate cold-Tb areas showing constant rainrates.
6. Version 1.3 was instituted as of 08Z 3 February 2005, providing several important upgrades:

- Precipitation estimates from the AMSR-E and the 3 AMSU-B sensors are incorporated in the HQ product (3B40RT), which nearly doubles the coverage by HQ data in the latitude band 50ºN-S from ~45% to nearly 80%.
- Inter-satellite calibration in the HQ product is climatological, reducing the real-time computational load and preparing for the eventual termination of TRMM. The calibrations of AMSU-B and AMSR-E to TMI each have one set of coefficients for land and a separate set for ocean, while SSM/I uses one set for land and 5 for ocean, covering the latitude bands 90-30ºS, 30-10ºS, 10ºS-N, 10-30ºN, and 30-90ºN. AMSR-E uses a 2-month set of match-ups to ensure sufficient sampling, while all of the others work with single-month accumulations. The AMSR-E and AMSU-B coefficients apply to the entire year, while SSM/I uses a separate set for each season.
- VAR coefficients are recomputed every 3 hr to better control unrealistically high VAR estimates when a batch of unusually cold IR Tb's are encountered in a region. The calculation is now done with all of the HQ-IR match-ups observed in the previous 5 pentads, plus whatever match-ups have occurred in the current pentad.

7. On 10 March 2005 a short-coming in GPROF's treatment of SSM/I input data was corrected. Previous to 10 March 2005 the GPROF-SSM/I estimates used in the TMPA-RT would very rarely display a rain area that had the correct shape, but unrealistically high values covering the entire feature. The problem was tracked to a lack of screening for unrealistic values in an interpolation routine, and subsequent processing that caused these values to damage all non-zero rain estimates in a 200-scan block, which is a chunk of the orbit about 22º of lat. in length. Known examples of this problem were all observed over ocean, but it is possible that less-obvious cases occurred over land as well. Very sporadic examples of such errors are embedded in the entire TMPA-RT record before 10 March 2005; 3B40RT and 3B42RT were directly affected because they incorporate the GPROF-SSM/I estimates, while 3B41RT was slightly affected to the extent that the occasional erroneous precipitation area was pooled with a month of other, normal estimates for the calibration. This short-coming is believed to affect all versions of GPROF, but only becomes a problem when the input data contain bad values. In particular, the Version 6 GPROF-SSM/I estimates are computed from the RSS version of Tb's, which contains significantly stronger quality controls than the FNMOC SDR Tb's used in the TMPA-RT.
8. The TMPA-RT data cut-off has been set at about 8 hours after observation time. At least occasionally with SSM/I, and more frequently with AMSU-B and MHS, the input data arrive too late to be included in the HQ (3B40RT) run for that hour.
9. NESDIS AMSU-B and MHS estimates are deficient in sensing light precipitation, leading to an underestimate that is regionally dependent, but nears 100% in light-rain areas. Because of this, the AMSU-B and MHS estimates are only used if no other HQ estimates are available, meaning that the AMSU-B's and MHS's deficiency is minimized in the TMPA. Nonetheless, it causes as much as a 10% bias in the zone 30ºN-S over oceans. As well, the AMSU-B record used in the (frozen) Version 6 data set has a time-varying effect, being absent before 2000, phasing in over the next two years, changing to a new, even sparser set of estimates in late August 2003, then upgrading to a better estimator in late May 2007.
10. The TMPA tends to display artifacts along some coasts, including around inland water bodies in the southeastern U.S. (Tian et al. 2007) and in desert locations such as Lake Nasser and the coasts of Egypt. These artifacts result from mis-identification of precipitation events in the input data sets, but there has not been a detailed study to determine the sensors and algorithm

versions most responsible. The artifacts are generally light, but persistent, so they can impact the daily and monthly estimates.

11. A long-standing inconsistency between counting total pixels and counting ambiguous and precipitating pixels was uncovered in 3B40RT. The effect was to under-screen (over-screen) ambiguous grid boxes for SSM/I (AMSR) data. Corrected data began with 18 UTC on 16 February 2010. The impact is primarily at high latitudes and along coasts. While there is no reprocessing for earlier times using the new scheme, the following files were reprocessed to recover from processing failures:
    3B40RT from 03-09 UTC 2/14/10
    3B41RT from 03-11 UTC 2/14/10
    3B42RT from 03-09 UTC 2/14/10
12. A coding error at NESDIS resulted in bad date/time information for MetOp MHS data in the granule bridging the start of 2011, which corrupted some intermediate files in TMPA-RT. As a result, no MetOp MHS data are included in the TMPA-RT products during 0000UTC/01-0940UTC/04 January 2011. No reprocessing was done, meaning the products depend more than usual on the IR estimates during that period. Similar date/time problems also exist for at least a few recent previous year boundaries.
13. Tests in the Version 6 TMPA show an apparent degradation in the NOAA-16 AMSU estimates in cold ocean regimes, likely as the result of gradually increasing instrument noise. Accordingly, there are potential errors from late 2010 until that data feed was terminated as of 12Z 16 February 2011.

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Some **known anomalies** in the data set are documented and left intact at the discretion of the data producers. As a real-time system the TMPA-RT has gaps due to delays in data delivery. No attempt is made to process data that arrives after the cut-off time. These gaps largely disappear as the Version 6 TRMM product 3B42 is computed (see"3B42").

An outage at FNMOC resulted in the following loss of SSM/I data:
F13: 20031008/09:55 - 09/19:39 UTC
F14: 20031008/10:16 - 09/18:39 UTC
F15: 20031008/11:20 - 09/19:24 UTC
As a result, 3B40RT for 20031008/12 - 10/15 UTC contains only TMI data, resulting in highly reduced data coverage. There is no effect on 3B41RT, and relatively little on 3B42RT.

Two events in late summer 2006 reduced the microwave data content in 3B40RT and 3B42RT. First, on 14 August 2006 DoD activated a radar calibration beacon on the F15 SSM/I that interferes with the 22V channel and effectively prevents reliable estimates with the current version of GPROF. Second, AMSR-E dropped out starting 5 September, first due to access issues, and then to a hardware failure at the AMSR-E data provider machine. GPROF is being modified to utilize data from the F16 SSM/IS follow-on to F15 and/or from F15. A temporary fix to the AMSR-E feed has been made; AMSR-E is absent from the products for the data times 12Z 07 September to 03Z 11 September 2006.

An Aqua data anomaly resulted in artifacts over the ocean just east of China in the AMSR-E precipitation estimates, and therefore in 3B40RT and 3B42RT, for the 06 UTC 2 Dec. 2007 data set. Due to its small scale, the anomaly will be documented and left in the data set. The AMSR-E data dropped out in the 3B4xRT products through the first half of the 18 UTC 12 December 2007 period. Subsequently, a processing anomaly led to a loss of AMSR-E data in the 3B4xRT products for the entire 12 UTC 22 December 2007 period through the first half of the 12 UTC 27 December 2007 period. In such cases the result is a slightly higher content of AMSU-B and lower total coverage in 3B40RT, and higher content of AMSU-B and IR-based estimates in 3B42RT.

AMSR-E data were unavailable through the first half of the 18 UTC 12 December 2007 period. Subsequently, a processing anomaly led to a loss of AMSR-E data in the 3B4xRT products for the entire 12 UTC 22 December 2007 period through the first half of the 12 UTC 27 December 2007 period.

Another hardware failure for the producers caused a loss of AMSR-E during the period 16 UTC 9 May to 14 UTC 11 May 2009 from the 3B4xRT products.

A discontinuity in the AMSR-E was introduced when the RT cut over to a new AMSR-E data feed starting with the 09Z 14 February 2011 products. Shutdown of the NOAA server Nanuk ended access (at least temporarily) to JAXA L1B AMSR-E data, which we had been converting to precipitation using GPROF-AMSR (roughly equivalent to GPROF2004). Now we are using the V11 real-time L2B (swath) precipitation estimates available on the NASA server LANCE. These estimates are computed at the GHRC DAAC from RSS V7 Tb's using GPROF2004. Users should not notice a large difference. Over ocean we see somewhat heavier values for light rain and lighter values for heavy rain, while over land there seems to be a general slight reduction in rain. Fractional coverages seem similar. It is possible that the new data have fewer coastal artifacts.

The AMSR-E gridder process locked up and so failed to provide AMSR-E input for 03-20UTC/20 February 2011.

Several exceptions have been made to the no-reprocessing rule:

1. Hurricane Isabel caused significant interruptions in receiving and processing the requisite IR input data, which precluded the computation of 3B41RT and 3B42RT estimates during parts of the days 16-22 September 2003. After real time the necessary IR input data became available and 3B41RT and 3B42RT were computed for the entire period of 18Z/16 - 12Z/22 September 2003. The microwave-based IR calibration coefficents used for the post-real-time computation were those generated on 00Z/23 September 2003, while those few files generated in real time were based on either the 00Z/13 or 00Z/18 September 2003 coefficient sets (for times before or from 00Z/18, respectively). Comparisons of a few recomputed files with available files computed in real time showed generally small differences, but a few were locally non-trivial. Consequently, for consistency the entire sequence of sparse real-time files for the period 18Z/16-12Z/22 September 2003 were replaced by the post-real-time files computed using the "new" coefficients.
2. A gap in real-time processing on 21-22 August 2004 was considered unacceptably long. The 3B40RT files were not easily recoverable, but 3B41RT files for the date/times

21 August 2004: 06-13, 15, 18, 21
22 August 2004: 00, 07-10, 12, 15

were computed using the calibration file created 31 August 2004, and 3B42RT files for the date/times

21 August 2004: 06, 09, 12, 15, 18, 21
22 August 2004: 00, 06, 09, 12, 15

were created using only 3B41RT as input. These results were posted on 19 November 2004.

3. Errors in creating GOES sectors within NOAA were included in the original CPC 4-km IR data and hence in 3B41RT and 3B42RT for the period 17Z 9 December to 06Z 11 December 2004. After the sectors were corrected and the CPC 4-km reposted, 3B41RT and 3B42RT were recomputed (with calibration coefficients updated on 00Z 11 December 2004) and reposted on 16 December 2004.
4. A disk space issue and data errors in the original CPC 4-km IR data combined to create an outage in 3B41RT and 3B42RT for the period 12Z 17 December to 12Z 20 December 2004. After the problems were corrected and the CPC 4-km reposted, 3B41RT and 3B42RT were computed and reposted on 22 December 2004.
5. Data problems at CPC created an outage in 3B41RT and 3B42RT for the period 00Z 26 December to 15Z 27 December 2004. After the problems were corrected and the CPC 4-km reposted, 3B41RT and 3B42RT were computed and reposted on 30 December 2004.
6. Erroneous GMS data for the span 00-13Z on 31 May 2006 forced us to recompute 3B41RT and 3B42RT data for that period. The original estimates were removed and the new posted to the trmmopen FTP site around 14Z on 5 June 2006. This only affects longitudes roughly from southeast Asia to New Zealand.
7. A Center-wide upgrade to the network at GSFC caused intermittent loss of input data for all 3B4xRT products during 6-7 January 2007. Most of the data subsequently arrived, so a general reprocessing was carried out for affected times, although some SSM/I data were not retrieved. The reprocessed files placed in the archive are:

3B40RT:		7 January 2007 00Z-15Z
3B41RT:	6 January 2007 14Z-23Z,	7 January 2007 00Z-19Z
3B42RT:	6 January 2007 15Z-21Z,	7 January 2007 00Z-18Z

8. Mistaken network administration rules caused the near-total loss of input data from outside GSFC in the period late on 2 April 2007 to mid-afternoon on 4 April 2007. Offline, 3B41RT and 3B42RT have been recomputed for the affected period, but users should be aware that little microwave data are available in 3B42RT. The reprocessed files placed in the archive are:

3B41RT: 12Z 3 April 2007 to 14Z 4 April 2007
3B42RT: 12Z 3 April 2007 to 12Z 4 April 2007

At the same time, episodic networking failures at NCEP denied deliver of AMSU-B estimates for significant parts of 30 March to 5 April 2007, so the microwave content of 3B40RT and 3B42RT is reduced during that period. Finally, a power failure at NCEP interrupted AMSU-B and IR data delivery in the period 0330-0830Z on 6 April 2007. This failure again reduced the microwave content of 3B40RT and 3B42RT, reduced the IR content of 3B40RT at 03Z and 08Z and of 3B42RT at 03Z, and eliminated IR in the interval 04-07Z, so no 3B41RT and 3B42RT were produced for those times. Users can use the 06Z 3B40RT to fill in the missing 3B42RT (but note the different format).

9. NESDIS inserted incorrect navigation was inserted into the processing stream for NOAA-16 during the period

   1050/09 - 1219/10 July 2007

   which caused all data to be displaced several thousand km down-track. Consequently, the NESDIS AMSU-B precipitation estimates for that period exhibit two errors. First, all estimates are mis-located. Second, the land/sea masking that the algorithm performs consequently worked on data from the wrong locations and passed through regions of extremely high artifacts in the high- and mid-latitude oceans, where icy/frozen surface was misinterpreted as oceanic precipitation. These errors appear in 3B40RT and 3B42RT for the time range

   12Z/09 - 12Z/10 July 2007

   in regions where the NOAA-16 estimates were not superseded by conical-scan microwave estimates.
10. A satellite commanding error caused errors in the AMSR-E precipitation estimates that were not recoverable. The original 3B40RT files contained bad data for the period 03Z 27 November to 15Z 28 November 2007. These were discarded and recomputed (without AMSR-E input). AMSR-E data returned around 03Z 29 November 2007, but were not incorporated in 3B40RT until the 12Z 29 November 2007 file. The 3B41RT (IR) fields are indirectly influenced due to the microwave calibration. Testing seemed to show minimal interference, but as a precaution, the calibration file was modified to exclude the period of bad AMSR-E data. It went into use with the 16Z 29 November 2007 3B41RT, so all 3B41RT and 3B42RT files from 03Z 27 November through 15Z 29 November 2007 were recomputed and reposted.
11. An Aqua data anomaly resulted in artifacts over the ocean just east of China in the AMSR-E precipitation estimates, and therefore in 3B40RT and 3B42RT, for the 06 UTC 2 Dec. 2007 data set. Due to its small scale, the anomaly will be documented and left in the data set. Subsequent AMSR-E precipitation estimates were missing until xxZ xx December 2007.
12. The infrared data suppliers at NOAA/CPC had a major hardware failure on 11 April 2008 that resulted in the loss of all infrared data in the TMPA-RT system for the period 01UTC 11 April through 17UTC 14 April 2008, except for 22UTC 13 April through 00UTC 14 April 2008. As a result, no 3B41RT and 3B42RT products were produced for those periods. Substitute 3B42RT products for the affected period were created off-line, using only the 3B40RT products as input. Since the microwave data cover 75 or 80% of each 3-hourly map, this fill-in should be satisfactory in most cases. Nonetheless, users should be aware that sampling error will be higher during the fill-in period.
13. The infrared data suppliers at NOAA/CPC had a major hardware failure on 11 April that resulted in the loss of all infrared data in the TMPA-RT system for the period 01UTC 11 April through 17 UTC 14 April 2008, for which 3B42RT was computed off-line using only the 3B40RT products as input.
14. Server configuration problems within NOAA caused faulty IR data to contaminate the 09 UTC 30 April 2008 3B42RT, which was recomputed from 3B40RT alone.
15. Hardware maintenance caused disruption to the NOAA/CPCP Merged IR data for parts of 1-2 June 2008, so some 3B41RT files are missing and some 3B42RT files are microwave-only. The 00Z 5 June 2008 IR field was faulty due to communication issues; Both 3B41RT and 3B42RT were deleted and recomputed.

16. A server problem at NOAA prevented the timely transmission of the CPC Merged IR product from 21 UTC 19 June 2008 through 21 UTC 20 June 2008. The IR data were back-filled from CPC and re-run.
17. Selected hours of IR data as processed in real time were defective for selected hours on 2, 4, 5 August and 4 September 2008. The corresponding 3B41RT estimates were deleted and corresponding 3B42RT files were recomputed without IR.
18. Starting on 11 September 2008, a series of bad IR data sets contaminated 3B41RT and 3B42RT. Data files for 16 3B41RT times and 9 3B42RT times were recomputed in the interval 21 UTC 11 September – 12 UTC 15 September. As well, the errors contaminated the microwave-IR calibration. The relevant period of data was dropped from the calibration, but users should be aware that this fix somewhat affected results until mid-October.
19. Local networking administration rule updates caused IR and SSM/I input data to be blocked for data times roughly spanning 17Z on 11 March 2009 to 11Z, 12 March 2009. Reloaded IR files were used to recompute 3B41RT and 3B42RT, which were re-posted for this span. However, we chose to accept the relatively small loss of coverage by the lone SSM/I and did not recomputed 3B40RT.
20. IR data server problems forced reprocessing of 3B41RT and 3B42RT on 07-23 UTC 11/7; 02,09-20 UTC 11/8; 23 UTC 11/9; 00 UTC 11/10; 10-19 UTC 11/14; 08 UTC 11/15 through 19 UTC 11/16.
21. Problematic IR input files caused re-runs of 3B41RT for 01-04 UTC 12/14 and 3B42RT for 03UTC 12/14.
22. Network issues prevented the timely reception of MHS data from early on 11 November 2010 through early on 12 November 2010. As a result, the 03 UTC 11 November 3B40RT and 3B42RT has under half the normal MHS coverage, there is only a small amount at 06 UTC, and then essentially no more until the 03 UTC 12 November 2010 time slot, when coverage returns to normal. Subsequently the entire 3B40RT, 3B41RT, 3B42RT sequence was reprocessed for the affected period.
23. Hung computer process at NASA/MSFC caused the AMSR-E data to be missing from both 3B40RT and 3B42RT for the date/times 20110407/15 through 20110411/09 (UTC) and 20110413/21 through 20110414/09 (UTC). The subscription service has been restarted, all missing files have been ingested, and the files were reposted.

....

10. Missing Value Estimation and Codes

There is generally no effort to **estimate missing values** in the single-source input data sets.
....

All products in the TMPA-RT use the **standard missing value** "-31999". In addition, grid boxes suspected of having artifacts and all non-missing values in grid boxes outside the latitude band 50ºN-S are considered to be highly uncertain, and are encoded to negative values. Accordingly, users generally should not employ these values.

....

All *missing hours* of a product result from completely absent input data for the given hour. If the input file(s) is(are) available, the product file is created, even if it lacks any valid data.
....

11. Quality and Confidence Estimates

The *accuracy* of the precipitation products can be broken into systematic departures from the true answer (bias) and random fluctuations about the true answer (sampling), as discussed in Huffman (1997). The former are the biggest problem for climatological averages, since they will not average out. However, for short averaging periods the low number of samples and/or algorithmic inaccuracies tend to present a more serious problem for individual microwave data sets. That is, the sampling is spotty enough that the collection of values over, say, one day may not be representative of the true distribution of precipitation over the day. For VAR, the sampling is good, but the algorithm likely has substantial RMS error due to the weak physical connection between IR Tb's and precipitation.

Accordingly, the "random error" is assumed to be dominant, and estimates could be computed as discussed in Huffman (1997). Random error cannot be corrected.

The "bias error" is likely small, or at least contained. This is less true over land, where the lower-frequency microwave channels are not useful for precipitation estimation with our current state of knowledge. The state of the art at the monthly scale is reflected in the study by Smith et al. (2006). Studies of the sub-monthly bias have not yet been performed.
....

The TMPA *intercomparison results* are still being developed. The time series of the global images shows good continuity in time and space across the geo-IR data boundaries. Overall, the analysis approach appears to be working as expected. See Huffman et al. (2007, 2009) for more information.

Validation studies are being conducted under the auspices of the International Precipitation Working Group in Australia, the continental U.S., western Europe, parts of South America, and Japan. Respectively, the web sites for these activities are:

http://cawcr.gov.au/projects/SatRainVal/validation-intercomparison.html
http://cics.umd.edu/~johnj/us_web.html
~~*http://kermit.bham.ac.uk/~ipwgeu/*~~ (currently in transition)
http://cics.umd.edu/~dvila/web/SatRainVal/dailyval.html
http://www-ipwg.kugi.kyoto-u.ac.jp/IPWG/sat_val_Japan.html
....

12. Data Archives

The *archive and distribution site* for the official release of the TRMM Real-Time Multi-Satellite Precipitation Analysis is:

Helpdesk
Precipitation Processing System
Code 610.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA
Phone: 301-614-5184
Fax: 301-614-5575
Internet: *helpdesk@pps-mail.nascom.nasa.gov*
Anonymous FTP: *ftp://trmmopen.gsfc.nasa.gov/pub/merged*

Interactive Web-based access to the data and related fields is provided through TOVAS; see that topic for details.

Independent archive and distribution sites exist for the input data sets, and contact information may be obtained through Dr. Huffman (see "Documentation creator").
....

13. Documentation

The **documentation creator** is:

Dr. George J. Huffman
Code 613.1
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA
Phone: +1-301-614-6308
Fax: +1-301-614-5492
Internet: *george.j.huffman@nasa.gov*
MAPB Precipitation Page: *http://precip.gsfc.nasa.gov/*
....

The **documentation revision history** is:

14 February 2002	Draft 1	by GJH
21 February 2002	Version 1	by GJH
22 March 2002	Rev. 1.1	by GJH
02 March 2003	Rev. 1.2	by GJH
25 September 2003	Rev. 1.3	by GJH
23 February 2003	Rev. 1.4	by GJH
10 October 2003	Rev. 1.5	by GJH
15 April 2004	Rev. 1.6	by GJH
23 November 2004	Rev. 1.7	by GJH,EJN
16 December 2004	Rev. 1.8	by GJH,EJN,DTB
23 December 2004	Rev. 1.9	By GJH
03 February 2005	Rev. 1.10	by GJH
10 March 2005	Rev. 1.11	by GJH

27 September 2005	Rev. 1.12	by GJH
05 June 2006	Rev. 1.13	by GJH
08 September 2006	Rev. 1.14	by GJH
12 September 2006	Rev. 1.15	by GJH
21 September 2006	Rev. 1.16	by GJH
06 April 2006	Rev. 1.17	by GJH
03 October 2007	Rev. 1.18	by GJH
30 October 2007	Version 2	by GJH,EJN,DTB – MSWord and PDF
28 December 2008	Rev. 2.2	by GJH
1 May 2008	Rev. 2.3	by GJH
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13 May 2009	Rev. 2.6	by GJH
08 September 2009	Rev. 2.7	by GJH
12 November 2009	Rev. 2.8	by GJH
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14 December 2009	Rev. 2.10	by GJH
17 February 2010	Rev. 2.11	by GJH
16 November 2010	Rev. 2.12	by GJH
6 January 2010	Rev. 2.13	by GJH
16 February 2011	Rev. 2.14	bu GJH

....

The list of *references* used in this documentation is:

Grody, N.C., 1991: Classification of snow cover and precipitation using the Special Sensor Microwave/Imager (SSM/I). *J. Geophys. Res*., **96**, 7423-7435.

Hollinger, J., R. Lo, G. Poe, J. Pierce, 1987: Special Sensor Microwave/Imager User's Guide, Naval Res. Lab., Washington, DC.

Hollinger, J.P., J.L. Pierce, G.A. Poe, 1990: SSM/I instrument evaluation. *IEEE Trans. Geosci. Remote Sens*., **28**, 781-790.

Huffman, G.J., 1997: Estimates of root-mean-square random error contained in finite sets of estimated precipitation. *J. Appl. Meteor*., **36**, 1191-1201.

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-global, multi-year, combined-sensor precipitation estimates at fine scale. *J. Hydrometeor*., **8**(1), 38-55. PDF available at *ftp://meso.gsfc.nasa.gov/agnes/huffman/papers/TMPA_jhm_07.pdf.gz*

Huffman, G.J., R.F. Adler, D.T. Bolvin, E.J. Nelkin, 2010: The TRMM Multi-satellite Precipitation Analysis (TMPA). Chapter 1 in *Satellite Applications for Surface Hydrology*, F. Hossain and M. Gebremichael, Eds. Springer Verlag, ISBN: 978-90-481-2914-0, 3-22. PDF available at *ftp://meso.gsfc.nasa.gov/agnes/huffman/papers/TMPA_hydro_rev.pdf*

Huffman, G.J., R.F. Adler, S. Curtis, D.T. Bolvin, E.J. Nelkin, 2007: Global rainfall analyses at monthly and 3-hr time scales. Chapter 23 of *Measuring Precipitation from Space: EURAINSAT and the Future*, V. Levizzani, P. Bauer, and F.J. Turk, Eds., Springer Verlag (Kluwer Academic Pub. B.V.), Dordrecht, The Netherlands, 291-306. [Invited paper]

Huffman, G.J., R.F. Adler, E.F. Stocker, D.T. Bolvin, E.J. Nelkin, 2003: Analysis of TRMM 3-hourly multi-satellite precipitation estimates computed in both real and post-real time. *Combined Preprints CD-ROM*, 83rd AMS Annual Meeting. Paper P4.11 in 12th Conf. on Sat. Meteor. and Oceanog., 9-13 Feb. 2003, Long Beach, CA, 6 pp.

Janowiak, J.E., P.A. Arkin, 1991: Rainfall variations in the tropics during 1986-1989. *J. Geophys. Res.,* **96**, 3359-3373.

Jost, V., S. Bakan, K. Fennig, 2002: HOAPS - A new satellite-derived freshwater flux climatology. *Meteorol. Zeit.*, **11**, 61-70.

Joyce, R.J., J.E. Janowiak, P.A. Arkin, P. Xie, 2004: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at 8 km, hourly resolution. *J. Climate*, **5**, 487-503.

Joyce, R.J., J.E. Janowiak, G.J. Huffman, 2001: Latitudinal and seasonal dependent zenith angle corrections for geostationary satellite IR brightness temperatures. *J. Appl. Meteor*., **40**(4), 689-703.

Kongoli, C., P. Pellegrino, R. Ferraro**,** 2007: The utilization of the AMSU high frequency measurements for improved coastal rain retrievals. *Geophys. Res. Lett.,* **34,** L17809, doi:10.1029/2007GL029940.

Kubota T., S. Shige, H. Hashizume, K. Aonashi, N. Takahashi, S. Seto, M. Hirose, Y.N. Takayabu, K. Nakagawa, K. Iwanami, T. Ushio, M. Kachi, K. Okamoto, 2007: Global precipitation map using satellite-borne microwave radiometers by the GSMaP Project: Production and validation. *IEEE Trans. Geosci. Remote Sens*. **45**, 2259-2275.

Kummerow, C., W.S. Olson, L. Giglio, 1996: A simplified scheme for obtaining precipitation and vertical hydrometeor profiles from passive microwave sensors. *IEEE Trans. Geosci. Remote Sens*., **34**, 1213-1232.

Kummerow, C., W. Barnes, T. Kozu, J. Shiue, J. Simpson, 1998: The Tropical Rainfall Measuring Mission (TRMM) sensor package. *J. Atmos. Oceanic Tech*., **15**(3), 809-817.

Smith, T.M., P.A. Arkin, J.J. Bates, G.J. Huffman, 2006: Estimating bias of satellite-based precipitation estimates. *J. Hydrometeor*., **7**(5), 841-856.

Sorooshian, S., K.-L. Hsu, X. Gao, H.V. Gupta, B. Imam, D. Braithwaite 2000: Evaluation of PERSIANN system satellite-based estimates of tropical rainfall. *Bull. Amer. Meteor. Soc*., **81**, 2035-2046.

Spencer, R.W., 1993: Global oceanic precipitation from the MSU during 1979-92 and comparisons to other climatologies. *J. Climate*, **6**, 1301-1326.

Tian, Y., C.D. Peters-Lidard, 2007: Systematic anomalies over inland water bodies in satellite-based precipitation estimates. *Geophys. Res. Lett*., **34**, doi:1029/2007GL030787.

Tian, Y., C. Peters-Lidard, J. Eylander, R. Joyce, G. Huffman, R. Adler, K.-L. Hsu, F. J. Turk, M. Garcia, J. Zeng, 2009: Component Analysis of Errors in Satellite-Based Precipitation Estimates. *J. Geophys. Res, - Atmos*., **114**, D22104, doi:10.1029/2009JD011949.

Turk, F.J., G.D. Rohaly, J. Hawkins, E.A. Smith, F.S. Marzano, A. Mugnai, V. Levizzani, 1999: Meteorological applications of precipitation estimation from combined SSM/I, TRMM and infrared geostationary satellite data. *Microwave Radiometry and Remote Sensing of the Earth's Surface and Atmosphere*, P. Pampaloni and S. Paloscia Eds., VSP Int. Sci. Publ., 353-363.

Vila, D., R. Ferraro**,** R. Joyce, 2007: Evaluation and improvement of AMSU precipitation retrievals. *J. Geophys. Res.*, **112**, D20119, doi:10.1029/2007JD008617.

Villarini, G., W.F. Krajewski, 2007: Evaluation of the research-version TMPA three-hourly 0.25°x0.25° rainfall estimates over Oklahoma. *Geopys. Res. Lett.*, **34**, doi:10.1029/2006GL029147.
Weng, F., L. Zhao, R. Ferraro, G. Poe, X. Li, N. Grody, 2003: Advanced Microwave Sounding Unit cloud and precipitation algorithms. *Radio Sci*., **38**, 8068-8079.
Wentz, F.J., and R.W. Spencer, 1998: SSM/I rain retrievals within a unified all-weather ocean algorithm. *J. Atmos. Sci*., **55**(9), 1613-1627.
Zhao, L., F. Weng, 2002: Retrieval of ice cloud parameters using the Advanced Microwave Sounding Unit. *J. Appl. Meteor*., **41**, 384-395.

Web Sites:

AMSR instrument: *http://www.ghcc.msfc.nasa.gov/AMSR/*
AMSU-B instrument: *http://www2.ncdc.noaa.gov/docs/klm/html/c3/sec3-4.htm* in the NOAA KLM User's Guide (September 2000 revision): *http://www2.ncdc.noaa.gov/docs/klm/index.htm*
IPWG Validation for Australia: *http://cawcr.gov.au/projects/SatRainVal/validation-intercomparison.html*
IPWG Validation for U.S.: *http://cics.umd.edu/~johnj/us_web.html*
IPWG Validation for western Europe: ~~*http://kermit.bham.ac.uk/~ipwgeu/*~~ (currently in transition)
IPWG Validation for western Europe: *http://cics.umd.edu/~dvila/web/SatRainVal/dailyval.html*
IPWG Validation for western Europe: *http://www-ipwg.kugi.kyoto-u.ac.jp/IPWG/sat_val_Japan.html*
MAPB Precipitation Page: *http://precip.gsfc.nasa.gov/*
MHS instrument: *http://www2.ncdc.noaa.gov/docs/klm/html/c3/sec3-9.htm* in the NOAA KLM User's Guide (September 2000 revision): *http://www2.ncdc.noaa.gov/docs/klm/index.htm*
PR User Guide: *http://pps.gsfc.nasa.gov/tsdis/Documents/PR_Manual_JAXA_V6.pdf*
TMPA data: *http://trmm.gsfc.nasa.gov/data_dir/data.html*
TMPA-RT Data: *ftp://trmmopen.gsfc.nasa.gov/pub/merged/*
TMPA-RT paper: ftp*://meso.gsfc.nasa.gov/agnes/huffman/papers/TMPA_jhm_07.pdf.gz*
TMPA-RT update: *ftp://meso.gsfc.nasa.gov/agnes/huffman/papers/TMPA_hydro_rev.pdf*
TOVAS: *http://disc2.nascom.nasa.gov/Giovanni/tovas/*
TRMM home: *http://trmm.gsfc.nasa.gov/*
....

14. Inventories

The **data set inventory** may be obtained by accessing the anonymous FTP site or contacting the representative listed in section 12.
....

15. How to Order Data and Obtain Information about the Data

Users interested in **obtaining data** should access the anonymous FTP site or contact the representative listed in section 12.

As well, Web-based interactive access to the TMPA-RT and related data is provided by TOVAS; see that topic for details.
....

The **data access policy** is "freely available" with three common-sense caveats:

1. The data set source should be acknowledged when the data are used. The International Polar Year (IPY) Data policy guidelines (http://.ipydis.org/data/citations.html) suggest a formal reference of the form

   Huffman, G.J., E.F. Stocker, R.F. Adler, D.T. Bolvin, E.J. Nelkin, 2009, last updated 2010: *TRMM Version 6 Real-Time Multi-Satellite Precipitation Analysis Data Set*. NASA/GSFC, Greenbelt, MD. Data set accessed <date> at ftp://trmmopen.gsfc.nasa.gov/pub/merged/.

   As an “Acknowledgment”, one possible wording is: "The TMPA data were provided by the NASA/Goddard Space Flight Center's Laboratory for Atmospheres and PPS, which develop and compute the TMPA as a contribution to TRMM."]
2. New users should obtain their own current, clean copy, rather than taking a version from a third party that might be damaged or out of date.
3. Errors and difficulties in the dataset should be reported to the dataset creators.

....

16. Appendices

Appendix 16.1 *Read a File of Data, C Example*

A file of data may be read with many standard data-display tools. The 2880-byte header is designed to be exactly the size of one row of data, so the header may be bypassed by skipping 2880 bytes or 1440 2-byte integer data points or one row. Alternatively, the data may be output under program control as demonstrated in this C example. Once past the header, there are always a precipitation field, a random error field, and 1-5 auxiliary fields. As documented in "Data File Layout", the grids are either 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT) and the data are either scaled 2-byte integer (precipitation, random error, and uncalibrated precipitation) or 1-byte integer (all others). Grid boxes without valid data are filled with the "missing" value -31999 for 2-byte integer fields and 0 for 1-byte integer fields.

The code appears in file read3B4XRT.c .
....

Appendix 16.2 *Read the Header Record, FORTRAN Example*

The header may be read with most text editor tools, although the size (2880 bytes) may be longer than some tools will support. Alternatively, the header record may be output under program control, as demonstrated in this FORTRAN example. The header is written in a "PARAMETER=VALUE" format, where PARAMETER is a string without embedded blanks that gives the parameter name, VALUE is a string that gives the value of the parameter, and blanks separate each "PARAMETER=VALUE" set. To prevent ambiguity, no spaces or "=" are permitted as characters in either PARAMETER or VALUE.

The code appears in file read_header.f .
....

Appendix 16.3 *Read a File of Data In a Single Read, FORTRAN Example*

A file of data may be read with many standard data-display tools. The 2880-byte header is designed to be exactly the size of one row of data, so the header may be bypassed by skipping 2880 bytes or 1440 2-byte integer data points or one row. Alternatively, the data may be output under program control using single block reads as demonstrated in this FORTRAN example. Once past the header, there are always a precipitation field, a random error field, and 1-5 auxiliary fields. As documented in "Data File Layout", the grids are either 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT) and the data are either scaled 2-byte integer (precipitation, random error, and uncalibrated precipitation) or 1-byte integer (all others). Grid boxes without valid data are filled with the "missing" value -31999 for 2-byte integer fields and 0 for 1-byte integer fields.

The code appears in file read_rt_file.f .
....

Appendix 16.4 *Read a File of Data, IDL Example*

A file of data may be read with many standard data-display tools as demonstrated in the following IDL example. The 2880-byte header is designed to be exactly the size of one row of data, so the header may be bypassed by skipping 2880 bytes or 1440 2-byte integer data points or one row. Alternatively, the data may be output under program control as demonstrated in this IDL example. Once past the header, there are always a precipitation field, a random error field, and 1-5 auxiliary fields. As documented in "Data File Layout", the grids are either 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT) and the data are either scaled 2-byte integer (precipitation, random error, and uncalibrated precipitation) or 1-byte integer (all others). Grid boxes without valid data are filled with the "missing" value -31999 for 2-byte integer fields and 0 for 1-byte integer fields.

The code appears in file read_rt_file.pro .
....

Appendix 16.5 *Read a File of Data Line-at-a-Time, FORTRAN Example*

A file of data may be read with many standard data-display tools. The 2880-byte header is designed to be exactly the size of one row of data, so the header may be bypassed by skipping 2880 bytes or 1440 2-byte integer data points or one row. Alternatively, the data may be output under program control using line-at-a-time reads as demonstrated in this FORTRAN example. Once past the header, there are always a precipitation field, a random error field, and 1-5 auxiliary fields. As documented in "Data File Layout", the grids are either 1440x720 (3B40RT) or 1440x480 (3B41RT, 3B42RT) and the data are either scaled 2-byte integer (precipitation, random error, and uncalibrated precipitation) or 1-byte integer (all others). Grid boxes without valid data are filled with the "missing" value -31999 for 2-byte integer fields and 0 for 1-byte integer fields.

The code appears in file read_rt_lines.f .
....