TRMM LBA Field Campaign Flight Leg Analysis
Common Radar Product Definition

Version 1.0
[April 25, 2002]

A. Overview

During each of the TRMM field campaigns (FC), ground-based radars (GBR) and airborne microphysical platforms interrogated coincident volumes of cloud in order to describe vertical profiles of hydrometeors in a variety of cloud structures and environments. Robust scientific interpretation of these datasets, as they pertain to TRMM algorithm development and model intercomparison, will be facilitated if in situ data are intercompared with collocated volumes of ground-based radar data. For example, GBR products can serve as an overall guide in the interpretation of microphysical products relative to the observed precipitation echo structure along a given flight track. Hence the goal of this document is to provide a common radar product definition (CRPD) for specific application to the TRMM-LBA field campaign GBR volumetric data collected during aircraft missions that have, or will be selected for generation of a TRMM common microphysics product (cf. TRMM Common Microphysics Product Definition [CMPD]; S. Yuter, U. of Washington). In this sense, the CRPD is best described as the *GBR equivalent of the CMPD*, which served as the template for this document.

The intended users of the TRMM-LBA Common Radar Product are not necessarily radar experts per se but rather TRMM PIs who are analyzing data from airborne instruments and would like a ground-based radar data set to compare to or to set context for diverse in situ and remotely sensed data fields. The primary applications of the GBR data for these users are:

- *GBR data for use in conjunction with airborne remote sensors such as AMPR, AMMR, ARMAR, and EDOP – requires a three-dimensional "swath" of data on either side of a flight track (nominally +/- 10 km width perpendicular to flight track) and for the full depth of the storm from the surface to echo top.*

- *GBR data for use in conjunction with TRMM satellite data in additional to airborne remote sensors and/or in situ data.*

To serve the needs of these users a description of the TRMM-LBA radar product is provided. This product is in *ASCII format* to eliminate the need for radar software packages that are usually required to view radar data.

B. Product

Essentially, the GBR data consist of gridded slabs of volumetric radar data that correspond temporally and spatially to a prioritized list of flight tracks (see Flight Track List, Sec. E) conducted by airborne microphysical platforms during the TRMM-LBA FC. Priority flight-track segments are defined by a starting time (UTC), starting latitude/longitude and ending latitude/longitude. The leg *orientation* as defined in this document is the east-west component of the leg vector pointing from start to ending leg points. Utilizing the TRMM-LBA flight leg coordinates, corresponding gridded radar data files for flight tracks occurring within 150 km of the *S-pol radar* were generated in *ASCII format* for the volume of atmosphere bounded by the flight leg endpoints (with ~5 km of "extra" data appended to the end of each leg) in the along track plane, +/- 10 km in the cross-track plane, and an altitude of 18 km in the vertical plane.

Note that the CRPD and CMPD both invoke ASCII data formats for consistency. ASCII-formatted data will facilitate use of the GBR product by a multitude of users in the algorithm, modeling and TRMM community at large that may be unfamiliar with more commonly used raw/processed radar data formats (e.g., IRIS, UF, DORADE, CDF, HDF etc.).

1. Radar Preprocessing, Gridding software, and specifications

Prior to gridding the raw S-pol polarimetric variables (UF format), the data were first preprocessed using a combination of ρ_{hv} and the variance of Φ_{dp} (propagation differential phase) to remove clutter and noise. Following removal of clutter, the specific differential phase (K_{DP}) was computed as a range derivative of Φ_{dp}. For specifics on CSU processing of the S-pol data, please see the following document (Carey et al., 2001), located on the web at:

http://radarmet.atmos.colostate.edu/trmm_lba/spol_rain_info/PrelimRptLBASPOLrain.htm

This document is a Colorado State University report that can also be downloaded in PDF form.

Gridding of the processed UF data was completed using the NCAR software package REORDER. REORDER input files for gridding the processed radar data were constructed as follows:

Note*- The leg "orientation" vector- begins at first flight leg lat/lon (0,0) and points toward ending lat/lon (X_N,0)

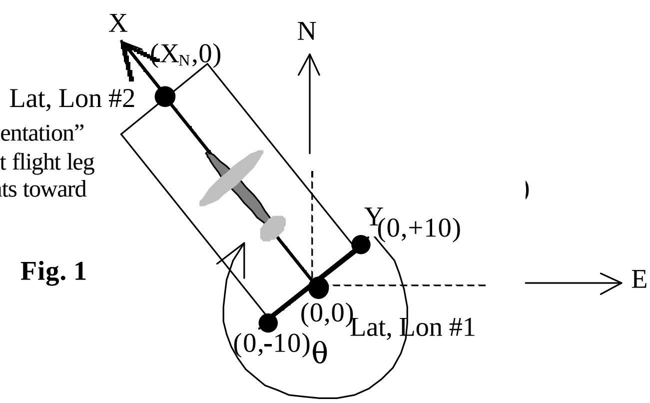

Fig. 1

i. Grid orientation and X, Y, Z start values: The grid coordinate system specified in REORDER was rotated angle[θ], clockwise from North [0°], as determined by the orientation of the flight leg end points (Fig. 1). In this fashion, *the grid x-axis is always aligned parallel to the flight track* (e.g., using the GBASELINE command in the REORDER input file). Note that flight legs with a *western* orientation begin at x=0 and end at x=-X_N (REORDER labeling convention). Hence flight legs with an *easterly* orientation will begin at x=0 and end at x=+X_N, where X_N is the end point of the grid-leg. The y-axis is aligned cross-track as in (Fig 1) and for easterly(westerly) orientations has positive y-values to the left(right) of the x-axis. The grid origin always corresponds to the first lat/lon point specified in the flight leg and begins at a height of z=1.0 km. The last X, Y grid cells are located just past (e.g., ~ 5 km) the grid increment that is closest to the endpoint of the flight-leg segment. The grid depth (z-axis) extends to 18 km.

ii. Grid spacing: δx, δy and δz are all equal to 1 km.
iii. Weighting scheme and Radius of influence: The REORDER Cressman weighting scheme with a 1 km radius of influence was used for all dimensions. Note that this combination of grid spacing and radius of influence reduces smearing of the radar data but does result in some empty "rings" of radar data at times. This product does minimal filling of space void of valid radar data; it was decided that this decision was better left to investigators using the product.
iv. Variables gridded: Reflectivity (DZ) and a Time Field (TI; time of each pixel relative to the beginning time of the flight leg in seconds) are always gridded. When available and of *research quality*, differential reflectivity (ZDR), correlation coefficient (RHV), and specific differential phase (KDP) are also gridded[1]. All radar variables are written to the product file utilizing two decimal place accuracy.

2. File naming convention and data format

The netCDF output of REORDER is converted to ASCII data with the following format and file naming convention.

i. File name: To match the file naming convention of the CMPD, CRPD files will be named as

crp_vers#_yymmddhhmm_expname_radarname_leg#

Example: crp_0.1_9902232054_trmmlba_spol_1

This ASCII GBR file consists of data collected during the priority flight leg of 23 February 1999 at 2054 UTC (rounded to the closest minute), during TRMM-LBA by the S-pol radar. The data correspond to the first priority leg specified for this case (leg# 1; see Sec. E).

ii. File header

The file header contains information about the radar, the sampling volume, the time the actual volume was collected, how long it took to collect it, and a list of variables in the gridded product volume.

Line 1. Integer value corresponding to number of lines in header (including this line)
Line 2. File name
Line 3. Time (UTC) at beginning of radar sample (nearest minute) volume and duration of scan (minutes:seconds).
Line 4-5. Grid-leg length and elevation angles for each scan. Note that if the flight track straddles volumes, more than one radar volume will be gridded for the flight leg product. If only one volume is used, –999.99 is indicated on line 5.

Example: 40 km–long leg that uses one volume of 5:01 duration and 12 tilts.

40.0 5:01 0.4 1.4 2.4 3.4 5.4 6.4 7.4 8.4 9.4 10.4 11.4 12.4
-999.99

[1] Note that due to the questionable accuracy of the S-pol LDR during TRMM-LBA, LDR is not currently included in the product.

Line 6. Radar lat/lon (decimal degrees, four-decimal place accuracy), beam-width (Deg.), gate-spacing (km), beamwidth (km) at beginning and ending of flight track.

Example: -11.2213 –61.9982 0.92° .150 1.0 1.4

Lines 7 and 8. List of fields in each record of the file (separated by 1 space) in the order they appear on each data line with units specified in parentheses. For example;

Z, X, Y (km) Lat. (decimal degrees), Lon. (decimal degrees), TI(sec) DZ(dBZ) ZDR(dB) RHV KDP(Deg/km)

**Note*: if line 8 is not used, value is –999.99.

Line 9- Flight leg start time (hours, minutes, seconds, UTC) and additional comments are included on this line. This line(s) can extend for as long as deemed necessary and should include other information relevant to the data fields (e.g., missing data value, data quality, calibration problems, etc.).

iii. Data format

All radar variables should be written using 2-decimal place accuracy, latitudes and longitudes 3-decimal place accuracy. Missing/bad data values will be encoded as -999.99 to be consistent with the CMPD.

Records for each +/- 10 km cross-track swath will be written for each altitude in ascending order and subsequently incremented by cross-track direction first (Y), along track direction second (X), and altitude (Z) third. Since the origin of the gridded product lies at the beginning point of the flight track, but the x-axis has been rotated to lie along the flight track, *positive (negative) Y-axis values will always lie to the right (left) of the flight track when the flight track is oriented west (east)* (cf. Fig. 1; also see the beginning and ending points of flight legs in the attached "Flight-Leg List section).

Each data line contains variables (cf. Sec. C.1) ordered as below (assuming a 3-D array for products, an X axis of N km, a Y axis of +/- 10 km (e.g. 21 Y-values), and a Z axis extending to 18 km in 1 km increments):

Example (does not include all variables):

Sample Array Indices	Sample Data Records
Z(1) X(1) Y(1) LAT(1,1) LON(1,1) TI(1,1,1)….	1.0 0.0 -10.0 -11.234 –63.213 240
Z(1) X(1) Y(2) LAT(1,2) LON(1,2) TI(1,2,1)….	1.0 0.0 - 9.0 -11.234 –63.203 241
. . . . . .	
. . . . . .	
Z(1) X(1) Y(21) LAT(1,21) LON(1,21) TI(1,21,1)…	1.0 0.0 10.0 -11.234 -63.003 242
Z(1) X(2) Y(1) LAT(2,1) LON(2,1) TI(2,1,1)…	1.0 0.0 -10.0 -11.224 -63.213 243
Z(1) X(2) Y(2) LAT(2,1) LON(2,2) TI(2,2,1)…	1.0 1.0 - 9.0 -11.224 -63.203 244
. . . . . .	
. . . . . .	
Z(1) X(2) Y(21) LAT(2,21) LON(2,21) TI(2,21,1)…	1.0 1.0 10.0 -11.224 -63.003 255

. . . . . .
Z(1) X(N) Y(21) LAT(N,21) LON(N,21) TI(N,21,1) 1.0 N 11.0 N –63.003 256
. . . . . .
Z(2) X(1) Y(1) LAT(1,1) LON(1,1) TI(1,1,2) 2.0 1.0 -11.0 -11.234 –63.213 269

D. Data Contact and Modifications to TRMM-LBA Common Radar Product

The current version of this product should be considered final unless egregious errors are found in the data or the organization of the data.

Questions can be addressed to:

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E. TRMM-LBA Flight-Leg List

Legs: 1-5, TRMM Satellite, Citation, and ER-2

```
 date    Times     CRPD Lat/Lon   Dur(min/sec) Desc.
990223  20:53:49 -10.5447 -62.0223  08 00  Curved leg (25 Kft) along
        21:01:49 -10.0217 -62.0223         conv. line under ER-2 and TRMM

990127  21:20:19 -10.1937 -61.9107  03 37  Citation under ER-2, long line in
        21:23:56  -9.9930 -61.9840         anvil/stratiform.  -2 C

990201  18:24:19 -11.3857 -61.3793  03 57  Citation under TRMM and ER-2
        18:28:15 -11.2713 -61.5820         in liquid and ice (-2C).

990130  19:12:46 -10.9073 -62.2600  02 13  Citation in decayed convection.
        19:14:59 -10.8427 -62.1470         Under TRMM, vcnty ER-2. -2.6C.

990130  19:17:30 -10.8577 -62.0720  02 18  2nd pass in decayed convection.
        19:19:48 -10.9277 -62.1807         Temp. +4.5 C. ER2, recent TRMM
```

Legs: 6-36, ER-2 and Citation

```
 date    Times   CRPD Lat/Lon   Dur(min/sec)  Desc.
990221  19:58:49 -10.5090 -61.2640  10 20  Stratiform pcpn ER-2 over
        20:09:09 -11.0667 -61.1323         Citation. Temps +3 to + 1.

990221  20:09:10 -11.1317 -61.1440  03 22  Citation in turn under ER-2.;
        20:12:32 -11.0410 -61.1740         bright band. Temps. +1 to -3.

990221  20:26:51 -10.4780 -61.4253  09 30  Stratiform, ER-2 right over
        20:36:21 -11.0420 -61.2690         Citation.  Temps. -6 C.
```

990221	20:39:14 20:49:31	-11.0950 -10.4570	-61.2590 -61.4277	10 17	Stratiform; ER-2 a little west. Temps. -12 C to -16 C.
990221	19:45:00 19:55:00	-11.0590 -10.5027	-61.1730 -61.2593	10 00	Stratiform, under ER-2 for last 2/3 of leg. Temp -5 C.
990217	19:44:41 19:56:31	-10.5820 -10.6520	-61.9550 -62.0470	11 50	Citation spiral descent (-31-0 C) near ER-2 in anvil of deep storm
990217	18:31:00 18:34:30	-10.6247 -10.8680	-61.8430 -61.9390	03 30	Citation directly under ER-2 in convective line/anvil. Temp -27 C.
990217	18:10:30 18:13:31	-10.6920 -10.9030	-61.8430 -61.8520	03 01	Citation criss-cross ER-2 in conv. and over Profiler. Temps. -18 C.
990217	18:20:50 18:26:01	-10.6093 -10.2970	-61.7760 -61.7517	05 11	Citation in anvil under ER-2. Temps -21 C to -26 C.
990130	20:36:51 20:54:55	-11.4387 -11.2790	-62.1740 -62.2593	18 04	Citation under ER-2 spiral in weak stratiform. +6 C to -2 C
990210	19:52:01 20:05:51	-10.9340 -10.9340	-62.1260 -62.2810	13 50	Citation spiral descent under ER2. Temps -28 C to -3 C.
990210	19:43:48 19:52:00	-10.8387 -11.1437	-62.1997 -62.1543	08 12	Citation/ ER-2; intense conv line temps -28 C. Lead into spiral.
990201	19:41:57 19:45:56	-10.6780 -10.4570	-61.7657 -61.8400	03 59	Citation/ER2 1rst pass in short line of convection. -2C.
990201	19:51:13 19:56:05	-10.4530 -10.7083	-61.8567 -61.7723	04 52	Citation/ER2 2nd pass in short line of convection +2C.
990201	18:49:46 18:52:08	-11.3400 -11.3330	-61.0920 -61.2190	02 22	Citation under ER-2 in convection First pass, short leg, +4 C
990201	18:57:17 18:58:41	-11.3630 -11.3600	-61.1650 -61.0780	02 24	Citation under ER-2 in convection Second pass, short leg, -2 C
990201	19:02:53 19:04:02	-11.3733 -11.4147	-61.0820 -61.1370	01 09	Citation under ER-2 in convection Third pass, short leg, -2.5 C
990212	20:05:48 20:13:21	-10.9460 -10.5060	-61.8147 -62.2523	07 33	Citation/ER-2, conv. over profiler. Temps. -23 to -26 C.
990212	19:47:39 19:53:00	-10.9093 -10.6817	-61.8060 -61.9567	05 21	Citation/ER-2 in conv. over profiler Temps. -18 C.
990212	19:54:15 19:56:33	-10.7540 -10.8383	-61.8553 -61.7330	02 18	Citation/ER-2 backside of small system ovr profiler. Temps -18.5C
990124	19:50:18 19:53:06	-11.4287 -11.5293	-62.6190 -62.4960	02 48	Citation/ER-2 sample edge of conv. line. Temps 0C to +1C.
990124	20:03:23 20:05:25	-11.4727 -11.5493	-62.6163 -62.5307	02 02	Citation/ER-2 sample edge of conv line (Next pass). Temps +8 C.

990130	19:52:00	-11.6990	-62.4103	03 34	Citation under ER-2 in decayed
	19:55:34	-11.5427	-62.5293		conv/weak strat. first pass, +1 C
990130	19:59:32	-11.5187	-62.6140	05 54	Citation under ER-2 in stratiform
	20:05:26	-11.7533	-62.3420		2nd pass; -2 C.
990223	20:18:38	-10.8583	-61.8827	05 21	Citation vcnty of ER-2 along conv.
	20:24:09	-10.5610	-62.0583		ovr profiler. Temps -6 to -17 C.
990223	20:30:26	-10.5483	-62.0450	08 34	Citation/ER2 along conv. over
	20:39:00	-11.0273	-61.7550		profiler. Temps -18 C.
990223	19:44:55	-10.5963	-61.7630	03 02	Citation under ER-2 in scattered
	19:47:58	-10.7157	-61.6090		stratiform. Temp -10 C.
990223	19:51:35	-10.8797	-61.4437	07 45	Citation in vcnty ER-2 in
	19:59:20	-11.2800	-61.2557		scattered stratiform. Temps.-3 C.
990214*	18:58:07	-10.5063	-61.7253	01 50	Citation on backside of conv.
	18:59:57	-10.6430	-61.7420		Temp -20 C. *ER-2 Nav file misg.
990214*	18:33:47	-11.5773	-61.3110	04 26	Citation on backside of conv.*ER-2
	18:38:13	-11.4037	-61.5280		Nav. file missing. Temp. -6.5 C.
990210	19:24:00	-10.9000	-62.1350	03 34	Citation/ER-2 in weak convection.
	19:27:34	-11.1643	-62.1060		Temps. -15 to -12 C.

Legs: 37-50, Citation only

date	Times	CRPD Lat	/Lon	Dur(min/sec)	Desc.
990126	21:43:53	-10.6900	-61.8610	28 27	Spiral descent over profiler
	22:12:10	-10.9310	-61.8610		stfrm.) then ascent (-1 to +15 C)
990123	20:21:25	-10.9067	-61.7193	13 13	Spiral ascent (rain)
	20:34:38	-10.8440	-61.6480		+22C to -3 C
990220	20:00:38	-10.9513	-61.5937	14 23	Spiral descent (rain)
	20:15:01	-11.0287	-61.5937		-7 C to 22.3 C
990219	20:08:51	-11.4010	-62.4660	14 44	Spiral descent in pcpn
	20:23:35	-11.3830	-62.4027		-9 C to 6 C (conv.)
990124	20:11:43	-11.5470	-62.5463	17 11	Spiral descent on edge of
	20:28:54	-11.4190	-62.5993		conv. pcpn. -2 to +4 C.
990126	20:32:13	-10.8403	-62.1337	00 57	1rst short leg through
	20:33:10	-10.8607	-62.1870		developing conv. -1C
990126	20:36:44	-10.8593	-62.1650	00 26	2nd short leg through
	20:37:10	-10.8467	-62.1440		developing conv. -2C
990126	20:44:54	-10.8703	-62.2050	01 03	1rst short leg through
	20:45:57	-10.8480	-62.1520		developing conv. 0 C
990126	20:50:23	-10.8257	-62.1650	00 32	2nd short leg through
	20:50:55	-10.8547	-62.1723		developing conv. +1 C

990126	21:04:10	-10.8410	-62.1130	00 54	Leg through developing
	21.05:04	-10.8920	-62.1170		cell -2 to -3 C
990129	20:56:03	-10.8480	-61.4390	00 26	Short leg through
	20:56:29	-10.8577	-61.4617		shallow conv. -3.5 C
990213	17:48:50	-10.5020	-62.3720	01 57	Ice init. -8 C
	17:50:47	-10.4127	-62.2910		1rst leg
990213	17:53:21	-10.4173	-62.4173	03 10	Ice init. -10.5 C
	17:56:31	-10.5677	-62.4027		2nd leg
990217	18:06:10	-10.4130	-61.7633	02 22	Short segment in conv. line.
	18:08:32	-10.5633	-61.8393		Temp. -18 C.

TOTAL 305.75 minutes