Global Precipitation Mission (GPM)
Ground Validation System

Validation Network Data Product User's Guide

October 14, 2011

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Document History

Document Version	Date	Changes
Draft	January 12, 2007	Initial draft
Draft 2	April 5, 2007	2nd Draft. Added REORDER grid documentation and updated PR and GV netCDF file format descriptions.
Draft 3	June 19,2007	3rd draft. Added new grid variables to GV netCDF file format description.
Version 1	August 13, 2007	Removed Draft designation. Added 2b-31 mention to PRgrids section.
Version 1.1	July 8, 2008	Updated path to netCDF files for new GPMGV FTP site. Corrected description of lat and lon variables for GVgridsREO (REORDER) netCDF files. Other minor edits and corrections.
Version 1.2	August 11, 2008	- Updated to reflect that tar files organized either by month or by site are now stored on the ftp site in separate directories. - Described the new criteria by which significant rain events are defined in the VN. - Changed "NEXRAD" references to "WSR-88D" in the text. - Added the location information for "other" participating sites: ARMOR/UAH, Darwin/BOM, Gosan/KMA - Fixed KHTX latitude/longitude in Table 1-1.
Version 2	November 5, 2008	- Added material and sections to document the origin and content of netCDF files from the new geometry matching technique.
Version 2.1	November 5, 2008	- Revised Section 2 and added Table 6-3.

Document Version	Date	Changes
Version 2.2	September 19, 2009	- Added Section 4 on ftp site directory structure. Removed sections related to the gridded VN method which is no longer supported. Change GV to GR when referring to the ground radar.
Version 2.3	September 13, 2010	- Corrected table numbering of 7.1 and 7.2, changed to 3.1 and 3.2. Fixed table number references in text for these and other tables. - Added Note for Table 3.1 describing the Scan and Range Edge point optionality in Version 1.1 of the POLAR2PR code. - Added Note for Table 3.1 describing AGL vs. MSL units for height variables. - Added site_elev variable definition to the netCDF file summary, and a note indicating it applies to version 1.1 of the file. - Corrected 'units' attribute of the BBheight variable, should have been 'm', not 'km'. - Added missing Bold/Italics formatting to VN ftp site directory tree structure.
Version 3	January 5, 2011	- Describes Version 2.0 of the geometry match netCDF files, which adds four new data variables and their 'presence' flags: have_threeDreflectMax have_threeDreflectStdDev have_BBstatus have_status threeDreflectMax threeDreflectStdDev BBstatus status

Document Version	Date	Changes
Version 3.1	October 14, 2011	- Describes Version 2.1 of the geometry match netCDF files, which adds five additional global variables listing the names of the PR and GR data files used in the matchup. - Updated URL for the GPM ground validation web site. - Noted change in PR data file name conventions for PR version 7 files from the PPS.

Contact Information

Additional information, including information on VN points-of-contact, can be obtained from the GPM Ground Validation web site:

http://pmm.nasa.gov/science/ground-validation

TABLE OF CONTENTS

1. Introduction

This document provides a basic set of documentation for the data products available from the GPM Ground Validation System (GVS) Validation Network (VN). In the GPM era the VN will perform a direct match-up of GPM's space-based Dual-frequency Precipitation Radar (DPR) data with ground radar data from the U.S. network of NOAA Weather Surveillance Radar-1988 Doppler (WSR-88D, or "NEXRAD"). Ground radar networks from international partners will also be part of the VN. The VN match-up will help evaluate the reflectance attenuation correction algorithms of the DPR and will identify biases between ground observations and satellite retrievals as they occur in different meteorological regimes. A prototype of the capability is currently in operation that performs the match-up of Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) data with ground-based radar (GR) measurements from a set of WSR-88D sites, plus data from meteorological agency radars in Korea and Australia, and a university radar in Huntsville, Alabama.

Two approaches to the PR-to-GR data matching have been developed. The original technique, described in earlier versions of this document, involves resampling PR and GR data to a fixed, common, 3-dimensional Cartesian grid centered on the GR site. This method, referred to as the *gridding technique*, is no longer actively supported as a VN method. Descriptions of this method are therefore not included in this document. A new (as of October, 2008) technique, the *geometry matching technique*, is based on determining the intersection of the individual PR rays with each of the elevation sweeps of the circularly-scanning ground radar. The horizontal and vertical locations and number of data points in the geometry matching technique are different for each case due to the randomness of the ray-to-sweep intersections. Section 5 of this document describes the algorithm used to generate geometry-matched data. Data output from the geometry matching technique are stored as netCDF files, with each netCDF file being specific to the TRMM overpass of an individual GR site.

1.1 Data Availability

VN match-up, input, and ancillary data are available via anonymous ftp from this site: **ftp://hector.gsfc.nasa.gov/gpm-validation/data**. The site provides access to the raw TRMM Precipitation Radar data, raw ground radar data, quality controlled ground radar data, as well as geometrically matched ground radar and precipitation radar data. The directory structure of the ftp site is described in detail in Section 4 of this document.

1.2 Software Availability

Software to perform the PR-to-GR geometry matching, and to display and compute PR-GR reflectivity statistics and analysis products from the data is available. Contact a member of the GPM GV team listed at http://pmm.nasa.gov/science/ground-validation.

1.3 Period of Record

The current period of record for the VN match-up datasets starts on August 8, 2006 and runs to the present. Because the input datasets for the VN match-ups are quality controlled by a human analyst there is a time lag of up to several weeks from observation to VN product generation.

1.4 Match-up Sites

At present there 21 WSR-88D sites are included in the VN. These are all located within the southeastern U.S. as illustrated in Figure 1-1.

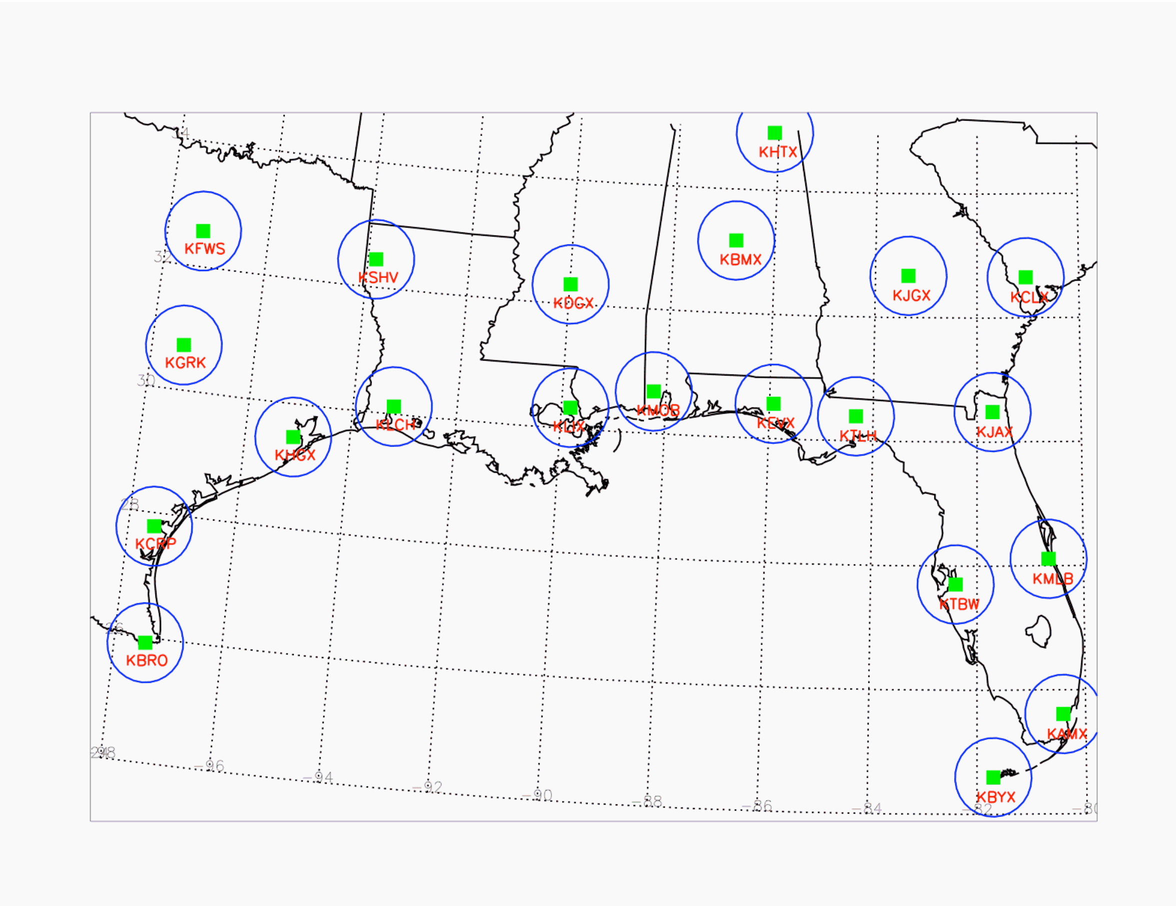

Figure 1-1. Location of VN match-up sites and associated site grid domains in the southeastern U.S. For each site, 100 km observation limits are also illustrated.

In addition to these WSR-88D sites, there are four additional GR sites with selected periods/dates of data included in the VN data set. These include the Darwin, Australia, Bureau of Meteorology CPOL (C-band polarimetric) radar (VN site ID: DARW); the ARMOR CPOL radar of University of Alabama, Huntsville (VN site ID: RMOR); the SPOL (S-band polarimetric) radar on Kwajalein atoll (KWAJ), and the Korean Meteorological Agency (KMA) S-band radar at Gosan, Jeju Island, South Korea (VN site ID: RGSN). Table 1-1 lists the VN site identifiers, long names, and the latitude and longitude of each. The VN short names are used in the VN product file naming convention described in Section 2 of this document. Although the list below was current at the time that this document was written, it is expected that additional VN sites will be added from time to time. More up-to-date information may be available on the GPM GV web site **`http://pmm.nasa.gov/science/ground-validation`**. Check with the GPM GV points-of-contact for current status.

Table 1-1. WSR-88D and other (in italics) ground radar sites used in the GPM GVS Validation Network.

Site ID	Site Full Name	Latitude	Longitude
KAMX	Miami, FL	25.6111 N	80.4128 W
KBMX	Birmingham, AL	33.1722 N	86.7697 W
KBRO	Brownsville, TX	25.9161 N	97.4189 W
KBYX	Key West, FL	24.5975 N	81.7031 W
KCLX	Charleston, SC	32.6556 N	81.0422 W
KCRP	Corpus Christi, TX	27.7842 N	97.5111 W
KDGX	Jackson, MS	32.3178 N	89.9842 W
KEVX	Red Bay/Eglin AFB, FL	30.5644 N	85.9214 W
KFWS	Dallas-Ft Worth, TX	32.5731 N	97.3031 W
KGRK	Central Texas (Ft Hood), TX	30.7219 N	97.3831 W
KHGX	Houston/Galveston, TX	29.4719 N	95.0792 W
KHTX	N.E./Hytop, AL	34.9306 N	86.0833 W
KJAX	Jacksonville, FL	30.4847 N	81.7019 W
KJGX	Robins AFB, GA	32.6753 N	83.3511 W
KLCH	Lake Charles, LA	30.1253 N	93.2158 W
KLIX	Slidell AP/New Orleans, LA	30.3367 N	89.8256 W
KMLB	Melbourne, Florida	28.1133 N	80.6542 W
KMOB	Mobile, AL	30.6794 N	88.2397 W
KSHV	Shreveport, LA	32.4508 N	93.8414 W
KTBW	Ruskin/Tampa Bay, FL	27.7056 N	82.4017 W
KTLH	Tallahassee, FL	30.3975 N	84.3289 W
DARW	*Darwin, Australia*	*12.2522 S*	*131.0430 E*
KWAJ	*Kwajalein atoll, Marshall Islands*	*8.71796 N*	*167.733 E*
RGSN	*Gosan, South Korea*	*33.2942 N*	*126.1630 E*
RMOR	*University of Alabama, Huntsville*	*34.6460 N*	*86.7713 W*

1.5 The "100-in-100" Criterion

In all cases, data products generated by the VN adhere to the "100-in-100" criterion. That is, event files described in subsequent sections of this document have 100 or more gridpoints indicating "Rain_Certain," as defined by the TRMM PR 2A-25 product, that fall within 100 km of a ground radar. For this purpose, selected 2A-25 variables are analyzed to temporary 4-km-resolution grids of 300x300 km extent, one centered on each GR site overpassed in a given orbit. Metadata concerning the precipitation and PR/GR overlap statuses of each overpass event are computed from the temporary grids and stored in the GPM GV database, which can be queried to determine which events meet the "100-in-100" criterion, or other user-defined criteria. Matched-up PR and GR radar data products in the form of netCDF files are generated and stored on the VN ftp directory **/netCDF/geomatch/** for any event that meets the 100-in-100 criterion (see Section 4 for a complete description of the VN ftp directory structure and file naming conventions).

The VN's internal database actually stores TRMM PR and ground radar data for *all* coincident events where the PR passes within 200 km of the ground radar, whether is it raining or not. Ground radar data are stored in the **/gv_radar** directory and Precipitation Radar data are stored in the **/prsubsets** directory of the VN ftp site. See Section 4 for a complete description of the VN ftp directory structure and file-naming conventions.

1.6 Validation Network data product netCDF format

The gridded GR and PR data products and the geometry match data product are formatted according to the network Common Data Format (netCDF) standard. netCDF is maintained by the Unidata Program of the University Corporation for Atmospheric Research (UCAR). More information on netCDF can be found on the Unidata website **http://www.unidata.ucar.edu/software/netcdf/.**

There are three basic components of the netCDF files termed *attributes, dimensions* and *variables*, which are described briefly below.

<u>*Attributes*</u> contain auxiliary information about each netCDF *variable*. Each *attribute* has a name, data type and length associated with it. netCDF also permits the definition of *global attributes*, but the GR and PR data products contain no such *global attributes* at this time.

<u>*Dimensions*</u> are named integers that are use to specify the size (dimensionality) of one or more *variables*.

<u>*Variables*</u> are multidimensional arrays of values of the same data type. Each *variable* has a size, type and name associated with it. *Variables* also typically have *attributes* that describe them.

2. Geometry-Matched Data Products

2.1 Archive site directory

As previously described in Section 1.1, VN match-up data are available via anonymous ftp from this site: **`ftp://hector.gsfc.nasa.gov/gpm-validation/data.`**

Data from the geometry-matching technique are located under the subdirectory **`netcdf/geo_match.`** The geometry-matching technique allows for comparison of actual space and ground network measurements (i.e., data are **not** resampled in 3 dimensions). This method has replace the heritage the gridding technique, which is no longer supported as a VN method.

2.2 File Name Convention

Geometry matching data in the **`netcdf/geo_match`** directory are stored as netCDF gzip-ed files by site (4-letter site ID, see Table 1-1), event date, and orbit number (see Section 4). These files will contain data for roughly the same set of events as the grid data, for a given event, since the "100-in-100" criteria described above are used to determine the events for which geometry matching data are computed. The data volume of each file varies depending on the number of "rainy" points in each file, but files of 10 to 100 or more MByte are typical.

The site specific gzip files unpack into a series of netCDF files identifiable by date and TRMM orbit number according to this convention:

GRtoPR.SHORTNAME.YYMMDD.ORBITNUMBER.nc.gz

where:

SHORTNAME	= 4-character GR site ID (see Table 1-1)
YY	= 2-digit year
MM	= 2-digit month
DD	= 2-digit day (in UTM)
ORBITNUMBER	= 5-digit TRMM orbit number.

The .nc designation indicates that the files are in the netCDF format. The .gz extension, if present, indicates that the file is compressed using gzip.

Each file includes TRMM PR and ground radar data stored in netCDF format as described in Section 3 of this document. PR data are obtained from the standard TRMM products as follows:

- Raw PR radar reflectivity (Zr) from TRMM product 1C-21.
- Attenuation-Corrected PR radar reflectivity (Zc) from TRMM product 2A-25.
- 3-D and Near-Surface Rain rate (mm/hr) from TRMM product 2A-25.

A land/ocean flag, near-surface rain rate, bright band height, rain type, rain/no-rain flag and other variables are also included from PR products 1C-21, 2A-23, and 2A-25. See the geometry-match netCDF file summary in Section 3.

Ground radar data included in these files are derived from the horizontal-sweep-scanning radar data that has been quality-controlled and processed into an intermediate 1C-UF product data file in Universal Format (UF).

Geometry matchup of the PR and ground radar data was performed using methods based on those described by Bolen and Chandrasekar[1].

2.3 Geometry Matching Data Format

Geometry matching netCDF data files are formatted with 5 dimensions: 3 for data arrays, and 2 for character variables. There are 48 regular variables, and 2 global attributes. The single- and multi-level spatial data fields in the geo-match netCDF files are not at fixed location as with the gridded data. Their horizontal locations are defined by the location of the PR rays within the PR scans. The number of PR rays whose data are included in the product depends on the number of rays whose surface location is within 100 km of the corresponding ground radar location. The vertical locations of the data points are defined by the intersections of the PR ray with each of the elevation sweeps of the ground radar. See Figure 2-1 for an illustration of the intersection of PR footprints with GR echoes.

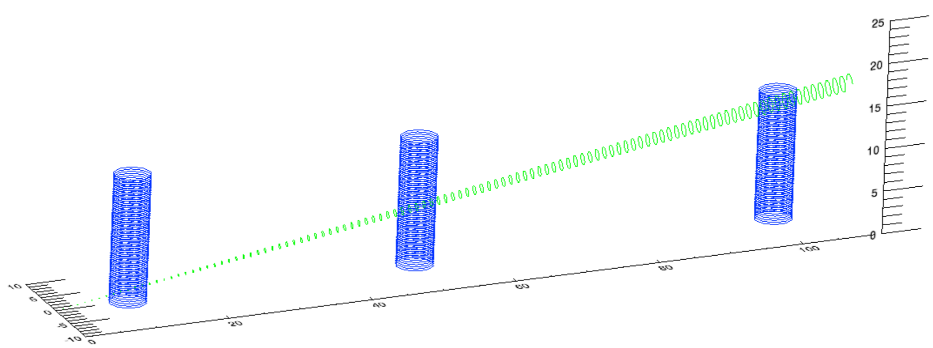

Figure 2-1. An illustration of the intersection between Ground Radar sweeps and Precipitation Radar footprints. Only a select number of radar echoes are illustrated in either case.

The multi-level, spatial data variables stored as 3-D grid fields in the gridded products are stored as 2-D arrays in the geo-match products, with dimensions of [elevationAngle, fpdim], where elevationAngle is the number of elevation sweeps in the ground radar volume scan, and fpdim is the number of PR rays (footprints) within the 100 km of the ground radar location. The variables holding the x- and y-locations of the four corners of the PR footprints have the additional dimension 'xydim', and are the only multi-level variables in the file requiring 3 dimensions.

1 Bolen, S.M. and V. Chandrasekar. 2003. Methodology for aligning and comparing spaceborne radar and ground-based radar observations. Journal of Atmospheric and Oceanic Technology 20:647-659.

The single-level, spatial data variables stored as 2-D grid fields in the gridded products are stored as 1-D arrays in the geo-match products, with dimension of [fpdim]. As in the grid data files, each single-level and multi-level "science" variable has an associated scalar 'flag' variable (e.g., have_rainType) that indicates whether the grid has been populated with actual values (flag = 0) or is just initialized with "Fill" values (flag = 1).

Since the horizontal and vertical positions of each data point in the geometry matching data set are essentially random, each data value of the spatial data variables has a set of associated horizontal and (for the multi-level variables) vertical position variables. All points have both a latitude and a longitude value, corrected for viewing angle in the case of the multi-level variables. The multi-level variables also have associated variables specifying the x- and y-corners of the PR footprint (in km, relative to a Cartesian coordinate system centered at the location of the ground radar, with the +y axis pointing due north), and the top and bottom height of the ground radar elevation sweep at the PR ray intersection point, in km above the surface. A summary is provided in Section 3 of this document of all *dimensions, attributes,* and *variables* in the Geometry Matching netCDF file.

2.4 The "expected/rejected" netCDF Variables

One set of geometry matchup variables in the netCDF files is concerned with the coincidence of ground radar (GR) and PR range gates. These variables provide a metric that can be used to assess the "goodness" of the matchup between the radars. These "expected/rejected" variables are described in some detail below, because their content and meaning may otherwise be difficult to understand. As for the other geometry matchup variables, valid values for categorical variables are listed in Section 3 of this document. The meaning of all other variables can be deduced from the complete list of the geometry matchup variables and their associated units, which can also be found in Section 3 of this document.

For a given PR ray, several ground radar (GR) range gates and rays will typically intersect several PR range gates, as illustrated in vertical cross section in Figure 2-1, below. The geometry matching algorithm converts PR and GR dBZ to Z, and then averages Z values for all PR range gates corresponding to an averaged GR volume for those areas where a GR elevation sweep intersects a PR ray.

Only those gates at or above a specified reflectivity or rain rate threshold are included in the PR and GR gate averages (variables PR_dBZ_min, GV_dBZ_min, and rain_min). The VN algorithm calculates the number of PR and GR gates expected (from a strictly geometric standpoint) and rejected (below the applicable measurement threshold) in generating these averages and stores them in netCDF variables as defined below.

- GR reflectivity: n_gv_expected, n_gv_rejected
- PR uncorrected reflectivity: n_1c21_z_expected, n_1c21_z_rejected
- PR corrected reflectivity: n_2A25_z_expected, n_1c21_z_rejected.

The effects of non-uniform beam filling can be minimized in cases where the number of rejected gates is zero in both of the GR and PR match-up volumes.

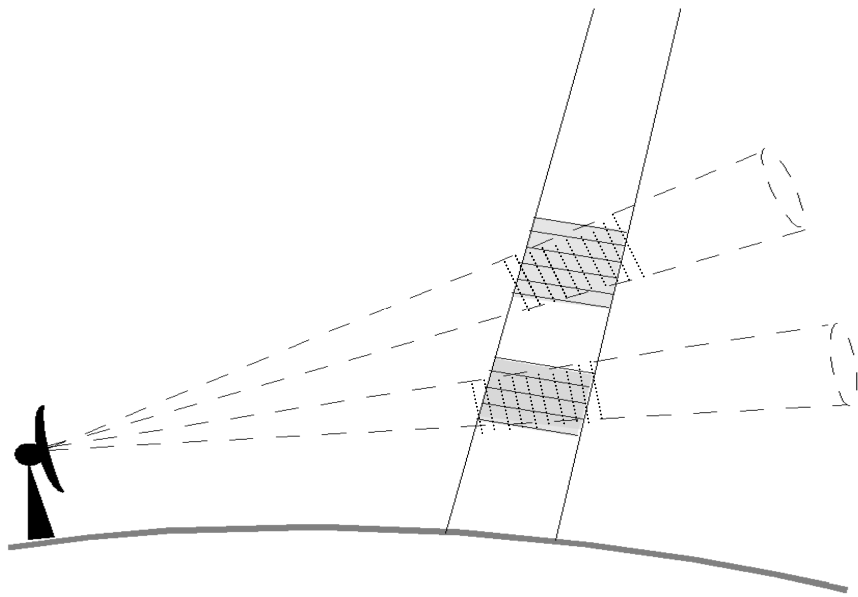

Figure 2-2. Schematic of PR gate averaging at GR sweep intersections. Shaded areas are PR gates intersecting two GR sweeps (dashed) at different elevation angles. Only one PR ray is shown.

3. Summary of the Geometry Match netCDF file

The format and content of the Geometry Match netCDF file is presented below, in the form of partial netCDF file creation instructions. The values for dimensions having a fixed size for all files are specified, while those for dimensions which vary on a file by file basis by site overpass event (fpdim and elevationAngle) are left unspecified. Note that the fill values for non-int variables have a type indicator appended to the numerical value, e.g. -888.f for a FLOAT fill value, 1s for a SHORT integer fill value. The global attribute GV_UF_Z_field has been assigned a value of "CZ" for purposes of the example. Other values (depends on the type of GR radar site) would result if a different data field is used as the source of reflectivity data from the GR radar Universal Format (UF) data files used as input to the geometry matching application. All other global variables are left at their default values.

Table 3-1 summarizes the name, type, dimension, and special values (e.g., Missing Data) associated with each "science" and geolocation array variable in the geo-match netCDF files.

```
dimensions:
	fpdim =  ;
	elevationAngle =  ;
	xydim = 4 ;
	len_atime_ID = 19 ;
	len_site_ID = 4 ;
variables:
	float elevationAngle(elevationAngle) ;
		elevationAngle:long_name = "Radar Sweep Elevation Angles" ;
		elevationAngle:units = "degrees" ;
	float rangeThreshold ;
		rangeThreshold:long_name = "Dataset maximum range from radar site" ;
		rangeThreshold:_FillValue = -888.f ;
		rangeThreshold:units = "km" ;
	float PR_dBZ_min ;
		PR_dBZ_min:long_name = "minimum PR bin dBZ required for a *complete* PR vertical average" ;
		PR_dBZ_min:_FillValue = -888.f ;
		PR_dBZ_min:units = "dBZ" ;
	float GV_dBZ_min ;
		GV_dBZ_min:long_name = "minimum GV bin dBZ required for a *complete* GV horizontal average" ;
		GV_dBZ_min:_FillValue = -888.f ;
		GV_dBZ_min:units = "dBZ" ;
	float rain_min ;
		rain_min:long_name = "minimum PR rainrate required for a *complete* PR vertical average" ;
		rain_min:_FillValue = -888.f ;
```

```
        rain_min:units = "mm/h" ;
    short have_threeDreflect ;
        have_threeDreflect:long_name = "data exists flag for threeDreflect" ;
        have_threeDreflect:_FillValue = 1s ;
    short have_threeDreflectStdDev ;
        have_threeDreflectStdDev:long_name = "data exists flag for threeDreflectStdDev" ;
        have_threeDreflectStdDev:_FillValue = 0s ;
    short have_threeDreflectMax ;
        have_threeDreflectMax:long_name = "data exists flag for threeDreflectMax" ;
        have_threeDreflectMax:_FillValue = 0s ;
    short have_dBZnormalSample ;
        have_dBZnormalSample:long_name = "data exists flag for dBZnormalSample" ;
        have_dBZnormalSample:_FillValue = 1s ;
    short have_correctZFactor ;
        have_correctZFactor:long_name = "data exists flag for correctZFactor" ;
        have_correctZFactor:_FillValue = 1s ;
    short have_rain ;
        have_rain:long_name = "data exists flag for rain" ;
        have_rain:_FillValue = 1s ;
    short have_landOceanFlag ;
        have_landOceanFlag:long_name = "data exists flag for landOceanFlag" ;
        have_landOceanFlag:_FillValue = 1s ;
    short have_nearSurfRain ;
        have_nearSurfRain:long_name = "data exists flag for nearSurfRain" ;
        have_nearSurfRain:_FillValue = 1s ;
    short have_nearSurfRain_2b31 ;
        have_nearSurfRain_2b31:long_name = "data exists flag for nearSurfRain_2b31" ;
        have_nearSurfRain_2b31:_FillValue = 1s ;
    short have_BBheight ;
        have_BBheight:long_name = "data exists flag for BBheight" ;
        have_BBheight:_FillValue = 1s ;
    short have_BBstatus ;
        have_BBstatus:long_name = "data exists flag for BBstatus" ;
        have_BBstatus:_FillValue = 0s ;
    short have_status ;
        have_status:long_name = "data exists flag for 2A23 status" ;
        have_status:_FillValue = 0s ;
    short have_rainFlag ;
        have_rainFlag:long_name = "data exists flag for rainFlag" ;
        have_rainFlag:_FillValue = 1s ;
    short have_rainType ;
        have_rainType:long_name = "data exists flag for rainType" ;
        have_rainType:_FillValue = 1s ;
```

```
float latitude(elevationAngle, fpdim) ;
      latitude:long_name = "Latitude of data sample" ;
      latitude:units = "degrees North" ;
      latitude:_FillValue = -888.f ;
float longitude(elevationAngle, fpdim) ;
      longitude:long_name = "Longitude of data sample" ;
      longitude:units = "degrees East" ;
      longitude:_FillValue = -888.f ;
float xCorners(elevationAngle, fpdim, xydim) ;
      xCorners:long_name = "data sample x corner coords." ;
      xCorners:units = "km" ;
      xCorners:_FillValue = -888.f ;
float yCorners(elevationAngle, fpdim, xydim) ;
      yCorners:long_name = "data sample y corner coords." ;
      yCorners:units = "km" ;
      yCorners:_FillValue = -888.f ;
float topHeight(elevationAngle, fpdim) ;
      topHeight:long_name = "data sample top height AGL" ;
      topHeight:units = "km" ;
      topHeight:_FillValue = -888.f ;
float bottomHeight(elevationAngle, fpdim) ;
      bottomHeight:long_name = "data sample bottom height AGL" ;
      bottomHeight:units = "km" ;
      bottomHeight:_FillValue = -888.f ;
float threeDreflect(elevationAngle, fpdim) ;
      threeDreflect:long_name = "GV radar QC Reflectivity" ;
      threeDreflect:units = "dBZ" ;
      threeDreflect:_FillValue = -888.f ;
float threeDreflectStdDev(elevationAngle, fpdim) ;
      threeDreflectStdDev:long_name = "Standard Deviation of GV radar QC Reflectivity" ;
      threeDreflectStdDev:units = "dBZ" ;
      threeDreflectStdDev:_FillValue = -888.f ;
float threeDreflectMax(elevationAngle, fpdim) ;
      threeDreflectMax:long_name = "Sample Maximum GV radar QC Reflectivity" ;
      threeDreflectMax:units = "dBZ" ;
      threeDreflectMax:_FillValue = -888.f ;
float dBZnormalSample(elevationAngle, fpdim) ;
      dBZnormalSample:long_name = "1C-21 Uncorrected Reflectivity" ;
      dBZnormalSample:units = "dBZ" ;
      dBZnormalSample:_FillValue = -888.f ;
float correctZFactor(elevationAngle, fpdim) ;
      correctZFactor:long_name = "2A-25 Attenuation-corrected Reflectivity" ;
      correctZFactor:units = "dBZ" ;
```

```
        correctZFactor:_FillValue = -888.f ;
float rain(elevationAngle, fpdim) ;
        rain:long_name = "2A-25 Estimated Rain Rate" ;
        rain:units = "mm/h" ;
        rain:_FillValue = -888.f ;
short n_gv_rejected(elevationAngle, fpdim) ;
        n_gv_rejected:long_name = "number of bins below GV_dBZ_min in threeDreflect average" ;
        n_gv_rejected:_FillValue = -888s ;
short n_gv_expected(elevationAngle, fpdim) ;
        n_gv_expected:long_name = "number of bins in GV threeDreflect average" ;
        n_gv_expected:_FillValue = -888s ;
short n_1c21_z_rejected(elevationAngle, fpdim) ;
        n_1c21_z_rejected:long_name = "number of bins below PR_dBZ_min in dBZnormalSample average" ;
        n_1c21_z_rejected:_FillValue = -888s ;
short n_2a25_z_rejected(elevationAngle, fpdim) ;
        n_2a25_z_rejected:long_name = "number of bins below PR_dBZ_min in correctZFactor average" ;
        n_2a25_z_rejected:_FillValue = -888s ;
short n_2a25_r_rejected(elevationAngle, fpdim) ;
        n_2a25_r_rejected:long_name = "number of bins below rain_min in rain average" ;
        n_2a25_r_rejected:_FillValue = -888s ;
short n_pr_expected(elevationAngle, fpdim) ;
        n_pr_expected:long_name = "number of bins in PR averages" ;
        n_pr_expected:_FillValue = -888s ;
float PRlatitude(fpdim) ;
        PRlatitude:long_name = "Latitude of PR surface bin" ;
        PRlatitude:units = "degrees North" ;
        PRlatitude:_FillValue = -888.f ;
float PRlongitude(fpdim) ;
        PRlongitude:long_name = "Longitude of PR surface bin" ;
        PRlongitude:units = "degrees East" ;
        PRlongitude:_FillValue = -888.f ;
short landOceanFlag(fpdim) ;
        landOceanFlag:long_name = "1C-21 Land/Ocean Flag" ;
        landOceanFlag:units = "Categorical" ;
        landOceanFlag:_FillValue = -888s ;
float nearSurfRain(fpdim) ;
        nearSurfRain:long_name = "2A-25 Near-Surface Estimated Rain Rate" ;
        nearSurfRain:units = "mm/h" ;
        nearSurfRain:_FillValue = -888.f ;
float nearSurfRain_2b31(fpdim) ;
        nearSurfRain_2b31:long_name = "2B-31 Near-Surface Estimated Rain Rate" ;
        nearSurfRain_2b31:units = "mm/h" ;
        nearSurfRain_2b31:_FillValue = -888.f ;
```

```
float BBheight(fpdim) ;
      BBheight:long_name = "2A-25 Bright Band Height above MSL from Range Bin Numbers" ;
      BBheight:units = "m" ;
      BBheight:_FillValue = -888.f ;
short BBstatus(fpdim) ;
      BBstatus:long_name = "2A-23 Bright Band Detection Status" ;
BBstatus:units = "Categorical" ;
      BBstatus:_FillValue = -888s ;
short status(fpdim) ;
      status:long_name = "2A-23 Status Flag" ;
      status:units = "Categorical" ;
      status:_FillValue = -888s ;
short rainFlag(fpdim) ;
      rainFlag:long_name = "2A-25 Rain Flag (bitmap)" ;
      rainFlag:units = "Categorical" ;
      rainFlag:_FillValue = -888s ;
short rainType(fpdim) ;
      rainType:long_name = "2A-23 Rain Type (stratiform/convective/other)" ;
      rainType:units = "Categorical" ;
      rainType:_FillValue = -888s ;
int rayIndex(fpdim) ;
      rayIndex:long_name = "PR product-relative ray,scan IDL 1-D array index" ;
      rayIndex:_FillValue = -888 ;
double timeNearestApproach ;
      timeNearestApproach:units = "seconds" ;
      timeNearestApproach:long_name = "Seconds since 01-01-1970 00:00:00" ;
      timeNearestApproach:_FillValue = 0. ;
char atimeNearestApproach(len_atime_ID) ;
      atimeNearestApproach:long_name = "text version of timeNearestApproach, UTC" ;
double timeSweepStart(elevationAngle) ;
      timeSweepStart:units = "seconds" ;
      timeSweepStart:long_name = "Seconds since 01-01-1970 00:00:00" ;
      timeSweepStart:_FillValue = 0. ;
char atimeSweepStart(elevationAngle, len_atime_ID) ;
      atimeSweepStart:long_name = "text version of timeSweepStart, UTC" ;
char site_ID(len_site_ID) ;
      site_ID:long_name = "ID of Ground Radar Site" ;
float site_lat ;
      site_lat:long_name = "Latitude of Ground Radar Site" ;
      site_lat:units = "degrees North" ;
      site_lat:_FillValue = -888.f ;
float site_lon ;
      site_lon:long_name = "Longitude of Ground Radar Site" ;
```

```
            site_lon:units = "degrees East" ;
            site_lon:_FillValue = -888.f ;
      float site_elev ;
            site_elev:long_name, "Elevation of Ground Radar Site above MSL" ;
            site_elev:units', "km" ;
      float version ;
            version:long_name = "Geo Match File Version" ;

// global attributes:
            :PR_Version = 6s ;
            :GV_UF_Z_field = "CZ" ;
            :PR_1C21_file = "Unspecified" ;
            :PR_2A23_file = "Unspecified" ;
            :PR_2A25_file = "Unspecified" ;
            :PR_2B31_file = "Unspecified" ;
            :GR_file = "Unspecified" ;
```

NOTES:

1) The variables **topHeight** and **bottomHeight** are in units of km above ground level (km AGL), while **BBheight** is in units of meters above mean sea level (m above MSL). Assuming all heights are converted to units of km, then the variable **site_elev** (km above MSL) relates above MSL and AGL:

```
HeightAGL = HeightMSL - site_elev
```

2) The variable **site_elev** is not present in geometry-match netCDF files with the **version** value of 1.0. It has been added for the version 1.1 netCDF file definition, corresponding to Version 1.1 of the POLAR2PR program.

3) The variables **have_threeDreflectMax**, **have_threeDreflectStdDev**, t**hreeDreflectMax**, t**hreeDreflectStdDev**, **have_BBstatus**, **have_status**, **BBstatus**, and **status** are not present in geometry match netCDF files prior to version 2.0.

4) The global variables PR_1C21_file, PR_2A23_file, PR_2A25_file, PR_2B31_file, and GR_file are not present in geometry match netCDF files prior to version 2.1.

Table 3-1. Variable name, type, dimensions, and interpretation of special data values for science and geolocation variables in Geometry Match netCDF files.

Variable Name(s)	Type	Dimension(s)	Special Values
threeDreflect, threeDreflectStdDev, threeDreflectMax	float	elevationAngle, fpdim	-888.0: Range edge delimiter, Fill Value -777.0: In-range PR scan edge delimiter -9999.0: Missing data -100.0: Below dBZ cutoff value
dBZnormalSample	float	elevationAngle, fpdim	-888.0: Range edge delimiter, Fill Value -777.0: In-range PR scan edge delimiter -9999.0: Missing data -100.0: Below dBZ cutoff value
correctZFactor	float	elevationAngle, fpdim	-888.0: Range edge delimiter, Fill Value -777.0: In-range PR scan edge delimiter -9999.0: Missing data -100.0: Below dBZ cutoff value
rain	float	elevationAngle, fpdim	-888.0: Range edge delimiter, Fill Value -777.0: In-range PR scan edge delimiter -88.88: Below rain rate cutoff threshold
n_gv_expected, n_gv_rejected, n_pr_expected	short	elevationAngle, fpdim	-888: Fill Value
n_1c21_z_rejected, n_2a25_z_rejected, n_2a25_r_rejected	short	elevationAngle, fpdim	-888: Fill Value
latitude, longitude	float	elevationAngle, fpdim	-888.0: Fill Value
topHeight, bottomHeight	float	elevationAngle, fpdim	-888.0: Fill Value
xCorners, yCorners	float	elevationAngle, fpdim, xydim	-888.0: Fill Value
PRlatitude, PRlongitude	float	fpdim	-888.0: Fill Value
landOceanFlag	short	fpdim	-888: Range edge delimiter, Fill Value
nearSurfRain	float	fpdim	-888.0: Range edge delimiter, Fill Value
nearSurfRain_2b31	float	fpdim	-888.0: Range edge delimiter, Fill Value
BBheight	float	fpdim	-888.0: Range edge delimiter, Fill Value
BBstatus	short	fpdim	-888: Range edge delimiter, Fill Value
status	short	fpdim	-888: Range edge delimiter, Fill Value
rainFlag	short	fpdim	-888: Range edge delimiter, Fill Value
rainType	short	fpdim	-888: Range edge delimiter, Fill Value
rayIndex	int	fpdim	-1: Edge-of-Range indicator -2: In-range PR scan edge indicator
elevationAngle	float	elevationAngle	N/A

Notes on Table 3-1:

1. Special Values are values outside of the normal physical range of the data field, and which indicate a special meaning at the data point (e.g., Missing data).

2. Range edge points are the footprints of the nearest PR rays outside of, but immediately adjacent to, the range ring surrounding the ground radar at distance = **rangeThreshold**, for a given PR scan. These points form a partial circle around points for the PR rays within the **rangeThreshold** of the ground radar, the latter which contain actual data values.
3. PR scan edge points are the footprints of single PR rays extrapolated just beyond either edge of the PR scan, and which fall within or immediately adjacent to the **rangeThreshold** distance from the ground radar.
4. The combination of the Range Edge points and the Scan Edge points serve to completely enclose the in-range PR footprints on the surface: a) defined by each elevation sweep (for multi-level variables), or b) at the earth surface (for single level variables). The purpose of these points is to prevent the extrapolation of "actual" PR data values outside of the in-range area, if the data are later analyzed to a regular grid using an objective analysis technique.
5. Range Edge points and Scan Edge points are indicated by **rayIndex** values of -1 and -2, respectively. **rayIndex** values of 0 or greater are actual 1-D equivalent array indices of PR rays within the full data arrays in the source PR product files.
6. ***Beginning with Version 1.1 of the POLAR2PR volume-matching code, Range and Scan Edge points are optional and, as a default, are disabled from being computed and output. If the "Mark Edges" parameter's default value is overridden, then these types of points will then be computed and output as described above.***
7. **Fill Value** is the value to which scalar or array variables in the netCDF file are initialized when the file is created. These values remain in place unless and until the data value is overwritten.
8. The variables **topHeight** and **bottomHeight** represent height above ground level (AGL) (i.e., height above the ground radar) ***in km***, while **BBheight** represents height above mean sea level (MSL; the earth ellipsoid, actually), ***in meters***. The difference between AGL height and MSL height is given by the value of the **site_elev** variable, the height above MSL of the ground radar, in km. To compare **BBheight** to **topHeight** or **bottomHeight**, first convert **BBheight** to km units. Then, either subtract **site_elev** from **BBheight** to work in AGL height units, or add **site_elev** to **topHeight** and **bottomHeight** to work in MSL height units. ***The* site_elev *variable is only available in files with a* version *value of 1.1 or greater.***

Table 3-2. Values of categorical variables in the geometry matching technique netCDF files.

Variable	Category definitions
landOceanFlag	0 = Water 1 = Land 2 = Coast 3 = Water, with large attenuation 4 = Land/coast, with large attenuation -888 = Point not coincident with PR
rainType	Stratiform = values 100-170 Convective = values 200-291 Others = values 300-313 No rain = -88 Missing data = -99 No data = -888 (not coincident with PR)
rainFlag	The Rain Flag indicates rain or no rain status and the rain type assumed in rain rate retrieval. The default value is 0 (no rain). Bit 0 is the least significant bit (i.e., if bit i=1 and other bits =0, the unsigned integer value is 2**i). The following meanings are assigned to each bit in the 16-bit integer if the bit = 1. bit 0: rain possible bit 1: rain certain bit 2: zeta^beta > 0.5 [Path Integrated Attenuation (PIA) larger than 3 dB] bit 3: large attenuation (PIA larger than 10 dB) bit 4: stratiform bit 5: convective bit 6: bright band exists bit 7: warm rain bit 8: rain bottom above 2 km bit 9: rain bottom above 4 km bit 10: not used bit 11: not used bit 12: not used bit 13: not used bit 14: data missing between rain top and bottom bit 15: not used

Variable	Category definitions

BBstatus	The "BBstatus" variable in the netCDF file is an unmodified copy of the 2A-23 "Bright Band Status" variable. It indicates the status of the bright band detection. This flag is a composite of three internal status flags:
	
	BB_status[j] = BB_detection_status[j] * 16
	+ BB_boundary_status[j] * 4
	+ BB_width_status[j]
	
	where each status on the right hand side takes the following values:
	
	1: poor,
	2: fair,
	3: good.
	
	These three internal flags would be computed from BB_status[j], for example, by something like as follows:
	
	if (BB_status[j]>0) {
	BB_detection_status[j] = BB_status[j] / 16;
	BB_boundary_status[j] = (BB_status[j]%16) / 4;
	BB_width_status[j] = BB_status[j]%4;
	}
	
	where % means MOD in FORTRAN;
	
	BB_status[j]%4 <----> MOD(BB_status(j),4)

status	The "status" variable in the netCDF file is an unmodified copy of the 2A-23 "Status Flag" variable. Its values are described in detail in Volume 4 of the TRMM Interface Control Specification. In brief, we can check the confidence level of data in each PR ray the following way: When Status ≥ 0 : Status Flag ≥ 100 : bad (untrustworthy because of possible data corruption) 100> Status Flag ≥ 10 : result not so confident (warning) Status Flag = 9 : may be good 9> Status Flag ≥ 0 : good The last digit of Status Flag indicates over ocean, land, etc.: Status % 10 = 0: over ocean 1: over land 2: over coastline 4: over inland lake 9: land/sea unknown

4. Directory Structure of the VN ftp site

This section describes the directory structure for the VN data ftp site:

ftp://hector.gsfc.nasa.gov/gpm-validation/data

In the directory structures shown below, all directory and filename values and/or fields indicated in regular text are literal fields which never vary from those shown. The fields shown in ***bold italics*** vary according to the value of the field code they represent. The field codes are defined in Table 4-1.

/coincidence_table/ (Note-1)
  CT.***YYMMDD***.V
  CT.***YYMMDD***.unl
  CT***YYMM***archive.tar.gz

/db_backup/ (Note-2)
  gpmgvDBdump.gz
  gpmgvDBdump.old.gz

/gv_radar (Note-3)
  /defaultQC_in
    /***xxxx***
      /1c51
        /***YYYY***
          /***MMDD***/
            1C51.***YYMMDD.N.TTTT.V***.HDF.gz
      /1cuf
        /***YYYY***
          /***MMDD***/
            YYMMDD.N.TTTT.V.hhmm.uf.gz
      /images
        /***YYYY***
          /***MMDD***/

  TTTT_FF_YYMMDD.hhmm.q1q2q3.q4q5q6q7.ee.gif
      /raw
        /***YYYY***
          /***MMDD***/
            XXXXYYYYMMDD_hhmmss.gz

  /finalQC_in (Note-3)
    /***xxxx***
      /1c51
        /***YYYY***
          /***MMDD***/
            1C51.***YYMMDD.N.TTTT.V***.HDF.gz
      /1cuf

/***YYYY***
/***MMDD***/
YYMMDD.N.TTTT.V.hhmm.uf.gz
/images
/***YYYY***
/***MMDD***/

TTTT_FF_YYMMDD.hhmm.q1q2q3.q4q5q6q7.ee.gif
/level_2
/***YYYY***
/gvs_2A-***5G***-dc_***XXXX_MM_YYYY***/
2A***5G.YYMMDD.N.TTTT.V***.HDF.gz

/mosaicimages (Note-4)
/archivedmosaic/
YYYY-MM-DD_hhmm.gif

/netcdf (Note-5)
/geomatch/
GRtoPR.***XXXX.YYMMDD.#####.***nc.gz

/prsubsets (Note-6)
/1c21/
1C21_CSI.***YYMMDD.#####.SSSS.V***.HDF.Z
1C21_GPM_KMA.***YYMMDD.#####.SSSS.V***.HDF.gz
1C21.***YYMMDD.#####.V***.sub-GPMGV1.hdf.gz
1C21.***YYMMDD.#####.V***.HDF.Z
/2a23/
2A23_CSI.***YYMMDD.#####.SSSS.V***.HDF.Z
2A23_GPM_KMA.***YYMMDD.#####.SSSS.V***.HDF.gz
2A23.***YYMMDD.#####.V***.sub-GPMGV1.hdf.gz
2A23.***YYMMDD.#####.V***.HDF.Z
/2a25/
2A25_CSI.***YYMMDD.#####.SSSS.V***.HDF.Z
2A25_GPM_KMA.***YYMMDD.#####.SSSS.V***.HDF.gz
2A25.***YYMMDD.#####.V***.sub-GPMGV1.hdf.gz
2A25.***YYMMDD.#####.V***.HDF.Z
/2b31/
2B31_CSI.***YYMMDD.#####.SSSS.V***.HDF.Z
2B31_GPM_KMA.***YYMMDD.#####.SSSS.V***.HDF.gz
2B31.***YYMMDD.#####.V***.sub-GPMGV1.hdf.gz
2B31.***YYMMDD.#####.V***.HDF.Z

Table 4-1
Field Definitions for Directory and Filename Conventions

Field Code	Definition
#####	TRMM orbit number, 1 to 5 digits
ee	sequential elevation sweep number, zero-based
FF	radar field variable: DZ (reflectivity), CZ (post-QC reflectivity), VR (radial velocity)
5G	TRMM GV level-2 gridded product subtype: 53 (2A-53), 54 (2A-54), 55 (2A-55)
hhmm	2-digit hour (hh) and minute (mm)
hhmmss	2-digit hour (hh), minute (mm), and second (ss)
MM	2-digit month
MMDD	2-digit month (MM) and day of month (DD)
N	nominal hour of data, from rounding up (1-24)
q1	QC Height Threshold: CAPPI height (km), 2-digit w. leading zero (e.g., 02)
q2	QC Height Threshold: Minimum cloud height (km), 2-digit w. leading zero
q3	QC Height Threshold: Max height QC search (km), 2-digit w. leading zero
q4	QC Reflectivity Threshold: Min Zmax @ 1.5 km (dBZ)
q5	QC Reflectivity Threshold: Min Zmax @ 3.0 km (dBZ)
q6	QC Reflectivity Threshold: Min Z @ lowest tilt (dBZ)
q7	QC Reflectivity Threshold: Min Zmax @ q1 height (dBZ)
SSSS	TRMM CSI Product Subset ID for products from the DAAC
TTTT	TRMM GV 4-letter station ID (see Table M)
V	product version number
xxxx	lower-case version of XXXX
XXXX	NWS (also GPM GV) 4-letter station ID (see Table 1-1)
YYMM	2-digit year (YY) and month (MM)
YYMMDD	2-digit year (YY), month (MM), and day of month (DD)

Field Code	Definition
YYYY	4-digit year

Note-1. Files in the **coincidence_table** directory are Daily Coincidence Table (CT) files from the TRMM Precipitation Processing Subsystem (PPS). The tables contain the orbit number, date, time, distance, and direction of the TRMM orbital subtrack's nearest approach to the ground radar sites configured for this purpose in the PPS. The CT cutoff distance is 700 km. Files in the form CT.***YYMMDD.V*** are the complete, original CT files from the PPS. Those with the ".unl" file extension contain CT data reformatted in a form to be loaded in the GPM GV PostgreSQL database, for only the ground radar sites used in the GPM Validation Network. Older daily files are accumulated into monthly tar files (CT***YYMM***archive.tar.gz), compressed using gzip.

Note-2. Files in the **db_backup** directory contain a backup (dump) of the GPM VN's PostgreSQL database 'gpmgv', created using the pg_dump utility, and compressed using gzip. The latest dump of the database is in the file 'gpmgvDBdump.gz'. This file is renamed to 'gpmgvDBdump.old.gz' as each new backup is performed. Only the current and previous dumps are retained.

Note-3. The files in under the top-level **gv_radar** directory contain ground radar data in multiple file formats. These radar data come mostly from U.S. domestic WSR-88D radars, but data from other ground radars are also located in this directory structure. Files that fall under the high-level directory **defaultQC_in** are from the KWAJ and WSR-88D radars, and have been subject to the default quality control processes within the TRMM GV. Files from the KWAJ and WSR-88D radars that fall under the higher-level directory **finalQC_in** are those that were subject to both automated and human quality control.

Ground radar data in both directories (**defaultQC_in** and **finalQC_in**) are organized into subdirectories in the following order: (a) station ID, (b) file type, (c) year, and (d) month/day (except for the **level_2** file type, where the lowest level directory is file_subtype/month).

Files in the **1c51** subdirectories contain a full volume scan of ground radar data in a Hierarchical Data Format-4 (HDF-4) file conforming to the TRMM 1C51 format and content. Each data file contains data for one ground radar volume scan. Within the individual data file names, the fixed field "HDF" designates that this is a HDF file, and ".gz" designates that this file has been compressed using gzip.

The files in the **1cuf** subdirectories contain a full volume scan of ground radar data conforming to the "Universal Format" data format. Each data file contains data for one ground radar volume scan. Within the individual data file names, the fixed field "uf " designates that this is a radar file in Universal Format.

Files in the **images** subdirectories are Plan Position Indicator (PPI) display images of reflectivity and radial velocity from the ground radar, for selected elevation sweeps. Files that fall under the high-level directory **defaultQC_in** are those that were subject to the default quality control procedures. Files that fall under the higher-level directory

finalQC_in are those that were subject to both automated and human quality control. The variable fields q1-q7 in the individual file names document the quality control threshold values applied in the TRMM GV quality control procedures. Within the individual data file names, the fixed field "gif" designates that the image file is in GIF format.

Files in the **raw** subdirectory are the original radar data files in their native format, as obtained from the data source. For the WSR-88D sites, the files are in the NEXRAD Level-II archive format, not to be confused with the TRMM GV Level 2 gridded radar products in the **level_2** subdirectory. Recent WSR-88D Level-II archive products are degraded from the Build 10 super-resolution format to the legacy Level-II archive format prior to quality control and ingest by the GPM VN prototype. Each data file contains data for one ground radar volume scan.

Files under the **level_2** subdirectory are three types of TRMM GV Level 2 gridded radar products: 2A-53, 2A-54, and 2A-55, with each type stored in separate lower-level subdirectories. Individual data files in this directory contain gridded ground radar data for both observed and derived variables, as documented in *Interface Control Specification Between the TSDIS and the TSDIS Science User (TSU), Volume 4; File Specifications for TRMM Products - Levels 2 and 3.* The Level 2 products in the VN data set contain data for only one ground radar volume scan. For these products, a lowest-level, product/site/month-specific subdirectory naming convention needs to be described, as follows:

/gvs_2A-5G-dc_XXXX_MM_YYYY

where:

gvs_2A- is fixed text
5G = 2-digit product ID number (53, 54, or 55)
-dc is fixed text
XXXX = 4-character ground radar station ID, see Table M
MM = 2-digit month
YYYY = 4-digit year

Note-4. Files under the **mosaicimages** directory are National Weather Service (NWS) WSR-88D national-scale radar mosaic images (RIDGE mosaics). RIDGE national mosaics are produced every 10 minutes by the NWS. Only those mosaics corresponding to the time of TRMM overpasses of the GPM Validation Network PR subset area in the southeastern U.S. are contained in the **archivedmosaic** subdirectory.

Note-5. The files in the **netcdf/geo_match** directory structure contain geometrically-matched ground radar and TRMM Precipitation Radar data in netCDF format as described above in Section 2 of the VN Data User's Guide. Each file corresponds to single ground radar volume scan taken nearest in time to where a TRMM satellite orbit's subtrack passes within 200 km of the ground radar during a "significant" rainfall event.

Note-6. The files in the **1c21** directory contain TRMM PR 1C-21 data products in HDF-4 format. Each file corresponds to an either an orbital subset of the TRMM PR data, where the orbital subset falls within a specific geographical "bounding box" that encompasses one or more Validation Network ground radars; or PR data for a full orbit. The file naming convention varies by orbit subset or full orbit, as follows:

Table 4-2
Filename conventions for TRMM PR Orbit Subset Products

Filename Convention	Description
1C21_CSI.***YYMMDD.#####.SSSS.V.***HDF.Z	Satellite Coincidence Subsetted Intermediate (CSI) Data from the Goddard Earth Sciences Data and Information Center (DISC, formerly DAAC), for one ground validation site indicated by the field **SSSS**.
1C21_GPM_KMA***.YYMMDD.#####.V.***HDF 1C21.YYYYMMDD.#####.V.GPM_KMA.hdf.gz	PR subset data from the TRMM PPS for the custom **GPM_KMA** subset area defined for the Korean radars.
1C21***.YYMMDD.#####.V.***sub-GPMGV1.hdf.gz 1C21.YYYYMMDD.#####.V.sub-GPMGV1.hdf.gz	PR subset data from the TRMM PPS for the custom **sub-GPMGV1** subset area defined for the southeastern U.S. radars.
1C21***.YYMMDD.#####.V.***HDF.Z	Data for a full orbit, from the Goddard DISC

Data values from variables within the 1C-21 data are extracted for inclusion in the VN match-up data files. The 1C-21 data are therefore one component of the "raw" PR data from which the VN matchup data products are generated.

The files in the **2a23** directory contain TRMM PR 2A-23 data products in HDF-4 format. The orbit subset and file naming conventions follow that used by the 1C-21 product (see Table 4-2), but with the file name prefixed by 2A23 in place of 1C21. The 2A-23 data are the second component of "raw" PR data from which the VN matchup data products are generated.

The files in the **2a25** directory contain TRMM PR 2A-25 data products in HDF-4 format. The orbit subset and file naming conventions follow that used by the 1C-21 product (see Table 4-2), but with the file name prefixed by 2A25 in place of 1C21. The 2A-23 data are the third component of "raw" PR data from which the VN matchup data products are generated.

The files in the **2b31** directory contain TRMM PR 2B-31 data products in HDF-4 format. The orbit subset and file naming conventions follow that used by the 1C-21 product (see Table 4-2), but with the file name prefixed by 2B31 in place of 1C21. Where available, the 2B-31 data are the fourth component of "raw" PR data from which the VN matchup data products are generated, but are optional to the matchup processing.

Note that the datestamp convention changed from YYMMDD to YYYYMMDD from Version 6 to Version 7 of the GPM_KMA and sub-GPMGV1 subset files.

5. Geometry Matching Algorithm Description

PR match-up sampling. The basic PR data processing algorithm is as follows:

1. For each PR ray in the product, compute the range of the ray's earth intersection point from the ground radar location. If greater than 100 km (adjustable), ignore the ray. If within 100 km, proceed as follows:
2. Examine the corrected reflectivity values along the PR ray. If one or more gates are at or above a specified threshold (18 dBZ), proceed with processing the ray, otherwise set the PR and GR match-up values to "below threshold".
3. Using the range from step 1, determine the height above ground level where the PR ray intersects the centerline of each of the elevation sweeps of the GR, and the width (as a vertical distance) of the GR beam at this range;
4. Compute a parallax-adjusted location of the PR footprint center at each GR sweep intersection height from step 3, as a function of height, the PR ray angle relative to nadir, and the orientation (azimuth) of the PR scan line. Retain these adjusted horizontal locations for the processing of the GR data;
5. Using the beam heights and widths from step 3, compute the upper and lower bound heights of each GR sweep at its intersection with the PR ray, correcting for height above MSL (the earth ellipsoid) as required for the PR height definition;
6. For each GR sweep intersection, determine the total number, and along-ray positions, of the PR range gates located between the upper and lower bound heights from step 5;
7. For the PR 3-D fields, perform a simple average of values over the set of range gates identified in step 6, for each GR sweep intersection (Figure 2). Reflectivity is converted from dBZ to Z before averaging, then the average Z is converted back to dBZ. Only those gates with values at or above specified reflectivity (18 dBZ) or rain rate (0.01 mm h^{-1}) thresholds are included in the average. Keep track of the number of below-threshold PR gates *rejected* from the vertical averages, and the number of gates *expected* in the averages from a geometric standpoint (from step 6);
8. For the 2-D PR field values (e.g., surface rain rate, bright band height), simply extract or derive the scalar field value for the given PR ray.

The 3-D PR fields which are vertically averaged, yielding one value per intersected GR sweep per PR ray, include:

- Raw PR reflectivity (Zr, in dBZ) from TRMM product 1C-21
- Attenuation-Corrected PR reflectivity (Zc, in dBZ) from TRMM product 2A-25
- Rain rate (mm/h) from TRMM product 2A-25.

The 2-D PR variables which are taken unaveraged, one value per PR ray, include:

- Raw PR reflectivity (Zr, in dBZ) from TRMM product 1C-21
- Surface type (land/ocean/coastal) flag
- Near-surface rain rate, mm/h
- Bright band height
- Rain type categorization (convective, stratiform, other)

- Rain/no-rain flag.

These scalar values are directly extracted and/or derived from data fields within PR products 1C-21 and 2A-25.

GR match-up sampling. The basic GR data processing algorithm is as follows:

1. For each PR ray processed, and for each elevation sweep of the GR, repeat the following:
2. Compute the along-ground distance between each GR bin center and the parallax-adjusted PR footprint center (from PR step 4);
3. Flag the GR bins within a fixed distance of the PR center. The fixed distance is equivalent to the maximum radial size of all the PR footprints processed.
4. Examine the reflectivity values of the flagged GR bins from step 3. If all values fall below a 15 dBZ threshold, then skip processing for the point and set its match-up value to "below threshold". Otherwise:
5. Perform an inverse distance weighted average of the GR reflectivity values over the bins from step 4 (Figure 3), using a Barnes gaussian weighting. Reflectivity is converted from dBZ to Z before averaging, then the average Z is converted back to dBZ. All GR bins with values at or above 0.0 dBZ are included in the average. Keep track of the total number of bins included in the average, and the number of these bins with values meeting the specified GR reflectivity threshold (15 dBZ).

6. Acronyms and Symbols

ACRONYM	DEFINITION
3-D	3-Dimensional
AGL	Above Ground Level
CSI	Coincident Subsetted Intermediate
DAAC	Distributed Active Archive Center
dBZ	Decibels (dB) of radar Reflectivity (Z)
DISC	(Goddard Earth Sciences) Data and Information Center
DPR	(GPM) Dual-frequency Precipitation Radar
GPM	Global Precipitation Measurement
GR	Ground Radar (a.k.a. GV radar)
GSFC	Goddard Space Flight Center
GV	Ground Validation
GVS	Ground Validation System
ID	Identification, Identifier
IDL	Interactive Data Language
km	kilometers
m	meters
mm/h	millimeters (mm) per hour (h)
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research (part of UCAR)
netCDF	network Common Data Form
NEXRAD	Next-generation Weather Radar (a.k.a. "WSR-88D")
PMM	Precipitation Measuring Missions
PPS	(TRMM) Precipitation Processing Subsystem
PR	(TRMM) Precipitation Radar
QC	Quality Control
TRMM	Tropical Rainfall Measuring Mission
UCAR	University Corporation for Atmospheric Research
US	United States
UTC	Coordinated Universal Time
VN	Validation Network
WSR-88D	Weather Surveillance Radar - 1988 Doppler (a.k.a. "NEXRAD")