THE STATISTICAL ANALYSIS AND DISPLAY PROGRAM FOR GPM VALIDATION NETWORK GEOMETRY-MATCHED PR AND GV DATA SETS

INTRODUCTION

The IDL procedure geo_match_z_pdf_profile_ppi_bb_prox_sca_ps.pro provides the capability to compute statistics and generate displays of PR and GV reflectivity from geometry-matched data produced by the GPM Validation Network prototype. These data are contained in a set of netCDF data files, one per "rainy" site overpass: a TRMM PR overpass of a ground radar (GV) site, with precipitation echoes present, referred to below as an "event". The procedure computes and displays tables of mean differences (PR-GV) between the PR and GV reflectivity from the geo-matched data for a selected event, with the data stratified into vertical layers in two manners: (1) by height above the surface, in 1.5-km-deep layers, for 15 levels centered from 1.5 to 19.5 km, and (2) into three layers defined by proximity to the bright band (freezing level): above, within, and below the bright band. For purposes of the latter, match-up samples are categorized as above (below) the bright band if their base (top) is 500 m or more above (750 m or more below) the mean bright band height. The remaining points are assigned as within the bright band. The mean bright band height is computed from the bright band analysis in the TRMM PR 2A-25 product. Only the attenuation-corrected PR reflectivity is used in the program, even though the "raw" PR reflectivity also is present in the netCDF data files.

The geo_match_z_pdf_profile_ppi_bb_prox_sca_ps procedure also launches an animation sequence of the PR and GV PPIs from the volume-matched data; displays vertical profiles of PR and GV reflectivity from match-up data averaged over the constant height levels, and histograms of PR and GV reflectivity accumulated in 2 dBZ bins, for match-up data stratified by proximity to the bright band: below, within, and above; and displays scatter plots of PR and GV reflectivity stratified by rain type and proximity to the bright band. As an option, the S-band to Ku-band frequency adjustments of Liao and Meneghini (2009) may be applied to the GV reflectivity values prior to generation of statistical and graphical display results.

Output options are: (a) to the screen (the default), and (b) to a Postscript file. The postscript output option is functional only if running a licensed copy of IDL. This document assumes that the user already knows the basics of running programs in IDL. Beginners can become familiar with IDL by reviewing the IDL online documentation at http://www.ittvis.com/portals/0/pdfs/idl/getstart.pdf.

SYNOPSIS

The geo_match_z_pdf_profile_ppi_bb_prox_sca_ps procedure takes a number of optional IDL keyword parameters that control the functionality of the program, and set up the local configuration of the host machine in terms of the data file paths. The complete calling sequence of geo_match_z_pdf_profile_ppi_bb_prox_sca_ps is as follows:

```
geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, SPEED=looprate,          $
      ELEVS2SHOW=elevs2show, NCPATH=ncpath, SITE=sitefilter,         $
      NO_PROMPT=no_prompt, PPI_VERTICAL=ppi_vertical,                $
      PPI_SIZE=ppi_size, PCT_ABV_THRESH=pctAbvThresh,                $
      SHOW_THRESH_PPI=show_thresh_ppi, GV_CONVECTIVE=gv_convective,  $
      GV_STRATIFORM=gv_stratiform, HISTO_WIDTH=histo_Width,          $
      HIDE_TOTALS=hide_totals, PS_DIR=ps_dir, B_W=b_w, S2KU=s2ku
```

Note that each keyword parameter is optional, and has a default value/behavior if left unspecified. The use of each keyword parameter is as follows:

SPEED: initial animation rate for the PPI animation loop on startup. Defaults to 3 if unspecified or value is outside of the allowed range of 0-100.

ELEVS2SHOW: number of PPIs to display in the PPI image animation, starting at a specified elevation angle in the volume, in the form 'N.s', where N is the number of PPIs to show, and s is the starting sweep (1-based, where 1 = first). Disables PPI plot if N <= 0, and displays a static plot if N = 1. Defaults to N=7.1 if unspecified. If s is zero or if only N is specified, then s = 1.

NCPATH: local directory path to the geo_match netCDF files' location. Defaults to **`/data/netcdf/geo_match`** if not specified. ***This parameter MUST be specified if the netCDF files are not located under*** **`/data/netcdf/geo_match`** ***on the local host.***

SITE: file pattern, which acts as a filter limiting the set of input files shown in the File Selector (Fig. 1), or over which the program will iterate. Mode of selecting the (next) file depends on the NO_PROMPT parameter. Default=* (all files)

NO_PROMPT: method by which the next file in the set of files defined by NCPATH and SITE is selected. Binary parameter (e.g., /NO_PROMPT or NO_PROMPT=1 to set to On). If unset or set to 0, defaults to using DialogPickfile (IDL's pop-up File Selector, shown in Figure 1). If set to On, then the program will automatically process each file in the set, in order of ascending site ID and date.

PPI_VERTICAL: controls orientation for PPI plot/animation subpanels. Binary parameter. If unset, or if SHOW_THRESH_PPI is On, then defaults to horizontal (PR PPI to left of GV PPI [Fig. 2]). If set, then PR is plotted above GV (Fig. 5)

PPI_SIZE: size in pixels of each subpanel in PPI plot. Default=375

PCT_ABV_THRESH: constraint on the percent of full-resolution PR and GV bins averaged into the geometric-matching volumes at or above their respective dBZ thresholds, specified at the time the geo-match dataset was created (18.0 dBZ for PR, 15.0 dBZ for GV). It is essentially a measure of "beam-filling goodness". 100 means use only those matchup points where all the PR and GV bins in the volume averages were

above threshold (the volumes are completely filled with above-threshold bin values). 0 means use all matchup points available, with no regard for thresholds (the default, if no pctAbvThresh value is specified).

SHOW_THRESH_PPI: Binary parameter, controls whether to create and display a 2nd set of PPIs plotting only those PR and GR points meeting the PCT_ABV_THRESH constraint. If set to On, then PPI_VERTICAL defaults to horizontal (PR left of GV)

GV_CONVECTIVE: GV reflectivity threshold at/above which GV data are considered to be of Convective Rain Type. Default = 35.0 if not specified. If set to <= 0, then GV reflectivity is ignored in evaluating whether PR indication of Stratiform Rain Type is a mismatch to a GV indication of Convective rain type.

GV_STRATIFORM: GV reflectivity threshold at/below which GV data are considered to be of Stratiform Rain Type. Default = 25.0 if not specified. If set to <= 0, then GV reflectivity is ignored in evaluating whether a PR indication of Convective Rain Type is a mismatch to a GV indication of Stratiform rain type.

HISTO_WIDTH: Bin size to be used in generating histogram totals for the reflectivity histogram plots. Default = 2.0 (dBZ)

HIDE_TOTALS: Binary parameter, controls whether to show (default) or hide the histogram and vertical profile plots for rain type = "Any".

PS_DIR: Directory to which postscript output will be written. If not specified or set to "Off", output is directed only to the screen.

B_W: Binary parameter, controls whether to draw vertical profile and histogram plots in Postscript file in color (default) or in black-and-white.

S2KU: Binary parameter, controls whether or not to apply the Liao/Meneghini S-band to Ku-band frequency adjustment GV reflectivity. Default = no

RUNNING THE PROGRAM (IDL License Available)

The following instructions apply to running the statistical analysis procedure with a licensed copy of IDL, or without an unlicensed copy, in time-limited evaluation mode. See the IDL Virtual Machine Option section for instructions on running the procedure with the IDL Virtual Machine.

The geo_match_z_pdf_profile_ppi_bb_prox_sca_ps procedure is provided as a precompiled and saved IDL binary file:
geo_match_z_pdf_profile_ppi_bb_prox_sca_ps.sav. To run the file, place it in a directory of your choice, and start IDL (either command-line mode or Development Environment [IDLDE]). At the IDL prompt (e.g., IDL>), change the current directory to

the one where the **geo_match_z_pdf_profile_ppi_bb_prox_sca_ps.sav** file is located (the quotes in the example commands are required):

```
IDL> cd, '/Users/Chuck/IDL_Save_Files'
```

Then 'restore' the saved binary procedure so that it can be run:

```
IDL> restore, 'geo_match_z_pdf_profile_ppi_bb_prox_sca_ps.sav'
```

The procedure can then be run. At a minimum, the NCPATH parameter will need to be specified on the command line so that the geo_match netCDF file path is set. For instance, if the netCDF files are located under /Users/Chuck/data/netcdf/geo_match, then run the procedure with NCPATH set as follows:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match'
```

The $ is a continuation character in IDL and allows you to enter a single command over several lines, for readability.

If all is well the procedure should then start and the file selector user interface should appear and be populated with the list of geo_match netCDF files, as shown in Fig. 1.

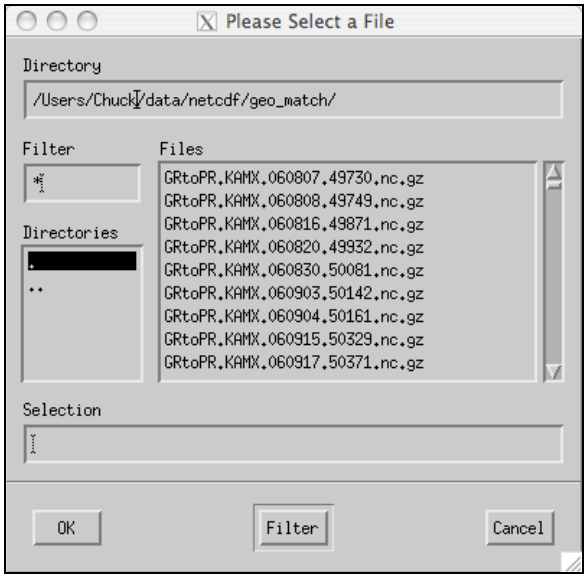


Figure 1. File selector for geometry-matched netCDF files.

Once a file has been selected from the list in the File Selector, diagnostic and statistical output from the procedure (Exhibit 1) will be listed in the terminal window (IDL command-line mode) or the IDLDE Console; an animation loop of PPI images of the PR and GV volume-matched data in the netCDF file will be displayed in one new window (e.g., Fig. 2); a four-panel plot with the vertical profile of reflectivity and histograms of reflectivity above, within, and blow the bright band will be displayed in a second window (e.g., Fig. 3); and scatter plots of PR and GV reflectivity will be displayed in a third

window (e.g., Fig. 4). Figure 2 shows one frame of the PPI animation. If the ELEVS2SHOW parameter is unspecified, then the elevation angles to be plotted in the PPIs will be the first seven elevation sweeps in the list of elevations in the GV volume scan. Otherwise, if ELEVS2SHOW=N.s is specified as a keyword parameter, then 'N' number of sweeps in the GV volume scan will be shown in the PPI animation, beginning from the elevation number 's', where s=1,2,…nsweeps, and 'nsweeps' is the number of sweeps in the volume scan. See the description of the ELEVS2SHOW parameter for other rules governing the N.s value.

Note that areas indicated as Stratiform rain type are shown on the PPIs with a horizontally-oriented line pattern, and areas of Convective rain type are shown with a vertical line pattern. Samples where the rain type is Unknown or Other are plotted with solid fill. Samples where a pattern appears on the dark gray background indicate a PR ray position where no valid reflectivity value is present at the elevation being displayed.

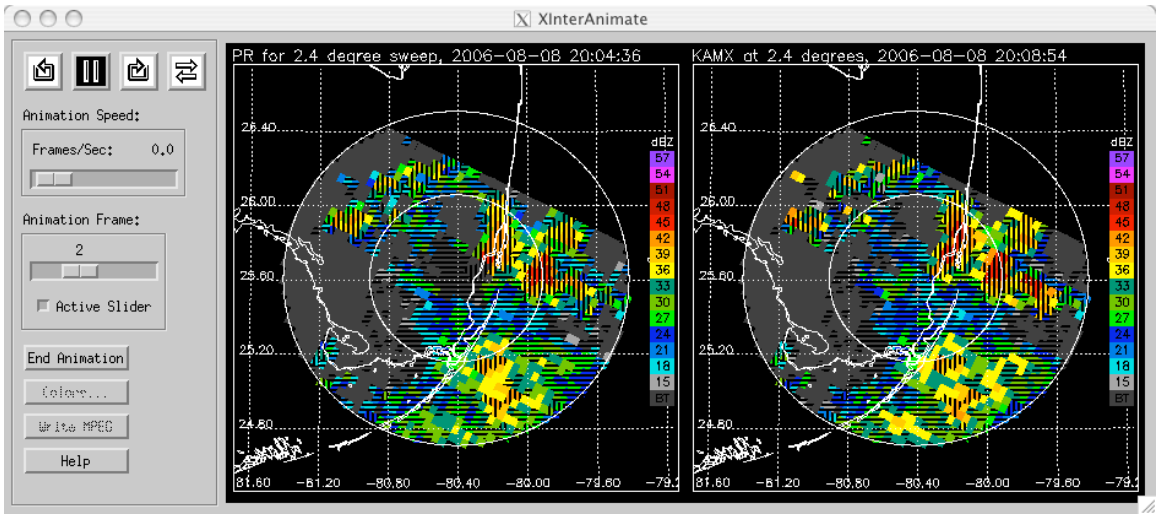


Figure 2. The PPI animation window of the statistical analysis tool, showing one frame of the animation. Case shown is with all display parameters using their default values.

If run as above with no other keyword parameters specified, the keyword parameters will take on their default values as described in the SYNOPSIS section, above. The procedure will produce diagnostic and statistical output in the terminal window from which IDL is run, or in the console window of IDLDE. Shown below in Exhibit 1 is the IDL output for the default case where no parameters other than NCPATH are specified, for the case shown in Fig. 2.

Figure 3 shows the on-screen output window containing the vertical profiles and histograms of PR and GV reflectivity. Separate profiles and histograms are shown for data points having rain types of convective, stratiform, and Any rain type (labeled All or Any/All), for both the PR and GV radars. By default, the Total rain type profiles and histograms are included in the plots. These may be excluded from the plots for clarity by setting the HIDE_TOTALS binary keyword parameter to "ON". Also, the width of the bins in which the reflectivity histograms are totaled is set to 2 dBZ by default. This value may be adjusted by specifying a different value for the HISTO_WIDTH keyword

parameter. A value of 1 results in the most detail in the histogram plots, but can be very noisy and jagged. A smoother plot results from raising the value of HISTO_WIDTH. By default, and for all output to the screen, the PR profiles and histograms are shown in red and the GV in green. For Postscript output only, black-and-white vertical profile and histogram plots result if the B_W binary keyword parameter is set to "ON".

The PCT_ABV_THRESH keyword parameter permits the analyst to constrain the volume-match data included in the displays and calculations to only those samples where the specified percentage of original PR and GV bins in their respective volume averages had reflectivity values exceeding fixed cutoff thresholds: 18.0 dBZ for the PR, and 15.0 dBZ for the GV radar. Application of this data percentage threshold is an attempt to limit the comparisons to points where partial beam filling of the sample volumes is not an issue. Each matchup point is an average of the full-resolution radar bins within the 3-D volume defined by the geometric intersection of a PR ray and a GV elevation sweep. Each PR and GV matchup point carries a value indicating the number of full-resolution radar bins included in the volume average from a geometric standpoint (n_pr_expected for PR, n_gv_expected for GV), and another value that indicates the number of "rejected" bins (n_2a25_rejected for PR, n_gv_rejected for GV) within the 3-D volume whose reflectivity values are below the fixed thresholds. For a given PCT_ABV_THRESH parameter value, points where the following two criteria are met will be included:

100*(n_pr_expected - n_2a25_rejected) / n_pr_expected ≥ PCT_ABV_THRESH
100*(n_gv_expected - n_gv_rejected) / n_gv_expected ≥ PCT_ABV_THRESH

In the example output shown Exhibit 1, the PCT_ABV_THRESH parameter uses its default value of zero, indicating that all matchup points with a valid reflectivity value are being included in the plots and statistics calculations. The default value of zero includes all points with a valid reflectivity value, regardless of the percentage of bins that are above the cutoff thresholds. A value of 100 means to include only points where every PR and GV bin included in their respective volume averages are above the cutoff thresholds (i.e., n_2a25_rejected and n_gv_rejected values are both zero for the point).

Each matchup point has an associated Rain Type value taken from the PR 2A-23 product, but no GV-derived rain type is present in the matchup data files. An implied, GV-based rain type value may be derived based on GV reflectivity thresholds specified by the parameters GV_CONVECTIVE and GV_STRATIFORM. The default, if parameter values disabling GV_CONVECTIVE and GV_STRATIFORM are not specified, is to override the PR rain type value for any point where the GV-implied rain type (based on applying the GV_CONVECTIVE and/or GV_STRATIFORM reflectivity thresholds) differs from the PR-indicated rain type. Points whose rain type values are overridden are moved from the Convective or Stratiform category to the Any/All rain type category, also called Other. See the SYNOPSIS section for the rules describing how the overrides are applied and/or disabled. A summary of the GV rain type reflectivity thresholds, and the number and type of points whose PR-indicated rain type values were overridden is included in the diagnostic output of the procedure, as shown in Exhibit 1.

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, ncpath='/Users/Chuck/data/netcdf/geo_match'
Defaulting to 7 for the number of PPI levels to plot, starting with the first.
Defaulting to * for file pattern.
Defaulting to 375 for PPI size.
Defaulting to 2.0 (dBZ) for PDF Histogram bins.
Defaulting to 0 for PERCENT BINS ABOVE THRESHOLD.
Defaulting to 35.0 dBZ for GV Convective floor threshold.
Defaulting to 25.0 dBZ for GV Stratiform ceiling threshold.
Defaulting to screen output for scatter plot.
tEmP_FiLe.GRtoPR.KAMX.060808.49749.nc

No. of footprints switched from Convective to Other = 5, based on Stratiform dBZ threshold = 25.0
No. of footprints switched from Stratiform to Other = 174, based on Convective dBZ threshold = 35.0
Mean BB (km), bblo, bbhi =       5.16300      4.50000      6.00000
Using histogram bin size =       2.00000

PR-GV Reflectivity difference statistics (dBZ) - GV Site: KAMX   Orbit: 49749
PR time = 2006-08-08 20:04:36   GV start time = 2006-08-08 20:06:46
Required percent of above-threshold PR and GV bins in matched volumes >= 0%


Statistics grouped by fixed height levels (km):

 Vert. |   Any Rain Type  |    Stratiform    |    Convective     |     Dataset Statistics      |     |
 Layer |  PR-GV    NumPts |  PR-GV    NumPts |  PR-GV    NumPts  | AvgDist   PR MaxZ   GV MaxZ | BB? |
 ----- | -------   ------ | -------   ------ | -------   ------  | -------   -------   ------- | --- |
  1.5      0.653     945      1.272     566     -0.378     219      43.520    49.020    50.601
  3.0      0.381    1097      1.086     609     -0.450     243      56.899    50.723    50.301
  4.5     -0.494     788     -0.113     409     -0.295     184      62.039    50.969    49.498  @ BB
  6.0      0.370     557      0.019     282      1.661     115      67.048    43.187    49.165  @ BB
  7.5      0.774     334      0.874     171      0.516      50      69.244    39.232    42.555
  9.0      2.377     116      2.927      57      1.221      23      59.670    34.897    30.068
 10.5      4.520      27      4.666      12      4.010      12      60.862    26.518    27.834
 12.0      6.158       4      6.764       2      5.500       2      49.941    19.764    17.080
No above-threshold points at height 13.500
No above-threshold points at height 15.000
No points at height 16.500
No points at height 18.000
No points at height 19.500
% LOADCT: Loading table GRN-RED-BLU-WHT


Statistics grouped by proximity to Bright Band:

Proxim.|   Any Rain Type  |    Stratiform    |    Convective     |     Dataset Statistics      |     |
 to BB |  PR-GV    NumPts |  PR-GV    NumPts |  PR-GV    NumPts  | AvgDist   PR MaxZ   GV MaxZ | BB? |
 ----- | -------   ------ | -------   ------ | -------   ------  | -------   -------   ------- | --- |
 Below     0.705    2785      1.415    1593     -0.629     618      52.162    50.969    50.601
Within    -0.103    1093     -0.024     552      0.466     247      67.454    49.436    49.165  @ BB
 Above     1.119     638      1.237     330      1.328     114      63.680    41.779    42.555
% LOADCT: Loading table Blue-Red

Click END ANIMATION button or close Animation window to proceed to next case:
```

Exhibit 1. Output diagnostics and statistics from the geo_match_z_pdf_profile_ppi_bb_prox_sca_ps procedure, sent to the terminal or IDLDE console. Statistics are for the case shown in Fig. 2, using default program parameters.

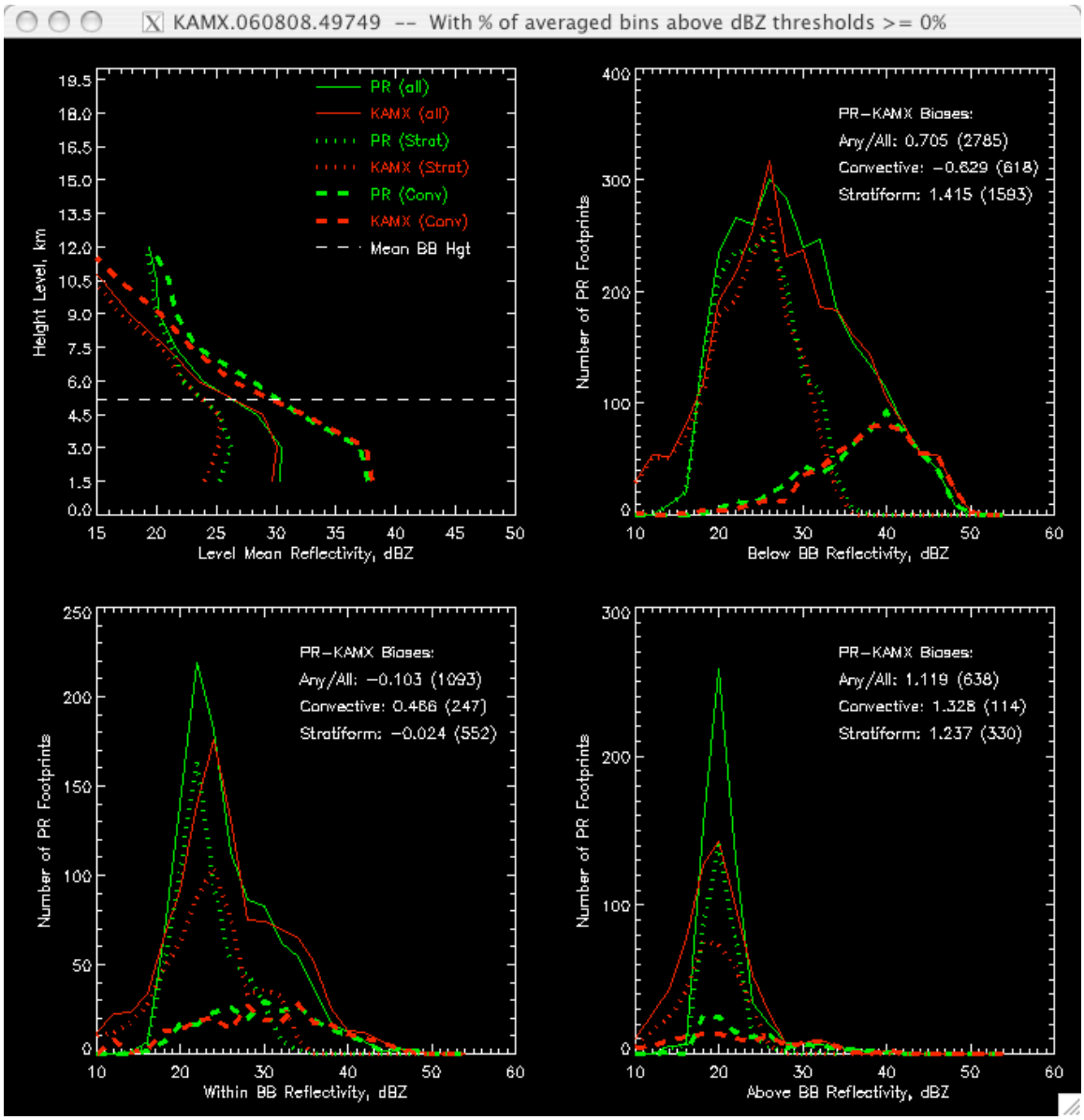


Figure 3. Vertical profiles and histograms of PR (in red) and GV (in green) reflectivity, for Convective (heavy dashed), Stratiform (dotted) and Any (solid) rain type, for the same case shown in Fig. 2, with all statistical parameters using default values.

Figure 4 shows scatter plots of PR vs. GV reflectivity for all combinations of the three bright band proximity levels (above, within, below) and the two rain types (stratiform and convective), for same case as shown in Figs. 2 and 3, and using the parameter defaults.

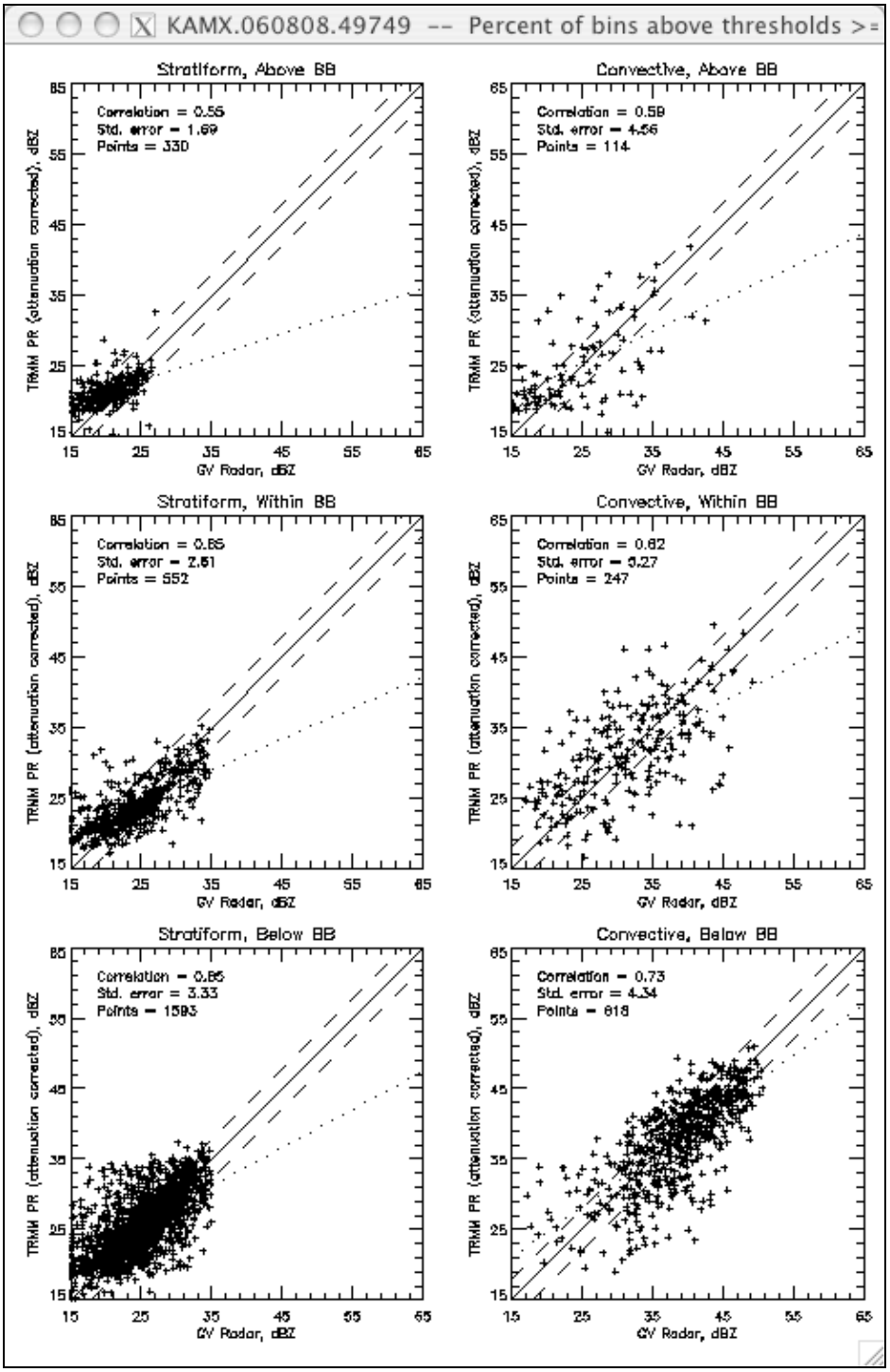


Figure 4. Scatter plots of PR vs. GV reflectivity using default parameters, for the same case as in Figs. 2 and 3. Solid line is PR=GV; dashed lines are for PR +/- 3 dBZ from GV; dotted line is the linear fit to the data.

OPTIONAL KEYWORDS

Two types of IDL keyword parameters are used in the procedure. The regular keyword parameters take specific numerical or text string values as the parameter value, in the format KEYWORD=value, and are listed on the command line following the name of the procedure, each separated by a comma. For those regular keywords whose values are strings, the string value must be enclosed in quotes, e.g., NCPATH='/data/netcdf/geo_match'. For those regular keywords whose values are numbers, the keyword values do not need to be in quotes, e.g., ELEVS2SHOW=6.3.

Binary keywords may be specified on the command line in either the KEYWORD=value format, or in the "slash" format: /KEYWORD. In the KEYWORD=value format, the option is turned "On" be specifying a numerical value of 1 (one) for the value (e.g., B_W=1), and "Off" by specifying a value of 0 (zero) for the value (e.g., B_W=0). Specifying the keyword name preceded by a slash (/) is equivalent to specifying a value of 1 to turn the option "On". For example, B_W=1 and /B_W are equivalent. If a binary keyword is not specified on the command line, it is "Off" by default.

File Selection Options

Selection of matchup netCDF files is controlled by the NCPATH, SITE, and NO_PROMPT keywords. NCPATH is used to specify a directory path to the matchup netCDF files to be processed. The SITE keyword takes part of a regular expression specifying a full or partial file name as its value, with a leading and trailing '*' being added to the value by default. All files in the NCPATH directory whose file names match the regular expression specified for SITE will be shown in the File Selector (Fig. 1). For example, if SITE='KTLH.0809' is specified as a parameter, then **KTLH.0809** will appear in the Filter field in the File Selector, and only/all those files for the KTLH radar in September, 2009 will be listed.

If the user wishes to process a large number of files at one time, then selecting files one at a time with the File Selector can be cumbersome. In this case, if the binary keyword NO_PROMPT is set, the File Selector will be bypassed and the set of files pointed to by NCPATH and SITE will be processed sequentially, in alphabetical order. As each new file is processed, the animation window will be displayed and the other graphical and textual output will be created for the file. The procedure will automatically open and process the next file when the user closes the animation window for the current file. In this automated mode, the program will ask the user after every 10^{th} file whether to continue automatically processing the list, in case there are a very large number of files specified by SITE. The user can then either Quit, Continue with the next 10 files, or Continue processing all the remaining files without asking again.

PPI Animation Options

The PPI animation loop is affected by the keywords SPEED, ELEVS2SHOW, PPI_VERTICAL, PPI_SIZE, SHOW_THRESH_PPI, and (if SHOW_THRESH_PPI is

set) PCT_ABV_THRESH. SPEED, ELEVS2SHOW, and PPI_SIZE are described in the SYNOPSIS section, and their effects cannot be shown here. Figure 5 shows the effect of setting the binary keyword PPI_VERTICAL to On, where the PR PPI is then plotted above the GV PPI in the animation window, rather than to the left of the GP PPI by default (Fig. 2).

If SHOW_THRESH_PPI is set to on, then a second set of PR and GV PPIs will be plotted in the image frames in the animation window. The second set of PPIs, plotted below the original PPIs, will show only those matchup points where the criteria defined by the value of PCT_ABV_THRESH are met. Figure 6 shows the animation window contents if the example shown in Fig. 2 is re-run with the IDL options set as follows:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', $
PCT_ABV_THRESH=95, /SHOW_THRESH_PPI
```

Note that if SHOW_THRESH_PPI is set to on, then the PPI_VERTICAL parameter has no effect on the output, and is Off by default (PR and GV PPIs are arranged side-by-side).

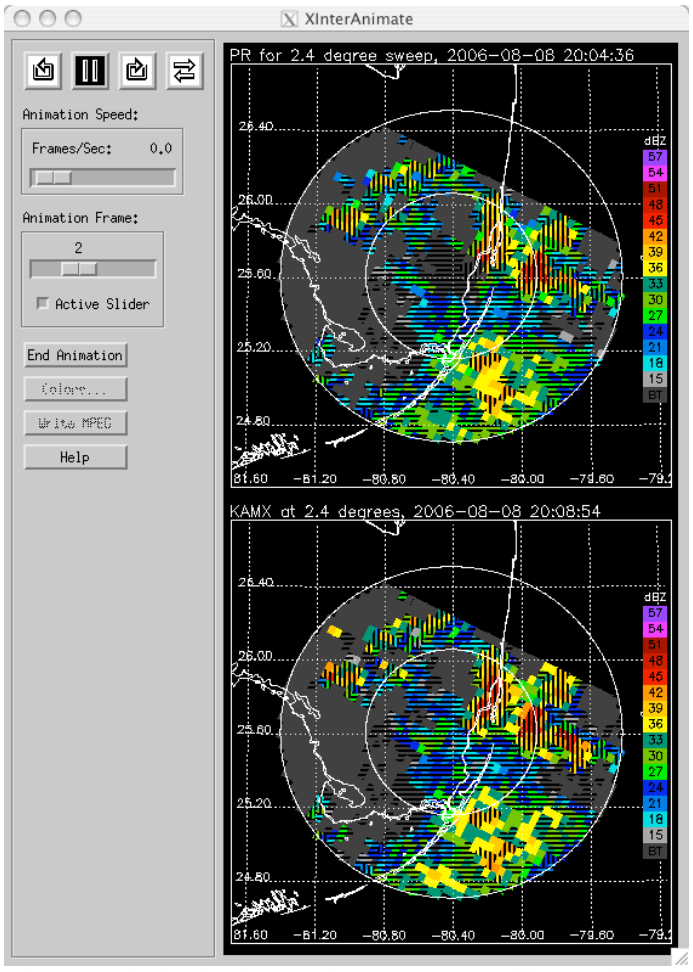


Figure 5. As in Fig. 2, but with PPI_VERTICAL option set.

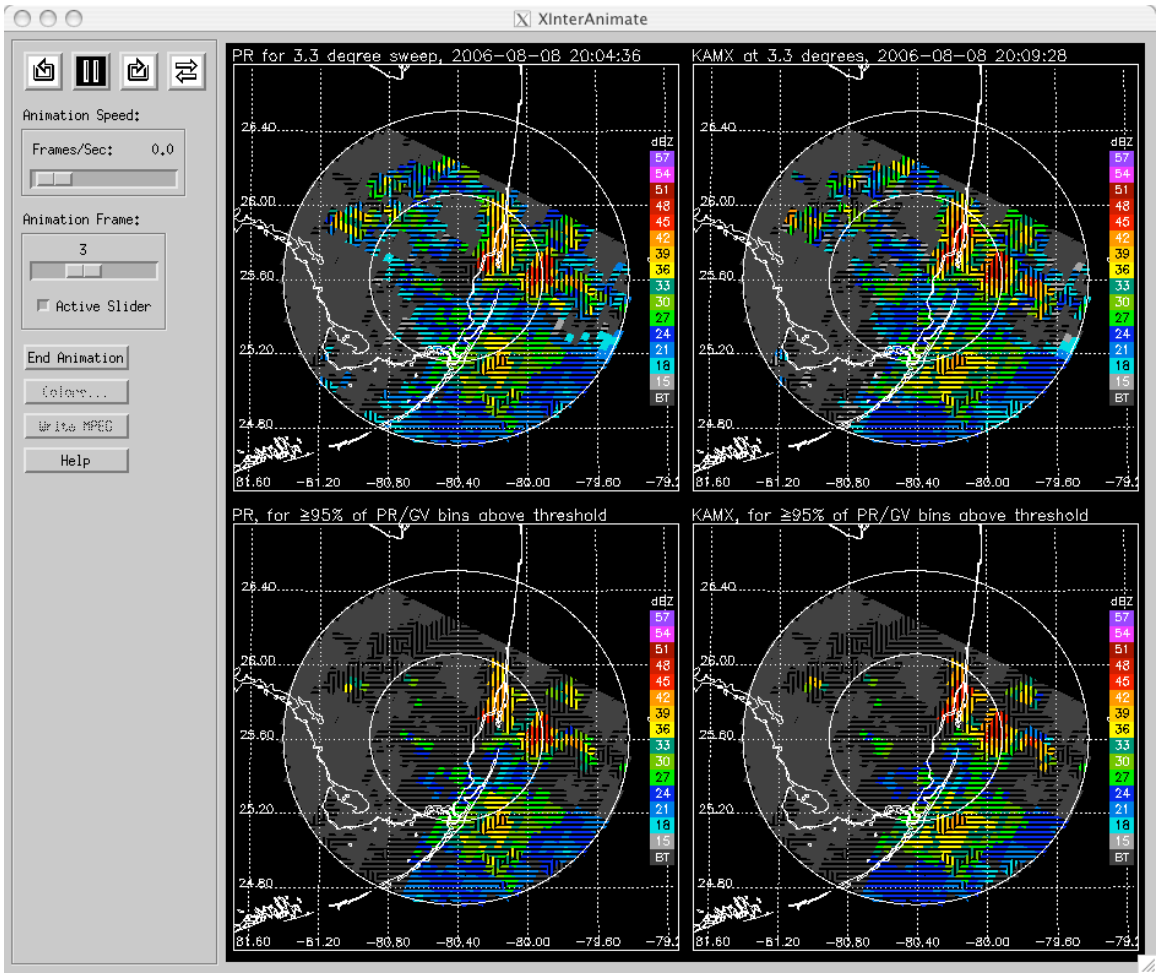


Figure 6. As in Fig. 2, but with the options PCT_ABV_THRESH=95 and /SHOW_THRESH_PPI set. The upper PPIs show all matchup points. The lower PPIs gray out those points not meetiing the restriction of having at least 95% of the bins in the sample averages above fixed dBZ thresholds.

Histogram/Profile Options

The HISTO_WIDTH and HIDE_TOTALS keyword parameters affect the plotting of the vertical profile and histogram graphics. Their effects on the plots have already been described above. Figure 7 shows an example of the vertical profile and histogram plots for the same case as Fig. 3, but with the HIDE_TOTALS binary keyword set, and with HISTO_WIDTH set to 1. These parameters have no effect on computation of the statistics shown on the graphics or in the tabular output. Options for Fig. 7 are:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', $
HISTO_WIDTH=1, /HIDE_TOTALS
```

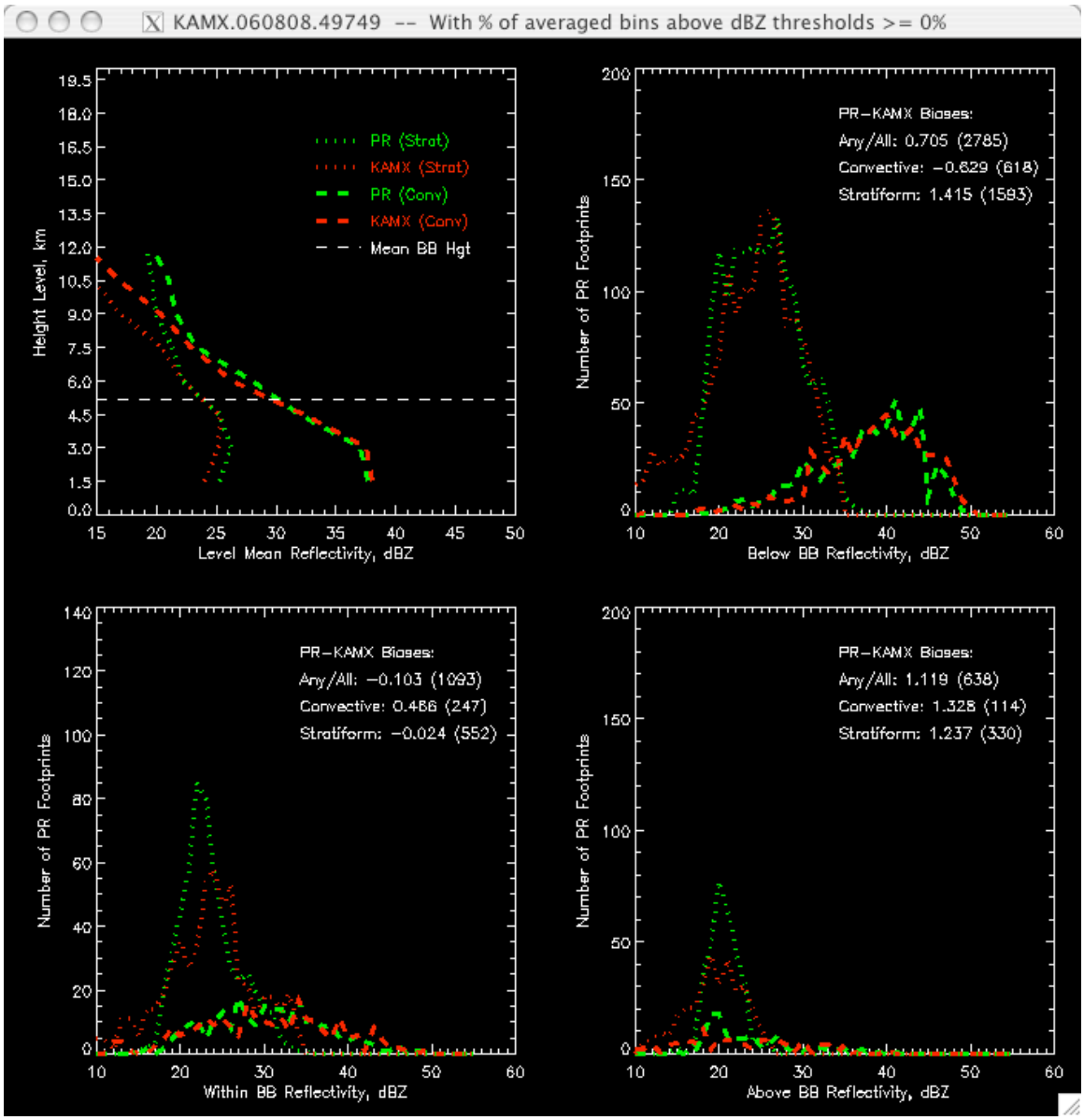


Figure 7. As in Figure 3, but with non-default options /HIDE_TOTALS and HISTO_WIDTH=1. Note the solid-line plots for Any/All rain type are hidden, and the histograms are less smooth.

Statistical/Computational Options

The PCT_ABV_THRESH, GV_CONVECTIVE, GV_STRATIFORM, and S2KU keyword parameters affect the output statistics and displayed graphics. The effect of the PCT_ABV_THRESH, GV_CONVECTIVE, and GV_STRATIFORM parameters have already be described above. These parameters serve to filter the data points being included in the statistical computations and data displays, for the points as a whole (PCT_ABV_THRESH) or for the points in each rain type category (GV_CONVECTIVE and GV_STRATIFORM). Figure 8 shows an example of the vertical profile and histogram plots for the same case as Fig. 3, but with PCT_ABV_THRESH=95. Figure 9 uses the same PCT_ABV_THRESH option as Fig. 8, but with both GV_CONVECTIVE and GV_STRATIFORM set to zero (no rain type adjustments, use PR rain types as-is).

Options for Fig. 8 are:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', $
PCT_ABV_THRESH=95
```

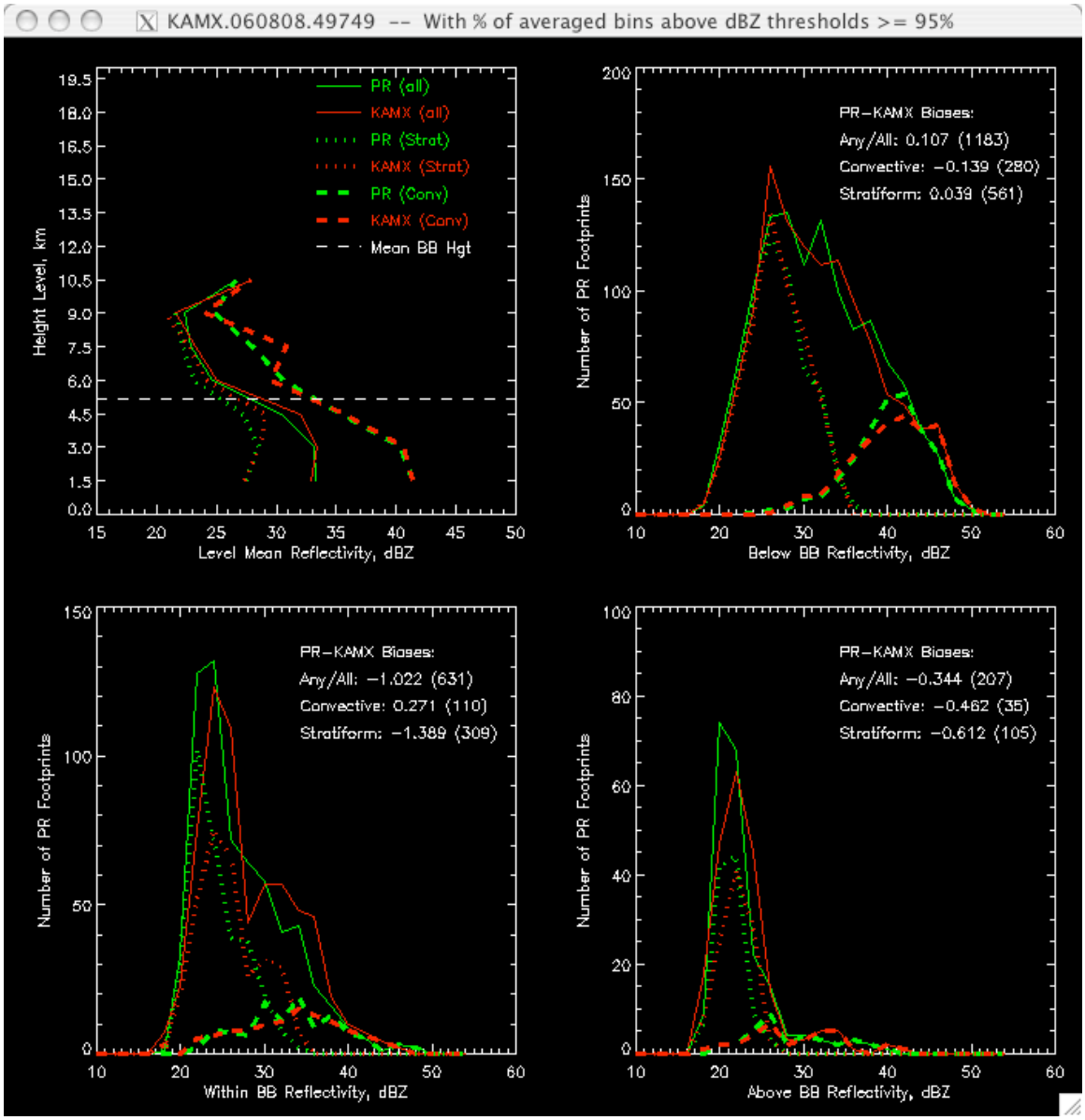


Figure 8. As in Fig. 3, but with non-default option PCT_ABV_THRESH=95 used. Note the fewer number of points in each category and improvement in mean difference statistics above and below the bright band as compared to Fig. 3, due to the filtering of "incomplete volume average" points.

Options for Fig. 9 are:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', $
PCT_ABV_THRESH=95, GV_CONVECTIVE=0, GV_STRATIFORM=0
```

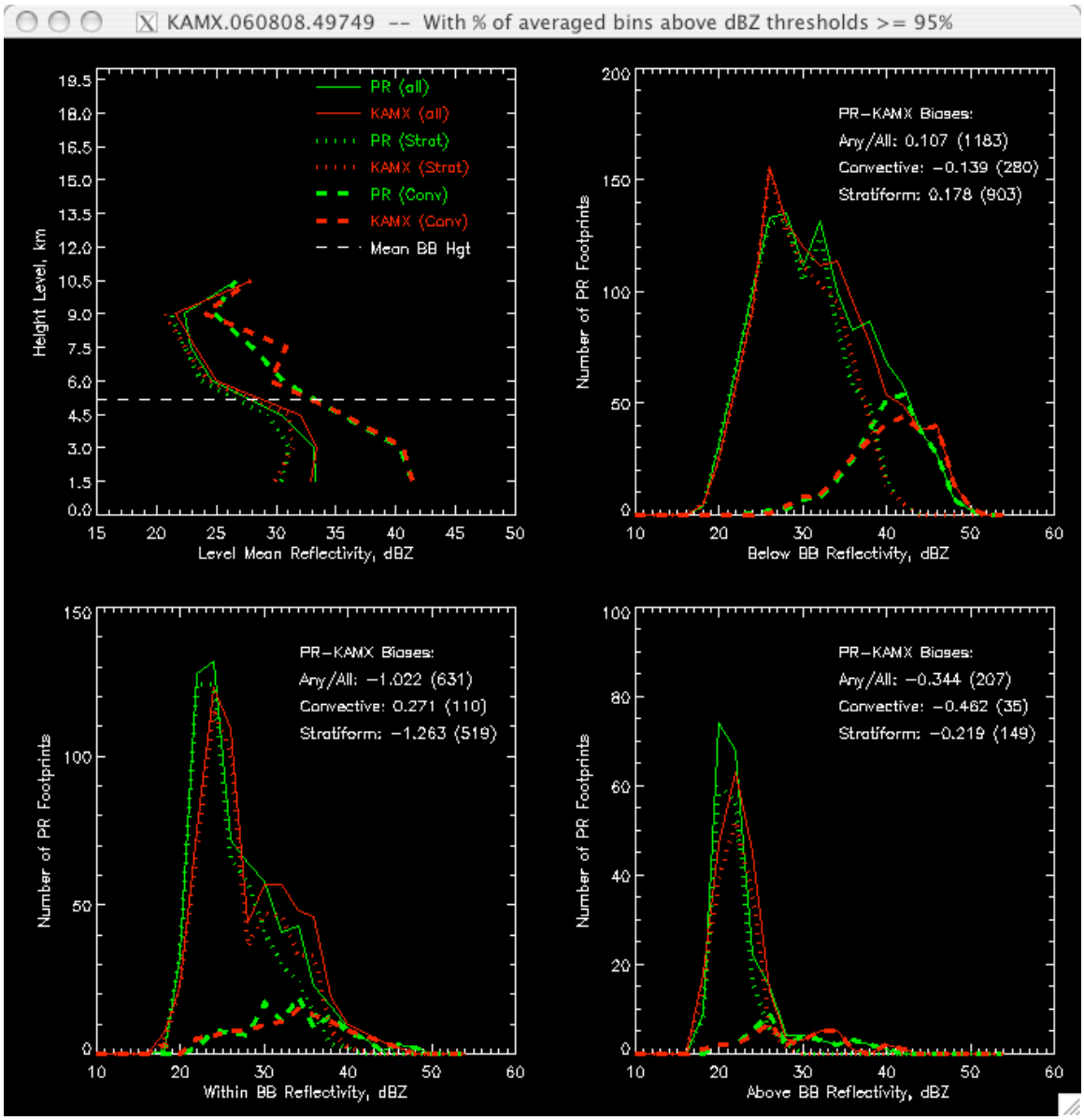


Figure 9. As in Fig. 8, but with GV_STRATIFORM and GV_CONVECTIVE parameters both set to zero, leaving PR rain type assignments unchanged. Note that there are more points in the Stratiform rain type category as a result, when compared to Fig. 8.

The S2KU binary keyword controls whether the Liao and Menghini (2009) S-band to Ku-band frequency adjustments are applied to the GV reflectivity prior to computation of the mean difference statistics and generation of the graphical plots. The adjustments account for the differences in reflectivity factor that occur when the same rain or snow targets are observed by S- and Ku-band radars. The snow correction is applied to data above the bright band, and the rain correction is applied to the data samples below the bright band. Figure 10 shows the same case as in Fig. 9, but with the /S2KU keyword parameter set. Options for Fig. 10 are:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', $
PCT_ABV_THRESH=95, GV_CONVECTIVE=0, GV_STRATIFORM=0, /S2KU
```

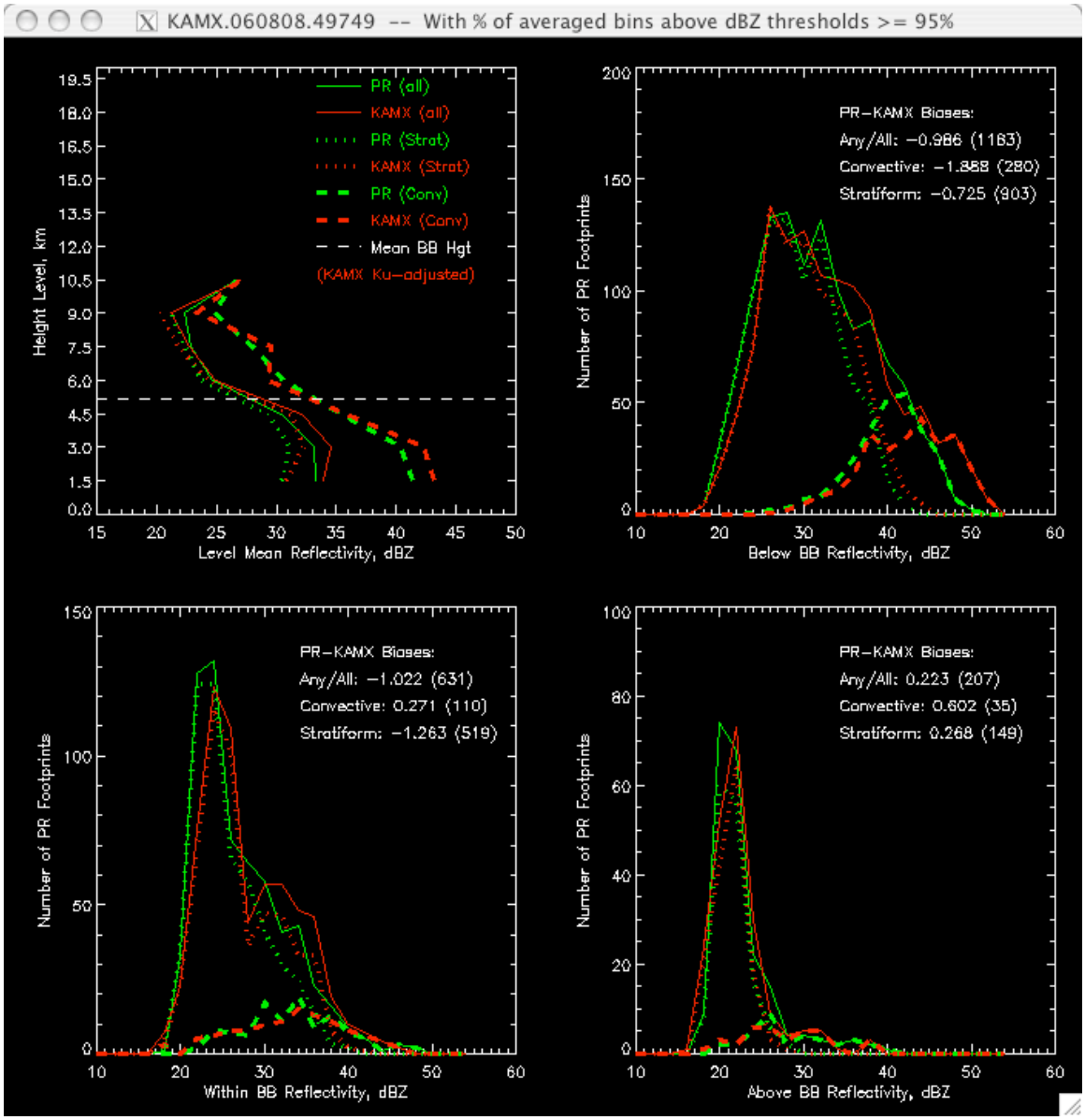


Figure 10. As in Fig. 9, but with the /S2KU keyword set to apply the S-to-Ku frequency adjustment to GV reflectivity above (snow) and below (rain) the bright band. No adjustments are made to points within the bright band.

Postscript/Adobe PDF Option

If the PS_DIR keyword is specified, then output from the procedure will be sent to a Postscript file whose name is derived from the matchup netCDF file. Depending on the presence of the unix/Linux utility 'ps2pdf', the Postscript output file may be converted to the Adobe Portable Document Format (PDF) file format.

NOTE: Output to a Postscript or PDF file is only available when running the procedure with a licensed copy of IDL.

The Postscript output option is activated by specification of a non-null value for the PS_DIR keyword parameter. The value of PS_DIR must point to an existing directory with write privileges.

For example, if the parameter specification PS_DIR='/tmp' is given within the command line invocation of the procedure, e.g.:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', PS_DIR='/tmp'
```

and the file GRtoPR.KAMX.060808.49749.nc.gz is selected for display, then the Postscript file **`/tmp/GRtoPR.KAMX.060808.49749Pct0_PDF_SCATR.ps`** will be created. The 'Pct0' portion of the name reflects the value of the PCT_ABV_THRESH parameter used in the run of the procedure, and is always included in the file name. The status of the S2KU parameter value is also reflected in the output file name. If the S2KU parameter is set to On, then the GV reflectivity values will have the S-to-Ku frequency adjustment applied for the statistical calculations, and the output filename will indicate this by insertion of the string '`_s2Ku_`' in the file name. Otherwise, if S2KU is unset, no indication will be present in the file name. For example, if the procedure is invoked as:

```
IDL> geo_match_z_pdf_profile_ppi_bb_prox_sca_ps, $
NCPATH='/Users/Chuck/data/netcdf/geo_match', PS_DIR='/tmp', $
PCT_ABV_THRESH=95, /S2KU
```

and the file GRtoPR.KAMX.060808.49749.nc.gz is selected for display, then the Postscript file **`/tmp/GRtoPR.KAMX.060808.49749Pct95_S2Ku_PDF_SCATR.ps`** will be created.

If the unix/linux utility 'ps2pdf' is present on the system, then the Postscript file will be converted to an Adobe Portable Document Format (PDF) file by default, and the '.ps' file extension will be replaced by '.pdf'. In the preceding example, the output file name **`/tmp/GRtoPR.KAMX.060808.49749Pct95_S2Ku_PDF_SCATR.pdf`** instead would be created.

When running with the Postscript option activated, the PPI animation window (e.g., Fig. 2) will still be created, and the statistical and diagnostic output (Exhibit 1) will still be sent to the terminal or IDLDE Console. The Postscript/PDF file will contain all the graphical and statistical output from the procedure on multiple pages, in the following order:

Page 1: vertical profile and histogram plots, as in Fig. 3

Page 2: mean difference tables by height and by bright band proximity, as in Exhibit 1
Page 3: scatter plots, as shown in Fig. 4.
Pages 4…n: images as within each individual frame of the PPI animation loop, one frame per page. The exact list of images to be included in the loop and output to the file are controlled by the ELEVS2SHOW parameter.

If the B_W binary keyword parameter is specified in the parameters and set to On (i.e., B_W=1 or /B_W), then the vertical profile and histograms plots will be drawn in black-and-white for Postscript/PDF output. The B_W parameter does not affect the on-screen display of the vertical profiles and histograms, nor does it affect the PPI images, which are always output in color.

An example of the procedure's complete set of output to a Postscript/PDF file is included as an appendix.

Running The Procedure Under The IDL Virtual Machine

The preceding instructions apply if the analyst has access to a machine with a licensed copy of IDL, or if running IDL in the 'demo' mode where each session is limited to 7 minutes. This can be very inconvenient if analyzing a large number of cases in a session, or if a large number of options need to be specified on the command line and edited between runs. As an alternative to these IDL run modes, a "wrapped" version of the procedure may be executed using the freely available IDL Virtual Machine, with or without an IDL license. The IDL Virtual Machine does not limit the length of a session, but has restrictions on the type of functions that are available. The major limitation for the statistical analysis procedures is that Postscript or other file output is not allowed.

The wrapped version of the statistical analysis procedure is in the precompiled IDL 'save' file: **wrapf_geo_m_z_pdf_profi_bbprox_sca_ps.sav**. The IDL Virtual Machine option has no mechanism of specifying parameters when invoking a procedure, so the wrapped version reads a plain-text control file with the keyword parameters entered on separate lines in a specific format. By convention, the name of the control file should end with the file extension '.ctl' (e.g., 'StatDisplayParamsKMOB.ctl'). Any number of control files may be created and saved under different names. A sample file of the required format, which includes all allowable keyword parameters for the on-screen output mode, is shown below:

```
ELEVS2SHOW=4.2
NCPATH=/Users/Chuck/data/netcdf/geo_match
SITE=KMOB
NO_PROMPT=0
PPI_VERTICAL=0
PPI_SIZE=375
PCT_ABV_THRESH=95
SHOW_THRESH_PPI=1
GV_CONVECTIVE=0
GV_STRATIFORM=0
HISTO_WIDTH=2
HIDE_TOTALS=1
S2KU=0
```

Note that there are no spaces between the keyword (on the left side of the equals sign) and its assigned value (on the right of the equals sign) in the control file, and there are no quote marks allowed, or needed, around the string-valued parameters such as the value for NCPATH. This is in contrast to specifying these parameter values on the command line in the regular versions of IDL, where the keyword values for string-type variables must be placed within single or double quotes. The keyword parameters may be listed in any order in the control file. As usual, if any of the keyword parameters is not present in the control file, the parameter will take on its default value (see SYNOPSIS section, above). **The "slash" form of the binary keyword parameters (e.g., /S2KU) is not allowed in the control file.** Assign a value of 0 to unset the binary keyword parameter (e.g., S2KU=0), or simply delete the line for binary keyword parameter from the control file. Assign a value of 1 to set the parameter to the "On" state (e.g., S2KU=1).

The PS_DIR and B_W parameters have been left out of the control file example, as Postscript output is not supported when running with an unlicensed copy of IDL. However, if running the procedure under the IDL Virtual Machine with a license, then PS_DIR and B_W may be defined and included in the control file, and will take effect.

To run the wrapper file, place it and the control file in a directory of your choice (preferably the current working directory) and start IDL in the Virtual Machine mode, using the procedures that apply to the host machine operating system. When IDL starts in the Virtual Machine mode, a file selector (Fig. 11) will appear and the analyst will be prompted to select an IDL save file. If the wrapper file '**wrapf_geo_m_z_pdf_profi_bbprox_sca_ps.sav**' does not appear, then edit either the Directory field or the Filter field as needed and click 'Filter', until the save file appears in the select list. Select the proper save file name and click OK to start the statistical analysis wrapper program.

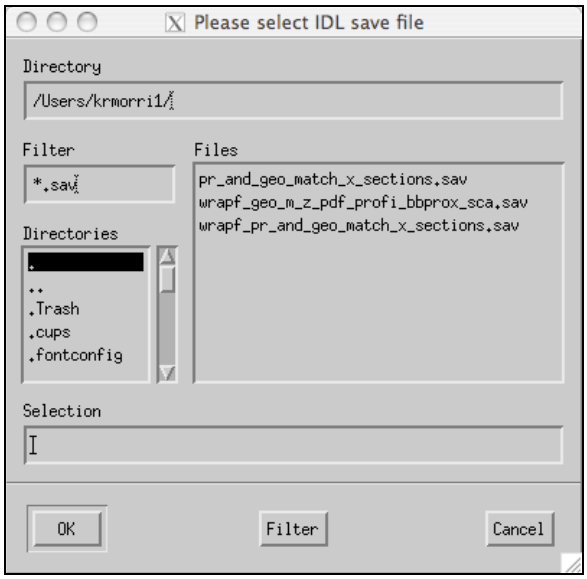


Figure 11. File selector for choosing as IDL 'save' file to be executed in IDL's Virtual Machine mode.

Once the wrapper program starts, the file selector (Fig. 12) will again appear and the analyst will be prompted to select the control file. Select the desired control file and click OK to start the statistical analysis program. From here on, the analyst can display and manipulate the data files as described in the preceding sections.

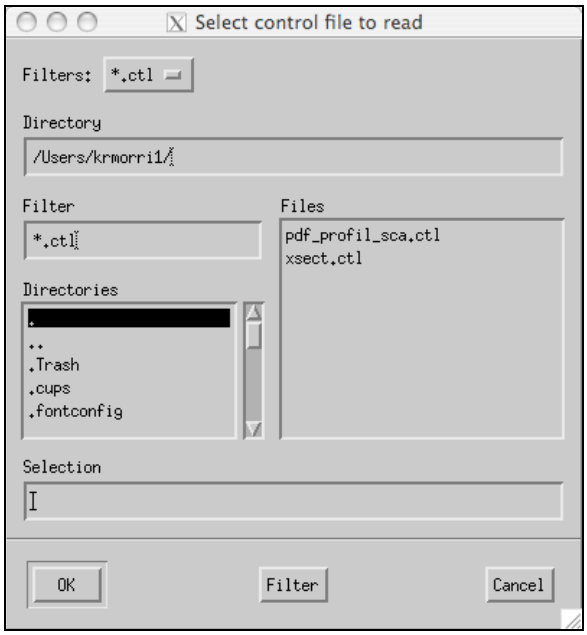


Figure 12. File selector to allow selection of the control file for a run of the statistical analysis wrapper program.

REFERENCE

Liao, L., and R. Meneghini, 2009: Changes in the TRMM Version-5 and Version-6 Precipitation Radar Products due to Orbit Boost. Journal of Meteorological Society of Japan. Complete citation to be added.

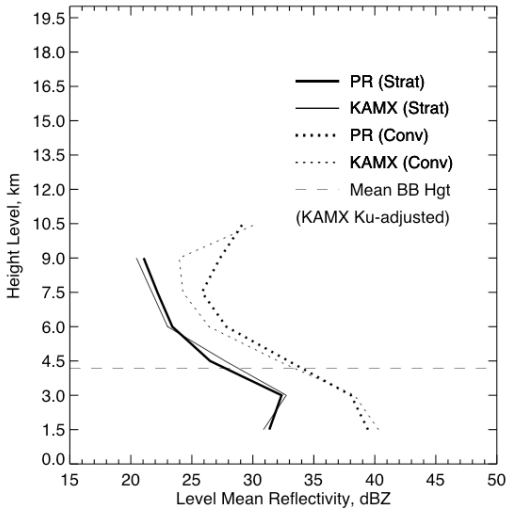
APPENDIX

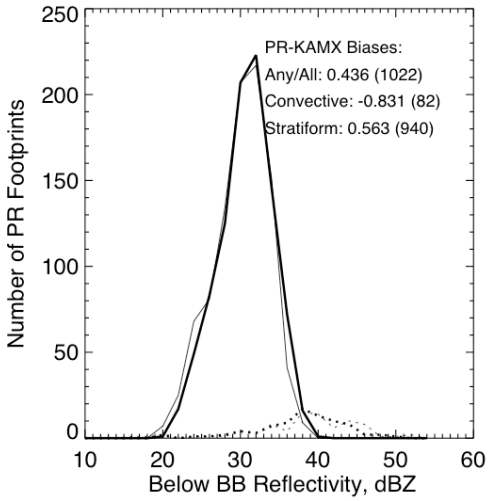
Sample Postscript/PDF file output.

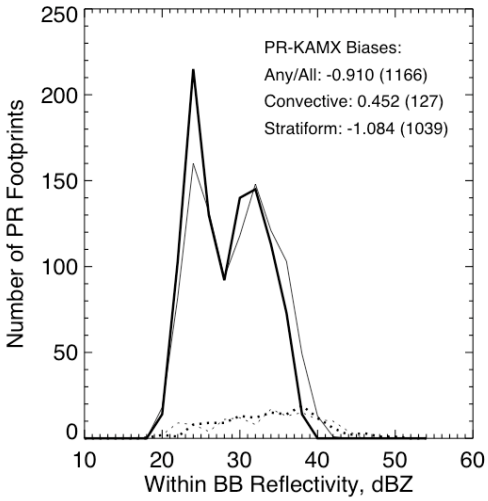
The following pages show a complete example of the procedure's multi-page output to a Postscript or PDF file. Each page below is a separate page in the Postscript or PDF file, appearing in file in the order shown. For brevity, only the first four elevation sweeps in the scan volume were specified for output in the PPI animation loop and Postscript/PDF file. Other options affecting the statistical results and appearance of this output include:

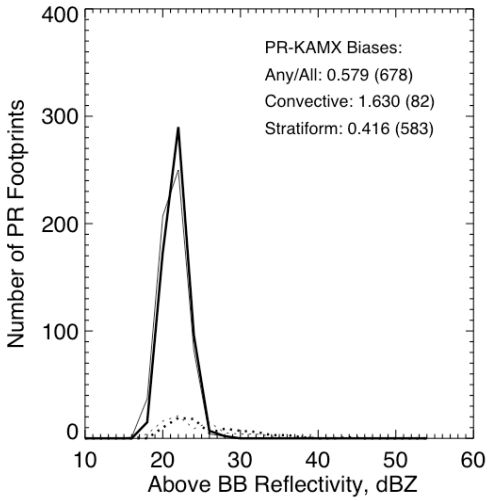
ELEVS2SHOW=4.1
PCT_ABV_THRESH=95
/SHOW_THRESH_PPI
GV_CONVECTIVE=0
GV_STRATIFORM=0
/HIDE_TOTALS
/B_W
/S2KU

See the document text for a description of these options and their affect on the output results.


PR (Strat)
KAMX (Strat)
PR (Conv)
KAMX (Conv)
Mean BB Hgt
(KAMX Ku-adjusted)
Height Level, km
Level Mean Reflectivity, dBZ


PR-KAMX Biases:
Any/All: 0.436 (1022)
Convective: -0.831 (82)
Stratiform: 0.563 (940)
Number of PR Footprints
Below BB Reflectivity, dBZ


PR-KAMX Biases:
Any/All: -0.910 (1166)
Convective: 0.452 (127)
Stratiform: -1.084 (1039)
Number of PR Footprints
Within BB Reflectivity, dBZ


PR-KAMX Biases:
Any/All: 0.579 (678)
Convective: 1.630 (82)
Stratiform: 0.416 (583)
Number of PR Footprints
Above BB Reflectivity, dBZ

PR-GV Reflectivity difference statistics (dBZ) - GV Site: KAMX Orbit: 53977
PR time = 2007-05-07 02:27:54 GV start time = 2007-05-07 02:27:42
Required percent of above-threshold PR and GV bins in matched volumes >= 95%
GV reflectivity has S-to-Ku frequency adjustments applied.

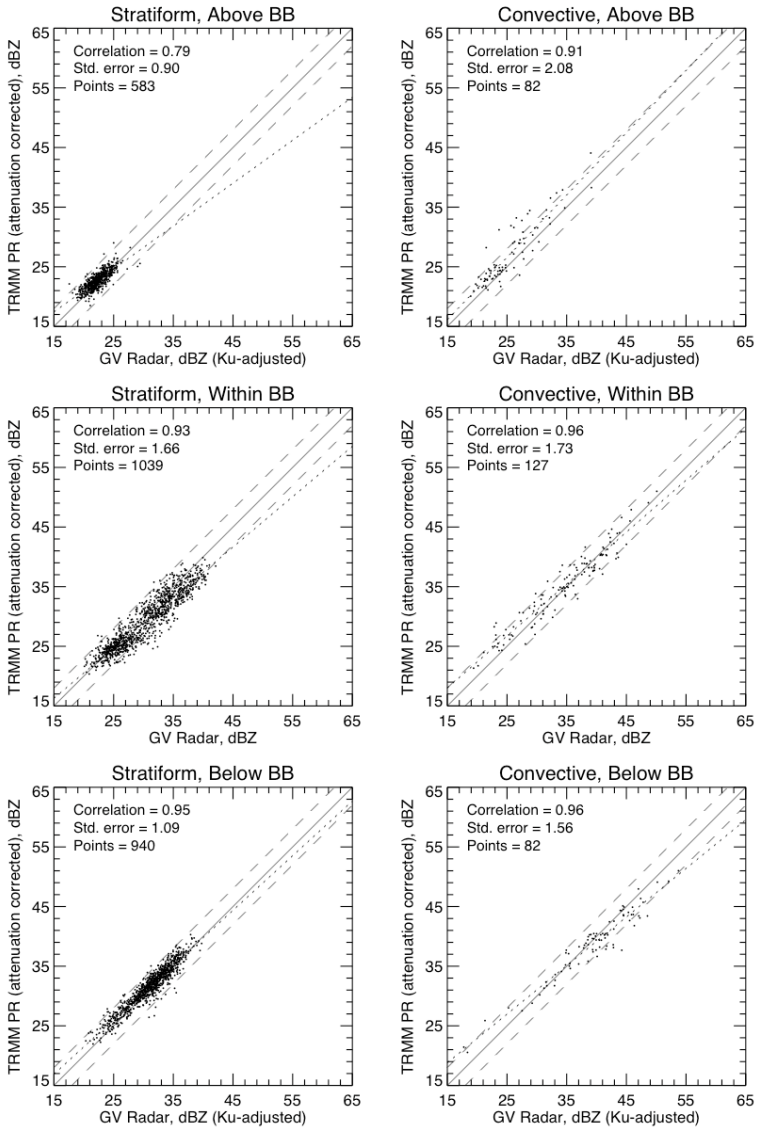
Statistics grouped by fixed height levels (km):

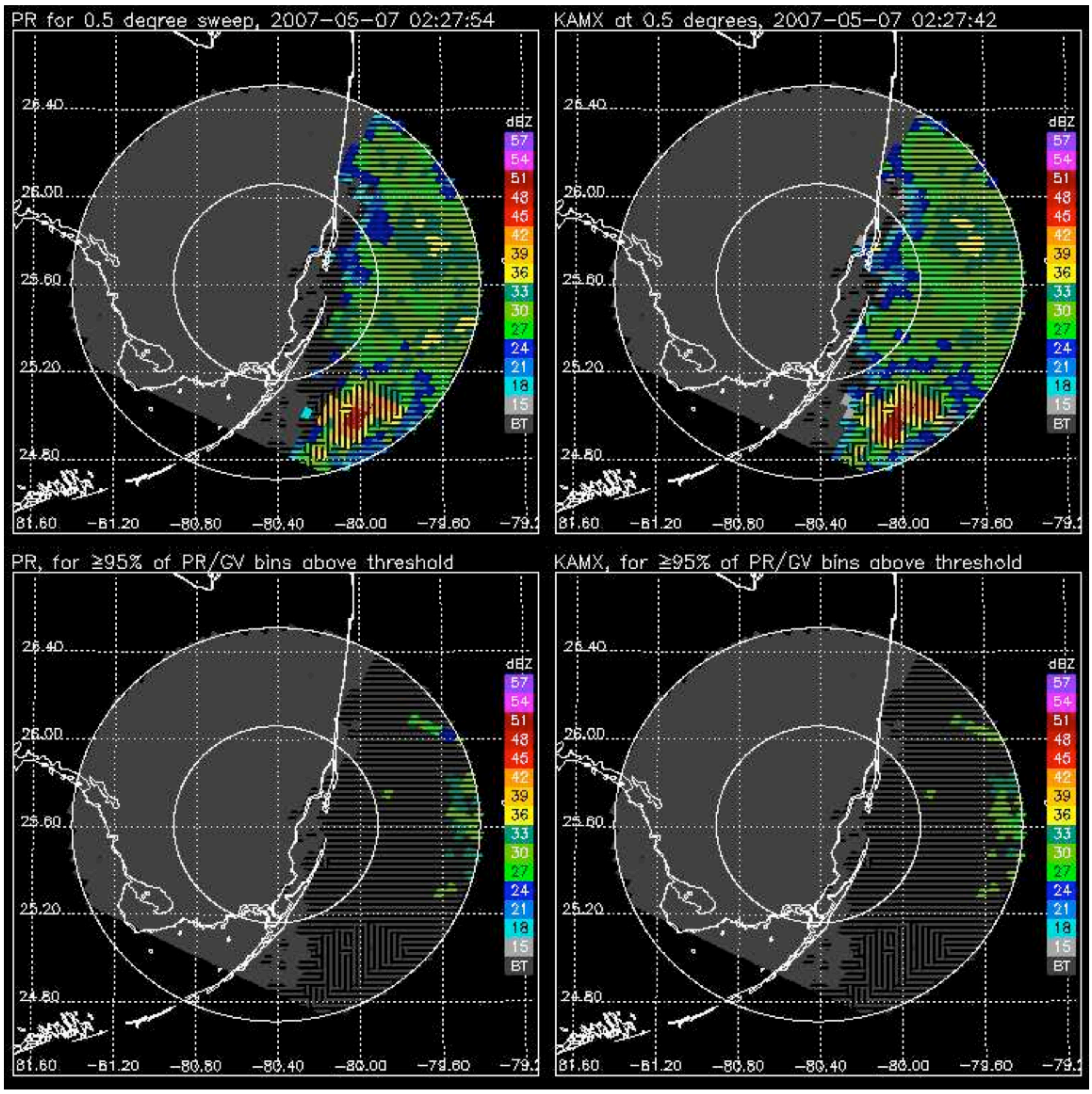
Vert.	Any Rain Type		Stratiform		Convective		Dataset Statistics			
Layer	PR-GV	NumPts	PR-GV	NumPts	PR-GV	NumPts	AvgDist	PR MaxZ	GV MaxZ	BB?
1.5	0.374	592	0.474	553	-0.857	39	68.195	49.252	52.082	
3.0	-0.373	929	-0.382	827	-0.305	102	75.341	51.010	53.724	
4.5	-0.974	577	-1.231	512	0.853	65	73.251	49.066	48.687	@ BB
6.0	0.514	418	0.384	367	1.418	48	70.366	44.073	39.145	
7.5	0.600	245	0.448	204	1.562	31	69.439	37.893	34.669	
9.0	1.242	24	0.595	19	3.351	5	72.437	31.891	30.119	
10.5	-1.154	1	-99.999	0	-1.154	1	84.637	29.181	30.334	

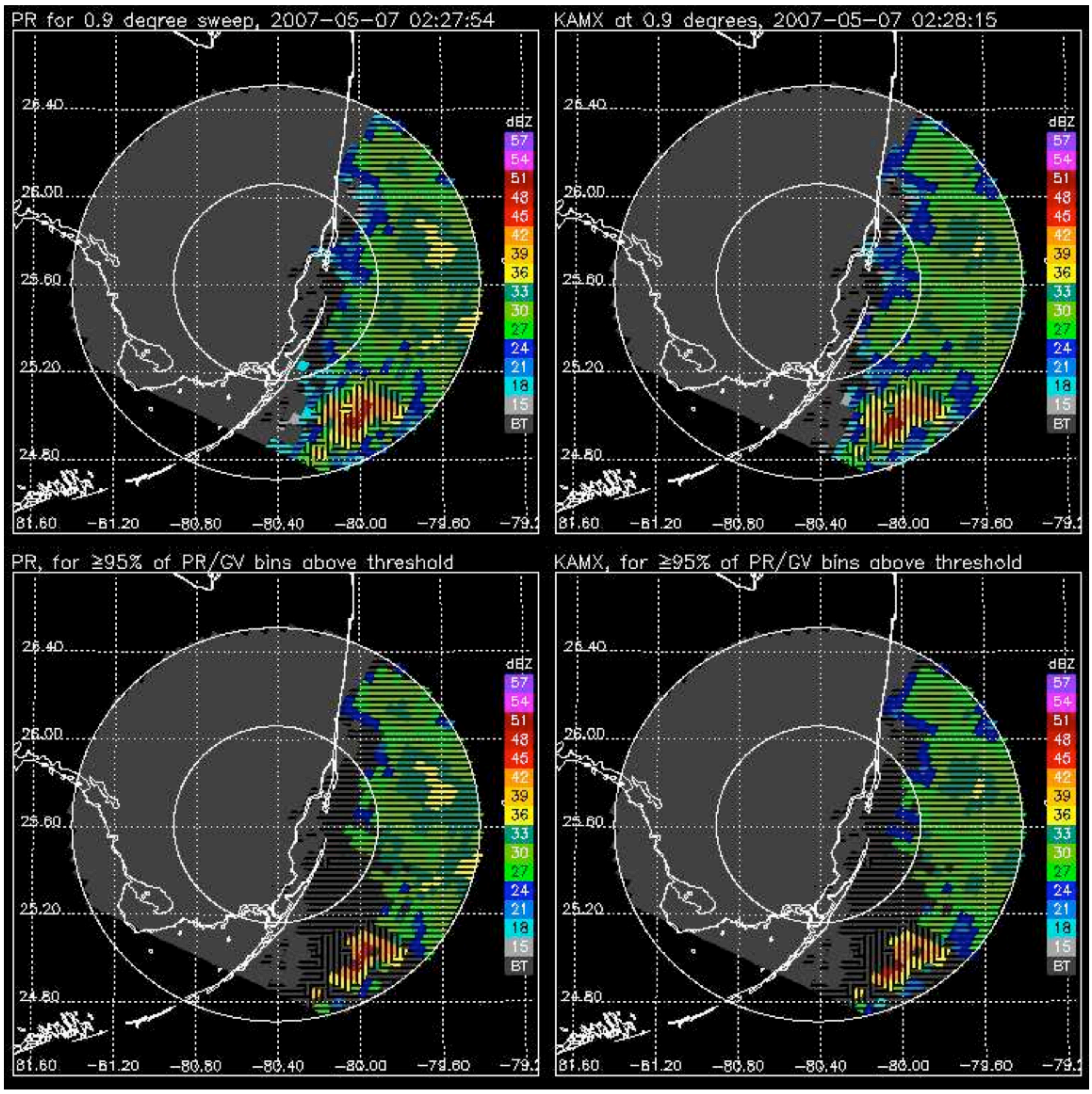
Statistics grouped by proximity to Bright Band:

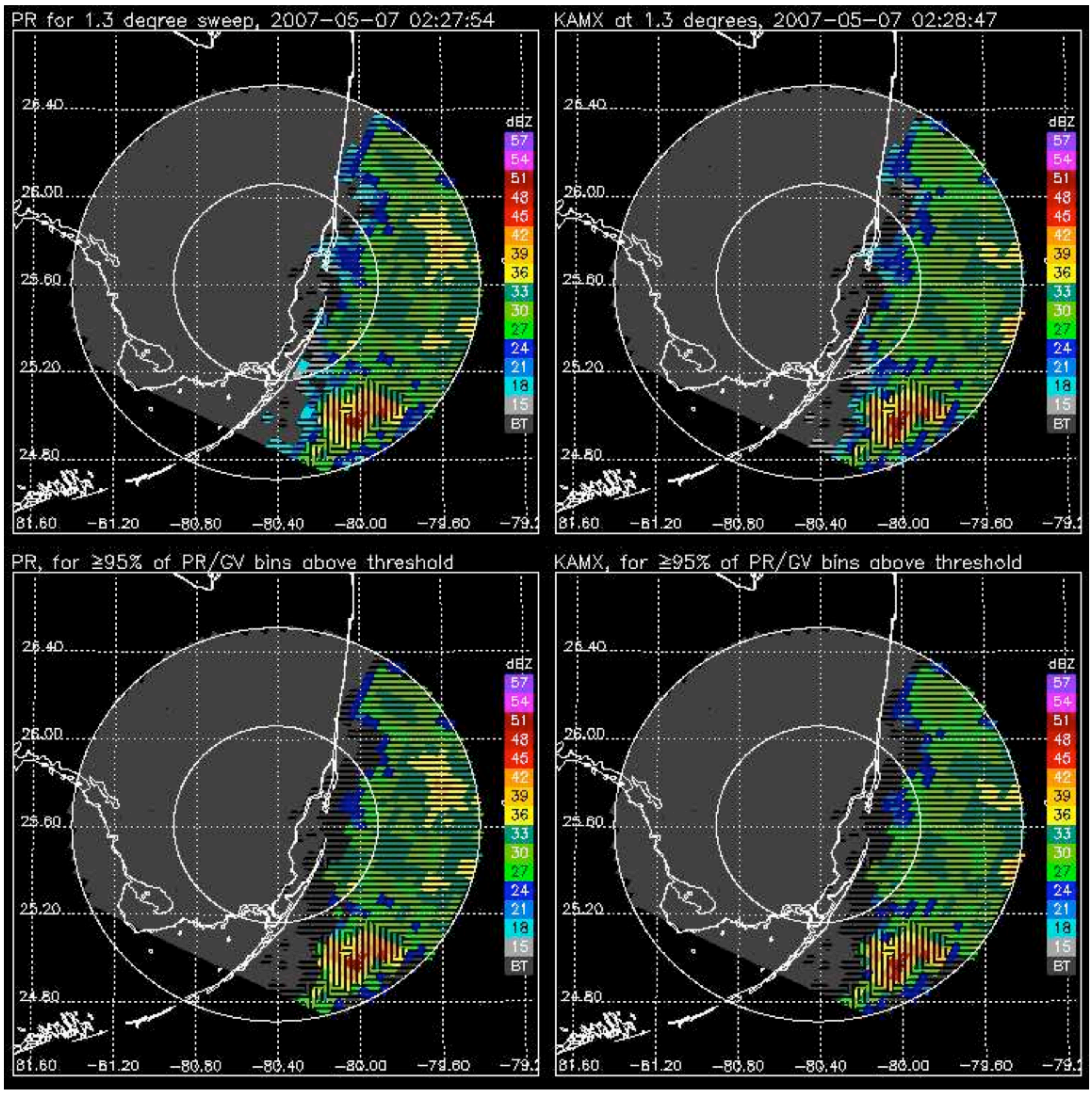
Proxim.	Any Rain Type		Stratiform		Convective		Dataset Statistics			
to BB	PR-GV	NumPts	PR-GV	NumPts	PR-GV	NumPts	AvgDist	PR MaxZ	GV MaxZ	BB?
Below	0.436	1022	0.563	940	-0.831	82	68.039	51.010	53.724	
Within	-0.910	1166	-1.084	1039	0.452	127	77.410	50.993	50.097	@ BB
Above	0.579	678	0.416	583	1.630	82	68.684	44.073	39.145	

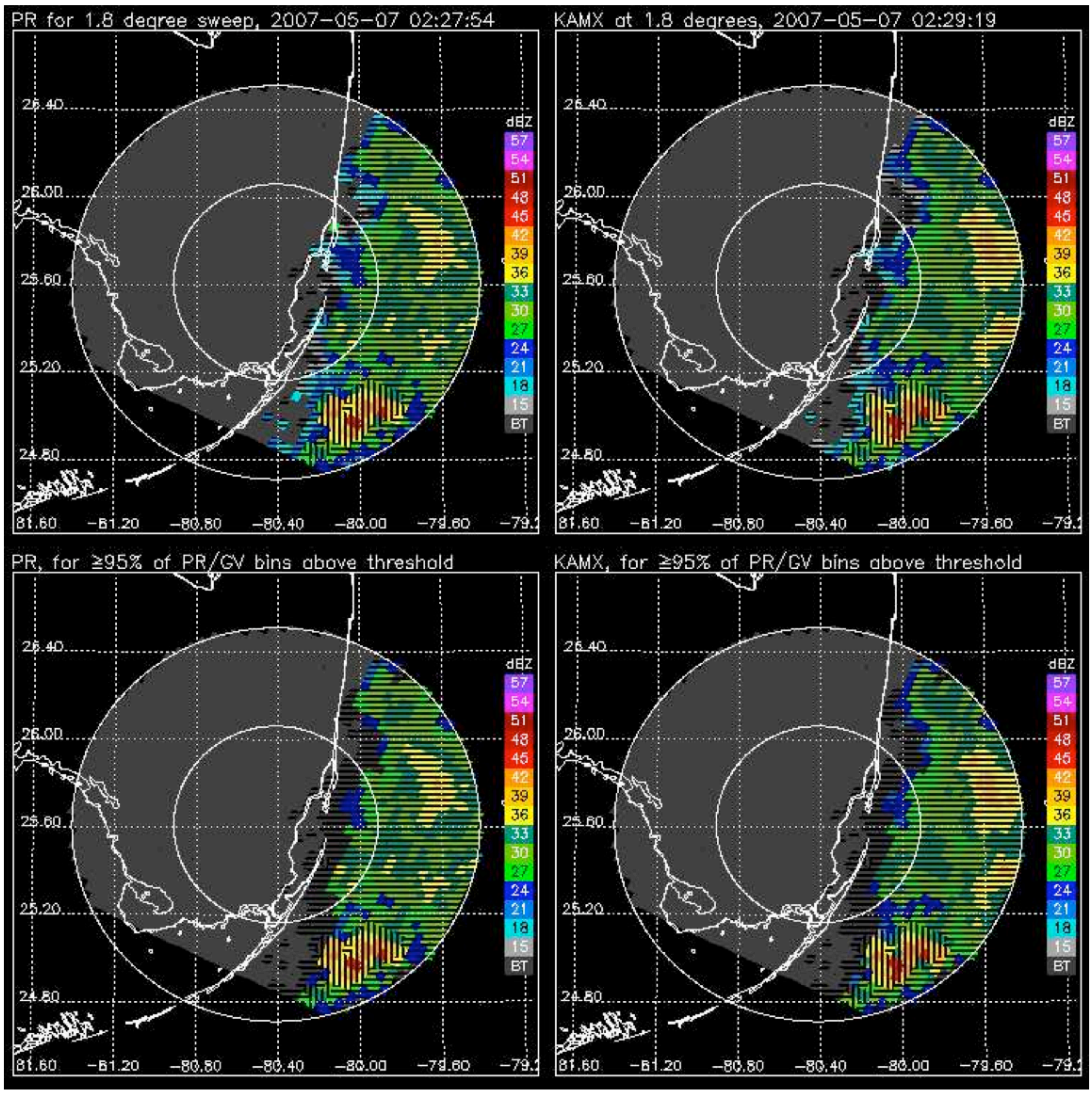
KAMX.070507.53977 -- Percent of bins above thresholds >= 95%




PR for 0.5 degree sweep, 2007-05-07 02:27:54
KAMX at 0.5 degrees, 2007-05-07 02:27:42
PR, for ≥95% of PR/GV bins above threshold
KAMX, for ≥95% of PR/GV bins above threshold
dBZ
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
BT
26.40
26.00
25.60
25.20
24.80
81.60
-81.20
-80.80
-80.40
-80.00
-79.60


PR for 0.9 degree sweep, 2007-05-07 02:27:54
KAMX at 0.9 degrees, 2007-05-07 02:28:15
PR, for ≥95% of PR/GV bins above threshold
KAMX, for ≥95% of PR/GV bins above threshold
dBZ
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
BT
26.40
26.00
25.60
25.20
24.80
-81.60
-81.20
-80.80
-80.40
-80.00
-79.60


PR for 1.3 degree sweep, 2007-05-07 02:27:54
KAMX at 1.3 degrees, 2007-05-07 02:28:47
PR, for ≥95% of PR/GV bins above threshold
KAMX, for ≥95% of PR/GV bins above threshold
dBZ
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
BT
26.40
26.00
25.60
25.20
24.80
-81.60
-81.20
-80.80
-80.40
-80.00
-79.60


PR for 1.8 degree sweep, 2007-05-07 02:27:54
KAMX at 1.8 degrees, 2007-05-07 02:29:19
PR, for ≥95% of PR/GV bins above threshold
KAMX, for ≥95% of PR/GV bins above threshold
dBZ
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
BT
26.40
26.00
25.60
25.20
24.80
-81.60
-81.20
-80.80
-80.40
-80.00
-79.60