THE VERTICAL CROSS SECTION DISPLAY PROGRAM FOR GPM VALIDATION NETWORK GEOMETRY-MATCHED PR AND GV DATA SETS

INTRODUCTION

The IDL procedure pr_and_geo_match_x_sections.pro provides the capability to interactively select locations for, and display, vertical cross sections 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 GV radar site, with precipitation echoes present). By default, the procedure also displays a vertical cross section of the difference (PR-GV) between the PR and GV reflectivity from the geo-matched data. By default, the cross sections are along the PR cross-track scan line through the point selected by the user (i.e., perpendicular to the orbit track). Random cross section alignments are not supported.

The procedure has a feature allowing a calibration offset to be applied to the GV reflectivity data. If a GV site or GV data for a particular event is known to have an error in calibration relative to the PR, the calibration of the GV reflectivity data may be adjusted up or down in 1 dBZ increments on the currently displayed cross sections, so that the relative vertical structures of the PR and GV reflectivity fields can be evaluated with the calibration bias removed.

The pr_and_geo_match_x_sections procedure allows the user to launch an animation sequence of the PR and GV PPIs while cross sections are being viewed, so that the alignment of the geometry-matched PR and GV data may be evaluated subjectively to determine whether the PR and GV cross sections represent the same precipitation echo areas. If the original Universal Format (UF) GV radar data files are available, the procedure will include a full-resolution PPI of the GV data in the animation sequence, interleaved between the PPIs of PR and GV volume-matched data.

If the original PR 2A-25 HDF product files are available, the procedure optionally will generate and display a matching cross section of full (250m) vertical resolution PR reflectivity for comparison to the volume-averaged PR and GV data. Where 2A-25 data are available, plotting of the full-resolution PR cross sections may be enabled/disabled by specifying a keyword parameter to pr_and_geo_match_x_sections when running it in IDL.

SYNOPSIS

The pr_and_geo_match_x_sections 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 pr_and_geo_match_x_sections is as follows:

```
pr_and_geo_match_x_sections, ELEV2SHOW=elev2show, SITE=sitefilter, $
                             NO_PROMPT=no_prompt, NCPATH=ncpath,   $
                             PRPATH=prpath, UFPATH=ufpath,         $
                             USE_DB=use_db, NO_2A25=no_2a25,       $
                             PCT_ABV_THRESH=pctAbvThresh
```

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:

ELEV2SHOW: sweep number of PR/GV PPIs to display for selection of the cross section location, starting from 1 as the lowest elevation angle in the GV radar volume. Defaults to approximately 1/3 the way up the list of sweeps if unspecified.

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

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). If set, then the program will automatically find the next file in the set, in order of ascending site ID and date.

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.***

PRPATH: local directory path to the original PR product files root (in-common) directory. Defaults to `/data/prsubsets`. By convention, the 2A-25 data files must be located in the `/2A25` subdirectory located immediately under PRPATH.

UFPATH: local directory path to the original GV radar UF file root (in-common) directory. Defaults to `/data/gv_radar/finalQC_in`

NO_2A25: Binary parameter (e.g., /NO_2A25). If set, then the full-vertical-resolution PR cross sections from the 2A-25 data will NOT be plotted by default, if the 2A-25 files are available and PRPATH is properly specified. This means the program can be run using only the geo_match netCDF data files. If PRPATH is incorrect and/or the 2A-25 files are NOT available, then this keyword parameter has no effect, and the procedure will proceed without producing a display of full-resolution PR data.

USE_DB: Binary parameter. If set, then query the 'gpmgv' database to find the PR 2A-25 product file that corresponds to the geo_match netCDF file being rendered. Otherwise, generates a 'guess' of the filename pattern and searches for the file under the directory prpath/2A25 (default mode).

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).

RUNNING THE PROGRAM (IDL License Available)

The following instructions apply to running the cross section 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 pr_and_geo_match_x_sections procedure is provided as a precompiled and saved IDL binary file: **pr_and_geo_match_x_sections.sav**. To run the file, place it in a directory of your choice, and start IDL (either command-line mode or Development Environment. At the IDL prompt (e.g., IDL>), change the current directory to the one where the **pr_and_geo_match_x_sections.sav** file is located (the quotes in the example commands are required):

```
IDL> cd, '/Directory/Of/My/Choice'
```

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

```
IDL> restore, 'pr_and_geo_match_x_sections.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> pr_and_geo_match_x_sections, $
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.

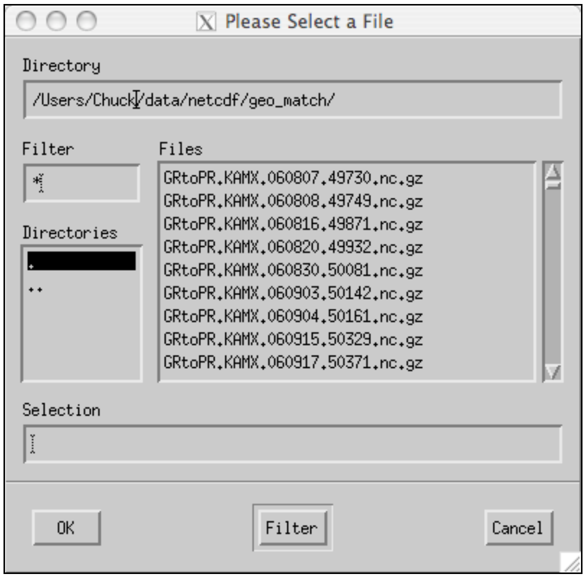

Figure 1. File selector for geometry-matched netCDF files.

Once a file has been selected from the list in the File Selector, a pair of PPI images of the PR and GV volume-matched data in the netCDF file will be displayed (Fig. 2). If the ELEV2SHOW parameter is unspecified, then the elevation angle that will be plotted in the PPIs will be for the sweep that is about 1/3 of the way up in the list of elevations in the GV volume scan, which is the 3.3 degree elevation sweep in the case shown in Fig. 2. Otherwise, if ELEV2SHOW=N is specified as a keyword parameter, then the Nth sweep in the GV volume scan will be shown in the PPIs. 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, are plotted with solid fill. Samples where a pattern appears but no color is shown indicate either a PR ray position where no valid reflectivity value is present at the displayed elevation, or where there is a valid reflectivity value but the sample does not meet the “percent complete” criteria specified by the PCT_ABV_THRESH keyword parameter if the threshold specified and is non-zero.

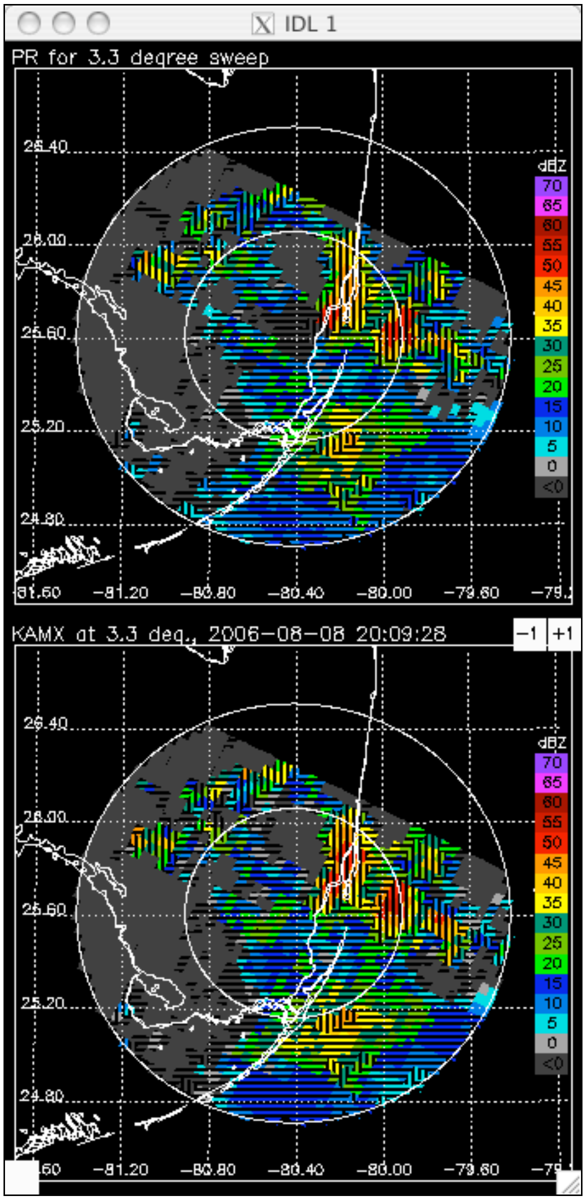

Figure 2. PPIs of PR (upper) and GV (lower) volume-matched reflectivity, used for selecting cross section locations. All available samples are shown in this example (i.e., PCT_ABV_THRESH=0). The patterned areas without color assignments show the locations of PR rays without valid volume-match data for this particular sweep elevation, but which do exist for other sweep elevations.

To display a cross section, select a desired feature on either of the PPI images with the cursor, and click the left mouse button. An A-B line will be drawn along the PR scan line through the selected point on the PPIs (Fig. 3), and vertical cross sections of geometry-matched PR and GV data will be displayed in a separate window, as shown in Figure 4. Note that the PPI images use a different color table than the geometry-match cross sections. The color table of the PPIs aggregates the data into 5 dBZ steps, which is not suitable for viewing small gradations or differences between reflectivity of the matching PR and GV volumes. The cross sections use a smoothly varying color table that shows variations of 1 dBZ or more between displayed volumes.

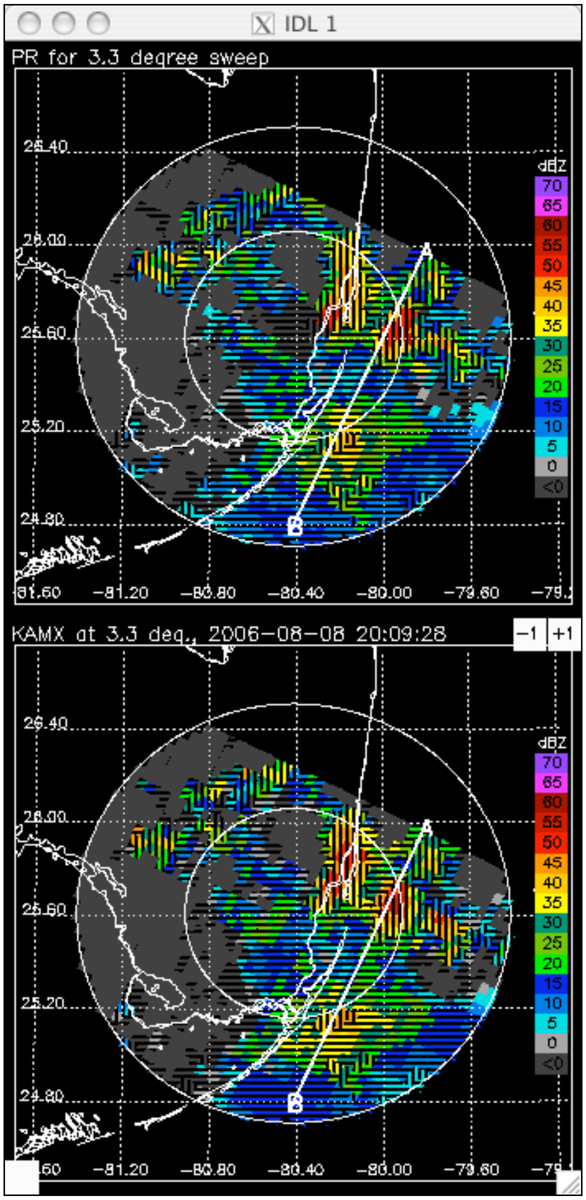

Figure 3. PR and GV PPIs showing the location of the user-selected cross section.

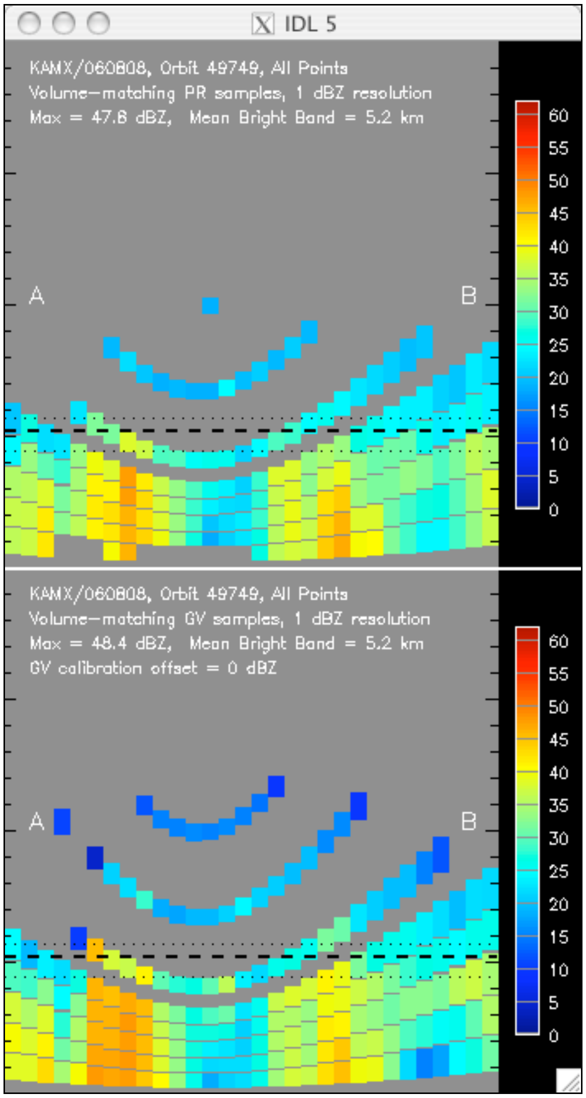

Figure 4. Vertical cross sections of geometry-matched PR (top) and GV (bottom) data along PR scan line through the user-selected location. All available samples are shown in this example (i.e., PCT_ABV_THRESH=0).

The vertical tick marks on either side of the cross section plots show the height above the surface in 1-km steps. The cross section height range is from 0 to 20 km, and major tick marks are at 5, 10, and 15 km. The displayed width of the cross sections is quasi-fixed so that the plots are approximately square. Each column of data in the cross section shows one PR ray along the PR scan line being plotted, and represents approximately 5 km in the horizontal. The displayed width of each PR ray is adjusted on the plot such that all PR rays between points A and B on the PPI are plotted on the cross section, and the square aspect ratio of the cross section plot is maintained. Where the sample volumes along a given ray overlap in the vertical, the samples are divided at the midpoint of the overlapping area for display purposes, and a 1-pixel-deep delimiter is plotted on the image between overlapping or touching volumes to indicate the division between elevation sweeps.

The heavy dashed horizontal line in the vertical cross section plots indicates the mean height of the bright band, as indicated in the PR level 2 product. Light dotted lines are plotted 500 m above and 750 m below the mean bright band. Any samples touching or falling in the layer between these two heights are considered to be affected by the bright band in statistical analyses of the volume-matched data. Those samples completely above the upper line are considered to be above bright band in the statistics, and those below the lower line are placed in the below bright band category. The orientation of the cross section relative to the PPIs is indicated by the letters A and B plotted on the cross section and the PPIs.

A PR-GV difference field will be computed for the selected cross section and displayed in a separate window, as seen in Figure 5. The difference field has its own unique color table, where the warm colors (red, orange, yellow) indicate relatively 'hot' GV radar reflectivity samples (PR<GV), and cool colors (green, blue, violet) indicate 'cool' GV radar samples (PR>GV). Samples plotted in white are where PR and GV reflectivity are within 0.5 dBZ of each other.

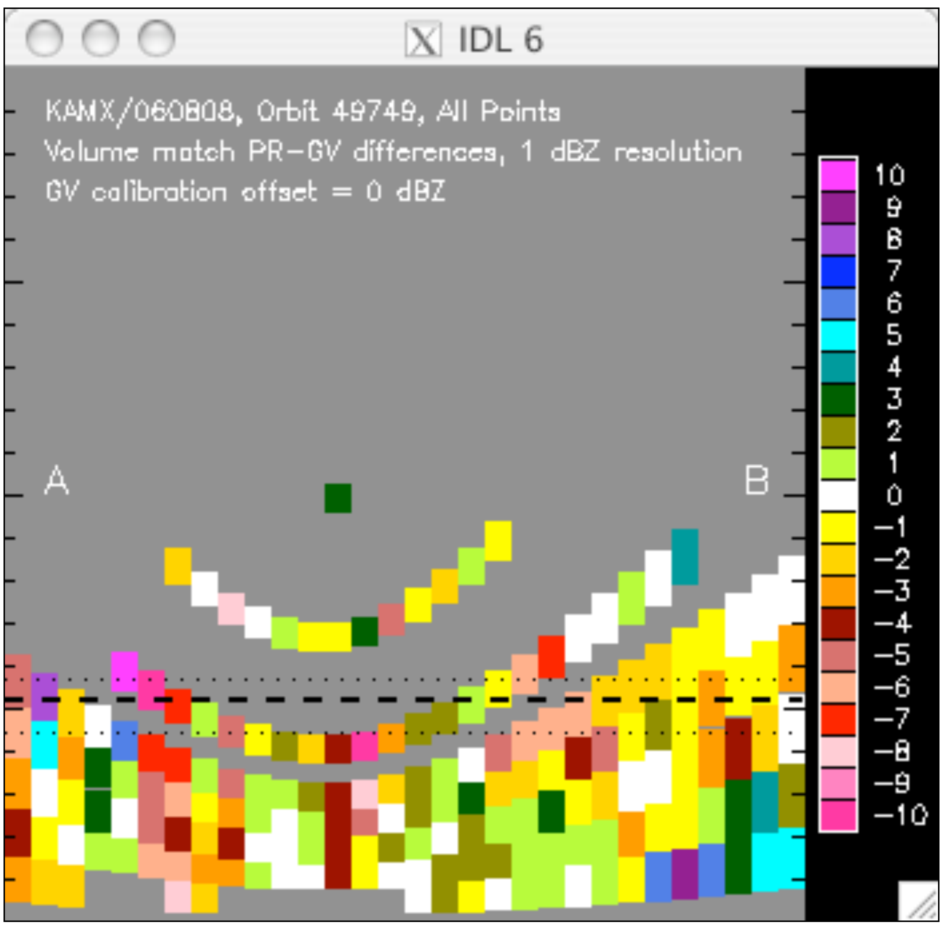

Figure 5. Cross section of reflectivity difference, PR-GV, from volume-matched data, for the case shown in Fig. 4.

If the PR 2A-25 product files are available on the local host, the PRPATH parameter points to the common directory above the /2A25 directory where these files are located, and the NO_2A25 keyword is unset (unspecified or set to 0), then a second pair of vertical cross sections showing the full-vertical-resolution PR reflectivity data will be plotted in a separate display window (Fig. 6). The upper panel in this set of cross sections shows the full-resolution PR data displayed using the same color scheme as the PPI images (Figs. 2 and 3), with 5-dBZ color steps. The lower panel shows the same data displayed using the smoothed color table of the cross section plots of the volume-match PR and GV data as shown in Fig. 4, with a 1-dBZ resolution. If the NO_2A25 keyword parameter is set, or if it is unset and the 2A-25 data file cannot be found, then the plot of full-resolution PR data will be skipped.

The full-resolution PR cross sections are <u>not</u> limited to the points with data in the geometry-matching data. All PR gates are shown in the full-resolution PR cross sections (Fig. 6), while the geometry-matched data (Fig. 4) exist and are shown only at locations where the PR rays intersect the GV elevation sweeps, which are typically discontinuous in the vertical and have a ‘cone of silence’ centered above the GV radar.

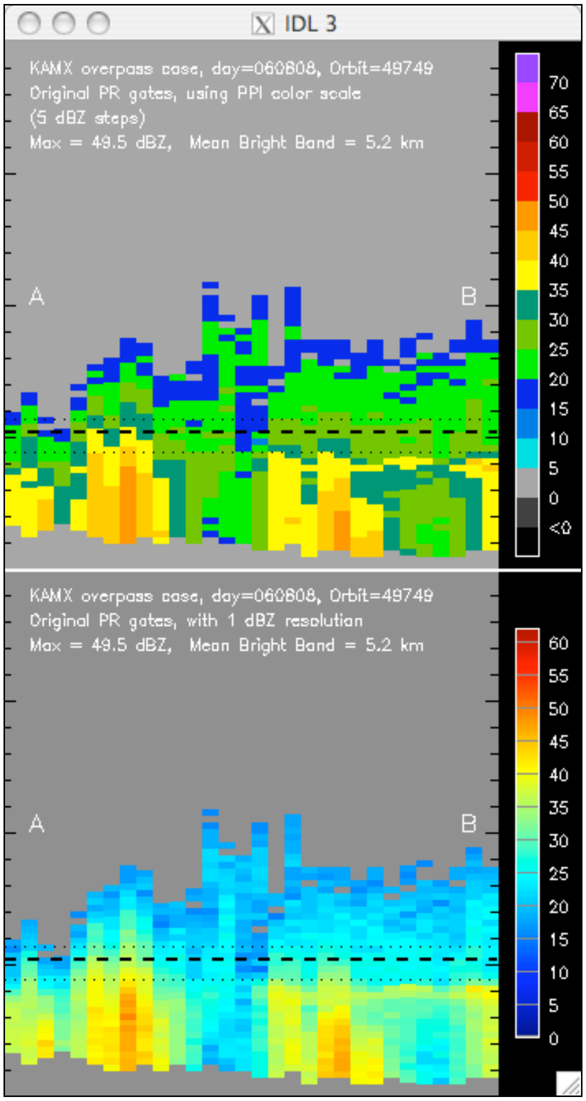

Figure 6. Vertical cross section of full-vertical-resolution (250 m) PR reflectivity data from the original, unaveraged 2A-25 attenuation-corrected reflectivity, for the case shown in Figs. 3-5. The same data are plotted in both panels – only the color table is different between the two.

<u>INTERACTIONS WITH THE PPI DISPLAY</u>

Select A New Cross Section Location:

The A-B line on Fig. 3, and the cross section displays of Figures 4-6 are updated each time the user selects a new point on the PPIs (Fig. 2), as long as the cursor is clicked within the PR/GV overlap area in the PPIs (dark gray or colored areas) using the left mouse button. To exit the current case and allow selection of the next case, right-click the mouse with the cursor positioned the within the overlap area.

Start a PPI Animation Loop:

Clicking on the small white square in the lower left of the GV PPI plot (Fig. 2 or 3) will launch another IDL procedure that will create an animation loop of the PPIs in a new window. This animation loop will contain a sequence of PPI images in the following order:

1) Volume-match PR PPI at the level of the first elevation sweep
2) Volume-match GV PPI at the level of the first elevation sweep
3) As in (1), but for the second elevation sweep
4) As in (2), but for the second elevation sweep

.
.
.

2*N–1) Volume-match PR PPI for the Nth elevation sweep
2*N) Volume-match GV PPI for the Nth elevation sweep

Figures 7 and 8 show examples of PR and GV PPI animation frames in the animation loop for the sample case of Figure 2.

The user can let the animation run on its own, but it is more useful to pause the animation, click on the slider bar, and then use the arrow keys on the keyboard to manually toggle between adjacent frames to check the alignment of the echoes between the PR and GV volume-matched data. This capability permits an analyst to make a subjective determination about the quality of the geometric alignment between the two data sources to decide whether the PR-GV values in the difference cross section represents calibration and/or measurement differences between the two data types, or is due to misalignment between the two data sources.

The number of elevation sweeps included in the animation sequence matches the sweep number specified in the ELEV2SHOW parameter, or computed internally as the default (approximately one-third of the available sweeps) if ELEV2SHOW is not specified. ***Specifying a keyword value of ELEV2SHOW=1 causes an error if one then attempts to launch an animation sequence under this condition.***

If the original Universal Format (UF) file containing the GV radar volume for the displayed case is available and located under the directory pointed to by the UFPATH keyword parameter, then the animation sequence will interleave a plot of the full resolution GV radar PPI for each displayed sweep in the animation sequence. There will be four PPIs for each elevation sweep displayed, in the following order:

1) Volume-match PR PPI at the level of the elevation sweep
2) Full-resolution GV PPI at the level of the elevation sweep (Fig. 9)
3) Volume-match GV PPI at the level of the elevation sweep
4) The PR PPI of item (1), repeated in the sequence

This sequence is then repeated for each elevation sweep to be displayed. This allows one to toggle back and forth between each of the data types: the volume-matched PR and full-resolution GV; the volume-matched and full-resolution GV; and the volume-matched PR and volume-matched GV.

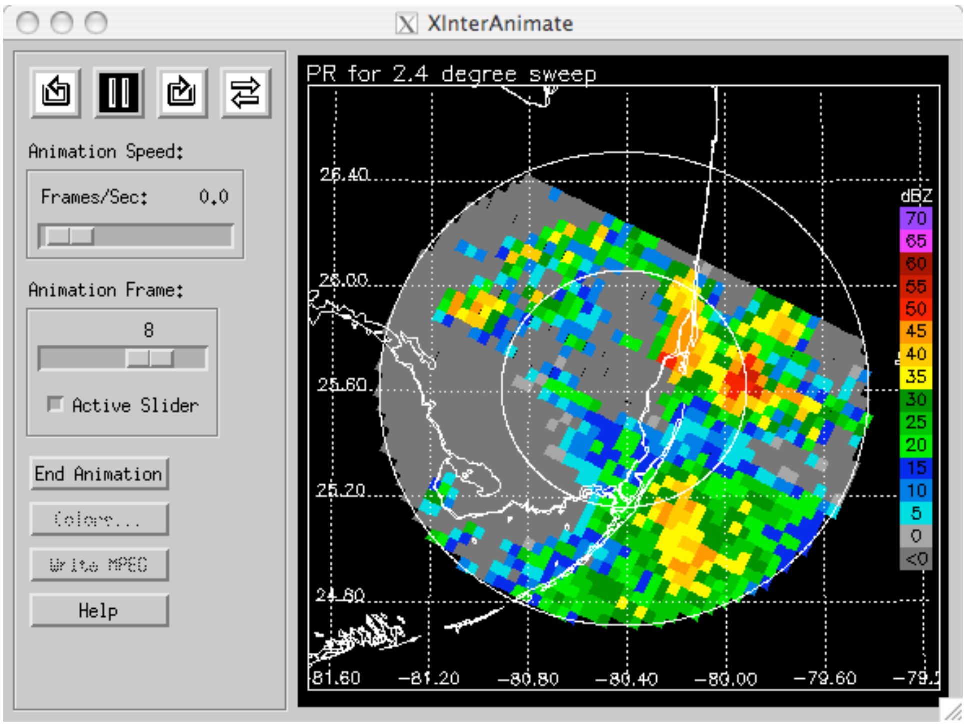

Figure 7. One PR frame of a PR and GV animation loop, showing volume-matched PR data for the 2.4 degree elevation sweep of the GV radar.

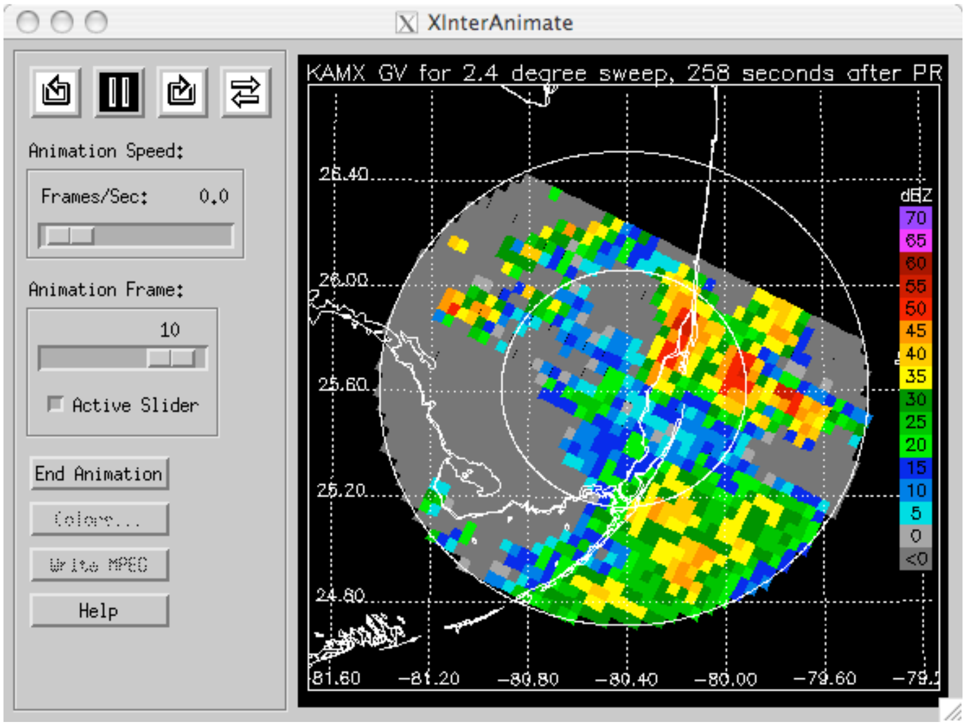

Figure 8. As in Fig. 7, but for volume-matched GV data. The time difference between the PR overpass and the GV radar sweep begin time is indicated in the plot title.

While the animation window is present it takes over the cursor focus and no interaction with the other PPI or cross section windows is possible. The animation window must be closed in order to select a new cross section location or a new case.

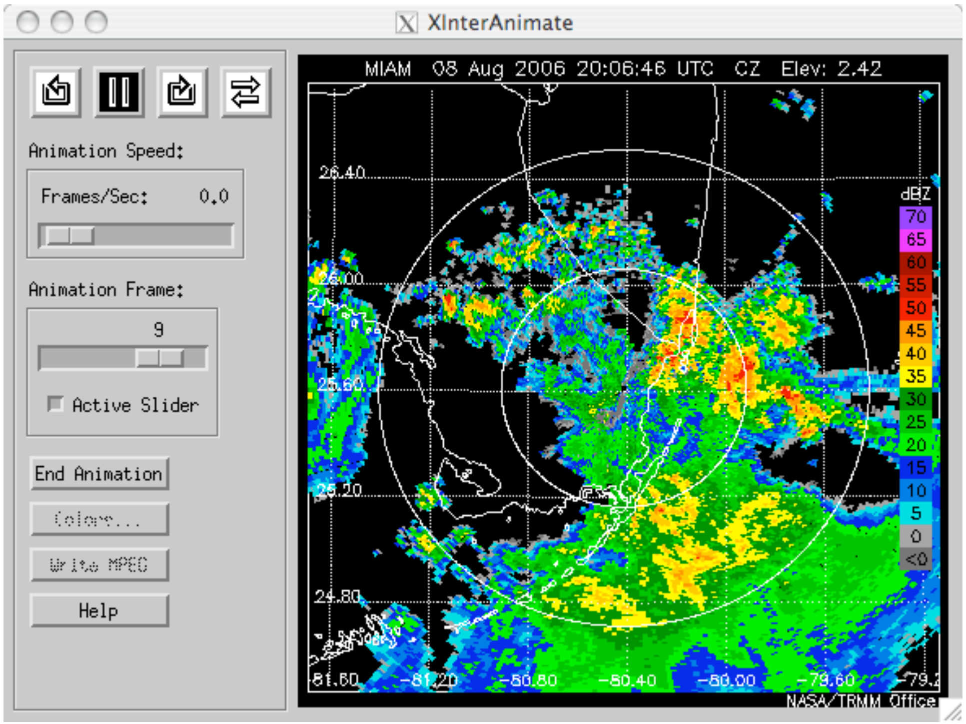

Figure 9. Full-resolution GV PPI from the original UF radar data file, if available, is interleaved with corresponding PPIs of volume-matched data (Figs. 7, 8) in the animation loop.

Apply a Calibration Adjustment to GV Reflectivity:

A calibration offset may be applied to the GV reflectivity by clicking on the white boxes with the + and – signs on the GV PPI plots in the cross-section location selection window (Figs. 2 and 3). Once a set of cross-sections has been displayed, clicking on the + or – sign will apply a +1 or -1 dBZ offset to the GV reflectivity and re-draw the existing cross section plots with the calibration offset applied. Both GV cross sections (lower panel in Figure 4) and PR-GV difference cross sections (Figure 5) will be redrawn with the GV offset applied. The effect is cumulative, so that each time a box is clicked the GV offset increases or decreases by 1 dBZ and the existing cross sections are redrawn. Figure 10 shows a difference cross section for the KGRK radar, which had a 2-3 dBZ low bias compared to the PR. Figure 10 shows the difference cross section with no GV correction, and Fig. 11 shows the same cross section with a +3 dBZ offset applied to the GV, to bring the above-bright-band differences to near zero.

Once an offset has been applied, it will automatically be applied to each new cross section location selected for the current case (current matchup netCDF file). If a different data file is selected, the offset will be reinitialized to zero for its cross section selections.

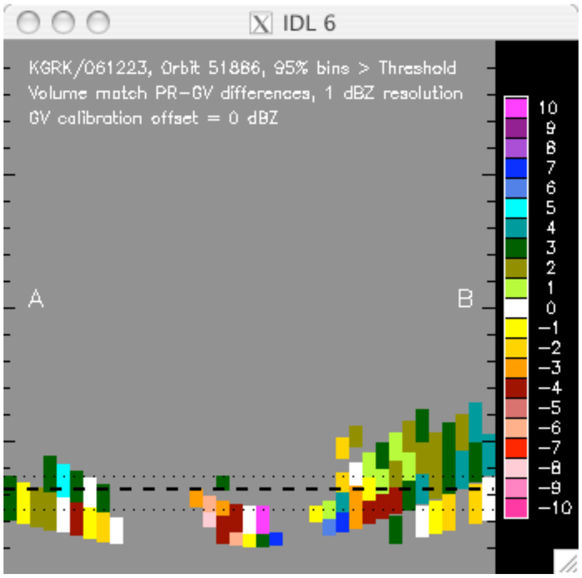

Figure 10. PR-GV difference cross section for the KGRK WSR-88D radar with 0 dBZ GV offset.

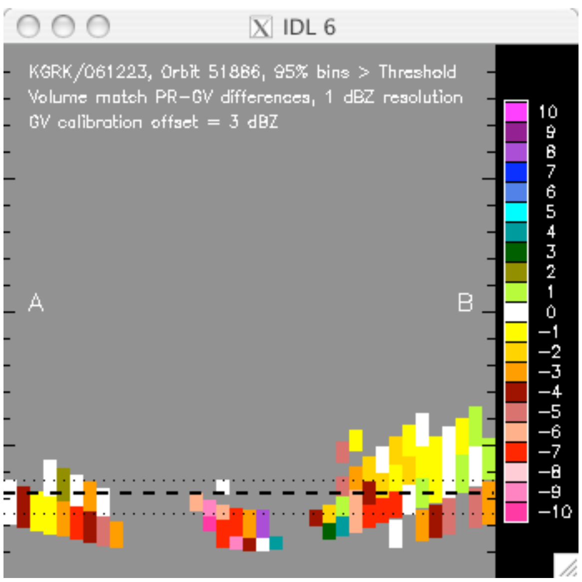

Figure 11. As in Fig. 10, but with a +3 dBZ calibration correction to the GV reflectivity.

CONSTRAINING DATA QUALITY

The PCT_ABV_THRESH keyword parameter permits the analyst to constrain the volume-match data shown in the selector PPIs and the cross sections of volume match data to only those samples where the percentage of original PR and GV bins in their respective volume averages had reflectivity values exceeding a cutoff threshold dBZ: 18.0 for the PR, and 15.0 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. Figure 12 shows the PR and GV PPIs of Fig. 2, and Figures 13 and 14 show the PR and GV volume-match data cross sections of Fig. 4 and 5, but under the constraint that the displayed samples are at least 95% complete.

There is currently no objective mechanism for constraining or validating the quality of the matchup geometry (echo offsets between the PR and GV radars). The PPI animation loops provide a mechanism for subjective evaluation of the matchup geometry.

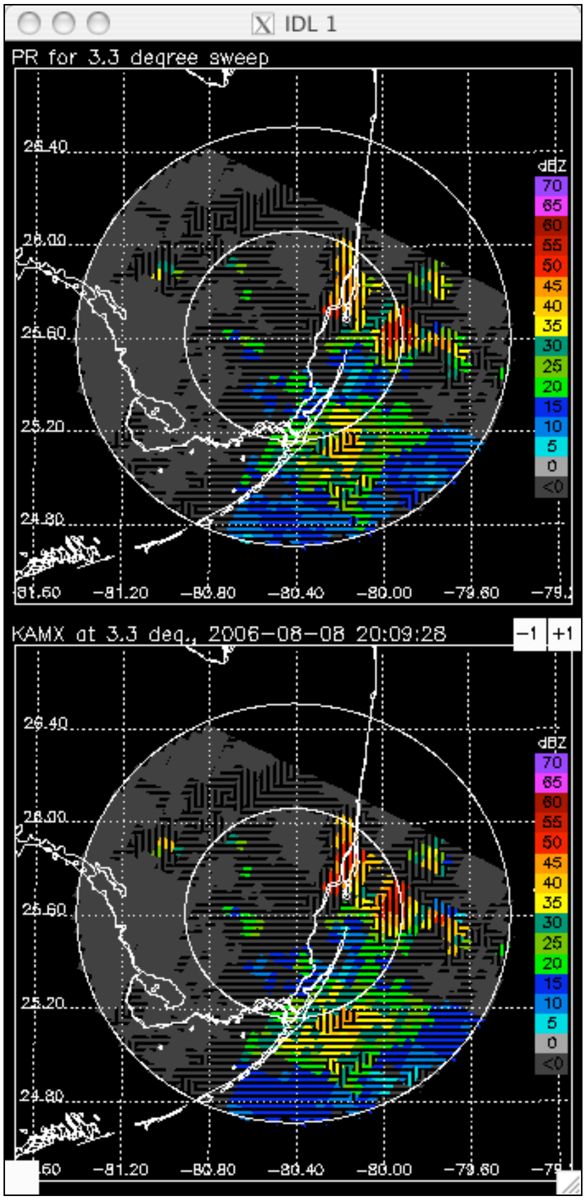

Figure 12. As in Fig. 2, but where the displayed volumes have been constrained to those where at least 95% of the bins included in the PR and GV volume averages met their reflectivity threshold values. The patterned areas without color assignments show the locations of points not meeting the completeness criteria and/or not having valid data for this sweep elevation.

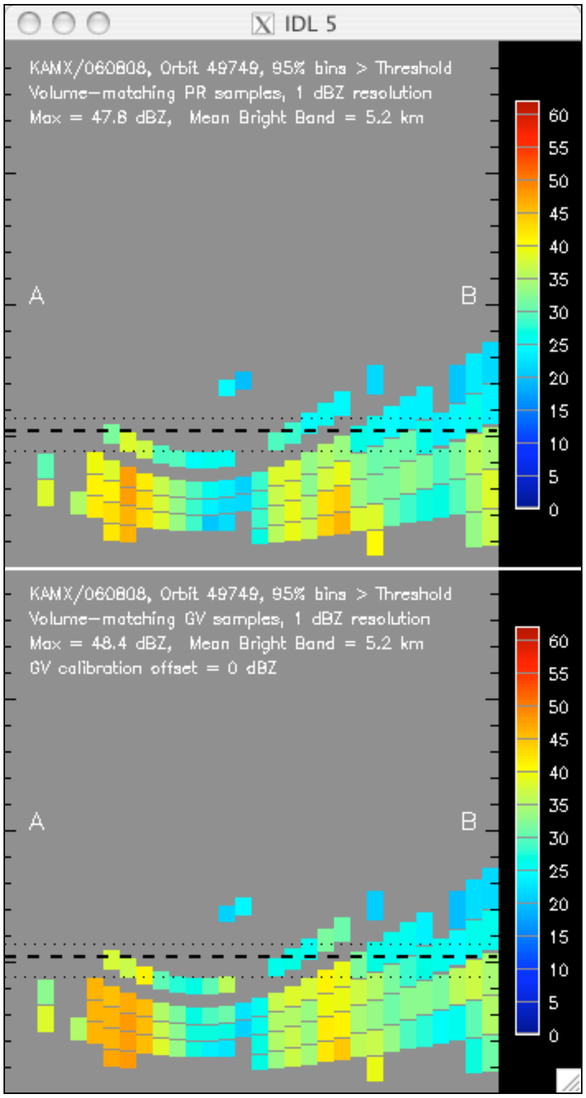

Figure 13. As in Figure 4, but limited to those samples where at least 95% of the PR and GV bins in the volume averages meet the reflectivity thresholds.

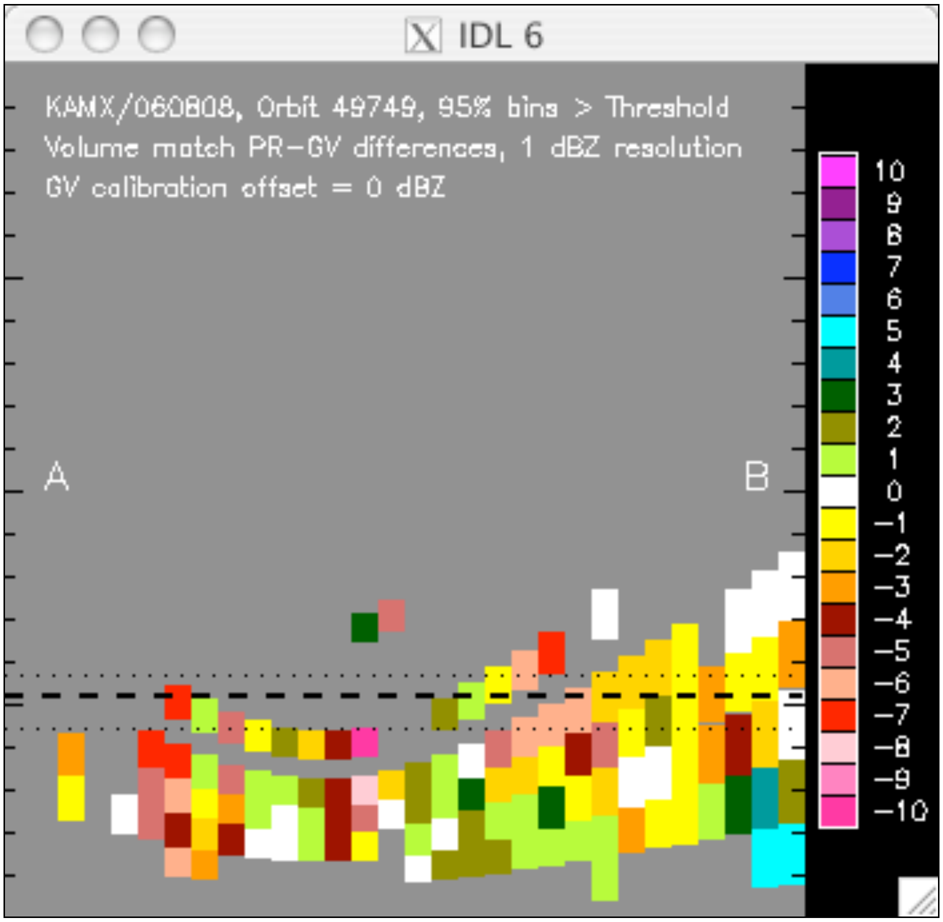

Figure 14. As in Fig. 5, but limited to those samples where at least 95% of the PR and GV bins in the volume averages meet the reflectivity thresholds.

IDL Virtual Machine option

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. As an alternative to the time-limited demo mode, a "wrapped" version of the procedure may be executed using the freely available IDL Virtual Machine. The wrapped version of the cross section procedure is in the IDL 'save' file: **wrapf_pr_and_geo_match_x_sections.sav**. It requires 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., 'XsectParamsKMOB.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, is shown below:

```
ELEV2SHOW=4
NCPATH=/Users/krmorri1/Documents/GPM/data/netcdf/geo_match
PRPATH=/Users/krmorri1/Documents/GPM/data/prsubsets
UFPATH=/Users/krmorri1/Documents/GPM/data/gv_radar
NO_PROMPT=0
SITE=KMOB
USE_DB=0
NO_2A25=1
PCT_ABV_THRESH=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), 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 licensed version 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., /NO_2A25) is not allowed in the control file.** Assign a value of 0 to unset the parameter (NO_2A25=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 (NO_2A25=1).

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. 13) will appear and the analyst will be prompted to select an IDL save file. If the wrapper file 'wrapf_pr_and_geo_match_x_sections.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 cross section wrapper.

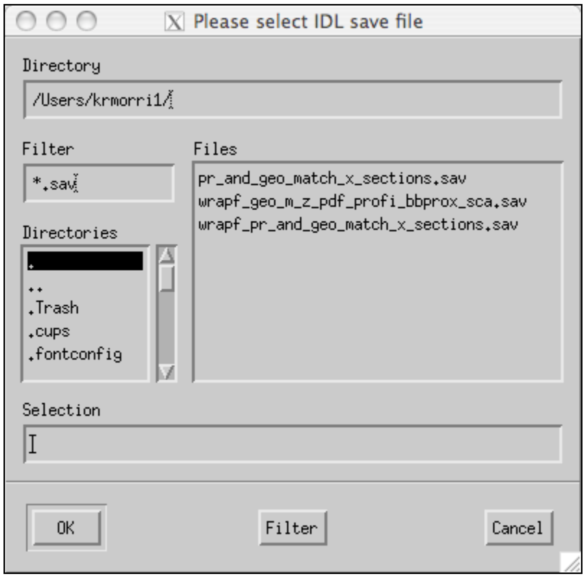

Figure 15. File selector for choosing as IDL 'save' file to be executed in IDL's Virtual Machine mode.

Once the wrapper program starts, the file selector (Fig. 14) 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 cross section program. From here on, the analyst can display and manipulate the cross sections as described in the preceding sections.

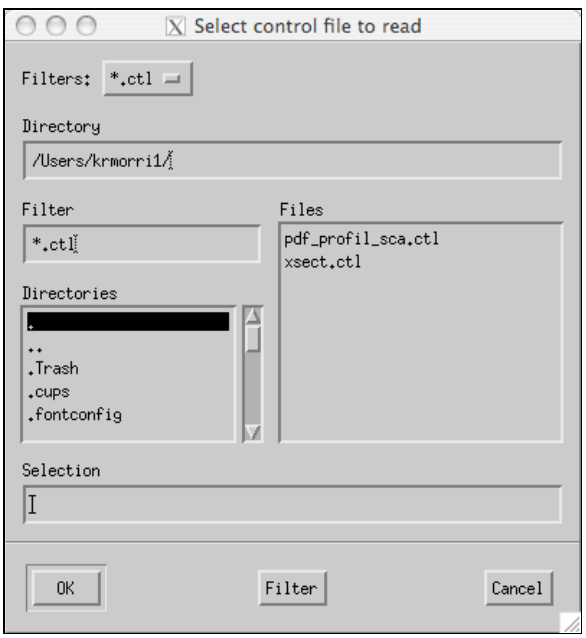

Figure 16. File selector to allow selection of the control file for a run of the cross section wrapper program.

Running Under Windows

Neither the regular nor the wrapped version of the cross section display program will run in IDL under Windows. The programs "spawn' native Unix/Linux commands (cp, mv, rm) and utility programs (gzip) that are not present on Windows. The programs have been run successfully on both Linux and Mac OS X.