RASS-R Radar Comparator Module

User Manual

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Abstract

The Radar Comparator Module (RCM) is a radar analysis software system. Using target of opportunity data it can be used to predict majority of the important performance parameters required by international ATC documents and organizations such as ICAO and Eurocontrol. The Radar Comparator Software can be operated in two separate modes: Mono- and Dual- radar analysis. The Mono-radar mode can be used in order to evaluate the Probability of Detection, Code Probabilities, False Plot Rate and Radar Accuracy. The Dual-radar data processing is generally used to measure the radar systematic errors.

Keywords

Systematic Errors	Random Errors	Probability of Detection	Target of Opportunity
Barometric Correction	Timestamp Statistics	Refraction Correction	Filtering
Trajectory Reconstruction	Plot-to-Track Association	Trajectory Analysis	Tabular Pd displays
Coverage Volume	Screening Angles	Measurement Tolerance	

CONTACT PERSON :	Andrey Pchelintsev	TEL : +32 14 231811	:

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> Intersoft Electronics
> Lammerdries, 27
> B-2250 Olen
> BELGIUM
> Telephone   :   (+32)14.23.18.11
> FAX   :   (+32)14.23.19.44

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> support@intersoft-electronics.com

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ABOUT THIS MANUAL

The RASS-R Radar Comparator Module User manual describes the Radar Comparator module and associated software components.
This manual is related to the specific Radar Comparator features, for general information about the RASS-R tools and organization refer please to the RASS-R Toolbox manual [1]. Some level of expertise with the general radar analysis principles and methods might be required in particular while running and interpreting results of the dual radar analysis.

ORGANIZATION OF THIS MANUAL

The RASS-R Radar Comparator Module User manual is organized as follows.

- Chapter contains some general information about this manual and product
- Chapter 2, Introduction, contains a basic introduction of the radar analysis methods and documents and some introduces several key features/concepts.
- Chapter 4, RCM basic operation, describes different software modules and its purpose in the Radar Comparator toolbox.
- Chapter 3, Installation verification and startup, contains software installation information.
- Chapter 4 RCM basic operation describes how to run sessions and individual software components.
- Chapter 5 RCM: Radar and Geodesic Setup contains a detailed description of the available software components and their configuration options.
- Chapter 6 RCM: Pre-processor describes in details pre-processor tools and methods
- Chapter 7 RCM: Filter describes in details filtering tool
- Chapter 8 RCM: Mono-radar Evaluation contains detailed information about the mono-radar evaluation mode
- Chapter 9RCM: Dual-radar Evaluation contains detailed information about the dual-radar evaluation mode
- Chapter 10 Tutorial explains how to getting started with the software

2. Introduction

2.1. RCM as a part of the RASS-R
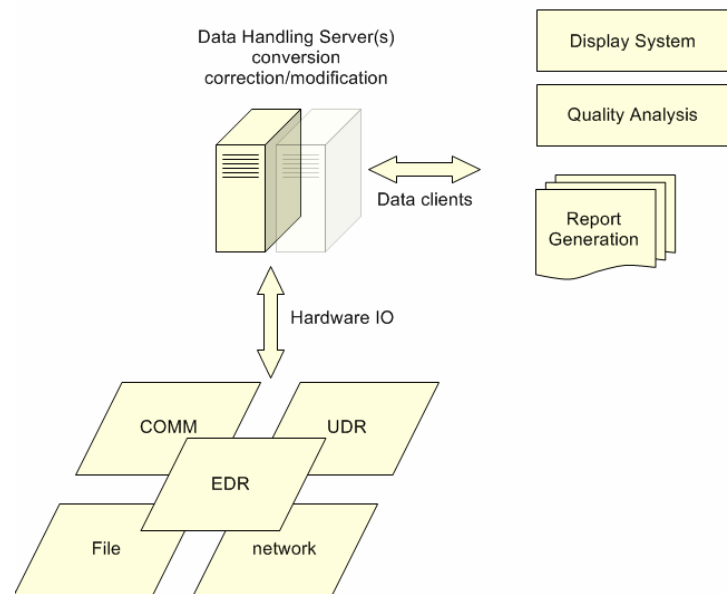
Figure 2.1 RASS-R Structure

Within RASS-R the Radar Comparator Module can process data delivered by DHM in order to generate performance figures for a radar accordingly to the existing international standards. On the other hand RCM may produce important correction parameters for DHM and further production of the data streams.

The Radar Comparator Module (RCM) is a radar analysis software system. Using target of opportunity data it can be used to predict majority of the important performance parameters required by international ATC documents and organizations such as ICAO and Eurocontrol. The Radar Comparator Software can be operated in two separate modes: Mono- and Dual- radar analysis.

The Mono-radar mode can be used in order to evaluate the Probability of Detection, Code Probabilities, False Plot Rate and Accuracy (random Range and Azimuth errors) generating separate performance figures for PSR-SSR and ModeS, both plot and track data can be processed.

The Dual-radar data processing is generally used to measure the radar systematic errors (Range and Azimuth biases, Range Gain and Timestamp bias) and more accurate measurement of the random errors (Range and Azimuth). The Dual-radar evaluation may be conducted for a cluster of radars always comparing them one-by-one. Due to such a measurement technique average values for the systematic errors (Range and Azimuth biases, Range Gain and Timestamp bias) for each radar can be produced as well as their standard deviations. The standard deviations provide quantitative estimates for the accuracy of the multi-radar measurement, making the measurement trustworthy. As opposed to the general multi-radar measurement (SASS-C), where the data coming from multiple radars are processed simultaneously the dual-radar analysis has the following benefits:

- non-specific errors (errors non-taken into account by the mathematical model) can be efficiently detected and handled;

- limited amount of the data ensures the better visibility, manageability and post-process analysis;

- tolerance on the multi-radar measurement can be produced

  Prior to the comparative analysis with the Radar Comparator Module, the raw radar data might need to be pre-processed in order to take into account the real distribution of the barometric pressure vs. height (as opposed to the ICAO 1964 Standard Atmosphere), effects of the atmospheric refraction, and eventual ACP encoder eccentricity. All three of these might be very harmful for dual-radar evaluation mode. The barometric correction is required for the mono-radar evaluation mode. Applying the barometric correction to the height of aircraft is also beneficial for more adequate radar coverage and probabilities calculation. The integrity of the data and timestamp problems can be also checked, this analysis is essential for the adequate measurement and radar statistics.

2.2. Benefits and possibilities of the system

- Efficient but easy to use software tool for the radar performance analysis

- Fully transparent radar data processing, versatile cross-referencing display functions throughout the analysis (the following displays types are available: XY, reconstructed trajectory (heading and speed vs. time), barometric correction error vs. height, random timestamp error vs. time, azimuth, plot density vs. time, atmospheric refraction error vs. range, random Range vs. random Azimuth error scattering diagram)

- User friendly radar evaluation setup configuration and operation

- S4 and D6 formats are directly used for the RCM analysis

- For the fast data access an intermediate index format files are generated

- MADREC format can be converted to a number of S4 files

- Barometric correction of the target altitude based on the barometric sounding data

- Correction of the range for the atmospheric refraction

- Timestamp statistics and correction (systematic and random)

- Extended plot, track, trajectory info reporting

- Quality indicator of the multi-radar measurement (average value and standard deviation for each systematic error)

- Quality indicators for a reconstructed trajectory and overall quality of the trajectory reconstruction

- Real time systematic errors calculation (the XY display is updated each iteration during the iterative process of the calculation with the current measurement)

- Versatile universal filter interface used throughout the Radar Comparator tools and utilities

2.3. Radar Comparator: Application Note

The Radar Comparator Software (RASS-R) is a new powerful radar evaluation tool developed by Intersoft-Electronics NV. This chapter is dedicated to explain the structure and the main principles underlying the software.

In the design of the Radar Comparator a number of general principles have been respected. First, we tried to keep everything as *simple* as possible so that, it is really easy to use the tool and interpret the results. 2-nd, the data processing has been made as *transparent* as possible so that, it is easy to check what is going on behind the scenes and detect specific problems in a more efficient way. The 3-rd rule was to process a *necessary minimum* of the data, in this way it is physically possible to analyze the data with a common human being capacity and within a short period of time. The 4-th rule was to use *clean data*, i.e. correct it for all known (and measured) significant systematic errors. The 5-th principle was to provide estimates for the accuracy (*tolerance*) on the measurement.

The ultimate goal of the analysis is to estimate radar performance according to the existing standards. The Radar Comparator has two main toolboxes: mono-radar and dual-radar evaluation toolboxes. The mono-radar tool is to be applied to evaluate probability of detection, false plot rate and code probabilities as defined in ICAO and EUROCONTROL ATC documents [2], [3].

The dual-radar toolbox is primarily used for the computation of the misalignment and accuracy, or the random errors. It has been shown that in general two radars are necessary and sufficient for the absolute measurement of the systematic errors and the accuracy. It is very important to realize that not all the radars fit for this type of measurement, i.e. not all the configurations are able to deliver the same accuracy of the measurement. Thus variability of the systematic errors measured in different campaigns may be primarily due to insufficient accuracy of the measurement. In other words for each measured systematic error, a tolerance should be specified. However it is a challenging task to predict the tolerance for a multi-parameter minimization algorithm. We can bypass this difficulty using the radar setup with N radars and comparing two by two all the radars in the setup. As a result (N-1) independent measurements for each radar are produced. The standard statistical parameters as the mean value and standard deviation will reflect the accuracy of the measurement. This approach has another benefit. In the case when one of the radars has a non-specific (error non taken into account by the mathematical model), as for example the eccentricity, results of such a comparison must be pointing to that radar. It must be easy to spot radars with non-specific problems, because of the differentiated results. Should the results obtained for a radar significantly scatter compared to the other radars within the setup, there is a strong likelihood of a hidden systematic error. On the other hand only selected radar pairs should be routinely compared to each other in order to determine all the systematic and random errors. More extensive evaluation including the comparison vs. the other radars would be required in suspicious cases when the results are far out of the normal range.

3. Installation verification and startup

The Radar Comparator Module is always installed together with the RASS-R installation. After installation of the RASS-R toolbox it is necessary that you reboot the target computer.

3.1. Running the background server

See the Data Handling Module User Manual for running in the background server mode.

3.2. Labview
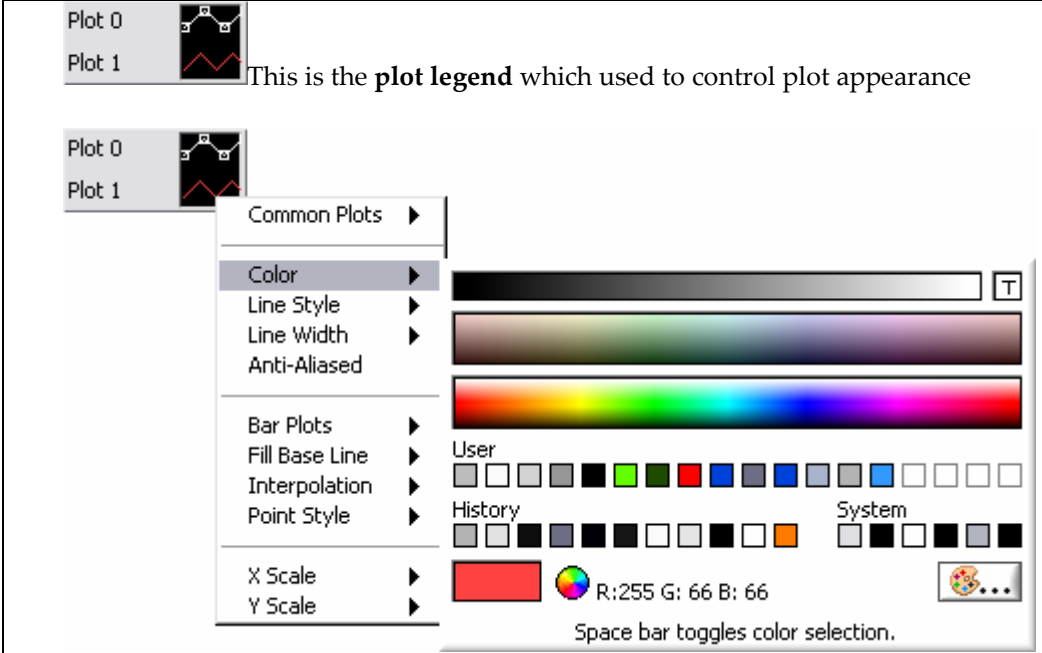
The Radar Comparator Software (RASS-R) is written with LabVIEW graphical programming language.

Most of the controls and indicators used have standard Windows outlook and meaning. The standard Windows file dialogues are extensively used throughout the program. Most of the non-standard dialogues also have obvious meaning and usage. For displaying purposes LabVIEW graphical interfaces are extensively used. These have a universal interface used to change plot types, appearance, scaling, precision, cursor options etc. All these functions are accessible trough popping-up menus and sub-menus. In general each graph may contain a few auxiliary indicators and controls. Some of the available pop-up menus and their options are given below.
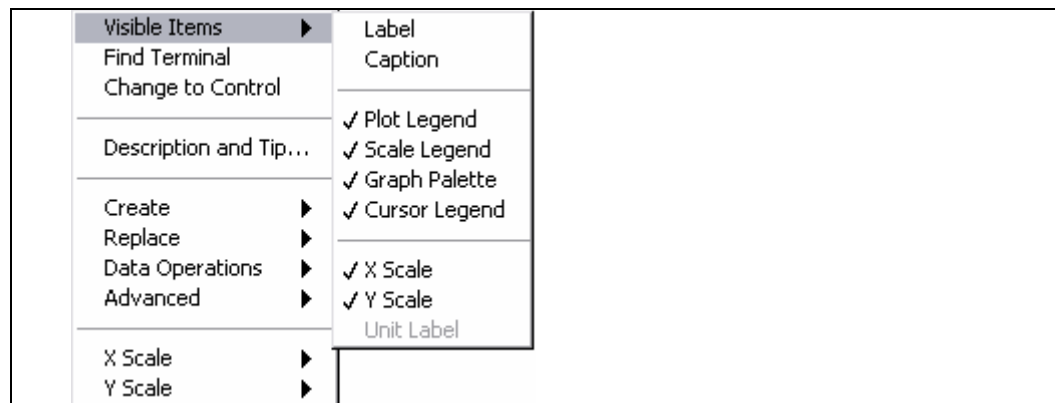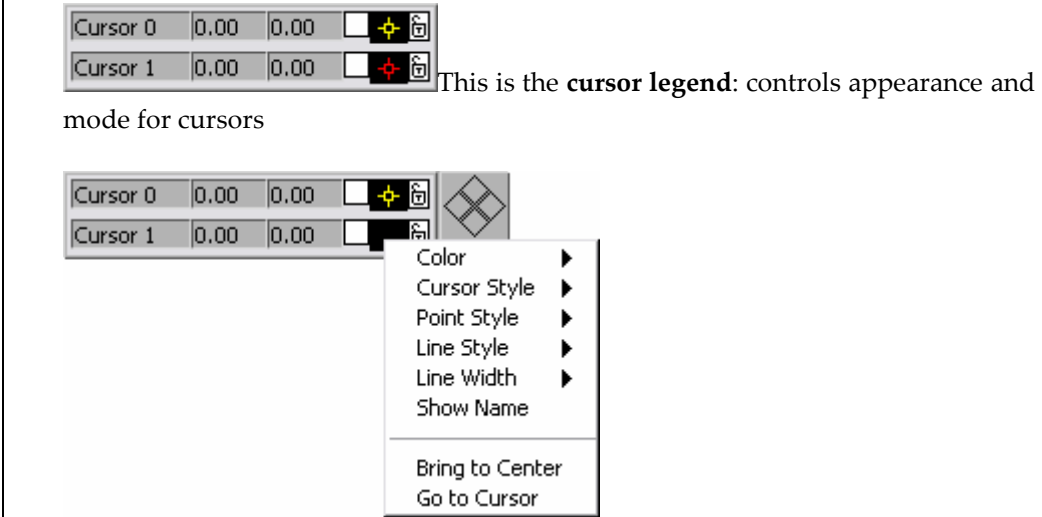
This is the main **pop-up menu**, accessible by a single right button click within the visible area of the graph. Set visible the required graph controls.

This is the **scale legend**: controls scaling, precision, axe names

This is the **graph palette**: controls visible area zooming, and translation, and cursors' motion

This is the **zoom menu** accessible through left click onto the zooming tool button (2D zoom, horizontal, vertical zooming, etc.
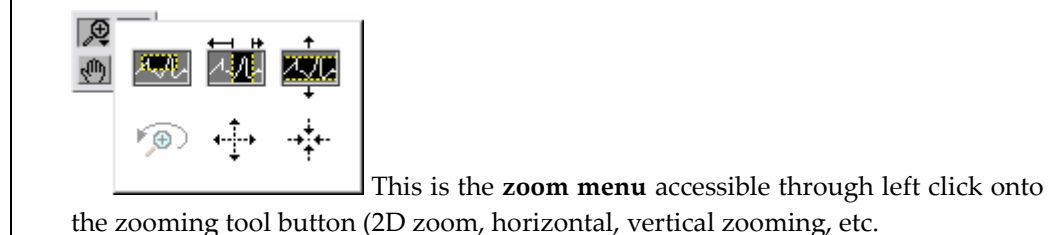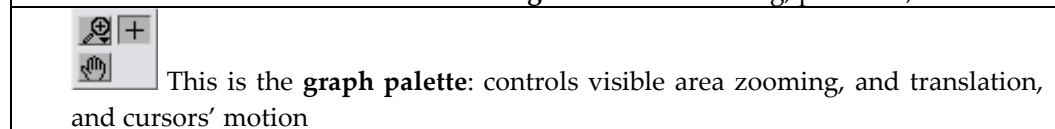
This is the **plot legend** which used to control plot appearance

This is the **plot color menu** accessible through left click onto the plot series symbol

This is the **cursor legend**: controls appearance and mode for cursors

This is the **cursor menu** accessible through left click onto the cursor sign (color, shape, show-hide name)
show name: shows the name of the cursor (handy to looking-up short plot info)
bring to center: brings the selected cursor to the center of the visible plot area
go to cursor: translates the visible plot area to the position centered around the current position of the cursor

Most settings for the cursors, plot types, and scaling options are straightforward and do not require further text explanations. You can modify all the enabled settings using the popping-up menus. The modifications can be stored for the next use when you leave the program. For more detailed information the introductory chapters of LabVIEW User Guide are recommended. Try the following link (http://www.ni.com/pdf/manuals/320999e.pdf) or browse internet for National Instruments Website and search for Labview User Manual.

4. RCM basic operation

4.1. Evaluation Setup Structure

The Radar Comparator Data structures are contained in RC root folder and organized as follows.

The Radar Comparator Module sessions (evaluations) are organized on the folder based principle. RADARDATA, FILTERS, SCREENING and RELIEF are commonly used folders by all the evaluations folders located under RC root. The CONFIG.RC is the program settings file which remembers the last stored settings. REF2.COR file contains the refraction correction look-up-table. Evaluation folders are also stored in RC folder for example CFG1 and CFG2 (see Figure 4.1). CFG1 is the default demo evaluation folder installed by the RASS-R installer. Each evaluation folder contains radar data files (in S4 and/or D6 format) located in the S4 subfolder, subfolder filters, and intermediate format files *.IFF and *.DAT as well as the temporary display files DISPLAY, MONO. Some extra files able to be located in the system might be barometric sounding file(s), eccentricity correction file(s) etc. RADAR.CFG is the evaluation folder configuration file consisting of radars ID the corresponding data files, screening info, timestamp type etc. Each evaluation folder also contains FILTERS subfolder, which should contain less general filters as opposed to RC\FILTERS location.

At start up the Radar Comparator will try to read CONFIG.RC file which contains last used program settings (sizes and/or positions of the windows, colour settings, last accessed evaluation folder, last used filter etc. The default configuration produced by the installer doesn't contain CONFIG.RC file, so that the default configuration settings will be used by the program. To store the current settings exit the program, if you leave the Radar Comparator closing the main window the current settings will be lost.

The *.IFF and *.DAT files are created or modified every time when input data file(s) is(are) read or processed by the program next time you open the RCM the last created *.IFF file will be automatically suggested by invoking the standard dialogue. Cancel and read the data again in the native format (S4 and/or D6) if you are not sure the *.IFF file is up to date.

GYRO1.ASC is a demo file containing the ACP eccentricity measurement. Such a file can be created using the eccentricity measurement with RASS-S PTE v 6.0.3 or newer [1] RGI 59x recording (group "Special", button "Mech"), and the correction file can be created using RGI 59x analysis in the same group. Alternatively the file can be created as a TAB separated text file using one of the standard programs (Excell).
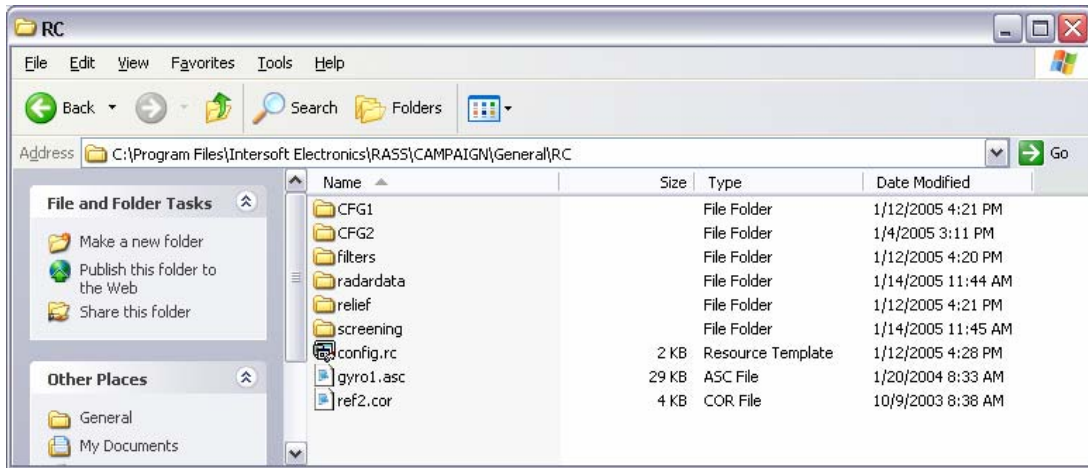
Figure 4.1 RC root folder structure
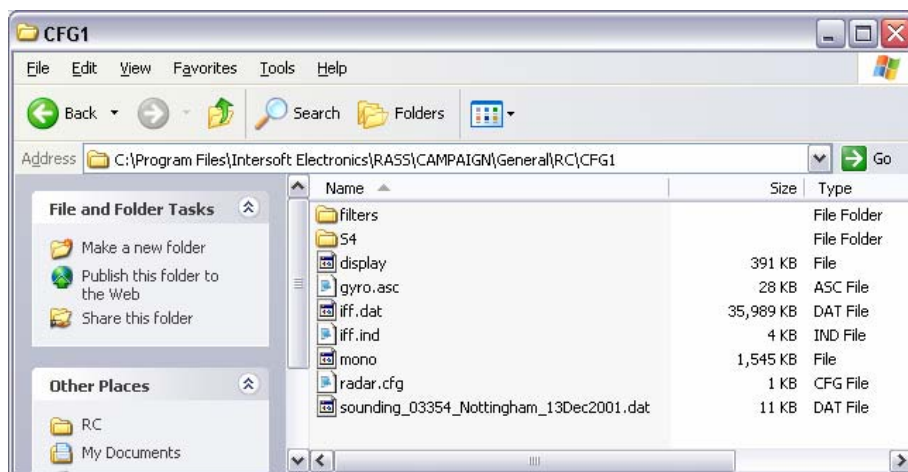
Figure 4.2 CFG1 demo folder structure

4.2. Running the Radar Comparator

First you need to launch RASS-R from the Windows start up menu, pressing the "Campaign Change" control select the current campaign for example **C:\PROGRAM FILES\INTERSOFT ELECTRONICS\RASS\CAMPAIGN\GENERAL**, as given in Figure 4.3.

Press the "Radar Comparator" selector from the "Analysis" menu (see Figure 4.4) selecting the option "Launch".
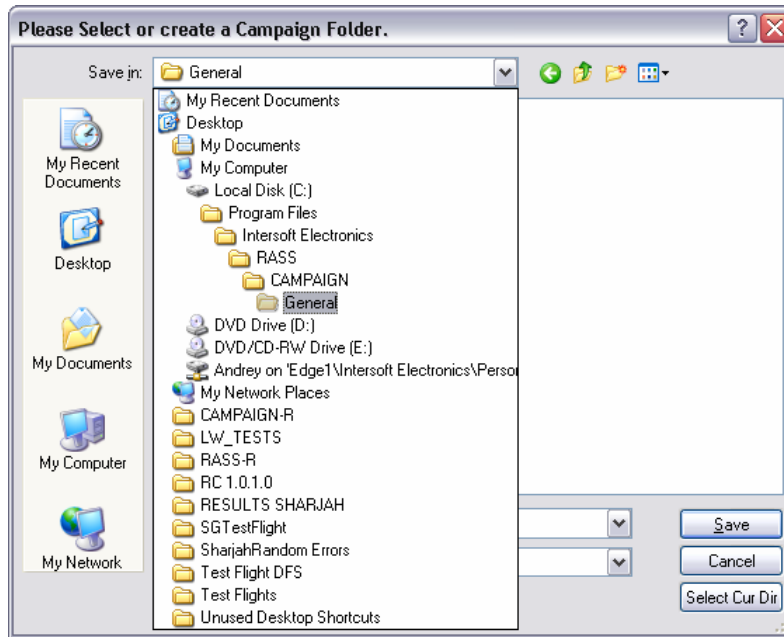
Figure 4.3 Select Current Campaign dialog
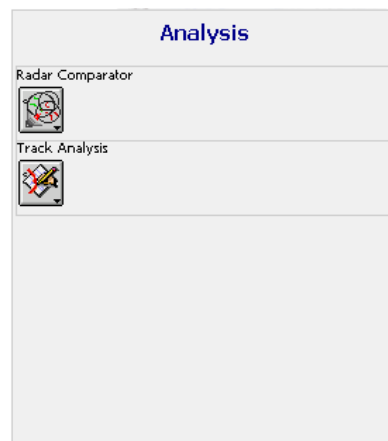
Figure 4.4 RASS-R: Analysis Menu
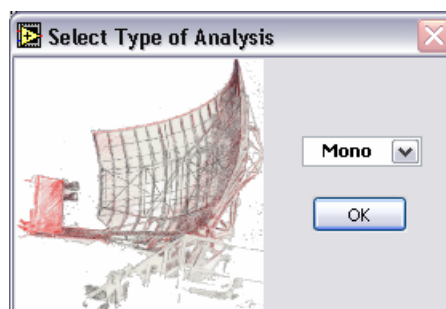
Figure 4.5 Radar Comparator: Startup Selection Dialog

The main window of the Radar Comparator as given in Figure 4.5 will appear. Select **MONO** if you want start a mono-radar analysis session. Select **DUAL** if you want start a dual-radar analysis session.

The **MONO**- radar mode can be used in order to evaluate the Probability of Detection, Code Probabilities, False Plot Rate and Accuracy (random Range and Azimuth errors) generating separate performance figures for PSR-SSR and ModeS, both plot and track data can be processed.

The **DUAL**- radar data processing is generally used to measure the radar systematic errors (Range and Azimuth biases, Range Gain and Timestamp bias) and more accurate measurement of the random errors (Range and Azimuth). The Dual-radar evaluation may be conducted for a cluster of radars always comparing them one-by-one.

4.3. General Utilities and Displays

The Radar Comparator software has a number of general data processing tools available for both types of radar evaluation (Mono- and Dual-). These tools include the following modules:

- Radar Geographic Setup builder. "Radar Geodesic Setup" builder is used to create new and edit existing evaluation setups. Each evaluation data are located in a separate folder

- Radar Data Preprocessor. "Preprocessor" corrects the input data for a number of possible non-specific errors, i.e. errors neglected by the used mathematical model but able to have the direct influence on the accuracy of the measurement

- Main Window. "Main Window" contains a number of common controls located in Tab SETUP. MONO and DUAL Tabs contain specific controls and indicators respective to mono-radar and dual-radar evaluation types

- XY Radar display. This generic window is used for Mono- and Dual- radar displays. User can easily redefine amount and type of the data presented on the display

- Plot(Track) info display. This window is used to access the plot (track) information.

- Filter. The filter is used to create, edit, load and store various filters. The filter files can be stored in RC\FILTERS for most general filters and in subfolders FILTERS of the corresponding evaluation folder for more specific filters.

MAIN WINDOW
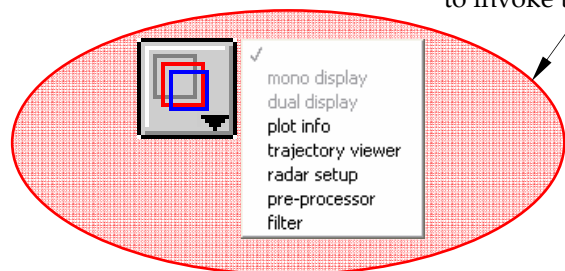
to invoke the tools and displays use

✓
mono display
dual display
plot info
trajectory viewer
radar setup
pre-processor
filter

Common Tools

MAIN (MONO)
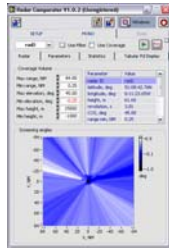
MAIN (DUAL)
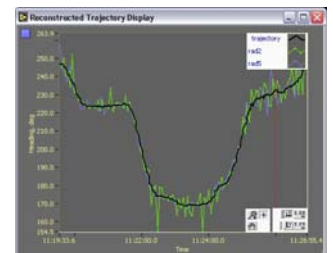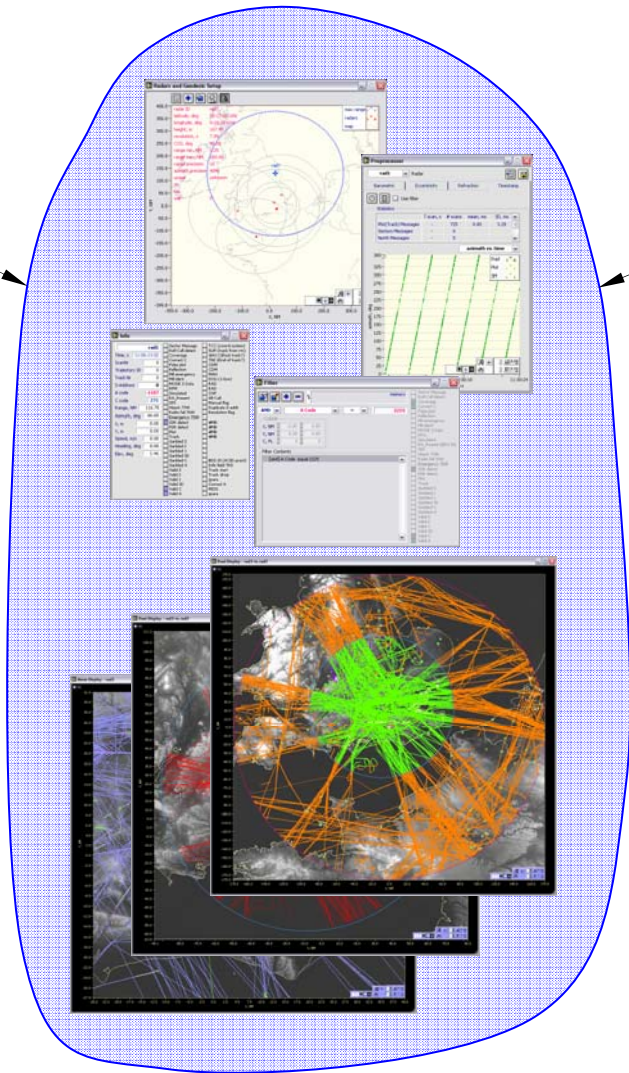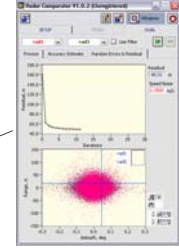
Figure 4.6 RCM Windows Structure

4.4. General Utilities and Displays: Radar and Geodesic Setup

Press the "Windows" control and select "radar setup" option to open the radar setup configuration window, as given in Figure 4.7. The "Radar and Geodesic Setup" window contains controls and displays to create new (edit existing) evaluation setups, new (edit existing) radar parameter files, modify radar configuration lists and the data file assignment, select source files, and look-up existing setups. For the detailed description address please to RCM: Radar and Geodesic Setup
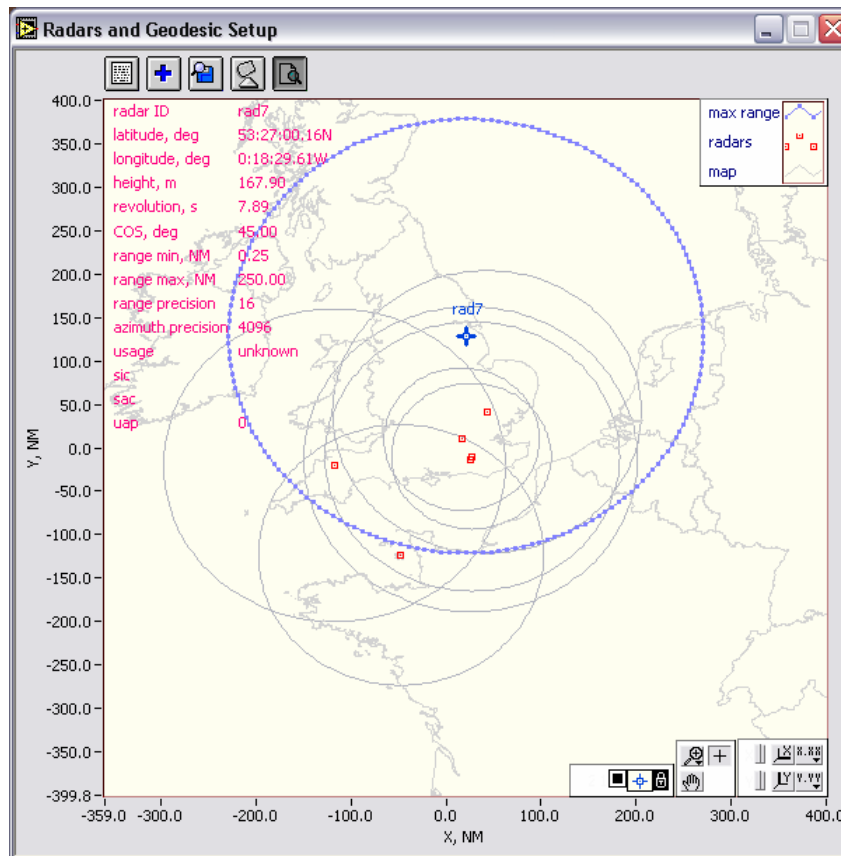
Figure 4.7 Radar and Geodesic Setup Configuration Module

4.5.   General Utilities and Displays: Main Window: Selecting Type of Analysis, Invoking Tools, and Exiting the program

The main window contains 3 Tabs (SETUP, MONO and DUAL). In Mono-radar evaluation mode SETUP and MONO are enabled, in dual-=radar evaluation mode SETUP and DUAL are enabled.
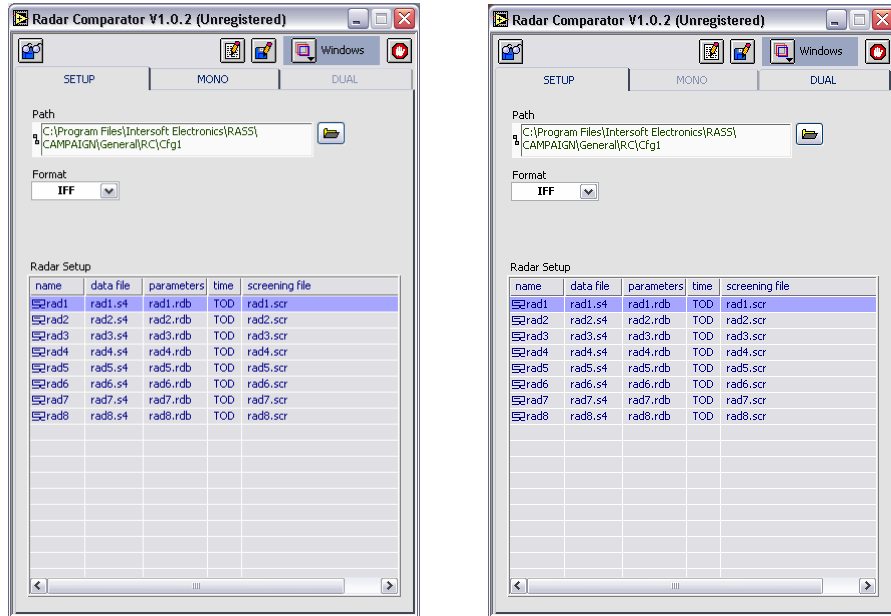
Figure 4.8 Radar Comparator: Main Window in MONO and DUAL modes

The main window contains the following controls

         Load the radar data files pressing the "Load Files" control, depending on the specified type you will be prompted to use the current *.IFF file, or radar data file in its native format (S4 or D6). The native format files (S4 or D6) are not modified by the program, *.IFF file on the contrary may be processed in view to apply corrections (barometric etc.). If you are not sure about the processing history of the current *.IFF file use the native format files.

         SASS-C users in order to have an independent result might want to convert SASS-C compatible formats to the Radar Comparator file formats. This is made possible implementing MADREC to S4 convert tool. Press the "Convert MADREC to S4" control to select MADREC source file and the corresponding S4 target files. As soon as these are generated by the converter you can readily use them for analysis with the Radar Comparator.

         You might want to store processed files in view to use these for other purposes (for example to investigate them in RASS-S Inventory). Press the "Save Corrected" control and follow the proposed options. The word "corrected" means the barometric correction available from preprocessor. The RC evaluation mode must be set to MONO. You have to run Pre-processor first and correct the selected radar, updating the *.IFF file.

         Press the "Windows" control and select one of the following options; mono display, dual display, plot info, trajectory viewer, radar setup, pre-processor, and filter as shown below
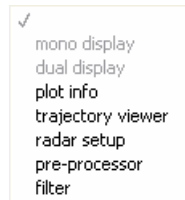
- mono display opens XY display window (available in mono-radar evaluation mode)
- dual display opens XY display window (available in dual-radar evaluation mode)
- plot info opens the plot info display window
- trajectory viewer opens the (reconstructed) trajectory display window
- radar setup opens the radar and geographic setup window
- pre-processor open the preprocessor window
- filter open the filtering window

 You may want to modify some settings (sizes of the display windows, color settings, current evaluation path and filter). The modifications will be stored for the next use when you leave the program pressing the "Exit" control. If you do not want to store the current program settings simply close the main window.

Table 3.　　　　Main Window: SETUP Tab: field descriptors

Field	Description
Path	Shows the current evaluation path, see the structure of an evaluation folder
Radar Setup	List of the radars together with the corresponding data files, parameter files, etc.
Format	S4, D6 or IFF (Index File Format), automatically created from S4(D6) files for faster data access. At startup IFF format is suggested and the corresponding file dialog is invoked. Press Cancel and select another format if required.

For detailed operation description in MONO and DUAL modes see further RCM: Mono-radar Evaluation.

4.6. General Utilities and Displays: Preprocessor

The radar data preprocessor has been primarily developed to prove importance of the radar data correction (especially barometric correction and eccentricity correction) for the SASS-C users. These errors were shown to be significant [1] and the corresponding corrections should be performed in order to produce more accurate results in multi-radar evaluation campaigns.

 Press the "Windows" control and select "pre-processor" option to open the radar pre-processor window. The "Pre-processor" window contains controls and displays to evaluate various types of the errors and to correct the data if required.

 To view the correction log file (list of the performed corrections). Only the current session of the pre-processing.

To update the current *.IFF file in order to use the corrections and proceed further with the analysis using other Radar Comparator tools and utilities. If you leave the Pre-processor closing the window without updating the IFF file, the corrections are lost.

The Pre-processor has Tab Selector with the following options (Barometric, Eccentricity, Refraction, Timestamp) according to the required type of the correction
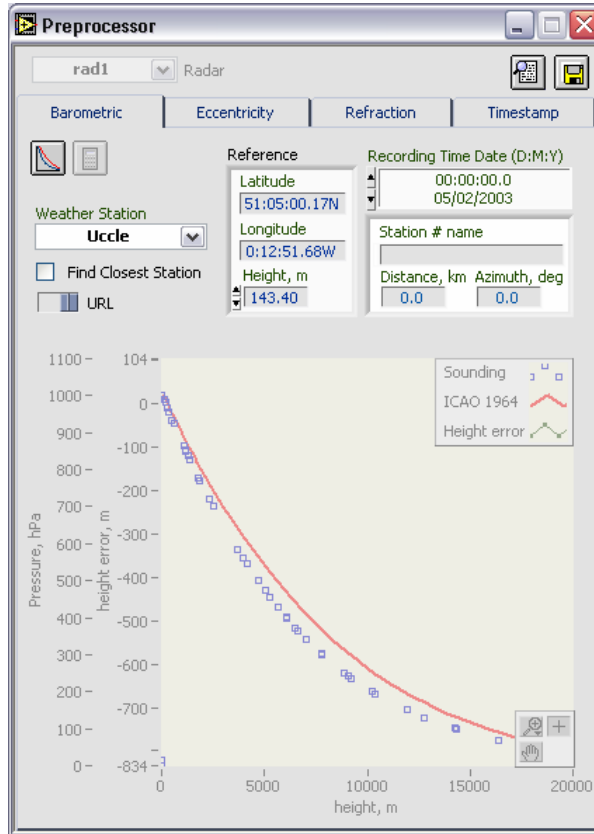
Figure 4.9 Radar Comparator: Preprocessor (view of the Barometric correction Tab)

For the detailed Pre-processor operation see further RCM: Pre-processor

4.7. General Utilities and Displays: Filter

Press the "Windows" control and select "filter" option to open the filter configuration window, as given in Figure 4.10. The "Filter" window contains controls and displays to create new (edit existing) filters, create and modify temporary filters. The utility is global and applied everywhere where the "Use Filter" is pressed
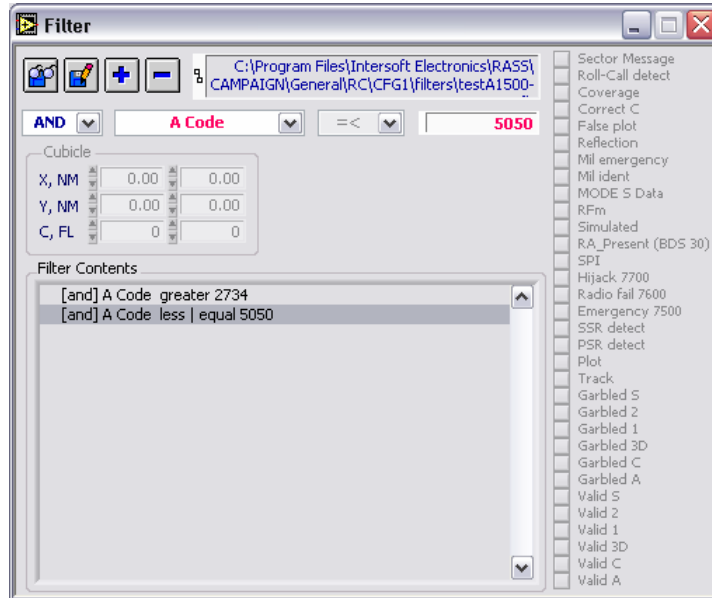
Figure 4.10 Filter Utility

The filter is designed to filter IN(OUT) groups of plots (tracks), and not filtering individual plots (tracks). Of course the individual plot message filtering is also possible applying multi-condition filtering. For the detailed Filter operation see further RCM: Filter

4.8. General Utilities and Displays: Plot (Track) Info Viewer

Press the "Windows" control and select "plot info" option to open the plot (track) info viewer, as given in Figure 4.11. The "Info" display window contains indicators, showing the most important fields in the plot (track) message. The "Info" display window is updated every time when the plot addressing cursor in one of the multiple displays allowing the plot info query, is changed.

RASS-R Radar Comparator Module

Error! No text of specified style in document.
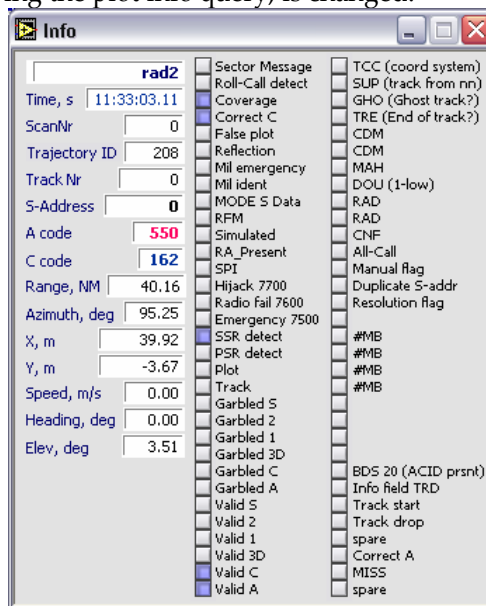
Figure 4.11 Plot (Track) info Viewer

Note: Not all the displays or data series are cross-referenced with the "Info" display window

4.9. General Utilities and Displays: Trajectory Viewer

Press the "Windows" control and select "trajectory viewer" option to open the reconstructed trajectory display, as given in Figure 4.12and Figure 4.13. The "Reconstructed Trajectory Display" display raw data originating from both radars as well as the reconstructed trajectory. Two types of presentation are available: heading (as a matter of fact the unwrapped heading is displayed) vs. time, and speed vs. time. The reconstructed trajectory typically demonstrates 5 to 10 times in the noise reduction both for speed and heading, which is important to have confidence in the method and use the reconstructed trajectory as the reference for the accuracy measurement. If you see the noise on either speed or heading for the reconstructed trajectory is comparable with the raw data, you must double check the configuration setup, radar positioning etc. The accuracy result (random range and azimuth error) is likely to be untrustworthy in such cases. Another indicator that might be used for the monitoring of the quality of the reconstructed trajectory is the "Speed Noise" indicator (Tab "DUAL", Sub Tab "Random Errors and Residual"
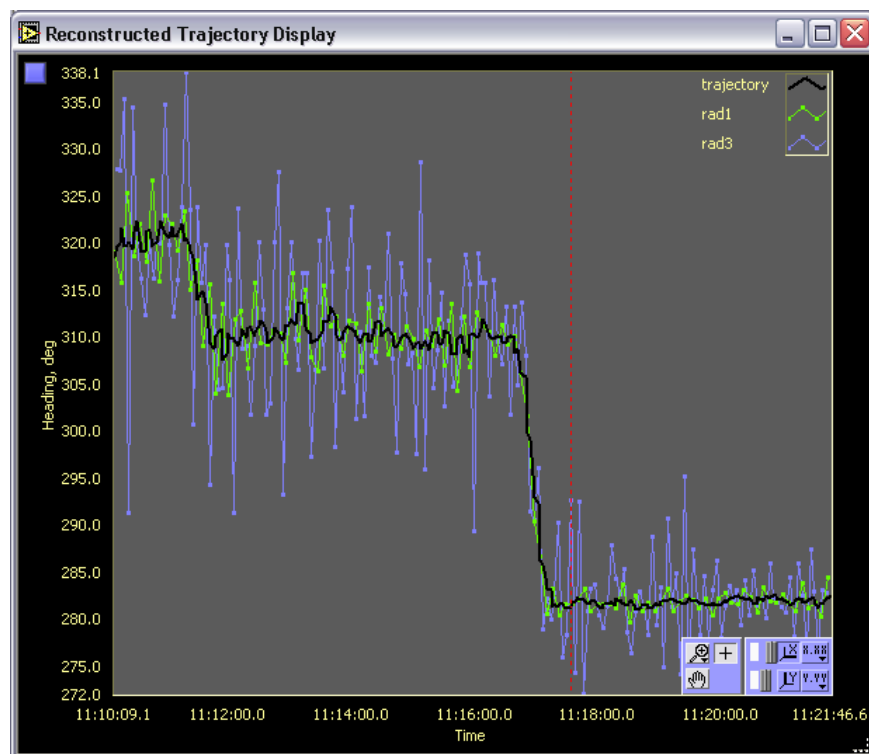
Figure 4.12 Reconstructed Trajectory Display Viewer (Heading)
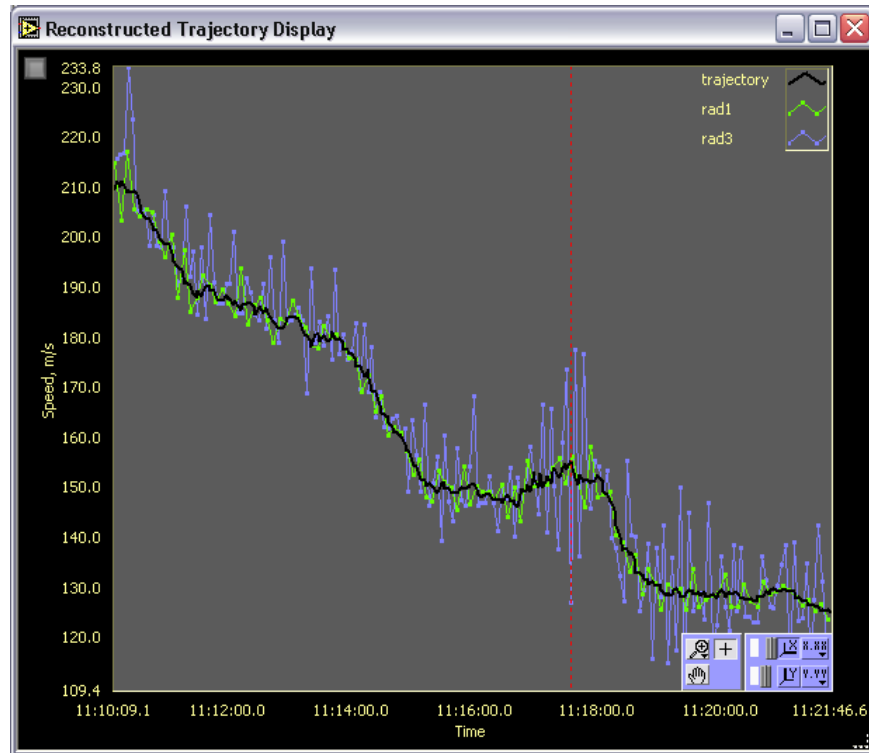
Figure 4.13 Reconstructed Trajectory Display Viewer (Speed)

Note: The "Reconstructed Trajectory Display" is cross-referenced with the "XY dual display" window

5. RCM: Radar and Geodesic Setup

The "Radar and geodesic setup" window contains the following press-button controls. Press the corresponding controls in order to produce the corresponding action:

Creates a new evaluation folder. Type the name you want to use and press OK

Adds new or edit existing radar parameters file. You may want to edit existing radar parameters files or add new radars. You use the standard windows copying functions to make copies of the existing files, and then edit those.

Copies the selected source file(s) to the evaluation folder tree. Each time one file is copied to "RC\EVALUATION\S4" subfolder

Creates (edit) radar configuration parameters. The radar configuration parameters include the following files: (radar parameter file, radar source file, radar screening file, timestamp type) as given in Figure 5.2. Use the standard dialogs to select the radar parameter, source and screening files, fill in the timestamp type (time of detection "d", or time of recording "r"). This menu actually defines the multi- or mono-radar setup.

Looks-up the radar parameters info viewer (default setting is ON). The radar parameter viewer is located in the upper left corner of the display.
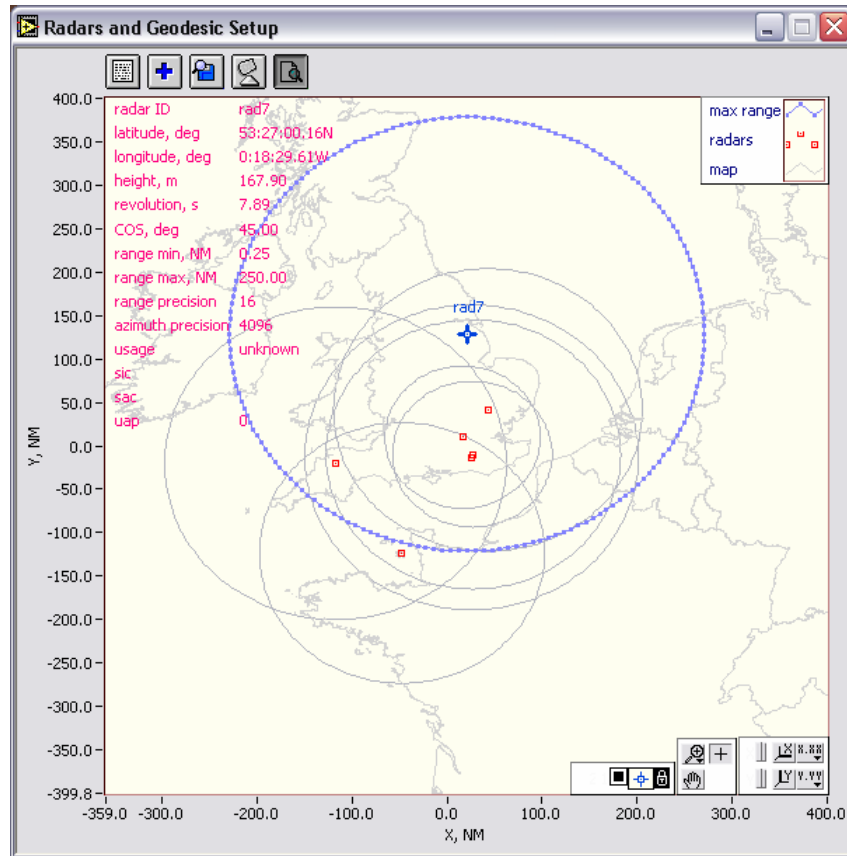
Figure 5.1 Radars and Geodesic Setup Window
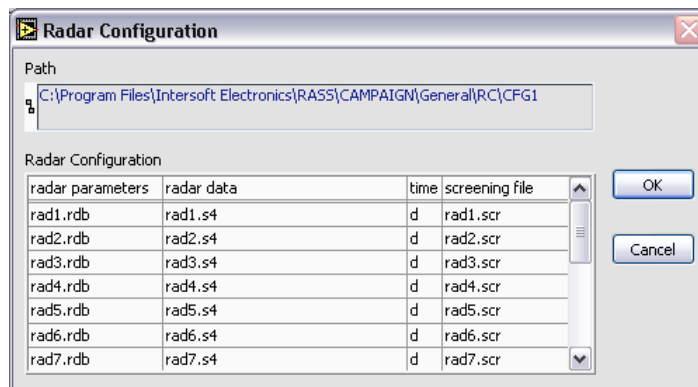
Figure 5.2 Radar Configuration Editor Window

6. RCM: Pre-processor

6.1. Barometric correction
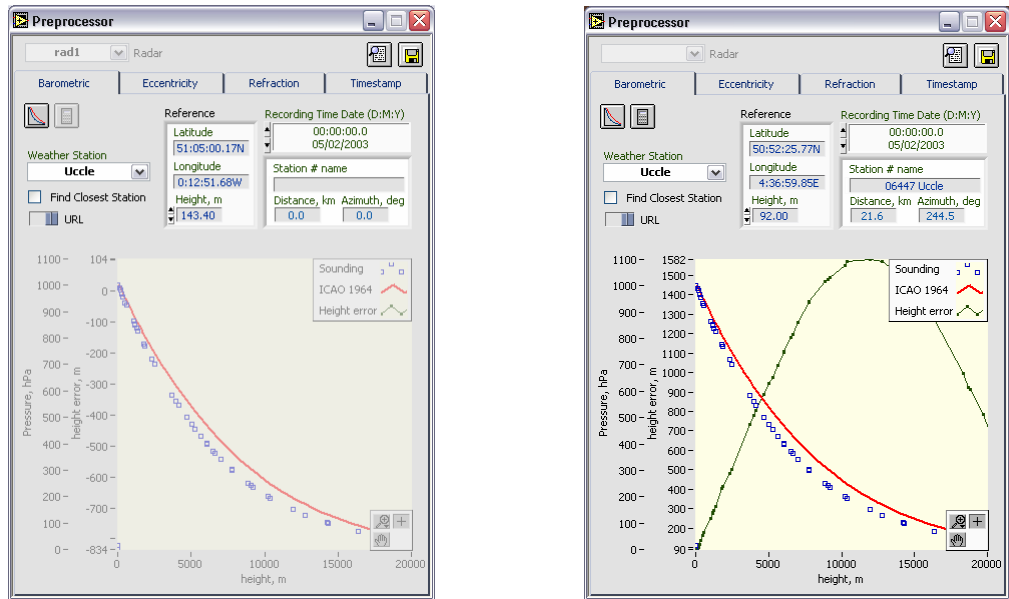
Figure 6.1 Pre-processor: Barometric Correction (left: startup screen, right: barometric data file is loaded)

The Tab "Barometric" selector consists of the following controls and indicators:

    Retrieves weather balloon soundings data over the network, or from the previously stored file.

    Corrects all the plots with validated C-code for the measured barometric height error. When the correction is done the control will be dimmed permanently to avoid correcting the same file again. Similar protection means have been developed for the other types of corrections: timestamp, refraction, and eccentricity.
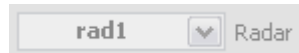
    The radar selector is disabled, for all the data will be corrected in the same way. The other fields in the barometric tab have the following meaning.

Field	Description
Recording date time (input)	Date and time of the recording (not of the processing), this field is used to download weather balloon sounding data to correct aircraft height (C-code)
Station (input)	List of the available meteorological stations (Europe). Use "Find Closest function" for the rest of the world
Find closest (input)	When selected, the station selector is disabled and the software searches for the closest to the reference station from the list, station ID and its position from the reference is given in retrieved station

	field
URL:file (input)	If URL is set the barometric data are retrieved from internet, if file is set a text file containing the barometric data can be selected to be used for the correction, this text file can be produced using the standard browser accessing URL: http://weather.uwyo.edu/upperair/sounding.html (an example of such a file is given below)
Reference (input)	Geodesic coordinates of a point selected as the reference for the barometric correction
Retrieved station (indicator)	Weather station ID and its position in terms of the offset and azimuth vs. the reference
Barometric graph (indicator)	Graph containing 3 curves: *ICAO 1964 Standard Atmosphere*, actual height vs. pressure measurement (balloon sounding), and the height error due to this difference.

The graph indicator stays dimmed till the moment the actual balloon sounding data are received. Pressing the "Retrieve Barometric Data" control will launch the web browser and automatically download the appropriate sounding file from the above site, as shown below in. The window contains the following controls:

 Navigate to Atmospheric Soundings Home Page. As opposed to the geographic selector functions available in "Pre-processor" window, you can use the browser capabilities and access the sounding data navigating to Atmospheric Soundings Home Page. To do so press the "Atmospheric Soundings Home" and follow the available links. Navigate to a desired station (region of the world) using the cursor, as the cursor goes over a station its identity is shown below (for example 10410 Essen (EDZE)), specify the date and hour). Click to retrieve the data, a new Internet Explorer window will be opened and download the corresponding data. Save the data as text or html. You will be able to retrieve this afterwards setting the "URL/File" control to "File" and pressing "Retrieve Barometric Data" control. The specified file will be loaded.

 Save the sounding data file(s) to a disk (might be either text or html). Type the file name and save the barometric sounding data to a disk. Immediately afterward the standard file dialog window will appear. Select the stored sounding file(s), press OK, and the sounding data will be visible on the graph, as given in Figure 6.3.
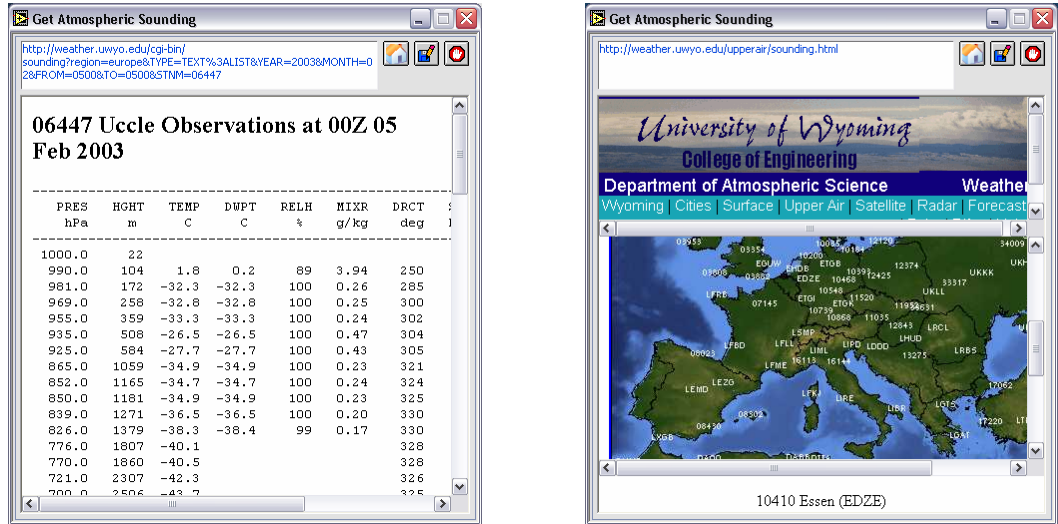
 Exit the browser window

Figure 6.2 Get Atmospheric Sounding Window (Left: download of the data selected, Right: browse worldwide locations)
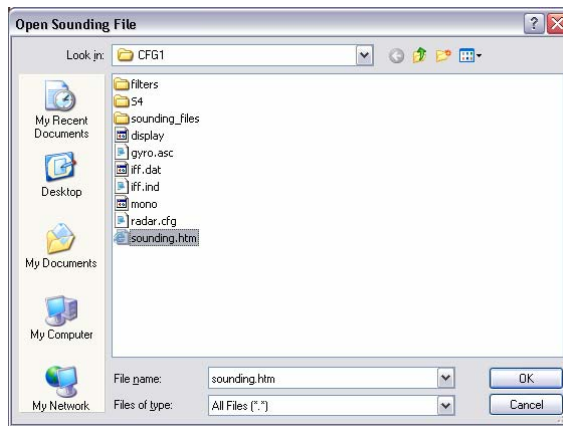

Figure 6.3 Select Sounding File Dialog

The "Correct C-code" control stays dimmed till the data are received from the network and read from the corresponding text or html file. When the data is received the graph indicator will show the sounding consisting of 3 curves as explained in Table 6. The user has to inspect the data integrity and consistency. Some sounding files contain height vs. pressure data only up to a few km high, probably due the balloon damage. In such cases it is advisable not to use the data. Routinely there are two soundings a day in most European countries and USA, at 00:00 and 12:00. However for some regions the data were found to be available only once a week[1]. If sometimes for the selected station the data is unavailable, another station in the neighborhood might be used. In general the pressure vs. height distribution stays nearly the same for hundred kilometer areas. If there was no data transfer effectuated, the graph indicator and "Correct C-code" control stay dimmed.

---

[1] Even the data obtained on the weekly basis is useful to draw a conclusion about the errors that might exist if no barometric correction is applied. In general there are always a number of recordings taken on the dates when the soundings data are available. So that significant discrepancies might be discovered when performing the Radar Comparator Dual analysis with and without the barometric correction. The user must realize that whenever the barometric correction is unavailable the results might be contaminated (range bias and range gain) with an errors of the similar magnitude. A statistical study is required to produce trustworthy estimates for this error.

You can also use any internet browser software on a standalone computer and save the downloaded page text (or html), if you do not have the direct network access on the computer. A sample of the sounding file is given below.

```
<HTML>
<LINK REL="StyleSheet" HREF="/resources/select.css" TYPE="text/css">
<BODY BGCOLOR="white">
<H2>06447  Uccle Observations at 00Z 05 Feb 2003</H2>
<PRE>
-----------------------------------------------------------------------
  PRES   HGHT   TEMP   DWPT   RELH   MIXR   DRCT   SKNT   THTA   THTE   THTV
  hPa     m      C      C      %     g/kg   deg    knot    K      K      K
-----------------------------------------------------------------------
 1000.0     22
  990.0    104    1.8    0.2     89   3.94    250     10   275.7  286.6  276.4
  981.0    172  -32.3  -32.3    100   0.26    285     21   242.2  242.9  242.2
  969.0    258  -32.8  -32.8    100   0.25    300     29   242.6  243.3  242.6
  955.0    359  -33.3  -33.3    100   0.24    302     32   243.0  243.7  243.1
  935.0    508  -26.5  -26.5    100   0.47    304     35   251.4  252.8  251.5
  925.0    584  -27.7  -27.7    100   0.43    305     37   251.0  252.2  251.0
  865.0   1059  -34.9  -34.9    100   0.23    321     38   248.3  249.0  248.4
  852.0   1165  -34.7  -34.7    100   0.24    324     39   249.6  250.3  249.7
  850.0   1181  -34.9  -34.9    100   0.23    325     39   249.6  250.2  249.6
  839.0   1271  -36.5  -36.5    100   0.20    330     39   248.9  249.5  248.9
  826.0   1379  -38.3  -38.4     99   0.17    330     38   248.0  248.5  248.1
  776.0   1807  -40.1                         328     36   250.6         250.6
  770.0   1860  -40.5                         328     35   250.7         250.7
  721.0   2307  -42.3                         326     32   253.5         253.5
  700.0   2506  -43.7                         325     31   254.1         254.1
  583.0   3715  -51.1                         325     30   259.1         259.1
  560.0   3976  -52.5                         325     29   260.4         260.4
  546.0   4139  -53.7                         325     29   260.9         260.9
  500.0   4700  -57.5                         320     31   262.9         262.9
  475.0   5021  -59.7                         320     29   264.0         264.0
  456.0   5277  -61.5                         324     32   264.9         264.9
  430.0   5639  -64.1                         329     37   266.1         266.1
  401.0   6065  -66.5                         335     43   268.3         268.3
  400.0   6080  -66.5                         335     43   268.5         268.5
  372.0   6518  -66.1                         339     53   274.6         274.6
  364.0   6649  -66.9                         340     56   275.3         275.3
  341.0   7040  -69.3                         338     59   277.2         277.2
  302.0   7761  -70.9                         335     64   284.8         284.8
  300.0   7800  -70.5                         335     64   285.9         285.9
  250.0   8890  -69.5                         335     70   302.6         302.6
  243.0   9059  -69.7                         335     72   304.8         304.8
  237.0   9208  -69.9                         335     72   306.7         306.7
  200.0  10220  -69.7                         335     70   322.2         322.2
  194.0  10401  -69.3                         335     69   325.7         325.7
  150.0  11930  -70.1                         335     58   349.1         349.1
  130.0  12770  -71.3                         335     62   361.5         361.5
  101.0  14252  -73.5                         320     60   384.4         384.4
  100.0  14310  -73.7                         320     60   385.1         385.1
   70.0  16390  -75.9                         305     70   421.7         421.7
   50.0  18320  -77.1                         300     72   461.4         461.4
   47.0  18675  -77.6                         300     74   468.4         468.4
   45.6  18848  -77.9                         297     75   471.8         471.8
   39.0  19743  -77.6                         280     82   494.0         494.0
   32.6  20770  -77.3                         277     82   520.9         520.9
   30.0  21250  -74.5                         275     82   541.0         541.0
   24.0  22559  -71.3                         265     72   585.8         585.8
   22.0  23070  -70.1                         255     76   604.2         604.2
   21.0  23343  -71.9                         250     78   607.0         607.0
   20.0  23630  -73.7                         255     80   609.9         609.9
   19.9  23659  -73.7                         255     80   610.8         610.8
   16.7  24689  -71.3                         263     95   649.9         649.9
   16.0  24945  -68.3                         265     99   667.5         667.5
   15.9  24983  -67.9                         265     99   670.1         670.1
   15.4  25174  -65.7                         265     98   683.5         683.5
   15.0                                       265     97
</PRE><H3>Station information and sounding indices</H3><PRE>
                            Station number: 6447
                           Observation time: 030205/0000
                            Station latitude: 50.79
                           Station longitude: 4.34
                           Station elevation: 104.0
                            Showalter index: 10.38
                              Lifted index: 11.58
       LIFT computed using virtual temperature: 11.58
                              SWEAT index: 108.78
                         Cross totals index: 22.60
                       Vertical totals index: 22.60
                         Totals totals index: 45.20
          Convective Available Potential Energy: 0.08
             CAPE using virtual temperature: 0.13
                      Convective Inhibition: -37.69
             CINS using virtual temperature: -37.81
                          Equilibrum Level: 820.79
       Equilibrum Level using virtual temperature: 820.76
                  Level of Free Convection: 829.47
             LFCT using virtual temperature: 829.47
                     Bulk Richardson Number: 0.00
           Bulk Richardson Number using CAPV: 0.01
       Temp [K] of the Lifted Condensation Level: 244.45
       Pres [hPa] of the Lifted Condensation Level: 954.48
              Mean mixed layer potential temperature: 247.74
                  Mean mixed layer mixing ratio: 0.57
                  1000 hPa to 500 hPa thickness: 4678.00
Precipitable water [mm] for entire sounding: 0.66
</PRE>
<P><A HREF="/upperair/indices.html">Description of the indices.</A>

<P>
<FORM>
<INPUT CLASS="button" TYPE="button" VALUE=" Close this window "
```

```
 onClick="window.close();">
<INPUT CLASS="button" TYPE="button" VALUE=" Select another map "
 onClick="window.blur();">
</FORM>
<HR SIZE="1"><I>Interested in
<a href="http://www-das.uwyo.edu/new_students/index.htm"
target=_top>
graduate school</a> or an
<a href="http://www-das.uwyo.edu/PhysicsPlus.htm" target="_top">
undergraduate degree</a> in meteorology?</I>
<HR SIZE="1"><FONT SIZE="-1">
Questions about the weather data provided by this site can be
addressed to <A HREF="mailto:ldoolman@uwyo.edu">
Larry Oolman (ldoolman@uwyo.edu)</A></FONT>
<HR SIZE="1">
<SCRIPT TYPE="text/javascript">
<!--
window.focus();
// -->
</SCRIPT>
</HTML>
```

After performing the required corrections use the following controls in the "Pre-processor" window:

Verify the current status of the corrections.

Updates the current *.IFF file (disk) with the performed corrections.

pressed. If the user chooses to close the preprocessor window without updating the *.IFF file **ALL THE CORRECTIONS WILL BE LOST!**

6.2. Eccentricity correction
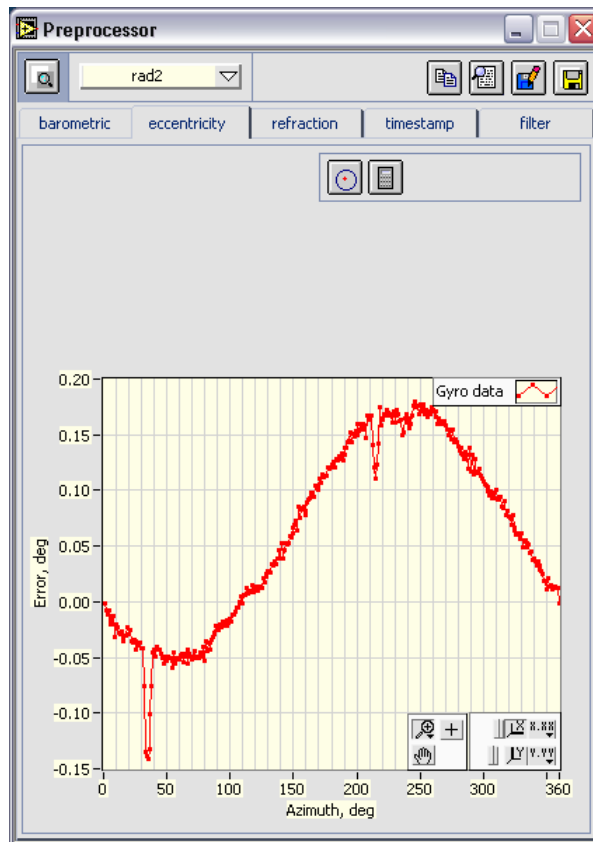
Figure 6.4 Pre-processor: Eccentricity Error Correction (*this is a real GYRO ACP eccentricity measurement*)

The eccentricity correction tab selector contains the two following press-button controls:

          Loads the eccentricity file (dialog)

          Corrects the eccentricity (dimmed whenever there is no eccentricity data file selected, or the correction is already done)

Press the "Select eccentricity file" control and select the file containing the radar eccentricity data, generated using an eccentricity measurement with the RASS-S PTE v 6.0.3 or better: the toolbox RGI 59x recording (group "Special", button "Mech"). The correction file is created using the toolbox RGI 59x analysis, a practical example of the eccentricity figure is given in Figure 6.4, the "Correct" control will become enabled once the eccentricity data is loaded from the selected file. The radar selector must be set to the radar to which the selected eccentricity file corresponds. Once the selected radar is corrected, the "Correct" control will be dimmed permanently for the current preprocessing session. If a wrong correction was performed just close the Pre-processor window, re-open it and repeat required corrections again.

After performing the required corrections use the following controls in the "Pre-processor" window:

Checks out the current status of the corrections.

Updates the current *.IFF file (disk) with the performed corrections.

6.3. Timestamp Analysis and Correction
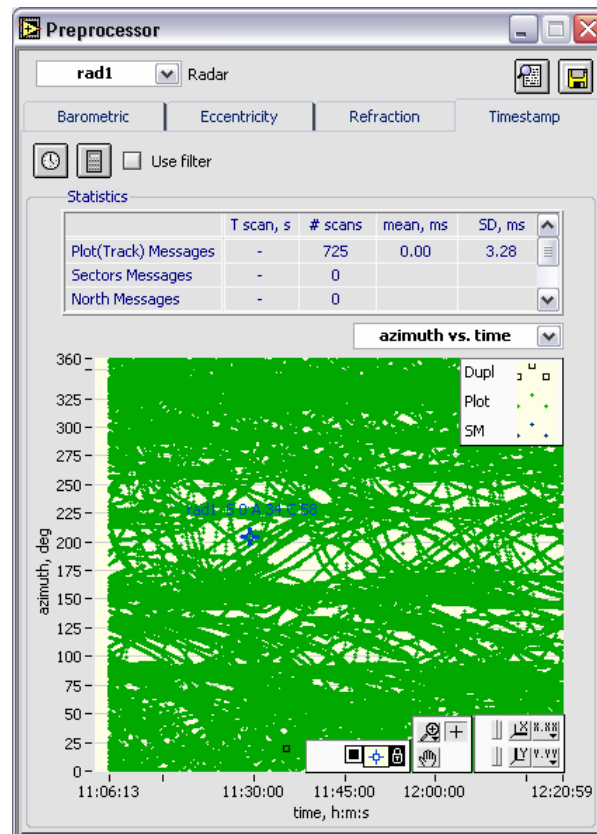
Figure 6.5 Pre-processor: Timestamp Statistics and Correction

Based on the limited multi-radar data statistics the timestamp correction (correction of the random timestamp error) always improves multi-radar (dual-radar) evaluation results for the range accuracy. On the other hand investigating the radar plot (track) message dynamics in time provides the powerful tool for the radar diagnostics and troubleshooting.

The timestamp tab selector contains the following controls:

Runs timestamp analysis and statistics

Corrects the random timestamp error

Use filter Filter IN or OUT for the timestamp analysis selected messages (use "Filter" window to create /modify the required filter. Radars in general produce asynchronous messages for RFM (remote field monitors) and synthetic targets. These data must be skipped for timestamp analysis. The timestamp error is calculated as follows. Plot messages for a number of rotations are grouped to produce a linear regression formula in order to measure the actual antenna rotation speed. Using this value and the azimuth of the plot the ideal timestamp value can be obtained. Asynchronous targets may significantly pull the measured antenna rotation speed away from its true value and generate unwanted errors in the timestamp error measurement.

rad1 Radar The radar selector is enabled for the timestamp analysis is done separately for each radar.
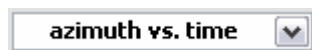
azimuth vs. time Timestamp analysis display type control

The "Statistics" indicator shows the timestamp statistical quantities, providing immediate insight regarding the presence of plot, sector, and north messages, their statistical parameters relative biases and so forth.

The graph indicator presents a graphical view of various timestamp parameters using one of the following plot types (azimuth vs. time, error vs. time, error vs. azimuth, and plot density vs. time). The time means timestamp, the error means timestamp error, the plot density is calculated per scan. This later view is particularly useful to detect scan based misses. Plot and sector messages are shown in the graph if they are present, duplicated messages (multiple messages with the same content)

The timestamp display has a cursor and if the display cursor name option is enabled, the cursor will produce the short info about the plot, containing radar ID, detection time, A and C codes. For additional plot info data the "Plot Info" window must be active, its content is updated with the plot data corresponding to the present cursor position.

The "Correct Timestamp" control is dimmed till the timestamp statistics for the selected radar is calculated.

The method for calculating the timestamp jitter is the following. It is assumed that the antenna conducts a uniform rotation. Given that, the unwrapped plot azimuth vs. the timestamp must be a linear function. Using typically a few rotations of the antenna the linear regression fit (intercept and slope) are produced, the timestamp jitter (error) is calculated as the deviation of the actual timestamp from the established linear fit. For modern radar the timestamp jitter of 3-5 milliseconds standard deviation is a typical result. Significantly higher timestamp jitter can be encountered, especially for the formats that do not carry timestamp information. The timestamp is then produced by the recording device, which depending on the data load may generate errors of around a few seconds magnitude. Useless to say that such a data can not be used for any multi-radar evaluation at all. Timestamp correction algorithm deduces the measured errors from the actual timestamp value. Attention! The tool may not be able to measure the timestamp errors comparable with or exceeding the time of the antenna revolution especially when the total plot density is low, or traffic pattern vs. azimuth is very restricted due to the mountains for example. However this kind of errors can be visualized using the "XY display" window taking advantage of the scan number values calculated by the tool as explained further.

Timestamp accuracy is very important for multi- (dual-radar) analysis, for timing error becomes the positional error. This error might seem to be less critical than the other error types discussed in this manual. Nonetheless one must realize that the timestamp jitter of 100 millisecond (standard deviation), is typically converted to 2-5 m random range error depending on the radar range accuracy and rotation speed of the antenna.

After performing the required corrections use the following controls in the "Pre-processor" window:

Checks out the current status of the corrections.

Updates the current *.IFF file (disk) with the performed corrections. If the user chooses to close the preprocessor window without updating the *.IFF file **ALL THE CORRECTIONS WILL BE LOST!**

6.4. Timestamp Analysis and Correction: Typical Cases

Radars often produce asynchronous messages (remote field monitors and asynchronous synthetic target messages are often asynchronous i.e. their timestamp and azimuth don't match according to the antenna rotation speed). Asynchronous targets may significantly deviate the measured antenna rotation speed from its true value and generate unwanted errors in the timestamp error measurement. THESE DATA MUST BE SKIPPED FOR TIMESTAMP ANALYSIS! (for details see further Filter Editor Utility)

Below several typical examples of timestamp analysis are given.

a)

b)

c)

RASS-R Radar Comparator Module

Error! No text of specified style in document.

d)
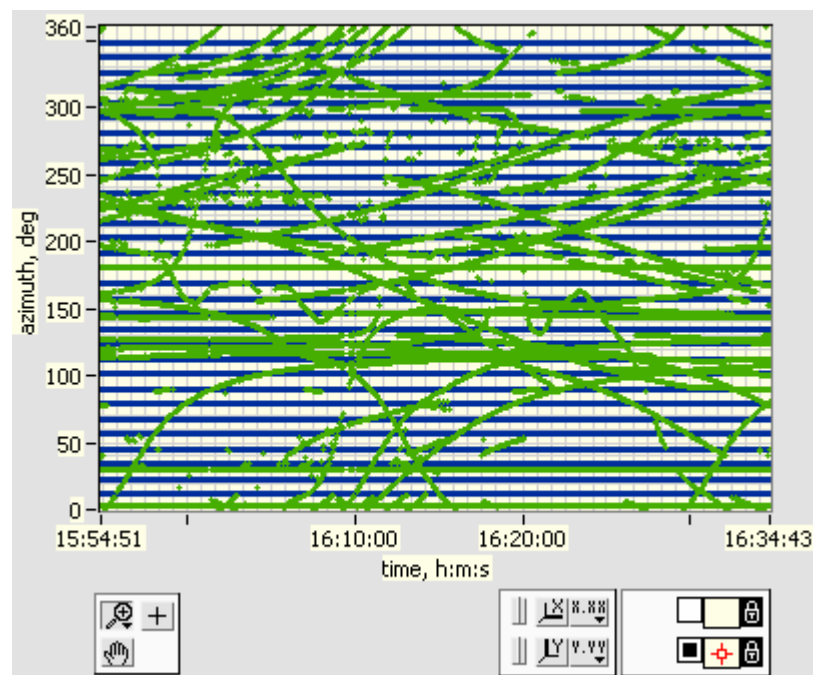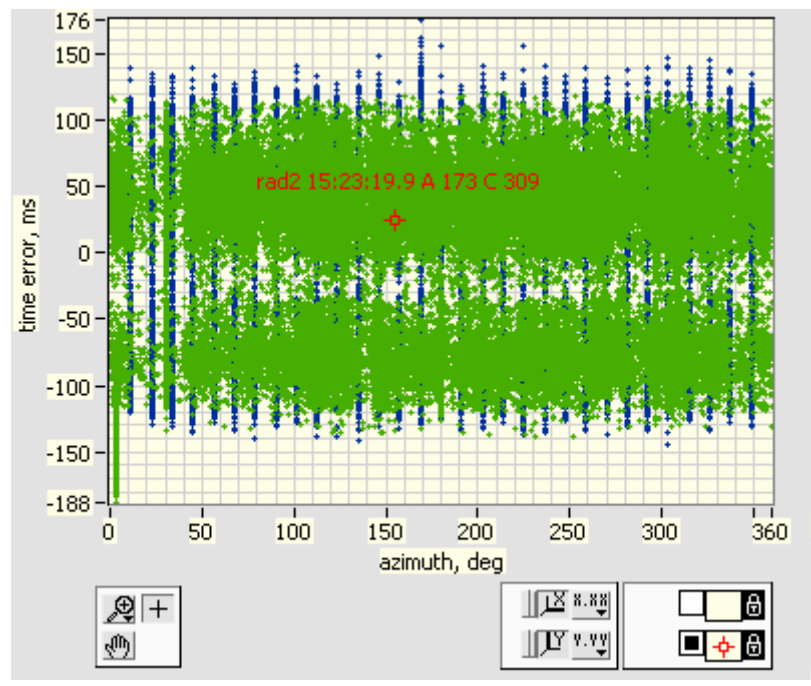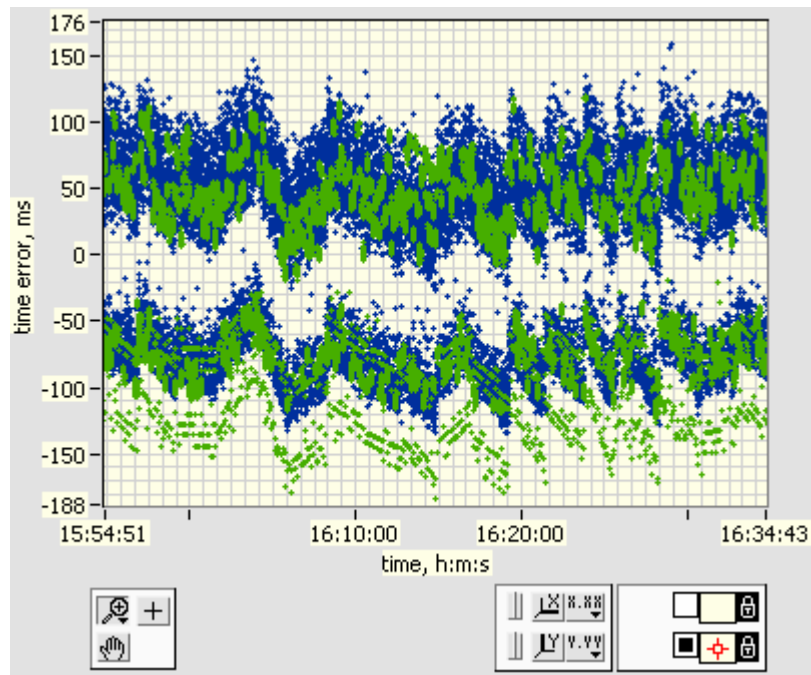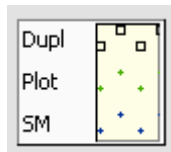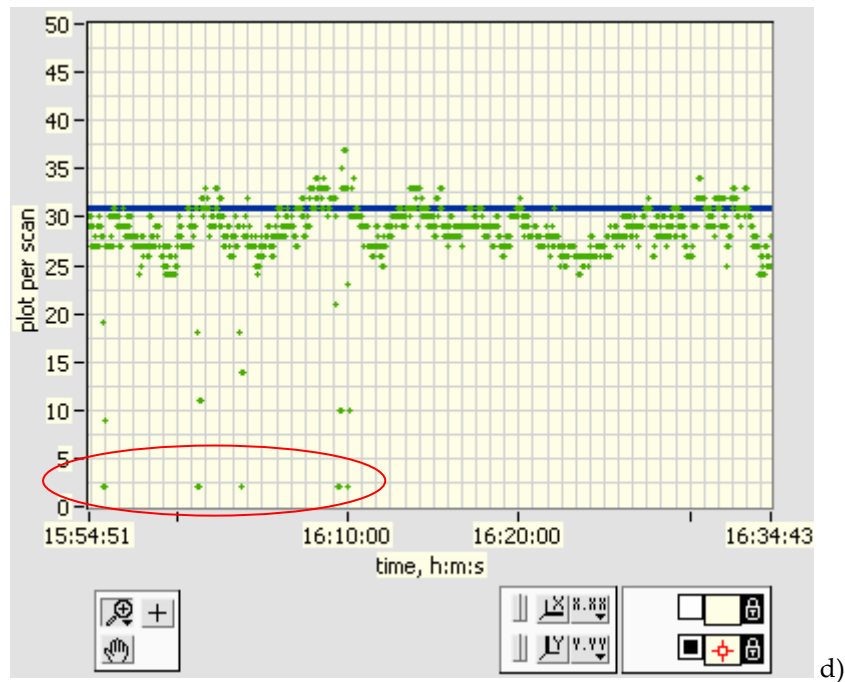
Three plot types are monitored: Duplicated, Plot (Track), and Sector Messages

Figure 6.6 Pre-processor: Timestamp Statistics Display Types: a) Azimuth vs. time (both target messages and sector messages are present), b) Timestamp error vs. time, c) Timestamp error vs. Azimuth, d) Plot per scan vs. time (a number of "empty scans are visible, this type of the radar malfunctioning is extremely hard to spot on PPI).

The timestamp display has a cursor and if the plot info window is active, the current plot (track) information can be viewed.

Performing timestamp statistics (pre-processor) is directly beneficial for both types of the analysis (MONO and DUAL). First of all the user should ascertain the integrity of the recording, should the stream be interrupted (a number of empty scans), the reason for such an event(s) should be established prior to conduct further analysis.

The method for calculating the random timestamp error is the following. It is assumed that the antenna conducts uniform rotation. Given that the unwrapped plot azimuth vs. the timestamp must represent a linear function. Using data of a number of antenna rotations the linear regression fit is produced, the timestamp random error is calculated as the deviation of the actual timestamp from the established linear fit. For modern radar the timestamp error of 3-5 milliseconds (in terms of standard deviation) is a typical result. A significantly large timestamp error was encountered on a number of radars, and an example with the 80 milliseconds standard deviation can be observed for example on "rad2" in "CFG1" demo evaluation folder. Timestamp correction algorithm deduces the measured errors from the actual timestamp value. Attention! The tool may not be able to accurately measure timestamp errors comparable with the period of the antenna revolution. However this kind of errors can be visualized using the Mono Display, taking advantage of the scan number values as explained further. Timestamp accuracy is very important for multi-radar analysis, for timing errors are converted to positional errors.

This error might be less critical than the others nevertheless one must realize that the timestamp jitter of 100 ms (in terms of standard deviation) is typically converted to 2-5 m random range error depending on the radar range accuracy and rotation speed of the antenna. Even if this error is not corrected in Pre-processor the user will typically have more insight in problematic cases, where not only the general statement about the problem is to be done but also the underlying reasons for the malfunctioning must be found.

6.5. Refraction correction
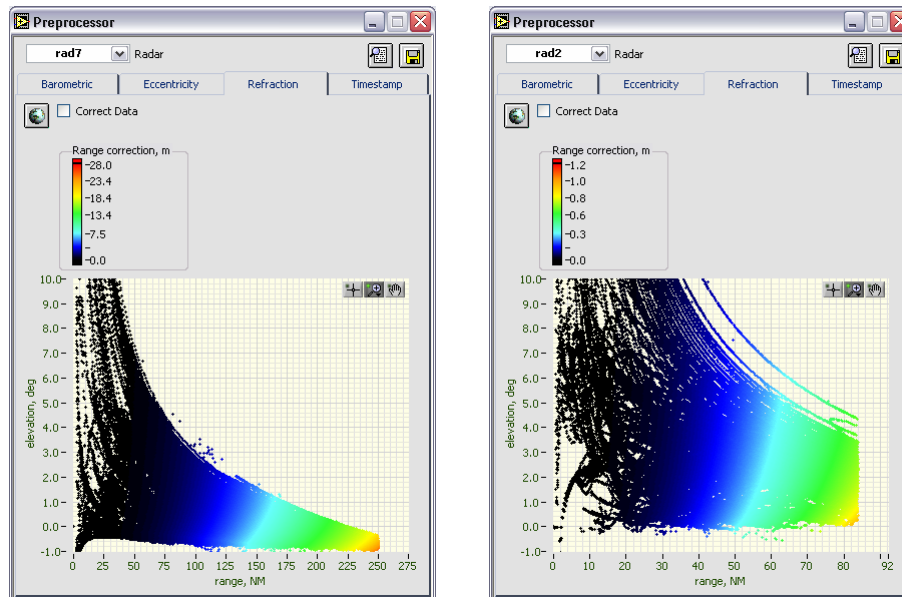
Figure 6.7 Pre-processor: Refraction Error Calculation and Correction (Left: example of a considerable error, Right: example of a minor error)

The Pre-processor Refraction Correction Tab contains the following controls:

  Calculates the refraction range error for the selected radar
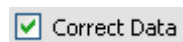
  Enable the refraction correction. If the flag is set pressing the previous control will correct the range field of the internally used data structure (copy of the IFF file structure).

Refraction of the radio waves in the atmosphere is due to the exponential change of the refraction coefficient with height. In the result the radar beam is not straight but slightly curved downwards, so that the range readings are slightly overestimated because range is measured along a curve, not along the straight line between the two points in the 3-D metrics. Very often this error doesn't exceed a few-meter level, but for ranges of around 250 NM, the error may grow up to around 30m, which if not taken into account, produces wrong estimates for the systematic errors (range bias and gain), see an example below. The magnitude of the correction is shown using the color scale, so as can be seen errors are significant even for shorter ranges, thus for 150 NM the typical correction is about 7-13m depending on the elevation angle. The correction is computed based on the

CRPL model atmosphere (CRPL Central Radio Propagation Laboratory of National Bureau of Standards). First, successive layers of the atmosphere are approximated, then refractivity is computed for each set of layers. The model assumes the exponential decrease of the refractivity with height. It is likely that the local atmospheric conditions are often significantly offset from the standard, so that the refractivity coefficient is a subject of temperature, humidity and pressure.

The gradient of the air density in the atmosphere produces the gradient of speed of light and is responsible for the atmospheric refraction. The main effect is that the radio-waves travel along slightly curved downwards trajectories. This produces an error in elevation angle and range. The effect is negligible for all but low elevation angles and long ranges. Using a stratified model for the atmosphere recurrent formulae allow evaluating the range error as follows. The refractive index of the troposphere is approximated by

$$N(h) = N_S \exp\left(-\frac{h}{7}\right) \tag{1}$$

where $N_S \approx 313$. Iterative process based on CRPL model with number of layers $\gamma = 16$.

After performing the required corrections use the following controls in the "Pre-processor" window:

Checks out the current status of the corrections.

Updates the current *.IFF file (disk) with the performed corrections. If the user chooses to close the preprocessor window without updating the *.IFF file **ALL THE CORRECTIONS WILL BE LOST!**

7. RCM: Filter

The "Filter" window contains controls and displays to create new (edit existing) filters, create and modify temporary filters. The utility is global and applied everywhere where the "Use Filter" is pressed, i.e. in the main window (MONO- and DUAL- tabs), and preprocessor. The "Filter" window contains the following controls:

Load an existing filter. You can locate filters everywhere you want on the hard disk, but there are two places where they logically belong. General filters such as status bit-wise filters should be stored in "RC\filters" subfolder. Evaluation oriented filters might be stored in "RC\EVALUATION\filters" subfolder. Every time you start the software the last used stored on the disk filter is revoked.

Save the current filtering content as a file

Add a Boolean sentence. Adds a sentence according to the current Field, Boolean operator, Condition, and Value.

Delete the selected Boolean sentence. The selected sentence is highlighted.

Boolean operator (available operators: AND, OR, XOR)

Filtering field (available fields: Timestamp, Track Nr, Scan Nr, S-address, A-code, C-code, Status, Status2, Range, Azimuth, Cubicle)

Condition (available conditions are: less, less or equal, equal, equal or more, more, not equal)
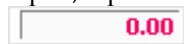
Value (depends on the Filtering Field type, can be cross-referenced with the XY display and pre-processor cursors, if these windows are open, otherwise the value can be typed in manually). The "Timestamp" field invokes 2 value field (beginning and end of the recording see below)
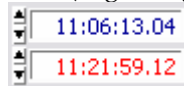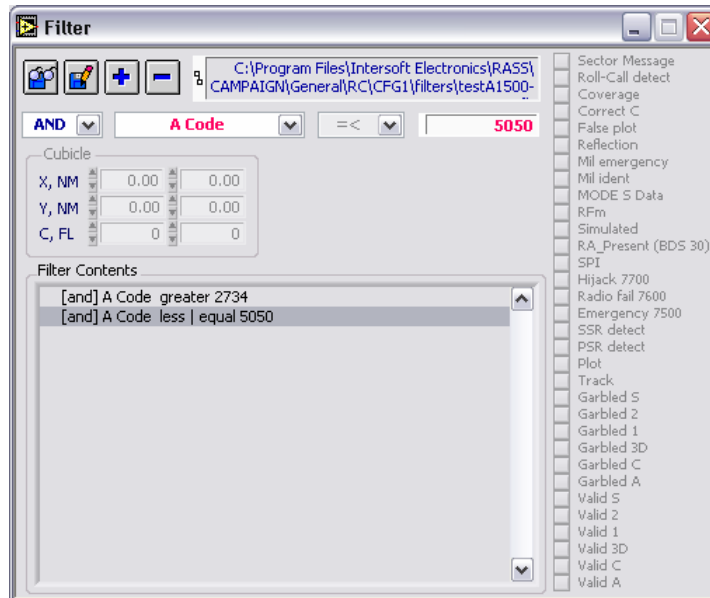
Figure 7.1 Filter Editor Utility

The filter is designed to filter IN(OUT) groups of plots (tracks), and not filtering individual plots (tracks) based on the source file information. Post-filtering i.e. filtering options available after performing the analysis (object correlation etc.) is not available in this version, see next RASS-R release for updates.

RASS-R Radar Comparator Module

Error! No text of specified style in document.

8. RCM: Mono-radar Evaluation

8.1. Progress Monitor

Whenever a process started with MONO- evaluation mode time consuming tasks are monitored with popping-up Progress window. If you press Stop control, the current process will be stopped and the current statistics results as well as the Tabular Pd displays will show arbitrary data. You can restart the stopped process. You can close the window. It will reappear when performing the next processing (not recommended).
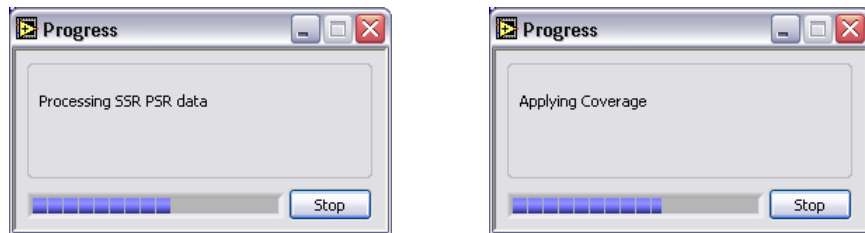
Figure 8.1 Progress monitor (examples)

8.2. Mono-radar Evaluation Setup

In the MONO-radar evaluation mode the MONO Tab of the main window will be enabled. The MONO Tab contains a number of controls and Sub Tabs as presented below:

"Run mono" start the mono-radar evaluation process according to the selected radar.

"Apply Coverage" using the specified coverage volume (see further)
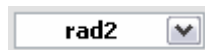
Selects a radar from the configuration setup list
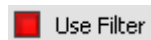
Use the current filter content. Can be created and edited via the "Filter" window (see RCM: Filter for details)
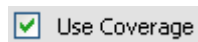
Use the current coverage information (required for Statistics only)

8.2.1. MONO-evaluation mode: Radar
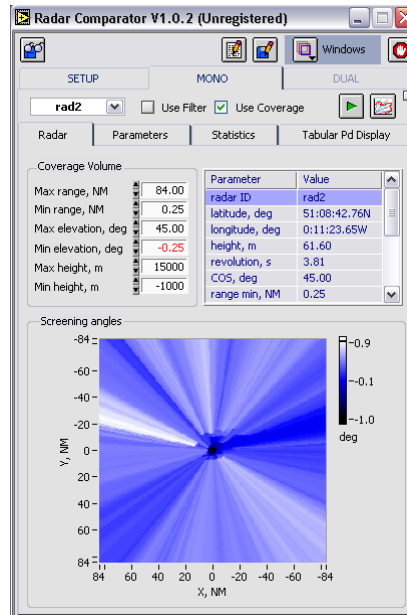
Figure 8.2 MONO-radar evaluation Tab: Radar

- Minimum Range [NM] is taken from the radar parameter file (*.RDB), but can be modified for as long as the selected radar is analyzed. Selecting another radar will rewrite the parameter using the parameter file of the radar.

- Maximum Range [NM] is taken from the radar parameter file (*.RDB), but can be modified for as long as the selected radar is analyzed. Selecting another radar will rewrite the parameter using the parameter file of the radar.

- Maximum Elevation [deg] represents the cone of silence COS value is taken from the radar parameter file (*.RDB), but also can be modified.

- Minimum Elevation [deg] default value is -0.25° can be modified by the user

- Maximum Height [m] default value is 15000 m (can be modified in the current evaluation session)

- Minimum Height [m] default value is -1000 m (can be modified in the current evaluation session)

- Screening angles is the screening angle vs. azimuth and range diagram of the selected radar.

- Table of the radar parameters is a look-up-table imported from the radar parameter file (*.RDB)

The above parameters are determining the radar coverage volume. To recalculate the current Pd and codes probabilities result change the volume definition (minimum and maximum range, height and elevation) and press the "Apply Coverage" control.

8.2.2. MONO-evaluation mode: Parameters
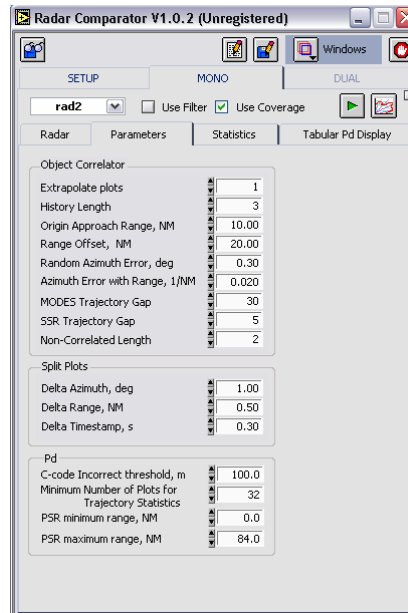
Figure 8.3 MONO-radar evaluation Tab: Parameters

- Extrapolate plots - a number of plots (missed) appended to an established trajectory. These plots are calculated using the current 3D heading of the AC.
- History Length – a number of plots used to calculate the current heading of the AC. Used to calculate extrapolated plots at the beginning and the end of a trajectory.
- Origin Approach Range [NM] – the range band where the next plot can be expected to have any azimuth (applicable for the vicinity of the radar origin when a fast moving target may produce azimuth change of about 180 degrees or greater.

The following three parameters are designed to model the random azimuth error in general using the formula $\sigma_{Az} = \sigma_{Az0} + \alpha (R - R_0)$ [2] where

- R_0 is the Range Offset [NM]
- σ_{Az0} is the Random Azimuth Error [deg]
- α is the Azimuth Error with Range [NM]
- MODES Trajectory Gap – a parameter setting the maximum MODES trajectory gap bridged by the program
- SSR trajectory Gap – a parameter setting the maximum SSR trajectory gap bridged by the program
- Non-Correlated Length – is the minimum number of plots associated to a trajectory considered as being true plots.

Three following parameters are dedicated for detection of the split plots:

- Delta Azimuth [deg]
- Delta Range [NM]
- Delta Timestamp [s]
- C-code Incorrect Threshold [m] – the height difference between the predicted by the C-code reconstruction and actual C-code[3]
- PSR Minimum Range [NM] - is the minimum range where PSR plot can be expected (used for PSR statistics only). Default settings for maximum and minimum ranges for PSR and SSR antenna are identical, when it is not the case specify explicitly PSR ranges.

---

[2] Accounts for the azimuth random error increase with range for mono-pulse radar
[3] This is done due to the absence of the absolute reference. Strict evaluation of this parameter is only possible with synthetic scenarios (for example available in RASS-S 6 RES)

- PSR Maximum Range [ ]NM]] - is the maximum range where PSR plot can be expected (used for PSR statistics only). Default settings for maximum and minimum ranges for PSR and SSR antenna are identical, when it is not the case specify explicitly PSR ranges.

8.2.3. MONO-evaluation mode: Statistics
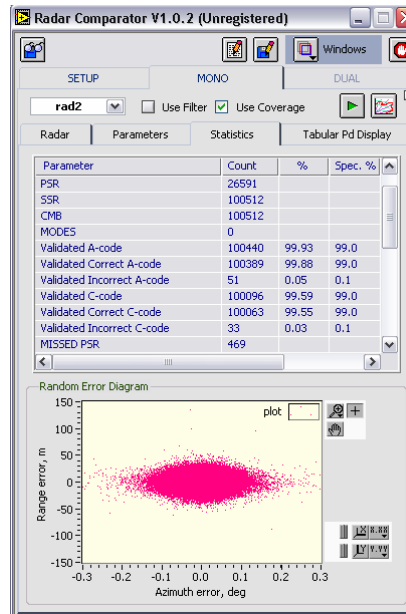
Figure 8.4 MONO-radar evaluation Tab: Statistics

Contains plot (track) statistics as well as the Pd and code probabilities required by ICAO document 8071. Most of the positions have straightforward meaning. For PSR statistics and probabilities you need to specify the minimum and maximum range for PSR see DUAL-radar evaluation Tab: .

8.2.4. MONO-evaluation mode: Tabular PD Display
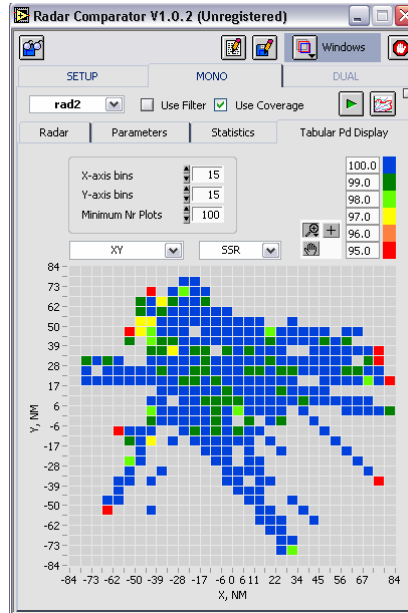
Figure 8.5 MONO-radar evaluation Tab: Tabular Pd Display

The tabular Pd views can be calculated separately for each type of the plot. Contains the following controls and indicators:

Recalculate the coverage (probabilities and the tabular Pd charts). Use the "Pre-processor" first to correct for the barometric error and so to correct screening angle diagram info.

Selects the required type of the diagram (XY, Azimuth vs. Range, and FL vs. Range (vertical))

Type of the plot (track) data to be used for the analysis
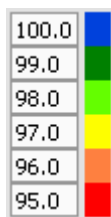
Color-Magnitude Scale (the Pd Values and Colors can be modified and hold for the current session)

- X-axis bins (to produce the tabular result)

- Y-axis bins (to produce the tabular result)

- Minimum Number of Plots. A cell with the total number of hits less that the specified is not taken into account for the tabular result, the cell is shown empty.

- The following display types are available:
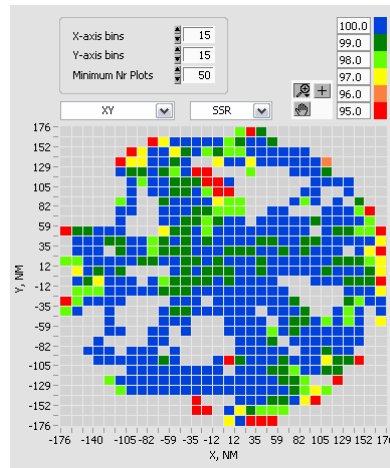
a) XY tabular display
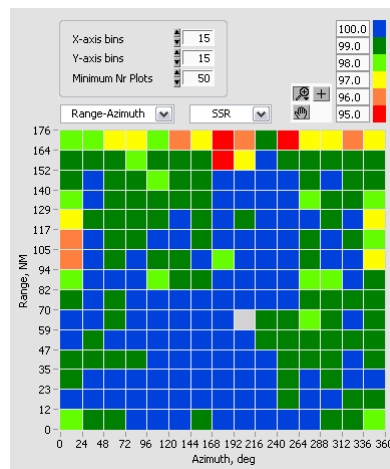
b) Range-Azimuth tabular display
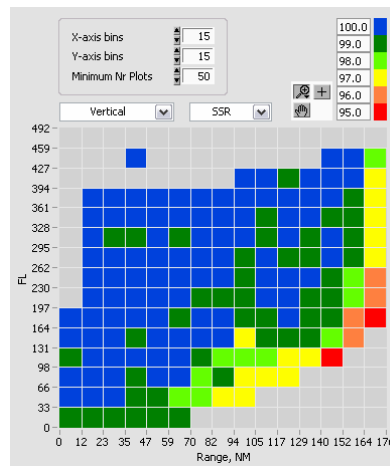
c) Range-Flight Level tabular display

Figure 8.6 Tabular Pd Display Types

8.2.5. MONO-evaluation mode: Trajectory Based Info

☐ Press the "Expand Window" control (upper right corner of "MONO" Tab) to view the trajectory based information. The main window will stay on the top until the expanded part is closed.
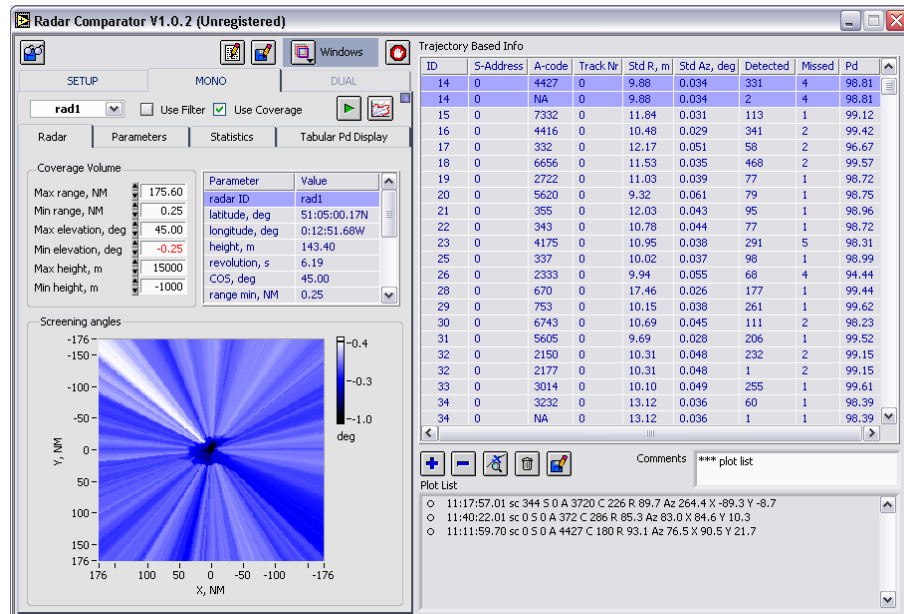
Figure 8.7 MONO-radar evaluation Tab: Trajectory Based Info

The trajectory based info is routinely calculated in the MONO- mode which can be very useful to detect AC with anomalous Pd, large random errors etc. This kind of anomalies usually doesn't have anything to do with the radar malfunctioning, but related to the transponder problems. This type of the problem can also be demonstrated with the Track Analysis Toolbox (RASS-R). Trajectories with abnormal statistics in common airspace with the other trajectories with "normal" statistics must be carefully handled and should be filtered out to obtain objective radar performance figures. However this type of the filtering must be performed with precaution without compromising the measurement objectivity and trustworthiness.

The user may want to store some plots (group of plots) as text for reporting. The following controls are available:

 Add a plot info addressed by the cursor in XY mono-display

 Remove the selected plot info record

 Get the list of non-correlated (false) plots

 Delete all the records

 Save the plot info file (fill in comments if required)

Comments: Add text comments to the stored file.

The mono-radar evaluation program routinely performs the plot-to track correlation. As a result misses are calculated along with a number of plots that could not be correlated with the existing tracks: non-correlated (NC) plots. User can create a list with specific plots he wants to report. For this purpose he can use the above controls to add (delete) records and save these as s file. The selected list might look like this.
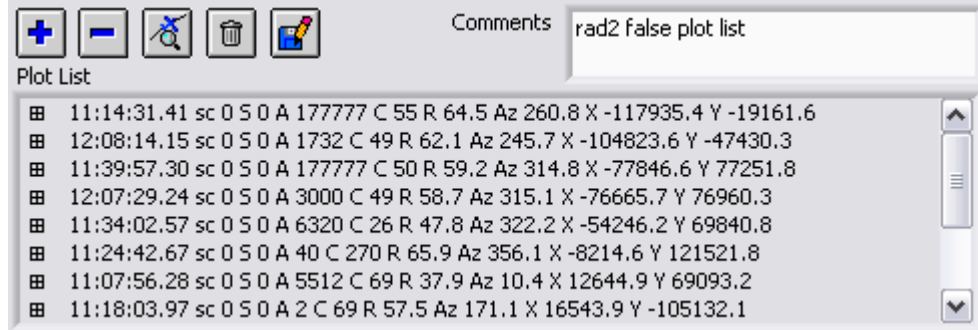
Figure 8.8 Plot list control for special case reporting

```
2/21/2005  12:09 PM
C:\Program Files\Intersoft Electronics\RASS\CAMPAIGN\General\RC\CFG1\S4\rad2.s4
rad2 false plot list
   11:14:31.41 sc 0 S 0 A 177777 C 55 R 64.5 Az 260.8 X -117935.4 Y -19161.6
   12:08:14.15 sc 0 S 0 A 1732 C 49 R 62.1 Az 245.7 X -104823.6 Y -47430.3
   11:39:57.30 sc 0 S 0 A 177777 C 50 R 59.2 Az 314.8 X -77846.6 Y 77251.8
   12:07:29.24 sc 0 S 0 A 3000 C 49 R 58.7 Az 315.1 X -76665.7 Y 76960.3
   11:34:02.57 sc 0 S 0 A 6320 C 26 R 47.8 Az 322.2 X -54246.2 Y 69840.8
   11:24:42.67 sc 0 S 0 A 40 C 270 R 65.9 Az 356.1 X -8214.6 Y 121521.8
   11:07:56.28 sc 0 S 0 A 5512 C 69 R 37.9 Az 10.4 X 12644.9 Y 69093.2
   11:18:03.97 sc 0 S 0 A 2 C 69 R 57.5 Az 171.1 X 16543.9 Y -105132.1
   11:52:56.43 sc 0 S 0 A 11 C 287 R 41.0 Az 167.2 X 16695.1 Y -73554.4
   11:18:57.38 sc 0 S 0 A 1426 C 65 R 53.6 Az 168.4 X 19996.7 Y -97213.7
   11:44:45.21 sc 0 S 0 A 5030 C 102 R 29.9 Az 158.6 X 20175.3 Y -51535.8
   11:51:47.85 sc 0 S 0 A 4102 C 237 R 57.2 Az 158.6 X 38541.0 Y -98449.3
   12:11:30.28 sc 0 S 0 A 177777 C 25 R 35.9 Az 59.1 X 57025.0 Y 34149.8
```

Figure 8.9 Example of the stored file

8.3. MONO-display

Press the "Windows" control and select "mono display" option to open the XY display for mono-radar mode, as given in Figure 8.10

The display can be resized, minimized, and maximized. The settings will be stored for the future use in the CONFIG.RC file.
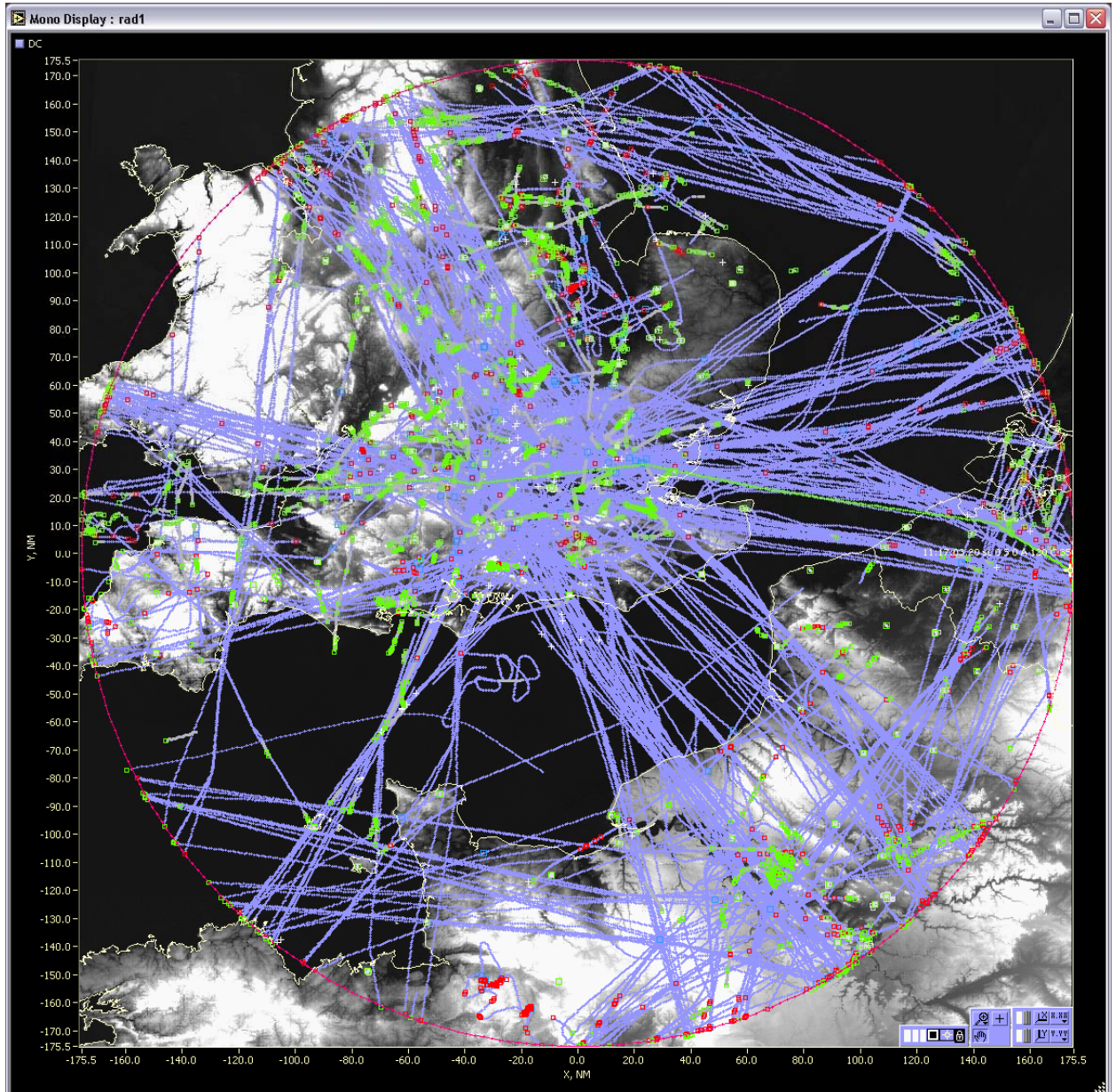
Figure 8.10 XY MONO Display

 Press the "Display Configuration" control and select displayed data series and options
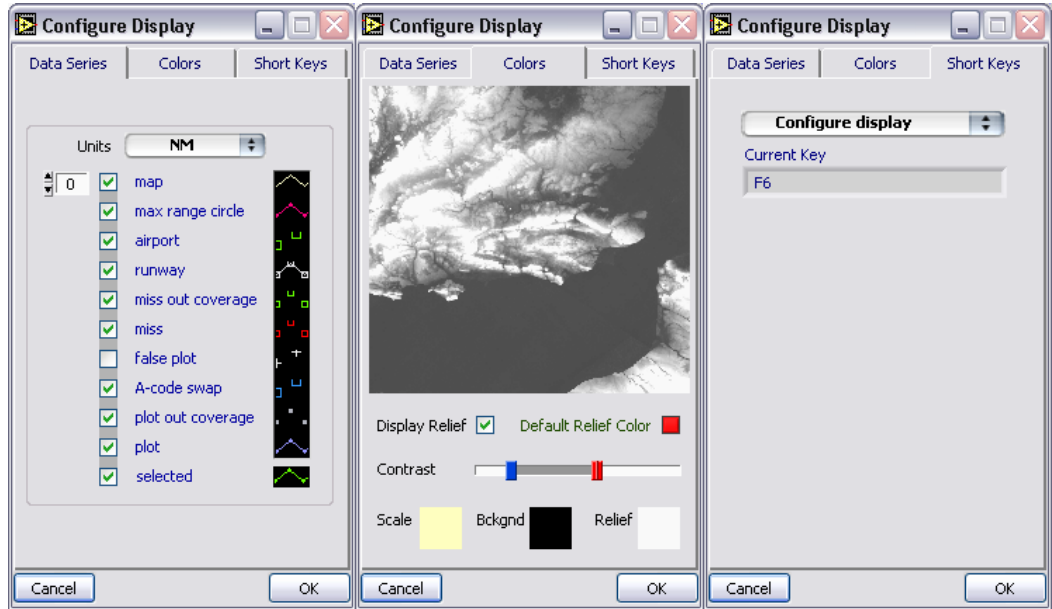
Figure 8.11 XY MONO Display: Configuration Window

The "Data Series" Tab contains the following controls:

 Units can be set to meters, kilometers, and Nautical Miles
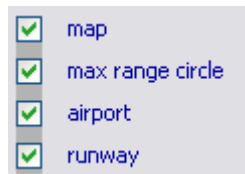
 following data series:

The displayed data series control containing the

Map content	Displays the map with geographical and country based
Maximum Range Circle	Displays the circle of the radar maximum range
Airport	Displays the airports
Runway	Displays runways
Miss out coverage coverage volume	Marks up misses occurred outside the specified
Miss bit	Displays all the misses independent from the coverage
False plot shorter than specified limit see	Displays plots and/or trajectories with the length
A-code swap	Displays occurrence of incorrect A-codes

Plot out coverage | Shows the plots (tracks) that declared "out coverage" based on the specified coverage volume.

Plot | Show all the detected plots (tracks)

Selected | Highlight the selected with the cursor trajectory

The relief colors and contrast, the graph scale and background colors can be changed, these settings can be stored for the future. The types of the presentation: colors, point and line styles are selectable. The user may select only a few data series to show in the XY display. This feature makes the analysis more efficient.

There are a number of useful short keys available to invoke the "Configuration Menu" and the cursor motion functions. The default settings are assigned to the following functional keys:

F6 | Invoke the display Configuration Menu

Home | Bring the cursor to the center

Left | Move the cursor in time one scan backward

Right | Move the cursor in time one scan forward

The "Color" Tab contains the following controls:

Display Relief ☑ display | To display relief in the background of the

Default Relief Color 🟥 | To set the relief color to default (BLUE)

Contrast | To modify brightness and contrast

Three Color Boxes to be used respectively for Scale, Background and Relief. Not all the settings are possible, for example if the "Display Relief" control is ON the "Background" color is set to BLACK (0), similarly if the "Background" color not equal to BLACK (0) disables the "Display Relief" flag.

The "Short Keys" Tab can be used to configure short keys.

The Configuration Menu is the modal dialog window, you must close it in order to access XY display window again.

9. RCM: Dual-radar Evaluation

9.1. Progress Monitor

Whenever a process started with DUAL- evaluation mode time consuming tasks are monitored with popping-up Progress window. If you press Stop control, the current process will be stopped and the current statistics results as well as the Tabular Pd displays will show arbitrary data. You can restart the stopped process. . You can close the window and it will reappear when performing the next processing (not recommended).
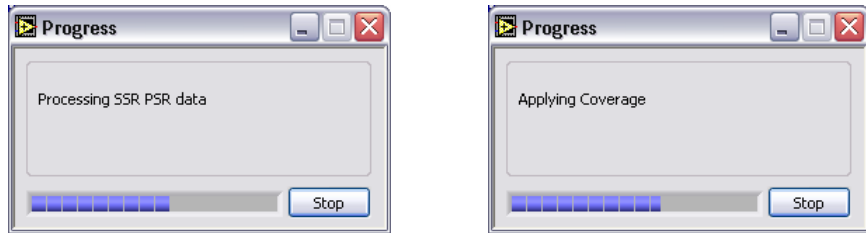
Figure 9.1 Progress monitor (examples)

9.2. Dual-radar Evaluation Setup
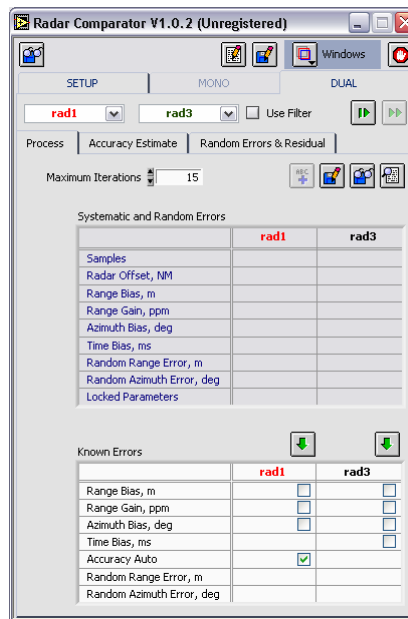
Figure 9.2 DUAL-radar evaluation Tab: Process

In the DUAL-radar evaluation mode the SETUP and DUAL Tabs of the main window will be enabled. The DUAL Tab contains a number of controls and Sub Tabs as presented below:

Start the dual–radar data correlation process, i.e. plot (track) association to the aircraft trajectories. When the correlation process is finished the Table Systematic and random errors will contain numbers of samples for each radar, and radar offset [NM]. Enabled when two different radars are selected.

Starts the process of computing the systematic errors. The process is iteratively cycled till either the maximum number of iteration or convergence criteria is reached. In each iteration the following systematic errors are evaluated: range bias, range gain, azimuth bias and relative time bias. The plot (track) data of each radar is corrected each iteration for the current estimates of the systematic errors. The control is disabled until the dual-radar data are correlated.

Selects the reference radar from the configuration setup list

Selects the radar under test radar from the configuration setup list
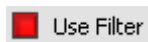
Uses the current filter content. Can be created and edited via the "Filter" window (for detailed filter operation see RCM: Filter)

9.2.1. DUAL-evaluation mode: Process

The MONO Process Tab contains the following controls:

Add the current results (Systematic and Random Errors) to a log. The log window pops-up with recent log data. The content is rewritten each new session.

Record the current result to a log file that contains comparative results of the comparative evaluation for different radar pairs

Read the contents of the current log file

View the current log file

Copy and paste the current systematic errors result into the respective radar fields

Known Errors	rad1	
Range Bias, m	☐	☐
Range Gain, ppm	☐	☐
Azimuth Bias, deg	☐	☐
Time Bias, ms		☐
Accuracy Auto	☑	
Random Range Error, m		
Random Azimuth Error, deg		

The "Known Errors" table may be useful when performing analysis of two closely located radars. In such cases the algorithm for systematic errors determination might not converge to the right values, because the computation matrix contains dependent parameters, so that the absolute measurement can't be performed. Then the following technique is recommended. One of the radars (for example rad1) should be compared with the third radar (rad3) having representative common coverage and offset from the radar under test not closer than 20NM. The obtained biases (systematic errors) for the radar (rad1) then can be pasted into the "Known Errors" table and fixed using the corresponding checkboxes☑. The radar (rad2) then will be evaluated in respect to (rad1), the measurement will be relative. Alternatively the known parameters can be input manually originating from other types of measurements, manufacturer specifications etc. Relative measurement has several limitations:

- If the known values are far from being the correct approximation for the systematic errors of the radar, the obtained results are corrupted.

- Random errors tend to be equally redistributed between the two radars in question, so that only statements of the following nature are strictly feasible. Assuming that one of the radars (for example rad1) is not worse than σR_1 and σAz_1, the radar under test is not worse than σR_2 and σAz_2. Of course such statements are always possible if the radar in question is compared to a radar with much better accuracy.
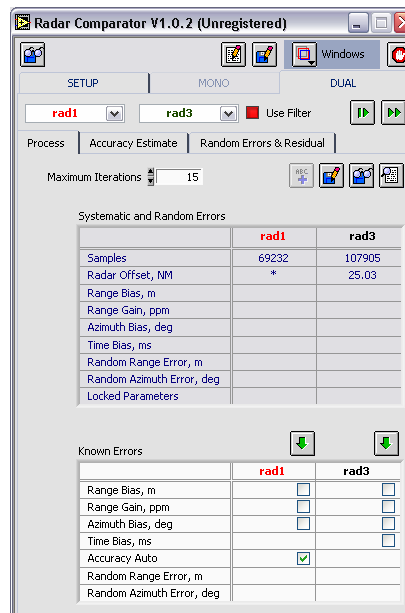
Figure 9.3 DUAL-radar evaluation Tab: Process (data have been correlated)

Table Systematic ands Random Errors contains the following entries

- Samples – number of plot (track) correlated messages for each radar
- Radar Offset, NM – distance between the radar origins
- Range Bias [m] – additive range error for each radar
- Range Gain [ppm] – multiplicative range error for each radar expressed in10^{-6}
- Azimuth Bias [deg] – azimuth misalignment error for each radar
- Time Bias [ms] – relative time bias (the bias of the radar under test vs. the reference radar)
- Random Range Error [m] – range accuracy of each radar (in terms of the standard deviation SD)

- Random Azimuth Error [deg] – azimuth accuracy of each radar (in terms of the standard deviation SD)

- Locked Parameters – the user can lock any of the 7 parameters corresponding to the selected systematic error of the radar. In this case the program will fix this parameter according to the value specified in the table "Known Errors". This method is required to analyze closely spaced radars, and co-located radars.

- Accuracy Auto is a control determining how the trajectory is reconstructed, if set off the trajectory reconstruction is performed based on the specified estimates for range and azimuth random errors (see Table "Known Errors"). Otherwise the program will calculate the estimates based on the algorithm of minimization of AC speed noise.

9.2.2. DUAL-evaluation mode: Accuracy Estimate

The Tab "Accuracy Estimate" contains accuracy estimates for the reference radar and radar under test evaluated on MONO-radar basis using only plots located in common coverage of both radars. These can also be used as the known accuracy estimates if the "Accuracy Auto" flag set off. On the other hand this is a quick independent check of the order of magnitude of the radar accuracy. In most cases these are very close to the DUAL-radar evaluation results. In cases of doubt the radars in questions should be processed also completely in MONO-radar mode in order to produce alternative measurement.
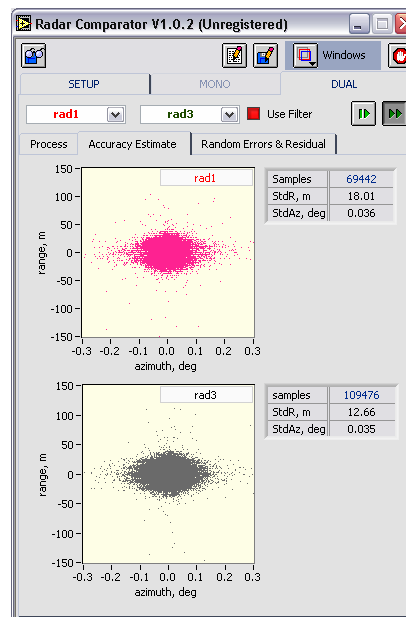
Figure 9.4 DUAL-radar evaluation Tab: Accuracy Estimate

9.2.3. DUAL-evaluation mode: Random Errors and Residual

The "Random Errors and Residual" Tab contains indicators showing the convergence of the minimization process, and random range and azimuth errors diagram

- Residual [m] is the average XY distance between two plots corresponding to the selected radars taken at the same time

- Speed noise [m/s] is the standard deviation on the speed noise taken for all reconstructed trajectories (illustrates the quality of the reconstruction). Setting

"Accuracy Auto" to ON will effectively minimize this parameter. Typical value for this parameter for modern radar is within 3 m.

The Error scattering diagram has the cursor which is cross-linked with the "XY display" cursors and "Plot Info" contents. This feature might be useful to investigate occurrences of large errors.
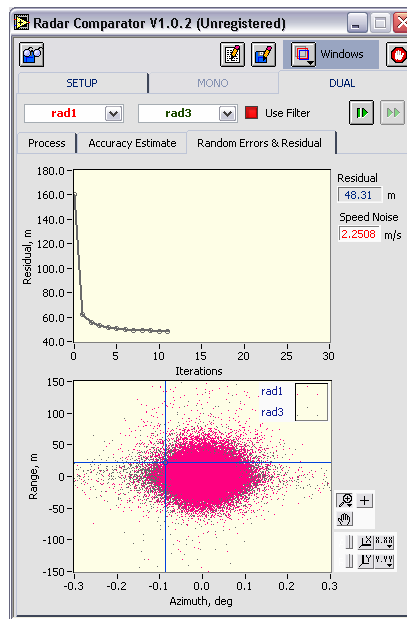
Figure 9.5 DUAL-radar evaluation Tab: Random Errors & Residual

9.2.4. DUAL-evaluation mode: Random Errors and Residual

There are two types of logging functions available for the results in DUAL Radar mode.

 Press the "Log results" control to store the current content of the Errors table. When you press the control next time the current log will be appended by a new result. The associate Log window is open where the user can inspect and compare results. This log record is not stored to the disk.
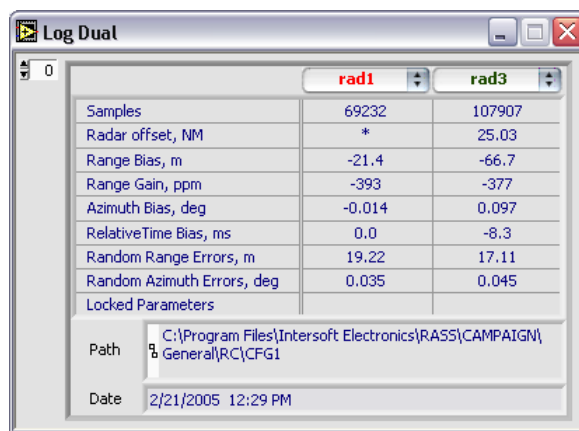
Figure 9.6 DUAL-radar evaluation mode: Log window

Press the "Add record to log" control to store the current content of the Errors table to a tabular structure where any radar is compared to any radar. If there is a log file left from the earlier work, pressing the button will overwrite the old log file. If you want to correct a few fields of an older log file, press first the "Retrieve log" control, then the older log file will be read from the disk. Each time you want to compare numbers obtained comparing different radars press the "View current log" control. Pressing the control will open the following window. You can open as many Results window as you want for various parameters as given for example in Figure 9.7.

Results — azimuth bias, deg (less, NM 20.0 more, NM 150.0)

	rad1	rad2	rad3	rad4	rad5	rad6	rad7	rad8	mean	stdev
rad1		0.000	-0.014	-0.044	-0.001	-0.059	-0.011	0.000	-0.026	0.025
rad2	0.000		-0.140	-0.135	-0.138	-0.128	-0.144	0.000	-0.137	0.006
rad3	0.099	0.096		0.103	0.107	0.100	0.103	0.092	0.100	0.005
rad4	0.015	0.016	0.014		0.024	0.019	0.026	0.016	0.016	0.002
rad5	0.050	0.050	0.059	0.053		0.050	0.033	0.045	0.047	0.010
rad6	-0.075	-0.073	-0.072	-0.064	-0.070		-0.071	-0.073	-0.071	0.004
rad7	0.028	0.028	0.029	0.011	0.024	0.028		0.027	0.027	0.002
rad8	0.000	0.000	-0.107	-0.103	-0.095	-0.100	-0.104		-0.102	0.005

Results — range bias, m (less, NM 20.0 more, NM 150.0)

	rad1	rad2	rad3	rad4	rad5	rad6	rad7	rad8	mean	stdev
rad1		0.00	-17.50	10.20	-20.10	15.10	-16.10	0.00	-5.68	16.88
rad2	0.00		-47.40	-41.30	-43.00	-42.30	-46.90	0.00	-44.18	2.78
rad3	-62.60	-52.30		-59.60	-57.70	-74.00	-51.00	-52.80	-58.57	8.02
rad4	82.40	64.90	74.80		35.40	92.80	75.50	74.60	77.90	10.39
rad5	-36.90	-19.90	-25.20	-24.90		35.90	-5.60	-25.10	-22.54	11.33
rad6	4.50	-57.80	-80.40	-29.30	-84.40		-143.80	-26.40	-37.88	32.43
rad7	-120.20	-146.90	-135.80	-145.30	-63.80	-268.90		-106.10	-114.56	32.31
rad8	0.00	0.00	-92.80	-105.90	-96.00	-98.00	-97.30		-98.00	4.85

Results — interdistance, NM (less, NM 20.0 more, NM 150.0)

	rad1	rad2	rad3	rad4	rad5	rad6	rad7	rad8	mean	stdev
rad1	0.0	3.8	25.1	143.2	57.3	132.2	142.2	4.1		
rad2	3.8	0.0	22.0	144.3	53.5	135.8	138.5	1.1		
rad3	25.1	22.0	0.0	137.2	41.0	147.9	118.9	22.7		
rad4	143.2	144.3	137.2	0.0	171.6	124.6	203.2	145.4		
rad5	57.3	53.5	41.0	171.6	0.0	187.9	90.2	53.4		
rad6	132.2	135.8	147.9	124.6	187.9	0.0	261.3	136.2		
rad7	142.2	138.5	118.9	203.2	90.2	261.3	0.0	138.8		
rad8	4.1	1.1	22.7	145.4	53.4	136.2	138.8	0.0		

Figure 9.7 DUAL-radar evaluation mode: Tabular Result window templates

range bias, m — The data type selector sets up the data type to display in the Results table. The available options are: range bias, range gain, azimuth bias, time bias, range standard deviation, azimuth standard deviation, and inter-distance. Radars offset by less than 20NM or more than 150 NM are marked with different colors from the rest of the setup, to give a warning that the results might be incorrect, these are not taken into account for the statistics. The statistics fields are not calculated for time bias, and inter-distance. The time bias is measured relatively, so that differences between the cells taken within one column meet within the measurement accuracy the same quantities calculated for another column.

This type of presentation showing the differentiated results for all the radars vs. the other radars is extremely useful and didactical providing much deeper insight than common multi-radar analysis tools (SASS-C) where all theses details are hidden inside the processing "black box" and the user has no clue whether the problem is real or apparent caused by a wrong positioning, eccentricity barometric error etc. Looking for example on the results in Figure 9.7 one can immediately see some particularity with "rad4" and "rad6" as opposed to the other radars (see for example range bias and azimuth bias for "rad1" vs. the other radars in the first line of the corresponding tables, 7:00-7:30 filter has been applied). It is clear that there is something special about "rad4" and "rad6". These produce different results in comparison with the rest of the "world". From the first sight this might be scary: (<u>THE TOOL DOESN'T WORK!</u>). Many SASS-C users will be delighted to make this statement without go any deeper into details. However the fact itself that only several radars drop out of the consistent results produced vs. "rad3", "rad5" and "rad7" rather stimulates further investigation. Further investigation discovered some special features of the timestamp error vs. azimuth for "rad4" see below in Figure 9.8 ("rad6" demonstrated relatively large timestamp error so that the eccentricity would not be visible there so it needs a more detailed check). The timestamp error for "rad4" shows the strong dependence on azimuth which can point out to possible eccentricity or other mechanical problems with ACP encoder. Of course the final conclusion should be made based on the radar check, including the ACP eccentricity measurement. Here is the real power of the tool! Don't be scared when you get discrepancies in comparing the same radar to a bunch of the others, they are more than real. Positioning errors are very often happen and they are critical, barometric errors are often very critical, eccentricity is often bigger than the ICAO [2] and EUROCONTROL [3] specifications for the maximum azimuth errors, and needless to say the eccentricity is able to change dramatically the apparent azimuth bias.

Ultimately information displayed in the "Results" window produces a very meaningful and indispensable parameter for the Radar Comparator as a measurement system the accuracy of the measurement.
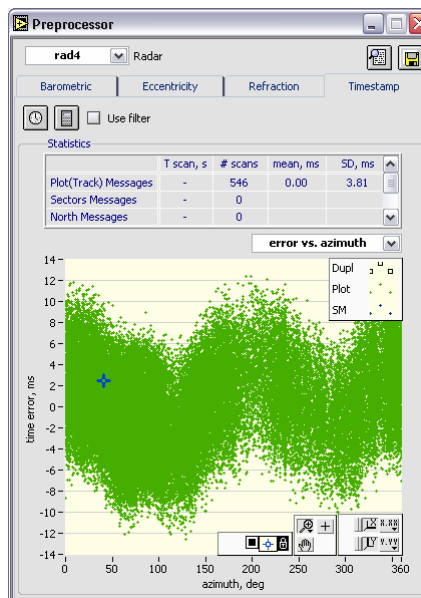
Figure 9.8 Timestamp error vs. azimuth for rad4 DEMO evaluation setup

9.3. DUAL-display

Press the "Windows" control and select "dual display" option to open the XY display for dual-radar mode, as given in Figure 9.9

The display can be resized, minimized, and maximized. The settings will be stored for the future use in the CONFIG.RC file.
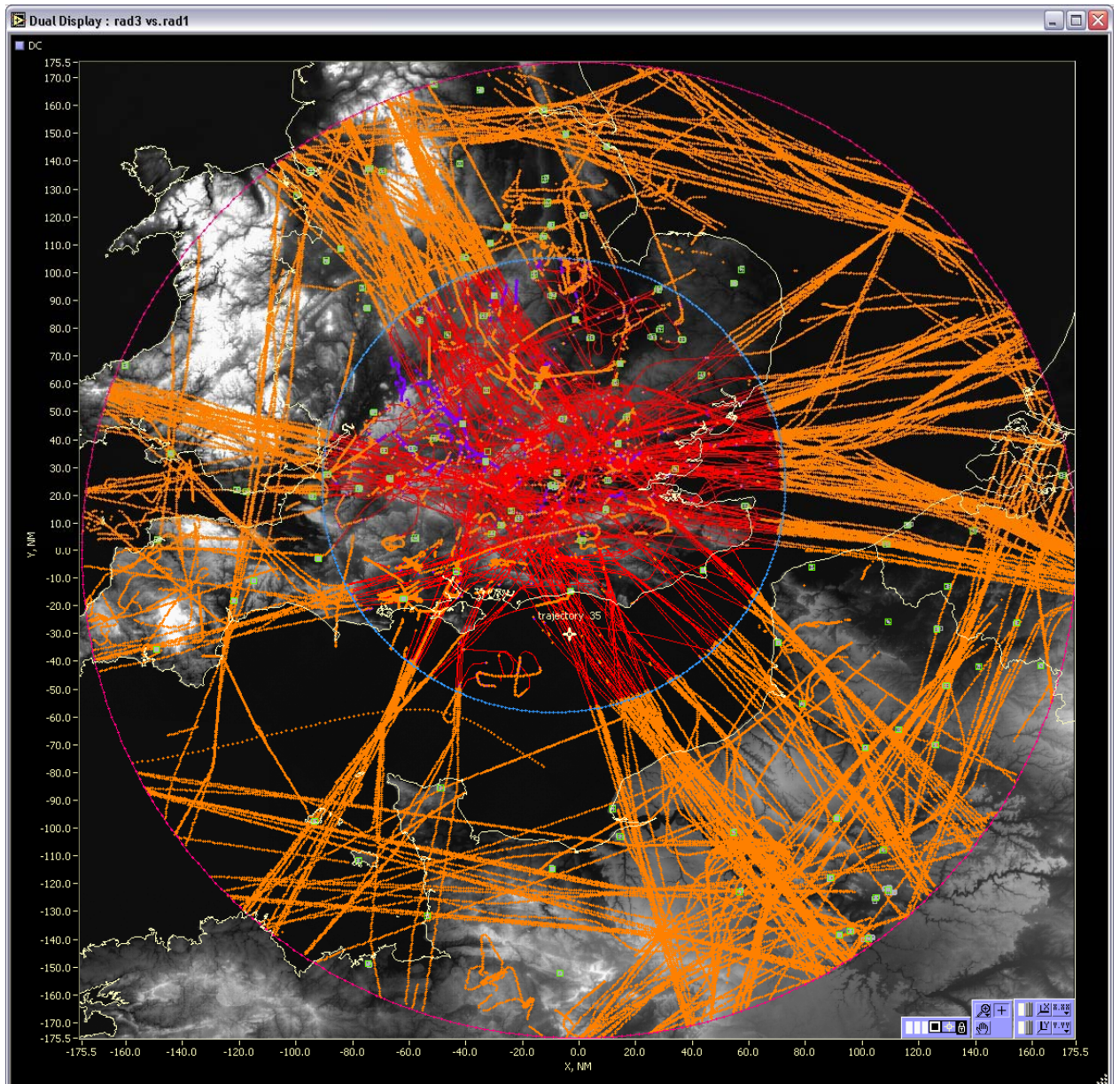
Figure 9.9 DUAL-radar XY display

█ DC   Press the "Display Configuration" control and select displayed data series and options
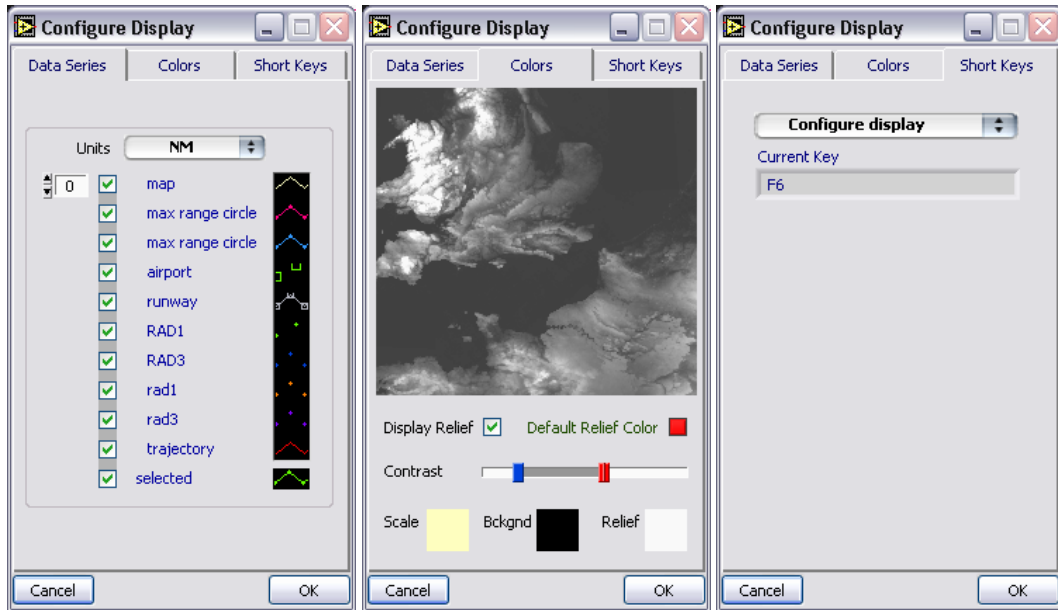
The "Data Series" Tab contains the following controls:

          Units can be set to meters, kilometers, and Nautical Miles

following data series: The displayed data series control containing the

Map   Displays the map with geographical and country based
content

Maximum Range Circles   displays the circle of the maximum range for both radars

Airport   displays the airports

Runway   Displays runways

"REFRAD" (name)   Displays plots (tracks) of the reference radar (REF) in the
common coverage

"RUTRAD" (name)   Displays plots (tracks) of the radar under test RUT) in
the common coverage

"refrad" (name)   Displays plots (tracks) of the reference radar (REF)
outside the common coverage

"rutrad" (name)   Displays plots (tracks) of the radar under test RUT)
outside the common coverage

Trajectory   Displays the reconstructed trajectory

Selected   Non Applicable

The relief colors and contrast, the graph scale and background colors can be changed, these settings can be stored for the future. The types of the presentation: colors, point and line styles are selectable. The user may select only a few data series to show in the XY display. This feature makes the analysis more efficient.

There are a number of useful short keys available to invoke the "Configuration Menu" and move the cursor.

The default settings are assigned to the following functional keys:

F6   Invoke the display Configuration Menu

Home   Bring the cursor to the center

Left   Move the cursor in time one scan backward

Right   Move the cursor in time one scan forward

The "Color" Tab contains the following controls:

Display Relief ☑   To display relief image

Default Relief Color ⬛   To set the relief color to default

Contrast [====▐====▌==]   To modify brightness and contrast

Three Color Boxes to be used respectively for Scale, Background and Relief. Not all the settings are possible, for example if the "Display Relief" control is ON the "Background" color is set to BLACK (0), similarly if the "Background" color not equal to BLACK (0) disables the "Display Relief" flag.

The "Short Keys" Tab can be used to configure short keys.

The Configuration Menu is the modal dialog window, you must close it in order to access XY display window again.

10. Tutorial

10.1. Tutorial: MONO-radar evaluation mode

This chapter describes how to getting started with the software based on the included DEMO data evaluation set. We would recommend starting with MONO-radar evaluation type, however if you have experience with the methods (software) of multi-radar analysis you may want to select DUAL-radar evaluation mode.

Launch Radar Comparator from RASS-R
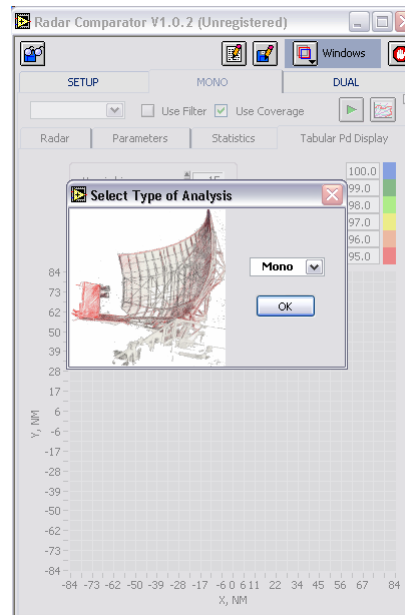
Select MONO, press OK
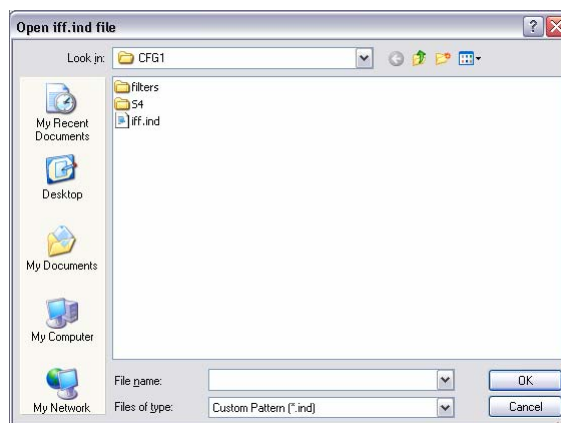
First time press Cancel, for the index file is outdated (next time you use the same evaluation folder you may want to select the proposed *.IFF file, which is the index file of the previously loaded source files).
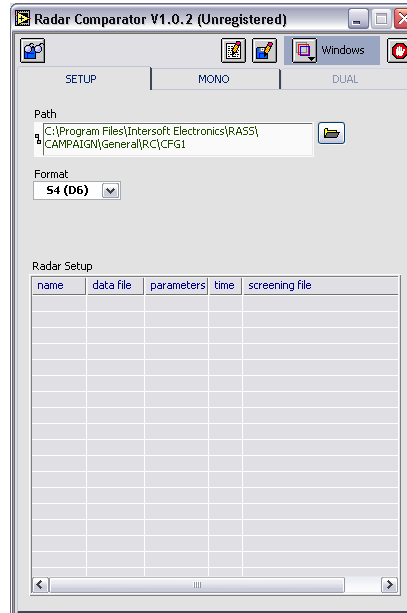
Select Format S4(D6) and press Load Source File control
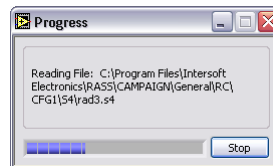
Wait till the files are loaded, or press stop to load a subset
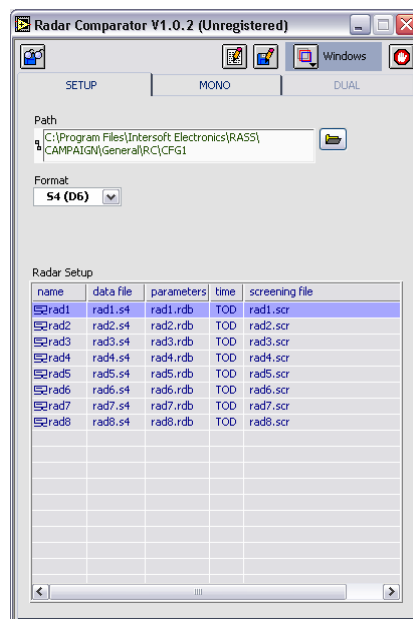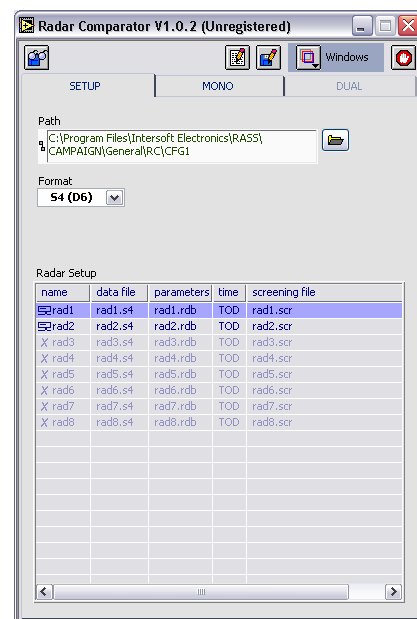
All the files are loaded   A subset (2 files) is loaded, unloaded radars are disabled

Select MONO tab.
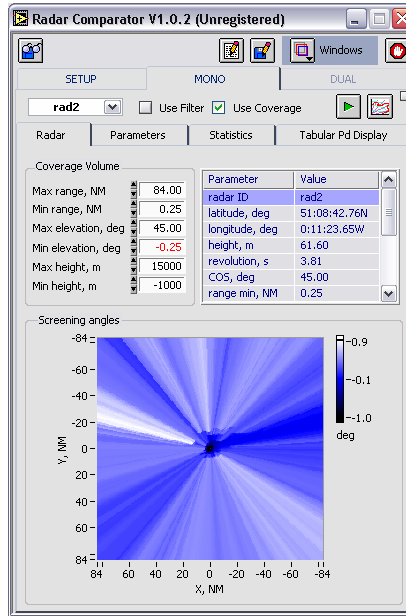
Select radar "rad2". When selecting "rad2" the screening angle info is displayed. Press the "Run Mono-radar" control.
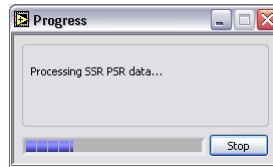
Wait till the processing is completed. If you close the window it will not be displayed till the next task is engaged (not recommended).
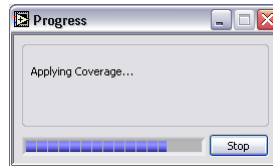
Wait till the processing is completed
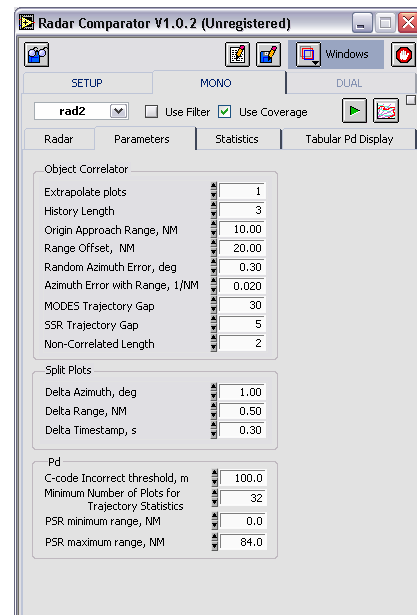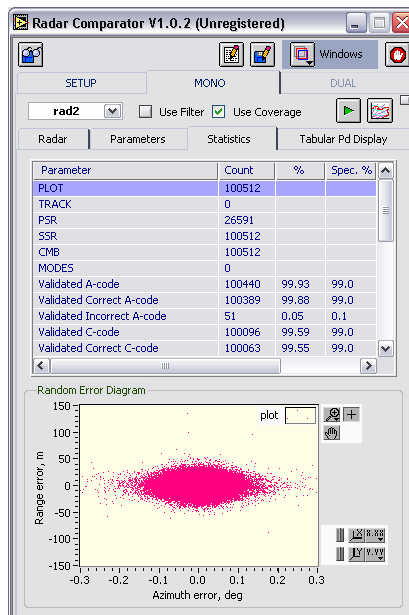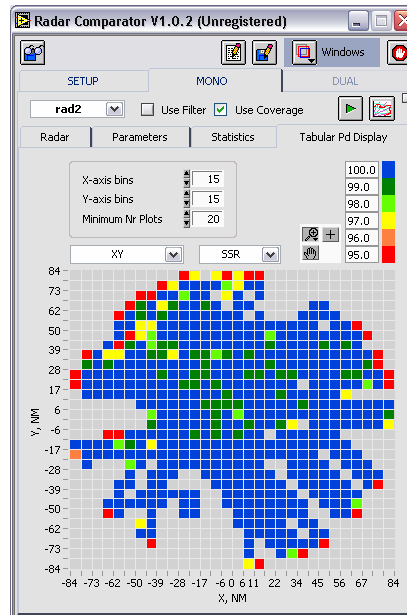
Inspect the results opening the following Tabs: "Statistics", "Parameters" and "Tabular PD Display". You may want to change the program parameters and repeat the processing again. To inspect the XY mono-display press "Windows" control and select "mono display". To expand window and view the trajectory based result press the small square blue control in the upper right corner of the MONO Tab.
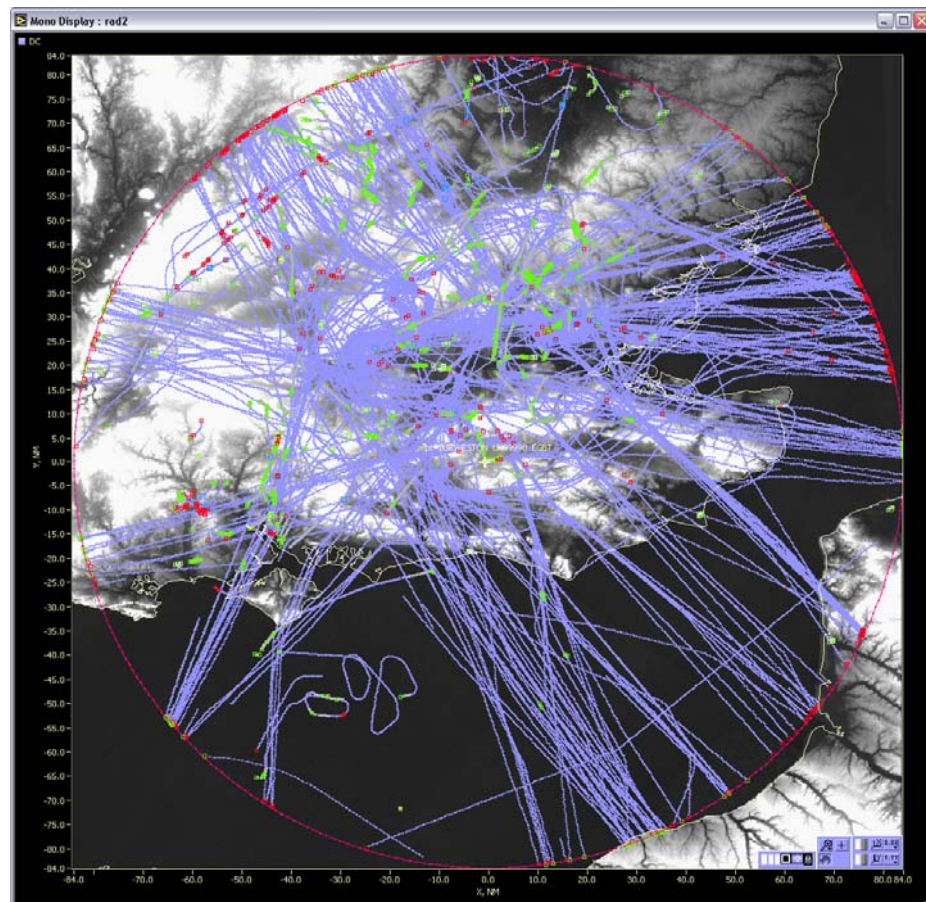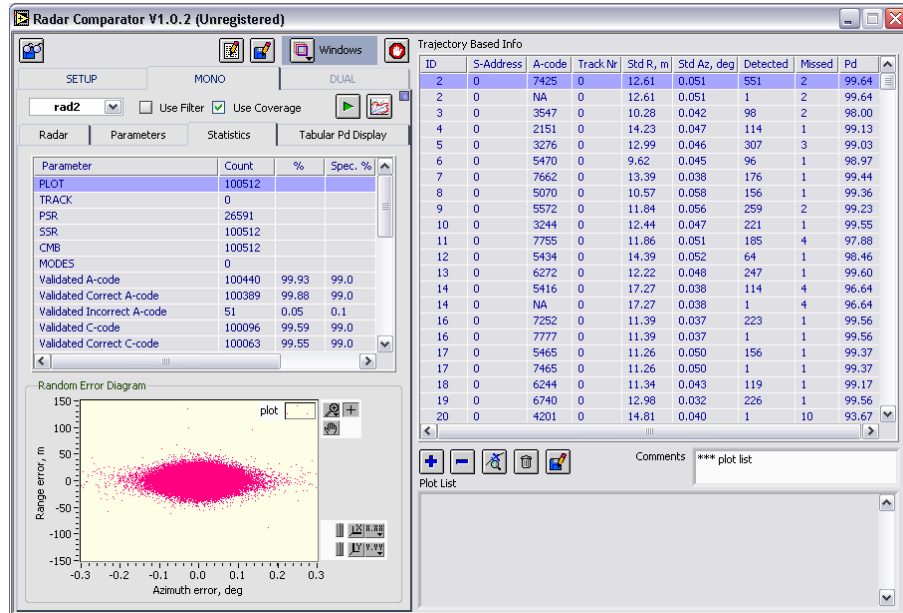
The trajectory based info table is cross-referenced with the XY mono-display cursor. Move the cursor and view the trajectory statistics in the table. Similarly If you select a trajectory in the table the cursor in the XY diagram will move to the first plot (track) of the corresponding trajectory.

10.2. Tutorial: DUAL-radar evaluation mode

This chapter describes how to getting started with DUAL-radar evaluation mode based on the included DEMO data evaluation set. Launch Radar Comparator from RASS-R
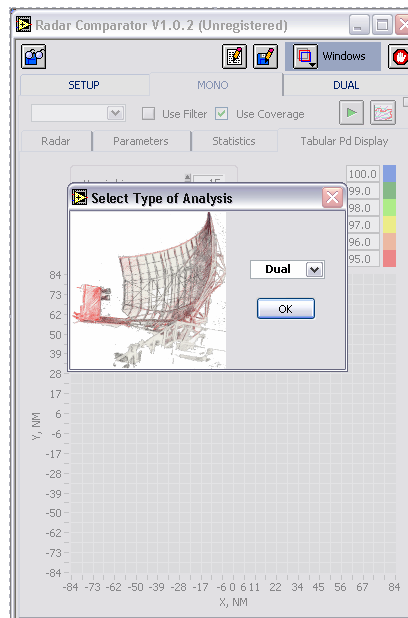
Select DUAL, press OK
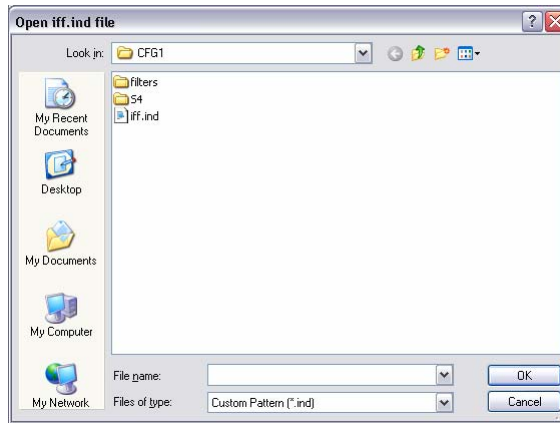
First time press Cancel, for the index file might be outdated.
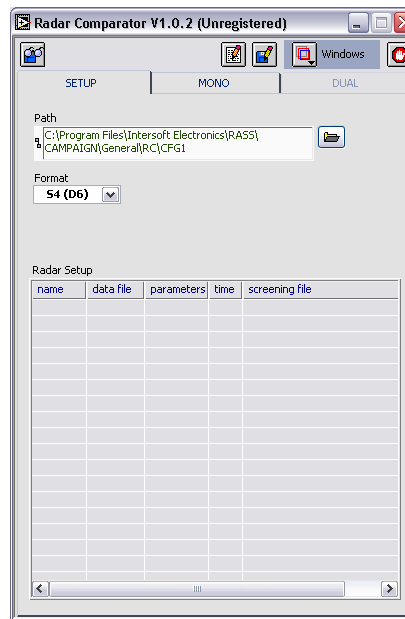
Select Format S4(D6) and press Load Source File control
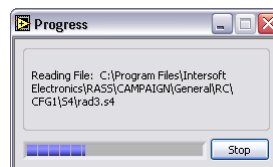
Wait till the files are loaded, or press stop to load a subset
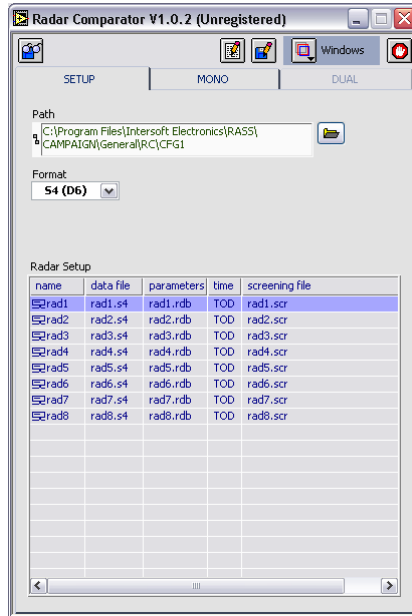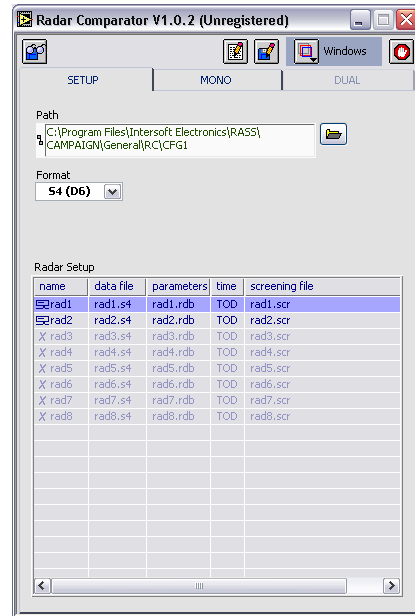
All the files are loaded   A subset (2 files) is loaded

Select DUAL tab.
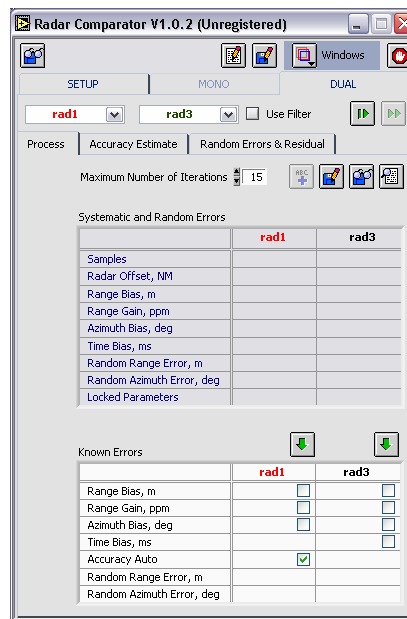
Select rad1 as reference and rad3 as radar under test, press the "Correlate" control
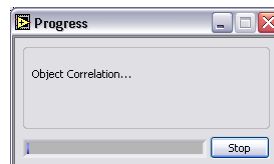
Wait till the processing is complete
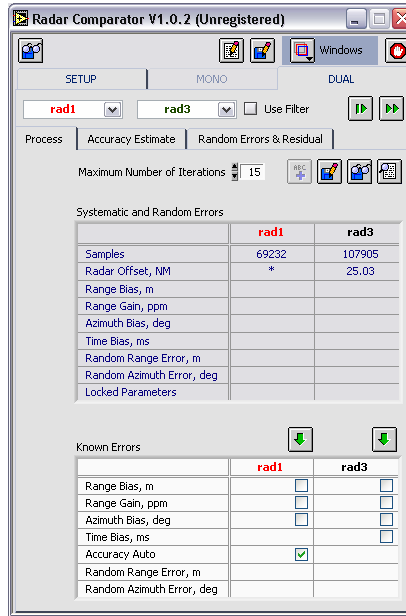
Inspect the number of plots (tracks) correlated for each radar. Press the "Run dual radar" control.
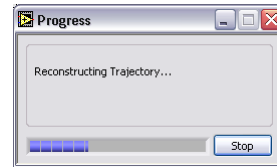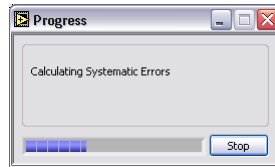
Wait till the processing is complete. This can take several minutes.
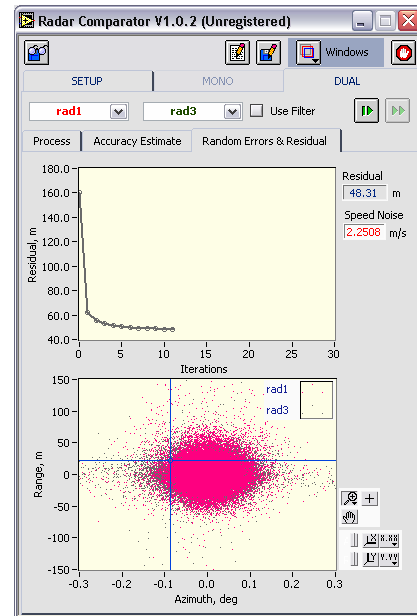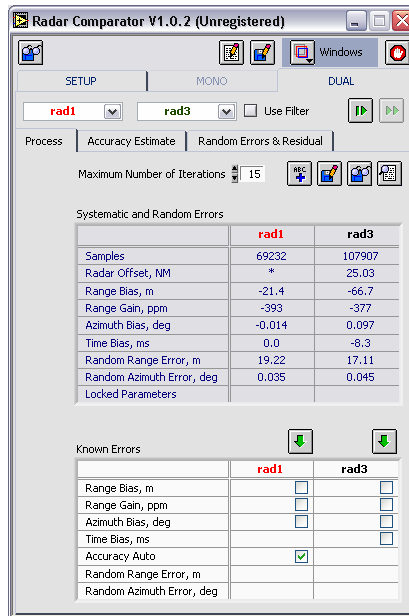
Inspect the results produced in the Systematic Errors Table as well as Random Errors & Residual Tab, where the convergence monitor and random errors diagram are placed.

To inspect the XY mono-display press "Windows" control and select "dual display".
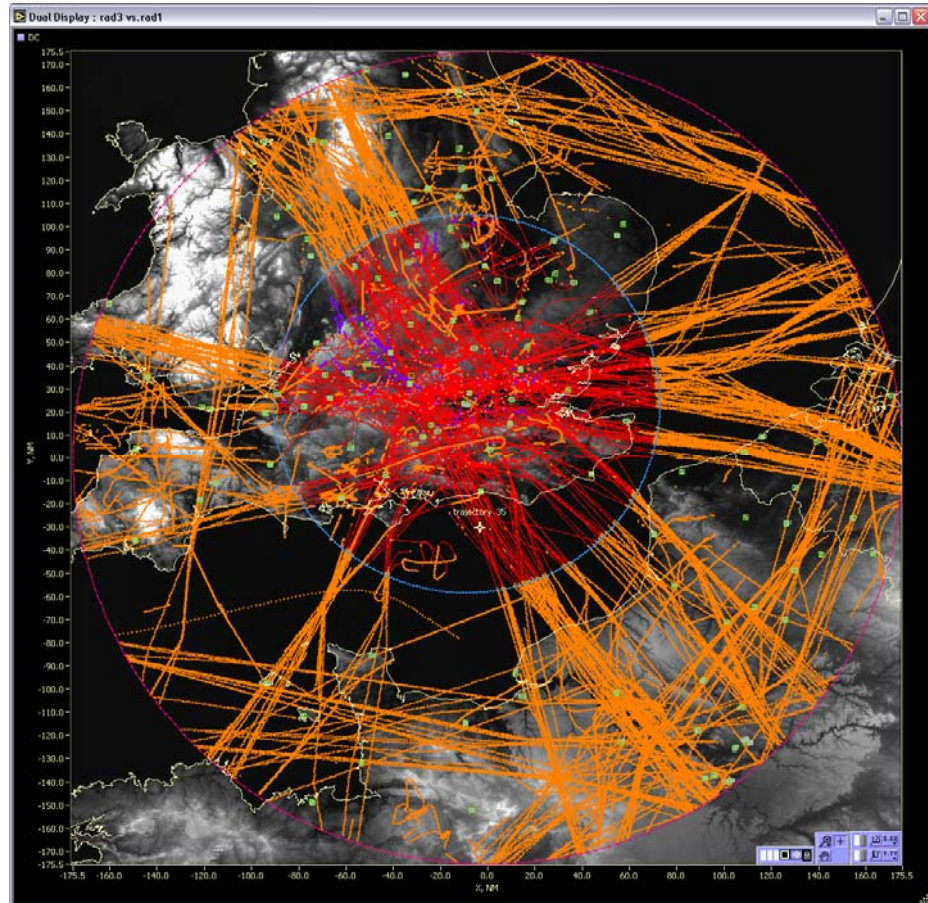
To inspect the reconstructed trajectories press "Windows" control and select "trajectory viewer".
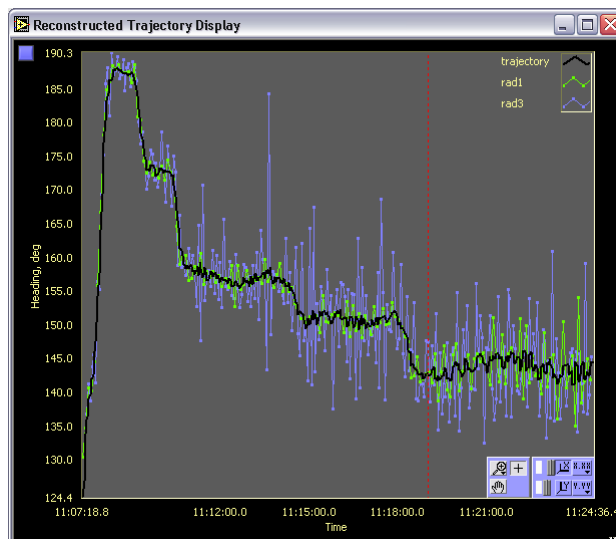
To inspect the plot info for a plot addressed by the cursor press "Windows" control and select "plot info".
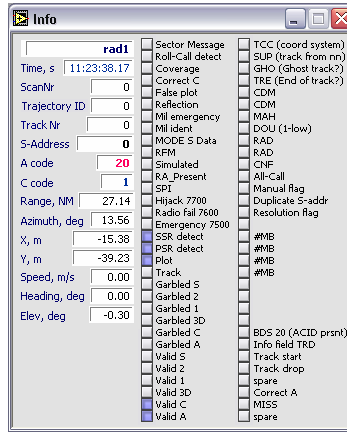
10.3. Tutorial: New Radar Setup Configuration

This chapter describes how to getting started with Radar Configuration. Launch Radar Comparator from RASS-R. Press the "Windows" control and select "radar setup" the following window will appear.
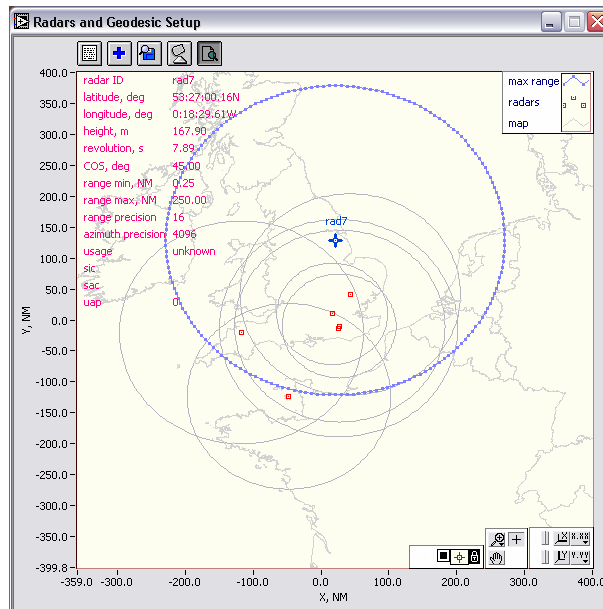
Press the "create new setup" control.
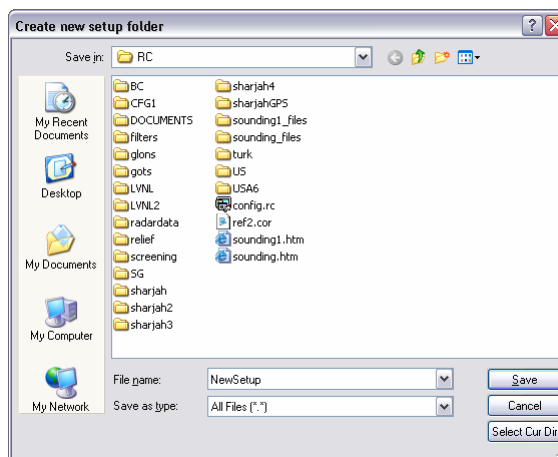
Specify a name for your new radar setup and press Save

Press the Add Edit Radar" control
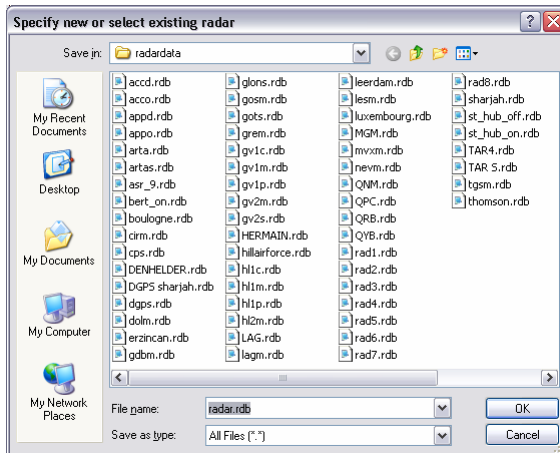
To create new just type in the desired name, and press Ok, to edit existing double-click on the existing radar parameter file. Should the file exist the following dialog appears. Select Ok or Cancel. Ok will open the existing radar parameter file for editing.
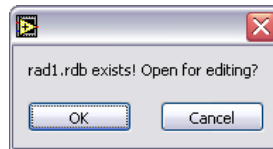
In the edit-mode the following radar parameter window will appear.
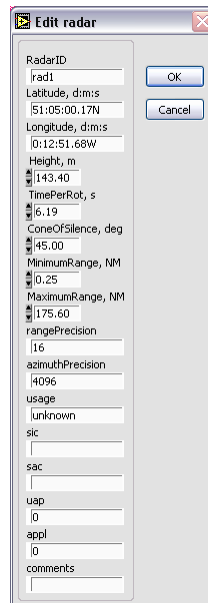
Edit the desired fields and press on Ok, Cancel will discard all the changes and close the file.

Press on the "Select Source file" and the following dialog will appear.
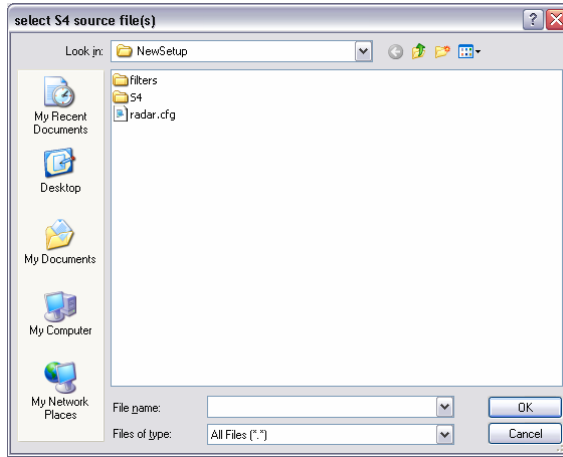
Select a source file in S4(D6) formats which must be somewhere on your hard disk or CDROM, and press Ok. The selected file will be copied to RC\NewSetup\S4. Should you copy more files repeat the procedure.

Press the "Radar List" control and the following window will pop-up.
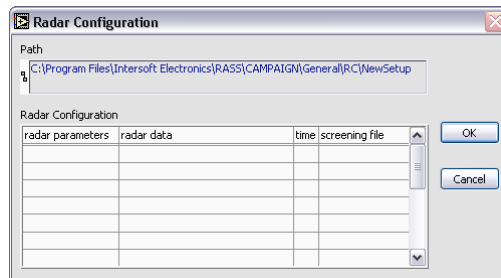
Clicking in the first column will select radar parameter files, clicking in the second column will select radar source files, the third column specifies the type of the timestamp to be used (type "d" for time of detection and "r" for time of recording. The fourth column selects the screening info file if available. The table may look like this
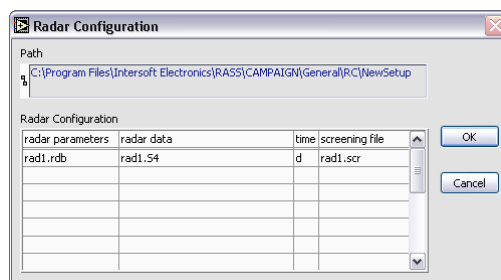
Press on OK.
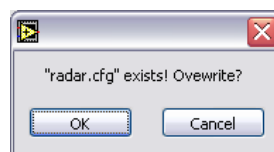
Press on Ok to overwrite the RADAR.CFG file. If the configuration is performed correctly you will see the specified radars on the map, for example as follows.
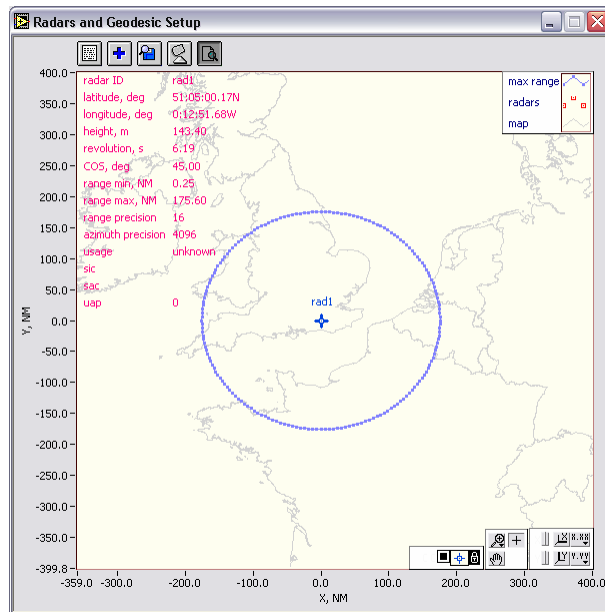
To start working with the created setup close the "Radar and Geodesic Setup" window and select the new evaluation folder (SETUP Tab)

GLOSSARY

OC	object correlator performing function of plot data combining into track data for Pd and accuracy analysis
Range bias	fixed range offset, additive range correction
Range accuracy	random range error, standard deviation
Refraction	deviation of the beam from the straight line propagation in the atmosphere due to the variation of the physical properties (density and refractivity)
Range gain	fixed multiplier for a radar, multiplicative range correction
Barometric error	altimeter error due to the difference between local atmospheric conditions and ICAO 1964 Standard Atmosphere
Azimuth bias	fixed azimuth offset, additive azimuth correction
Azimuth accuracy	random azimuth error, standard deviation
ACP	Azimuth Count Pulse
ACP eccentricity	azimuth error due to mechanical misalignment of the antenna and ACP encoder, producing particular sinusoid like pattern for azimuth errors vs. azimuth
Transponder delay	time delay between reception of an interrogation pulse and the corresponding reply
Timestamp bias	fixed timestamp offset, additive timestamp correction
Random timestamp error	timestamp random error, standard deviation
TR quality	quality of the trajectory reconstruction
Systematic errors (biases)	range bias, range gain, azimuth bias, and timestamp bias
Mono-radar evaluation	evaluation type when the data are originated from one source
Dual-radar evaluation	evaluation type when the data are originated from two independent sources
Pre-processor	software tool performing input analysis and correction of the data (timestamp, barometric height error, eccentricity and refraction)
Trajectory reconstruction	(dual-radar processing) algorithm producing more accurate estimate for the target position than the raw position data originated from both radars

REFERENCES

Reference	Document
[1]	RASS-R User Manual, Intersoft Electronics 2005
[2]	ICAO Document 8071 Volume III Manual on Testing of Radio Navigation Aids , Testing of Surveillance Radar Systems
[3]	EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas
[4]	SASS-C Study on MURATREC Multi Radar Trajectory Reconstruction Toolbox. Part Two, Intersoft Electronics 2003

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