RAOB

The Complete RAwinsonde OBservation Program

A product of Eosonde Research Services, LLC

User Guide & Technical Manual

Version 7.0

Note: This document contains information regarding all available program modules & options.

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The RAOB program is distributed without warranty of any kind, expressed or implied. The author assumes no liability for damages, direct or consequential, which may result from the use of this program.
Standardized algorithms are used wherever possible for data processing. There are several output parameters that use only one of potentially many methods of derivation. These output data should be used with caution and must not be interpreted as definitive solutions.

PROGRAM SUPPORT

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GENERAL DESCRIPTION.

1.1 Program Overview. RAOB is a multi-functional, fully interactive sounding analysis program, capable of decoding data from standard WMO formats and many commonly used commercial and institutional formats. RAOB can plot soundings reaching up to 0.001 mb and containing thousands of data levels per sounding. Data files containing multiple soundings can be automatically looped for quick viewing. Temperature profiles and wind plots can be interactively modified as analyses data/graphics simultaneously update. Soundings are plotted on Skew-T, Emagram, or Tephigram diagrams, upon which several sounding parameters can be alphanumerically displayed, while others are graphically overlaid. Graphic overlays include: icing (clear & rime), clouds, clear air turbulence, mountain-wave turbulence, low-level wind shear, thermal turbulence, energy/buoyancy areas, inversions, frontal layers, lightning, contrails, and more. The sounding's wet-bulb and virtual temperature profiles can also be overlaid. There are numerous computational options, including turbulence and icing algorithms, and even an option for automatic or manual cloud layer data. RAOB has options for analytical comparison of two soundings or simultaneous overlays of up to five soundings. Alphanumeric data displays include, hail size, surface gust potential, SWEAT, TT, LI, K-index, helicity, CAPE, EHI, and many others. All significant level data (LCL, CCL, LFC, & associated ELs) are listed, including the option to graphically label each level and plot parcel lifting sequences. Diagram options include temperature scaling in °F, °C , or °K; while vertical scaling options include pressure (mb or hPa), kilometers, feet, or miles. Special “severe weather”, “winter weather”, "fire/air-quality", and "tropical weather" displays help analyze storm and precipitation potential, respectively. Winds can be displayed on a full-screen, a fully interactive hodograph, or via an interactive 3-D trajectory hodogram. Each sounding is supported with a variety of data listings providing over 100 original and calculated parameters, which can be printed or saved to disk file. Severe weather potential can be quickly identified using a user-defined parameter table that can be graphically displayed with the sounding. Use the optional Soundingram to compare data profiles of various parameters, including temperature, ozone, winds, and more. An optional Fronts & Forecast module can use thermal wind advections and/or upwind soundings to create “forecast” soundings. An optional vertical cross-section module can plot from 2 to 2000 soundings in either a time-based or distance-based orientation. The cross-section has numerous data analysis options and can automatically interpolate a complete composite sounding, including temperatures and winds. An optional mountain wave module interactively accepts mountain parameters and produces single or double mountain (harmonic) lee wave analyses along with detailed wave graphics and turbulence category data listings. RAOB also contains a unique aerosol decoders module, and a one of kind Doppler decoder & display module which can simultaneously produce PPI/VAD & RHI scan images with a vertical wind plot on the same screen.

1.2 Data Overview. RAOB can decode a wide variety of data types, including the common WMO coded data and unique data formats available from the WeatherBank, Weather Network, WSI™, NCDC/FSL's CD-ROM historical CARDS format soundings, NOAA/ARL's forecast soundings, BUFKIT & RUC/MAPS forecast data, UWYO, PAOS, SH4/NASA, Vaisala HiRes and Vaisala ETD data, IGRA, ACARS aircraft data, KMA, RASS, SHARP modified data, BUFR & GRIB binary data, Hurricane Dropsonde data, microwave and acoustic profiler data, Sodar & Lidar data, and CLASS/NCAR data which can contain thousands of data levels per sounding, and many other data formats. For coded WMO sounding data and other formats, RAOB can access files containing hundreds of soundings per file. RAOB can also decode data in the raw format, where data elements are conveniently listed by Pressure/Temperature and Height/Wind groups. Raw data, however, are not as readily available as coded data, but can be obtained from the National Climatic Data Center (NCDC) at Asheville, NC, along with other types of archived weather data. RAOB also uses the intrinsic CSV (spreadsheet style) data format, enabling a wide variety of applications.

Coded (WMO) data that does not follow the standard formats specified by the Federal Meteorological Handbook No. 4 (FMH-4) can either result in unusual data displays or cause RAOB to display a data processing error message.

See the section on DATA SOURCES for information regarding availability of sounding data.

1.3 Program Modules. RAOB is a modular program. This User Manual describes the capabilities of all program modules regardless of those modules purchased. The Basic Module is the only stand-alone module and is necessary for the operation of the other optional modules.

RAOB Basic Module:
Fully scalable Skew-T and Emagram sounding diagrams up to 100 mb.
Partially scalable Tephigram sounding diagram (only up to 100 mb).
Download sounding data directly from the Internet via HTTP and FTP methods.
Numerous thermodynamic and storm indices data are calculated and displayed.
Graphic and text displays of key sounding parameters, including LCL, LFC, and CCL.
Includes Station Locator file editor.
Mini-hodograph display in upper corner of plotted sounding diagram.
An interactive Soaring diagram that produces lift indices, including thermal & trigger temperatures.
Processes RAOB Raw & CSV data, WMO Coded data, SHARP, BUFKIT, and UWYO data formats.
Encodes any of the above data formats into RAOB's Raw data format.
Includes the highly versatile Custom View display system.

RAOB Lite:
The RAOB Lite program is an introductory version of the RAOB Basic program. It is a scaled down version that contains essential functionality for accurate and thorough analyses. The RAOB Lite program contains the following key features:

- The WMO and BUFKIT data decoders.
- The Soaring diagram and displays.
- The classic parameter listing of key weather indices.
- Internet download capability plus standard input / output functions.
- Sounding diagram configuration options.
- Data scanner displays up to 10 parameters.

The following key features will become functional upon upgrade to the Basic program module:

- UWYO, SHARP, and RAOB"s CSV data decoders.
- DeCoded and Source data editors.
- Diagram dual temperature scaling option.
- Diagram sounding profile color options.
- Diagram variable wind shafts option.
- Diagram custom Height and Temperature line options.
- Diagram adiabat and mixing-ratio display options.
- Personalized logo overlay display option.
- Custom parameter data display listing options.
- Multi-system configuration options.
- Data scanner displays up to 30 parameters.
- Data sequencer to 3-D sounding profile viewing.

RAOB Optional Program Modules. The RAOB Basic program is a prerequisite for any of these optional program modules. The RAOB Lite program can not access any of the following modules, until it is upgraded to the Basic program configuration.

Aerosol Decoders Module:
This module contains decoders which can process non-conventional atmospheric parameters, such as dust, particulate matter, and other parameters of interest. This decoder is unique in that it can process atmospheric parameters without the need for associated Temperature or Wind data. The only requirements are a Station Elevation and parameter Heights. RAOB can process up to 3 different parameters for each profile. If the aerosol data in binary format, then the optional Binary Data Deoders module is required. Additionally, time-height diagrams can be created with use of the Cross-Section module, and soundingrams can be created with the Soundingram module.

Analytic Module:
Includes text/graphic displays of CAT, LLWS, Thermals, Icing, CAPE graphics, Clouds, Contrails, Inversions, Wind speed & shear, RH, ThetaE, Refractivity/ducting analyses, and others.
Allows a versatile array of configurable program algorithms for turbulence, icing and other parameters.
Contains the Complete, Analyses & Severe Weather data listings.
Severe weather parameter table for storm potential analyses – configurable.
Severe Weather, Winter Weather, Fire/Air-Quality, and Tropical Weather specialty display screens.
Layer Analyzer screen allows detailed analyses of any sounding layer.
Cloud data editor with manual or automatic cloud generation options.
Comprehensive fog detection and type table. User configurable.
Audio/visual weather alert system. User configurable.
Detailed comparisons of any 2 soundings or multiple overlays of up to 5 soundings.

Binary (BUFR & GRIB & netCDF) Decoder Module:

BUFR: Plots and analyzes the special WMO code form FM 94 BUFR (Binary Universal Form for the Representation) of meteorological data containing various forms of binary meteorological data including sounding data. This decoder only processes the sounding data formats, including the unique formats produced by the US NWS. BUFR data sets can contain single or multiple sounding files.

GRIB: Plots and analyzes the special WMO code form FM 92 GRIB (Gridded Binary) data containing various forms of binary meteorological data including sounding data. RAOB can only decode the popular GRIBv1 data formats. The newer GRIBv2 format contains too many unique (3rd party) compression schemes, plus most data can be retrieved in the simpler GRIBv1 format

netCDF: netCDF (network Common Data Form) is another form of binary data that contains single sounding and data arrays in grid format, similar to GRIB data. It was developed at the Unidata Program Center in Boulder, Colorado. The netCDF decoder uses the same user display screen as the GRIB data. RAOB uses the "ncdump" utility to retrieve sounding data for specific locations. This utility was also developed by Unidata personnel. Currently, only the most common data fields are decoded. If a customer finds netCDF data that does not correctly process, please notify ERS.

Cross-Section (Standard) Module:
Produces time-base and distance-based cross-section using 2 to 100 soundings.
Diagrams are scalable while cross-section data can easily be edited for sequence and labels.
Analyze/contour cross-sections using most analysis options available to sounding diagrams.
Each analysis option can be user-configured for data interval, color, line-type & thickness.
Automatically interpolate a complete sounding anywhere along the cross-section diagram.
Unique Composite Sounding Map screen allows sounding interpolation from any group of sounding data.

Cross-Section (Advanced) Module:
Contains all features available with the Standard Cross-Section module plus …
Produces cross-sections containing up to 6,000 soundings.
Analyses can also be produced in vivid colorized, or painted displays, including unique coloring schemes.
View data in a split-screen format, or display weather symbols below the sectional diagram.
Colorized analyses can be user-defined with the built in Gradient Editor.
Can also display 2 or 3 or 4 panels on the same screen – great for comparison purposes.
Ability to ZOOM into any portion of the diagram – and save as a new diagram.
Compare 2 different cross-section or time-section diagrams simultaneously.
Capable of batch-generation of time-height diagrams.

Doppler Decoder/Display Module:
The Doppler screen is unique because it plots 3 different lidar-based images on one display: PPI/VAD, RHI, and DBS (or vertical wind plots). In addition to a complete set of interactive screen display options, this display also includes a full menu of Batch & Timer options.

Encoders Modules:

Standard Encoders Module:
With this module RAOB can encode sounding data into any of these data formats:
- RAOB's RAW (or decoded temperature & wind format)
- RAOB's CSV (comma-separated, spreadsheet style)
- WMO Coded (Land fixed, Land mobile, and Ship)
- BUFKIT
- GSD (FSL)
- SHARP (SPC) Encoder

Binary Encoders Module:
With this module RAOB can encode sounding data into any of these data formats:
- BUFR (binary format)
- netCDF (binary format)

STANAG (NATO) Encoders (& Decoders) Module.

Export Module (Advanced):
Powerful, full-featured, menu-driven exporting system capable of exporting sounding elements for each data level, calculated data parameters, and various layer data such as icing and turbulence. Data can be exported as Text or in spreadsheet CSV and TSV formats. User can adjust data positioning and data units. The Standard Export function is included with the optional Analytic module, but this Advanced Export module offers many more options and features and is continually being expanded to meet new customer needs.

Fronts & Forecast Module:
Automates long-established "single-station-analysis" techniques.
Automatically forecast maximum surface temperatures from early morning soundings.
Uses thermal wind data to analyze frontal information and associated weather patterns.
Produces forecast soundings using thermal wind advections or from upwind sounding data.

High Altitude Module:
Plot sounding data above 100 mb and up to the 0.001 mb level. All associated text and parameter data are also presented for high altitude levels. High level processing is also applied to other program displays and modules, such as the hodographs, cross-sections, and soundingrams.

Hodograph & Interactive Module:
Click & drag sounding profile (temperature & dewpoint) graphical modifications.
Click & keystroke wind plot (speed & direction) graphical modifications.
Multiple parcel lifting options including options to adjust the entire sounding.
Automatic dry adiabatic lapse rate (DALR) surface layer modifications.
Zoom (in & out) on any portion of the sounding diagram's temperature profile.
Full-screen, fully interactive click & drag hodograph with corresponding wind data.
Full-screen, 3-D hodogram (trajectory diagram) with interactive tilt & rotation options.

Merge module (Standard):
Merges from 2 to 6,000 soundings into a single composite sounding.
Or, automatically merges the "last" sounding of multi-sounding time-series datafiles.
This module also includes features of the Batch & Timer functions.

Merge module/utility (Advanced):
Automatically merges temperature/dewpoint and wind (UVW) data for the entire multi-sounding file.
Creates both individually merged sounding files and a composite multi-sounding file.
Contains a variety of data management options, timer functions, and FTP capabilities.
Module can run independently of the RAOB Program, while feeding RAOB's real-time processors.

Radiometer Decoder modules.
Radiometer sounding data is produced by surface-based microwave profilers. Soundings typically include liquid-water and vapor-density data in addition to standard temperature and moisture data. Wind data is not produced. Soundings can extend to a height of 10 km and can be produced every few seconds. RAOB can processes both SCAN and ZENITH data types. This data type can also be processed with RAOB's Real-Time Display (an optional program) module, which automatically updates time-height diagrams. The Advanced Radiometer Decoder Module can also process 6 additional scalar parameters: Rain (yes/no), Quality Flag, Integrated Vapor & Liquid, and Cloud Base Temperature & Heights.

Real-Time Cross-Section Data Processor Module:
This module requires use of the optional Advanced Cross-Section module.
Automatically detects and decodes new sounding data (programmable to 1-second intervals).
The current cross-section diagram is automatically re-plotted.
The cross-section data analyses are automatically updated.

Sodar/Lidar/Radar (with Acoustic/Radio) Decoder module:
Plot data from the Sonic Detection And Ranging (Sodar), Light Detection and Ranging (Lidar), and Radio Acoustic Sounding System (RASS) sounding data. These methodologies take advantage of three technologies (laser, acoustic, and electromagnetic) to provide real time temperature and/or wind profiles.

Soundingram (Standard) Module:
Performs detailed profile analyses and comparisons of key sounding data, including
- potential temperature, shear, ozone, density, refractivity, and more...

Diagrams are fully configurable similar to the standard sounding diagram.
Plot sounding data profiles on one or two separate diagrams.
Compare up to four soundings on one or two diagrams.

Soundingram (Advanced) Module:
Performs all functions contained in the Standard Soundingram module, plus...
Displays 3 Soundingram panels at the same time, if a wide-screen monitor is used.
Displays an optional "difference profile" when comparing 2 soundings.
Provides Batch & Timer and Batch-Load functions for greater automation.

Special Data Decoders Module:
Plot and analyze over 90 popular sounding data formats. These decoders are constantly kept up-to-date as data codes and formats change. Program updates are routinely compiled and made available for download to RAOB customers. New decoders are added upon request of customers. New decoders can be added in as little as 24-hours, especially for those formats that are in ASCII or human-readable text. See the section on RAOB DATA for details on all data formats decoded.

Turbulence & Mountain-Wave Module:
Analyzes mountain (lee) wave turbulence with respect to single or double mountains.
Provides wave characteristics, including wavelength, amplitude and vertical velocity.
Automatically append mountain parameters to individual sounding files.
Use a mountain parameter data file to catalogue mountain ranges.
Configurable exponential wave decay function.

2. **SYSTEM REQUIREMENTS**.

2.1 Computers. RAOB requires a computer with a hard drive, keyboard, mouse, and a color super-VGA monitor. RAOB program files require approximately 100 MB of disk space. Computers with less than a 1000MHz processor will experience sluggish performance. A CD-ROM drive is required to load and install the RAOB program. NOTE: RAOB is best displayed using a screen resolution of 1024x768, or better. New code has been added to take better advantage of new widescreen computer monitors. Note that RAOB will may not function with some dual-monitor systems.

2.2 Printers. RAOB will print to any device supported by the Window's environment.

2.3 Software. RAOB will function within any Windows environment, but not with virtual systems.

2.4 Program Files. When RAOB is activated, the program first searches for all necessary program files. If a required file cannot be located, the program displays a warning message. If this occurs, the user must re-install the RAOB program or locate and replace the missing file by some other means.

3. **GETTING STARTED**.

3.1 Program Installation. RAOB is installed onto the computer's harddrive by executing the SETUP.EXE program located on the distribution CD-ROM, or by using the downloadable installation file. During installation, program and data directories will automatically be created. The program's configuration files will be created upon the initial activation of RAOB. Below are the recommended (default) sub-directories that the installation program will generate.

C:\Program Files\RAOB Program	for program files.
C:\Program Files\RAOB Program\RAOBDATA	for rawinsonde (sounding) data files.
C:\Program Files\RAOB Program\CROSDATA	for cross-section dataset files.
C:\Documents and Settings\user\My Documents\My Pictures	for images
C:\Documents and Settings\user\Application Data	for working files & settings

3.2 Plot a Sounding. The RAOB program starts with a blank sounding diagram. Load a sounding by selecting FILE from the Menu Bar and then select OPEN to access a data file. Once plotted, the sounding can be analyzed using the ANALYSE menu item. The diagram can be adjusted by using the OPTIONS then DIAGRAM menu items. To access the vertical cross-sections screen, use the DISPLAYS menu option. Use of the HELP files will assist with familiarization with the program's many other capabilities and features.

3.3 Station Data*. The RAOB.STN data file contains station data from around the world. All station data are listed with respect to WMO numbers, which RAOB searches for during the decoding process. Automatic retrieval of station elevation and coordinates only occur when WMO coded data is accessed. If a favorite sounding station is not included in the RAOB.STN file, it can easily be added. Additions, deletions or modifications can be made to the RAOB.STN file with any text editor or by using RAOB's built-in editor.

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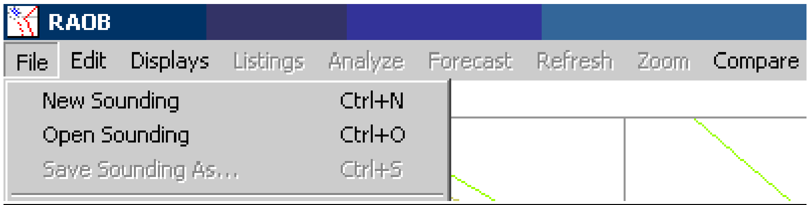
* CAUTION: File structure and data format must be exactly followed or program errors will occur. If file editing is performed, be sure to keep all WMO numbers in numerical sequence and ensure commas are used between each data item. Do not remove the title and associated text information preceding the tabular data.

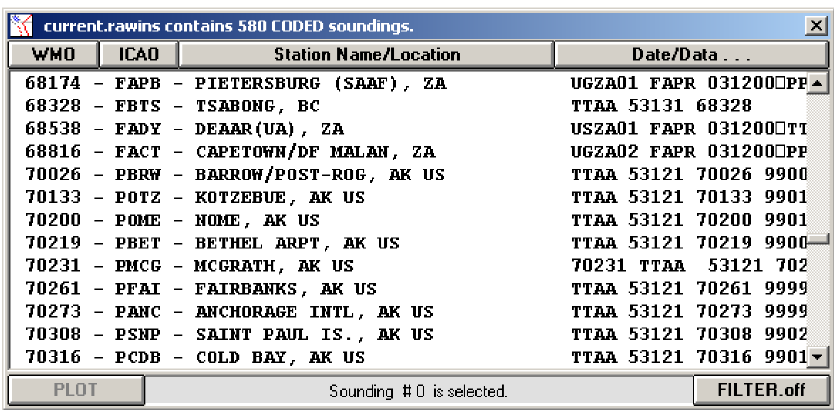
4. **SOUNDING DIAGRAM (Menu Bar)**.

4.1 **File**. (Open sounding data and Filter station data options.)



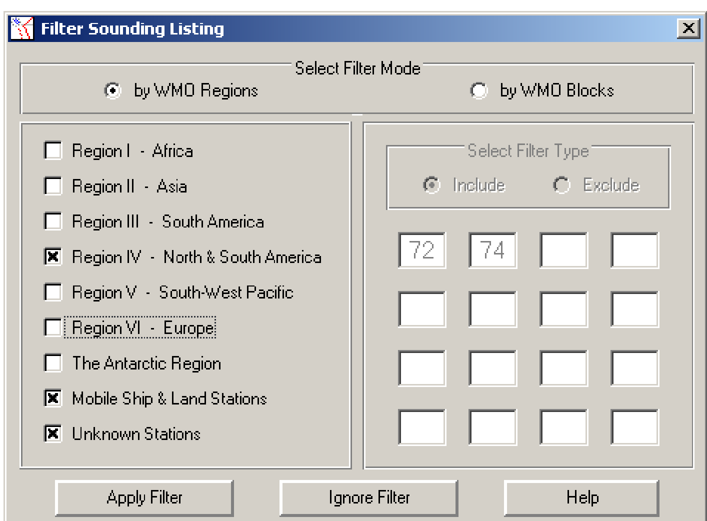
New Sounding. Creates a new, blank diagram. Data can be manually entered to create a special or custom sounding. Create a new sounding by using the data editors found under the EDIT option located on the Menu Bar. With the optional Interactive Module, data can be graphically added to the diagram using the mouse – see the Interactive Module section for details.

Open Sounding. Opens the computer's data directory, enabling selection of a previously saved data file. See opened List box below...



When a datafile containing multiple soundings is accessed, the Sounding List Box (at left) is displayed.

When a file of WMO Coded soundings is displayed, the column headers (WMO, ICAO, etc) can be sorted by clicking on the headers. Also, the FILTER button at the lower-right can be used to help select or restrict the display of specified groups of data. See example below…



When the FILTER button (see above) is used, two filter Mode options become available.

1. WMO Regions. This is a quick and easy way to selectively display only the desired global sounding regions. The "Help" button provides a list of WMO numbers contained in each WMO Region.

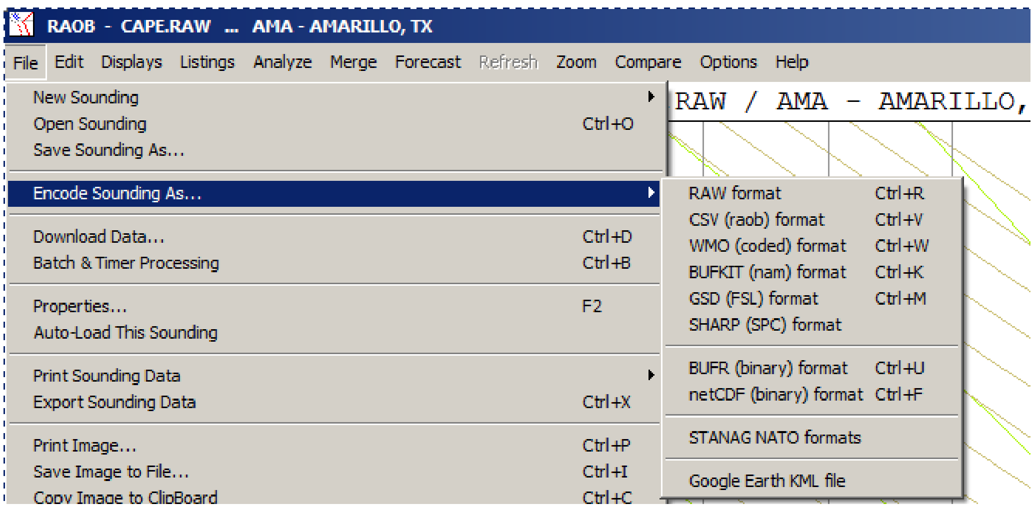
2. WMO Blocks. This option provides very selective capabilities to "Include" or "Exclude" specific WMO Block numbers.

<u>File Menu Continued…</u>

Save Sounding As … This option will save the currently plotted sounding with a user defined filename. The data format will not be changed. However, if the plotted sounding is from a datafile containing multiple soundings, then only the currently displayed sounding will be saved. (In order to save the entire datafile with a different name, you must first access the file using the EDIT menu's "Edit Entire File" option, and then save the file with a different name.)

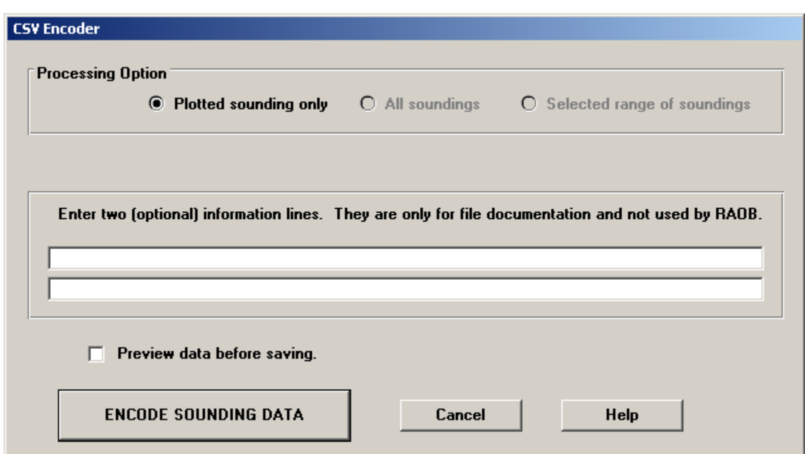
<u>Standard Data Encoders Module</u>. This is an optional program module.

The "**Encode Sounding As …**" option allows a variety of data saving formats. The first option (see below) is the RAW format, which is indigenous to the RAOB program. This format is visible when using the RAW data editor (press F3) which is listed as the "Edit DeCoded Data" option under the EDIT menu. The RAW data format structure is described in greater detail in the "RAW DATA FORMAT" section of this manual. Other encoders (CSV, WMO, BUFKIT, GSD/FSL, SHARP) are only available with the optional Standard Encoders module. The BUFR & netCDF encoders are only available with the optional Binary Data Encoder module. The STANAG encoder is included with the STANAG Encoders/Decoders module.



The Google Earth option is available to all RAOB programs. It creates a KML file which can be shared with others with Google Earth installed on their PCs.

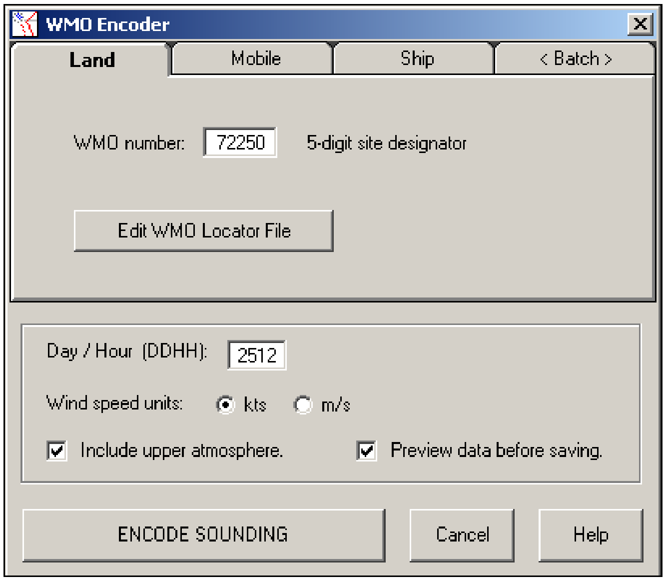
CSV Encoder. This option saves the sounding in RAOB's CSV format, this is a spread-sheet style (comma-separated) format. This is a very versatile format which allows a variety of data options, including single or multiple-sounding files.



The CSV format is described in greater detail in the "CSV DATA FORMAT" section located near the end of this manual. In addition to the standard pressure, temperature, and wind data. This format also allows Ozone, Omega, Radiometric, vertical wind (W) data, cloud cover (CFRL) data, and many other types of data elements.

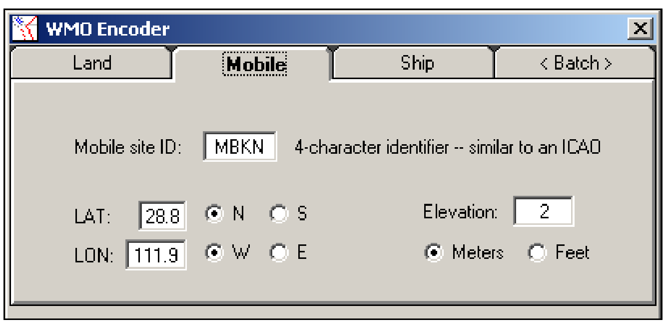
<u>Data Encoders continued…</u>

WMO Encoder.



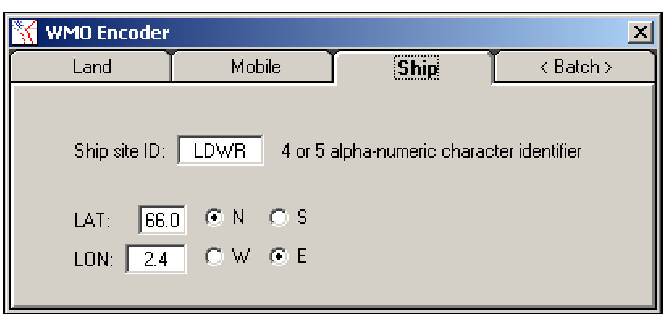
The WMO encoder saves the sounding in the common WMO coded format as defined by FMH-4 on Radiosonde Codes. Saved data groups include TTAA, TTBB, and PPBB from the surface to 100 mb and include TTCC, TTDD, PPCC and PPDD for data above 100 mb. Note that the optional High Altitude module is required for data above 100 mb (which is also true for the CSV data encoder described above). Unlike the CSV Encoder, the WMO Encoder can not encode multiple sounding files.

The WMO encoder can save data in the Land (fixed station), Mobile (mobile station), or Ship (ocean mobile station) mode formats.



The Land mode needs a valid WMO number as a reference to ensure accurate correlation to station elevation and coordinates. If RAOB does not detect a valid WMO number, one must be entered into RAOB's Locator File (file: RAOB.STN) via the Edit button.

The WMO encoder also requires entry of the Day/Hour information and whether wind speeds will be coded as knots or meters-per-second. This data is needed for all 3 modes.

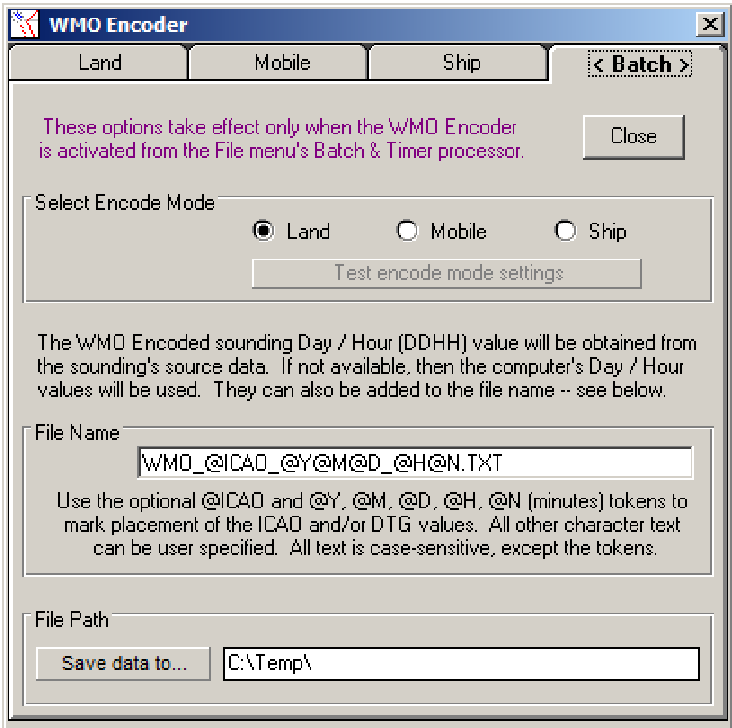


The Mobile mode does not need a WMO number, but instead requires a mobile site ID designator – similar to the station ICAO. Also required are the site's coordinates and elevation.

The Ship mode also needs a site ID, which can be 4-5 characters in length. Coordinates are also needed, but elevation is not required since all ship sounding data are assumed to be based at sea level.

The next page discusses the 4th mode of the WMO Encoder < Batch >, which permits automated encoding using the File menu's <u>Batch & Timer Processing</u> option.

WMO Encoder continued…

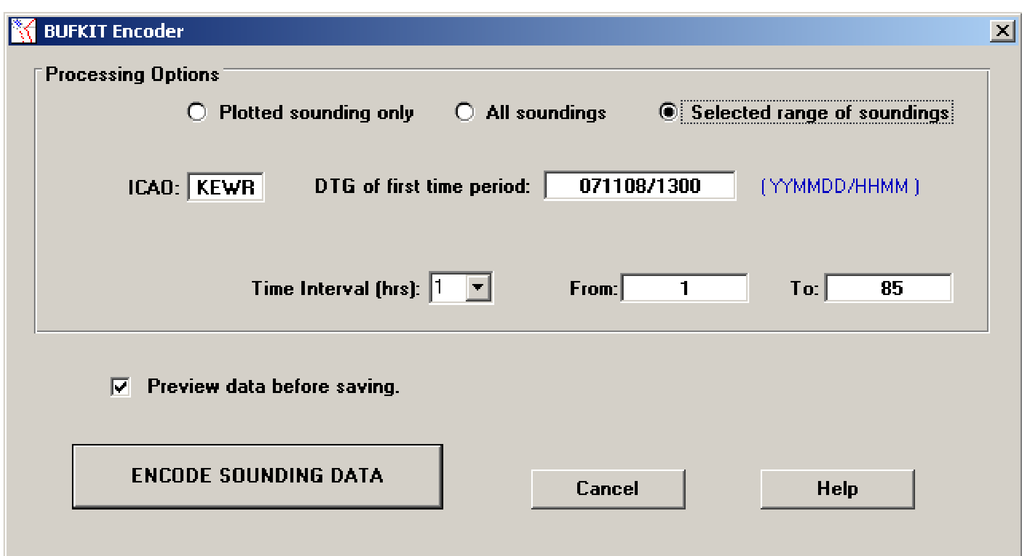


The WMO encoder can be invoked for batch processing by two methods; each is discussed later in this chapter. They are the System/DOS batch command process options and RAOB's Batch & Timer Processing options, which are found in the File menu options.

For either method of invoking; the Encode Mode, File Name, and File Path must be pre-specified on the panel shown at left.

The File Name construct allows an ICAO and date & time tokens for Day, Hour, and Minutes. When included in the File Name, RAOB will automatically replace the tokens with the 2-digit values found from the computer's internal date & time settings. If needed, the user can manually enter the Year or any other unique data.

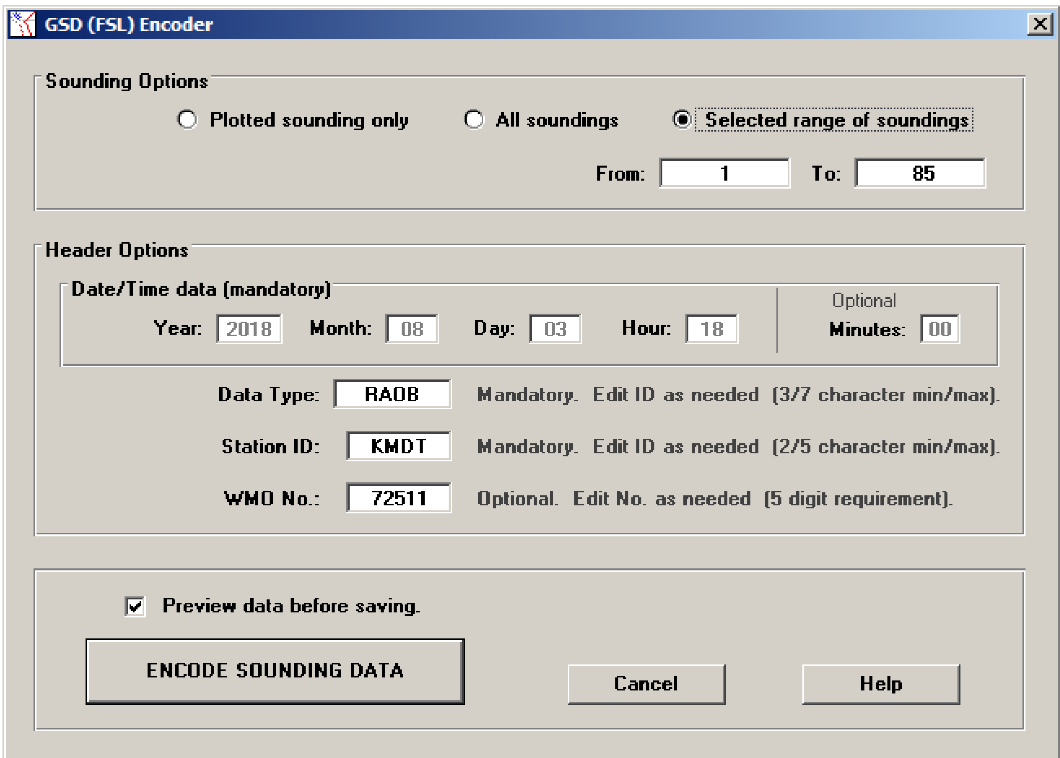
BUFKIT Encoder. This option saves the sounding in the popular BUFKIT (nam style) format. When encoding multiple soundings, they should be a time-series collection since DTG information is attached to each sounding. The user must identify the ICAO (Station ID), the start time and time intervals as shown below. Omega and CFRL (cloud cover) data will also be included if available. In addition to the sounding's standard data (pres, temp, wind), BUFKIT data also contains supplemental data parameters (such as Helicity, Storm-Motion, and CAPE). Note that RAOB will calculate its own supplemental data values, even if provided by source sounding data, such as from the source BUFR data files.



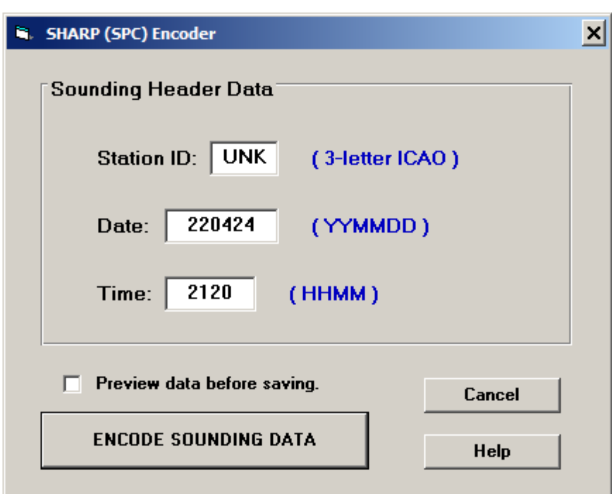
Data Encoders continued…

GSD (FSL) Encoder. This encodes data in the NOAA Global Systems Division (GSD) format, formerly known as Forecast Systems Laboratory (FSL).

When encoding multiple soundings, they should be a time-series collection, since DTG information is attached to each sounding. RAOB will automatically fill in "Header Options" data if available. Otherwise, the user must identify "Date/Time" information, "Data Type", and "Station ID" (or ICAO). The WMO number is optional, but should be entered if known. RAOB links the WMO number with the RAOB.STN station reference tables.



SHARP (SPC) Encoder. This encodes data in the SHARP SPC (Storm Prediction Center) format.

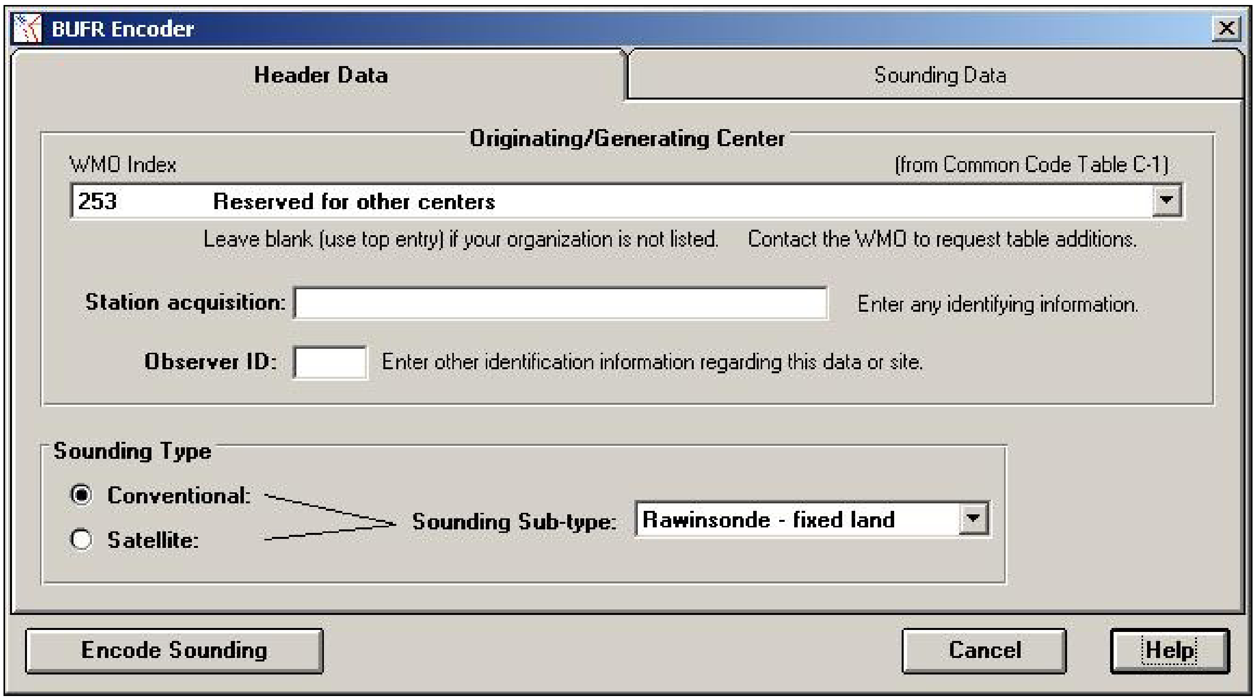


Data Encoders continued…

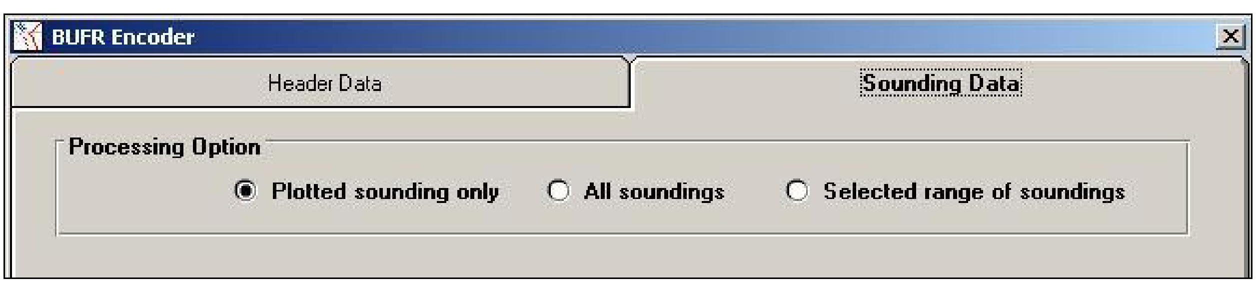
Binary Encoders Module. This is an optional program module, which includes the BUFR and netCDF data encoders.

BUFR Encoder. This option saves the sounding in the special WMO code form FM 94 BUFR (Binary Universal Form for the Representation) data format. Both single and multiple sounding files can be encoded into the BUFR format.

The first tab of the BUFR encoder is shown below. It encodes administrative qualifiers necessary for the proper function of BUFR decoders. The topmost entry, "WMO Index" is a restricted entry field, as it only allows predetermined table options (reference: Common Code Table C-1). If you do not represent any of the allowed table entries, then you must contact the WMO to add your organization to the table listing. In contrast, the "Station acquisition" and "Observer ID" entries are optional and completely free form. The "Sounding Type" entries should be selected to best identify your sounding data.



The second tab of the BUFR encoder allows encoding of either a single sounding, all soundings within a multi-sounding file, or a specified range of soundings. Note that the BUFR Encoder only encodes the following parameters: Pressure, Temperature, Dewpoint, Height, and Winds (U,V,W components).

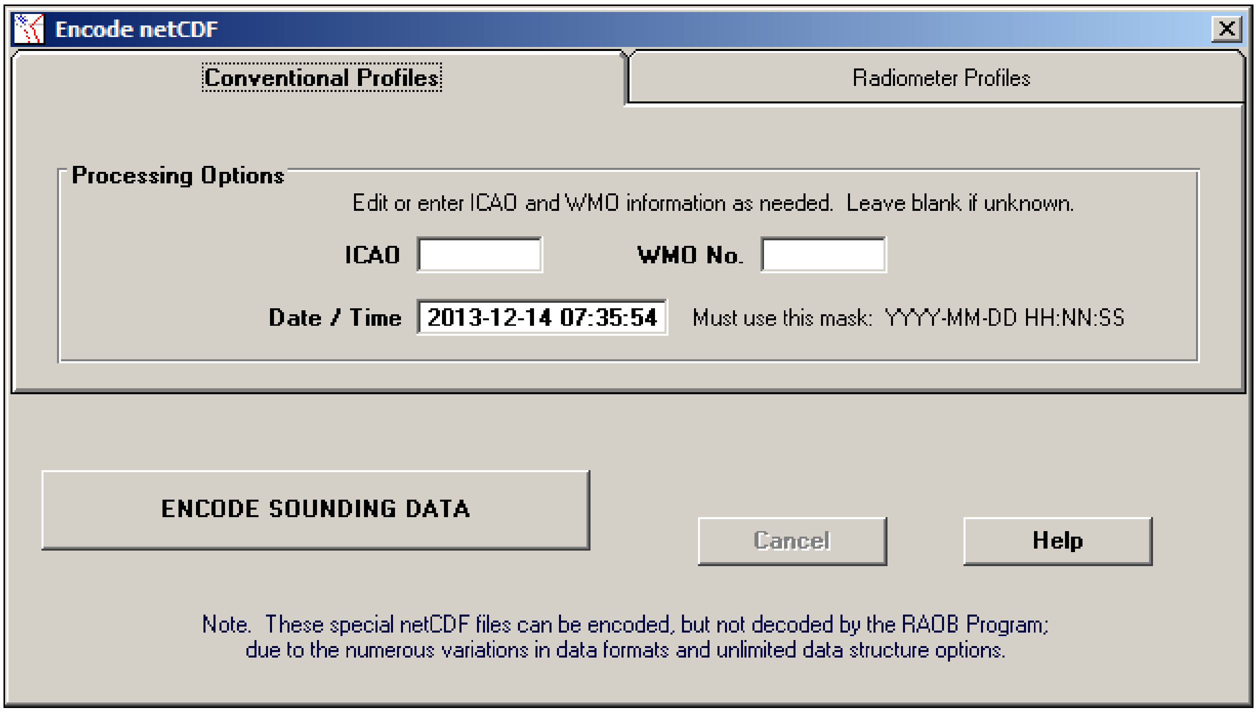


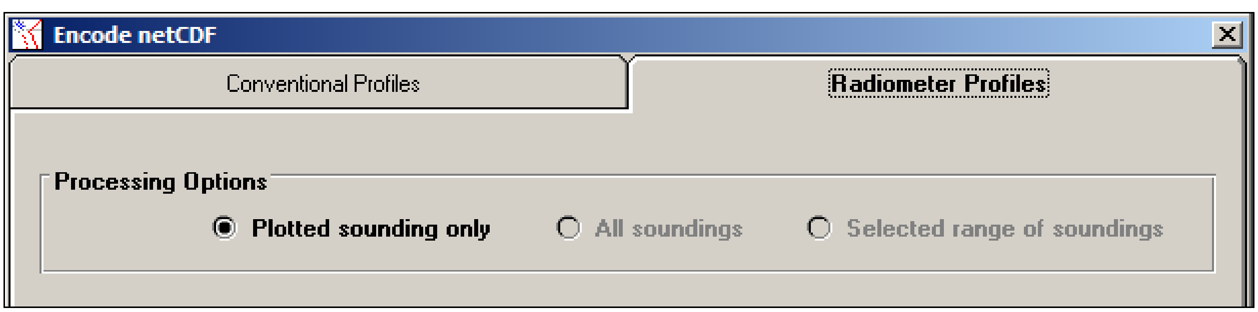
Data Encoders continued…

netCDF Encoder. This option saves the sounding in the netCDF (network Common Data Form). It was developed at the Unidata Program Center in Boulder, Colorado. RAOB uses the "ncgen" utility to encode the sounding data into a binary format. This utility was developed by UCAR, where the netCDF copyright notice and disclaimer can be found in the section call Binary Decoders.

Please note that while RAOB can encode sounding data as explained below, RAOB does not decode the encoded netCDF data files. However, RAOB can decode commonly used netCDF formatted data as explained in the Binary Decoders module section.

Below is the netCDF Encoders options panel. There are currently 2 options: Conventional and Radiometer profiles. The Conventional option only encodes one sounding at a time (one per file), and includes temperature and wind data. The Radiometer option can encode single soundings, or multiple, time-series, soundings per data file.



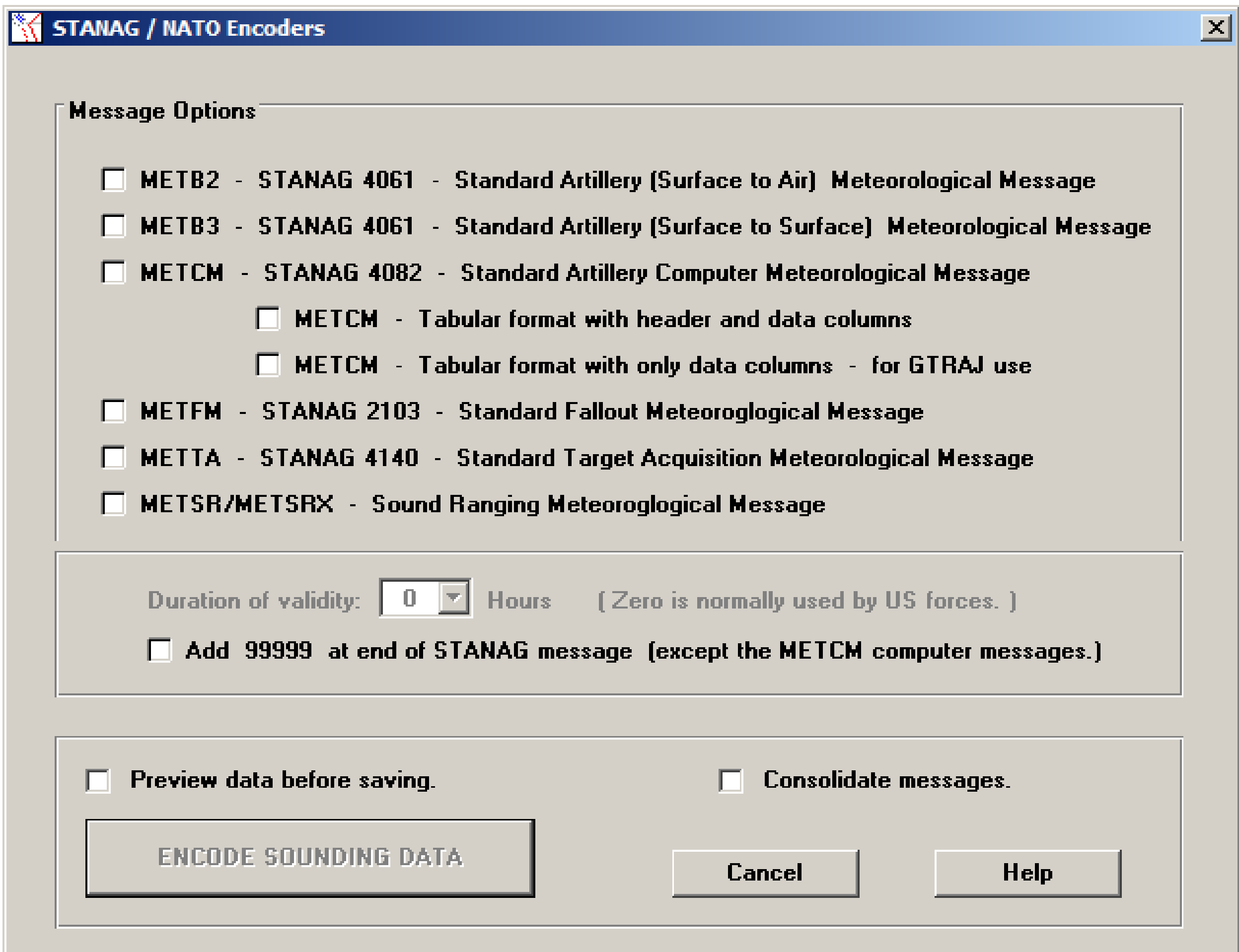


Data Encoders continued…

STANAG (NATO) Encoders Module. This is an optional program module, which includes also includes STANAG decoders.

A STANAG is a NATO Standardization Agreement.

RAOB's STANAG Encoders module is based on information contained in NATO STANAG weather message standards. This encoder offers output options for eight NATO messages:



Duration of validity. Values range from 0 to 12 hours. The zero value is typically used by US forces.

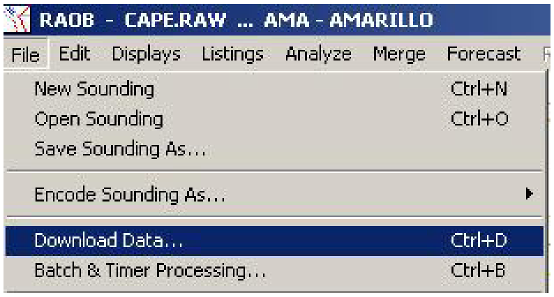
Add 99999 at end of STANAG message. Only some end users require this option.

Consolidate messages. If more than one STANAG message is selected, all messages will be appended to one text document.

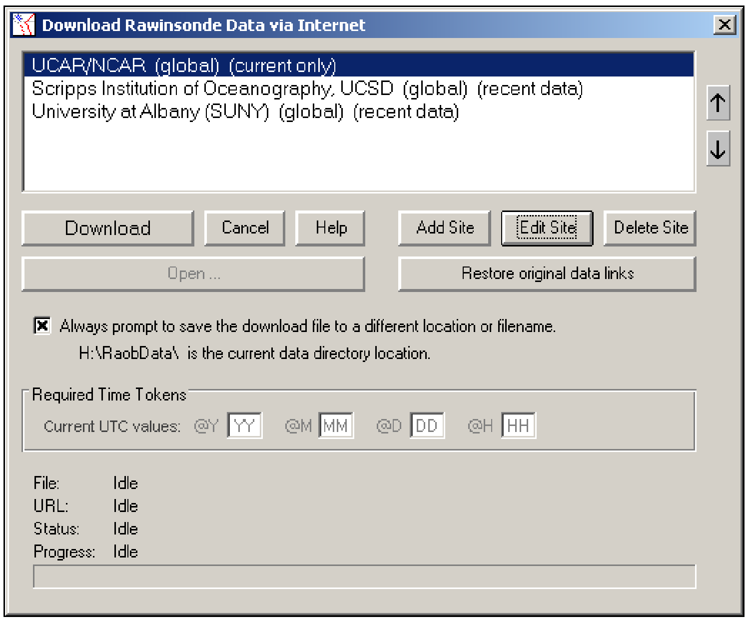
Note 1. GTRAJ = General Trajectory Program created by the US Army Ballistic Research Laboratory, Aberdeen Proving Grounds. MD.

Note 2. METTA encoding uses RAOB derived cloud/fog/refractivity calculations for message creation.

File Menu Continued…



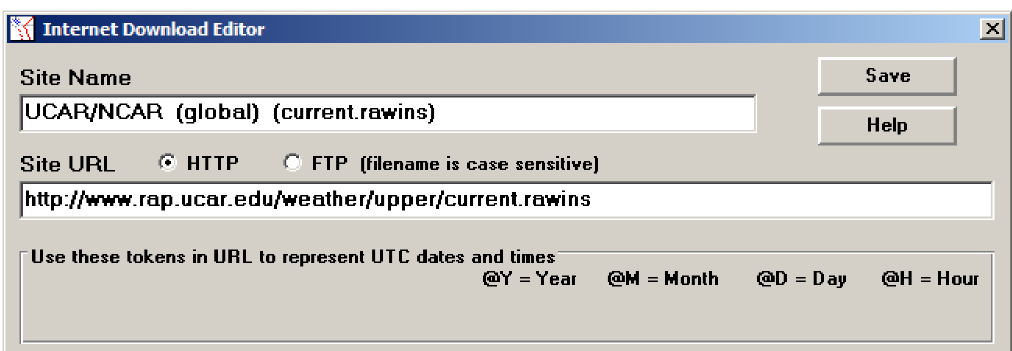
Download Data… Use this option to easily retrieve favorite sounding data directly from Internet sites. After clicking on the "Download Data…" option, the **Download Rawinsonde Data via Internet** display screen appears (as shown below). Use this screen to configure you favorite data sites.



Just click the **Download** button to retrieve data. The data can be automatically saved to a specified directory and can be quickly opened for analyses.

Some Internet sites require specific identification of Date & Time information before data access can occur. Since many sounding datafile names use Date & Time information in the filename, "time tokens" are used for file identification purposes. If time tokens are required, then the **Required Time Tokens** data box will become enabled, whereupon the user must then supply the required "date/time" information before data retrieval can begin.

Use the above **Add Site** or **Edit Site** buttons to add/edit Internet site URLs. When accessed, the **Internet Download Editor** is displayed as shown below, where Internet sites can be added & edited.

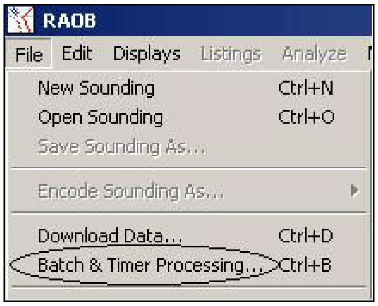


Use the Time Tokens to specify particular data files associated with each URL address. The above UCAR/NCAR address does not require time tokens. The URL address shown below does require tokens, which when used, requires the user to specify time values in the **Required Time Tokens** box (above).

Token Example: http://meteora.ucsd.edu/weather/observations/upperair/@Y@M@D@H_upa.wmo

Note: Use @YYY (versus @Y) for 4-digit year groups.

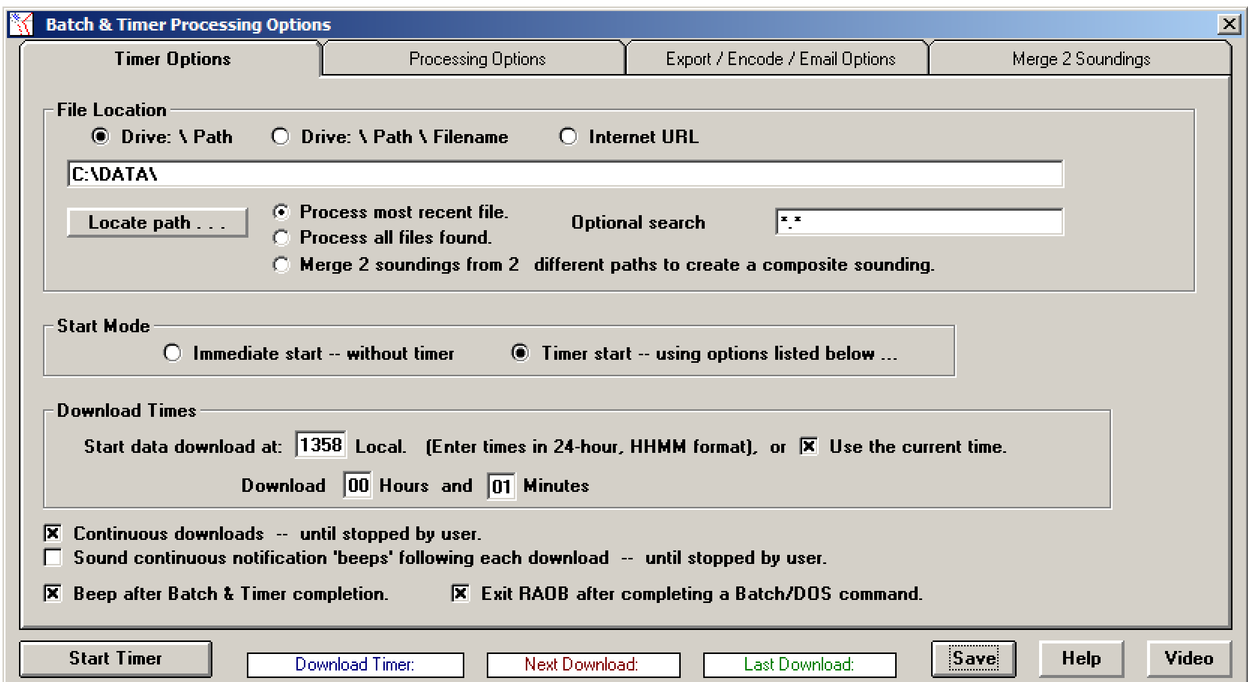
File Menu Continued…



Batch & Timer Processing… These features are available with either the optional Analytic or Standard Merge modules. By selecting this option, the program's Batch & Timer-based options become available as shown below.

RAOB allows both **Timer-based** and **Command-line** processing options. The Command-Line (batch or script) options are explained later in this section, including examples.

When the above **Batch and Timer Processing** option is selected, the following screen is displayed as shown below.



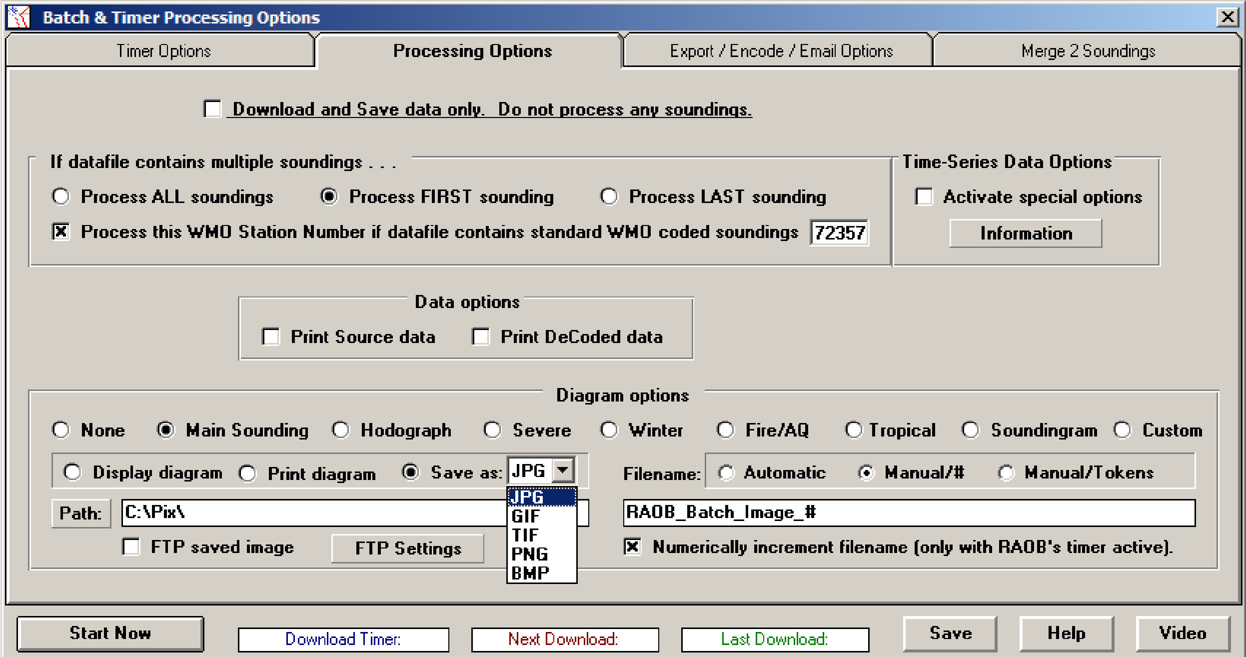
File Location. The user can select source data from either the local PC's **Drive\Path** (with wildcard options for most recent or all files found), the **Drive\Path\Filename** (selects a specific file), or from an **Internet URL**. When the Internet URL option is selected, the user can choose where data is to be saved.

Start Mode. The **Immediate start** option is very useful for testing a batch setup.

Download Times. Select the beginning download time and follow-on download intervals. If the download must start at a future time, then uncheck the "Use the current time" box and complete the "Local" text box with the desired start time. If the "Download every" interval data is entered, then the user must check the **Continuous downloads** box option to enable automatic follow-on downloads. The **Sound** box option should be used if user wants to hear an audible beep following each download.

File Menu Continued…

The **Processing Options** tab (shown below) determines how the downloaded data is processed.



If data consists of multiple soundings … The user can select these options: Process **ALL, FIRST, or LAST** sounding in the datafile. If the datafile contains WMO formatted data, then a specific WMO station number can be entered for processing.

Time-Series Data Options. This is a special data processing procedure for a unique customer requirement. Details are listed in the panel's "Information" button.

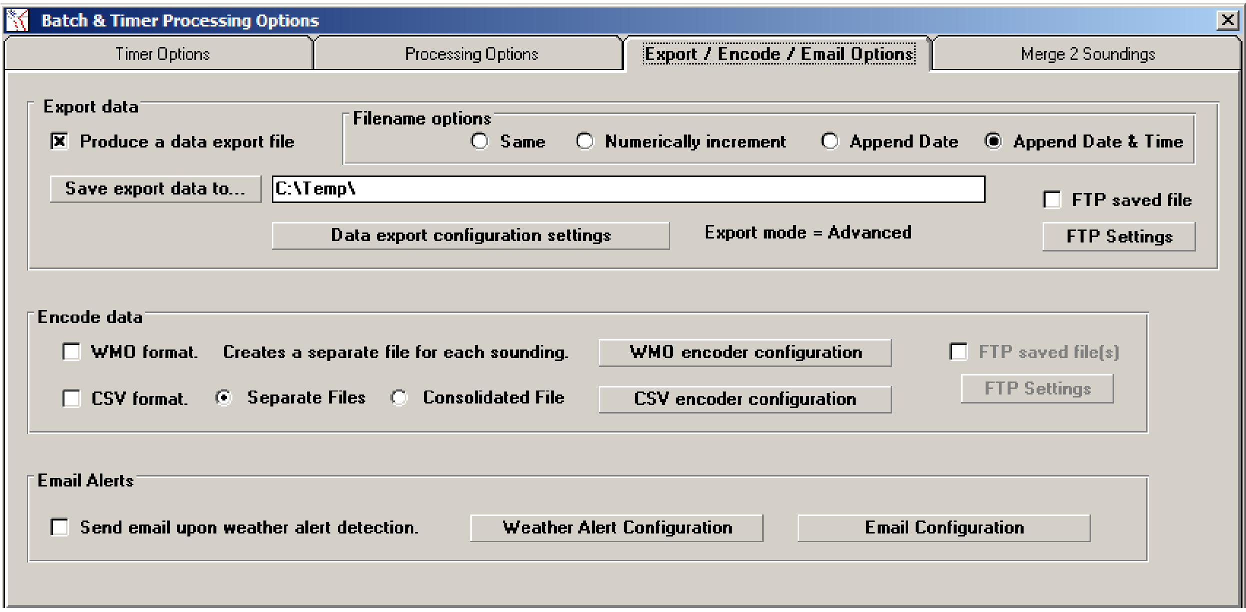
Data options. Sounding data can be printed in the "Source Data" or "DeCoded Data" format. Both formats can be viewed and edited using their respective data editors, which are available for use from RAOB's Edit menu.

Diagram options. Select one of the diagram options, which will either be displayed, printed, or saved to file (as selected from the recessed options box located just below the diagram options). Note that the "Custom View" option can not be printed to paper, but its image can be saved to file. If the **Save as** option is selected, the user then must set three more configuration options … the **File Type**, the **File Path**, and the **Filename** (with either automatic or manual filename entry). The **Numerically increment filename** option automatically adds numbered sequences onto the user specified filenames.

FTP. Use the "FTP saved image" option to automatically send saved images to other locations. Use the "FTP Settings" button to configure FTP Host, Username, and Logon Password.

File Menu Continued…

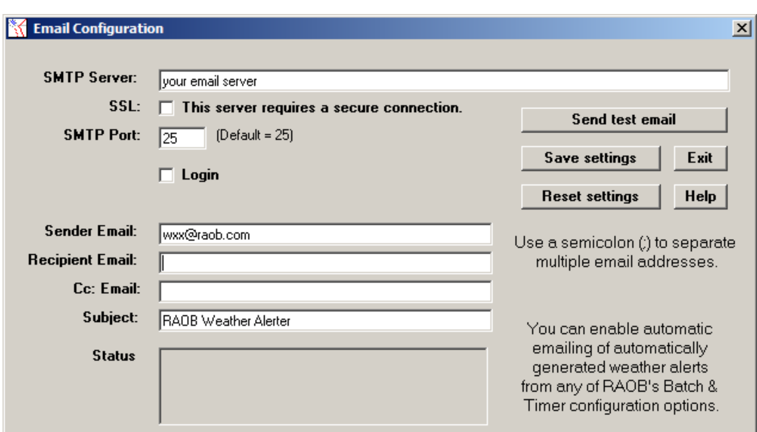
The **Export & Encode Options** tab (shown below) additional data processing options.



Export data. Check the **Produce a data export file** to export data to file in accordance with configuration settings established in the **Export Sounding Data** File Menu option (as discussed on the next few pages). Check the **Same** option for no filename changes; or check the **Numerically increment** option to sequentially number filenames if the **Continuous downloads** are selected (see the previous Timer Options tab); or check the **Append Date** to add only the Date to the filename; or check the **Append DTG** to add both Date & Time to the filename. Use the **Data export configuration settings** button to display the current export settings and change options.

Encode data. Data can be encoded in the WMO format or RAOB's CSV format, which require the optional "Standard Encoders" module. Use the **"encoder configuration"** buttons to display the current export settings and change options as needed. WMO encoded soundings are only saved as single files. For CSV encoded soundings, when processing files containing multiple soundings, you can select either Single sounding output files or a Consolidated output file containing all processed soundings.

Email Alerts. RAOB can send email alerts for severe weather parameters that meet or exceed user-defined thresholds. Use the Weather Alert Editor to configure alerts, as seen later in this Manual.



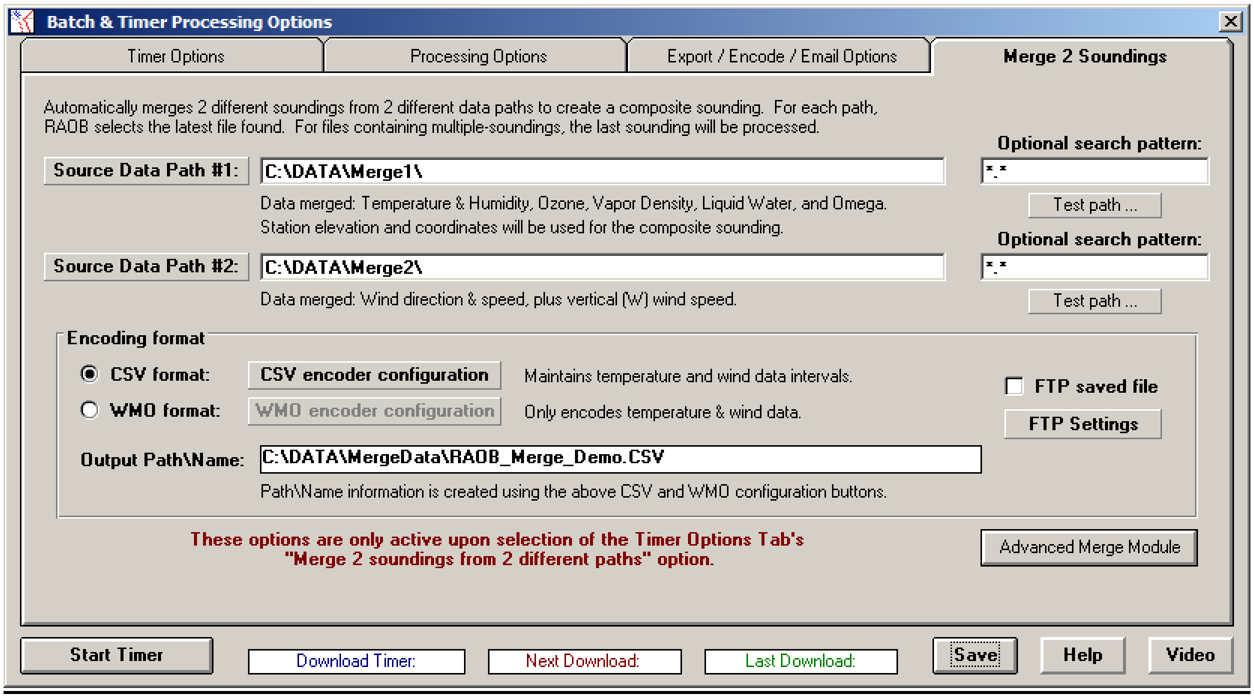
At left is the Email Configuration panel. A successful "Send test email" must be performed before emails can be sent.

The SMTP Server is "your" email server host system. For Gmail accounts, you always use "smtp.gmail.com"

More information is available via RAOB's Help files.

File Menu Continued…

The **Merge 2 Soundings** tab (shown below). Functions on this tab are only available with the optional Standard Merge Module.



Source Data Path #1. Merges sounding temperature and humidity (dewpoint) data -- not wind data. Supplemental data will also be merged, such as ozone, radiometric data (vapor density and liquid water), and omega data – if they exist. This sounding's Station Elevation and Coordinates will also be used for resulting composite sounding.

Source Data Path #2. Merges sounding wind data only -- including vertical wind (W) component values.

Encoding format. Select either CSV or WMO encoding.

- CSV Format. This format maintains the original temperature and wind data intervals. This format will also retain supplemental data, such as ozone, radiometric data (vapor density and liquid water), and omega data. The resulting sounding will be formatted in accordance with the RAOB CSV format.

- WMO Format. This format will only transform temperature and wind data into the WMO standard and significant data levels (such as TTAA, TTBB, etc.). Any supplemental data will be ignored as it is not possible to encode this data into the WMO format.

Advanced Merge Module. Permits quick access to the optional Merge Module utility, which runs independently of the RAOB Program and can automatically process all soundings within multi-sounding data files. This module is discussed later in this manual.

<u>File Menu Continued…</u> **(Batch Processing, Command-line options)**

Batch Processing. The RAOB program can be executed from the Windows RUN command or from MS-DOS. When called from a batch command, the RAOB program is activated, then performs requested tasks, and then closes. The batch format is as follows ...

RAOB (Config#,)Data(WMO#),Option1,Option2, etc...

An example follows ...

```
C:\Programs\RAOB Program\RAOB Config1,C:\Data\DAT.UPR(72250),Sounding/P,Export
```

- Note: that the "Config#" setting is an optional parameter.

The above example uses RAOB's configuration setting #1, and processes the "Example.txt" sounding datafile, then prints the standard sounding diagram, and then exports the sounding data using default options as configured within the RAOB program.

Explanation of example batch ...
RAOB is the location of the RAOB executable file ... C:\Program Files\RAOB Program\RAOB
Data is the location of the sounding datafile to be processed ... C:\Raobdata\Example.txt
(WMO#) is used to process a specified WMO station. It is used only for multi-sounding files containing WMO coded data. It will override any WMO settings used in the program's menu options.

Options ...
Sounding/P = print the standard sounding diagram
Hodograph/P = print the standard hodograph diagram
Severe/F = save the "severe weather" sounding diagram to file
Winter/P = print the "winter weather" sounding diagram
Fire/F = save the "fire-weather & air-quality" diagram to file
Tropical/P = print the "tropical weather" display diagram
Custom/F = save the "custom view" diagram to file
Source = print the sounding's "source" data
Decoded = print the sounding's "decoded" data
Export = create an export datafile using default options contained within RAOB

Batch Timer Option. There is a special batch command option, which lets you automatically activate the "Batch and Timer Processing Options" using the settings last saved by the user. An example batch command follows . . .

```
C:\Program Files\RAOB Program\RAOB Start-Timer
```

File Menu Continued… **(Batch Processing, Command-line options : Continued)**

Special Batch Option. This special batch function only downloads data. It is only activated from a DOS or script command, where RAOB opens, downloads data, and then closes. This is commonly used to download BUFKIT forecast soundings from the Internet, where the complete BUFKIT datafile is displayed on the webpage.

The RAOB command line is: FTP,Path\Filelist

Where Path\Filelist is the computer Path (or folder location) of the Filelist. The Filelist contains the FTP URLs identifying the data to download. The Filelist can contain up to 5,000 URLs, which must be created in a text-only format.

Below is an example of the contents of a Filelist containing 3 URLs for BUFKIT data. The first line must be "startftp" and the last line must be "endftp". For each FTP download, the data line begins with the URL, then the FTP Username (UN), the FTP Password (PW), "Text", and the Path location where the downloaded data is to be saved on your PC system. Each item in the data line must be separated with the pipe character (|).

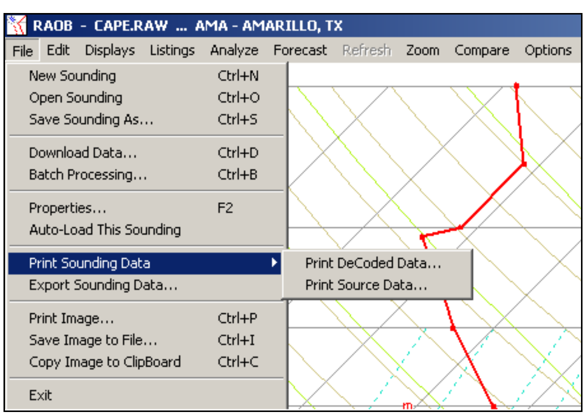
```
startftp
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_kavp.buf|UN|PW|Text|c:\ftpdata
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_keyw.buf|UN|PW|Text|c:\ftpdata
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_kgcn.buf|UN|PW|Text|c:\ftpdata
endftp
```

If the FTP login Username (UN) and Password (PW) are not required, then leave them blank, which would then look like the below example.

```
startftp
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_kavp.buf|||Text|c:\ftpdata
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_keyw.buf|||Text|c:\ftpdata
ftp://ftp.meteo.psu.edu/pub/bufkit/namm_kgcn.buf|||Text|c:\ftpdata
endftp
```

Note: you should first test the URL used (including applicable UN and PW values) before including them in the Filelist. This test should be done using Sounding's "Download Data" option found via the File Menu.

Properties, Auto-Load, and Printing …

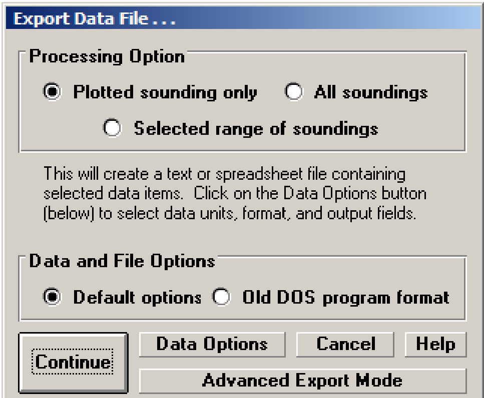


Properties. Displays basic information regarding file size & location and basic sounding data.

AutoLoad This Sounding. If selected, the currently displayed sounding is automatically loaded & plotted upon the next activation of the RAOB program.

Print Sounding Data. Print either the Source (coded) or DeCoded (raw) data. Both of these data types can be viewed using the “Edit” menu option located on the main menu bar.

<u>File Menu Continued…</u>   **Export Sounding Data - "Classic Export Mode"**



This is only available with the optional Analytic Module. This option allows creation of a coma-separated text data file of key sounding parameters which can be used for other data automation needs. Processing options allow for selection of either the "Plotted sounding only", or "All soundings", or a "Selected range of soundings" from multiple sounding data files.

There are 2 file output options – the old DOS format (for continued use for prior program users) or the new and user-configurable Default format.

The "**Advanced Export Mode"** is explained next…

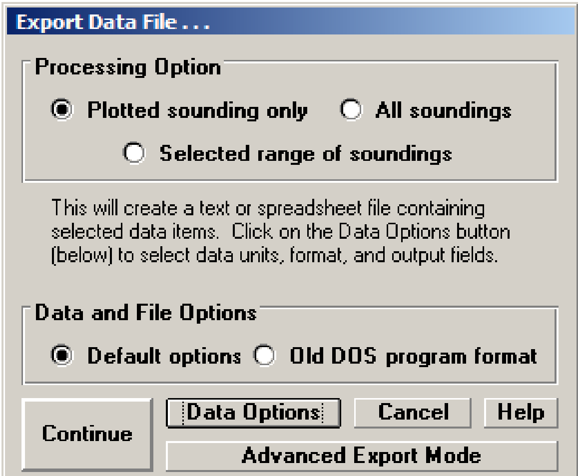
Old DOS Format. Below is an example "dump" output, where the first 10 lines include header information that describes the 16 output parameters per data level. The first 5 data levels are included in this example. Each dump file is created using units defined by the user, such as feet versus meters and AGL versus MSL . . .

```
"WIND","96996 - YPCC - COCOS ISL INTL ARPT, AU"," ","03-19-2002"
"ELEVATION (FT) = ",10
"LAT/LONG: 12°11'00"" S   96°49'00"" E"
"DATA LEVELS = ",41
"NOTE 1:  Most data levels have HT(height) and PR(pressure) values."
"NOTE 2:  Missing dewpoint data is represented by the 999.9 value."
"NOTE 3:  No data is represented by the -999 value."
"DATA:  PR(mb), HT(m,AGL), T(C), Td(C), DD(deg), FF(m/s), PT(K), ePT(K),"
"        RH(%), MixR(g/Kg), Water(cm), Den(Kg/m3), VirT(C), WetBulb(C),"
"        Shr/kFT(kts/1000ft), Ri"
1014,0,25.2,20.2,125,4.1,297.2,342,74,14.87,1.189,1.174,27.9,21.7,-999,0
929,763,18.6,16.1,-999,-999,298,336.2,85,12.5,.124,1.101,20.8,16.9,-999,0
918,865,18.8,11.8,-999,-999,299.2,328,64,9.52,.506,1.089,20.5,14.4,-999,0
868,1344,15.2,12.1,-999,-999,300.3,332,82,10.28,.078,1.042,17,13.2,-999,0
856,1463,17.6,-7.4,-999,-999,304,311.1,16,2.38,.011,1.024,18,5.9,-999,0
```

Default Format. This new format not only provides a level-by-level listing of sounding data, but it also provides a listing of all key sounding indices and related analyzed parameters, such as CAPE, SWEAT, significant levels, inversion levels, thickness levels, and more. See a partial example output below:

```
"RAOB 5.6  07-22-2004"
""
"Data Format Information/Header ..."
"NOTE:  No data is represented by the -999 value."
"DATA:  PR(mb),HT(m,MSL),T(C),Td(C),DD(deg),FF(kts),PT(K),ePT(K),RH(%)"
""
"FILENAME = CAPE.RAW"
"DATA TYPE = RAW Format"
"NUMBER OF SOUNDINGS LISTED = ",1
""
"SOUNDING = ","AMA - AMARILLO, TX"
"ELEVATION (M) = ",1099
"LAT/LONG = ",35.22,"N",101.83,"W"
"DATA LEVELS = ",48
882,1099,29.6,16.6,170,17,313.8,356.3,46
- - - - -
100,16616,-68.9,-999,-999,-999,394.3,0,0
"*** Significant Data ***"
"FRZG Lvl = ",4492," m MSL ",591," mb"
"cclEL = ",13800," m MSL ",156," mb ",-63.7,"C"
"lfcEL = ",13655," m MSL ",159," mb ",-62.7,"C"
"LFC = ",3206," m MSL ",691," mb ",11.7,"C"
"CCL = ",3165," m MSL ",694," mb ",12,"C"
"LCL = ",2746," m MSL ",730," mb ",13.6,"C"
"Water = ",3.11," cm "
"Hail = ",.64," cm"
```

Export Sounding Data (continued) ...

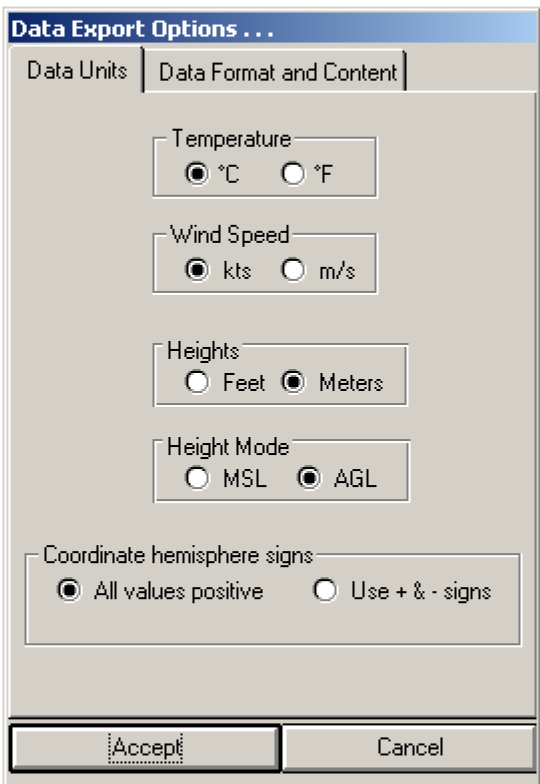


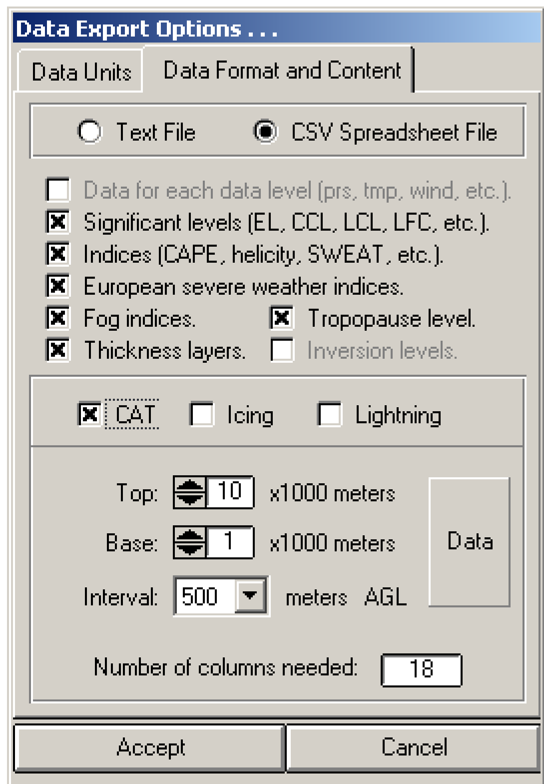
Processing Options allow selection of files containing single or multiple soundings.

Click the "Data Options" button to display the "Data Export Options" configuration box and two Tabs of processing options (shown below)…

Tab 1. **Data Units**. This tab allows the user to select from four configuration unit options to be applied to the output export file.

Tab 2. **Data Format and Content**. This tab allows control over which data sets are included in the export file, including file type (either an ASCII text file or a CSV spreadsheet file).

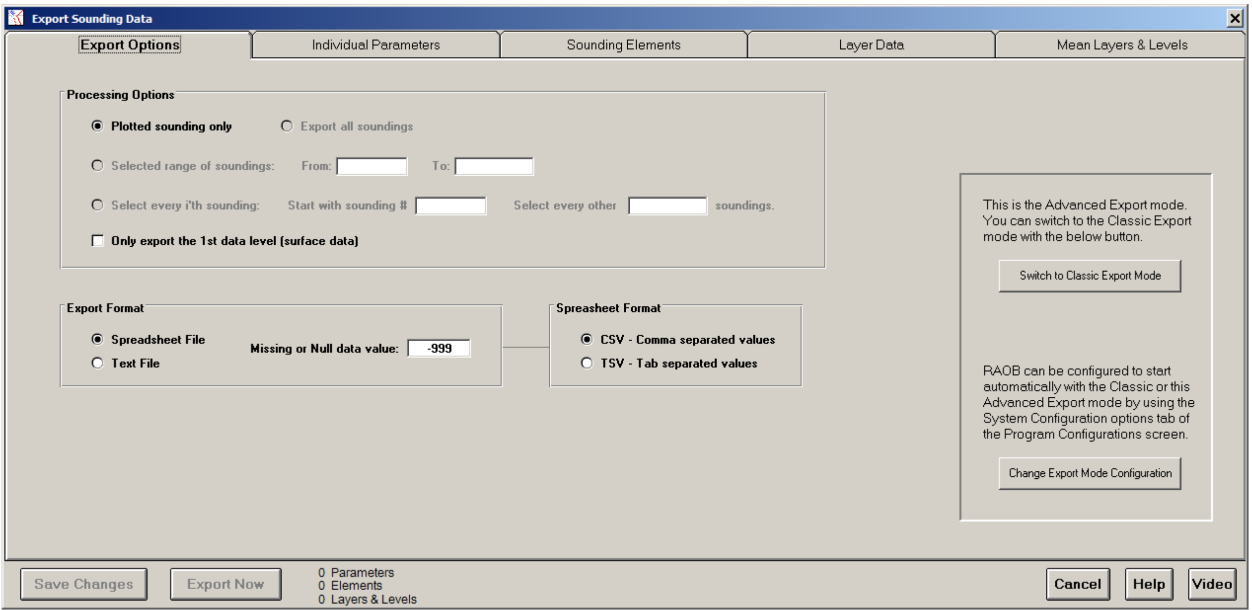




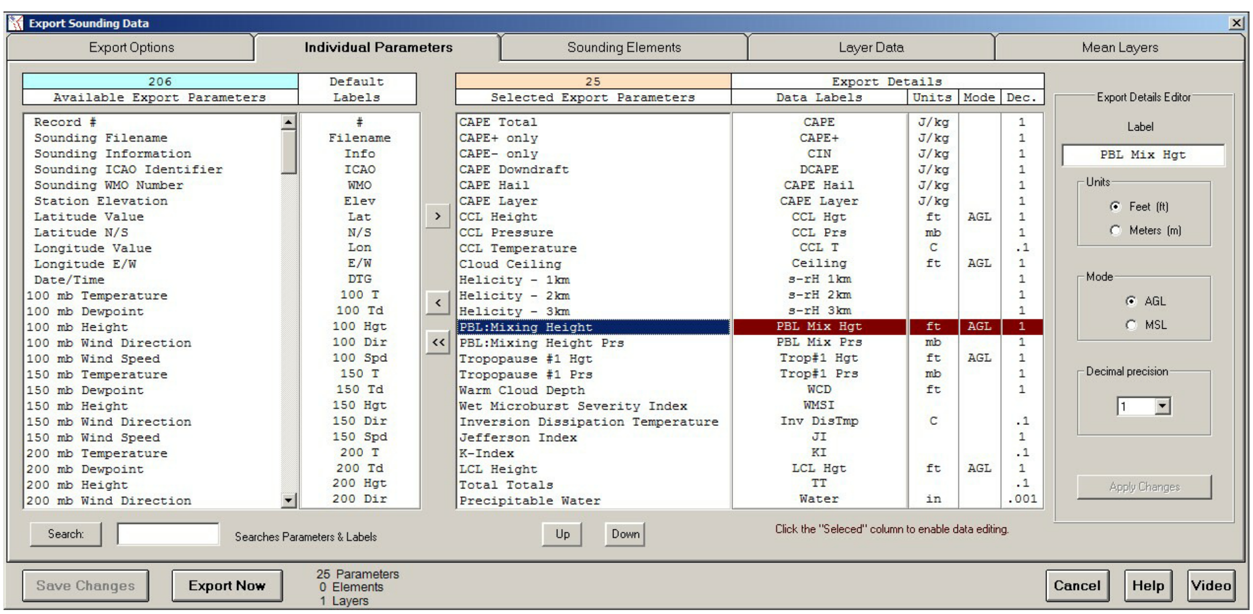
<u>Data Format and Content</u>. The "CSV Spreadsheet File" option (as shown above) allows output for CAT, Icing, and Lightning data. The user must specify the layer of interest (via the Top & Base options) and vertical resolution (via the Interval option) – whereupon the program will display the number of columns needed to display requested data (which is 18 columns for the above example). Since the CAT, Icing, and Lightning data have no associated standard numeric values, RAOB produces output as integers ranging from 0 – 7 (where 0 = a null value and 7 = a max value). Clicking the "Data" button will remind users of this numeric display range. The **Advanced Export Module** has many more export options.

Export Sounding Data (continued) ... **Advanced Export Mode (optional module).**

Export Options. The Advanced Export Mode is a full-featured, menu-driven export system that gives the user complete control of what and how data are exported. The 1st tab (Export Options) identifies which soundings are to be exported. Data can be exported as plain text or in spreadsheet format, with additional options for CSV or TSV formats.

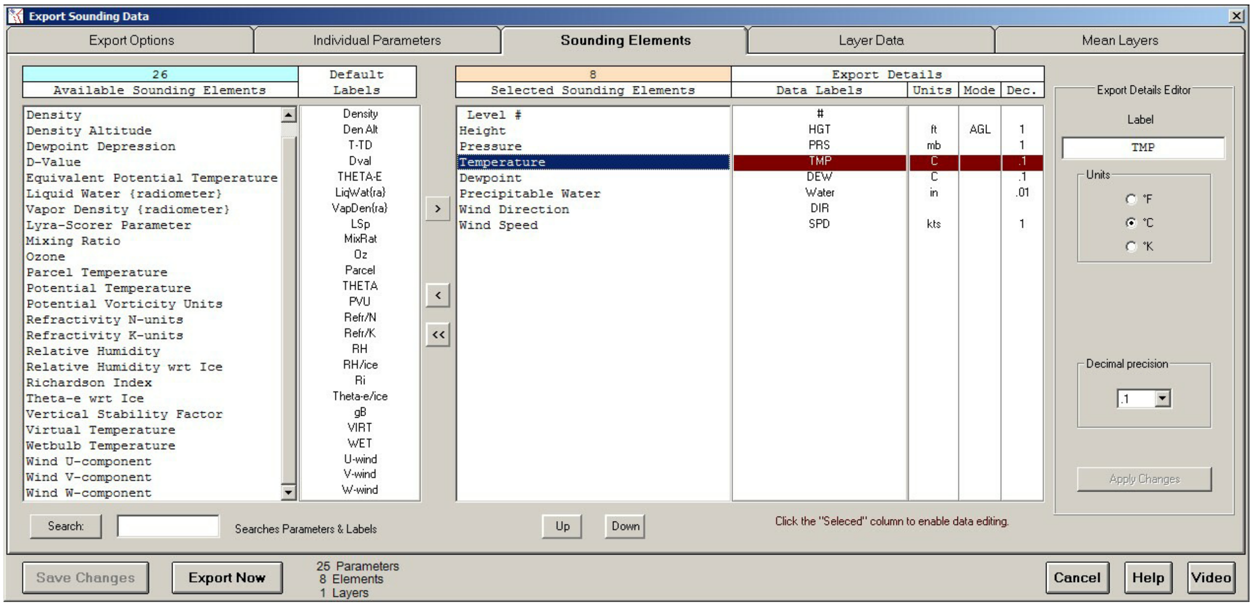


Individual Parameters. This tab allows exporting of over 200 parameters that are either taken directly from the sounding data or calculated by RAOB. The left column lists available export parameters where the right column lists those selected for export. The SEARCH button helps locate desired export items. The UP and DOWN buttons allow specific positioning of export items. The far right side of the tab permits individual specification of export data labels, units, data mode, and decimal precision. A summary of selected export parameters, elements, and layers are listed at the bottom of the configuration panel.

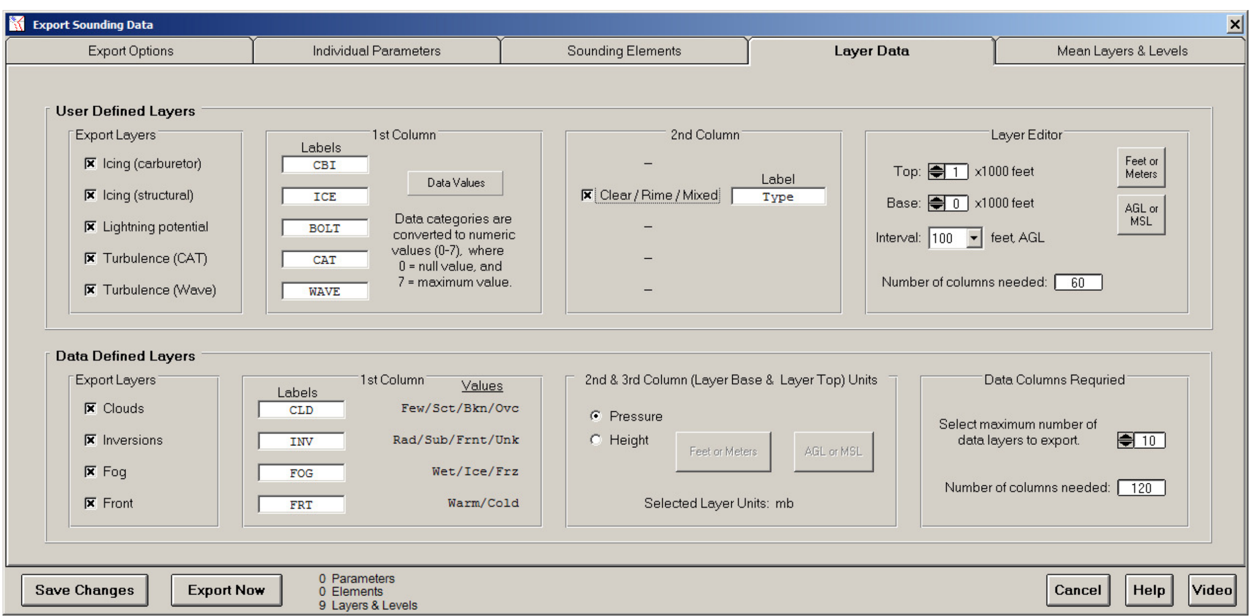


Export Sounding Data (continued) ... **Advanced Export Mode (optional module).**

Sounding Elements. This tab allows exporting of all "traditional" sounding data contained in the source datafile, such as temperature, pressure, winds, etc (including Ozone). Supplemental profiles (like Virtual temperature) can also be exported. This tab allows the user to re-create the sounding data. The user interface for Sounding Elements is identical to the prior Individual Parameters found on the 2nd tab.



Layer Data. This tab is unique in that it allows exporting of data that are best organized by layers, such as icing and turbulence. Layer regions and data intervals can be individually specified, thereby allowing the user to identify the degree of vertical resolution required.



See the next page for explanation of 1st Column data values.

Export Sounding Data (continued) ... **Advanced Export Mode (optional module).**

Layer Data & Export Values. Exported Layer Data consists of numeric values that represent data categories of each Export Layer. The text related data categories (such as Light or Severe) are converted to numeric values (0-7), where 0 represents the minimum (or null) value and 7 represents the maximum value. The following table shows how text categories are converted to numeric values:

Layer Data \ Export Values	0	1	2	3	4	5	6	7
Icing (carburetor)	Null	TRC	-	LGT	-	MDT	-	SVR
Icing (structural)	Null	TRC	-	LGT	-	MDT	-	SVR
Lightning Potential	No	-	-	-	-	-	-	Yes
Turbulence (CAT)	Null	LGT	L-M	MDT	M-S	SVR	S-X	XTR
Turbulence (Wave)	Null	LGT	-	L-M	-	M-S	-	SVR

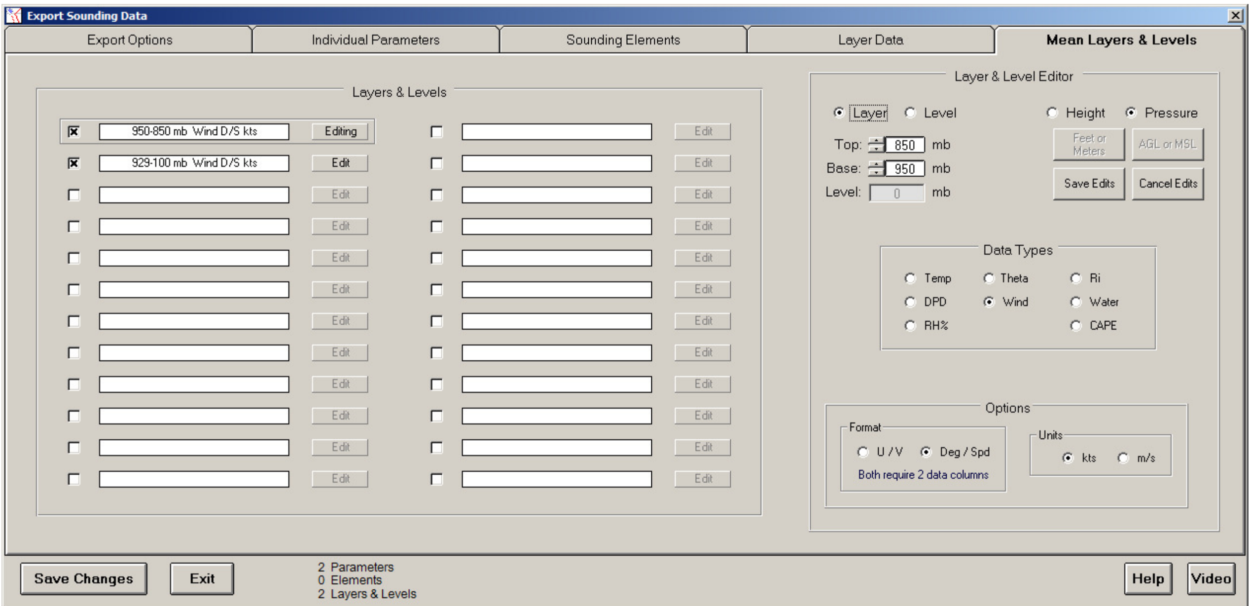
Descriptions for Icing and Turbulence categories:
TRC = trace
LGT = Light
MDT = Moderate
SVR = Severe
XTR = Extreme
L-M = Light to Moderate
M-S = Moderate to Severe
S-X = Severe to Extreme

Note 1. A dash indicates that a specific numeric value is not exported since there are no data categories for that value. For example, Lightning potential is only determined to be Yes or No, which is represented by a 7 for Yes and a 0 for No. Only the Turbulence (CAT) export contains data categories for all 7 numeric values.

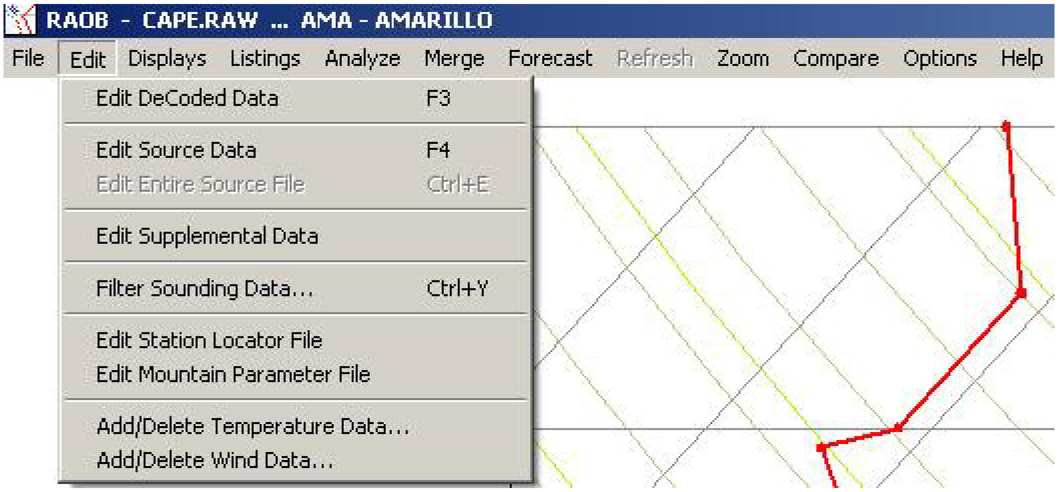
Note 2. The above export table of numeric values also applies to how layer data are exported in the Classic Export mode, however, only Structural Icing, Lightning Potential, and CAT Turbulence is exported in the Classic Export mode.

Export Sounding Data (continued) ... **Advanced Export Mode (optional module).**

- **Mean Layers & Levels**. This tab permits the export of 8 user-specified "Data Types", including Wind, Temperatures, and others. Up to 24 separate layers/levels can be exported, where the user can specify layer depth in feet or meters (in either AGL or MSL), or the user can specify the layer with respect to pressure values (mb or hPa). Units options are also available for wind, temperature, and precipitable water data items.



4.2 **Edit**.



Edit DeCoded Data. Use RAOB's unique raw* data editor to easily add/modify data in the convenient Pressure/Temperature and Height/Wind data groups. Other sounding information, such as station elevation and location coordinates can also be identified. All data saved from this editor are only saved in RAOB's indigenous "raw" format* and all data is thoroughly checked for error limits and consistency.

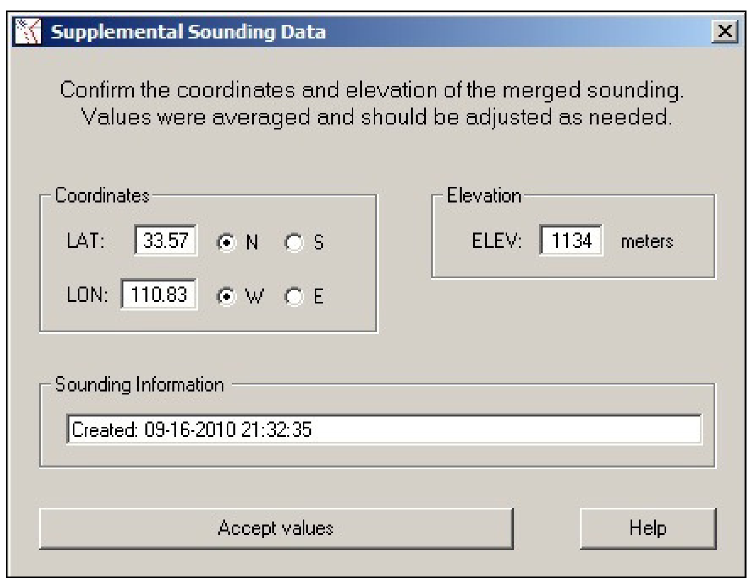
Edit Source Data. Use Microsoft's WordPad (text) editor to add/modify the sounding data. Caution: the RAOB program does not quality control the changes made to data files via this editor – use the DeCoded Data editor (above) for data quality control checking.

Edit Entire Source File. This also uses Microsoft's WordPad (text) editor to add/modify data. This editor displays all data contained in the datafile being accessed – including multiple soundings. Like the Source Data editor above, no quality control checking is performed.

Edit Supplemental Data.

This form permits changes to the sounding's coordinates, elevation, and descriptive information. This display is also presented following the Merge sounding process (discussed later).

NOTE: If the sounding data is not already in RAOB's indigenous RAW* format, any changes to the values on this Supplemental Data form automatically change the sounding's format to the RAW format, which can be saved to file and then recalled for later processing. This data can also be "encoded" into other formats using RAOB's encoder modules.



* See the RAW DATA FORMAT section of this manual for details about the structure of the raw data format.

Filter Sounding Data. This option converts a sounding into its conventional data levels: standard, significant, and mandatory levels as per FMH-3 in accordance with WMO-coded procedures. The filter process is especially useful for high-density soundings, such as those with more than 200 data levels per sounding.

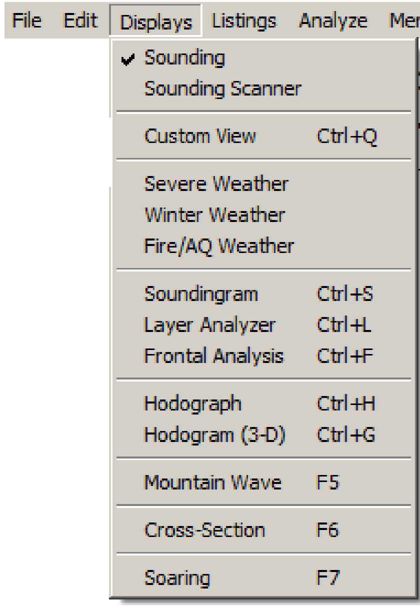
Edit Station Locator File. Use this option to edit the RAOB.STN sounding locator file. Note: it is important to remember to keep all entries in numerical WMO sequence. Additionally, it is very important to use comas between each data item. The locator file can also be modified using any text editor.

Edit Mountain Parameter File. This item is only available with the optional Mountain-Wave Module. Use this option to edit the RAOB.MTN parameter file. This file associates specific mountains with individual sounding sites (via WMO numbers). This enables automatic mountain parameter retrieval during sounding processing. See the Mountain Waves chapter for more information regarding mountain parameters.

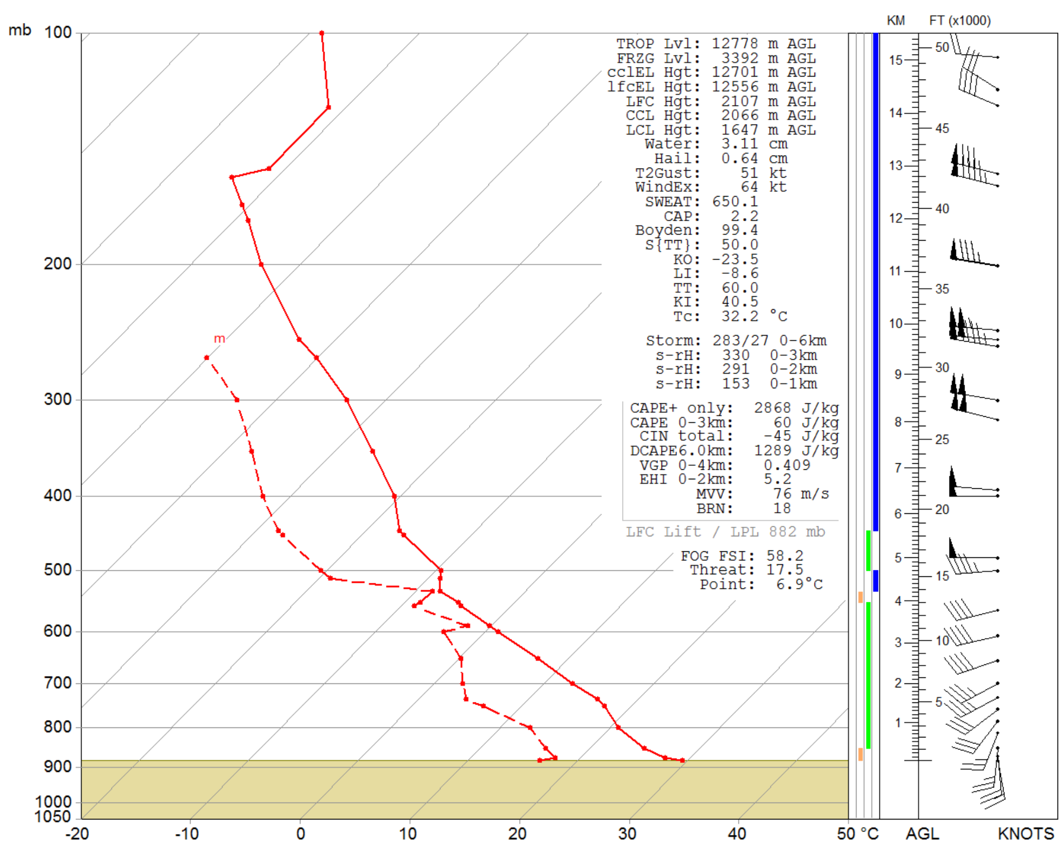
Add/Delete Temperature Data… & Add/Delete Wind Data… These two options only provide information about how to graphically add and remove data points on the sounding's plotted profile. These menu options are only available when the optional Interactive/Hodograph Module has been registered.

Data Saving. When sounding data is saved using the FILE & SAVE SOUNDING AS menu options or when using the Source data editors, the data is automatically saved in its original format, such as Raw, Coded, etc. When sounding data is saved using the DeCoded (or raw) data editor, data is always saved in the RAW format -- even if the data was originally accessed in another format such as the WMO Coded format. In order to save data in other formats, use the File Menu's ENCODE SOUNDING AS menu option. NOTE: Raw data files can be used with earlier DOS versions of RAOB, but they must be limited to no more than 48 Pressure data levels and no more than 48 Wind data levels.

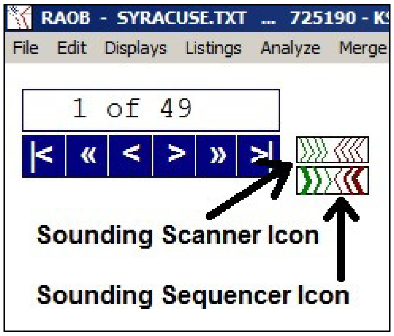
4.3 **Displays**. RAOB provides a variety of display formats to view sounding data.



<u>Sounding Display</u>. This is RAOB's default sounding display. This example shows the common Skew-T diagram. RAOB can also produce Emagram and Tephigram diagrams along with many configurable diagram parameter and scaling options. See the section called Diagram Configuration for a complete list of all diagram options. With the optional Hodo/Interactive Module, all graphic and text displays are automatically updated as the sounding (profile and/or winds) are interactively modified, added, or deleted.

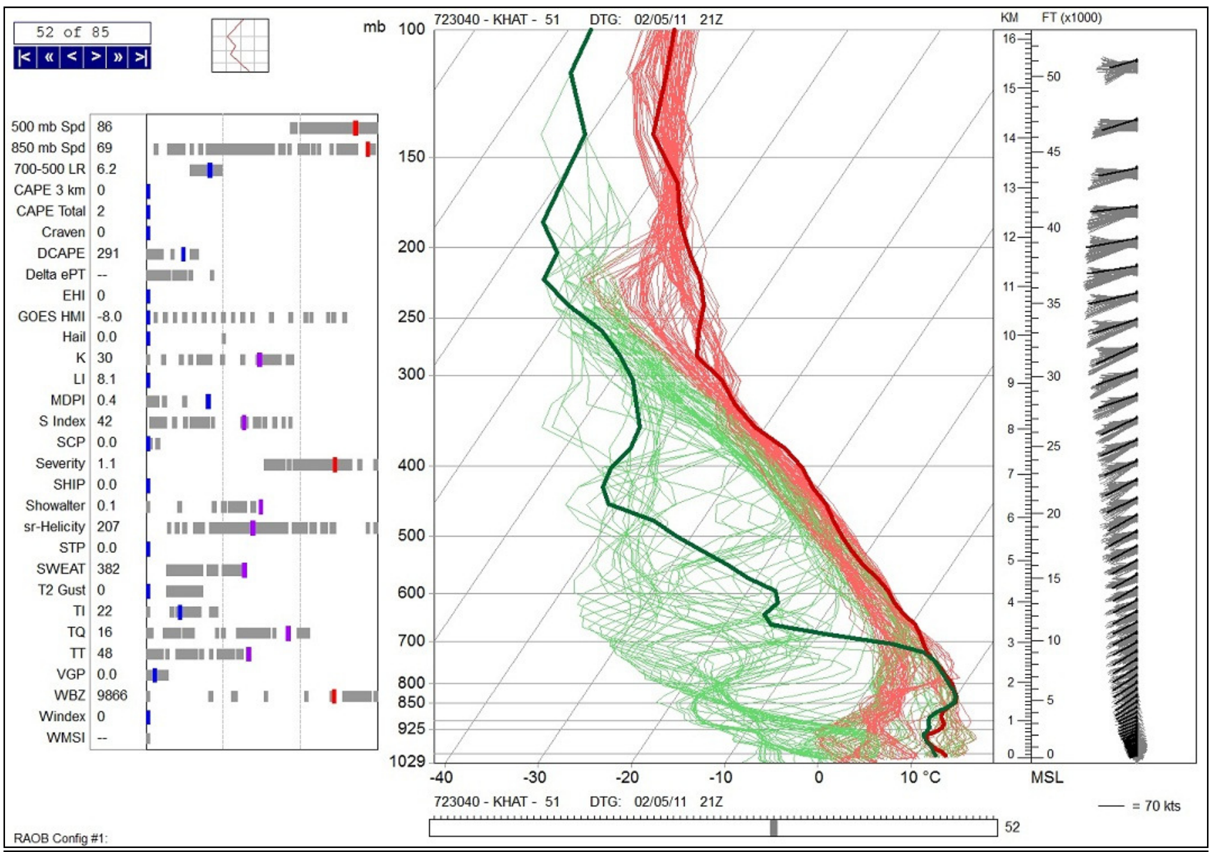


Sounding Scanner Display.



When a multiple sounding datafile is loaded into RAOB, three icons appear at the upper-left corner of the computer screen. First, there is the Sounding Controller, which permits sequencing and looping of the sounding profiles. Left & right arrows permit forward and backward sequencing and looping. Second, there is the Sounding Scanner activation icon represented by a small rectangular box surrounding small green & red mini-profiles. Third, there is the Sounding Sequencer activation icon, which is discussed on the next page.

When the **Sounding Scanner** activation icon is activated with a click of the mouse, the Sounding Scanner screen appears as seen below. The Sounding Scanner activation icon is replaced by a small Sounding Profile icon, which can be used to return to the main Sounding screen.



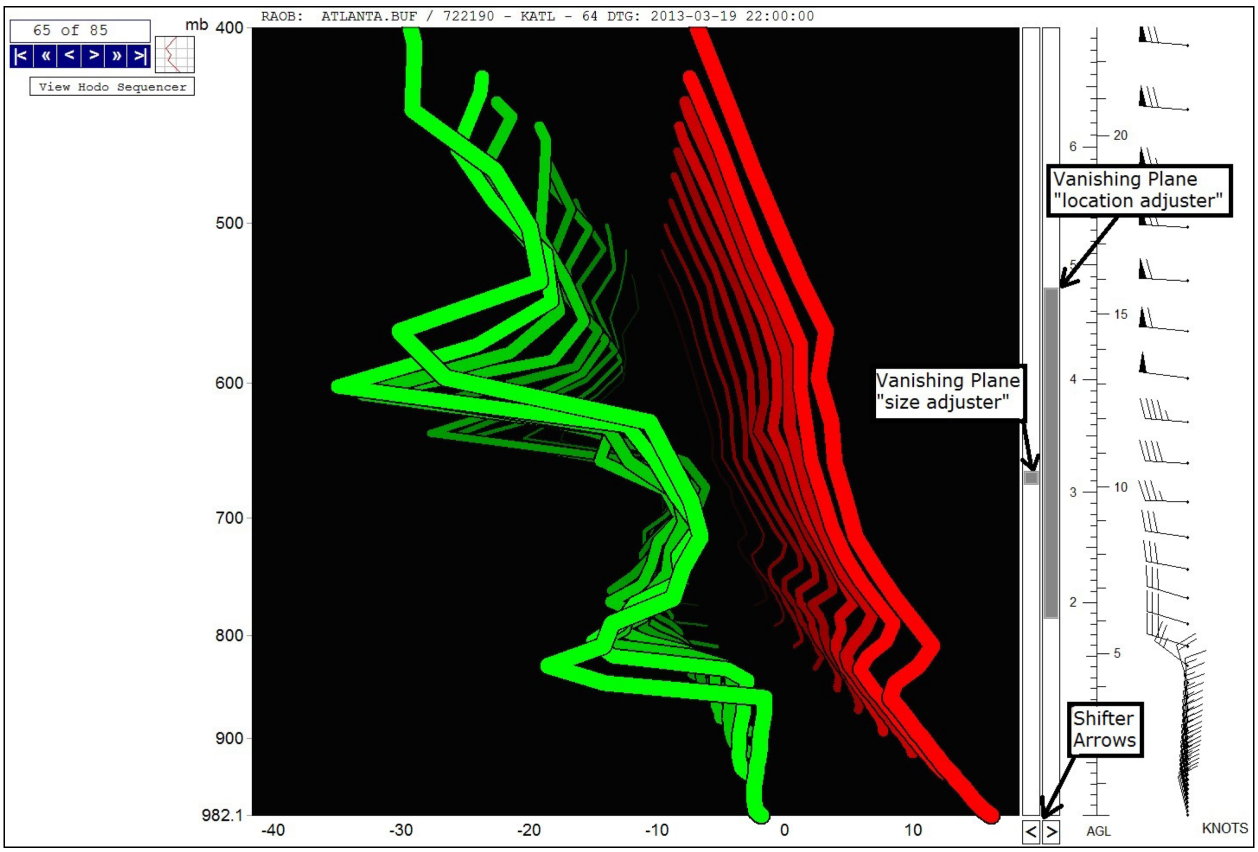
The Sounding Scanner screen first initializes itself by running all the datafile's soundings through RAOB's data processor to calculate dozens of significant weather parameters for later display. During initialization, each sounding profile is plotted using Green moisture profiles and Red temperature profiles. All winds are plotted in Black along the right side. All calculated sounding profile parameters are plotted in light gray in the data matrix box to the left of the sounding plots. Once initialization is complete, the first sounding of the datafile is highlighted with bold profile plots and color-coded data parameters. The sounding profile and data parameter colors can be configured by right-clicking over the area of interest. Scanning is ccomplished by either: (1) using the Sounding Controller icons, (2) using Left/Right keyboard arrow keys, or (3) using the mouse to drag the gray-colored marker along the bottom of the plotted sounding profiles.

Sounding Sequencer Display.

The Sounding Sequencer requires use of the optional Hodograph & Interactive program module.

The Sounding Sequencer is activated with the activation Icon (as seen on prior page) or by using the DISPALYS' Menu "Sequencer" option. As with the Sounding Scanner display the Sequencer is only available when viewing sounding files that contain multiple soundings. More importantly, this feature is most useful when viewing time-series soundings of forecast profiles. The Sounding Sequencer can display both sounding profiles (as seen below) and sounding hodographs.

The Sounding Sequencer displays 10 profiles in the file sequence, where each sequential profile is progressively thinner and dimmer. Temperature profiles are Red and dew-point profiles are Green. Profile sequencing is performed with either the mouse or keyboard arrows.



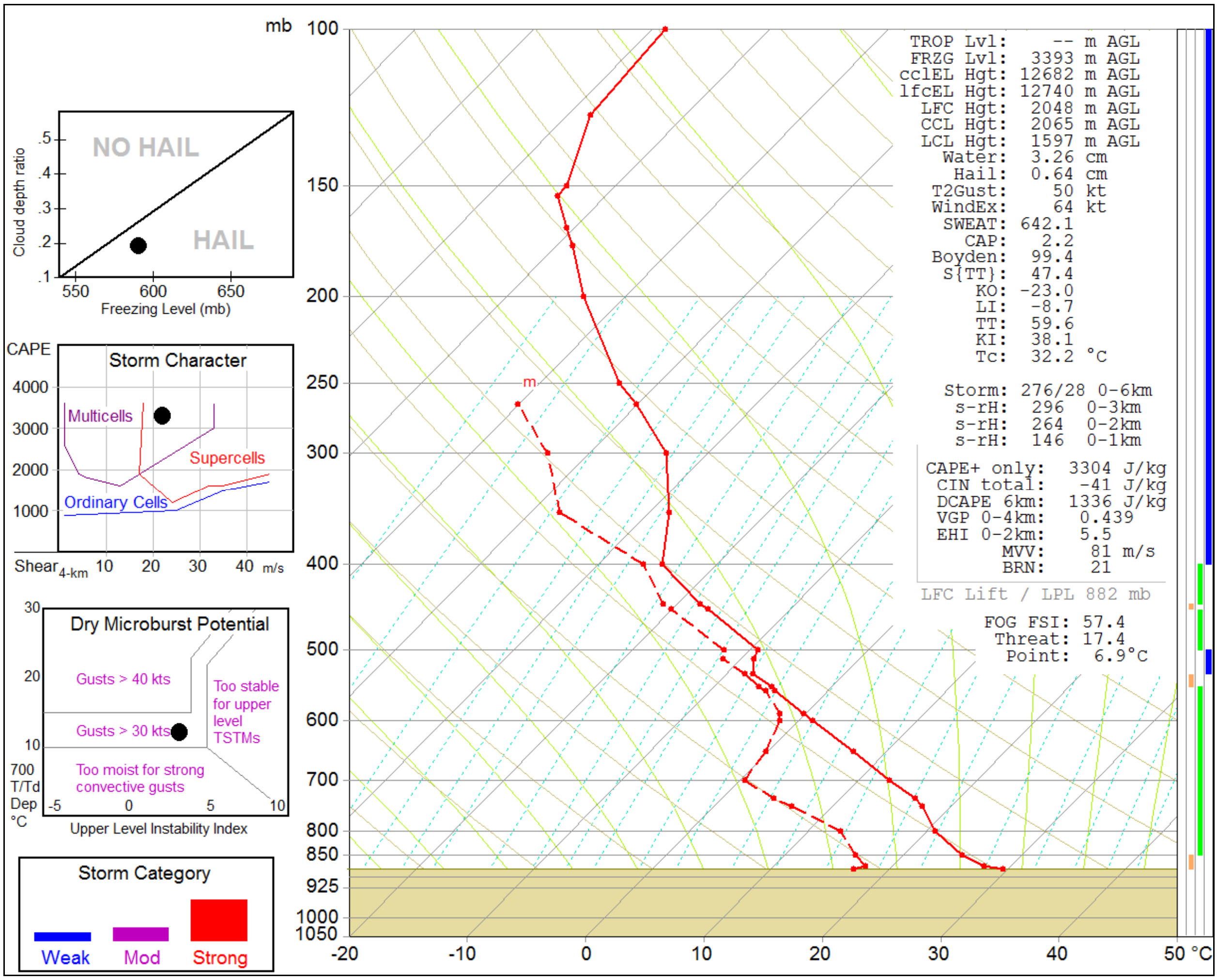
The Sounding Sequencer screen offers the user 3 unique display controls...

1. The Vanishing Plane size adjuster, which is located immediately to the right of the sequencer image. Just move the vertical slider bar up & down accordingly.

2. The Vanishing Plane location adjuster, which is located immediately to the right of the Vanishing Plane size adjuster. Just move the vertical slider bar up & down accordingly.

3. The sequence image Shifter Arrows, which are located immediately below the Vanishing Plane size & location adjuster bars. These Left/Right arrow icons, when clicked, incrementally move the viewing orientation left and right, which give the user perspective options when viewing unique profile sets.

<u>Severe Weather Display</u>. This is only available with the optional Analytic Module.

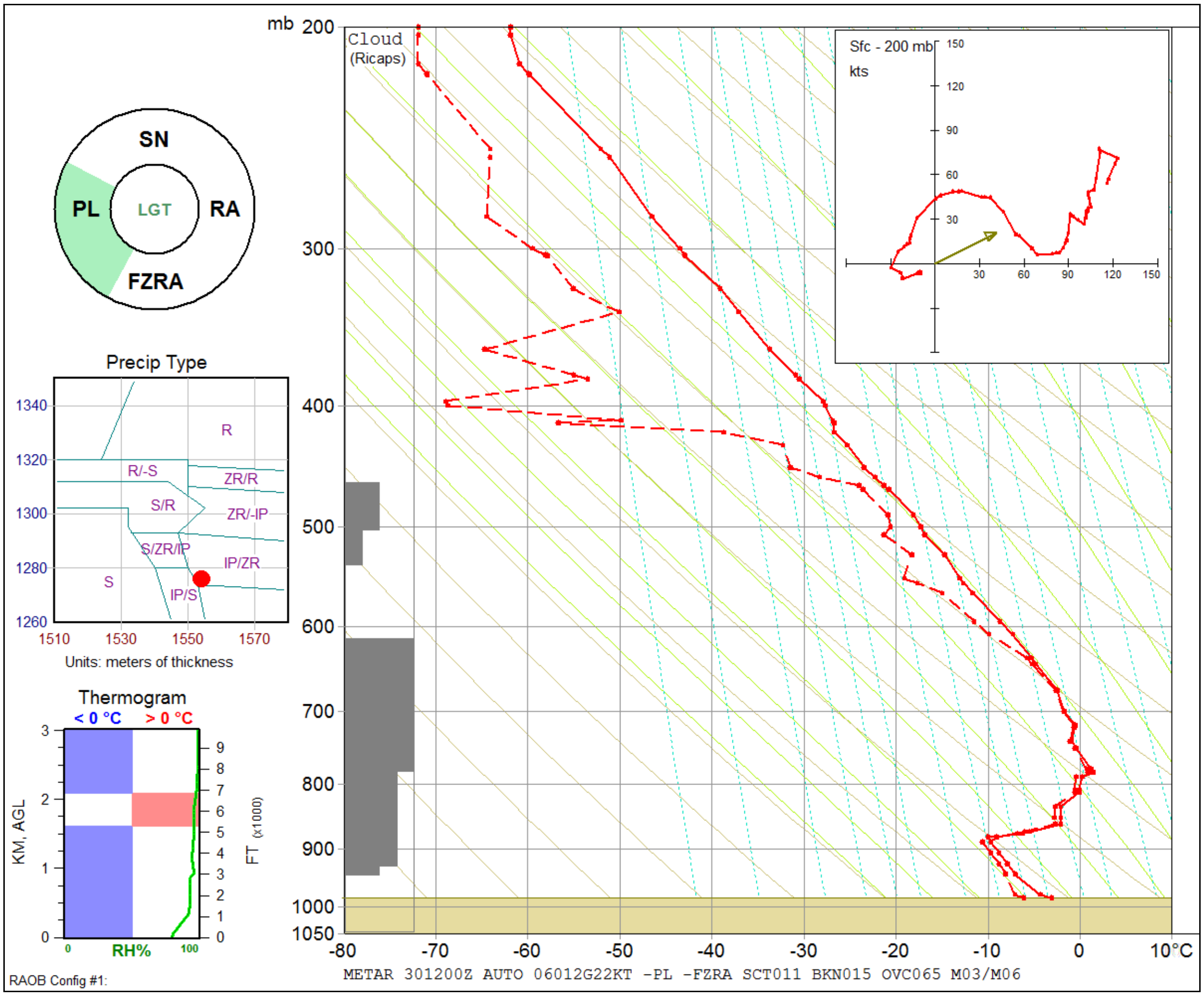


This example <u>Severe Weather</u> display is similar to the standard Sounding display, but also includes the Hail/No Hail nomogram, the Storm Character nomogram, the Dry Microburst Potential nomogram, and Storm Category chart. The **Hail/No Hail nomogram** supplements the Hail size parameter value that is displayed within the column of weather parameters. This nomogram is a function of the Cloud Depth Ratio*. The **Storm Character nomogram** graphically displays the correlation of CAPE (total) and Shear (0-4km, AGL) values. This nomogram is often used by forecasters to evaluate overall storm potential. The **Dry Microburst nomogram** correlates the 700 mb T/Td depression with the Upper Level Instability Index (Mielke et al, 1987), which is designed to identify the potential for microburst activity from high-level convective storms. The **Storm Category chart** is a visual representation of RAOB's Severe Weather Parameter Table's summary data. Additional information can be displayed by right-clicking over any of the four nomograms. With the optional Interactive Module, all graphic and text displays are automatically updated as the soundings (profile and/or winds) are interactively modified.

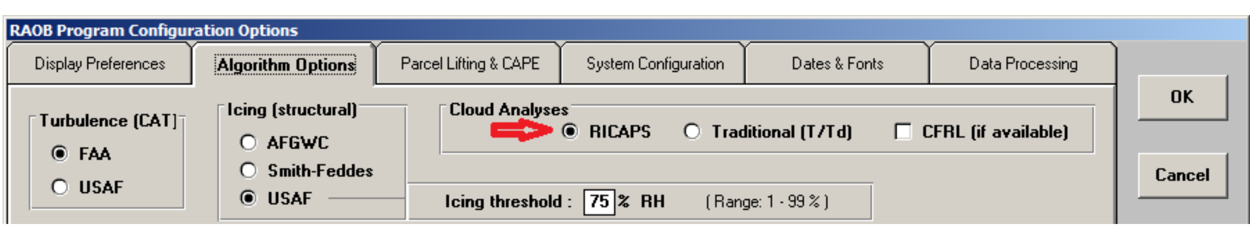
**Note: The Hail / No Hail nomogram is a function of the Cloud Depth Ratio (CDR). The equation follows:*

CDR = (Freezing Level – CCL) / (EL – CCL) where all heights are in millibars

Winter Weather Display. This is only available with the optional Analytic Module.

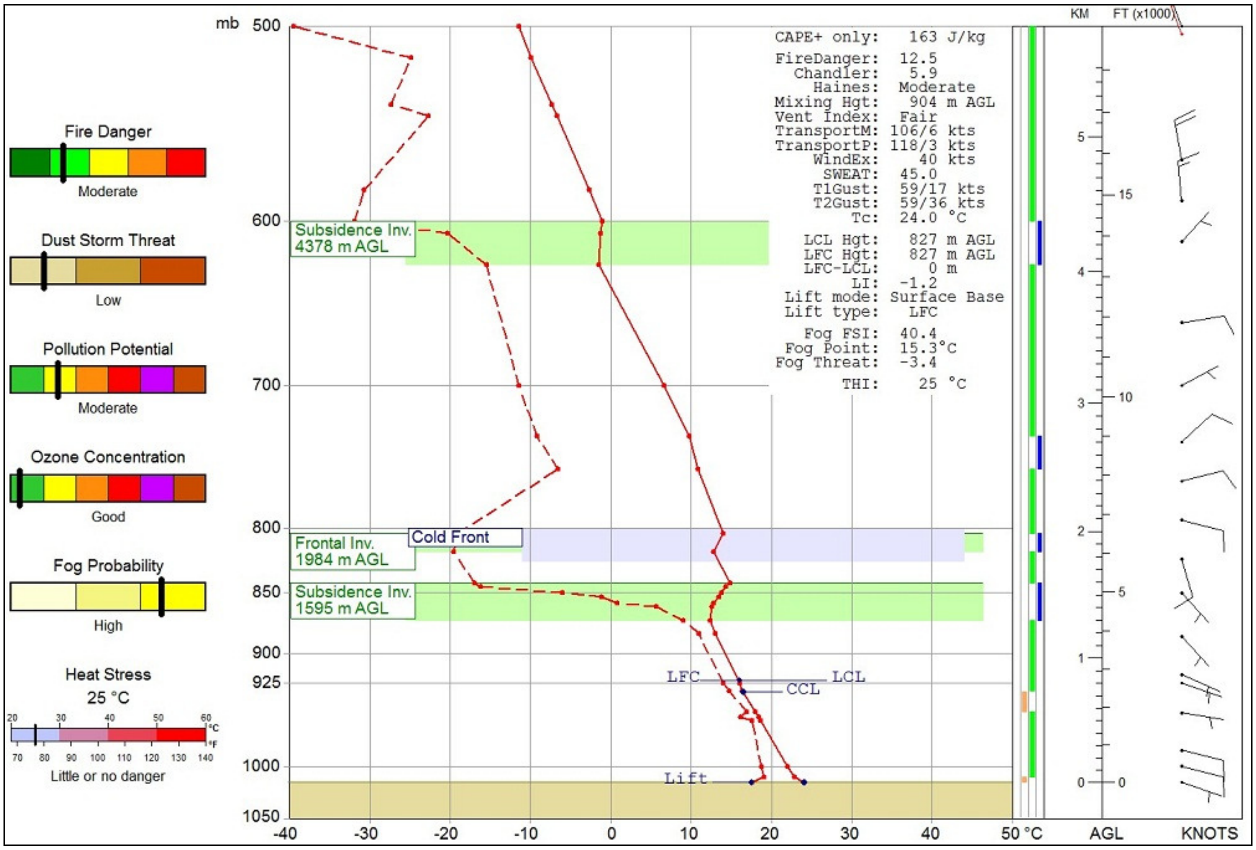


This example Winter Weather display is similar to the standard Sounding display, but also includes the RICAPS Precipitation Donut, the Precip Type (Ptype) nomogram, and the Thermogram. The Precipitation Donut is an interactive, graphic representation of precipitation type and intensity. The **Precip Type nomogram** graphically displays the correlation of the 1000-850mb thickness (Y-axis) and the 850-700mb thickness (X-axis). This multi-section nomogram is mostly used by forecasters in the mid-Atlantic U.S. region to evaluate precipitation type during winter weather. The **Thermogram** graphically depicts sounding layers that are above or below freezing (red or blue shading, respectively) with a green RH% overlay plot. This aids analyses of frozen versus liquid precipitation. The user can right-click on any nomogram or table for more information. With the optional Interactive Module, all graphic and text displays are automatically updated as the sounding is interactively modified. Note: when RICAPS is not active, then the Precipitation Donut is not available. RICAPS is activated from the below Options panel…

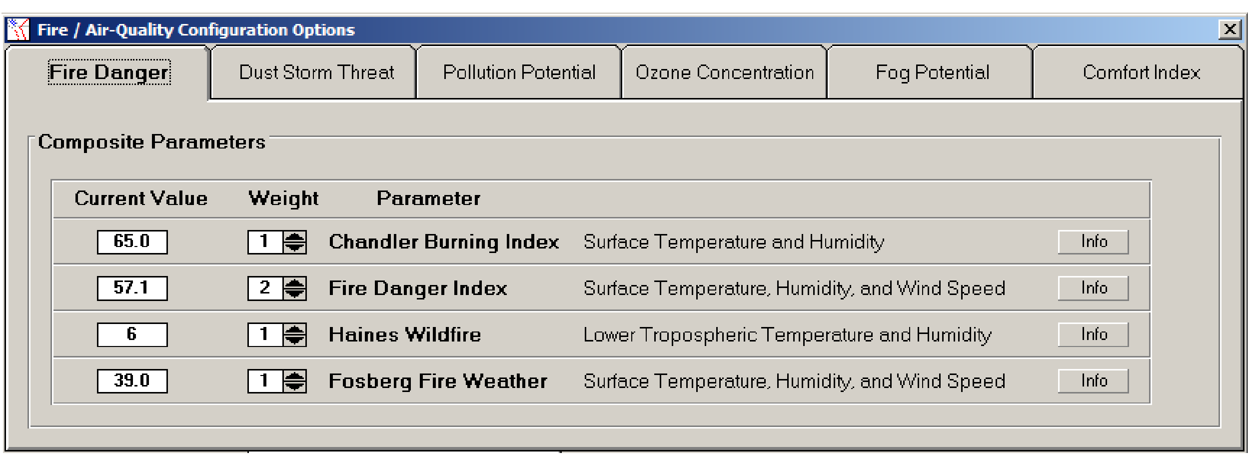


<u>Fire/AQ Weather Display</u>. This is only available with the optional Analytic Module.

This Fire-Danger / Air-Quality display was specifically designed to help monitor common atmospheric problems and threats. This screen consists of six atmospheric threats, where each can be user configured by right-clicking over any threat scale (color bar). The Ozone scale will only appear if the analyzed sounding contains ozone data. The other five scales (Fire Danger, Dust Storm Threat, Pollution Potential, Fog Probability, and Heat Stress or Wind Chill) will always appear on the screen.

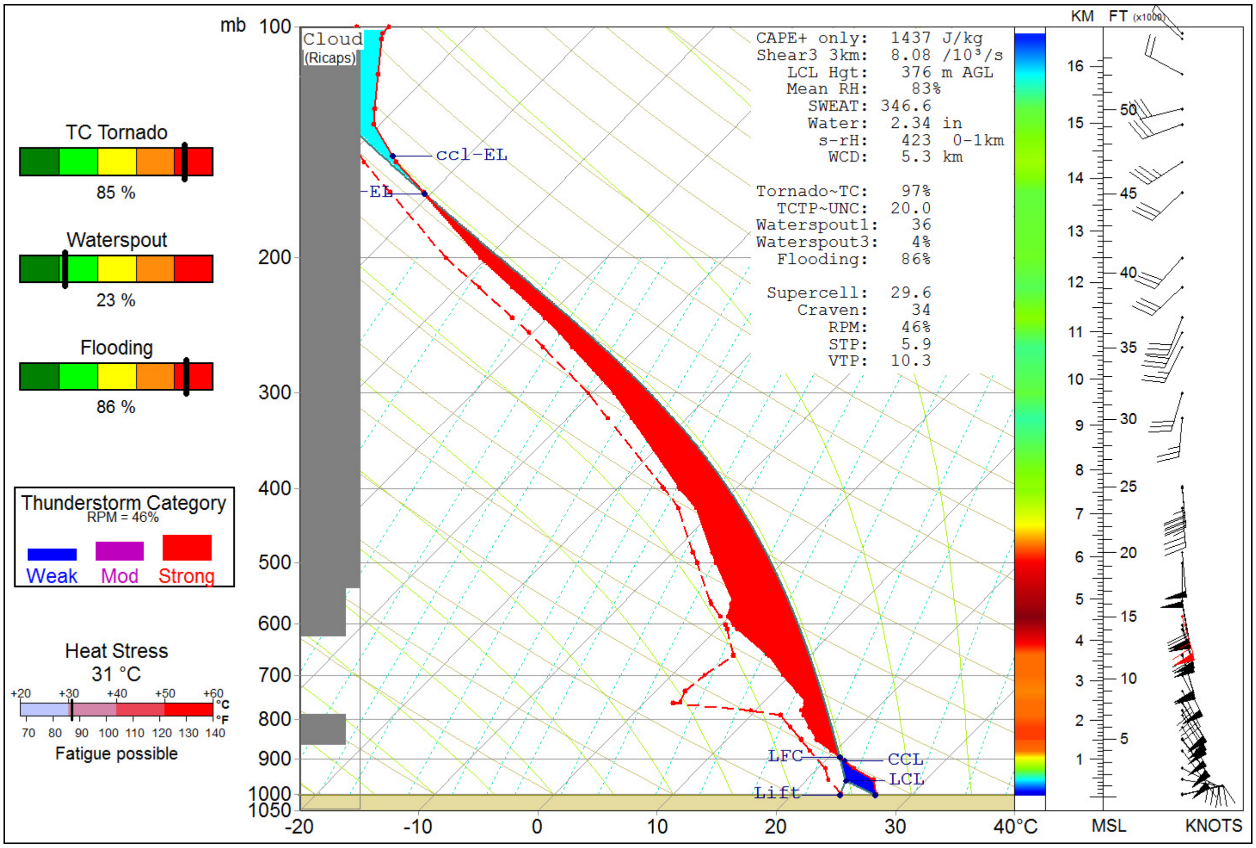


Below is the configuration table that is displayed upon right-clicking the Fire-Danger scale. Note that the Fire Danger index is a composite of 4 separate indices, all of which can be individually configured and weighted for local conditions and requirements. The other threat configuration tabs are also available.



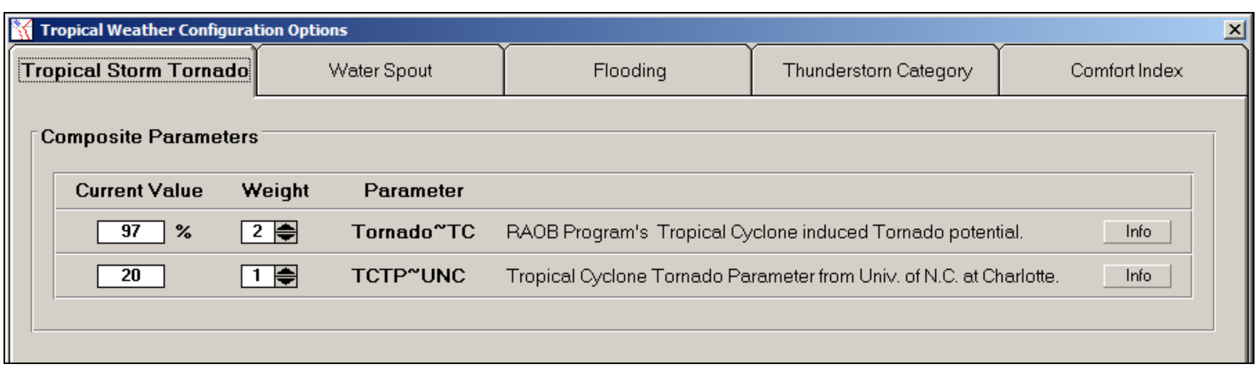
<u>Tropical Weather Display</u>. This is only available with the optional Analytic Module.

This Tropical Weather display was specifically designed to help with weather hazards in tropical and sub-tropical environments. This screen consists of five nomograms, where each can be user configured by right-clicking over any chart or nomogram (color bar) left of the sounding diagram. Note that the "Thunderstorm Category" chart also appears on the Severe Weather display, while the "Heat Stress" nomogram also appears on the Fire/AirQuality Weather display.

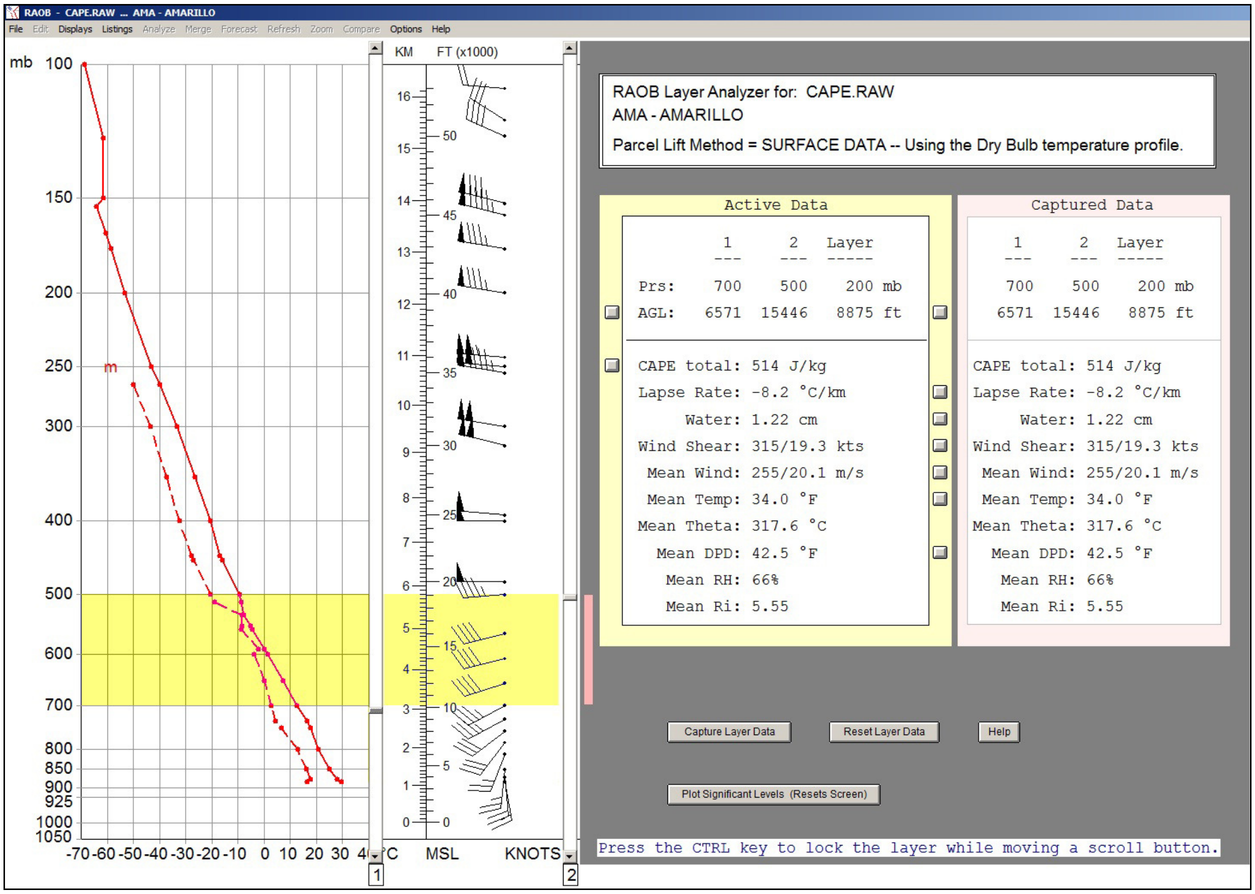


The "TC Tornado" index represents parameters that measure potential for tornado formation associated with landfalling tropical cyclones (hurricanes & typhoons). The "Flooding" index can be applied to any flood prone region in the world.

Below is the configuration table that is displayed upon right-clicking the "TC Tornado" scale. Note that this index is a composite of 2 separate indices, all of which can be individually configured and weighted for local conditions and requirements. The four other threat configuration tabs are also available.



<u>Layer Analyzer</u>. This is only available with the optional Analytic Module.



The <u>Layer Analyzer</u> allows the user to analyze key data at any layer of the plotted sounding. The two vertical scroll bars allow definition of the layer's top / bottom locations as the layer area is painted yellow. As the scroll bar buttons are moved (up & down), layer data are simultaneously computed and displayed in the "Active Data" box with the yellow border. The little square buttons located within the yellow border permit the user to toggle data units. Data unit options are displayed as the mouse hovers over each button. Note that the yellow layer (depth) can be locked by pressing the CTRL key while moving either the Top or Bottom layer scroll button.

Just below the Active Data display box, are three command buttons that control the display of layer data.

1 - The "Capture Layer Data" button allows the user to create a frozen display of current layer data, which is separately displayed to the right of the Active Data box in the "Captured Data" box, which is surrounded by a pink-colored border. A pink-colored vertical bar is also produced alongside vertical scroll bar #2 to visually identify the captured layer. This display option is useful for data/layer comparison purposes.

2 - The "Reset Layer Data" button erases the captured data box.

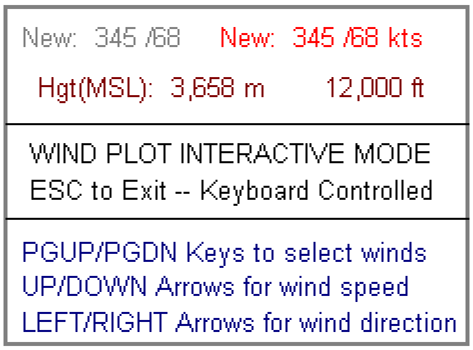
3 - The "Plot Significant Levels" command button is similar to the "Significant Levels" toolbar analyses button, where the sounding's significant levels (CCL, LCL, etc) are graphically displayed on the plotted diagram. Once this button is used, it is disabled until the "Reset Layer Data" button is used.

NOTE: The Advanced Export module's "Mean Layers & Levels" tab allows exporting of the "layer" parameters displayed in the above Layer Analyzer screen.

The following functions are only available with the optional Hodo / Interactive Module.

RAOB's interactive data processing capabilities are available on the Sounding and Hodograph screens. After changes are made, the sounding can be returned to its original values by clicking the "Restore" menu option, or the changes can be permanently retained by using the "File" and "Save As" menu options. If any of the sounding's analyses options have been selected during the interactive session, all associated text and graphic analyses displays will be simultaneously updated as the sounding data changes.

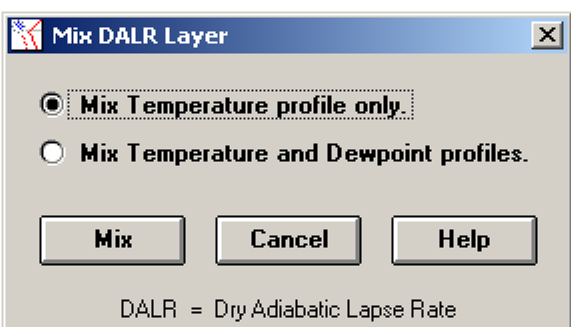
Sounding Screen. Use the mouse to click & drag any temperature plot point. Once the mouse is released, the "red" sounding profile will stay in place while a "grey" line will mark the original location of the sounding profile. Wind data can also be interactively modified. This is accomplished by first clicking on the wind plot of interest, and then modified by using the keyboard's cursor (or arrow) keys. See below…



This information box (at left) will appear after a wind plot is selected with a mouse click, where the numeric data identifies the selected wind plot data. Wind speed is altered using the Up/Down keys, while wind direction is altered using the Left/Right keys. The ESC key is used to exit the wind plot interactive mode.

Hodograph Screen. Use the mouse to click & drag any wind vector data point. Once the mouse is released, the "red" wind plot will stay in place while a "grey" line will mark the original position. Like the Sounding, the Hodograph's wind plots can also be interactively modified using the keyboard's cursor keys (see above). Note that the Storm-Motion vector can also be interactively modified by click & drag actions on the tip (arrow) of the vector.

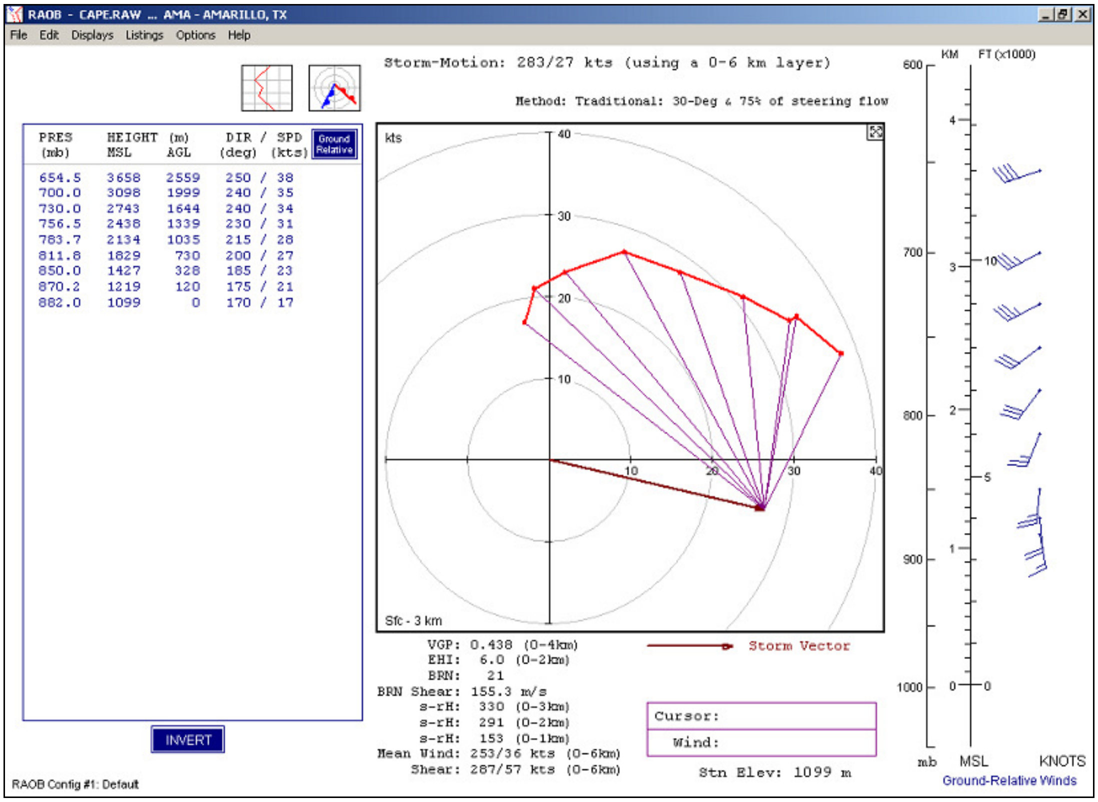
The DALR (Dry Adiabatic Lapse Rate) option. Note: the DALR function is often used to define the "mixing layer" or "mixing height". Whenever the sounding's surface temperature data is altered, a "Mix DALR Layer" option will appear just below the diagram as a hot spot. When this hot spot is clicked, the DALR options box is displayed (see below), from which the user can select one of two options.



When the "temperature" profile is mixed, the lower sounding is redrawn using the dry-adiabat associated with the surface temperature, and extends to where the dry-adiabat first intersects the sounding. "Dewpoint" mixing is done by incorporating proportional temperature changes through the same dry-adiabatic layer.

The "Mixing Height" value can be displayed on the plotted sounding's parameter listing. This is accomplished by first calling the "Sounding Display Options" screen, then clicking on the "Analyses Data" tab, then selecting the "Custom Data Displays" option. For best results, the surface temperature should be adjusted to the expected maximum temperature for the day – or for the time period of interest.

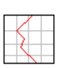
Hodograph Display. This full-screen hodograph is only available with the optional Interactive Module.

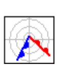


The hodograph diagram is fully interactive. Just click & drag the hodograph wind vectors, the storm motion vector, or click & keyboard change the wind plots to begin interactive changes. During interactive activity, all analyses data and text listings are simultaneously updated, including the wind plots on the right side of the screen. The wind data listing (at left) can be scrolled using the scroll buttons below the data listing (shown only when the data list extends beyond the data box) or by using the keyboard's cursor (arrow) keys. The above example also displays the optional storm-motion wind vectors originating from the Storm Motion vector. (Note: click on the Storm-Motion arrowhead in order to interactively drag the vector.)

Hodograph hot-spot images …

 … Click to expand (zoom) the hodograph to a full-screen image to better see diagram details. This image is located at the upper-right corner of the hodograph.

 … Click to switch display to the main sounding diagram screen. This image is located at the upper-left section of the screen.

 … Click to switch display to the Frontal Analysis screen. It is located at the upper-left section of the screen. This image is only available with the optional Fronts & Forecast Module.

… Click to toggle "Ground-Relative" and "Storm-Relative" wind displays. This image is located at the upper-right corner of the data listing box, which is located to the left of the Hodograph.

Hodograph Display - Options.

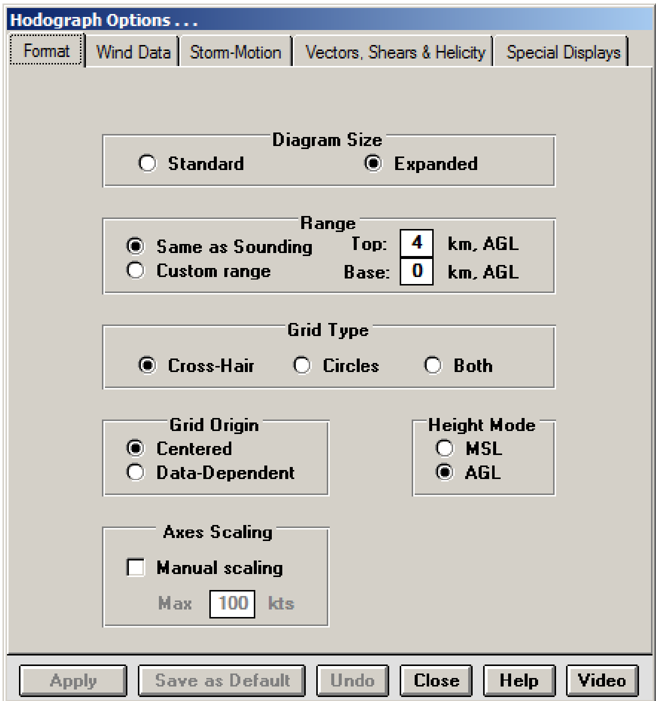


Diagram Size. Select Standard or Expanded.

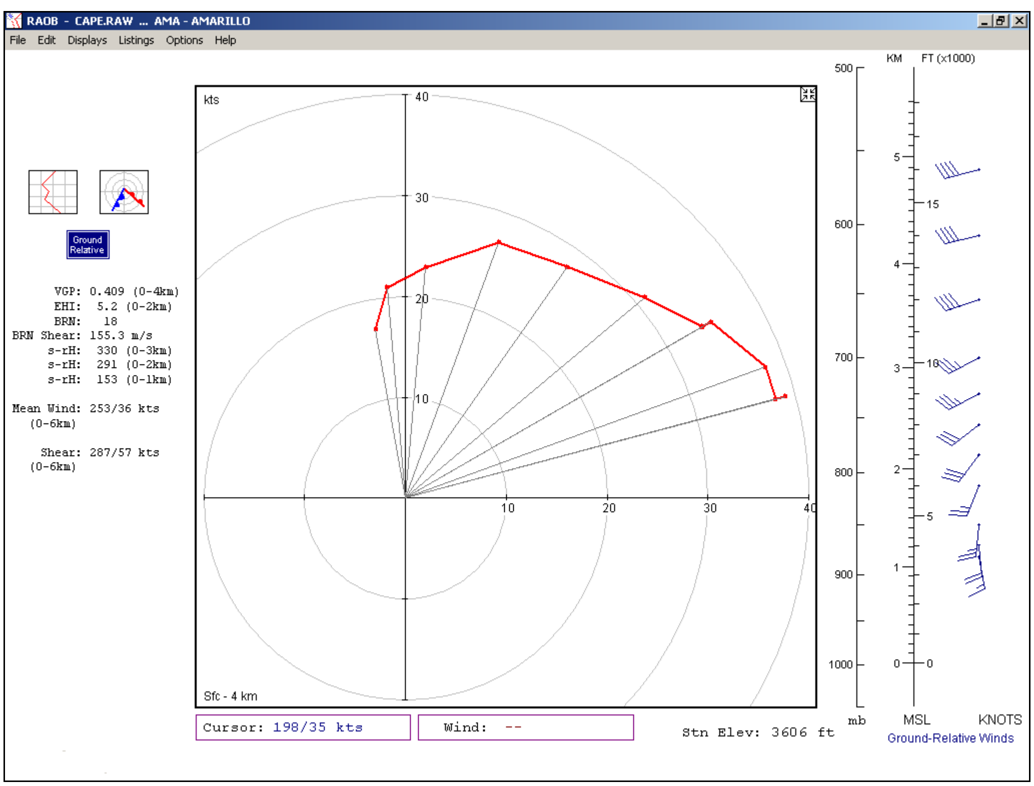
Range. Select "Same as Sounding" or "Custom range" which allows specification of the hodograph's Top and Base limits.

Grid Type. Select Cross-hair, circles, or both.

Grid Origin. "Centered" freezes origin location, while "Data-Dependent" zooms in on the quadrant with the most wind vectors.

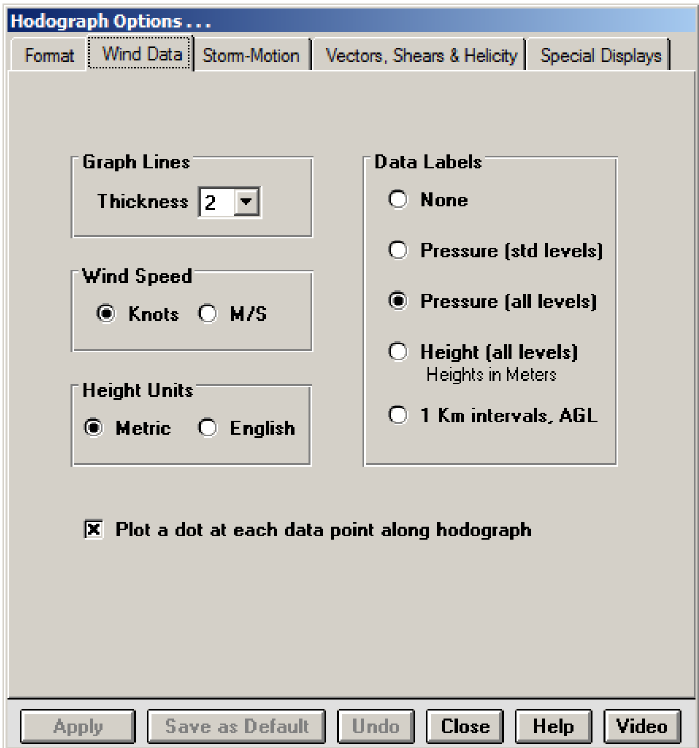
Height Mode. Choose MSL or AGL.

Axes Scaling. When "Manual scaling" is selected the user specifies the maximum values (wind speed) to be displayed on the cross-hair axes.



The example at left uses the above selected options. This example is drawn in the Expanded size. It also includes the Ground-Relative wind vectors, that are drawn in thin black lines from the graph origin.

Hodograph Display – Options (continued) …



Graph Lines. Select line thickness value.

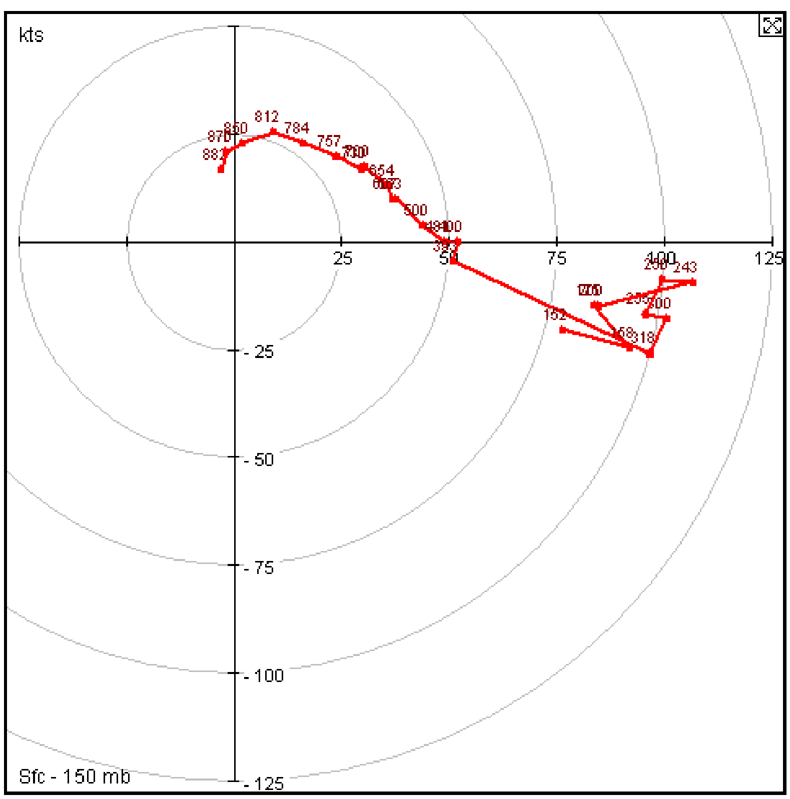
Wind Speed. Knots or meters/second (m/s).

Data Units. Select Metric or English.

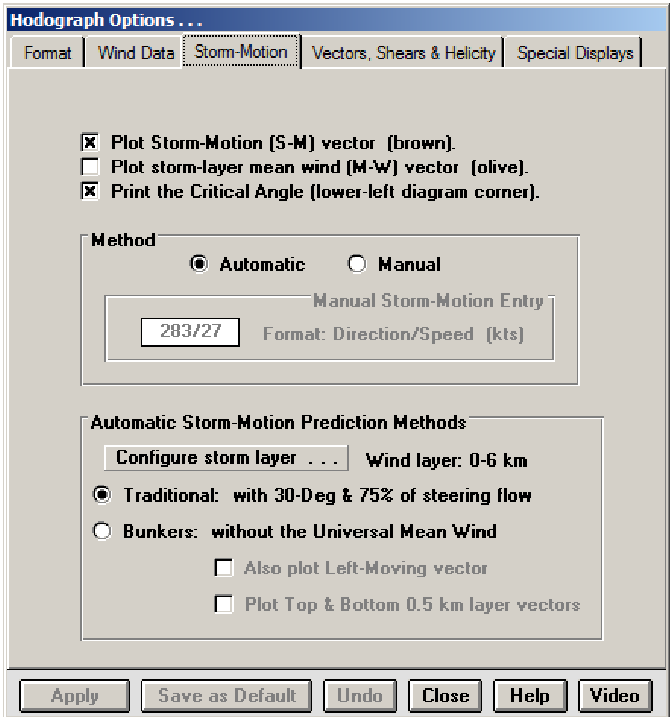
Plot a dot at each data point along hodograph.
A user preference option.

Data Labels. Select whether data points are identified with pressure or height labels. Standard (std) pressure labels are 1000, 925, 850 mb, etc.

The example below uses the above selected options. This example displays all wind vectors through the entire sounding – from the surface to 150 mb.



Hodograph Display – Options (continued) …



Plot Storm-Motion vector. Displays a brown vector originating from the origin.

Plot storm-layer mean wind vector. Displays wind layer as configured.

Print "Critical Angle" in a red color.

Method. Choose storm-motion type:

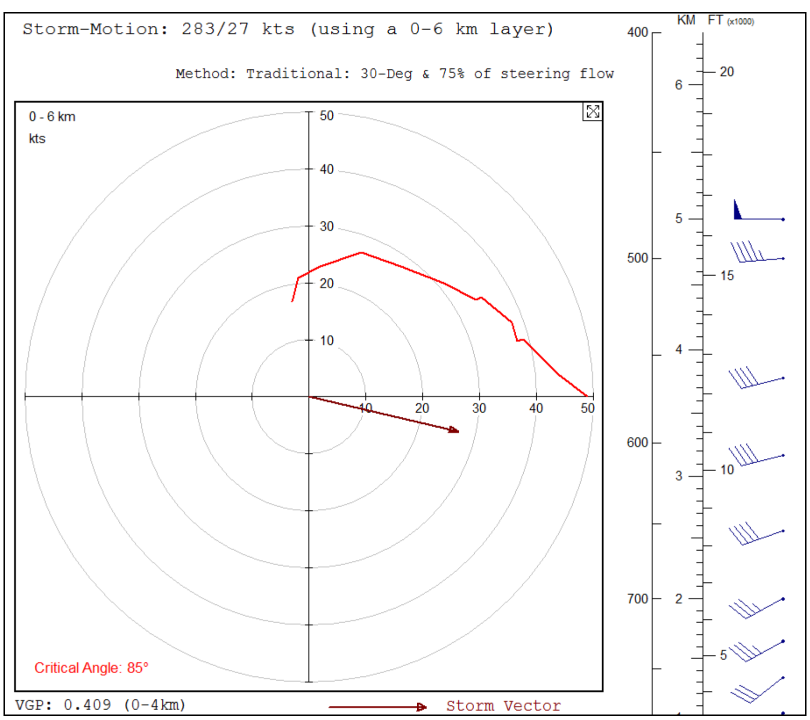
- **Manual Method**. Input desired vector direction and speed. When selected, the "Manual Storm-Motion Entry" vector box is made available.

- **Automatic Methods**. Alter the Wind-Layer depth for either method by using the "Configure storm layer" command button.

--- **Traditional method**. Steering flow options are also configurable with the Command button.

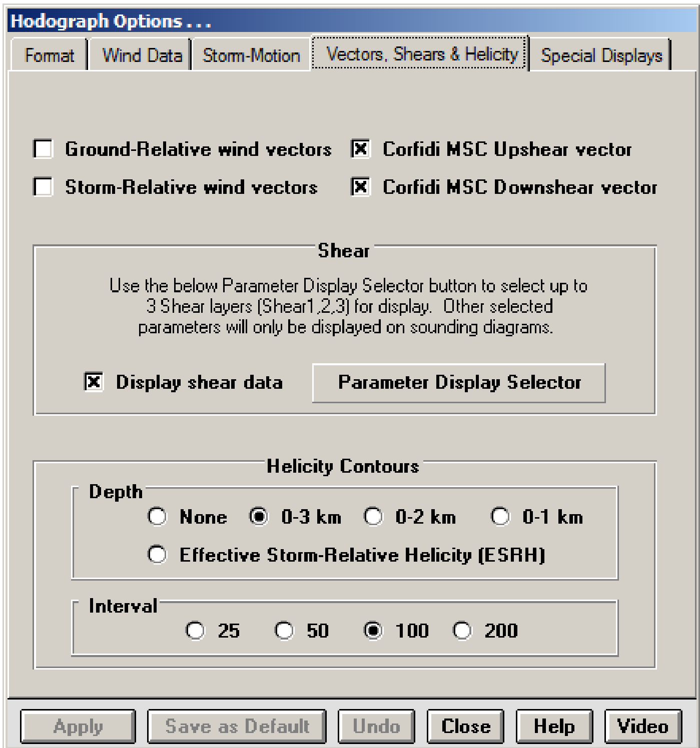
--- **Bunkers method**. Also contains options for the Left moving vector and boundary layer plots.

The below example uses above selected options. Note the "Critical Angle" is printed in a red color.



The **Critical Angle"** is the angle defined by the storm-relative inflow vector at 10 m and 10-500 m shear vector. Studies show that the tornadic storms, and in particular the significant tornadic storms, tended to be characterized by angles near 90°, whereas the non-tornadic storms were not.

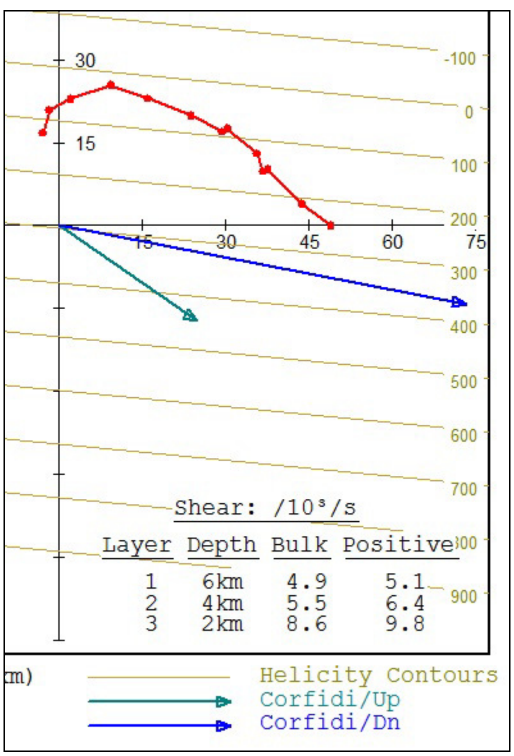
Hodograph Display – Options (continued) … Shears Bulk and Positive



Vectors. The ground-relative vectors are drawn from the hodograph's origin. The storm-relative vectors are drawn from the tip of the Storm-Motion vector. The Corfidi Upshear (or MBE) & Downshear vectors are drawn from the origin. The Up vector is drawn in green; the Down vector is drawn in blue.

Shear. Use this option to display up to 3 user specified wind shear layers in the lower right corner of the diagram. The depth of each shear layer can be user specified by clicking on the Parameter Display Selector button.

Helicity Contours. Choose depth and interval options. They are drawn and labeled in a light tan color. Note: the tip of the Storm-Motion vector always coincides with the helicity value displayed below the diagram (not shown in this example). The Effective Storm-Relative Helicity (ESRH) option is discussed on the next page.



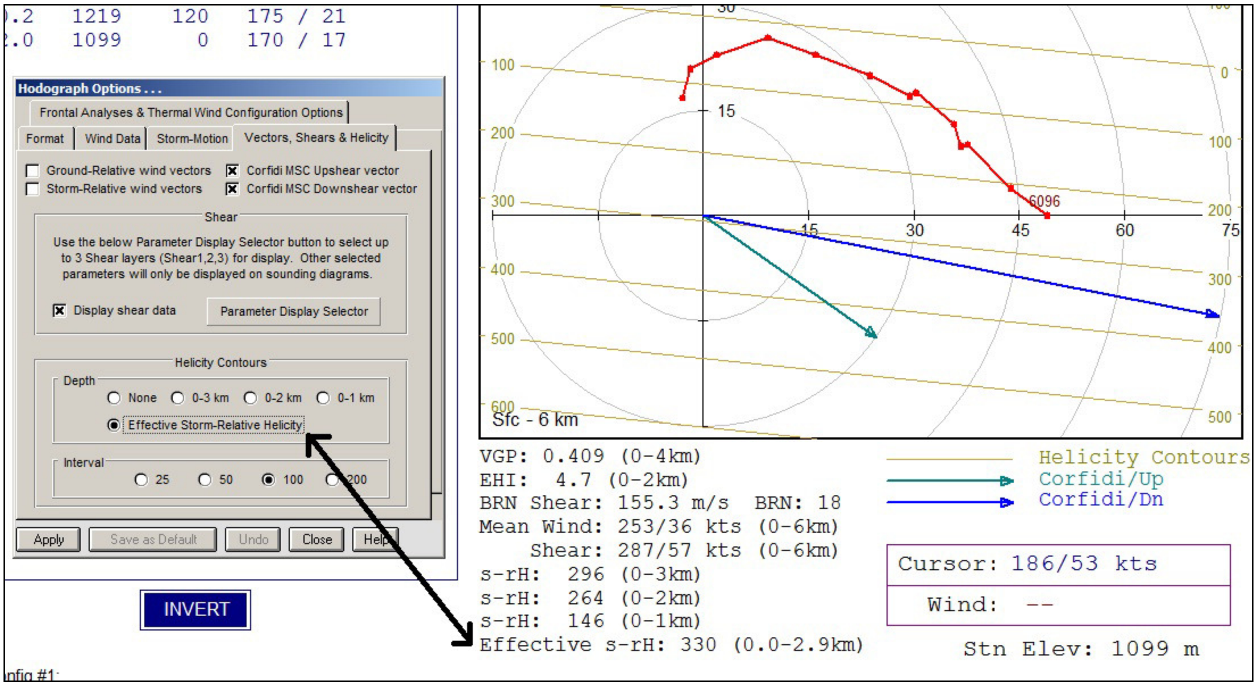
See example at left with above selected options.

Bulk Shear. Bulk shear is most commonly represented by the vector difference between the winds at two different levels. For example, the 4km bulk shear value (seen left) is the difference between the surface and the 4-km winds. Note that each shear value is obtained by dividing the vector difference by the layer depth – in this case it is 4km.

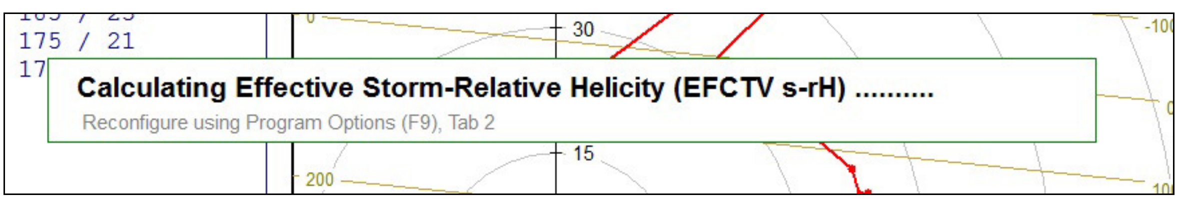
Positive Shear. Positive shear is similar to Total Shear (which is not calculated or displayed), except that only the neutral and clockwise-curving shear segments are summed, which is then normalized by the depth of the shear layer. Conversely, negative shear uses the neutral and counterclockwise- curving shear segments. For a unidirectional hodograph, the total, positive, and negative shear would be similar. For a purely clockwise turning hodograph, the total and positive shear would be similar, and the negative shear would be zero. (Bunkers et al 2002)

Hodograph Display – Options (continued) …

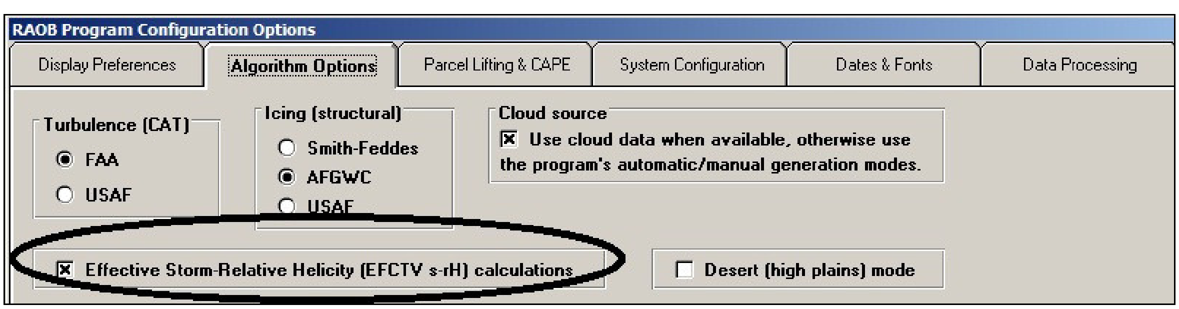
Selection of the "Effective Storm-Relative Helicity" option results in the additional data display as indicated below by the double arrow.



Selection of the Effective Storm-Relative Helicity (Effective SRH, or ESRH) informs RAOB to determine the depth of the helicity layer as a function of the CAPE layer. Resulting SRH calculations take much more processing time and will significantly slow down looping & multi-sounding operations. ESRH data is automatically applied to the STP, VTP, and SCP composite indices. During interactive sessions, such as altering wind vectors with click & drag operations, RAOB displays a status window (shown below) indicating the extra processing time needed to calculate Effective SRH data.

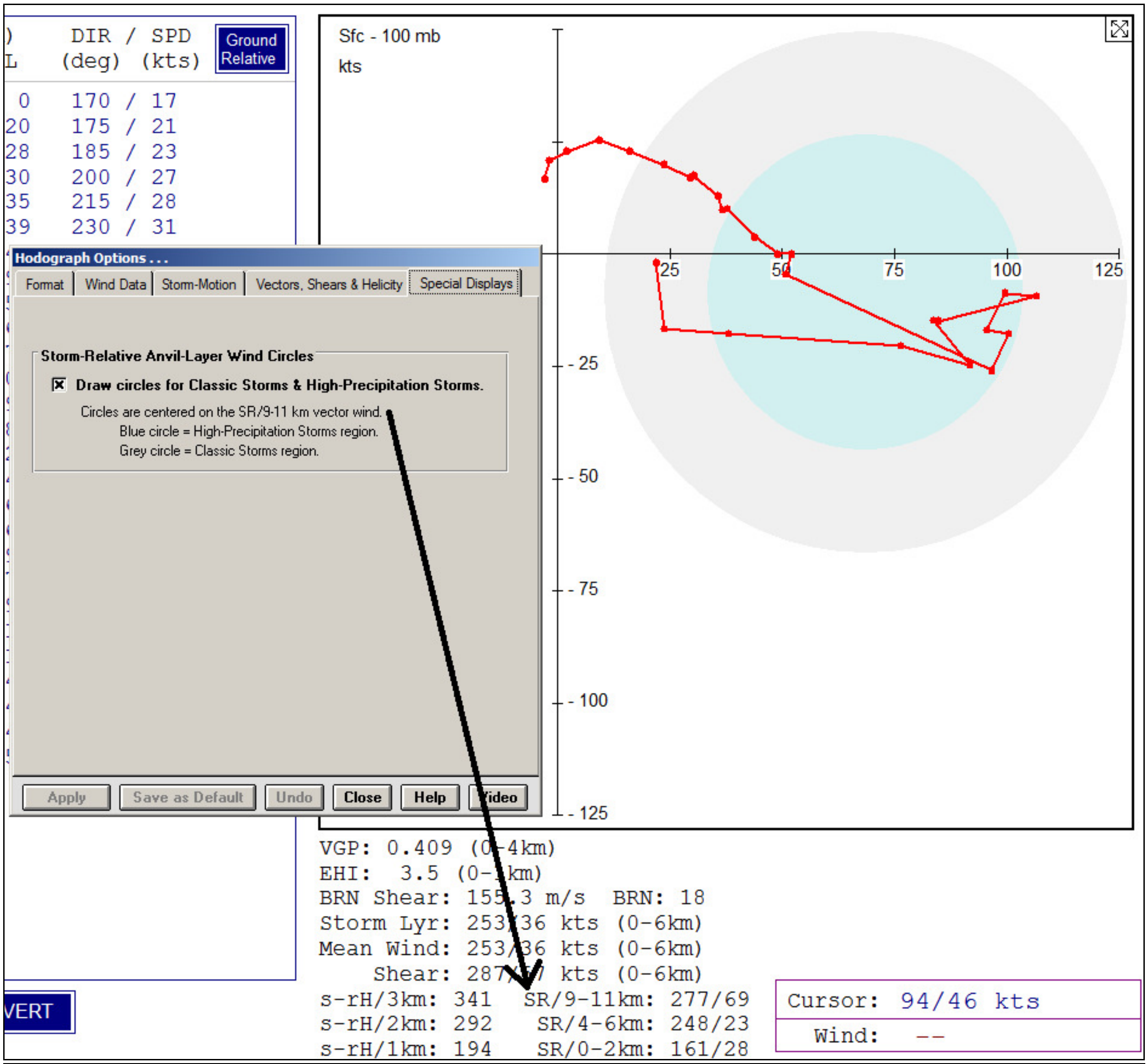


Effective SRH calculations are only calculated if specifically selected from the Program Options (F9), the Algorithm Options (Tab 2) option (see below).



<u>Hodograph Display – Options (continued)</u> …

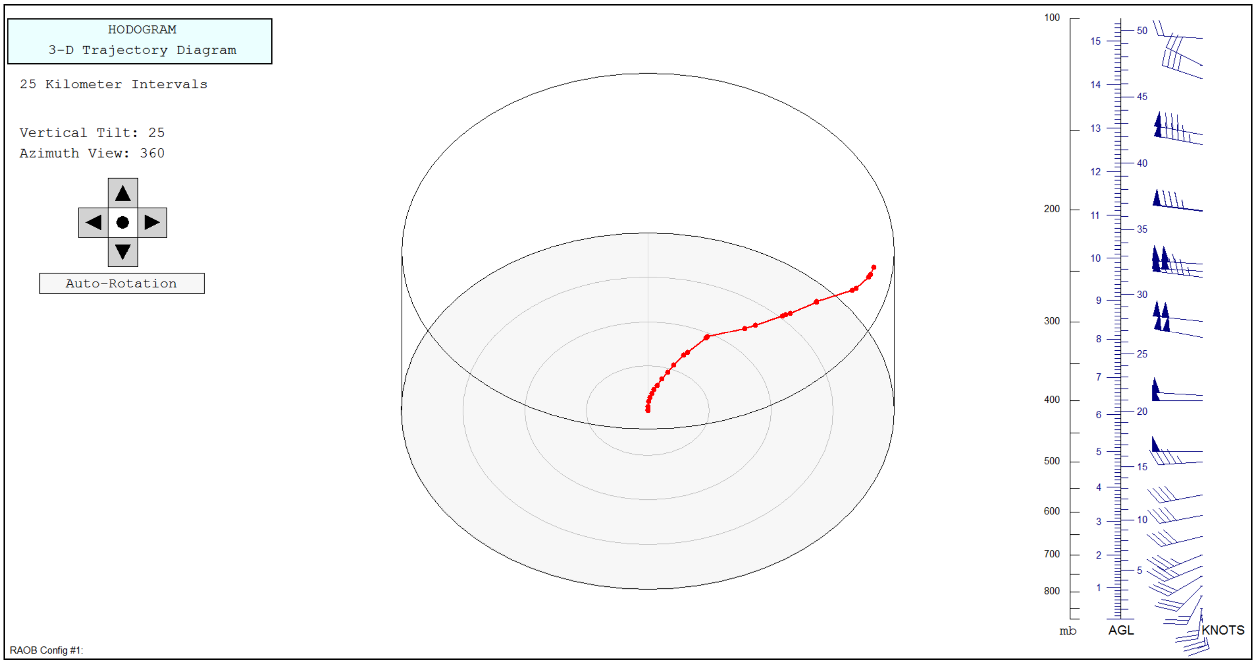
Storm-Relative Anvil-Layer Wind Circles.



The Anvil Level SR (**<u>S</u>**torm **<u>R</u>**elative) winds and SR winds from 9-11-km are meant to discriminate supercell type.

In general, upper-level SR winds less than 35 knots correspond to "high precipitation" supercells (blue circle), 35-58 knots SR winds denote "classic" supercells (grey circle), while SR winds greater than 58 knots correspond to "low precipitation" supercells.

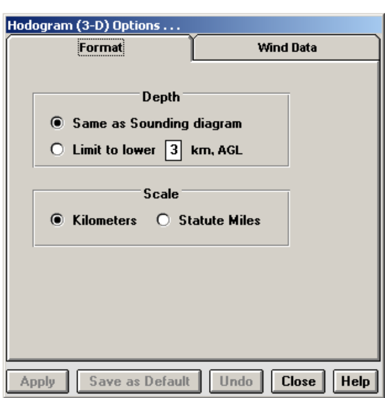
<u>Hodogram (3-D trajectory) Display</u>. This full-screen hodogram is only available with the optional Hodograph & Interactive Module.

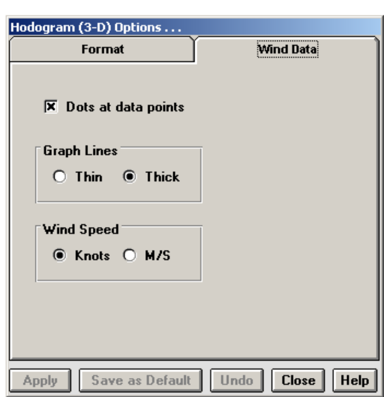


The hodogram is a trajectory diagram, showing the 3-dimensional voyage of the sounding balloon from launch to burst. Since most sounding data do not list the time intervals between data levels, all trajectories are calculated using a standard uniform ascent rate of 5 meters-per-second.

The hodogram is interactive in terms of graphical display only. The data cannot be altered, but the view angles can be rotated manually or automatically. The hodogram can be rotated 360 degrees and/or rotated 90 degrees into a vertical position. Hodogram angles can be adjusted using the four arrow buttons located left of the diagram. The center "circle" button resets the diagram to its initial default orientation. Hodogram angles can also be altered using the keyboard's cursor (arrow) keys. The "Auto-Rotation" button sets into motion continuous rotation of azimuth and tilt angles. This auto-rotation can be stopped by again clicking the rotation button or by pressing the ESC key.

If the sounding wind data also contains the vertical motion component (W) data, then the Hodogram's red trajectory plot changes to Red segments for Upward motion and Blue segments for Downward motion.





The hodogram has its own configuration options menu, which can be accessed by right-clicking while over the diagram, or by using the OPTIONS menu bar method. The Hodogram's configuration options are shown at left.

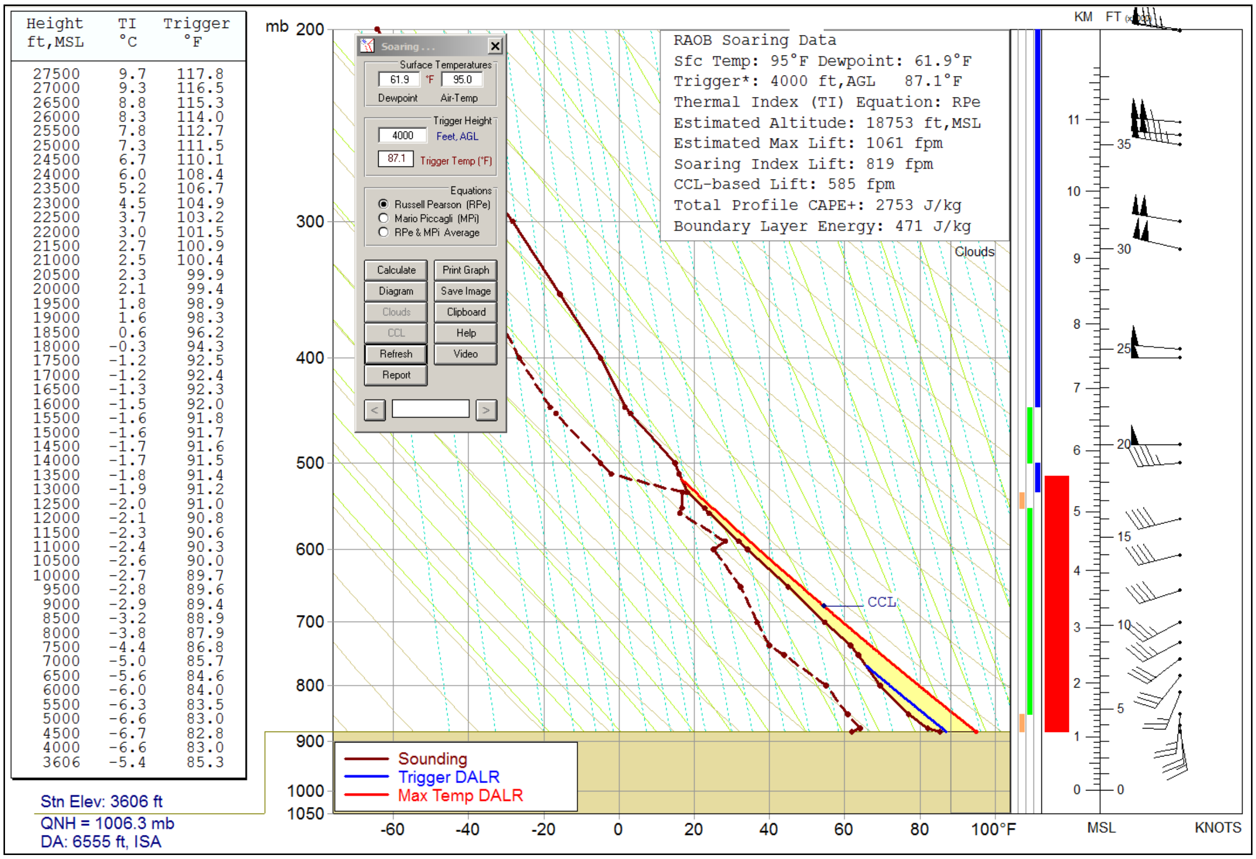
Soaring Display.

The Soaring Menu option (when clicked) displays the Soaring analysis screen (shown below). The sounding screen is modified in order to allow for the display of soaring data along the left side of the plotted sounding.

The Soaring Menu Tool permits temperature, trigger height, and mathematical equation options. The Calculate button displays results of selected data options, while the Diagram button allows re-configuration of the diagram format and plotted sounding options.

By clicking on the Calculate button, various soaring data and indexes are displayed. The solid (red) vertical bar between the sounding and the wind plot height scale represents the estimated lift altitude.

While important soaring and TI (thermal index) data are displayed along the left side of the sounding diagram, the Report button produces a NWS-style "Soaring Guidance Report", which can be printed, saved to file, and even emailed as an attached text file.

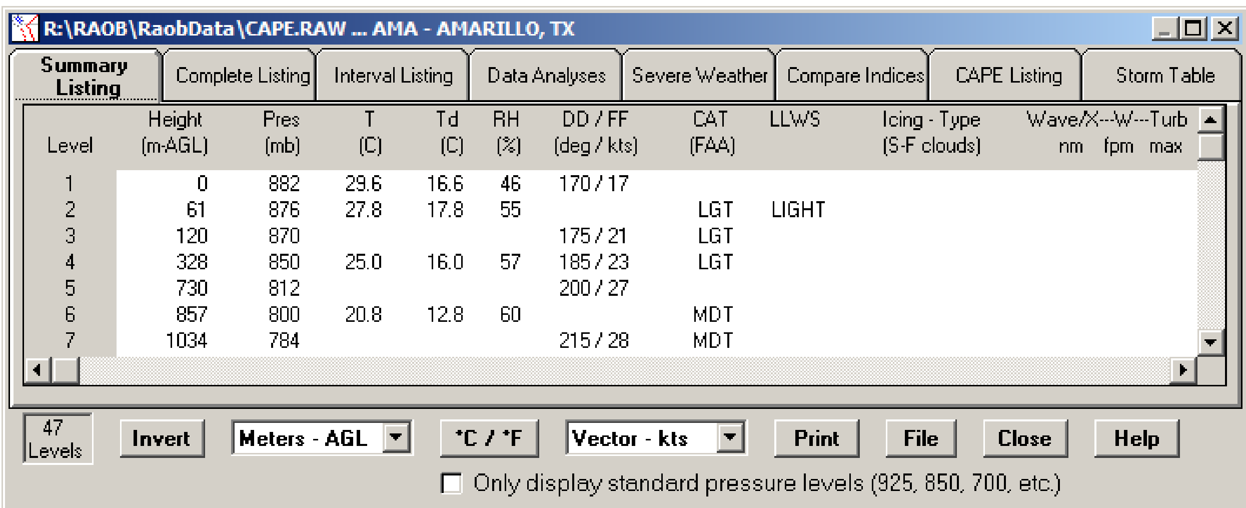


Details regarding diagram displays, algorithms and data options can be found in the SOARING Calculations section located near the back of this Manual.

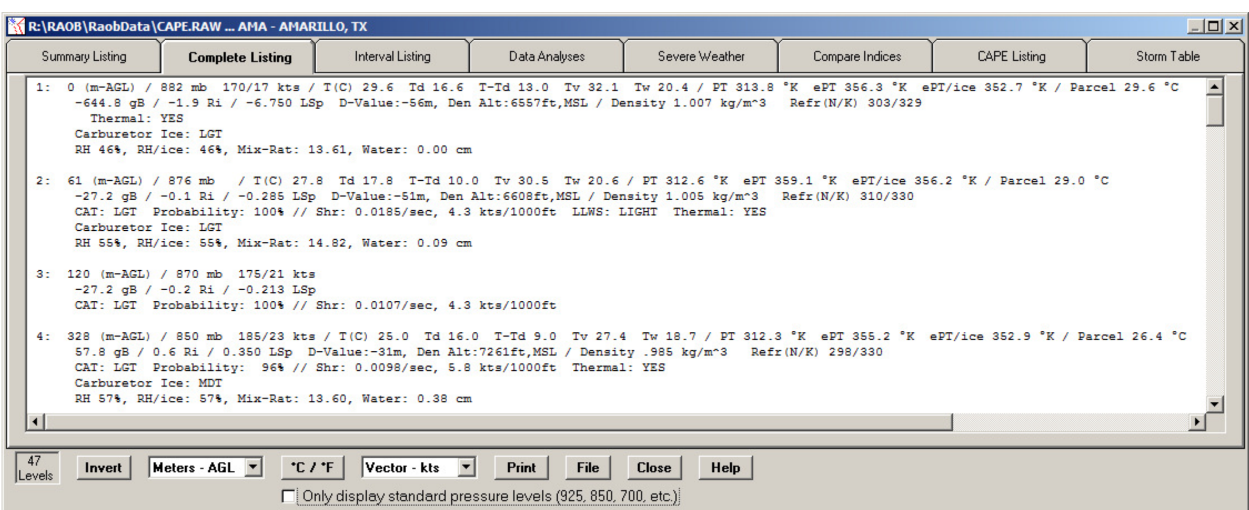
4.4 **Listings**. Provides eight different formats for displaying alphanumeric sounding data.
To display these listings, use the Display Menu option, or press the Space-Bar.

Summary Listing -- Tabular list of primary sounding data with icing & turbulence parameters.
Complete Listing -- Grouped list of significant sounding data associated with each data level.
Interval Listing -- View data levels via pressure or height and via user-defined intervals.
Data Analyses Listing -- List of key analyses and calculated parameters, such as inversions.
Severe Weather Parameter Table -- Displays a user-configurable significant weather parameter list.
Compare Indices Table – Comparison displays of Surface, Most-Unstable, and Mean Layer lifting.
CAPE Listing – Configurable table of CAPE values for any layer within the sounding profile.
Storm Table – Configurable listing of storm vectors, shear, and helicity values for specified layers.
Fog Table – Individually configure both Radiation and Advection fog types.

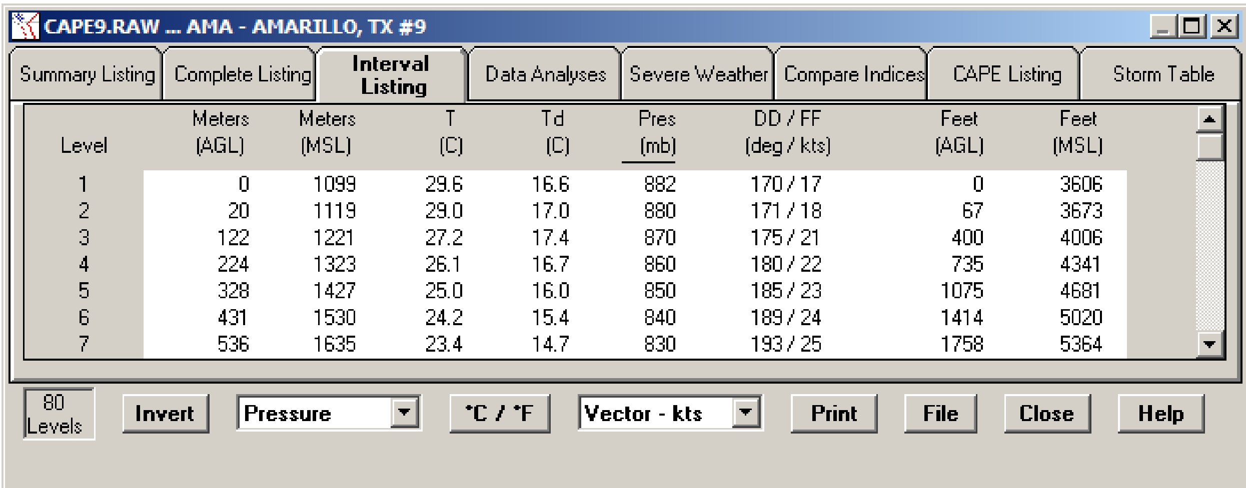
Summary Listing. Provides tabular data of key sounding parameters. Listing can be inverted, displayed with optional temperature (C/F) units, or wind speed (kts/ms) units. A drop-down box offers a variety of height units, including Feet, Meters, Miles in either MSL or AGL. Use the "Only display standard pressure levels" checkbox option to filter the data display to only standard WMO pressure levels.



Complete Listing. This list is only available with the optional Analytic Module. This listing includes key sounding data (observed and calculated) which pertain to individual data levels. As with the Summary listing, several configuration options are available to the user.

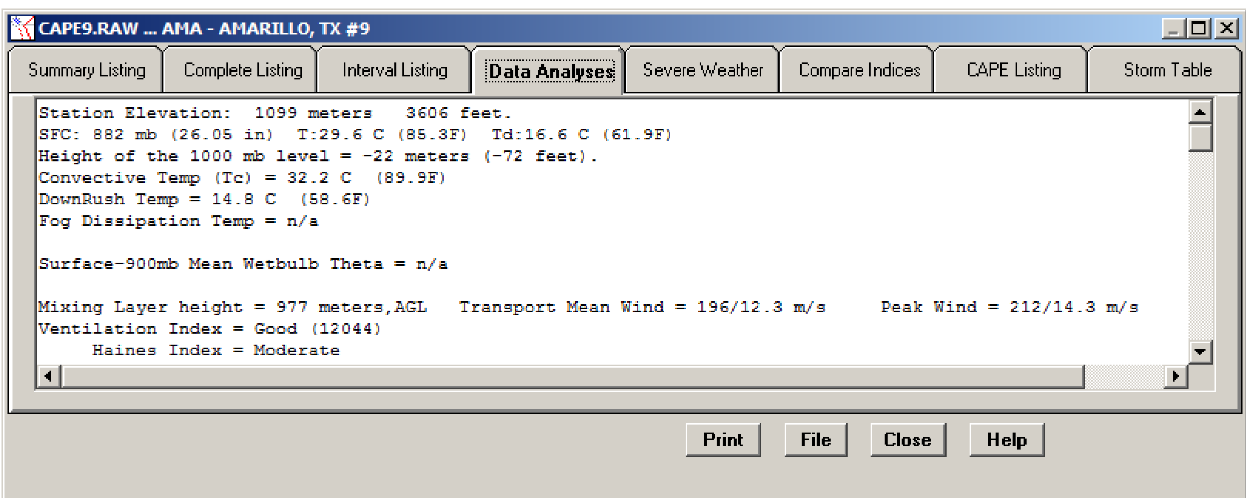


Interval Listing. See the example image below. This listing's drop-down box allows the user to define the vertical interval in either Pressure, Feet, or Meters (AGL or MSL); after which another option box prompts for the vertical interval value. The below example shows a vertical Pressure display in 10 mb intervals and the corresponding interpolated temperature and wind data.

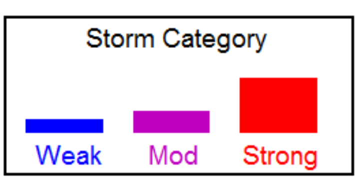


Level	Meters (AGL)	Meters (MSL)	T (C)	Td (C)	Pres (mb)	DD / FF (deg / kts)	Feet (AGL)	Feet (MSL)
1	0	1099	29.6	16.6	882	170 / 17	0	3606
2	20	1119	29.0	17.0	880	171 / 18	67	3673
3	122	1221	27.2	17.4	870	175 / 21	400	4006
4	224	1323	26.1	16.7	860	180 / 22	735	4341
5	328	1427	25.0	16.0	850	185 / 23	1075	4681
6	431	1530	24.2	15.4	840	189 / 24	1414	5020
7	536	1635	23.4	14.7	830	193 / 25	1758	5364

Data Analyses. This listing is only available with the optional Analytic Module. It provides key non-level specific data, such as inversion layers, thickness layers, CAPE data, significant level information, and many other analyses data that are not otherwise displayed. Program algorithm parameter settings are also displayed at the end of this listing.

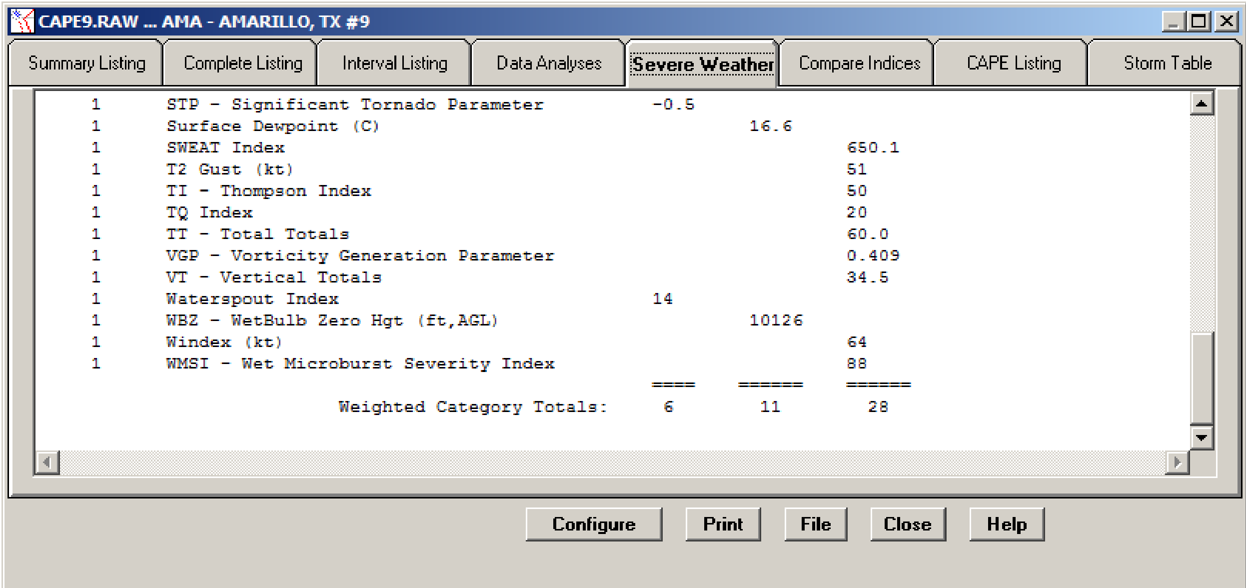


Severe Weather. Provides a tabulated display of weighted severe weather parameters and the resultant categories of Weak, Moderate, and Strong potential. The example (at the top of the next page) only shows the last 13 parameters available to the user. Parameter "weights" and "threshold limits" are all user-definable through the Severe Weather Table configuration menu option. The results from this table can also be graphically displayed on the plotted sounding using the Analyze Menu option described next.

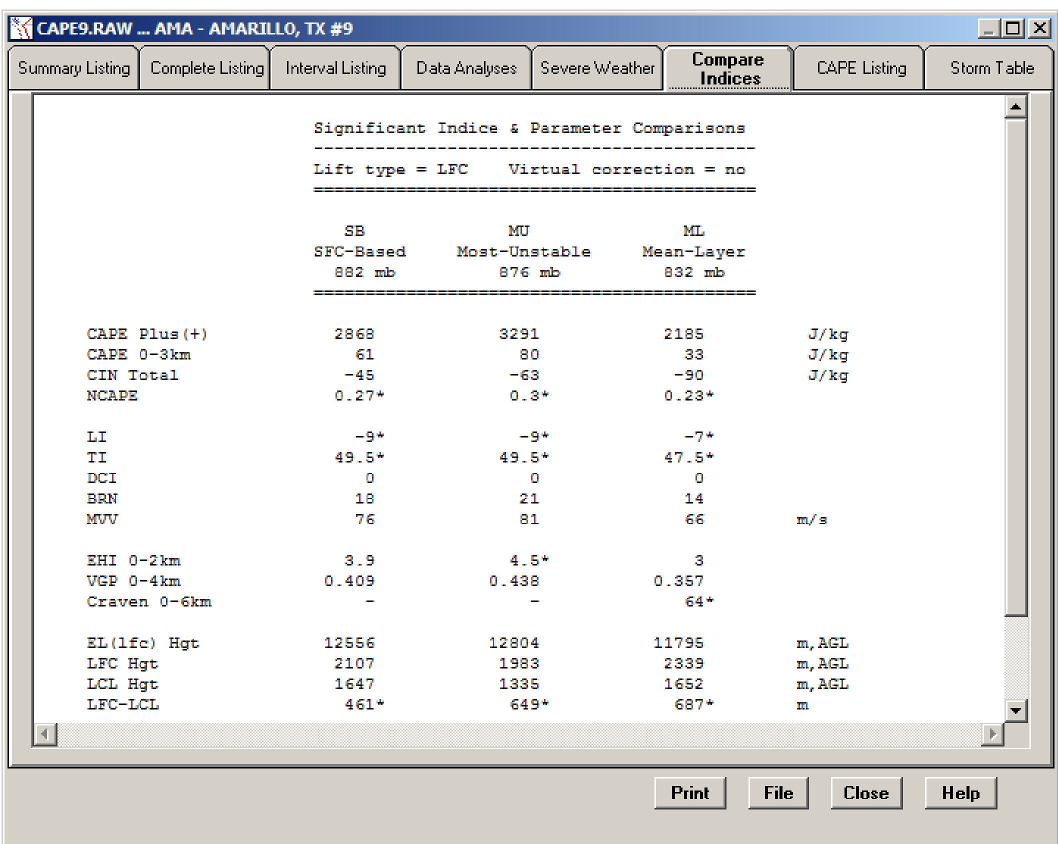


The Storm Category box at left is an example of the graphical representation of the summarized tabular data from the Severe Weather Parameter Table (shown on next page). This Storm Category box is automatically displayed when viewing the Severe Weather Sounding Display screen (see Displays Options for more information).

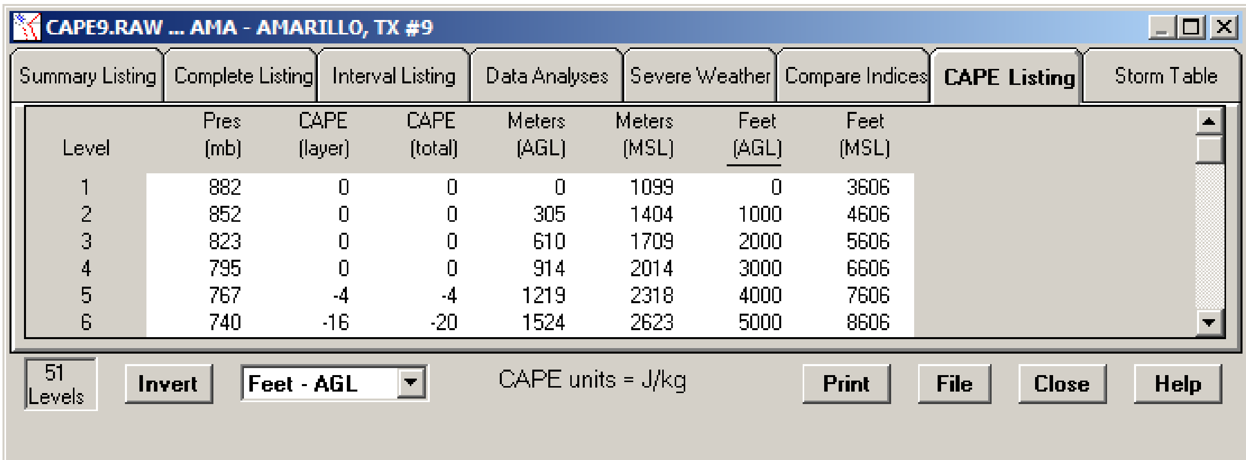
Severe Weather Tab (continued) …



Compare Indices. This listing provides a comparison table of severe weather parameters with respect to the three modes of parcel lifting: Surface-Based (SB), Most-Unstable (MU), and Mean-Layer (ML). The asterisks (*) that follow some of the parameter values indicate that they exceed the "moderate" potential threshold for severe weather (as defined by the user in the Severe Weather Parameter Configuration Table, viewed via Menu shortcut F12).

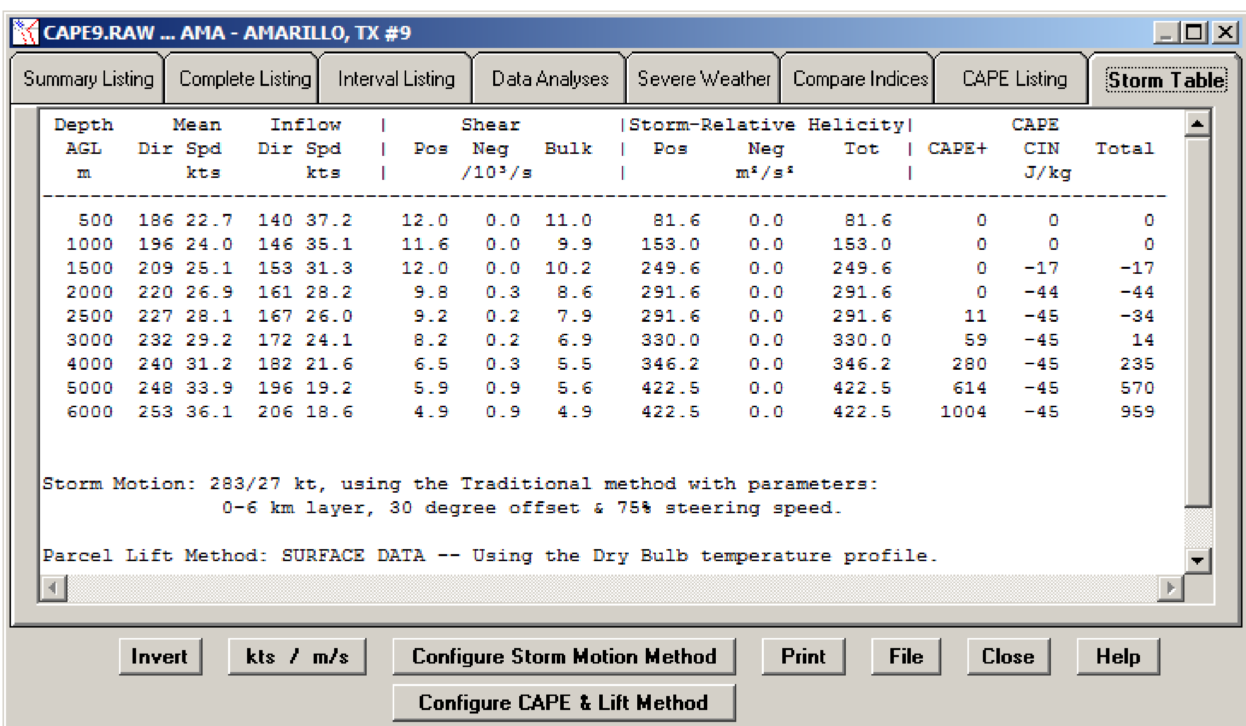


CAPE Listing. This listing is similar to the "Interval Listing" display, but its primary purpose is to present CAPE values for any sounding layer or thickness. CAPE values for each layer are displayed, including the accumulative CAPE from the surface level. Layers can be defined by Pressure, Meters, or Feet and by AGL or MSL. This example shows CAPE values for layers defined by at every 1,000 Feet, AGL.



Level	Pres (mb)	CAPE (layer)	CAPE (total)	Meters (AGL)	Meters (MSL)	Feet (AGL)	Feet (MSL)
1	882	0	0	0	1099	0	3606
2	852	0	0	305	1404	1000	4606
3	823	0	0	610	1709	2000	5606
4	795	0	0	914	2014	3000	6606
5	767	-4	-4	1219	2318	4000	7606
6	740	-16	-20	1524	2623	5000	8606

Storm Table. The Storm Table is only available with the optional Hodograph & Interactive module. It provides important storm vector, shear, storm-relative helicity, CAPE values for specified layers. The "Inflow" values reflect the vector difference between the Storm Motion vector and the Mean wind vectors (shown in the table). The "kts / m/s" button allows toggling of the wind speed units. Storm-motion and Parcel information are also displayed at the bottom of the table. Easy access configuration buttons are also provided for the Storm-motion and Parcel lifting parameters.

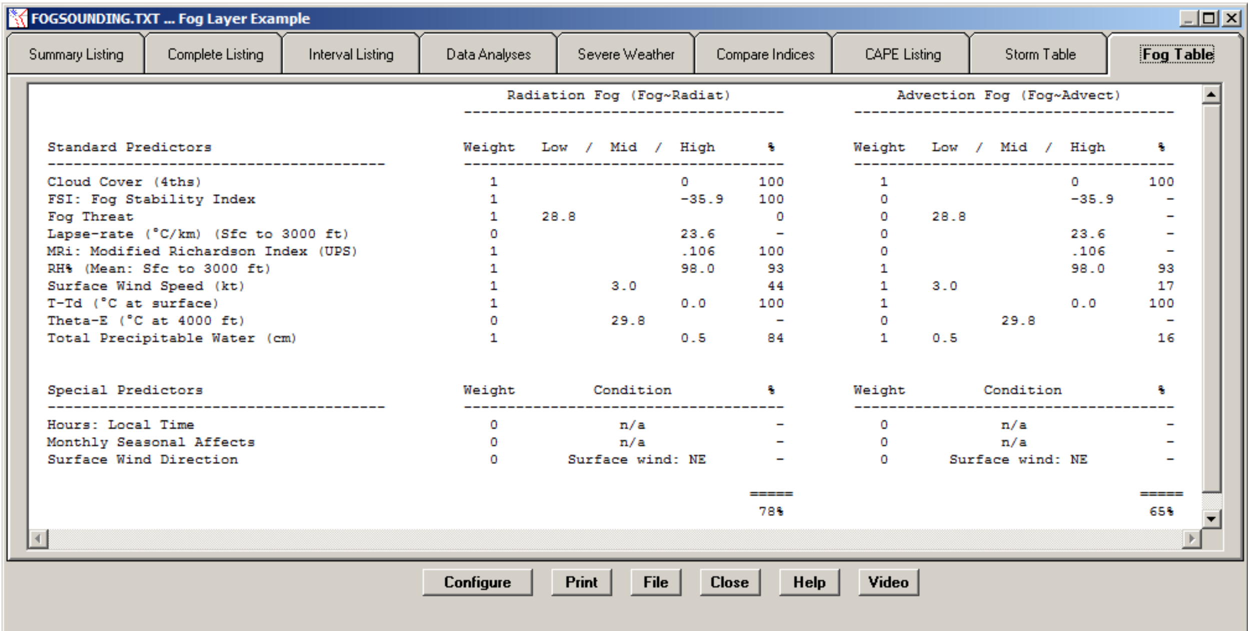


Depth AGL m	Mean Dir	Mean Spd kts	Inflow Dir	Inflow Spd kts	Shear Pos	Shear Neg /10³/s	Shear Bulk	Storm-Relative Helicity Pos	Storm-Relative Helicity Neg m²/s²	Storm-Relative Helicity Tot	CAPE+	CIN J/kg	Total
500	186	22.7	140	37.2	12.0	0.0	11.0	81.6	0.0	81.6	0	0	0
1000	196	24.0	146	35.1	11.6	0.0	9.9	153.0	0.0	153.0	0	0	0
1500	209	25.1	153	31.3	12.0	0.0	10.2	249.6	0.0	249.6	0	-17	-17
2000	220	26.9	161	28.2	9.8	0.3	8.6	291.6	0.0	291.6	0	-44	-44
2500	227	28.1	167	26.0	9.2	0.2	7.9	291.6	0.0	291.6	11	-45	-34
3000	232	29.2	172	24.1	8.2	0.2	6.9	330.0	0.0	330.0	59	-45	14
4000	240	31.2	182	21.6	6.5	0.3	5.5	346.2	0.0	346.2	280	-45	235
5000	248	33.9	196	19.2	5.9	0.9	5.6	422.5	0.0	422.5	614	-45	570
6000	253	36.1	206	18.6	4.9	0.9	4.9	422.5	0.0	422.5	1004	-45	959

Storm Motion: 283/27 kt, using the Traditional method with parameters:
0-6 km layer, 30 degree offset & 75% steering speed.

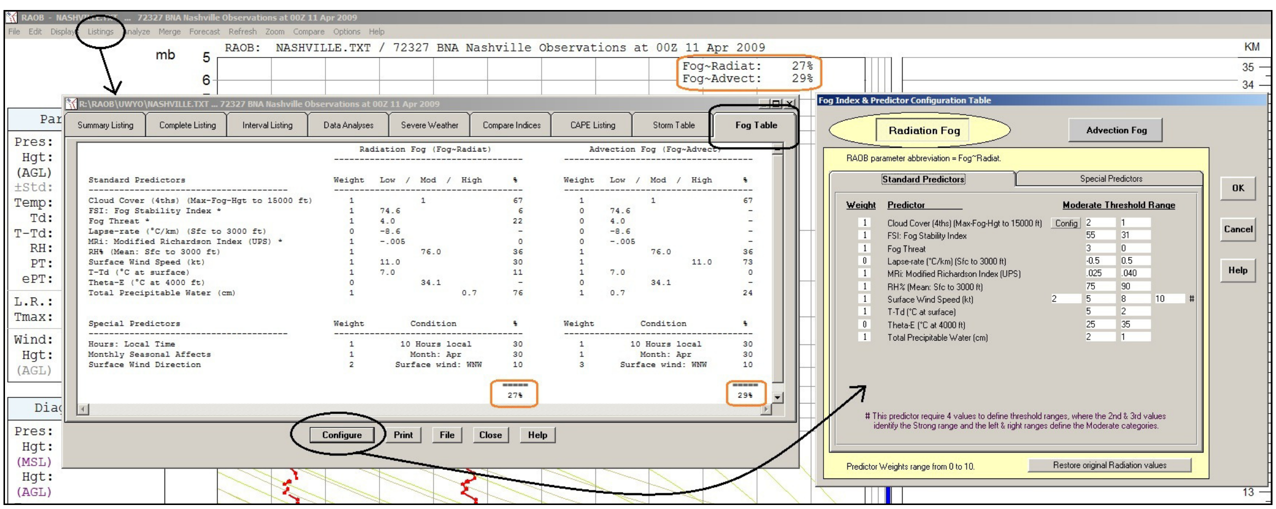
Parcel Lift Method: SURFACE DATA -- Using the Dry Bulb temperature profile.

Fog Table. This tab lists the separate configuration parameters for both the Radiation and Advection fog types. The percentage probabilities for both types are listed at the bottom of the table.



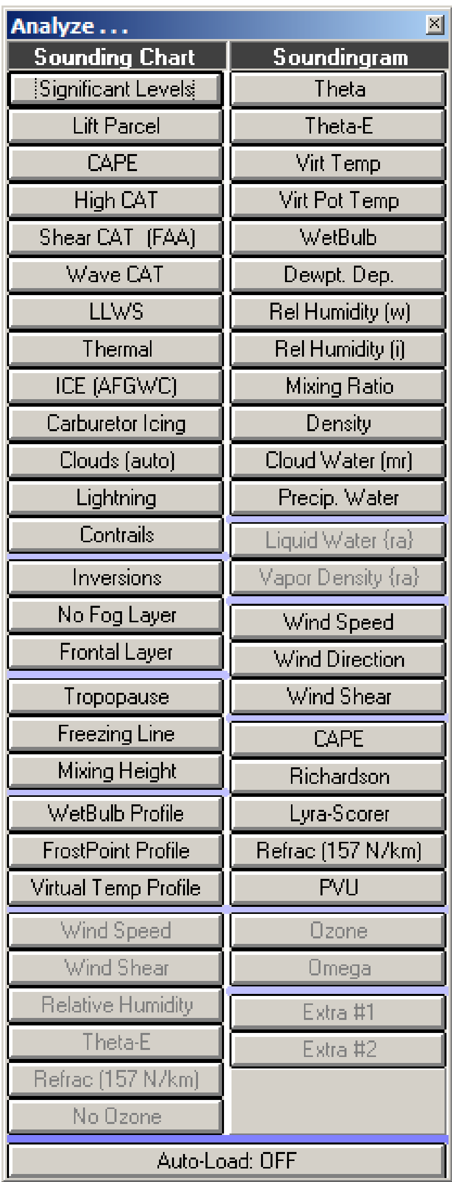
Fog Table (continued)…

The below image shows how the “Configure” button will activate the “Fog Table” configuration panels.



4.5 **Analyze**. This menu option displays a floating toolbar from which several analysis options can be toggled on/off. This toolbar can also be activated by pressing the right mouse button over the area to the left of the sounding diagram. See the chapter on SOUNDING ANALYSES for detailed explanations how the parameters are calculated and their typical usage. Use of a widescreen monitor is recommended.

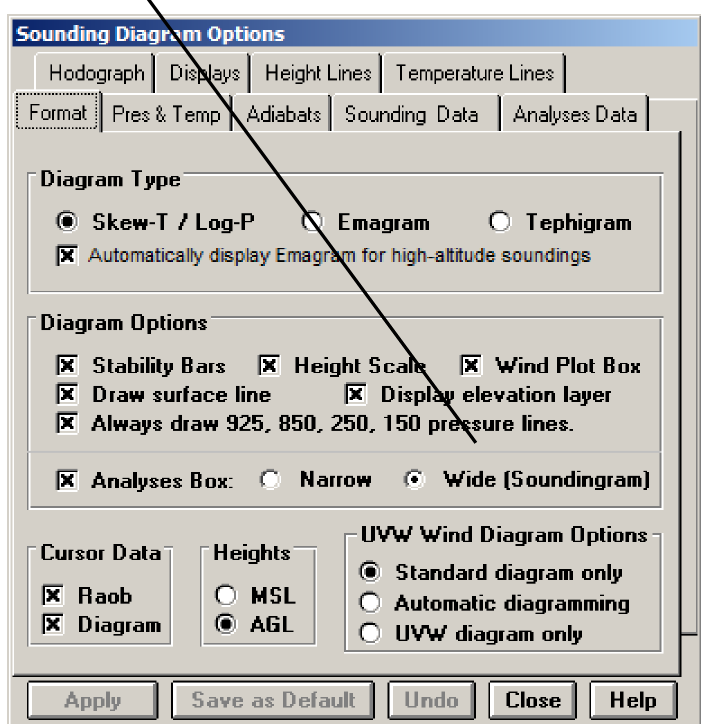
The Analyze toolbar shown below will normally be the first method used to analyze the plotted sounding. Each tool option presents graphical (and in some cases text) displays overlaid on top of the plotted sounding. Each analysis display item can be removed (toggled on/off) by clicking the tool button. Most of the toolbar's selections have configurable options which can be accessed by right-clicking on the button.



The LEFT toolbar column "Sounding Chart" buttons only apply to the standard sounding (skew-t) diagram. The RIGHT toolbar column "Soundingram" buttons only apply if the "Wide" Analyses Box option is selected as shown below in the Sounding Diagram Options menu.

The "Wide" Analyses Box option can only be selected if the computer display screen is capable of widescreen graphics.

If the "Narrow" Analyses Box option is selected, then the last 6 buttons on the LEFT column (which are grayed out) will then become active.



The "Auto-Load Analyses" button (when activated) will direct the RAOB program to automatically display currently selected analyses upon future reactivation of the RAOB program. When this button is selected, the button's caption changes to "Remove Auto-Load", which then permits de-selection of this option.

Analyze Toolbar – Left Column ...

The sounding toolbar show below is the standard LEFT column (as seen on the previous page), which applies to any plotted sounding diagram (skewt, emagram, or tephigram).

* The first 3 options (Significant Levels, Lift Parcel, and CAPE) display a combination of graphic & text overlays. The Lift & CAPE options display parcel trace lifting sequences and potential energy (color-coded red & blue) shading between the parcel trace and the sounding profile. If the sounding has no CAPE, then the third button's caption changes to "NO CAPE".

The next 10 options (High CAT, Shear CAT, Wave CAT, LLWS, Thermal, ICE, Carburetor Icing, Clouds, Lightning & Contrails) graphically overlay designated analyses along the left side of the diagram. Intensity, magnitude, or coverage of each data item increases from left to right and graphically represent visual depictions of numerical source data which can be viewed using RAOB's Listings Menu option, which presents data in a convenient tabular format.

Note: The Wave CAT button is only available with the optional Turbulence & Mountain-Wave Module. Output is similar to the CAT displays.

Below the Contrails option are the Inversions, Fog Layer, and Frontal Layer buttons. The Inversions button will display inversions using a combination of graphics (blue-shaded depth) & text overlays (specifying the inversion-type). Fog layers will be displayed as Wet, Freezing, or Ice fog types. The Frontal Layer button displays the predominant Warm or Cold front layer as determined by the hodograph's thermal wind vectors.

Note: The Frontal Layer button is only available with the optional Fronts & Forecast Module. Output is similar to the "Inversions" layers.

The next 3 options (Tropopause, Freezing Line, and Mixing Height) display colored horizontal lines (respectively: purple, blue, orange) at the appropriate diagram height. Only the Freezing Line and Mixing Height options have configurable options, which can be displayed by right-clicking the toolbar button.

The next 3 options (WetBulb, FrostPoint, and Virtual Temp Profiles) display color-coded vertical profiles of the sounding's selected item. Like all other options, they can also be toggled on/off.

The last 6 options (Wind Speed, Wind Shear, Relative Humidity, E-Theta {equivalent potential temp}, Refractivity {& ducting}), & Ozone graphically overlay (in either a line and/or bar format) data to the right of the Stability Bars. These data items are displayed in the diagram's Analyses Box, near the plotted winds.

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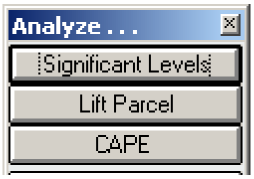
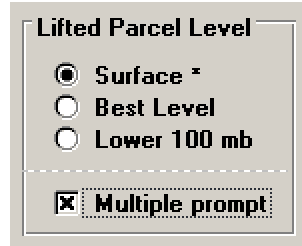
* The following buttons are only available with the optional Analytical Module: CAPE, High-CAT, CAT, LLWS, Thermal, ICE, Carburetor Icing, Clouds, Lightning, Contrails, Fog Layers, Profiles, Wind Speed/Shear, Relative-Humidity, E-Theta, and Refractivity.

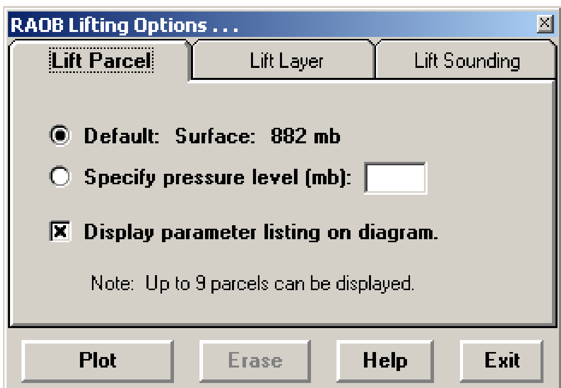
Analyze Lift Options (only available with the Optional Interactive Module).



When the "Lift Parcel" analyze button (left) is selected and the Parcel Lift Configuration option for "Multiple prompt" (right) is selected, then three types of lifting options become available … parcel lifting, layer lifting, and sounding lifting.

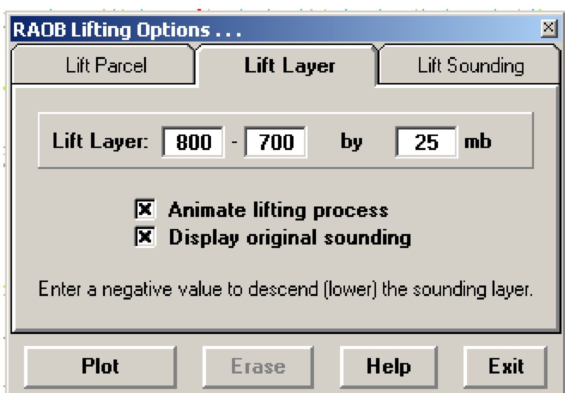


Press F9 *(then Tab 3)*



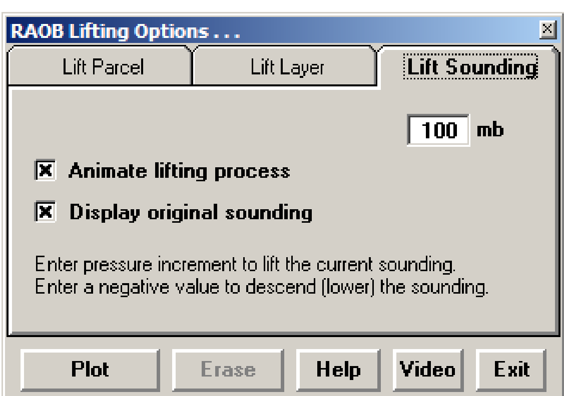
This special "Lifting Options" panel, *which is only available with the optional Interactive Module*, is activated after pressing the **Lift Parcel** toolbar button shown above. This display prompts the user to select the sounding's surface pressure level or input a specific pressure level for parcel lifting calculations and associated graphic displays.

Selection of the "Display parameter…" option produces a printed listing of each lifting sequence at the top of the sounding diagram.



This special Lifting Options panel, *which is only available with the optional Interactive Module*, is activated after pressing the **Lift Parcel** toolbar button shown above. This display prompts the user to select or input the number of millibars (hPa) to adjust (up or down) a specified layer of the sounding. (Winds are also height adjusted.)

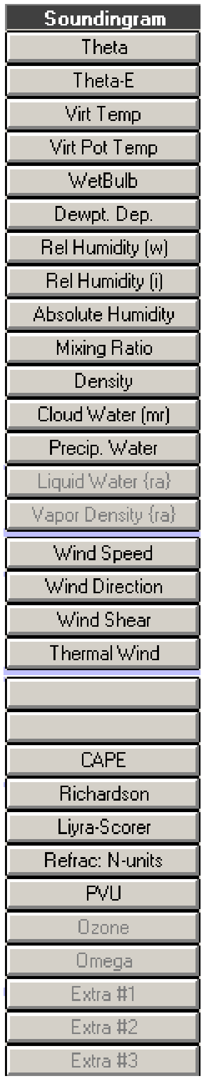
Temperatures are lifted dry-adiabatically and dewpoints are lifted along their mixing-ratio lines until saturated, after-which temperatures and dewpoints are lifted moist-adiabatically. This method is also used for the "Lift Sounding" option discussed next.



This special Lifting Options panel, *which is only available with the optional Interactive Module*, is activated after pressing the **Lift Parcel** toolbar button shown above. This display prompts the user to select or input the number of millibars (hPa) to adjust (up or down) the entire sounding. (Winds are also height adjusted.)

This option is great for simulating sounding passage up and down mountainous terrain.

Analyze Toolbar – Right Column . . .



The sounding toolbar show at left is the optional RIGHT column (of the two-column toolbar shown a prior page), which applies graphic analyses when the wide-screen display option is used. In the wide-screen display mode, the Analyses Box is expanded into a soundingram-style graph box that is located between the sounding profile and the wind plot – as shown below. Unlike the Left Column analyses button options, where multiple analyses can be overlaid, these analyses can only be displayed one at a time. If multiple analyses need to be plotted on this type of diagram, then the optional Soundingram module must be used.

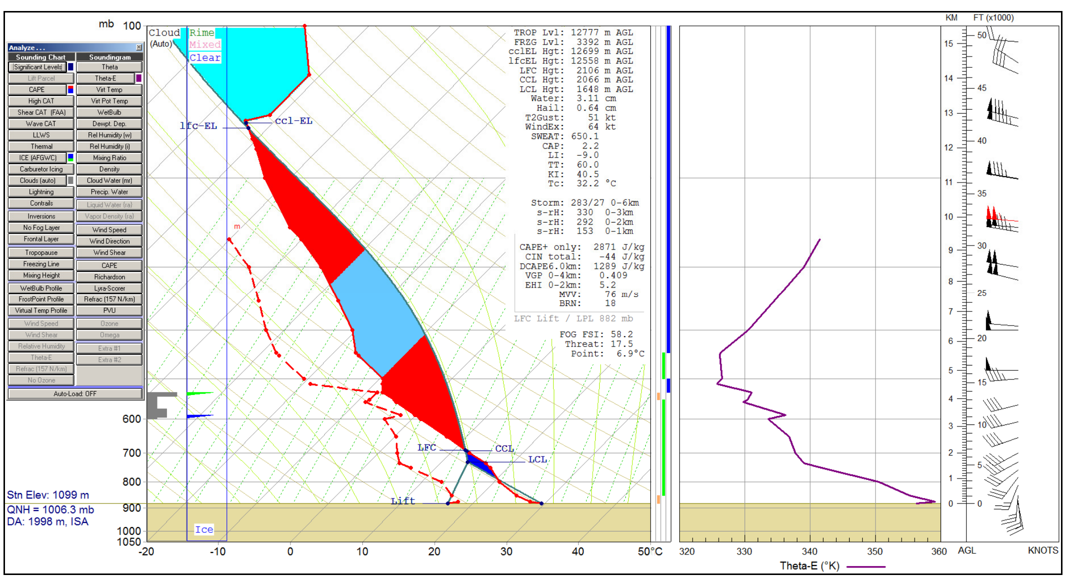
All analyses buttons can be configured. Configuration options are displayed by right-clicking on the button of interest.

The seven buttons labeled Liquid Water, Vapor Density, Ozone, Omega, and Extra #1 & #2 & #3 are grayed out because those data types are not available with the example sounding image below.

Note: The Extra #1 & #2 & #3 buttons will display/analyze data items that are decoded from Aerosol data, or which are made available when using RAOB's CSV Data Format, which is explained near the end of this manual.

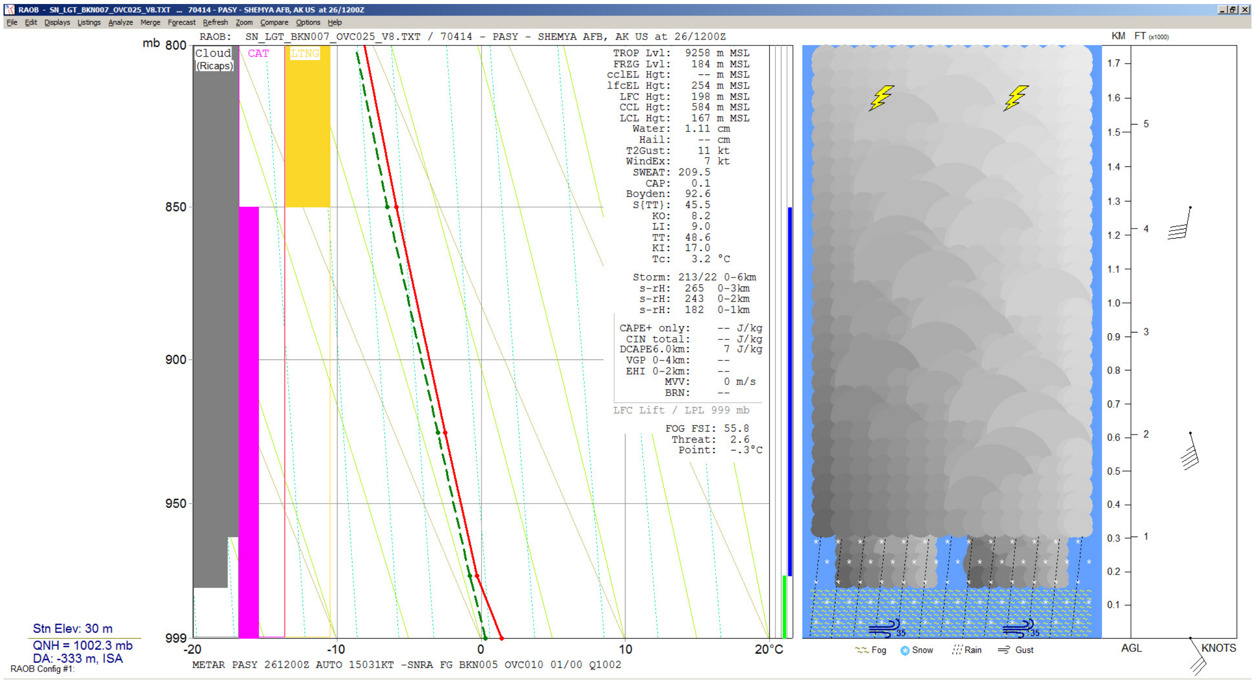
===

The example wide-screen display shown below was made possible by selecting the Analyses Box: "Wide (Soundingram)" option from the Diagram Options menu. The "Theta-E" analysis plot was created by selecting the "Theta-E" analysis button from the Right-Column of the Analyses Toolbar.



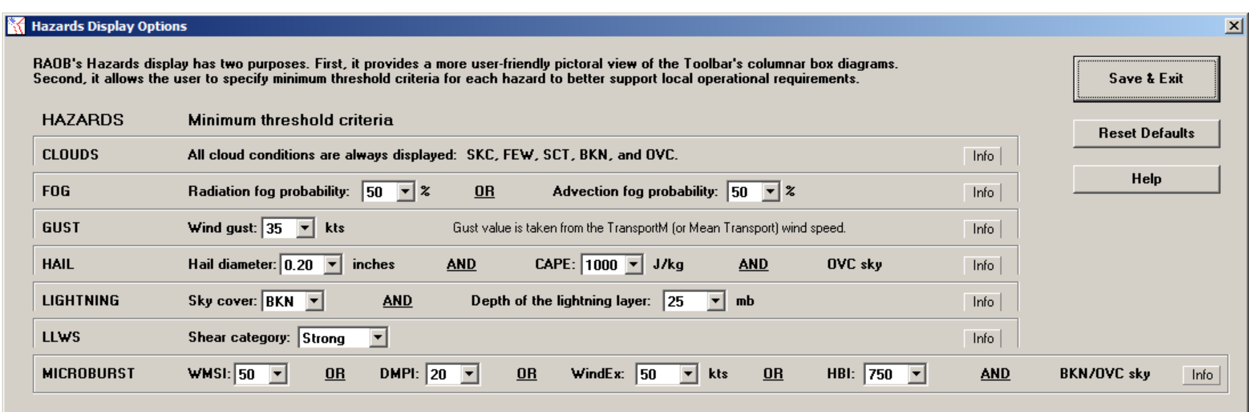
Analyze Toolbar – Hazards Display . . .

When the analyses of the Toolbar's "right column" is refreshed (or erased), the Hazards Display is then displayed by default -- until the next right column Toolbar button is activated. RAOB displays the Hazards within the Soundingram section, which is just to the right of the sounding diagram. It contains a blue sky background, with clouds and other significant hazards. See the below example. The Hazards Display is only functional when the RICAPS cloud generation option is selected in RAOB's Program Options.



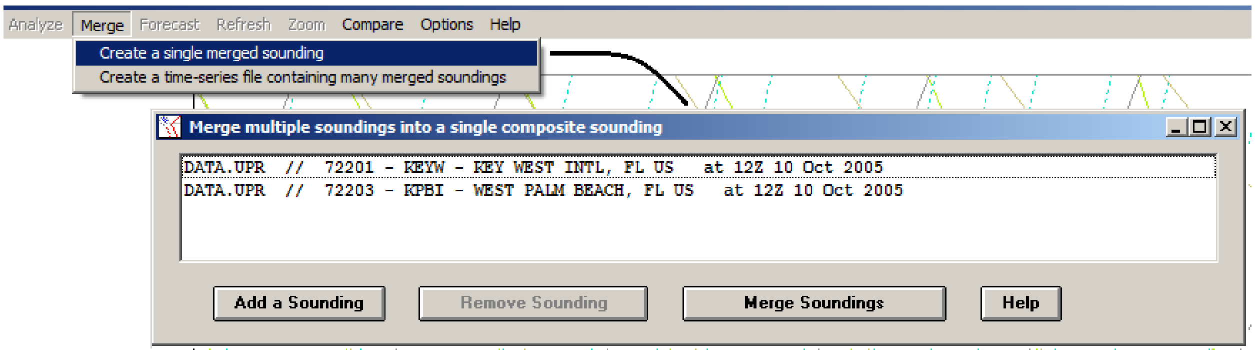
Note: The above Hazards display requires use of a wide-screen monitor.

By right-clicking the mouse while over the Hazards Display, a Hazards configuration options panel is displayed, as seen below. These options let the user individually configure each hazard to local conditions.



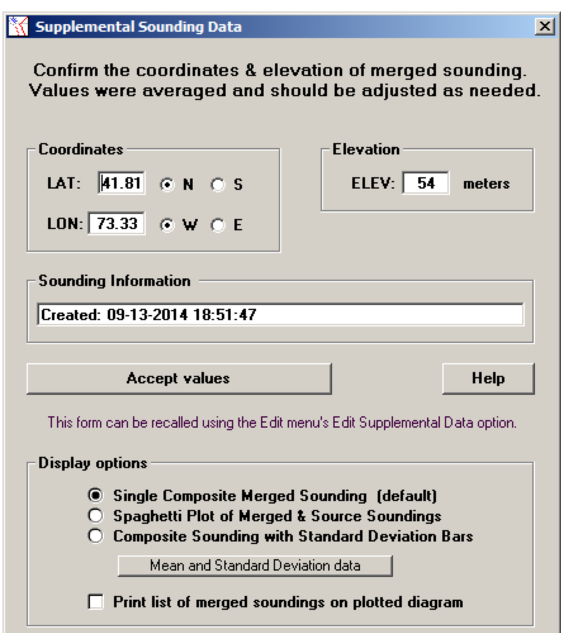
4.6 **Merge**: **the Standard Merge Module**.

The Merge menu presents the user with two options: (1) Create a single merge sounding, and (2) Create a time-series file containing many merged soundings. The first option is available with the optional Standard and Advanced Merge modules (as explained below), while the second option is only available with the Advanced Merge module (as explained on the next page).



Selection of the 1st MERGE menu option opens the above data selection display. Use the **Add a Sounding** button to list up to 6,000 soundings. The operation of this display is identical to that used to create vertical cross-section datasets (explained later this manual).

Use the **Merge Soundings** button to begin the merge process. RAOB automatically determines the new station elevation and latitude & longitude coordinates, and then adds this information to the new data file. All significant temperature data are maintained in the merged sounding. Additionally, standard significant pressure levels (i.e., 1000, 850, etc.) are added to the merged sounding, if missing. All significant wind data are also maintained in the merged sounding. However, if the sounding has less than 4 winds, then RAOB automatically interpolates wind data at 2,000 foot intervals, MSL. The resulting merged sounding data will always be saved using RAOB's indigenous RAW format.



Once data merging is complete, the resulting merged sounding is displayed and the **Supplemental Sounding Data** panel (at left) is presented. Sounding coordinates, elevation, and sounding description can be edited as needed.

From the **Display Options** section, you can also view a "spaghetti" plot of all source soundings, or view "standard deviation" bars for reference.

The **Mean and Standard Deviation Data** button provides a text listing of S.D. data.

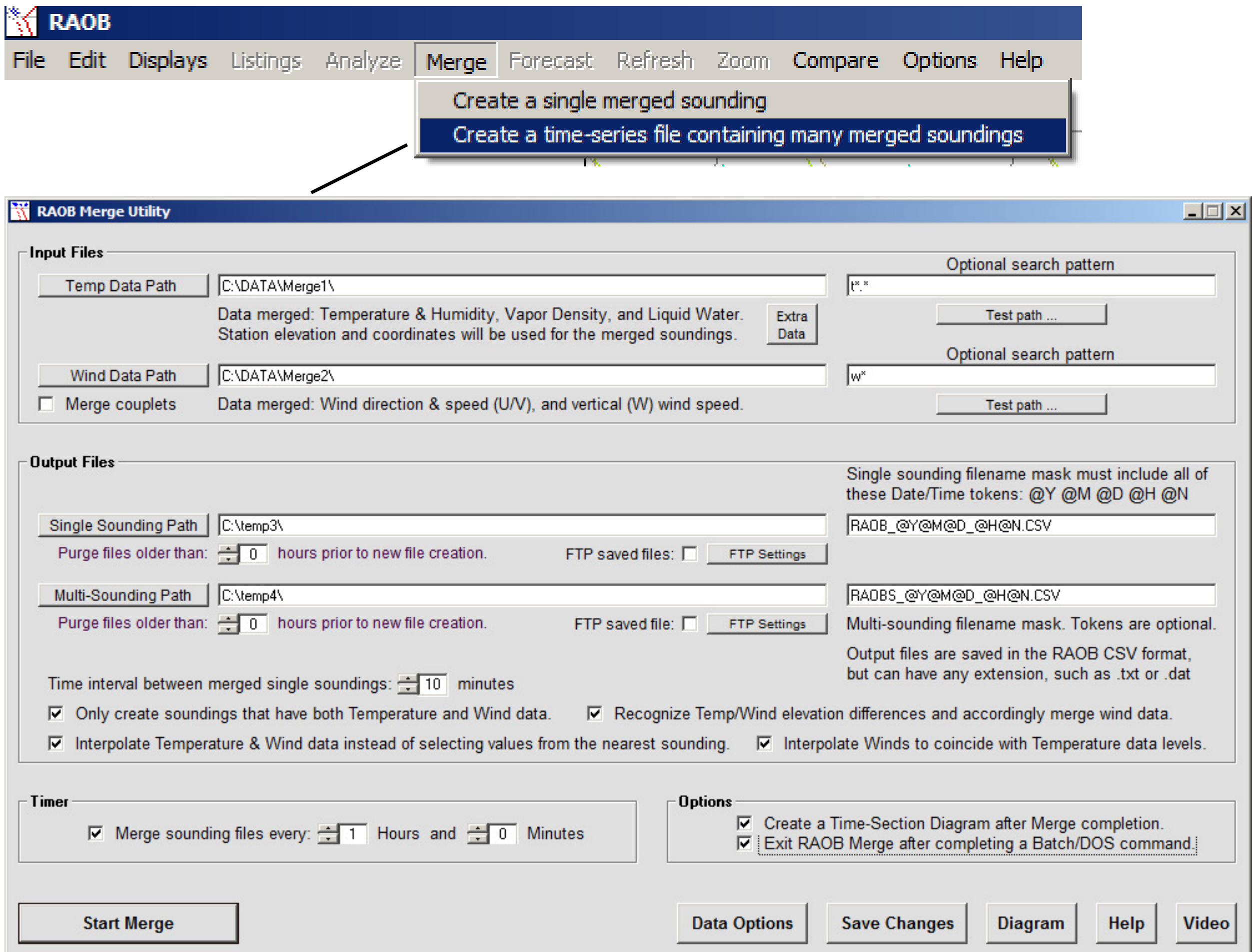
A checkbox near the bottom of the display permits a text listing of all soundings used to create the merged sounding.

Note that this Supplemental Sounding Data display can be recalled with any plotted sounding. It can be found under the sounding diagram's Edit menu.

Another feature of the Standard Merge module is included with the Batch & Timer functions, where RAOB automatically merges 2 soundings from 2 different paths to create a single composite sounding, where pressure & temperature data taken from one sounding, and height & wind data are taken from the other.

Merge (continued): **the Advanced Merge Module**.

Selection of the 2nd MERGE menu option opens the RAOB Merge Utility, which is only available with the optional Advanced Merge module.



This module will ingest two time-series multi-file soundings and merge them into one multi-sounding datafile. Temperature/pressure data will be taken from the first file, while Wind/height data will be taken from the second file. Except for binary data, the two input datafiles can be from any data format that the RAOB Program can process. For example, you can merge Temperature data from radiometer soundings and wind data from wind profiler soundings. All merged output files will be hydrostatically balanced.

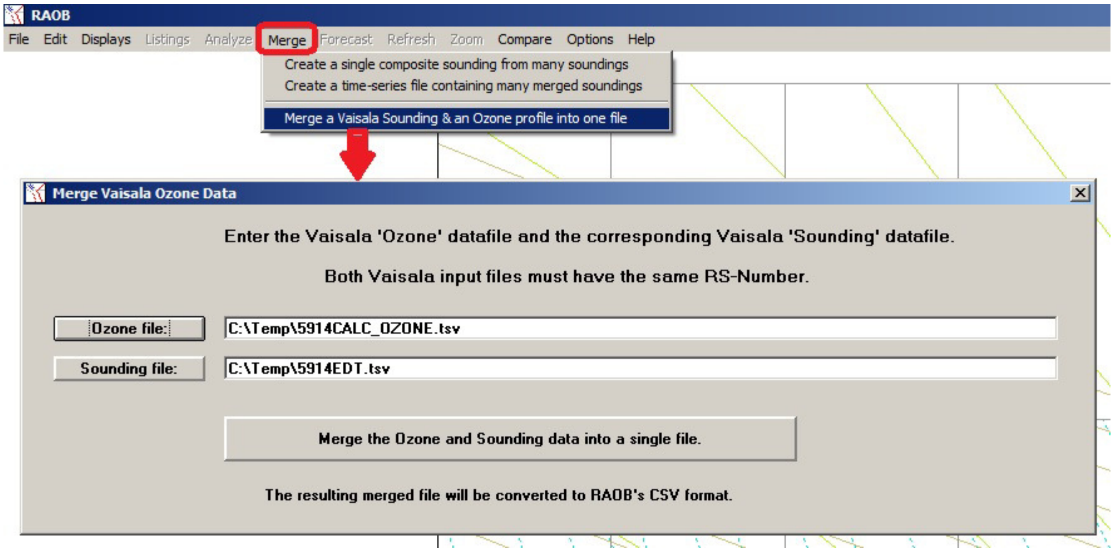
Special Notes: If the Temperature based sounding data contains Liquid-Water and Vapor-Density data, or if it contains RAOB's CSV "extra" data types, they will also be merged. If the Wind based sounding data contains vertical wind component (W) data, it will also be merged. The special **Merge couplets** option ignores the temperature data path and only merges wind couplets having Hi and Low data profiles.

This optional program module (RAOBMERGE.EXE) is unique because it runs independently of the RAOB program; however, it must be located in the same computer system folder as the RAOB.EXE program file.

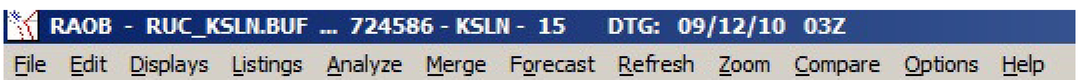
Once the merged sounding files are created, you can then use RAOB's Real-Time Data Processing module to automatically display and update time-section diagrams using the "Single Sounding" files. Time-section diagrams can be created with RAOB's Cross-Section module by using the appended "Multi-Sounding" data files.

Merge (continued): **the Advanced Merge Module**.

Below image shows menu option to merge Vaisala Ozone with corresponding Vaisala Sounding data.



4.7 **Refresh (and Restore)**.



^

The REFRESH menu item immediately clears all overlaid analyses information (graphics & text). The RESTORE menu item appears whenever the sounding profile is graphically modified.

4.8 **Zoom (and Stop-Zoom & Un-Zoom)**.

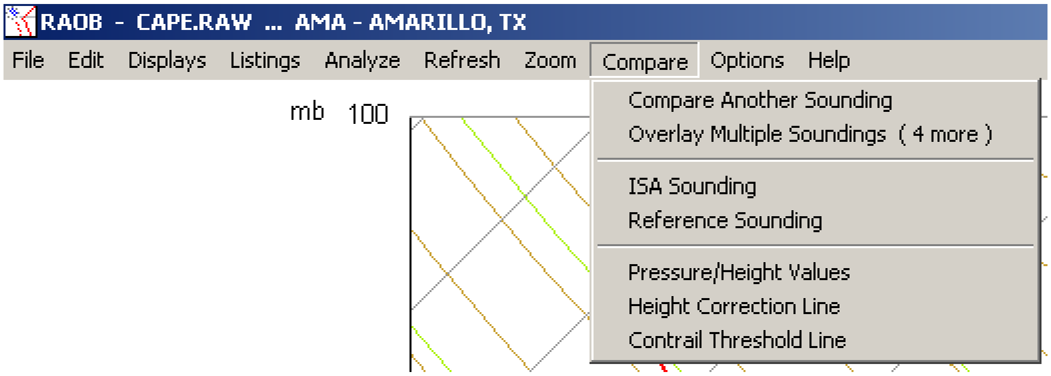
These two menu options are only available with RAOB's optional Interactive/Hodograph Module. The ZOOM menu option, when clicked, activates a new mouse cursor, which contains the word "zoom" next to a cross-hair image. Once Zoom is activated, the Zoom instructions box (seen above) is displayed.

Zoom-In – Left Click. Zoom-Out – Right Click.

At the same time, the "Zoom" Menu item changes, as the "Stop-Zoom" Menu item and the "Un-Zoom" Menu item are added to the menu bar. By clicking on the Stop-Zoom item, all prior menu items are restored for use, such as data listings and analyses options. By clicking on the Un-Zoom item, the sounding profile is immediately restored to its original diagram scaling settings. Also, all of RAOB's interactive capabilities and analyses overlay options remain functional during zoom activities.

Note: ZOOM does not work with the Tephigram diagram, because it's coordinate equations are complex.

4.9 **Compare**.



Compare Another Sounding*. Permits detailed analytical comparison of two soundings. Data analyses are displayed side-by-side along with wind data plots and hodograph plot (if configured). The first sounding is plotted in red and the second sounding is plotted in blue. If the hodograph display option is active, it will always be drawn in the upper-right corner of the sounding diagram.

Overlay Multiple Soundings*. Permits overlays of up to 4 other soundings including plotted wind data. Each sounding and associated wind data are drawn in different colors. Note that data analyses are not available for this display (since there isn't enough room on the screen). The hodograph is also not available for this display, since there would be too much clutter. This and the above "Compare Another" option has a LIFT option for additional comparison purposes.

ISA Sounding. Plots the International Standard Atmosphere (ISA) reference line. The International Standard Atmosphere (ISA) Sounding is a hypothetical vertical distribution of atmospheric temperature (and other properties) which, by international agreement (ICAO & WMO), is taken to be representative of the atmosphere. The air is assumed to obey the perfect gas law and the hydrostatic equation. The ISA line can be configured to always appear on all sounding diagrams through use of the Diagram Configuration options, which is accessible from the Options Menu Bar.

Reference Sounding. Plots the "reference sounding" as identified by the user. This sounding, which can be any single sounding data file, must be saved using the REFERENCE.DAT name. This is useful for comparing sounding profiles against a local, user-defined standard.

Pressure/Height Values*. Displays height data along the left inside margin of the diagram over the primary pressure grid lines. These values directly align with the values of the height scale plotted to the right of the diagram. Note that all height scales are hydrostatically coupled to pressure level data, thereby ensuring exact pressure-height readings. Each sounding, therefore, will have its own unique height scale.

Height Correction Line*. This line displays a graphical representation of height corrections associated with the plotted sounding. This line, used by some aviation interests, plots the pressure height values (ft/1000) with respect to the °C temperature scale.

Contrail Threshold Line*. This line identifies the threshold area for contrail formation. If the sounding profile line falls left (or colder) than the threshold line, then there exists favorable potential for contrail formation. This line can be used in conjunction with the ANALYSES' Contrail option to better visualize contrail potential.

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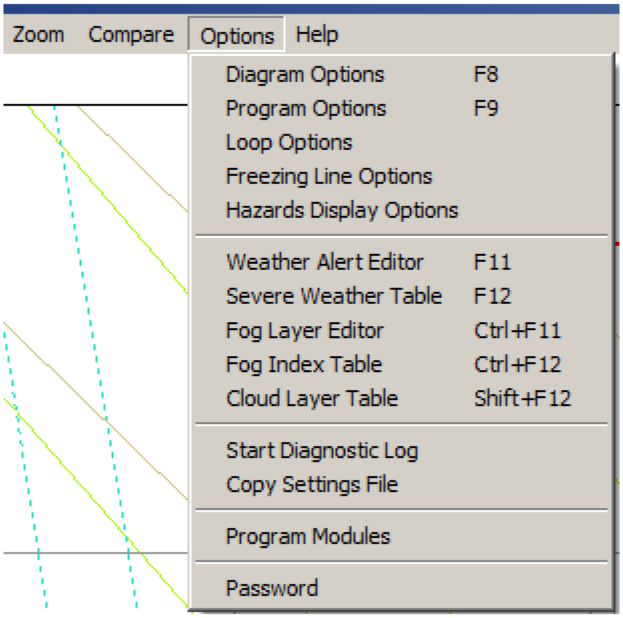
* These comparison tools are only available with the optional Analytic Module.

4.10 **Options**.



Details of each of the following options menus (except the Loop Options) can be found in the following sections of this user manual. Loop options are presented at the bottom of this page.

Diagram Options. Offers grid, unit, scaling, format, data, reference lines, and graphical display options. These options can also be displayed by clicking the 'right' mouse button when over the sounding diagram.

Program Options. Offers various system-wide options regarding screen displays, algorithm options, parcel lifting, energy calculation options, and many other configuration settings for various applications.

Loop Options.* Looping is only available with datafiles that contain multiple soundings (see below).
Freezing & Hazards Options. Offer several user controls for plotting and display purposes.
Weather Alert Editor. Allows the user to select specific alerts, which are displayed in a pop-up window.
Severe Weather Table. Allows customization of the weighting factors and threshold values of key indices.
Fog Layer Editor & Index Table. Permit configuration options for Radiation & Advection fog types.
Cloud Layer Table. Offers manual or automatic cloud layer generation and precipitation modes.
Start Diagnostic Log. This option is only used during ERS-directed problem solving coordination.
Copy Settings File. Used for special ERS-directed program diagnostic purposes.
Program Modules. Used to activate newly purchased optional program modules.
Password. Allows the user to assign a startup password to the RAOB program.

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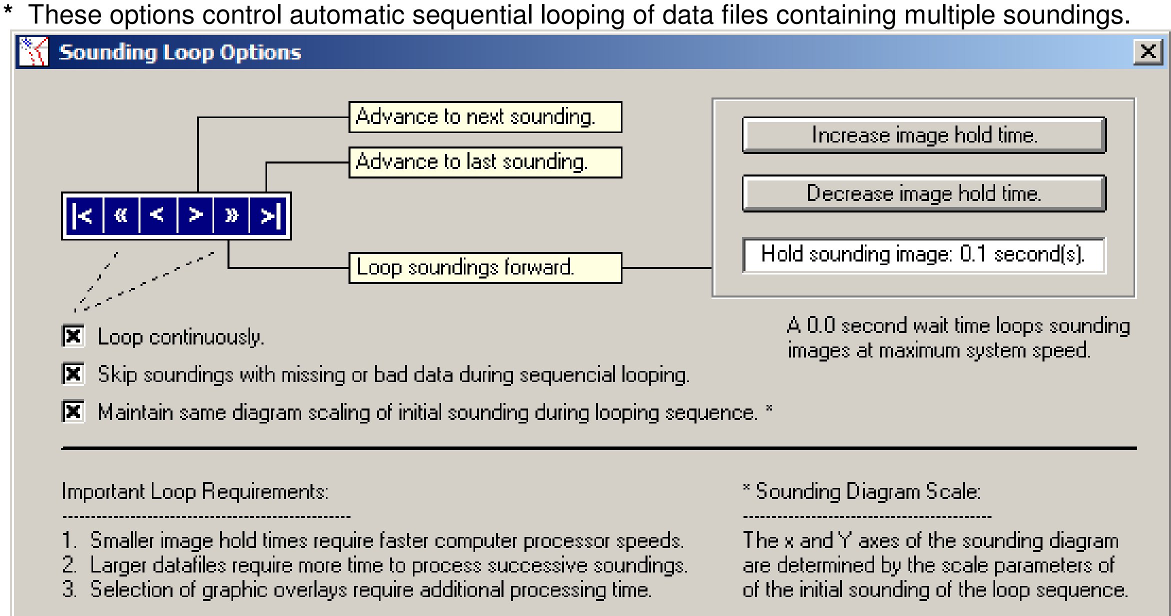
* These options control automatic sequential looping of data files containing multiple soundings.



5. **DIAGRAM CONFIGURATION**.

5.1 **TAB 1 – Format**.

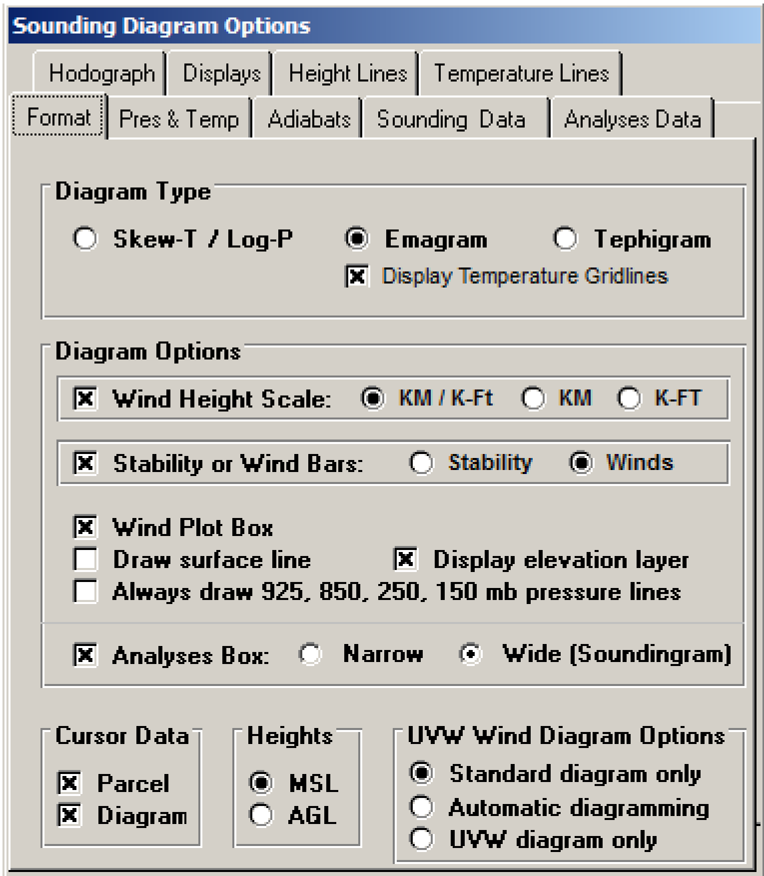
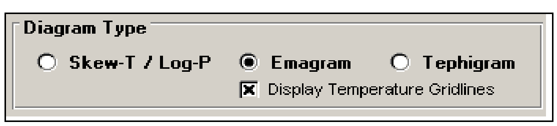


Diagram Type.

Skew-T (Log-P). Commonly used worldwide. Best for soundings 100 mb and below. Co-option exists which automatically produces an Emagram diagram for soundings that extend above 100 mb.

The Emagram and Tephigram diagrams are discussed below.

Emagram (or adiabat chart). Best for soundings that extent above 100 mb and best for viewing inversions at all levels. A co-option exists for temperature grid displays. (This diagram is similar to the Stuve chart.)



Tephigram. Although similar to the Skew-T chart and commonly used in the UK, Canada and some other countries, it is the only sounding diagram which has thermodynamically proportional areas. In other words, any area on the diagram is completely proportional to energy – this is especially useful for viewing CAPE-shaded areas. However, due to the complexity of this diagram's construction algorithms, RAOB's diagram scaling options are very limited. When graphic analyses are applied to a Tephigram plot, the "Display warning message …" option warns that the displayed analyses of certain parameters (such as CAT, icing, etc.) are only vertically proportional (true) to the pressure scale of the Skew-T and Emagram diagrams. This is because the Tephigram's pressure grid is composed of curved versus straight lines.

Diagram Options. (Tab 1 Continued)

Stability Bars or Wind Bar. Stability Bars are drawn as thin colored vertical bars drawn between the plotted winds and the temperature profile. They are color-coded indicators of lapse rate classification of the plotted sounding segments. From left to right, the Stability Bar color codes are:

Color	Lapse-Rate (LR) of the Sounding
Red	Auto-convective: LR > 34.1 °C / km
Yellow	Unstable (super-adiabatic): LR > dry-adiabatic
Green	Conditionally unstable: dry-adiabatic $\geq$ LR $\geq$ saturation
Blue	Stable: LR < saturation-adiabat

The Wind Bar option produces a single vertical representation of wind-speed as a colored gradient, which is user-configurable to better emphasize specific wind speed ranges and layers.

Height Scale. This height scale is drawn immediately to the left of the plotted winds. As with all RAOB program height scales, each scale is hydrostatically coupled to the sounding's pressure levels.

Wind Plot Box. This is the area immediately to the right of the Height Scale, where the sounding's winds are plotted. This box must be selected if the sounding's winds are to be plotted and displayed.

Draw Surface Line. This line extends beyond the left wall of the sounding diagram, where station elevation, surface altimeter setting (QNH), and density altitude (DA) information are displayed.

Display elevation layer. When this option is checked, a tan-colored layer is displayed which represents the surface elevation (or ground layer above sea level) of the sounding station.

Always draw 925, 850, 250, 150 pressure lines. This option produces reference lines for all standard TTAA pressure levels, including 925, 850, 250, and 150 millibars (hPa).

Analyses Box*. The following Analyses options are graphically overlaid in the area to the right of the Stability Bars. Each item can be displayed (toggled on/off) using the ANALYSES' Tool Bar.

Wind Speed. Line graph of relative wind speeds.
Wind Shear. Line graph of relative wind shear values.
Relative Humidity. Line graph of relative "relative-humidity" (RH) values.
E-Theta. Line graph of relative equivalent potential temperatures.
Refrac. Line graph of Refractivity N-units. "Trapping" layer is highlighted in Red.
Ozone. Line graph of Ozone data when present with sounding data.

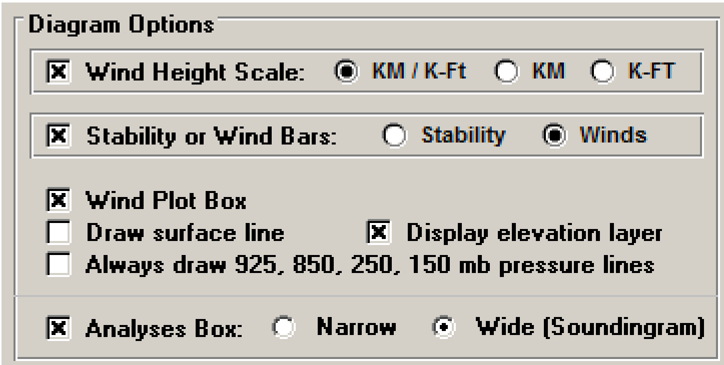
** The above 6 Analyses Box options are available with the "Narrow" display option. See the next page for a discussion of display features available when using the "Wide" display option.*

Cursor Data.
Parcel. Provides continuous display of *sounding data* values. Located at upper-left of screen.
Diagram. Provides continuous display of *diagram grid* values. Located at mid-left of screen.

Height Mode.
Select either MSL (mean sea level) or AGL (above ground level) for the height scales and other related parameters.

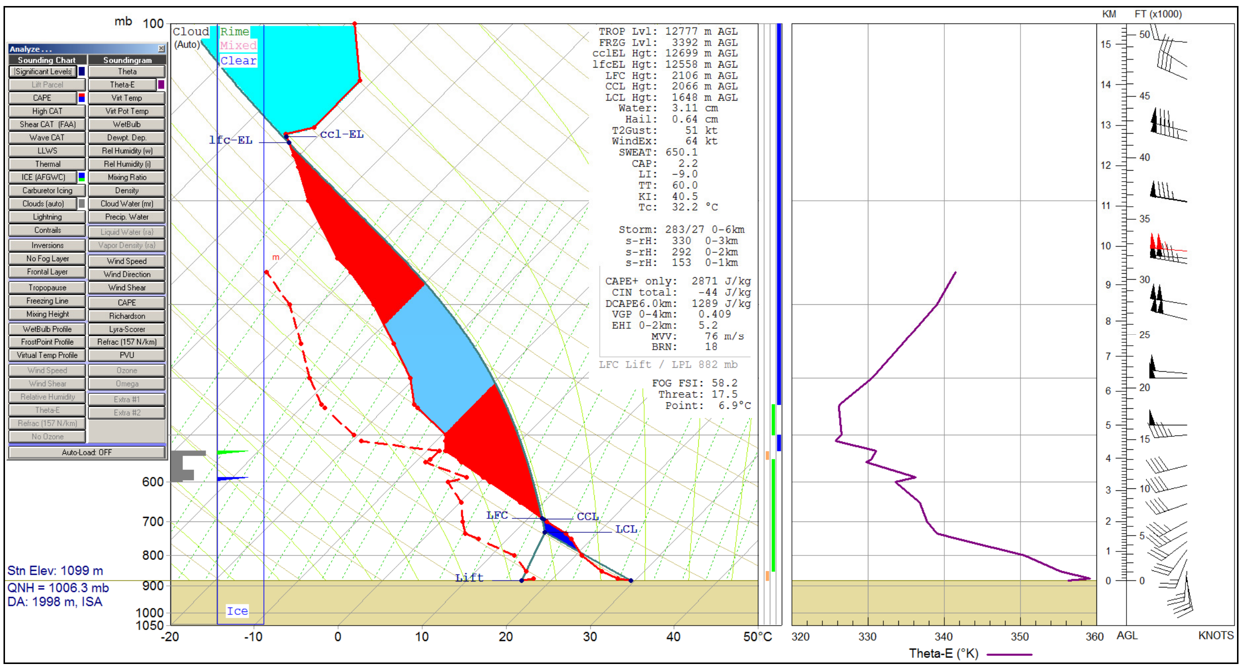
UVW Wind Diagram Options. These options determine if the standard sounding diagrams (skewt, emagram, or tephigram) will be displayed or the unique UVW wind diagram will be displayed. Further discussion and examples are presented on the page after next.

<u>Analyses Box (Wide Display) option</u>…



Using the Analyses Box "Wide" option as shown at left, the below example sounding diagram will be plotted – if using a wide-screen monitor. The analyses box is essentially expanded into a soundingram-type format.

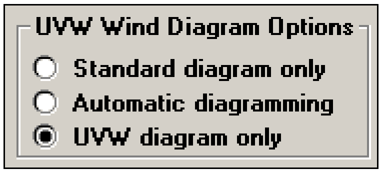
The below sounding diagram image uses the "Wide" Analyses Box display, which expands the Analyses Box between the Stability Bars and the Wind Plot Box. This feature requires a widescreen monitor.



When using the "Wide" Analyses Box display, a double panel Toolbar becomes available. The left column of the Toolbar is always present, but the right column (labeled Soundingram) applies to the expanded Analyses Box. This Soundingram-style display allows better visualization of supplemental sounding data, such as Theta and Virtual temperatures. Each Toolbar button will present data configuration options by right-clicking on the button of interest.

Note that the special parameters (Liquid Water, Vapor Density, Ozone, Omega, and Extra #1 & #2 & #3) are only available if present with the source sounding datafile.

<u>UVW Wind Diagram Options</u>…

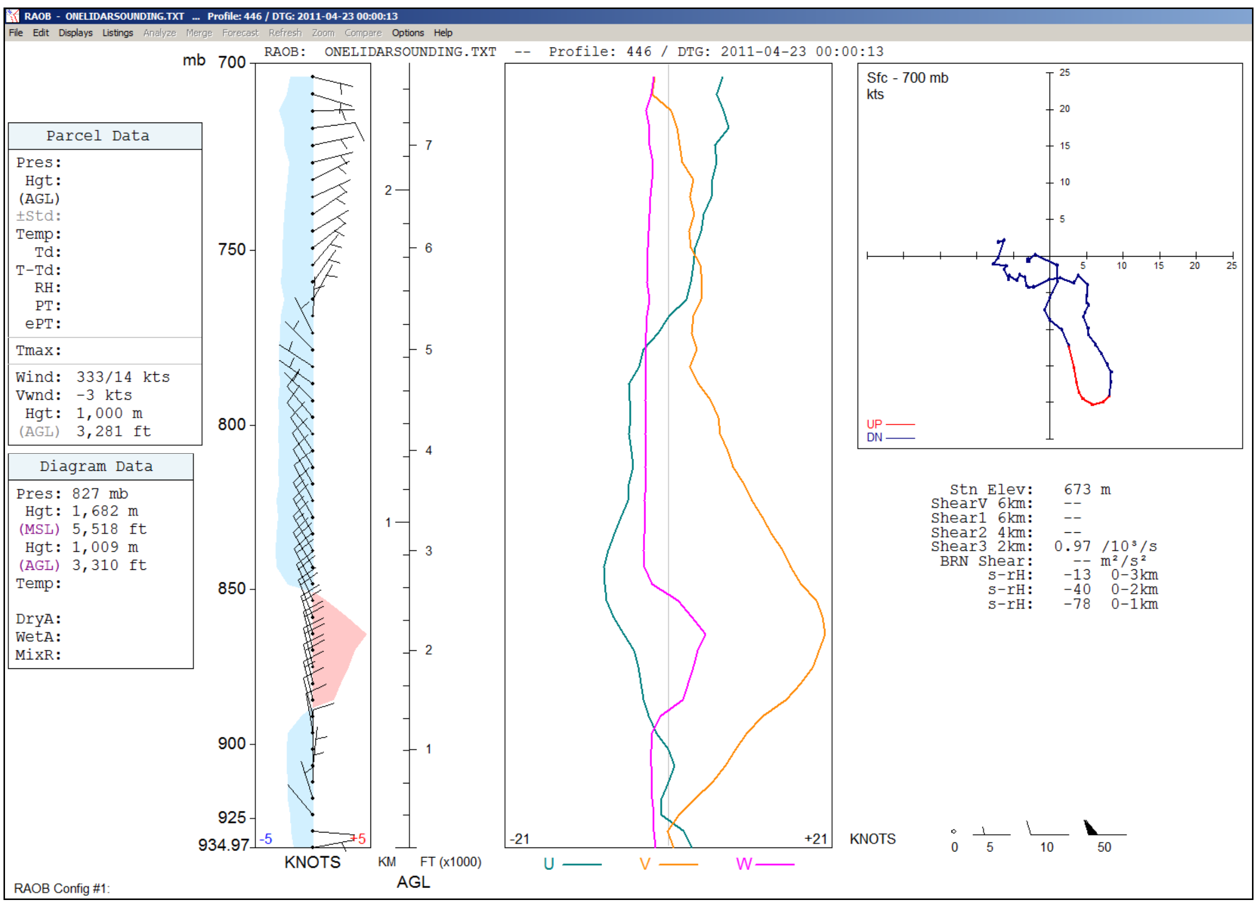


The UVW diagram was specifically created to graphically display 3-dimentional wind data: commonly referred to as U-V-W, wind components – where the W component represents the vertical wind.

Standard diagram only. This option always displays standard sounding diagrams: including skewt, emagram, and tephigram diagrams.

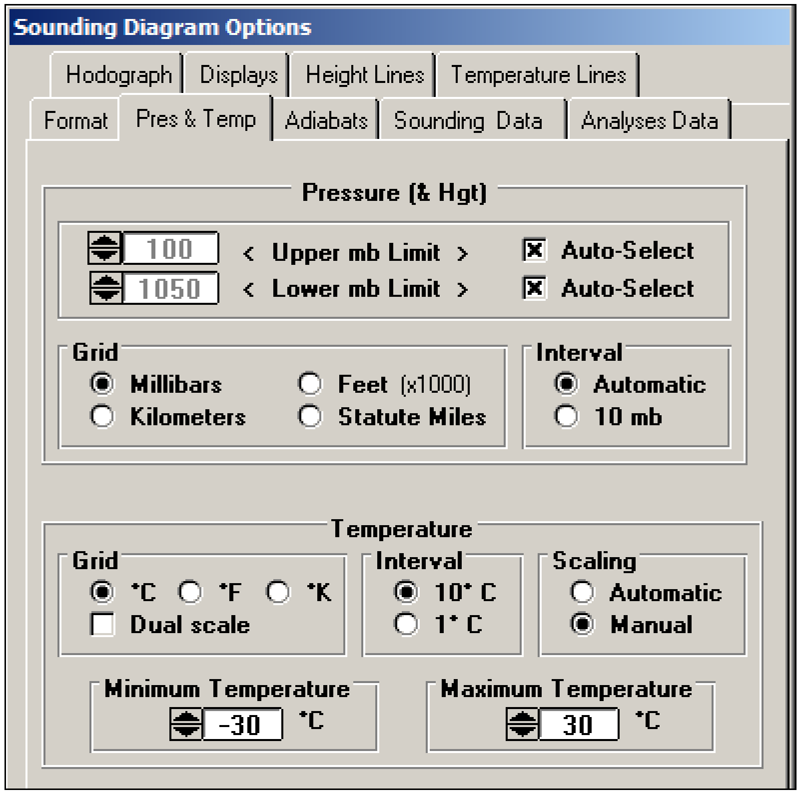
Automatic diagramming. This option will display standard diagrams if temperature data are present, but the UVW diagram will be displayed if only wind data are present.

UVW diagram only. This option always displays the UVW diagram, even if temperature data are present. An example of the UVW diagram is shown below.



The above UVW diagram consists of 3 sections. Section 1 (left most diagram) consists of the common sounding wind plot (UV data) with colored shading of the vertical (W) component, with blue shading for downward motion and red shading for upward motion. Section 2 (middle diagram) consists of a soundingram type display of the UVW wind components for simultaneous comparison purposes. Section 3 (right most diagram) is the common hodograph, but with colored vectors representing upward and download motion by the red and blue colors, respectively.

5.2 **TAB 2 – Pressure & Temperature**.



Pressure (& Hgt).

Upper Millibar Limit. Use the up/down arrow keys to select the highest mb level (0.001 to 1000 mb) to be displayed on the sounding diagram. Note: the Tephigram is preset to 100 mb.
Lower Millibar Limit. Selects the lowest mb level for the sounding diagram, but not for the Tephigram. This lower limit setting can not be saved as a configuration item.

Auto-Select. Use these options to have RAOB automatically determine the diagram's upper / lower limits.

Grid. Select Millibars, Kilometers, Feet, or Statue Miles for the vertical scale. For the Millibars option, mb or hPa units can be selected as the system-wide default via Program Options configuration. Note: The Tephigram diagram grid is preset to Millibar units.

Interval. Select either automatic or predetermined intervals depending on selected Grid.

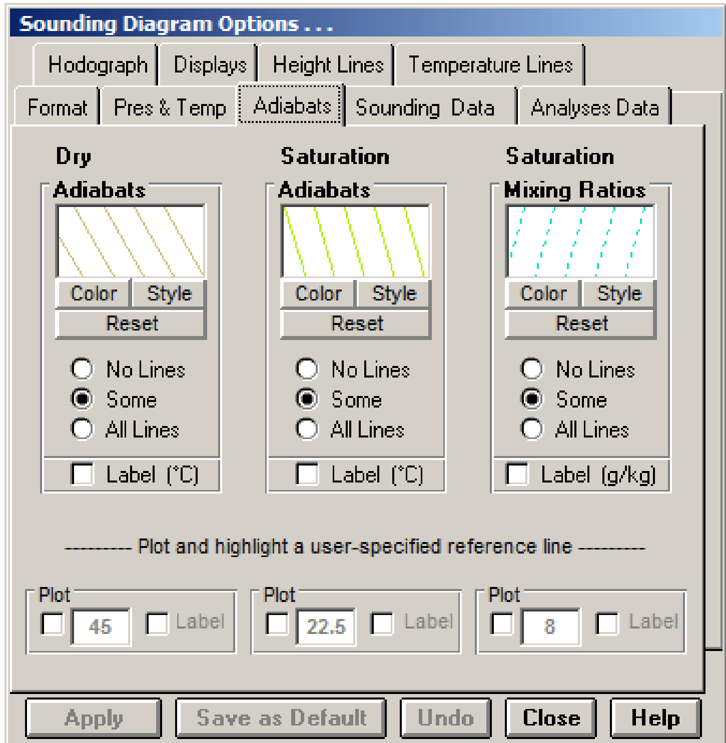
Temperature.

Grid. Select either °C (Celsius) or °K (Kelvin) or °F (Fahrenheit).
Selection of the "Dual scale" option displays both (°C and °F) temperature scales.

Interval. Select either 10° or 1° temperature intervals.

Scaling. Select either Automatic or Manual temperature scaling of the sounding diagram's temperature scale. If Manual is selected, the user must select the Minimum and Maximum temperatures used to scale the diagram. Note: the Tephigram has preset pressure and temperature scaling.

5.3 **TAB 3 – Adiabats.**



Standard Reference Lines.

The following three reference lines are typically found on thermodynamic diagrams.

Dry Adiabats. Lines of constant potential temperature, used to lift a parcel dry-adiabatically. These lines are often used to identify the maximum surface convective temperature and many other significant parameters which uniquely define each sounding.

Saturation Adiabats. Lines of constant wet-bulb potential temperature, used to lift a parcel moist-adiabatically. These lines are often used to define CAPE areas and other energy parameters.

Saturation Mixing Ratios. Lines of constant mixing ratio, used to graphically identify key thermodynamic parameters. These lines are often used to help define hail potential and many other moisture related parameters.

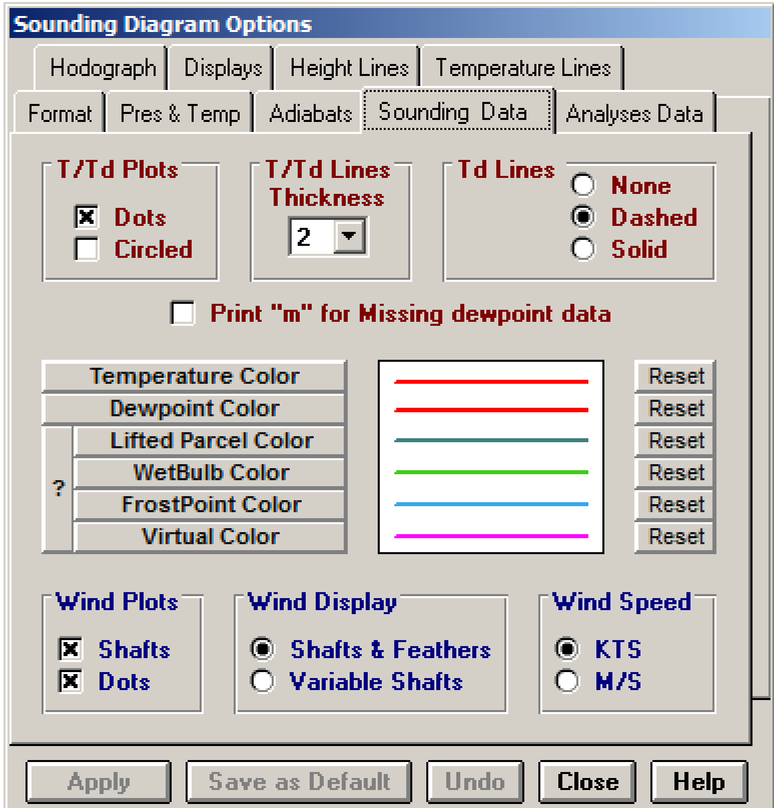
Line Options: Color, Style, or Reset. Select line colors/style or reset to default parameters.

None. No lines are drawn.
Some. Some lines are drawn.
All. All available lines are drawn.

Labels. Displays numeric values on the Lines selected for display.

Plot and highlight a user-specified reference line. For each of the above three reference lines, the user can specify any line value to be drawn on the sounding diagram. It will be drawn in the same color selected for that type of reference line, but this "specified" line will be drawn in a larger (thicker) format for easier visual identification. The user can also select whether this specified line will be labeled.

5.4 **TAB 4 – Sounding Data**.



T/Td = Temperature/Dewpoint data.

T/Td Plots. Select display of T/Td dots and/or circles on the diagram.

T/Td Lines. Select line thickness from a range of 1 – 9.

Td Lines. Select none, dashed, or solid dewpoint profiles.

Print "m" for Missing dewpoint data. This is the conventional method used to indicate missing dewpoint values on a plotted sounding diagram.

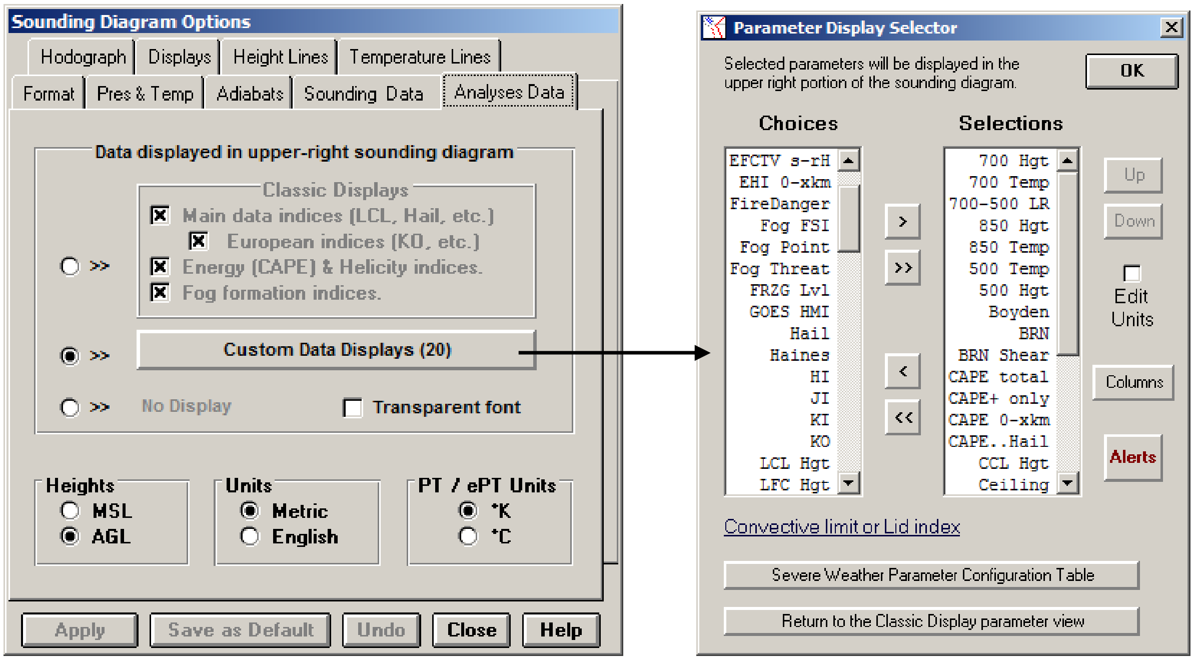
Color Selections. The user can select colors for Temperature, Dewpoint, Lifted Parcels, Wetbulb, FrostPpoint, and Virtual temperature profiles plotted on the Sounding diagram. Note: the last 4 profiles can only be plotted on the sounding diagram by using the Analyze Toolbar's option buttons.

Wind Plots. Select display of shafts and/or dots at origin of wind plot.

Wind Display. Shafts & Feathers. Conventional wind plot display.
Variable Shafts. Shaft length denotes relative wind speed, since feathers are not drawn.

Wind Speed. Select knots (kts) or meters-per-second (m/s) for wind speed plots, which are plotted to the right of the sounding diagram.

5.5 **TAB 5 – Analyses Data**. Analyses data appear in the upper-right portion of the sounding diagram. Use of the Custom Data Displays selector allows the user complete control of displayed data items.



Select the "Classic" or newer "Custom Data Displays" display options. Also select options for MSL/AGL and Metric/English units. The PT/ePT units option applies to the 'RAOB cursor Data' box, which is displayed to the left of the sounding diagram.

When the "Custom Data Displays" button (shown upper-left) is selected, the above Parameter Selector editor is presented. See the following pages for listings of available parameters.

==

Below is an example of the "Classic Display" data analyses listing (including data grouping annotations).

```
 TROP Lvl: Tropopause height
 FRZG Lvl: Freezing level
cclEL Hgt: CCL-based EL
lfcEL Hgt: LFC-based EL
  LFC Hgt: Level of Free Convection
  CCL Hgt: Convective Condensation Level
  LCL Hgt: Lifted Condensation Level
    Water: Water content of column
     Hail: Hail size (estimated)
   T2Gust: Convective gust potential
   WindEx: Microburst potential
    SWEAT: Severe Weather Threat Index
      CAP: similar to LID index
   Boyden: UK thunderstorm index
    S{TT}: German thunderstorm index
       KO: German thunderstorm index
       LI: Lifted Index
       TT: Total Totals
       KI: K-Index
       Tc: Convective temperature (sfc)
    Storm: Storm motion (estimated)
     s-rH: Helicity (per layer)
     CAPE: Convective Available Potential Energy
      CIN: Convective Inhibition Energy
      VGP: Vorticity Generation Parameter
      EHI: Energy Helicity Index
      MVV: Maximum Vertical Velocity
      BRN: Bulk Richardson Number
      LPL: Lifted Parcel Level
  FOG FSI: Fog Stability Index
   Threat: Radiation fog potential
    Point: Radiation fog formation temperature
```

Main Data, & Indices

European Indices

Helicity, CAPE, etc.

Fog Indices

Analyses Data: Custom Data Displays (continued) …

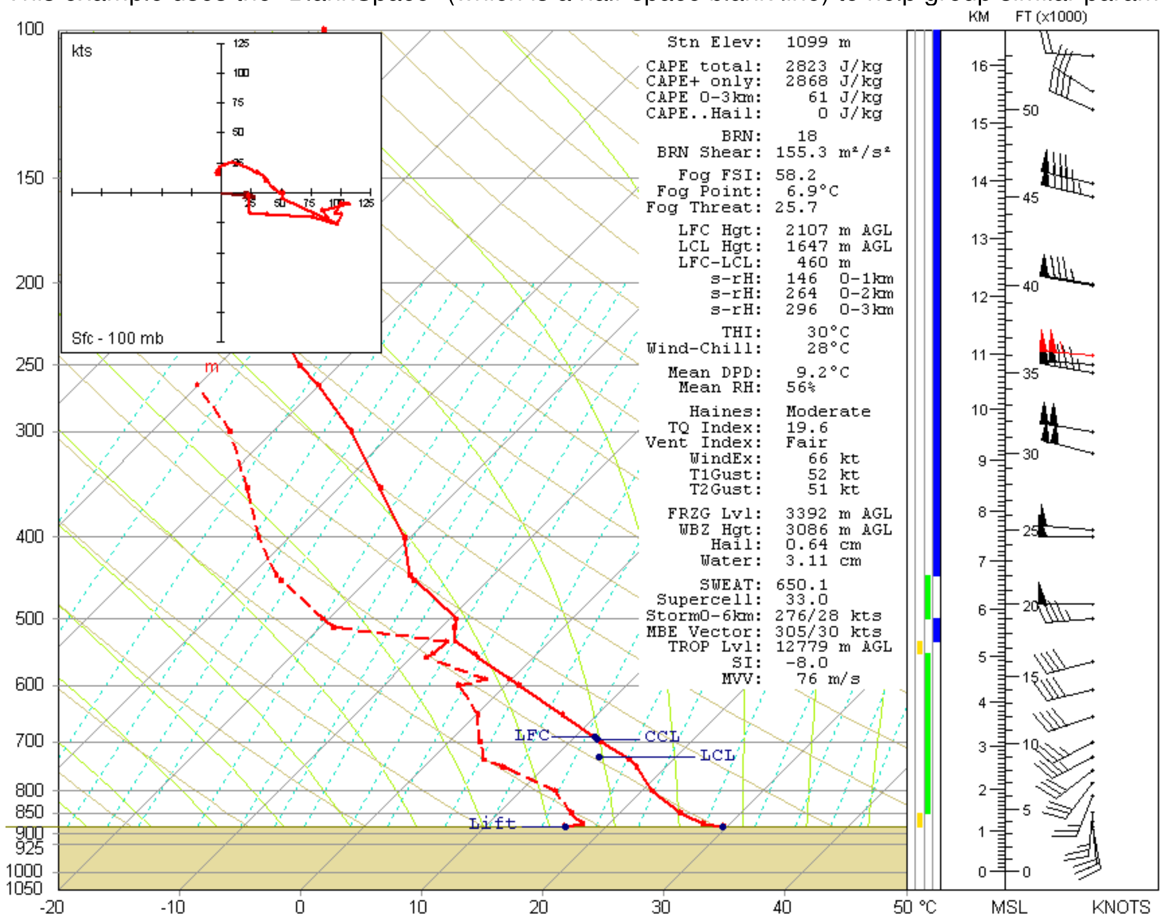
Sounding parameter display options. Any combination or sequence of the following parameters can be selected for display in the upper-right corner of the sounding diagram.

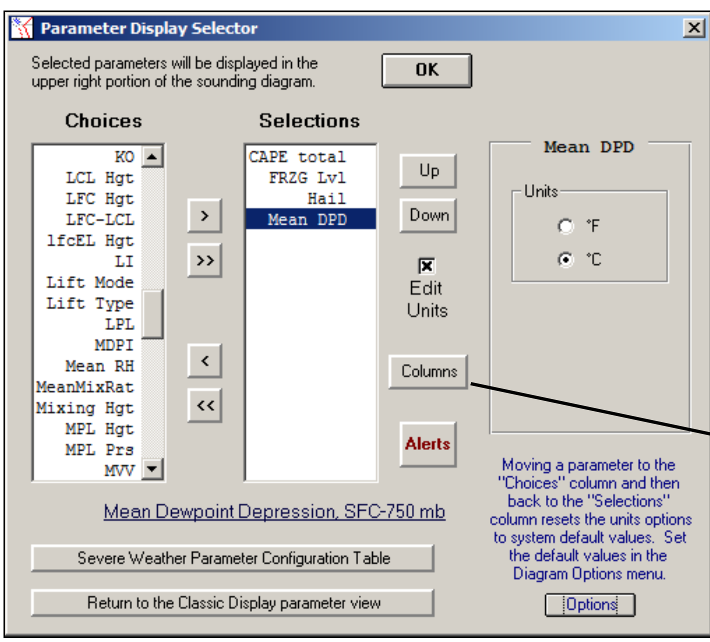
BlankSpace: Insert a blank half-space
850/700/500 mb Temp: Selected temperatures
850/700/500 mb Hgt: Selected heights
700 mb: Wind & Dewpoint Depression
700-500 LR: 700-500 mb lapse-rate (°C/km)
Boyden: European (UK) thunderstorm index
BRN: Bulk Richardson Number
BRN Shear: Bulk Richardson Number shear
CAP: Convective limit or Lid Index
CAPE total: Convective Available Potential Energy
CAPE+ only: Positive CAPE only
CAPE 0-xkm: CAPE for a specified layer
CAPE..Hail: CAPE within the –10 to –30 °C layer
CCL Hgt: Convective Condensation Level
Ceiling: Cloud ceiling height
Chandler: Chandler Burning Index (CBI)
CIN total: Convective INhibition Energy (CAPE-)
Corfidi/Dn: Down/shear – forward shear vector.
Corfidi/Up: Up/shear – also called MBE vector
Craven: Craven SigSvr Parameter (ML-lifting only)
CT: Cross Totals index
DCAPE 6km: Downdraft CAPE for 6km MSL
DCI: Deep Convective Index
Delta ePT: Delta Theta-e, wet microburst potential
DMP Gust: Dry Microburst Potential - Gust
DMPI: Dry Microburst Potential Index
DownRush-T: Surface DownRush Temperature
ESRH: Effective Storm-Relative Helicity
EHI 0-xkm: Energy Helicity Index, at specified layer
GOES HMI: GOES Hybrid Microburst Index
cclEL Hgt: CCL-based Equilibrium level
lfcEL Htb: LFC-based Equilibrium level
Flooding: RAOB flood/flash-flood potential
FireDanger: Fire Danger Index (FDI)
Fog DisTmp: Fog Dissipation Temperature
Fog FSI: Fog Stability Index
Fog Point: Fog formation temperature
Fog Threat: Fog potential
Fog~Advect: Advection Fog potential
Fog~Radiat: Radiation Fog potential
FRZG Lvl: Freezing level
Hail: Hail diameter
Haines: Haines index (also called LASI)
Heat Burst: Heat Burst Index (HBI)
HI: Humidity Index
Inv DisTmp: Inversion Dissipation Temperature
JI: Jefferson index
KI: K-Index
KO: KO-Index, European thunderstorm potential
LCL Hgt: Lifting Condensation Level height
LFC Hgt: Level of Free Convection height
LFC-LCL: LFC/LCL height difference (meters)
LI: Lifted Index
Lift Mode: Parcel lifting method (via configuration)
Lift Type: LFC or CCL lifting method employed
LPL: Lifted parcel level (mb)
MDPI: Microburst Day Potential Index
Mean DPD: Mean T-Td Depression (Sfc-750mb)
Mean RH: Mean Relative Humidity (Sfc–750 mb
MeanMixRat: Mean mixing ratio
Mean RH: Mean Relative Humidity (Sfc-750mb)
Mixing Hgt: Mixing height (function of the DALR)
MPL Prs: Maximum Parcel Level pressure
MPL Hgt: Maximum Parcel Level height
MVV: Maximum Vertical Velocity
NCAPE: Normalized CAPE
RPM: RAOB Parameter Metric (for severe weather)
S{TT}: S-Index, European thunderstorm potential
Severity: Thunderstorm Severity Index
Shear xkm: Wind shear (default system vector)
Shear1 xkm: 1^{st} shear depth (sounding & hodo)
Shear2 xkm: 2^{nd} shear depth (sounding & hodo)
Shear3 xkm: 3^{rd} shear depth (sounding & hodo)
SHIP: Significant Hail Parameter.
SI: Showalter Index
Stn Elev: Station elevation
Storm: Severe storm motion vector
STP: Significant Tornado Parameter
Supercell: Supercell Composite Parameter (SCP)
s-rH 0-3km: Storm-relative Helicity (0-3km layer)
s-rH 0-2km: Storm-relative Helicity (0-2km layer)
s-rH 0-1km: Storm-relative Helicity (0-1km layer)
SR 0-2km: Storm Relative (low-level) wind
SR 4-6 km: Storm Relative (mid-level) wind
SR 9-11km: Storm Relative (anvil-level) wind
SWEAT: Severe WEAther Threat index
T1Gust: Thunderstorm gust potential (T1 method)
T2Gust: Thunderstorm gust potential (T2 method)
Tc: Convective temperature (function of CCL)
TCTP~UNC: Tropical Cyclone Tornado Parameter (from UNC)
Temp Base: Temperature lift method (dry or wet)
THI: Temperature-Humidity Index
TI: Thompson Index
Tornado~TC: RAOB tropical cyclone tornado potential
TQ Index: Low-topped convection potential
TransportM: Mean mixing-layer wind
TransportP: Peak mixing-layer wind
TROP Lvl: First tropopause level
TT: Total Totals index
Vent Index: Ventilation index
VGP 0-xkm: Vorticity Generation Parameter
VirtTempCor: Virtual Temperature Correction
VT: Vertical Totals index
VTP: Violent Tornado Parameter
Water: Total precipitable water of column
Waterspout1: Charleston (NWS) Index for southeastern US
Waterspout2: Szilagyi (SWI) Index for US Great Lakes region
Waterspout3: Key West (NWS) Florida probability index
WBZ Hgt: Wet-Bulb Zero Height
WCD: Warm Cloud Depth (km)
WindEX: Microburst gust potential
Wind Chill: Equivalent temperature due to wind
WMSI: Wet Microburst Severity Index

For those above parameters that are listed in the Severe Weather Parameter Table (shortcut F12), they can be color coded with respect to the Low, Moderate, or High severity thresholds.

Example of several "Custom Data Displays" parameters.

This example uses the "BlankSpace" (which is a half-space blank line) to help group similar parameters.





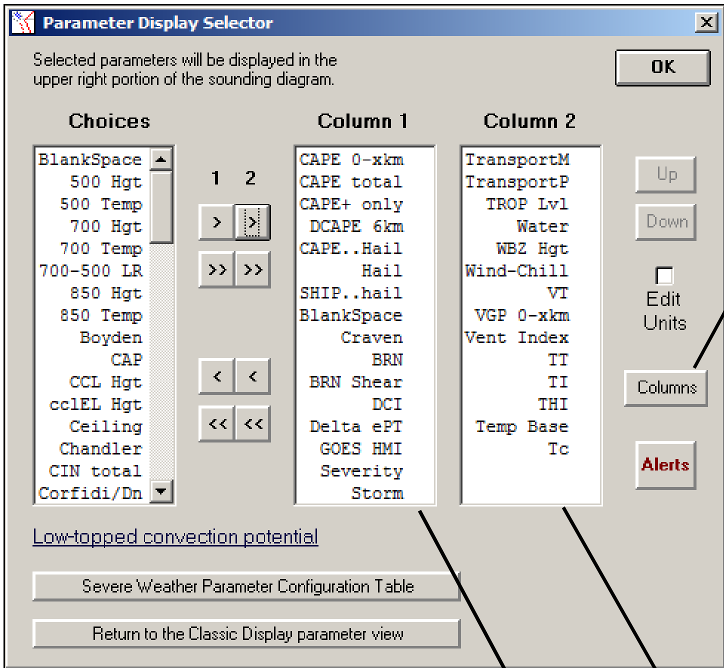
The Parameter Display editor (left) is accessed by right-clicking the mouse while hovering over the sounding's data listing. Here the user can define which data are displayed and the sequence of data items.

The "Edit Units" checkbox allows the user to define data units, which over-ride any system defaults. Note that not all data have units options (such as SWEAT).

The "Columns" box option is discussed on the next page.

The "Alerts" box displays the Weather Alert Editor to configure automatic detection of thresholds.

Example of dual-column "Custom Data Displays", plus Right-side Hodograph.

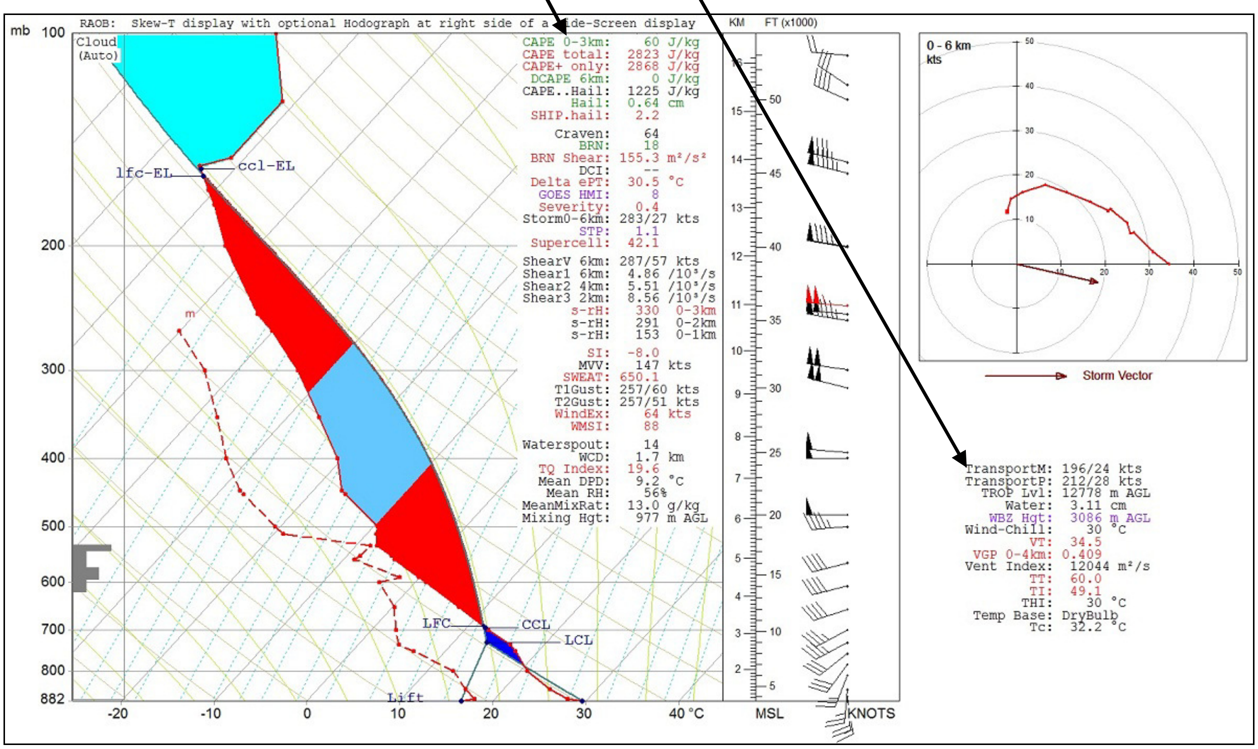


These options are available when using a wide-screen monitor.

The dual-column data display options appear when the "Columns" command box is selected (as seen on the left).

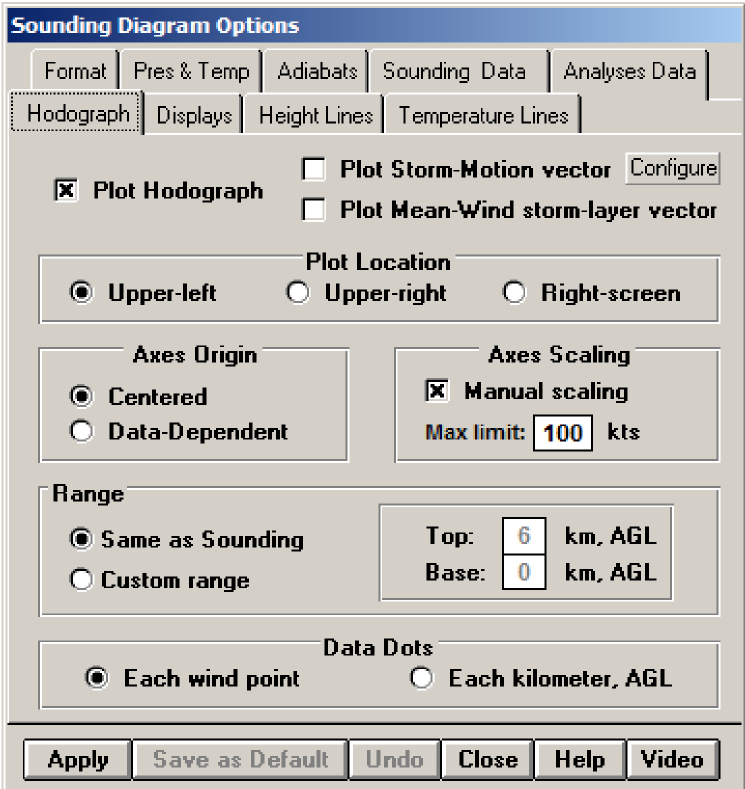
Column #1 data are listed in the upper-right section of the sounding diagram, while the Column #2 data are listed to the right side of the sounding diagram.

Note that when the Hodograph is plotted to the right side of the sounding diagram, the Column #2 data list is automatically shifted below the Hodograph image.



See the next page for information on how to place the Hodograph image to the right-side of the sounding.

5.6 **TAB 6 – Hodograph**.



Plot Hodograph. Plots a mini-hodograph on the sounding diagram screen. Options exist for plot location, scaling, and storm motion; and are discussed in the Hodogram Options configuration section.

See the DISPLAYS section for further description of the unique Hodogram, which is a separate 3-dimensional representation of the sounding's vertical wind structure.

Plot Storm-Motion vector. Select this option to plot the estimated storm-motion vector.

Plot Mean-Wind storm-layer vector. Select this option to plot the mean wind in an olive color.

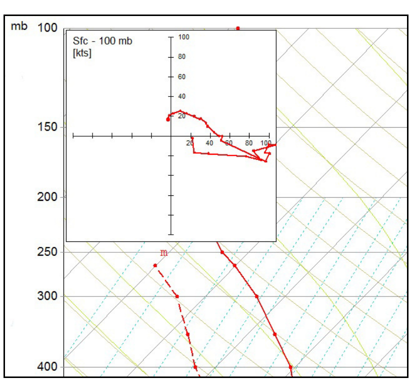
Plot Location. Choose the Upper-Left or Upper-Right corner of the sounding diagram for any display monitor. Choose the Right-screen only if using a widescreen monitor. (See prior page for an example.)

Axes Origin. A Centered grid will always keep the x-y axes centered in the Hodograph box. A Data-Dependent grid focuses on the quadrant with the majority of wind vectors and accordingly offsets the grid origin. Both options employ auto-scaling.

Axes Scaling. Allows manual selection of maximum axes wind speed. Useful for comparison purposes.

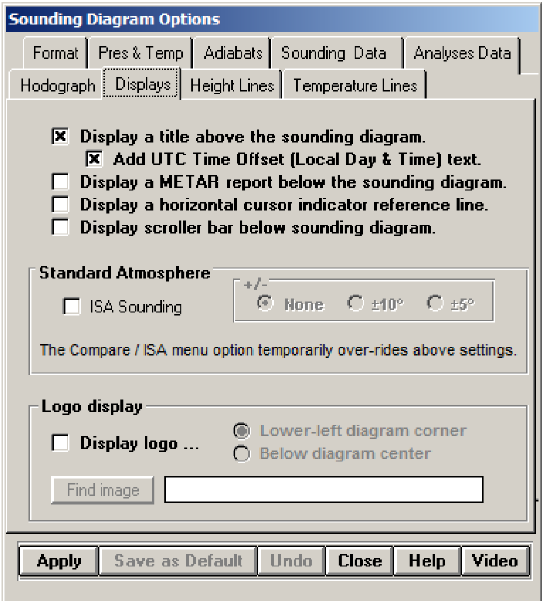
Range. Select the Same as Sounding to display all the winds that are plotted on the parent sounding diagram. Select Custom range to manually specify the vertical depth of the displayed wind data.

Data Dots. Select Each wind point to plot red dots for each wind level, or Each kilometer for red circles identifying each kilometer of height along the hodograph line.



Example of a mini-hodograph plotted with the above configuration options, including the "thick line" plotting option which is found on the Sounding Data tab.

5.7 **TAB 7 – Displays.**



<u>Display a title above the sounding diagram</u>. This option is useful for imaging and printing purposes. <u>Add UTC Time Offset text</u> appends the LOCAL Day and Time after the above Sounding "Titlte" line.

<u>Display a METAR report below the sounding</u>. METAR reports are only produced when the RICAPS (cloud & precip) mode is selected via the Algorithm Options.

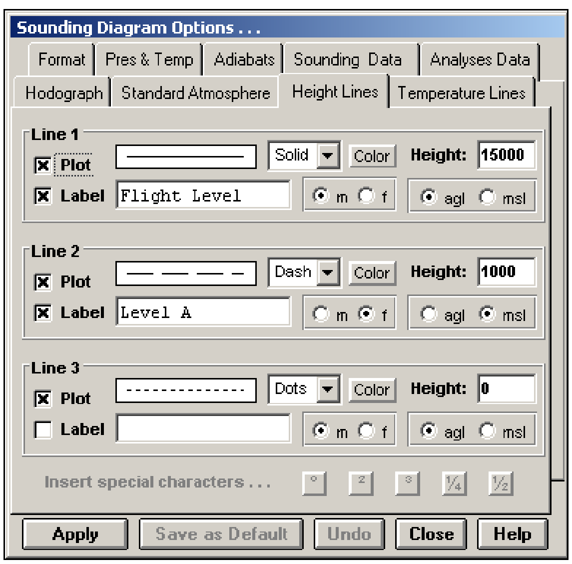
<u>Display a horizontal cursor indicator line</u>. This line is very useful for graphic referencing.

<u>Display scroller bar below sounding diagram</u>. Provides another option for viewing multi-sounding files.

<u>ISA Sounding</u>. The International Standard Atmosphere Sounding (ISA Sounding) is a hypothetical vertical distribution of the atmosphere. Select the desired interval of ISA sounding grid overlays.

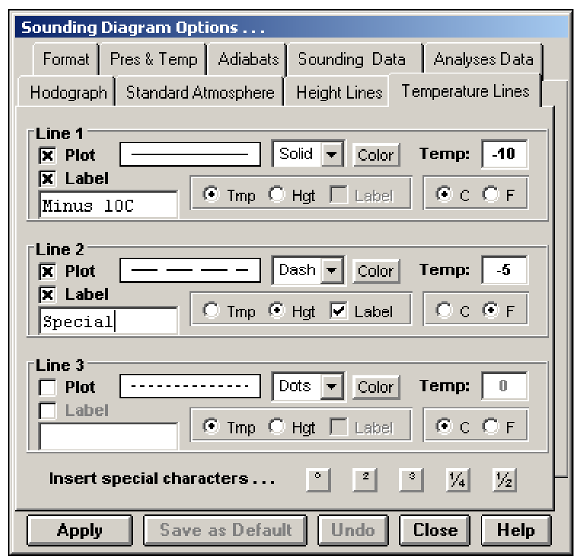
<u>Logo display</u>. This allows display of a custom logo image created by the RAOB user.

5.8 **TAB 8 – Height Lines.**



RAOB allows up to three horizontal height lines to be drawn on the sounding diagram. Each line can be individually configured to meet user needs, including printed labels, colors, line style, location, and height units. Example uses are identification of "flight level" or other significant reference heights.

5.9 **TAB 9 – Temperature Lines.**

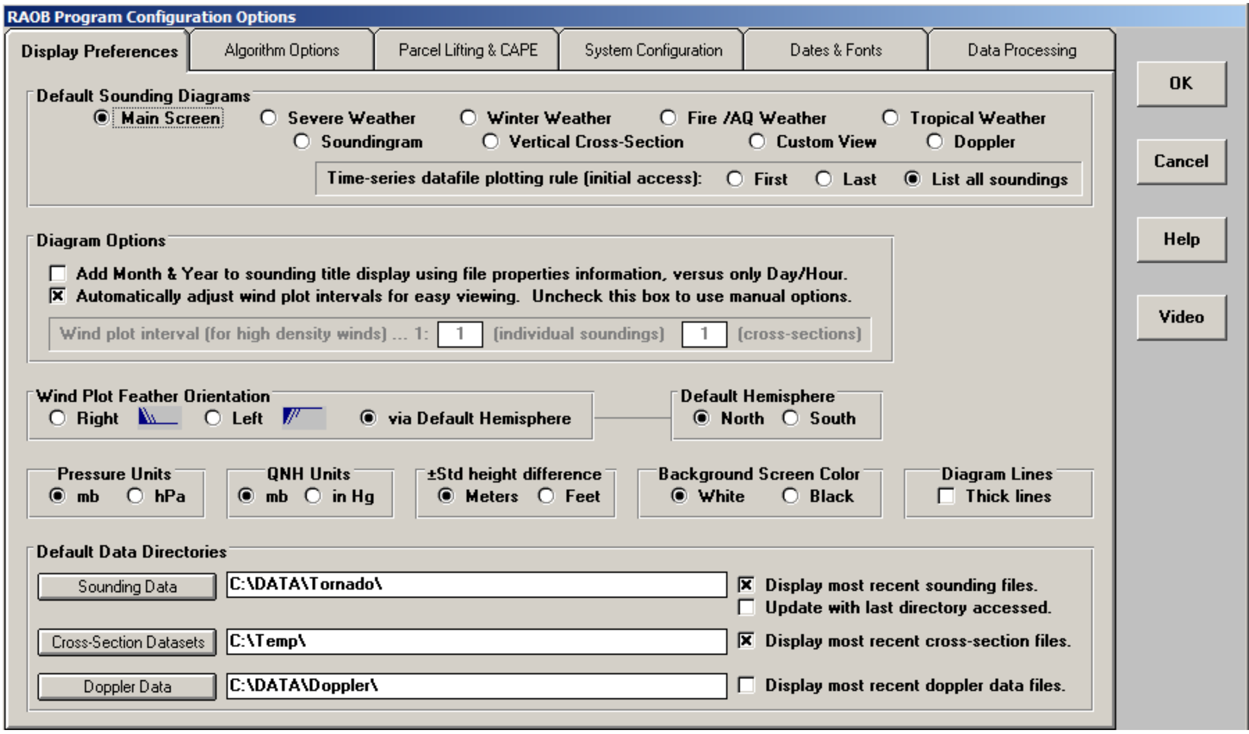


RAOB up to six temperature lines on the diagram. Each line can be oriented either as a temperature (Tmp) coordinate line or a height (Hgt) coordinate line. These options are useful for highlighting temperatures or thresholds of interest or to enhance graphics for display purposes.

Use the "Insert special characters" buttons to include characters not directly available on the keyboard.

6. **PROGRAM CONFIGURATION**.

6.1 **TAB 1 – Display Preferences**.



Default Sounding Diagrams.

Main Screen. The generic, all-purpose sounding display. Useful for most purposes.
Severe Weather. Provides specialized severe weather nomograms and charts.
Winter Weather. Provides specialized winter weather nomograms and charts.
Fire/AQ Weather. Provides Fire Danger / Air-Quality displays of configurable nomograms.
Tropical Weather. Provides tornado, waterspout, and flooding analysis charts and nomograms.
Soundingram. Provides X-Y diagrams of significant atmospheric parameters.
Vertical Cross-Section. Enables displays of distance-base and time-series sounding data.
Custom View. Gives the user complete control of displayed diagrams, text, size and locations.
Doppler. Produces a unique multi-view screen designed for VAD, PPI, RHI and other displays.

Time-series datafile rule (initial access). Select from the "First", "Last", and "List all soundings" options to determine how time-series datafiles are initially processed. After initial datafile access, RAOB reverts back to the default "List all soundings" data handling mode.

Diagram Options.

<u>Add Month & Year to sounding title displays using file properties information, versus only Day/Hr</u>. This option only applies to standard WMO coded sounding data, since this data only has the sounding's "day" and "hour" launch date, while "month" and "year" are not specified. By choosing this option, RAOB will add the month and year as obtained from the data file's creation date. The file's creation date must be accurate in order for this option to produce a correct title display.

<u>Automatically adjust wind plot intervals for easy viewing</u>. This is the default method for displaying high-density wind plot data. Uncheck this option box to use the manual plot options, using the ***Wind plot interval*** data options, where the user specifies Sounding and/or Cross-Section intervals.

Wind Plot Feather Orientation.

Right. Northern hemisphere plotting convention – used for all soundings when checked.
Left. Southern hemisphere plotting convention – used for all soundings when checked.
via Default Hemisphere. RAOB automatically determines feather orientation based on the Latitude value associated with each sounding or as determined from information obtained from the RAOB.STN station locator file. If the sounding's latitude cannot be determined, then the default hemisphere and associated convention is applied.

Default Hemisphere. Select North or South. Affects wind plot feathering and severe storm steering algorithms.

Pressure Units. Select millibars (mb) or hectopascals (hPa).

QNH Units. Select millibars (mb) or inches-of-Mercury (in Hg) for the surface altimeter setting. The QNH will only be displayed when the DIAGRAM's "Draw surface line" configuration option is selected.

+/- Std Height Difference. Select meters or feet for geopotential height difference units between the sounding and standard atmosphere heights. These values are sometimes called D-values or D-Val. "D-Value" is an analysis toolbar option for Cross-Section and Time-Height diagrams. It is visible on the Sounding Listing's "Complete Listing" view, and is an option with the Advanced Export module.

Background Screen Color. Select White or Black.

Diagram Lines. Select the "Thick lines" box to increase line thickness of all program diagram lines.

Default Data Directories.

Sounding Data. Specify the default location of sounding data files.

Display most recently used sounding files. Select this option to display the 5 most recently used sounding files (displayed under the File Menu option).

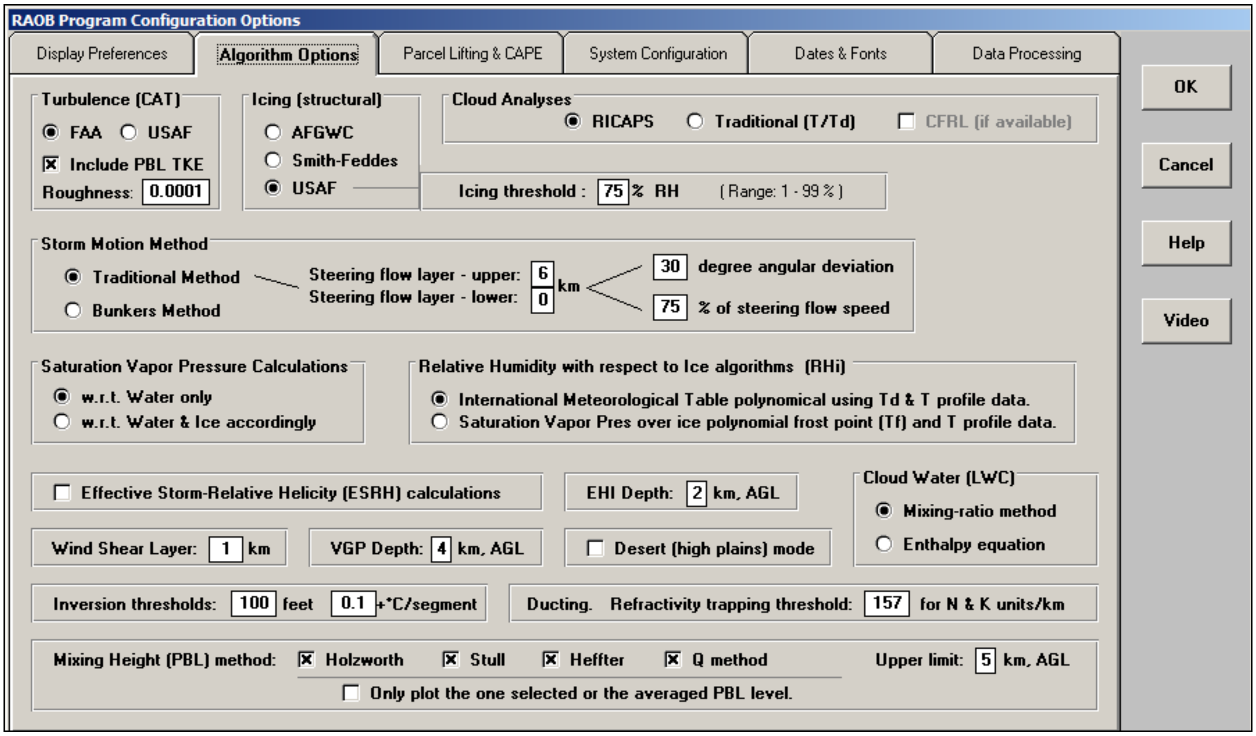
Always update with last directory accessed. Select this option to automatically update the default sounding directory with the last directory used for sounding access and selection.

Cross-Section DataSets. Specify the default location of cross-section dataset files. It is highly recommended that this "dataset" directory be different than the above "sounding" directory. Note: this option is only available with the optional Cross-Section Modules.

Display most recently used cross-section files. Select this option to display the 5 most recently used cross-section files (displayed under the File Menu option).

Doppler Data. Specify the default location of Doppler derived data files.

6.2 **TAB 2 – Algorithm Options**. (This Tab is only available with the optional Analytic Module.)



Turbulence (CAT). CAT = Clear Air Turbulence. Both CAT options are described in the SOUNDING ANALYSES section of this manual. Note: Turbulence associated with mountain-wave activity is available with the optional Turbulence & Mountain-Wave program module, which is discussed later in this manual. The **FAA** criteria are based on a July 1967 meeting of the Sub-committee/AMS as reflected in the Weather Service Operations Manual (WSOM) and the Airman's Information Manual (AIM). The **USAF** criteria are based on USAF Air Weather Service studies as reflected in AFGWC/TN-79/001.

The PBL TKE option includes the affects of terrain-induced mechanical turbulence within the boundary layer (PBL); where TKE represents Turbulent Kinetic Energy. Surface "Roughness" is a user option, which ranges from 2.0 for large buildings & forests to 0.0002 for smooth/calm open water.

Icing (structural). All three options are described in the SOUNDING ANALYSES section.

• The **AFGWC** criteria are based on the Air Force Global Weather Central icing algorithms, which only use temperature, moisture, and lapse rate as predictors (Cornell et al, 95).

• The **Smith-Feddes** criteria are based on the studies from two USAF Air Weather Service publications, USAFETAC TN 74-1 (Smith, 74) and TN 74-4 (Feddes, 74). This method is highly dependent on cloud amount. RAOB allows the user to select the source of cloud information. This is done with the adjacent "Cloud Analyses" options box to the right (which is explained in detail on the next page).

• The **USAF** criteria are based on USAF Air Weather Service studies as reflected in AWS/TR-80/001. When selected, the **Icing Threshold** % option is displayed. Use this option to define the relative humidity (RH) threshold at which icing is detected. Suggest initially using the 85% default value, until the actual RH associated with confirmed icing can be determined. Note: a 85% threshold will usually over-forecast icing, but this is only for identifying "potential" icing layers. This threshold should be adjusted for local conditions. A 100% threshold is not necessary for icing, since icing is produced by super-cooled water droplets in cloud layers.

Cloud Analyses.

RICAPS Method. RICAPS (RAOB Integrated Cloud And Precipitation System).

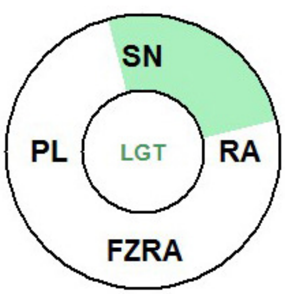
RICAPS requires use of the optional Analytic program module.

RICAPS performs a sophisticated series of bottom-up scans to determine cloud layers. This system is superior to the older "Traditional" temperature/dewpoint relationship algorithm (see below), which over-analyzes low clouds and under-analyzes high clouds. The RICAPS cloud algorithm works with any sounding profile and is completely independent of modeled cloud fields. These cloud algorithms use a combination of temperature, dewpoint, relative humidity, wet-bulb & frostpoint temperatures and their associated lapse-rates. In addition to superior cloud analyses, the RICAPS system also determines precipitation type and intensity.

- Precipitation Type is determined using an advanced top-down scan methodology. It consolidates the strengths of the commonly used top-down P-Type methods, including the Baldwin, Ramer, and Bourgouin methods. Most importantly, it also eliminates their weaknesses, such as inability to determine precipitation rate, the lack of dry-layer detection & feeder-seeder integration, lack of ability to use humidity for nucleation determination, lack of wet-bulb interrogation at key thresholds, and the assumption that ice crystals are always present during the top-down initiation process. In addition to eliminating the above weaknesses, the RICAPS method not only determines the percentage of ice crystals during top-down initialization, but it also continually updates this percentage while scanning downward at 100-foot intervals. Special analyses are additionally performed each time the profile crosses the zero-degree isotherm and at the base of dry-layers. And if a dry-layer is encountered, RICAPS then begins a unique, dual-track, top-down process, which simulates the effects of feeder-seeder processes. RICAPS can be used with any sounding profile and is geographically independent since it can be used at any location and any elevation, unlike the Partial-Thickness (P-Type) nomogram method.

- Precipitation Intensity is determined using both Bottom-Up and Top-Down scans of the entire profile. The algorithm uses a combination of cloud layers, relative humidity, and associated temperature and dewpoint lapse-rates.

When the RICAPS algorithms are activated, you can also configure RAOB to produce a complete METAR report at the base of Sounding diagrams. See the Diagram Options' "Display" Tab for this option.



When RAOB's "Winter Weather" sounding diagram display option is used, a unique Precipitation Donut nomogram is displayed (see sample image at left). The Precipitation Donut is an interactively graphic representation of precipitation type and intensity. The precipitation type and intensity (such as -SNRA) can even be displayed in the Custom Data Listing as the "PrecipType" data item.

Traditional Method. This method uses the very simple Temperature – Dewpoint spread relationship, which is explained in the Cloud Layer Table section of this User Manual.

CFRL Method. CFRL is cloud coverage data as produced by numerical weather models, such as available with BUFKIT data. If CFRL data is not available, then RICAPS or Traditional mode data is used.

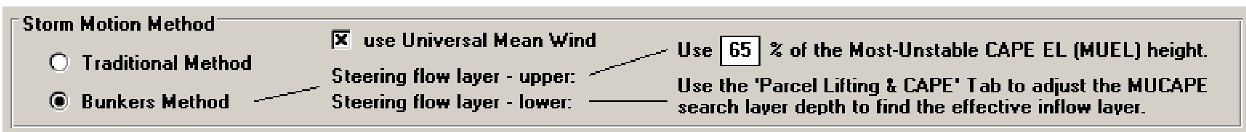
Humidity. RAOB uses Relative Humidity (RH) for Icing, Clouds, and many other standard applications. RAOB also calculates Absolute Humidity, but it is not used for any indices or applications.

Storm Motion Prediction.

Traditional Method. This method is widely used as a first guess for predicting storm movement. It traditionally uses a steering flow depth of 0 to 6 km and a steering motion derived from 30-degrees & 75% of steering flow wind. RAOB allows the user to individually configure all storm motion variables, including flow depth (top and bottom limits), angular deviation, and storm speed percentage.

This simple steering method was statistically derived and has shown to be reliable in most cases. Normally, storm motion moves to the right of mean wind in the northern hemisphere and to the left in the southern hemisphere. Additionally, RAOB calculates the mean wind using the popular and preferred thickness-weighted method.

Bunkers Method. An "internal dynamics" method of predicting supercell motion that is physically-based and shear-relative. It has been shown to be statistically superior to other simple statistical methods, especially in higher wind regimes. The standard Bunkers method can become less reliable with lower-speed winds, but this has been addressed with the new "Universal Mean Wind" option, which is shown below. For further discussion of the Bunkers methodology, please see the "Storm Motion Prediction" paragraphs of the SOUNDING ANALYSES section. (See "Reference" section for 3 source publications.)



Saturation Vapor Pressure Calculations.

w.r.t. Water only. The "with-respect-to (w.r.t.) Water only" option will replicate Saturation Adiabat and Saturation Mixing Ratio diagram reference lines as commonly seen on standard sounding plotting charts. All calculations are derived on a Clausius-Clapeyron based equation for vapor pressures over water only.

w.r.t. Water & Ice. This option employs two different equations – one for "w.r.t water only" (as discussed above) and one for "w.r.t. ice only." The author has been unable to locate a single equation, which accurately calculates vapor pressures over both surfaces. Consequently, use of this option results in a very small discontinuity of Saturation Adiabat (and to a lesser extent, Saturation Mixing Ratio) lines as seen on the diagram at the zero degree temperature line.

Equations for both algorithms discussed above were taken from the International Meteorological Tables.

Relative Humidity with respect to Ice algorithms (RHi). There are 2 options ...

> International Meteorological Table polynomial using Td & T profile data. This RHi method uses conventional Vapor Pressure (of Td) over water divided by conventional Saturation Vapor Pressure (of T) over ice.
>
> Saturation Vapor Pres over ice polynomial frost point (Tf) and T profile data. This RHi method uses Saturation Vapor Pressures over ice for both the derived Frostpoint temperature (Tf) divided by the Dry Bulb (T) temperature.

Effective Storm-Relative Helicity (ESRH) calculations. When selected, RAOB determines the depth of the helicity layer as a function of the CAPE layer. Resulting ESRH calculations take much more processing time and will significantly slow down looping & multi-sounding operations. When activated, the ESRH data is automatically applied to the STP (Significant Tornado Parameter), VTP (Violent Tornado Parameter), and SCP (Supercell Composite Parameter) indices.

EHI Depth. EHI or Energy Helicity Index combines shear and instability into one parameter. It is a function of s-rH and positive CAPE (B+). The inflow layer depth can be specified by the user, although the 0-1 km or 0-2 km depths are most common. Recent studies indicate that that the lowest 1km shear has the greatest influence on determining whether supercells will produce tornadoes or not.

Wind Shear Layer. This option exists to allow the user to define the standard depth for wind shear calculations used throughout the program. (The standard layer is 6 km.) Note that the sounding's "shear" vector can be optionally displayed on the sounding diagram as part of the data analyses listing.

VGP Depth. VGP or Vorticity Generation Parameter is the rate at which horizontal vorticity is converted to vertical vorticity through tilting. Like the EHI Depth option, the user specifies the desired depth. Details of this parameter can be found in the SOUNDING ANALYSES chapter.

Desert (high plains) mode. This option is appropriate for soundings that have a Station Elevation of 1,500 meters (or 5,000 feet) or higher. The Desert mode option affects the Showalter Index, the European S-Index, and the Total-Totals / Cross-Totals / Vertical-Totals values. When selected, the 850 mb temperature and dewpoint are replaced by the 700 mb values, and the 500 mb temperature is replaced by the 400 mb temperature.

Cloud Water (LWC). There are 2 methods which measure the Cloud Water, or LWC (Liquid Water Content), in clouds ...

> Enthalpy equation. This method uses the adiabatic Enthalpy (gamma) lapse-rate equation, where LWC is a function of density, specific heat at constant pressure, latent heat of vaporization, dry adiabatic lapse rate, and the moist adiabatic lapse rate. (Reference: Gultepe, ICCP, 2008.)
>
> Mixing-ratio method. This method uses an algorithm consisting of mixing-ratios and density parameters as defined in AWS/TR-80/001, Forecasters' Guide on Aircraft Icing.

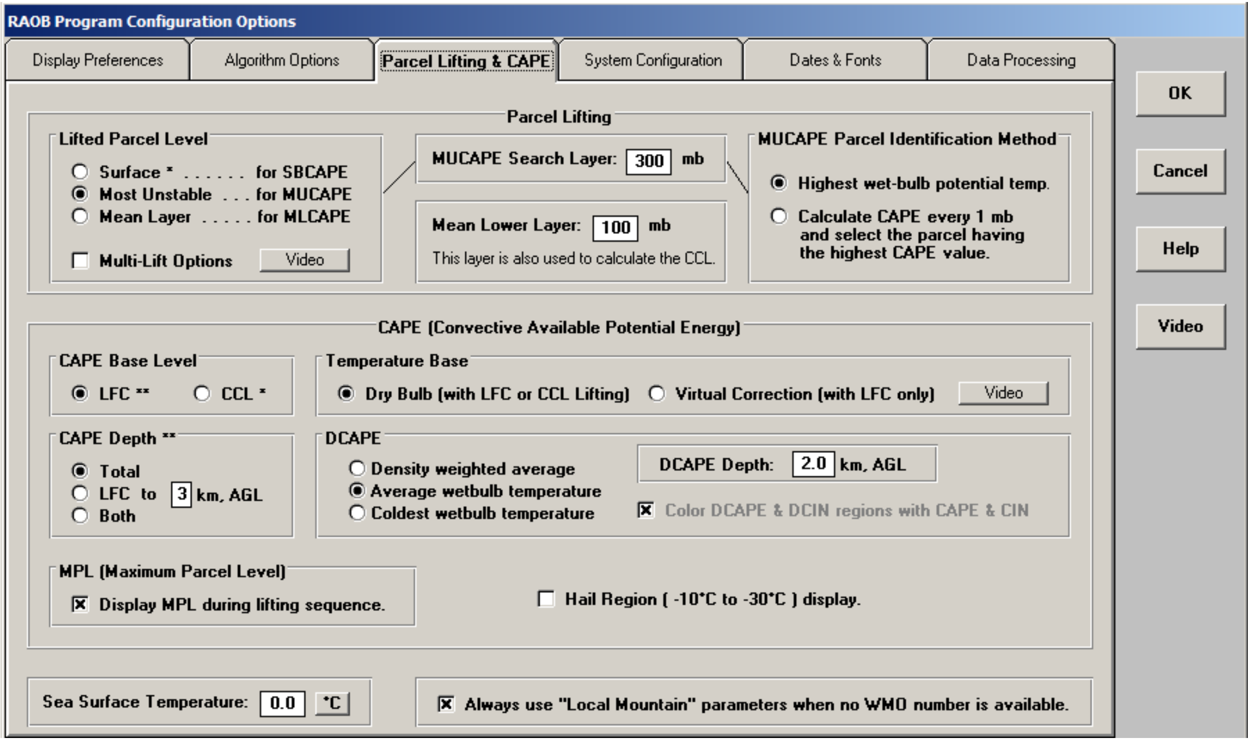
Inversion Thresholds. Control the minimum thickness and lapse-rate for inversion detection.

Ducting. Refractivity Trapping Threshold is a user option. RAOB calculates atmospheric refractivity (N & K-units) and detects steep N-unit gradients used to locate "trapping" layers and subsequent propagation ducting potential. A "trapping" layer is identified when the N gradient is greater than a defined threshold, which is typically 157 N/km (the commonly accepted default value).

Mixing Height (PBL) method. There are 4 methods which estimate the Mixing Height, or Planetary Boundary Level (PBL) ...

> Holzworth method. Holzworth is the standard "theta" method which lifts the surface parcel dry adiabatically until it intersects the sounding profile. If no intersection is found, the height is located at the top of surface inversion, or else at the bottom of 1st elevated inversion.
>
> Stull method. The Stull method uses "virtual theta" data and lifts parcels with the sounding's virtual temperature profile.
>
> Heffter method. The Heffter method finds the lowest critical inversion which meets Theta gradient and lapse-rate criteria as specified by Heffter (1980).
>
> Q method. The Q method finds the minimum vertical gradient of Specific Humidity (q).
>
> Note: One or all 4 PBL methods can be selected. If more than one is selected, then all those selected will be averaged into a single PBL value for display and/or export purposes.

6.3 **TAB 3 – Parcel Lifting & CAPE**.



Lifted Parcel Level (LPL).

Surface . This is the most direct and common form of parcel lifting. It calculates SBCAPE.

Most Unstable. This is the MUCAPE option, which finds the "Best Level" parcel. It uses the parcel level with the highest CAPE within the lowest, user-identified search layer.

MUCAPE Search Layer (mb). Enter the lower depth (mb/hPa) range for finding the most unstable parcel. The recommended default depth is 300 mb.

MUCAPE Parcel Identification Method.

Highest wet-bulb potential temperature. The default and fastest method.
Calculate CAPE evey 1 mb and select the parcel having the highest CAPE value.
This option is very time-consuming, but most accurate.

Mean Layer. This parcel is calculated from a thickness-weighted average of all temperatures (and dew points) within the lowest xxx mb layer (see below). It calculates MLCAPE.

Mean Lower Layer (mb). This "mean layer" is used to define the depth of the Lower_x_mb_layer of the LPL. This value is also used to determine the mean mixing ratio and find the CCL.

Multiple prompt. *This feature is only available with the optional Interactive Module*. This capability is activated by using the "Lift Parcel" button on the Sounding's Analyses Toolbar. When activated, the user is presented with a "RAOB Lifting Options" box containing three lifting methods. (1) Lift Parcels. The user can lift any data level and overlay up to 9 lifting sequences. (2) Lift Layer. The user can specify any layer to be moved up or down within the sounding. This option can help simulate convective events such as found within thunderstorm cells. (3) Lift Sounding. The user can adjust (up or down) the entire sounding (including winds) by a prescribed pressure amount. It can simulate mountain/valley changes.

CAPE (Convective Available Potential Energy) Base Level.

LFC. Standard option. This option must be used in order to use the 2nd & 3rd options of CAPE Depth (see below), since they are LFC-based.

CCL. This option can only be used if the surface parcel is lifted. When CAPE is calculated using the CCL as the base, the lifted parcel's free air temperature is identified by the Convective Temperature (Tc).

Temperature Base.

The Dry Bulb option is standard for most analyses and can be used with either the LFC or CCL base level.

The Virtual Temperature selection is often used to simulate the maximum thermodynamic potential of the atmosphere as represented by the plotted sounding. In a moist atmosphere, the virtual temperature is always greater than the actual temperature, taking into account the moisture's energy potential. It affects the values of the LFC and CAPE-related parameters. When the Virtual temperature base is selected and the ***Classic Data Display*** is used, affected data displays will be followed by a purple [**>**] character instead of the standard white [**:**] symbol. This option can only be used with the LFC base level option.

CAPE Depth.

Total. This is the standard method of CAPE calculation and display. All positive (B+) energy is represented by CAPE and all negative (B-) energy is represented by CIN (or Convective Inhibition). When displayed on the sounding, CAPE is colored *RED* and CIN is colored *BLUE*.

0-x km above LFC. This option will only calculate CAPE (B+) from the LFC to x km above the LFC. This region has been found useful in differentiating between tornadic and non-tornadic supercells. The most common region studied is the 0-3km depth. When displayed on the sounding, this region is colored *RED*.

Both. This option will calculate and display "Total" and "0-x km" CAPE. When displayed on the sounding, the "0-x km" CAPE is colored *Dark RED*, while the remaining CAPE is colored *Light RED*.

DCAPE (Downdraft CAPE). Choose from the more time-consuming density weighted averaged method, the default average wetbulb method, or the fastest coldest wetbulb temperature method. When a multiple-sounding datafile is sequentially looped, RAOB automatically uses the fastest method, but the program then reverts back to the 'configured' option when stopped for data viewing purposes. DCAPE depth is user-configurable, but the common standard is 6 km.

Color DCAPE & DCIN regions with CAPE & CIN. This option is only available with the "Coldest wet-bulb temperature" DCAPE option. DCAPE is colored *Dark PURPLE* and DCIN is colored *Light PURPLE*.

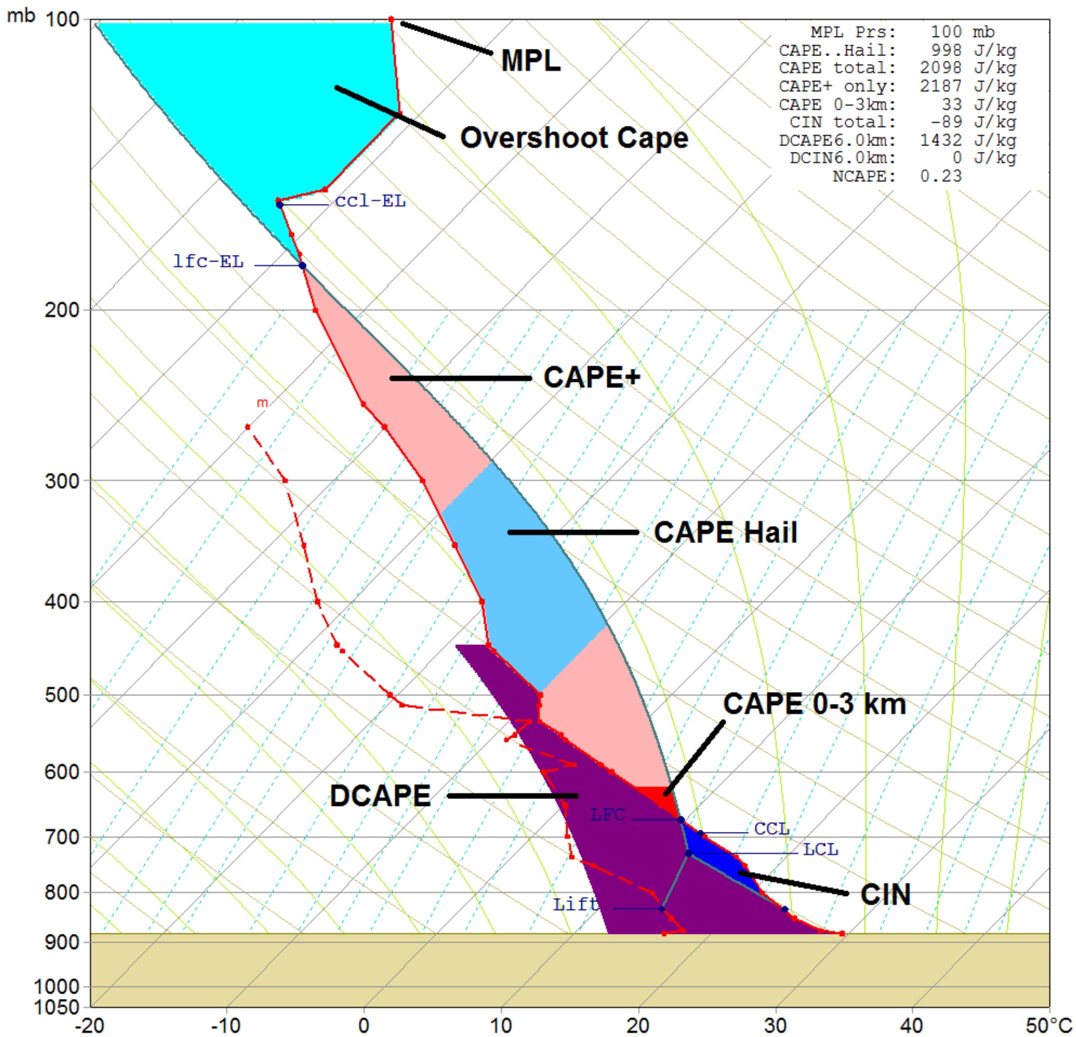
Maximum Parcel Level (MPL). Toggles on/off the MPL displays of text (which appears on the sounding diagram after activating the Significant Levels Analyses option) and graphics (which appears on the sounding diagram after activating the CAPE Analyses option). *See the next page for an example.*

Hail Region. Select this option to analyze the CAPE area that exists within the -10ºC and -30ºC temperature zone. This zone is shaded a medium blue color and represents the most favorable hail growth region, especially for large hail (as per NOAA/NWS Advanced Warning Operations Course, 2004). This parameter is listed as "CAPE..Hail" on the sounding's data listing. Studies show that steep lapse rates in a sounding's hail growth zone are favorable for large hail. The thicker the CAPE..Hail graphic area, the greater the probability for large hail. *See next page for example image.*

Sea Surface Temperature . Used as an input parameter for the Waterspout-2 (Szilagyi) index.

Always use "Local Mountain" parameters when no WMO number is available. This is used for the Froude Number calculations. Mountain parameters are stored (and edited) in the RAOB.MTN resource file.

The below diagram shows how RAOB displays the various types of CAPE regions.



Overshoot Cape (light blue). This region is always above the Equilibrium Level (EL). This Cape region is only displayed when the MPL (Maximum Parcel Level) option is selected from the Program Configuration Options menu (see prior page). When displayed, the trace of the lifted parcel will continue past the EL until the positive (B+) and negative (B-) CAPE energies cancel each other. This represents the maximum potential height of convective cloud tops. In the above example, the overshooting CAPE area stops at the 100 mb level only because the sounding plot does not continue any higher.

Cape+ (light red). This region is the predominant positive CAPE (also called B+).

Cape..Hail (medium blue). This region depicts the primary hail growth zone (-10 to -30^{O}C).

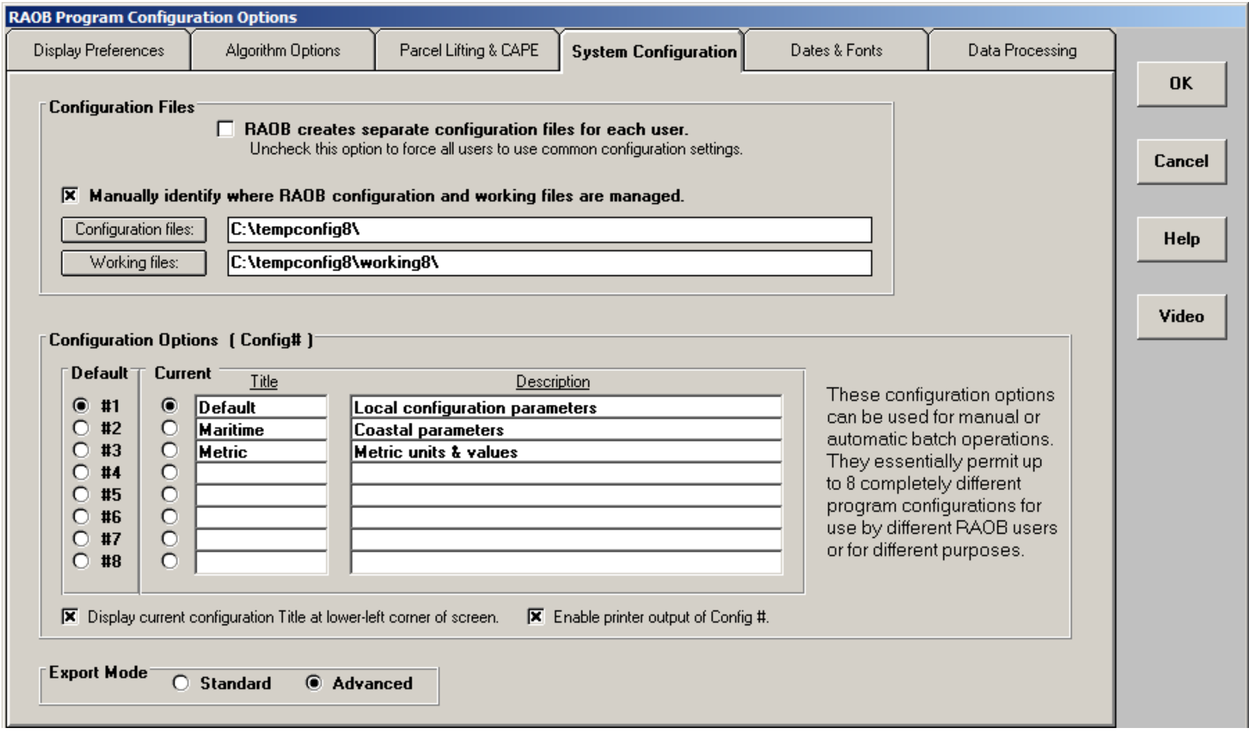
Cape 0-3km (dark red). This is a special interest region and is also part of the Cape+ area.

CIN (dark blue). This region represents Convective Inhibition (also called B-).

DCAPE (dark purple). This is the Downdraft CAPE region.

DCIN (light purple). Not shown, because region does not exist with this sounding.

6.4 **TAB 4 – System Configuration**.



Configuration Files.

RAOB creates separate configuration files for each user. Control whether multiple users use the same or different program configurations. Uncheck this option to force all users to access the same program configuration settings.

Manually identify where RAOB configuration files are managed. Specify the location of all RAOB “Configuration files” and “Working files”.

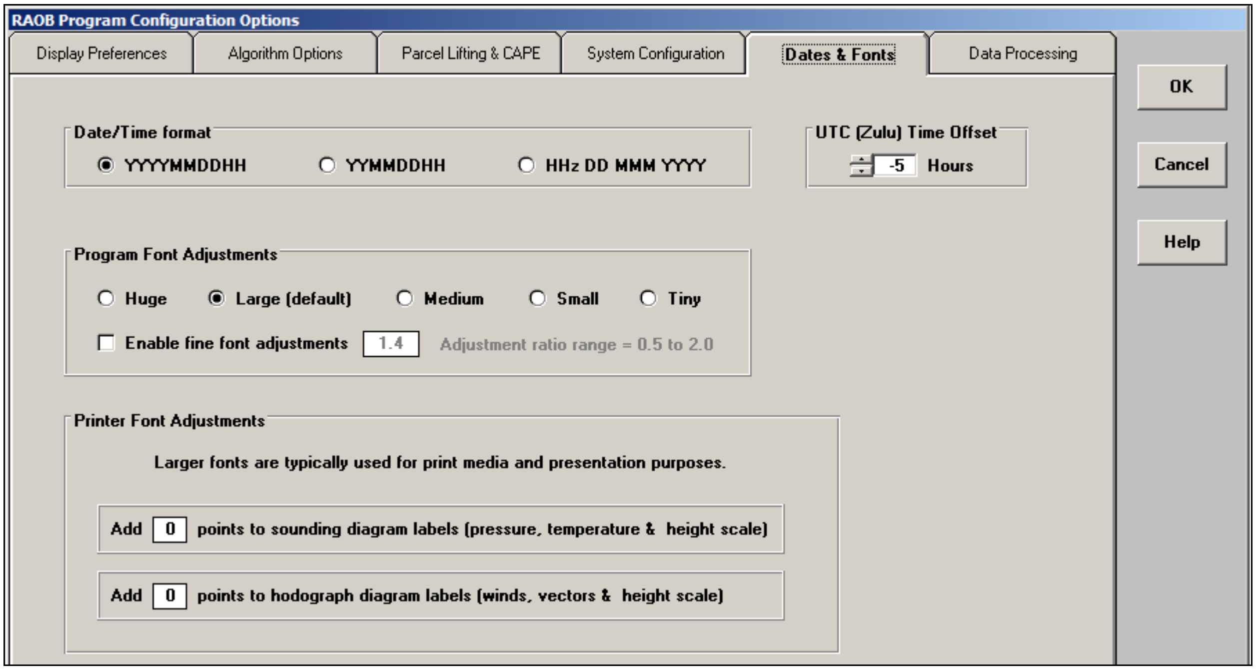
System Configuration. Currently allows up to eight (8) system-wide configurations.

The Default option identifies which configuration is used upon initial RAOB activation.
The Current option identifies which configuration is currently in use.

The configuration Title is displayed in the lower-left portion of the screen display, unless the “Display” checkbox (located below these options) is not checked. The configuration Description is only used to further describe the configuration title and is not displayed anywhere else in the program.

Export Mode. The Export Mode selection determines which method automatically appears when the Export Sounding Data menu is selected. The Advanced mode permits selective exporting of nearly all parameters which RAOB produces. It was added with the RAOB 6.3 version and will continue to be updated with newer versions. The Standard (or Classic) mode consists of exporting functions available with RAOB 6.2 and older versions. This mode is only made available for those who wish to continue with this export method. Both exporting methods are discussed earlier in the File Menu section.

6.5 **TAB 5 – Dates & Fonts**.



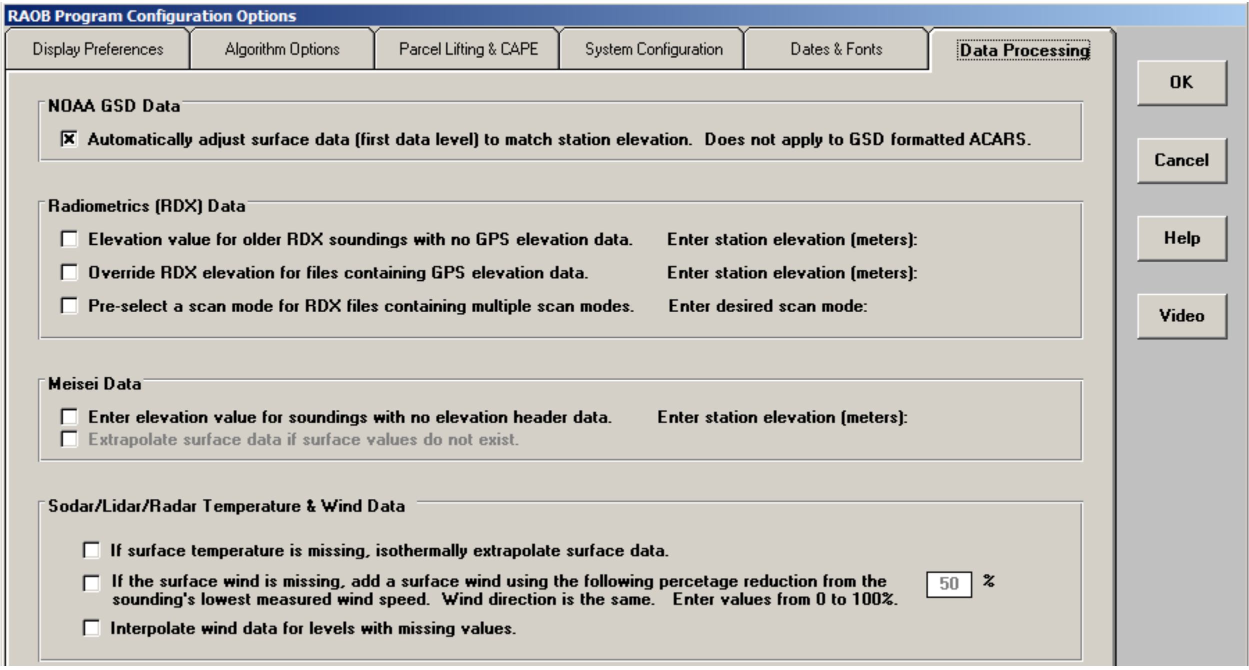
Date/Time format. Select the desired DTG format for sounding title displays and export functions.

UTC (Zulu) Time Offset. UTC = Coordinated Universal Time; also known as Zulu (or Z) time. The Offset value is needed to determine LOCAL Time, for uses such as Fog prediction. Use positive values in the Eastern Hemisphere and negative values in the Western Hemisphere.

Program Font Adjustments. Some PC displays require font size adjustments. This option is global in nature. Select either Huge, Large (the default option), Medium, Small, or Tiny fonts. For additional fine tuning of displayed fonts, check the "Enable fine font adjustments" options box and then enter smaller or larger font ratios as desired. These adjustments will not affect printed output.

Printer Font Adjustments. These options allow users to increase font sizes for printer purposes. This is especially useful for certain print media and presentation purposes. These options only affect the Sounding and/or Hodograph diagrams as indicated. Point values between 0 and 3 can be entered.

6.6 **TAB 6 – Data Processing**.



NOAA GSD Data. Automatically adjust surface data (first data level) to match station elevation. Some GSD sounding data do not contain values that correspond to the station's elevation. When checked, RAOB enforces this correlation. This option does not apply to GSD formatted ACARS data.

Radiometrics (RDX) Data.

Elevation value for older RDX soundings with no GPS elevation data. Use as needed.
Override RDX elevation for files containing GPS elevation data. Required for some processing cases.
Pre-select a scan mode for RDX files containing multiple scan modes. This option is useful during automation processing where user selection is not needed or desired for each datafile. If the datafile only contains one Scan Mode, then that mode will be selected regardless of which mode is defined in the data entry box. If the preselected Scan Mode does not exist in the RDX datafile, then a Scan Mode prompt screen will display a list of available Scan Modes.

Meisei Data.

Enter elevation value for soundings with no elevation header data - use as needed.
Extrapolate surface data if surface values do not exist. Creates pressure, temperature, and wind data.

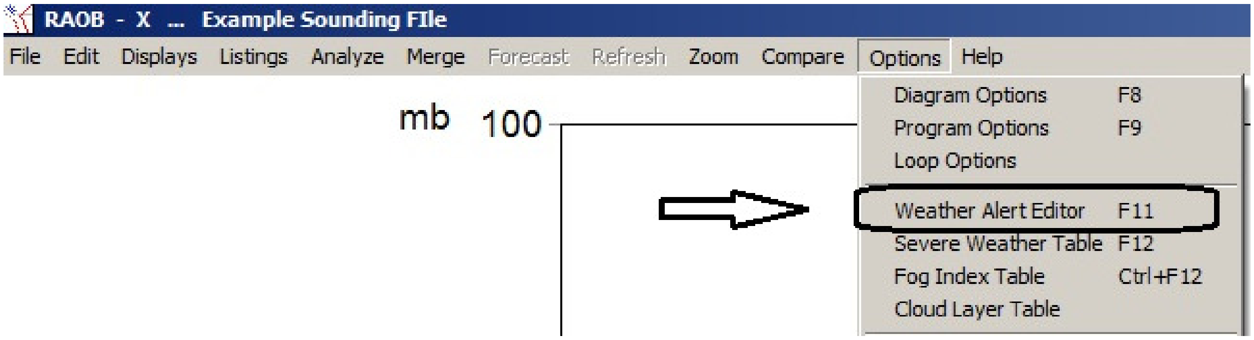
Sodar / Lidar / Radar Temperature & Wind Data.

If surface temperature is missing, isothermally extrapolate surface data. The corresponding surface temperature will be the same as the 1^{st} (lowest elevation) temperature found on the sounding profile.

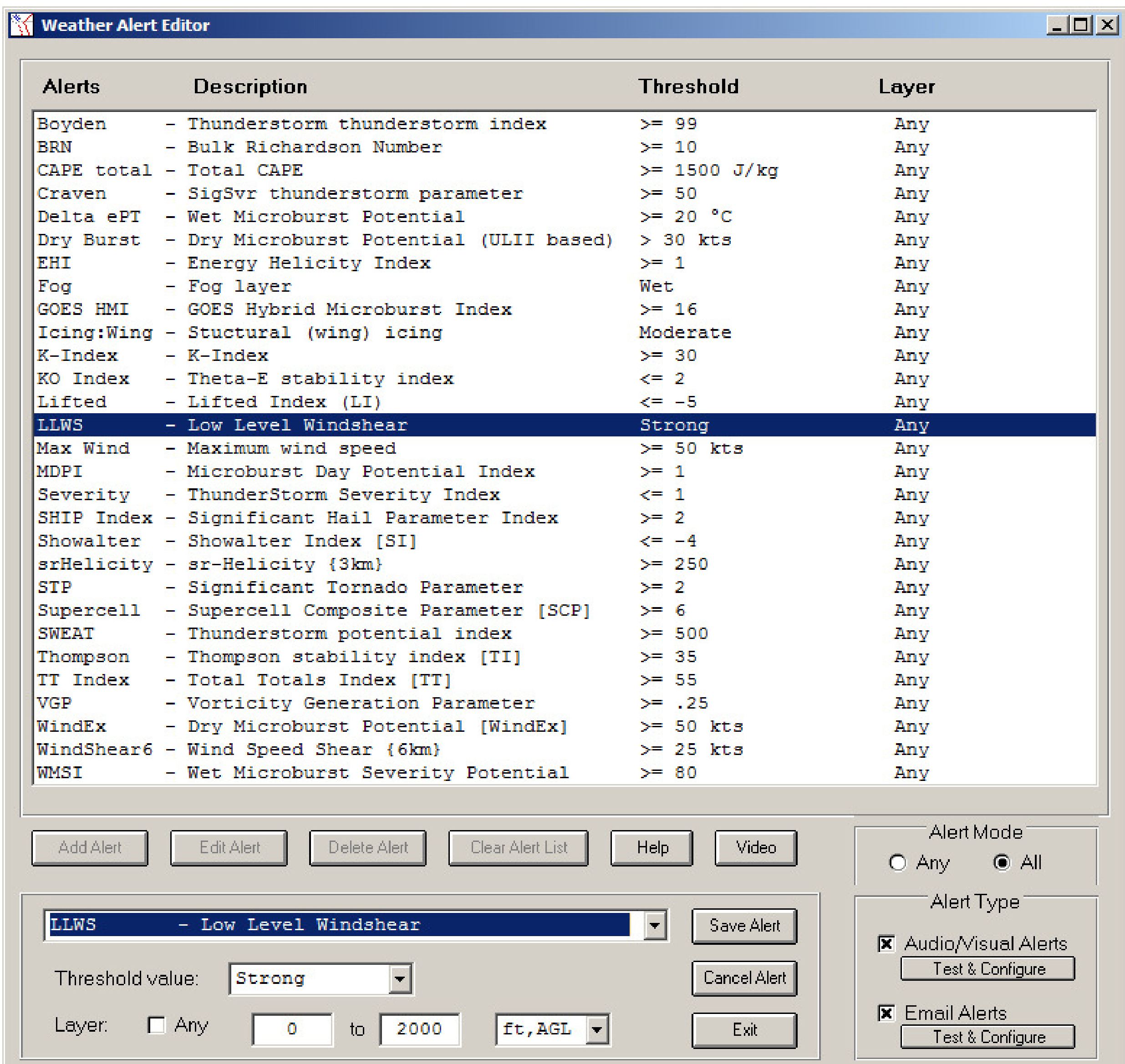
If the surface wind is missing... Then RAOB adds a surface wind level. The surface wind speed is reduced by the user defined percentage (%) of the lowest wind found. The wind direction remains the same. If the wind profile contains a vertical wind component (W), then that value is set to zero (0).

Interpolate wind data for levels missing values. This will interpolate wind data for those data levels where wind data is missing. *This currently only functions for DeTect radar wind profiles.*

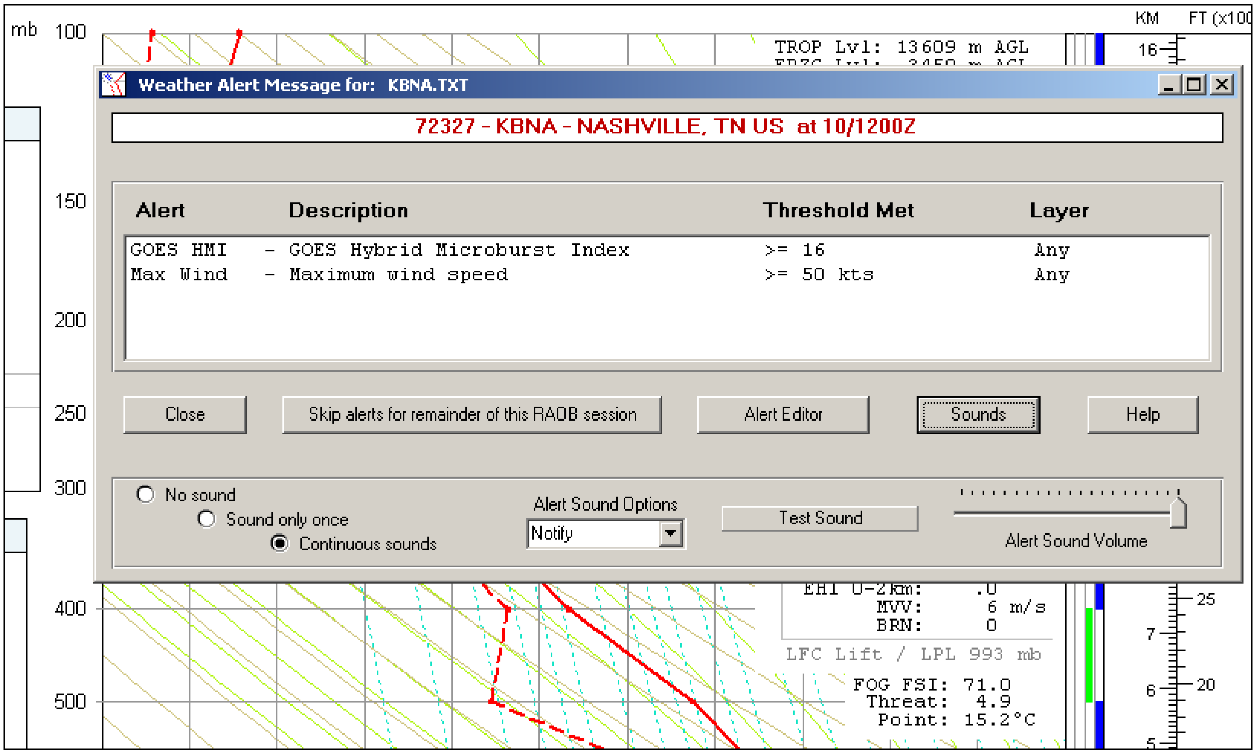
7. **Weather Alert Editor**. (Available with the optional Analytic Module.)



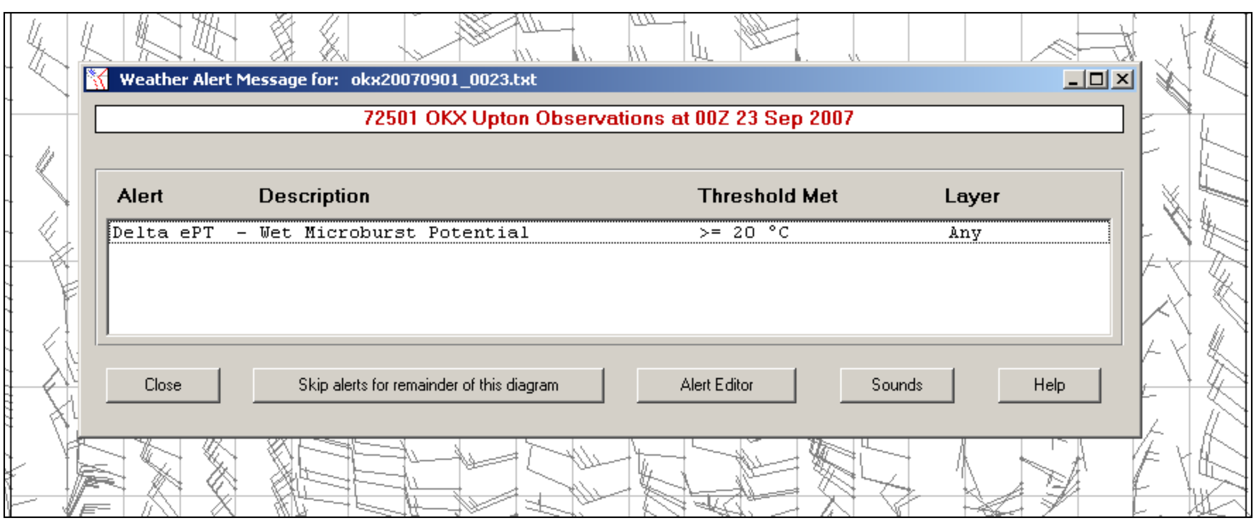
The below Weather Alert Editor example shows all currently available alert options. The user can specify a minimum threshold value for each alert. In some cases, such as for LLWS and Fog, a specific layer can also be specified. LLWS is being edited in the below example image. More options are planned.



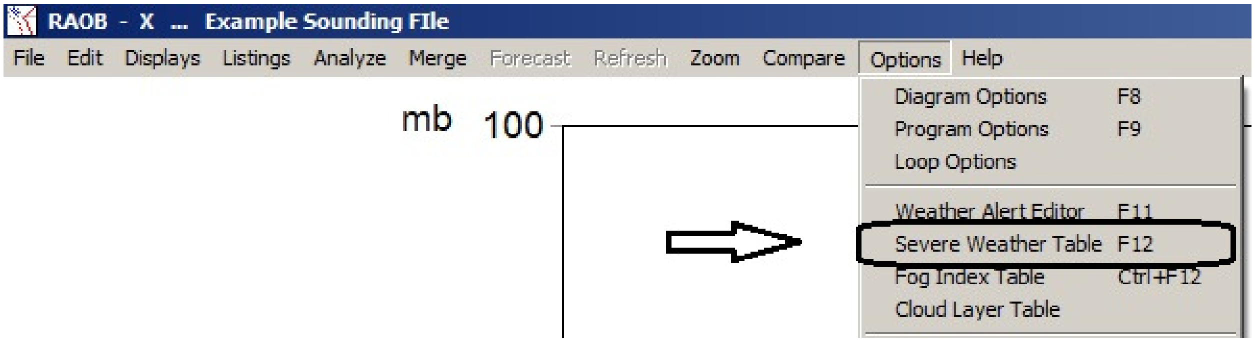
Below is an example Skew-T sounding with the weather alert pop-up display. From all the alert options selected on the opposite page, only two alerts reached threshold values for this example sounding. When the pop-up display is presented, the user can also select sound notification options for audio alerts (as seen below). If a sound option is selected, the sound will continue (if "continuous" is selected) until the user clicks on the pop-up display. The user can also click the "Skip" button to silence alerts for the remainder of the current RAOB session, or enter the Alert Editor to re-activate the alert mode.

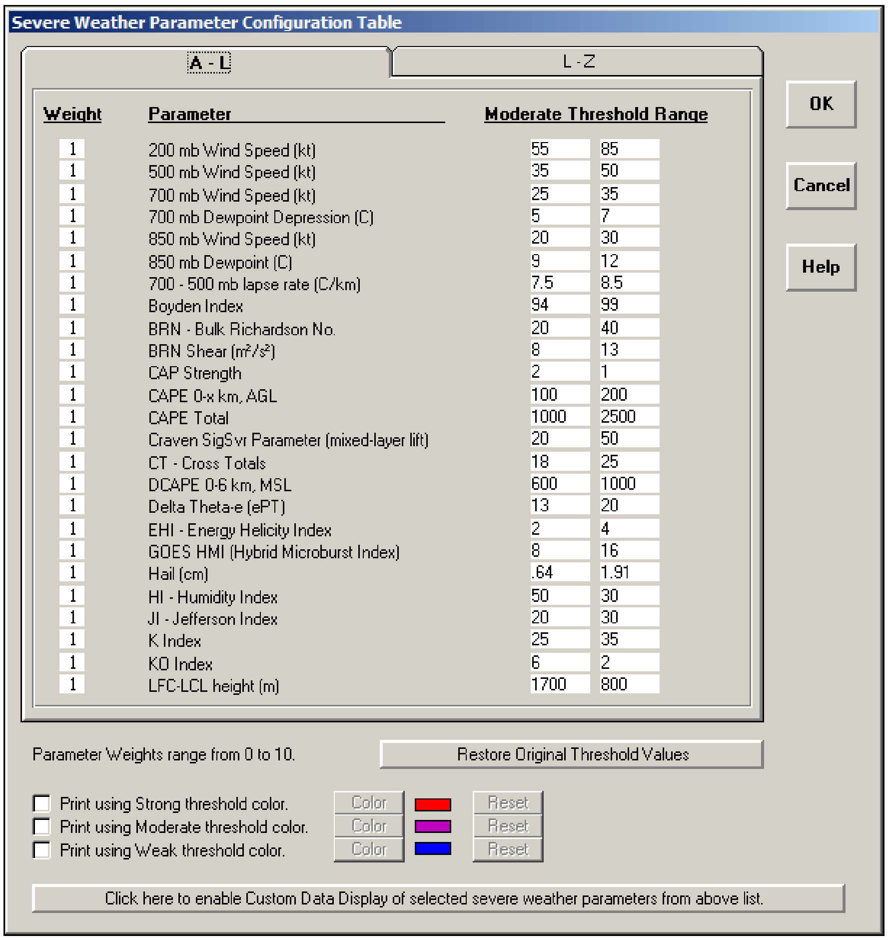


If the optional Real-Time Display module option is used (along with the optional Advanced Cross-Section module), the weather alert feature also becomes available. Below is an example of an alert pop-up as displayed on a Time-Height diagram, where the last (right-most) sounding has met threshold criteria for the displayed alert. Alert sound options are also available similar to the sounding diagram alerts.



8. **Severe Weather Parameter Table.** (Available with the optional Analytic Module.)





This table provides a quick look at a sounding's key meteorological, severe weather parameters and indices, which can be configured for local conditions. Each parameter has two configuration options: Threshold Definition and a Weighting Factor.

Displayed and printed parameters can be color-coded as defined by the user. The "Print using…" checkboxes can be used to activate color coding of parameter data. Use the "Color" buttons to define colors and the "Reset" buttons to restore the original default colors.

<u>Threshold Definition</u>. Severe weather tables are typically designed to list each parameter with respect to 3 categories (weak, moderate, strong) as defined by threshold values. RAOB allows the user to specify these threshold values for each parameter. This is accomplished by defining the lower and upper data thresholds for the "Moderate" category, where data values less than the lower threshold will result in a Weak category and data greater than the upper threshold will result in a Strong category. The RAOB program is distributed with default threshold values, which are typically valid for either the central U.S. or for the specific geographical region where the parameter was developed. Through this configuration menu option, parameter thresholds can be modified to better reflect data ranges that are significant to the user's local area of interest. The default threshold values can be restored at any time using the "Restore" button at the bottom of the display page.

Weighting Factors. RAOB also allows the user to assign weighting factors for each parameter. Assigned weights can range from 0 to 10. Default weights are set at 1 for all parameters. This weighting option is especially useful for selectively eliminating table parameters of little or no significance to a local area of interest. This is accomplished by assigning a weighting factor of 0 (zero). Once a weight of 0 is assigned, that parameter will not be listed on the output table. Weighting factors greater than 1 will cause RAOB to increase the parameter's relative significance with respect to the other parameters. For example, if all parameters were equally weighted with ones (1), and only 5 parameters had data values in the Strong category, then the total count for the Strong category would be 5. However, if the first parameter had a weight of 2 and the second had a weight of 3, then the total count for the Strong category would be 8 or (2 + 3 + 1 + 1 + 1 = 8). Weighting factors higher than a value of 1 should normally be used for parameters statistically proven to be relatively more significant than the other parameters.

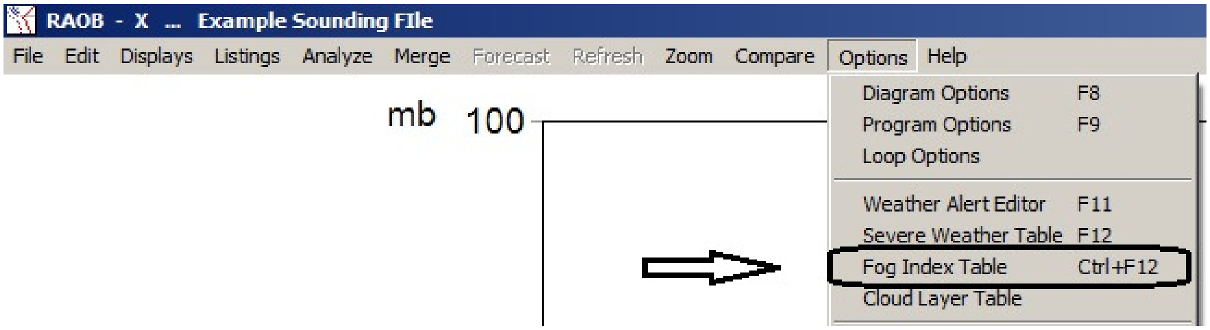
Below is an example of the resulting application of how the Severe Weather Parameters are processed for display. The example display is presented for viewing by selecting the "Listings" menu option (or by pressing the keyboard's SpaceBar). The Listings display (explained in greater detail earlier in this manual) example below presents the "Severe Weather" tab, which shows the Severe Weather Parameter results. For each parameter, the Weight, Parameter Name, and Threshold value (for Weak, Moderate, or Strong) is displayed. Each threshold column is totaled at the bottom of the display.

r:\raob\raobdata\CAPE.RAW ... AMA - AMARILLO, TX

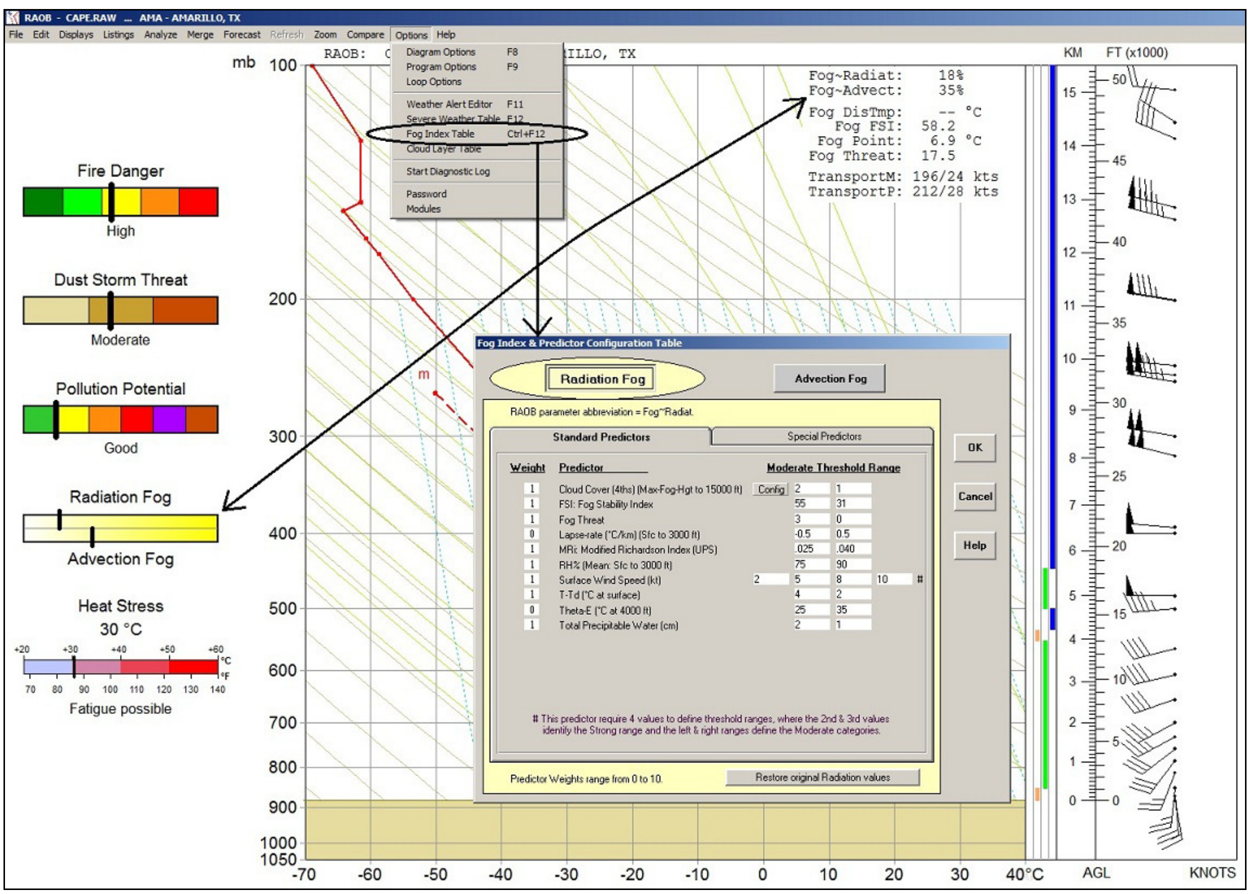
Summary Listing | Complete Listing | Interval Listing | Data Analyses | Severe Weather | Compare Indices | CAPE Listing | Storm Table

Weight	Parameter	Weak	Moderate	Strong
1	200 mb Wind Speed (kt)			85
1	500 mb Wind Speed (kt)		44	
1	700 mb Wind Speed (kt)		35	
1	700 mb Dewpoint Depression (C)			10.0
1	850 mb Wind Speed (kt)		23	
1	850 mb Dewpoint (C)			16.0
1	700 - 500 mb lapse rate (C/km)	-8.2		
1	Boyden Index			111.6
1	BRN - Bulk Richardson No.		21	
1	BRN Shear (m^2/s^2)			155.3
1	CAP Strength	2.6		
1	CAPE 0-3 km, AGL			
1	CAPE Total			3231
1	Craven SigSvr Parameter (mixed-layer lift)			n/a
1	CT - Cross Totals			25.5
1	DCAPE 6.0 km, AGL			1289
1	Delta Theta-e (ePT)			30.5
1	EHI - Energy Helicity Index			6.0
1	GOES HMI (Hybrid Microburst Index)		8	
1	Hail (cm)		0.64	
1	HI - Humidity Index		30.0	
1	JI - Jefferson Index			35
1	K Index			40.5
1	KO Index			-23.5
1	LFC-LCL height (m)			647
1	LFC - Level of Free Convection (mb)		701	
1	LI - Lifted Index			-9.0
1	MDPI - Microburst Day Potential Index			1.1
1	NCAPE (Normalized CAPE)			0.30
1	S Index			50.0
1	SCP - Supercell Composite Parameter			42.2
1	Severity - Thunderstorm Severiry Index			0.2
1	SHIP - Significant Hail Parameter			2.2
1	SI - Showalter Index			-8.0
1	srH - storm-relative Helicity (0-3 km)			330
1	STP - Significant Tornado Parameter		1.1	
1	Surface Dewpoint (C)		16.6	
1	SWEAT Index			650.1
1	T2 Gust (kt)			51
1	TI - Thompson Index			50
1	TQ Index			20
1	TT - Total Totals			60.0
1	VGP - Vorticity Generation Parameter			0.438
1	VT - Vertical Totals			34.5
1	Waterspout Index	14		
1	WBZ - WetBulb Zero Hgt (ft,AGL)		10126	
1	Windex (kt)			64
1	WMSI - Wet Microburst Severity Index			101
	Weighted Category Totals:	3	11	32

9. **Fog Index Table.** (Available with the optional Analytic Module.)

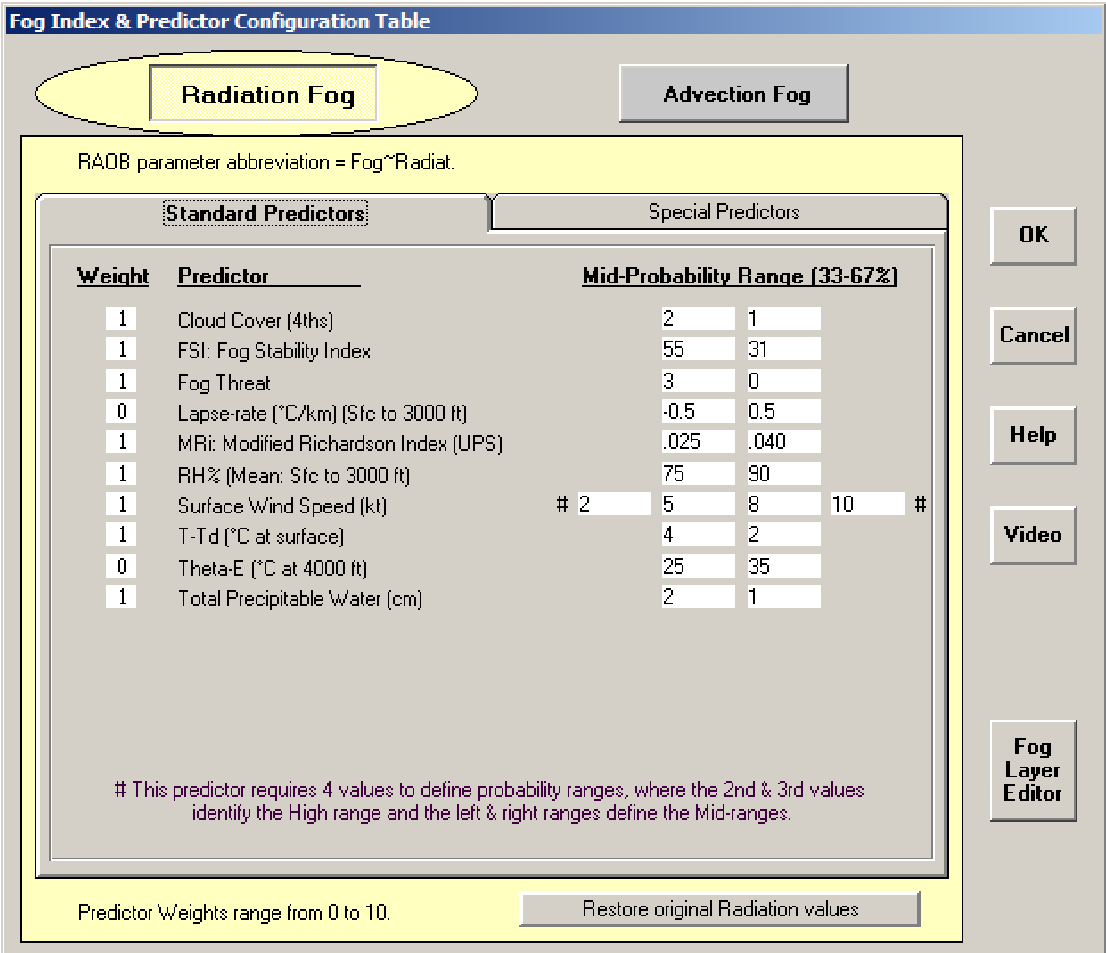


The Fog Index & Predictor Configuration Table provides an easy method to configure a sounding's key parameters and indices which help predict fog occurrence. RAOB uses this table's configuration settings to produce the Fog~Radiat & Fog~Advect parameters as fog predictors for Radiation and Advection fogs, respectively. These 2 parameters can be displayed on the Sounding diagram as seen below. By using the Custom Data Displays listing option (also seen below), both fog types can be plotted on the Cross-Section, Time-Section, or Custom View meteograms. The RAOB fog table permits individual configuration options for Radiation and Advection fogs. Each fog predictor has 2 configuration options: a Weighting Factor and Probability Ranges, which are explained in detail on the next 2 pages.



Example "Fire & Air-Quality" screen display showing graphic and text Fog displays.

Fog Index & Predictor Configuration Table (the Standard Predictors)



Weighting Factors. Each predictor can be assigned a weight from zero to ten (0 - 10). The default value is one, but non-global predictors are initially set to zero, where a zero value eliminates the parameter from table summaries. Values greater than one add more relative weight to predictors that are more significant.

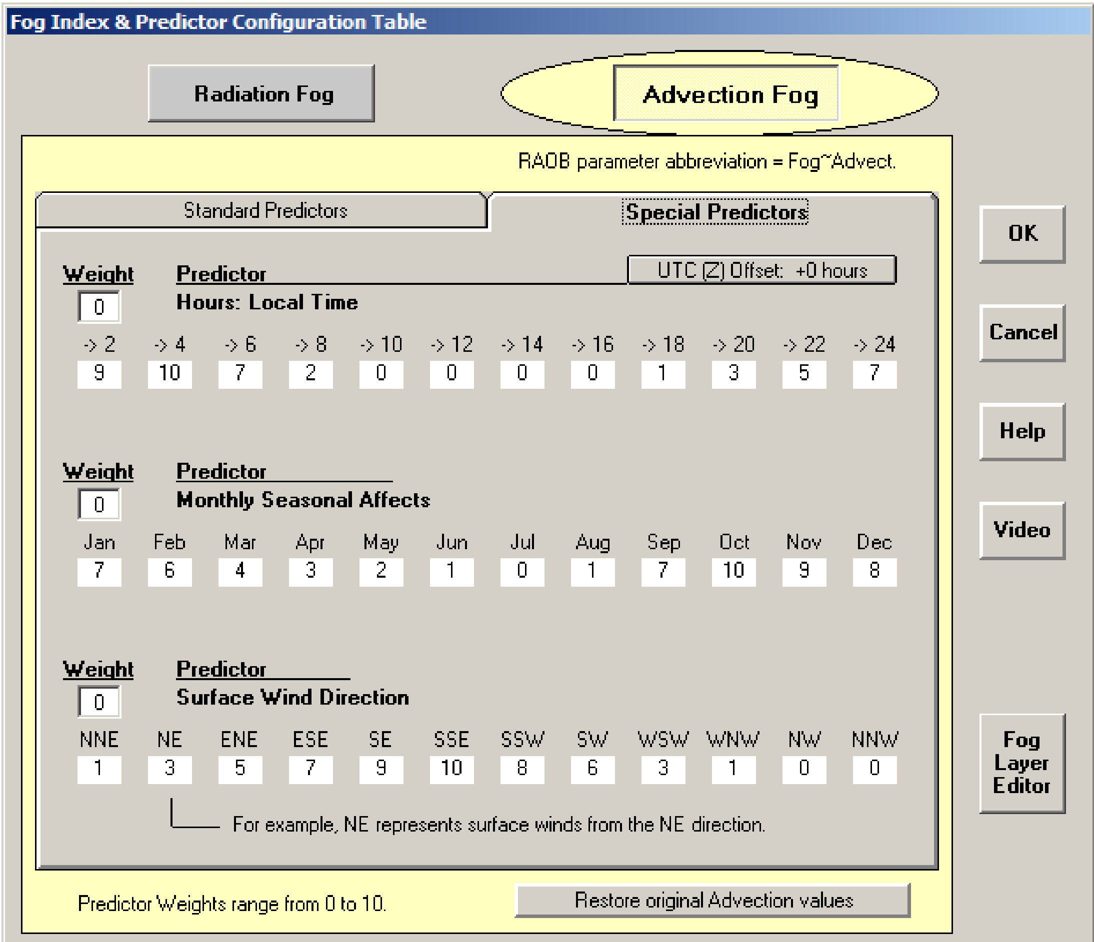
Probability Ranges. Fog probability ranges are defined with respect to 3 levels of significance: Low, Mid, and High. RAOB allows the user to define the lower & upper limits of the "Mid" probability range, thereby permitting automatic definition of the remaining "Low" and "High" probability ranges. The default values are typically valid for the eastern U.S. region, but all values should be modified to reflect local conditions.

The "Cloud Cover" predictor is unique because it only uses 4 categories for cloud cover (0=clear, 1=few, 2=scattered, 3=broken, and 4=overcast). These values are automatically determined from RAOB's internal cloud algorithms (unless manually entered via the Cloud Layer Table).

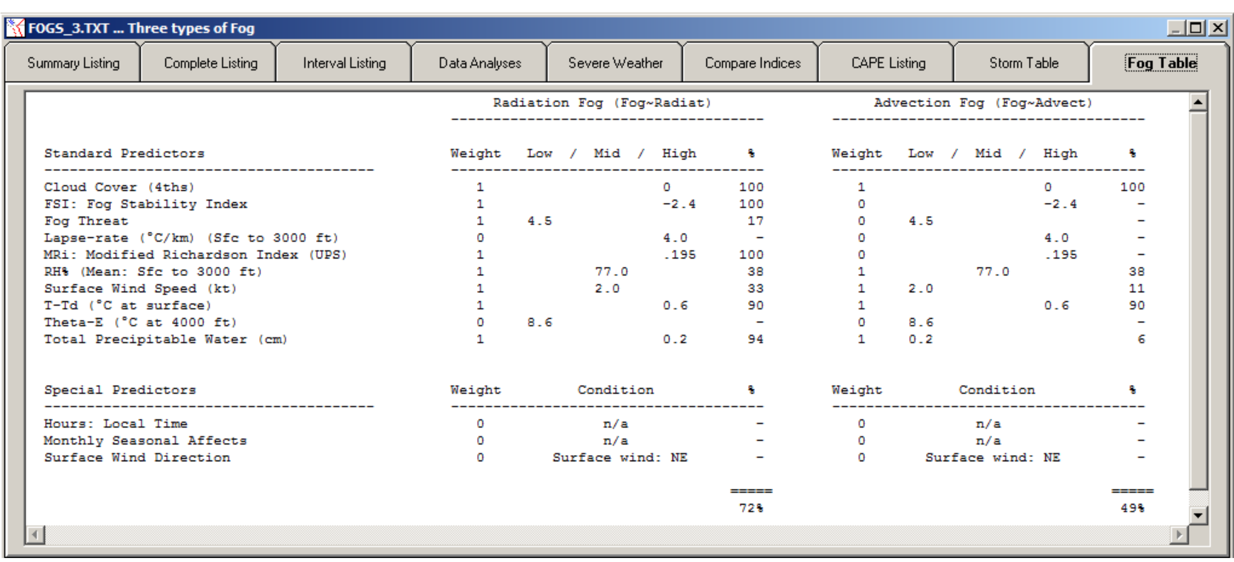
It is important that the sequence of the Mid (left & right) probability values be correct. For example, increasing numbers indicate that the parameter potential increases with bigger values (like RH%), whereas decreasing numbers indicate that the parameter potential increases with smaller values (like T-Td). Note that the "Total Precipitable Water" (TPW) predictor uses opposite trends, because larger TPW values favor advection fogs while smaller TPW values favor radiation fogs.

For parameters that have double-sided limits (such as the "Surface Wind Speed"), two additional probability values are needed to accurately define probability boundary values. In these cases, the first two and the last two values define the "mid" ranges, while the middle two values define the "high" range.

The Special Predictors. The "Special Predictors" are initially set to a weight of zero, because they are most sensitive to local conditions and can not be easily configured to reflect global conditions. These "Special" predictors must be individually configured to reflect local conditions.



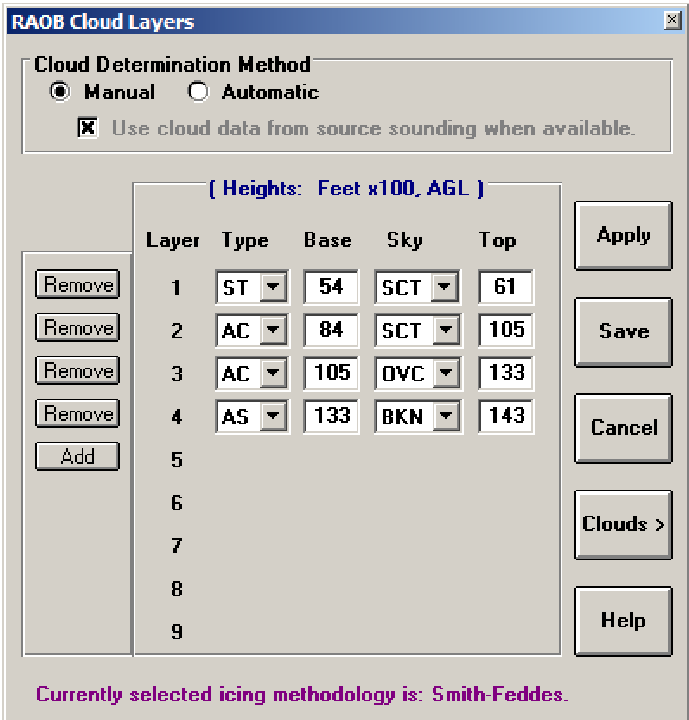
The below **Fog Table** example shows how all data can be displayed as text with the Listing Menu option.



	Radiation Fog (Fog~Radiat)					Advection Fog (Fog~Advect)				
Standard Predictors	Weight	Low	Mid	High	%	Weight	Low	Mid	High	%
Cloud Cover (4ths)	1			0	100	1			0	100
FSI: Fog Stability Index	1			-2.4	100	0			-2.4	-
Fog Threat	1	4.5			17	0	4.5			-
Lapse-rate (°C/km) (Sfc to 3000 ft)	0			4.0	-	0			4.0	-
MRi: Modified Richardson Index (UPS)	1			.195	100	0			.195	-
RH% (Mean: Sfc to 3000 ft)	1		77.0		38	1		77.0		38
Surface Wind Speed (kt)	1		2.0		33	1	2.0			11
T-Td (°C at surface)	1			0.6	90	1			0.6	90
Theta-E (°C at 4000 ft)	0	8.6			-	0	8.6			-
Total Precipitable Water (cm)	1			0.2	94	1	0.2			6

Special Predictors	Weight	Condition	%	Weight	Condition	%
Hours: Local Time	0	n/a	-	0	n/a	-
Monthly Seasonal Affects	0	n/a	-	0	n/a	-
Surface Wind Direction	0	Surface wind: NE	-	0	Surface wind: NE	-
			=====			=====
			72%			49%

10. **Cloud Layer Table**. (Available with the optional Analytic Module.)



Cloud layer and precipitation data are required for the Smith-Feddes (but not the USAF or the AFGWC) icing methodologies. Cloud data are always automatically generated by RAOB for all newly displayed soundings, unless the user specifies cloud layers through this manual input form.

For optimum accuracy with icing and lightning analyses, manual input of known cloud layers is essential.

← Clouds. Toggle this button to display typical cloud layer heights, which are useful when manually entering cloud layer data.

Cloud Determination Method.

Manual. The above image shows the "Manual" method, where the user can "Add" and "Remove" layers as needed. This method is highly recommended for those needing to precisely study cloud layers and associated icing conditions and other related atmospheric parameters. This method is normally used when cloud layer data is available form other independent sources.

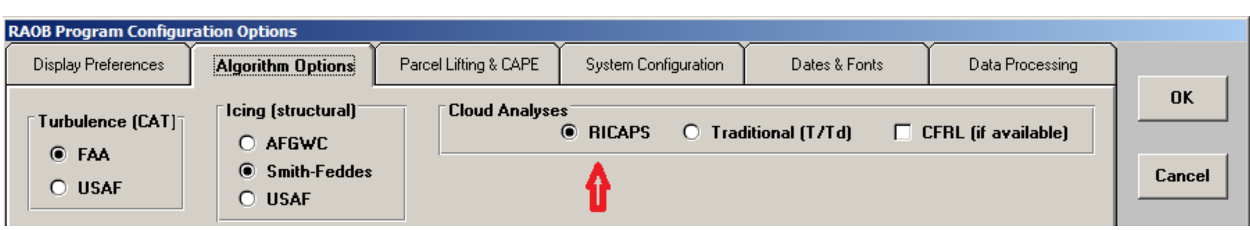
Automatic. During automatic cloud generation, RAOB only determines basic cloud types from the sounding's data profile. RAOB uses 2 methods of determining cloud coverage: Traditional and RICAPS...

1. Traditional Method. This is done using this simple temperature-dewpoint spread algorithm.

Few:	if T/Td spread <= 5 °C
Scattered:	if T/Td spread <= 3 °C
Broken:	if T/Td spread <= 1.6 °C
Overcast:	if T/Td spread <= 0.6 °C

Stratiform if lapse rate is <= 1.8 °C/1000 feet, or else the cloud is Cumuliform.

2. RICAPS Method. The RICAPS method is superior to the Traditional method since it uses a sophisticated series of bottom-up scanning processes to identify cloud layers. RICAPS is activated from the Program Options configuration panel's "Algorithm Options" Tab as seen below.



11. **DATA DECODERS**.

All data (except BUFR, GRIB, and netCDF) must be in the standard ASCII (or human readable) format. RAOB can read data files containing single or multiple soundings per file (depending on the data type). If a data file contains multiple soundings, then a sorted list of available soundings is presented from which the user can easily select the desired sounding for processing. RAOB can automatically read and decode rawinsonde data from just about any source and format. Since there are always new sounding formats being generated worldwide, please let ERS know of any new or changed formats, as we will do our best to accommodate these changes as quickly as possible. In some cases, new decoders can be developed and be made ready for download within 24 hours.

11.1 Basic Module Decoders. The following 6 data decoders are available to the RAOB Basic module.

11.1.1 CSV Data. This format is unique to the RAOB program. This is a very popular format that allows users a great variety of data input options. It is a spreadsheet style (comma-separated value) format that currently allows up to 30,000 data levels per sounding and allows any combination of temperature, wind, and ozone data. This format also accepts vertical wind component (W) data, BUFKIT's Omega & CFRL data, Radiometric's Vapor Density & Liquid Water data, and other user-defined data elements. An example of the CSV format is listed at the end of this manual. The CSV format has an optional WMO identifier field. If this field is used and if the same WMO number is listed in the RAOB.STN locator file, then the other optional fields (latitude, longitude, and elevation) are not necessary since this data will be automatically pulled from the station locator file. Likewise, if the same WMO number is listed in the RAOB.MTN parameter file (and if the optional Mountain-Wave Module is used), then associated mountain parameters will be automatically used for all mountain-wave analyses.

11.1.2 Raw Data. The Raw data format is RAOB's indigenous format. All data accessed for processing by RAOB are first converted to this Raw format for all internal processing purposes. Raw data are organized into two data groups, the Pressure/Temperature and Height/Wind groups. The raw data format is the simplest and easiest to work with. Raw data allow greater definition and accuracy of sounding data. For example, raw data often contain pressures that are reported to the tenth of a millibar, all temperature and dew points are both reported to tenths of a degree, and all wind directions are reported to the nearest degree. Users will find it much easier to edit a sounding after it is converted to the Raw format. Once in the Raw format, it becomes very easy to insert or remove data levels. For a detailed description of the Raw data format, please see the RAW DATA FORMAT Section. Note that NCDC refers to this Raw data as 'edited' data, since it undergoes quality control processing and editing before archiving; but RAOB always refers to this form of data as 'raw' data. Note that each raw data file can only contain one sounding.

11.1.3 WMO Coded Data. RAOB can decode all standard code groups. Each group should end with either the *equal sign* (=) or *semicolon* (;) character. Most commercially available WMO coded data can be decoded and processed by RAOB. See the DATA SOURCES Section for a partial list of data sources. RAOB also decodes SHIP and LAND MOBILE (often coded as MOBIL) data and displays site location (lat & long) in the header information line. RAOB can also decode WMO coded Dropsonde data. Below are listed the standard WMO data types ...

Surface to 100 mb	TTAA – Combined temperature & wind data TTBB – Temperature data only (including 21212 & 51515 wind data) PPAA – Wind data with respect to standard pressure levels PPBB – Wind data only
Above 100 mb	TTCC – similar to the TTAA data format TTDD – similar to the TTBB data format PPCC – similar to the PPAA data format PPDD – similar to the PPBB data format
RAOB also processes	- SHIP (UUAA...) - LAND-MOBILE (IIAA...) - DROP-SONDE (XXAA... hurricane eye data)

- **TTAA** -- contains lower atmosphere (below 100 mb) mandatory level data that normally arrives within an hour after observation. These data give height, temperature, dewpoint, wind directions and speed data for set pressure levels: surface, 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150 and 100 millibars plus tropopause and maximum wind level data.

- **TTCC** -- contains upper atmosphere (above 100 mb) mandatory level data which arrives shortly after the TTAA data. These data give height, temperature, dewpoint, wind directions and speed data for set pressure levels: 70, 50, 30, 20 and 10 millibars

- **TTBB** -- contains lower atmosphere significant level data. Significant level data contain temperature and dewpoint information at pressure levels other than the mandatory levels where significant changes in the temperature and dewpoint profiles occur.

- **TTDD** -- contains upper atmosphere significant level data. Significant level data contain temperature and dewpoint information at pressure levels other than the mandatory levels where significant changes in the temperature and dewpoint profiles occur.

- **PPAA --** contains lower atmosphere mandatory level wind information. This information is included in the TTAA data but some stations only report wind data and thus the PPAA is more appropriate.

- **PPCC --** contains upper atmosphere mandatory level wind information. This information is included in the TTCC reports, but like the PPAA data, it is for stations that only report winds.

- **PPBB --** contains lower atmosphere (below 50,000 feet) significant wind data with respect to heights. These data only contain wind direction and speed information at heights in between mandatory levels reported at even multiples of 1000 feet.

- **PPDD** -- contains upper atmosphere (above 50,000 feet) significant wind data with respect to heights. These data only contain wind direction and speed information at heights in between mandatory levels reported at even multiples of 1000 feet.

11.1.4 SHARP Modified Data. RAOB will read and process data files created by the popular SHARP (Skew-T and Hodograph) program. RAOB locates the ICAO identifier from the SHARP data file for correlation with the RAOB.STN locator file, from which the station name and latitude/longitude information are retrieved. However, since the Modified SHARP file also contains the station elevation, RAOB uses this value instead of the value in the RAOB.STN file. If necessary, the user can manually modify this value using RAOB's data edit (F3 or F4) capabilities. NSHARP and NSHARP2 data can also be processed by RAOB.

11.1.5 BUFKIT Data. BUFKIT data files contain hourly sequential sounding data for selected stations, which can be looped for visual analyses purposes. RAOB also processes BUFKIT’s Omega (vertical motion) data and the CFRL (cloud coverage) data – of which both can be accommodated in RAOB’s CSV data format. Note: BUFKIT is a forecast profile visualization program developed by NWS staff from Buffalo, NY and Norman, OK. RAOB can process NAM, NAMM, GFS3, and RUC data formats. RAOB also processes BUFKIT’s SREF Member data.

11.1.6 University of Wyoming Data (UWYO). Due to its popularity, RAOB contains a special decoder for these unique datasets. UWYO data files can contain multiple soundings, which RAOB can process.

NOTE: The RAOB Lite program only contains the WMO and BUFKIT data decoders.

11.2 Special Decoders Module. The following data decoders are available with this optional module.

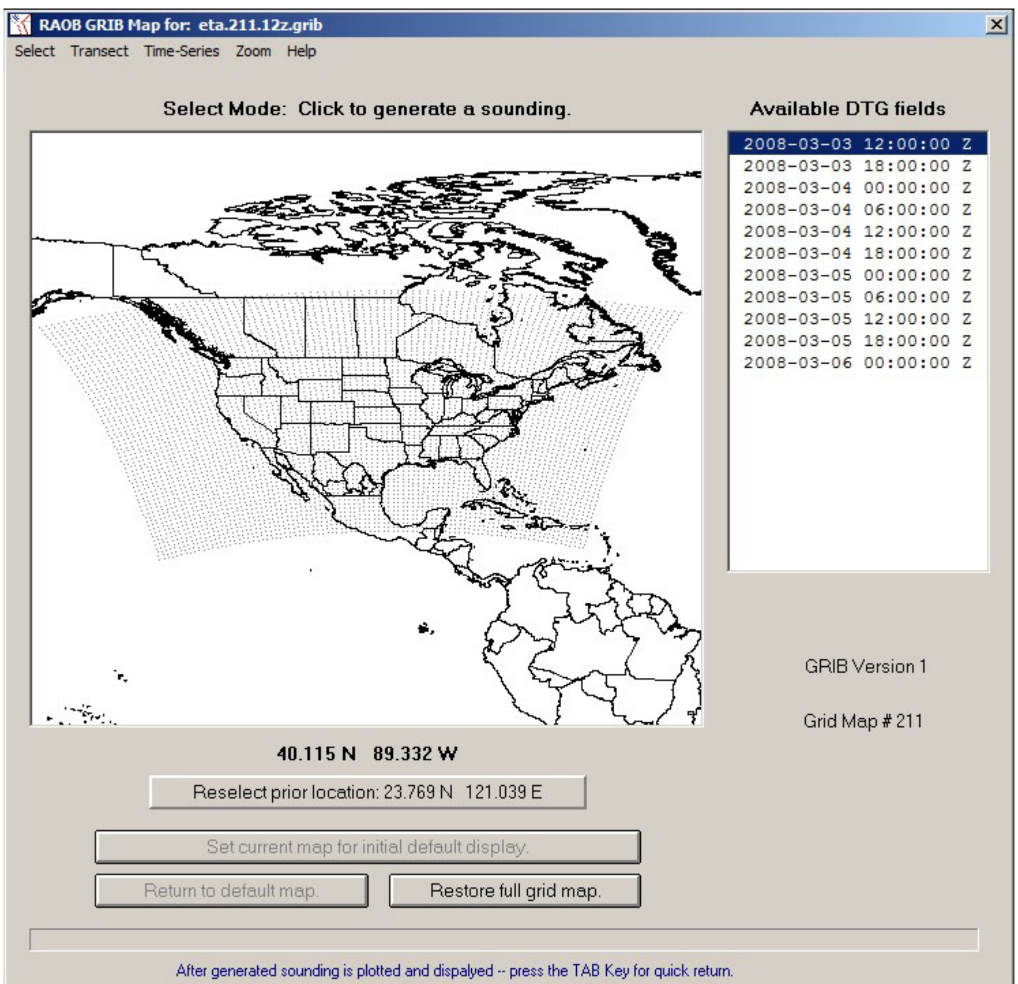
ACARS/AMDAR. Aircraft Communication Addressing and Reporting.
ACTA. Contains multi-sounding, time-series data of standard vertical resolution.
BOM. This data is produced by Australia's Bureau of Meteorology.
Canadian. Forecast soundings in the "ObsTephi" format.
Catalonia. Files contain high-density, single profile sounding data.
CLIMAT TEMP and Surface Layer CLIMAT monthly profiles.
CLASS/NCAR. Data apparently has very little quality control before its dissemination.
ENSCI. High-density Ozonesonde data; produced by the ENSCI Corporation.
FSL/NCDC. Forecast Systems Laboratory (FSL) at Boulder, Colorado.
German. Singe sounding files produced by the German weather service.
GRAW. Produced by GRAW, each file contains a single, high-density sounding.
GSD. Produced by FSL, Global Systems Division (GSD) data.
GTS1. Chinese radiosonde data.
HiDensity. A unique, columnar data format containing one high-density sounding.
IGRA. Integrated Global Radiosonde Archive (IGRA) data is produced by NCDC.
InterMet (IMET). Produced by the International Met Systems company.
KMA. Korea Meteorological Administration (KMA) data from the South Korean weather services.
Komoline / KEPL. From the Komoline Electronics Private Limited (KEPL) company in India.
Lockheed Martin. This data contains either temperature (PTU) data or wind (Dir & Spd) data.
MAPS. Mesoscale Analysis and Prediction System (MAPS) from NOAA's FSL offices.
Meisei. From the Meisei Electric Company: RS-06, SNJ, CSV formats.
Meteociel Data. French model forecast sounding format.
Meteomodem. French radiosonde (M10) data.
MeteoSwiss™.
NCAR / 4DWX. From NCAR's Four-Dimensional Weather (4DWX) System.
NCDC CARDS/GTS. From the National Climatic Data Center (NCDC) at Asheville, NC.
NCDC UA. This data contains the sounding's original WMO coded (TTAA, TTBB, etc) data.
NOAA / FSL Forecast Soundings.
NOAA / READY Forecast and non-forecast Data.
NUCAPS. NWS/AWIPS-derived satellite soundings.
Ogimet. Repackaged global WMO-format global sounding files.
PAOS. Program in Atmospheric and Oceanic Sciences, from the Univ of Colorado at Boulder.
Pisharoty Data. Indian sonde format.
PTU Data. PTU (or Pressure, Temperature, Humidity) data.
RUC. Rapid Update Cycle (RUC) from NOAA's FSL offices.
SH4/NASA Space Shuttle Data. Primarily used by the NASA community.
Sippican RTSO The Sippican Real-Time Serial Output (RTSO) data.
SkyProbe. A launch-your-own sounder kit from Affordable Research Technologies.
SkySonde. High-density, NOAA/GMD soundings which contain ozone data.
Tephis. Produced by the Canadian GEM regional model (15 km resolution).
TLP. From the National German Weather Service.
TwisterData.com. Tabular sounding data available only via the Internet.
Vaisala. Formats: EDT GAUS, HiRes, UMQ, EOL, RS92, RS41, and many others.
Weather Network™.
WSI™.
Wxcaster.com: Worldwide model forecast soundings.

11.3 Binary (BUFR / GRIB / netCDF) Decoders module. This is an optional decoder module.

BUFR. RAOB can process the special WMO code form FM 94 BUFR (Binary Universal Form for the Representation of meteorological data) containing various forms of binary meteorological data including sounding data. This decoder only processes the sounding data formats. This includes the unique formats produced by the United States' NWS and the NWS RUC NCEP forecast soundings. All BUFR data are automatically converted to RAOB's CSV format for display purposes. Currently, only the most common sounding data types are decoded, but if a customer encounters a BUFR sounding datafile that does not process, please notify ERS for resolution.

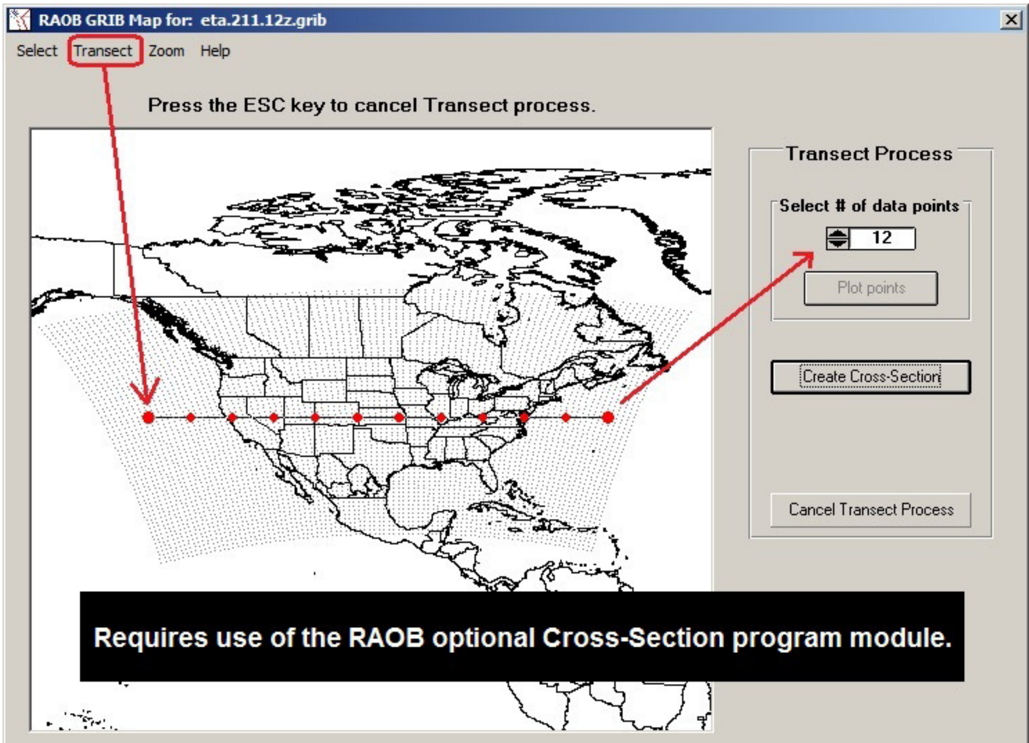
GRIB. GRIdded Binary (GRIB) data are defined by WMO FM-92 documents. RAOB can process GRIB Version 1 and 2 data, however, if Version 2 data use the 3rd party JPEG2000 data compression constructs, then RAOB can not process this data, because the JPEG2000 system uses an extremely expensive propriety data processing system. Similar to the BUFR decoded data, the decoded GRIB data are also automatically converted to RAOB's CSV format for display purposes. Currently, only the most common gridded / regional data fields are decoded, but if a customer encounters a GRIB sounding datafile that does not process, please notify ERS for resolution.

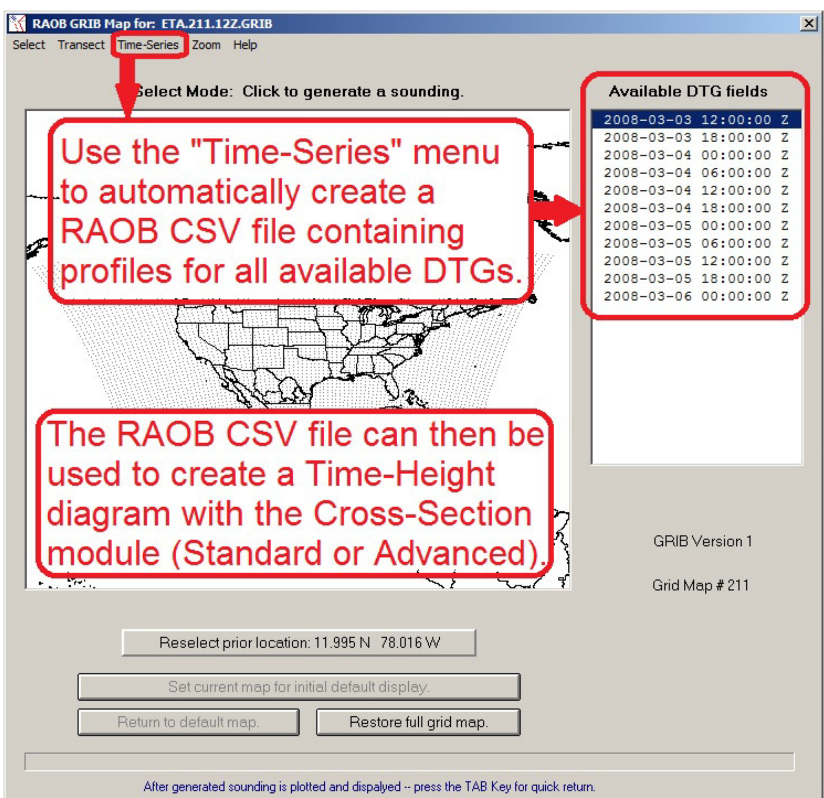
Below is a typical GRIB decoder map selector display, where the each data grid point is represented by a dot and available forecast fields are listed in the DTG fields display. Use the "Select" and "Zoom" menu options to change the mouse pointer functions. The "Reselect" button allows selection of prior locations. Use the three "map" buttons under the field map to quickly switch between desired geographic regions. The "Transect" and "Time-Series" menu options are discussed on the next page.



GRIB Decoder - Coninued...

The "Transect" menu option allows the user to draw a line across the grid map to automatically create a Cross-Section diagram, which requires access to the Standard or Advanced Cross-Section module.





netCDF. netCDF (network Common Data Form) is another form of binary data that contains data arrays in grid format, similar to GRIB data. It was developed at the Unidata Program Center in Boulder, Colorado. The netCDF decoder uses the same user display screen as seen on the prior page showing the GRIB example. RAOB uses the “ncdump” utility to retrieve sounding data for specific locations. This utility was also developed by the Unidata personnel. Currently, only the most common data fields are decoded, but if a customer encounters a netCDF datafile that does not correctly process, please notify ERS for resolution.

RAOB uses the **ncdump.exe** utility to extract netCDF data. Since this utility was developed by UCAR, the following copyright notice and disclaimer is provided below…

11.4 Sodar/Lidar/Radar Decoder module. This is an optional decoder module.

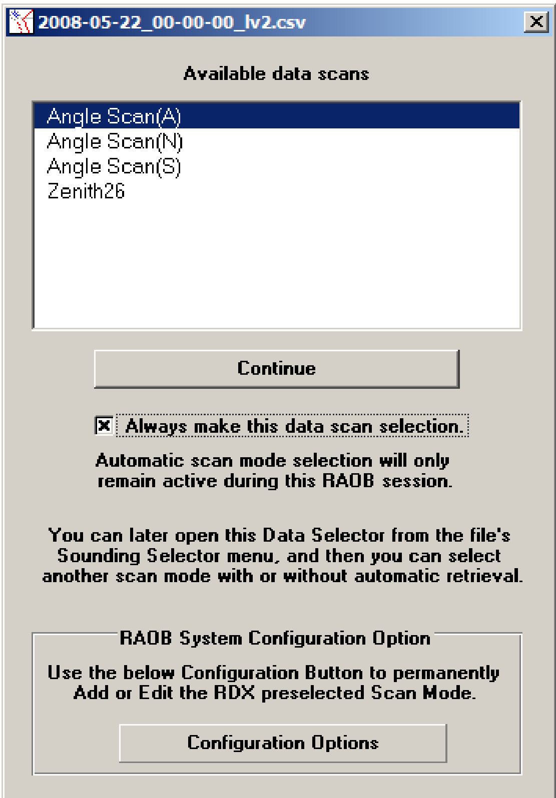
This module contains decoders for wind data that are derived from Sodar, Lidar, Radar, and various acoustic sounders – such as RASS. Many of these sensors are capable of measuring winds in three dimensions, providing U/V/W wind components. SoDAR (or Sonic Detection And Ranging) technologies are used to obtain wind data, which is typically only obtained in the boundary levels. Lidar (or Light Detection and Ranging) is a form of laser radar capable of measuring winds in the boundary levels. RASS (or Radio Acoustic Sounding System) sounding data includes temperature and wind data. The RASS radar takes advantage of the combination of two technologies, acoustic and electromagnetic, to provide a real-time temperature profile and deduce from it, with good temporal resolution, the "strength" of the temperature gradient. The RASS applies a simple principle of physics: the relationship of the speed of sound and air temperature. RASS soundings are often produced with having either temperature only or wind data only. These two complimentary soundings can be easily combined into a single sounding using RAOB’s “Merge” menu option or the AutoMerge function, that are discussed in prior sections of this manual. This module currently contains decoders for the following manufacturer / formats: AMP, Raptor (DeTect), Leosphere, Mitsubishi, CASIC, BIRM, Nexrad VWP, RemTech, Scintec, Zephit Lidar, and NASA DRWP.

11.5 Aerosol Data Decoders module. This is an optional decoder module.

This module contains decoders which can process non-conventional atmospheric parameters, such as dust, particulate matter, and other parameters of interest. This decoder is unique in that it can process atmospheric parameters without the need for associated Temperature or Wind data. The only requirements are a Station Elevation and parameter Heights. RAOB can process up to 3 different parameters for each profile. If the aerosol data is in a binary format, then the optional Binary Data Deoders module is required. Additionally, time-height diagrams can be created by using the Cross-Section module, and soundingrams can be created with the Soundingram module.

<u>11.6 Radiometer Decoder module</u>. This is an optional decoder module.

Radiometer sounding data is produced by surface-based microwave profilers. In addition to the standard temperature and moisture data, these soundings also include liquid-water and vapor-density data. Wind data are not produced. Soundings can extend to a height of about 10 km and can be produced every few seconds. The below description covers capabilities of the Standard Radiometer Decoder Module. Note that the Advanced Radiometer Decoder Module can also process 6 additional scalar parameters: Rain (yes/no), Quality Flag, Integrated Vapor & Liquid, and Cloud Base Temperature & Heights.

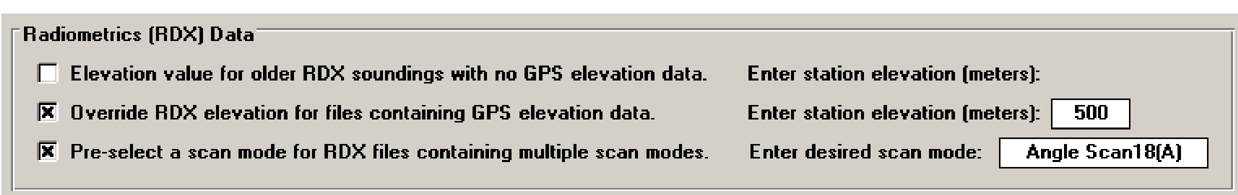


RAOB processes all available Radiometrics (RDX) data modes, including SCAN(A), SCAN(N), SCAN(S), ZENITH data, and many others. When a data file contains more than one data mode, the user is presented with the available data options (see image at left). Only one mode can be selected for processing at a time.

There is a checkbox option to **Always make this data scan selection** each time a new file is processed, but only while the current RAOB session is active. The data scan mode can be changed at any time while viewing the Data Selector screen which lists all available soundings within the datafile.

By using the **Configuration Options** button the user can configure RAOB to bypass this prompt screen and always select a particular Scan Mode for all future sessions of RAOB. Clicking this button automatically displays the Program Configuration options' "Data Processing" tab as shown below . . .

The below image shows the RDX data processing configuration options, which can be found on the Data Processing tab of the Program Options menu (or press F9). The **Override the RDX elevation** option permits manual override of GPS derived surface elevation values. The **Pre-select a scan mode** option permits selection of a specific Scan Mode, thereby bypassing the above Data Scans selection box prompt as shown in the above image. If the datafile only contains one Scan Mode, then that mode will be selected regardless of which mode is defined in the below data entry box. If the preselected Scan Mode does not exist in the RDX datafile, then the above Scan Mode prompt will be displayed.



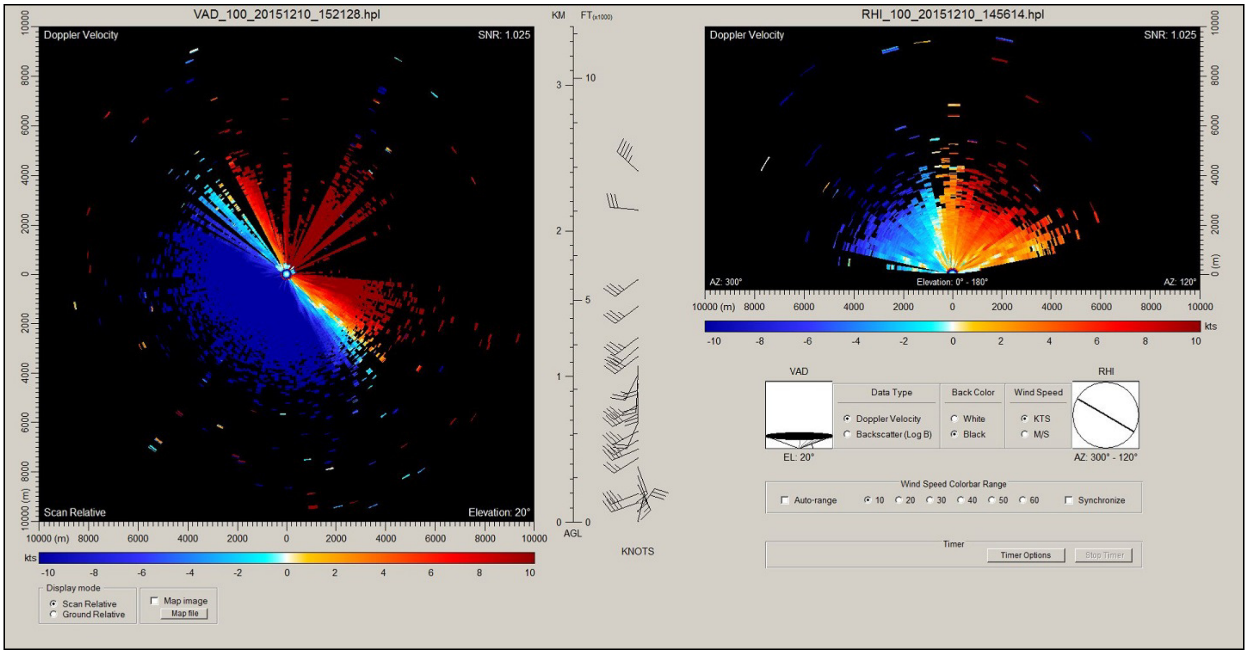
Once the data mode is selected, and if the datafile does not contain surface elevation information, the user must next manually input the elevation of the sounding site. RAOB will then process the data and plot the sounding.

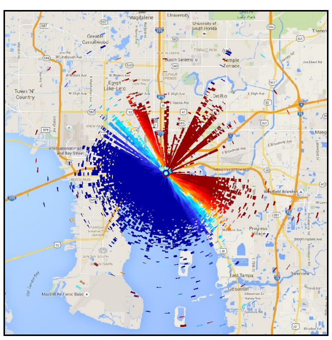
11.7 Doppler Decoder/Display module. This is an optional decoder module.

The Doppler Decoders currently process lidar-based scans from:

- Leosphere WindCube data (PPI, RHI, DBS, and FIXED time-series)
- HALO-Photonics Stream Line data (VAD, RHI, Wind-Profiles, and STARE time-series)

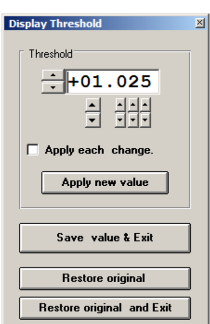
The Doppler screen is unique because it plots 3 different lidar-based images on one display: PPI/VAD, RHI, and DBS (or vertical wind plots). See example image below. In addition to a complete set of interactive screen display options, this display also includes a full menu of Batch & Timer options.





The "Map Image" option is located below the PPI display. It allows inclusion of any geographic map image to help position the scan data. See example image tot he left.

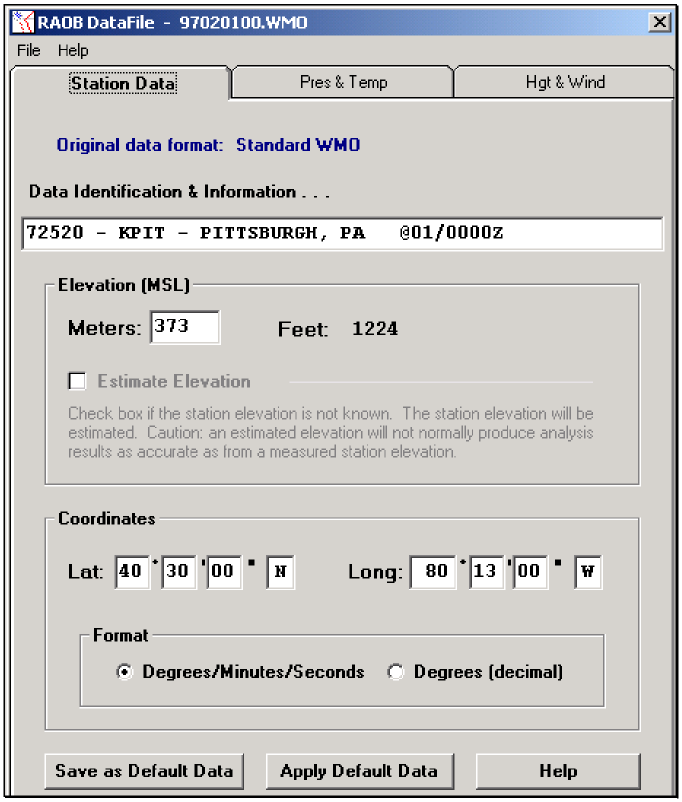
Map images can be in the BMP, GIF, or JPG format. Images should be scaled to the maximum range of the PPI / VAD scans. Images must also be square sized, or RAOB will stretch (or resize) the image to fit the PPI scan display. When an image is used, the user will be presented with a slider-bar to enable fading of the scan image to better see details of the map image.



All doppler based scan data have associated SNR (signal-to-noise ratio) or CNR (carrier-to-noise ratio) data. The SNR/CNR data can be used to selectively control which data values are displayed or ignored.

The SNR/CNR toolbar (seen to the left) is accessed via the Menu Bar, or simply by right-clicking the mouse over any display image. The user can then adjust the value to create the desired image result.

12. **DeCODED (raw) DATA EDITOR**.



Access this data editor through RAOB's EDIT menu.

All sounding data processed by RAOB can be viewed and edited using this DeCoded (or Raw) Data editor.

When RAOB reads data containing a WMO number, the RAOB.STN data file is searched for a matching WMO number. If a match is found, then the station's ICAO identifier and station name & location are automatically placed in the sounding's Identification & Information line. Additionally, if a match is found, both the elevation and coordinate data are also automatically attached to the data file for processing. For stations not listed in the RAOB.STN file and for all newly entered raw data soundings, both the elevation and coordinates must be manually entered as described next.

12.1 **Station Data**.

The Original Data Format line identifies the format of sounding data's source file. To view the source data and its original format, use the Sounding's EDIT Menu and then the SOURCE Data Editor.

The Data Identification & Information line is a free form text line available to the user. RAOB will automatically fill this line with significant information regarding the sounding, which is found from the source file or from information obtained using a WMO match from the RAOB.STN locator file. This information line is always initially displayed upon activating the Add and Edit modes. This information line is always displayed along with the sounding's filename on all screen displays and on all output products.

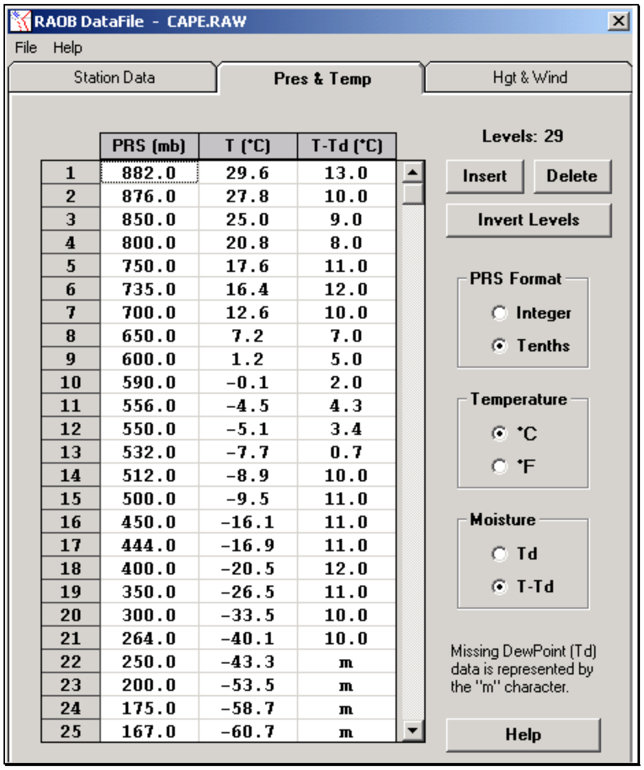
Station Elevation must be entered in Meters (MSL). Elevations below sea-level are entered using a minus sign (e.g., -20). If the elevation is not known, RAOB will then estimate the station elevation using the Pressure-Altitude method. To do this, first remove data from the Meters data box, and then click on the Estimate Elevation check box. Entry of the sounding site's surface elevation is essential for accurate data processing by RAOB's algorithms. Caution: Elevation estimation is only an approximation -- only the actual measured station elevation will produce accurate results.

Coordinates can be entered in one of two different formats:

Degrees/Minutes/Seconds - or - Decimal-Degrees.

Default Data options exist to help automate entry of new data soundings for the same location. The SAVE option records the above data, while the APPLY option pastes the saved information onto the Station Data edit form.

12.2 **Pressure & Temperature Data**.



	PRS (mb)	T (°C)	T-Td (°C)
1	882.0	29.6	13.0
2	876.0	27.8	10.0
3	850.0	25.0	9.0
4	800.0	20.8	8.0
5	750.0	17.6	11.0
6	735.0	16.4	12.0
7	700.0	12.6	10.0
8	650.0	7.2	7.0
9	600.0	1.2	5.0
10	590.0	-0.1	2.0
11	556.0	-4.5	4.3
12	550.0	-5.1	3.4
13	532.0	-7.7	0.7
14	512.0	-8.9	10.0
15	500.0	-9.5	11.0
16	450.0	-16.1	11.0
17	444.0	-16.9	11.0
18	400.0	-20.5	12.0
19	350.0	-26.5	11.0
20	300.0	-33.5	10.0
21	264.0	-40.1	10.0
22	250.0	-43.3	m
23	200.0	-53.5	m
24	175.0	-58.7	m
25	167.0	-60.7	m

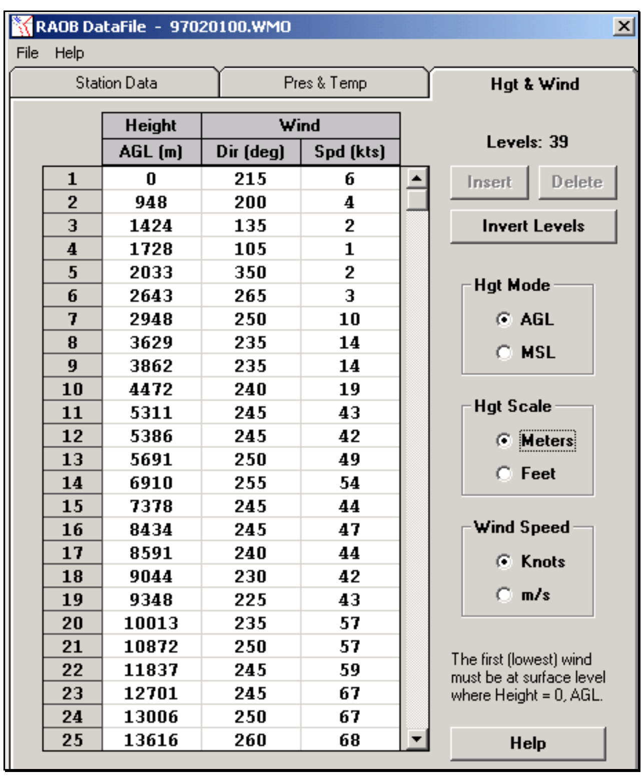
This form allows entry of pressure-level data, including temperatures and dewpoints (or dewpoint spread information). Various data options give the user maximum flexibility during data entry.

A missing dewpoint (Td) must be entered with a small "m".

New or edited data will only be recorded if the user presses the ENTER key.

RAOB continually checks data entries for vertical consistency and against standard pressure-temperature relationships.

12.3 **Height & Wind Data**.



	Height	Wind	
	AGL (m)	Dir (deg)	Spd (kts)
1	0	215	6
2	948	200	4
3	1424	135	2
4	1728	105	1
5	2033	350	2
6	2643	265	3
7	2948	250	10
8	3629	235	14
9	3862	235	14
10	4472	240	19
11	5311	245	43
12	5386	245	42
13	5691	250	49
14	6910	255	54
15	7378	245	44
16	8434	245	47
17	8591	240	44
18	9044	230	42
19	9348	225	43
20	10013	235	57
21	10872	250	57
22	11837	245	59
23	12701	245	67
24	13006	250	67
25	13616	260	68

This form allows entry of height-level data, including wind speed & wind direction. Various data options give the user maximum flexibility during data entry.

The first wind must be entered as the surface wind. Also, this wind's height must be zero (0) feet or meters (AGL) or else RAOB will display a warning message.

New or edited data will only be recorded if the user presses the ENTER key.

RAOB continually checks data entries for vertical consistency and against standard wind data relationships.

13. **DATA PROCESSING**. All sounding data processing is based on the actual data obtained from the source data file. No data interpolation or smoothing is employed, unless specifically selected by the user from various program options. However, if a key application or parameter requires a specific value, such as a 500 mb temperature, and the sounding does not have this value, then RAOB will interpolate the required data for that specific need. Logarithmic interpolations are used when processing pressure/height data. At a minimum, RAOB requires at least two levels of temperature or wind data to begin processing the sounding. If using Coded data, these data can be from either the TTAA, TTBB, or PPBB data groups. RAOB can process sounding data containing only temperature or only wind data.

13.1 Coded WMO Data. All data are processed from the surface through 1 mb, if available. In addition to processing standard data items in each TTAA, TTBB, PPAA, PPBB, TTCC, TTDD, PPCC and PPDD group, RAOB also processes TTAA's 88xxx data and TTBB's 21212 & 51515 wind data.

RAOB also detects and processes SHIP (UUAA, UUBB, etc.), LAND MOBILE (IIAA, IIBB, etc.), and Hurricane Dropsonde data (XXAA, XXBB, etc.).

RAOB also detects whether winds are reported in meters-per-second or knots.

13.2 Raw Data. This is RAOB's indigenous data format. All sounding data that is used by RAOB is first converted to this internal format for all data processing purposes. Not only is the Raw format the most basic form of sounding data, but it also reflects the structure of the sounding data as it is originally obtained via the rawinsonde equipment. This Raw data format can be easily viewed and edited by using the DeCoded Data Editor (F3).

When processing WMO Coded data, if adjacent pressure/temperature and height/wind data levels are detected within 100 feet of each other, they are combined into a single data level. This simplifies vertical integration of some key atmospheric parameters. Combined data groups not only eliminate duplicate data elements, but they also result in data levels with a complete representation of atmospheric parameters similar to the coded TTAA and TTCC standard data levels.

13.3 Data Quality Checks. Since coded rawinsonde data are quality checked prior to dissemination, RAOB does not perform validity checks. However, RAOB performs basic format checks on coded data and other data formats, and then flags the user if non-numeric data is detected. If the user manually enters data using the Raw Data Editor, RAOB performs several validity checks during data entry. For example, RAOB ensures that dew points are equal to or less than associated temperatures, and heights and winds are checked against basic range limits. When a data anomaly is detected, an ERROR message is displayed until a correction is made.

13.4 Numerical Analyses. All pressure-level heights are hydrostatically computed using the standard hypsometric equation, where the mean virtual temperature of each layer is calculated. The virtual potential temperature is used in the calculation of stability and mixing height factors. RAOB uses the hydrostatically adjusted height information to create unique height scales for each sounding, thus producing exact height readings for all pressure and height parameters.

The gravity factor (g) is adjusted for station elevation and latitude. If no coordinate information is available, then a default 45° latitude value is used. (It is therefore important to provide the sounding station's elevation and coordinates to help ensure the most accurate data processing possible.) All meteorological constants are taken from the International Meteorological Tables or the Smithsonian Meteorological Tables. Data processing algorithms are taken from several standard, reliable sources.

14. **SIGNIFICANT LEVELS**.

14.1 Lifting Condensation Level (LCL). This is the height at which a parcel of air becomes saturated when it is lifted dry-adiabatically. The LCL is typically used to identify the base of clouds from lifting due to terrain and frontal systems. The LCL for a surface parcel is found at or below the CCL.

14.2 Convective Condensation Level (CCL)*. This is the height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until condensation starts. This is typically used to identify the base of cumuliform clouds, which are normally produced from surface heating and thermal convection. By using the day's maximum surface temperature (along with the corresponding dewpoint and necessary upper-level temperature adjustments), the maximum potential instability of the day's atmosphere can be determined.

14.3 Level of Free Convection (LFC). This is the height at which a parcel of air lifted dry-adiabatically until saturated (at the LCL), then lifted moist-adiabatically thereafter would first become warmer than the surrounding air (sounding temperature profile) -- at the LFC. The parcel will then continue to rise freely above the LFC until it becomes colder than the temperature profile (surrounding air) -- at the EL (see below). The LFC is a critical component to other variables, which are dependent on how the LFC is determined. For that reason, RAOB can be configured to calculate the LFC from three different methods (see PROGRAM CONFIGURATION Section). These methods are defined with respect to the LPL (see below).

14.4 Lifted Parcel Level (LPL). Identifies the level from which parcel lifting processes begin. See PROGRAM CONFIGURATION for more information.

14.5 Equilibrium Level (EL)*. This is the height where the temperature of a buoyantly rising parcel again becomes equal to (and then cooler than) the temperature of the environment. The equilibrium level is the point in the atmosphere where the temperature of a rising parcel, following a moist adiabat, crosses back over the temperature plot/profile. Parcel lifting typically begins from either the CCL or LFC, depending on current atmospheric dynamics. Thus, ELs are usually defined as two different types, the EL resulting from convection initiated from the CCL (ccl-EL) and the EL resulting from convection initiated from the LFC (lfc-EL). The EL is commonly used to estimate the tops of convective clouds, especially thunderstorms. The user controls how the EL is calculated by choosing whether lifting occurs from the CCL or LFC. This choice is made through the program Configuration Options (Tab 3), CAPE Base Level.

14.6 Maximum Parcel Level (MPL). MPL is the level above a parcel's EL where the negative buoyant energy cancels any excess CAPE(B+) energy. MPL represents the potential height of convective cloud tops. MPL is displayed with graphics and text on the sounding diagram and as text in the Analysis data summary. Energy areas between the parcel's EL and the MPL are shaded in a light blue color. An MPL can only exist if the CAPE (B+) is greater than CIN (B-).

14.7 WetBulb Zero (WBZ) height. This is the height where the wet-bulb profile transitions from a positive to a negative temperature. The wet-bulb profile (plotted in green) can be displayed when viewing the sounding diagrams using the Analyses toolbar. WBZ data is commonly used as one of many factors in estimating hail size and severe weather potential.

14.8. Tropopauses. RAOB determines tropopause locations in accordance with the WMO definition of the 1^{st}, 2^{nd}, and 3^{rd} tropopause (if they exist), including applicable of the 3 qualifying remarks regarding short soundings, tropopauses below 500 mb, and lapse rate rules. The "first tropopause" is typically defined as the *conventional tropopause*. RAOB always determines the location of the tropopause(s), even if the sounding source file contains such information.

* The CCL and ccl-EL levels are derived from a mean mixing ratio, regardless of the selected LPL.

15. **SOUNDING INDICES**.

Sounding indices are convenient numerical indicators of atmospheric stability and other key parameters. The following indices are automatically calculated by RAOB and displayed throughout the program. These indices are also available in RAOB's Severe Weather Parameter Table. (See Sturtevant, 1995, for additional discussion of these indices and related meteorological data, including interpretation and application.) Standard severe weather threshold values are listed below. All temperatures are Celsius (°C), unless otherwise indicated.

15.1 Boyden Index. This index was developed by the British Meteorological Office to forecast the probability of frontal thunderstorms in the UK (Boyden, 63). Available documentation indicates that it forecasts correctly approximately 60 to 65 percent of the time. If the index is $\geq$94, then thunderstorms are most likely.

$$\text{Boyden Index} = \frac{\text{(1000-700mb Thickness)}}{10} - T_{700} - 200$$

where the thickness is measured in meters, and T is in Celsius.

15.2 Bulk Richardson Number (BRN). BRN is the ratio between CAPE and a wind shear vector difference (Hart & Korotky, 91).

$$BRN = CAPE / (.5 * (BRN\_SHR)^2)$$

where: BRN_SHR is the magnitude of the vector difference between the 0-6 km mean wind and the 0-500 m mean wind, where both mean winds are density weighted. The individual mean wind values are listed in the Analyses data screen display.

Note: The RAOB program also produces and evaluates the BRN Shear value, which is composed of the entire denominator of the BRN number.

15.3 CAP. CAP strength, also called the Lid Index, is determined by finding the maximum temperature difference between the environmental and the lifted parcel profiles, within the layer bounded by the lifted parcel level and the LFC. The *lifted* profile is defined by the dry adiabat below the LCL and the moist adiabat above the LCL. Note: CAP does not consider elevated convection, and it is a warm season – warm sector index. CAP is meaningless if there is zero CAPE in the troposphere. A cap of 2 degrees Celsius or greater is a good inhibitor of convection. A strong cap can hold energy down too much and thus cause thunderstorms not to break. A weak cap can cause development to occur before enough energy builds up for the cells to become severe. A median of a strong cap and a weak cap (a cap strength from 1-2°C) is generally ideal to allow enough time for energy to build and then break the cap, allowing storms to go severe and possibly tornadic.

15.4 Craven SigSvr Parameter. The product of the 100 mb Mixed-Layer CAPE (MLCAPE) and the 0-6 km magnitude of the vector difference (m/s; often referred to as "deep layer shear") accounts for the compensation between instability and shear magnitude. Units are scaled to the nearest 1000.

Craven = (mlCAPE J/Kg) * (SHR6 m/s) / 1000

15.5 Cross Totals (CT) Index. This index is commonly used as a severe weather indicator and is based on temperature and moisture data (AWS/TR 200).

$$CT = Td_{850} - T_{500}$$

CT Index	Thunderstorm Potential
< 20	Weak
20 to 28	Moderate
> 28	Strong

15.6 DCI (Deep Convective Index). The DCI (Barlow, 93) attempts to combine the properties of equivalent potential temperature (ePT) at 850 mb with instability (via the Lifted Index, LI). The DCI equation is presented below where the T and Td values reflect 850 mb temperature data:

$$DCI = T_{850} + Td_{850} - LI$$

15.7 Delta Theta-e. This parameter is displayed as “Delta ePT” within the RAOB program for consistency with other program parameters. This parameter is used to assess the potential for “wet microbursts” and is based on a study of pulse type storms during the summer over the southeastern U.S. It is derived from the difference between the theta-e at the surface and the lowest theta-e in the mid levels (Atkins and Wakimoto, 1991). RAOB defines Delta Theta-e between the surface and 300 hPa.

Delta ePT	**Wet Microburst Potential**
> 20	Likely
< 13	Unlikely

15.8 DMP Gust. Dry Microburst Potential (DMP) Gust. The DMP Gust is derived from the "Dry Microburst Potential" nomogram which is displayed on the "Severe Weather" display sounding diagram. The "gust" value is produced from an algorithm using the 700 mb T-Td spread and the Upper Level Instability Index (ULII or UI) value. UI (or ULII) is defined in AFWA TN-98/002, July 1998, page 3-25.

15.9 DMPI (Dry Microburst Potential Index). The DMPI was derived primarily by Wakimoto (1985) during the JAWS project. Even though DMPI was originally developed in the Denver, CO region, the RAOB program uniquely modifies the DMPI for the elevation of each sounding to ensure the algorithm uses the same relative height logic. Instead of using the original 700 mb and 500 mb data levels, RAOB uses 5,000 feet and 13,000 feet (AGL) data levels. This ensures DMPI results can be consistently used for any worldwide sounding, regardless of elevation differences.

$$DMPI = G + (T - Td)_{5000ft} - (T - Td)_{13000ft}$$

G = Lapse Rate (deg C km-1 -5000 ft to 13000 ft)
T = Temperature (deg. C) and Td = Dew Point Temperature (deg. C)

15.10 Energy Helicity Index (EHI). RAOB calculates the Storm-Relative Helicity (s-rH), which integrates the effects of streamwise vorticity and the storm-relative winds through the inflow layer (Woodall, 90 and Leftwich, 90). Helicity has been found to correlate strongly with the development of rotating updrafts. The correlation with tornadoes is less clear. It is an estimate of the rotation (mesocyclone) potential for the storm moving through a vertically sheared environment. The EHI is a function of the positive 0-2 km storm-relative Helicity (+s-rH) and CAPE (B+) values (LaPenta, 92).

$$EHI = (+s\text{-}rH_{2km} * CAPE) / 160{,}000$$

15.11 Flooding. RAOB's Flooding Potential index is the only flash-flood/heavy-rain metric that is completely derived from the sounding's profile. All other flooding metrics require visual identification of the sounding's structure along with evaluation of related atmospheric parameters. RAOB quantitatively combines all profile information into a single index. It has the characteristic tall-skinny CAPE profile with uniformly deep moisture profile. Other key features are cloud structure, deep warm cloud depth (WCD), and high water content.

RAOB is able to determine a sounding's CAPE-profile and cloud-structure qualities through use of its "pattern recognition" methodology. Like today's medical CT-Scan technologies, RAOB does this by first creating multiple scans of key thermodynamic data elements through the entire sounding at 1-mb intervals. Next RAOB performs numerous top-down and bottom-up interrogations to detect and then quantify key sounding structures, such as profile lapse-rates, moisture patterns, cloud layers, precipitation types, and wind relationships. Using proprietary coefficients, RAOB then combines these results with the standard WCD and water-content parameters into a single flood potential index.

15.12 Fog Stability Index (FSI). FSI was developed by USAF meteorologists for use in Germany, but can be applied to similar climates. It was introduced by the USAF publication 2WW/TN-79/008 and is designed to indicate the potential for radiation fog.

$$FSI = 4 * Ts - 2(T_{850} + TDs) + FF_{850}$$

where: Ts = Surface Temp (C)
TDs = Surface Dewpoint (C)
FF_{850} = 850mb Wind Speed (kts)

FSI	Likelihood of Radiation Fog
>55	Low
31 to 55	Moderate
<31	High

15.13 Fog Point. This value indicates the temperature at which radiation fog will form (AWS/FM-90/001). It is determined by following the saturation mixing ratio line from the dew point curve at the LCL pressure level to the surface (temperature).

15.14 Fog Threat. This value indicates the potential for radiation fog as described in AWS/FM-90/001.

$$\text{Fog Threat} = WBPT_{850} - \text{Fog Point}$$

where: $WBPT_{850}$ = 850mb wet bulb potential temperature.

Fog Threat	Likelihood of Radiation Fog
> 3	Low
0 to 3	Moderate
< 0	High

15.15 GOES HMI. The GOES Hybrid Microburst Index (HMI) is designed to detect conditions favorable for both wet and dry microbursts (Pryor, 2006), which are:

- Significant CAPE.
- A deep, dry adiabatic lapse rate layer below the cloud base.
- A dry (low theta-e) layer overlying a moist mid-tropospheric layer.

The GOES HMI algorithm is designed to sense aspects of an intermediate microburst environment by incorporating the sub-cloud temperature lapse rate (between 670 and 850 mb levels) as well as the dew point depression difference between the cloud base (670 mb) and the middle of the sub-cloud layer (850 mb). The Hybrid Microburst Index (HMI) is defined as:

$$HMI = G + (T - Td)_{850} - (T - Td)_{670}$$

Where: G is the lapse rate in degrees Celsius per kilometer from 850 to 670 mb, and T and Td are respective pressure level temperatures in degrees Celsius.

GOES HMI	Downburst risk
< 8	Downbursts Unlikely
8 - 24	Downbursts Likely
> 24	High Risk of Downbursts

15.16 Haines Index. This index was developed by Donald Haines (2000) to help forecast fire “blow up” potential. This index is a function of lower atmospheric stability and moisture content. Both parameters vary with respect to station elevation. Note: The Haines Index is also called the Lower Atmospheric Stability Index (or LASI).

Haines Index = Stability Term + Moisture Term

Elevation	Stability Term	Moisture Term
Low	T950 - D850	850 dewpoint depression
	1 – 3C or less	*1 – 5C or less*
	2 – 4 to 7C	*2 – 6 to 9C*
	3 – 8C or more	*3 – 10C or more*
Mid	T850 – T700	850 dewpoint depression
	1 – 5C or less	*1 – 5C or less*
	2 – 6 to 10C	*2 – 6 to 12C*
	3 – 11C or more	*3 – 13C or more*
High	T700 – T500	700 dewpoint depression
	1 – 17C or less	*1 – 14C or less*
	2 – 18 to 21C	*2 – 15 to 20C*
	3 – 22C or more	*3 – 21C or more*

Haines Index	Fire “blow up” Potential
2 – 3	Very Low
4	Low
5	Moderate
6	High

15.17 Heat Burst Index. The Heat Burst Index is an empirical proprietary RAOB index designed to help forecast the rare "heat burst" event. The heat burst is a Dry Microburst event with exceptionally high surface temperatures and damaging wind gusts. This index is able to capture the thermodynamic and physical structure of the "Inverted-V" profile, which is the signature sounding shape associated with dry microbursts and heat bursts. This index goes beyond the more limited DMPI (Dry Microburst Potential Index) parameter, and includes lapse-rates, moisture profiles, cloud layers, wind shear, energy potential, inversions, and other physical properties associated with the Inverted-V sounding structure. Since many of these burst events contain little or no CAPE, the Heat Burst index can predict these events better than the conventional CAPE-related storm indices..

Suggested Heat Burst index probability thresholds:		
	>500	Weak
	>750	Moderate
	>1000	Strong

15.18 Humidity Index (HI). The Humidity Index is a standard moisture sampling algorithm proved very reliable for instability measures and convection potential, especially in the Mediterranean regions of the world (Litynska et al, 1976). Smaller HI values reflect higher moisture content and greater instability potential. Note that the HI is similar to, but different than, the K Index, described later in this section. The HI is also different than the THI (temperature humidity index), also described later in this section. As with any index, the HI should be adjusted for geographic regions and seasonal variations.

$$\text{HI Index} = (T\text{-}Td)_{850} + (T\text{-}Td)_{700} + (T\text{-}Td)_{500}$$

Humidity Index (HI)	Instability Potential
> 50	Weak
30 - 50	Moderate
< 30	Strong

15.19 Jefferson Index (JI). The JI has been tested and used in both maritime and arid areas, and is therefore very important that threshold values be adjusted for the local area of interest. Non-frontal thunderstorms can be expected for index values of 27 or 28 and above (Jefferson, 63-66).

$$JI = 1.6 * WBPT_{850} - T_{500} - .5 * T\_Depression_{700} - 8$$

where: WBPT is wet-bulb potential temperature.

15.20 K Index. The K Index is a function of 850, 700 and 500 mb temperature and moisture information (Hart & Korotky, 91).

$$K\ Index = T_{850} + Td_{850} - T_{700} + Td_{700} - T_{500}$$

K Index	Thunderstorm Potential
< 25	Weak
25 to 35	Moderate
> 35	Strong

15.21 KO Index. This index was developed by the Deutsches Wetterdienst (German Weather Bureau) to estimate thunderstorm potential in Europe. It is more sensitive to moisture than other, more traditional, stability indices and is best used in cooler, moist climates (AWS/FM-90/001). If the surface level is above 1000 mb, then $\theta e_{surface}$ is used. If any others are missing, then no KO Index is calculated.

$$KO\ Index = \frac{(\theta e_{500} + \theta e_{700})}{2} - \frac{(\theta e_{850} + \theta e_{1000})}{2}$$

where θe is equivalent potential temperature

KO Index	Thunderstorm Potential
> 6	Weak
2 to 6	Moderate
< 2	Strong

15.22 Lifted Index (LI). The LI is a modified SI and eliminates the 850 mb dependency (Johns & Doswell, 92). The LI is determined from the same process as that used for the SI, but the low level LCL is found by using the mean moisture content in the lower 3000 feet.

LI	Thunderstorm Potential
> -3	Weak
-3 to -5	Moderate
< -5	Strong

15.23 Maximum Vertical Velocity (MVV). This is the maximum vertical velocity of the potential convective updraft. MVV is a function of CAPE(+).

$$MVV = \sqrt{(2 * B+)}$$

15.24 Microburst Day Potential Index (MDPI). MDPI was developed by the 45WS and NASA/Applied Meteorology Unit (AMU) as a result of a microburst event on 16 August 1994 (Wheeler 1996, 1997). This index is solely a function of the sounding's equivalent potential temperatures (θe). The following equation is based in part on the results from the Microburst and Severe Thunderstorm (MIST) project (Atkins and Wakimoto, 1991). The greater the spread between the two numerator factors, the greater the effect that relatively cool, dry environmental air will have on a developing downburst. When the MDPI is greater than or equal to one, microbursts are likely. The 30 knot denominator is a local tuning constant.

$$MDPI = \frac{[\, Max\theta e_{(Sfc - 850mb)} - Min\theta e_{(660 - <500mb)} \,]}{30 \text{ knots}}$$

15.25 Richardson Index (Ri). A non-dimensional number arising in the study of shearing flows of a stratified fluid, where Ri = gB / (δU/δz)2θ ... where g is the acceleration of gravity, B a representative vertical stability (commonly dθ/dz, where θ is potential temperature) and dU/dz a characteristic vertical shear of the wind. Note that the virtual potential temperature is used to calculate the gB stability factor.

15.26 S Index. This index was developed by the German Military Geophysical Office (as documented by 2WW/FM-88/001) and is primarily used to indicate thunderstorm potential from April through September.

S Index = TT - $(T - TD)_{700}$ - K (T and TD are 700mb temps)
where: K is defined as: 0 when VT $\geq$25
2 when VT >22 and <25
6 when VT $\leq$22

where: VT is the Vertical Totals index = $T_{850} - T_{500}$

S Index	Thunderstorm Potential
< 40	None
40 to 46	Possible
> 46	Likely

15.27 Severity. The Thunderstorm Severity Index is used to help measure and predict the severity of thunderstorm events (Maglaras and LaPenta, 1997). Severity is calculated from this …

S = 4.943709 – 0.000777 * CAPE – 0.004005 * WMAX + 0.181217 * EHI – 0.026867 * SSPD – 0.006479 * SRH

Where: CAPE = positive Convective Available Potential Energy (J/kg)
WMAX = maximum wind speed in the sounding (kts)
EHI = Energy Helicity Index
SSPD = forward speed of the storm cell (kts)
SRH = Storm-relative Helicity (m^2/s^2)

Index	Severity
S > 3.5	Non-Severe Event
2.5 < S < 3.5	Minor Event
1.5 < S < 2.5	Major Event
S < 1.5	Tornadic Event

15.28 SHERB Index. SHERB = *S*evere Hazards in Environments with Reduced Buoyancy. For more information see ... https://sites.google.com/ncsu.edu/mdparker/hslc

15.29 Showalter Index (SI). The SI is dependent upon 850 mb data and is most reliable when the moist layer extends above the 850 mb level (Hart & Korotky, 91). The SI is determined by following the moist-adiabat from the 850 mb based LCL to 500 mb, and then subtracting the found temperature from the 500 mb sounding temperature.

SI	Thunderstorm Potential
$\geq$ 4	Weak
-4 to 4	Moderate
$\leq$ -4	Strong

15.30 Significant Hail Parameter (SHIP). The SHIP index was developed using a large database of surface-modified, observed severe hail proximity soundings. It is based on 5 parameters, and is meant to delineate between *significant* ($\geq$ 2" diameter) and *non-significant* (<2" diameter) hail environments. SHIP values greater than 1 indicate a favorable significant hail environment, whereas values greater than 4 are considered very high. It is important to note that SHIP is "not" a forecast for hail size.

SHIP = (A * B * C * D * E) / 44,000,000

Where: A = MU_CAPE (j/kg), where MU_CAPE = Most Unstable CAPE
B = Mixing Ratio of MU_Parcel (g/kg)
C = 700-500mb Lapse-Rate (c/km)
D = 500mb Temperature (^{o}C)
E = 0-6km Shear (m/s)

15.31 Significant Tornado Parameter (STP). The STP is an index composed of four normalized parameters that have some ability to discriminate between tornadic and non-tornadic supercells. A majority of significant tornadoes (F2 or greater damage) have been associated with STP values greater than 1, while most non-tornadic supercells have been associated with values less than 1.

The original STP algorithm is composed of four terms: ML_CAPE (mean layer CAPE), mean layer parcel LCL, 0-1 km storm-relative helicity (SRH), and the 0-6 km shear magnitude. The "mean layer" depth is defined as being the lower 100 mb, but this depth is configurable using the Parcel Lifting & CAPE tab of the Program Options screen. The new STP algorithm replaces the 0-6 km shear with the surface-based effective bulk shear, the SRH is replaced with the effective SRH value, and a new term is added – the mean layer parcel CIN value. Like the SCP index, the "new" STP algorithm is only used if the Effective SRH (ESRH) option is selected on the Algorithm Options tab of the Program Options screen.

15.32 Supercell Composite Parameter (SCP). The SCP is a multi-parameter index that includes 0-3-km storm-relative Helicity, CAPE, and BRN Shear. Each parameter is normalized to supercell "threshold" values. SCP values greater than 5 usually represent the threshold of significant cell development.

The original SCP algorithm is composed of three terms: MU_CAPE (most unstable CAPE), 0-3 km storm-relative helicity (SRH), and the BRN shear value. The new SCP algorithm replaces the BRN value with the effective bulk shear and the 0-3 km SRH is replaced with the effective SRH. Like the above STP index, the "new" SCP algorithm is only used if the Effective SRH (ESRH) option is selected on the Algorithm Options tab of the Program Options screen.

15.33 SWEAT Index. SWEAT was specifically created to help predict severe thunderstorms and tornadic activity (AWS/TR 200). Caution: SWEAT should not be used to predict ordinary thunderstorms.

$$SWEAT = 12 * Td_{850} + 20 * (TT-49) + 2 * F_{850} + F_{500} + 125 * (S+.2)$$

where: Td_{850} is set to zero if value is negative
(TT-49) is set to zero if value is negative, where TT = Total Totals
F_{850} is speed of 850 mb wind in knots
F_{500} is speed of 500 mb wind in knots
S is the Sine of (500 mb - 850 mb wind directions)

and: 125 * (S+.2) is set to zero if any of the following are not met:
850 mb wind must be in the 130° through 250° range
500 mb wind must be in the 210° through 310° range
500 mb - 850 mb wind direction must be positive
500 mb and 850 mb wind speeds are at least 15 knots

SWEAT	Thunderstorm Potential
< 300	Weak
300 to 399	Moderate
400 to 599	Strong
> 600	High

15.34 T^1Gust. This method is quite reliable in indicating maximum average wind gusts, as described in AWS/TR 200. If the sounding has an inversion, the moist adiabat is followed from the warmest point in the inversion to 600 millibars. The temperature difference between the intersection of the moist adiabat at the 600-mb isobar and the temperature of the dry bulb at 600 mb is T1. If no inversion appears on the sounding, or if the inversion is above 200 mb above the surface, then T1 is found by projecting the moist adiabat from the surface temperature (maximum forecast temperature) to the 600-mb level, and then taking the difference between the 600-mb moist adiabat intersection and the 600 mb dry-bulb temperature. T^1Gust is obtained by applying the T1 value to a Gust table found in AWS/TR 200.

Prior to the RAOB 6.2 program, only the sounding's temperature data were used to compute the gust factors. Using supplemental options in AWS/TR 200, the maximum peak gust is determined by adding 1/3 of the mean wind expected in the lower 5,000 feet AGL to the temperature-derived gust values. An additional option is used to determine the wind direction of this maximum peak gust by finding the mean wind direction in the layer between 10,000 to 14,000 AGL. If the gust wind direction can not be found due to a lack of wind data above 10,000 feet, then the zero value is used for the "wind direction" to indicate a variable (VRB) wind direction. If wind data are not available at any level, then RAOB reverts to calculating these gust factors using only temperature data. Note that use of the sounding's upper-level wind direction is also applied to the T^2Gust factor as described next, but not for the low-level wind speed values.

15.35 T^2Gust. The maximum probable gust as derived from the T^2 method (AWS/TR 200) is most useful for isolated air-mass thunderstorms and/or squall line gust potential. The method first finds the surface temperature identified by the moist adiabat that intersects the WBZ. This temperature is then subtracted from the surface dry-bulb temperature, which is then applied to a non-linear relationship between the calculated temperature difference and surface gusts. This method works best with the passage of a thunderstorm in association with moderate to heavy rain. Note that this method only uses the sounding's temperature profile and that the sounding's winds are not a factor. Gust output is displayed in knots. Note that the T^2Gust factor does not incorporate the low-level mean wind speed data, but can use the upper-level wind direction as described in the preceding paragraph.

15.36 Temperature Humidity Index (THI). The THI, also known as the discomfort index, determines the effect of summer conditions on human comfort, by combining temperature and humidity. Studies have shown that relatively few people in the summer will be uncomfortable from heat and humidity while THI is 70 or below; about half will be uncomfortable when THI reaches 75; and almost everyone will be uncomfortable when THI reaches 79.

$$THI = T - 1.0799e^{.03755T}\,[1 - e^{.0801(D-14)}]$$

where: T = temperature (ºC)
D = dewpoint (ºC)

15.37 Thompson Index (TI). The TI is primarily used to determine thunderstorm potential in the Rocky Mountains (Sturtevant, 95).

TI = K Index - LI.

TI	Thunderstorm Potential
< 30	Weak
30 to 35	Moderate
> 35	Strong

5.38 Tropical Cyclone Tornado Parameters (TCTP):

Tornado~TC. RAOB's unique TCTP which is a combination of statistical and empirical relationships and is completely composed of sounding data and independent of external data. While specific Tornado~TC component coefficients remain proprietary, the contributing components are (1) Favorable environmental lapse-rate structure*, (2) Low-level shear, (3) SRH, and (4) a mid-level dry layer. RAOB detects and quantifies the mid-level dry layer using the program's unique "pattern recognition" scanning. As with any meteorological predictor, the user must apply local conditions to maximize parameter effectiveness. All TCTP studies find that the greatest probability for tornado development is in the right-front quadrant of moving tropical cyclones -- which the Tornado~TC index always assumes.

TCTP~UNC. This TCTP was created by Dr Eastin from the University of North Carolina as Charlotte. It's component factors are (1) 0-3 km shear, (2) 0-1 km SHR, and (3) the mean RH 2-4 km. Study results show that tornadoes are likely when TCTP values are greater than 1.0.

15.39 Total Totals (TT) Index. This index is commonly used as a severe weather indicator and is based on temperature and moisture data (AWS/TR 200).

$$TT = T_{850} + Td_{850} - 2 * T_{500}$$

TT Index	Thunderstorm Potential
< 45	Weak
45 to 55	Moderate
> 55	Strong

15.40 TQ Index. The TQ Index is used to assess the low-topped convection potential.

$$TQ = (T_{850} + Td_{850}) - 1.7 * (T_{700})$$

TQ Index	Low-Topped Convection Potential
> 12	Lower troposphere is unstable and TSRA is possible outside of stratiform clouds.
> 17	Lower troposphere is unstable and TSRA is possible when stratiform clouds are present.

15.41 Ventilation Index. This index is used for air pollution management throughout the United States (Hardy et al, 2002). It is the product of the mixing height and mean wind speed (or Transport Wind) of the mixing layer. Some use the surface wind speed or the wind speed at the height of a smoke stack, for example. The TransportM and TransportP wind parameters are the "mean" and "peak" mixing layer winds (respectively), which can be listed on screen or exported.

Ventilation Index (square meters per second)	Classification
0 – 1200	Poor
1201 – 2400	Marginal
2401 – 3600	Fair
> 3600	Good

15.42 Vertical Totals (VT) Index. This index is commonly used as a severe weather indicator and is based on temperature and moisture data (AWS/TR 200).

$$VT = T_{850} - T_{500}$$

VT Index	Thunderstorm Potential
> 28	Possible

15.43 Violent Tornado Parameter (VTP). The VTP is an augmented STP (Significant Tornado Parameter) parameter. It is used to help identify very strong tornados. (Hampshire, et al.)

$$VTP = STP * 3CAPE/50\ J/Kg * 3LR/6.5\ ^{o}C/km)$$

where: 3CAPE = MLCAPE from 0-3 km AGL (capped at a value of 2.0)
3LR = Lapserate from 0-3 km AGL

15.44 Vorticity Generation Parameter (VGP). The VGP is the rate at which horizontal vorticity is converted to vertical vorticity through tilting.

$$VGP = S * \sqrt{CAPE}$$

Where S is the mean 0-x km shear (length of the 0-x km hodograph divided by x).
Typical VGP ranges are: .116 for ordinary cells
.213 for supercells
.270 for significant tornadic supercells

15.45 Warm Cloud Depth (WCD). The WCD is the distance between the LCL and where the lifted parcel crosses the freezing level. The larger the depth between the two levels, the deeper the layer over which the warm rain process can occur (Cotton & Anthes). Values of WCD for heavy rain vary by region, with typical values for the Midwestern United States between 2.5 - 3.0 km while southeastern United States values range from 3 - 4 km. The WCD is sometimes called the COAL, or the warm rain coalescence layer.

15.46 Water Vapor. The IWV (Integrated Water Vapor) parameter is vertically integrated water vapor density, where vapor density is defined as the water vapor pressure divided by the specific gas constant and the temperature (Kelvin). When then divided by the density of water vapor, you then get the total water (Precipitable Water Vapor) value. The LWP (Liquid Water Path) value, however, consists of the vertical integration of LWC values, or liquid water content data.

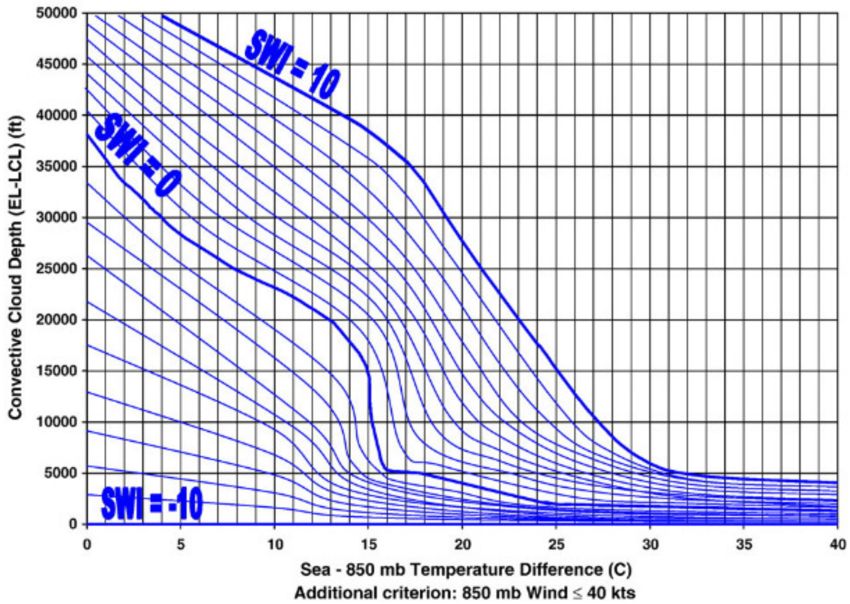
15.47 Waterspout Indexes.

WaterSpout1. Charleston (NWS) Index for the Southeast US. This "non-tornadic" waterspout index is produced from an algorithm composed of 18 different parameters, including CAPE, wind speeds, lapse rates and others. The index was developed by Pete Mohlin, a NOAA/NWS forecaster. RAOB calculates the Waterspout Index and produces a numeric value, which the developer has categorized accordingly…

Waterspout Index	Waterspout Risk
59 - 86	High Risk
37 - 58	Moderate Risk
15 - 36	Low Risk
0 - 14	None

WaterSpout2. Szilagyi Waterspout Index (SWI) for the US Great Lakes region. Output ranges from 0-10. The SWI source nomogram is shown at right. RAOB contains code which transforms the SWI nomogram into numeric algorithms. This index is unique in that it requires one external input, the Sea Surface Temperature, which is user-defined within RAOB's "Program Configuration Options, on the "Parcel Lifting & CAPE" tab.

The Szilagyi Waterspout Index (SWI) nomogram ...



WaterSpout3. Key West (NWS) Florida probability estimate index. This NWS proprietary index was developed by Andrew Devanas, Science and Operations Officer at NWS Key West and Lydia Stefanova, FSU COAPS (Weather & Forecasting, April 2018). RAOB calculates this index using the following parameters: Total-Totals, Corfidi Down Speed, 3,000 foot layer mean wind, 1000-700 mb lapse-rate, 100 mb wind, and the surface wind. Output values range from 0 to 100% probability "estimate" of occurrence.

15.48 Wet Microburst Severity Index (WMSI). WMSI (Pryor & Ellrod) was developed to better assess the potential severity of wet microbursts. WMSI was originally implemented as part of the GOES sounder-derived product package and is gradually being used by other forecast services. WMSI is a product of CAPE (positive values only, and using the Most Unstable lifting parcel option) and Delta Theta-e (Delta ePT) – of which both parameters are calculated and displayed by RAOB.

$$WMSI = (CAPE * Delta\ ePT) / 1000$$

WMSI	Wind Gusts (kt)
< 10	Convection/Microbursts Unlikely
10 - 49	< 35
50 - 79	35 – 49
> 80	> 50

15.49 WINDEX. WINDEX is an index of microburst potential and is a measure of downdraft instability. The WINDEX equation was obtained from Donald McCann's article in Weather and Forecasting, Dec 94. Like the above surface gust potential, WINDEX is also only based on the sounding's temperature profile. WINDEX is also displayed in knots.

15.50 Wind-Chill Temperature index. This index quantifies the threat of rapid cooling during breezy or windy conditions that may result in hypothermia in cold conditions. The WCT equation is from the United States National Weather Service.

$$WCT = 35.74 + 0.6215 * T - 35.75 * V^{0.16} + 0.4275 * T * V^{0.16}$$

Where: V is wind speed in mph and T is temperature in ºF

16. **SOUNDING ANALYSES**. CAUTION: The derivations and category classifications for the following atmospheric parameters use but one of several methods available, and therefore, the resulting output from RAOB should not be interpreted as definitive solutions. Additionally, probability data are provided as objective indicators of the likelihood of icing and turbulence, and like the above caution, they are not absolute indicators of subject events.

16.1 CAPE

Convective Available Potential Energy (CAPE). Both positive (CAPE) and negative (CIN or Convective Inhibition) buoyancy totals can be automatically displayed on the sounding diagram. CAPE energy is summed only above the LCL (*note 1*). CIN energy is summed both above and below the LCL.

$$\text{CAPE} = -R \int_{\text{Base}}^{\text{EL}} \delta T \, d(\ln p) \qquad\qquad \text{CIN} = -R \int_{\text{LPL}}^{\text{EL}} \delta T \, d(\ln p)$$

$\delta T = T_{Parcel} - T_{environment}$ *(where T can be Dry Bulb or Virtual temperature)*
Base = LFC or CCL
LPL = the level of the lifted parcel (e.g., surface, best_level, etc.)

CAPE and CIN can be displayed in several ways. The ANALYSES Toolbar has two options, "Lift Parcel" and "CAPE". The Lift Parcel option highlights the CAPE/CIN areas by tracing the path of the lifted parcel (*note 2*). The CAPE option shades the CAPE and CIN areas red and blue, respectively.

CAPE Notes:

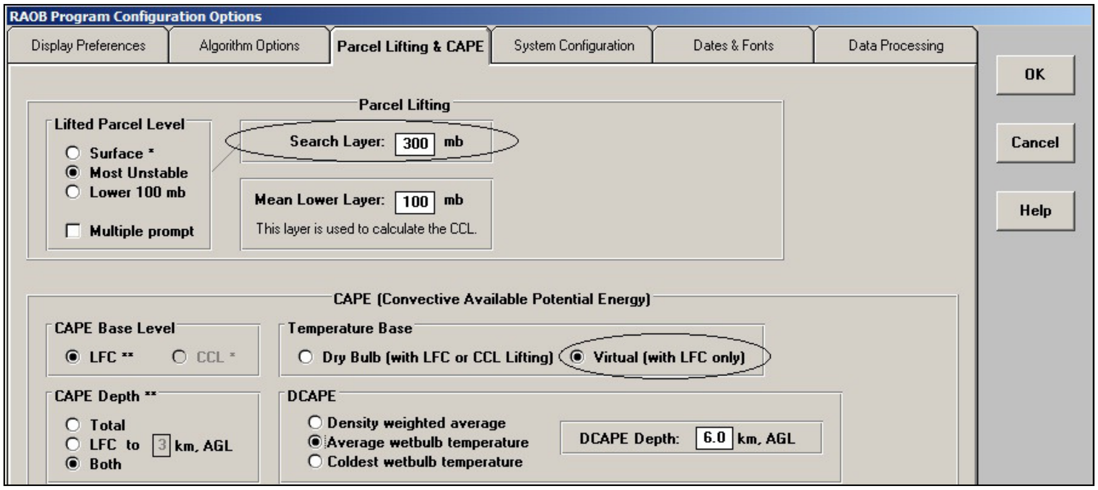
1. There is a special situation when only a portion of the lapse rate below the LCL is superadiabatic -- a positive energy area. These areas are typically small and infrequent. Since the author could not find any literature describing the appropriate mathematical disposition of these areas, they were not applied to the CAPE or CIN values.

2. The dry adiabat cannot be "traced" via the Lift Parcel option when the entire low-level lapse rate is superadiabatic -- under this condition only the mixing ratio line is traced.

CAPE is typically calculated with respect to the LFC level. RAOB also provides an option to calculate CAPE with respect to the CCL level, but only if the surface parcel is lifted. CCL selection can be made from the Lift Parcel option by right-clicking on the toolbar button which will then display the configuration screen. When CAPE is calculated using the CCL as the base, the lifted parcel's free air temperature is identified by the Convective Temperature (Tc). The CCL based CAPE simulates the onset of convection due to low-level heating, whereas the LFC based CAPE simulates the onset of convection due to dynamic lifting, such as those produced by frontal and orographic processes.

RAOB offers the user options to calculate and display CAPE in two different ranges. CAPE can be calculated throughout the entire depth of the sounding, or between the LFC and a specified height (km) above the LFC, or both. These values can be displayed on the sounding diagram and/or exported.

RAOB also offers the option to calculate CAPE with respect to the Dry Bulb or Virtual temperature profiles. These temperature options can also be identified during program configuration or via the sounding diagram's LIFT menu. The use of Virtual temperature to calculate CAPE is a suggested standard methodology as recommended by Doswell and Rasmussen (Weather and Forecasting, Dec 94). Doswell and Rasmussen also recommend that the most unstable level in the lowest 300 mb be used as the lifting parcel. An example of the Virtual Temperature and lowest 300 mb program settings can be seen in the example Program Configuration menu screen as seen next.



Virtual Temperature (Tv) Correction Notes. Tv correction is accomplished by first calculating the parcel ascent curve of the original sounding profile and then applying the Tv correction to this ascent curve. The Tv corrected parcel ascent curve uses the dewpoint of the ascending parcel (which is along the mixing ratio line below the saturation point, and is equal to the temperature along the moist adiabat which the parcel ascends at and above the saturation point). The LCL is always the same as that found using the uncorrected parcel ascent process, whereas the CAPE, CIN, LFC, EL are found from the Tv corrected sounding's ascent trace. Also, the Tv correction process almost always pushes the LFC point to the right and down (toward warmer temperatures and higher pressures). Sometimes, the LFC is at the surface!

Normalized CAPE (NCAPE). NCAPE is CAPE that is divided by the depth of the buoyancy layer. Values near or less than .1 suggest a "tall, skinny" CAPE profile with relatively weak parcel accelerations, while values closer to .3 to .4 suggest a "fat" CAPE profile with large parcel accelerations possible. Normalized CAPE and lifted indices are similar measures of instability. (Blanchard, 98)

$$\text{NCAPE} = \text{CAPE} / (\text{El}_{hgt} - \text{LFC}_{hgt})_{meters}$$

Downdraft CAPE (DCAPE). DCAPE is defined as the maximum energy available to a descending parcel. RAOB defines DCAPE as the graphical area between the environmental temperature curve and the moist downdraft adiabat, and between the surface and a user-defined depth (typically 6 km, AGL). The downdraft adiabat is defined by the sounding's moist adiabat that corresponds to a specified wet-bulb temperature. Initial DCAPE methods used the coldest wet-bulb temperature to define the moist adiabat (which is one of RAOB's options), but this has been shown to frequently over-forecast storm potential, because this method does not adequately address entrainment. Therefore, most now recommend the use of a weighted average of all DCAPEs through the layer of interest, using air density as the weighting factor … which the RAOB program also offers as an option. If a sounding contains numerous data points within the 6 km layer, the DCAPE calculations can take a long time. Therefore, RAOB offers the user three options depending on desired processing speed and needed accuracy. All options are presented on the 3rd tab (Parcel Lifting & CAPE) of the RAOB Program Configuration Options (F9).

Option #1. Density weighted average. This is the slowest, but most desirable method. It calculates the DCAPE for each temperature data point between the surface and 6 km. For example, if the sounding's 6 km layer contains 11 temperature points including the surface temperature, then RAOB calculates 10 individual DCAPEs using the moist adiabat associated with each data point, and then takes the density-weighted average. Note: all CAPE/DCAPE calculations are performed at the 1 mb (hPA) interval for maximum accuracy; and if the 6 km layer represents a 500 mb thickness, then DCAPE would perform 5,000 calculations, plus the final average. Each integration involves several significant processing steps.

Option #2. Average wet-bulb temperature. This option is faster than #1 but somewhat slower than #3. This option first finds the average wet-bulb temperature in the 6 km layer before performing integrations. This is the best option when analyzing high-density soundings.

Option #3. Coldest wet-bulb temperature. This is the fastest option and is provided since the above density weighted method (#1) can significantly slow down RAOB performance, especially if the user PC has a relatively slow processor and there are many temperature points in the 6 km layer. Note: when data files with multiple soundings are looped, and if Option #1 is selected, RAOB automatically reverts to the faster Option #3 for DCAPE calculations, then switches back to Option #1 when looping stops.

Forecasters at the NWS' Storm Prediction Center have found that, in general, DCAPE values tend to be lower for F2+ tornado environments and larger for damaging wind/hail environments. Initial research on storm threshold potential has produced the following general relationships:

DCAPE Value	Storm Potentail
< 600 J/kg	small
600 – 1000 J/Kg	modest
1000 – 1400 J/Kg	large
> 1400 J/Kg	extreme

16.2 **Contrails**. Condensation trails (contrails) are elongated tubular-shaped clouds composed of water droplets or ice crystals that form behind jet aircraft when the exhaust wake becomes supersaturated with respect to water. Depending upon their origin, they are sometimes called either "aerodynamic" or "engine-exhaust" trails. Contrails are possible if a critical temperature (Tcrit) threshold is reached. AWS/TR - 81/001 provides the following algorithm for Tcrit, which is a polynomial that is second-order in the natural logarithm of pressure and third-order regarding relative humidity:

$$x = -93.9 + 4.92*\ln(p) + 0.45*\ln(p)^2$$
$$y = 0.30*RH\% - 0.0074*RH\%^2 + 0.000053*RH\%^3$$
$$Tcrit = x + y$$

Tcrit is only calculated for pressure level data between 1000 and 40 millibars. If the environmental temperature is at or below the Tcrit temperature, then RAOB will display contrail information. RAOB's Analyses toolbar "Contrail" option will graphically highlight areas of contrail potential, while the Listing's Complete Data tab will also provide the Tcrit temperature.

16.3 **Convective Temperature (Tc**). The Tc is found by following the dry adiabat from the CCL down to the surface level. The Tc is the temperature the surface of the earth must warm to in order for thunderstorms to occur in the absence of synoptic forcing mechanisms. The Tc is most likely to be reached in the late afternoon hours. Once the Tc is reached, air parcels can rise freely to the CCL and will thus be free to rise due to positive buoyancy throughout the troposphere to develop thunderstorms. The strength of the CAP (or LID index) determines if the convective temperature will be reached. When the CAP is very strong, the convective temperature will be higher than the high temperature for that day and thus no storms develop. The amount of low level moisture also determines storm development. A higher CCL results in a higher Tc.

16.4 **Corfidi MSC Vectors**. These Mesoscale Convective System (MCS) vectors were developed by Corfidi to better forecast storm motions. There are two vectors – the Upshear and Downshear vectors.

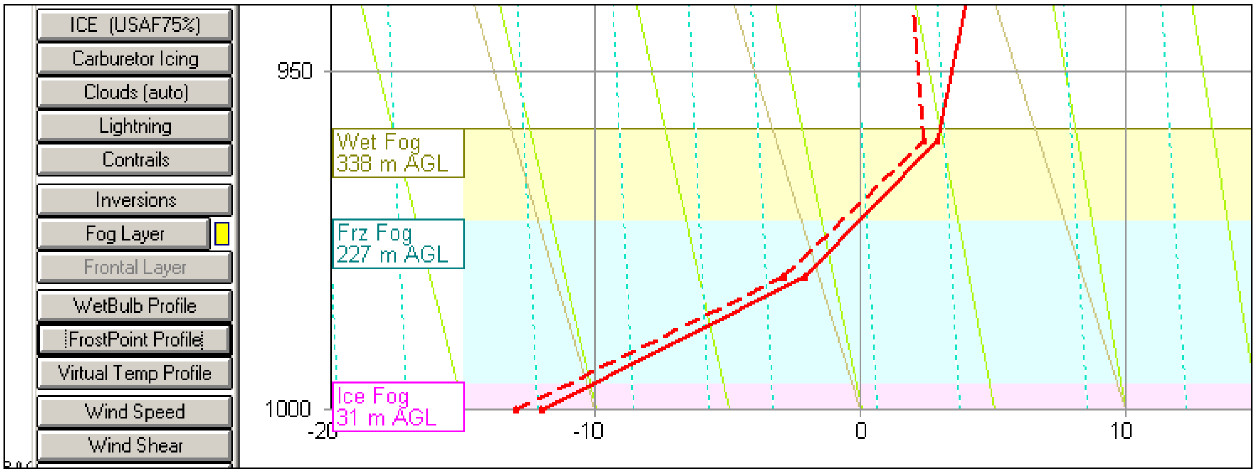
The Corfidi Upshear Vector is commonly referred to as the meso-beta scale convective elements (MBE) vector (Corfidi, 1996). The MBE vector (VMBE) is defined as …

VMBE = (VCL – VLLJ)
Where: VCL = vector of the Cloud Layer (850-300 mb mean wind)
VLLJ = vector of the Low-Level Jet (Bonner, 1968)
Where Low-Level Jet exists at or below 1.5 km AGL.

The Corfidi Downshear Vector is commonly referred to as the "forward propagating" MCC vector (Corfidi, 2003), where the Cloud Layer vector is added to the MBE (or Upshear) vector.

16.5 **Downrush Temperature**. The downrush temperature is found by extending a line moist-adiabatically from welt-bulb zero (WBZ) to the surface.

16.6 **Fog Layers**. Fog layer analyses are derived independently of the Fog FSI, Fog Threat, and Fog Point parameters as defined in the previous Sounding Indices section of this manual. Whereas those three fog parameters were derived for a specific European region, these "Fog Layer" analyses are globally applicable. Similar to the Inversions and Frontal Layers analytical options, the fog layers can be displayed on the sounding diagram through use of the Analyze Toolbar as depicted below.

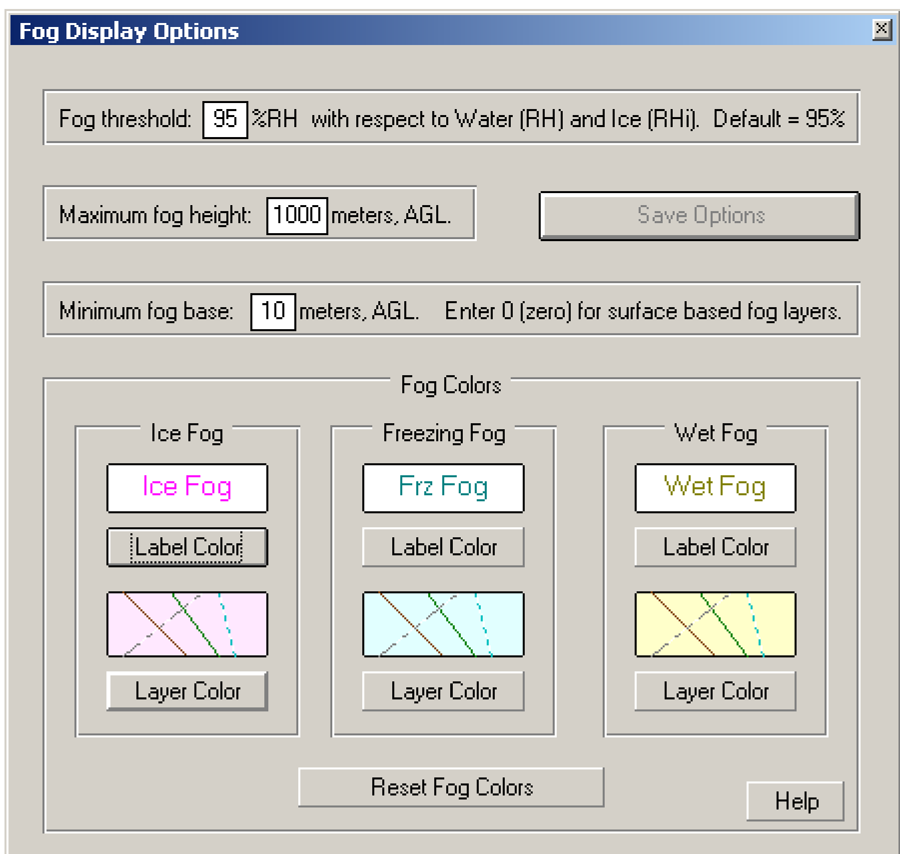


By right-clicking on the Fog Layer toolbar button seen above, the Fog Display Options menu appears as shown to the right.

Options include fog threshold criteria and fog boundary conditions. This gives the user the flexibility to specify moist regions with respect to low cloud versus fog conditions.

Graphic display options include color definitions and coordinated text identification editors.

Fog layers can also be displayed on cross-sections.



<u>Fog Layers continued …</u>

Algorithms used to identify the "ice" and "freezing" fog layers were obtained from Dr. Ismail Gultepe (ICCP, July 2008).

Ice fogs commonly occur in the northern latitudes when temperatures are below -20ºC. Normally, formation of ice fog happens when the relative humidity becomes saturated with respect to ice (RHi). Although the RHi threshold is user-configurable (see prior page), the program default value is >95%. RHi is defined below:

$$RHi = e_i(T_f) / e_{si}(T)$$

Where: $e_i(Tf)$ = vapor pressure with respect to the frost-point temperature.
$e_{si}(T)$ = vapor pressure with respect to the environment temperature.
T_f = frost-point temperature = Dewpoint temperature (Td) + Δf

Where: $\Delta f = p_1 Td^3 + p_2 Td^2 + p_3 Td + p_4$

$p_1 = 0.000006$ $p_2 = -0.0003$ $p_3 = -0.1122$ $p_4 = 0.1802$

Note that the frost-point temperature can be higher than the environment temperature (T). In order to help identify the three fog layers (ice fog, freezing fog, wet fog) found in different temperatures, the following table shows how RAOB classifies fog layers…

Fog type	Temperature Threshold
Ice	$\leq$ -10ºC
Freezing (Frz)	> -10ºC and < 0ºC
Wet	$\geq$ 0ºC

16.7 **Hail**. Hail size is estimated using procedures developed from data obtained in reports of wind-tunnel tests and estimates of updraft velocities in thunderstorms (Fawbush & Miller, 53). The derived hail size is reduced if the sounding's WBZ height is above 10,500 feet, which simulates hail melt in tropical air.

16.8 **Icing**.

<u>Carburetor Icing</u>. Carburetor (or induction) icing occurs whenever the cooling effect of the air flowing through the carburetor is sufficient to bring the temperature of the carburetor throat down to 32ºF (0ºC) or colder AND there is sufficient moisture in the air. In 1970 the Fuels and Lubricants Laboratory of the National Research Council of Canada conducted a study of carburetor icing in aircraft engines. A report submitted by L. Gardner and G. Moon of the laboratory contained a chart of the icing probability of light aircraft engines which was based on the data by the D.O.T. Accident Investigation Division (AOPA PILOT, 1988). The RAOB program uses this icing chart (which is a function of ambient air temperature versus dewpoint temperature) to determine carburetor icing categories. RAOB's carburetor icing categories range from 1 through 4 and represent the following chart criteria for increasing levels of icing severity:

1 - Light icing – potential icing at cruise or cruise power.
2 - Serious icing – at glide power.
3 - Moderate/Serious icing – moderate at cruise power, or serious at cruise power.
4 - Serious icing – in pressure type carburetors.

Structural Icing. Structural (or wing) icing can be derived by RAOB from one of three different criteria. RAOB refers to these three criteria as the Smith-Feddes, AFGWC, and USAF methodologies, which can be specified during program configuration. For the Smith-Feddes and USAF methods, the resulting liquid water content (LWC) values are matched to icing categories (LGT, MDT, etc.), which are based on NACA studies (Lewis, 47).

• The **Smith-Feddes** algorithms (Smith, 74 and Feddes, 74) are based on an initial maximum cloud LWC values for each cloud level. The LWC of each level is then adjusted for relative height within the cloud, the presence of precipitation, fraction of liquid versus frozen cloud droplets, and amount of sky cover.

• The **AFGWC** criteria are discussed in AFCCC/TN-95/004, A Comparison of Aircraft Icing Forecast Models (1995), where the AFGWC (RAOB) method proved better than the NODDS or TESS icing algorithms. The AFGWC method is the default for this RAOB program. The AFGWC method uses temperature, moisture, and lapse rate to determine icing conditions. Unlike the other two icing options, this method only produces three categories (trace, light, moderate) while the others also produce the "severe" intensity category. Additionally, this method does not produce icing probabilities (as explained below).

• The **USAF** criteria are based on USAF Air Weather Service studies as reflected in AWS/TR-80/001 (Lewis, 47). RAOB automates the graphical methodology employed by the AWS/TR, including the two nomograms, which were designed as overlays for the USAF Skew-T Log-P diagrams (Cox, 59), one for frontal environments and the other for non-frontal environments. The original methodology requires the user to apply the nomograms to layers containing sufficient moisture to produce icing. Instead of using cloud layers as an icing prerequisite like the Smith-Feddes method, the USAF method determines sufficient moisture using a minimum relative humidity value as an icing threshold. This icing threshold is user-definable during program configuration and diagram display options. A 85% relative humidity threshold is suggested for initial processing. This threshold should be adjusted as based on known cloud layer RH values with respect to actual icing conditions. (Note: RAOB generated cloud layers are not used for USAF icing calculations.) This icing method is also dependent on the existence of frontal systems. RAOB automatically determines frontal presence via frontal inversions. The user can override automatic frontal detection by clicking on the designated prompt just below the plotted diagram. RAOB determines the base of icing layers (in millibars) as a function of either the LCL or the RH threshold, as appropriate.

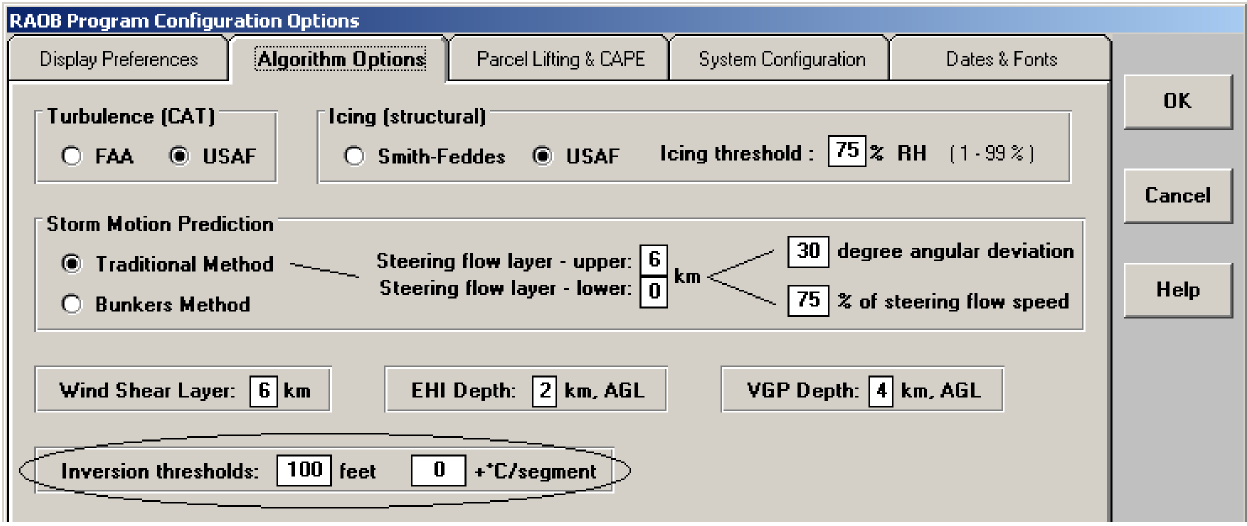
Rime ice is indicated if the sounding is absolutely stable, whereas, clear ice is indicated if the sounding is conditionally unstable. Mixed ice can occur within the intermediate zones.

Icing probabilities are derived from several studies correlating icing to both air temperatures and temperature-dew point spreads. The icing probability data is the product of two non-linear correlations: one is a function of temperature and the other is a function of the temperature-dew point spread. For reference, the temperature-based probability is 100% if the temperature is -8°C (with decreasing probabilities in either temperature direction), while the probability based on temperature-dew point spread is 100% at saturation (with decreasing probabilities with drier conditions). Although icing probabilities are indicated for each icing level, these probability studies were based on icing reported in stratiform clouds.

16.9 **Inversions**. RAOB only detects and lists the first 10 inversions above the surface. Inversion information can be graphically displayed onto the plotted sounding diagram via the Analyses Menu option or can be viewed via the Listing's Analyses Tab. Three types of inversions are possible:

Radiation	- Only exists at the surface.
Frontal	- Exists where both temperature and dewpoint increase with height.
Subsidence	- Exists where temperature increases and dewpoint decreases with height.

Very weak or very shallow inversions are not listed. This weak/shallow threshold is user-configurable and can be specified from the Program Options menu as seen on the next page…



(see discussion on prior page)

16.10 **Lightning Potential**. The probability of an upper-level lightning event is indicated as a “YES” for applicable data levels listed under the Complete Listing’s LTNG item. Lightning can also be graphically overlaid the plotted sounding using the Analyses toolbar “Lightning” option. Lightning is determined for each sounding level where the following criteria are met (Appleman, 71). Note … for the most accurate analyses for both icing and lightning research (especially for post-analysis and forensic work), it is always best to manually enter known or measured cloud layer data using RAOB’s Cloud Layer Table (F12).

- Temperature is within ±8°C
- Height is $\geq$ 3000 feet AGL.
- Cumuliform clouds exist.

16.11 **Liquid Water Content (LWC)**. Maximum cloud LWC is determined from the Smith-Feddes matrix, which is strictly a function of cloud type and air (dry-bulb) temperature. LWC is only calculated for levels, which contain both temperature and cloud layer data.

16.12 **Low-Level Wind Shear (LLWS)**. LLWS is only calculated for the lower 2000 feet AGL, from which original studies were based (7WW, 91). Categories follow:

Vertical Wind Shear	Category
1-4 kts / 30 m	Light
5-8 kts / 30 m	Moderate
9-12 kts / 30 m	Strong
> 12 kts / 30 m	Severe

16.13 **Potential Vorticity Units (PVU)**. PVU are a function of density, Coriolis, and Theta gradients:

PVU = 1/Density * Coriolis * d(Theta)/d(Z)

16.14 **Precipitable Water**. This is the total precipitable water of the entire sounding column. It represents a vertical integration of mean mixing ratios. RAOB displays **Water** as the Total Precipitable Water, and **Eff_Water** as the Effective Precipitable Water. Eff_Water is always less than Water, because it takes into account the lower relative humidity layers the rain must fall through. (For additional information on water calculations, see discussions on IWV and LWP for more information.)

16.15 **Refractivity**. The following algorithms were obtained from the VHF/UHF MANUAL (3rd edition).

N-Units. Atmospheric refractivity (N-units) are calculated via the following equation:

N = (77.6 / T) ∗ (P + (4810 ∗ e) / T) where T = temp(K), P = pres(mb), e = vapor pres(mb)

When the N-unit gradient is greater than 157 N/km, electromagnetic (EM) propagation is "trapped" and EM ducting typically occurs below this layer. The 157 N/km is the (configurable) default value.

K-Units. Potential refractivity (K-units, and sometimes referred to as B-units) are calculated via the following equation, where all temperature and moisture data are adiabatically adjusted to 1000 mb:

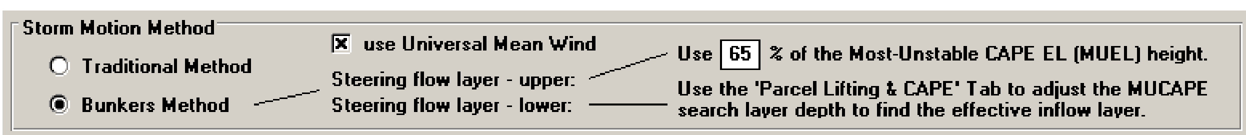
K = (77.6 / PT) ∗ (1000 + (4810 ∗ ε) / PT) where PT = potential temperature (K)
ε = vapor pres (mb) at 1000 mb of the dew-point adjusted to 1000 mb via the mixing ratio line.

K-units have the advantage of emphasizing major air mass discontinuities of interest in radio meteorology. K-unit gradients are easily observed in vertical cross-sections and time-sections.

16.16 **Storm Motion Prediction**. Storm motion prediction is determined by one of two methods: the Bunkers Method or the Traditional (30-Deg & 75% Steering Flow) Method.

• The Bunkers Method is an "internal dynamics" method of predicting supercell motion that is physically based and shear-relative. It has been shown to be statistically superior to other simple statistical methods by Bunkers et al (Weather & Forecasting, Feb 2000). This method was obtained from a statistical sample of many supercell motions associated with many wind profiles. This method, however, can produce unrealistic results under conditions of relatively light winds.

In 2014 (J. Operational Meteor, 2[11]) the Universal Mean Wind option was added, which can better define the storm steering flow for supercells of varying sizes and location. The base of the universal wind layer is defined as the first level where CAPE >= 100 and CIN <= 250. The top of the universal wind layer is by default defined at 65% of the MUCAPE EL (MUEL) height, where the MUEL is user configurable.



• The Traditional (30-Deg & 75% of the Steering Flow Wind) Method is a common statistical algorithm using the 0-6 km thickness-weighted mean wind as the basis of calculations. The storm motion is typically determined as 30 degrees to the right and 75% of the magnitude of the 0-6 km thickness weighted mean wind. Using the Configuration Options menu, RAOB now permits the user to configure all parameters associated with this method: flow depth, angular deviation, and speed percentage.

Storm motion calculations are based on the common assumption that supercells will deviate to the right of (in the Northern Hemisphere), and move more slowly than, the mean. (Recent research indicates that the use of higher mean wind layers, such as a 0-10 km mean wind, is better for larger storms.)

RAOB uses all available wind data to calculate the mean wind, where the winds are weighted according to the relative vertical interval (thickness) of adjacent winds. It should be noted that mean steering winds can also be calculated via density weighted winds, versus thickness weighted winds. RAOB however uses thickness weighting since all wind data have associated height values, but only some wind data have associated densities, such as TTAA wind data.

During the helicity summation, RAOB calculates three s-rH values based on the following inflow layers: 0-3 km, 0-2 km, and 0-1 km layers. During summation through the inflow layers, both positive and negative values are summed.

16.17 **Turbulence**.

Clear Air Turbulence (CAT). CAT can be derived by one of two different criteria. RAOB refers to these two criteria as the FAA and USAF methodologies, which can be specified during program configuration.

The FAA criteria are based on a July 1967 meeting of the Sub-committee/AMS as reflected in the WSOM and AIM. These criteria are a function of wind shear as follows:

Intensity	Vertical Shear (kts/1000ft)
LGT = Light	3 - 5
MDT = Moderate	6 - 9
SVR = Severe	10 - 14
*XTR = Extreme**	*$\geq$ 15**

* NOTE: The available FAA references do not specify the vertical shear criteria for the "XTR" category, but list the SVR intensity as $\geq$ 10 kts/1000ft. The author has taken the liberty to identify shear criteria for the XTR category only to better differentiate (and graphically visualize) high-end wind shears.

The USAF criteria are based on Air Weather Service studies as reflected in AFGWC/TN 79/001 and are derived from an empirical relationship correlating turbulence intensity to both wind shear and wind speed. Since the original study only produces turbulence intensities when wind speeds are greater than or equal to 40 knots, the author took the liberty to extrapolate matrix correlations to lower wind speeds, thereby resulting in respectively lower turbulence intensities. Results of this extrapolation are consistent with the FAA criteria, which indicate turbulence with respect to smaller wind shears. All USAF CAT intensities produced by RAOB are with respect to 'light' aircraft, whereas heavier aircraft are generally less sensitive to turbulence. Output is displayed via the following intensity categories:

LGT	=	Light	SVR	=	Severe
L-M	=	Light to Moderate	S-X	=	Severe to Extreme
MDT	=	Moderate	XTR	=	Extreme
M-S	=	Moderate to Severe			

All CAT probabilities are derived from limited studies correlating the Richardson Number (Ri) to reported turbulence. Probabilities are determined from a linear relationships from these boundary conditions:

Probability = 100% if $Ri \leq 0.25$ Probability = 0% if $Ri \geq 10.25$

High Level Turbulence (High CAT)). High CAT (or dynamic turbulence) analyses differ from standard CAT analyses (as described next) in two ways. High CAT is only calculated above the tropopause and is only a function of lapse rates and not wind shears. Sinclair and Kuhn developed an empirical equation, as described in their 1991 article “Infrared Detection of High Altitude Clear Air Turbulence,” to predict high level turbulence using only temperature profiles. This equation defines a non-dimensional CAT predictor called SLAT, or “S” Layer Advance Turbulence (warning) factor, which is defined as:

$$SLAT = [\gamma_{ML} - (\gamma_T + \gamma_B)]\ [20{,}000\text{ft} - \Delta z]\ /\ [10°C - \Delta T_{NET}]$$

Where: γ define lapse rates and subscripts ML, T, and B refer to mixing-layer, top, and bottom.

The term “S” layer is derived from the prime lapse rate configuration that produces CAT, which, when present, resembles an “S” in the sounding profile. This condition exists when two inversion layers are separated by a non-inversion layer. Layer depths and lapse rate slopes are critical to SLAT results. The High CAT algorithms used by RAOB were provided by a US government customer.

Thermal Turbulence (THRML). All thermal turbulence is assumed to be of Light intensity. Its depth is determined to exist between the surface and the height where the environmental potential temperature equals the surface potential temperature.

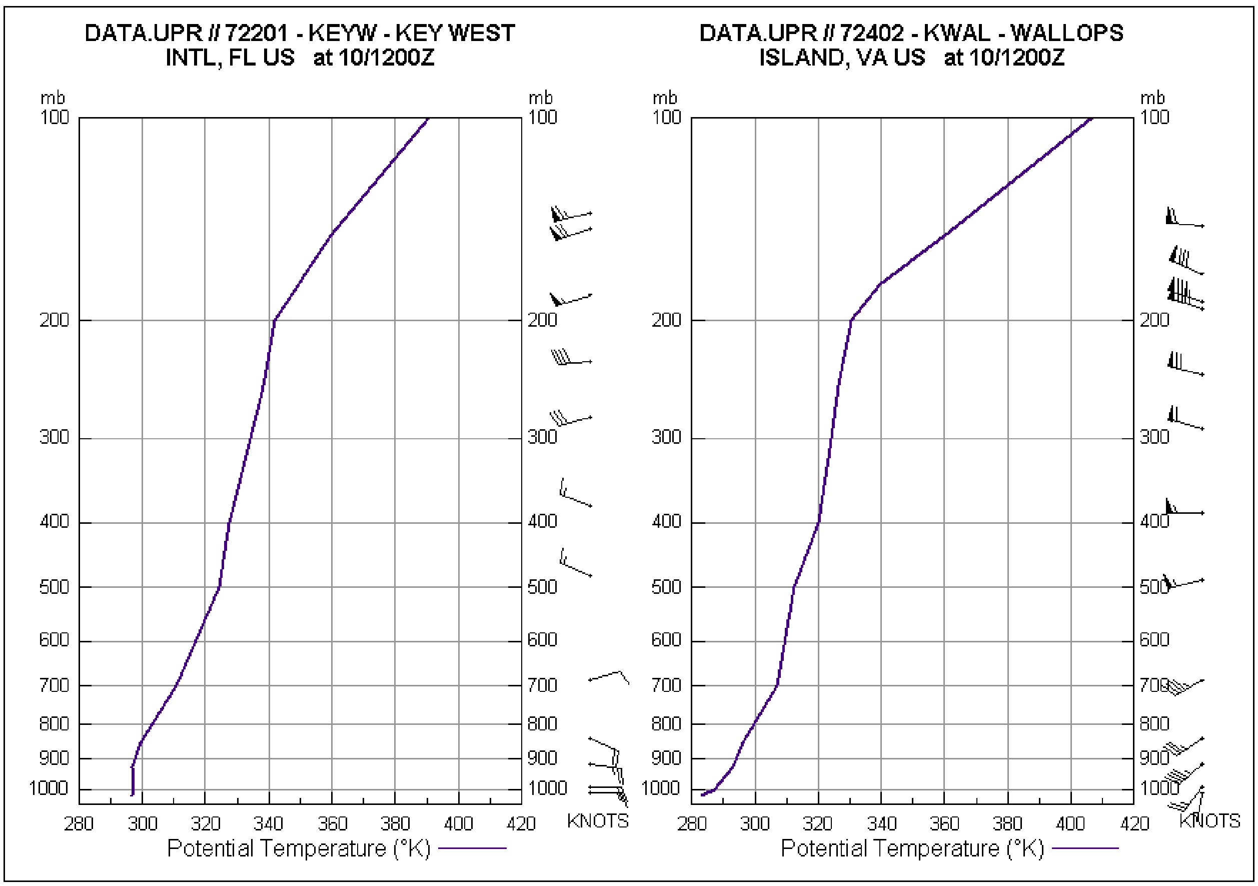
17. **SOUNDINGRAM**.

This is the optional Standard Sounding module, unless otherwise discussed.

17.1 **Soundingram Screen**.

The RAOB Soundingram is composed of ordinary X-Y graphs with orthogonal coordinates (similar to the Emagram sounding diagram). The special feature of the Soundingram is its ability to plot sounding parameters that are continuous in nature. Whereas RAOB's "Sounding diagram" only plots temperature and dewpoint, the "Soundingram" can also plot potential temperature, wind speed, ozone, and many other parameters. The Soundingram's toolbar is used to select which parameters are displayed.

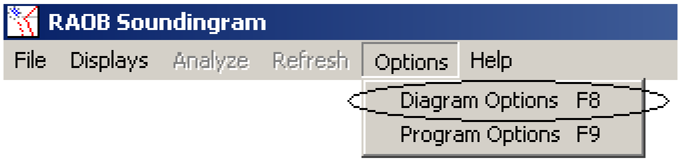
As with all RAOB diagrams, the Soundingram is fully user-configurable. Additionally, all parameter scaling is automatic; and when multiple parameters are displayed, similar scale units are merged for improved display appearance. In order to minimize the clutter from coordinate scaling grids and associated labels, a maximum of 3 parameters can be plotted on any one Soundingram. Another feature is the option for dual-panel displays and the ability to plot parameters from four different soundings for detailed comparisons.



The above example Soundingram compares potential temperature plots from two different soundings. Up to 3 parameters can be plotted on each graph. The profile color and thickness of each plotted sounding parameter can be individually configured. The wind plots (displayed along the right-sides of each graph) also have configurable options.

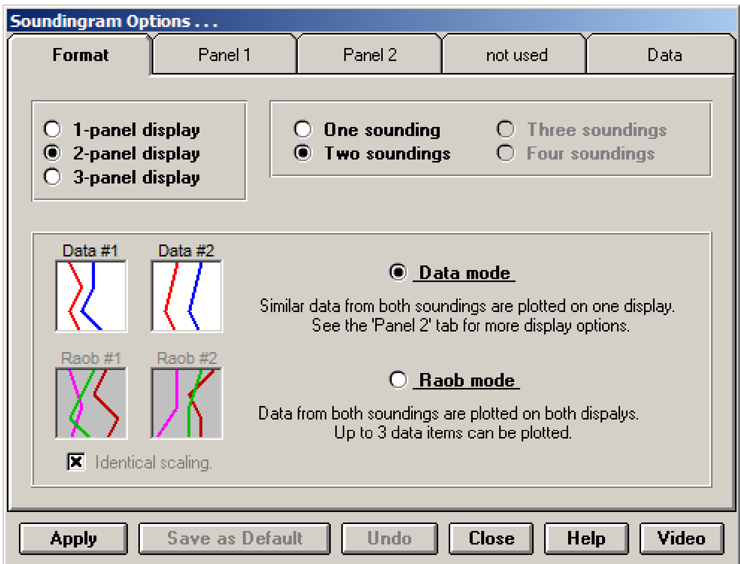
The following pages provide additional Soundingram examples and configuration options.

17.2 **Soundingram Configuration**.



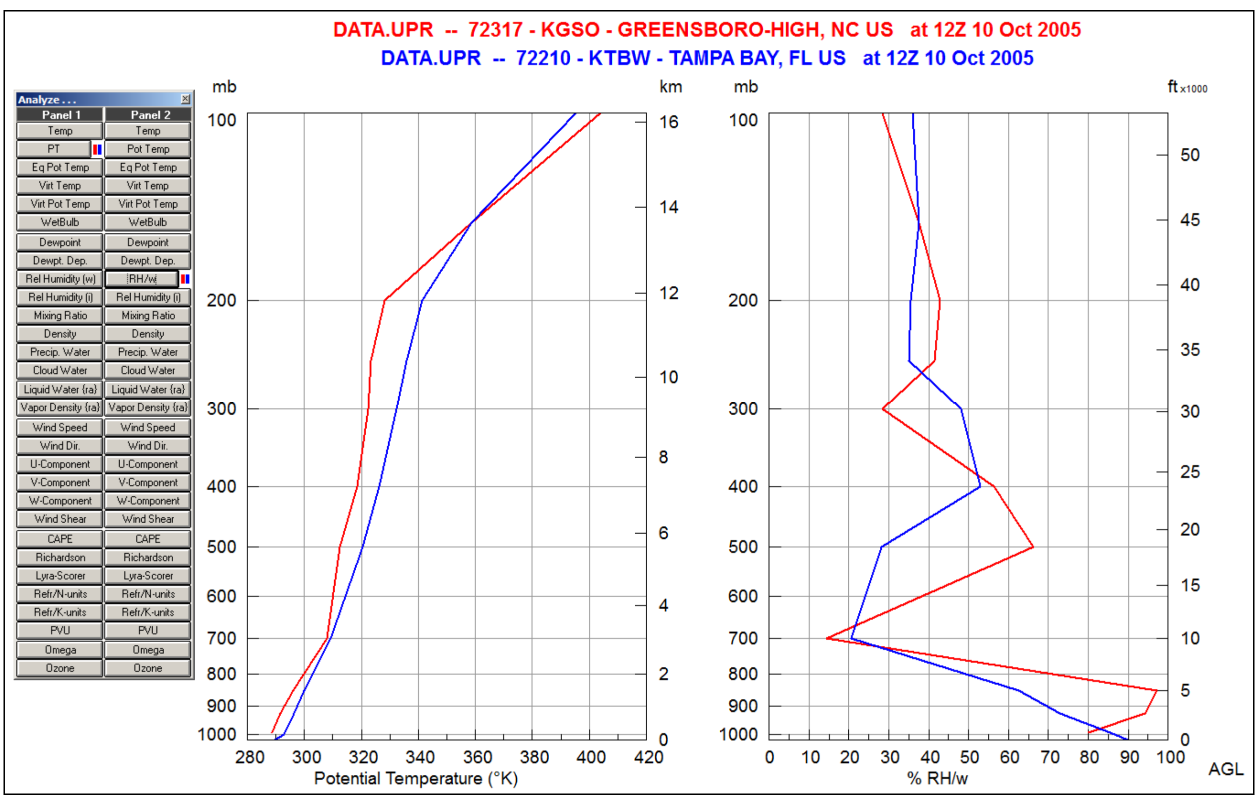
The Soundingram's configuration options are accessed from the Options menu as shown left.

TAB 1 – Format.



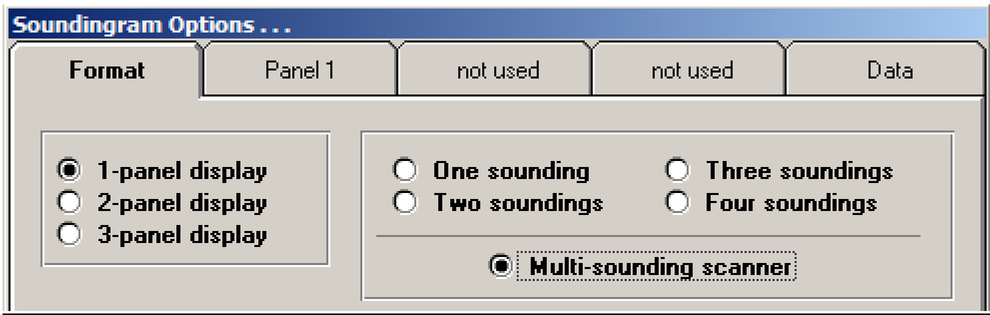
TAB 1 (left) allows selection of up to four soundings, and displays using 1, 2, or 3 diagram panels. (The 3-panel option requires the Advanced Soundingram module, where the "not used" tab then becomes active.)

Using the format options as selected on the example Tab 1, which reflects a two panel display with two soundings, the "Data mode" display option is selected which allows a unique method of data comparison. An example soundingram display is shown below. Here the left panel displays the potential temperature of two soundings while the right panel displays the relative humidity.

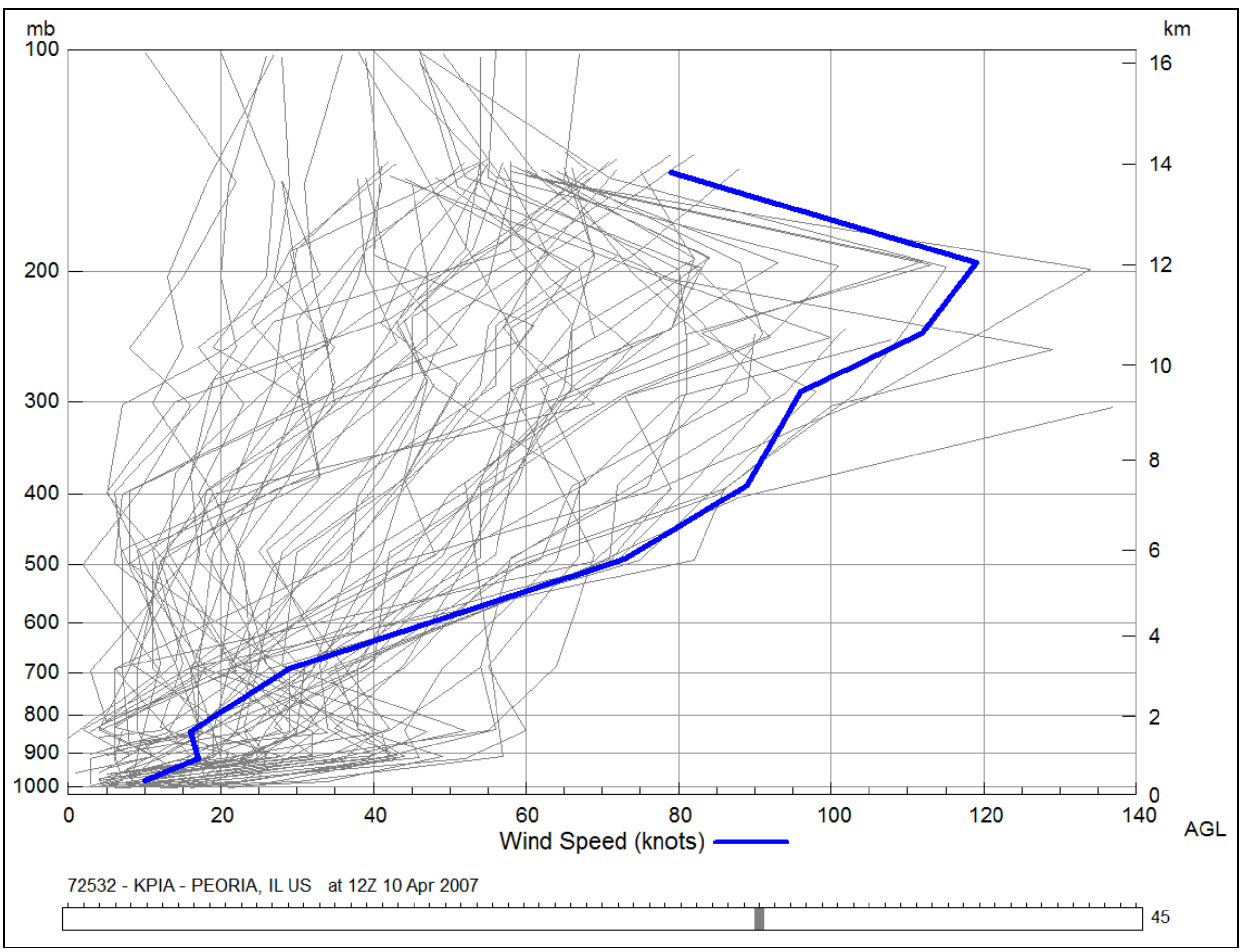


<u>Soundingram Configuration (continued)</u>.

Similar to the Sounding diagram's "Scanner" mode, the Soundingram display also has a Soundingram Scanner mode. This mode can be activated by selecting the "Multi-sounding scanner" option, as seen in the image below. The scanner mode is only possible when using the "One panel display" format.

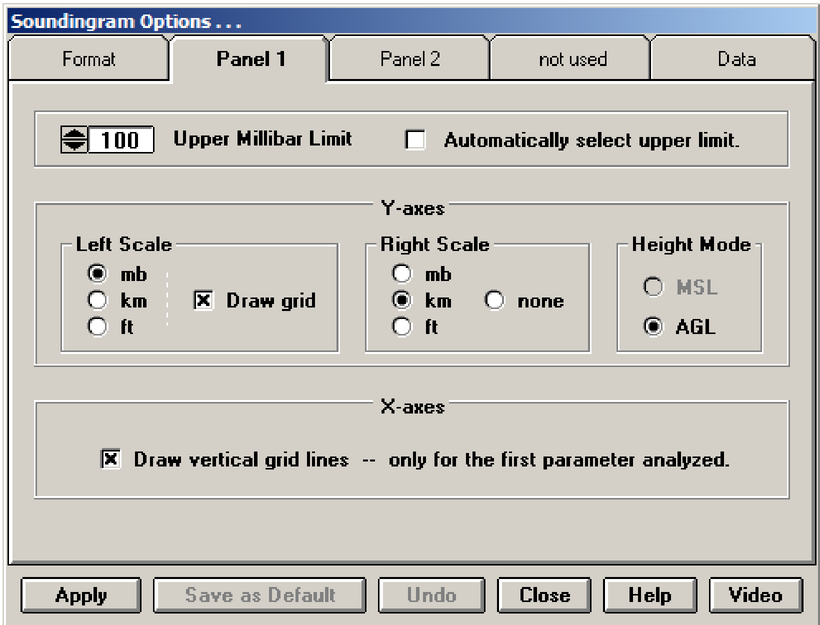


The below scanner mode example shows a simultaneous plot of 69 soundings from across the United States from a single synoptic time. In this particular case, the soundings' Wind Speed (kts) is plotted on the soundingram. In this example, the wind speed plot from the Peoria sounding is highlighted in a thick blue color. Its relative position is shown on the scroll bar at the bottom, which can be moved by the mouse or by the keyboard's cursor keys.



Soundingram Configuration (continued).

TAB 2 – Panel 1.

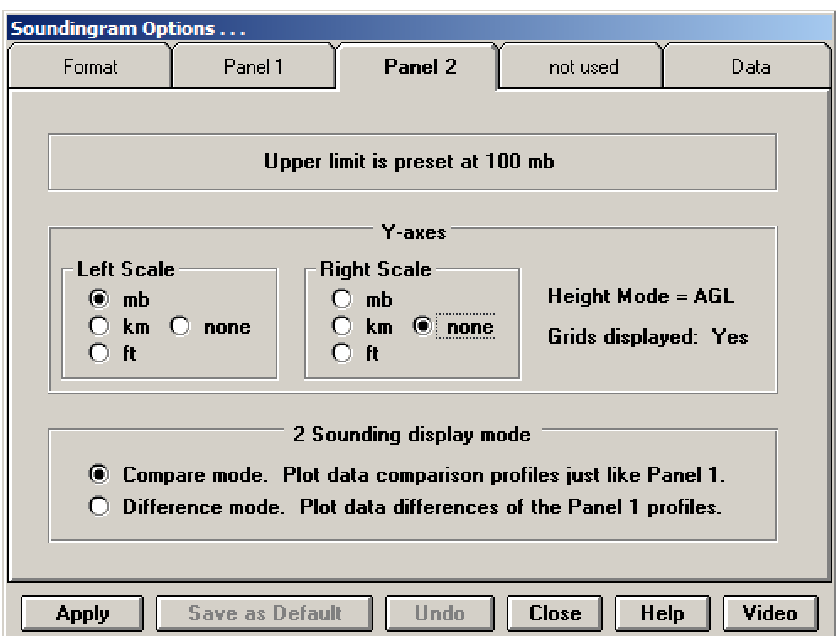


Panel 1. Options include the selection of the "upper millibar limit", similar to options available on most other RAOB diagrams.

The Y-axes options control left and right side diagram scaling, including grid options. The "Height Mode" option is only available when one sounding is being analyzed.

The X-axes option will only draw vertical grid lines for the 1st data parameter analyzed. Otherwise, there would be too much grid clutter with multiple sets of lines.

TAB 3 – Panel 2.



Panel 2. This is only available when the user selects the two-panel display option on the Format tab. The "upper mb limit" is only set from the Panel 1 options tab.

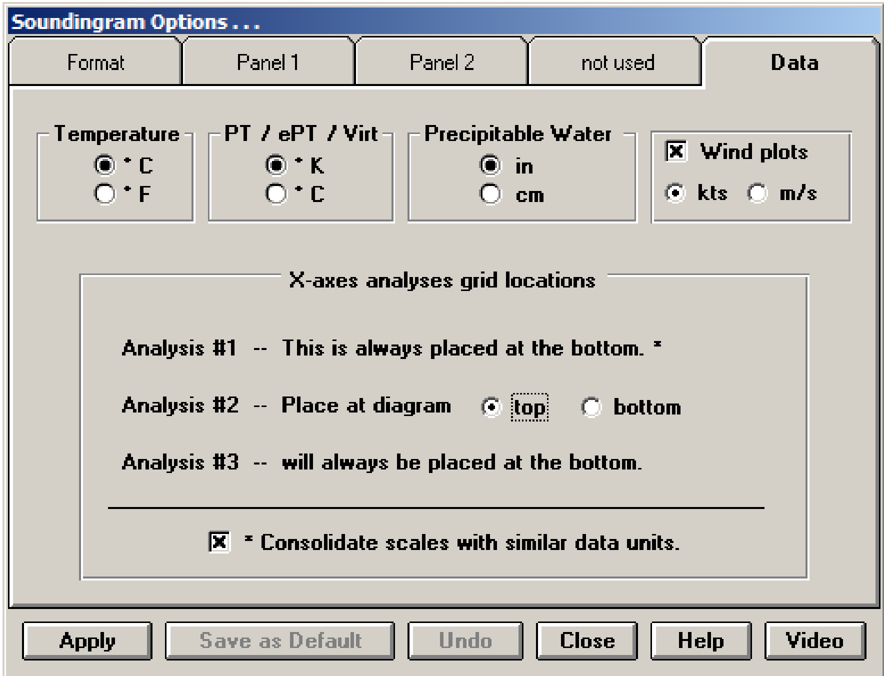
The Y-axes options function in the same manner as those available on the Panel 1 tab.

Height-mode and grid lines are also set from Panel 1 tab.

It is sometimes useful to experiment with one or two panel displays to see which provides the best method for data comparisons.

NOTE: The "2 Sounding display mode" option is only available with the optional Advanced Soundingram module, which is discussed on the page after next.

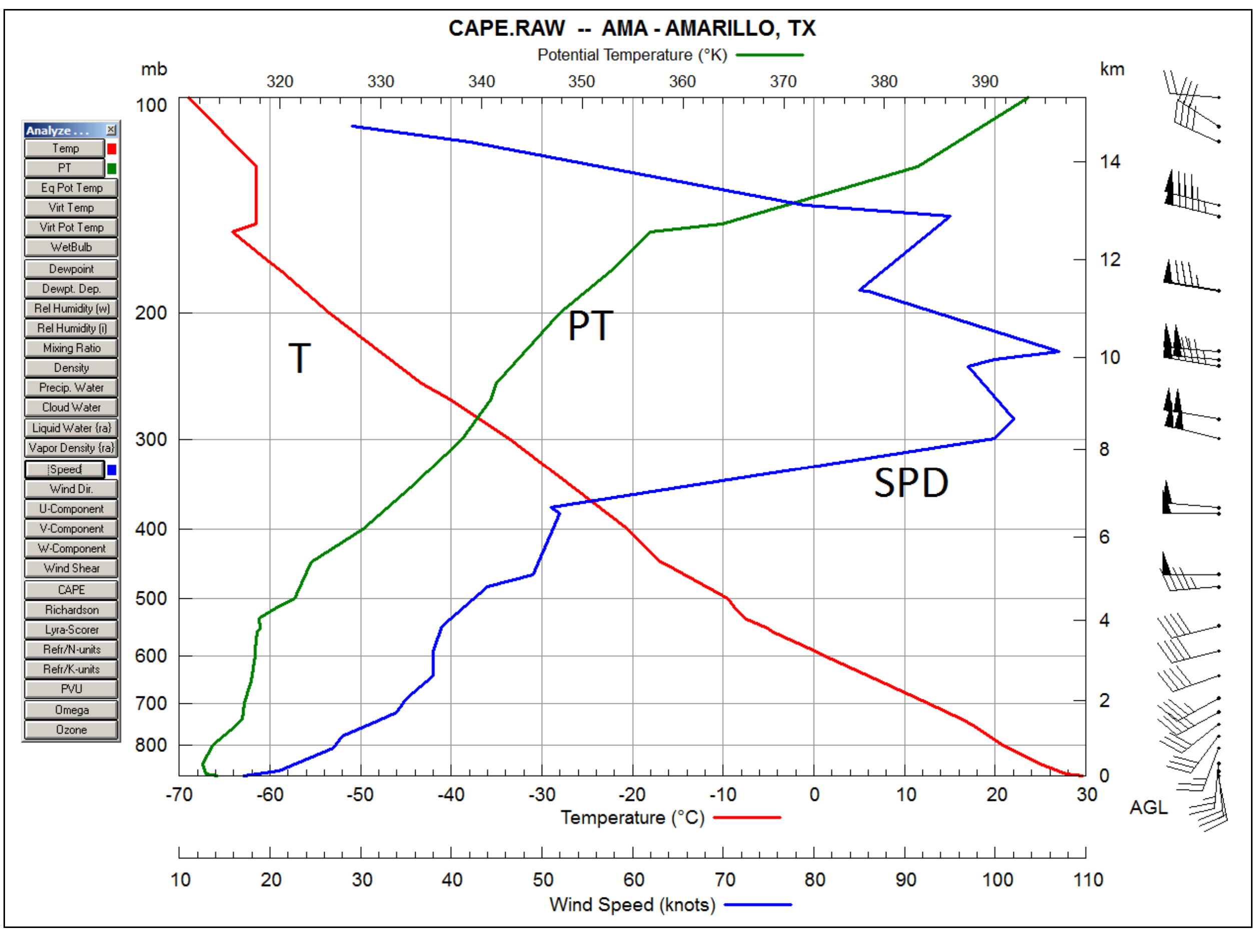
Soundingram Configuration (continued).



Data Tab. This tab offers control over data units and X-axes grid labels.

The X-axes grid options control where the 2nd and 3rd data labels are placed on the diagram. Analysis #1 is always placed at the bottom. Selection of the Analysis #2 parameter also controls the 3rd parameter label. The "Consolidate scale" option only applies to analyses with the same data units.

Below is an example soundingram comparing 3 analyses, where the vertical grid (lines) reflects the 1st parameter - Temperature.

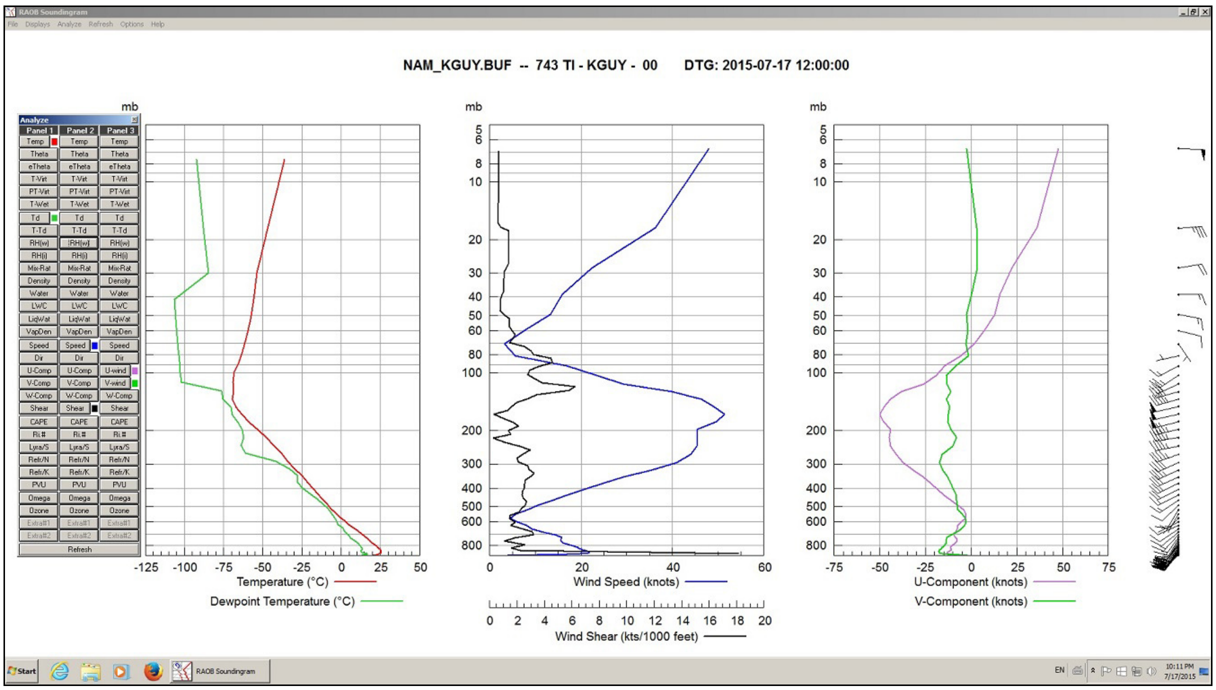


17.3 **Advanced Soundingram**.

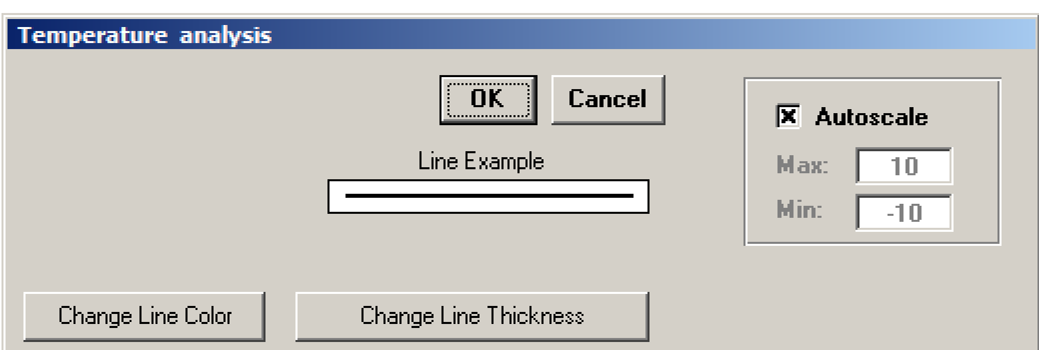
In addition to all the features associated with the Standard Soundingram module, the Advanced module has 4 additional features:

1 - Display 3 diagram panels.
2 - Parameter "Autoscale" option.
3 - Produce a "Difference" diagram.
4 - Includes Batch & Timer functions.

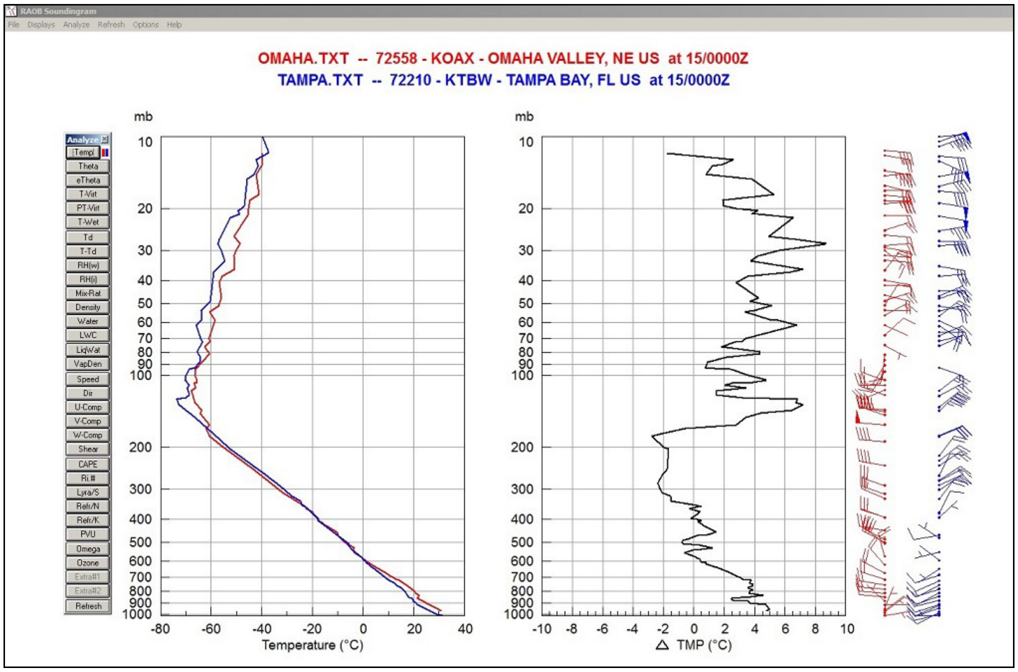
Advanced feature #1. The Soundingram display can display 3 panels of diagram analyses (as seen below). This option requires use of a wide-screen monitor.



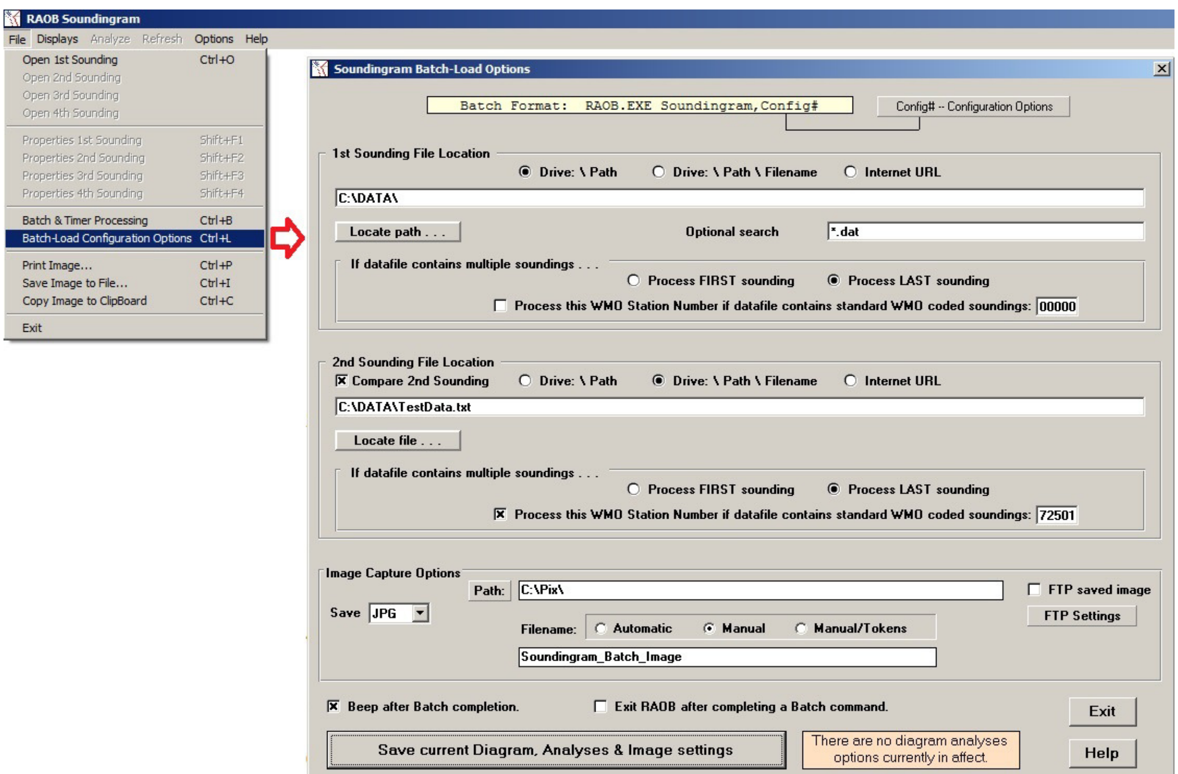
Advanced feature #2. Each analysis parameter can be individually configured for diagram Auto-scaling (as seen below). If "Autoscale" is unchecked, the diagram's Max and Min boundaries can be manually set by the user. Note: Autoscale is the default option.



Advanced feature #3. This module can produce a special "difference" diagram, thereby graphically showing the variations between 2 plotted sounding profiles (see below example). The left panel plots the actual sounding data, while the right panel depicts the "difference" (or delta) profile.



Advanced feature #4. This module also has Batch & Timer functions for fully automated RAOB use, including a special "Batch Load" menu system which allows fully automated script operations.



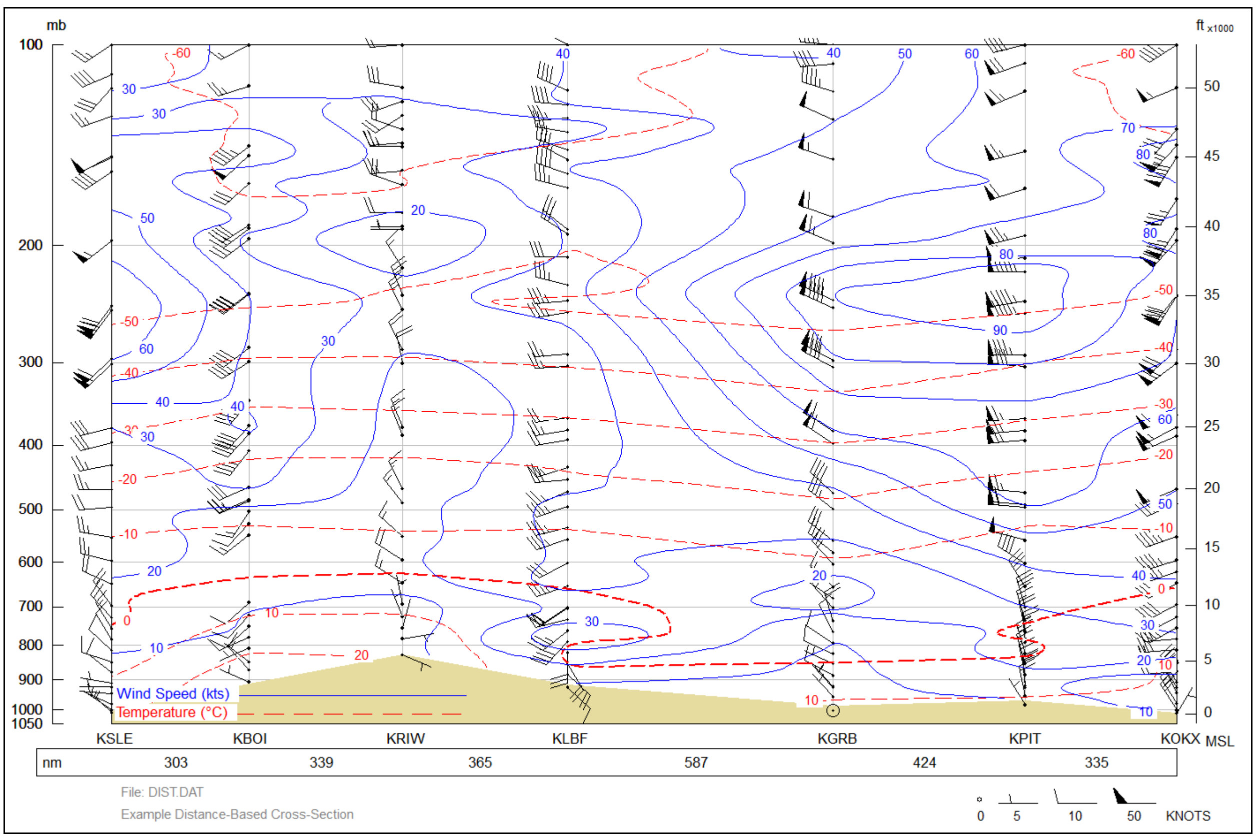
18. **CROSS-SECTIONS**.

18.1 **Cross-Section Screen**.

The vertical cross-sections screen (both time-based and distance-based) is only available with the optional Cross-Section Modules. Most features discussed here are available with the Standard Cross-Section module. The Advanced Cross-Section module (discussed later in this section) contains several additional features

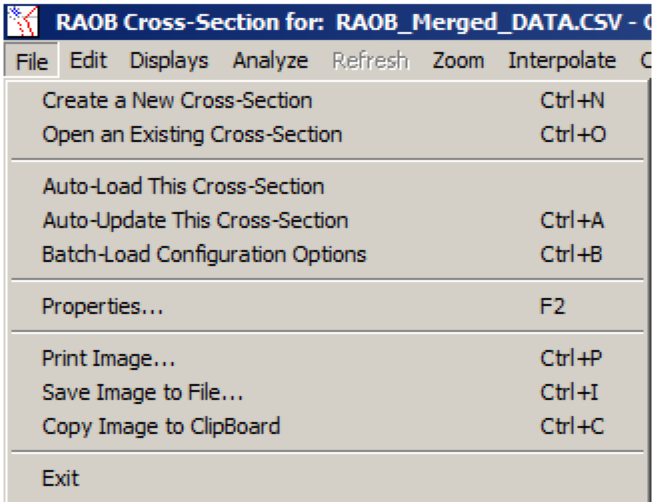
The Standard Cross-Section can process up to 100 soundings per diagram. The Advanced Cross-Section can process up to 6,000 soundings, with many more display options (as described later).

When a cross-section is generated, RAOB saves all data associated with the source soundings, that were used to create the cross-section, into a working file called a “dataset”. These datasets can be easily recalled for later display and analyses. They can be shared with others. These datasets can also be edited as needed. Note: Each "dataset" also contains all calculated parameters and indices, which means any future changes to RAOB configuration options (such as lifting or shear depth options) will not affect data saved to the "dataset" file. The dataset contents are static. However, this module does provide a multitude of display and analysis options, which are all configurable.



The above example “distance-based” cross-section is composed of 7 soundings. This example shows analyses for temperature and wind speed up to the 100 millibar (hPa) level. The wind barbs and wind legend are diagram options. Terrain is shaded in a tan color. When the cursor passes over a sounding’s vertical reference line, a different “hand” mouse icon appears, upon which the user can then click the “hand” icon to display a mini-sounding graphic overlay of the highlighted sounding. This mini-sounding can then be further clicked to expand into a full-sized sounding screen. Analyses above 100 mb are available when the RAOB program has the optional High-Altitude module.

18.2 **Cross-Section File Menu**.



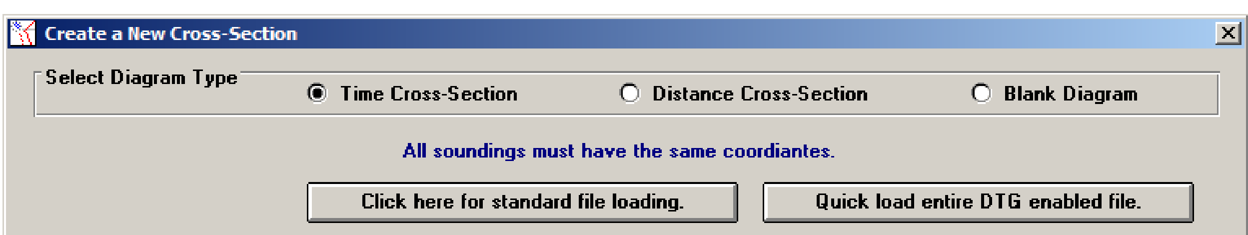
The Cross-Section "Create" and "Open" functions are discussed further below.

Similar to the File Menu options available to the plotted SOUNDING screen, the "Auto-Load This Cross-Section" option allows the user to identify a particular cross-section (dataset) which will automatically be loaded and plotted upon the next activation of the RAOB program. In this way, RAOB's Cross-Section mode can be used as the default initial display screen.

Auto-Update an Existing Cross-Section. When selected, RAOB will automatically update both distance-based and time-based cross-sections. Auto-Update will locate the files containing the original soundings that created the cross-section, and then reload the soundings from files having the original filenames. The update will only succeed if the original filenames and file locations are the same. Time-based cross-sections can only be automatically updated if the sounding files originate from single source datafiles ... those which contain multiple soundings, such as BUFKIT, MAPS, or NOAA Forecast files. The datafiles must contain new date/time sounding data, or the cross-section's appearance will remain unchanged as the sounding data would be no different than originally processed.

Batch-Load Configuration Options. This "Advanced" Cross-Section module function is discussed in the next section of this chapter.

18.3 **Cross-Section Creation**. To create a new cross-section, select the Create a New Cross-Section menu option. A cross-section editor will then appear (see below). You must first decide whether you want to create a time-based or distance-based cross-section. Time-based cross-sections (also called time-height diagrams) contain soundings from the same location (identical coordinates), while distance-based cross-sections must contain soundings from different locations. Once the "type" of cross-section is selected, then click on the "Click after diagram type is selected" button to activate the cross-section editor (see next page).

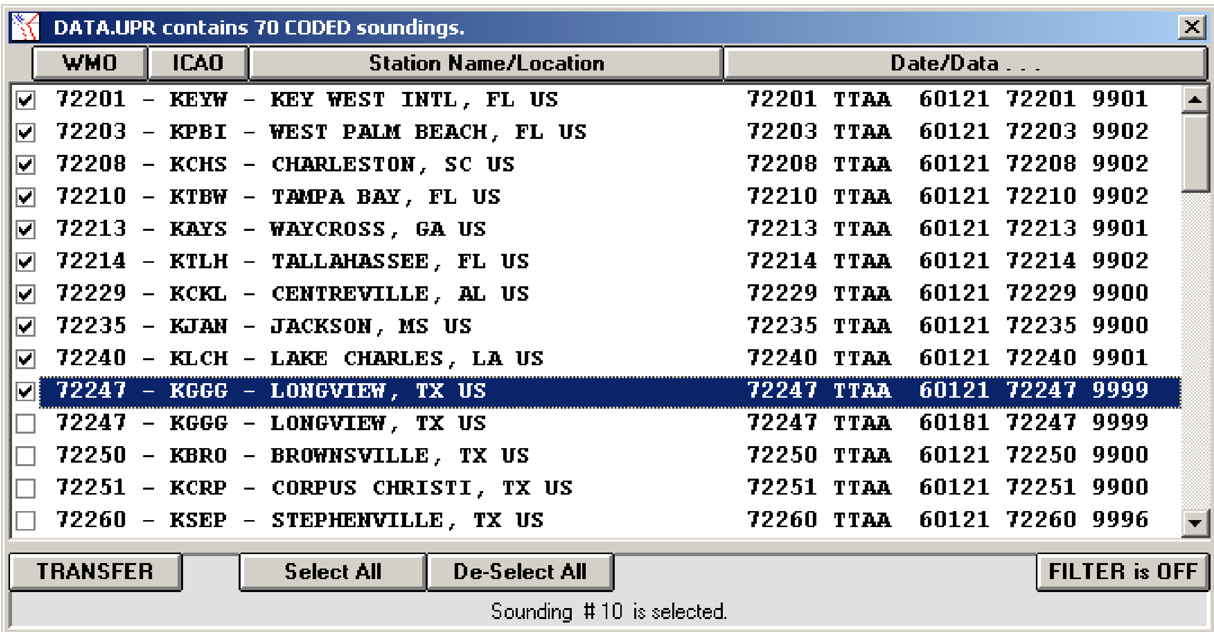


If the "Time Cross-Section" option is selected, an optional processing button called "Quick load entire DTG enabled file" option is presented. When activated, RAOB will automatically create a time-height diagram from all soundings found in multi-sounding file containing time series soundings. However, each sounding must contain sufficient Date/Time (DTG) information to create a complete data/time field. An example of a complete DTG field follows:

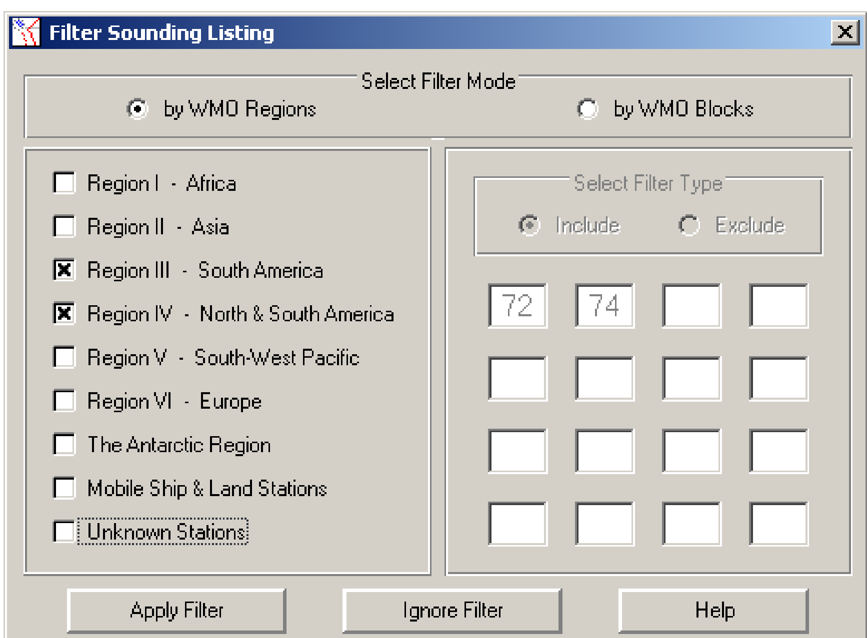
DTG: 2013-10-15 12:00:00

Cross-Section Creation (continued).

If a “Distance Cross-Section” is chosen, and a data file containing multiple soundings is selected, then the following edit screen is displayed. Once the desired soundings are individually selected using the checkboxes to the left of each sounding, click on the “TRANSFER” button to begin creation of the cross-section file.

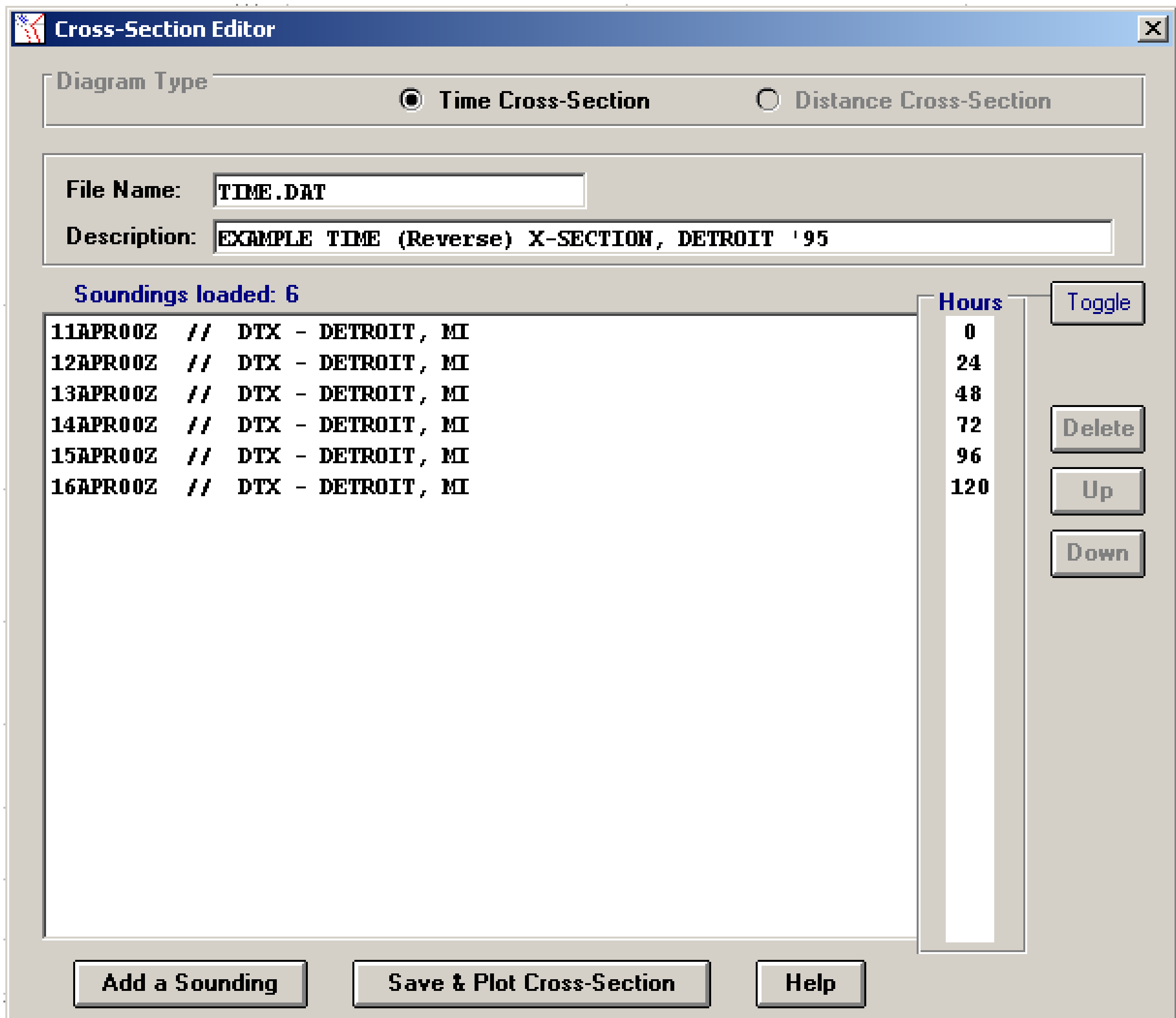


If the above data file contains numerous multiple soundings, the user can click the “FILTER is…” button to filter soundings by either WMO Region or WMO Block as shown below. If the WMO Block filter option is used, the user can additionally filter the data file using the “Include” or “Exclude” options. These filter options allow the user to quickly eliminate un-needed soundings from the selection listing.



Cross-Section Creation (continued).

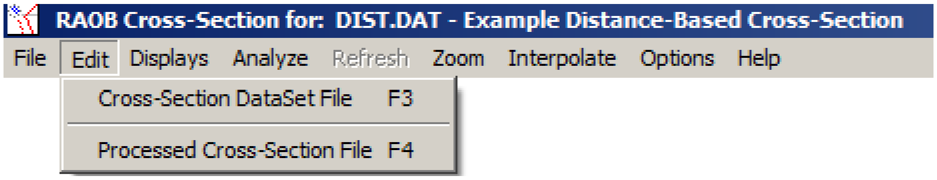
Once a time-based or distance-based cross-section is selected, the following edit screen is displayed. This is an example of a time-based (or time-height) sectional, where all the soundings are from the same location. Unlike distance-based cross-sections, each of the time-height soundings must be labeled with specific time intervals. In this example, "Hours" are the desired interval, but by using the "Toggle" button, other units (such as minutes, hours, days, weeks, months, or years) can be selected. Once soundings are loaded into this cross-section editor, the Delete, Up, and Down buttons can be used to edit the relative graph location or sequence of individual soundings.



The cross-section editor (shown above) can process up to 100 soundings with the Standard module and up to 6,000 soundings with the Advanced module. It is highly recommended that cross-section dataset files be saved to a directory separate from the individual sounding data files. Note that upon initial program installation, RAOB automatically generates a separate default directory for cross-section files.

Use the "Save & Plot Cross-Section" button to save and display the cross-section. Once this button is pressed, the cross-section diagram screen will be displayed with the plotted cross-section diagram.

18.4 **Cross-Section Editing**.

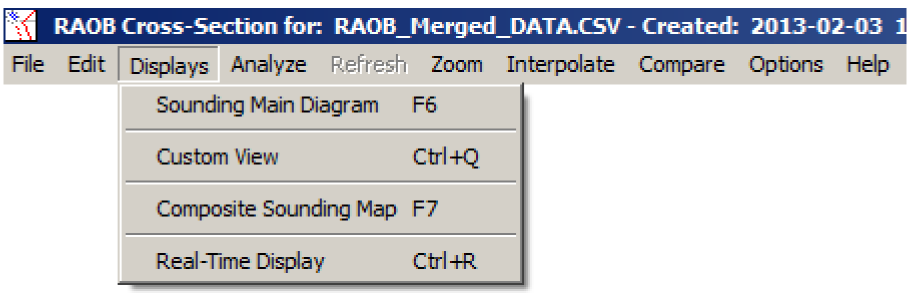


Once the cross-section is created and displayed, the file containing the cross-section's data is called the dataset file. This dataset file can be accessed by one of two methods.

Cross-Section DataSet File. This menu option displays the same cross-section editor used to create the cross-section (as seen on the prior page). This editor allows sounding additions and removal in addition to individual sounding position adjustments (and time scaling for time-based cross-sections).

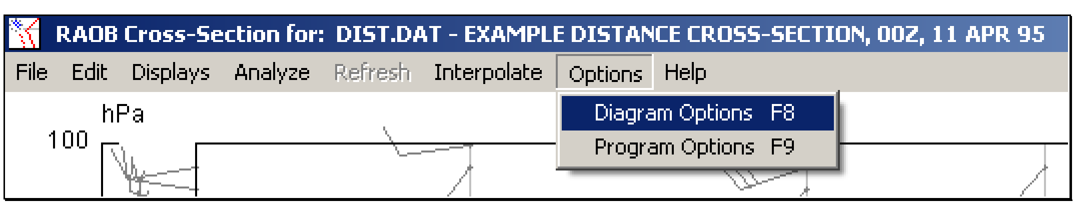
Processed Cross-Section File. This menu option uses a text editor to display the complete contents of the cross-section's dataset file. This method should only be used by the more advanced RAOB users who wish to inspect (and even edit) individual sounding data elements. Inspection of this file can assist in the resolution of cross-section analyses problems and anomalies.

18.5 **Cross-Section Display Options**.



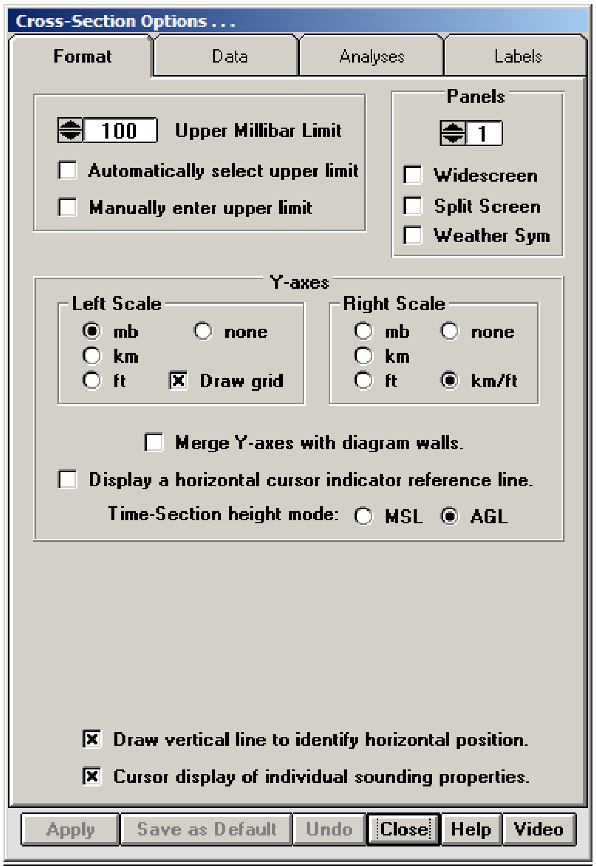
From the cross-section screen, you can easily return to the **Sounding Main Diagram** from the "Displays" menu. Select **Custom View** to design your own diagram layouts. You can also view an area map of Cross-Section soundings by using the **Composite Sounding Map** option. As described later in this section, the Composite Sounding Map allows the generation of interpolated soundings using a 2-dimensional map of plotted soundings from which to select the location of the interpolated sounding. Available only with the optional Real-Time Processor module, the **Real-Time Display** option presents user-configurable options for automatically detecting new sounding data, updating the displayed cross-section, and then re-analyzing selected data fields. Real-Time processing features are discussed later.

18.6 **Cross-Section Configuration**.



Similar to the SOUNDING screen, the cross-section's diagram (configuration) options can also be conveniently displayed by clicking the right-mouse button while over the diagram.

TAB 1 – Format.



See next page for additional information.

Upper hPa (or mb) Limit of Cross-Section. Use the up/down arrow keys to select highest pressure level. This option is identical to RAOB's Sounding diagram options. Select Automatically select upper limit to have RAOB automatically scale the diagram's upper limit. Select Manually enter upper limit to specify a top level value (100 to 1000 mb).

Panels. Choose from 1 to 4 cross-sections. *

Widescreen. Select this option to maximize the display area on wide-screen computer monitors.

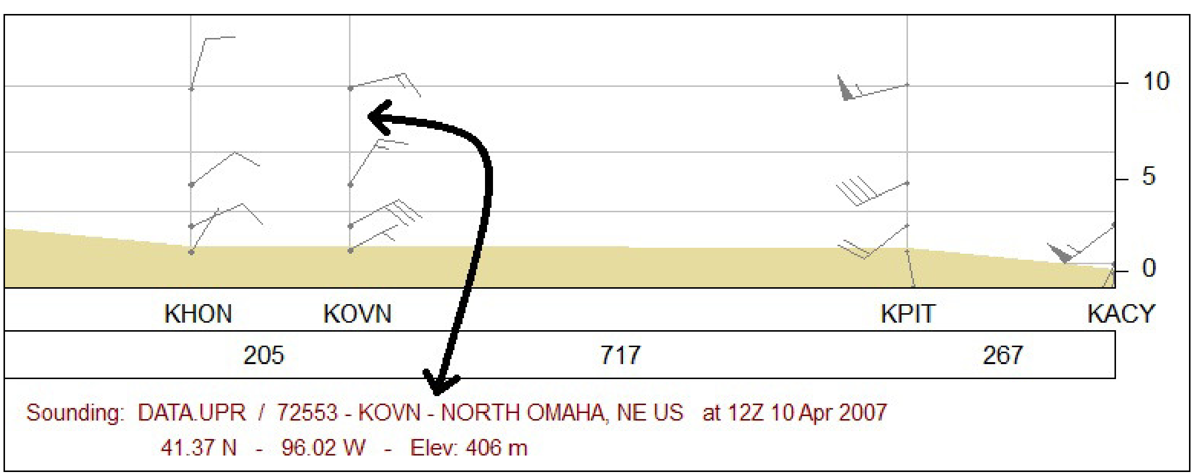
Split Screen. Displays both a Cross-Section diagram with a Sounding diagram. *

Weather Sym. Displays Weather Symbols below the diagrams' X-Axis labels. Requires RICAPS, and can only be used with single-panel displays. *

Y-axes. Select hPa (or mb), km, or ft for the vertical scales for the Left & Right sides of the diagram. Check the Draw grid box to draw horizontal lines across the diagram. Use the Merge Y-axes with diagram walls to co-located y-axes with diagram walls and force wind barbs inside diagram walls. The horizontal cursor option only functions with single-panel diagrams. When distance-based cross-sections are displayed, only the MSL mode is used because of different sounding site elevations.

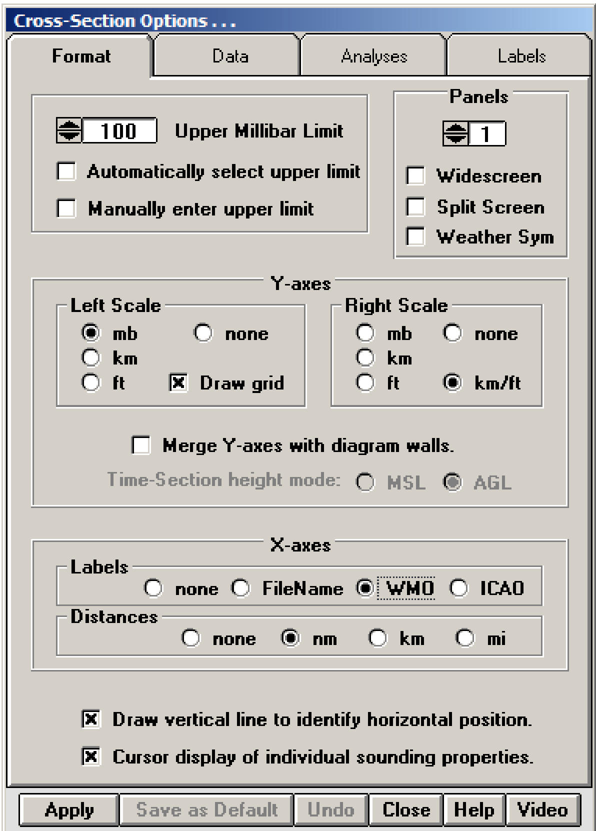
** Requires the Advanced Cross-Section module.*

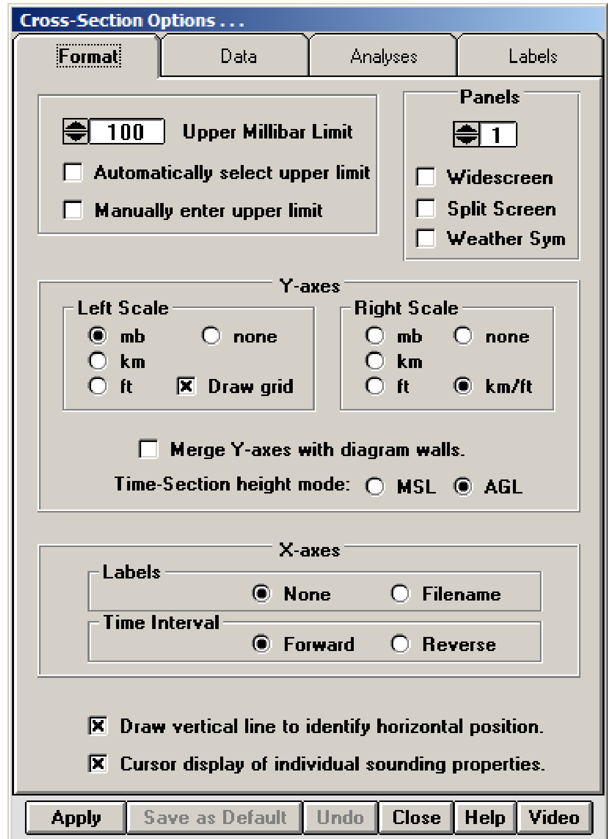
The below example image shows the "**Draw vertical line to identify horizontal position**" option which has a thick black line to illustrate the horizontal position of each diagram sounding. When this option is used, and the mouse passes over the KOVN line, the KOVN station's identification information is displayed below the cross-section in dark red as indicated by the bold curved line below.



TAB 1 – Format (continued) …

The **Format** Tab is again shown below, but this time reflecting the two different sets of options associated with the X-Axes. The left set of options appear when a Distance-Based diagram is plotted, while the right set of options appear when a Time-Based diagram is plotted.





<u>**X-axes (for distance-based diagram)**</u>.

Select <u>Labels</u> and <u>Distances</u> options.

If either WMO or ICAO labels are selected and either of these identifiers is not available for a particular station, then no information will be displayed. However, this information can be manually entered (or changed) via the Edit menu option for the Processed Cross-Section File. The MSL / AGL height mode option is only available when using Time-based diagrams.

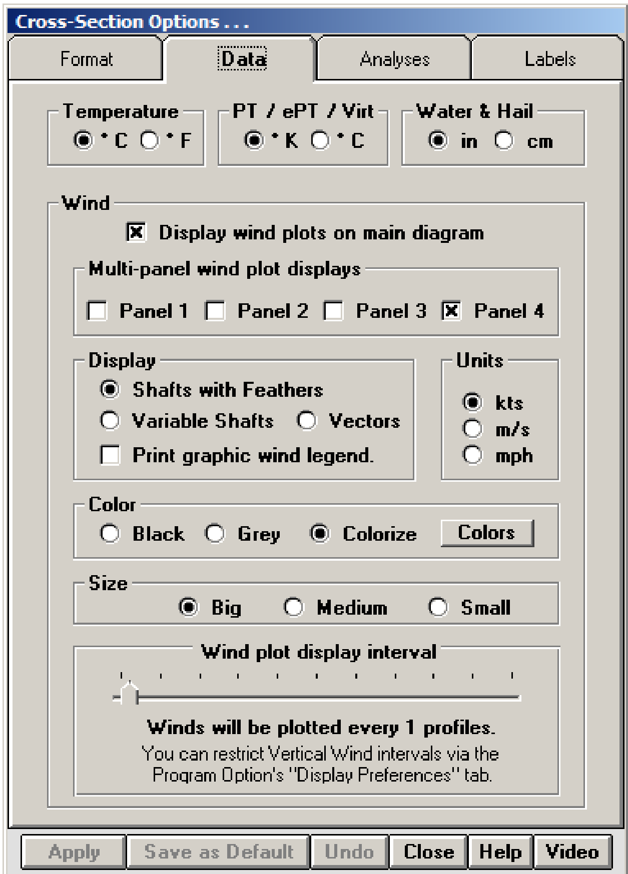
<u>**X-axes (for time-based diagram)**</u>.

Select the <u>Labels</u> and <u>Time Interval</u> options desired for display.

The Filename label option is most useful for cross-sections generated from sounding files with unique filenames. The Time Interval option can be used to quickly reverse the sequence of all soundings without having to manually edit sequences via the Edit menu option for the Cross-Section Data File.

TAB 2 – Data.

Temperature and PT/ePT. Select either Celsius or Fahrenheit units for contour (isopleth) labels. (Note: ePT = equivalent PT). **Water & Hail**. Select either inches (in) or centimeters (cm).



Wind Options.

Display wind plots. Check this box to graphically display sounding wind data.

Multi-panel wind plot displays. Specify which panels contain wind plot data.

Display. Select Shafts with Feathers, Variable Shafts, or Vector winds.

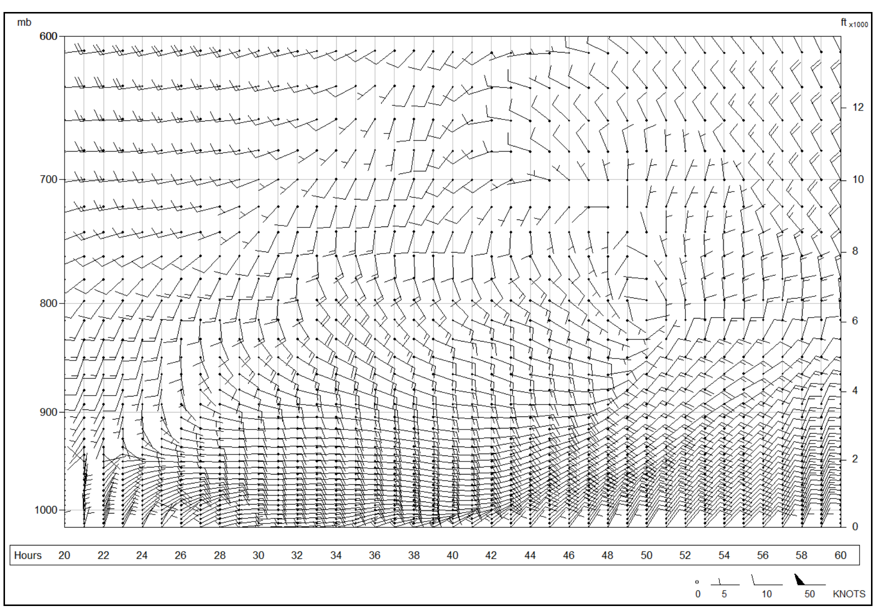
Print graphic wind legend. The legend appears at the lower-right diagram margin.

Units. Select kts, m/s, or mph.

Color. Select Black, Grey, or Colorize winds. The colorize option requires the Advanced Cross-Section program module.

Size. Select: Big, Medium, or Small winds.

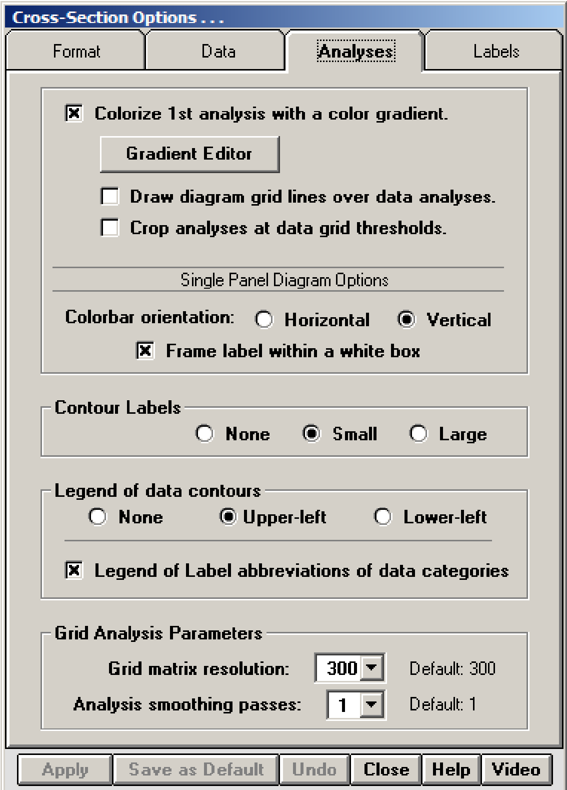
Wind plot display interval.
This option allows thinning of displayed wind data, which is especially useful for cross-sections containing many soundings.



The example image at left shows a time-series diagram which has its wind data plotted with the "Shafts with Feathers" option.

Additionally, the "Print graphic wind legend" option is used, which displays the legend at the lower-right corner, below the diagram.

TAB 3 – Analyses.



** Options require the Advanced Module.*

Colorize. Select this option to paint the first cross-section parameter analysis in full color. Follow-on analyses are then overlaid as contour lines. *

Gradient Editor. Activates color Editor menus. *

Select desired "**grid line**" and "**crop analyses**" colorizing options.

Colorbar orientation for single panel diagram. Select the Horizontal or Vertical style. *

Contour Labels. For diagram contour labels.

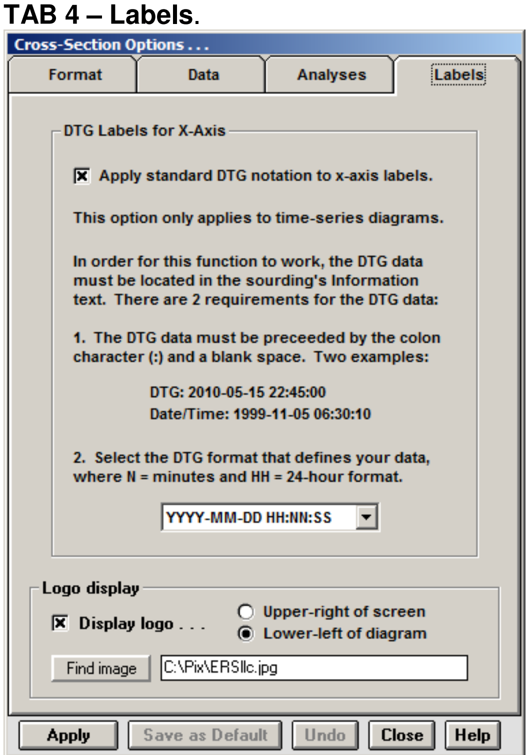
Legend of data contours. The legend is displayed within the cross-section diagram.

Legend of Label abbreviations of data categories. Legend information is only used for non-numeric labels, such as “OVC = Overcast”

Grid matrix resolution. Select larger values to help analyze finer details in contour gradients.

Analysis smoothing passes. Helps eliminate rough looking analyses especially when using higher grid matrix resolutions, or irregularly spaced data sets.

TAB 4 – Labels.



Check the **Apply standard DTG notation to x-axis labels** checkbox for a more traditional date & time display format. The DTG data must be available in the sounding’s “information” text.

<u>DTG = Date Time Group</u>

1. The DTG data must be preceded by one of the following two DTG indicators…

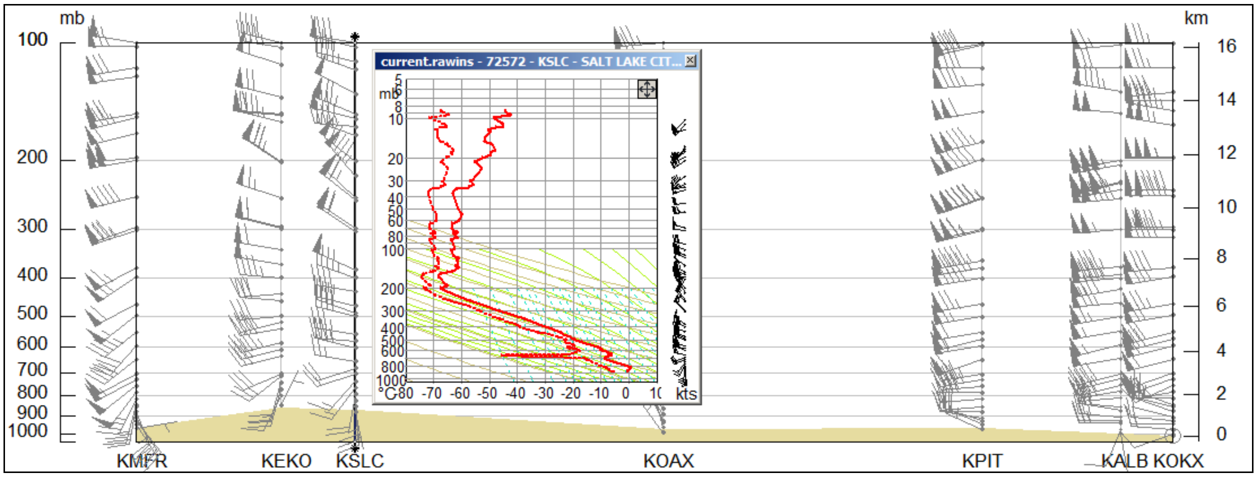
DTG:
Date/Time:

2. The user must select the DTG format that is reflected in the sounding’s text.

Logo display. Select Logo placement at the screen’s upper-right corner, or within the diagram’s lower-left corner.

18.7 **Cross-Section Mouse & Click Operations**.

Mini-Sounding. While moving the mouse over the cross-section, the mouse-pointer will change shape into a "hand" image, which when clicked, will produce a mini-sounding of that data (see below example). This mini-sounding can be expanded into a full sized sounding by clicking the small “expand box” icon, which is located in the upper-right corner of the mini-sounding.



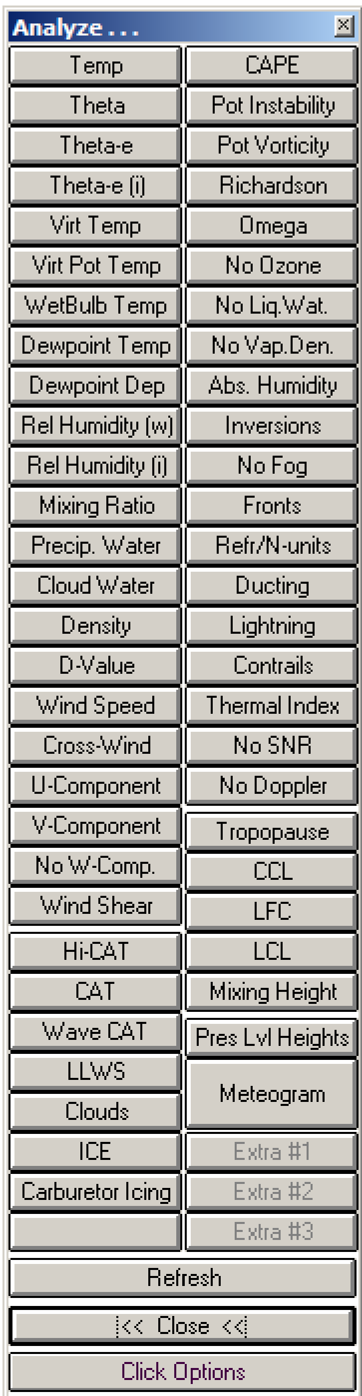
Title. The cross-section's Title can be edited with a mouse-click when over the title text.

X-Axis. The cross-section's x-axis Label can be edited with a mouse-click when over the label's text area.

Zoom. When using the optional Advanced Cross-Section module (discussed in the next few pages), the "rubber-band-zoom" mode is activated with a CTRL-Click of the mouse.

Data Plots. When viewing a plotted cross-section diagram, and while the Toolbar is displayed, click on any Toolbar button while pressing down the SHIFT or CTRL key – and the actual data values will appear on the diagram. This option is often used in the classroom, so students can manually analyze a cross-section or time-height diagram.

18.8 **Cross-Section Analyses**. The Menu's ANALYZE option displays a floating toolbar (similar to the Sounding diagram toolbar) from which several analyses options can be toggled on/off. This toolbar can also be activated by pressing the right mouse button while over the area to the left of the diagram (just like for the Sounding diagrams). Each of the toolbar's dual-column buttons are explained on the following pages.



The Cross-Section's toolbar buttons function similar to the Sounding diagram's toolbar. However, they also have additional functionality as explained here:

Contour Mode (non-painted).

Left-click (1st instance): Draws data contours with labels.

Left-click (2nd instance): Removes data contours and labels.

Painted Mode (colorized) – for Advanced Cross-Section.

Left-click (1st instance): Paints diagram according to the selected color gradient option.

Left-click (2nd instance): Overlays contour analyses over the painted diagram analysis of the 1st instance.

Left-click (3rd instance): Removes painted and contour analyses.

Any mode.

Right-click: Displays data configuration options panel. See the next four pages for further information and examples.

CTRL-click: Prints actual data values onto the diagram screen. When printed on paper, this option allows manual analyses of the cross-section diagram, which is very useful for educational purposes.

Unique to the Cross-Section's toolbar is its dual-column display. For descriptive purposes, this display is split into two separate sections – the left-column being displayed on this page and the right-column being displayed on the next page.

Temperature (°C or °F)
Potential Temperature [Theta] (°K)
Equivalent Potential Temperature [Theta-e] (°K)
Equivalent Potential Temperature wrt Ice [Theta-e(i)] (°K)
Virtual Temperature (°C or °F)
Virtual Potential Temperature (°K)
WetBulb Temperature (°C or °F)
Dewpoint Temperature (°C or °F)
Dewpoint Depression (°C or °F)
Relative Humidity wrt Water (%)
Relative Humidity wrt Ice (%)
Mixing Ratio (g/Kg)
Precip. Water (precipitable water) (in. or cm.)
Cloud Water Content (g/m^3) *
Density (kg/m^3)
D-Value (ISA standard atmosphere height deviation) (m)
Wind Speed (kt or m/s)
Cross-Wind Speed (kt or m/s)
U-Component of the Wind Speed (kt or m/s)
V-Component of the Wind Speed (kt or m/s)
W-Component (vertical) of the Wind Speed (kt or m/s)
Wind Shear (kts/1000ft)

The following options are only available with the Analytic Module.

Hi-CAT High-altitude turbulence categories
CAT Clear-Air Turbulence categories *
Wave CAT categories. *Only with the Mountain Wave Module.* *
LLWS : Low Level Wind Shear
Cloud Layers categories
ICE Structural icing categories *
Carburetor Icing (induction) categories

More >> This button expands the toolbar to display the more analysis options.

* NOTE: These parameters (LWC, CAT, icing, ducting, etc.) are solely determined by the configuration settings in effect at the time which the cross-section datafile was created.

This is the right-column display of the cross-section's toolbar. This toolbar panel also offers the ozone and omega (if data are available) and radiometric (radiometer data) buttons for analyses.

CAPE* Convective Available Potential Energy (J/kg)
Potential Instability (Theta-e gradients, C/km)
Potential Vorticity (PVU)
Richardson Number (Ri)
Omega (vertical motion) (microbars/second)
Ozone {if present} (nbar, mPa, or ppb)
Liquid Water (radiometric data)
Vapor Density (radiometric data)
Abs. (Absolute) Humidity
Inversions (frontal & subsidence)
Fog (radiation & advection)
Fronts (cold & warm)

Refractivity (N-units or K-units)
Ducting (trapping) potential
Lightning potential
Contrails potential
Thermal Index

SNR (signal to noise ratio)
Doppler units

The following analyses are displayed as a single line depicting parameter height.
Tropopause
CCL / LFC / LCL
Mixing Height
Pres Lvl Heights – Plots heights of standard pressure levels (100 mb, 200 mb, etc.). See example in the following pages.

Meteogram – select from a variety of parameters for overlay displays. See example in the following pages.

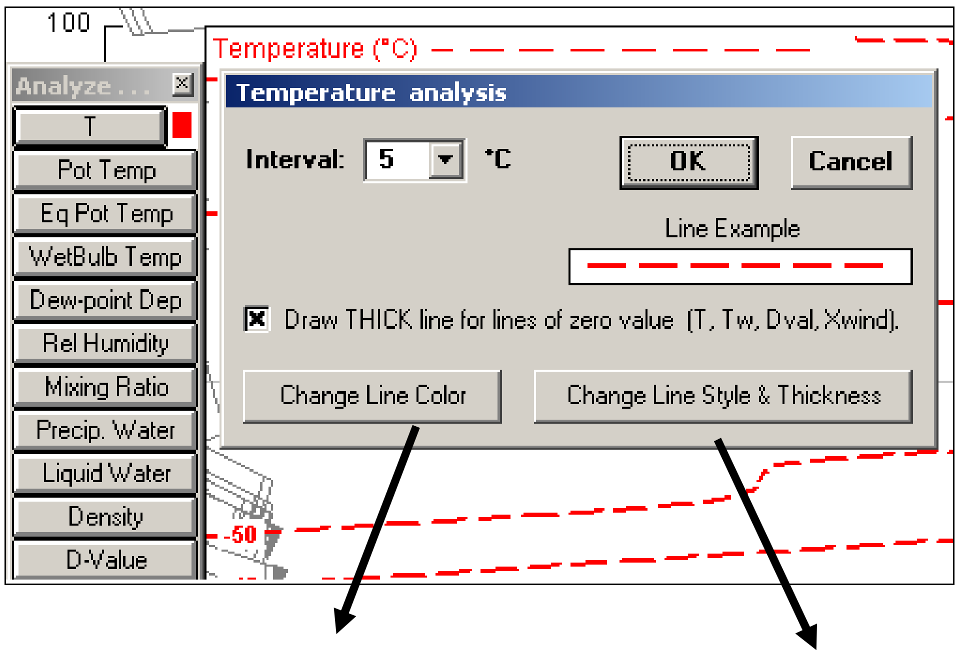
The Extra#1, Extra#2, and Extra#3 analyses buttons become active when one or more data types are included as data items, either from Aerosol profile data, or from sounding files created in the RAOB CSV data format. The CSV format can be used to analyze any user-defined data items. The CSV Format is described at the end of this User Manual.

* Examples of CAPE analyses can be found in the next few pages.

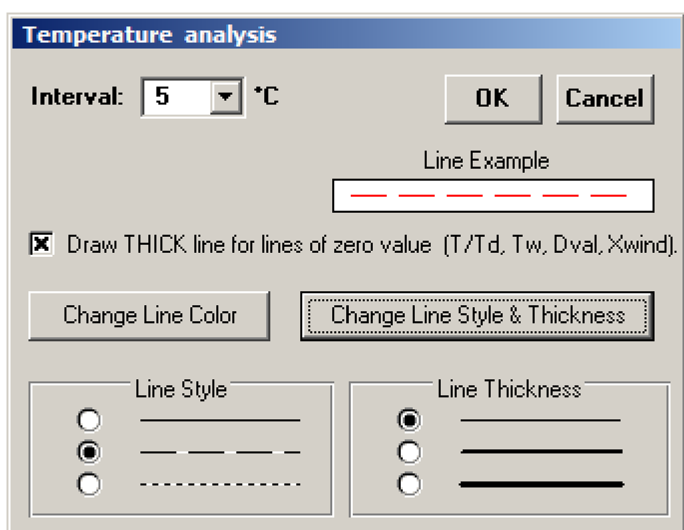
Each toolbar analysis button has configurable options. These options can be displayed by right-clicking on each button (see next page for example).

Standard Cross-Section Data Analysis Options.

Below is an example of the “Temperature” configuration options panel. Each panel is displayed after right-clicking the mouse over the toolbar’s parameter button. For this example, the temperature’s contour interval, color, and line style can be altered. Additionally, for those data items that can have a zero (0) value (e.g., temperature, wet-bulb temperature, D-Val, and cross-winds); the **zero value line** can be plotted thicker for enhanced visualization of the contour patterns.

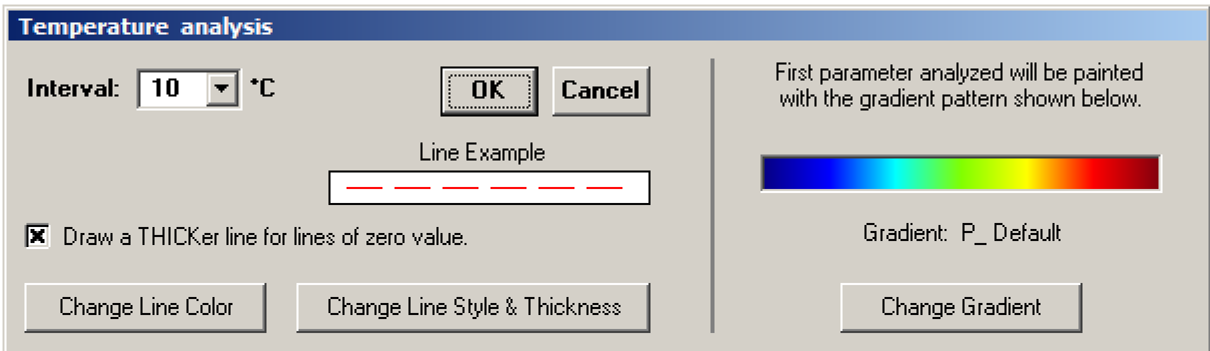


The below-left shows the “Color” options panel which is displayed upon selecting the above “Change Line Color” button. The below-right image is another Temperature analysis options box, but this one shows additional line options, which become available upon selecting the above “Change Line Style & Thickness” button.

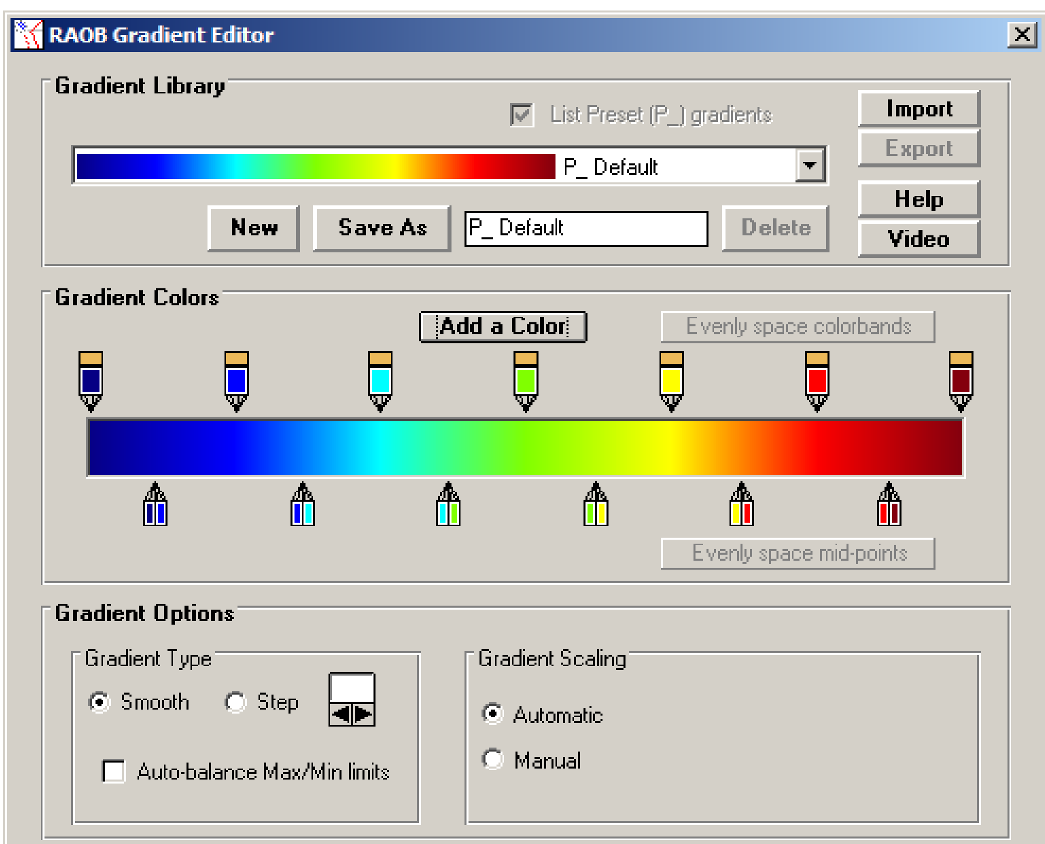


Advanced Cross-Section Data Analysis Options.

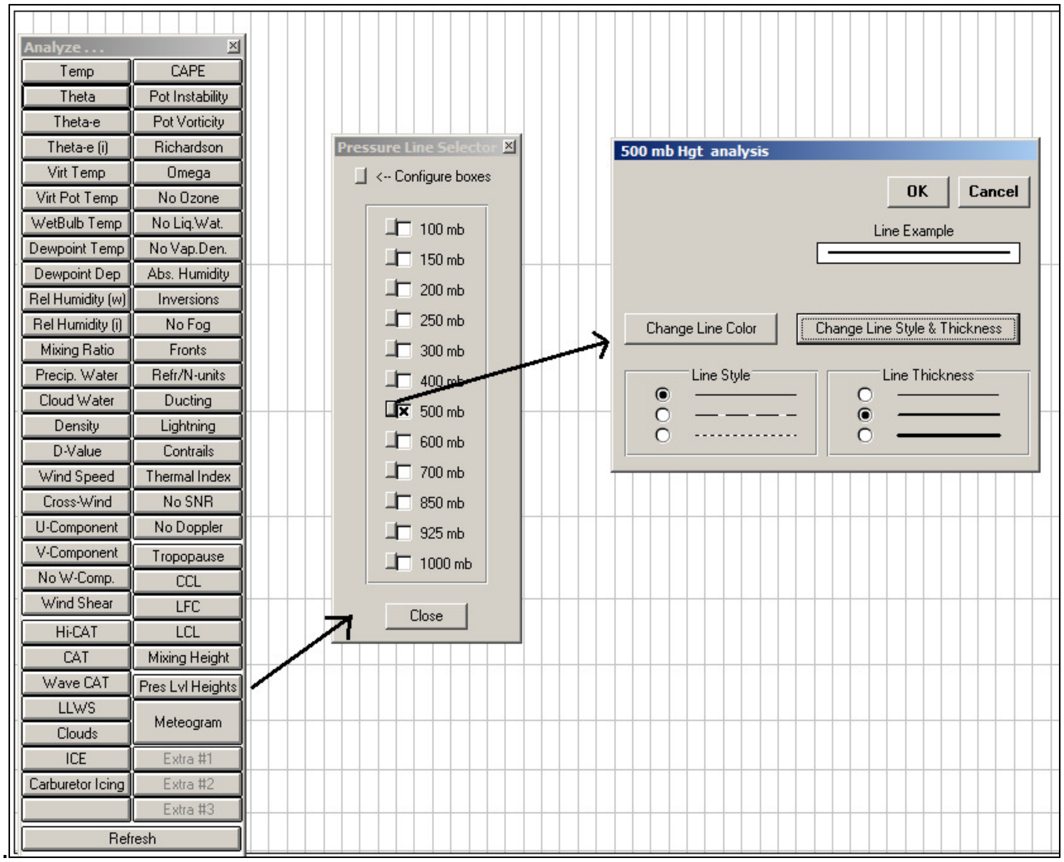
The prior page shows how the Temperature analysis options box appears when RAOB is configured to only display isopleth analyses, or when only the Standard Cross-Section module is available. When using the optional Advanced Cross-Section module (or enabling analysis colorizing), the below Temperature analysis box is displayed. This analysis options box is now expanded to the right with a Gradient (or colorizing) option. It shows the current Gradient selected for analysis, and it provides a "Change Gradient" button which allows the user to change the color Gradient.



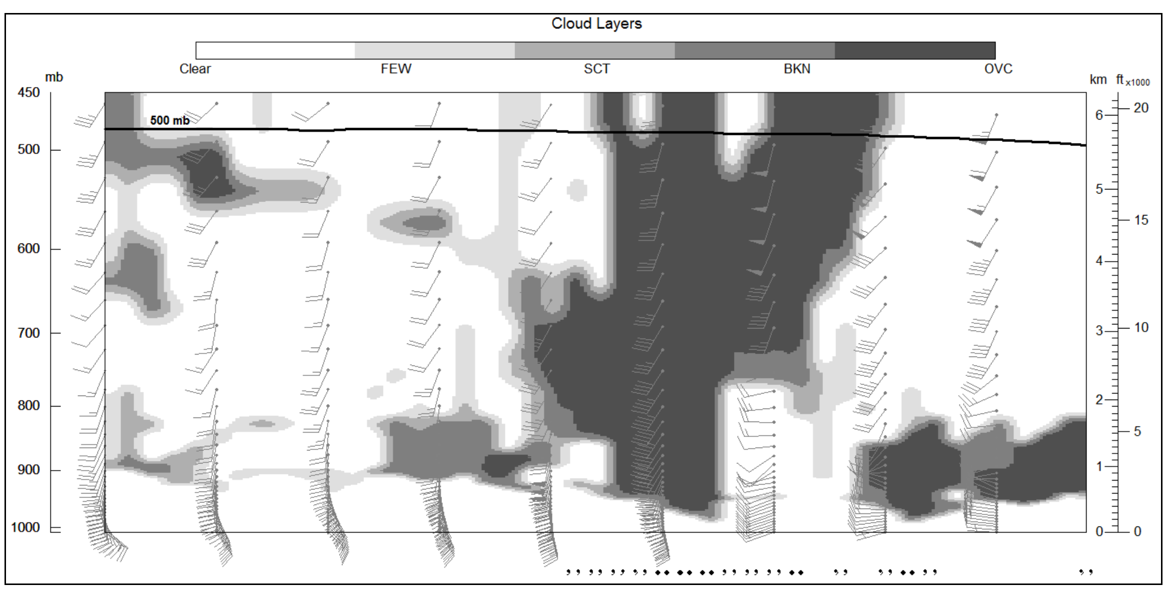
When the "Change Gradient" button is selected, the below Gradient Editor is displayed. Here the user can either select a different Gradient for analysis, or the user can create a new and unique gradient. Please see the following pages on the Advanced Cross-Section module, which provides additional explanation and discussion about this full-featured Gradient Editor.



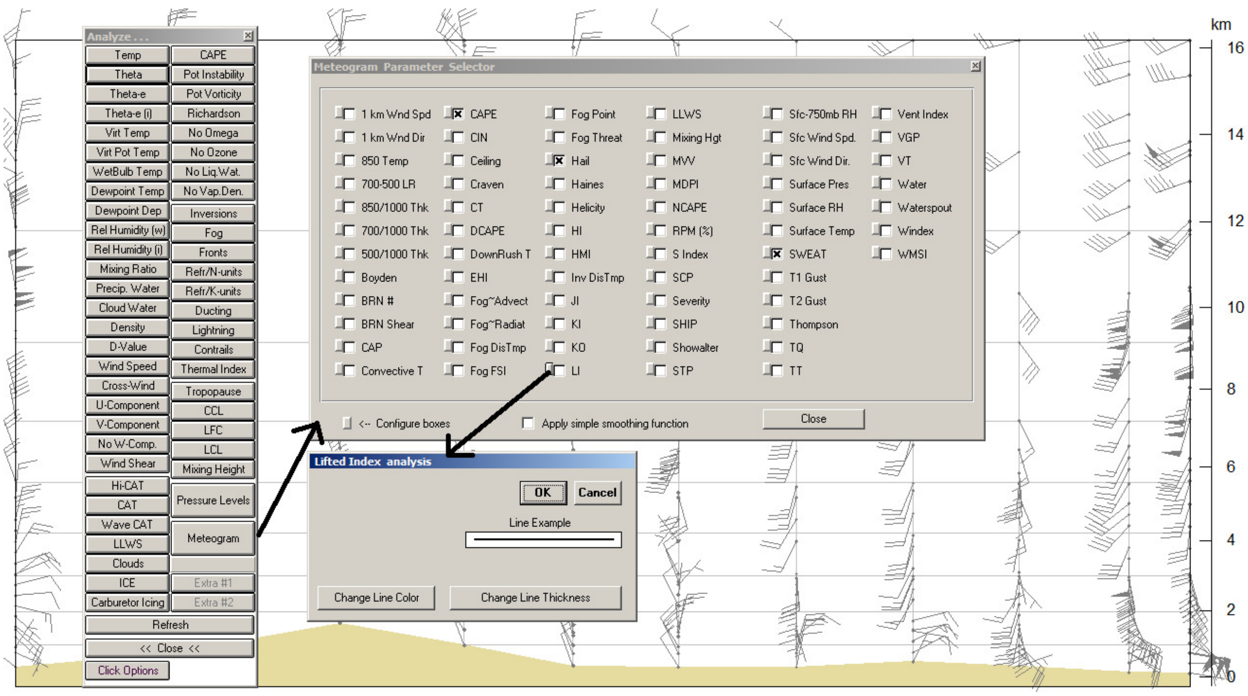
Pressure Heights. This option plots the "heights" of the standard pressure levels. Below shows how to select and configure a pressure level for overlay. First right click on the “Pres Lvl Heights” button. Then select which standard pressure level to plot. Each level can be configured for color and line thickness. To do this, just click on the small square buttons just left of the pressure level check boxes as shown below



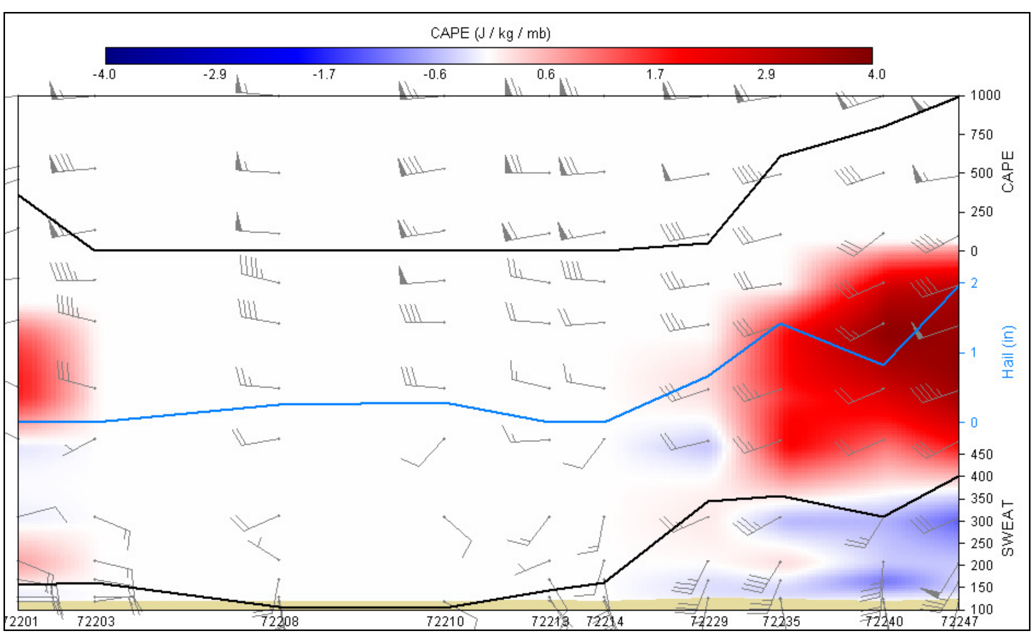
This example sectional overlays the 500 mb heights over the "Clouds" analysis. Note that the “colorized” CAT analyses can only be done with the Advanced Cross-Section module.



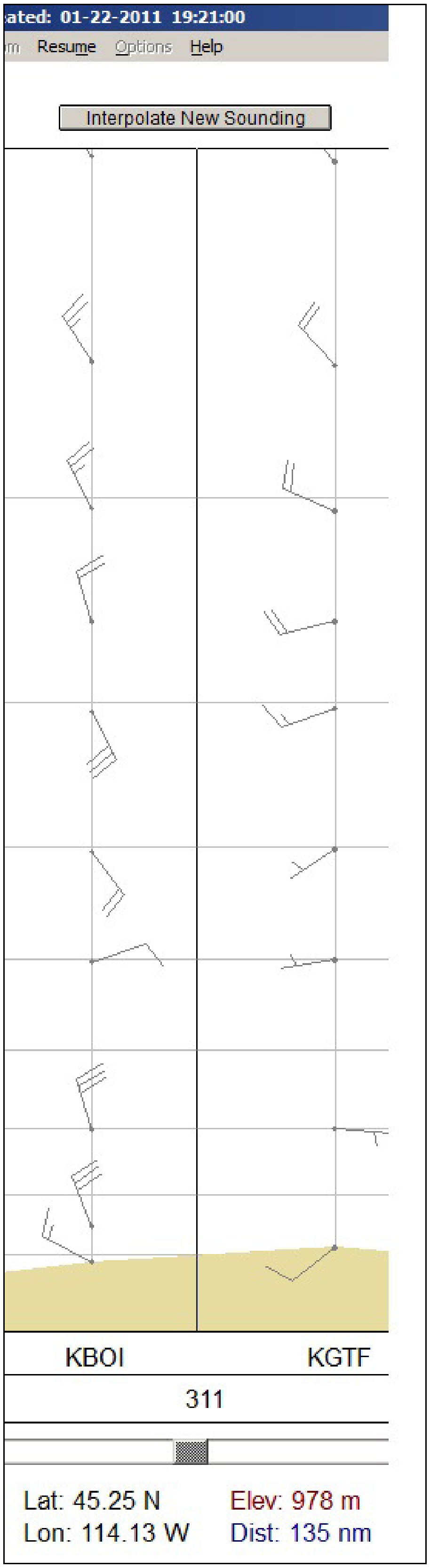
Meteogram Options. Below is an illustration of how to select and configure a specific meteogram parameter for a cross-section or time-height overlay. The user must first right click on the “Meteogram” button to select which parameters to plot. Each parameter can be individually configured for color and line thickness. To do this, just click on the small square buttons just left of the meteogram parameter check boxes as shown below.



This example cross-section overlays three meteogram parameters over the "CAPE" analysis field. Note that the “colorized” CAPE analyses can only be done with the Advanced Cross-Section module.



18.9 Interpolation of a Cross-Section Sounding.



Click on the menu bar's INTERPOLATE option to activate the sounding generation (or interpolation) feature. Upon activation, a blinking vertical line and associated horizontal scroll bar is displayed. The coordinates of the pending interpolated sounding are displayed just below the scroll bar. Once the blinking line is positioned at the desired location (in space or time), just click on the "Interpolate New Sounding" button to begin the interpolation process. To exit the interpolation mode, just click on the "Resume" menu option or press the ESC key.

RAOB automatically determines the new station elevation and latitude & longitude coordinates (for distance-based cross-sections), then adds this information to the new sounding.

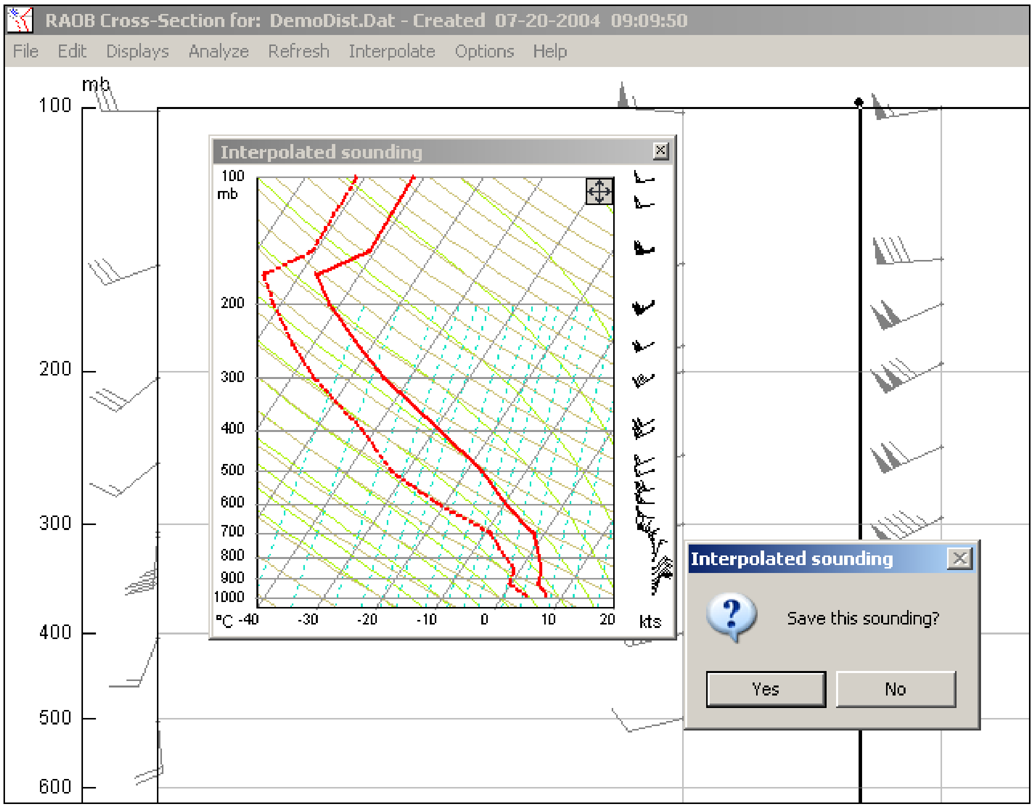
All significant temperature data are maintained in the interpolated sounding. Additionally, standard significant pressure levels (i.e., 1000, 850, etc.) are added to the interpolated sounding, if missing.

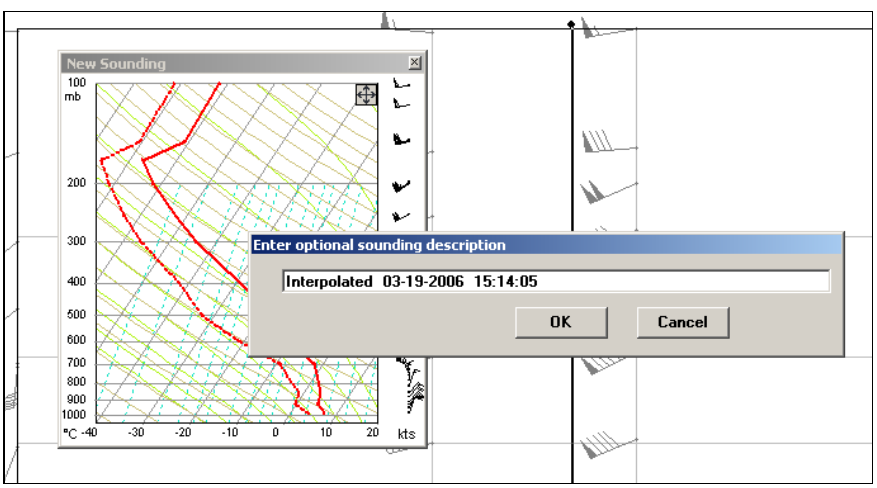
All significant wind data are also maintained in the interpolated sounding. However, if the interpolated sounding has less than 4 winds, then RAOB automatically interpolates wind data at 2,000 foot intervals, MSL.

Note: For distance-based cross-sections (such as this example) where surface elevations differ, RAOB employs additional interpolation algorithms in order to generate a representative "surface boundary layer" which maintains similar low-level temperature and wind gradients. In some cases with very steep surface terrain differences, this additional interpolation may not produce a reasonable profile and manual adjustments may be necessary, especially if the user is primarily interested in surface or boundary related data analyses.

Sounding Interpolation (continued).

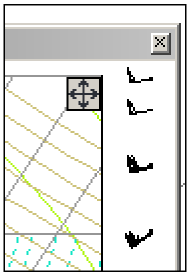
After the "Interpolate New Sounding" button is pressed and RAOB completes the interpolation process, the following screens appear. First, an overlaid mini-sounding screen presents a plot of the newly created sounding. Second, alongside the mini-sounding is a prompt which asks the user to save or cancel the new sounding.





Once the new sounding is accepted and given a file name, the user is then prompted to enter an optional "description" line, which will be included in the newly created sounding file. RAOB automatically adds a date & time entry for the "description," which can be edited now or at a later time.

Sounding Interpolation (continued).



After the newly created sounding has been given a file name and optional file description, the sounding can be easily expanded and transferred to the Sounding diagram screen as a full-sized diagram by clicking on the 4-arrow expansion icon located at the upper-right corner of the mini-sounding.

Sounding Interpolation Limitations.

Data Coordinate Limitations.

Coordinates between any two consecutive soundings must be less than or equal to 90 degrees. Distances greater than 90 degrees will cause unpredictable results.

Data Analysis Limitations and Suggestions.

Due to the great variety of data types that may be analyzed, cross-section algorithms were chosen to best fit common data resolutions and the use of relatively low grid resolution to increase processing speed. In the more unusual cases where data gradients are very small compared to the diagram grid, the user can alter three program options to better see the analysis…

1. Decrease the 'smoothing' passes as much as possible (Diagram Options, Tab 3). This helps see the finer details of data patterns. However, if the data gradients are very tight, then irregular isopleth patterns may occur.

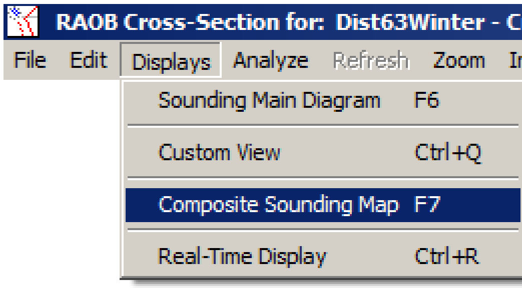
2. Lower the upper pressure level of the cross-section diagram (Diagram Options, Tab 1). This has the affect of vertically expanding the diagram's lower layers and effectively increasing the grid resolution of the low-level analyses.

3. Increase the grid matrix resolution (Diagram Options, Tab 3). This will allow higher resolution analyses and will result in better definition of data with strong gradients. This option will require more computer processing speed. This option may also produce irregular isopleth patterns, which may need more smoothing to improve appearance.

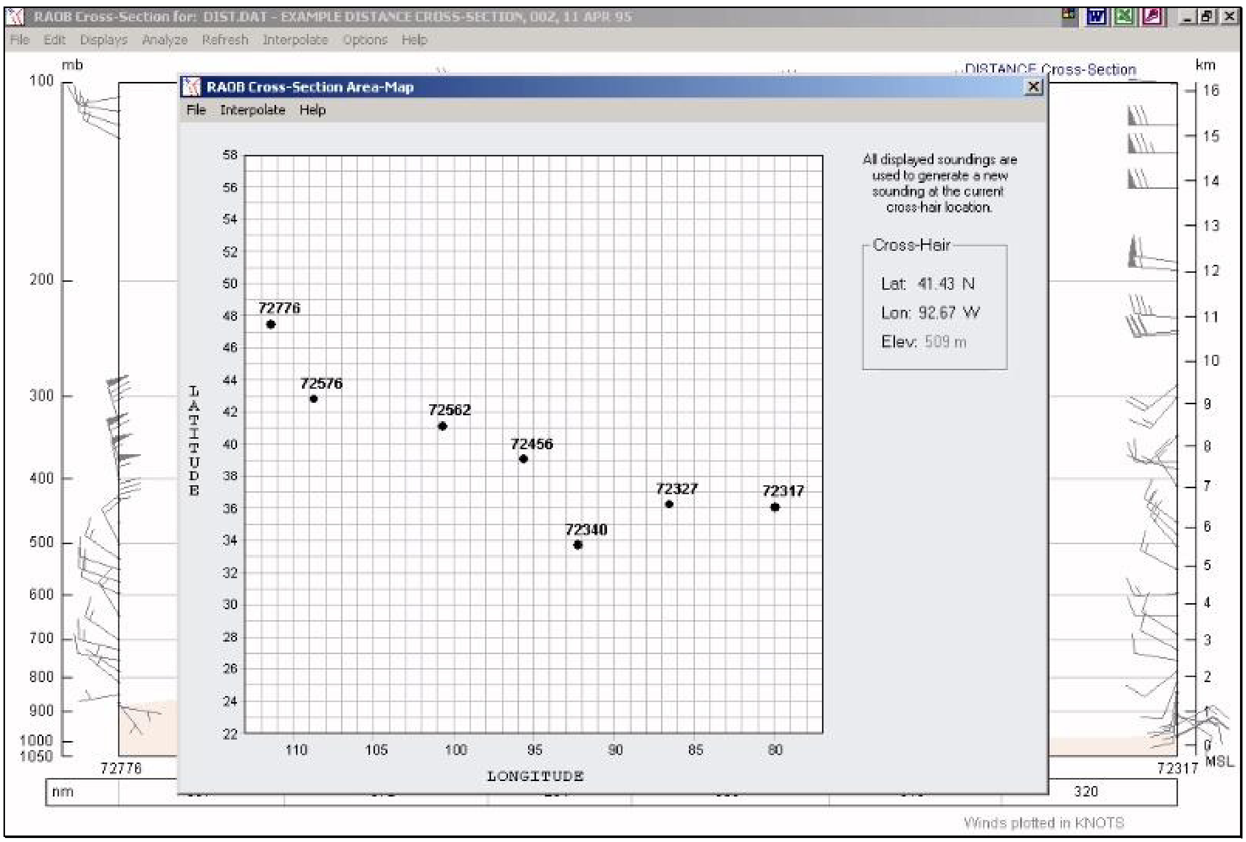
Sounding Interpolation Limitations.

If generated winds are interpolated from 2 opposing wind directions, the result may not be of the desired orientation, but will instead be 180 degrees out. In these instances, the wind directions must be manually adjusted by editing the sounding data via the "Sounding" display screen data editing options.

18.10 **Composite Sounding Map**.



Below is a Composite Map screen example, which can be toggled on/off with the TAB key.

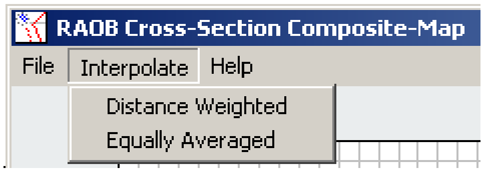


The Composite Map allows alternative methods of generating an interpolated sounding. Instead of performing the standard distance-based or time-based cross-section interpolation, this screen allows either distance weighting or equal averaging of all selected soundings. This is especially useful for points of interest that do not lie between any pair of soundings. In other words, this screen will allow the user to generate a sounding for any location in the region of the cross-section. However, the accuracy of the resulting sounding is bounded by the proximity (locations and distances) of surrounding soundings.

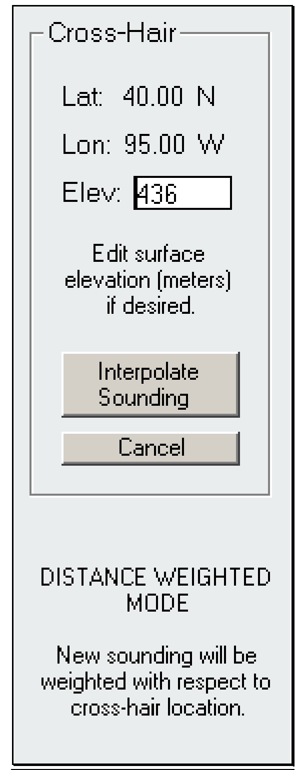
The Composite Map shows the relative positions of each sounding. By using the cursor keys or mouse, a blinking cross-hair icon can be moved within the map area. The position of the cross-hair determines the coordinates of the resulting interpolated sounding. The new sounding is then generated by one of two processing options, distance or equal weighting. These options are presented next.

Composite-Map (continued).

When the cross-hair icon is positioned at the desired location, then click on the INTERPOLATE Menu to display two interpolation options as seen here…



Distance Weighted. Activation of the Distance Weighted option will produce a sounding as a function of the distance of plotted soundings with respect to the location of the cross-hair icon. Before processing begins, the user will be asked to specify an elevation for the interpolated sounding or accept the computer's *interpolated* elevation. (See example of a Distance Weighted interpolation prompt screen at right.)



Equally Averaged. Activation of the Equally Averaged option will produce a sounding based on equal weighting of all plotted soundings regardless of the location of the cross-hair icon. Like the above Interpolation option, the user will also be prompted to specify an elevation for the averaged sounding or accept the computer's *averaged* elevation.

Upon activation of the INTERPOLATE SOUNDING button (seen at right), the same interpolation sequence of sounding display and file identification is presented as occurs during the interpolation process associated with the main cross-section screen.

Composite-Map Interpolation Limitations.

Data Coordinate Limitations.

Coordinates between any two consecutive soundings must be less than or equal to 90 degrees. Distances greater than 90 degrees will cause unpredictable results.

Sounding Interpolation Limitations.

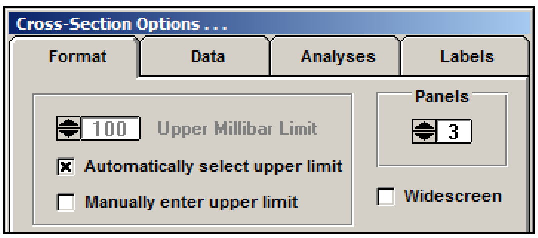
If generated winds are interpolated from 2 opposing wind directions, the result may not be of the desired orientation, but will instead be 180 degrees out. In these instances, the wind directions can be easily modified by using the editing capabilities of the full screen mode display of the interpolated sounding.

18.11 **Advanced Cross-Section Module**. RAOB's Advanced Cross-Section module contains all the features of the Standard Cross-Section module plus the following additional features ...

1 – Maximum of 6,000 soundings.
2 – Display up to 4 panels on the same display.
3 – Zoom diagram capabilities.
4 – Compare two different cross-section or time-height files.
5 – Batch generation of time-height diagrams.
6 – Colorizing.
7 – Weather Symbols.
8 – Split Screen.

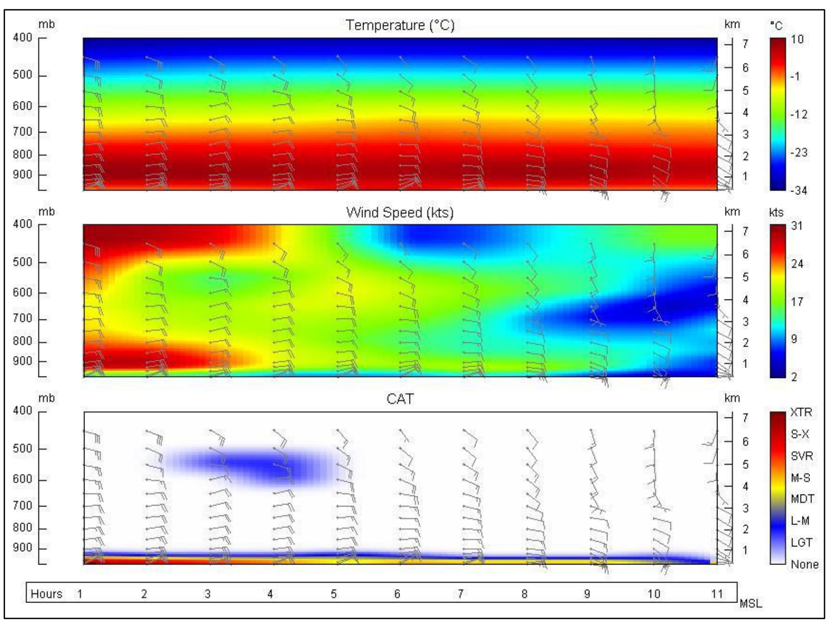
Advanced feature #1: 6,000 Soundings. Whereas the Standard module has an upper limit of 100 soundings per cross-section, the "Advanced" module allows up to 6,000 soundings per cross-section. This is especially useful for detailed studies of time-series sections where sounding data is produced by surface-based sounding systems with very high temporal resolutions.

Advanced feature #2. 1-4 Panels.



Plot one, two, three or four diagram panels on the computer's display screen at the same time.

Use the **Panels** selector shown at left to select desired number of panels. Select the Widescreen option to maximize diagram size.



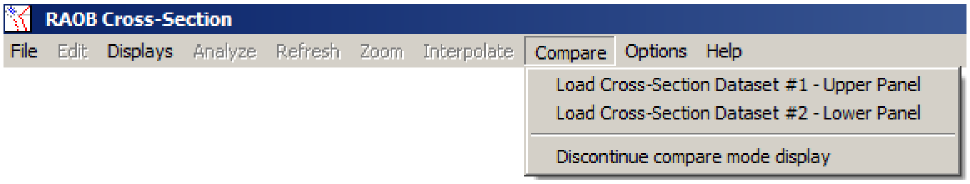
The image at left contains an example 3-panel cross-section. Each panel can be individually selected for different analyses and meteogram overlays.

Although not shown in the example, overlays of data isopleths with labels can also be added to these diagrams.

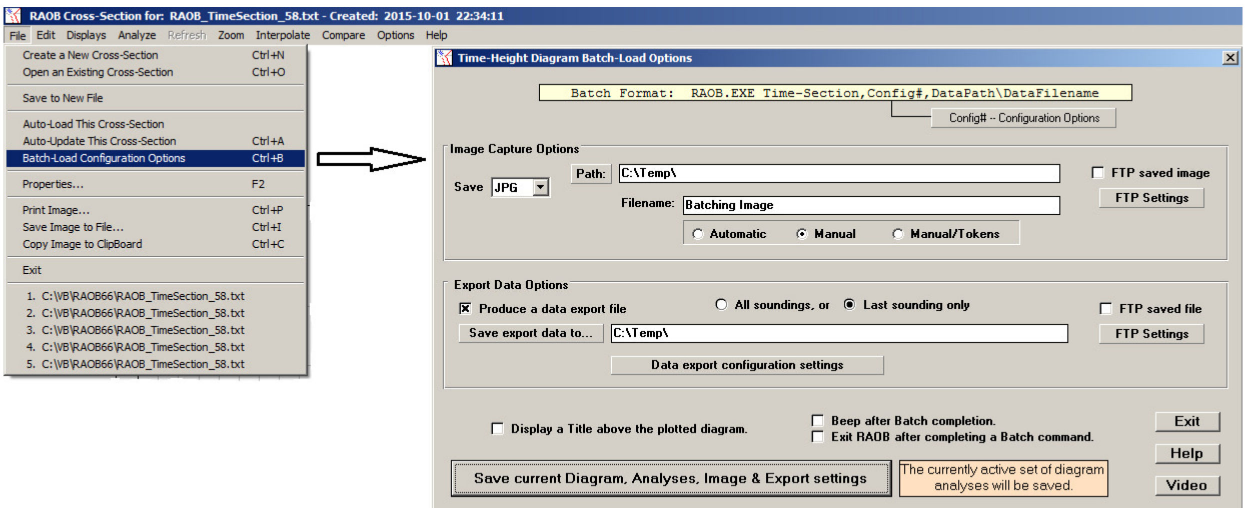
Advanced feature #3. Zoom. After a cross-section diagram is plotted, the Zoom function is activated using the CTRL key and Mouse clicks …

ZOOM-IN -- Press the CTRL key during MOUSE click & drag action.
ZOOM-OUT -- Click the RESTORE option located on the menu bar.

Advanced feature #4. Compare. This function permits the display of 2 different cross-section and/or time-height diagrams simultaneously. The Upper/Lower diagrams are individually selected as seen below.



Advanced feature #5. Batch generation of Time-Height diagrams. Selection of the FILE menu's "Batch-Load Configuration Options" (as seen below) presents the main control panel enabling batch processing of time-height diagrams. RAOB will be ready to process a batch command after activation of the "Save current Diagram, Toolbar/Analyses, Image Capture, and Data Export settings" command button. This command button not only saves the Image & Export options, but also the currently active Diagram display format and the analyses Toolbar selections, which will all be reproduced during the batch.



The light yellow box in the above panel of Batch options presents the Batch Format. Below is an example of a complete batch command. The "Config#" parameter (Config1 through Config8) is optional.

`C:\Program Files\RAOB Program\RAOB.EXE Time-Section,Config1,D:\Data\Data.txt`

Note that one wildcard asterisk (*) can be used in the Filename, where the most recent file will be used.

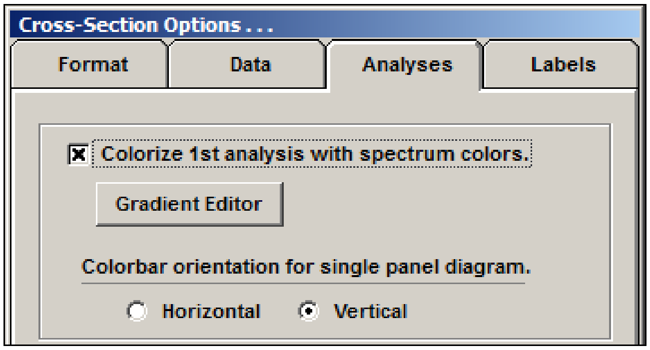
There is one other batch command option that applies to the unique sounding files in the Radiometrics (RDX) format, where the files can contain multiple scan modes. In these cases, the desired scan mode must be specified at the end of the batch command (as seen below) or else the first scan mode found will be used. Note: there is one exception to this RDX rule – if the RAOB Program configuration options panel (access via F9), the Data Processing tab's "Pre-select a scan mode…" option is used, then this pre-selected scan mode will override any batch command settings.

Example RDX command line > **`RAOB.EXE Time-Section,D:\RDXdata.CSV,Angle Scan18(A)`**

Once the Batch Load options are set and the batch command line is established, there is one final requirement for successful time-height diagram generation. All the soundings in the multi-sounding datafile must have sufficient data/time (DTG) information for RAOB to create the necessary DTG field which is used to properly locate the soundings on the time-height diagram

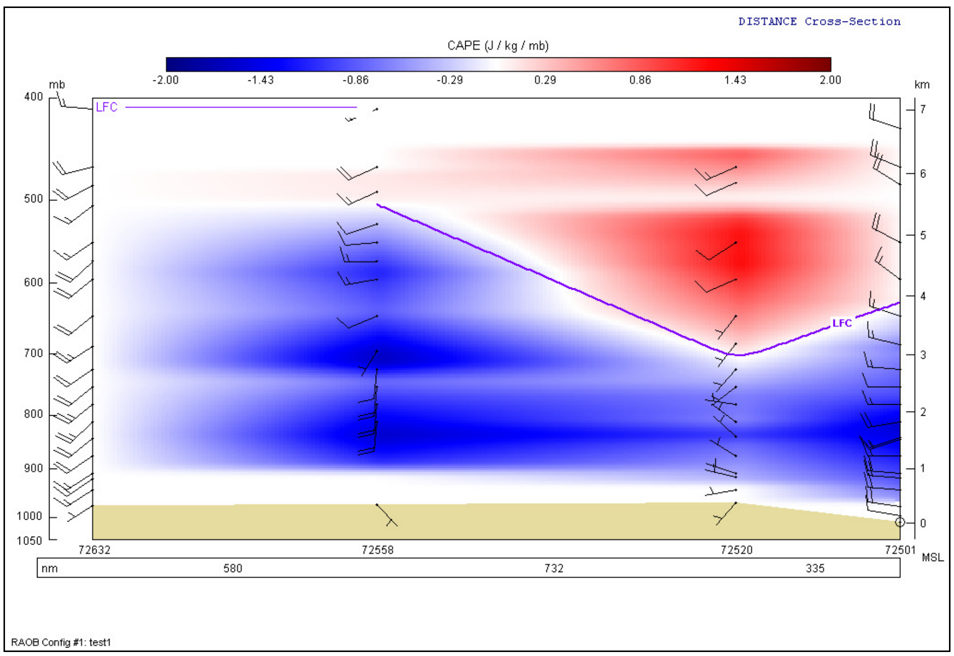
Note: The "Data Export" function requires use of the optional Advanced Export module.

Advanced feature #6. Colorizing.

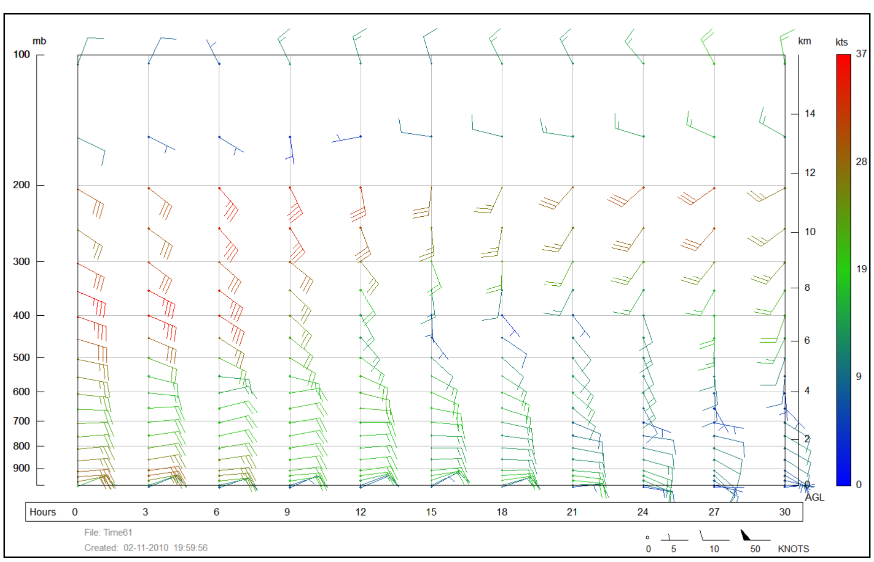


By checking **the Colorize 1st analysis with spectrum colors** box, the user can apply colored analyses to most toolbar parameters. Further analyses of the same parameter will be applied to the diagram as overlays of isopleths.

The Color Gradient Editor is discussed in the next section of this manual.



At left is an example of a colorized CAPE analysis (including an isopleth overlay of the LFC analysis). For those viewing this example in black & white, the CAPE+ areas are located above the LFC line (and are colored red) while the CAPE- areas are located below the LFC line (and are colored blue).

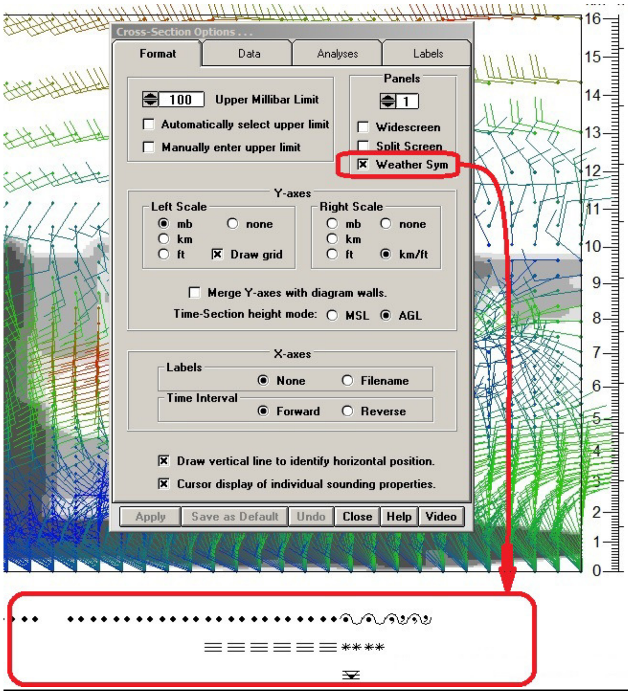


At left is an example single panel display of colorized winds.

The colorbar is displayed along the right side of the diagram. There is an option to display the colorbar at the top of the diagram. This menu option can be seen at the top of this page.

The winds colorizing option is located on the Data Tab of the Cross-Section Options.

Advanced feature #7. Weather Symbols.



Weather Symbols example.

At left is an example time-height diagram with the "Weather Symbol" option activated.

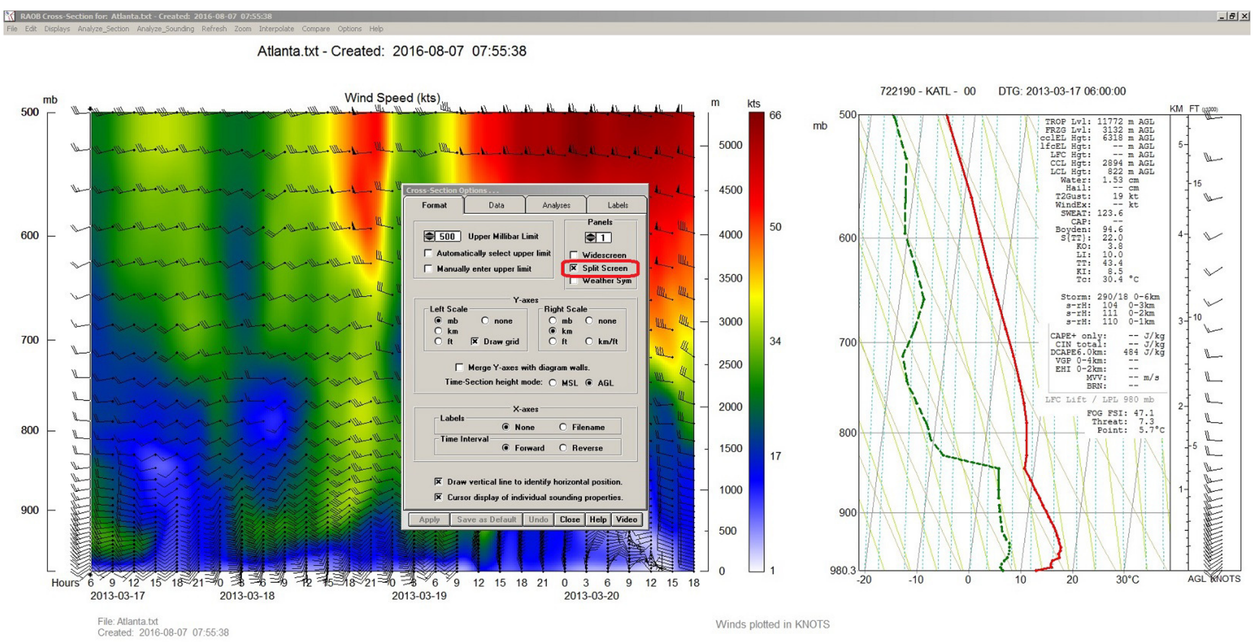
This option is only available when displaying a single-panel sectional.

When activated, it displays standard WMO weather symbols immediately below the respective weather producing profile.

To ensure maximum display of weather information, RAOB creates up to 3 lines of weather symbols.

Not shown in the adjacent image, is the time-height diagram's "timeline", which is always displayed immediately below the weather symbol section.

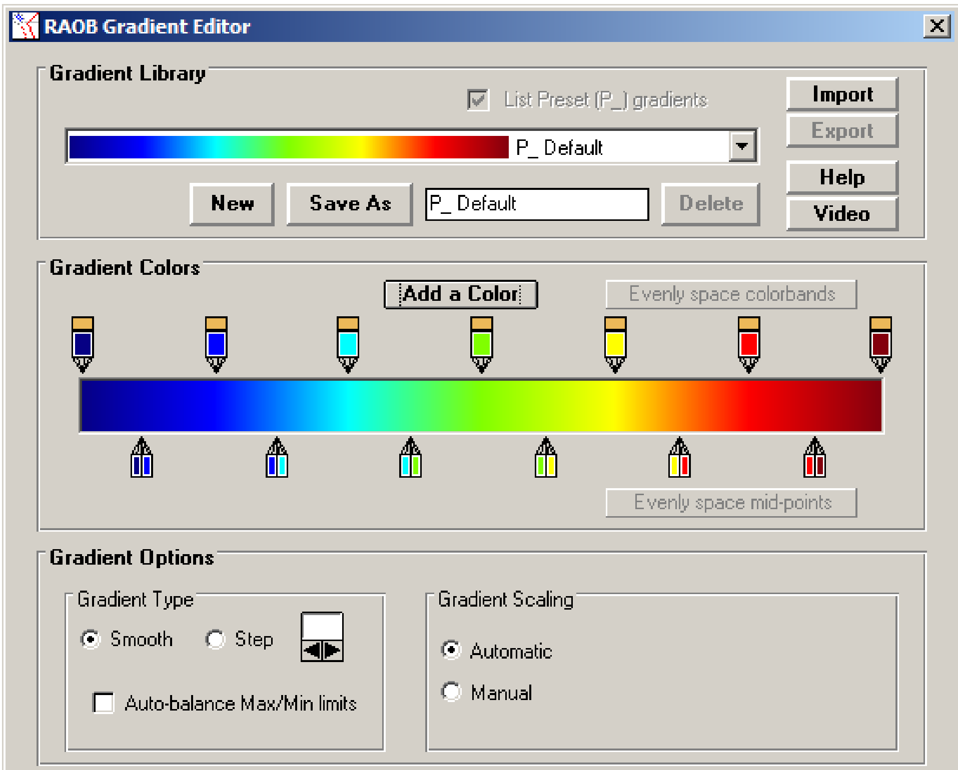
Advanced feature #8. Split Screen.



RAOB's unique "Split Screen" option requires use of a wide-screen monitor. While the above display shows a single-panel sectional, it can also work with multi-panel (2-4) displays. The left side Sectional and the right side Sounding (SkewT or Emagram) diagrams are independently configurable. Whenever the mouse cursor (or arrow keys) move across the Sectional diagram, RAOB instantly updates the associated Sounding diagram. The Sounding diagram also has analyses and other display options.

18.12 **Gradient Editor**.

RAOB's Gradient Editor is accessed by one of 2 methods. (1). From the 3rd (Analyses) tab of the cross-section's diagram options screen. (2). From the cross-section's Analyses Toolbar, by right-clicking on the parameter of interest. Only from this second access method does the "Apply" button become functional.



The above gradient editor example displays the preset color scheme for "Default" analyses (mainly used for temperature & moisture fields). The top drop-down box lists all available saved gradients. The Preset gradients (those with a "P_" prefix) can not be added, edited, or deleted, but user-defined gradients can be added and deleted. Once a gradient is selected, it is placed in the "Gradient Colors" section for editing.

Colorband Pens. These pens are located above the gradient edit box.

- Drag the pen left & right to adjust widths of colorbands.
  The "Evenly space colorbands" button resets all pens.
- Right-click the pen to change the color.
- Click on the Eraser to remove the color from the gradient.

Mid-Point Pens. These pens are located below the gradient edit box.

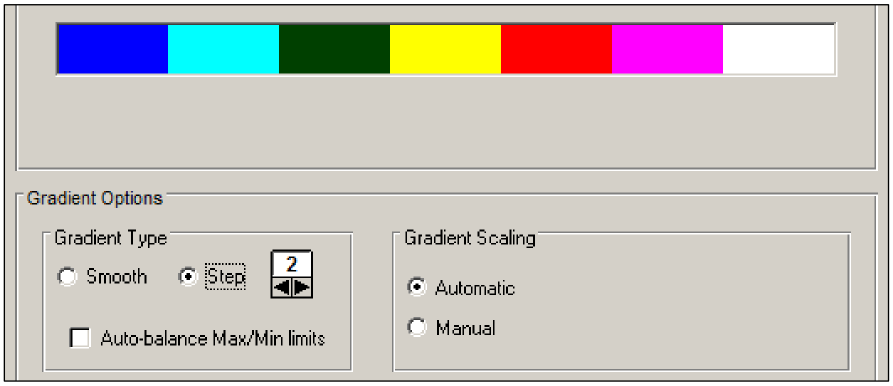
- Drag the pen left & right to adjust colorband mid-points.
  The "Evenly space mid-points" button resets all pens.
- Right-click the pen to flip colorband colors.

New Gradient. To create a new gradient…

- Click on the "New" button.
- Click on the "Add a Color" button for each new color.
- Click on the "Save As" button to save the gradient for diagram analyses.
- Click on the "Apply" button to link a gradient to a specific toolbar parameter.

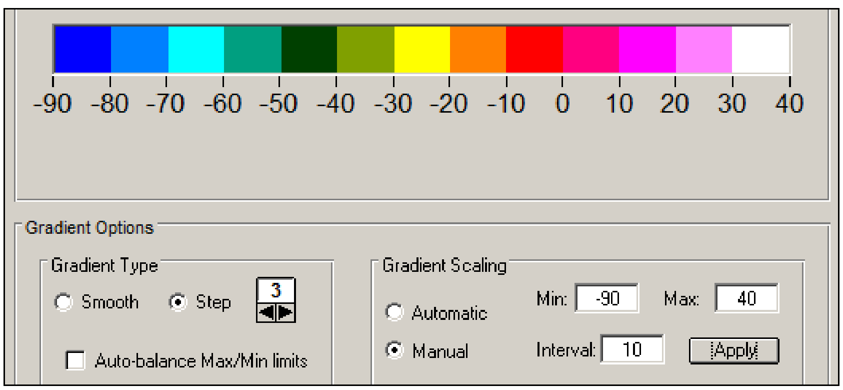
Gradient Editor Tools.

Gradient Type. The example gradient on the prior page shows a "Smooth" gradient.

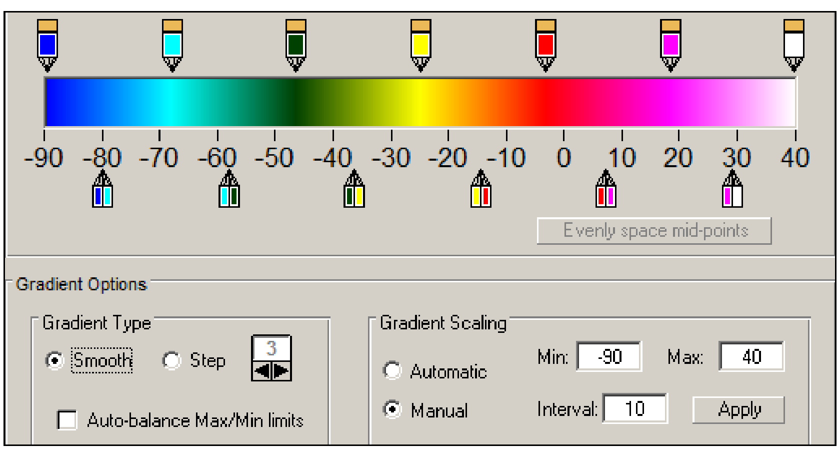


At left is an example gradient with the "Step" option applied, which is set to "2" steps per colorband. Increase the number of Steps to produce smoother color transitions between steps. Note that the color pens are removed in the "step" mode and all colorbands are evenly spaced.

Gradient Scaling. The first example below contains the same gradient as above, but with 3 Steps per colorband with the addition of "Manual" Gradient Scaling. This scaling scheme could be used, for example, for analyses of temperatures using Celsius units.



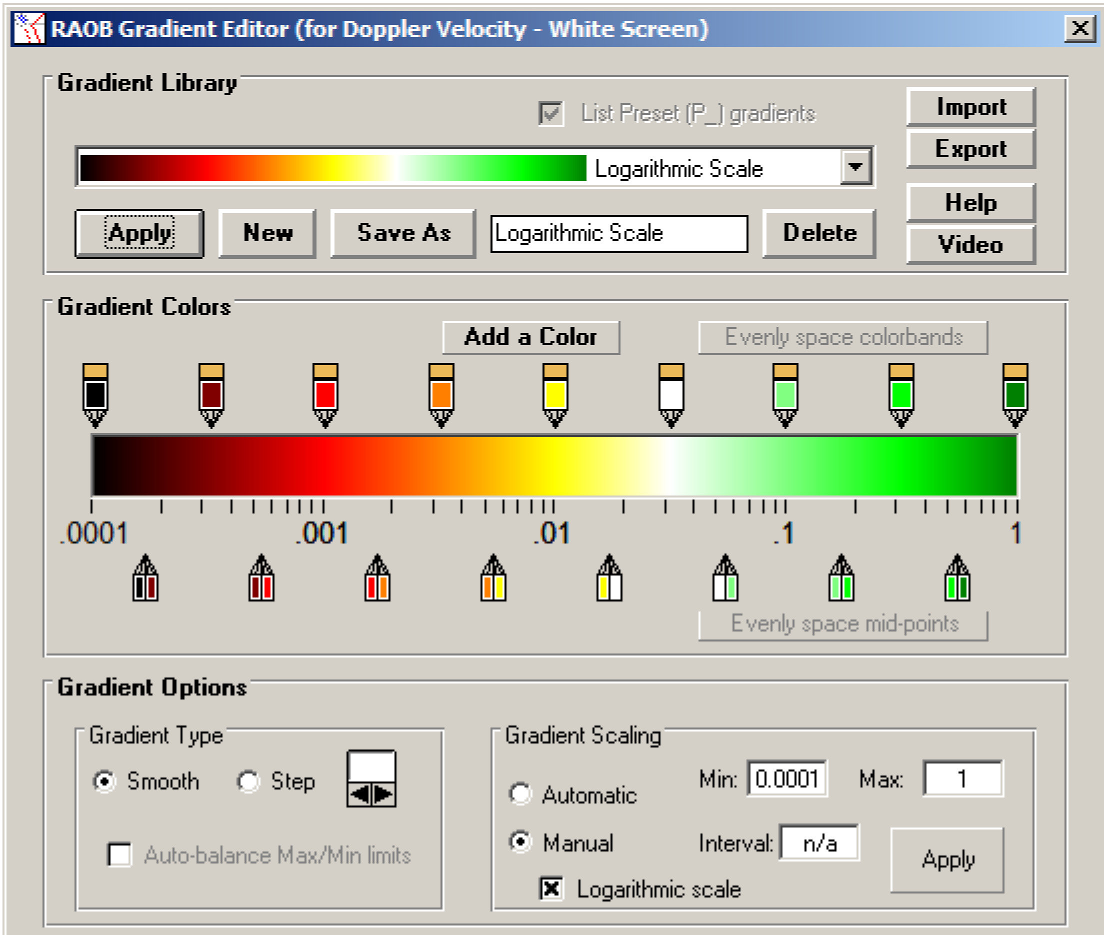
If this scaling is used, any diagram temperatures falling outside the scale's max/min limits will not be analyzed (colored) and will be left blank. If the "Automatic" scaling mode is used, the entire diagram will be analyzed and the colored step pattern will not necessarily coincide with overlaid isopleths due to data smoothing differences.



The second example (shown at left) uses the same gradient, but with the "Smooth" color mode, which allows the user to manually adjust the gradient using the color pens.

Auto-balance Max/Min limits. The auto-balance option can not be changed for Preset (P_) gradients. When checked, RAOB will automatically find the higher "absolute" value of the max and min values, and force the lesser value equal to the higher value -- and of the opposite sign.

Gradient Editor Tools (continued).

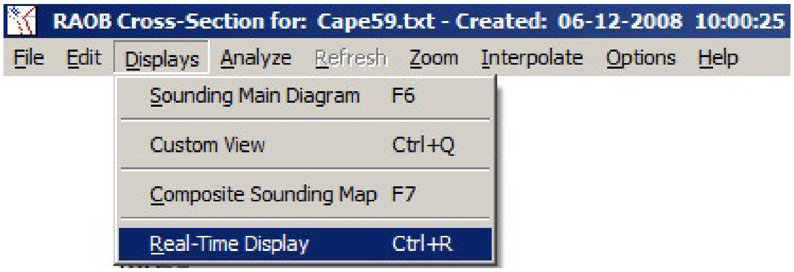


^

Logarithmic scale. Below the Gradient Scaling's "Manual" option, there is the special "Logarithmic scale" option. When selected, the "Interval" option is no longer needed and becomes disabled. The "Max" value is automatically set to the number one or ten (1 or 10). The "Min" value can be any one of the following values:

0.1
0.01
0.001
0.0001

18.13 **Real-Time Display – An Automated Cross-Section Data Processor Module**. This is an optional program module for which the Advanced Cross-Section module is a prerequisite. This module is only used for Time-Sections. When activated, RAOB uses timed intervals to search for new sounding data, and if found, automatically adds the new soundings to the existing cross-section diagram.

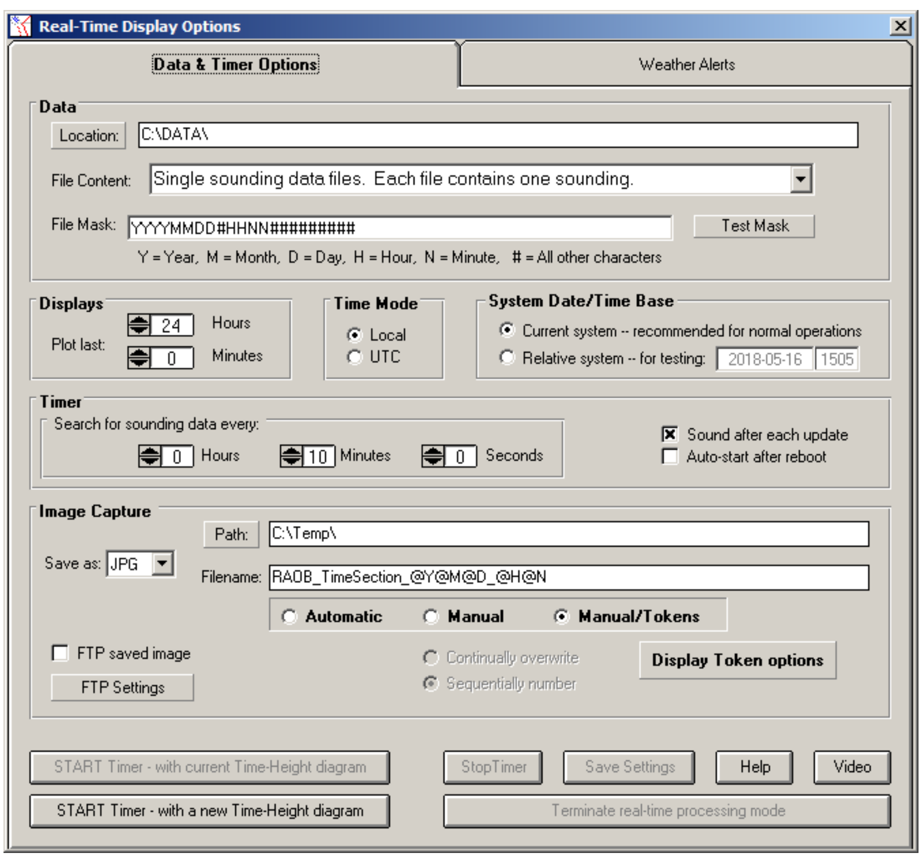


Location. The Real-Time Display Options screen requires identification of sounding data location.

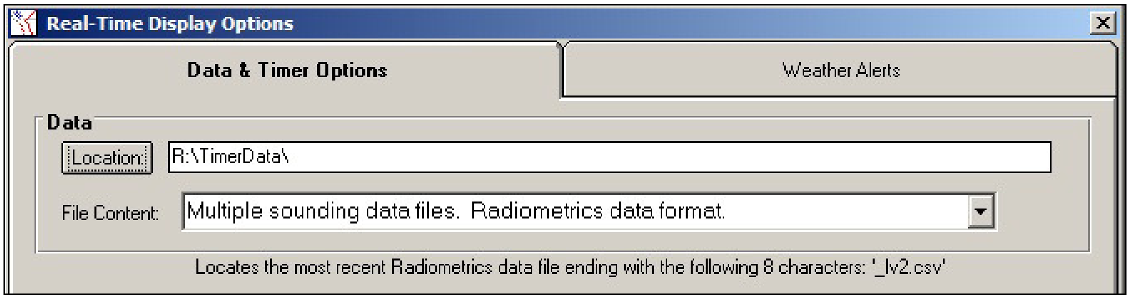
File Content. This drop-down box offers 2 options – (1) Single sounding data files, or (2) Multiple sounding data files. Example discussions follow…

Single sounding data files. Any data type can be used for this option, but all sounding data filenames must use the same name convention as defined in the **File Mask** box. Each sounding file must contain only one sounding, and each filename must contain year (Y), month (M), day (D), hour (H), and minute (N) information; while all other information is represented by the pound (#) character. Use the **"Test Mask"** button to verify the existence of data using the File Mask format. Below is an example use of the mask.

```
Filename: 20071015_1200_RAOB.CSV
    Mask: YYYYMMDD#HHNN#########
```



Multiple sounding data files. While the "single sounding" data format option allows data of any format to be processed, this option only processes the RDX (or Radiometrics Corp) data files. These multiple sounding files contain not only temperature and moisture data, but also liquid water and vapor density data. Special datafile names are not required since data dates & times are embedded within the data files. Since the RDX data files can be very large, RAOB needs extra time to process the files.



Note: Processing of RDX data requires the optional RDX Decoder program module.

Displays. Use the Displays options to specify the time period (hours & minutes) displayed on diagram.

Time Mode. Select Local or UTC (Zulu) time.

System Date/Time Base. Select the Current system for normal operational use. Use the Relative system option to test historical or other datasets. This is done by simulating a different clock date & time, while leaving the computer's operational time clock unchanged. Once the real-time processor is started, the specified Date/Time value moves forward in time.

Timer. Use the Timer options to select how often RAOB looks for new sounding data. When new data is found, the data is processed and added to the existing cross-section. Use the Auto-start option to automatically load the existing cross-section and continue the updates with current timer options.

Image Capture. Define how and where diagram images are stored.

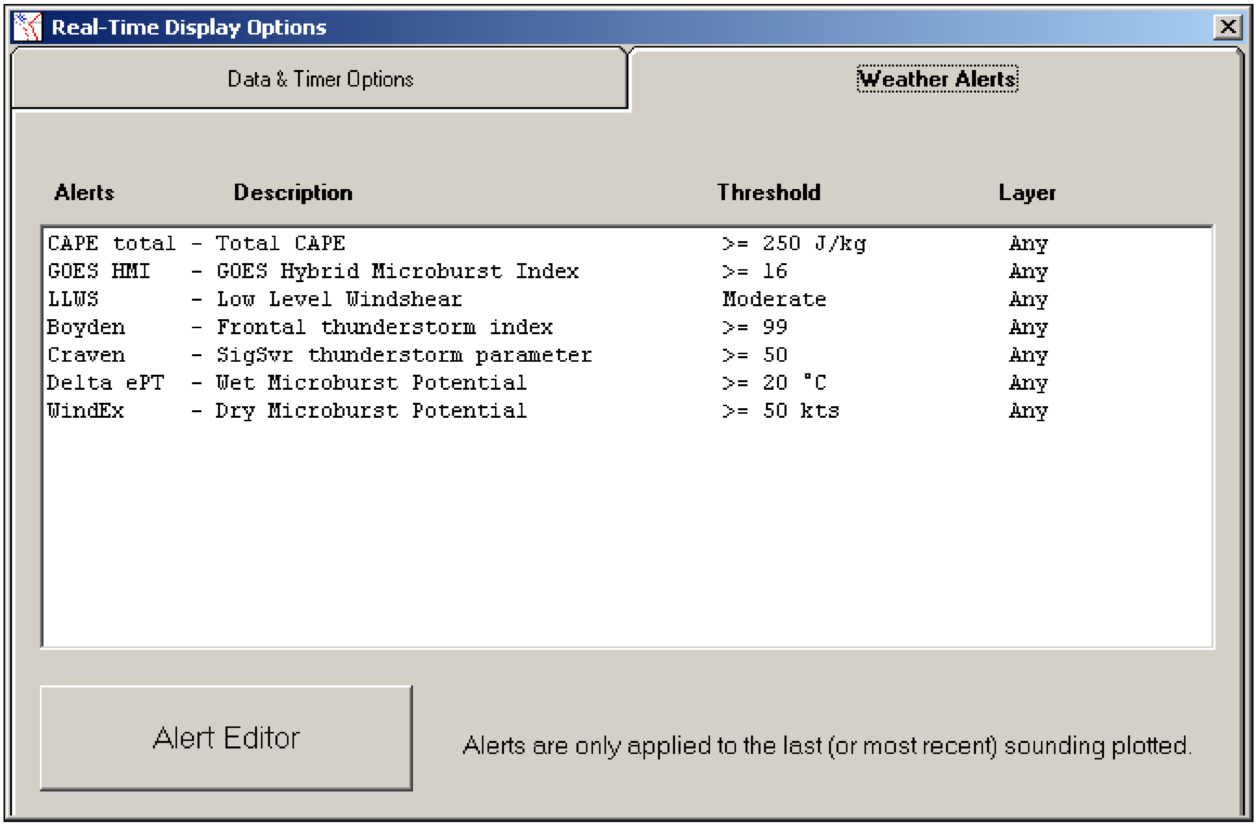
Start Timer Buttons. Automatic cross-section processing is activated by either of the two "Start Time" buttons, depending on whether a new or existing diagram is desired. Once the real-time diagram is initiated, processed and displayed, a "Stop Timer" button appears above the diagram (see below), which functions as a Start/Stop toggle switch to control processing.

Stop Timer. This option temporarily halts the timer.

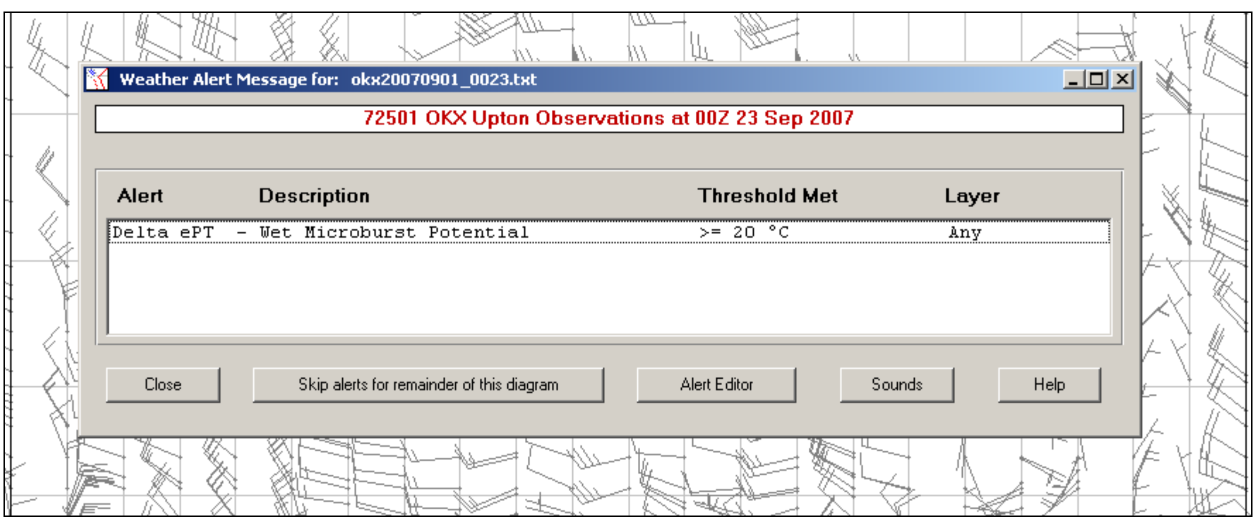
Save Settings. This button saves all options to the programs configuration files for later recall.

Terminate real-time processing mode. This button stops the real-time updating of the cross-section diagram, which then makes available other cross-section options which were previously disabled.

Real-Time Display: Weather Alerts. Any alerts listed in the Weather Alerts window will automatically be checked against the last (or right-most) sounding plotted during real-time updates. Use the "Alert Editor" button to modify the alert list.



Below is an example of a "Delta ePT" alert notification during a real-time updated time-section. The pop-up alert box remains displayed until the user acknowledges the alert. Just as with the Sounding diagram's alert options, these alerts also have associated sound alert options.



19. **MOUNTAIN WAVES and WAVE TURBULENCE**.

19.1 **Wave Turbulence Overview**.

This is an optional program module.

The RAOB program is the only commercially available sounding analyses program that produces mountain (lee) wave turbulence analyses. Even though RAOB also produces standard CAT and High Altitude CAT analyses, these forms of turbulence only use wind shear and lapse rates (respectively) as determining factors. Wave turbulence, however, is dependent on both wind speed, lapse-rate, and surface terrain information. In fact, results show that just the slightest variations in surface terrain can produce wave turbulence when the necessary wind shear and stability conditions are present – and the RAOB program has algorithms that objectively measure their combined effect upon the atmosphere.

There are literally hundreds of published articles on various mathematical solutions for wave turbulence, many of which have specific boundary conditions such as limited atmospheric layers or require explicit atmospheric lapse rates, wind shears, and terrain shapes. RAOB, on the other hand, consistently produces reasonable wave turbulence analyses using everyday soundings with user-definable mountain parameters, and without restriction to pre-defined lapse rates or wind shear. Even though RAOB has a default mountain range parameter algorithm, that will always produce a maximum wave scenario, it is absolutely essential that the user provide RAOB with actual mountain parameters in order to produce the best possible wave turbulence results for any individual sounding. This necessity is discussed in more detail in the following pages of this section.

All mathematics used by RAOB to produce wave turbulence are taken from widely acknowledged and quoted sources of wave turbulence theory (which are detailed in the following pages). These theories were developed before the age of computers and no applications algorithms existed until Richard E. Cale (an internationally recognized Certified Consulting Meteorologist) converted these equations into a standard set of automated procedures for use on programmable calculators. Using these procedures, Mr. Cale has had repeated success in analyzing mountain wave turbulence over the Rocky Mountains and other worldwide locations during many years of research on numerous aviation incidents and related atmospheric phenomena.

With Mr. Cale's assistance, the wave turbulence algorithms were incorporated into the RAOB program in a powerful interactive format, which dramatically increased application functionality. Test results were remarkable as very good correlations were noted between soundings and reported wave activity. RAOB even produced good correlation of observed low-level wave induced clouds over the mid-western United States, where a large hill was the only significant terrain feature. The source literature used to develop RAOB's wave algorithms similarly reflect the sensitivity of this methodology to analyze waves produced by even the slightest variations in terrain. Note however, that the success of these algorithms require accurate mountain information. The user must provide the RAOB program with specific mountain parameters for each sounding location in order to obtain the best possible mountain wave and related turbulence results.

It is important to note that even though RAOB consistently produces reasonable wave turbulence results, nearly all mountain and lee wave source documents indicate that there is no single set of equations that can accurately explain all wave phenomena. Furthermore, even though RAOB uses three parameters to define terrain (height, half-width, and ridge axis orientation), mountain shapes are much more complex than these simple definitions may suggest. In the meantime, improved and new methods are being sought for use in RAOB.

The mountain-wave screen also has a powerful option which produces Froude Number analyses and graphics, which are very important to forecasting enhanced mountain precipitation and downslope winds.

For those that require a *complete* analysis of atmospheric turbulence (with or without local terrain influences), RAOB's Turbulence & Mountain-Wave module is a must-have tool.

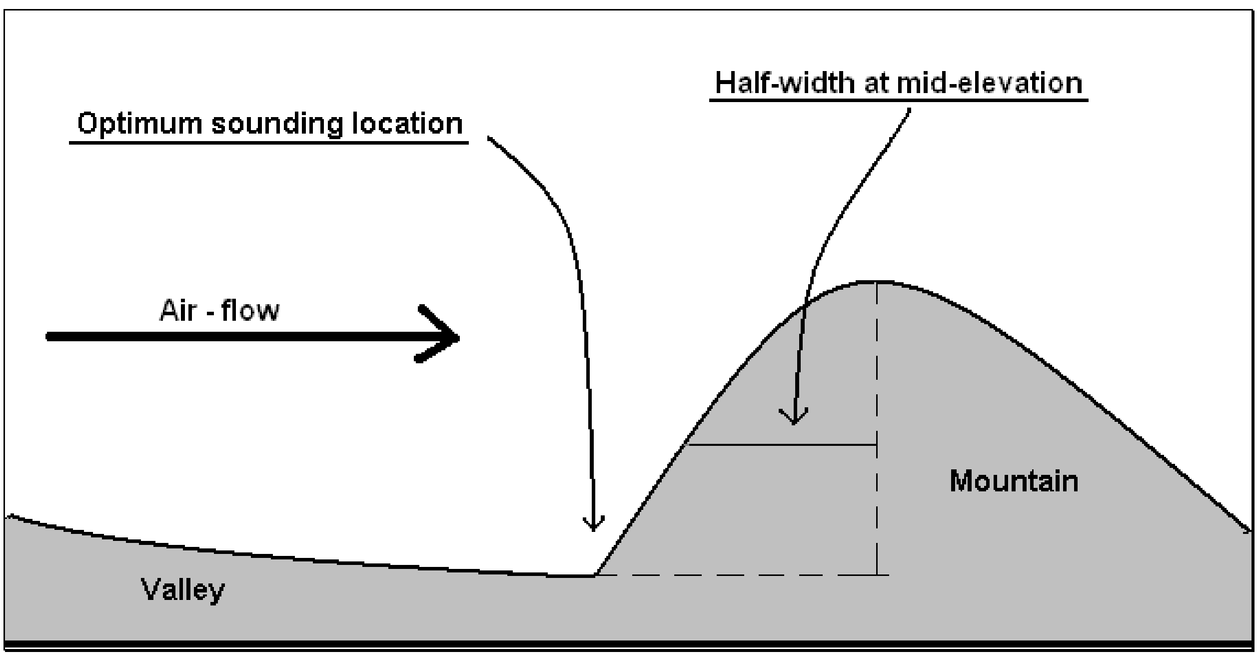
19.2 **Wave Turbulence Method**.

There are two basic rules that must be followed in order to achieve the best possible wave turbulence results. Any deviation to these rules will most likely result in less reliable results.

1. The sounding must be upwind of the mountain. The optimum location is at the foot (or in the immediate upwind valley) of the mountain. If an upwind sounding is not available and if there are sufficient adjacent soundings, then it should be possible to interpolate an appropriate sounding using RAOB's Merge function.

2. Specific mountain parameters must be provided. Use of RAOB's "default" mountain parameters are solely designed to produce the maximum potential wave scenario for the optimum mountain shape pertaining to the analyzed sounding. Mountain definition is composed of three parameters:

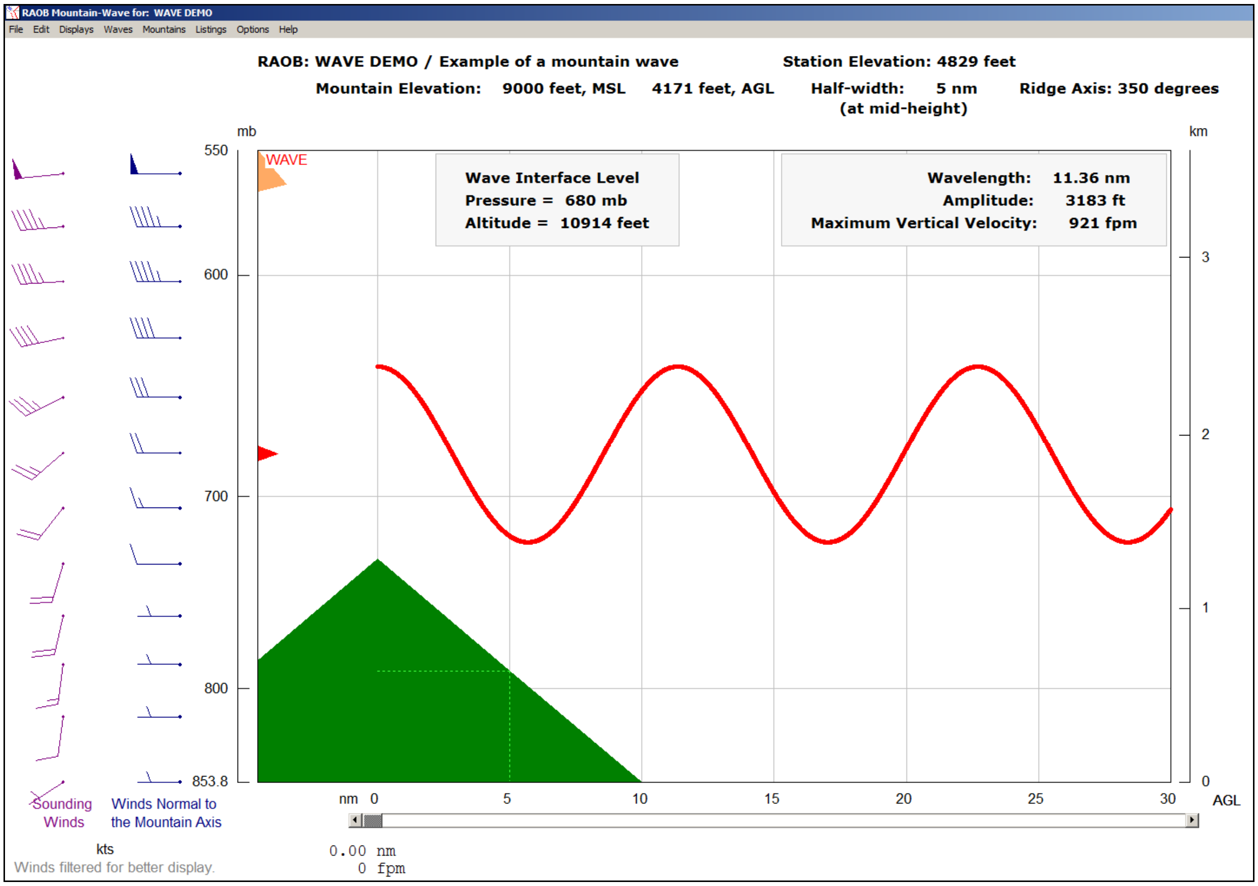
    (1) Mountain height (MSL).
    (2) Half-width at the mountain's upwind mid-elevation (see figure below).
    (3) Ridge axis (degrees). Use 0 (zero) degrees for conical mountains.



The above figure illustrates the optimum upwind location of the sounding and proper half-width definition at the mountain's mid-elevation. Note that the "mid-elevation" is defined as the height midway between the elevation of the sounding station and the mountain top. It is also important that the elevation of the sounding station (as listed in the RAOB.STN locator file) be accurate.

19.3 **Mountain Wave Screen**. *This is only available with the optional Mountain-Wave Module.*

Below is an example mountain-wave diagram. This diagram is obtained from the main Sounding Diagram screen by pressing F5 or by selecting the DISPLAY Menu option and then the Mountain-Wave option. The F5 function key will return the user back to the Sounding Diagram.



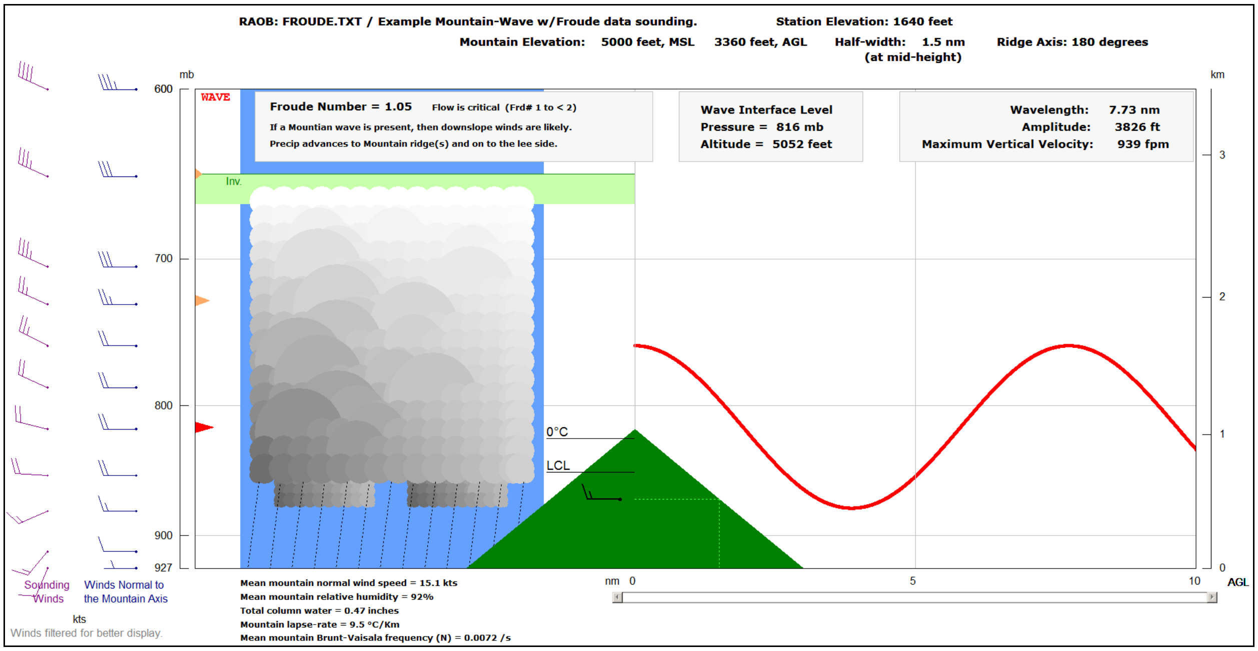
The Sounding's title line and station elevation are listed above the example wave diagram. Just below are listed the mountain elevation and related parameters, which are explained later in this section. A typical atmospheric sounding can have none to several mountain-wave levels. This example has 2 waves, where the predominate wave (the wave with the longest wavelength) is initially plotted by default. Located along the top inside border of the diagram are details about the plotted wave. Parameter units for these data items and units for the mountain characteristics are user-defined and are discussed later in this section.

Located along the left side of the diagram are two wind plots. The "Sounding Winds" reflect the winds as reported from the sounding's datafile. The "Normal Winds" reflect the wind components that are perpendicular (or normal) to the mountain ridge. In this case, the mountain ridge axis was defined to be at a 350-degree orientation. The "normal" wind is always plotted relative to the mountain axis. The "normal" winds are always plotted as if the mountain axis has a north-south orientation, regardless of the actual mountain.

At the bottom of the screen is a slider button which is used to move a blinking cursor-line along the diagram as it displays downwind distances and the wave's associated vertical velocities.

19.4 **Mountain Wave & Froude Number Display.**

The prior page describes RAOB's standard mountain wave display screen, which is available to all RAOB program versions. The below image was created by the new Expanded display screen, which requires use of both the optional Analytic module and a wide-screen computer monitor.



The above expanded mountain wave screen not only displays the same standard mountain-wave images and functions, but it also displays Froude Number data. Froude Number data is important to forecasting enhanced mountain precipitation (rain & snow), and potential for mountain-gap wind funneling and downslope winds (such as Foehn and Chinook winds).

This screen also displays RAOB's RICAPS cloud & precipitation analyses, which is represented by the blue region upwind (left) of the mountain. This RICAPS analysis display represents weather associated with the analyzed sounding, which ideally is situated in a valley just upwind of the mountain. Inversions are also plotted as horizontal green bars. The black colored wind, that is plotted mid-way up the mountain's windward side, represents the mean normal wind, which is used to calculate the Froude Number ...

Froude Number = U / (N x H) [uses virtual potential temperature {wet} data]

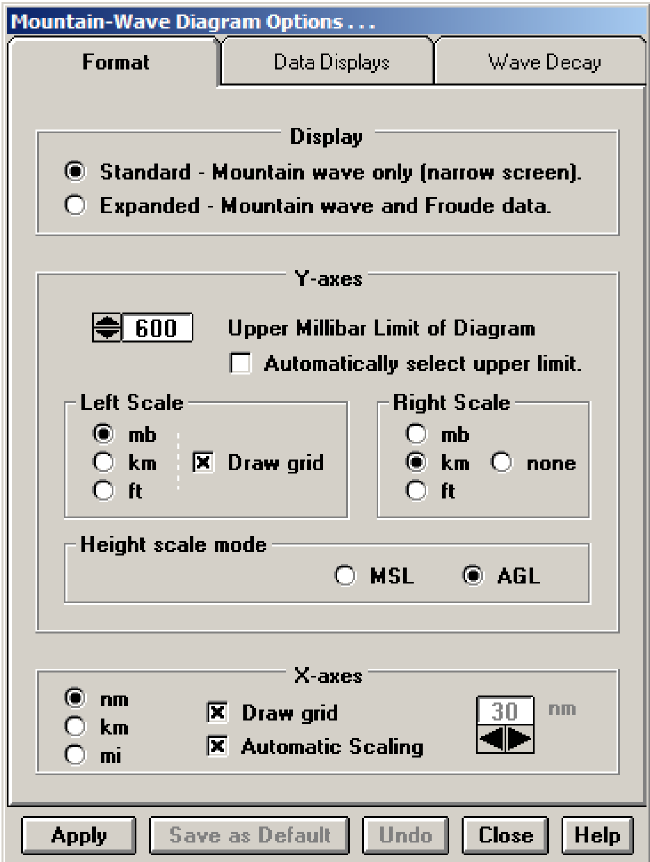
where: U = the mean normal wind between the surface and mountain peak
N = the mean Brunt-Vaisala frequency from the surface to mountain peak.
H = the height of the mountain.

Studies show that Froude Numbers less than 1 reflect blocked mountain wind flow, while numbers greater than 1 indicate winds that flow freely over mountains, thereby increasing potential for downslope winds. RAOB's expanded screen will display the following based on these Froude Number categories:

Froude No.	Expected Wind Flow & Weather Pattern
< 0.5	Upslope clouds/precipitation backed farther upwind of and up to mountain crest.
0.5 to < 1.0	Upslope clouds/precipitation falls immediately upwind of mountain crest.
1.0 to < 2.0	Precipitation advances to mountain ridge and on to the lee side.
>= 2.0	Air flows freely over mountain crest along with scattered downwind weather.

19.5 **Mountain-Wave Diagram Options**.

Like RAOB's other diagrams, these options are presented when selected via the Options Menu or just by right-clicking while the mouse is located over the diagram.

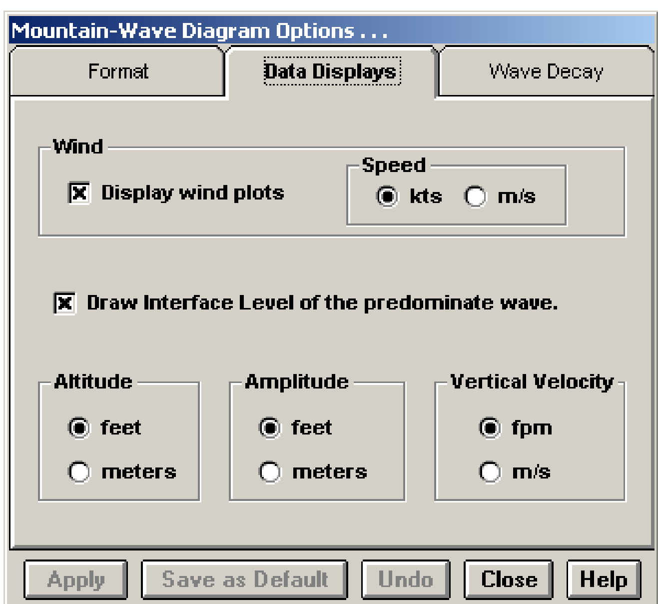


Format.

Display. Select either the Standard or Expanded display options. The Expanded option requires use of the optional Analytic module and a wide-screen computer monitor. The prior page illustrates the Expanded display format.

Y-axes. As with the sounding diagram, the user can select either manual or automatic scaling. Options exist to display left and right height scales, including a horizontal grid option for the left scale.

X-axes. The user can select from one of 3 scaling units in addition to the selection of manual or automatic scaling. There is also a vertical grid option.



Data Displays.

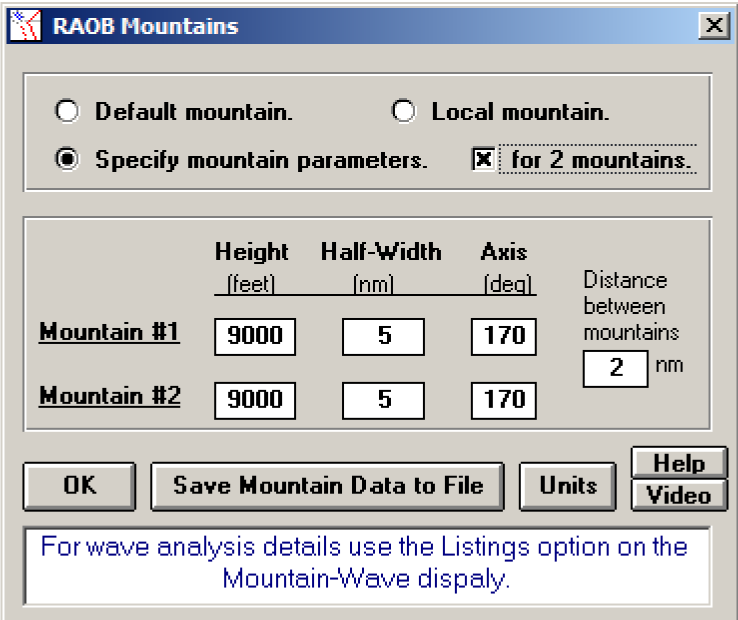
Wind. Choose wind speed units in addition to a wind plot display.

Interface Level. Select this option to display a horizontal line depicting the wave altitude.

Wave Units. Select units desired for display of wave Altitude, Amplitude, and Vertical Velocity.

NOTE: The Wave Decay Tab options are discussed later in the Wave Decay section of this chapter.

19.6 **Mountains & Parameter Definitions**.



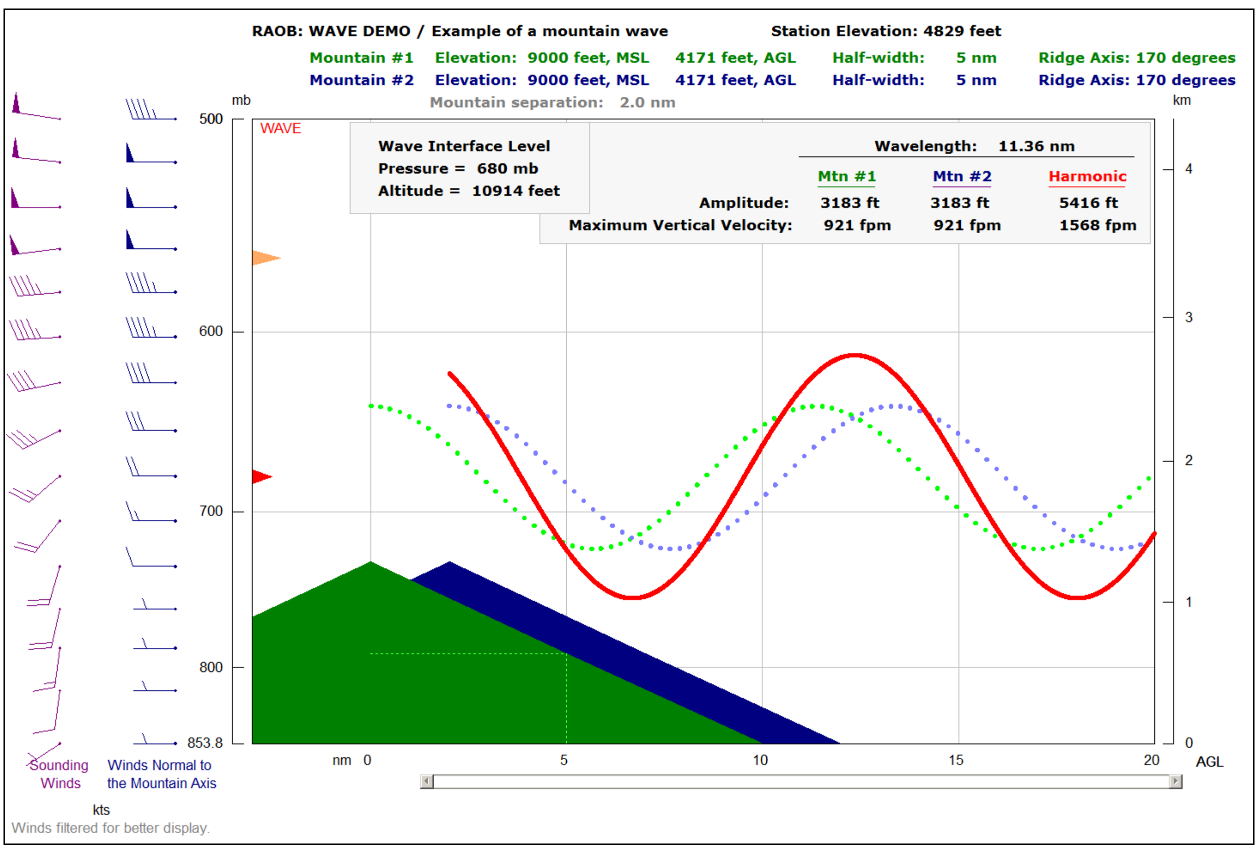
The Mountains definitions box (left) is displayed by either clicking on the Mountains Menu option or by clicking directly on the diagram's mountain.

The "Default" mountain option will always result in the analysis of maximum wave and turbulence potential.

The "Local" mountain option displays the user-defined local mountain parameters for quick access to a common mountain. This is defined using WMO # 00000 as explained on the next page.

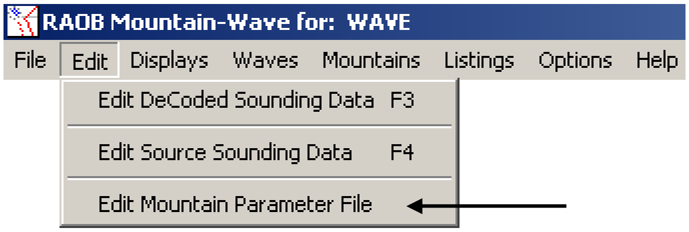
The user should specify actual mountain parameters to achieve the best results.

Up to 2 mountain ridges can be specified when using this option. Both mountains should have the same height for best results. See example below…



The solid wave line is the harmonic (or resonant) wave, derived from the two individual waves (shown as dotted lines), as produced by the airflow over two mountain ridges.

19.7 **Mountain Data**.



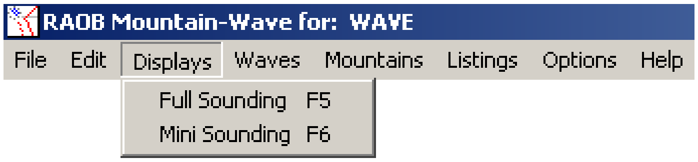
Mountain data is entered into the RAOB program via 2 methods. First, the user can enter one or two mountain ridges using the Mountain data entry screen shown on the prior page. Second, the user can select the “Edit Mountain Parameter File” menu option shown above. By using this option, mountain data can be stored in the RAOB.MTN data file for automatic retrieval. The RAOB.MTN parameter file is only accessed when WMO coded (TTAA, etc.) data or data files containing WMO station numbers are used. The sounding’s WMO number is used to link station information with associated mountain data.

Below is a listing of the RAOB.MTN file provided with RAOB’s distribution file. Like the locator file, the header and format of the RAOB.MTN file must be maintained. All mountain data are listed by WMO number, similar to the format of the RAOB.STN locator file. The RAOB.MTN file can be accessed using the EDIT Menu option shown above, or with a standard text editor. The file’s header includes key information about data entry. The file also contains 4 example mountain listings, where WMO #00000 indicates the optional “Local Mountain”. The “Local Mountain” (also explained in the prior page) allows quick access to mountain parameters that are used frequently, regardless of the WMO number of the sounding. The RAOB.MTN file also permits listing of double mountain data.

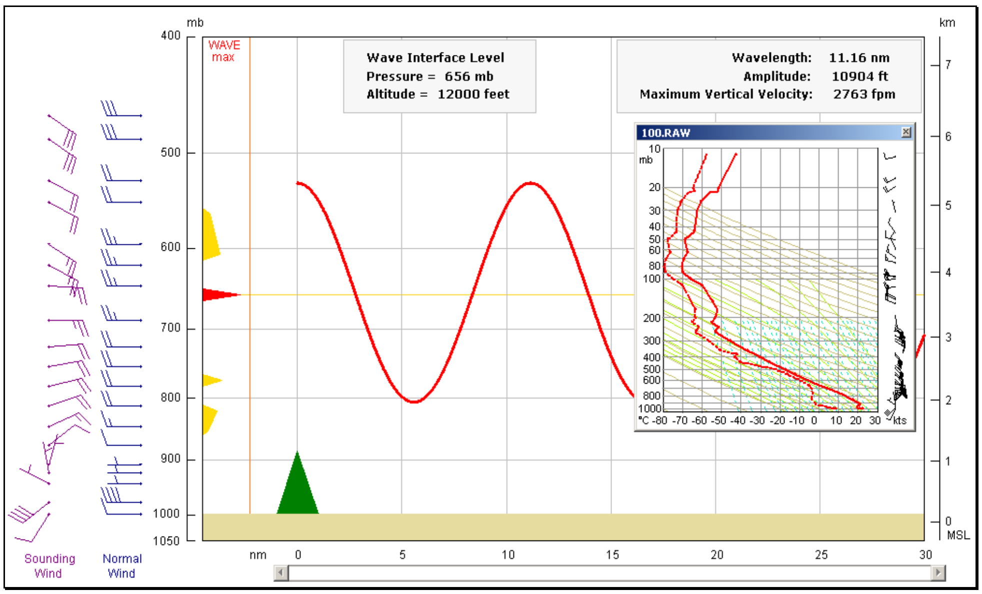
```
=====================================================================
                    RAOB MOUNTAIN PARAMETER LISTING
------------------------------------------------------------------------
Entries may be added, deleted, or edited, BUT FORMAT MUST BE MAINTAINED.
------------------------------------------------------------------------
All data items must be comma-separated.
HEIGHT:  Height of mountain top -- Feet -- Mean Sea Level.
HALF-WIDTH:  Mid-elevation upwind slope distance (nm) from mountain ridge.
AXIS:  Orientation of mountain ridge (degrees).  Use 0 for any angle.
2nd MTN data are optional BUT must be filled with zeros (0s) if not used.
------------------------------------------------------------------------
Units options (English or Metric) use either for the data header below:
WMO      (feet)     (nm)     (deg)     DIST (mn)     (feet)     (nm)     (deg)
WMO      (meter)    (km)     (deg)     DIST (km)     (meter)    (km)     (deg)
------------------------------------------------------------------------
NOTE:  First 4 entries are examples only -- they use the English option.
       You can also enter a WMO Code of 00000 which (if entered) will be
       designated as the LOCAL Mountain.  The LOCAL Mountain can be
       loaded via the Sounding Toolbar and from the Wave Display screen.
------------------------------------------------------------------------
        HEIGHT  1/2WIDTH  AXIS     2nd MTN      HEIGHT  1/2WIDTH   AXIS
WMO     (feet)    (nm)    (deg)    DIST (mn)    (feet)    (nm)     (deg)
=====   ======   ======    ===     =======      ======   ======     ===
00000,   9000,      4,      0,         0,           0,       0,       0
00001,   2500,      3,      0,         0,           0,       0,       0
00002,   4500,    4.2,    330,         0,           0,       0,       0
00003,   8000,    2.3,     10,         5,        7000,       3,      25
99999
=============================================================================
```

Note: The DIST column data identifies the distance between mountain ridges and is only used when two mountains are identified for any particular WMO number.

19.8 **Mountain-Wave Display Options**.

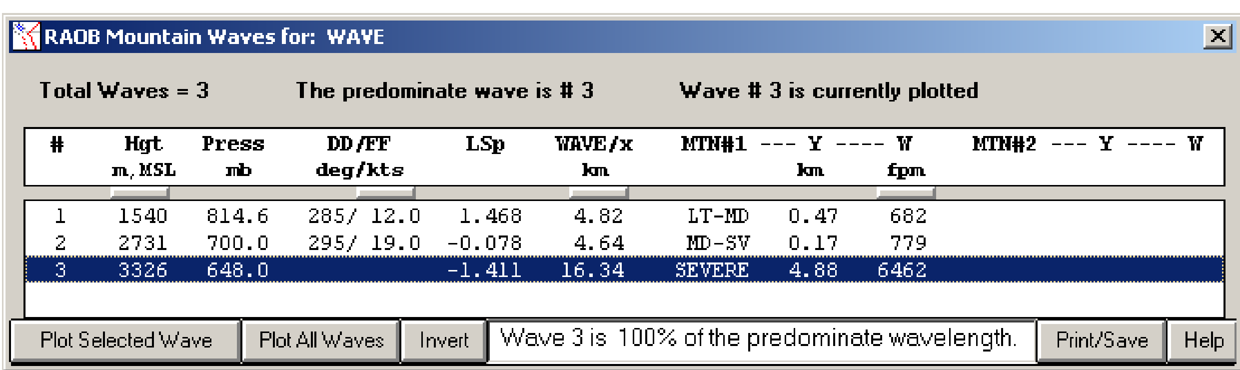


The DISPLAYS Menu option contains two options. The "Full Sounding" returns the user back to the original plotted sounding. The "Mini Sounding" produces the following screen example.



^

When the WAVES Menu option is activated, a list of all analyzed sounding waves is displayed as shown below. It can also be activated by left-clicking on the wave diagram. The small buttons just below the column headers toggle data units. Use this display to select which wave to plot, including an option to plot all waves at the same time.



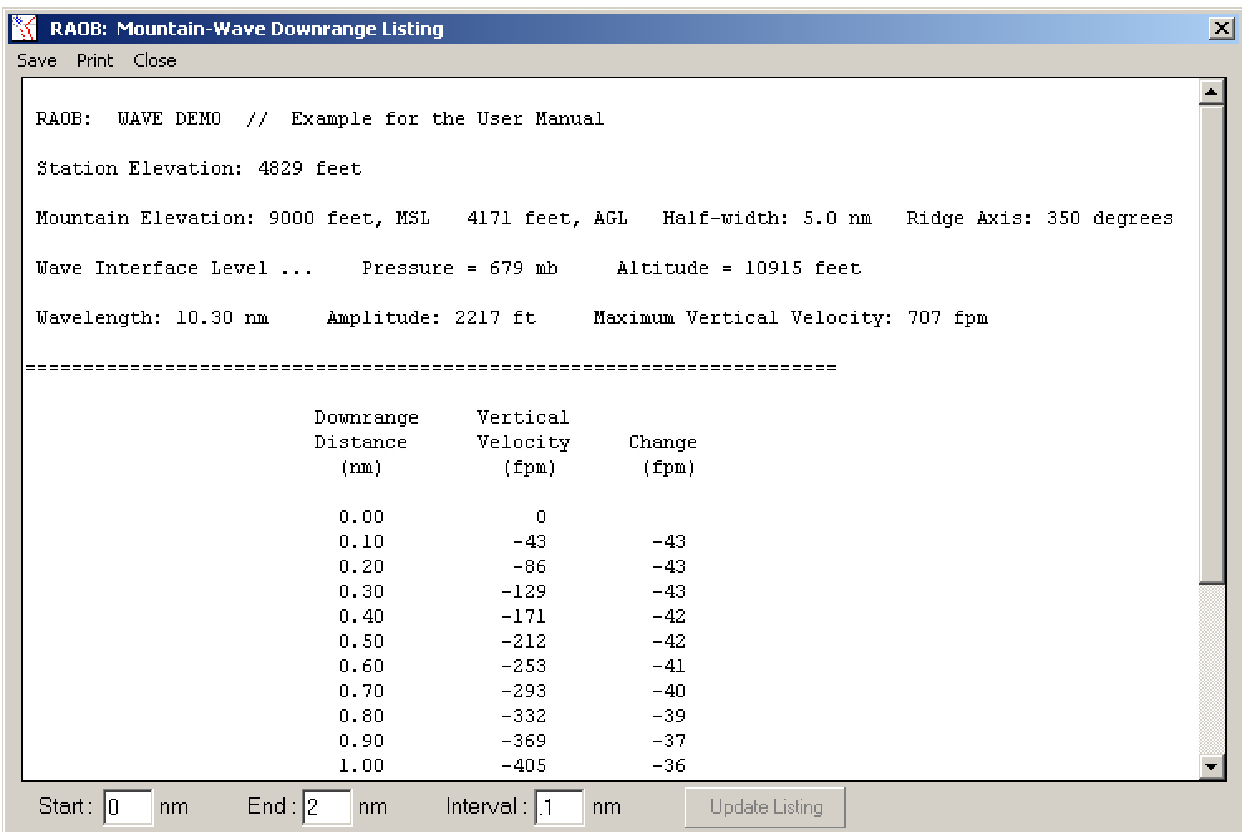
Mountain-Wave Display Options (continued).

The Wave Display listing (on prior page) contains several columns of wave parameter data:

LSp	Lyra-Scorer parameter. LSp must decrease with height for wave formation.
WAVE/x	Wavelength (along diagram's x-axis). The longest value = predominate wave.
MTN#_	Turbulence intensity category.
Y	Wave amplitude (along diagram's y-axis). Vertical extent of wave.
W	Wave's maximum vertical velocity. Located at inflection points.

^

When the LISTINGS Menu option is activated, a user-configurable listing of downrange wave distances and wave vertical velocities is displayed. This display can be edited and saved/printed. This listing can also be activated by pressing the Space-Bar while viewing the Wave diagram.



RAOB: WAVE DEMO // Example for the User Manual

Station Elevation: 4829 feet

Mountain Elevation: 9000 feet, MSL 4171 feet, AGL Half-width: 5.0 nm Ridge Axis: 350 degrees

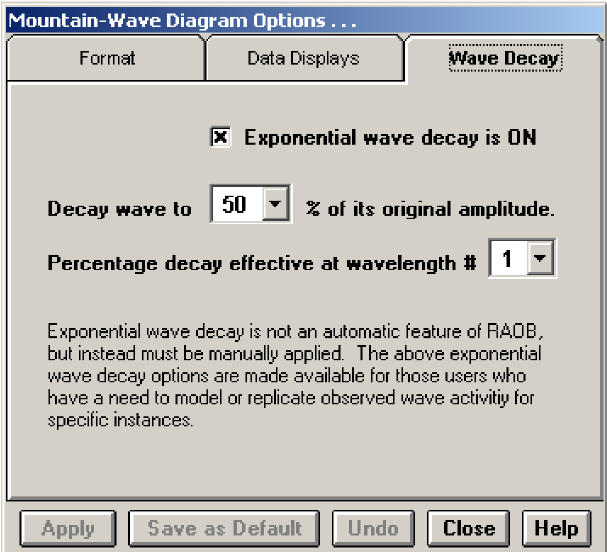
Wave Interface Level ... Pressure = 679 mb Altitude = 10915 feet

Wavelength: 10.30 nm Amplitude: 2217 ft Maximum Vertical Velocity: 707 fpm

==

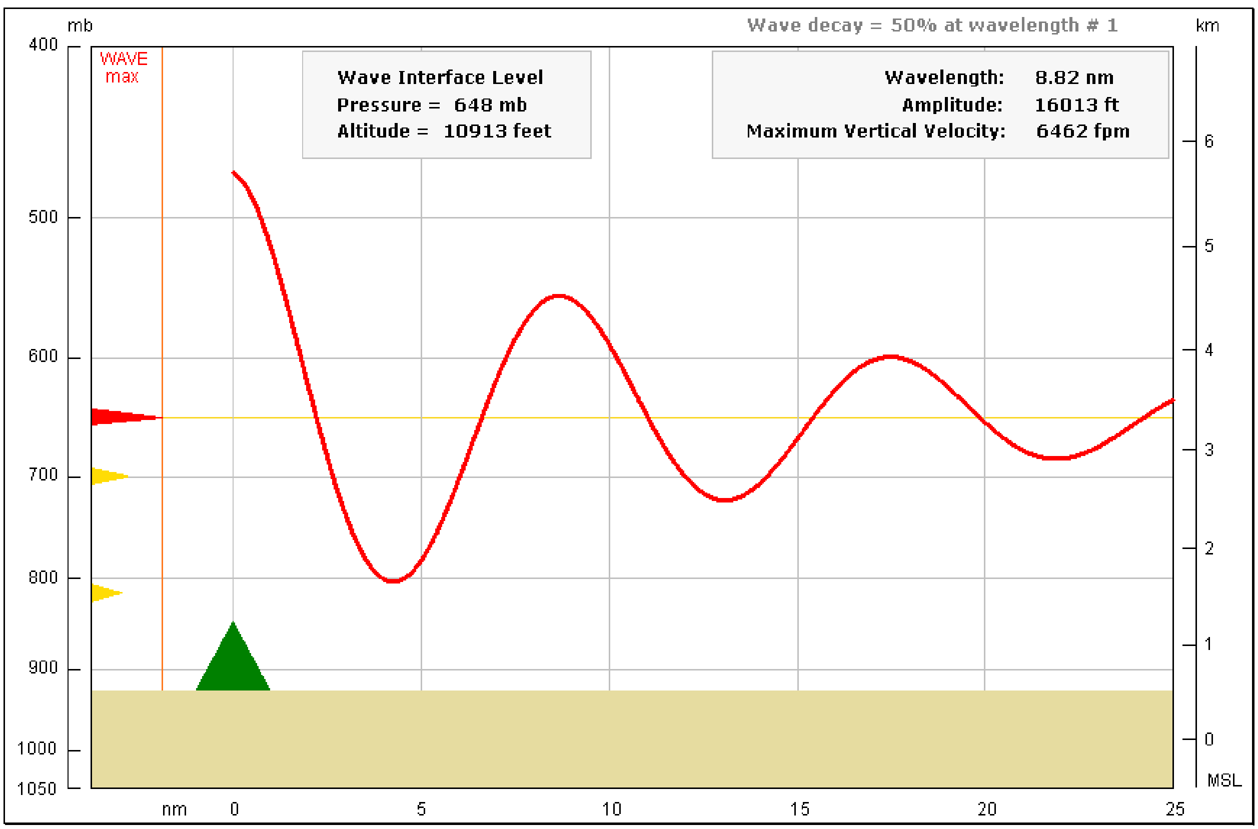
Downrange Distance (nm)	Vertical Velocity (fpm)	Change (fpm)
0.00	0	
0.10	-43	-43
0.20	-86	-43
0.30	-129	-43
0.40	-171	-42
0.50	-212	-42
0.60	-253	-41
0.70	-293	-40
0.80	-332	-39
0.90	-369	-37
1.00	-405	-36

19.9 **Wave Decay**.



Decay (dampening). RAOB's wave analyses equations do not incorporate wave decay in either the horizontal or vertical. This "decay" of the plotted wave is only superficially applied (when selected by the user) to help simulate observed conditions for a particular event.

Note: caution should be used with wave data beyond one wavelength downwind from the mountain. Similarly, caution should also be used with double ridge analyses when the 2nd mountain is beyond one wavelength of the 1st mountain.



Above is an example of applied wave decay using the decay configuration options presented above. Note that the decay function should only be used for specific wave cases where observation data is available to reasonably identify the decay rate. The decay feature is only made available to the RAOB program for graphic simulation purposes and is not an objective forecast tool.

19.10 **Mountain-Wave Computations**.

RAOB determines the existence of mountain waves and categorizes turbulence intensities based on theoretical work by Lyra (1943) and Scorer (1949) with applications algorithms developed by Foltz (1967) and Foldvick (1962). The critical factor in these wave calculations is the Lyra-Scorer parameter (LSp), which is a function of atmospheric stability and vertical shear. Mountain (or lee) waves can only occur if the LSp decreases with height. (LSp values are listed on the Complete Data listing for all data levels.)

$$LSp^2 = (\text{Lyra factor})^2 - (\text{Scorer factor})^2$$

where: Lyra factor $= g\beta/U^2$ where $\beta = 1/\theta * \partial\theta/\partial Z$

where: $g\beta$ = stability factor
g = acceleration of gravity
θ = potential temperature
Z = height
U = wind component normal to mountain

where: Scorer factor $= \partial^2 U/\partial z^2 * 1/U$

When RAOB finds a region where LSp decreases with height, mountain parameters are then used to determine wave characteristics. Three mountain parameters are required for wave analyses.

Height (ft). Must be with respect to sounding site elevation.
Half-width (nm). Distance between the mountain ridge (center line) and windward slope as measured at the mid-elevation of the mountain.
Axis (deg). Angle (orientation) of mountain ridge. A value of 0 (zero) will treat all winds as being perpendicular (normal) to the mountain.

The following equation was used by Foltz as the basis for development of his algorithms that are used by RAOB. This equation determines the maximum vertical displacement of an air parcel traversing a mountain lee wave.

$$\zeta_z = -2\pi hbe^{-kb} * (U_1/U_z) * \psi_{zk} * (\partial\psi_{1k}/\partial k)^{-1} * \sin(kx)$$

where: ζ_z is the vertical displacement of a streamline from its undisturbed height z.
U_1 is the horizontal gradient level wind component normal to the mountain.
U_z is the horizontal wind component normal to the mountain at level z.
x is the horizontal downwind distance from the mountain.
h is the height of the mountain.
b is the half-width of the mountain at mid-elevation.
ψ_{zk} is the streamfunction at level z for wave number k.
ψ_{1k} is the streamfunction at gradient wind level for wave number k.

19.11 **Wave Turbulence Categories**.

Wave turbulence categories (Light, LT-MD, MD-SV, and Severe) are displayed on the Mountain-Wave screen in addition to Sounding diagram's Summary and Complete data listings. These wave turbulence categories are determined as a function of W (maximum vertical velocity) and λ (wavelength) as developed by Foltz (1967).

For best results, the sounding should be upwind of the mountain, where the sounding is located at the lowest part of the upwind valley floor. In most cases, wave analyses are needed at locations were no sounding sites exist. In these cases, a representative sounding will first need to be created, either manually or by using RAOB's optional vertical cross-section module or RAOB's Merge function. When generating a sounding, be sure that the sounding's base elevation is coincident with the base of the mountain. It is also very important to obtain accurate mountain parameter data. This data is best obtained from detailed USGS topographic maps or other reliable sources.

If mountain data are not provided, RAOB then automatically uses a default 1km high mountain with a half-width that is adjusted to the natural wavelength of the airstream, which then produces the maximum potential wave amplitude (Corby and Wallington, 1956). This is useful for determining the maximum extent of lee waves, but should be used with caution until actual mountain data are used for the specific area of interest.

When viewing the plotted sounding, wave turbulence analyses are graphically depicted along the left side of the diagram, similar to the CAT and Icing graphics produced on Sounding diagrams. Alphanumeric wave data are available on both the Summary and Complete data listings of Sounding diagrams and are displayed as follows:

LSp: Lyra-Scorer parameter; waves are possible when LSp decreases with height.
Wave/X: Wavelength; longest X is the predominant wave.
Wave/Y: Amplitude; vertical extent of the lee wave.
Wave/W: Maximum vertical velocity of the wave; located at inflection points.

Waves with very small X, Y, or W values are filtered out.

Depending on atmospheric conditions and mountain parameters, wave analyses may result in none to many individual waves. It is important to note that the source literature indicates that the wave with the longest wavelength is the predominant wave (this is the Wave/X data item displayed in the alphanumeric listings). Even though the longest wavelength is the predominant wave, waves with wavelengths consisting of fractional multiples (e.g., 1/2 or 1/4 size wave lengths) are also significant. For example, if the predominate wave has a wavelength of 10 nm, another wave having a wavelength of 5 nm would also be significant, but to a lesser extent.

There are many theories and examples of wave decay in the vertical. However, RAOB does not attempt to replicate this phenomena. The user may find some assistance with the analyses of specific wave instances through the analysis of the secondary (non-predominate) waves produced by RAOB.

Wave turbulence can also be greatly affected by extended or multiple mountain ridges. The following paragraph shows how RAOB can assist with these analyses.

19.12 **Double Mountains**. RAOB computes the resonant (or harmonic) effects of double mountain ridges upon lee waves. Foldvick's resonant wave equation was derived for use with two mountains of the same height. This equation, however, is applied to all double mountain sets entered for analyses, and therefore, caution should be used for harmonic analyses resulting from mountains of significantly different heights. RAOB minimizes this limitation by only computing wave harmonics for waves that exist at the same height (interface level) for both mountains.

The basic equation by Foldvick (1962) is listed here for mountains with the same height.

$$W = 2 * w * \cos(\pi d/\lambda) * \cos(2\pi/\lambda) * (x\text{-}d/2) \qquad \text{for } x > d$$

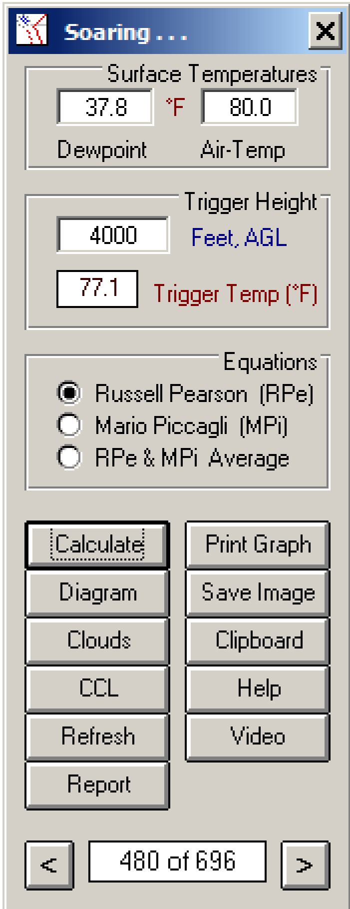
where: W = resonant vertical velocity
d = distance between ridges
x = downwind distance from 1st ridge
λ = wavelength
w = sum of both vertical velocities at x

Parameters for the 2nd mountain can be entered when viewing the Wave Screen or as an entry in the RAOB.MTN file as previously described. (See the example mountain data included with the distributed RAOB.MTN file for format.) When viewing the Wave Screen, the 1st mountain is drawn in green and the 2nd mountain is mountain is drawn in blue. The wave from the 1st mountain is plotted with green dots and the wave from the 2nd mountain is plotted with blue dots. The resultant resonant wave is plotted in solid red. As mentioned above, only waves existing for both mountains (with respect to the same interface level) are analyzed for resonant effects, even though each single mountain may have many more independent waves.

Among the assumptions employed by the wave turbulence algorithms, the Coriolis force is neglected because of the local character of the phenomena.

RAOB's wave turbulence analyses are only valid in the troposphere. Higher altitude results should be used with caution.

20. SOARING Calculations.



The Soaring Menu Tool permits selection of surface temperatures to simulate maximum heating for the day. Both Surface (air-temp) and Dewpoint temperature data can be entered. Before the calculations begin, RAOB first adjusts the lower sounding by making the sounding dry-adiabatic from the user-supplied surface temperature (T). An optional dew point temperature (Td) entry is used to adjust the same lower layer, where the dew point change gradually diminishes with height. The adjusted T and Td profiles are displayed in light red, while the original sounding is plotted in dark red.

The adiabat representing the temperature associated with the Trigger Height is plotted in blue as a reference line. All other text output is displayed in the upper-right section of the sounding diagram.

The Trigger Temperature is automatically calculated and displayed each time the Trigger Height is altered.

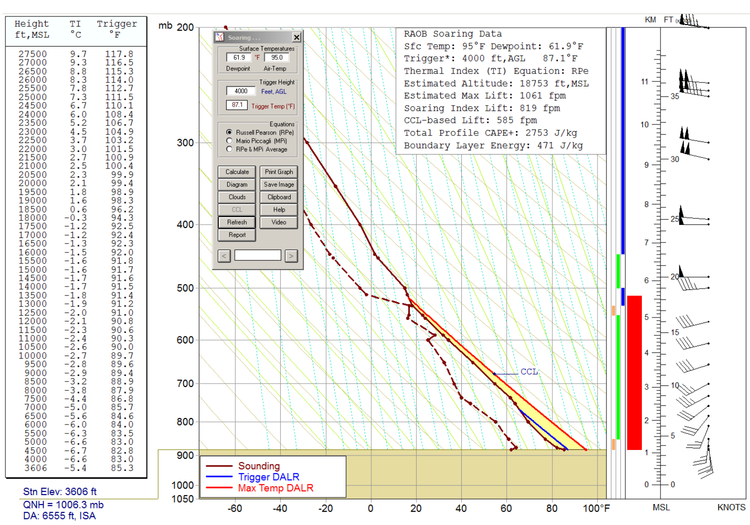
The “Clouds” button is only available with the optional Analytic module.

Use the "CCL" button to display the location of the Convective Condensation Level. (see the CCL below)

The “Report" button produces a NWS-style "Soaring Guidance Report" which can be printed, saved to file, and even emailed as an attached text file.

For files containing multiple sounding profiles, the arrows at the bottom of the Soaring toolbar allow sequencing of each profile.

CCL Note. The soaring CCL is determined from surface temperature data only. The RAOB program allows users to configure CCL calculations with respect to the "mean lower layer", which will normally result in different CCL values. So to be sure you have consistent CCL values, you must configure the CCL "mean lower layer" to the 1 mb (hPa) value via Program Options’ “Parcel Lifting & CAPE” tab.



Soaring Data. By clicking on the Calculate button, various soaring data and indexes are displayed. The solid vertical red-colored bar between the sounding and the wind plot height scale represents the estimated lift altitude.

Lindsay (1988) presents a good overview of this data and its application to soaring. Pearson (1995) presents a “do-it-yourself” approach to soaring using TI and related data.

SOARING Analyses (continued).

Thermal Index (TI) Data. This information is displayed along the left side of the diagram. TI data help soaring (and hang-glider) pilots estimate flight altitudes and the strength of vertical lift. The TI is determined by subtracting the environmental profile temperature from the temperature of the surface-based dry-adiabat profile for each level of interest (NWS Handbook No. 3). Most soaring literature indicates that a TI value of -3 to -4 reflects a very good chance of sailplanes reaching the altitude of this temperature difference. TI values of -8 to -10 generally indicate very good lift conditions. TI values of 0 or greater are generally unfavorable for soaring.

Researchers have correlated soaring altitudes and lift strength to TI data. Most work has been done with respect to the height at which the dry-adiabatic lapse rate, which originates from the maximum surface temperature, first intersects the sounding's temperature profile. This is where TI = 0. This height is referred to as $H\gamma_d$, both in this manual and in RAOB's displays. RAOB allows the user to select from 2 sources of $H\gamma_d$ based altitude and lift equations. The user can also select a third option, which averages the 2 results. The sources are:

Rpe for Russell Pearson, whose equations were developed for use over the southwestern U.S.
MPi for Mario Piccagli, whose equations were developed for use over U.S. Mid-Atlantic States.

The equations for estimated soaring altitude (feet, AGL) are:

RPe: $ALT = 133.72 + 1.03 * H\gamma_d$ — $H\gamma_d$ is in feet, AGL.
MPi: $ALT = 1580 + 0.57 * H\gamma_d$

The equations for estimated lift strength (feet-per-minute, fpm) are:

RPe: $LIFT = 41.49 + 0.07 * H\gamma_d$ — $H\gamma_d$ is in feet, AGL
MPi: $LIFT = 50.0 + 0.049 * H\gamma_d$

The above equations apply only to *dry thermals*, which are conditions where no clouds exist. The effects of moisture on thermal development and cloud formation are discussed in WMO's Handbook of Meteorological Forecasting for Soaring Flight. Although not employed in RAOB, this handbook presents several manual techniques for analyzing soaring potential with respect to atmospheric moisture. One good indicator of low-level moisture is the Convective Condensation Level (CCL), which typically identifies the height of cumuliform cloud bases, and which is normally produced from surface heating and associated thermal activity. Mario Piccagli (e.g., MPi) developed a lift equation using the height of the CCL (CCL_{HT}), from which RAOB also displays resulting lift strength in fpm. This equation is:

MPi: $LIFT_{CCL} = -10.0 + 0.078 * CCL_{HT}$ — CCL_{HT} is in feet, AGL

Trigger Temperature. This is the surface temperature required to produce a dry-adiabatic lapse rate that will intersect the sounding at the altitude specified. This altitude is initially set at 2,500 feet, but it can be changed by editing the "Trigger Height" text box.

Soaring Index (SI) data. Researchers have recently developed the Soaring Index which is designed to incorporate the vertical temperature gradient between the trigger temperature and the maximum altitude of thermal activity (Armstrong and Hill, 1976). Like the above Pearson and Piccagli lift strength estimates, the Soaring Index also produces an estimated lift strength in feet-per-minute (fpm).

$$\text{Soaring Index} = 3 * (Z/100) + 10 * t$$

where: Z = maximum thermal altitude, feet, AGL
$t = T_{TRIGGER} - T_{MAXTHERMAL}$ (°C)
$T_{TRIGGER}$ = sounding temperature at trigger altitude
$T_{MAXTHERMAL}$ = sounding temperature at Z (max thermal altitude)

21. FRONTAL ANALYSES.

The features presented in this section are only available with the optional Fronts & Forecast module.

21.1 Overview.

The RAOB program provides the user with a vast array of analytical tools and displays. RAOB's editing and interactive functions allow the user to simulate or estimate what-if scenarios and more importantly – provides users rudimentary ability to create forecast soundings. RAOB's "Fronts & Forecast" module now offers the user a fast and objective method for creating reliable short-term forecast soundings, completely independent from outside forecast data. RAOB is a complete, single-station, analysis and forecast tool.

RAOB's Fronts & Forecasts module can locate frontal zones and create short-term forecasts solely from the sounding data itself. RAOB creates forecast soundings via two different methods: (1) Temperature advections derived from thermal wind data, and (2) Temperature/dewpoint & wind advections derived from upstream soundings. RAOB offers a variety of forecast options for both forecast modes. The first forecast method (using only thermal wind data) is described below.

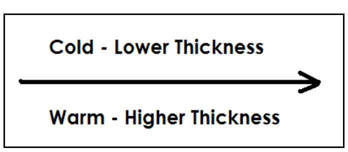
21.2 Thermal Wind Theory.

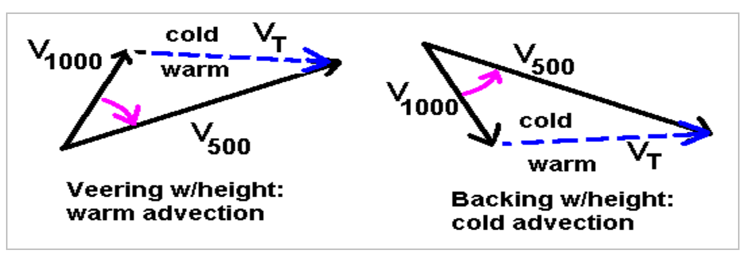
Forecasts created using the "thermal wind" method use classic thermodynamic relationships to identify temperature advection and frontal layers from a sounding's wind data. This method historically involved manually intensive procedures to arrive at a forecast sounding, which have mostly been abandoned since the advent of numerical products. RAOB automates those manually intensive and cumbersome procedures, turning thermal wind theory into a powerful forecast tool. In cases where the user only has a surface observation and a local sounding, RAOB systematically applies thermal wind theory to create a forecast sounding. In the "old days" this process was known as *single station analysis*.

The earliest comprehensive examination of thermal wind theory was documented by Oliver & Oliver (1945). It is important to note that the thermal wind is not a wind, but is the difference in geostrophic wind between two levels in the atmosphere – it is a wind shear vector (V_T). The thermal wind is a theoretical wind that blows parallel to the thickness lines, which is analogous to how the geostrophic wind blows parallel to the height contours. The significance of the thermal wind is that it correlates the vertical geostrophic wind shear between two levels of a sounding to the mean horizontal temperature gradient in the layer between the same two levels. Furthermore, looking downwind of the thermal wind vector, colder air is always on the left side and warmer air is on the right side. In the Southern Hemisphere, this relationship is reversed. The summary importance of thermal wind (V_T) theory is two-fold:

(1). When the geostrophic winds turn clockwise (or veer) with height, warm air advection occurs.
(2). When the geostrophic winds turn counter-clockwise (or back) with height, cold air advection occurs.

Thermal wind (V_T)





By applying the above correlations to a sounding's hodograph, thermal advections can be inferred and a reliable short-term forecast sounding can be created. Following several requests from RAOB users to apply thermal wind theory to this program, manual techniques from several sources were consolidated into the procedures described on the following pages. Some of these sources, originally in German, were translated by Gilbert Christoffel, who also provided valuable assistance with converting these long established manual procedures into RAOB program algorithms.

21.3 **Thermal Wind Equation.**

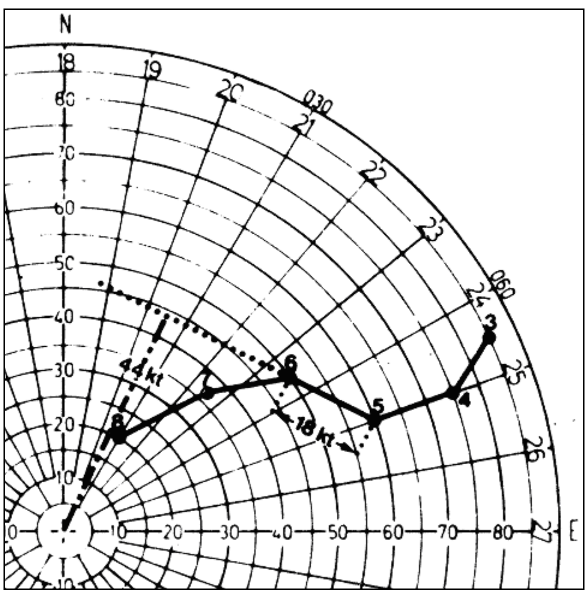
The following thermal wind equation was taken from Holton (1972).

$$V_T = -R/f \int_{P_0}^{P_1} (k \times \nabla T)\, d\ln p$$ where : P_1 and P_0 are upper and lower pressure levels.

Through a series of transformations, this equation can be used to estimate the mean horizontal temperature advection in a layer. These advections can then be applied to the sounding's temperature profile to obtain a forecast sounding. Advection is thus defined as:

$$\Delta T/\Delta t = \Delta T/\Delta n \cdot Vn$$ where : $\Delta T/\Delta n$ = the mean temperature gradient
Vn = the vector normal to the thermal wind

And where $\Delta T/\Delta n = V_T \cdot f/(R \cdot \ln(P_0/P_1)) \cdot C$ where : V_T = the thermal wind
f = the Coriolis parameter
R = the gas constant for dry air
P_0/P_1 = adjacent pressure levels
C = units conversion constant



The diagram at left illustrates the calculation of the Advection term ($\Delta T/\Delta t$) for one layer of the hodograph.

For this example the Advection is calculated for the 500 to 600 mb layer. The thermal wind (V_T) and the normal wind (Vn) are directly measured as 18 kt and 44 kt, respectively.

Variable factors within the gradient ($\Delta T/\Delta n$) term are the thermal wind (V_T), the Coriolis parameter (f) for a certain latitude, and the pressure level ratio (P_0/P_1) of 500/600 mb.

The constants R and C remain the same for all sounding levels.

Using the above example diagram and data, the temperature advection for the 600 to 500 mb layer can be calculated. Since Advection = $\Delta T/\Delta t$ = $\Delta T/\Delta n \cdot Vn$, we already know Vn = 44 kt. We now need to calculate the Gradient term $\Delta T/\Delta n$ ...

$$\Delta T/\Delta n = V_T \cdot f/(R \cdot \ln(P_0/P_1)) \cdot C = 18 \cdot f/(R \cdot \ln(600/500)) \cdot C = 18 \cdot 0.00197 = 0.0355 \text{ °C/nm}$$

where : the Coriolis parameter (f) is with respect to 38 degrees latitude.

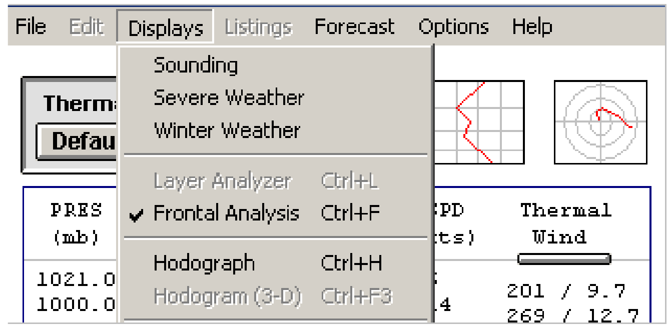
Therefore, Advection = $\Delta T/\Delta t$ = $\Delta T/\Delta n \cdot Vn$ = $0.0355 \cdot 44$ = +1.56 °C/hr for the 600 to 500 mb layer.

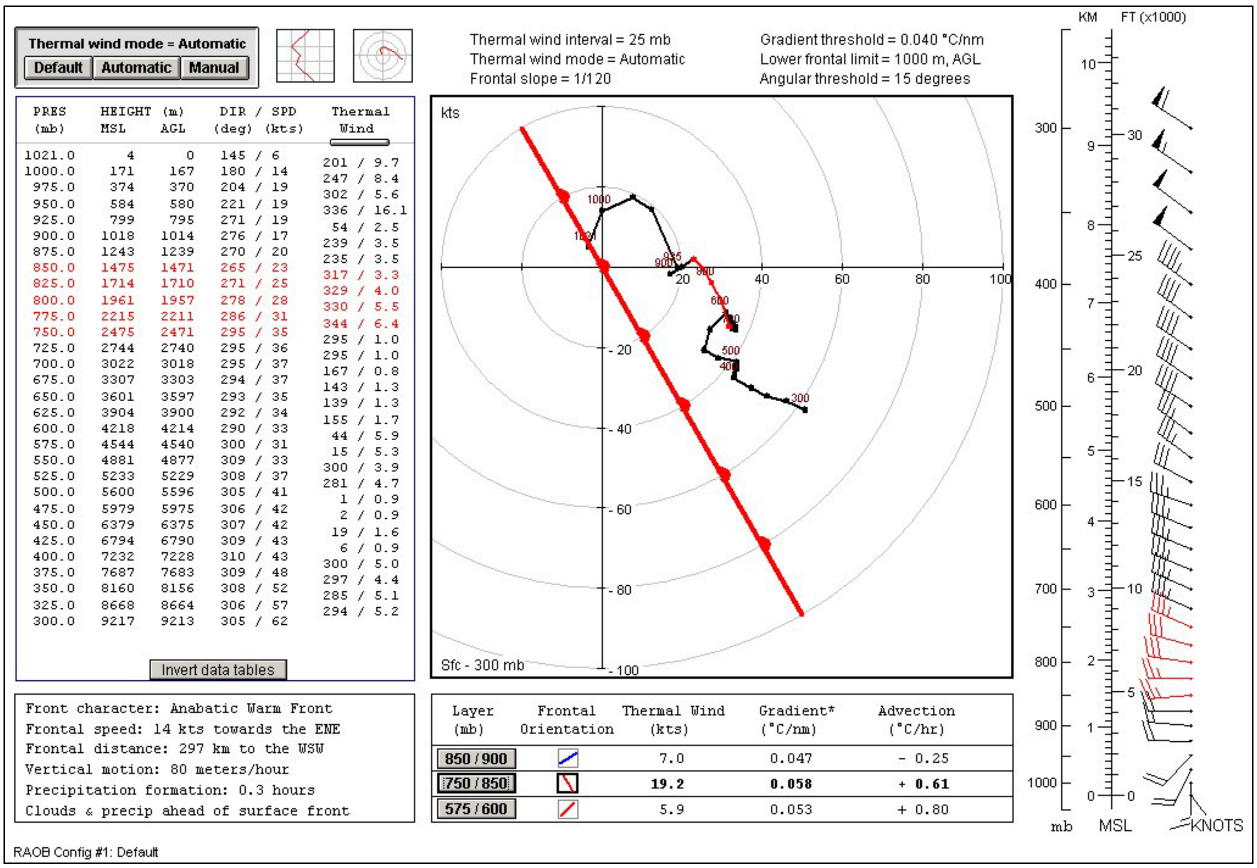
When the temperature advections for each layer are computed, the advection rates can then be applied to the sounding's temperature profile to create a short-term forecast sounding. Although the above example reflects winds at 100 mb intervals, RAOB's thermal wind calculations are always done at 25 mb intervals.

21.4 **Frontal Analysis Screen.**

Right. The sounding's frontal layers can be visualized by using RAOB's "Frontal Analysis" display option (or by pressing the Ctrl-F keys).

Below. Similar to the Hodograph, the frontal analysis screen provides a variety of tools and text data used to select the predominant front. (Unlike the Hodograph, the wind vectors are not graphically interactive.)





The data box immediately below the hodograph contains key data for frontal layer identification. Click on the "Layer (mb)" buttons to see any of the sounding's three most significant frontal zones. The front with the highest "Gradient (°C/nm)" value is usually the predominant frontal layer and is initially plotted on the hodograph. If the orientation of the actual surface front matches (as closely as possible) the front displayed on the hodograph, then the hodograph's predominant front is further justified.

As each front is displayed (by clicking the Layer buttons), a text box displaying key frontal characteristics is presented in the adjacent text box located at the lower-left corner of the screen. These frontal characteristics can help with the timing and location of frontal precipitation and associated weather.

At the top center of the screen are listed current frontal configuration settings, which are described later.

Frontal Analysis Screen (continued).

The two boxes shown below can be found immediately below the frontal analysis screen's hodograph. Upon initial viewing of the analysis screen, the hodograph's three most significant fronts with respect to Gradient (°C/nm) values are displayed (see box at right). The front with the largest Gradient value is always initially displayed and plotted on the hodograph – and is highlighted in bold in the frontal data box. In this case, the "850/750" frontal layer is being displayed and plotted on the hodograph. (Note: you can right click on the 850/750 button to reverse the button's text to 750/850.)

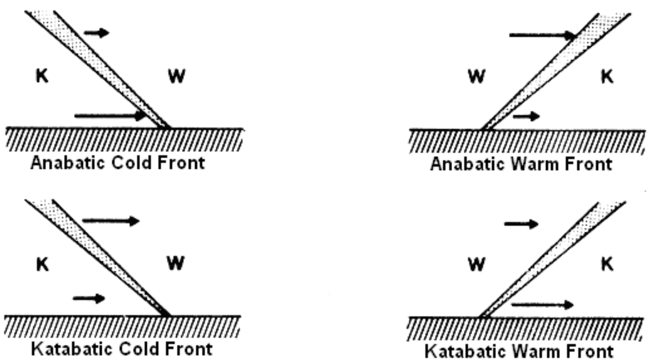
```
Front character: Anabatic Warm Front
Frontal speed: 14 kts towards the ENE
Frontal distance: 297 km to the WSW
Vertical motion: 80 meters/hour
Precipitation formation: 0.3 hours
Clouds & precip ahead of surface front
```

Layer (mb)	Frontal Orientation	Thermal Wind (kts)	Gradient* (°C/nm)	Advection (°C/hr)
900/850		7.0	0.047	- 0.25
850/750		**19.2**	**0.058**	**+ 0.61**
600/575		5.9	0.053	+ 0.80

The text box (shown above left) always displays details about the front that is plotted on the hodograph. In this case, the front being described is the "850/750" frontal layer.

Front character is determined by the wind characteristics below and above the frontal layer as depicted below. RAOB automatically applies the following frontal slopes as listed below, however, the user can specify other slope ratios via the diagram configuration screen (see next section).

Warmfronts (both types): 1:120 -- Anabatic Cold Front: 1:80 -- Katabatic Cold Front: 1:40



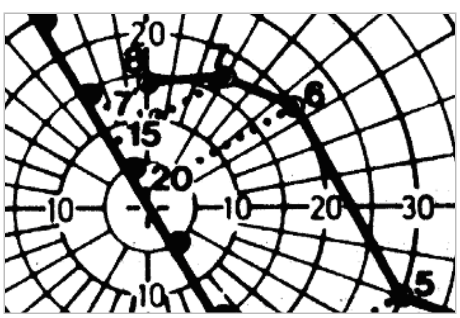
Bergeron Front Classifications

W = Warm air flow.
K = Cold air flow.

Ana = Upwards flow.
Kata = Downwards flow.

Frontal speed is determined by the average "normal" winds below the frontal layer. "Normal" winds are defined as the perpendicular wind between the plotted front and the hodograph's wind plot. Normal wind data can be toggled for viewing by clicking on the thin horizontal button just below the "Thermal Wind" data header →

Thermal Wind	Normal Wind
201 / 9.7	-0.5
247 / 8.4	7.0
302 / 5.6	15.4



In the hodograph example at left, a warm front is analyzed between the 600 and 500 mb wind layer. The warm front is drawn perpendicular to the 600/500 mb thermal wind. The "normal" winds are drawn as dotted vectors. The frontal speed is, therefore, calculated as:

Frontal Speed = (7 + 15 + 20) / 3 = 14 kts

Frontal Analysis Screen (continued).

Frontal distance is calculated using the mean height of the frontal layer and the frontal slope with respect to sounding's location.

Vertical motion (w) can be roughly calculated accordingly … for a warm [cold] front, subtract the mean "normal" winds below [above] the frontal layer from the mean "normal" winds above [below] the front, and then divide by the frontal slope. RAOB uses the 300 mb level as the upper-limit for these calculations.

Precipitation formation (Δt hours) can also be roughly calculated by the following equation:

$$\Delta t = \overline{\sum}(T\text{-}Td) \cdot 100 / w$$

where $\overline{\sum}(T\text{-}Td)$ = mean dewpoint depression between the frontal layer and 600 mb.
100 represents the factor (meters) necessary to lift every T-Td (°C) to saturation.
w (meters/hour) represents the vertical motion (listed above).

Clouds and precip designations are based on the "front character" as defined on the prior page. Only anabatic cold and warm fronts lead to substantial precipitation as they are accompanied by significant lifting (w) of the frontal layer.

21.5 **Frontal Selection**. This is the main focus of "single station analyses" … how to best identify the sounding's frontal layer (or layers), which then allows better identification of associated weather patterns, which then leads to a better forecast. While there is no one rule that can always be guaranteed to select the predominant frontal layer of a sounding, the following guidelines should be used:

(1). Select the hodograph front (layer) that most closely matches the orientation of the surface front as shown on the current synoptic surface map. The "Hodo-Front Manual Mode" screen (described later in this section) provides more tools to assist with this selection.

(2). Look for the frontal layer with the largest temperature gradient (°C/nm).

(3). Look for frontal and subsidence inversion* layers that coincide.

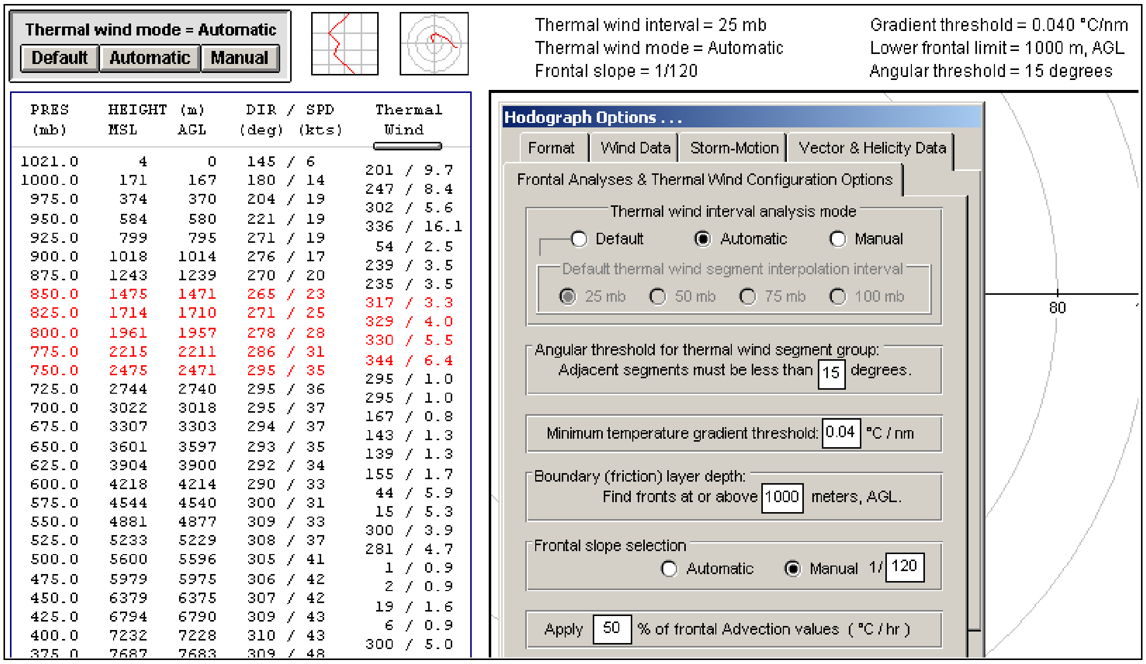
(4). Look for the presence of clouds* as detected on the sounding diagram.

(5). For warm fronts, the user should choose a sounding that lies ahead of the surface front. For cold fronts, the user should choose a sounding that lies behind the surface front.

---

* These parameters are only available for display when using the optional Analytic program module.

21.6 **Frontal Analysis Configuration.** Right-click while over the hodograph to display the "Frontal Analyses & Thermal Wind Configuration Options" tab. These options are critical to the selection of the sounding's predominant frontal layer.



It is important to understand that RAOB calculates thermal wind data at four different vertical intervals (25, 50, 75 & 100 mb) to help the user better identify the predominant front. Remember, the predominant front should, as closely as possible, match the orientation of the actual surface front (warm or cold).

Thermal wind interval analysis mode. (See the 3-button options box located at the upper-left corner of the above image.) When using the Default mode, RAOB displays the 3 fronts with the largest Gradient (°C/nm) values using the selected thermal wind (25, 50, 75, or 100 mb) interval. All thermal wind intervals are searched when the Automatic mode is used. With the Manual option, the program automatically displays the Hodo-Front Manual Mode screen, which is shown on the next page.

Angular threshold for thermal wind segment group. This option becomes increasingly applicable as the "thermal wind interval" decreases. This option permits the grouping of similarly oriented wind vectors.

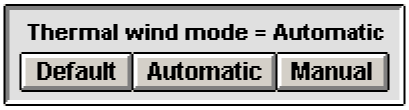
Minimum temperature gradient threshold (°C/nm). This option filters out the weak frontal layers. The default value is 0.04 °C/nm. Remember, the predominant front usually reflects the layer with the highest gradient value. If the analyzed sounding produces no frontal layers, then try reducing the threshold value.

Boundary (friction) layer depth. This option eliminates false frontal layers within the friction layer, which are commonly caused by the Ekman spiral. A depth of 1000 meters typically avoids most friction effects.

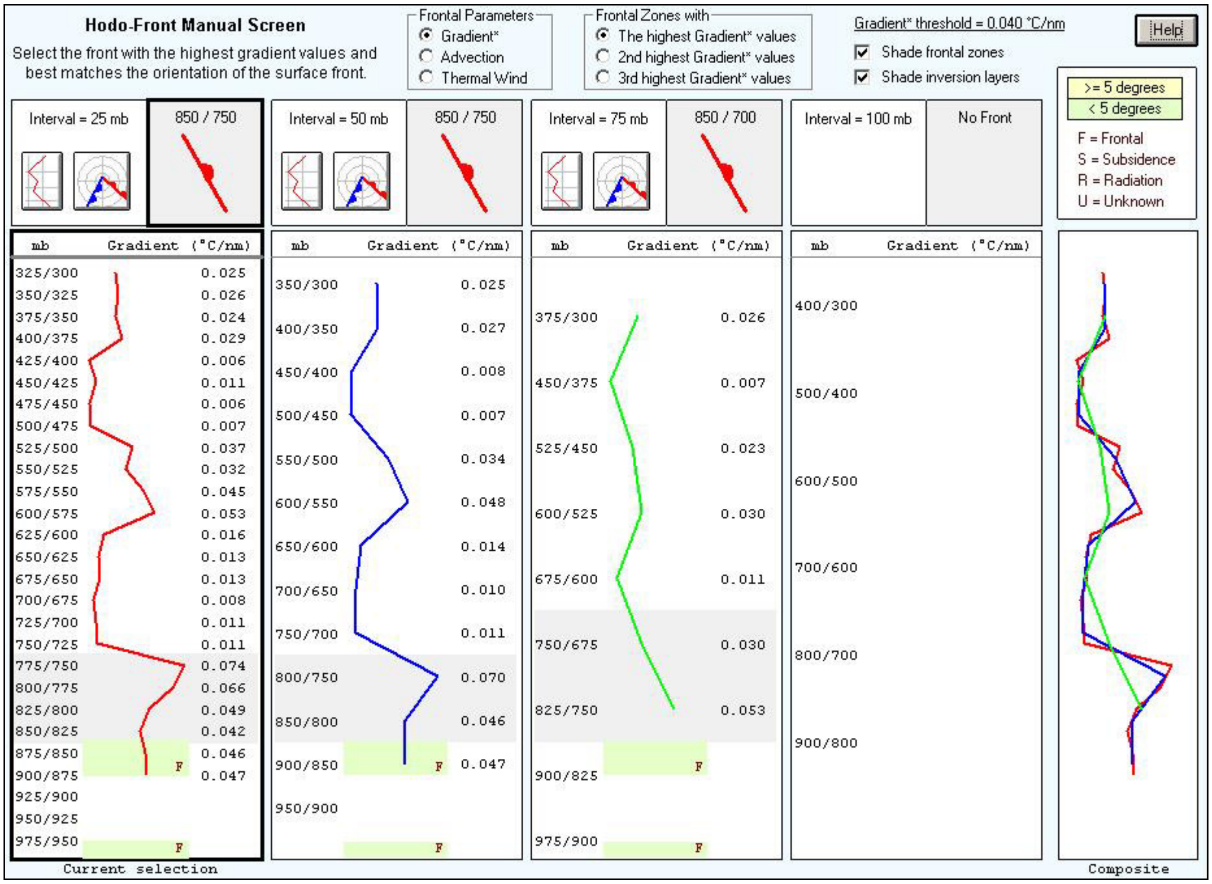
Frontal slope selection. This option is not used for frontal selection, but is instead only used during the creation of the "frontal characteristics" text box, located at the lower-left corner of the display screen. It is best to use the Automatic option, unless knowledge of the frontal slope is reasonably known.

Apply % of frontal Advection values (°C/hr). Experience shows that the temperature advection rates are usually half (50%) of the calculated advection values. As with the frontal slope option, this option only affects the frontal diagnostics, and are displayed in the frontal layer table below the diagram.

21.7 **Hodo-Front Manual Screen.**



Click the Hodograph's "Manual" button to display the Hodo-Front Manual Mode screen (shown below) for detailed front data.



The "Hodo-Front Manual Screen" permits the user to thoroughly study the sounding's 3 most significant frontal layers. The primary goal, however, is to select the front that best matches the orientation of the actual surface front. The orientation of each front is plotted in red (warm front) or blue (cold front) as miniature frontal images near the top of each of the four data columns. In the example shown above, the 100 mb wind interval (4th data column) does not display a front, because no frontal zones met the Gradient threshold of 0.040 °C/nm (see Configuration Options on prior page) at 100 mb intervals.

Frontal Parameters. These three options allow the display of the sounding's Gradient, Advection, and Thermal Wind data. When comparing the four data intervals, the user should select the interval with the strongest gradient values and the front that best matches the surface front orientation. The "Gradient" parameter is typically the most significant parameter for selection purposes.

Frontal Zones with... This option lets the user see the other (weaker) fronts within the sounding, which is similar to the three frontal display options available on the main Frontal Analysis screen (see image at right). The 2nd and 3rd most significant fronts can help analyze an airmass containing more than one frontal layer.

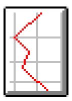
Layer (mb)	Frontal Orientation	Thermal Wind (kts)	Gradient* (°C/nm)	Advection (°C/hr)
900/850		7.0	0.047	- 0.25
850/750		**19.2**	**0.058**	**+ 0.61**
600/575		5.9	0.053	+ 0.80

Hodo-Front Manual Screen (continued).

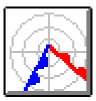
Shade frontal zones. Select this option to display the physical location of each frontal zone (layer). These zones are shaded in a medium gray color.

Shade inversion layers. This option also helps with frontal selection, as the four types of inversions are shaded on the diagram. Stronger inversions (>= 5°C spread) are shaded in yellow while weaker inversions (< 5°C spread) are shaded in light green.

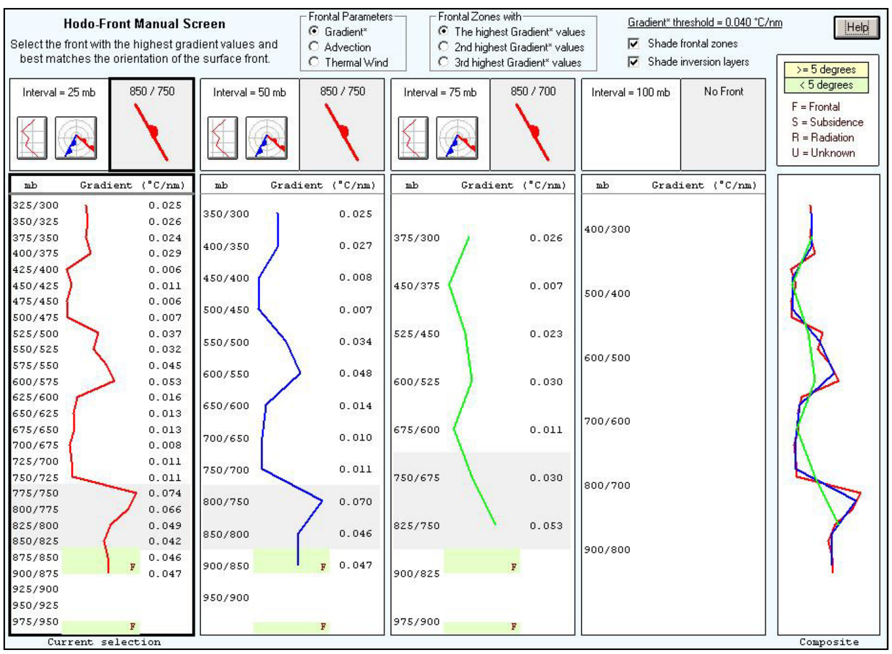
Action Buttons. Near the top of each wind interval column are 2 action buttons...



Use this button to exit the Hodo-Front screen and plot the respective front on the main Sounding Diagram screen.

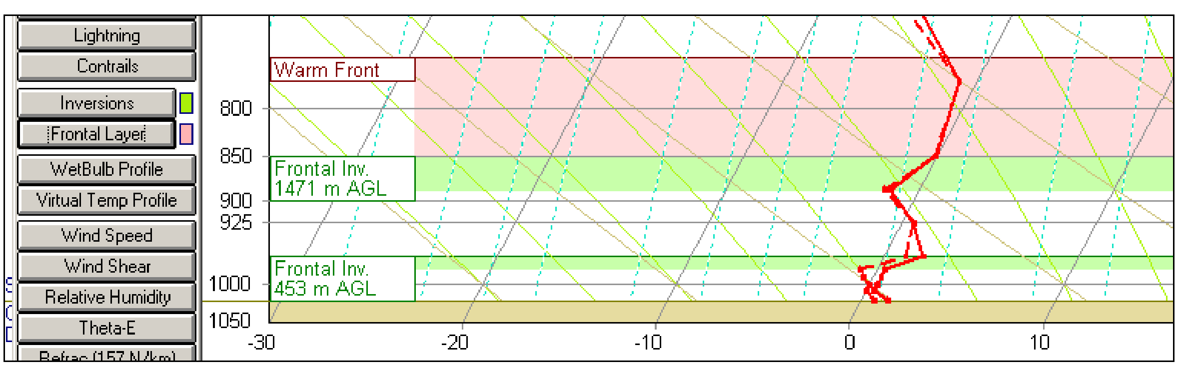


Use this button to exit the Hodo-Front screen and plot the respective front on the Frontal Analysis screen.



Historically, manual hodo-front analyses were only performed using the 100 mb data interval (4th column) since most data only consisted of the standard WMO formatted TTAA data sets. Computerization now allows easy interpolation of smaller interval wind (25, 50 & 75 mb) data, which allows detection of frontal zones with greater accuracy when matching surface frontal orientations.

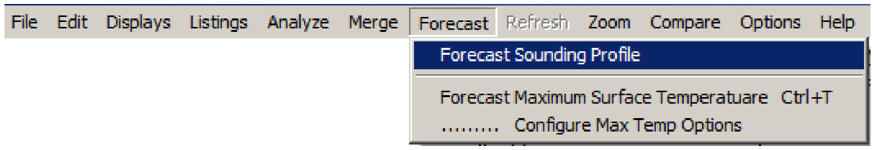
The image displayed below shows the corresponding sounding plot with the same shaded frontal zone and inversion layers.



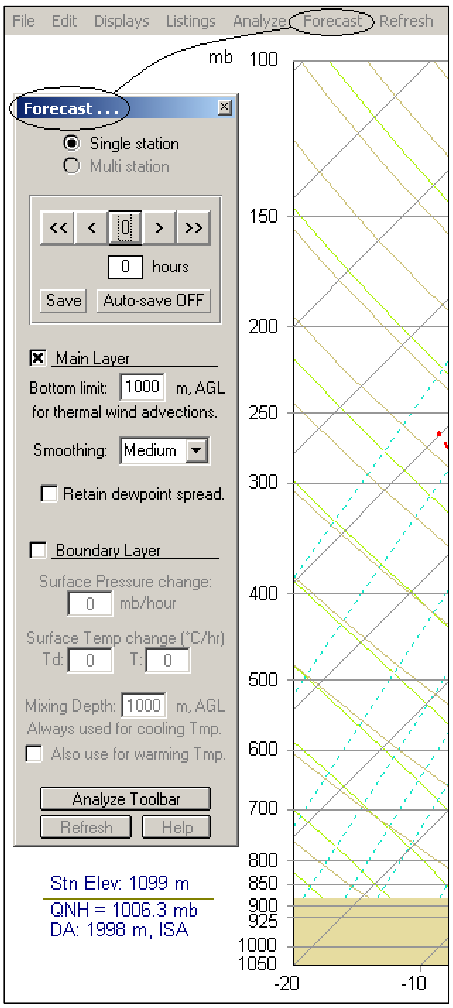
22. FORECAST SOUNDINGS.

Features presented in this section are only available with the optional Fronts & Forecast program module.

22.1 Overview



The Forecast Toolbar.



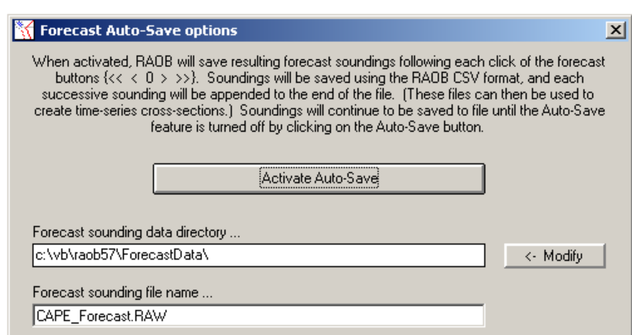
RAOB's Fronts & Forecast module creates forecast soundings using only observed data. The Forecast Toolbar (at left) controls forecast functions. RAOB creates forecast soundings by one of two different methods: (1) Temperature (drybulb only) advections derived from thermal wind data, and (2) Temperature & dewpoint advections, along with wind changes, that are derived from upstream soundings.

By selecting the "Forecast" Menu bar option, a new control panel called **Forecast …** is displayed along the left side of the sounding diagram (as shown to the left). In this example, the plotted sounding comes from a datafile containing just one sounding, therefore, the "Single station" panel option is only available. The "Multi station" option also becomes available with datafiles containing more than one sounding (which is discussed later in this section).

The buttons marked with the **>** and **<** symbols apply +/- 1-hour time steps to the sounding, whereas the **>>** and **<<** buttons apply +/- 6-hour time steps. The **0** button resets the sounding to its original state. The box immediately below the **0** button displays the current forecast hour.

Use the **Save** button to save any forecast sounding data to file. The user will be prompted for a file path and filename. Use the **Auto-save** button to have RAOB automatically save each sounding's time step to file. When selected, the **Forecast Auto-Save options** display screen appears (as shown below). After the **Activate Auto-Save** button is selected, sounding data will be saved to the same file as appended data sets following selection of each forecast time step. Data will be saved in the RAOB.CSV format.

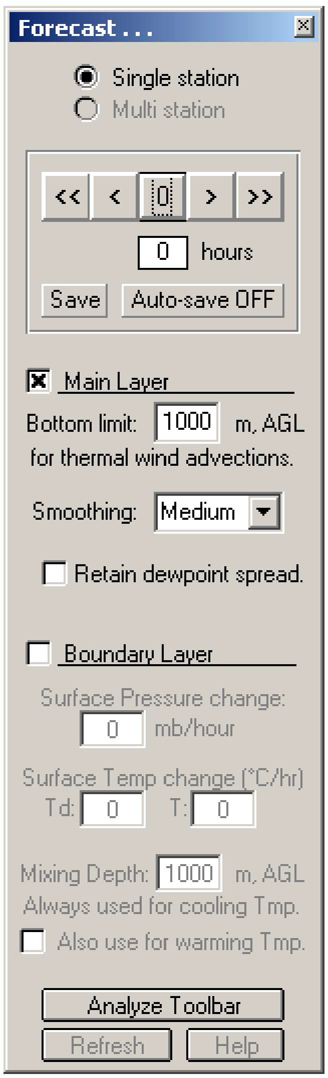
This auto-save capability can create a file containing sequential forecast soundings, which then can be used to create a time-series (time-height diagrams) using the optional Cross-Section program module.



22.2 **Single Station Forecasting**.

This forecast option can be extremely useful when no other regional sounding information is available. A very reasonable, short-term forecast can be made from the sounding's inherent thermal wind characteristics. The single station forecast mode only uses thermal wind temperature advections when generating forecast soundings. Forecast values are only applied to the sounding's environmental (dry bulb) profile, while dewpoint and wind data remain unchanged. Note: The sounding's thermal wind temperature advection data can be viewed by using the Sounding's **Frontal Analysis** Menu Display option, and are independent of any warm or cold front selections.

With each forecast time increment selected, the thermal wind advections are applied through the entire sounding using 25 mb (hPa) intervals, after which, RAOB then filters the sounding in order to display only the significant temperature gradients and standard pressure levels in accordance with WMO standards.



The **Single station** forecast mode allows the user to control the forecast process with respect to two layers: the Main Layer and the Boundary Layer.

The **Main Layer** options can control thermal wind advections throughout the entire depth of the sounding. The Main Layer's upper limit is preset at 300 mb, while the lower limit is set using the Bottom limit box. The **Bottom limit** box allows the user to prevent forecast advection data from being applied to a specified lower layer, such as the boundary or friction layer. In cold weather at higher latitudes, it is usually safe to use 0 meters for the bottom limit since solar heating is minimally affective. In warmer environments, a 1000 meter limit is reasonable, where the user should then also either manually adjust boundary level data or use the "Boundary Layer" forecast options discussed below.

Use the **Smoothing** option to reduce irregular gradients for a more natural profile. Use the **Retain dewpoint spread** option for those situations were moisture spread consistency is important.

The **Boundary Layer** section is used to help simulate diurnal affects and produce a more representative forecast sounding at the lowest levels. When used, the boundary layer's surface pressure and temperature & dewpoint changes can be controlled. (Positive and negative values are allowed.)

The **Mixing Depth** limit is always applied to cooling surface temperatures as it uses the common DALR (dry adiabatic lapse rate) method to establish the depth of the mixing layer. The mixing depth can also be applied to warming surface temperatures if the **Also use for warming Tmp** box is checked, which disables the DALR mode.

Note: The use of the Mixing Depth layer overrides any forecast data created by the Main Layer advections.

The **Analyze Toolbar** and **Refresh** buttons function in the same fashion as the sounding's Analyze feature where various indices and parameters can be graphically applied to the sounding diagram. The sounding's forecast profile will be retained upon exiting the Forecast mode, until the Restore menu option is applied.

22.3 **Multi Station Forecasting**.

The multi station forecast mode is only available when using a datafile containing multiple soundings (of WMO format), where each sounding represents a different geographic location.

This mode is especially useful if there are several soundings upwind of the base sounding. This mode can give the user good short-term forecast information before conventional forecast products are available from centralized data processing centers.

The user can select the upstream search radius through use of the **Sounding range (km)** data box. When this mode is initially used, the user must click the **Search for soundings** button so RAOB can locate the upstream soundings. Once the upstream stations have been located, this button changes its "button name" to **View soundings**, where after clicked, will display a map of the selected stations (see next page for examples).

The upstream sounding station selection criteria are a direct function of the base soundings' wind directions. Upstream selections are made at a 1 KM vertical resolution. RAOB first segments the sounding's wind data into 1 KM winds, from which it then locates upwind stations out to the range specified in the "Sounding range (km)" user option (discussed above). The 1 KM vertical resolution guarantees a representative selection of upwind stations throughout the entire sounding. (The user can also manually override the automatic upwind selections as described on the next page.) As the forecast time steps increase, data from soundings further upwind are systematically used for advections.

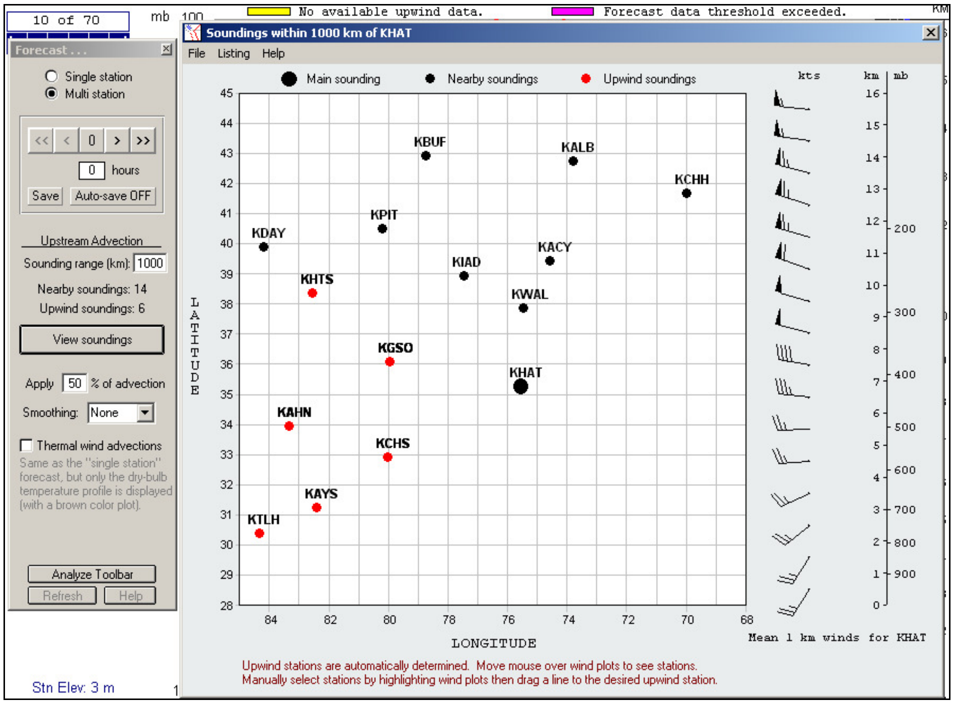
Temperature and wind forecast change rates are determined solely by the wind speeds of the base sounding's winds. However, the user can control the degree of advection by using the **Apply % of advection** input field. If the prevailing winds are zonal, then a high advection value is appropriate. However, if the wind patterns are of high amplitude, then lower advection values are appropriate.

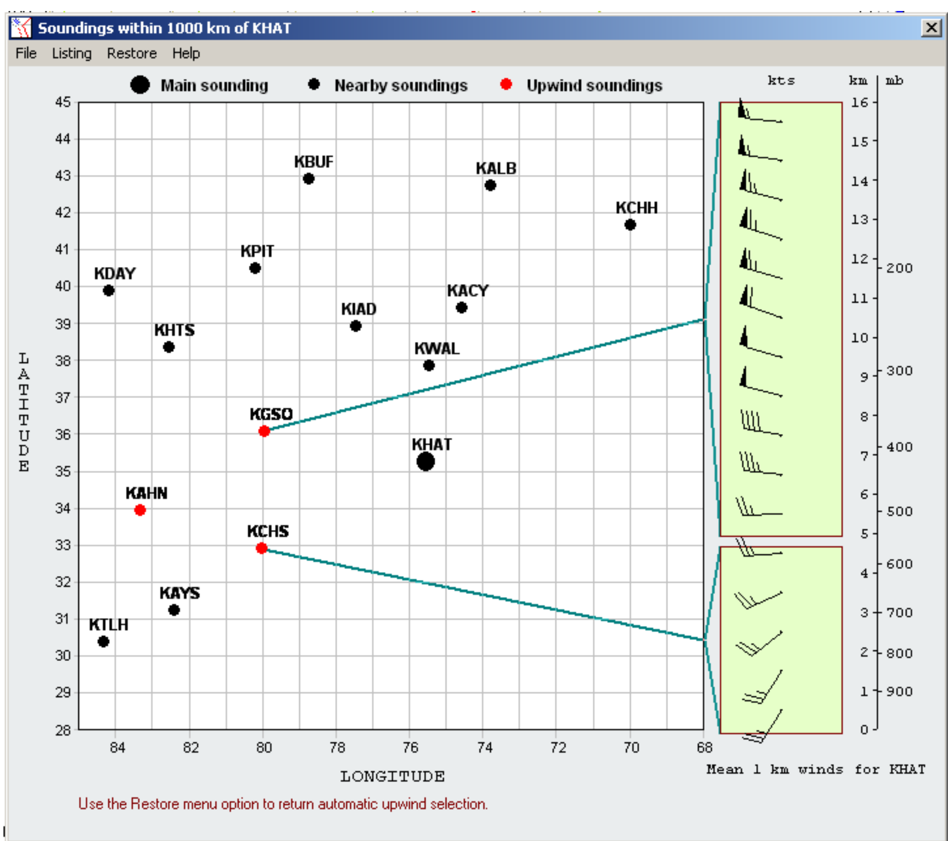
The **Smoothing** option is equivalent to the single-station smoothing option, as it reduces irregular gradients for a more natural profile appearance.

The multi station forecast mode makes excellent use of upstream sounding data. However, there are times when it is useful to also see the advections produced by the sounding's thermal wind data (e.g., the forecast sounding produced via the Single station forecast mode). Therefore, the **Thermal wind advections** option is made available so the user can easily compare forecast data. This comparison can be especially useful for the very short-term forecast range. When used, the "thermal wind" forecast sounding profile is plotted in a brown color in order to differentiate forecast profiles.

The **Analyze Toolbar** and **Refresh** buttons function in the same fashion as the sounding's Analyze feature where various indices and parameters can be graphically applied to the sounding diagram. The sounding's forecast profile will be retained upon exiting the Forecast mode, until the Restore menu option is applied.

Multi Station Forecasting (continued).





Upon activation of the "View soundings" button, a map of nearby soundings is displayed. All soundings are within the range specified by the "Sounding range" input box on the Forecast Toolbar. Sounding dots plotted in a Red color indicate those soundings that are "upwind" of the base sounding, which is plotted with a large Black dot. By moving the mouse cursor over the plotted wind images, the user can see which upstream soundings coincide with each 1 KM mean wind.

The selection of "upstream" soundings is initially automatically determined by RAOB (they are plotted with Red dots.) However, these soundings can be manually adjusted using these 3 steps:

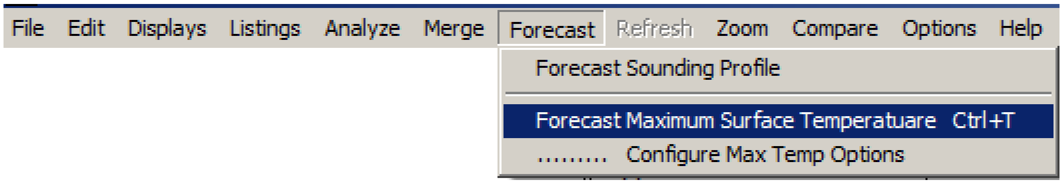
<u>One.</u>
Click down and hold the mouse button to highlight (green box) selected winds.

<u>Two.</u>
Drag mouse to preferred "upwind" station to be used for forecast advections.

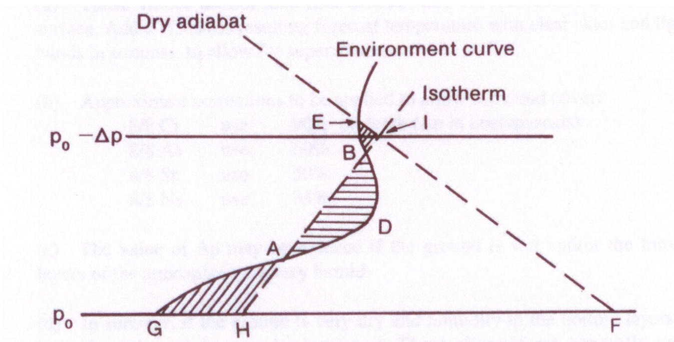
<u>Three.</u>
Release mouse button over preferred "upwind" sounding.

Use the "Restore" menu option to return automatic upwind selections.

22.4 Forecast Maximum Surface Temperature.

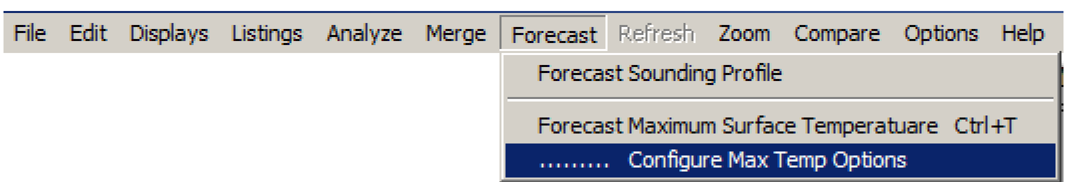


You can easily forecast the maximum surface temperature by clicking on the above menu option.

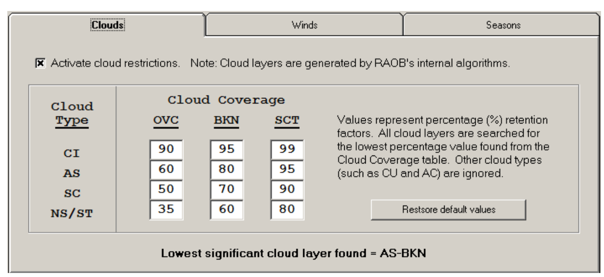


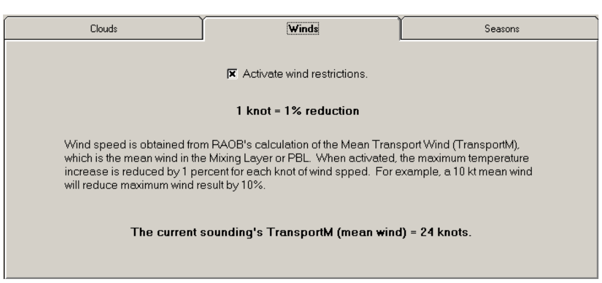
Using an early morning sounding, RAOB uses the diagram at left and calculates the shaded areas to graphically find equal energy areas of vertically and horizontally hatched regions. This represents the potential change in surface temperature from point G to point F as a result of solar heating. This method assumes that at maximum heating the sounding profile will become dry adiabatic. (line EF).

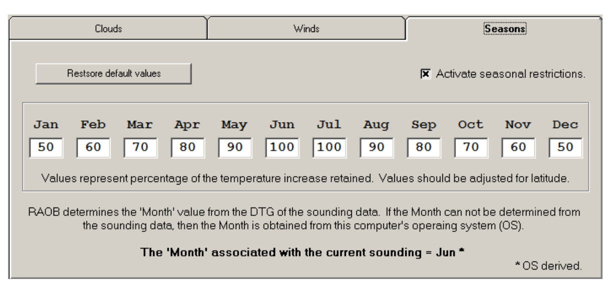
This method is often referred to as Gold's (1933) equal-area methodology of forecasting maximum surface temperatures. This method assumes no clouds, light winds, and summer months. The user can override these assumptions by using the configuration options shown below.



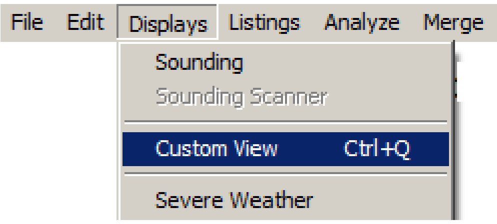
By selecting the above "Configure Max Temp Options" menu option, Gold's 3 assumptions can be individually configured for Clouds, Winds, and Seasons as seen in the 3 following panels. Each assumption panel can be turned ON or OFF with the Activate option.



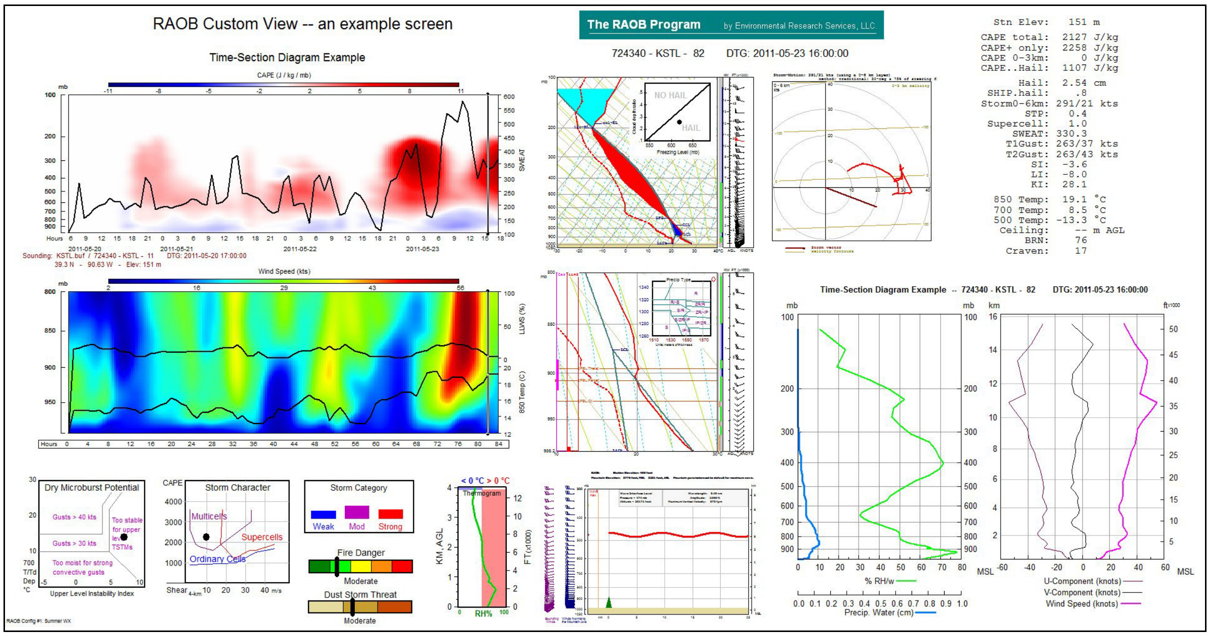




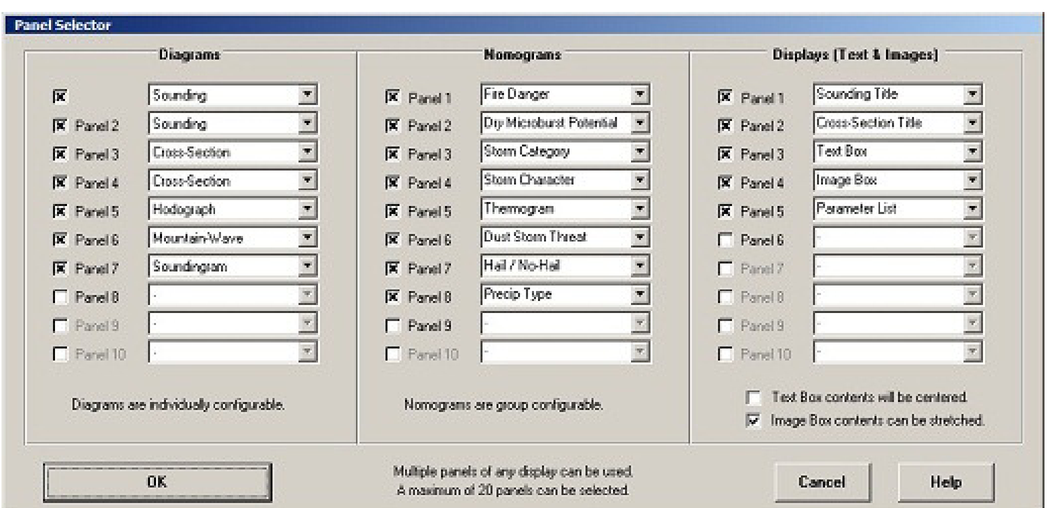
23. Custom View.



RAOB's Custom View display system lets you design your own RAOB display screen, regardless of screen size or orientation (horizontal or vertical). The below example contains 20 panel images using a widescreen monitor. Two panels are even embedded within other panels. Note the Hail / No-Hail image is placed within the top Sounding panel while the Precip-Type image is placed within the lower Sounding panel.



The Custom View display screen allows up to 20 panels. The only requirement is selection of at least one Diagram panel, such as a Sounding or Cross-Section diagram. See the below image for the Panel Selector options used for the creation of the above Custom View screen. Note that this example contains 2 Sounding panels and 2 Cross-Section panels, and 16 other panel selections. The Displays (Text & Images) panel options even offer blank panels, which allow free form Text entry or display of any customer provided images.

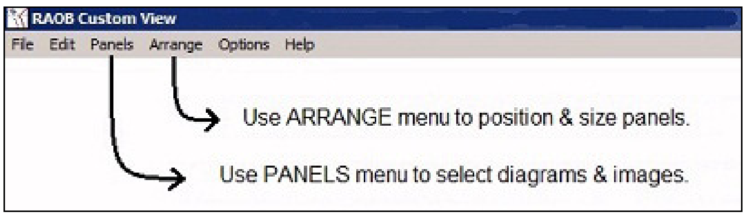


Custom View (continued).

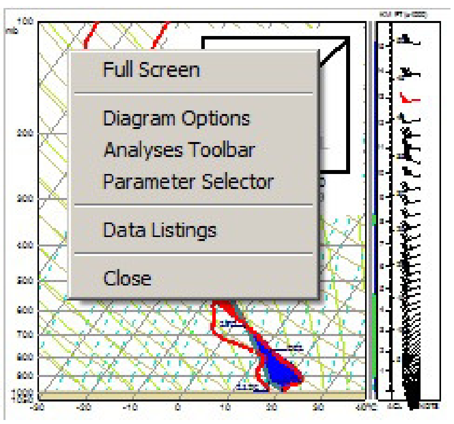
A key advantage of the Custom View screen is that all panels are synchronized to the same sounding data. There are 2 types of data synchronization modes:

Mode 1: Sounding Data. When a sounding file is loaded, all panels will display data from the same sounding file. All graphic and text panels will display their respective images and data. A Cross-Section panel should not be included with this display mode.

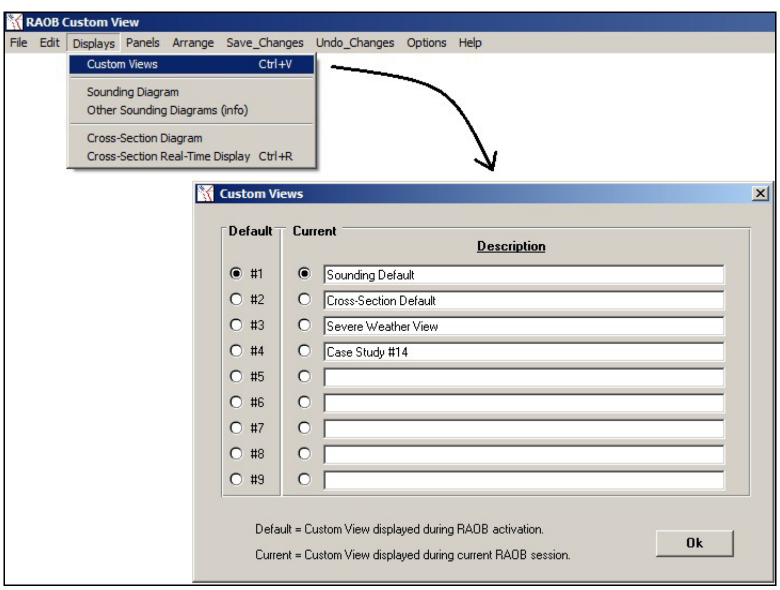
Mode 2: Cross-Section Data. When a cross-section file is loaded, the Cross-Section panels will display the same sectional data, while all the Sounding-related panels (such Hodograph and Mountain-Wave) will display the individual sounding profile as selected from the Cross-Section display. Individual sounding profiles are selected from the Cross-Section images by using either a mouse click, the movie-loop controller, or cursor keys. The above Custom View example employs this mode of data synchronization.



Use the Panels and Arrange menu options (shown at left) to design your custom view. The Panels menu displays the "Panel Selector" as shown on the prior page.



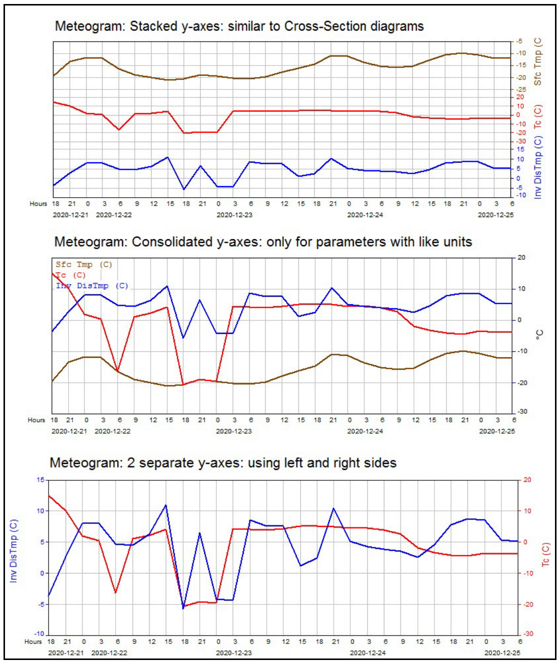
You may ask that with all the different kinds of diagrams and images, "how are the diagram and related configuration options handled?" Each panel contains its own unique menu. The menus are accessed simply by clicking on the image. A left-click presents the main popup menu (as shown left), while for the more involved diagrams (such as the Sounding and Cross-Section images), a right-click produces the same unique menuing action as experienced on the full screen version of the panels. You'll note that the top-most popup menu option always lists the "Full Screen" option, which when selected, automatically transfers the user to the diagram's home display screen.



Some diagram interactive features, such as the Sounding's "click & drag" functions are not available with the Custom View. However, full diagram interactive functionality is quickly available just by clicking on the "Full Screen" menu option. Other data control options will appear when hovering the mouse over the panel of interest.

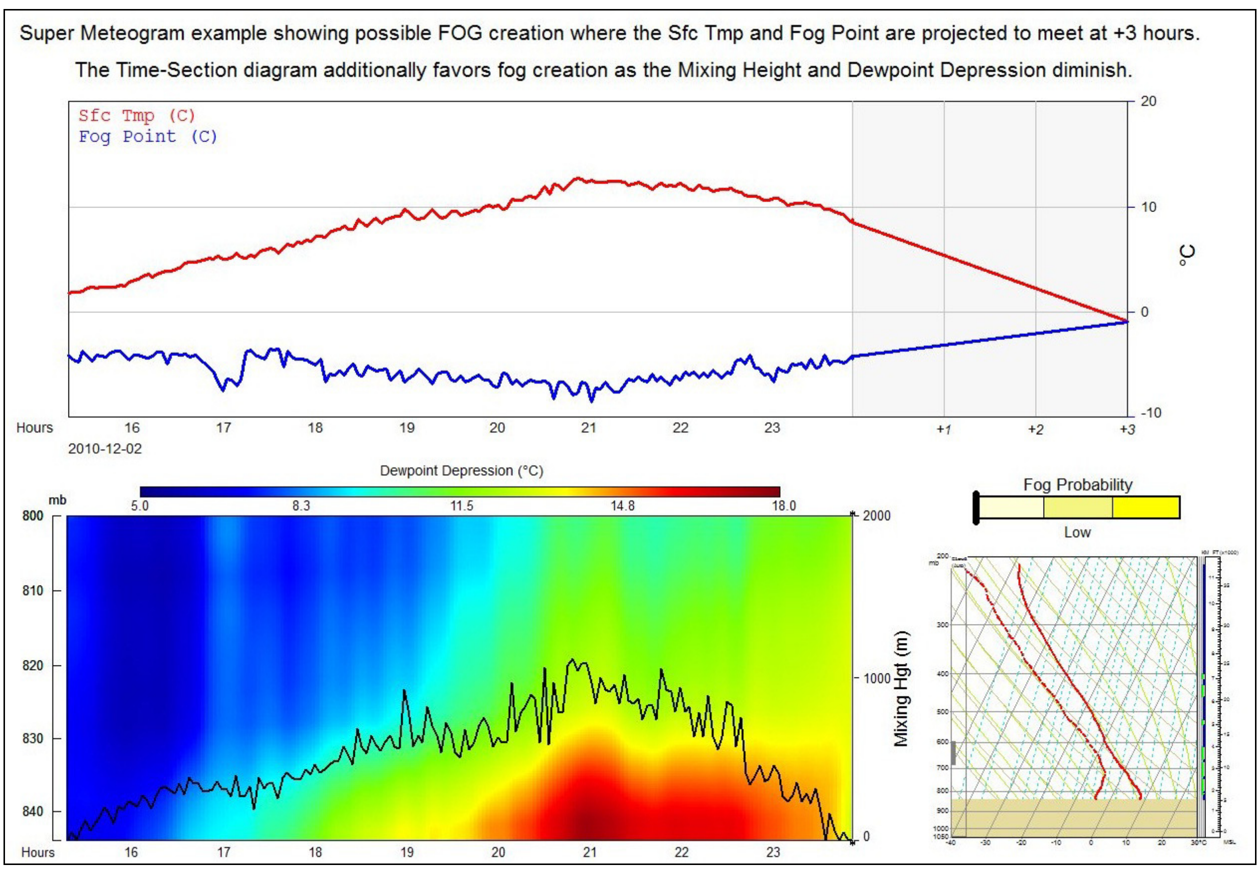
There's more. You can save up to 9 different display configurations for instant recall. Just use the "Custom Views" menu option as shown at left.

Custom View (continued): the Super Meteogram.



The one diagram option not shown on the prior Custom View examples is the new Super-Meteogram display. It not only provides the standard meteogram graphs, but it is also fully user configurable and provides three Y-Axis display modes as shown at left.

Additionally, the Super-Meteogram offers a one-of-a-kind data projection (extrapolation) function which provides short-term parameter forecasts out to 3 hours. Note that these projections only work for time-series sounding data, and they are only intended to be used with "real-time" sounding data produced by the non-conventional sounding profilers: microwave / laser / radar / acoustic. The below Custom View example contains the Super-Meteogram, a Time-Series diagram, a Sounding diagram, and a Fog index display.



24. **RAW DATA FORMAT**. Below is a short example:

```
"RAOB6116","Example sounding data file",1,2,3
32.07,"N",110.56,"W",789,100
"AUTO",1,"NO",2,0,0,0,0,0,0
927,2,.8
850,1.2,-3
0,150,4
125,180,5
430,245,8
"ST",59,"SCT",74
3500,5,20
8,2700,4,25
```

HEADER Lines (3)

First line:	"RAOB6116"	RAOB program version used when data file is saved. The last 4 digits are the first 4 digits of the program serial number.
	"Sounding"	Information line, either automatically or manually entered.
	1	No. 1 indicates a "raw" data file.
	2	Indicates two (2) pressure/temp data levels.
	3	Indicates three (3) height/wind data levels.
Second line:	32.07	Latitude (32 degrees and 7 minutes).
	"N"	"N"orth latitude.
	110.56	Longitude (110 degrees and 56 minutes).
	"W"	"W"est longitude.
	789	Station height is 789 meters.
	100	Height of first sounding temperature: AGL, meters. Value is 0 (zero) if data starts at the surface.
Third line:	"AUTO"	Indicates Cloud data is "automatically" determined.
	1	Indicates RAOB only found 1 cloud level.
	"NO"	Indicates "precipitation" was not occurring.
	2	Indicates 2 sets of mountain parameters (double ridge).
	0,0,0,0,0,0	These last 6 fields are reserved for future use.

NOTE: for new datafiles, highly recommend the 3rd header line be entered as this example line above. The program will make any necessary changes later.

PRESSURE/TEMPERATURE Data
Format: Pressure (mb), Temperature (°C), Dewpoint (°C)

HEIGHT/WIND Data
Format: Height (m, AGL), Wind direction (degrees), Wind speed (knots)
Note: Heights are saved in decimal format to retain accuracy when data are originally entered in feet.

CLOUD Data (Optional: permits manual specification of cloud layers.)
Format: Cloud type, Cloud base (ft x 100), Cloud coverage, Cloud tops (ft x 100)

MOUNTAIN Data (Optional: requires use of the Turbulence & Wave module.)
Format: 1st Mtn: Height (ft), Base half-width (nm), Axis orientation (degrees)
2nd Mtn: Distance from 1st Mtn (nm), 2nd Mtn: Hgt, Half-Width, Axis

25. **RAOB CSV data format & example**.

```
RAOB/CSV, Example CSV Data Sounding Title
INFO:1, First line of freeform text
INFO:2, Another freeform text line
DTG, 2013-01-25 14:15:30
LAT, 25.12, N
LON, 123.45, W
ELEV, 50, M  (F option available beginning with RAOB 6.8)
WMO, 12345
TEMPERATURE, C
MOISTURE, TD
WIND, kts
GPM, MSL, M  (F option available beginning with RAOB 6.8)
MISSING, -999
SORT, YES
OZONE, mPa
EXTRA#1, Extra#1Name, Extra#1Units
EXTRA#2, Extra#2Name, Extra#2Units
SCALAR#1, Scalar#1Name, Scalar#1Value, Scalar#1Units
SCALAR#2, Scalar#2Name, Scalar#2Value, Scalar#2Units
RAOB/DATA
PRES, TEMP,   TD, WIND, SPEED, GPM, OZONE, OMEGA, CFRL, VapDen, LiqWat, WSPEED, Extra1, Extra2
1000,   20,   10,  270,  10,    50,  3.21, -0.3,    0,   3.660,  0.000,    1,     13,    4.1
 850,   15,    0,  290,  20,  1400,  3.31, -0.6,   10,   3.580,  0.000,    3,     14,    5.2
-999, -999, -999,  330,   5,  2500,  2.25, -0.3, -999,    -999,   -999,    2,     15,    6.3
 700,   10,   -5,   90,  10,  -999,  6.90,  0.0,    5,   3.331,  0.000,   -1,     16,    7.4
 500, -999, -999,  240,  25,  -999, 10.11,  0.4, -999,    -999,   -999,   -2,     17,    8.5
```

<u>FILE HEADER Descriptions . . .</u>

Mandatory. “RAOB/CSV” is a required header line.
The following data fields are optional, but should used if known.

INFO:1 and INFO:2 are both optional freeform text lines, and must not contain commas.

DTG is the “Date-Time-Group” field. It is in UTC (or universal) time. Example: **`2013-01-25 14:15:30`**
Highly recommended if soundings are to be used for Time-Height diagramming.

LAT is required for cross-sections. Latitude is in “decimal degrees”. Next data field is “N” or “S”.
LON is required for cross-sections. Longitude is in “decimal degrees”. Next data field is “E” or “W”.

ELEV is optional, but highly recommended, with "M"eters or "F"eet units. "M" is the default value.
If the sounding is “elevated” like ACARS and Satellite-derived” profiles, then use this header:
“ELEV, Elevated” and the 1st data line must then contain a height value in the GPM column.

WMO (5-digit identifier number) is optional. When used, and if this WMO number is listed in the RAOB.STN locator file, then the Lat/Lon & Elev data will automatically be accessed. If this number is listed in the RAOB.MTN file, the associated mountain data will be accessed.

TEMPERATURE. Optional Kelvin (K) units. Default is Celsius (C).

MOISTURE. Optional dewpoint (TD) or humidity (RH) input. Default is TD

GPM. Optional wind height type, “MSL” (default) or “AGL”. Units are: "M"eters (default) or "F"eet.

MISSING. Optional missing data value. Default is –999. Value must be within +/-32000.

SORT. Optional data sorting option. Default is YES

OZONE. Flags the use of this optional data column. Units: nbar or mPa

WIND. Optional wind speed units, “kts” or “m/s”. Default is kts
Note: Add “U/V” after the wind Units to flag data as having U/V wind components. When using U/V component winds, change the data header from WIND to UU and SPEED to VV as shown in the below example header …

```
PRES, TEMP, TD, UU, VV, GPM, WSPEED
```

The vertical wind data column (WSPEED) must use the same Wind Speed units as U/V data. The upward motion values are positive and downward motion values are negative.

Wind direction can reported in NATO Mils (vs degrees) units by adding "MILS" after wind speed units.

EXTRA DATA. Optional 1, 2 or 3 user-defined data types. Use any kind of data that can numerically represent a profile, such as Temperature. The ExtraData Names can be any alpha-numeric combination up to 15 characters long. The last field is the Units of the data values (7 character max), such as “dB”.

Example: EXTRA#1, SNR, dB
Note: When “Units” with exponents are entered with a caret (^) symbol, such as “m^3”, RAOB will automatically convert the units numeric value to superscript, like this: “m^3”.

SCALAR DATA. Optional 1 or 2 user-defined scalar Names (up to 10 characters) and their Units (up to 7 characters). Display on the Sounding’s custom parameter List and plot on Cross-Section’s Meteograms. The Note about “Units” (see above) also apply to the Units of SCALAR data.

Example: SCALAR#1, SeaTemp, 35, C

DATA HEADER Descriptions . . .

Mandatory. “RAOB/DATA” is a required header line.

Mandatory. Data column headers are required. The first 6 data columns are mandatory and they (PRES, TEMP, TD, WIND, SPEED, GPM) must be present in this exact sequence and spelling for each data file. The remaining 8 data items (OZONE, OMEGA, CFRL, VapDen, LiqWat, WSPEED, Extra1, Extra2) are optional and can be listed in any sequence or grouping. For example, after the required GPM column header, CFRL and OZONE can be listed if needed.

DATA COLUMN Descriptions . . .

There can be 6 to 15 columns of data (which must correspond to the above header data) . . .

PRES, TEMP, TD, WIND, SPEED, GPM, OZONE, OMEGA, CFRL, VapDen, LiqWat, WSPEED, Extra1, Extra2, Extra3

Pressure (mb or hPa). Precision: tenths.
Temperature (°C). Precision: tenths.
Moisture. Precision: tenths. TD (°C) or RH (%).
Wind direction. Degrees (default) or Mils. Precision: whole degrees or Mils.
Wind speed (kts or m/s). Precision: tenths.
GPM Wind height (meters, MSL or AGL).
OZONE (nbar or mPa). Precision: hundredths.
OMEGA (microbars/second). Precision: tenths.
CFRL (percentage of cloud cover). Precision: tenths.
VapDen (g/m^3) and LiqWat (g/m^3). Precision: thousandths.
Vertical Wind (W) speed (kts or m/s). Precision: tenths.
EXTRA#1 and EXTRA#2. User-defined data types. Precision is automatically determined.

NOTE 1: Maximum data levels are currently 10,000.
NOTE 2: There must be at least 2 levels of Pres/Temp data or 2 levels of Height/Wind data.

26. **REFERENCES**.

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