Micro Pulse LiDAR System

SigmaMPL2015

Software Manual

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Sigma Space Corporation
4600 Forbes Blvd
Lanham, MD 20706, USA

Tel. +1 301.552.6000 (Main)
Fax +1 301.552.6411
info@sigmaspace.com

www.sigmaspace.com
www.micropulselidar.com

Table of Contents

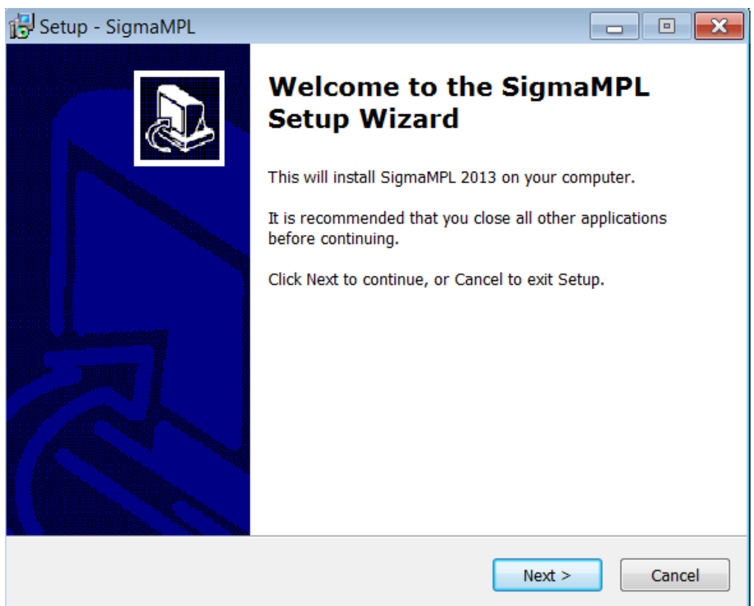
1. Introduction

SigmaMPL is custom software developed by Sigma Space Corporation that is specifically designed to process and display data from Sigma's Micro Pulse LiDAR product line. *SigmaMPL* offers the user the ability to view collected data in real time (*Real Time Hardware Control*) or playback previously recorded data (*File Playback Mode)*. In either mode, *SigmaMPL* can detect various atmospheric features (Planetary Boundary Layer heights, Cloud Heights, Cloud Bases, etc.) with built in algorithms and display them in two different plots. The software continuously displays a single vertical aerosol profile of data and a time sequence plot. This allows the user to view both the real time atmospheric structure and the temporal and spatial trends in aerosol and cloud structure. *SigmaMPL's* algorithms, features, and plots are all fully configurable.

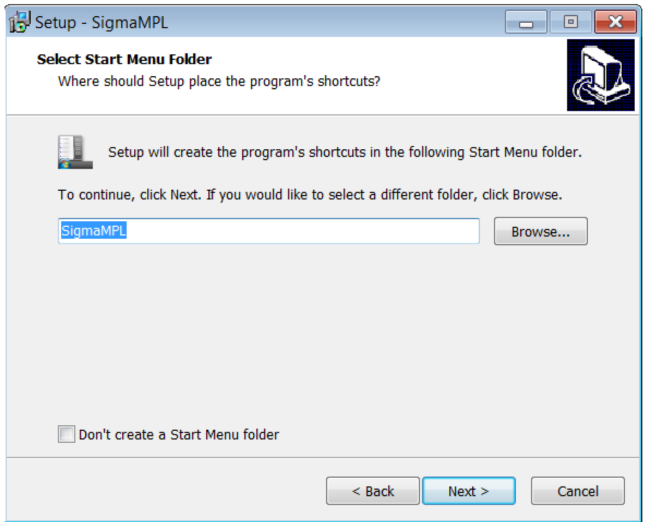
2. SigmaMPL Software Installation

SigmaMPL software comes preinstalled onto the laptop of any new MPL/MiniMPL purchase. For other cases, follow the steps below to install *SigmaMPL* onto a computer.

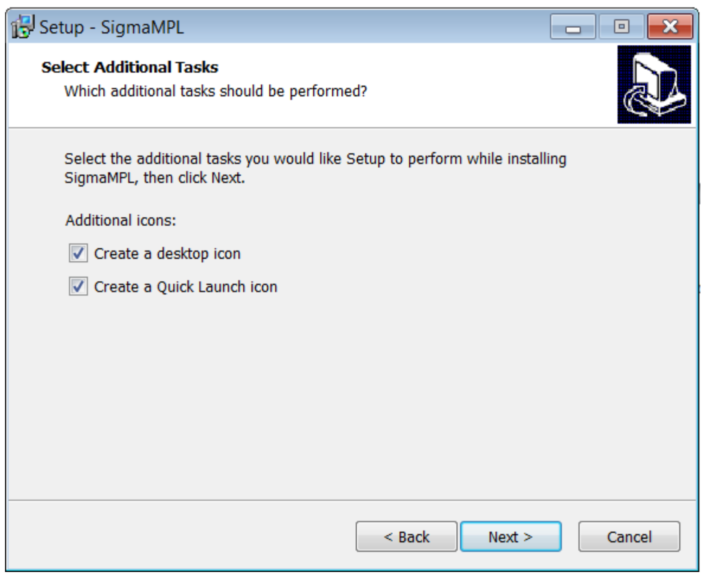
2.1. Run the *SigmaMPLsetup.exe* program from the provided SigmaMPL Software.



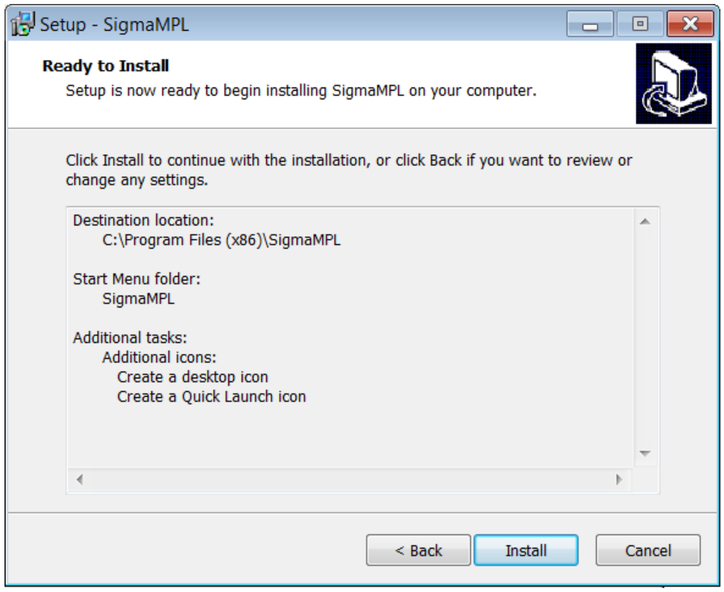
2.2. Select the Start Menu Folder where the software will be installed.



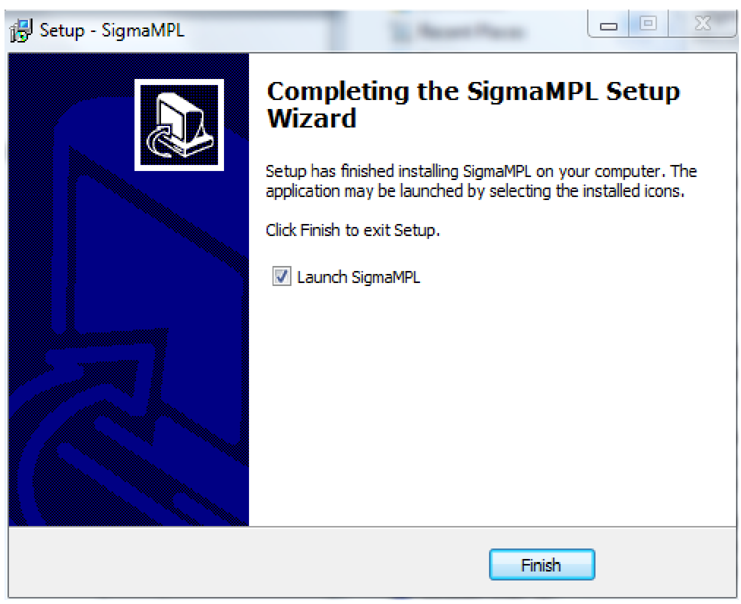
2.3. Select Additional icons.



2.4. Click the Install button to install the software.



2.5. Click **Finish** to launch *SigmaMPL.*



3. AMCS USB Driver Installation

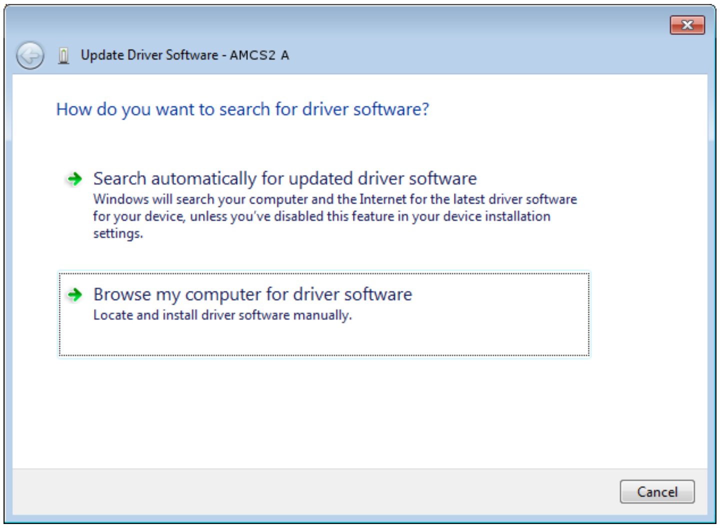
AMCS USB Drivers come preinstalled on all new computers provided by Sigma Space. To install the LiDAR drivers manually on additional data acquisition computers, follow the steps below.

3.1. Connect the computer to the LiDAR using the provided USB cable.
3.2. Switch the LiDAR power ON.
3.3. The "Found New Hardware" dialog box will appear in the lower right corner of the computer.

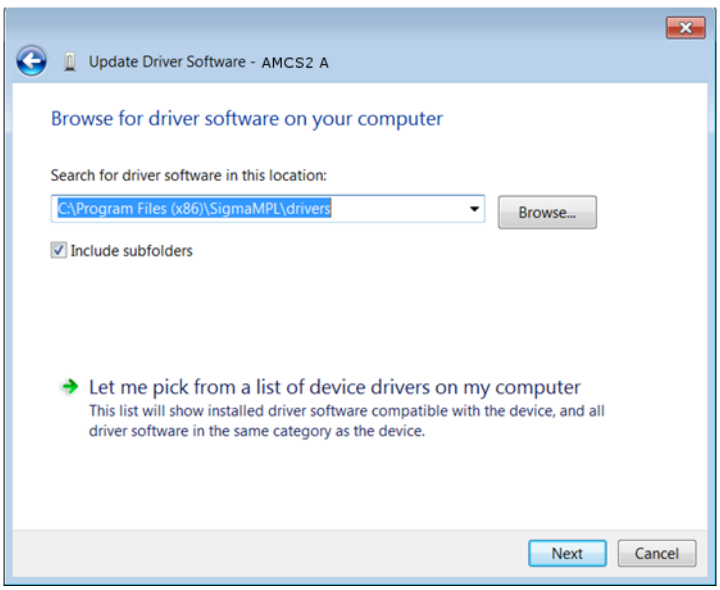
3.4. Open "Device Manager" and find "Other Devices".

3.5. Right click on the driver AMCS2 A and choose "Update Driver Software"

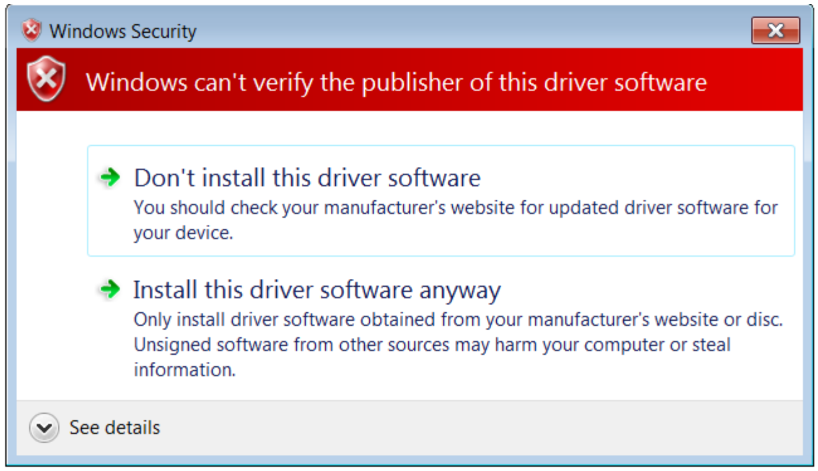
3.6. Select "Browse my computer for driver software"



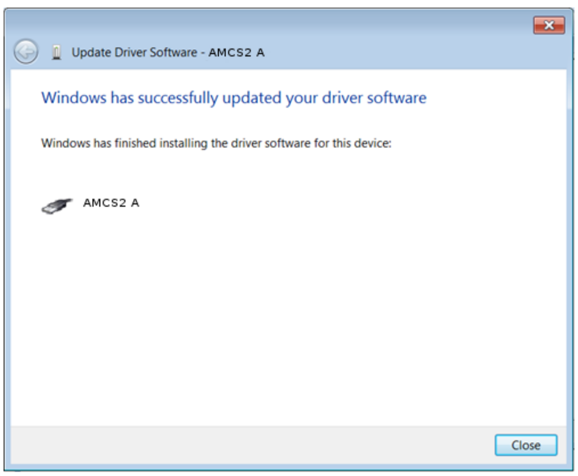
3.7. Browse to **C:\Program Files (x86)\SigmaMPL\drivers**. Select "Include subfolders" option.

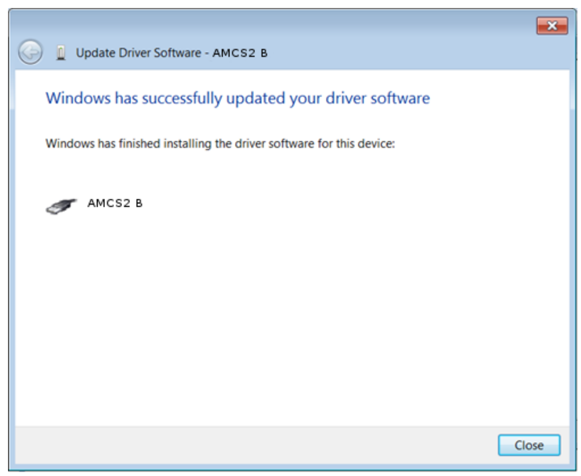


3.8. Disregard the warning about being unable to verify the publisher of the driver software and select "Install this driver software anyway".



3.9. Repeat these steps to install driver AMCS2 B.





4. SigmaMPL Operation

4.1. Starting SigmaMPL

4.1.1. Open *SigmaMPL2015* (or newer version) via the desktop shortcut or under **Start→All Programs→SigmaMPL**. The opening window is displayed in Figure 1.

4.1.2. The language can be changed under the Language menu. Currently the only supported languages are English or Chinese (simplified). The language translation can be changed at any time.

4.1.3. The software consists of four main sections for both *Real Time Hardware Control* and *File Playback Mode*. The sections are shown in Figure 1 and explained in Table 1.

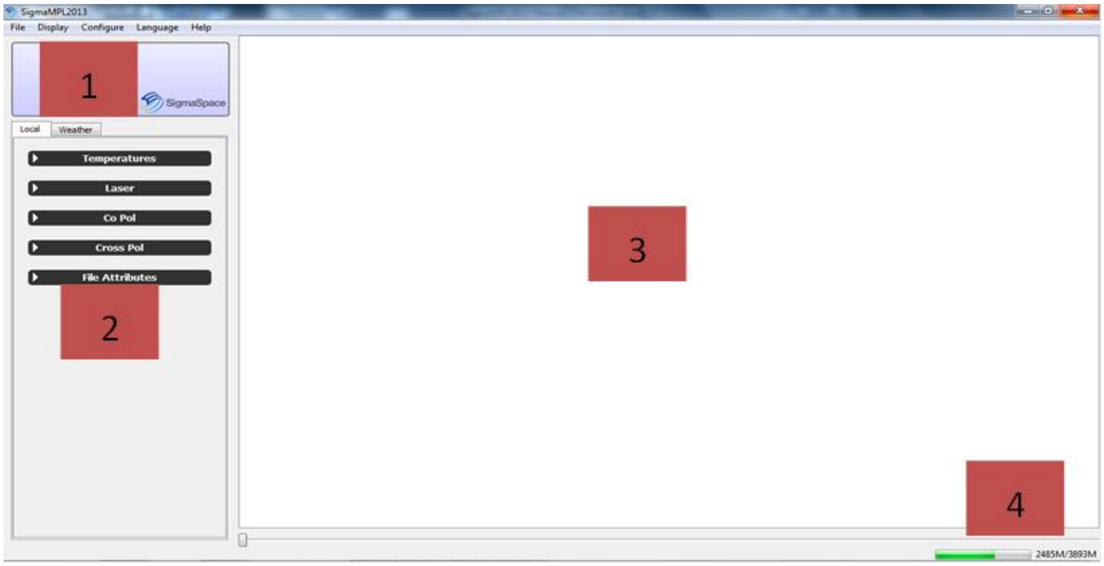


Figure 1: *SigmaMPL* Opening Window

Table 1: *SigmaMPL* Layout Description

Section		**Description**
1	Profile Information	Displays the LiDAR type, serial number, profile number, date, and time of the current profile being viewed in (3).
2	Instrument Information and File Attributes	<u>Local Tab</u> Displays the characteristics of the data that are specific for each profile. • **Temperatures**: Detector, laser and telescope temperature readings • **Laser**: Laser energy and Pulse rate • **Co Pol and Cross Pol**: Background and standard deviation for the two polarization channels (Co Pol and Cross Pol) The **File Attributes** section displays characteristics of the data that do not change across profiles • Number of channels • Number of Bins • Bin Size • First Data Bin • Software Version • File Version The **Hardware Status** (*Real Time Hardware Control* mode only) section displays status and error messages pertaining to data acquisition. <u>Weather Tab</u> Displays profile specific information about atmospheric features. • Planetary Boundary Layer (PBL) Height • Cloud Base Heights • Cloud Types • Weather station data (if equipped)

Section		Description
		All of the sections in this area are expanded when data acquisition is active or in playback mode and can be collapsed by clicking on the triangle.
3	Graph Area	Location of graphs after opening files for playback or during *Real Time Hardware Control*. The top plot shows the currently selected profile while the bottom plot is a time sequence.
4	Memory Used	This section displays the amount of memory being used by the software and the total available memory on the computer.

4.2. Real Time Hardware Control

The *Real Time Hardware Control* mode is the data acquisition section of *SigmaMPL* and displays the LiDAR data in real time.

4.2.1. From the opening window of *SigmaMPL*, press Ctrl+R or select **File→Real Time Hardware Control** (Figure 2).

4.2.2. Tabs for Raw Data, R^2 Corrected, SNR and Housekeeping will be displayed automatically. The NRB tab will be displayed only if the three LiDAR configuration files (Afterpulse, Overlap, and Dead Time Correction) are loaded (see Section 4.13 below for more information).

4.2.3. Select the **Bin Resolution** and **Averaging Time**.

4.2.4. Check the **Save Data** box if you wish to record the data. The files will automatically be named.

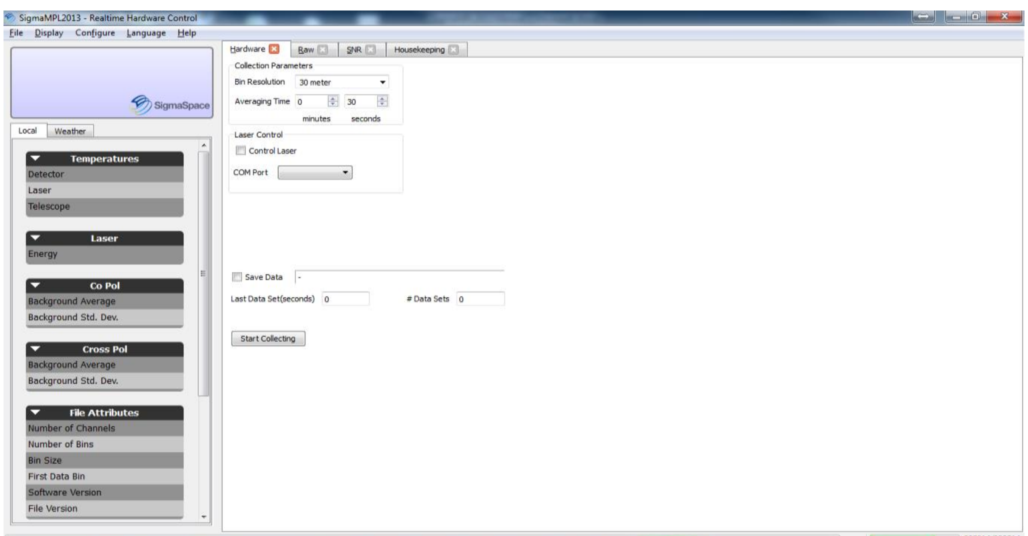


Figure 2: Real Time Hardware Control Window

4.2.5. The software needs to be configured for the LiDAR type before collecting data. To do this select **Configure→Algorithm Setup** and select **Default MiniMPL Parameters** or **Default MPL Parameters** (Figure 3). Click **Apply** followed by **OK** to save the changes.

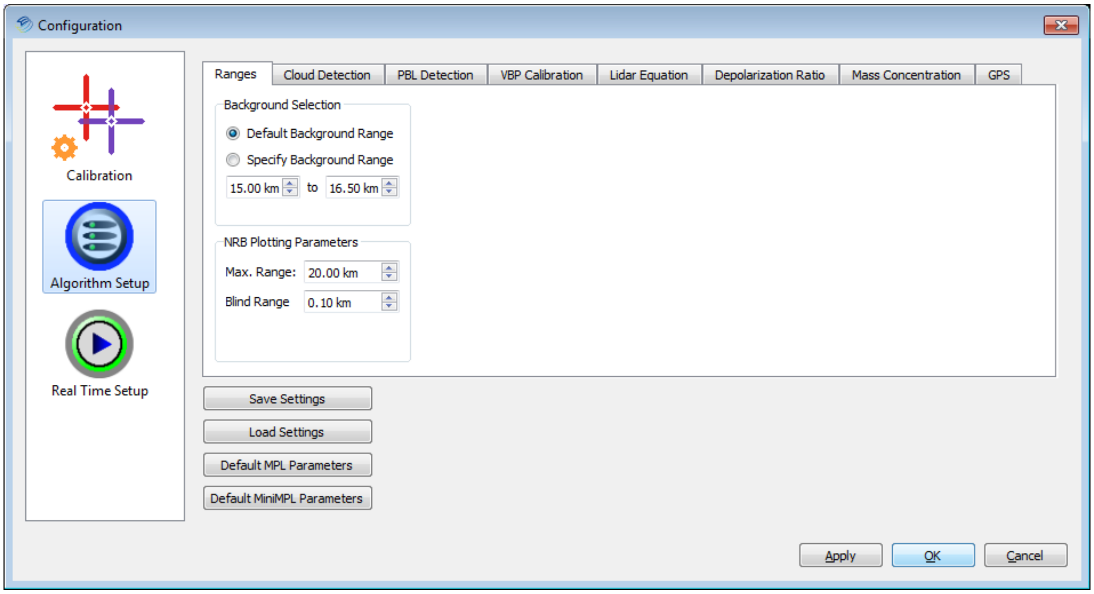


Figure 3: Configure Collection Parameters for LiDAR Type

4.2.6. Toggle the **Start Collecting** button to begin collection.

4.2.7. To stop collecting data toggle the **Stop Collecting** button.

4.2.8. For a detailed explanation of the plots displayed in *Real Time Hardware Control,* refer to Section 4.6.

4.3. Real Time Hardware Control Plot Setup

4.3.1 In *Real Time Hardware Control* mode, some tabs will not show up by default. To configure the Real Time tabs, select **Configure→Real Time Setup** and check all of the desired display options under "Plot Display". You can also select the profile history number to display (Figure 4).

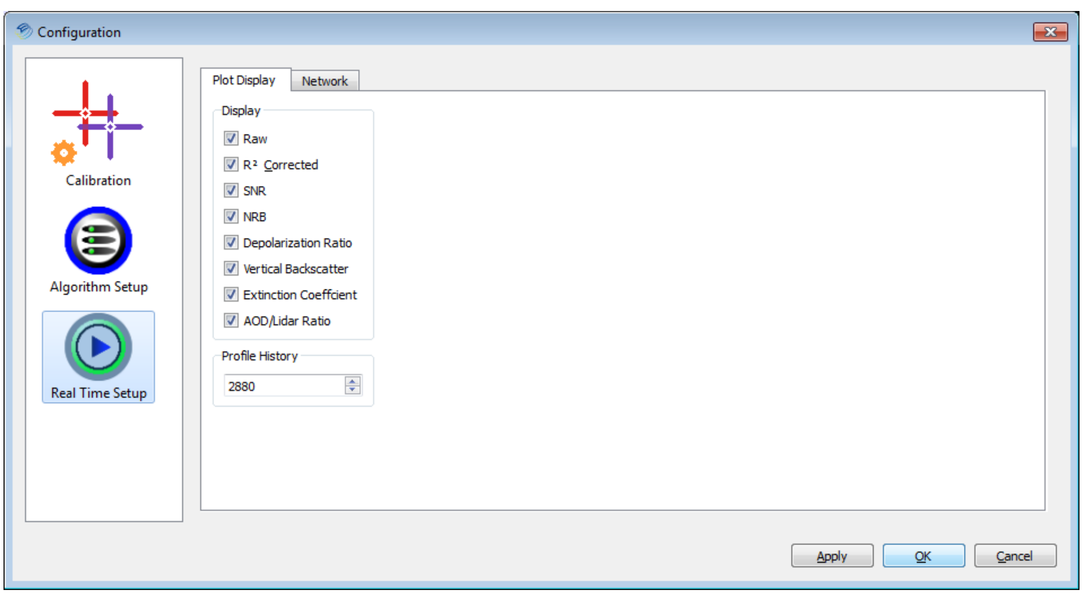


Figure 4: Real Time Hardware Control Setup Plot Display Parameters

4.4. File Playback Mode

File Playback Mode is the section of *SigmaMPL* that allows the user to view previously acquired data.

4.4.1. To enter *File Playback Mode* press Ctrl+O or select **File→Open Files**

4.4.2. The Open File(s) window shown in Figure 5 has four sections. These sections are explained in Table 2.

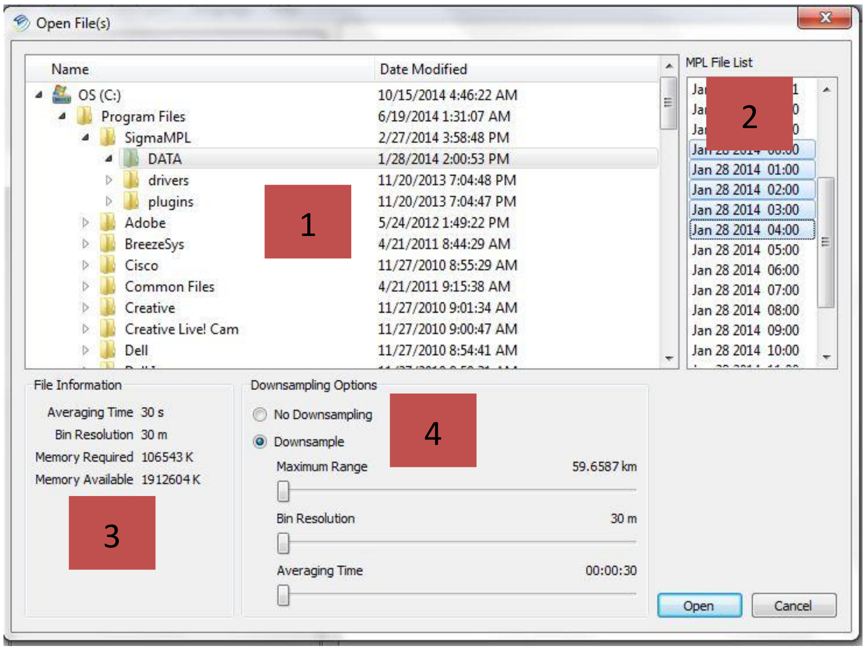


Figure 5: *SigmaMPL* Open File(s) Window

Table 2: Description of Open File(s) Sections

Section	Description
1 File Directory	The default SigmaMPL and DATA folders are displayed. By default, all *.mpl* files are displayed in the DATA folder. If the default data storage folder is changed, navigate to that folder to view *.mpl* files.
2 MPL File List	*SigmaMPL* data files (*.mpl* files) from the DATA folder are displayed here. Individual files or a set of files can be selected. If no *.mpl* files exist in the selected folder, then the message "No MPL files found" is displayed.
3 File Information	Displays the attributes of the selected file(s). These attributes are updated every time a file or set of files are selected. If the *Averaging Time* and/or *Bin Resolutions* are not the same for the selected files, "Not Uniform" will be displayed next to the appropriate parameter. **NOTE**: If either the *Averaging Time* or *Bin Resolutions* are non-uniform, the files cannot be opened together. The approximate memory required to process the selected files is displayed above the available memory for the computer. If the memory required exceeds the memory available, a prompt will appear asking to continue or cancel with opening the selected files. **NOTE:** Exceeding the memory limits of the system will cause the program to become unstable.
4 Downsampling Options	This section displays the downsampling options for the selected files. To downsample the selected files, select *Downsample* and drag the sliders to reduce the maximum range of data, decrease bin resolution, and increase averaging time. The downsampling algorithm processes data in this order. The memory required will update as each parameter is changed.

4.4.3. After selecting the desired files, click **OPEN** to display the files in playback mode. Refer to Section 4.6 below for a detailed explanation of the graphs in each tab.

4.5. Graph Tabs

Plots are displayed as tabs along the top of the graph area. The order of the tabs can be changed by clicking and dragging a tab to a new spot. Tabs can be closed by clicking the **X** in the appropriate tab. To reopen a closed tab, select it under the *Display* menu (Figure 6). Tabs that are already open, denoted by a check mark in the *Display* menu, can also be closed from this menu.

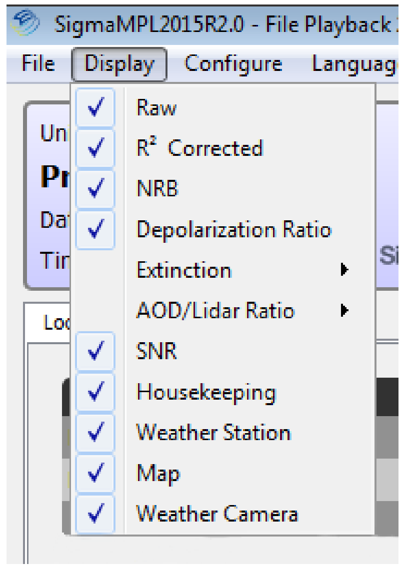


Figure 6: Accessing Graph Tabs

When switching between *Real Time Hardware Control* and *File Playback Mode* the default tabs (Hardware, Raw Data, R^2 Corrected, SNR and Housekeeping) are loaded. The other tabs can be displayed by toggling them on in the *Display* menu. Refer to Section 4.6 below for a detailed explanation of the graphs in each tab.

4.6. Plot Types

Table 3: Description of Plot Types

Tab	**Description**
Raw	Raw detector counts with no additional processing
R^2 Corrected	Range corrected signal with background subtracted. Defined as: $$R^2\ Corrected\ Signal = (Raw - Background)\ x\ Range^2$$
NRB	Normalized Relative Backscatter. Defined as: $$NRB = \frac{[(Raw\ x\ Dead\ Time\ Correction) - Afterpulse - Background]}{[Overlap\ x\ Laser\ Energy]}$$
Depolarization Ratio	$$Depolarization\ Ratio = \frac{\frac{NRB_{cross}}{NRB_{co}}}{\frac{NRB_{cross}}{NRB_{co}} + 1}$$
Extinction	Vertical Backscatter: Displays a profile of the layered Backscattering Coefficient. Extinction Coefficient: Displays a profile of the layered Extinction Coefficient. Mass Concentration: Displays a profile of the layered Mass Concentration.
AOD/LiDAR Ratio	The Aerosol Optical Density (AOD)/LiDAR Ratio is displayed and calculated in different ways, depending on how the user configures the detection algorithms. The three algorithms (AOD Enclosure, Fernald, Fernald and Slope) can be configured by navigating to **Configuration→Algorithm Setup→LiDAR Equation.**
SNR	Signal to noise ratio
Housekeeping	Displays LiDAR temperature, laser energy, background, and sync pulses (MiniMPL only)
Weather Station	Displays weather station data (if applicable)
Map	Displays GPS and scanner data (if applicable)
Weather Camera	Displays weather camera images (if applicable)

4.7. Graph Layout and Options

SigmaMPL displays the data in two different plot types; a vertical aerosol profile and a time series graph (Figure 7). The graphs are explained in Table 4.

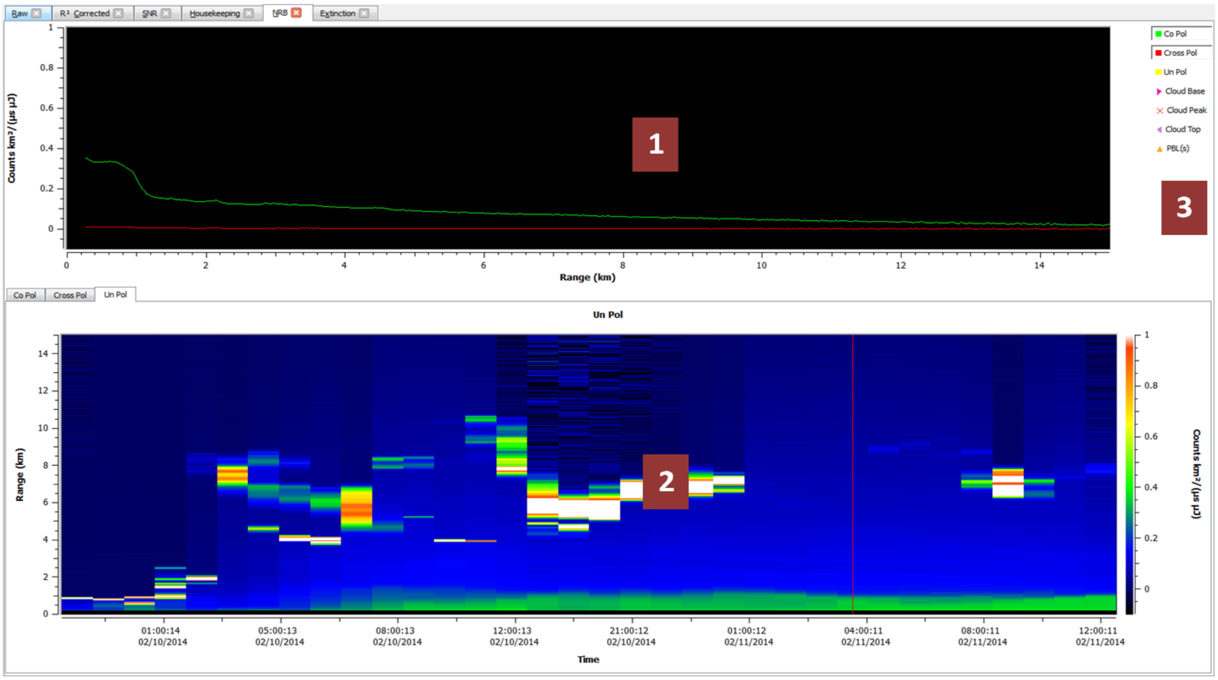


Figure 7: *SigmaMPL* Graph Layout

Table 4: Description of Graph Area Sections

Section	**Description**
1 Profile Graph	The Profile Graph shows the currently selected profile plotted as Range vs. Counts. The Profile Graph is a snapshot of the atmosphere displaying aerosol and cloud structure at one time value.
2 Time Series Graph	The Time Series Graph represents the data as a false color plot with Time along the x-axis, Range along the y-axis, and color denoting the signal level. The Time Series Graph displays both the real time atmospheric structure and the temporal and spatial trends in aerosol and cloud structure. A red line passes through the center of the currently selected profile.
3 Data Products/Graph Markers	The legend contains the available products that can be displayed in the Profile Graph as well as available graph markers for both the Profile and Time Series Graphs (only for NRB plot). These items can be toggled by clicking them on the legend.

4.7.1. The Profile and Time Series Graphs can both be zoomed by using the mouse. Clicking and dragging zooms in on the selected area. Plots can be continuously zoomed in this manner. To zoom out one step, click on the graph with the middle mouse button (scroll wheel). To zoom out all the way, double click on the graph with the left mouse button. Since all of the Time Series plots are synchronized, if a Time Series plot is zoomed all other time plots will automatically zoom in the other tabs. This is not the case for the Profile Graphs. All Profile Graphs zoom independently.

4.7.2. The color bar indicating the color-coordinated values is located at the right of each Time Series Graph. The color bar contains 23 hard-stop colors that span the selected scale. Values on the graph that exceed the scale's upper bound are set to white while values that are below the lower bound are set to black. The color bar scale for each time plot can be changed individually. To select a new scale right click on the plot and select *Set Color Range* to bring up the color bar menu (Figure 8). *Set Color Range* brings up the dialog box to change the upper and lower bounds of the color bar respectively. Currently, these colors and their order cannot be changed.

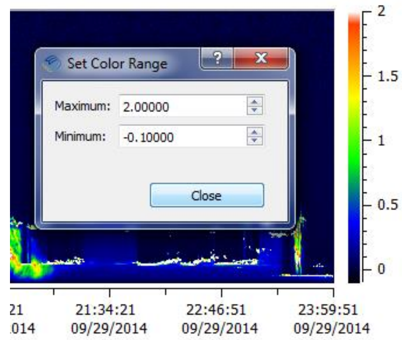


Figure 8: Changing the Color Range for Time Series Plots

4.7.3. The Profile Graph can be changed by right clicking on the plot and selecting *Graph Options* (Figure 9).

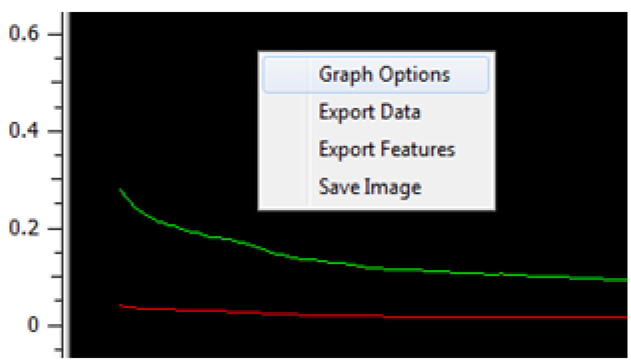


Figure 9: Selecting the Graph Options Menu

The *Graph Options* menu (Figure 10) changes the currently selected profile plot. The *X Axis* and *Y Axis* controls allow for real time updates on signal and range axes. Checking "Auto" will automatically adjust the X and Y-axis scales. The Y-axis has the option of "Linear" or "Logarithmic" scaling factor.

The *Plot Colors* section lets the user change the colors of the currently selected profile plot. The default colors are displayed in Figure 10.

The *Grids* section displays the Major and Minor Axis grid lines. The color and style of the gridlines can also be changed.

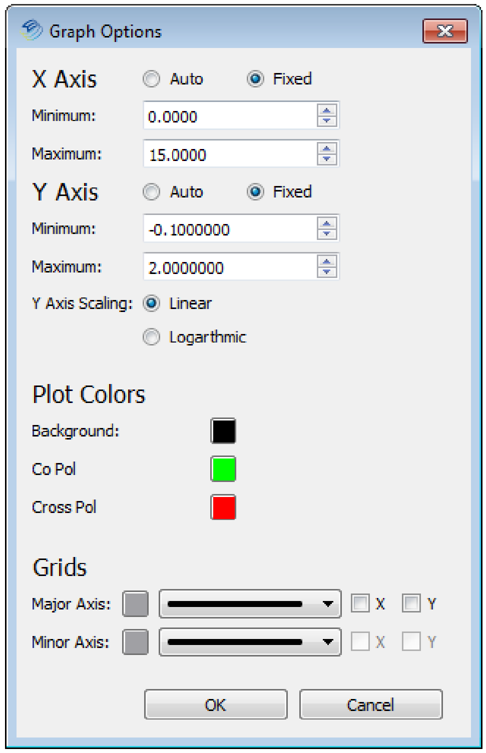


Figure 10: Graph Options Dialog Box

4.8. Saving Plot Images

Images of the Profile and Time Series graphs can be saved by right clicking on the plot image and selecting *Save Image* (Figure 11). The size and resolution of the saved image is user selectable.

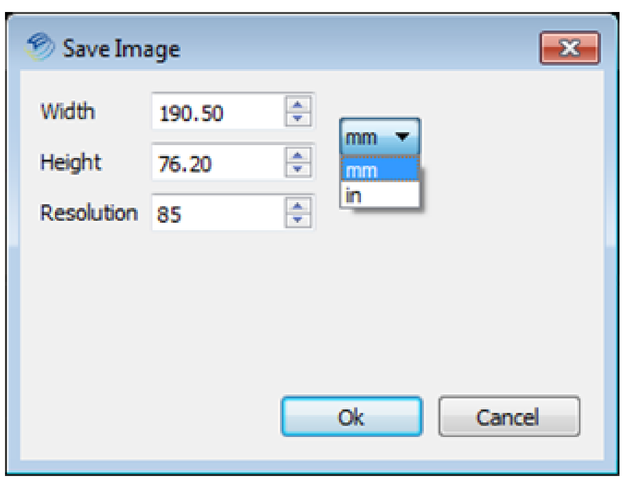


Figure 11: Save Plot Image Dialog Box

Although the image can be saved in several formats, the default file format is .pdf (Figure 12).

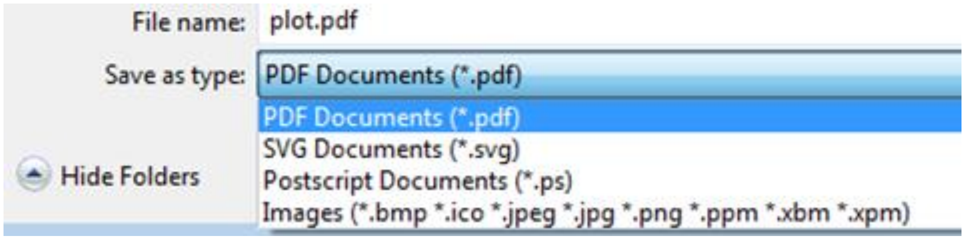


Figure 12: Available File Formats for Saving Plot Images

4.9. Exporting Data and Features

Data and atmospheric features from the profile plots can be exported in *File Playback Mode* by right clicking the plot image and selecting *Export Data* and *Export Features*. The *Export Data* and *Export NRB Features* dialog boxes are displayed in Figure 13 and Figure 14.

4.9.1. Select the start and end profiles to export.

4.9.2. Select "Include profile header" to add the date and time of each profile in the header of the exported data file.

4.9.3. Select *Co Pol* and/or *Cross Pol* to export one or both channels.

4.9.4. Select **OK** to export to a .CSV (comma-separated variable) format file. This format is recognized by a large variety of programs for import and is the only data export format currently supported in *SigmaMPL*.

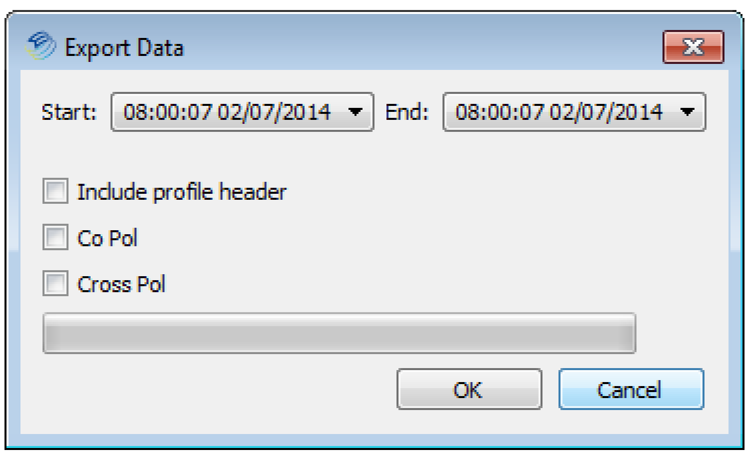


Figure 13: Exporting Data Dialog Box

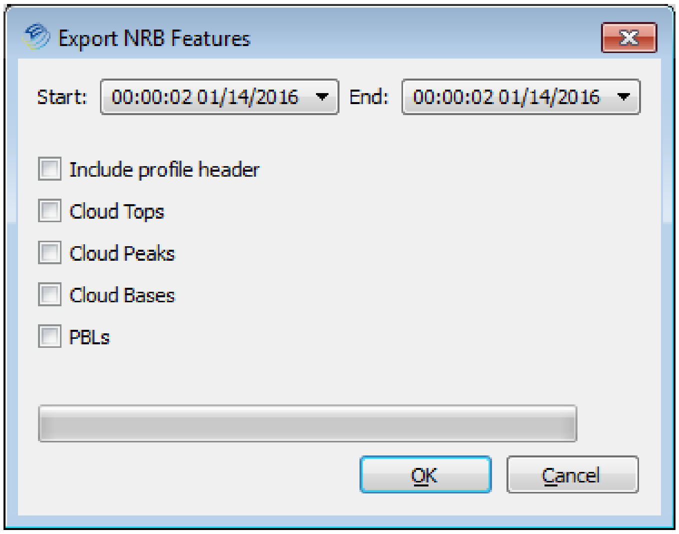


Figure 14: Exporting NRB Features Dialog Box

4.10. Creating and Transmitting NetCDF Files

SigmaMPL software comes with the capability to send .mpl files, NetCDF files, and NRB images to multiple servers.

4.10.1. Setting up a Network Server

Select **Configure→Real Time Setup→Network** and then select "Add Server" to begin setting up a server. *SigmaMPL* software currently supports up to three different network servers (Figure 15). Fill in all fields under Network Server Settings (Figure 16) and select the desired data products. All file names use the following format: MPL_UnitNumber_YYYYMMDDHHmm.nc.

NOTE: Destination folders will not be created through the *SigmaMPL* software.

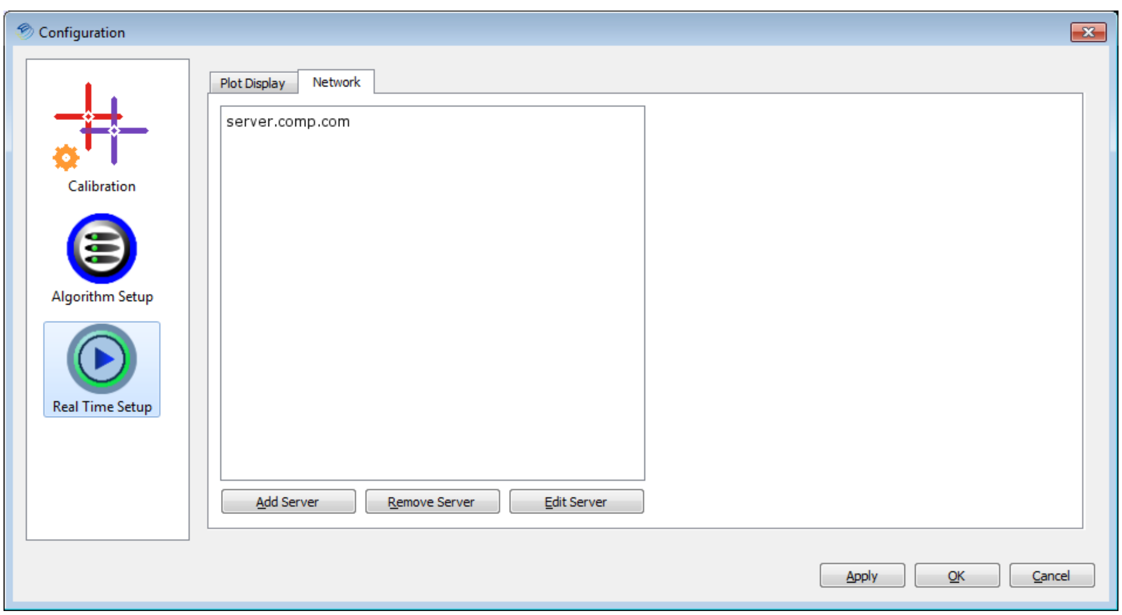


Figure 15: Real Time Hardware Control Setup Network Multiple Servers

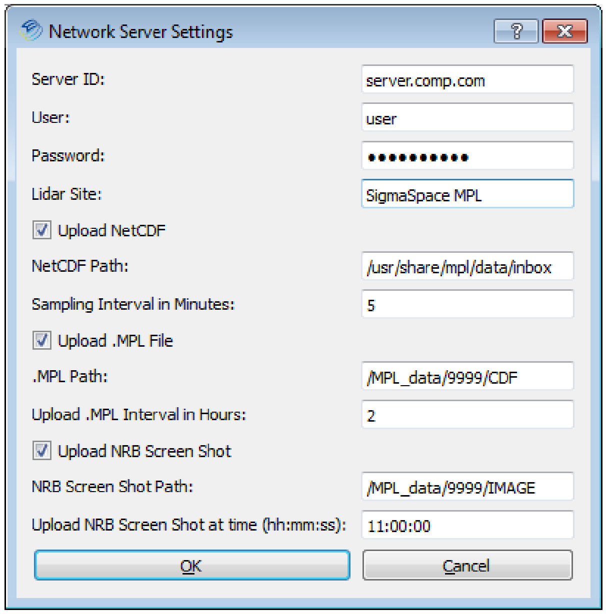


Figure 16: FTP Servers

4.10.2. Creating NetCDF Files in Post Mode

Creating NetCDF files in Post Mode enables the user to convert existing LiDAR data to the *SigmaMPL* NetCDF file format.

Select **File → Create NetCDF Files in Post Mode**, to open the "Create NetCDF Files" dialog box which allows the user to select profiles and save the NetCDF files to a user specified folder (Figure 17).

See Appendix for NetCDF Data File Format.

NOTE: *Create NetCDF Files in Post Mode* requires the desired LiDAR data to be opened in *SigmaMPL* software with all NRB related data available.

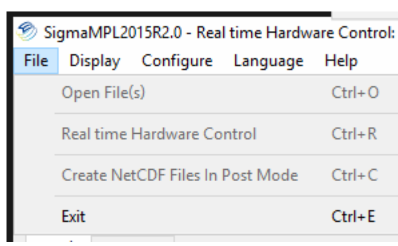


Figure 17: Menu of Create NetCDF Files in Post Mode

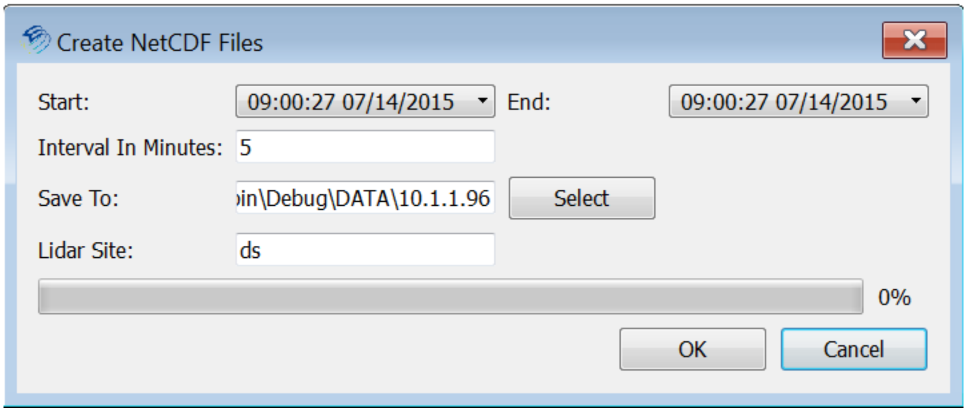


Figure 18: Creating NetCDF Files In Post Mode Configuration

4.11. Configuration Options

SigmaMPL can be customized for better detection and/or characterization of the user's local atmosphere. The user configurable parameters can be accessed by clicking on the *Configure* menu and selecting *Algorithm Setup*. The *Algorithm Setup* menu is displayed in Figure 19 below. Each user configurable setting is explained in Table 5**.**

A preferred setting can be saved or loaded with the **Save Settings** and **Load Settings** buttons. The **Default MPL Parameters** and **Default MiniMPL Parameters** buttons load preset values for the items listed in Table 5. The default settings have been tested over a wide range of data sets taken in different weather conditions. Use these default values if you are unsure of which settings to use. Upon installation, the default MPL parameters are loaded. If using a MiniMPL, make sure to select **Default MiniMPL Parameters** before collecting data.

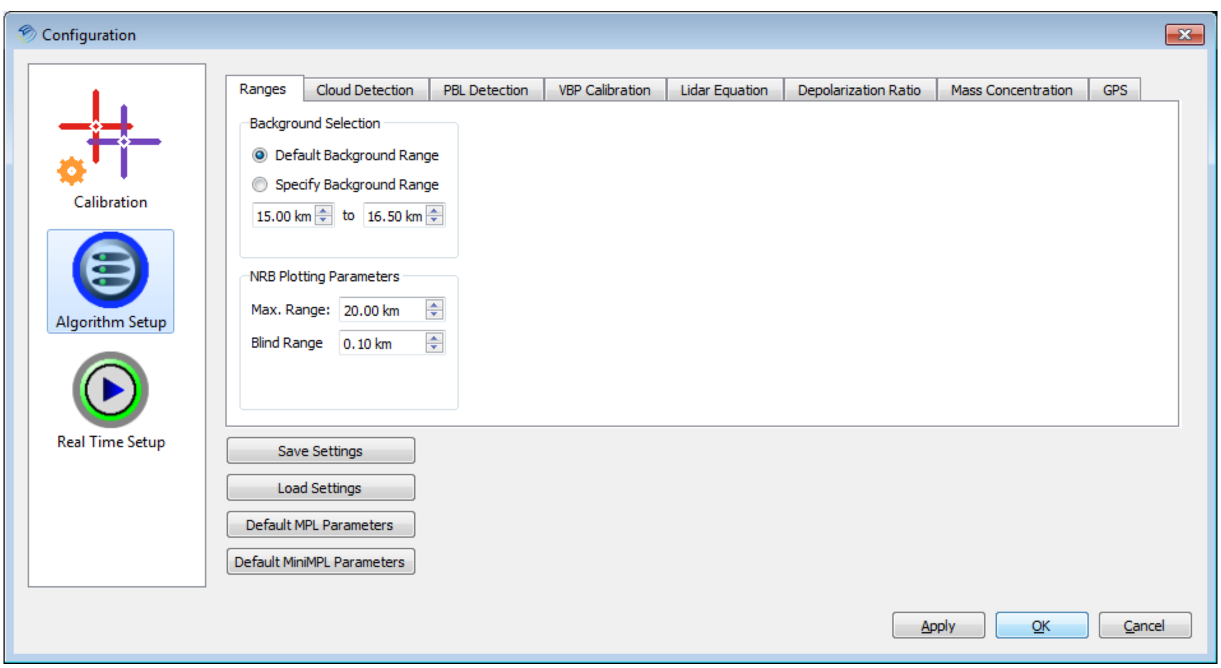


Figure 19: Algorithm Setup Menu

Table 5: Configuration Setup Options

Algorithm Tab	**Item**	**Notes**
Ranges	*Default Background Range*	Uses default data values to estimate background noise,
	Specify Background Range	Select a portion of the data range to estimate background noise.
	Max. Range	Maximum range for calculating NRB to eliminate noisy signal from atmospheric detection.
	Blind Range	Starting range to eliminate laser pulse in the signal.
Cloud Detection	*Max. Cloud Height*	The maximum range that the atmospheric feature detection algorithms will detect clouds.
	Min. Cloud Peak Spacing	Minimum distance between detectable cloud peaks.
	Far Noise Scale	Cloud detection scale for a range of 6km and above. Increase this scale to reduce false alarm rate. Decrease to detect small clouds.
	Near Noise Scale	Cloud detection scale for a range of 6 km and below. Increase this scale to reduce false alarm rate. Decrease to detect small clouds.
	Attenuation Coefficient	We use an exponential curve as the near field noise floor. A large attenuation coefficient will reduce noise floor at approximately a 6 km range.
	Min. Cloud Thickness	Minimum thickness of a detectable cloud.
	Merge Overlapping Clouds	If clouds overlap or touch, merge them into a single cloud.
	SNR Cloud Top Threshold	Cloud tops with an SNR greater than this threshold are considered real. Without this threshold, false cloud top detection is possible due to the laser not being able to penetrate the clouds.

Algorithm Tab	Item	Notes
PBL Detection	*PBL Height Limit*	Maximum range of PBL detection.
	Max. PBL Thickness	Maximum detectable thickness of a PBL.
	Multiple PBLs	Detect multiple PBLs if applicable.
	Multilayer Limit	Ratio between the secondary peak in wavelet transform coefficients and the main peak required for detection.
VBP Calibration	*Boundary Location: Detected Top Aerosol Layer*	Use the detected top of the aerosol layer as the boundary location. The boundary location specifies where the boundary value is taken to solve the LiDAR equation.
	Boundary Location: Fixed height	Uses user specified height as the boundary location (recommended). The boundary location specifies where the boundary value is taken to solve the LiDAR equation.
	Boundary Value: Fixed Point	Uses the NRB at a fixed range as the boundary value.
	Boundary Value: Section Average	Uses the NRB averaged from a section that is centered at the boundary location with a user specified width.
	Horizontal VBP	Set horizontal boundary values: α, start point (km), end point (km).
LiDAR Equation	*AOD Enclosure*	The AOD Enclosure uses AERONET AODs as boundary condition to solve LiDAR equation.
	Fernald Algorithm	The Fernald Algorithm uses a known LiDAR ratio as the boundary condition to the solve LiDAR equation.
	Fernald and Slope Algorithm	The Fernald and Slope Algorithm is similar to Fernald Algorithm but covers all slope angles.
Depolarization Ratio	*Depolarization Noise Ratio*	When the Co pol and Cross pol data is below the product of the *Depolarization Noise Ratio* and noise standard deviation, it is considered noise and the depolarization ratio will be forced to a negligible value. This is to improve the signal to noise ratio of the depolarization ratio for high altitude features such as cirrus clouds.

Algorithm Tab	**Item**	**Notes**
Mass Concentration	*Location*	Mass concentration is calculated from values identified in "Remote Sensing of Particulate; Pollution from Space: Have We Reached the Promised Land?" by Raymond M. Hoff and Sundar A. Christopher. (2009) Locations can be modified by the user in MC.txt file
	Constant A *Constant B*	*Mass Concentration = A x (Extinction Ratio) + B*
GPS	*GPS Time* *GPS Altitude*	Use GPS time or Computer system time GPS Altitude in AGL or ASL (if applicable)

4.12. NRB Plot and Atmospheric Feature Detection

Normalized Relative Backscatter (NRB) is a data product derived from the raw signal after applying instrument specific calibrations. The NRB data is an instrument independent measure of the atmosphere. The NRB data is utilized in various atmospheric feature detection algorithms. Currently the only atmospheric features available for detection in *SigmaMPL* are Cloud Base(s), Cloud Peak(s), Cloud Top(s) and PBL(s).

Refer to Sections 4.3 above 4.5 above for details on how to enable the NRB tab if it is not already displayed. During *Real Time Hardware Control*, NRB and the subsequent atmospheric features detection are implemented. During *File Playback mode*, NRB must be selected from the *Display* menu in order to display it and initiate atmospheric feature detection. The Vertical Backscatter and Extinction Ratio tabs rely on calculation of NRB and do not become available for viewing until NRB is selected.

Detection of cloud base(s), cloud peak(s), cloud top(s), and PBL occurs the first time NRB is calculated and displayed.

Atmospheric features are only available on the NRB graphs (Figure 20). These markers can be turned on and off by toggling the corresponding marker located in the legend to the right of the profile graph. The details of each feature are displayed when the cursor is in close to proximity to the feature marker. Currently, the color and shape of the atmospheric features icons cannot be changed.

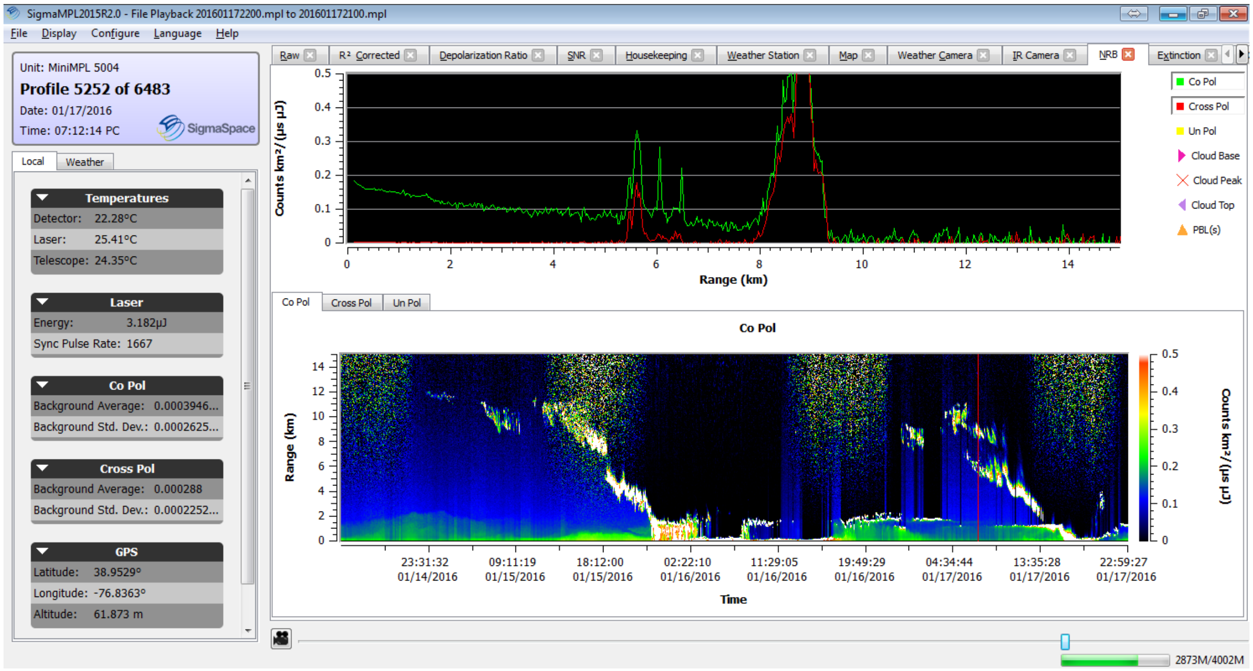


Figure 20: NRB Plots with Atmospheric Feature Markers

4.13. NRB Calibration

Three calibration files are needed to calculate NRB: Afterpulse, Overlap, and Dead Time Correction.

These files are set in Calibration under the Configure menu as shown in Figure 21. Click **Apply** followed by **OK** to load the calibration files.

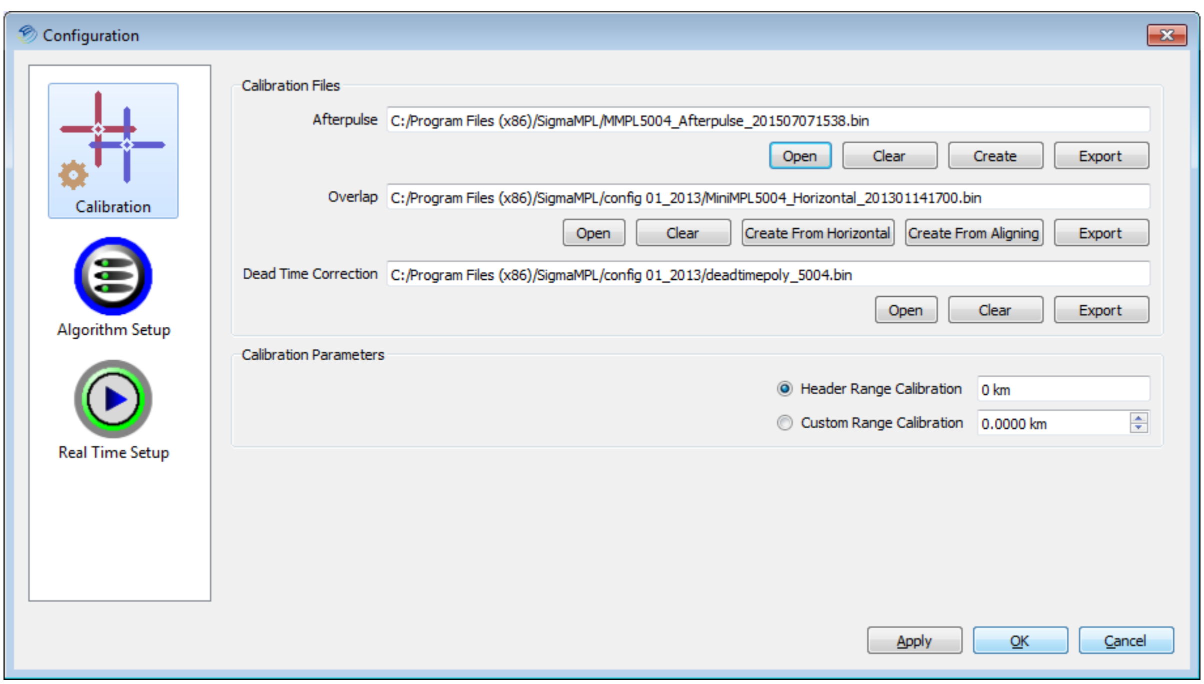


Figure 21: NRB Calibration Setup Menu

4.13.1. **Creating the Afterpulse Calibration File**

Afterpulse occurs when internally scattered laser light saturates the detector at the beginning of each sampling period, creating a blind zone in the near field. The afterpulse signal decays exponentially to a residual value until the end of the current sampling period. To measure the afterpulse profile of the LiDAR, please follow the guidelines below:

- Close the lid of the LiDAR telescope.
- Set the appropriate bin resolution and average time that would be used in normal operation. The default afterpulse file supplied by Sigma Space uses a 30 meter bin resolution with 30 sec averages. The bin resolution must be the same resolution that the LiDAR uses when collecting atmospheric data.
- Select *Save Data*, then *Start Collecting*.
- Take data for 10 minutes.

After the afterpulse (.mpl) file has been saved, it must be converted to a calibration file (.bin) using the following guidelines:

- Open the Calibration menu (**Configuration→Calibration**) and select **Create** under the *Afterpulse* section*.*

- In the "Afterpulse File Creator," select **Open**, navigate to the saved afterpulse .mpl file and select **Open** again. The afterpulse file is now loaded into the "Afterpulse File Creator". The calibrated afterpulse signal is averaged across all profiles in the file and displayed in the graph.

- Select **Save** to save the afterpulse calibration file in the desired folder. The afterpulse .mpl file will now be converted to a .bin file. While the user has the option to change the name of the afterpulse file, Sigma Space recommends saving the file with the LiDAR type and serial number followed by the date/time the file was taken. For example: MMPL5017_Afterpulse_201404220400 or MPL4230_Afterpulse_201404220400. Click **Save** again when ready to create the calibration file.

- The user will be prompted to "Replace existing afterpulse file with newly created file?" Select **Yes** to replace the file or **No** to continue using the currently set file.

- To open a previously saved afterpulse calibration file, select **Open** under *Afterpulse* in the Calibration dialog.

- The afterpulse calibration file can be exported as a .csv file by selecting **Export**.

4.13.2. **Creating the Overlap Calibration File**

The overlap function used in *SigmaMPL* is different from the conventional definition. The LiDAR overlap range is the distance when the receiver field of view is inside the transmitter field of view. This allows all of the backscattered signal to reach the detector. The near field signal (signal inside of the overlap region) is over-attenuated by the R^2 correction as described in the LiDAR equation. The overlap configuration file corrects for the over attenuated near field signal in NRB.

SigmaMPL allows the user to create an overlap calibration file using a horizontal line of sight. To collect data for the calibration file use the following guidelines:

- Orient the LiDAR such that the telescope is parallel with the horizon. Keep the line of sight clear by avoiding any buildings, trees or solid structures. Avoid any predictable plumes or exhaust.
- Set the desired bin resolution and averaging time that would be used in normal operation.
- Collect and save data at a time when the aerosols are well mixed, such as late in the afternoon.

After an overlap (.mpl) file has been saved, it must be converted to a calibration (.bin) file using the following guidelines:

- Open the calibration menu (**Configuration→Calibration**) and select **Create From Horizontal** under the *Overlap* section. An afterpulse calibration file is required to create the overlap calibration file.
- In the "Overlap File Creator" (Figure 22), open the .mpl file with the horizontal data. The natural log of the range-corrected signal is averaged across all profiles. The resulting averaged signal is displayed in the top graph (blue points).

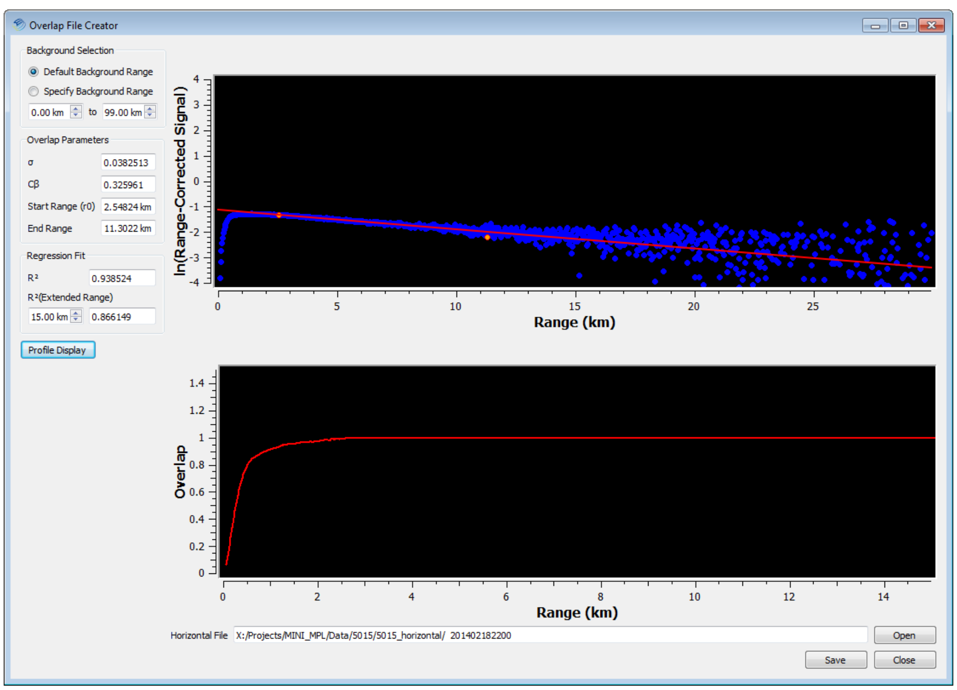


Figure 22: Overlap File Creator Window

- To zoom in on the range-corrected graph click and drag a selection with the left mouse button. To zoom out one step click the middle mouse button. To zoom out completely double-click the left mouse button.
- The overlap function (Figure 22) is dependent upon the linear region selected in the range-corrected signal. The region is selected by clicking and dragging the orange end

points to designate the linear region. The parameters and overlap function update after every endpoint change. An R^2 (coefficient of determination) regression fit is also calculated for the linear region bounded by the selected endpoints.

- Abnormal profiles caused by fluctuating temperatures can skew the averaged signal. Select **Profile Display** to observe individual profiles and temperatures (Figure 23). Profiles can be added and removed from the averaged signal by clicking on the purple triangles in the *Horizontal Profiles* section. The range-corrected and overlap signals update after every change. This graph can be zoomed in the same way as the range-corrected signal graph.

- Select **Save** to save the overlap calibration file in the desired folder. The overlap .mpl file will now be converted to a .bin file. While the user has the option to change the name of the overlap file, Sigma Space recommends saving the file with the LiDAR type and serial number followed by the date/time the file was taken. For example: MMPL5017_Overlap_201404220400 or MPL4230_Overlap_201404220400. Click **Save** again when ready to create the calibration file.

- The user will be prompted to "Replace existing overlap file with newly created file?" Select **Yes** to replace the file or **No** to continue using the currently set file.

- To open a previously saved overlap calibration file, select **Open** under *Overlap* in the Calibration dialog.

- The overlap calibration file can be exported as a .csv file by selecting **Export**.

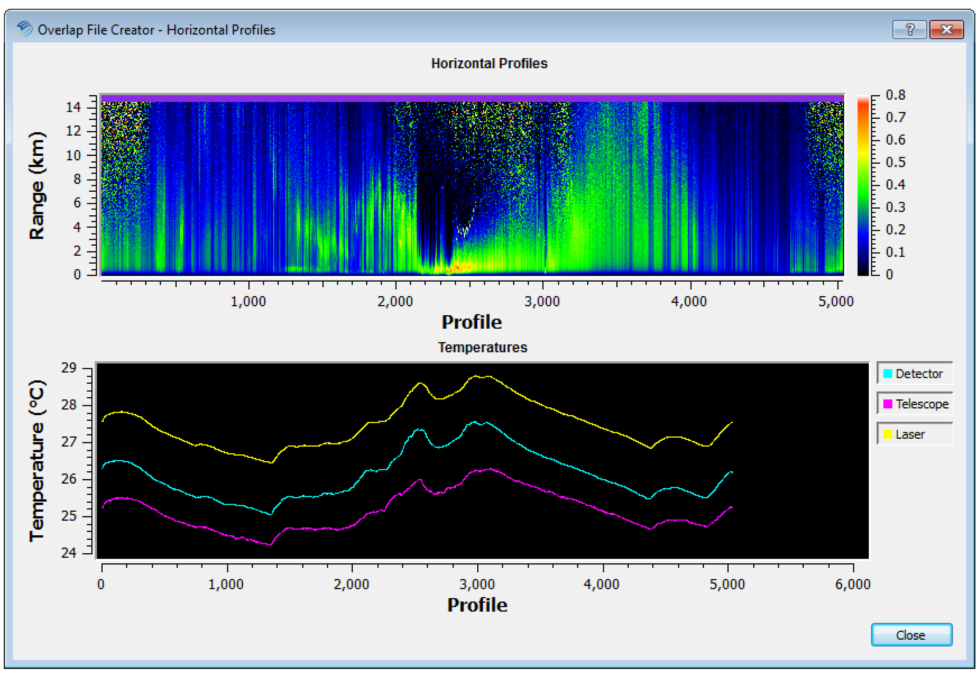


Figure 23: Horizontal Profile Selector Window for Overlap File Creator

4.13.3. Creating the Dead Time Correction Calibration File

Dead Time Correction accounts for the saturation effect of the detector when high count rates occur. When the detector is saturated, the count rate displayed is lower than the actual count rate, resulting in a non-linear relationship between the two rates. A lookup table is created to correct for the detector's non-linear behavior and is supplied with the LiDAR. Since Dead Time Correction is detector dependent, it is unique for each LiDAR. The included Dead Time Correction calibration file should remain set for the lifespan of the detector.

To set the Dead Time Correction file: Open the calibration menu (**Configuration→Calibration**) and select **Open** under the *Dead Time Correction* section.

The equation used to calculate Dead Time Correction can by exported to a text file by selecting **Export**.

4.14. Depolarization Ratio Plot

4.14.1. Depolarization Ratio

The MPL/MiniMPL instruments measure the intensity ratio between the perpendicular component and the parallel component (against the polarization plane) of the outgoing polarized beam. The parallel component is measured with a linearly polarized beam while the perpendicular component is measured with a circular polarized beam. The linear depolarization ratio is calculated as $\frac{NRB_{cross}}{NRB_{co}} / \left(\frac{NRB_{cross}}{NRB_{co}} + 1\right)$ where NRB_{cross} is the perpendicular measurement and NRB_{co} is the parallel measurement.

4.14.2. Particle Type

SigmaMPL software can classify particle types based on predefined measurements of particle range, depolarization ratio, cloud type, and LiDAR ratio. These values are configurable and can be adjusted in the PC.txt file.

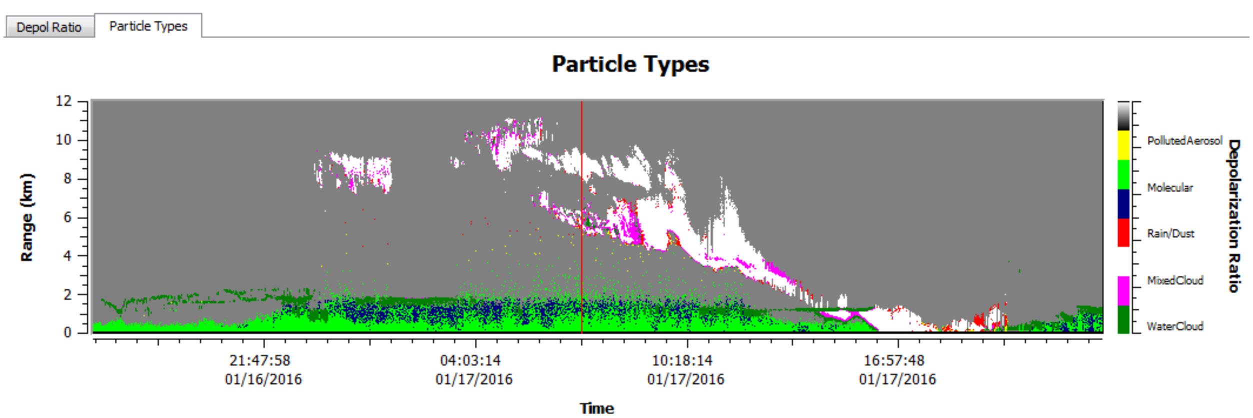


Figure 24: Particle Types

4.15. Vertical Backscatter Plot

The Backscattering Profile can be calculated either recursively or from an initial value. These options are set in the *Configuration* dialog under **Configuration→Algorithm Setup→LiDAR Equation**. In non-recursive mode, the **LiDAR Ratio** is configurable. In recursive mode, the **Aerosol Optical Density** is configurable. Once the Backscattering Profile has been calculated once, changing either the recursive mode or the corresponding parameters will update the graphs immediately without having to select the **OK** button first.

4.16. Extinction Coefficient Plot

The Extinction Coefficient Plot is derived from the backscattering profile by dividing by the LiDAR ratio. *SigmaMPL* assumes that the LiDAR ratio is a constant in the atmosphere.

4.17. Mass Concentration Plot

The Mass Concentration profile is derived from the extinction ratio: Mass Concentration = Constant A * (Extinction Ratio) + Constant B. Constants A and B are configurable.

4.18. AOD Enclosure Algorithm

SigmaMPL requests AOD data from AERONET either directly or a through proxy server (Figure 25). For additional information about AERONET data, please see their website at: http://aeronet.gsfc.nasa.gov/new_web/index.html

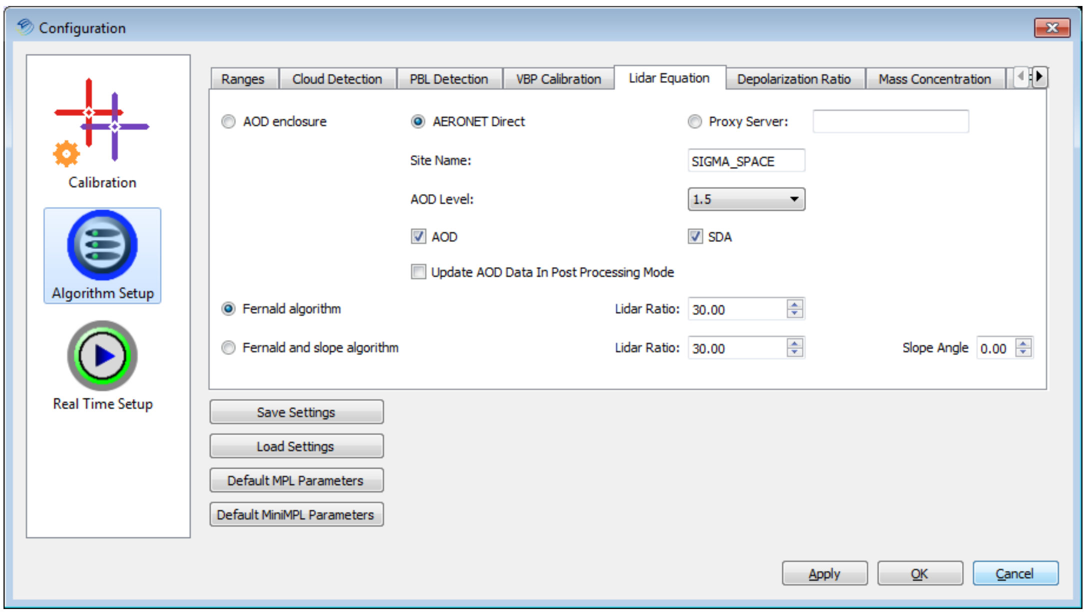


Figure 25: AOD Enclosure Configuration

4.18.1. AERONET Direct

SigmaMPL software requests AOD data from AERONET every 5 minutes. If no data is available at that time, *SigmaMPL* uses the most recent value from the last 7 days. If no AOD data is available from the past 7 days, *SigmaMPL* automatically switches to the Fernald Algorithm. Once AERONET data is available, *SigmaMPL* will switch back to using AOD Enclosure. AOD delayed time will be displayed on the top of AOD/LiDAR Ratio plot.

4.18.2. Proxy Server

SigmaMPL software can also request AOD data from AERONET through a proxy server.

4.18.3. AOD Data In Post Processing Mode

When *Update AOD Data In Post Processing Mode* is selected, *SigmaMPL* will request AOD data from AERONET before calculating VBP. *SigmaMPL* will use locally saved AERONET data if new data is unavailable. If no locally saved AERONET data exists and new data is unavailable, the user cannot select the AOD enclosure algorithm when calculating the LiDAR equation.

5. SigmaMPL Configuration Files

SigmaMPL has a number of options for instrument control that can be set through configuration files. The LiDAR data acquisition parameters are set in the *mpl.ini* file. The software can also be configured to run automatically upon power up.

5.1. MPL.INI File

SigmaMPL has many parameters to determine LiDAR and software settings. These parameters are loaded from a file called *mpl.ini*. Any changes to this .ini file must be made before the software is opened. The *mpl.ini* file resides in the same directory as SigmaMPL.exe (**C:/Program Files (x86)/SigmaMPL**). The .ini file must be labeled as *mpl.ini* in order for *SigmaMPL* to read it.

The *mpl.ini* file contains section headers, keys, and values as shown below.

```
[section1]
; Comment lines starts with a semicolon
key1=value1
key2=value2
```

Table 6 lists the possible fields found in the *mpl.ini* file. The default value is the value that is assumed if that key was not in the file. Some fields are specific for MPL or MiniMPL.

Table 6: *mpl.ini* File Parameter Options

Section	Key	Default Value	Notes
[MAIN]	Unit	0000	LiDAR serial number. All templates use 0000
	AccumDelayAdd	400	For MPL only. This value is the time delay (in nanoseconds) between laser trigger and laser optical pulse
	AveragingTimeInSeconds	1	Last used number of seconds per accumulation in setup display. This value is overwritten by SigmaMPL software each time it starts a new data acquisition.
	CardType	2 (MPL) 3 (MiniMPL)	0: MPL Normal (IDS) 1: 24-bit MiniMPL 2: MPL Normal (IDS) with 5-meter resolution

Section	Key	Default Value	Notes
			3: 16-bit MiniMPL with 5-meter resolution
	5Meter	0	0: Disable 5-meter mode 1: Allow 5-meter mode in setup dialogs. Additional timing settings are required
	McsMode	1	0: No polarization 1: Polarization
	Scanner	0	0: Disable Scanner display in SigmaMPL software 1: Enable scanner display in SigmaMPL software
	MCSCardType	1	0: MCS Card Version 1 1: MCS Card Version 2
	Polarizationshotcount	250	Polarization switches every 1, 50, 125, or 250 laser shots
[POLAR]			MPL only IDS timing parameters for polarization systems. The default parameters allow for 27 km (180 μs) data range.
	CollectionDuration	399	The time (in microseconds) that the MPL collects data.
	PreTriggerDuration	180	The time interval (in microseconds) before the trigger pulse is reserved for background noise.
	BackgroundStart	160	The time (in microseconds) when background collection starts. Offset from start of collection. NOTE: 5-meter cards ignore this and start at 0.
	BackgroundDuration	19	The time (in microseconds) that the system spends collecting background measurements.

Section	Key	Default Value	Notes
[MINIMPL]			MiniMPL only timing parameters (5-meter and non-5-meter) for polarization systems. The default timing allows for 30 km data range with background being collected from 27-29.8 km.
	CollectionDuration	200	The time (in microseconds) that the MiniMPL collects data for during each laser pulse.
	DataDuration	200	The time (in microseconds) that the MiniMPL collects atmospheric data.
	BackgroundStart	180	The time (in microseconds) when the MiniMPL starts collecting background information.
	BackgroundDuration	19	The time duration (in microseconds) of the background collection.
	PolarSwitchTime	201	The time (in microseconds) during the collection period that the polarization state switches.
	LaserTriggerRate	2500	The rate that the AMCS card generates triggers for the laser. Available options are 5000Hz, 4000Hz, 3000Hz, or 2500Hz. If another trigger rate is selected, the energy readings will not be reported correctly.
[AMCS]	PulsePolarity	167	Base of MCS register value. Modified by selected laser rates, etc.
	NumberChannelsUsed	1	Change number of channels to collect. Value is equal to "# channels – 1". Default = 1

Section	Key	Default Value	Notes
			(2 channels).
	AccumulationDelay	1	AMCS register value. Determines the time after the sync that binning starts. Non-Polarization mode only.
	PulseADelay	3	Pulse A delay register value for non-polarization modes. Controls A/D signal conversion to read energy monitor.
	PulseBDelay	4095	Pulse B delay register value. Controls the energy monitor reset for non-polarization modes.
	Polar_PulseADelay	3 (MPL) 1000 (MiniMPL)	Pulse A delay register value for polarization modes. Controls A/D signal conversion to read energy monitor.
	Polar_PulseBDelay	4095 (MPL) 2367 (MiniMPL)	Pulse B delay register value. Controls the energy monitor reset for non-polarization modes.
	TriggerWidth	Laser Dependent (MiniMPL)	It sets the trigger pulse width for the MiniMPL laser. The set value is between 1 and 63. With a 6.25us step for CardType= 3. The actual pulse width is between 6.25us and 393.75us. For example, TriggerWidth= 20 ==> Actual Pulsewidth = 20*6.25=125us. Previous version of software or CardType = 1 use 3.8us or 2.25us step.

Section	Key	Default Value	Notes
[LASER]	PORT	NONE	Serial port number for communication to the laser. Requires RS232 cable. MPL only.
	CURRENT	1.2	The current that the laser is set to on power up. For MPL only.
	CONTROL	0	0: Disable laser control from software 1: Enable laser control from software
[STORAGE]	DIR1	NONE	String where the data files are stored. Must end with a "\". Example: C:\Program Files (x86)\SigmaMPL\DATA\
	RECORDS_PER_FILE	20	0: Tells the software to generate a new file each hour ELSE: The number of records each file contains
[DISPLAY]	EM_POLY_1 EM_POLY_0	1.0 0.0	Polynomial values used to convert the energy monitor counts into actual energy. The formula is: Laser Energy = EM_POLY_1 x (Reading) + EM_POLY_0 These values are unique for each instrument. They are already set for the LiDAR. Do not change these values unless directed to by Sigma Space personnel.
	TEMP_POLY_0 TEMP_POLY_1	-273.0 0.1220703125	Polynomial values used to convert the raw temperature sensor readings into actual temperature. Do not change these values.
[LAST RUN]			This section saves the last

Section	Key	Default Value	Notes
			user selections made when an attempt to start data collection was made. When the SigmaMPL software is restarted, these parameters will be applied as the default setting.
	BinResolutionMode	0	0: 5 m 1: 15 m 2: 30 m 3: 75 m
	UseScanFile	0	0: No scan patter file 1: Use a preset scan pattern file to scan. Only set to "1" if a scanner has been purchased.
	McsMode	1	0: Non-Polarization system 1: Polarization system
[SCANNER]	CONTROL	0	0: Don't control scanner 1: Control scanner
	TYPE	1	Scanner.dll version
	PORT	NONE	Serial port number for communication to the scanner.
	PATTERNFILE	NONE	Location of the scanning pattern file.
[TOOLBOX]			Sensor suite setup parameters
	PTZ_CAMERA	0	0: Do not enable weather camera display and control. 1: Enable weather camera display and control.
	WEATHER_STATION	NONE	Input the weather station ID number in the format of and IP address: 00:00:00:00:00:00. Comment this line with a ";"

Section	Key	Default Value	Notes
			if there is no weather station.
	GIS	0	0: Disable map display 1: Enable map display
	GPS	0	0: Disable GPS coordinate display 1: Enable GPS coordinate display
[NETCDF]	netCDFFTP	0	0: Disable NetCDF feature 1: Enable NetCDF feature
[AMCSTIMEOUT]	AutoRestart	0	0: Disable AutoRestart after timeouts 1: Enable AutoRestart after timeouts

5.2. MC.txt

The MC.txt file lists predefined mass concentration values as identified in "Remote Sensing of Particulate; Pollution from Space: Have We Reached the Promised Land?" by Raymond M. Hoff and Sundar A. Christopher (2009). Locations can be modified by the user in the MC.txt file found in the default *SigmaMPL* directory **C:\Program Files (x86)\SigmaMPL\MC.txt.**

5.3. Automatic Startup and Resume

The *SigmaMPL* software has the ability to run or resume LiDAR acquisition automatically when the computer is started or restarted because of a power outage. This feature is designed for unattended instruments that may experience power interruptions. **NOTE:** The automatic data acquisition feature was designed to work with desktop computers. Notebook computers may require a manual restart to resume data acquisition.

The following two steps are needed in order to enable the automatic startup feature.

- Right click on the *SigmaMPL* icon on the desktop and select **Properties**. Navigate to the *Shortcut* tab and add the word "auto" to the end of the file path displayed in the *Target* field. The full path should read **"C:\Program Files (x86)\SigmaMPL\SigmaMPL2015R2.0.exe" auto** (Figure 26). Select **Apply** followed by **OK** to save the changes and exit the properties dialog box.

- Copy the *SigmaMPL* icon from the desktop to the Startup folder. The Startup folder can be accessed by clicking on **Start→All Programs→Startup→Right Click→Open**.

In order for the automatic feature to work correctly:

- Verify that all of the LiDAR settings, such as bin resolution, integration time, etc. are set to the desired values.
- Make sure the [LASER] section parameters in the *mpl.ini* file are correct. When automatic startup is invoked, the software initializes the laser. This is for MPL only.
- Start the data collection. The LiDAR data system will save the desired settings to the *mpl.ini* file.

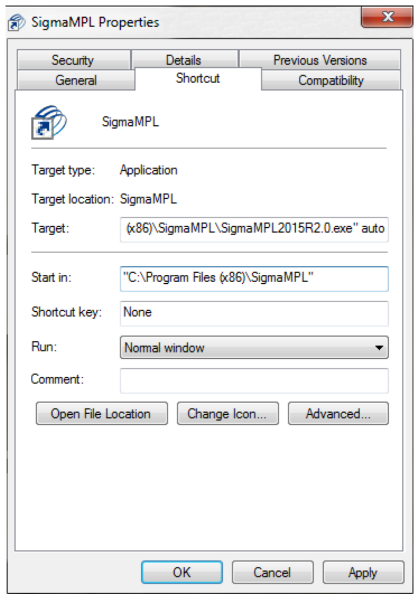


Figure 26: Automatic Startup Setup

6. SigmaMPL Data File Format

The LiDAR data files are created when data collection starts and a new file is created every hour after that. The files are named using the following format: YYYYMMDDHHmm.mpl

For example, if the file was called *201406241105.mpl*, then it was created on June 24, 2014 at 11:05 AM (computer time). If a new file is created in the same minute as an existing file then the new file will append '_01' or '_02' if '_01' already exists and so on.

Note that the MCS data is converted to a normalized value. The normalization will leave the value in counts/microseconds.

The format of each record in the data file is given in Table 7. All multi-byte numbers are little-endian (PC format).

Table 7: *SigmaMPL* Data File Format

Record Entry	**Format**	**Usage**
Unit Number	uint16	Unique number for each data system
Version	uint16	Software version of the EXE that created this file. If the SigmaMPL.exe version is 3.00 then this value would be 300.
Year	uint16	Record Collection Time
Month	uint16	

Record Entry	Format	Usage
Day	uint16	
Hours	uint16	
Minutes	uint16	
Seconds	uint16	
Shots Sum	uint32	Number of laser shots collected
Trigger Frequency	int32	Laser fire rate (usually 2500)
Energy Monitor	uint32	Mean of the Energy Monitor readings * 1,000
Temp #0	uint32	Mean of the A/D #0 readings * 100
Temp #1	uint32	Mean of the A/D #1 readings * 100
Temp #2	uint32	Mean of the A/D #2 readings * 100
Temp #3	uint32	Mean of the A/D #3 readings * 100
Temp #4	uint32	Mean of the A/D #4 readings * 100
Background Average	float32	Background Average for Channel #1
Background Std Dev	float32	Background Standard Deviation for channel #1
Number Channels	uint16	MCS Channels collected. Either 1 or 2
Number Bins	uint32	Number of bins recorded in the file per channel
Bin Time	float32	Bin width in seconds (100, 200, or 500 nanoseconds)
Range Calibration	float32	Default is 0; will indicate range calibration offset in meters measured for particular unit
Number Data Bins	uint16	Number of data bins (not background) following First Data Bin
Scan Scenario Flag	uint16	0: No scan scenario used 1: Scan scenario used
Number of Background Bins	uint16	Number of background bins following First Background Bin
Azimuth Angle	float32	Azimuth angle of scanner
Elevation Angle	float32	Elevation angle of scanner
Compass Degrees	float32	Compass degrees (currently unused)
Polarization Voltage #0	float32	Not used
Polarization Voltage #1	float32	Not used
GPS Latitude	float32	(Optional) Decimal degrees (-999.0 if GPS unit not used)
GPS Longitude	float32	(Optional) Decimal degrees (-999.0 if GPS unit not used)
GPS Altitude	float32	(Optional) in meters (-999.0 if GPS unit not used)
A/D Data Bad flag	Byte	0: A/D data good 1: A/D data probably out of sync. Energy monitor collection is not exactly aligned with MCS shots.
DataFileVersion	Byte	Version of the file format. This table describes format '1'.
Background Average 2	float32	Background Average for Channel #2
Background Std Dev 2	float32	Background Standard Deviation for Channel #2

Record Entry	Format	Usage
McsMode	Byte	MCS mode register Bit #7 (MSB): 0: No Polarization Switching but the signal is driven high (Debug Versions Only) 1: No Polarization Switching 2: Polarization Switching Bit #6-5: Polarization toggling (For software versions Pre 2015 Only): 00: Linear polarizer control 01: Toggling polarizer control 10: Toggling polarizer control 11: Circular polarizer control
First data bin	uint16	Bin # of the first return data
System Type	Byte	0: Normal MPL 1: MiniMPL
Sync Pulses Seen Per Second	uint16	MiniMPL Only; indicates average number of laser pulses seen to validate if laser is operating correctly
First Background Bin	uint16	Used primarily for MiniMPL (will always be 0 for normal MPL as background is collected pre-trigger)
Header Size	uint16	Total size of the header in bytes
Weather Station Used	byte	0: Weather station not used 1: Weather station used
Weather Station: Inside Temperature	float32	Temperature in degrees Celsius
Weather Station: Outside Temperature	float32	Temperature in degrees Celsius
Weather Station: Inside Humidity	float32	Humidity by percent (value of 32.1 means 32.1%)
Weather Station: Outside Humidity	float32	Humidity by percent (value of 32.1 means 32.1%)
Weather Station: Dew Point	float32	Dew point in degrees Celsius
Weather Station: Wind Speed	float32	Wind speed in kilometers per hour
Weather Station: Wind Direction	short int	Wind direction in degrees
Weather Station: Barometric Pressure	float32	Barometric pressure in hectopascal (hPa)
Weather Station: Rain Rate	float32	Rain rate in millimeters per hour
Channel #1 Data	float32 array	Data is converted from raw values to counts per microsecond. For MPL systems without POL-FS option, the return signal array is stored here. For MPL systems with the POL-FS option, the cross-polarized

Record Entry	Format	Usage
		return signal array is stored here. Number of bins of data is stored in header.
Channel #2 Data	float32 array	Used only with POL-FS option. Data is converted and stored like Channel #1 data. The co-polarized return signal array is stored here.

7. Customer Service

For any software related questions, comments, or suggestions please contact:

Sigma Space Corporation

4600 Forbes Blvd, Lanham, MD 20706, United States of America

Telephone: +1 301.552.6000

Fax: +1 301.552.6411

http://micropulseLiDAR.com

http://www.sigmaspace.com

8. Appendix: NetCDF Data File Format

```
Netcdf MPL_UnitNumber_YYYYMMDDHHmm {
dimensions:
        time = 1 ;
        range_raw = 1000 ;
        range_nrb = 664 ;
        range_vbp = 197 ;
        number_of_clouds = 10 ;
        number_of_cloud_outlines = 3 ;
        number_of_particle_type = 8 ;
variables:
        float range_raw(range_raw) ;
                string range_raw:description = "Range_From_Instrument" ;
                string range_raw:unit = "kilometers" ;
        float time(time) ;
                string time:description = "Fractional_Julian_Day" ;
                string time:unit = "percent_day_of_year" ;
        float copol_raw(time, range_raw) ;
                string copol_raw:description = "Copol_Raw" ;
                string copol_raw:unit = "(counts/us)" ;
        float crosspol_raw(time, range_raw) ;
                string crosspol_raw:description = "Crosspol_Raw" ;
                string crosspol_raw:unit = "(counts/us)" ;
        float weather_inside_temperature(time) ;
                string weather_inside_temperature:description = "weather_inside_temperature" ;
                string weather_inside_temperature:unit = "degree_C" ;
        float weather_outside_temperature(time) ;
                string weather_outside_temperature:description = "weather_outside_temperature" ;
                string weather_outside_temperature:unit = "degree_C" ;
        float weather_inside_humidity(time) ;
                string weather_inside_humidity:description = "weather_inside_humidity" ;
                string weather_inside_humidity:unit = "Humidity %" ;
        float weather_outside_humidity(time) ;
                string weather_outside_humidity:description = "weather_outside_humidity" ;
                string weather_outside_humidity:unit = "Humidity %" ;
        float weather_wind_speed(time) ;
                string weather_wind_speed:description = "weather_wind_speed" ;
                string weather_wind_speed:unit = "km/h" ;
        float weather_wind_direction(time) ;
                string weather_wind_direction:description = "weather_wind_direction" ;
                string weather_wind_direction:unit = "degree" ;
        float weather_barometric_pressure(time) ;
                string weather_barometric_pressure:description = "weather_barometric_pressure" ;
                string weather_barometric_pressure:unit = "hPa" ;
        float weather_dew_point(time) ;
                string weather_dew_point:description = "weather_dew_point" ;
                string weather_dew_point:unit = "degree_C" ;
        float weather_rain_rate(time) ;
```

```
		string weather_rain_rate:description = "weather_rain_rate" ;
		string weather_rain_rate:unit = "mm/h" ;
	float elevation_angle(time) ;
		string elevation_angle:description = "Transceiver_Elevation_Angle" ;
		string elevation_angle:unit = "degrees" ;
		string elevation_angle:valid_range = "0.f,90.f" ;
	float azimuth_angle(time) ;
		string azimuth_angle:description = "Transceiver_Azimuth_Angle" ;
		string azimuth_angle:unit = "degrees" ;
		string azimuth_angle:valid_range = "0.f,90.f" ;
	float copol_background(time) ;
		string copol_background:description = "Copol_Background_Count_Rates" ;
		string copol_background:unit = "photoelectrons/microsecond" ;
	float crosspol_background(time) ;
		string crosspol_background:description = "Crosspol_Background_Count_Rates" ;
		string crosspol_background:unit = "photoelectrons/microsecond" ;
	float telescope_temperature(time) ;
		string telescope_temperature:description = "MPL_Box_Temperature" ;
		string telescope_temperature:unit = "degrees_C" ;
	float detector_temperature(time) ;
		string detector_temperature:description = "MPL_Detector_Temperature" ;
		string detector_temperature:unit = "degrees_C" ;
	float laser_temperature(time) ;
		string laser_temperature:description = "MPL_Laser_Temperature" ;
		string laser_temperature:unit = "degrees_C" ;
	string date_yyyyMMdd(time) ;
		string date_yyyyMMdd:description = "Date_String_YYYYMMDD" ;
	string time_hhmmss(time) ;
		string time_hhmmss:description = "Time_String_HHMMSS" ;
	float year(time) ;
		string year:description = "Year" ;
	float month(time) ;
		string month:description = "Month" ;
	float day(time) ;
		string day:description = "Day" ;
	float hour(time) ;
		string hour:description = "Hour" ;
	float minute(time) ;
		string minute:description = "Minute" ;
	float second(time) ;
		string second:description = "Second" ;
	int aod_age_secs(time) ;
		string aod_age_secs:description = "aod_age_secs" ;
	float latitude(time) ;
		string latitude:description = "GPS_Latitude" ;
		string latitude:unit = "degrees" ;
		string latitude:valid_range = "-90.f,90.f" ;
	float longitude(time) ;
```

```
        string longitude:description = "GPS_Longitude" ;
        string longitude:unit = "degrees" ;
        string longitude:valid_range = "-180.f,180.f" ;
    float altitude(time) ;
        string altitude:description = "GPS_Altitude" ;
        string altitude:unit = "meters" ;
    float laser_energy(time) ;
        string laser_energy:description = "Energy_Monitor" ;
        string laser_energy:unit = "microjoules" ;
    uint syncpulse(time) ;
        string syncpulse:description = "Syncpulse" ;
        string syncpulse:unit = "number_of_laser_shots" ;
    float copol_snr(time, range_raw) ;
        string copol_snr:description = "copol_snr" ;
        string copol_snr:unit = "TODO" ;
    float crosspol_snr(time, range_raw) ;
        string crosspol_snr:description = "crosspol_snr" ;
        string crosspol_snr:unit = "TODO" ;
    float range_vbp(range_vbp) ;
        string range_vbp:description = "vbp_range" ;
    float range_nrb(range_nrb) ;
        string range_nrb:description = "range_nrb" ;
    uint number_of_clouds(number_of_clouds) ;
        string number_of_clouds:description = "number_of_clouds" ;
    float copol_nrb(time, range_nrb) ;
        string copol_nrb:description = "Normalized_Relative_Backscatter" ;
        string copol_nrb:unit = "(counts/(microsecond*microjoule))*kilometer^2" ;
    float crosspol_nrb(time, range_nrb) ;
        string crosspol_nrb:description = "Crosspol_Normalized_Relative_Backscatter" ;
        string crosspol_nrb:unit = "(counts/(microsecond*microjoule))*kilometer^2" ;
    float clouds(time, number_of_clouds, number_of_cloud_outlines) ;
        string clouds:description = "clouds" ;
    float pbls(time, number_of_clouds) ;
        string pbls:description = "pbls" ;
    float extinction_coefficient(time, range_vbp) ;
        string extinction_coefficient:description = "Extinction Coefficient" ;
        string extinction_coefficient:unit = "Extinction Coefficient" ;
    float mass_concentration(time, range_vbp) ;
        string mass_concentration:description = "Mass Concentration" ;
        string mass_concentration:unit = "Mass Concentration" ;
    float VBP(time, range_vbp) ;
        string VBP:description = "vertical_backscatter" ;
        string VBP:unit = "vertical_backscatter_coefficient" ;
    float depolarization_ratio(time, range_nrb) ;
        string depolarization_ratio:description = "depolarization_ratio" ;
        string depolarization_ratio:unit = "depolarization_ratio" ;
    uint particle_type(time, range_nrb) ;
        string particle_type:description = "depolarization_type" ;
```

```
    string particle_type_mapping(time, number_of_particle_type) ;
        string particle_type_mapping:description = "particle_type_mapping" ;
    double lidar_ratio(time) ;
        string lidar_ratio:description = "lidar_ratio" ;
        string lidar_ratio:unit = "lidar_ratio" ;
    double aod(time) ;
        string aod:description = "aods" ;
        string aod:unit = "TODO" ;

// global attributes:
        :device_serial_number = XXXXU ;
        string :card_type = "MiniMPL" ;
        string :range_bin_resolution = "30 meter" ;
        string :temporal_resolution = "5 minutes" ;

}
```