Lidar Analysis

User Manual – Ver.1

Athens 10/8/2016

Contents

Introduction

This software provides all the tools that user can use to view, edit work and display raw lidar datafiles. Additionally, provides advanced tools for lidar analysis and estimation of several lidar products.

Installing Lidar Analysis software

Raymetrics software does not need to be installed.

Just copy the Lidar Analysis folder and run the Lidar_Analysis.exe file.

However, before you can use the software you need to:

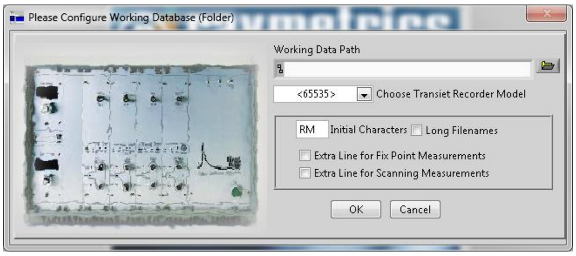
1) Install (if not already) the Labview 10 Runtime engine

(you can download this free from the internet or you can find it at the Third Party Software folder.

2) Install the ASPT_RT.msi file (you can find it at the Third Party Software folder)
3) To have a valid folder with raw datafiles and their associated datalog.dat file.

Getting Started

Before you start using the software you need to have a folder with raw datafiles along with their associated datalog.dat file. If you run the software for the first time it will prompt you to locate and select such a folder. Additionally you have to configure some other parameters.



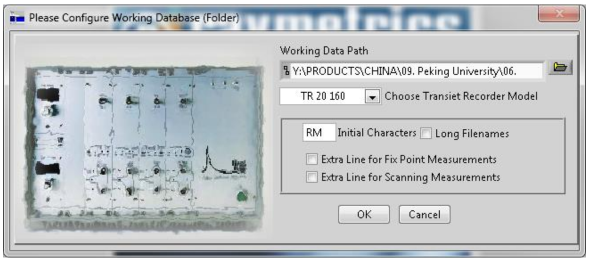
First click the folder icon to locate a folder and select a valid datalog.dat file.

Then you have to Choose the Transient Recorder model of your lidar. Usually it is TR20-160 or TR40-160 (if you are not sure please read the specs of your lidar or contact Raymetrics or the data provider).

Enter the first two letters of the raw datafiles. Usually it is RM but during lidar acquisition configuration user can have select something different.

Then if the raw datafiles have long type file format then check the Long Filenames.

Then leave the other two check boxes unchecked. However, if you have data from a scanning lidar then probably you have to check the Extra Line for Scanning Measurements.



Click the OK button.

After that a small window appears asking you to enter some parameters for the gluing method.

At the moment, you can use the default values. More about gluing Analog and PC datasets below.

About Long and Sort type of filenames

Sort Type Filenames (*??YYMDDhh.mms)*: ?? are the two **First Letters**, YY is the year of the century, M is the month (hexadecimal, 0 – C), DD is the day of the month, hh is the current hour of the day, mm are the minutes, s tenth of the seconds,
For example, the filename RM1612011.281 indicates a file that was created on January 20, 2016, between 11:28:10 and 11:28:19.

Long Type Filenames: (*??YYMDDhh.mmssdd)*: ?? are the two **First Letters**, YY is the year of the century, M is the month (hexadecimal, 0 – C), DD is the day of the month, hh is the current hour of the day, mm are the minutes, ss seconds and dd miliseconds

Note: Scanning lidars are always use Long Type Filename format as default

About the Datalog files

Every time lidar performs sequential fixed point measurements a new raw (line is added to a file named usually datalog.dat) This is a binary file. Each line of this file contains the following information: user name – Lidar Serial number, Location, Start Date, Start Time, Stop Date, Stop Time.

By using this information software can find which raw datafiles corresponds to a specific selected raw of the datalog.dat file. All these files have been made with the same lidar configuration. In this way user can not make a mistake and analyse datafiles that have been acquired with a different configuration.

About Type of Lidar measurements

Fixed point measurements

If your lidar does not have scanning capabilities then only fixed pointing measurements are possible. Fixed point measurements means that lidar head (laser beam and telescope) is pointing constantly at the same point (example: Vertically) during measurements. In this case each raw datafile have the same zenith and azimuth angle.

Duration of a raw datafile (temporal resolution)

The duration of a raw datafile depends on the laser repetition rate (frequency) and the number of laser pulses that lidar averaging before provides a lidar profile (datafile). For example if a lidar has a laser that operates at 20 Hz this means that laser emits 20 pulses per second. If user has configure the lidar to average 1200 laser pulses then the duration of a profile (measurement) is 1 minute (60 seconds)

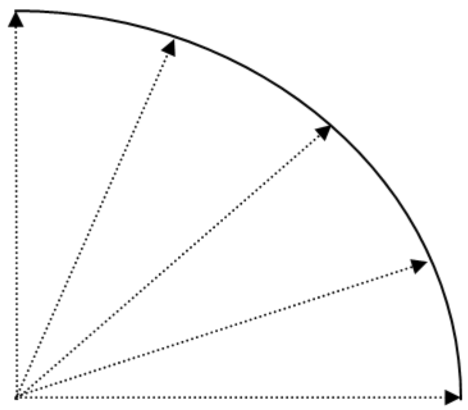
Duration vs effective range

More laser shots a lidar averages better signal to noise ratio. This means that the effective range of a measurement increase.

Scanning Type of measurements

Scanning Lidars can performed PPI and RHI scans (A scans is a set of sequential measurements – profiles (raw datafiles) at different directions). In the first case the azimuth angle is always constant while the zenith angle changes in steps defined by the user, while in RHI scans zenith angle is constant and the azimuth values.

Note: While the lidar head moves from one angle to another the lidar does not measure. This means that lidar points to a direction make a measurement then moves to another direction and so on.



Example of a PPI scan from 0 to 90 degrees in 5 steps

Note: Lidar is capable to get only one profile (datafile) at each direction

Spatial Resolution and the duration of a scan

The radial spatial resolution is fixed by the sampling rate of the lidar data acquisition system. For a lidar that samples at 20 MSample/sec (TR20) the spatial resolution is 7.5 meters (20 Msample/sec corresponds to 50 ns which means 15 meters. Since light travel from the lidar and back the spatial resolution is 15/2).

The resolution at the plane changes as the angle step changes. For small angle steps one can get better spatial resolution, however the duration for a scan can increase significant.

In general the duration of a scan depends on a) the duration of each profile (see above) b) the number of different directions of a scan c) the moving speed of the tracker (positioner), degrees/second

For more info about scanning measurements please read the acquisition manual.

About raw datafiles

Raw datafile is in binary format. Actually, a datafile consists from some header lines and columns of integer number. The number and the type of columns depends on the configuration of the lidar during acquisition. Lidar Analysis program can read this type of binary files and display the datasets (columns) as plots or as numerical values (worksheet).

Usually a datafile contains several datasets (colums) depending on the number of channels-wavelengths (devices) a lidar measures. In most of the cases one channel-wavelength is measured simultaneous with two methods Analog and Photon Counting method. So actually, for a single channel usually we have two datasets, one with Analog data (mVolts) and one with Photon Counting Data (MHz).

Each recorded dataset is described in a header line at the beginning of the datafile. There are as many variable header lines as the number of recorded datasets. Each recorded dataset is actually the detected backscatter signal from a channel (wavelength) in analog or in photon counting mode.

Lidar Analysis software opens binary datafiles and translates binary data to mVolts or MHz based on the following formulas

$$mVotls = \frac{Raw\ data \times Input\ Range \times 1000 \times 2^{-ADC\ Bits}}{Shotnumber}$$

From the corresponding header variable line you can get the Input Range the ADC Bits and the Shotnumber
Example:

Shotnumber

1 0 1 16380 1 0815 7.50 00355.p 0 0 09 000 **12 000301 0.500** BT0

ADC Bits

Input Range

$$MHz = \frac{Raw\ data \times \frac{150}{binwidth}}{Shotnumber}$$

Binwidth: Radial Spatial Resolution (usually 7.5 meters)
ADC Bits: 12
Shotnumber: The number of averaged laser pulsed during acquisition for each profile
Input Range: The selected Input Range of the A/D pre-amplifier during measurements. Usually 500 or 100 mVolts depend on the lidar configuration.

Ranging

Each dataset is a column (An array of data). The index number of the array multiplied by the spatial resolution gives as the range. So the backscatter signal (P(r) from a range-distance r) is P(i*7.5) where i is the index number of the dataset (r=i*7.5)

Backscatter Lidar signal

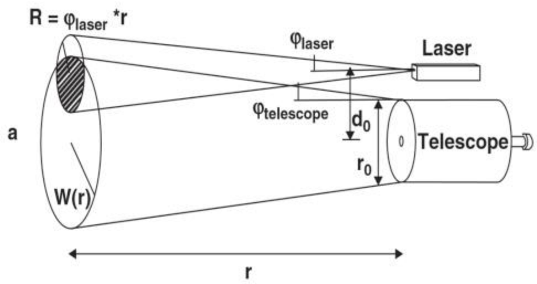
As we mentioned above a lidar detected backscattered signal at a wavelength. No matter the digitation method a lidar can detect elastically and inelastically (Raman) backscatter signals.

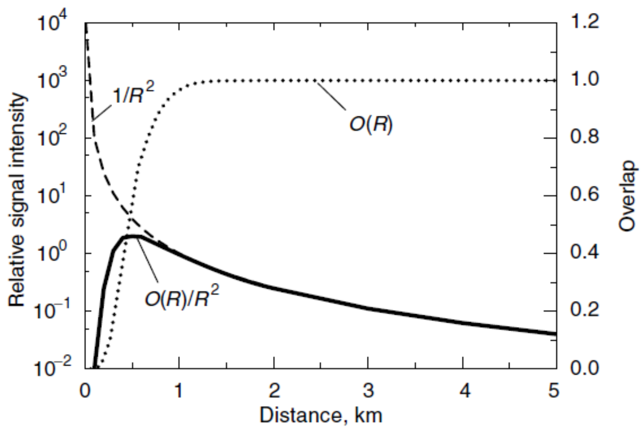
An elastic backscatter signal detected by a lidar is given from the following equation (lidar equation)

$$P(r) = \frac{P_o n Q(r) \beta(r) exp\left\{-2\int_0^r a(r')dr'\right\}}{r^2} + P_{bgr} \text{ Eq.1}$$

P_o: is the laser energy
n: is an instrumental constant related with the efficiency of the system
Q(r): The overlap function of the lidar
β(r): is the backscatter coefficient: $\beta(r)=\beta_{mol}(r)+\beta_{aer}(r)$
α(r): is the extinction coefficient: $\alpha(r)=\alpha_{mol}(r)+\alpha_{aer}(r)$
P_{bgr}: is the background due to electronic noise and photons from other sources except the lidar laser (for example sun during the day or moon and stars during the night). This signal is range independent.

The backscatter signal of a lidar looks like above. At long ranges, the signal falls off as $1/r^2$, as implied by lidar equation. At short ranges, the telescope does not "see" the laser beam. As the beam travels away from the lidar, more and more of the laser beam is "seen" by the telescope until, near the peak of the signal, the entire beam is inside the telescope field of view (in this point the Q(r)=1)





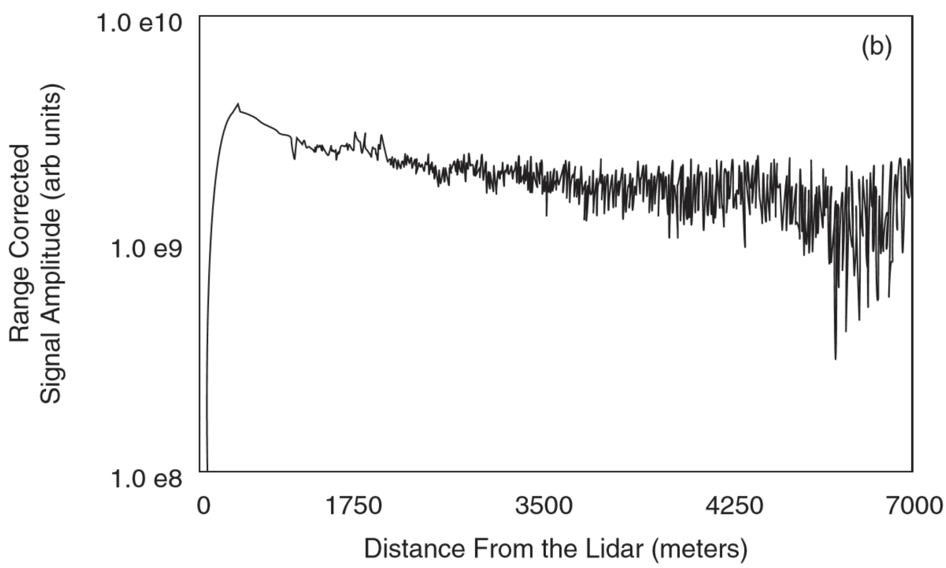
Influence of overlap function Q(z), at lidar signal

The offset corrected lidar signal or in other worlds the background corrected signal is the backscatter signal with subtracted the background.

$$S(r) \equiv P(r) - P_{bgr} \text{ Eq.2}$$

We can further correct the signal for the decrease with range, one obtains the range-corrected lidar signal, shown below

$$RCS(r) \equiv \left[P(r) - P_{bgr}\right] \times r^2 = P_o n Q(r) \beta(r) exp\left\{-2 \int_0^r a(r')dr'\right\} \text{ Eq.3}$$



This lidar signal is often plotted in a semilogarithmic form to emphasize the attenuation of the signal with range.

If the amount of atmospheric attenuation is small, the amplitude of the range-corrected signal is roughly proportional to the aerosol density.

Although not strictly true, this approximation is useful in interpreting the lidar scans. Note that the signal immediately following the signal peak decreases more or less linearly with range. This is the source of the slope method of determining the average atmospheric extinction.

The variations in the signal are due to variations in the backscatter coefficient along the path and signal noise.

Pulse averaging is often used to increase the useful range of the system. Because the size of the backscattered signal rapidly decreases with range, while the noise level remains approximately constant over the length of the pulse, the signal-to-noise ratio also decreases dramatically with range. vThis effect is aggravated by the signal range correction.

Averaging a limited number of pulses increases the signal-to-noise ratio and can significantly increase the useful range of a system. A series of pulses are summed to make a single scan along a given line of sight. A number of scans are used to build up a two-dimensional map of the range-corrected lidar return. A wide range of scanning products can be made with lidars possessing that capability. By changing the elevation angle (zenith angle) while holding the azimuth constant, a range height indicator (RHI) scan is produced showing the changes in the range-corrected lidar return in a vertical slice of the atmosphere. Conversely, holding the elevation constant while changing the azimuth angle produces a plan project indicator (PPI) scan showing the relative concentration changes over a wide area.

Lidar Data Preview

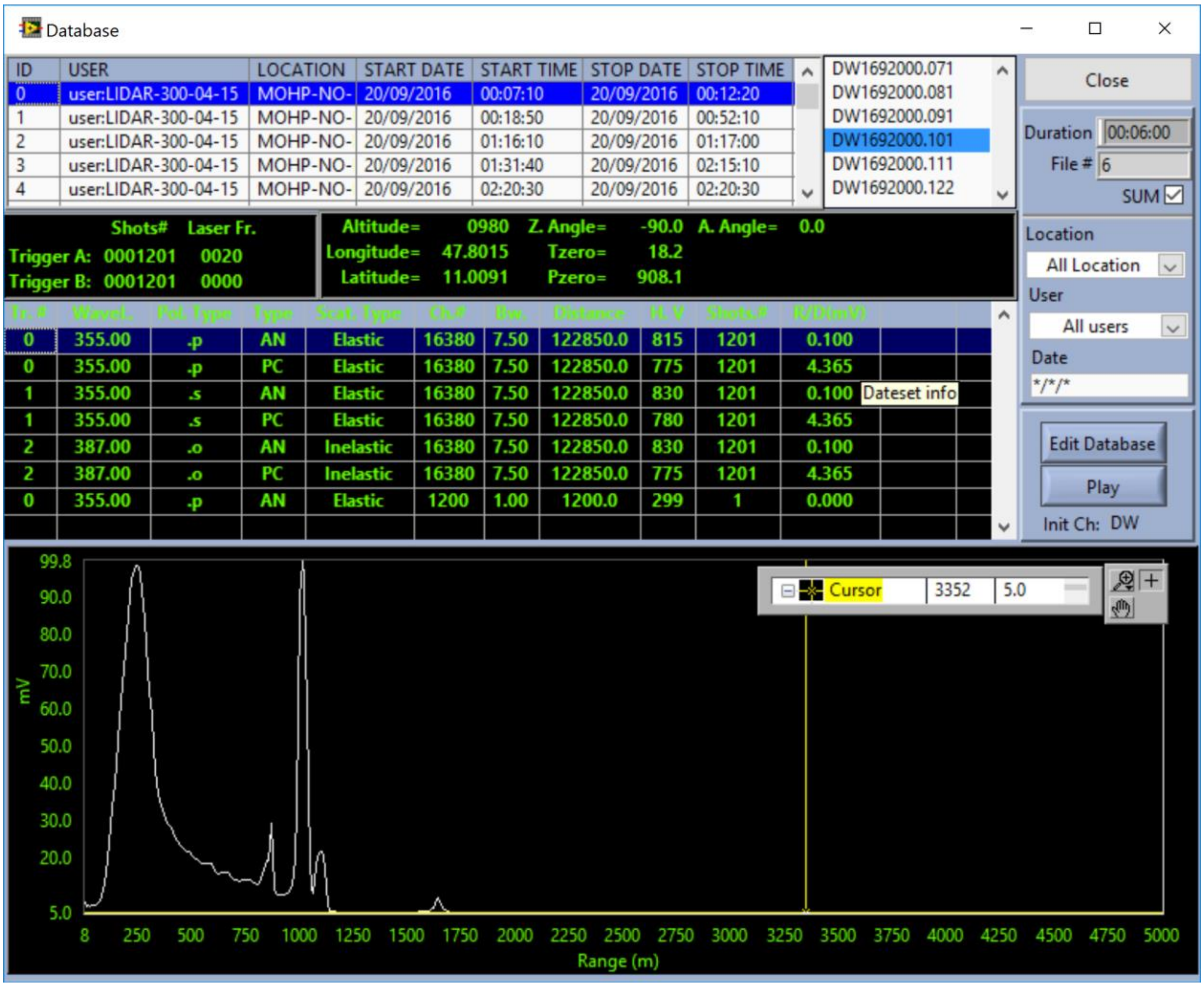
The easiest way to open a lidar datafile and preview the raw datasets it is to open the DB window. There you can select any datafile and any dataset and the associated data will be plotted and displayed among with other info related to them (global info, like location latitude longitude altitude ground temperature and pressure)

Alternatively one can open a 2D graph and import into it one or more datasets from selected datafile. If user want to see the numerical values of the dataset then it has to open a worksheet window and import into it one or more datasets.

The DB window

To open the DB window just click on the most left icon.

Then select a raw from the datalog table, select a raw datafile from the right list (this list contains sequential datafiles that have been acquired during the time period that the raw of the table describes. Then at the middle of the window there is a table with all the variable lines for the selected datafile. If you click on one of them the associated data will be plotted at the graph below.



User can select more than one files additionally can check the sum check box if he want to plot also the averaging of the selected files.

Duration indicator: indicates the duration of the selected set of datafiles (raw of a datalog file).
File#: The number of raw datafiles of the set

Click at the Axis min and max values to change them and zoom at the graph. Or you can use the appropriate symbol at the top right corner of the graph.

Right click on the graph to Autoscale or to export data or to save as image.

Edit Datalog file

When you click Edit Datalog button you can
Delete a row: To delete a row double click on it and select that option. You will be asked if you like to delete from your hard disk also the associated datafiles.
Add a row manually
Connect two datalog files into one
Edit datafiles associated with a selected table row

Share Lidar Data

Probably the easiest way to share lidar data with a partner is just to copy and paste raw datafiles. Since however a lidar can produce huge amount of datafiles there is another way that helps the use control better the process and gets what he is really need much more easy.

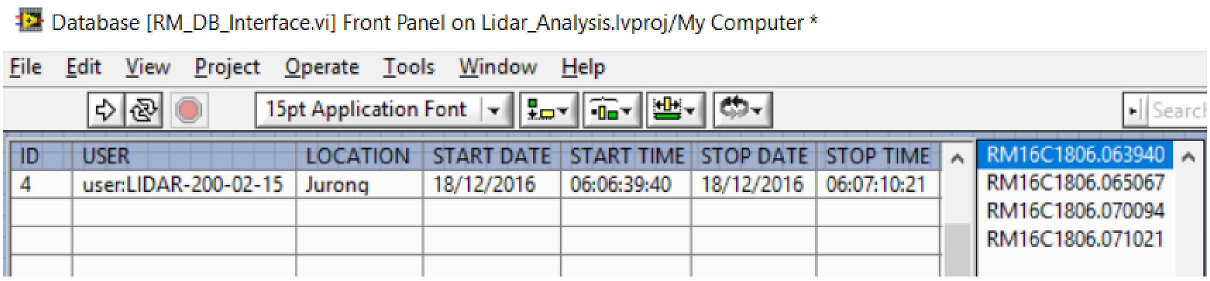
Open the Database window. Then click the Edit database button. Select one or more rows from the table and click Copy Selection button. An explore window will appear asking you to select a folder. Locate a folder or create a new one. Then get into that folder and click the Current Folder button. Then all the corresponding datafiles from the previously selected rows will be copied at the folder you just selected. Zip that folder and share it to you partners.

DB Window Troubleshooting

Window opens and run successfully but no files appear in the left list or not all of them

You do not have configure correctly your database (Configuration option). Close window, go to File menu - > Configure DB and make sure that you have select the right Initial Characters and Long or Short filename format.

DB window fails to load correctly



You have select an incompatible datalog.dat file or it is corrupted. Try to select another one.

The Worksheet window

Use this window get the numerical values of datasets from raw datafiles and/or from Ascii files. Additionally you can get in numerical values lidar products after lidar analysis. You can then edit the values, plot them or export them as asci.

The 2D Graph window

Use this window to plot directly raw datasets or lidar products after lidar analysis. Then you can edit and save the graph as an image or to save the numerical data of the plots of the graph into an asci file.

The surface graph

Use this window to create temporal evolution graphs of a dataset from a set of sequential raw datafiles. You can plot raw dataset or a lidar data product.

Find and select raw datafiles to analyse

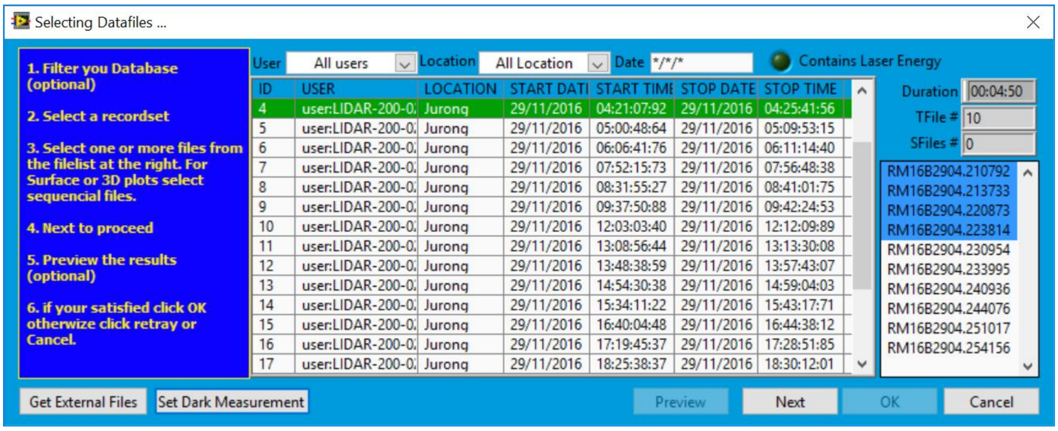
Select raw datafiles to analyse

First you need to select some raw datafiles to work, analyse and produce some lidar products.

Fixed Point Measurements

Depending in which form you need to display the products select one of the three available interfaces (Worksheet, 2D-Graph, Surface graph). Open it and then click on the Import Data.

Select the option from DB. Then a window appears allow use to select a row of the datalog and a list of the corresponding raw datafiles. Select one or more datafiles and click the Next button.



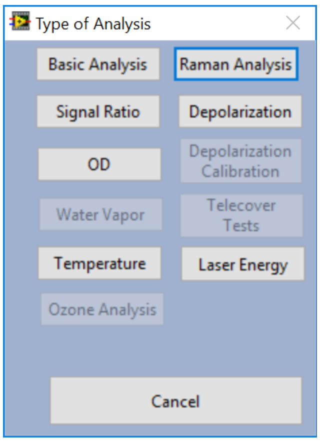
If the selected row corresponds to raw datafiles that contains raman singals then the raw is marked with green colour otherwise it is marked blue. This is an easy way to locate files that contain raman signals.

The Set Dark Measurements button

Click this button if you want to set a file (or a set of files) as a dark measurement file for the rest of analysis.

The Get External Files

Click on this button to select a set of sequential files to analyse which are not located inside the folder that you are already work.



After clicking Next button a new dialog appears asking user to select the type of lidar analysis and then to select the datasets to work with. Depending on the selected datafiles various options can be available for analysis. For example if lidar raw dataset contains 387 and 408 nm channels then the Water Vapor analysis button is activated. Otherwise is de-activated and user can not select it.

Type of Lidar Analysis

Basic Analysis

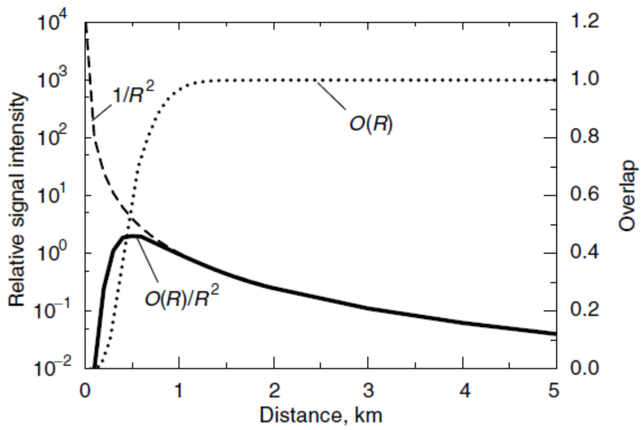
Use this type of analysis to solve the lidar equation based on Klet algorithm

The elastically backscatter signal from a range r from a lidar is given from the following equation (Lidar Equation)

$$P(r) = \frac{n \times P_o \times A \times O(r) \times [\beta_{mol}(r) + \beta_{aer}(r)] \times \exp[-2\int_0^r [a_{mol}(r') + a_{aer}(r')]dr'}{r^2} + P_{bgr}$$

P(r) is the received power from a distance r

O(r) describes the range-dependent measurement geometry (overlap function)



Influence of overlap function O(R), at lidar signal

$\beta(r) = \beta_{mol}(r) + \beta_{aer}(r)$ is the backscatter coefficient. The backscatter coefficient β(r) is the primary atmospheric parameter that determines the strength of the lidar signal. It describes how much light is scattered into the backward direction, i.e., towards the lidar receiver. Molecular scattering (index mol), mainly occurring from nitrogen and oxygen molecules, primarily depends on air density and thus decreases with height, i.e., backscattering decreases with distance if the observation is made from the ground. Particulate scattering (index aer for aerosol particles) is highly variable in the atmosphere on all spatial and temporal scales. Particles represent a great variety of scatterers: tiny liquid and solid air-pollution particles consisting of, e.g., sulfates, soot and organic compounds, larger mineral-dust and sea-salt particles, pollen and other biogenic material, as well as comparably large hydrometeors such as cloud and rain droplets, ice crystals, hail.

The last term in the lidar lidar equation, we have to consider the fraction of light that gets lost on the way from the lidar to the scattering volume and back. The transmission term T(r) can take values between 0 and 1 and is given by

$$T(r) = \exp\left[-2\int_0^r a(r')dr'\right] \text{where } a(r) = a_{mol}(r) + a_{aer}(r)$$

This term results from the specific form of the Lambert–Beer–Bouguer law for lidar. The integral considers the path from the lidar to distance r. The factor 2 stands for the two-way transmission path.

The sum of all transmission losses is called light extinction, and α(r) is the extinction coefficient. Extinction can occur because of scattering and absorption of light by molecules and particles.

Solving the Lidar Equation

In any form the Lidar Equation has two unknown quantities (β and α). So this is an intrinsic problem of an elastic backscatter lidar. One has to measure two quantities with only one equation. Several solutions (depending on different assumptions) have been proposed in literature in order to solve the lidar equation.

Here for Basic Analysis we follow the **Inver Klett-Fernard method (Far-end solution)**

This method is valid for highly turbid, moderately turbid atmospheres. In order to apply it, the following assumptions are made:

The molecular atmosphere scattering properties, $\beta_{mol}(r)$ and $a_{mol}(r)$, are considered known and are determined from the best available meteorological radiosonde data or approximated from a standard atmospheric model. Furthermore, we assume that the extinction-to-backscattering ratio (lidar ratio) for aerosols, $L_{aer}(r) = \frac{a_{aer}(r)}{\beta_{aer}(r)} = L$, remains constant with range, meaning that the size distribution and composition of the aerosol scatterers are not changing with range from the lidar, and that variations in backscattering from aerosols are only due to changes in their number density. Furthermore, the lidar ratio for molecular scatterers is considered constant and equal to:

$$L_{mol}(r) = \frac{a_{mol}(r)}{\beta_{mol}(r)} = \frac{8\pi}{3}$$

Step by step solution:

We subtract the background signal (offset) Pbgr and the we define the Range Corrected Signal (RCS(r)) as:

$S(r) = P(r) - P_{bgr}$ then

$$RCS(r) \equiv S(r) \times r^2 = n \times P_o \times A \times O(r) \times [\beta_{mol}(r) + \beta_{aer}(r)] \times \exp[-2\int_0^r [a_{mol}(r') + a_{aer}(r')]dr'$$

Then after a number of steps the final solution is:

$$\beta(r) = \frac{RCS(r)\exp\left(2(L - L_{mol})\int_r^{r_{ref}} \beta_{mol}(r')dr'\right)}{\frac{RCS(r_{ref})}{C * \beta_{mol}(r_{ref})} + 2L\int_r^{r_{ref}} RCS(r')\exp\left(2(L - L_{mol})\int_{r'}^{r_{ref}} \beta_{mol}(r'')dr''\right)dr'} \quad \text{eq.4}$$

Where

$$C = \frac{\beta_{mol}(r_{ref}) + \beta_{aer}(r_{ref})}{\beta_{mol}(r_{ref})} \quad \text{eq.5}$$

r_{ref} is, as before, a reference height, in case there are no aerosol (free troposphere) at that reference high then it is safe to assume that $\beta_{aer}(r_{ref}) = 0$. In this case C=1 (In lidar analysis software user can find C notated as RFDisk)

Eq. 11 can lead to a simple numerical integration scheme by dividing the sampled atmosphere into adjacent layers of ΔR thickness (adjacent data points range ΔR apart). Thus, we can express $\beta_{aer}(\lambda, R)$ and $a_{aer}(\lambda, R)$ one data step beyond the calibration range (reference height). The lidar data can, therefore, be analysed in successive steps that can move either out or in from the assigned calibration range [5,6].

Note: For Raman, Depolarization and Water Vapor analysis there are separate manuals. For more info please refer to them.

Select a dataset to work with

When you want to just preview a dataset or calculate some lidar products from it somehow you have to select it.

Note: Just for preview raw datasets the easiest way is to use the DB window.

Depending on the lidar type and the configuration of the measurements (raw datafile) one can have several options. User can select a wavelength (channel) and the dataset that corresponds to the type of detection (Analog or Photon Counding). If the wavelength is simulated detected with Analog mode and Photon Counting mode then software also offers a third option which is the Glue. So in general user can work with

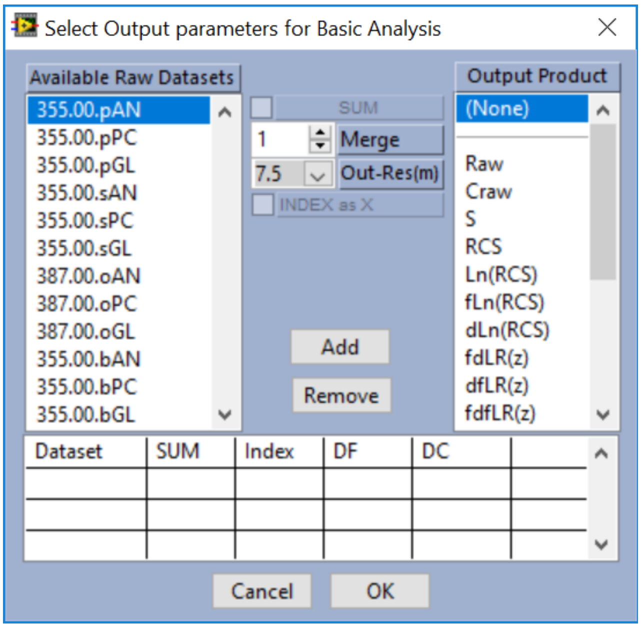
W_Analog (W_An), W_Photon Counding (W_PC) and W_Glue (W_Gl).

For example: 355_AN, 355_PC and 355_GL.

For depolarization lidars there is an extra option. One can ask to work with the total signal (.b) instead of working with .p (parallel) or .s (cross – pollar) signal

So as an example for a depolarization lidar at 355 nm a user can work with:

355.p_AN, 355.p_PC, 355.p_GL, 355.s_AN, 355.s_PC, 355.s_GL, 355.b_AN, 355.b_PC and 355.b_GL



The main dataset and output product selection interface

Note: Analog datasets are good for near field (the first couple of kilometres), PC datasets are better for far field. In case that gluing the two datasets is possible then we suggest to use glue datasets.

In case that you select to work with total signals (.b) you have to provide a calibration factor since

$$P_{.b}(r)=P_{.p}(r)+V^{*}xP_{.s}(r)$$

If such a parameter is explicitly provided inside the Config.ini file (it is located at the same folder with the Lidar Analysis.exe file) then the total signal will be calculated automatically otherwise software will ask you to provide a valid depolarization calibration constant. In general the V* for analog and PC datasets can be different so user has to pro

[Depolarization Calibration Constants]

355_AN = 0.015

355_GL = 0.880493

355_PC = 1.000000

532_GL = 0.012000

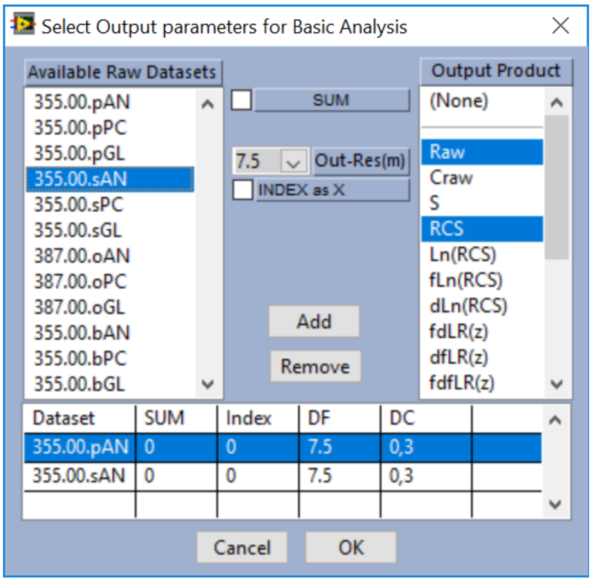
532_PC = 0.012000

532_AN = 0.700000

Depending on the type of the lidar analysis different output products are available

Note: with <Ctrl>+H you always can one a help window to get more info for the selected control (if it is available)

If you output your products to a worksheet or to a 2D plot then you can select multiple output products for a dataset or/and to select multiple dataset as in the following example



To do that select a Raw Dataset then select one or two products and click Add button. Then select another Dataset and do the same.

Basic Analysis Output Products

As it is mentioned above the Basic Analysis it provides the steps to solve lidar equation. As output products (to plot or to see their numerical values) are the following:

None: With this option software, will provide just the selected raw dataset (full range)

Raw: Once more we get just the raw dataset but in this case user has the option to select the range of interest instead of getting back the full range of the dataset.

CRaw: Once more we get just the raw dataset but in this case user has the option to select the range of interest instead of getting back the full range of the dataset and in addition to use an overlap correction function for the dataset and to get the dead time corrected data (if he has select a Photon Counting dataset). More about Dead Time Corrected photon counding dataset in Appendix

S: It is actually the S(r) given from eq.2

RCS: It is the Range Corrected Signal RCS(r) given from eq.3

Ln(RCS): It is the natural logarithm of RCS(r)

fLn(RCS): It is the Ln(RCS) but we apply a sliding average filter before we output data (More at Appendix)

dLn(RCS): It is the derivative of the natural logarithm of the Rance Corrected Signal

$$\frac{d[ln(RCS(r))]}{dr}$$

fdLn(RCS): It is the derivative of Ln(RCS) but we apply a sliding average filter before we output data

dfLn(RCS): It is the derivative of the filterer natural logarigm of the range corrected signal fLn(RCS).

fdfLn(RCS): It is the derivative of the filterer natural logarigm of the range corrected signal fLn(RCS) but we apply an extra sliding average filter before we output data

Bmol(z): It is the molecular backscatter coefficient $\beta_{mol}(r)$ calculated from a radiosonde or from a US standard atmosphere 1976 model.

NBmol(z): It is defined from the following equation

If we define a range between to hights (z_{min} and z_{max}) where there are no aerosols then for any r at this range $\beta_{aer}(r)=0$ and $a_{aer}(r)=0$ we get from the lidar equation

$$RCS(r) \equiv S(r)\times r^2 = n\times P_o \times A\times \beta_{mol}(r)\times \exp[-2\int_{z\min}^{z\max}[a_{mol}(r')]dr'$$

We define NBmol(z) as

$$N\beta_{mol}(r) \equiv \beta_{mol}(r)\times \exp[-2\int_{z\min}^{z\max}[a_{mol}(r')]dr' \quad \textbf{eq.5}$$

NRCS(z): It is the normalized Range Corrected Signal

$$NR(z) \equiv RCS(z)\times \frac{\dfrac{\sum_{z_{\min}}^{z_{\max}} RCS(z)}{z_{\max}-z_{\min}}}{\dfrac{\sum_{z_{\min}}^{z_{\max}} N\beta_{mol}(z)}{z_{\max}-z_{\min}}} \quad \textbf{eq.6}$$

Btotal(z): It is the total coefficient $\beta(r)=\beta_{mol}(r)+\beta_{aer}(r)$

Baer(z): It is the aerosol (particle) backscatter coefficient $\beta_{aer}(r)=\beta(r)-\beta_{mol}(r)$. Where $\beta(r)$ is calculated from eq.4

A(z): It is the aerosol (particle) extinction coefficient

$$a_{aer}(r)=L_{aer}(r)\beta_{aer}(r) \quad \textbf{eq.6}$$

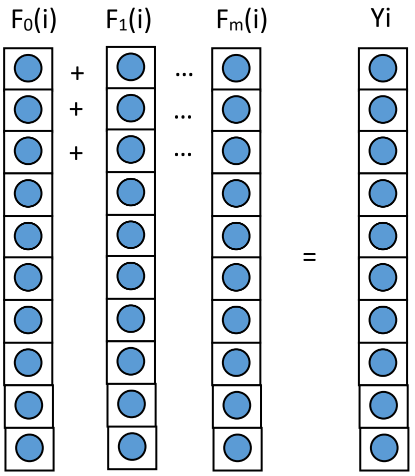
R(z): It is the backscatter ratio which is the ratio between the total backscatter coefficient and the molecular backscatter coefficient. In a clear atmosphere values are equal to 1.

$$R(r)=\frac{\beta_{mol}(r)+\beta_{aer}(r)}{\beta_{mol}(r)} \quad \textbf{eq.7}$$

The Sum check box – How to merge (average) more than one datafile

If you have select multiple raw datafile to work with then software give the option to average the selected dataset from the selected datafiles. In this way, you can increase signal to noise ratio (so the effective range where the data products will be calculated).

When use creates temporal evolution graphs of a product the Sum checkbox is deactivated. However there is the option to **Merge** number of datafiles. So, for example if user has select 1000 files each one of 1200 laser shots (1 minute) and wants to produce a surface graph with better SNR he can merge 2 or 4 or 6 … datafiles into one so instead of displaying profiles every 1 minute can display profiles every 2 or 4 or 6 which have better SNR.



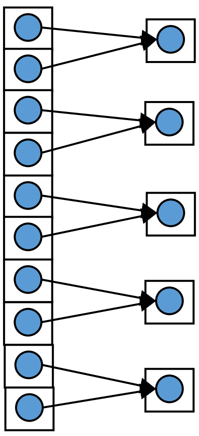
$F_j(i)$ dataset from raw datafile j (the number of selected datafiles). m number of datasets to merge

m=1 to N where in the number of selected datafiles.

Merged dataset $y(i) = \frac{\sum_{j=o}^{m} F_j(i)}{m}$

The Output Resolution Option – Data binning (Smoothing method)

Depending on the lidar specs and the lidar configuration during measurements the spatial resolution of raw datafiles have a value for example every 7.5 or 15 meters. However, in post analysis user can decrease radial spatial resolution and improve SNR by binning data.



Schematical example for a dataset with raw resolution 7.5 meters and Output resolution = 15 metres

x_i raw dataset i=0,1 to n_i . In General:

Data binning dataset $y(j) = \frac{\sum_{j=i}^{m} x(i)}{m}$

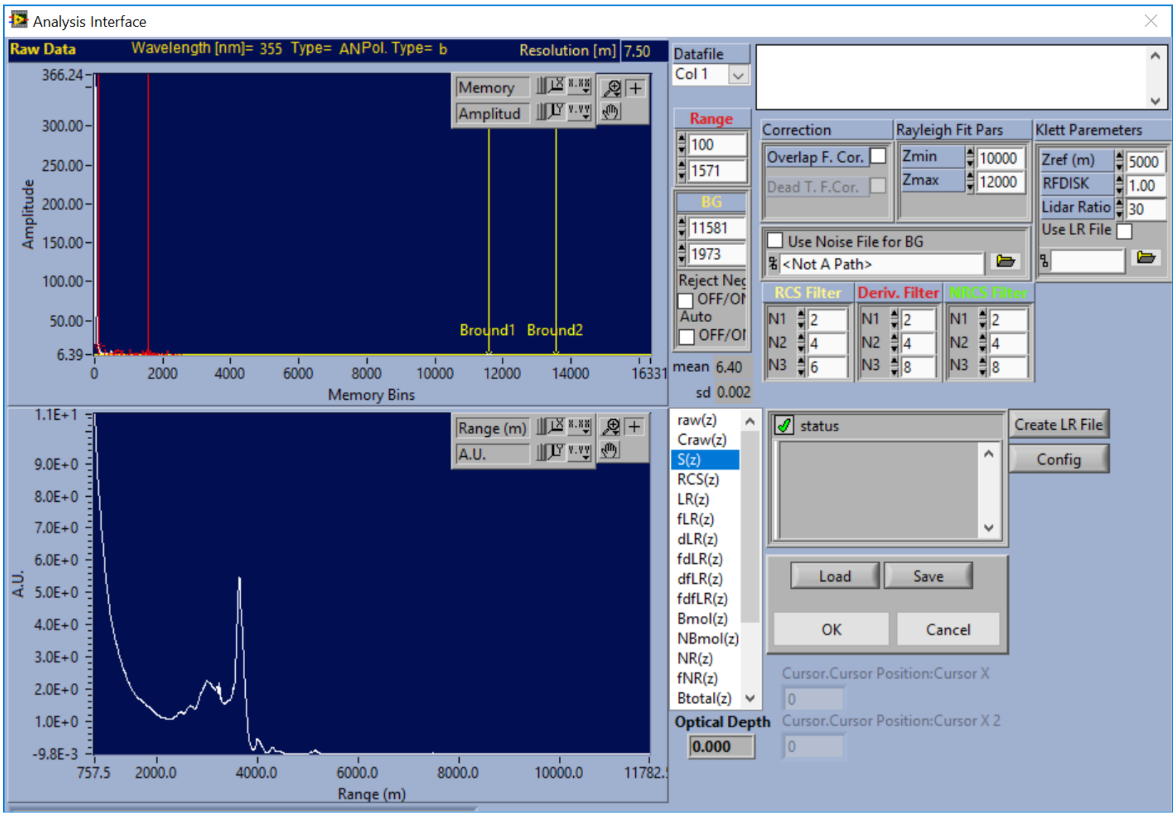
m=(Output Resolution)/(Raw Resolution)

j=0, 1…n_j where n_j=n_i/m

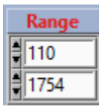
Note: More you data binning better SNR (more effective range) smaller radial resolution

The Basic Analysis GUI Interface

This is the main interface for to calculate a lidar product to solving lidar equation or just to define a range of interest (a range that you want to get out for plotting).



At the top graph the selected raw dataset is displayed. At the bottom graph the selected parameter from the list is displayed. Multiple selection is possible by <Ctrl>+Left Click



To select (zoom) a range use the two red cursor from the top graph or type the min and max range bin at the corresponding control

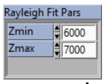
How to subtract background (offset)

You can use the two yellow cursors at the top graph to define a range where there is no any backscatter signal any more just the noise (electronic and/or from sun or other light source). The software calculate a mean value and subtract it from the signal. Instead of using the cursors user can enter values to the corresponding control box. First value is the index number of the first cursor (i) while the second value is the number of bins (window length - N) where to calculate the man value.

$$P_{bgr} = \frac{\sum_{r=i}^{i+N} P(r)}{N}$$

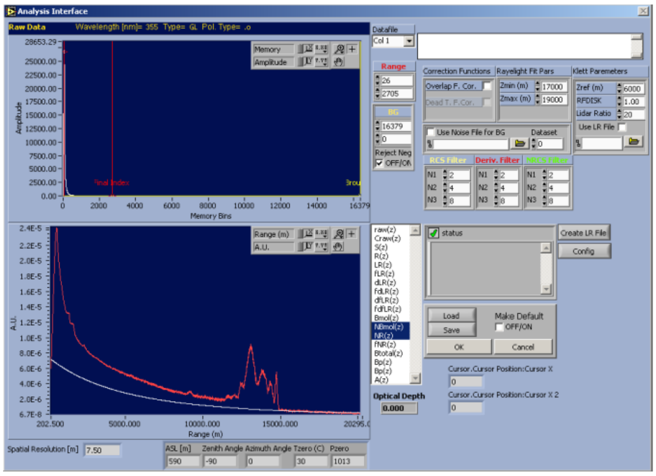
There however two additional option. User has the option to check the auto background check box. In this case the software will try to define the “most appropriate” range to calculate the mean value (Softare auto calculates i and N). Additionally, user can use a dark measurement to reduce non linearity of analog signals.

Rayleigh Fit Parameters

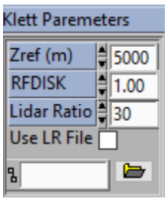


You can set the z_{min} and z_{max} for calculating eq.5 and eq.6. In a perfectly aligned system the molecular signal should fit to the real signal at a part of the atmosphere which is free of aerosols.

You can check the fit if you plot at the same graph the $N\beta_{mol}(r)$ and the NRCS(r)



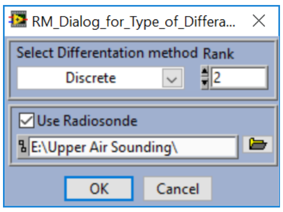
The Klett parameter section



Here user can set the z_{ref} high (Usually selected where there are no aerosols and still the signal to noise ratio is good enough) the RFDISK=C and the L (Lidar Ratio). Look eq.4 and eq.5

Use a Radiosonde File

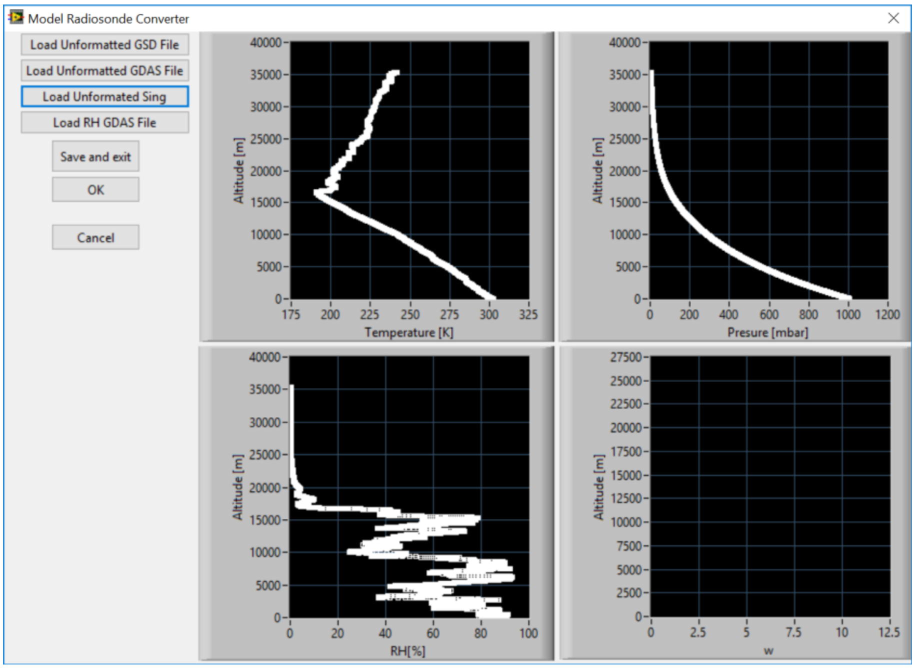
To use a radiosonde file for calculating **Bmol(z)** instead of using the US standard atmosphere 1976 model. Click on the Config button. A dialog box appears. Check the Use Radiosonde check box and select a valid txt radiosonde file.



Raymetrics software needs to read an ascii file with three columns separated by tab.
First Column: Altitude in meters
Second Column: Temperature in K
Third Column: Pressure in hPa.

Raymetrics provide a software tool and instructions to convert you radiosonde data format to the above suitable format. Go to the menu bar of the main window click on Tools -> Analysis->Radio Sonde Converter. Then a new interface appears that it is suitable to convert a couple of Radiosonde type.

1. From: Model Radiosonde from http://rucsoundings.noaa.gov/
2. From: Model Radiosonde from http://weather.uwyo.edu/upperair/sounding.html
3. From: Radiosonde from Sig:….



Appendix

Dead Time Corrected Photon Counting Signals

If N is the observed (recorded) photon count rate and S is the true count rate, then the dead time photon counding corrected signal is given from the following equation

$$S = \frac{N}{1 - N * \tau_d}$$

Sliding Average (Moving) Filter

Up to three zones can be defined where different number of data points can be averaged.

For each zone filtered signal is given from the following equation

fsignal(i) = $fsingal(i) = \frac{\sum_{i-N/2}^{i+N/2} singal(i)}{N+1}$