TroposServer

OPERATING MANUAL

Academy of Science
Institute of Physics
Laboratory of Optics of Scattering Media
Minsk, The Republic of Belarus

Rev. 1.0

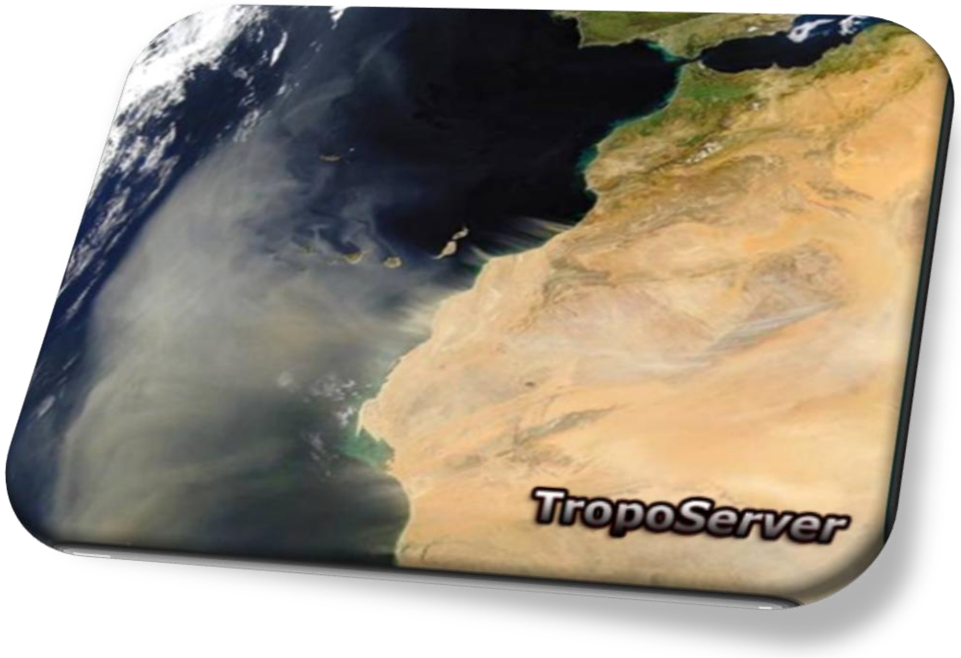
Table of Contents

Welcome to TropoServer

Thank you very much for using **«TropoServer»** - Aerosol Characteristics Calculating Program.

We believe that you'll quickly feel comfortable with **«TropoServer»**.

We even think you will enjoy it soon.



This manual will let you get acquainted with the basic functionality of **«TropoServer»**.

Let's have a look at the user interface to get started...

Use the table of contents on the left to navigate by clicking on it.

Synopsis

Current document contains information concerning operator's actions while using **«TropoServer»** program to calculate optical characteristics of atmosphere aerosol with possibility to export results into MS Access database.

Considered questions of proper installation, configuration, program starting and ending, as well as the functionality thereof, including the choice of mathematical libraries for data processing, assignment of atmospheric model input and other essential parameters.

Current version is 5.14.9.17.

Hardware and software requirements

Requirements for hardware

- CPU at least 1 GHz;
- RAM volume mostly defined by the number of records in database. Recommended at least 2 GB;
- free HDD space mostly defined by the size of databases;
- SVGA True Color Graphics Adapter with resolution 1024x786 pixels at least.

Requirements for software

- Microsoft Windows XP and above;
- Microsoft Excel and Access 2000 and above;
- Microsoft Visual C++ 2005 redistribution libraries (must be installed separately);
- escape.dll library (included with **«TropoServer»** installer);
- CIRA.xls file (included with **«TropoServer»** installer);
- Fortran dynamic library dfort.dll (included with **«TropoServer»** installer);
- mathematical processing library lidbscat.dll or another one (included with **«TropoServer»** installer).

Purpose of the program

A software module **«TropoServer»** for remote sensing data processing and calculation of atmospheric aerosol characteristics is part of the software package **«TropoSuite»** for mathematical manipulation of databases lidar measurements. It is designed to calculate the aerosol microphysical parameters and store it in the standard MS Access database.

Program execution

Adjusting the program

During the initial launch the program configured independently using default settings.

Data are stored for reuse in the file «prm.ini», automatically created in the folder location of the program. This is a plain text file that can be edited manually.

This file contains several logical sections with the keys, features a method of calculation and presentation of data on the screen when the program starts.

Program interface

Common view of the program is represented at figure 1.

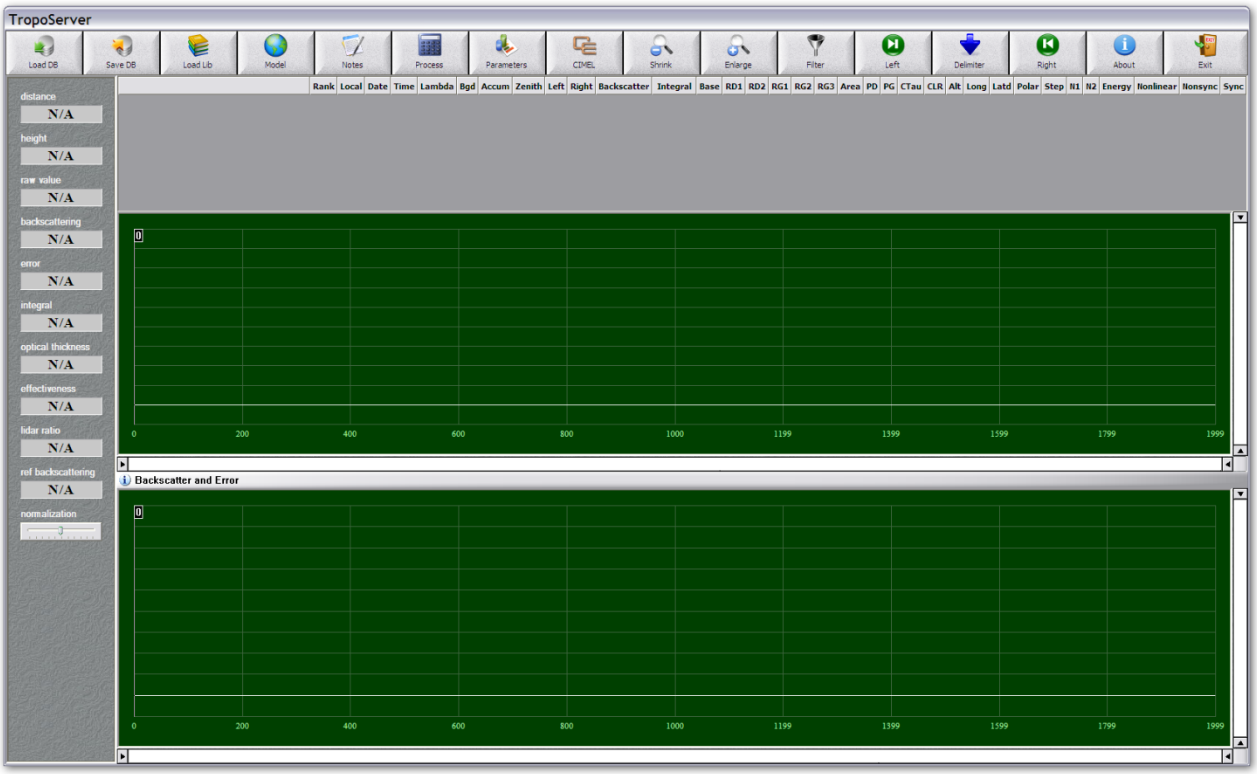


Figure 1

The end of the work is done by pressing the key combination «Alt + F4», or by selecting the button «Exit» (figure 2).

Figure 2

Screenshots for comparison

Only fields with blue background in grid table are editable.

For comparison taking screenshots display areas untreated (figure 3) and treated (figure 4) profiles.

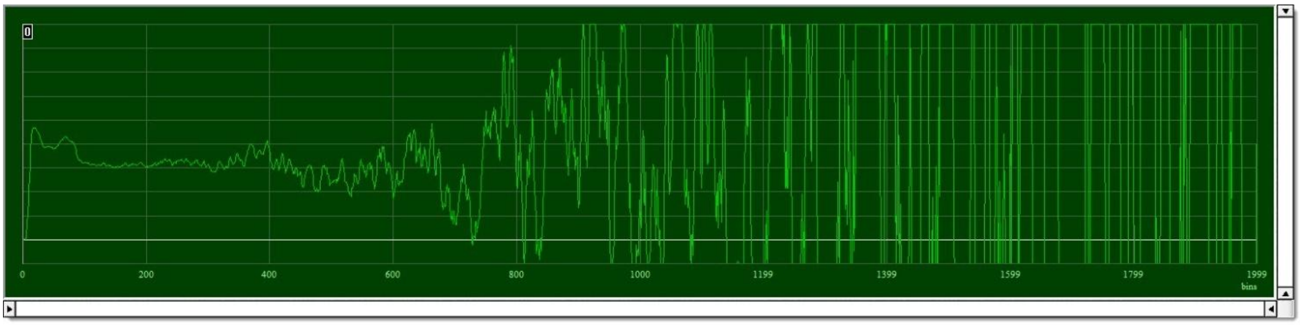


Figure 3

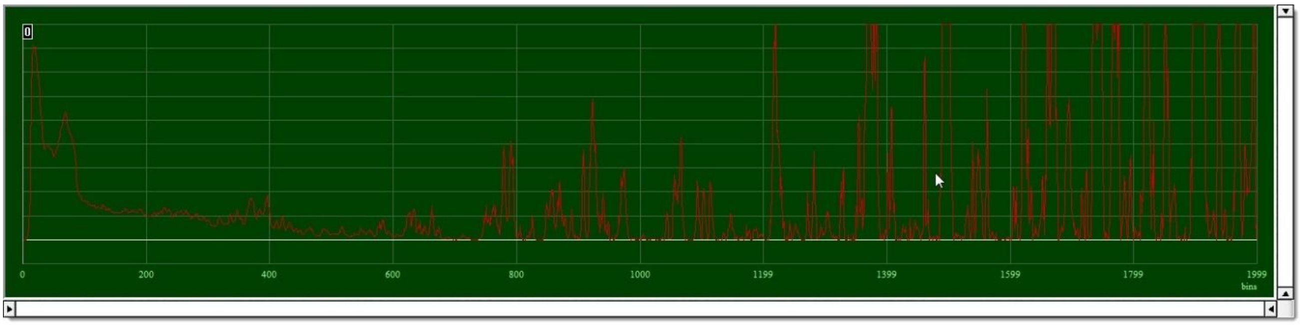


Figure 4

Toolbar

Toolbar is not too complex and very intuitive. It consists of the following elements or keys (figure 5).

Figure 5

Selecting and loading the measured lidar database for processing

Press «Load DB» button (figure 6) and select desired database (figure 7).

Figure 6

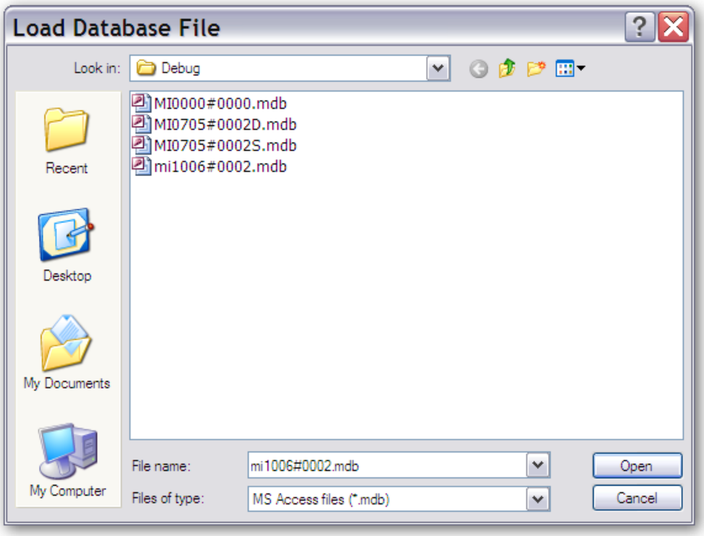


Figure 7

The main screen will appear (figure 8).

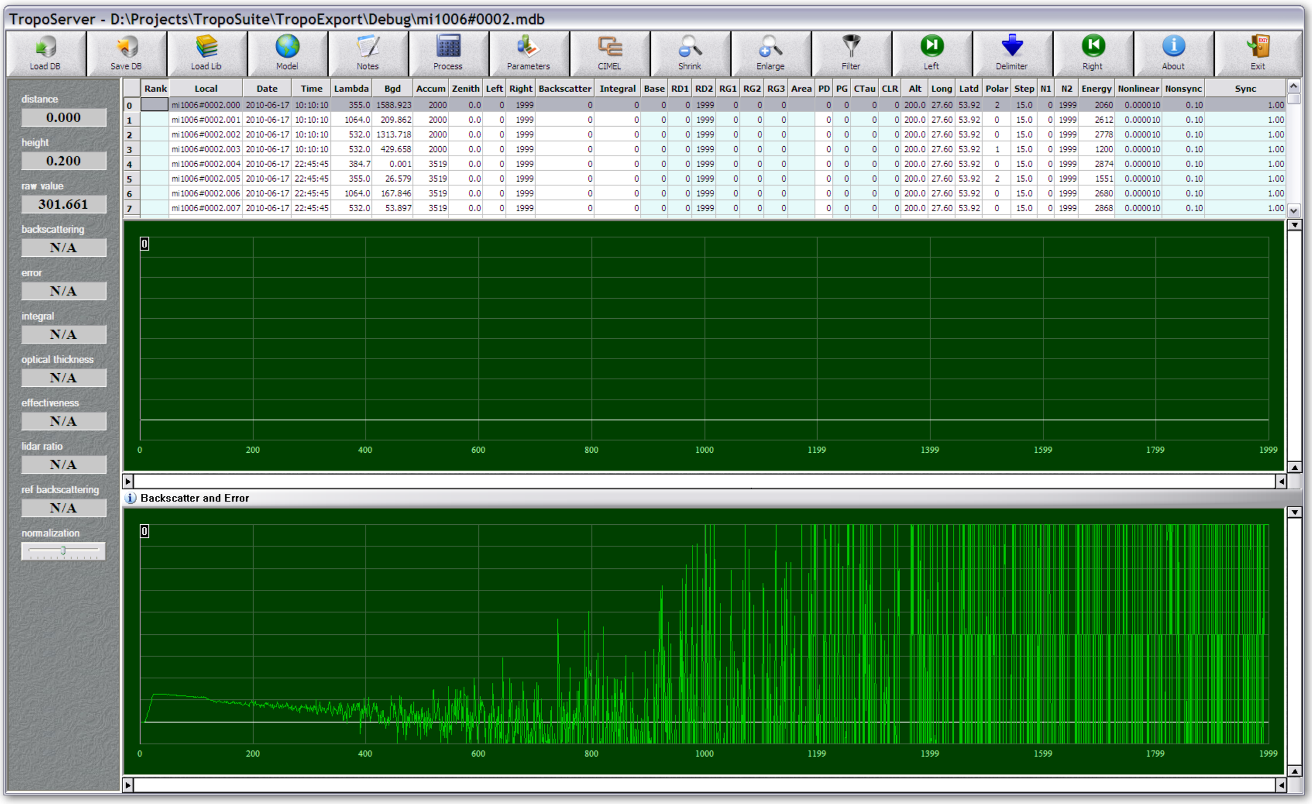
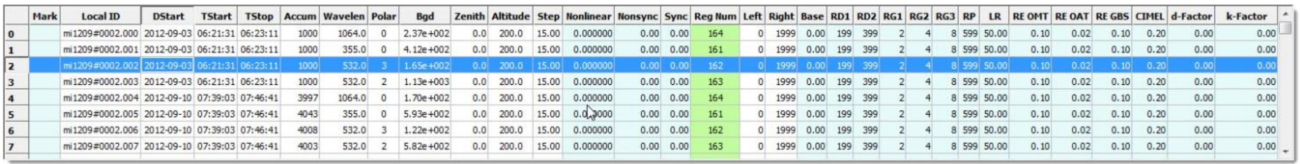


Figure 8

Profile selection

After database loading the first record in a grid table is highlighted by default.

Any other record can be selected simply by using the mouse as shown in figure 9



	Mark	Local ID	DStart	TStart	TStop	Accum	Wavelen	Polar	Bgd	Zenith	Altitude	Step	Nonlinear	Nonsync	Sync
0		mi1209#0002.000	2012-09-03	06:21:31	06:23:11	1000	1064.0	0	2.37e+002	0.0	200.0	15.00	0.000000	0.00	0.00
1		mi1209#0002.001	2012-09-03	06:21:31	06:23:11	1000	355.0	0	4.12e+002	0.0	200.0	15.00	0.000000	0.00	0.00
2		mi1209#0002.002	2012-09-03	06:21:31	06:23:11	1000	532.0	3	1.65e+002	0.0	200.0	15.00	0.000000	0.00	0.00
3		mi1209#0002.003	2012-09-03	06:21:31	06:23:11	1000	532.0	2	1.13e+003	0.0	200.0	15.00	0.000000	0.00	0.00
4		mi1209#0002.004	2012-09-10	07:39:03	07:46:41	3997	1064.0	0	1.70e+002	0.0	200.0	15.00	0.000000	0.00	0.00
5		mi1209#0002.005	2012-09-10	07:39:03	07:46:41	4043	355.0	0	5.93e+002	0.0	200.0	15.00	0.0[illegible]000	0.00	0.00
6		mi1209#0002.006	2012-09-10	07:39:03	07:46:41	4008	532.0	3	1.22e+002	0.0	200.0	15.00	0.000000	0.00	0.00
7		mi1209#0002.007	2012-09-10	07:39:03	07:46:41	4003	532.0	2	5.82e+002	0.0	200.0	15.00	0.000000	0.00	0.00

	Reg Num	Left	Right	Base	RD1	RD2	RG1	RG2	RG3	RP	LR	RE OMT	RE OAT	RE GBS	CIMEL	d-Factor	k-Factor
0	164	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
1	161	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
2	162	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
3	163	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
4	164	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
5	161	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
6	162	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
7	163	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00

Figure 9

Math library selection for calculations

At the moment, the following are turned mathematical algorithms performing the functions of processing the raw data:

- restoration of the backscattering coefficient at the single-wave sensing;
- restoration of the backscattering coefficient at multi-wave sensing;
- restoration of the backscattering coefficient at sounding together with the sun photometer;
- restoration of the backscattering coefficient when defining variable height lidar ratio.

Press “Load Lib” button (figure 10) and select desired math processing library (figure 11).

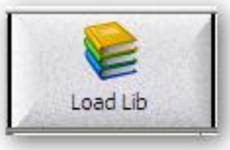


Figure 10

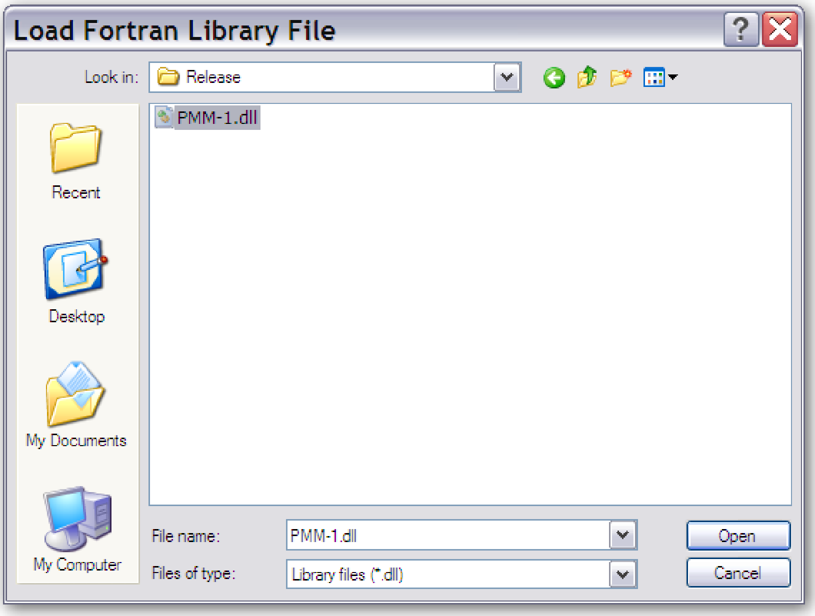


Figure 11

Atmosphere model selection

Press “Model” button to select atmosphere model for calculations (figure 12).

Figure 12

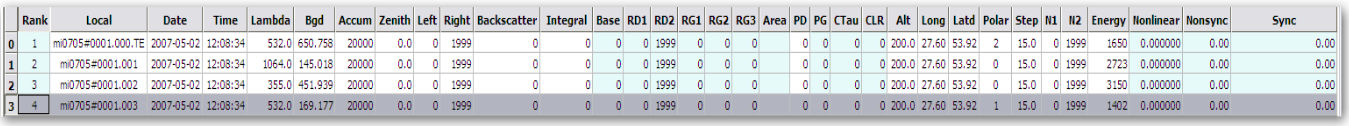
Mark the desired atmosphere model or select a user-defined (figure 13).

Figure 13

Note that the user's model of the atmosphere can be applied in the case where a local weather station data is available. It is necessary to prepare a table modeled as CIRA.xls (Canadian Internet Registration Authority).

Define raw data smoothing parameters

Change smoothing parameters in the grid table (figure 14).



	Rank	Local	Date	Time	Lambda	Bgd	Accum	Zenith	Left	Right	Backscatter	Integral	Base	RD1	RD2	RG1	RG2	RG3	Area	PD	PG	CTau	CLR	Alt	Long	Latd	Polar	Step	N1	N2	Energy	Nonlinear	Nonsync	Sync
0	1	mi0705#0001.000.TE	2007-05-02	12:08:34	532.0	650.758	20000	0.0	0	1999	0	0	0	0	1999	0	0	0		0	0	0	0	200.0	27.60	53.92	2	15.0	0	1999	1650	0.000000	0.00	0.00
1	2	mi0705#0001.001	2007-05-02	12:08:34	1064.0	145.018	20000	0.0	0	1999	0	0	0	0	1999	0	0	0		0	0	0	0	200.0	27.60	53.92	0	15.0	0	1999	2723	0.000000	0.00	0.00
2	3	mi0705#0001.002	2007-05-02	12:08:34	355.0	451.939	20000	0.0	0	1999	0	0	0	0	1999	0	0	0		0	0	0	0	200.0	27.60	53.92	0	15.0	0	1999	3150	0.000000	0.00	0.00
3	4	mi0705#0001.003	2007-05-02	12:08:34	532.0	169.177	20000	0.0	0	1999	0	0	0	0	1999	0	0	0		0	0	0	0	200.0	27.60	53.92	1	15.0	0	1999	1402	0.000000	0.00	0.00

Figure 14

Each plot can be smoothed for three regions defined by delimiters (strobes) in the fields «RD1» and «RD2».

The degree of smoothing is determined by the number of strobes (RG * 2 + 1) involved in averaging (fields «RG1», «RG2» and «RG3»), for each region in separate and neatly linkable onto delimiters «RD1» and «RD2», as shown in figure 15.

RD1	RD2	RG1	RG2	RG3	RP
199	399	2	4	8	599
199	399	2	4	8	599
199	399	2	4	8	599
199	399	2	4	8	599
300	1200	4	10	20	599
199	399	2	4	8	599
199	399	2	4	8	599
199	399	2	4	8	599

Figure 15

Profile before smoothing (figure 16)

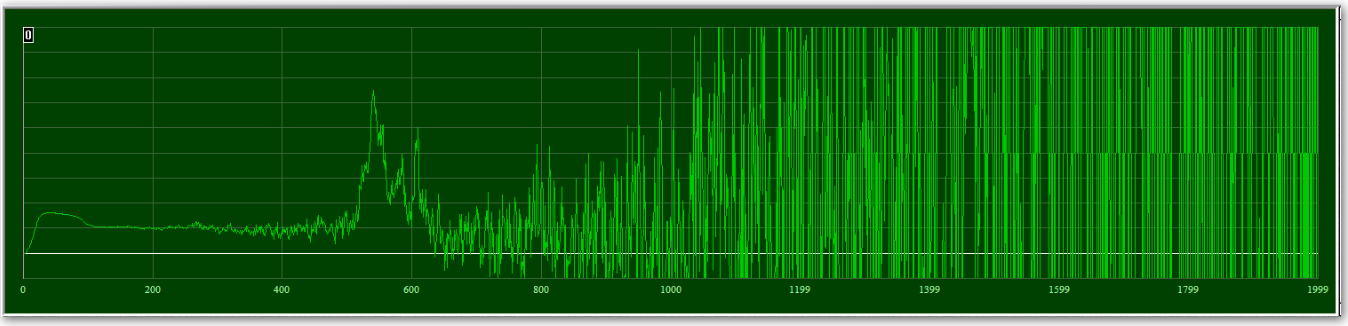


Figure 16

Profile after smoothing (figure 17)

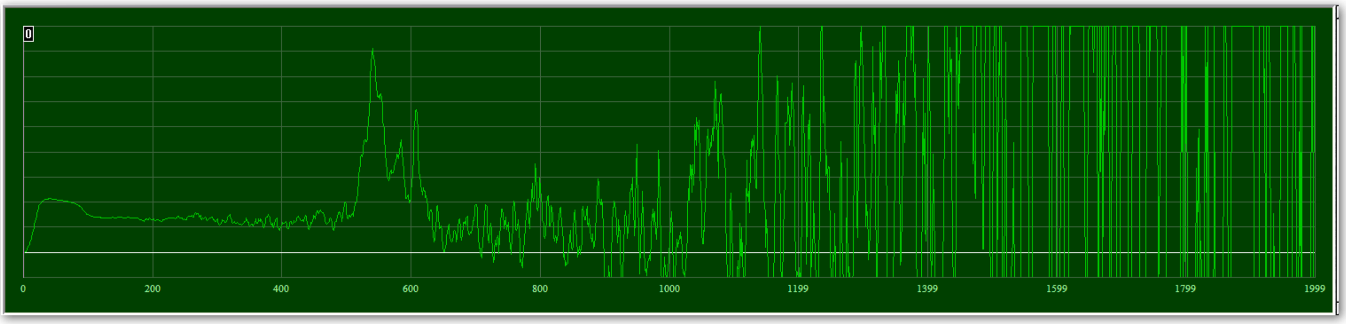


Figure 17

Cutting left and right borders

Artificially limit the processing range can be by excluding the left and right borders with the arrow keys «Left Stop» and «Right Stop» respectively, as shown in figures 18-21.

Figure 18

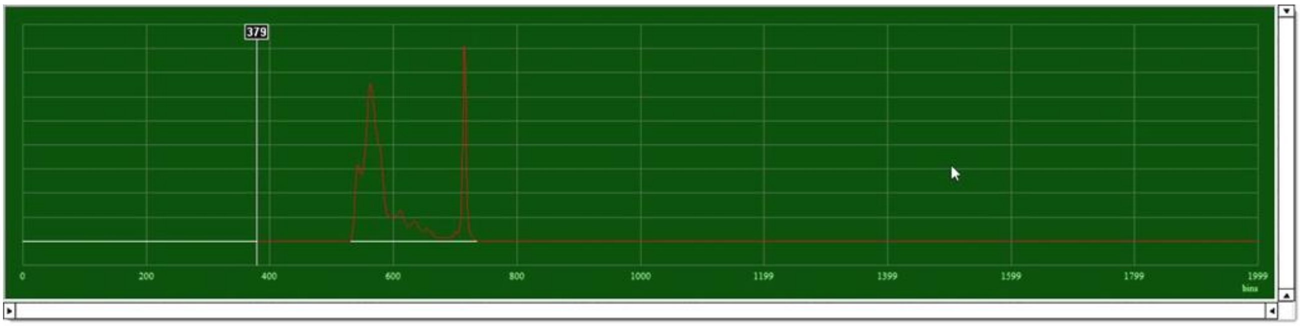


Figure 19

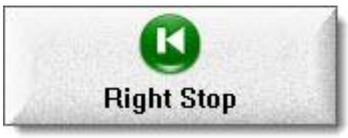


Figure 20

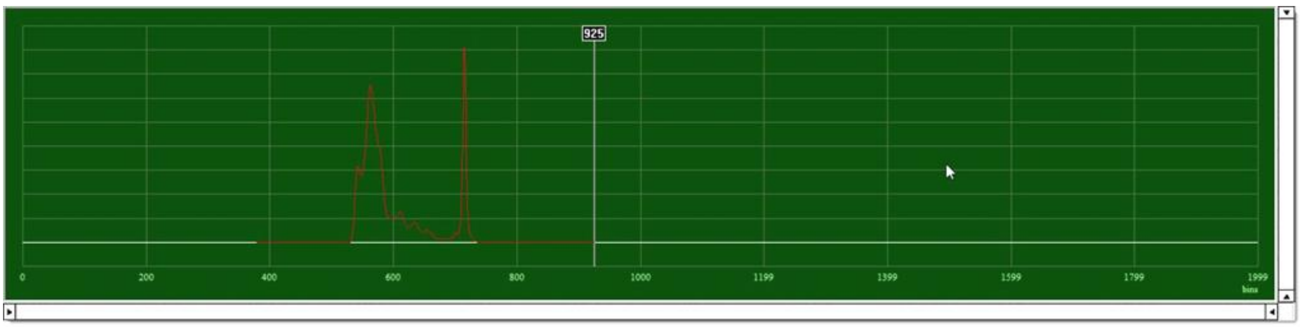


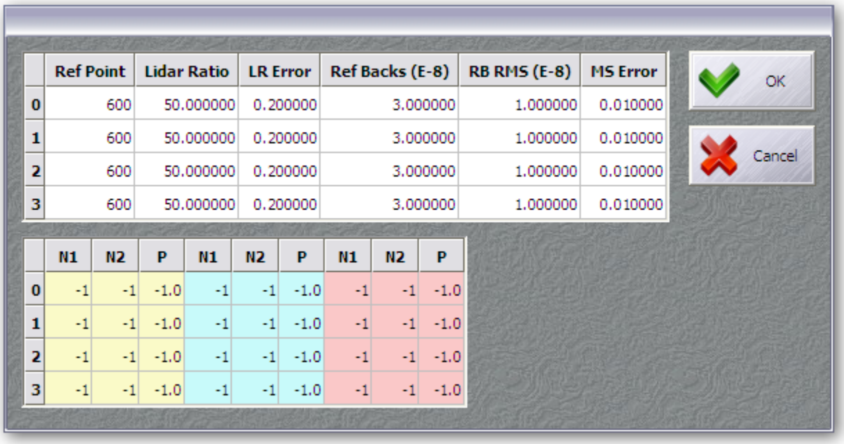
Figure 21

Define additional parameters

Press «Parameters» button to change processing parameters if needed (figure 22).

Figure 22

Change any parameters for calculations (figure 23).



	Ref Point	Lidar Ratio	LR Error	Ref Backs (E-8)	RB RMS (E-8)	MS Error
0	600	50.000000	0.200000	3.000000	1.000000	0.010000
1	600	50.000000	0.200000	3.000000	1.000000	0.010000
2	600	50.000000	0.200000	3.000000	1.000000	0.010000
3	600	50.000000	0.200000	3.000000	1.000000	0.010000

	N1	N2	P	N1	N2	P	N1	N2	P
0	-1	-1	-1.0	-1	-1	-1.0	-1	-1	-1.0
1	-1	-1	-1.0	-1	-1	-1.0	-1	-1	-1.0
2	-1	-1	-1.0	-1	-1	-1.0	-1	-1	-1.0
3	-1	-1	-1.0	-1	-1	-1.0	-1	-1	-1.0

Figure 23

The lower table allows you to specify an aerosol lidar ratio on the track sounding a three-link piecewise constant parameter. The boundaries of the segments defined by the numbers of first N_1 and last N_2 strobes of the working interval.

The value of the aerosol lidar ratio in the interval is P.

Define photo-receiver characteristics

Characteristic fields of photo-receiving modules shown at the grid fields as per figure 24.

Nonlinear	Nonsync	Sync
0.000000	0.00	0.00
0.000000	0.00	0.00
0.000000	0.00	0.00
0.000000	0.00	0.00
0.000000	0.00	0.00

Figure 24

One of the most important parameters registration lidar signals are linear (non-linearity) output characteristics of transformation (field «Nonlinear»), ie, dependence of the amplitude of the output signal vs the intensity of the backlight. The linearity of the output characteristic is very important to select the correct measurement. This characteristic is determined by a special method during debug for each module separately.

Field «Sync» describes interferences introduced by internal generator pulses of module (figure 22).

Field «Nonsync» describes interferences depended on parameters of amplifier and introduced by capacity-resistive circuit of module (figure 25).

You can play these parameters in order to observe real changes.

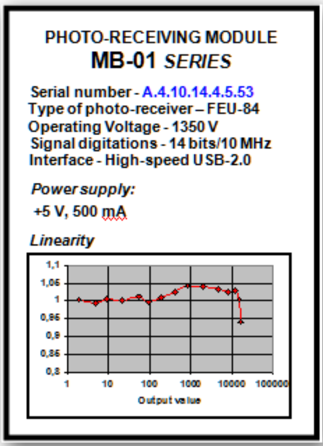


Figure 25

Artificial background compensation

It is possible to manually compensate the background by introducing positive or negative additive in the «Base» field (figure 26).

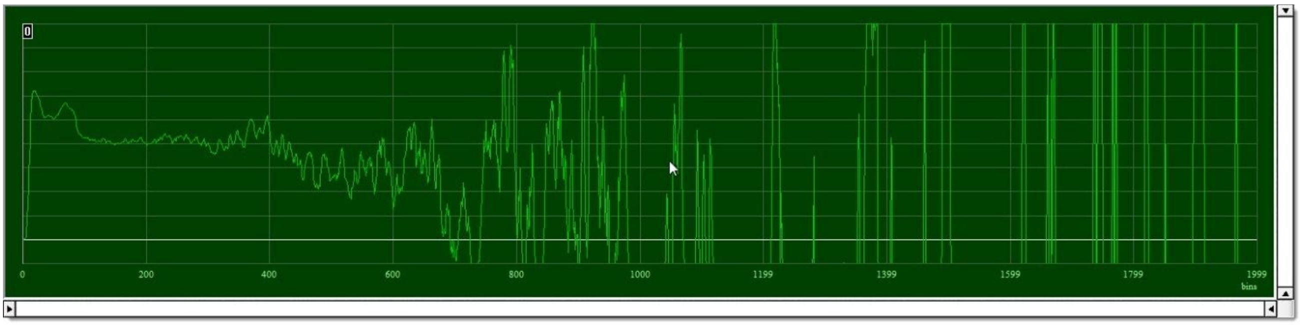


Figure 26

Compare with figure 3.

Reference point (another words, strobe), field «RP», inside lidar profile is selected from the following considerations:

- minimal aerosol scattering;
- sufficient accumulation to avoid the random noise.

Aerosol lidar ratio, field «LR», can be set artificially, if known. Default value is equals to 50.

Setting relative errors

Calculated relative errors in the determination of the molecular optical thickness (field «RE_OMT»), the aerosol optical thickness (field «RE_OAT») and lidar ratio (field «RE_LR») can be adjusted in the appropriate fields of the grid table settings, as shown in figure 27. Default values are specified.

RE OMT	RE OAT	RE LR
0.10	0.02	0.10
0.10	0.02	0.10
0.10	0.02	0.10
0.10	0.02	0.10
0.10	0.02	0.10

Figure 27

Field «RE_OAT» contains the relative error value of the total aerosol optical thickness measurements by sun photometer (or obtained by other means), if available, otherwise the default value is used.

Field «RE_OMT» contains the relative error value of the molecular optical thickness.

Field «RE_LR» contains the relative error value of the lidar ratio.

Using Gaussian random number generator

The program has a mechanism for the generation of additional "white" Gaussian noise by using a random number generator. If a predetermined operation of adding a "white" noise is allowed, the field «d-Factor» and «k-Factor» becomes editable, otherwise - no.

«D-Factor» is the coefficient multiplying the amplitude of the noise taken from a prepared table «noise.xls».

«K-Factor» is the distortion factor of amplitude.

For the implementation of noise reduction it is necessary to fill the column in the table «noise.xls» for all channels (file attached as a sample) values obtained from the website http://www.random.org/gaussian-distributions/ or any other way performing the same function. Do not forget to make sure that you fill in the full scope of the strobes.

Plot area manipulations

As can be seen in figure 1, the program interface is provided with two plot display areas, upper and lower. Manipulation applied to one of the areas are automatically transferred to the other.

The lower pane displays the raw data, calculated as:

(signal - background) * distance square / atmospheric correction factor

In the upper region data is calculated as:

dispersion error of the effective lidar signal

Normalization is done by calculating the plot of maximum on the interval defined by the restriction of the right border with a special slider (figure 28) in a percents of the full range, as shown in figure 29.

Figure 28

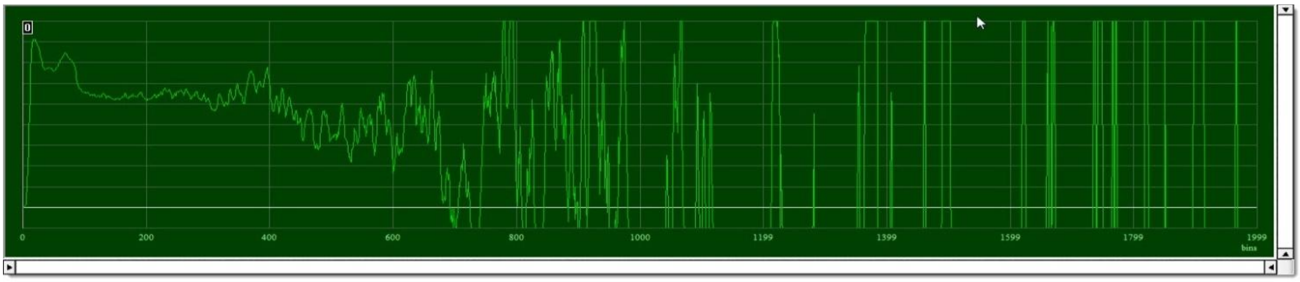


Figure 29

There are two options for positioning the reper:

- set up the manipulator to the desired point of the display area and click on the right button;
- use the scroll mouse wheel for smooth manipulator to increment or decrement shift of the reper.

Implemented two ways to limit the scope of observation:

- use horizontal and vertical sliders in the usual manner, as is done in Windows;
- press and hold the left button of the manipulator, to outline the desired boundaries, then release the button, as shown in figure 30.

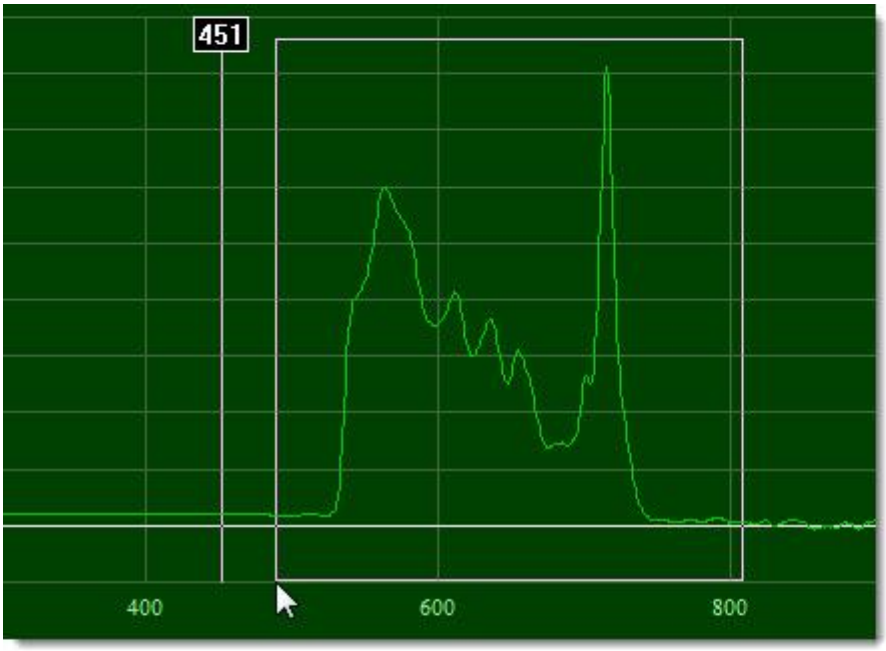


Figure 30

Double click on left mouse button to restore plot to default view state.

Zero line scaling

Zero line (in a white color) can be redefined by the buttons «Enlarge» and «Shrink» (figures 31-32), see the figure 33.

Figure 31

Figure 32

Figure 33

This operation can be very useful for evaluate the behavior of the signal at the tail of the lidar profile relative to the zero line.

Compare with figure 3.

Start calculation process

The program allows you to handle multiple profiles simultaneously. Just check the box «Mark» with any number to secure the entry list (figures 36 and 37).

	Mark	Local ID	DStart	TStart	TStop	Accum	Wavelen	Polar	Bgd	Zenith	Altitude	Step	Nonlinear
0	1	mi1209#0002.000	2012-09-03	06:21:31	06:23:11	1000	1064.0	0	2.37e+002	0.0	200.0	15.00	0.000000
1		mi1209#0002.001	2012-09-03	06:21:31	06:23:11	1000	355.0	0	4.12e+002	0.0	200.0	15.00	0.000000
2	1	mi1209#0002.002	2012-09-03	06:21:31	06:23:11	1000	532.0	3	1.65e+002	0.0	200.0	15.00	0.000000
3		mi1209#0002.003	2012-09-03	06:21:31	06:23:11	1000	532.0	2	1.13e+003	0.0	200.0	15.00	0.000000
4	1	mi1209#0002.004	2012-09-10	07:39:03	07:46:41	3997	1064.0	0	1.70e+002	0.0	200.0	15.00	0.000000
5		mi1209#0002.005	2012-09-10	07:39:03	07:46:41	4043	355.0	0	5.93e+002	0.0	200.0	15.00	0.000000
6	1	mi1209#0002.006	2012-09-10	07:39:03	07:46:41	4008	532.0	3	1.22e+002	0.0	200.0	15.00	0.000000
7		mi1209#0002.007	2012-09-10	07:39:03	07:46:41	4003	532.0	2	5.82e+002	0.0	200.0	15.00	0.000000

	Nonsync	Sync	Reg Num	Left	Right	Base	RD1	RD2	RG1	RG2	RG3	RP	LR	RE OMT	RE OAT	RE GBS	CIMEL	d-Factor	k-Factor
0	0.00	0.00	164	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
1	0.00	0.00	161	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
2	0.00	0.00	162	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
3	0.00	0.00	163	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
4	0.00	0.00	164	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
5	0.00	0.00	161	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
6	0.00	0.00	162	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00
7	0.00	0.00	163	0	1999	0.00	199	399	2	4	8	599	50.00	0.10	0.02	0.10	0.20	0.00	0.00

Figure 36

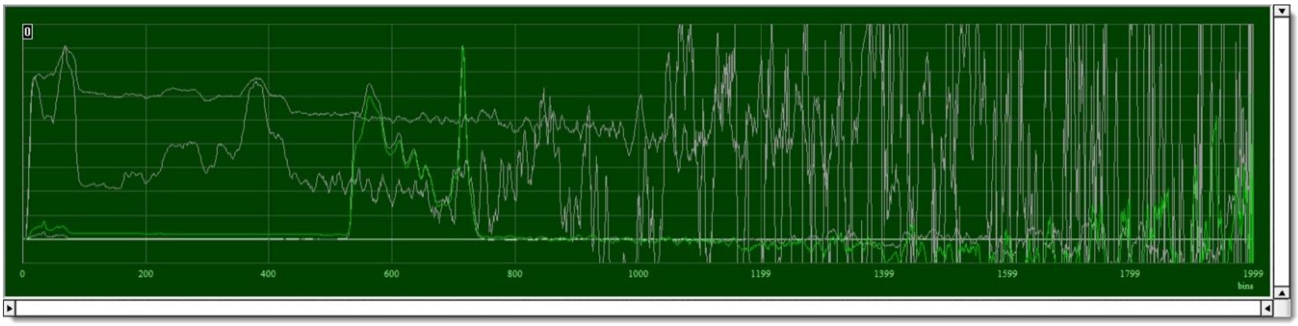


Figure 37

Press «Process» button to start calculations (figure 34).

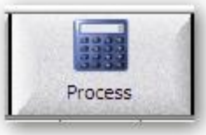


Figure 34

Smoothing calculated plot

If necessary, smooth the profile obtained processing result by pressing the «Delimiter» button (figure 35) and is given gate in the grid table for averaging.

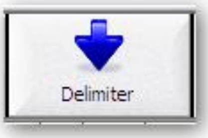


Figure 35

Saving results

Press «Save DB» button to store results into database (figure 36).

Figure 36

Program version info

Press «About» button (figure 37) to become familiar with the current version of the program (figure 38).

Figure 37

Figure 38

Error messages

In the case of erroneous actions of the operator program inform of the pop-up window prompts, for example (figure 39).

Figure 39

Mathematical algorithm of data processing

Input signal

The input signal is the output signal of the program Synthesizer:

- λ wavelength, given parameter in the database;
- $P_n^* = P^*(l_n)$; $n \in (N1, N2)$ lidar signal, icon (*) denotes a measured value. The values of the primary and the synthesized signal are recorded in the OLEData array into field “Array”;
- B^* background value recorded in the parameter “Background” field, in the synthesized (joint) signal is always equals to zero;
- B_n^* background for the raw signal, $B_n^* = B^*$ effective background for the synthesized signal, specified as an array into field “Barray”;
- accumulation value in the raw signal is stored into field “Accumulation”. In the synthesized signal is stored into “Aarray” field array;
- Z_0 zenith angle for the raw signal into field “Zenith”, in the synthesized (joint) signal – зенитный угол трассы, на которую проектируются все лидарные сигналы, записан в строке параметров в ячейке “Zenith”;
- Z_n для простого сигнала $Z_n = Z_0$, в синтезированном сигнале – зенитный угол трассы, по которым производиться зондирование, записывается массивом ZenithArray (в Excel таблице – “ZArray”)

- $N^*(n)$ - исходный сигнал, для простого сигнала $N^*(n) = P_n^*$; для синтезированного сигнала ???
- $N^*(n)$ is initial signal (for a simple signal $N^*(n) = P_n^*$ and for a synthesized signal ???)
- $N^*(n)$ записан массивом OriginalSignalArray, (в Excel таблице – SArray);
- $N^*(n)$ is written by array OriginalSignalArray, (in the Excel table it corresponds SArray);
-
- Таблица CIRA – региональная модель атмосферы, xls – файл.
- Table CIRA represents regional atmospheric model (see the corresponding xls file).

4.2. Параметры для обработки

4.2. Parameters for the data processing

- B - Base – дополнительная к фону постоянная составляющая, определяется в таблице главного меню программы TropoServer;

- B or Base is an additional to the background constant component that is defined in the Table by the basic menu of the computer code TropoServer;

- N1, RD1, RD2, N2 – граничные точки шкалы расстояния при усреднении; RD1, RD2 определяются в таблице главного меню программы OpticalCalculator;

- N1, RD1, RD2, N2 are the boundary points of the distance scale after the averaging; RD1, RD2 are defined in the Table of the main menu of the code OpticalCalculator;

- RG1; RG2; RG3 – значения полуширины окна усреднения M_n (число стробов) в граничных точках (RD1; RD2, N2). В граничной точке N1 окно усреднения равно 0; определяются в таблице главного меню программы OpticalCalculator;

- RG1; RG2; RG3 are the values of the half-width of the window averaging (number of gates) at the boundary points (RD1; RD2, N2). At the boundary point N1 averaging window is equal to 0. These values are defined in the table of the main menu of OpticalCalculator;

- *s* – шаг дискретизации;

- *s* is the sampling step;

- $p_a(l) = \varepsilon_a(\lambda, l) / \beta_a(\lambda, l)$ - аэрозольное лидарное отношение; вводится таблицей меню Parameters, открываемой кнопкой Parameters в таблице главного меню; задается как константа или кусочно-постоянная;

- $p_a(l) = \varepsilon_a(\lambda, l) / \beta_a(\lambda, l)$ is the aerosol lidar ratio, which is defined by the basic menu in the Table of parameters. The menu can be opened by the button Parameters in the Table of the basic menu (is defined as a constant or piecewise constant);

- $p_m = \varepsilon_m(\lambda, n) / \beta_m(\lambda, n) = 8\pi / 3 = 8.377$ - молекулярное лидарное отношение molecular lidar ratio;

- λ - длина волны, задается параметром ??? wavelength is defined by parameter ???

-

- $\varphi = \dfrac{\delta\beta_m(n)}{\beta_m(n)}$ - относительная погрешность оценки показателя обратного рассеяния молекулярного рассеяния; вводится из таблицы меню Parameters, открываемой кнопкой Parameters в таблице главного меню; задается как константа;

- $\varphi = \dfrac{\delta\beta_m(n)}{\beta_m(n)}$ is the relative error of the estimated molecular backscattering coefficient, which is introduced from the table menu Parameters. It can be opened by Parameters button in the table of the main menu and is defined as a constant value.

- $\theta = \frac{\delta p_a}{p_a}$ - относительная погрешность оценки лидарного отношения is the relative error of the estimated lidar ratio;

- v - параметр нелинейности канала регистрации; определяется параметром nonleniar в таблице главного меню программы OpticalCalculator is the nonlinearity parameter of the registration spectral channel, which determined by the nonleniar parameter in the table main menu OpticalCalculator;

- g - амплитуда шума темнового тока и случайного шума в канале регистрации, определяется параметром Nonsinchron в таблице главного меню программы OpticalCalculator is the amplitude of the dark noise and random noise in the channel registration, which is defined by the parameter in the table Nonsinchron main menu of OpticalCalculator;

- u - амплитуда синхронной помехи в канале регистрации, определяется параметром Sinchron в таблице главного меню программы OpticalCalculator is the synchronous amplitude noise in the channel registration, which is defined by the parameter in the table Sinchron main menu OpticalCalculator;

- q - коэффициент дробового шума в канале регистрации, характеристика канала регистрации; вводится параметром shot_noise в файле prn.ini программного пакета OpticalCalculator is a shot-noise ratio in the channel registration. We introduce this important characteristic by parameter shot_noise in the prn.ini file of OpticalCalculator software package;

4.3. Предварительная обработка
4.3. Preliminary data processing

Производятся операции:

The following operations are performed:

- расчет сигнала signal calculations $\hat{P}_n^* = P^*(l_n) - B^* - B$

- осреднение сигнала с полушириной окна Δ_n, изменяющейся линейным образом по шкале расстояний со значениями (0, RG1; RG2; RG3) в граничных точках (N1, RD1; RD2, N2)/

Averaging of the signal under the half-width of the window Δ_n. In so doing, the half-width is changed linearly on the distance scale with values (0, RG1; RG2; RG3) at the boundary points (N1, RD1; RD2, N2) /

$$\left\langle \hat{P}_n^* \right\rangle = \frac{1}{2\Delta_n + 1} \sum_{n+\Delta_n}^{n+\Delta_n} \left(\hat{P}_n^* \right) \tag{1}$$

4.4. Расчет показателя обратного рассеяния молекулярной атмосферы
4.4. Computations of the molecular backscattering coefficient

Предусматриваются три варианта расчета молекулярной модели??? (плотности атмосферы).

There are three ways of how to compute the molecular model (the density of the atmosphere).

а)- Стандартная модель атмосферы Standard model of the atmosphere:

Расчет показателей молекулярного ослабления??? и обратного рассеяния:

Computations of the molecular extinction and backscattering:

Для расчета показателей молекулярного ослабления и рассеяния используются оценки и таблицы, полученные в работах:

To compute the molecular extinction and backscattering we use data from the following references:

1. Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations. CALIOP Algorithm Theoretical Basis Document. Document No: PC-SCI-201. 2006.
2. Rayleigh scattering coefficients and linear depolarization ratios at several EARLINET lidar wavelengths. Volker Freudenthaler, Feb. 2010, version 1.4d

Спектральные зависимости коэффициентов в формулах, определяющих показатели молекулярного ослабления и рассеяния, аппроксимируются аналитическими выражениями и соответствуют результатам расчетов в [1, 2] с точностью до 0.1%.

The spectral dependence of the molecular extinction and scattering are approximated by analytical expressions and the approximation errors are within 0.1% as compared with the reference data in [1, 2].

Показатель молекулярного рассеяния $\sigma_m(n,\lambda)$ на расстоянии $l_n = ns$ рассчитывается по формуле

The molecular scattering coefficiant $\sigma_m(n,\lambda)$ at the distance $l_n = ns$ is calculated using the following equation

$$\sigma_m(n,\lambda) = C_s(\lambda)\frac{P(ns\times\cos(Z_0)+H_0)}{T(ns\times\cos(Z_0)+H_0)}\frac{M}{R^*}\frac{R^*}{M} = \frac{R^*}{M}C_s(\lambda)\hat{d}(ns\times\cos(Z_0)+H_0) = \quad (2)$$
$$= 287.05287 C_s(\lambda)\hat{d}(ns\times\cos(Z_0)+H_0)[1/m]$$

$H_n = ns\times\cos(Z)+H_0)$ - высота над уровнем моря.

where $H_n = ns\times\cos(Z)+H_0)$ is altitude above sea level.

Здесь: Z - зенитный угол; H_0 - высота размещения лидара над уровнем моря.

Here Z is zenith angle and H_0 is the lidar altitude location above sea level.

Параметр $C_s(\lambda)$ определяется формулой:

Parameter $C_s(\lambda)$ is defined by the equation:

$$C_s(\lambda) = 0.01\left(a + b\lambda^c\right)^{-\frac{1}{d}}\left[K/(Pa*m)\right] \quad (3)$$

$$\lambda[nm],$$

где where a= -21.693798344267826;

b= 0.00087342438635830215;

c= 2.2366776150227192;

d= 0.55824437003908689

Показатель обратного молекулярного рассеяния определяется формулой:

The molecular backscattering coefficient is defined by the following equation:

$$\beta_m(n,\lambda) = \frac{3}{8\pi}\frac{\sigma_m(ns\times\cos(Z_0)+H_0,\lambda)}{k_{C,T}(\lambda,\Delta\lambda)}, \quad (4)$$

Или

or

$$\beta_m(n,\lambda) = \frac{3}{8\pi}\frac{1}{k_{C,T}(\lambda,\Delta\lambda)}\frac{R^*}{M}C_s(\lambda)d\left(ns\times\cos(Z_0)+H_0\right) = 34.26441\frac{1}{k_{C,T}(\lambda,\Delta\lambda)}C_s(\lambda)d\left(ns\times\cos(Z_0)+H_0\right)$$

$$P_m(\lambda) = \frac{8\pi}{3}k_{C,T}(\lambda,\Delta\lambda)$$

где $k_{C,T}(\lambda,\Delta\lambda)$ - поправочный коэффициент, учитывающий долю молекулярного вращательного комбинационного сигнала в регистрируемом лидарном сигнале [1,2];

where $k_{C,T}(\lambda,\Delta\lambda)$ is a correction coefficient that accounts for the proportion of molecular rotational Raman lidar signal in the recorded lidar signal [1,2];

$$k_{C,T}(\lambda,\Delta\lambda) = k_c(\lambda) - \Delta k(\lambda) W(\lambda,\Delta\lambda) \quad (5)$$

$$\Delta k(\lambda) = k_C(\lambda) - k_T(\lambda,\Delta\lambda)$$

В формуле (5) параметры $k_c(\lambda), \Delta k$ определяются выражениями

In equation (5), parameters are defined by the following expressions

$$k_c(\lambda) = \sqrt{a_1 + a_2\lambda^2 + \frac{a_3}{\lambda^2} + \frac{a_4}{\lambda^4}}\,, \quad (6)$$

где

where

a_1 = 1.0779363729155738;

a_2 = -1.4114618324124403E-11;

a_3 = 896.96823089693635;

a_4 = 52062355.046277404

$$\Delta k(\lambda) = a\lambda^{b+\frac{c}{\lambda}} + d\,, \quad (7)$$

где a= 5.371109819764088;

b= -1.48754255361213716;

c= 81.002440828712594;

d= 0.024633566682161448

Параметр $W(\lambda, \Delta\lambda)$ вычисляется из выражения:

Parameter $W(\lambda, \Delta\lambda)$ can be defined by the following equation

$$W(\lambda, \Delta\lambda) = W(x_0) = \int_0^{x_0} \frac{x}{b^2} \exp\left(-\frac{x^2}{2b^2}\right) dx \quad (8)$$

или

or

$$W(\lambda, \Delta\lambda) = W(x_0) = 1 - \exp\left(-\frac{x_0^2}{3528}\right) \quad (9)$$

где

where

$$x_0 = 10^7 \left(\frac{1}{\lambda} - \frac{1}{\lambda + \frac{\Delta\lambda}{2}} \right) \quad (10)$$

$\lambda[nm]$

b= 42

$\Delta\lambda$ - спектральная ширина интерференционного фильтра в канале регистрации лидарного сигнала

$\Delta\lambda$ is a spectral width of the interference filter in the channel registration lidar signal

$W(x_0) \Rightarrow 0$ если if $x_0 \Rightarrow 0$ и and

$W(x_0) \Rightarrow 1$ если if $x_0 \Rightarrow \infty$, точнее $\Delta\lambda > 10nm$.

При обработке данных Института физики будем брать $\Delta\lambda = 4nm$ или, в обратных сантиметрах – 88.

In the data processing at Institute of Physics we will assume $\Delta\lambda = 4nm$ or, in the reciprocal centimeters - 88. As this takes place $W(x_0) \approx 0.75$.

4.5. Расчет высотных профилей давления и температуры

4.5. Calculation of vertical profiles of temperature and pressure

P_n - атмосферное давление в Па, T_n - температура в градусах Кельвина.

Давление и температура воздуха рассчитываются послойно.

Pressure and temperature are calculated in layers.

Введем переменное:

Let us consider a variable

$$L_n = \frac{rH_n}{r + H_{n\ n}} \tag{11}$$

r - радиус Земли

where r is radius of the Earth

Тогда температура воздуха определиться выражением:

Then the temperature is determined by the expression:

$$T_n = T^* + b(L_n - L_n^*), \tag{12}$$

Знак * обозначает нижнюю границу слоя;

The sign * indicates the lower boundary layer;

$$L_n^* = \frac{rH_n^*}{r + H_{n\,n}}, \tag{13}$$

H_n^* - нижняя граница слоя, которому принадлежит строб n.

H_n^* is the lower boundary layer, which owns the strobe

Давление определяется выражениями:

The pressure can be defined by the following equations

$$P_n = 10^{\lg P_n}; \tag{14}$$

$$\lg P_n = \lg P^* - \frac{g_c}{b\hat{R}} \lg\left(\frac{T_n^* + b(L_n - L_n^*)}{T_n^*}\right) \quad \text{если if } b > 0 \text{ или or } b < 0 . \tag{15}$$

$$\lg P_n = \lg P^* - \frac{0.434294 g_c}{\hat{R}T}(L_n - L_n^*) \quad \text{если if } b = 0 . \tag{16}$$

Параметры слоев атмосферы, используемые для расчета профилей температуры и давления атмосферы, приведены в таблице 1.

Atmospheric parameters used to calculate the temperature and pressure profiles of the atmosphere are given in Table 1.

Пример расчета приведен в Excel файле Atmosph_mol_model.xls

A typical example of the calculations are given in Excel file Atmosph_mol_model.xls

Таблица 1 - Таблица параметров слоев атмосферы

Table 1 - Table represents parameters for different Atmospheric layers

Номер слоя	H*(min)	H(max)	T*	b	r	g_c	$\hat{M}$	$\hat{R}^*$	$\hat{R}$	P*
	m	m	K	K/m	m	m/(c^2)	kg/kmol	J/(K*kmol)	J/(kg*K)	Pa
1	0	11019	288.15	0.0065	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	101325
2	11019	20063	216.65	0	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	22632.28
3	20063	32162	216.65	0.001	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	5474.992
4	32162	47350	228.65	0.0028	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	868.0056
5	47350	51412	270.65	0	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	110.9071
6	51412	71802	270.65	0.0028	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	66.94258
7	71802	86152	214.65	-0.002	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	3.956316
8	86152	95411	186.65	0	**6356767**	**9.80665**	**28.96442**	**8314.32**	**287.0528 7**	0.363404

ь)-Сезонная региональная модель атмосферы CIRA-86

b) regional seasonal model of the atmosphere CIRA-86

Представлена специальной Excel-таблицей **CIRA.xls**.

This model is presented by a special Excel-table CIRA.xls.

Модель задает профили давления и температуры на границах атмосферных слоев в Северном полушарии для определенной полосы широт и определенного месяца.

The model defines pressure and temperature profiles at the borders of the atmospheric layers in the Northern Hemisphere for a certain latitude band and for a certain month.

Аппроксимация внутри слоя:

Approximation within the layer:

- для температуры - линейная T(h)=T(i)+(T(i+1)-T(i))*(h-h(i))/(h(i+1)-h(i))

It is linear for the temperature T(h)=T(i)+(T(i+1)-T(i))*(h-h(i))/(h(i+1)-h(i))

- для давления – логарифмически линейная lgp(h)=lgp(i)+(lgp(i+1)-lgp(i))*(h-h(i))/(h(i+1)-h(i))

and log-linear for the pressure lgp(h)=lgp(i)+(lgp(i+1)-lgp(i))*(h-h(i))/(h(i+1)-h(i))

c) - custom model

Может использоваться модель, созданная пользователем. Представляется файлом, аналогичным CIRA.xls модели CIRA.

It is possible to use any other model created by the user. In this case, the custom model is represented by a file, which is similar to CIRA.xls of CIRA model.

4.6. Расчет показателя обратного аэрозольного рассеяния

4.6. Computational of the aerosol backscattering coefficient

Расчет показателя обратного аэрозольного рассеяния $\beta_{a,n} = \beta_a(l_n)$ по трассе зондирования в точке n на расстоянии $l_n = n \times s$ от лидара производится по формуле

Computational of the aerosol backscattering coefficient $\beta_{a,n} = \beta_a(l_n)$ along the track of sensing at a point of n and at a distance $l_n = n \times s$ from the lidar is based on the following equation

$$\beta_{a,n} = -\beta_{m,n} + \frac{X^*(l_n)\exp\left[-2\int_{l_r}^{l_n}(p_a(l) - p_m)\beta_m(l)\frac{dl\cos(Z_0)}{\cos(Z(l))}\right]}{\frac{X^*(l_{n_r})}{\beta_{a,n_r} + \beta_{m,n_r}} - 2\int_{l_r}^{l_n} p_a(l)X(l)\exp\left[-2\int_{l_r}^{l}(p_a(\zeta) - p_m)\beta_m(\zeta)\frac{d\zeta\cos(Z_0)}{\cos(Z(\zeta))}\right]\frac{dl\cos(Z_0)}{\cos(Z(l))}}$$

(17)

Здесь

In this equation

$dl > 0$, $d\zeta > 0$ если if $l_n > l_{n_r}$ $(n > n_r)$

и and

$dl < 0$, $d\zeta < 0$ если if $l_n < l_{n_r}$ $(n < n_r)$

В выражении (16) использованы обозначения:

In equation (16) we use the notation:

$$X^*(l_n) = \langle \hat{P}_n^* \rangle l_n^2,$$

где where $l(n) = n \times s$ - расстояние is a distance;

$l_r = n_r \times s$ - расстояние до реперной точки is a distance to the reference point;

s – шаг дискретизации is the sampling step;

n – номер строба is a number of strobe;

n_r - номер строба реперной точки is a number of strobe for the reference point;

$\beta_a(l)$ - показатель аэрозольного обратного рассеяния is the aerosol backscattering coefficient;

$\beta_m(l)$ - показатель молекулярного обратного рассеяния is the molecular backscattering coefficient;

$p_a(l) = \varepsilon_a(\lambda, l) / \beta_a(\lambda, l)$ - аэрозольное лидарное отношение is the aerosol lidar ratio;

$p_m = \varepsilon_m(\lambda, n) / \beta_m(\lambda, n) = 8\pi / 3 = 8.739$ - молекулярное лидарное отношение is the molecular lidar ratio for aerosol;

ε_a - показатель аэрозольного ослабления is the aerosol extinction coefficient;

ε_m - показатель молекулярного ослабления is the molecular extinction coefficient;

λ - длина волны is wavelength

4.7. Расчет среднеквадратичного отклонения оценки показателя обратного аэрозольного рассеяния

4.7. The calculation of the standard deviation for the estimated aerosol backscattering coefficient

$$\delta\beta_{a,n} = \sqrt{R_n^2\beta_{m,n}^2\left(\left(\frac{1}{R_n^2}+\frac{1}{R_{n_r}^2}\right)\varphi^2+v^2\left(N^*(n)\right)^2+\frac{1+g^2+q^2N^*(n)}{A_n(2M+1)\left(N^*(n)-B_n^*\right)^2}+\frac{u^2}{\left(N^*(n)-B_n^*\right)^2(2M+1)}+\right.\\ \frac{1+g^2+q^2N^*(n_r)}{A\ (2M+1)\left(N^*(n_r)-B_{n_r}^*\right)^2}+\frac{u^2}{P^2(n_r)(2M+1)}+\frac{\delta^2\beta_{a,n_r}}{\beta_{m,n_r}^2}+\\ \left.+4\varphi^2\left(\sum_{i=n_r}^{i=n-1}p_m\beta_{m,i}\frac{s\cos(Z_0)}{\cos(Z_n)}\right)^2+4\theta^2\left(\sum_{i=n_r}^{i=n-1}p_{a,i}\beta_{a,i}\frac{s\cos(Z_0)}{\cos(Z_n)}\right)^2\right)}$$

(18)

Здесь In this equation

$$R_n = \frac{\beta_{a,n}+\beta_{m,n}}{\beta_{m,n}}$$

4.8. Расчет показателя обратного аэрозольного рассеяния при наличии данных радиометра

4.8. Computation of the aerosol backscattering coefficient when the radiometer data are available

Признаком перехода к расчету по данному алгоритму является наличие записи τ_R в ячейке **CTau** главной таблицы меню программы **OpticalCalculator**.

Sign of the transition to the calculation according to this algorithm is the existence of a record in the primary table cell CTau (menu OpticalCalculator).

В этом случае формула расчета показателя обратного рассеяния остается такой же, как (16).

In this case, equation for calculating the backscattering coefficient remains similar to that in equation (16)

Однако в (16) вместо параметра β_{a,n_r} и параметра p_a, задаваемые в основной таблице в разделе **Parameters,** используются их оптимальные значения $\hat{\beta}_{a,n_r}$ и $\hat{p}_a$, которые определяются из условия минимума функционала:

At the same time, instead of parameters β_{a,n_r} and p_a in equation (16) we have to utilize their optimal values that could be found by minimizing the following quadratic form:

$$W = \sqrt{\frac{\left(\tau_R - Cos(Z)\,p_a\left(\sum_{n1}^{n2}\beta_a(n,\beta_{a,n_r},\hat{p}_a) + \beta_a(n1)\times n1\times s\right)\right)^2}{\tau_R^2} + C_1^2 \exp\left(\frac{(P_R-\hat{p}_a)^2}{C_2^2 P_R^2}\right)} \quad (19)$$

где where τ_R - аэрозольная оптическая толща на длине волны is the aerosol optical thickness at a wavelength of λ из радиометрических измерений from radiometric measurements, записанная в главной таблице меню программы OpticalCalculator, в ячейке CTau The wavelength is indicated in the main table menu in the sell CTau;

P_R - лидарное отношение, полученное из радиометрических измерений,

записанное в главной таблице меню программы TroposServer, в ячейке CLR. Если запись отсутствует, считается, что $P_R = p_a$ - где p_a - значение лидарного отношения, записанное в основной таблице в разделе Parameters;

P_R is the lidar ratio retrieved from the radiometric measurements. The ratio is recorded in the basic menu of the Table (sell CLR). If there is no recorded value in the cell then it means that что $P_R = p_a$ where p_a is the lidar ratio value recorded in the basic table (section Parameters).

$\beta(n1)$ - значение показателя обратного рассеяния в нижней точке измерений is value of the backscattering coefficient at the lower measuring point;

$C_1 = \mathrm{cf\_br}$ - весовой множитель, задается в параметрах файла prn.ini, записано

cf_br=1.000000

$C_2 = \mathrm{cf\_pl}$ - масштабный множитель, задается в параметрах файла prn.ini,

записано cf_pl=1.000000

Параметр $\hat{\beta}_{a,n_r}$ может изменяться в диапазоне **[bs_min - bs_max]***Ref Backs,** где величины **bs_min** и **bs_max** указаны в файле **prn.ini**; записаны: bs_min=-2.000000; bs_max=2.000000

The parameter $\hat{\beta}_{a,n_r}$ can range **[bs_min - bs_max] * Ref Backs**, where the quantities **bs_min** and **bs_max** are listed in the file prn.ini; they are written as bs_min = -2.000000; bs_max = 2.000000

Параметр $\hat{p}_a$ может изменяться в диапазоне **[p_min - p_max]*** P_R**,** где величины **p_min** и **p_max** указаны в файле **prn.ini**; записаны p_min=0.400000; p_max=4.000000.

The parameter $\hat{p}_a$ can range **[p_min - p_max] *** p_R, where the quantities **p_min** and **p_max** are listed in the file **prn.ini** and recorded as p_min = 0.400000; p_max = 4.000000.

После получения решения рассчитать его эффективность: отношение $\frac{W_{res}}{W_0}$ - отношение результирующего значения функционала W к его начальному значению, рассчитанному по нулевому приближению, когда параметры $\hat{\beta}_{a,n_r}$ и $\hat{p}_a$ равны их табличным значениям; значение эффективности записать в окошко главного меню. Определяется пороговое значение эффективности (**relerror=1.00000** в **prn.ini).** Если эффективность решения выше порогового, считается, что решение не найдено и оставляется нулевое решение.

The computer code permits estimation of the retrieval efficiency. By this reason, we estimate the ratio of the resulting functional value to its initial value($\frac{W_{res}}{W_0}$)calculated by the zero-order approximation, when the parameters $\hat{\beta}_{a,n_r}$ and $\hat{p}_a$ are equal to their tabulated values. The efficiency value is written in the main menu window. Determined threshold efficiency (relerror = 1.00000 in prn.ini). If the efficiency of the solution exceeds the threshold, it is assumed that the solution has not been found and remains to the trivial one.

После получения решения параметры $\hat{\beta}_{a,n_r}$ и $\hat{p}_a$ записываются в окошки главного меню.

We recorded parameters $\hat{\beta}_{a,n_r}$ and $\hat{p}_a$ in the windows of the main menu when the retrieval is completed.

Если оптимизированное решение для показателя обратного аэрозольного рассеяния получено, то погрешность его оценки определяется по следующей формуле:

When an optimized solution for the aerosol backscattering coefficient is obtained then, the error of its assessment is determined by the following equation:

$$\delta\beta_{a,n} = \sqrt{R_n^2\beta_{m,n}^2\left(\left(\frac{1}{R_n^2}+0x\frac{1}{R_{n_r}^2}\right)\varphi^2+v^2\left(N^*(n)\right)^2+\frac{1+g^2+q^2N^*(n)}{A_n(2M+1)\left(N^*(n)-B_n^*\right)^2}+\frac{u^2}{\left(N^*(n)-B_n^*\right)^2(2M+1)}+\frac{1+g^2+q^2N^*(n_r)}{A\ (2M+1)\left(N^*(n_r)-B_{n_r}^*\right)^2}+4\varphi^2\left(\sum_{i=n_r}^{i=n-1}p_m\beta_{m,i}\frac{s\cos(Z_0)}{\cos(Z_n)}\right)^2+4\theta^2\left(\sum_{i=n_r}^{i=n-1}p_{a,i}\beta_{a,i}\frac{s\cos(Z_0)}{\cos(Z_n)}\right)^2\right)}$$

(20)