ALGORITHMS AND SOFTWARE FOR LIDAR DATA PROCESSING IN CIS-LINET

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ABSTRACT

A software package is developed for lidar data processing to provide data uniformity and quality assurance in the CIS-LiNet lidar network. Software development is targeted to implement all procedures for data processing in CIS-LiNet while atmosphere aerosol and ozone sounding. The package is free for distribution for all teams beyond of the CIS-LiNet.

1. INTRODUCTION

To provide data uniformity and quality assurance in the CIS-LiNet lidar network, it was decided to design, as far as possible, a multi-purpose software package, which will be opened for the extension and to install it at all CIS-LiNet stations. The package includes the program to convert CIS-LiNet data base files into EARLINET [1] ones. Information concerning new programs versions and their description are presented at CIS-LiNet info-site: http://www.cis-linet.basnet.by/. The package is free for distribution for all teams beyond of the CIS-LiNet.

2. STRUCTURE OF SOFTWARE PACKAGE

Software package structure as well as current status of its development is presented at the Fig. 1. The package developed envisages performing the following data processing stages:
- Measurement of lidar signals and their presentation as a database.
- Visualization and preliminary processing of lidar signals.
- Preliminary processing of additional information (primarily, data of the AERONET network [2]).
- Retrieval aerosol parameters.
- Presentation of the processed data as a database file

3. ESSENTIAL FEATURE

3.1 Storage of row and processed data as a Database

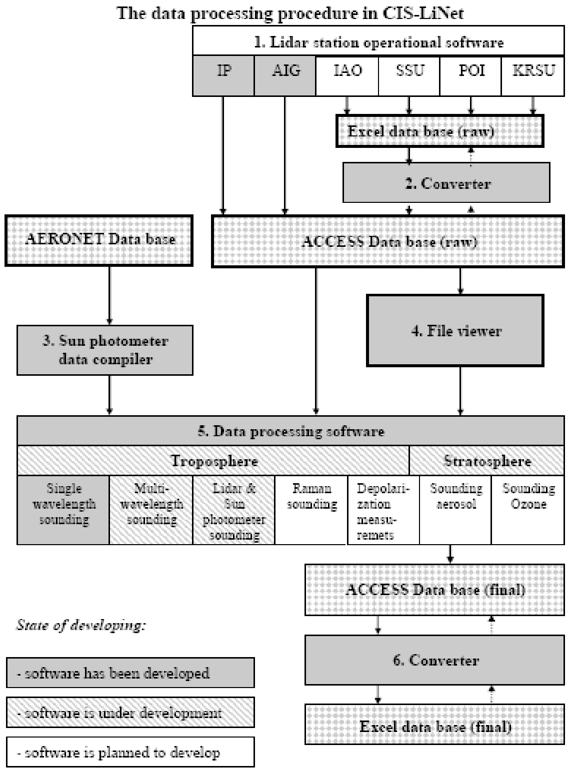

Fig. 1. The structure of the software package

Row and processed data are stored not as the set of separate files, bat as DATABASE. The database ACCESS was selected as a basis. Row database is created and updated during the measurements by the **UIIS** program. Final database with processed data is created and updated by a processing program.

3.2 Designing additional programs for processing Sunphotometer/AERONET data and for convert of ACCECC data files to EXCEL tables and vice versa

The special program for Sun-photometer data compile (**Make_Files**) calculates optical aerosol thickness at a lidar sounding wavelength as well as aerosol backscatter coefficient integral over the atmospheric layer and contribution of fine and coarse aerosol fractions to the coefficient while making a full cycle of radiometric measurements. Two **CONVERTER** variants have been developed to convert ACCESS-files containing data measured or processed into EXCEL Tables.

3.3 Construction of main processing program as shell program and processing modules

The mane program for retrieval aerosol and ozone parameters **(Troposerver)** includes a **Shell program** (SP) and **Processing modules** (PM). The SP is being designed as a universal program operating with different calculation modules and providing input of lidar and AERONET radiometer measurement data, preprocessing of raw data, transferring of the data to a PM, visualization of raw data and of processing results, writing processing results to the database.

3.4 Processing algorithms

The Processing Modules are being designed as a dynamic link library (DLL) to be loaded by the shell program. Presently 3 modules are designed for data processing of single-wavelength lidar sounding:

- **PM-1** - step-by-step aerosol backscatter retrieving $\beta_a(z)$ from maximum altitude z_0

$$\beta_a(z_n) = -\beta_m(z_n) + \frac{X(z_n)}{X(z_0)} \times T^2(z_n, z_0) \qquad (1)$$

$$T(h_n, H) = \exp[-\tau(z_n, z_0)] \qquad (2)$$

$$\tau(z_n, z_0) = \tau(z_{n-1}, z_0) + \\ + [S_a(z_n)\cdot \beta_a(z_{n-1}) + S_m(z_n)\cdot \beta_m(z_n)](z_{n-1} - z_n) \qquad (3)$$

Here: $X(z) = P(h) * z^2$; $P(h)$ - lidar signal; $S_a(\lambda, z)$ - aerosol lidar ratio; $S_m(\lambda, h)$ - molecular lidar ratio; a_m and β_m - molecular extinction and backscatter coefficients. Reference value $\beta_a(z_0)$ and lidar ratio S_a are calibration parameters and should be estimated or guessed from a priori information.

Calculation of the errors $\delta\beta_a(z)$ in retrieved parameter β_a using the finite difference estimation method.

- **PM-2** - Klett- Fernald equation: well-known lidar equation solution is used in the form:

$$\beta_a(z) = -\beta_m(z) + \frac{X(z)\exp\left[-2(S_a - S_m)\int_{z_0}^{z}\beta_m(\zeta)d\zeta\right]}{\frac{X(z_0)}{\beta_a(z_0)+\beta_m(z_0)} - 2S_a\int_{z_0}^{z}X(\zeta)\exp\left[-2(S_a - S_m)\int_{z_0}^{\zeta}\beta_m(z')dz'\right]d\zeta} \qquad (4)$$

For moderate values of aerosol optical thickness and small step Δh of lidar signal array formation both algorithms (1-3) and (4) lead to the close results.

- **PM-3** – for retrieving backscatter coefficient $\beta_a(z)$ with using Sun radiometer data from AERONET.

Additional AERONET radiometer data that are τ_a^* - aerosol optical thickness and S_a^* - aerosol lidar ratio. They enable one to give objective estimation of calibration parameters $\beta_a(z_0)$ and S_a while retrieving altitude profiles of aerosol characteristics.

In that case profile $\beta_a(z)$ is calculated by the algorithm of Eq. (4), but the parameters S_a and $\beta_a(z_0)$ are determined as ones minimizing the functional:

$$\frac{(\tau_a^* - \tau_a)^2}{\tau_a^{*2}} + W\left[1 - \exp\left(-\frac{(S_a^* - S_a)^2}{2\sigma_S^2}\right)\right] \qquad (5)$$

Here $\tau_a = S_a \int_{z1}^{z2} \beta_a(z)dz$.

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4. REFERENCES

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