25B2 TECHNIQUE FOR DETERMINING ATMOSPHERIC AEROSOL OPTICAL PARAMETERS BY MULTI-WAVELENGTH LASER SOUNDING

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At the single scattering approximation, the lidar signals $P(\lambda_i,z)$ are related to atmospheric optical parameters by the set of equations governing multi-wavelength sounding (Ref.1)

$$P(\lambda_i,z) = A(\lambda_i,z)\,P_0(\lambda_i,z)\,z^{-2}\beta_\pi(\lambda_i,z)*$$

$$*\exp\left(-2\int_0^z \sigma(\lambda_i,z')dz'\right), \qquad (1)$$

In (1), z is range from lidar, λ_i the wavelength, i=1,...,n, n the number of working wavelengths, $A(\lambda_i,z)$ the system constant, $P_0(\lambda_i)$ the laser output energy, $\beta_\pi(\lambda_i,z)$ and $\sigma(\lambda_i,z)$ the backscatter and extinction respectively coefficients,

$$\beta_\pi(\lambda_i,z) = \beta_{\pi a}(\lambda_i,z) + \beta_{\pi m}(\lambda_i,z), \quad (2)$$

$$\sigma(\lambda_i,z) = \sigma_a(\lambda_i,z) + \sigma_m(\lambda_i,z), \quad (3)$$

In above, subscripts "a" and "m" represent the values for aerosol and air molecules respectively. The values $\beta_{\pi m}(\lambda_i,z)$ and $\sigma_m(\lambda_i,z)$ can be evaluated with the air density profile.

The equations (1)-(3) involve n measured functions $P(\lambda_i,z)$ and $2n$ functions $\beta_{\pi a}(\lambda_i,z)$, $\sigma_a(\lambda_i,z)$ which remain to be determined. It is obvious, the equations (1)-(3) need to be added by another relation before to be inverted for aerosol spectral parameter profiles. We use the relationship between the values $\beta_{\pi m}(\lambda_i,z)$ and $\sigma_a(\lambda_i;z)$ by the operator W, which was defined earlier in Ref.1, viz. $\sigma_a(\lambda_i,z) = W\ [\beta_{\pi a}(\lambda_j,z)]$, i,j=1,...,n.

From our point of view, in processing multi-wavelength data use can be made of the approximate estimator for $\sigma_a(\lambda_i,z)$, built as the multi-dimension linear regression, i.e.

$$\sigma_a(\lambda_i,z) = \sum_j c_j(\lambda_i)\beta_{\pi a}(\lambda_j,z). \quad (4)$$

The coefficients $c_j(\lambda_i)$ of Eq.(4) can be find with including apprior information about properties of the statistical ensemble formed by probable aerosol particle size distributions. Our information respecting the statistical ensemble proceeds from the assumption that aerosol is as composed by the fractions, let of number m, having different causes of origin. The fractions and their mean particle size distributions $\varphi_0^q(r)$ are taken from the atmospheric models presented by Ref.2. In the basis of deriving the coefficients $c_j(\lambda_i)$ the requirement lies that

$$g = \overline{\left(\sigma_a(\lambda_i) - \sum_j c_j(\lambda_i)\beta_{\pi a}(\lambda_j)\right)^2} = \min \quad (5)$$

where the overscribed bar is the designation for the ensemble average. When the number n of working wavelengths is fairly large and $n>m$, it is expedient to introduce additional linear constraints, for the estimator (4) be more insensitive, as follows

$$\sigma_a^q(\lambda_i) = \sum_j c_j(\lambda_i)\beta_{\pi a}^q(\lambda_j), \quad q=1,\dots,m. \quad (6)$$

The physical meaning of Eq.(6) is that the estimator of the form (4) gives an exact extinction coefficient value at given backscatter ones, if aerosol particle size distribution is rigorously defined by a linear combination of the modeling functions $\varphi_0^q(r)$. The calculation for the arrays $c_j(\lambda_i)$ based on Eqs.(5), (6) is the usual computer practice. It requires the covariant for particle size distribution be previously independently specified. For this, we use statistical information from literature concerning data obtained by aerosol counters. Note, the approach based on Eqs.(5), (6) can be used with no modification to find another aerosol integral characteristics (e.g., mass concentration, mean section) with experimental data.

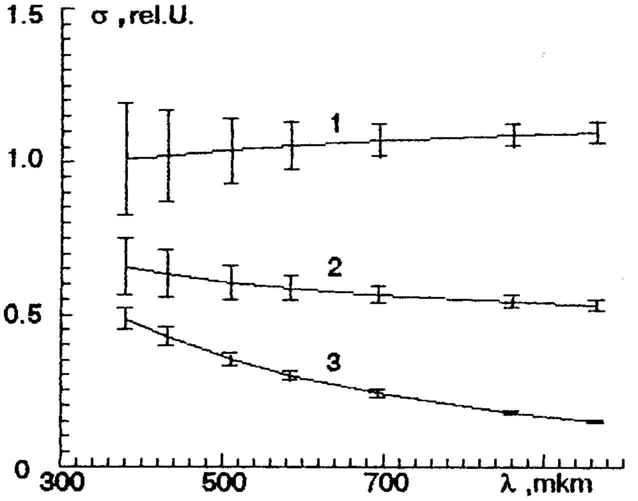

Fig.1. The effect of observation error on accuracy for $\sigma_a(\lambda_i)$ provided by estimator (4): 1 - Oceanic; 2 - Maritime, 3 - Water-soluble.

Fig.1 illustrates the numerical experiment that seeks to ascertain effect of observation error on accuracy for $\sigma_a(\lambda_i)$ provided by estimator (4). In the experiment, the aerosol fractions and their microphysical parameters, therefore the functions $\varphi_0^q(r)$, were taken from the aerosol model "maritime" of Ref.2. Three situations were considered. At the given fractions $\varphi_0^q(r)$ the precise extinction and backscatter values were first calculated at the seven wavelengths. In the figure, results for the extinction are denoted by 1,2,3. As the second step, the random error subjected to the normal distribution of the variance ten per cent were introduced for the backscatter coefficient. Then, at the given $\beta_{\pi a}(\lambda_i)$, i=1,...,7, and random error, the extinction coefficient spectra $\tilde{\sigma}_a(\lambda_i)$ were reconstructed by Eq.(4) with the predetermined matrix formed by the coefficients $c_j(\lambda_i)$. The procedure was repeated 8000 times to provide statistical data behavior. The calculated variance for $\sigma_a(\lambda_i)$ is marked at the correspond lines in the figure.

The iterative algorithm employing Eqs.(1-4) has been described in Ref.3. It has two main distinct features. First, the chosen reference point is the end point of sounding. This gives the advantage to get result in the form of converging solutions (Ref.4). Second, the algorithm includes the procedure to correct the aprior backscatter coefficient at the reference point, which allows for the calibration data at the start point of sounding.

From our report in Ref.5 one can see that the processing data technique, presented above, met with success in immediate practical determining aerosol characteristics from lidar sounding experiments.

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