# THE DIFFERENTIAL METHOD FOR DETERMINATION OF BASIC OPTICAL PARAMETERS OF ATMOSPHERIC AEROSOL IN UV BAND

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In the article "The differential method for determination of basic optical parameters of atmospheric aerosol" the new approach to calculation of optical depth and Junge index is proposed. This approach is based on proposed differential method and previously proposed three-wavelength method of measurements in UV band.

It is well known, that the aerosol is one of main parts of the Earth's Atmosphere. The basic optical parameter of the atmospheric aerosol is optical depth of aerosol and some other parameters, including Junge index [1]. Also it is well-known, that main and widely used method for determination of aerosol optical depth is Langley method [2].

The essence of this method is that we should take logarithm from both sides of equation of extinction of optical irradiation in atmosphere and bring this equation to the linear type, where slope of which will be equal to linear sum of separate optical depths:

$$\tau_{\sum} = \tau_{aer} + \tau_{oz} + \tau_{mol} + \tau_{\mathrm{Re}\,y}, \qquad (1)$$

where $\tau_{aer}, \tau_{oz}, \tau_{mol}, \tau_{\mathrm{Re}\,y}$ are accordingly optical depths of aerosol, total ozone, gas molecules and Reyleigh scattering.

In Langley method in order to calculate $\tau_{aer}$ we should use known, computed, or measured outside of UV band parameters $\tau_{oz}$, $\tau_{mol}$ and $\tau_{\mathrm{Re}\,y}$ for some fixed wavelengths.

Therefore problems related with direct measurements of optical depth of aerosol in UV band leads to necessity to carry out non-direct measurements and then to calculate the optical depth using parameters determined outside of UV band. Here we also should note that well – known ozonometrical method of Dobson envisages in some cases removal of aerosol error using two pair of wavelength method for linear approximation of wavelength dependence of aerosol optical depth, but this method doesn't allow us to carry out aerosol measurements removing influence of atmospheric ozone.

As a result the Dobson method cannot be considered as universal and accurate method for research of optical parameters of components of the atmosphere in UV band. Such a universal property is possessed according to our view – point by three-wavelength method of atmospheric measurements in UV band that was described in [3].

In this article we shall describe the variant of application of this method for determination of main optical parameters of aerosol. First of all we should describe the differential method that will be also used. As it is well known [1], the optical depth of aerosol $\tau_{\lambda\,aer}$ is determined by Ongstrem formula

$$\tau_{\lambda\,aer} = C\,\lambda^{-\alpha}, \qquad (2)$$

where *C*- parameter of Ongstrem; $\alpha$ - parameter related with Junge index *n* as follows:

$$\alpha = n - 3.$$

Taking derivative of equation (2) on $\lambda$ we have following equation

$$\frac{d\tau_{\lambda\,aer}}{d\lambda} = -\alpha\,C_1\,\lambda^{-(\alpha+1)} \qquad (3)$$

or

$$\frac{\Delta\tau_{\lambda\,aer}}{\Delta\lambda} = -\alpha\,C\,\lambda^{-(\alpha+1)}. \qquad (4)$$

The foregoing formula (4) is the basis of proposed differential method. The formula (4) is the transcendental equation in relation to parameter $\alpha$, and this equation may be solved using graphic method.

The essence of the graphic method includes plotting of set of curves of function

$$\frac{\Delta\tau_{\lambda\,aer}}{\Delta\lambda} = f(\alpha, \lambda, \tau_0) \qquad (5)$$

for given discrete values of $\lambda$, for given continuous interval $\alpha = \alpha_{min} \div \alpha_{max}$.

The crossing points of above curves with the horizontal line $y = \frac{\Delta\tau_{\lambda\,aer}}{\Delta\lambda}$ will give us needed values of $\alpha_1, \alpha_2, \ldots, \alpha_n$. This process of solution of equation (5) is illustrated conditionally in fig. 1.

It is obvious, that solution of equation (5) envisage presence of estimate of differential parameter $\frac{\Delta\tau_{\lambda\,aer}}{\Delta\lambda}$. In order to calculate this parameter we use abovementioned three-wavelength method.

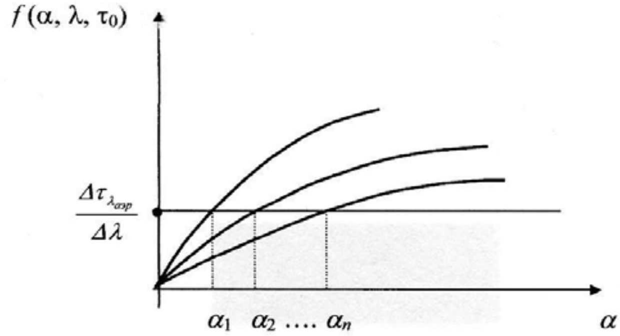


*Fig. 1.* Schematic illustration of proposed method.

Now we describe in brief the basics of this method and the variant of its application for considered task. According to three-wavelength method we should carry out measurements in three-wavelength $\lambda_1$, $\lambda_2$, $\lambda_3$ where $\lambda_1 < \lambda_2 < \lambda_3$. As a result we obtain parameters $I_1(\lambda_1)$; $I_2(\lambda_2)$ and $I_3(\lambda_3)$ which accord to intensities of Solar irradiation at the Earth level in appropriate wavelengths. Then we should calculate following relative parameter $Z$

$$z = \frac{\sqrt[d]{I_1(\lambda_1)\cdot I_3(\lambda_3)}}{I_2(\lambda_2)}, \qquad (6)$$

where $d=2\pm\Delta$; $\Delta$ - parameter which is regulated by computer.

For further description of the method we use the Bouger – Beer formula, which in general may be written as

$$I = \Delta\lambda \cdot \omega \cdot S_0 \cdot 10^{-\left[\gamma\,\mu\, X + \tau_{Rey}\, m + \tau_{aer} m_1\right]}, \qquad (7)$$

where $S_0$- the solar irradiation flux at the level of upper border of the atmosphere; $\gamma$ - optical absorption of ozone; $\mu$ - optical mass of ozone; $X$ - total content of ozone; $\tau_{Rey}$ - optical depth of Reyleigh scattering; $m$ - optical mass of Reyleigh scattering; $\tau_{aer}$ - optical depth of aerosol; $m_1$ - optical mass of aerosol.

Taking into considerations formulas (6) and (7) we have:

$$z = \frac{\sqrt[d]{S_{01}\cdot S_{03}}}{S_{02}}\cdot 10^{-\left[\mu X\left(\frac{\gamma\lambda_1+\gamma\lambda_3}{d}-\gamma\lambda_2\right)+m\left(\frac{\tau_{Rey\lambda_1}+\tau_{Rey\lambda_3}}{d}-\tau_{Rey\lambda_2}\right)+m_1\left(\frac{\tau_{aer\lambda_1}+\tau_{aer\lambda_3}}{d}-\tau_{aer\lambda_2}\right)\right]}. \qquad (8)$$

In order to obtain the aerosol part of formula (8) we should regulate the parameter $d$ in such order that meets following equation

$$\mu X\left[\frac{\tau_{0\lambda_1}+\tau_{0\lambda_3}}{d}-\tau_{0\lambda_2}\right]+m\left[\frac{\tau_{Rey\lambda_1}+\tau_{Rey\lambda_3}}{d}-\tau_{Rey\lambda_2}\right]=0. \qquad (9)$$

The indication of meeting of the condition (9) is to be carried out by auto correlation analysis of parameter $Z$. The computer should regulate the value of $d$ till achievement of maximal value of ratio of high frequency component of parameter $Z$, to the low frequency part because the aerosol has most variability among other components of atmosphere. After meeting the condition (9) the equation (8) will be transformed to following formula

$$z = \frac{\sqrt[d]{S_{01}\cdot S_{03}}}{S_{02}}\cdot 10^{-m\left(\frac{\tau_{aer\lambda_1}+\tau_{aer\lambda_3}}{d}\tau_{aer\lambda_2}\right)}. \qquad (10)$$

Then assuming linear type of dependence of function $\tau_{aer}(\lambda)$ in narrow band $\lambda_1 \div \lambda_3$ we have

$$z = \frac{\sqrt[d]{S_{01}\cdot S_{03}}}{S_{02}}\cdot 10^{-m\left(\tau^*_{aer\lambda_1\lambda_3}-\tau_{aer\lambda_2}\right)}, \qquad (11)$$

where

$$\tau^*_{aer\lambda_1\lambda_3} = \frac{\tau_{aer\lambda_1}+\tau_{aer\lambda_3}}{d}. \qquad (12)$$

From the equation (11) we obtain following formula

$$\left(\tau^*_{aer\lambda_1\lambda_3}-\tau_{aer\lambda_2}\right) = ln\frac{\sqrt[m+d]{S_{01}\cdot S_{03}}}{\sqrt[m]{z\cdot S_{02}}}. \qquad (13)$$

Taking into consideration the linear dependence of $\tau_{aer}(\lambda)$ in the narrow band $\lambda_1 \div \lambda_3$ we have

$$\frac{\Delta\tau_{aer\lambda_1,\lambda_2,\lambda_3}}{\Delta\lambda^*} = \frac{1}{\Delta\lambda^*}ln\frac{\sqrt[m+d]{S_{01}\cdot S_{03}}}{\sqrt[m]{z\cdot S_{02}}}, \qquad (14)$$

where

$$\Delta\lambda^* = \left|\frac{\lambda_1+\lambda_3}{d}-\lambda_2\right|. \qquad (15)$$

Therefore, the considered combination of proposed differential method and three-wavelength method allows us to obtain estimates of differential parameter $\frac{\Delta\tau_{\lambda aer}}{\Delta\lambda}$, which is necessary for calculation of parameter $\alpha$ and parameter $n$ using formula (4).

Summarizing the foregoing we can formulate the proposed method of calculation of atmospheric aerosol optical parameters (optical depth and Junge index) as follows.

1. Carrying of three-waves measurements, in such regime, when ratio of high – frequency component of autocorrelation function of parameter $Z$ to low frequency part reaches its maximal value.
2. Calculation of differential parameter $\frac{\Delta\tau_{\lambda aer}}{\Delta\lambda}$ on the basis of data, obtained during realization of item 1.
3. Carrying out of graphical solution of equation (5) shown in fig. 1.

In conclusion we should stress out, that the proposed differential method in comparison with the Langley method bases on results of direct measurements in UV band, which conditions high authenticity of results obtained using this method.

[1] *P. Gushchin, N.N. Vinogradova.* Total Content of Atmospheric Ozone, Leningrad, Gidrometeoizdat, 1983. (In Russian).

[2] *T.F. Eck, B.N. Holben, L.S. Reid.* J. of Geoph. Res., 1999, v.104D, N.24, p.31.

[3] *H.H. Asadov, M.M. Aliyev, A.A. Isayev*. Fizika, 2004, v.X, N.1-2, p. 52-56.


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## ATMOSFERDƏKİ AEROZOLUN ƏSAS OPTİK PARAMETRLƏRİNİN UB DİAPAZONDA TƏYİN EDİLMƏSİ ÜÇÜN DİFFERENSİAL METOD

Qeyd edilmişdir ki, mövcud metodlar atmosferdə aerozolun optik sıxlığını UB diapazonda dəqiq təyin etməyə imkan vermirlər. UB diapazonda atmosferdəki aerozolun optik sıxlığını təyin etmək üçün Anqstrem qanununa və əvvəllər təklif edilmiş üç dalğalı ölçmə metoduna əsaslanan differensial metod təklif edilmişdir. Metod riyazi cəhətdən əsaslandırılmış, onun tətbiqi ardıcıllığı şərh edilmişdir.

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## ДИФФЕРЕНЦИАЛЬНЫЙ МЕТОД ДЛЯ ОПРЕДЕЛЕНИЯ ОСНОВНЫХ ОПТИЧЕСКИХ ПАРАМЕТРОВ АЭРОЗОЛЯ АТМОСФЕРЫ В УФ ДИАПАЗОНЕ

Отмечено, что существующие методы не позволяют точно определить оптическую плотность аэрозоля атмосферы в УФ диапазоне. Для определения оптической плотности аэрозоля атмосферы в УФ диапазоне предложен дифференциальный метод на основе закона Ангстрема и ранее предложенного трехволнового метода измерений. Дано математическое обоснование метода, пояснено последовательность его применения.

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