It is shown to be theoretically possible to balance out almost completely the total error in measurements with a three-wave ozone meter used to determine the total ozone content in the atmosphere. The working algorithm is given together with the theoretical basis for the compensation condition.

Key words: ozone content, aerosol error, ozone meter, optical density, two-wave method.

The basic method measuring total ozone in the atmosphere is [1] a two-wave one based on Bouguer’s law on the attenuation of radiation in the atmosphere, which takes the form

\[ S_\lambda = S_{\lambda_0} \cdot 10^{-10 \alpha_\lambda X + \beta_\lambda m + \delta_\lambda m_1}, \]  

where \( S_\lambda \) is the flux of direct solar radiation at the Earth’s surface; \( S_{\lambda_0} \) is the flux at the outer surface of the atmosphere; \( \alpha_\lambda \) is the radiation absorption parameter for ozone at wavelength \( \lambda \); \( X \) is the total ozone in the atmosphere; \( \beta_\lambda \) is the optical density of the clean atmosphere, which is characterized by Rayleigh scattering; \( \delta_\lambda \) is the optical density of the atmospheric aerosol at wavelength \( \lambda \); and \( \mu, m, \) and \( m_1 \) are the relative optical densities of the ozone layer, the clean atmosphere, and the layer of aerosol, which are their ratios in the inclined direction to the corresponding densities in the vertical direction.

The physical meaning of (1) is that the attenuation is due to absorption by the ozone, scattering in the clean air, and attenuation in the aerosol.

The error in measuring the total ozone by the two-wave method (\( \lambda_1 \) and \( \lambda_2 \)) can [1] be found from

\[ \Delta X = \frac{\beta_{\lambda_1} - \beta_{\lambda_2}}{\alpha_{\lambda_1} - \alpha_{\lambda_2}} m X + \frac{\delta_{\lambda_1} - \delta_{\lambda_2}}{\alpha_{\lambda_1} - \alpha_{\lambda_2}} m_1 X. \]  

The first component in line (2) characterizes the measurement error due to the Rayleigh scattering in the atmosphere and the second represents the effect from the aerosol attenuation.

We have proposed a new three-wave method of measuring the total ozone, which enables one to eliminate almost completely the aerosol error or perform complete mutual compensation of the above two error components [2].

Here we consider the general aspects of the implementation of this three-wave method.

The general algorithm for three-wave ozonometry can be presented as a sequence of operations:

1. One measures the direct radiation flux at the Earth’s surface at wavelengths \( \lambda_1, \lambda_2, \) and \( \lambda_3 \), in which \( 300 \text{ nm} < \lambda_1 < \lambda_3 < \lambda_2 < 340 \text{ nm} \), which give the corresponding readings at the ozonometer output: \( I_{\lambda_1}, I_{\lambda_2}, \) and \( I_{\lambda_3} \), where we note that \( \alpha_\lambda \) increases as \( \lambda \) decreases [1], so the relation is \( I_{\lambda_1} < I_{\lambda_3} < I_{\lambda_2} \).
2. One calculates from the formula

\[ I_c = \frac{2\pm\Delta}{\sqrt{I_{\lambda_1} I_{\lambda_2}}}, \]

where \( \Delta \) is a correcting quantity whose meaning is explained below.

3. We calculate the ratio

\[ \frac{I_c}{I_3} = \frac{2\pm\Delta}{\sqrt{I_{\lambda_1} I_{\lambda_2}}}. \]  

(3)

4. We determine the correcting parameter \( \Delta \) for a particular realization of the three-wave method (eliminating the aerosol error or providing complete mutual balancing of the above two errors in measuring the total ozone content).

5. We calculate the total ozone content.

Before we give a detailed explanation of this algorithm, we consider the logic circuit (Fig. 1) of the measuring device, where \( I \) is an ultraviolet photocell used for all the measurement channels, 2 the preamplifier, 3 a two-position switch, 4 and 5 shaping amplifiers, 6 programmed multiplication unit and the extraction of the roots of degree \( 2 \pm \Delta \); 7 unit formulating the quantity \( \Delta \), 8 block recording the given condition for compensating the error, and 9 the device for calculating the ratio \( S_c/S_3 \) and determining the total ozone content.

It is clear that in the technical implementation, all the functions of the units 6–9 may be combined in a single microprocessor.

We now formulate the error balancing conditions. From (1) and the actual widths of the optical spectral channels, we have that (3) can be put in the following extended form:

\[
\frac{I_c}{I_3} = 10 \left\{ \frac{m_1(\delta_{\lambda_1} + \delta_{\lambda_2})}{2\pm\Delta} \right\} \int_{\lambda_{11}}^{\lambda_{21}} \omega_{\lambda_1} S_{\lambda_1} \cdot 10^{-\alpha_{\lambda_1} X_{\mu}} d\lambda \times
\]

\[
\times 2\pm\Delta \int_{\lambda_{22}}^{\lambda_{12}} \omega_{\lambda_2} S_{\lambda_2} \cdot 10^{-\alpha_{\lambda_2} X_{\mu}} d\lambda \left[ 10^{-(m_1\delta_{\lambda_3} + m\beta_{\lambda_3})} \int_{\lambda_{13}}^{\lambda_{23}} \omega_{\lambda_3} S_{\lambda_3} \cdot 10^{-\alpha_{\lambda_3} X_{\mu}} d\lambda \right]^{-1},
\]

(4)

where \( \lambda_{1i} \) and \( \lambda_{2i} \) are the transmission limits of optical channel \( i \), whose spectral sensitivity is \( \omega_{\lambda_i} \).

From (4) we get the above condition for the first way of realizing the three-wave meter with complete compensation of the aerosol error:

\[
\frac{\delta_{\lambda_1} + \delta_{\lambda_2}}{2\pm\Delta} = \delta_{\lambda_3}.
\]  

(5)

The condition for the second case with complete mutual compensation of the errors takes the form

\[
\frac{m_1(\delta_{\lambda_1} + \delta_{\lambda_2})}{2\pm\Delta} + \frac{m(\beta_{\lambda_1} + \beta_{\lambda_2})}{2\pm\Delta} = m_1\delta_{\lambda_3} + m\beta_{\lambda_3}.
\]

(6)

The linear dependence of the aerosol attenuation coefficient on the wavelength enables us to write (5) as

\[
\frac{\delta_{\lambda_1} + \delta_{\lambda_2}}{2} = \delta_{\lambda_3},
\]

and in that case it is not necessary to adjust \( \Delta \).