APPLICATION OF NUMERICAL MODEL OF RADIATIVE TRANSFER IN THE ATMOSPHERE FOR CALIBRATION OF NET SPECTROPHOTOMETERS AND INTERPRETATION OF THE RADIATION MEASUREMENTS IN THE UV

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We consider in this paper a numerical model of the radiation transfer and the method of field calibration of the instrumentation operated in the UV spectral region. Under favorable atmospheric conditions the distortions introduced by the atmospheric layer into the Sun brightness may be small enough thus enabling one to exactly take those into account. Using that type of calibration procedure the instrumentation readouts are referred to the Sun brightness as if it is observed at the upper boundary of the atmosphere. As the estimates made show the accuracy of absolute power calibration of spectrophotometers that are operated in the 310 nm *region is better than 5% at the spectral irradiance values above* 65 W/($\mathrm{m}^2\cdot\mu\mathrm{m}$). *We also present in the paper a description of the software complex for calculating the UV radiation field in the atmosphere – underlying surface system that allows for multiple aerosol and Rayleigh light scattering, absorption of light by aerosol as well as the absorption at lines of atmospheric gases, while simultaneously taking into account the reflecting properties of the underlying surface. Some results of a comparison made between the calculated and experimentally measured values are being discussed in the paper as well.*

1. INTRODUCTION

The decrease in the atmospheric ozone content has an important consequence that the UV flux reaching the Earth surface increases.[1] Such an increase could be easily calculated if the spatial features of the long-term behavior of ozone in the atmosphere were known, as well as the variations of all other factors determining the radiation transfer, for example, extinction of radiation by aerosol and clouds. Because of the lack of reliable information about these processes the direct measurements on the Global Atmospheric Watch (GAW) incorporating the background and ozonometric stations[2] are used to estimate trends in the UV radiation in different geographic regions.

Normally, Brewer spectrophotometers and instruments of some other types[3] are used to measure UV radiation fluxes. Those instruments provide for acquiring spectral distribution of the solar radiation energy reaching the Earth's surface in the UV–A (320–400 nm) and UV–B (280–320 nm) regions. Since the main task of the network measurements is to detect trends of the order of units of percent per a decade, the calibration and comparison of the instruments distributed round the world and operated under strongly varying conditions[1–3] is the key element in the maintenance of the observation system.

Brewer spectrophotometers and other similar devices for measuring the UV radiation fluxes are calibrated using standard lamps that, in their turn, are certified by the method of comparison with the state standard sources, or with certified emitters of a higher class. The metrological system for quantifying the spectral illuminance measured with the spectral devices in the UV solar spectrum using the primary state standard is described in Refs. 4 and 5.

As a rule, tungsten ribbon-filament lamps are used as standards. Calibration of the field instruments with the help of such lamps is not reliable enough because those are certified only for the radiation coming from a small portion of the ribbon-filament within a narrow angular pattern. Emitters of a diffuse type, in the form of incomplete photometric sphere with a halogen lamp built-in into the sphere, have been developed[6–8] at the measurement network to meet the similarity of the spatial and angular characteristics of the radiation field from the calibration source and the radiation field measured with an instrument at the observation stations. Much sophisticated laboratory installations are normally used to certify these emitting spheres by comparing with the standard lamps. The total error that can provide thus calibrated, in the laboratory conditions, meters in measurements of the illuminance is estimated[7] to be about 12%.

The spectrophotometers that are operated at a number of European stations to measure the illuminance by solar radiation in the UV spectral region, and which are regularly calibrated, have been compared in Panorama (Greece) in 1992, and in Garmisch-Partenkirchen (Germany) in 1993.[4,5] Ratios of the illuminance measured with these instruments to some reference values depend on the zenith angle of the Sun, and mainly are in the range from 0.9 to 1.1. The values of the illuminance obtained by averaging readouts from three instruments that showed the lowest discrepancies were taken as the reference ones. Such a procedure of estimation provides for revealing the lowest level of errors.

In this paper we propose a technique for field calibration of spectrophotometers that uses the Sun as a standard reference source. Under favorable atmospheric conditions (clear sky, high altitude of the station) the influence of the atmosphere on the illuminance of the Earth's surface may be quite weak, and thus it can accurately be taken into account. In this case the control of readouts of an instrument may be done using the solar radiation flux incident on the top of the atmosphere. In the 290–320 nm region it is a stable value ($m < 2\%$), provided that the dependence on the orbital motion of the Earth relative to the Sun is excluded.

Thus, the error of calibration against the natural source is determined by the accuracy with which the atmospheric transmission function is known, and, in principle, may be noticeably higher than that when calibrating using an artificial source of radiation. Since the UV radiation measurements in the GAW network are carried out simultaneously with the observations of active gases, aerosol, as well as of some other optical parameters of the atmosphere, these data bring the model closer to real conditions in a given place and at a given time. In case of a long-term comparison one can verify the model even more comprehensively.

The model proposed is based on the operator method of solving the radiation transfer equation. Other optical models of the atmosphere are also known and widely used.[10–13] On the whole, all these models describe the optical properties of the atmosphere more or less reliably. We use the operator method as being sufficiently accurate and most convenient for including in the existing software of the Brewer spectrophotometers that are most widely employed at the World's network of atmospheric monitoring.

2. DESCRIPTION OF THE PROGRAM COMPLEX FOR CALCULATION OF THE UV RADIATION TRANSFER IN THE ATMOSPHERE

The optical model of the atmosphere is being built on the basis of the solution of the radiation transfer equation. We have chosen the operator method of solution of the radiation transfer equation primarily because it is quite convenient for creating the corresponding computer codes on a PC. Solution of the one-dimensional transfer equation can be obtained accurate to any degree desired. We propose to use the method we have developed in the form of the program complex "TestB as a computational method to accurately allow for the optical properties of the atmosphere. The Sun radiance, in the 0.27–0.35 μm region, is calculated taking into account multiple Rayleigh scattering, extinction by aerosols, absorption of radiation at the spectral lines of the atmospheric gases, and reflection properties of the underlying surface.

Six program modules can be isolated in the program by their functional purpose. The basic module defines the sequence of operations and governs the execution of other modules. There are also blocks of atmospheric parameters, Fourier transformations, integral and matrix operations, and integration over the layers in this program. The software package is also supplied with the database of geographic and spectrometric constants. The modular structure of the program provides for a possibility of replacing one or other of its blocks depending on the error level desired, spectral region, etc. Cloud amount, type of clouds, the cloud base height, thickness of the cloud layer have been added to the array of the initial input data, as compared to the previous version of the program,[16] as well as the user interface has been developed to make the software IBM PC compatible. The interface is operated in DOS environment. Presented below is a description of the atmospheric model used.

3. THE ATMOSPHERIC MODEL USED

The atmospheric model used includes NSL-parameters that is k, Σ, Σ_r, ΔL, for each wavelength, where NSL is the number of homogeneous atmospheric layers. The values of the absorption and scattering coefficients, Rayleigh scattering coefficient, and thickness are set for each atmospheric layer. The number of plane atmospheric layers in this model of the atmosphere may be varied by a user in order to achieve optimal accuracy. The phase function for every atmospheric layer is calculated by the following formula:

$$P(\gamma) = \frac{\tau_a}{\tau_a + \tau_r} P_a(\gamma) + \frac{\tau_r}{\tau_a + \tau_r} P_r(\gamma), \tag{1}$$

where $P_a(\gamma) = R + A(1 + B\cos^2\gamma)^{-m}$ and $P_r(\gamma) = \frac{3}{16\pi}(1 + \cos^2\gamma)$ are the aerosol and Rayleigh scattering phase functions, respectively; τ_r, τ_a are the Rayleigh and aerosol optical thickness for each atmospheric layer, respectively; R, A, B, m are parameters describing aerosol scattering phase function; γ is the scattering angle; λ is the wavelength.

Let us first consider a simple exponential model to describe variations of the aerosol scattering and absorption with altitude. Often such a model quite closely describe natural situations.[11] Secondly, we have a possibility to model a variety of the vertical distributions at a fixed optical thickness by varying only one parameter which may be the altitude of homogeneous atmosphere. Third, as calculations show, down going radiation flux is determined by the optical thickness of the atmosphere and only weakly depends on the height distribution of aerosol. The dependence of aerosol absorption and scattering coefficients on height z is described by the following expressions:

$$K_a(\lambda, z) = K_a(\lambda, 0)\exp(-z/H);$$
$$\Sigma_a(\lambda, z) = \Sigma_a(\lambda, 0)\exp(-z/H), \qquad (2)$$

where H is the height of homogeneous aerosol atmosphere, that is an input parameter of the program. In calculations the height dependence of aerosol scattering and absorption coefficients is expressed through the optical thickness:

$$\Sigma_a(\lambda, z) = \frac{\tau(\lambda)\exp(-z/H)}{H\,[1 + \rho(\lambda)]}; \qquad (3)$$

$$K_a(\lambda, z) = \frac{\tau(\lambda)\,\rho(\lambda)\exp(-z/H)}{H\,[1 + \rho(\lambda)]}. \qquad (4)$$

The function $\rho(\lambda)$ in the relations (3) and (4) is the ratio

$$\rho(\lambda) = K_a(\lambda, z)/\Sigma_a(\lambda, z).$$

The formula relating $\rho(\lambda)$ to the macroscopic parameters of aerosol follows from the Mie theory:

$$\rho(\lambda) = \frac{\int x^2\,[Q(x) - Q_s(x)]\,n(x)\,\mathrm{d}x}{\int x^2\,Q_s(x)\,n(x)\,\mathrm{d}x}, \qquad (5)$$

where x is the reduced radius of particles; Q and Q_s are the Mie efficiency factors of extinction and scattering, respectively; $n(x)$ is the density of particle-size distribution. The values of $\rho(\lambda)$ function are tabulated for several types of aerosol and may vary in the program in the interactive regime. Concentration of the atmospheric particles $N(z)$ is determined by the equation of ideal gas $P = NkT$, where T is temperature; k is the Boltzmann constant, P is the pressure.

The thickness of atmospheric layers is chosen so small that the temperature in each layer may be presented as $T = T - \eta z$, where $\eta = -\mathrm{d}T/\mathrm{d}z$ is the vertical temperature gradient which is constant within each layer. In an isothermal layer ($\eta = 0$) the pressure and concentration of the gases are determined by the relationships:

$$N(z) = N_0\exp(-mgz/kT_0);$$
$$P(z) = P_0\exp(-mgz/kT_0). \qquad (6)$$

In the isogradient layer the following relationships are valid:

$$N(z) = N_0\left(\frac{T_0 - \eta z}{T_0}\right)^{(mg/\eta k - 1)};$$

$$P(z) = P_0\left(\frac{T_0 - \eta z}{T_0}\right)^{(mg/\eta k)}, \qquad (7)$$

where m is the parameter, which has a dimension of mass and is chosen in such a way that provides for better agreement between the atmospheric temperature and pressure variation with height and the model of standard atmosphere; g is the acceleration of gravity. Temperature and pressure in each atmospheric layer are calculated from layer to layer using the pressure and temperature values near the ground surface, which serves as an input parameter to the program. Absorption coefficient for each layer is calculated as a sum of the aerosol absorption coefficient, and absorption caused by water vapor, oxygen, ozone, and other atmospheric gases. Variation of the water vapor density and ozone with height is given in the form of an array and corresponds to a standard atmosphere. The actual density of a gas within each layer is obtained by multiplying its standard density by the ratio Ω/Ω_{st}, where Ω is total gas content which is an input parameter to the program, Ω_{st} is the total gas content from the model of the standard atmosphere. Weak dependence of the ozone absorption cross-sections on temperature may be neglected.

The above described model of the atmosphere assumes the typical distribution functions of the optical and meteorological parameters with height in the absence of strong upward fluxes and well developed mixing under weather conditions favorable for calibration, for example, under a steady state anticyclone. Let us call such an atmospheric model as the 4quasi-balance’ one.

4. CONSIDERATION OF THE ILLUMINANCE FROM CLOUDS

In the above version of the atmospheric model the program can calculate the radiation field in the approximation of a plane atmosphere. However, such situations, are observed rather rarely. The contribution to the illuminance of the entrance pupil of an instrument due to multiple reflections of solar radiation from clouds must be properly accounted for to reduce the measurement errors. The approach we used in our study is described below.

Cloudiness is considered as a plane atmospheric layer with the parameters of absorption and scattering corresponding to type of clouds chosen. Solution of the radiation transfer equation is obtained for this case in a way similar to that normally used for a clear sky atmosphere. The field of scattered radiation in the atmosphere I is sought as a combination of two fields in the form:

$$I = (1 - b)\,I_0 + bI_b, \qquad (8)$$

where I_0 is the field of scattered radiation in a clear sky atmosphere; I_b is the field of scattered radiation with a plane cloudy layer; b is the relative cloud amount $(0 < b < 1)$. The component of attenuated solar radiation is represented in two forms. The first one corresponds to the direct solar irradiation. The second one corresponds to the irradiation in the shadow from clouds. The approach proposed is quite justified for the case of uniform spatial distribution of clouds and low cloud amount $b < 0.3$. More accurate approximations should take into account the distribution of clouds. Even if the program could allow one to make such calculations without approximations, the problem should certainly arise in that case on the determination of all input parameters including cloud heights, their mutual disposition, etc. Unfortunately, no data are available on the spectral absorption and scattering coefficients of different clouds from the literature. Therefore there is still some uncertainty in the absorption and scattering constants in the cloudiness. One can use the data of numerical modeling,[14] or address to the Lowtran spectroscopic database. Some qualitative consequences of using our model can be experimentally proved. The influence of the background albedo on the UV radiation intensity in near the ground surface has been confirmed experimentally.[15] An increase in the scattered UV radiation intensity caused by snowfalls may reach up to 40%. To make a detailed comparison, data of more accurate systematic and quantitative observations are needed.

Let us turn to the results. The illuminance of the input pupil of an instrument in the control example presented was calculated using the following values of the input parameters. The temperature was taken to be 297°C, pressure to 1 atm, radiation wavelength to 0.3 μm, aerosol optical thickness to 1.2, albedo of the surface at the observation point to 0.1, total ozone content to 0.3 cm, and the height of homogeneous atmosphere to 1.75 km. Along with this the calibration errors of the instrument have been studied by calculating the illuminance at the entrance of a spectrometer at different input parameters of the program 4TEST'. The error of radiation calibration has been investigated using the following relationship:

$$\Delta I = \left|\frac{\partial I}{\partial p}\right| \Delta P + \left|\frac{\partial I}{\partial t}\right| \Delta T + \left|\frac{\partial I}{\partial O_z}\right| \Delta O_z + $$

$$+ \left|\frac{\partial I}{\partial \tau}\right| \Delta\tau + \left|\frac{\partial I}{\partial A}\right| \Delta A + \left|\frac{\partial I}{\partial b}\right| \Delta b, \qquad (9)$$

where ΔO_z is the uncertainty in ozone content, $\Delta\tau$ is the uncertainty of the aerosol optical thickness; ΔA is the uncertainty in the albedo; ΔT and ΔP are the uncertainties of temperature and pressure; Δb is the uncertainty of the cloud amount. The analysis performed has shown that the uncertainty in the ozone content introduces the largest error to the calibration dependence. In Table I, as an example, the experimental and calculated values of the illuminance by the UV radiation are given.

Calculations were made using the following parameters: 1) $\lambda = 311$ nm, non-resonance optical thickness is 2.2, albedo for the background is 0.05; 2) $\lambda = 319$ nm, non-resonance optical thickness is 1.8, albedo for the background is 0.1.

TABLE I. Dependence of illuminance, W/(m^2·μm), *of the Earth's surface by UV radiation on the total ozone content.*

Date of measurement		8.02.97	11.03.97	15.03.97	25.11.96	11.11.96	18.11.96	9.11.96	8.10.96
Ozone content, cm		0.378	0.333	0.320	0.298	0.291	0.278	0.265	0.258
Zenith angle of the Sun, °		70.24	70.637	69.811	69.848	70.254	70.273	69.756	67.434
319 nm.	Measured	81.50	73.84	77.98	76.77	78.42	74.97	81.19	76.07
	Calculated	80.94	87.23	89.14	92.53	93.65	95.73	97.89	99.08
311 nm.	Measured	17.79	17.87	21.34	22.45	22.82	23.15	26.97	26.05
	Calculated	21.59	25.95	27.39	30.03	30.92	32.67	34.54	35.58

When making field calibrations of the UV spectrometers, the total ozone content should be controlled either by determining its value with the help of a calibrated instrument, or using different instrumentation and methods (for example, TOMS data). As it follows from the numerical results, the uncertainty in the preset value of the total ozone content is the main source of errors in estimations of the UV radiation influx.

The influence of other input parameters have been investigated in a similar way. The second among the most important parameters is albedo of the underlying surface (the mean reflection coefficient of the landscape around the spectrometer) that governs the lateral illuminance. The next one is the cloud amount. Contribution of the illuminance caused by radiation scattered from clouds may exceed the illuminance from the underlying surface. The aerosol optical thickness along vertical direction and temperature follow on this list. Having the above parameters fixed, one may see that the uncertainties in the assignment of pressure, height of homogeneous atmosphere, and aerosol properties introduce, on the whole, less error than the errors due to the temperature uncertainty.

The spectral illuminance by the UV radiation at different zenith angles of the Sun is given in Table II.

The measurements were carried out on June 9, 1994 during the campaign on intercomparison of spectrophotometers at the aerological observatory of Izan (Tenerife island, 28.3059° N, 16.4495° E, 2400 m altitude above the sea level). The illuminance was calculated by the method described in this paper. The solar constant at the top of the atmosphere was taken to be 537.2 W/(m^2·μm), at the wavelength $\lambda = 300$ nm.

The calibration assumes constructing the relationship between the brightness of a white ($A = 1$) Lambertian screen, in units of W/(m^2·μm), illuminated by direct and scattered solar radiation, and readouts from the instrument. The calibration curve is written as follows:

$$Y = kX + B, \qquad (10)$$

where Y is the spectral illuminance of the screen by the UV radiation in W/(m^2·μm); X is the corresponding readout of the instrument in relative units. The initial data for calibration are presented in Table II. When calculating the illuminance, the albedo of the scattering screen was taken to be equal to 1. The calculated values of the illuminance are quite accurately approximated by a linear function. Values of the calibration coefficients determined by the least squares method were found to be:

$k = 0.0051$, $B = 14.40$.

The rms deviation of the experimental data on the illuminance from a linear function, is $\sigma = 3.41$ W/(m^2·μm). If this value may be considered as the accuracy estimate, then the error of the proposed method does not exceed 5% in the illuminance range above 65 W/(m^2·μm). Comparison of the calculated and measured illuminance values are presented in Table III.

TABLE II. Values of the UV illuminance according to measurements at Izan observatory, June 9, 1994.

Greenwich Time, min	Zenith angle of the Sun,°	Number of readouts	Spectral illuminance, W/(m^2·μm)
536.6	55.65	1390	16.19
559.5	50.68	2543	25.65
593.0	43.34	5430	43.03
615.6	38.37	7932	55.97
653.1	30.13	12397	79.17
690.5	21.93	16878	98.83
724.1	14.74	20117	110.27
765.6	6.973	22449	128.74
787.2	5.474	22741	133.08
791.1	5.624	22931	132.64
815.4	8.77	21660	123.59
847.4	15.08	19566	109.70
903.3	27.15	13321	87.46
959.1	39.42	6669	53.16

TABLE III. Comparison of the calculated I_c and measured I_{exp} illuminance values; τ is the nonresonance optical thickness, τ_t is the total optical thickness.

Wavelength, μm	Ozone content is 0.378 cm Measurements 02.08.97 Zenith angle of the Sun is 59.88°				Ozone content is 0.320 cm Measurements 03.15.97 Zenith angle of the Sun is 59.93°				Albedo
λ	I_{exp}	I_c	τ_t	τ	I_{exp}	I_c	τ_t	τ	A_b
305.5	6.19	9.66	4.042	2.9	11.35	14.15	3.860	2.9	0.005
307.5	17.01	18.48	3.506	2.7	24.72	24.65	3.372	2.7	0.005
310	25.9	23.5	2.785	2.1	32.63	29.39	2.686	2.1	0.005
313	70.43	70.04	2.555	2.1	79.06	81.53	2.495	2.1	0.01
314.5	80.28	60.55	2.333	2.0	84.9	69.22	2.28	2.0	0.1
318	113.58	97.94	2.113	1.8	112.99	106.87	2.08	1.8	0.15
320	168.26	143.01	2.023	1.8	164.77	153.18	1.996	1.8	0.15
320.5	204.97	186.21	2.004	1.6	196.31	200.99	1.975	1.6	0.15
323	162.51	138.14	1.896	1.6	152.43	145.8	1.877	1.6	0.15
324.5	233.76	205.82	1.843	1.6	212.10	213.52	1.829	1.6	0.15
325	209.40	183.40	1.827	1.6	192.73	190.36	1.814	1.6	0.15

5. OBSERVATIONS OF THE UV RADIATION AT KISLOVODSK STATION

Observations of the ultraviolet radiation in the UV–B region as well as total ozone content were carried out at the high-altitude scientific station (HSS) “KislovodskB IAPh, RAS. The station is located in North Caucasus, on Shadzhatmaz plateau in alpine meadow area, its coordinates being 43.73°N, 42.66°E and the altitude above the sea level of 2070 m. Near the station there are no sources of atmospheric pollution, the nearest health resort town Kislovodsk is 18 km far to the North. In a southward direction from the station at a distance of 46.5 km there is the Mt. Elbrus peak of the Main Caucasus mountain ridge. Duration of the insolation in the vicinity of the station is about 2100–2200 hr per year. The number of days favorable for UV radiation and total ozone content measurements using direct solar radiation equals to 280–310. The conditions of clear horizon allow the observations to be performed at sunrise and sunset. At Kislovodsk station regular measurements are being carried out of the spectral composition of solar radiation in the spectral range of 290 to 325 nm as well as of TOC using a Brewer spectrophotometer MKII No. 043 (SCI–TEC Inc., Canada). The spectral resolution of the instrument is of 0.5 nm; a diffuse Teflon plate placed under a quartz cap in the form of a hemisphere, that receives solar radiation serves as a receiving element in the case of observations in the UV–B region. The spectrophotometer measures the radiation flux incident on a horizontal surface from the entire upper hemisphere. The latest calibration of the instrument has been carried out in August, 1996 using a standard lamp and a mobile standard spectrophotometer Brewer No. 017 of the Canadian Environmental service.

The UV–B radiation fluxes (in 295–325 nm region) under clear sky conditions at three zenith angles of the Sun (50, 60, and 70°), at different total ozone content are presented in Figs. 1–3. The observations were carried out since September, 1996 and until March, 1997. Data on the cloudiness were presented by the nearest meteorological station Shadzhatmas.

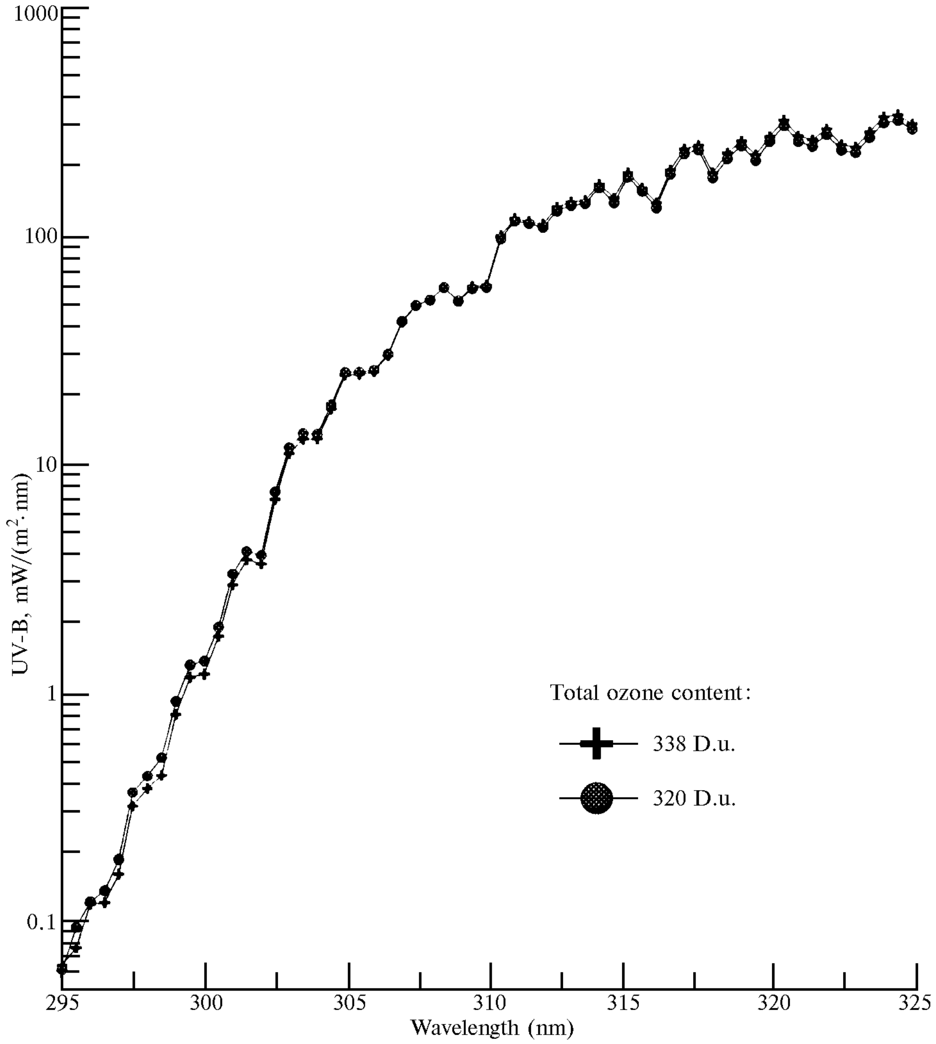

FIG. 1. UV-B radiation fluxes at the zenith angle of the Sun of 50° *and at different total ozone content under clear sky conditions obtained with an ozone spectrophotometer Brewer No. 043 (SCI – TEC Inc., Canada) at Kislovodsk station (altitude above sea level is* 2070 m*), Russia.*

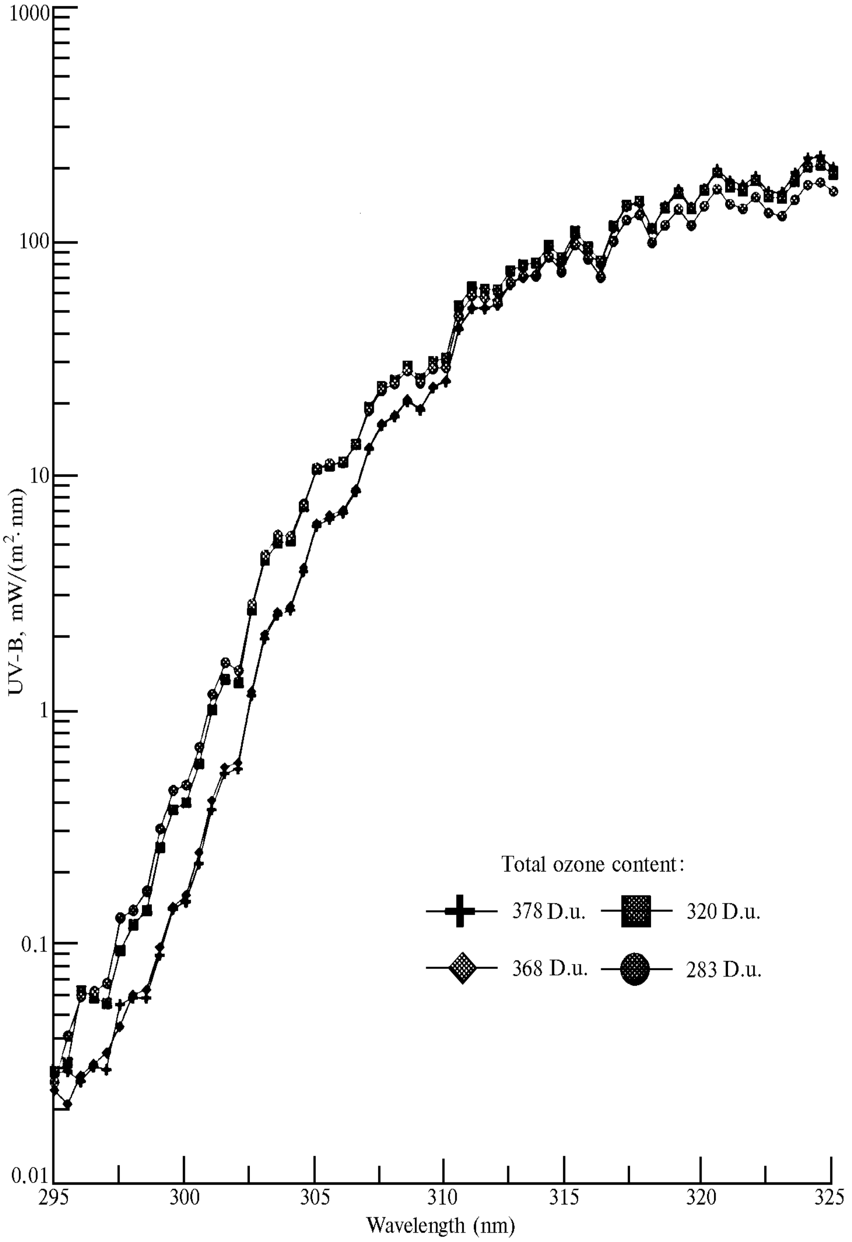

FIG. 2. UV-B radiation fluxes at the zenith angle of the Sun of 60° *and at different total ozone content under clear sky conditions obtained with an ozone spectrophotometer Brewer No. 043 (SCI - TEC Inc., Canada) at Kislovodsk station (altitude above sea level is* 2070 m*), Russia.*

These data confirm the results of the numerical calculations and demonstrate a good agreement between the optical model of the atmosphere and its real state. Absorption by ozone is responsible for the value of UV flux in the short-wave portion of spectrum, while the influence of the cloudiness is uniformly distributed along the entire spectrum. In fact, only at a cloud amount exceeding 3, the UV radiation flux significantly differs from its values under clear sky conditions (Fig. 4). Attenuation of the radiation by ozone begins to dominate over the attenuation by the clouds at the wavelengths shorter than 305–310 nm that well agrees with the calculations performed. On the whole the numerical model considered adequately reproduces the measured values of UV radiation fluxes.

The method proposed for calibration is planned to be checked over a longer time at the stations included in the system of Global Atmospheric Observations (GAO).

In conclusion let us list the advantages of the proposed method. There is no need to often use large and expensive laboratory complexes for calibration in the regime of field measurements. The field of solar radiation used for calibration is quite similar to the field of measured radiation in its spectral and spatial characteristics. Calibration is carried out at different values of the illuminance and provides a dynamical range of its variation up to 10 times.

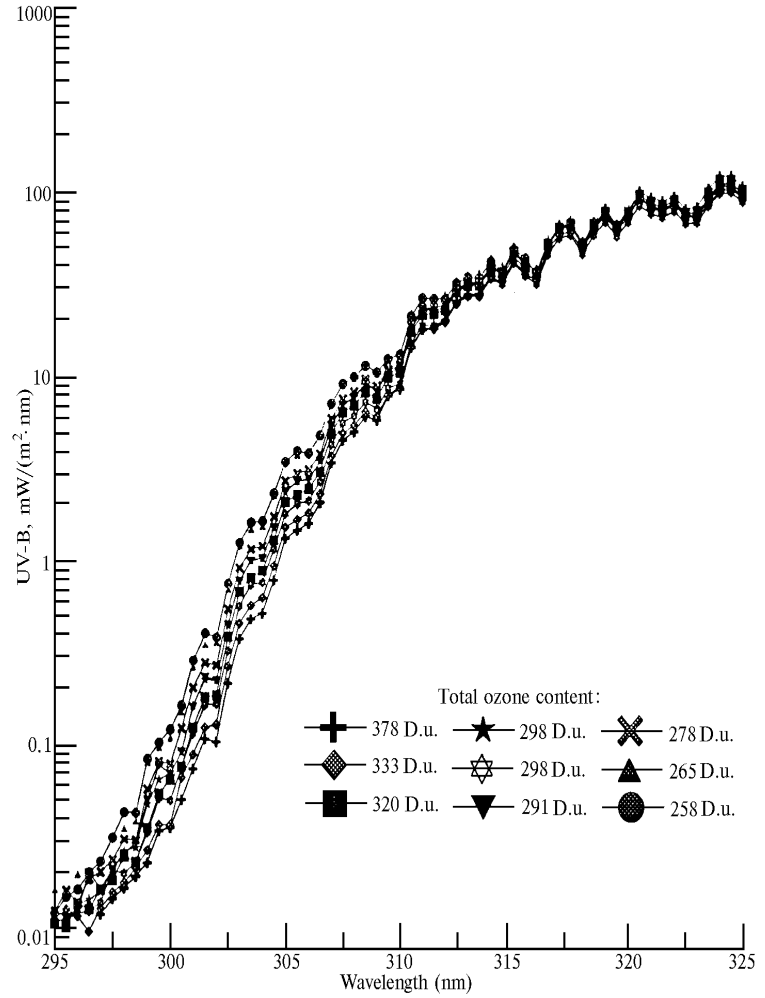

FIG. 3. UV-B radiation fluxes at the zenith angle of the Sun of 70° *and at different total ozone content under clear sky conditions obtained with an ozone spectrophotometer Brewer No. 043 (SCI–TEC Inc., Canada) at Kislovodsk station (an altitude above sea level is* 2070 m*), Russia.*

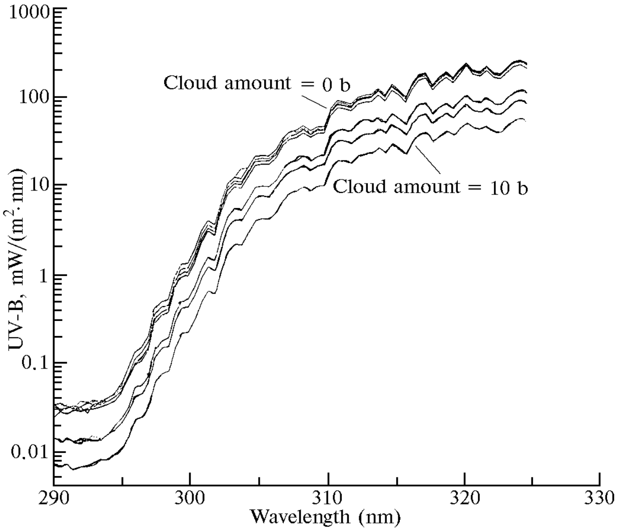

*FIG. 4. UV-B radiation fluxes (*295–325 nm *region) at the zenith angle of the Sun of* 50° *at a total ozone content* 295–320 D.u. *under cloudy conditions obtained with an ozone spectrophotometer Brewer No. 043 (SCI–TEC Inc., Canada) at Kislovodsk station (altitude above sea level is* 2070 m*), Russia.*

The conditions most suitable for performing the calibration measurements are the conditions of a high-altitude observatory and winter time. At optimal field calibration it is possible, in our estimations, to reduce the measurement error in the illuminance of UV-radiation down to about 5%.

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