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RESULTS OF THE MEASUREMENT OF THE VERTICAL PROFILE OF OZONE UP TO A HEIGHT OF 70 km BY MEANS OF THE MR-12 AND M-100 SOUNDING ROCKETS

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Translation of "Rezul'taty izmereniy vertikal'nogo profilya ozona do vysoty 70 km na meteoraketakh MR-12 i M-100," Meteorologicheskiye Issledovaniya, No. 23, 1977, pp. 30-35

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16. Abstract The photometers used and methods of calculation of the vertical ozone concentration profile are described. The results obtained in several series of MR-12 and M-100 sounding rocket launchings are presented and discussed.

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RESULTS OF THE MEASUREMENT OF THE VERTICAL PROFILE OF OZONE UP TO A HEIGHT OF 70 km BY MEANS OF THE MR-12 AND M-100 SOUNDING ROCKETS

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The development of concepts of the physics of the upper atmosphere indicates the major role of ozone, both as a factor which determines the thermal regimen of the stratosphere and mesosphere, and as an active participant in a huge number of chemical and photochemical reactions which determine the concentrations of other minor impurities. At the same time, ozone, which is the most accessible for direct measurement, can serve as an indicator of the physical processes in the upper atmosphere. In connection with this, further detailed study of the ozone content at various altitudes and of its seasonal, daily and latitudinal variations are becoming of great importance. For the solution of this major problem, a broad network of ground based, satellite and rocket observations is required. Despite the fact that rocket observations lay no claim to being global, they rightfully have an important role in study of the ozonosphere. Rocket observations provide the most reliable determination of ozone concentration and thermodynamic parameters of the upper atmosphere. The reference use of rocket observations is necessary for working out methods of both satellite and ground based observations of the vertical distribution of ozone. /30*

With respect to present day studies of the section of physics of the high layers of the atmosphere, TsAO [Central Astronomical Observatory], and the department of physics of the atmosphere, MGU [Moscow State University], rocket sounding of the vertical ozone profile has been carried out for a number of years.

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*Numbers in the margin indicate pagination in the foreign text.

The simplest and most reliable method of determination of the ozone concentration by rocket is the absorption method, based on the unusually strong absorption of solar radiation by ozone in the 230-330 nm region. Direct solar radiation spectra at various altitudes, calculated for sun height $h_{\odot}=5^{\circ}$, are presented in Fig. 1. The calculations were based on the Bouguer formula

$$I_\lambda(h) = I_\lambda^0 10^{-\mu\alpha_\lambda \chi(h) - m\beta_\lambda(h)}, \quad (1)$$

where I_λ^0 is the extraatmospheric solar radiation intensity, α_λ is the coefficient of absorption of ozone, $\chi(h)$ is the ozone content above h, $\beta_\lambda(h)$ is the Rayleigh coefficient of attenuation and μ and m are the ozone and air optical masses.

It was assumed in the calculations that, for h>26 km, μ=m, since approximately the same altitude variation is observed for air and ozone above the ozone layer maximum.

The data presented in Fig. 1 show the nature of the observed direct solar radiation in different spectral sections, and they assist in selection of the spectral characteristics of the equipment for study of the vertical ozone distribution in a given altitude interval. The observations described in this /31 work were conducted by means of filter instruments, which are extensively used in rocket observations, because of their reliability, great sensitivity and low inertia, compared with spectral equipment. The characteristics of the light filters used are presented in Fig. 2. The spectral profile of the solar radiation intensity "clipped" by the filter is calculated by the formula

$$I_\lambda'(h) = \Pi_\lambda I_\lambda^0 \cdot 10^{-\mu\alpha_\lambda \chi(h) - m\beta_\lambda(h)}, \quad (2)$$

where Π_λ is the spectral transmission of the filter.

Function $I_\lambda(h)$ of filter 2, which has two separated transmission maxima λ=2500 A and λ=3100 A, is presented in Fig. 3.

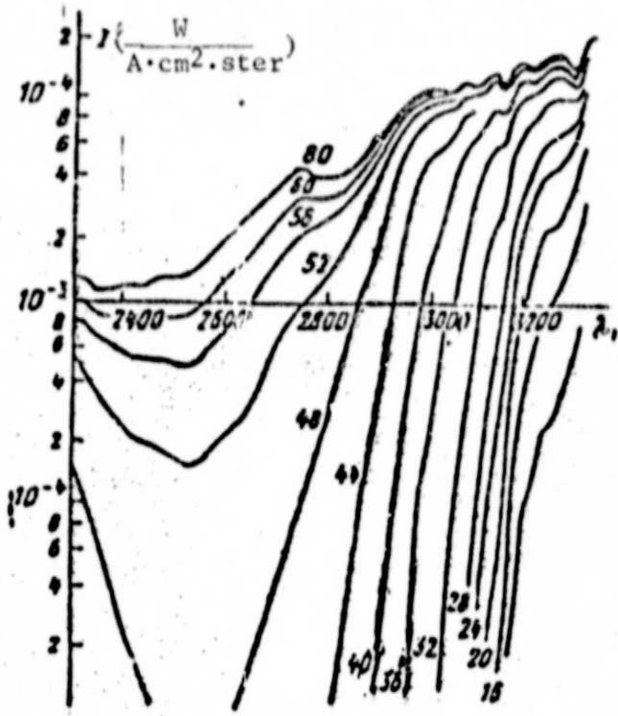

Fig. 1. Direct solar radiation absorption spectra at various altitudes.

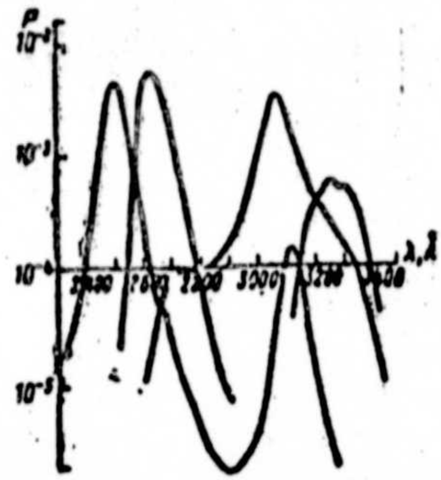

Fig. 2. Spectral transmission of light filters used in the study.

It is evident from the figure that this filter permits measurement of the ozone concentration in the 0 to 60 km altitude interval. A smooth transition from the longwave to the shortwave region of spectral transmission Π_λ occurs at altitudes of 40-50 km. This corresponds to entry of the radiation in the 3100-3300 A region into the level of extraatmospheric radiation and still complete absorption of radiation in the 2400-2600 A region.

By integration of expression (2) over λ, a theoretical profile of the current recorded by the FEU [photomultiplier] can be obtained, if the spectral sensitivity of the latter P^{λ}_{FEU} is known. /32

$$I(h) = \int_{\lambda_{min}}^{\lambda_{max}} P^{\lambda}_{FEU} \Pi_\lambda I^0_\lambda 10^{-\mu\alpha_\lambda \chi(h) - m\beta_\lambda (h)} \, d\lambda. \qquad (3)$$

In connection with the Forbes effect, a change of the coefficient of absorption of ozone α_λ occurs with altitude. Therefore, the effective coefficient $\alpha_{\lambda_{EFF}}$ can be introduced,

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according to the formula

$$\alpha_{\lambda_{eff}} = \frac{1}{\mu\chi(h)} \log \frac{\sum_{\lambda_i} \Pi_{\lambda_i} I^0_{\lambda_i} 10^{-m\beta_{\lambda_i}(h)}}{\sum_{\lambda_i} \Pi_{\lambda_i} I^0_{\lambda_i} 10^{-\mu\alpha_{\lambda_i}\chi(h) - m\beta_{\lambda_i}(h)}} . \quad (4)$$

Expression (4) is valid for sufficiently small intervals $\Delta\lambda$. Besides, we consider that P^{λ}_{FEU} and β_{λ} change little within one transmission maximum.

For instruments with two transmission maxima, the relative change of P^{λ}_{FEU} in the maxima was taken into account and, for β_{λ}, $\beta_{\lambda}(h)=\beta(h)$ at $h<40$ km and $\beta_{\lambda}(h)=\beta(k)_{3100A}$ at $h>40$ km were assumed.

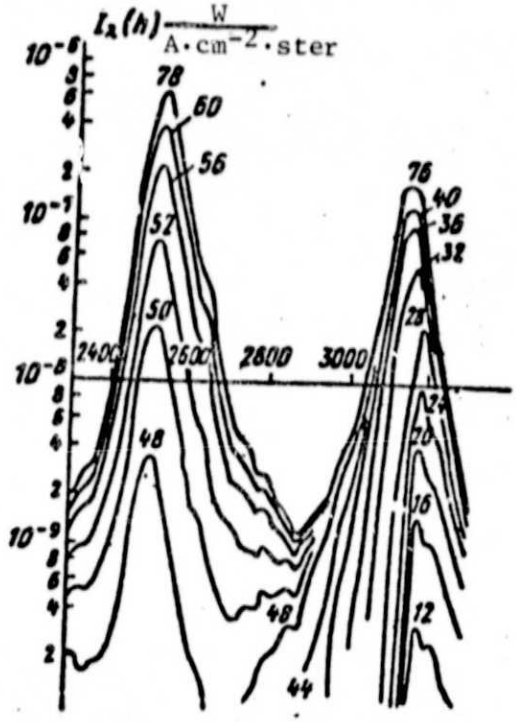

Fig. 3. Spectral profile of direct solar radiation "clipped" by light filter (see Fig. 1).

After introduction of α_{eff}, expression (3) takes the form

$$I(h) = I_0 10^{-\mu\alpha_{eff}(h)\chi(h) - m\beta(h)}, \quad (5)$$

where

$$I_0 = \int^{\lambda_{max}} P^{\lambda}_{FEU} \Pi_{\lambda} I^0_{\lambda} d\lambda$$

is the saturation current. Relationship (5) permits $\chi(h)$ to be found

$$\chi(h) = \frac{1}{\mu\alpha_{eff}(h)} \left(\log \frac{I_0}{I(h)} - m\beta(h) \right) . \quad (6)$$

In calculation of $\alpha_{eff}(h)$, in the first approximation, the standard USA-1975 model of $\chi(h)$ was used [3, Fig. 6]. Further calculations were carried out by sequential approximations.

For further improvement of this method of treatment, the following must be taken into account:

1. Aerosol attenuation, especially below 25 km;
2. μ vs. altitude, for which $\mu=f(h)$, calculated for standare ozone distribution, can be introduced; subsequently, especially for low sun height, μ can be calculated by the natural ozone concentration values found in the preceding calculation cycles;
3. Spectral functions P^{λ}_{FEU}, $\beta_{\lambda}(h)$ and aerosol attenuation;
4. Scattered radiation, which affects the readings for $h<20$ km with a large inlet aperture.

To make measurements in the absorption mode, the BISUF (solar ultraviolet study unit) photometer was developed, with two optical channels, for measurement of direct and scattered solar radiation. The latter is used to determine the vertical profile of the scattering coefficient, and it is of auxiliary value in our problem. Therefore, we dwell in greater detail on the optical and electrical scheme of the direct solar radiation channel.

A block diagram of the BISUF is presented in Fig. 4. The optical input of the instrument is an Ulbricht sphere. This is a hollow aluminum sphere with inlet and outlet windows located at a specific angle, usually 90-100°. The tube attachment in /33
front of the inlet window of the sphere provides the photometer a 40° field of view. This optical device fills the part of a direct solar radiation diffuser. Therefore, the inner surface of the sphere must scatter light in a diffuse way. Selection of the material and the method of treatment of the inner surface is of great importance. We selected aluminum, since it easily undergoes accurate mechanical treatment, and a sufficiently

uniform, diffusely scattering surface is obtained by chemical etching of it. The diaphragms located beyond the sphere form a parallel beam, in order to eliminate a change in characteristics of the filter due to oblique incidence of the rays. In this study, a Kura FEU 57 and FEU-116 were used, for which low spectral sensitivity in the visible region and near ultraviolet are characteristic. This permits elimination of the effect of possible weak secondary transmission maxima of the light filters. To amplify the FEU current, a logarithmic amplifier (UMI) was used, which has an approximately logarithmic current-voltage characteristic and a 10^{-5}-10^{-9} A amplifiable current range.

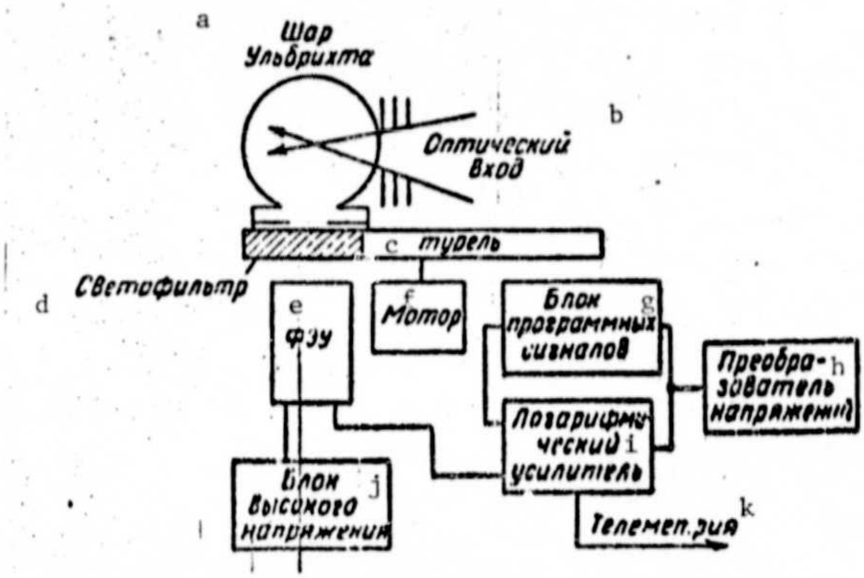

Fig. 4. BISUF photometer diagram.

Key:
a. Ulbricht sphere
b. optical inlet
c. turret
d. light filter
e. photomultiplier
f. motor
g. program signal unit
h. voltage converter
i. logarithmic amplifier
j. high voltage unit
k. telemetry

The input signal enters a relay, which has two positions and permits connection of the amplifier tothe program signal unit every 30 sec, thereby monitoring the amplifier sensitivity, the characteristics of which depend on temperature.

During the test period (1.5 sec), the program signal unit gives three calibration levels, which permit tracing the change in amplifier characteristics during the flight. A stabilized voltage converter is used for the UMI and program signal unit power supply, and the high voltage unit, for the FEU voltage divider power supply. To increase the spectral range of observation, switching of the filters, which are installed on a motor rotated platform, is provided for in the BISUF photometer.

The BISUF photometer permits observation of both direct and scattered radiation in six spectral intervals.

Analysis of Results

The equipment for measuring ozone concentration was tested in three launches. The first experiment was conducted 19 June 1973 in a MR-12, at $h_{\odot}=3.5^{o}$. The filter parameters are presented in Fig. 2. The interference filter had two transition maxima at $\lambda=2620$ A and $\lambda=3300$ A.

For the purpose of greater suppression of the right, "red" maximum and improvement of contrast, a liquid filter (0.1 normal solution of HNO_3), with a 200 A transmission band at $\lambda_{max}=2600$ A, was superimposed on the interference filter. The spectral characteristics of this component filter are presented in Fig. 2. Since the photometer was installed under flaps, which were ejected at an altitude of 50 km, a current profile was obtained from 50 to 70 km. The radiation which the right maximum transmits produces a constant, small background in this region, and a change in signal occurs only in the $\lambda=2500$-2700 A region. /34

The use of the "double peak" filter, as was stated above, can significantly enlarge the range of altitudes studied. We used this possibility in the second launch, 21 September 1974, also on a MR-12 ($h_{\odot}=5^{o}$). To increase the contrast of the transmission maxima, a complex filter was used, which was made up of two approximately equal interference filters with two transmission maxima, at λ=2500 A and P=20% and at λ=3120 A at P=4%. The characteristics of this filter also are presented in Fig. 2. Before ejection of the flap at 53 km, the direct solar radiation was recorded through a specially constructed tube in the flap of the rocket. This permitted measurement of the direct solar radiation from 0 to 80 km.

An instrument of this type was first installed aboard a M-100 sounding rocket in 1975, which is more promising from the point of view of operational study of the ozonosphere than the MR-12 rocket. A filter was used in this launch (Fig. 2), with a transmission maximum around λ=3070 A. /35

The experimental current profiles obtained in 3 launches are presented in Fig. 5, and the results of the vertical ozone profile calculations for all three cases, in Fig. 6. For comparison, the USA-75 ozonosphere model [3] and nighttime measurements of I. Carver [5], are presented in this figure.

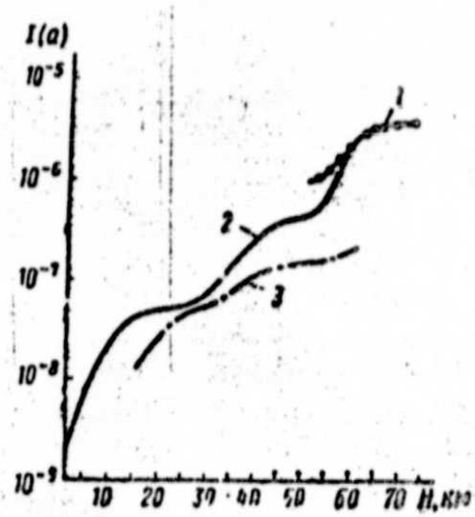

Fig. 5. Experimental current profiles: 1. TsAO, MR-12, 19 June 1973, $h_{\odot}$=3.5°; 2. TsAO, MR-12, 21 September 1974, $h_{\odot}$=5.0°; 3. TsAO, M-100, 19 September 1975, $h_{\odot}$=13°.

A comparison of our results with American standard and the nighttime measurements shows that, within the limits of measurement error, all the ozone concentration profiles differ by a factor of 3-4. The height of the uniform atmosphere turned out to be 4 km on the average, in the 30-60 km section.

The pronounced concentration maximum in the 55 km region, recorded in the 21 September 1974 launch, attracts attention.

The 19 June 1973 analog of this maximum, in the form of a small swelling of the $O_3(h)$ curve, was noted at a higher altitude, around 60 km.

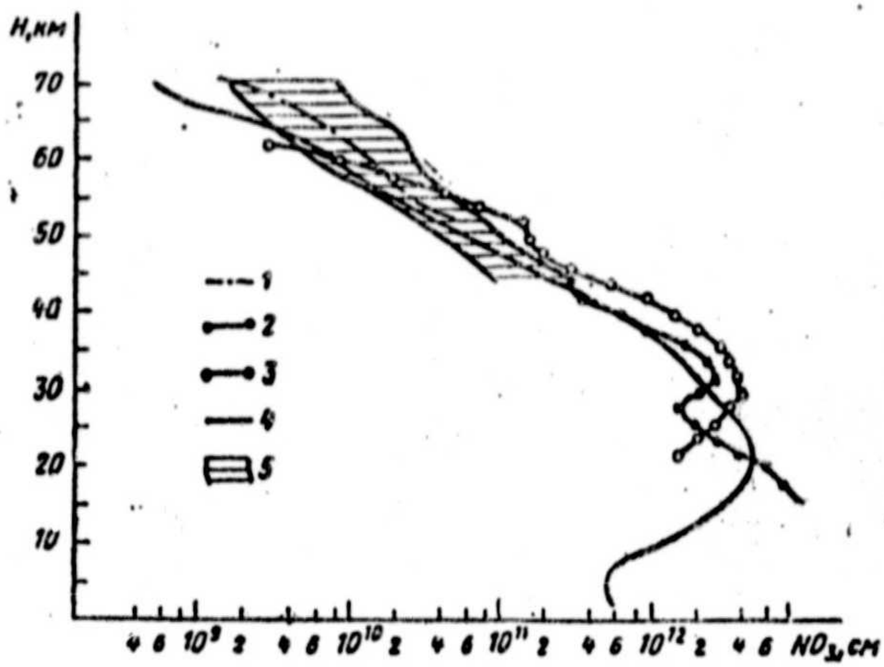

Fig. 6. Vertical ozone concentration profiles: 1. TsAO, MR-12, 19 June 1973, $h_{\odot}=3.5^{\circ}$, 2. TsAO, MR-12, 21 September 1974, $h_{\odot}=5.0^{\circ}$; 3. TsAO, M-100, 19 September 1975, $h_{\odot}=13^{\circ}$; 4. USA-75 model [3]; 5. Carver nighttime measurements [5].

REFERENCES

1. Makarova, Ye. A. and A. V. Kharitonov, Raspredeleniye energii v spektre Solntse i solnechnaya postayannaya [Energy Distribution in the Solar Spectrum and the Solar constant], Nauka Press, Moscow, 1972.

2. Inn, E. C. and Y. Tanaka, "Ozone absorption coefficients in visible and ultraviolet regions," Ozone Chemistry and Technology, Washington, 1959.

3. Krueger, L. and R. A. Minzner, "A mid-latitude ozone model for the U. S. Standard Atmosphere 1975," Goddard Space Flight Center, Preprint X-912-74-291, 1974.

4. Kondrat'yev, K. Ya., Radiatsionnyye kharakteristiki atmosfery i zemnoy poverkhnosti [Radiation Characteristics of the Atmosphere and the Earth's Surface], Gidrometeoizdat Press, Leningrad, 1969.

5. Carver, I. H., B. H. Norton and R. S. O'Brien, "Ozone determination by lunar rocket photometry," Planet Space Sci. 20/ 2, (1972).