

MEASUREMENT OF THE VERTICAL OZONE DISTRIBUTION WITH THE HELP OF OZONESONDES IN THE COURSE OF THE SATOR EXPERIMENT

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The experience is described of measuring the vertical ozone distribution with sondes which make use of the electrochemical method. Some vertical ozone profiles obtained in the course of the SATOR experiment are presented for illustration.

Ozone is one of the most important trace impurities of air and plays the protective role in the atmosphere. By absorbing the hard ultraviolet solar radiation, ozone protects the biosphere from the harmful effect of this radiation. In recent years the urgency of the investigations in ozonosphere has become still greater. This is explained by the continuously increasing pollution of air, which results in two different effects observed in the vertical ozone distribution, that is, the ozone content decrease in the stratosphere and increase in the air ground layer. Therefore, in recent years much attention is devoted to the problem of ozone by the world scientific community.

Systematic measurements of ozone content are carried out at 130 stations, 35 of which are located in the CIS. However, the majority of the stations measure the total ozone content solely and only at some of them the measurements of the vertical ozone distribution are carried out. For the present the means of spaceborne remote sounding make it impossible to retrieve the reliable vertical ozone profiles below a pressure altitude of 30 hPa.¹ For this reason the measurements of the vertical ozone distribution are carried out mainly with the ozonesondes attached to the standard meteorological radiosondes and seldom with the help of rockets. The methods of remote (laser) sounding are also promising.

Up to date three types of ozonesondes such as optical, chemiluminescent, and electrochemical have been the most well-known instruments. Their principles of operation were briefly described in Refs. 2 and 3. For the first time the vertical ozone distribution was measured in 1938–1939 in USA with the help of optical ozonesondes.⁴ But these ozonesondes like the subsequent ones^{5–10} are not widely used. This is due to impossibility of data acquisition in the troposphere, gross measurement errors, and relatively high expense of the sondes.

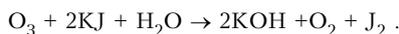
Chemiluminescent sondes were used for sounding in 1962–1964 at some stations of the North and Central America and Greenland. However this sonde with gas-filled balloon envelope has not yet found widespread use. It is difficult to explain this especially taking into account its small time lag, which is the decisive factor in the rocket sounding.¹¹ Nevertheless, these sondes are under development so far.¹²

The electrochemical ozonesondes are being most widely used now. Since 1964 these sondes have been used for the routine ozone measurements in Boulder (USA) and Poona (India) and since 1966 in Talvil (Switzerland). For the first time the electrochemical ozonesonde was proposed by Brever and Milford (Great Britain) while later it was modified in combination with radiosonde for serial production in USA by the Mast Development Company.¹³ Now the ozonesondes

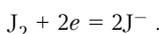
of such a type are used for the network observations in USA, Canada, India, and Germany.^{14,15}

Since 1981 the sounding of the atmosphere has been started in Tomsk with the help of the OSE–3 ozonesondes manufactured in former DDR.¹⁶ In addition to the study of the vertical ozone distribution these measurements accompanied the lidar measurements of this constituent. In this paper some of the obtained results are presented.

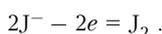
The operating principle of the OSE–3 ozonesonde is analogous to that of the Brever—Mast ozonesonde (model 730). Either sonde employs the method based on the reaction of ozone with potassium iodide



If two electrodes are placed in solution and a low voltage is applied to them, the molecules of iodine near cathode will dissociate into ions



The applied voltage sets them in motion toward the anode where the iodine molecules are reduced



If the reduced iodine is prevented from its returning to the solution, the cell will conduct the electric current proportional to the amount of ozone reacting with the solution. The advantage of this method is its high sensitivity because 1 μg of ozone yields 5.3 μg of iodine. On the other hand, its main disadvantage is its nonselective character. So, oxidizers such as NO_2 take part in reaction as ozone does, while other substances (reductants) such as H_2S , SO_2 , and NH_3 cause back reaction. In this connection, the most stringent requirements are imposed on the ozone gas composition of the mixture used for calibrations and on the cleanness of surrounding air in the preflight preparation of the device. The ignorance of these requirements is the reason for the most failures in the preflight preparation and launch of the ozonesondes. The cell of the OSE–3 ozonesonde is made of polystyrene in the form of a cylinder. It consists of a cylindrical cathode in the form of platinum grid (with total area of about 6 cm^2) and of anode in the form of silver wire 3 cm in length and 0.5 mm in diameter. The casings of the cell, delivery pipe, piston, and pump are made of materials chosen so that to ensure minimum destruction of ozone when it propagates to the solution.³ In order to further decrease the ozone destruction, the cell is pumped through by air with the maximum ozone content during the preflight preparation.

The functional diagram of ozonesonde¹⁶ is shown in Fig. 1. Air is pumped through the cell 2 by the pump 3 which is put into operation by the engine 4. For ensuring a constant rate of rotation of the engine rotor and, as a consequence, the constant rate of the air flow through the cells the stabilizer of the rotation frequency of the engine rotor 5 is used. The engine is supplied by the water-filled battery 6. The measuring transducer 1 is of a current-frequency type. It is supplied by the battery of the MARZ radiosonde. When the electric current of the cell varies from 0 to 7 μA, the frequency at the transducer output increases from 50 to 200 Hz. All the assemblies of the ozonesonde except the battery are inclosed in the casing made of foam plastic in order to maintain their temperature not lower than +2...+7°C by the flight end.

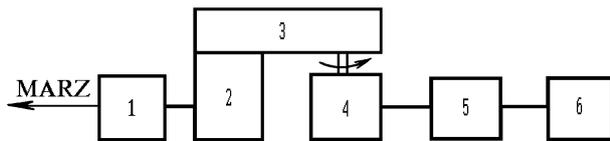


FIG. 1. Functional diagram of the OSE-3 ozonesonde: 1) measuring transducer, 2) cell, 3) pump, 4) pump engine, 5) engine stabilizer, and 6) engine supply battery.

The ozonesonde cell is filled with solution 2 cm³ in volume, 1 liter of which contains 2.522 g of Na₂HPO₄ · 12 H₂O, 1.150 g of NaH₂PO₄ · H₂O, and 1.000 g of KJ.¹⁶ The boiling and freezing points of this solution coincide at a pressure of about 6 hPa, therefore the measurements at a pressure higher than 6 hPa are not reliable. In fact this pressure is the theoretical limit which can be recommended for use in this method. The partial pressure of ozone is given by the formula

$$P_3 = 1.171 t \frac{T_p}{T_0} i f,$$

where t is time required for 100 cm³ of air to be pumped through, T is the temperature of the pump, $T = 273.15$ K, i is the electric current in μA, f is Brewer's correction for the destruction of ozone in air intake ($f = 1.04$). In practice each cell exhibits individual dependence of partial pressure on the current in the form of a graph which is examined and corrected during the preflight preparation. It should be noted that the measurement errors can appear resulting from the fact that the efficiency of the pump depends on the air pressure.¹⁷ In the procedure developed by the scientists of DDR the correction on the pressure and the temperature inside the cell is introduced in this case. This correction reaches 1% at $P = 100$ hPa, 6.5% at 30 hPa, 17% at 10 hPa and 26% at 6 hPa (see Ref. 15).

In the course of measurements the radar station "Meteor" was used for radiosonde tracking. Since the lowest frequency of the ozonesonde transducer is 50 Hz, the parameters of the circuit consisting of C87, R141, and C88 in the MT-32 unit of radar station "Meteor" were adjusted in order to extend the range of pulse counting. In the first series of measurements the ozonesonde was attached to the RKZ-2 radiosonde. To this end, the RKZ-2 radiosonde was significantly modified. The electromechanical commutator of the RKZ-5 radiosonde, whose segment corresponding to the measurement time of the temperature had been cut, was used instead of a baroswitch. A source follower was added to the output circuit of the transducer unit. Pulses from the transducer output passed through the source follower, separating capacitance, and a relay controlled by the commutator, were directly applied at the control grid of the valve of the measuring generator of the

radiosonde. During the time of transmission of the ozone frequency the measurement circuits of the hygrometer and thermometer were disconnected. No substantial failure of operation of the modified radiosonde and no change in the characteristics of the measuring transducer were found in the course of the laboratory investigations and subsequent measurements. The radiosonde was modified after testing the electrical parameters of the radio unit. The radiosonde was checked using the technique described in Ref. 19.

In the subsequent series of measurements the OSE-3 ozonesonde was launched together with the MARZ-2-1 radiosonde.^{16,20} The procedure of preflight preparation of the OSE-3 followed the technique described in Ref. 16. Its main stages were cleaning the cell by flushing, pumping air with high ozone content through the cell, forming the cell, "training" the cell, and testing the calibration curve of the measuring transducer.

It should be noted once more that the basic requirement for the preflight preparation is the maximum possible cleanness of the surrounding air. In the course of the preflight preparation of the ozonesondes for calibration, a GS-02 ozone generator and a 3-02P1 chemiluminescent ozone meter developed in the Laboratory of Ecological Control (LEC) (Leningrad) were employed.

The ozonesondes were elevated with the use of the conventional balloons made of latex. In the course of measurements no effect of "traces" of kerosene (gasoline) on the cell readings was found similar to that pointed out in Ref. 3. Nevertheless, to decrease the probability for the cell to be polluted by kerosene (gasoline) vapor the sonde was tethered to the balloon with the rope 20-30 m long.

The radiosounding data were processed following the procedure described in Refs. 16, 19, and 20. The ozone partial pressure was converted to a mass concentration according to the formula

$$\rho_3 = \frac{P_3}{0.1732 \cdot 10^{-3} T},$$

where ρ_3 is the ozone mass concentration in μg/m³, P_3 is the ozone partial pressure in nb, and T is the air temperature in Kelvin.

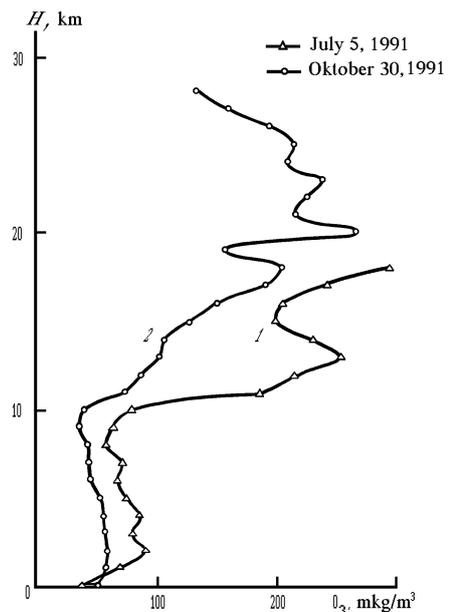


FIG. 2. The vertical ozone distribution measured on July 5, 1991 (1) and on October 30, 1991 (2).

Two of the obtained vertical profiles of ozone mass concentration are shown in Fig. 2. The first profile on July 5, 1991 was measured with the OSE-3 ozonesonde attached to the RKZ-2 radiosonde, while the second profile on October 30, 1991 was measured with the ozonesonde attached to the MARZ-2-1 radiosonde. Both profiles were obtained during formation of a number of air jets, and this could be explained why two maxima rather than one are seen in the profiles.²¹ However, additional aerosynoptic information is required to make more comprehensive analysis, which we failed to obtain so far.

In conclusion it should be noted that the OSE-3 ozonesonde is relatively hard in operation and needs rather a wide set of instruments for the preflight preparation. Nevertheless, its high reliability should be pointed out given that the prescribed procedure of the ozonesonde preflight preparation is carefully performed.

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