ON THE DEVELOPMENT OF OZONESONDES AT THE CENTRAL AEROLOGICAL OBSERVATORY

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Electrochemical, chemiluminescent, and semiconducting ozonesondes developed at the Central Aerological Observatory have been described. The ozonesondes of the first two types have been investigated under laboratory and field conditions and that of the third type only under laboratory conditions. The CAO electrochemical ozonesondes have the metrological parameters on a level with the best specimens in the world. In particular, the correction factor (the main metrological parameter of ozonesondes), averaged over twenty flights at five stations of the Routine Balloon Network (located in the territory of the Commonwealth of Independent States) performed in 1991–1992, *is* 1.053±0.079. *Among the advantages of the chemiluminescent ozonesondes are quick operation (which allows one to obtain high spatiotemporal resolution), high sensitivity, and simple preflight preparation. The semiconducting ozonesonde is much lower in cost and is promising for simultaneous ozone and aerological sensing. However, its production process needs further development. Its metrological parameters also should be investigated. Based on the results of our investigations, a conclusion can be drawn that the CAO ozonesondes meet the international quality requirements and can be used for scientific researches.*

At present aerological ozonesondes of several types are used in the world to measure the vertical ozone profiles. Among them the electrochemical concentration cell (ECC) ozonesonde designed by Komhyr[1,2] is most widely used. Its advantages are: 1) sufficiently high metrological characteristics; 2) moderate requirements for the operator's skill, relatively simple operating conditions, and the easy course for training of operators; and, 3) simple preflight preparation (made without serious difficulties under field conditions), in particular, insensitivity to possible violations of operating rules by an unskilled operator. At the same time, the ECC ozonesonde has some disadvantages, namely: 1) high cost (total cost of consumed materials increases five times when ozone sensing is performed simultaneously with routine aerological sensing; for this reason, ozone sensing is performed more rarely than aerological one) and all the disadvantages common to electrochemical ozonesondes, namely: 2) slow operation (its time constant is about 30 s near the ground and may even increase when a balloon ascends) that makes fine spatial resolution within an ozone layer difficult, 3) sharp decrease of measurement accuracy at altitudes above 25 km due to the uncontrolled decrease of the pump circulation rate, 4) maximum measuring range of about 32 km, and 5) inconvenient use of water-soluble chemicals at the stage of preflight preparation. In Russia, the ozonesondes should be adapted to our Russian system of aerological data communication and processing. To this end, we accomplished much research work in 1989 in an attempt to make the ozone sensing system more suitable for use in Russia. In the present paper, we briefly describe the design of the Russian ozonesonde and give some examples of its application. In addition to the ozonometer of electrochemical type (below referred to as a sensor), the possibility of using chemiluminescent and semiconducting sensors is also discussed in the paper.

The most important metrological parameter characterizing the accuracy of ozonesonde measurements is the correction factor K (often called the normalization factor in foreign literature) defined as a ratio of total ozone (TO) measured with a precision ground-based ozonometer (for example, with the Dobson spectrophotometer) to the integral of the measured vertical ozone profile (VOP). Special-purpose metrological studies of the ECC ozonesonde[3–5] undertaken by various groups of operators have shown that K is between 0.93 and 1.04 and its standard deviation (SD) is about 0.07 (the factor K, retrieved from the data[6] of regular measurements of ozone at the NASA station in Natal, Brazil in 1983–1987, was found to be 0.98±0.11).

By 1990, the electrochemical ozonesonde was developed at the CAO. Process of its production was

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described in Refs. 7–9. Its design was similar to that of the ECC–5a ozonesonde made in the U.S.A. but differed in the composition and the technology of production of some components. It also used materials produced only in Russia. A system of data communication from the combination of the ozonesonde with the MARZ radiosonde to a ground-based radar station (RS) of the "MeteoriteB (or "Meteorite–2B) series was developed by V.I. Ermakov. The information about columnar ozone and standard atmospheric meteorological parameters (air temperature and humidity) was recorded on a paper tape of a recorder together with the data of radar tracking.

The design of the CAO electrochemical ozonesonde was similar to that of the most widespread and most advanced ECC ozonesonde[4] made in the U.S.A. by the Science Pump Corporation. It consisted of a pump with a circulation rate of 3 ml/s and the Komhyr electrochemical concentration cell[1] enclosed in protective housing. Its output signal was the current varying from 0.001 to 6 μA. The ozonesonde weighed about 0.6 kg with two 3336-type power supply batteries. Measurements of columnar ozone are performed every 40 s considering the speed of the ozonesonde operation (all electrochemical ozonesondes have the time constants between 35 and 40 s in the troposphere, slightly increasing in the stratosphere). This allowed us to obtain a vertical resolution of about 300 m. The correction factor K of the CAO ozonesonde, averaged over the data of twenty balloon flights[10-12] conducted at five stations in the territory of the Commonwealth of Independent States in 1991–1992, was found to be 1.053±0.079 (see Table I). This is quite acceptable and on a level with the corresponding values of the ECC ozonesondes.[3,4]

TABLE I. Values of the correction factors obtained in ozonesonde flights.

Station	Flight date		Number	K	$SD(K)$
	Year	Month	of flights		
Volgograd	1991	6, 7	6	1.102	0.079
Tashkent	1991	5, 11	5	1.056	0.080
Dushanbe	1991	11	4	1.012	0.082
Khorog	1991	11	2	1.115	0.092
Dolgoprudnyi	1992	11	3	0.963	0.058
All stations	1991–1992		20	1.053	0.079

An example of the vertical ozone profiles measured simultaneously with the Russian and foreign balloon-borne ozonesondes during balloon ascents is shown In Fig. 1.

At the same time, balloon investigations in 1988–1990 demonstrated that the speed of operation of the electrochemical balloon-borne ozonesondes was insufficient for ozone measurements during balloon ascent at bast at some altitude ranges. This circumstance gave impetus to the development of faster chemiluminescent ozonesonde by Ermakov and me (see Refs. 7 and 8). The chemiluminescent ozonesonde consists of a pump with a circulation, rate of 10 ml/s, a solid-state chemiluminescent ozone-sensitive element (SCDE), and a luminescence recording system built around a lowcost photomultiplier (FÉV–27 was used). The SCOE represents a compound layer of gallic acid and coumarin–47 deposited on a polymer.

Substrate permeable to air[8,13] and allows one to obtain the temporal resolution of several tenths of a second (see Ref. 14). The chemiluminescent ozonesonde has the following advantages over the electrochemical ozonesonde: 1) capability of operation at any attainable altitude (in practice, up to 45 km); 2) fine vertical resolution (its time constant is about 1 s instead of 25 s); 3) simple preflight preparation without manipulation with solutions; 4) relatively simple production process. Among its, disadvantages are nonlinear dependence of the signal parameters on the ozone concentration, noticeable temporal change of the SCOE sensitively (within an hour), and the dependence of the signal parameters on the prehistory of ozone air-mixture circulation. The output signal frequency of the chemiluminescent ozonesonde varies from 30 to 1500 Hz. Its weight is about 0.8 kg with electric power supply battery weighing as much as 0.3 kg. Since the columnar ozone is measured in flight in relative units, data processing requires knowledge of the total ozone or any referencing to absolute units.

An example of simultaneous measurements of columnar ozone with the balloon-borne electrochemical and chemiluminescent ozonesondes is shown in Fig. 2. It is seen that in some cases only chemiluminescent ozonesonde provides the adequate vertical resolution (most likely this situation was observed at the cloud boundary). The chemiluminescent ozonesonde is of considerable interest for studying the small-scale variability of columnar ozone, especially in airborne experiments.

We also investigated semiconducting ozone sensors weighing as much as 1 g. They were produced at the Karpov Scientific-Research Institute of Physics and Chemistry. Technology of their production, experimental procedure, and specifications were described in Refs. 15 and 16. In addition to ozone, these sensors are sensitive to water vapor (but to a lesser degree, so that in the surface layer a signal from ozone dominates), nitrogen oxides, chlorine, and other minor gas components (but their sensitivity to these components is no higher than to the equivalent relative amount of ozone). These sensors are very promising for use with aerological ozonesondes, because of their relatively low sensitivity to water vapor in the free atmosphere and much smaller amount of any interfering minor gas component in comparison with ozone. The cost of a commercial semiconducting ozone sensor is comparable to that of the humidity sensor.

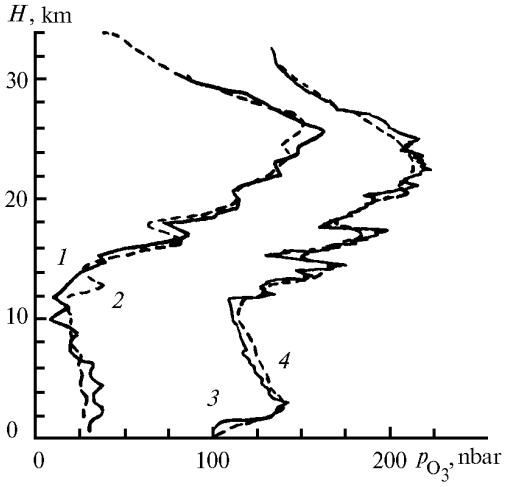

FIG. 1. Results of simultaneous measurements of the vertical ozone profile with the CAO electrochemical ozonesondes over Dushanbe (1) and Khorog (2) at 7:30*, Moscow time, on November* 7, 1991 *and with the ECC-5a (3) and CAO (4) ozonesondes over Moscow at* 12:35*, LT, on November* 12, 1992*. Here, curves 3 and 4 are shifted to the left by* 100 nbar.

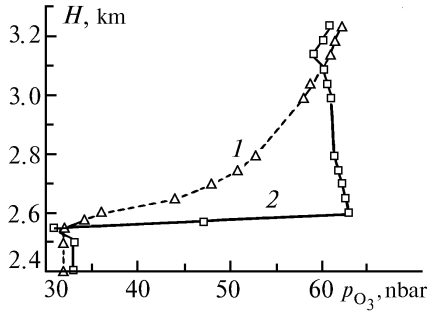

FIG. 2. Results of simultaneous measurements of the vertical ozone profiles during ascent (with a velocity of 6 m/s*) of balloon-borne electrochemical (1) and chemiluminescent (2) ozonesondes in Ryls'k of the Kursk Region at* 12:00*, Moscow time, on September* 12, 1989.

Our data testify that the CAO electrochemical ozonesonde meets the international quality requirements and can be used for regular measurements of vertical ozone profiles in scientific research. Among the advantages of the CAO chemiluminescent ozonesondes are quick operation (providing high spatiotemporal resolution), high sensitivity, and simple preflight preparation. The CAO chemiluminescent ozonesonde can be used alone and in combination with the electrochemical ozonesonde to reveal the fine structure of the vertical ozone profile in scientific research. The semiconducting sensor is much lower in cost. It is promising for simultaneous routine aerological and ozone sounding, but the process of its production needs further improvement and its metrological parameters must be investigated, especially in the presence of the interfering gas components.

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