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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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GEOPHYSICS

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ROCKET MEASUREMENTS OF THE TEMPERATURE AND WIND OF THE UPPER ATMOSPHERE IN THE POLAR REGION BY THE METHOD OF ARTIFICIAL LUMINOUS CLOUDS

(Presented by Academician E. K. Fedorov on 9 III 1970)

In the autumn of 1967 and the spring of 1968, on Hayes Island (80°37′ N), joint Franco-Soviet experiments were carried out to measure the temperature of the upper layers of the atmosphere with the aid of artificial luminous clouds ($NaNO_3$ + AlO). Six launches of Soviet meteorological rockets MR-12 were made, carrying French containers (sodium evaporators) on board. Optically thin spherical clouds were formed at altitudes of 120 and 170 km. At the same time, wind measurements and determination of the diffusion coefficient were carried out from the same clouds. During the period indicated, two launches were also made with Soviet-made containers for forming optically dense sodium clouds. In one of these experiments the temperature at an altitude of 160 km was also measured.

Measurement of temperature was carried out with a ground-based electrophotometer by an absorption method based on measuring the Doppler broadening of the resonance radiation of the sodium D lines by means of partial absorption of this radiation during its passage through a special cuvette containing saturated sodium vapor of known optical thickness ([1]).

Fig. 1

The clouds were photographed, for the purpose of obtaining wind and diffusion

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data, with aerial cameras ($d/f = 1:2.5$, $f = 2.5$ cm and $d/f = 1:2.5$, $f = 10$ cm). The artificial clouds were photographed from two points separated from one another by a distance of about 14 km.

The results of the experiments carried out are presented in Table 1. Let us consider them in sequence. Analysis of the data obtained shows that there is a substantial difference in the temperature of the thermosphere both for different seasons and as a function of the level of solar and geophysical activity.

It is known ([2]) that during the autumn (1967, 9-10 X) and spring (1968) series of experiments the geophysical situation was comparatively quiet. However, the temperature data obtained in these seasons turned out to be substantially different. In autumn, according to the results of two launches, the temperature at altitudes of 120 and 170 km was respectively 500 and 900-1000°K, whereas in spring (28 II–20 III 1968), also according to the results of two launches at an altitude of 170 km, the temperature was approximately 2 times lower. Thus, these measurements showed the presence of a clearly

Table 1

Date	Time	Solar incidence angle, deg	Altitude, km	Temperature, °K	Absolute error, °K	Wind speed, m/s	Displacement azimuth, deg	Zonal component, m/s	Meridional component, m/s	D_{exp}, cm^2/s	$D_{\text{calc.}}$, CIRA, 1965, cm^2/s	Density, g/cm^3	Density, CIRA, 1965, g/cm^3
09 X 1967	18 h 40 m	−8	120	500	$±$30	–	–	–	–	–	–	–	–
09 X 1967	18 h 55 m	−9	158	1030	$±$40	–	–	–	–	–	–	–	–
10 X 1967	20 h 00 m	12	155	950	$±$60	110	162	+34	−104	$2.0 \cdot 10^8$	$1.5 \cdot 10^8$	$2.0 \cdot 10^{-12}$	$2.15 \cdot 10^{-13}$
10 X 1967	17 h 55 m	7	–	–	–	–	–	–	–	–	–	–	–
28 II 1968	19 h 05 m	10	–	–	–	–	–	–	–	–	–	–	–

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Date	Time	Solar incidence angle, deg	Altitude, km	Temperature, °K	Absolute error, °K	Wind speed, m/s	Displacement azimuth, deg	Zonal component, m/s	Meridional component, m/s	D_{exp}, cm^2/s	$D_{\text{calc.}}$, CIRA, 1965, cm^2/s	Density, g/cm^3	Density, CIRA, 1965, g/cm^3
28 II 1968	18 h 00 m	6	171	520 ↓ 400	$±$20	66	194	−16	−64	$6.1\cdot 10^8$	$4.3\cdot 10^{-8}$	$4.3\cdot 10^{-13}$	$8.91\cdot 10^{-13}$
16 III 1968	18 h 50 m	9	–	–	–	–	–	–	–	–	–	–	–
16 III 1968	20 h 50 m	9.5	172	1100 ↓ 930	$±$50	72	219	−45	−56	$5.0\cdot 10^8$	$4.0\cdot 10^8$	$8.6\cdot 10^{-13}$	$8.41\cdot 10^{-13}$
19 III 1968	20 h 08 m	10	121	–	–	154	285	−149	+40	$1.1\cdot 10^7$	$0.8\cdot 10^7$	–	$2.49\cdot 10^{-11}$
19 III 1968	20 h 50 m	9.5	171	–	–	172	210	−85	−147	$5.9\cdot 10^8$	$4.0\cdot 10^8$	–	$8.24\cdot 10^{-13}$
21 III 1968	0 h 30 m	9	171	–	–	300	239	−256	−154	$5.8\cdot 10^8$	$4.1\cdot 10^8$	–	$8.37\cdot 10^{-13}$
21 III 1968	0 h 30 m	9	174	400 °K	$±$20	83	227	−66	−68	$5.6\cdot 10^8$	$4.0\cdot 10^8$	$4.0\cdot 10^{-13}$	$8.24\cdot 10^{-13}$

of a pronounced seasonal variation in the temperature of the thermosphere of the polar region (see Fig. 1). The fact that such variations exist is new.

It should be noted that in work (3) the low value of the thermospheric temperature of the polar region in the winter period is also indicated.

Of particular interest is also the result of the temperature measurement on 16 III 1968, during a period of strong geomagnetic disturbances. Data for various parameters characterizing geophysical activity from 10 to 23 III are given in Fig. 2.

As can be seen from the figure, geomagnetic activity increased sharply during

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Fig. 2

Figure 2: Fig. 2

the night of 15-16 III. In addition, during the hour before the rocket launch, riometers at 32 MHz recorded three absorption bays of the order of 1 db, whereas during the period from 1 to 16 III no absorption at all was observed. Data from the ionospheric sounding station also indicate the presence of an anomaly on 16 III.

During the rocket experiment on 16 III, a sharply increased temperature value was observed (approximately 1000°K as against 400-500°K before and after this launch—28 II and 20 III).

Thus, data have been obtained on a substantial dependence of temperature on the level of geoactivity; these data confirm the possibility of sharp changes in the temperature of the polar thermosphere, noted in the experiment (4) of 22 V 1963 at Fort Churchill (Canada).

During photometry of the clouds on 28 II and 16 III, a decrease in temperature was observed over the course of the experiment. These experiments

were carried out in the evening twilight; therefore the decrease in temperature may be interpreted as cooling of the atmosphere during the evening twilight. However, this effect requires additional verification.

In order to confirm the results obtained and to reveal new regularities, in March 1969 a large series of experiments was successfully carried out on Hayes Island; these experiments are currently being processed.

Fig. 2

The results for wind and the diffusion coefficient given in Table 1 were obtained by processing the data by methods analogous to those described in works (5-7). The maximum error in determining the wind velocity is 10-20 m/sec, and in the diffusion coefficient 25-30%.

Table 1 gives the geodetic azimuth. The zonal and meridional components are taken as positive to the east and north, respectively. In all cases the diffusion coefficient was determined from reagent AlO, with the exception of the experiment of 28 February 1968, in which D was determined from Na. In addition to the experimental data on wind and diffusion, the table gives values of the atmospheric density ρ, calculated from the experimental values of D and T. The calculations were performed using the formula of gaskinetic

theory (^8), under the assumption that the concentration of the reagent molecules is much less than the concentration of air molecules.

For comparison, data are given on the density of the atmosphere, borrowed from models 4 and 6 of the CIRA 1965 tables (^11), and the values of the diffusion

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coefficients for AlO, calculated using these same models.

It follows from the table that in all cases, at an altitude of about 170 km, the wind direction was approximately the same, while the speed varied very substantially.

Attention is drawn to the presence of winds having very large values of speed (300 m/sec, 19 March 1968). It should be noted that wind-speed values significantly exceeding 200 m/sec have also been observed by other authors at various latitudes (^9, ^10). It is also interesting to note that in all cases, at an altitude of about 170 km, the meridional component was predominant, except for the anomalously high speed on 19 March 1968, when the zonal component predominated.

Comparison of the experimental values of the diffusion coefficient with the calculated values shows that the experimental D systematically exceeds the values of D calculated from tabular data. However, this difference is about 25%, i.e., it does not differ from the measurement error of D. It should be noted that the temperatures obtained above are given without corrections for wind, since under the existing winds (except for the values of 19 March 1968, when it was not possible to obtain the temperature) these corrections would have been smaller than the experimental errors.

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