OBSERVATIONS OF THE TOTAL OZONE CONTENT IN THE ARCTIC OVER HEISS ISLAND (81°N) IN WINTER 1989

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Results of observations of the total ozone content over Heiss Island during the polar night, obtained with the help of a Brewer automated spectrophotometer using moonlight, are presented. According to these data, no significant depletion of the total ozone over Heiss Island was observed in January-March in the Arctic, unlike the depletion observed in the Antarctic in spring.

INTRODUCTION

Since the middle of the 1980's a stable spring depletion (up to 50 %) of the total ozone content (TOC) in the atmosphere over Antarctica has been observed. During the last decade there was a tendency toward a decrease in the TOC in the 30°–60°N latitude belt of the Northern Hemisphere, and an intensification of the total ozone content depletion in the higher latitudes is predicted.[1] The reason for such a change has not yet been found out and it is possible that these processes are caused by anthropogenic factors. At the same time the substantial differences between the dynamic processes in the atmosphere over the Arctic and the Antarctic do not allow straight comparisons or a direct analogy to be made concerning the behavior of the ozone layer in the higher latitudes of the Southern and Northern hemispheres. In addition to this, the number of ozonometric stations in the Arctic that work during the polar night and the beginning of the polar day is extremely small, which hinders the acquisition of representative sets of data for analysis.

In this connection it is of pressing interest to expand the investigations of the ozone layer in the Arctic and develop measurements of the TOC in the winter–spring season, when the depletion of the ozone content in the atmosphere is expected. An international experiment was begun in the winter of 1988–89 over the islands of Heiss and Franz-Joseph (81°N, 58°E) for the purpose of investigating the of structure and dynamics of the ozone layer in the Arctic region of the USSR. In order to make observations of the TOC, we prepared Brewer spectrophotometer No. 045 produced by the Canadian company SCI-TEC. When measuring the total ozone content during the polar night, the Moon was used as the source of radiation.

THE TOC MEASUREMENT METHOD

The Brewer device is an automated spectrophotometer-ozonometer and is designed to measure TOC in the UV spectral region using solar and lunar radiation.[3,4] To obtain the values of the total ozone content a technique for the calculation of the TOC was used which is standard for the Brewer spectrophotometer and involves the use of radiation measurement data at four wavelengths, 310.1, 315.5, 316.7, and 321.1 nm.[5] The result of a single TOC measurement is an average of five consecutive ozone observations, with each of the observed TOC values being determined from 80 consecutive cycles of scanning and storage of the data on the spectrum of recorded lunar radiation. The period of a single TOC measurement lasts 10 minutes. The observations of the total ozone content were carried out at atmospheric ozone masses within the interval $1.6 < \mu < 3.5$.

Table I presents a fragment of a listing of the TOC observations data using moonlight, taken on January 19, 1989, that characterizes the variance of the single ozone measurements under conditions of good atmospheric transparency over Heiss Island. During the three hours of this record fragment were recorded the lowest TOC values during the entire expedition, equal to 311 Dobson units (D.u.).

To check out the quality of the measurements made using Brewer ozone spectrophotometer No. 045, a number of comparisons runs were made using that device and other ozonometers in which the TOC observations were made using a direct solar radiation.

Table II shows the results of a comparison of the ozone measurements made using three Soviet-owned Brewer spectrophotometers after attaching them to the standard Brewer etalon device No. 008 in Canada and transporting them from North America to the USSR. Differences between the readings of all three spectrometers do not exceed 0.8%. After the termination of the winter measurements of the TOC over Heiss Island the Brewer spectrophotometer No. 045 was compared in Dolgoprudnyi with the Dobson spectrophotometer No. 107 (CAO), which was calibrated earlier (in 1988) with the world standard, i.e., the Dobson spectrometer No. 83 in Boulder (NOAA), by American and Soviet specialists.[6] The results of this work are shown in Tables III and IV.

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TABLE I.

A fragment of the observation data of the total ozone content, Heiss Island, January 19, 1989

Time (Greenwich)	Device temperature	μ	TOC (D.u.)	Deviation (D.u.)
14:20+06	21	1.89	310.1	7.9
14:31:36	20	1.876	309.7	15.5
14:43:04	21	1.855	311.9	9.8
14:54:36	20	1.837	303.2	12.3
15:06:06	21	1.820	323.2	17.7
15:17:37	21	1.802	305.2	5.7
15+29:08	19	1.786	312.4	12.7
15:40:37	19	1.772	311.6	13.0
15:52:06	18	1.759	311.9	7.1
16:03:35	18	1.746	317.5	8.5
16:15:06	19	1.735	314.3	2.6
16:26:36	19	1.724	320.5	2.8
16:38:07	19	1.714	313.0	5.8
16:49:38	19	1.705	302.8	15.1
17:01:07	17	1.697	304.5	20.0

Notes.

1. The average TOC value is 311±6 D.u.
2. Type of observations — by moonlight.

TABLE II.

Results of the TOC measurements by Brewer spectrophotometers No. 043, 044, and 045. Moscow, 1988.

Date	TOC values (D.u.)		
	No. 043	No. 044	No. 045
22.08.1988 measured 50 times	312.4	312.2	314.7
23.08.1988 measured 18 times	305.9	305.7	307.3

The results of the comparison reveal good agreement between the readings of the Brewer ozonometer No. 045 and the Dobson spectrophotometer No. 107. The next test of the Brewer device No. 045 we made together with specialists from the Canadian Environmental Protection Agency and SCI-TEC, using the portable Canadian standard Brewer device No. 017, in June, 1989, in Alma-Ata. The spread in the mean daily values of the TOC here also did not exceed 1 %

The tests which were performed testify to the stable operation of the Soviet-owned Brewer spectrophotometer No. 045, and indicate that the observed data on the total ozone content obtained during the winter period of 1989 over Helss Island are high quality data.

TABLE III.

Results of the intercalibration of the Soviet-owned Dobson spectrophotometer No. 107 (CAO) and the world standard Dobson spectrophotometer No. 83 (USA) in 1988. Boulder, NOAA, USA.[6]

TOC readings	1.15<μ<1.5	1.5<μ<2.0	2.0<μ<2.5	2.5<μ<3.2	1.15<μ<3.2
X_D No 83 (D.u.)	293	293	294	291	293
X_D No 107 (D.u.)	293	293	293	292	293
ΔX_D (%)	-0.16	-0.08	-0.20	-0.46	-0.05

TABLE IV.

Results of TOC measurements with the No. 107 Dobson spectrophotometer and the No. 045 Brewer spectrophotometer. CAO, Dolgoprudnyi, USSR, June 26, 1989.

TOC readings	1.15<μ<1.5	1.5<μ<2.0	2.0<μ<2.5	2.5<μ<3.2	1.15<μ<3.2
X_D No 107 (D.u.)	350	350	350	349	350
X_B No 045 (D.u.)	351	349	349	349	349
ΔX (%)	0.29	-0.34	-0.17	-0.10	-0.28

TABLE V.

Mean daily values of the TOC over Heiss Island in January-March, 1989, (from the data obtained using the Brewer spectrophotometer No. 045). Observations were made by moonlight

Data	Average daily readings of the TOC (D.u.)	standard deviation (D.u.)	Number of observations
14.01	329	±26	4
17.01	331	±13	9
18.02	319	±11	42
19.01	314	±10	25
20.01	323	-	1
21.01	344	± 8	11
22.01	338	±10	6
23.01	340	± 6	21
24.01	336	± 6	13
25.01	345	±11	11
13.02	354	± 6	6
14.02	363	±12	5
15.02	375	± 6	9
18.02	364	±35	3
19.02	540	±20	14
20.02	533	±18	5
21.02	539	±13	4
15.03	447	±24	8

ANALYSIS OF THE TOC DATA

The first TOC data at high latitudes in the Soviet Arctic were obtained over Heiss Island in March-September of 1958 using direct sunlight.[7] TOC observations have been continued for some years with the help of filter ozonometers, and are currently performed using an M-124 device during the daytime from the second half of March up to October. Expeditions were first undertaken in 1989 to measure the total ozone content during the polar night, using moonlight. Table V shows the mean daily values of the total ozone content and their mean-square deviations over Helss Island based on the results of ground-based optical measurements using the Brewer spectrophotometer No. 045. Figure 1a shows the variation in the TOC during January-March, 1989. In January, 1989 the ozone observations were carried out for 10 days, in February — for 7 days, and in March they were carried out for only one day — March 15, 1989.

The values of the TOC varied during the second half of January within the limits 314–345 D.u. The lowest readings of the total ozone content were recorded on January 18–20, and on January 19, the mean dally values of the TOC dropped to 314 D.u. The mean monthly value of TOC in January was 332 D.u. The second half of January was characterized by extremely low temperatures in the upper atmosphere (see Fig. 1b), where the temperature at the 30 mbar level often reached — 86°C. The same period was characterized by the presence of a steady polar stratospheric vortex. A sudden increase in the TOC from 364 D.u. to 540 D.u. was recorded over a period of several days at the time of a strong stratosphere warming in February. The variation in the total ozone content observed correlates well in general with the temperature time-course at the 30 and 50 mbar levels.

Note further that the values of the TOC during January, 1989, at Heiss Island were found to be lower than those of the very limited and scanty data of ground-based optical measurements of TOC made in January in nearby polar regions. Figure 1a shows the

values of the TOC at the station Longyear, Spitzbergen (78°N) (averaged over 1950–1957), obtained with the help of a Dobson spectrophotometer using moonlight, and here also a variation in the zonal-averaged values for this latitude is observed. The values of TOC at Heiss Island in January, 1989 turned out to be lower than the above-mentioned ones by 15–20 %. The same figure shows the variation in the TOC that corresponds to the empirical model of V. Bekoryukov[8] for Heiss Island. The discrepancy between theTOC measured values and the model values in January is 3–4 %.

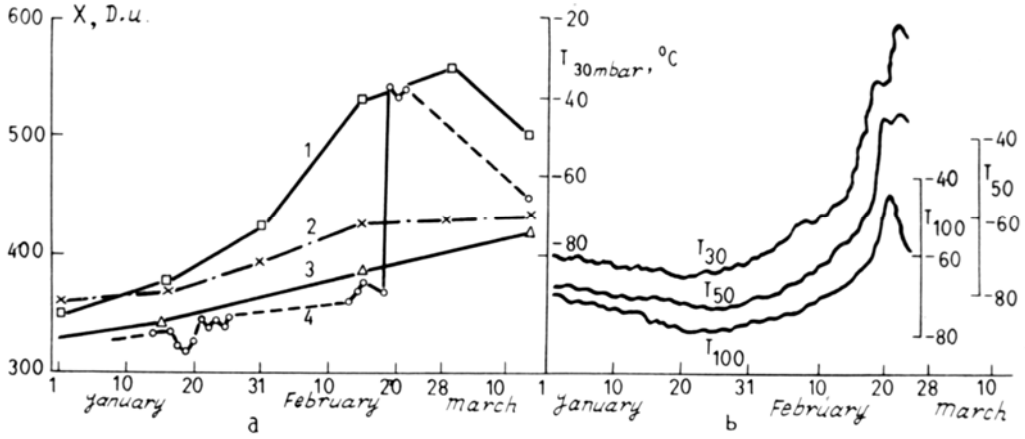

FIG. 1. Results of total ozone content measurements (a) and the temperature time-covrse at the 30.50 and 100 mbar levels (b) over Heiss Island, winter of 1989. Longyear (78°N (1), zonal-average (78°N) (2), the moael for Heiss Island (3), Heiss Island, 1989 (81°N) (4).

CONCLUSION

1. For the first time in the most northern Arctic territory of the USSR, over Heiss Island and Franz-Joseph Island a representative set of ground-based optical observations of the total ozone content during the period of the polar night was obtained using an automated Brewer spectrophotometer.

2. According to the results of the TOC observations during winter-spring of 1989 over Heiss Island no strong total ozone content depletion, similar to that recorded in the spring in the Antarctic, was found.

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