MEASUREMENTS OF TOTAL OZONE AND NITROGEN DIOXIDE CONTENT AT THE ANTARCTIC STATIONS MOLODEZHNAYA AND MIRNYI IN SPRING 1987–FALL 1988

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Measurements of total ozone and nitrogen dioxide contents at the Antarctic stations in November–December, 1987 (Molodezhnaya) and in February–April, 1988 (Mirnyi) are presented. An irregular growth of the total ozone content was observed during November–December, 1987, characterizing the filling–up of the ozone "hole". Simultaneously the warning and the increase in the total NO_2 *content occurred in the stratosphere. During the summer and fall the total* NO_2 *content gradually decreased. The total* NO_2 *content in evenings were regularly higher than in mornings thereby indicating that the* NO_2 *content varies from day to night.*

At present studying the trace gaseous impurities in the atmosphere over the Antarctic has become one of the most topical problem of the Antarctic researches. It is important to measure the total ozone and nitrogen dioxide contents and to examine their temporal variability under the specific conditions of the Antarctic atmosphere, to study the mechanisms of the ozone layer formation, and to determine the reasons for the spring deficiency of the ozone content over the Antarctic (the effect of "ozone hole" in September–October).

In this paper we present our measurements of the total ozone and nitrogen dioxide contents at the coastal Antarctic stations Molodezhnaya (67°40' S and 45°50′ E) and Mirnyi (66°33′ S and 93°01′ E) in November–December, 1987 (Molodezhnaya) and in February–April, 1988 (Mirnyi) during the 33rd Soviet Antarctic expedition.

We measured the total ozone and NO_2 contents using direct and scattered solar radiations with the help of spectral devices on the basis of an MDR–4 monochromator (for measurements of direct solar radiation) and an MDR–23 monochromator (for measurements in the zenith direction). The spectral resolution of the MDR–4 monochromator was 0.4 nm and that of the MDR–23 monochromator – 0.7 nm (see Ref. 1).

Measurements in the zenith direction were computer–controlled. Measurements of direct solar radiation were performed in two different regimes:

1) with recording of the spectra on a diagram chart of the automatic recorder;

2) with computer–controlled storing of the spectra on magnetic tape.

The total ozone content was measured at the solar zenith angles 70°. Multiwavelength technique[2] was used for the determination of the total ozone content from the spectra of direct solar radiation. Nomograms calculated in the single scattering approximation were implemented for the determination of the total ozone content from the spectra of solar radiation scattered in the zenith direction. Comparison of the total ozone content measured using direct solar radiation and the scattered in the zenith direction demonstrated a good agreement.

The total NO_2 content was measured in the morning and/or in the evening at solar zenith angles of 70 – 95°. Measurements in the zenith direction were performed under cloudy weather conditions. To calculate the total NO_2 content from the spectra of direct solar radiation recorded during the first regime of operation we implemented the differential absorption technique, which was previously used in Ref. 3, at wavelength of 434.9, 437.9, 439.0, 439.7, 441.2, and 442.0 nm. In the case of the second regime of operation, when we measured the direct solar radiation, as well as in the case of dusk measurements the total NO_2 content was calculated by the method proposed in Ref. 4. The enhancement factors needed for the determination of the total NO_2 content from the zenith measurements were calculated with the help of the spherical model of the atmosphere in the single–scattering approximation with an account of refraction. The model covers the altitude range up to 78 km with a height resolution of 1 km.

The stratification parameters of the model were calculated from radiosonde data averaged over the corresponding time periods. For higher altitudes we used the long–term average monthly data of Ref. 5 that were obtained in the mid–latitude belt and then interpolated at the latitude of the station. The vertical model profile of NO_2 was prescribed in the form of a Gaussian curve with a half–width of 5 km (the half–width was defined as the difference between the altitudes at which the NO_2 content equaled half the maximum). The altitude of the maximum of the model layer of NO_2 varied with a sampling step of 4 km.

The resulting measurements of the total ozone content are shown in Figs. 1*a* and 1*b*. The temporal behavior of temperature at the 50 mbar level derived from the radiosonde data is shown in Fig. 1*b*. The vertical straight line on the right of the figure separates the measurements at the stations Molodezhnaya (to the left of it) and Mirnyi (to the right of it). The random errors in the measurements of the total NO_2 content using the direct solar radiation are denoted by vertical segments in Fig. 1*a*. The corresponding errors in measurements in the zenith direction are not shown, because they were less than $1 \cdot 10^{14}$ mol/cm^2 (the rms errors were less than 5%). The random errors in a single measurement of the total ozone content were less than 3 Dobson units (D.u.).

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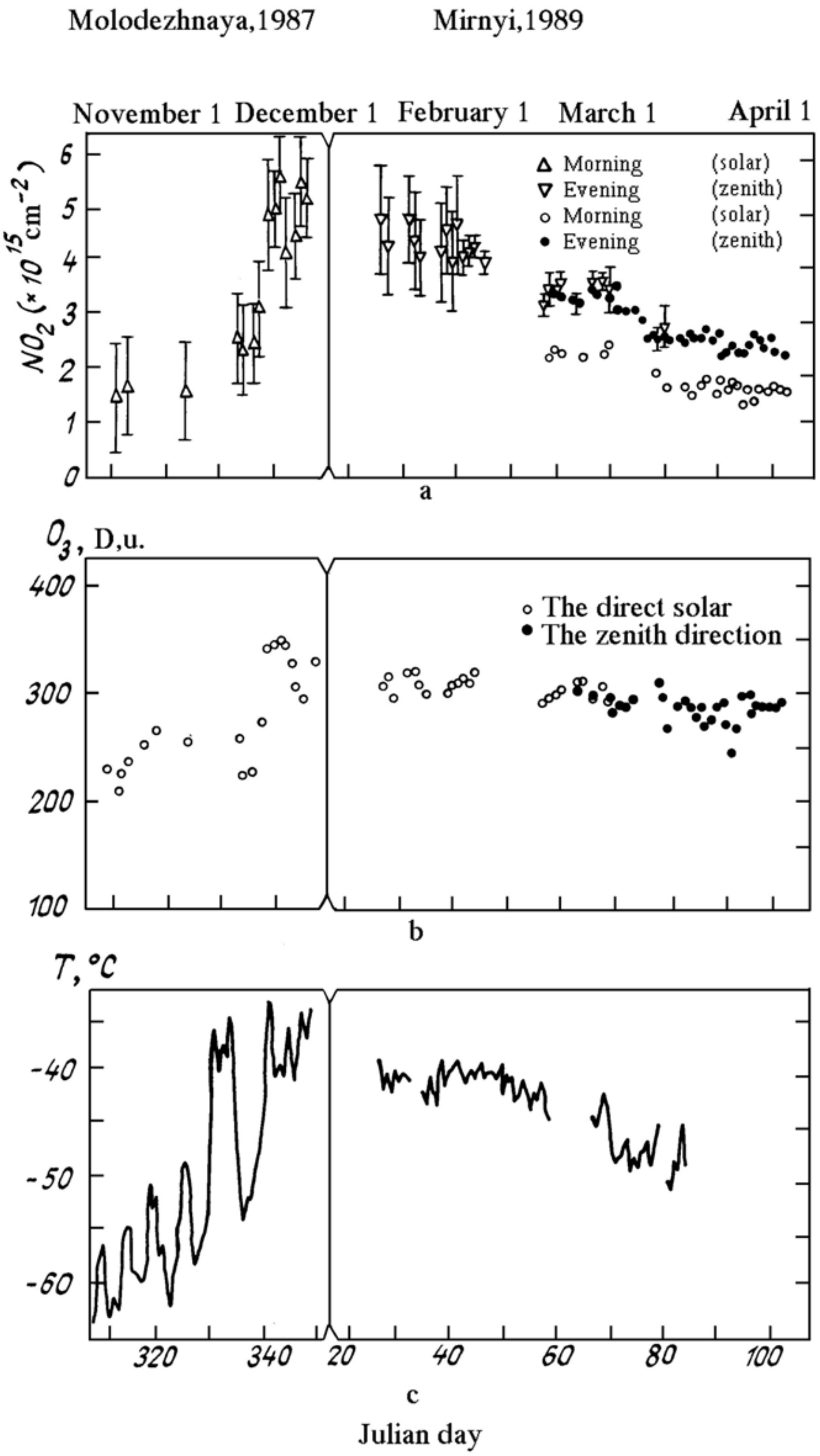

FIG. 1. Total content of NO_2 *(a), ozone (b), and temperature at the 50 mbar level (c) at the stations Molodezhnaya and Mirnyi. Random errors in the measurements of the total* NO_2 *content using direct solar radiation are denoted by vertical segments.*

An irregular growth of the total ozone content from 210 to 340 D.u. characterizing the filling–up of the "ozone hole" can be seen in Fig. 1 during November–December, 1987. Simultaneously, warming of the stratosphere and an increase in the total NO_2 content from $1.5 \cdot 10^{15}$ in November to $5.5 \cdot 10^{15}$ mol/cm^2 in December took place. The sharpest increase in the total ozone and NO_2 contents was recorded at the beginning of December. The lowest (over the measurement period) total ozone content, equaled 207 D.u., was observed on November 6 and the highest one, amounting to 346 D.u., –

on December 7, 1987. The highest total NO_2 content was recorded on December 7 too.

The lowest total ozone contents were usually observed in September–October and substantially varied both in their absolute value and in the time of occurence depending on the conditions of transformation of the circulation of the Antarctic stratosphere.[6,7] The spring increase in the total NO_2 content as well as that in the total ozone content that can be seen from Fig. 1 are associated with their influx from the lower latitudes as a result of an attenuation of the circumpolar vortex.[8] The transformation of the stratospheric circulation over the Antarctic and the final warming of the stratosphere in spring 1987, which is associated with this transformation, occurred unusually late.[9] This explains the fact of late (in the first decade of September) filling–up of the "ozone hole" in Fig. 1.

During winter and spring of 1988 (from February to April) the total ozone content over the station Mirnyi slowly decreased, and its mean value equaled ~295 D.u. Synoptical processes, for the most part, gave rise to the variations in the total ozone content during that time. Thus, there was an appreciable negative correlation between the total ozone content and the tropopause height during February–March, 1988. On April 1 a low value of 247 D.u. was observed for the total ozone content. Unfortunately, since March 23 aerological data were unavailable. Note that very low values (200 D.u.) of the total ozone content were recorded at the station Syova at the same time.[10]

During the same period (from February to April) a depletion of the total NO_2 content occurred above the station Mirnyi, revealing the typical annual behavior of NO_2 with maximum in summer light time and with minimum in winter dark time.[3,11,12] The total NO_2 content had an approximately constant value of $4.5\cdot10^{15}$ mol/cm^2 from the end of January to the beginning of February. This was followed by the gradual depletion with the mean rate of $1.3\cdot10^{15}$ mol/cm^2 per month, while from the end of March to the beginning of April it again assumed an approximately constant value of $2.4\cdot10^{15}$ mol/cm^2. Some interdiurnal variations associated with the synoptical processes were superimposed on the general temporal behavior of the total NO_2 content during summer and fall.

Comparison of the total NO_2 content obtained in the morning and in the evening shows a regular excess of the evening values over the morning by ~30%, thereby revealing the NO_2 variations from day to night owing to the slow transformation of the nitrogen oxides into N_2O_5 during night time with a subsequent day–time increase in NO_2 as a result of N_2O_5 photodissociation.[11,12]

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