

OZONE AND NITROGEN DIOXIDE ABOVE THE NORTHERN TIEN SHAN

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ABSTRACT

The results of systematic perennial measurements of the total ozone (since 1979) and nitrogen dioxide column (since 1983) in the atmosphere in the European-Asian continent center above the mountainmass of the Tien Shan are given. This region is distinguished by a great number of sunny days during a year. The observation station is at the Northern shore of Issyk Kul Lake (42.58°N 77.04°E 1650 m above the sea level). The measurement results are presented as the monthly averaged atmospheric total ozone and NO₂ stratospheric column abundances (morning and evening). The peculiarities of seasonal variations of ozone and nitrogen dioxide atmospheric contents, their regular variances with a quasi-biennial cycles and trends have been noticed. Irregular variances of ozone and nitrogen dioxide atmospheric contents, i.e. their positive and negative anomalies in the monthly averaged contents relative to the perennial averaged monthly means, have been analyzed. The synchronous and opposite in phase anomalies in variations of ozone and nitrogen dioxide atmospheric contents were explained by the transport and zonal circulation in the stratosphere (Kamenogradsky et al., 1990).

1. INTRODUCTION

The total ozone (X) has been measured with the multiwave length method on the base of the UV absorption measurement results in the atmosphere within 305 - 315 nm with a random error of a single measurement of 0.6 % (Semyonov et al., 1983). The data obtained are in agreement with the world ozonometric scale within a 2 % uncertainty found

during simultaneous measurements with two spectrophotometers (Dobson No. 108, Russia National Standard, and Brewer No. 44, the latter being calibrated with Brewer No. 17, the secondary reference standard, see Ishov et al., 1991). The NO₂ column (Y) has been measured by the multiwave length method from the absorption of the sun radiation scattering from zenith within 438-442 nm for the sun zenith angles of 85-92° with a random error of a single measurement less than 12 % (Sinyakov and Spectorov, 1987). A comparison of the Issyk Kul NO₂ results with coincident in time and geographical latitude NO₂ data for Toronto (Kerr, 1988) has demonstrated the difference of 5-7 % in the average values for the NO₂ column over the measurement period for these two data sets and the coincidence of their phase annual and year-to-year variations.

2. MEASUREMENT DATA AND DISCUSSION

The monthly averaged total ozone and nitrogen dioxide contents for morning and evening over the whole measurement period in the Issyk Kul Lake region are shown in Figs. 1-3.

According to the perennial measurement data the amplitude of seasonal variations is about 20 % of the annual average X and seasonal variations phases are determined with the highest X during the period from January to April and the least during August-November. The amplitude of Y seasonal variations is about 70 % of its annual average value and seasonal variations phases are determined with the highest Y values during June - July and the least - during December - January. The values of Y in the morning are smaller than those for the evening because the NO₂ quantity increases during the day time through

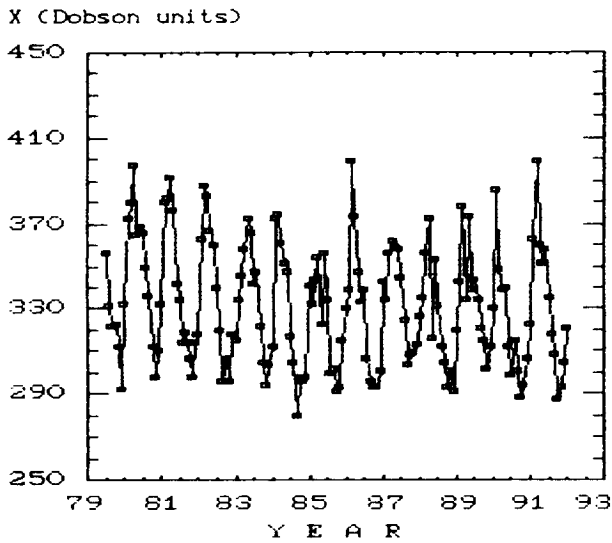


Fig. 1. The monthly averaged atmospheric total ozone in the Issyk Kul Lake region.

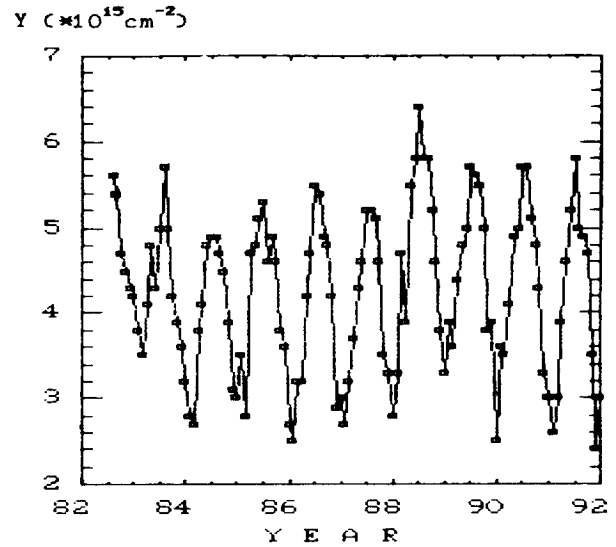


Fig. 2. The monthly averaged NO_2 stratospheric column abundance (morning) in the Issyk Kul Lake region.

NO_2 photolysis and acceleration of NO transformation into NO_2 at the sunset. Annual changes of Y coincide in phase with seasonal variations of the sun radiation sums. The permanent displacement in time is between the seasonal variations of X and Y : the maxima in X are 3 - 5 months ahead the maxima in Y . The seasonal variations of X are in advance of the sun seasonal radiation variations. At such an advancing increase of X an effect is revealed (Khragian and Kuznetsov, 1981) of transport processes in the lower stratosphere (where the main part of ozone molecules is concentrated and where they are protected from photochemical destruction) on atmospheric ozone. An excess of ozone molecules formed during photochemical processes in the tropical middle stratosphere is transported into the lower stratosphere of the high latitudes with the meridional component of general circulation there and simultaneous down-drafts. The accumulation of ozone in the amounts above the photochemical balance causes the motion of ozone molecules in the lower stratosphere towards equator. The intensity of such transport is regulated by the velocity of zonal circulation in the lower stratosphere. The meridional transport in the lower stratosphere towards equator is the most intensive in the middle latitudes from the end of winter to the beginning of summer and results in the beginning of

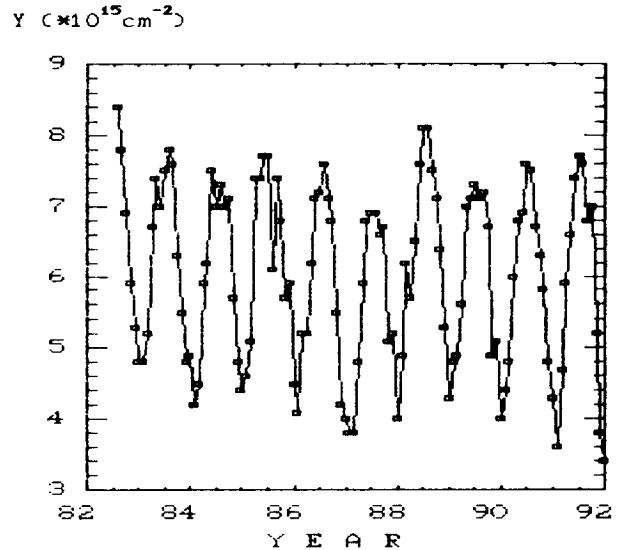


Fig. 3. The monthly averaged NO_2 stratospheric column abundance (evening) in the Issyk Kul Lake region.

the advanced maximum in the seasonal variations of X. An increase of zonal wind velocity in the lower stratosphere gives a somewhat belated appearance of a maximum X and a decrease of their values ("barrier" effect, see Khrgian and Kuznetsov, 1981).

The trends of X and Y have been obtained with a twelve-month moving averaging of their monthly mean values series. They indicate that X for the last ten-year period in the region of measurements decreased by 23 units of Dobson (6.8% of the mean value found for the whole ten-year period), and Y does not vary essentially. Regular variances of X and Y with the quasi-biennial cycle are found by means of the spectral analysis. For X its period is 21 months, and amplitude is 1.8 units of Dobson (0.5% of the mean value found for the ten-year period). For Y its period is 20 months, and amplitude is $0.16 \cdot 10^{15} \text{ cm}^{-2}$ (4% of perennial mean values). Irregular components of X and Y variations are anomalous ΔX and ΔY . They were obtained with subtraction of perennial averaged monthly means of X and Y from their perennial monthly means series. Positive ΔX , ΔY correspond to the ozone and nitrogen dioxide excess and negative - to the deficit in their climatic standards. ΔX larger than the standard deviations of perennial observation values (5.5% in winter, 2.5% in spring, see Bojkov, 1987) and ΔY more than 10% have been analyzed. The analysis has shown that ΔX and ΔY varied synchronously when the activity of the circulation processes increased in the lower and middle stratosphere above the observation site. When the transport circulation occurs in the lower stratosphere only, and nitrogen dioxide variability is governed by the photochemical processes in the middle stratosphere, the appearance of negative ozone anomalies coincides in time with formation of positive nitrogen dioxide anomalies, i.e. the variations of ΔX and ΔY are opposite in phase. For example, the synchronous variations of ΔX and ΔY were observed in January - March of 1987, and the variations of ΔX and ΔY in the opposite phase - in January - April of 1985.

In winter at the baric levels of 10-30 hPa the form and the position of the circumpolar vortex (CPV) center about the North Pole vary under the influence of the Canadian or Siberian anticyclones. CPV acquires the form of an elongated ellipse, its south boundary reaching 30°N in separate zones. The center of the CPV changed form shifts often towards the low latitudes. The latitude where the "winter" values of

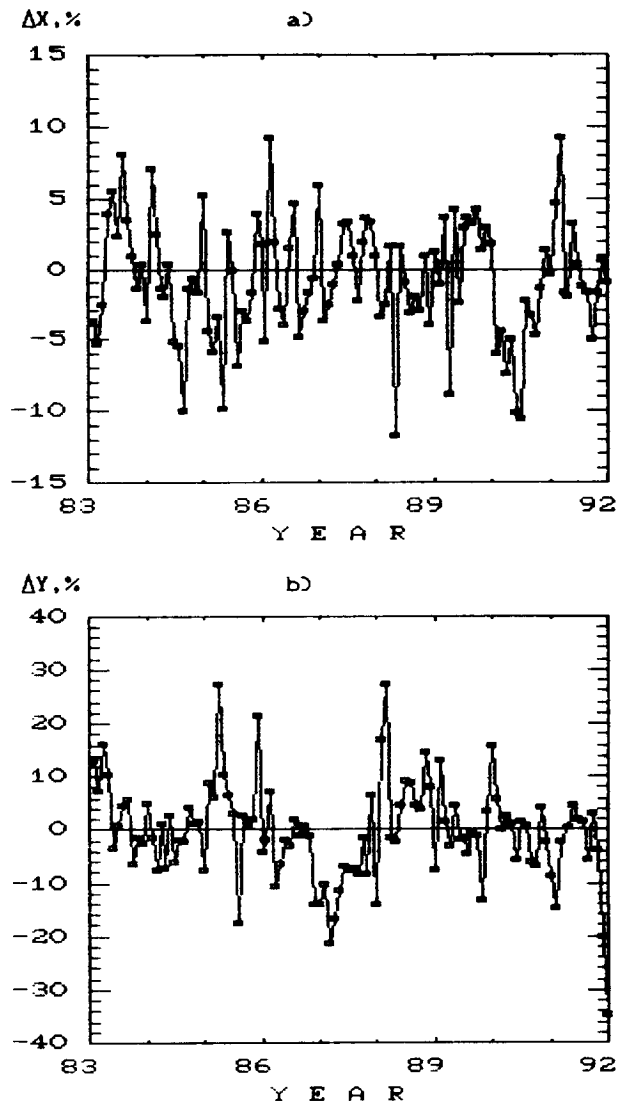


Fig. 4. Anomalies in the monthly averaged atmospheric total ozone ΔX (a) and NO_2 stratospheric column abundance ΔY (b) (evening) in the Issyk Kul Lake region relative to the perennial averaged monthly means.

the pressure gradient replaced by their "summer" values can be taken as the CPV south boundary. The life-time of NO₂ molecules in the polar night conditions within the CPV boundaries is of several days, that is a result of photochemical reactions between the molecules of NO_x odd nitrogen complexes.

The analysis of the baric topography maps for 10-30 hPa has shown that the observation station was in January - March of 1987 in the CPV boundaries during almost all the Y measurements. On those days in the stratosphere there were the air masses formed in the polar night zone 3 - 5 days before the Y measurement time, therefore they contained small amounts of NO₂ molecules. By this the deficit of Y (negative anomalies of Y) observed during this period can be explained. At the same time an intensification of transport in the lower stratosphere was observed as well as the appearance of X negative anomalies, the occurrence of which can be explained by an enhancement of the "barrier" effect. As it is shown in Fig. 4, the synchronous variations of ΔX and ΔY were fixed in January - March of 1987.

During the measurement of X and Y in January - April of 1985 the CPV was to the north of the observation station, and the air masses from the low latitudes with large NO₂ content were above it. Therefore, during this time the positive anomaly of Y (to 27% in March) was observed. The winter of 1984-1985 differed by an extraordinary high intensity of zonal transport in the lower stratosphere (the zonal component of wind velocity in November of 1984 was 20 m/s more than the climatic standard), so not only the maximum values of X became smaller in 1985 but a deep longitudinal negative anomaly of X appeared also in January - April of 1985. This time, as it is seen from Fig. 4, ΔX and ΔY were opposite in phase.

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