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TOTAL OZONE AND TOTAL NO_2 LATITUDINAL DISTRIBUTION DERIVED FROM MEASUREMENTS IN THE ATLANTIC OCEAN IN MAY 1988

Alexander S. Elokhov and Alexander N. Gruzdev

Institute of Atmospheric Physics
Russian Academy of Sciences, Pyzhevsky per.3
Moscow 109017, Russia

ABSTRACT

Total ozone and NO_2 were measured aboard a ship in the 40S - 40N latitude band in the Atlantic Ocean in the second half of May 1988. The main features of the latitudinal distributions of total NO_2 and ozone are similar. There are seen an increase of total ozone and NO_2 from the tropical to subtropical latitudes, strongest in the region of the subtropical jet stream. The fine structure has been revealed in the total ozone and NO_2 latitudinal distributions, connected most likely with stratosphere-troposphere exchange processes in the tropopause folding zone.

1. INTRODUCTION

The main features of the latitudinal distribution of total ozone are well known (see e.g. Perov and Khrgian, 1980). Some features of the latitudinal distribution of total NO_2 were discussed by Noxon (1979). Particularly, he has found the tropical total NO_2 minimum, the middle latitude maximum in winter and spring in the Northern Hemisphere (NH), and the abrupt decrease of total NO_2 to the north of 50N in winter. Measurements aboard an airplane, done by Coffey et al. (1981) and Girard et al. (1983), have shown a decrease of the stratospheric part of total NO_2 in the equatorial direction and low NO_2 values to the north of 40N in winter. In May the decrease of total NO_2 in the NH middle latitudes are not noted. In summer, by contrast to winter, total NO_2 increases with latitude. The qualitative features of the total NO_2 distribution were reproduced by Solomon and Garcia (1983) in two-dimensional model calculations. They have also revealed the continuous increase with latitude of evening total NO_2 in the polar region of the summer hemisphere. Qualitatively similar features were observed by Karcher et al. (1988) from an airplane. Satellite measurements of the NO_2 vertical distribution have given the global latitudinal distribution of the upper-stratospheric part of total NO_2 in different seasons (Mount et al., 1984; Chu and McCormick, 1986; Remsberg and Russel, 1987).

This paper deals with the results of total ozone and NO_2 measurements done in the second half of May 1988 in the Atlantic Ocean aboard the "Akademik Feodorov" ship.

2. INSTRUMENTATION AND METHODS OF OBSERVATIONS

The MDR-23 grating scanning spectrometer (Soviet commercial device) with the 0.7 nm spectral resolution was used for the measurements. Both total ozone and NO_2 measurements were zenith sky measurements. Total ozone was measured in the 303-333 nm spectral range at solar zenith angles $\leqslant 70^{\circ}$. Total NO_2 was measured in the 435-450 nm spectral range during morning and evening twilights at solar zenith angles 84°-96°. The spectrometer scanning rate is 51.2 nm/min. Total ozone was derived using nomograms calculated with the use of single-scattering approach. Total NO_2 was derived using method similar to that of Solomon et al. (1987). An additional information about the methods used can be found in Elokhov and Gruzdev (1991).

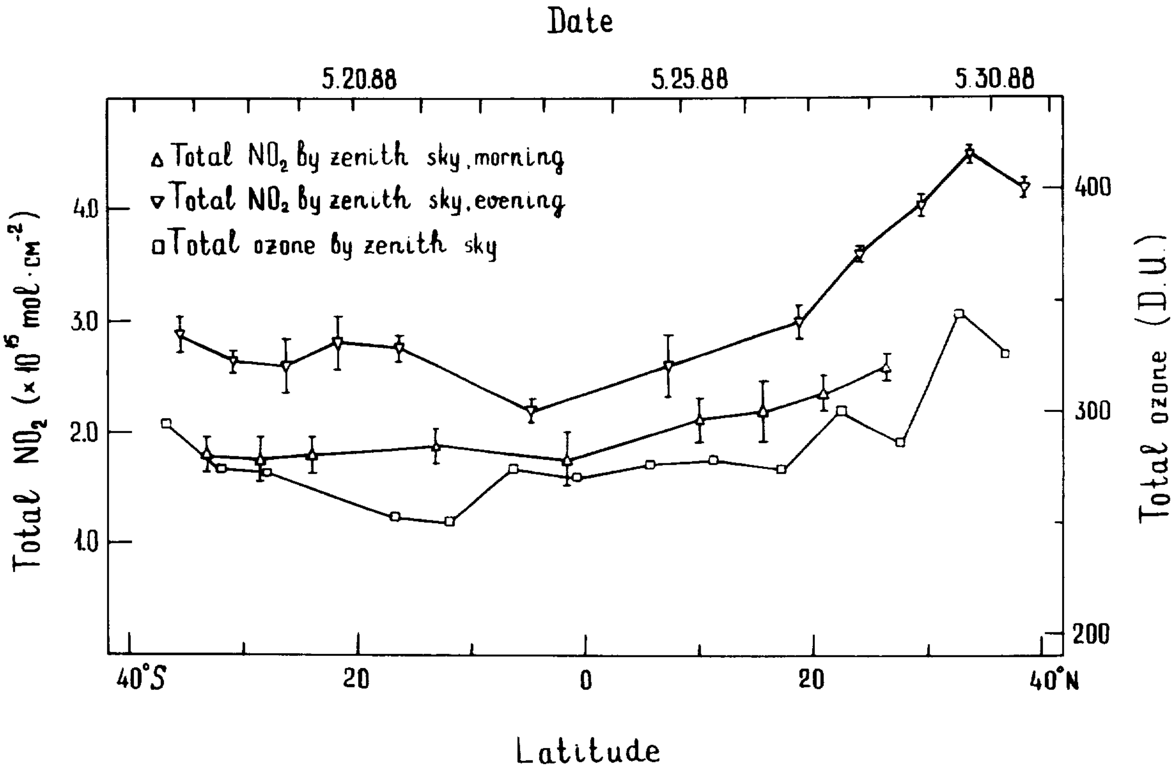


Fig.1. Evening and morning total NO_2 and total ozone as functions of latitude. The upper abscissa shows dates of measurements. The random errors of total NO_2 measurements are shown by vertical segments. The total ozone random errors are about 1% and not shown.

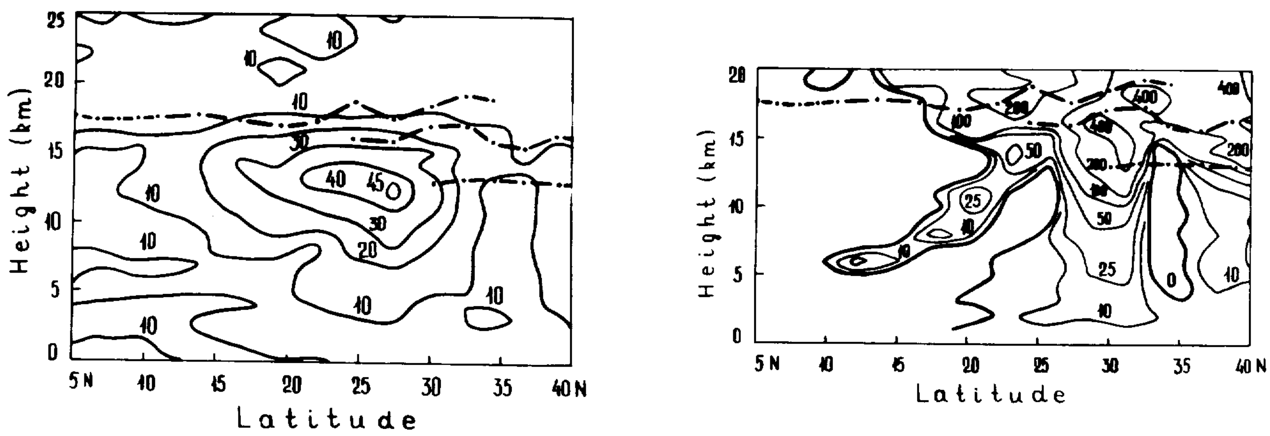
3. RESULTS OF MEASUREMENTS AND ANALYSIS

The results of the measurements of total ozone and NO_2 are shown in Fig.1. The ship went north-east. The data correspond to the 55E-15E longitudinal range. The total ozone latitudinal distribution has a typical total ozone increase with latitude in the tropics. The total ozone latitudinal increase is monotonous and slow in the Southern Hemisphere (SH), but not monotonous in the NH. The mean latitudinal gradient in the 17-33N latitude band is 2.5 times as large as the gradient in the SH.

The evening total NO_2 contents in Fig.1 exceed systematically the morning ones by 20-40%, the difference increasing with a latitude. This reflects diurnal NO_2 variations. The evening total NO_2 content has the near-equatorial minimum and increases with latitude in the tropics. In the NH the latitudinal gradient of evening total NO_2 increases sharply (3 times) to the north of 20N. To the north of 34N the evening total NO_2 content decreases following the total ozone decrease.

The latitudinal dependence of morning total NO_2 resembles some features of the evening total NO_2 latitudinal distribution. In the NH tropics the morning total NO_2 content hasthe same latitudinal gradient as the evening NO_2 content does. Note that to the north of 20N, where the evening total NO_2 latitudinal gradient increases sharply, the latitudinal gradient of morning total NO_2 stays at the former low level, at least up to 26N.

Fig.2a,b show the altitude-latitude cross-sections of wind velocity and potential vorticity in the NH derived from radiosondes launched from the ship (there were no soundings in the SH). The characteristic feature of Fig.2a is the



(a) (b)

Fig.2. Altitude-latitude cross-sections of (a) wind velocity (m/sec) and (b) potential vorticity ($m^4 g^{-1} sec^{-3}$). The dashed-dotted lines denote the tropopause.

upper tropospheric jet stream with the extreme wind velocity at 28N. Above the core of the jet stream the tropopause folding zone is seen. Another tropopause folding zone is seen over the northern (cyclonic) periphery of the jet stream. Fig 2b shows the penetration of positive potential vorticity values from the stratosphere into the troposphere in the tropopause folding zones. The strongest sag of lines of constant potential vorticity is seen at the cyclonic periphery of the jet stream. This points out the intensive stratospheric injection in this zone.

Comparison of Fig.1 and Fig.2a shows that the two maxima of the total ozone latitudinal distribution in Fig.1 correspond to the tropospheric edges of the two tropopause folding zones in Fig.2. The maxima seem to be caused by descending air motions in the tropopause folding zones (according to the Normand and Dobson principle). The maximum of evening total NO_2 corresponds to the northern folding zone and can be connected both with a similar effect of NO_2 accumulation due to deformation of NO_2 vertical distribution by descending motion, and with a simple NO_2 photochemical redistribution which depends upon the ozone content.

There is no second maximum in the total NO_2 latitudinal distribution which would correspond to the NH low-latitude maximum of total ozone. There may be some reasons of such a discrepancy. First, the low-latitude tropopause folding seen in Fig.2 can be of limited scale and localized either above or upwind (to the west) of the site of the observations. The difference between conditions of total ozone and NO_2 observations (total ozone is observed when the Sun is high, but total NO_2 is observed during morning and evening twilights) points out such a possibility. The fact that the latitudinal gradient of the evening total NO_2 content increases, but the latitudinal gradient of the morning total NO_2 content stays at the former low level in the zone of the low-latitude tropopause folding, speaks in favour of such a possibility too. Second, Fig.2b shows that the stratospheric-tropospheric exchange in the zone of the low-latitude tropopause folding is weak and, most likely, does not influence appreciably the vertical redistribution of these species above the tropopause folding, but only increases the upper tropospheric contents of the species. As the method of total NO_2 measurements is most sensitive to changes in stratospheric NO_2 (Solomon et al., 1987), the tropospheric addition of NO_2 cannot be manifested in Fig.1. Furthermore, the stratospheric injection cannot increase essentially tropospheric NO_2 because of the relatively short lifetime of nitrogen oxides in the troposphere (Fehsenfeld et al., 1988).

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