503920

TOTAL OZONE SEASONAL AND INTERANNUAL VARIATIONS IN THE PRINCIPAL AIR MASSES OF THE NORTHERN HEMISPHERE IN 1975-1990.

Karol I.L., Klyagina L.P., Shalamyansky A.M., Jagovkina S.V.

Main Geophysical Observatory
Karbyshev Str., 7, St.-Petersburg, 194018, Russia

ABSTRACT

The diurnally mean total ozone X from the Northern Hemisphere ground based 90 stations for 1975-1990 are averaged over the Arctic $(\bar{X}_A)$, Intermediate $(\bar{X}_I)$ and Tropical $(\bar{X}_T)$ air mass areas, divided by the jet stream axes on the isobaric surfaces 300 and 200 mb. The mean square variations of the so averaged X are considerably smaller than of the X, averaged over the corresponding zonal belts.

This property allows one to improve considerably the statistical significance of X trends and changes over various time periods, taking into account the time correlation of data for adjacent time intervals. $\bar{X}_A$, $\bar{X}_I$ and $\bar{X}_T$ trends are estimated over the periods of solar activity rise and fall in its 21-st and rise in its 22-nd 11 year cycles and over the periods of west and east phases of the known quasibiennial oscillation (QBO). Solar activity variations affect mostly $\bar{X}_T$, $\bar{X}_I$ trends in summer months, while QBO phases influence the X changes mostly during the cold half year. X are lower in the west QBO phase and their trend is negative in spring during the almost all period considered. The anthropogenic effects on the X is also estimated.

1. INTRODUCTION

Numerous statistical studies of total ozone X variations in space and time have suffered from the high level X variability "noise" of different scales. This essential feature of ozone content fields in the troposphere and lower stratosphere leads to low statistical significance of the ozone content trend and other statistical parameter estimation as indicated in (WMO, 1985; Karol et al.,1987) and in many other publications. A basic cause of such variability is the successive passage of ozone rich and ozone poor air masses over the observing station guided by the planetary atmospheric transport systems.

A new concept of "dynamical" distributing and grouping of the Northern Hemisphere total ozone fields over the known basic planetary air masses: Arctic (AM); Intermediate (IM) and Tropical (TM) as divided by the jet stream axes at the 300 and 200 hPa isobaric surfaces has been introduced and developed by Shalamyansky and Romashkina (1980),

Karol et al.(1987,1990). These air mass borders, being variable interdiurnally, have regular seasonal courses of their mean monthly positions in the atmosphere, which have been studied in the above publications. Fig. 1,2 present the examples of seasonal variations of mean monthly values of some of these parameters, based on aerological data for 1962-1980 period. The comparison of the mean square deviations (msd) $\sigma_{\bar{X}}$ of mean monthly total ozone $\bar{X}$, averaged over the air masses and over the corresponding zonal belts at Fig.3, reveal a considerable zonal belts $\sigma_{\bar{X}}$ reduction for the air masses. This reflects the almost homogeneous X distributions within the each air mass boundaries with permanent and sufficient X differences in the adjacent air masses.

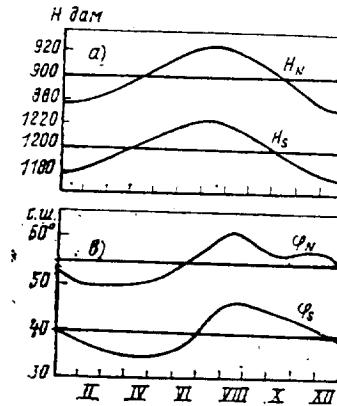Fig.1.Seasonal variations of zonally averaged mean monthly: heights of air mass borders h_N and h_S - a; latitudes of air mass borders φ_N and φ_S - b relative to their mean annual values. Bars indicate the mean square deviations (m.s.d.) of the mean.

Such air mass processing was applied to the total ozone data from the Northern Hemisphere ground-based ozonemetering stations with about 50 Dobson's and 40 filter ozonometers for the period 1975-1990. These processed data are used for evaluation of connections of mean monthly X, averaged over the above air masses, with several ozone distribution forming factors of natural origin: eleven year cycle of solar activity (SAC); quasibiennial oscillation (QBO) and of anthropogenic stratospheric chlorine content increase.
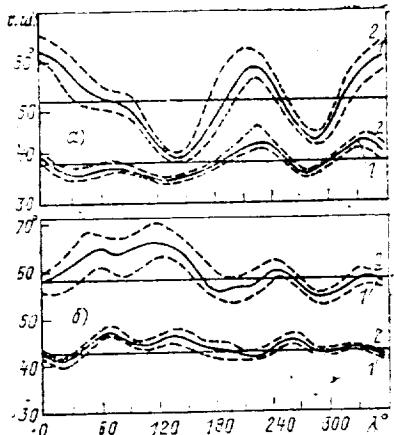
Fig. 2. Longitudinal profiles of mean monthly latitudes of air mass borders φ_N and φ_S for January and July averaged over 1962-1980 period - full lines; $\varphi \pm \sigma_\varphi$ - dashed lines.
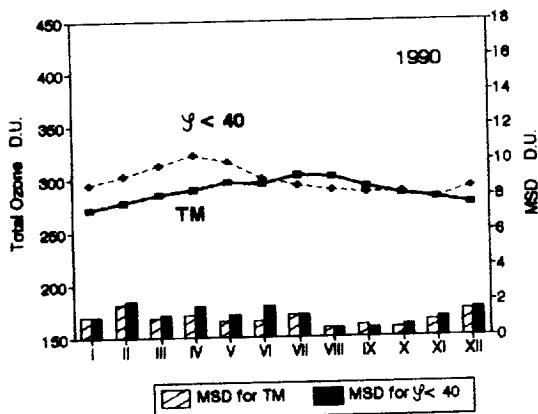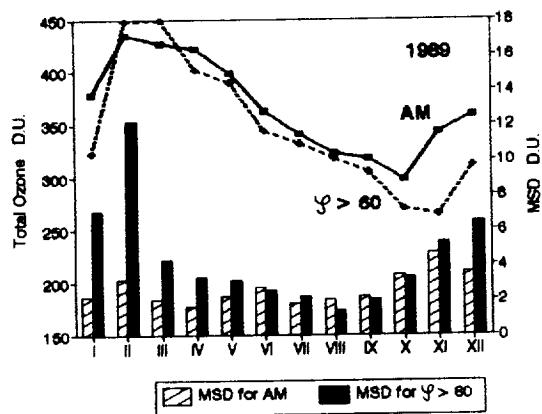

Fig.3. Seasonal variations of mean monthly total ozone for 1989 and 1990 averaged over the air mass areas - a and over the zonal belts - b. Bars indicate mean square deviations of the mean $\sigma_{\bar{x}}$.

2. DATA PROCESSING

For the ozone - QBO connections studies the mean monthly X_A, X_I and X_T, averaged over the corresponding Arctic, Intermediate and Tropical air masses are grouped into the east (E) and west (W) QBO phase periods, using the mean monthly zonal winds data at equatorial stations from (Naujokat et al., 1991) and averaged over the same months in each phase. Variances σ_E^2, σ_W^2 in groups are the sums of all monthly mean variances of monthly $\bar{X}$, averaged over the period and they are presented at Fig.4 as bars to seasonal variation profiles. These profiles reveal the evident difference between the $\bar{X}_E$ and $\bar{X}_W$, which are highly statistically significant in each air mass in the first half of the year. The probability of non-zero difference $\bar{X}_E-\bar{X}_W$ is not less than 85-90% for each month of this period, being 99% in March and April for all air masses.
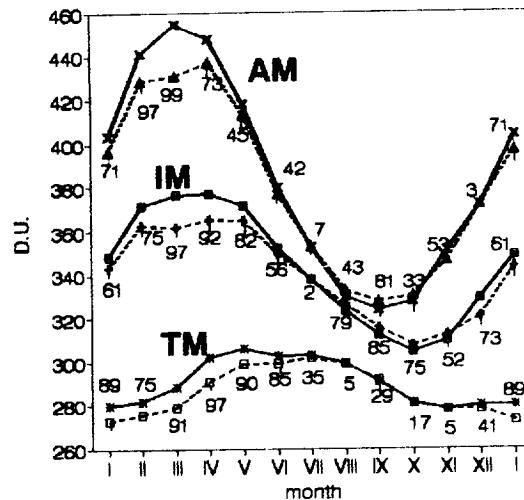

Fig.4 Seasonal variations of mean monthly total ozone X_E and X_W averaged over the air mass areas and over periods of E (dotted lines) and W (full lines) of QBO phases. Bars indicate the m.s.d. of the mean σ_x; numbers are the percent probabilities of the non zero difference of X_E and X_W for 1975-1990 period, according to Student's two sided test.

For evaluation of the interannual monthly $\bar{X}$ covariation, the interannual autocorrelation functions of monthly X deviations from their means for the E and W phases are calculated. In both phases during the cold half-year (October-March for AM and IM, November-April for TM) covariation of X is weak and they are practically noncorrelating. But during the warm half-year $\bar{X}$ covariation is stronger, and being exponentially approximated as $R(t)=e^{-\alpha t}$, has $\alpha=1,53$; 1,20; 1,15; for AM, IM and TM correspondingly, with relaxation time $\tau=\alpha^{-1}=0,66$; 0,83; 0,87 year. The account of X interannual correlation according to procedure in (Polyak, 1979) makes only slight corrections in $\bar{X}_E$

402

and $\bar{X}_W$ means, their trends and variances, being practically indistinguishable from their noncovariated values.

Linear trends of X are estimated within the groups of E and W QBO phases and also for periods 1975-1986, 1980-1990 of full eleven year cycle of solar activity, according to procedures proposed by Polyak (1979).

3. TOTAL OZONE VARIATIONS IN QBO PHASES

Fig.4 demonstrates that total ozone X in E phase is significantly higher than in W phase for all AM only in January-June. Therefore the linear trends for E and W phases are estimated for these months for periods 1975-1986 and 1980-1990. Analysis of these trends for 1980 -1990, presented at Fig.5, reveals the negative trends almost for all masses and months considered, being bigger by value in E phase for TM and IM and in W phase for AM. Comparing this with seasonal X_A variations at Fig.4, one must emphasize that maximal X_A negative trend in March- May for W phase takes place for X_A relative low values with local minimum in these months, reflecting probably the averaged effect of local ozone "mini holes" in Arctic atmosphere (WMO/UNEP,1989, 1991).
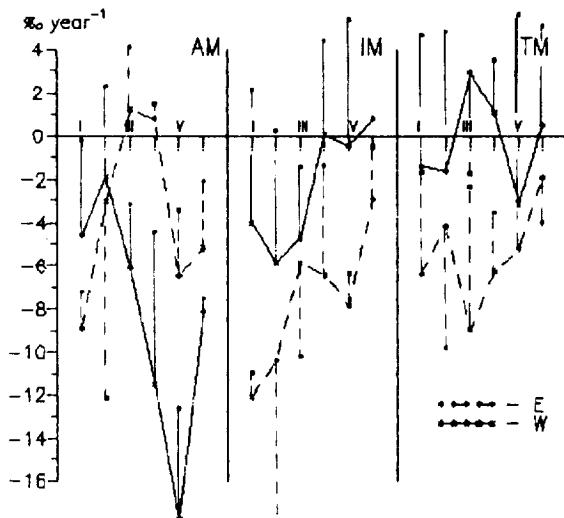

Fig.5. Linear trends ($^0/oo$ year^{-1}) of $\bar{X}_E$ (dashed lines) and $\bar{X}_W$ (full lines) for January-June 1980-1990. Bars indicate the m.s.d. of the trend value.

Trend distributions at Fig.5 may be well explained by meridional air transport scheme, proposed recently by Trepte and Hitchman (1992) and based on the analysis of SAGE measurements of stratospheric aerosol optical thickness in 1980-ies. In this scheme the QBO E phase conditions are favorable for detrainment of substance from the upper part of lower tropical stratosphere, where the ozone concentration global maximum is situated, and for substance transport to the pole of the winter hemisphere. This enhanced transport may
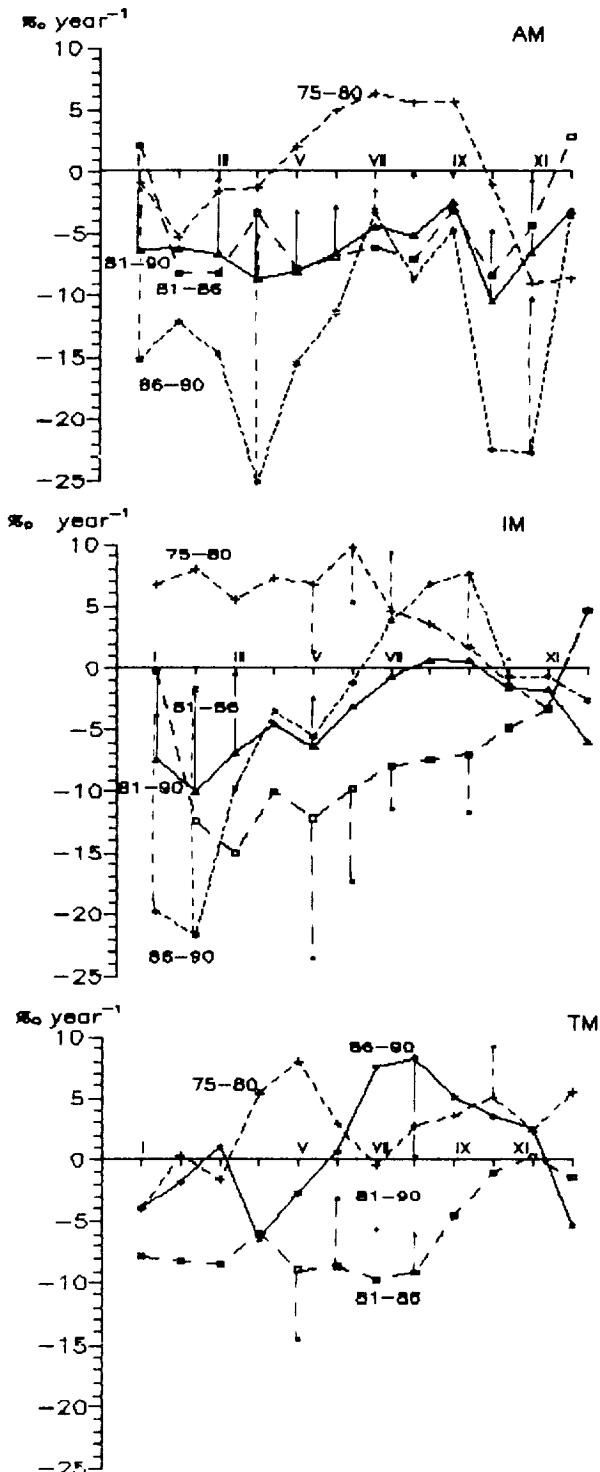

Fig.6. Linear trends ($^0/oo$ year^{-1}) of mean monthly $\bar{X}$ for the air mass and periods indicated. Bars denote the 90% significant confidence limit of nonzero trend, according to Student's two-sided test.

explain the relatively small X_A trends. Large negative X_A trends in QBO W phase in their turn may be the result of reduced air (and ozone) transport intensity into the polar zone from tropics in winter by the transient planetary waves (WMO/UNEP, 1989). According to Trepte and Hitchman's scheme in the QBO W phase the air and substance are detrained mostly from the lower layer of the tropical lower stratosphere with smaller ozone content, resulting in small and nonsignificant X_T trend. All this explains the Fig.4 and Fig.5 results qualitatively, but quantitative analysis will be necessary in the future.

4. TOTAL OZONE VARIATIONS IN ELEVEN YEAR SOLAR CYCLE.

Fig.6 presents the X_A, X_I, X_T linear trends for the above indicated periods of rise and fall of solar activity in its 21-st (1975-1986) and 22-nd (1986-1997) eleven year cycles. For the period 1975-1980 of solar activity increase, trends are positive for all air masses during the warm half year, being however nonsignificant at 90% confident level for most of months. Negative X_A, X_I and X_T trends for the period 1981-1986 reflect the effect of solar activity and of anthropogenic ozone depletion intensity increase, which becomes almost equal to solar activity variation effect at that period, according to model calculations (Karol et al., 1989). Big negative X_A trends and positive for July-November X_I and X_T trends for the period 1986--1990 reflect evident effect of opposite forcings on the ozone of the above two factors. In the polar ozone the anthropogenic ozone depletion is dominant, but X_A negative trends are minimal in value in the summer months June-September. During these months solar activity increase was dominating over the anthropogenic ozone depletion in intermediate and tropical air masses, where the solar radiation is more intensive.

For the whole decade 1980-1990 X_I and X_T trends are near zero for the second and are small negative for the first half of the year. These negative trends are 90 % confident for X_I (excluding April and June) and nonsignificant at this level for X_T. But X_A trends for decade 1980-1990 are negative and significant at 90% level of confidence for almost all months. All this agrees well with the recent observational results for the total ozone changes in the above decade, when nonsignificant changes have been observed in the tropics and trends of about 3-6% and 4% per decade were estimated in middle and polar northern latitudes (WMO/UNEP, 1991).

5. SUMMARY AND CONCLUSIONS

Total ozone X data from the Northern Hemisphere ground based ozonemetering network for the 1975-1990 are averaged over the principal Arctic, Intermediate and Tropical air mass areas with interdiurnally changing, but when monthly averaged, seasonally regularly varying borders. Due to significant reduction of the mean square deviations of these monthly and area averaged $\overline{X}$ in comparison to regular zonal averaging, more fine and statistically significant variations of monthly

and air mass averaged X are estimated, as affected by QBO and 11-year solar activity cycle.

The trends of total ozone depletion due to anthropogenic influence in 1980-1990 are maximal for Arctic air mass in winter and spring and are close to those estimated for that period from observations in (WMO/UNEP,1991).

The reduced statistical noise and enhanced X_A, X_I, X_T sensitivity to ozone forming factors are promising to use this approach as basement for long term prediction of the total ozone variations.

REFERENCES

Karol I.L., Klyagina L. P., Shalamyansky A. M., Frolov A.D., 1987 Ozone and temperature fields within air mass borders.- Meteorol.Gidrol.N10, 47-52 (in Russian)

Karol I.L., Kiselev A.A., Rosanov E.V. 1989. Model assessment of ozone and ozone active atmospheric gas content changes due to anthropogenic influences and to solar activity variations. In "Ozone in the atmosphere (R.Bojkov, P. Fabian eds.) Deepak Publ.

Karol I.L., Klyagina L.P., Shalamyansky A.M., 1990. Trends of total ozone in Northern Hemisphere principal air masses in 1975 - 1986.- Meteorol. Gidrol., N8,84-88 (in Russian).

Naujokat B. et al., 1991. Beilagen zu Berliner Wetterkarte (Free Univ. of Berlin) Berlin.

Polyak I.I.,1979. Methods for the analysis of random processes and fields in climatology, Gidrometizdat Leningrad (in Russian).

Shalamyansky A.M., Romashkina C.I., 1980. Distribution and transformation of total ozone in various air masses - Trans. USSR Acad. Sci., Atmosph., Ocean. Phys., 6.N12,1258--1267, (in Russian).

Tepte C.R., Hitchman M.H., 1992. Topical stratospheric circulation deduced from satellite aerosol data.- Nature, 355,626-628.

WMO, 1985. Atmospheric ozone 1985, v.II. WMO Global Ozone Research and Monitoring Project. Rep.N16, WMO Geneva.

WMO/UNEP, 1989. Scientific assessment of atmospheric ozone. 1989. WMO Global Ozone Research and Monitoring Project. Rep.N20, v.I,WMO, Geneva.

WMO/UNEP, 1991. Scientific assessment of ozone depletion. 1991, WMO Global Ozone Research and Monitoring Project, Rep.N25, WMO, Geneva.