N95- 10643

303595

TOTAL OZONE CHANGE ESTIMATIONS FOR DIFFERENT TIME INTERVALS

Vitali E. Fioletov

Central Aerological Observatory,
Dolgoprudny, Moscow Region, Russia

ABSTRACT

To investigate total ozone behavior in different time intervals for the 40°-52°N and 53°-64°N latitudinal bands sliding 11 year linear trends with the first interval from 1959 to 1969, and the final one from 1980 to 1990 were computed.

The most recent 11-year trends are negative and have larger absolute values than in the past. The trend values in the period from 1980 to 1990 in the 53°-64°N band are -4.3% (winter), -3.2% (summer), -3.8% (annual) per decade, and in the 40°-52°N band they are -5.9% (winter), -2.7% (summer), -3.6% (annual) per decade.

1. INTRODUCTION

A thorough investigation of the available data conducted by the NASA / WMO Ozone Trend Panel [1988] (OTP) has shown that in the winter time some ozone depletion occurs in the middle and high latitudes.

To examine the question of the starting of ozone depletion and its temporal variations considered are total ozone trends' estimations at various 11-year intervals in the middle (40°-52°N) and subpolar (53°-64°N) latitudinal zones using the Dobson and filter network data. The investigation was conducted with the linear and "hockey stick" trend functions. The analytical relationship between these two trend functions has been analyzed.

2. DATA SET

The data used in the analysis were monthly mean total ozone values with revisions done by Dr.R.Bojkov and by the national operating agencies for the period from January 1958 to March 1991. Besides the Dobson, the revised data of 29 stations of the USSR network (see Bojkov and Fioletov, 1992) for the period from January 1973 to March 1991 were also used.

Before the zonal means calculation the annual circle was removed from the series of individual stations, and deviations from the annual circle at individual stations for each month were averaged over all the stations in the latitudinal belt.

The solar flux data at 10.7 cm wavelength were used as an indicator of the solar activity.

3. STATISTICAL MODEL

For obtaining trend estimates with minimum errors all the periodical constituents present in the series should be taken into account. For QBO-component isolation the Ormsby bandpass filter was used, which was applied by Hasebe [1980] to the total ozone series. The solar activity influence was isolated by the regression procedure.

A "hockey stick" dependence in the capacity of the trend function was offered by OTP: up to a certain moment this function is constant, and farther it grows linearly:

$$f(i) = \begin{cases} a, & -m+1 \le i < 0 \\ a+ib_s, & 0 \le i \le n \end{cases}$$

In the OTP report point "zero" corresponds to December 1969; the data were analyzed for the period from December 1964 to November 1986. The "hockey stick" function use is possibly justified when we search for the freons influence on ozone, but this function is hardly suitable for the investigation of trends in total ozone behavior in various periods. For this purpose the linear trend function (l-trend) has been studied in the paper:

$$f(i) = a+ib_l, 0 < i \le n.$$

Total ozone changes for the period of n years for s- and l-trends equal *bn*. The least squares method yields the following estimates for the total ozone changes :

- for l-trend (Δ_l):

$$\Delta_l = b_l = \frac{12\sum_{i=1}^{n}(x_i-\bar{x})\,i}{(n+1)\,(n-1)}$$

- for s-trend (Δ_s):

$$\Delta_s = b_s n = \frac{12\,(n+m)\sum_{i=1}^{n}(x_i-\bar{x})\,i}{(n+1)\,(n^2-n+4nm+2m)} + \frac{6\,(\bar{x}-\bar{\bar{x}})\,nm}{(n^2-n+4nm+2m)}$$

where

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i,\ \bar{\bar{x}}=\frac{1}{m}\sum_{i=-m+1}^{0}x_i$$

Thus, Δ_s and Δ_l are related by the relationship:

$$\Delta_s=\Delta_l\left(1-\frac{3m(n+1)}{n^2-n+4nm+2m}\right)+\frac{6\,(\bar{x}-\bar{\bar{x}})\,nm}{n^2-n+4nm+2m}$$

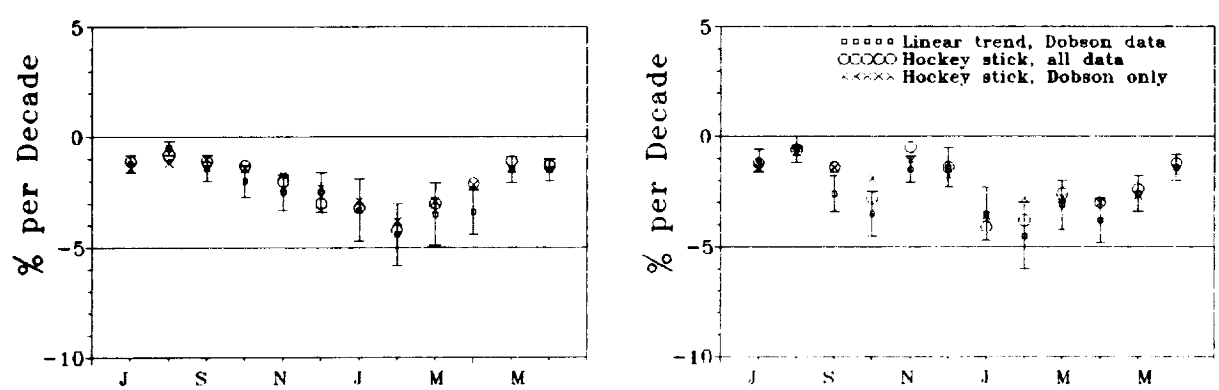
4. THE TOTAL OZONE TRENDS ESTIMATIONS

In Figure 1 the estimations results of ozone changes for l- and s- trend functions in the interval from December 1969 to November 1990 are shown; for s-function estimation all the data since December 1964 are being used. The discrepancy between the estimations is relatively small and is within the limit of one standard error. The filter data addition does not practically effect trend's estimation. Trends are negative practically in all month in both latitudinal belts.

To study total ozone behavior in different time intervals for the latitude bands 40°-52°N and 53°-64°N computed were sliding 11-year linear trends with the first interval from 1959 to 1969, and the final one from 1980 to 1990. The annual, winter (DJFM) and summer (MJJA) trends were computed (Figure 2). Standard errors of the trend estimations are, approximately, 2% per decade for winter trends, 1% for summer, and 0.7% for annual.

The results are little affected by the type of the data set used, irrespective of the fact either it is Dobson, or both Dobson and filter data. When computing the trends QBO and the solar cycle were taken into account.

The annual average trend is positive in the early part of the record in each of the two latitude bands. Since the 11 year period from 1965 to 1975 the trend at both latitudes has been consistently negative. The winter trend is also positive at the beginning of each record, more so in the 53°-64°N band. The winter trend in the 40°-52°N band is negative in every 11 year interval starting with 1962 through 1972. Till recently the maximum negative trend in this latitude band occurs in the 1966 to 1976 interval (4.7% per decade), also large



(a) (b)

Fig. 1. Total ozone trends versus month for the period December 1969 - November 1990 on the 40°-52°N (a) and 53°-64°N (b) latitude bends for different data sets and trend functions. Bars show one sigma intervals for linear trend.

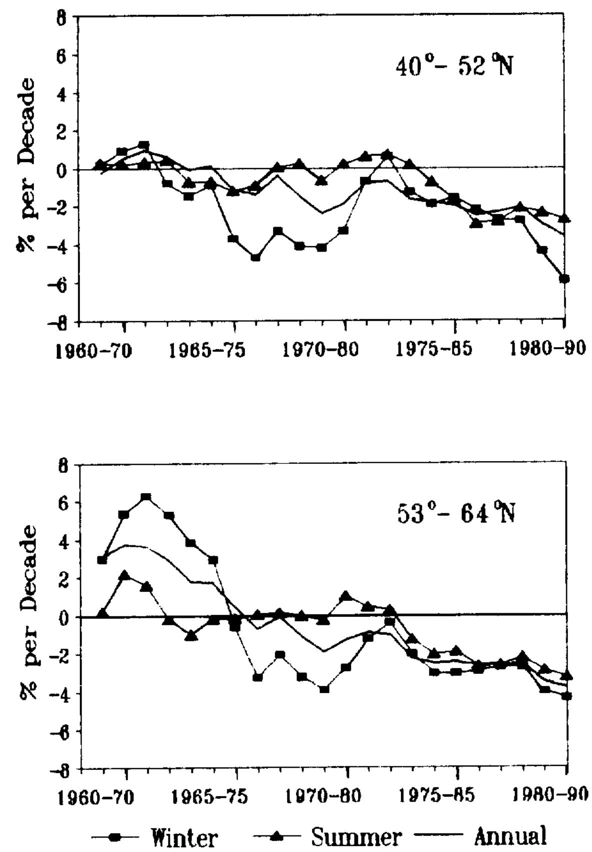


Fig. 2. Sliding 11-year trend determined for the latitude bands 40°-52°N and 53°-64°N (all data). Each point on the graph was obtained by fitting a linear 11-year trend through the given time period.

(>3% per decade) negative trends occur in all the 11-year periods ending in the 1975-1980 range. At this time the winter trends in the 53°-64°N band are also negative (2%-3.9% per decade) with the maximum value in the 1969-1979 interval. The summer trends in both latitude bands are near zero over most of the record. The first 11-year period with a significant negative trend occurs in 1973-1983. The most recent 11-year trends have larger absolute values than in the past. The trend values in the period from 1980 to 1990 in the 53°-64°N band are -4.3% (winter), -3.2% (summer), -3.8% (annual) per decade, and in the band 40°-52°N they are -5.9% (winter), -2.7% (summer), -3.6% (annual) per decade.

5. SUMMARY AND DISCUSSION

The largest absolute values of negative trends take place in the last decades. Ozone decrease occurs in both latitudinal zones in winter as well as in summer months.

Large positive winter trends in the 60-s and early 70-s in the 53°-64°N latitudinal belt are hardly trustworthy. In thus period the zonal means were estimated from the data of three-four stations only.

Significant negative trends in the winter time in both zones in the intervals from 1966-1976 to 1970-1980 are probably connected with the relatively high ozone values in the winter time at the end of 60-s. It should be noted that between the ozone minima (or maxima) and the western (eastern, respectively) QBO phase there is a clear correlation. But in January 1968 and 1970 maxima were observed during the western QBO phase! At the same time in these months a sudden stratospheric warming occurred which is extremely seldom occurred during the western phase [Labitzke, 1982]. Only twice for all the observation period there occurred a stratospheric warming during the western phase in January. Stratospheric circulation changes during the period of warming lead to the penetration of the tropical and middle latitudes air, rich in ozone, into the polar regions, thus causing total ozone increase.

REFERENCES

Bojkov, R.D., V.E. Fioletov, Ozone changes from Eastern Europe to Far East, Quadrennial Ozone Symposium, Carlottesville, Virginia, 1992, Abstracts, p. 185.

Hasebe, F., A global analysis of the fluctuation of total ozone. II Non-stationary annual oscillation, quasi-biennial oscillation and long-term variation in total ozone, J.Meteorol.Soc.Japan, 58, 104-107, 1980.

Labitzke, K., On the internal variability of the middle stratosphere during the northern winters, J. Meteorol. Soc. Japan, 60, 124-139, 1982.

Reinsel, G.C., G.C.Tiao, S.K.Ahn, M. Pugh, S. Basu, J.J.DeLuisi, C.L.Mateer, A.J.Miller, P.S.Connell, and D.J.Wuebbls, An analysis of the 7-yea r record of SBUV satellite ozone data: global profile features and trends in total ozone, J.Geoph.Res., 93, 1689-1703, 1988.

Watson, R.T., M.Prather, and M.J.Kurylo, Present state knowledge of the upper atmosphere 1988: An assessment report, NASA reference publication, 1208, 1988.