Total ozone variations over Greece as deduced from satellite observations

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Abstract

The total ozone time series derived from the observations of the Total Ozone Mapping Spectrometer (TOMS) since 1978 have been used to asses the influence of the Quasi-Biennial Oscilation to the long term trends over Athens , Greece (38^{o}N, 24^{o}E). The result shows that the Quasi -Biennial Oscilllation has little effect on the calculated total ozone depletion trend.

1. Introduction

Many studies have been made by various authors to investigate long term variations of the atmospheric ozone (both total ozone content and ozone concentration vertical profile) due to different causes. Most known among them are the variations depending on the solar activity, the Quasi-Biennial Oscillation (QBO) and the El Nino/Southern Oscillation (ENSO) (Watson et al. 1988; Varotsos, 1989; WMO, 1988, 1991). Stolarski et al. (1991) using TOMS data for the period 1978-1991 estimated (by regression analysis) total ozone content fluctuations and found that the solar cycle contributes about 1.5% over the solar cycle) while the QBO contributes about 1% (over a QBO cycle). The strongest indication of a correlation between the total ozone content variations due to the QBO and the ENSO has been found in the upper stratosphere where the ozone life-time is short and its vertical distribution is significantly controlled by photochemistry. However, indications of other variabilities of the total ozone content also exist, which can only be explained through an impact of the circulation patterns in the stratosphere and troposphere (Varotsos, 1989).

Intercomparisons between TOMS observations and similar data from other observations have shown that TOMS accuracy and precision are of the order of 2% or better (Krueger, 1983; Bhartia et al, 1984). The small drift in the data of approximately -0.4% per year (Fleig et al., 1988) may be corrected by using an algorithm assuming that this drift is proportional to the wavelength separation (Herman et al., 1991; WMO, 1988).

We have previously used the TOMS data from 1979 to 1991 inclusive (i.e. 13 years of data) to determine the trends in both the mean monthly total ozone and the mean annual total ozone over Athens (Varotsos and Cracknell, 1993). The purpose of this paper is to study the effect of the QBO and longer-period oscillations on the calculated ozone depletion over Athens from satellite (TOMS) data for the period 1979-1991.

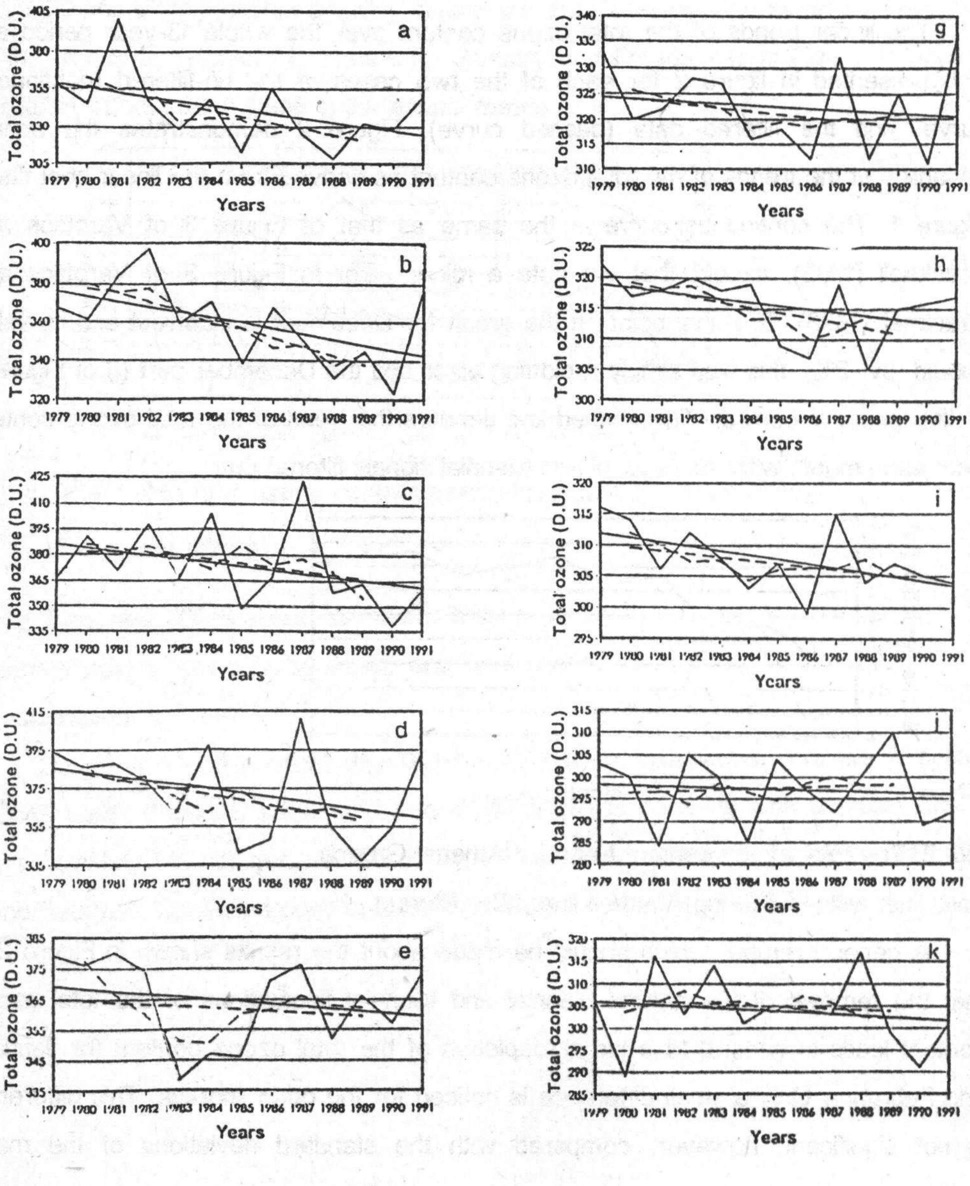
2. Data and Analysis

For the purposes of this study we have used the daily total ozone observations made by the TOMS instrument on Nimbus-7, since November 1978. To take into account the calibration drift of the TOMS instrument a new method (Herman et al. 1991) of the data processing has been used, which is based on a requirement of internal consistency of ozone measured with different wavelength pairs. These reprocessed data (version 6) were obtained from the NASA Goddard Space Flight Center, Greenbelt, Maryland. The data were supplied giving the total ozone content in Dobson units on a daily basis for the time period 1979-1991.

By regression analysis of the reprocessed TOMS data supplied by NASA we have estimated the trends in total ozone over Athens, Greece, in the case of monthly average values, in a similar way to that which we have described previously (Varotsos and Cracknell 1993). However, we have applied a filter of 4-year running means to eliminate the effects of oscillations with a 2-year or 3-year period from the general trend results. This was done in order to eliminate any effect of biennial or triennial waves in the total ozone content. These trend calculations have been performed both with the monthly mean total ozone content for each month and also for the annual mean total ozone content.

3. Total ozone over Athens, Greece

Figure 1 shows the TOMS time series of the total ozone content over Athens, Greece, for each month separately throughout the period 1979-1991. The continuous curve represents the monthly mean ozone data derived from the TOMS data and the continuous straight line represents the result of a least-squares fit to this data, without the filtering. The dashed curves represent the total ozone content after smoothing with a 4-year running means filter. The dashed straight line represents the trend in the total ozone content after the filtering.



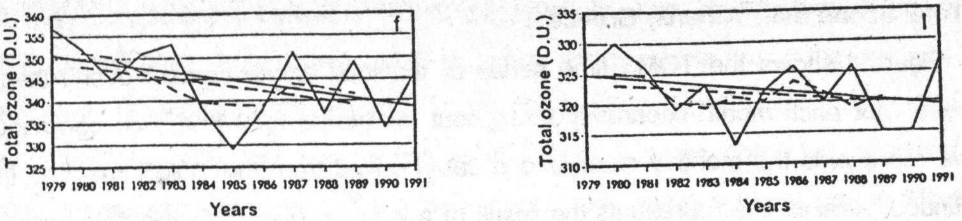


Fig. 1. The TOMS total ozone content trends for various months of the year for Athens, Greece, during the time period Nov. 1979-Jan. 1991. (a): Jan.,..., (l): Dec.
Solid lines: real TOMS observations and least squares fit.
Dashed lines: 4-year running means and least squares fit.

The linear trends of the total ozone content over the whole 13-year period are also presented in figure 2 for each of the two cases of the un-filtered (continuous curve) and the filtered data (dashed curve). Figure 2 demonstrates the annual variability of the trends of the total ozone content as derived from the linear best fits in Figure 1. The continuous curve is the same as that of Figure 3 of Varotsos and Cracknell (1993), except that we note a minor error in Figure 3 of Varotsos and Cracknell (1993). The final point on the graph for December is incorrect and its value should by -2%; this was simply a plotting error and the December part (l) of Figure 2 of that paper is correct. The dashed line denotes the trend of the total ozone content from each month with the biennial and triennial signals filtered out.

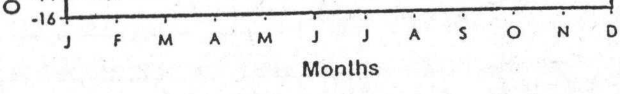


Fig. 2. The total ozone content trend for Athens, Greece.
Solid line: without filtering. Dashed line: after filtering.

A general remark which should be made about the results shown in Figure 2 is that the removal of the natural biennial and triennial fluctuations of the total ozone content leads in general to a larger depletion of the total ozone content for January and February. Only a small difference is noticed for the other months. This difference is not significant, however, compared with the standard deviations of the mean monthly values of the total ozone content over that region (Varotsos and Cracknell, 1994).

Figure 3 illustrates the TOMS time series of the mean monthly values of total ozone content (solid curve) over Athens, Greece, throughout the period 1979-1991. The continuous straight line represents the result of a least-squares fit to this data, without filtering. The dashed curve represent the total ozone content after smoothing as 4-year running means. The dashed straight line represents the trend after filtering. Inspection of Figure 3 shows that the slopes of the continuous and dashed straight lines are almost identical so that the trend of ozone depletion is virtually unaffected by the QBO and ENSO, except possibly in January and February. The modest corrections to the trends in the monthly means for January and February (see Figure 2) have a negligible effect on the trend in the annual mean.

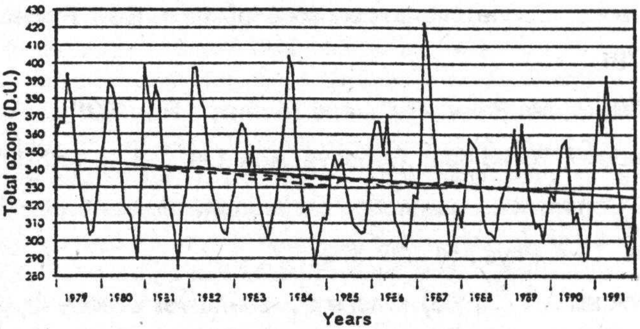


Fig. 3. The TOMS total ozone content trends for Athens, Greece, during the period 1979-91.

Solid lines: real TOMS observations and least squares fit.

Dashed lines: 4-year running means and least squares fit.

4. Conclusions

The total ozone content over Athens, Greece, as deduced from the Nimbus-7 TOMS data throughout the time period 1979-1991 is declining with a mean rate of approximately 5% per decade. Corrections for the quasi-biennial oscillation and the El Nino/Southern Oscillation contributions do not significantly affect this figure.

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