CONDITION OF THE STRATOSPHERIC AND MESOSPHERIC OZONE LAYER OVER BULGARIA FOR THE PERIOD 1996-2012: Part 1 - TOTAL OZONE CONTENT, SEASONAL VARIATIONS

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Abstract. A detailed analysis of the variations of the stratospheric and mesospheric ozone over Bulgaria, in the period 1996-2012, is presented in the article on the basis of ground and satellite measurements of the Total Ozone Content (TOC). The move of the most important components: yearly running mean values, amplitudes and phases of the first four harmonics of the seasonal cycle. Their mean values for the period and the existing long term trends have been found.

Key words: total ozone content, seasonal curves, long term trend, trigonometric approximation, sliding time segment.

Introduction

The increased interest to the ozone layer condition of the Earth atmosphere, over the last decades, is due to the understanding that the protection of the whole biosphere from solar radiation UVB (280-315 nm) depends, to some extent, on this little atmospheric compound. Besides, the variations in its concentration have a substantial impact on the temperature regime and hence – on the whole dynamics of the middle atmosphere namely because of the property of ozone to absorb solar energy. In relation to the task assigned to NIGGG by governmental organs to study the condition of the ozone layer over Bulgaria, a daily monitoring of the Total Ozone Content was organized in 2008 with ground facilities working in Sofia also at present. Since it is not possible to obtain a continuous data row (measurements with ground appliances are possible only by clear weather), the data was complemented with measurements from satellite appliances. The output row of daily values allows tracking the condition of the ozone layer in the atmosphere over Bulgaria for a sufficiently long period: from 1996 to 2012 and to make some conclusions regarding the factors which have the greatest impact on it.

Total ozone content in years 1996-2012

The measurements of TOC in NIGGG are conducted with the sun photometer Microtops II, a production of Solar Light Company, USA, http://www.solarlight.com. The appliance is a 5-channel sun photometer with narrowband filters for five wave lengths in the field of ultraviolet solar radiation. The registering of solar radiation flux on the Earth's surface of three of the wave's lengths – 300, 305 and 312 nm allows to determine the total ozone content in the atmosphere by given geographical coordinates of the place of measurement, universal time, and by using the data of the built-in meter of atmospheric pressure. The special electronic with a low noise level and a built-in 20-bit analogue-to-digital converter with high linearity and a dynamic range provide for a high precision of the measurements. An original compensating algorithm for correction of the value received from the relations of the different channels is built in the appliance. The results are obtained fully automatically from the built-in microcomputer; the only manual operation by the measurement is targeting the sensors of the appliance to the Sun for the purpose of which an optical targeting system is provided in the appliance. The accuracy of the appliance, given by the manufacturer, is 1-2%. The error amounts to 6 DU by an average amount of the total content about 300 DU.

The measurements with Microtops II are complemented with data from Ozone Monitoring Instrument (OMI) working on AURA Satellite which are available on http://toms.gsfc.nasa.gov/. The data are presented in a grid with a step of one geographical degree by geographic latitude and longitude. Those which are in relation to the territory of Bulgaria are from 42 to 44°N and from 23 to 28°E. The measurement method of the total ozone is based on the reflection of solar radiation from the cloud cover by conditions close to local noon. The relation between the data obtained from Microtops II and OMI for the period September 2009 to June 2009 is displayed on Fig. 1.

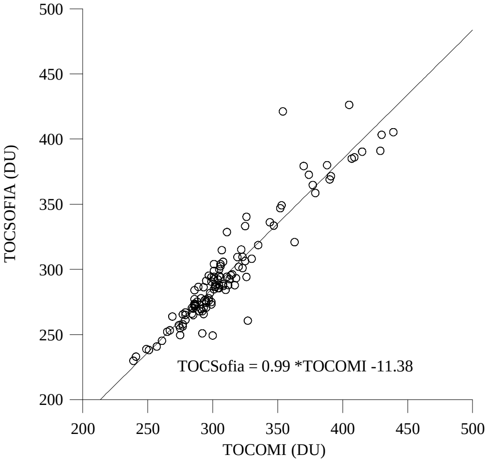

Fig. 1. Relation between the values of the total ozone obtained from the measurements in Sofia and the respective satellite data of OMI

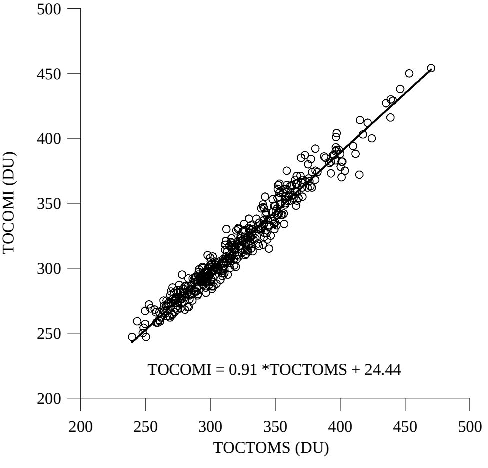

Fig. 2. Relation between the values of the total ozone from OMI and TOMS.

There is a little systematic bias between the two types of measurements, about 11 DU, which allows recalculating the data from OMI and tying them to the data of Microtops II. The data row was extended to 1996 with the data from Total Ozone Mapping Spectrometer (TOMS) aboard the Nimbus 7 polar-orbiting satellite. The simultaneous data from TOMS and OMI from October 2004 to December 2005 allow to calibrate the data of TOMS to OMI and then to the data of Microtops II (Fig. 2).

The resulting data row, notwithstanding that it is obtained from different appliances, should be considered free of systematic bias. The move of the annual monthly values of TOC over Bulgaria is displayed on Fig. 3. A certain seasonal cycle of the total ozone with a spring maximum and an autumn minimum may be readily seen. The initial value of ozone amounts to 305.4 DU by the indicated linear approximation. The resulting positive trend of 0.022 DU a month (0.26 DU a year) is insignificant and allows making the conclusion that the ozone layer over Bulgaria is generally stable in the period under consideration, and there are no reasons to expect trends towards its destruction. Stolarski et al, 1991, Fig. 1 defines a negative trend of the total ozone at 40N latitude of about 0.5 DU/year on the basis of data from TOMS from 1978 to 1990. The present study shows that the negative trend changed to positive in the period of time to follow.

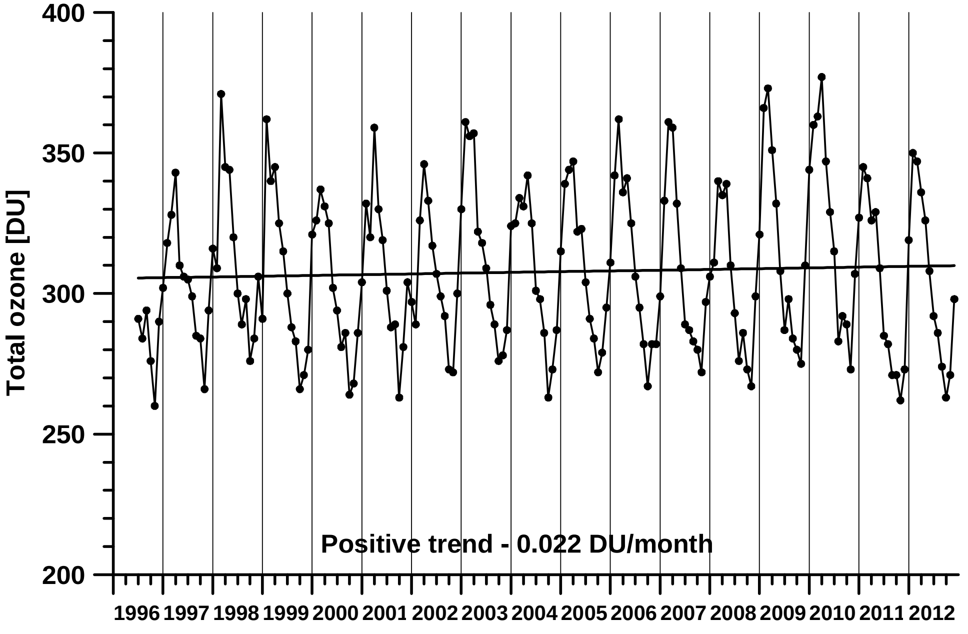

Fig. 3. Mean monthly values of TOC over Bulgaria 1996-2012.

A detailed study of the behavior of the total ozone is appropriate to make on the basis of the components of the seasonal cycle over the studied period. A decomposition of the daily values has been made with a sliding time segment of a year with a step of one day, and the components of the seasonal cycle from the first to the fourth harmonic have been included in the decomposition (that is mean annual value, yearly oscillation, semi-yearly oscillation, 4- and 3-month oscillation). This corresponds to a decomposition in Fourier series but the amplitudes and phases have been defined by the least squares best fit (Bowman et Krueger, 1985) because of data gaps. The results are presented for the period 1997-2012 because 1996 is not complete, and we have the opportunity to use the data from 2013 until now for the second half of 2012.

The moves of the yearly running mean values of the total ozone displayed in Fig. 4 show three clearly pronounced height sections about 1998, about 2003-2007 and in 2009-2010 and the respective low ones in 2000, 2007 and in 2011. The difference between the highest and the lowest value is about 25 DU. The mean value, indicated with a dotted line, is 308.4 DU and practically coincides with that obtained above on the basis of mean monthly values. The polynomial best fit (degree 2) which shows an upward trend in the first half of the period that changes to a downward trend in the second half is shown as the most common characteristic of the trend to changes of the mean annual value but those trends are very weakly expressed and may hardly be interpreted as an impact, for example of the 11-year solar activity cycle displayed in Fig. 5 with smoothed monthly mean solar radio flux F107. The 16-year period used in the present work does not allow confirming the study (Kilifarska, 2011, 2012) which shows an impact of the solar activity and galactic cosmic rays on the total ozone measured in Arosa (Switzerland).

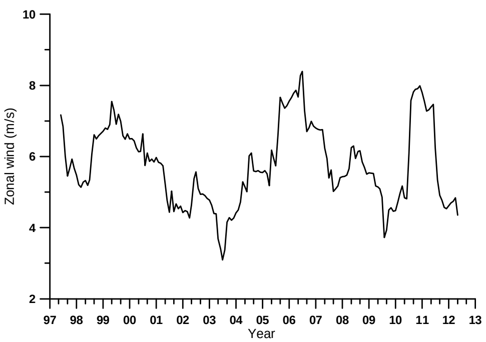

Fig. 4. Running yearly mean TOC.

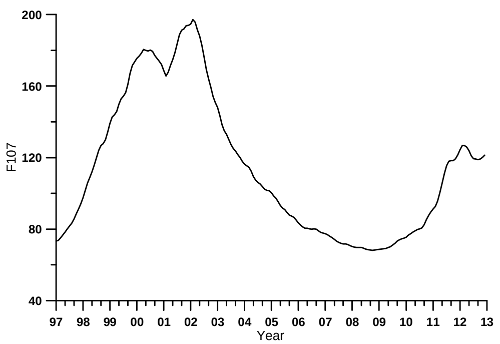

Fig. 5. Smooted monthly mean solar radio flux.

Certain similarity is observed between the running mean annual values of the total ozone and the analogous values of the mean zonal wind speed at 68hPa on Fig. 6 (about 21 km altitude, close to the level of maximal concentration of ozone) obtained from assimilated atmospheric data-set of UKMO for coordinates close to those of Sofia with an accuracy of 2.5° latitude and 3.5° longitude. There is no similarity with the move of temperature. A Quasi-Biennial Oscillation is readily seen in the move of temperature which cannot be observed in the move of TOC (Fig. 7).

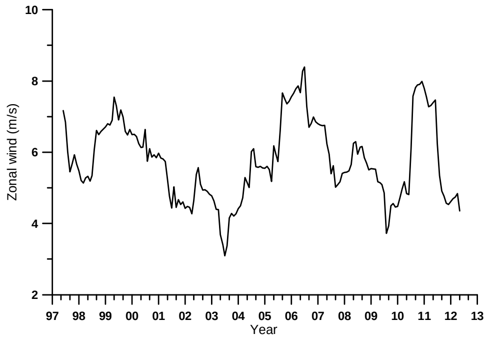

Fig. 6 Running yearly mean zonal wind at 68 hPa (21 km).

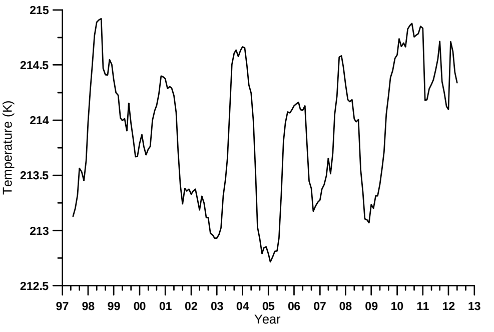

Fig. 7. Running yearly mean temperature at 68 hPa (21 km).

Huang et al, 2008 obtains distinctive Quasi-Biennial Oscillation in the concentration of ozone at altitudes between 30 and 40 km according to data of SABER/TIMED for the period 2002-2004 but predominantly in the equatorial region. The results shown confirm the stable character of the total ozone content over Bulgaria in the studied period. The question whether there is solar dependence of TOC cannot be solved on the basis of the data with which we dispose but it may be presumed that even if there is such dependence, it is sufficiently weak.

The curve of a 12-month amplitude and phase is displayed on Fig. 8 and Fig. 9. This is the strongest variation of the total ozone related to the seasonal cycle. The amplitude of the annual oscillation shows a steady upward trend in the studied period, for example from 30 to 40 DU. This means an increase in the maximal and a decrease in the minimal value over the year on condition that the mean annual value, as it turned out, has no significant upward or downward trend. It can be noticed that the temporary increases and decreases in the amplitude occur in the same periods in which there is an increase of the mean annual value. The linear regression of the amplitude displayed in the figure is: Amplitude=31.3 + 0.64.(year-1997). The mean value for the period, indicated with a dotted line, is 36.4 DU.

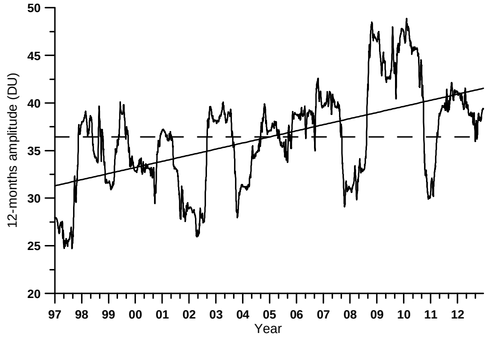

Fig. 8. 12-months amplitude.

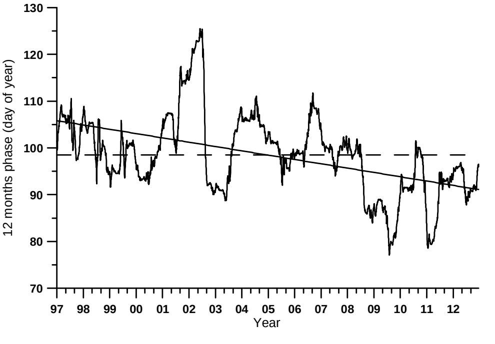

Fig. 9. 12-months phase.

The phase of the annual oscillation shows a distinctive downward trend. The phase (that is the maximal momentum of the annual amplitude) is about the 98th day of the year (the beginning of April) as an average for the period. The negative linear trend is 0.9 days/year. It is not possible to evaluate whether this trend will continue in the future and whether it is related to any long term atmospheric trends on the basis of the available material.

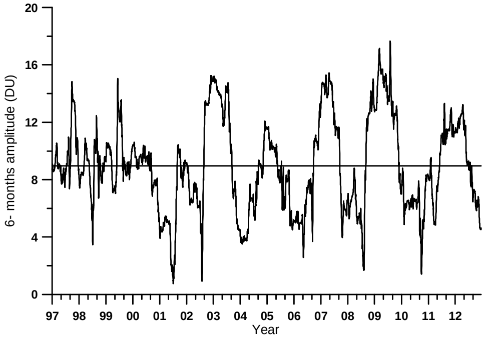

Fig. 10. 6-months amplitude.

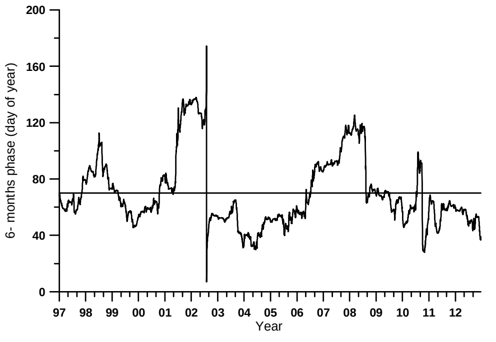

Fig. 11. 6-months phase.

The amplitude and the phase of the semi-annual oscillation of the seasonal cycle of TOC do not show significant trends for the studied period. The amplitude varies in wide ranges: almost from zero until about 16 DU while the mean value is 9 DU (Fig. 10). The mean value of the phase is the 70th day of the year (Fig. 11). A Quasi-Biennial Oscillation can readily be seen in the period 2001 to 2012 which period coincides well with the period of distinctive Quasi-Biennial Oscillations in the temperature of 68 hPa, displayed on Fig.7.

The dependency is, obviously, negative: a decrease in the amplitude of the semi-annual oscillation of TOC corresponds to an increase of the temperature. The amplitudes of the other two components of the seasonal cycle of TOC, with periods of 4 and 3 months, are displayed on Fig. 12, 13. Their values approximate the measurement error. Most probably, their variations are of a random character. Bowman et Krueger, 1985 obtain values of the annual amplitude for the period 1978 - 1982 of about 40 DU and of the semi-annual - about 5 DU, approximately the same values that have been obtained in the present research.

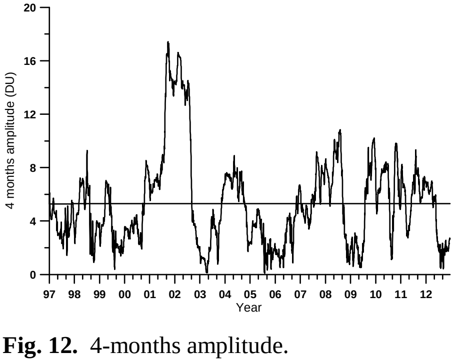

Fig. 12. 4-months amplitude.

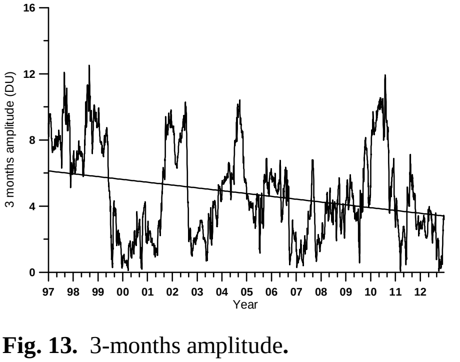

Fig. 13. 3-months amplitude**.**

Conclusions

The analysis of the seasonal cycle of the Total Ozone Content over Bulgaria, made on the basis of assimilated dataset of daily values, obtained by ground and satellite measurements and smoothed between each other with the use of regression fitting, shows that the condition of the stratospheric ozone which is the most important for the protection of the Earth's surface from the harmful impact of the ultraviolet solar radiation is stable during the studied 16-year period (1997-2012) and no trends towards its destruction are observed. The observed variations of the semi-annual value are most probably due to variations of the dynamic stratospheric row which have a purely internal atmospheric character. It has been found that that the natural seasonal cycle of TOC is described by a mean annual value and the amplitudes and phases of the 12-month and 6-month component. The annual component shows clear trends of the amplitude and phase which are, most probably, also due to long term variations in the stratospheric region while the most marked similarity is observed with the variations of the mean annual values of the zonal wind at 68 hPa.

Acknowledgements. The study was funded by FP7-PEOPLE-2009-IRSES (Grant No.247608) IGIT- Integrated geo-spatial information technology and its application to resource and environmental management towards the GEOSS.

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Състояние на стратосферния и мезосферен озон над България за периода 1996-2012 г: Част 1 - Сезонни вариации на тоталното съдръжание на озон

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Резюме: В статията е представен подробен анализ на вариациите на стратосферния и мезосферен озон над България през периода 1996 - 2012 на базата на наземни и спътникови измервания на тоталното съдържание на озон (ТСО). Изследван е ходът на най-важните компоненти - пълзяща средногодишна стойност, амплитуди и фази на четирите първи хармоника на сезонния ход. Установени са техните средни стойности за периода и съществуващите дългопериодични трендове.