Ozone Dynamics over Bulgaria during the 23rd Solar Cycle

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Abstract The aim of this paper is to investigate the total ozone content (TOC) over Bulgaria in the time period 1997-2008. Data from the satellite experiments TOMS-EP (1997-2002) and SCIAMACHY (2003-2008) are used. The course of the monthly mean ozone values is presented. The seasonal TOC variations are clearly marked. A quasi-biennial periodicity in the amplitudes of the ozone maxima can be seen. The experimental data show that practically there isn't any trend in the TOC course during the indicated interval. The influence of the solar activity on the total ozone during the current 23-rd solar cycle is analyzed.

Keywords: Total ozone content, Solar activity, Ultraviolet solar radiation, Earth atmosphere, Solar cycle.

Introduction

The role of the ozone for the thermal balance and the temperature structure of the Earth's atmosphere is examined as well as its importance as a trace species and a major participant in the photochemical processes [1, 2]. Besides, as a shield, protecting the Earth's biosphere from the harmful UV solar radiation, the ozone is an interactive component of the atmosphere as a climatically significant gas. That is why in the last years the dynamics of the atmospheric ozone is actively monitored both through measurements by ground-based instruments, located in a large number of stations all over the globe, and by instruments on board artificial satellites.

A special aspect of the ozone dynamics is its dependence on the solar activity. This problem and the issue for the mechanism of the ozone-solar activity relationship are discussed in many publications [3, 4, 5]. Most authors have received a positive ozone-solar activity correlation, while others have obtained a negative relationship.

The solar cycle is the dynamic driver and the energy source of all solar phenomena It determines the structure of the solar wind and modulates the full radiation flux, in particular the one in the shortwave range – from the ultraviolet to the X-rays The variations of the UV radiation, penetrating the Earth's atmosphere during the solar cycle can influence the ozone dynamics.

The aim of this paper is to investigate the total ozone content (TOC) over Bulgaria in the time period 1997-2008, which is identical with the 23-rd solar cycle.

Instruments and data

The ozone dynamics is analyzed using data from the Total Ozone Mapping Spectrometer on the Earth Probe satellite (TOMS-EP) and the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) on board ENVISAT (ESA).

TOMS-EP continues the NASA Program for mapping and research of the global ozone distribution in the Earth's atmosphere in the period from 1996 to 2005. The TOMS measurements cover the near ultraviolet region of the electromagnetic spectrum where the solar radiation is partially absorbed by the ozone. The intensity is registered in 6 wavelengths. TOMS measures the total ozone content in an atmospheric column from the Earth's surface to the upper atmospheric boundary under different geophysical conditions.

SCIAMACHY is an imaging spectrometer, which carries out global measurement of various trace gases in the troposphere and stratosphere. They are retrieved from the instrument by observation of transmitted, back-scattered and reflected radiation from the atmosphere in the wavelength range between 240 nm and 2400 nm. In Nadir Mode, the global distribution (total column values) of the atmospheric trace gases, including the ozone, is observed.

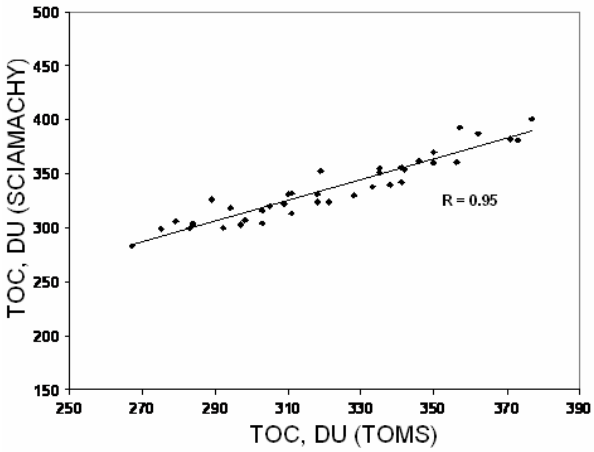

Fig.1. Correlation straight line between TOC monthly mean values (2002-2005), measured by TOMS-EP and SCIAMACHY

Results and discussion

An analysis of the total ozone over Sofia (42o 39' N, 23o 23' E), Bulgaria is presented. To track out the TOC course for a longer period we use TOMS and SCIAMACHY data. We compare the results from both instruments, simultaneously operating in the period 2002 – 2005. There is a good agreement between them: R = 0.95 (Fig.1).

This allows to use the consecutive TOMS data (1997-2002) and the SCIAMACHY data (2003-2008) for investigation of the ozone behaviour in the period 1997-2008 (Fig.2). This figure leads us to the following conclusions for the ozone course over Bulgaria:

- The seasonal course of the ozone content is clearly expressed, showing an abrupt maximum in the spring and a decrease to the minimum in the autumn.

- A quasi-biennial periodicity in the amplitudes of the ozone maxima can be seen. For example, in 1999, 2001, 2003, etc., these amplitudes are bigger than those in 2000, 2002, 2004 etc., as the biggest TOC maximum (400 DU) is registered in March 2003 while the smallest one (357 DU) – in March 2000.

- Our analysis shows that there isn't any trend in the TOC course in this period. Despite the absence of a trend in the whole period, the calculations give different trend values in the various seasons. Thus, in winter (December) and in spring (March) the linear trend is positive, 2.2% and 0.2%, respectively, and in summer (July) and in autumn (September) it is negative : -3.5% and – 1.6%. This result shows that probably there is a seasonal dependence of the TOC trend.

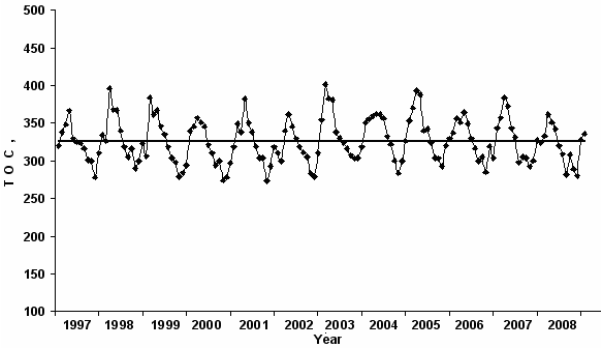

Fig.2. Behaviour of the monthly mean ozone data from TOMS-EP (1997-2002) and SCIAMACHY (2003-2008) over Sofia

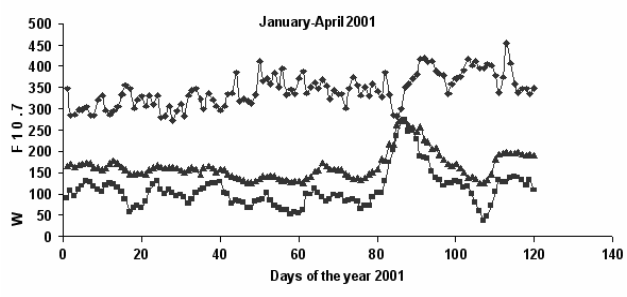

Fig.3. A case of positive correlation between the total ozone column (TOC) and the parameters, characterizing the solar activity W and F10.7

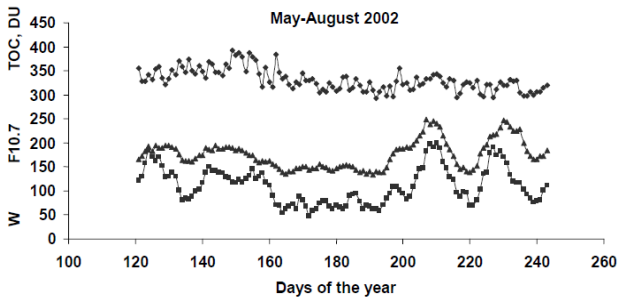

Fig.4. An example of missing correlation between the ozone and solar activity parameters

The observed period is a part of the 23-rd solar cycle. The influence of the solar activity on TOC has been studied, analyzing the ozone response to sharp changes of parameters, characterizing the solar activity: sunspot daily numbers (W) and solar radio flux at 10.7 cm (F10.7). Some of the examined cases showed a positive correlation between TOC, on the one hand, and W and F10.7 on the other, but in other cases, a negative correlation was found. The course of three parameters: TOC, W and F10.7 in the spring of 2001 (around the maximum of the 23-rd solar cycle), is shown in Fig.3, for example. After sharp increases in W and F10.7, a sharp rise in TOC (from 280 to 420 DU with a phase lag of about 4 days) can be seen. This example demonstrates the positive TOC response to the solar activity. Similar ambivalent results (positive and negative) for the relation between the total ozone and the solar activity are presented in the studies of Soukharev [3] and. Varotsos [6]. In our results there are some cases when the sharp increases of the solar activity did not provoke any TOC changes (Fig. 4). We suppose that the registered TOC variations have been provoked by various changes in the atmospheric circulation, caused by the solar dynamics.

Conclusion

The analysis of the total ozone content over Sofia, Bulgaria in the period 1997-2008

shows the following major results:

- The seasonal TOC variations, typical for middle latitudes, are clearly marked.

- A quasi-biennial periodicity in the amplitudes of the ozone maxima can be seen.

- The experimental data show that there is no trend in TOC course in this period.

- The total ozone response to the solar activity is not simple. Probably, the TOC variations are provoked by changes in the atmospheric circulation, caused by the solar dynamics.

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