# OZONE DYNAMICS OVER BULGARIA

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***Keywords:*** *Total ozone content (TOC), annual TOC course, satellite measurements.*

***Abstract:*** *This paper presents the total ozone column (TOC) behaviour over Stara Zagora, (42° 25' N, 25° 37' E), Bulgaria in the period 1997-2012. The ozone dynamics is investigated by using satellite data from the Total Ozone Mapping Spectrometer-Earth Probe (TOMS-EP) and Ozone Monitoring Instrument (OMI).*

*The course of the daily and monthly mean ozone values is presented. The seasonal TOC variations are clearly marked. These variations are expressed by an abrupt maximum in the spring and a gently sloping decrease in the autumn.*

*For tracking out the TOC course for a longer period we use TOMS-EP and OMI data. The results from both instruments, simultaneously operating in 2005, are compared. There is a good agreement between them : R = 0.944. This allows to use the consecutive TOMS-EP data (1997–2004) and the OMI data (2005-2012) for investigation of the ozone behaviour in the period 1997-2012.*

*Our analysis shows that the trend in the TOC course is negative (-1.94%) during the period 1997-2012. The calculations give different trend values in the various seasons.*

# ДИНАМИКА НА ОЗОНА НАД БЪЛГАРИЯ

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***Ключови думи:*** *Общо съдържание на озона (ОСО), годишен ход на ОСО, спътникови измервания.*

***Резюме:*** *Докладът представя поведението на общото съдържание на озона (ОСО) над Стара Загора, (42° 25' N, 25° 37' E), България в периода 1997-2012 г. Динамиката на озона е изследвана чрез използване на спътникови данни от Total Ozone Mapping Spectrometer-Earth Probe (TOMS-EP) и Ozone Monitoring Instrument (OMI).*

*Показан е ходът на дневните и средномесечните стойности на озона. Сезонните вариации на ОСО са ясно изразени. Тези вариации се проявяват със стръмен максимум през пролетта и полегато намаление през есента.*

*За проследяване хода на ОСО за по-продължителен период ние използваме данните от TOMS-EP и OMI. Сравнени са резултатите от двата уреда, работили едновременно през 2005 г. Между тях има добро съвпадение: R = 0.944. Това ни позволява да използваме последователните данни от TOMS-EP (1997–2004 г.) и от OMI (2005-2012 г.) за изследване поведението на озона в периода 1997-2012 г.*

*Нашият анализ показва, че трендът в хода на ОСО е отрицателен (-1.94%) в периода 1997-2012 г . Пресмятанията дават различни стойности на озоновия тренд през различните сезони.*

## Introduction

The ozone is one of the components of the Earth's atmosphere, which strongly absorbs the short-wave solar ultraviolet (UV) radiance, which damages the biosphere. At the same time, the ozone is a gas, major for the thermal conditions of the stratosphere. The significant changes of the total ozone amount in the atmosphere over the South pole regions, observed during the last decades, have attracted the attention of the scientific community. Together with the ozone decrease in the polar atmosphere, similar behavioral features have also been observed at mid-latitudes [1,2]. The measurements show unambiguously that the total ozone over northern mid-latitudes decreased from 1980 to the mid-1990s. Since then TOC depletion hasn't been registered [3,4,5]. Therefore, the monitoring of the ozone amount in global scale is considered nowadays a task of primary significance for the life of our planet.

For this purpose the Global Atmosphere Watch (GAW) network has been created to monitor the total ozone by a set of ground-based instruments. Simultaneously, several projects such as the Total Ozone Mapping Spectrometer (TOMS), the Global Ozone Monitoring Experiment (GOME), the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY), Ozone Monitoring Instrument (OMI) etc. investigate the ozone from space.

**Instruments and methods**

This paper presents the total ozone column (TOC) behaviour over Stara Zagora, (42°25' N, 25° 37' E), Bulgaria in the period 1997-2012. The ozone dynamics is investigated by using satellite data from the Total Ozone Mapping Spectrometer-Earth Probe (TOMS-EP) and Ozone Monitoring Instrument (OMI).

TOMS-EP continues the NASA Program for mapping and research of the global ozone distribution in the Earth's atmosphere 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 any geophysical daily conditions.

Ozone Monitoring Instrument flies on the Aura satellite since July 2004. OMI is a nadir-viewing wide-field-imaging spectrometer giving daily global coverage. It employs hyperspectral imaging in a push-broom mode to observe solar backscatter radiation in the visible (350-500 nm) and ultraviolet (270-380 nm). Two algorithms, OMI-TOMS and OMI-DOAS (Differential Optical Absorbtion Spectroscopy) are used to produce OMI daily total ozone datasets. OMI is continuing the TOMS record for total ozone and other atmospheric parameters related to ozone chemistry and climate.

**Data analysis and results**

Fig.1 shows the annual TOC variations by data of TOMS-EP (1999-2005). The data of the ground-based spectrophotometer Photon, working in Stara Zagora Department of SRTI-BAS, are presented too.

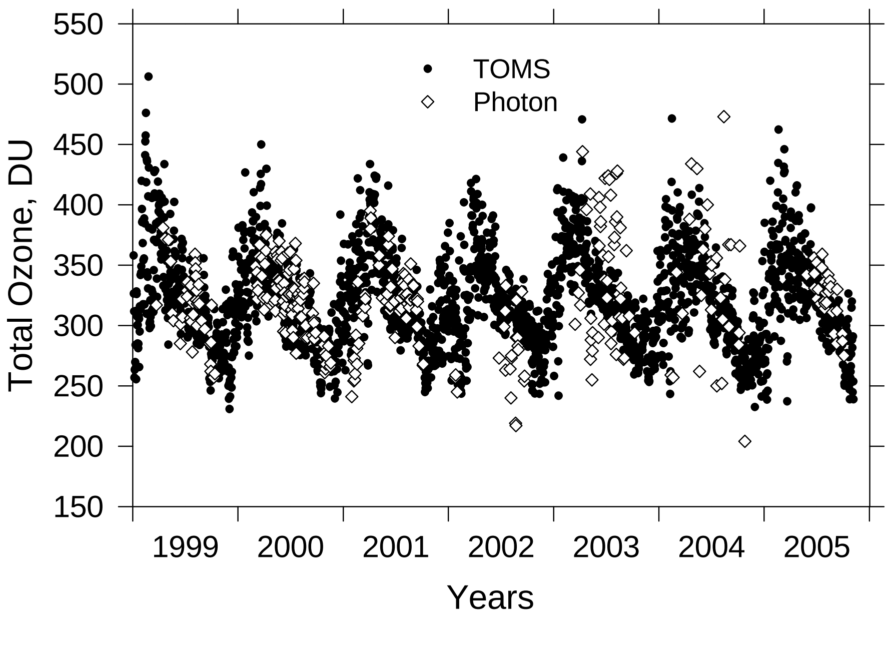


Fig. 1. Annual TOC variations, measured by TOMS-EP and Photon during 1999-2005

Fig. 2 shows the annual TOC variations in the period 2005-2012 by data of OMI. The ozone variations in both figures are expressed by an abrupt maximum in the spring and a gently sloping decrease in the autumn. This ozone seasonal course doesn't correspond to the solar radiation energy distribution throughout the year. It is also different from the course of other parameters, such as temperature, humidity, air pressure, which follow the course of the solar radiation with a certain delay at all latitudes.

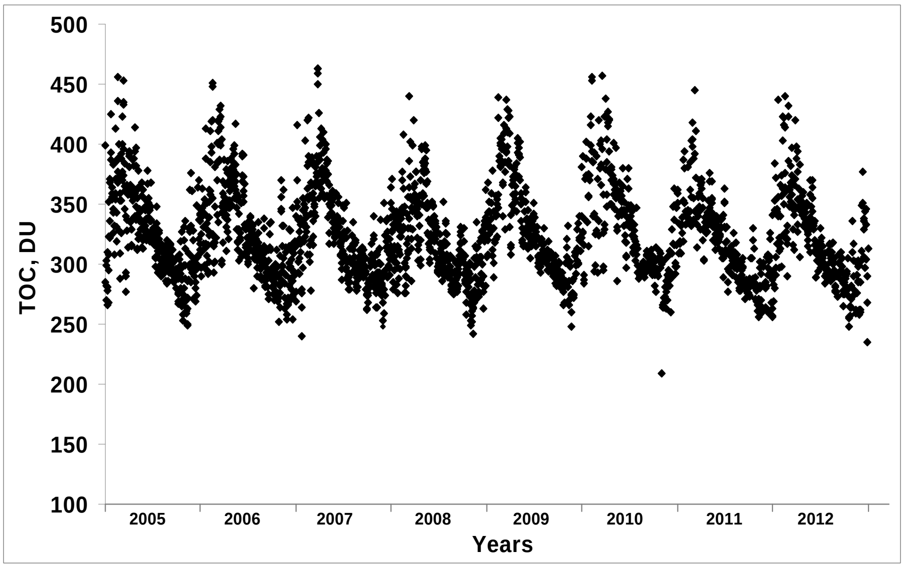


Fig. 2. Annual TOC variations, measured by OMI during 2005-2012

For tracking out the TOC course for a longer period we use TOMS-EP and OMI data. The results from both instruments, simultaneously operating in 2005 are compared. There is a good agreement between them : R = 0.944 (Fig.3). This allows to use the consecutive TOMS-EP data (1997–2004) and the OMI data (2005-2012) for investigation of the ozone behaviour in the period 1997-2012.

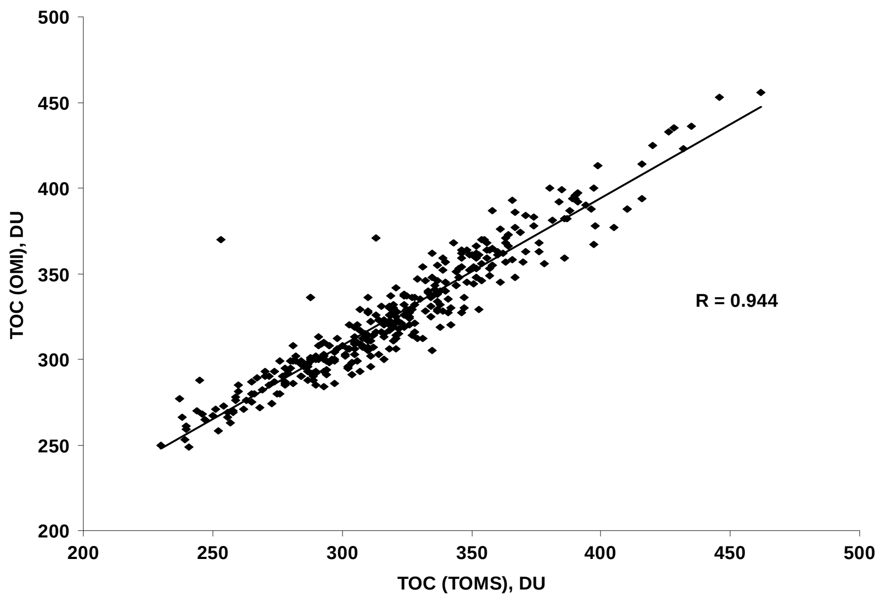


Fig. 3. Correlation straight line between ozone values, measured by TOMS-EP and OMI in 2005

Fig. 4 presents the monthly mean ozone values in the period 1997-2012 by data of TOMS-EP and OMI. During this time period the biggest ozone maxima are measured in March 1998: 396 DU, in February 2003: 401 DU and in March 2009: 390 DU. The smallest TOC maxima are in April 1997: 366 DU, in March 2000: 357 DU and in March 2008: 352 DU. The deepest TOC minima are registered in October 2000,2001: 273 DU, in November 2002: 279 DU , in November 2011 and in October 2012: 278 DU.

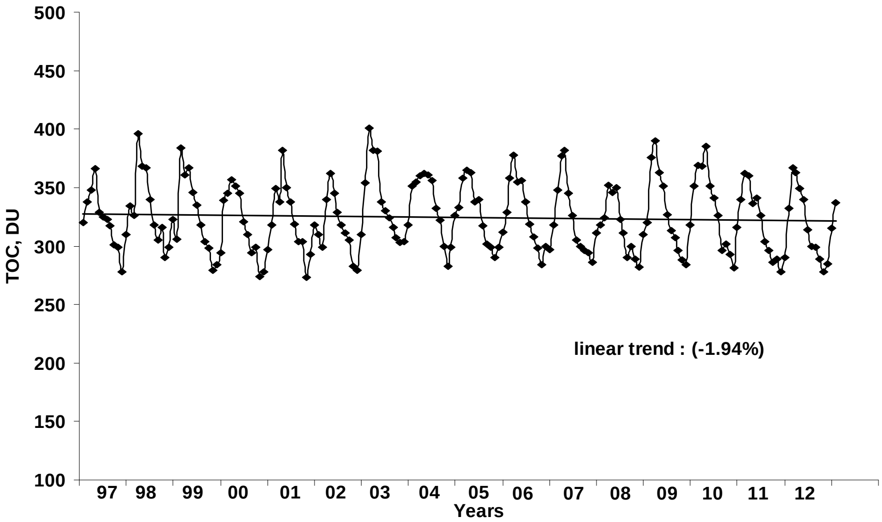


Fig. 4. Behaviour of the monthly mean ozone data from TOMS-EP (1997-2004) and OMI (2005-2012)

The existence of long-term ozone data enables the study of the ozone trends. In the last years many scientists in various projects have focused their attention on this problem. The EU CANDIDOZ project (Chemical And Dynamical Influences on Decadal Ozone Change) investigated the chemical and dynamical influences on decadal ozone trends focusing on the Northern Hemisphere [6].

The overall synthesis of the individual analysis in this project shows clearly one common feature in the northern mid-latitudes and in the Arctic: an almost monotonous negative trend from the late 1970s to the mid 1990s followed by an increase.

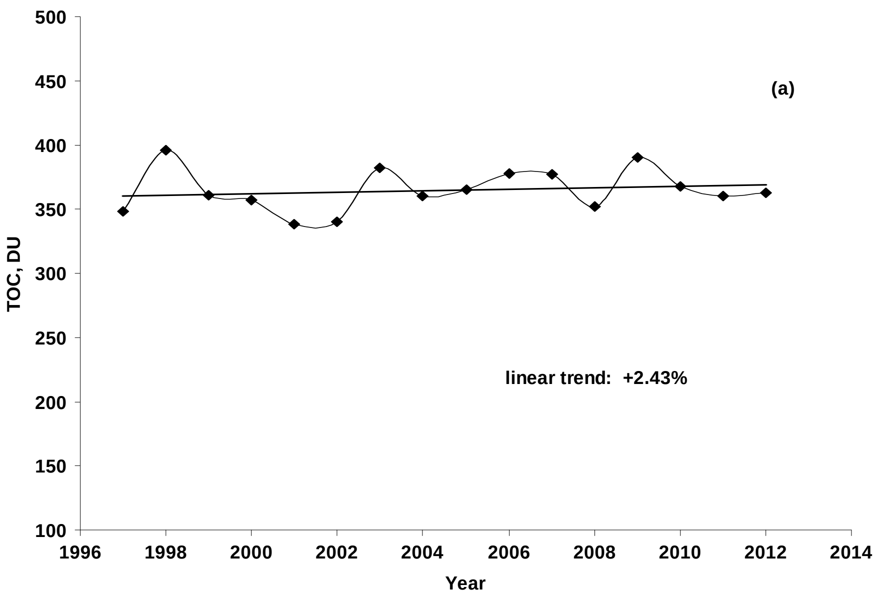


Fig. 5a. TOC monthly mean values from TOMS-EP and OMI (1997-2012): March

To investigate the total ozone behaviour over Bulgaria we have used monthly mean ozone satellite data in the period 1997-2012. Our analysis shows that the trend in the TOC course is negative: (-1.94%). The calculations give different trend values in the various seasons (Fig.5a,b,c,d).

Thus, in spring (March), in autumn (October) and in winter (January) the linear trend is positive: +2.43%, +0.53% and +3.48% respectively. In summer (July) it is negative: -4.01%. Zanis et al. found also a positive ozone trend over Arosa during the winter to spring period [7]. These results show a probable seasonal dependence of the TOC trend.

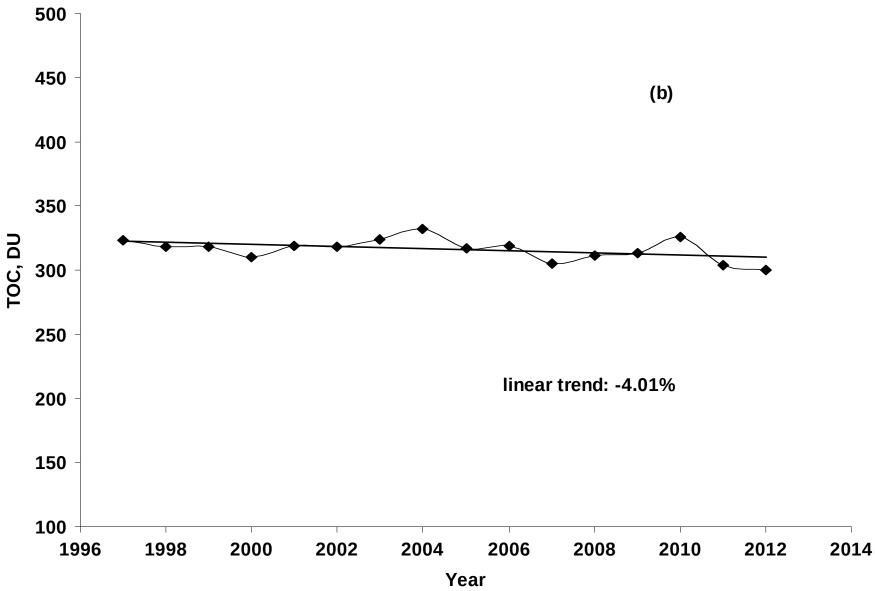


Fig. 5b. TOC monthly mean values from TOMS-EP and OMI (1997-2012): July

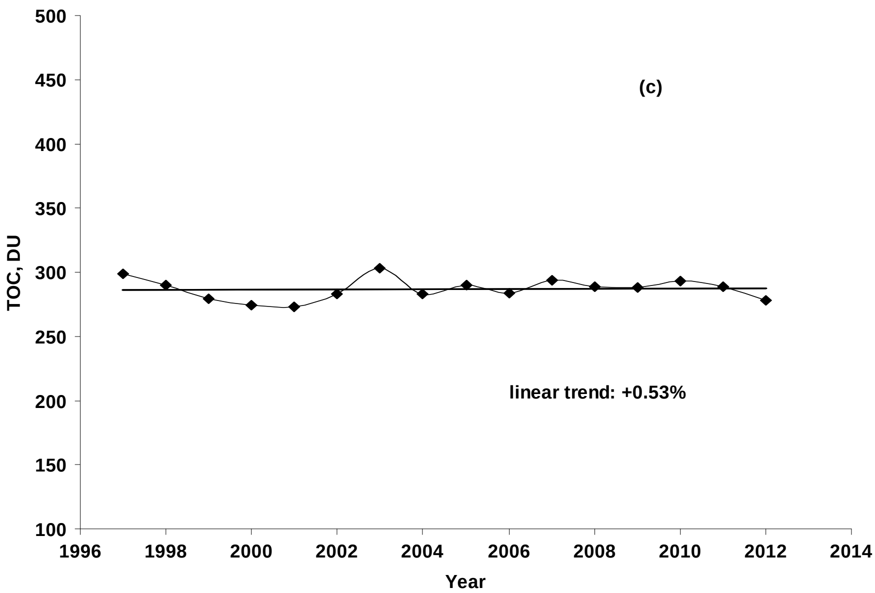


Fig. 5c. TOC monthly mean values from TOMS-EP and OMI (1997-2012): October

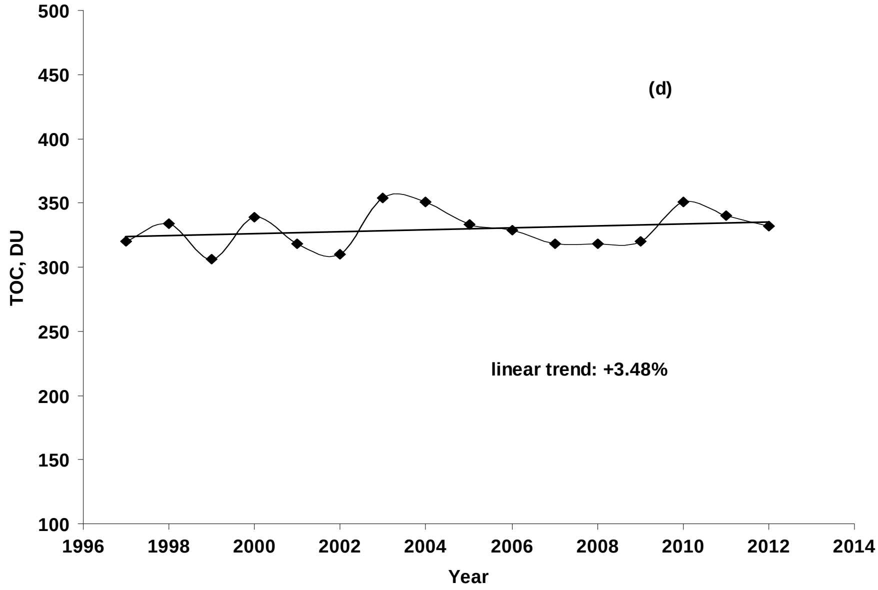


Fig. 5d. TOC monthly mean values from TOMS-EP and OMI (1997-2012): January

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