Proceedings of 33rd Annual European Meeting on Atmospheric Studies by Optical Methods.
IRF Sci. Rep., 292, 51–54, 2008
http://www.irf.se/publications/proc33AM/mendeva-etal.pdf
ISSN 0284-1703, ISBN 978-91-977255-1-4, © Author(s) 2008

Spectrophotometric investigation of the atmospheric ozone over Bulgaria

B. Mendeva[1]**, Ts. Gogosheva**[2]**, D. Krastev**[1]**, and B. Petkov**[1,3]

[1]Solar Terrestrial Influences Laboratory, Bulgarian Academy of Sciences, 6000 Stara Zagora, P.O.Box 73, Bulgaria, (bmendeva@abv.bg)
[2]Institute of Astronomy, Bulgarian Academy of Sciences, 6000 Stara Zagora, P.O.Box 442,Bulgaria, (gogosheva@abv.bg)
[3]Institute of Atmospheric Sciences and Climate, National Research Council, Via P.Gobetti 101, 40129 Bologna, Italy (b.petkov@isac.cnr.it)

Abstract. The results from the ground-based measurements of the total ozone content (TOC), performed at Stara Zagora (42°25' N, 25°37' E), Bulgaria are presented and compared with the satellite (TOMS-EP and GOME) data. The ozone amount was determined using the scanning ultraviolet spectrophotometer Photon, which measures the direct solar UV radiation (300–360 nm) reaching the Earth's surface.

The analysis shows a good agreement between the ground-based and satellite ozone data in the time period 1999–2005. Seasonal variations are observed, typical for the middle latitudes - maximum in the spring and minimum in the autumn. The TOC changes for different months are examined. The biggest fluctuations of the TOC monthly average values are in the winter–spring and the smallest - in the summer. There is not a statistically significant trend in the total ozone over Bulgaria in this period.

The influence of the solar activity on TOC is investigated, analyzing the ozone response to sharp changes of sunspot daily numbers (W) and solar radio flux at 10.7 cm (F10.7).

Keywords. Total ozone content, Ultraviolet solar radiation, Scanning spectrophotometer

1 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 focused the attention of the scientific community. Together with the ozone decrease in the polar atmosphere, similar behavioral features have been registered also at mid-latitudes (Bojkov et al., 1994; Zerefos, 2001). For example, Steinbrecht et al. (1998) have shown that the total ozone in the northern mid-latitudes has declined by about 3% per decade over the last 30 years. Thus, the monitoring of the ozone amount in global scale is concerned nowadays a task of primary significance for the life of our planet.

For this purpose the Global Atmosphere Watch (GAW) network has been created and aimed to monitor the total ozone by a set of ground-based instruments. Simultaneously, several projects like the Total Ozone Mapping Spectrometer (TOMS) and the Global Ozone Monitoring Experiment (GOME) sought to investigate the ozone from space.

Many researchers (Stolarski et al., 1991; Chandra and McPeters, 1994; Kondratyev and Varotsos, 1995; Hood, 2004) have tried to connect the observed interannual ozone anomalies with the solar activity. It was shown that the ozone variations caused by the 11-y solar cycle are within the limits of 1–3 %.

This study presents some results from the investigation of the total ozone content (TOC), determined by ground-based and satellite measurements (300–360 nm) of the UV solar radiation over Stara Zagora (42°25' N, 25°37' E), Bulgaria.

2 Instruments and methods

2.1 Ground-based measurements

The ground-based measurements are performed at Stara Zagora, Bulgaria, by the scanning spectrophotometer Photon (Petkov et al., 2001). This instrument is used to measure and examine the temporal variations of the ultraviolet radiation, reaching the Earth's surface and the total ozone content (TOC) in the atmosphere. The spectrophotometer measures the direct solar light in the range 290–360 nm, with 1 nm resolution. The sensor is a Seya-Namioka monochromator with

Correspondence to: B. Mendeva
(bmendeva@abv.bg)

Published by the Swedish Institute of Space Physics.

a concave diffraction grating, connected with a stepper motor, performing the scanning. A photoelectronic multiplier is used as a photoreceiver, sensitive in the UV part of the spectrum. The sensor of the spectrophotometer is fixed on the solar-tracking system of a telescope. This ensures high precision of the instrument orientation to the Sun and permanent illumination of the input slit during spectrum scanning.

The scanning time interval of the specified range is 140 s. The system is controlled by a microprocessor and a PC records the data. The calibration is made by a mercury lamp and by intercalibration with a sample Brewer spectrophotometer in Greece and Norway.

The method for determination of the total ozone content is similar to the method, applied in the classical Brewer spectrophotometers. TOC is determined from direct solar spectra by applying the Bouguer-Lambert's law for radiation attenuation during transition through the Earth's atmosphere and different absorption of the separate wavelengths by the ozone molecules. We, however, use the intensity of rather more wavelength pairs (about 20). In this way enhanced precision in the determination of TOC is achieved, which with this multiwave method is 5% (Petkov et al., 2001).

2.2 Satellite measurements

TOMS-EP continues the NASA Program for mapping and research of the global ozone distribution in the Earth's atmosphere since 1996. 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.

GOME is a spectrometer, measuring the spectrum of the Earth's light flux - mainly solar, which is reflected by the atmosphere back to space as well as the direct solar spectrum. The relation between the intensity of the flux, reflected by the Earth and the direct solar signal is used to calculate the total ozone content. The instrument measures the spectra in a wide range - from 240 nm to 790 nm with high resolution (0.2–0.4 nm).

In our investigation we have used ozone data from these satellite measurements made over Stara Zagora, Bulgaria (http://earth.esa.int/ers/gome/), (http://toms.gsfc.nasa.gov). The purpose was to compare the values of TOC and its behaviour over one place, registered from the ground and from the space.

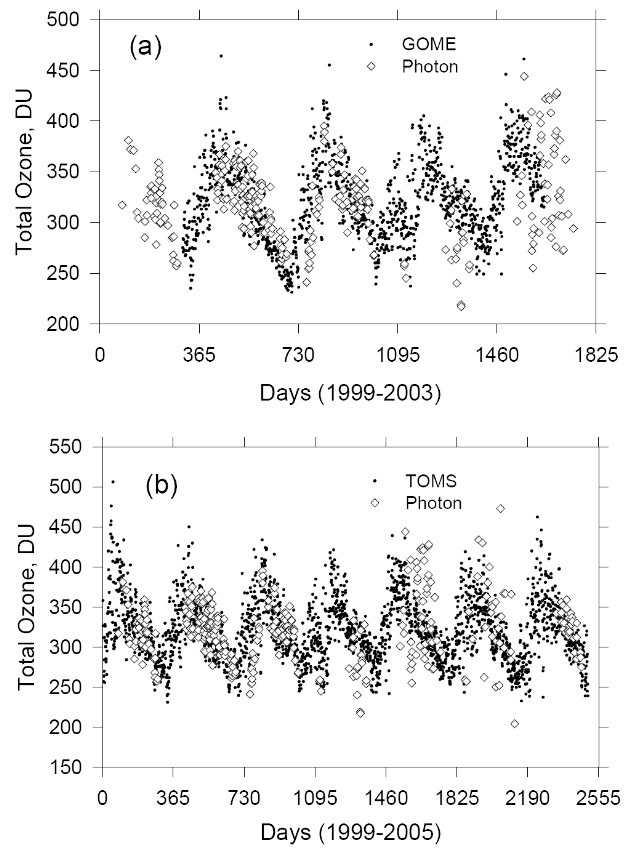

Fig. 1. Annual TOC variations, measured by the Photon spectrometer (open diamonds) presented together with (a) GOME on ERS-2 satellite data (black circles) during 1999–2003 period and with (b) TOMS data (black circles) during 1999–2005.

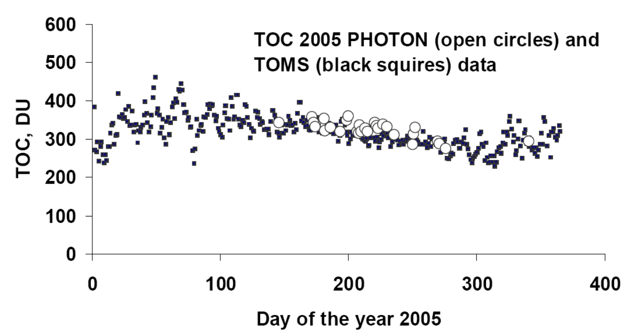

Fig. 2. Annual TOC variations, measured by the Photon spectrophotometer and by TOMS-EP, 2005.

3 Conclusions

Results and discussion

This work presents the dynamics of the total ozone content over Stara Zagora (42°25' N, 25°37' E), Bulgaria by using data from TOC measurements by the ground-based spectrophotometer Photon as well as by the satellite instruments TOMS-EP and GOME.

Fig. 1 shows annual TOC variations in the period 1999–2003 by data of Photon and GOME (Fig. 1a) and by Photon

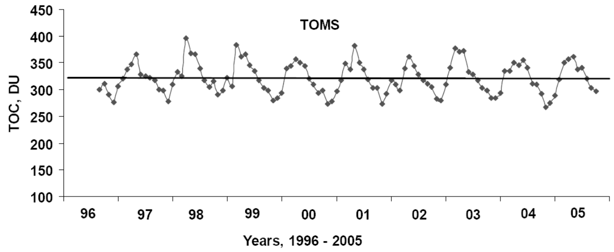

Fig. 3. The variability of the TOC monthly mean values, measured by TOMS-EP, 1996–2005.

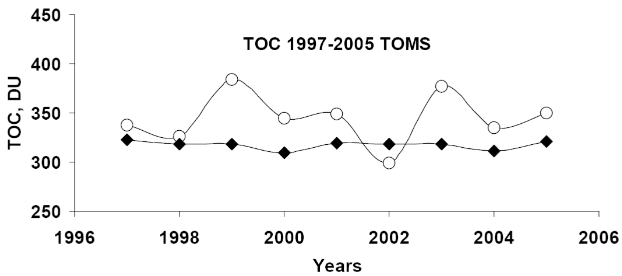

Fig. 4. TOC monthly average values for February (rings) and July (diamonds) using TOMS data, 1997–2005.

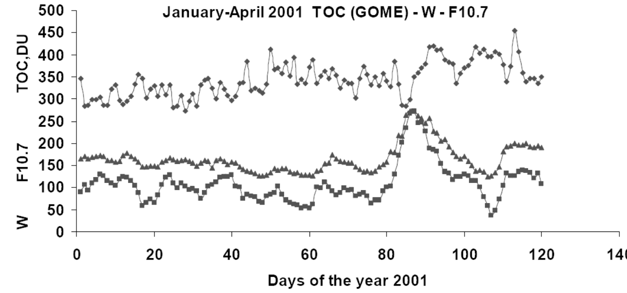

Fig. 5. A positive correlation between the ozone and solar activity parameters.

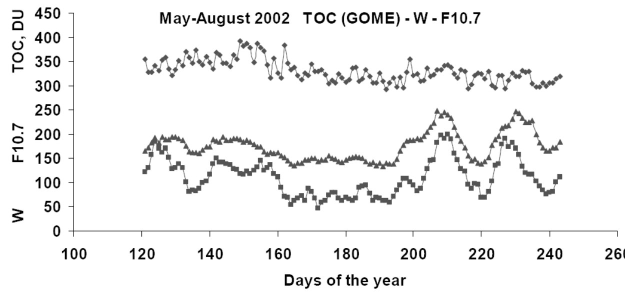

Fig. 6. An example of missing correlation between the ozone and solar activity parameters.

and TOMS (1999–2005) (Fig. 1b). A good agreement between the ground-based and the satellite data, as well as seasonal variations can be seen. These variations are expressed by an abrupt maximum in the spring and a decrease to the minimum in the autumn. This is also well shown in Fig. 2 in the TOC course for 2005 by Photon and TOMS. This seasonal march 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 solar radiation variations with a certain delay at all latitudes.

The average monthly TOC values, measured by TOMS for the period 1996–2005 are presented in Fig. 3. Except the known seasonal variations, an important result is evident here, showing that for this period there isn't a statistically significant trend in the TOC course over Bulgaria. Similar results for this time interval are obtained by Varotsos (2005) for latitudes of 62.5° S and by Semenov et al. (2004) for 42.6° N.

Using the TOMS data for 1997–2005, we track the TOC variations for the separate months of these years. The largest ozone fluctuations are in the winter-spring months of all years, and the lowest - in the summer months. Fig. 4 shows that in February and July the difference in the ozone behaviour is most strongly expressed. This might be due to the enhanced dynamics of the Earth's atmosphere in the spring, producing ozone transfer as well as mixing and alteration of the main atmospheric components. The latter yields a change in the ozone photochemistry and a change of its total content, respectively.

A response of the atmospheric ozone to the solar radiation variability has been studied using the TOC data from the satellite experiment GOME on ERS-2 in the time period 2000–2003. These are years about the maximum of the 23-rd cycle of solar activity. The sunspot daily numbers W and the solar radio flux at 10.7 cm (F10.7) have been taken as parameters characterizing the solar activity. The solar activity influence on TOC is estimated by an analysis of the ozone response to some separate cases of sharp changes in the course of W and F10.7 in the examined period.

A positive ozone-solar activity relation is presented in Fig. 5. The courses of three parameters: TOC, W and F10.7, determined from their daily values in the spring of 2001 are shown. The sunspot daily numbers have a mean value of 95 for January and February, but from 20 March on a rebuff enhancement of W is beginning. It reaches a value of 273 on 28 March. After this maximum a smooth decrease to 36 comes on 17 April. The flux F10.7 sharply increases, too - from 133 to 272 (124 on 16 April). A rebuff rise is registered in TOC - from 280 to 420 DU with a phase lag of about 4 days.

In the investigated time period some negative correlations between the ozone and W, F10.7 are registered. There are some cases when the sharp increases of the solar activity don't provoke any TOC changes (Fig. 6).

Similar ambivalent results for the relation between the total ozone and the solar activity are presented in the studies of Varotsos (1989); Soukharev (1997); Terez and Terez (1997). In these papers, the ozone response to the solar activity changes is connected with the different phases of quasi-biennial oscillation (QBO) of zonal winds in the equatorial stratosphere. It is shown that there is a linear correlation between the total ozone and the solar activity parameters (W and F10.7), considering the QBO phases. During the West phases of QBO, positive correlations are observed and during the East phases - negative correlations. Based on the analysis for connections between the index of stratospheric circulation C1 and the sunspot numbers considering the QBO phase as well as on the obtained correlation between the variations of total ozone and C1, Soukharev (1997) concludes that the connection solar cycle–QBO–ozone occurs through the dynamics of the stratospheric circulation.

In compliance with the above we might suppose that the TOC variations we've registered, connected with the solar activity, have been provoked by different changes in the atmospheric circulation.

Acknowledgement. The editors thank one referee for assistance in evaluating this paper.

References

Bojkov, R. D., Fioretov, V. E. and Shalamiamnsky, A. M.: Total ozone changes over Eurasia since 1973 based on reevaluated filter ozonometer data, J. Geophys.Res., 99, 22985–22999, 1994.

Chandra, S. and Mc.Peters, R. D.: The solar cycle variation of ozone in the stratosphere inferred from Nimbus 7 and NOAA 11 satellites, J. Geophys. Res., 99, 20665–20671, 1994.

Hood, L. L.: Effects of solar UV variability on the stratosphere, Pap, J., Fox, P. (Eds.), Solar Variability and its Effect on the Earth's Atmospheric and Climate System, AGU Monograph Series, Washington, DC, 283–304, 2004.

Kondratyev, K. Ya. and Varotsos, C. A.: Atmospheric ozone variability in the context global change, Int. J. of Remote Sensing, 16, N 10, 1771–1776, 1995.

Petkov, B. H., Gogosheva, Ts. N. and Krastev, D. G.: Measurements of the total ozone content over Bulgaria by scanning ultraviolet spectrometer, Comptes rendus de l'Academie bulgare des Sciences, 54, N 7, 35–38, 2001.

Semenov ,V. K., Ignacova, N. I., Arefev, V. N. et al.: Measurements of solar UV radiation and total ozone in mountain region of Northern Tien Shan, Proceedings QOS, Greece, 2004.

Soukharev, B.: The sunspot cycle, the QBO, and the total ozone over Northeasten Europe: a connection through the dynamics of stratosphere circulation, Ann. Geophysicae, 15, 1595–1603, 1997.

Steinbrecht, W., Clade, H., Kohler U. et al.: Correlation between tropopause height and total ozone: Implications for long-term changes, J. Geophys. Res., 103, 19183–19192, 1998.

Stolarski, R. S., Bloomfield, P., McPeters, R. D. and Herman, J. R. Total ozone trends deduced from Nimbus 7 TOMS data, Geophys. Res. Lett., 18, 1015–1018, 1991.

Terez, G. A. and Terez, E. I. Influence of 11-y solar activity cycle on the total ozone changes, Geomagn. and Aeronomy, 37, (in Russian), 1997.

Varotsos, C., Comment on connection between the 11-year solar cycle, the QBO and total ozone, J. Atmos. Terr. Phys., 51, N 5, 367–370, 1989.

Varotsos, C. Power-law correlations in column ozone over Antarctica, Int. J. Remote Sensing, 26, N 16, 3333–3342, 2005.

Zerefos, C. S. Long-term total ozone and UV variations through the year 2000, Report IAGA/ICMA workshop, 25–28, 2001.