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10 YEARS INVESTIGATIONS OF THE SOLAR UV RADIATION AND TOTAL OZONE IN STARA ZAGORA, BULGARIA

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Abstract. Some major results from the ground-based measurements of the ultraviolet solar radiation and total ozone content (TOC), performed in Stara Zagora (42°25‘N, 25°37’E), Bulgaria in the last decade, are presented. The UV radiation reaching the Earth’s surface at different conditions is investigated. The ozone amount is determined using the scanning ultraviolet spectrophotometer Photon, which measures the direct solar UV radiation (300-360 nm). The TOC dynamics is analyzed using data from ground-based measurements made by Photon, as well as these by satellite instruments (GOME, TOMS-EP and SCIAMACHY). The seasonal TOC variations are clearly marked. Quasi-biennial periodicity in the amplitude of the ozone maximums can be seen. The experimental data show that there is no any trend in the ozone course during the period 1997-2008.
The solar eclipse is an event, which gives the opportunity to receive important information about the sun itself as well as about the influence of the solar radiation on the processes, defining the atmospheric components dynamics. The results from the TOC and UV measurements during two solar eclipses: on 29 March 2006 and on 11 August 1999, carried out in Stara Zagora, are presented.

Introduction

The ultraviolet radiation has the strongest biological effect of the whole solar radiation spectrum. Depending on the irradiance intensity, the wavelength and the conditions of the Earth’s atmosphere, the UV radiation has both positive and negative effect on the biosphere.

The significance of the relation between the total ozone content (TOC) in the atmosphere and the quantity of ultraviolet radiation (UVR) reaching the Earth’s surface, stimulates the research in this area, especially after the certain reduction of the ozone layer, established in the last decades and the related increase of the UVR, dangerous for the biosphere. The impact of the ozone content on the UVR, penetrating the atmosphere and reaching the Earth’s surface is both qualitatively analyzed and quantitatively evaluated in a number of publications [1, 2, 3].

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 [4, 5]. 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.

The aim of this paper is to present some results of the UV and ozone investigations using ground-based measurements, performed in Stara Zagora, Bulgaria, and satellite data in the last decade.

Instruments and methods

The ground-based measurements are performed in Stara Zagora, by the scanning spectrophotometer Photon [6]. 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 300-360 nm, with 1 nm resolution. The sensor is a Seya-Namioka monochromator with 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% [6].

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)

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.

SCIAMACHY is an imaging spectrometer, which carry 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 ozone, is observed.

Major results

From the measurements made using the scanning spectrophotometer Photon a number of direct solar spectra was obtained. This allows the investigation of UV solar radiation reaching the Earth's surface at different conditions. Because a clear sky is necessary for direct solar spectra, there isn't frequent such measurements during the winter-spring period. Typical Photon's spectra are shown in Fig. 1.

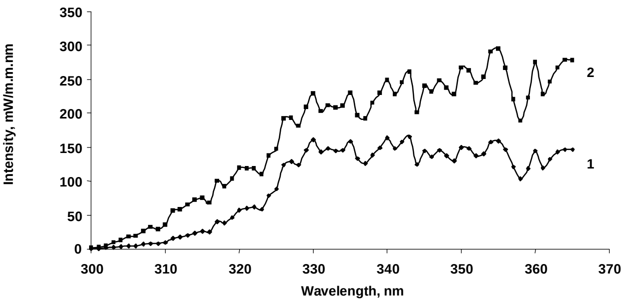

Fig. 1. *UV solar spectra, registered by Photon , at different solar zenith angle: (1) SZA=53, (2) SZA=22.*

The dependence analysis of the UV radiation on the solar zenith angle (SZA) at fixed total ozone shows a decrease of all wavelengths intensities with the increase of the SZA, but different for each of them.

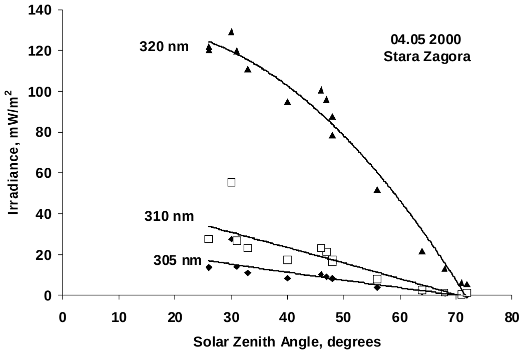

Fig. 2. *Dependence of the UV irradiance on the solar zenith angle at fixed TOC.*

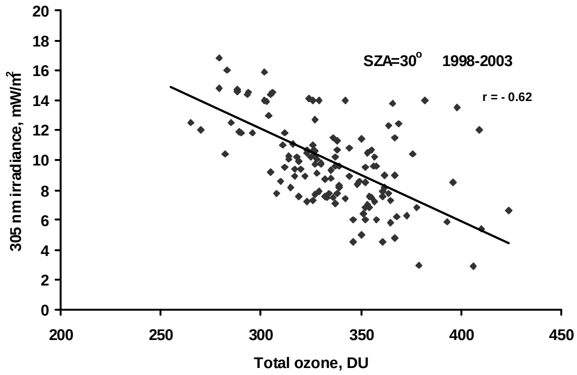

Fig. 3. *Dependence of the 305 nm wavelength irradiance on the TOC, using Photon data*

The shorter wavelengths change more than the longer ones with equal changes of SZA. The results, presented in Fig. 2, show that the radiation at used wavelengths changes approximately with an order of 2 in (26° - 72°) SZA interval.

Fig. 3 shows instantaneous values of solar UV irradiance at 305 nm measured at 30° SZA together with the total ozone. Reduction in the ozone leads to an increase of these wavelengths reaching the Earth's surface. The inverse relationship of these two variables is significant (r = -0.62 ± 0.18) at 98% confidence level.

The dynamics of the total ozone content over Stara Zagora is investigated using data from TOC measurements by the ground-based spectrophotometer Photon as well as by satellite instruments. Fig. 4 shows the annual TOC variations by data of Photon and GOME (Fig. 4a) and by Photon and TOMS-EP (Fig. 4b). 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 gently sloping decrease in the autumn. The difference between the maximum and minimum TOC values is about 150 DU. This ozone seasonal course doesn't correspond to the solar radiation energy distribution throughout the year. It is different from the course of other parameters as well, such as temperature, humidity, air pressure, which follow the course of the solar radiation with a certain delay at all latitudes.

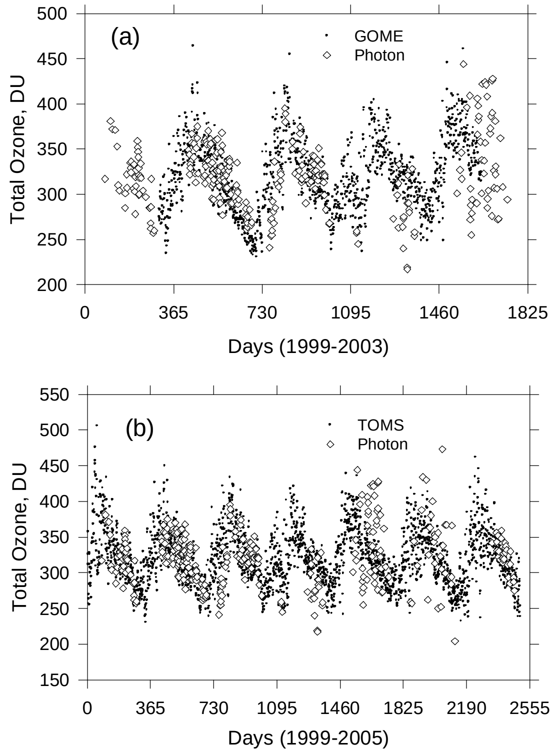

Fig. 4. *Annual TOC variations, measured by the Photon spectrometer (open diamonds) presented together with (a) GOME on ERS-2 satellite data (black circles) during 1999-2003 and with (b) TOMS data (black circles) during 1999-2005.*

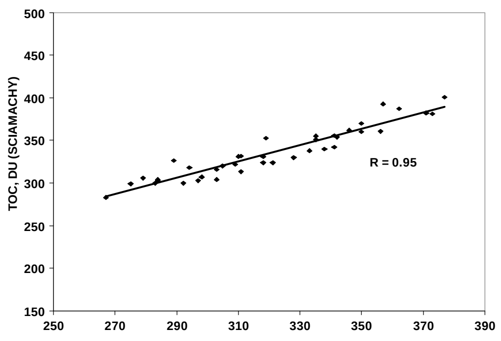

Fig. 5. *Correlation straight line between TOC monthly mean values (2002-2005), measured by TOMS-EP and SCIAMACHY*

For tracking out the TOC course for a longer period we use TOMS and SCIAMACHY data. The results from both instruments, simultaneously operating in the period 2002 – 2005 are compared. There is a good agreement between them : R = 0.95 (Fig.5). This allows to use the consecutive TOMS data (1997–2002) and the SCIAMACHY data (2003-2008) for investigation of the ozone behavior in the period 1997-2008 (Fig. 6).

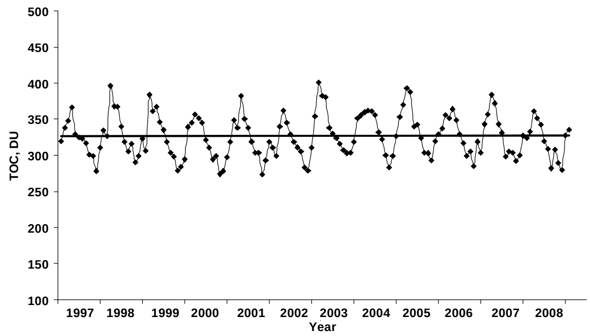

Fig. 6. *Behaviour of the monthly mean ozone data from TOMS-EP (1997-2002) and SCIAMACHY (2003-2008).*

This figure shows a quasi-biennial periodicity in the amplitudes of the ozone maximums. For example, in 1999, 2001, 2003 etc. these amplitudes are bigger than in 2000, 2002, 2004 etc. and the biggest TOC maximum (400 DU) is registered in March 2003 and the smallest one (357 DU) – in March 2000. Our analysis shows that there is no any trend in TOC course in this period. Despite the absence of a trend in the whole period, different trend values have been obtained for the various seasons. Thus, in winter (December) and in spring (March) the linear trend is positive, respectively 2.2% and 0.2%, and in summer (July) and in autumn (September) it is negative : -3.5% and – 1.6%. This result shows that a seasonal dependence of TOC trend probably exists.

The solar eclipse is an event, which gives the opportunity to receive important information about the sun itself as well as about the influence of the solar radiation on the processes, defining the atmospheric components dynamics.

The course of some wavelength irradiances, registered by Photon during the eclipse on 29 March 2006 (76% max coverage for Stara Zagora) and on 11 August 1999 (96% max coverage) describes very well the moments characterizing the eclipse: beginning, maximum phase, end (Fig. 7). The analysis of the results shows that the radiation decrease near the max phase is different for separate wavelengths. The irradiance at shorter wavelengths is reduced more than at longer ones (limb darkening effect).

The TOC variability, registered by Photon's measurements, during two solar eclipses: on 11 August 1999 and on 29 March 2006, is illustrated in Fig. 8. It shows almost the same time-patterns features during both of them. After the first contact TOC began to decrease till the maximum obscuration, reaching values which turned out to be less by about 75 DU for 11 August 1999 and 82 DU for 29 March 2006 with respectto the corresponding ones before the eclipses. In both cases, two maxima on either side of the totality were also found. The registered behaviour of the total ozone around and after the maximum obscuration is quite similar to the one, obtained by Mims and Mims [7] and Chakrabarty et al. [8].

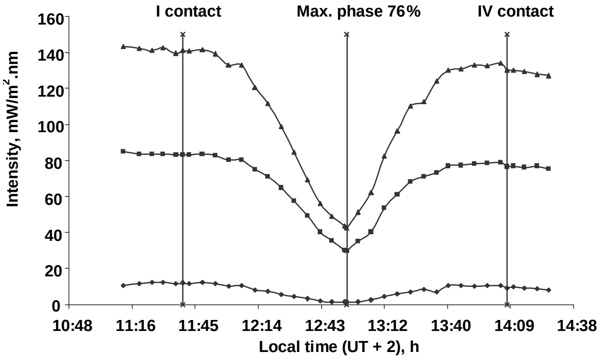

Fig. 7. The behaviour of UV solar radiation during the solar eclipse on March 29th 2006 in Stara Zagora.

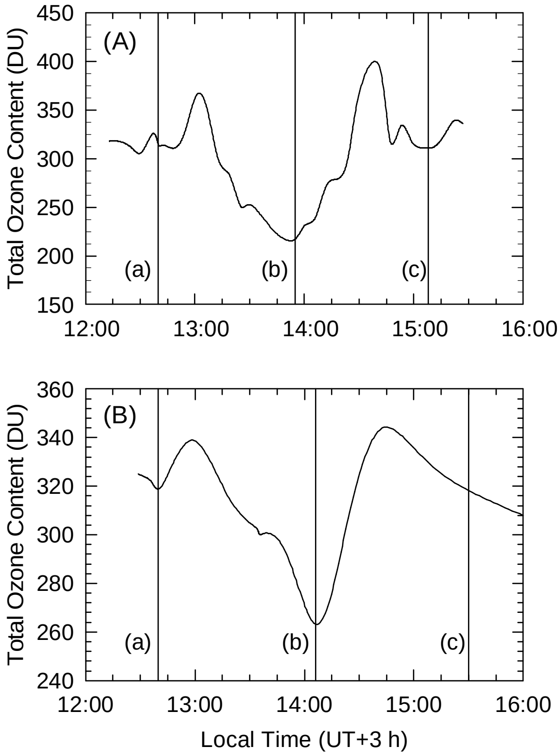

Fig. 8. TOC variations during the solar eclipse (A – 29.03.2006; B – 11.08.1999).Moments: a – I contact; b – max phase; c – IV contact.

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