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Short note

# TRENDS OF UV INDEX MEASURED IN NOVI SAD FROM 2004 TO 2013*

**Zorica Podrascanin**, Zoran Mijatovic, Ana Firanj Sremac**

University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia

***Abstract**. We studied the trends of UV index in the city of Novi Sad (latitude 45.3N, longitude 19.8 E at the 80m height) in the 2004-2013 time period. The measurements of UV index were performed with the Yankee Environmental System (YES) UVB-1 pyranometer. The linear regression method was used to calculate the trends of UV index. The yearly trend of UV index from the relative monthly differences considered with climatological value was investigated. We obtained the positive yearly UV trend of 7.9±1.7% per decade at the location of Novi Sad. Further on, the monthly UV trends were investigated. We obtained significant positive trends in April, August, October and December, with no significant negative UV trends.*

***Key words**: UV index, trend, total ozone amount*

## 1. INTRODUCTION

The harmful UV radiation is mostly absorbed by the ozone layer in the stratosphere. The part of extraterrestrial solar UV radiation that reaches the earth surface is about 10%. To include the influence of that solar UV radiation on humans, the UV spectra is weighted to erythemal CIE spectra [1]. The 25 mW/m$^2$ erythemally weighted irradiance is 1 UV index (UVI), which is common used unit for solar UV radiation. The UVI depends on the following factors: solar zenith angle (SZA), total column ozone (TCO), surface albedo, effect of clouds and effect of aerosols [2].

The knowledge of UVI value is necessary to prevent the negative impact of UV radiation on humans and it could be measured either by satellites or by ground based systems. The estimation of UVI trend is important for assessing these impacts and for adopting proper measures [3]. In this paper we studied the trends in UVI measured values in Novi Sad for different solar zenith angles and without cutting trends in TCO, aerosol optical depth and cloudiness. However, short discussion about TCO trends will be included. For that purpose, we used satellite TCO measurements.

## 2. MEASUREMENTS AND METHODS

The UVI have been measured with Yankee Environmental System (YES) UVB-1 pyranometer in Novi Sad since 2003. The instrument is situated on the roof of the Faculty of Agriculture, where the horizon is free up to very high solar zenith angles (45.3 N, 19.8 E, 80 m). The near surroundings are an urban area, a small park and the Danube River. The YES UVB-1 pyranometer spectral response is not same as erythemal irradiance spectra. The correlation method, used to convert the measured spectra to erythemal irradiance spectra, together with the cosine correction were adopted from by Dicher et al. 1993 [4]. The combination of uncertainty stated by manufacturer and error introduced by A/D conversion introduce the error less than 7%. The YES UVB-1 pyranometer was calibrated in 2009 to insure that the spectral response of the instrument was not changed during the entire measured period. The UVI measurements have been made every 30 s, and the values averaged over 10 minutes have been written in database. The results recorded at this site are the longest time series of UVI measurements in Serbia.

In this paper, we used maximum daily UVI values from 2004 to 2013. The monthly values were calculated averaging daily values. The 10-year climatology values of a particular month were calculated as average monthly values through the years 2004-2013 [1]. To eliminate the influence of seasonal variation of SZA, we used the monthly relative differences. The monthly relative difference was calculated as:

$$diff. = \frac{UVI_m - UVI_{mc}}{UVI_{mc}} 100\% \qquad (1)$$

where $UVI_m$ is the monthly UVI value for a particular year and $UVI_{mc}$ is the monthly climatology UVI value. The magnitude of trends was calculated using the least square linear regression method. The Student's t-test

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** zorica.podrascanin@df.uns.ac.rs

was used to check the trend significance. This was done at several significance levels: α<0.1 (- not significant) α=0.1 ($^{+}$ significant) and α=0.01 ($^{*}$ very significant), where α is the probability of rejecting the alternative hypothesis erroneously [5].

The TCO values have been measured with the Ozone Monitoring Instrument (OMI). OMI is a compact nadir viewing ultraviolet-visible imaging spectrometer aboard NASA EOS-Aura satellite [6]. This satellite was launched in July 2004. The OMI global TCO are available at http://ozoneaq.gsfc.nasa.gov/tools/ozonemap/. The TCO monthly relative differences and magnitude of yearly and monthly trends were calculated in the same manner as UVI monthly relative differences and trends.

## 3. Results

First, the yearly trend using relative monthly differences from climatology value was investigated. In Figure 1, the yearly trend was shown. The positive yearly trend is 7.9±1.7% per decade and it is significant. After that the monthly trends were investigated (Figure 2). Positive significant monthly trends were obtained for April, August, October and December. There are no significant negative monthly trends.

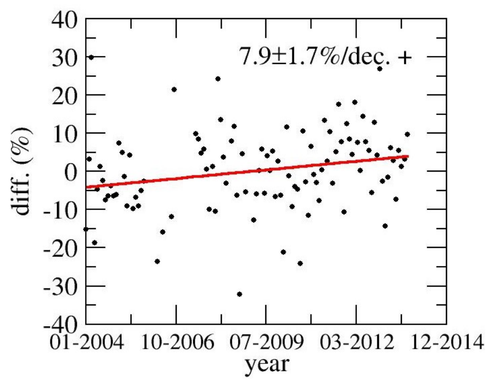


Figure 1. Yearly UVI trend

The increasing UVI suggest decreasing TCO. To find out if the changes in UVI are mainly driven by changes in TCO, we studied TCO trends (Table 1). Opposite to UVI trend there is no significant yearly trend in TCO (-0.7±0.7$^{-}$%/dec.). Only monthly significant TCO trends were observed during March and August and they were negative. However, the UVI trend during March is not significant. During August, the UVI trend is positive and significant and it is the only case when the UVI and TCO had a significant and opposite trend. That implies that only for August we can be sure that the change in TCO is one of factor that caused the change in UVI. For all other months, factors such as cloudiness and aerosol optical depth seem to be more pronounced.

The gaps in the time-series are duo to periods during which the instrument was not operating. In some months the number of data-points is very small. The gaps are unevenly distributed which could lead to biases. To avoid data gap errors season trends were calculated. The UVI trend in DJF, MAM, JJA and SON are 3.9±4.5%/dec.$^{-}$, 9.0±3.58%/dec.$^{-}$, 10.1±2.7%/dec.$^{+}$ and 10.6±2.7%/dec.$^{-}$, respectively. The seasonal UVI trends are positive and significant only in JJA. Otherwise seasonal TOC trends are negative in MAM (-5.7±1.4%/dec.$^{+}$), JJA (-0.7±1.0%/dec.$^{-}$) and SON (-0.7±1.1%/dec.$^{-}$) and positive in DJF (4.3±2.2%/dec.$^{-}$). Only the MAM TOC trend is significant. Again, there is no evidence that TOC trends drive UVI trends.

The UV radiation trends in Europe are also reported in papers by Fitzka et al., 2012 [7], De Bock et al., 2014 [8] and Fountoulakis et al. 2015 [9]. In paper by Fitzka [7] the long-term records of spectral UV irradiance at mountain site Hoher Sonnblick (47.05° N, 12.95° E, 3 106 m above sea level) from period 1997-2011 were investigated. Among other results they found significant positive yearly trend 8.3±3.4%/dec. of erythemally weighted irradiance daily doses for all sky-conditions. The only significant seasonal trend of erythemally weighted irradiance daily doses for all sky-conditions was during spring +9.7±5.5%/dec. De Back et al., 2014 [8] investigated trends of erythermal UV dose at Uccle, Belgium (50◦480 N, 4◦210 E, 100 m a.s.l.) over time period of 23 years (1991-2013). The significant positive yearly trend of 7±2%/dec. was found. The seasonal trends in MAM, JJA and SON were positive at this station. The trend of erythermal UV dose at Uccle in DJF was negative. Variability in spectral UV irradiance at 307.5, 324 and 350 nm for the period 1994–2014 was presented in paper by Fountoulakis et al. 2015 [9]. Positive changes in annual mean anomalies of UV irradiance from 2 to 6 %/dec. was found. The changes are generally greater for larger solar zenith angles and for shorter wavelengths. In all mentioned papers the yearly trends are positive which is similar to our results. The difference was in seasonal trends. The possible reason for this difference is duration of time series and analyzed UV variables.

## 4. Conclusions

In this paper, we investigated the trends in UVI measurements in Novi Sad from 2004 to 2013. The positive yearly trend was found. Monthly significant positive trends were obtained for April, August, October and December. The significant negative monthly trends were not found. There is no significant yearly TCO trend. Investigation of monthly TCO trends indicates that the only negative TOC trends in March and August are significant. Analyzing UVI and TOC trends we can conclude that changes of the UVI in Novi Sad are not mainly driven by changes of TCO.

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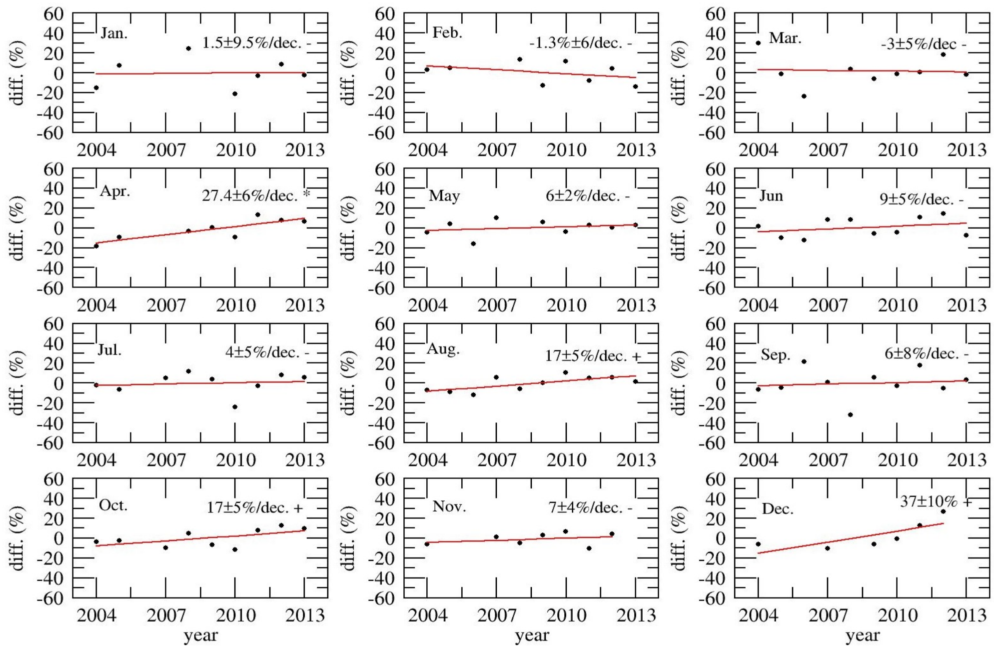


Figure 2. Monthly UVI trends

Table 1. TCO trends

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun |
|---|---|---|---|---|---|---|
| Trend (%/dec.) | $3.8\pm4.1^-$ | $6.5\pm4.4^-$ | $-19\pm2.8^+$ | $-6.7\pm3.4^-$ | $-0.2\pm0.9^-$ | $2.1\pm2.0^-$ |
| Month | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
| Trend (%/dec.) | $1.8\pm1.6^-$ | $-6.6\pm1.6^+$ | $-0.3\pm2.1^-$ | $2.0\pm1.7^-$ | $1.3\pm2.3^-$ | $2.2\pm3.47^-$ |

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