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The importance of ground-based and satellite observations for monitoring and estimation of UV radiation in Novi Sad, Serbia

OUTLINE
- Introduction
- Monitoring details
  - UV index
  - Total ozone column
- Estimation details
  - Model *NEOPLANTA*
  - Reconstruction techniques

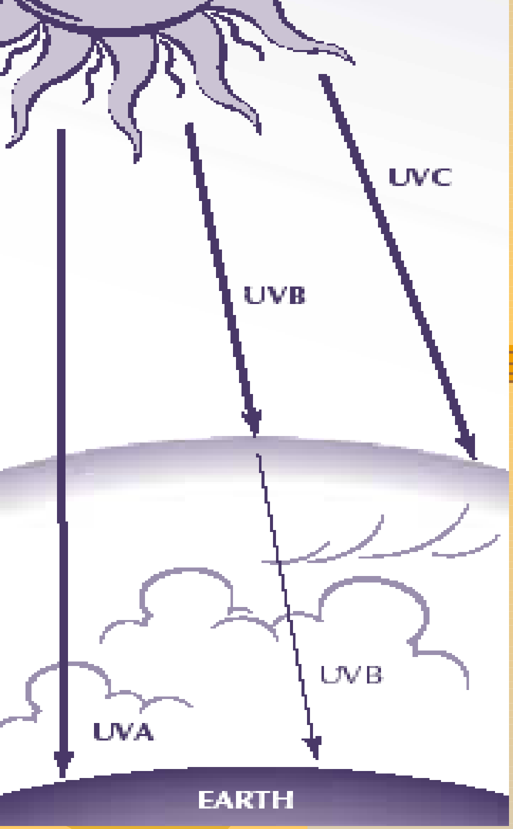
University of Novi Sad, Novi Sad, Serbia

Ultraviolet (UV) radiation

UVC 100-290 nm

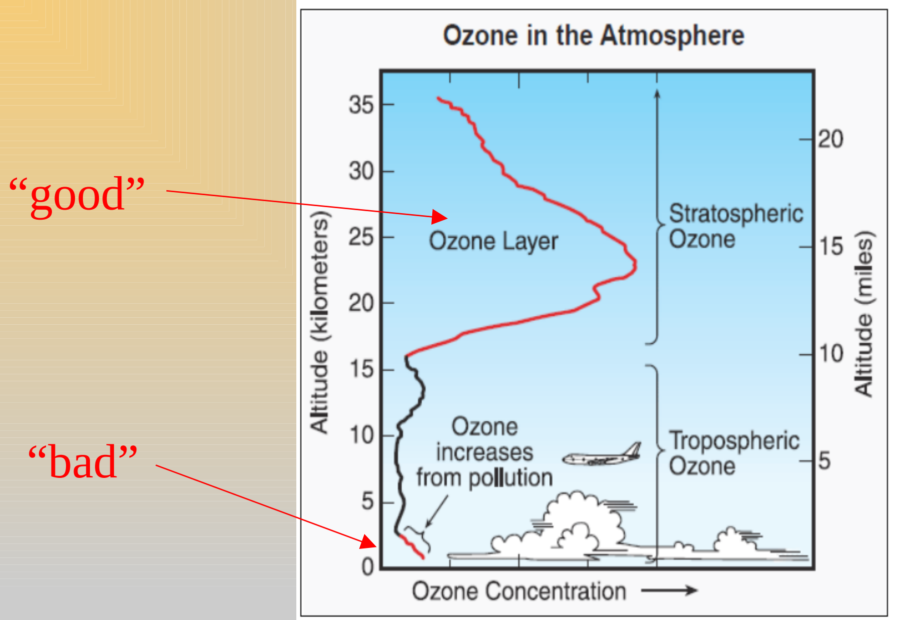
UVB 290-320nm

UVA 320-400 nm



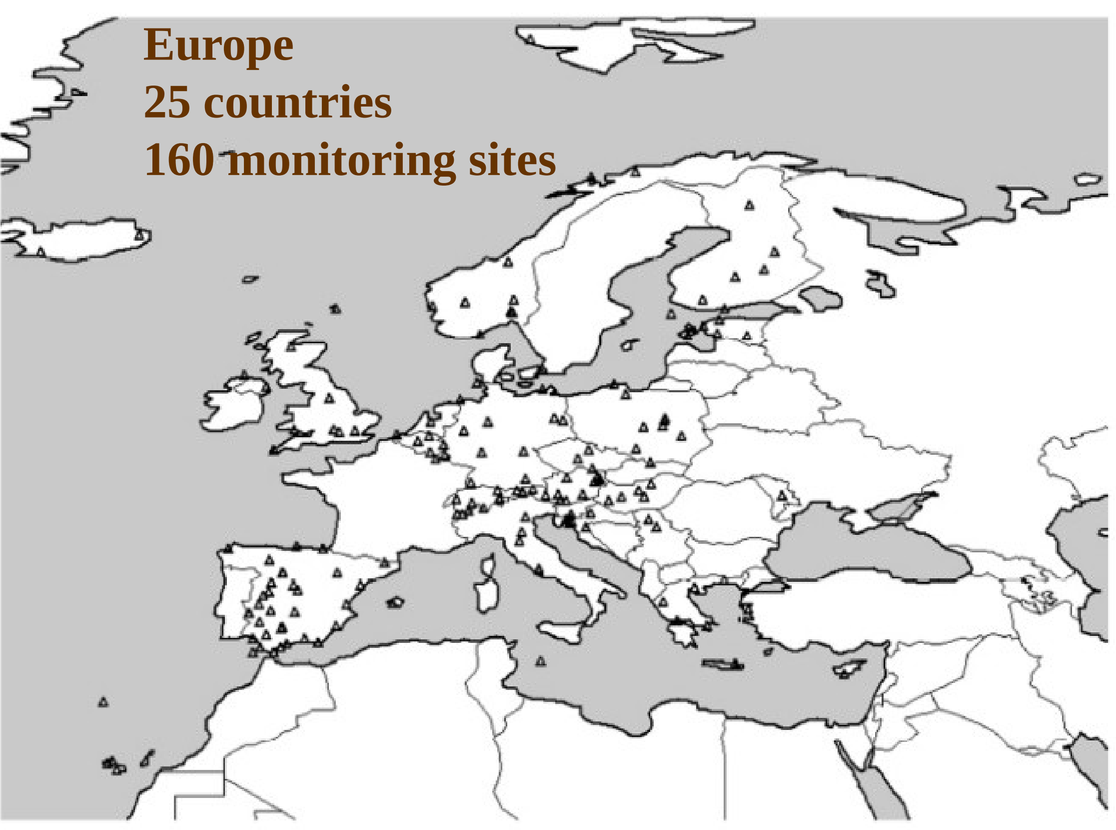
MAIN FACTORS AFFECTING UV RADIATION:

- **Clouds**
- **Stratospheric Ozone**
- **Aerosols**
- **Altitude**



- 1974 - chlorofluorocarbon (CFC) gases destroy ozone layer
- 1984 - springtime Antarctic ozone hole is discovered
- 1977 - an increased incidence in skin cancer is noticed in USA
- Late 1970th – beginning of measurements
- 1987 - Montreal Protocol – global agreement designed to phase out the use and production of substances that were known to deplete ozone in the stratosphere

Measurements of the UV radiation



Ground-based

- late 1970s Australia and USA
- global network - a random mixture of national measurement schemes
- no standardized instrument
- WOUDC

Main types of radiometers

Spectrophotometers- intensity of radiation per wavelength
Narrowband Radiometers-narrow part of the spectrum
Dosimeters - integrated UV doses
Broadband UV Radiometers (biometers)-total UV irradiance over a certain wavelength range, UVA, UVB or erythemally-weighted UV radiation

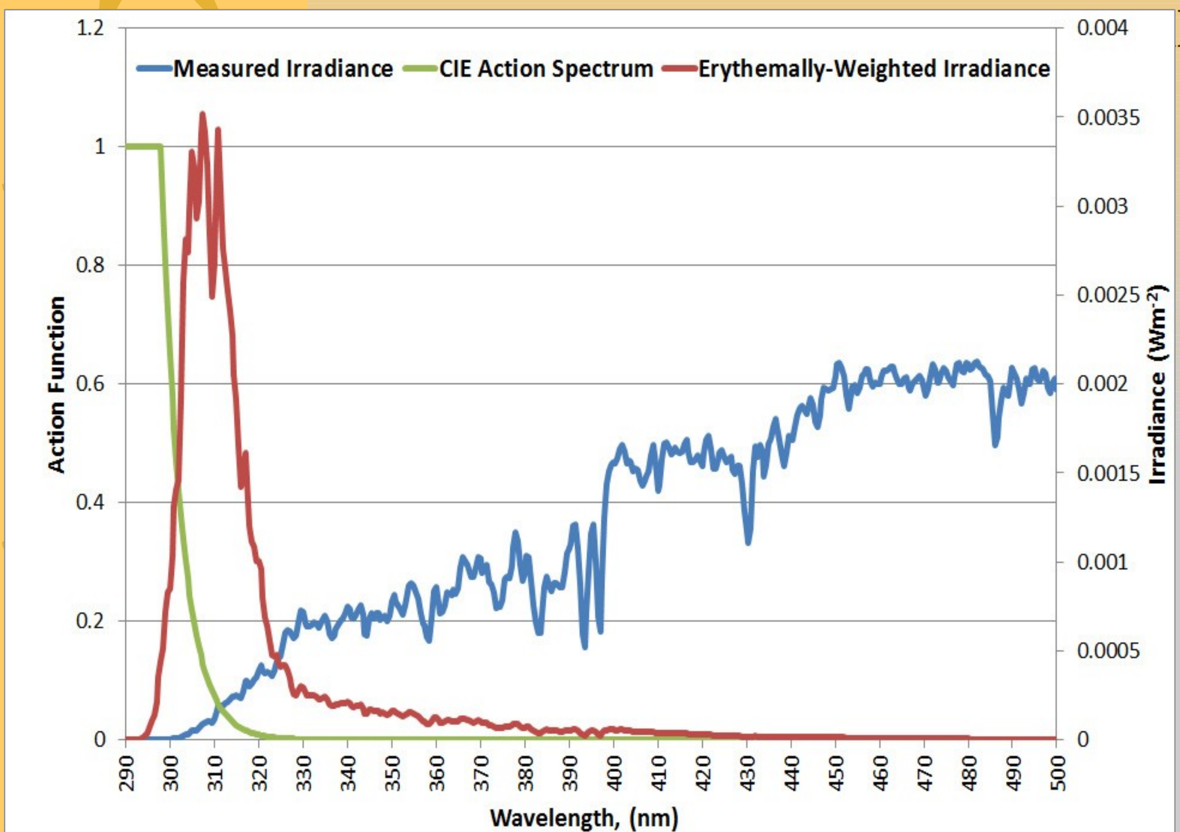
Satellite-based

NASA
Total Ozone Mapping Spectrometer (TOMS)
Ozone Monitoring Instrument (OMI)
ESA
Global Ozone Monitoring Experiment (GOME), SCIAMACHY, GOME2

UV index

- **inform public about the risk from solar radiation**
- **WMO, WHO 1995**

- **the integration of spectral UV irradiance in the range of 290 and 400 nm which is weighted with CIE erythemal action spectrum**



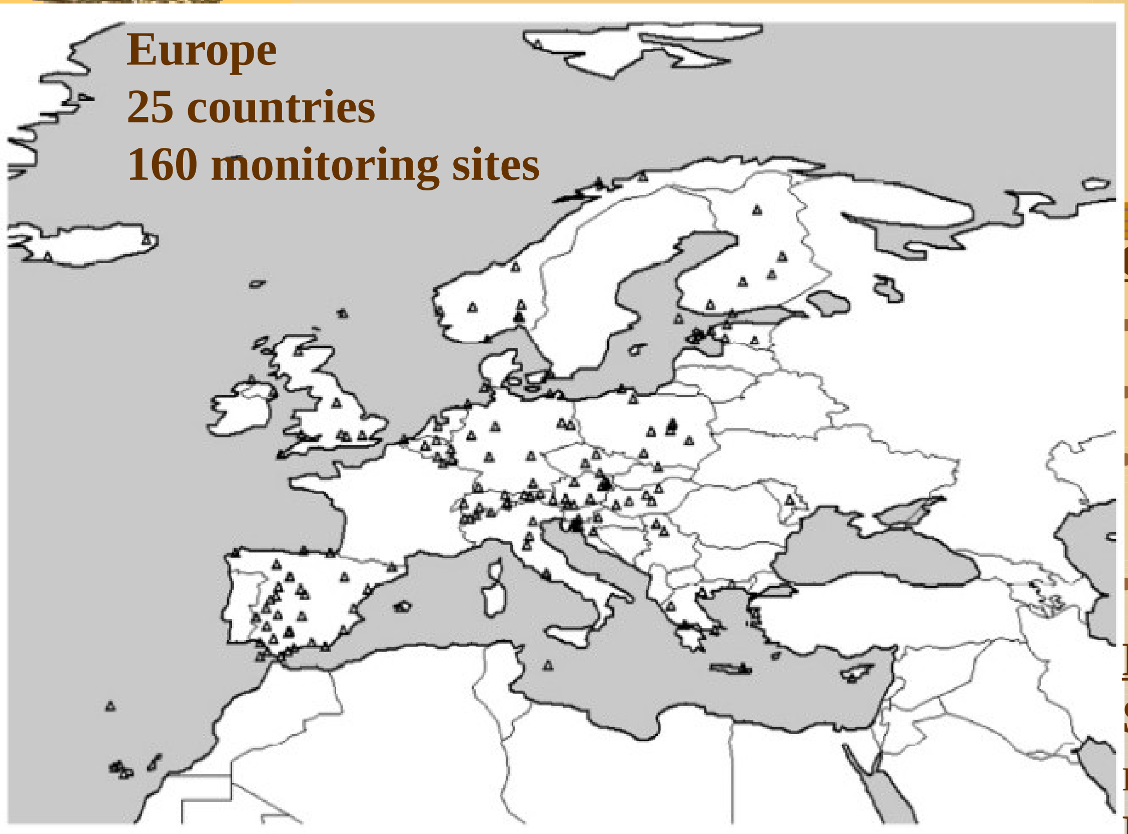
ly weighted UV irradiance

<u>global UV radiation at the ground</u>
6% is UV-B

<u>erythemal UV radiation at the ground</u>
83% is UV-B

UV dose is integrated the total amount of erythemally weighted UV that actually can reach the human skin during a day or in a certain period of time.

Measurements of the UV radiation



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UV measurements in Novi Sad

Start - 2003

Yankee Environmental System (YES) UVB-1 pyranometer
https://www.df.uns.ac.rs/uvindex/UV_index_sr.php
long stability check

UV measurements in Novi Sad

https://www.df.uns.ac.rs/uvindex/UV_index_eng.php

Numerical value UVI
min
avg
max

Date and time

About UV index

Recommended protection

UV index

Date and time of measurement:
Apr 18th, 2019 at 15:10

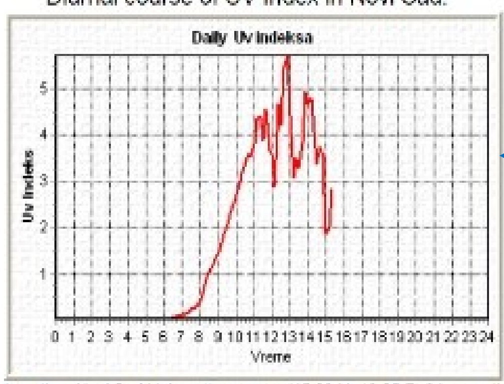
min: 2.2 **AVG: 2.81** **max: 3.2**

The **UV index** is an international standard measurement of how strong the ultraviolet (UV) radiation from the Sun is at a particular place on a particular day. It is a scale primarily used in daily forecasts aimed at the general public. Its purpose is to help people to effectively protect themselves from UV light, of which excessive exposure causes sunburns, eye damage such as cataracts, skin aging, and skin cancer (see the section health effects of ultraviolet light). Public-health organizations recommend that people protect themselves (for example, by applying sunscreen to the skin and wearing a hat) when the UV index is 3 or higher; see the table below for complete recommendations.

UV Index	Description	Media Graphic Color	Recommended Protection
0 - 2	Low danger to the average person	Green	Wear sunglasses; use sunscreen if there is snow on the ground, which reflects UV radiation, or if you have particularly fair skin
3 - 5	Moderate risk of harm from unprotected sun exposure	Yellow	Wear sunglasses and use sunscreen, cover the body with clothing and a hat, and seek shade around midday when the sun is most intense.
6 - 7	High risk of harm from unprotected sun exposure	Orange	Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 AM to 4:00 PM during summer in zones that observe daylight saving time).
8 - 10	Very high risk of harm from unprotected sun exposure	Reddish-purple	Same precautions as above, but take extra care - unprotected skin can burn quickly
11+	Extreme risk of harm from unprotected sun exposure	Violet	Take all precautions, including: wear sunglasses and use sunscreen, cover the body with a long-sleeve shirt and pants, wear a broad hat, and avoid the sun from two hours before to three hours after solar noon

Presentation by colors

Diurnal course of UV Index in Novi Sad:



Location: Novi Sad University campus (45.33 N, 19.85 E, 84 m a.s.l)

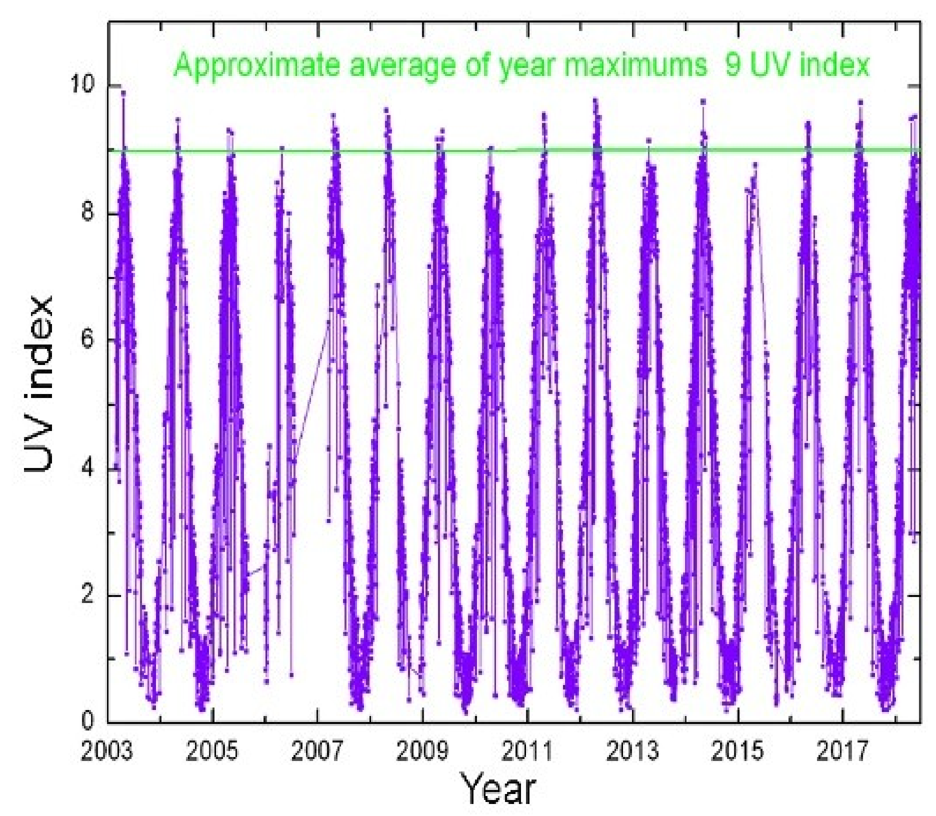
Graphical presentation

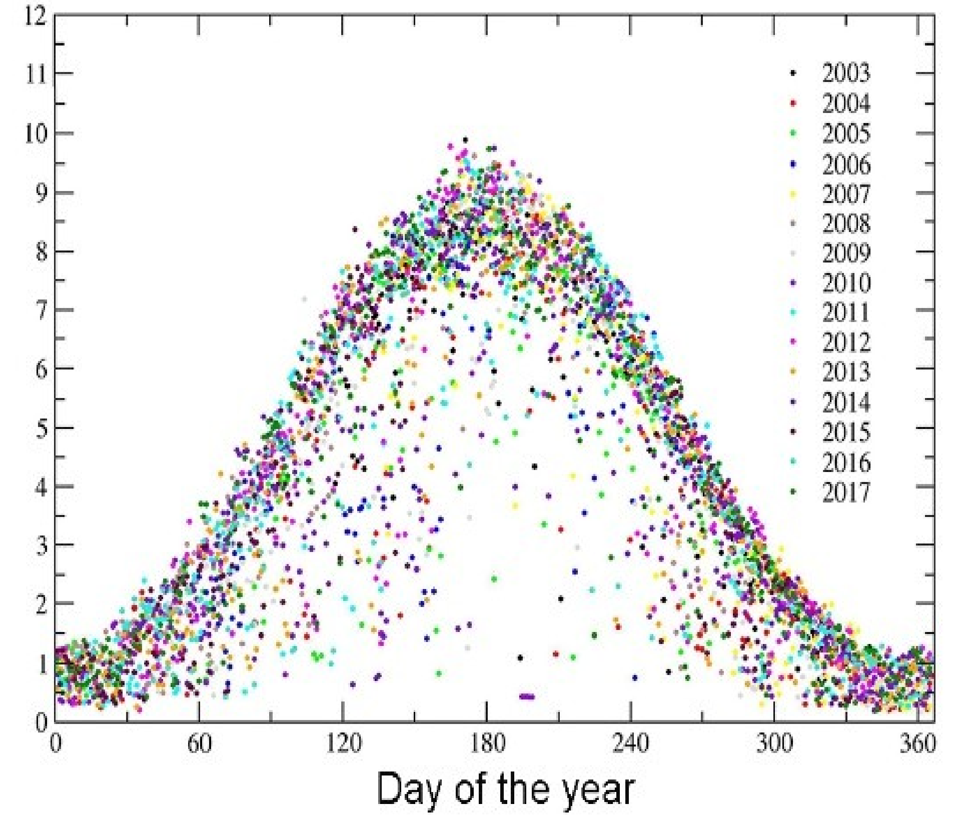
Measuring Equipment:

Radiometer YANKEE UVB-1

UV measurements in Novi Sad

High levels (≥ 6 UVI) April-September
Very high levels (≥ 8 UVI) May-August

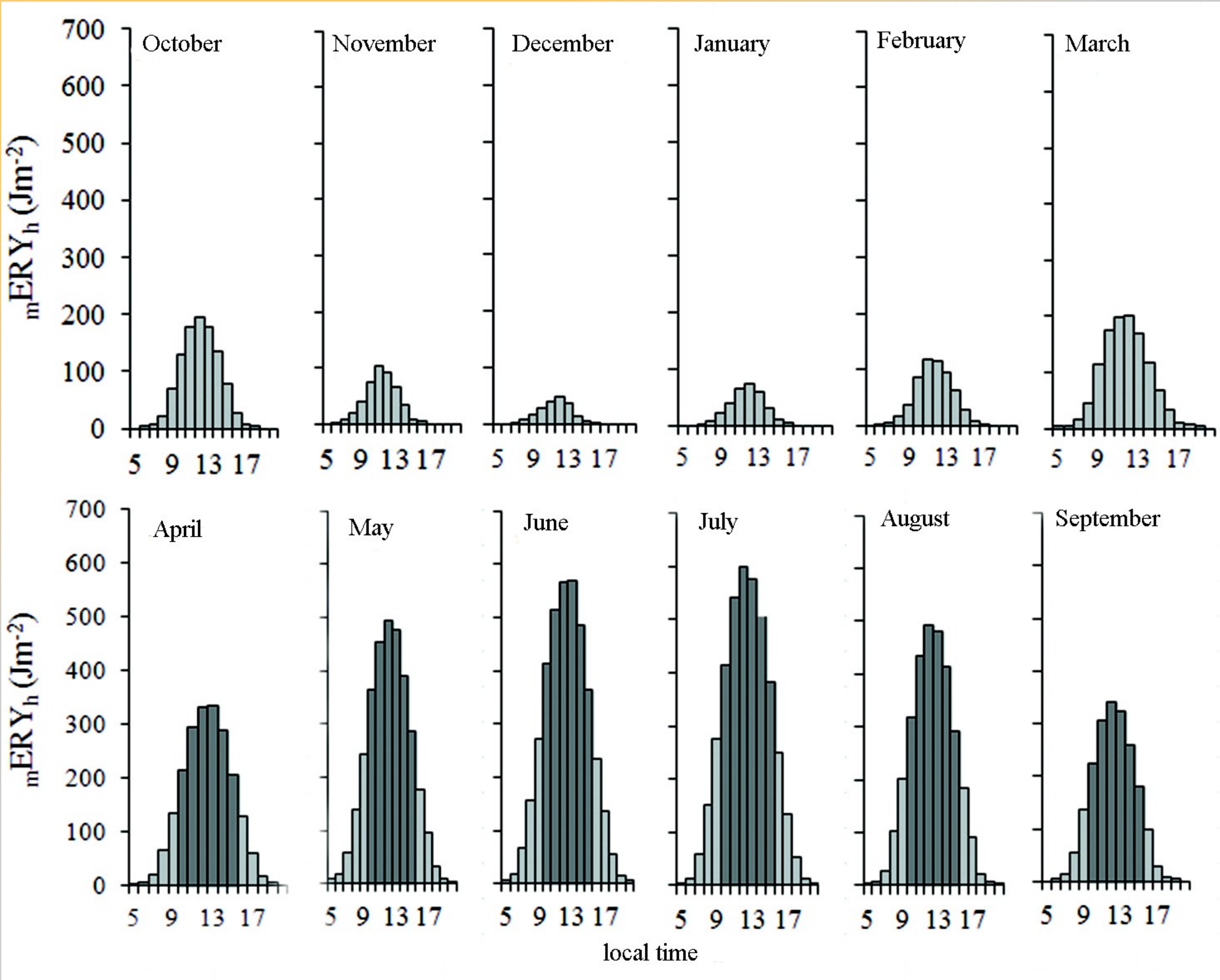




UV measurements in Novi Sad

Hourly erythemal UV dose

April – September → 10-16h → 70-80% of daily dose



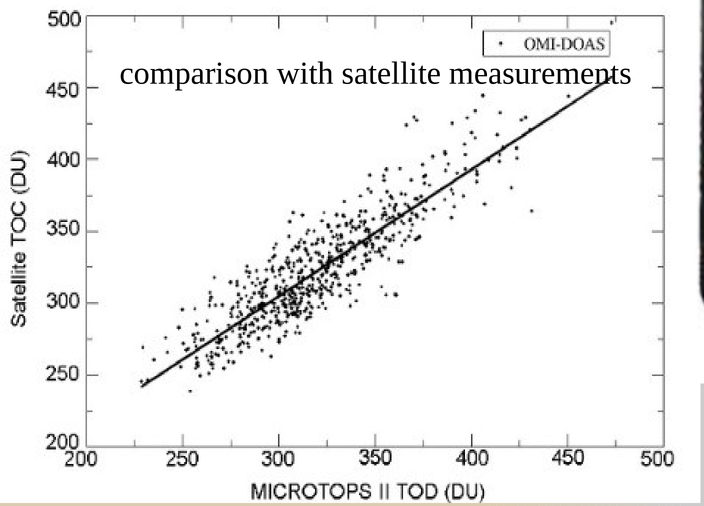
Ozone measurements in Novi Sad

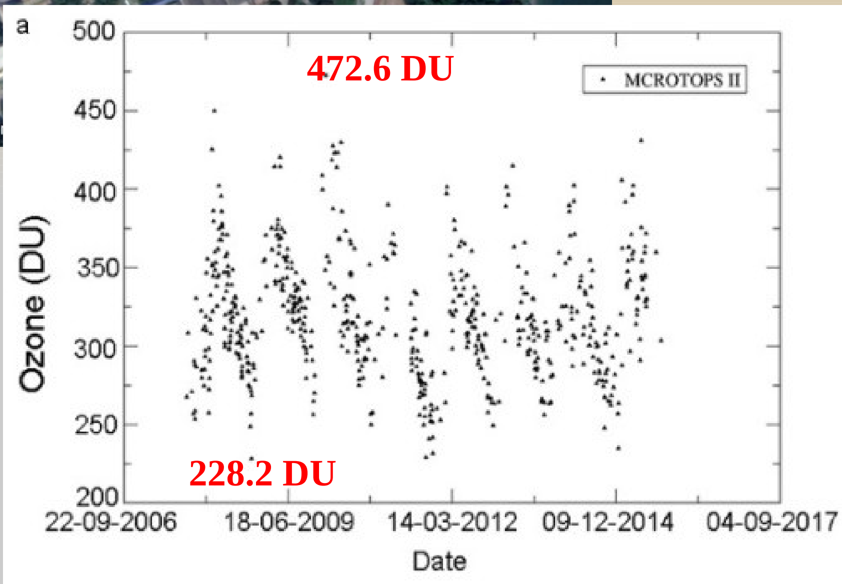
Start - September 2007

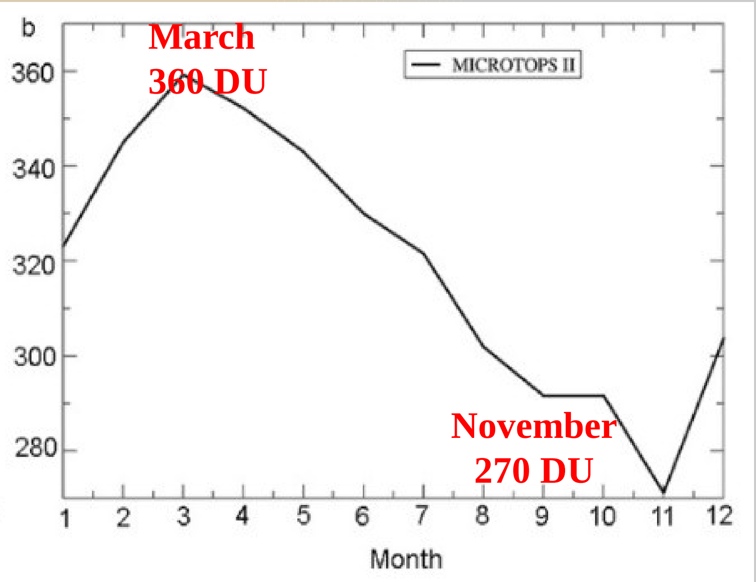
MICROTOPS II instrument -uses measurements of solar irradiance at 3 wavelengths in the UV region to derive the TOC

-once a day during completely cloudless conditions

Faculty of Sciences, the University of Novi Sad







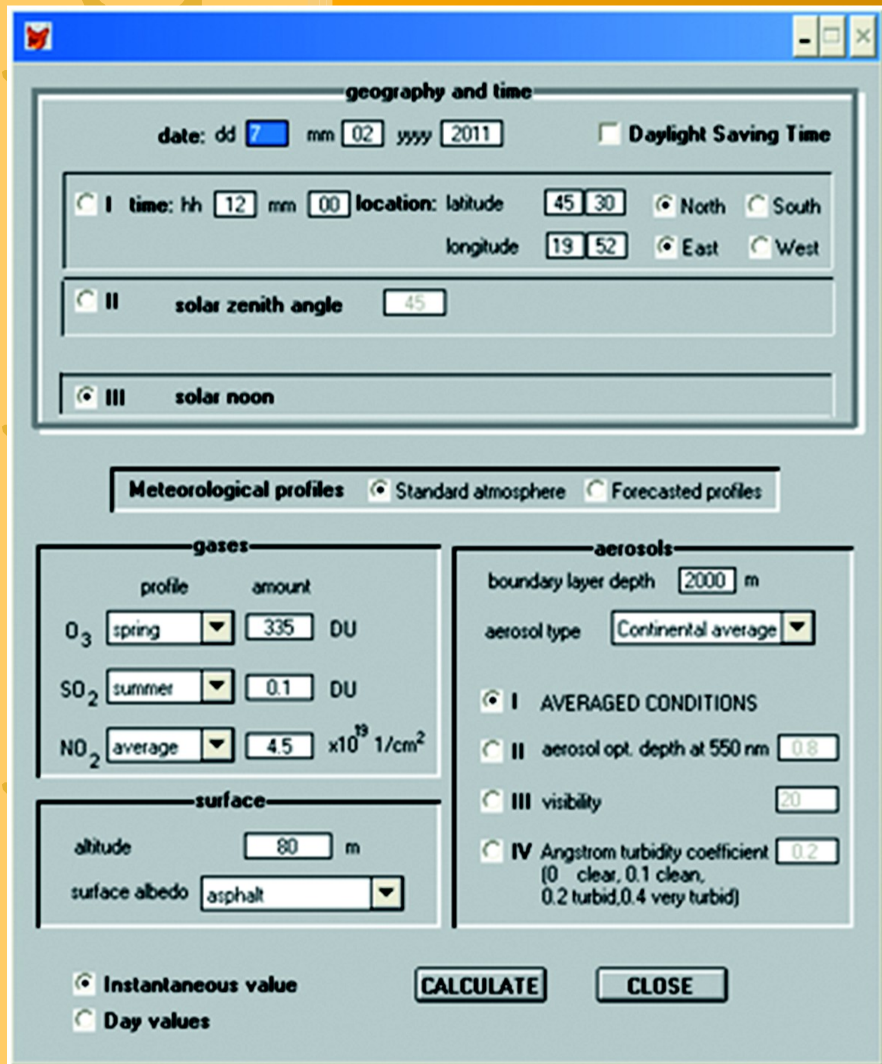
NEOPLANTA parametric model

Center for Meteorology and Environmental Modelling, University of Novi Sad

Malinović, 2003, M.S. thesis

Malinović et al. 2006, Journal of Applied Meteorology and Climatology

Malinović-Milićević and Mihailović, 2011, Atmospheric Research



Input parameters

- geographical coordinates and time (or SZA)
- Amount of gases
- Altitude
- Surface albedo
- Aerosols type and amount
- Optional – forecasted meteorological profile

Output parametrs

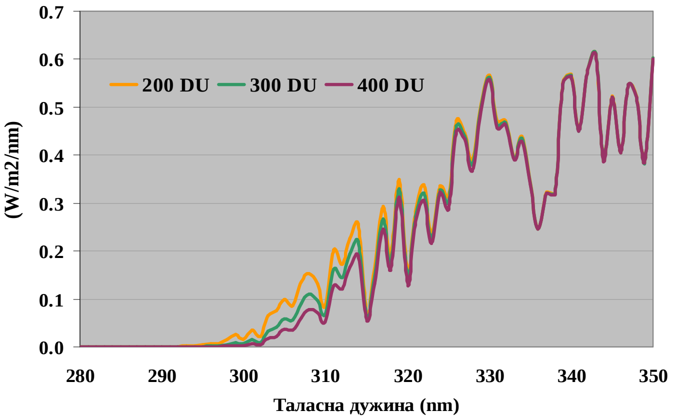
- spectral direct, diffuse, and global UV irradiance divided into the UV-A and UV-B
- the erythemally weighted UV irradiance
- UV index
- spectral optical depth and spectral transmittance for each component

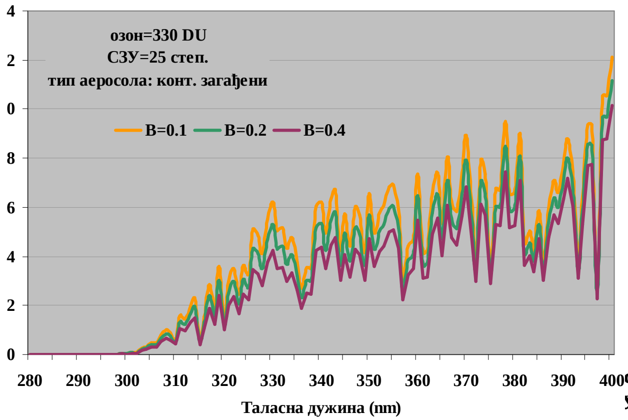
NEOPLANTA parametric model

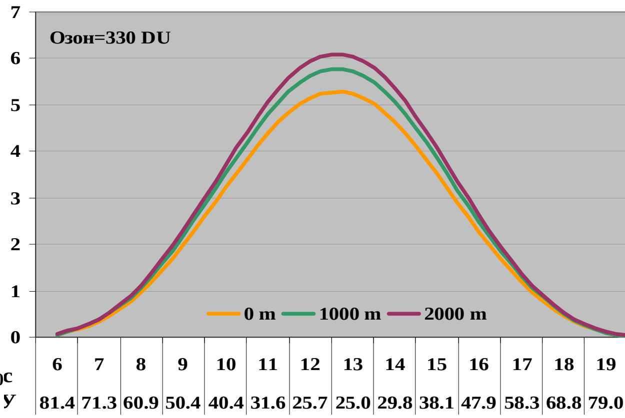
Sensitivity tests

properly simulation changes in the intensity of UV radiation and ratio of direct and diffuse radiation with the change in input parameters

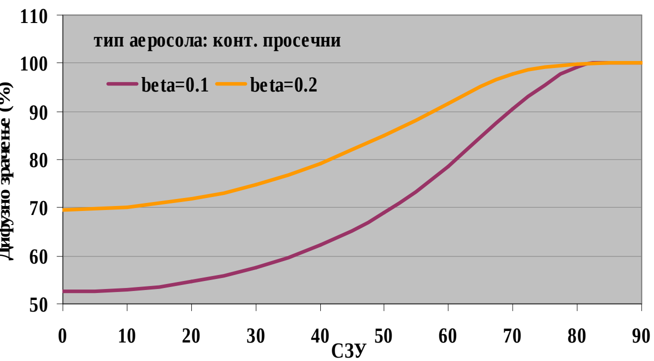
The simulations qualitatively agree with the existing knowledge:
(i) the intensity of UV radiation decreases with increasing the thickness of the ozone layer, with increasing the amount of aerosol, with decreasing altitude and with the increasing SZA

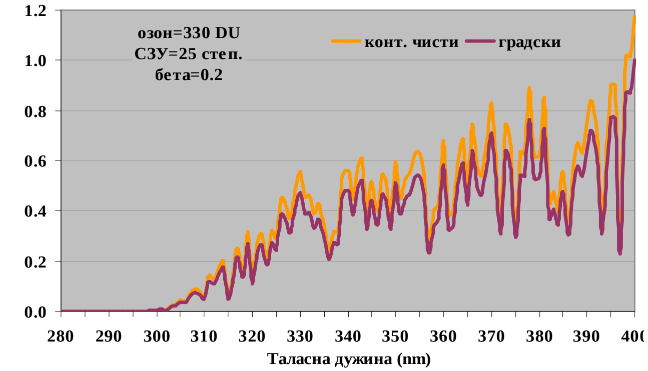


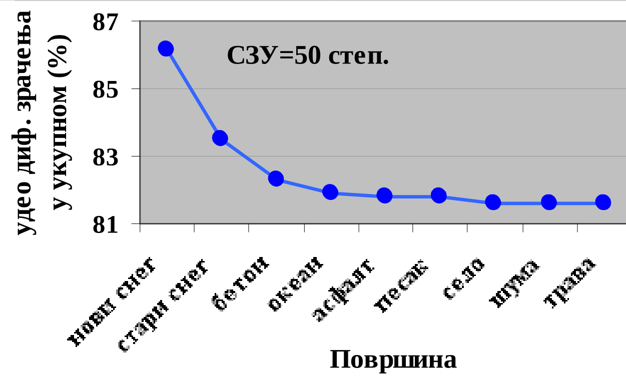




(ii) the contribution of diffuse UV radiation increases with increasing SZA, the amount of aerosols, the presence of aerosols with a higher amount of water-soluble particles, air humidity, and more reflecting surface.

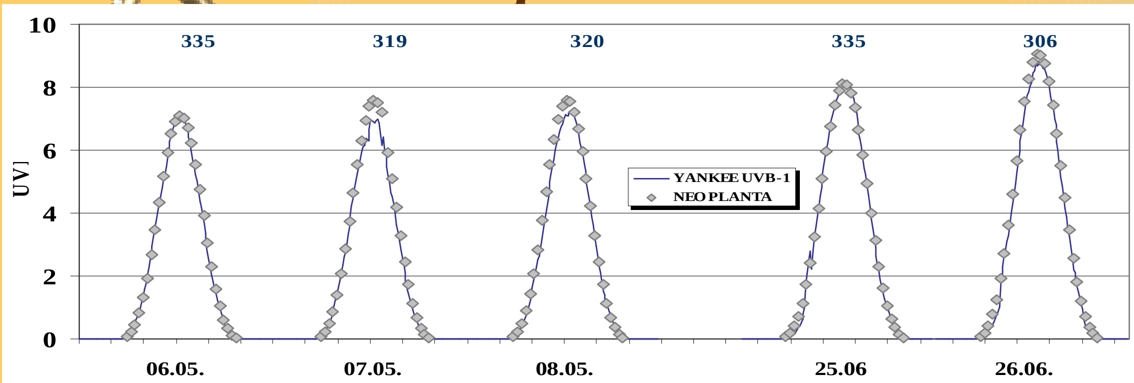


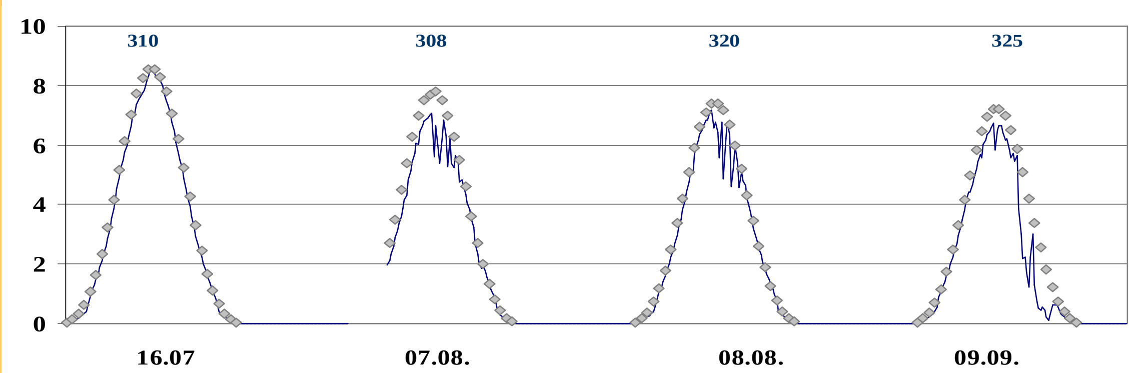




NEOPLANTA parametric model

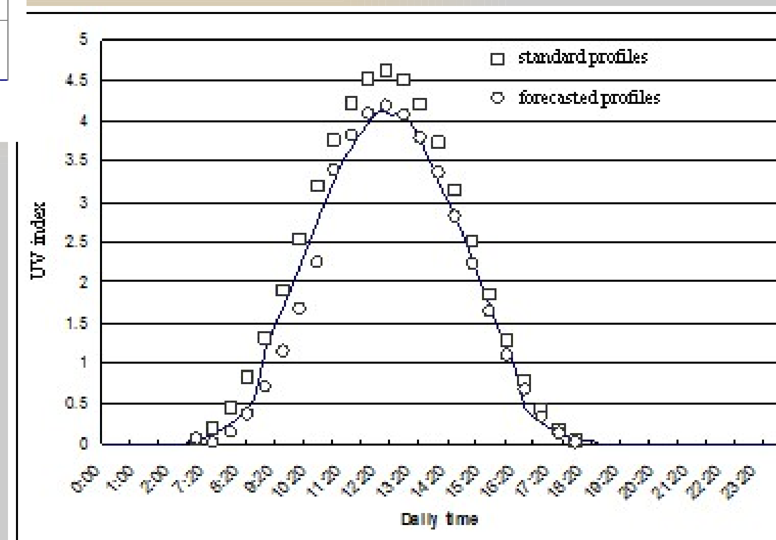
Comparison with measurements





Cloudless conditions ±0.5 UVI

Cloudiness ≤ 2 tenths 95%



Reconstruction techniques

- utilize measurements of commonly available meteorological data
- total ozone column measurements is important contributor in reconstructions

In Novi Sad reconstruction of UV radiation has been done in three ways:

(i) by an empirical estimation which uses ground-based meteorological measurements;

(ii) by an empirical estimation which uses ground-based measurements, satellite measurements, and model NEOPLANTA; and

(iii) by using neural network technique that uses available input parameters

(i) An empirical estimation which uses ground-based meteorological measurements

Malinović-Milicević (2012) *PhD thesis*

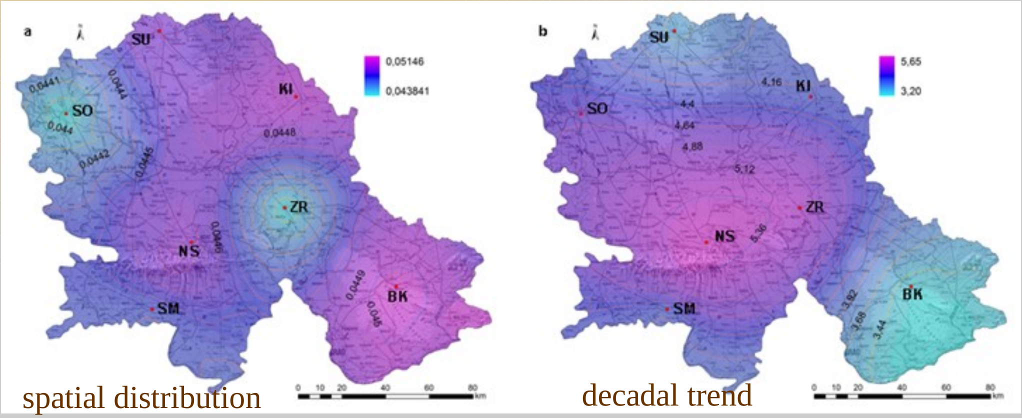
Simple empirical formula for estimation daily doses of UV-B radiation based on the relationship between daily UV-B doses derived from UVI measurements and daily global radiation doses in Novi Sad.

- $UVB_d = 0.002507 G_d - 5.985$

- caution because of it does not take into account past and future ozone changes, so the reconstruction and projection are based on the present relationship between the global and UV-B radiation.

Malinović-Milicević et al. (2013) *Climate Research*

- used for reconstruction of UV-B doses for seven places in Vojvodina region back to 1981



spatial distribution

decadal trend

Malinović-Milicević et al. (2015) *Thermal Science*

- used for the projection of the UV-B doses in the period 2021-2100 (SRES-A2)

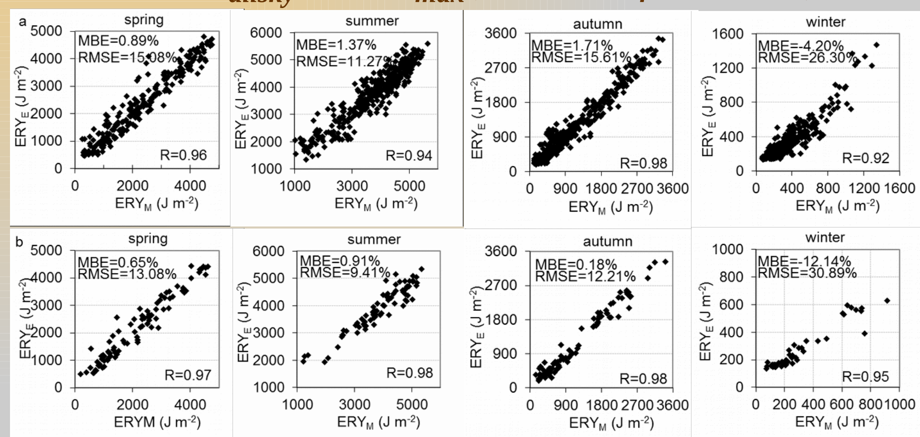
- the annual mean UV-B doses will recover by 5.2%, in Vojvodina region by the end of this century
- The recovery is expected to be the highest in autumn and spring.

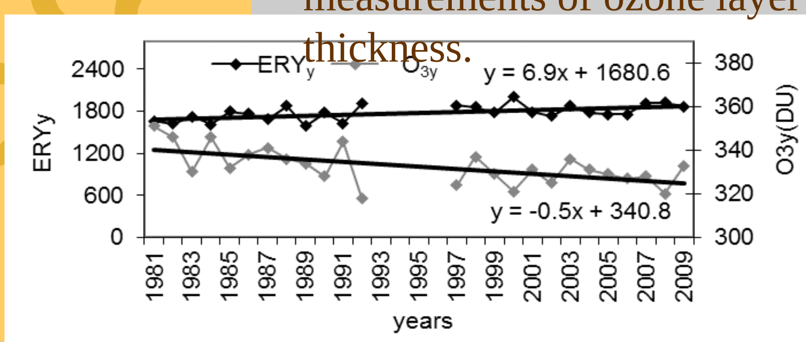
(ii) An empirical estimation which uses ground-based measurements, satellite measurements, and model NEOPLANTA

Malinović-Milićević et al. (2015) ***Theoretical and Applied Climatology***

- empirical equation for reconstruction daily erythemal UV doses (ERY_{allsky}) under all sky conditions
- ground-based measurement of sunshine duration (S), satellite measurements of total ozone column (TOC) and estimation of clear sky ERY from NEOPLANTA model (ERY_{max})
- good agreement between the estimated and measured data during spring, summer, and autumn
- The improvement over the previously used technique lies in the fact that this formula takes account of the ratio of UV radiation and the duration of sunshine in the past, which is made possible by using measurements of ozone layer thickness.

$$ERY_{allsky}=ERY_{max}(0.5343S_r+0.3589)$$



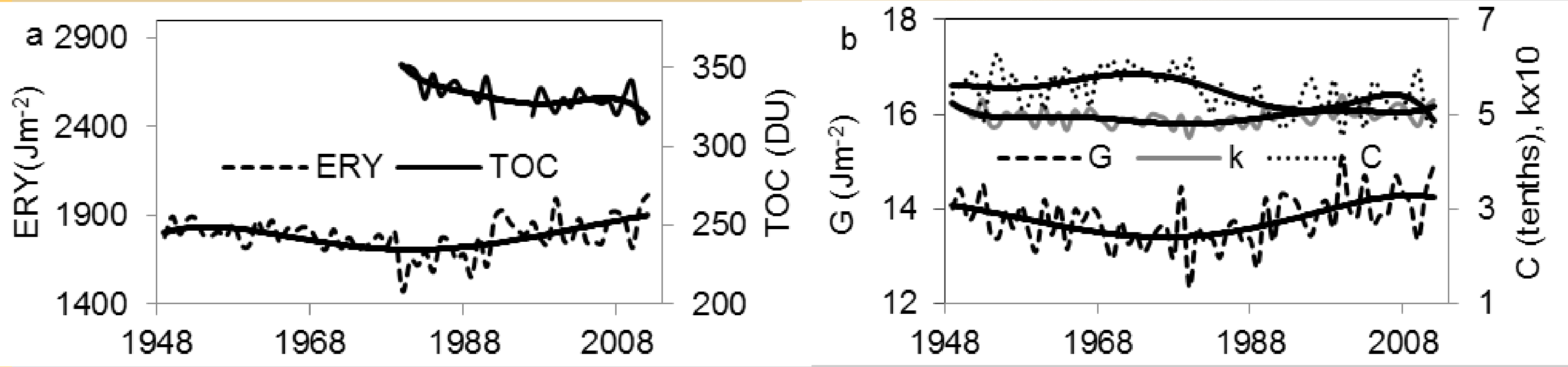


- decreasing trend in the TOC since 1981 (0.5 DU per year and p=0.001) and an increasing trend in daily ERY (6.9 J m^{-2} per year and p=0.007).

(iii) Reconstruction by using neural network technique that uses available input parameters

Malinović-Milicević et al. (2018) ***International Journal of Climatology***

- neural network technique for estimating ERY that implies use one of two models, depending on the availability of the input parameters
- NN1 model as predictors uses global radiation (G), clearness index (k), cloudiness (C) and air mass (m) ⇒ **1949-1977**
- NN2 model adds TOC to the NN1 inputs. ⇒ **1978-**



- variations in annual averages of daily doses are in accordance with appropriate variations of input parameters
- derived trends in erythemal UV radiation in several different subperiods between 1949 and 2012 are in accordance with findings in other studies
- the increase in the ERY in the period 1981-1996 is mainly caused by TOC, while the increase after 1996 is largely caused by cloudiness

Future plans

- connection with European centers for UV monitoring with the purpose of international intercomparison of the instruments
- compare ground based UV measurement in Novi Sad with satellite measurement
- use reanalyzed ozone data to estimate UV radiation and get series without gaps

Thank you for your attention