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CHANGES IN UV RADIATION INTENSITY AND THEIR POSSIBLE IMPACT ON SKIN CANCER IN POLAND

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Abstract

UV radiation is a high-energy part of sunlight. Simultaneous changes in global radiation have been observed during recent decades. Close relationships have been found between UV intensity near ground level and the destruction of the stratospheric ozone layer known as the ozone hole. This has great consequences for all ecological systems on Earth as well as for human health. The UV Index (*UVI*) was developed for the monitoring of the level and composition of UV rays reaching the lower troposphere. The paper presents changes in the *UVI* in Poland in the period 1996-2011. We also discuss the possible influence of changes in level of ultraviolet radiation (represented by *UVI*) on the frequency of skin cancer.

Key words

UV radiation • *UVI* • skin cancer • Poland • climate change

Introduction

Solar radiation is the main determinant of climate and energy source for living processes on Earth. The input of solar radiation to the ground is regulated both by solar activity and by the physical and chemical features of the atmosphere. The most active range of solar radiation is the ultraviolet, and especially UV-B (Tab.1).

Table 1. Biological effects of various spectral ranges of solar radiation.

Range of solar radiation	Wave length (μm)	Biological effects
Far ultraviolet (UV-C)	0.200-0.280	germicidal effect, destruction of living cells
Middle ultraviolet (UV-B)	0.281-0.315	erythemal effect, late pigmentation, anti-rickets and germicidal effects, skin ageing, cataract, skin cancer, reduction of immunity
Near ultraviolet (UV-A)	0.316-0.400	immediate pigmentation, skin ageing, psoriasis treatment
Visible radiation	0.401-0.760	stimulation of nervous and hormonal systems, regulation of circadian rhythms
Infrared	0.761-4.000	thermal effect, stimulation of metabolism

Source: Jendritzky (1995).

UV radiation has several positive features (e.g. in the erythemal effect, late pigmentation, anti-rickets and germicidal effects, anti bacterial effects), which are widely used in medical treatment, especially in heliotherapy in health resorts (Green et al. 1992; Sokołowski et al. 2008). However, large doses of UV can involve several pathological effects in an organism, e.g. skin and eye diseases as well as disturbances to the immune system (Lucas et al. 2006; Confalonieri et al. 2007). The list of radiation related diseases is relatively long, from mild effects like a tendency to excessive drying of the skin, skin discolouration and hardening, skin aging and sunburn up to the destruction of the DNA in skin cells leading to various forms of skin cancer including melanoma. UV radiation can also influence the eye system and can induce cataract. Photo-allergies are also more frequent (Lityńska et al. 2001; Kieć-Świerczyńska & Kręcisz 2008).

The UV index (*UVI*) is used to compare the intensity of ultraviolet radiation near ground level (Vanicek et al. 1999). The *UVI* is an international standard measure of the strength of solar ultraviolet radiation at a particular place. It is a unit for measuring UV levels relevant to its effects on human skin (UV induced erythema). *UVI* is defined as the effective irradiance obtained by integrating the spectral irradiance weighted by the CIE (International Commission on Illumination) reference action spectrum for UV-induced erythema on the human skin (ISO 1999) up to and including 400 nm normalised to 1.0 at 297 nm. *UVI* is expressed numerically as the equivalent of multiplying the time weighted average effective irradiance ($W \cdot m^{-2}$) by 40 (e.g. an effective irradiation of 0.2 $W \cdot m^{-2}$ corresponds to a UV Index of 8.0). The *UVI* is a dimensionless quantity defined by the following formula (WHO 2002):

$$UVI = k_{er} \cdot \int_{250nm}^{400nm} E_{\lambda} \cdot s_{er}(\lambda) d\lambda \qquad (1)$$

where:

E_{λ} – is the solar spectral irradiance (expressed in $W \cdot m^{-2} \cdot nm^{-1}$) at wavelength λ,

$d\lambda$ – is the wavelength interval used in the summation,

$s_{er}\lambda$ – is the erythema reference action spectrum,

k_{er} – is a constant equal to 40 $m^2 \cdot W^{-1}$.

UVI is categorized according to possible health risks. Several recommendations regarding protection against UV risks are given in Table 2. One of the most important health risks is skin cancer.

The aim of the paper is to present seasonal as well as multiannual changes in *UVI* in Poland. We will also discuss the possible influence of UV radiation (expressed by *UVI*) on skin cancer morbidity in Poland.

Materials and methods

The basic data concerning UV index were taken from the UV Radiation Monitoring Service of the Tropospheric Emission Monitoring Internet Service (TEMIS, http://www.temis.nl/uvradiation) affiliated to the Dutch Meteorological Service. The service provides *UVI* values which are derived from total ozone column data as measured by GOME (the Global Ozone Monitoring Experiment, http://www.temis.nl/uvradiation/GOME), on board the ERS-2

Table 2. *UVI* Assessment scale.

UVI	Health risks	Possible protection
0-2	No danger to the average person	No action necessary.
3-5	Little risk of harm from unprotected exposure to the sun	Wear sunglasses and use SPF 30+ 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 exposure to the sun	Wear sunglasses and use SPF 30+ sunscreen, cover the body with sun protective clothing, wear a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 to 16:00 during summer).
8-10	Very high risk of harm from unprotected exposure to the sun	Wear SPF 30+ sunscreen, a shirt, sunglasses, and a hat. Do not stay out in the sun for too long.
>10	Extreme risk of harm from unprotected exposure to the sun	Take all precautions, including: wear sunglasses and use SPF 30+ sunscreen, cover the body with a long-sleeve shirt and trousers, wear a very broad hat, and avoid the sun from two hours before to three hours after solar noon (roughly 11:00 to 16:00 during summer).

Source: WHO (2002); EPA (2011).

(European Remote Sensing) satellite and SCIAMACHY (the SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY, http://www.temis.nl/uvradiation/SCIA) on board the European Space Agency satellite ENVISAT (ENVIronmental SATellite) (van Geffen et al. 2004). The daily data for 4 Polish stations: Łeba, Legionowo, Belsk and Zakopane, for the period August 1995 – March 2012 are available there. The data represent *UVI* calculated for clear sky conditions. The TEMIS service also provides hourly data on the total ozone column for the period November 1978 – December 2008. The data from Kaunas, Potsdam and Poprad were taken to characterise the situation on Polish territory. Additionally the data for the North Pole and Vostok stations were analysed for comparison. The TEMIS ozone column dataset was supplemented by observations carried out at the Geophysical Observatory in Belsk for the period 1963-2008 reported by Chief Inspectorate of Environmental Protection (GIOŚ 2009).

Skin cancer data for Poland are available in special reports of the Centre of Oncology for the period 1999-2009 (Ministry of Health 2010). The register provides information about the total number and standardised value (per 100,000 inhabitants) of melanoma and other skin cancers. Data regarding skin melanoma deaths in the period 1961-2009 were adapted from the website of the World Health Organization's International Agency for Research on Cancer (WHO 2012).

In the paper seasonal fluctuations of *UVI*, calculated as average values of the four Polish stations used for consecutive days of the year for the period 1996-2011, are discussed. The changes in *UVI* are compared with fluctuations in total ozone column in the atmosphere. The statistical analyses were made using the STATGRAPHICS 2.0 software package.

Results

UVI variations

The data from Belsk Geophysical Observatory show that *UVI* values are closely correlated with total ozone column in the atmosphere. *UVI* increases proportionately to the decrease in ozone column (Fig. 1). Both, mean and maximum annual values of UV index are significantly correlated (at the 99% confidence level) with ozone content.

The UV index is a function of the intensity of ultraviolet radiation. We must remember that UV intensity is not only influenced by total ozone column, but also by cloud cover, atmospheric aerosols, sun elevation and altitude. Thus, a clear annual cycle of *UVI* is observed with the lowest values (below 1.0) being registered in the winter months. Winter is the period when *UVI* shows very little regional variation. Summer peaks of mean index values vary from about 6 in Łeba through 6.5 in central Poland (Belsk, Legionowo) up to 7.5 in Zakopane. This is an effect of the altitude of the sun (smallest in the north – Łeba and highest in the south – Zakopane) and elevation above sea level; while Łeba is a coastal station, Zakopane is located at about 1,000 m a.s.l. It can be a little confusing that there are high *UVI* values in Zakopane

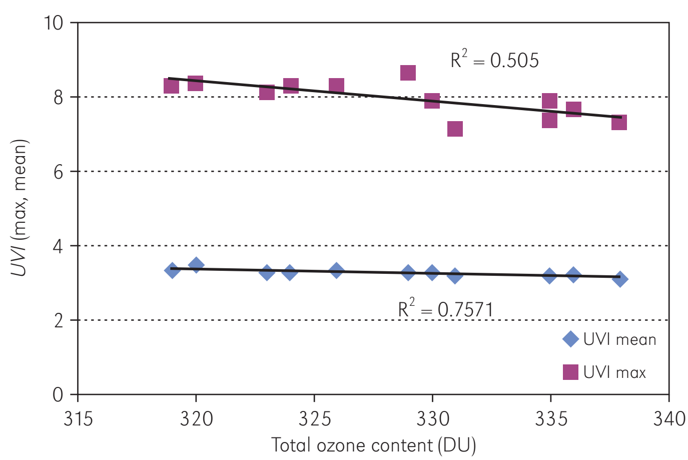

Figure 1. Relationships between total ozone content in the atmosphere and mean annual (*UVI* mean) and maximum annual (*UVI* max) values of UV index in Belsk, 1996-2008.

which is a mountain town characterised by increased air pollution and cloudiness. However, the *UVI* values used in the paper represent clear sky conditions and do not take into consideration local features of the locations being compared (Fig. 2).

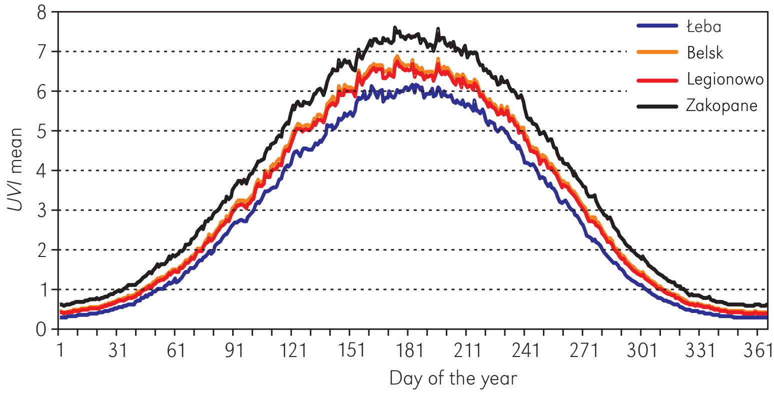

Figure 2. Annual variations of mean daily values of UV index (*UVI*) in Poland, daily data averaged for the period 1996-2011.

UVI changed significantly during observation period (1996-2011) at all Polish stations examined. Mean annual values of the index increased gradually (Fig. 3). The trends lines are significant at 90 and 95% confidence levels. Significant trends (at 95 and 99% levels) are also observed for the frequency of days with *UVI* > 6 (these values of *UVI* indicate at least a high risk of harm from unprotected exposure to the sun). The increase is observed in central and northern Poland while in Zakopane (mountain region) the number of days with high *UVI* risk is relatively stable and the trend line for this characteristic is insignificant (Tab. 3).

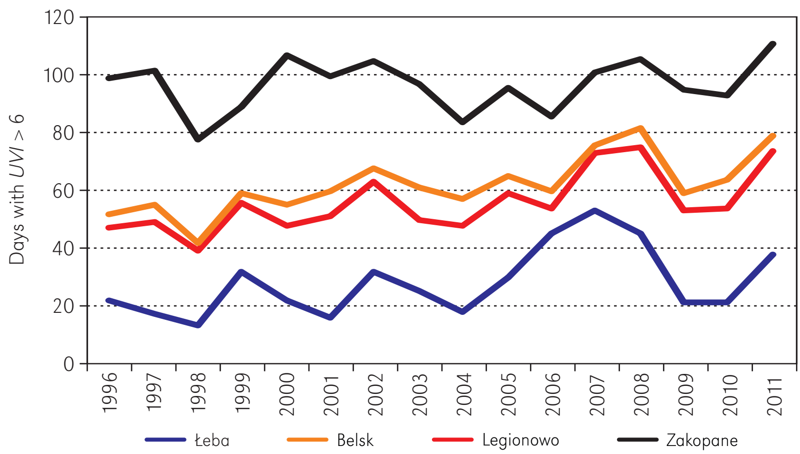

Figure 3. Multiannual variations of the number of days with *UVI* > 6, 1996-2011.

Table 3. Correlation coefficients of trend lines of *UVI* avg and days with *UVI* > 6, 1996-2011.

Station	*UVI* avg	Days with *UVI* > 6
Łeba	0.484*	0.500**
Belsk	0.486*	0.715***
Legionowo	0.456*	0.646***
Zakopane	0.507**	-

Statistical significance of trend lines at confidence levels: * – 90%, ** – 95%, *** – 99%.

In Zakopane, which is the region with the highest mean *UVI* values, the frequency of dangerous UV conditions is two times higher than in central Poland and even 5 times higher than on the Baltic coast (Łeba) (Fig. 3). The increased frequency of days with high *UVI* values in Zakopane can be explained by the high altitude of this station (about 1,000 m a.s.l.); in general, intensity of solar radiation rises with increase in altitude (Błażejczyk 1998; Bogdańska & Podogrocki 2000).

Ultraviolet radiation and skin cancer

During the last 50 years a significant increase in skin melanoma deaths has been observed in Poland. While less then 100 people died annually from skin melanoma in the early 1960s, in the first decade of 21st century the number of fatalities had reached 1,100-1,200 (Fig. 4). The reduction in the ozone column over Poland, especially during the last 40 years, can be considered as one

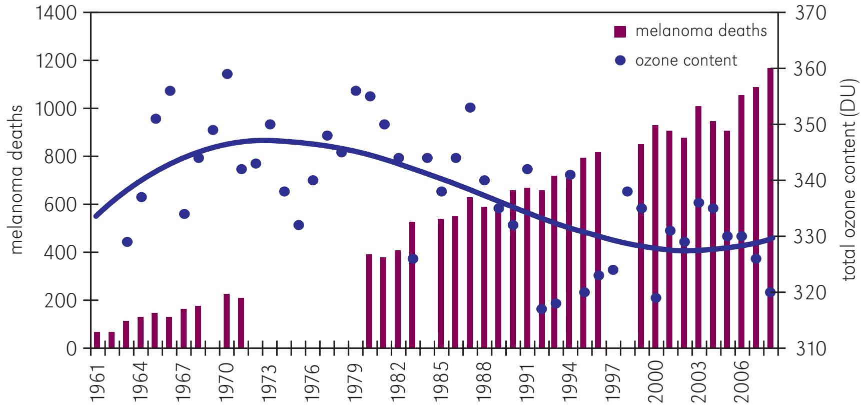

Figure 4. Changes in melanoma deaths in Poland and total ozone content over Poland (Geophysical observatory in Belsk) (the blue line presents a polynomial function of ozone content).

Source: Rajewska-Więch (2009); WHO (2012).

of the factors which influence the dramatic rise in incidence of skin melanoma and deaths. As shown in Figure 1, the reduction in ozone content in the atmosphere has resulted in an increase in UV index. An additional cause of the increased number of skin cancer cases is a change in people's behaviour (use of solaria, sunbathing, spending winter holidays in tropical and subtropical countries etc.).

The reduction in stratospheric ozone is mainly observed over the southern hemisphere (from about 280 DU in 1980 to about 240-250 DU at the beginning of 21st century). The content of stratospheric ozone over the northern hemisphere is significantly higher than over Antarctica. However, both at the North Pole and in central Europe, the ozone content was reduced from about 350 DU in 1980 to about 320 DU in 2008 (Tab. 4).

Detailed analysis of newly registered cases of skin cancer in Poland is possible for the period 1999-2009. During this period the total number of skin cancers gradually rose from about

Table 4. Ozone content (DU) in the atmosphere at selected stations in central Europe as well as over the North Pole and in Antarctica (Vostok station).

Year	Potsdam	Poprad	Kaunas	North Pole	Vostok	Belsk
1979	351	347	352	357	287	356
1980	350	348	355	349	289	355
1981	346	348	350	336	287	350
1982	345	345	346	333	276	344
1983	324	326	324	329	266	326
1984	344	342	343	344	267	344
1985	339	334	343	347	249	338
1986	340	338	339	326	260	344
1987	343	341	348	366	252	353
1988	334	336	340	339	280	340
1989	332	332	334	340	262	335
1990	328	329	329	310	250	332
1991	338	341	339	345	259	342
1992	314	315	315	329	244	317
1993	314	314	313	323	256	318
1994	334	334	336	341	266	341
1995	319	321	319	322	253	320
1996	321	325	319	331	246	323
1997	318	322	323	314	248	324
1998	335	336	339	353	244	338
1999	334	332	335	349	240	335
2000	323	323	324	324	253	319
2001	334	332	337	358	241	331
2002	325	326	327	335	278	329
2003	331	335	334	345	247	336
2004	332	332	335	345	264	335
2005	326	330	327	326	252	330
2006	330	329	332	355	246	330
2007	328	329	328	329	239	326
2008	323	322	324	335	251	320

Source: GIOŚ (2009); ozone data from TM3DAM-MSR1 (http://www.temis.nl/protocols/o3field/overpass_msr1.html).

Table 5. Number of the cases of skin melanoma and other skin cancers registered in Poland in the years 1999-2009.

Type of cancer	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Skin melanoma	1,606	1,731	1,757	1,831	1,985	1,926	2,188	2,101	2,195	2,286	2,562
Other skin cancers	5,302	5,362	5,672	6,124	6,818	6,945	8,310	8,230	8,307	8,679	9,291

Source: Ministry of Health (2010).

7,000 in 1999 to almost 12,000 in 2009. The rate of the most dangerous skin melanoma was relatively stable and during whole period analysed it consisted of about 20-24% of all cases of skin cancer (Tab. 5).

The incidence of skin cancer cases per 100,000 population changed from 25 in 1999 to over 35 in 2009 (a 40% increase). In general, the male population is more affected by skin cancers than the female population. The relationship is 55% to 45% (Fig. 5).

The observation series of *UVI* and skin cancers are relatively short. However, the resource of 11 years of detailed registers of cancer deaths allows some findings to be defined. For the analysis, the absolute number of all skin cancers and skin melanomas was compared with various characteristics of UV radiation, averaged for *UVI* data from all the observation stations in Poland (Łeba, Legionowo, Belsk and Zakopane).

Figure 6 shows the statistical relationships between skin cancer cases (both, all and melanoma) and mean *UVI* values in Poland. The correlation coefficients between the values being compared are significant at the 95% confidence level for all

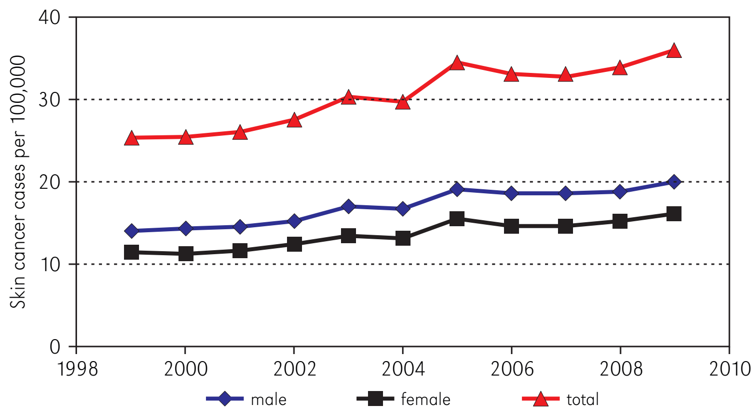

Figure 5. Rates of all skin cancer cases per 100,000 population in Poland.

Source: Ministry of Health (2010).

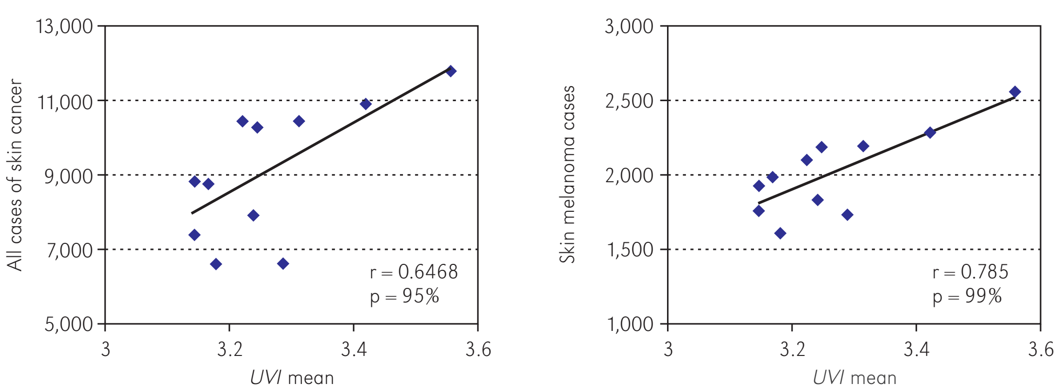

Figure 6. Relationships between mean annual values of UV index for Poland (*UVI* mean) and all cases of skin cancer as well as skin melanoma, 1999-2009.

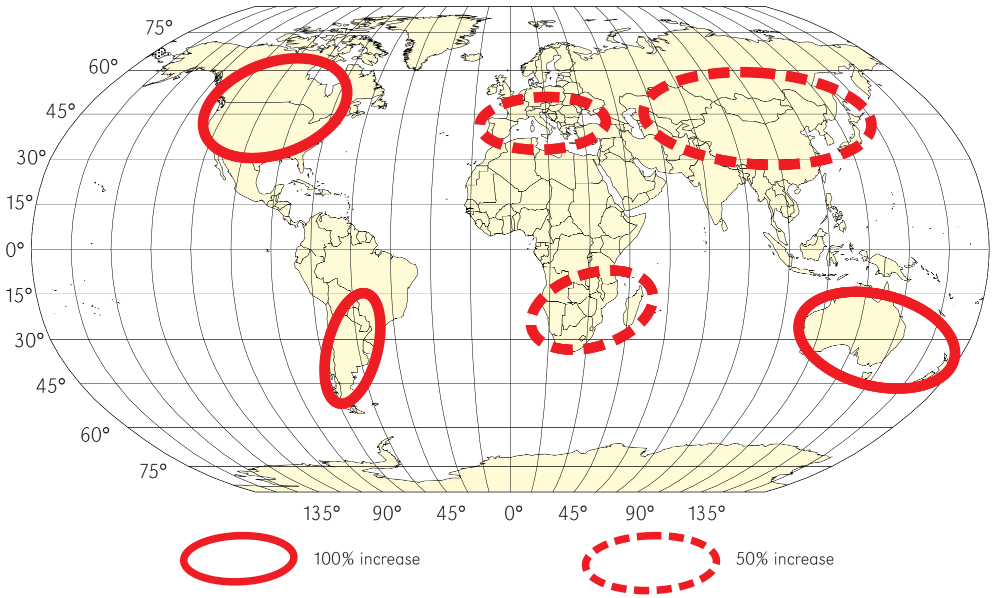

Figure 7. Increase in skin cancer in the period 2020-2060: 1 – 50% increase, 2 – 100% increase.

Source: Bovet et al. (2007).

cases of skin cancer and at the 99% level for skin melanoma. More than 40% of skin cancers in particular years can be explained by the changes in mean annual value of the UV index. For skin melanoma, the correlation coefficient is even higher and about 62% of this disease can be explained by *UVI* value. For other *UVI* characteristics (*UVI* max, days with *UVI* > 6) the relationships are statistically insignificant.

Conclusions

The change in UV radiation reaching the lower troposphere is an effect of the reduction in the stratospheric ozone layer, a phenomenon which has been observed in both the southern and northern hemispheres. The degradation of stratospheric ozone leads to an increase in skin cancer. The forecasts for the next 50 years are very worrying. Simulations made in the Dutch Institute of Public Health indicate a 50% increase in skin cancer in the Mediterranean countries and central Europe (including Poland), in the centre of Asia and in southern Africa and a 100% rise in Argentina, United States and Australia (Fig. 7). To reduce such a risk the WHO propose intensifying educational efforts presenting the sun as an important factor in health problems (WHO 2003). The recommendations should also be applied to Poland (WHO/ICO 2010).

Changes in *UVI*, especially its mean annual values and the frequency of days with *UVI* > 6 (or at least, a high risk of harm from unprotected exposure to the sun) have been observed in the first decade of 21st century. The changes in UV index lead to significant increases in skin melanoma and other skin cancers.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the author(s), on the basis of their own research.

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