UV- Index for the Public

A guide for publication and interpretation of solar UV Index forecasts for the public
prepared by the Working Group 4 of the COST-713 Action
“UVB Forecasting”

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COST-713 Action
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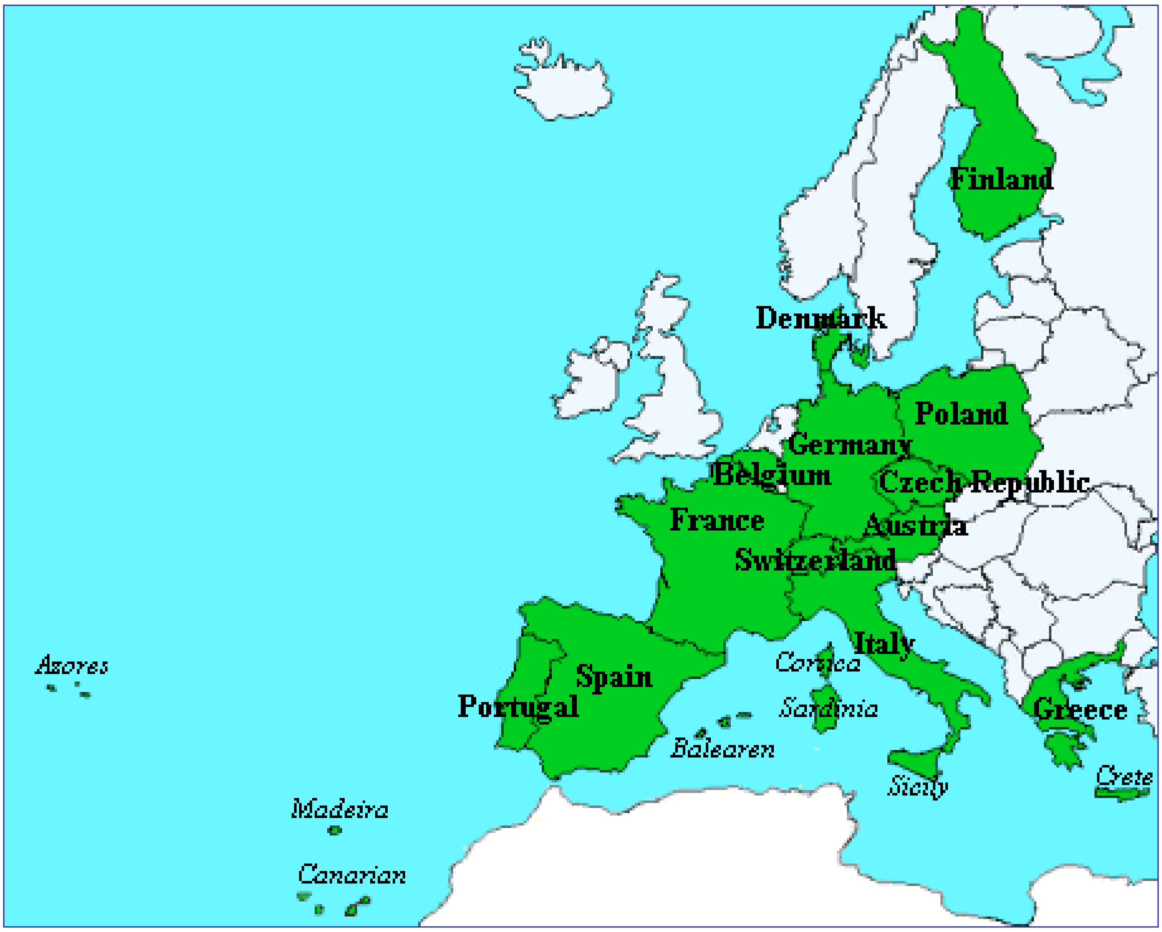
COST-713 participating countries



Acknowledgements

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Contents

1. Introduction

Solar radiation is an important natural factor because it forms the Earth's climate and has a significant influence on the environment. The ultraviolet part of the solar spectrum (UV) plays an important role in many processes in the biosphere. It has several beneficial effects but it may also be very harmful if UV exceeds "safe" limits. If the amount of UV radiation is sufficiently high the self-protection ability of some biological species is exhausted and the subject may be severely damaged. This also concerns the human organism, in particular the skin and the eyes. To avoid damage from high UV exposures, both acute and chronic, people should limit their exposure to solar radiation by using protective measures.

The diurnal and annual variability of solar UV radiation reaching the ground is governed by astronomical and geographical parameters as well as by the atmospheric conditions. Since human activities affect the atmosphere, such as polluting the air and influencing the ozone layer, they also affect the UV radiation reaching the ground. As a consequence, solar UV radiation is a highly variable environmental parameter that differs widely in time and space. The need to reach the public with simple-to-understand information about UV and its possible detrimental effects led scientists to define a parameter that can be used as an indicator of the UV exposures. This parameter is called the UV Index. It is related to the well known erythemal effects of solar UV radiation on human skin and it has been defined and standardised under the umbrella of several international institutions such as WMO, WHO, UNEP and ICNIRP (see Appendix E).

The UV Index (UVI) is now widely used in many operational weather reports and forecasts. In Europe, for example, there are more than a dozen forecasting centres that release estimated UVI values for countries or regional areas. Different methods are used to predict the UVI and all kinds of information systems and presentations are seen. To co-ordinate these activities and to improve their scientific background an international research project was established under the program "Cooperation in Science and Technology" (COST) of the European Commission. The project titled COST-713 action (UV-B Forecasting) was initiated in 1996. The following European countries participated: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Poland, Portugal, Spain and Switzerland. A list of the participating institutions is given in Appendix A.

The development of efficient methods for dissemination of the UVI forecasts and the improvement of how they are interpreted by the public were key tasks for COST-713. This booklet is one product of the action and is mostly intended for users coming from different professional communities who can assist in a wider use of the UVI. It may also be useful to users who want to know about the details of the physical and biological background.

It is expected that the readers will use this information not only in their professional activities but also for communication to the public. The international and local institutions listed in the booklet (Appendix B) may serve as reference centres for further information and assistance.

The main goal of the publication is to:

- Present a basic description of solar UV radiation
- Define the UV Index and the reasons for its implementation
- Describe the methods for UV Index forecasting
- Describe how the public can use the UV Index in practice
- Inform about the variability of the UV Index in Europe and in the World
- Give a list of participants and other reference institutions in the COST-713 countries
- Inform about Internet Web pages and other sources with information on the UV Index

2. UV solar radiation – a basic review

Solar radiation includes ultraviolet (UV) radiation, visible radiation (light), and infrared (IR) radiation. The radiation is often characterised by its wavelength, usually expressed in nanometers ($1nm=10^{-9}m$). When describing biological effects ultraviolet radiation is often subdivided into three spectral bands: UV-C radiation (100-280nm), UV-B radiation (280-315nm) and UV-A radiation (315-400nm). UV radiation can be measured as an irradiance – the power incident upon a surface unit area – in units of W/m^2, or as a radiant exposure, or dose – the energy incident upon a surface unit area during a specified period of time – in units of J/m^2. The most important factors affecting the UV radiation reaching the Earth's surface are described below.

Atmospheric ozone

UV radiation is absorbed and scattered in the atmosphere. UV-C radiation is completely absorbed in the upper atmosphere by oxygen and ozone molecules. Most of the UV-B radiation is absorbed in the stratosphere by ozone molecules and only a few percent reach the surface of the Earth. Therefore, at the surface of the Earth the solar UV radiation is composed of a large amount of UV-A radiation and only a very small amount of UV-B radiation. UV-B radiation is known to be biologically damaging, whereas UV-A radiation is much less damaging but is known for its ability to tan the human skin. As ozone is the main absorber of UV-B radiation the UV-B intensity at the Earth's surface depends strongly on the total amount of ozone in the atmosphere, thus on the thickness of the ozone layer. A factor, which describes the relation between the sensitivity of the UV-B intensity to changes in total ozone, is the so-called Radiation Amplification Factor (RAF). For small changes in the ozone layer thickness the RAF represents the percent change in UV-B intensity for a 1-percent change in the total column ozone. For CIE-weighted irradiance, i.e., for the erythemally effective UV radiation, and for varying solar elevations and ozone, the RAF's are in the range of 1.1-1.3.

Solar elevation

Solar elevation is the angle between the horizon and the direction to the sun. The solar zenith angle (SZA) is often used in place of the solar elevation: it is the angle between the zenith and the direction to the sun. For high solar elevations the UV radiation is more intense because the rays from the sun have a shorter path through the atmosphere and therefore pass through a smaller amount of absorbers. As the UV irradiance depends strongly on the solar elevation it changes with latitude, season and time, being highest in the tropics, in summer and at noon.

Altitude

The UV irradiance increases with altitude because the amount of absorbers in the overlaying atmosphere decreases with altitude. Measurements show that the UV irradiance increases by 6-8% per 1000 m increase in altitude.

Atmospheric scattering

At the surface of the Earth solar radiation is composed of a direct and a scattered (diffuse) components. Solar radiation is scattered on air molecules and on particles such as aerosols and water droplets. The direct component consists of the rays from the sun that has passed directly through the atmosphere without being scattered or absorbed. The diffuse component consists of rays that have been scattered at least once before reaching the ground. Scattering depends strongly on wavelength. The sky looks blue because blue radiation is scattered more than the other components. UV radiation is scattered even more and at the surface of the Earth the UV-B is roughly composed of a 1:1 mixture of direct and diffuse radiation.

Clouds and haze

The UV irradiance is higher when the sky is cloudless. Clouds generally reduce the UV irradiance but the attenuation by clouds depends on both the thickness and the type of clouds (optical depth of clouds). Thin or scattered clouds have only a little effect on UV at the ground. At certain conditions and for short times a small amount of clouds may even enhance the UV irradiance comparing the fully clear skies. In hazy conditions UV radiation is absorbed and scattered on water vapour and aerosols and this leads to decreasing of the UV irradiance.

Ground reflection

Part of the UV radiation that reaches the ground is absorbed by the Earth's surface and part of it is reflected back to space. The amount of reflected radiation depends on the properties of the surface. Most natural surfaces such as grass, soil and water reflect less than about 10% of the incident UV radiation. Fresh snow, on the other hand, may reflect up to about 80% of the incident UV radiation. During spring and a cloud-free sky the reflection of snow may increase the UV irradiance on inclined surfaces to summer values. This is important at higher altitudes and at higher latitudes. Sand may reflect about 25% of the UV radiation and can increase the UV exposure at the beach. About 95% of the UV radiation penetrate into the water and 50% penetrate to a depth of about 3 m.

3. Definition of the UV Index and its physical explanation

UV radiation and action spectra

An action spectrum describes the relative effectiveness of UV radiation at a particular wavelength in producing a particular biological response. The biological response may refer to various detrimental effects on biological subjects including humans, animals or plants. An action spectrum for a given biological effect is used as a wavelength-depending weighting factor to the spectral UV irradiance (280 to 400nm) and then integrating over wavelength to find the actual biologically effective irradiance (in W/m^2). The effective UV dose (in J/m^2) for a particular exposure period is found by summing (integrating) the effective irradiance over the exposure period. The most important for common use are the erythemal, DNA absorption and non-melanoma skin cancer action spectra.

Minimal Erythemal Dose

As sunburn is a frequent detrimental effect on human skin the CIE Erythemal action spectrum is recommended for use in assessing the skin-damaging effect of UV radiation. The ”Minimal Erythemal Dose” (MED) is used to describe the erythemal potential of UV radiation and 1 MED is defined as the effective UV dose that causes a perceptible reddening of previously unexposed human skin. However, because human individuals are not equally sensitive to UV radiation due to different self-protection abilities of their skin (pigmentation), 1 MED varies among the European population within the range of between 200 and 500 J/m^2. If national studies of the erythemal sensitivity of the population are not available the values of MEDs for different skin types according to DIN-5050 shown in Table 2 may be consulted.

The UV Index - a UV parameter for the public

Originally the UV Index was formulated independently in several countries and used in programmes for public information about UV radiation. Its definition has later been standardised and published as a joint recommendation by the World Health Organization (WHO), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Commission on Non-Ionizing Radiation (ICNIRP) (see Appendix E). The UV Index is recommended as a vehicle to raise the public awareness about the potential detrimental effects on health from solar UV exposure and to alert people of the need to adopt protective measures. If cloud cover and other relevant environmental variables are accounted for when calculating the UV Index, the modifying factors that are used in the calculation should be stated. Although the UV Index is defined for an exposed horizontal surface the exposure conditions for an inclined surface may be more relevant to human exposure. If the UV Index is referring to an inclined surface it must be stated.

The UV Index

- Is a unit of measure of UV levels relevant to the effects on human skin (UV induced erythema)

- Is defined as the effective irradiance obtained by integrating the spectral irradiance weighted by the CIE (1987) reference action spectrum up to and including 400 nm normalised to 1.0 at 297nm

- Is expressed numerically as the equivalent of multiplying the time weighted average effective irradiance (W/m^2) by 40

Example: An effective irradiation of 0.2 W/m^2 corresponds to a UV Index of 8.0

- If daily maxima are reported or forecast a 30-minute time averaged values of the effective irradiance should be used when calculating the UV Index

- If real-time observations of the UV Index are presented, it is recommended to use 5-10 minute averages

UV Index forecasting

Operational UV Index forecasting has already been implemented in many countries (see Appendix C and D). The forecast methods vary from simple statistical methods used for local areas to more complicated methods with global coverage and with forecast times from a few hours to several days, either for clear sky or all sky conditions. A general forecast approach is described in the diagram shown in Figure 1. The accuracy of UV forecasts is limited mainly by the amount and quality of the input data. In the future, a large-scale assimilation of ground-based and satellite observations of ozone, aerosol and clouds may considerably improve the accuracy.

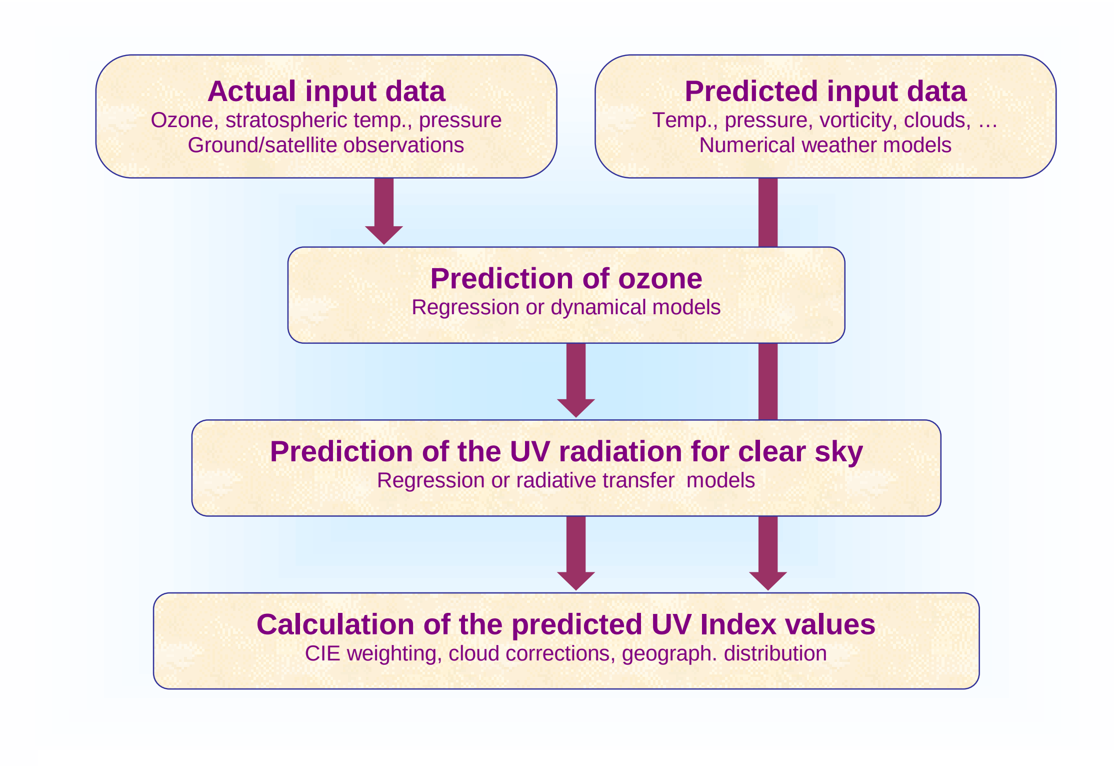


Figure 1: A general approach for forecast the UV Index

4. Practical use of the UV Index

UV Index and its modification by clouds and altitude

As mentioned in section 2 the UV irradiance at any given place is affected by clouds and depends on the altitude above sea level. If, at a certain altitude, UVI_0 represents the UV index for a cloud-free sky the following equation may be used to calculate the UV index, *UVI* , for a cloudy sky and at a different altitude:

$$UVI = UVI_O \times CMF \times (1 + 0.08 \times \Delta H)$$

where *CMF* is a so-called Cloud Modification Factor (a number between 0 and 1 – see Table 1) and ΔH is the difference in altitude (in km) from where UVI_0 is referring to. Table 1 shows *CMF*s for different cloud types and different cloud cover.

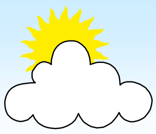
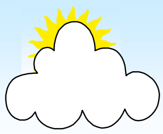
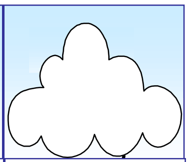
Amount of clouds				
Octas	**0 – 2**	**3 – 4**	**5 – 6**	**7 - 8**
High	1.0	1.0	1.0	0.9
Middle	1.0	1.0	0.8	0.5
Low	1.0	0.8	0.5	0.2
Fog	-	-	-	0.4
Rain	-	-	-	0.2

Table 1: Cloud Modification Factors for different cloud types and amounts of cloud cover (O octas representing clear sky, 8 octas representing overcast

Skin type	Tan	Burn	Hair colour	Eye colour	1MED
I	never	always	red	blue	200 J/m²
II	sometimes	sometimes	blond	blue/green	250 J/m²
III	always	rarely	brown	gray/brown	350 J/m²
IV	always	never	black	brown	450 J/m²

Skin types

The harmful effects of UV radiation depend not only on the received UV dose but also on the sensitivity of the individual. Human skin is often classified into four main groups according to the skin's ability to tan. This classification is shown in Table 2 which also gives the approximate dose (in J/m^2) required to obtain a reddening of the skin (1 MED). Thus 1 MED varies for different skin types.

Table.2: Definition of basic skin types for the European population

Sunburn times

The sunburn time is the maximum time to stay unprotected in the sun without receiving a sunburn. Sunburn times can be calculated for each skin type from the UV Index and the value of 1 MED for each skin type. As an example, Figure 3 shows the sunburn times in minutes for different UV Index values and MEDs defined by DIN-5050 (shown in Table 2). It is important to point out that the value of 1 MED is not a precisely determined number for each skin type. Dermatological studies have shown that within one of the skin types the value of 1 MED may differ depending on the disposition of individuals. To further describe this phenomenon sophisticated regional studies of the photosensitivity of populations are needed.

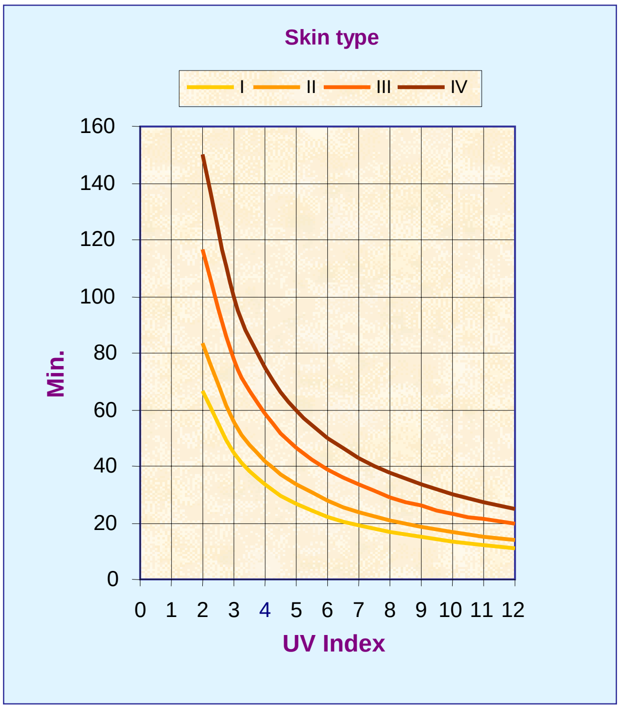


Figure2: Sunburn times in minutes for skin types I, II, III and IV and 1 MED according to DIN-5050 calculated for clear sky days

Exposed to the sun

The skin and the eyes are the organs with the highest exposure to the sun's ultraviolet rays. Although hair and nails are well exposed they are less important from a medical point of view. Exposure to solar UV radiation may result in acute and chronic health effects to the skin, the eye and to the immune system. Acute effects of UV exposure include erythema (sunburn) of the skin and photokeratitis (welder's flash, snowblindness) of the eye. Chronic skin effects are skin cancer and premature ageing of the skin while chronic effects to the eye include cataract, pterygium and droplet keratopathy. While UV-B radiation mainly cause erythema and various skin cancers UV-A radiation has a pronounced effect on the subcutaneous tissue and can alter the structure of collagen and elastin fibres and hence accelerate ageing of the skin. It is important to understand that the skin has a capacity to adapt to UV radiation by producing melanin (tan) that protects against UV exposure. The human eye does not have such a capacity.

Protection of the skin

The skin is best protected by clothes. A shirt, a hat and trousers offer the best protection. UV-transparent clothes ought to be marked clearly. Skin parts that are not protected by clothes should be protected with a sunscreen containing UV-B and UV-A filters. During the first exposures to the sun a sunscreen with a Sun Protection Factor (SPF) of about 15 is recommended, while it should be at least 20 for children. Particular care should be exercised with babies and small children. Note that the protective effect of sunscreens depend not only on the quality of the sunscreen but also on a correct application of the sunscreen. Most people apply too little. For an adult body the correct amount of sunscreen is about 30-40 g (a good handful) in order to obtain the effect of the sunscreen's stated SPF. It should be applied well before exposure to the sun and it should be reapplied after a swim. If sunscreens are properly used they can protect from sunburn, skin cancer and skin ageing.

Sunscreens and Sun Protection Factor

The Sun Protection Factor stated on sunscreens indicate how much longer you can stay in the sun without having a sunburn compared to your personal sunburn time. For example, if your personal sunburn time is 30 minutes and you then apply a sunscreen with a SPF of 8 you can stay 8 times longer in the sun, i.e., 4 hours, without having a sunburn. It is important to note that applying the same sunscreen several times in succession does not prolong the "safe" time – there is no additional protection, and the only way to get extra protection is to apply a sunscreen with a higher SPF. Also, the sunscreen you apply does not help you the next day – the protection is offered only for the day when the sunscreen is applied. Sunscreens with SPF of more than 30 actually do not make sense and are mainly produced of marketing advantages.

UV Index	Skin type I	II	III	IV
2.0	-	-	-	-
2.0 – 3.9	6	4	-	-
4.0 – 6.9	11	8	5	4
7.0 – 8.9	14	10	8	5
over 9.0	18	12	8	7

Table 3: Sun Protection Factors recommended for different skin types and UV Index values. In snow covered areas the recommended SPFs are roughly twice as high as those shown in the table because of increasing of UV doses due to higher reflection.

Users should be aware of the different definitions of the SPF. The products of the European Community use the COLIPA system (Comité de Liaison des Associations Européenne de L'Industrie de la Parfumerie, des Cosmetiques et des Toilette) whereas in the U.S.A. the FDA (Food and Drug Administration) system is used. The two systems cannot be compared but the FDA system allows much higher SPFs than the COLIPA system.

Besides of the skin type, possible cutaneous or ocular reactions could modify efficiency of protective measures. Such photosensitivity reactions may be caused by a number of external or internal agents. Some drugs like psoralens, porphyrins, coal tar, antibiotics or various kinds of anti-inflammatory agents, antimicrobial products, fragrances, plants etc. could cause erythema even for lower UV doses.

Protection of the eye

The eyes can be protected by sunglasses containing UV-B and UV-A filters – a type of filter must be indicated bay the producer. Sunglasses with UV-B and UV-A filters are especially important for children because the transmittance of UV radiation through the eye is higher for children than for adults – a child's retina is less protected. The rationale is that sunglasses without UV protecting filters should not be used.

A simple guide for application of UV protective tools for different values of the UV Index and for the most photosensitive skin (skin type I and babies) and for more tolerant skin type III is given by Table 4. This guide only presents a rough guidance and is an example of how the public could be addressed in a leaflet.

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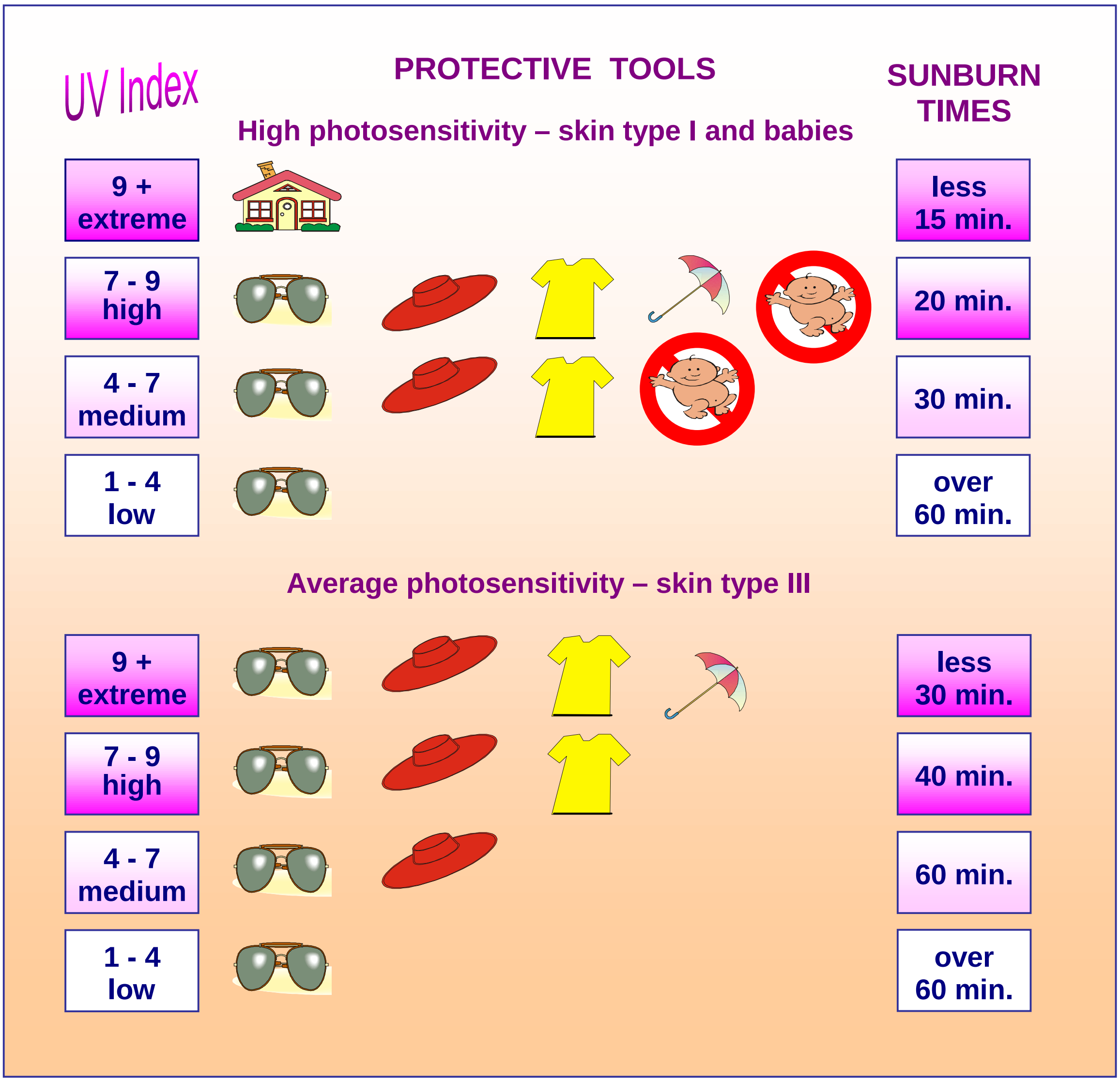

Table 4: A simple guide for application of UV protective tools

5. Estimation of the UV Index climatology - examples

Operational forecasting of the UV Index gives information about its short-term changes in given the forecast region. However, the temporal and geographical variation of the UV-Index are important for people moving or travelling to different climatic conditions where their home experiences with UV radiation cannot be used. This concerns tourism in subtropical and equatorial regions in particular.

Figures 3 – 6 give a general overview of how the UV Index varies on clear days during the year and during the day at different geographical latitudes. The figures have been produced from the model developed at the University of Veterinary Medicine in Vienna using ozone observations from satellites (NASA/EPTOMS, 1996-1999).

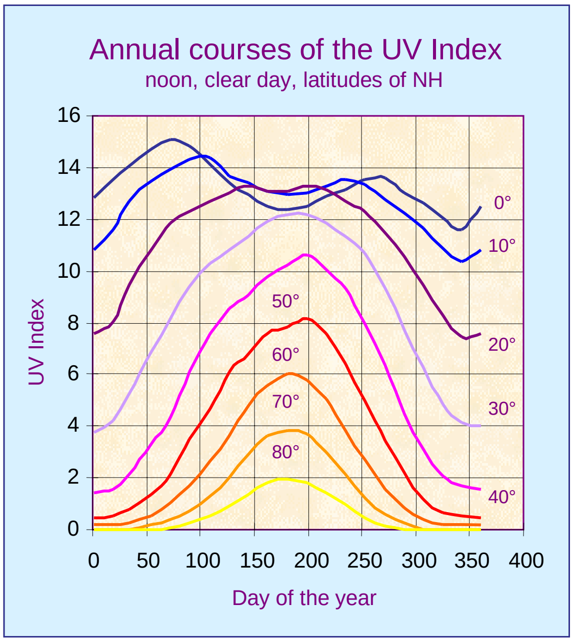

Figure 3: Annual courses of the UV Index for different latitudes of NH at noon on clear days at sea level

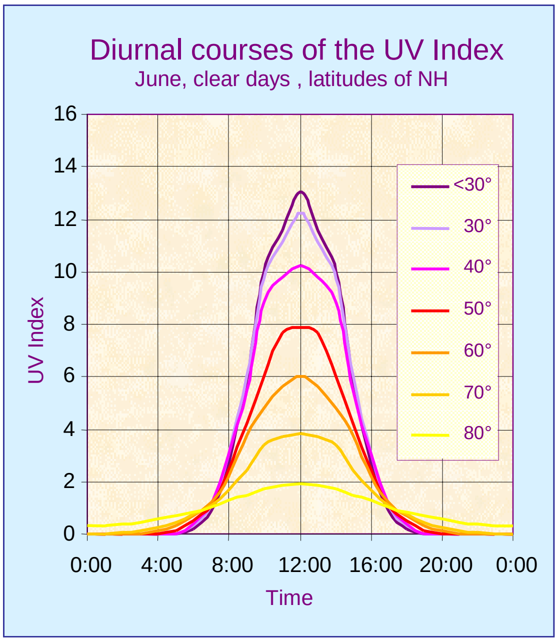

Figure 4: Diurnal courses of the UV Index for different latitudes of NH in June on clear days

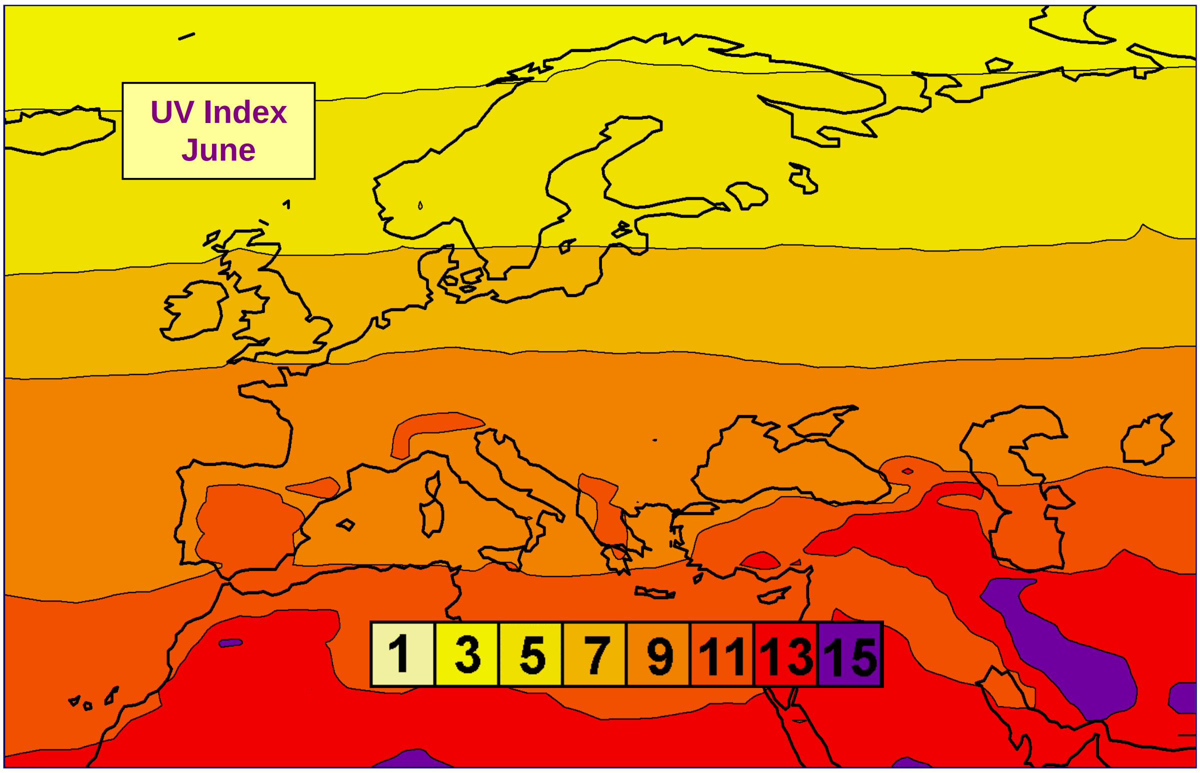

Figure 5: Estimation of geographical distribution of the UV Index in the European region in June, at noon, for clear days, orography included

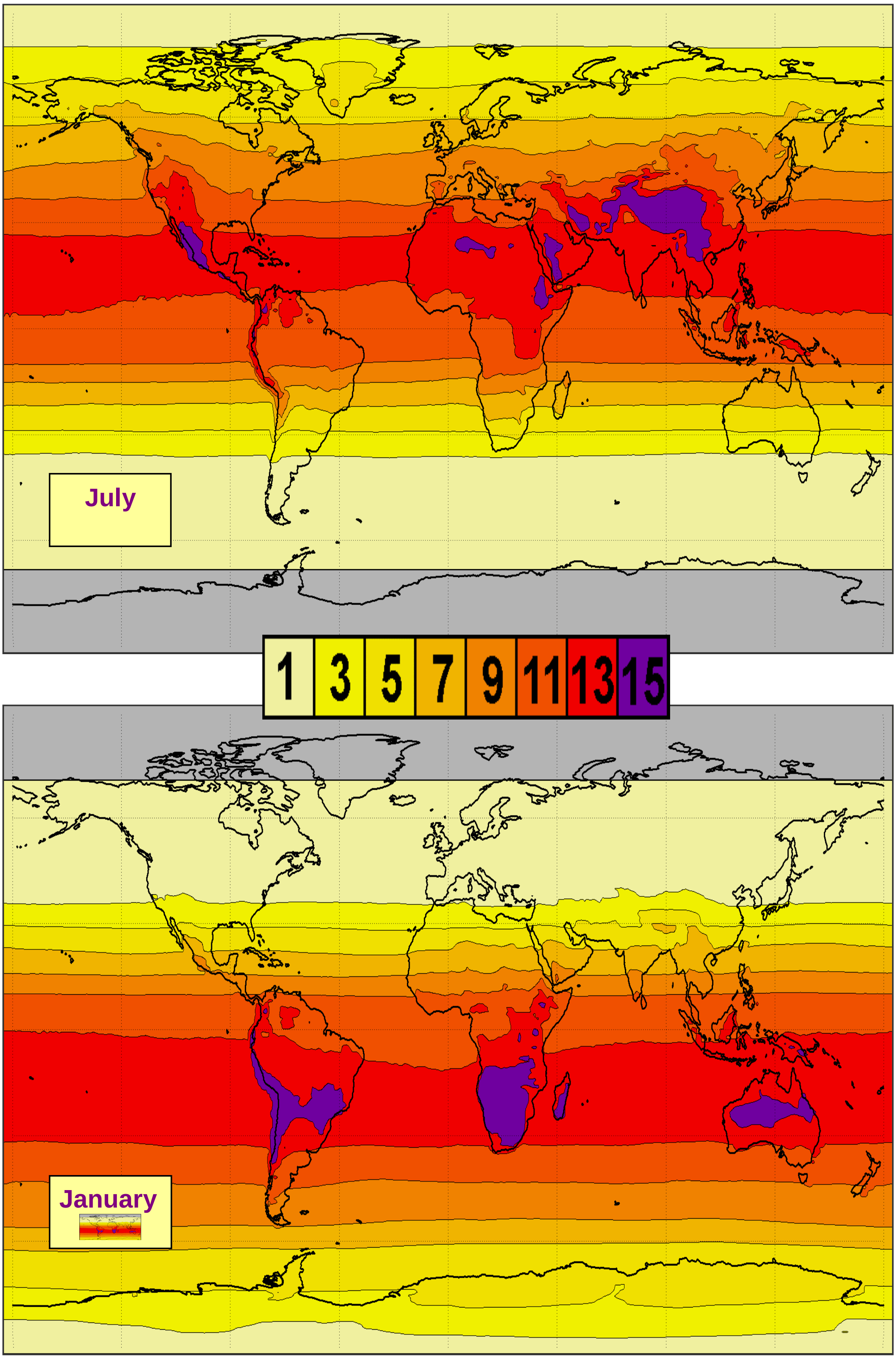

Figure 6: Estimation of global geographical distribution of the UV Index in the summer (July) and winter (January) months at noon, for clear sky

6. UV Index in the 21st century

The inverse correlation between the total ozone column and the UV-B irradiance has been confirmed by measurements at several locations. These measurements show that long-term changes of the stratospheric ozone layer may modify the UV climatology, particularly at middle and high latitudes. An expected recovery of the ozone layer in the middle of the 21st century should therefore also allow for a stabilisation of the UV-B radiation in the next decades.

The present trends and the behaviour of the ozone layer are strongly influenced by radiative, chemical and dynamical processes in the stratosphere. The significance of these processes may be augmented by human activities (e.g. the "greenhouse effect") and result in higher short-term variations of the ozone layer and the UV-B radiation. The negative impacts on human health could be eliminated by a professional public awareness based on, for example, UV Index information. In any case, the next century brings a challenge for a more active and individual control of UV exposure and protective measures, at least for the large photosensitive part of the population.

UVB radiation and YOU in the 21. century

- Learn to control your exposure to solar UV radiation by using your own experience as well as professional recommendations
- Adjust your exposure to solar UV radiation by respecting the changes in UV Index values
- Learn to take protective measures and teach the young generation to use them
- If you move from your home region adjust your behavior in the sun to the new climatic condition

Appendix A

20 key questions and answers about the UV radiation

Fact or fiction	Answer	Explanation
You cannot get sunburn on a cloudy day	Wrong	Although clouds attenuate UV the diffuse sky radiation is sufficiently intense to get a sunburn unless the clouds are low and thick
Too much sun is dangerous no matter your age	Right	The human skin and the immune system are sensitive to UV radiation through a whole life cycle
Sunscreens protect me so I can sunbathe much longer	Wrong	Sunscreens protect you but their efficiency decrease after application - you should not stay longer in the sun than the SPF warrants
You should avoid the sun between 11 and 16 h	Right	Due to the highest sun elevation the UV radiation is the strongest during a day at this time
If I don't feel the heat from staying in the sun I will not get sunburn	Wrong	UV radiation can not be sensed by the human because it is absorbed in the outermost skin layers
UV radiation not only concerns the skin but also the eyes	Right	Sunburn is perhaps the most known effect, but UV radiation may also cause development of cataract
Just re-aply your sunscreen to stay longer in the sun	Wrong	The sunscreens protects only for a certain length of time. After this any additional UV exposure is harmful
People with fair skin and red hair are particularly sensitive to UV radiation	Right	The people with this skin and hair type combination is the most sensitive group of the population
A tan protects you from an additional sunburn	Wrong	A tan is already a reaction on UV exposure and it only partially protects your skin
The negative effects of sunburns are cumulative	Right	The ability of the human body to protect and repair UV-induced damages decrease during a lifetime

Fact or fiction	Answer	Explanation
The sun in winter and spring is not dangerous	Wrong	The UV intensity depends also on latitude, altitude and ground reflection like of snow
Children should be especially protected	Right	Because of the high sensitivity of their skin and the cumulative effects of sunburns
The darker your skin the more attractive you are	Wrong	This social attitude is changing - just a century ago you were more attractive when you were pale
Reflection of UV radiation by sand and water must be considered	Right	The direct rays from the sun and the diffuse sky radiation are equally important for UV exposures after reflection at the ground
It is necessary to stay in the sun because vitamin D is produced by UV radiation	Wrong	The time of exposition you need for vitamin D production is so short, that you always get enough without sunbathing
The shorter your shadow is the more dangerous the sun burns	Right	When your shadow is short the sun elevation is high and UV radiation is more intense
You cannot get a sunburn while you are in the water	Wrong	Water attenuates UV radiation but you may easily get a sunburn when swimming
The higher the altitude the more the sun burns your skin	Right	The higher the altitude the smaller is the attenuation of UV radiation by the atmosphere
It is not important to change your sun habits	Wrong	A change of personal habits is a first step in active protection against UV exposure
The cheapest and the best sun protection is shade	Right	Shade protects you against the direct rays. However, you should still protect yourself against the diffuse sky radiation

Appendix B
Reference institutions in the COST-713 countries

Austria
Inst. of Med. Physics and Biostatistics
University of Veterinary Medicine
Veterinaerplatz 1, A-1210 Vienna
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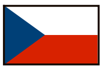

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Germany and	Service	German Meteorological exp. TV, radio periods corr. press,online	UV Index, tolerable	Health services, forecasts for 1 day Fed. Environmet. clouds and	Nowcasting
	Federal Agency for	altitude commercial	April-September UV Index, sunburn	Agency	Forecasts for
Greece Index, sunburn		Nowcasting and Aristotle University of		TV, radio, Thessaloniki times on clear days	UV forecasts
Italy Forecasts for 1 day		Press,	ENEA	UV Index on clear Ital. Meteo. Serv.	
	University of days May-September			Internet	
Poland	Meteorology and Water UV Index for clear	Institute for Internet free days at noon	Nowcasting, State Insp. for		
Portugal	TV, radio, UV Index, sunburn	Portuguese Public health	Nowcasting for Meteorological		
Spain doses,	Forecasts for 1 day	University of Barcelona	Press		UV-B eryth.
Switzerland 1 day	Swiss Meteorological TV, radio,		Public health UV Index corrected	Institute for altitude and	Forecasts for

Appendix D

List of the www pages with UV information - 1999

COST-713 countries

Others

Projects

Austria
http://www.med-physik.vu-wien.ac.at/uv/uv_online.htm

Belgium
http://www.meteo.oma.be/IRM-KMI/ozone/uvindex.html

Czech Republic http://www.chmi.cz/meteo/ozon/o3uvb-e.html

Denmark
http://www.dmi.dk /f+u/

Finland
http://www.ozone.fmi.fi/o3group/o3home.html

France http://www.securite-solaire.org

Germany
http://www.dwd.de/services/gfm/uv_index/

http://www.bfs.de/uvi/index.htm

Greece
http://www.lap.physics.auth.gr/uvindex/

Italy
http://www.lamma.rete.toscana.it/eng/uv/uvnew0eng.html

Poland
http://www.imgw.pl

Portugal
http://www.meteo.pt/uv/uvindex.htm

Spain