organisms include viruses, bacteria, fungi and protozoa. Their size may be as small as the wavelength of light. For humans and animals a variety of microbes are necessary to stay healthy while other microbes can cause severe diseases.

Micro-organisms can be damaged by UV radiation easily. Damage can be manifold like grow reduction, reduction of reproduction rate, of metabolism rate, of infectivity, of mobility and others.

Hygiene applications like disinfection make use of UV inactivation. Inactivation means that micro-organisms lose the ability of reproduction. UV inactivation occurs as a result of the direct absorption of UV radiation by the micro-organism. This brings about an intracellular photochemical reaction that changes the biochemical structure of nucleic acids. These changes may lead to the inhibition of transcription and replication of nucleic acids, thus rendering the organism sterile and disables infection when entering a host.

The wavelength range where UV is most effective in inactivation is quite similar to that where DNA has the highest absorbency (UV-C and UV-B range) with maximum effectiveness - of course outside the natural UV - around 265nm. The range of highest efficiency is also called germicidal range.

Dose-response curves vary. For some micro-organisms no response at low doses was found while others do react. Some show a slow increase with dose. In the middle part response is mostly linear. For high doses the increase of response may become weak again.

Micro-organisms which possess pigments in their outer layer are more resistant. High resistant to UV radiation are spores and (oo)cysts. However sensitivity varies quite high within a group, even by a factor of ten.

Recently, studies have reported an increased UV resistance of environmental bacteria and bacterial spores, compared to lab-grown strains. This means that they could have the ability to adapt to their UV environment.

Free moving micro-organisms receive UV radiation from all directions. With that the optical properties of the surrounding medium are important. Solid or organic particulate matter in water or air, reduces transmittance of UV. Micro-organisms have also the ability to adhere on surfaces so, they can make use of particulate matter as radiation protection and vehicles. Clumping of micro-organisms is also a strategy of radiation protection.

Additionally, effectiveness of UV is decreased by magnitudes if a (pathogenic/parasitic) micro-organism has entered a host.

Micro-organisms – as all other livings - are not defenceless at the mercy to UV radiation. There are repair mechanisms that may equalise damage to a certain degree. Nucleid acids, for example, can be repaired in a process termed ‘photoreactivation’ in the presence of light, or ‘dark repair’ in the absence of light.

Damage is not the only effect of UV radiation to micro-organisms. UV may also act in igniting new stages in development like sporulation in many species of fungi. Also a variety morphogenetics depend on UV. Micro-organisms can make use of UV for environmental information too.

As any other livings, micro-organisms are adapted quite well to their environment.

In generally, an increase of UV radiation is detrimental resulting in a reduced life span, a decreased ability of reproduction, a shorter pathway, a reduction of the habitat or a decreased number in the species.

But, there are many ways where micro-organisms may profit from environmental or climatic changes. Decreased UV radiation e.g. by enhanced cloudiness, aerosol load or dust, result in a decreased damage which may allow a longer pathway to find a potential host. In the case of pathogens a higher transmission and outbreaks of diseases may occur more frequently.

The seasonal outbreak pattern of influenza in many parts of the world is a prominent example. Differences in the outbreak between Spring and Autumn can be explained by different total ozone content and cloudiness, which change the relation between damage and photoreactivation.

If other environmental parameters change (like temperature), micro-organisms can settle in a new environment where damage through solar radiation is maybe lower and potential hosts are not prepared to the blight. It was observed, that during the past years pathogens have already started migrate to northern latitudes.

### 3.4. UV radiation and Plants

The effect of UV radiation on vegetation is a relatively new field of scientific research. A strong rationale for such research has been the attempt to understand and quantify the possible effect on plants of the increase of UV-B irradiance at ground, associated with the depletion of the stratospheric ozone layer. Results of first pioneer researches were impressive, showing dramatic reductions in the photosynthesis and consequently in plant growth and crop yield. Nevertheless, it was later demonstrated that they were strongly affected by the fact that the experiments were conducted in growth chambers or glasshouses, which tended to exaggerate the negative effects of high UV-B on vegetation. The unrealistic low level of radiation at other wavelengths, active in the damage repair mechanisms, erroneously conditioned these experiments. During the 1990s new experimental approaches were developed to study the effect on vegetation of both, enhanced and attenuated UV in field conditions. The experiments on enhanced UV were conducted supplementing the global solar radiation with UV-B emitting fluorescent lamps. In the second case, the UV in global solar radiation was attenuated using spectrally selective plastic films.

These new experiments indicated that the effects of UV radiation on plants were more modest, subtle and in many cases indirect. They further indicated that also UV-A component, whose role was underestimated for a long time, may have important effects and has to be taken into consideration.

#### Direct effects

UV-B can cause stresses or act as a developmental signal, depending on its fluence levels, but little is known about how non damaging low-fluence-rate UV-B is perceived to regulate plant morphogenesis and development.

Large body of knowledge acquired in recent years, indicates two major consistent responses of vegetation to changes in UV irradiance at ground: a moderate reduction in the growth and a relevant modification of plant biochemistry.

High levels of UV-B tend to depress plant growth, affecting *plant biomass* including root system. This is mainly due to a reduced leaf expansion, that is more affected than photosynthesis efficiency per unit leaf area. Cell enlargement has been demonstrated to inversely respond to light quality and quantity: high level of UV (mainly UV-B) inhibits cell enlargement and leaf expansion resulting in a smaller leaf dimensions. *Plant height* is also negatively affected by UV levels as well as *plant architecture* which is also influenced by changes in the quantity and quality of solar radiation distribution (including UV components) along the canopy profile.

These effects on plant growth characteristics were found to be species specific: consequently they can strongly affect competition between different species both in natural ecosystems and crops.

*Allocation of biomass* is another growth factor affected by UV radiation. Under high UV the *root/shoot ratios* is significantly affected, mainly because of larger limitation to root biomass. Since UV penetration into the soil is marginal, this phenomenon is generally explained invoking a systemic response of the root system to the above ground UV irradiance. Nevertheless, more recently it has been hypothesized a direct perception of roots even at low UV-B fluence rates.

*Plant chemistry* of secondary metabolites is the other main target of UV radiation. The accumulation of UV-absorbing pigments in the vacuole of the epidermal cells is the more efficient mechanism of plant *acclimation* to high UV radiative environments. The major chemical compounds involved are phenolic compounds, such as flavonoids: they act as selective filters attenuating UV transmission without modifying the visible region of the spectrum, primarily the Photosynthetic Active Radiation (PAR) (Fig. 3.4.1). It is worth to remember that some of these UV-filtering compounds have also an antioxidant function. Finally, UV radiation has influence also on the abundance of other substances that may be appreciated in the food production (in horticulture as well as in viticulture) or by the pharmaceutical industry, that could derive antioxidant products, essential oils or natural dyes from some species properly exposed to UV radiation.

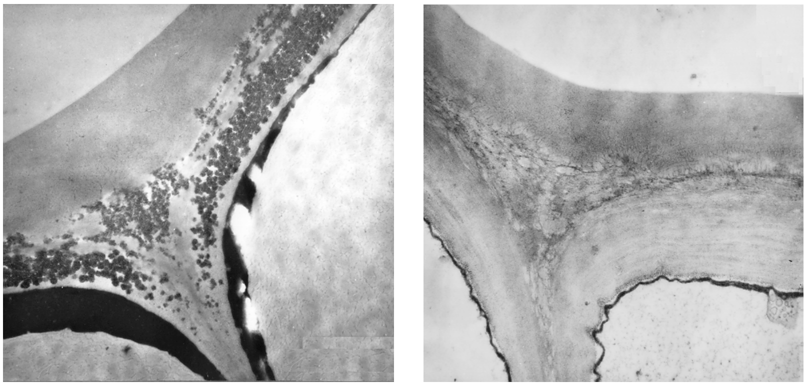

**Fig. 3.4.1:** Adaxial epidermis (leaf) of enhanced UV-B (left) and normal solar radiation treated Oak plants (right). Accumulations of phenolic compounds (protection) are clearly visible in the secondary wall of cells in UV-B treated leaf.

**Indirect effects**

UV radiation has also a relevant ecological role, influencing the interaction of plants with animals and other micro-organisms.

UV radiation stimulates expression of genes that play a primary role in the plant defence from several biotic and a-biotic stressors and in particular from pathogens attack, suggesting an important role of UV radiation in promoting resistance to plant diseases. In fact two different responses to UV radiation are active during a pathogen attack, one being directly related to a reduced pathogen aggressiveness (in particular for “naked” pathogens) and the other connected to an increased host resistance to the attack stimulated by the accumulation of UV-induced substances.

*UV radiation and plant-animal interaction*: The accumulation in the tissues of plants exposed to high UV radiation of secondary metabolites (phenolics) and carbohydrates and nitrogen compounds, tends to reduce the attractiveness for herbivore insects and in some cases also for oviposition. Moreover, changes in the secondary metabolism induced by UV, may be responsible for improvement in the forage quality for ruminants thanks to improved digestible dry matter content. Nevertheless, this effect is species specific and dependent on other environmental parameters as rainfall. Decomposition of *leaf litter* is also affected by UV-B radiation as a result of both, photochemical breakdown of complex compounds (lignin) and modification of the decomposer population active in the soil. The latter may be associated to changes in the root exudates composition and quantity stimulated by changes in the above ground UV irradiation.

*Interaction with other environmental parameters:* Actual understanding of the interaction of UV radiation with other environmental parameters, like $CO_2$ concentration, temperature, soil water availability and soil nutrient content, is yet limited and further investigations are needed mainly for possible impact of climate changes on terrestrial ecosystems.

### 3.5. UV and aquatic systems

#### Transmittance of UV radiation

UV radiation penetrates water and even ice and snow. A modest snow cover of 15cm reduces UV levels to the ground by approximately two orders of magnitudes. In ice a reduction of UV in the orders of two magnitudes is caused by a layer of 2.5 m. Transparency depends on age and clearness of the ice and on wavelength. The UV-B is attenuated stronger than the UV-A and the visible radiation.

Penetration of water depends as well on wavelength and on the optical properties of water, however transmittance in water is much lower than in the atmosphere.

At the water-air boundary the index of refraction changes and must be taken into account. Reflection of UV at the boundary is in the order of 10%.

Transmittance through water depends on the clearness. The depth for a 10% transmission can vary from about dozens of meters to a few centimetres in brown humic waters. Solvents as salinity decrease transmittance, but most important is the amount of absorbing and scattering particles in the water. Especially in eutrophic fresh water systems and coastal regions the transparency is affected strongly by these particles.

Main contributors are the so-called “yellow substances”, chlorophyll and other photosynthetic pigments, as well as dissolved particulate organic and inorganic matter. UV is also absorbed and scattered by organisms living in water as plantkton, algae and sea grasses that may build large canopies.

Transparency of water is not constant over time but shows a temporal (seasonal) variability which goes hand in hand with the changing amount of solved and dissolved matter in the water. Meteorological factors may cause also variability – snow melting and flood water may transport large amounts of unsolved substances. In general, transparency is highest in the clear ocean water and high alpine lakes and lowest in brown (humic) waters.

UV radiation on sessile aquatic livings becomes extreme in regions were water lacks from time to time as caused by low water flow and by tides.

As it can be seen from Fig. 3.5.1 and 3.5.2 shorter wavelength UV radiation is absorbed more than longer wavelength UV. Fig. 3.5.2 shows modelled values for DNA-damage weighted spectral solar irradiance for different depth levels in ocean and coastal water. It can be seen that the ozone affected UV-B range delivers the highest amount of irradiance for DNA-damage, although UV-B from the sun and transmittance through water are lower than for UV-A.

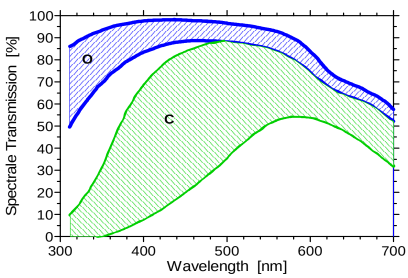


**Fig. 3.5.1:** Spectral transmission through 1m of ocean (o) and coastal waters (c).

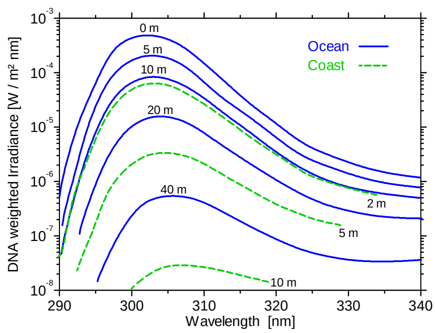


**Fig. 3.5.2:** DNA-weighted spectral irradiance in ocean and coastal waters for various depth.

### Effects on aquatic livings

As in other ecosystems most of the photoeffects on aquatic livings are driven by the visible solar radiation but a considerable fraction is due to the UV wavelengths. The largest part of the earths biomass results from bacterioplankton and picoplankton, phytoplankton, zooplankton, cynobacteria, macroalgae and seagrasses. Compared to these, the biomass of higher organisms is negligible.

**Plankton**

***Bacterioplankton, nanoplakton and picoplankton*** decompose organic matter in water and play an important role in the carbon flux of the ecosystem. Bacterioplankton may serve as food for picoplankton and as host for viruses. These types of plankton do not possess protective UV screening pigments and are therefore high sensitive to UV radiation. Main target of UV is DNA. Protection is mainly through photoreactivation. Vertical mixing of water brings them also somewhat deeper where damaging UV-B is lower and photoreactivating UV-A and blue light is relatively higher.

***Phytoplankton*** is the most important biomass producer in aquatic ecosystems. Phytoplankton can be found in the top layer of waters where they receive enough photosynthetic radiation. This layer can range from a few decimetres to hundred metres in clear water. UV effects photosynthesis, metabolism, growth, reproduction, survival and distribution. Phytoplankton may actively swim or use buoyancy to reach the optimum depth. However, wind and waves can disturb their vertical distribution. Phytoplankton is feed for zooplankton and higher organisms. Radiation protection is provided by caretenoids and pigments. As some of the latter are chemically quite stable, they can be found in the sediments of lakes and therefore, it could be possible to reconstruct UV into the past.

Main target for UV in ***zooplankton*** is DNA and effects are similar to other small livings. Their protection against UV results from depth control in the water and from pigmentation. However, depth depends also on the availability of food sources (plankton).

**Algae and seagrasses**

***Blue-green-algae*** *(Cynobacteria)* possess a plant-type oxygenic photosynthesis. Several kinds of cynobacteria are able to fix atmospheric nitrogen. They have a high degree of adoption to different environmental conditions and being therefore cosmopolitans. Cynobacteria can be found also in wet soil like in rice paddies and are therefore involved in one of the human most important food production. UV radiation effects not only survival but also motility, growth, photosynthesis, metabolism. Pigmentation of cynobacteria is a well working sun protection for their DNA.

UV exposure of ***macroalga*** and ***seagrasses*** varies very much. Some kinds grow at coast and are even above the water during tidal changes, other live always under water up to depth, were light is some orders of magnitude less intensive than at the surface. As higher plants, macroalgae use the same photoinhibition mechanism for protection from high irradiance. Effects of UV on seagrasses are similar to that on ground plants. They play an important role as habitats for higher organisms.

## 4. Expectations for the future

The levels of surface UV radiation in the future will depend on the variations of radiation emitted by the Sun and on the evolution of various factors, known to influence the propagation of solar UV radiation through the atmosphere. These factors include ozone, aerosols, clouds, UV absorbing air pollutants and surface reflectivity, and are strongly linked with Climate Change. A comprehensive discussion on the likely future changes of UV irradiance at the Earths surface is included in the most recent Scientific Assessment of Ozone Depletion: 2006 (WMO, 2007) and the Environmental Effects of Ozone Depletion and its Interactions with Climate Change: 2006 Assessment (UNEP, 2006). For the next few centuries, the expected changes of solar output due to orbital variations of the Earth, the so called Milankovich cycles with periods between 40000 and 20000 years, are very small (less than 1%). Similarly sub-percent changes in UV-B and UV-A radiation are expected from the changes in solar activity (i.e. the sunspot number variations with periods of 11 years and their 27-days rotation). Thus, mainly the changes in the earth's atmosphere will dominate the variations of surface UV radiation in the coming centuries.

Stratospheric ozone is one of the major factors which determine the levels of surface UV radiation. During the last third of the 20$^{th}$ century stratospheric ozone has been severely depleted and its concentrations continue to be low, particularly in Antarctica. Recent observations suggest that the concentration of ozone depleting substances in the atmosphere have started to decrease as a result of the measures taken under the Montreal Protocol and its Amendments and Adjustments (WMO, 2007), marking the onset of the stratospheric ozone recovery (Yang et al., 2008; Angell and Free, 2009). As ozone will be returning to its pre-1980 levels, surface UV radiation will be decreasing accordingly. Climate change will influence cloudiness, aerosols and surface albedo in a complex manner introducing regionally and seasonally different effects (IPCC, 2007). Consequently, surface UV radiation changes due to these factors are also expected to vary between regions and seasons. Yet, the links between climate change and ozone depletion are not clearly understood increasing the uncertainty about the timing of the ozone recovery (e.g., Waugh et al., 2009).

Coupled Climate Chemistry models provide future predictions of the above mentioned UV influencing factors allowing the simulation of surface UV levels in the coming decades (WMO, 2007; Eyring *et al.*, 2007; Tourpali *et al.*, 2009). Under cloud free conditions, surface erythemal irradiance has been calculated to decrease globally as a result of the projected stratospheric ozone recovery at rates that are larger in the first half of the 21st century and smaller towards its end. Between 2000 and 2100 the decrease over midlatitudes ranges between 5 and 15%, while at the southern high latitudes the decrease is twice as much. Since effects from changes in cloudiness, surface reflectivity and tropospheric aerosol loading, have not been considered, over some areas the actual changes in future UV radiation may be different depending on the evolution of these parameters.

According to the Fourth Assessment Report of the IPCC 2007, multi-model simulations based on the SRESA1B scenario suggest that cloud cover will decrease by the end of the 21st century in most of the low and middle latitudes of both hemispheres by up to 4%. This would result in an increase in surface UV radiation in these regions (e.g. by about 4% for erythemal irradiance), counteracting the decrease from ozone recovery. The opposite is expected in high latitudes and in a few low-latitude regions where cloud cover is predicted to increase. A decrease in surface reflectivity in the high to polar latitudes of both hemispheres due to reduction of ice covered areas (e.g., Overland and Wang, 2007; Comiso et al., 2008) would result in a decrease of surface UV radiation over these and neighbouring areas, enhancing the projected decrease in surface erythemal irradiance due to changes in ozone. Surface reflectivity enhances the upwelling radiation, part of which is backscattered by atmosphere thus increasing the irradiance at the surface and over areas within several kilometres.

In summary, the projected recovery of the ozone layer during the 21st century in conjunction with the expected changes in other UV influencing factors due to climate changes are expected to modify accordingly the UV solar irradiance at the Earth's surface. In general, decreases are largest in areas where the ozone depletion has been most pronounced, such as over Antarctica. The projected UV changes have large uncertainties due to the approximations inherent in the assumptions for cloudiness, aerosols and surface albedo.

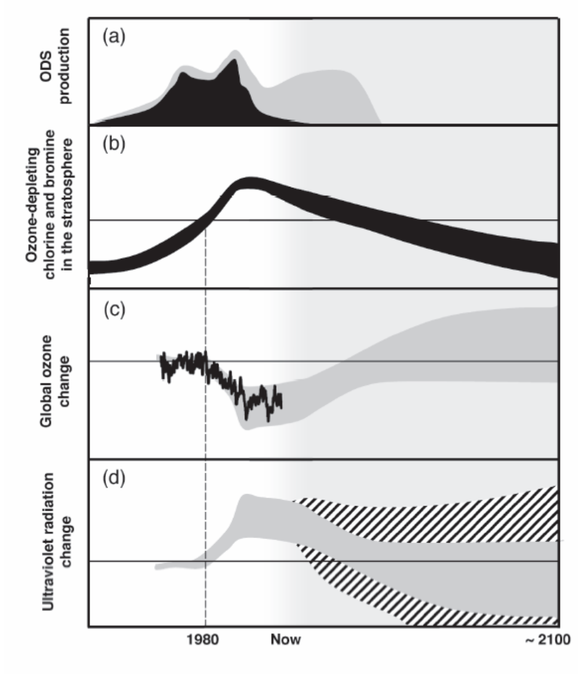


**Fig. 4.1:** Adapted from (WMO, 2007), Executive Summary.

(a) Production of ozone-depleting substances (ODSs) before and after the 1987 Montreal Protocol and its Amendments, from baseline scenario A1. Chlorofluorocarbons (CFCs) are shown in black: additional ODSs from hydrochlorofluorocarbons (HCFCs) are in gray. Note: HCFCs, which have been used as CFC replacements under the Protocol, lead to less ozone destruction than CFCs.

(b) Combined effective abundances of ozone-depleting chlorine and bromine in the stratosphere. The range reflects uncertainties due to the lag time between emission at the surface and the stratosphere, as well as different hypothetical ODS emission scenarios.

(c) Total global ozone change (outside of the polar regions: $60^{o}$S-$60^{o}$N). Seasonal, quasi-biennial oscillation (QBO), volcanic, and solar effects have been removed. The black line shows measurements. The gray region broadly represents the evolution of ozone predicted by models that encompass the range of future potential climate conditions. Pre-1980 values, to the left of the vertical dashed line, are often used as a benchmark for ozone UV recovery.

(d) Estimated change in UV erythemal (“sunburning”) irradiance for high sun. The gray area shows the calculated response to the ozone changes shown in (c). The hatched area shows rough estimates of what might occur due to climate-related changes in clouds and atmospheric fine particles (aerosols).

## Appendix A: Reference Institutions in the COST726 Countries

**Austria**

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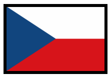

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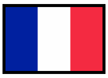
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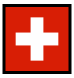

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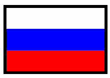

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**Appendix B: List of www pages with UV information**

**Austria**

http://www.uv-index.at

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

**Belgium**

http://www.meteo.be/meteo/view/en/522044-UV.html

http://www.meteo.be/meteo/view/en/65239-Home.html

http://ozone.meteo.be/meteo/view/en/1351412-OzoneC+UV+and+Aerosol+studies.html

http://www.aeronomie.be/en/topics/interplanetary/uv_live_belgium.htm

**Cyprus**

http://lap.physics.auth.gr/uvnet.gr

**Czech Republic**

http://www.chmi.cz/meteo/ozon/UV_online.html

**Denmark**

http://www.dmi.dk/dmi/index/danmark/solvarsel.htm

http://www.dmi.dk/dmi/index/verden/uv_idag.htm

http://promote.dmi.dk

**Estonia**

http://sputnik.aai.ee/koduleht

**Finland**

www.fmi.fi/uvi

**France**

http://www.soleil.info/uv-meteo/

**Germany**

http://www.uv-index.de

http://orias.dwd.de/promote/index.jsp

http://www.suvmonet.de

http://www.dwd.de/mol/

**Greece**

www.uvnet.gr

**Italy**

http://www.uv-index.vda.it

**Netherlands**

http://www.temis.nl/uvradiation/index.html

http://www.knmi.nl/kodac/weer_en_gezondheid/zonkracht.html

http://www.rivm.nl/milieuportaal/onderwerpen/straling-en-EM-velden/ultraviolette-straling/

**Norway**

http://www.nrpa.no/uvnett/default_en.as
px
http://retro.met.no/varsel/index.html
http://uv.nilu.no/index.cfm?fa=uv.main
http://www.fys.uio.no/plasma/ozone/

**Poland**

http://www.pogodynka.pl/indeksuv
http://www.igf.edu.pl/pl/zaklady_naukow
e/fizyki_atmosfery/ozon_uv

**Portugal**

http://www.meteo.pt/en/ambiente/uv

**Slovakia**

http://www.shmu.sk/sk/?page=73

**Spain**

http://www.aemet.es/es/eltiempo/observ
acion/radiacionuv

**Sweden**

http://www.smhi.se/cmp/jsp/polopoly.jsp
?d=7850&l=en
http://produkter.smhi.se/strang/
http://produkter.smhi.se/strang/omna/
http://www.smhi.se/cmp/jsp/polopoly.jsp
?d=5626&l=sv
http://www.stralsakerhetsmyndigheten.s
e/Allmanhet/UV--laser/

**Switzerland**

http://www.uv-index.ch/de/home.php
http://www.meteoswiss.admin.ch/web/e
n/weather/health/uv-index.html
http://www.meteoswiss.admin.ch/web/e
n/weather/health/uv-
index/uv_measurement.html
http://www.meteoswiss.admin.ch/web/e
n/weather/health/uv-
index/uv_radiation.html
http://www.meteoswiss.admin.ch/web/e
n/research/projects/cost_726.html

**United Kingdom**

http://www.hpa.org.uk/webw/HPAweb&
HPAwebStandard/HPAweb_C/1195733
761671?p=1158934607746

**Intersun, World Health Organization (WHO)**

http://www.who.int/uv/en/

## Appendix C: List of reference publications

### COST Action 726 publications:


1. Gröbner, J., Hülsen, G., Vuilleumier, L., Blumthaler, M., Vilaplana, J. M., Walker D., Gill, J. E., *Report of the PMOD/WRC Calibration and Intercomparison of Erythemal Radiometers*, COST Office, 2009
2. Johnsen B., Kjeldstad B., Nakken Aalerud T., Tove Nilsen L., Schreder J., Blumthaler M., Bernhard G., Topaloglou C., Meinander O., Bagheri A., Slusser J. R., Davis J., *Intercomparison of Global UV Index from Multiband Filter Radiometers: Harmonization of global UVI and spectral irradiance*, GAW Report No. 179, WMO/TD-No. 1454, 2008
3. Koepke, P., De Backer, H., Bais, A., Curylo, A., Eerme, K., Feister, U., Johnsen, B., Junk, J., Kazantzidis, A. Krzyscin, J., Lindfors, A., Olseth, J., den Outer, P., Pribullova, A., Schmalwieser, A., Slaper, H., Staiger, H., Verdebout, J., Vuilleumier, L., Weihs, P., *Modelling solar UV radiation in the past: Comparison of algorithms and input data,* COST Action 726 Final Report, ISBN 978-92-898-0043-3, COSt Office, 2008
4. Lityńska Z., Koepke P., de Backer H., Gröbner J., Schmalwieser A., Vuilleumier L., Chubarova N., Feister U., Kaurola J., Kazantzidis A., Krzyścin J., Lindfors A., den Outer P. N., Slaper H., Staiger H., Verdebout J. and Walker D., *Final Scientific Report for COST Action726 "Long term changes and climatology of UV radiation over Europe,* (prepared for publication)
5. Vilaplana J. M., Serrano A., Antón M., Cancillo M. L., Parias M., Gröbner J., Hülsen G., Zablocky G., Dıaz A., de la Morena B. A., *Report of the "El Arenosillo"/INTA-COST Calibration and Intercomparison Campaign of UVER Broadband Radiometers*. "El Arenosillo", Huelva, Spain, 15 August – 21 September 2007', ISBN 978-84-692-2640-7, COST Office 2009
6. Webb, A., Gröbner, J., Blumthaler, M., *A practical guide to operating broadband instruments measuring erythemally weighted irradiance*, ISBN 92-898-0032-1, COST Office, 2006


### International reports:


1. IPCC (Intergovernmental Panel on Climate Change) , Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited

by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007, http://www.ipcc.ch/ipccreports/ar4-wg1.htm

2. UNEP (United Nations Environment Programme), *Environmental effects of ozone depletion and the interaction with climate change: 2006 assessment*, Nairobi, 2006, http://ozone.unep.org/Assessment_Panels/EEAP/eeap-report2006.pdf
3. WHO (World Health Organization), *Global Solar UV Index, A practical Guide*, ISBN 92 4 159007 6, Geneva, Switzerland, 2002, http://www.who.int/uv/publications/en/GlobalUVI.pdf
4. WHO (World Health Organization), *Solar Ultraviolet radiation, Global burden of disease from solar ultraviolet radiation*, ISBN 92 4 159440 3, Geneva, Switzerland, 2006, http://www.who.int/uv/health/solaruvradfull_180706.pdf
5. WMO (World Meteorological Organization), *Scientific Assessment of Ozone Depletion: 2006, Global ozone Research and Monitoring Project*, Report No. 50, Geneva, Switzerland, 2007, http://www.wmo.int/pages/prog/arep/gaw/ozone_2006/ozone_asst_report.html

**References to paragraph 4: "Expectations for the future" published after the dates of international reports publication:**

1. Angell, J.K., and M. Free, *Ground-based observations of the slowdown in ozone decline and onset of ozone increase*, *J. Geophys. Res., 114*, D07303, doi:10.1029/2008JD010860, 2009
2. Comiso, J.C., C.L. Parkinson, R. Gersten, and L. Stock, *Accelerated decline in the Arctic sea ice cover*, *Geophys. Res. Lett., 35*, L01703, doi:10.1029/2007GL031972, 2008
3. Eyring, V., D.W. Waugh, G.E. Bodeker, E. Cordero, H. Akiyoshi, J. Austin, S.R. Beagley, B.A. Boville, P. Braesicke, C. Brühl, N. Butchart, M.P. Chipperfield, M. Dameris, R. Deckert, M. Deushi, S.M. Frith, R.R. Garcia, A. Gettelman, M.A. Giorgetta, D.E. Kinnison, E. Mancini, E. Manzini, D.R. Marsh, S. Matthes, T. Nagashima, P.A. Newman, J.E. Nielsen, S. Pawson, G. Pitari, D.A. Plummer, E. Rozanov, M. Schraner, J.F. Scinocca, K. Semeniuk, T.G. Shepherd, K. Shibata, B. Steil, R.S. Stolarski, W. Tian, and M. Yoshiki, *Multi-model projections of stratospheric ozone in the 21st century*, *J. Geophys. Res., 112*, D16303, doi:10.1029/2006JD008332, 2007

4. Overland, J.E., and M. Wang, *Future regional Arctic sea ice declines*, *Geophys. Res. Lett., 34*, L17705, doi:10.1029/2007GL030808, 2007
5. Tourpali, K., A.F. Bais, A. Kazantzidis, C.S. Zerefos, H. Akiyoshi, J. Austin, C. Brühl, N. Butchart, M.P. Chipperfield, M. Dameris, M. Deushi, V. Eyring, M.A. Giorgetta, D.E. Kinnison, E. Mancini, D.R. Marsh, T. Nagashima, G. Pitari, D.A. Plummer, E. Rozanov, K. Shibata, and W. Tian, *Clear sky UV simulations in the 21st century based on Ozone and Temperature Projections from Chemistry-Climate Models*, *Atmos. Chem. Phys. Disc., 9* (4), 1165-1172, 2009
6. Waugh, D.W., L. Oman, S.R. Kawa, R.S. Stolarski, S. Pawson, A.R. Douglass, P.A. Newman, and J.E. Nielsen, *Impacts of climate change on stratospheric ozone recovery*, *Geophys. Res. Lett., 36*, 2009
7. Yang, E.S., D.M. Cunnold, M.J. Newchurch, R.J. Salawitch, M.P. McCormick, J.M. Russell, III, J.M. Zawodny, and S.J. Oltmans, *First stage of Antarctic ozone recovery*, *J. Geophys. Res., 113*, 2008

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